FORT HILLS ENERGY CORPORATION

FORT HILLS OIL SANDS PROJECT

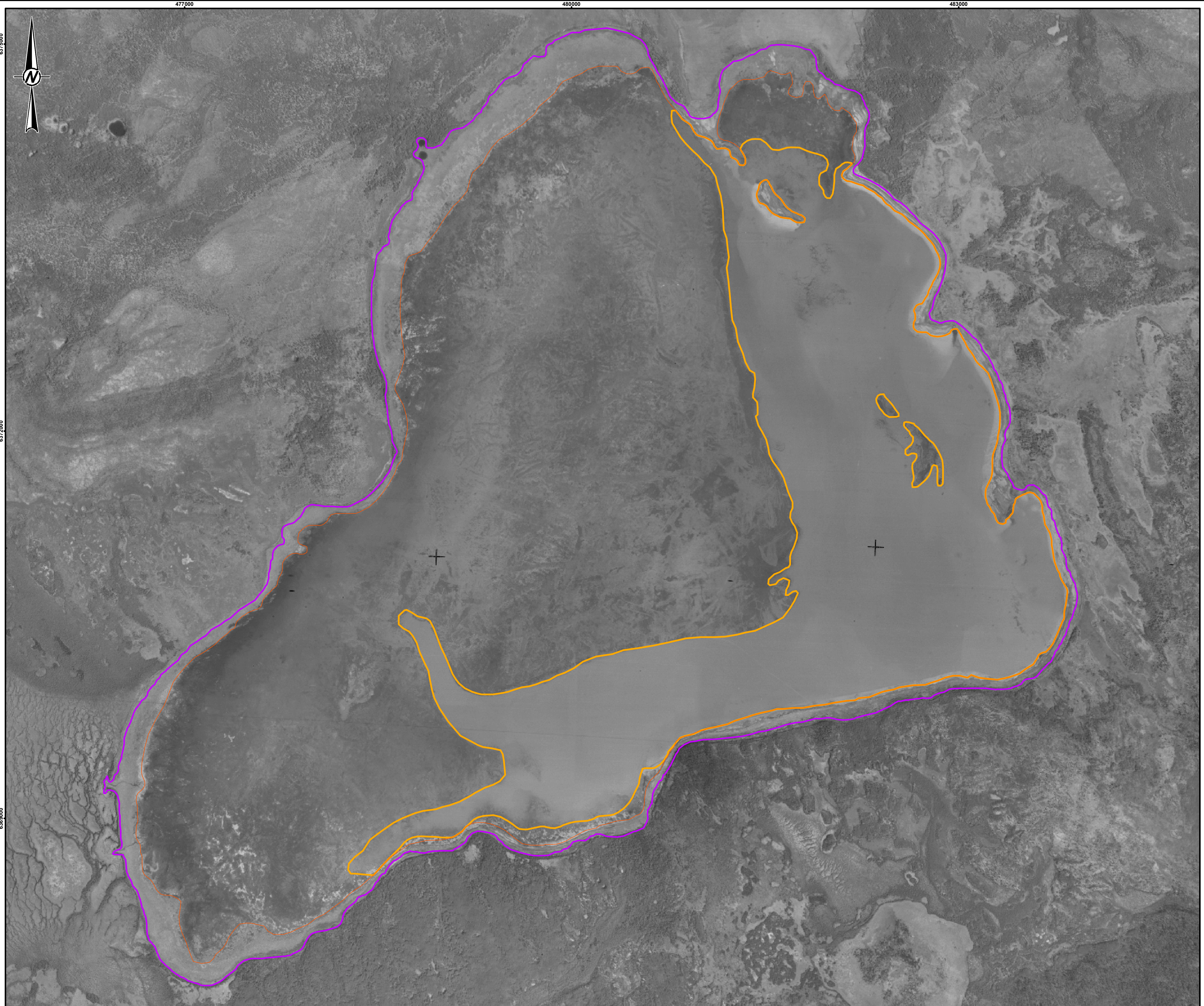
MCCLELLAND LAKE WETLAND COMPLEX OPERATIONAL PLAN APPENDICES

December 2021

Operated by SUNCOR ENERGY

Appendix A

Aerial Images of McClelland Lake During the Period from 1950 to 2017



LEGEND

- MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998
- **INTERPRETATION 1** - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*
- **INTERPRETATION 2** - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

NOTE(S)

THERE ARE UNCERTAINTIES, WHICH COULD NOT BE RESOLVED IN THIS STUDY, AS TO THE LAKE AREA EXTENT FOR THE 1950 AERIAL IMAGE. THE STUDY REPORT PROVIDES ADDITIONAL DISCUSSION OF THESE UNCERTAINTIES IN SECTION 11.3.

0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 1950 (AUGUST/SEPTEMBER)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-1

PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:24:20 AM

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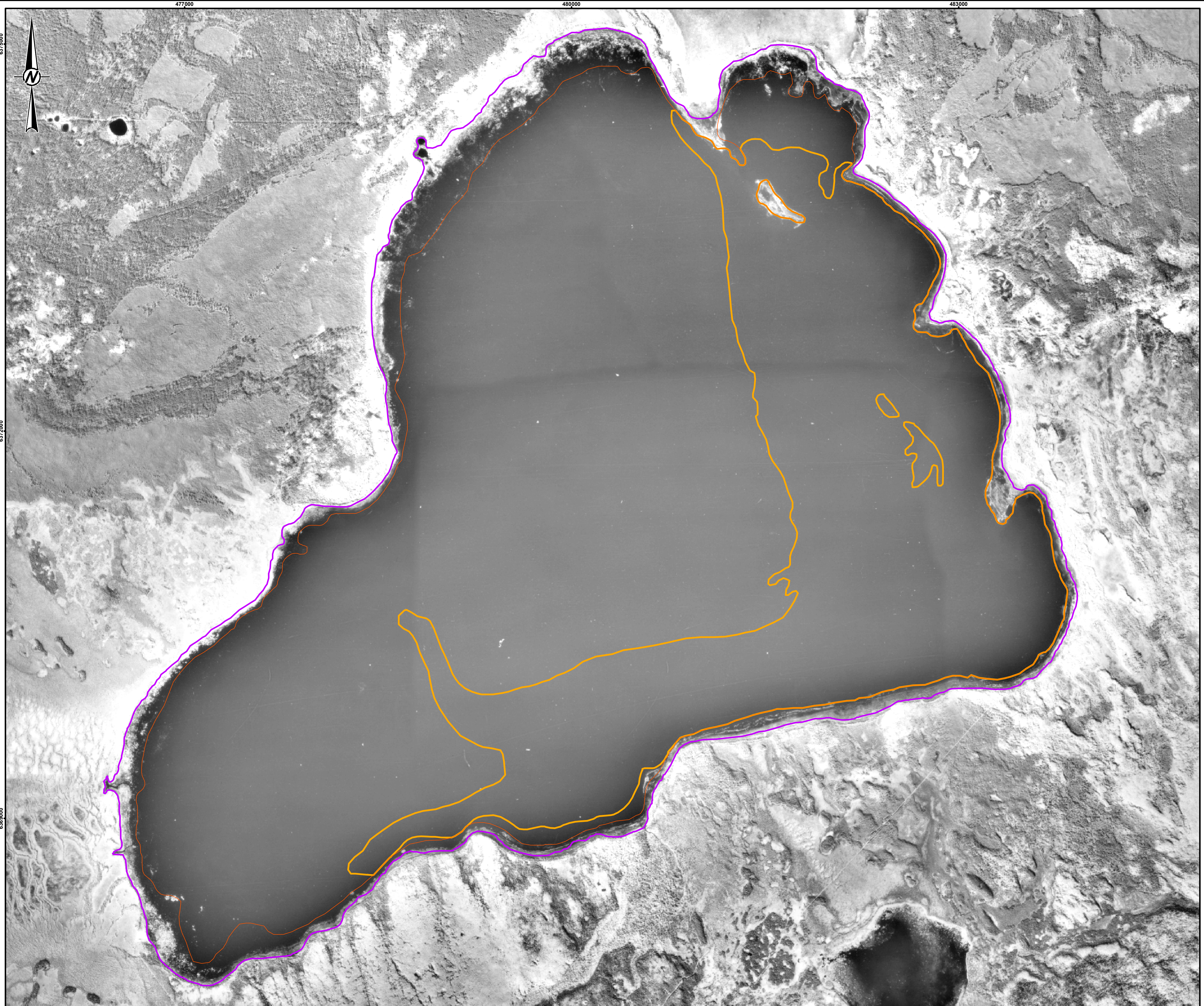

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

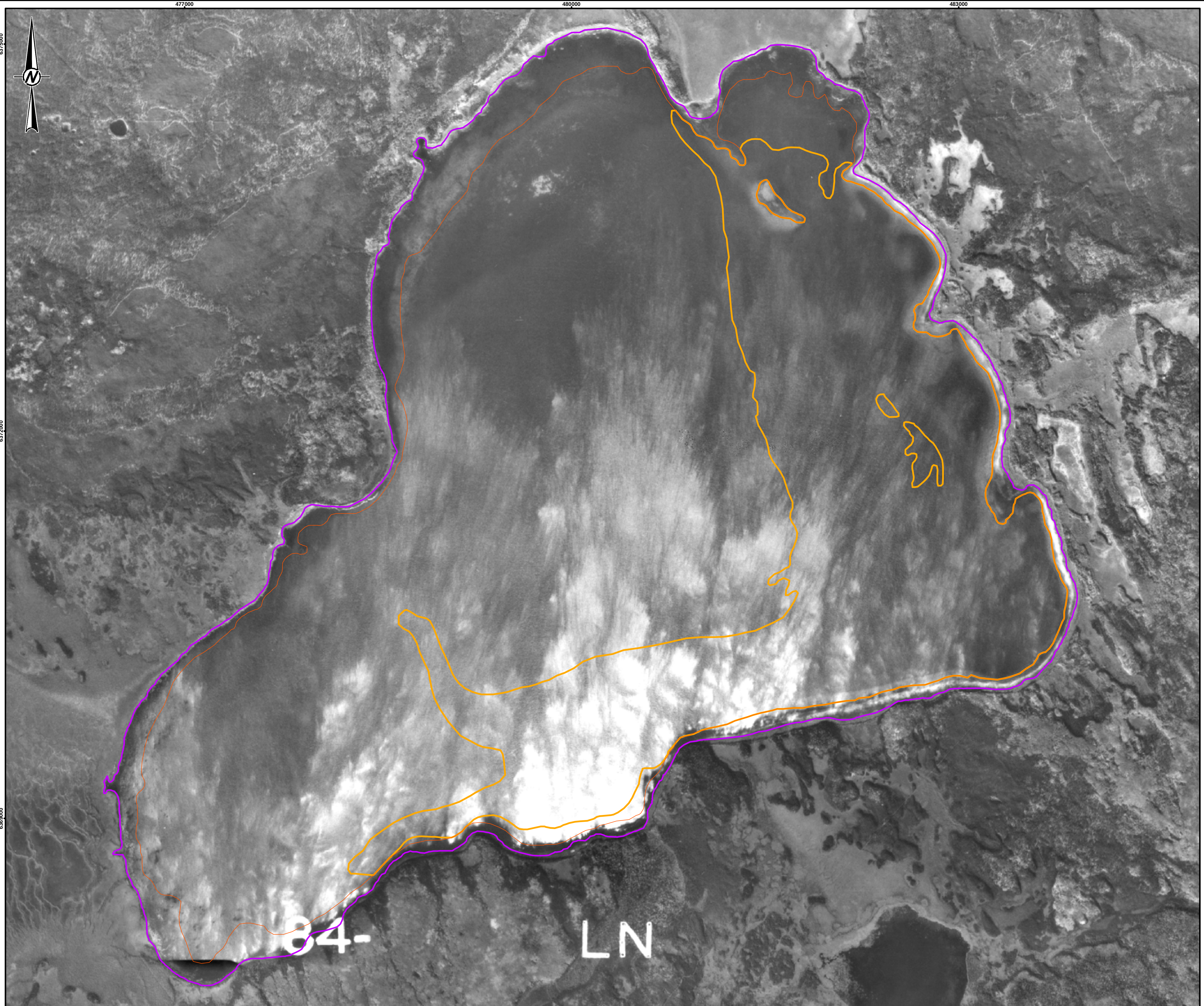
MCCLELLAND LAKE EXTENT - 1967 (MONTH NOT AVAILABLE)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-2



LEGEND

MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998

INTERPRETATION 1 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

INTERPRETATION 2 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

NOTE(S)

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 1984 (MONTH NOT AVAILABLE)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-3

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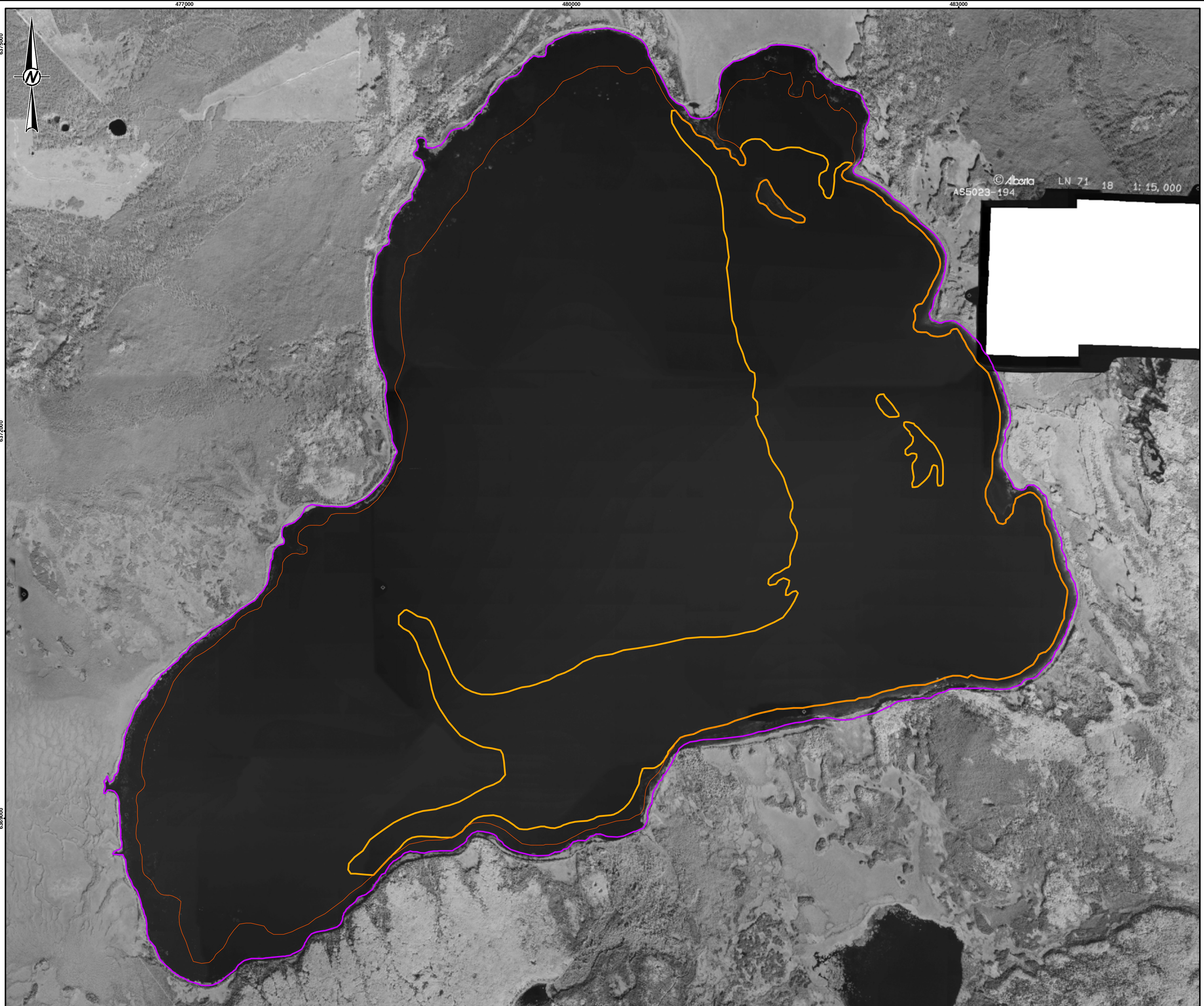

LEGEND

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 1998 (SEPTEMBER)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-4

PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:24:41 AM

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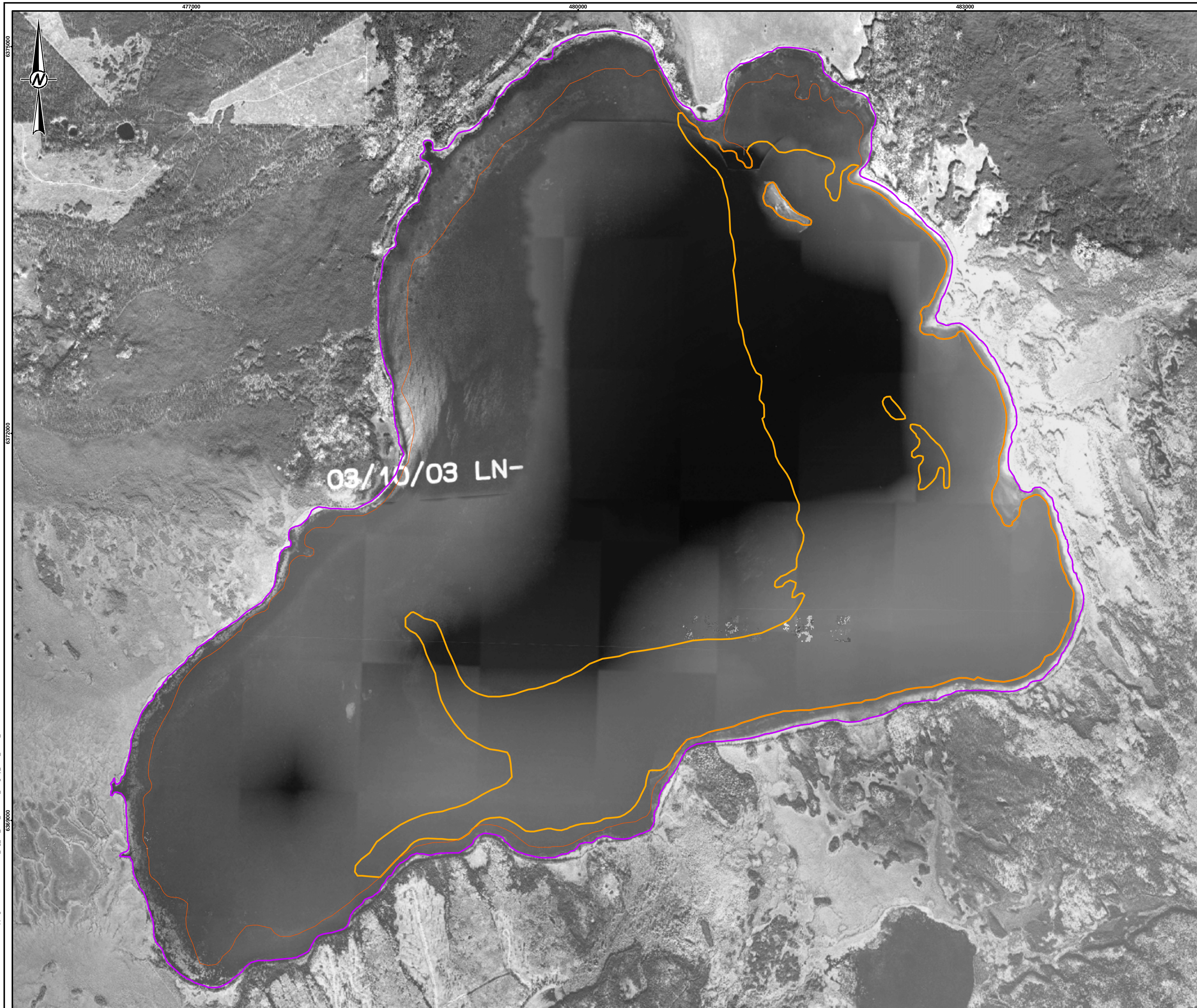

LEGEND

MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998

INTERPRETATION 1 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2003 (OCTOBER)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
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LEGEND

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2011 (SEPTEMBER)

CONSULTANT

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-6

25mm

LEGEND

MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998

INTERPRETATION 1 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

INTERPRETATION 2 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2012 (JUNE)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
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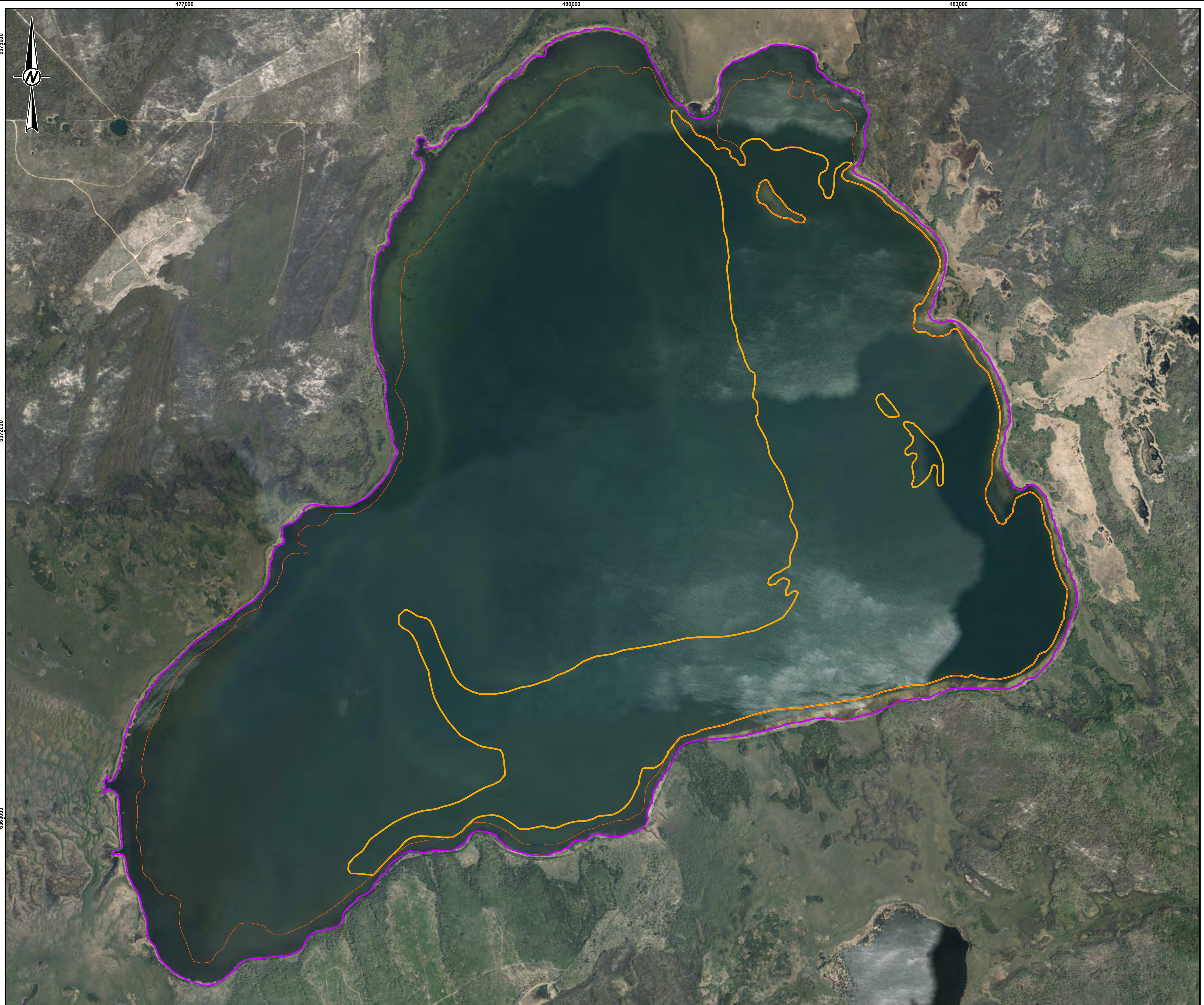

LEGEND

MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998

INTERPRETATION 1 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

INTERPRETATION 2 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2013 (MAY)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
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PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:26:20 AM

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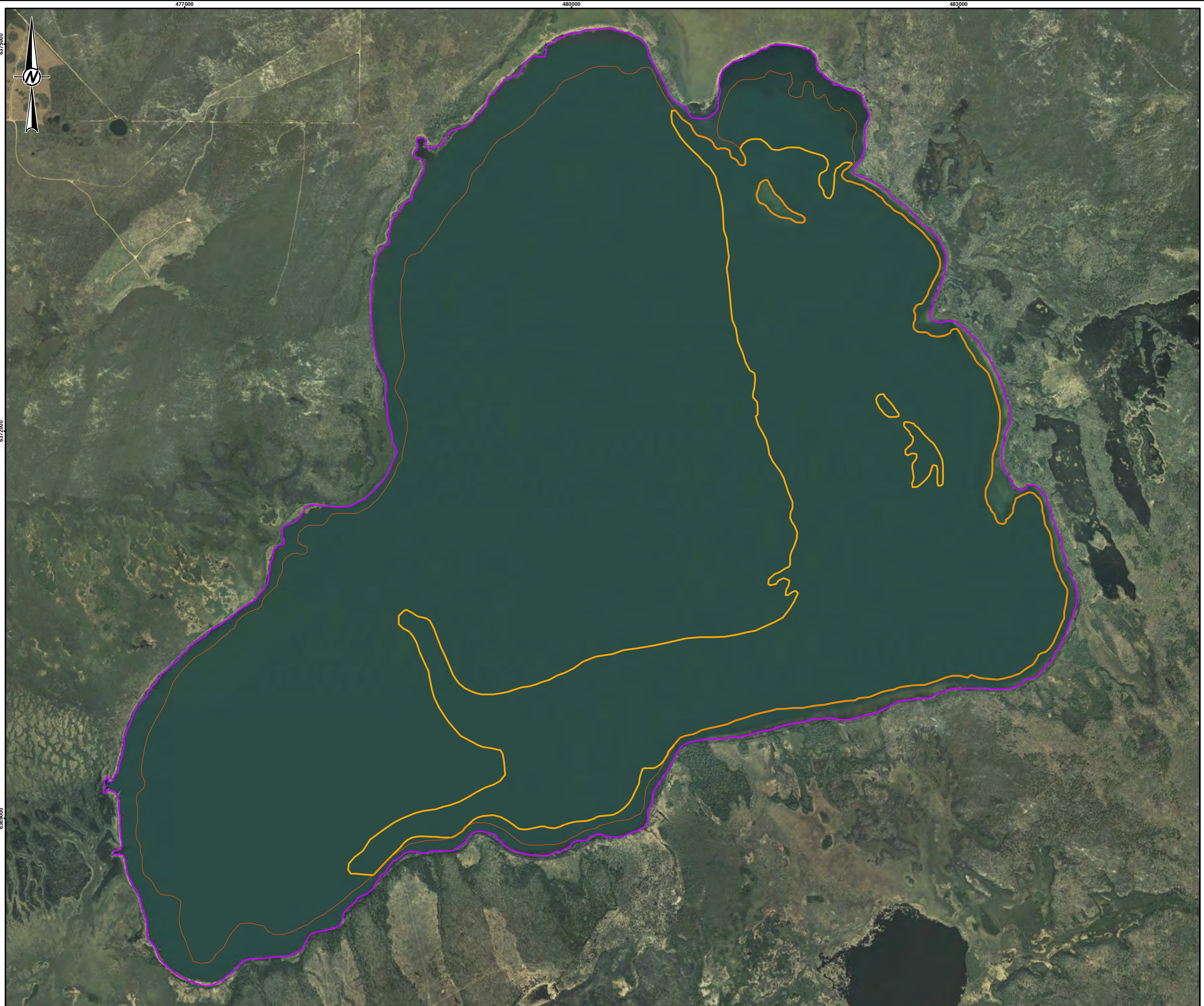
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B



LEGEND

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT
PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2014 (AUGUST)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
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PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:27:01 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

25mm

LEGEND

MAXIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX - 1998

INTERPRETATION 1 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

INTERPRETATION 2 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2016 (JUNE)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
1895988		0	G3-10

PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:27:39 AM

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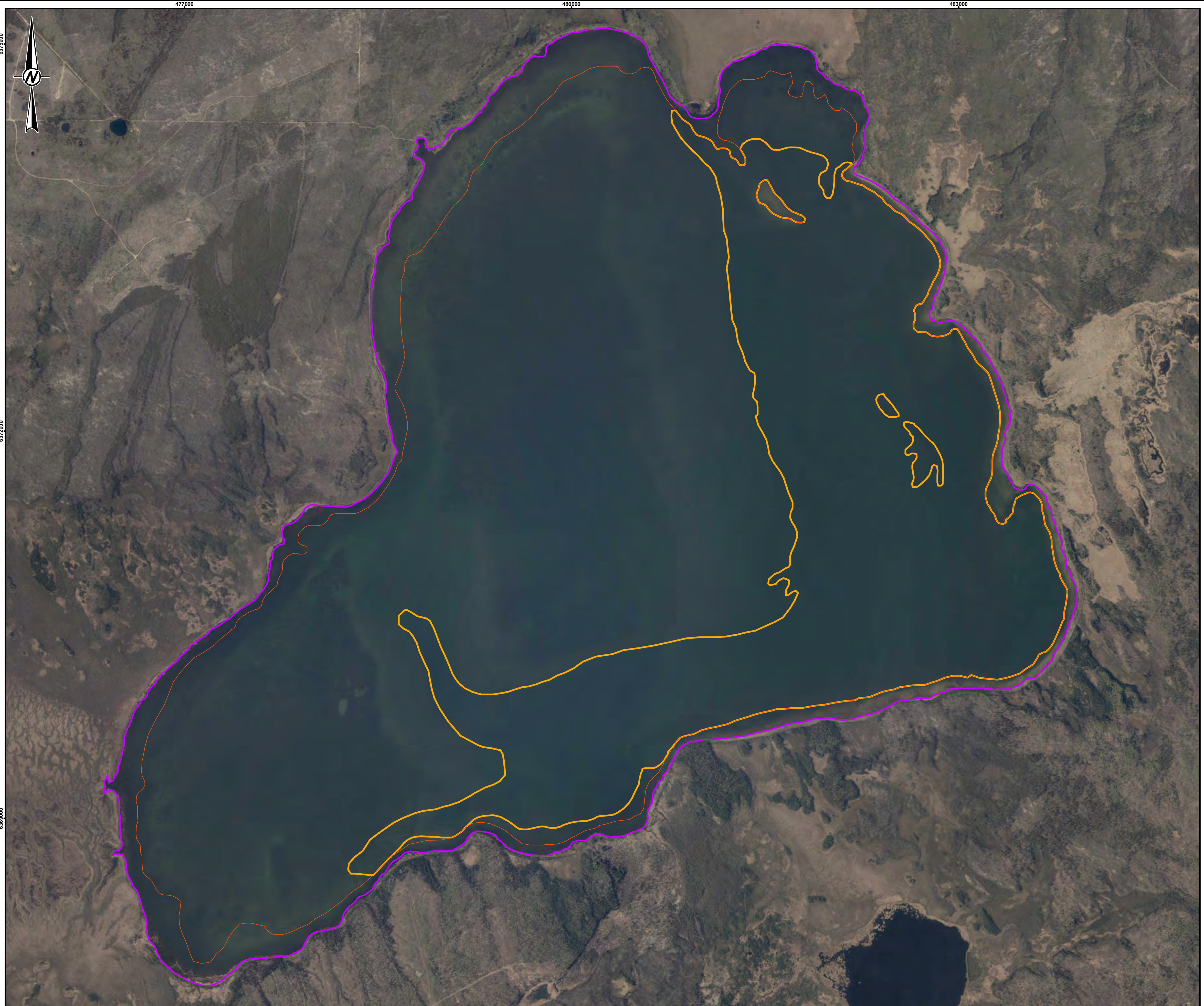

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INTERPRETATION 2 - MINIMUM LAKE EXTENT AMONG THE AERIAL IMAGES PRESENTED IN THIS APPENDIX – 1950*

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0 750 1,500

1:30,000 METRES

REFERENCE(S)

IMAGERY PROVIDED BY CLIENT

PROJECTION: UTM ZONE 12 DATUM: NAD 83

CLIENT

PROJECT

2018 MCCLELLAND LAKE WETLAND COMPLEX DATA SYNTHESIS

TITLE

MCCLELLAND LAKE EXTENT - 2017 (JULY)

CONSULTANT

GOLDER

YYYY-MM-DD	2018-08-30
DESIGNED	KS
PREPARED	BP
REVIEWED	KS
APPROVED	JW

PROJECT NO.	CONTROL	REV.	FIGURE
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PATH: I:\CLIENTS\SUNCOR\1895988\Mapping\MXD\General\1895988_Fig_G3_1-11_Historical_Imagery_Lake_Extent_Rev0.mxd PRINTED ON: 2018-08-30 AT: 9:28:26 AM

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

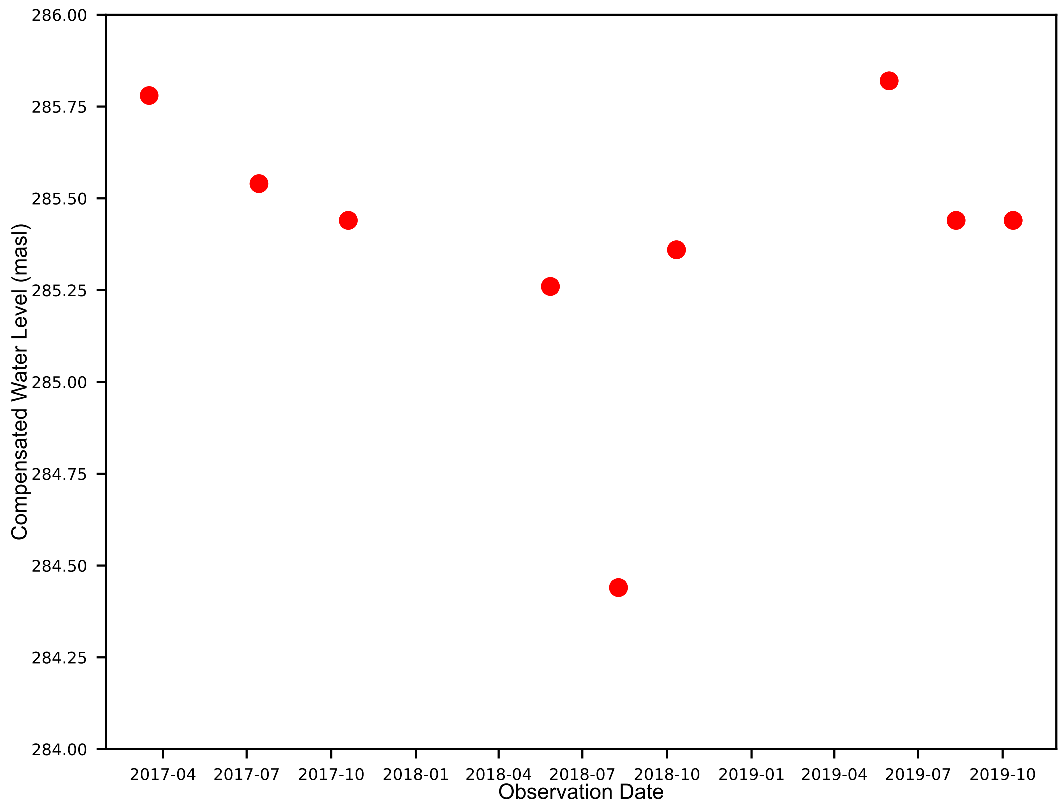
25mm

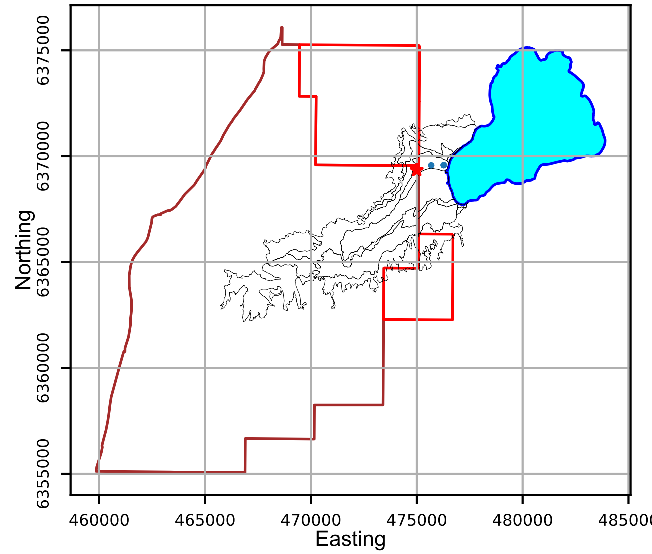
Appendix B

Supporting Tables and Figures for the Groundwater Levels

B1 Hydrographs for Ecohydrology Zone 1

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 43.15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE
FH17-WR418-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-1

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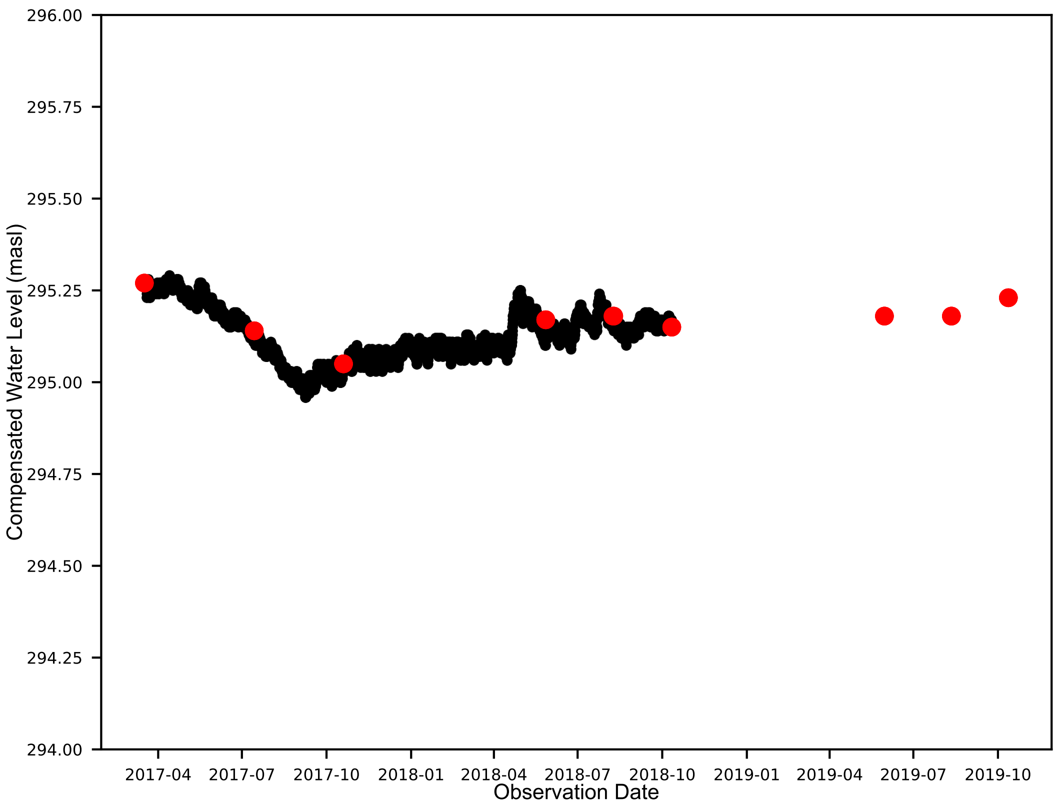

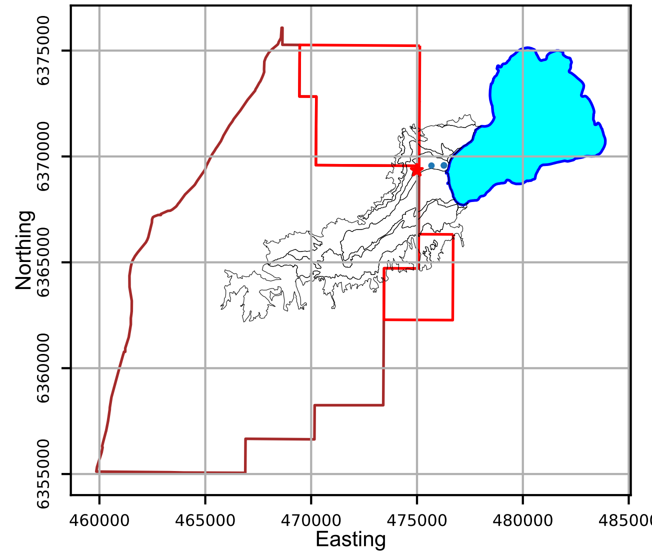

Hydrograph Legend

- Manual measurement
- Transducer measurement

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.42 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR418-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
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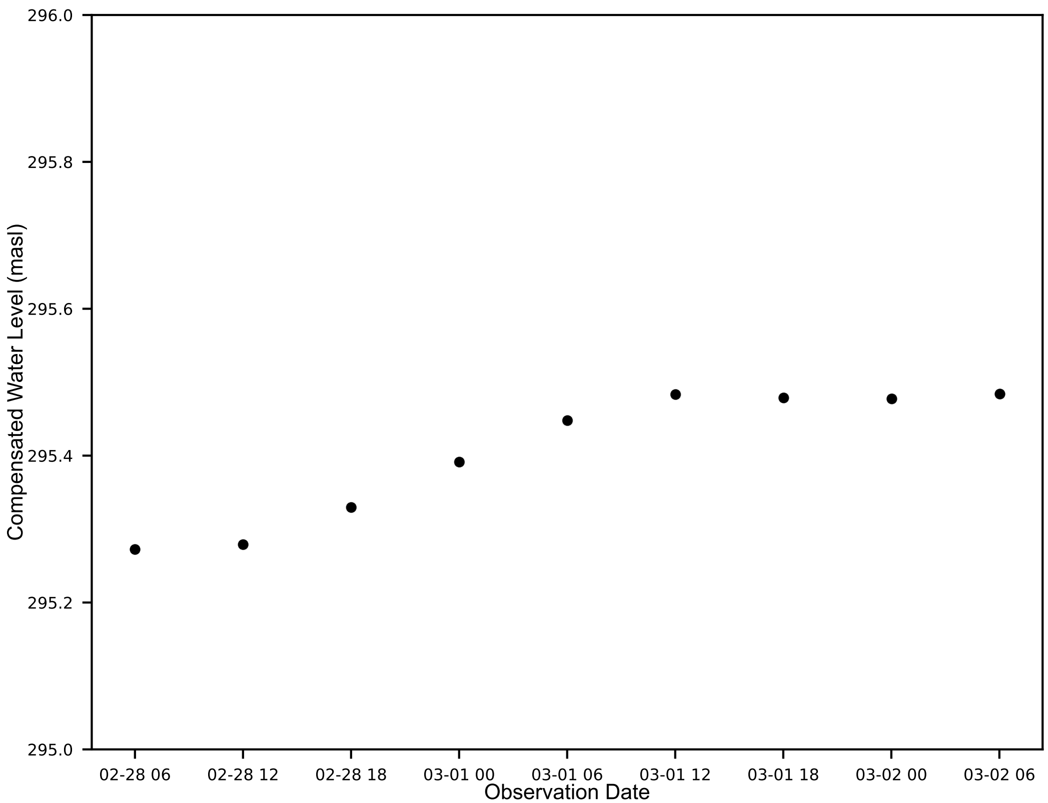
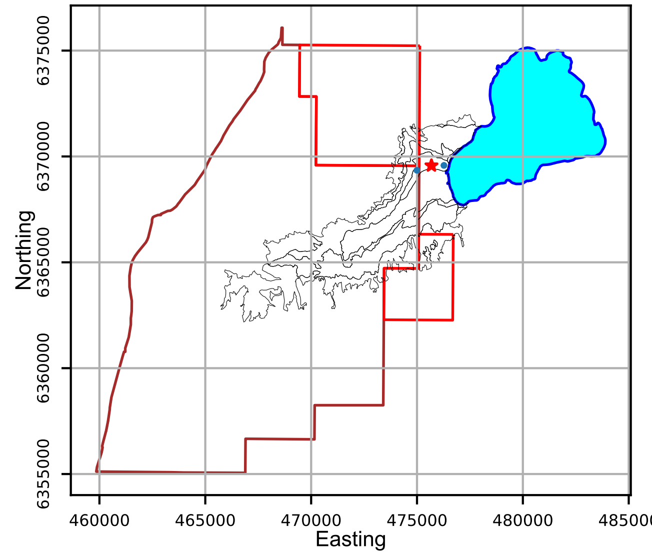




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

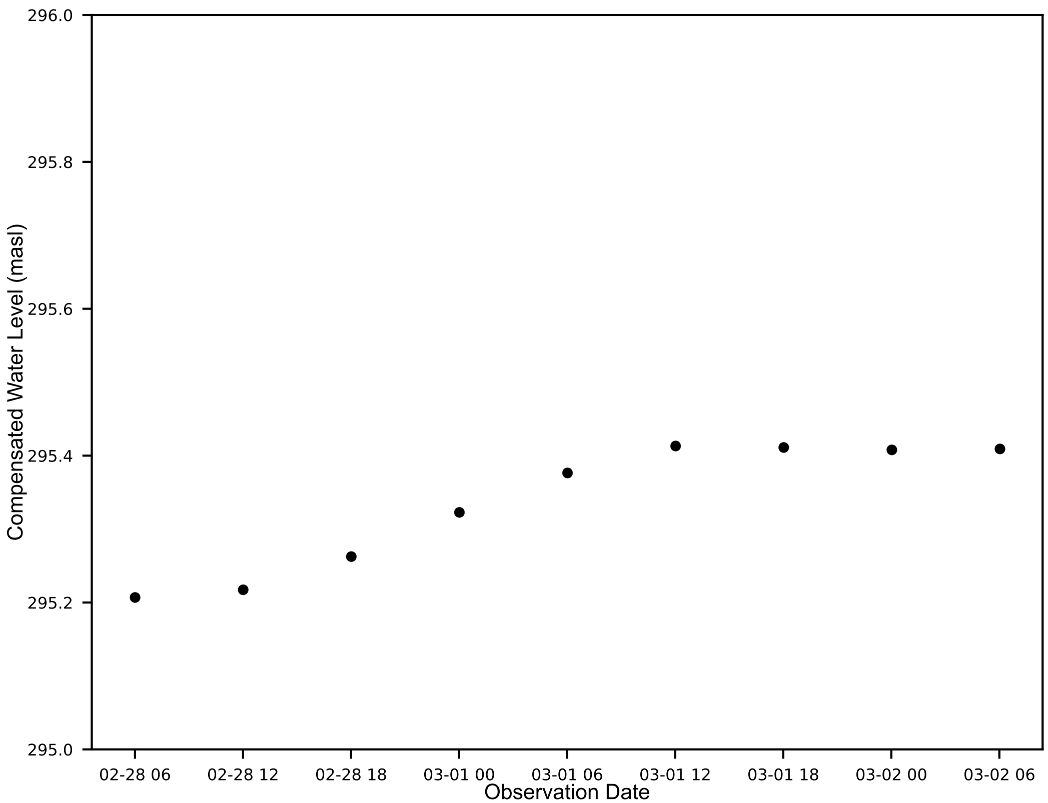
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

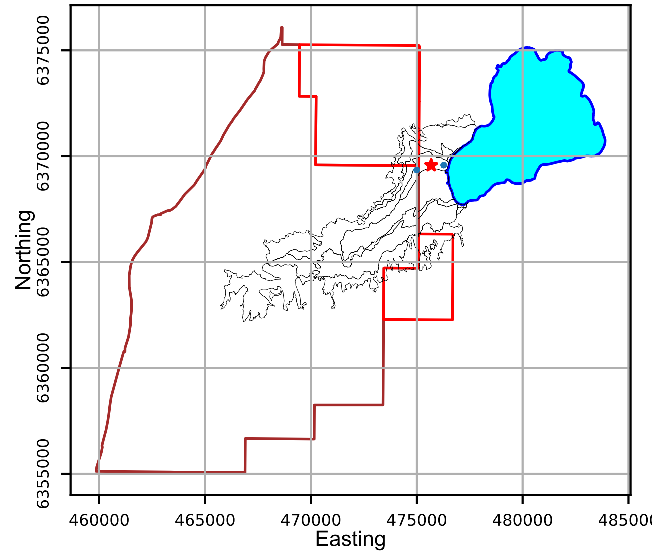
TITLE

FH19-ES608-SN1 - 14.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-3

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES608-SN1 - 29.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
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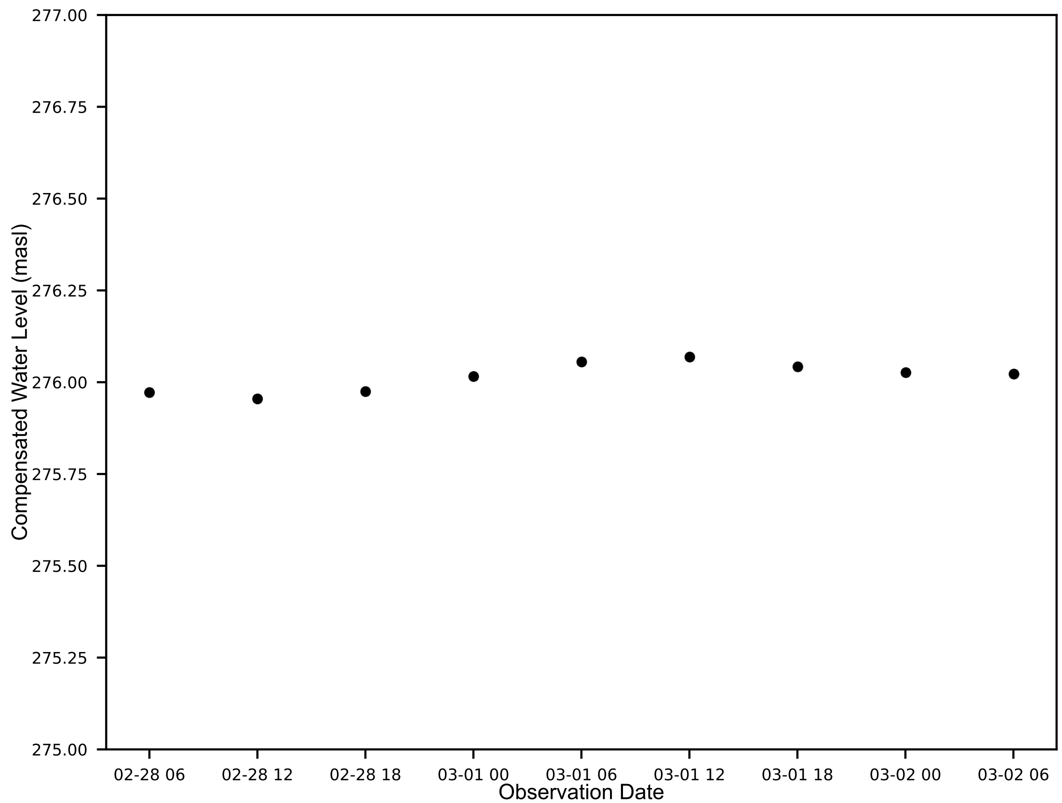
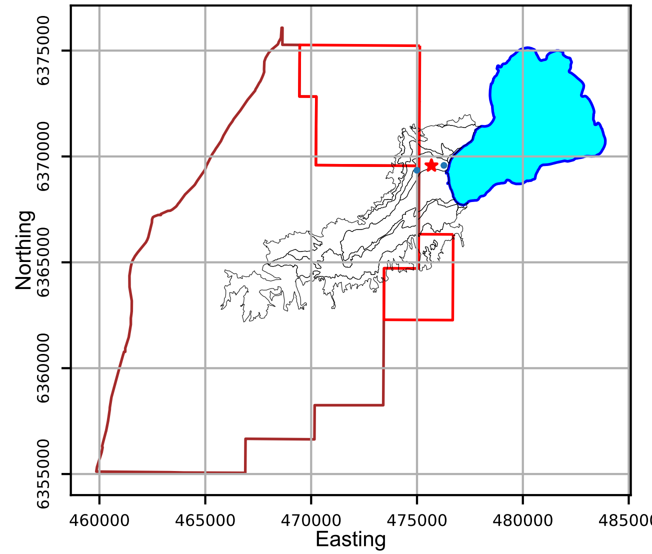




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 43.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

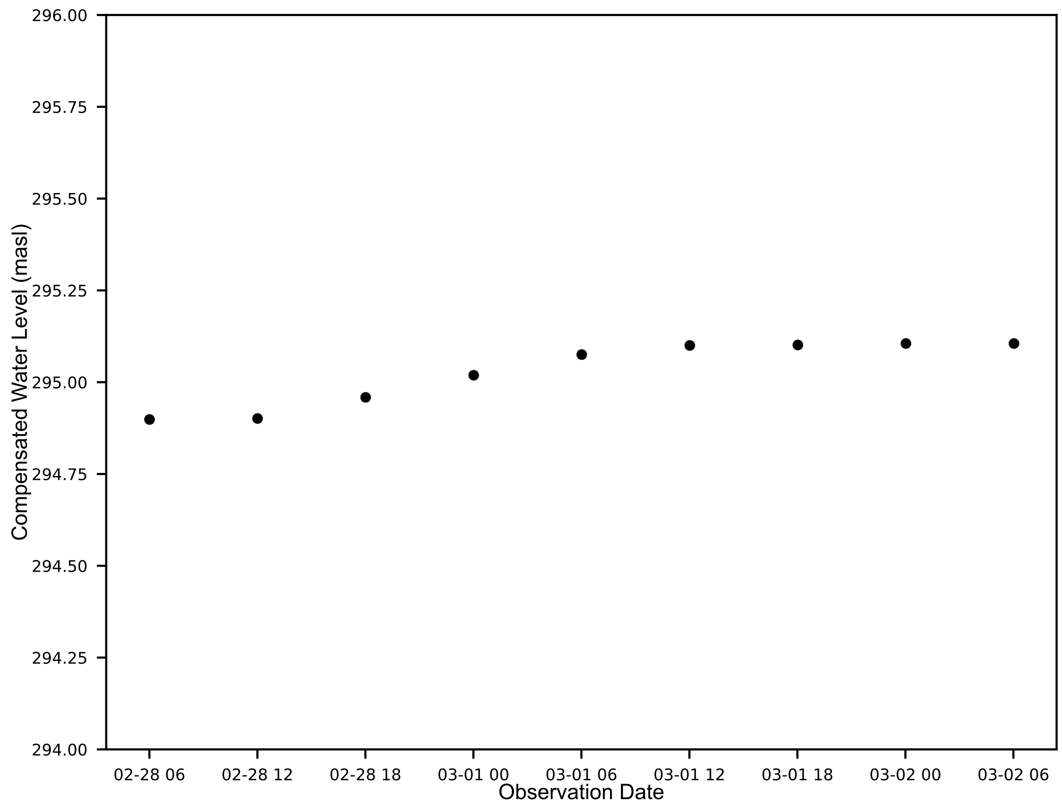
FORTHILLS
Operated by Suncor Energy

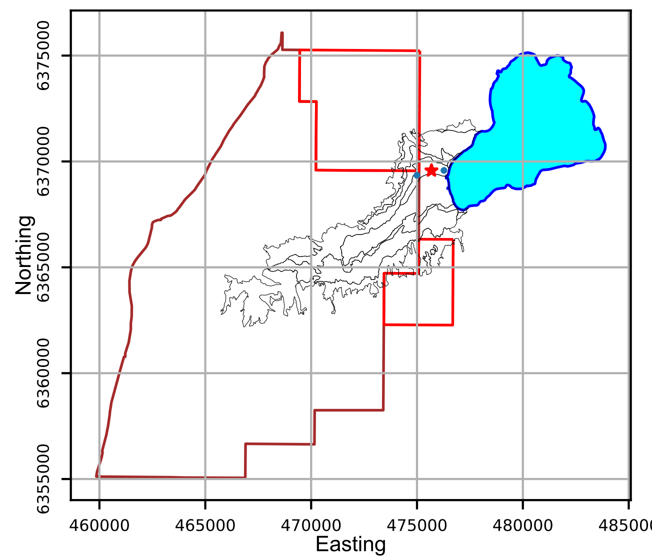
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES608-SN1 - 43.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-5

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

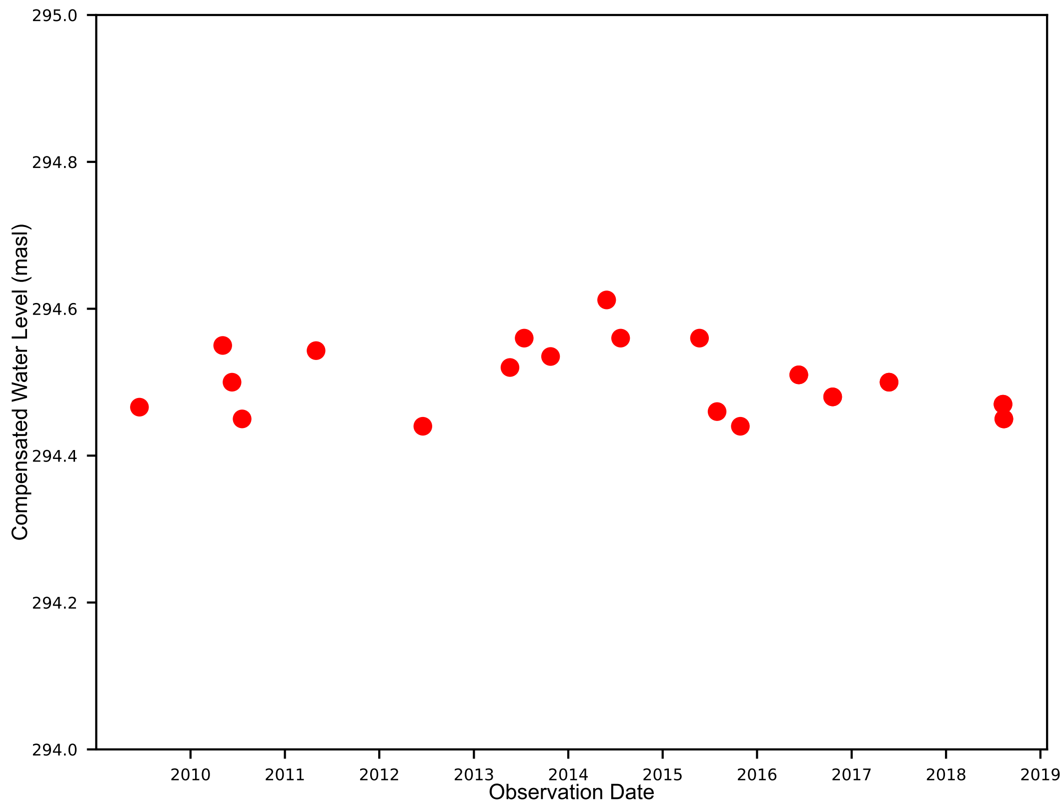
FORT HILLS
Operated by Suncor Energy

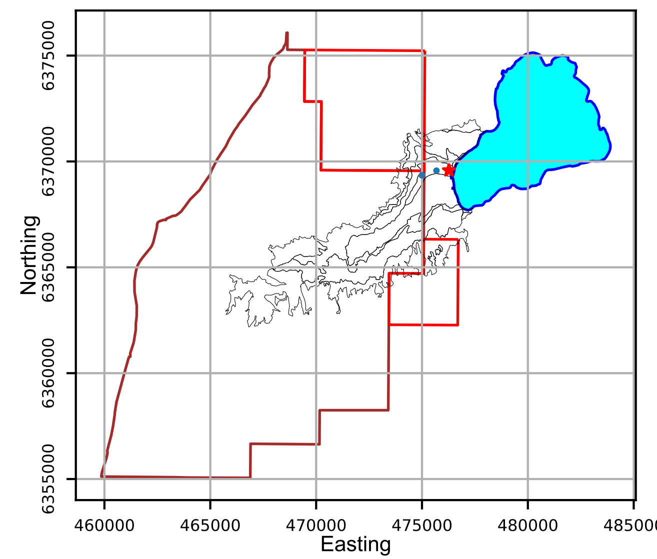
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES608-SN1 - 8.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-6





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-305A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-7

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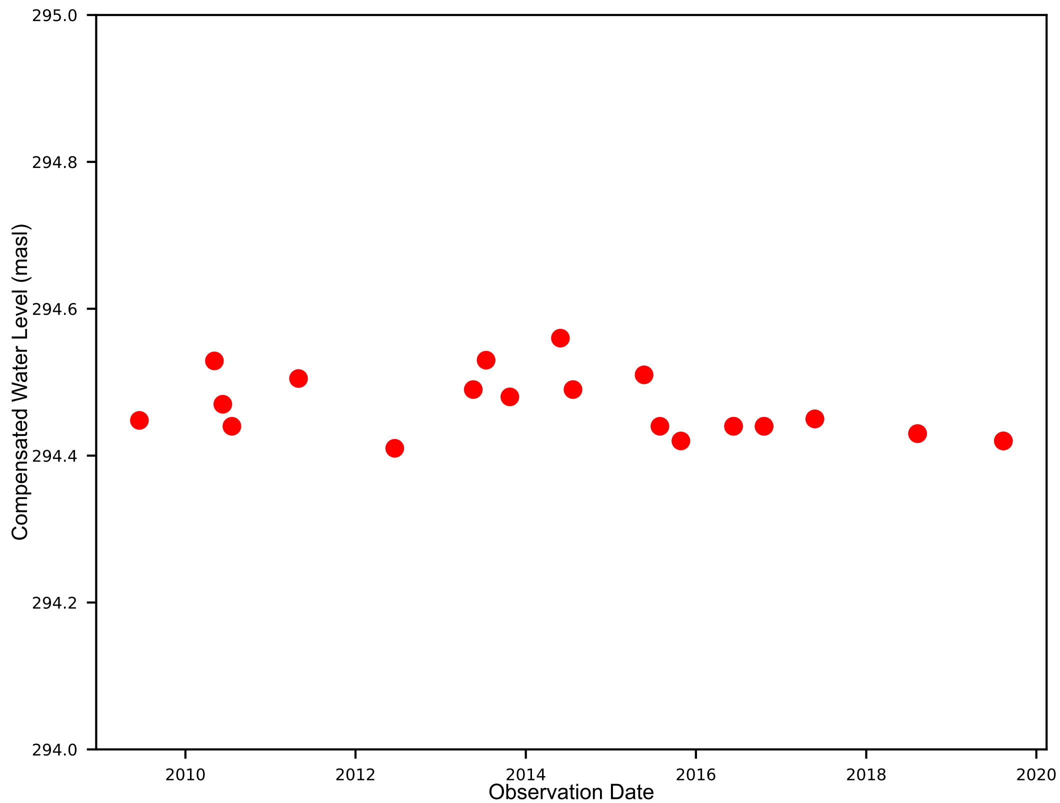
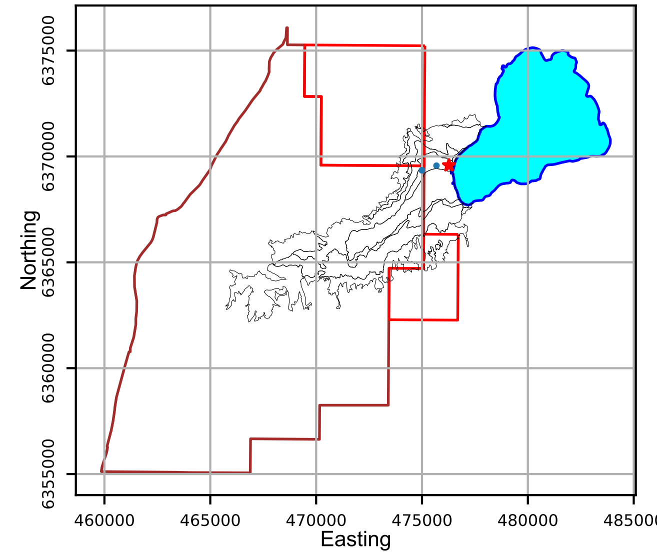




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

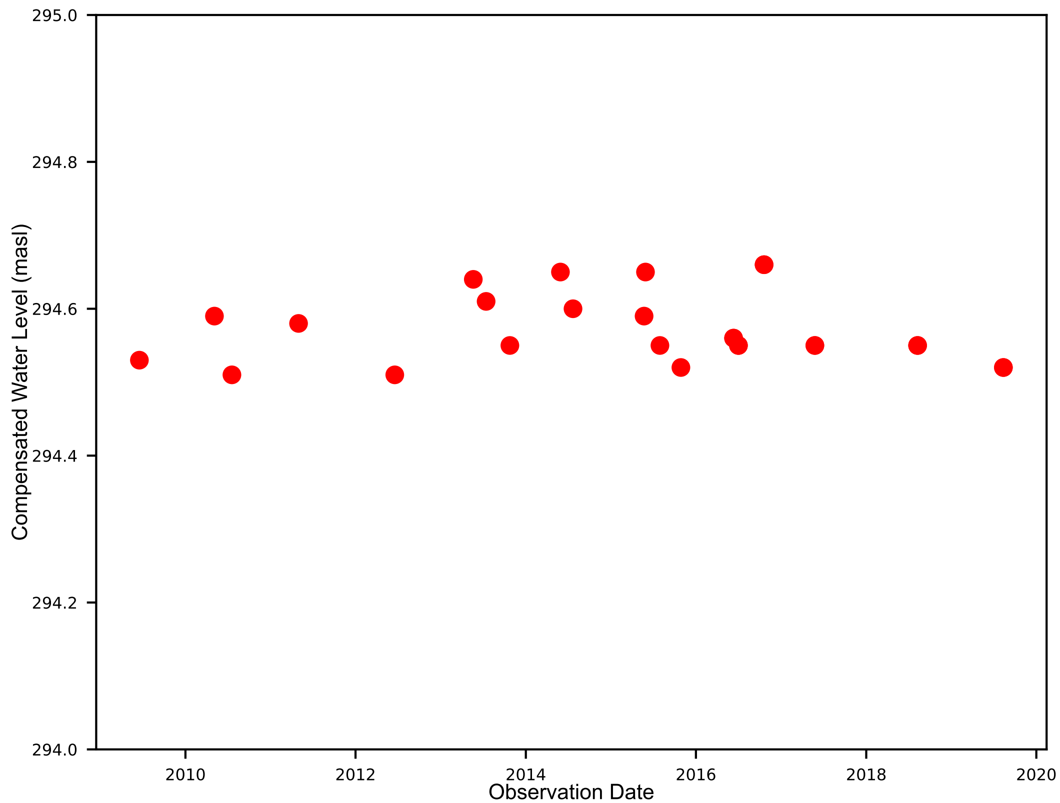
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

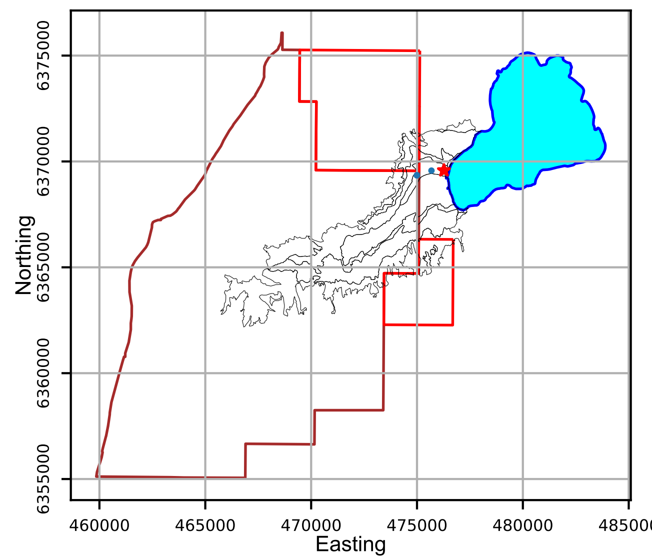
TITLE

MW08-305B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-8

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW08-305C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B1-9

B2 Hydrographs for Ecohydrology Zone 2

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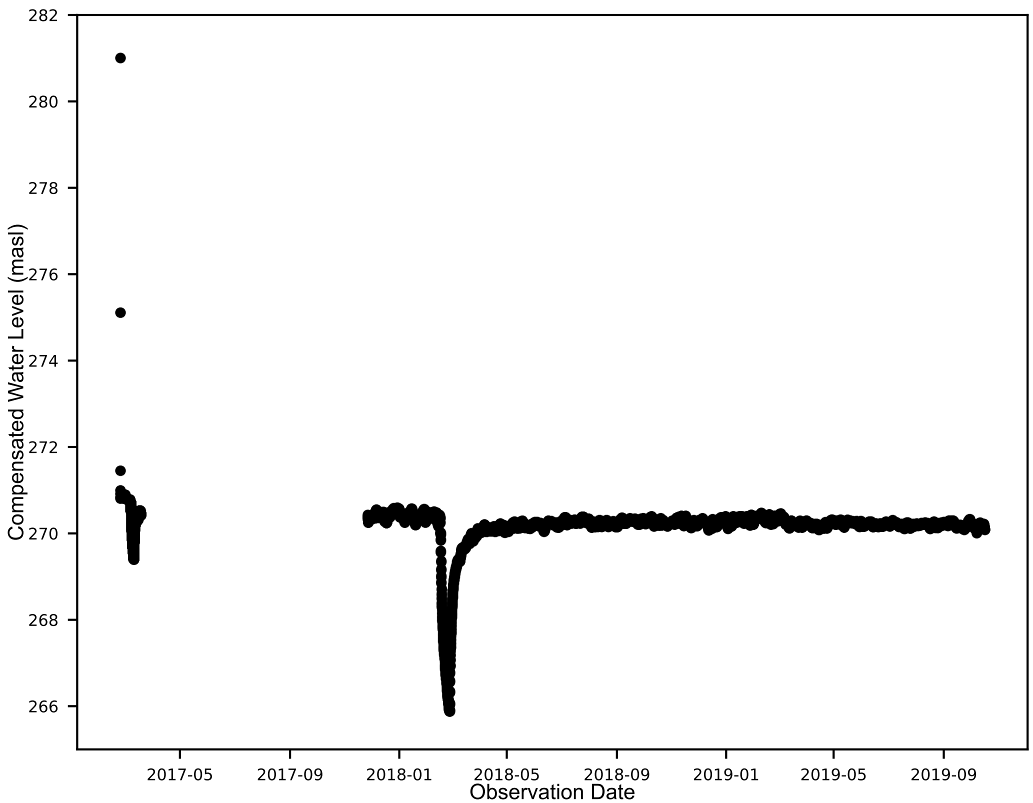

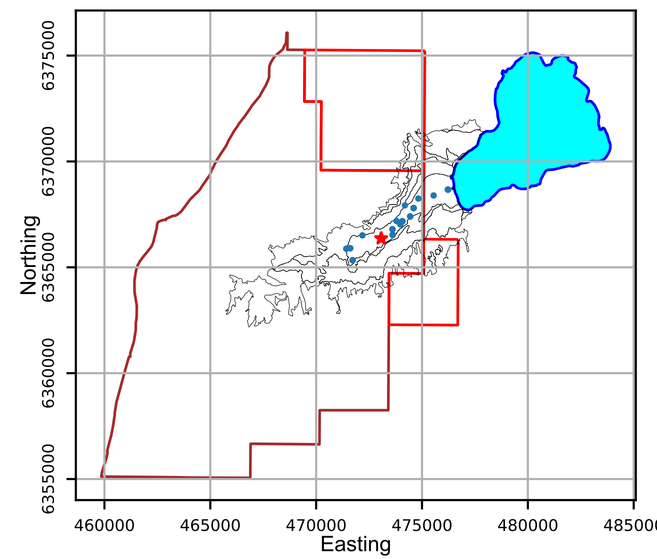

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 107 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR401-MR1 - 107.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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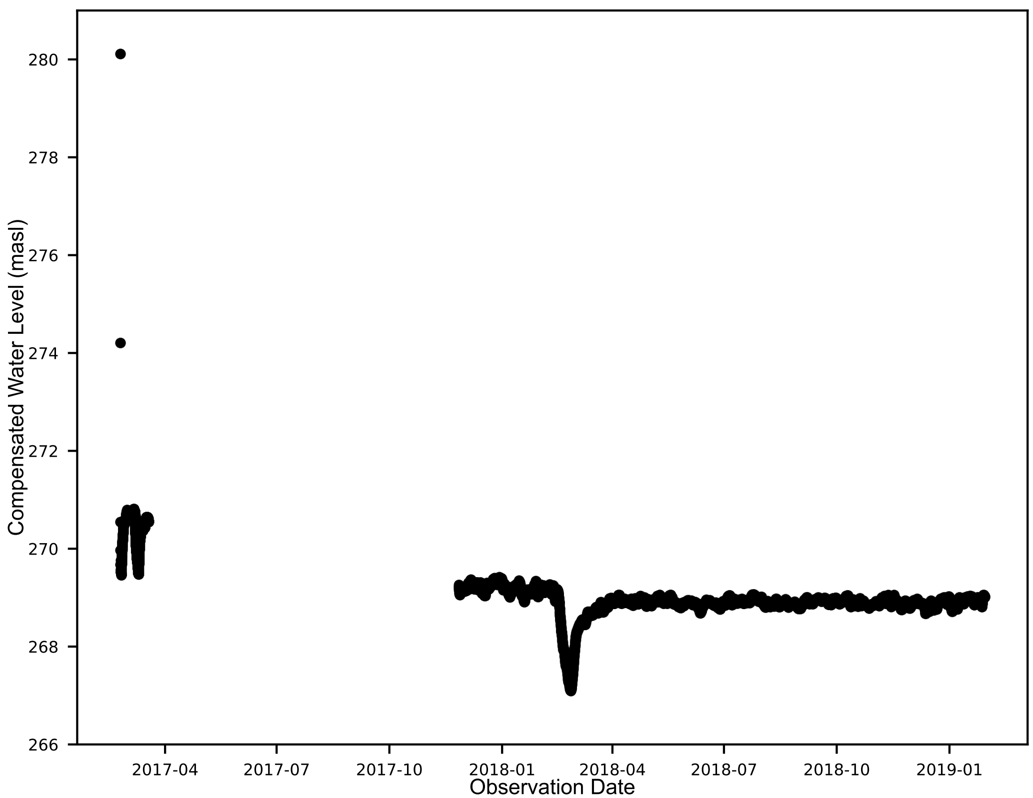
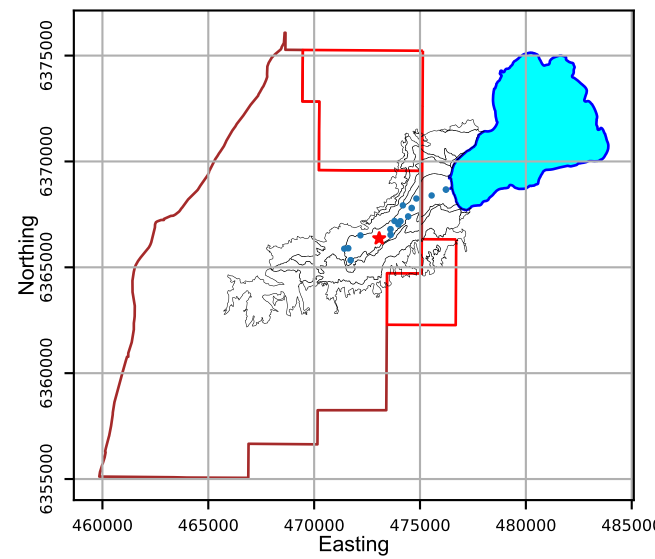
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 115 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR401-MR1 - 115.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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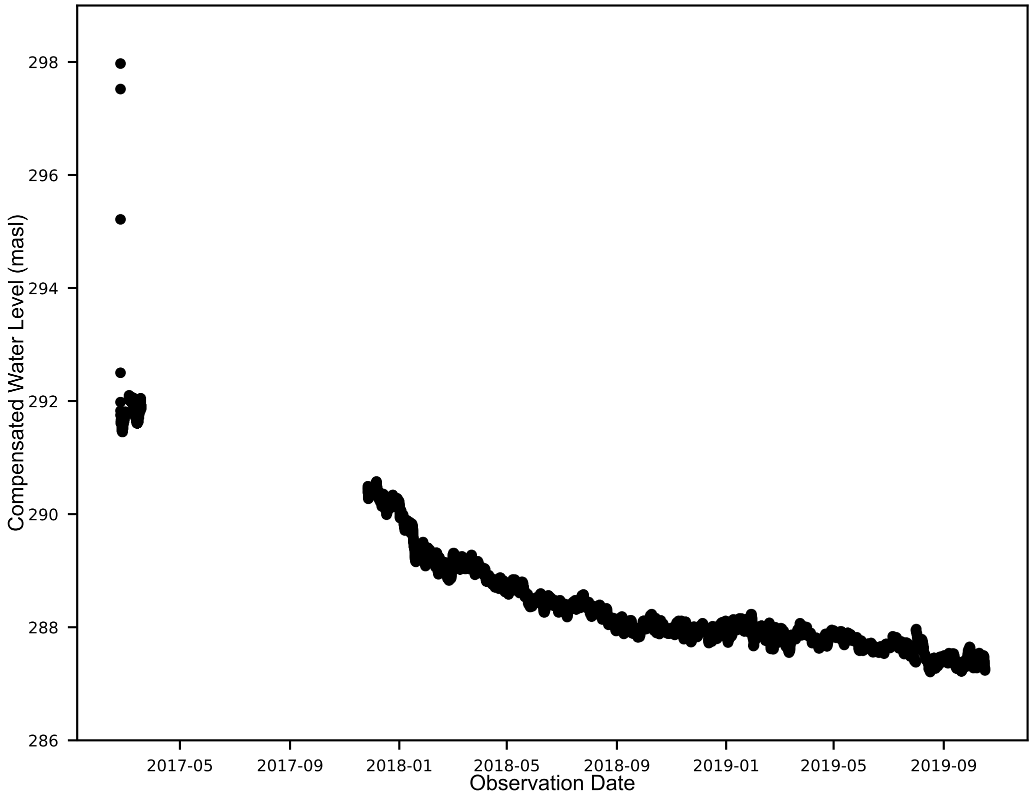
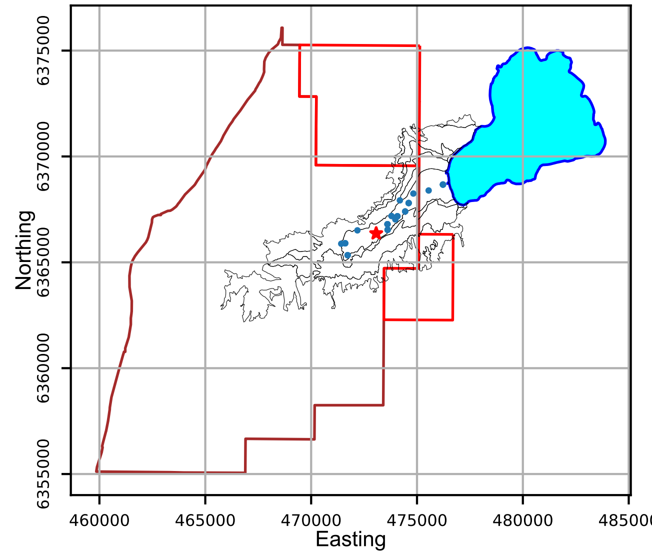




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 70 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

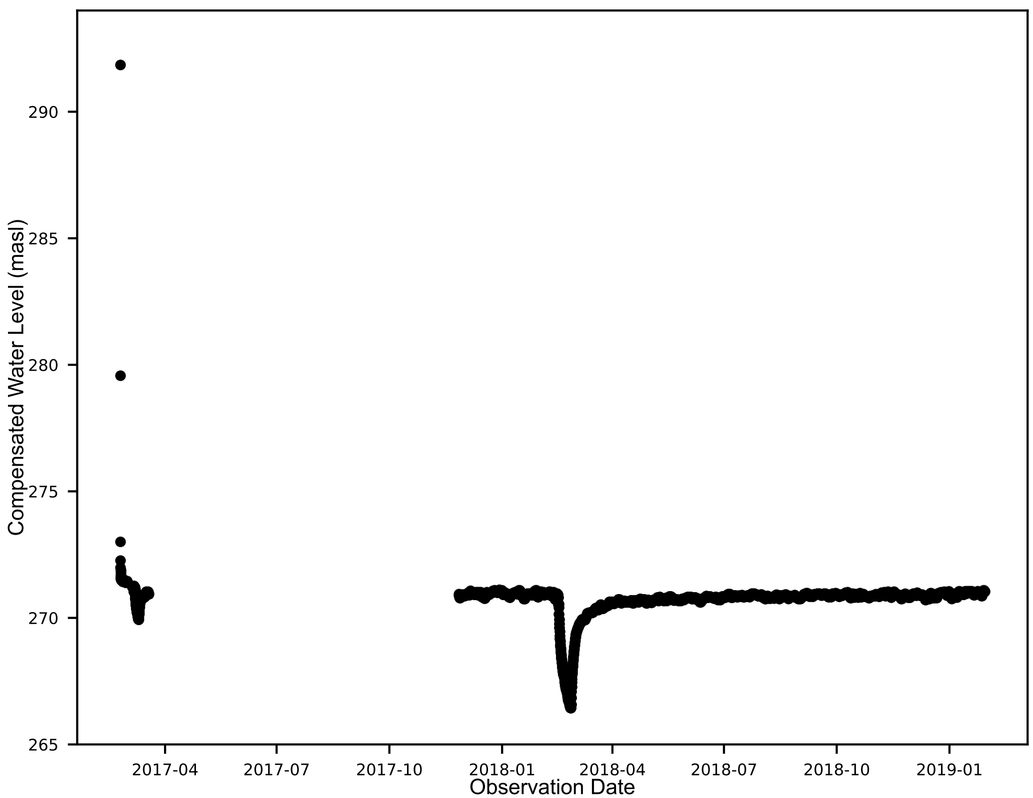
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

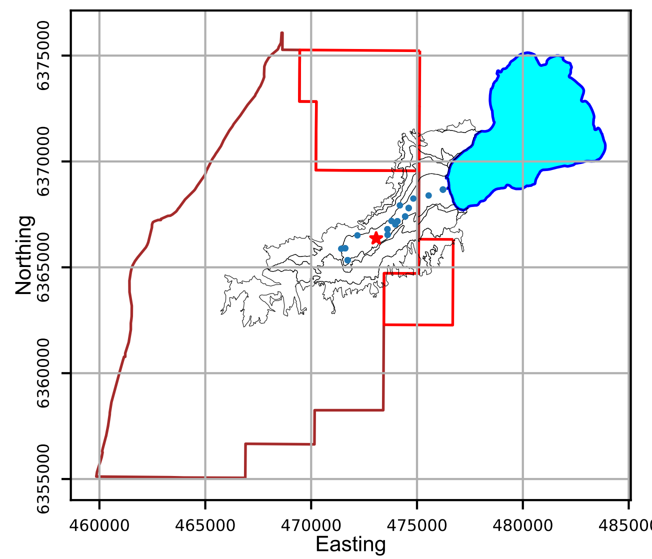
TITLE

FH17-WR401-MR1 - 70.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-3

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 90 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

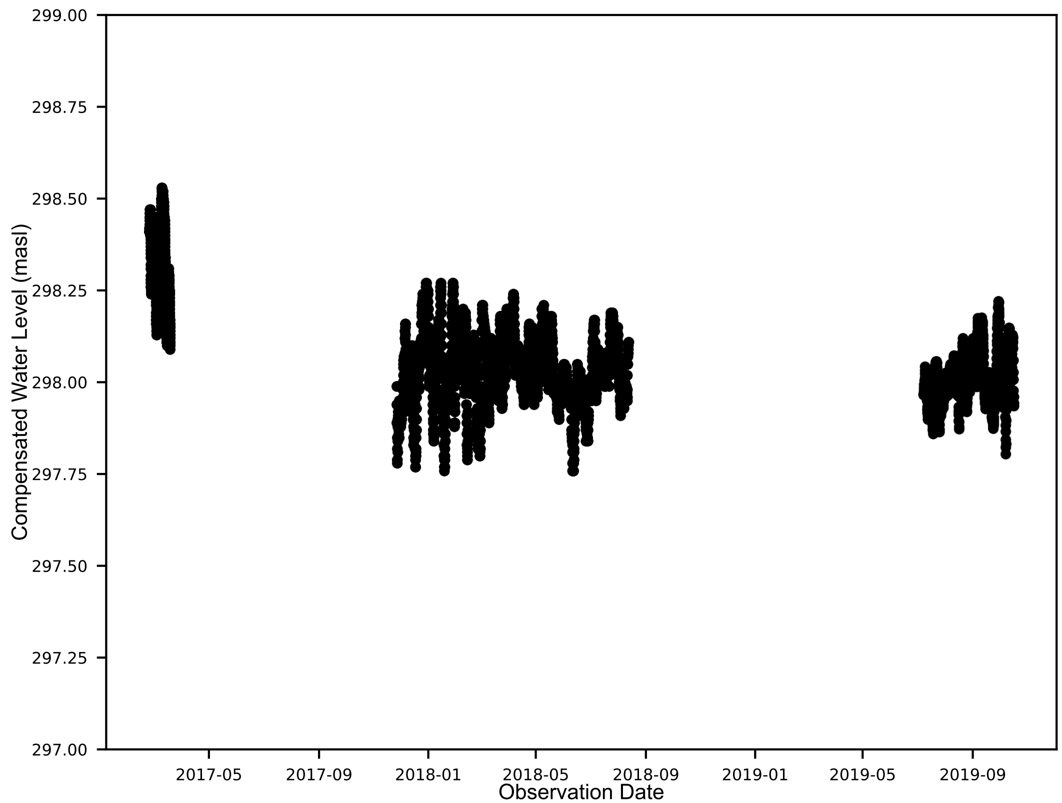
TITLE

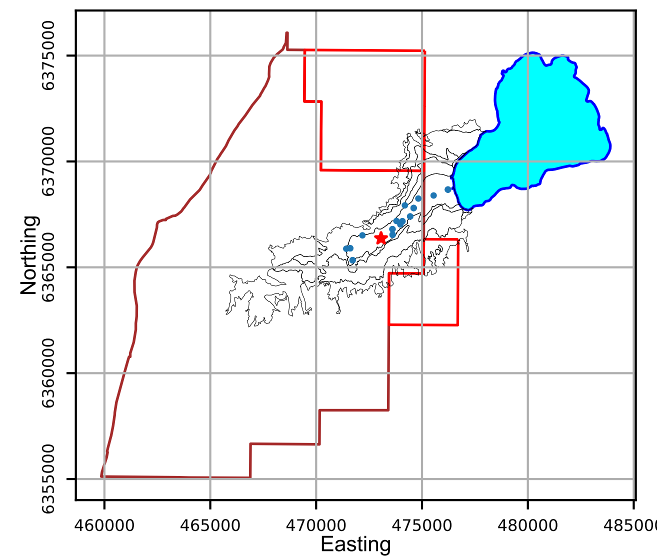
FH17-WR401-MR1 - 90.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-4

1 in

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 23 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR401-SN1 - 23.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-5

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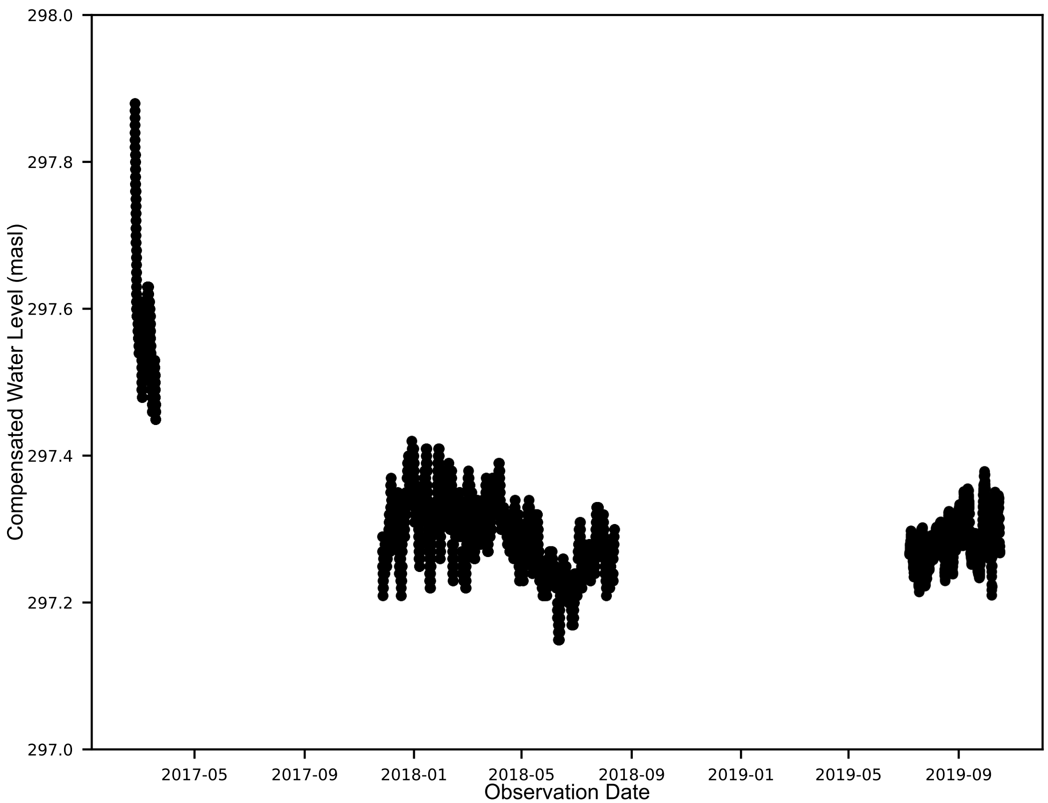
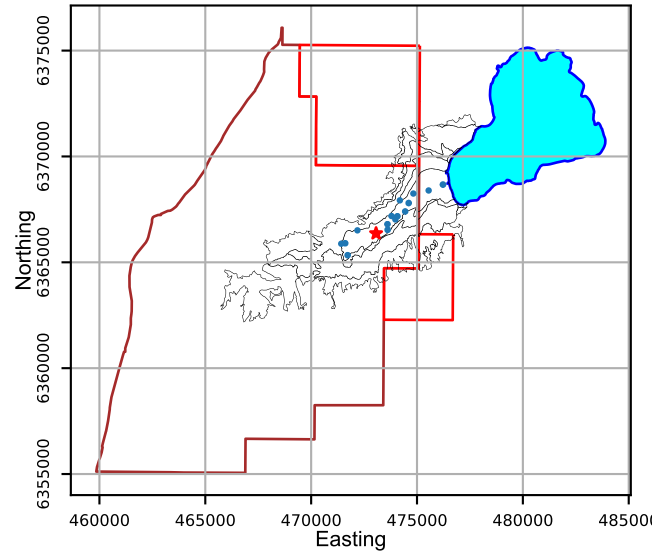




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 36 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

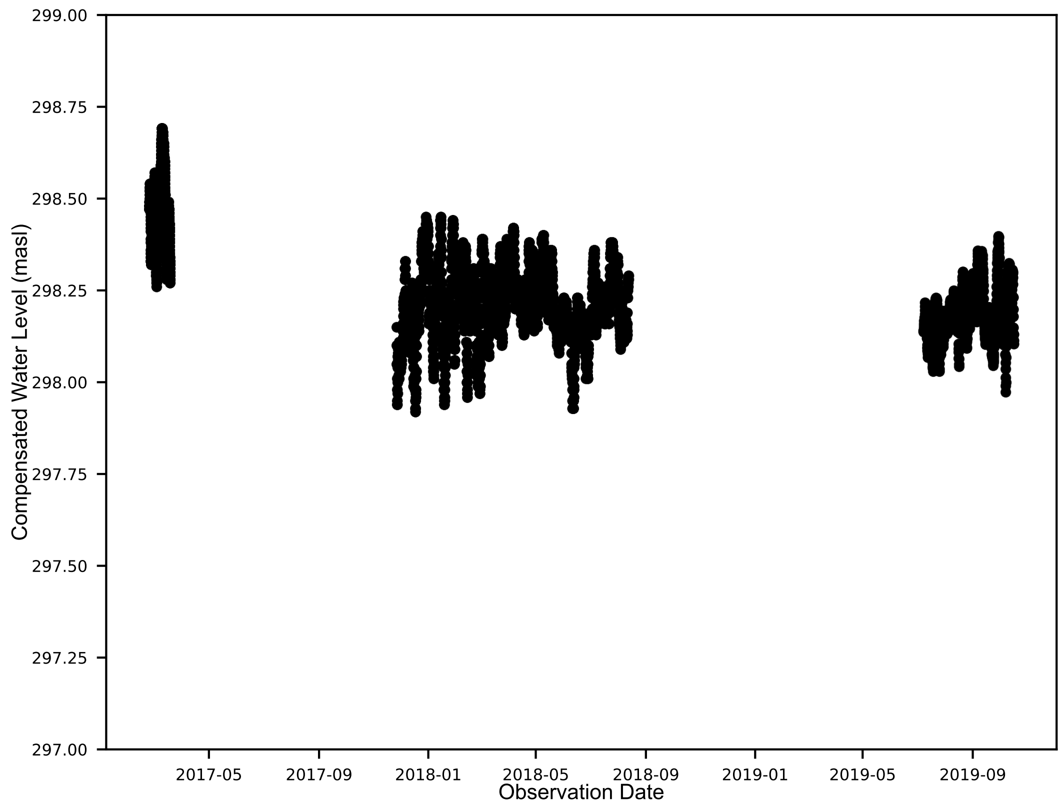
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

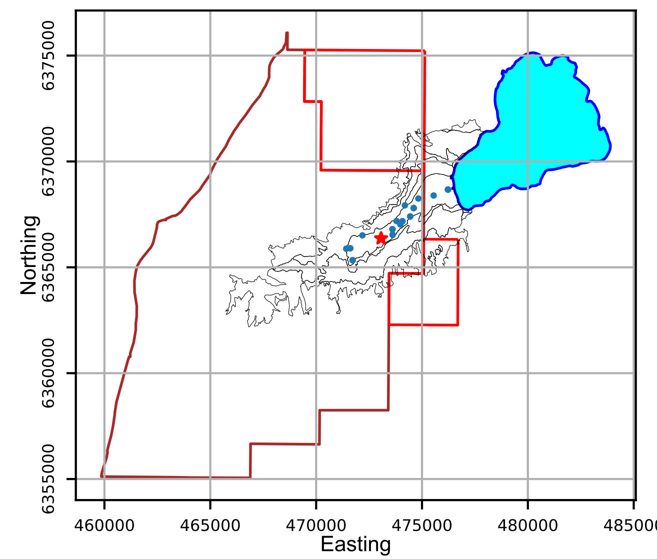
TITLE

FH17-WR401-SN1 - 36.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-6

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR401-SN1 - 9.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-7

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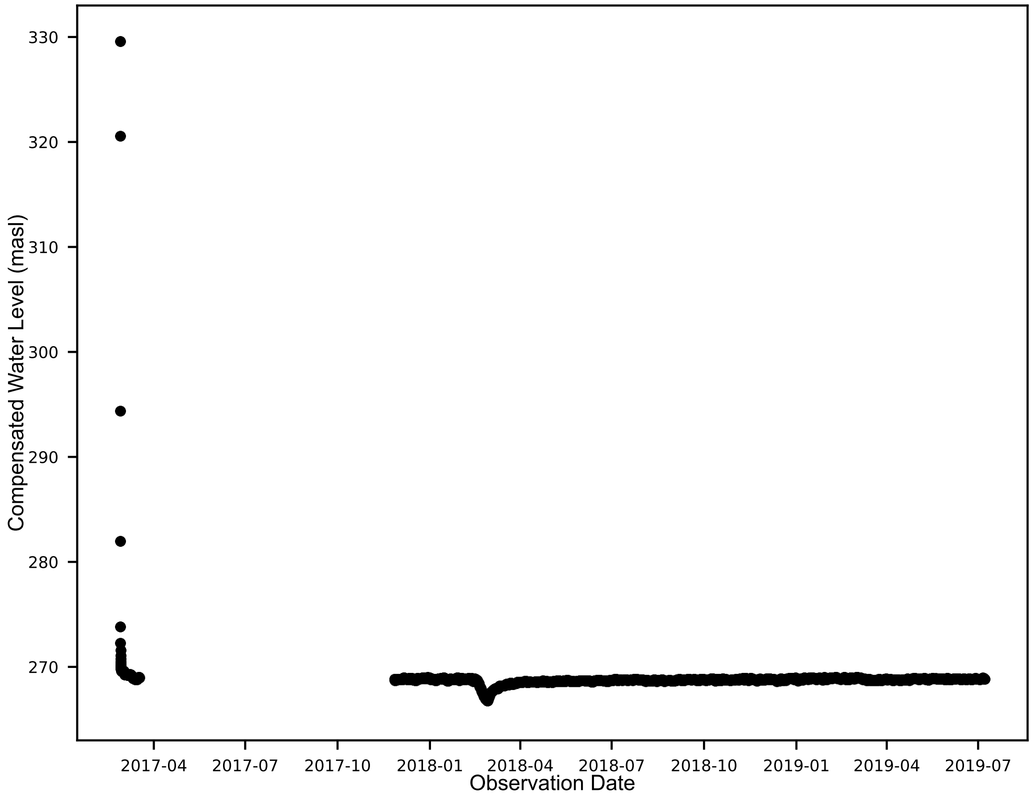
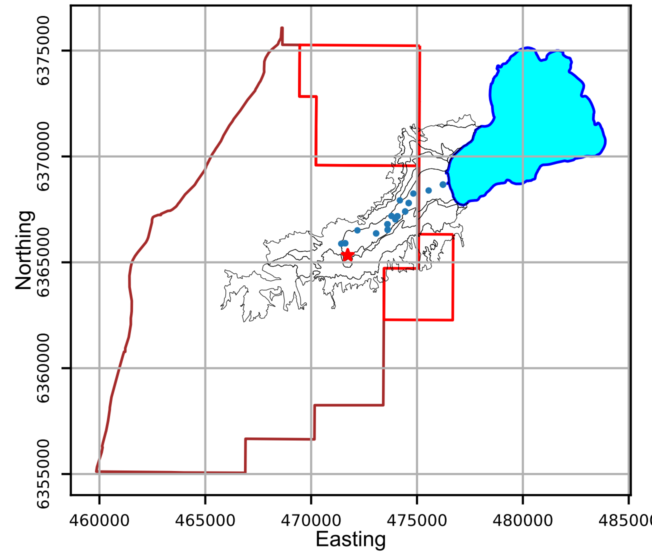




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 107 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

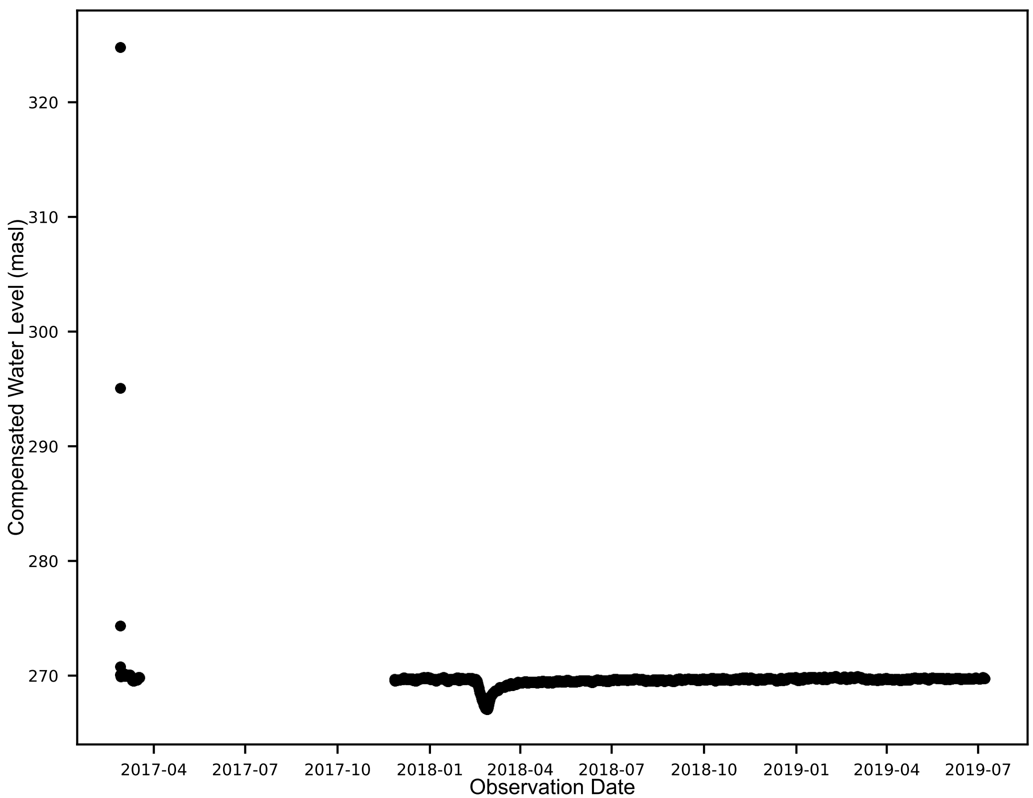
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

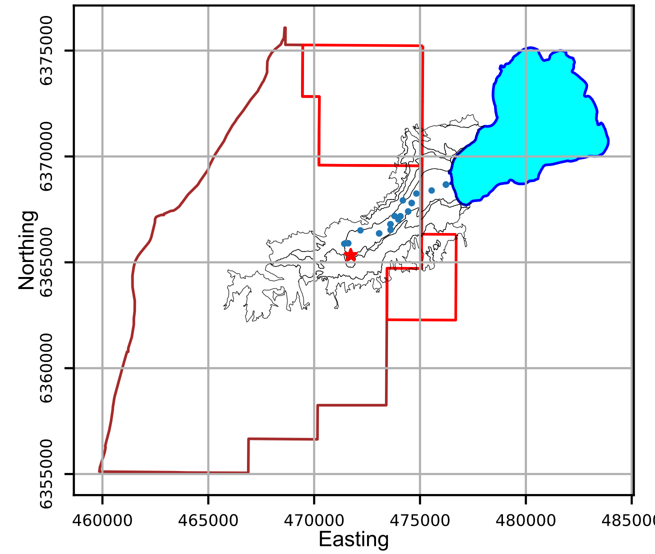
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR404-MR1 - 107.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-8





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 125 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR404-MR1 - 125.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-9

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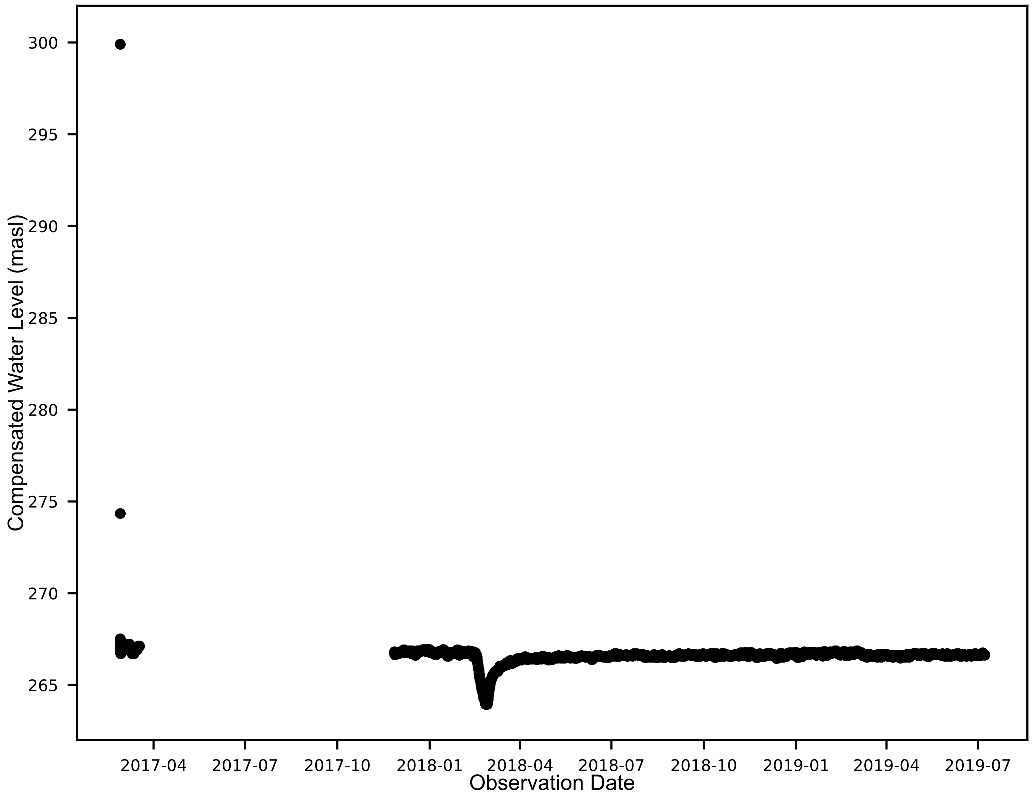
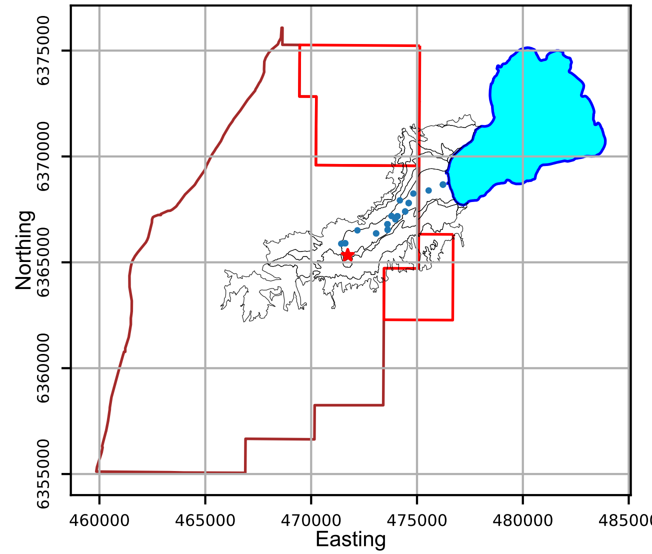




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 134 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

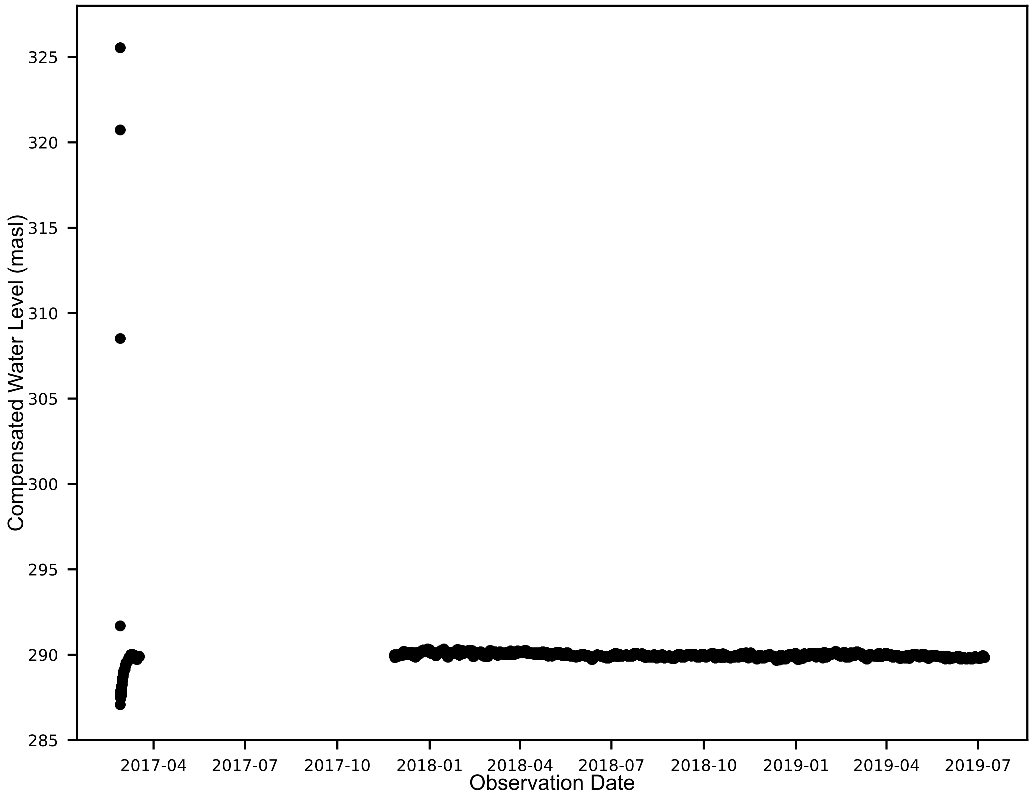
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

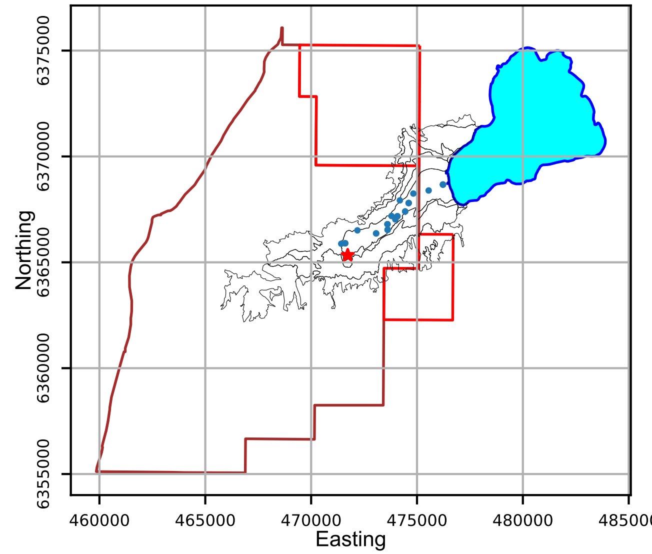
TITLE

FH17-WR404-MR1 - 134.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-10

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 88.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

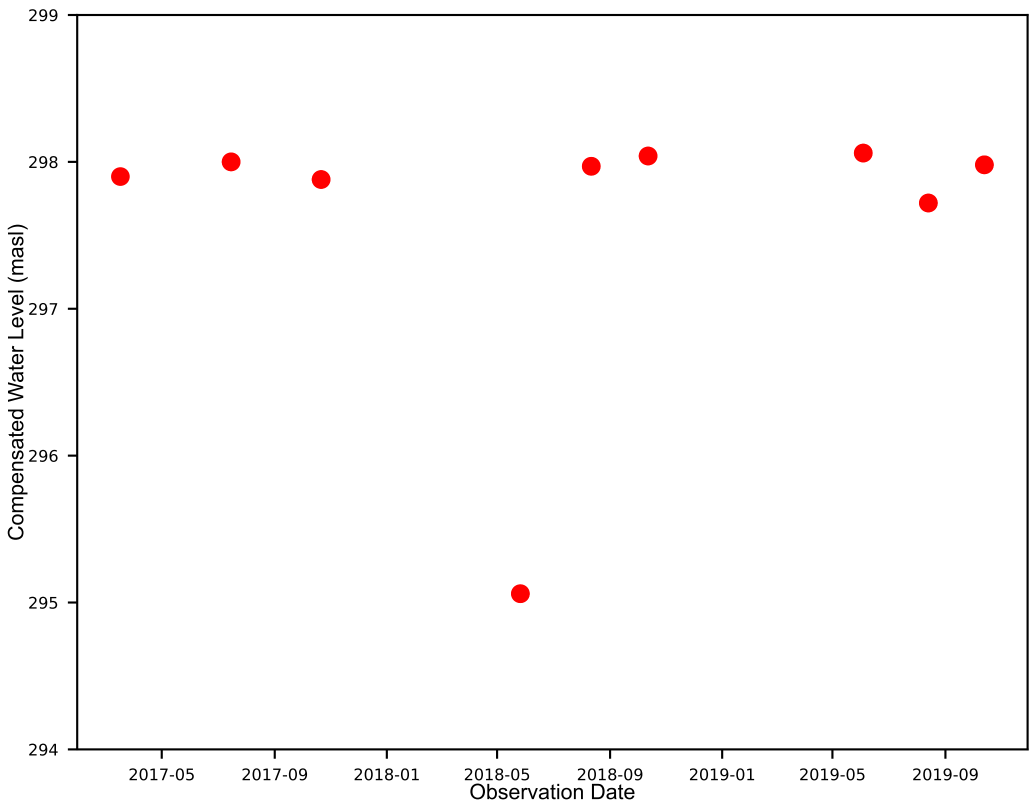
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

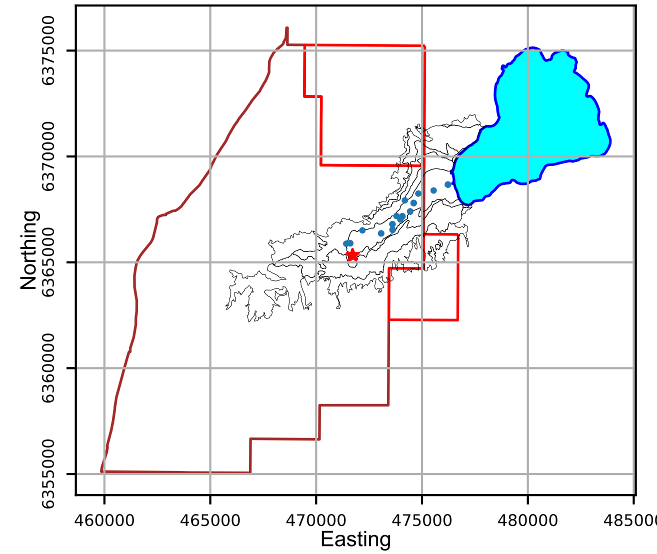
TITLE

FH17-WR404-MR1 - 88.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-11

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 36 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

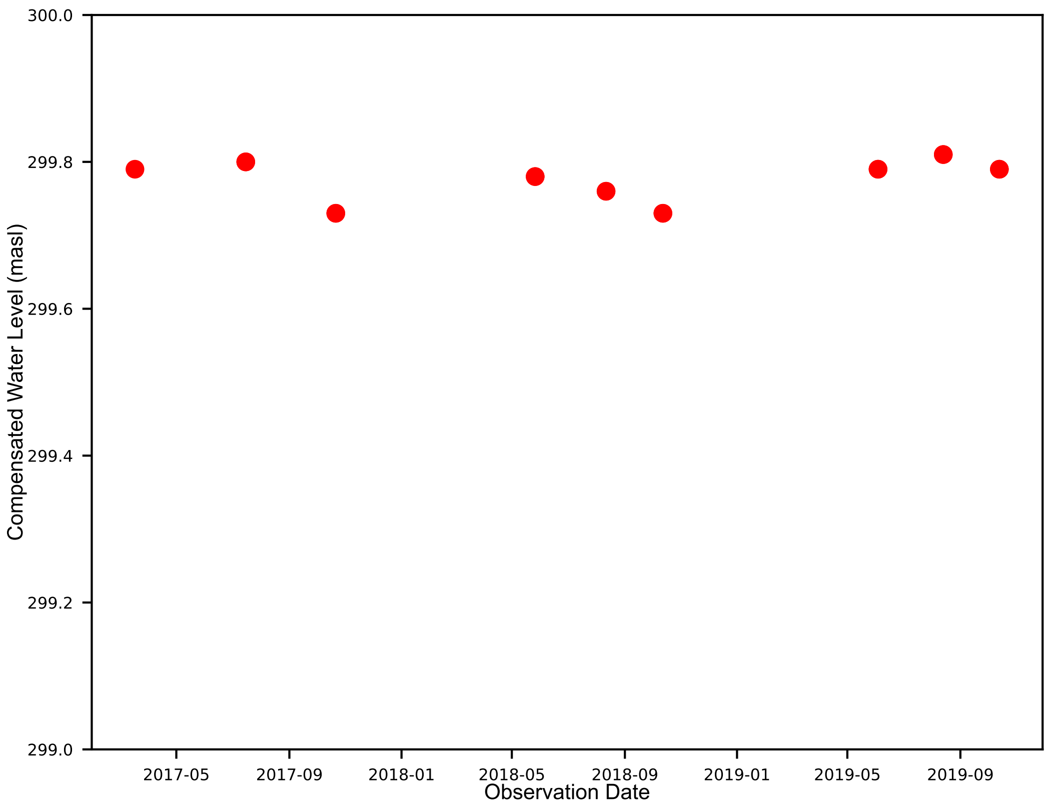
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

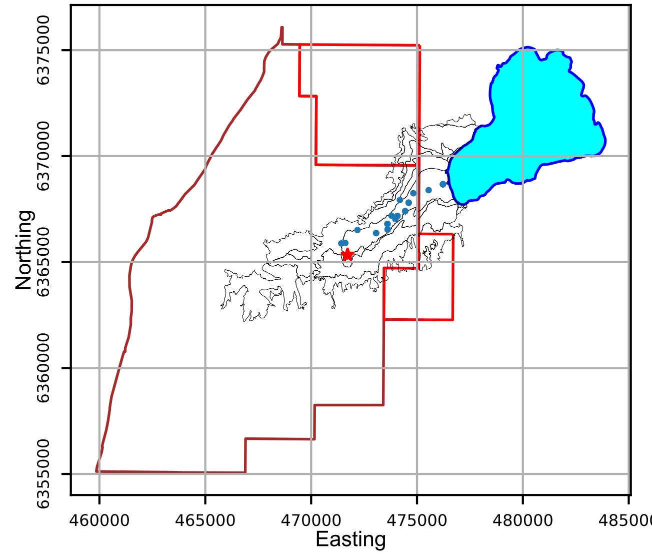
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR404-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-12

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well
Wells
McClelland Lake
Approved Project Area
Ecohydrology Zone
Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement
Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.35 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR404-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-13

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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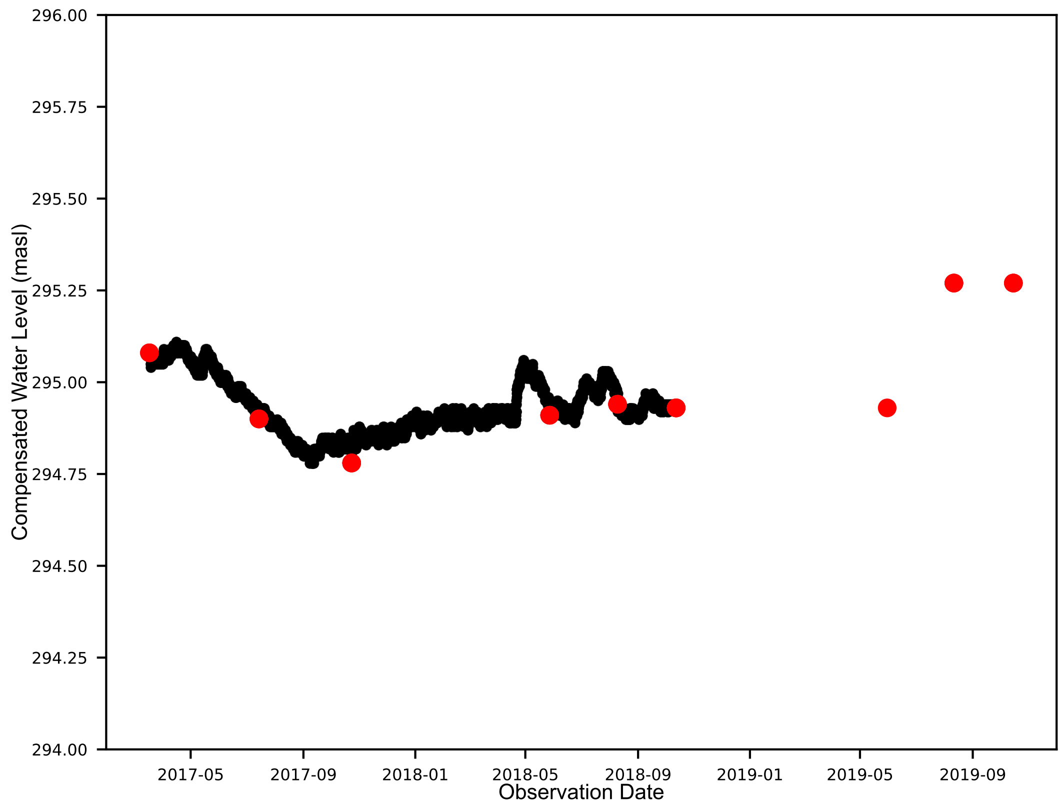
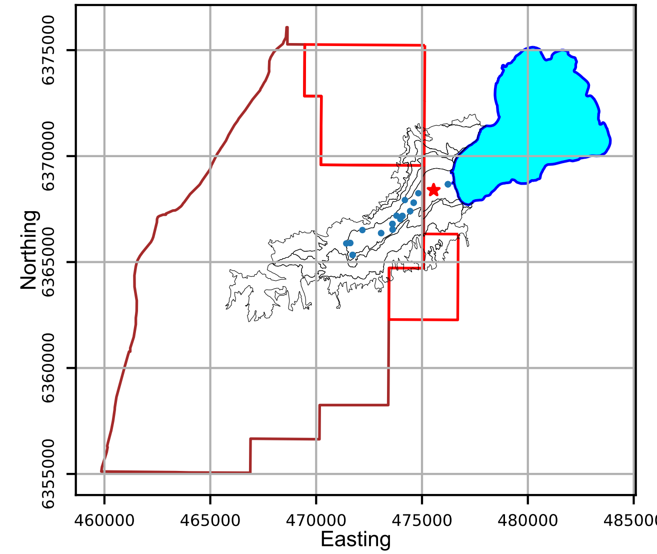




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

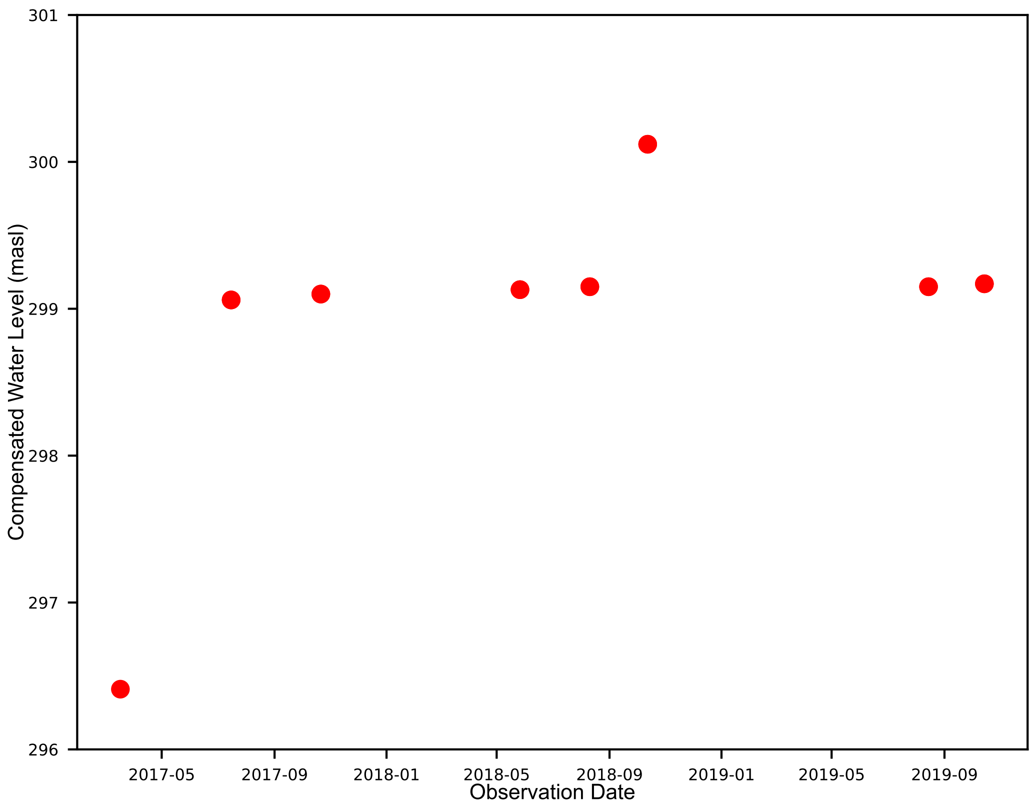
FORTHILLS
Operated by Suncor Energy

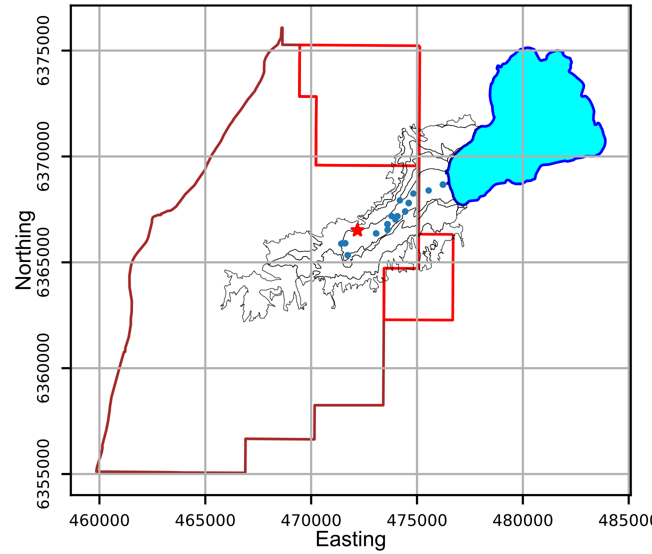
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR416-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-14

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 21.34 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR427-SN1
PROJECT No.	20140450
CONTROL	100
Rev.	A
FIGURE	B2-15

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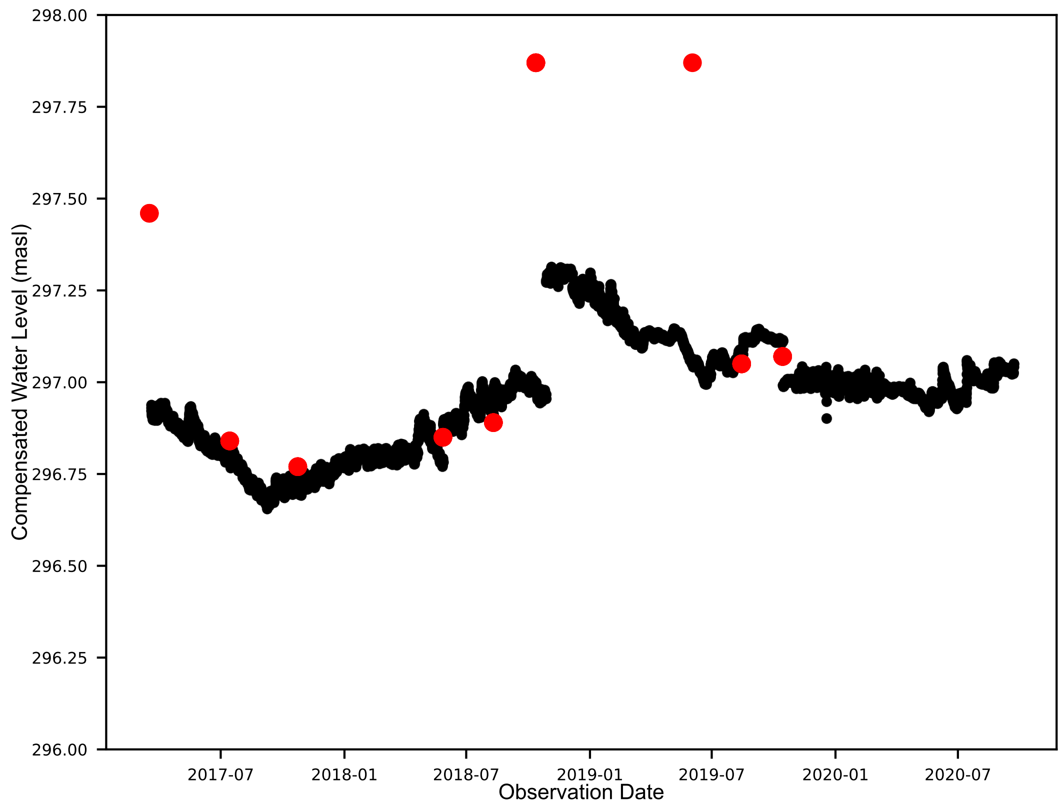

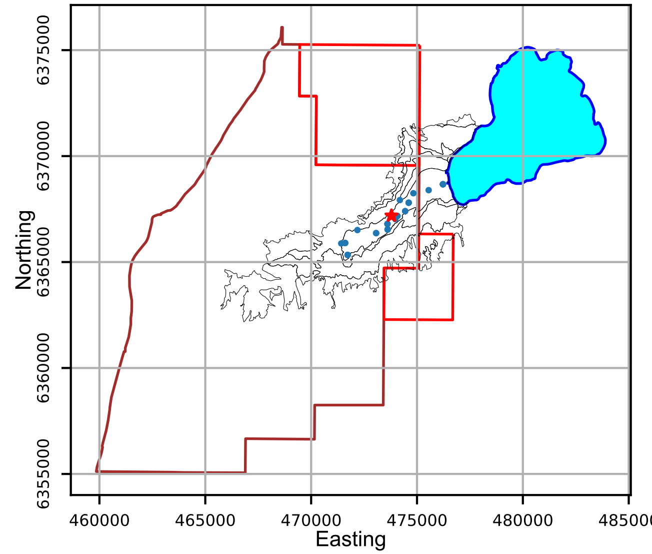

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 11.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR440-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-16

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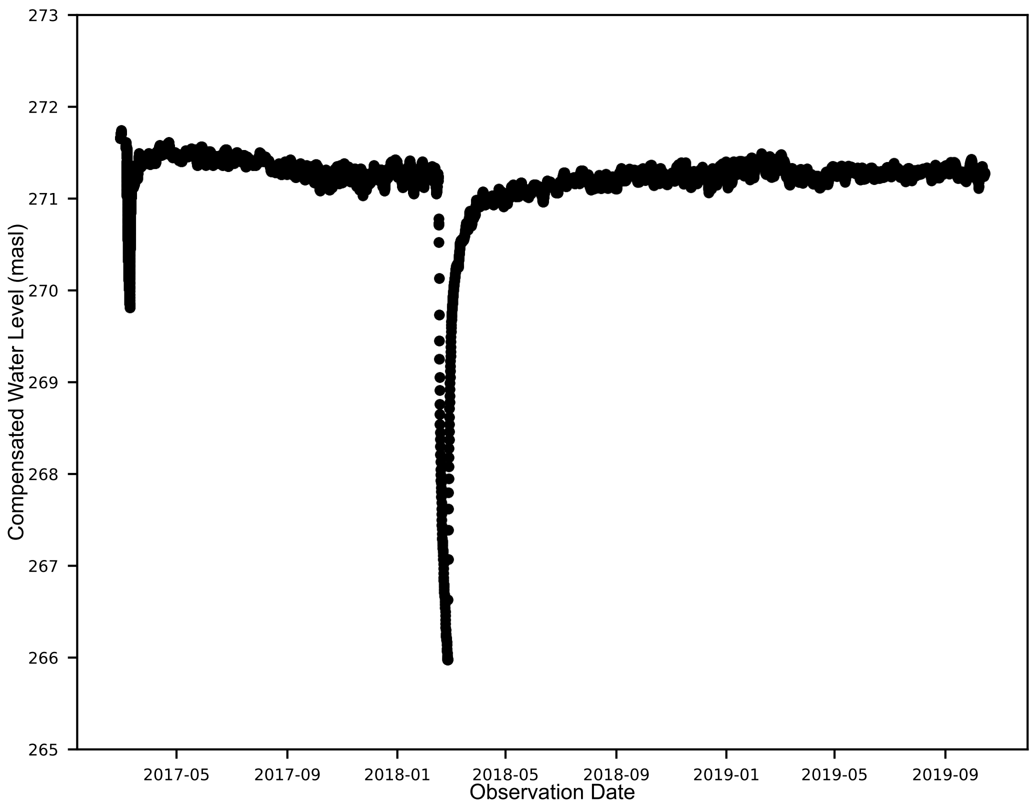
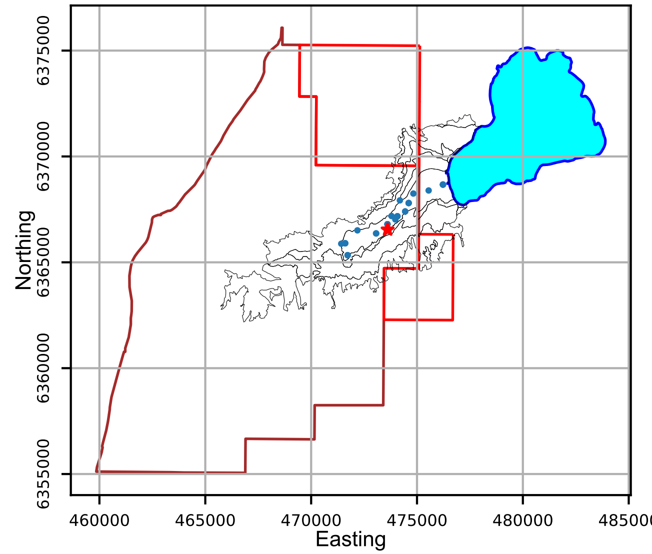




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 104 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

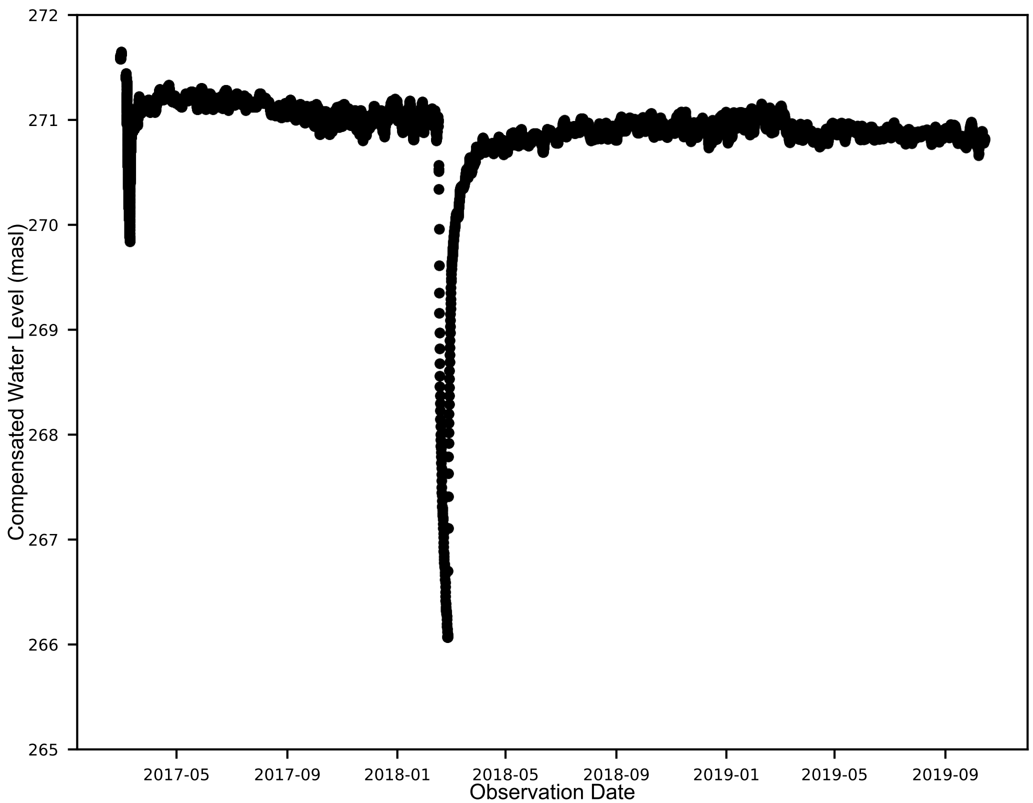
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

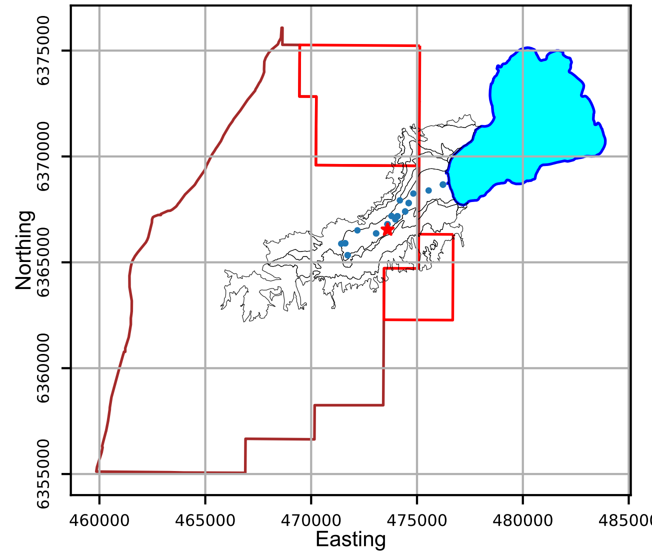
TITLE
FH17-WR446-MR1 - 104.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-17

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 119 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR446-MR1 - 119.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B2-18

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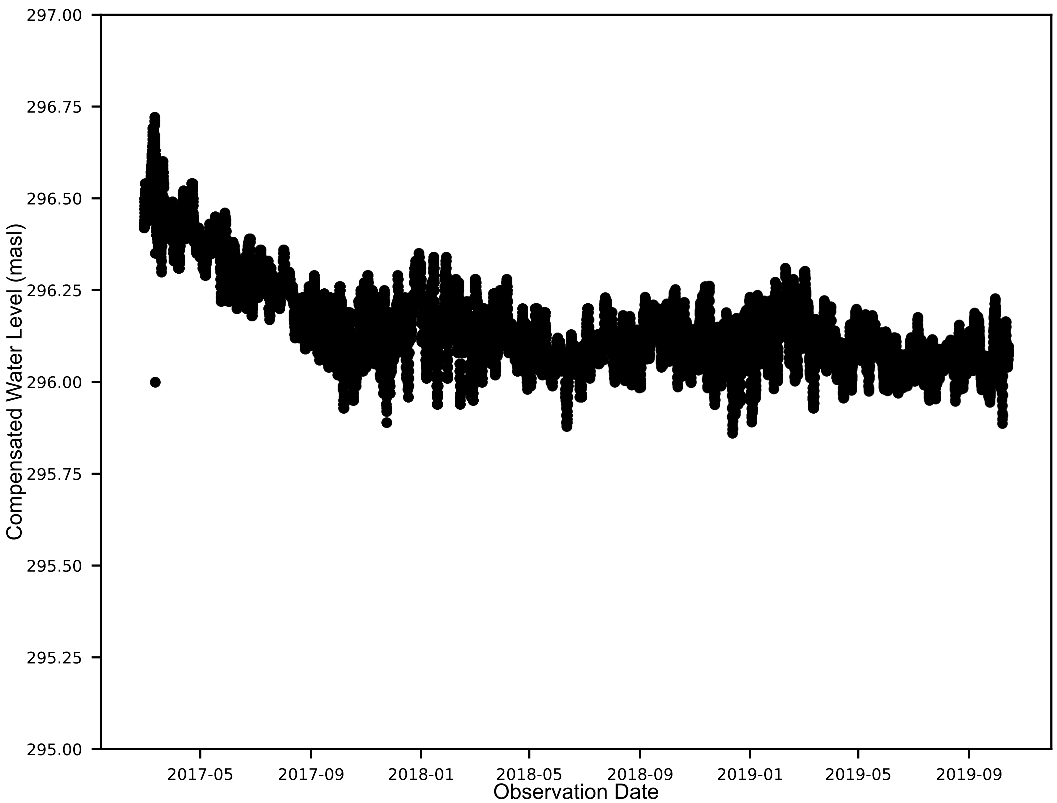
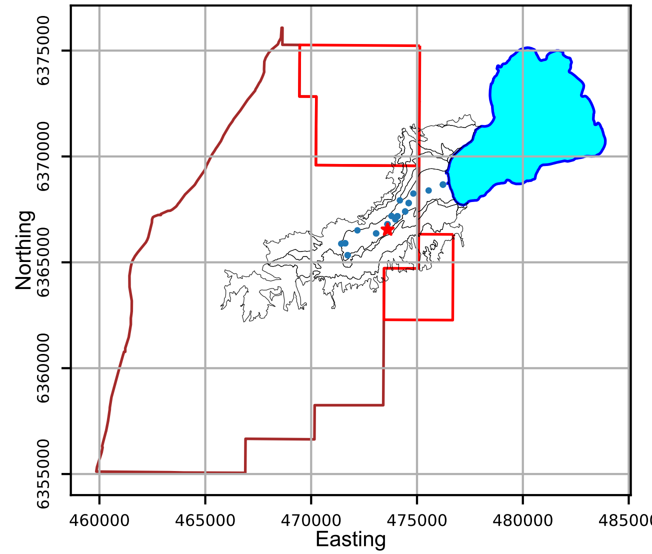




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 57 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

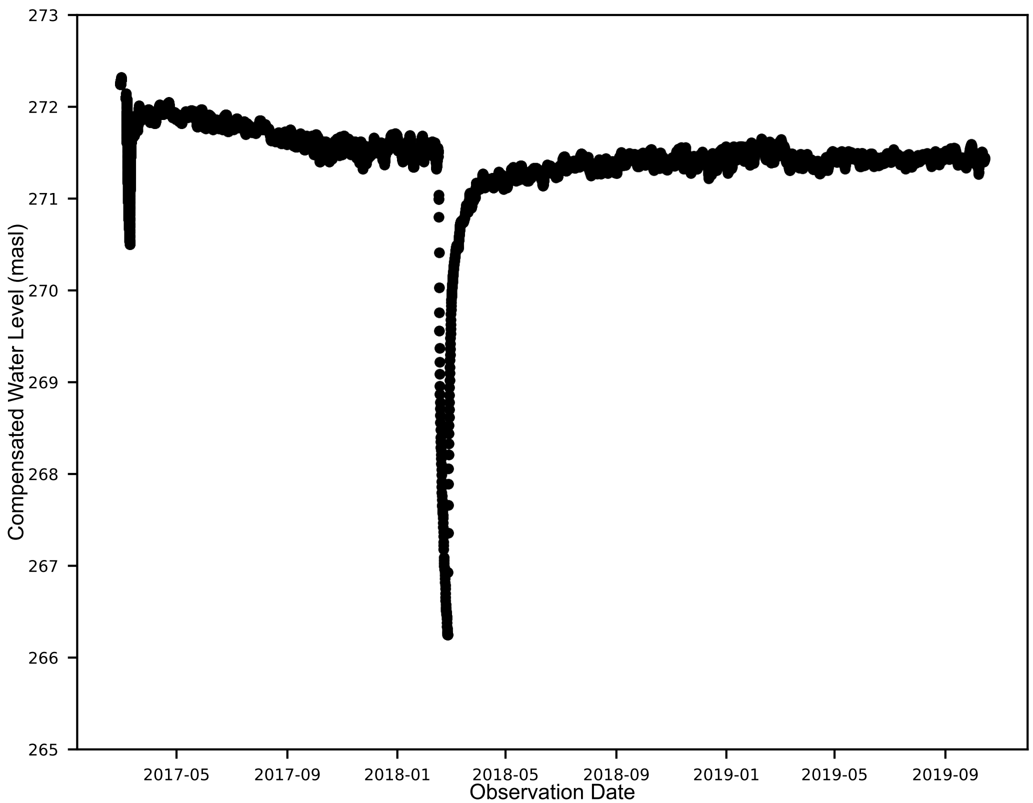
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

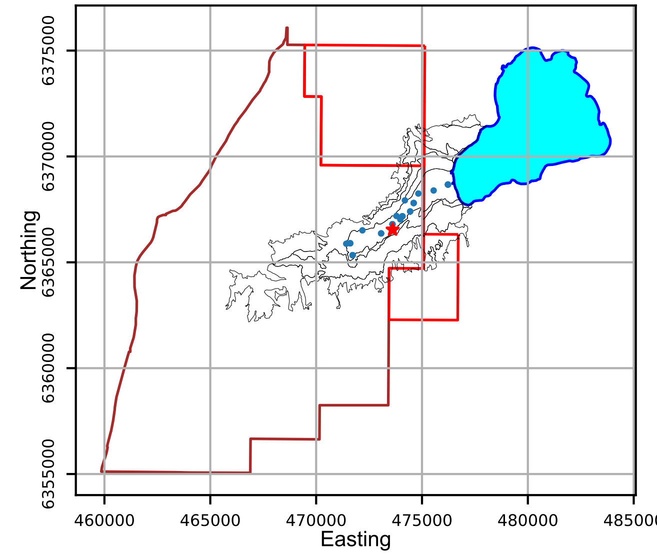
TITLE

FH17-WR446-MR1 - 57.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-19

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 90 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

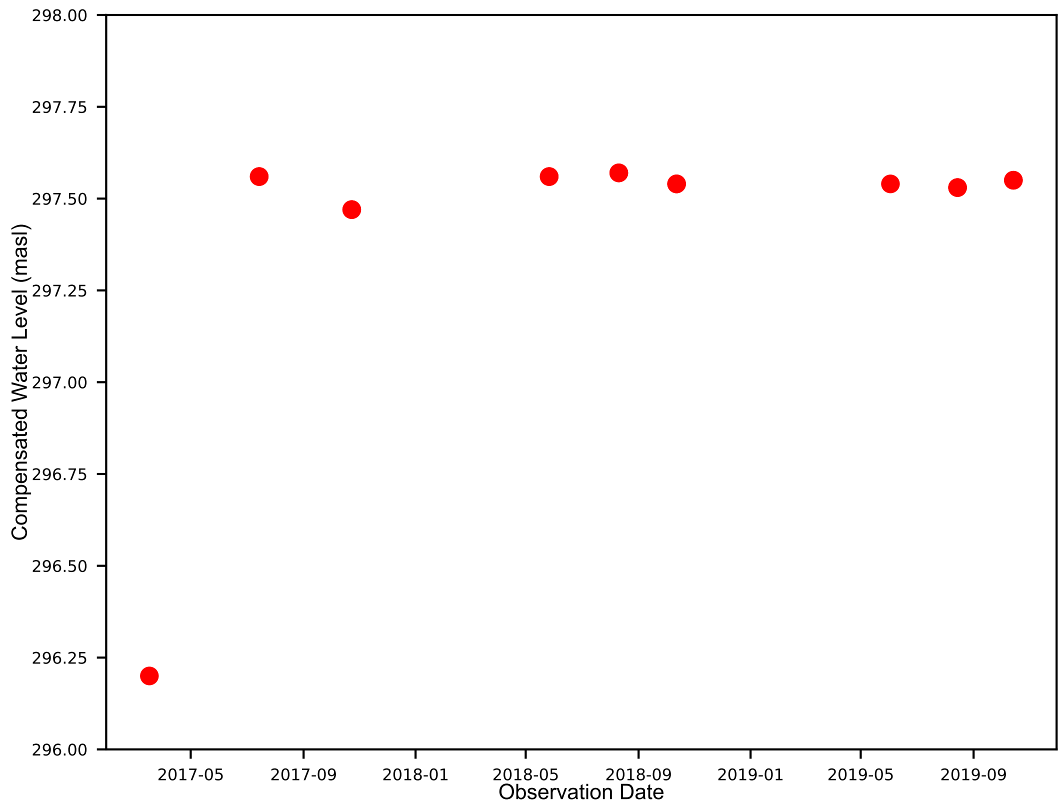
FORTHILLS
Operated by Suncor Energy

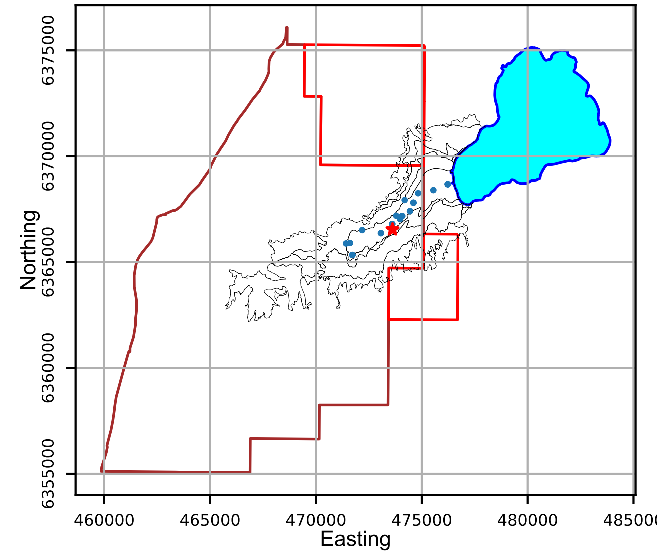
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR446-MR1 - 90.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-20

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 13.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR446-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-21

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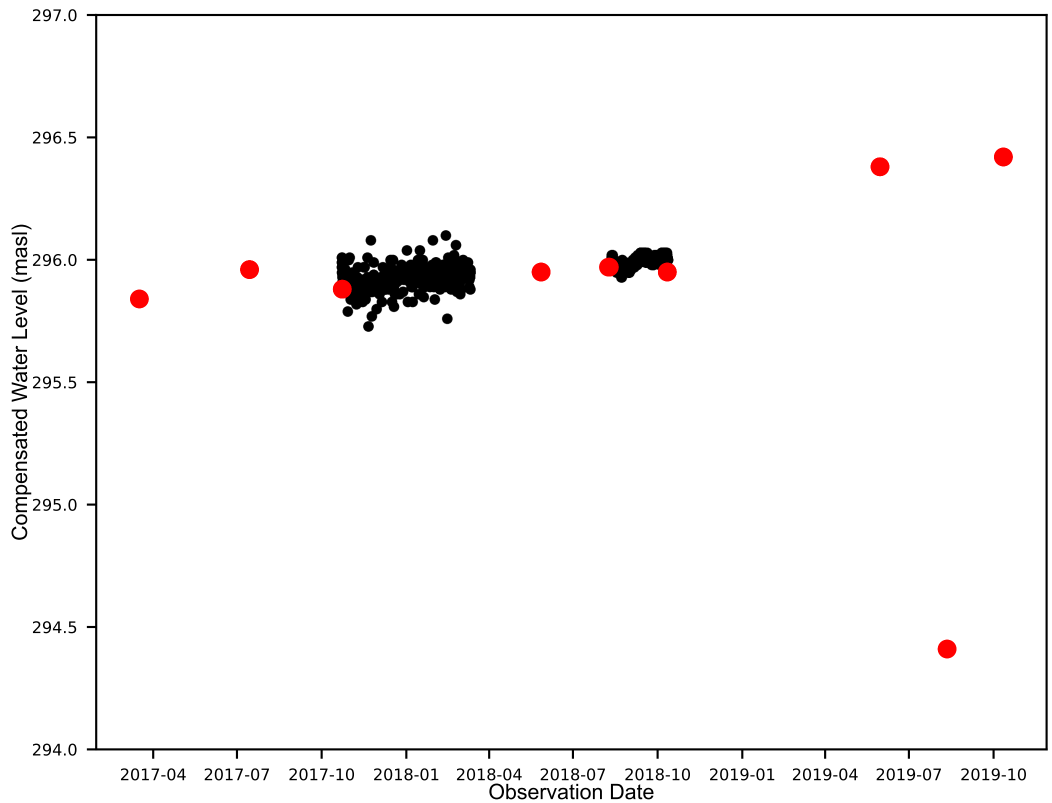
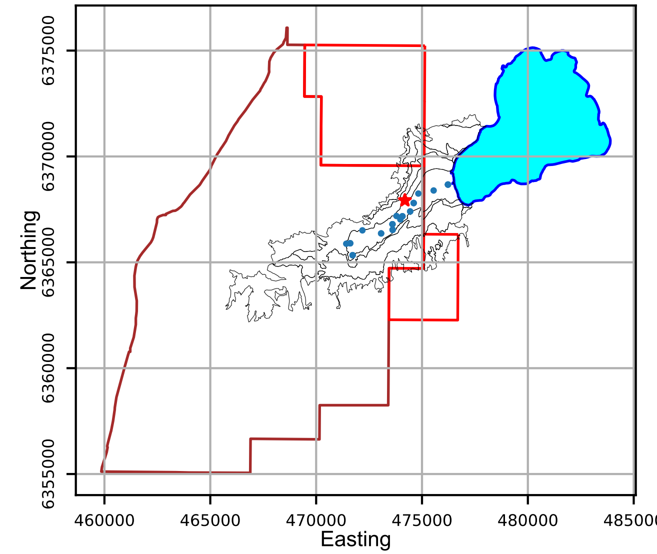




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

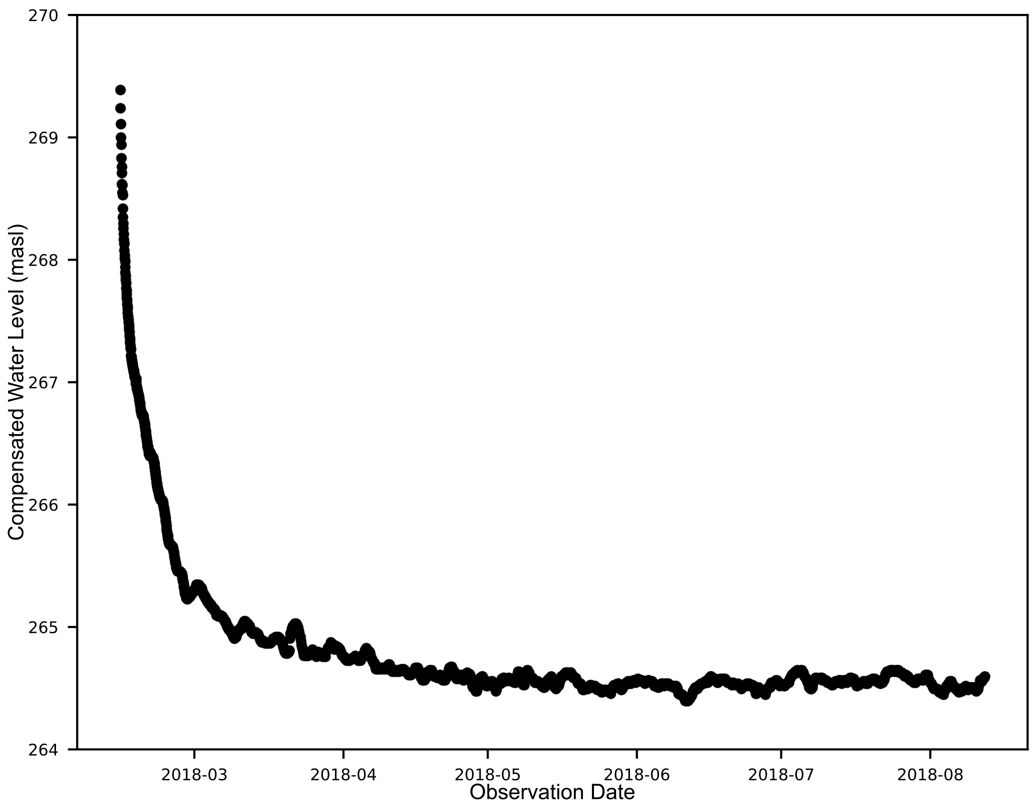
FORTHILLS
Operated by Suncor Energy

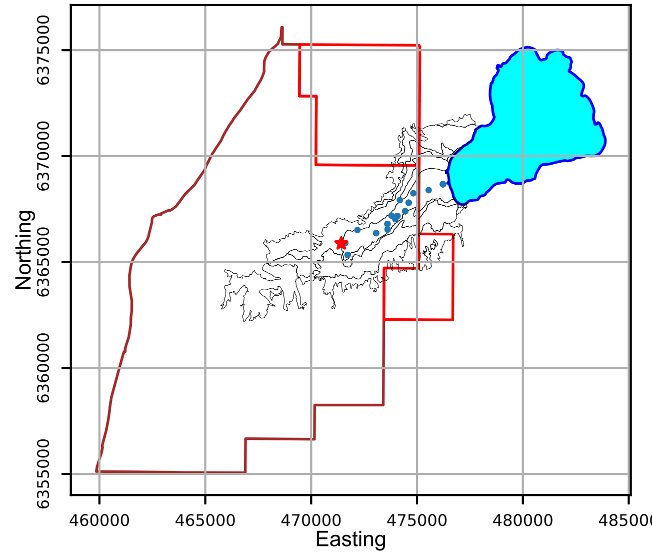
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR450-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-22

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 106 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

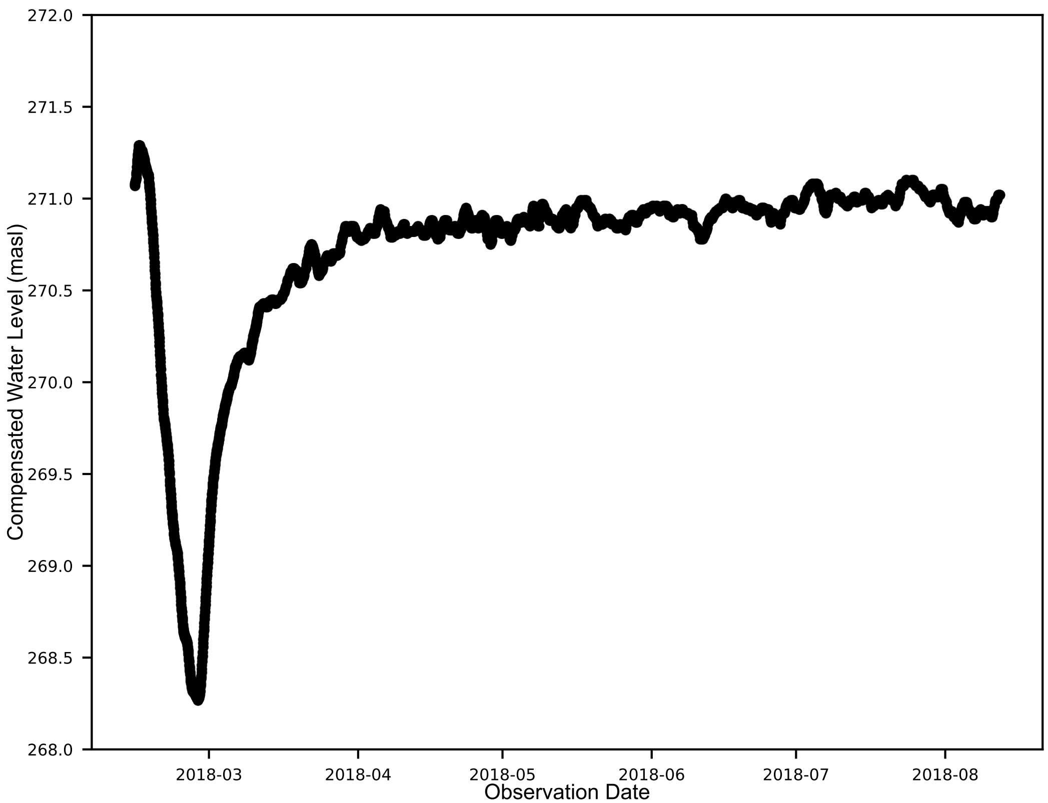
FORT HILLS
Operated by Suncor Energy

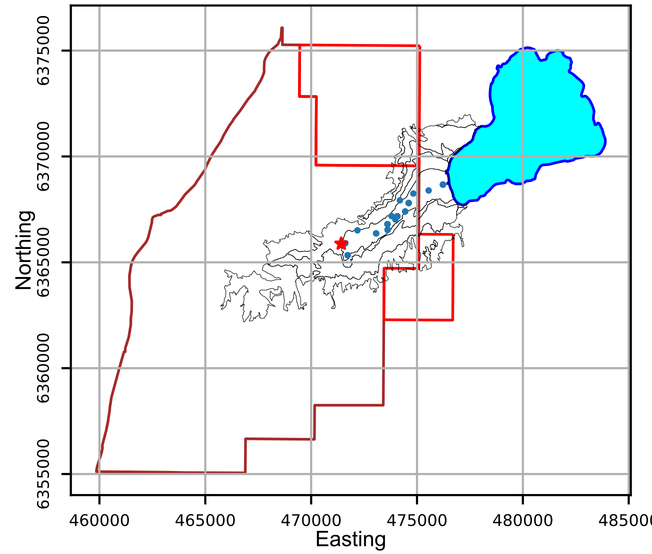
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES424-MR1 - 106.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-23

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 119.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

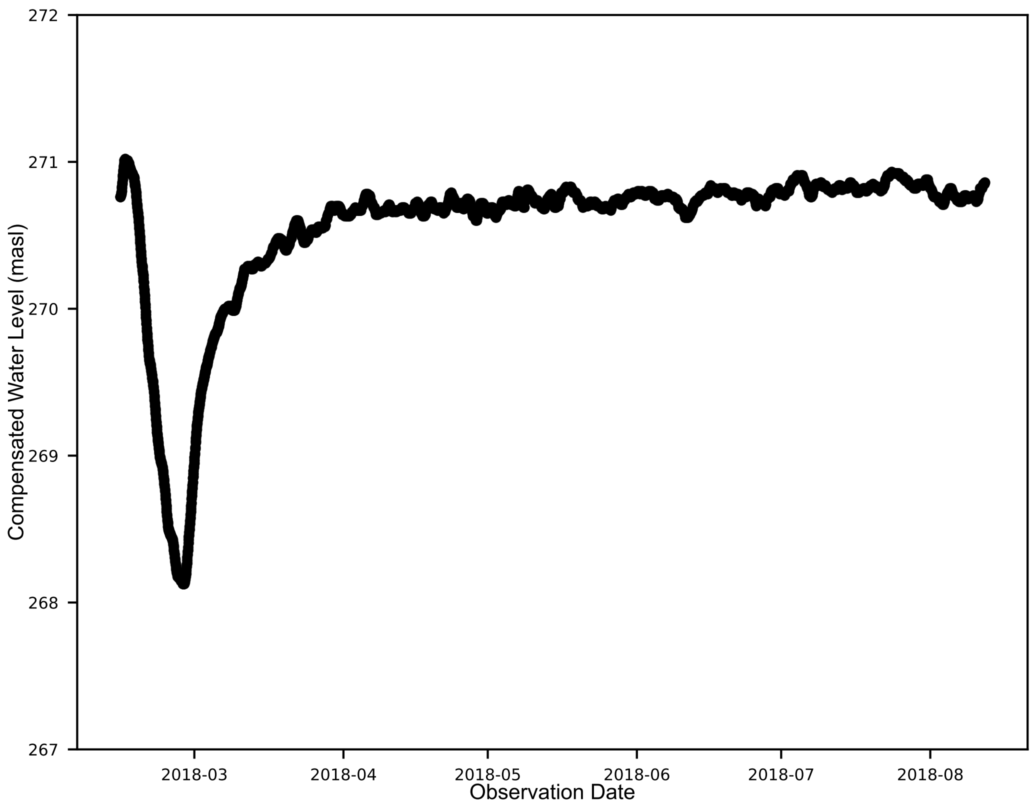
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

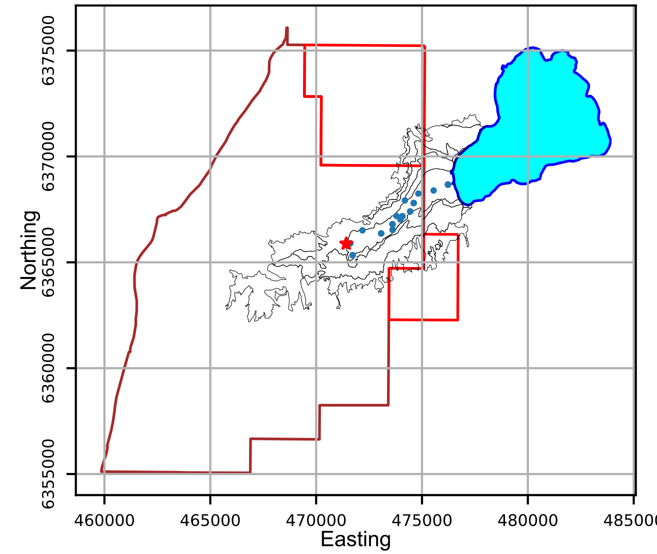
TITLE

FH18-ES424-MR1 - 119.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-24

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 126 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH18-ES424-MR1 - 126.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-25

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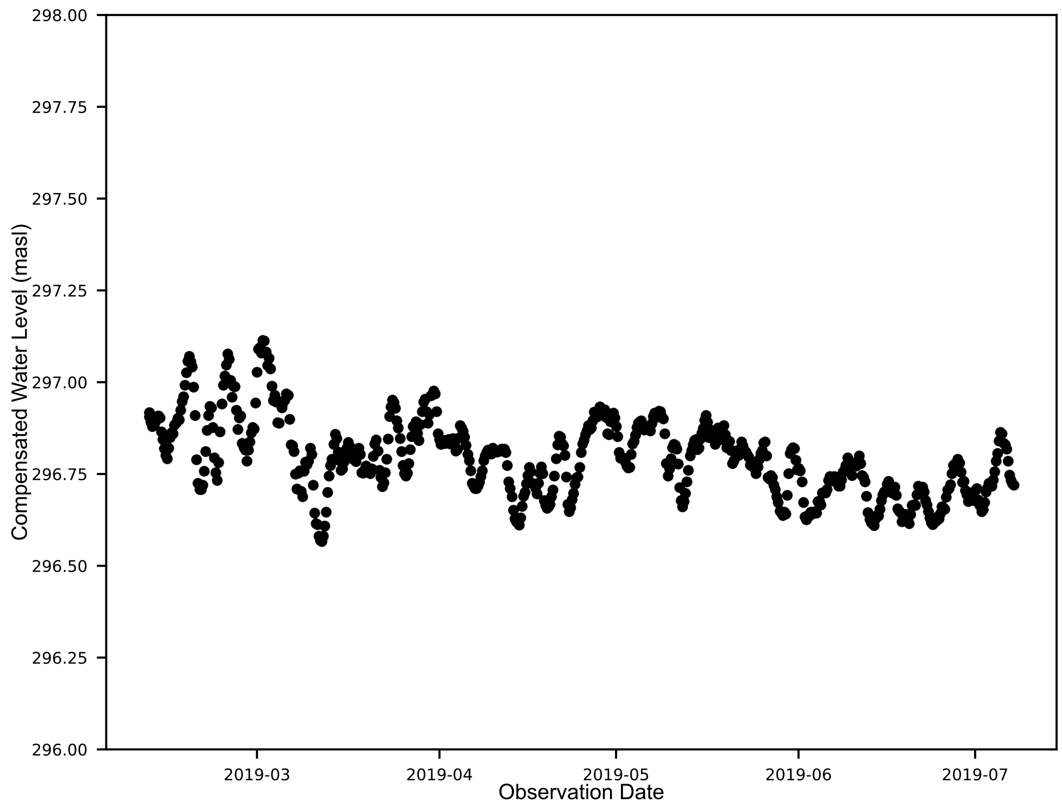

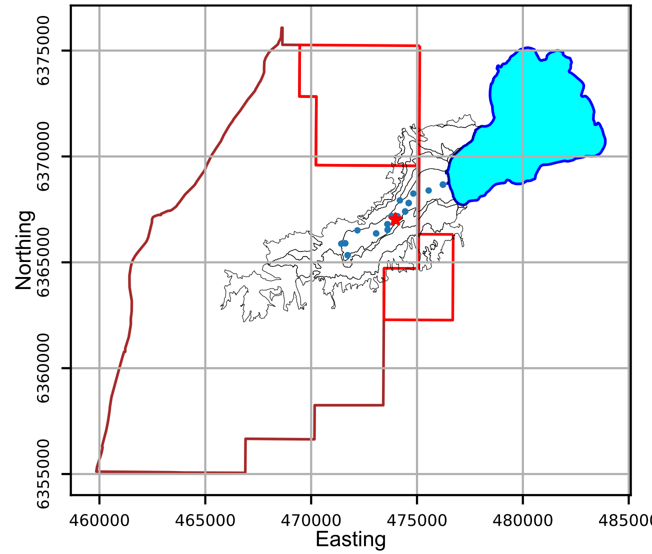

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 3.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES620-SN1 - 3.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-26

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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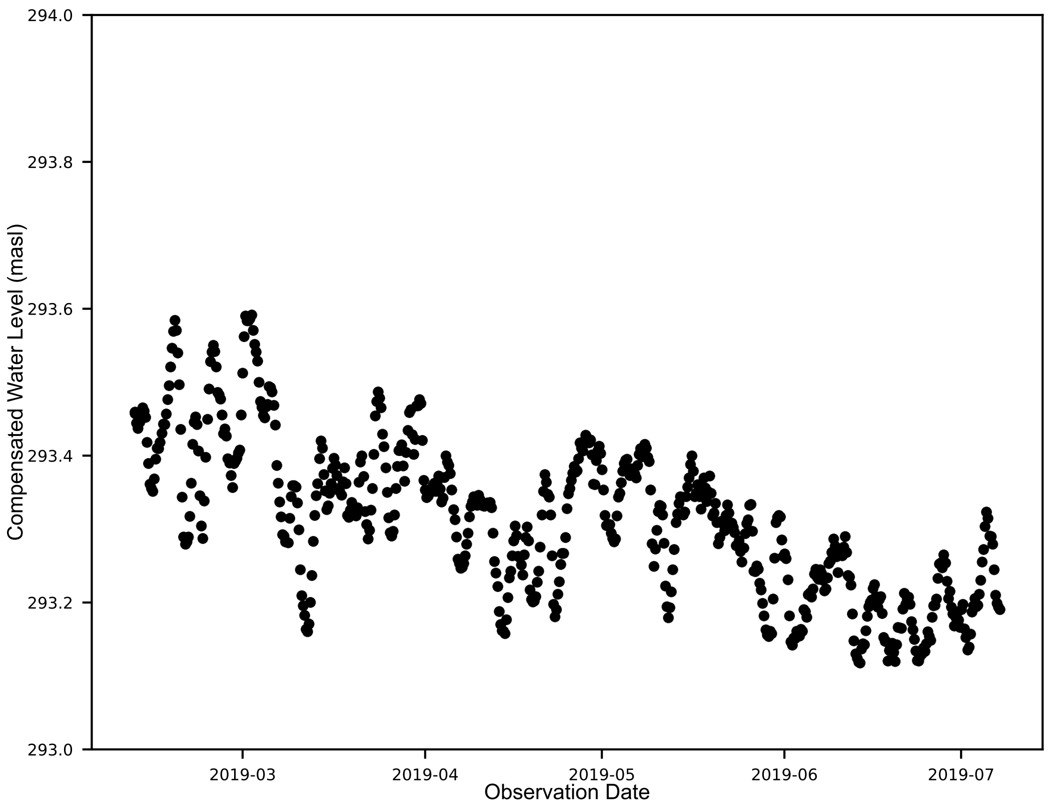

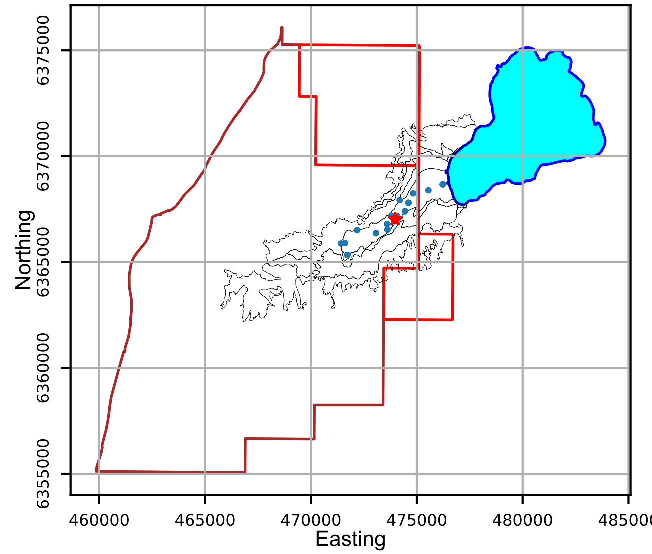

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 31 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH19-ES620-SN1 - 31.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-27

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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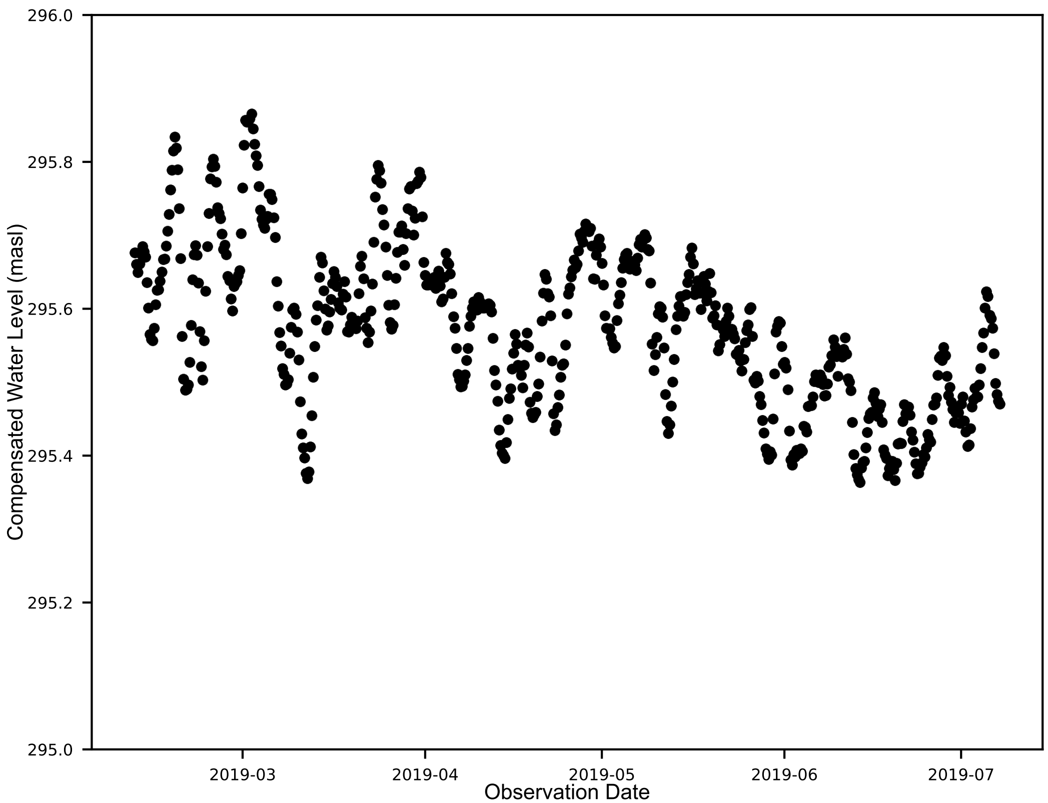

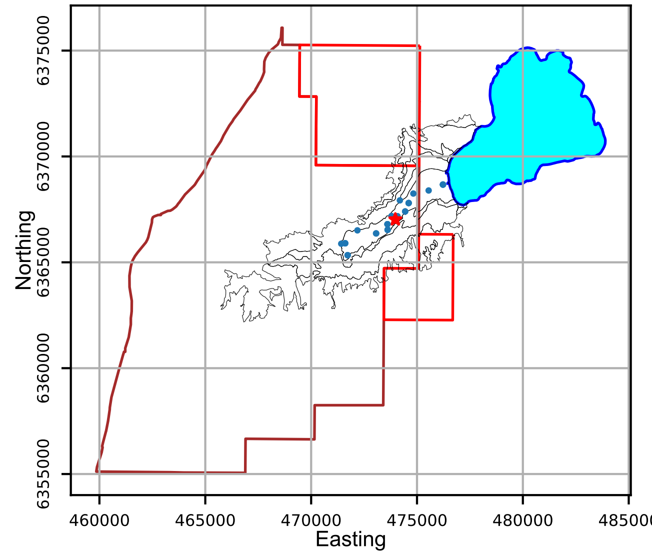

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES620-SN1 - 9.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-28

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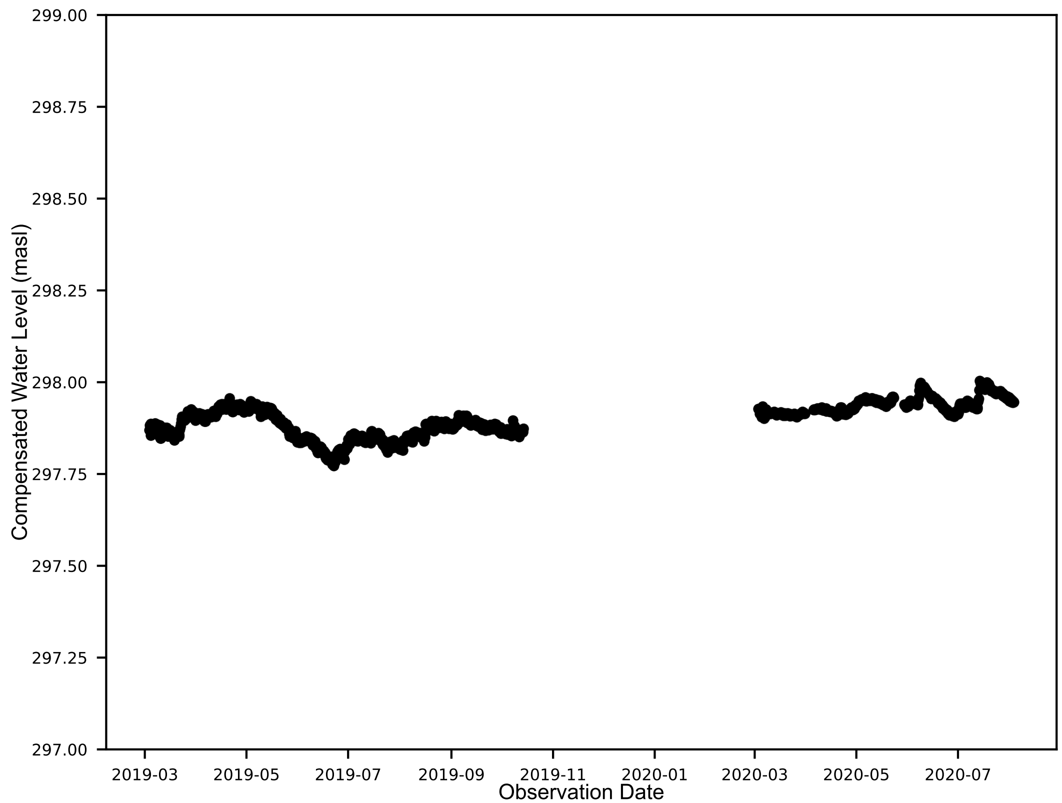

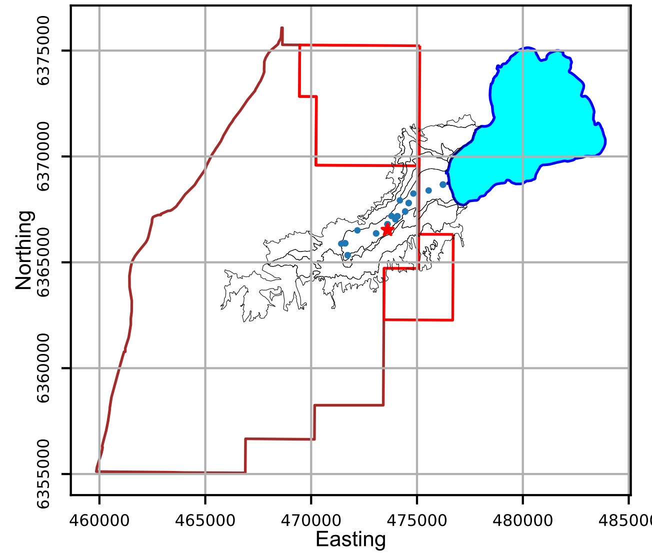

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 11.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES625-SN1 - 11.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-29

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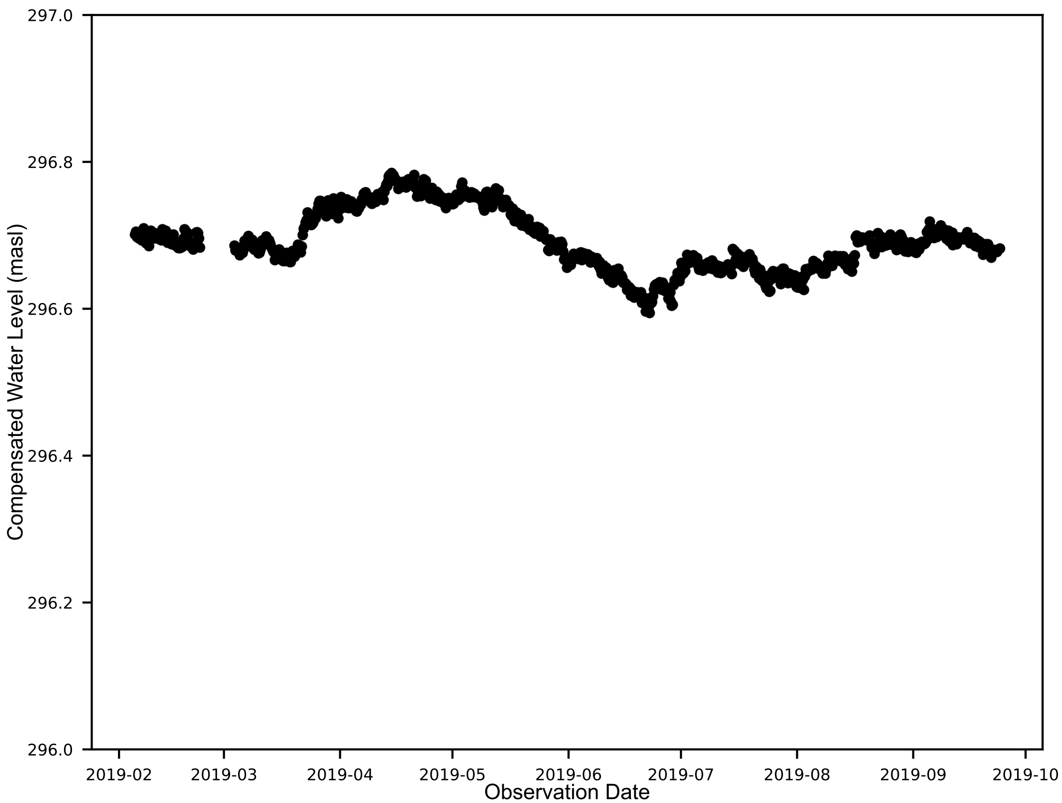
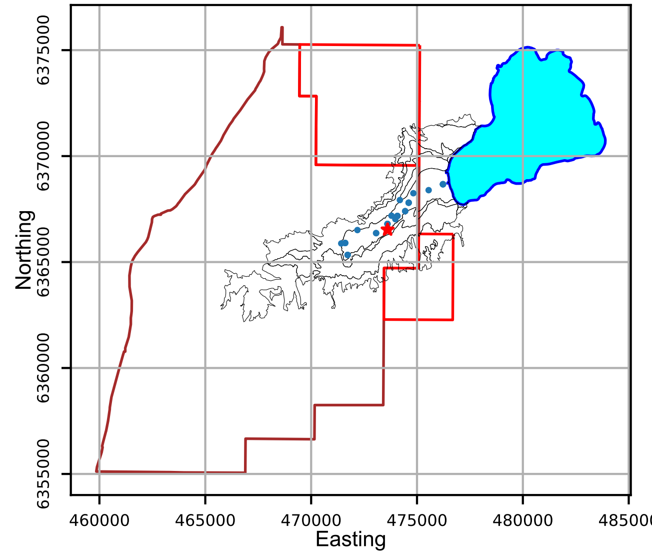




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 5.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

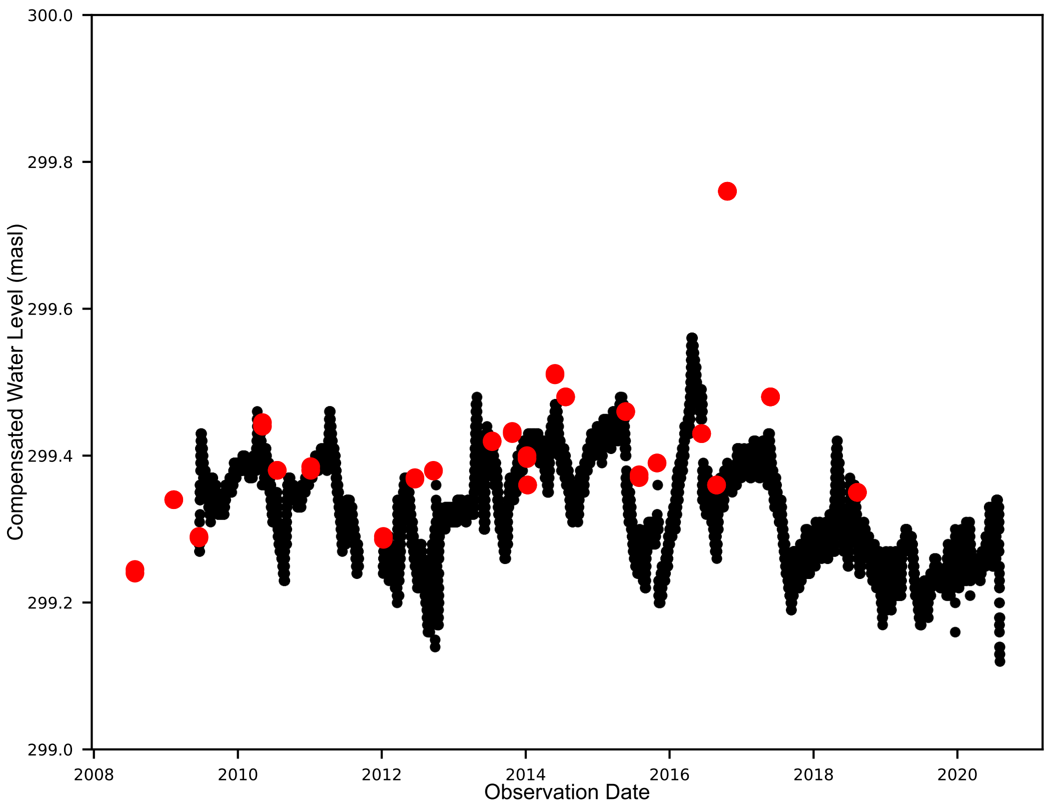
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

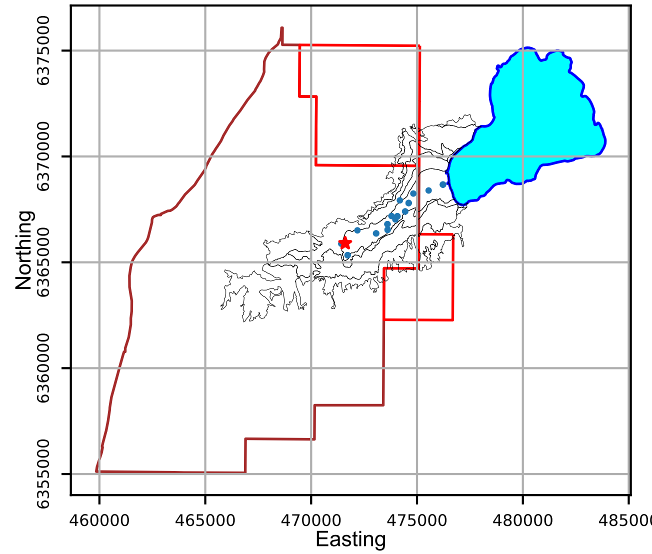
TITLE

FH19-ES625-SN1 - 5.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B2-30

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

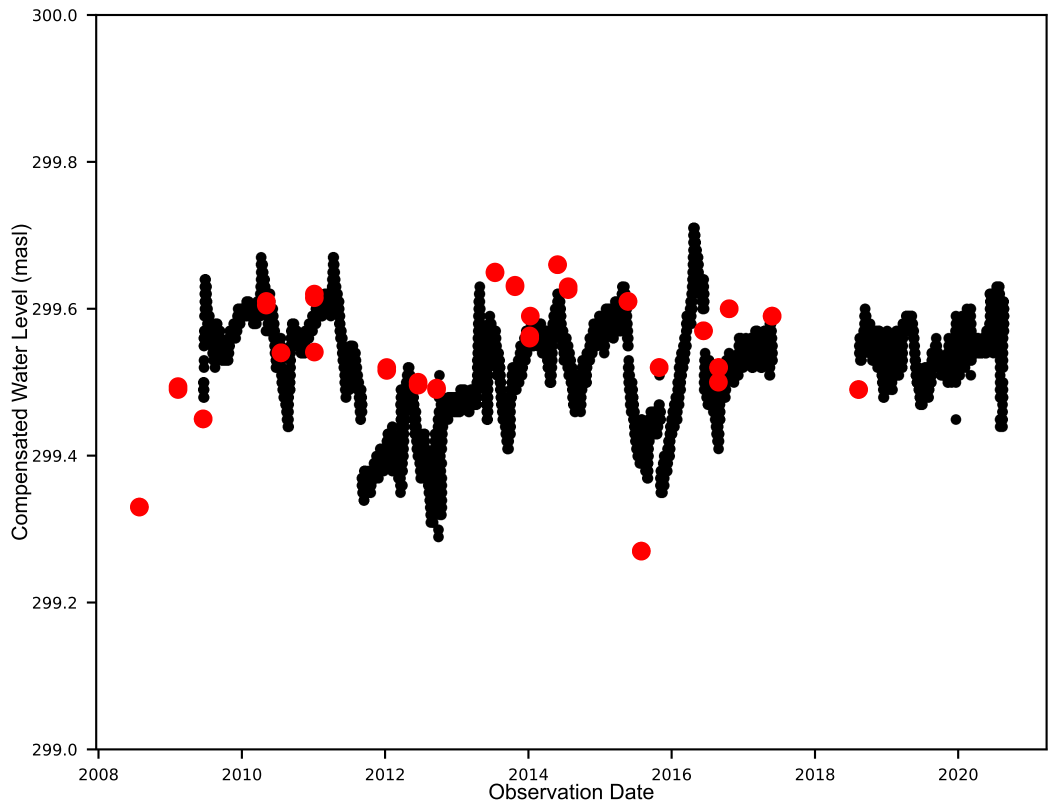
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

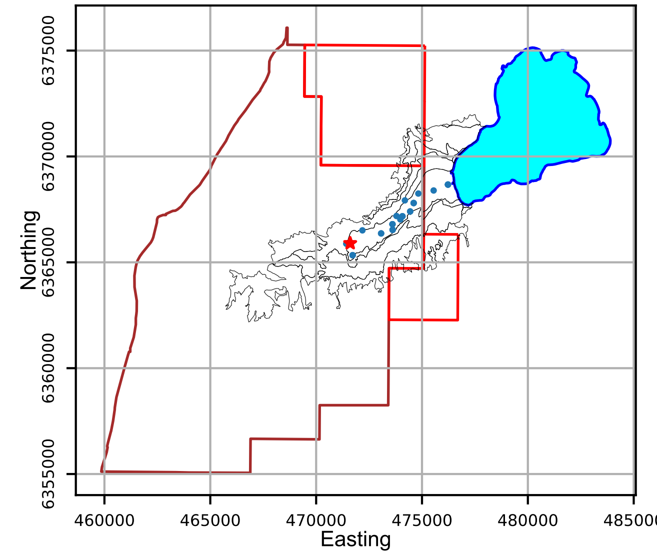
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-091A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-31





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

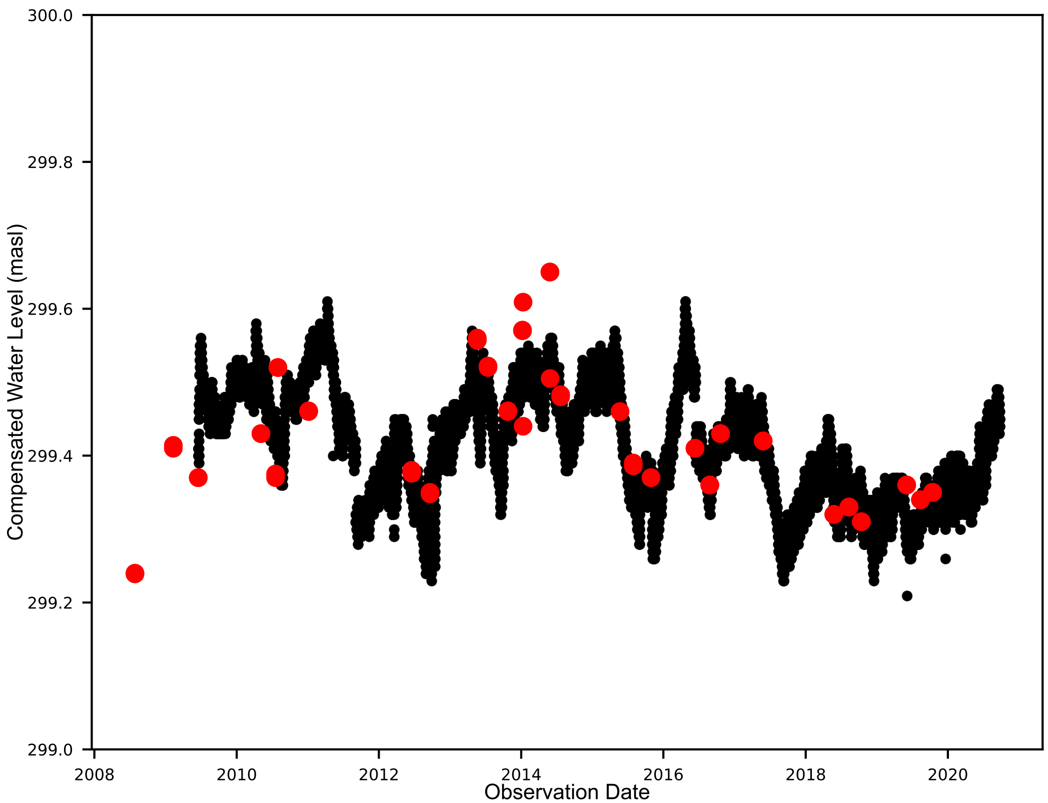
FORT HILLS
Operated by Suncor Energy

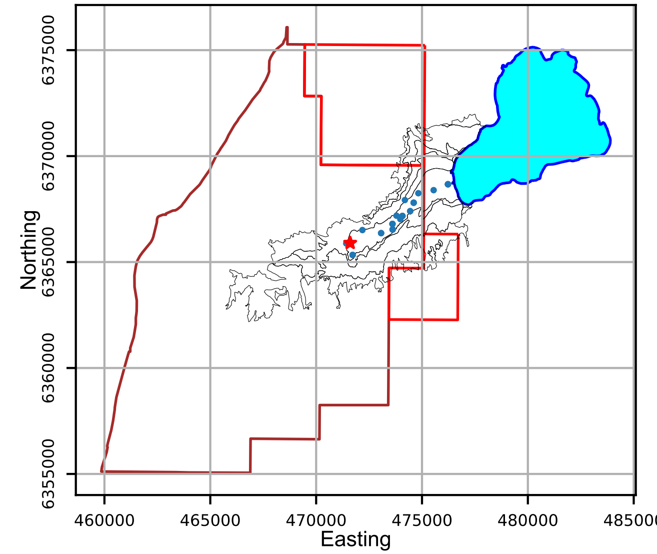
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-091B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-32

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-091C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-33

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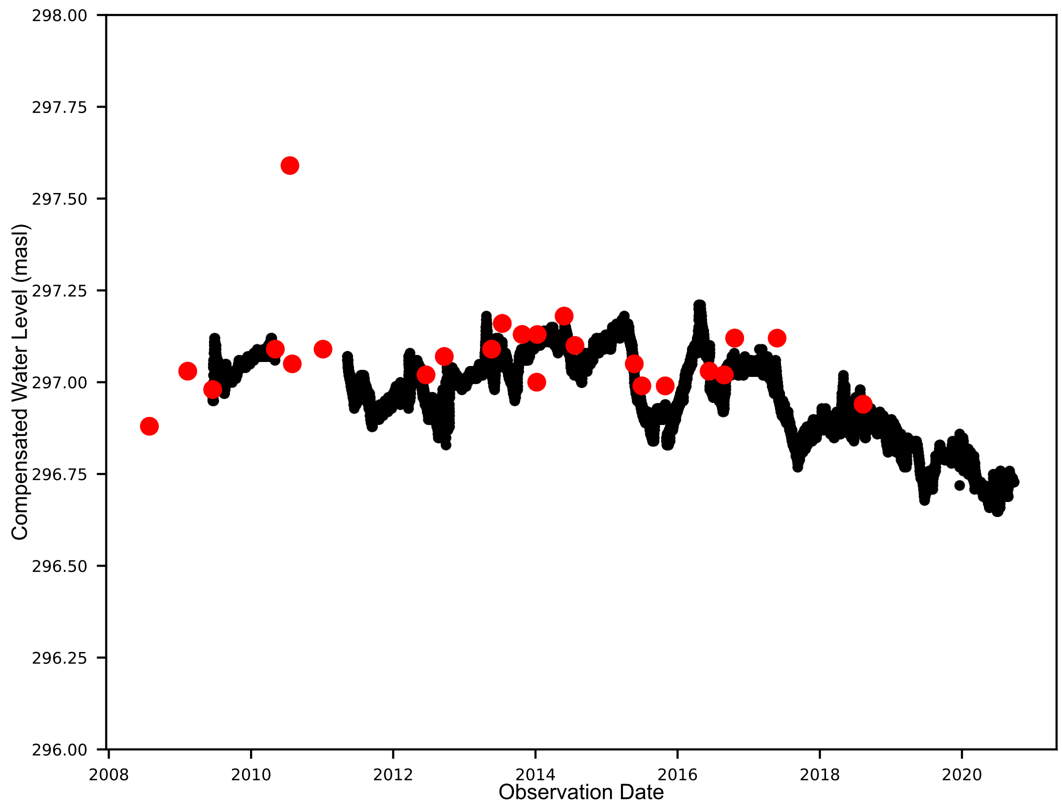
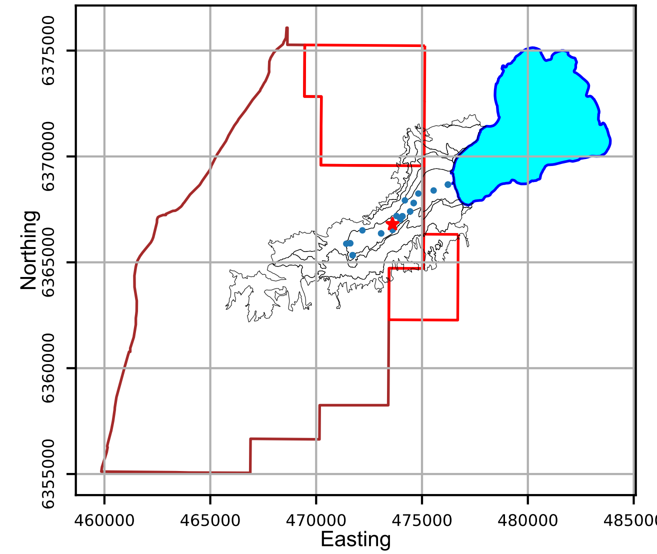




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 12.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

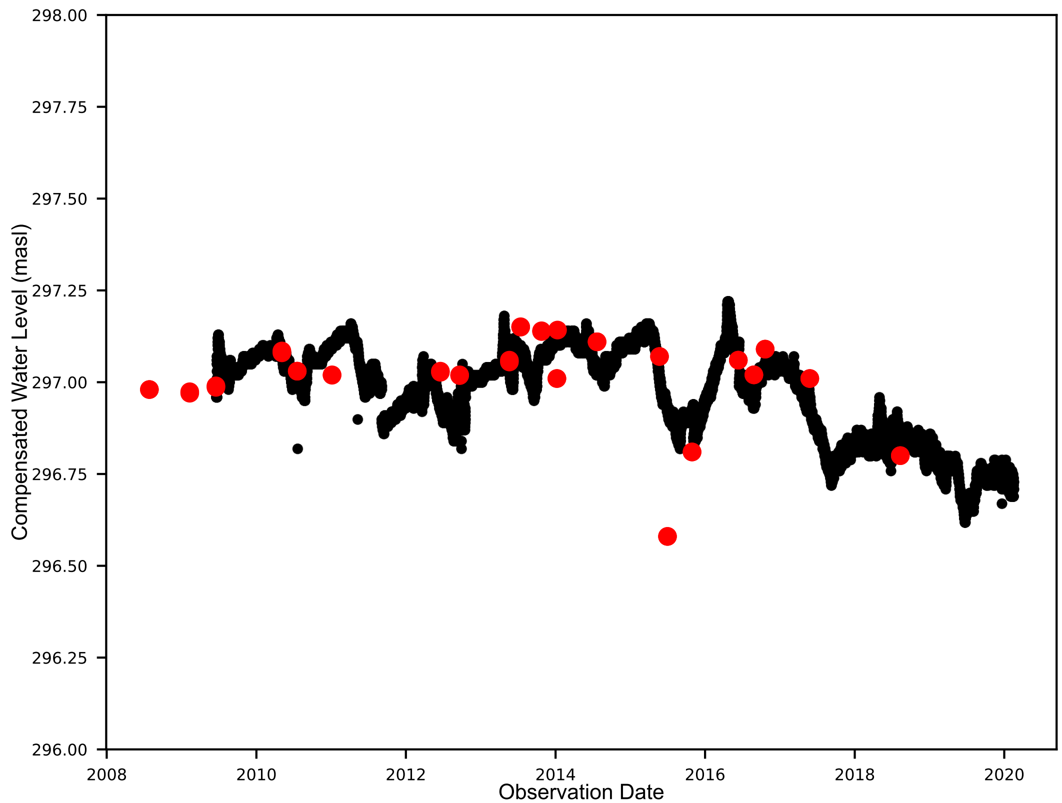
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

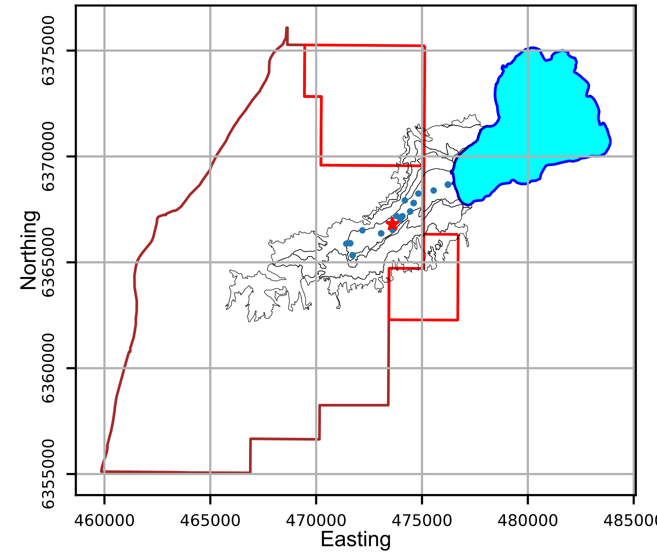
GT07-092A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-34



Hydrograph Legend

- Manual measurement
- Transducer measurement



Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

GT07-092B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-35

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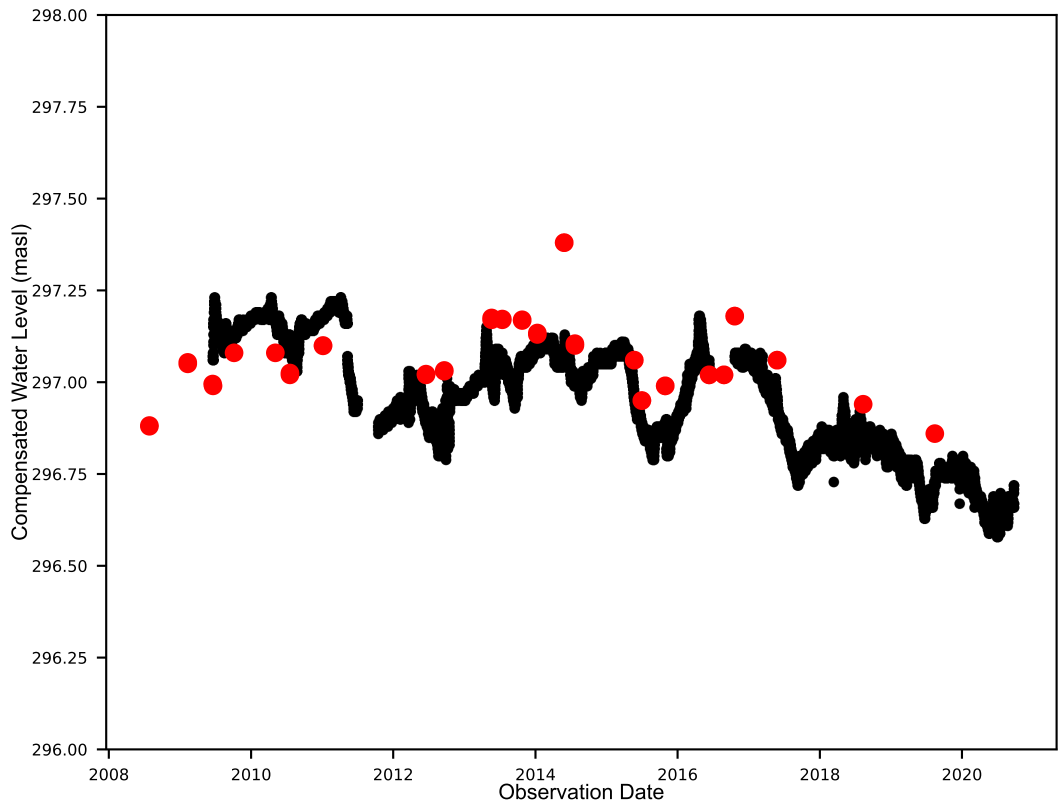
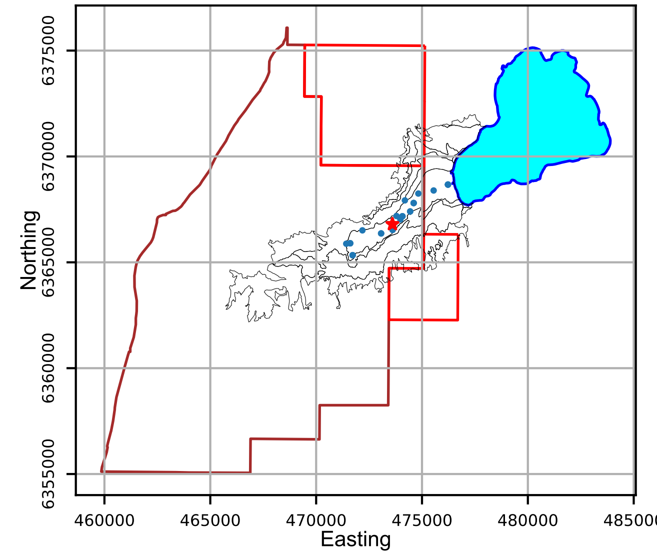




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 4.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

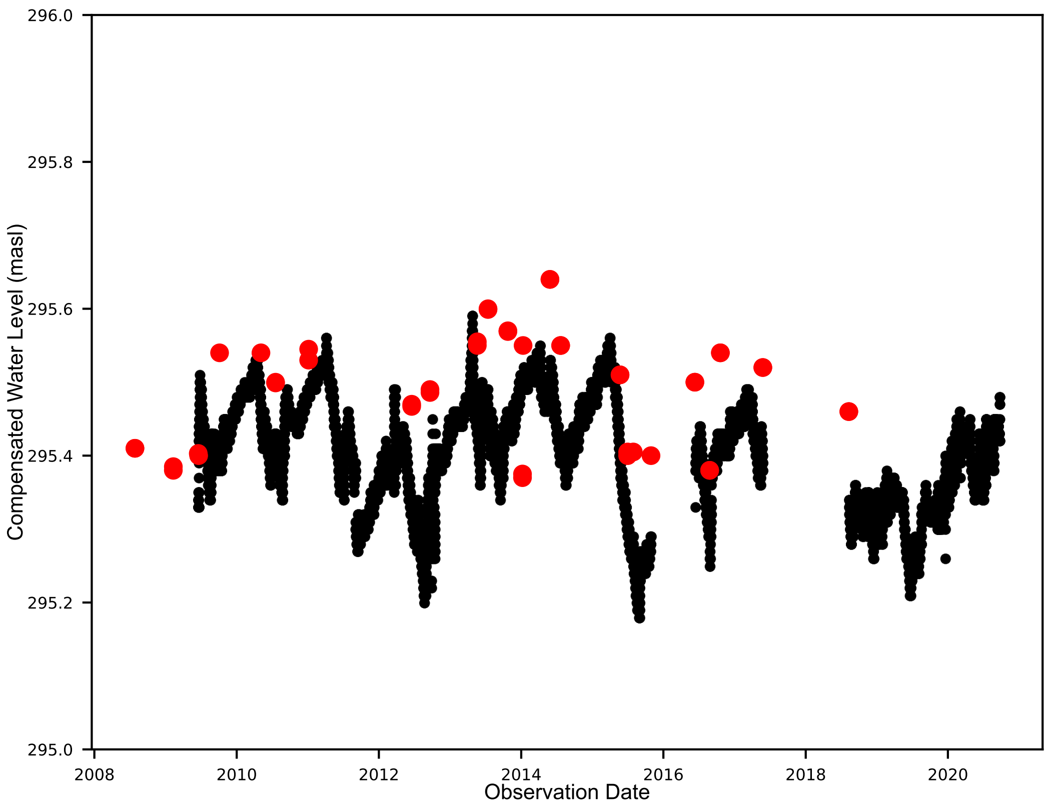
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

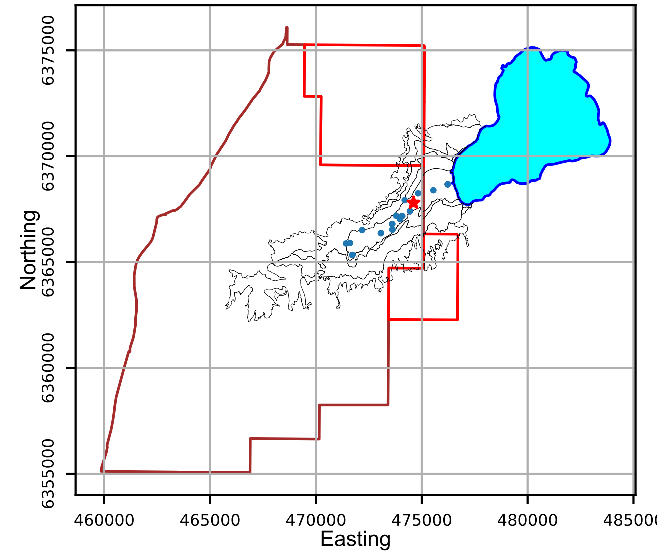
TITLE

GT07-092C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-36

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-093A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-37

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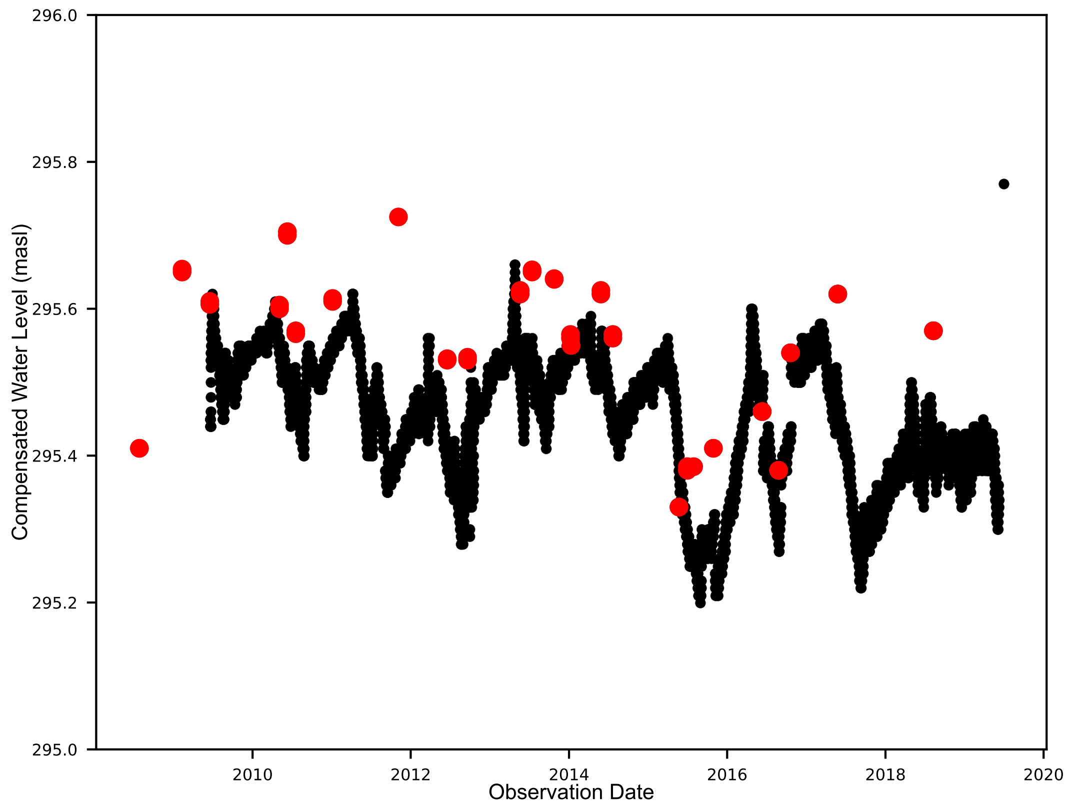
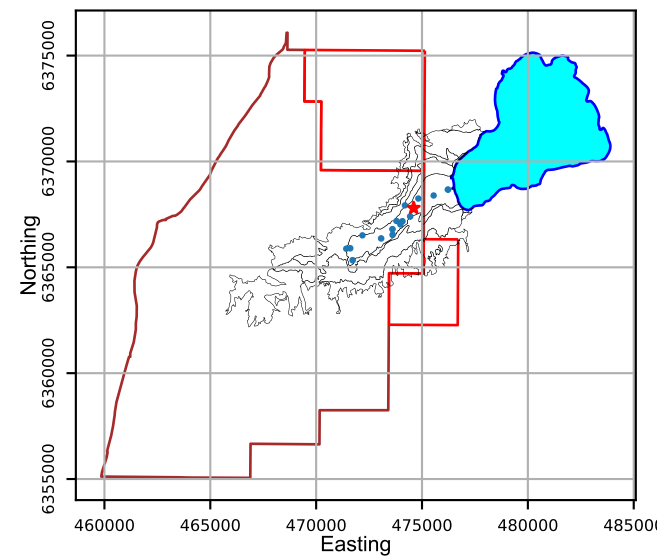




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 4.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

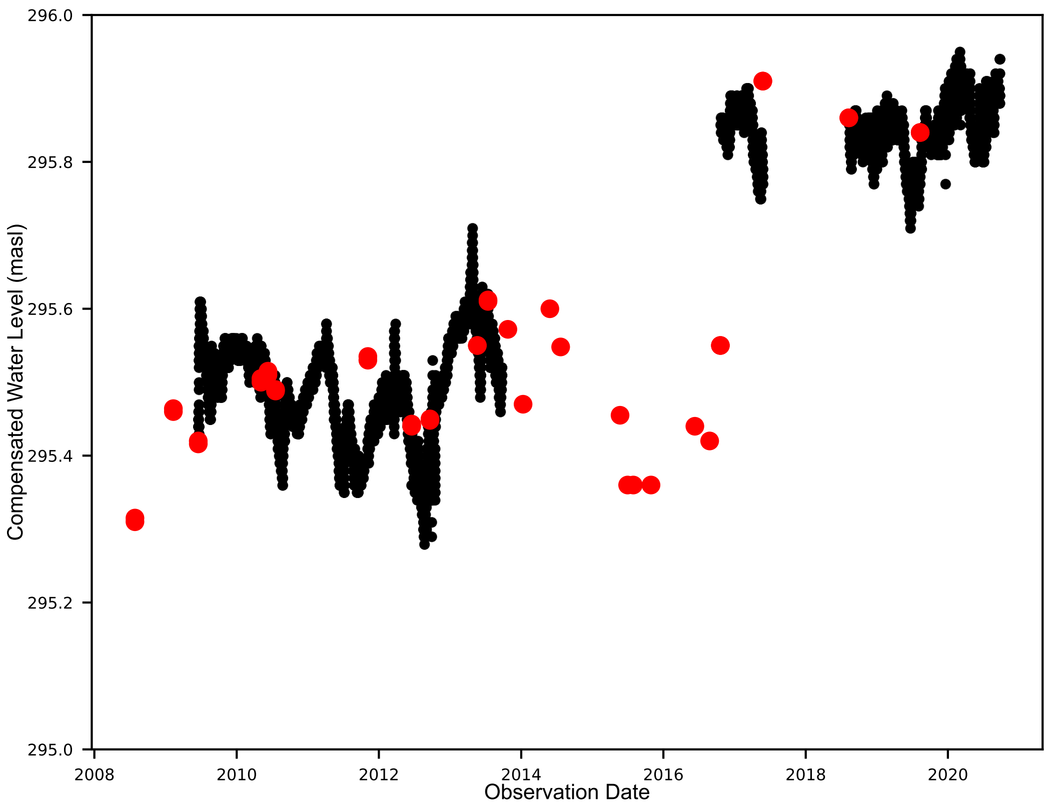
FORTHILLS
Operated by Suncor Energy

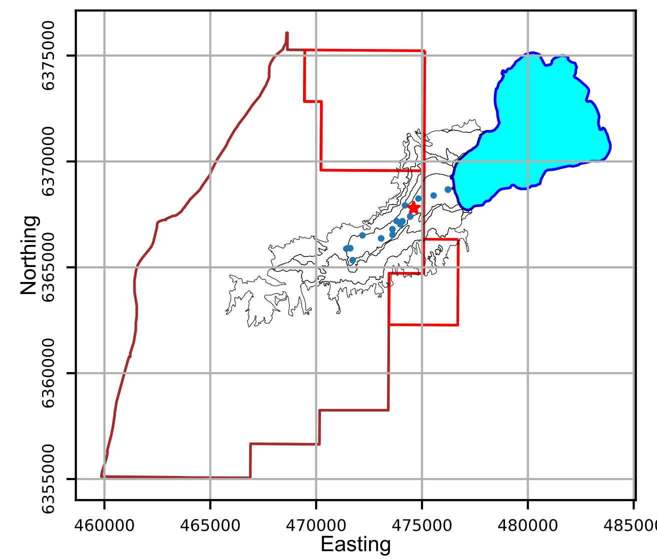
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-093B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-38

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 1.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

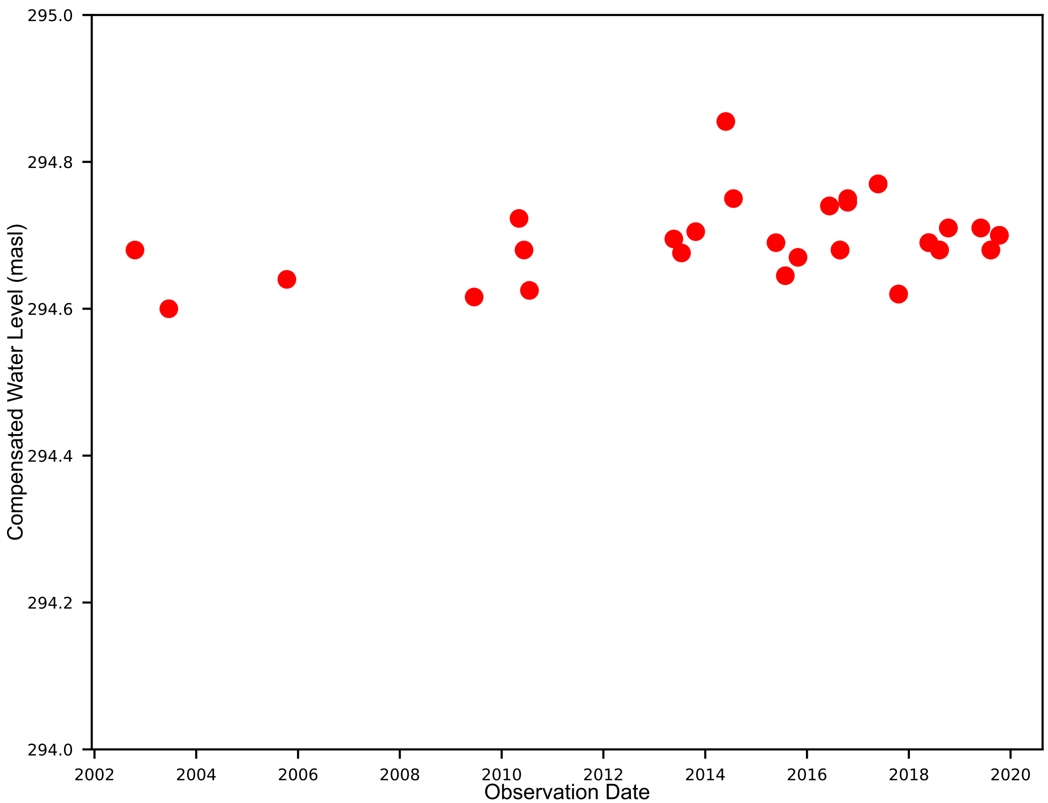
FORTHILLS
Operated by Suncor Energy

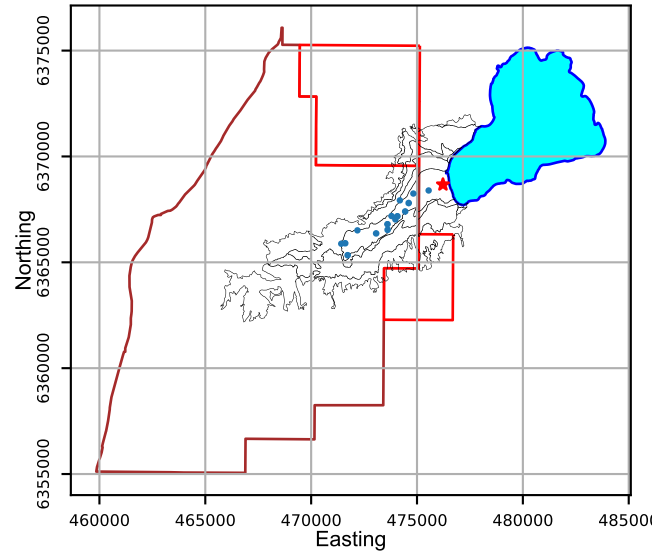
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-093C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-39

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

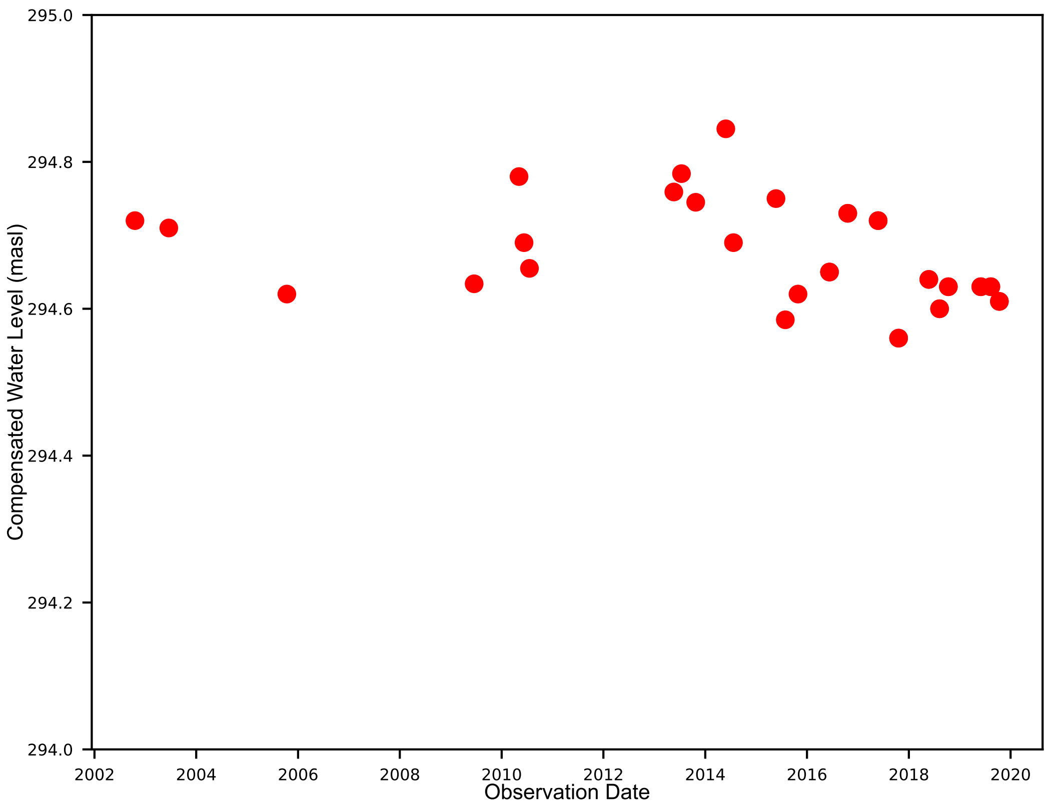
CLIENT
FORT HILLS ENERGY CORPORATION

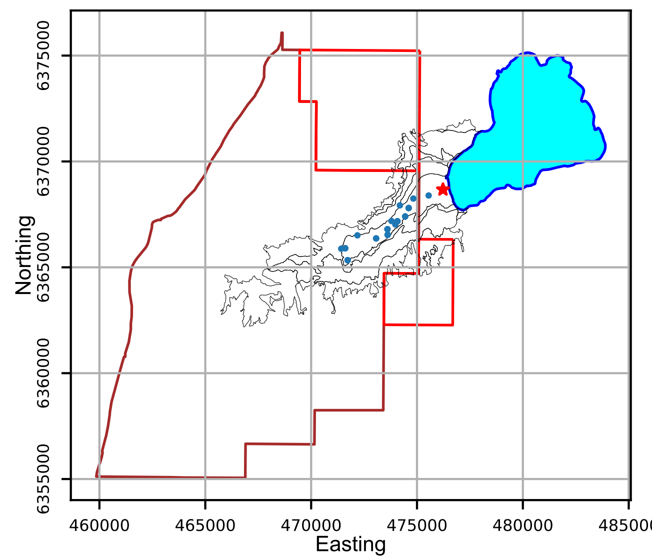
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC1-P100

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-40





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

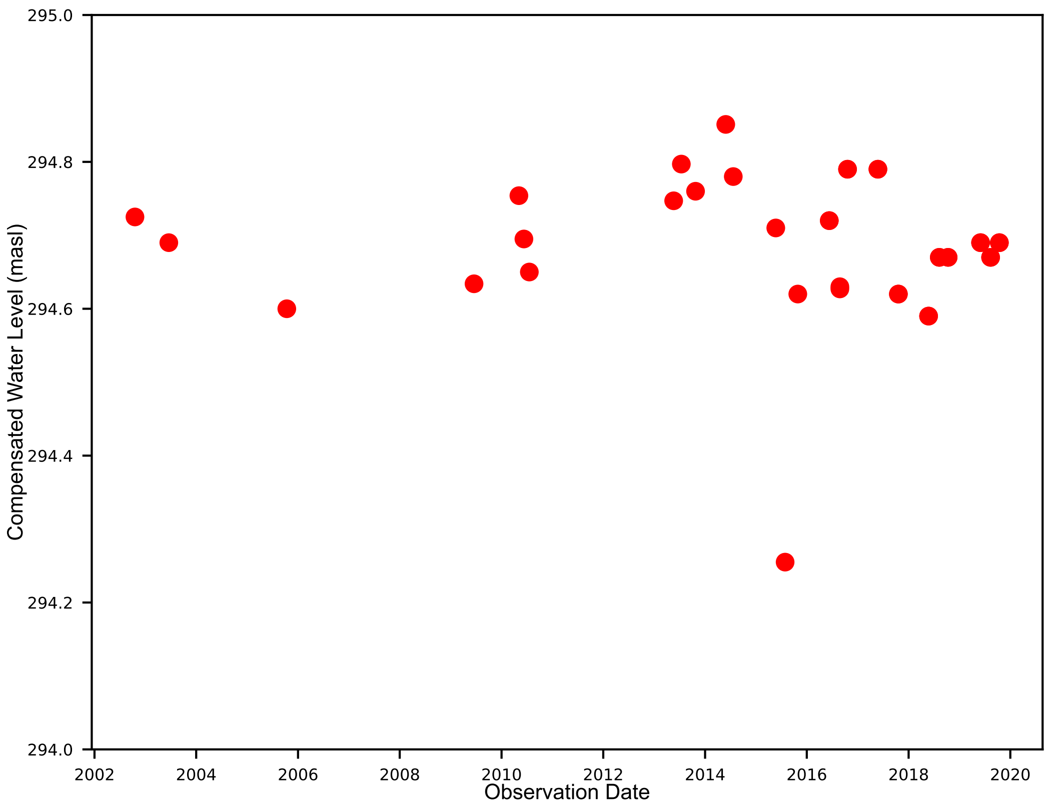
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

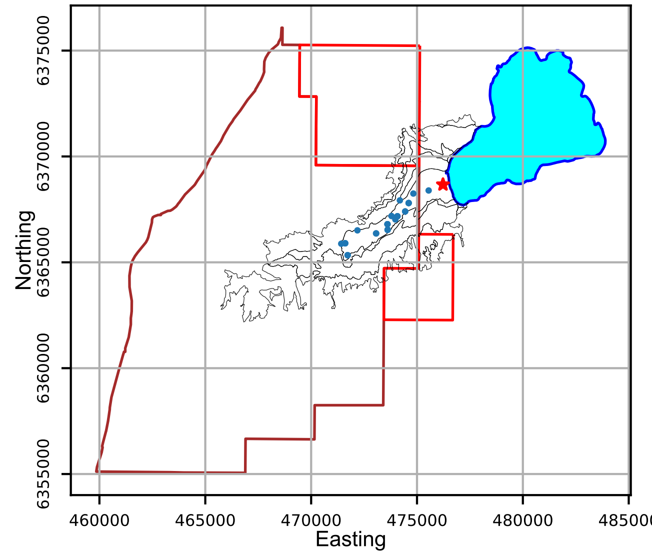
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC1-P250

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-41





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 4.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

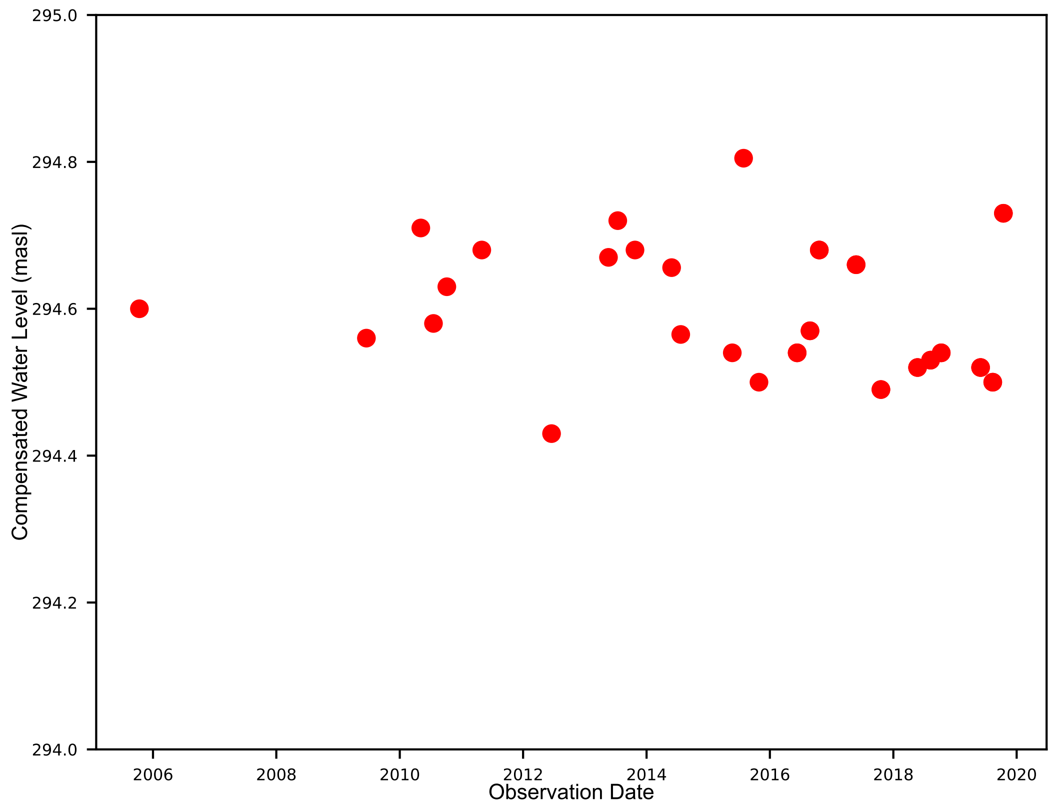
FORTHILLS
Operated by Suncor Energy

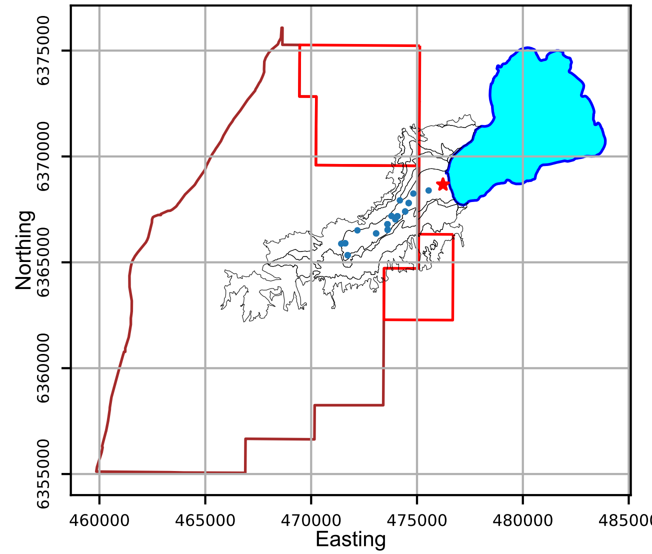
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC1-P460

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-42

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 5.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

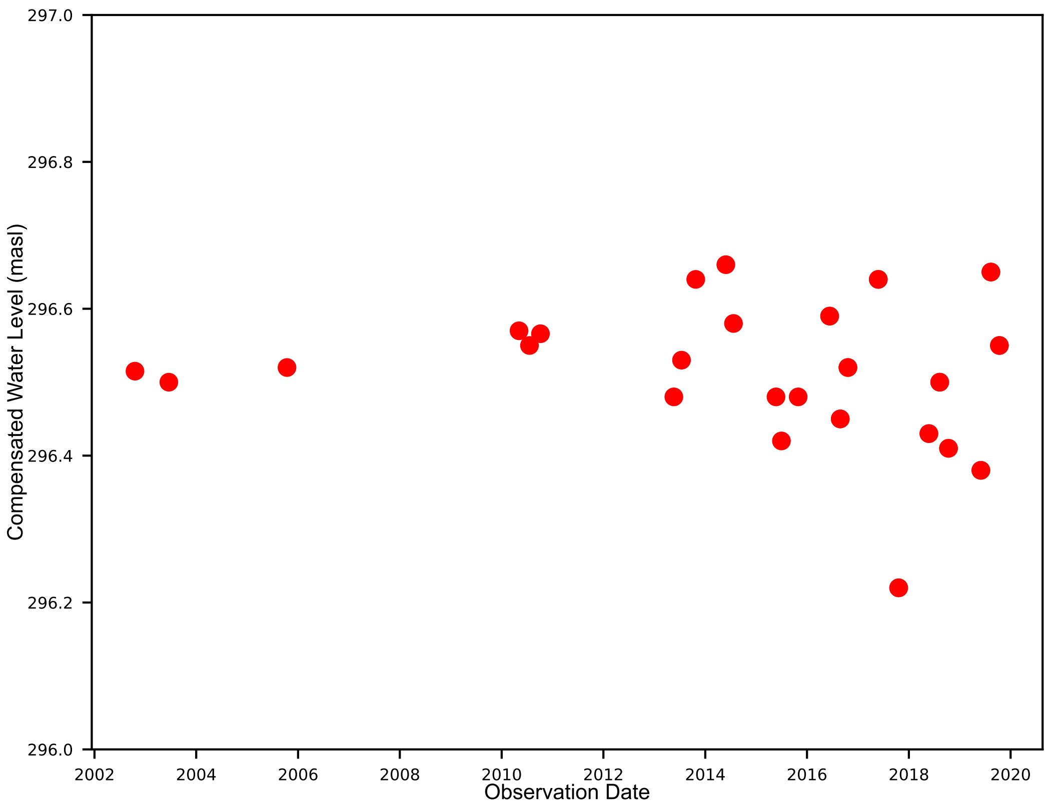
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

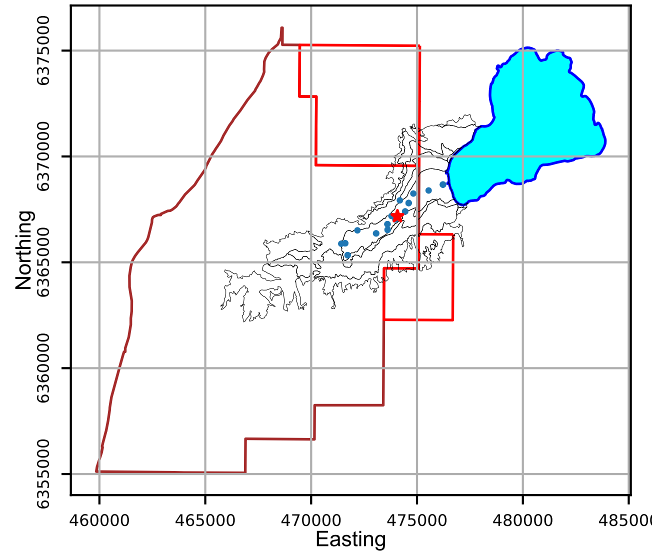
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC1-P530

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-43

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC2-P100

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-44

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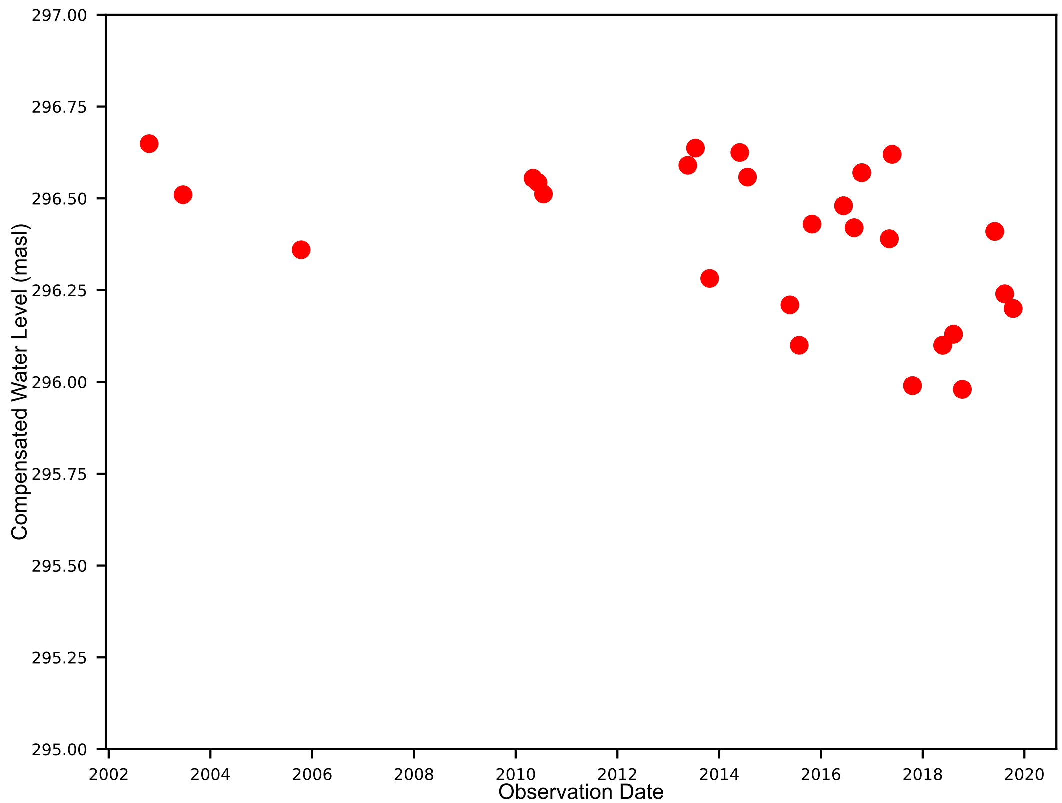

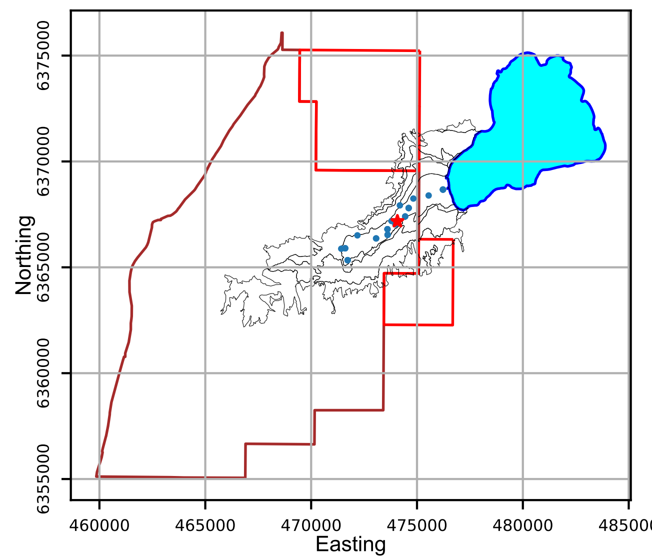

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MLWC2-P250

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-45

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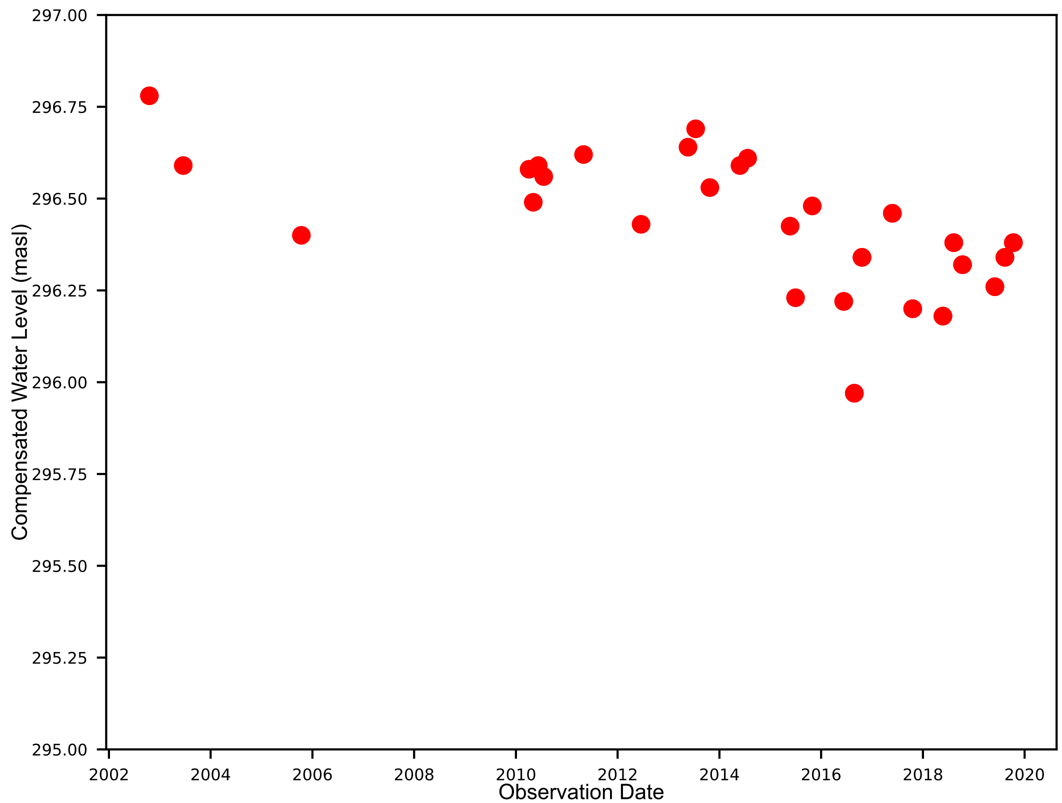

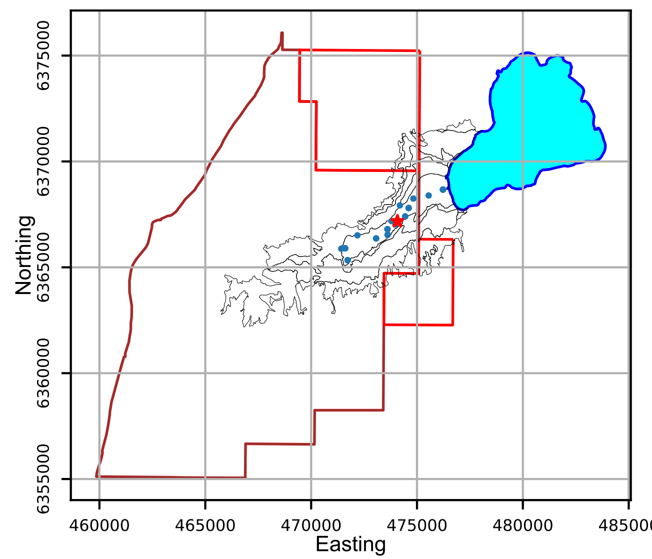

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 5.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MLWC2-P560

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-46

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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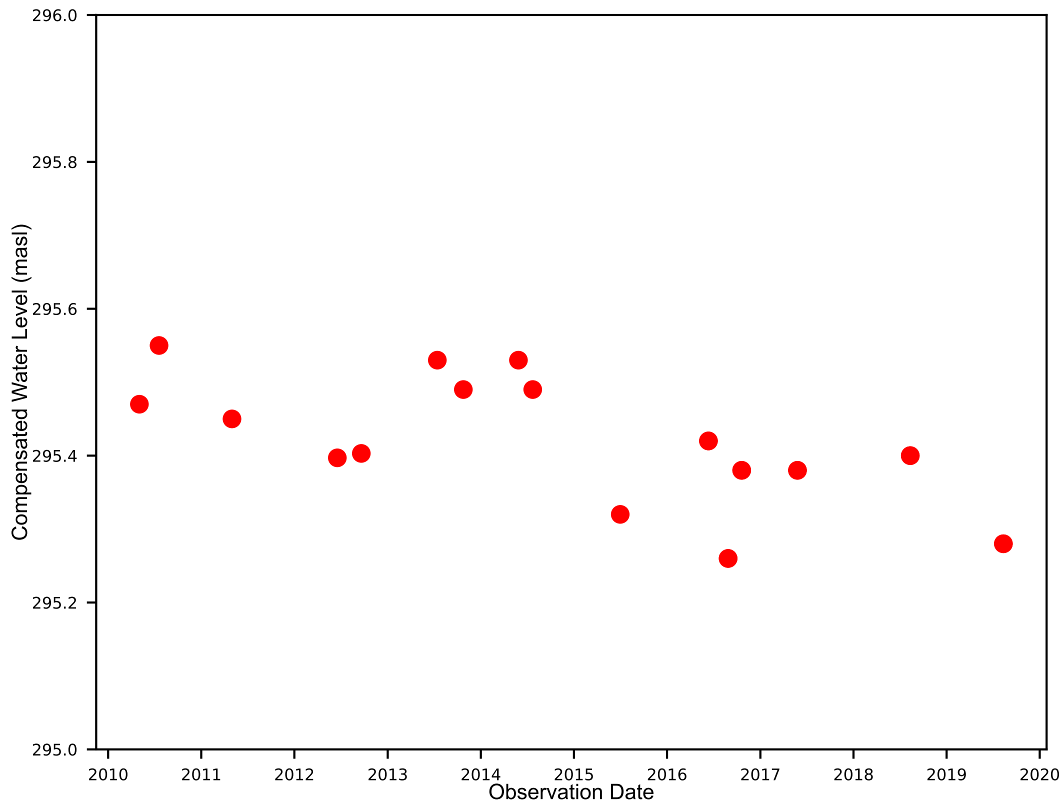

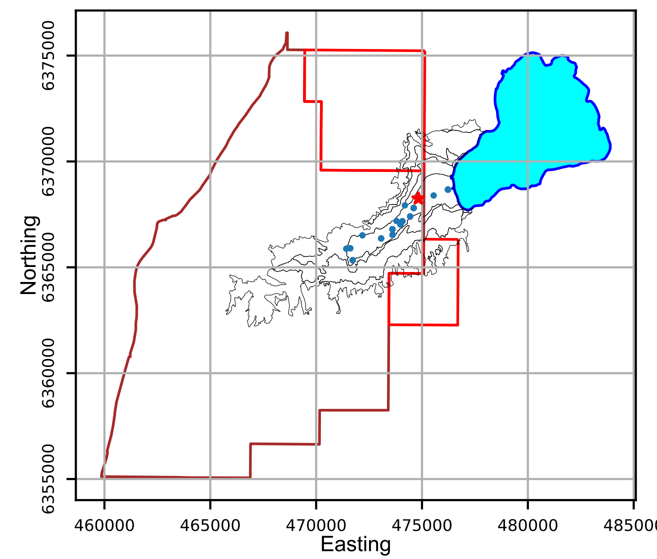

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW-08-307B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-47

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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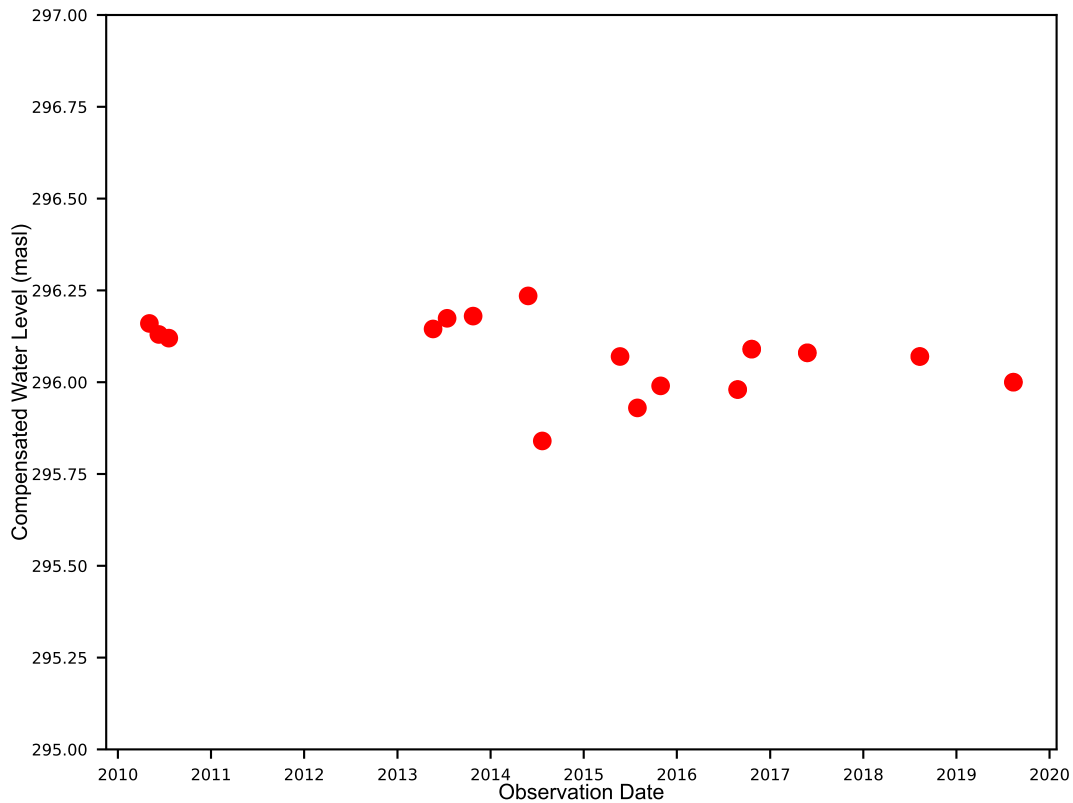
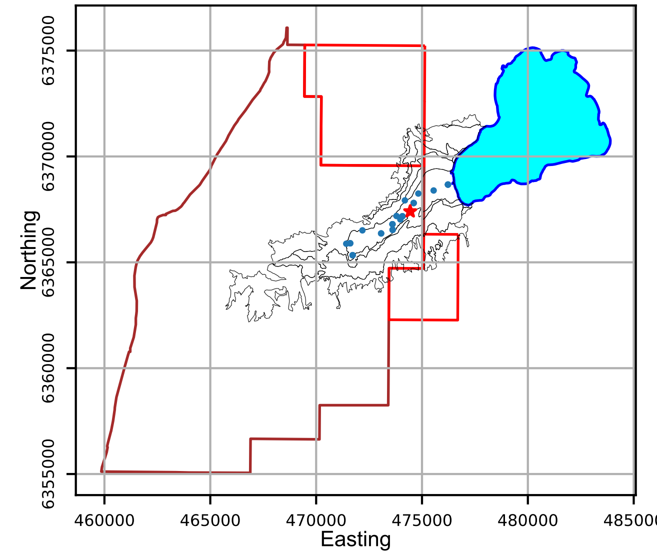




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

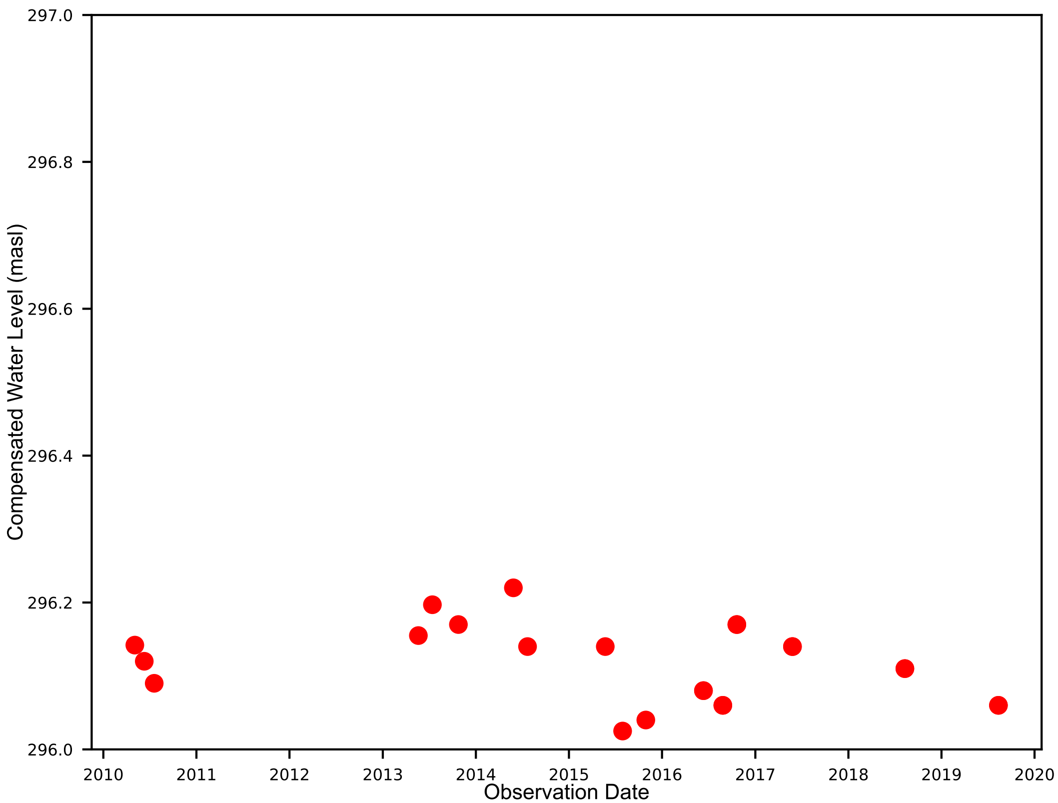
FORTHILLS
Operated by Suncor Energy

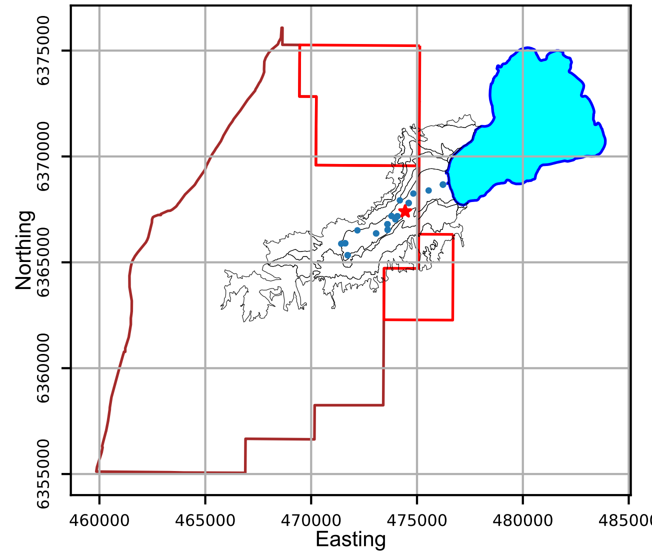
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-309A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-48





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

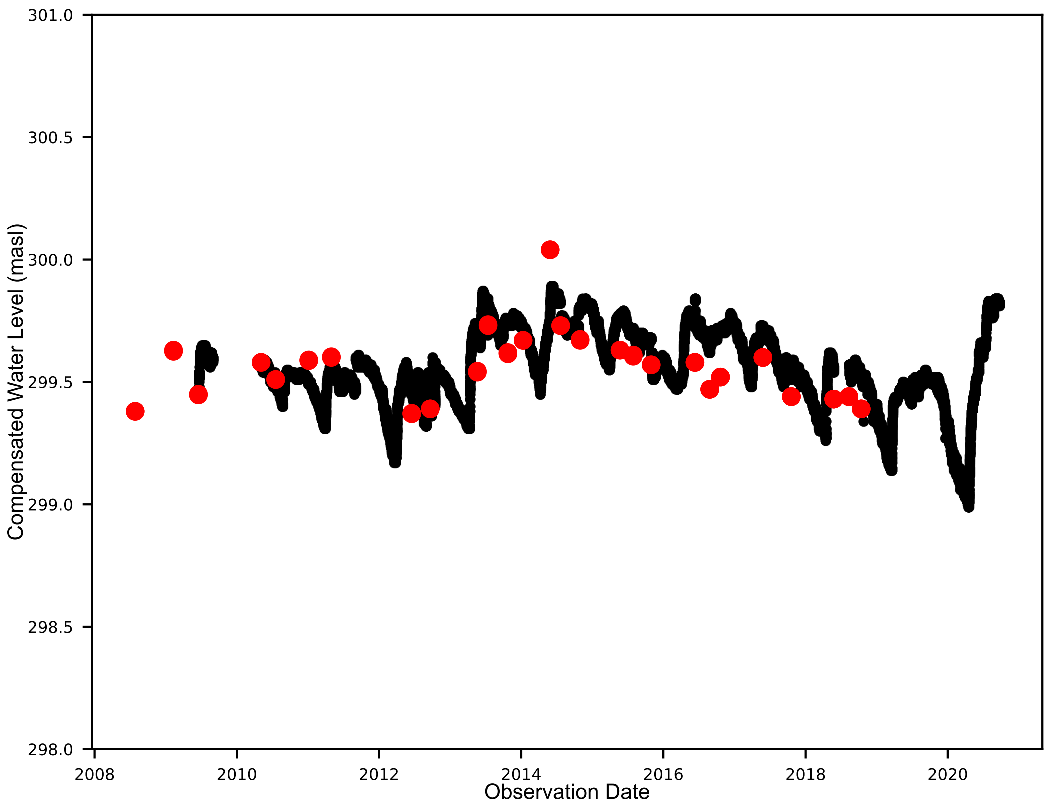
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

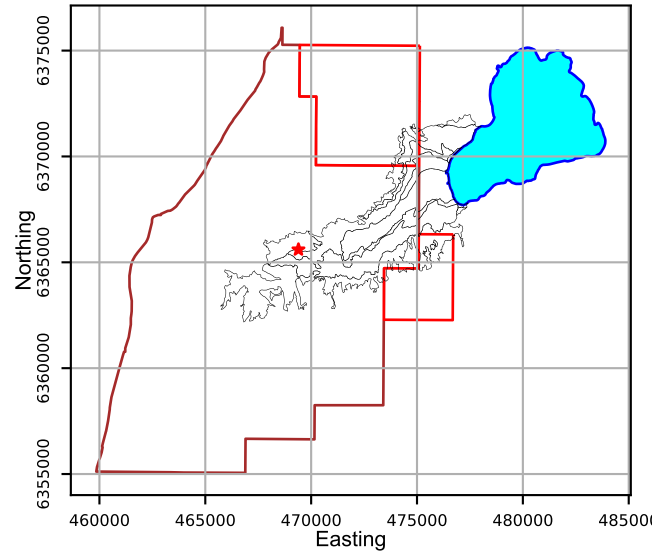
TITLE

MW08-309B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B2-49

B3 Hydrographs for Ecohydrology Zone 3





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

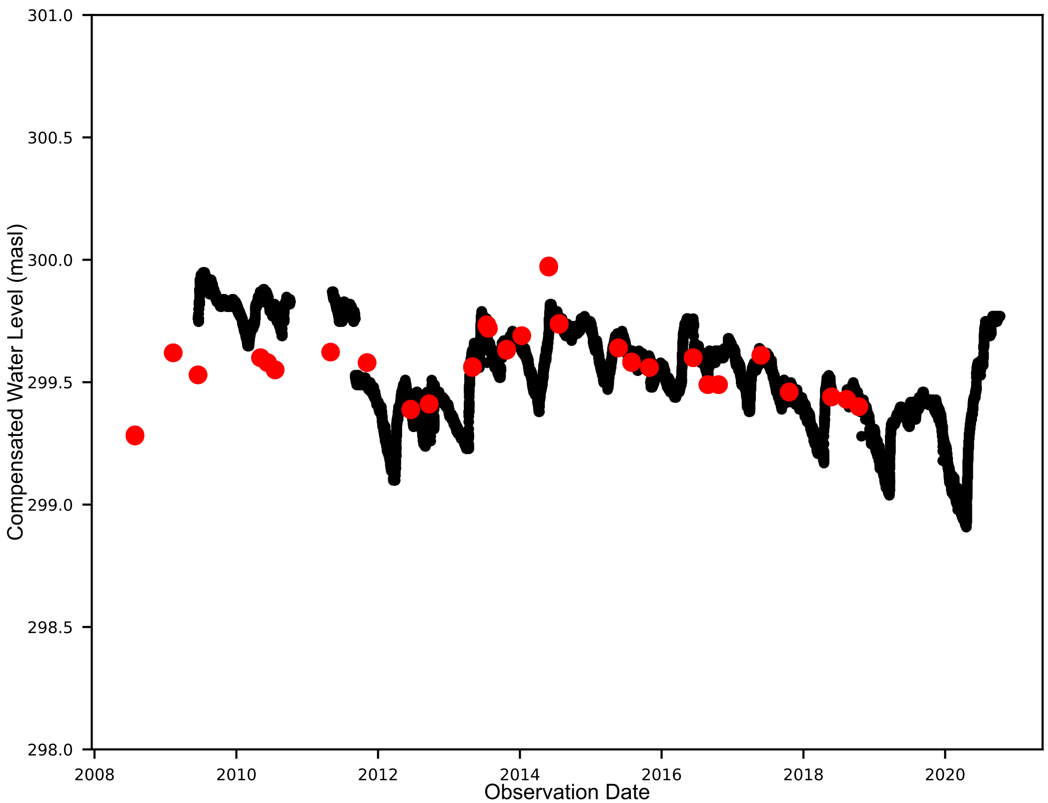
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

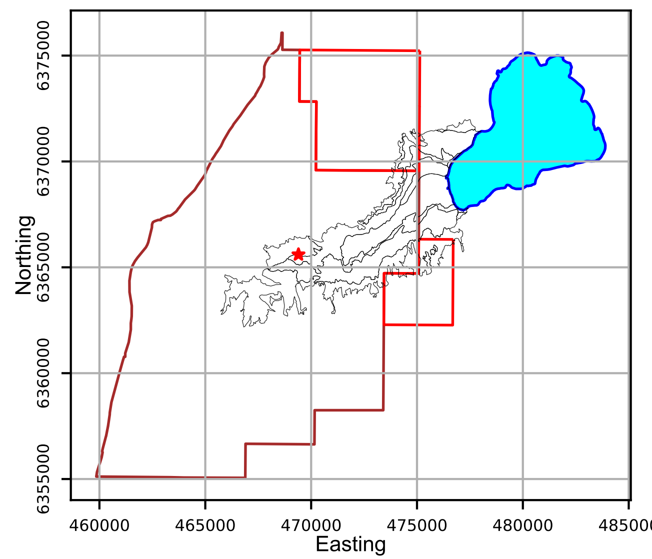
TITLE

GT07-090A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B3-1

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

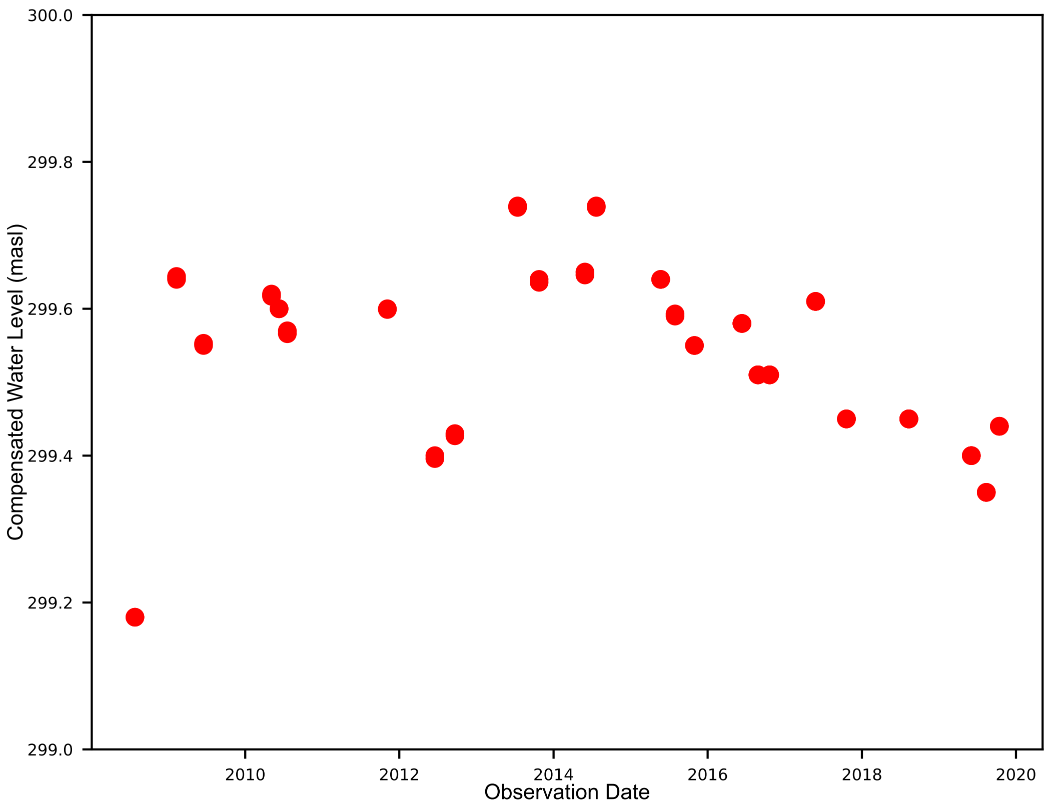
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

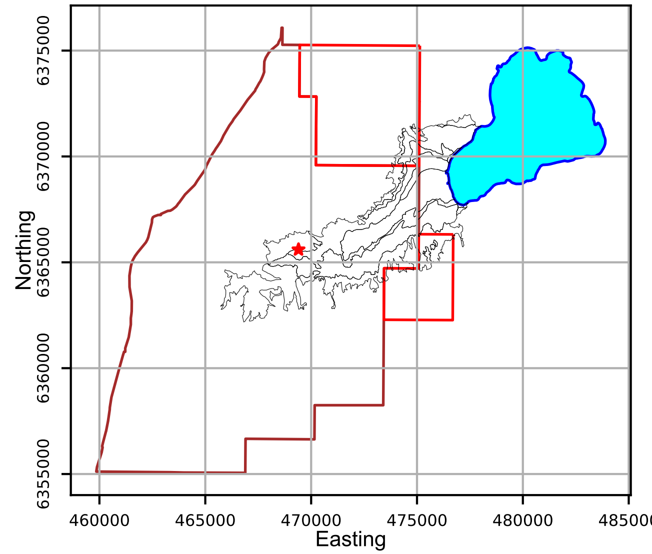
TITLE
GT07-090B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B3-2

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder



Hydrograph Legend
Manual measurement
Transducer measurement



Map Legend
Plotted Well
Wells
McClelland Lake
Approved Project Area
Ecohydrology Zone
Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 1.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-090C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B3-3

B4 Hydrographs for Ecohydrology Zone 4

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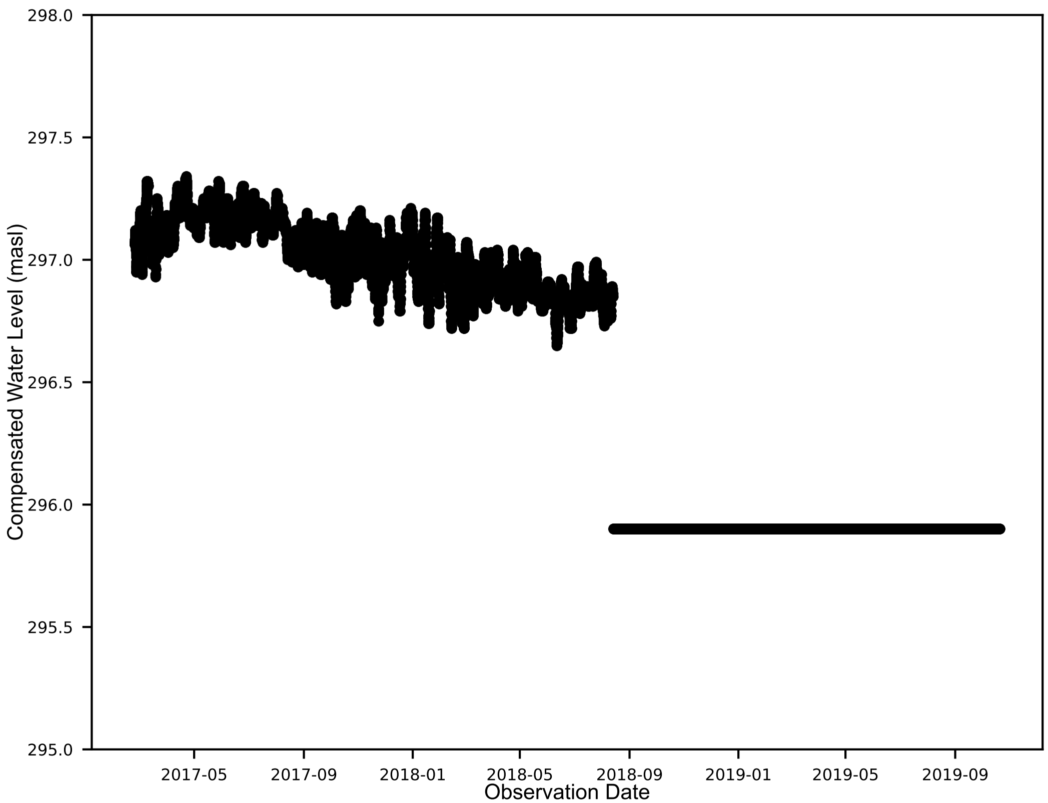

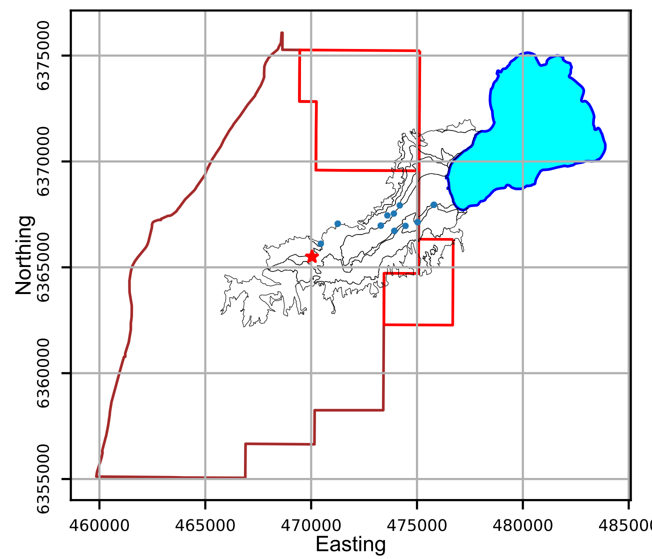

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 31.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR406-MR1 - 31.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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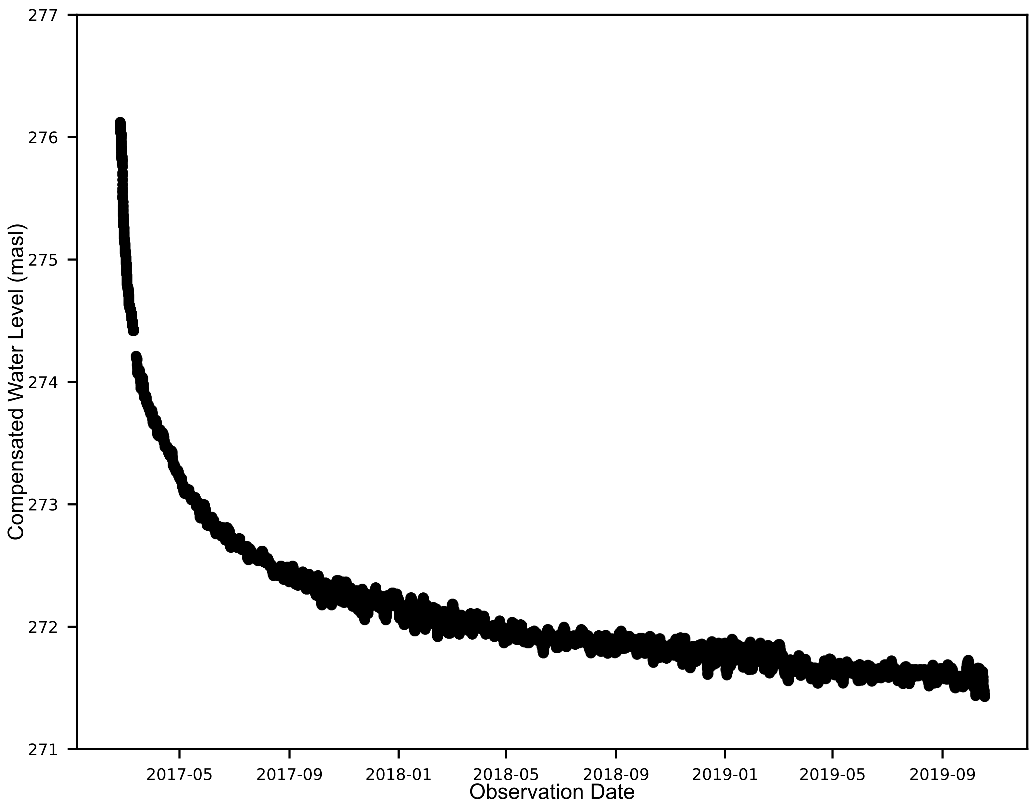

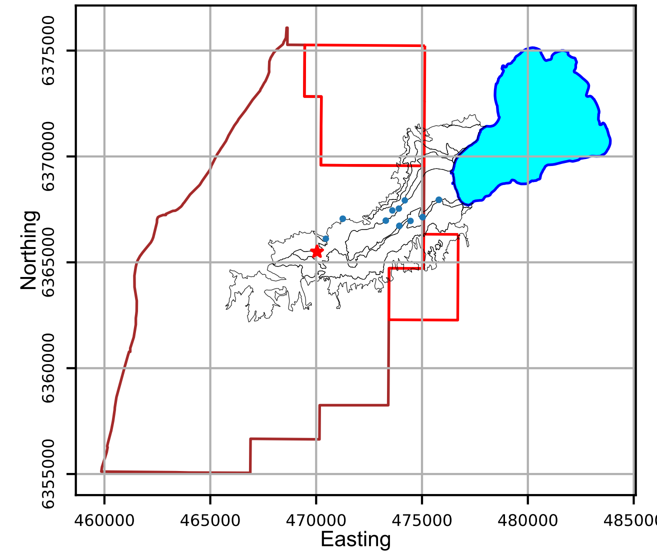

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 66 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR406-MR1 - 66.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-2

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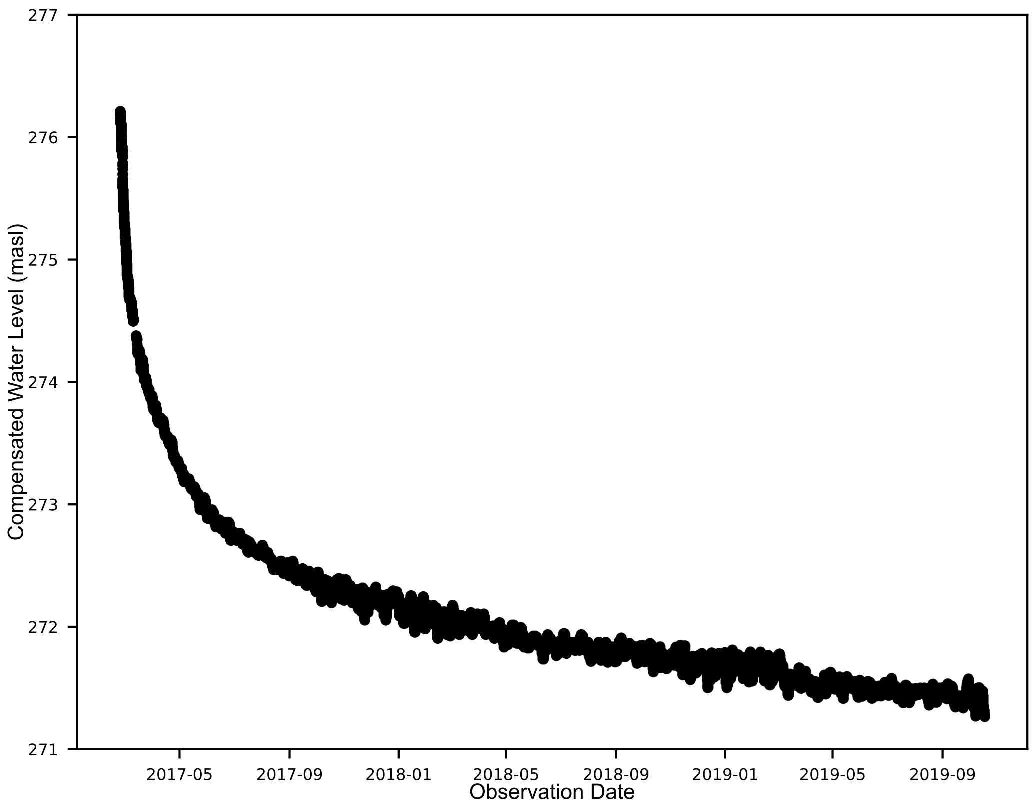

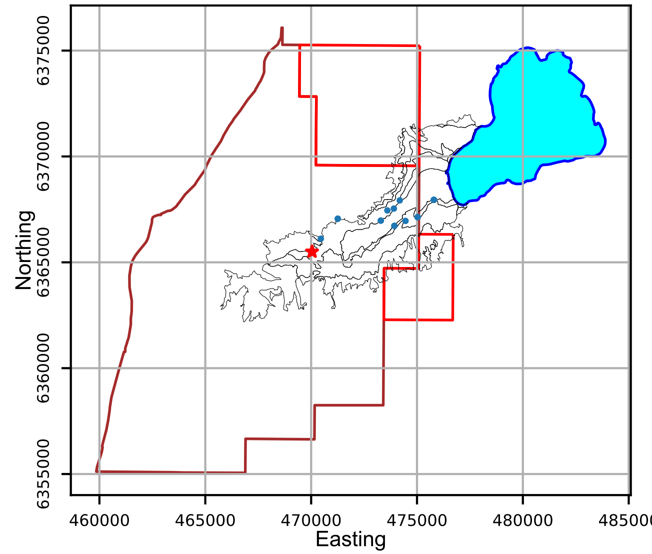

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 73 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR406-MR1 - 73.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-3

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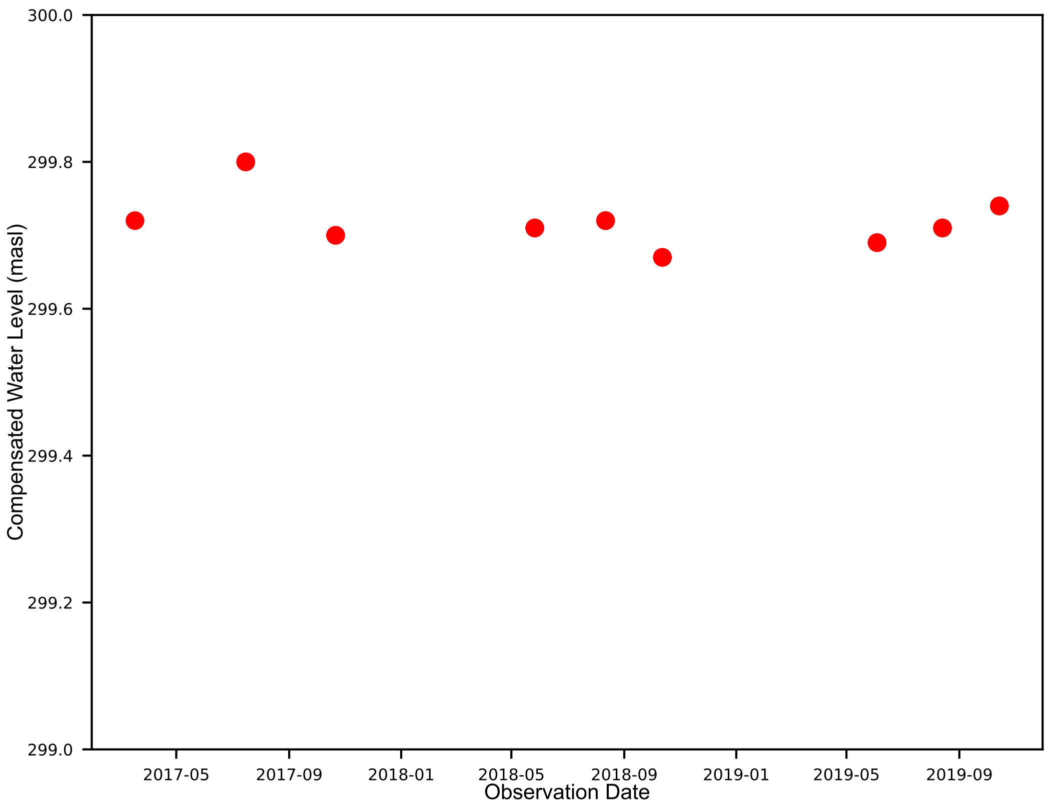

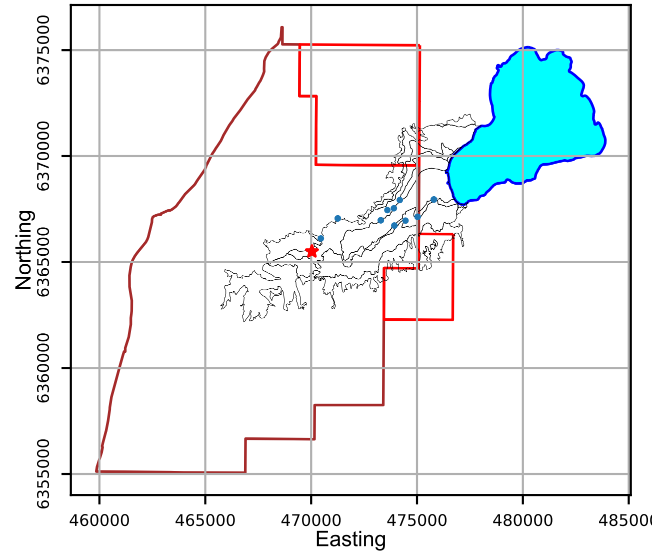

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR406-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-4

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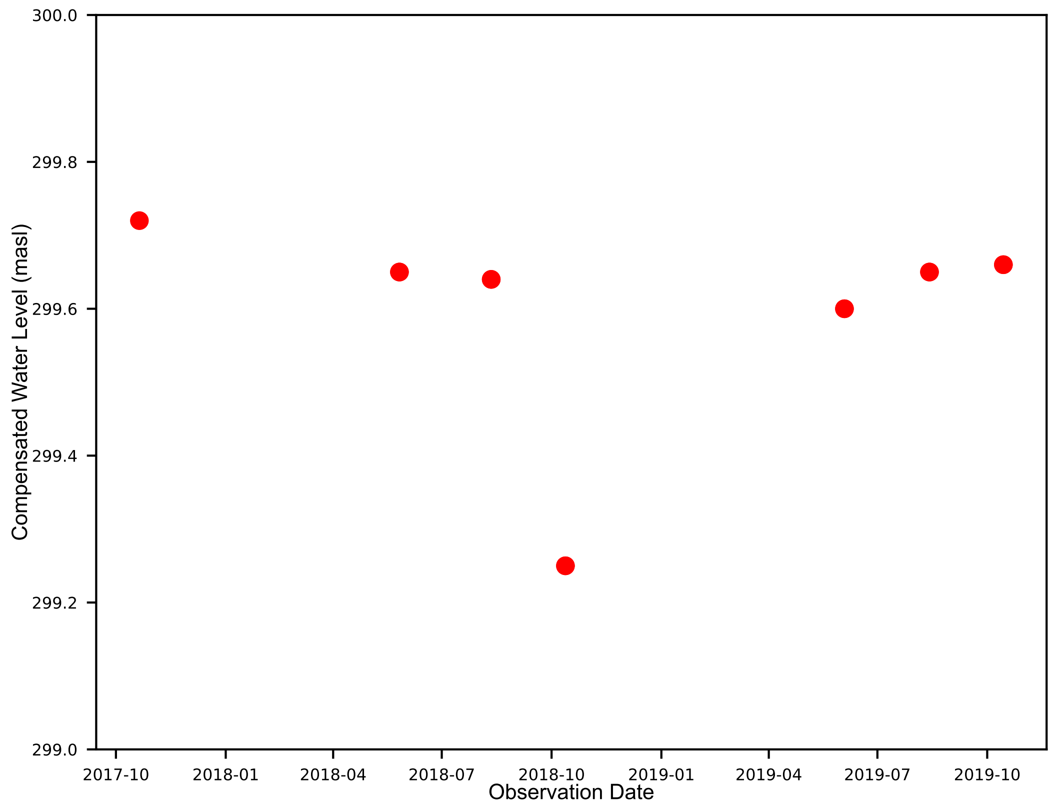

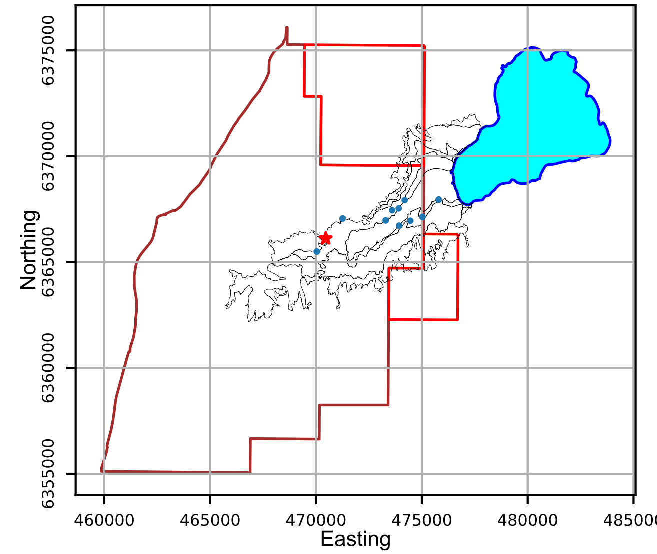

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 13.97 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH17-WR433-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-5

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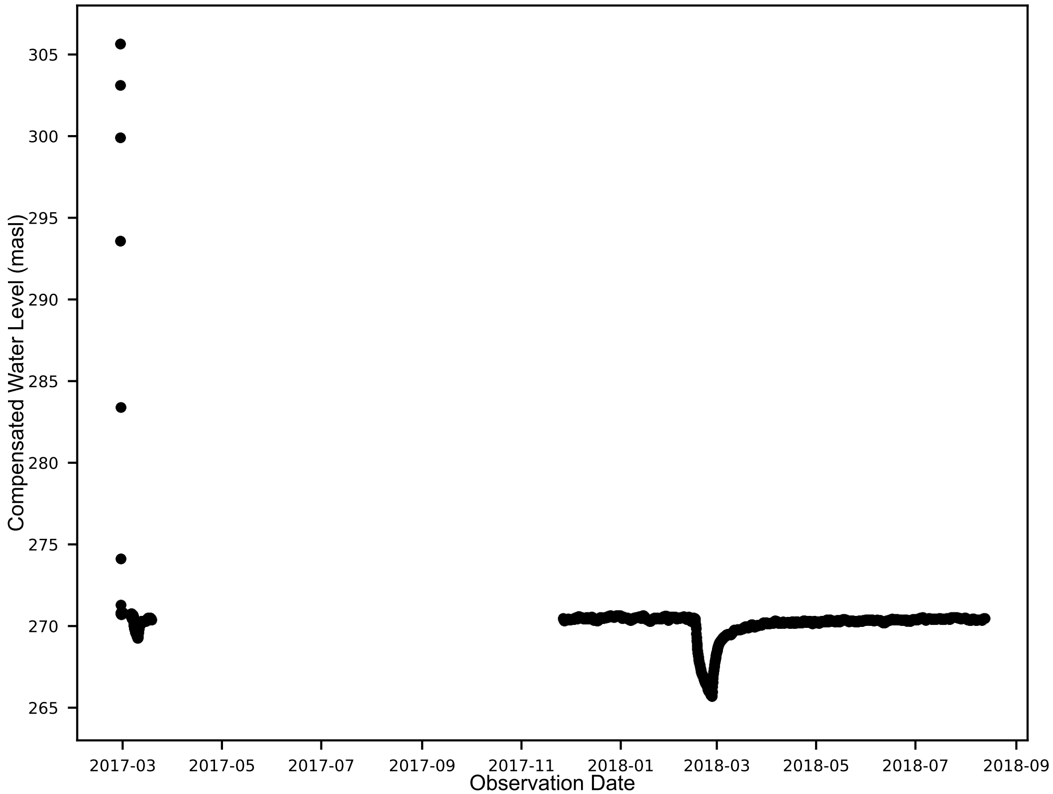

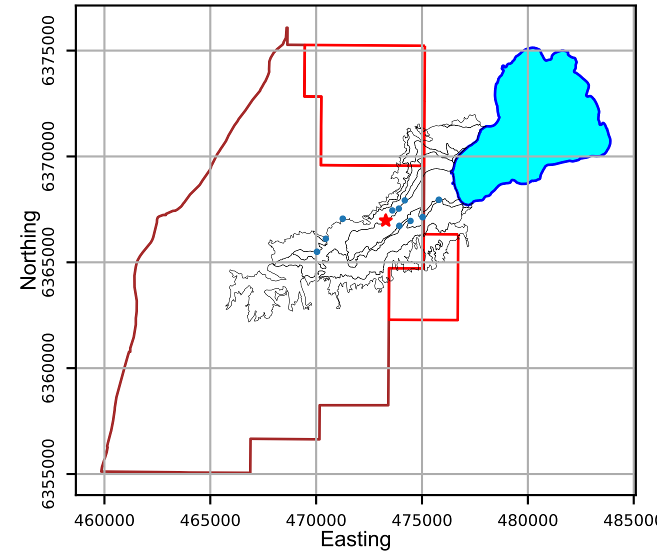

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 100 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH17-WR445-MR1 - 100.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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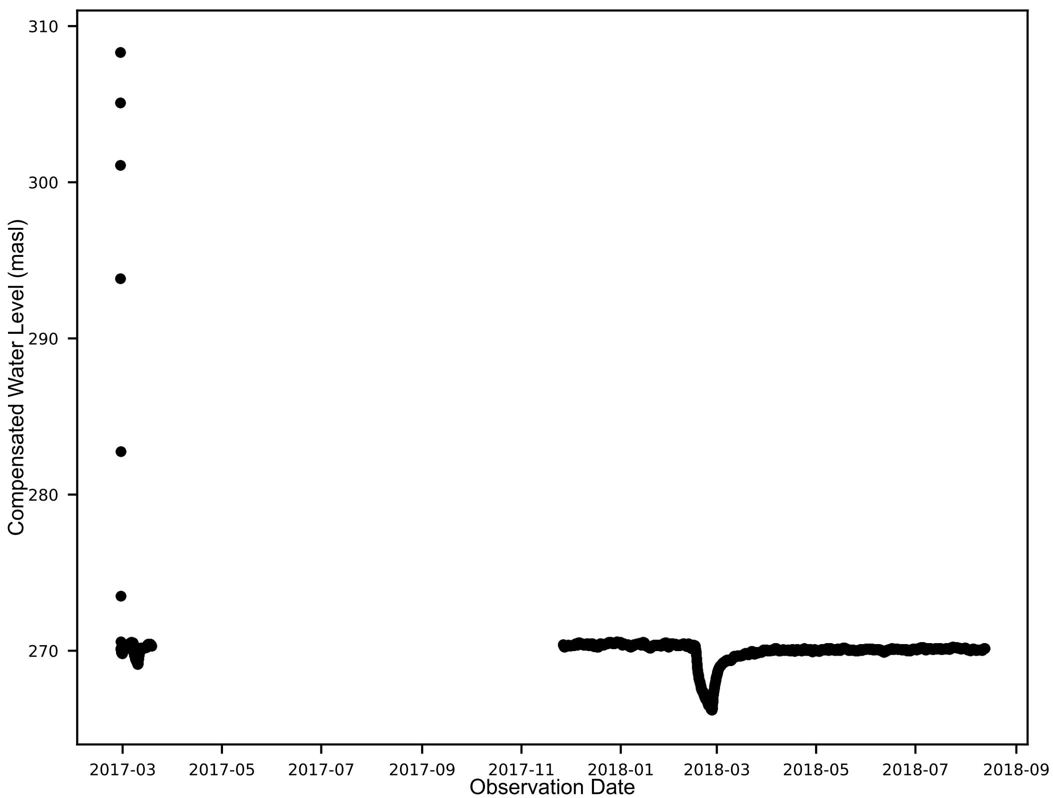
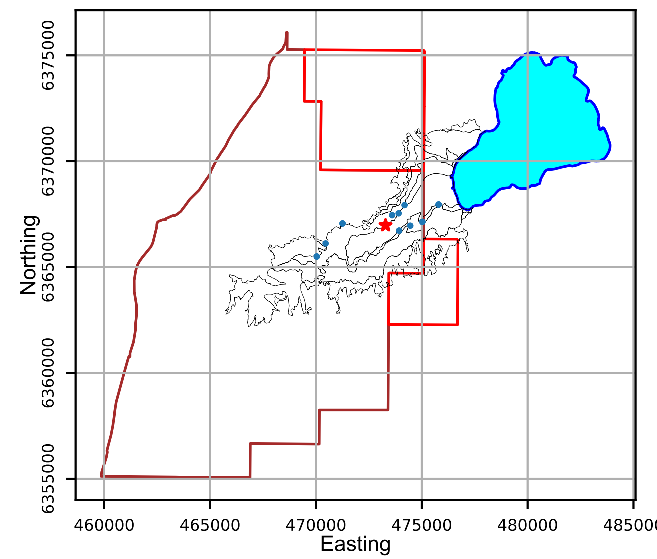




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 108 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

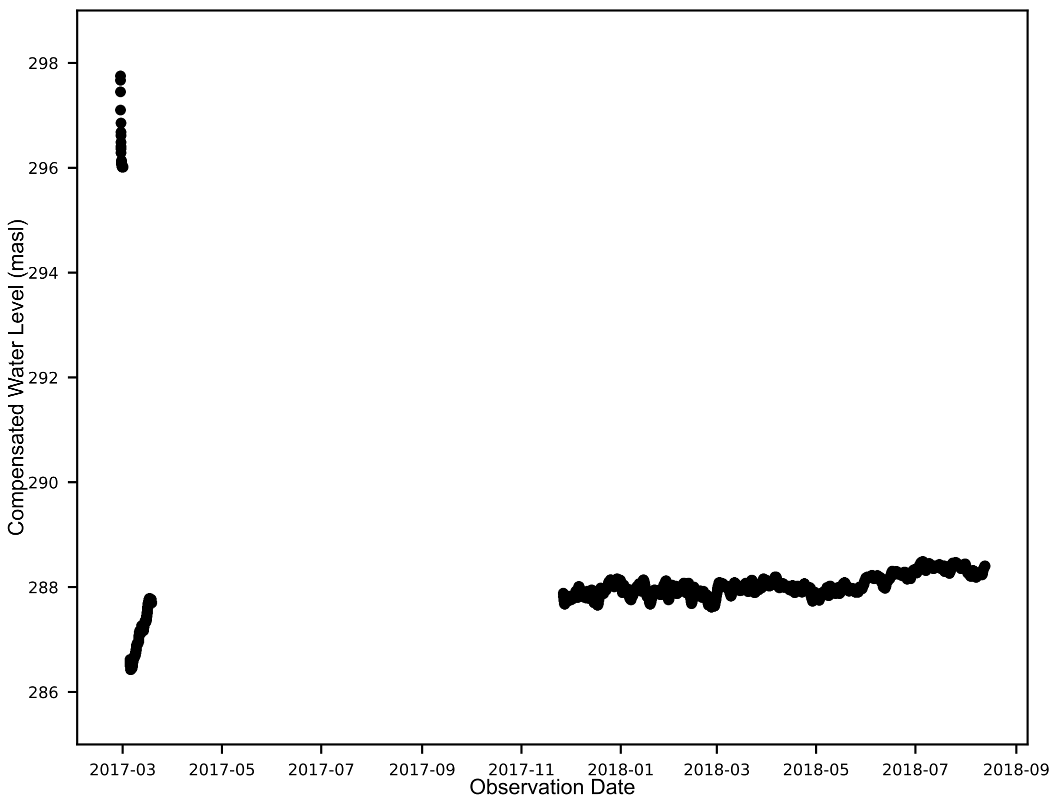
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

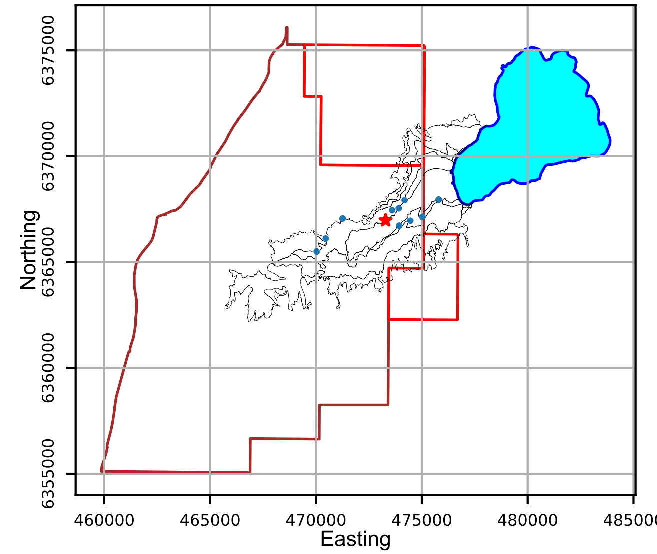
TITLE

FH17-WR445-MR1 - 108.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-7

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Hydrograph Legend

- Manual measurement
- Transducer measurement

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 68.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE
FH17-WR445-MR1 - 68.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-8

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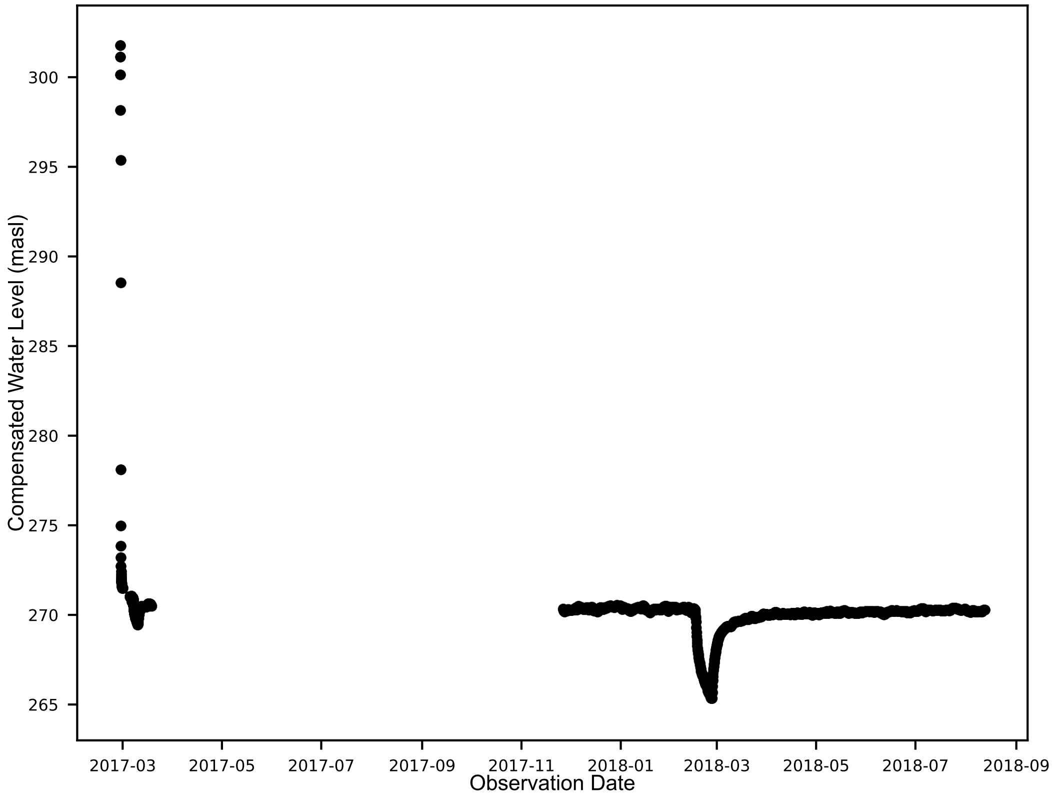

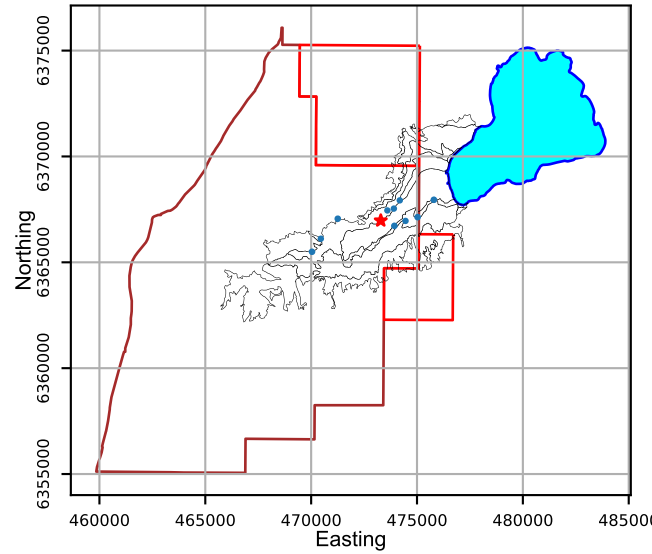

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 85 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR445-MR1 - 85.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-9

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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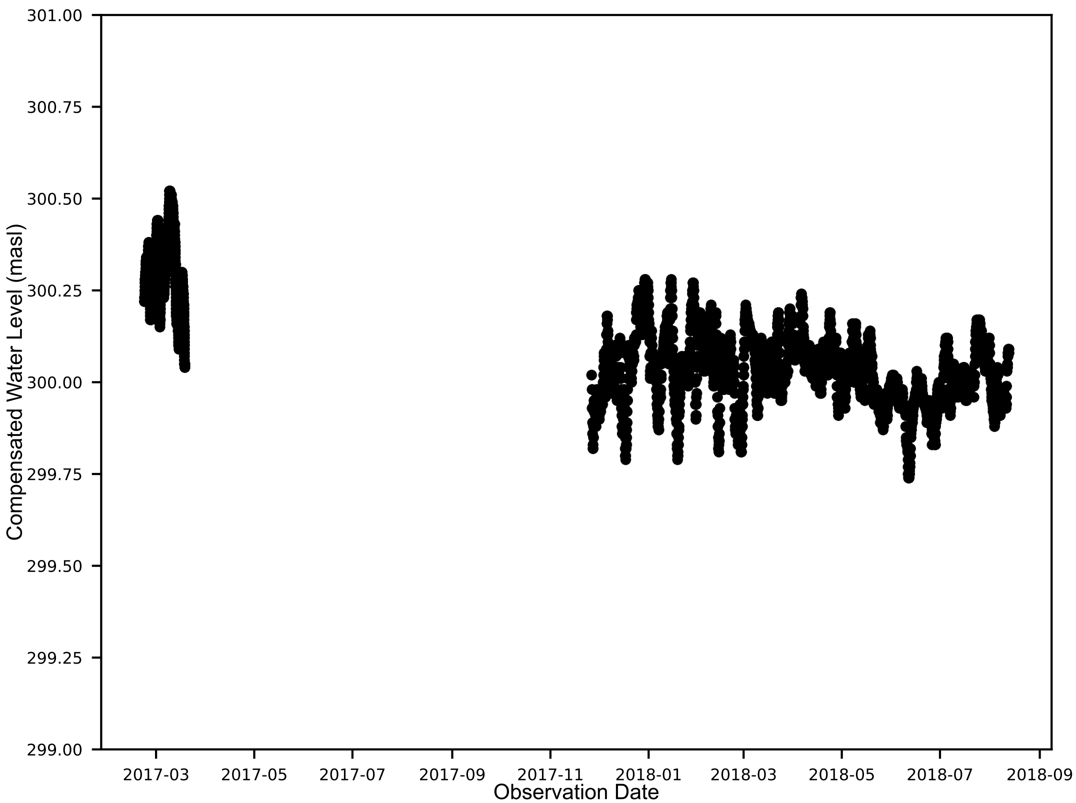

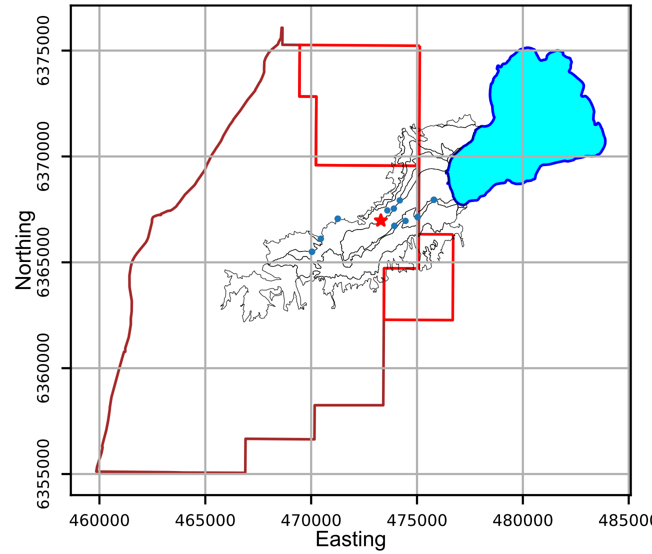

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 20 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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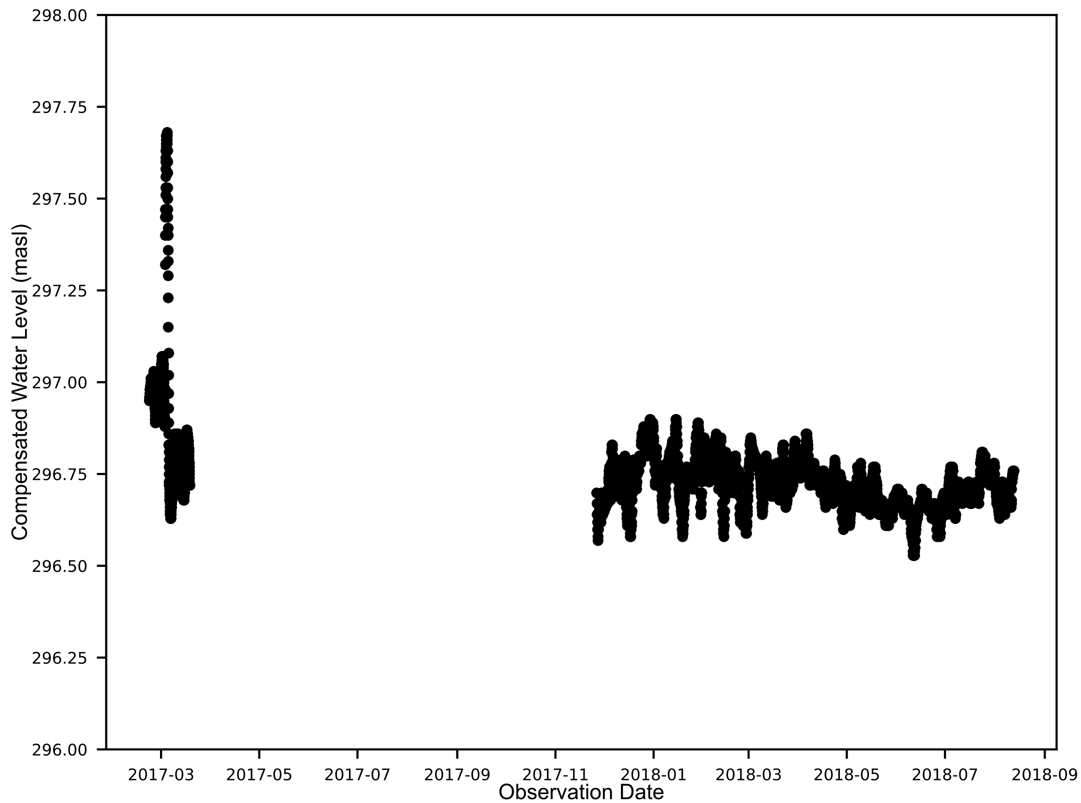
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

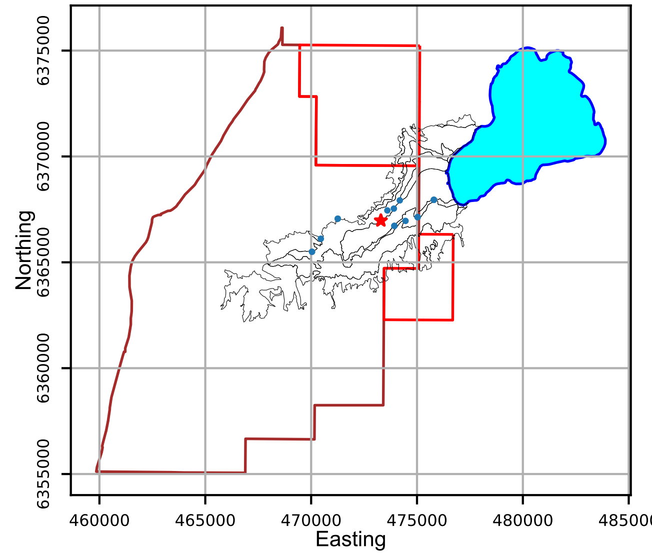
TITLE

FH17-WR445-SN1 - 20.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-10

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 34.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR445-SN1 - 34.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-11

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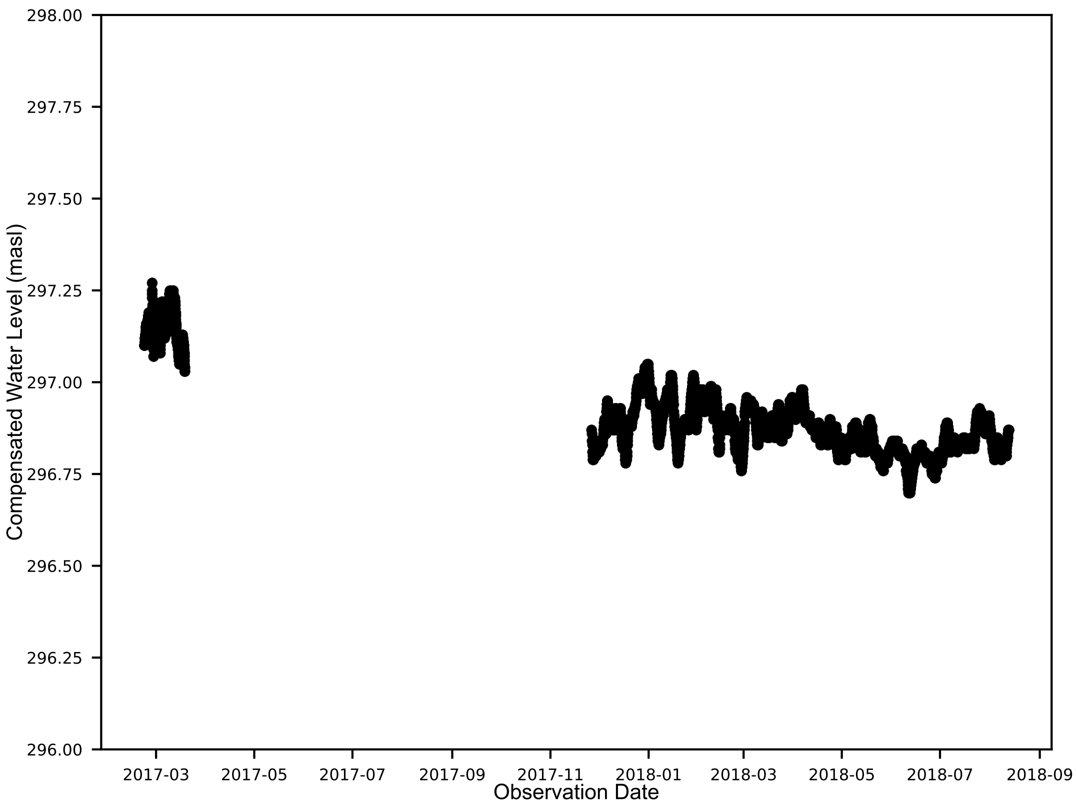

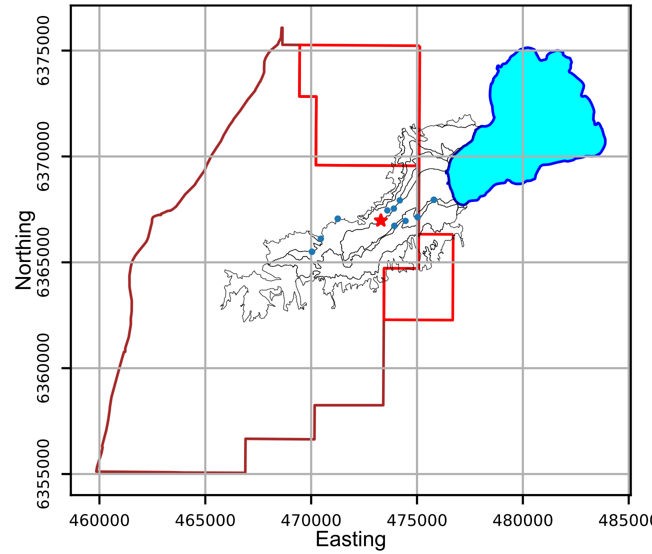

Hydrograph Legend

- Manual measurement
- Transducer measurement

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 39 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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DESIGN	MO
REVIEW	LW
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TITLE
FH17-WR445-SN1 - 39.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-12

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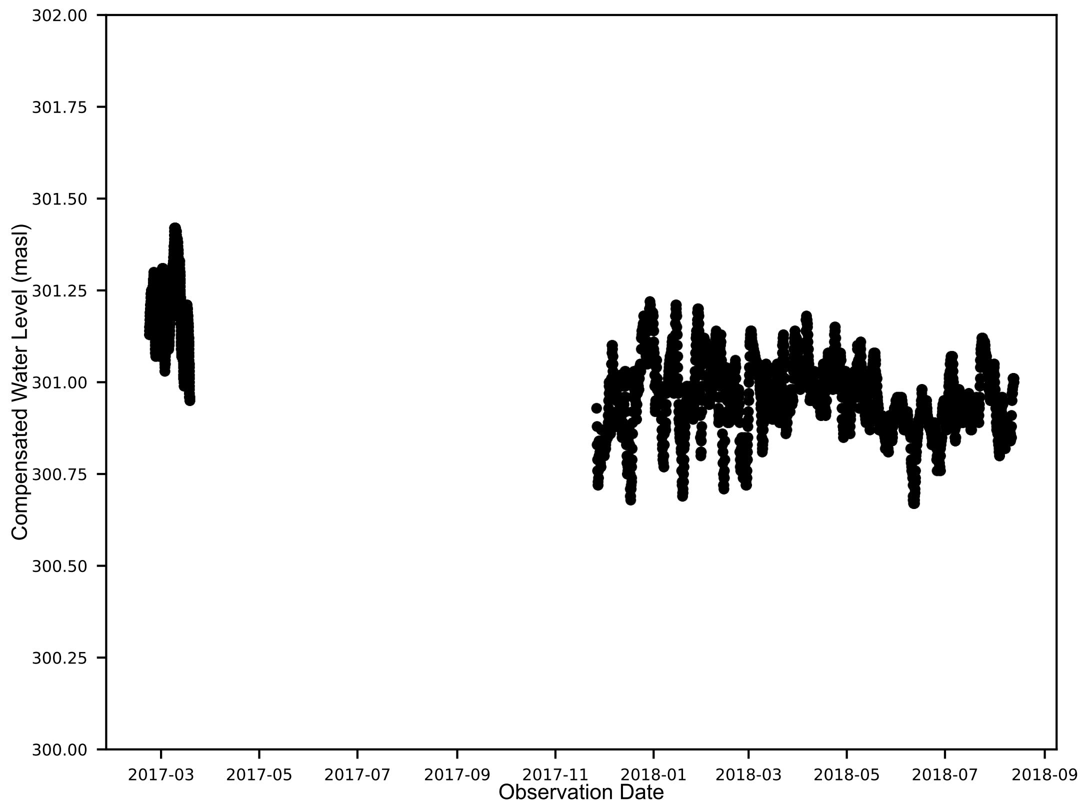
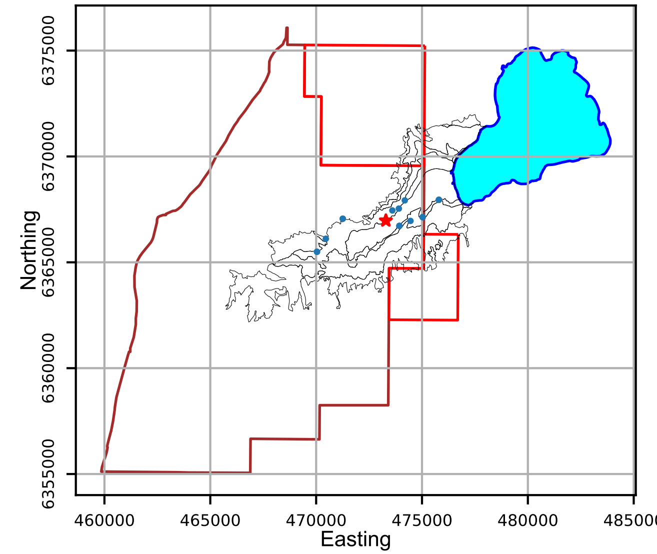


Hydrograph Legend

Manual measurement

Transducer measurement



Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR445-SN1 - 8.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-13

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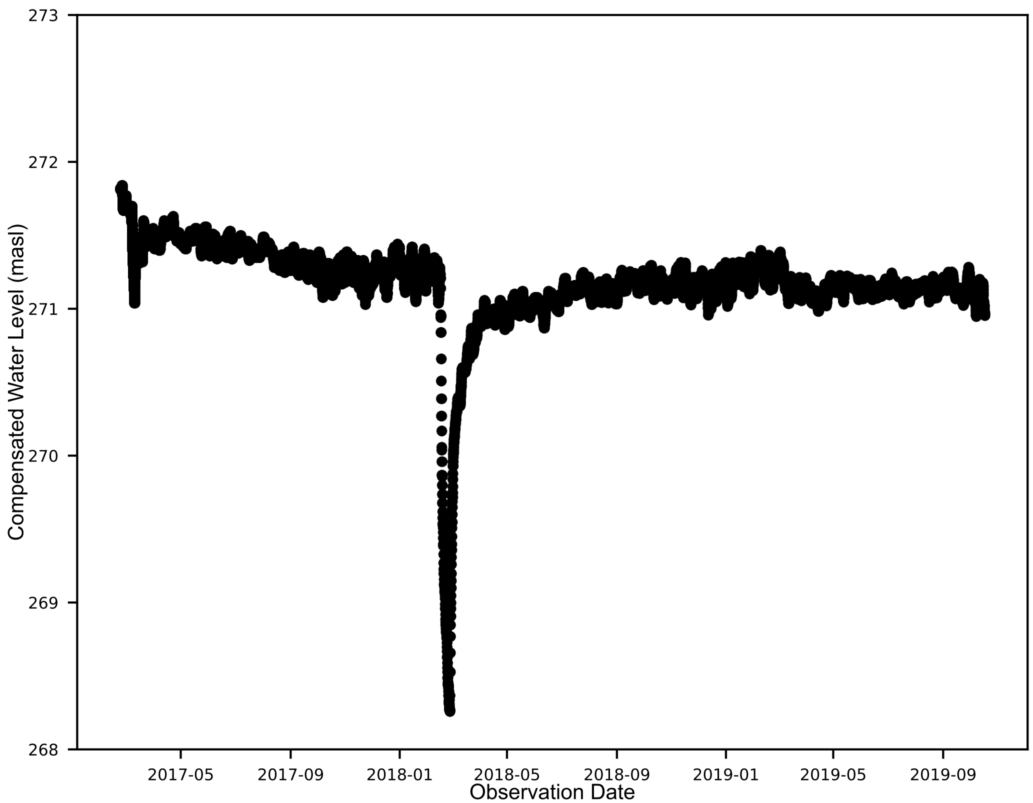

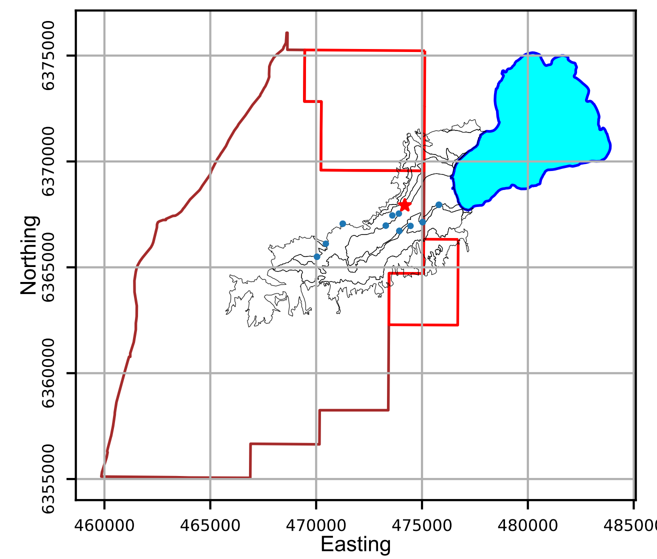

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 100 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR450-MR1 - 100.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-14

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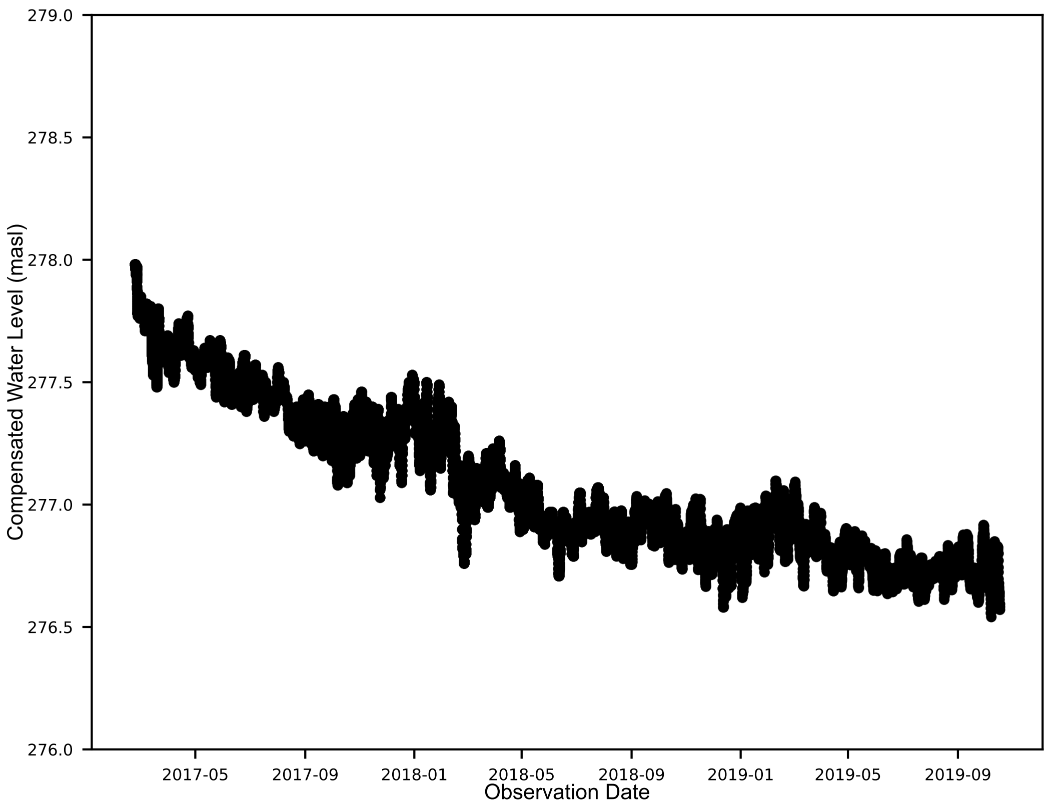

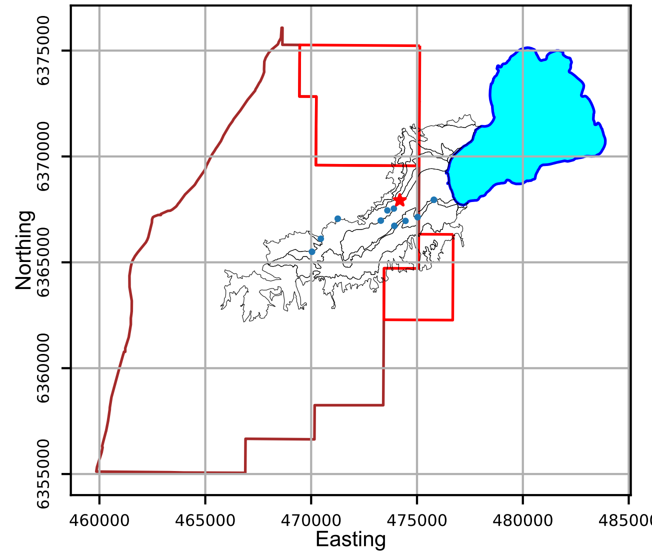

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 67 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR450-MR1 - 67.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-15

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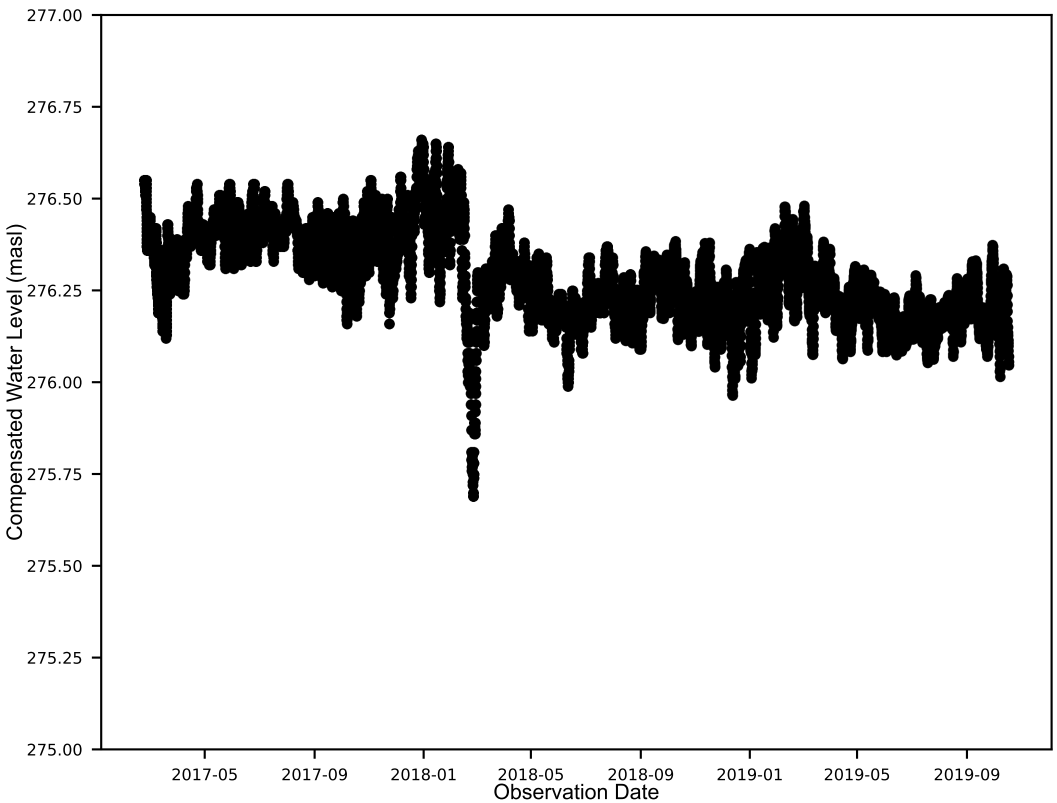

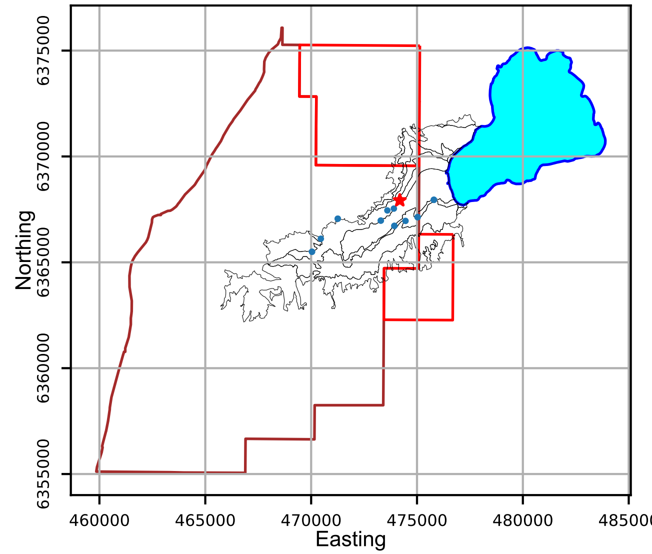

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 70 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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TITLE
FH17-WR450-MR1 - 70.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-16

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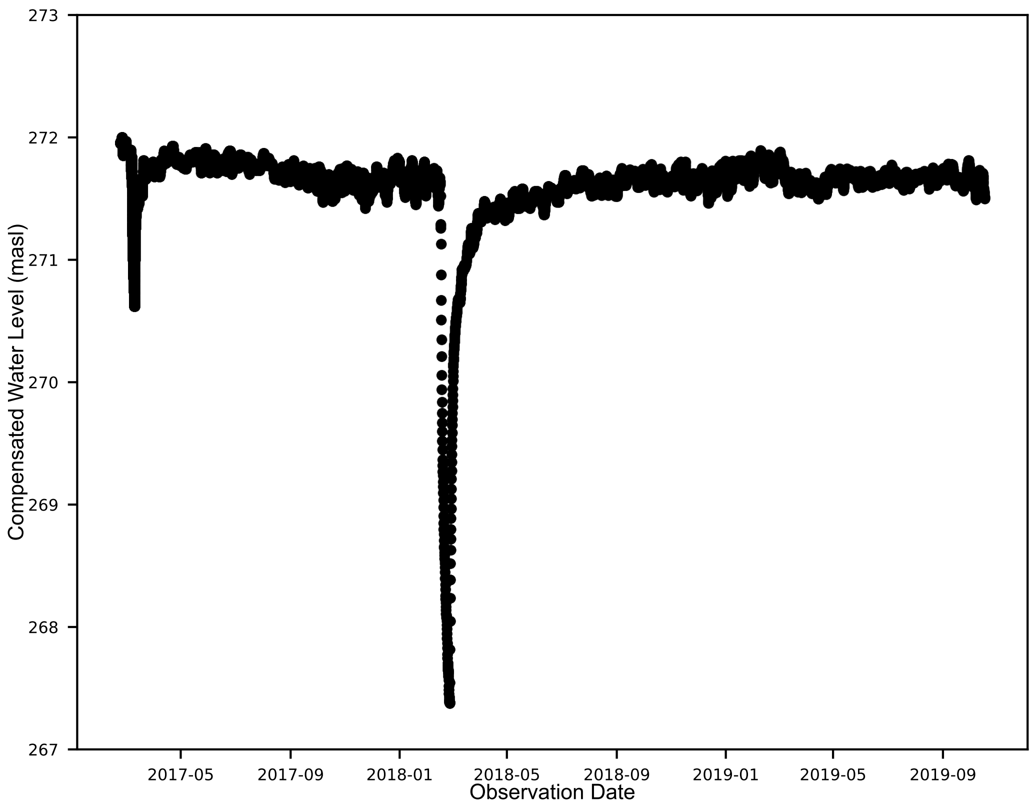

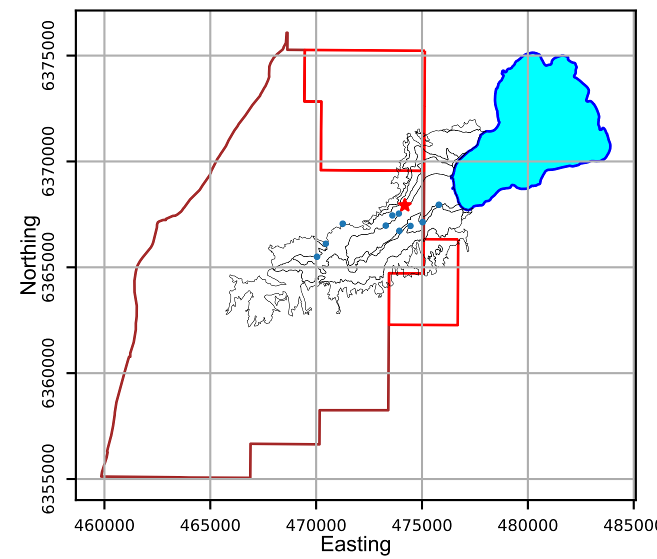

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 85 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR450-MR1 - 85.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B4-17

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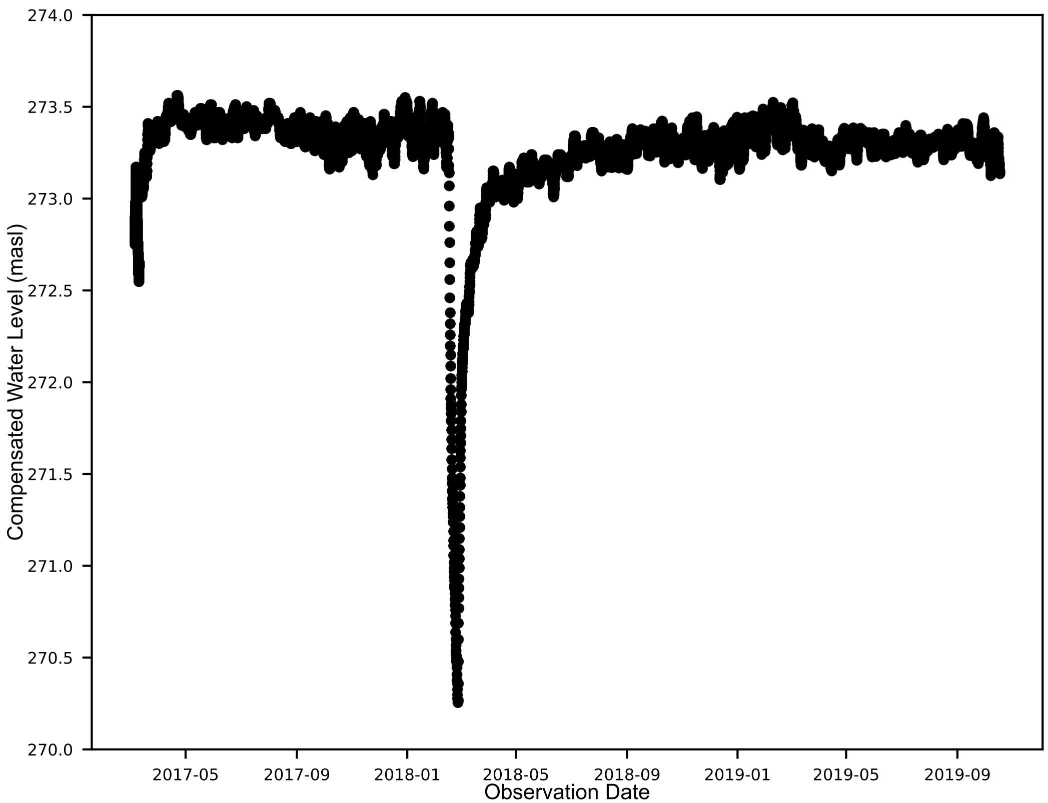

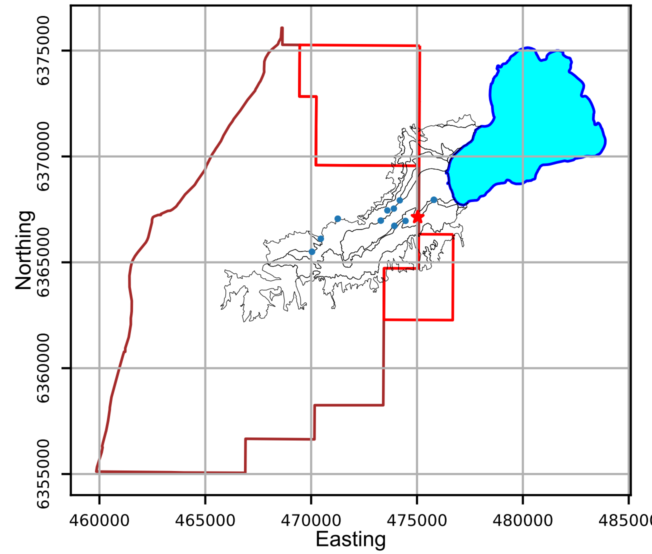

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 107 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR451-MR1 - 107.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B4-18

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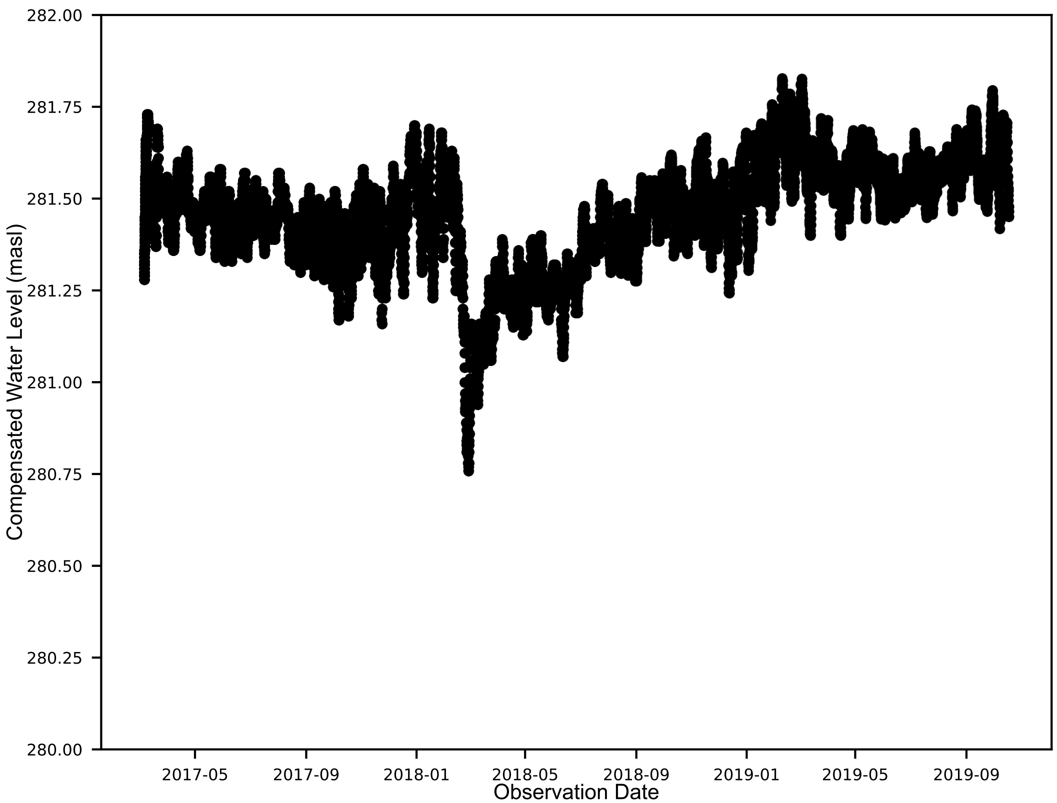

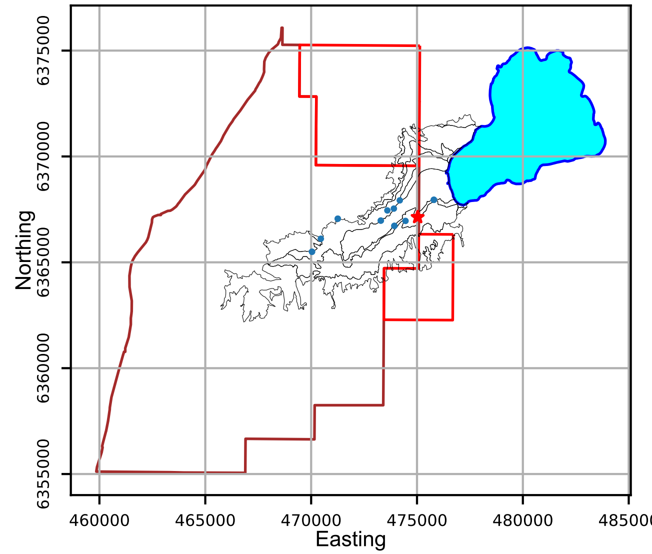

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 59 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR451-MR1 - 59.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-19

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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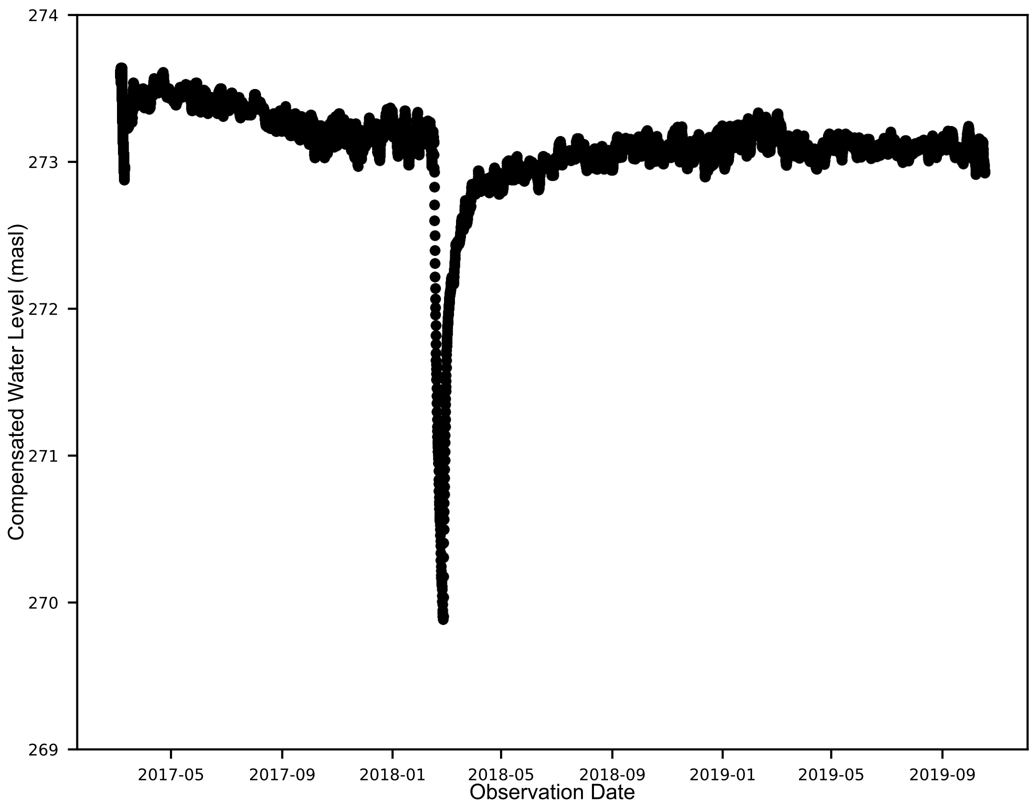

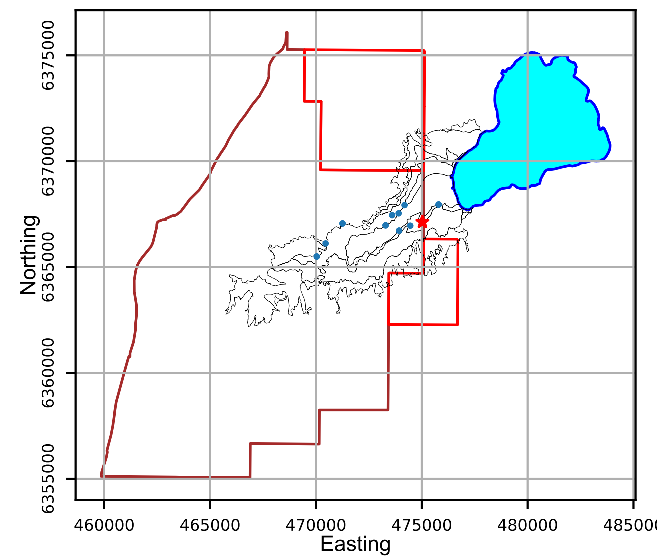

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 86 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR451-MR1 - 86.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-20

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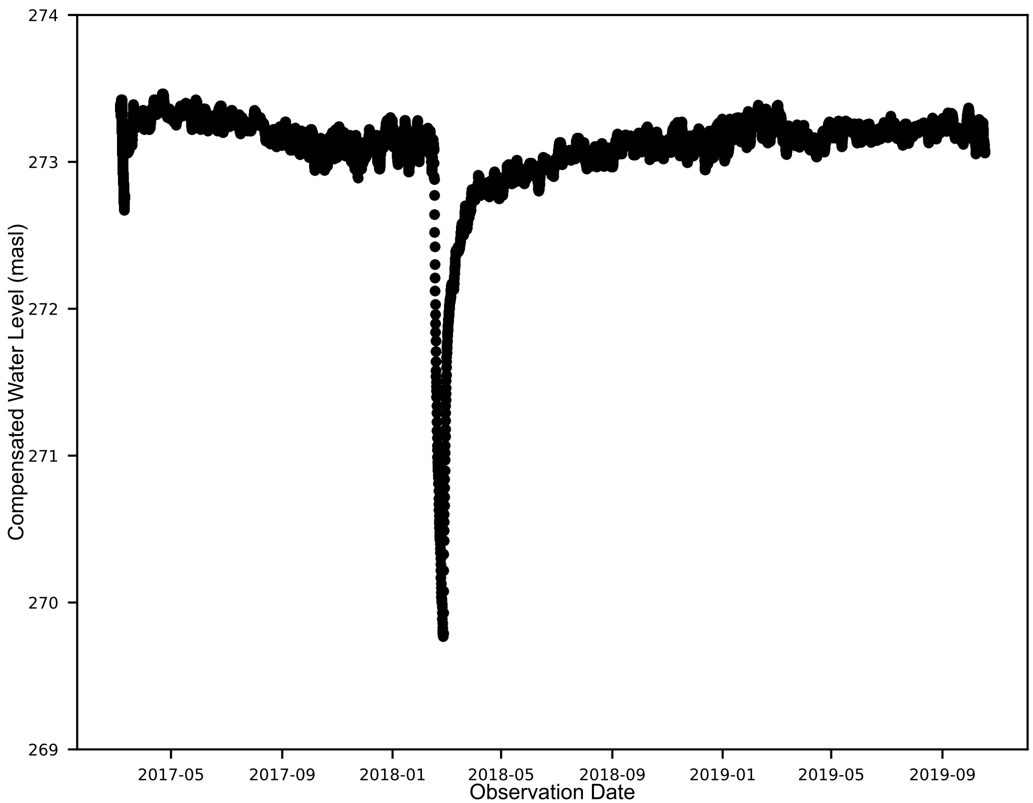

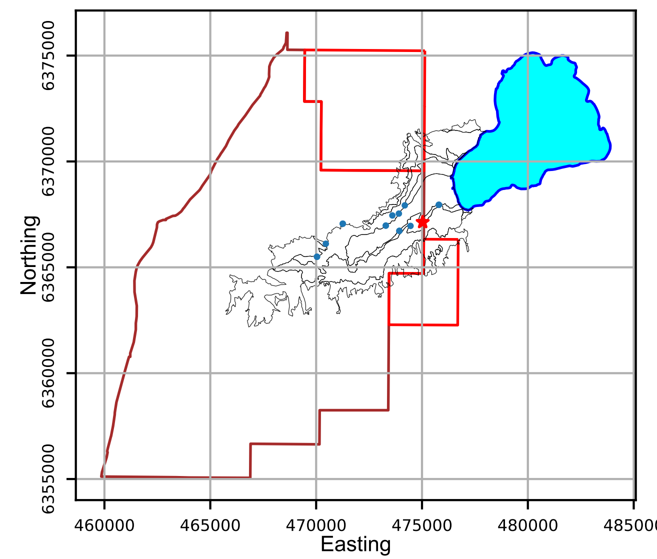

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 95 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR451-MR1 - 95.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-21

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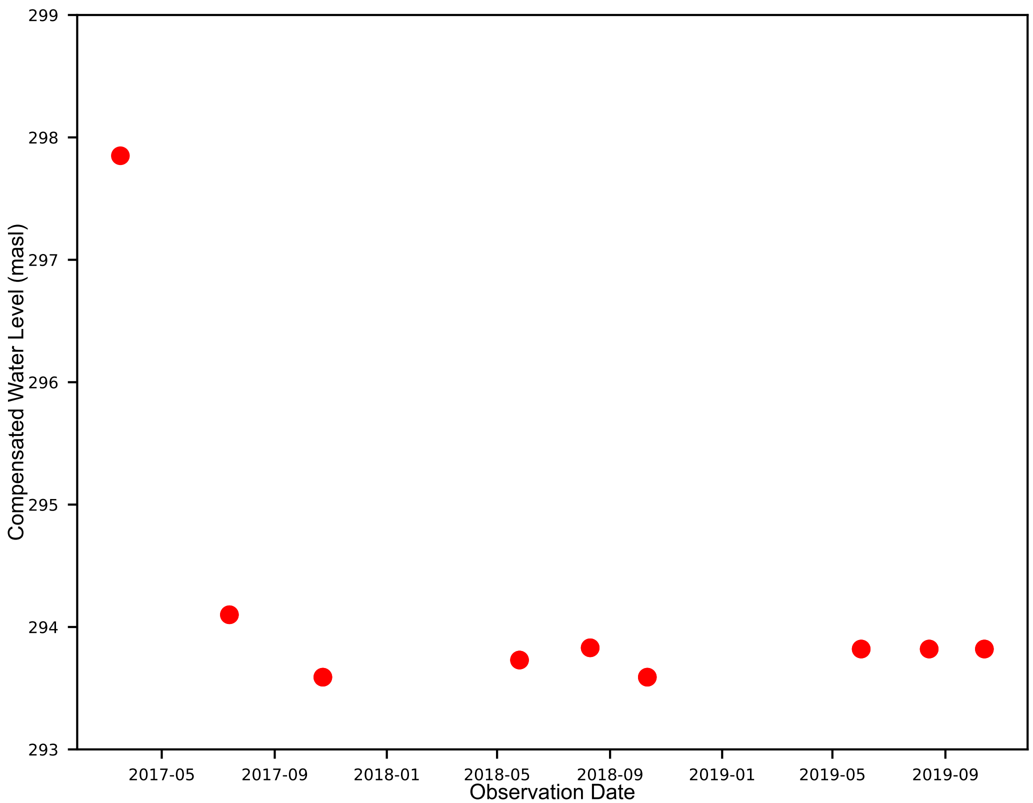

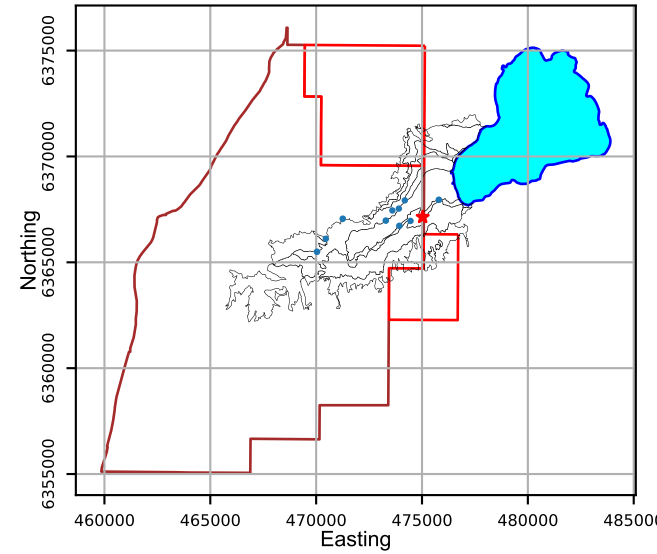

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 36 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

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DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR451-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-22

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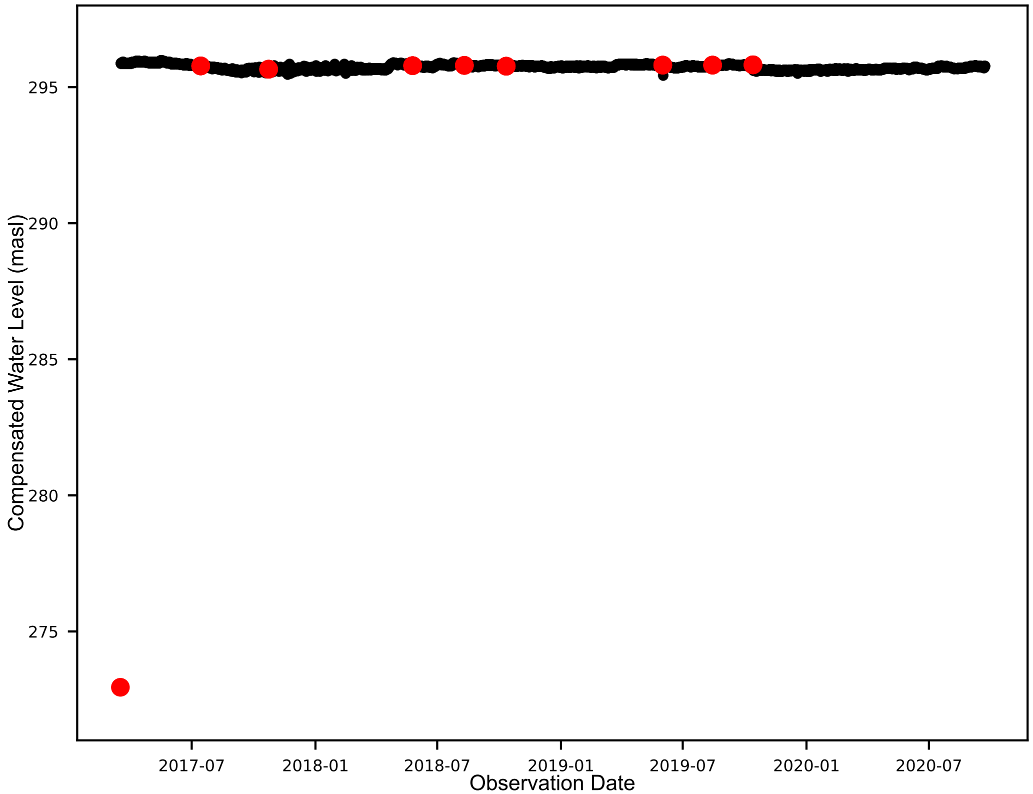

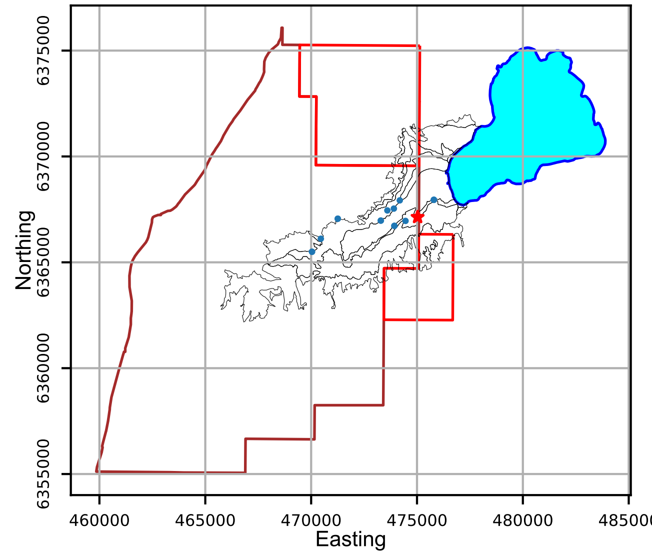

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 12.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR451-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-23

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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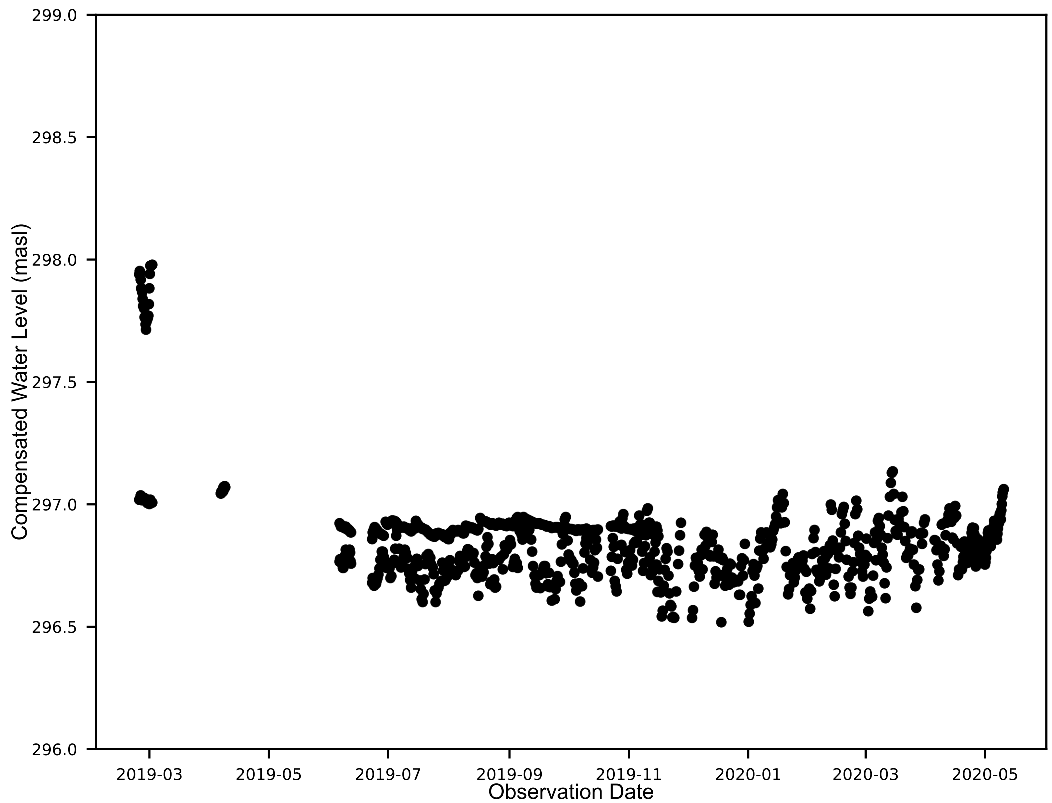
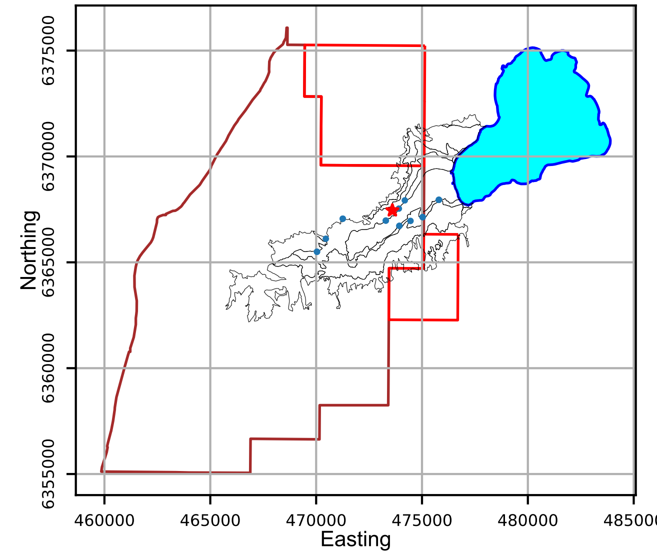




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 25 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

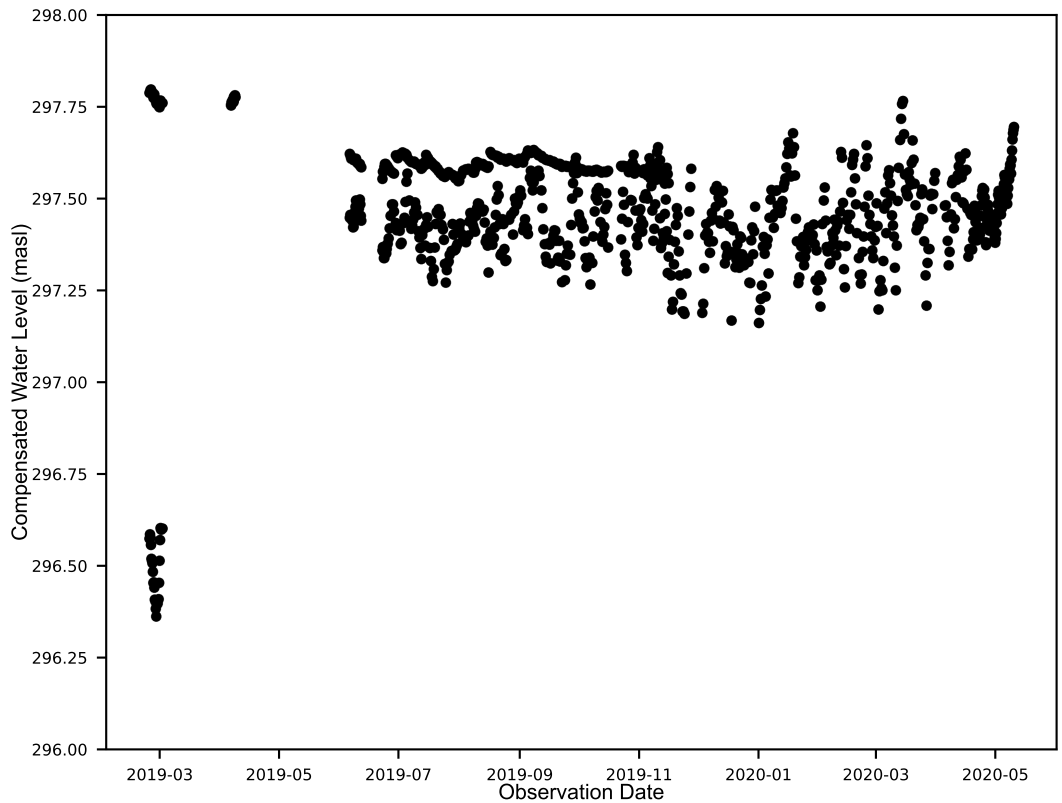
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

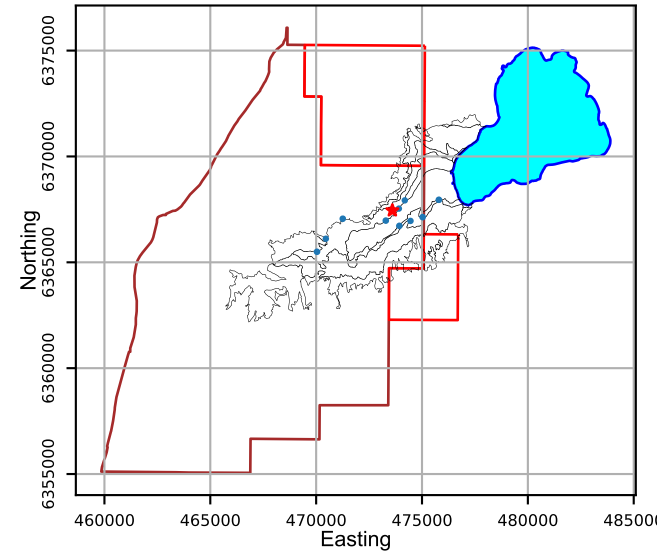
TITLE

FH19-ES615-SN1 - 25.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-24

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 38.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
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APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES615-SN1 - 38.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-25

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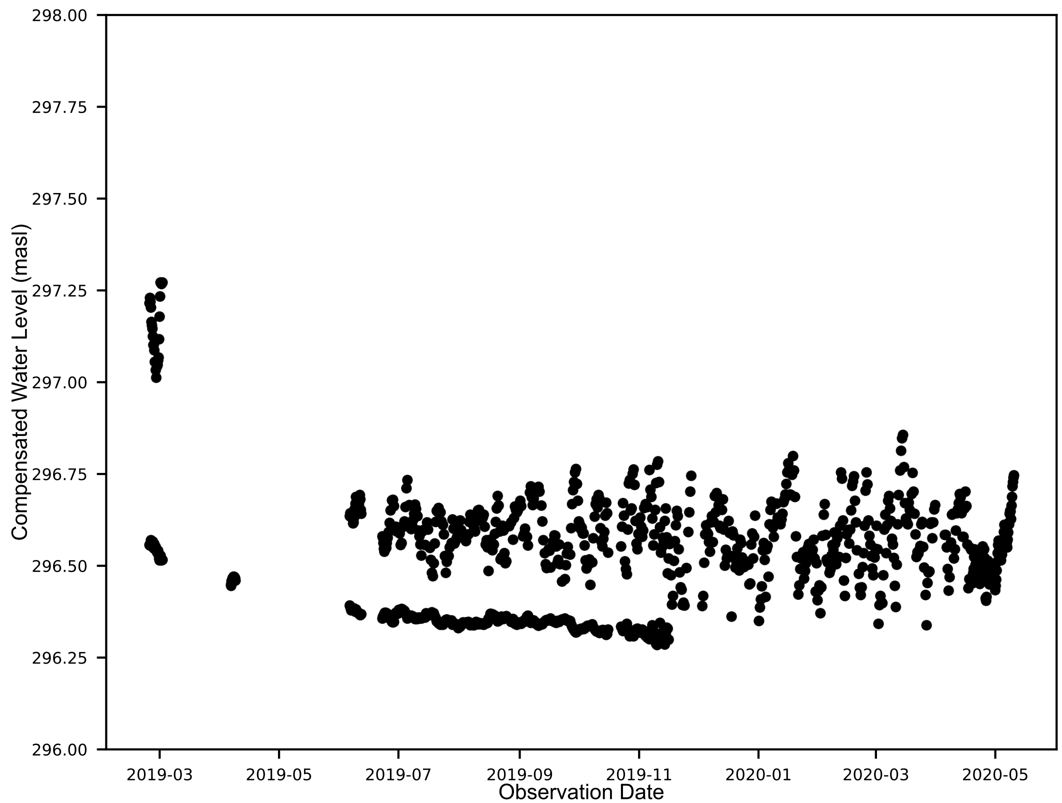

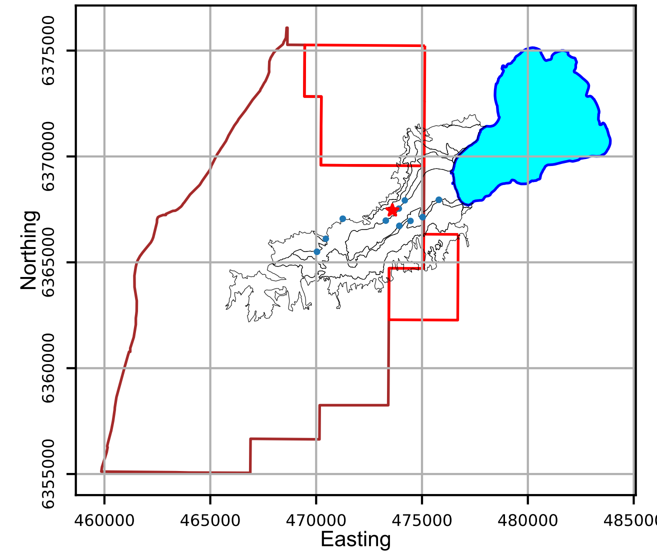

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH19-ES615-SN1 - 9.5 M BELOW GROUND SURFACE

FORTHILLS
Operated by Suncor Energy

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-26

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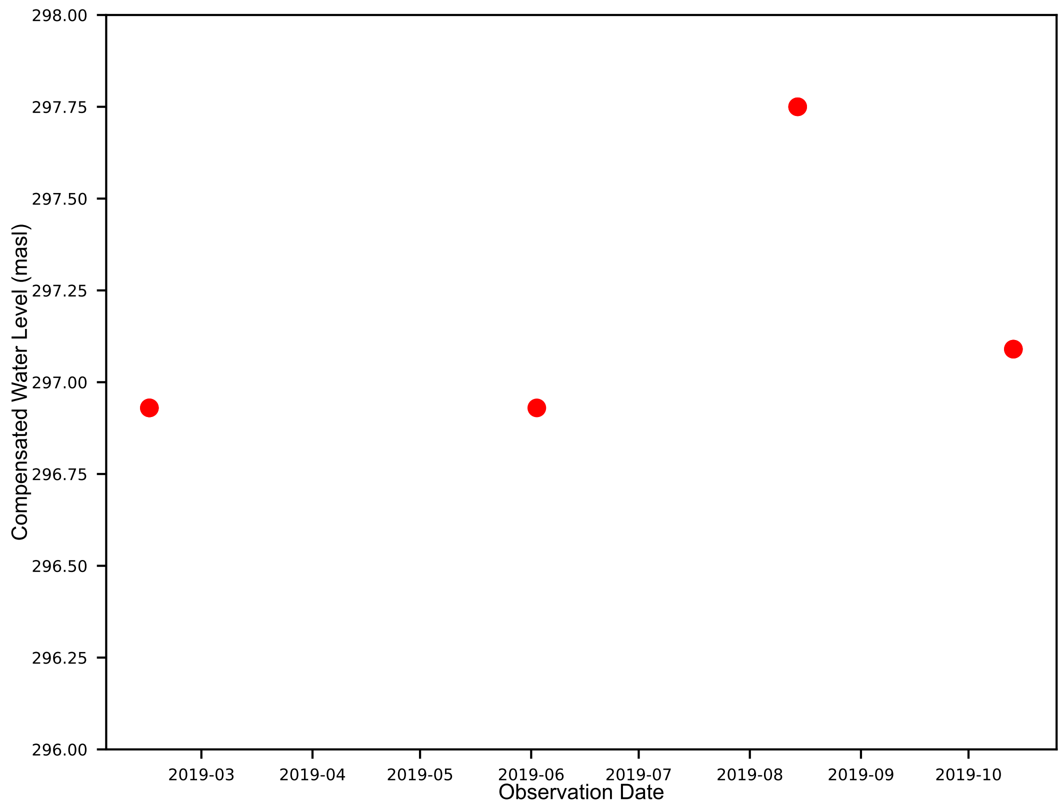

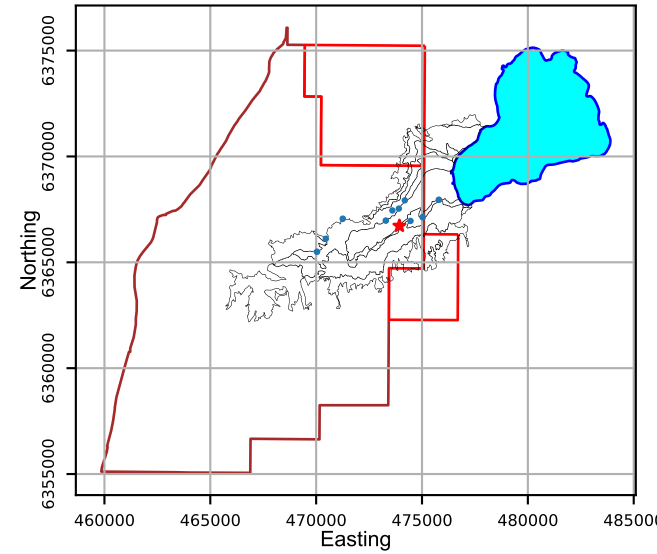

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 30.24 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES623-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-27

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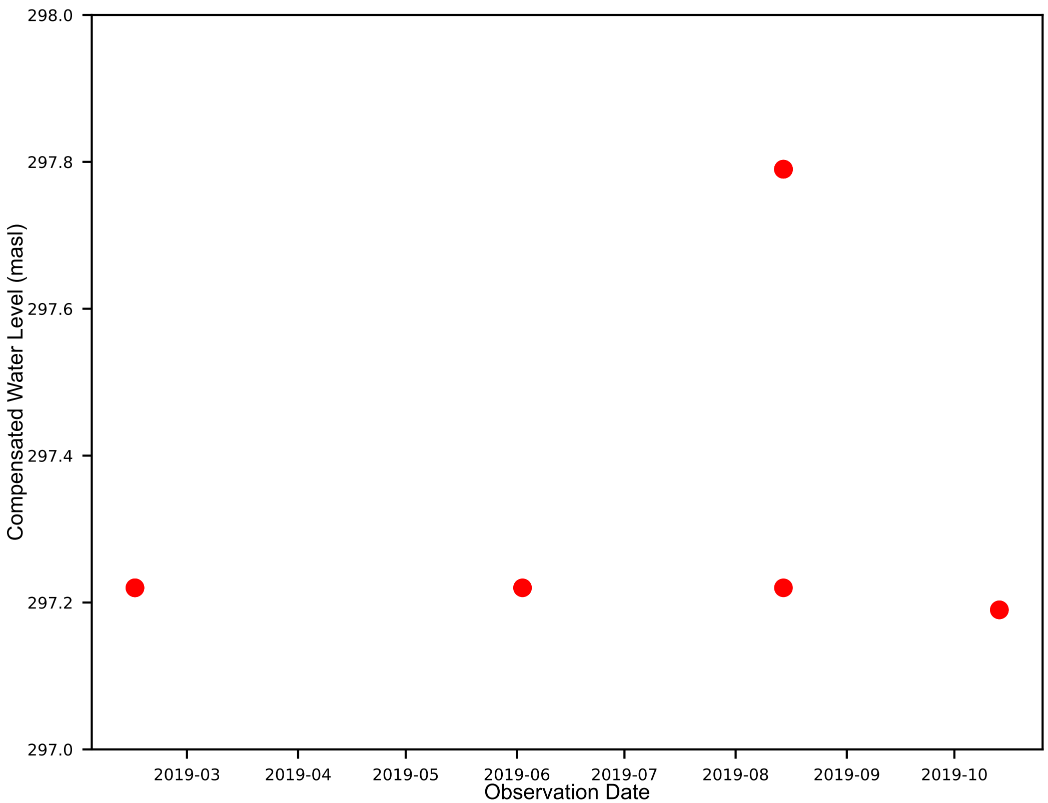

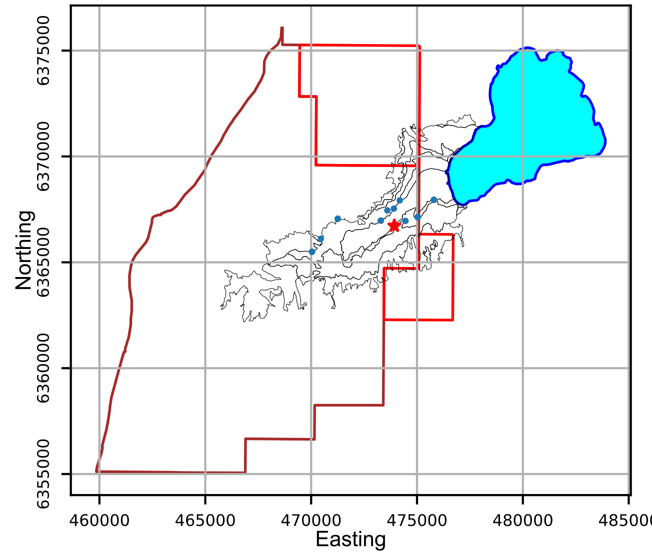

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES623-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-28

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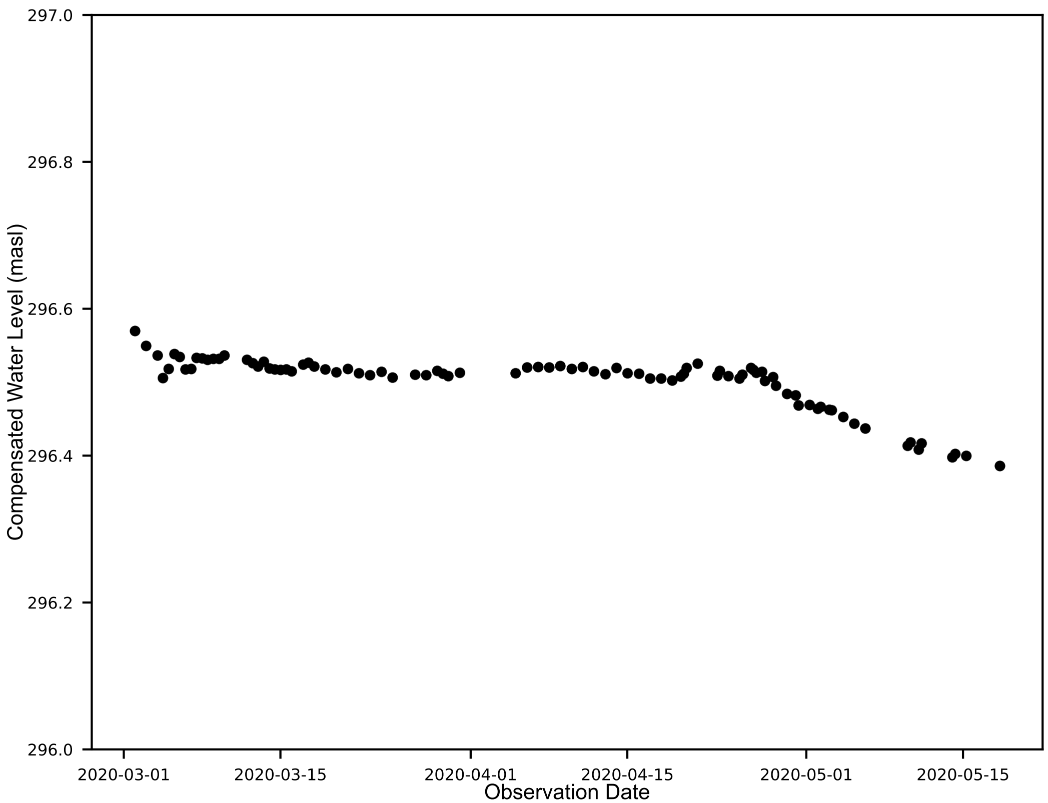
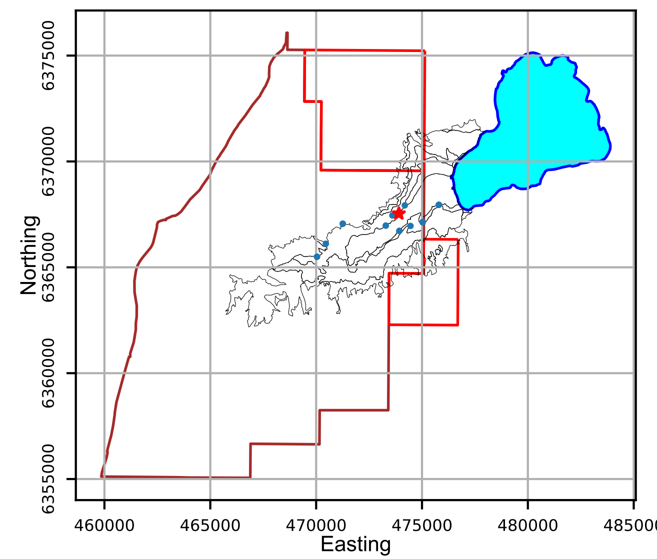




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 13 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

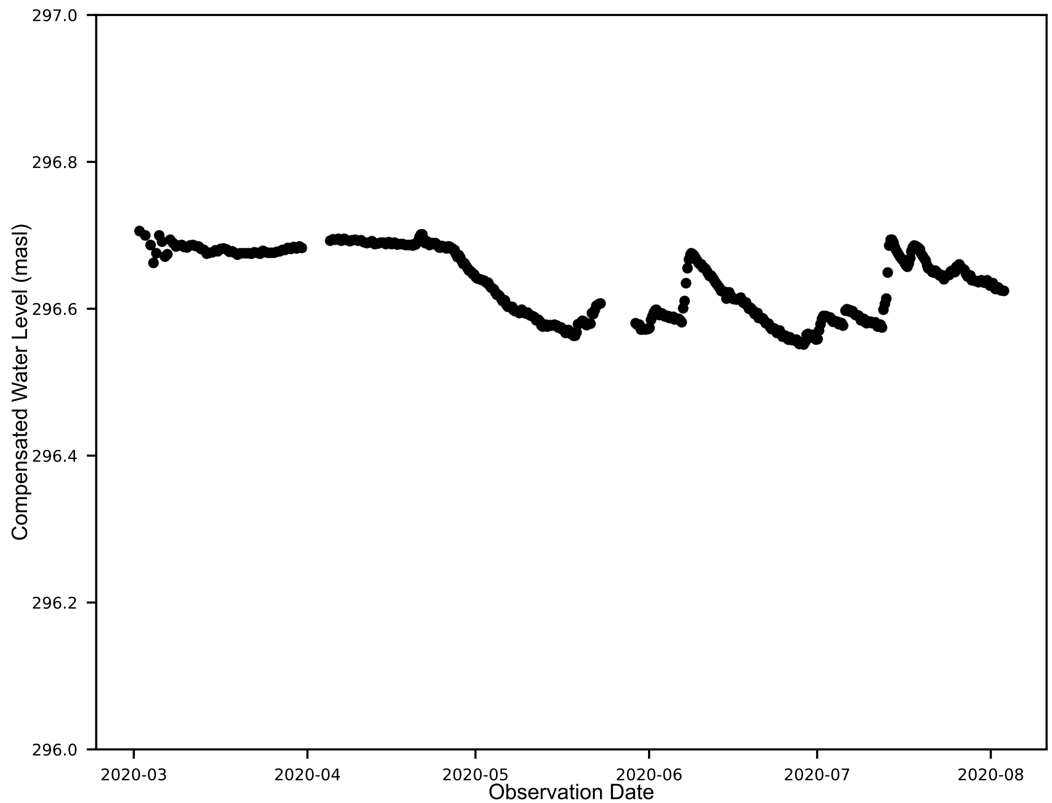
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

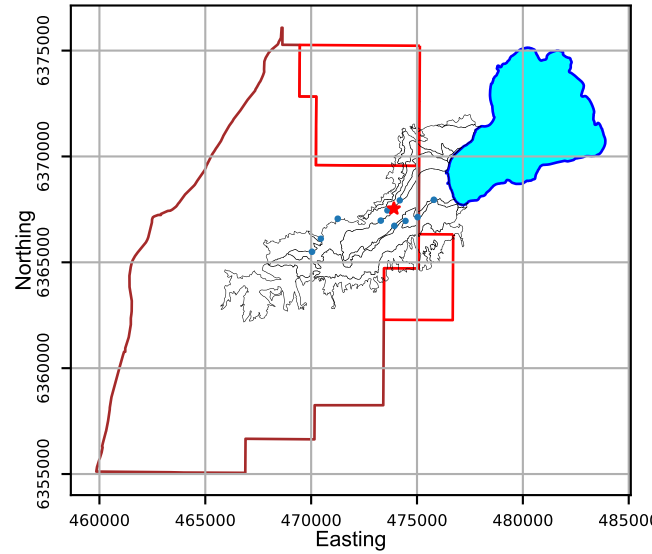
TITLE
FH20-WR657-SN1 - 13.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-29

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH20-WR657-SN1 - 7.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-30

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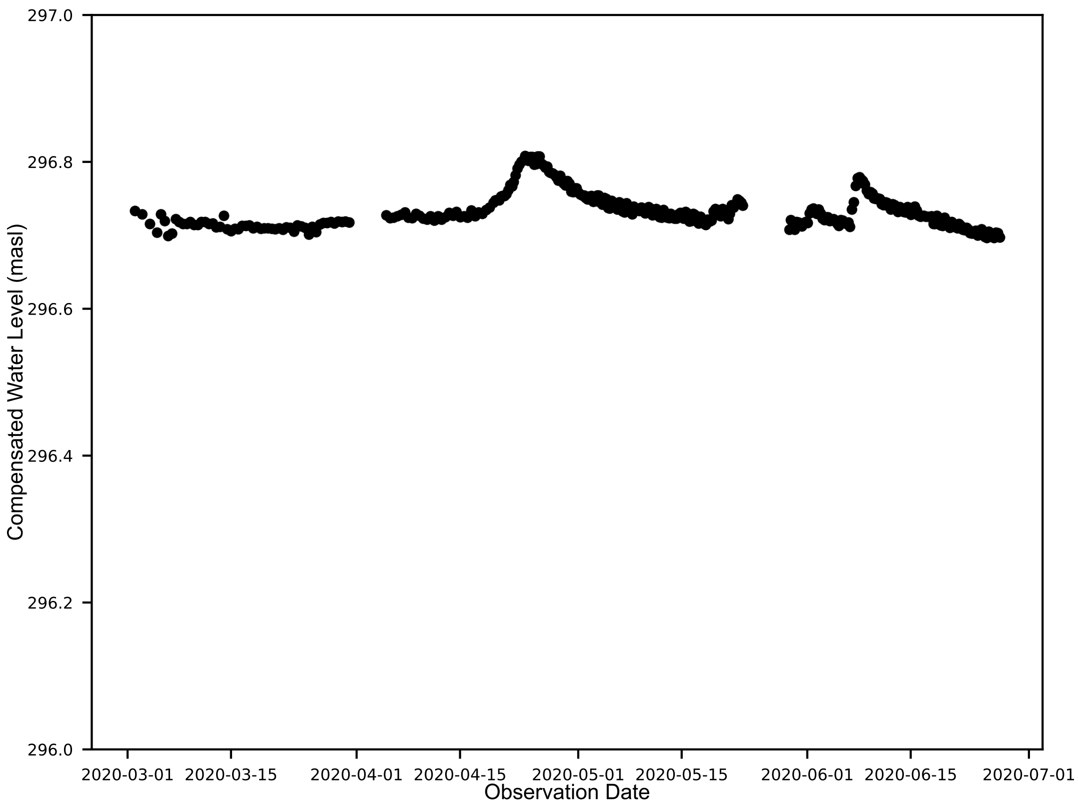

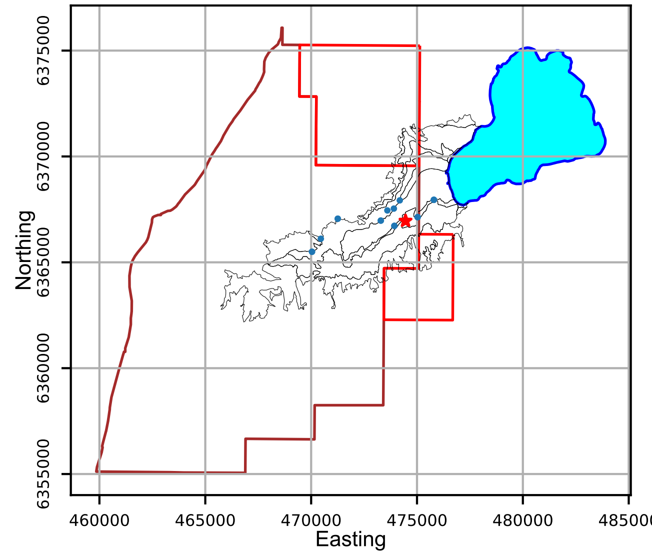

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH20-WR664-SN1 - 29.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-31

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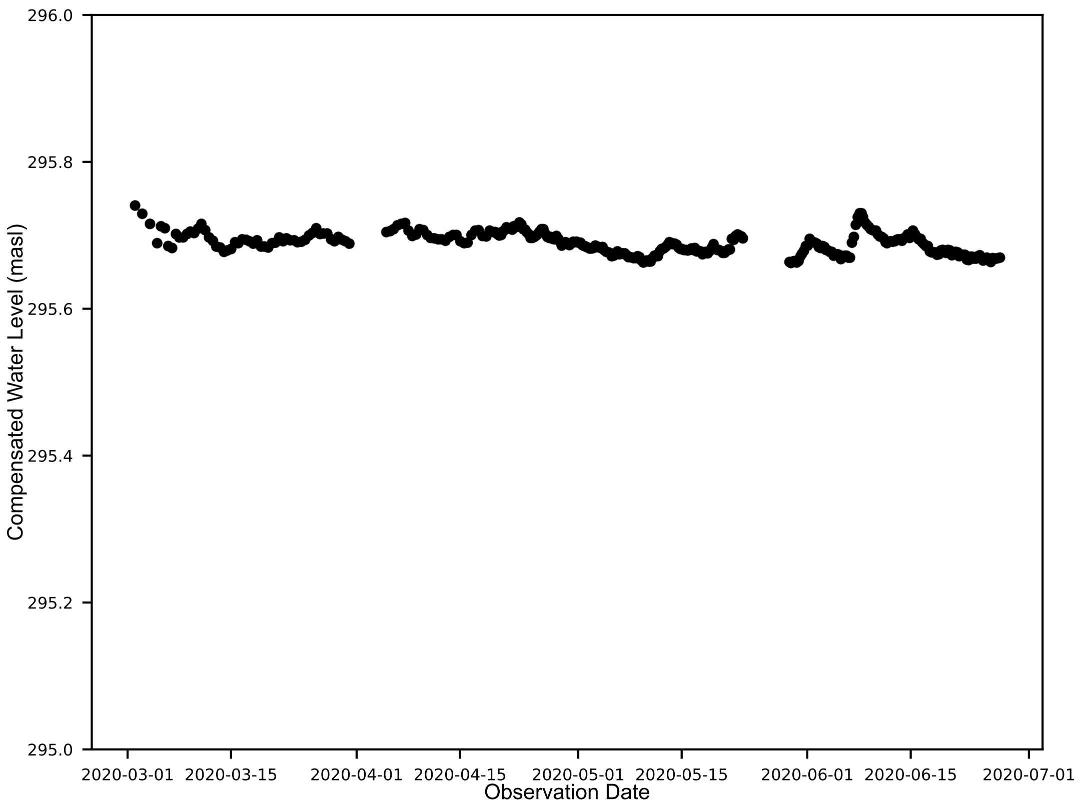

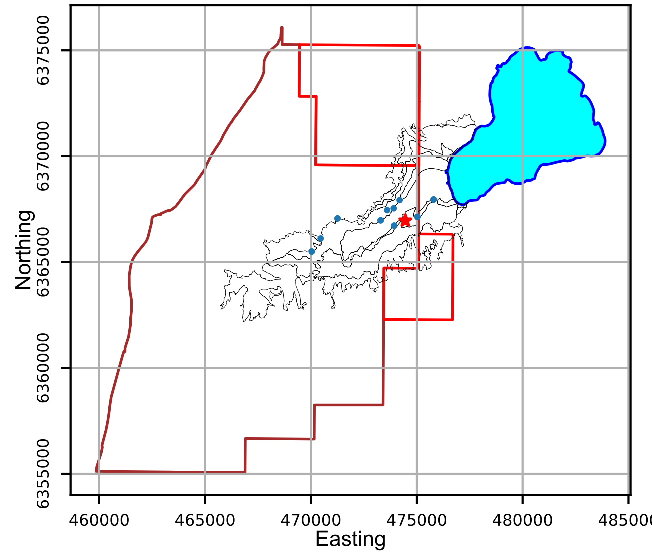

Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH20-WR664-SN1 - 8.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-32

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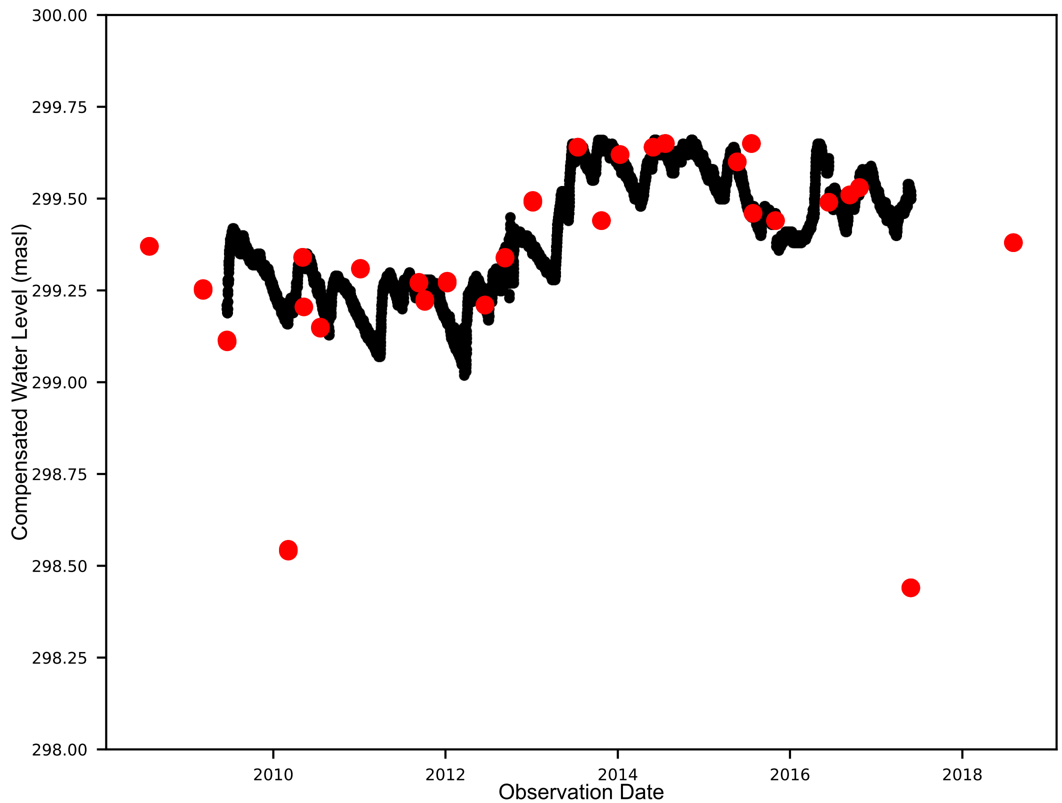

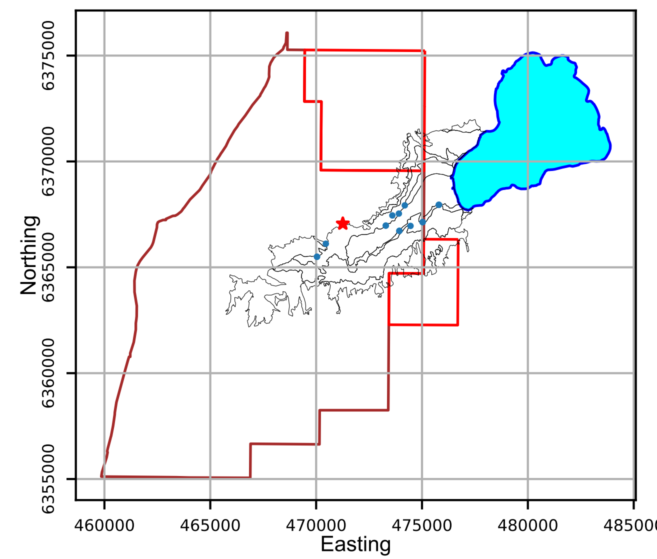

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 13.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-095A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-33

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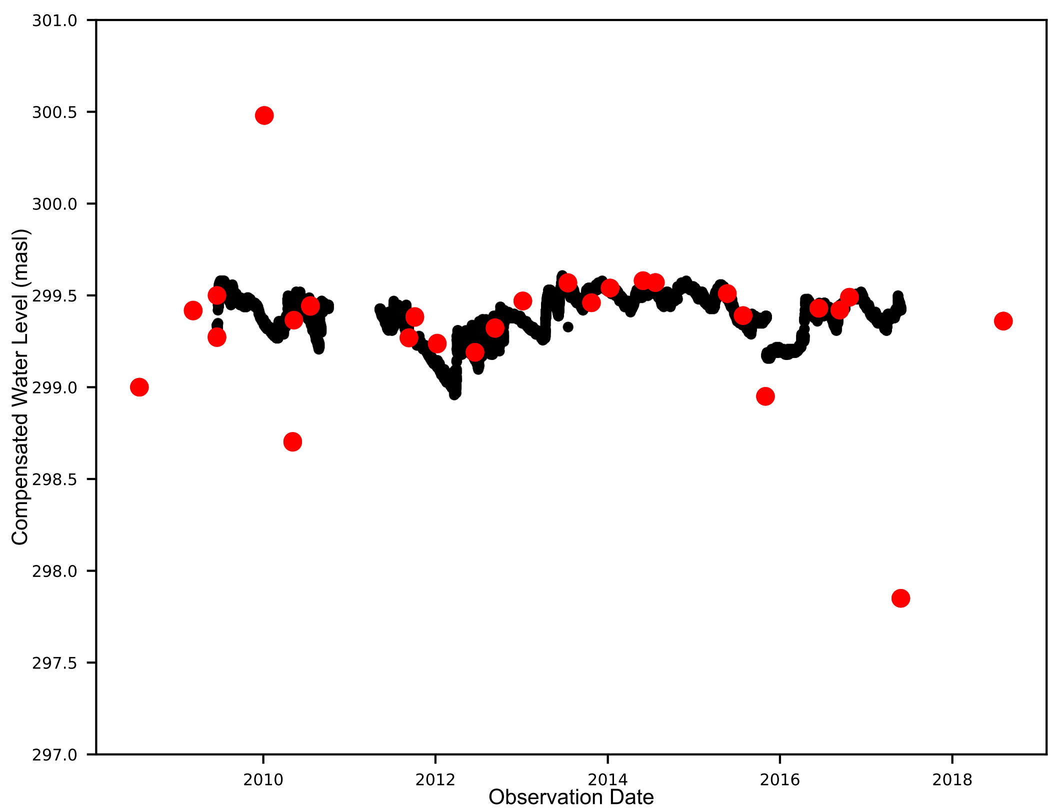

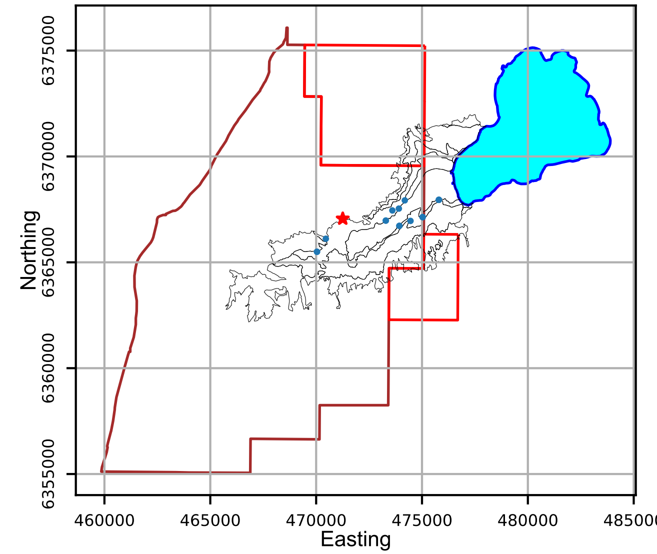

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 1.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

GT07-095B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-34

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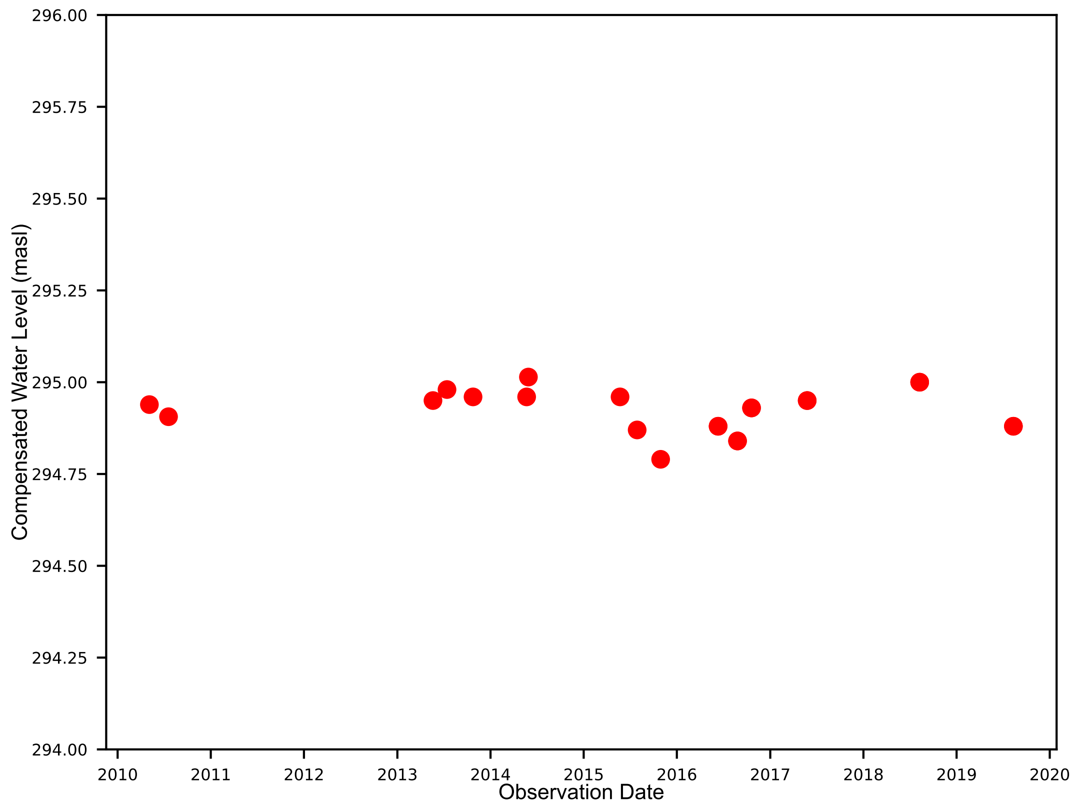

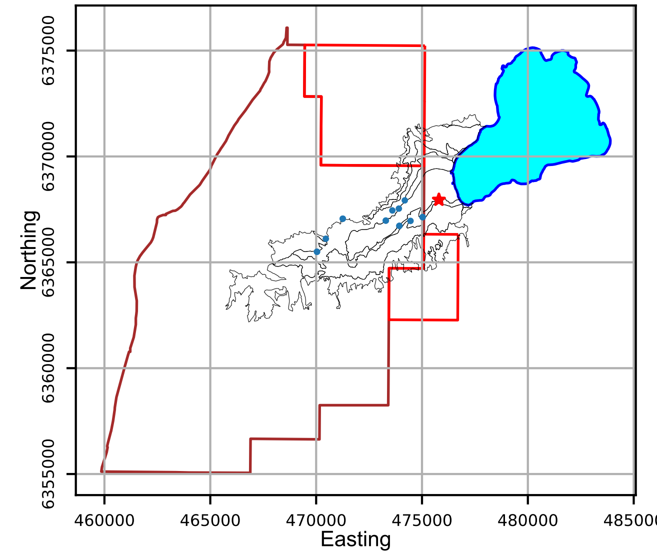

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
MW-08-308C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-35

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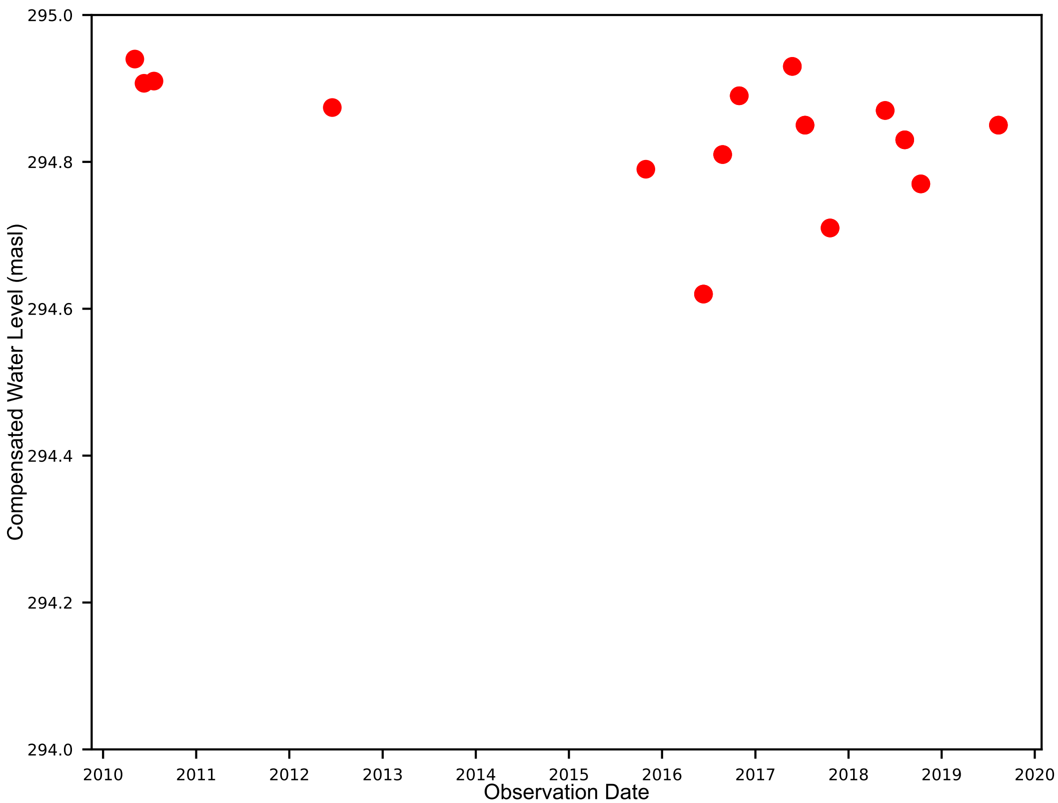

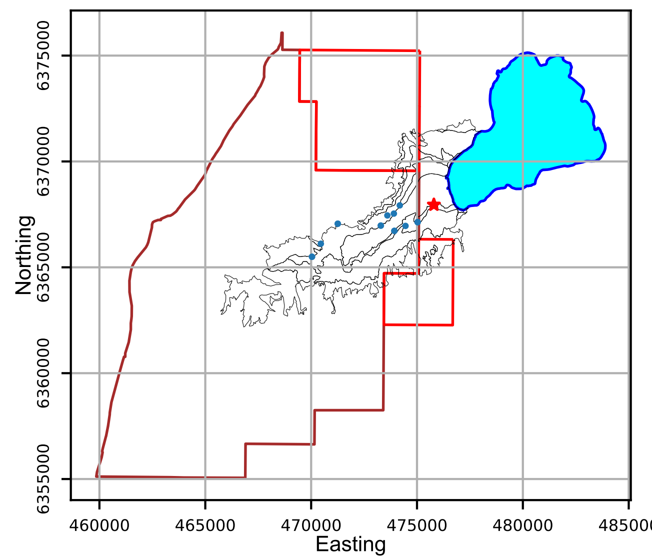

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-308A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-36

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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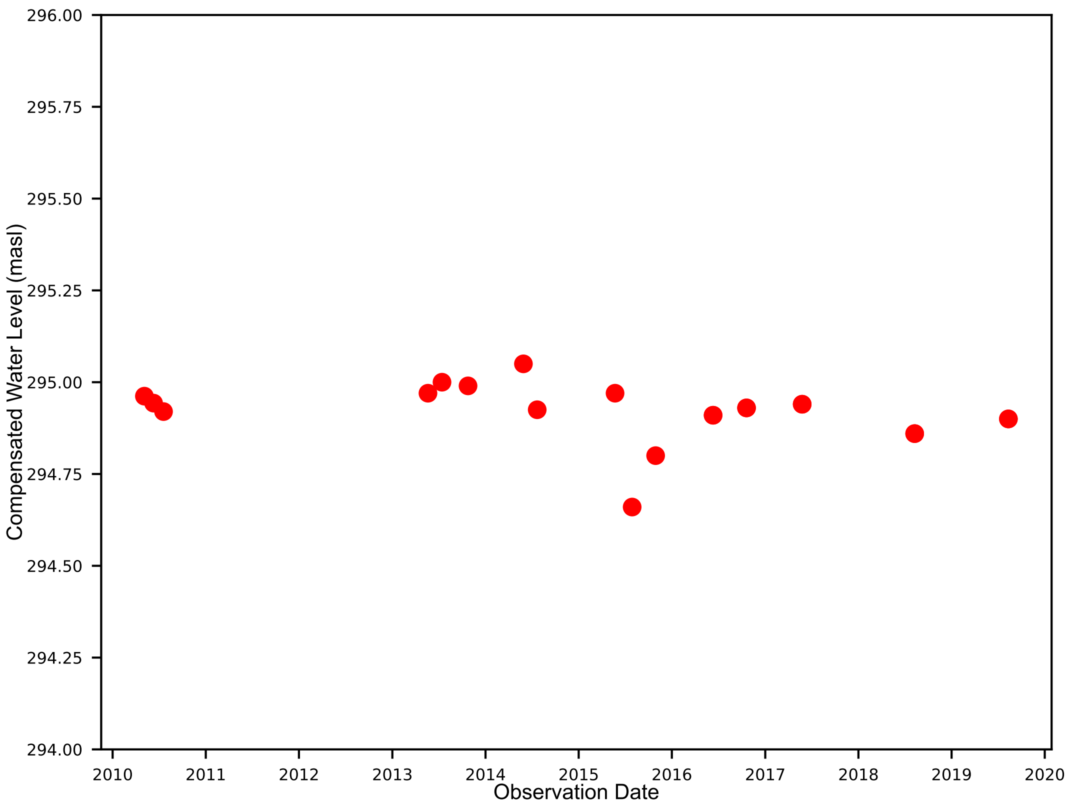

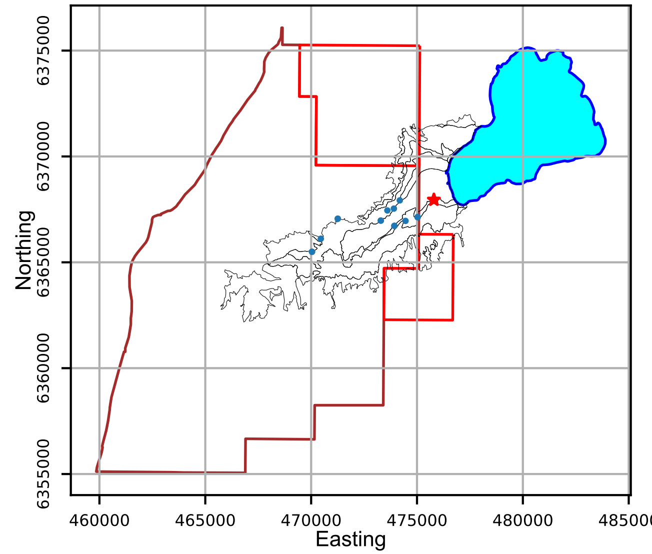

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-308B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B4-37

B5 Hydrographs for Ecohydrology Zone 5

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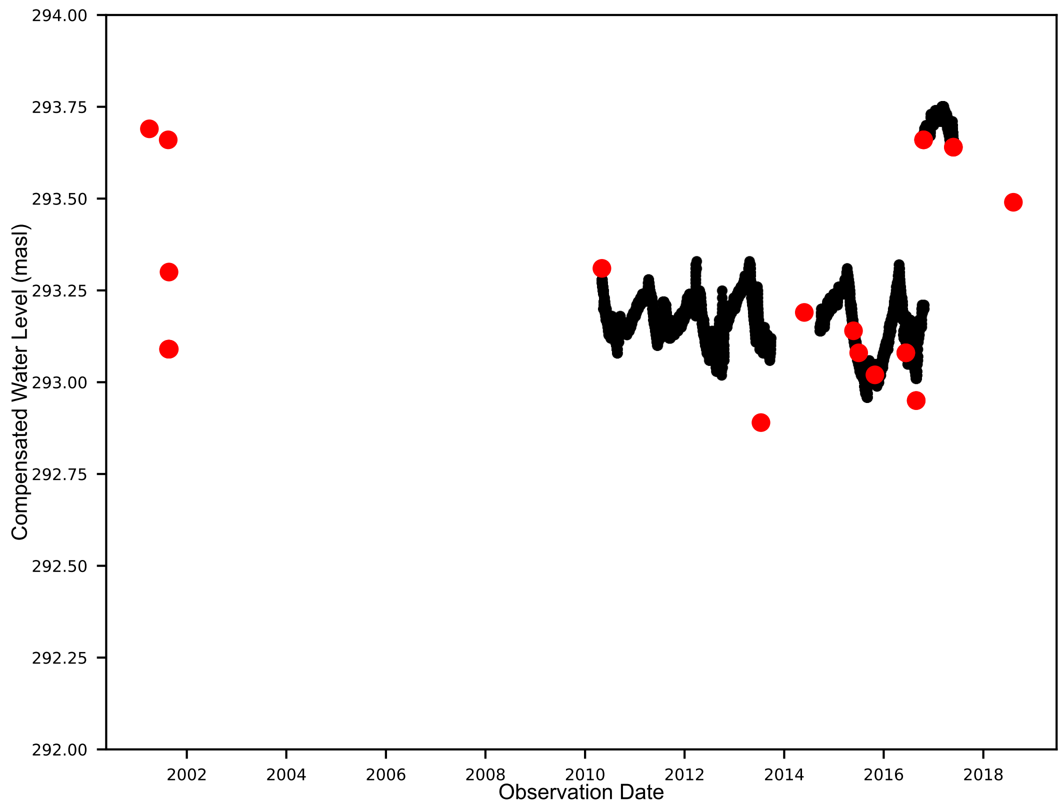

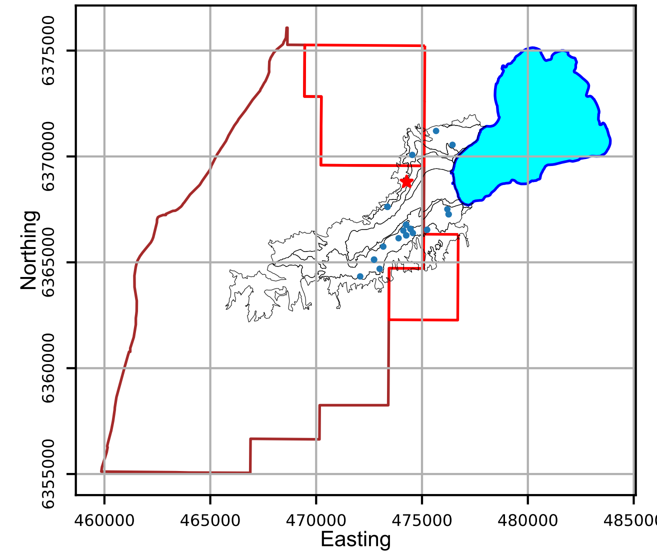

Hydrograph Legend

- Manual measurement
- Transducer measurement

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Unconfined
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

AA-11-32-097-09

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-1

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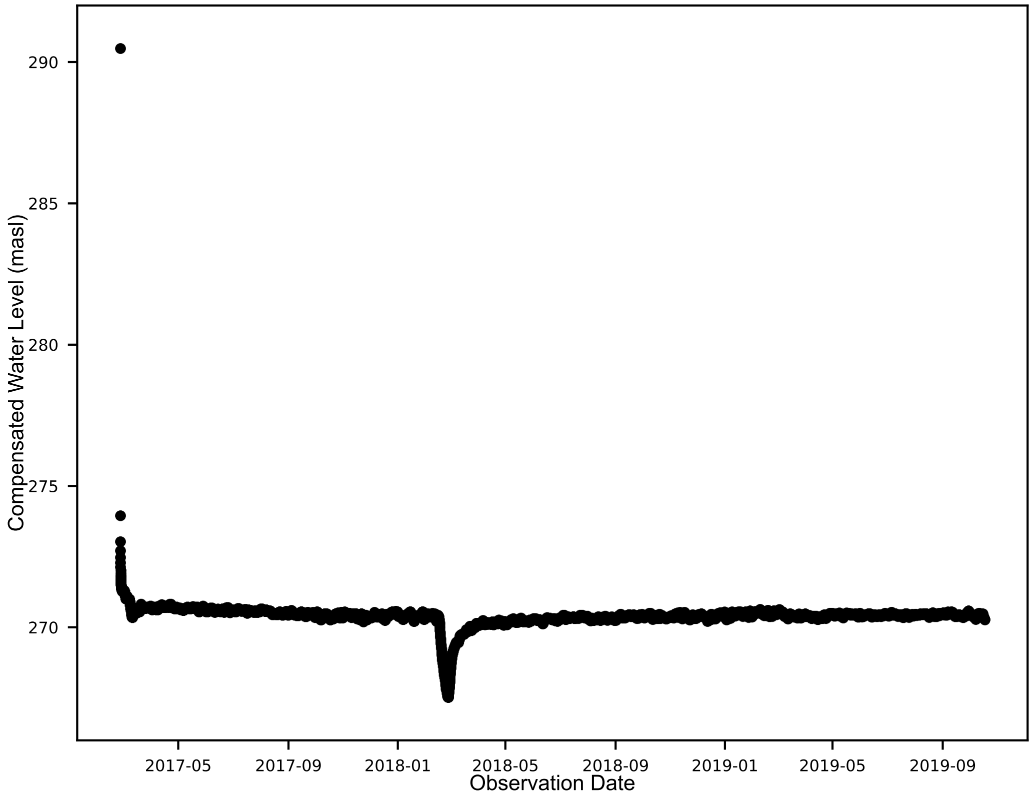

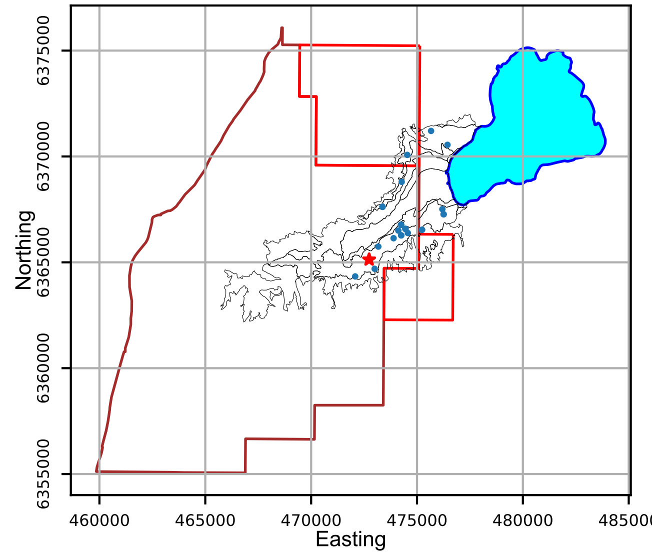

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 102 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR402-MR1 - 102.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-2

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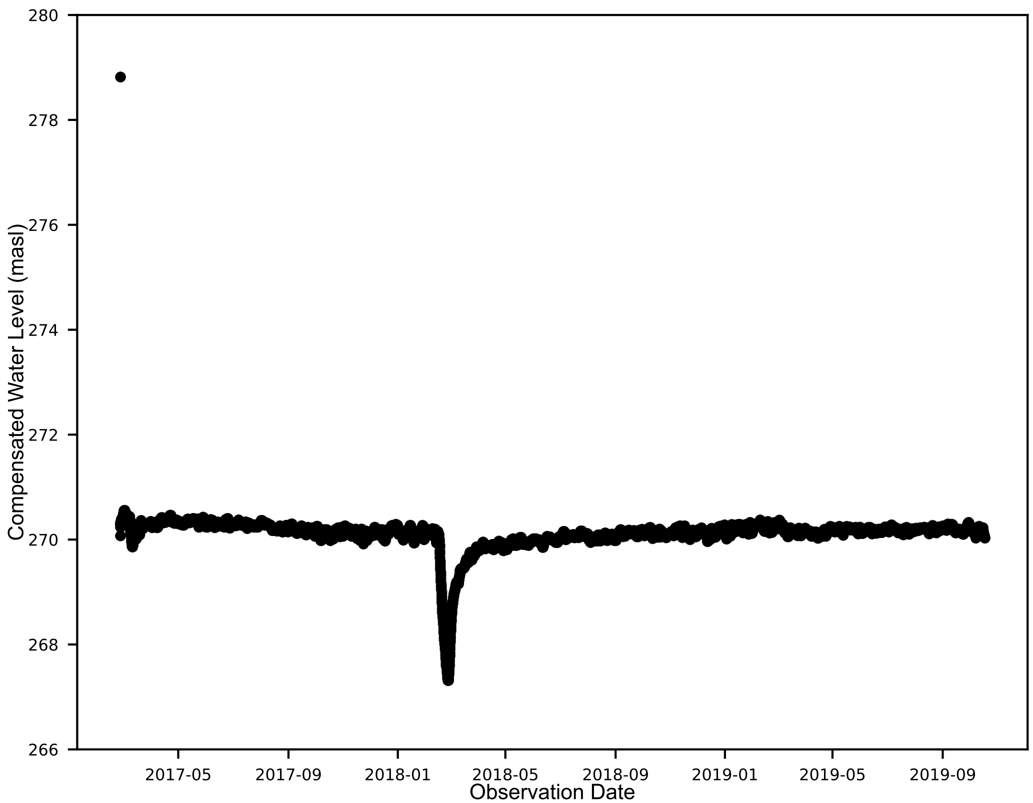
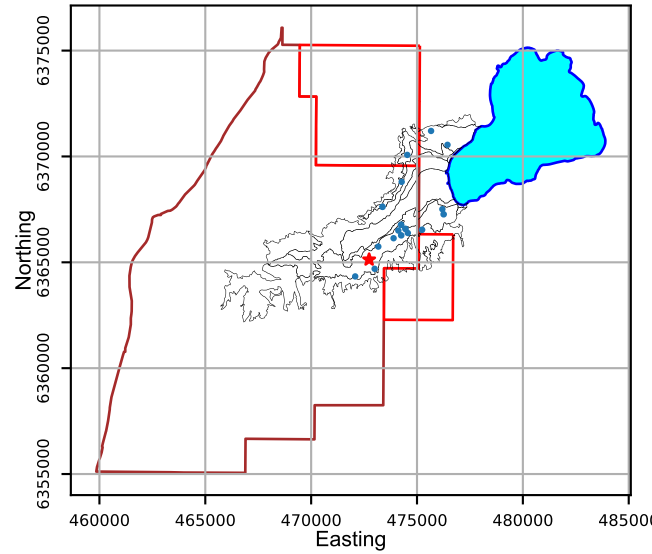




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 117 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

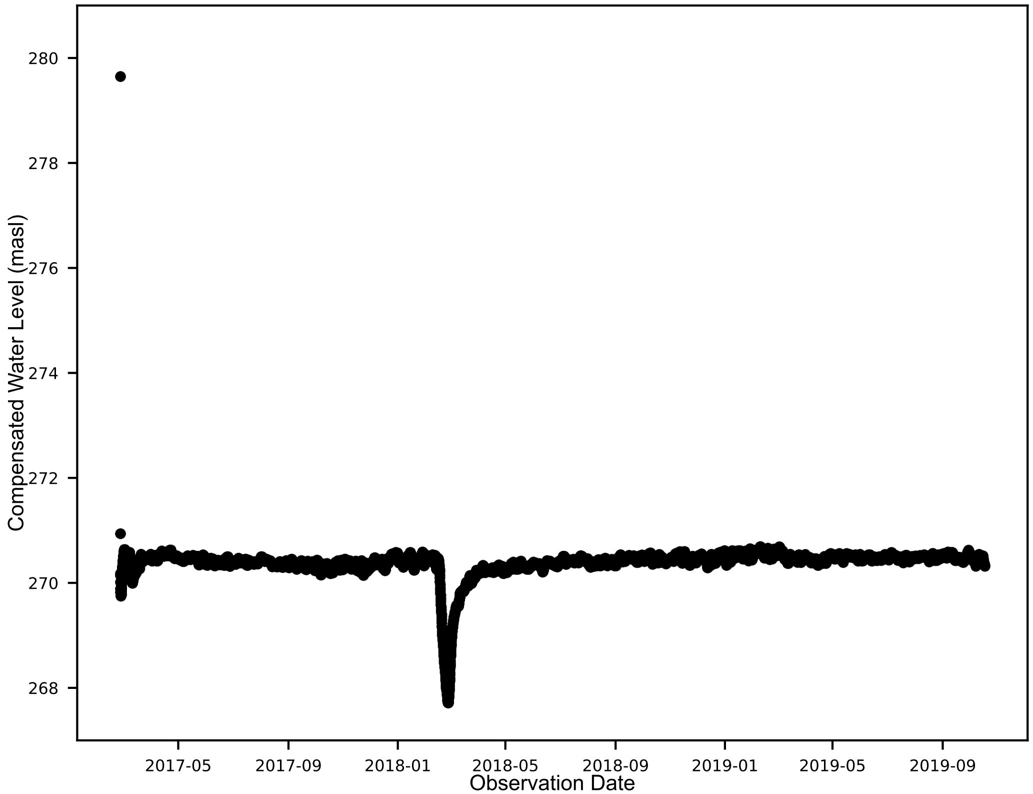
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

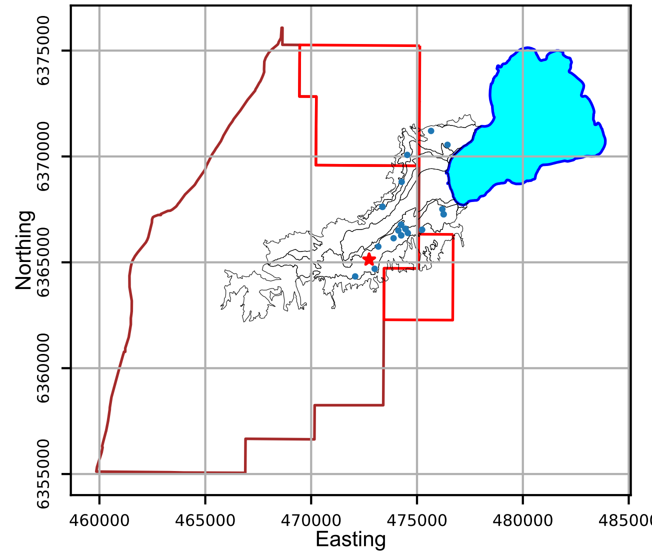
TITLE

FH17-WR402-MR1 - 117.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-3

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 128 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR402-MR1 - 128.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-4

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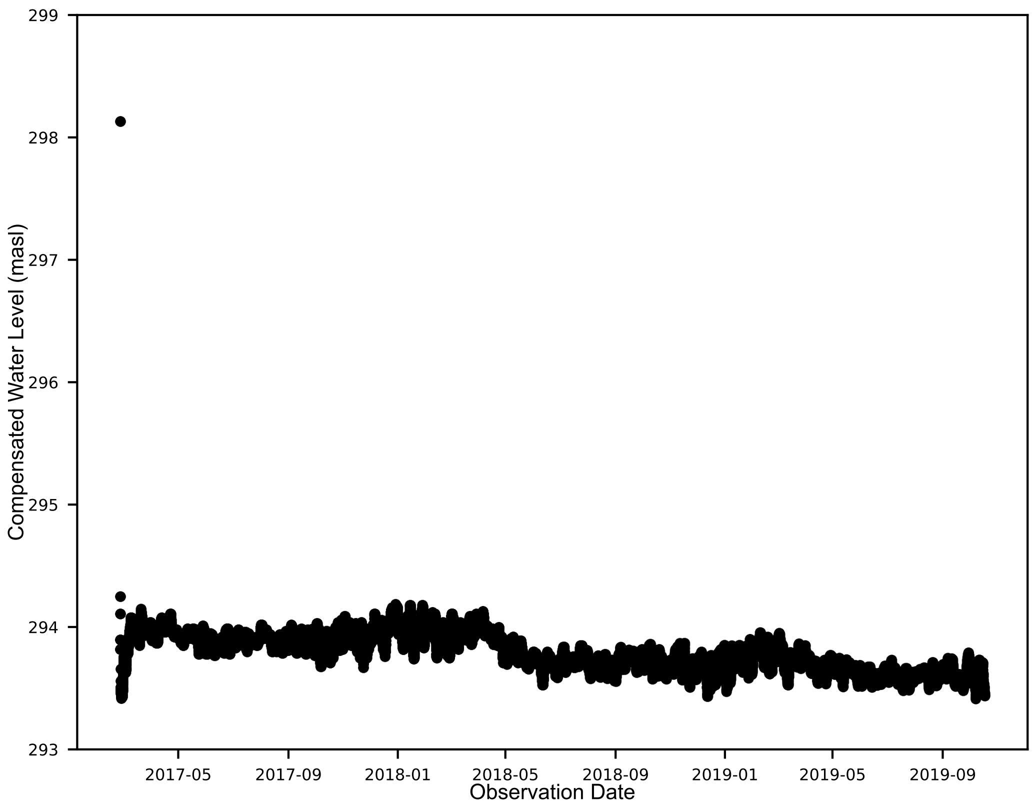
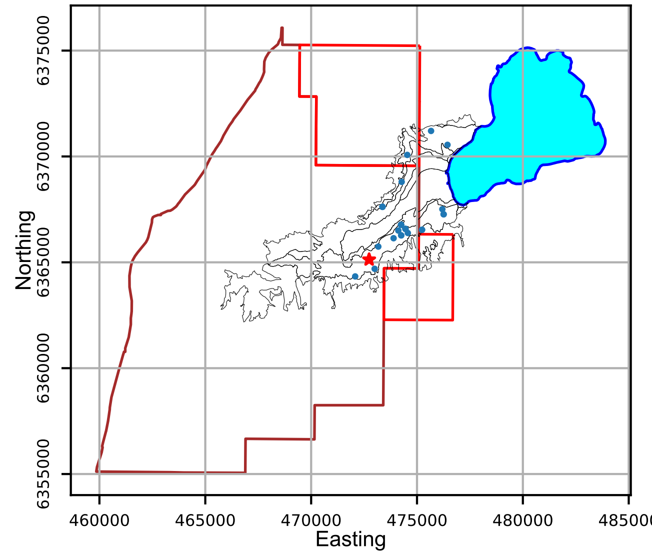




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 81 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

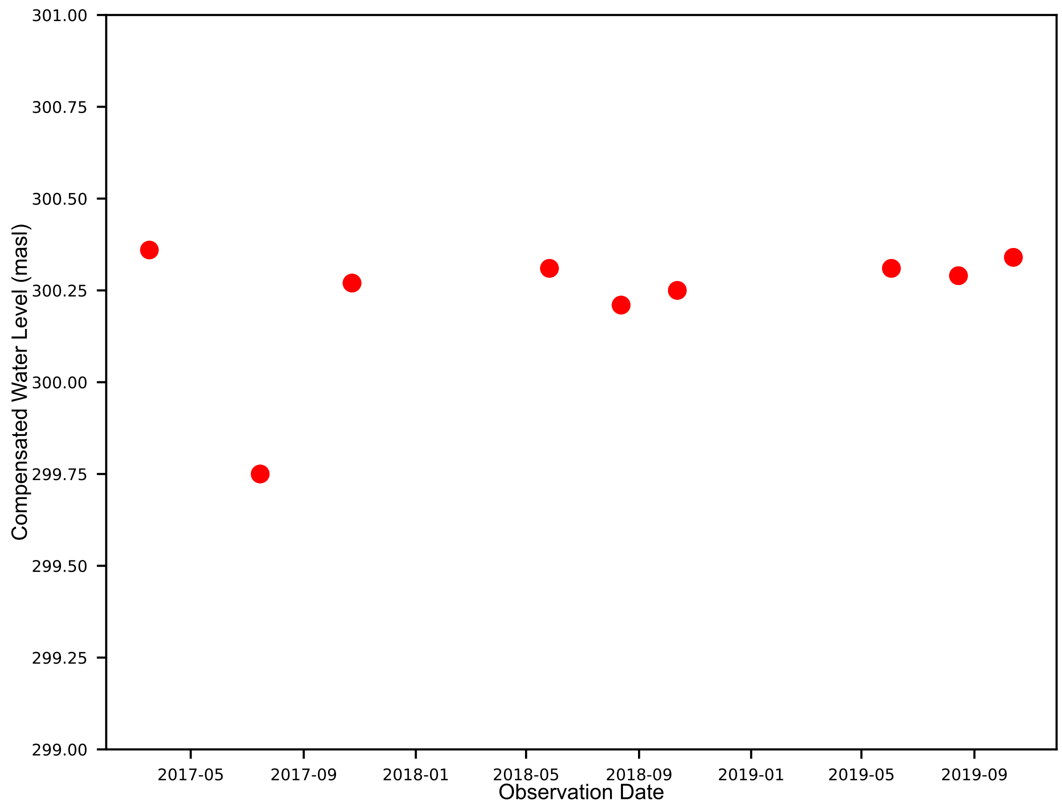
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

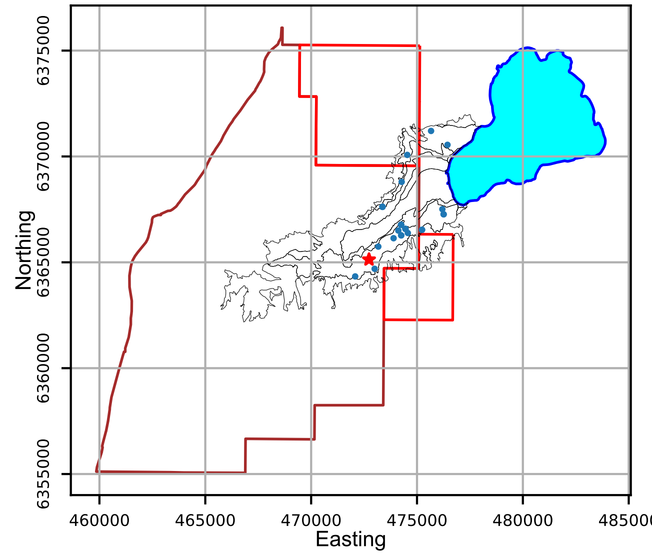
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR402-MR1 - 81.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-5

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.93 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

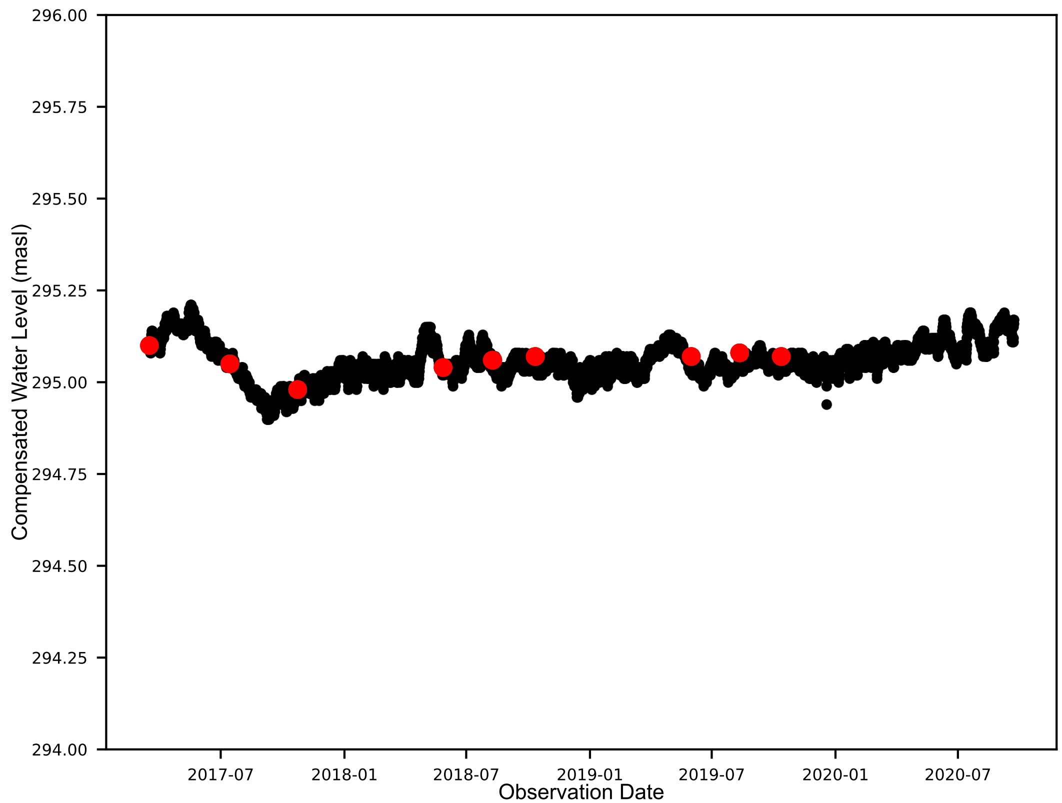
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

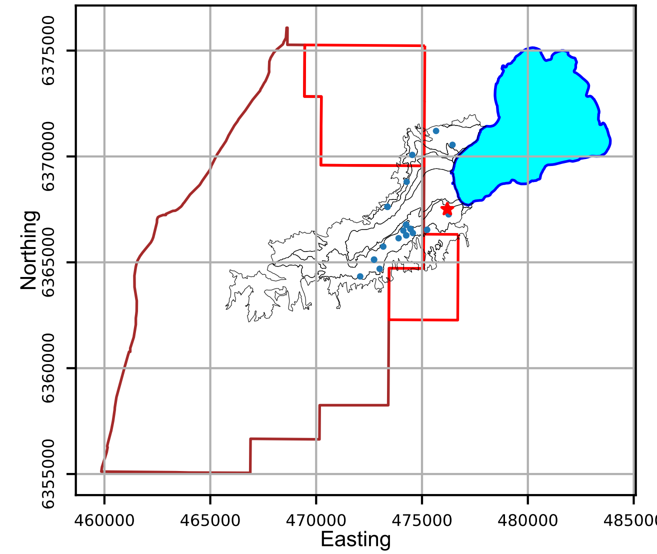
FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR402-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-6

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

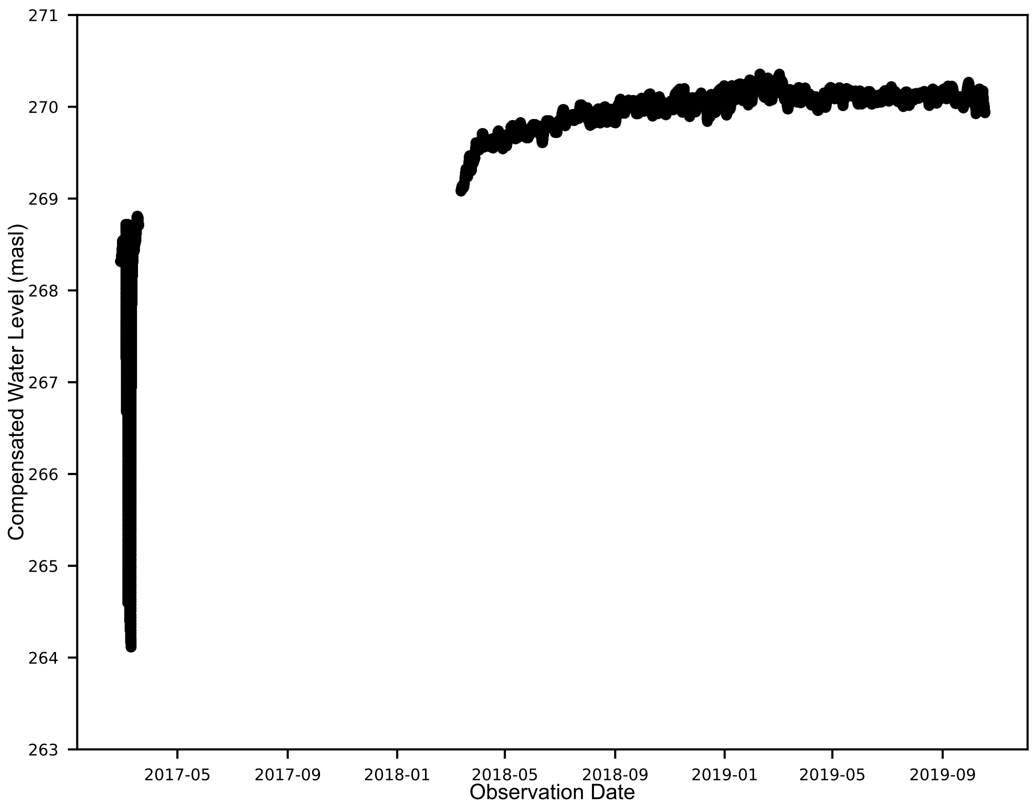
CLIENT
FORT HILLS ENERGY CORPORATION

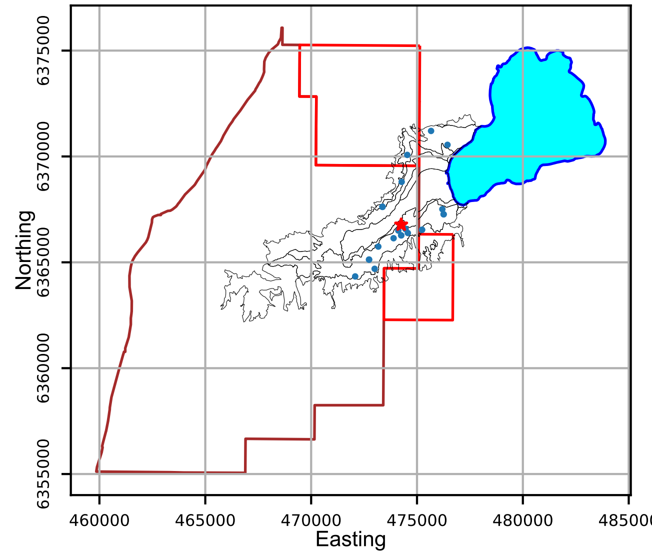
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR420-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-7





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 100 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

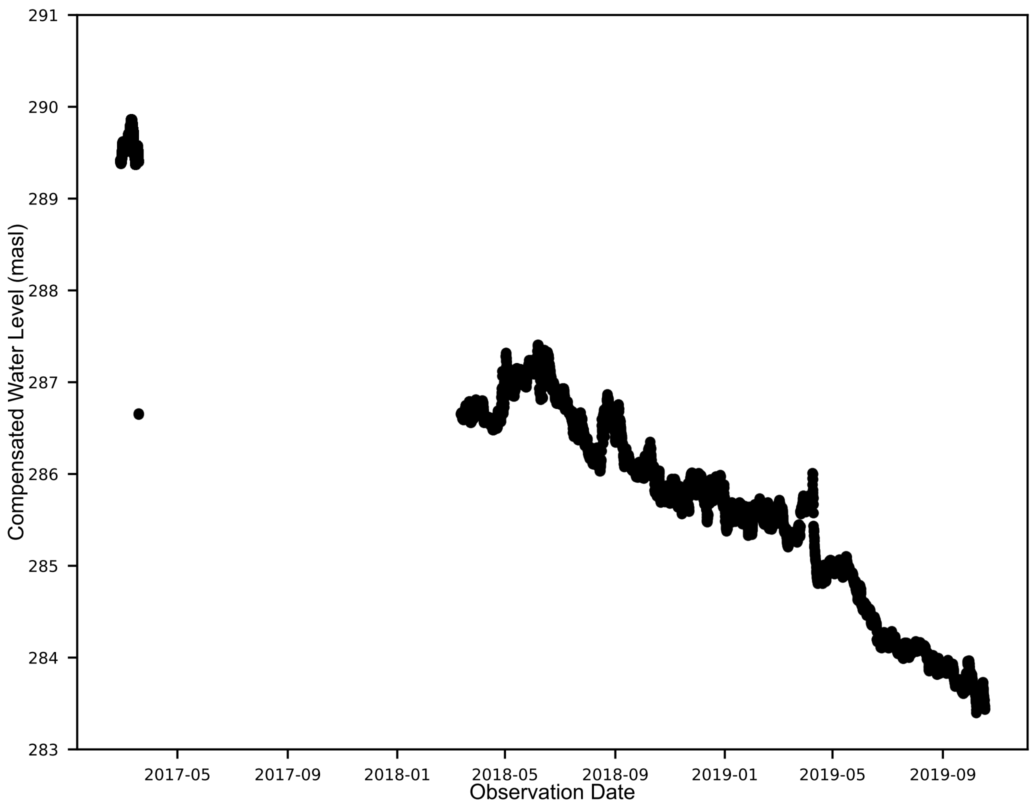
FORTHILLS
Operated by Suncor Energy

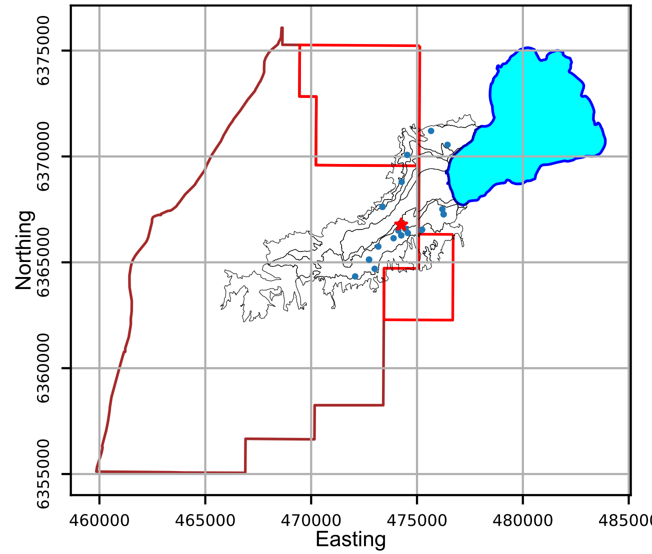
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-MR1 - 100.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-8

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 60 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

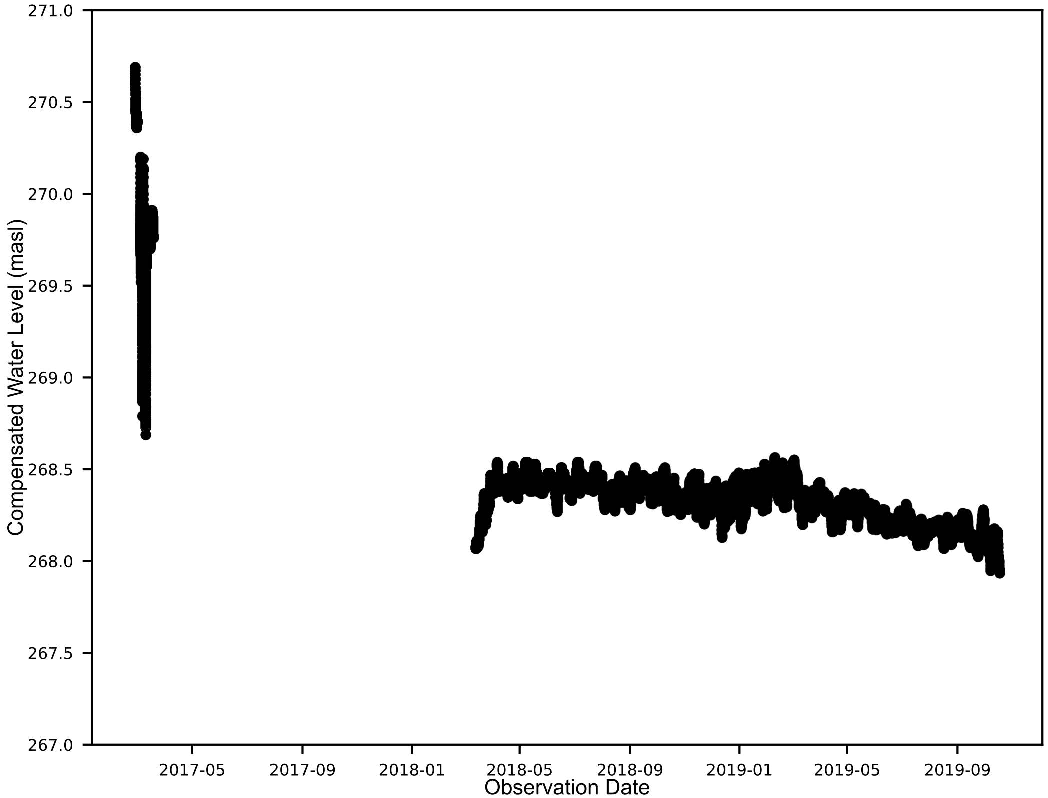
PROJECT

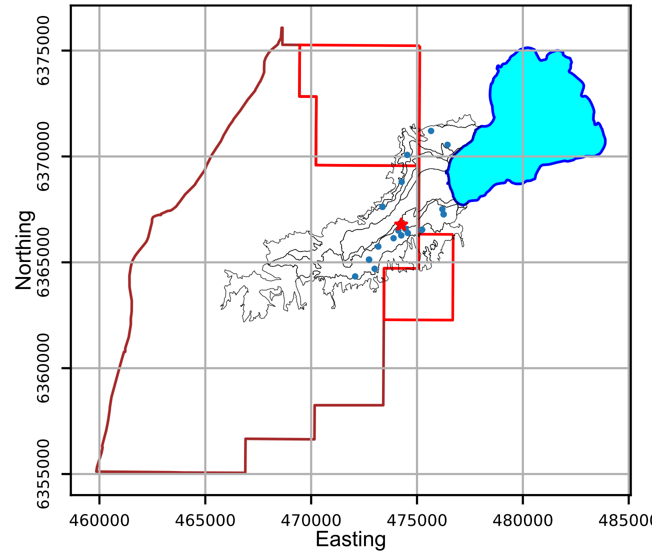
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR421-MR1 - 60.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-9





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 73 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-MR1 - 73.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-10

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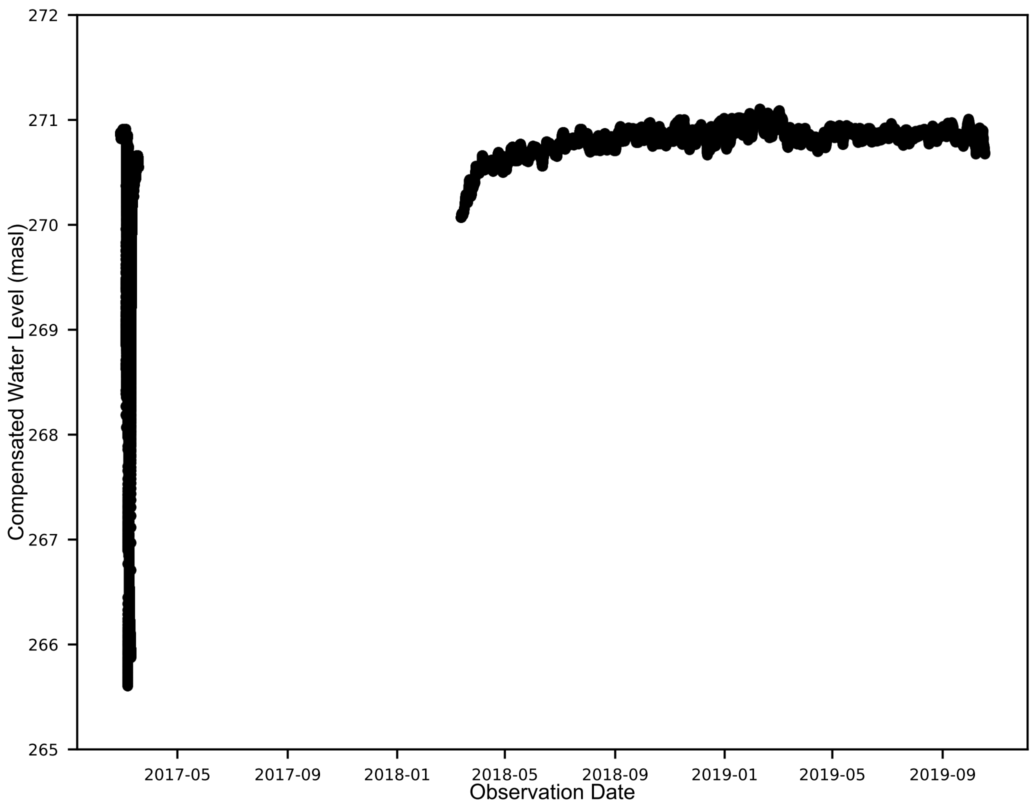
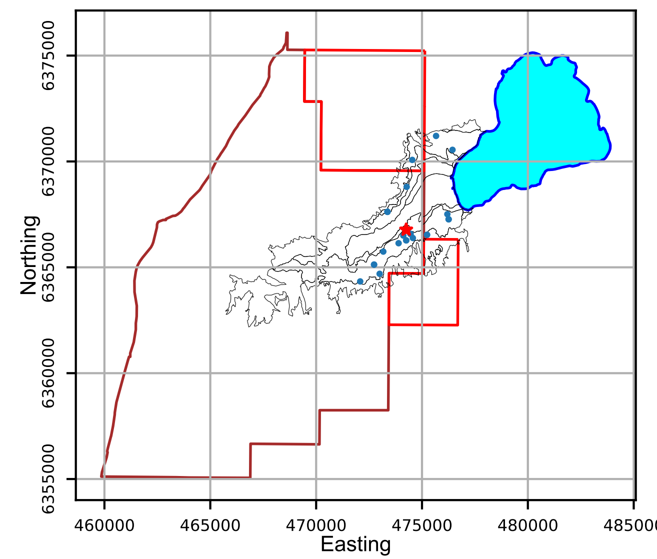




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 93 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

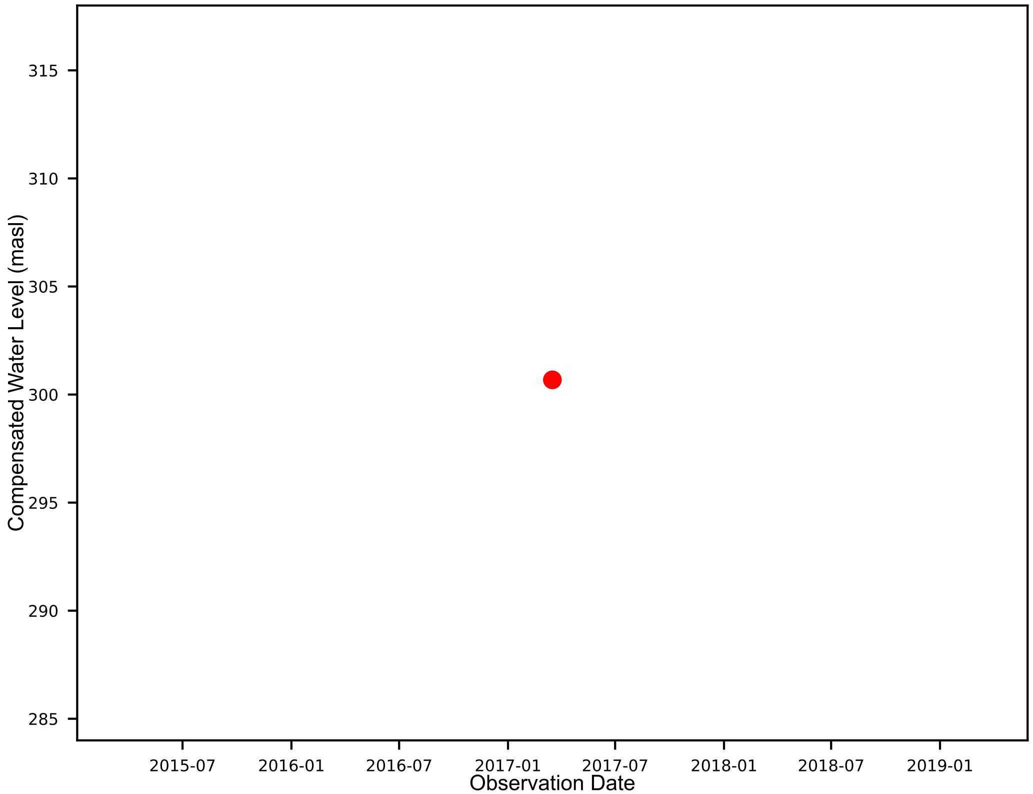
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

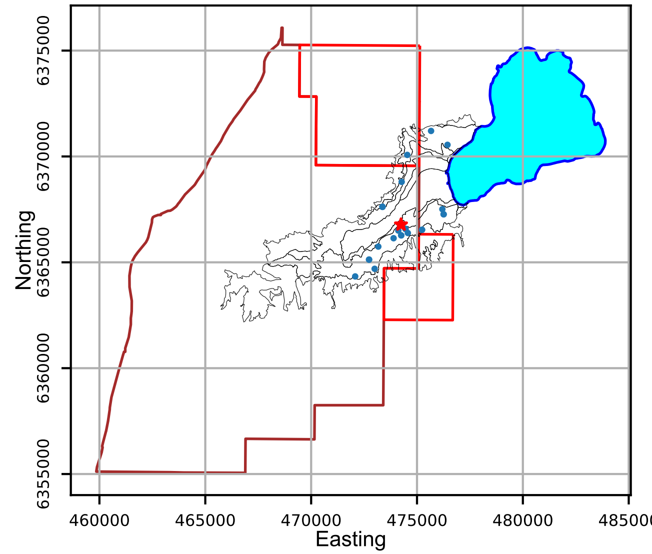
TITLE

FH17-WR421-MR1 - 93.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-11

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 93.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR421-MR2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-12

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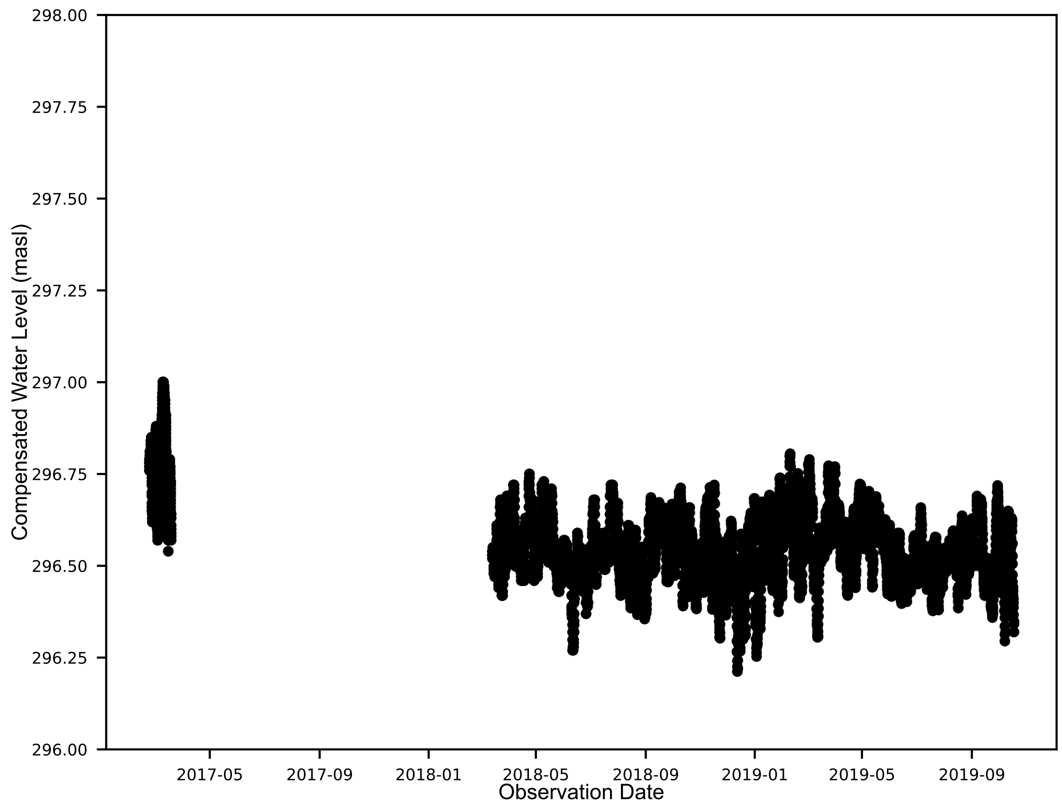
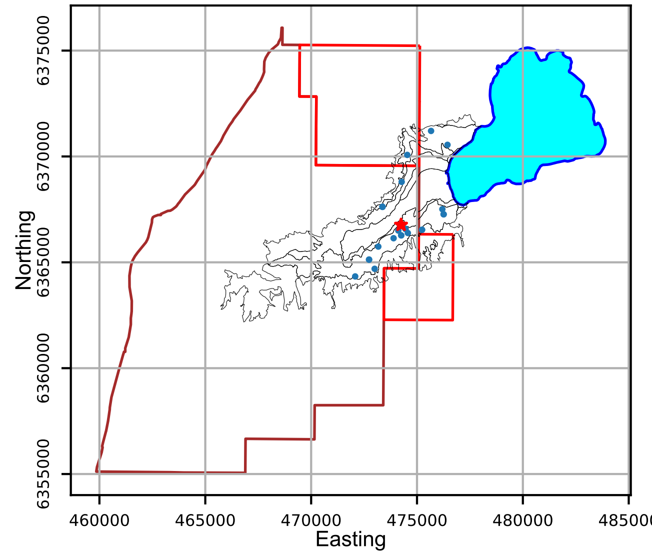




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

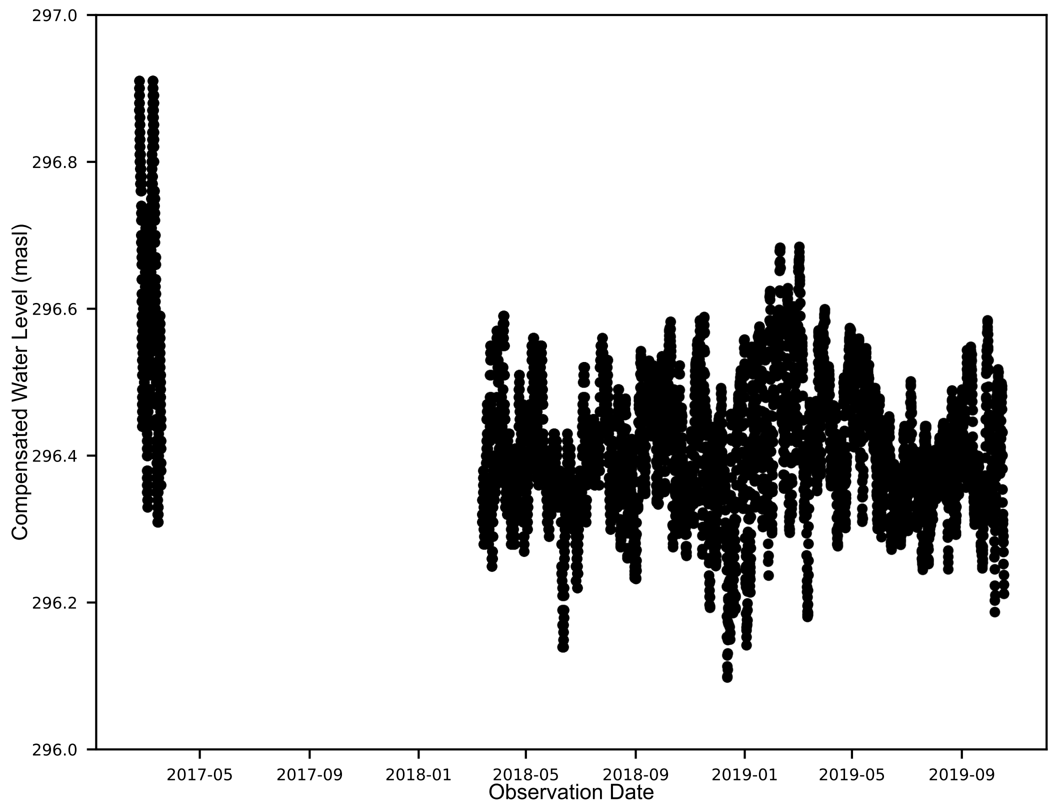
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

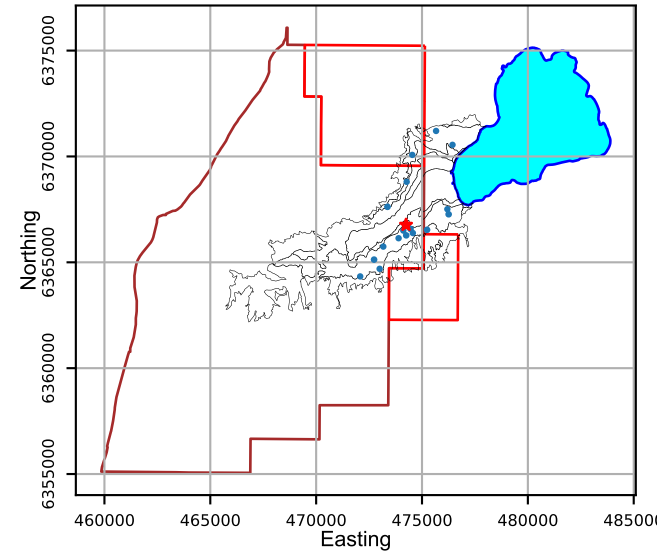
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-SN1 - 10.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-13





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 16 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-SN1 - 16.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-14

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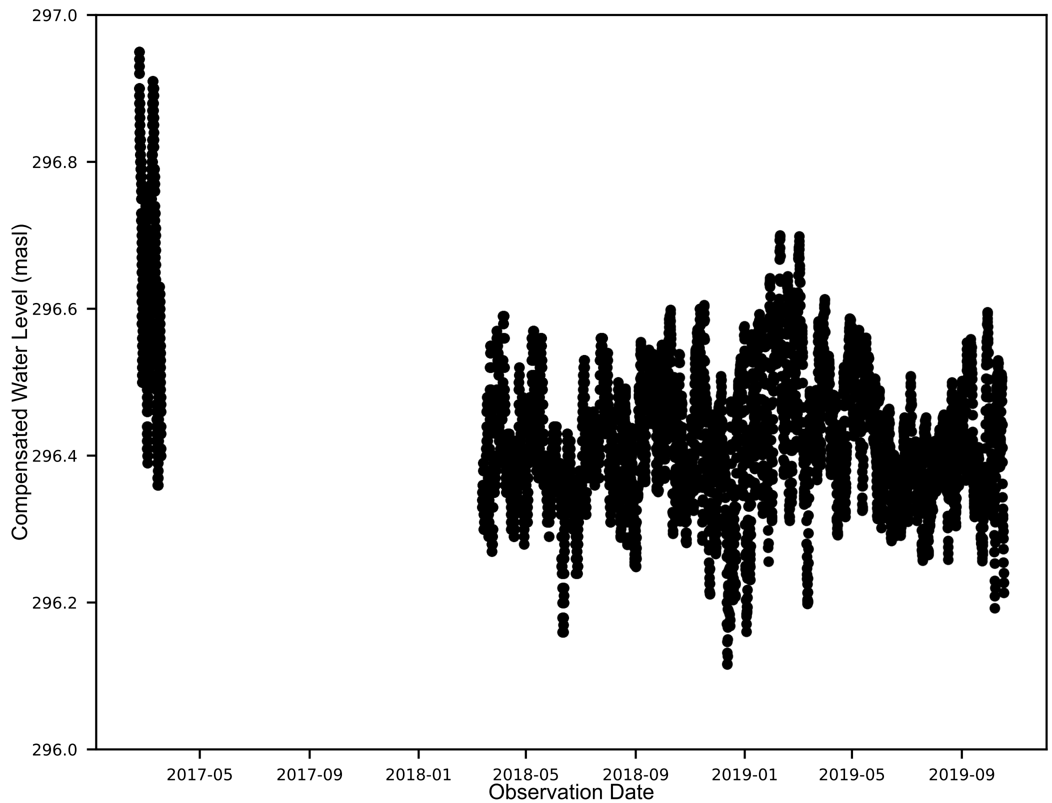

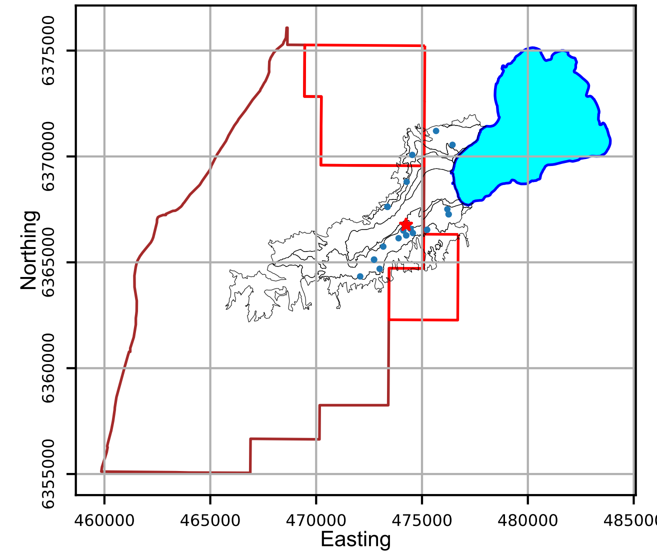

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 19 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-SN1 - 19.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-15

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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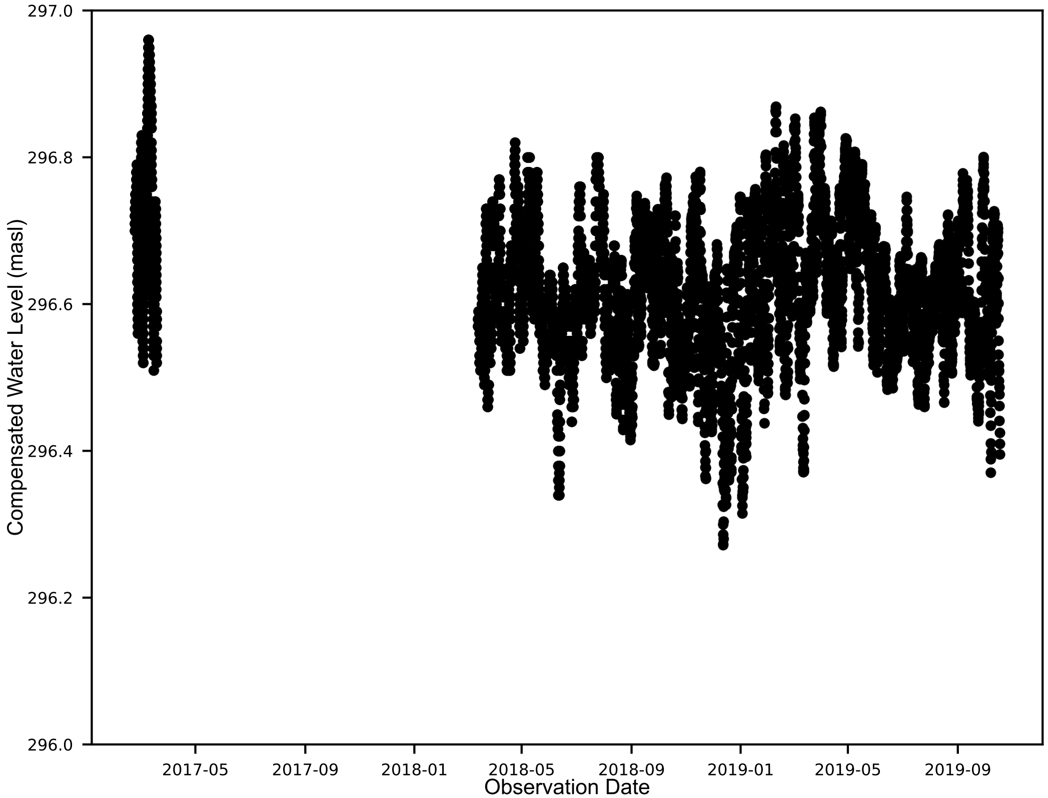

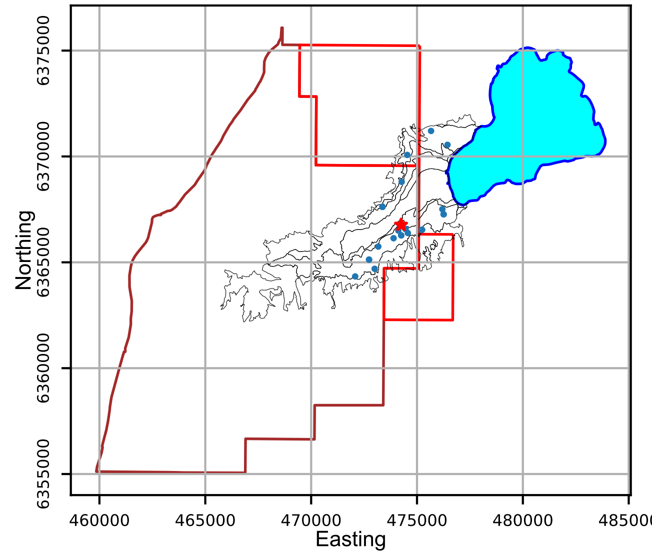

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR421-SN1 - 6.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-16

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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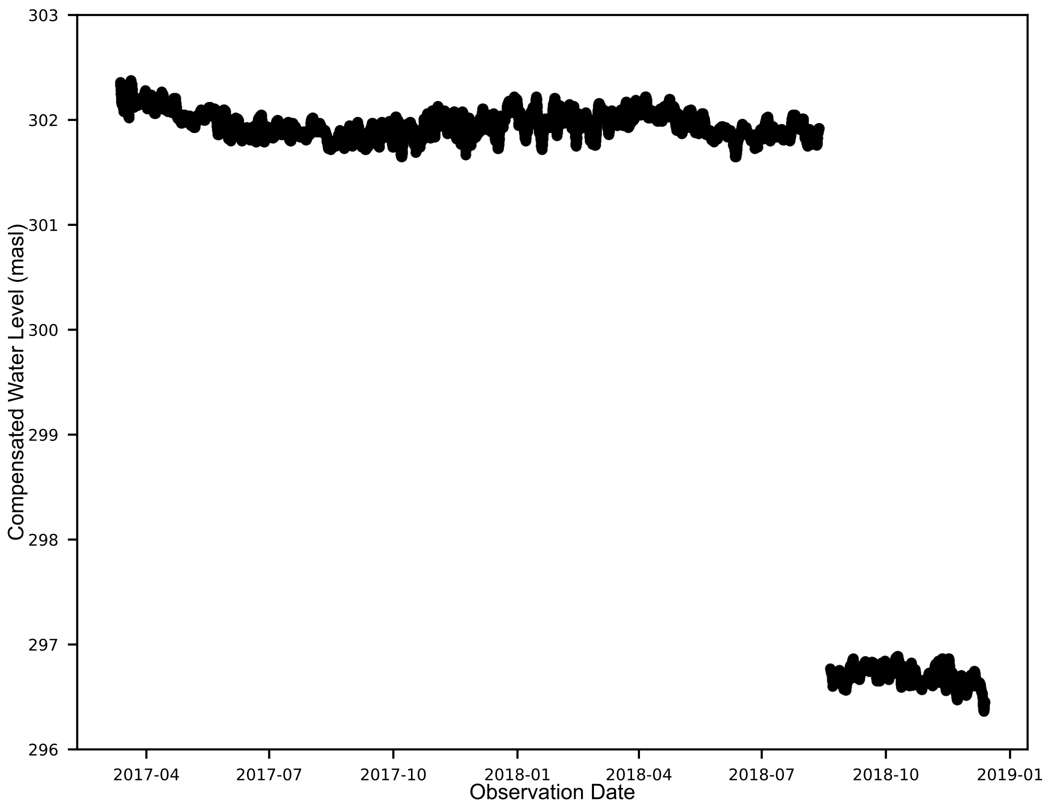
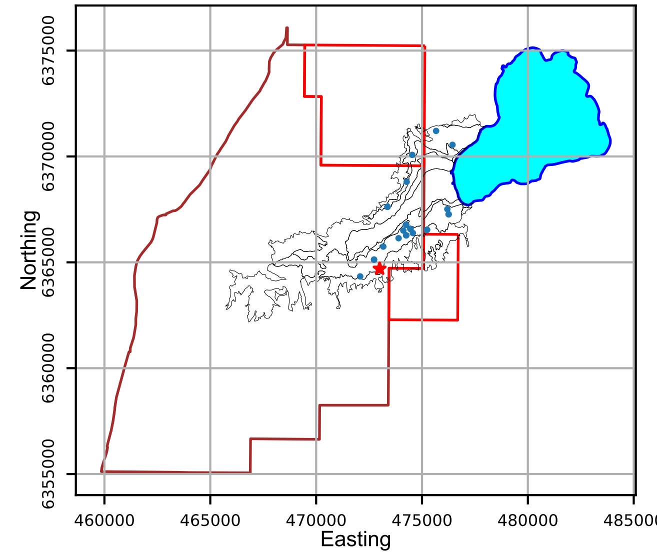




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 19 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

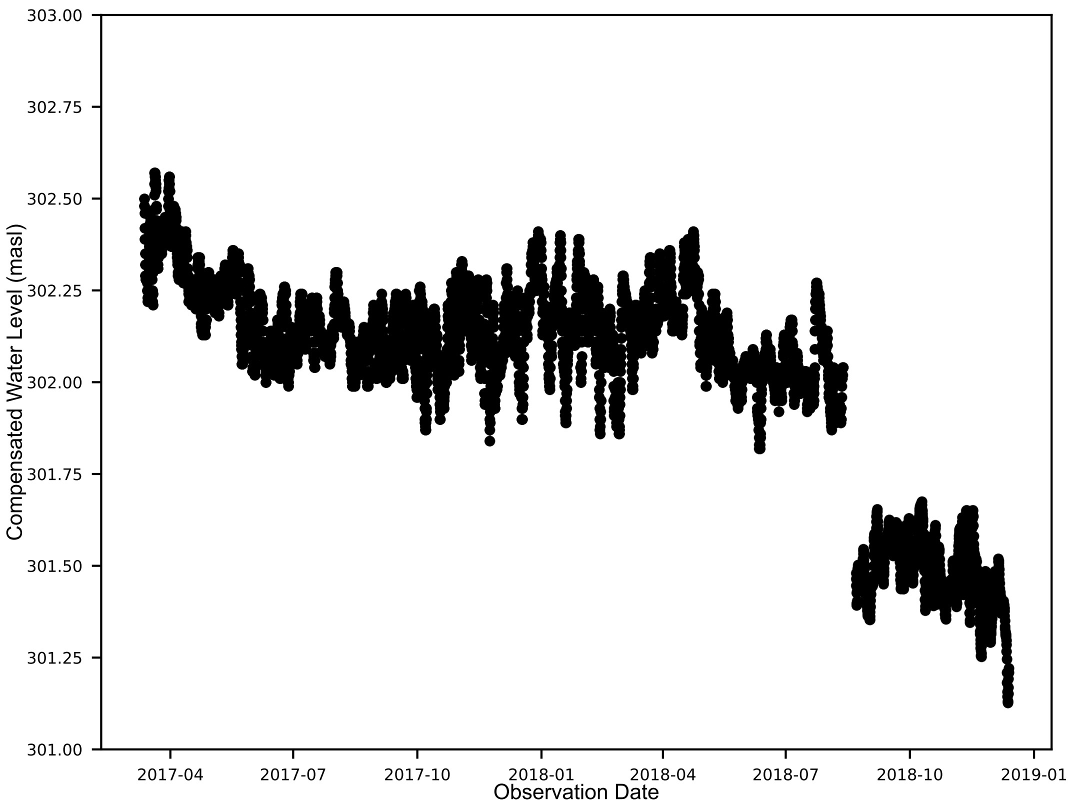
FORTHILLS
Operated by Suncor Energy

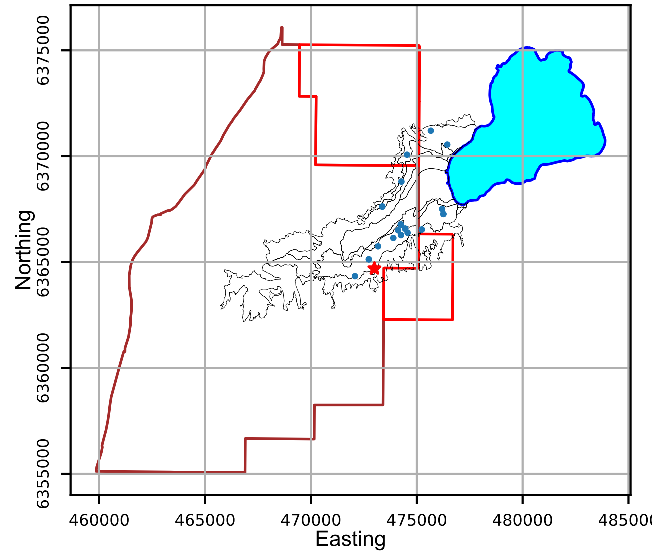
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR422-SN1 - 19.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B5-17

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 2.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

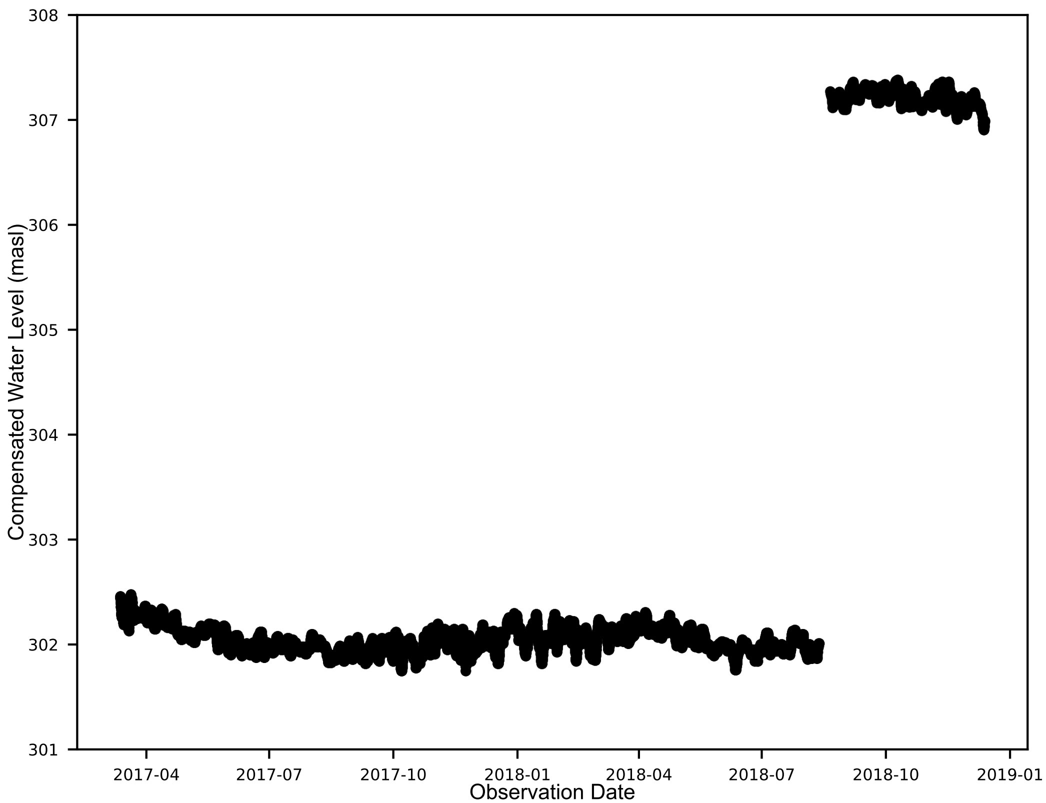
FORTHILLS
Operated by Suncor Energy

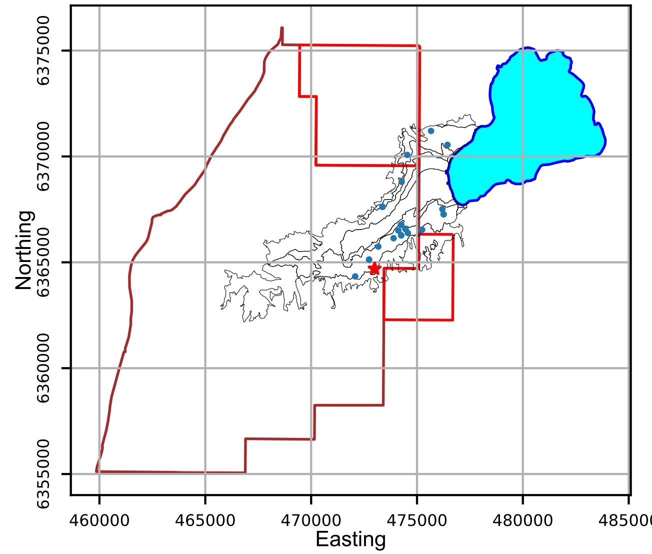
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR422-SN1 - 2.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-18

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 27.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR422-SN1 - 27.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-19

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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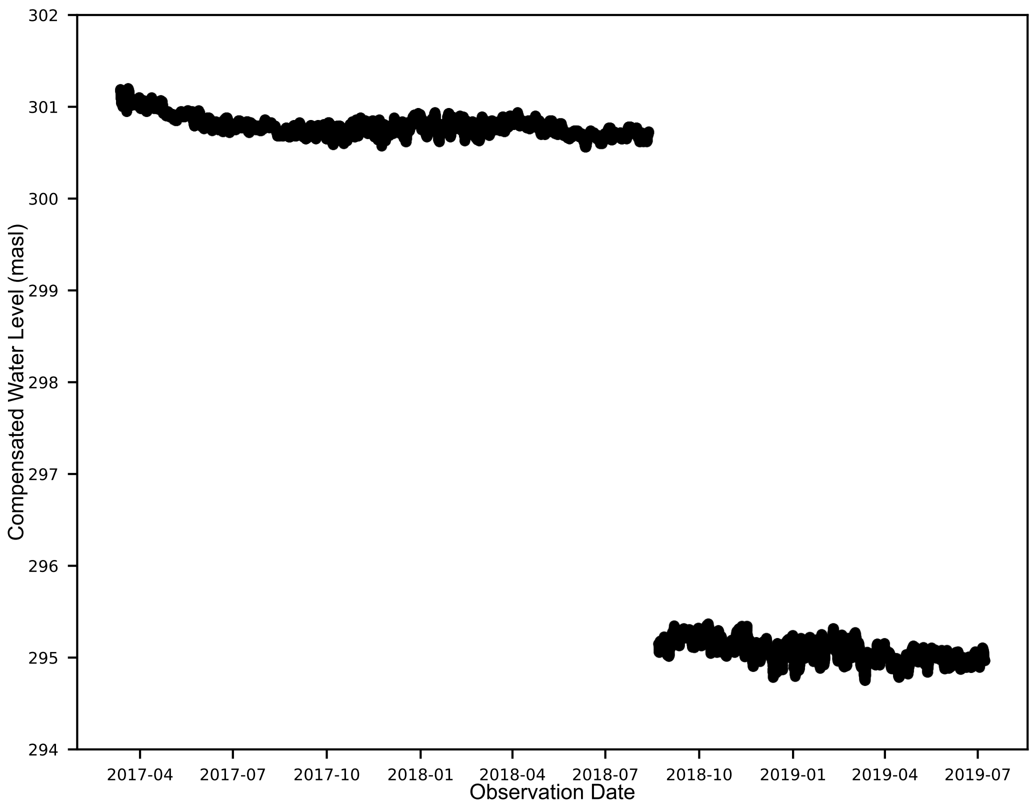

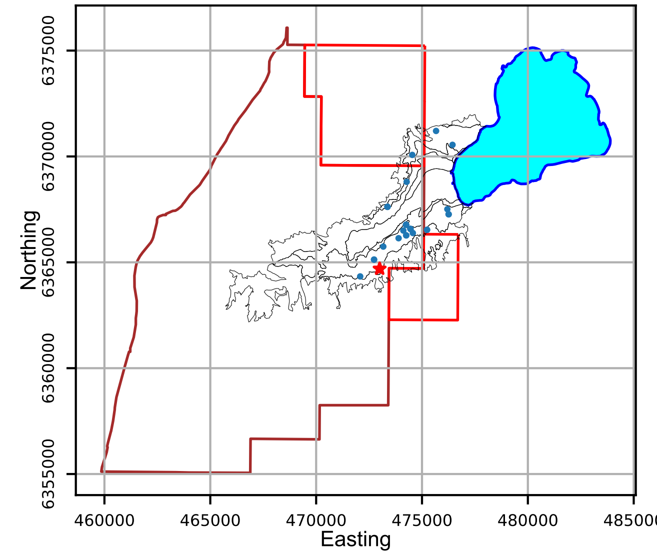

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 37.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR422-SN1 - 37.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-20

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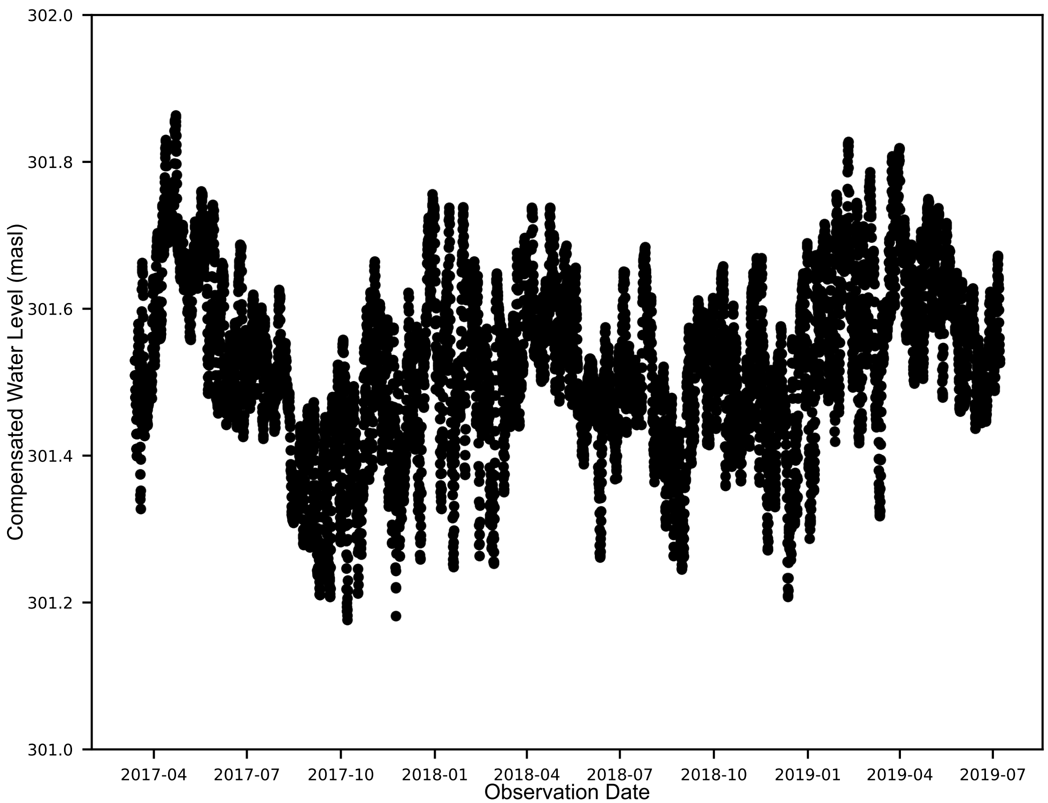

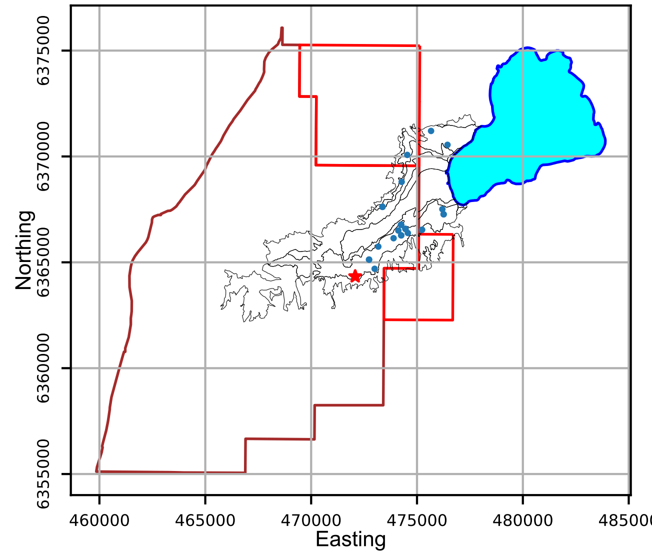

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 16.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR423-SN1 - 16.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-21

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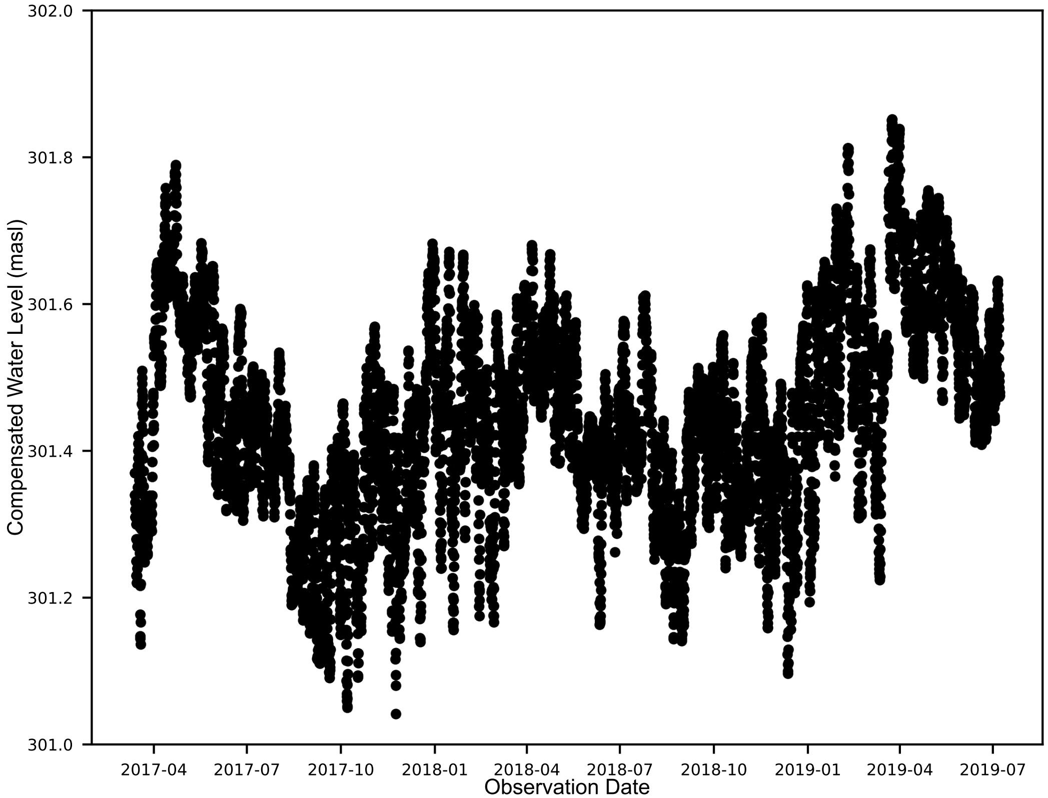

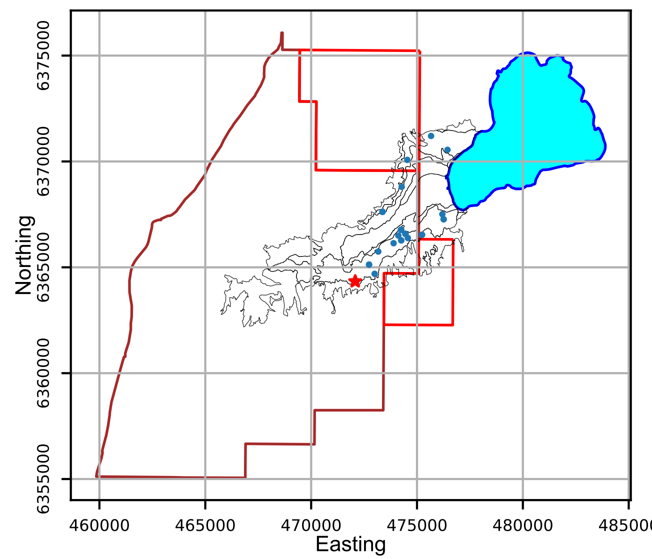

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR423-SN1 - 2.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-22

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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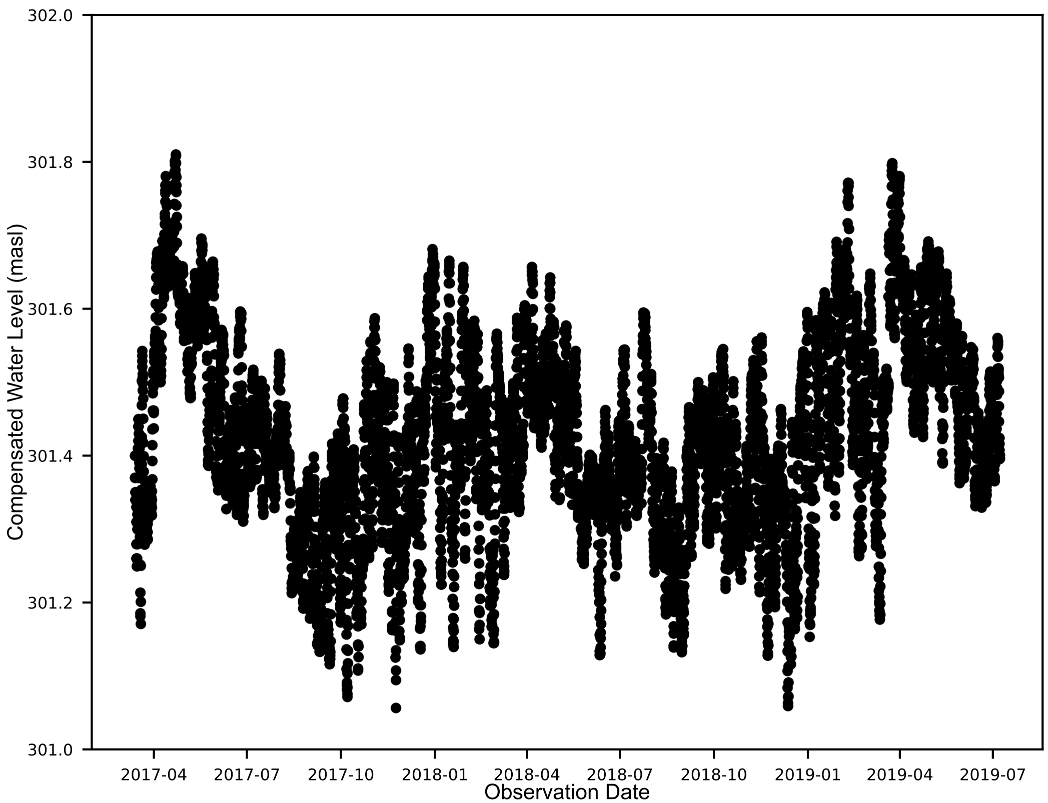
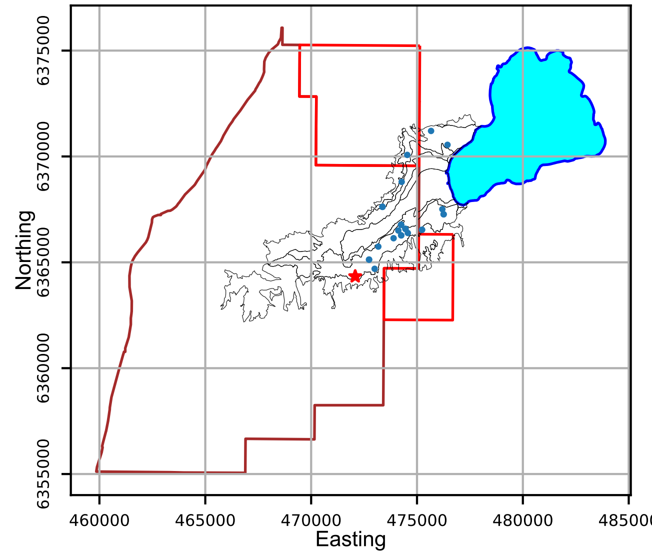




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

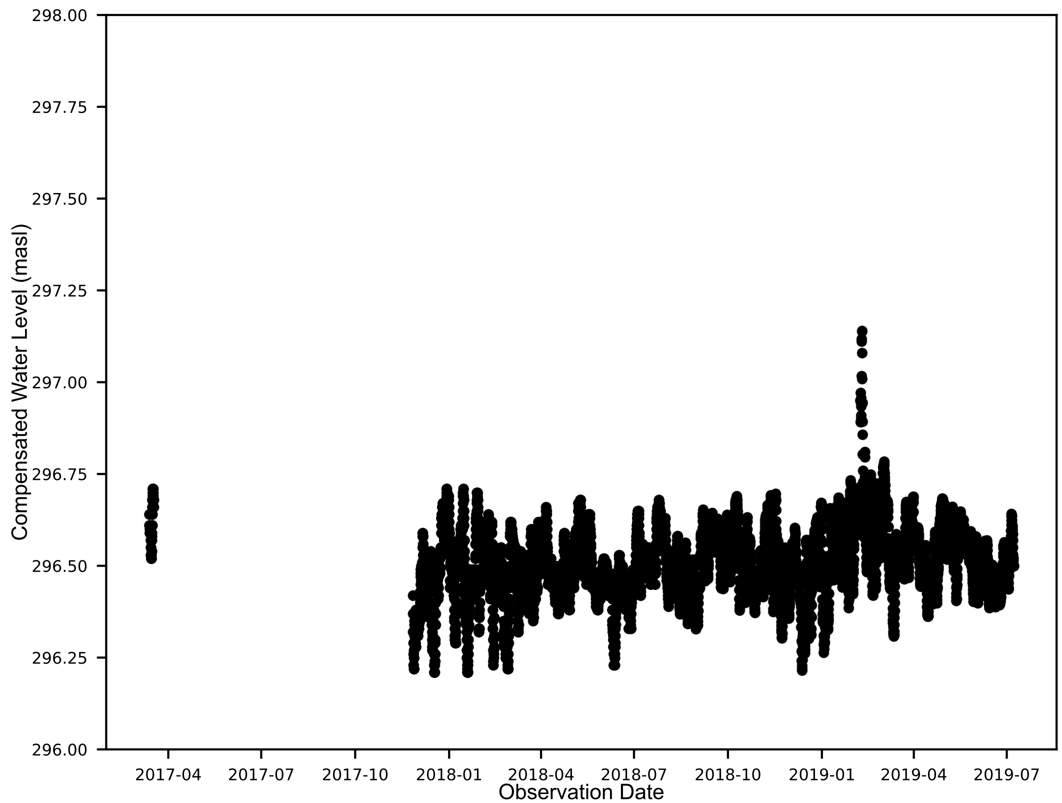
FORT HILLS
Operated by Suncor Energy

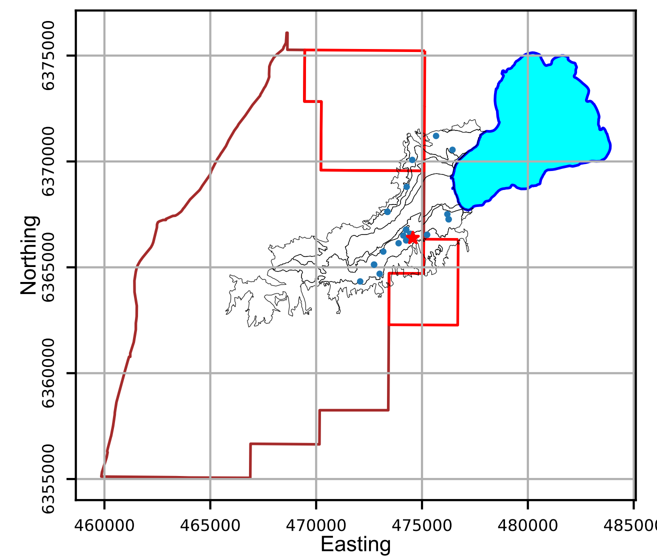
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR423-SN1 - 3.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-23

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 19 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

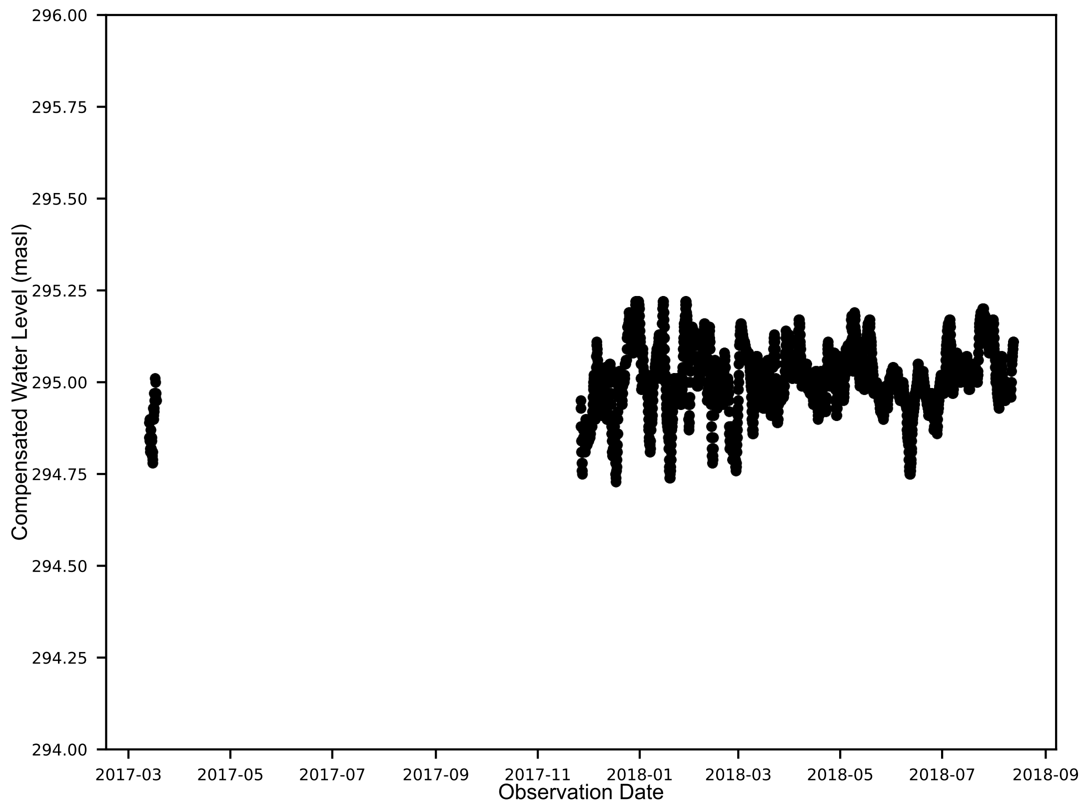
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

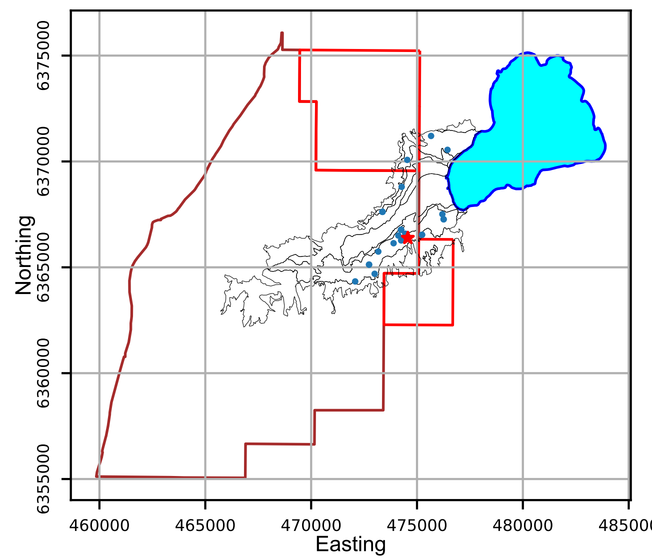
TITLE

FH17-WR439-SN1 - 19.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-24

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR439-SN1 - 6.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-25

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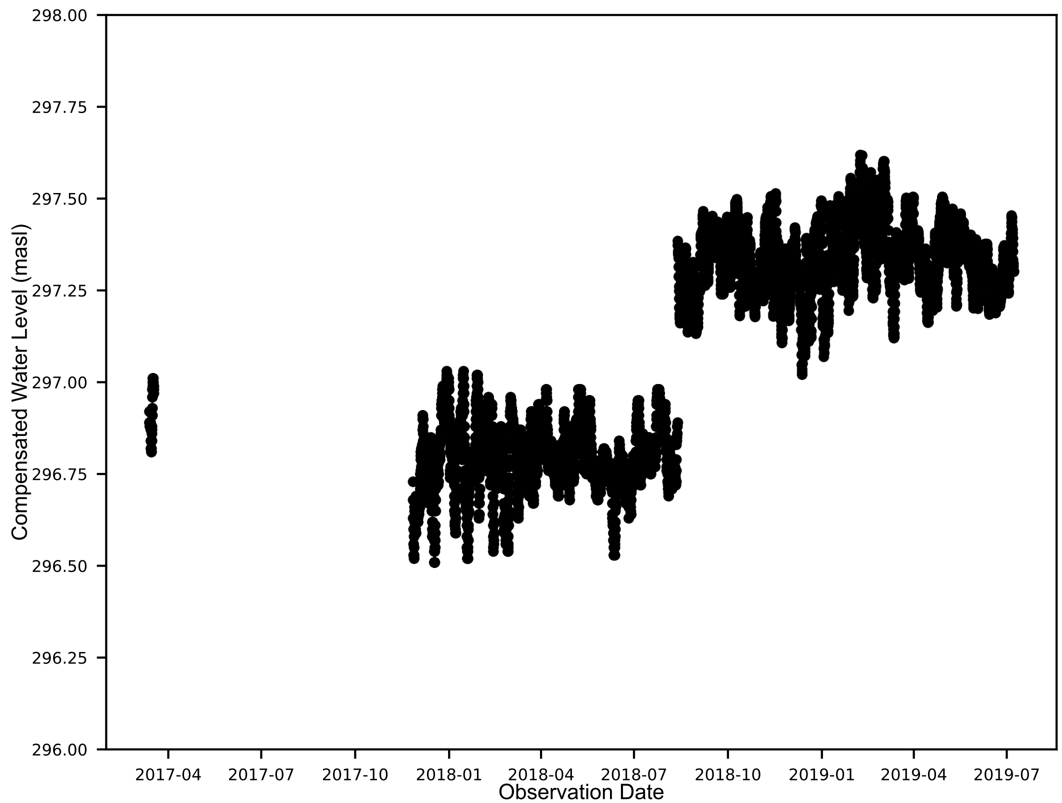
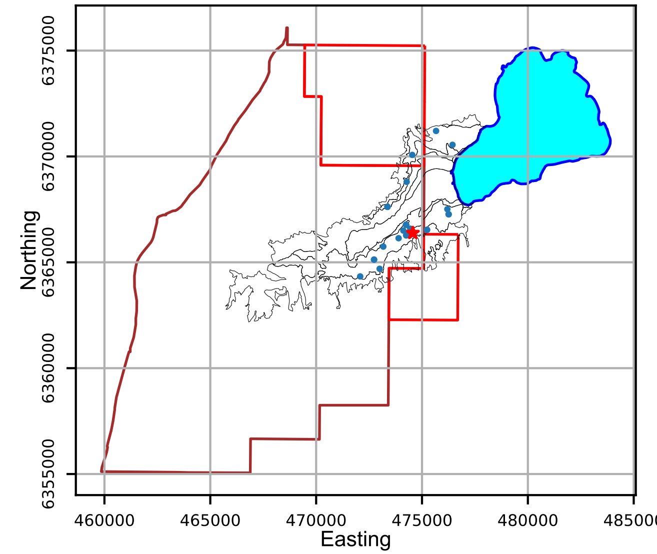
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR439-SN1 - 9.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-26

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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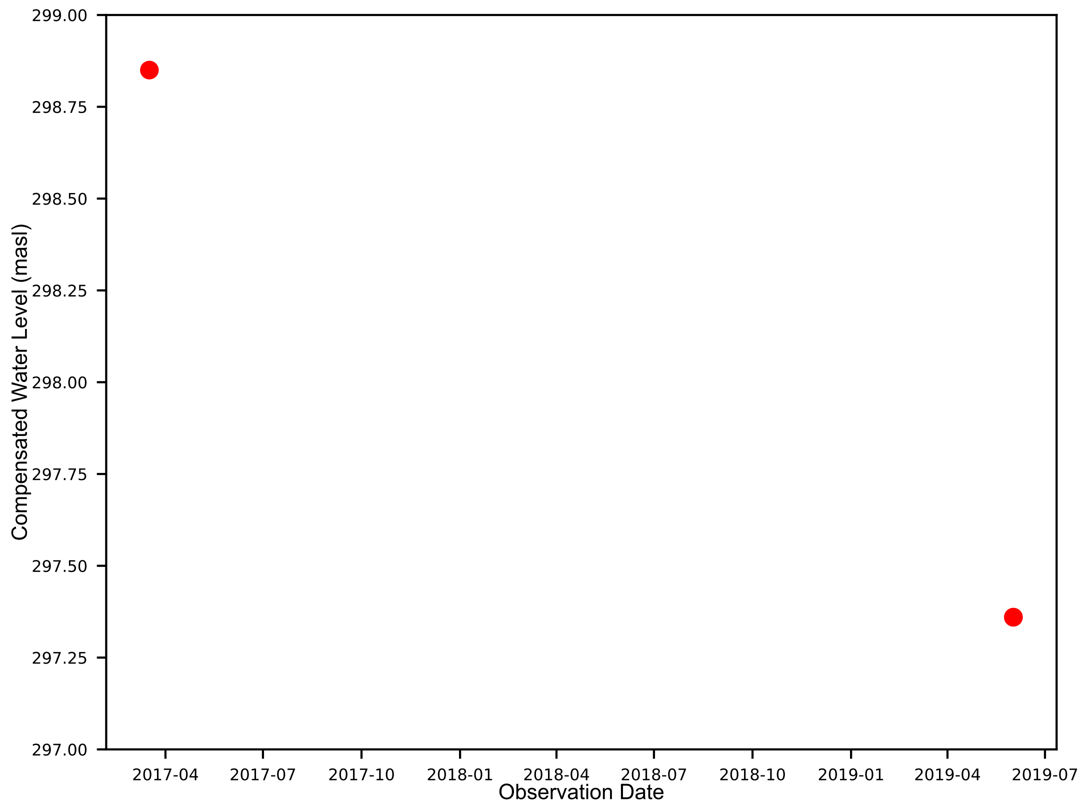
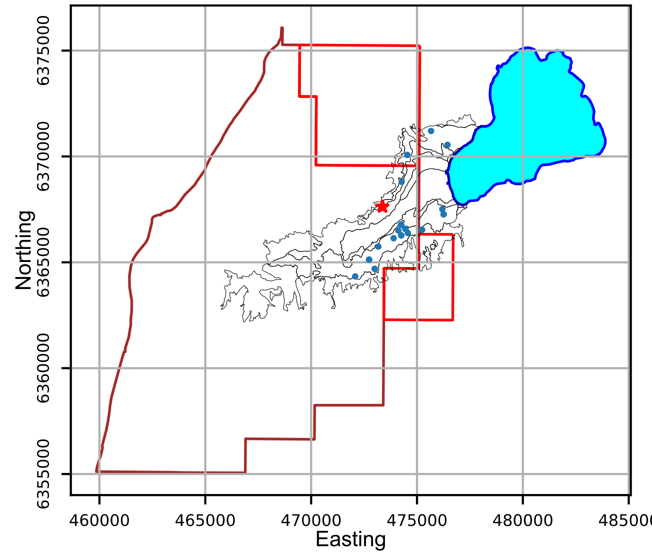




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

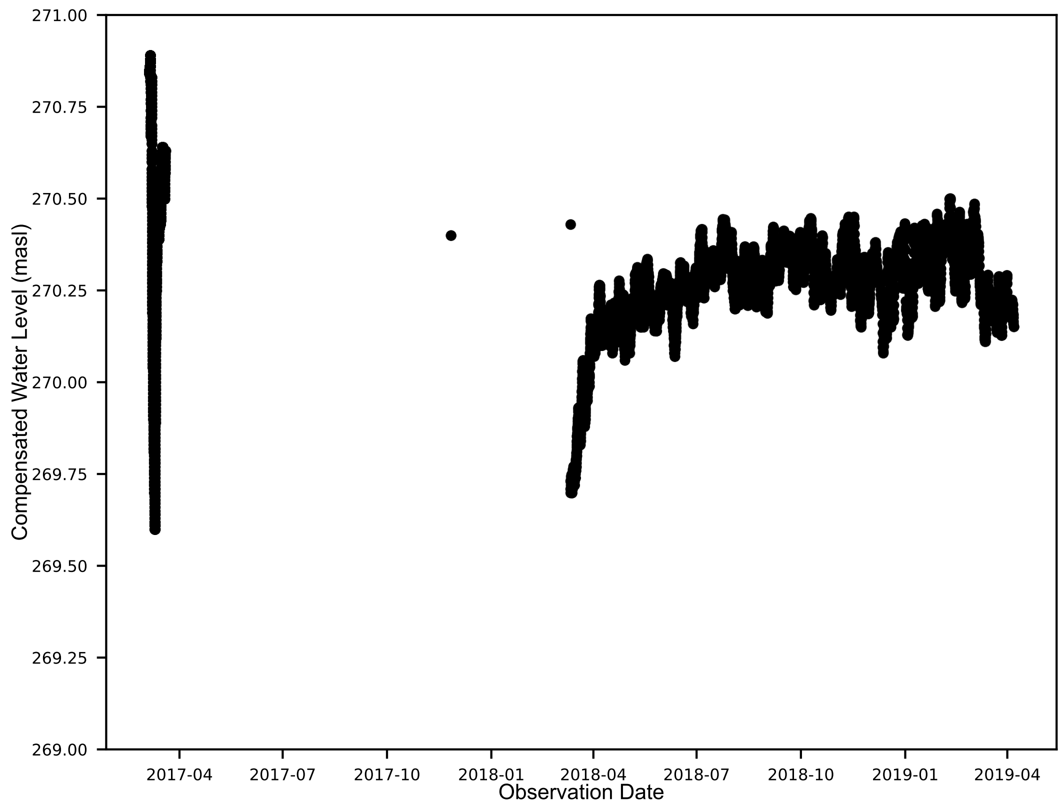
FORT HILLS
Operated by Suncor Energy

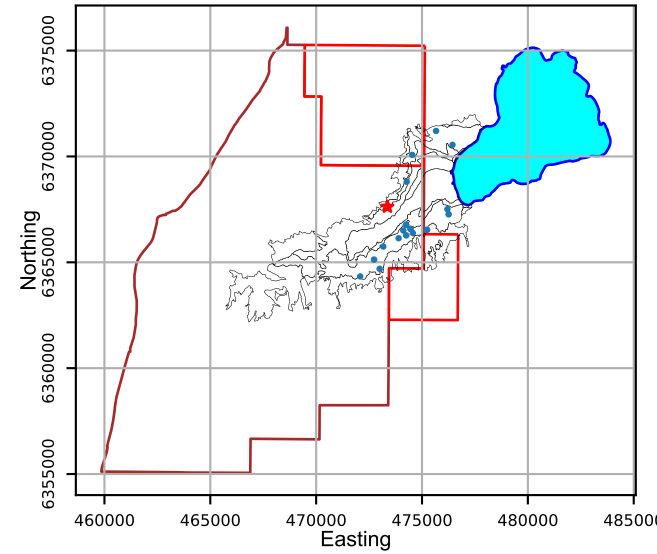
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR441-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-27





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 105 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

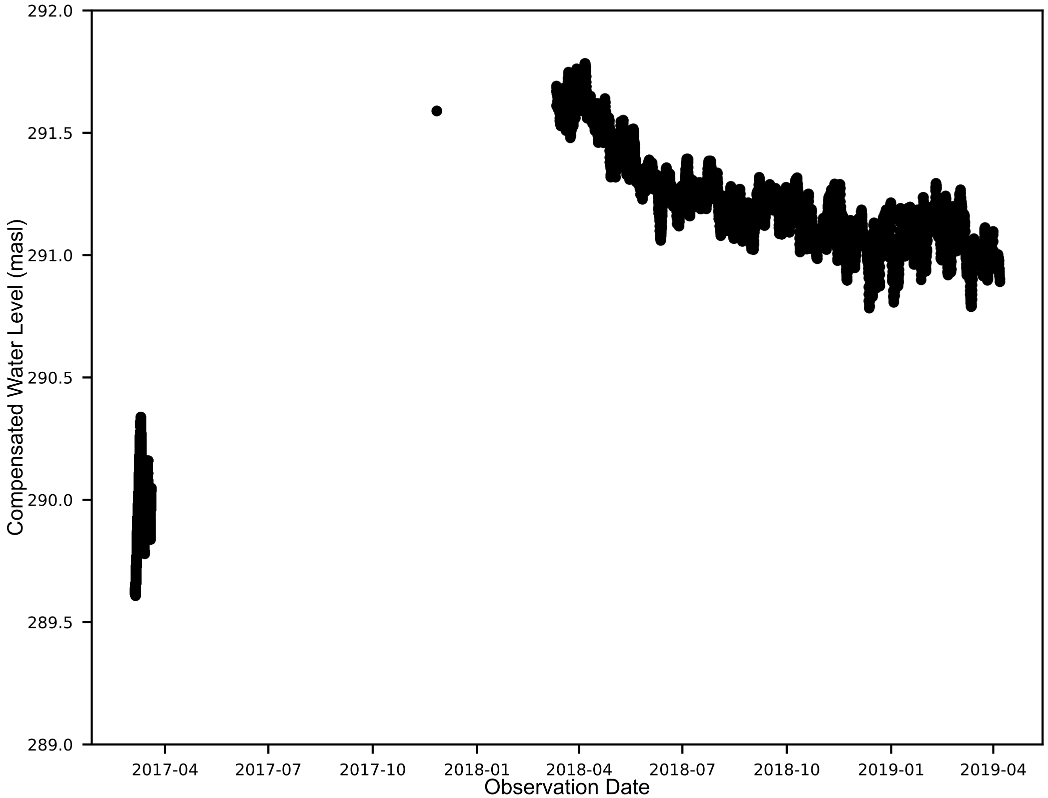
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

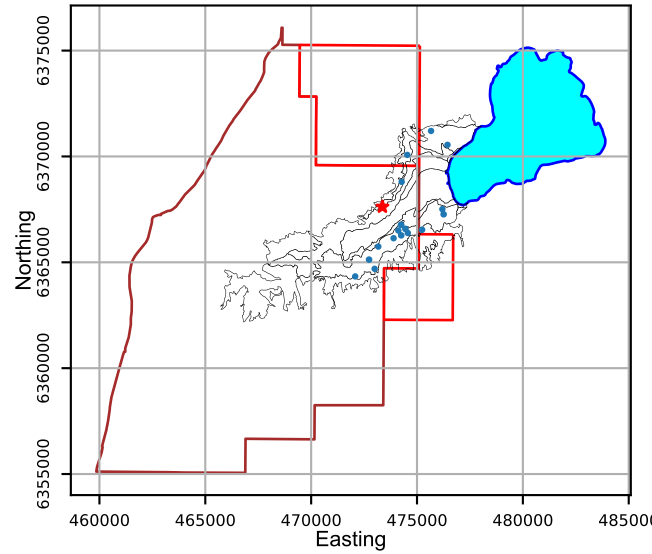
FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR441-MR1 - 105.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-28

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 66 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH17-WR441-MR1 - 66.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-29

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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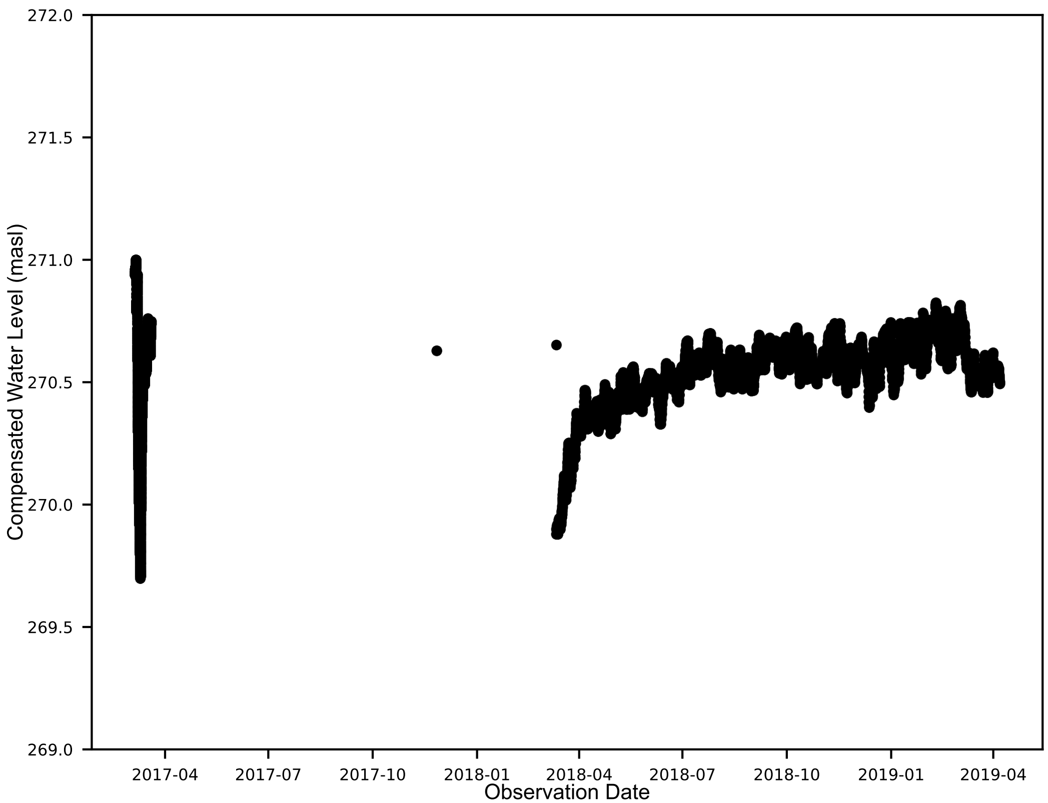

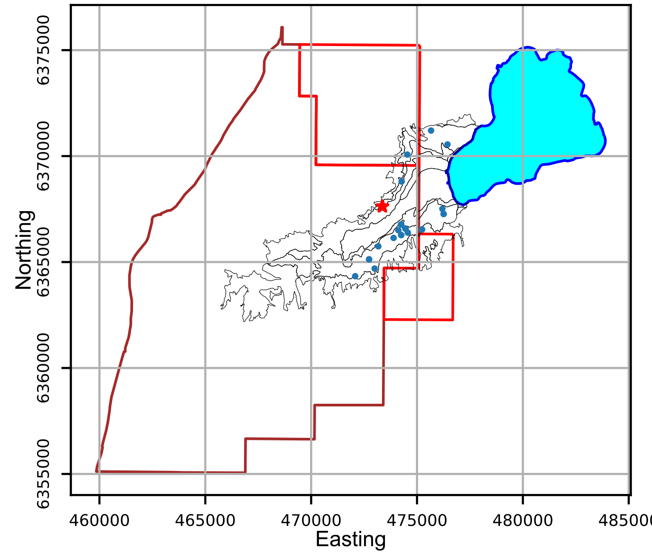

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 93 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR441-MR1 - 93.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-30

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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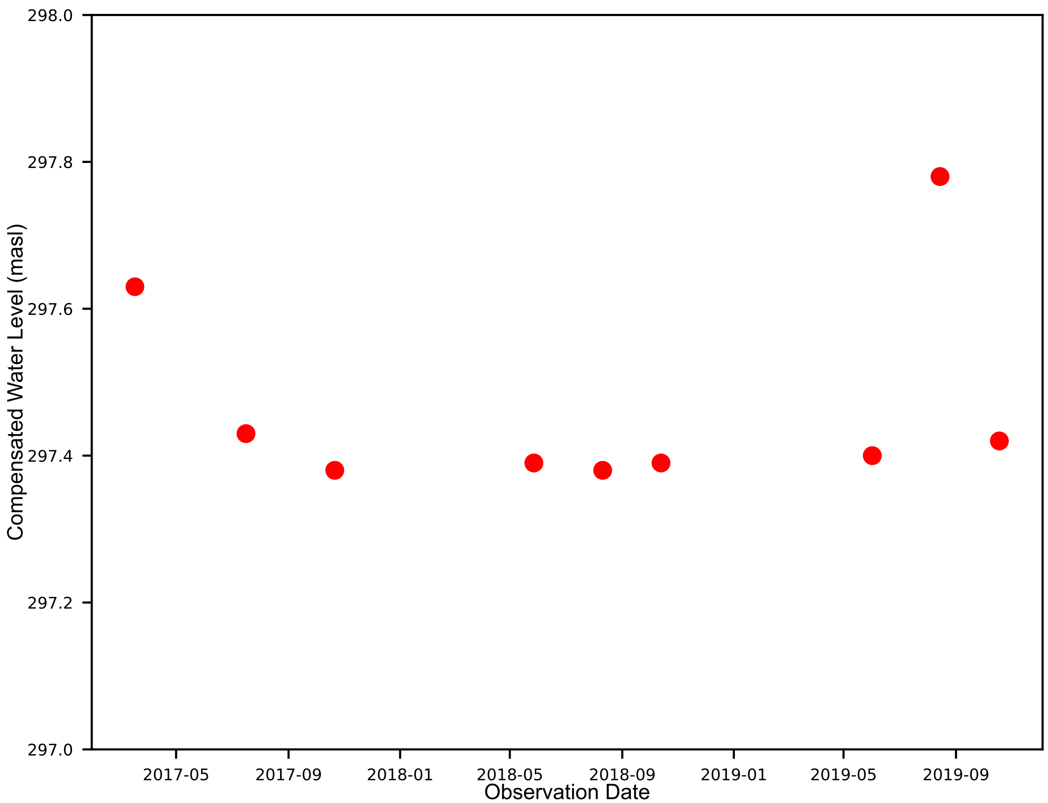

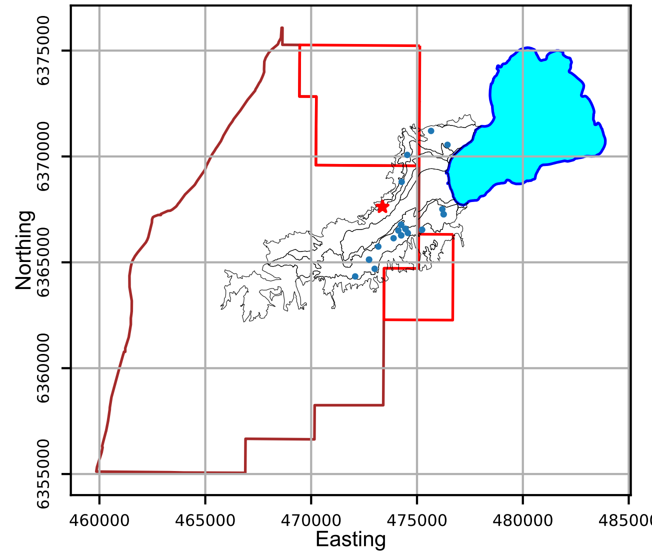

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR441-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B5-31

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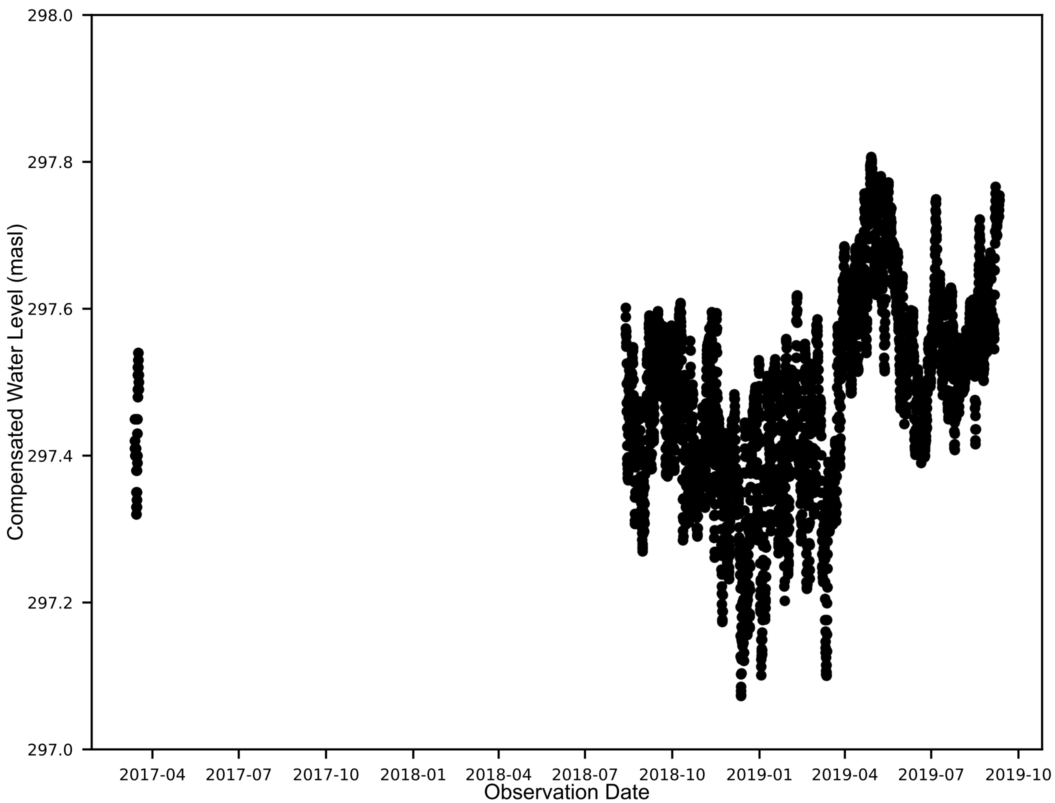
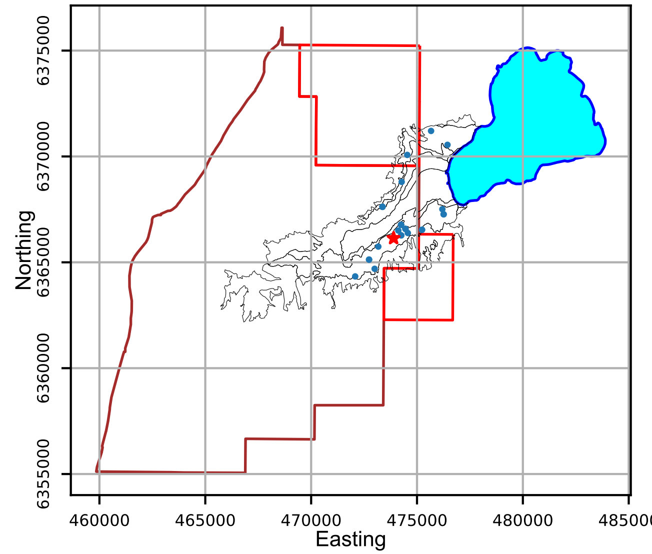




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till

Depth of Measurement: 10.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

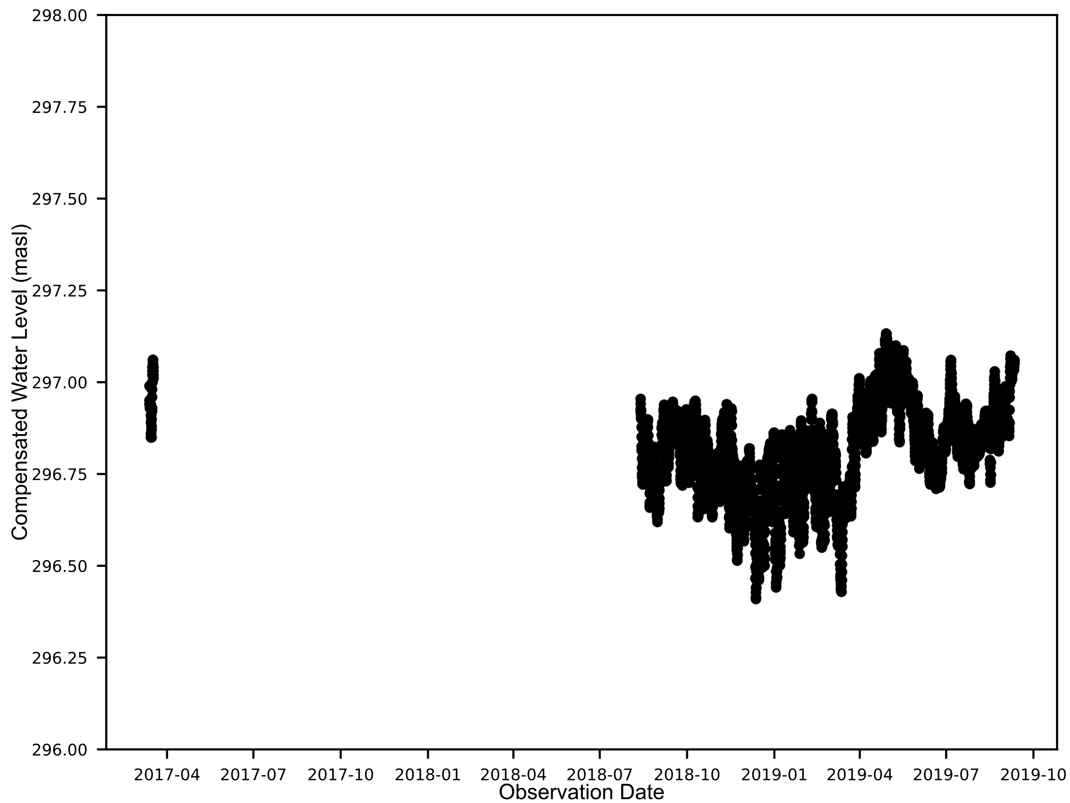
FORT HILLS

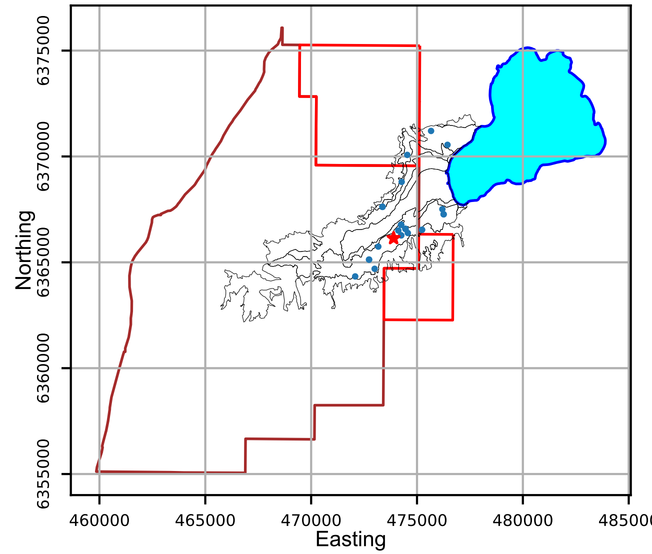
Operated by Suncor Energy

TITLE

FH17-WR447-SN1 - 10.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-32





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR447-SN1 - 15.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-33

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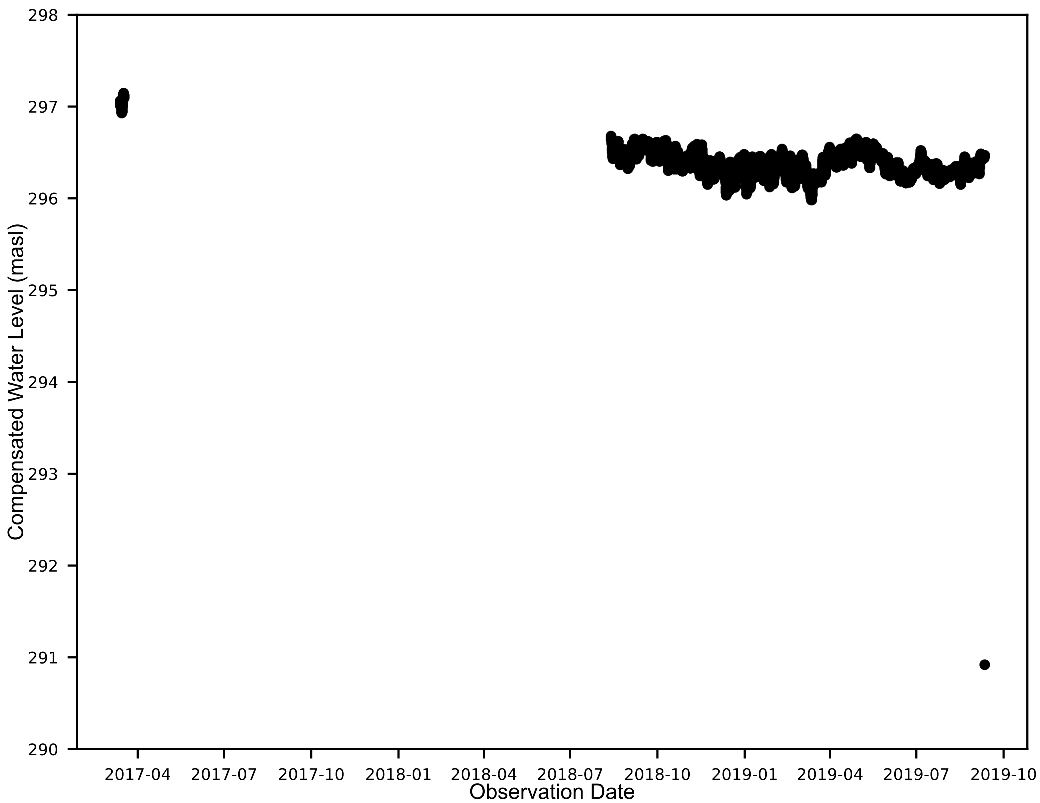
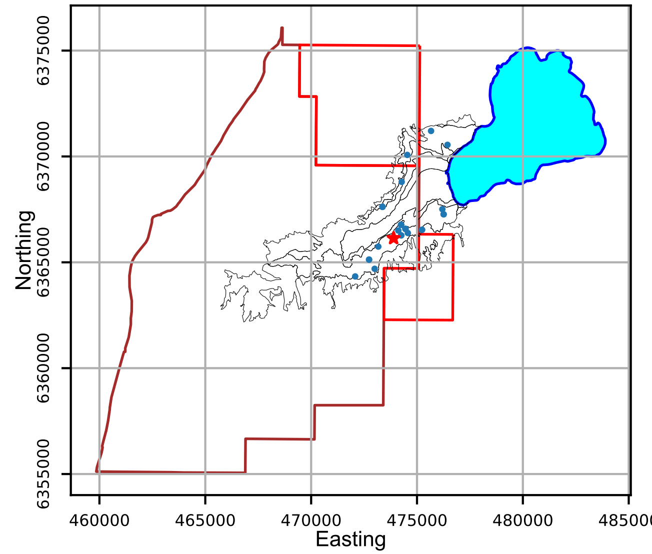




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

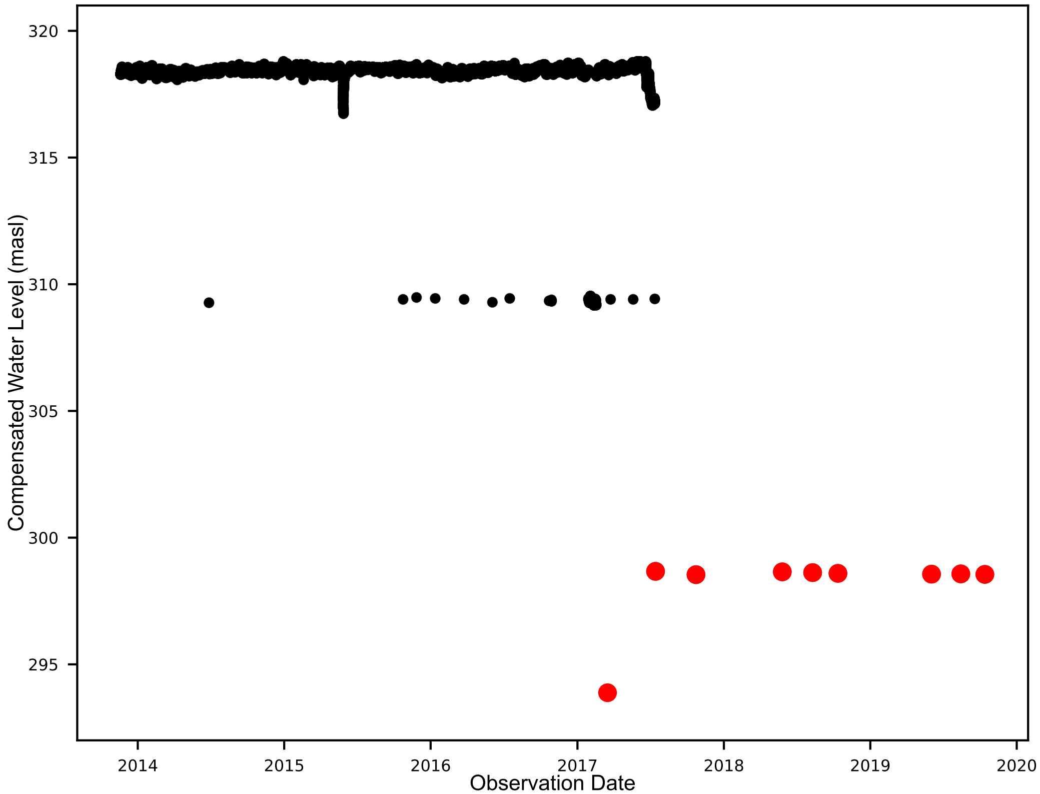
FORTHILLS
Operated by Suncor Energy

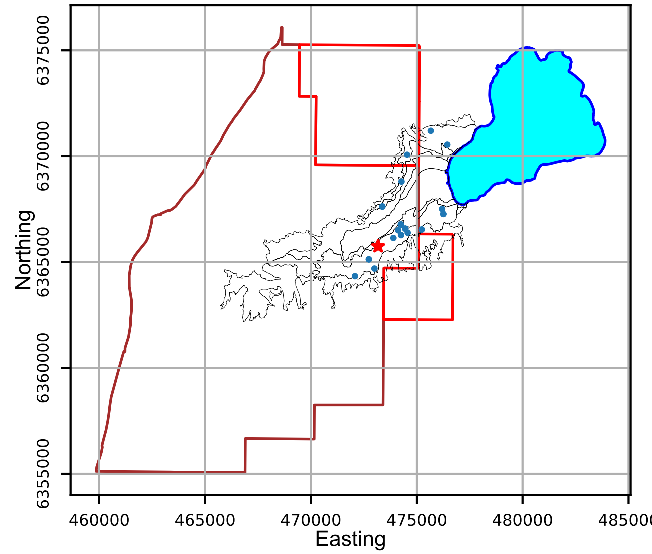
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR447-SN1 - 7.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-34

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

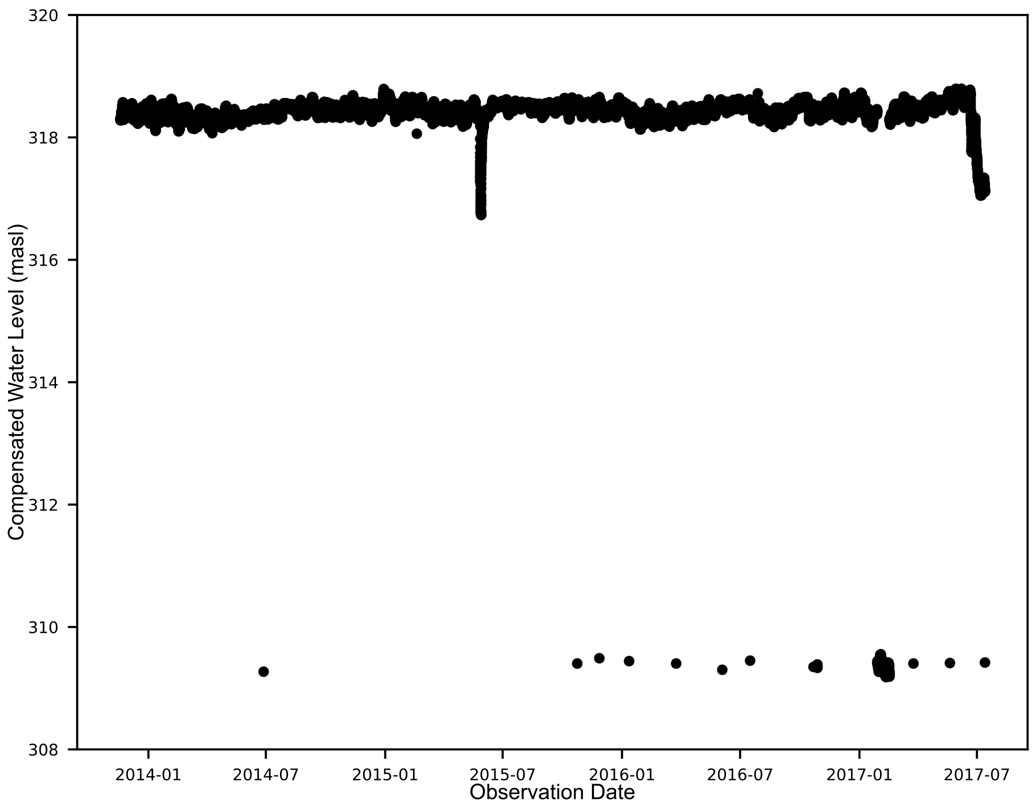
Operated by Suncor Energy

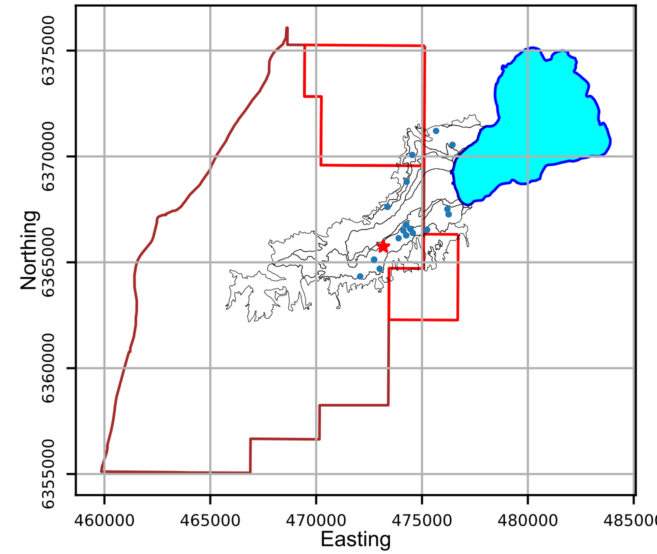
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR449-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-35





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

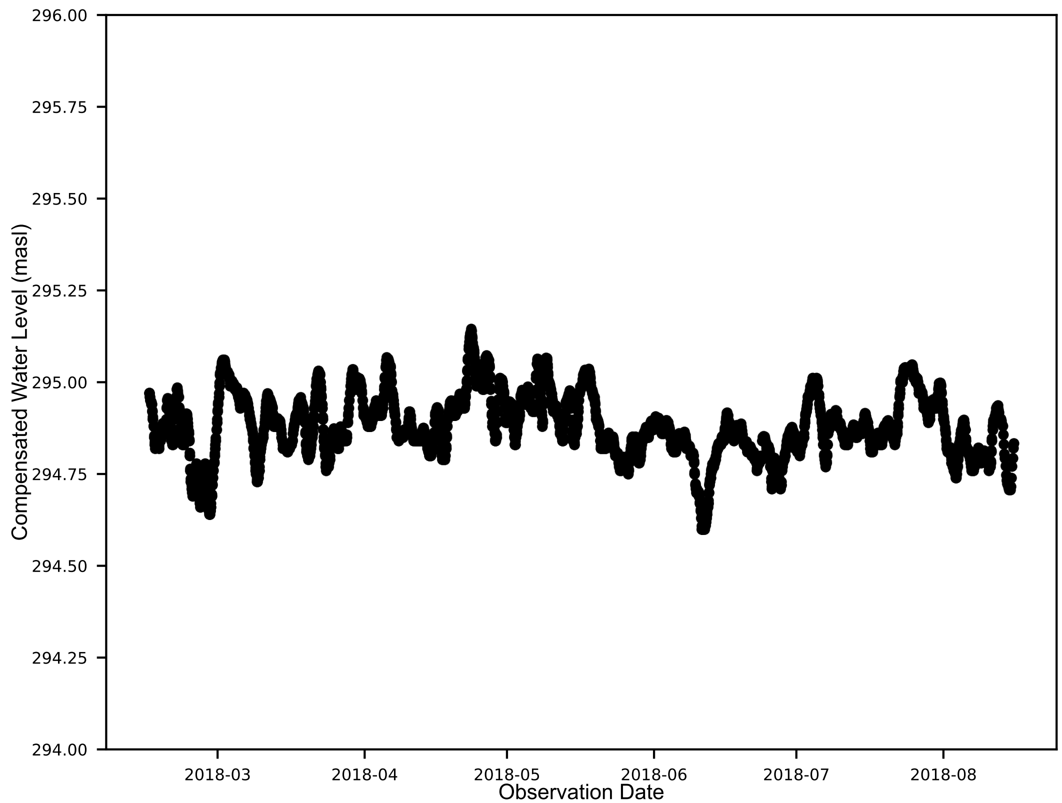
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

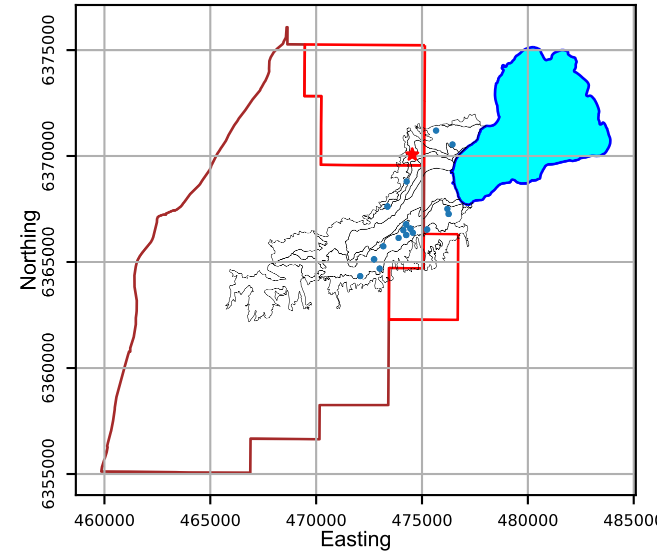
TITLE

FH17-WR449-SN1 - 0.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-36

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

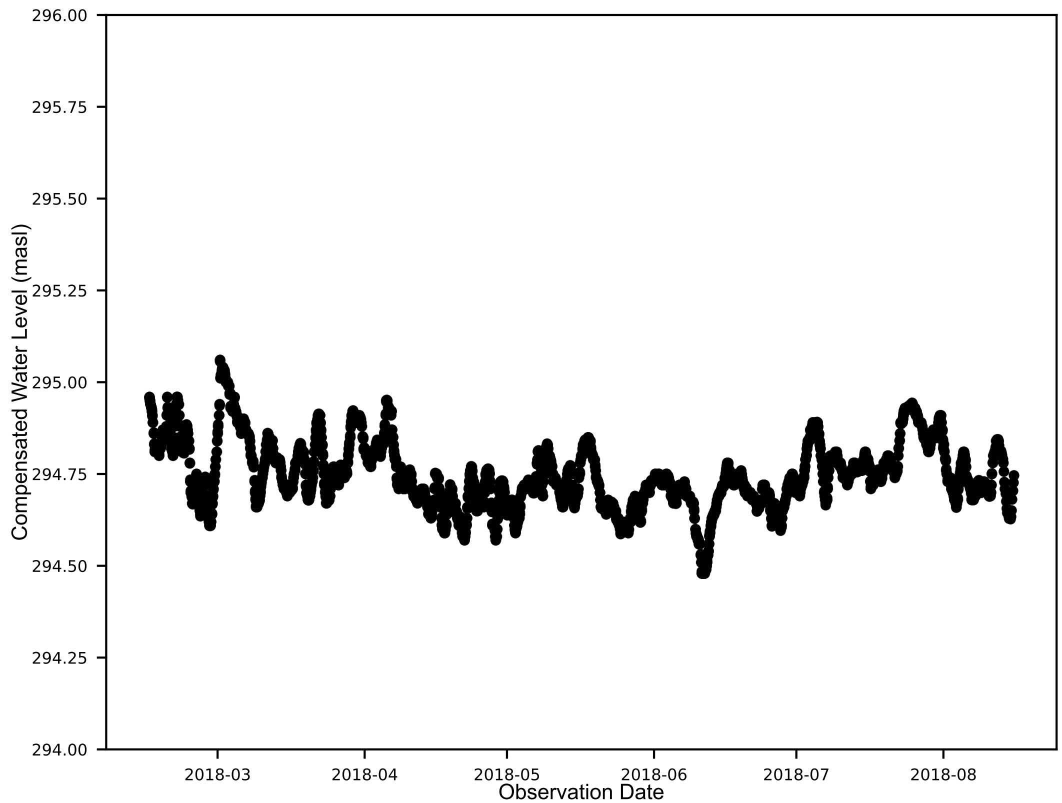
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

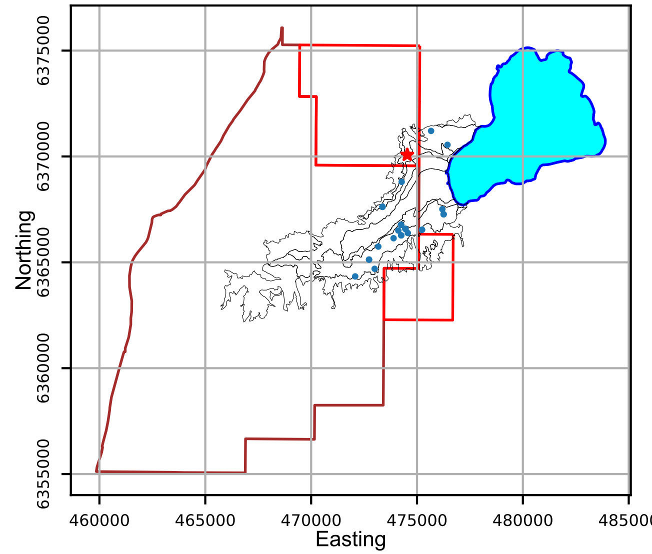
TITLE
FH18-ES415-SN1 - 14.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-37

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

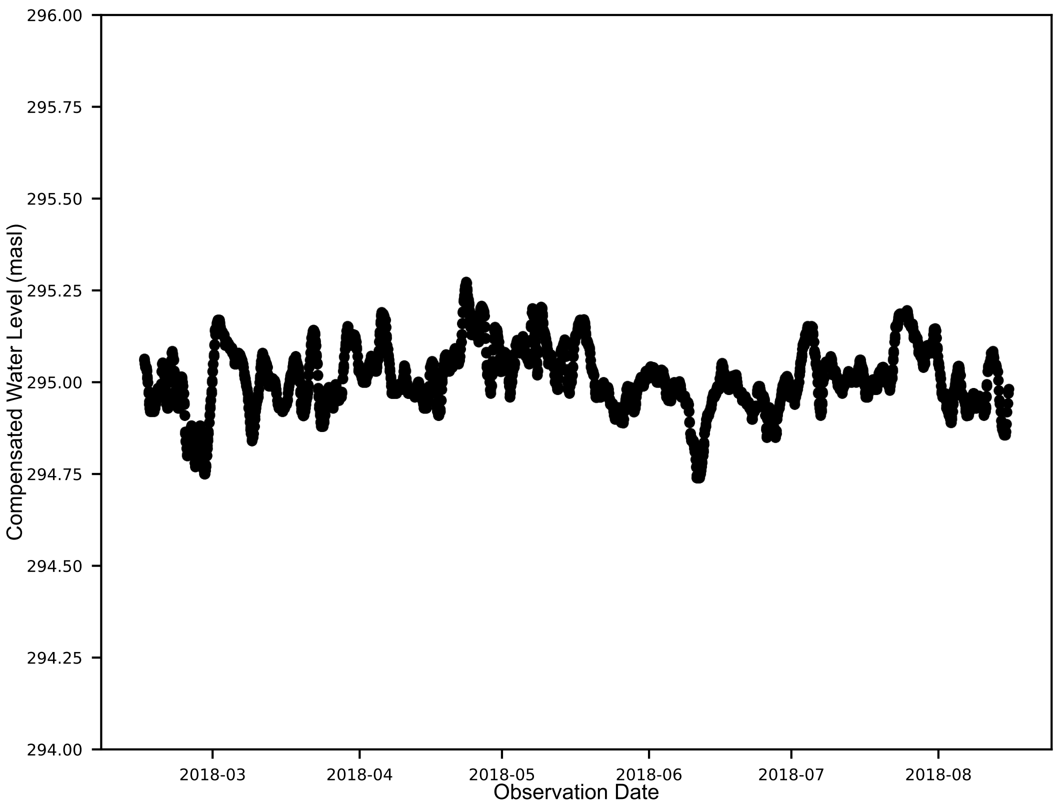
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

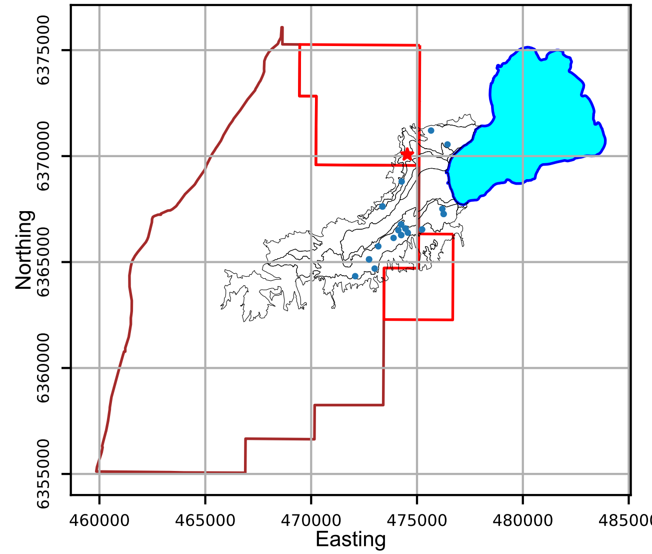
TITLE
FH18-ES415-SN1 - 2.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-38

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

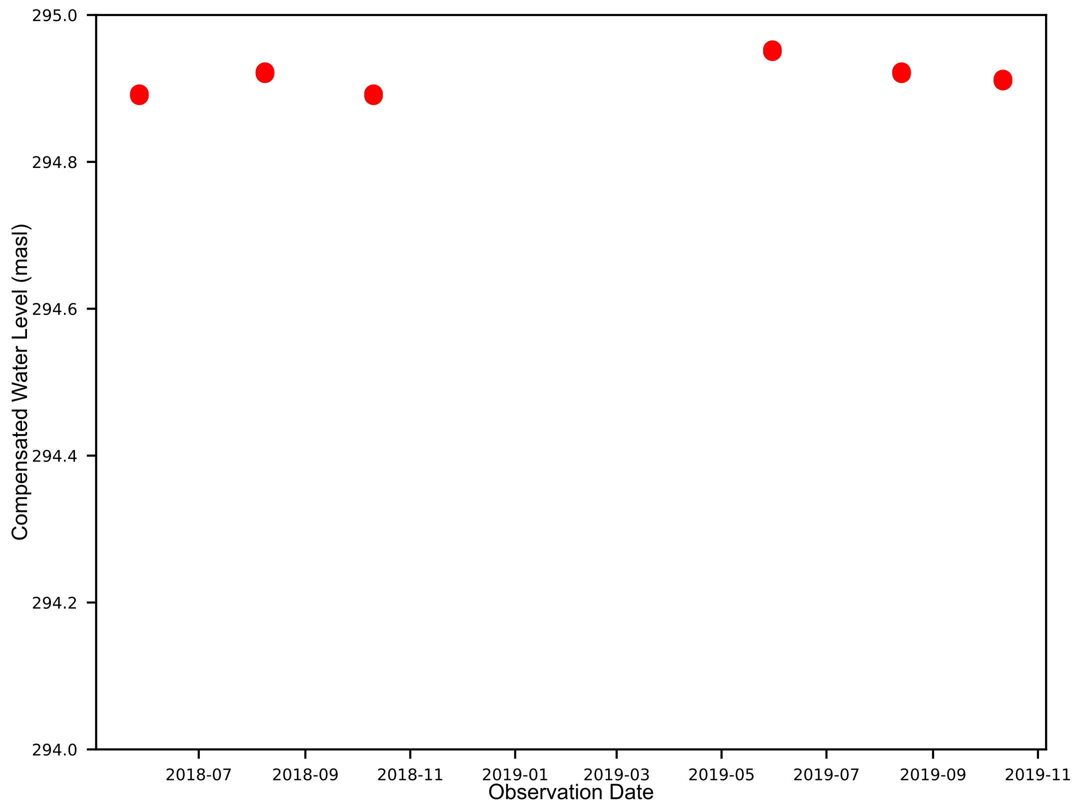
FORT HILLS
Operated by Suncor Energy

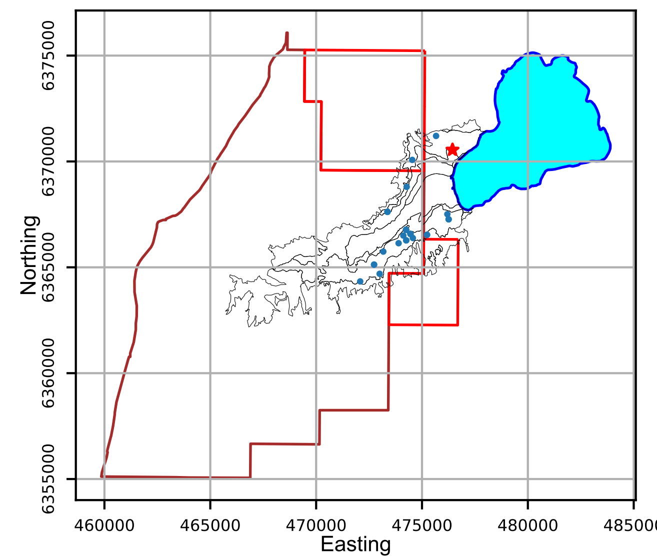
TITLE

FH18-ES415-SN1 - 8.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-39

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 20 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

FORT HILLS
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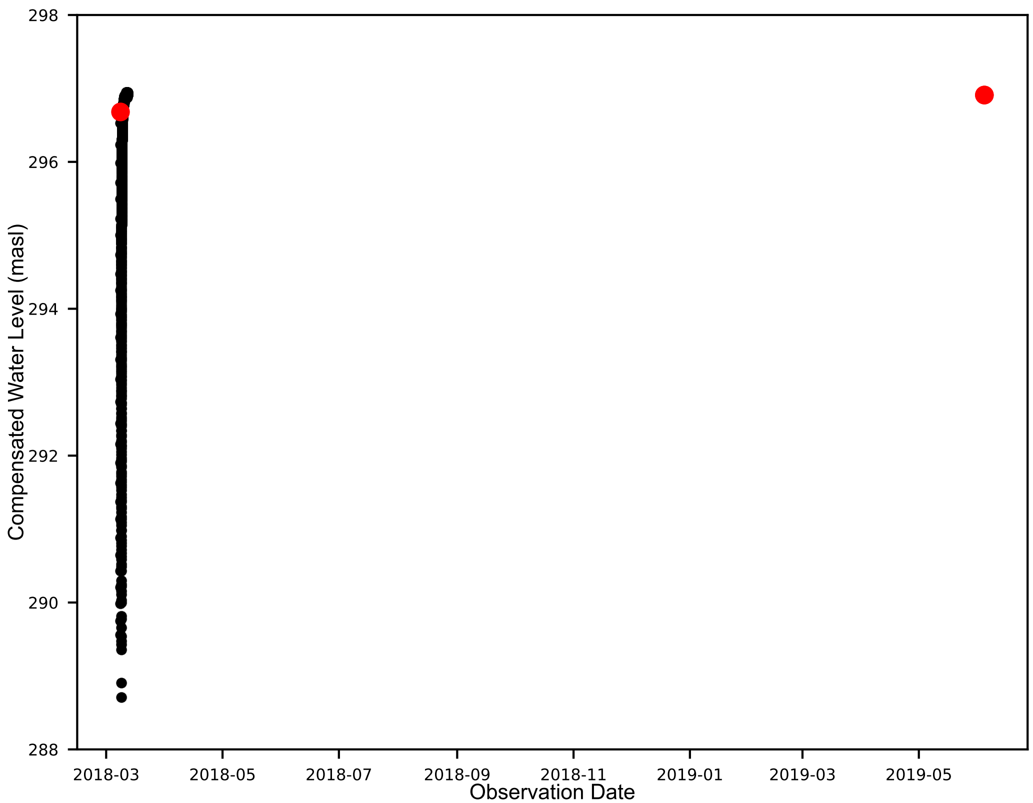
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

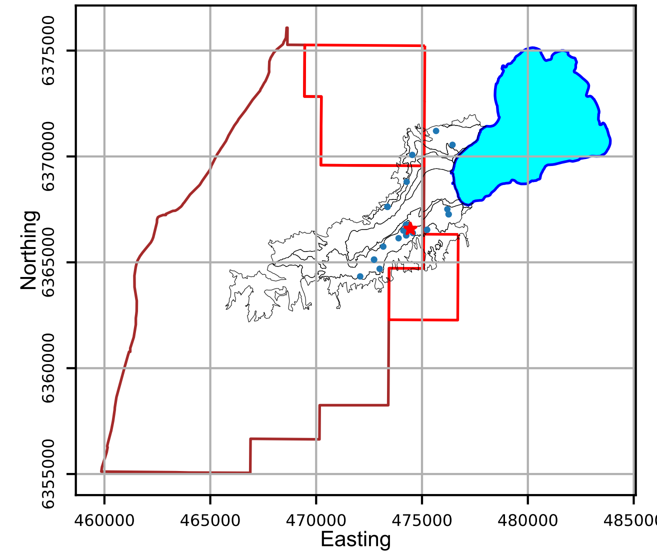
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE
FH18-ES416-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-40

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

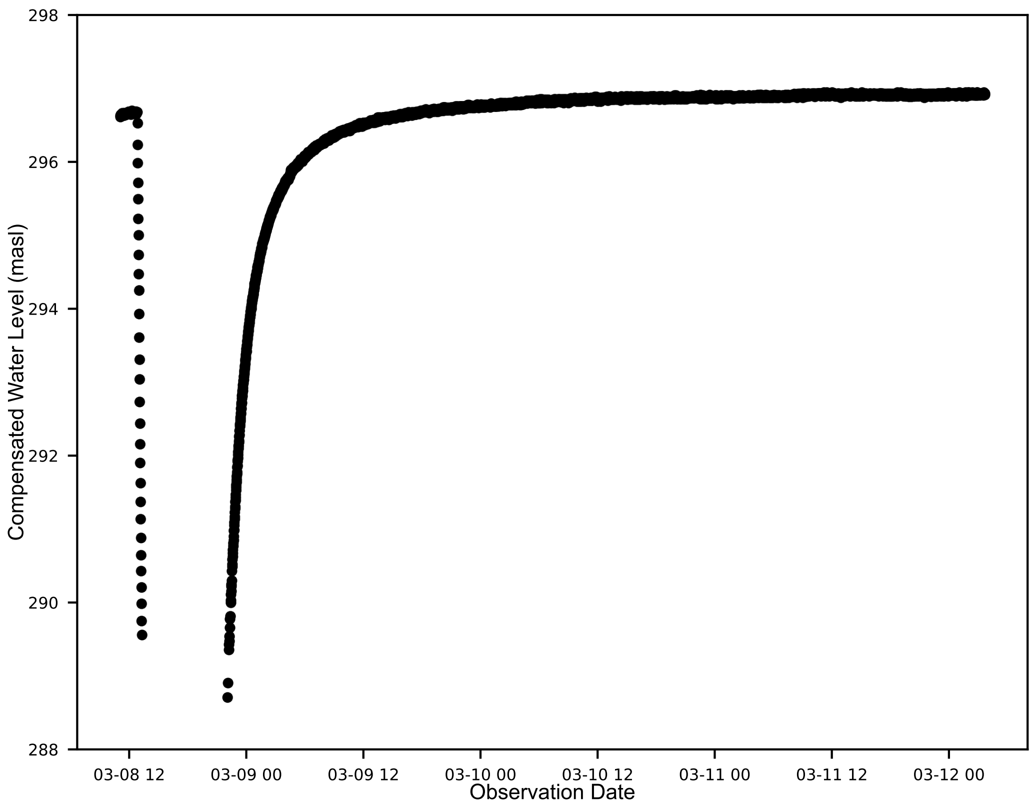
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

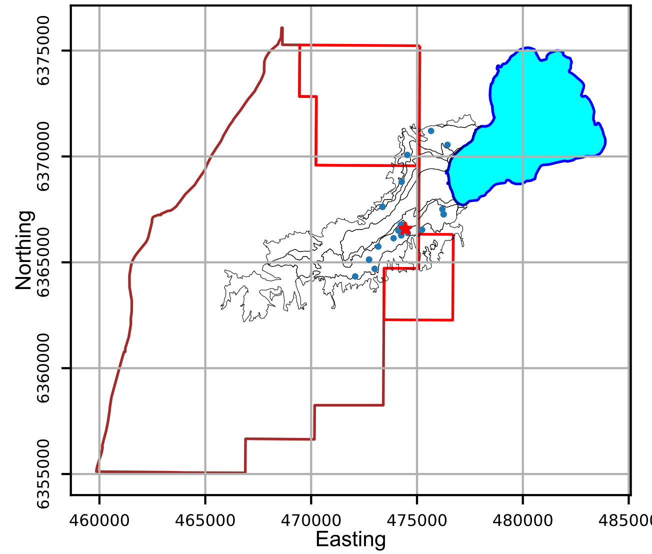
TITLE

FH18-ES426-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-41

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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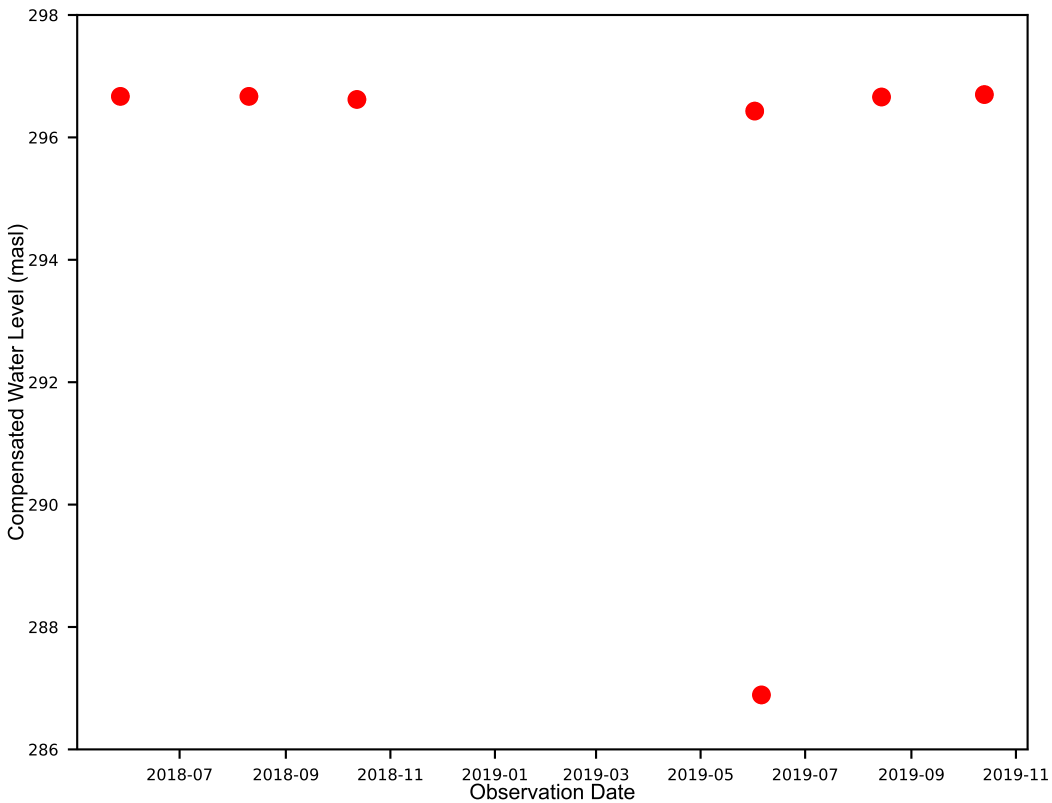
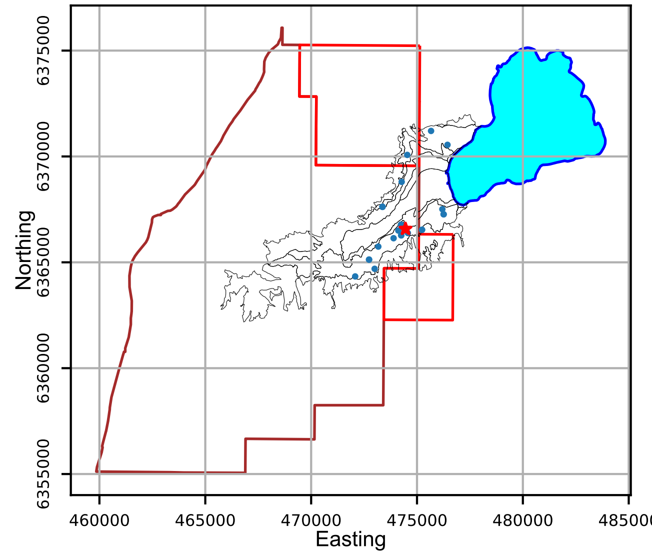
TITLE
FH18-ES426-DR1 - 17.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-42

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 22.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

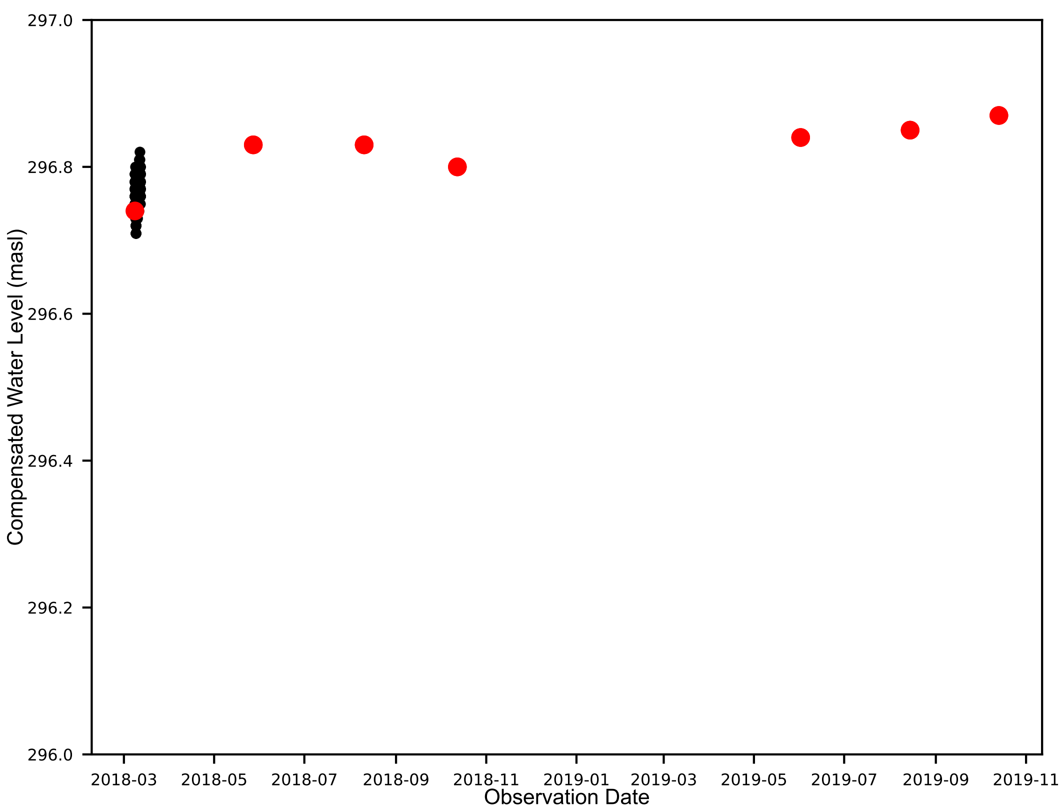
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

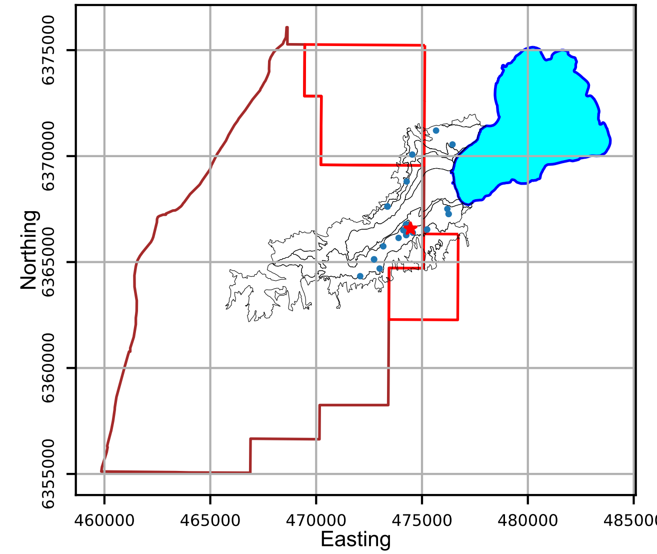
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH18-ES426-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-43





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES426-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B5-44

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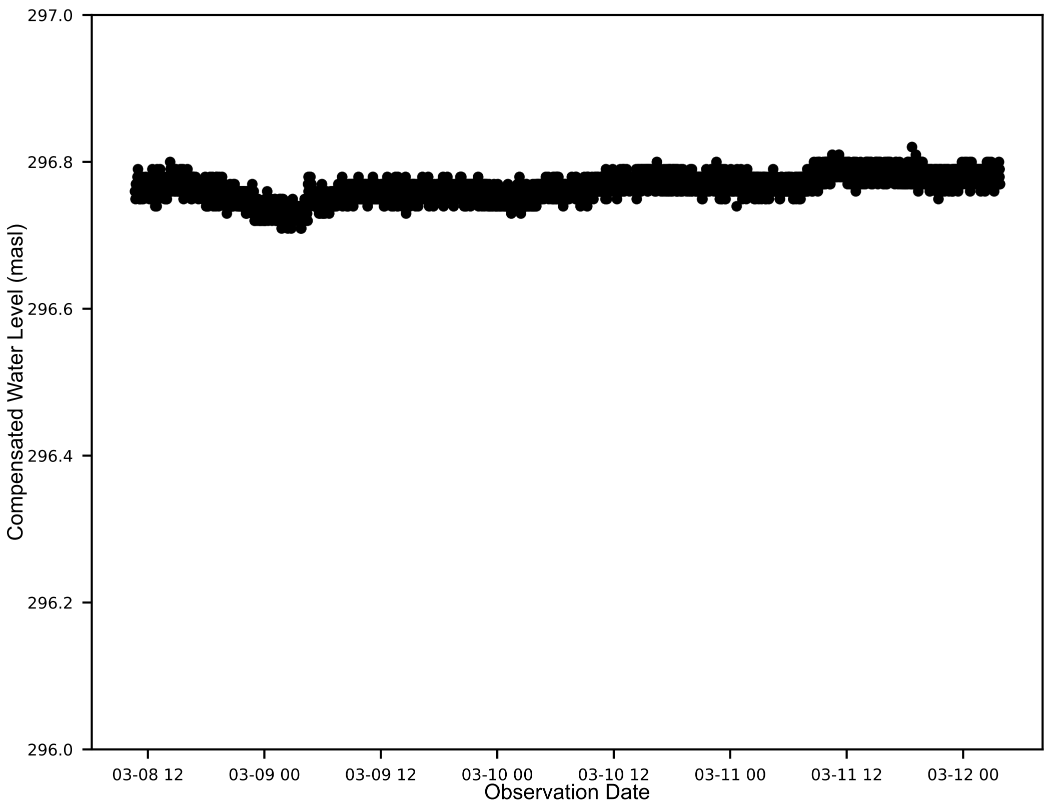
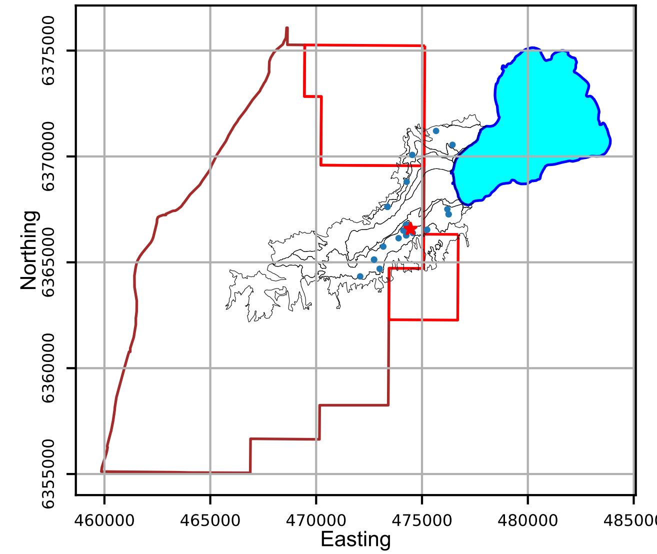




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

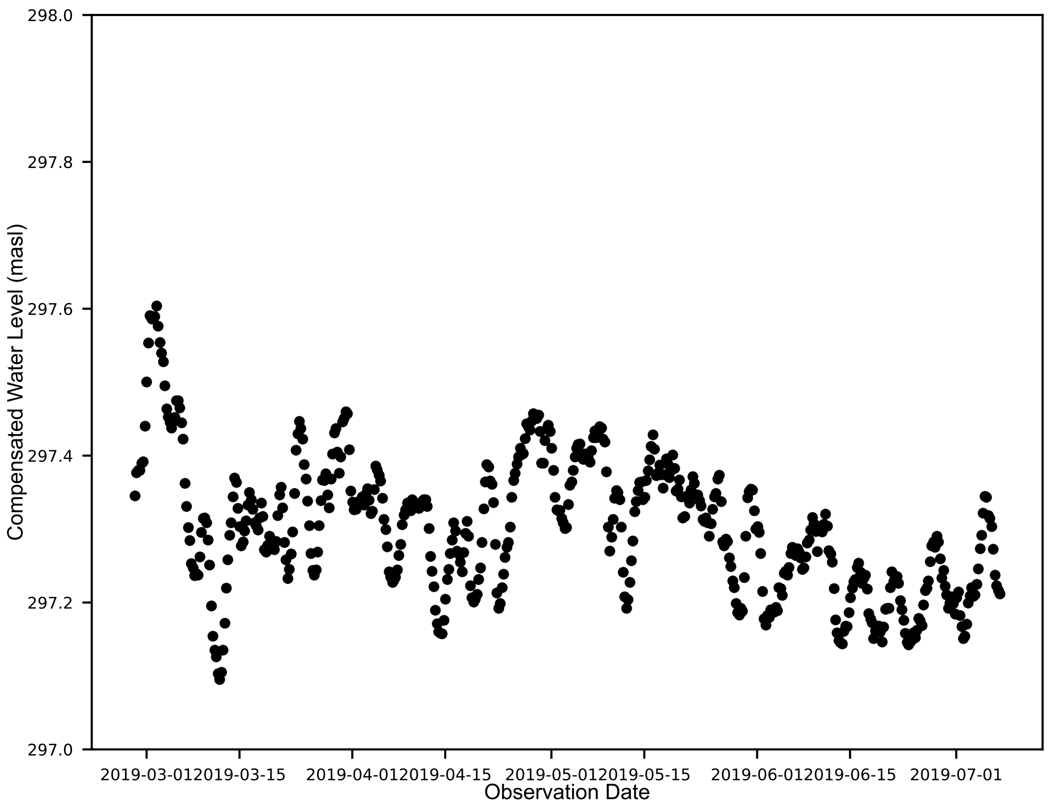
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

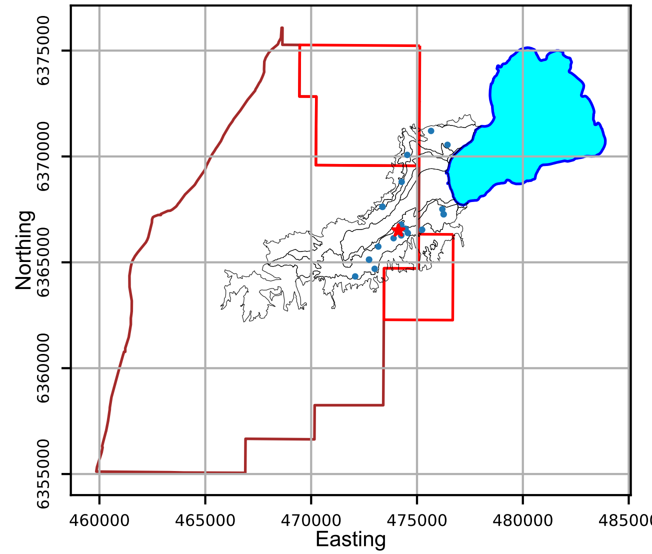
TITLE

FH18-ES426-SN2 - 7.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-45

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 27.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

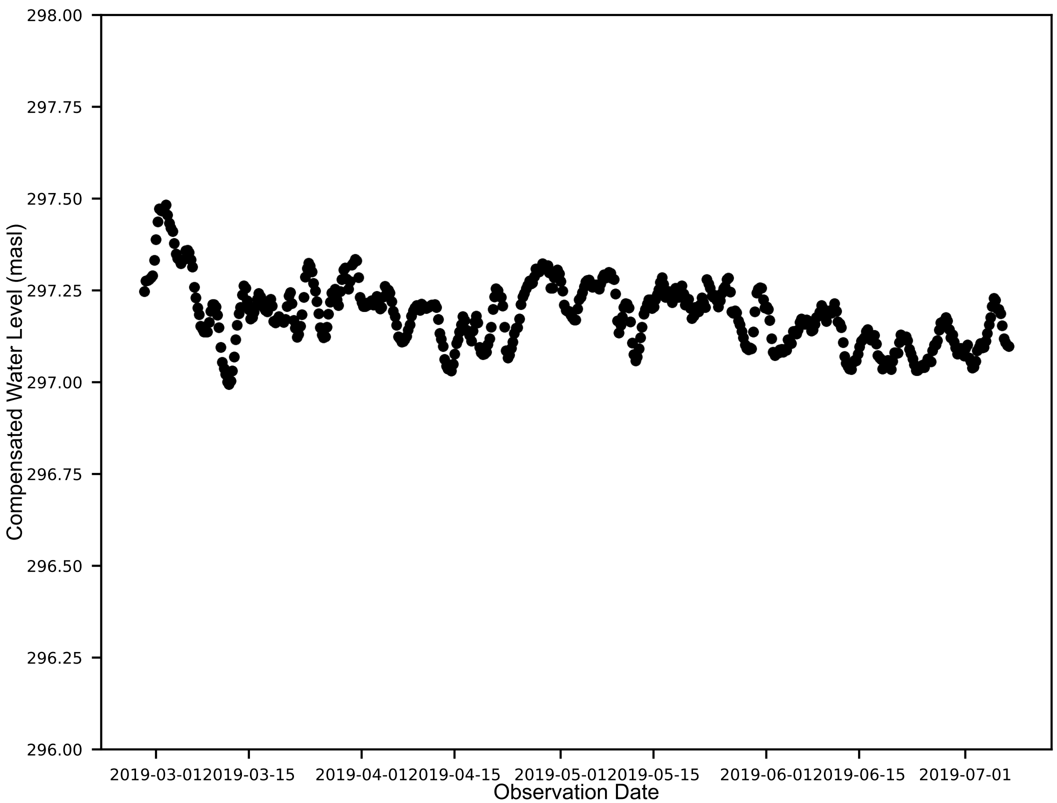
TITLE

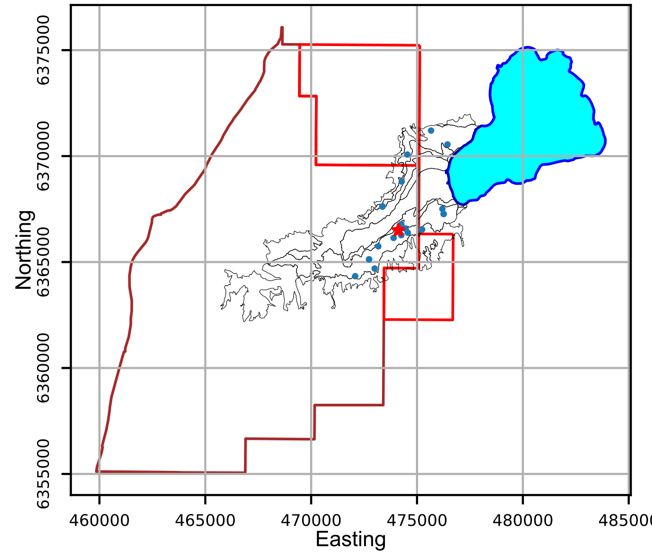
FH19-ES627-SN1 - 27.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-46

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

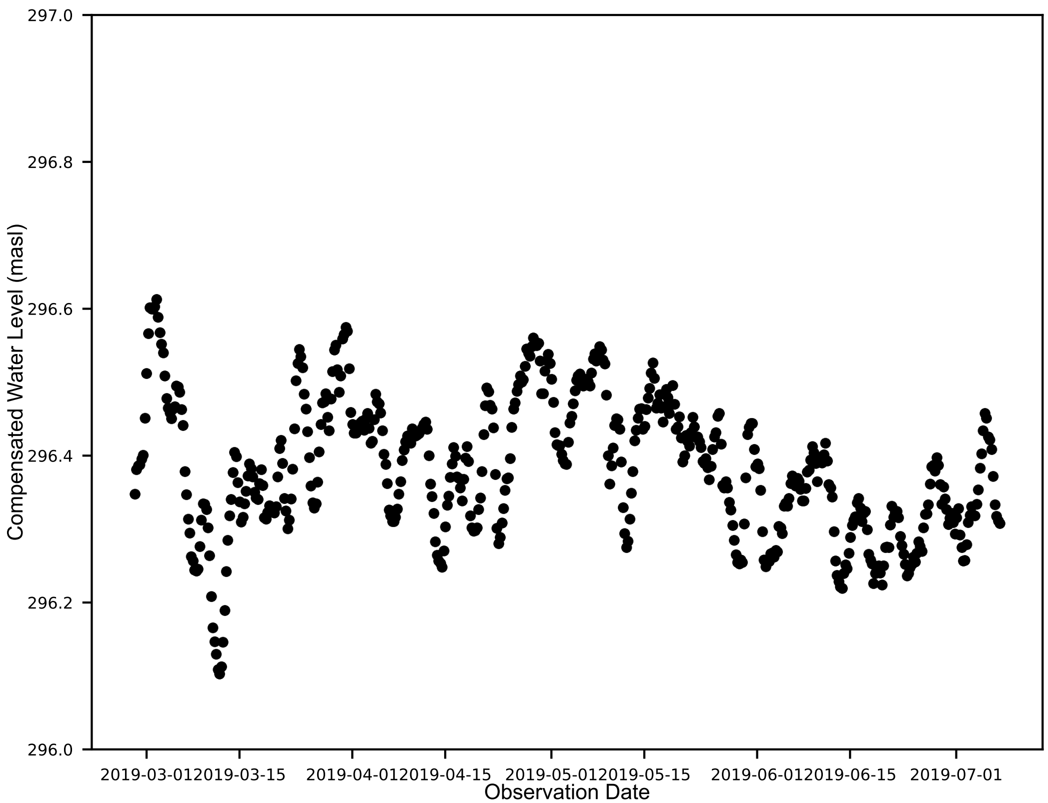
FORT HILLS
Operated by Suncor Energy

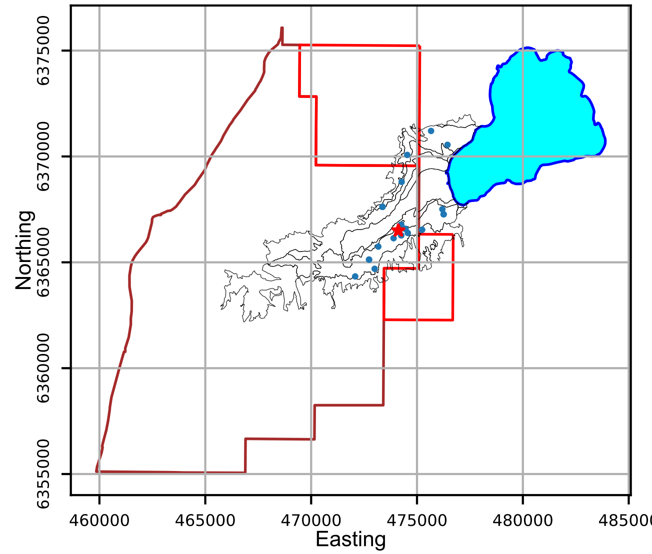
TITLE

FH19-ES627-SN1 - 32.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-47

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

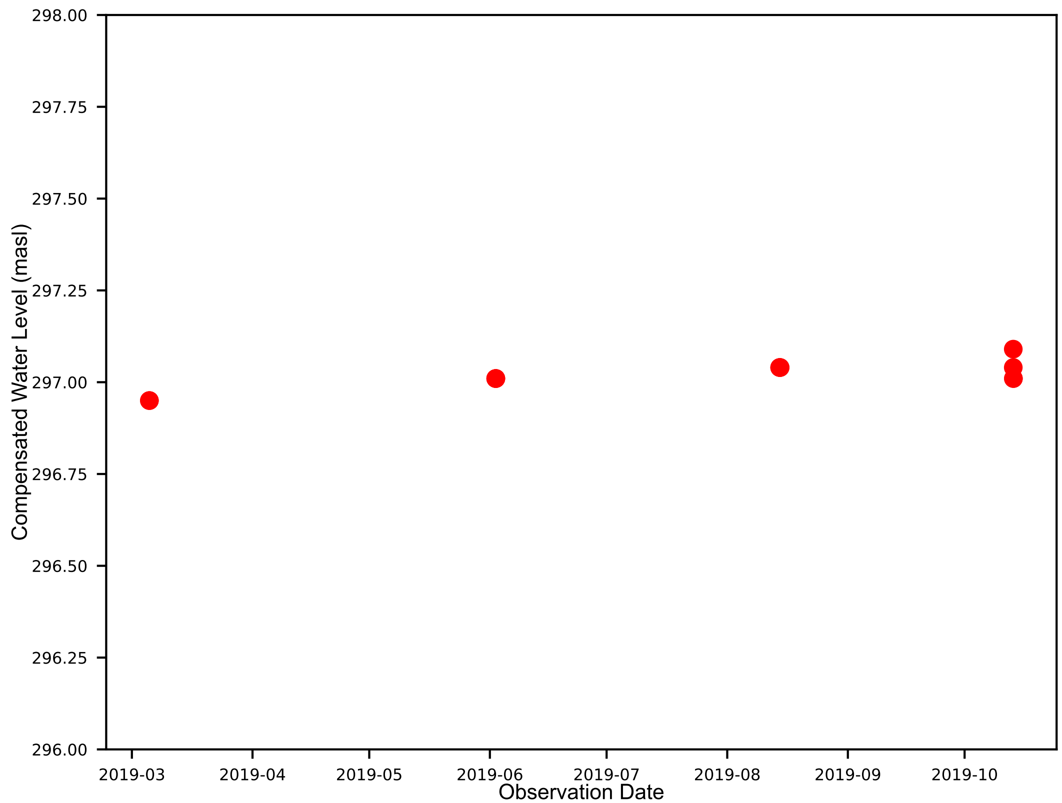
FORTHILLS
Operated by Suncor Energy

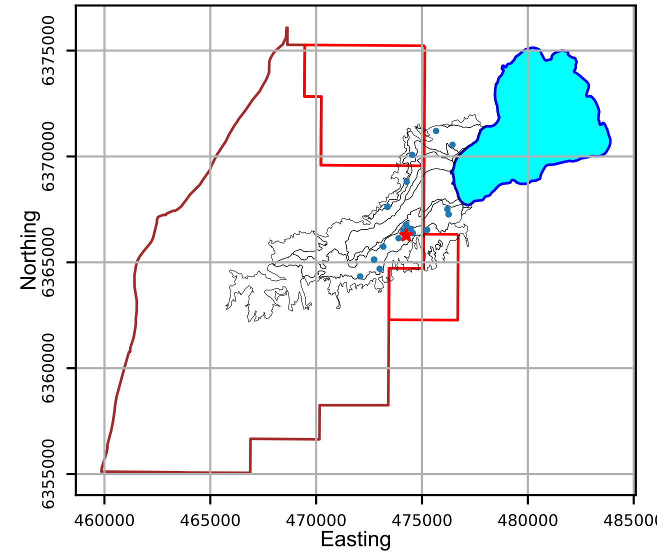
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES627-SN1 - 7.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-48

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 35.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

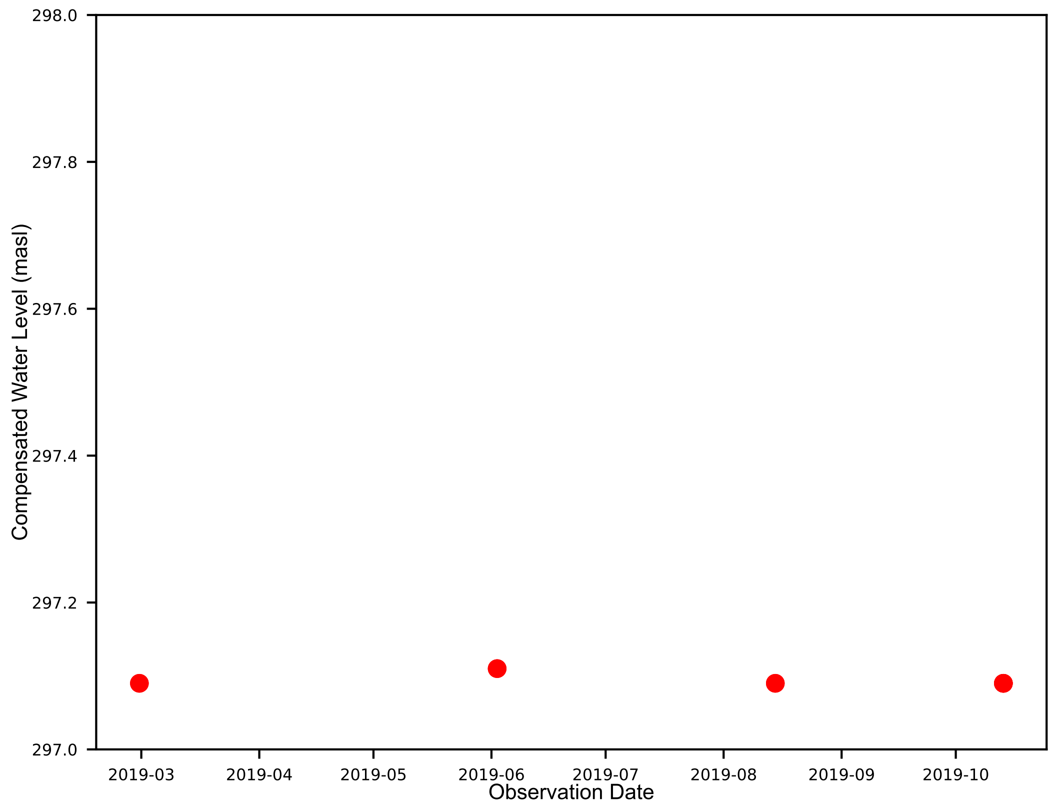
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

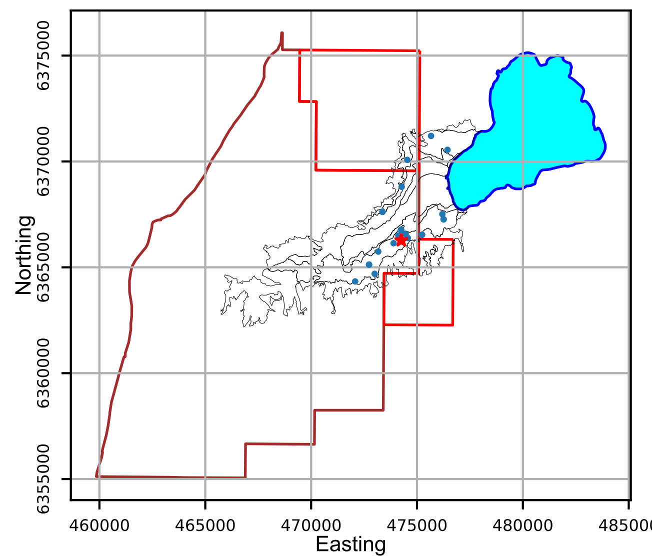
TITLE

FH19-ES631-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-49

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.28 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

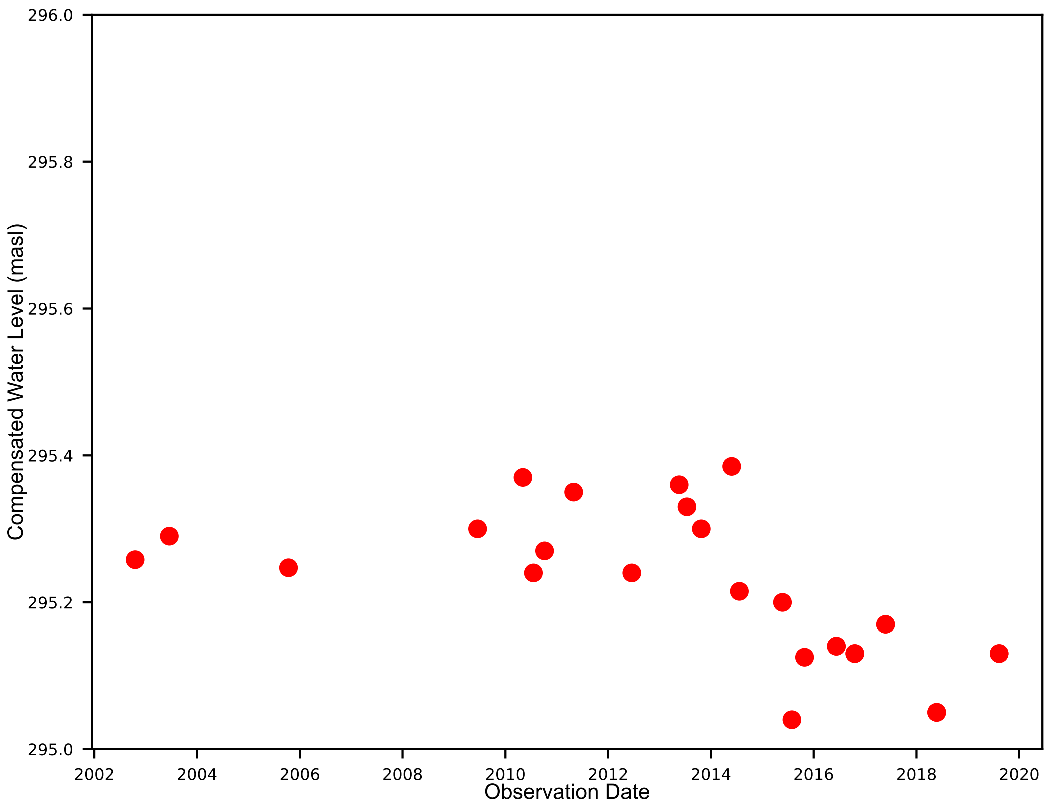
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

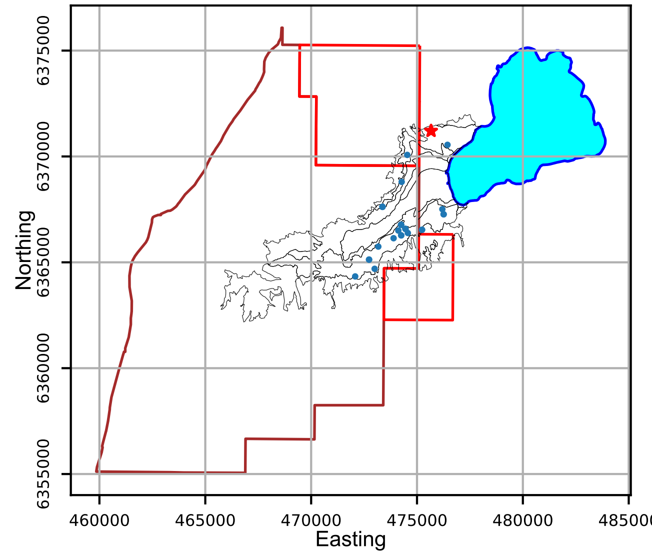
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES631-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-50





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 3.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

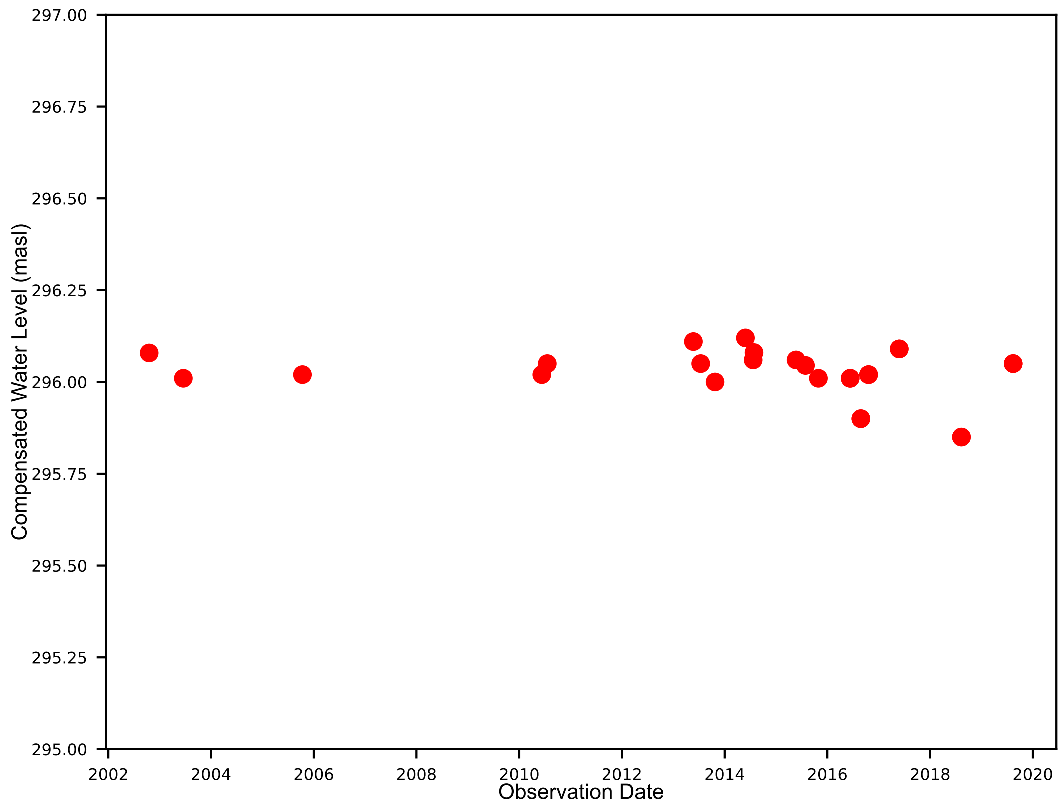
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

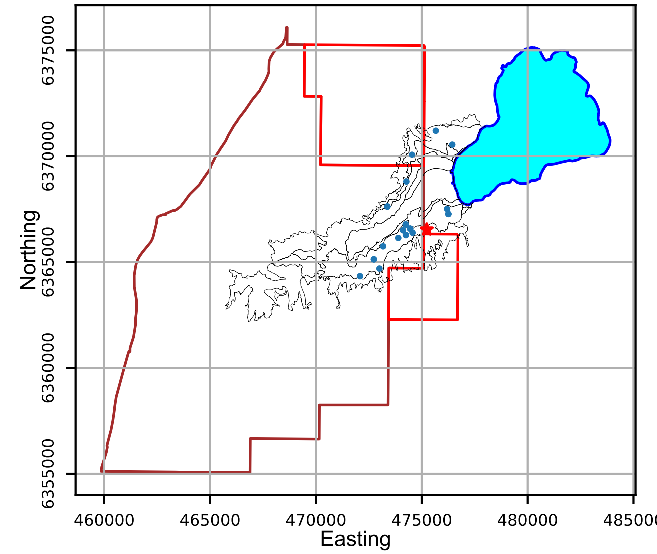
TITLE

MLWC4-P360

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-51

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

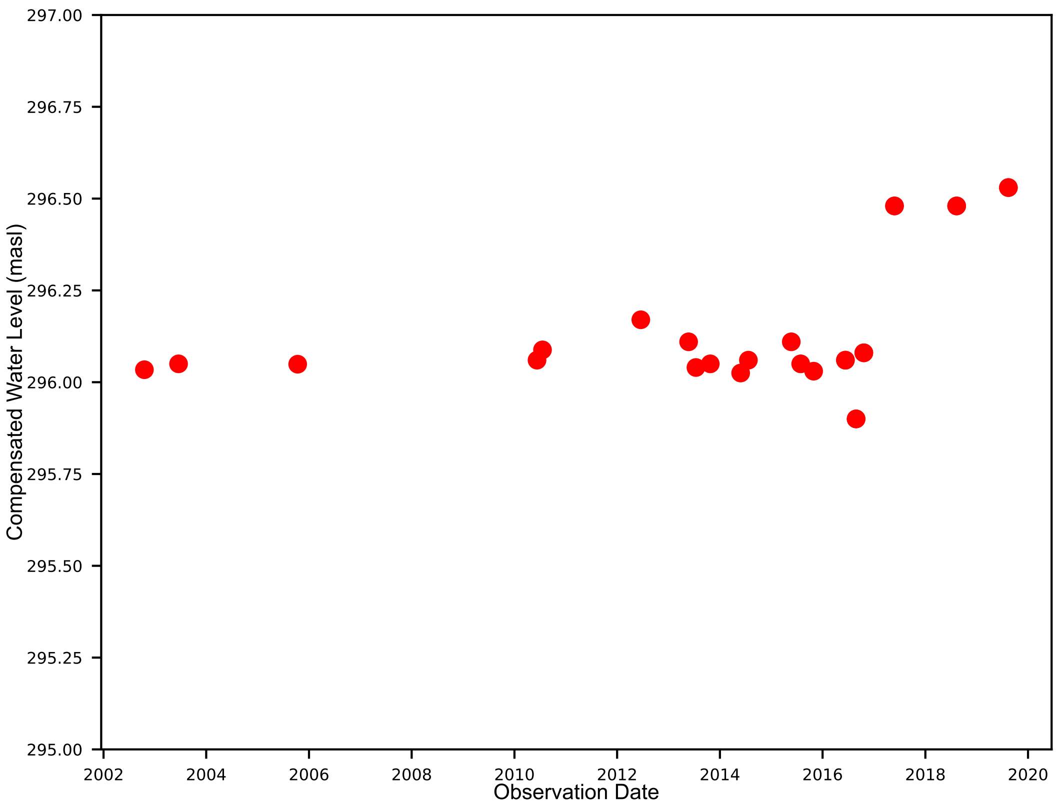
TITLE

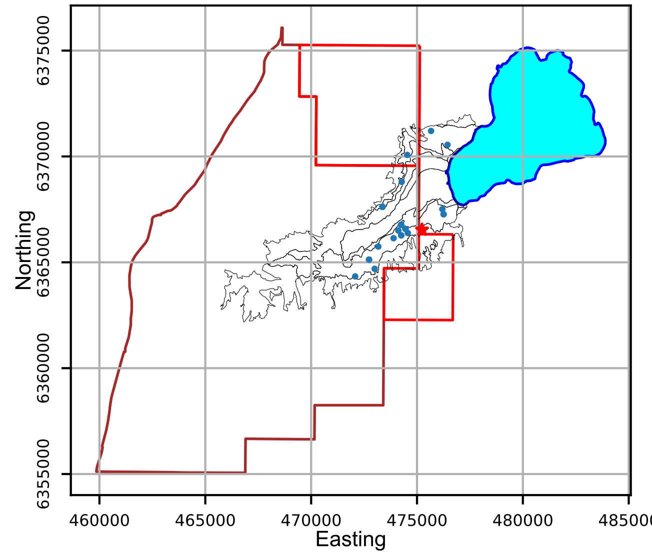
MLWC5-P100

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-52

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 1.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

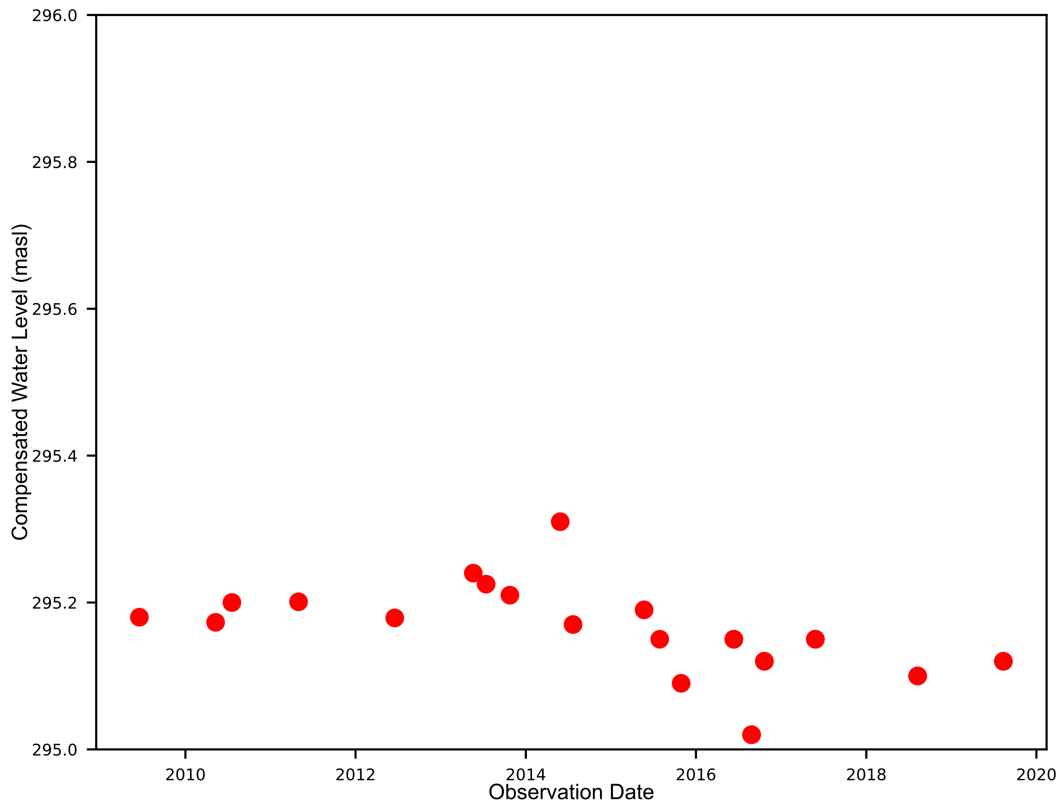
FORTHILLS
Operated by Suncor Energy

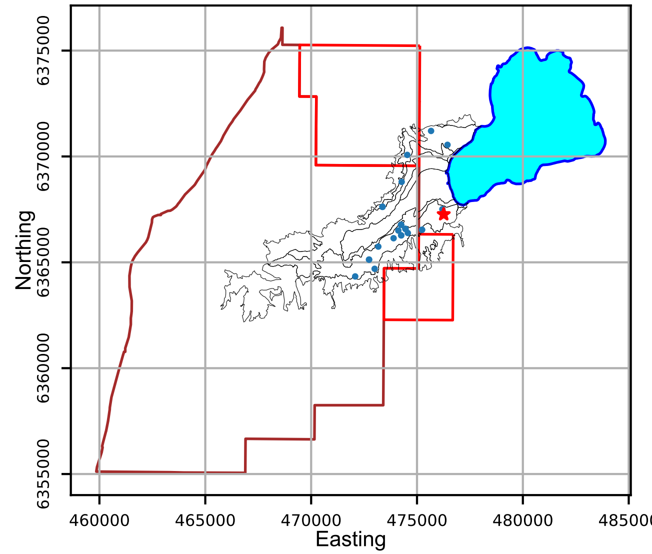
TITLE

MLWC5-P200

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-53

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

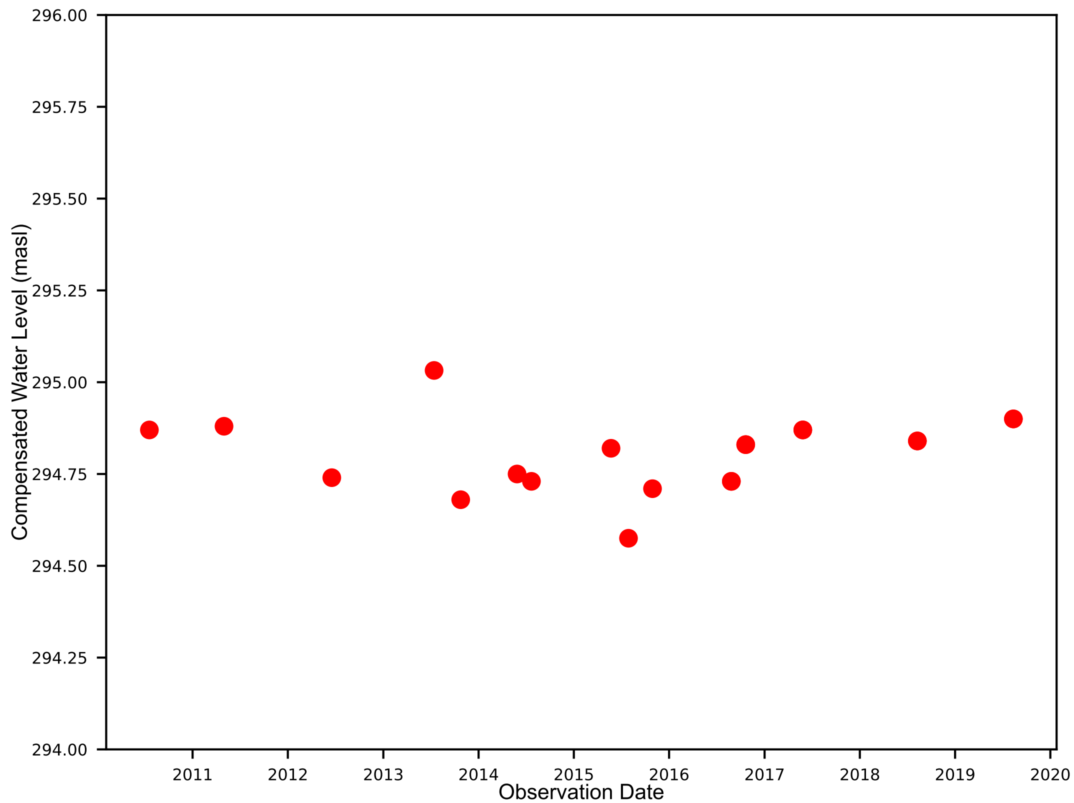
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

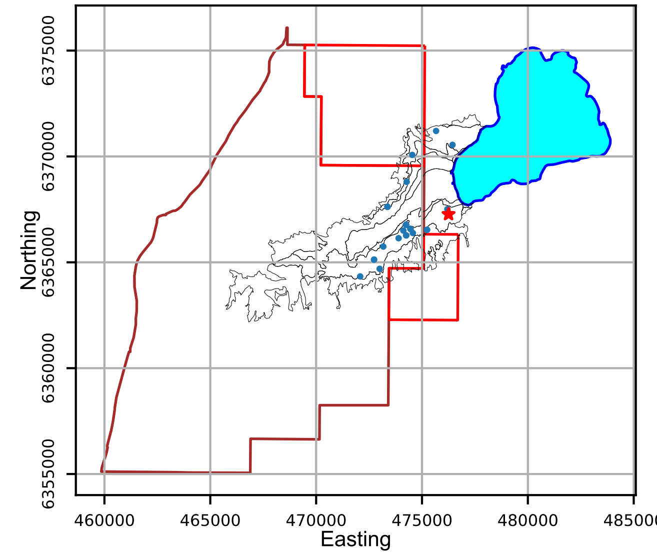
TITLE
MW08-304A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-54

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 0 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

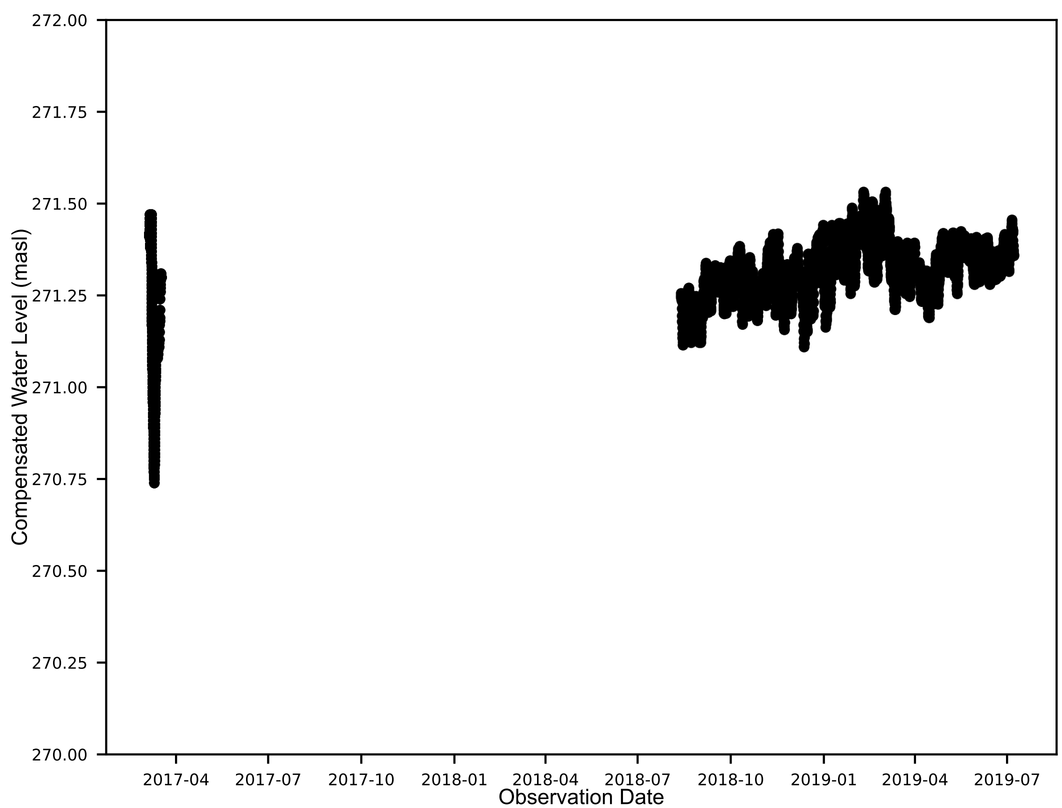
TITLE
MW08-304B

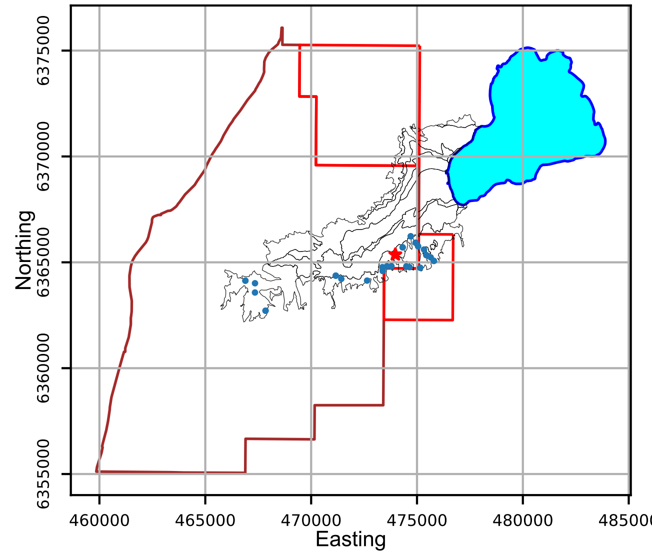
PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B5-55

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

B6 Hydrographs for Ecohydrology Zone 6

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 105 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS

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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

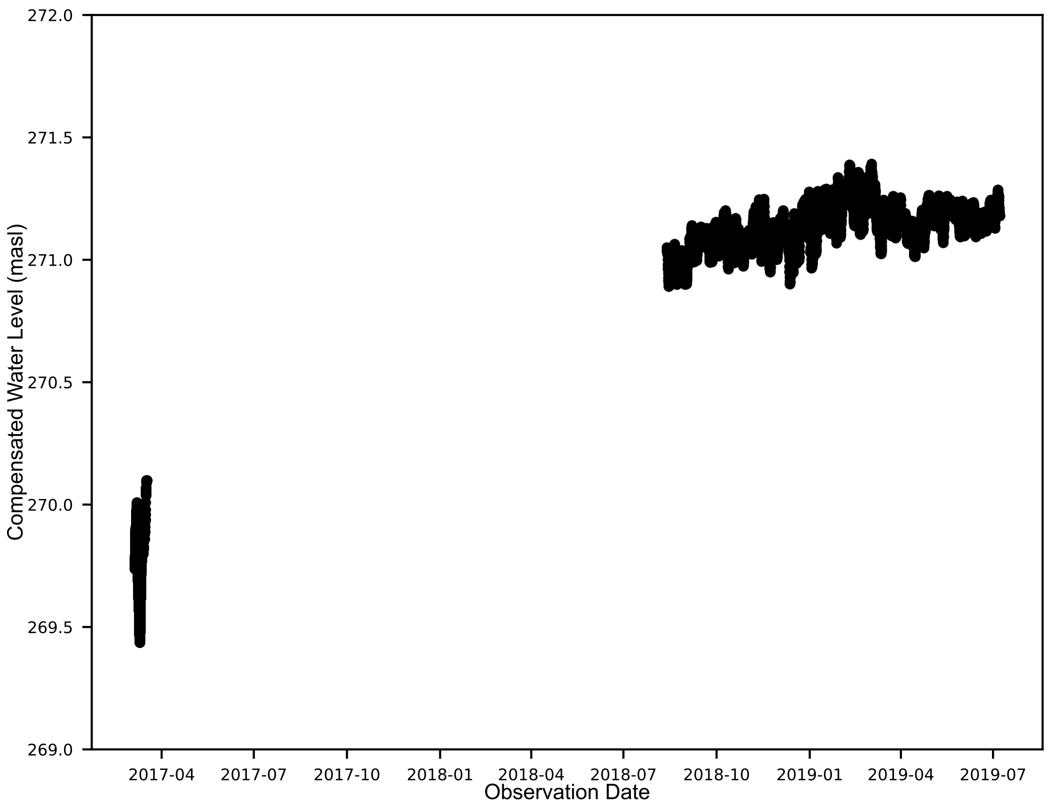
TITLE

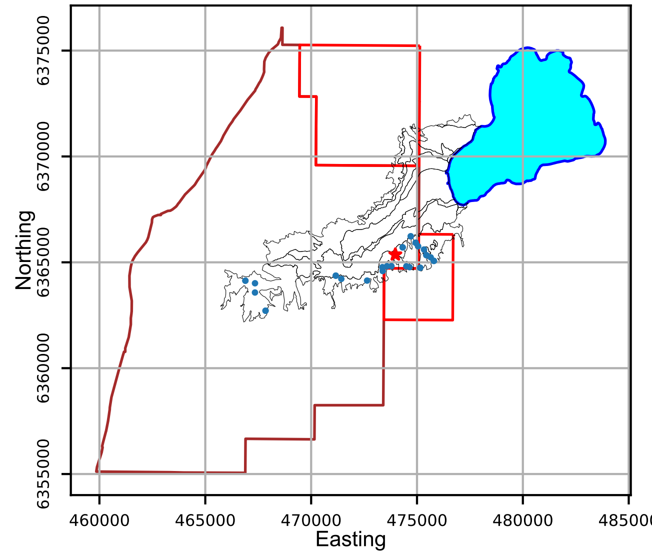
FH17-WR403-MR1 - 105.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 118 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

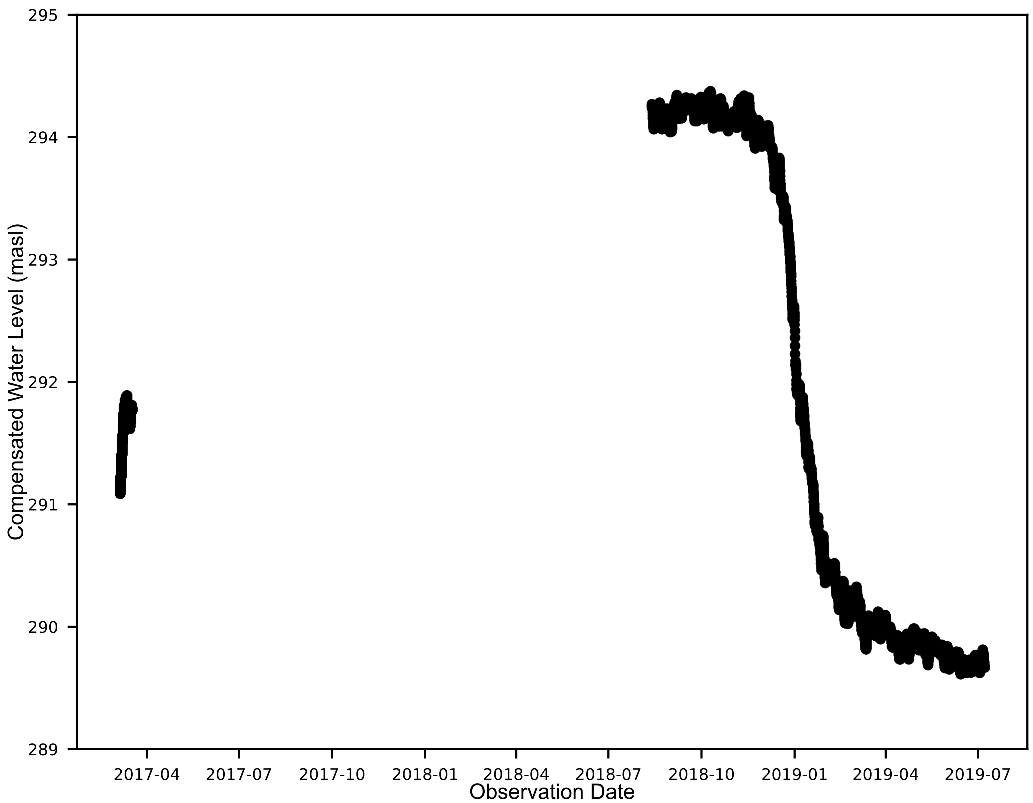
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

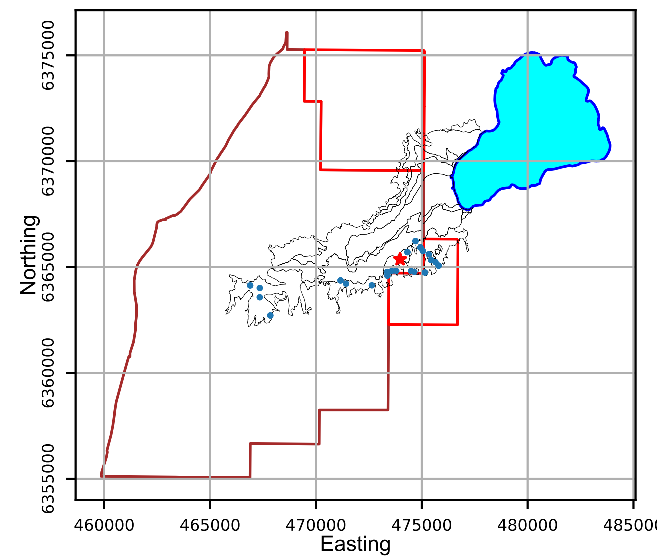
TITLE

FH17-WR403-MR1 - 118.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-2

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 80 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

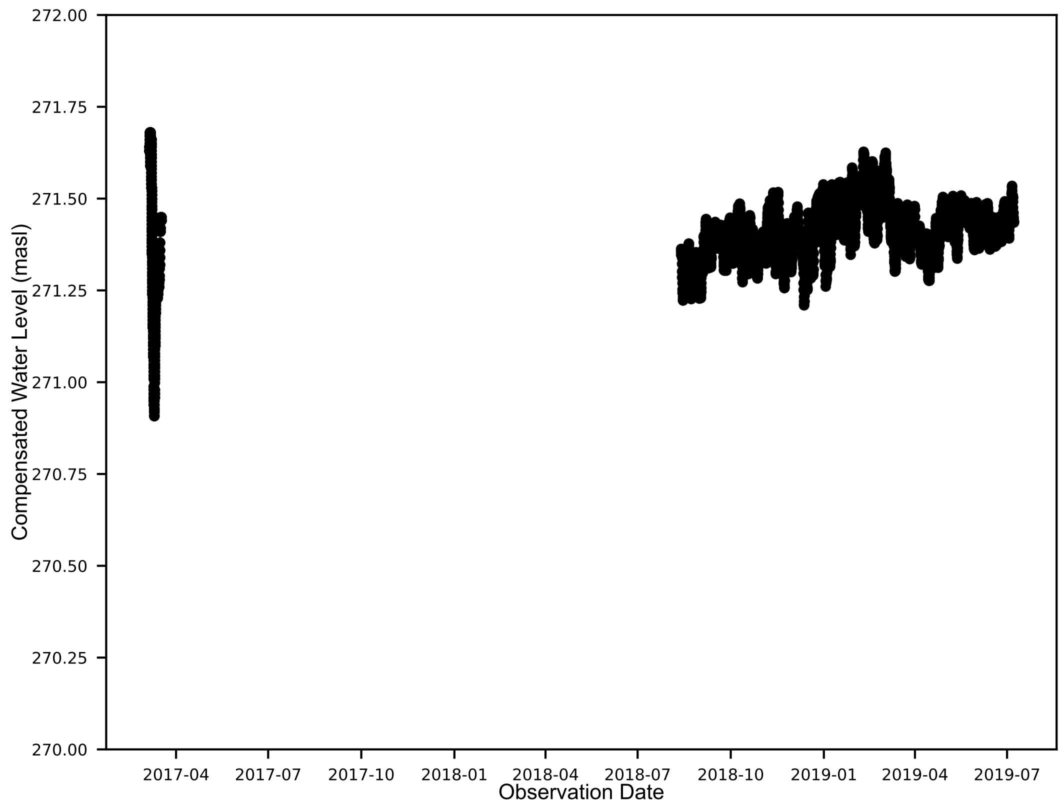
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

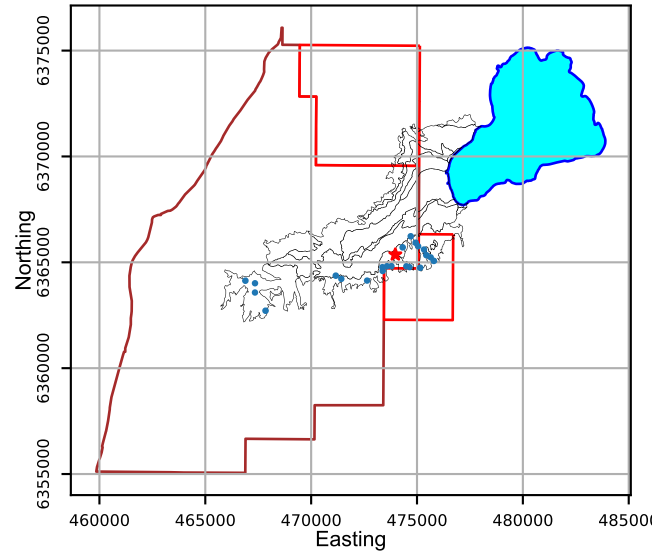
TITLE

FH17-WR403-MR1 - 80.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-3

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 95 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR403-MR1 - 95.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-4

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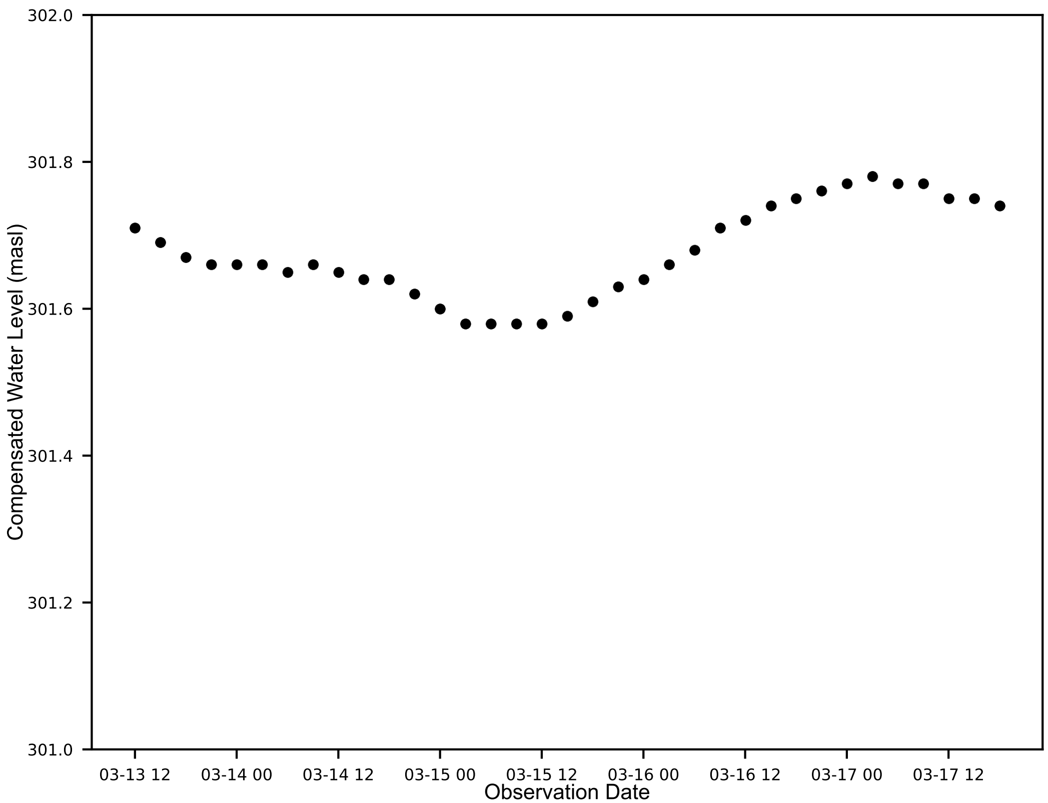
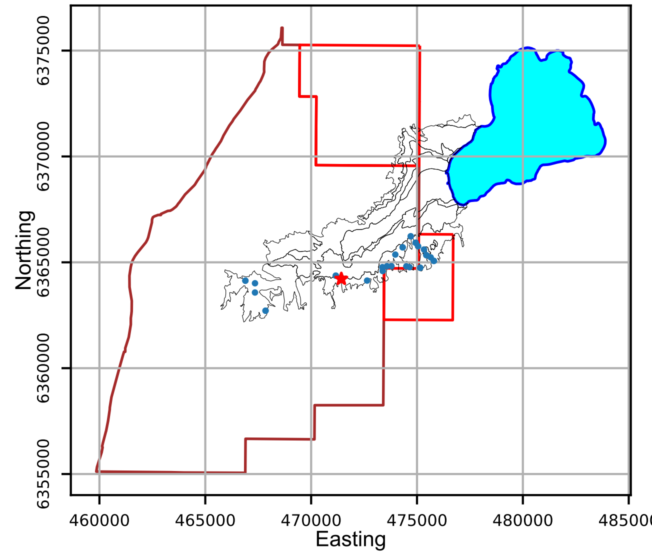




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

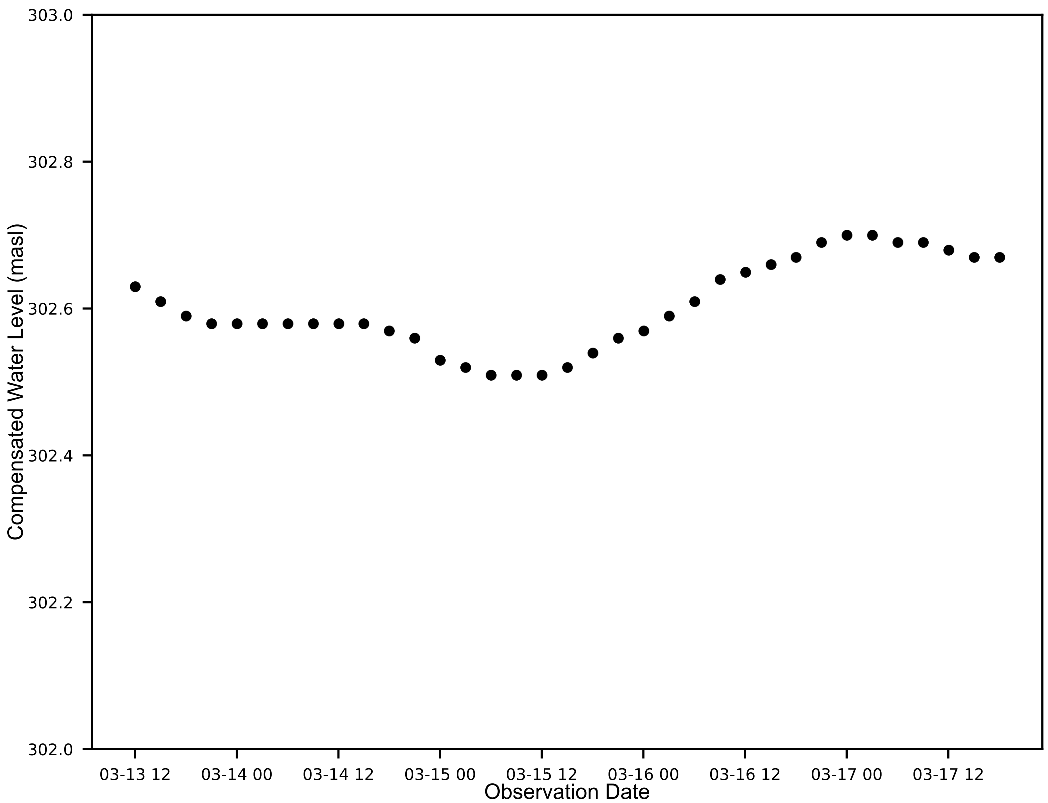
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

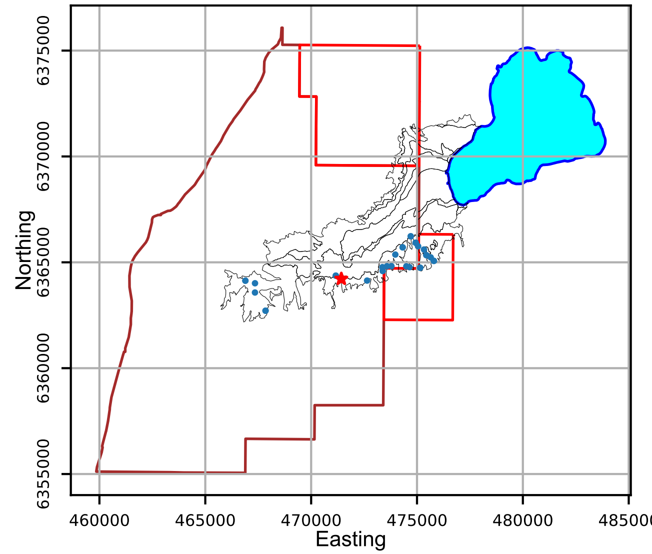
TITLE

FH17-WR424-SN1 - 2.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-5

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

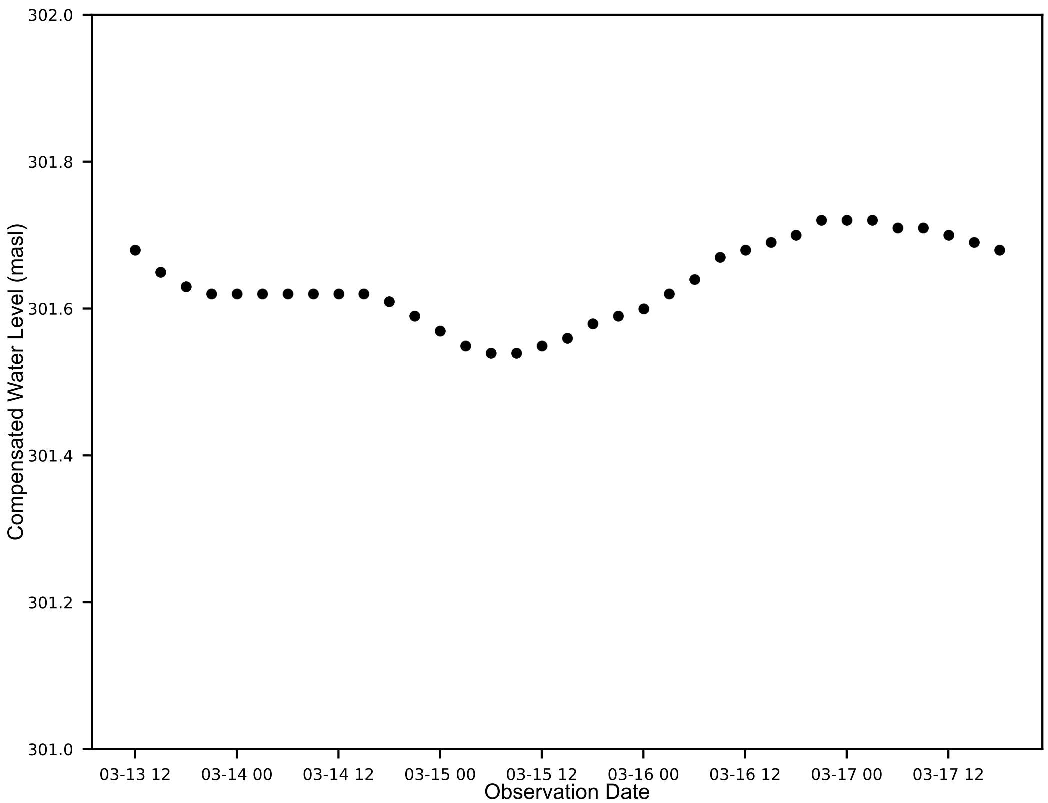
TITLE

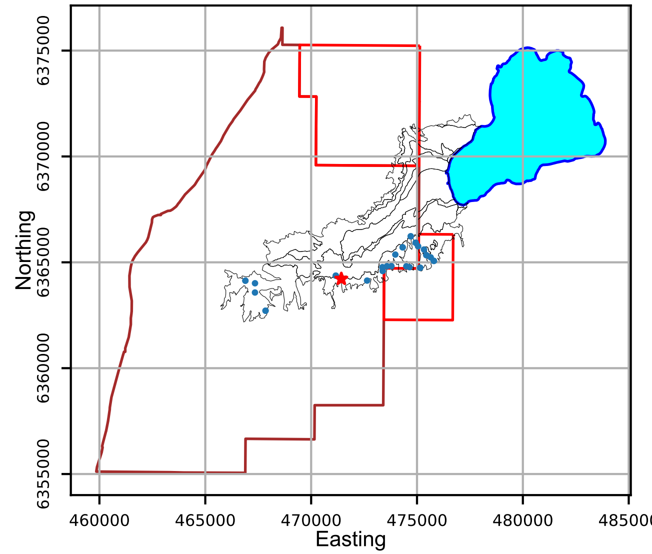
FH17-WR424-SN1 - 4.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-6

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Indeterminate
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

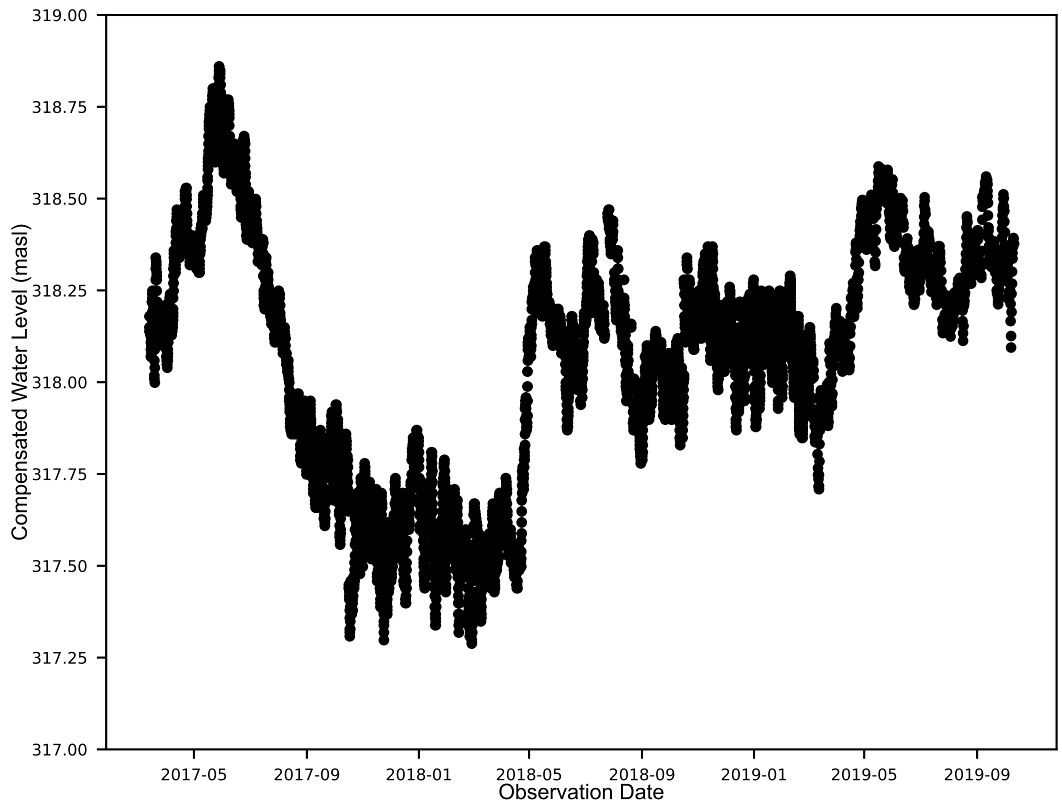
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

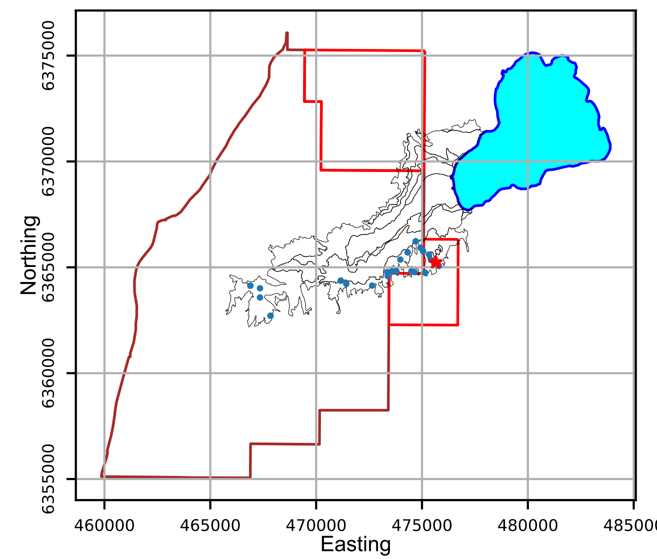
TITLE

FH17-WR424-SN1 - 7.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-7

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 08 Till Aquitard AT2

Depth of Measurement: 18.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

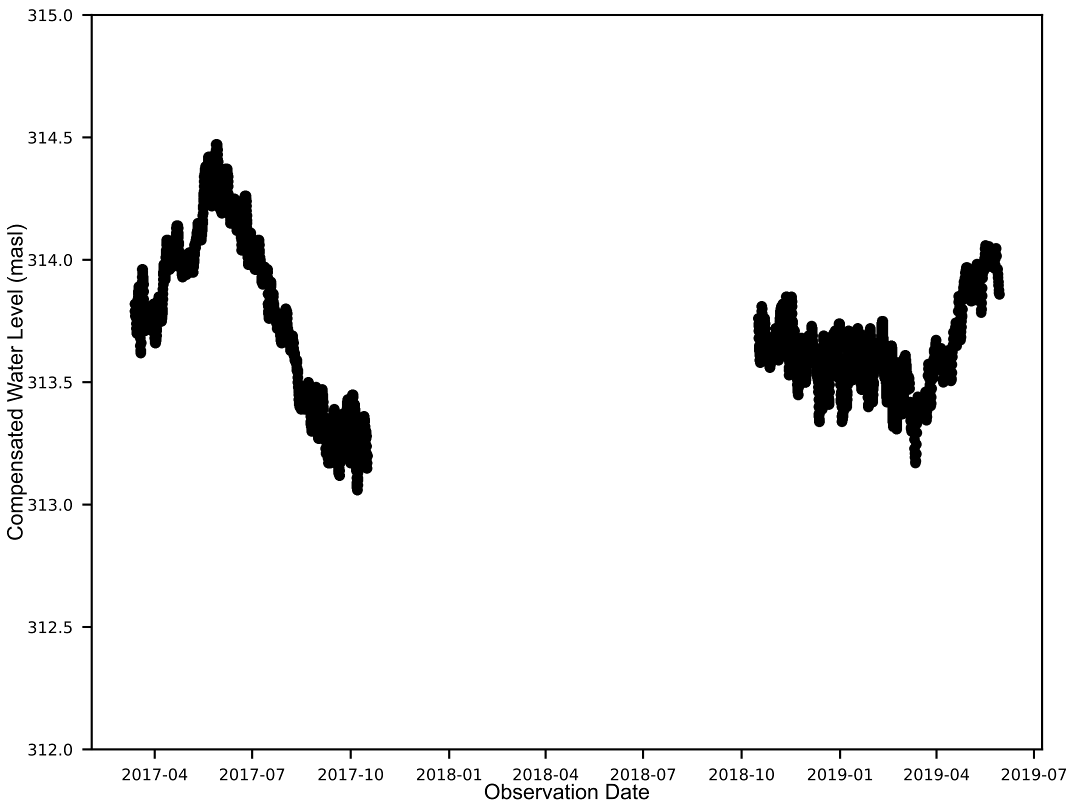
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

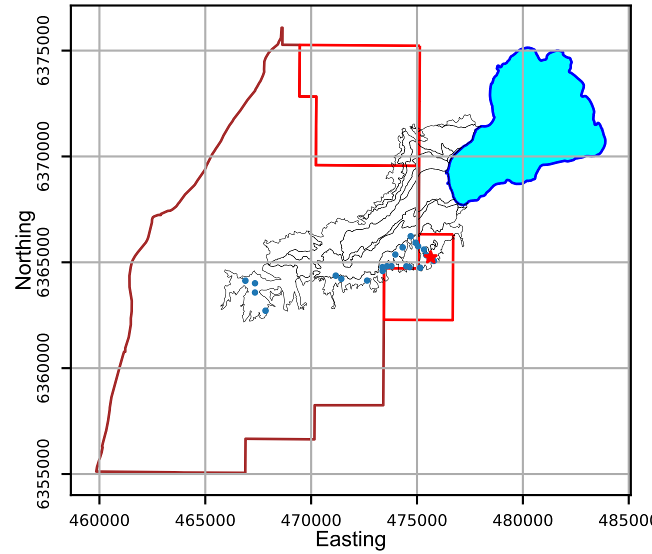
TITLE

FH17-WR436-SN1 - 18.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-8

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 24.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

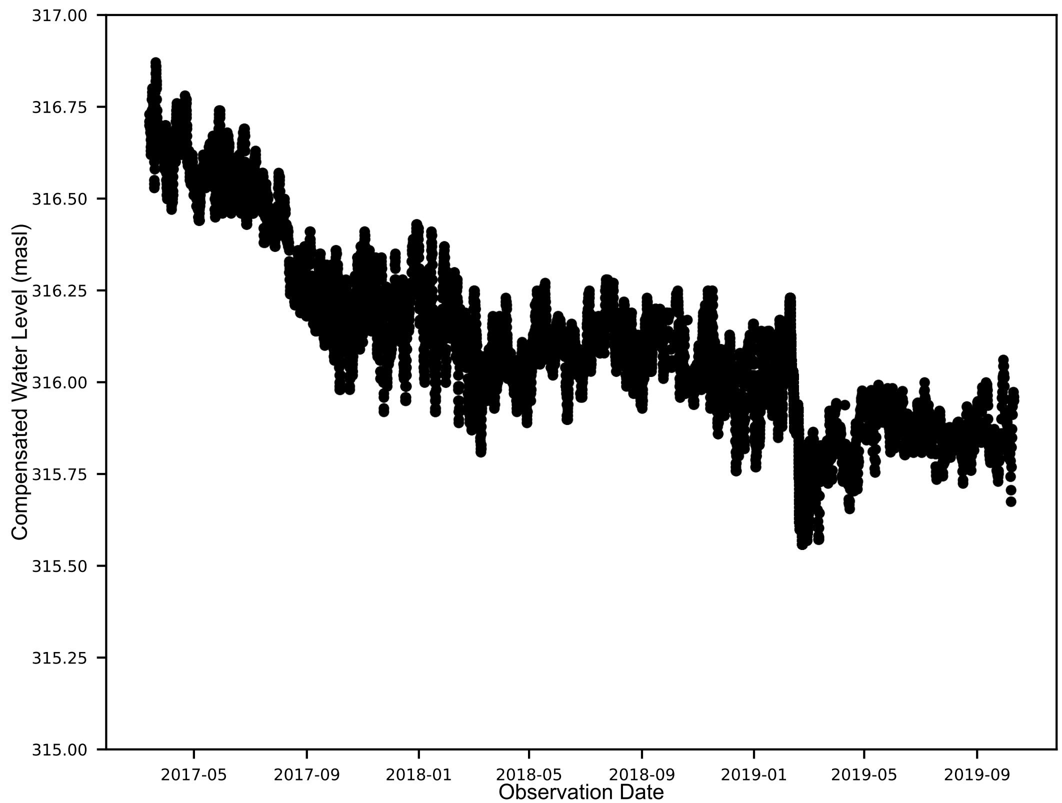
FORTHILLS
Operated by Suncor Energy

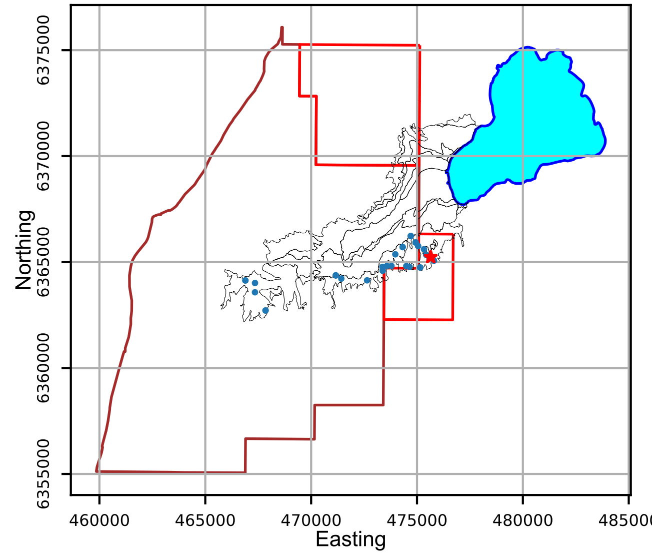
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR436-SN1 - 24.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-9

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR436-SN1 - 36.4 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-10

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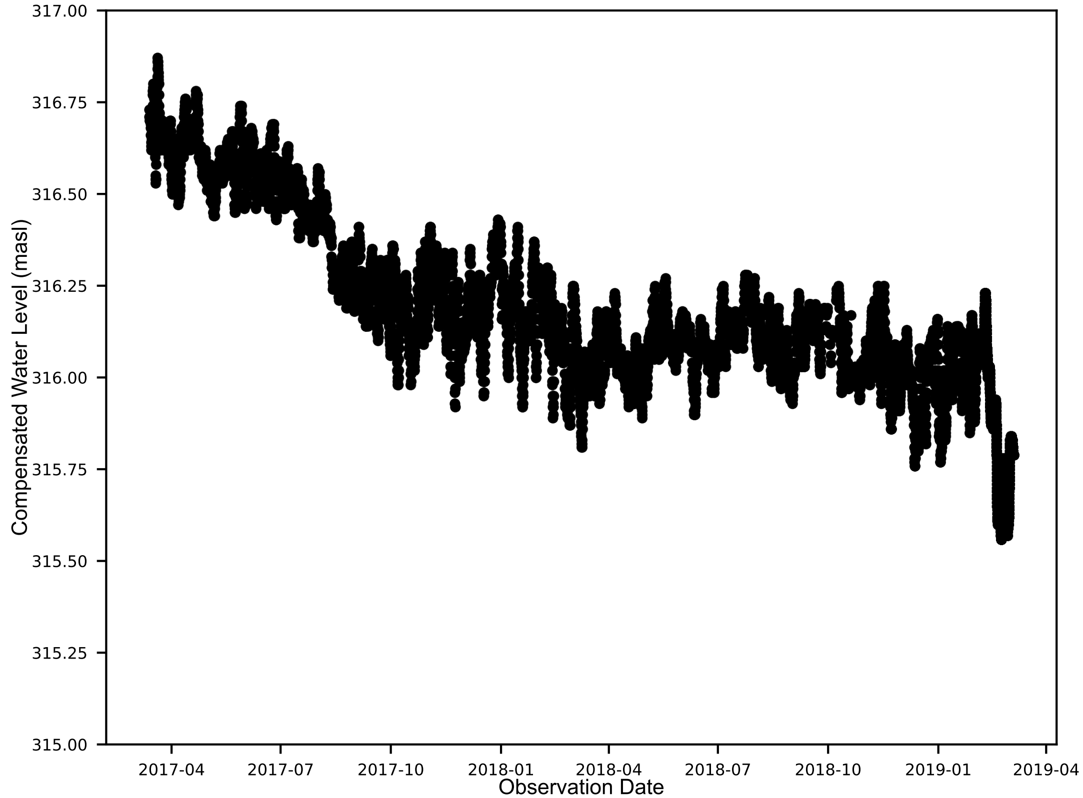
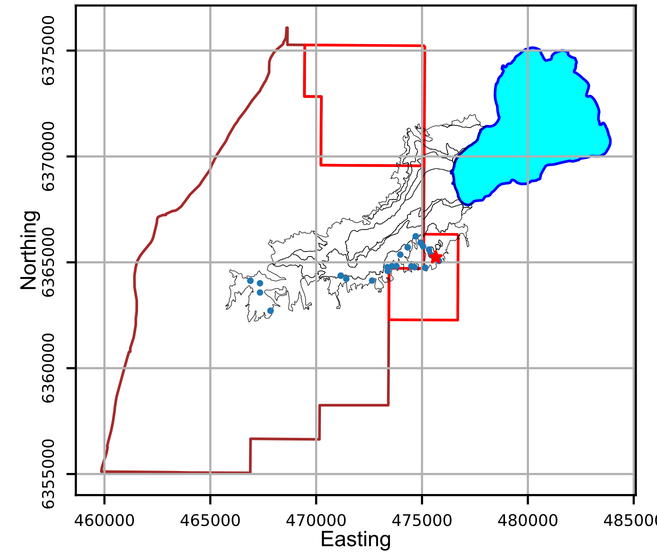




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 36.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

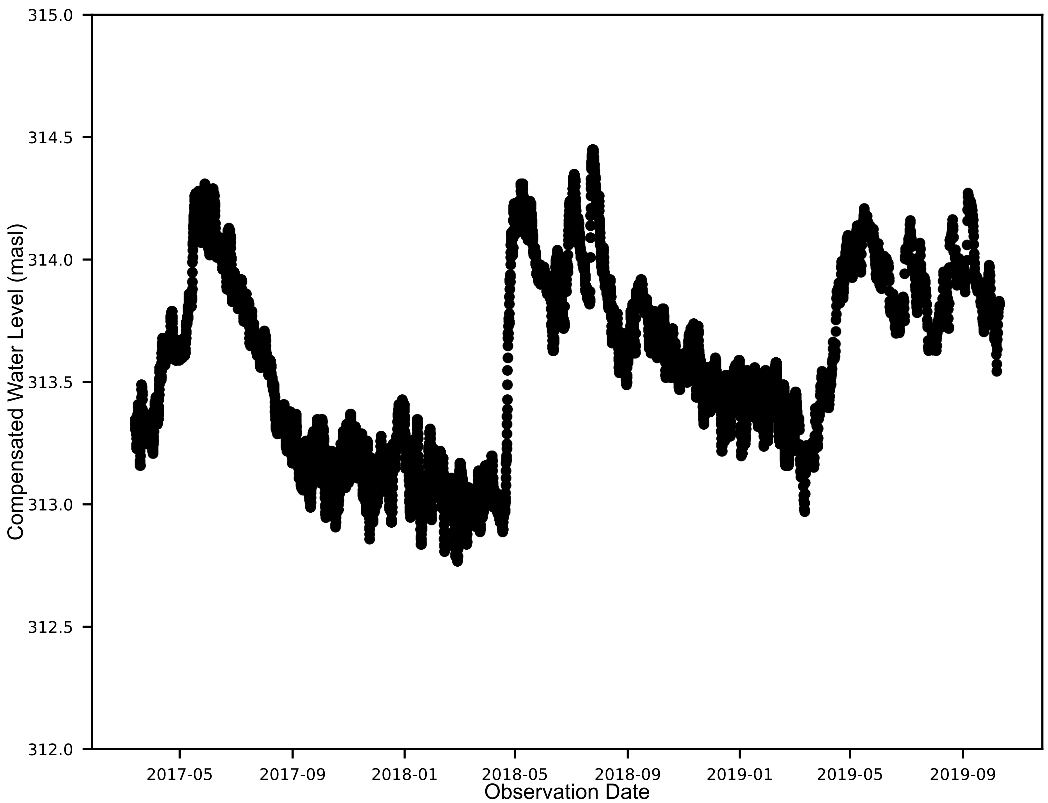
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

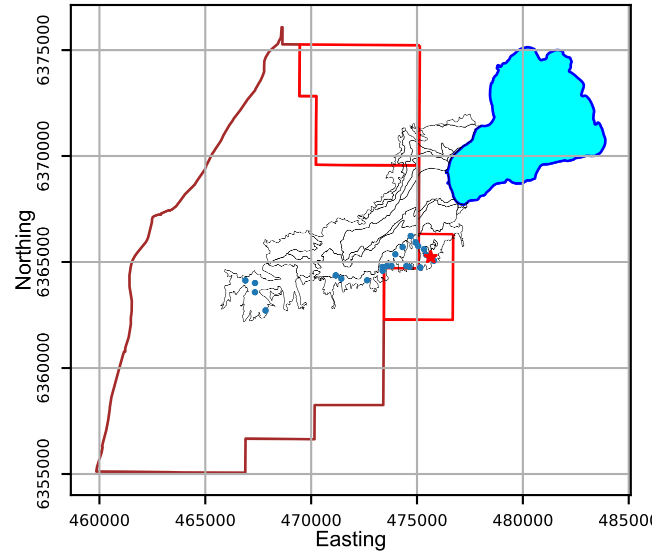
FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR436-SN1 - 36.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-11

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

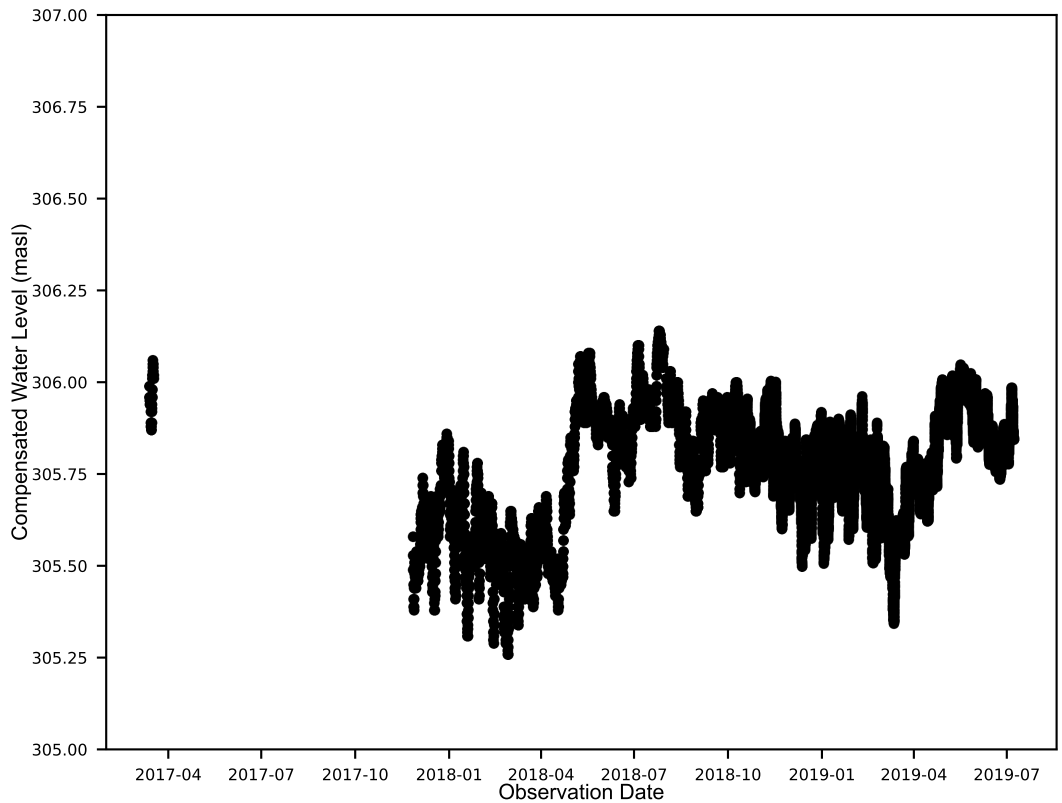
FORT HILLS
Operated by Suncor Energy

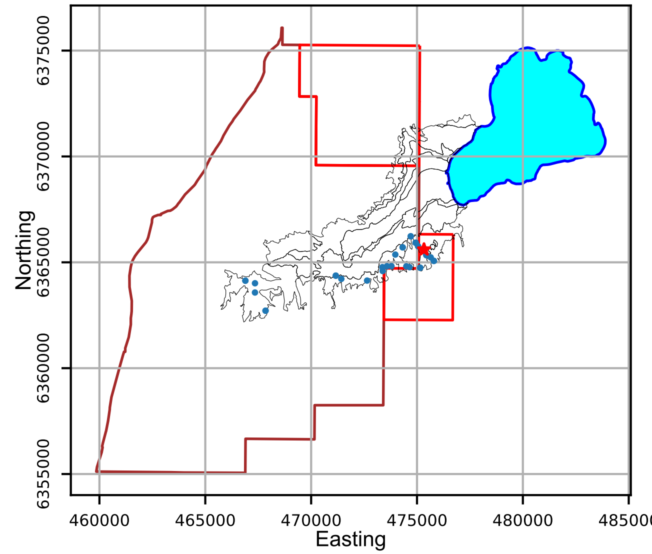
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR436-SN1 - 9.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-12

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR437-SN1 - 14.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-13

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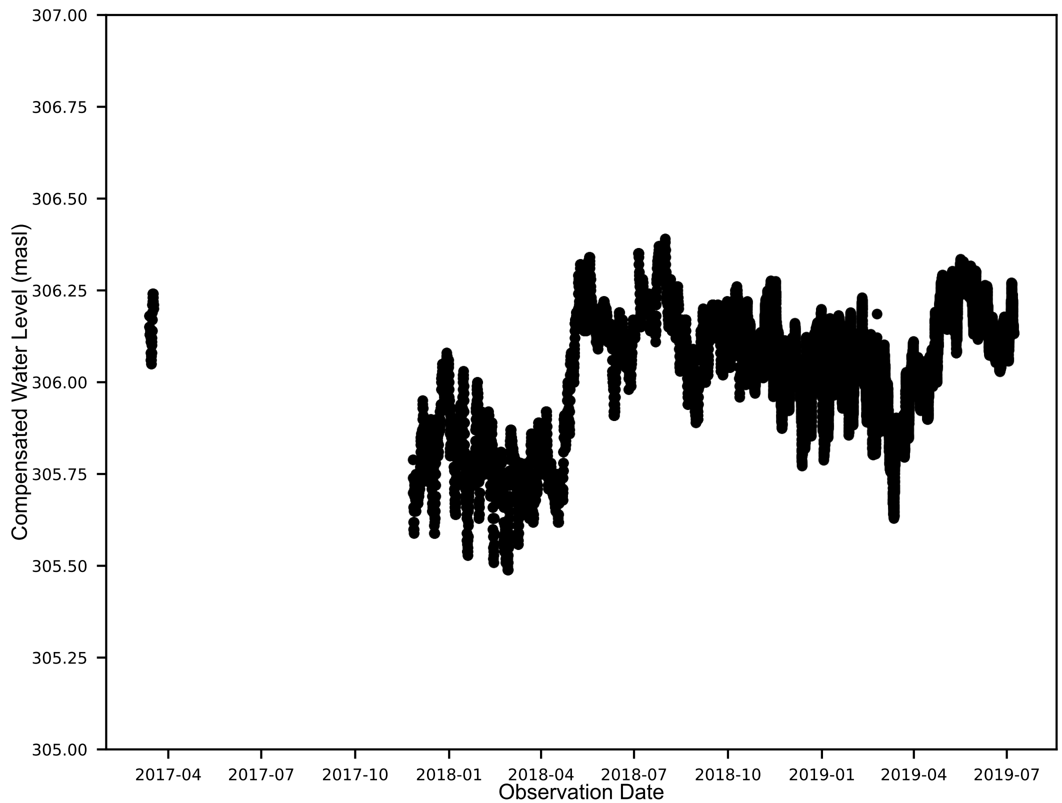
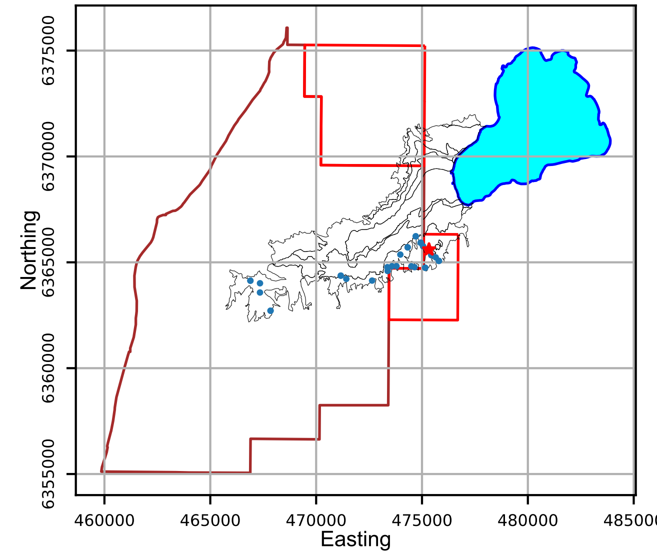
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 30 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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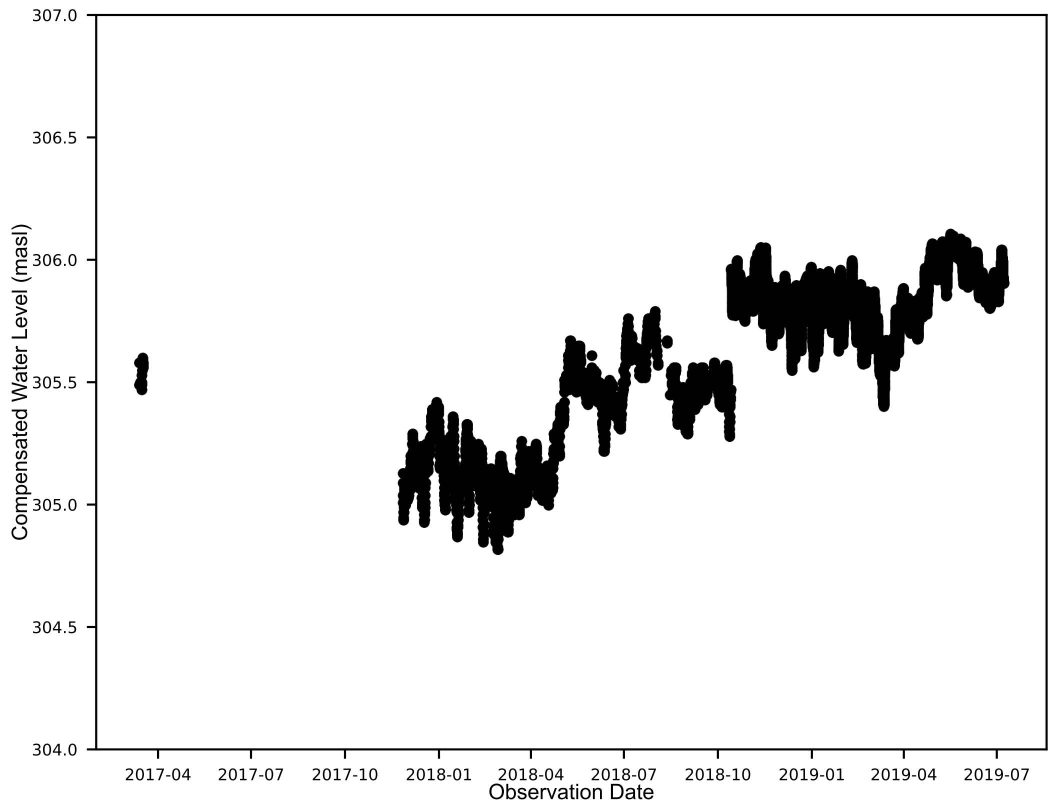
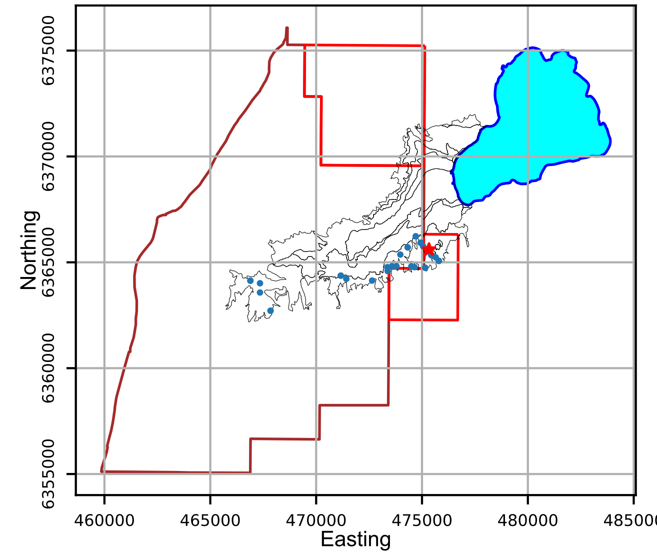
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR437-SN1 - 30.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-14





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 41 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

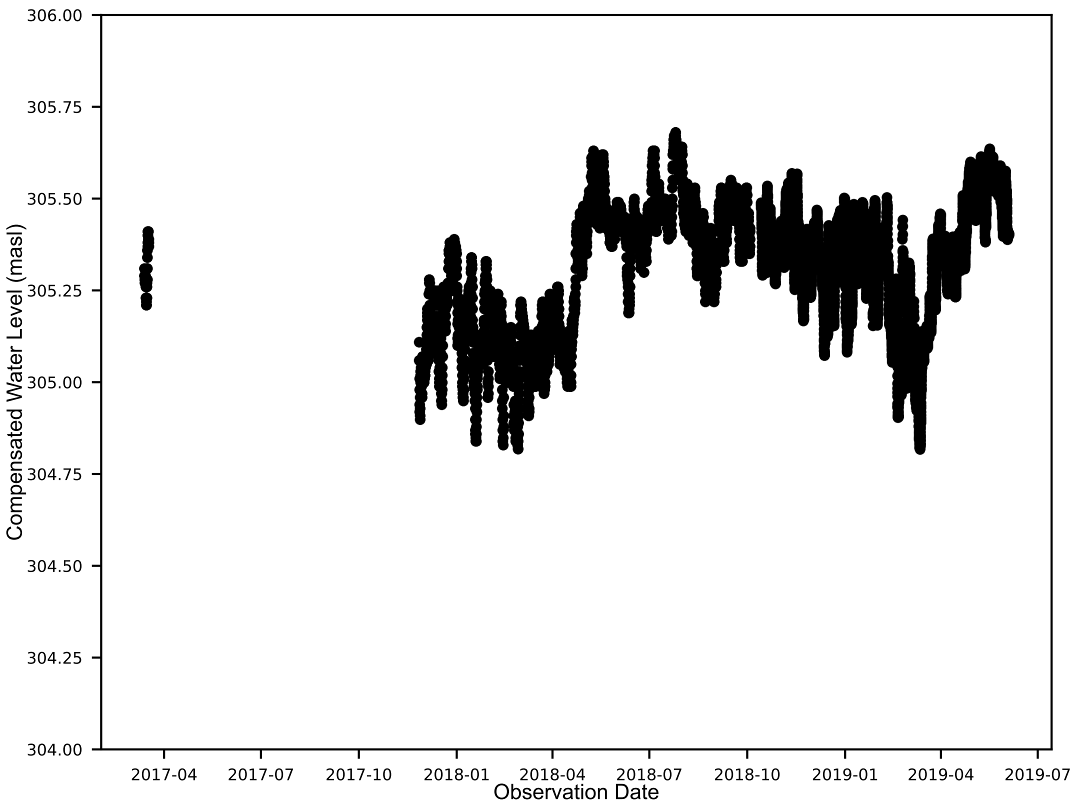
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

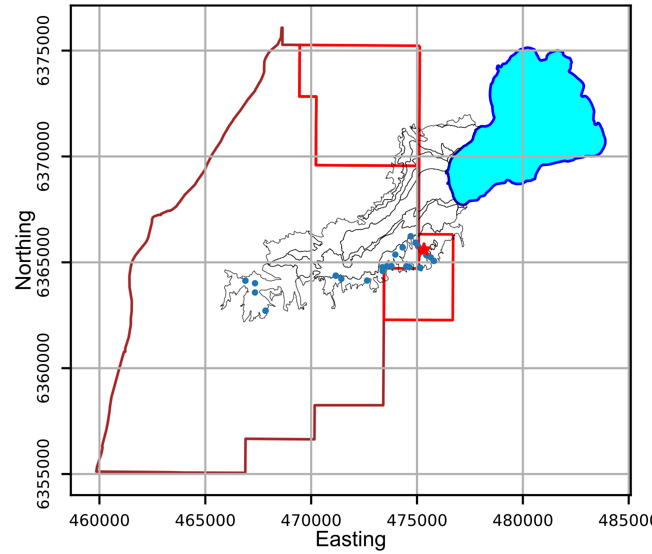
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR437-SN1 - 41.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-15

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

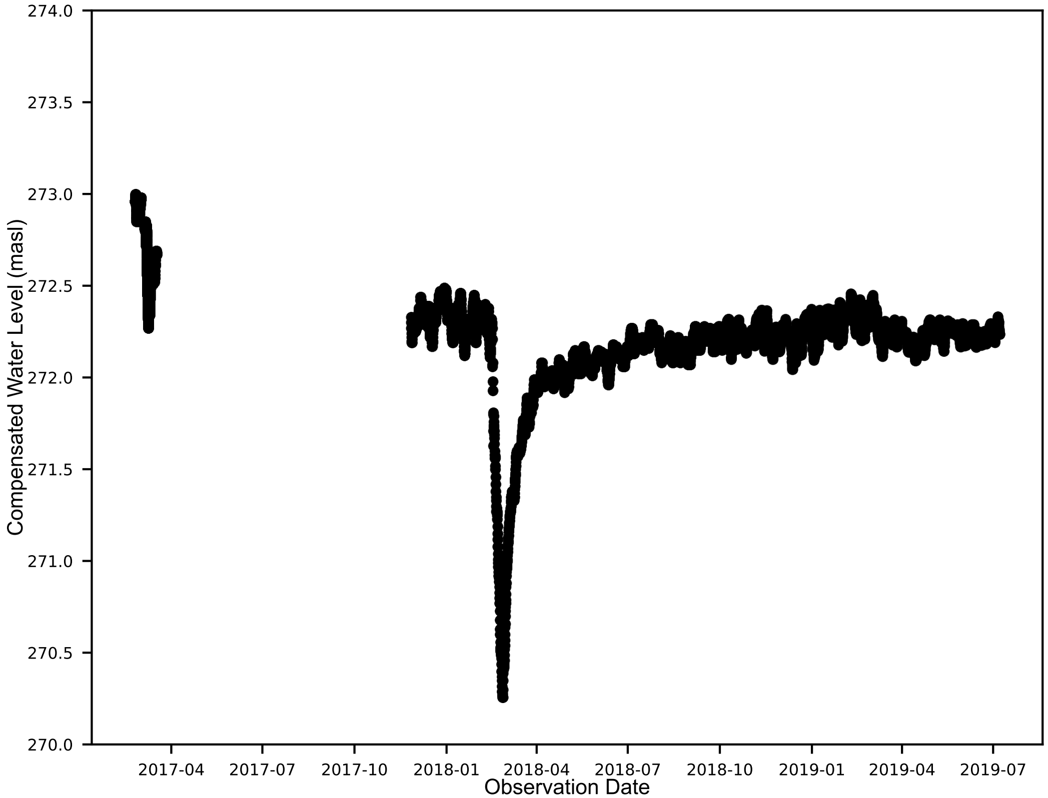
Operated by Suncor Energy

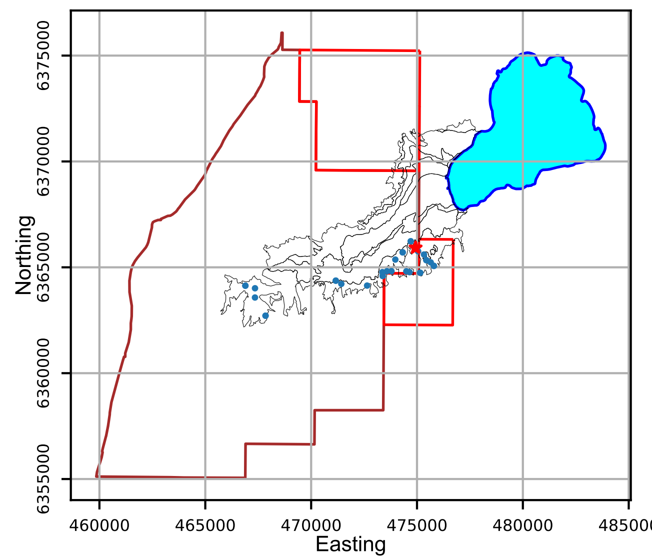
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR437-SN1 - 6.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-16





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 102 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR438-MR1 - 102.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-17

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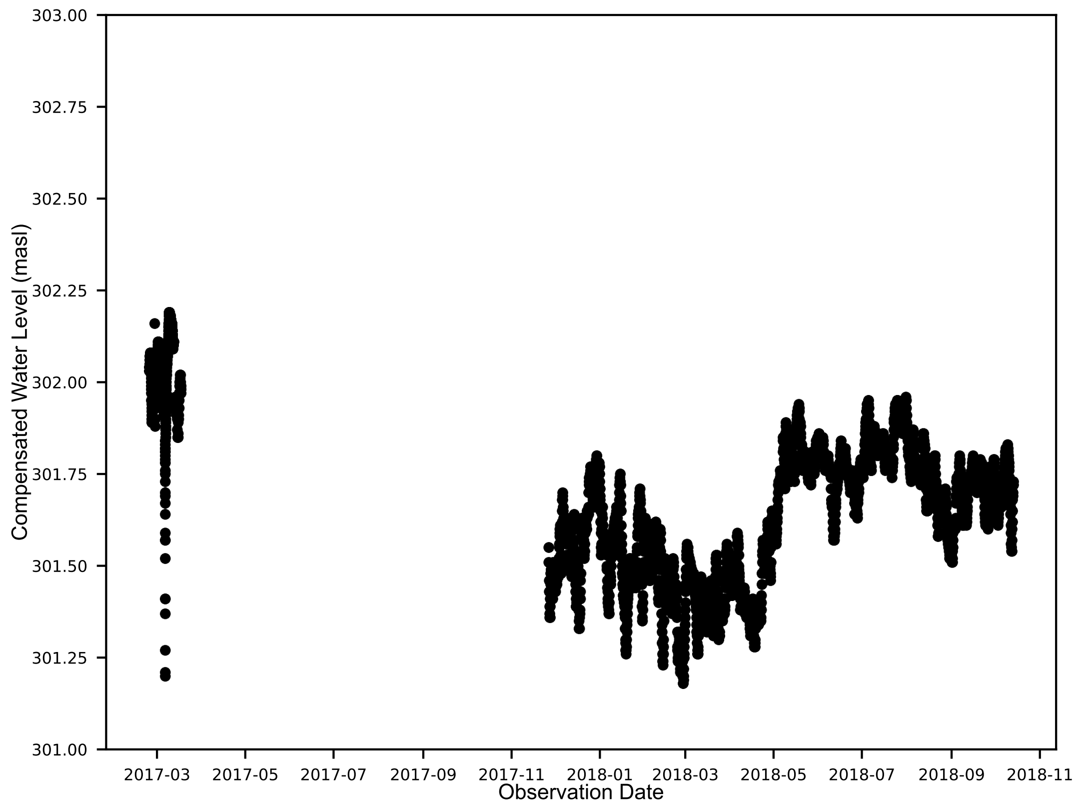

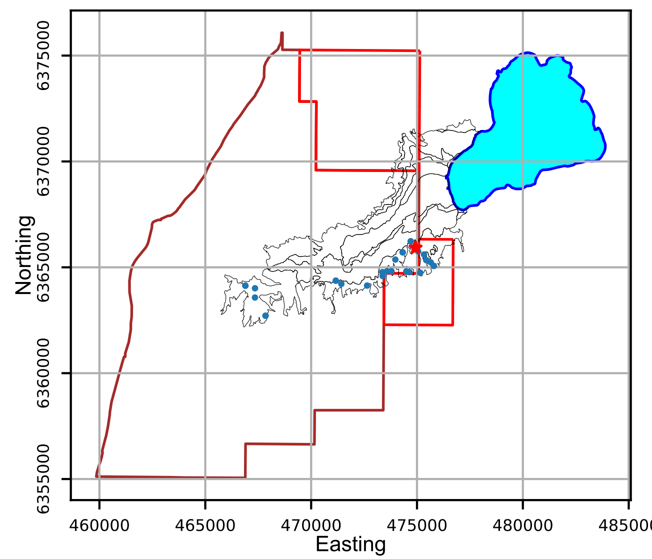

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 38.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR438-MR1 - 38.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-18

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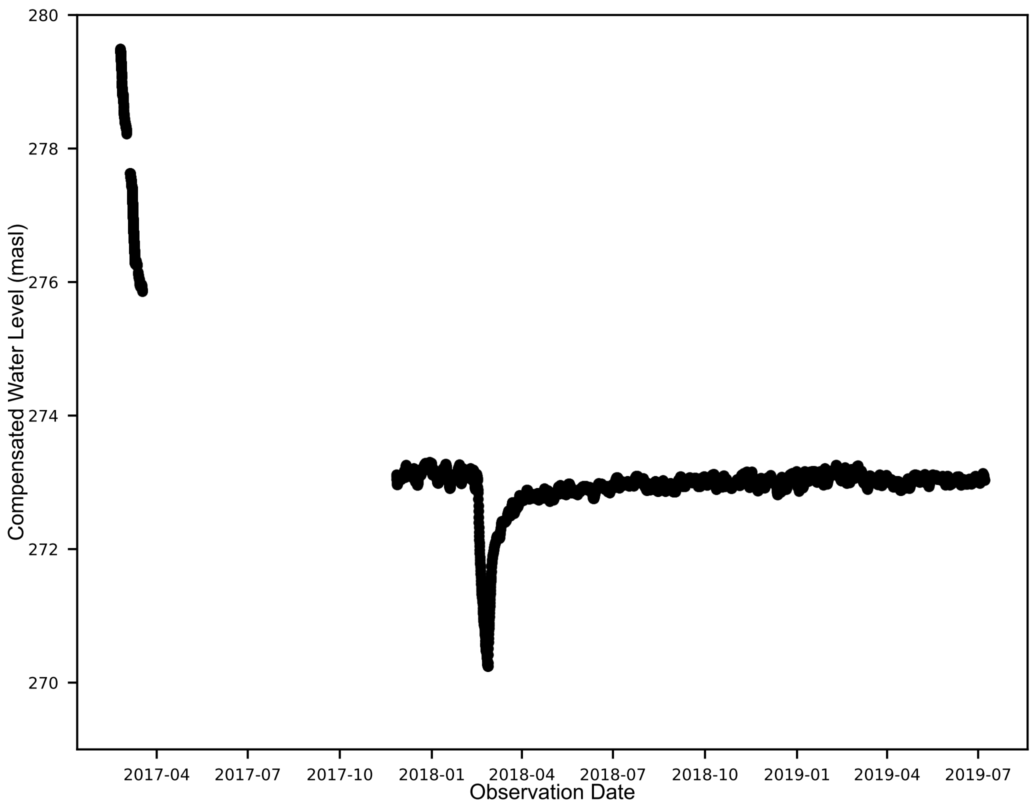

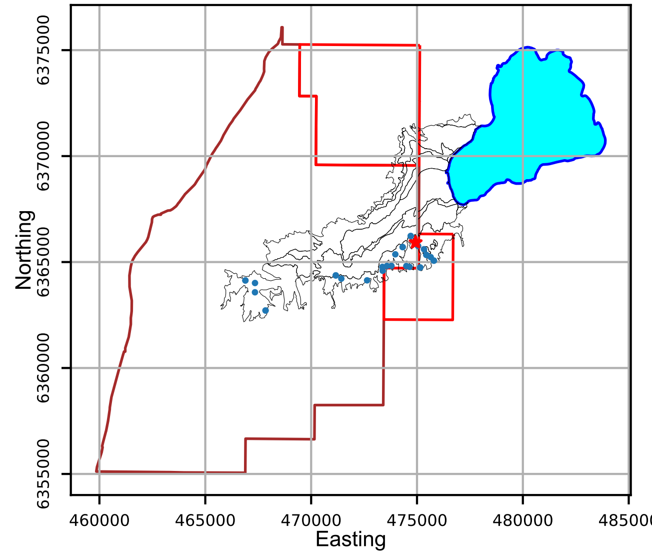

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 57 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH17-WR438-MR1 - 57.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-19

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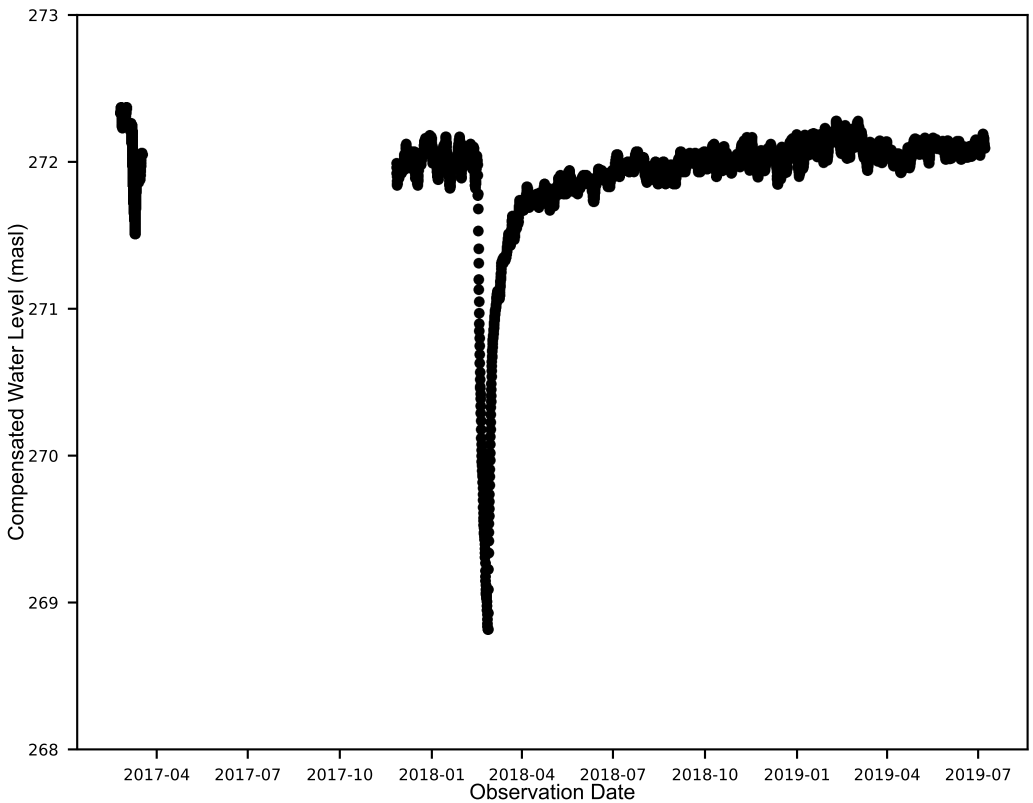

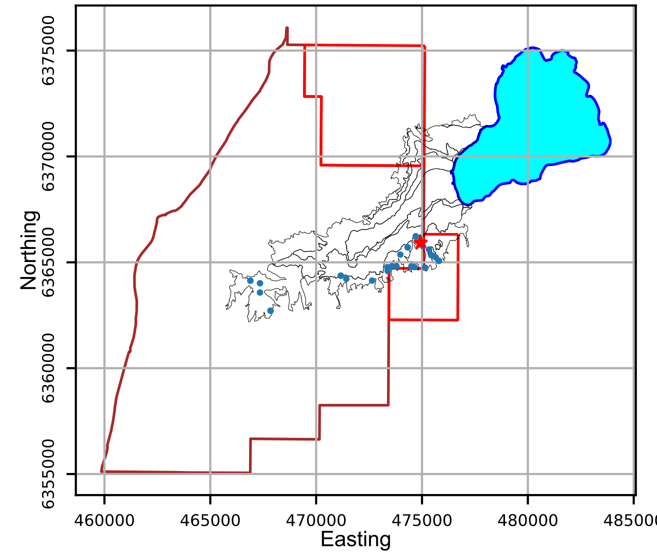

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 88 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR438-MR1 - 88.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-20

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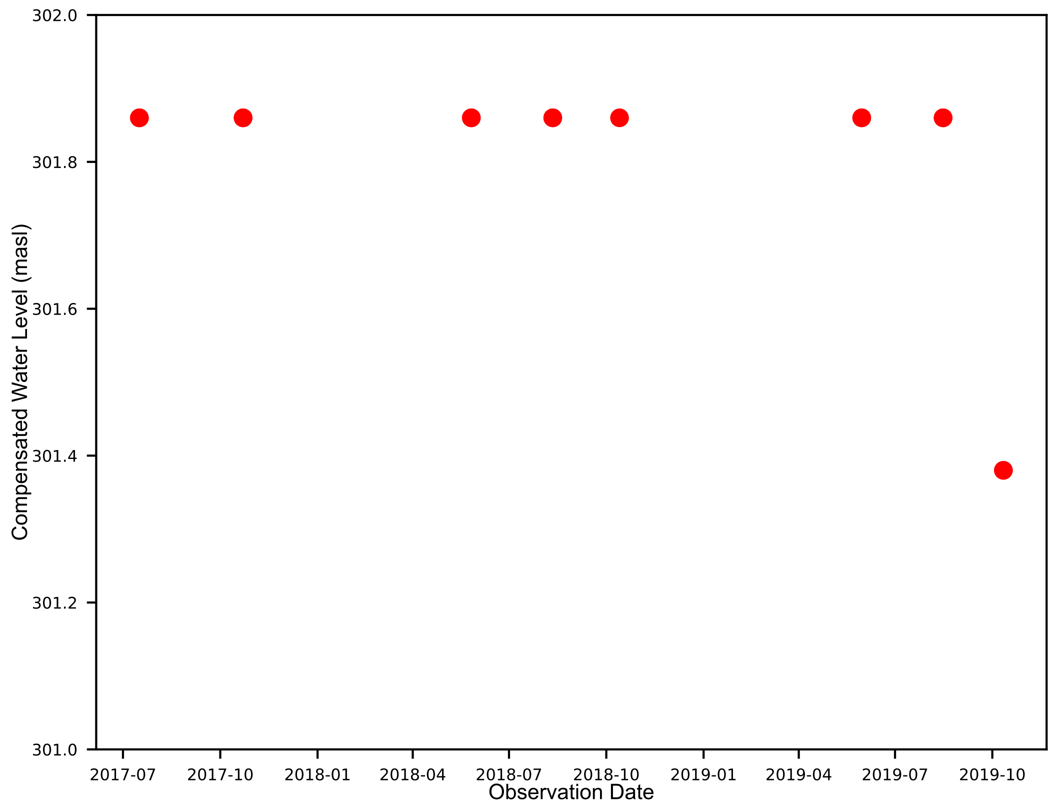

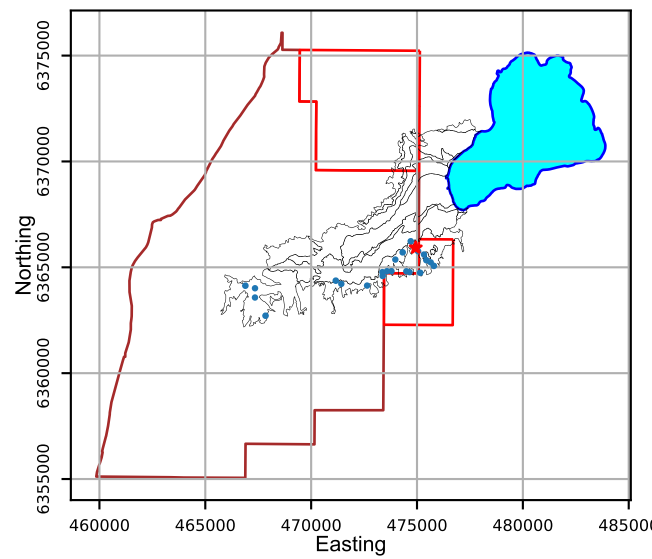

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 31 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE
FH17-WR438-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-21

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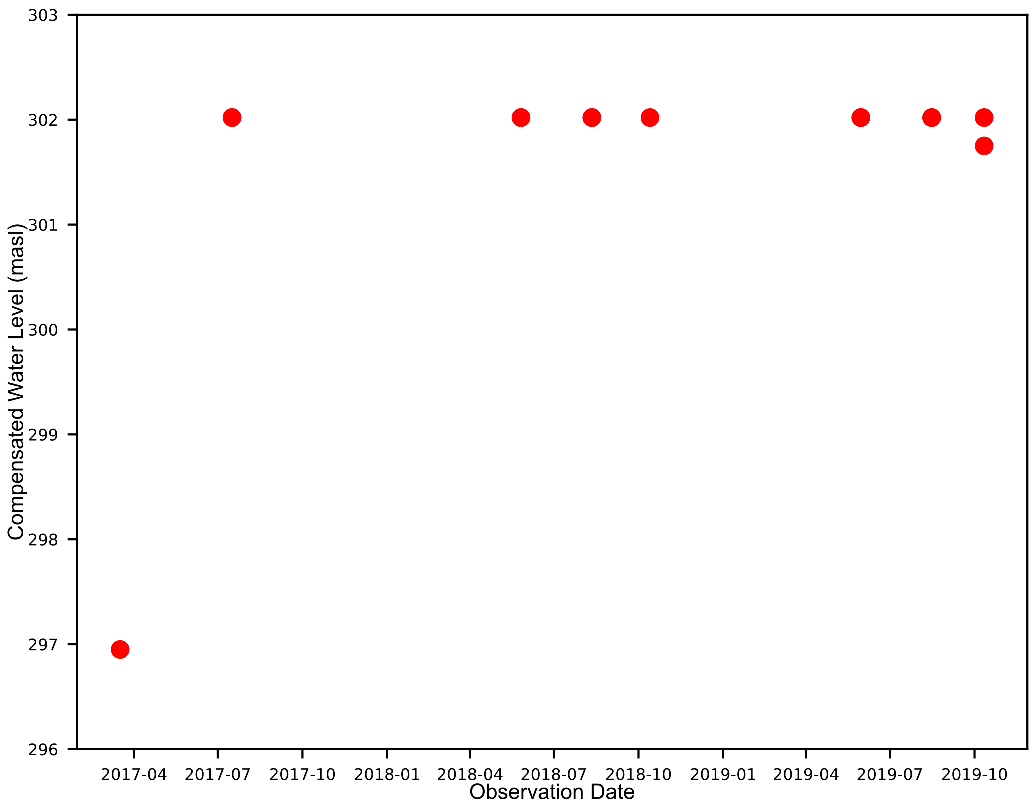

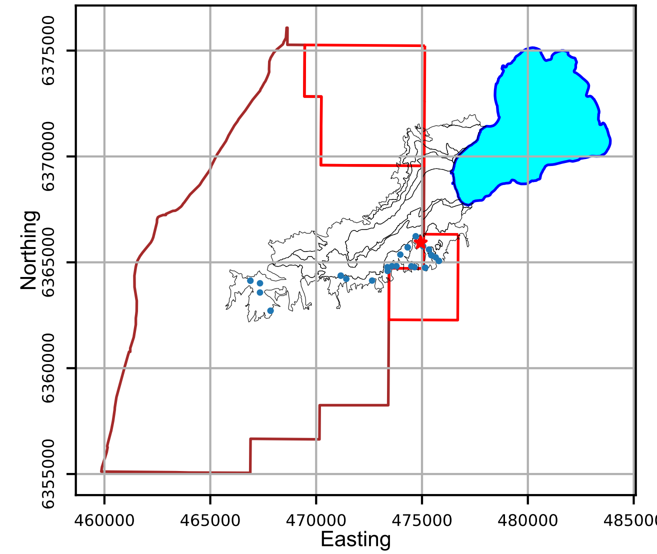

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR438-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-22

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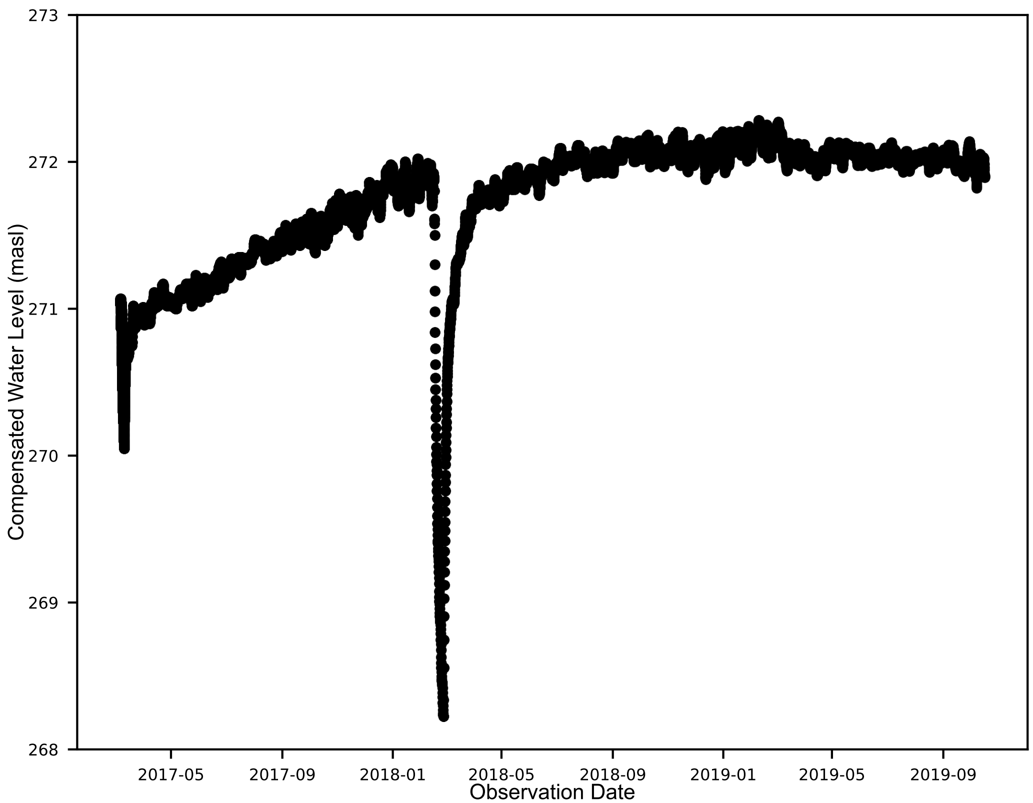

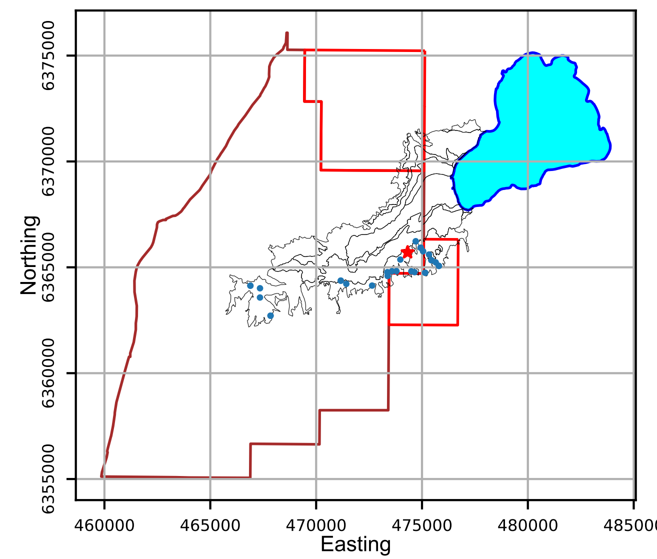

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 105 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR448-MR1 - 105.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B6-23

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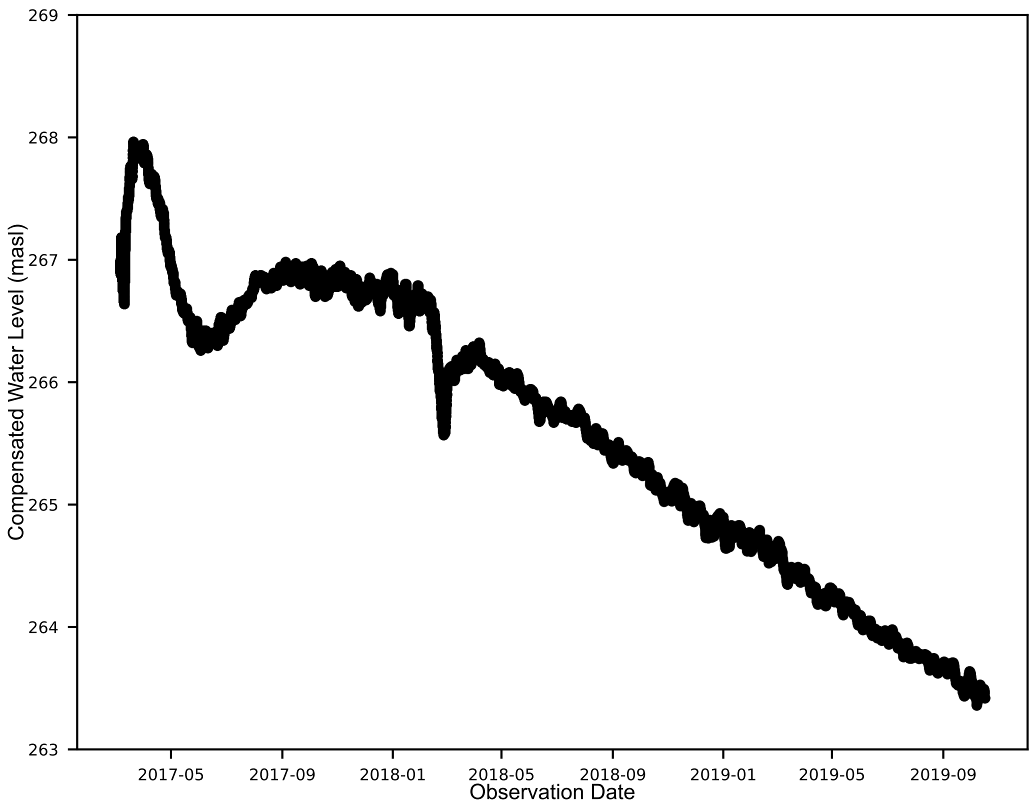

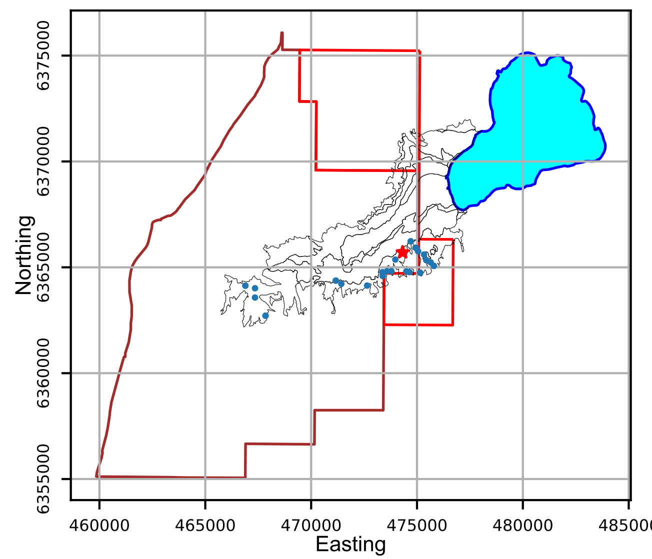

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 116 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR448-MR1 - 116.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-24

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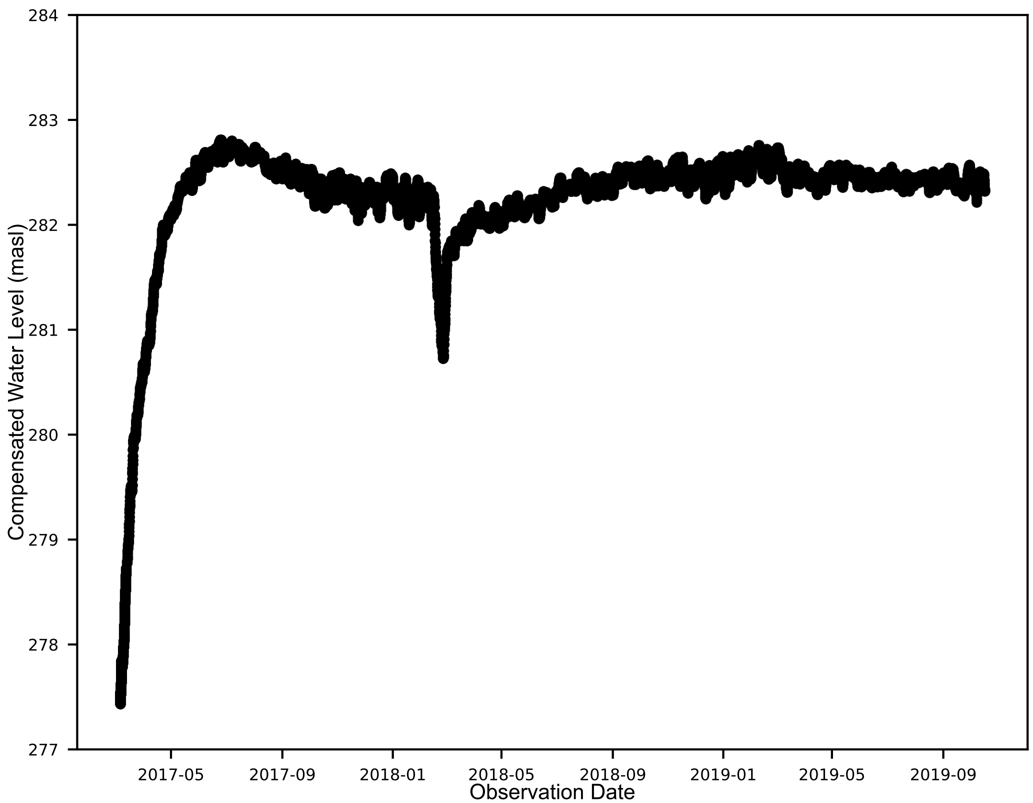

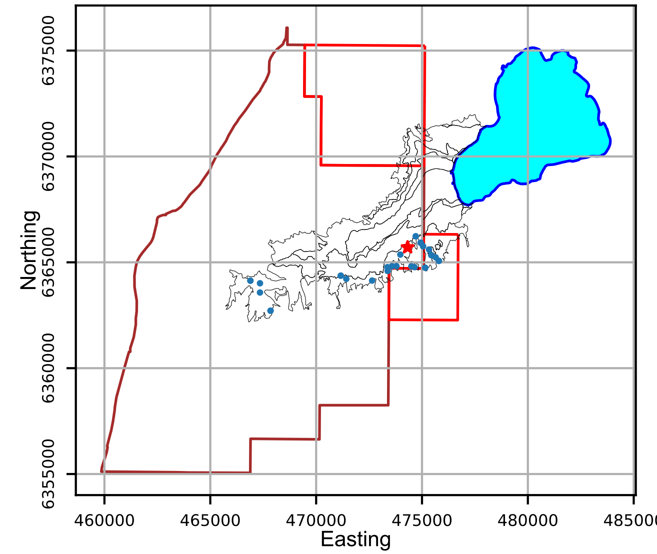

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquitard
Depth of Measurement: 71 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH17-WR448-MR1 - 71.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-25

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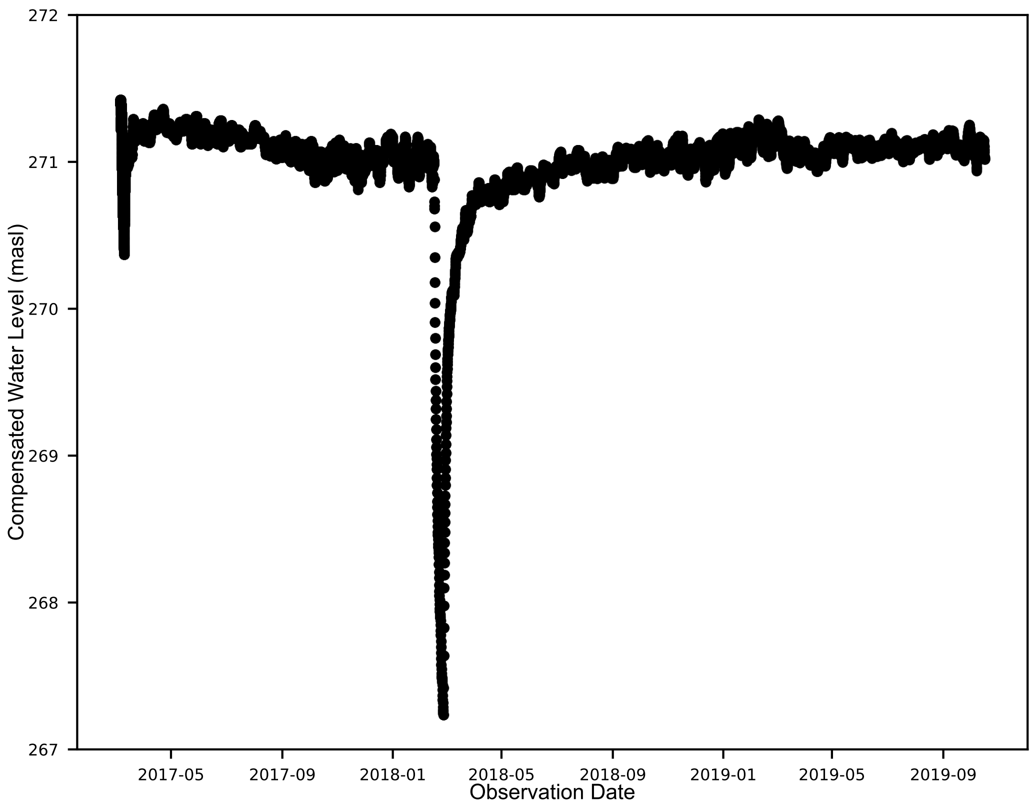
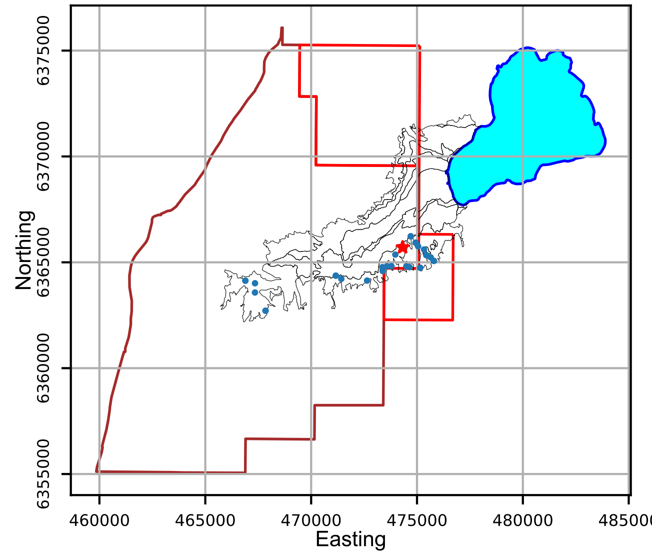




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 85 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

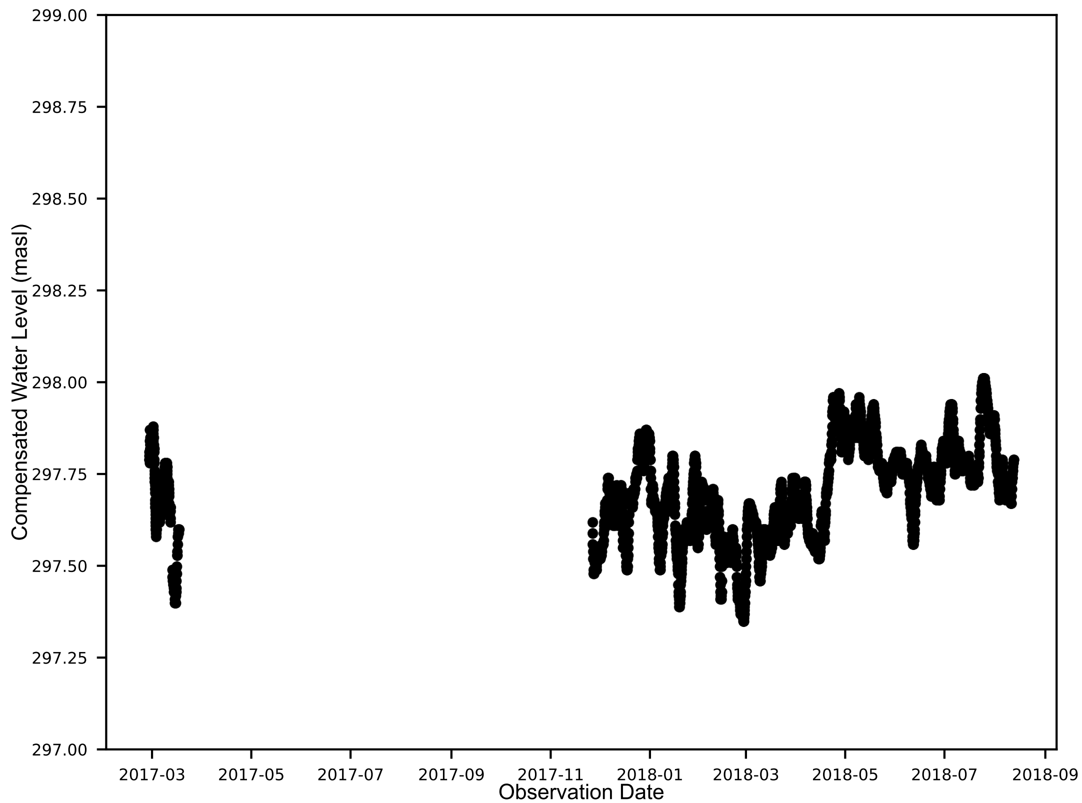
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

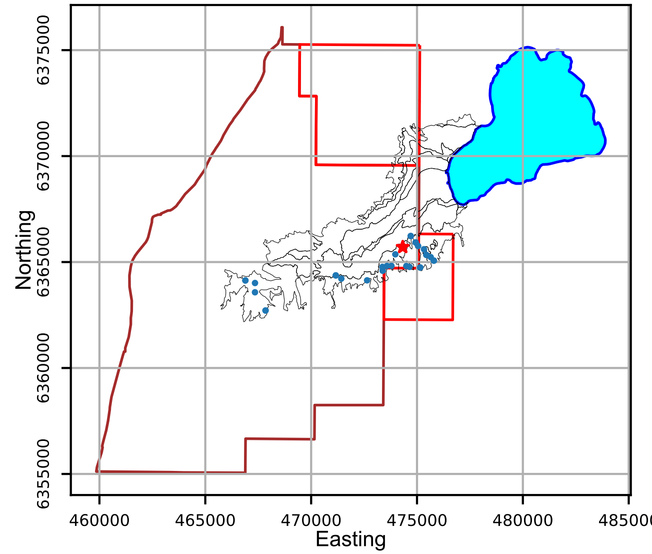
TITLE

FH17-WR448-MR1 - 85.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-26

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

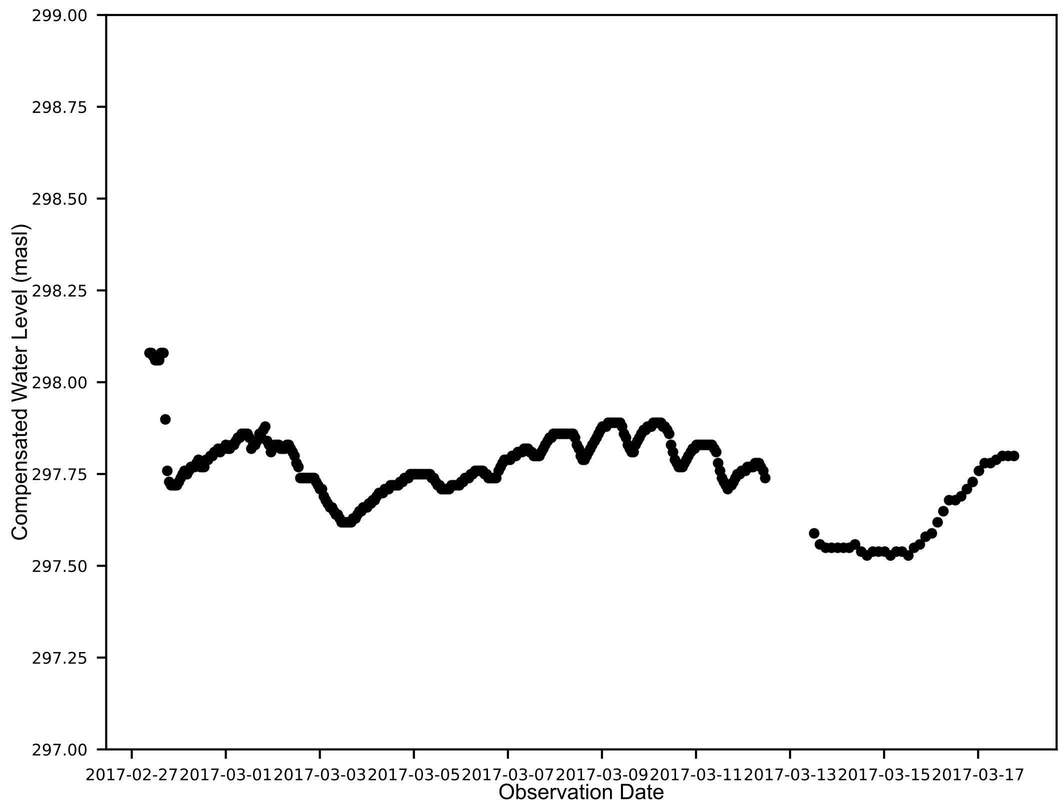
PROJECT

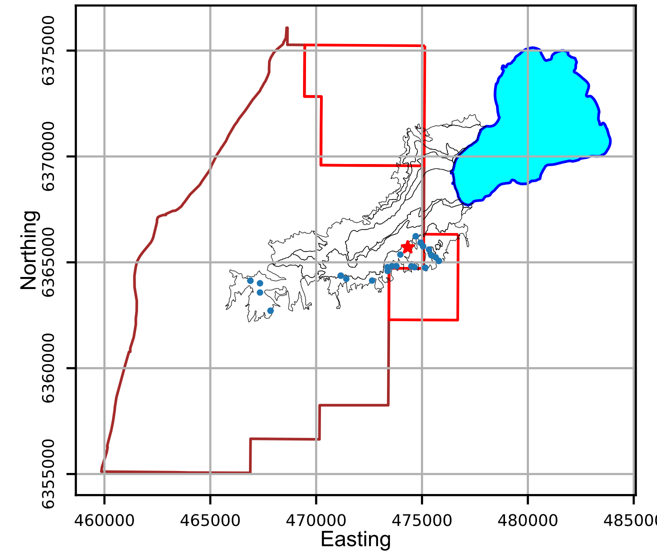
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR448-SN1 - 11.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-27





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR448-SN1 - 4.0 M BELOW GROUND SURFACE

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PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-28

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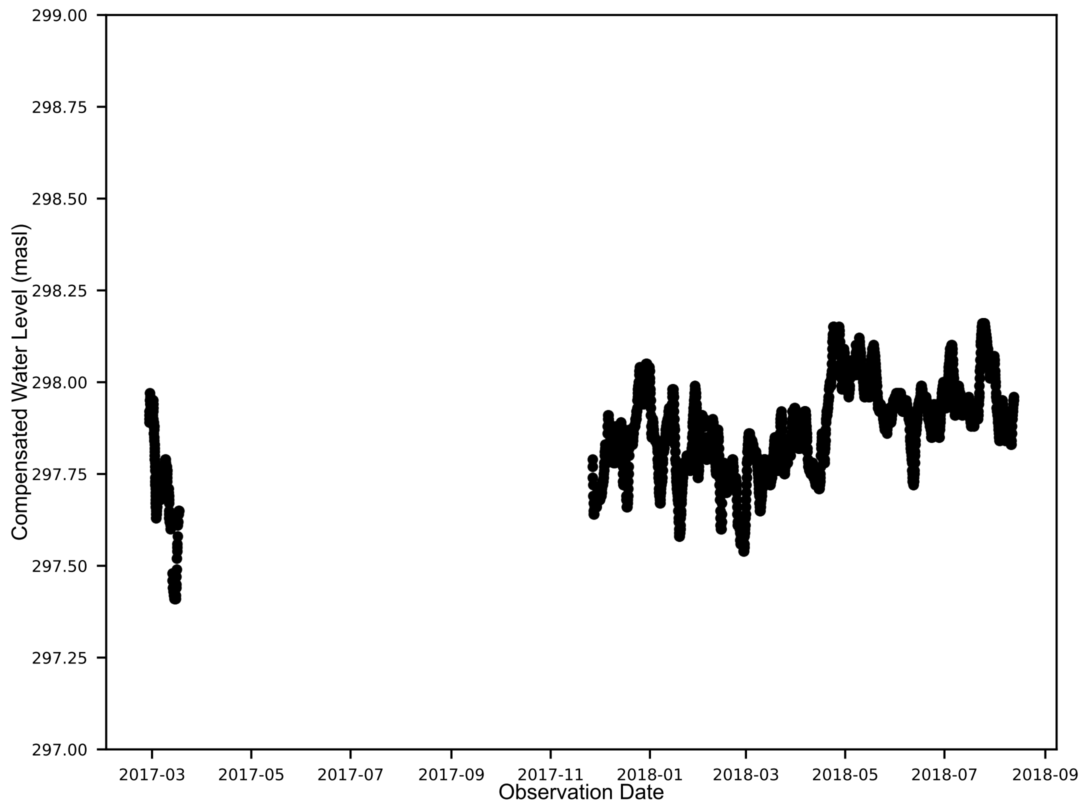

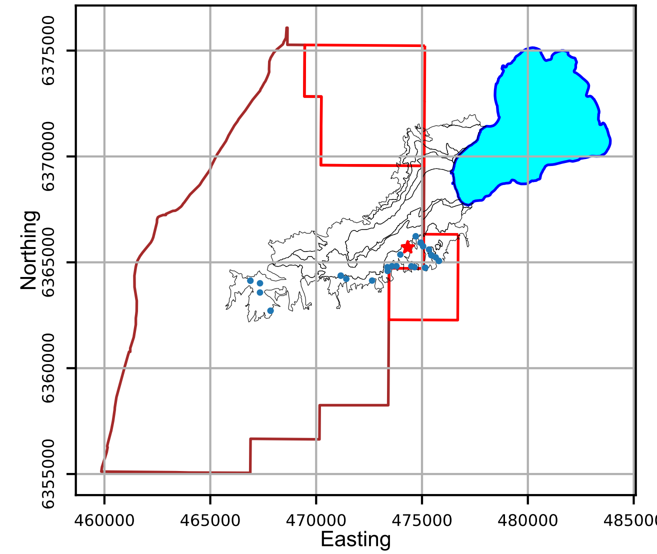

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 08 Till Aquitard AT2
Depth of Measurement: 7.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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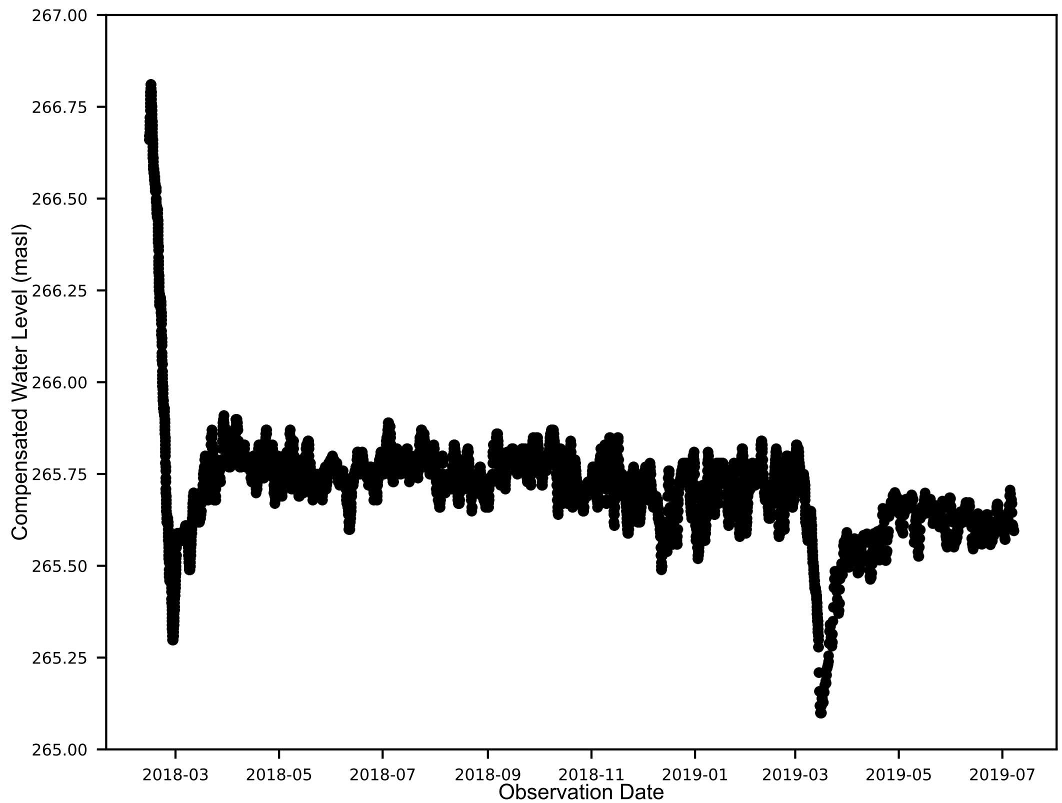
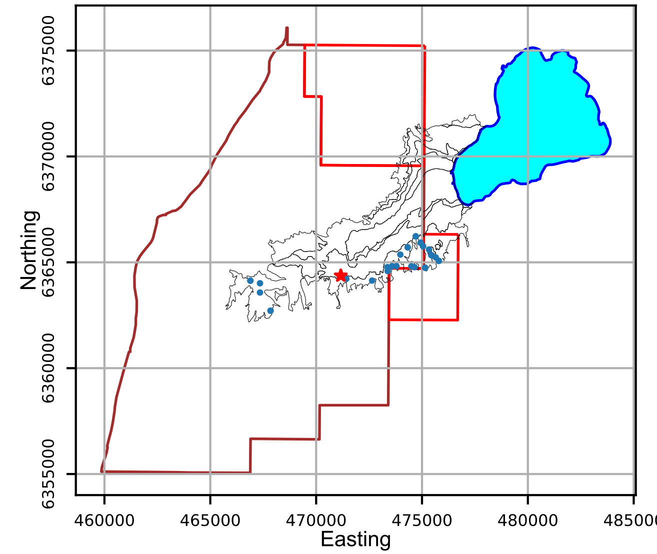
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR448-SN1 - 7.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-29





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 112 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES431-MR1 - 112.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
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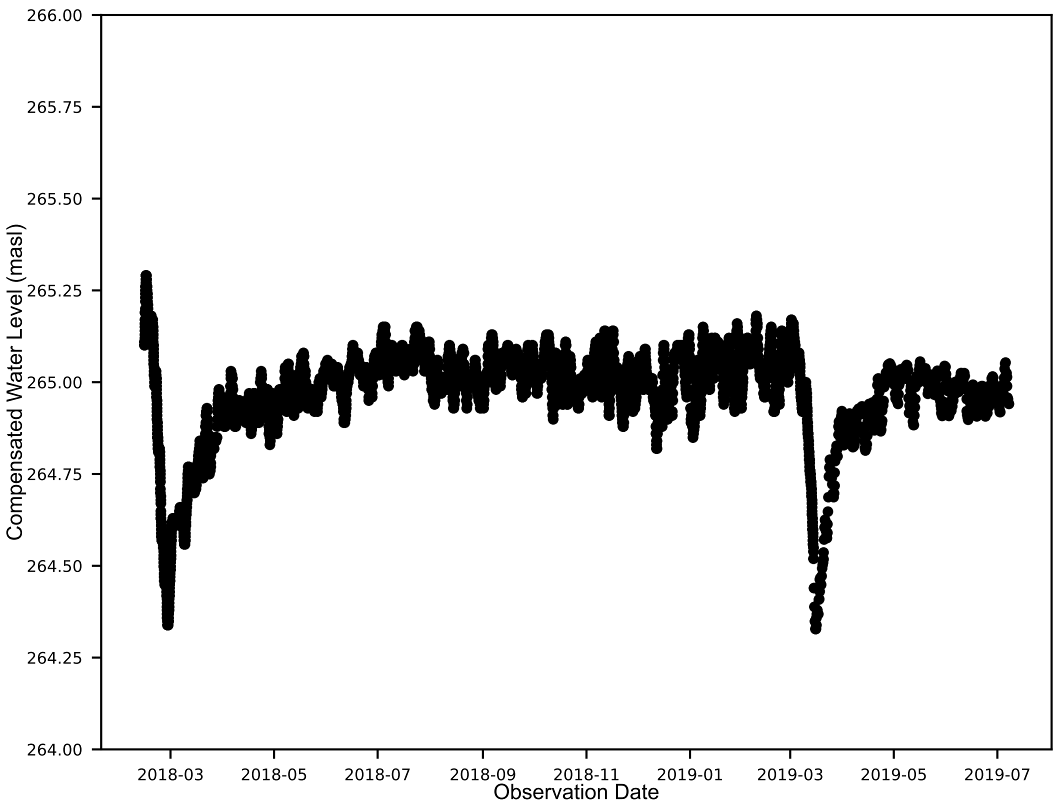

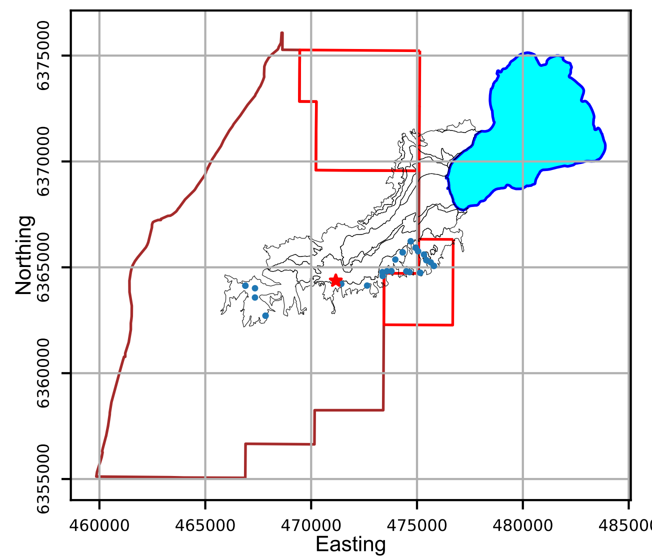

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 120 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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DESIGN	MO
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FORT HILLS
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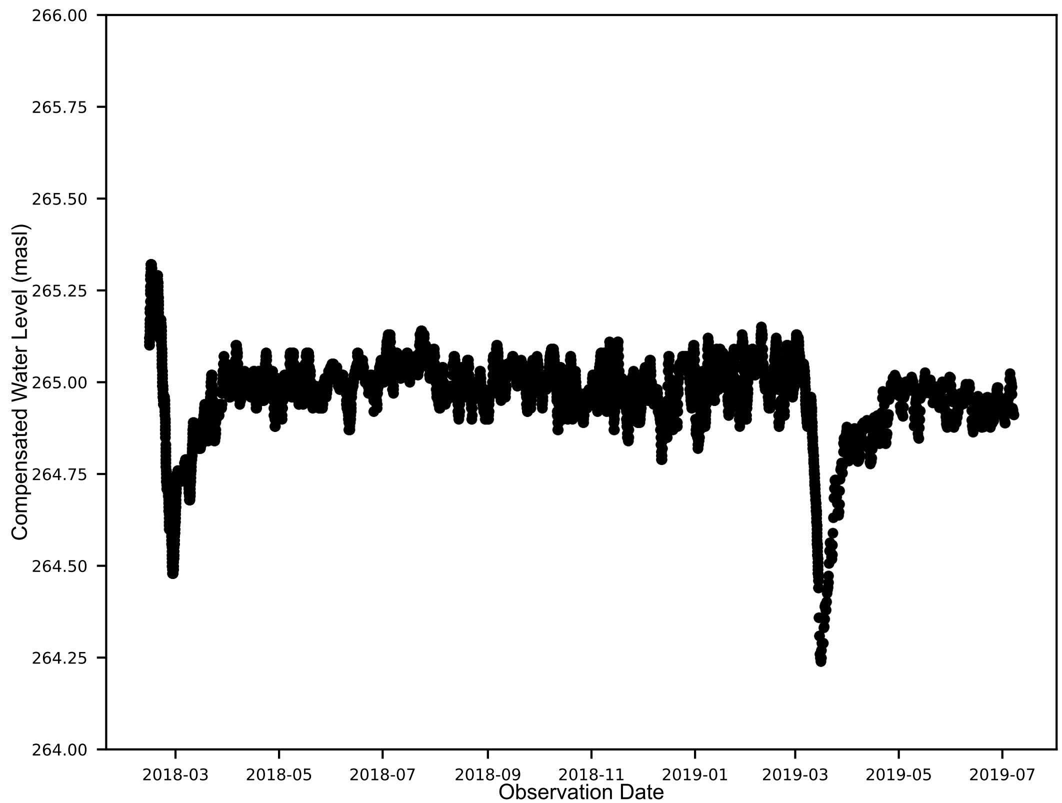
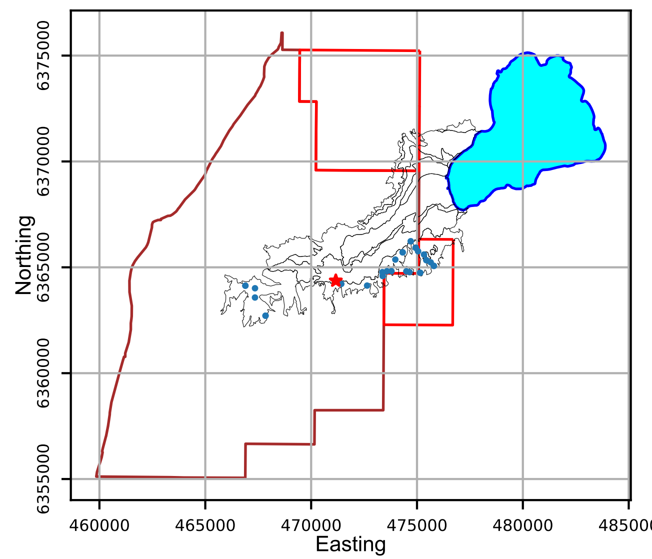
TITLE

FH18-ES431-MR1 - 120.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-31

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 130 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES431-MR1 - 130.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-32

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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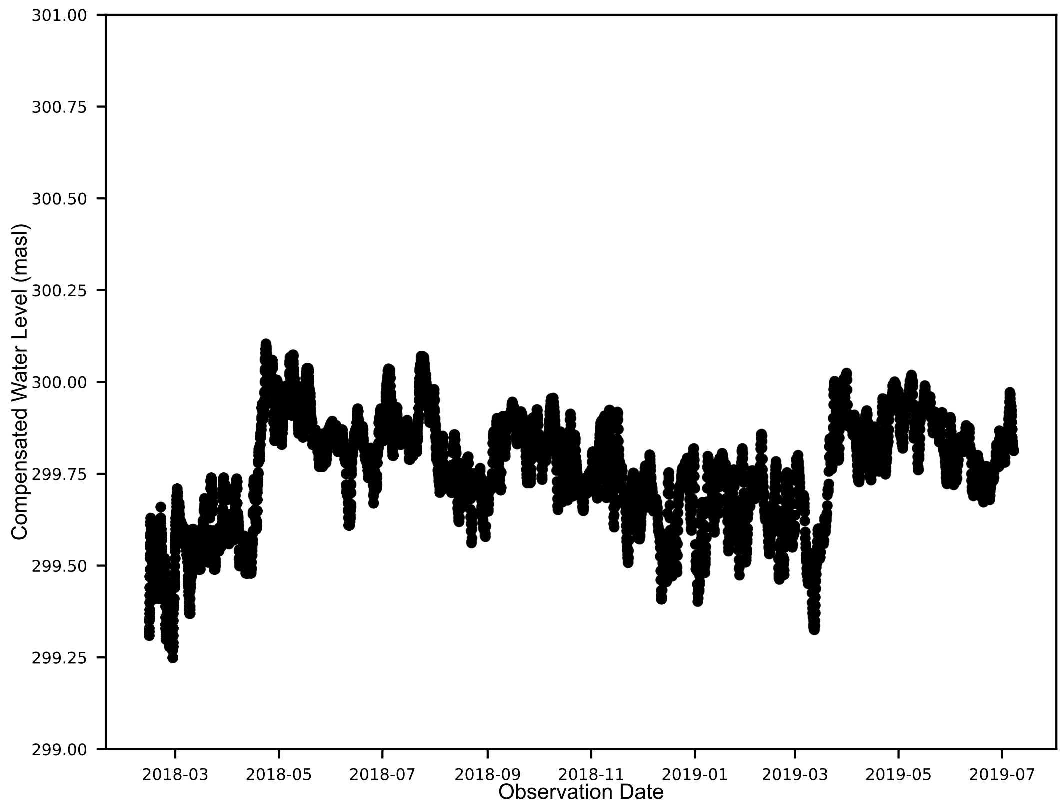

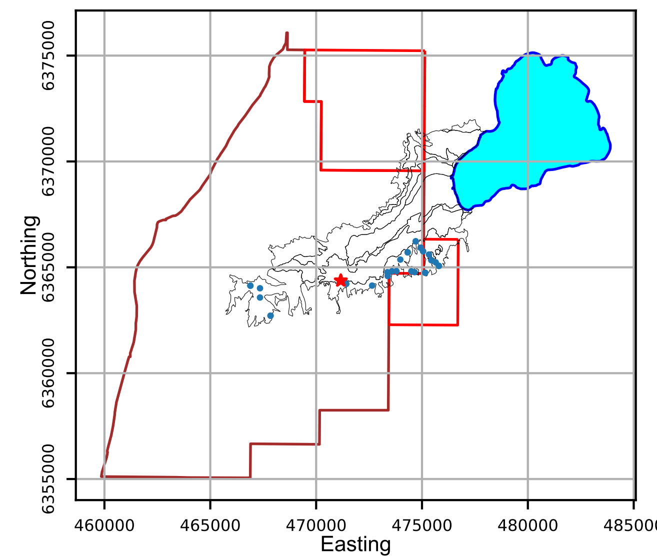

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 10.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES431-SN1 - 10.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-33

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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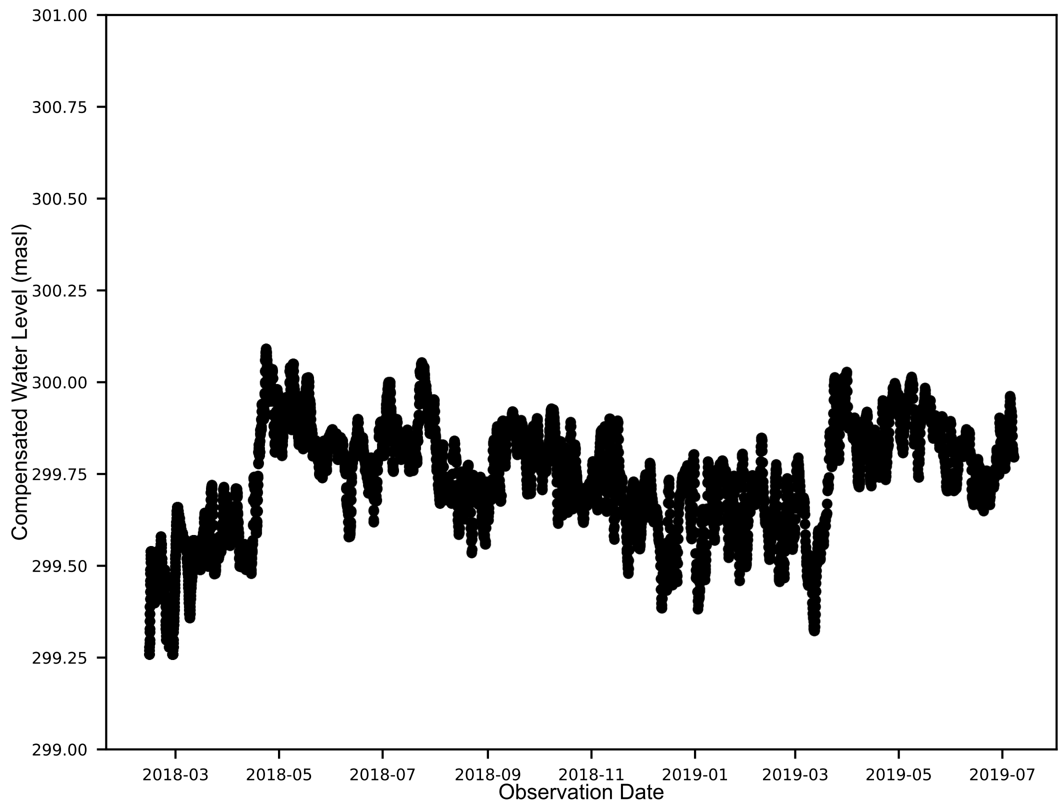

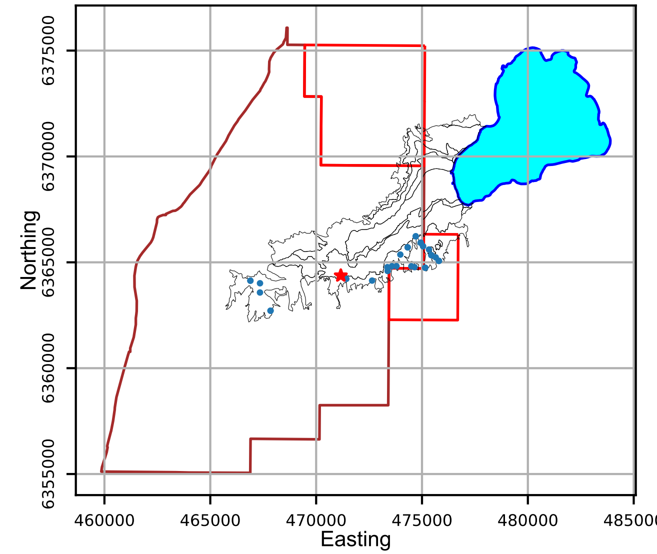

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 2.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES431-SN1 - 2.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-34

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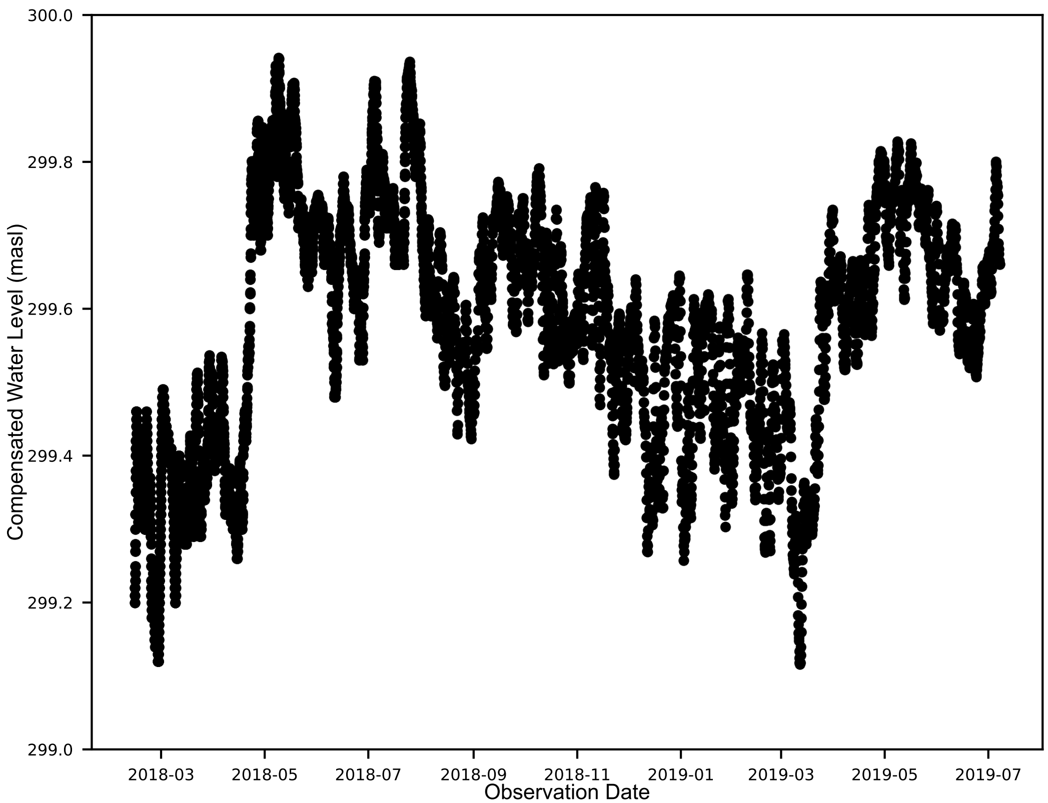

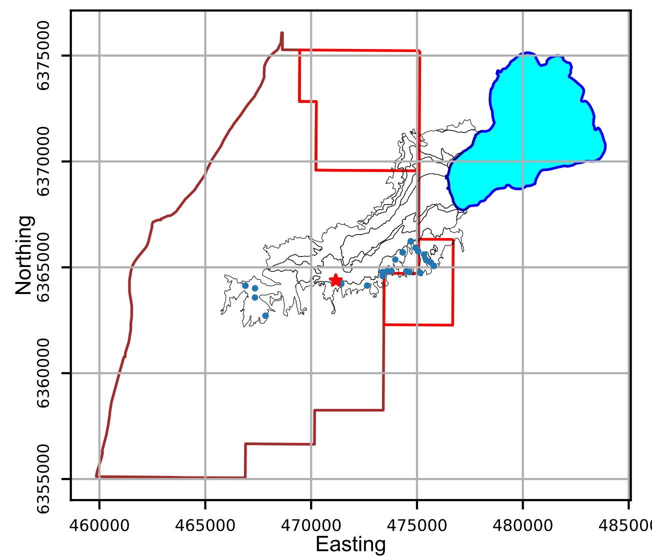

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 20.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES431-SN1 - 20.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-35

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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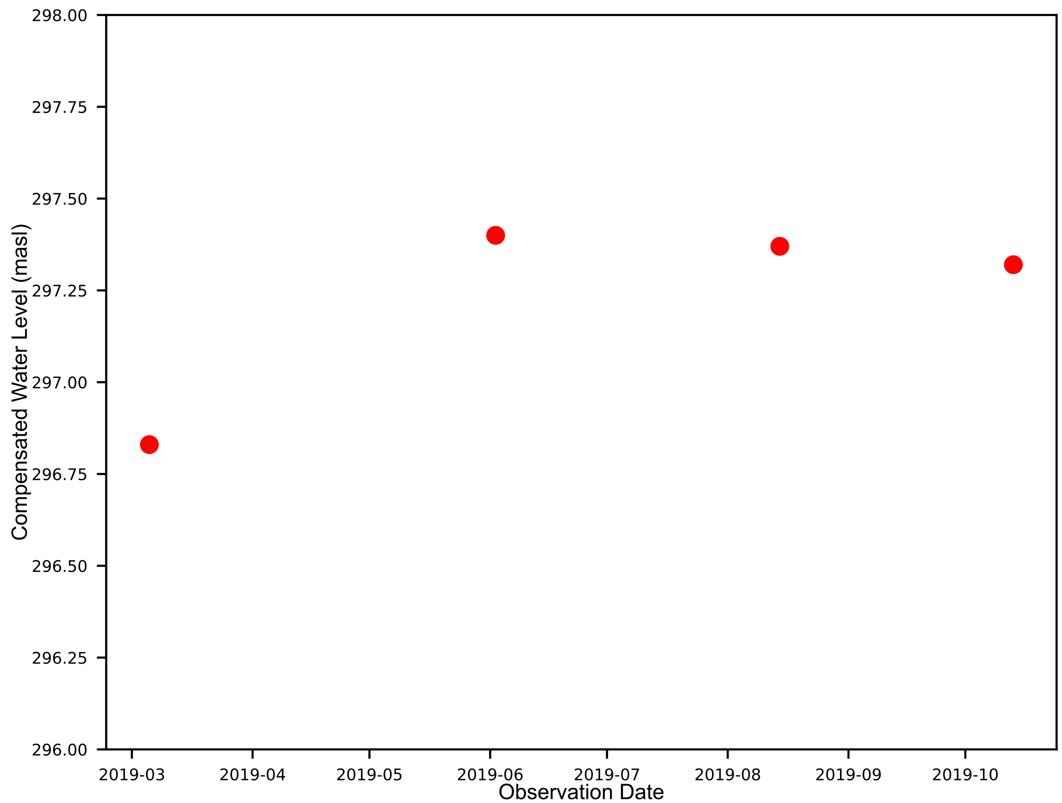

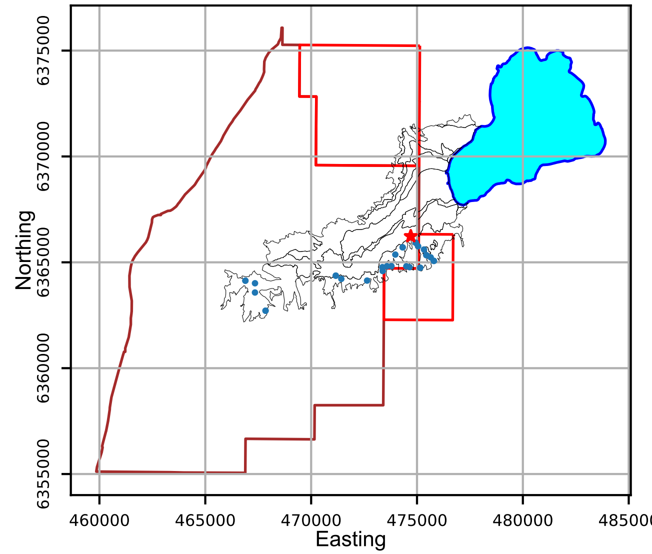

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 16.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH19-ES634-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-36

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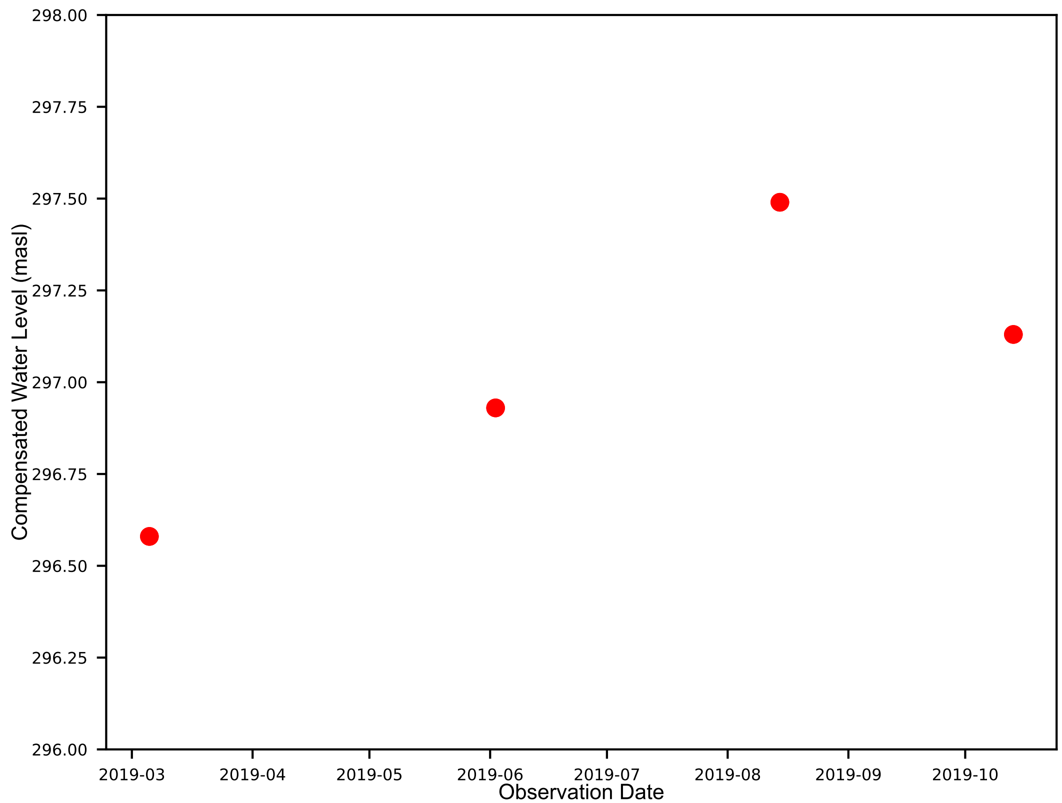
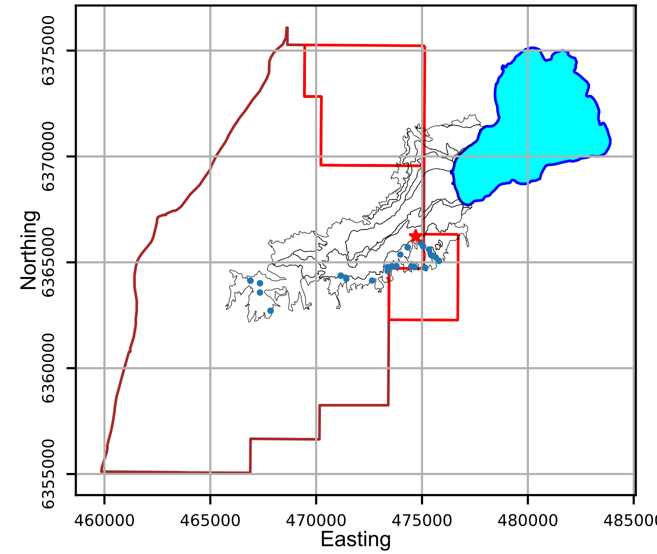




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 12.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

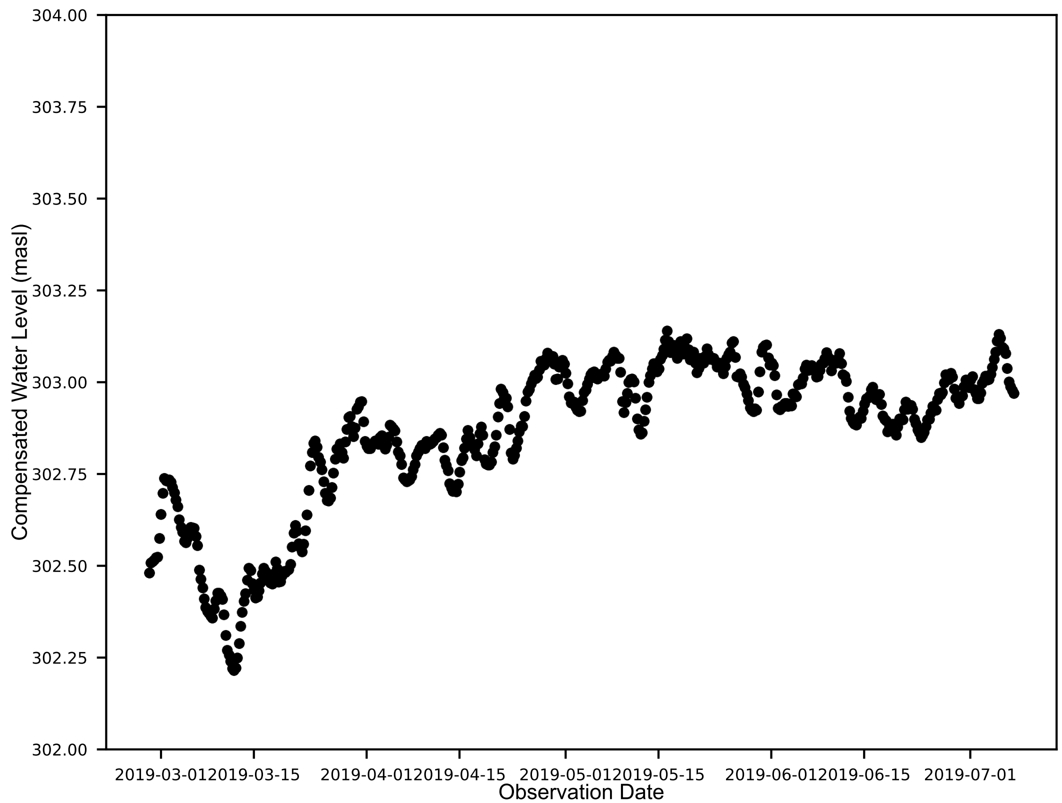
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

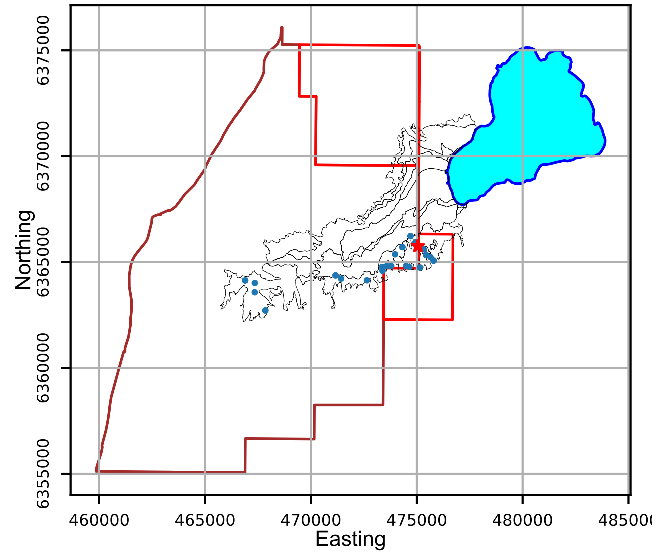
TITLE

FH19-ES634-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-37

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 17.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

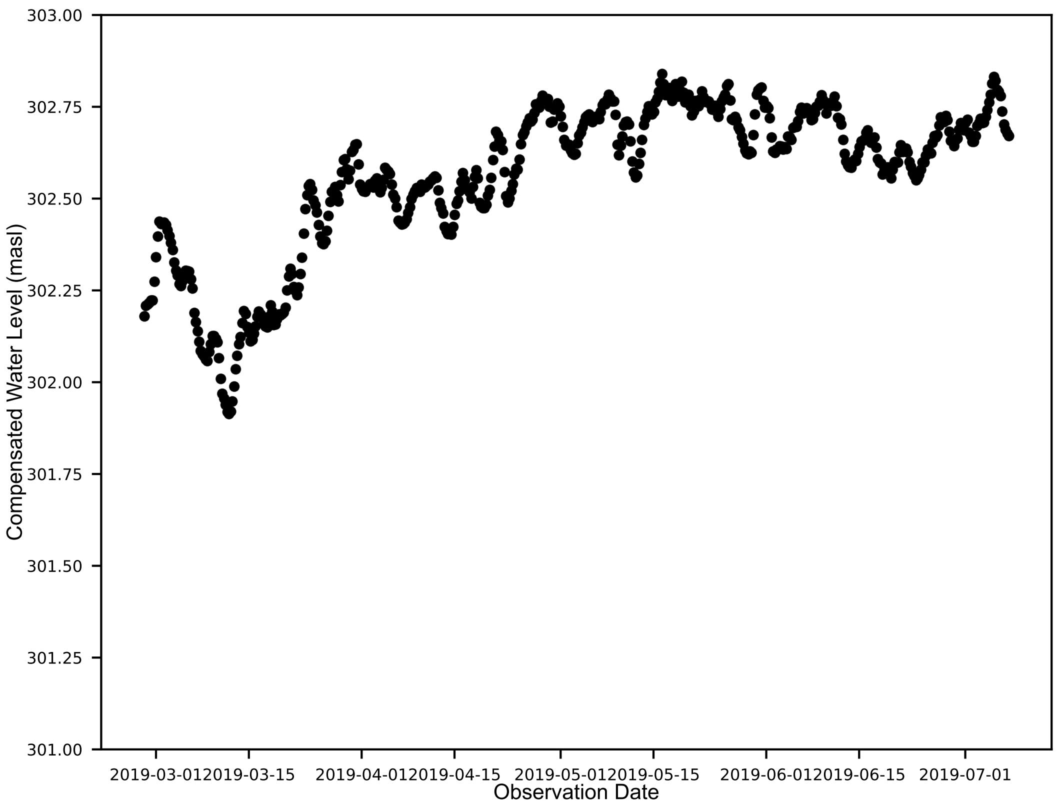
FORT HILLS
Operated by Suncor Energy

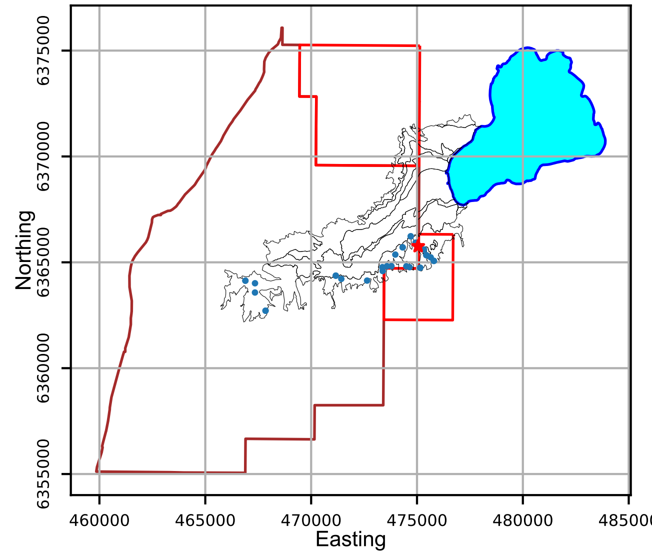
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES641-SN1 - 17.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-38

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 17.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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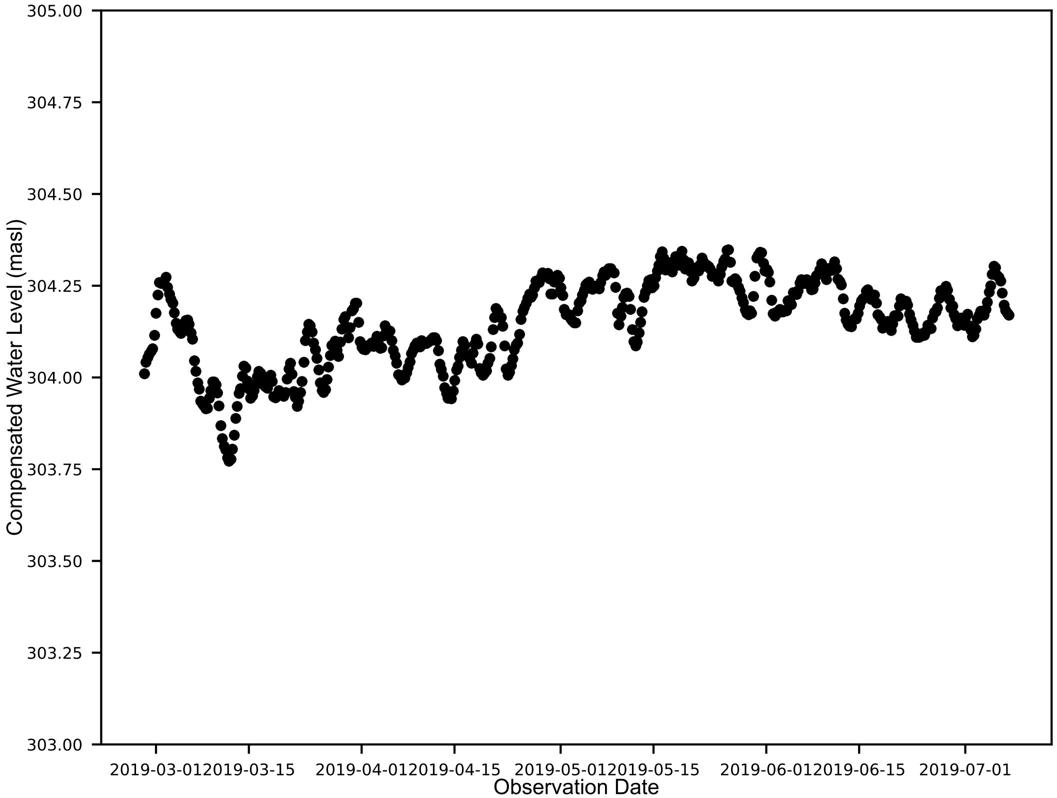
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

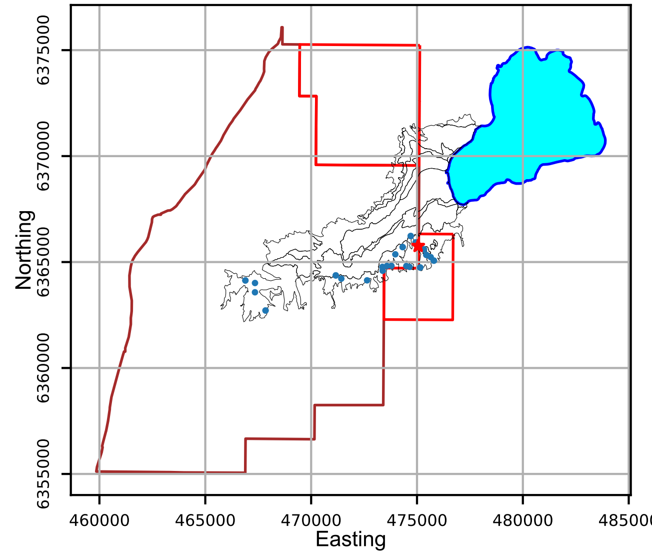
TITLE
FH19-ES641-SN1 - 17.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-39

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 23.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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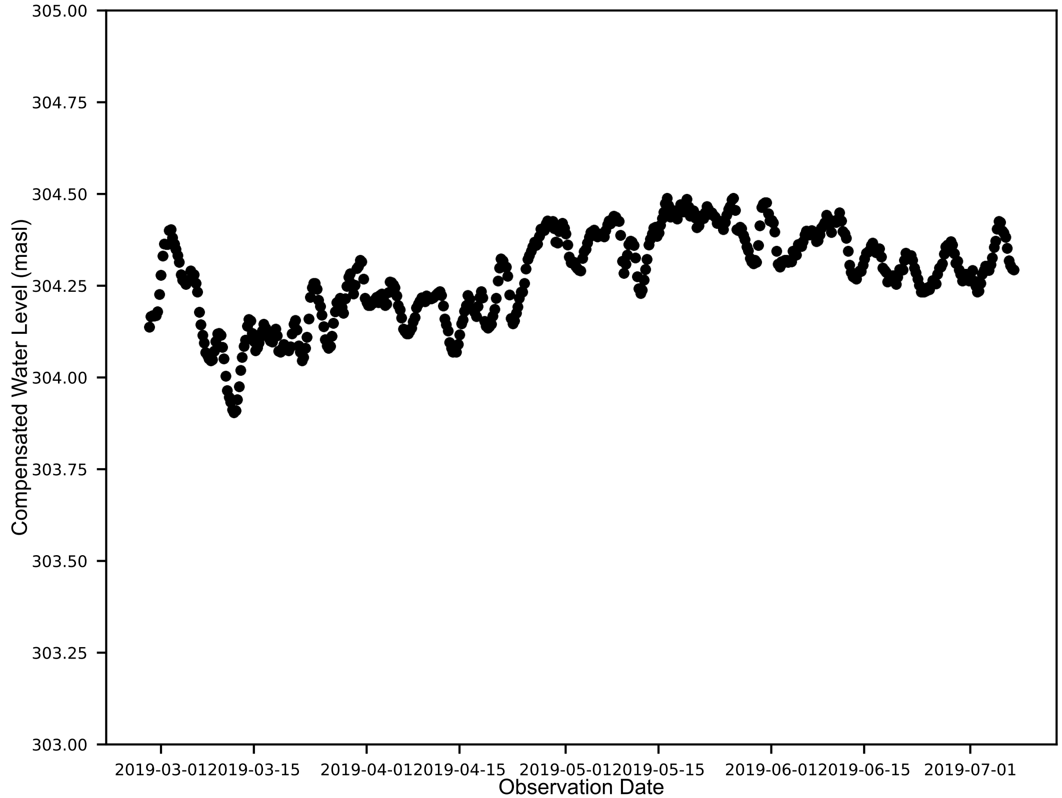
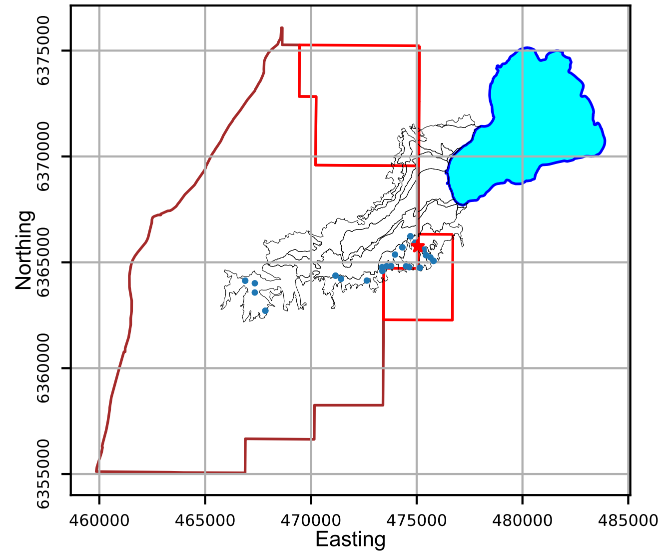
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES641-SN1 - 23.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-40

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 27.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES641-SN1 - 27.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-41

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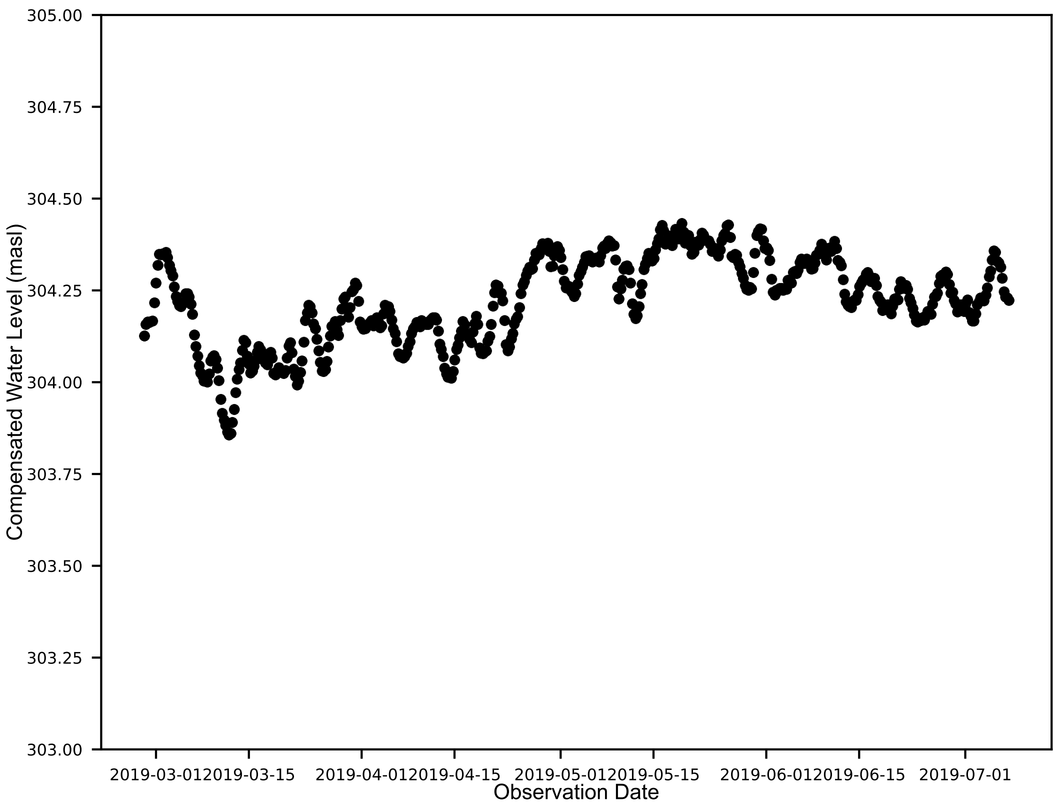

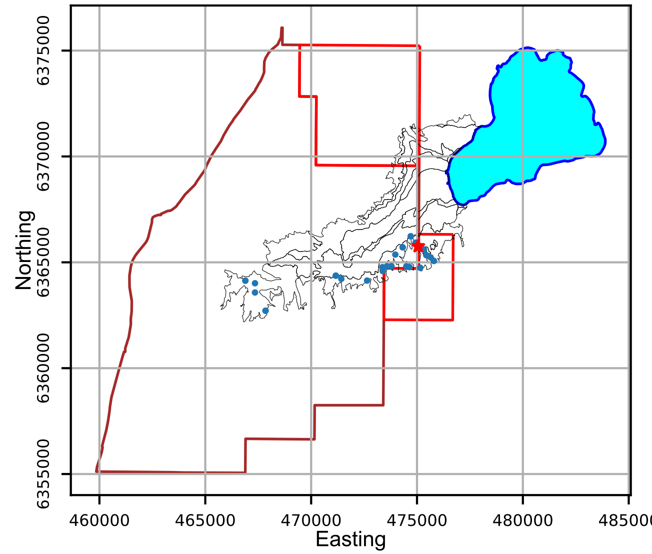

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 36.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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REVIEW	LW
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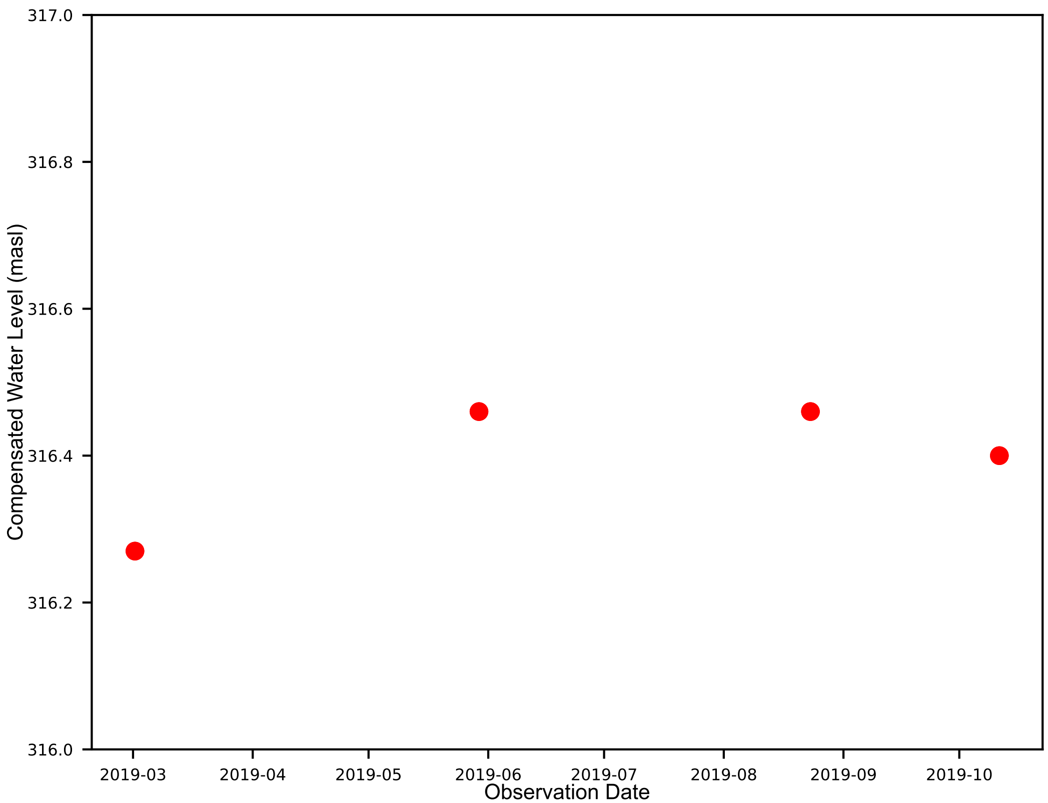
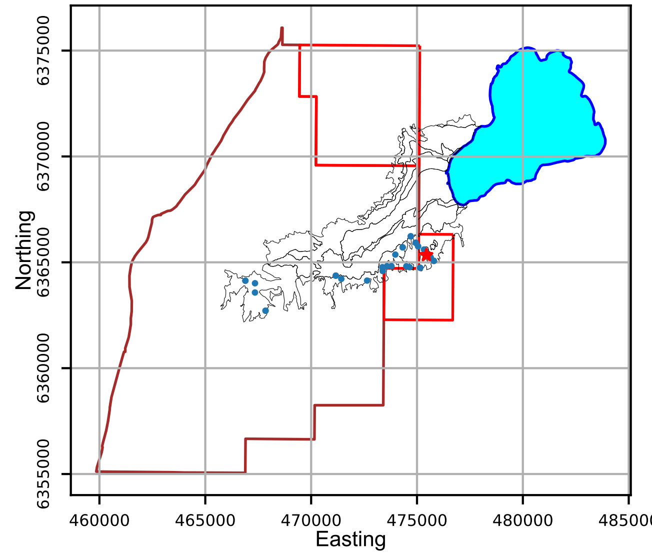
Operated by Suncor Energy

TITLE
FH19-ES641-SN1 - 36.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-42

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 41.15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

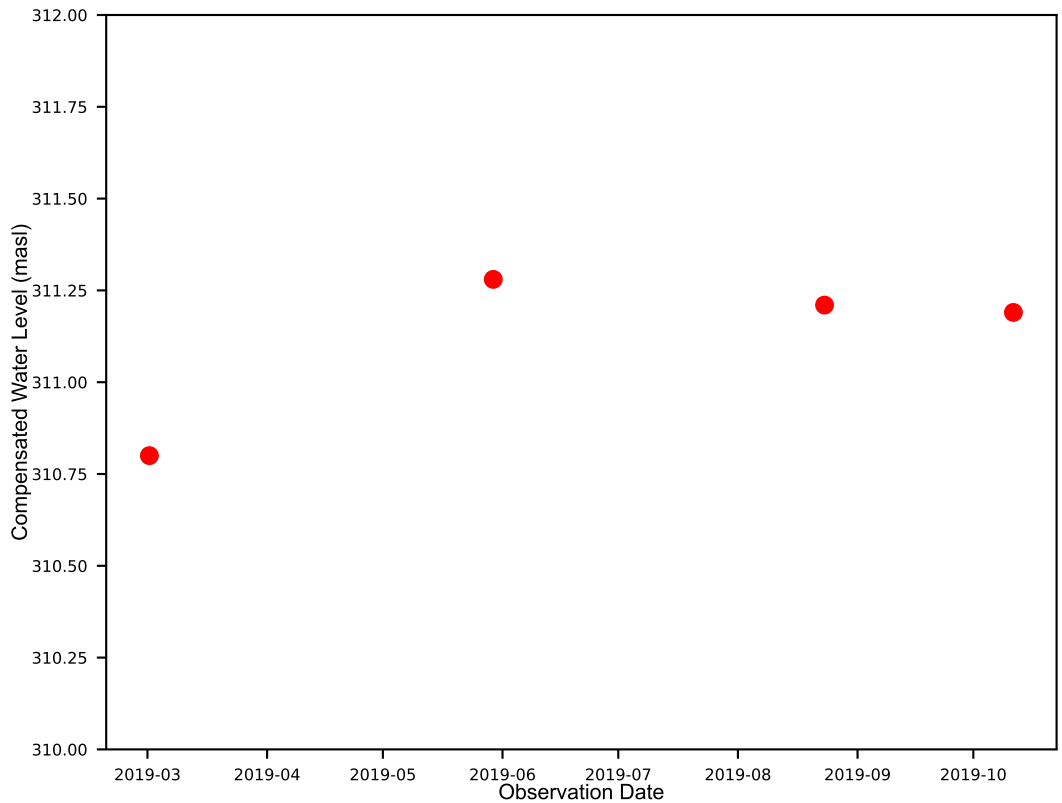
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

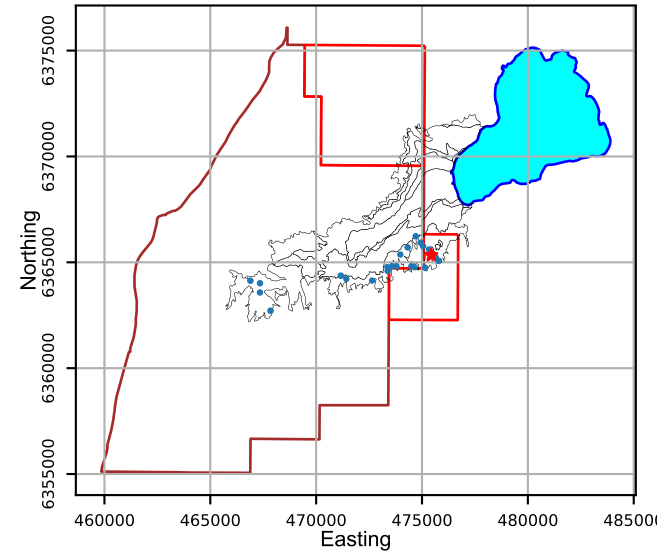
FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES651-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-43

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 18.31 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

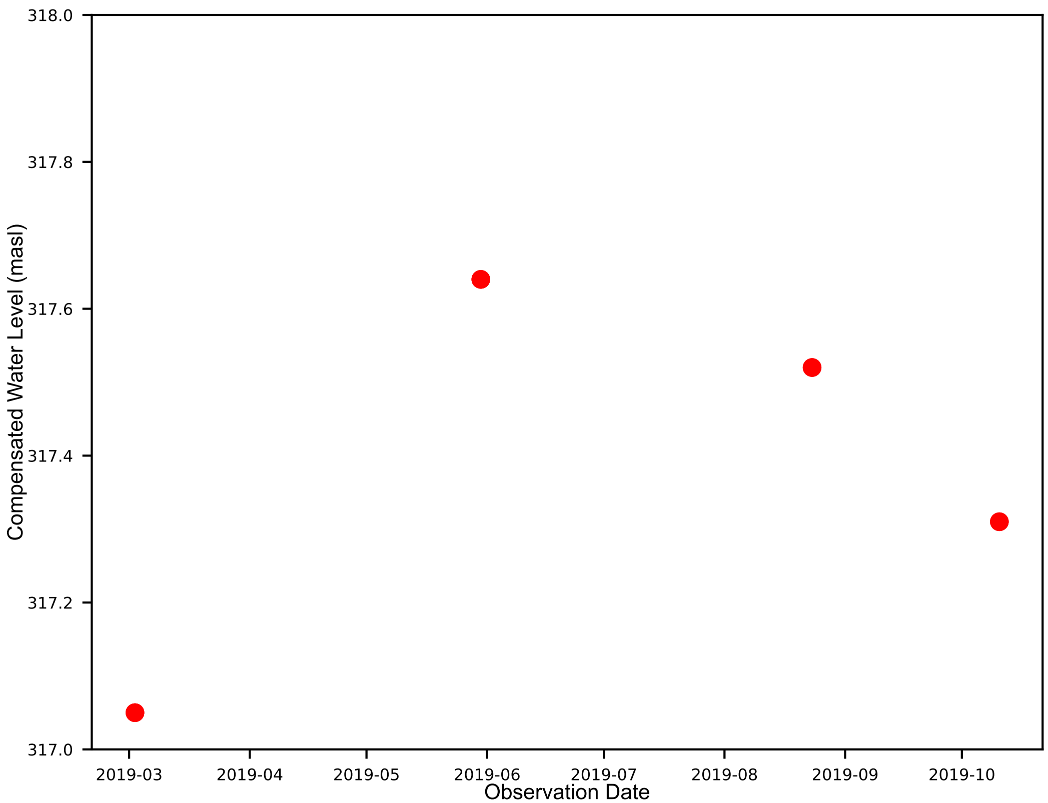
FORT HILLS
Operated by Suncor Energy

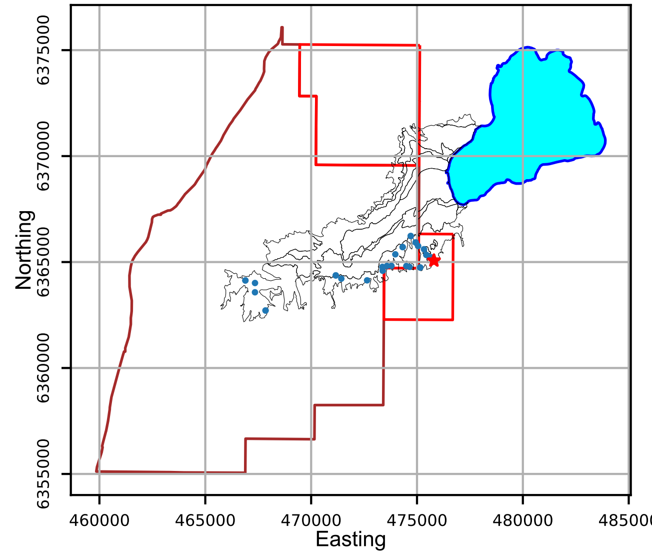
TITLE

FH19-ES651-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-44

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 52.28 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

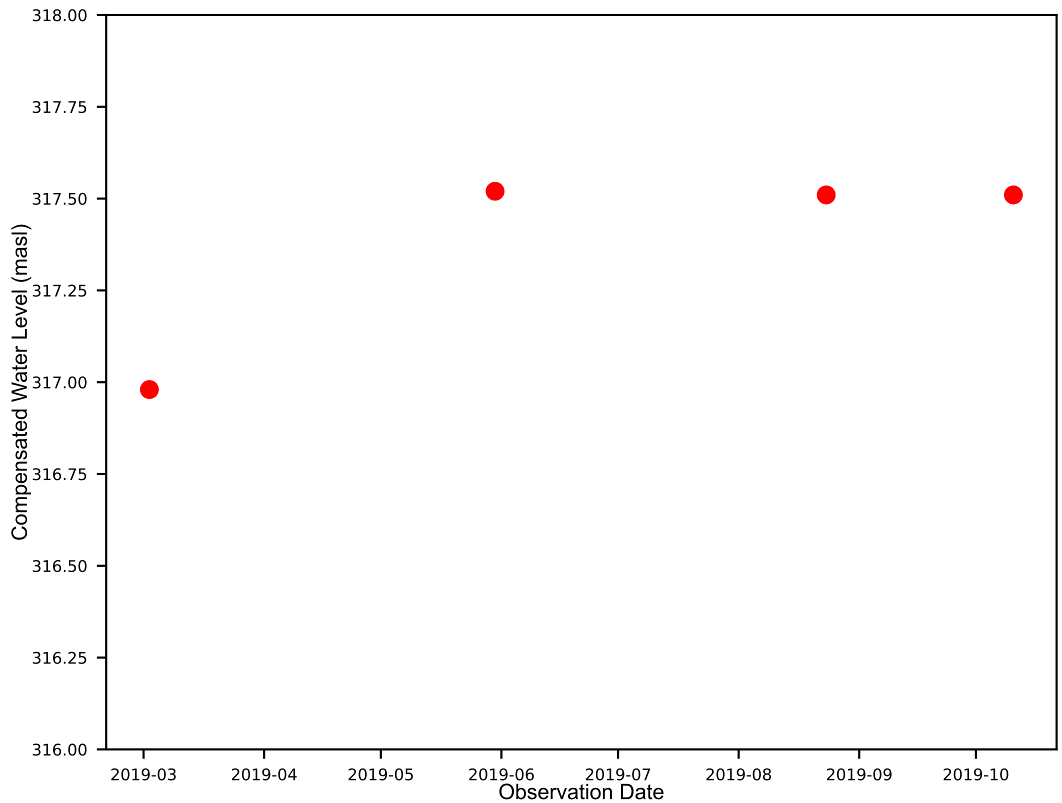
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

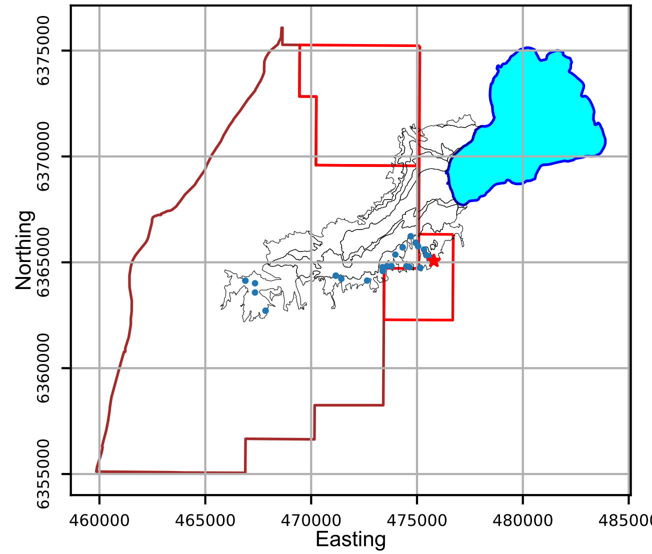
FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES659-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-45

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 40 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

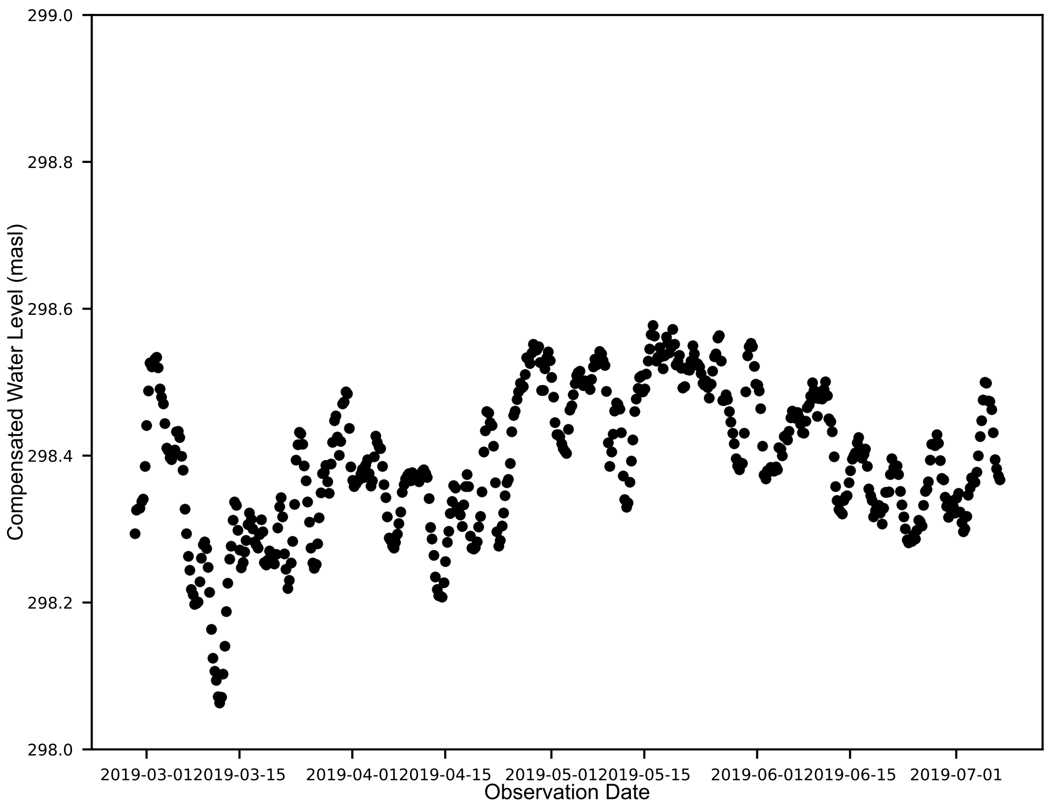
FORT HILLS
Operated by Suncor Energy

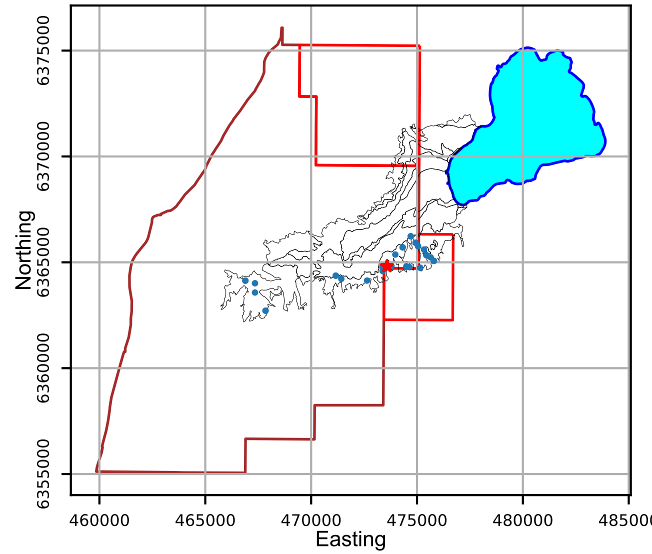
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES659-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-46

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
1 in





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 28.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

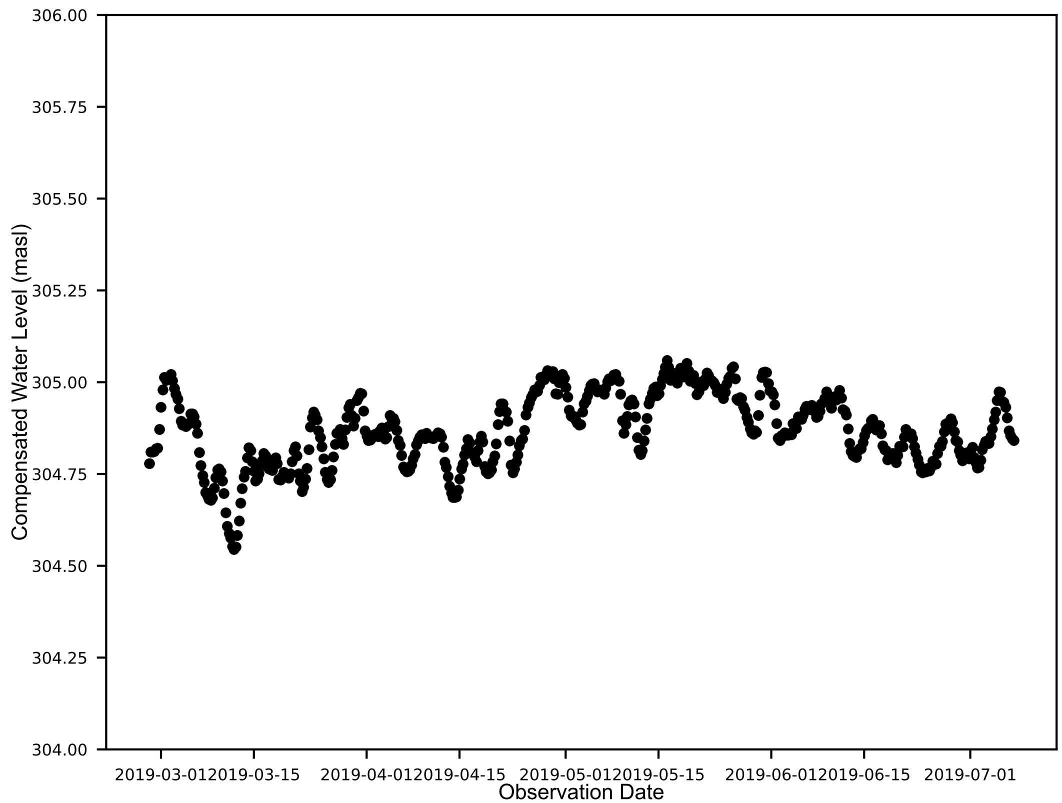
FORTHILLS
Operated by Suncor Energy

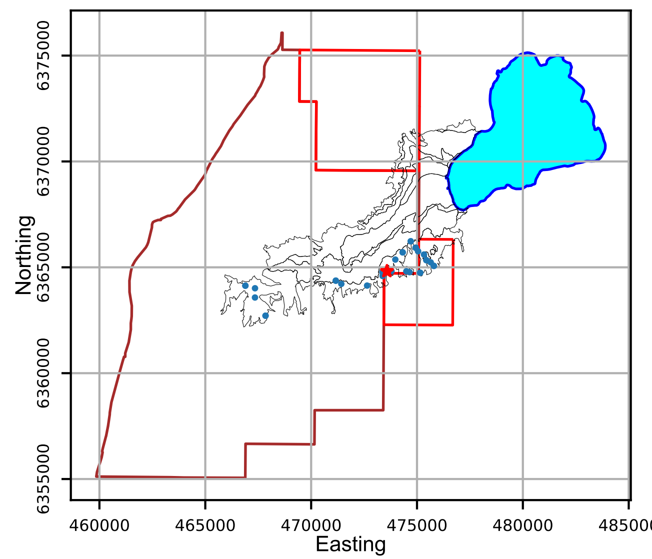
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES666-SN1 - 28.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-47

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4

Depth of Measurement: 29.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

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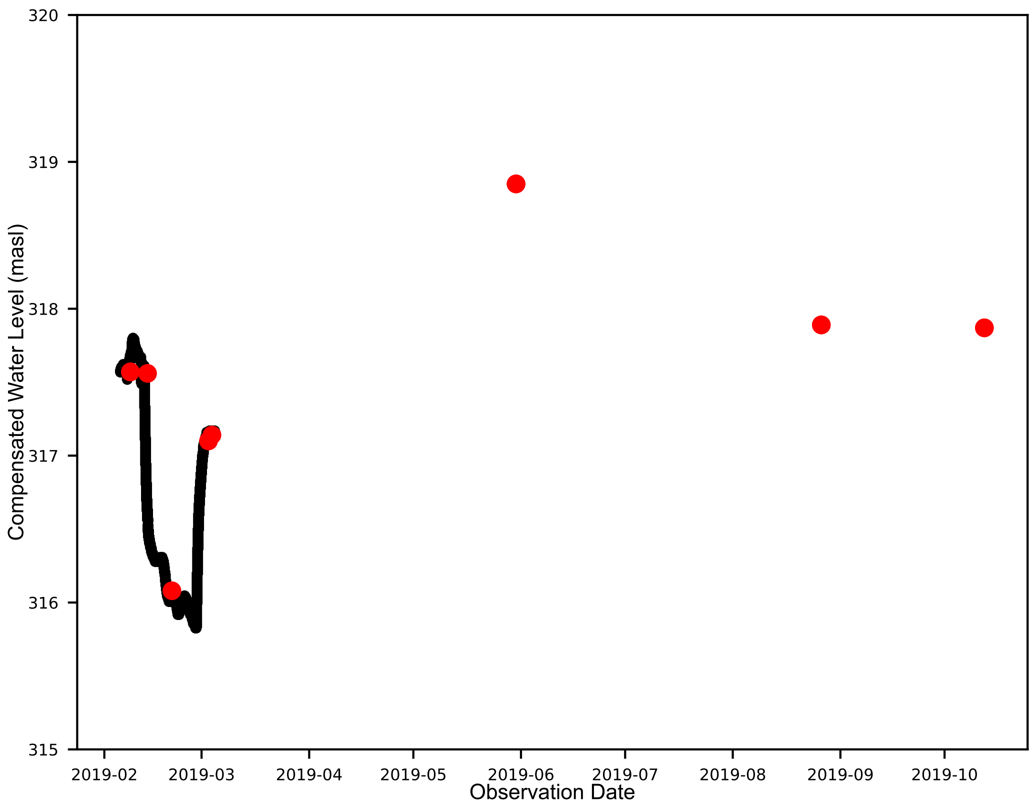
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

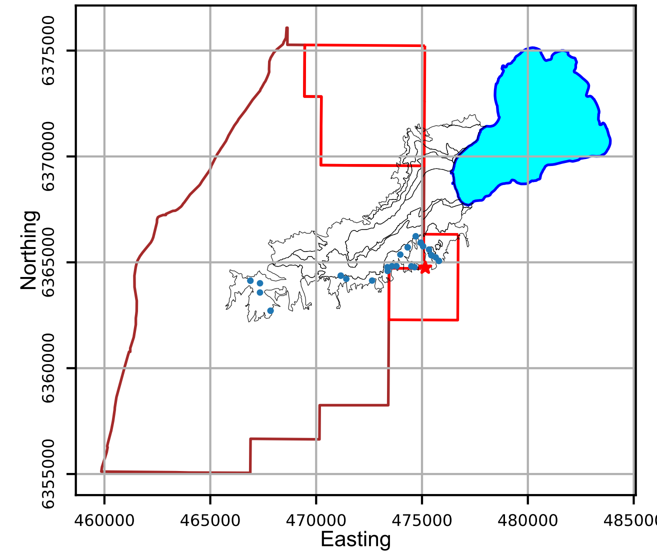
TITLE

FH19-ES666-SN1 - 29.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-48

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 41.17 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

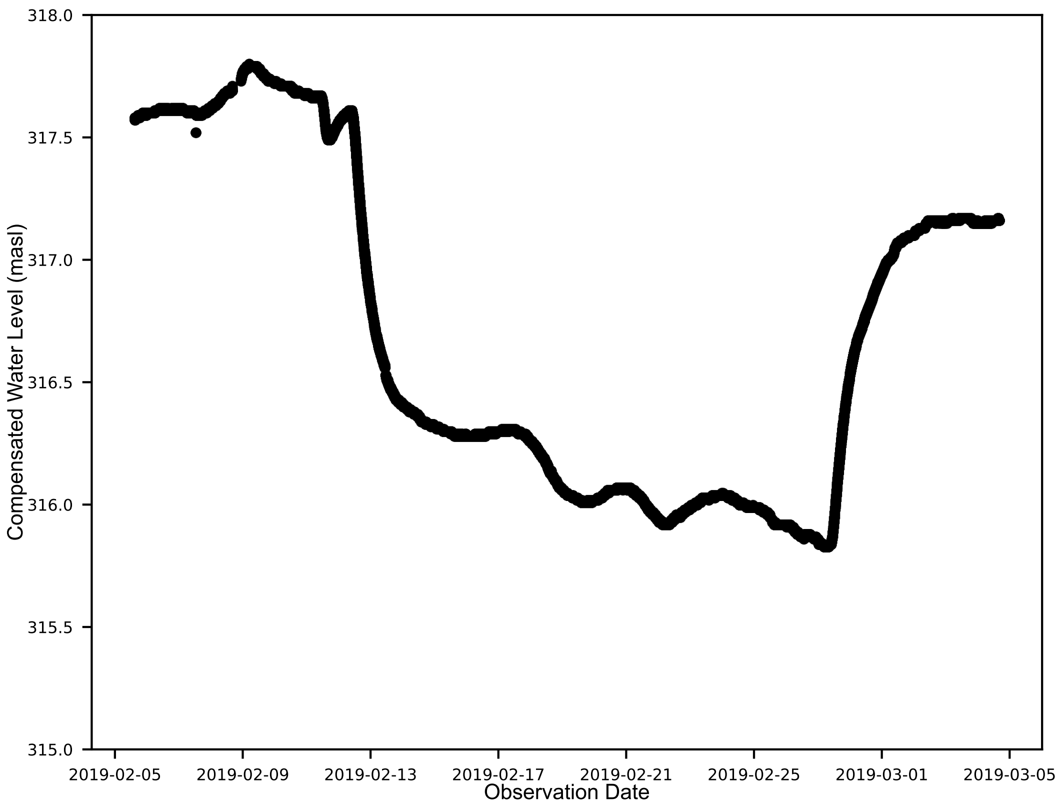
FORTHILLS
Operated by Suncor Energy

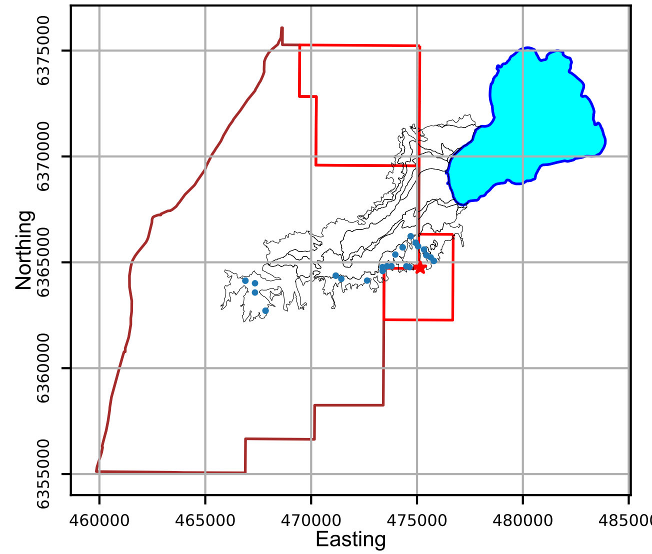
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES668-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-49

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 41.17 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES668-SN1 - 18.32 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
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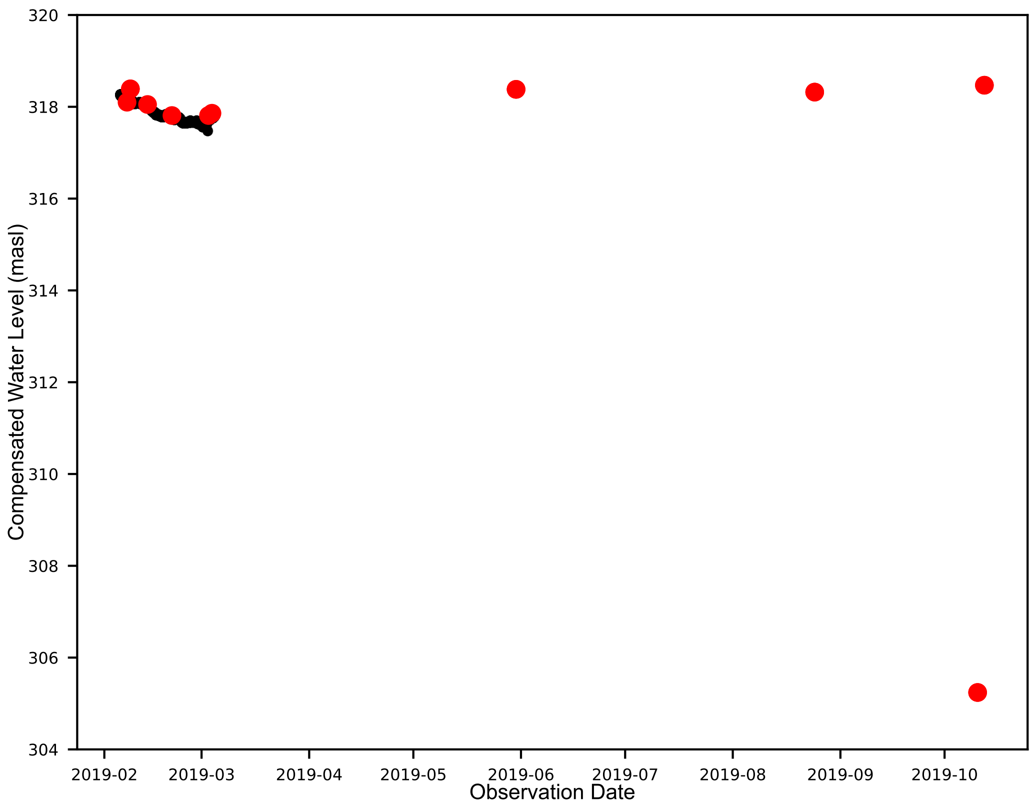
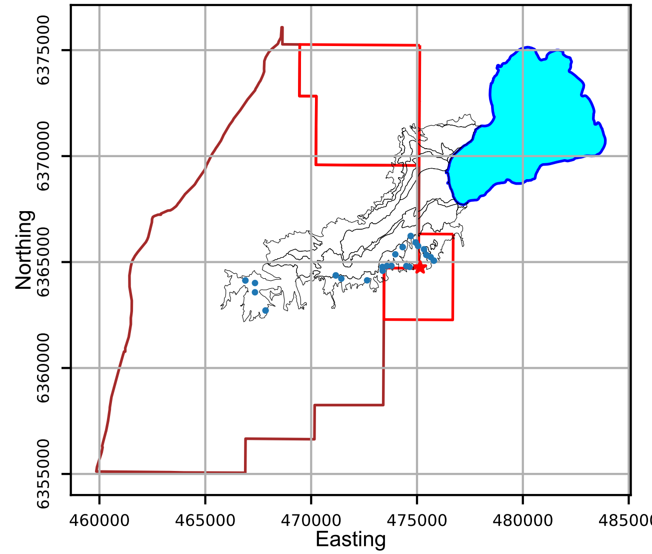




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 14.56 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

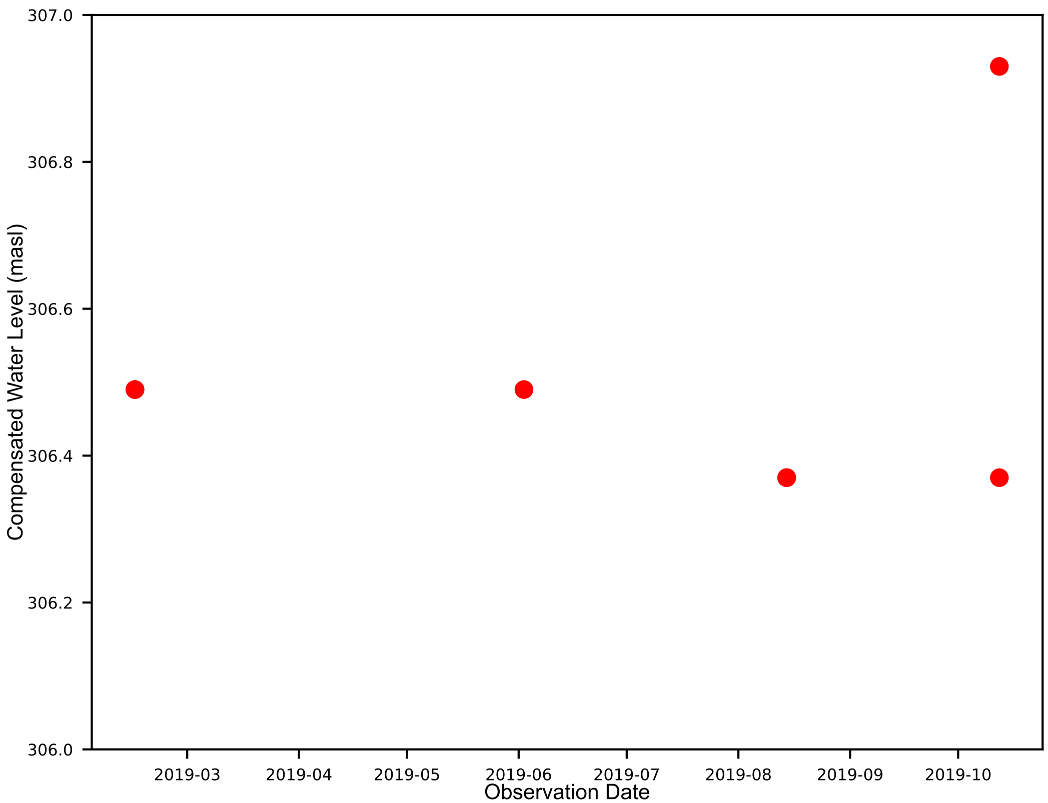
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

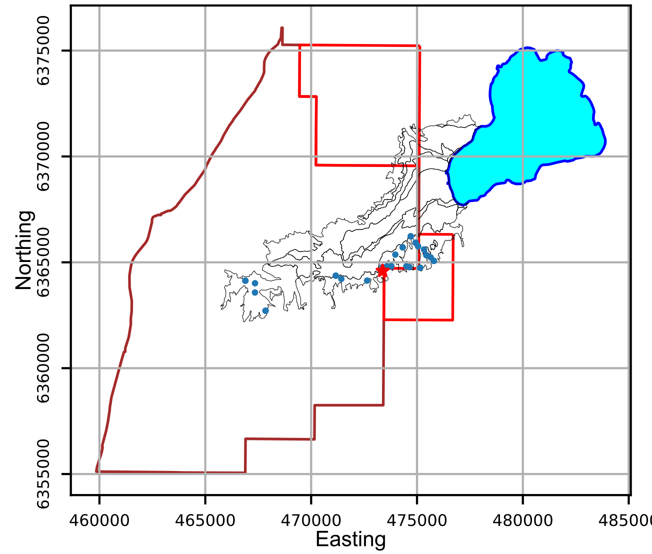
FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES668-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-51

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 35.77 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

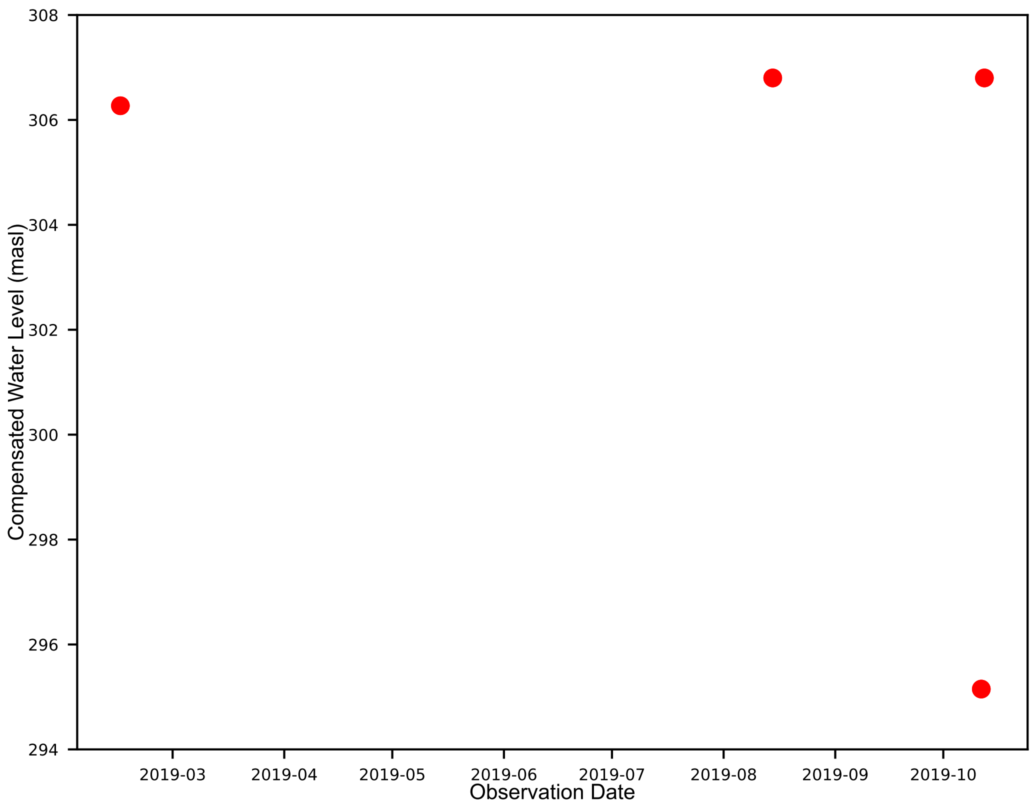
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

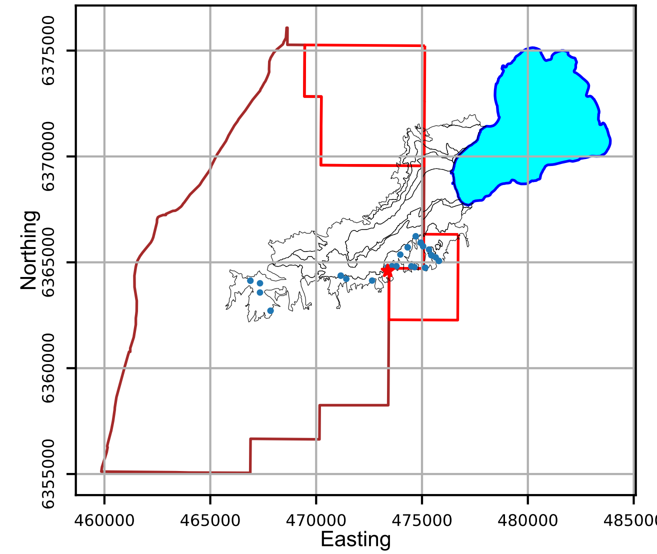
TITLE

FH19-ES676-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-52

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 18.64 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

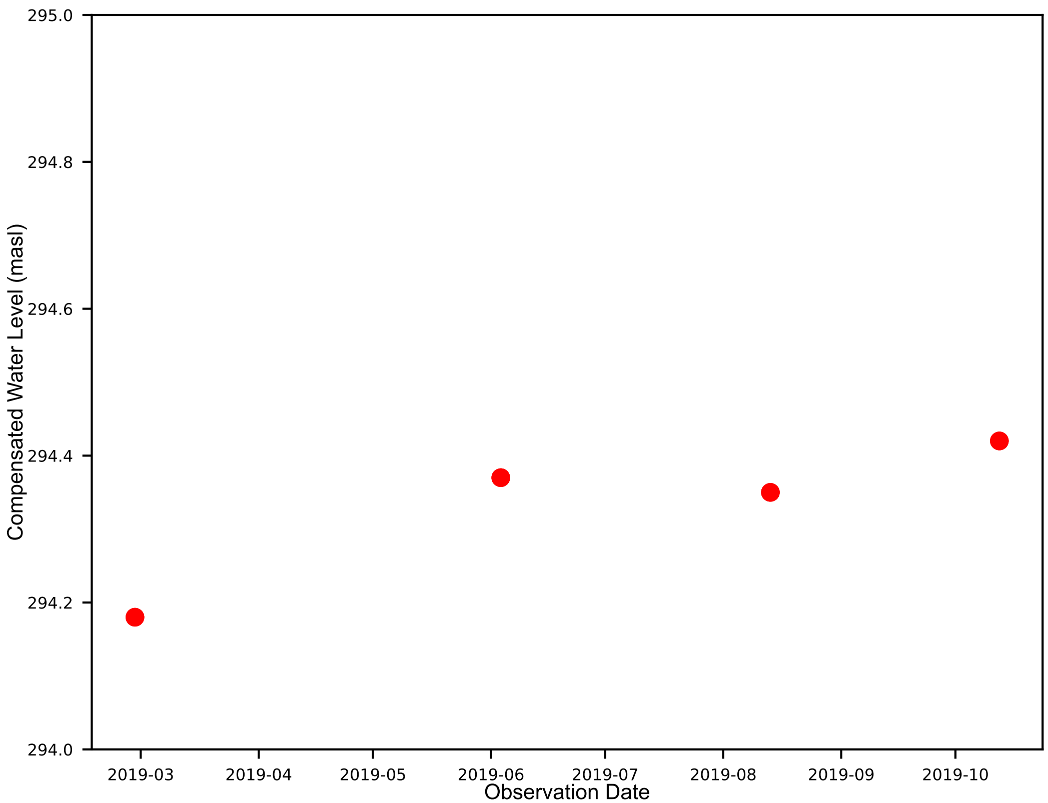
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

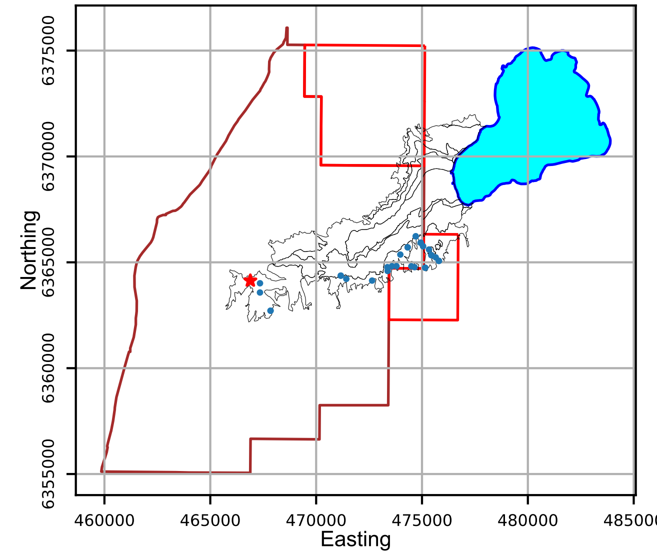
TITLE

FH19-ES676-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B6-53

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 35.79 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

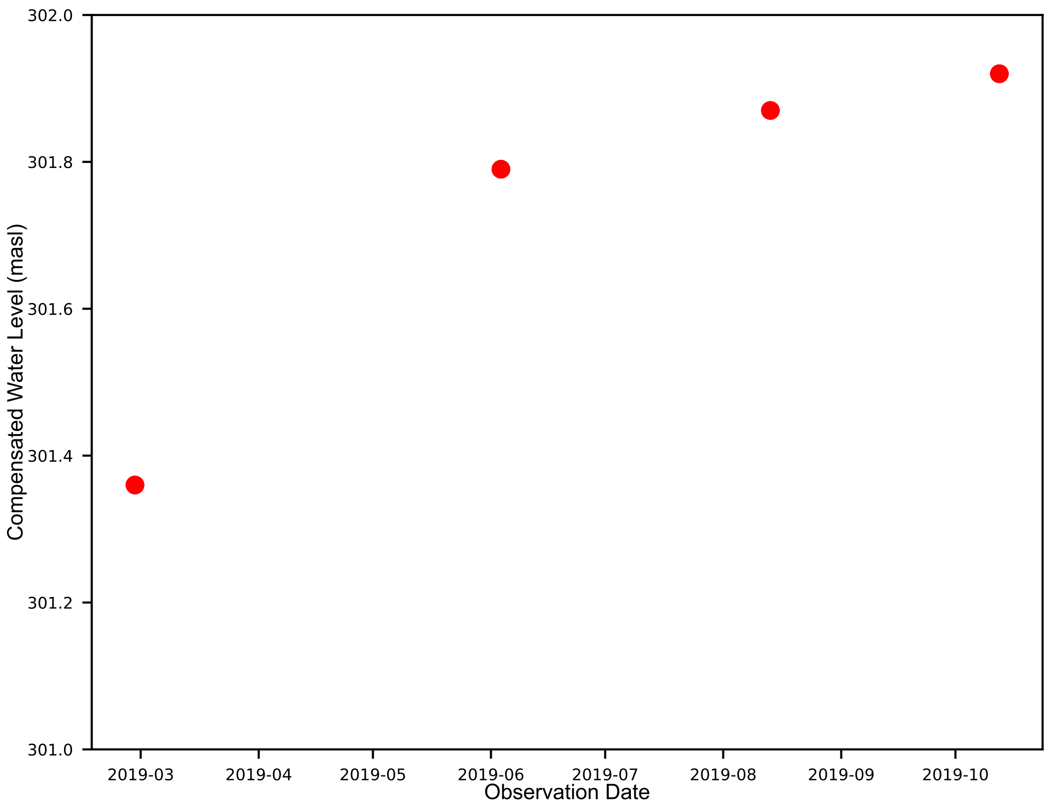
FORTHILLS
Operated by Suncor Energy

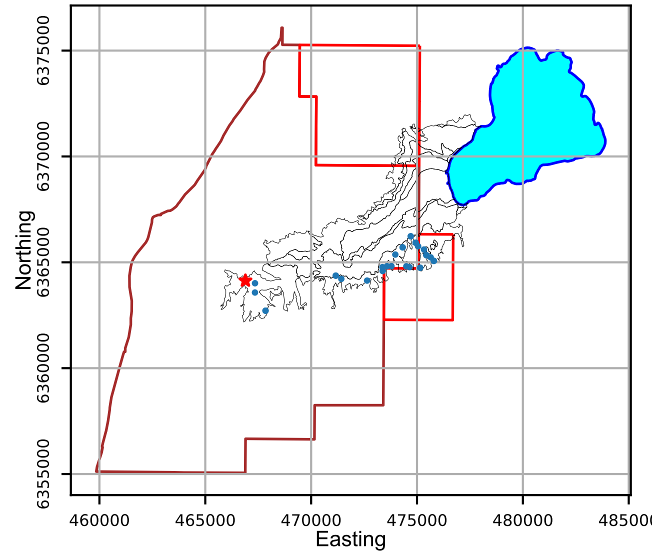
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES682-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-54

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 6.55 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES682-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B6-55

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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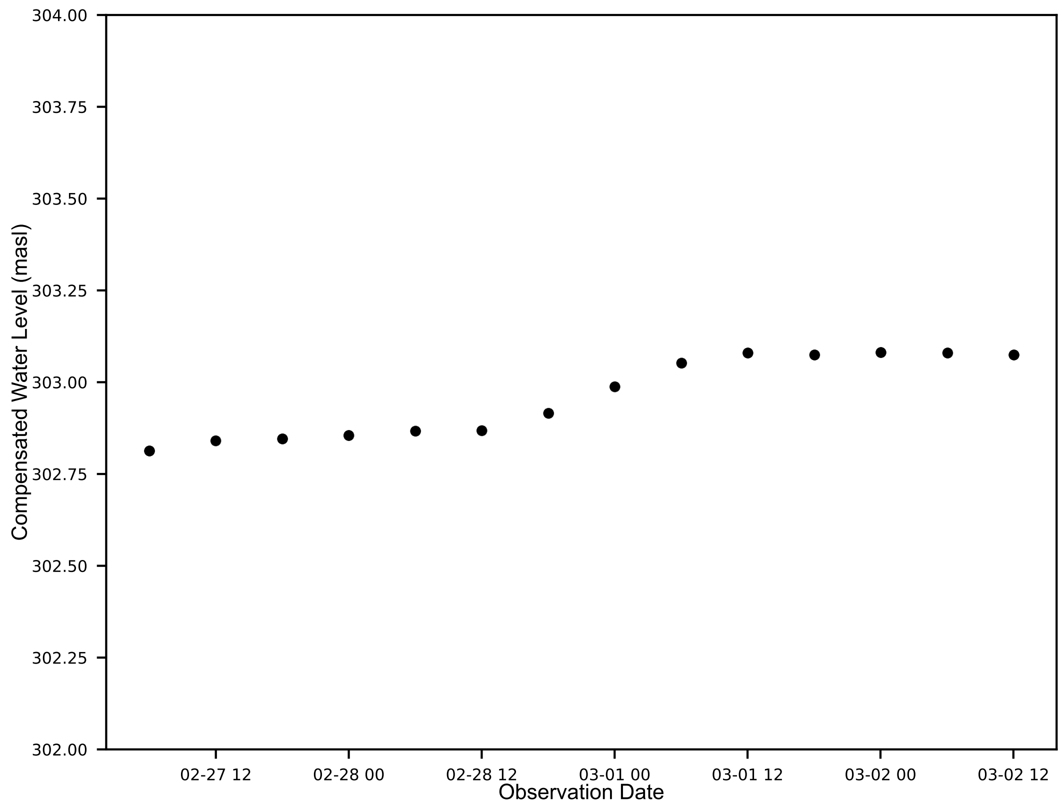
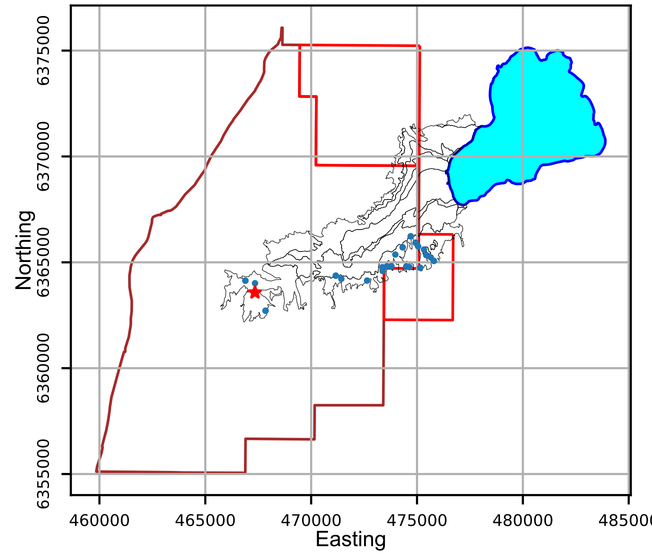
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 08 Till Aquitard AT2

Depth of Measurement: 13.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

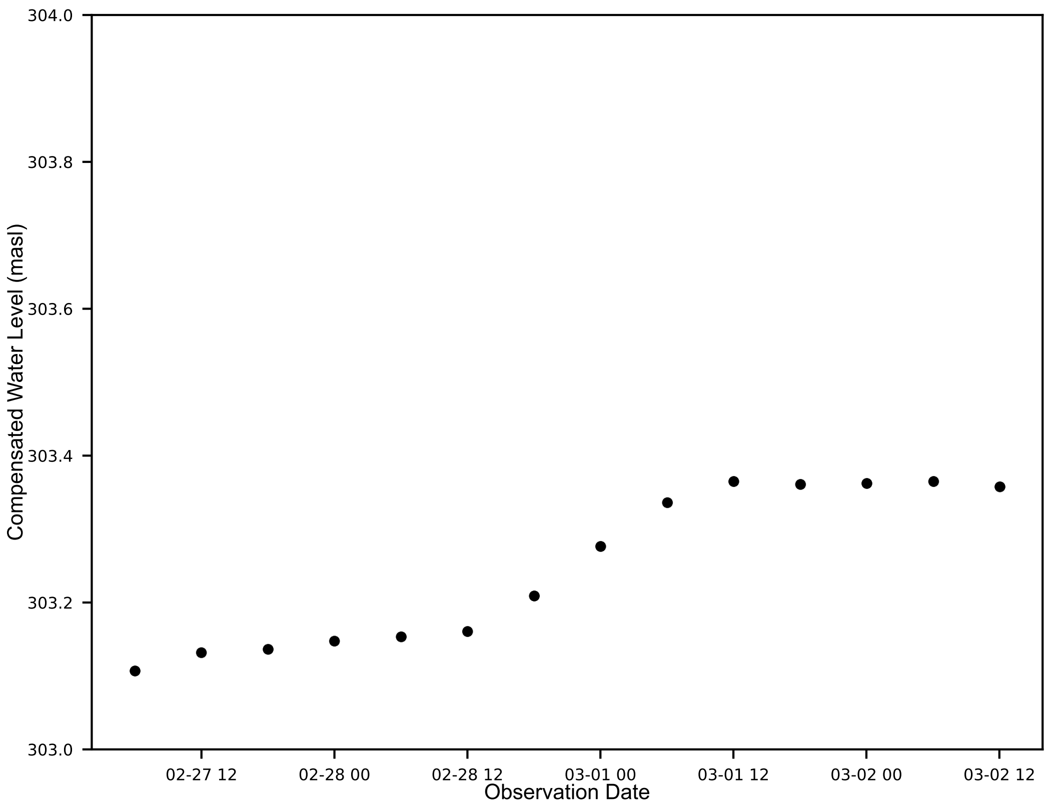
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

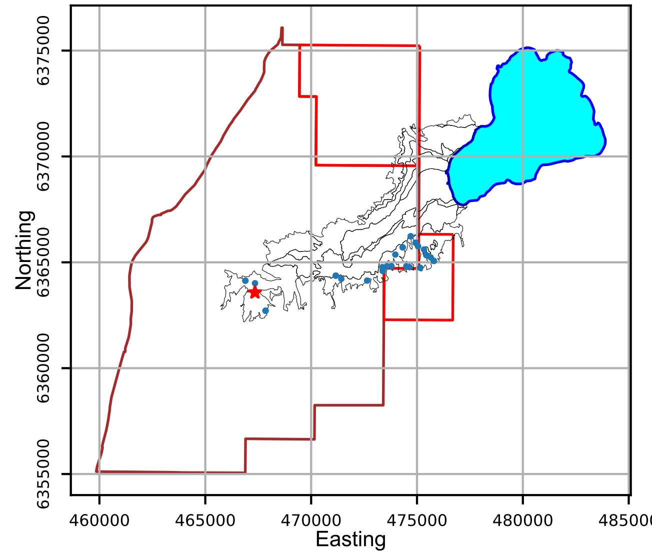
TITLE

FH19-ES691-SN1 - 13.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-56

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 20.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

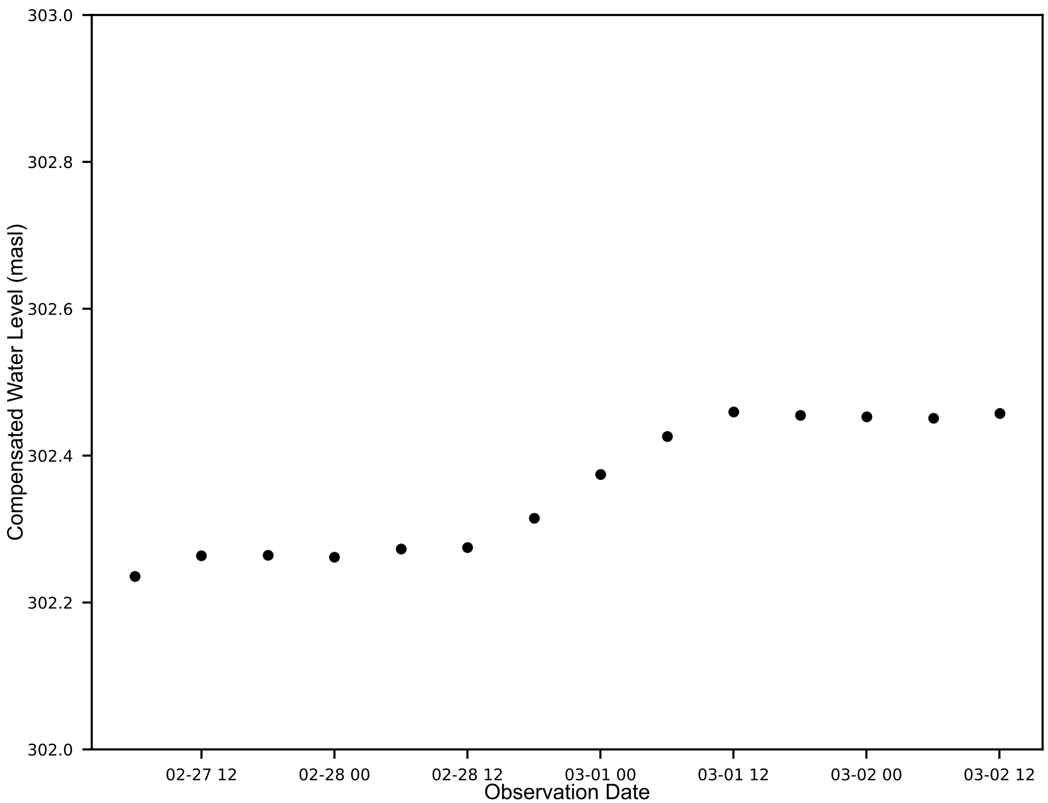
FORTHILLS
Operated by Suncor Energy

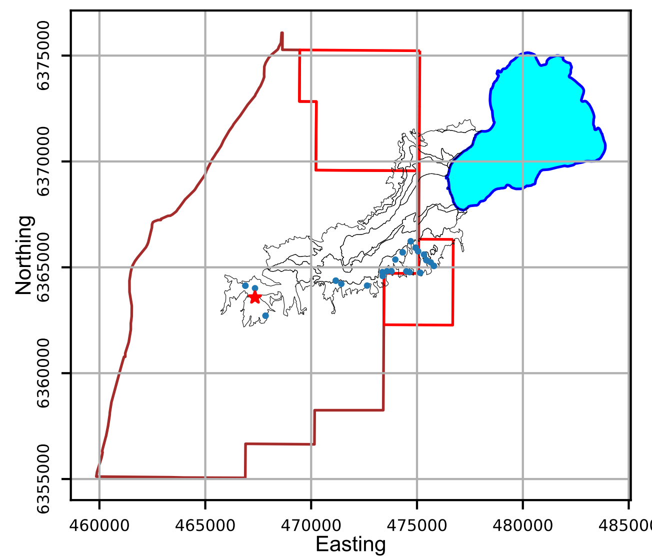
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES691-SN1 - 20.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-57

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES691-SN1 - 32.4 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-58

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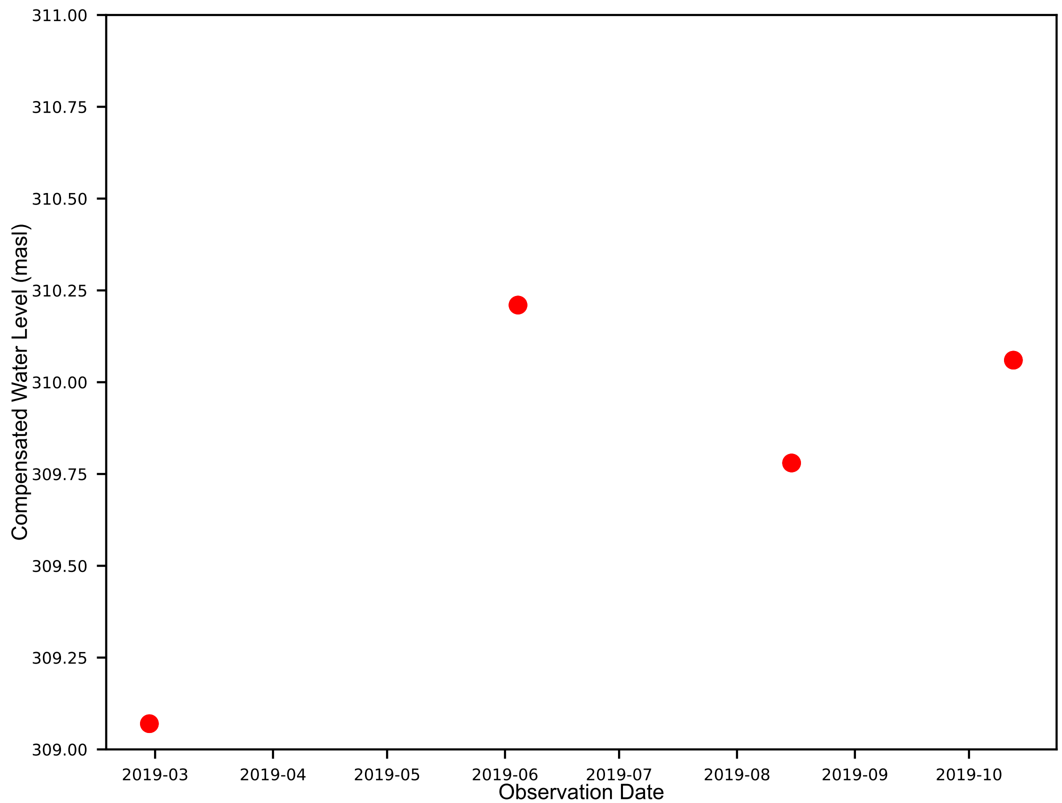

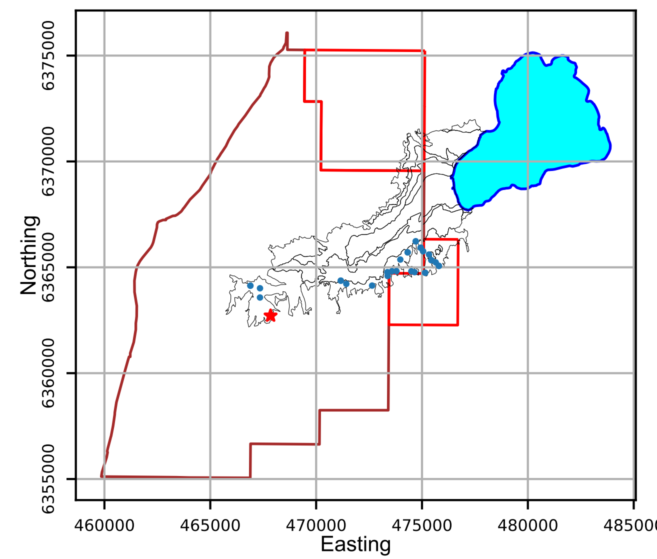

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 27.25 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES702-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-59

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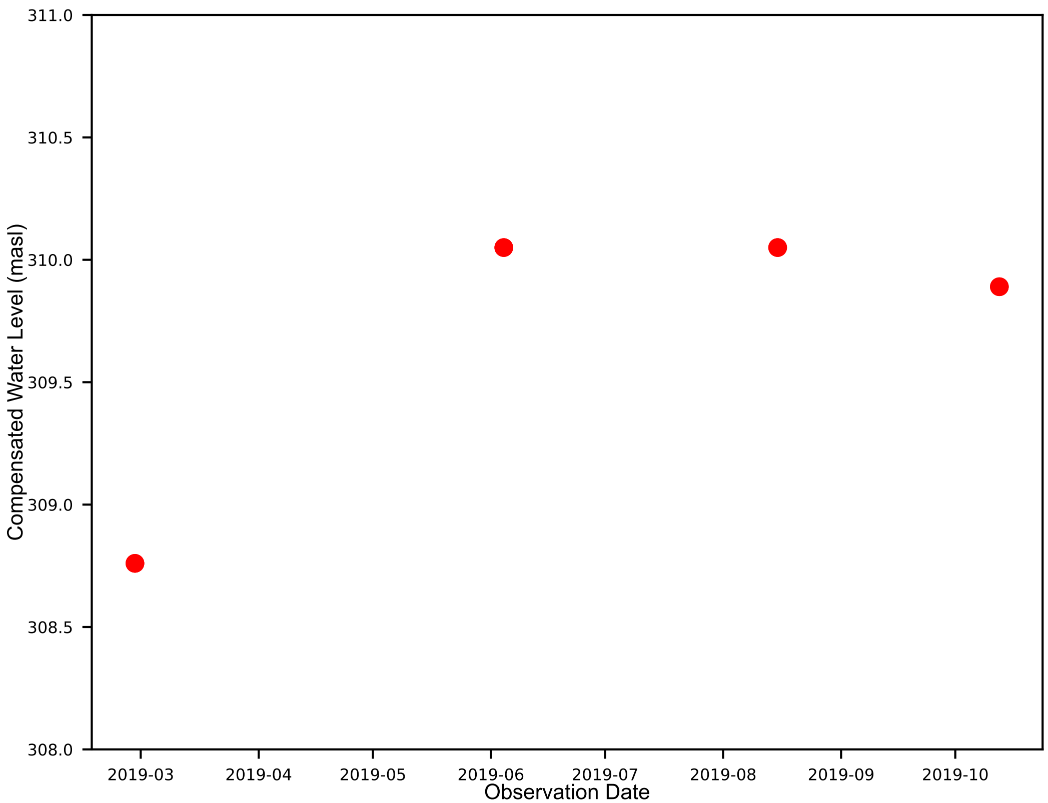

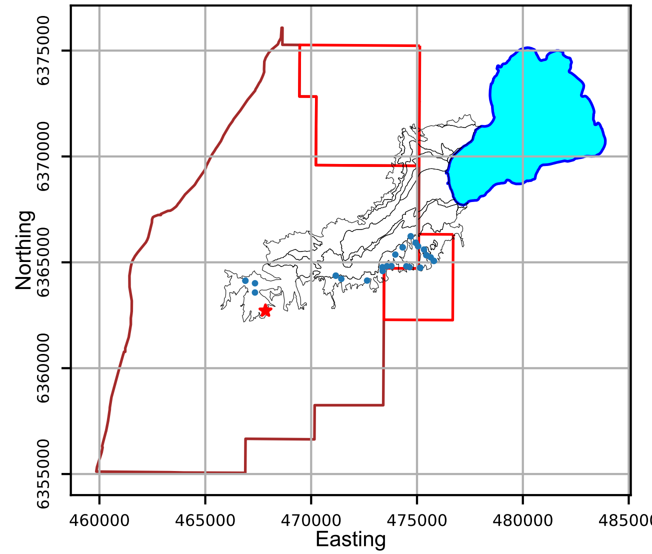

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 9.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH19-ES702-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B6-60

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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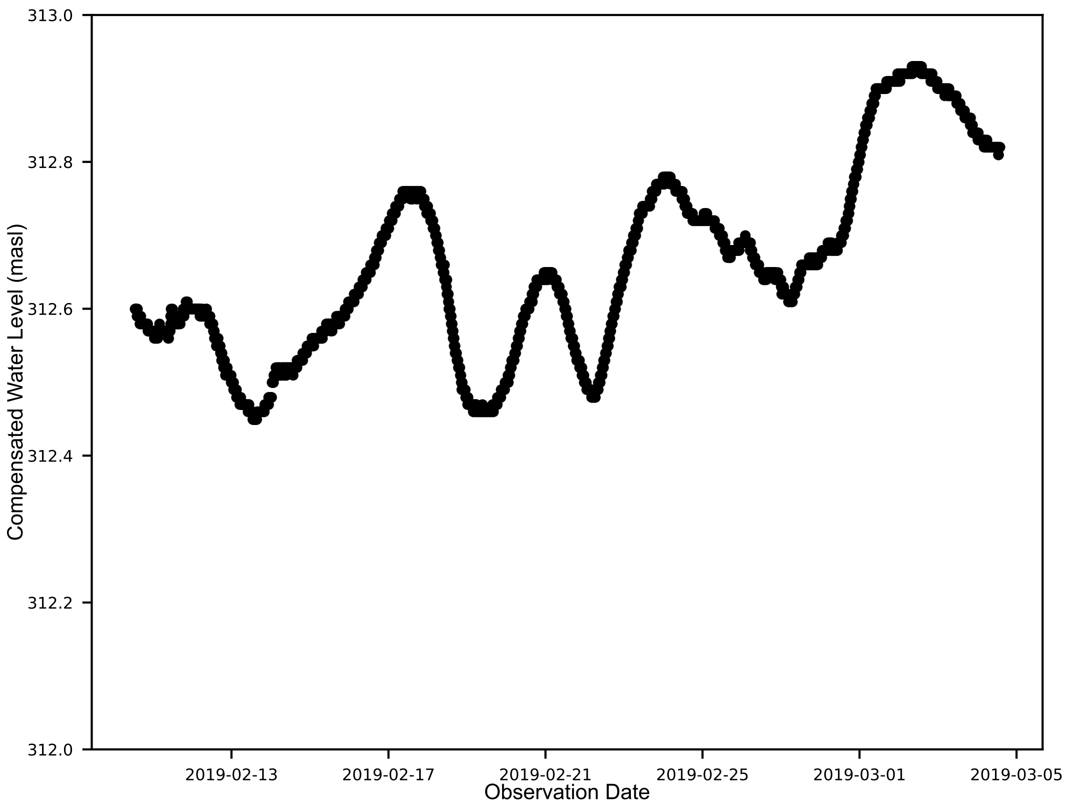

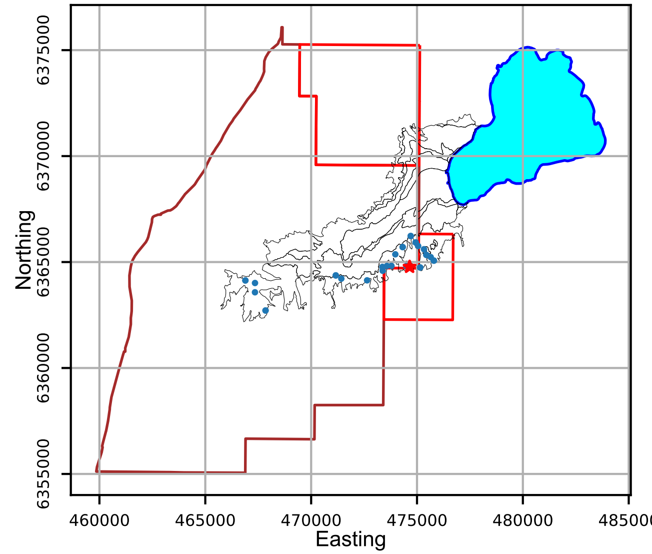

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 16 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION	PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09	TITLE	FH19-GL667-SN1 - 16.0 M BELOW GROUND SURFACE
PREPARED	RS		
DESIGN	MO		
REVIEW	LW		
APPROVED	RM		

FORT HILLS
Operated by Suncor Energy

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-61

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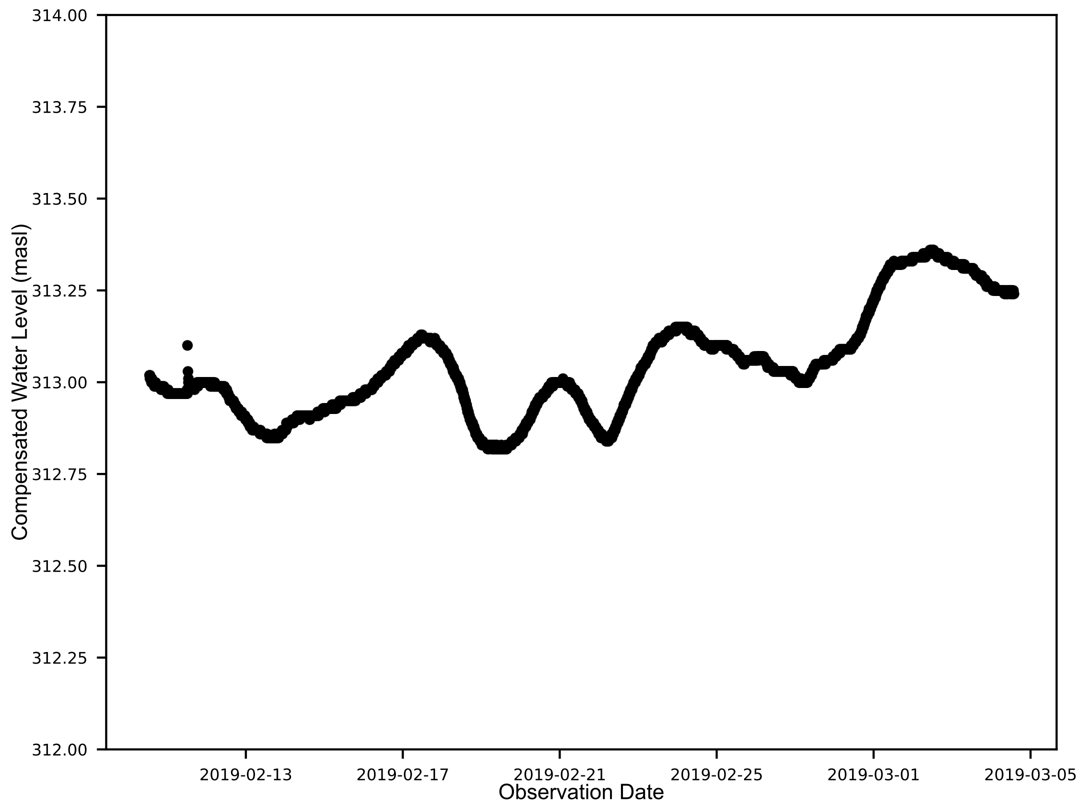

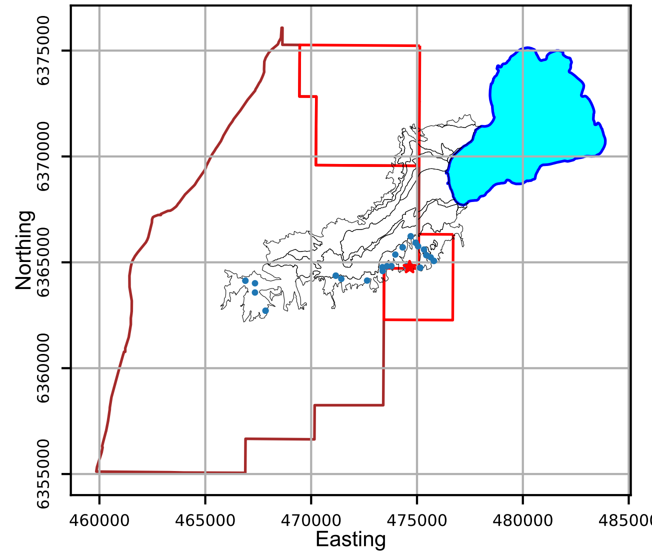

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-GL667-SN1 - 28.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-62

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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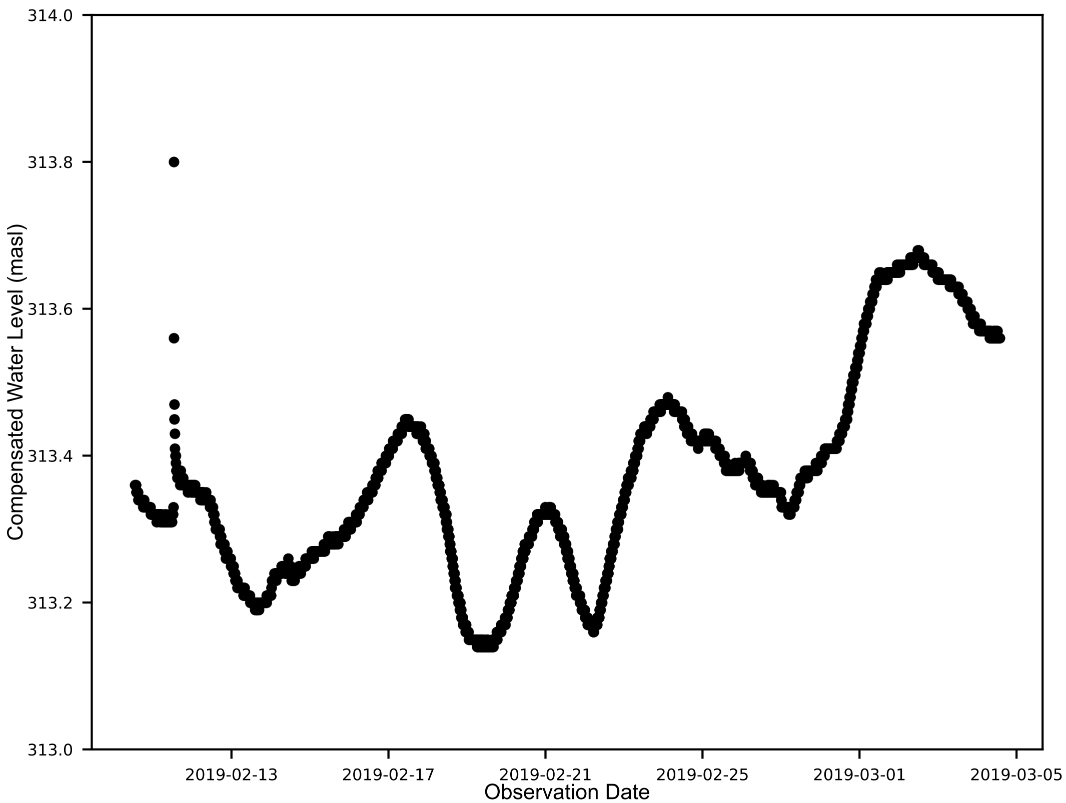
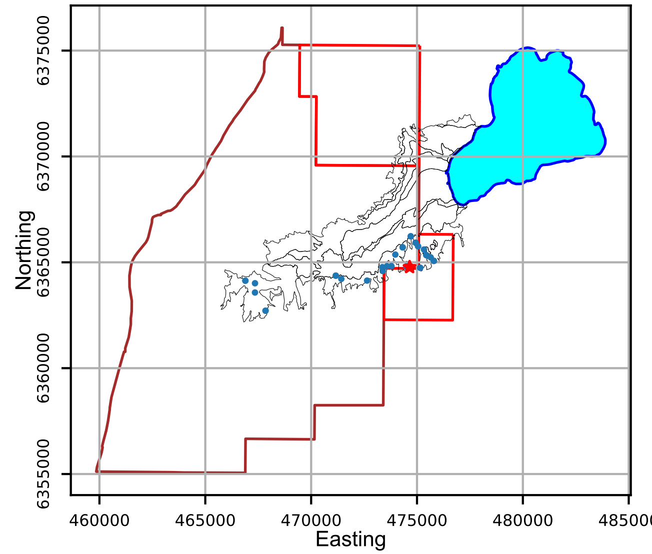




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 38.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

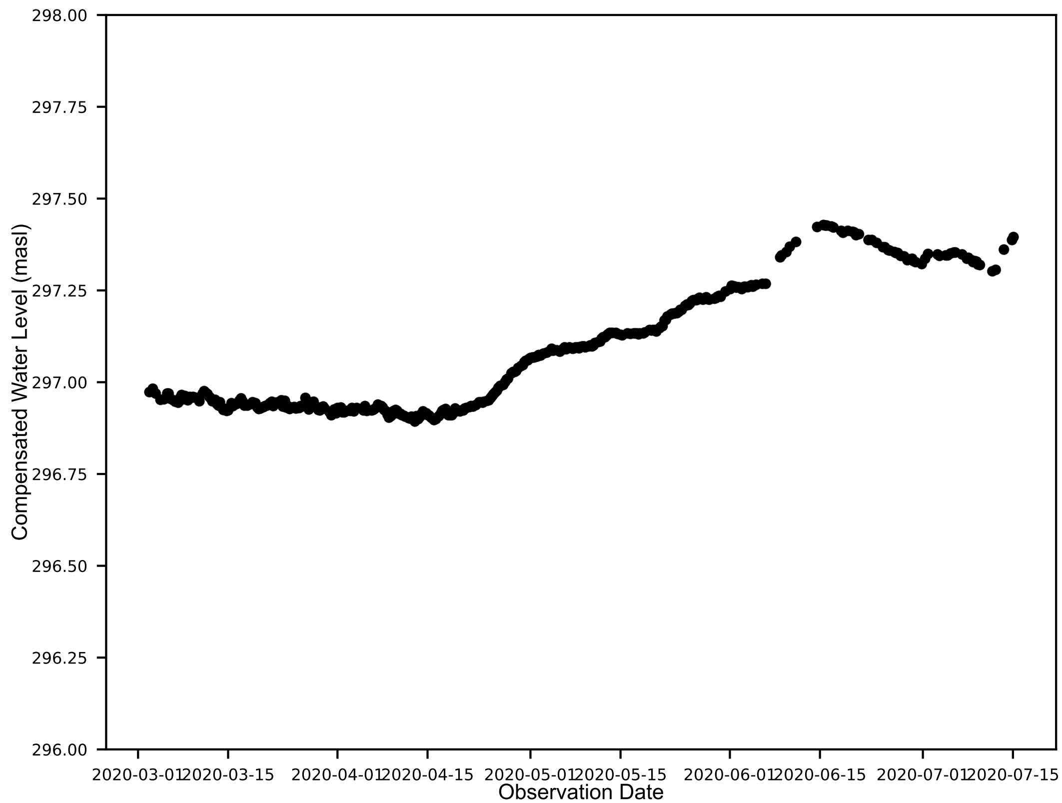
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

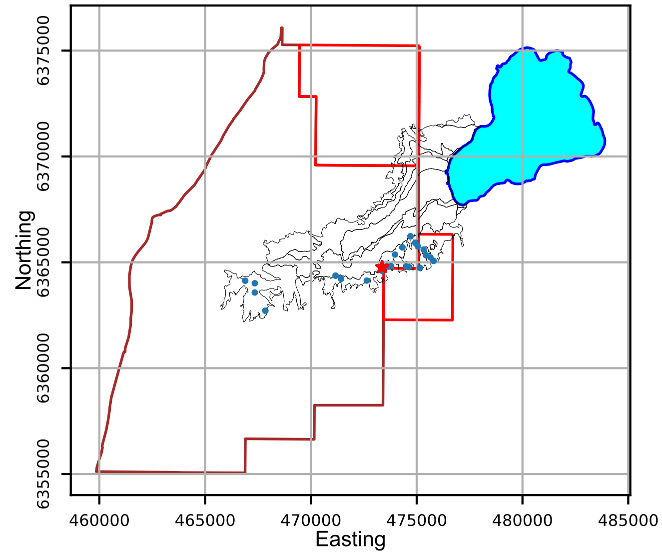
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH19-GL667-SN1 - 38.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-63





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 18.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
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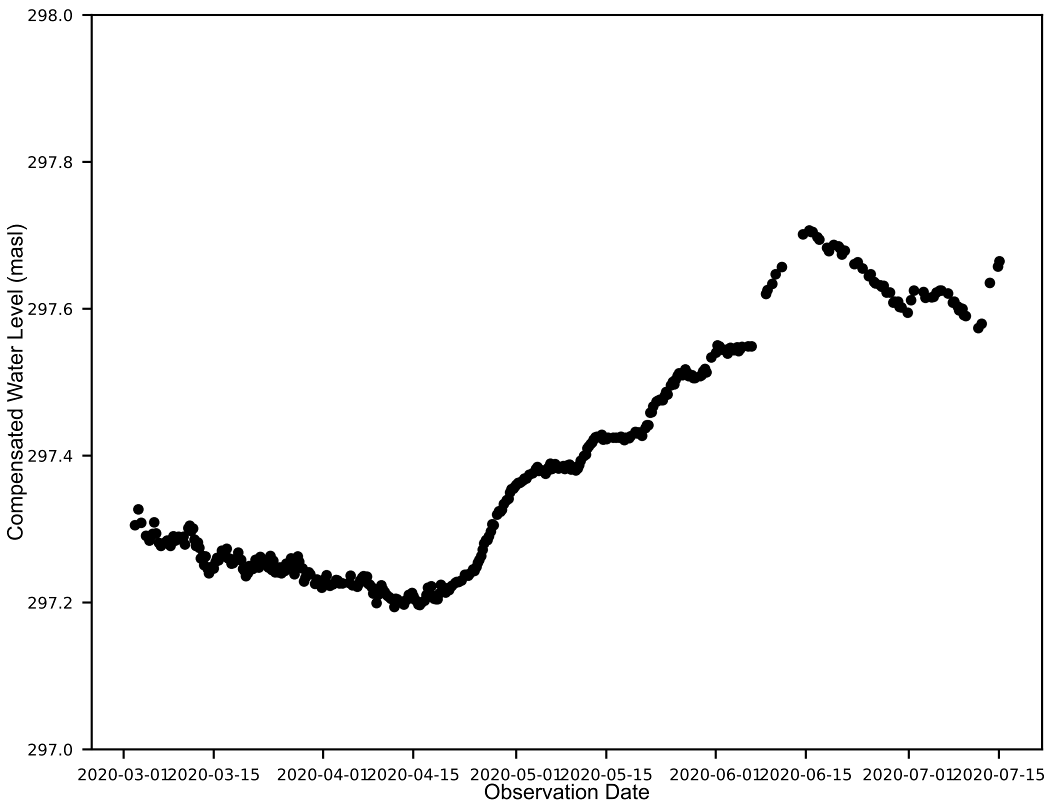
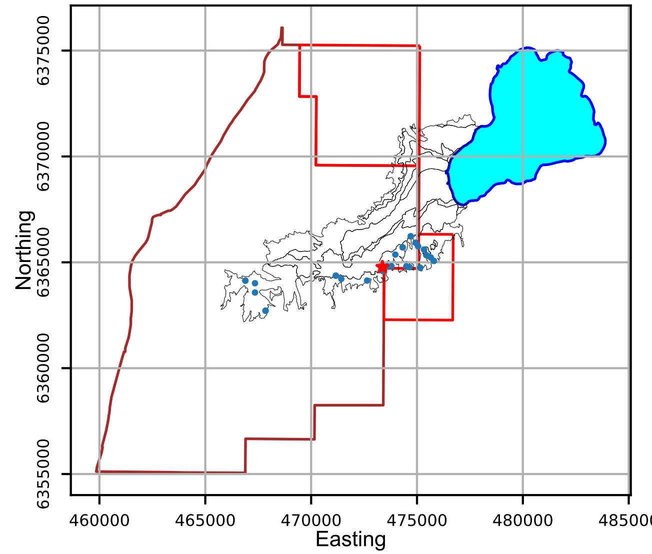
TITLE
FH20-WR680-SN1 - 18.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-64





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 24.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH20-WR680-SN1 - 24.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-65

FORTHILLS
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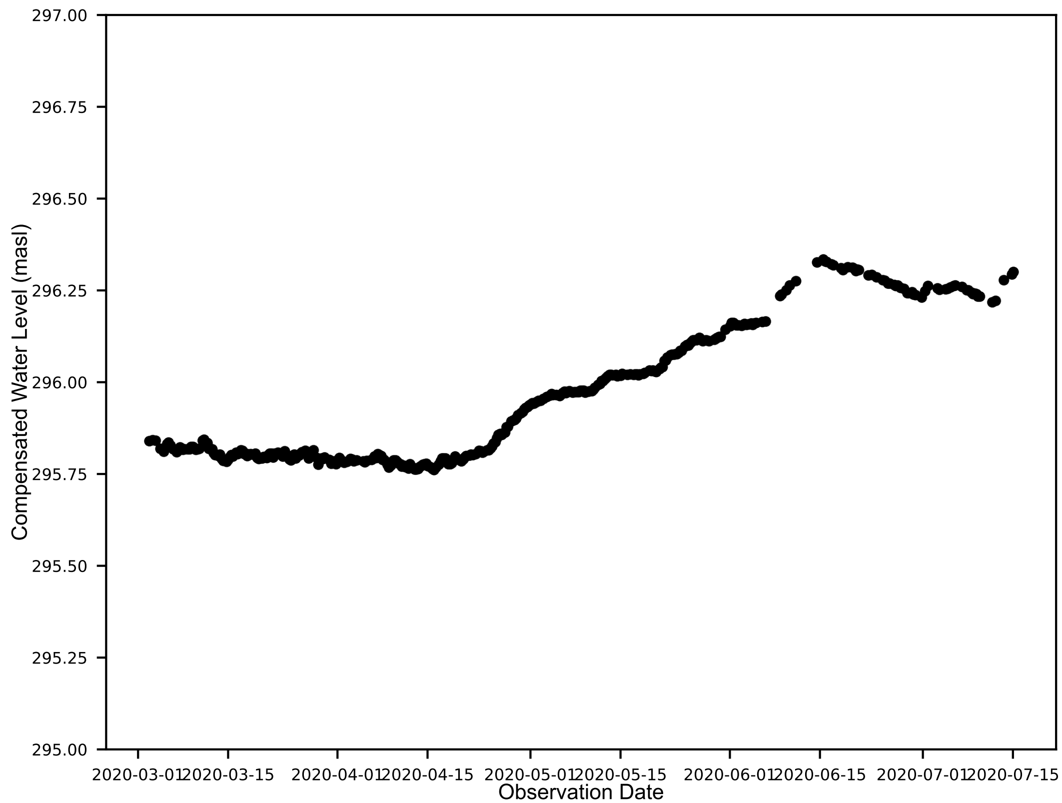
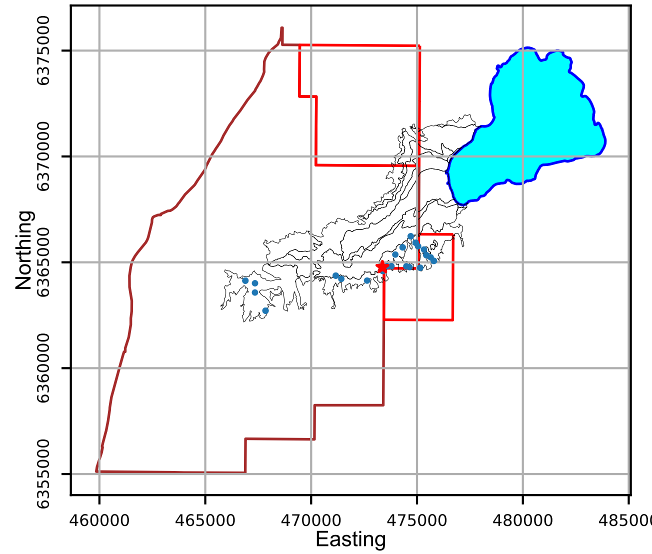
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 34 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH20-WR680-SN1 - 34.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-66

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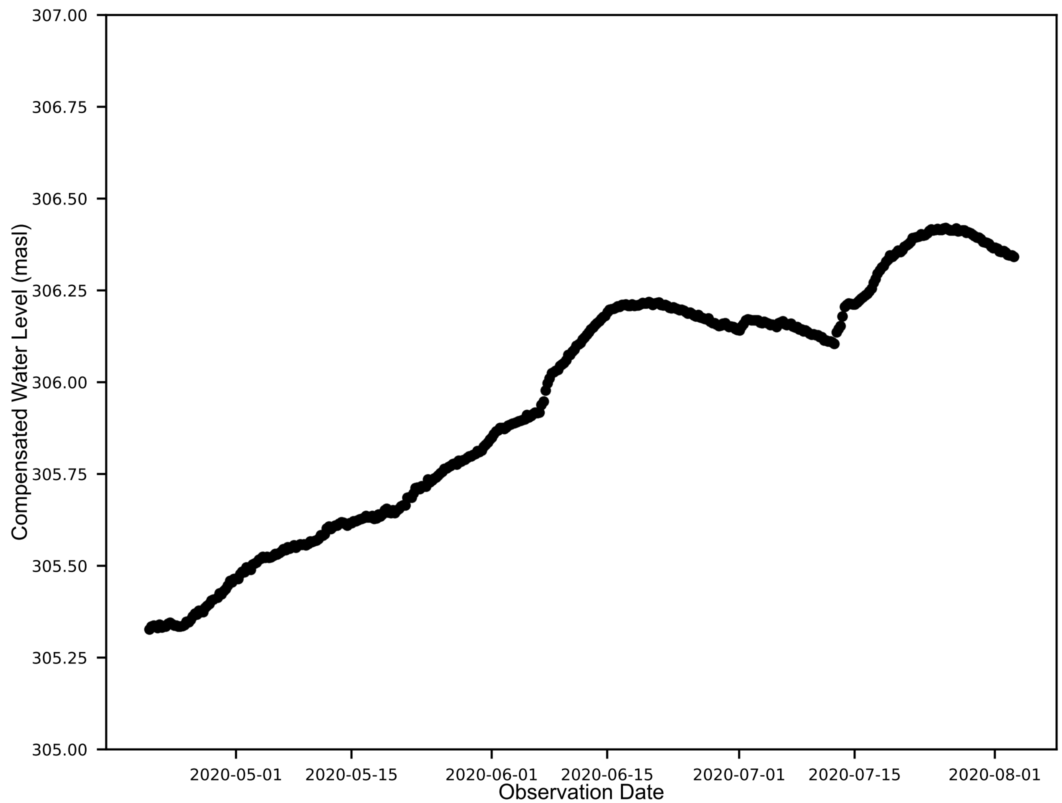
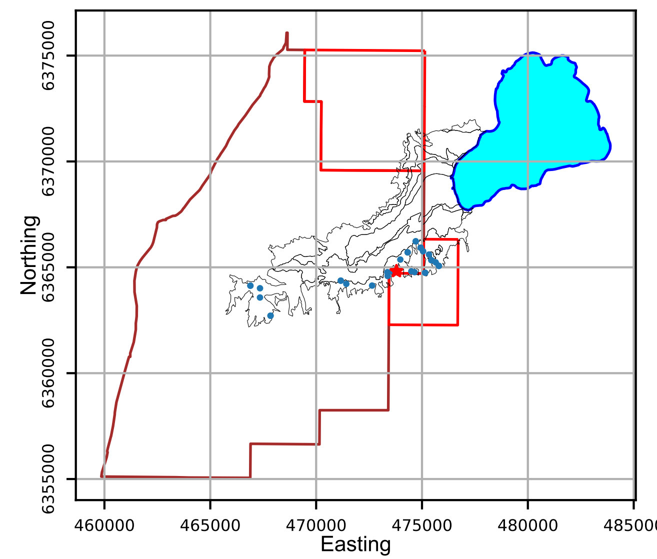




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 16 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

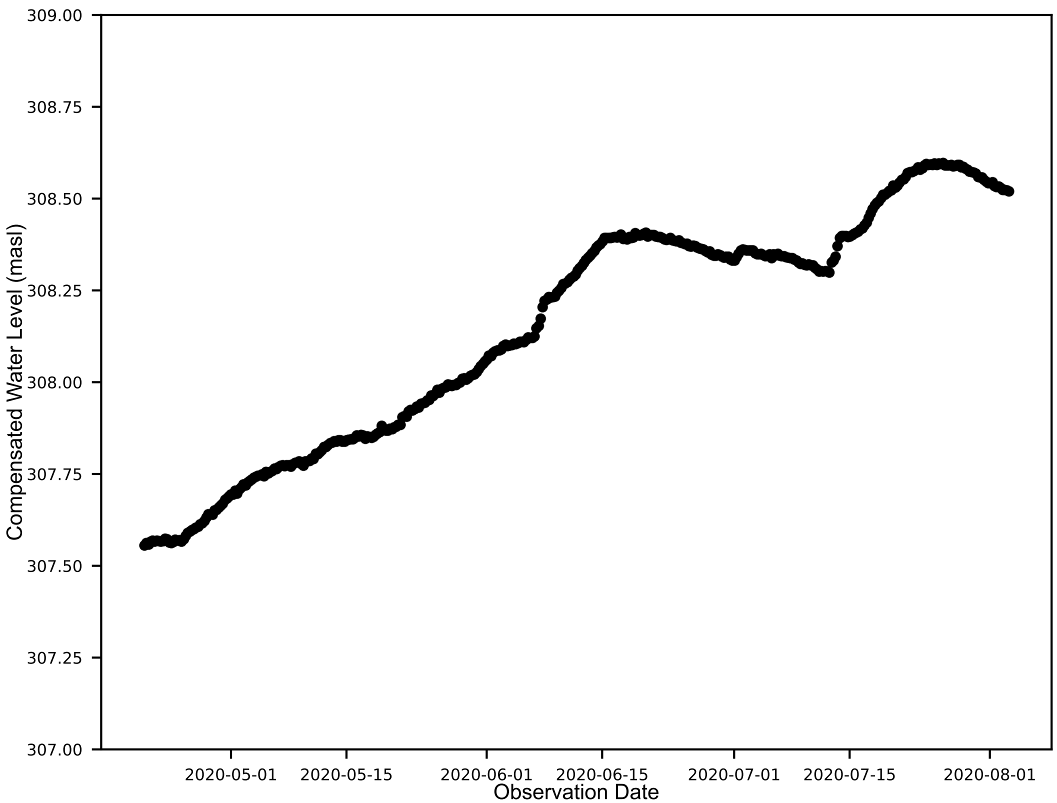
CLIENT
FORT HILLS ENERGY CORPORATION

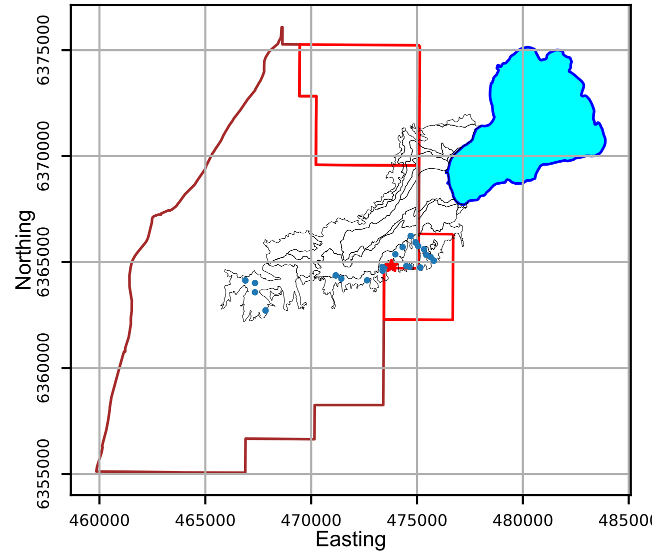
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH20-WR681-SN1 - 16.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-67





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH20-WR681-SN1 - 29.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-68

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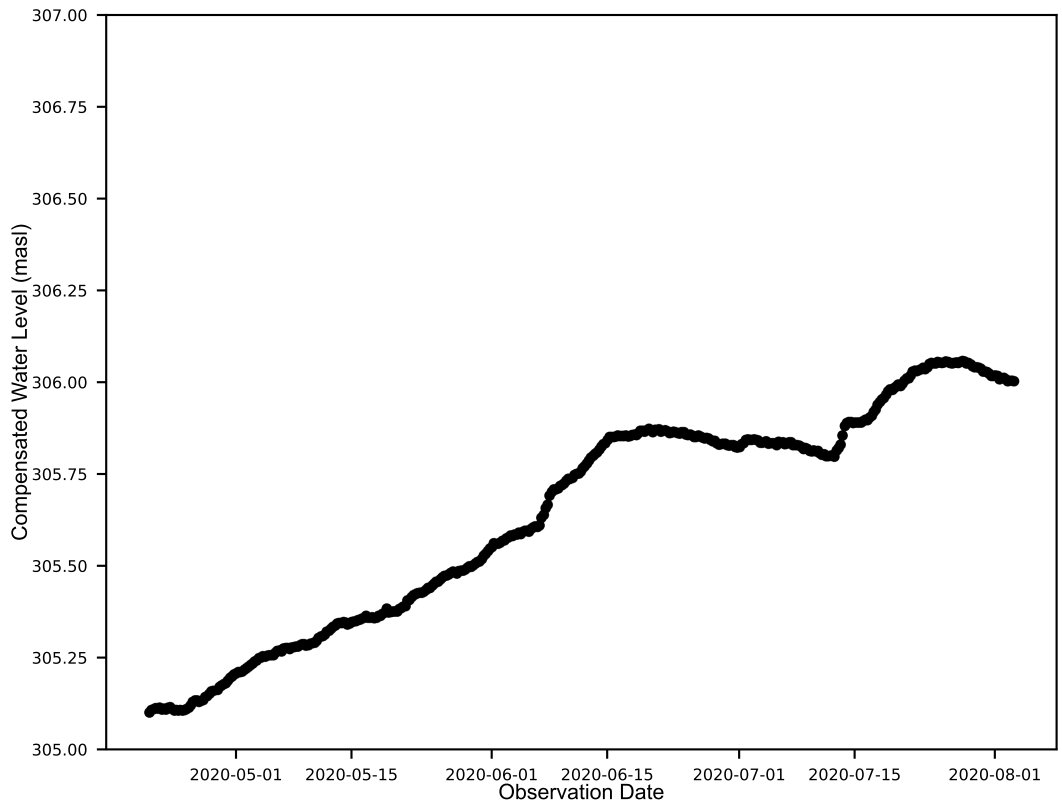

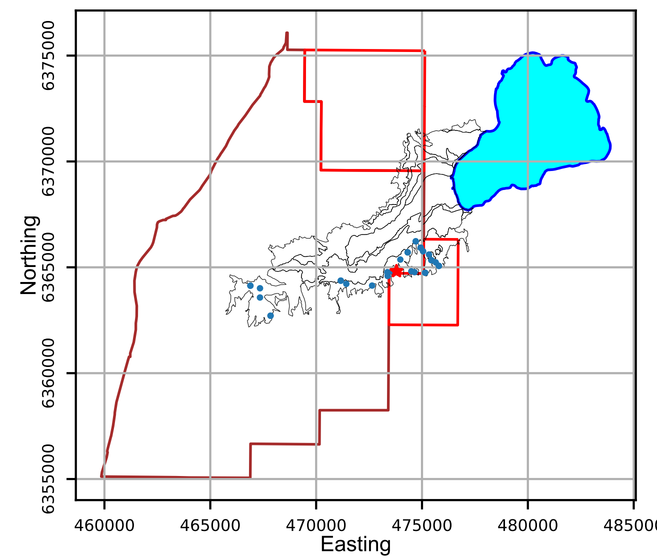

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 38.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH20-WR681-SN1 - 38.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-69

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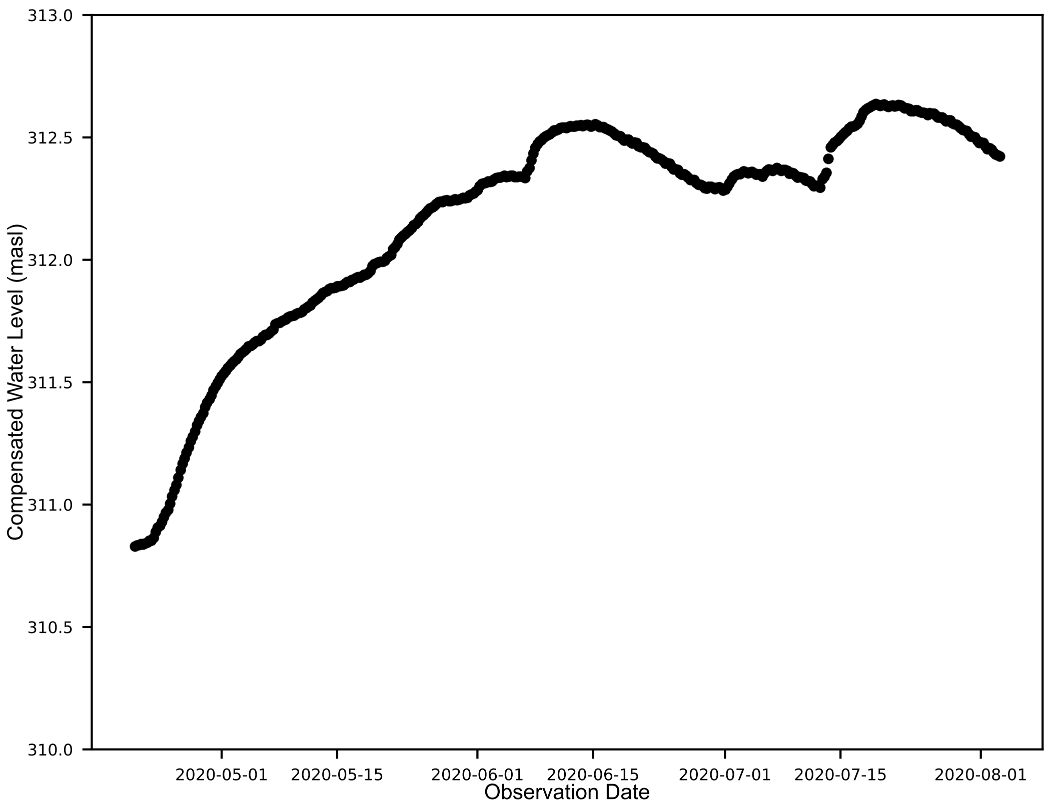

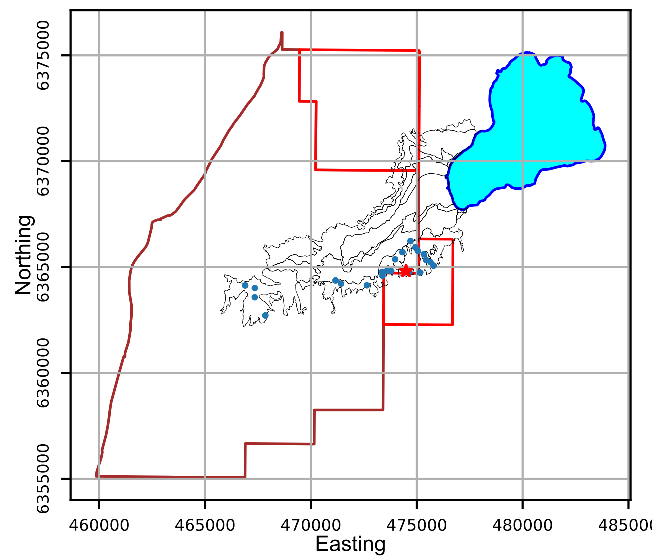

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 08 Till Aquitard AT2
Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH20-WR684-SN1 - 11.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-70

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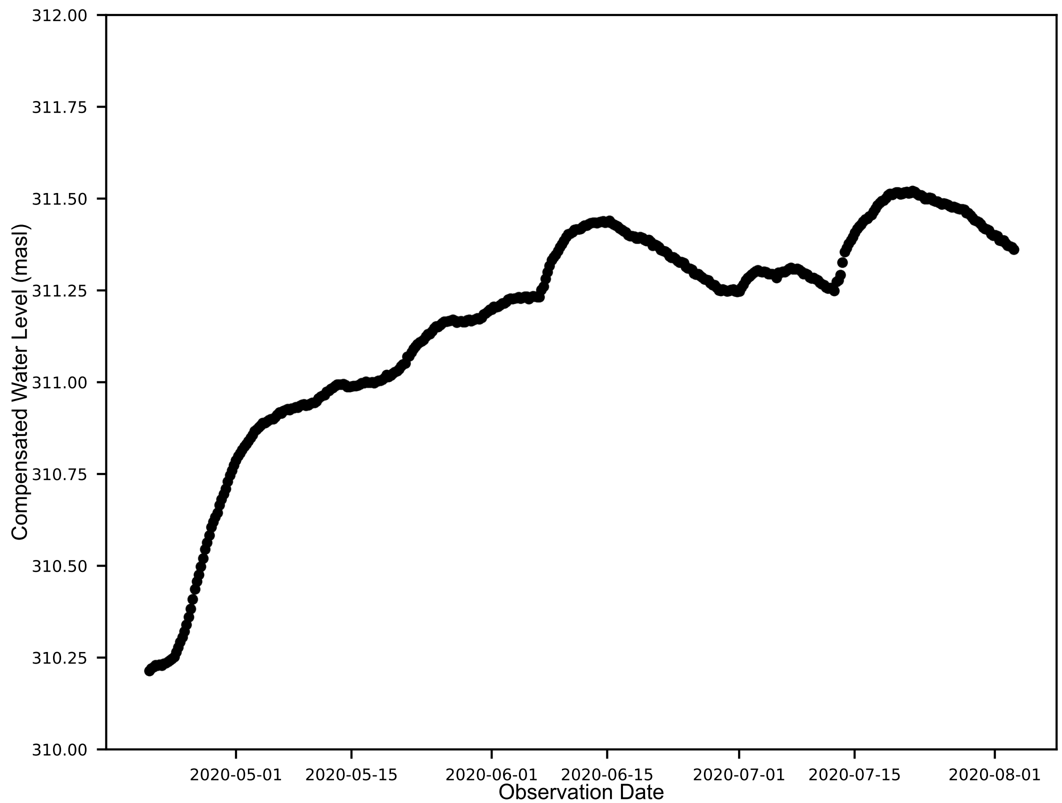

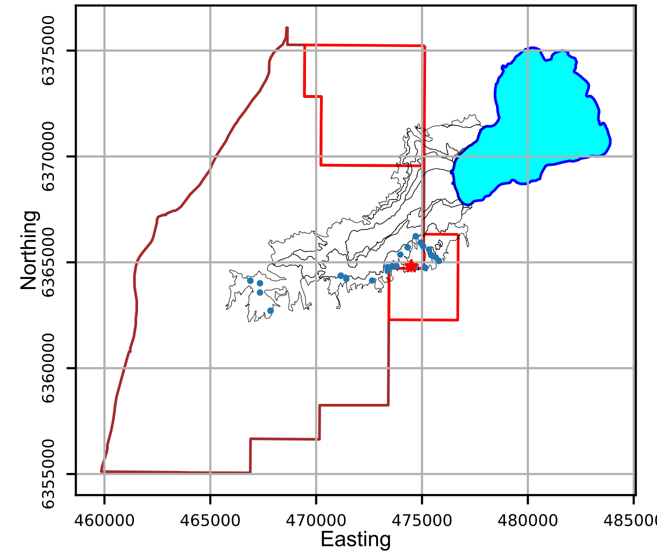

Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 34 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH20-WR684-SN1 - 34.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-71

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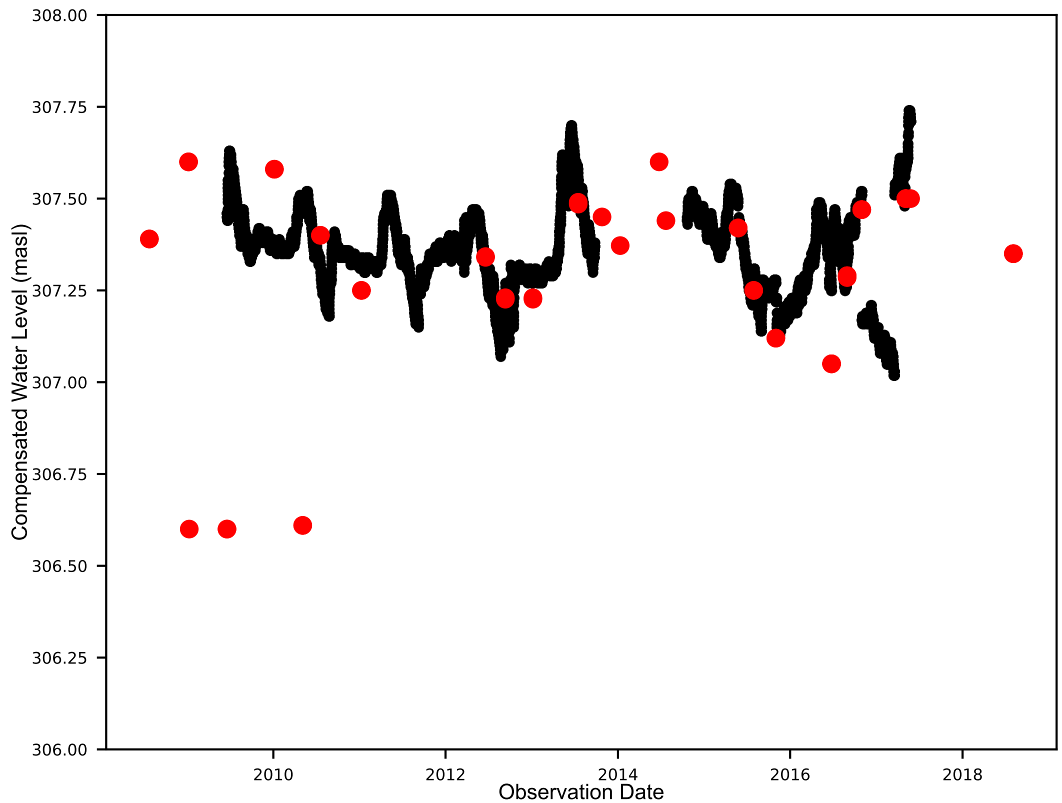

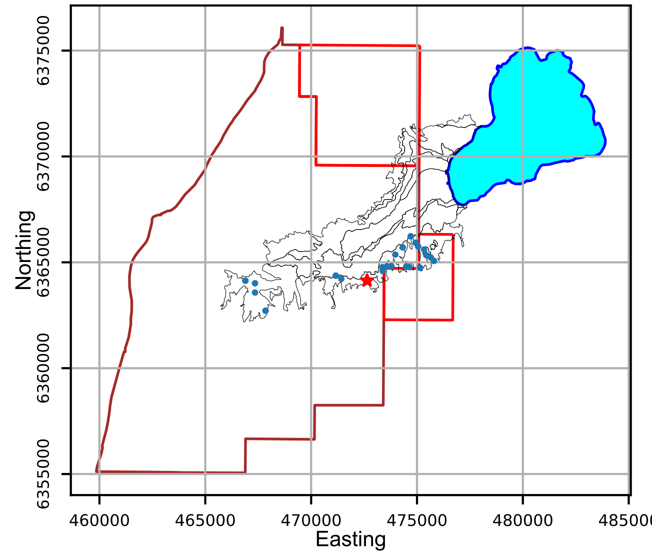

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 11.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-096A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-72

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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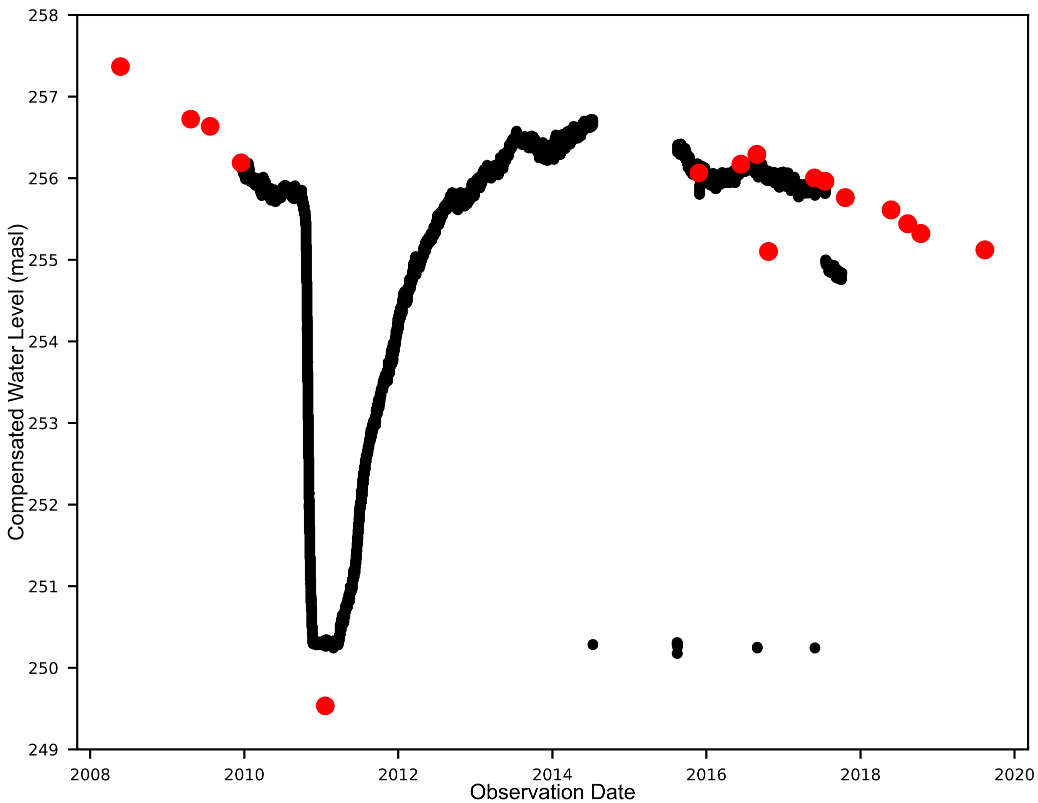

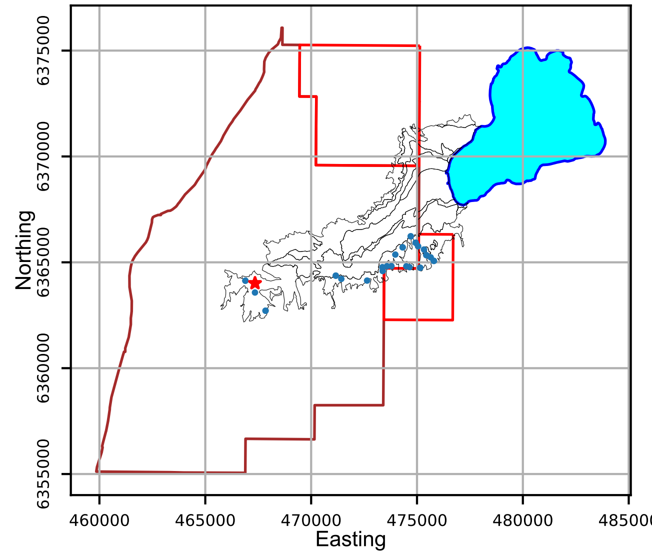

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 138.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

MW07-122

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B6-73

B7 Hydrographs for Fort Hills Upland Complex

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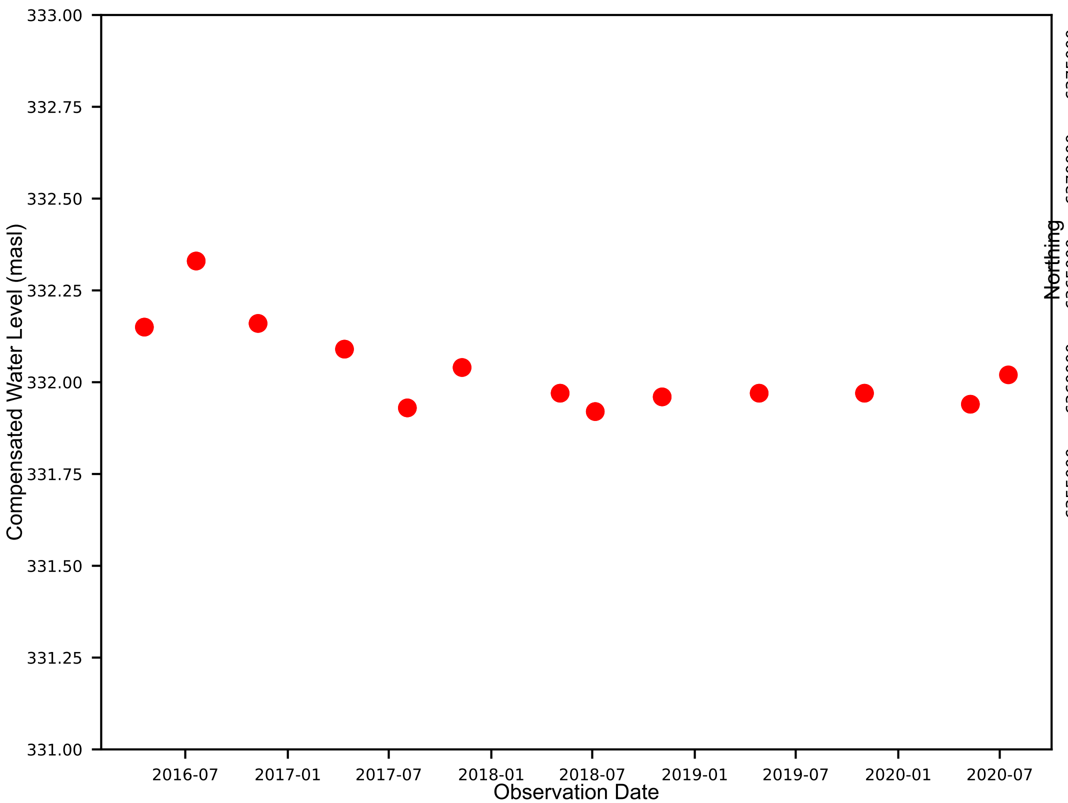

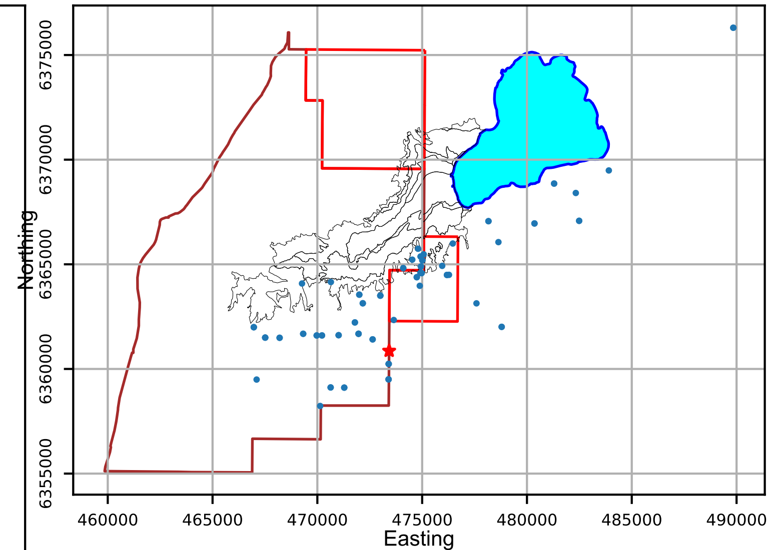

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 13 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-20-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-1

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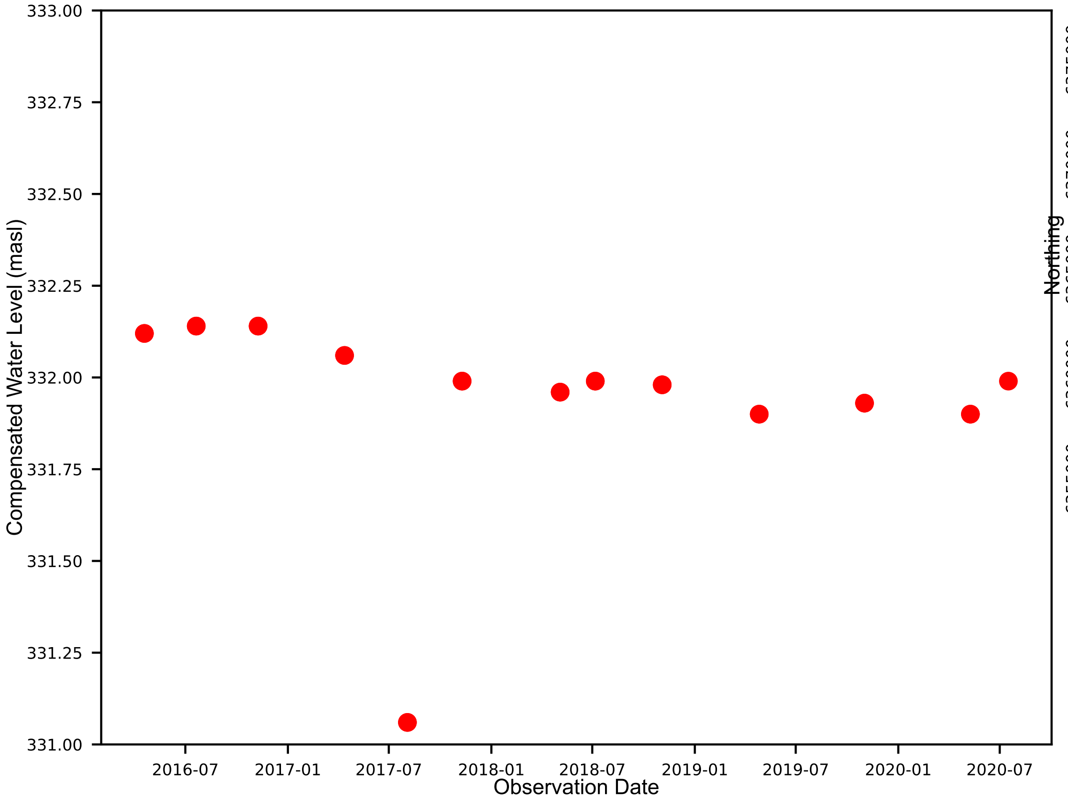

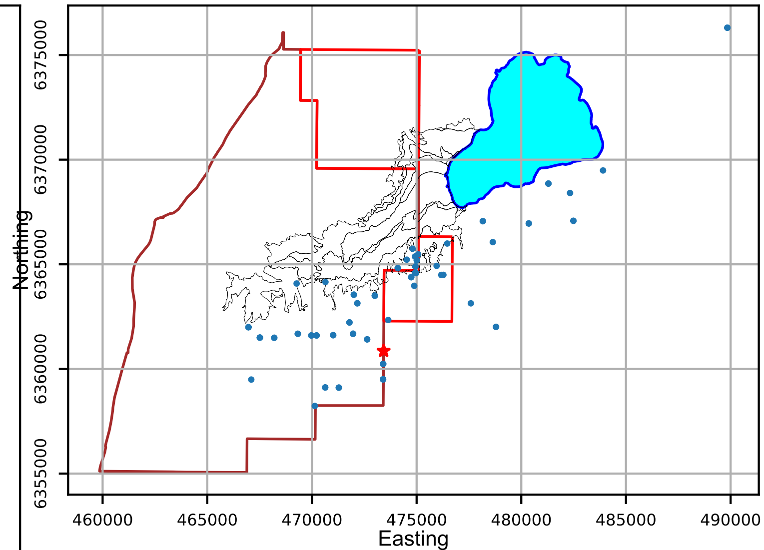

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 21.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

A-20-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-2

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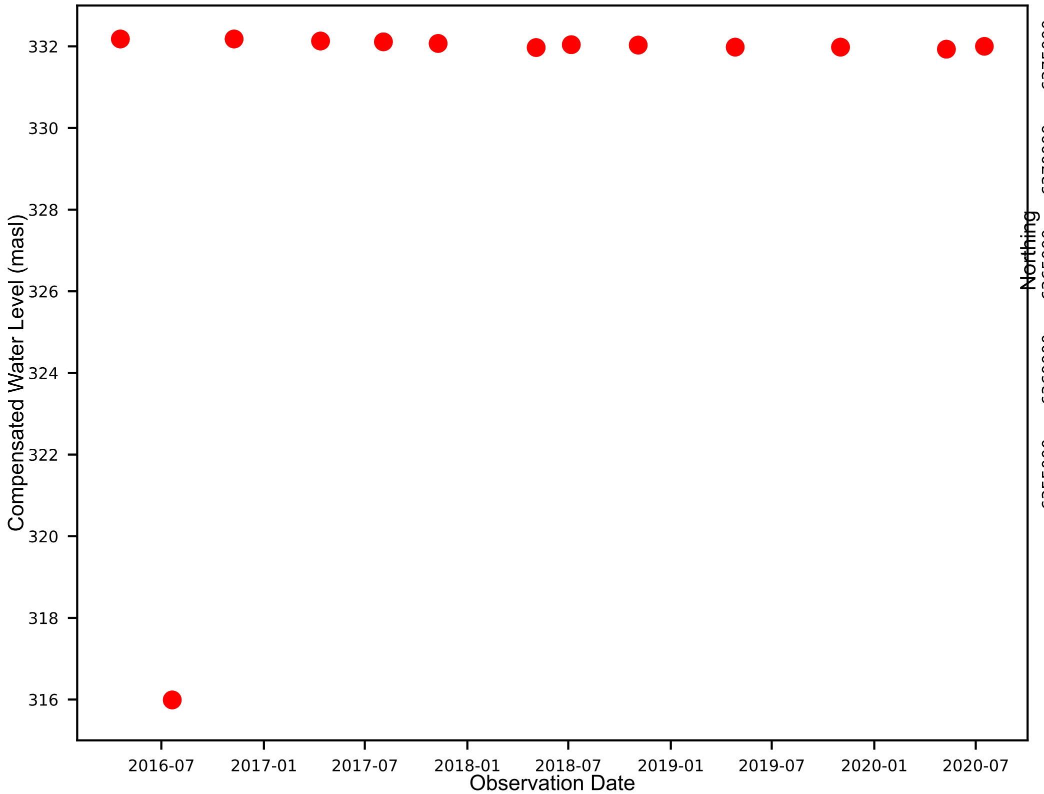

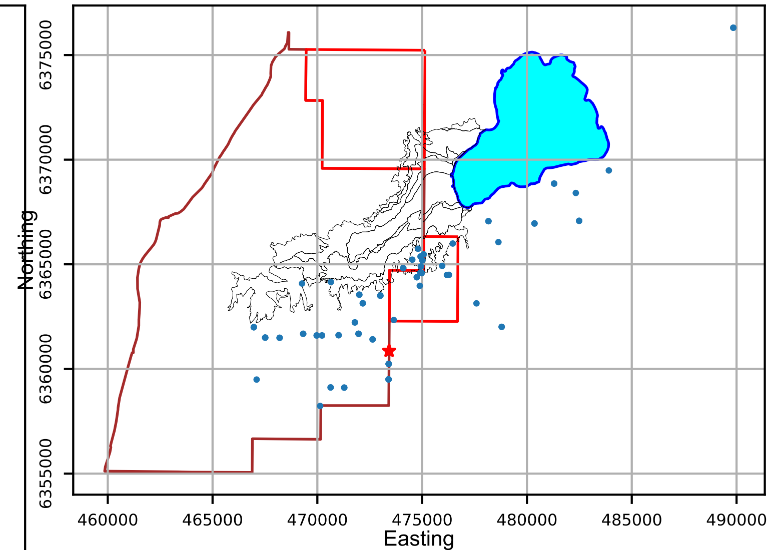

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 08 Silty Sand AT2
Depth of Measurement: 26.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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TITLE

A-20-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-3

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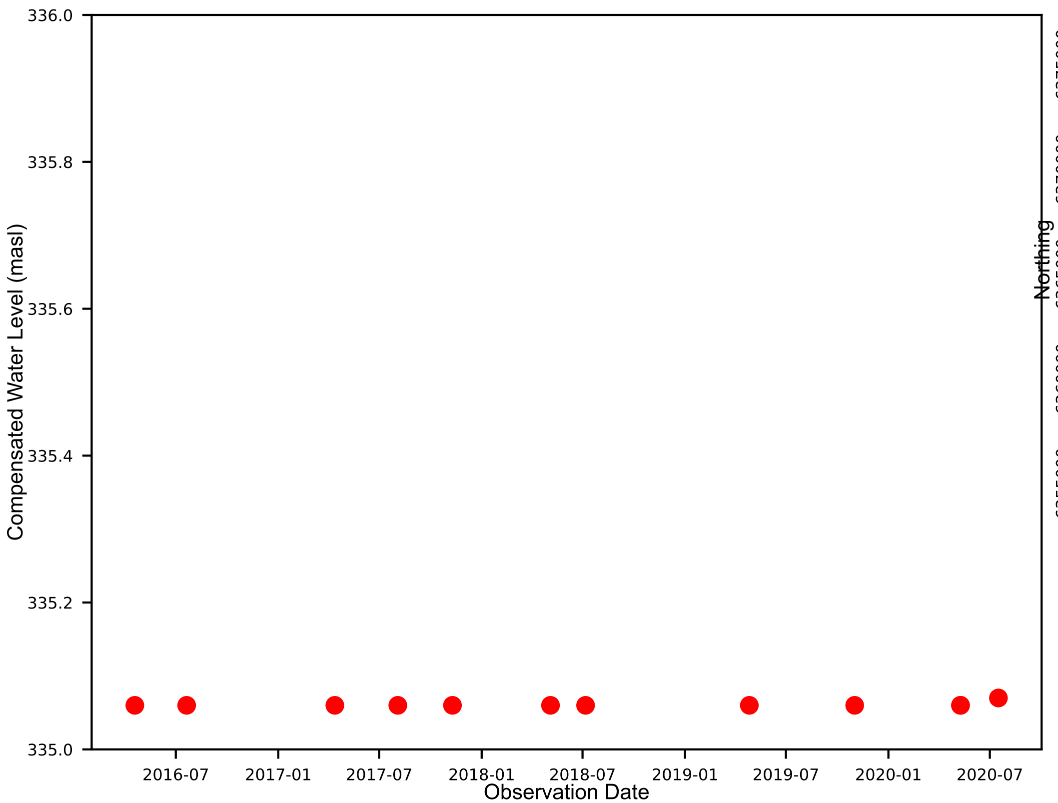

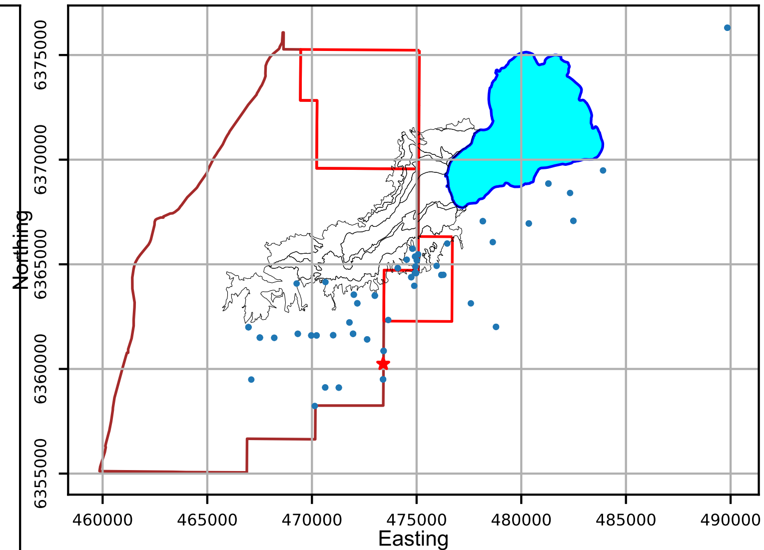

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 05 Silty Sand AQ1 AQ2
Depth of Measurement: 11.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

A-21-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-4

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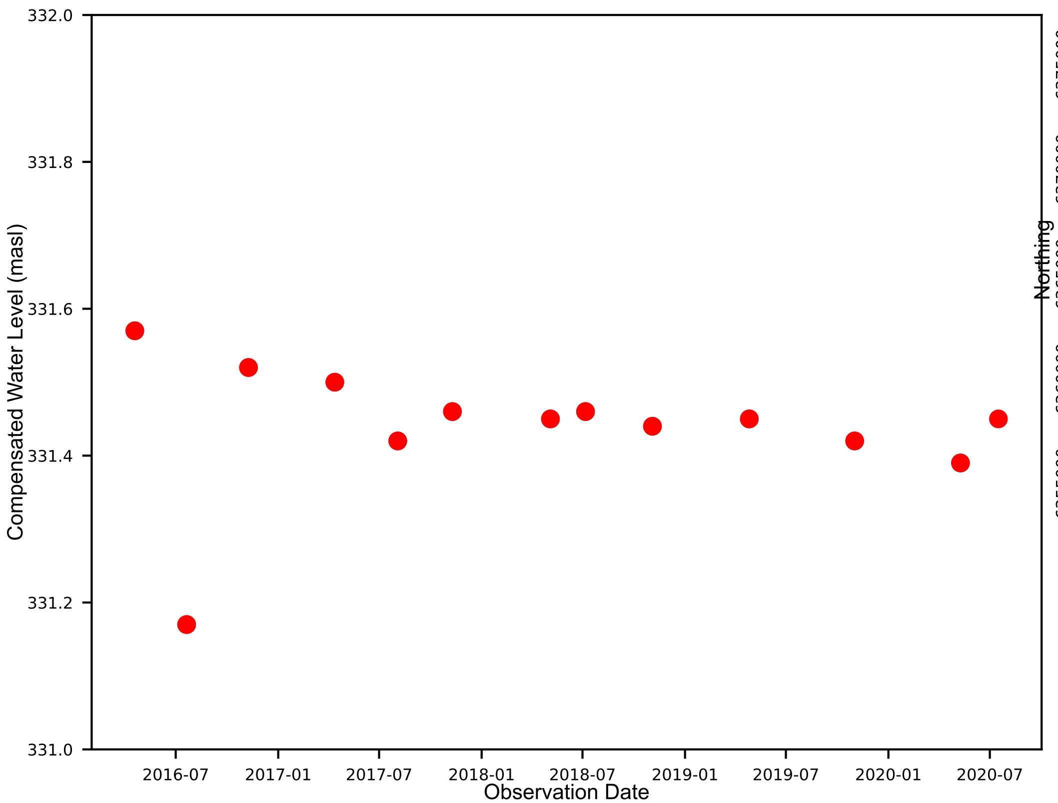

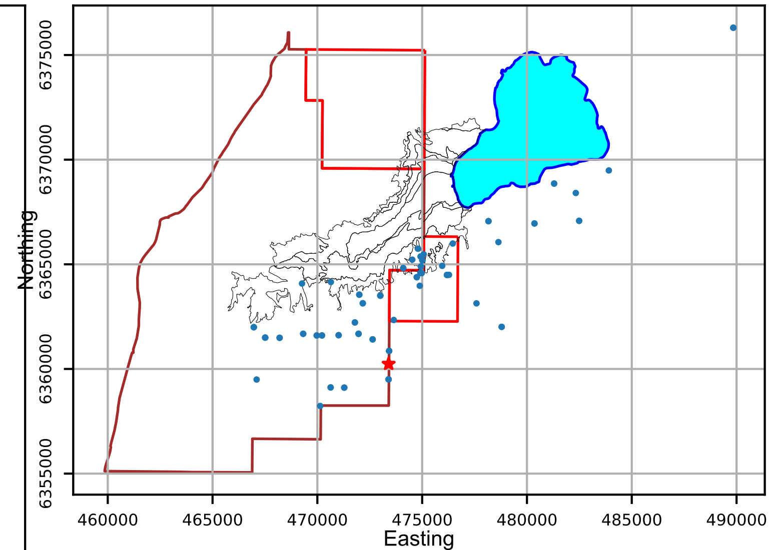

Hydrograph Legend

- Manual measurement
- Transducer measurement

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 20 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-21-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-5

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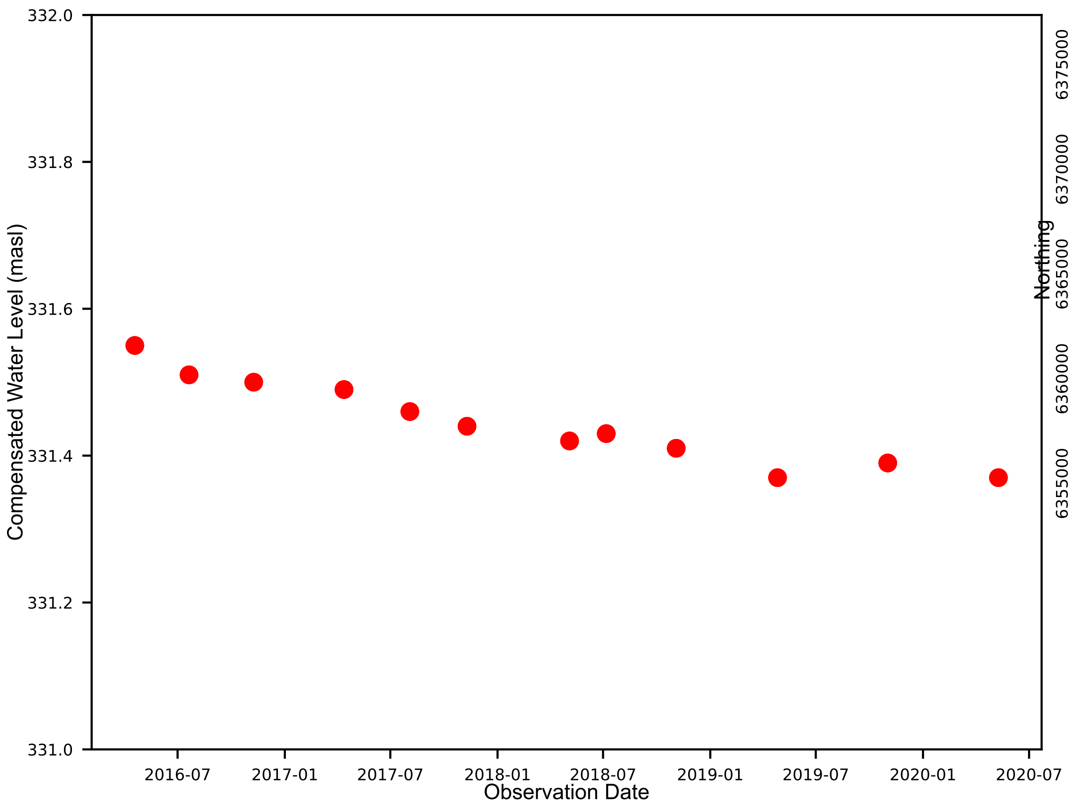

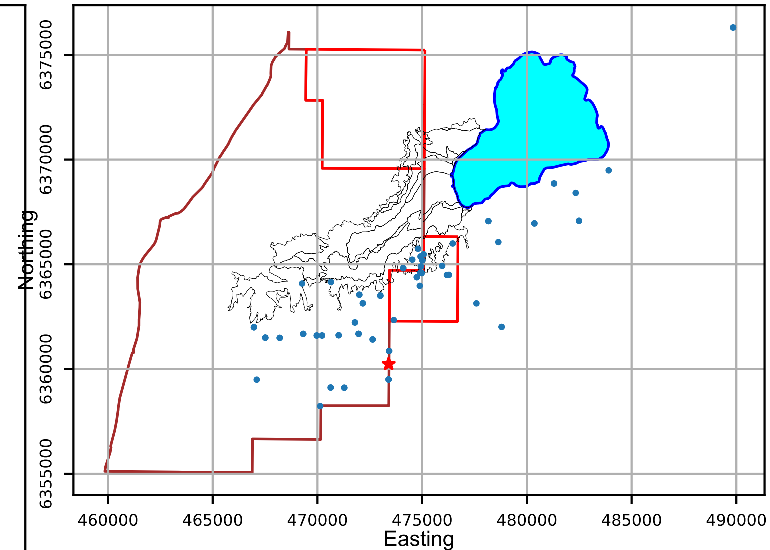

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 28.25 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-21-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-6

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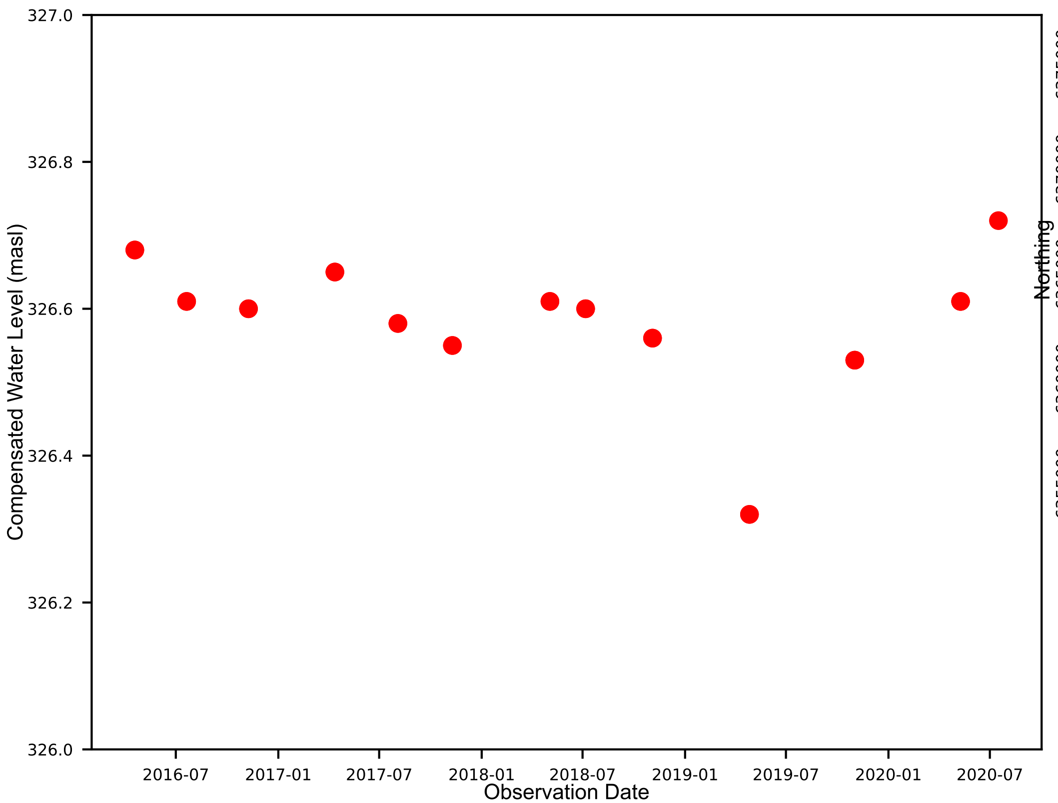
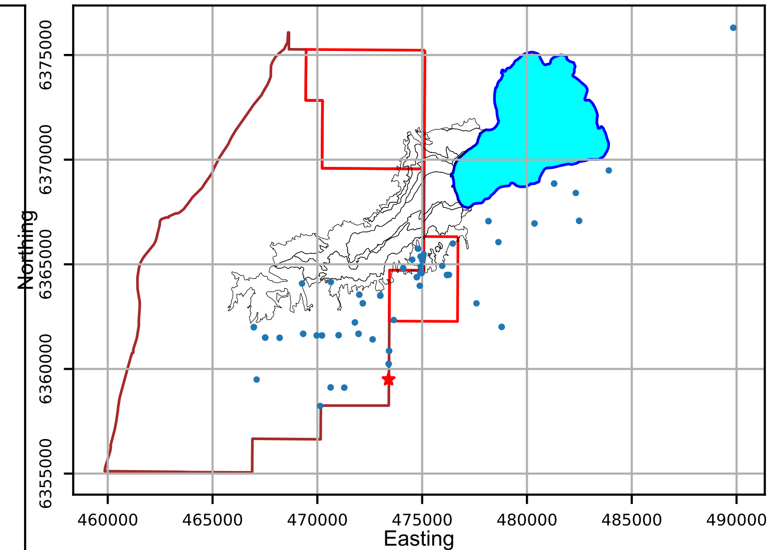




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 14.96 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

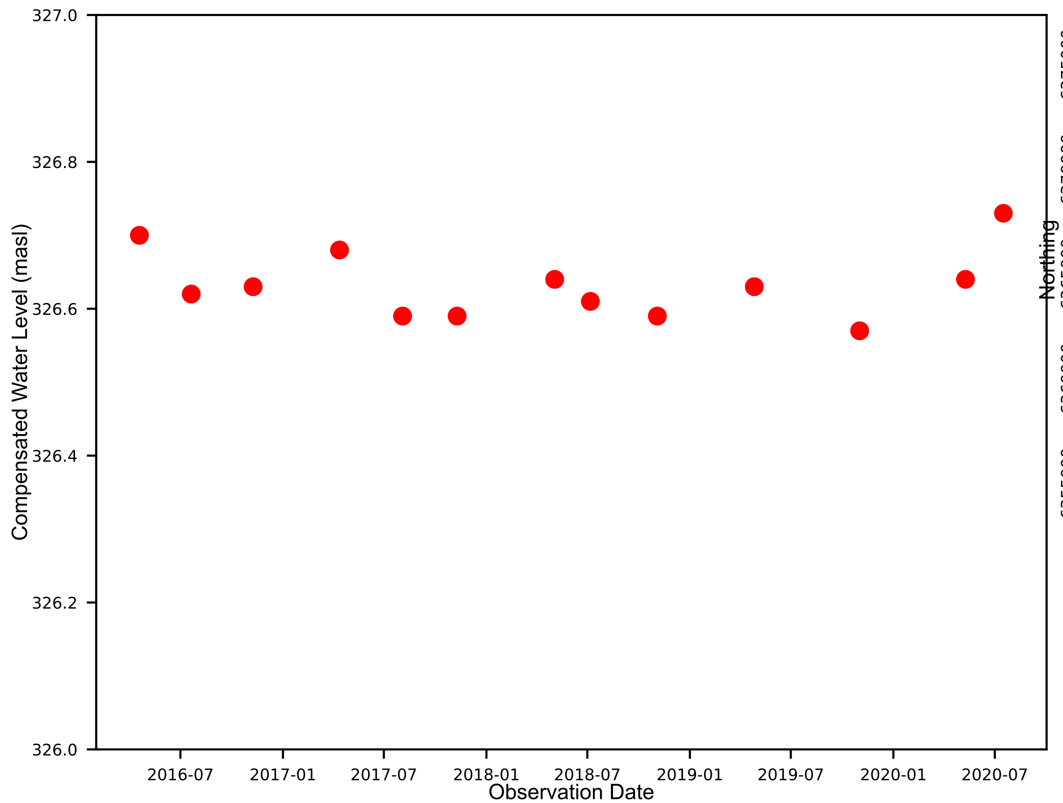
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

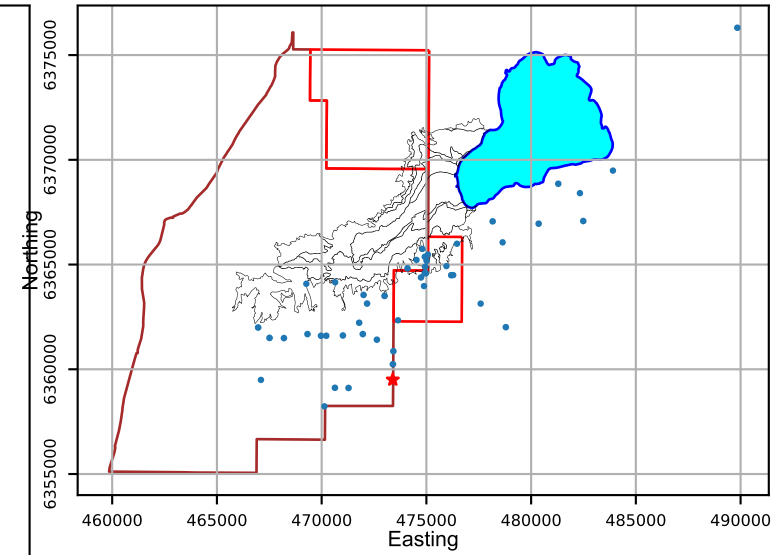
TITLE

A-22-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-7

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 22.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

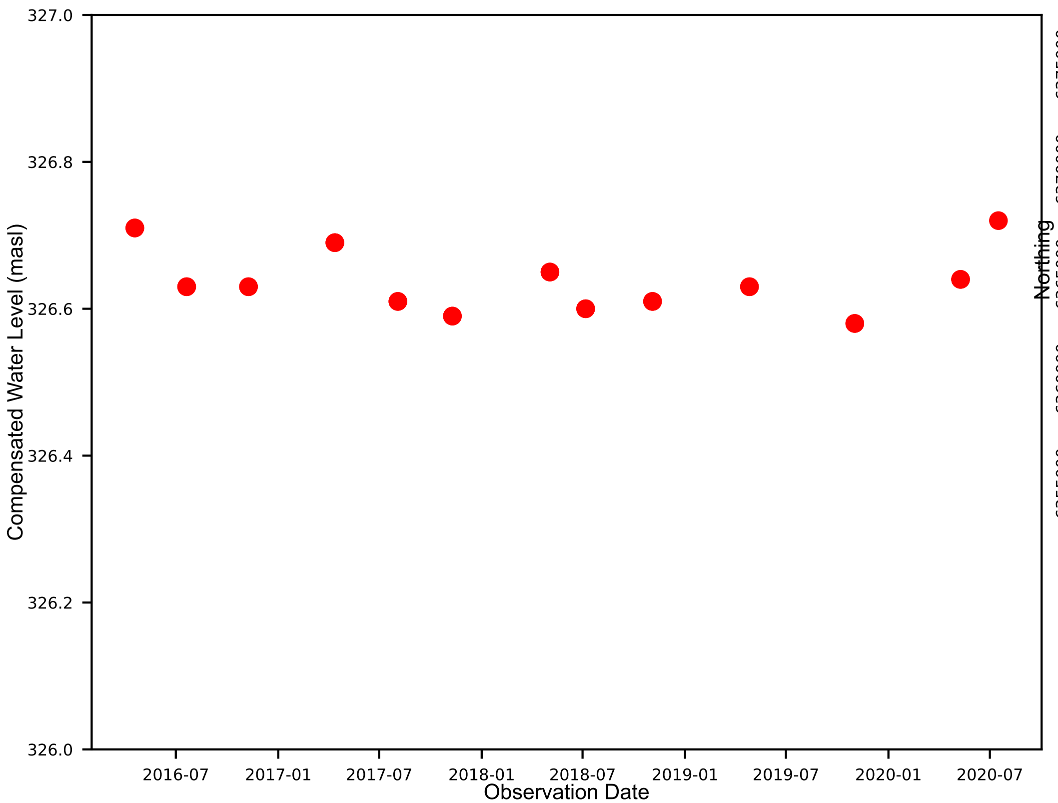
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

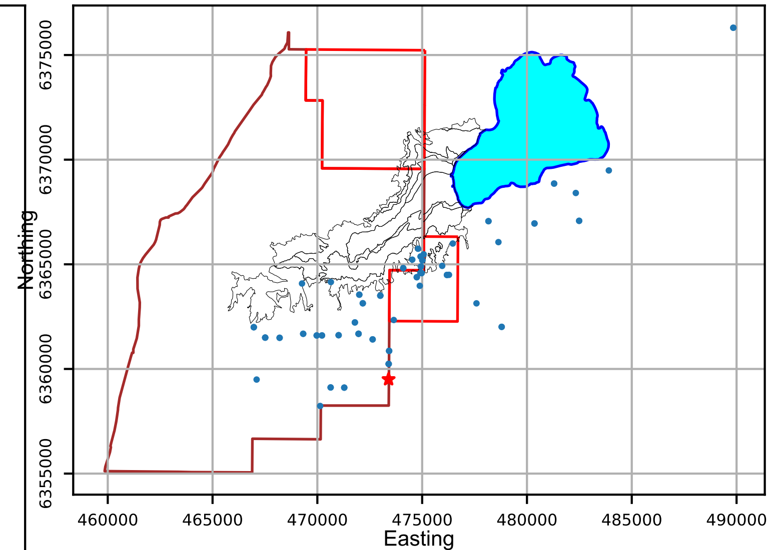
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-22-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B7-8





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 27.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-22-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-9

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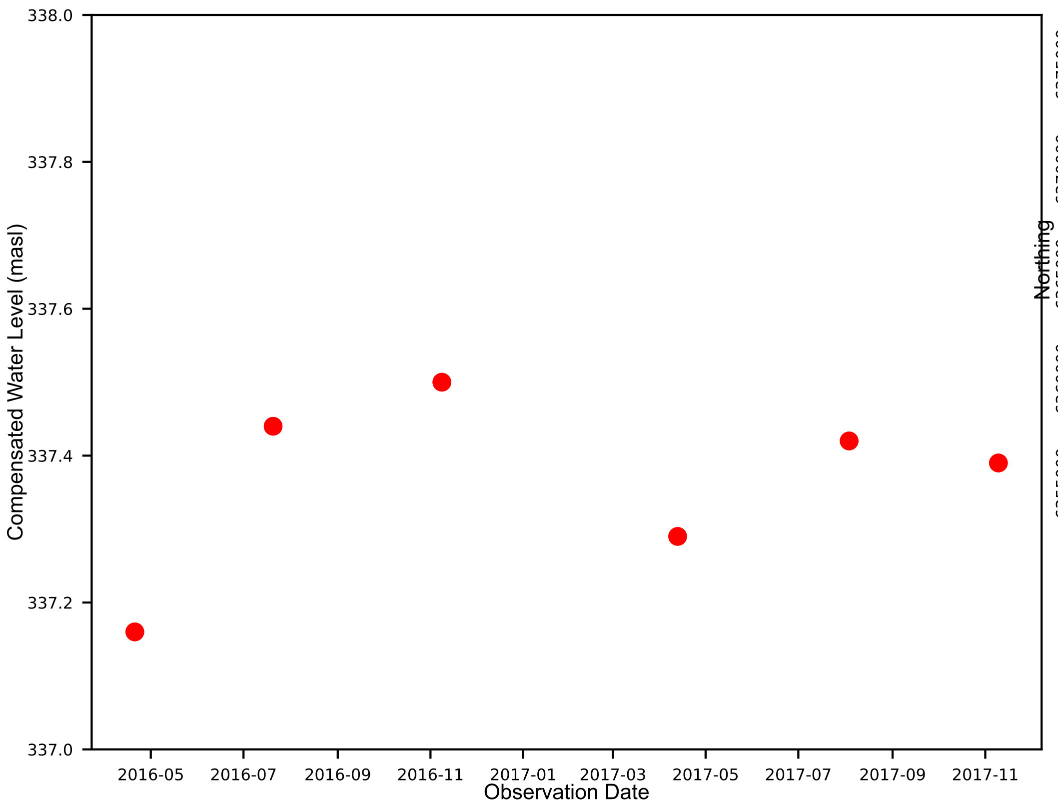
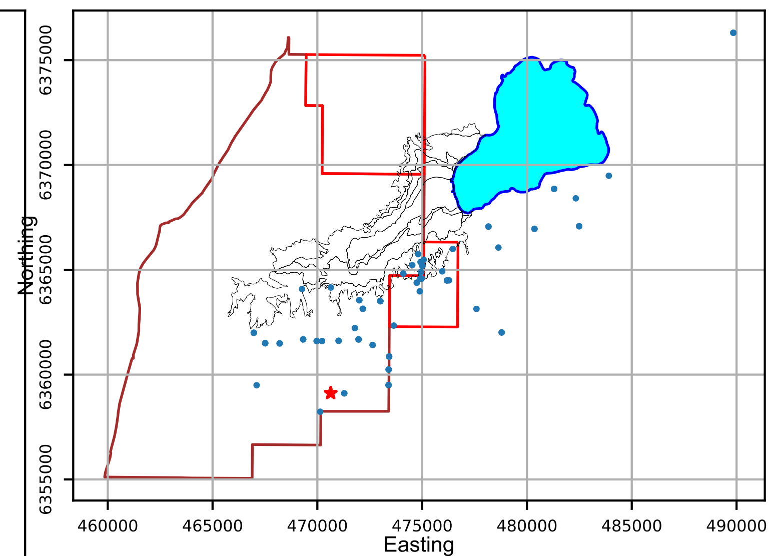




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 11.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

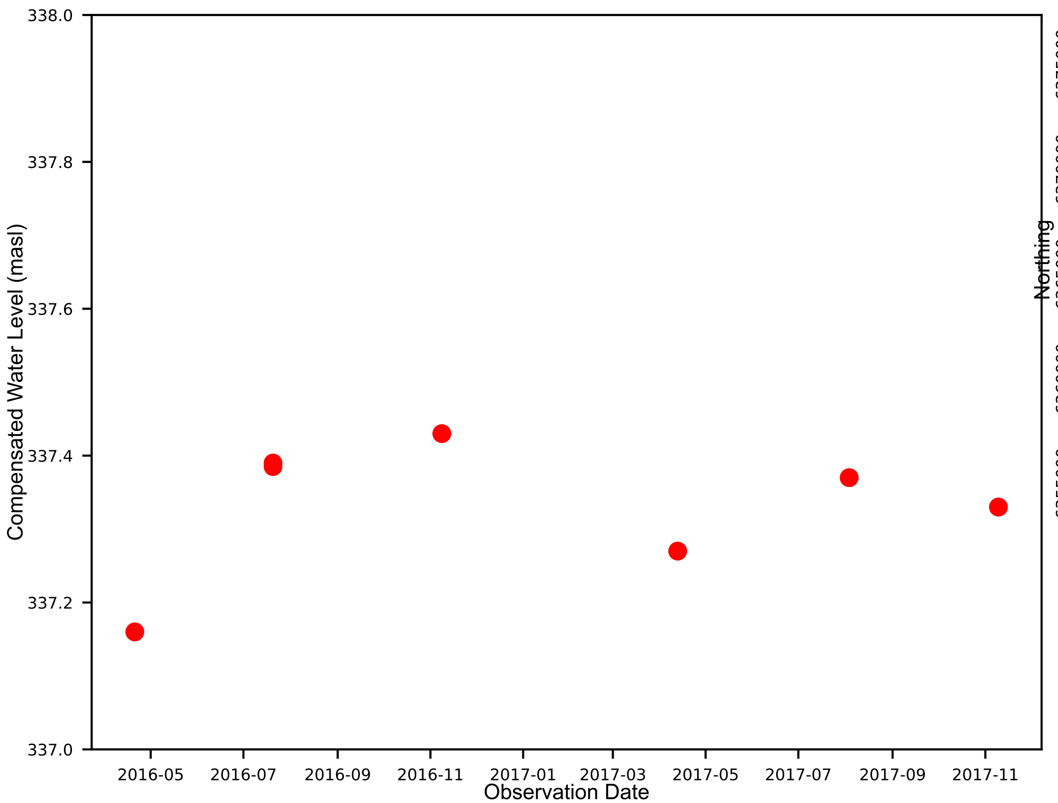
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

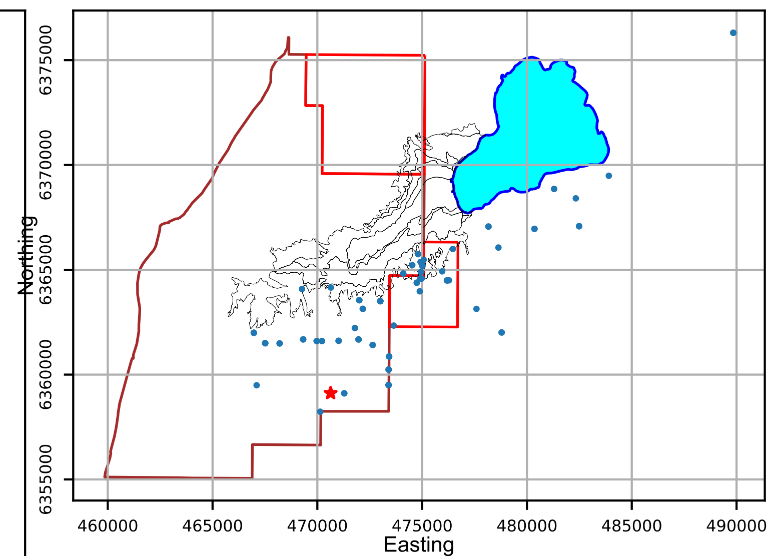
FORT HILLS
Operated by Suncor Energy

TITLE

A-25-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-10





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 25.09 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	A-25-AQ3
PROJECT No.	20140450
CONTROL	100
Rev.	A
FIGURE	B7-11

FORT HILLS
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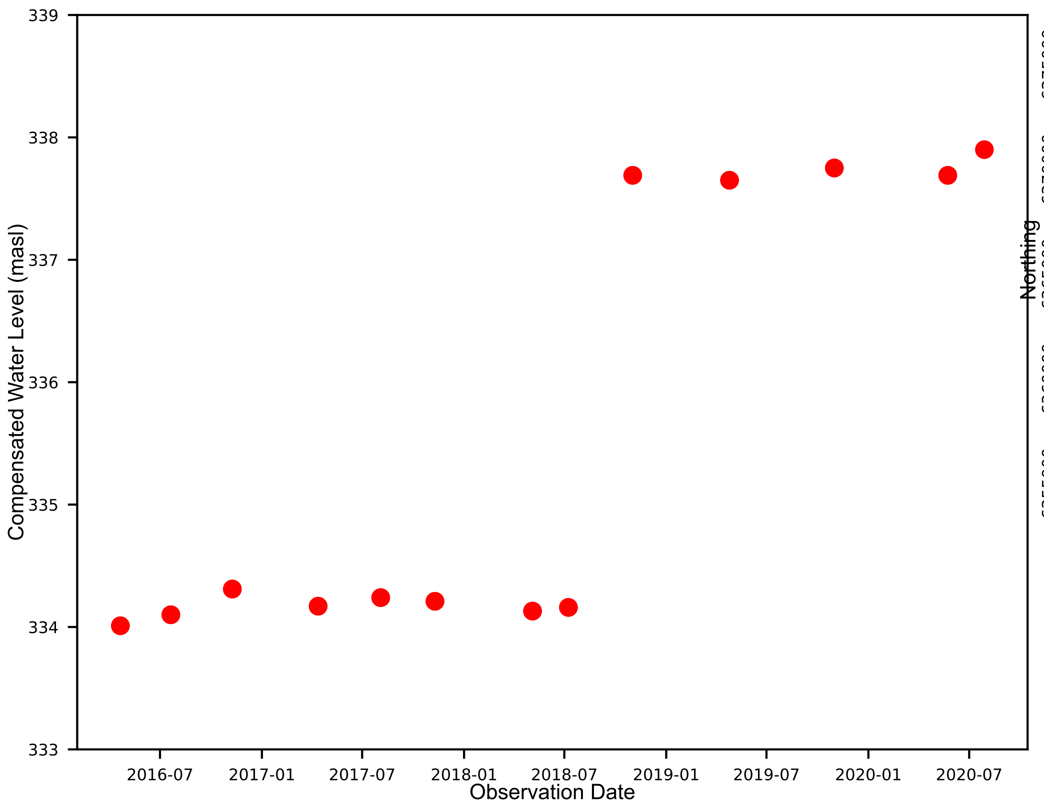

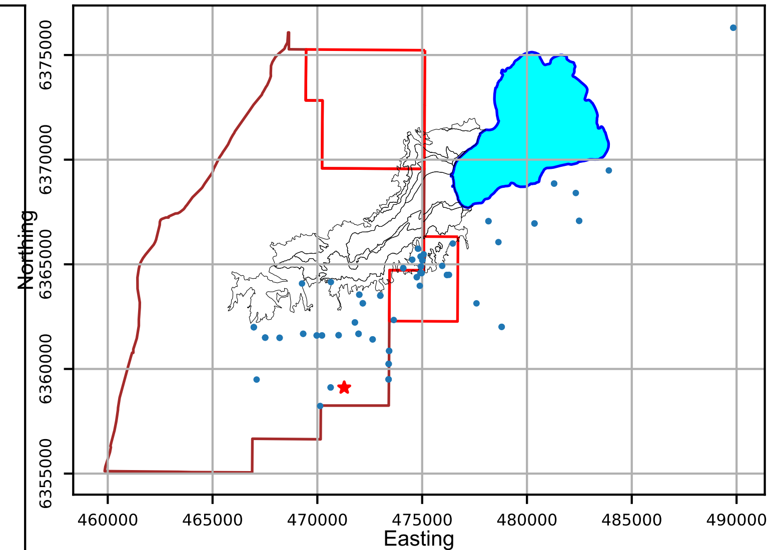

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 13.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-26-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B7-12

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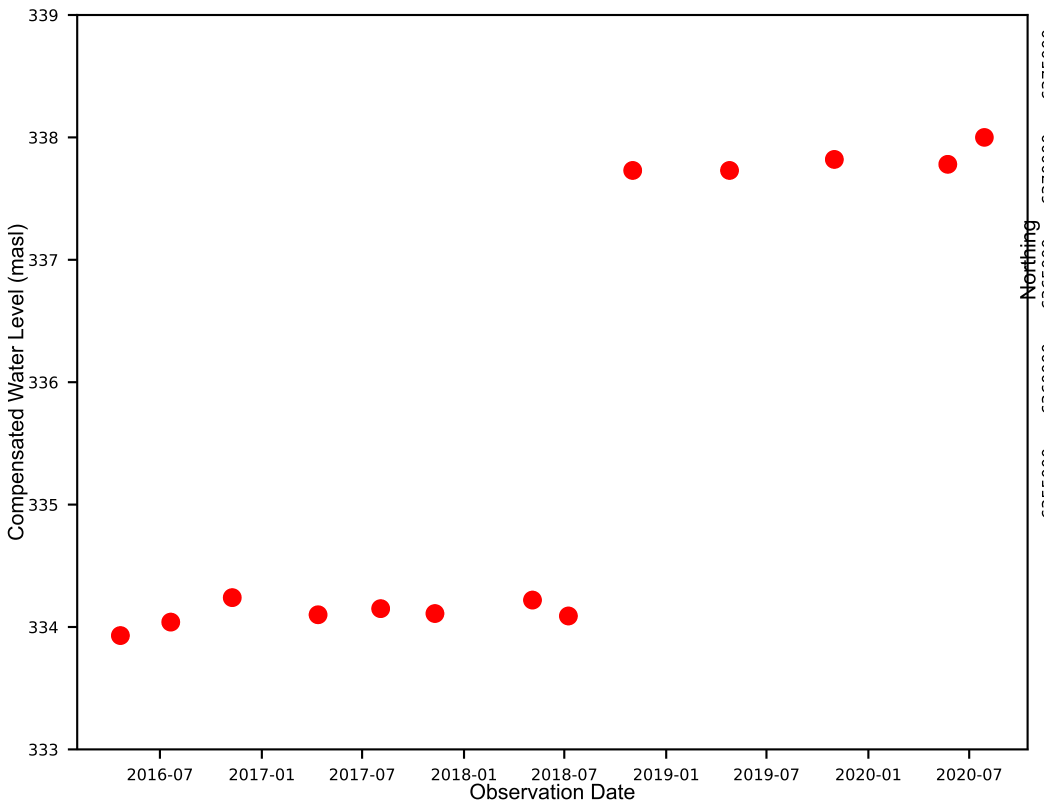

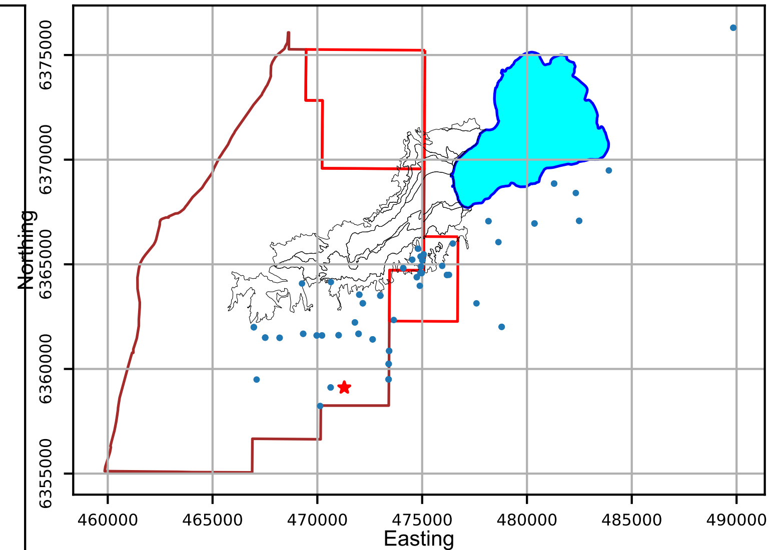

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 32.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
A-26-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-13

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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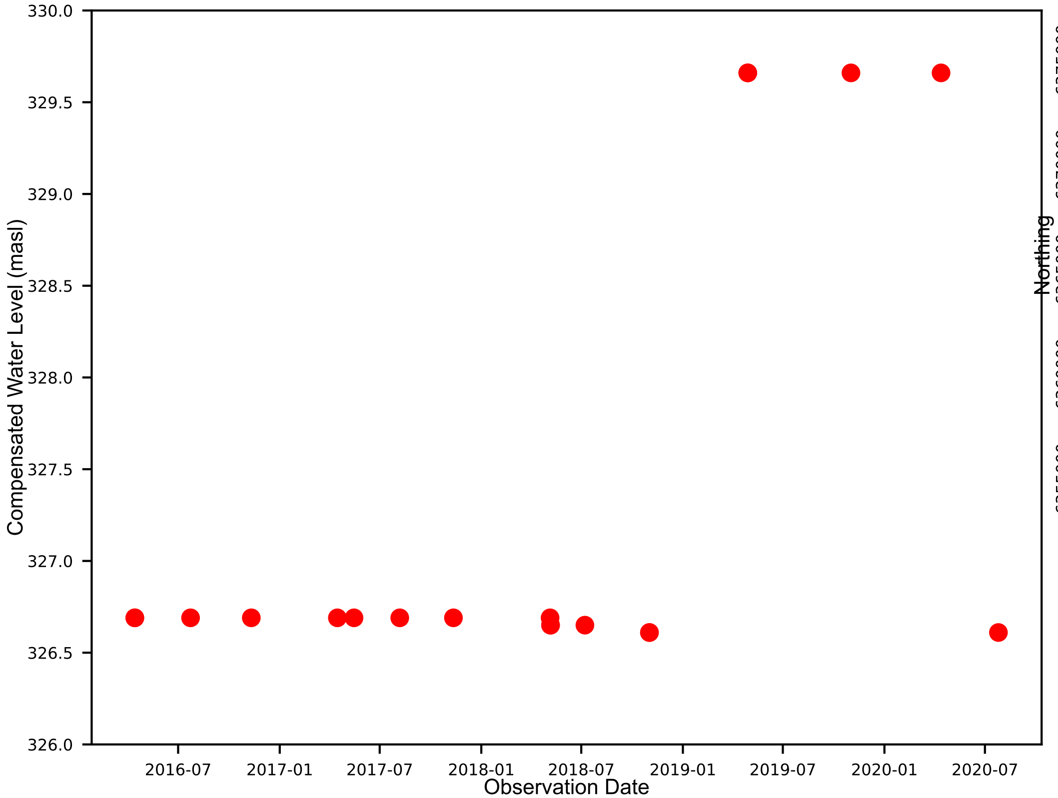
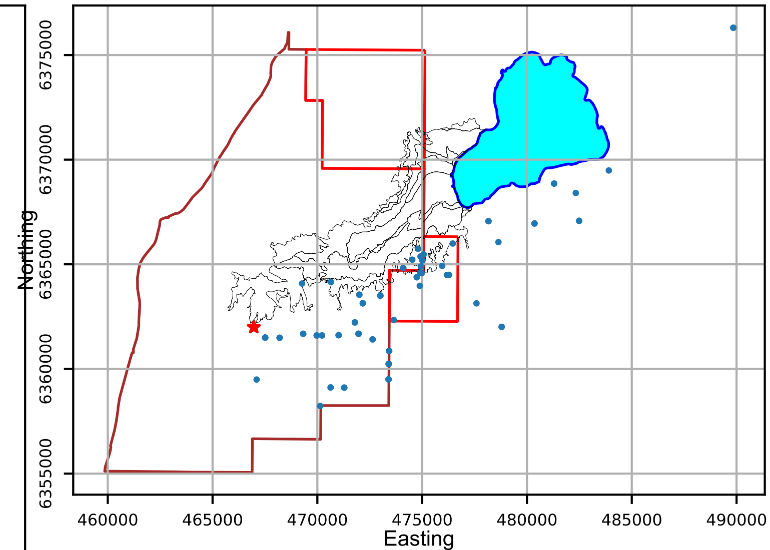




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Unconfined
Depth of Measurement: 1.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

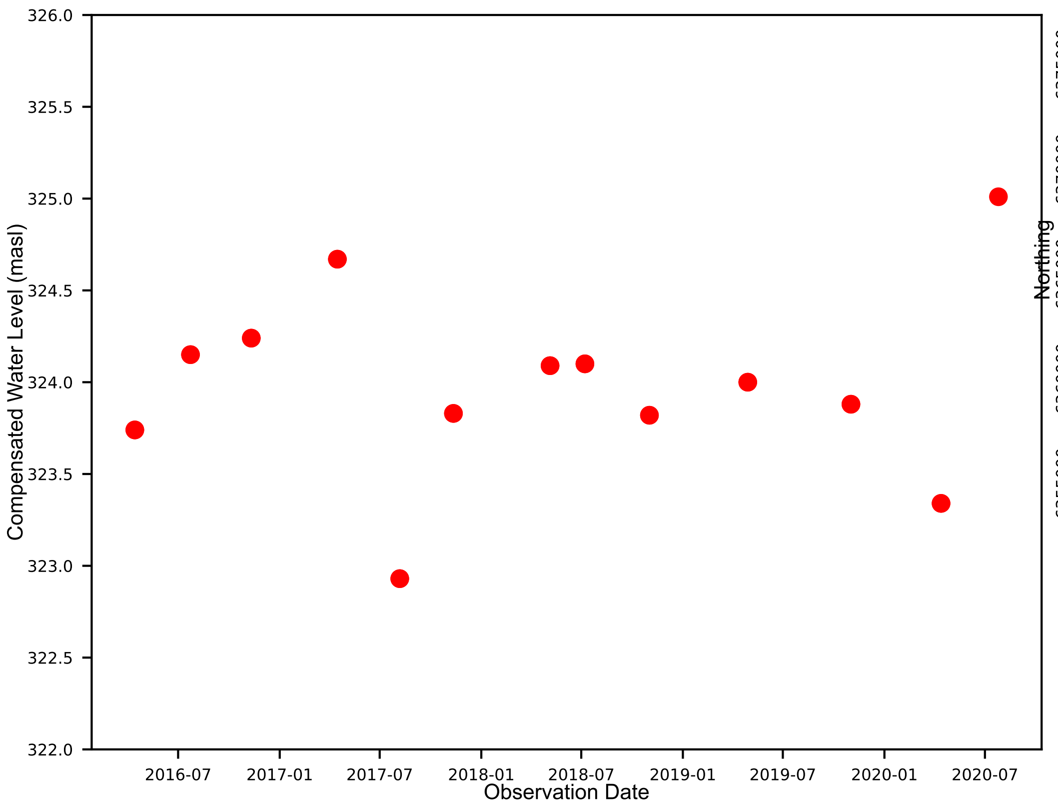
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

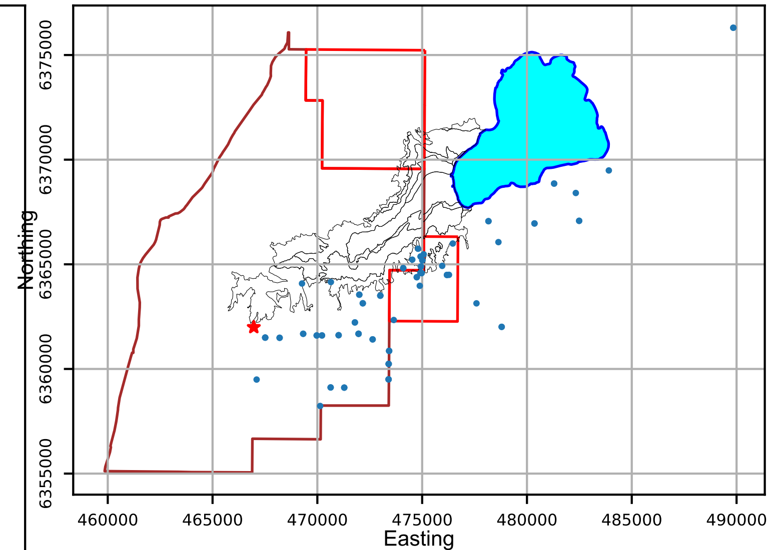
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-27-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-14





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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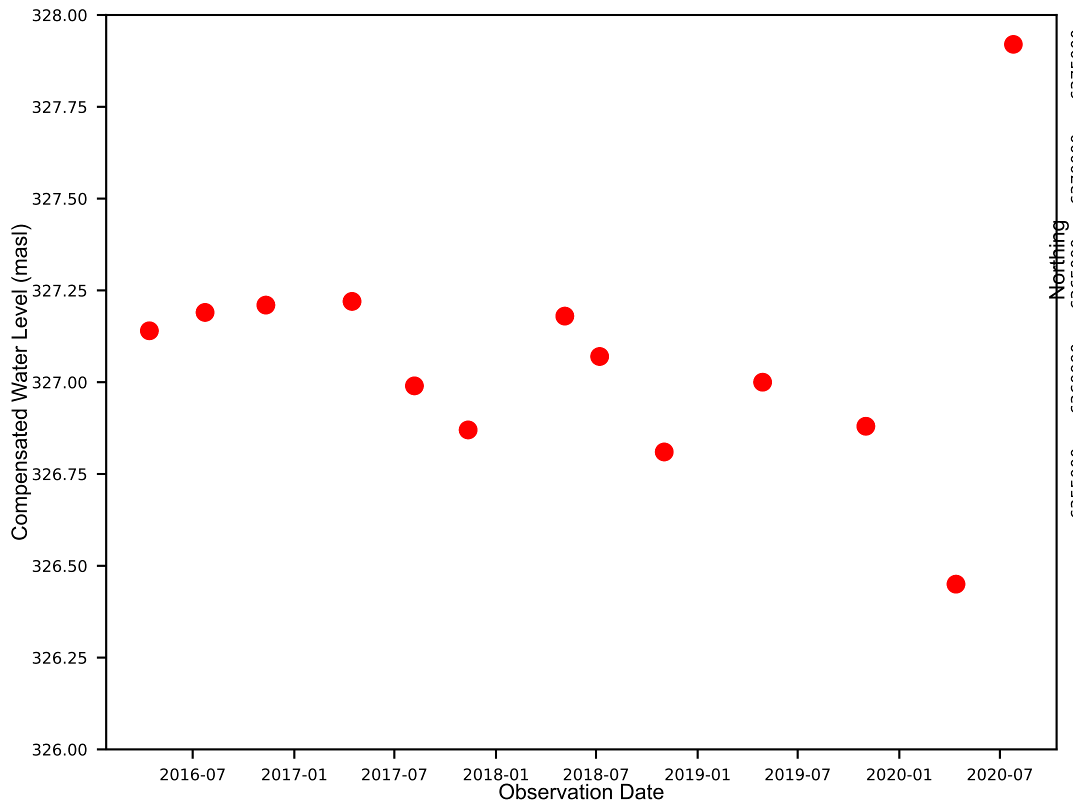
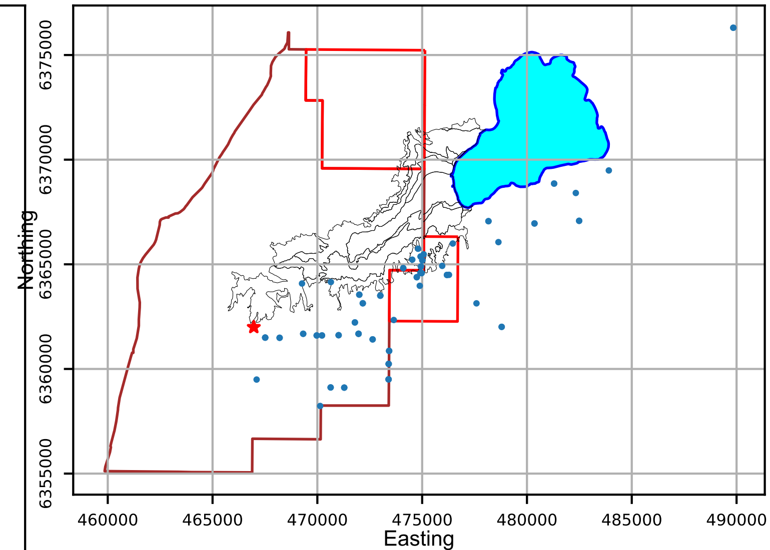
TITLE
A-27-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-15





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 43.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-27-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-16

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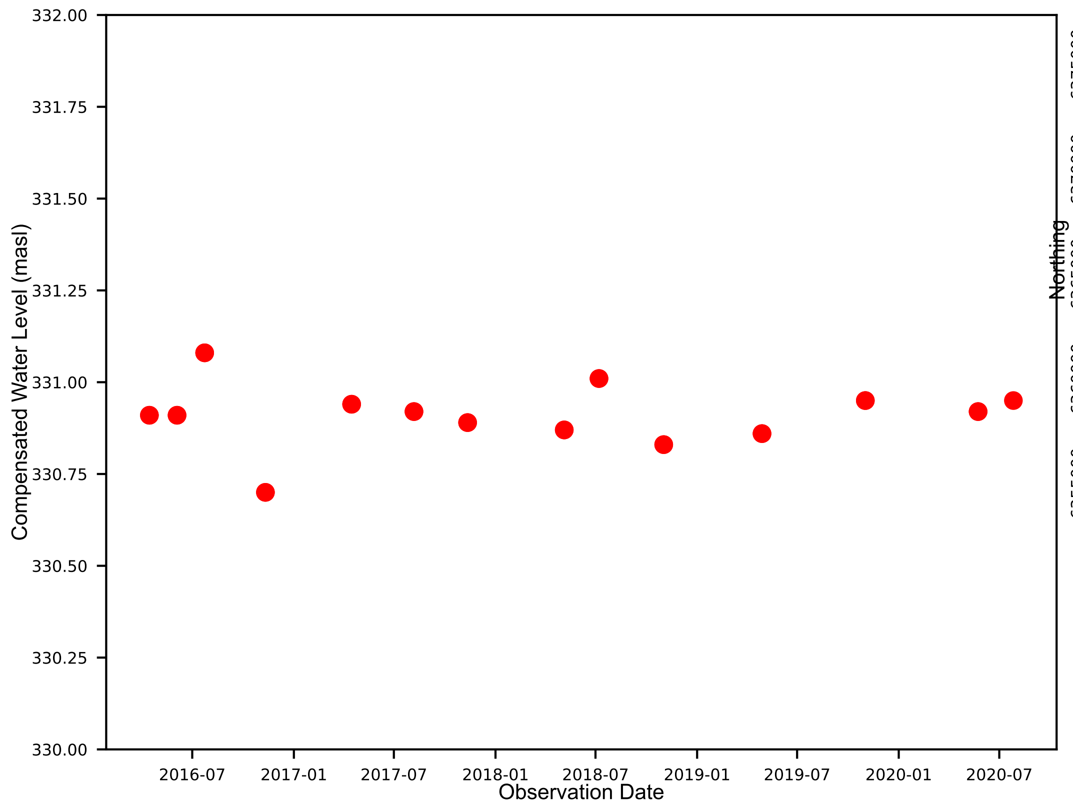

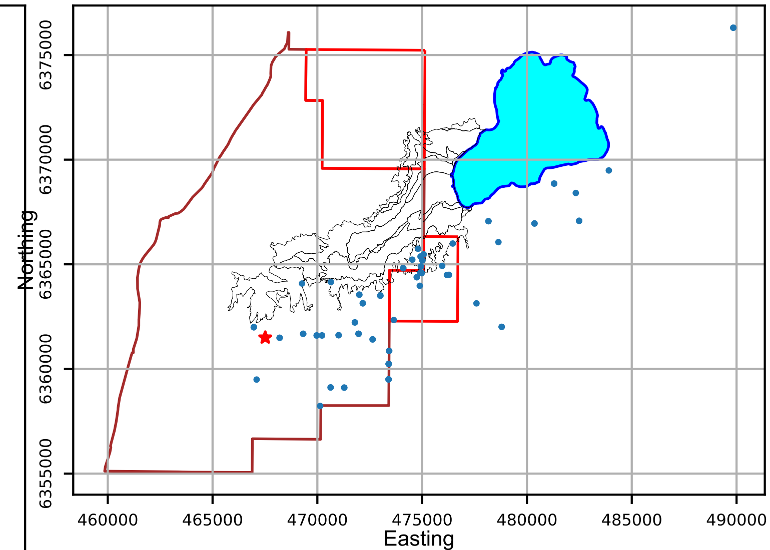

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
A-28-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-17

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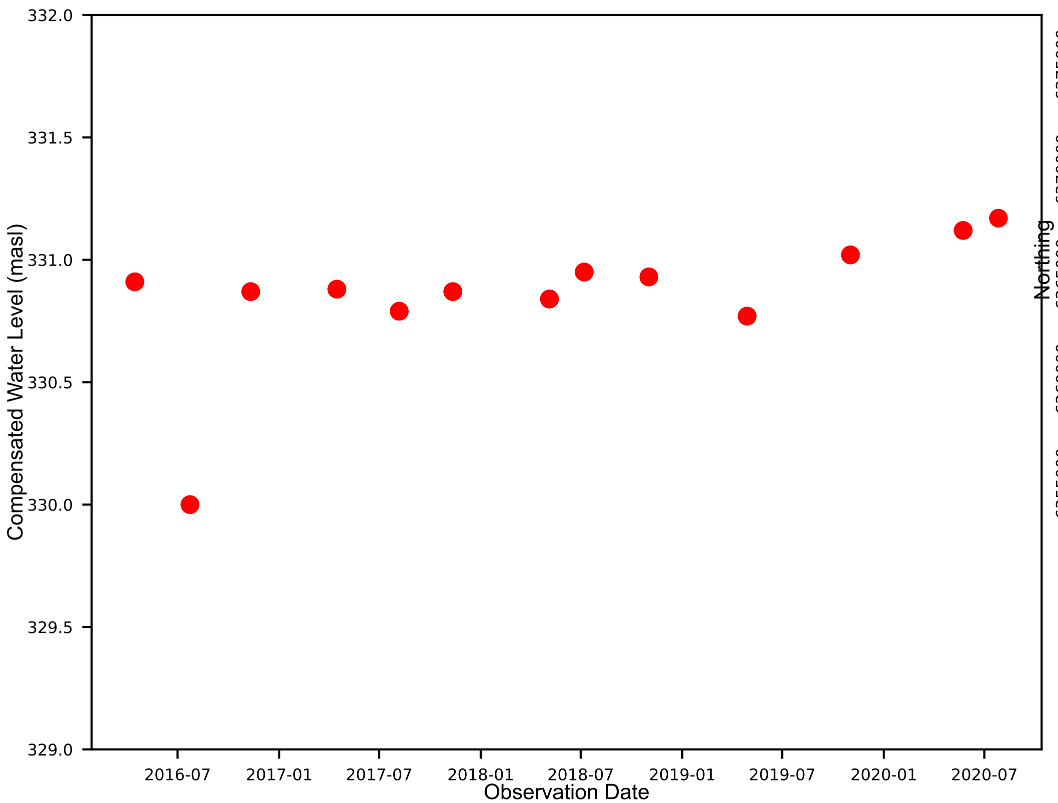

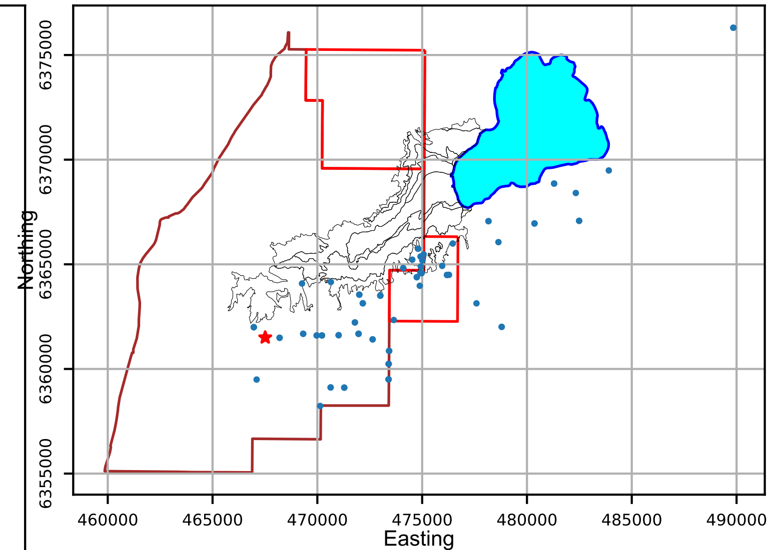

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-28-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-18

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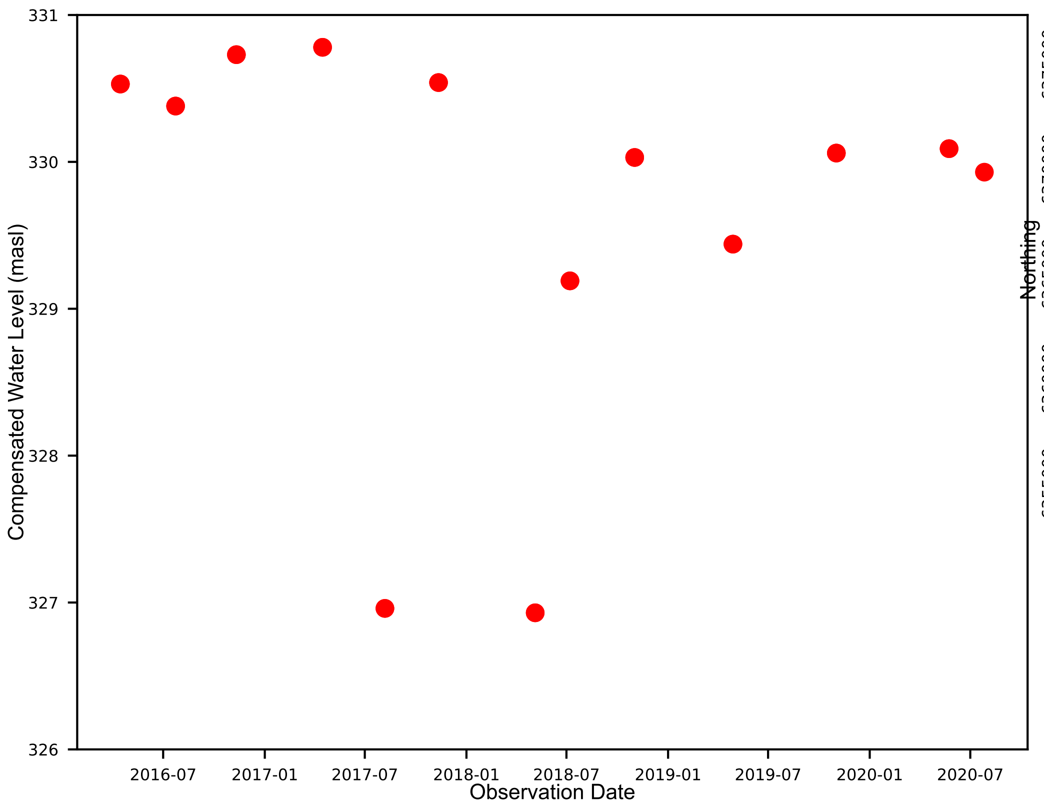

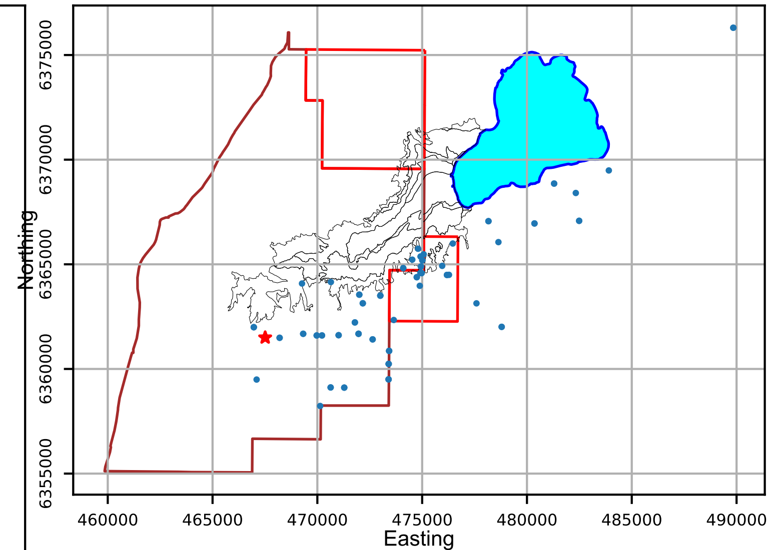

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE
A-28-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-19

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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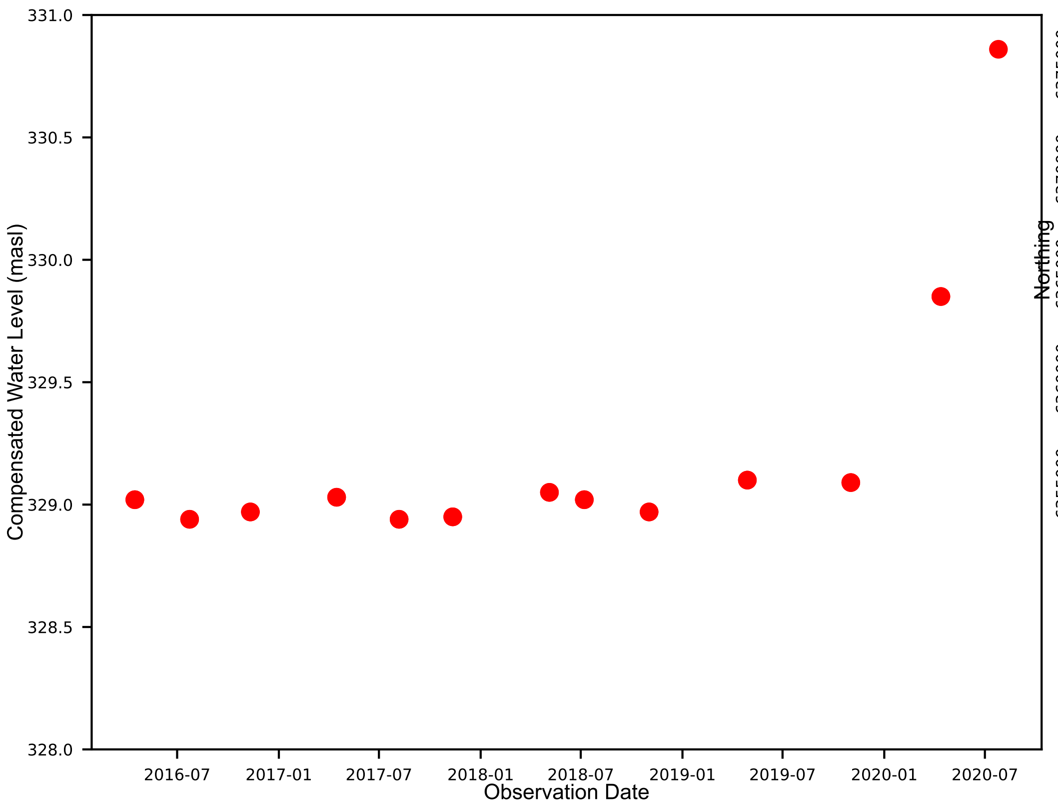

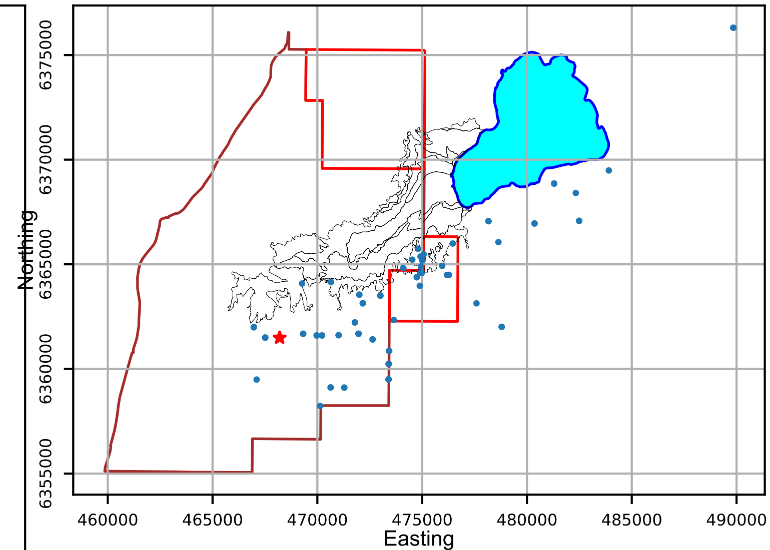

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

A-29-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-20

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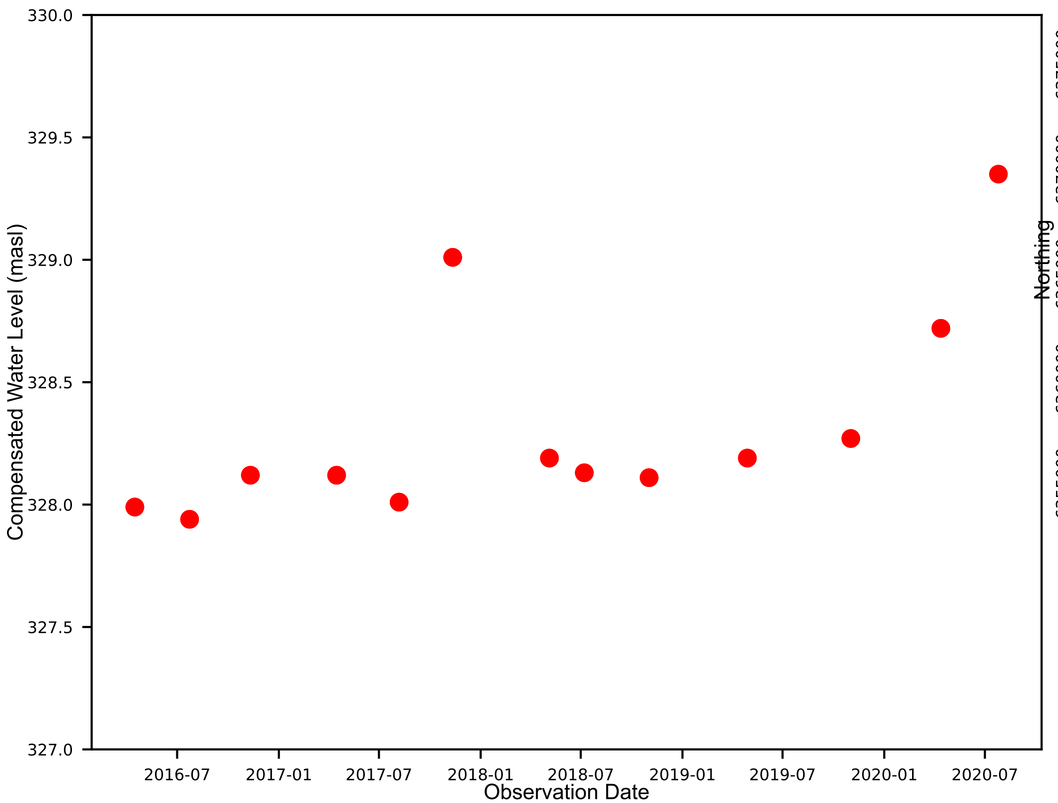

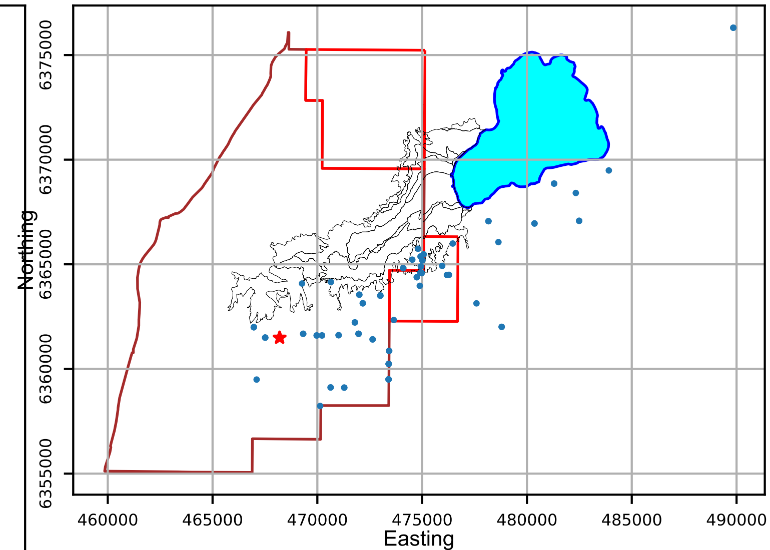

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 34.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

A-29-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-21

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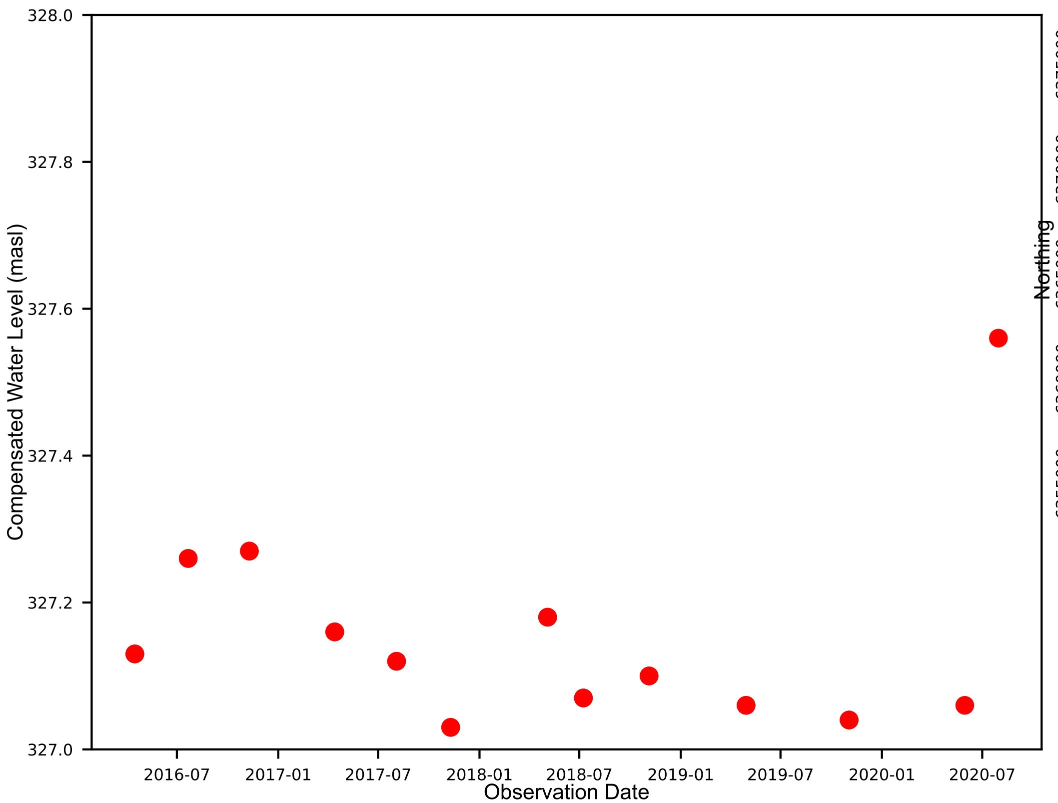

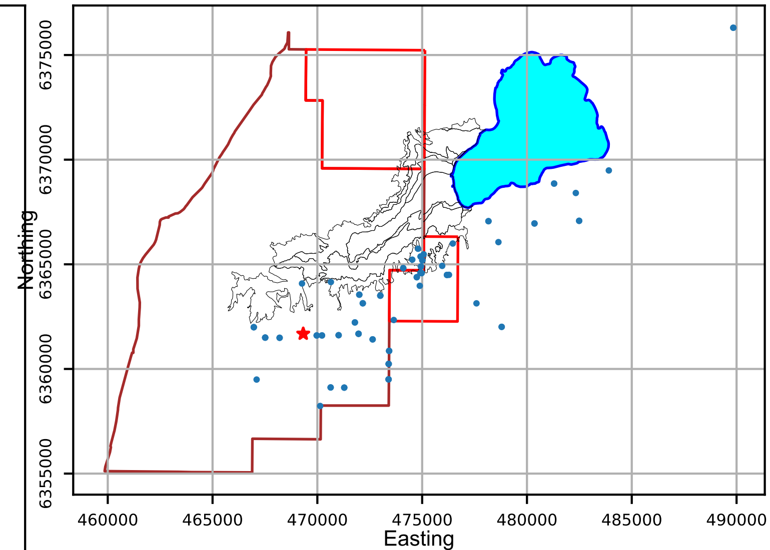

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 9.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-30-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-22

1 in
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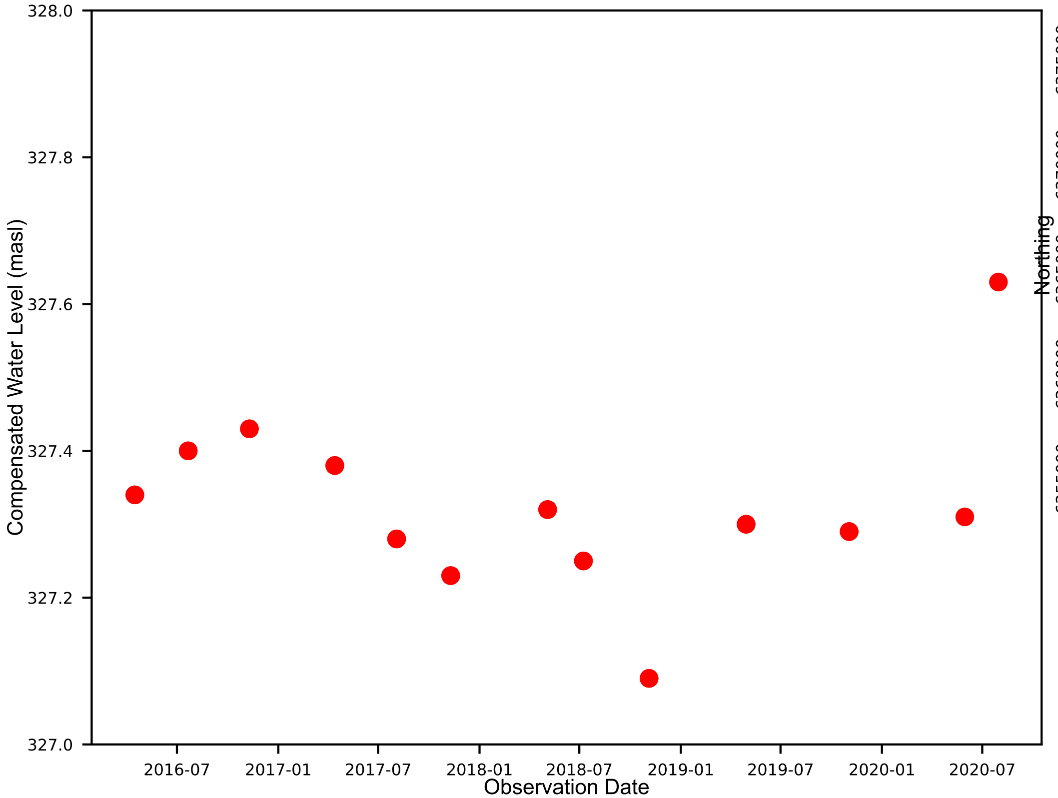

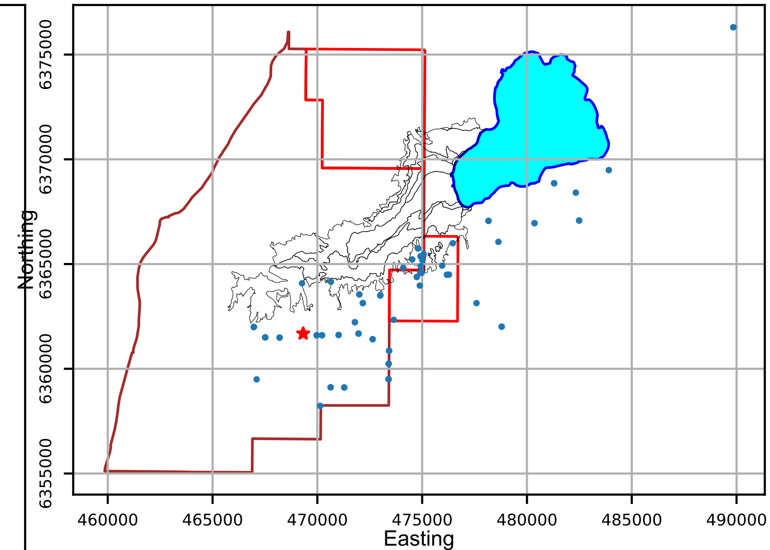

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 29.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-30-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-23

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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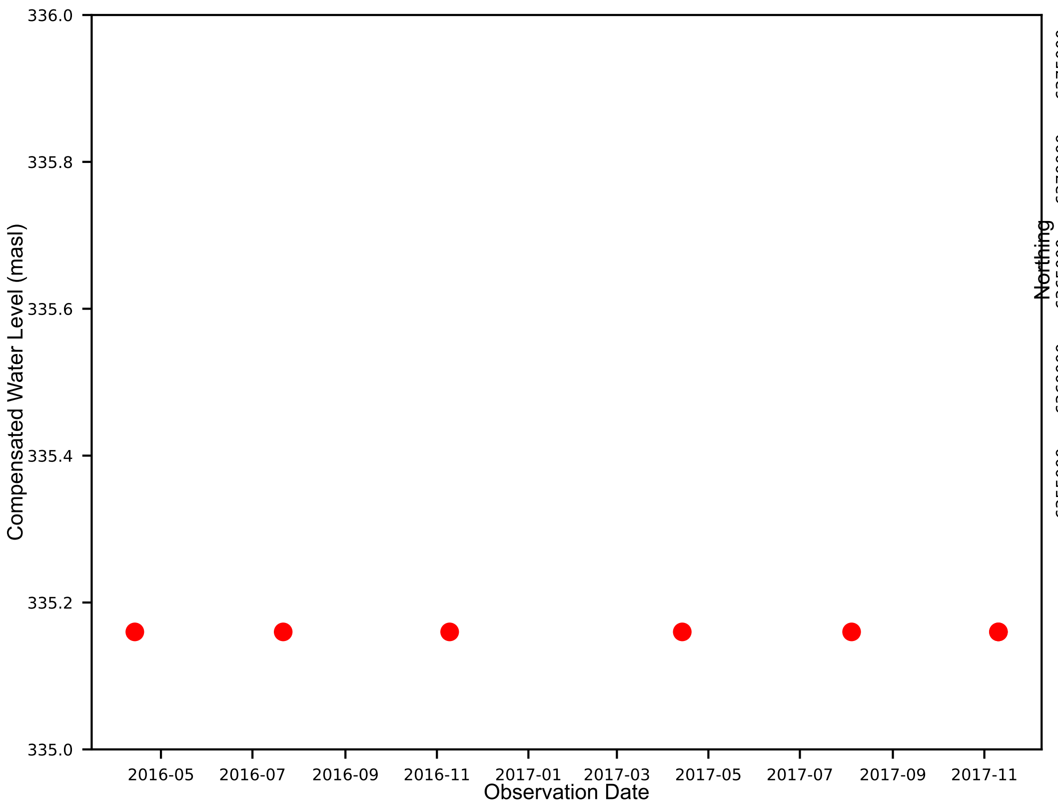

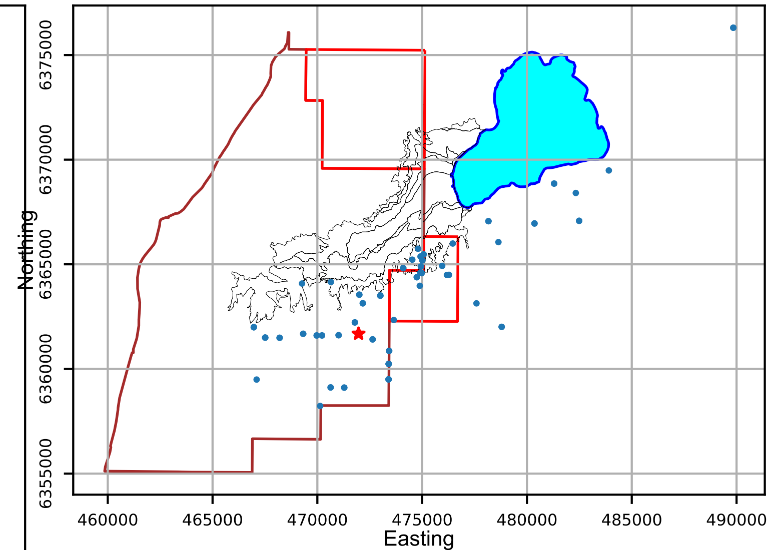

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 13.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-31-AQ1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-24

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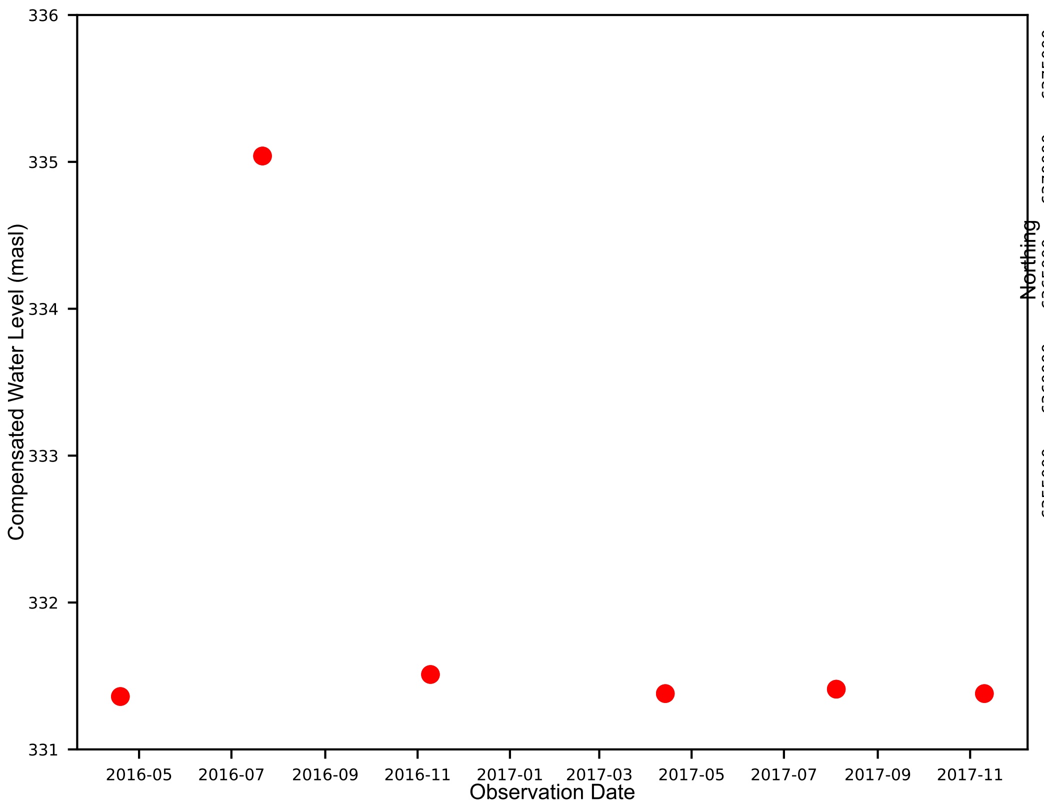

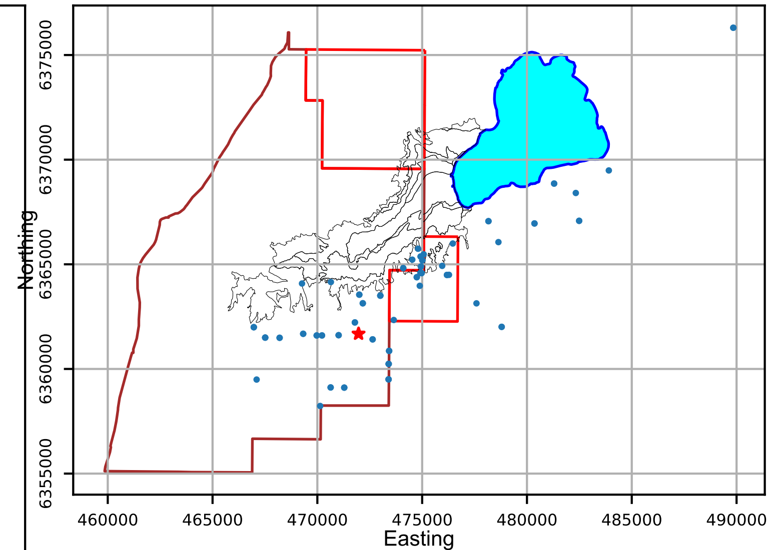

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 45.78 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
A-31-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-25

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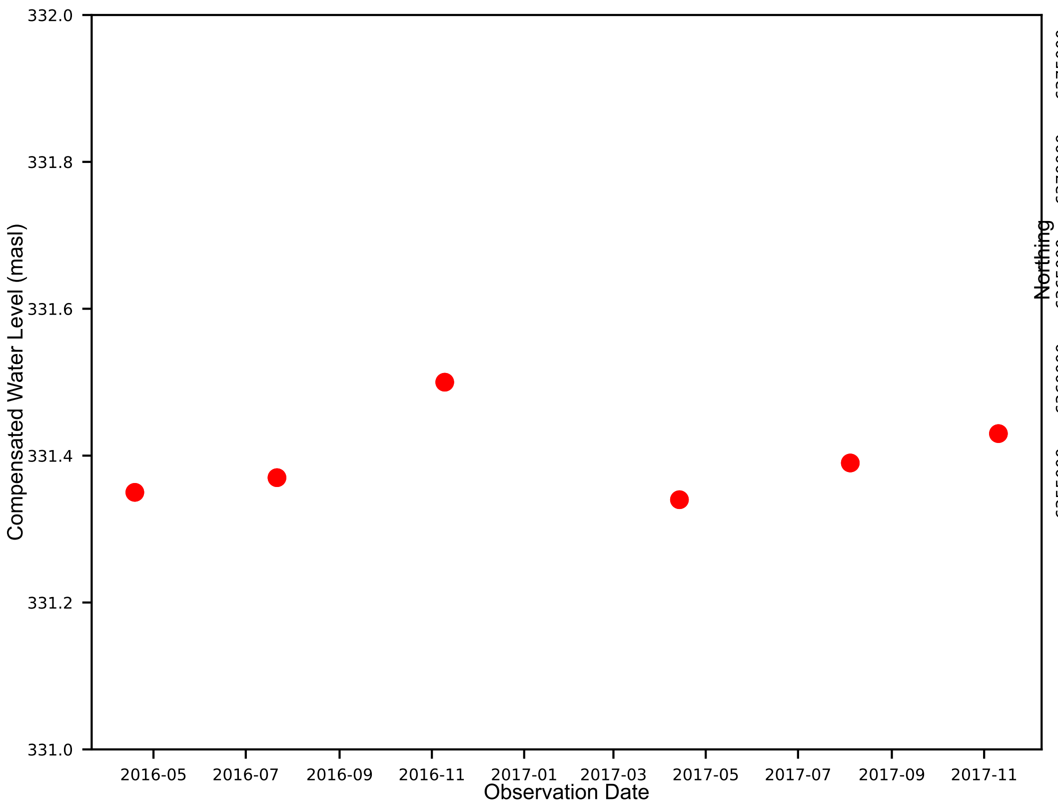

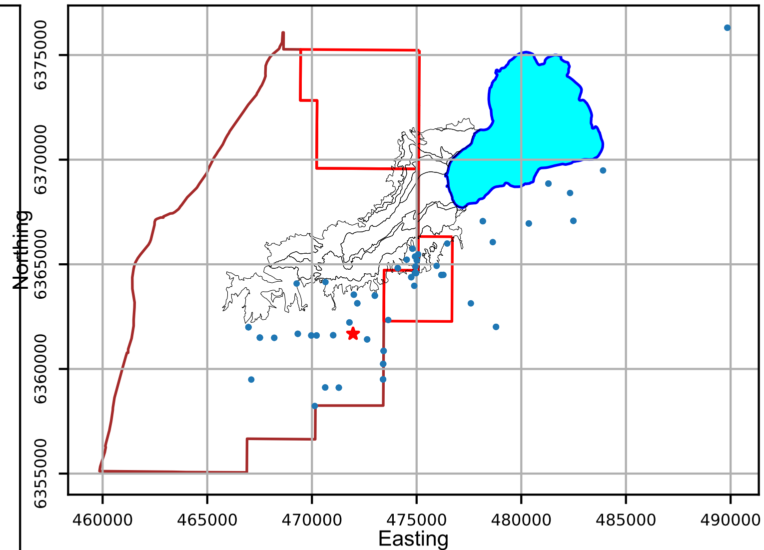

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 61.57 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
A-31-AQ3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-26

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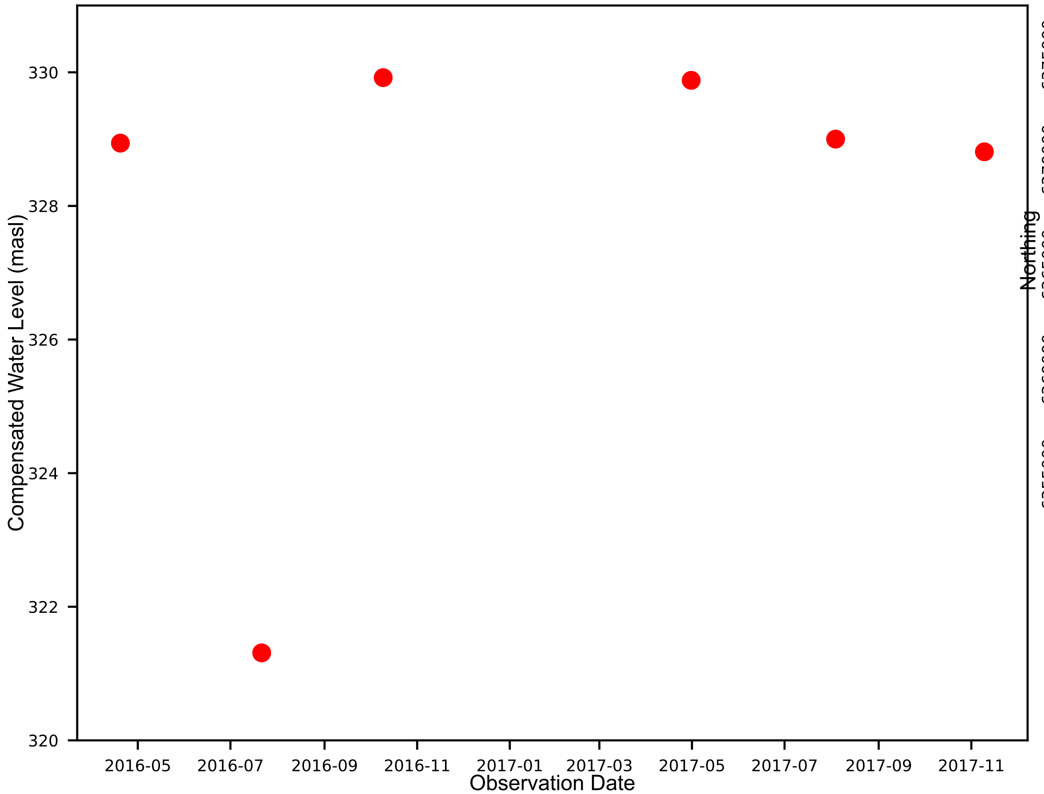

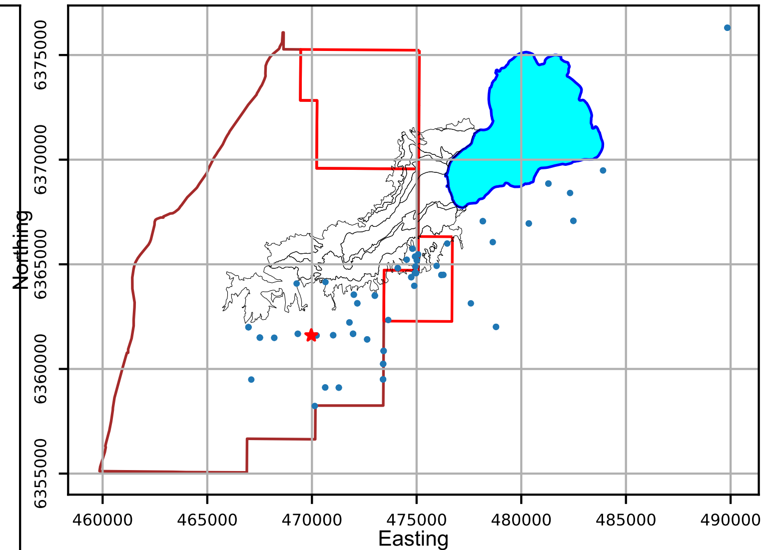

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	A-40-AQ1
PROJECT No.	20140450
CONTROL	100
Rev.	A
FIGURE	B7-27

FORTHILLS
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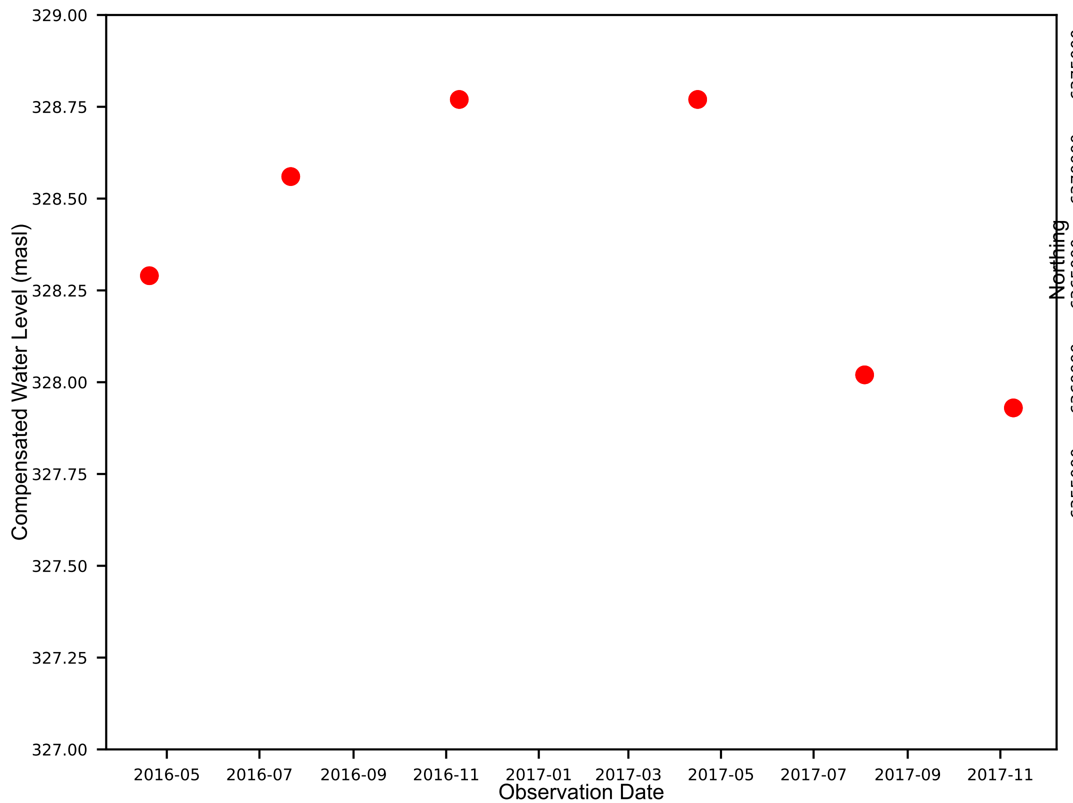
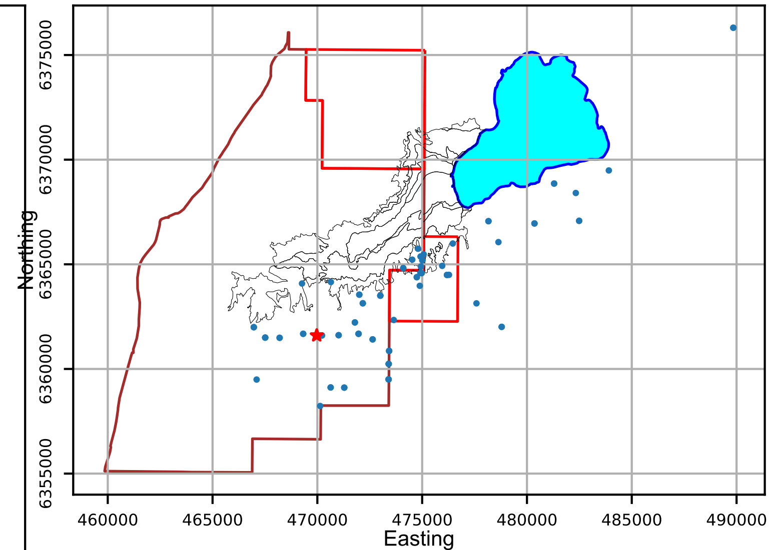
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 29.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

A-40-AQ2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-28

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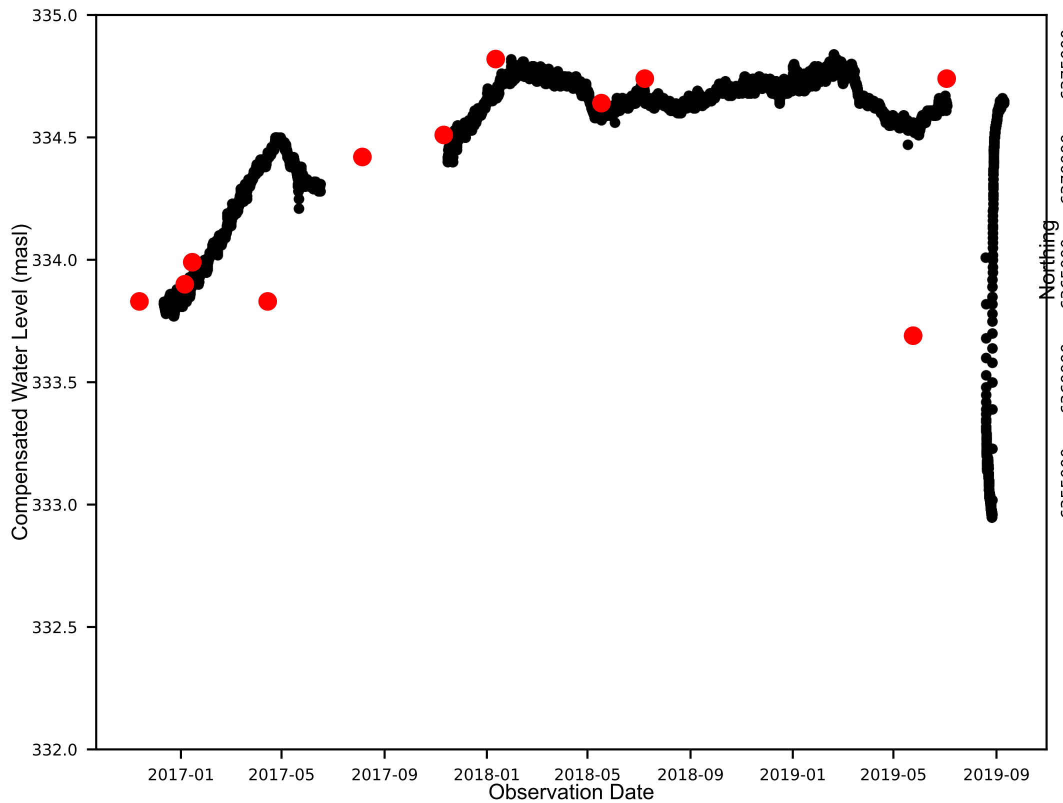

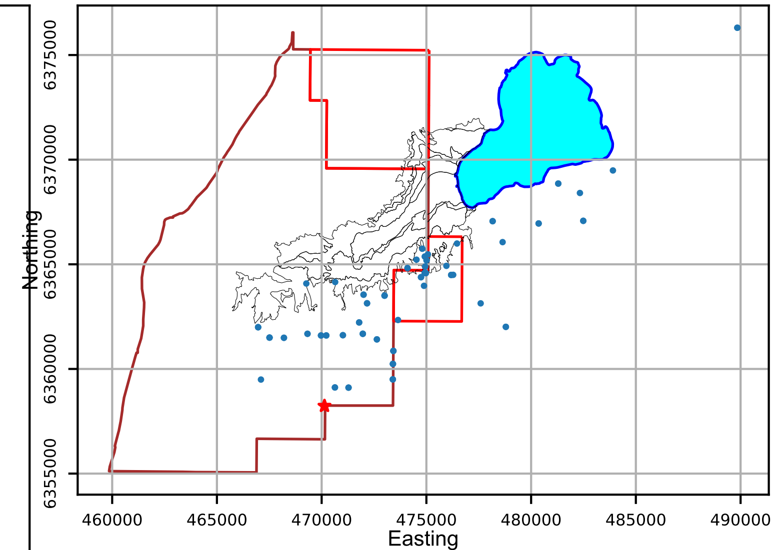

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 05 Silty Sand AQ1 AQ2
Depth of Measurement: 9.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH16-WR659-SN2-MW

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-29

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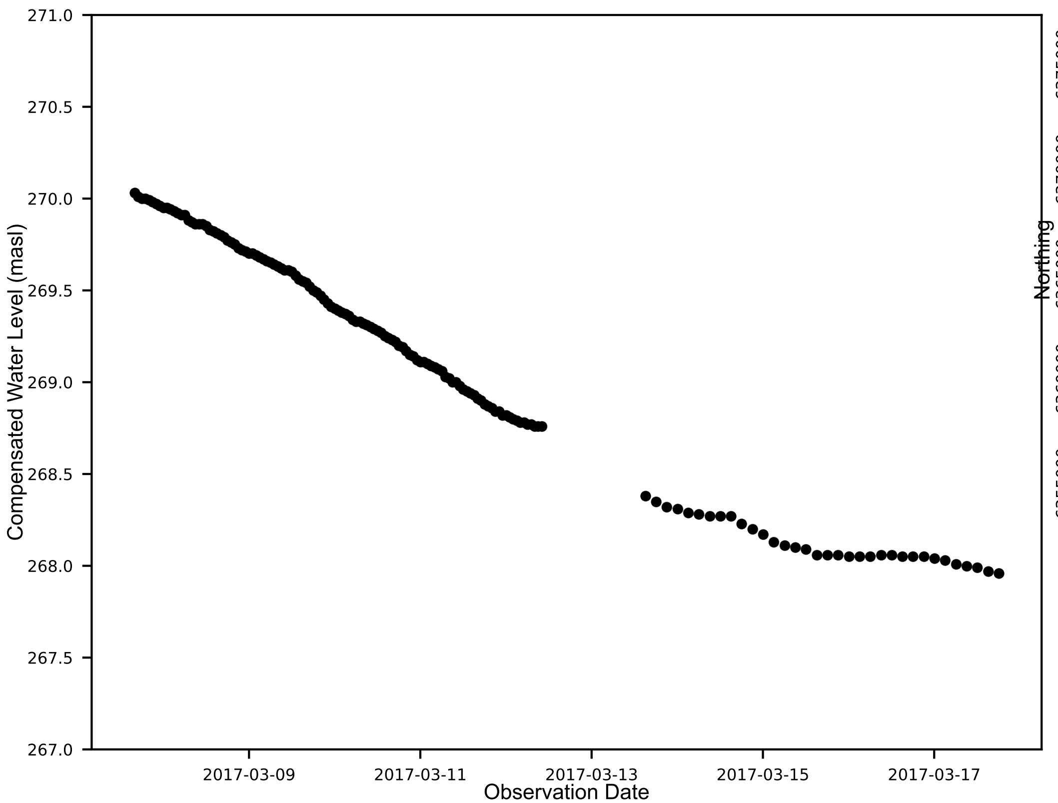

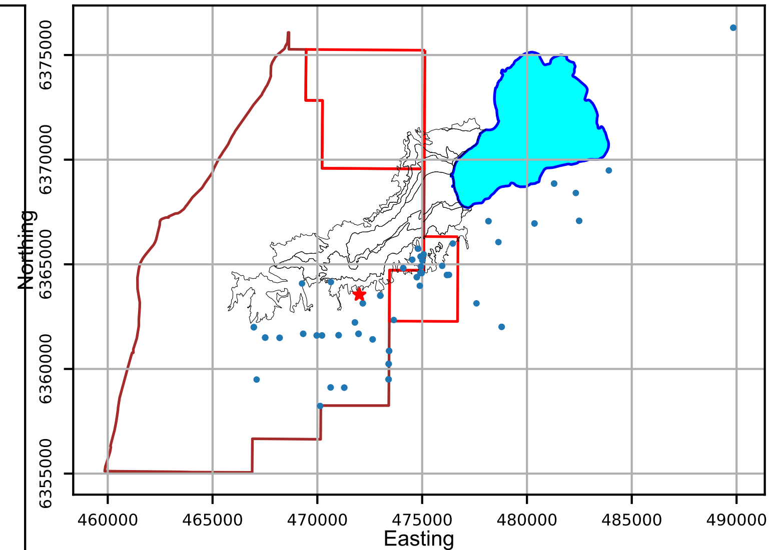

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 112 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR405-MR1 - 112.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-30

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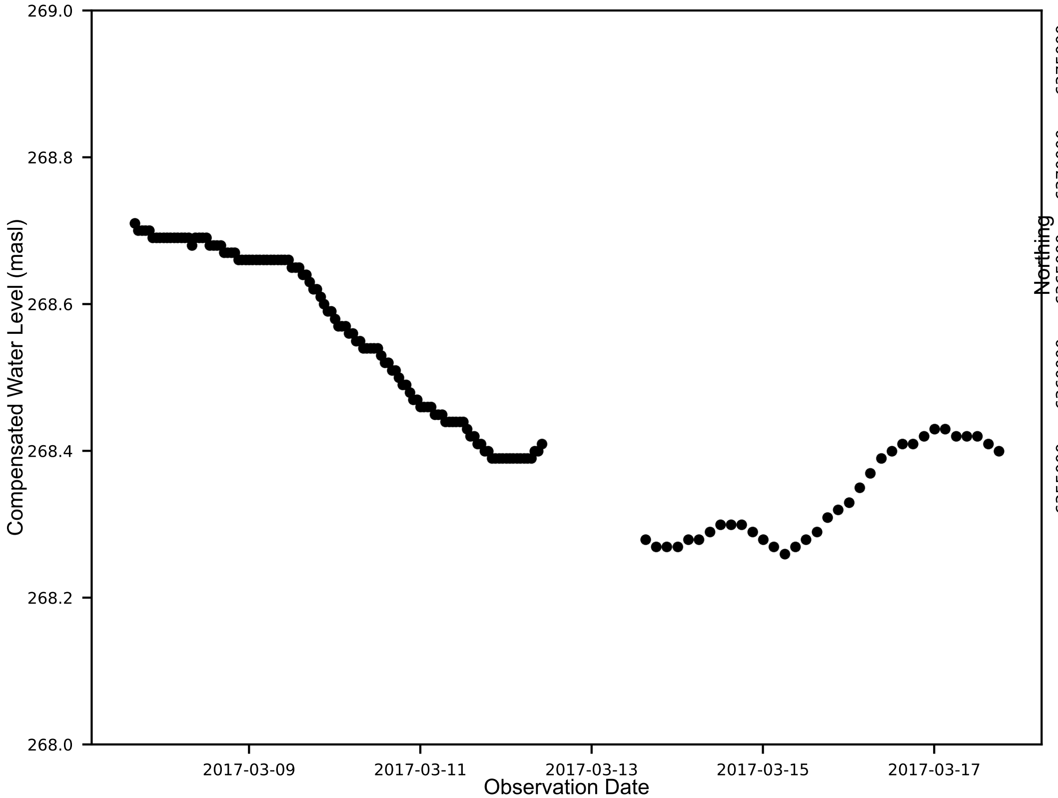
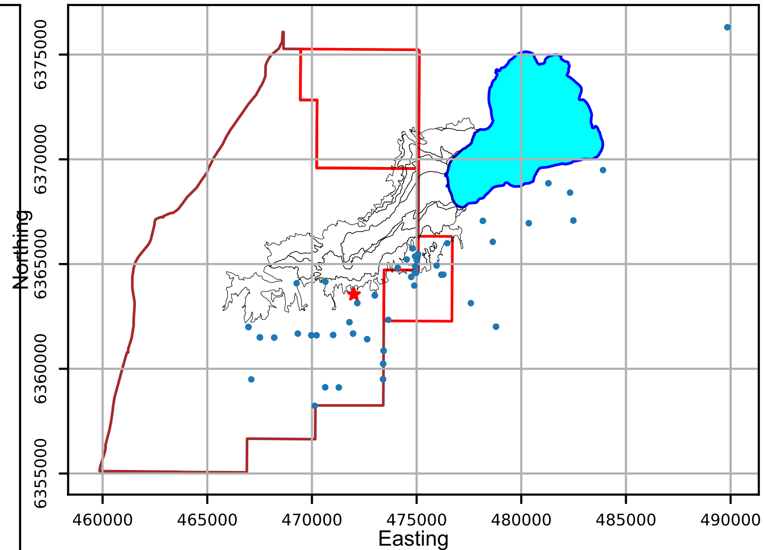




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 123 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

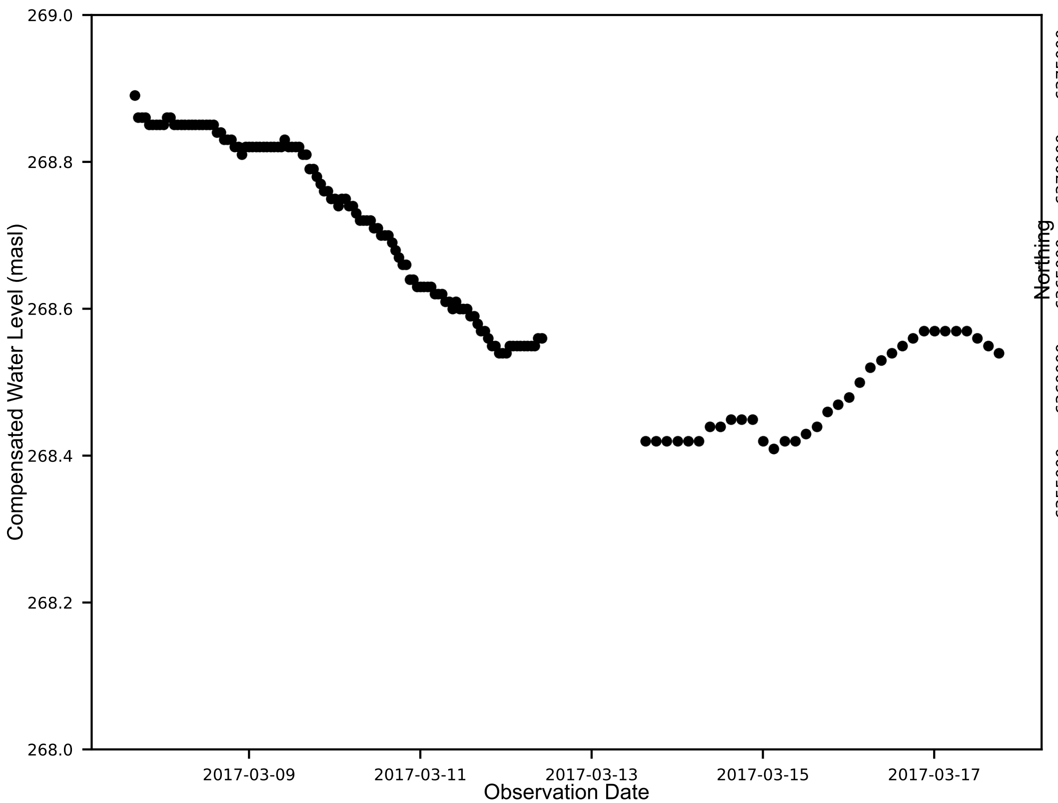
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

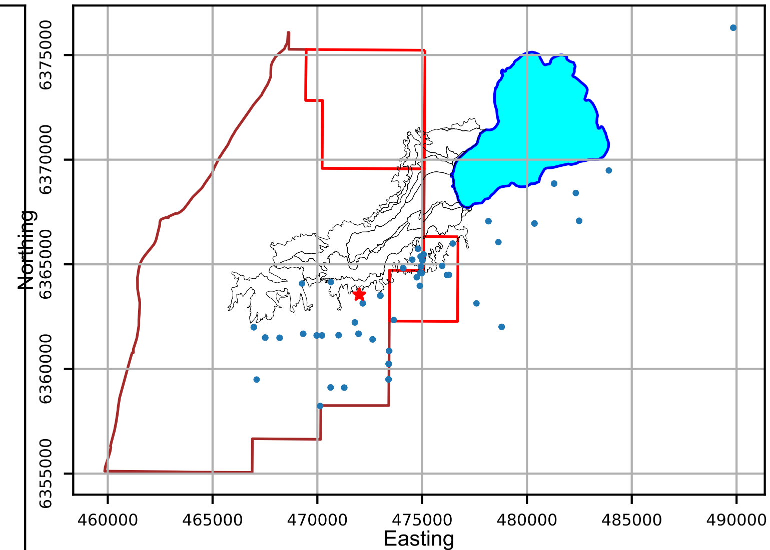
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR405-MR1 - 123.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-31





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 133 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR405-MR1 - 133.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-32

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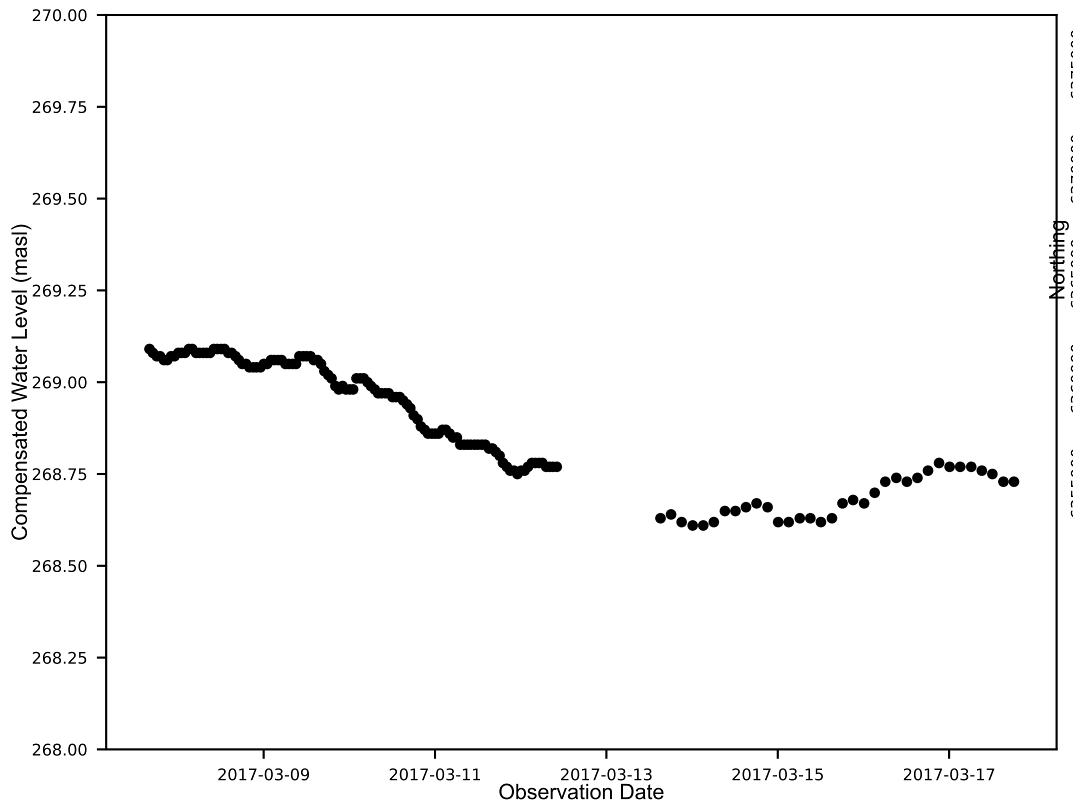

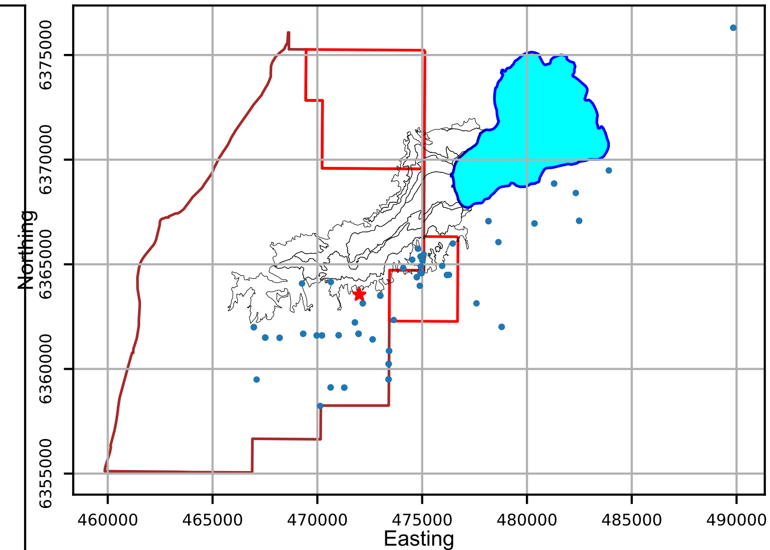

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 143 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR405-MR1 - 143.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-33

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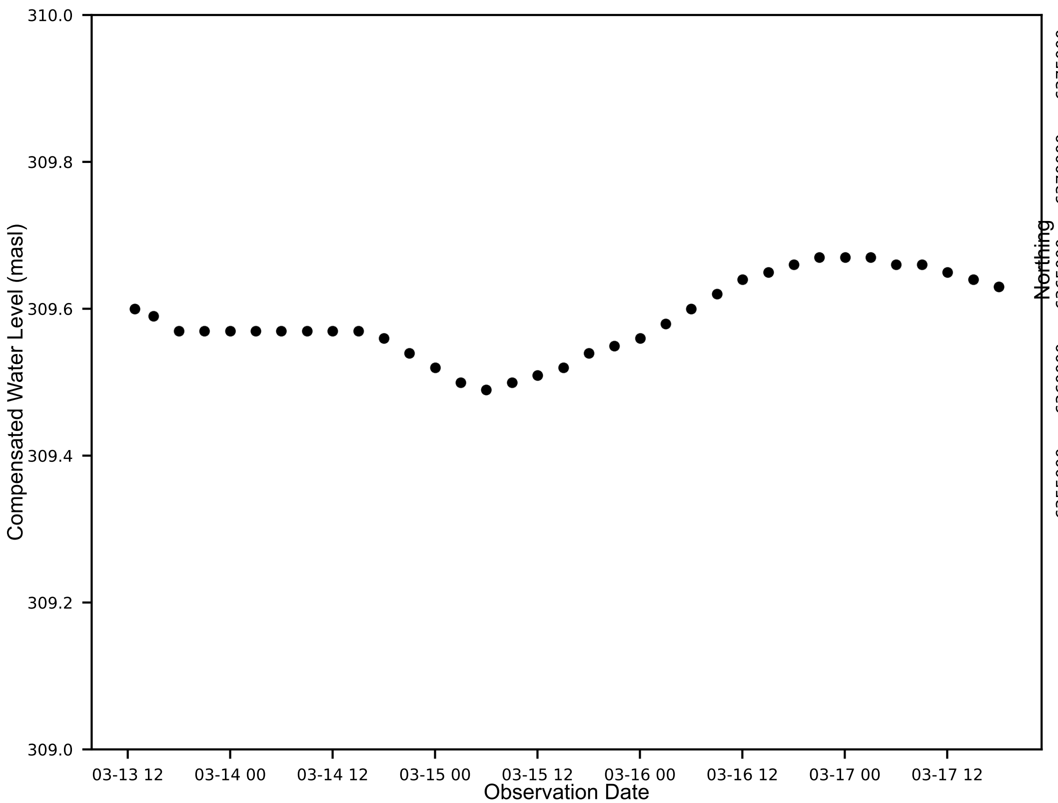

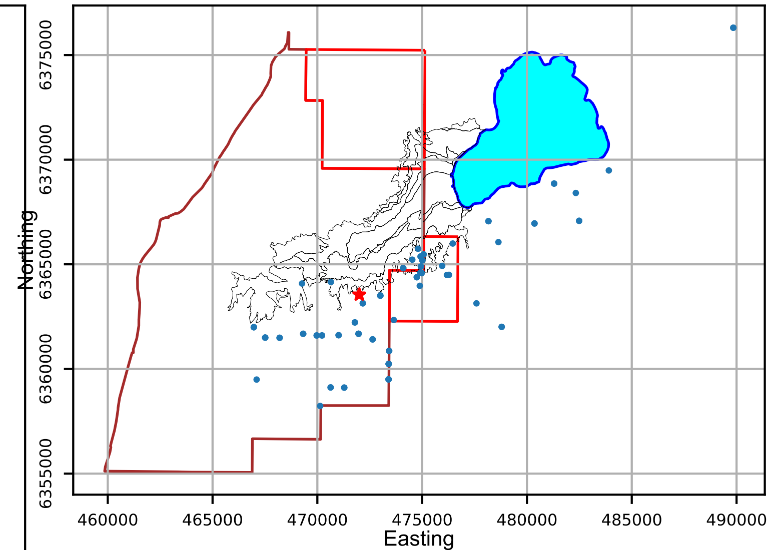

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 33 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR405-SN1 - 33.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-34

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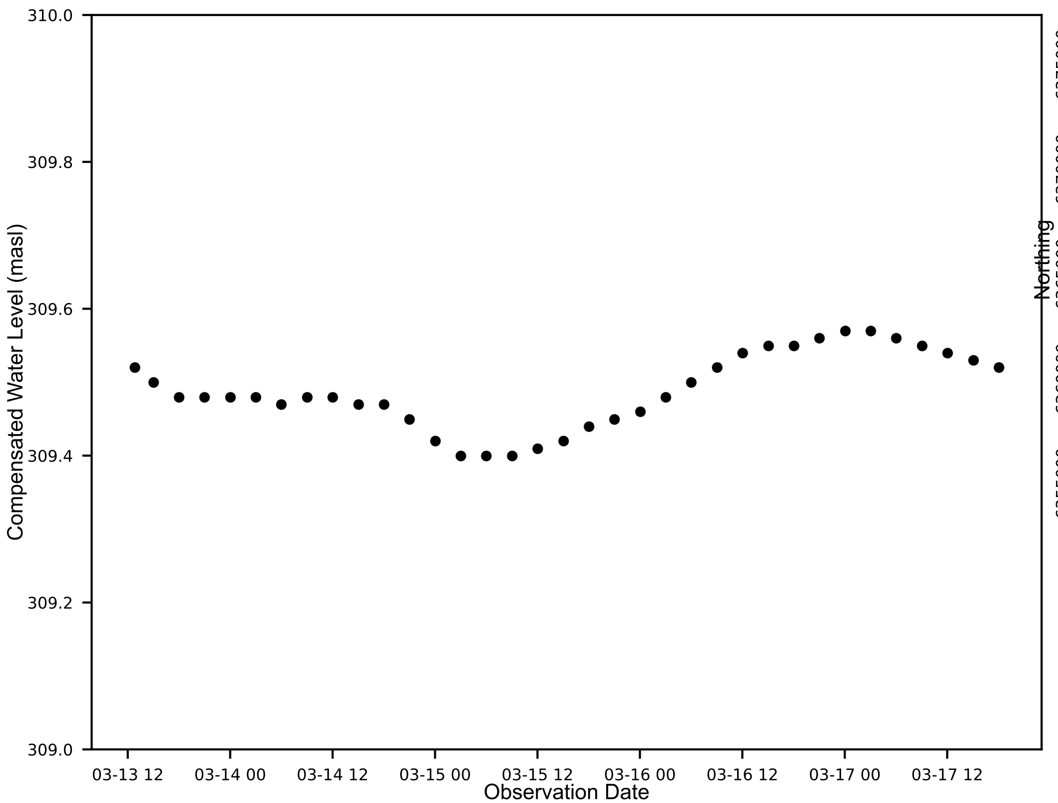

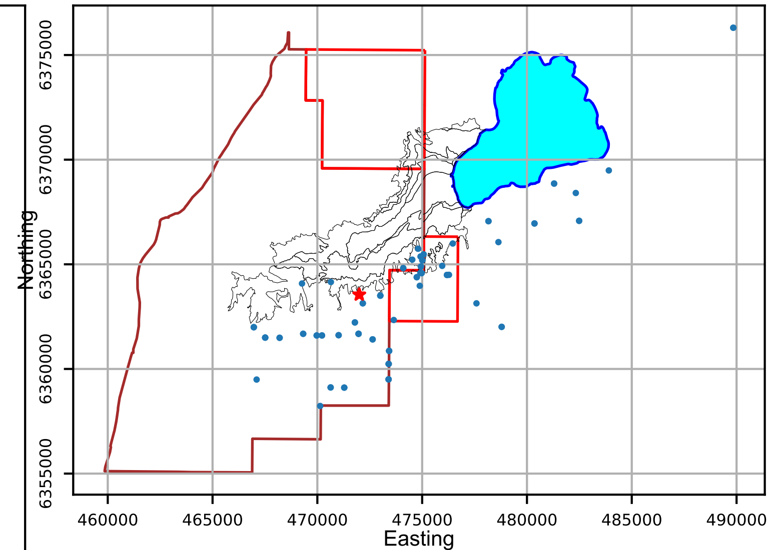

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 42.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR405-SN1 - 42.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-35

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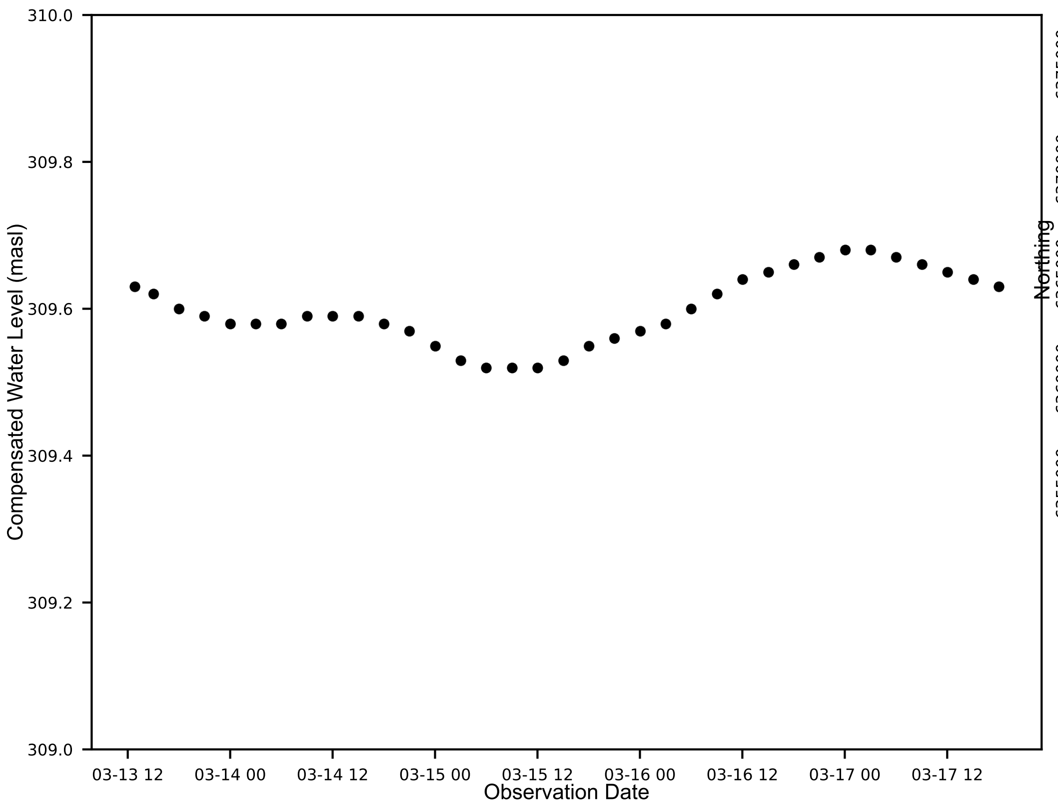
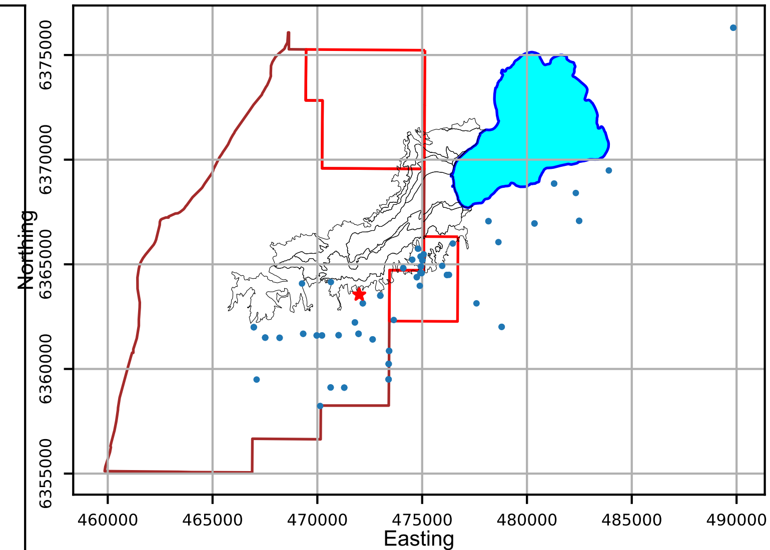




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

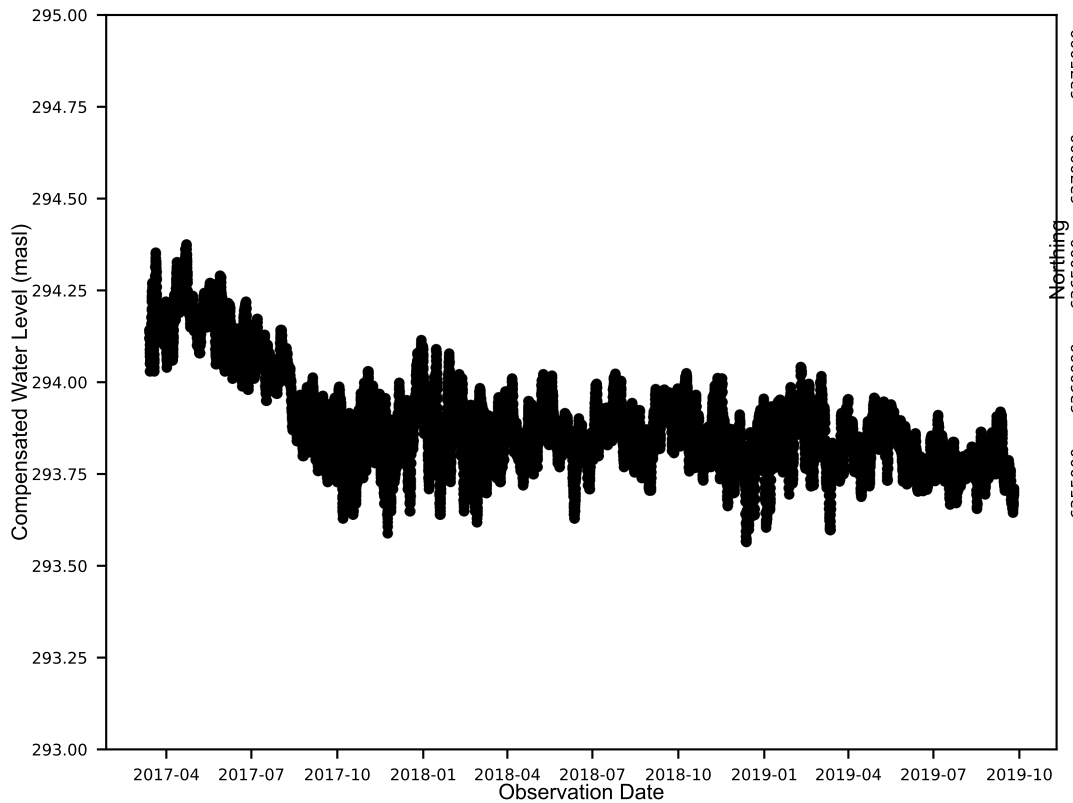
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

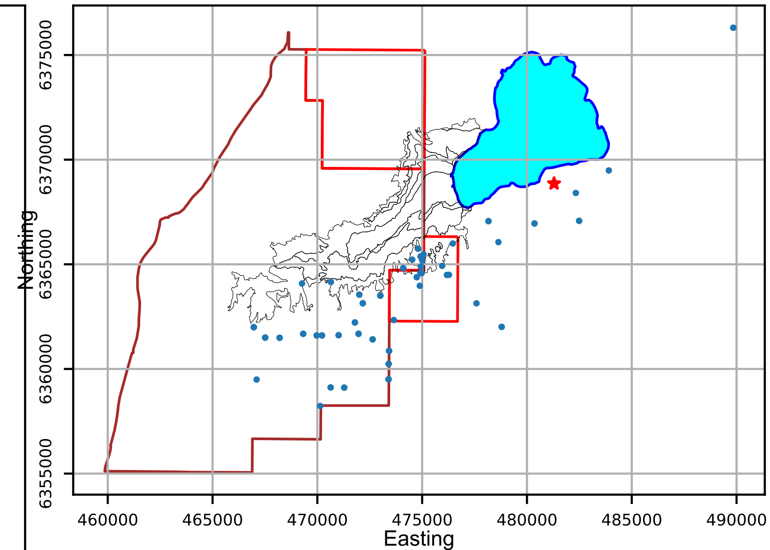
TITLE

FH17-WR405-SN1 - 5.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-36

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 60 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

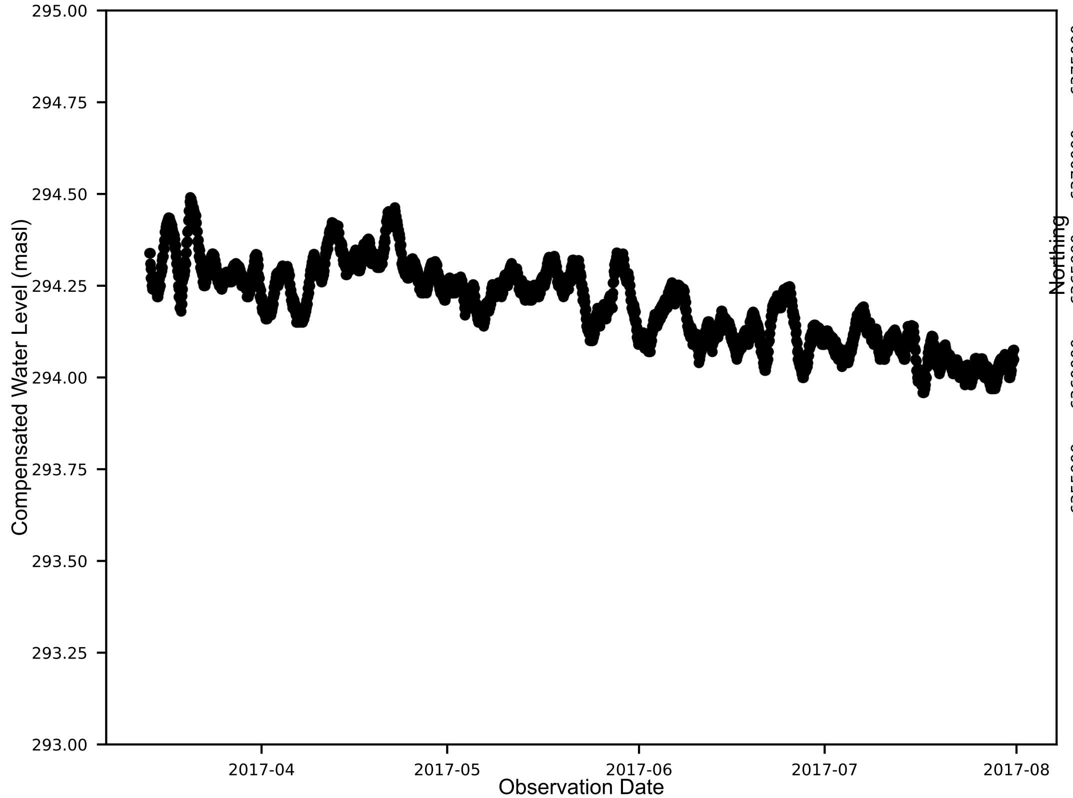
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

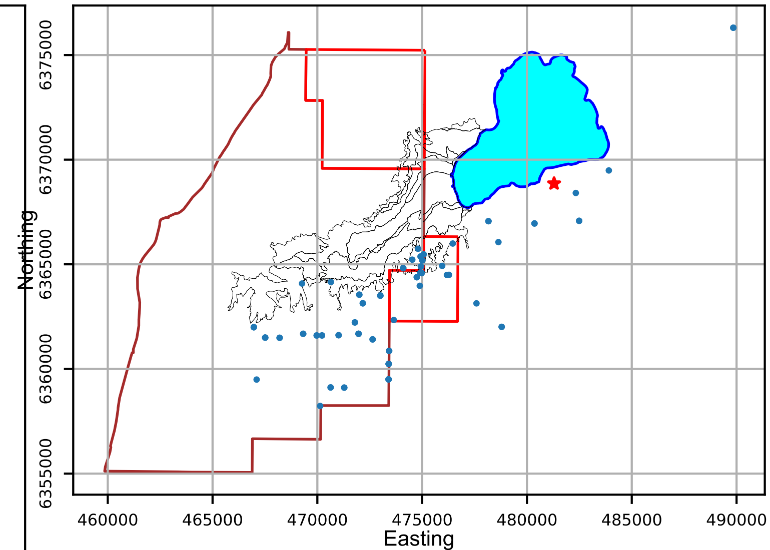
TITLE

FH17-WR409-MR1 - 60.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-37

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 73 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

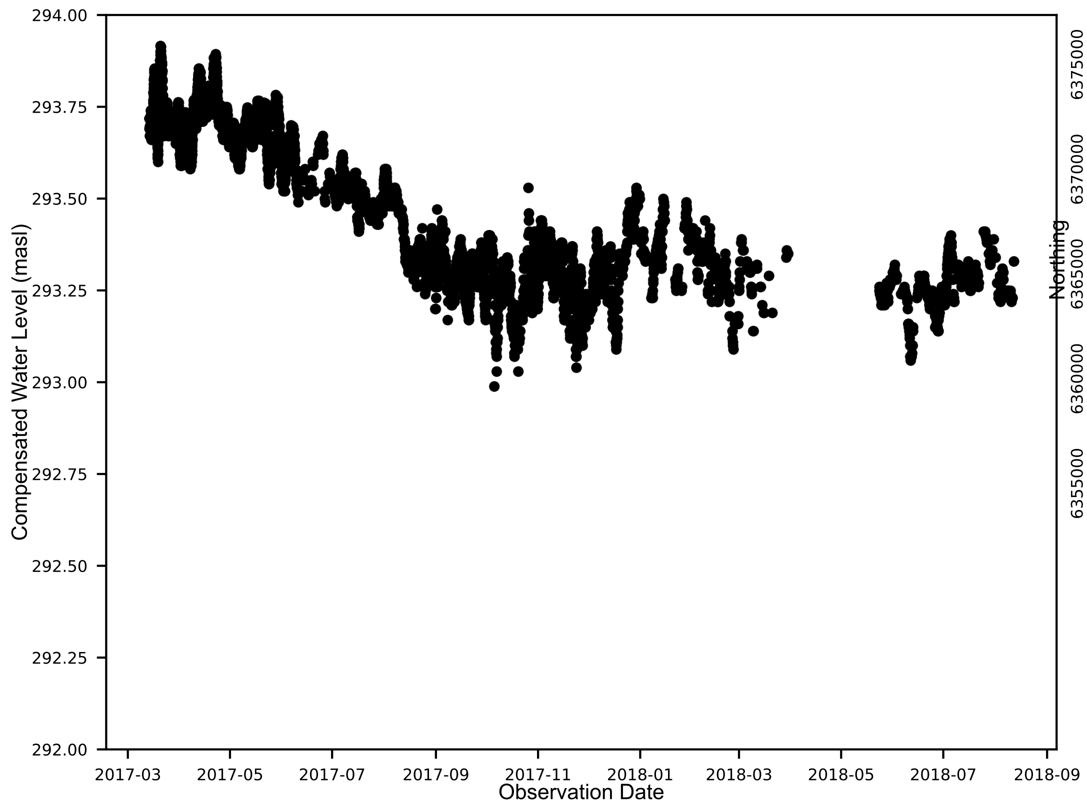
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

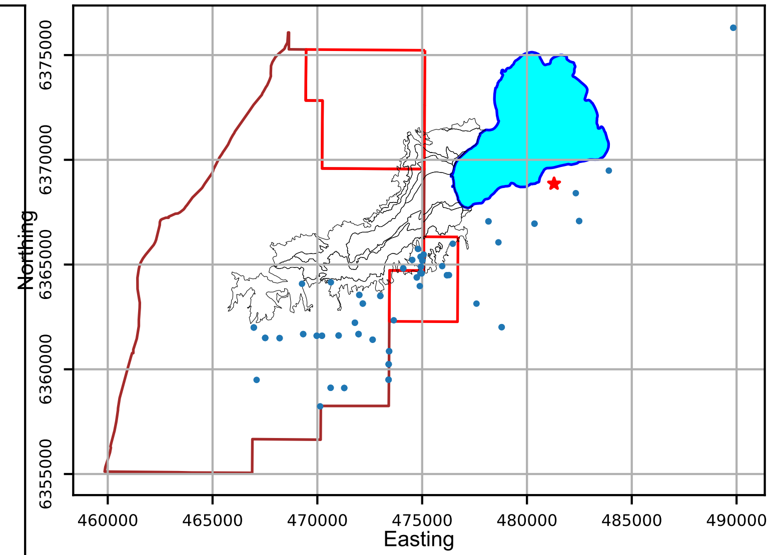
FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR409-MR1 - 73.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-38

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 80 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

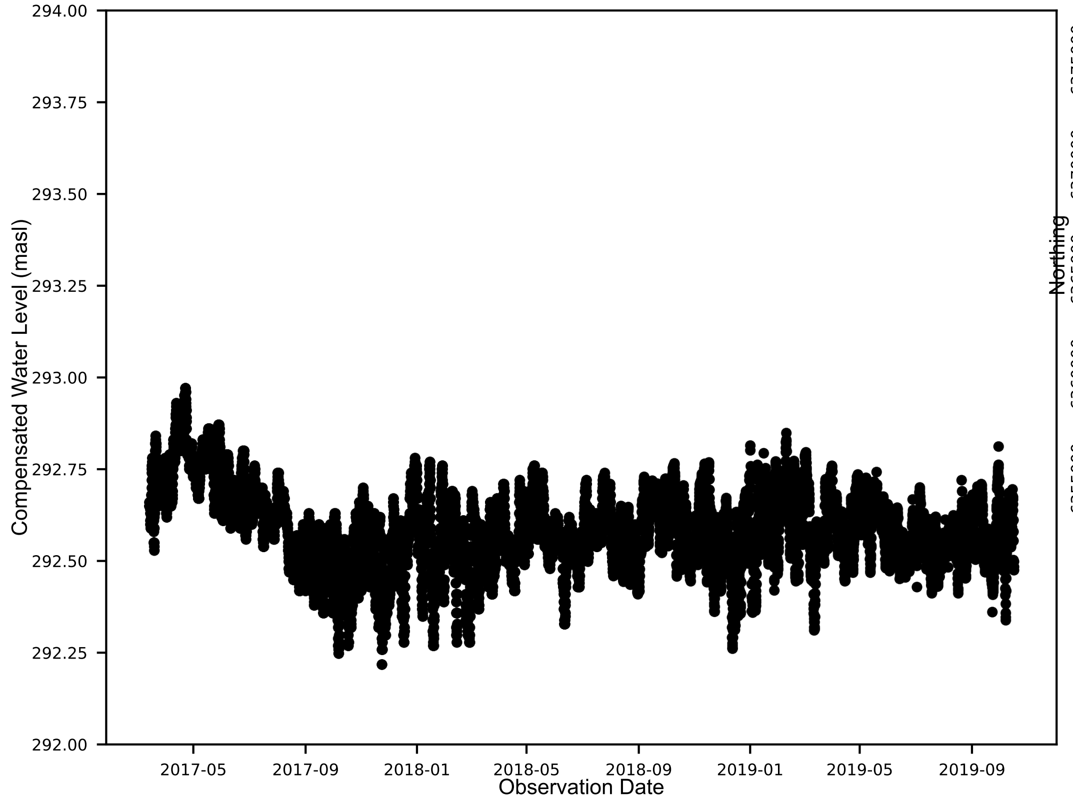
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

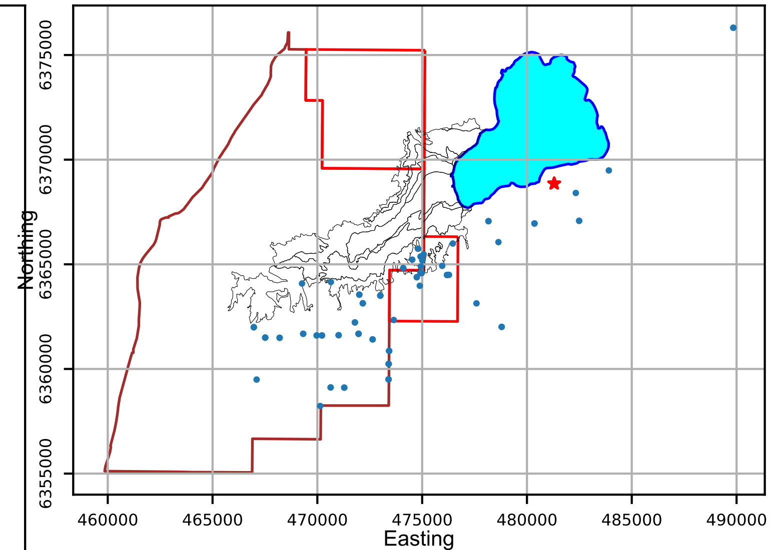
TITLE

FH17-WR409-MR1 - 80.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-39

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 16.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

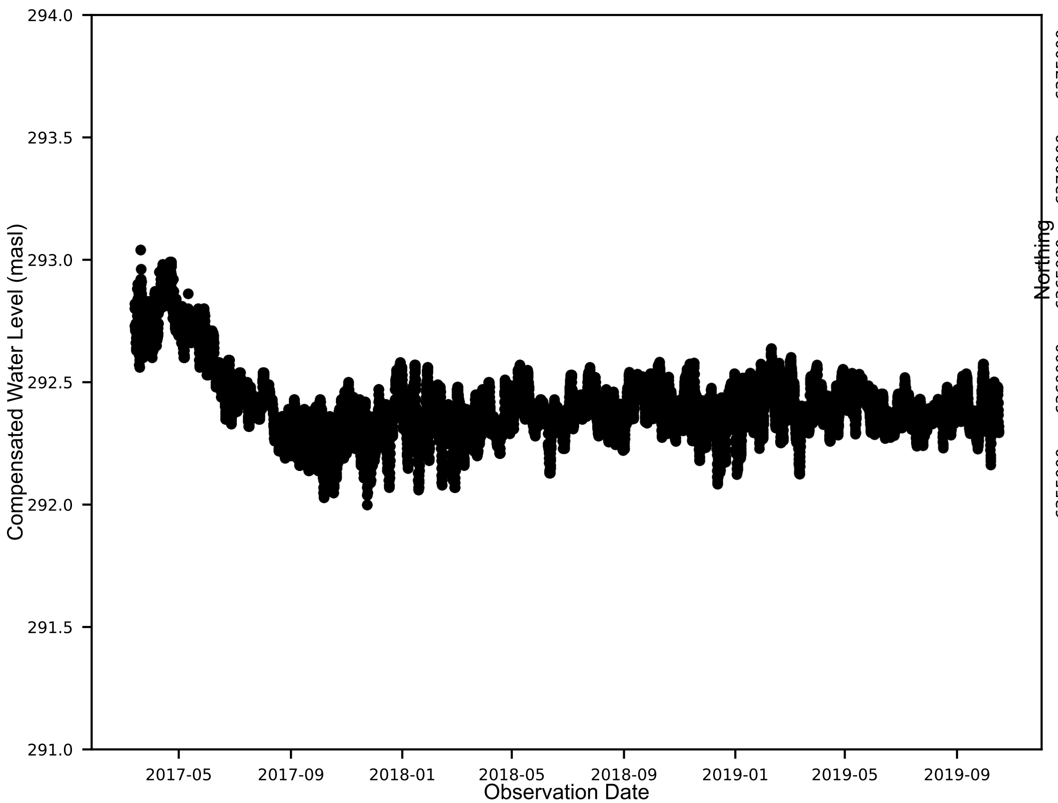
FORT HILLS
Operated by Suncor Energy

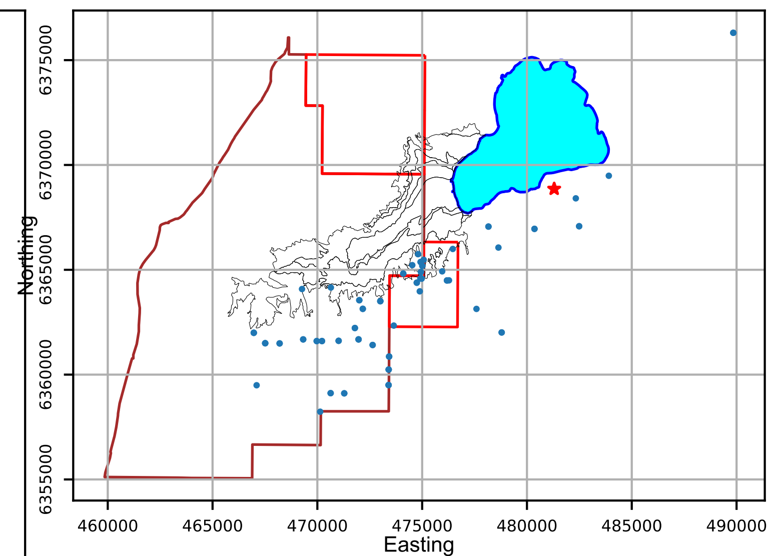
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR409-SN1 - 16.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B7-40





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR409-SN1 - 29.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	**100**	**A**	B7-41

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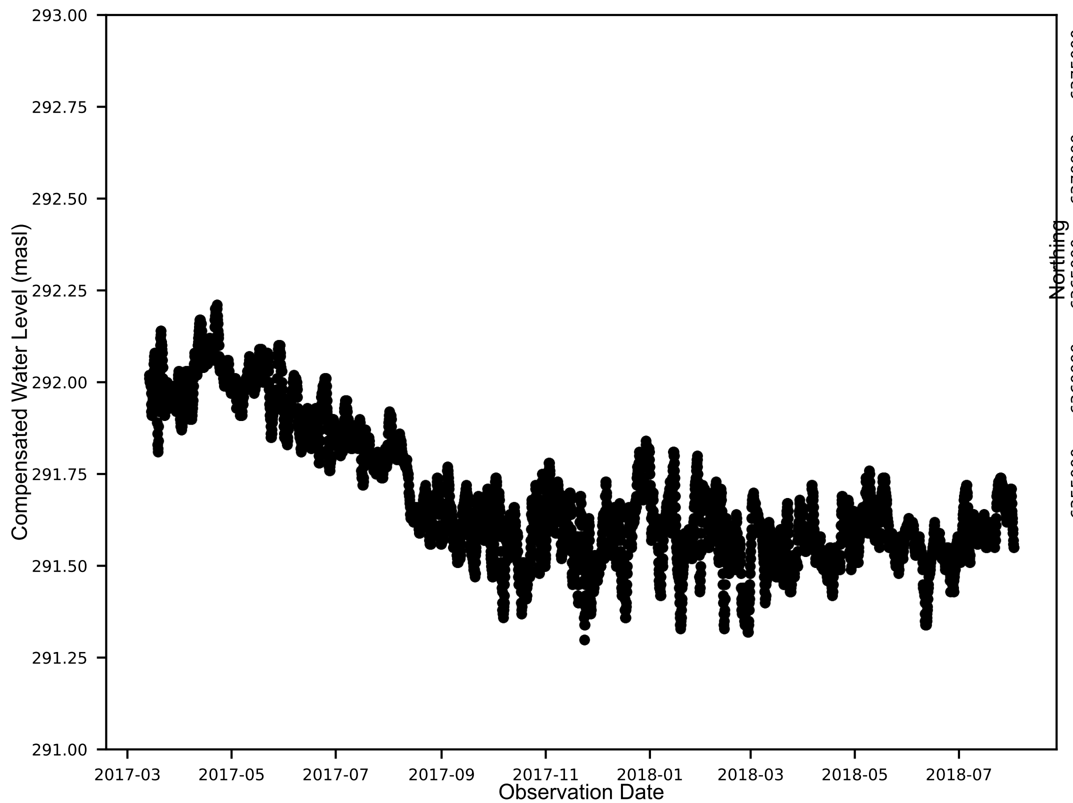
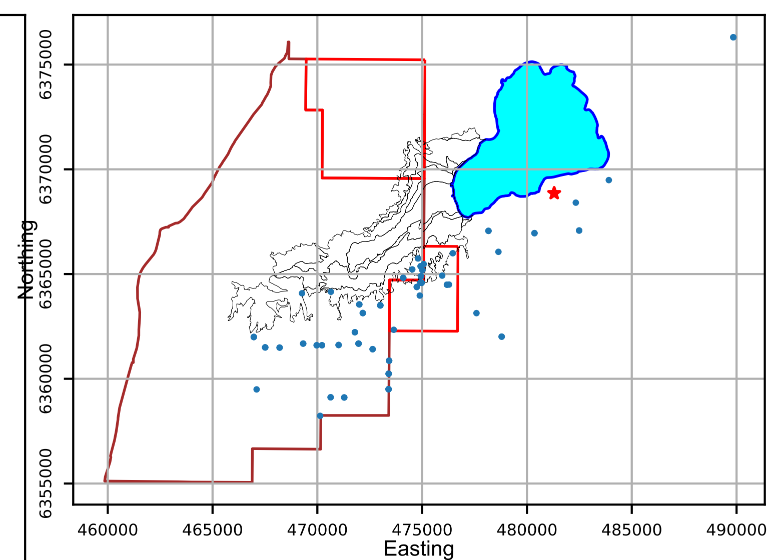




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 40.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

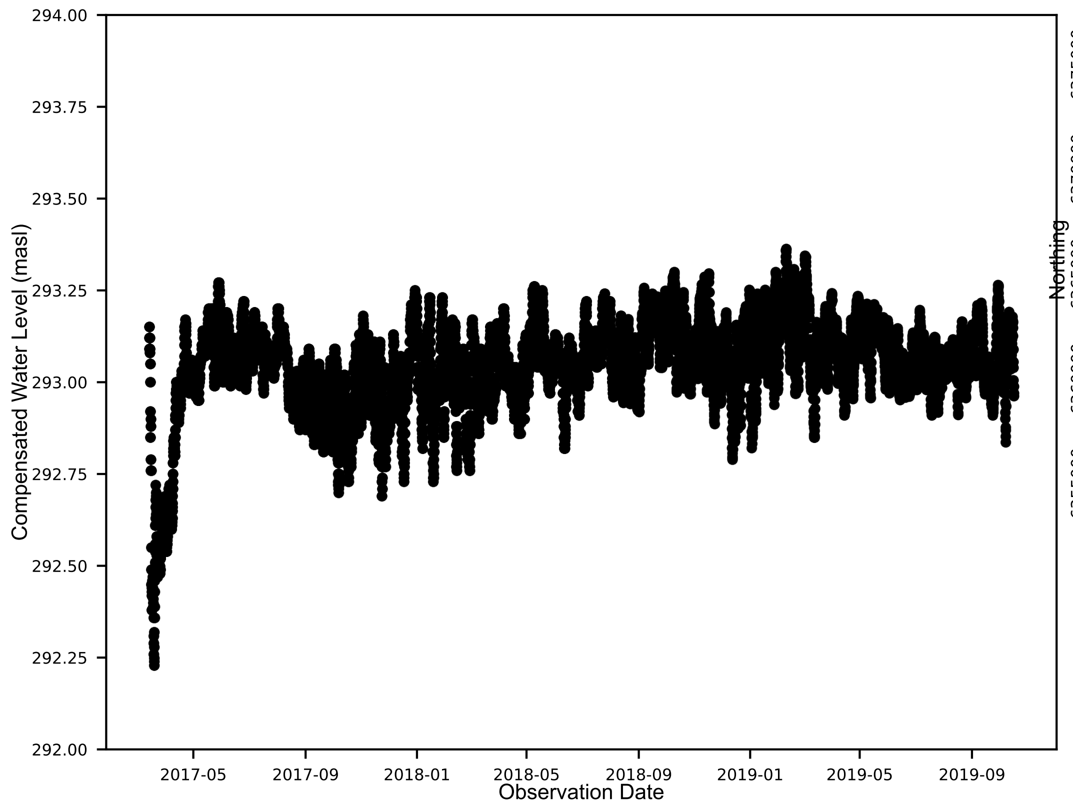
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

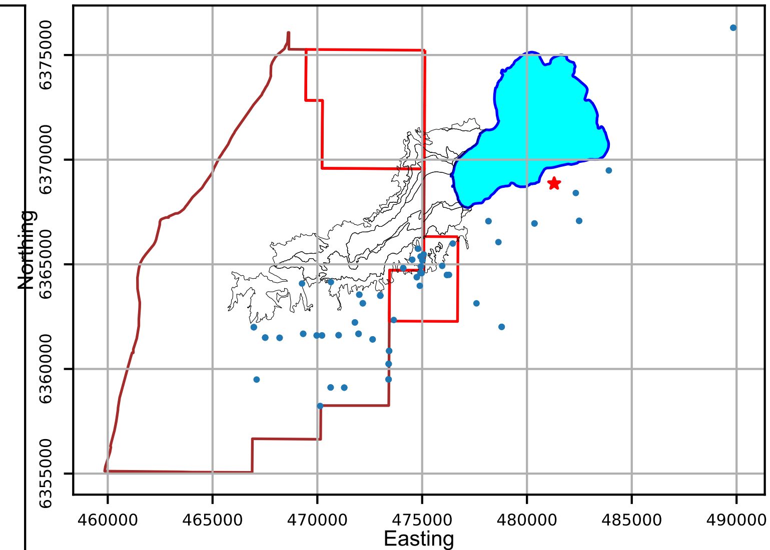
TITLE

FH17-WR409-SN1 - 40.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-42

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 6.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR409-SN1 - 6.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-43

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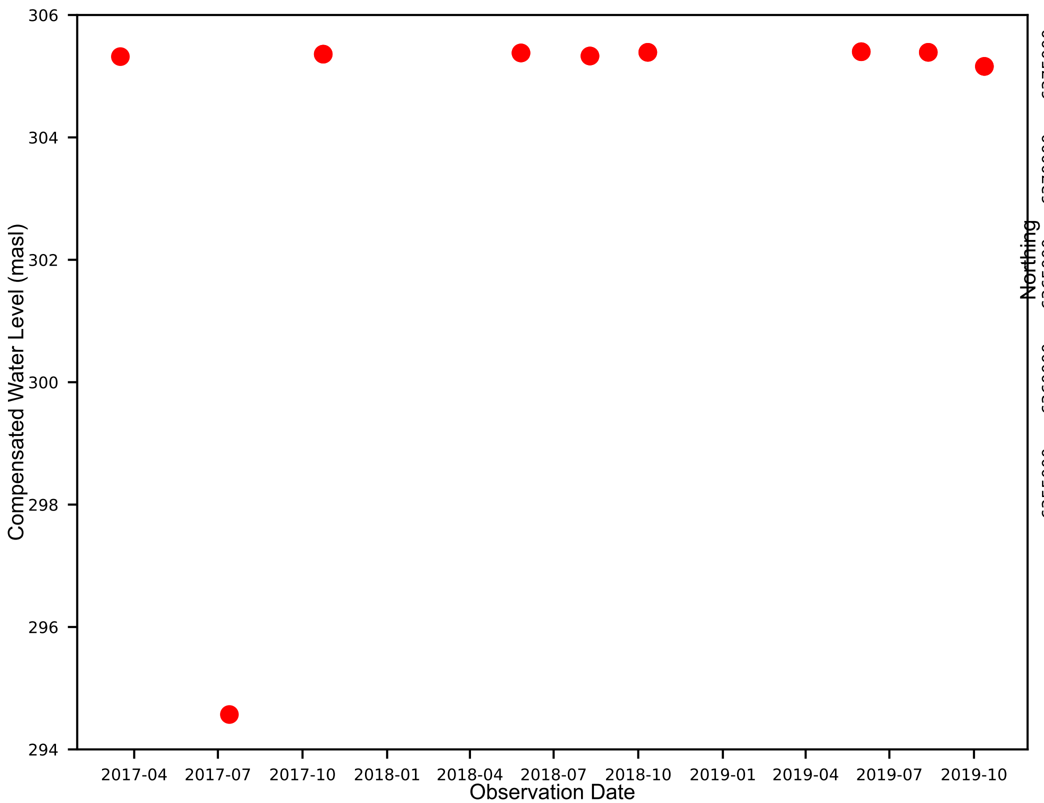

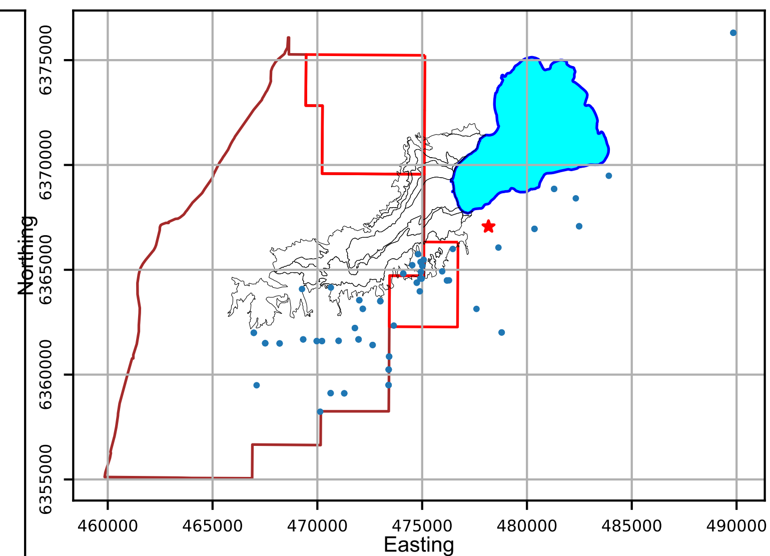

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 47.75 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR414-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-44

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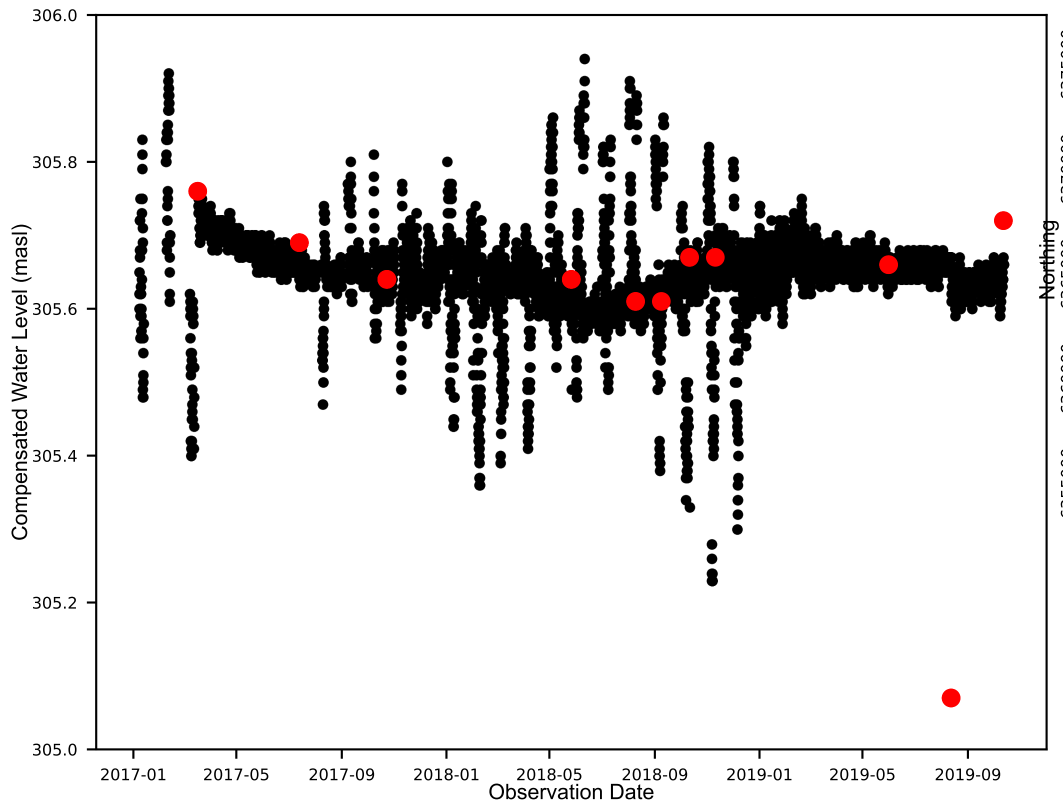

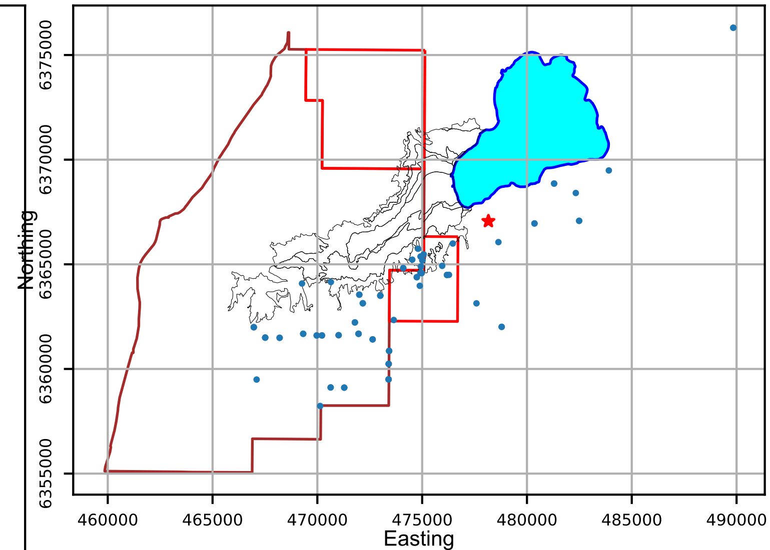

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 20.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR414-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-45

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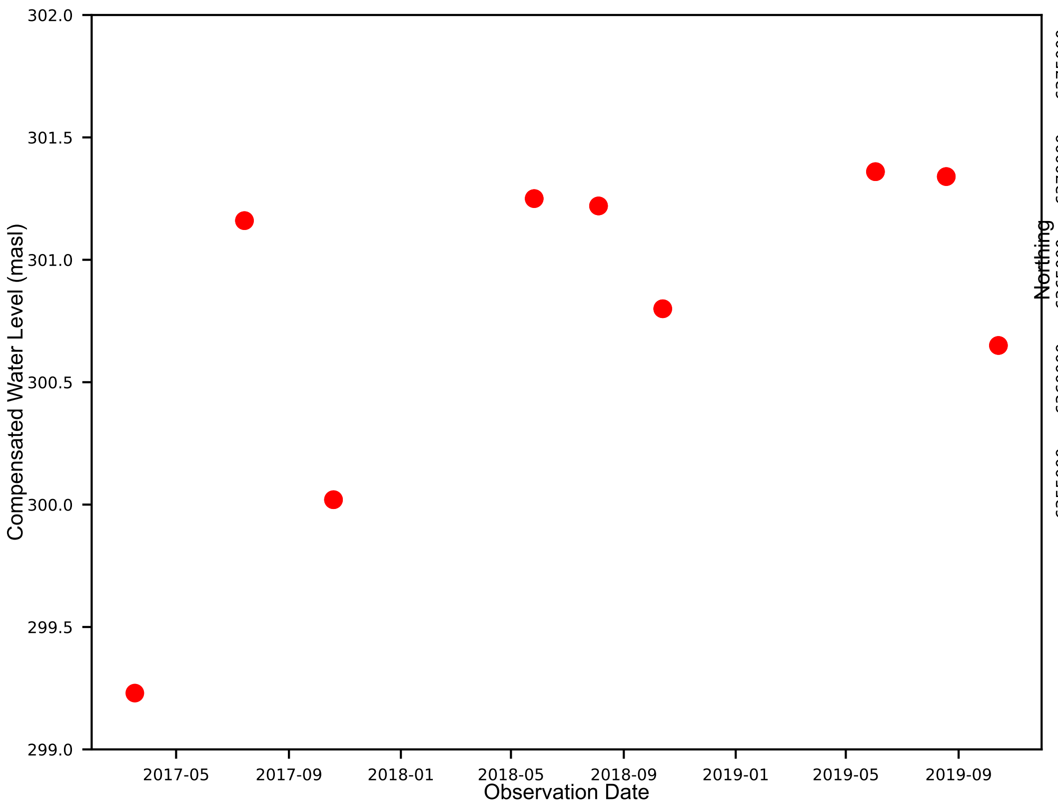

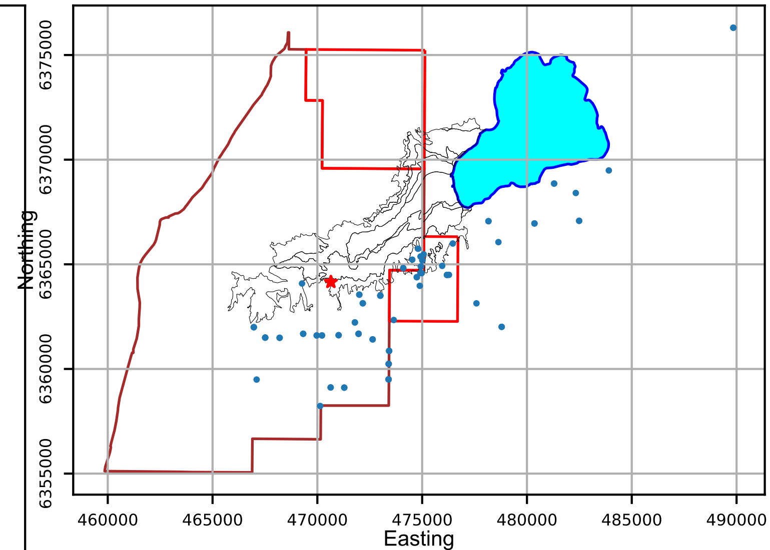

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 10.97 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR425-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-46

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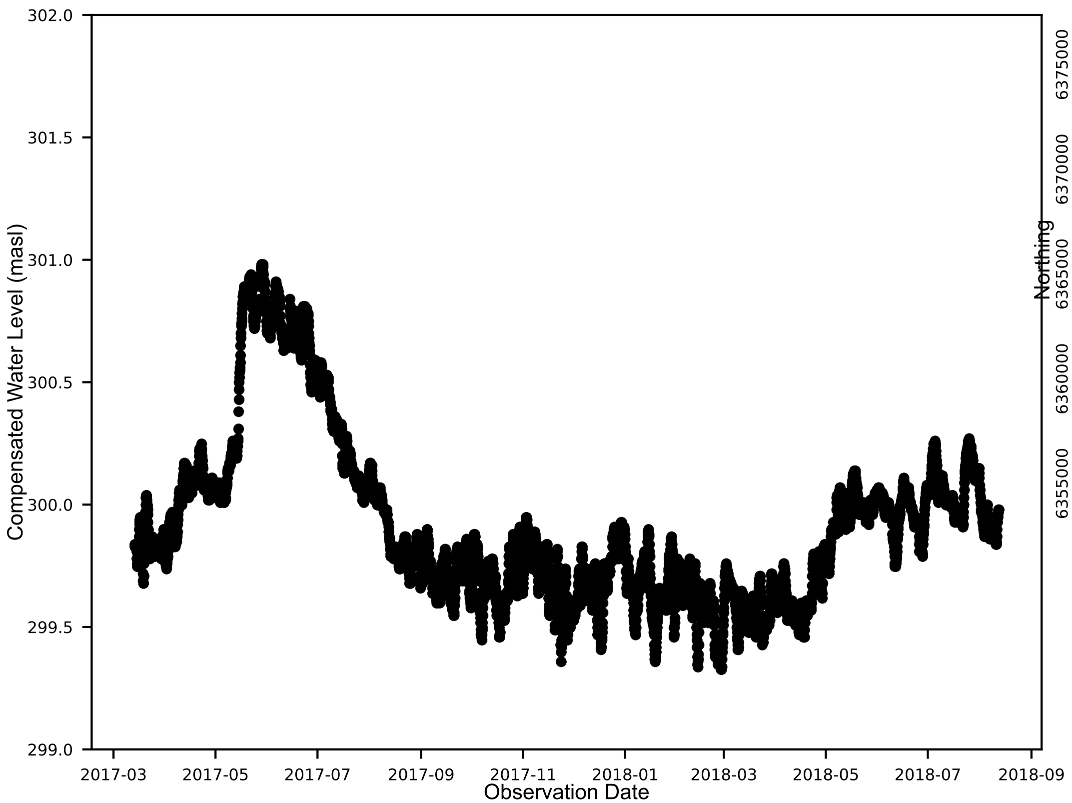

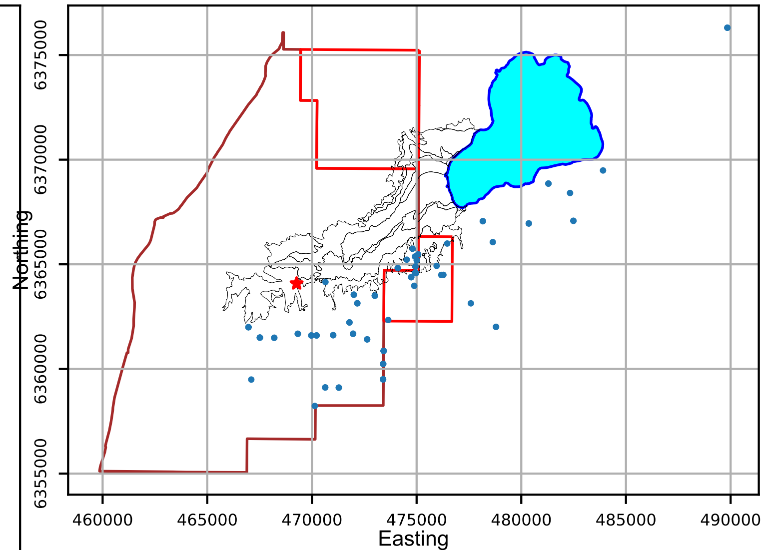

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 4.75 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH17-WR426-SN1 - 10.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-47

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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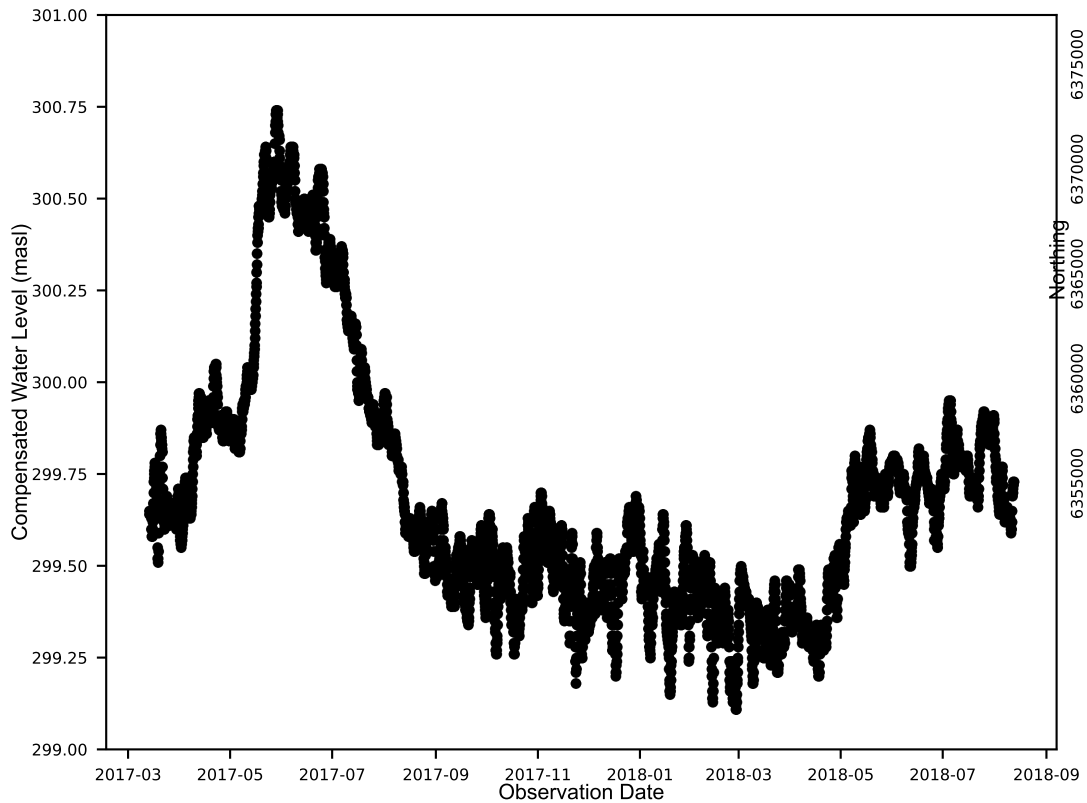

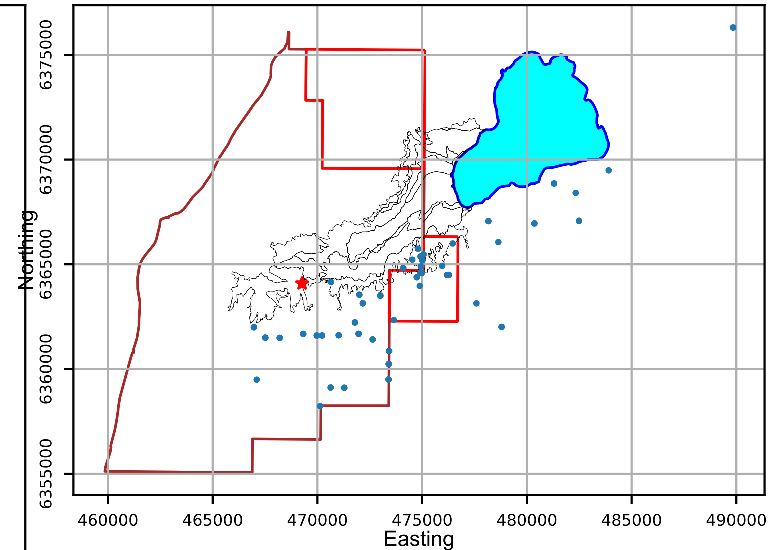

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 20 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR426-SN1 - 20.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-48

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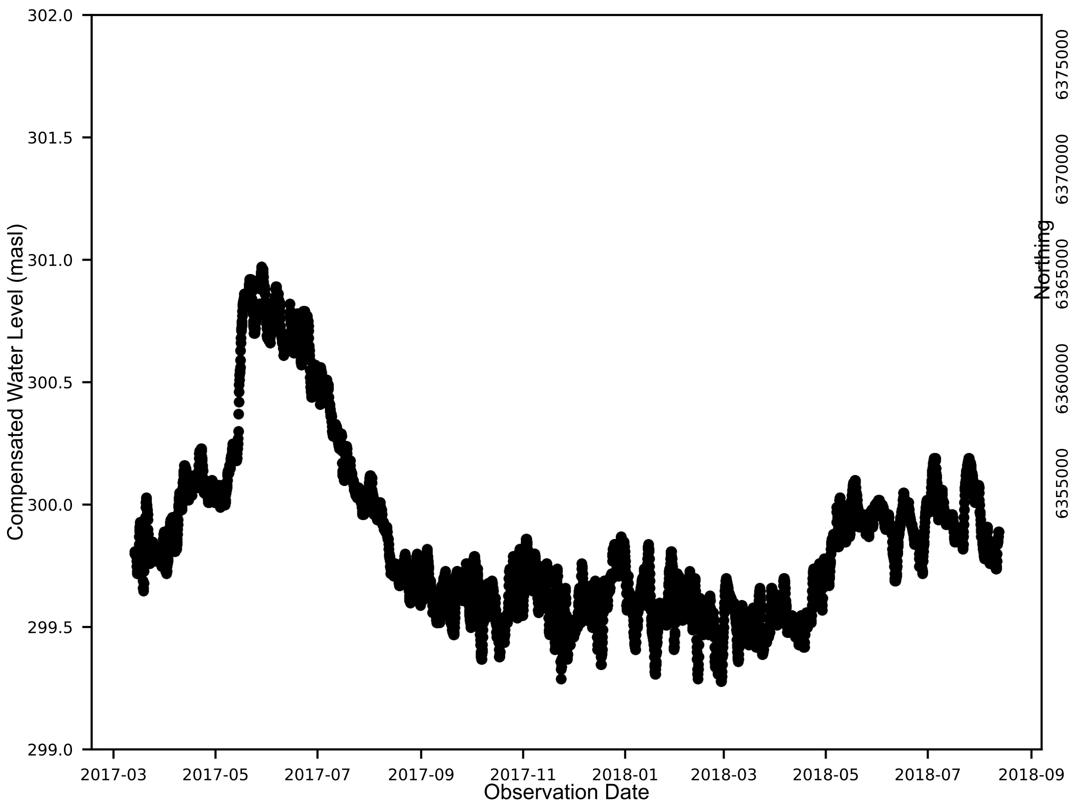

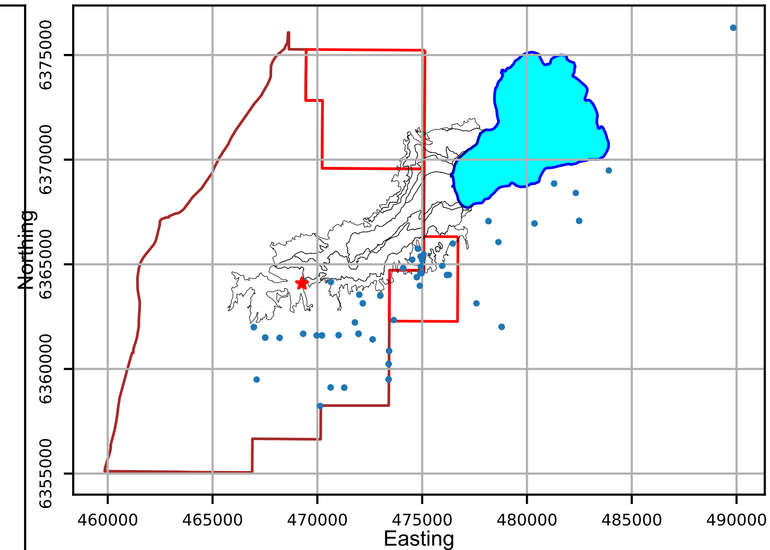

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 4.75 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR426-SN1 - 4.8 M BELOW GROUND SURFACE

FORTHILLS
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PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-49

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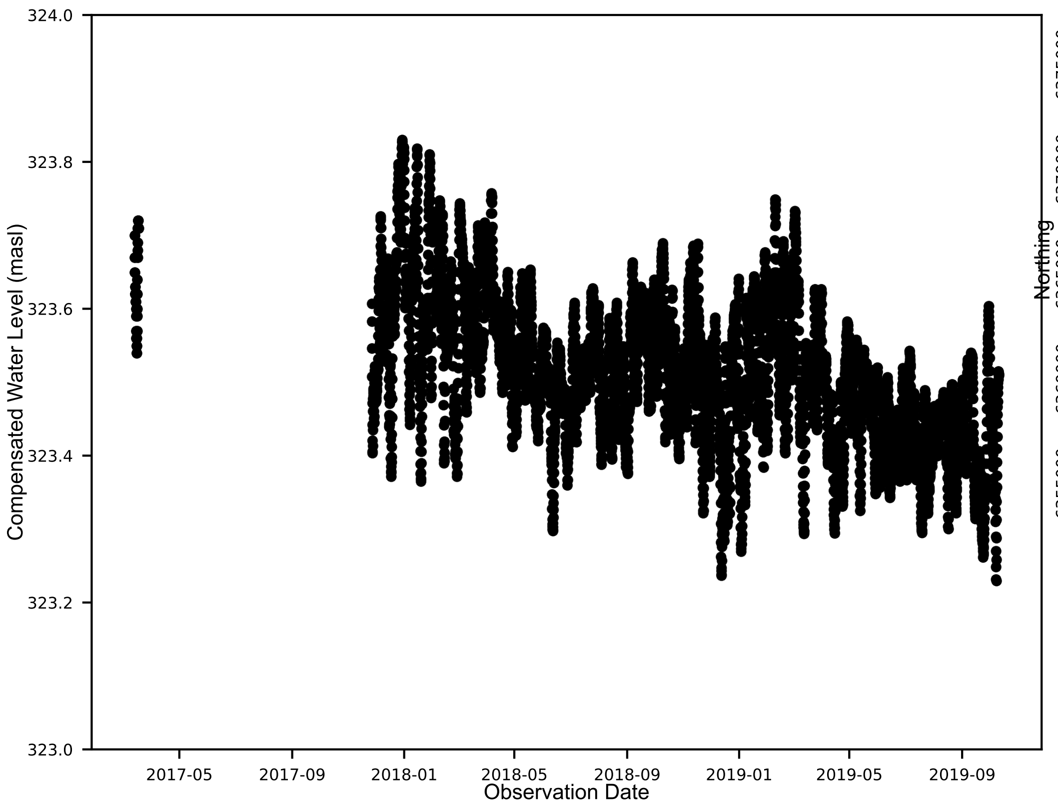

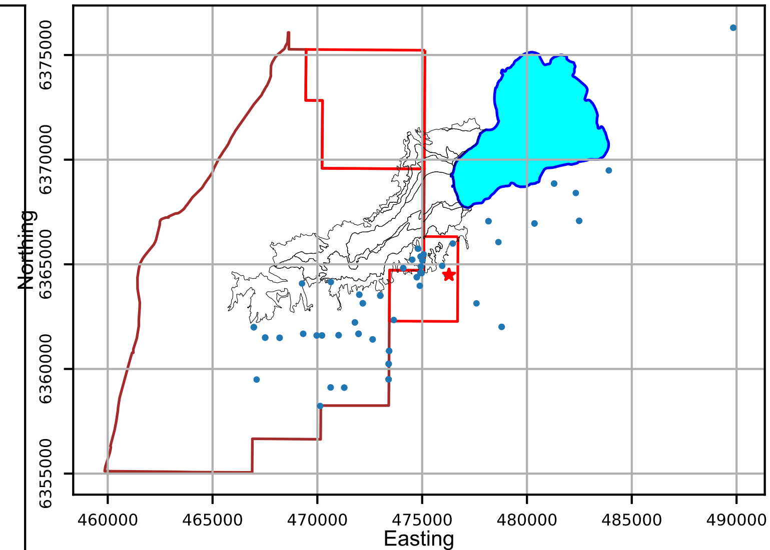

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 25.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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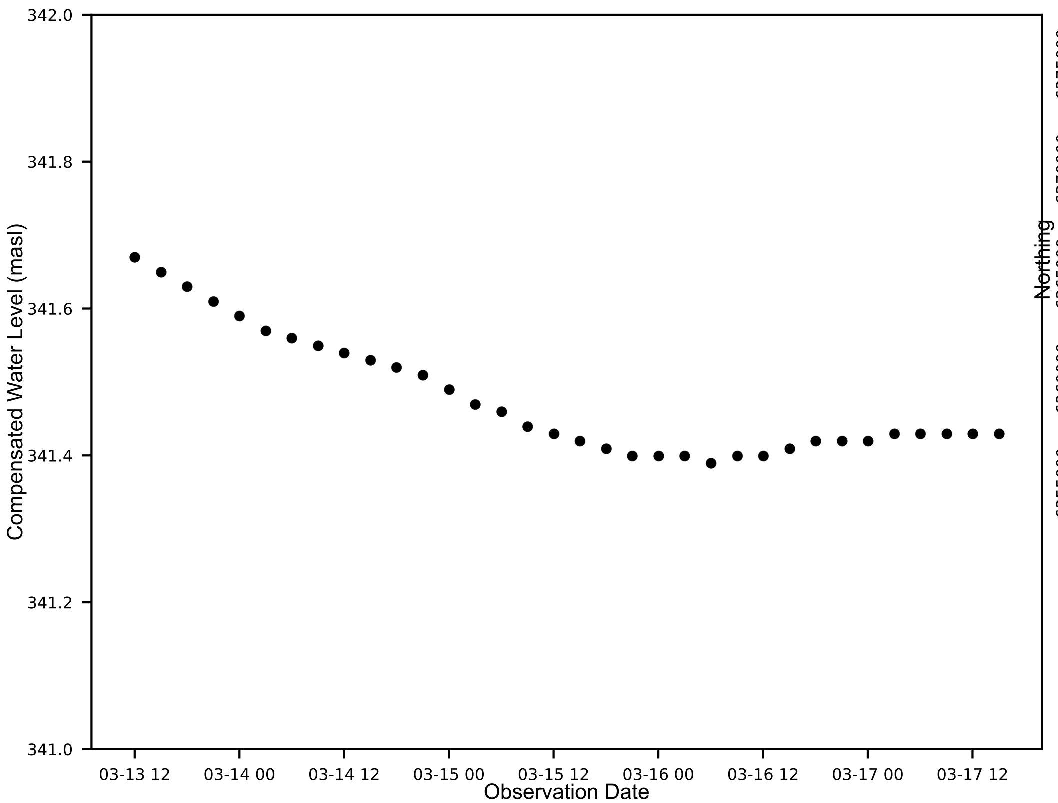
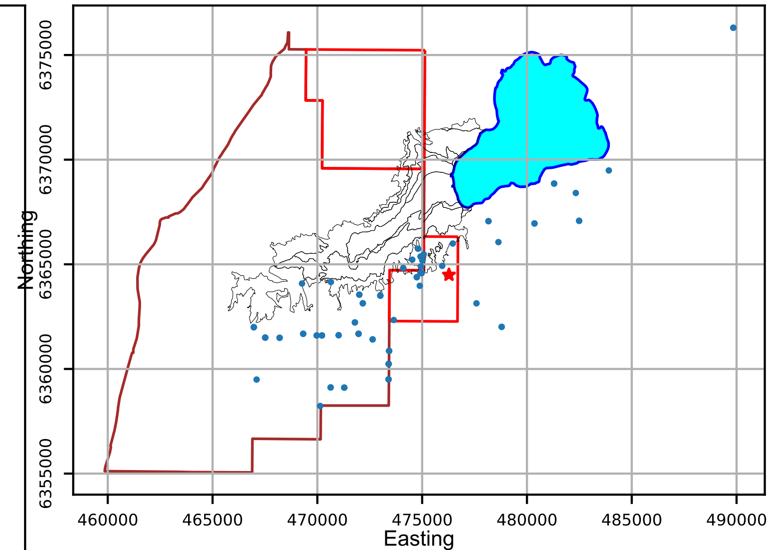
TITLE
FH17-WR434-SN1 - 25.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-50

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

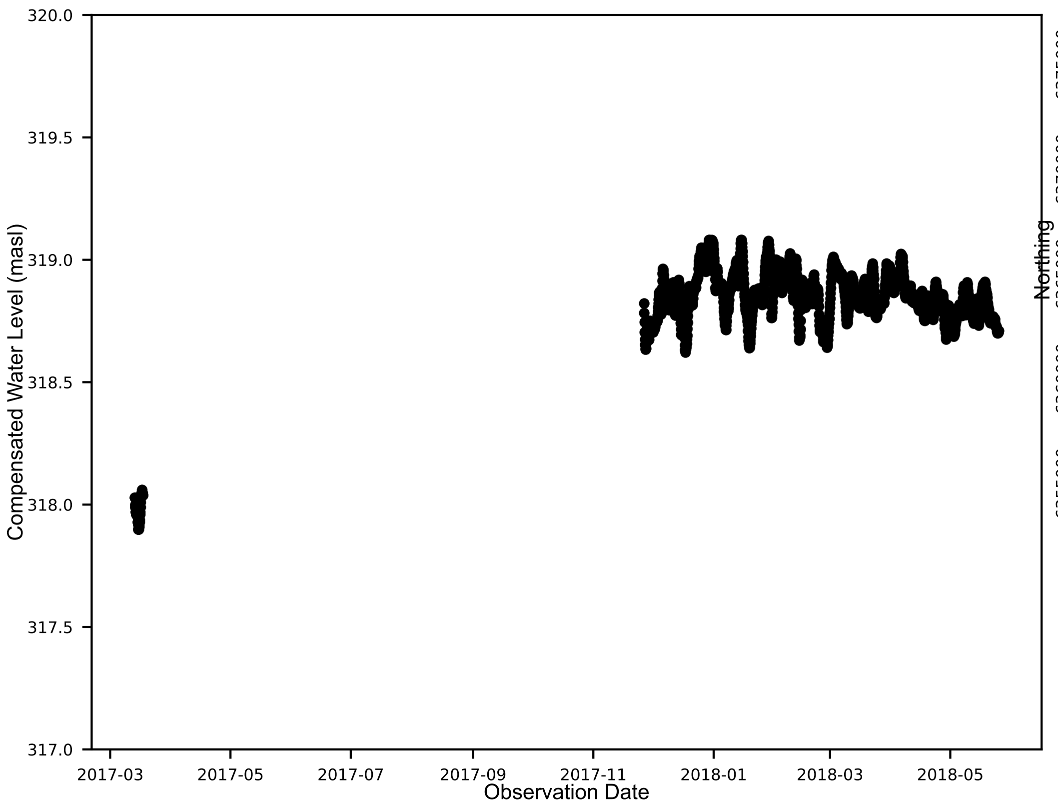
PROJECT

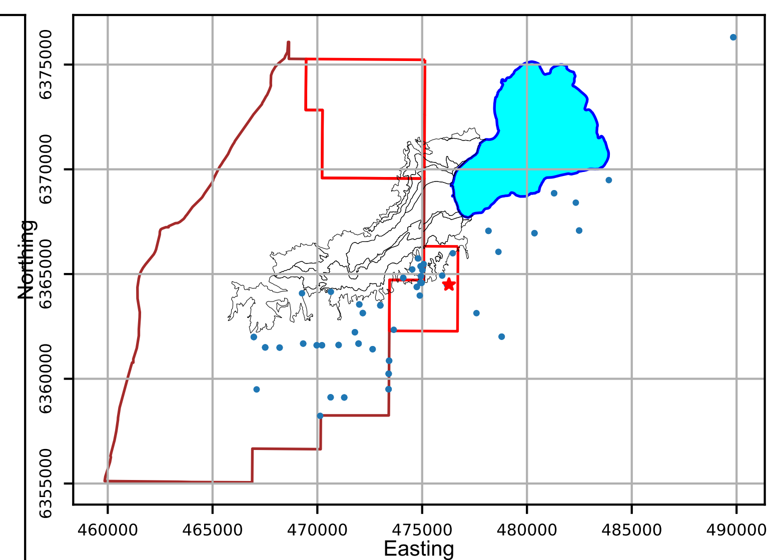
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR434-SN1 - 4.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-51





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 50 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR434-SN1 - 50.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-52

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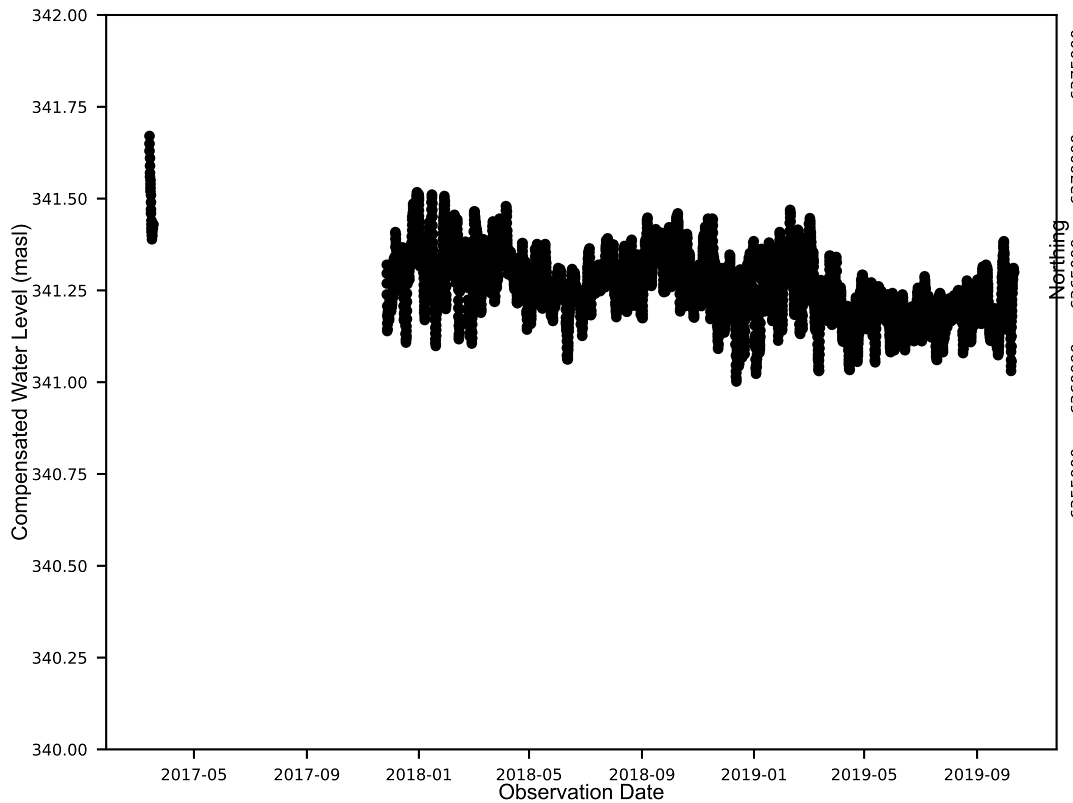

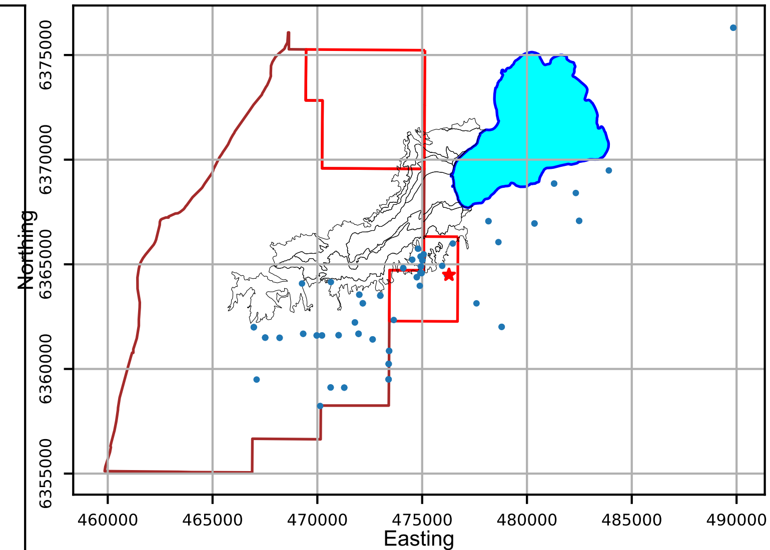

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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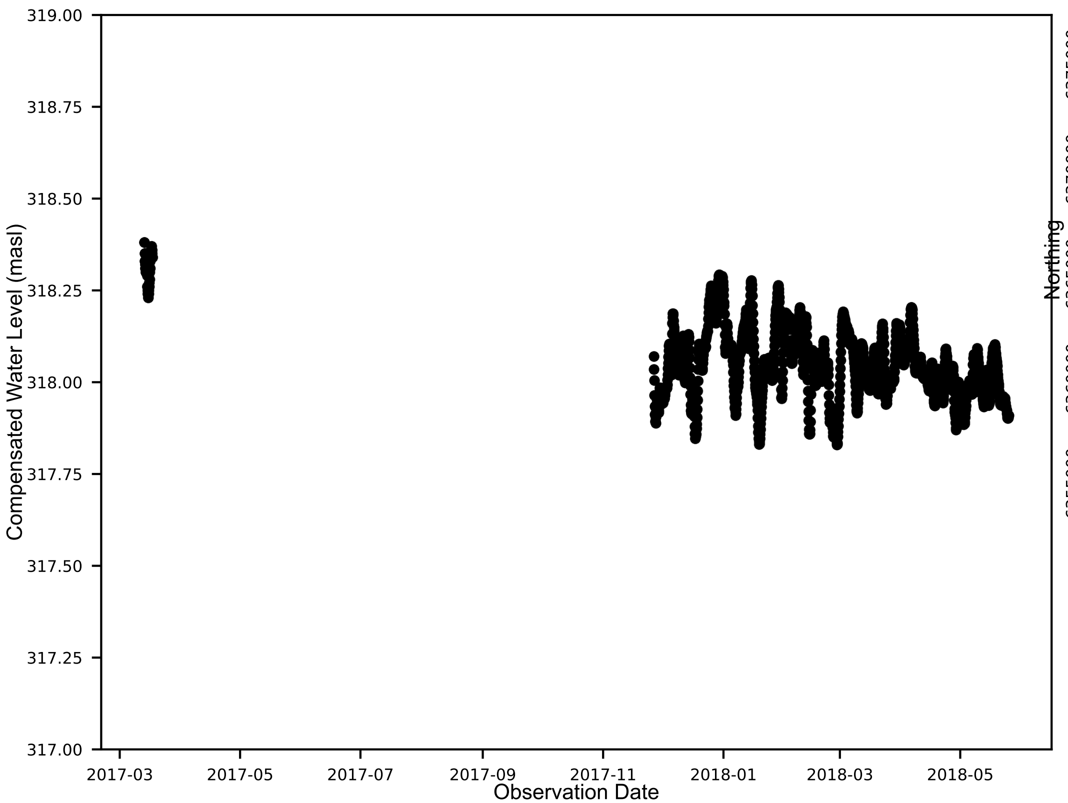
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

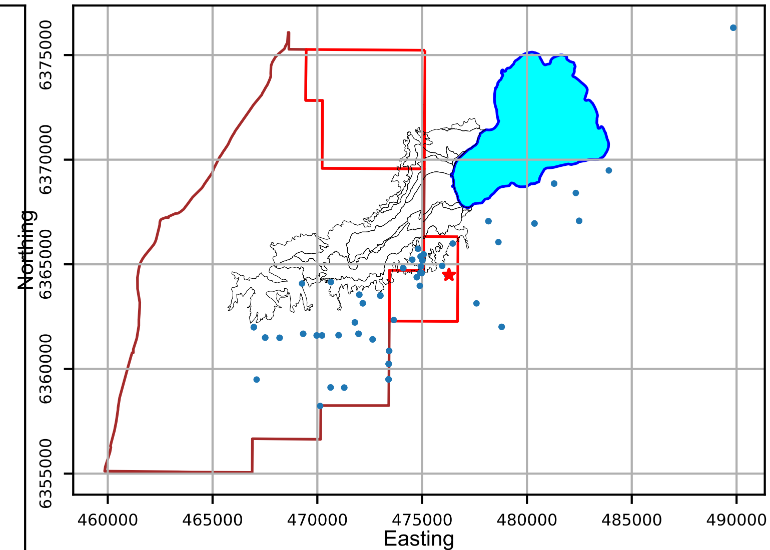
FORTHILLS
Operated by Suncor Energy

TITLE

FH17-WR434-SN1 - 7.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-53





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 75.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR434-SN1 - 75.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-54

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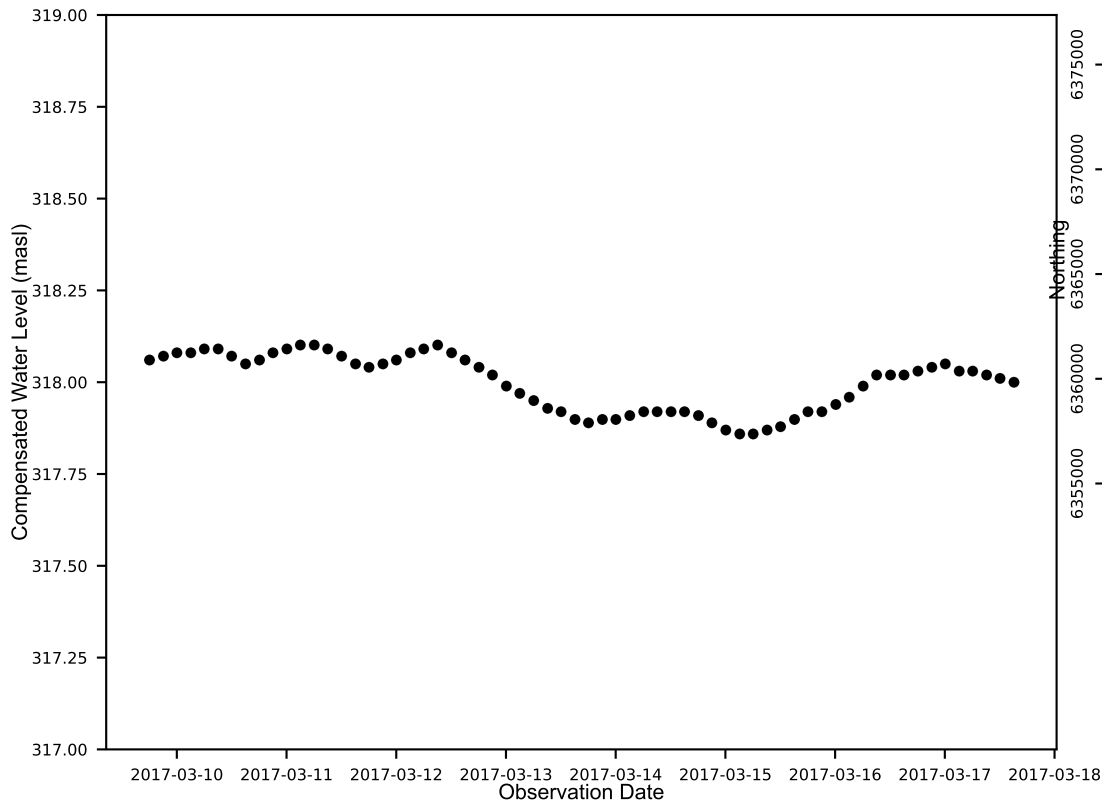

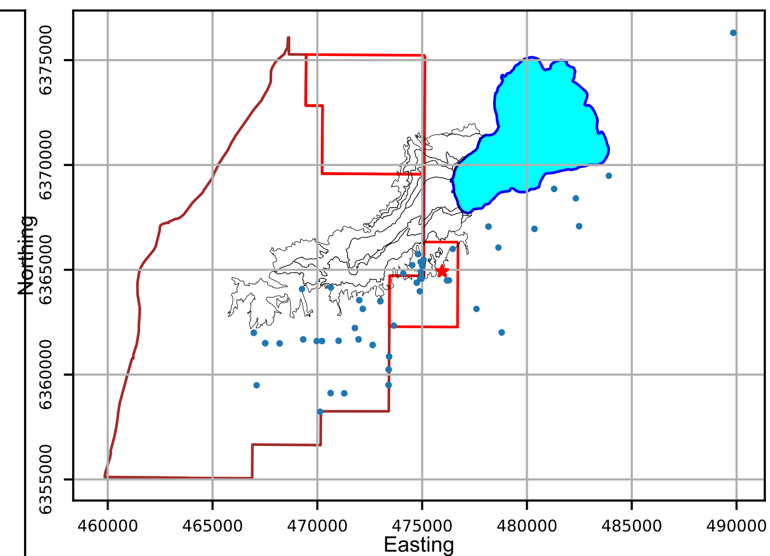

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 18 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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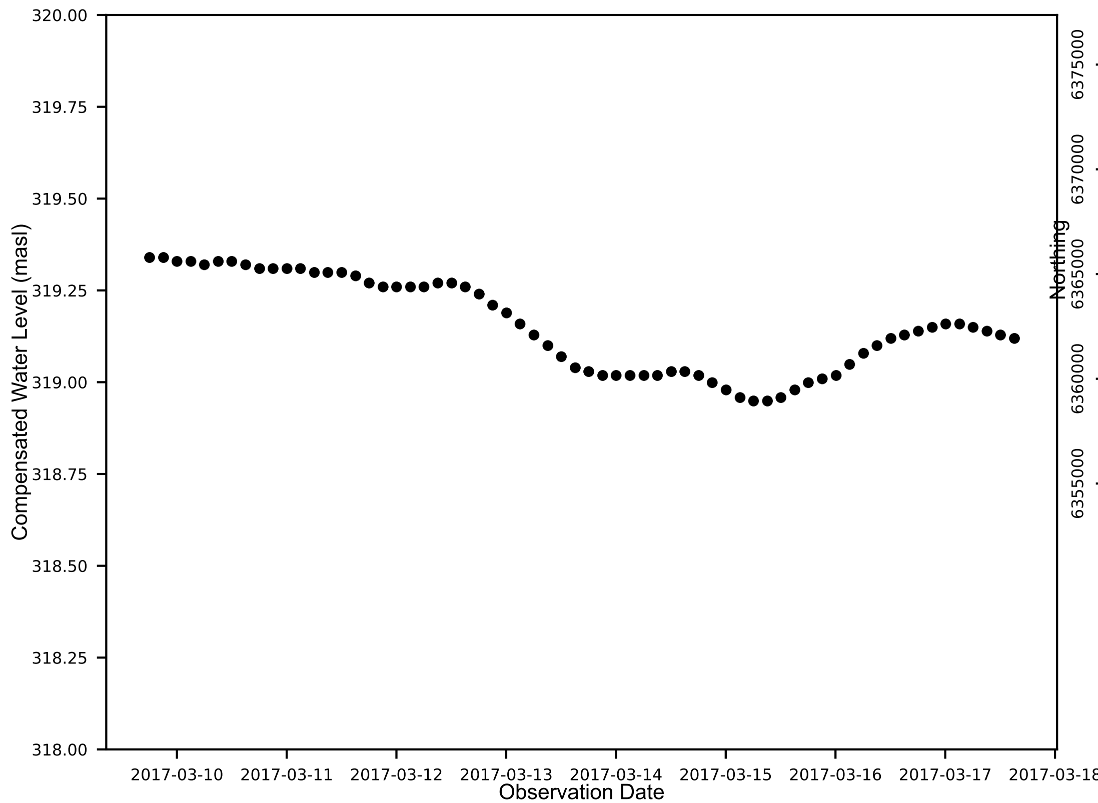
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

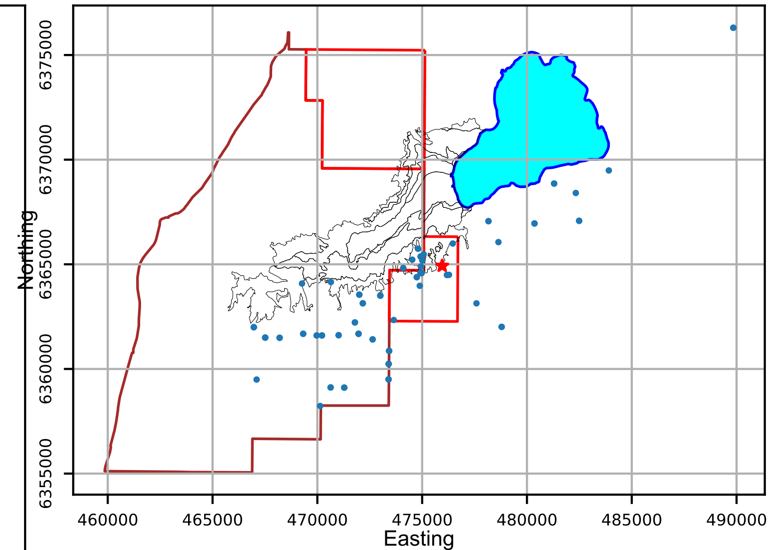
TITLE

FH17-WR435-SN1 - 18.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-55

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 3.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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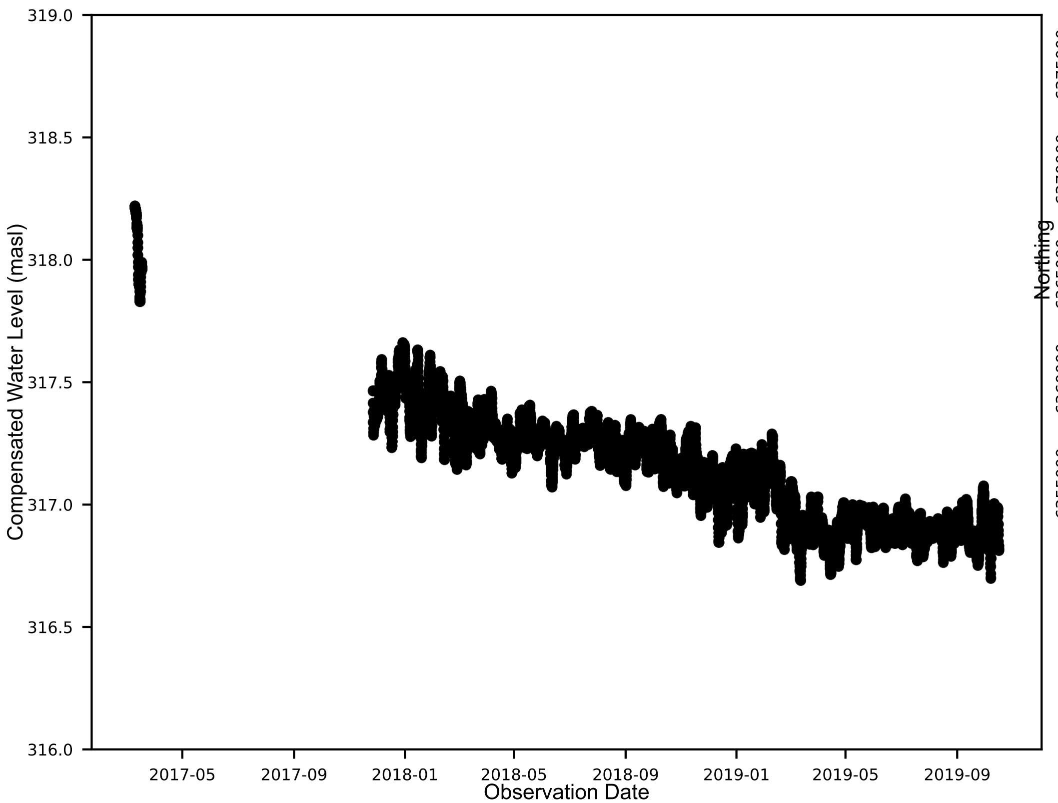
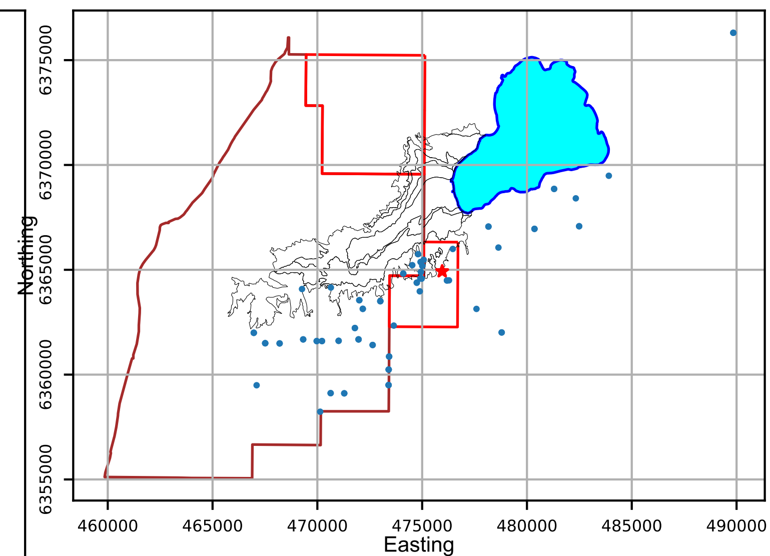
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR435-SN1 - 3.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-56





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 50 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
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DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR435-SN1 - 50.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-57

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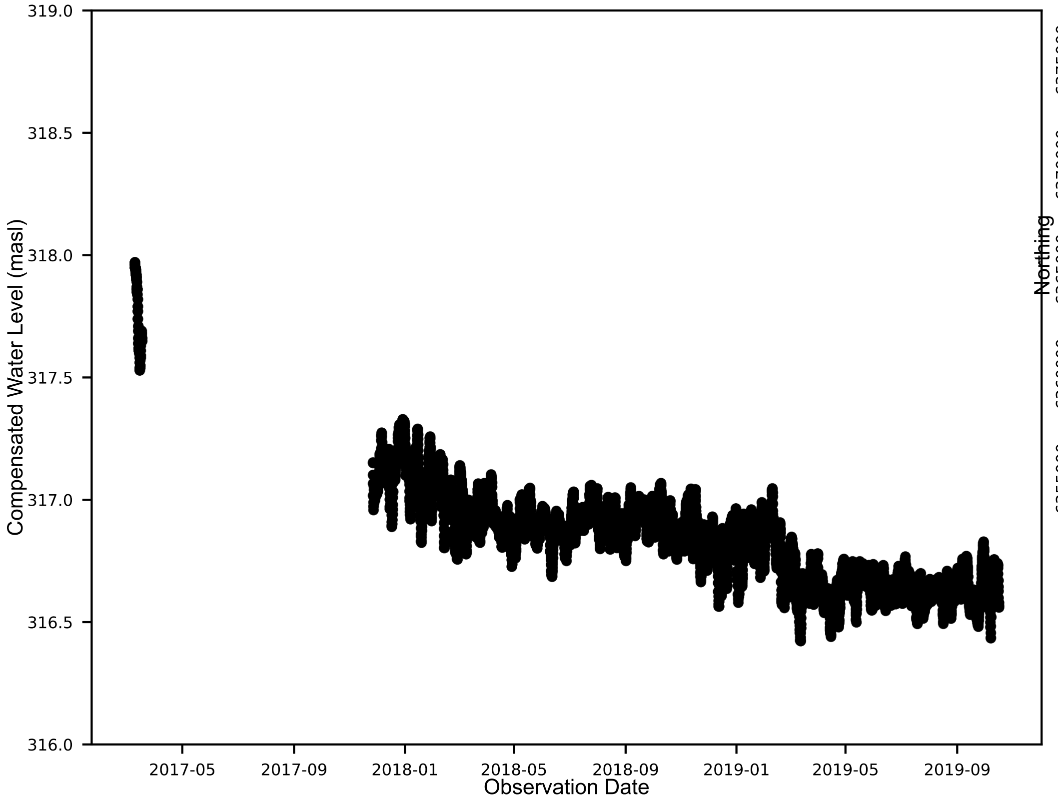

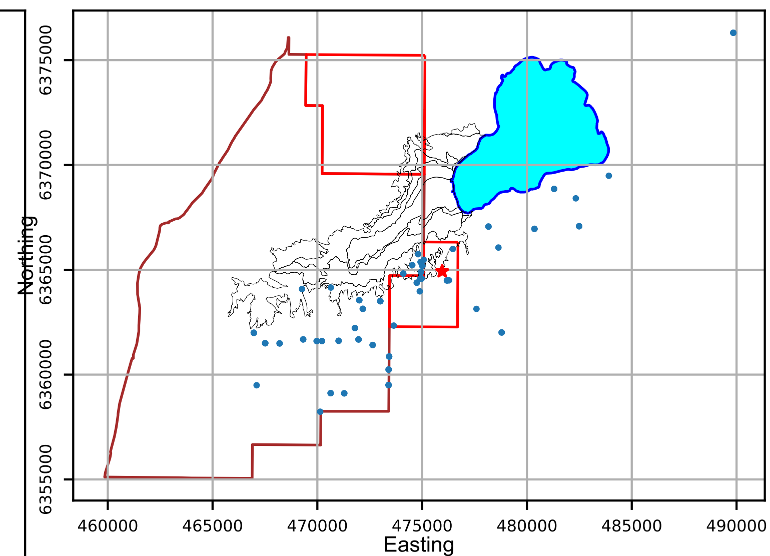

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 60 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR435-SN1 - 60.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-58

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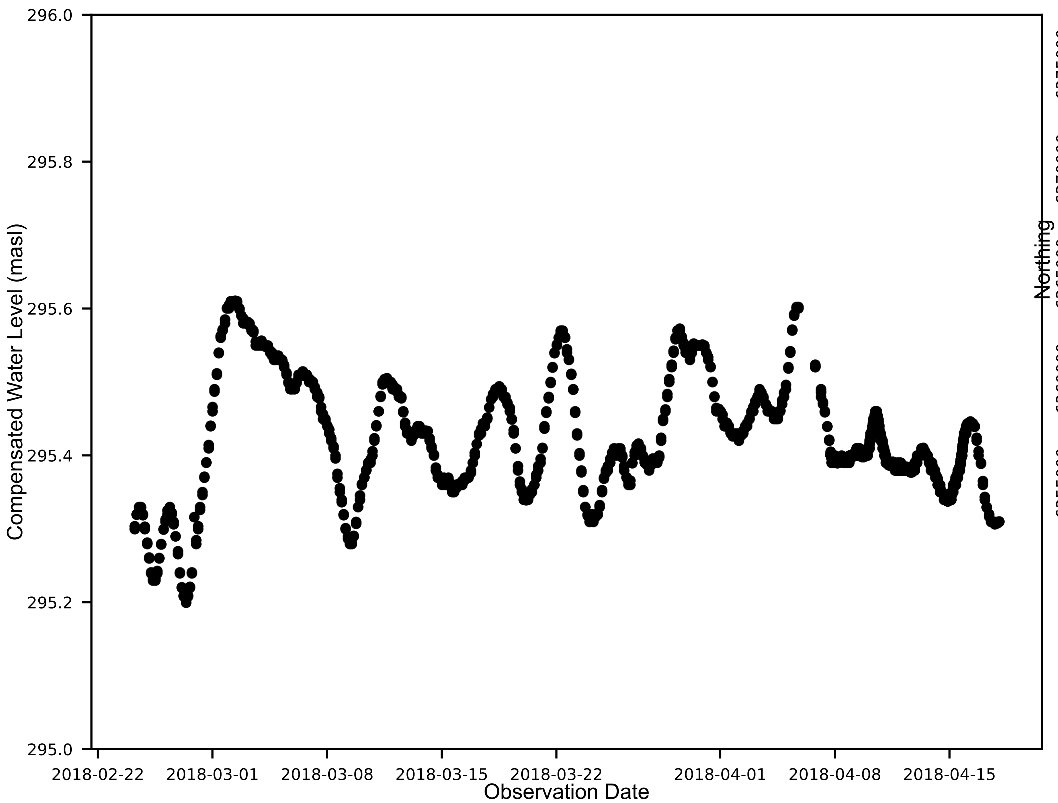

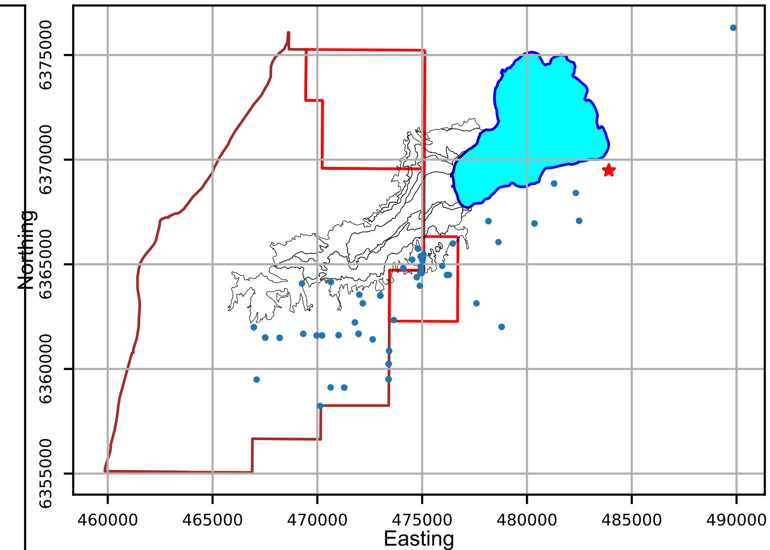

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 16.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES417-SN1 - 16.4 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-59

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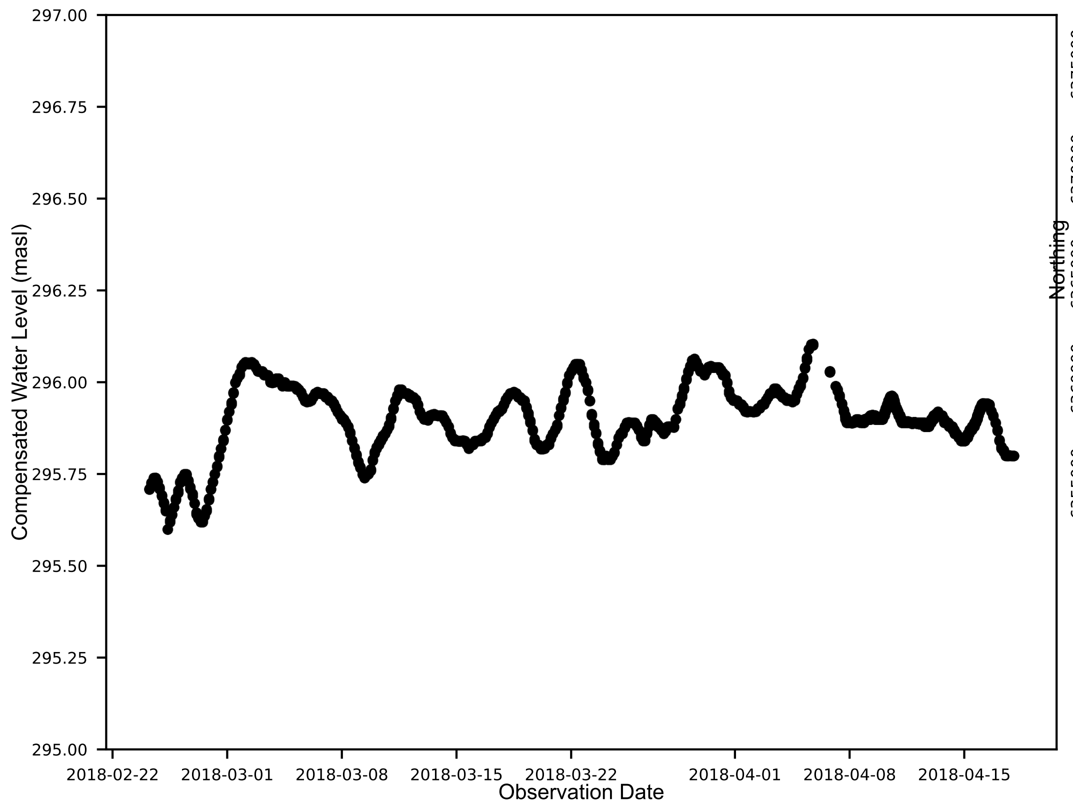

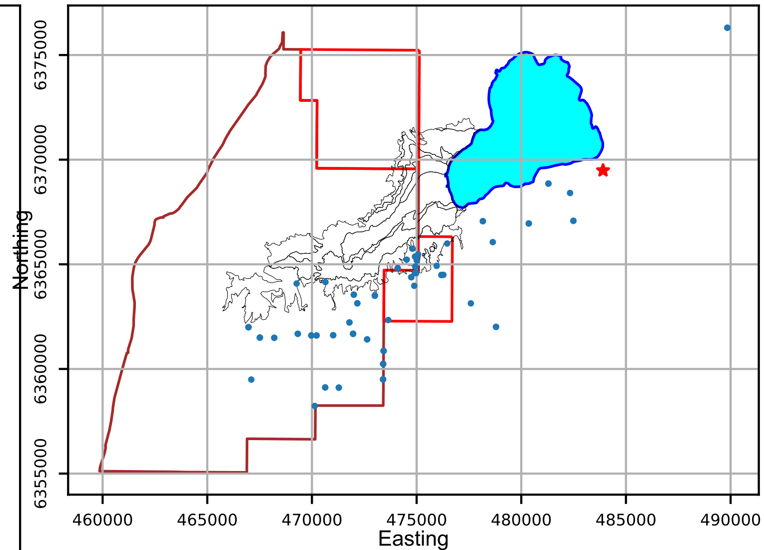

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 4.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES417-SN1 - 4.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-60

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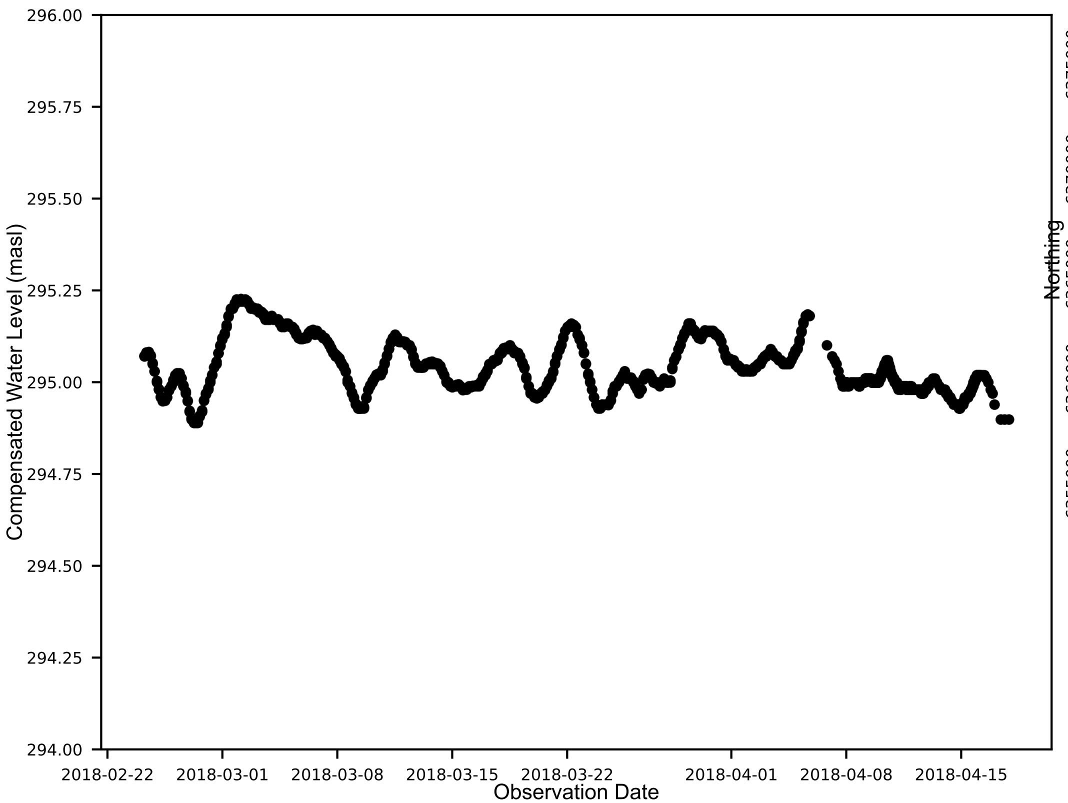

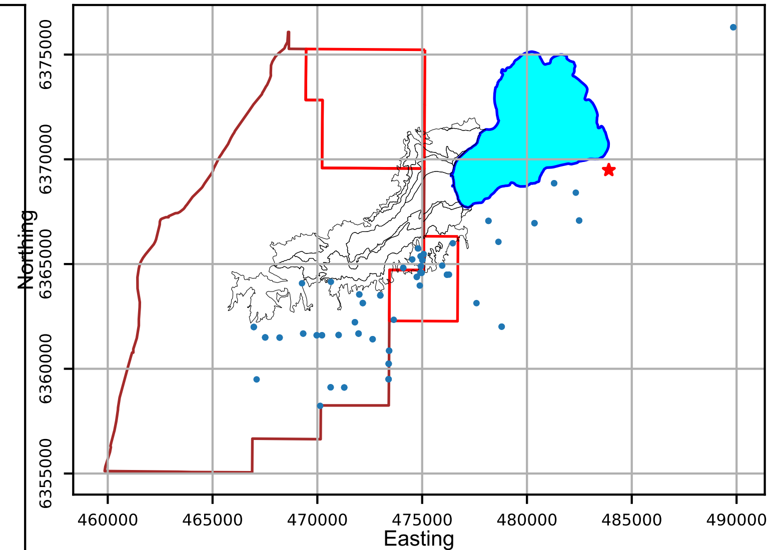

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 46.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES417-SN1 - 46.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-61

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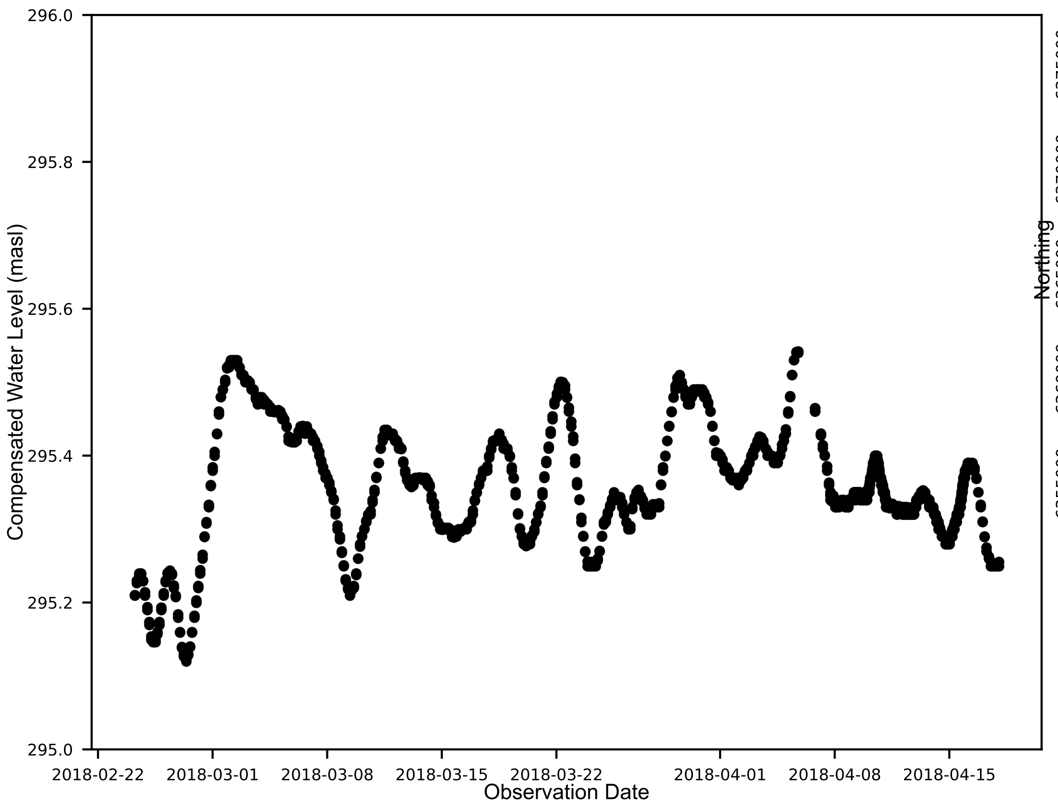

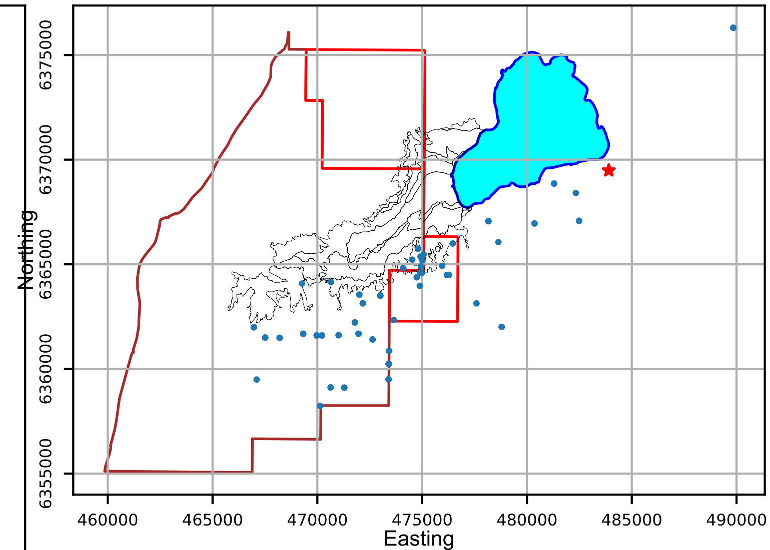

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 8.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES417-SN1 - 8.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-62

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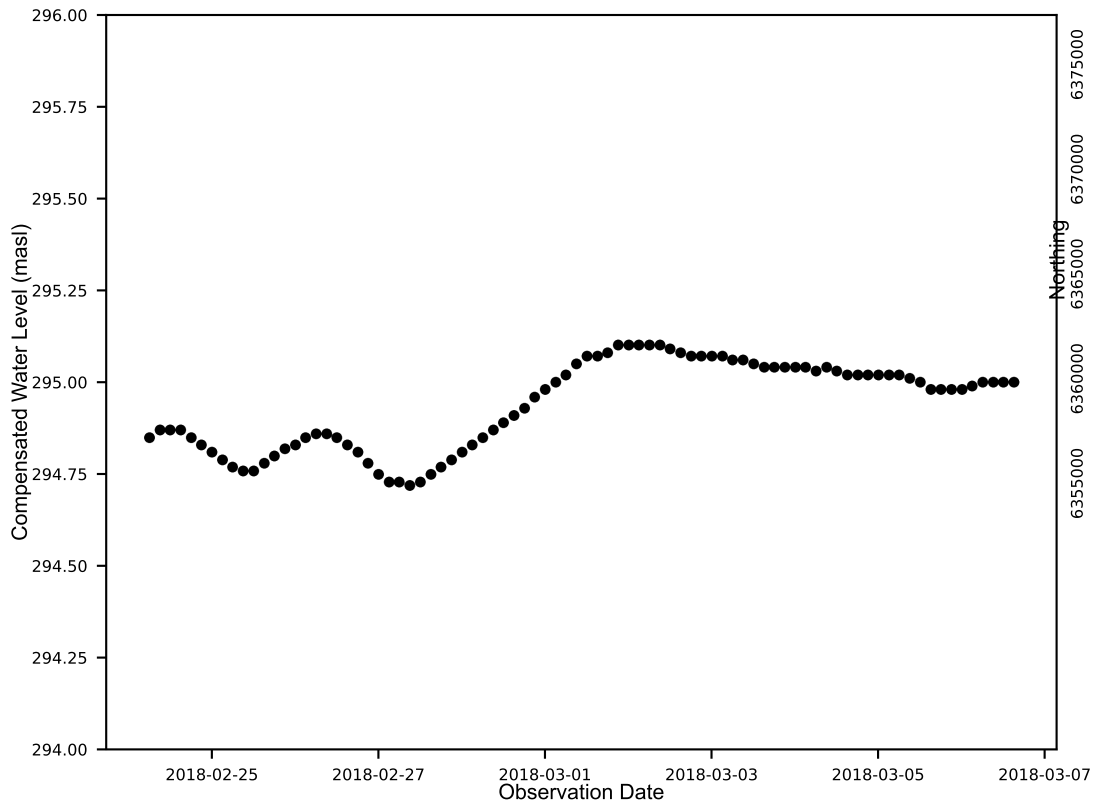

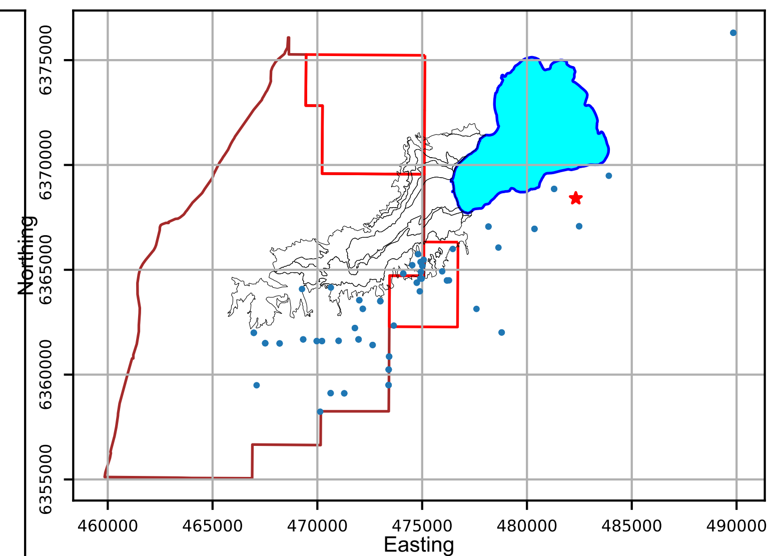

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 35.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH18-ES421-SN1 - 35.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-63

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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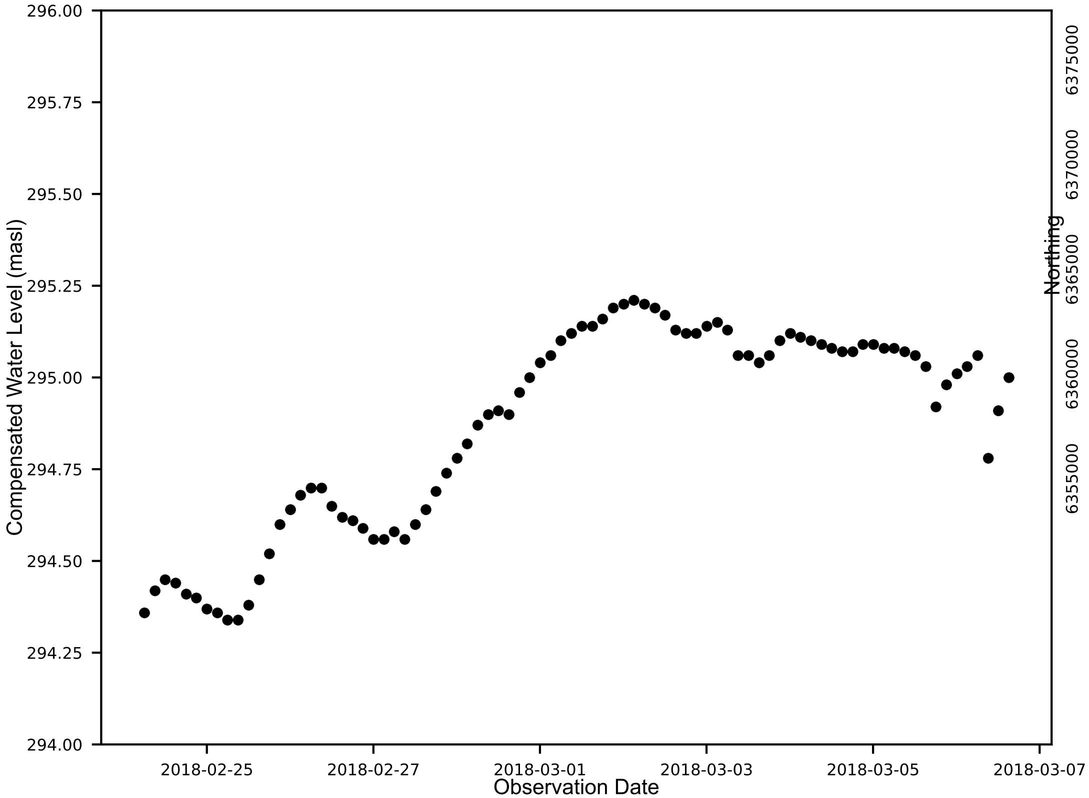

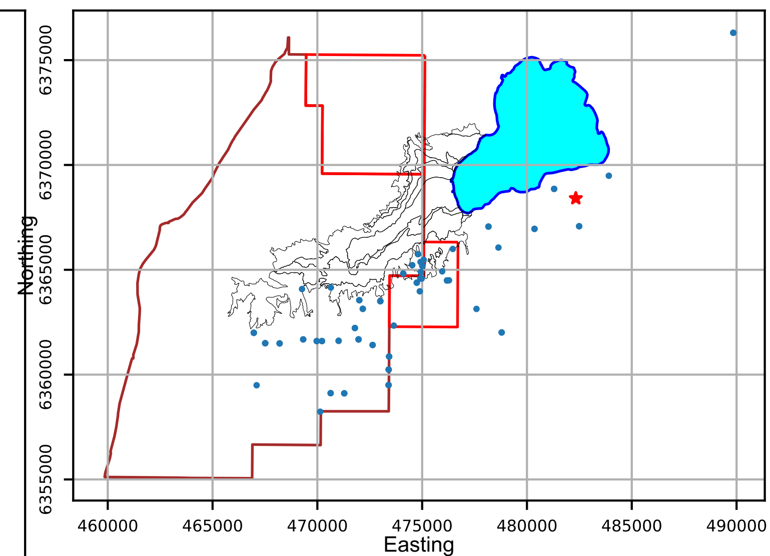

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 4.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

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FORT HILLS
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TITLE

FH18-ES421-SN1 - 4.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-64

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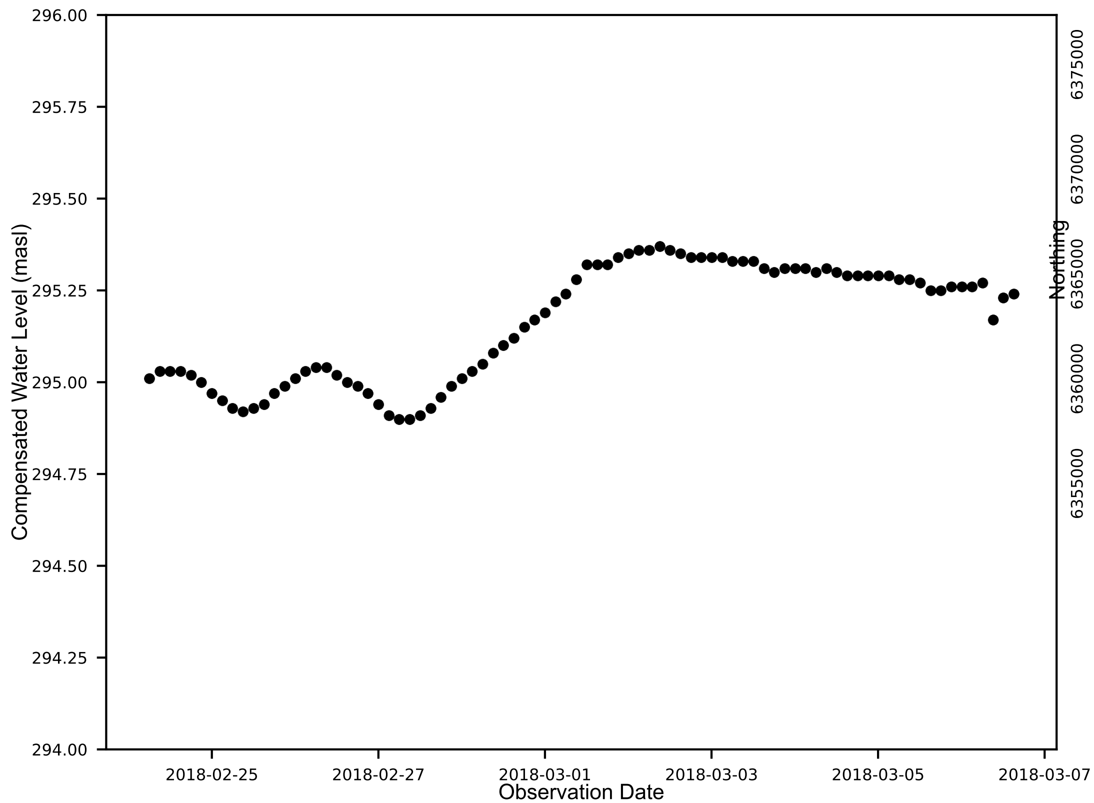

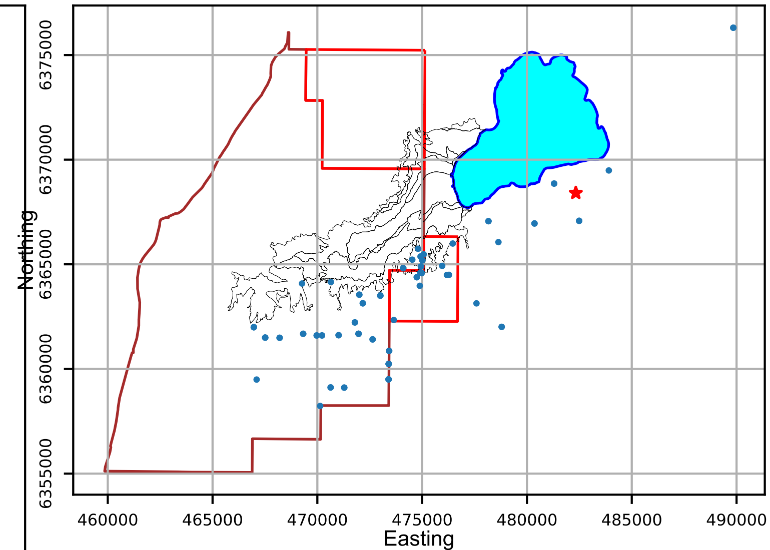

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES421-SN1 - 7.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-65

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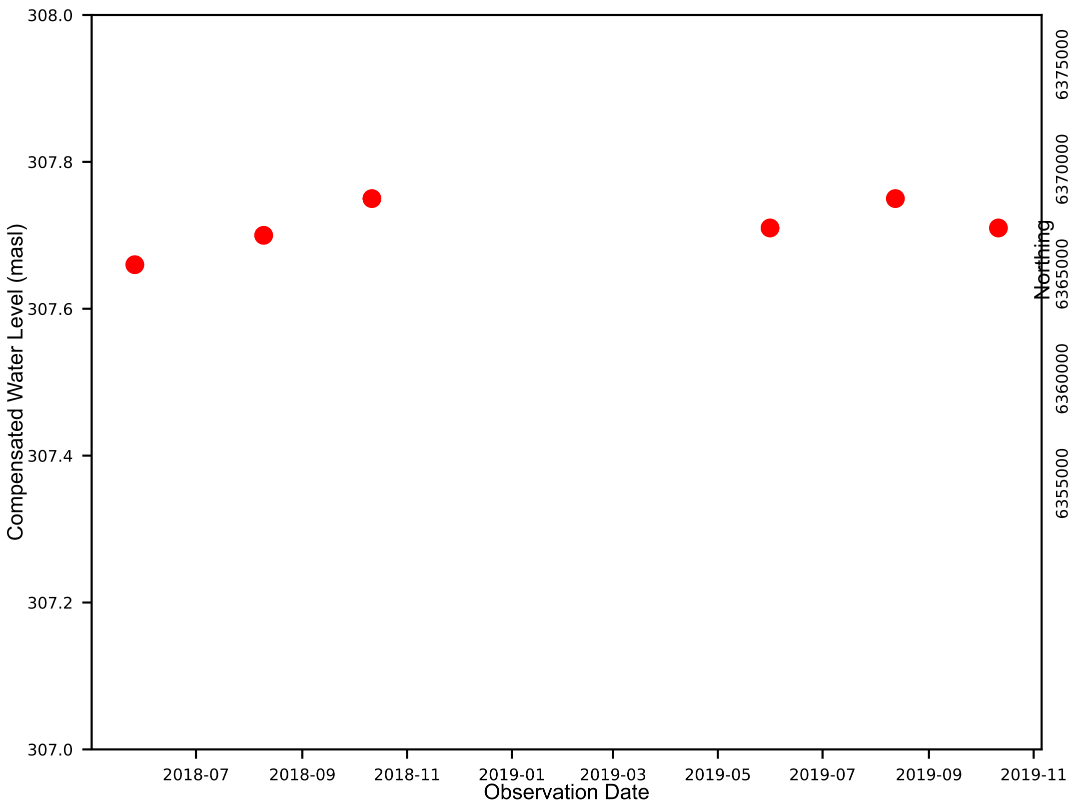

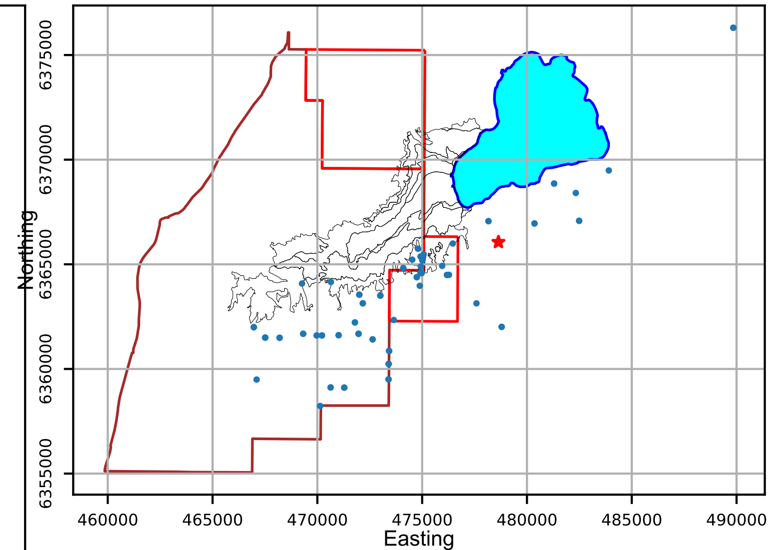

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 07 Silty Sand AQ3
Depth of Measurement: 25.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH18-ES427-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-66

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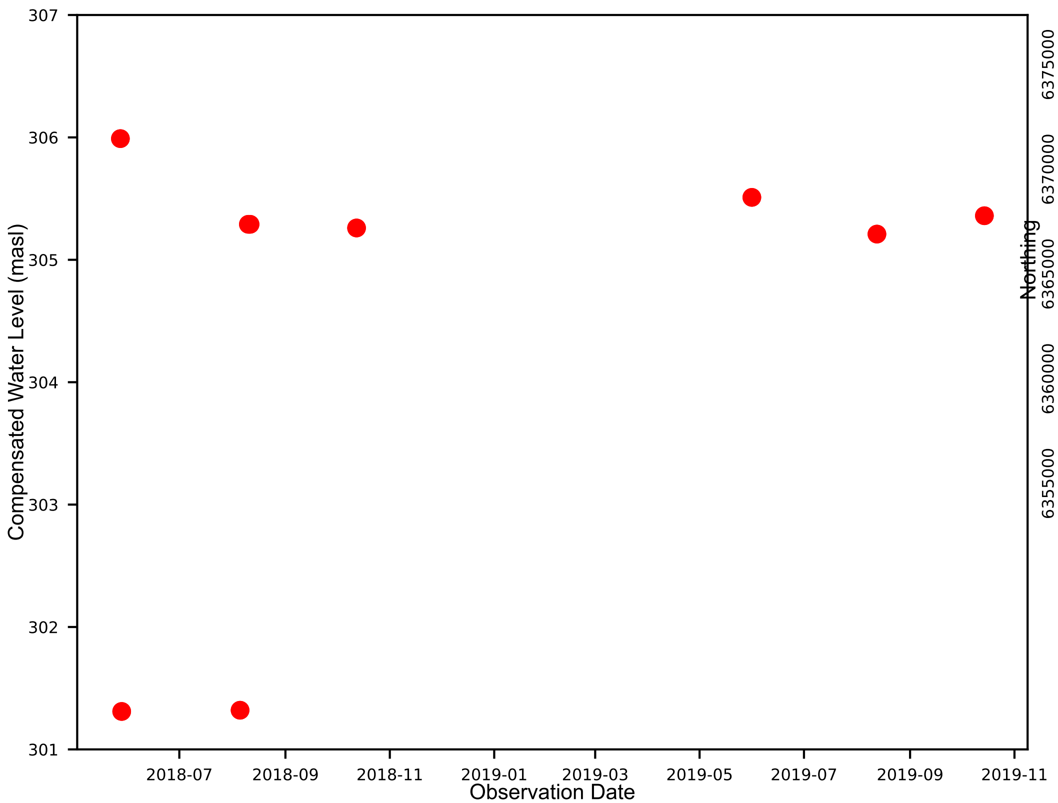

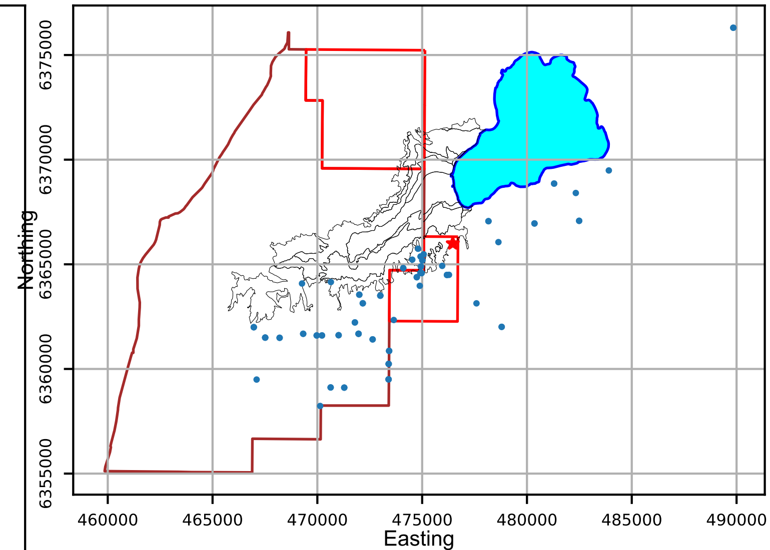

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 25.91 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES430-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-67

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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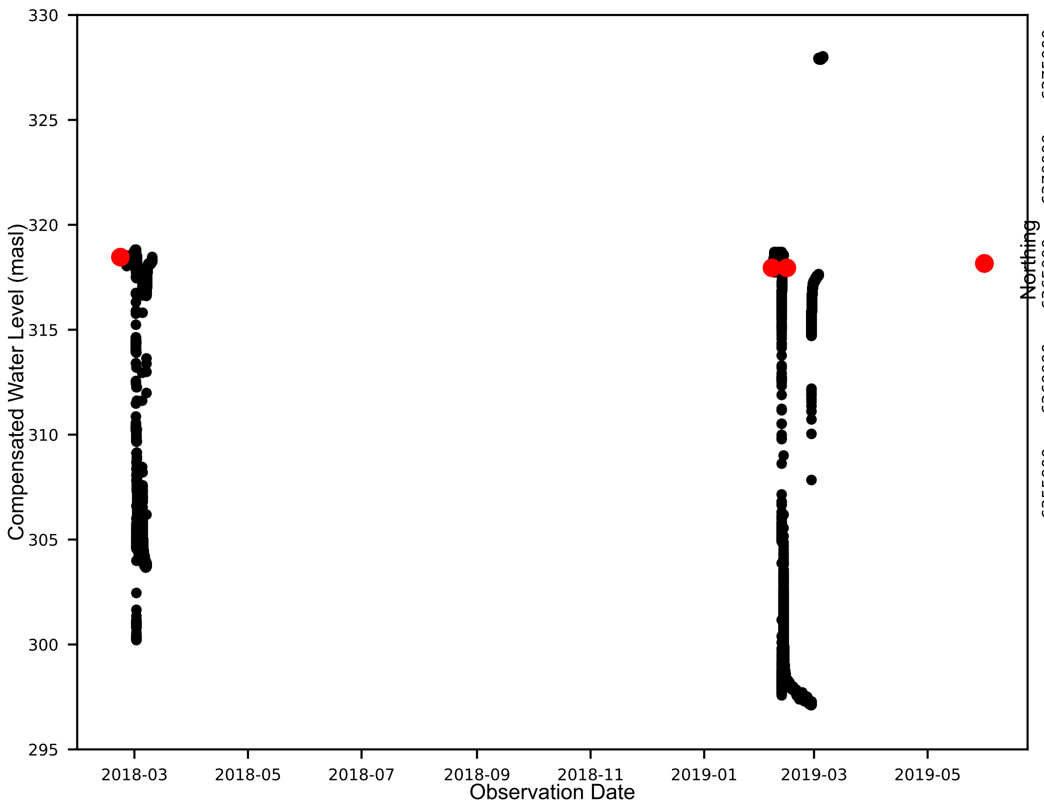
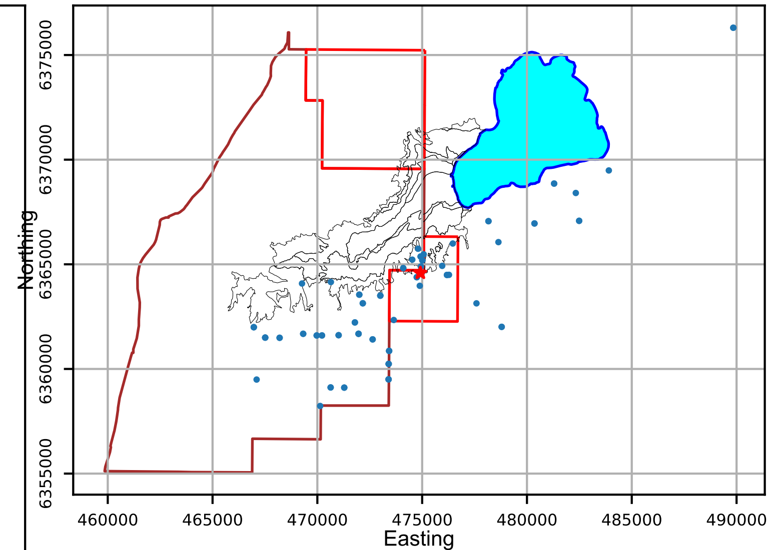
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

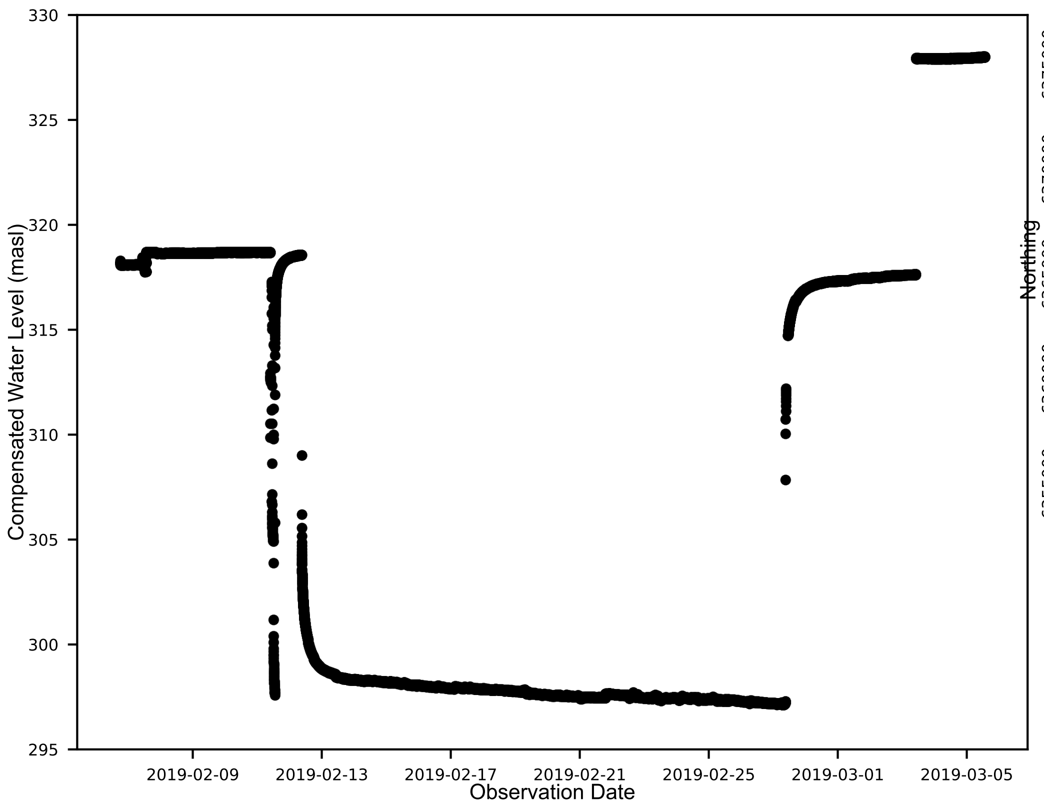
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

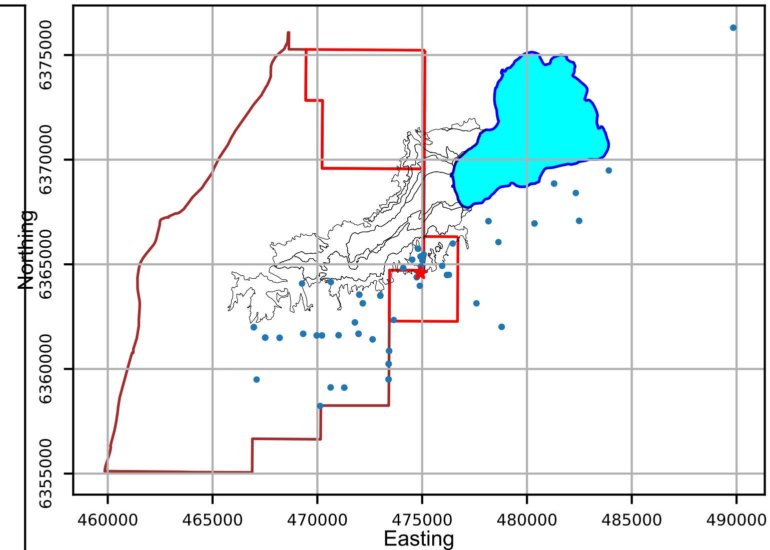
FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES436-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-68

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4

Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

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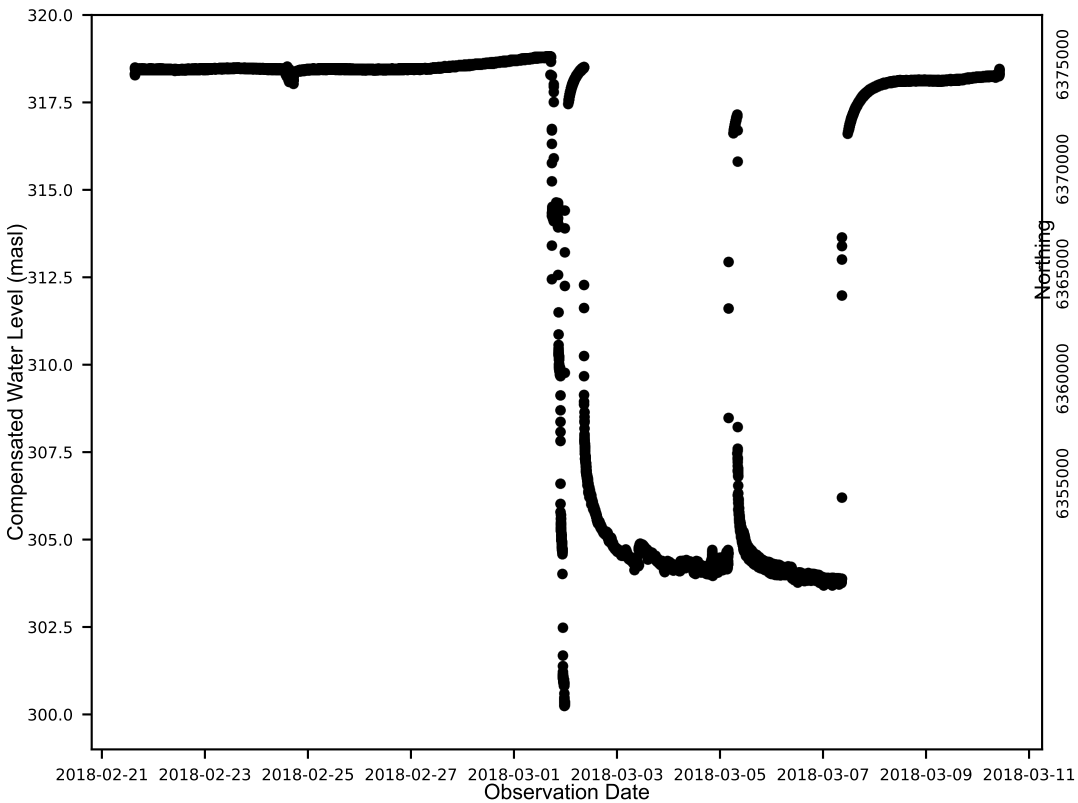
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

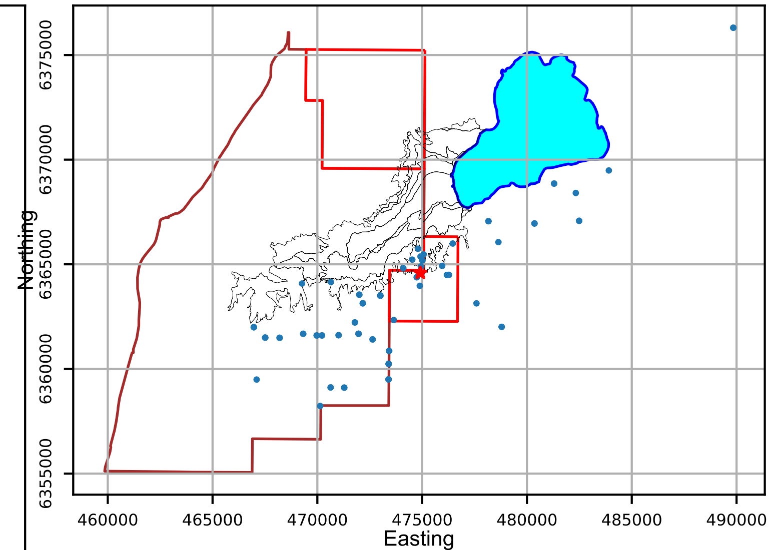
TITLE

FH18-ES436-DR1 - 30.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-69

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4

Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

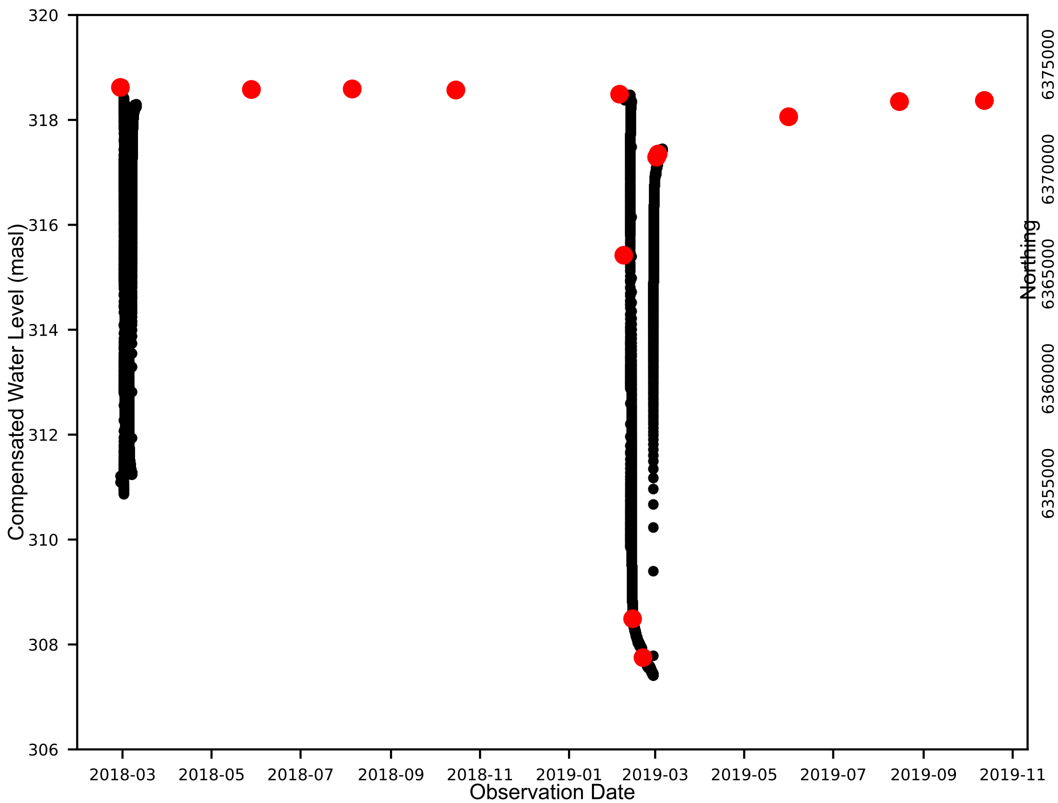
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

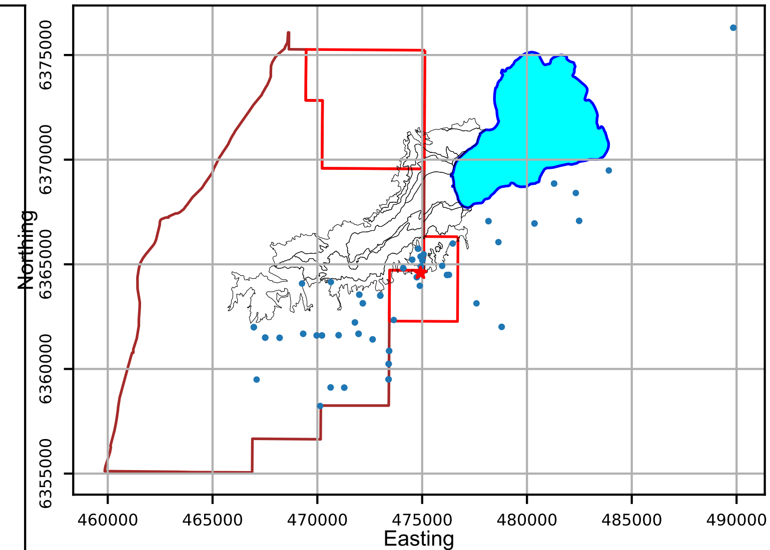
TITLE

FH18-ES436-DR1 - 31.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-70

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 38.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

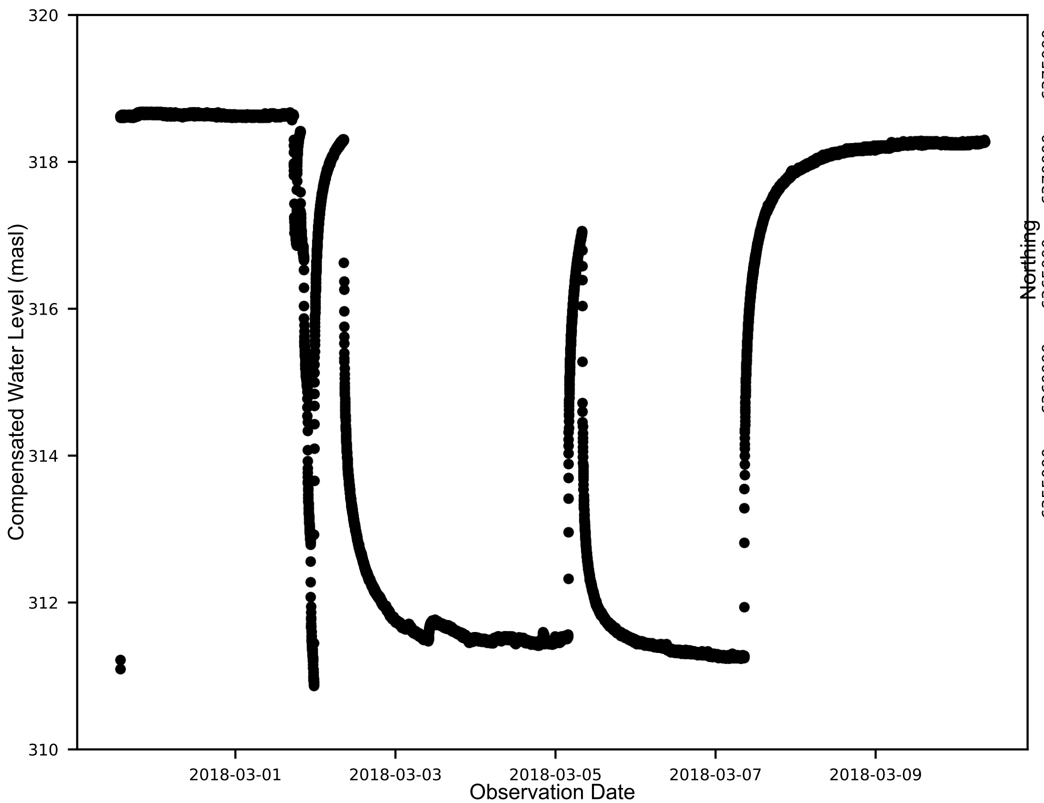
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

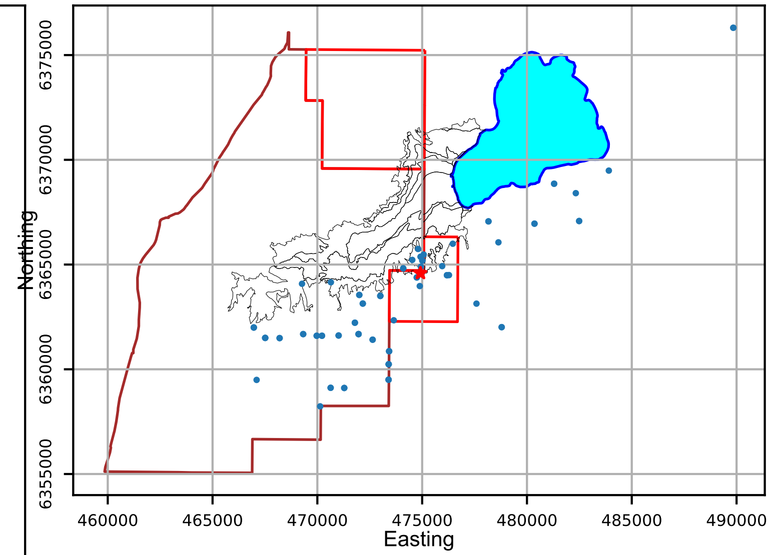
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES436-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-71





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 38.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

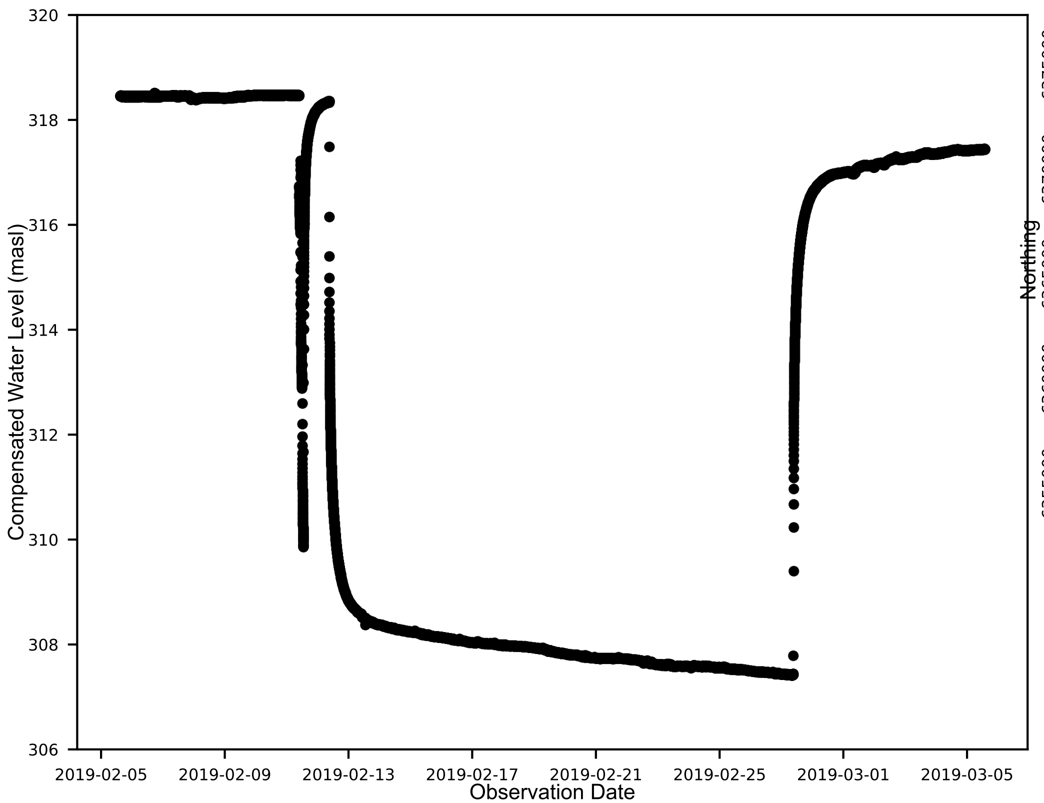
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

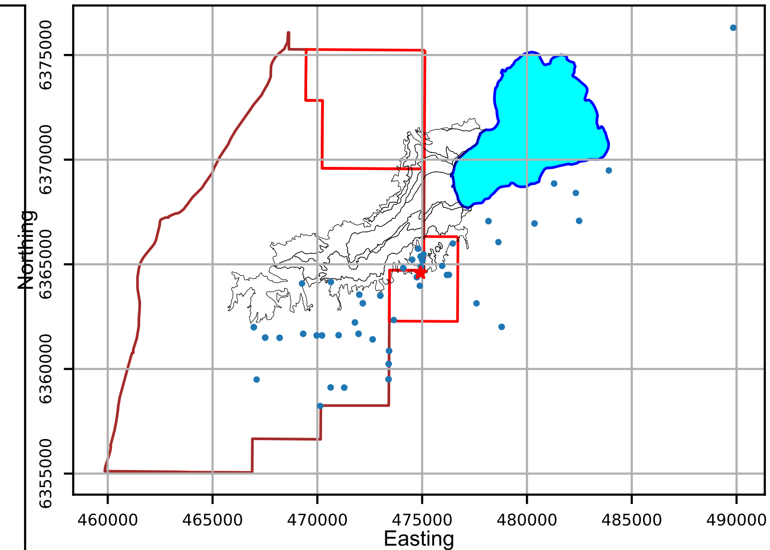
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES436-SN1 - 33.81 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-72

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 38.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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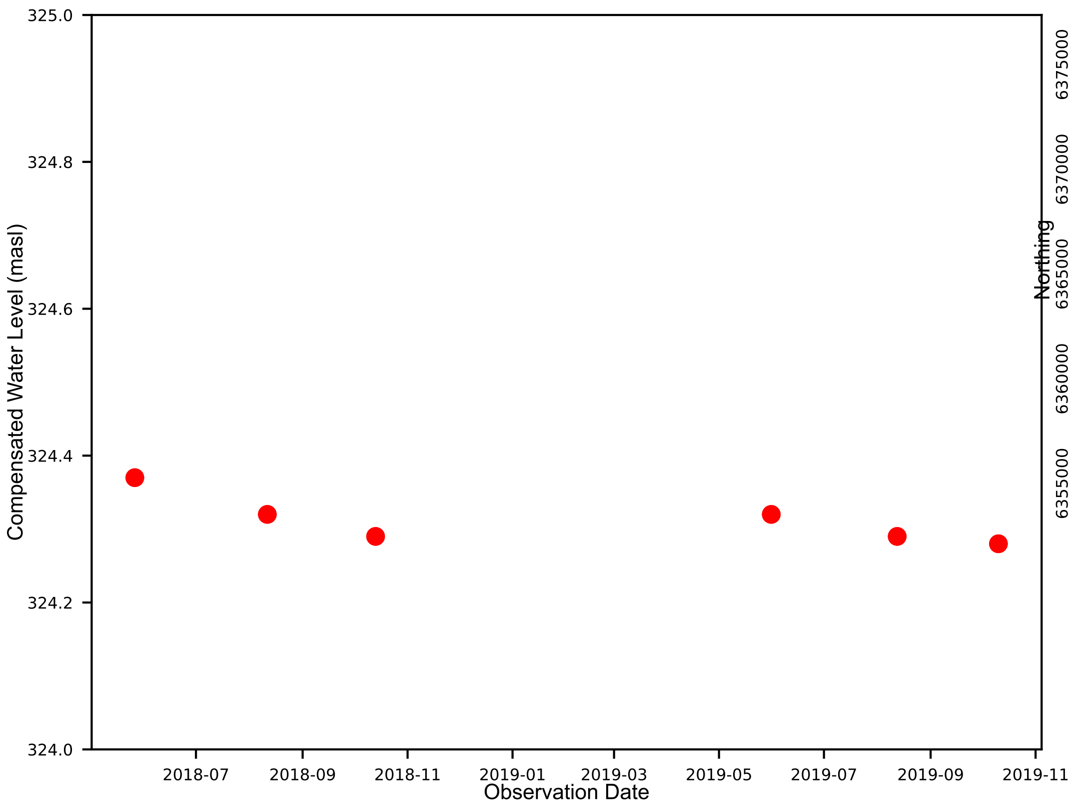
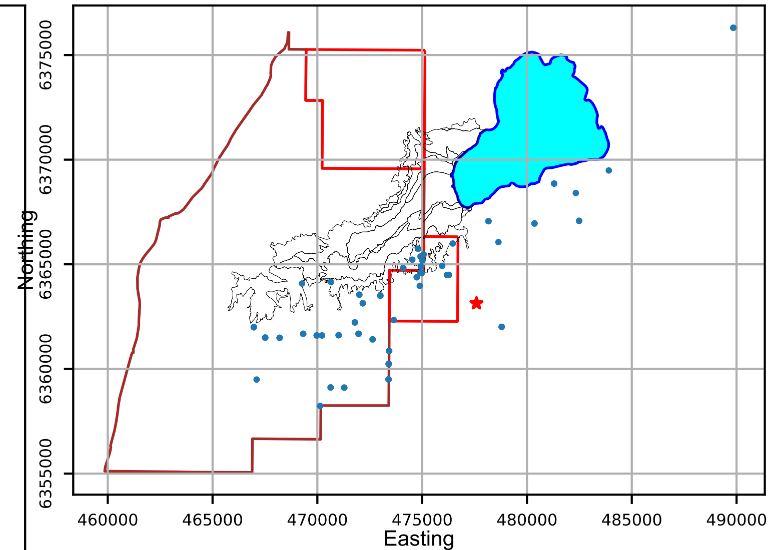
TITLE
FH18-ES436-SN1 - 35.16 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-73

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 60.05 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES437-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-74

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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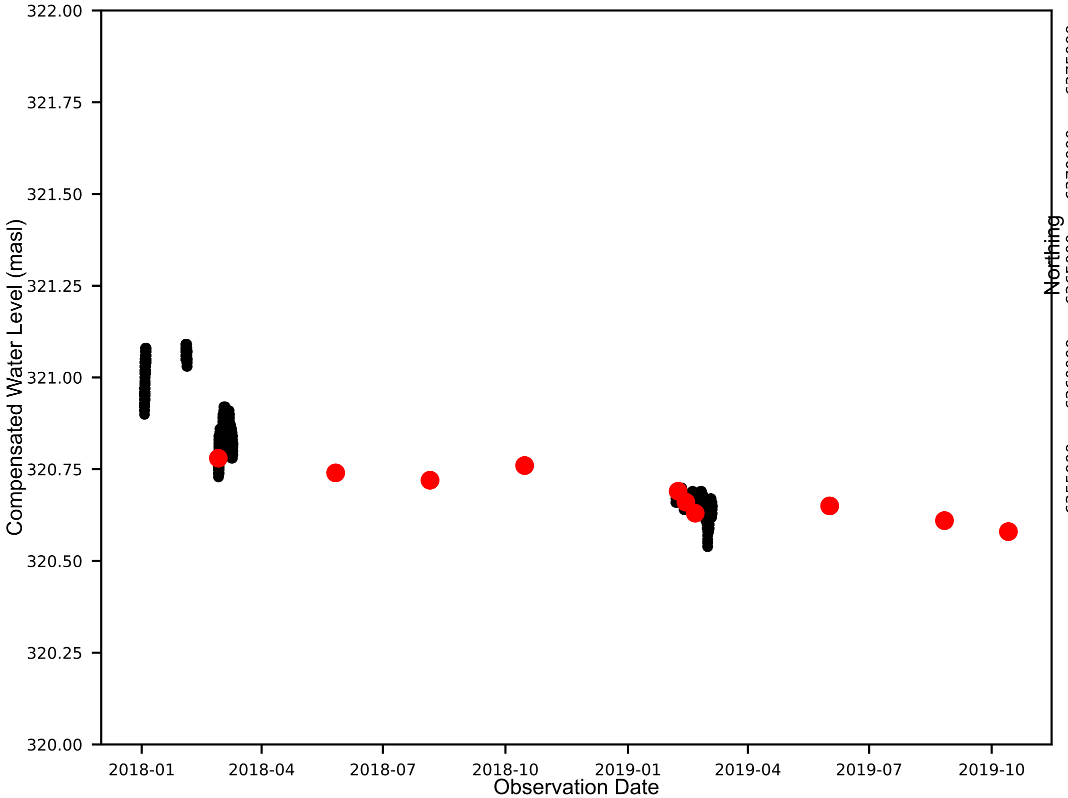
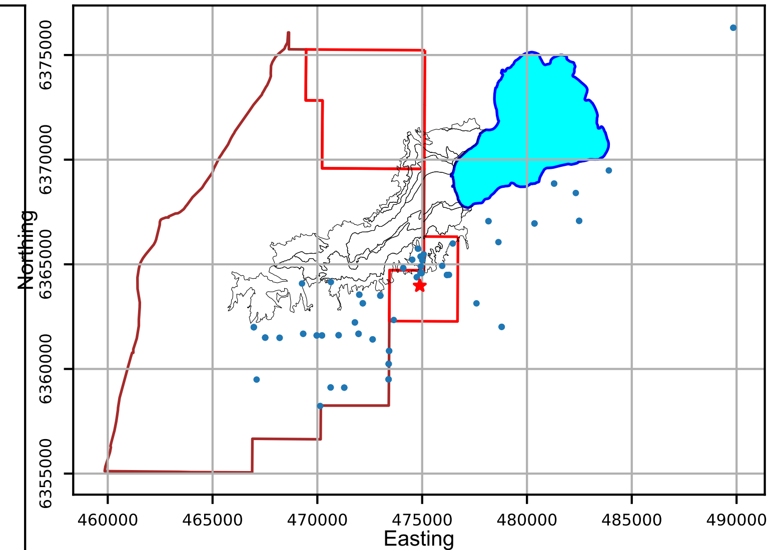




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 32.61 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

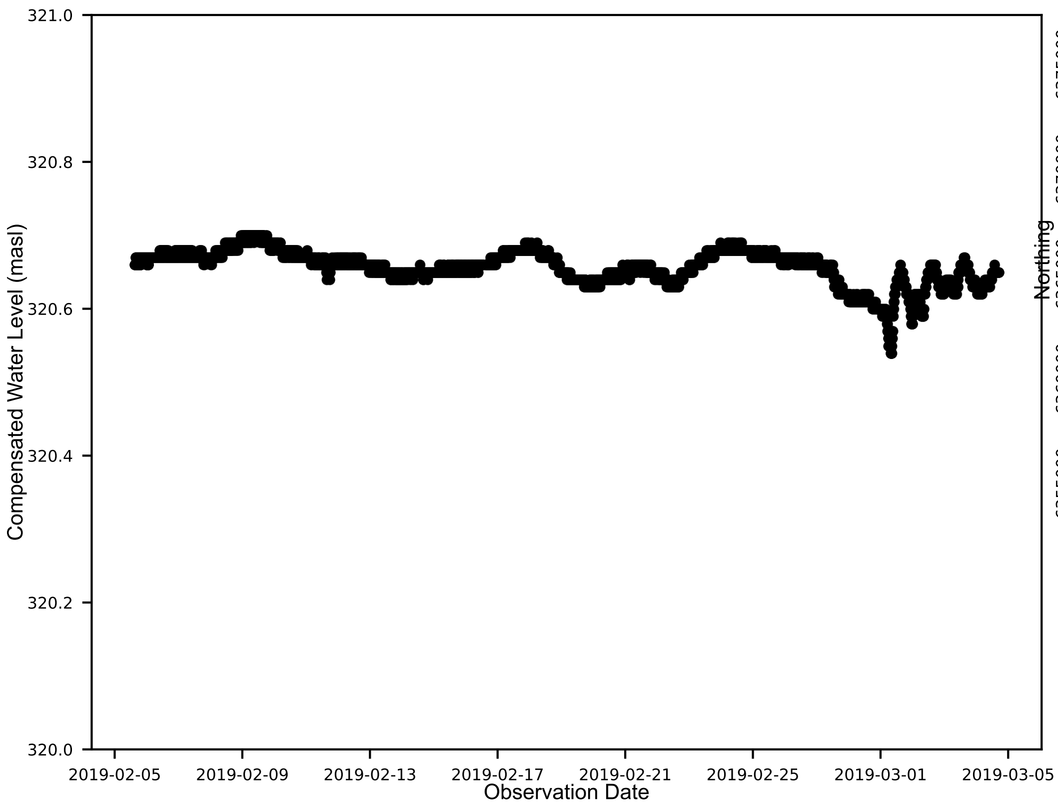
FORTHILLS
Operated by Suncor Energy

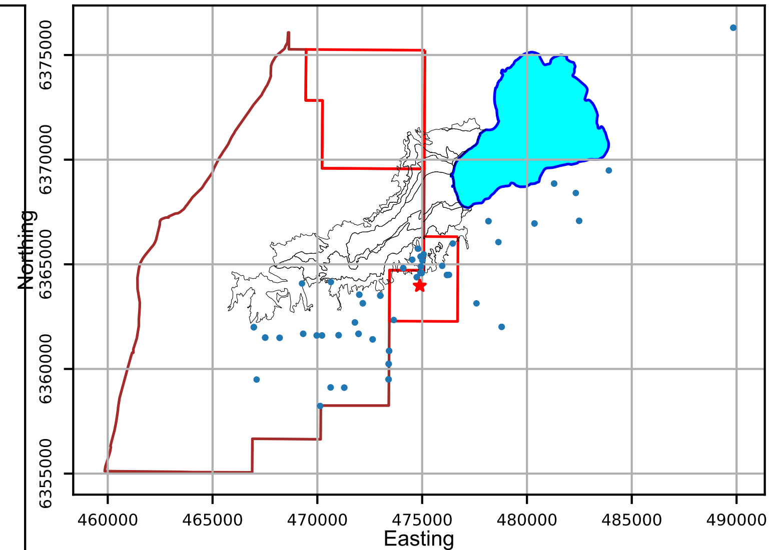
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES438-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-75

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 32.61 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

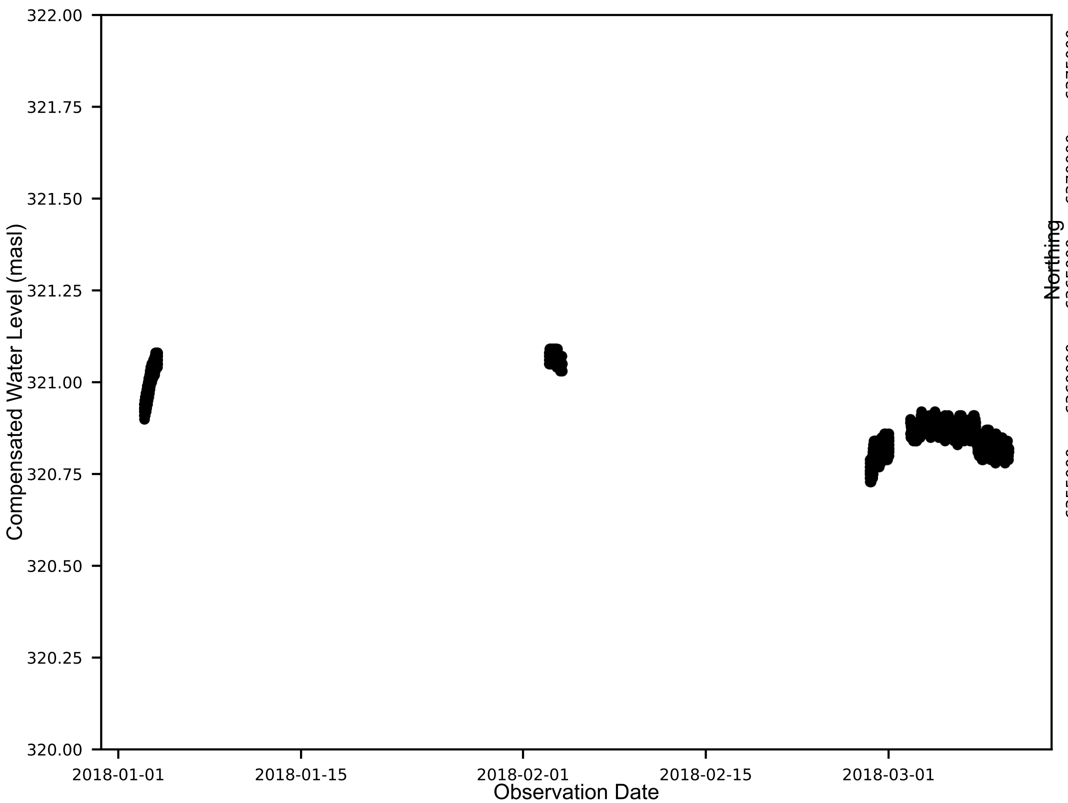
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

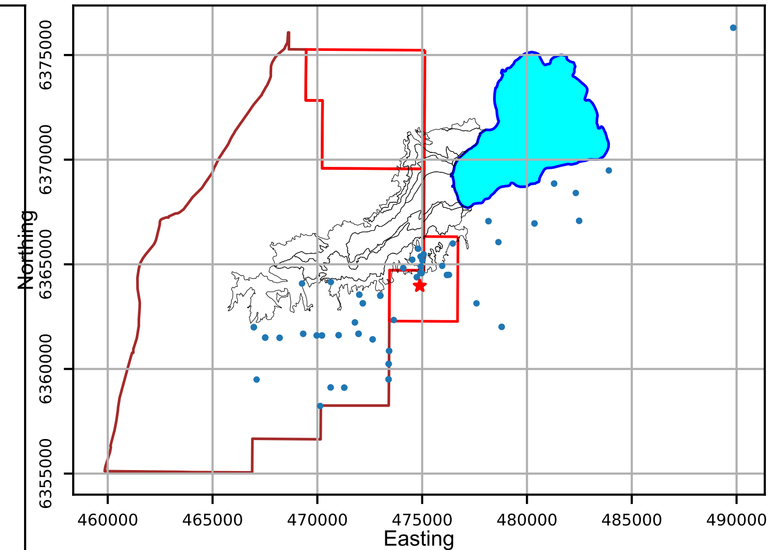
TITLE

FH18-ES438-SN1 - 26.75 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-76

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 32.61 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

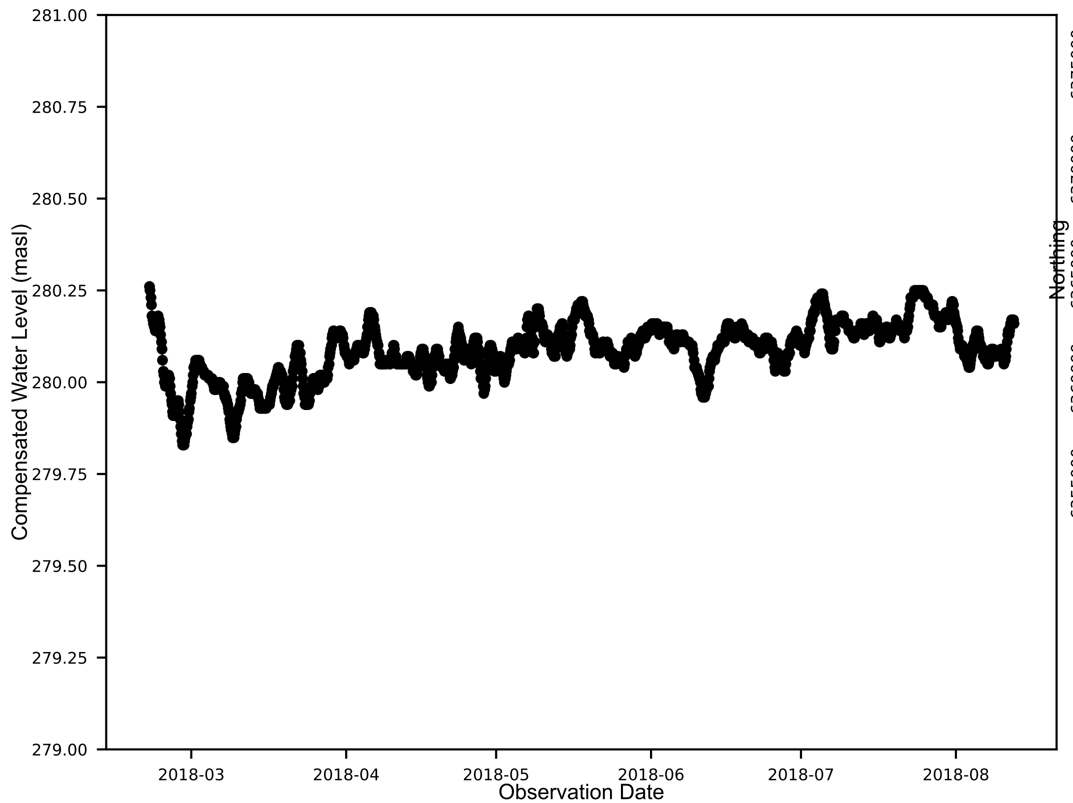
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

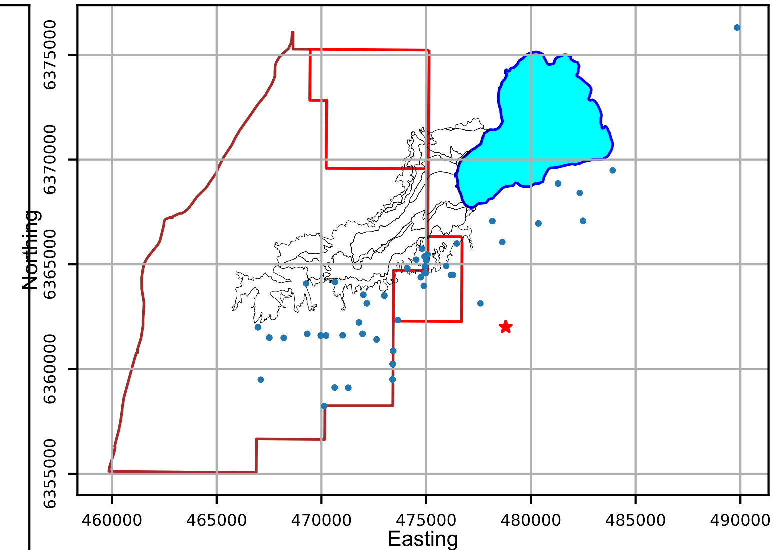
FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES438-SN1 - 31.53 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-77

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 134 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

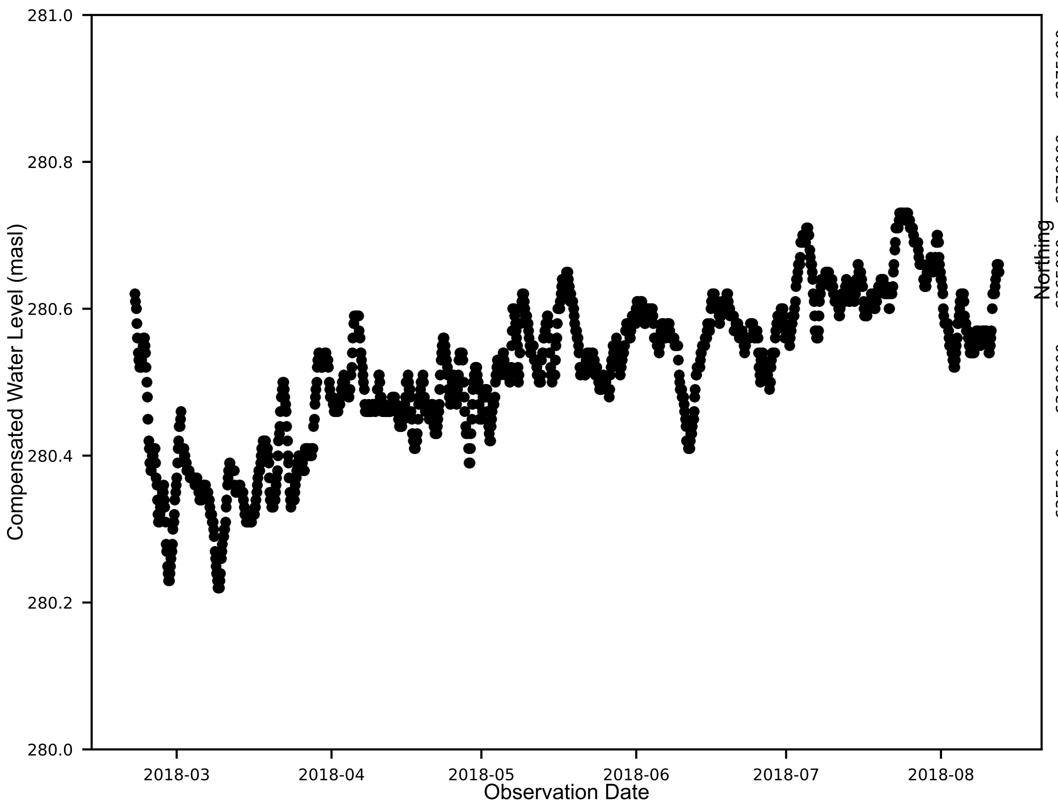
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

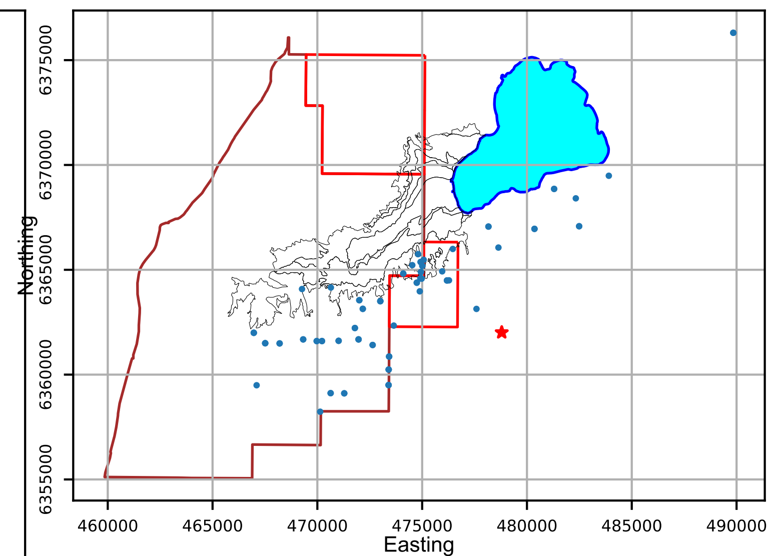
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES440-MR1 - 134.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-78





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 142 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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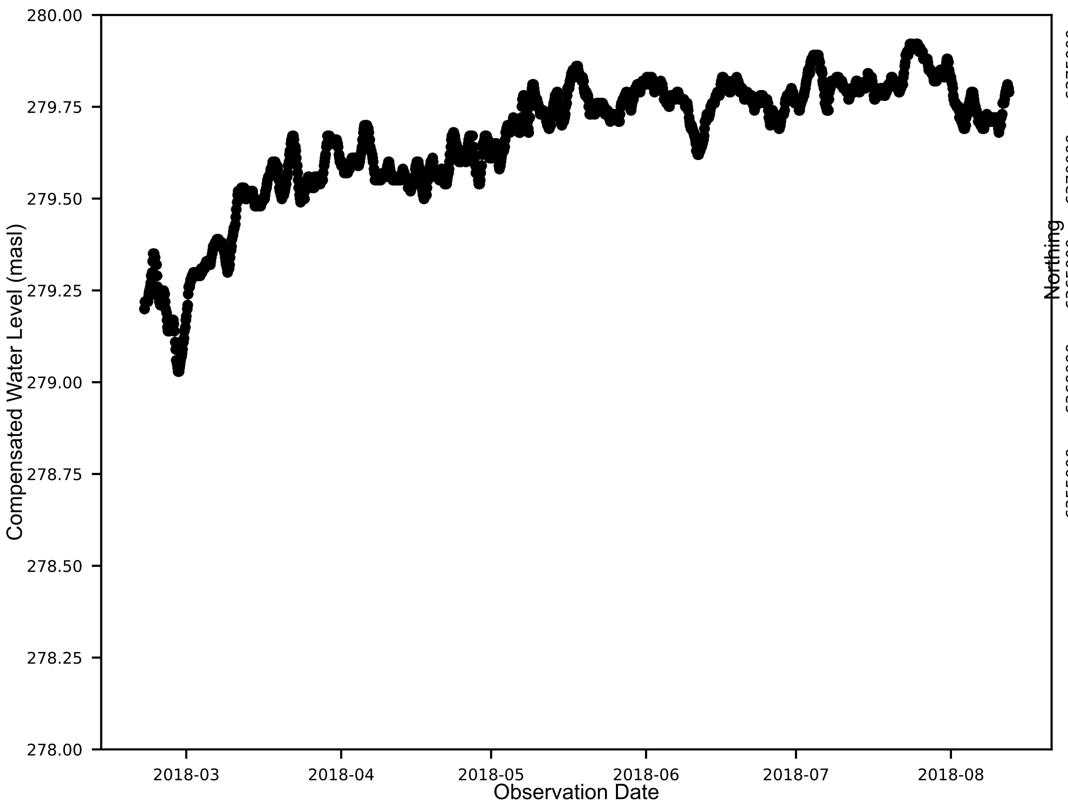
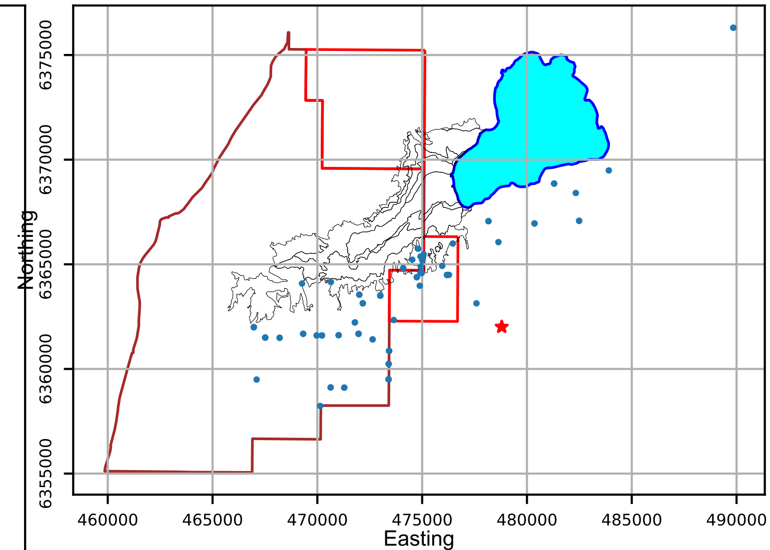
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES440-MR1 - 142.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-79

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 152 masl

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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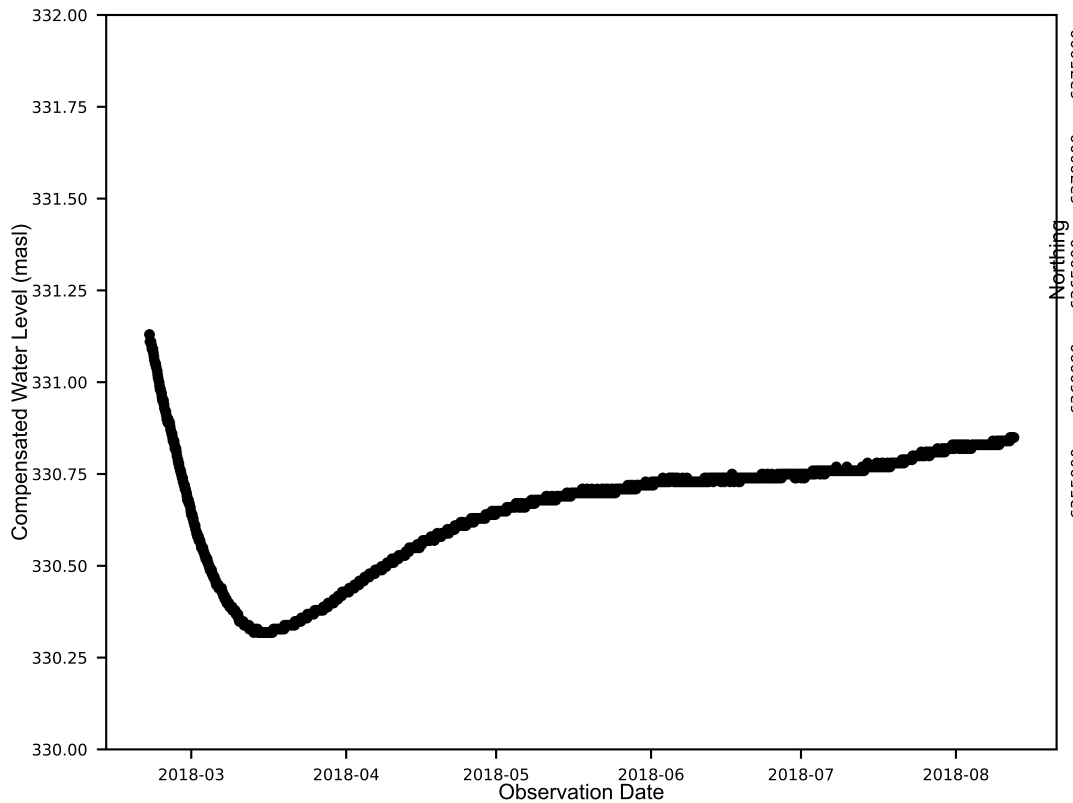
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

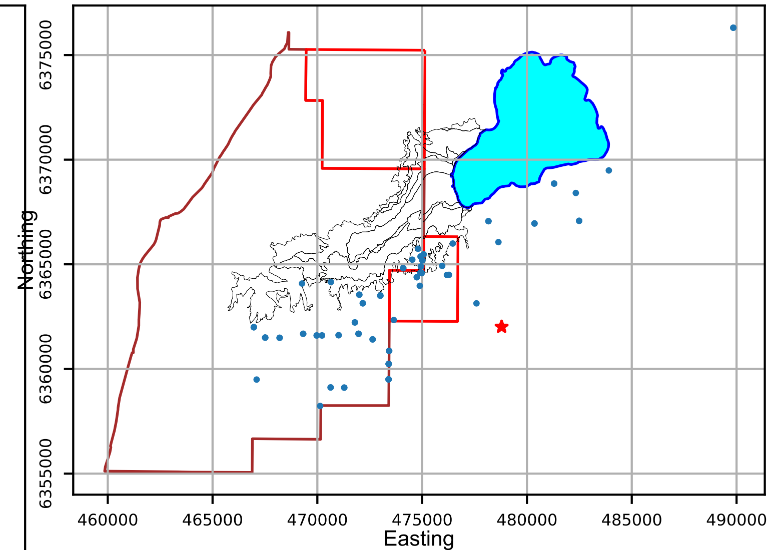
TITLE

FH18-ES440-MR1 - 152.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-80

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 11.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH18-ES440-SN1 - 11.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-81

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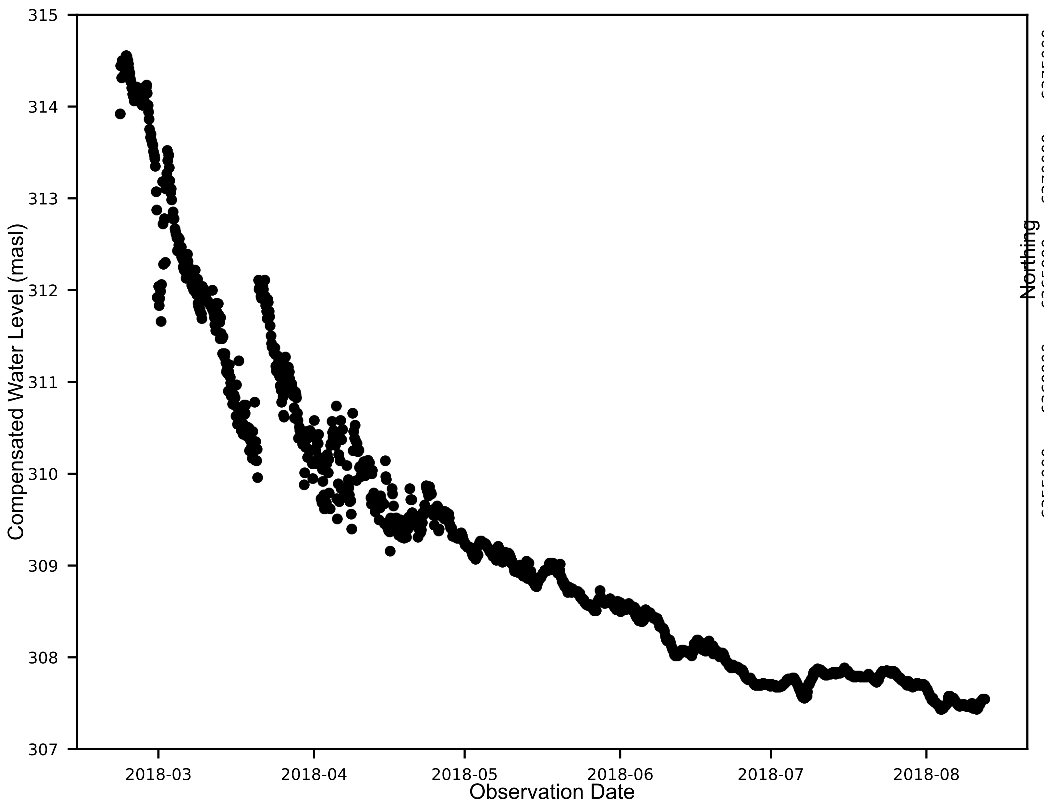
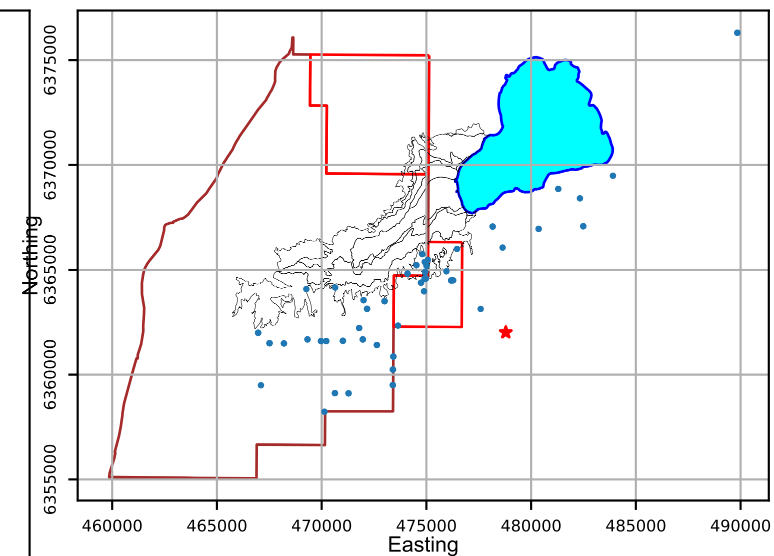




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 40.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

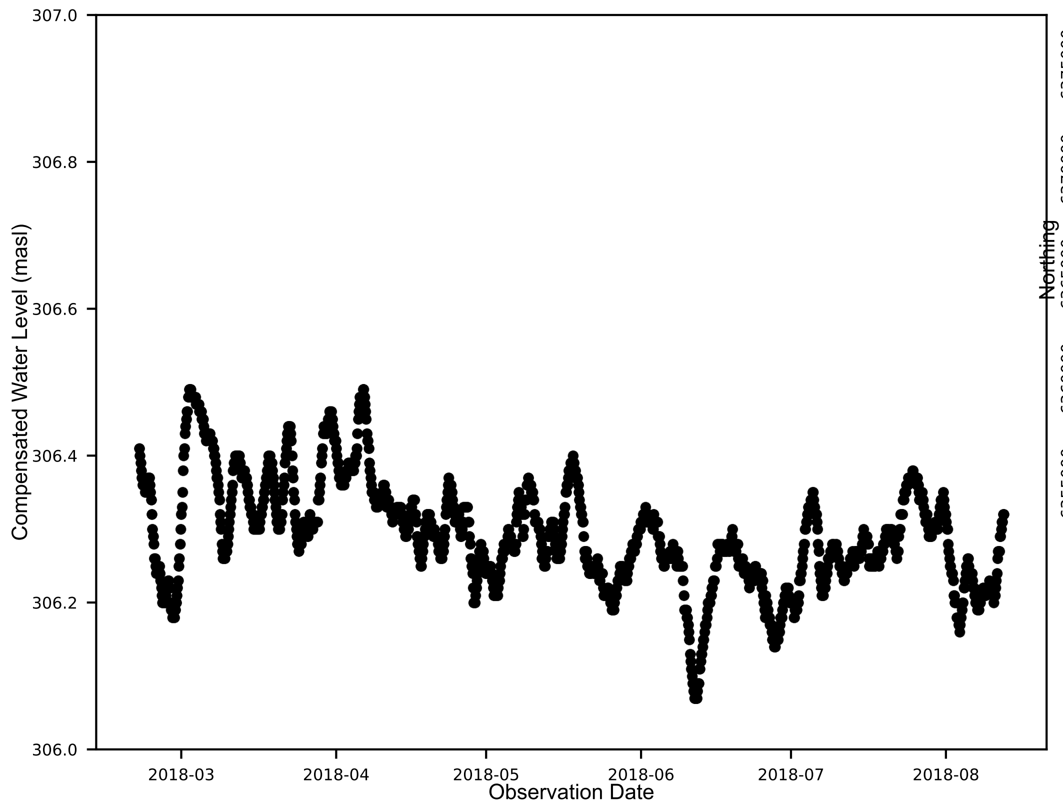
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

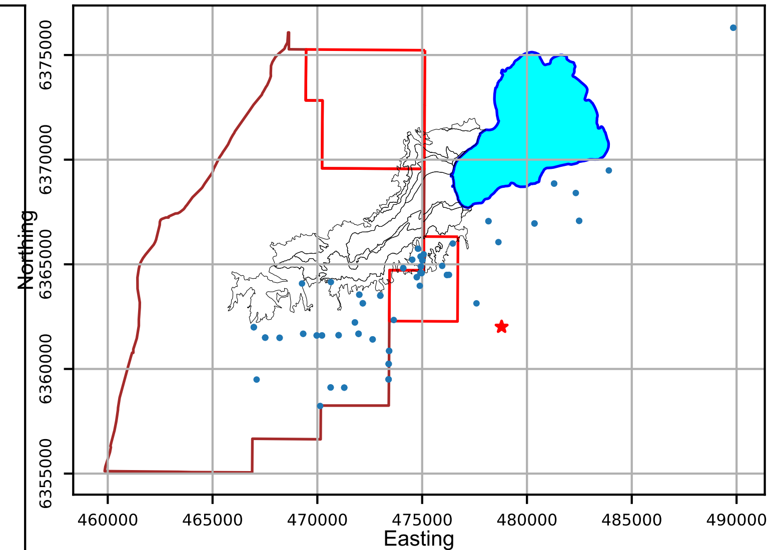
TITLE

FH18-ES440-SN1 - 40.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-82

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 65 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

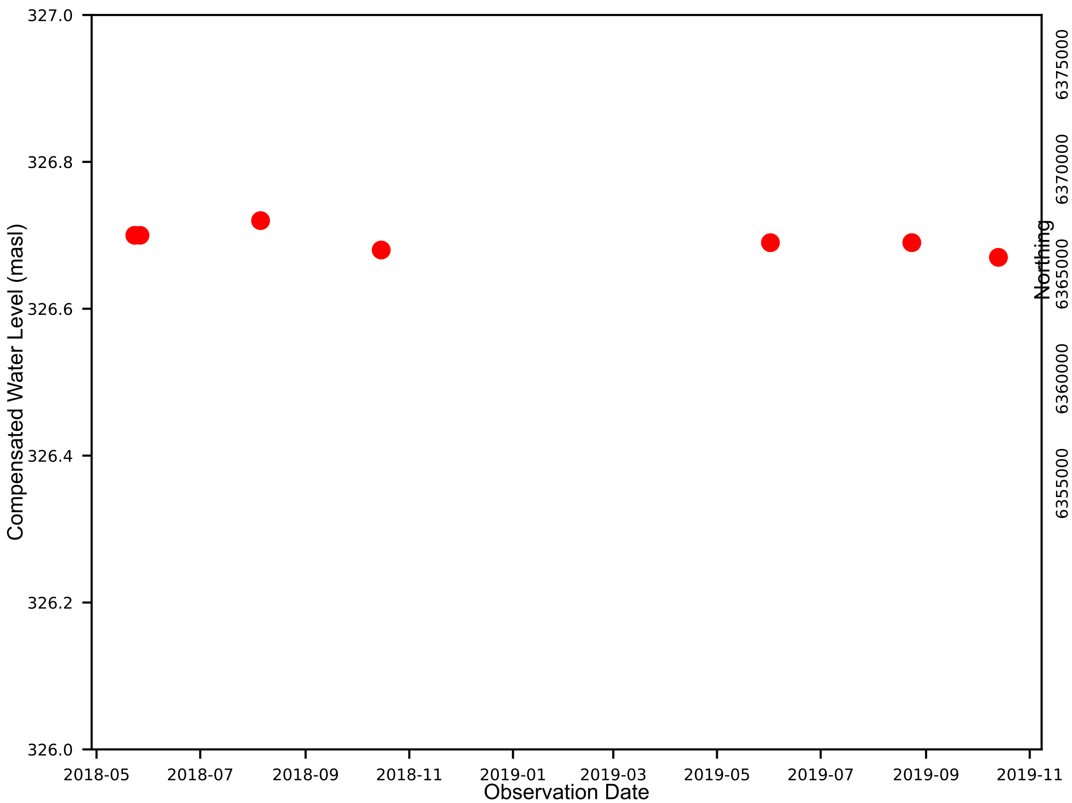
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

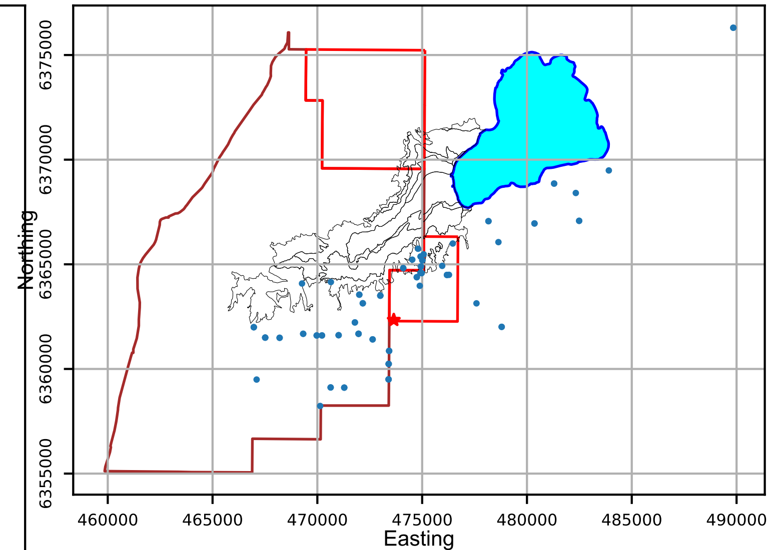
TITLE
FH18-ES440-SN1 - 65.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-83

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 35.05 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES441-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-84

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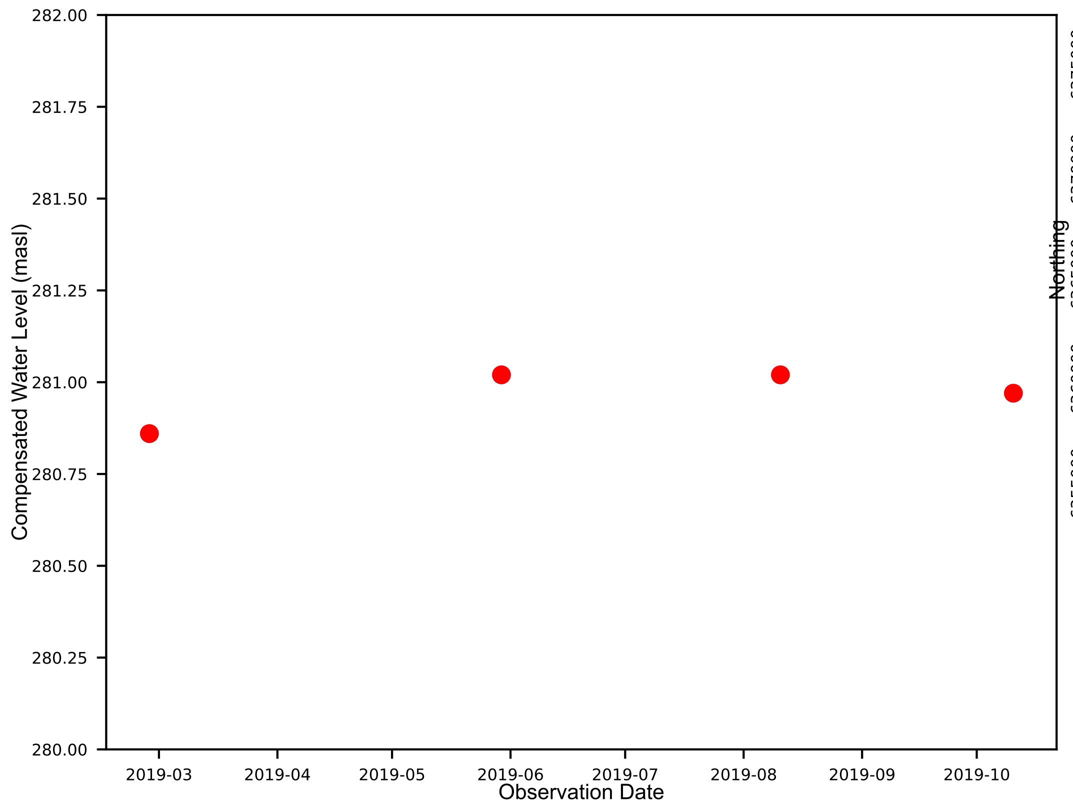
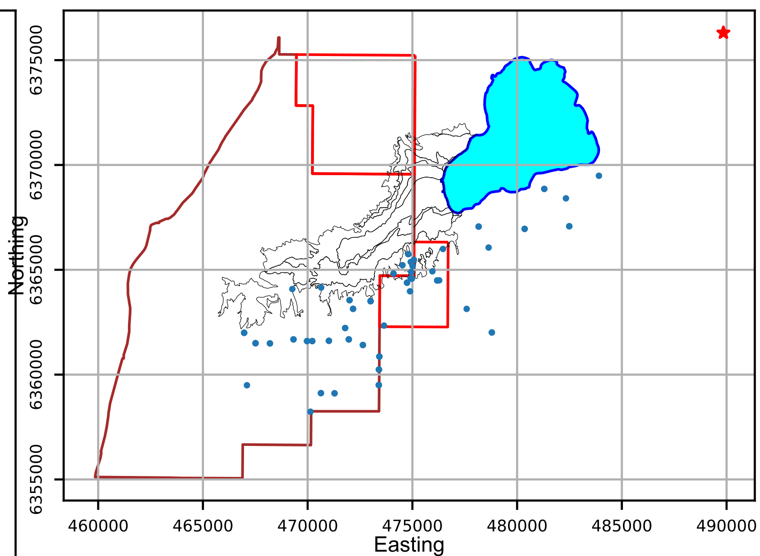




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 40.85 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

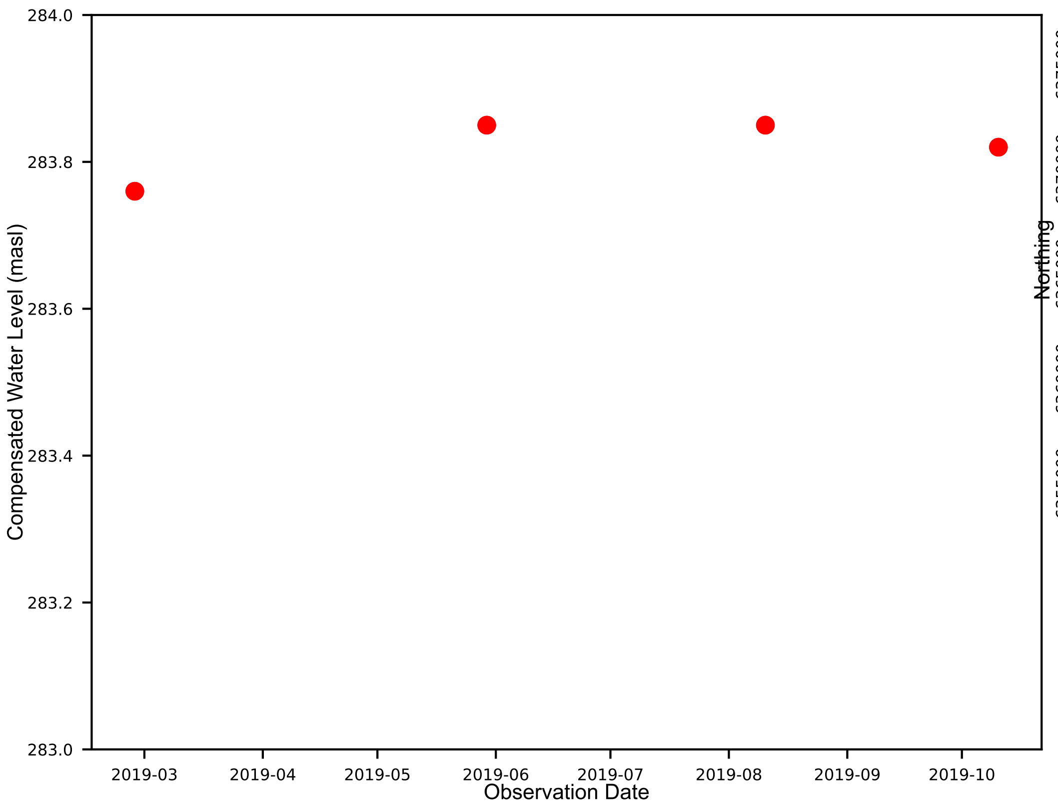
FORT HILLS
Operated by Suncor Energy

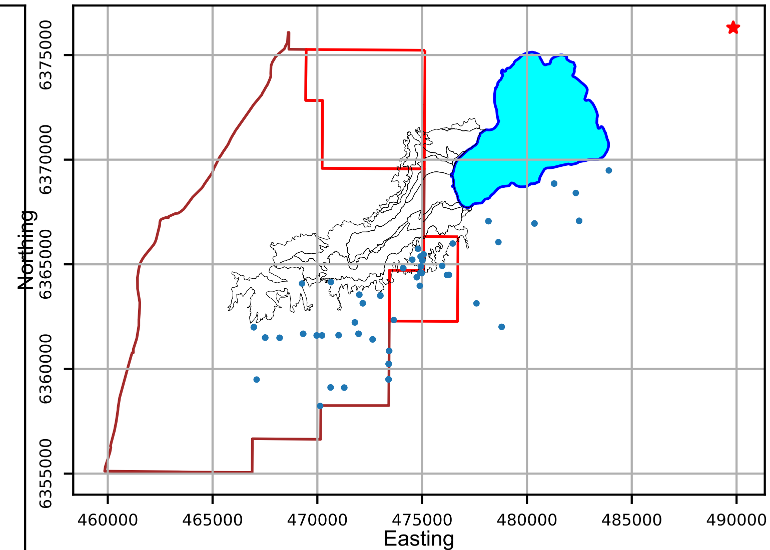
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES601-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-85

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.58 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES601-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-86

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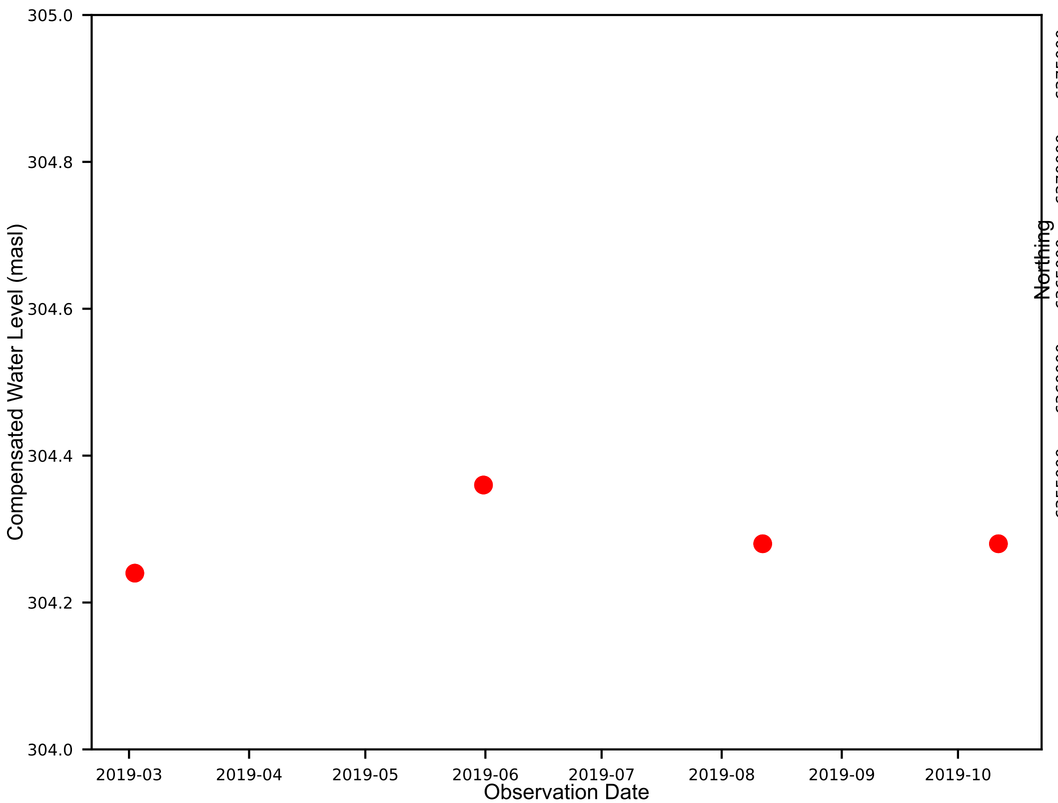
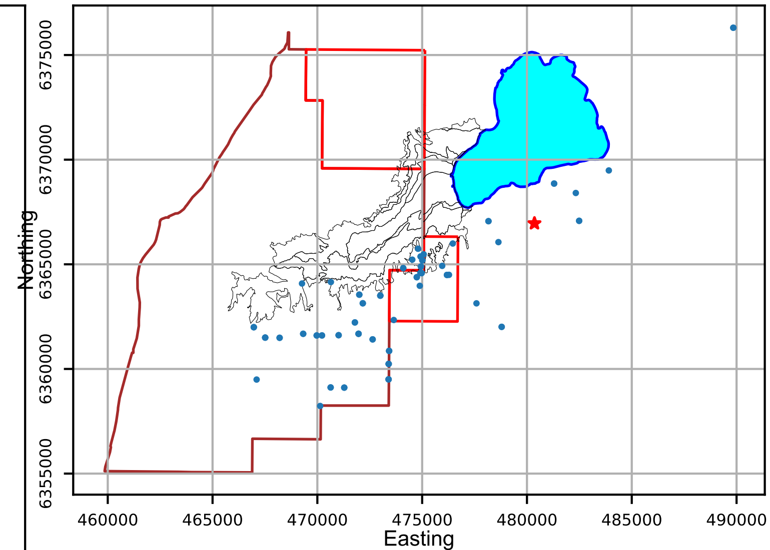




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 36.66 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

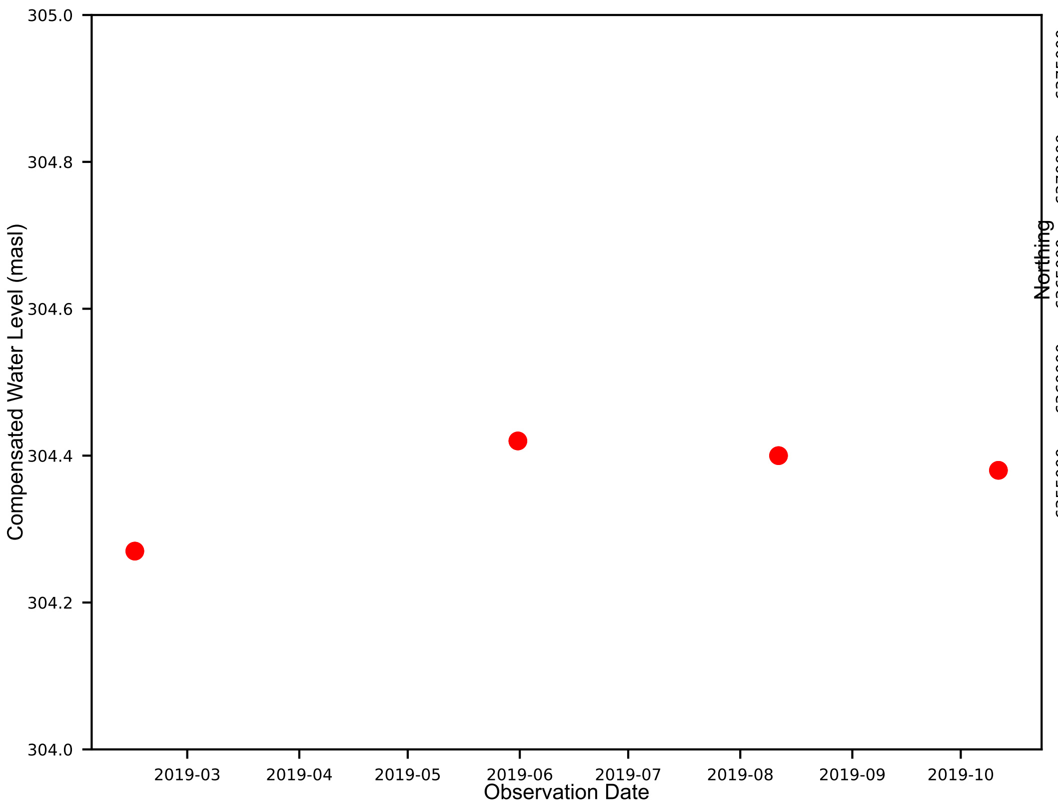
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

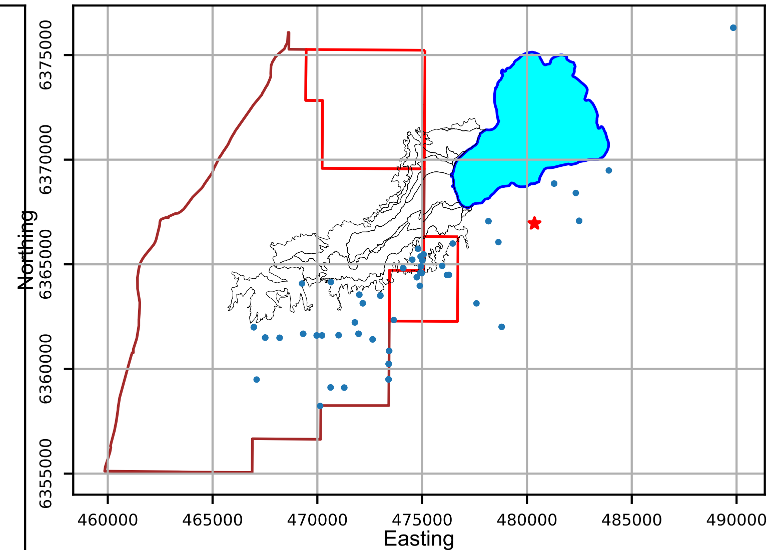
TITLE

FH19-ES621-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-87

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 20.89 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

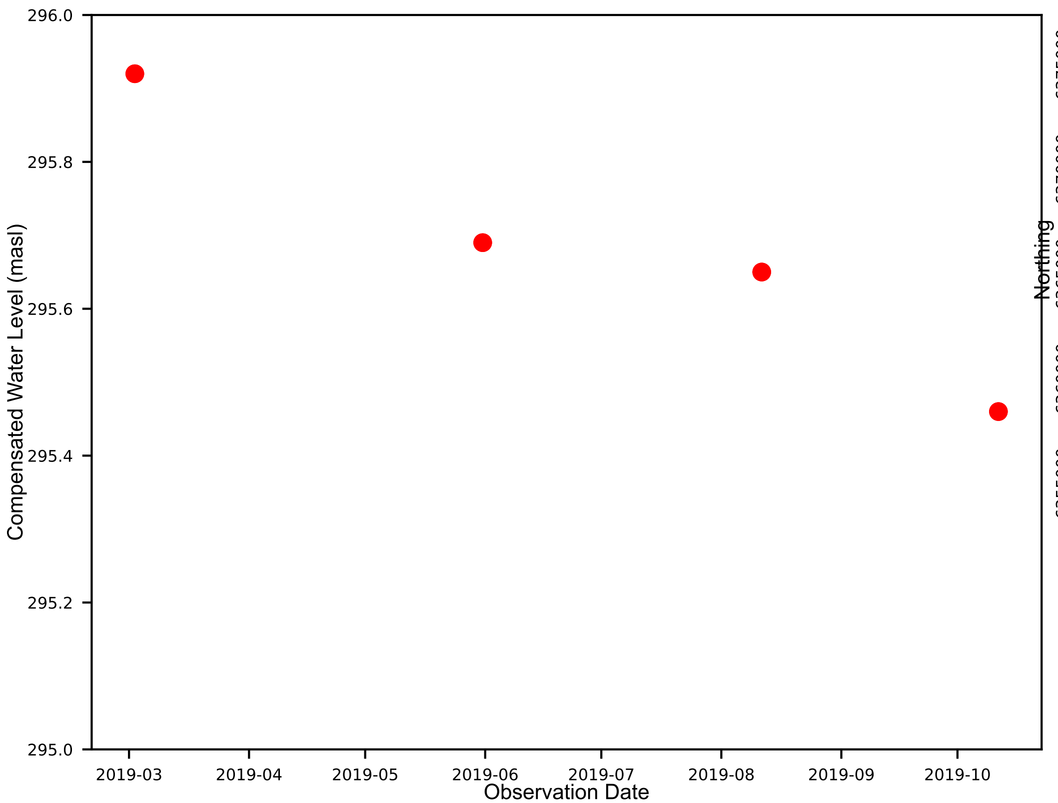
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

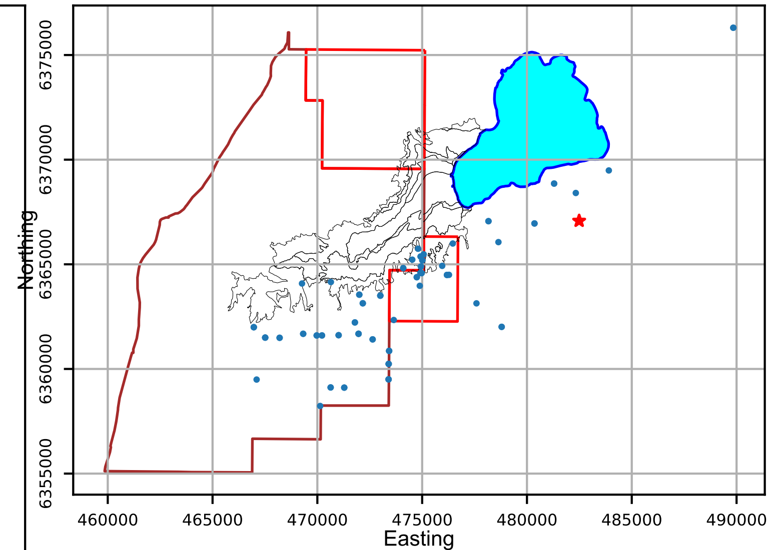
TITLE

FH19-ES621-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-88

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

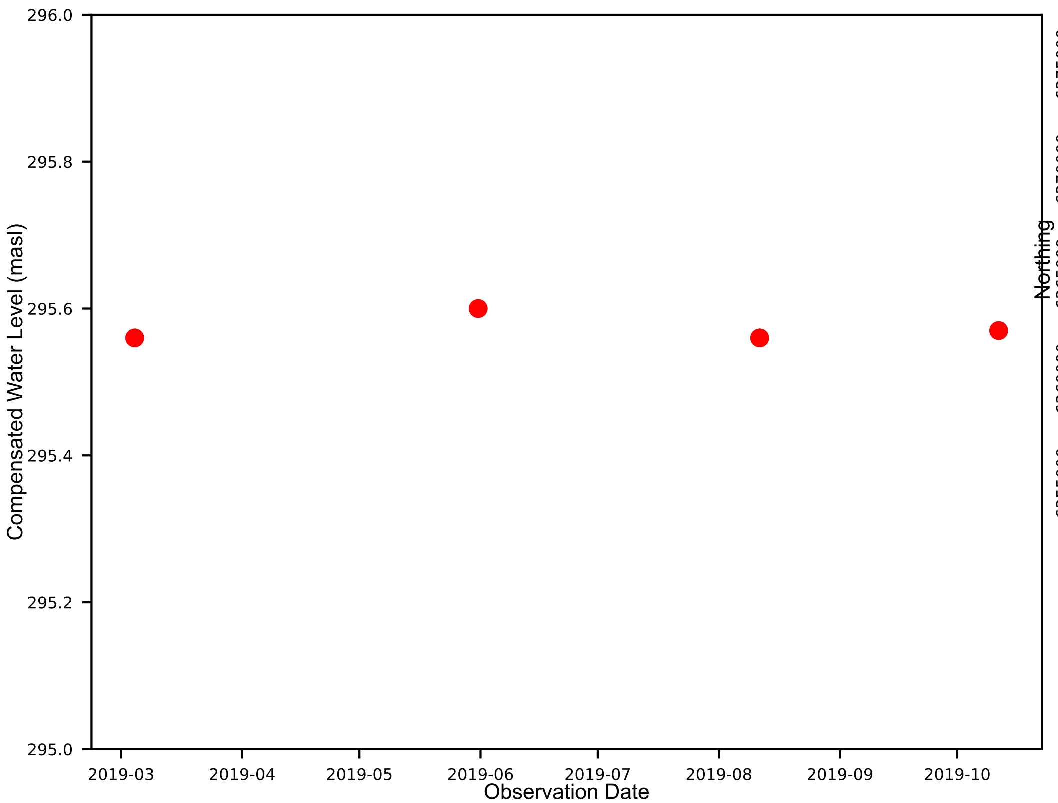
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

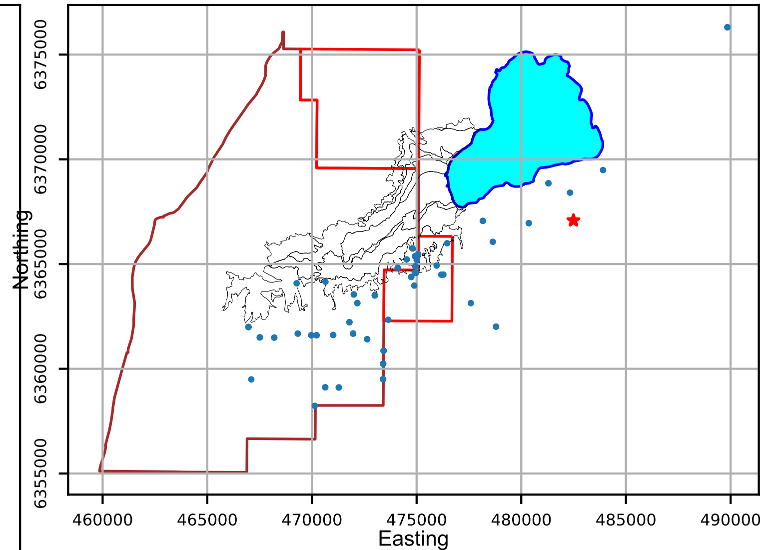
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES640-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-89





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 5.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES640-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-90

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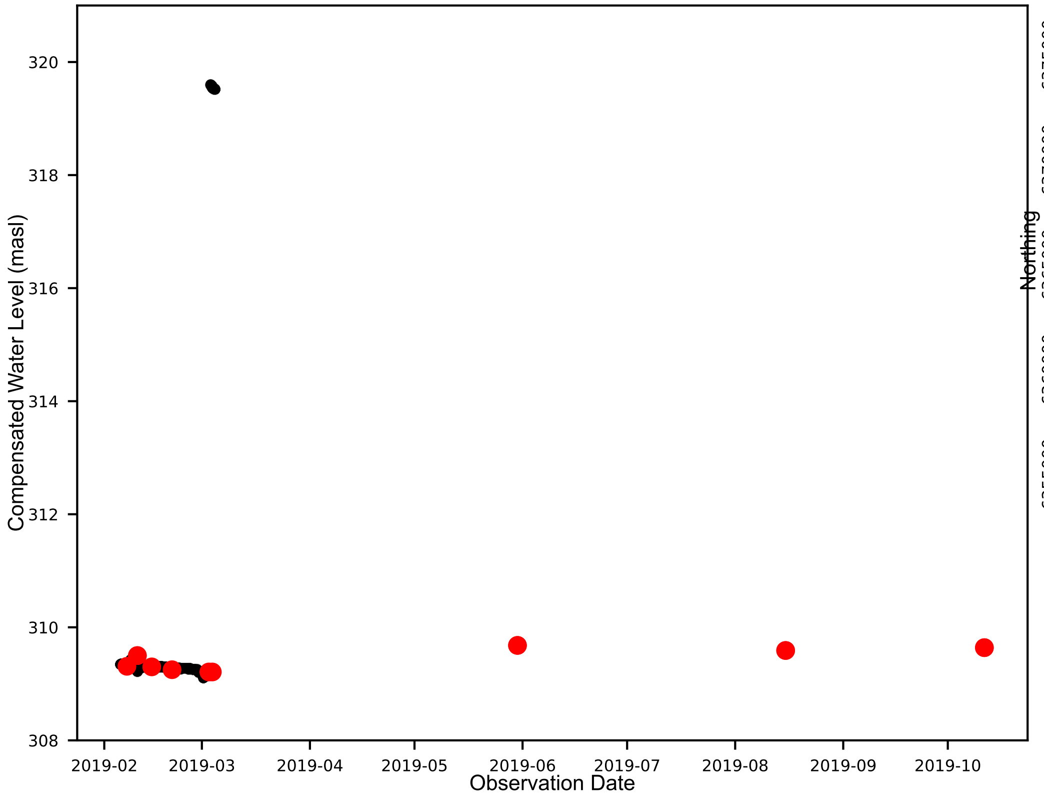
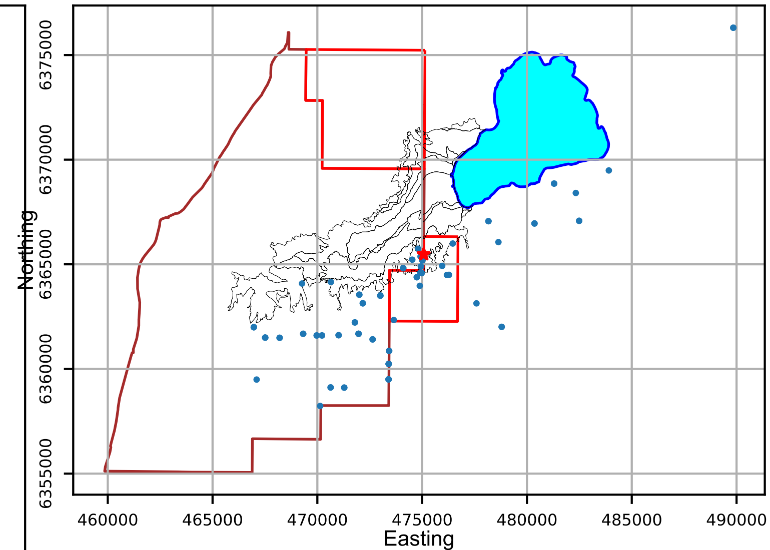




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 26.28 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

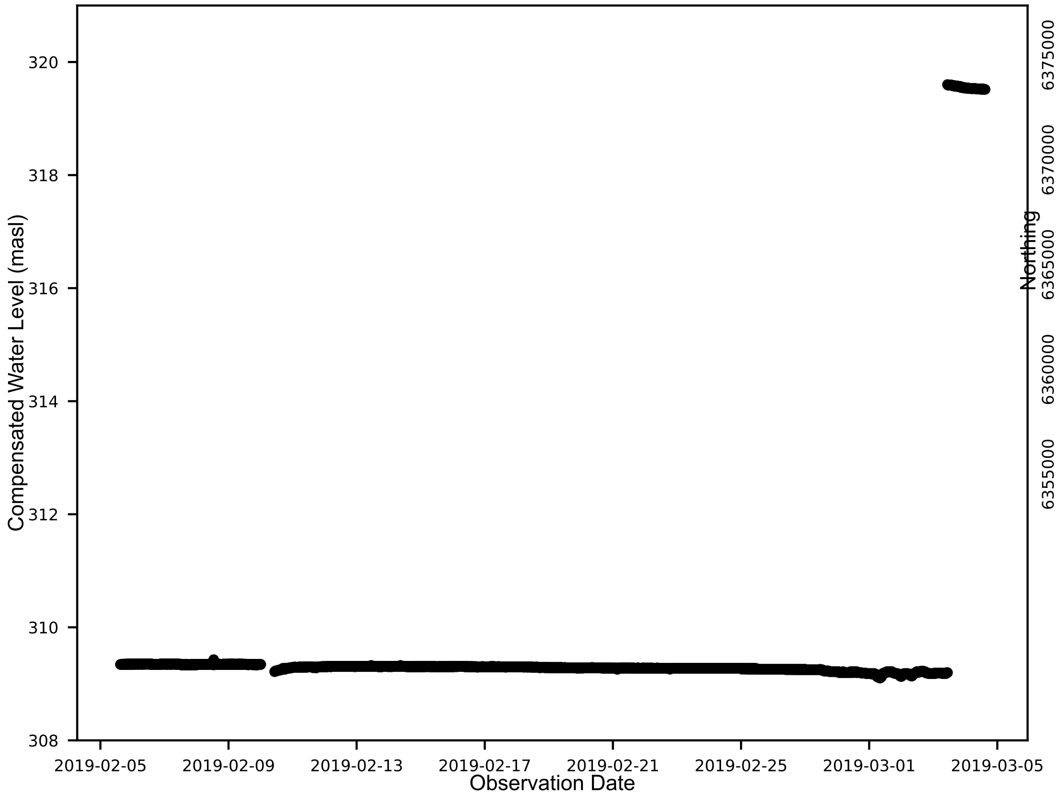
TITLE

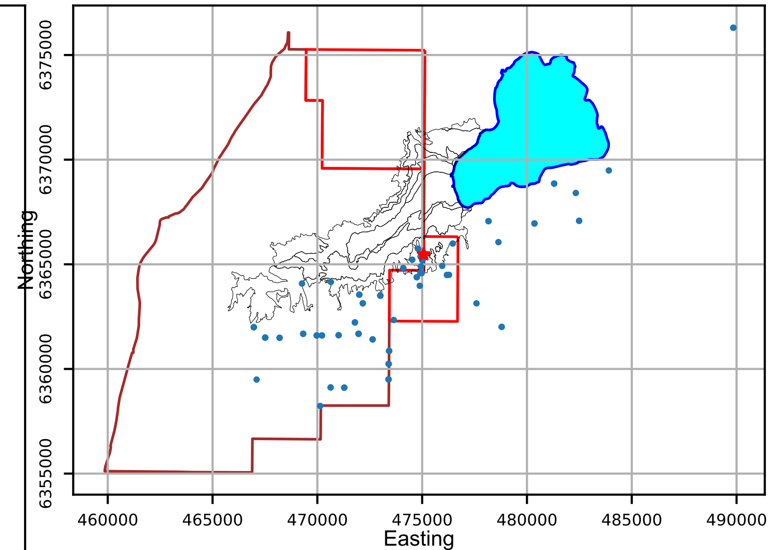
FH19-ES647-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-91

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 26.28 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

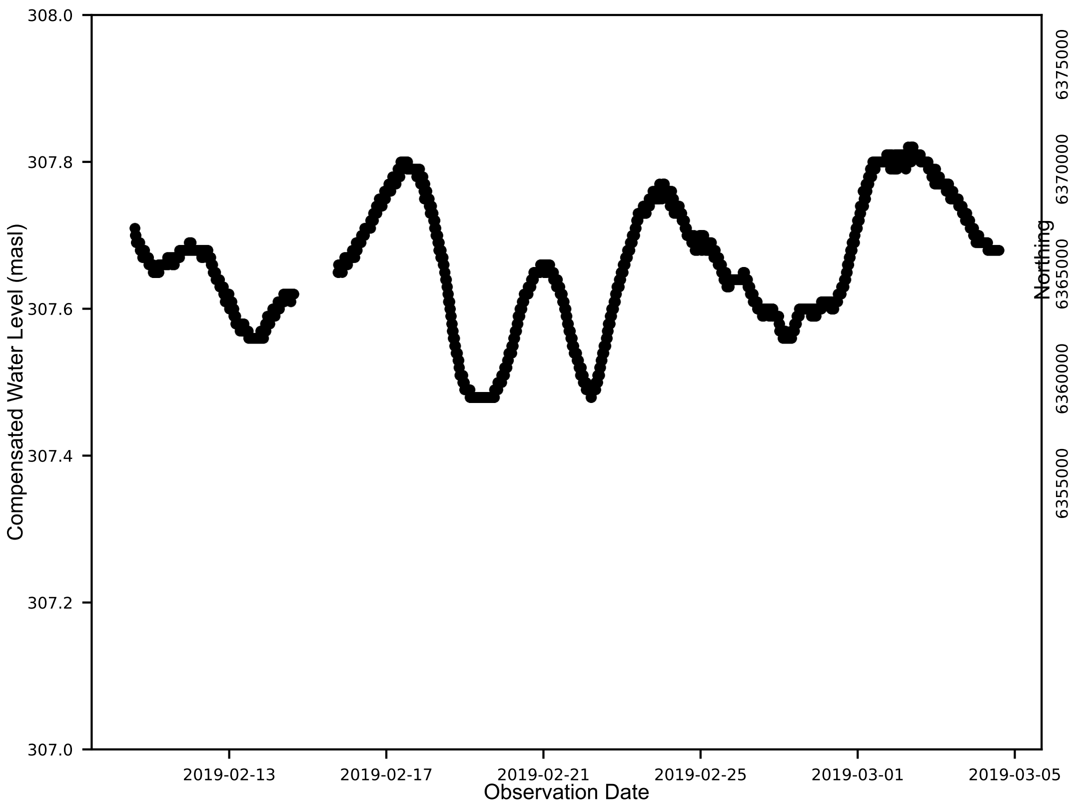
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

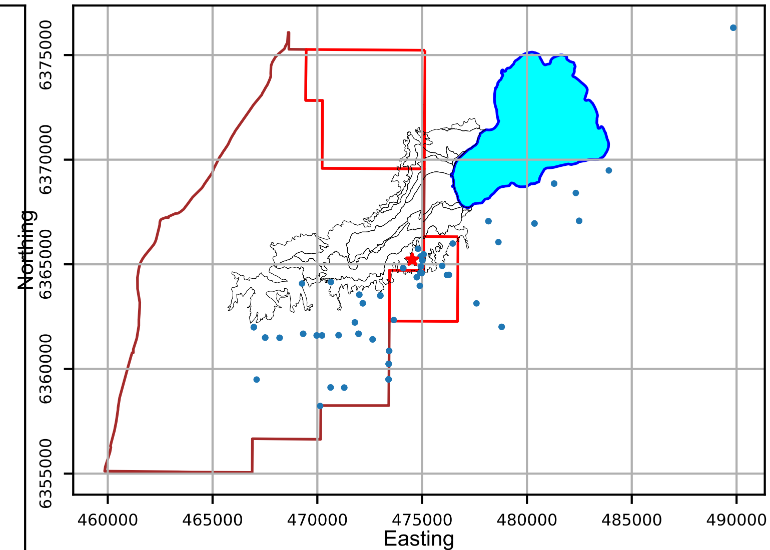
TITLE

FH19-ES647-SN1 - 12.86 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-92

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 11.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

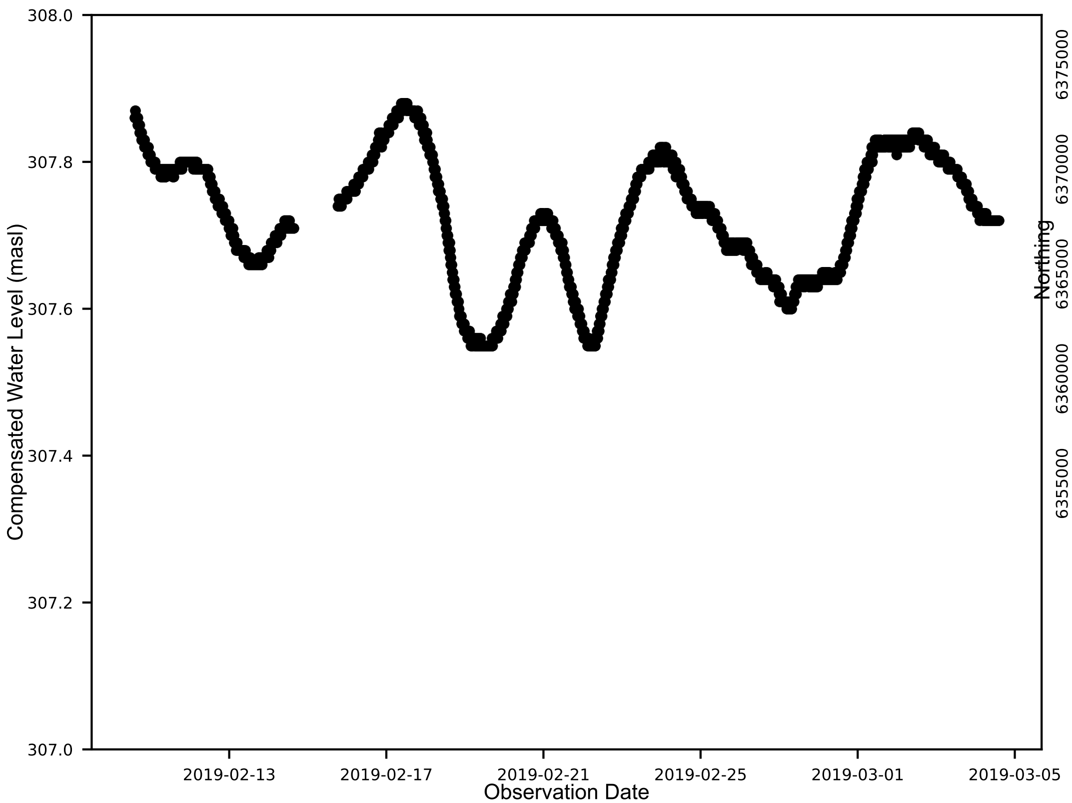
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

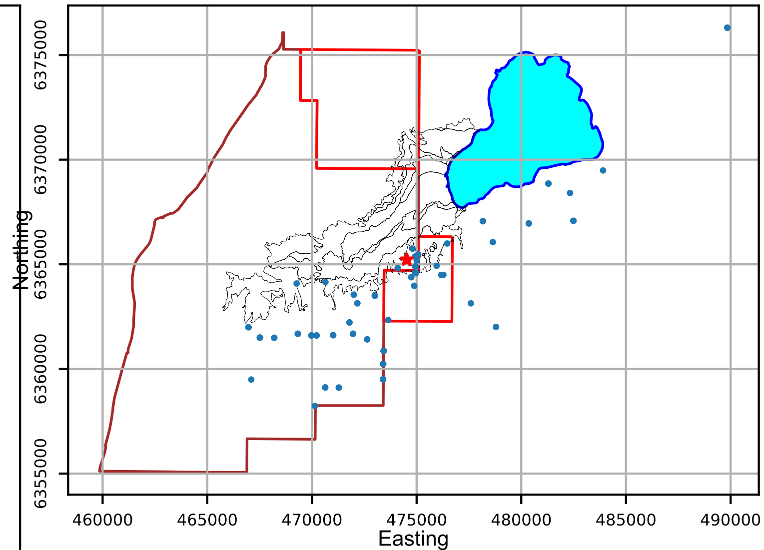
TITLE

FH19-ES652-SN1 - 11.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-93

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 23.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES652-SN1 - 23.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-94

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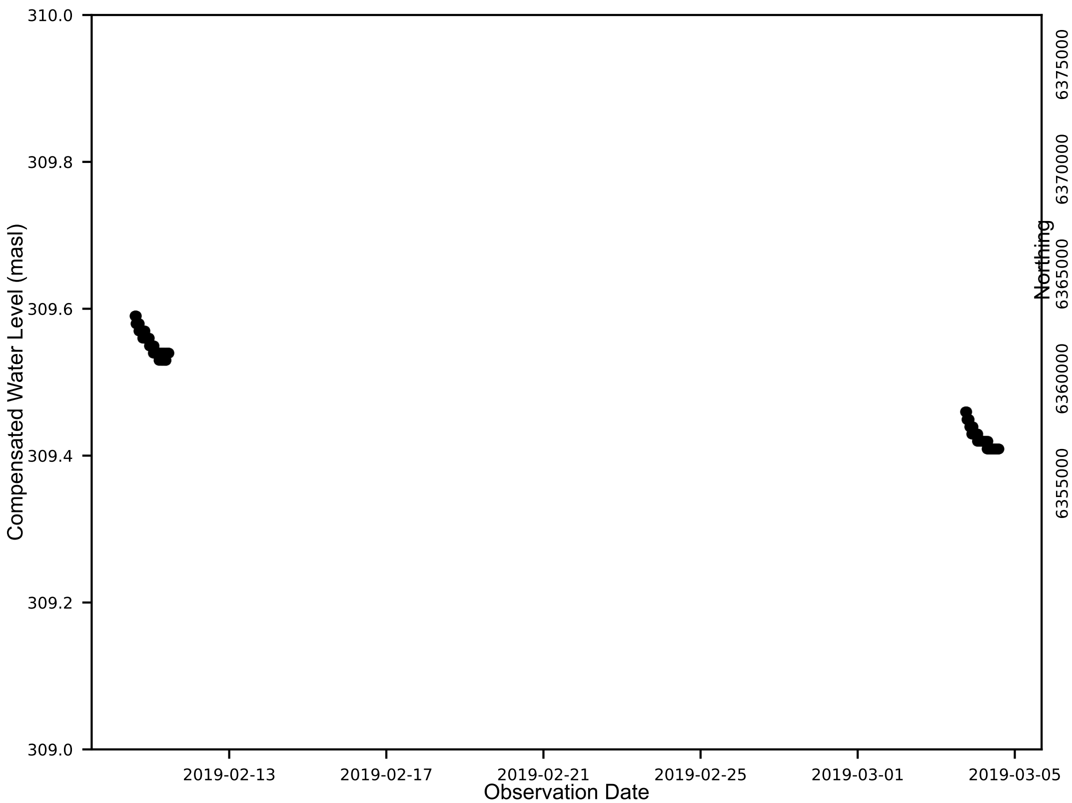
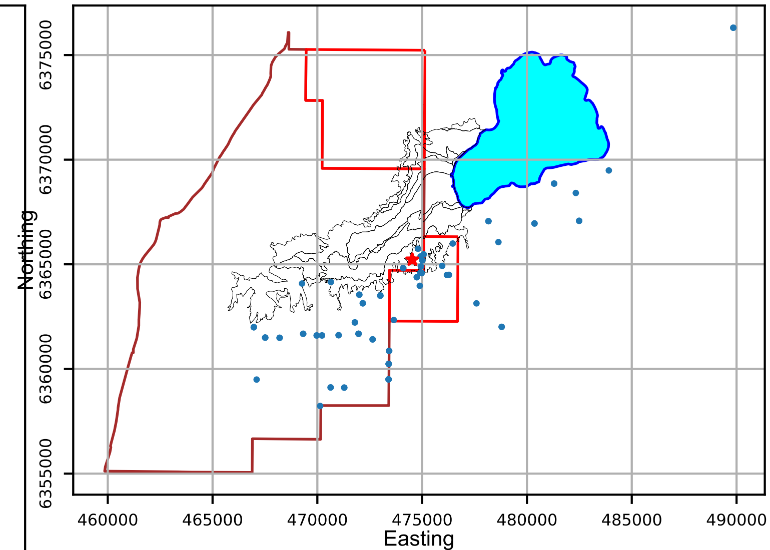




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 38.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

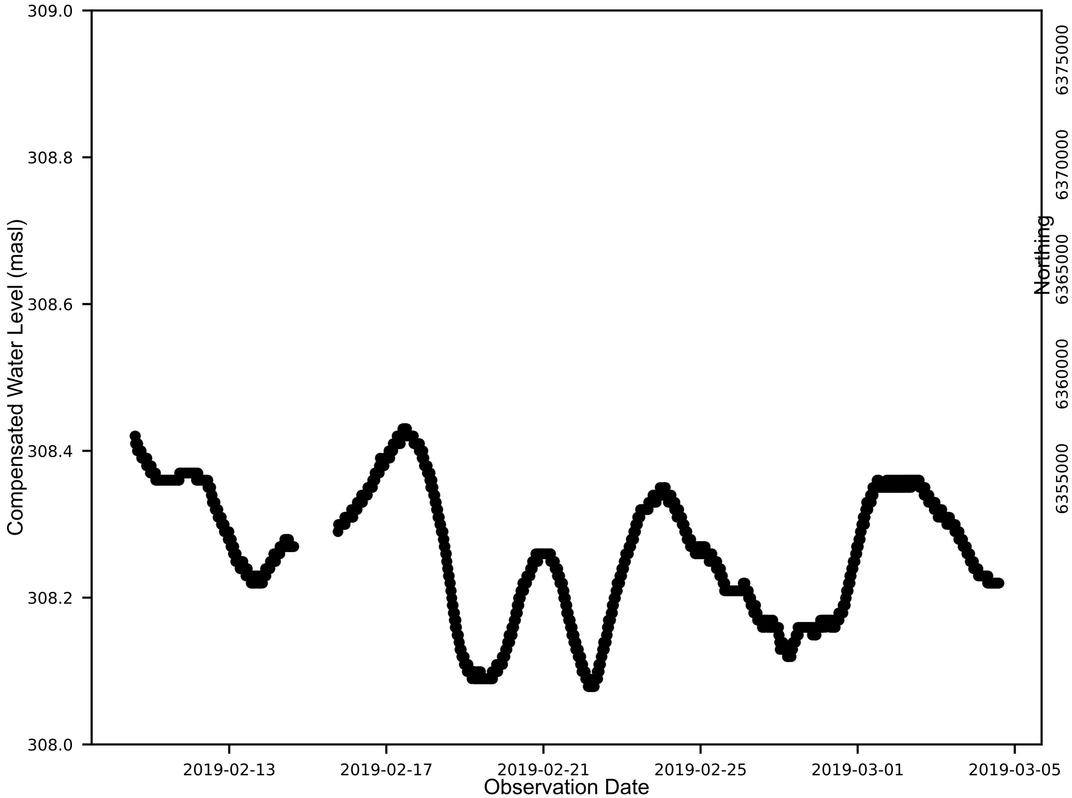
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

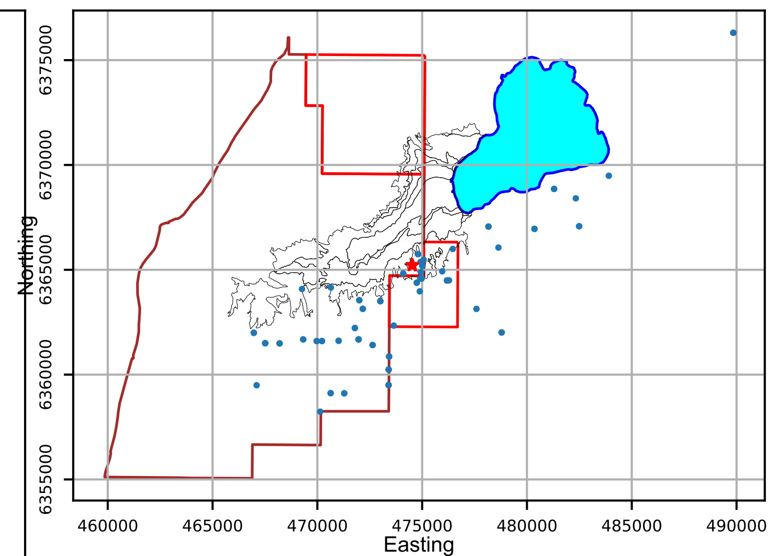
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES652-SN1 - 38.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-95

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 45 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

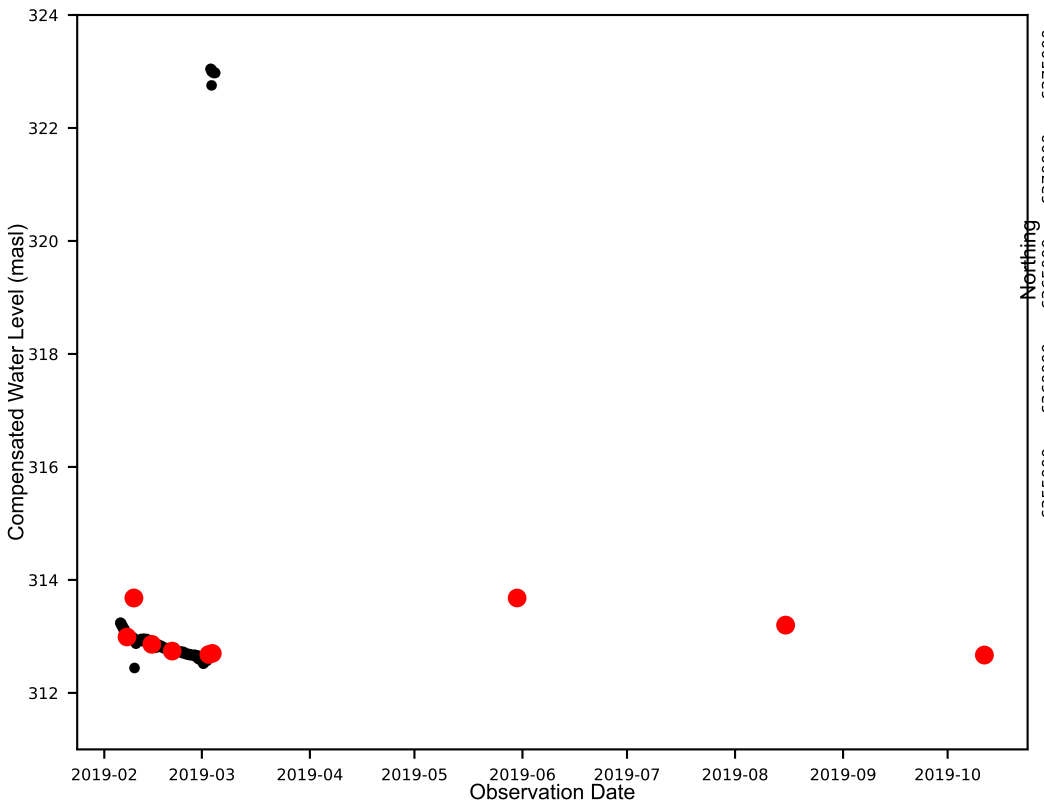
FORT HILLS
Operated by Suncor Energy

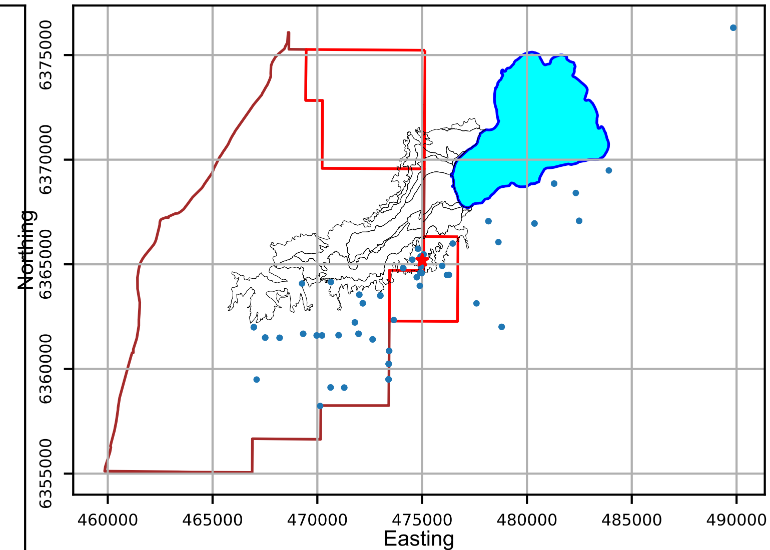
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES652-SN1 - 45.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-96

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.81 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

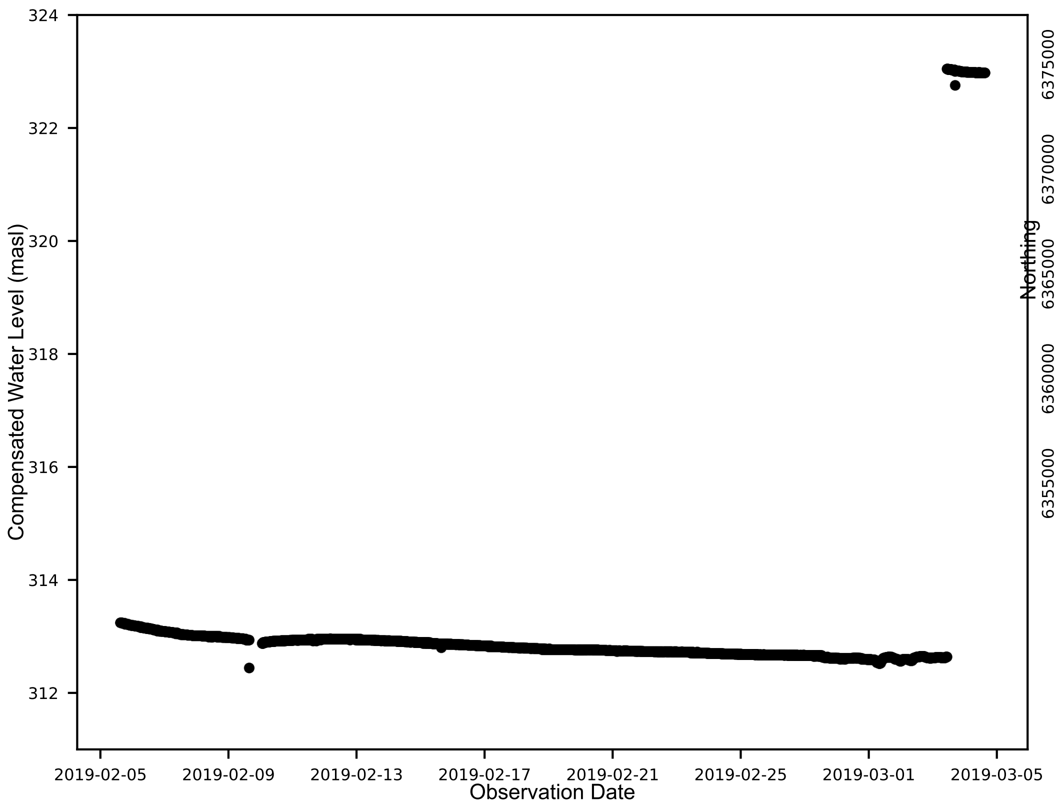
FORTHILLS
Operated by Suncor Energy

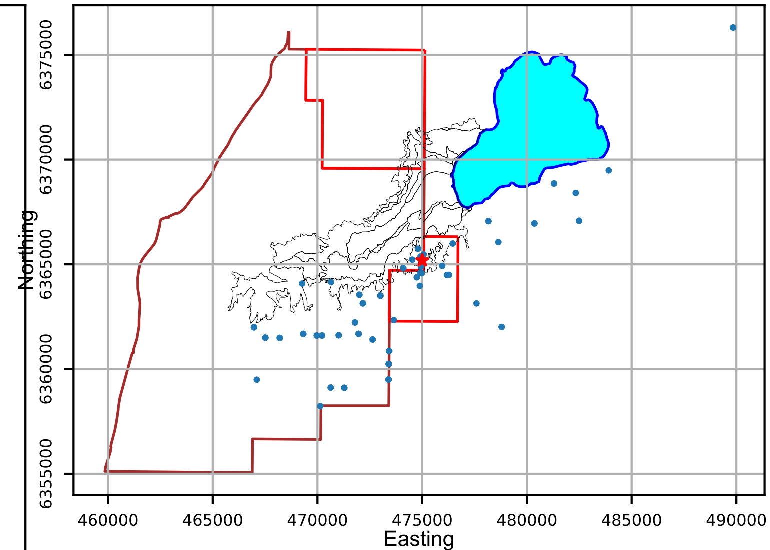
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES656-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-97





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.81 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

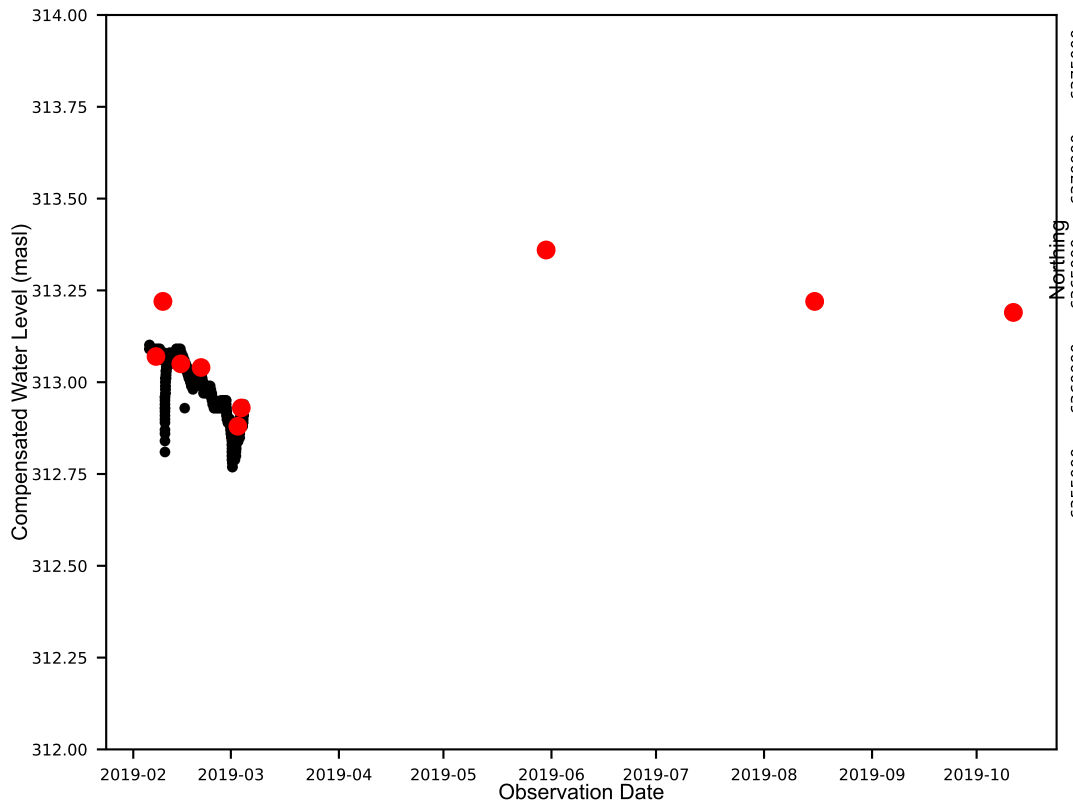
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

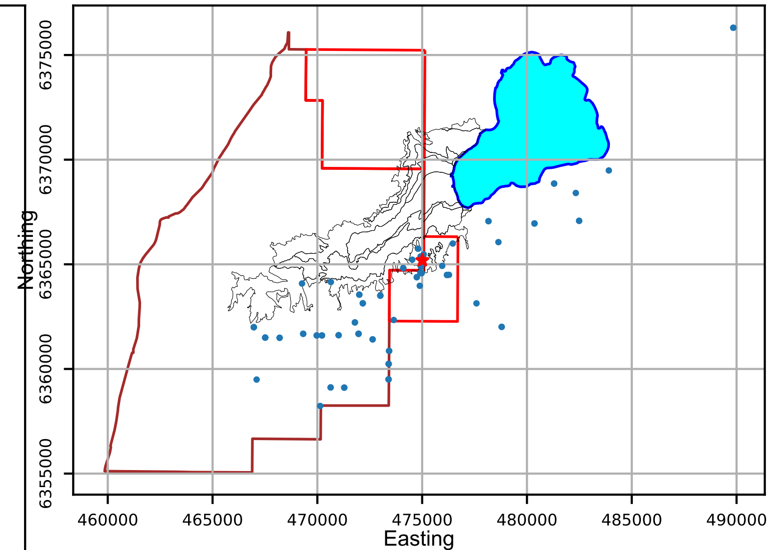
TITLE

FH19-ES656-SN1 - 18.57 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-98

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 26.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

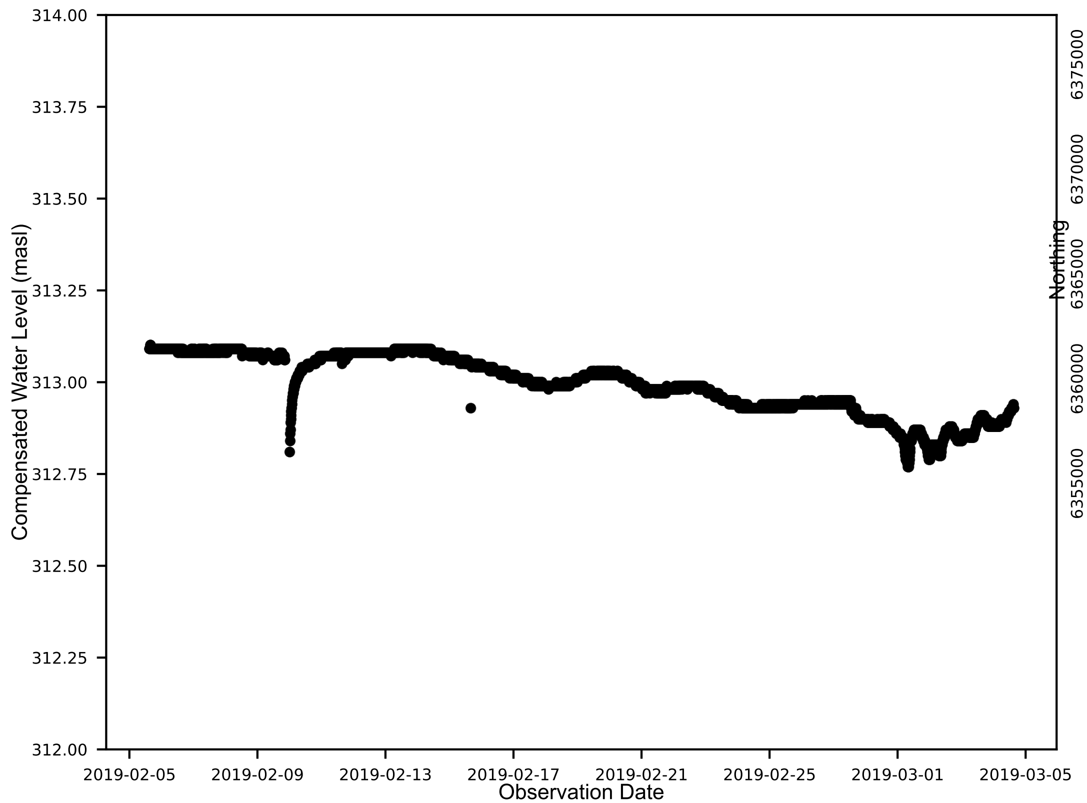
FORT HILLS
Operated by Suncor Energy

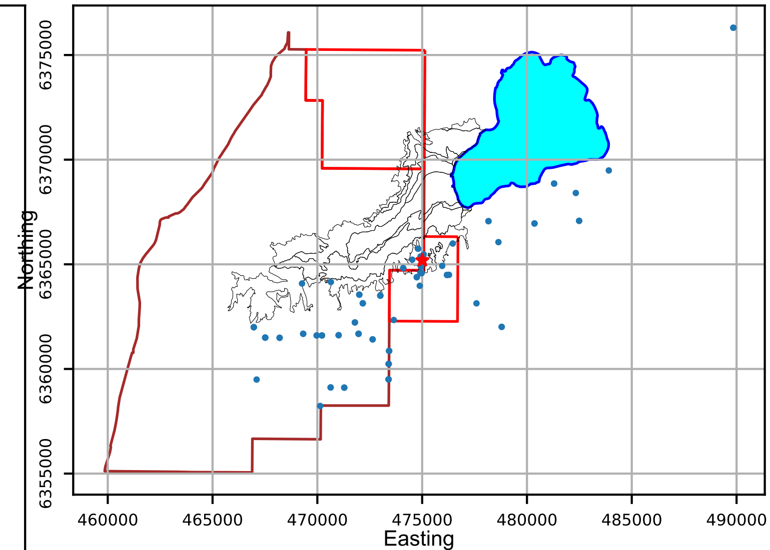
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES656-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-99





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 26.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
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FORTHILLS
Operated by Suncor Energy

PROJECT

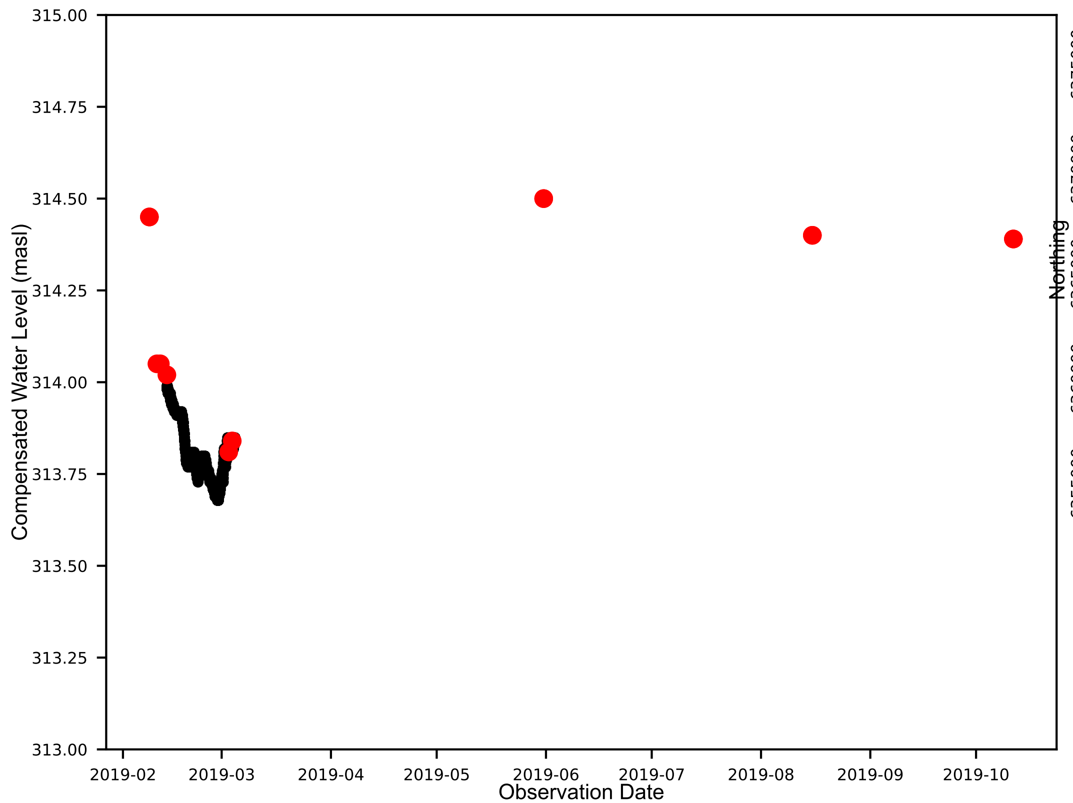
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

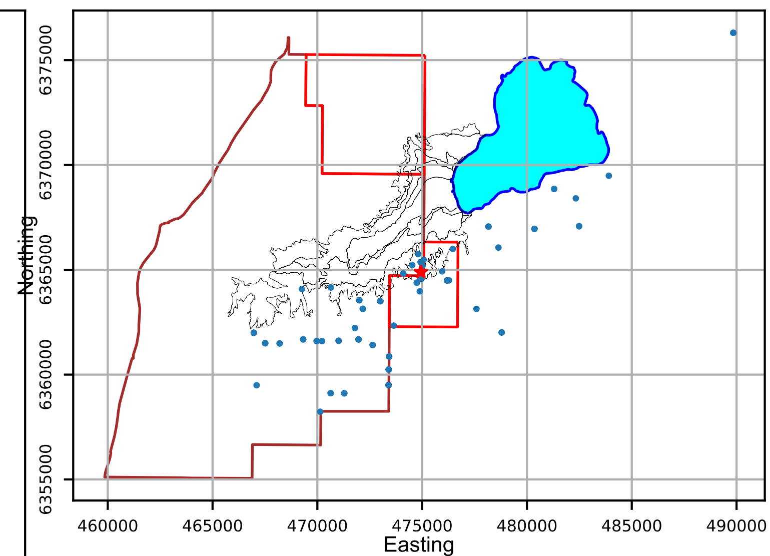
TITLE

FH19-ES656-SN2 - 20.63 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-100

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 53.58 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

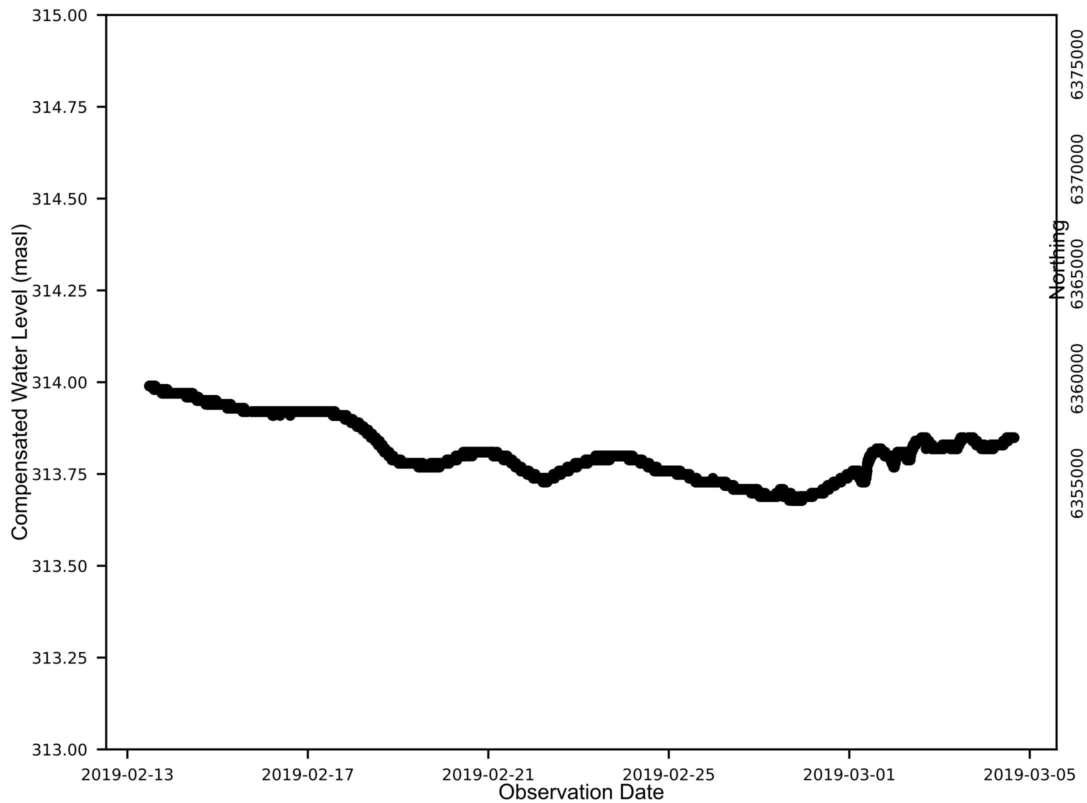
TITLE

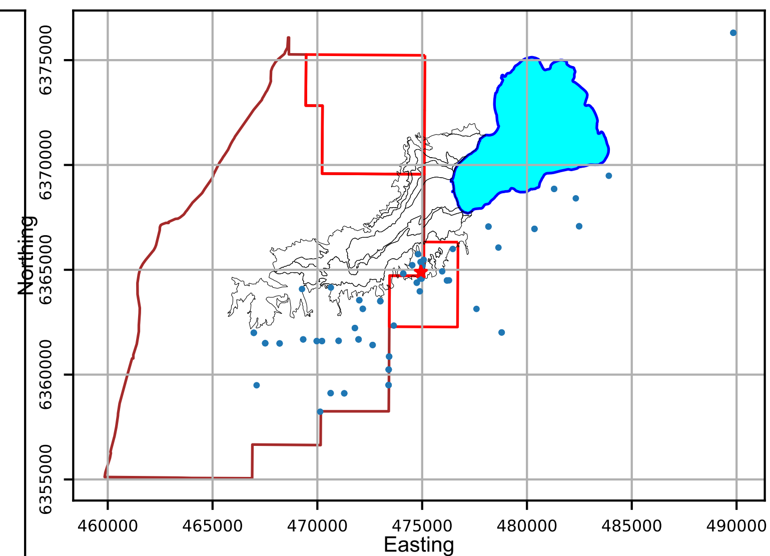
FH19-ES663-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-101

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 53.58 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES663-SN1 - 19.33 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-102

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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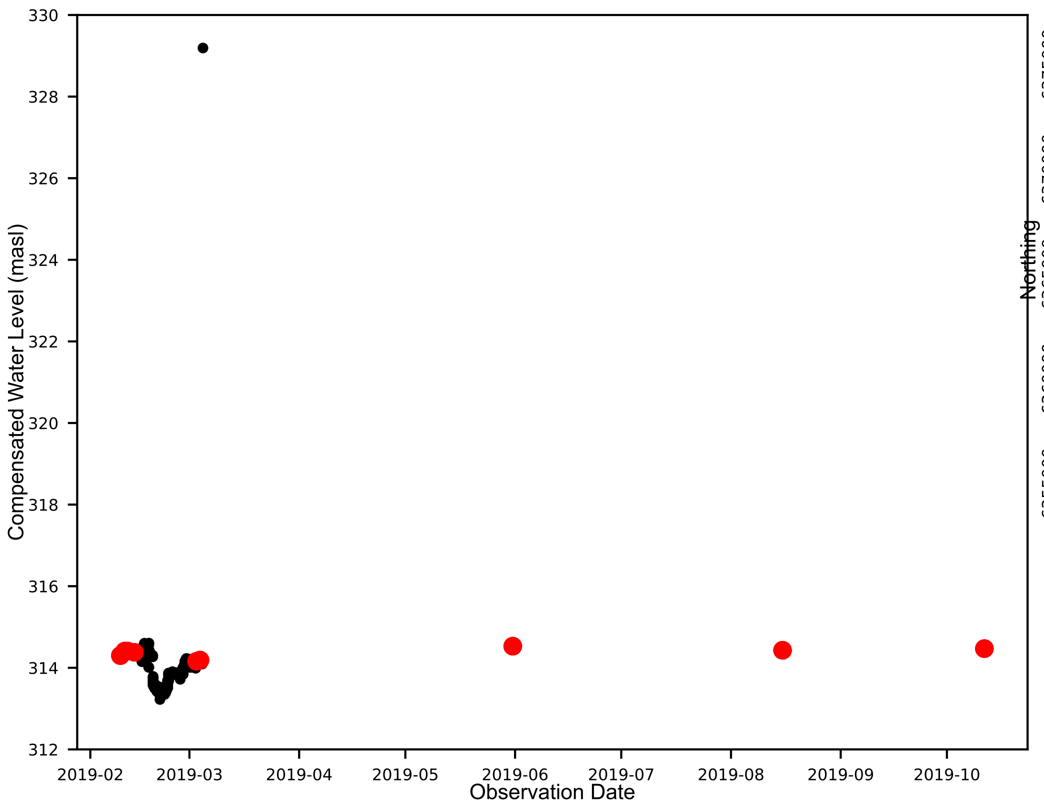
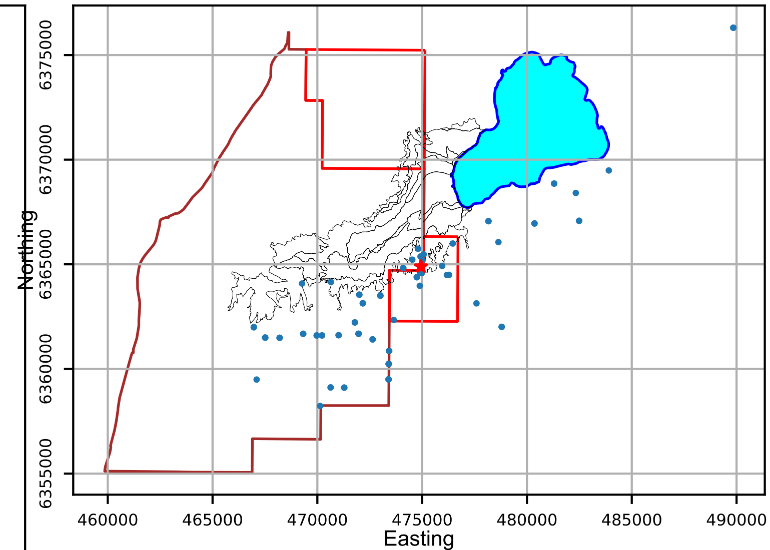




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.71 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

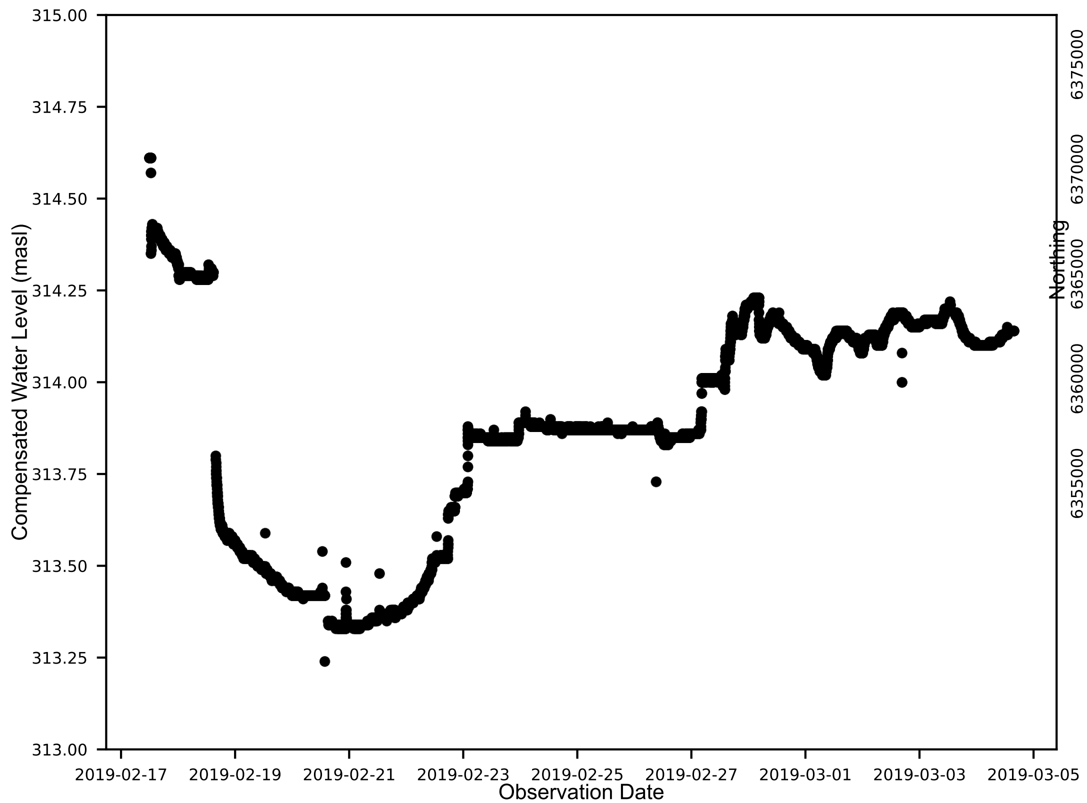
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

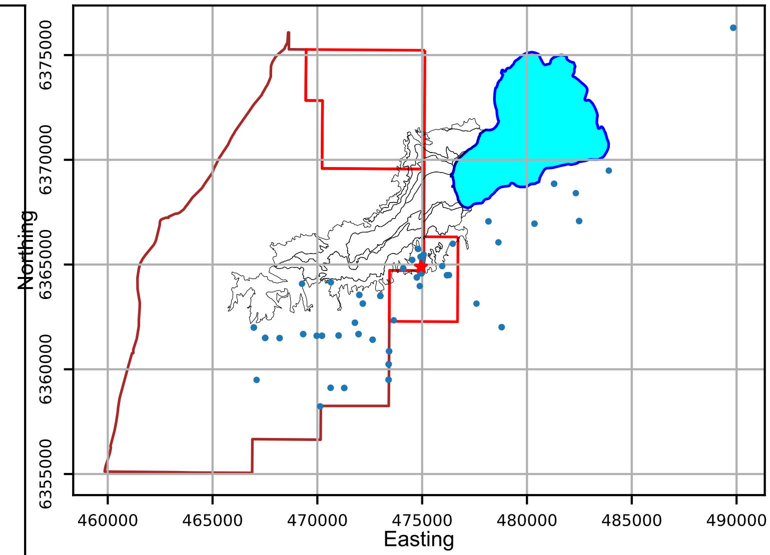
TITLE
FH19-ES663-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-103

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.71 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH19-ES663-SN2 - 18.307 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-104

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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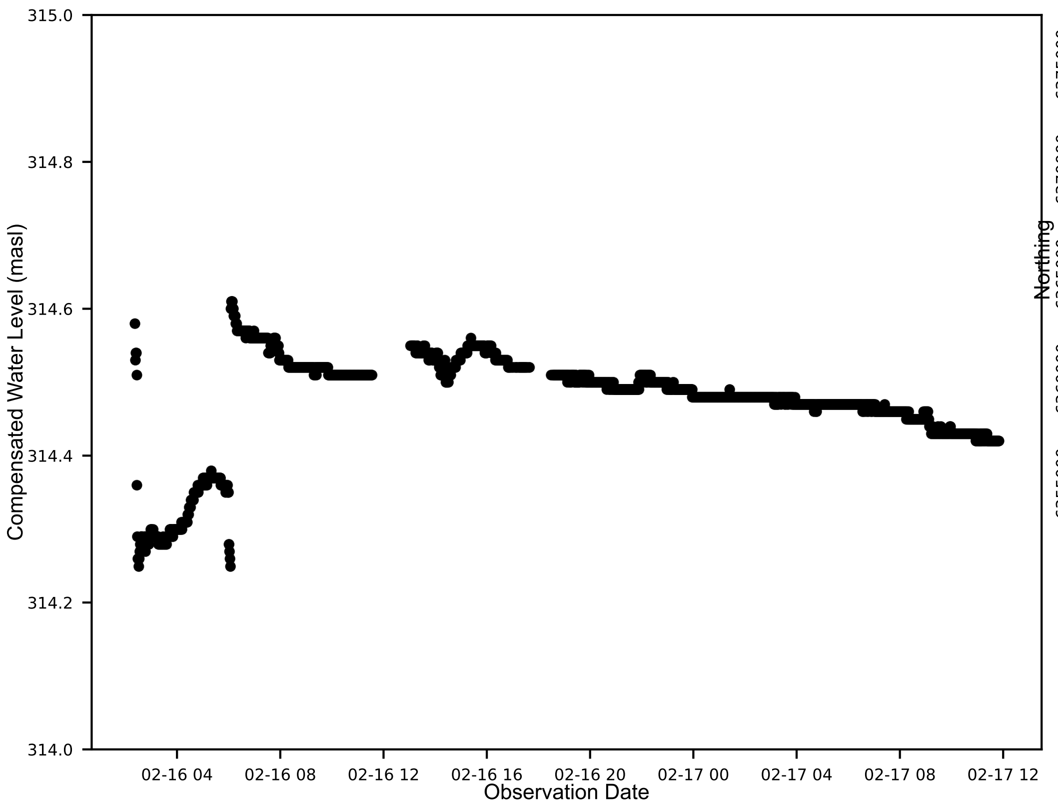

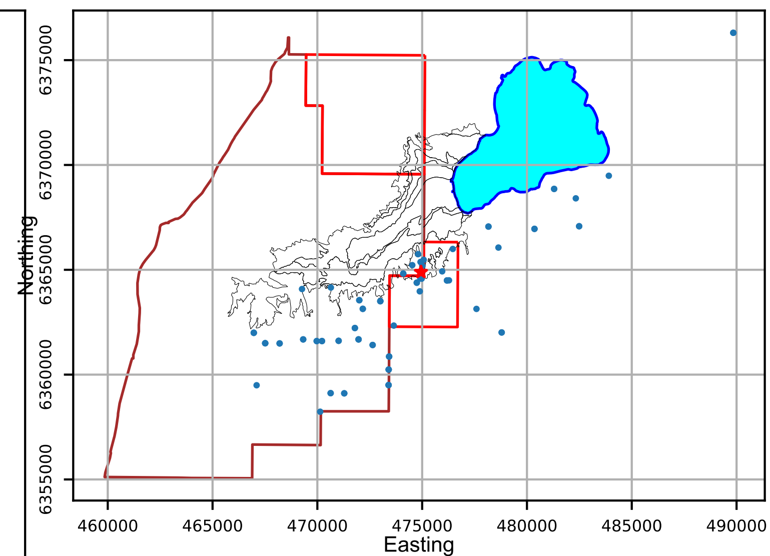

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.71 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
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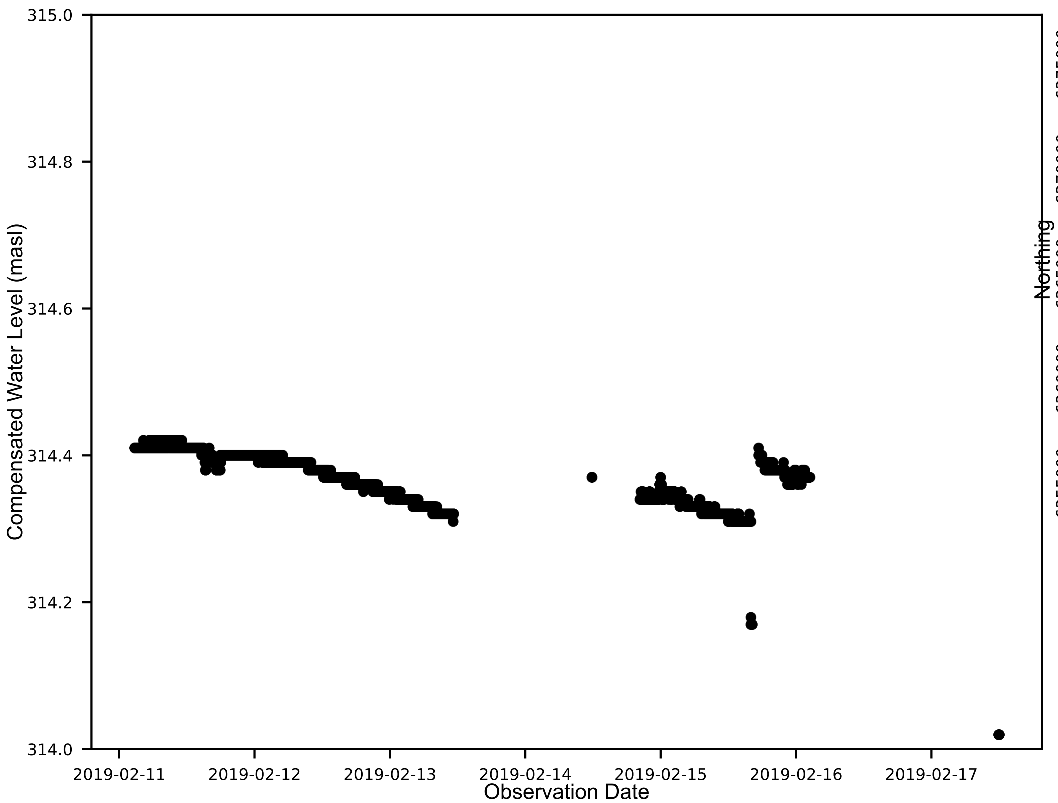
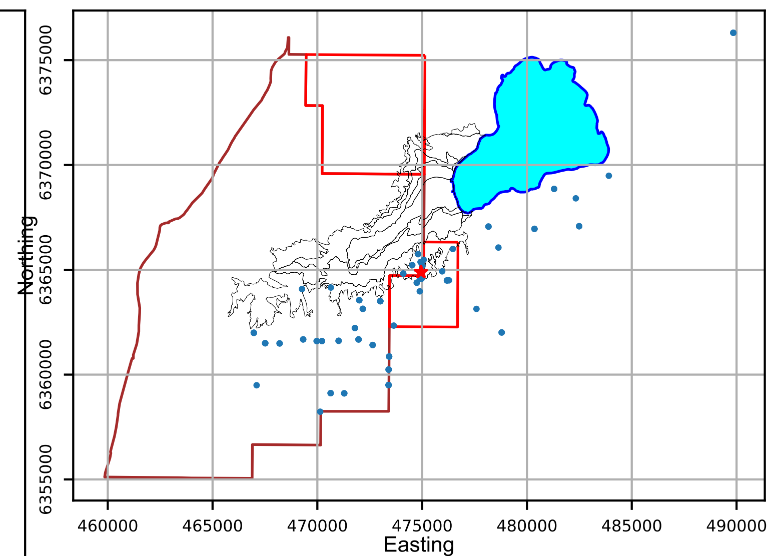
TITLE

FH19-ES663-SN2 - 18.497 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-105

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.71 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

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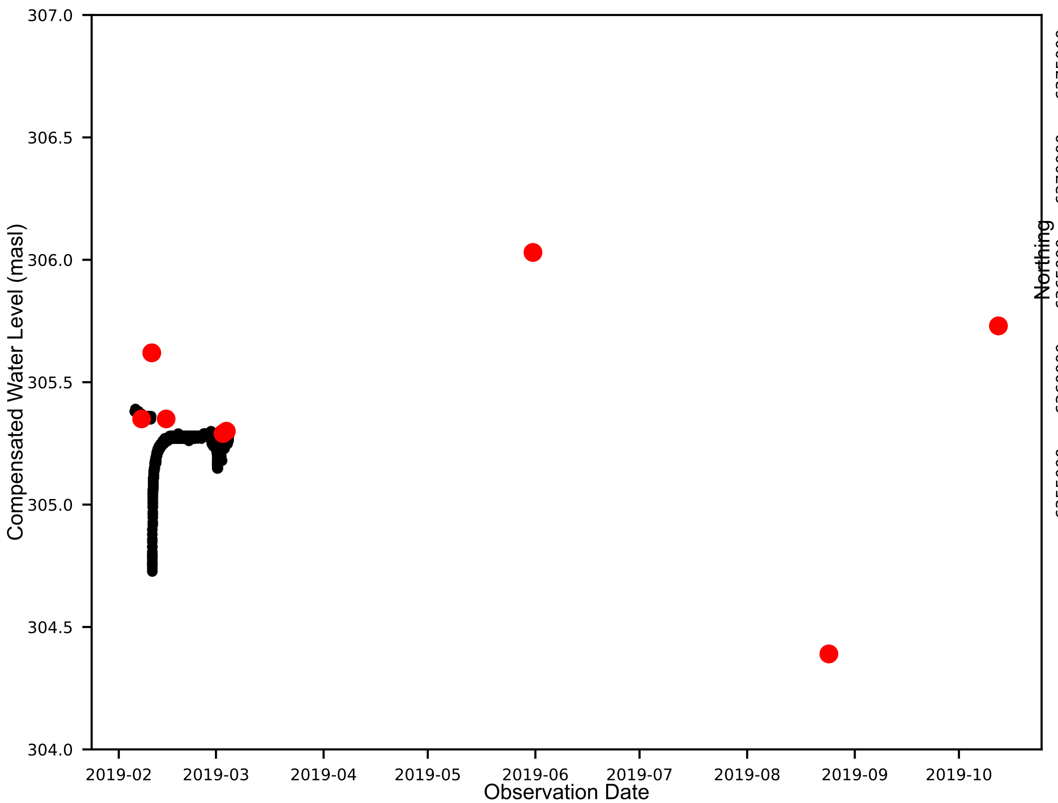
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

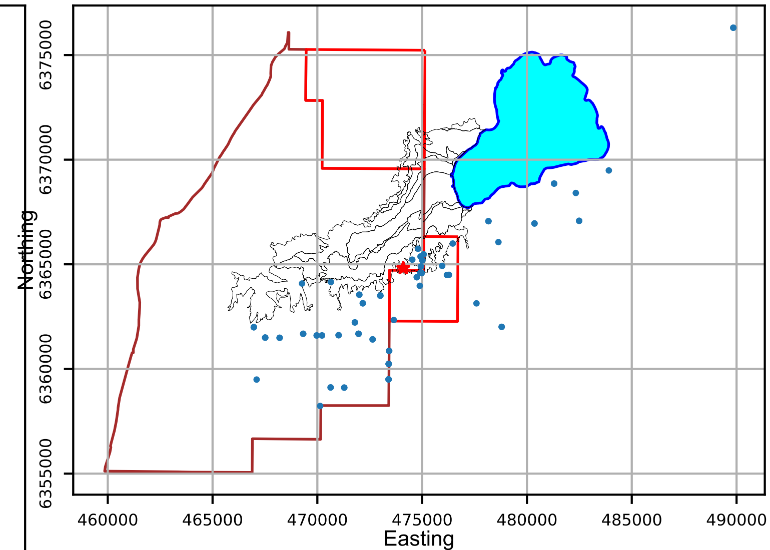
TITLE

FH19-ES663-SN2 - 18.897 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-106

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 37.24 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

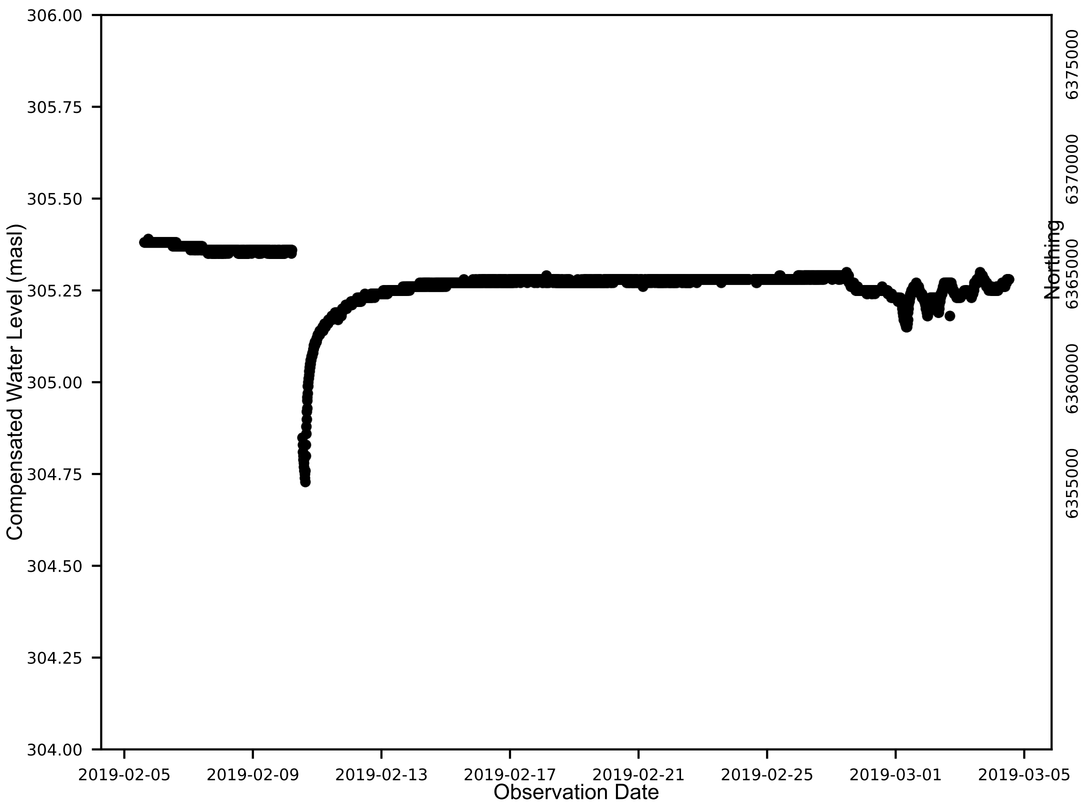
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

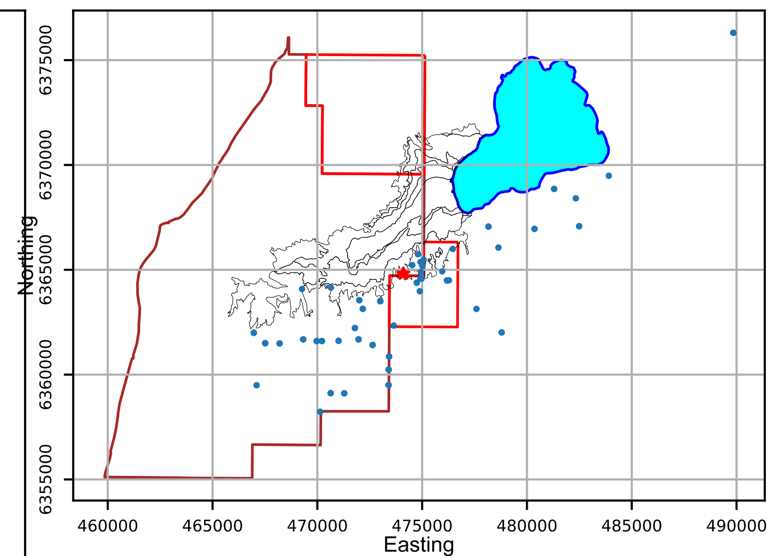
FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES665-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-107

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 37.24 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

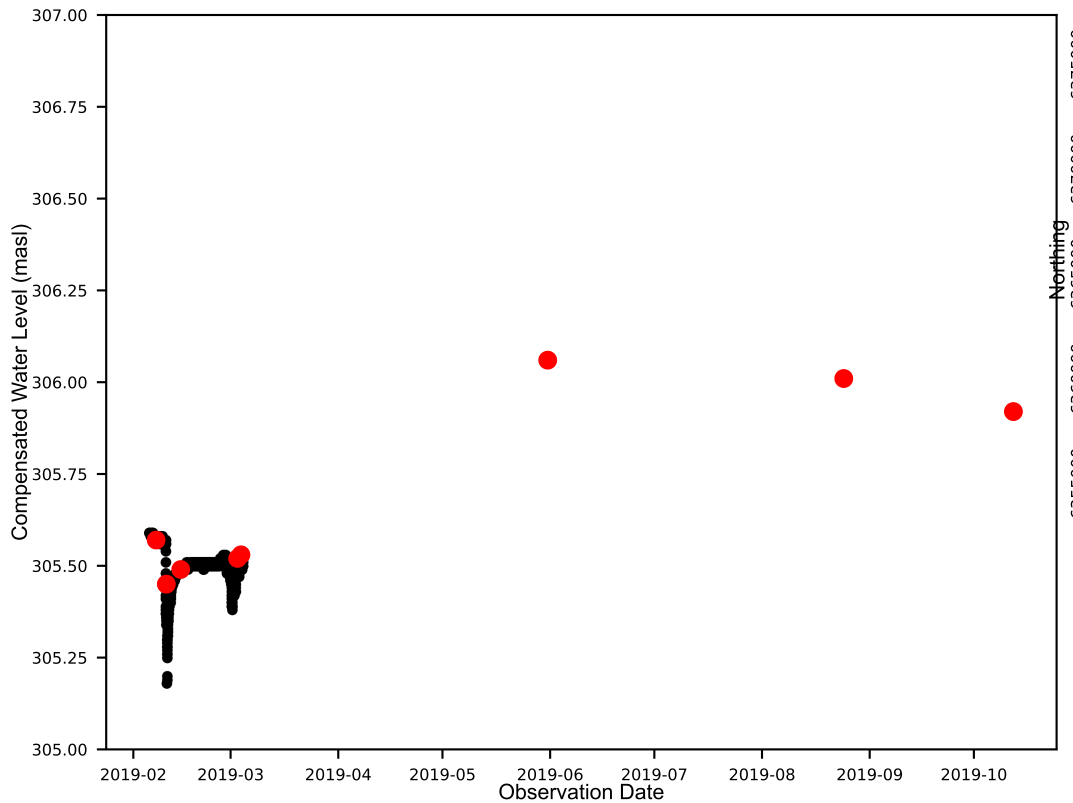
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

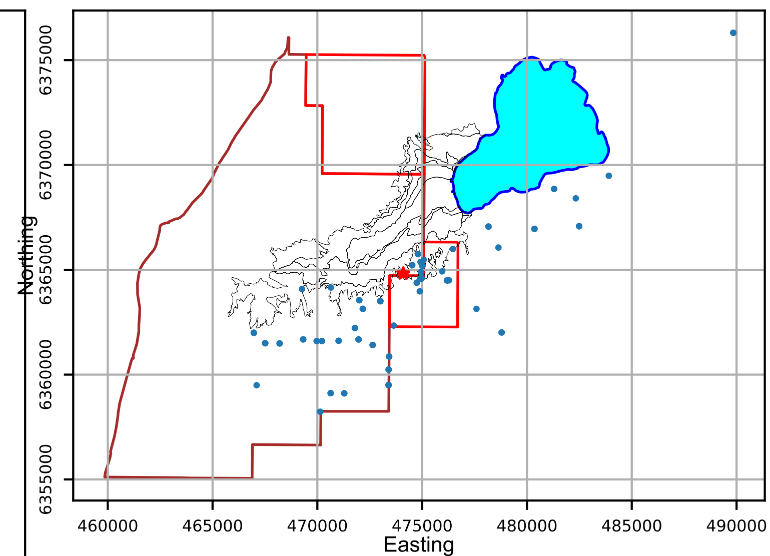
TITLE
FH19-ES665-SN1 - 22.91 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-108

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

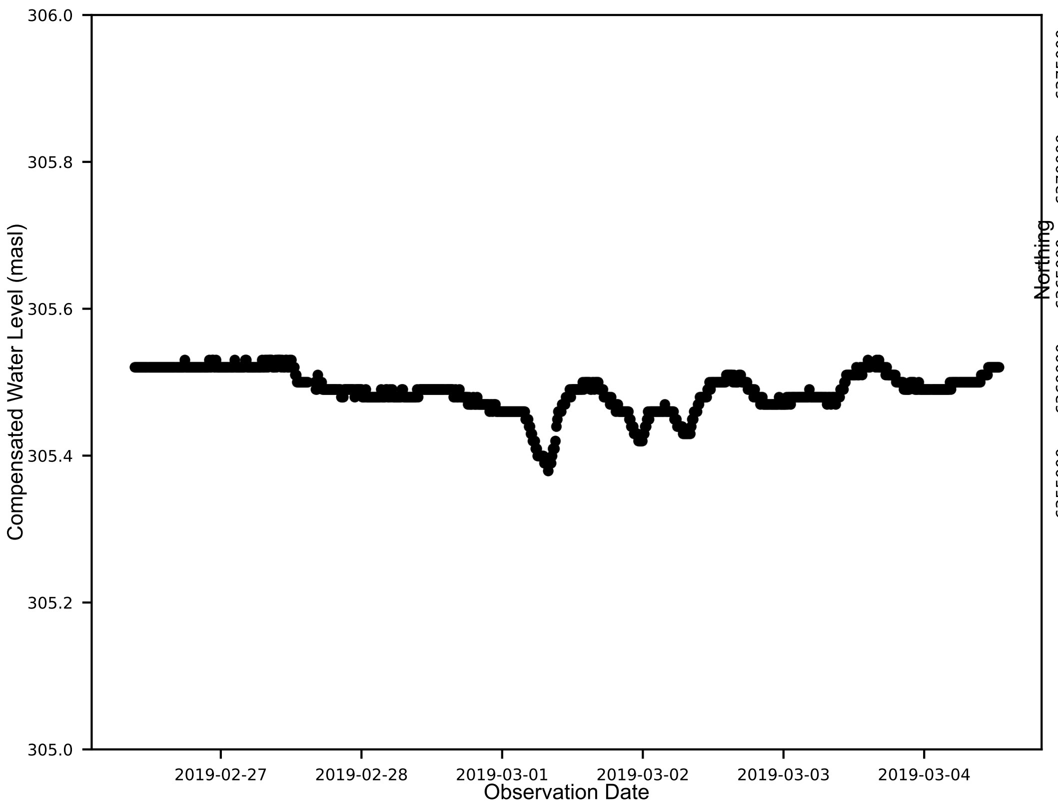
FORTHILLS
Operated by Suncor Energy

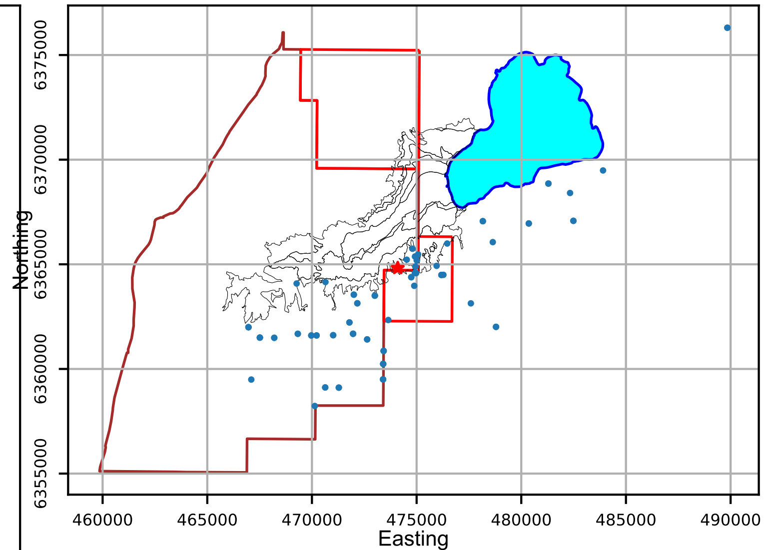
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES665-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-109

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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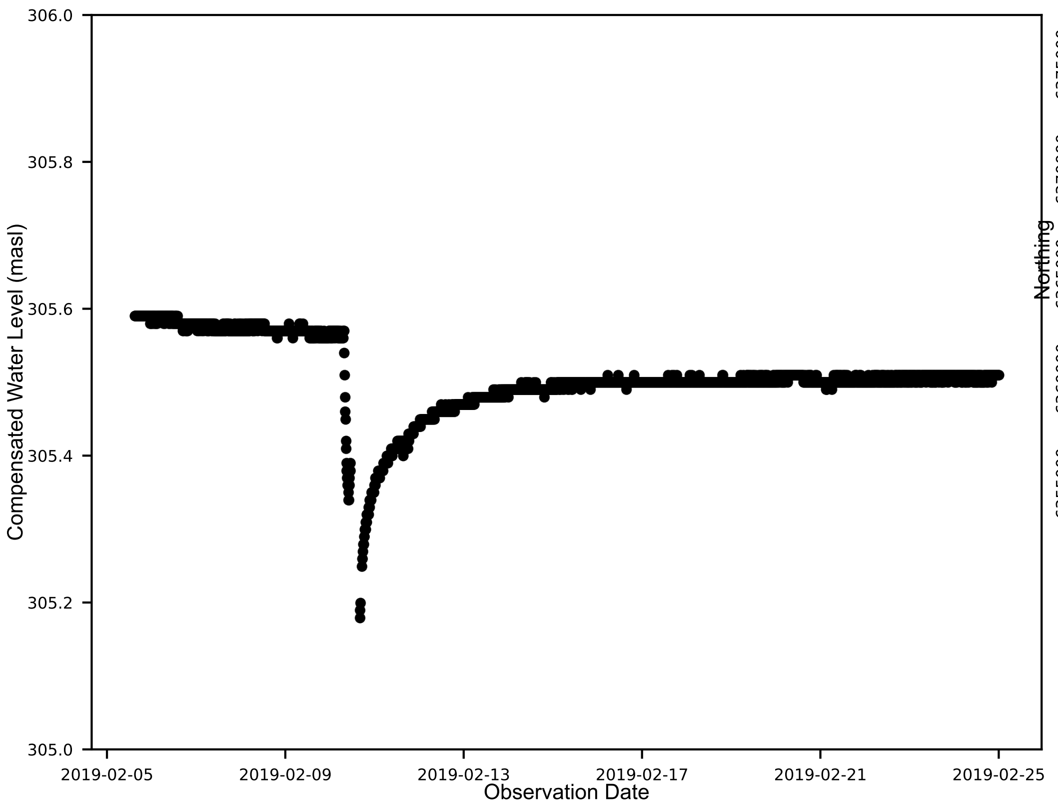
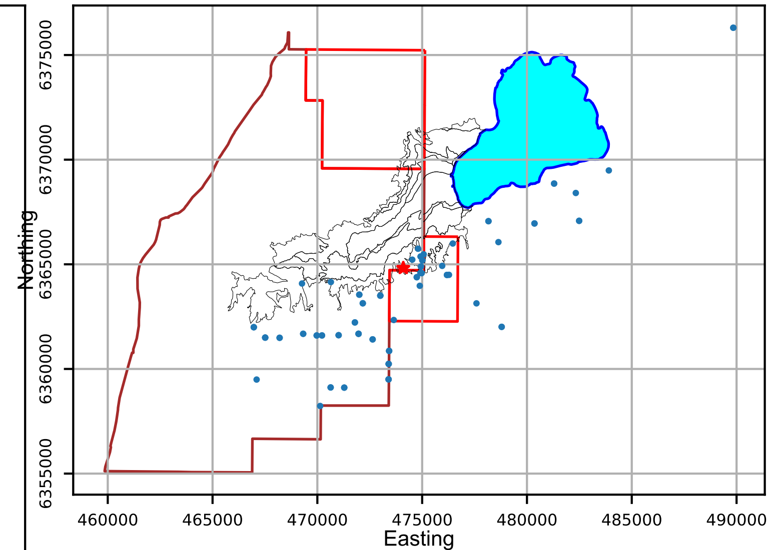
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES665-SN2 - 28.38 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-110

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

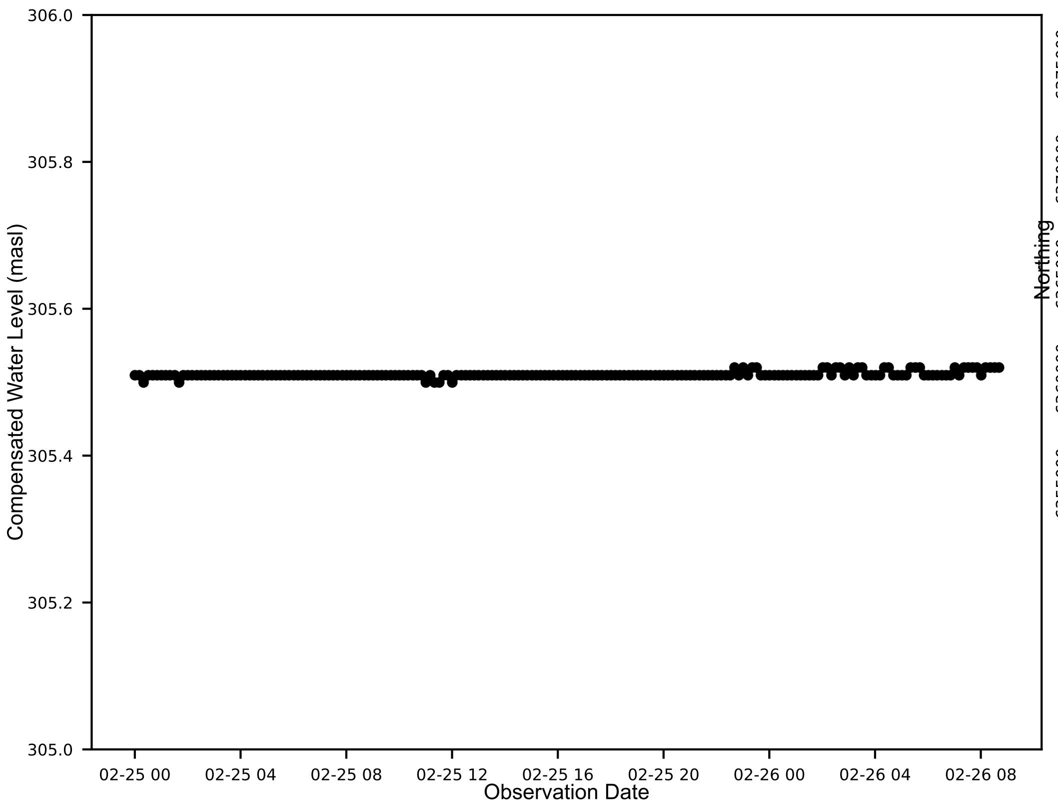
FORTHILLS
Operated by Suncor Energy

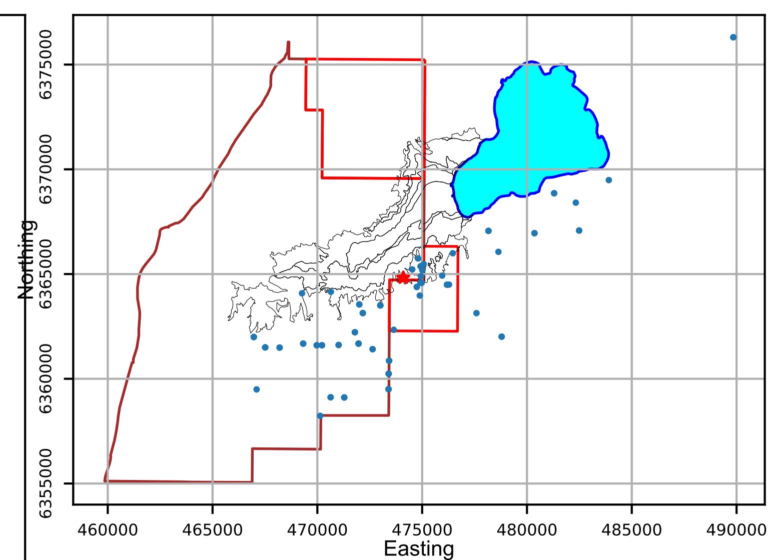
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES665-SN2 - 28.387 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-111

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 28.12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

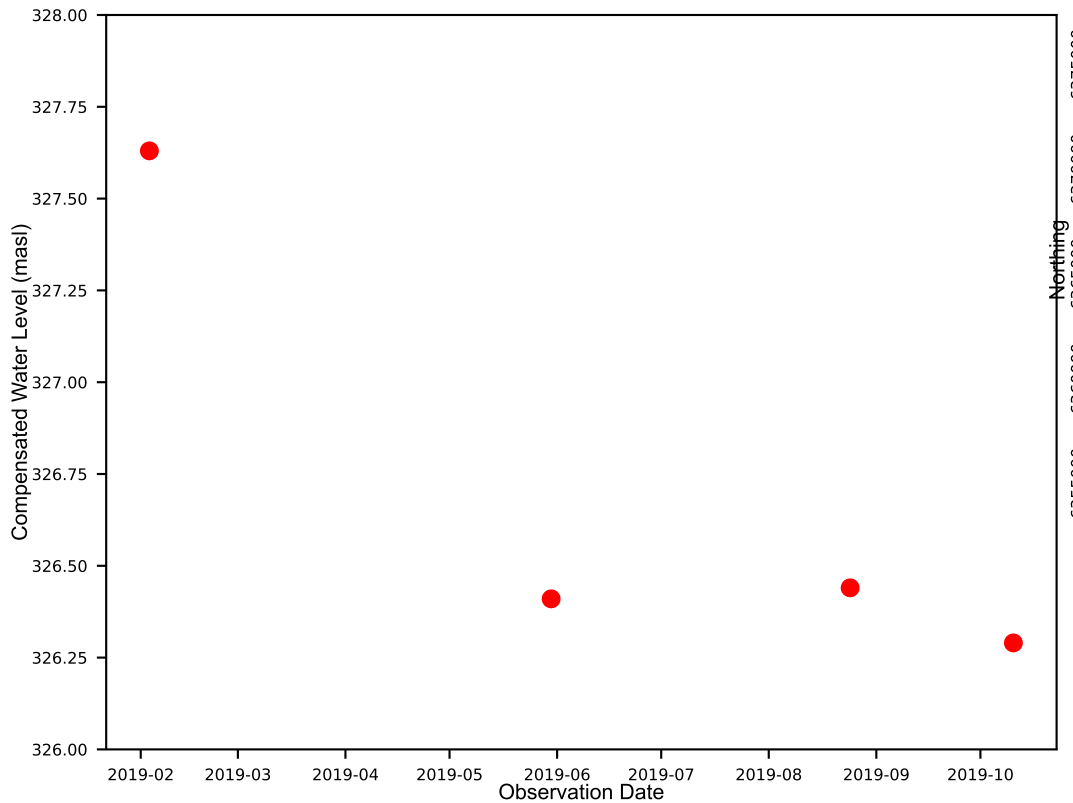
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

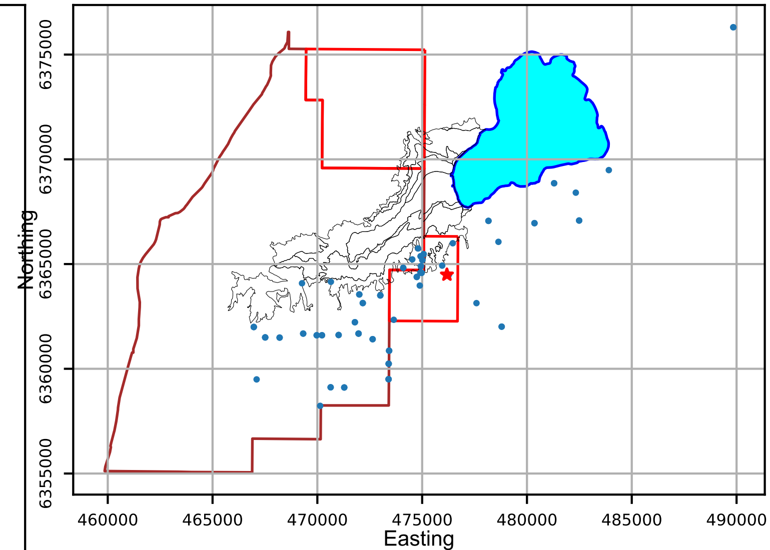
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES665-SN2 - 28.56 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-112

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 78.45 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

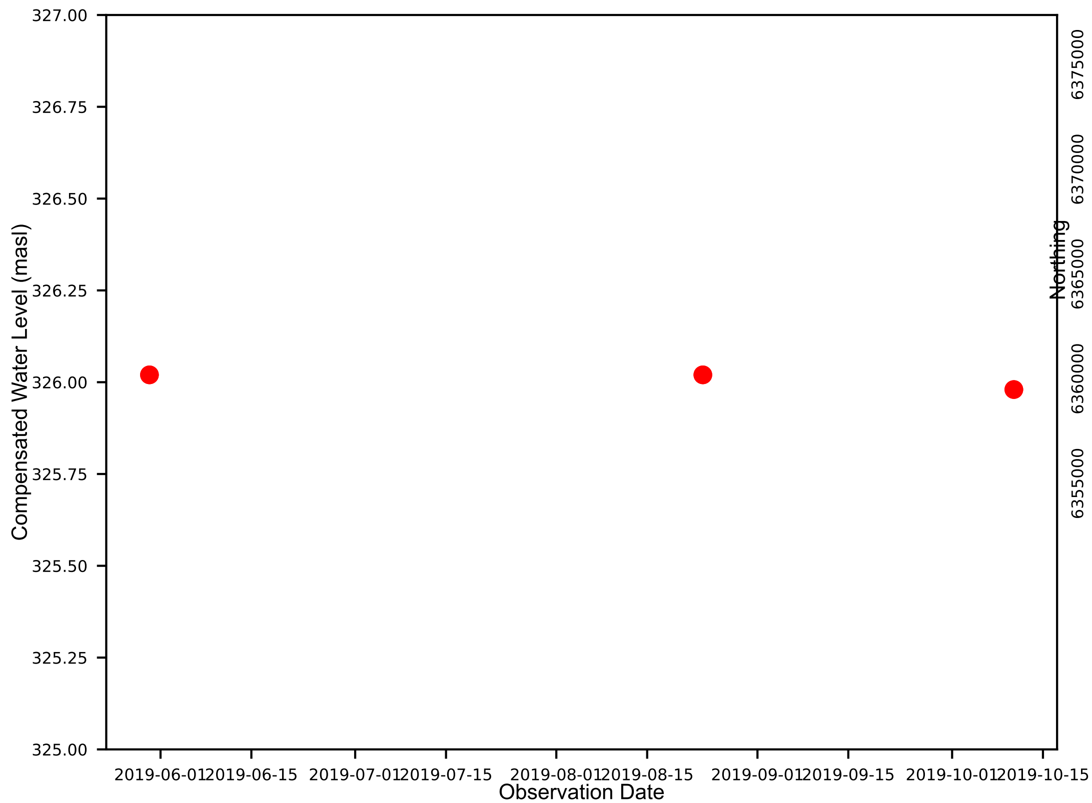
FORTHILLS
Operated by Suncor Energy

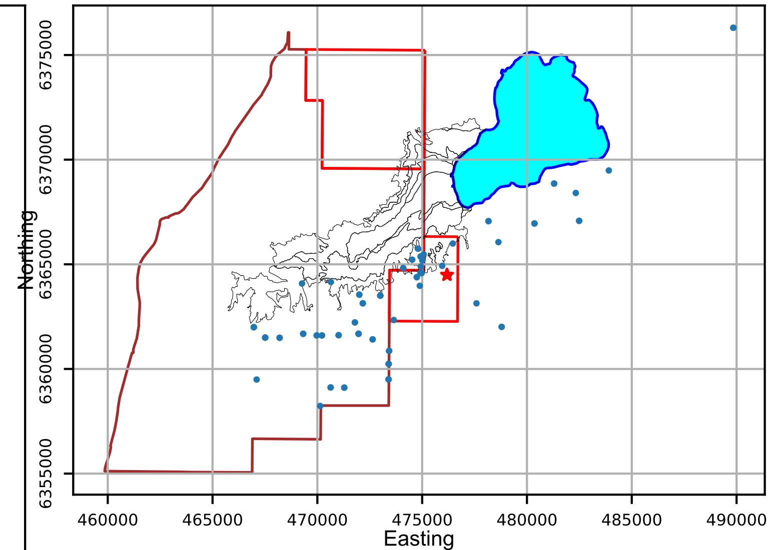
TITLE

FH19-ES670-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-113

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 30 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

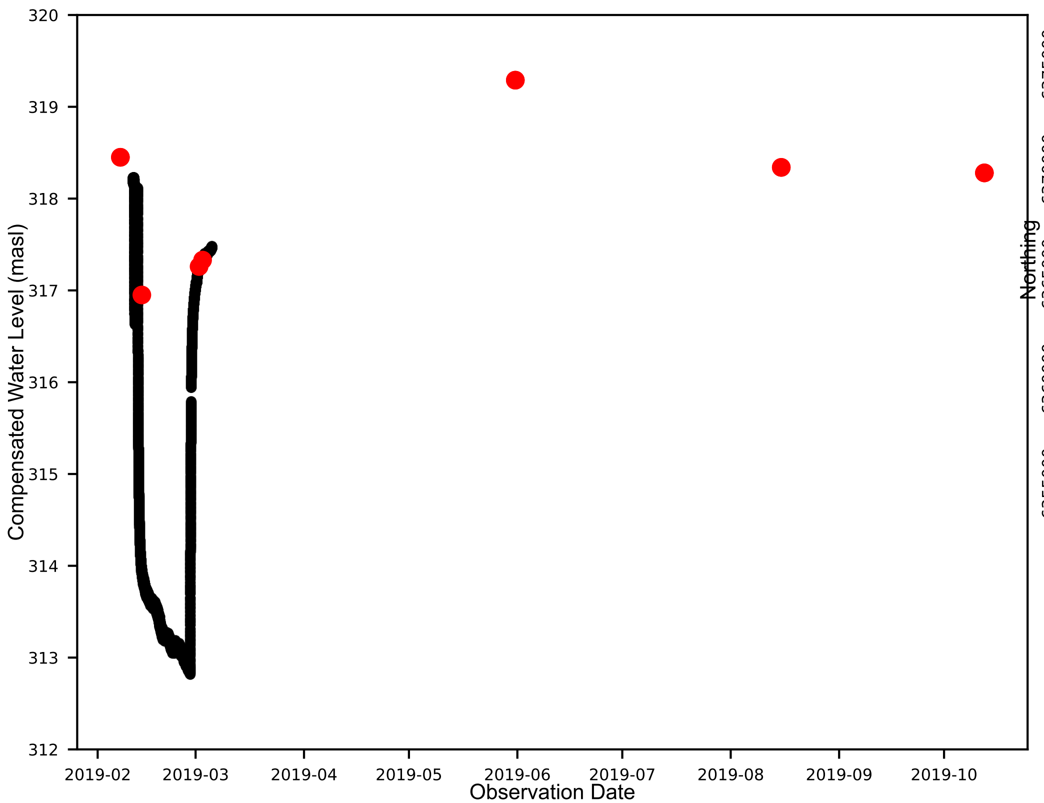
FORTHILLS
Operated by Suncor Energy

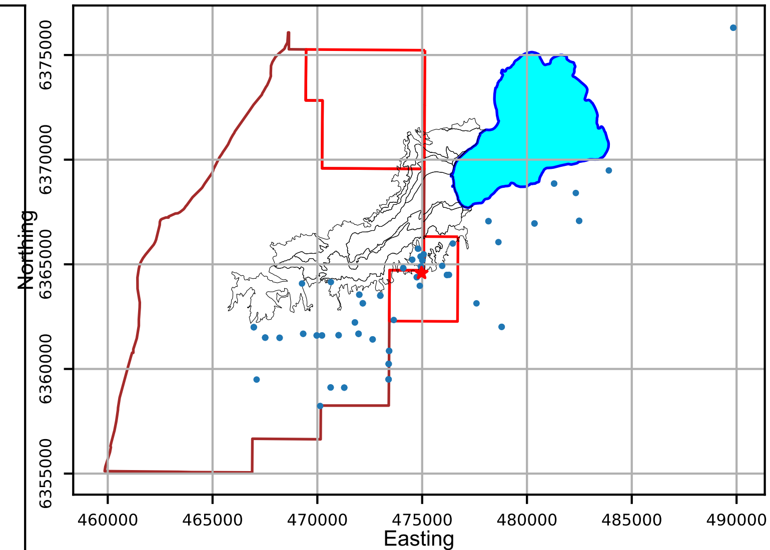
TITLE
FH19-ES670-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-114

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 53.38 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

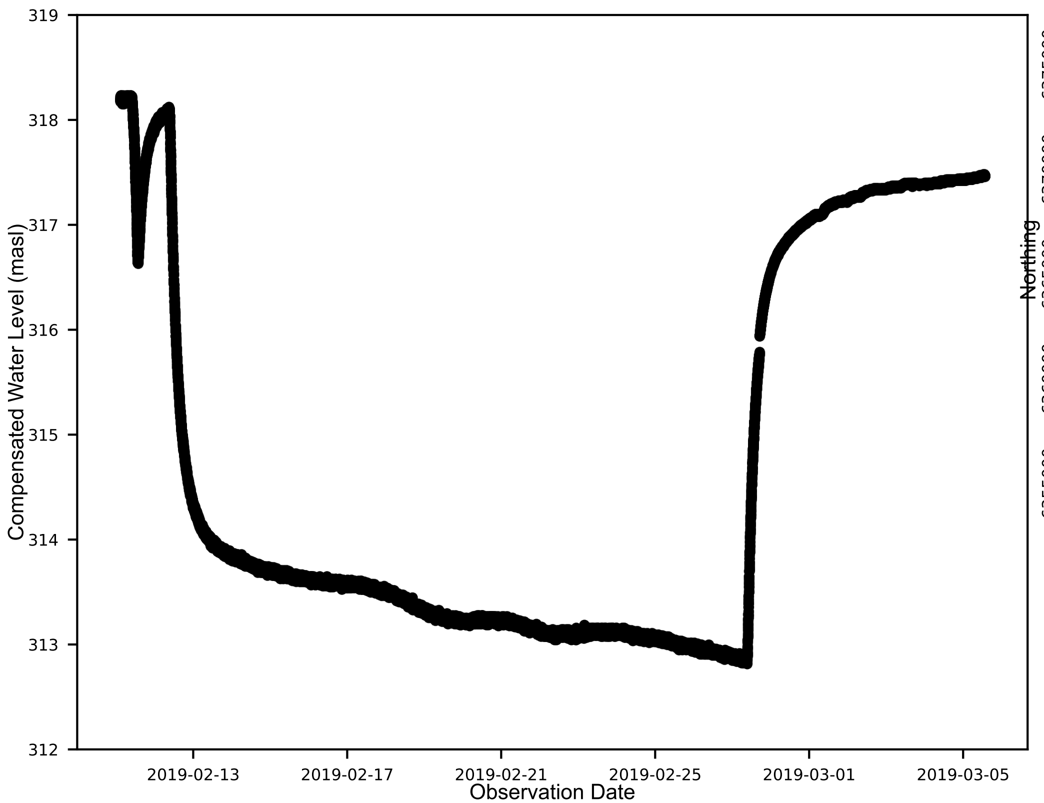
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

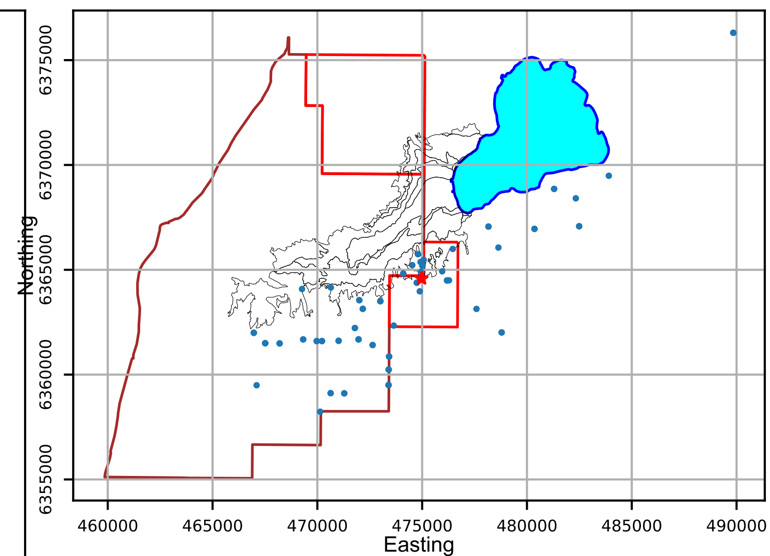
TITLE

FH19-ES672-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-115

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 53.38 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

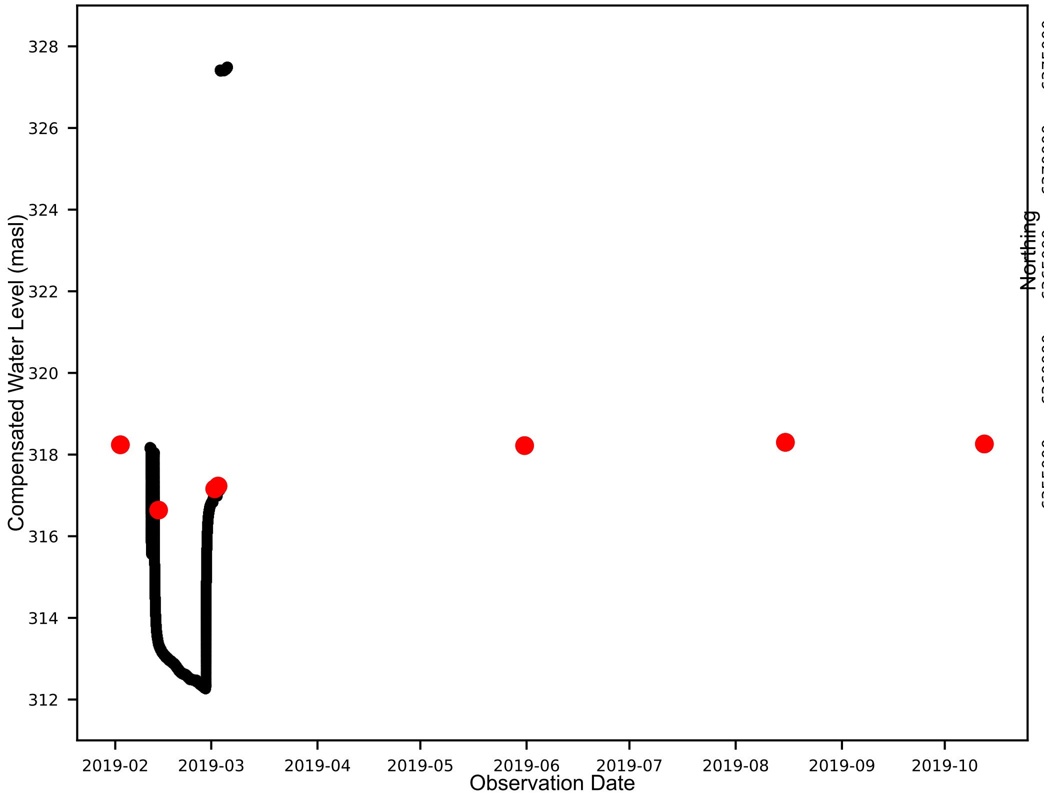
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

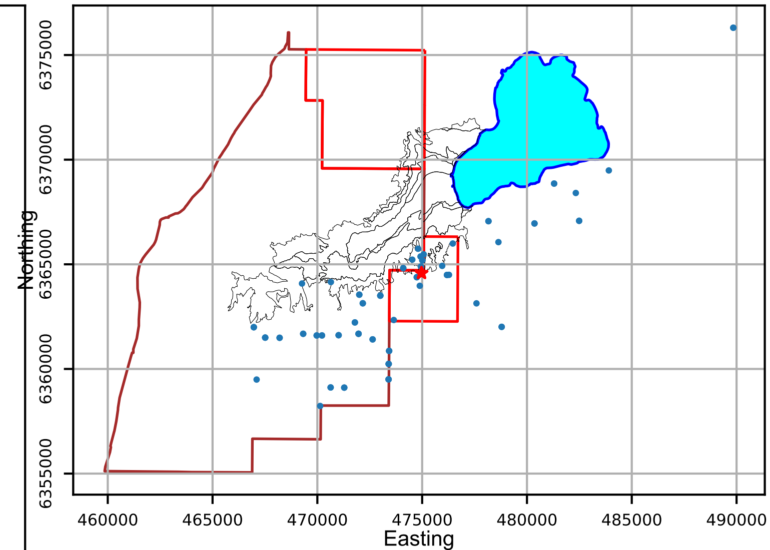
FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES672-SN1 - 48.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-116

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 39.45 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

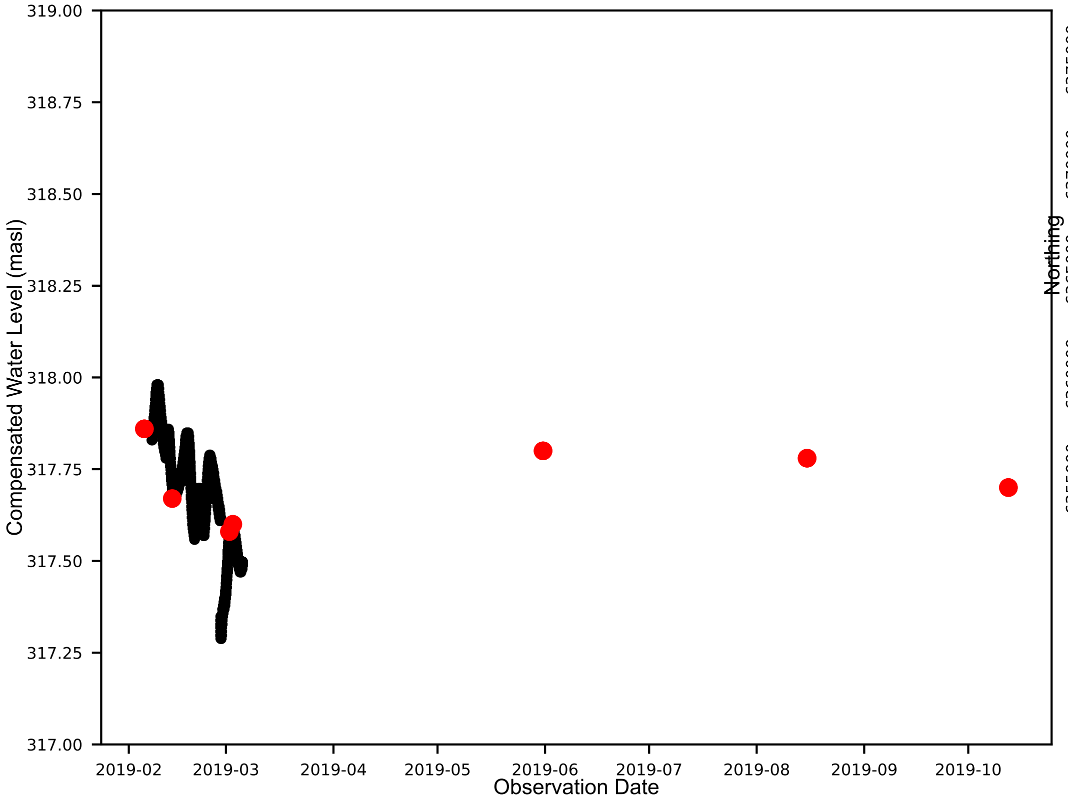
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

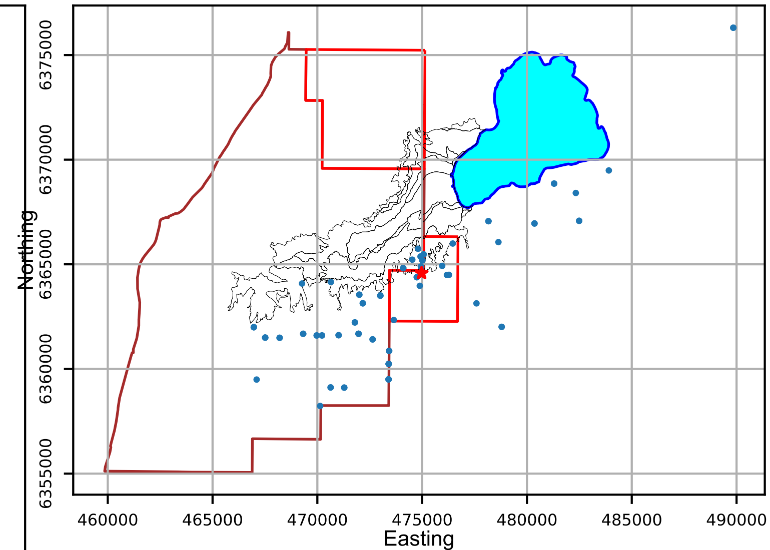
TITLE

FH19-ES672-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-117

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 18.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

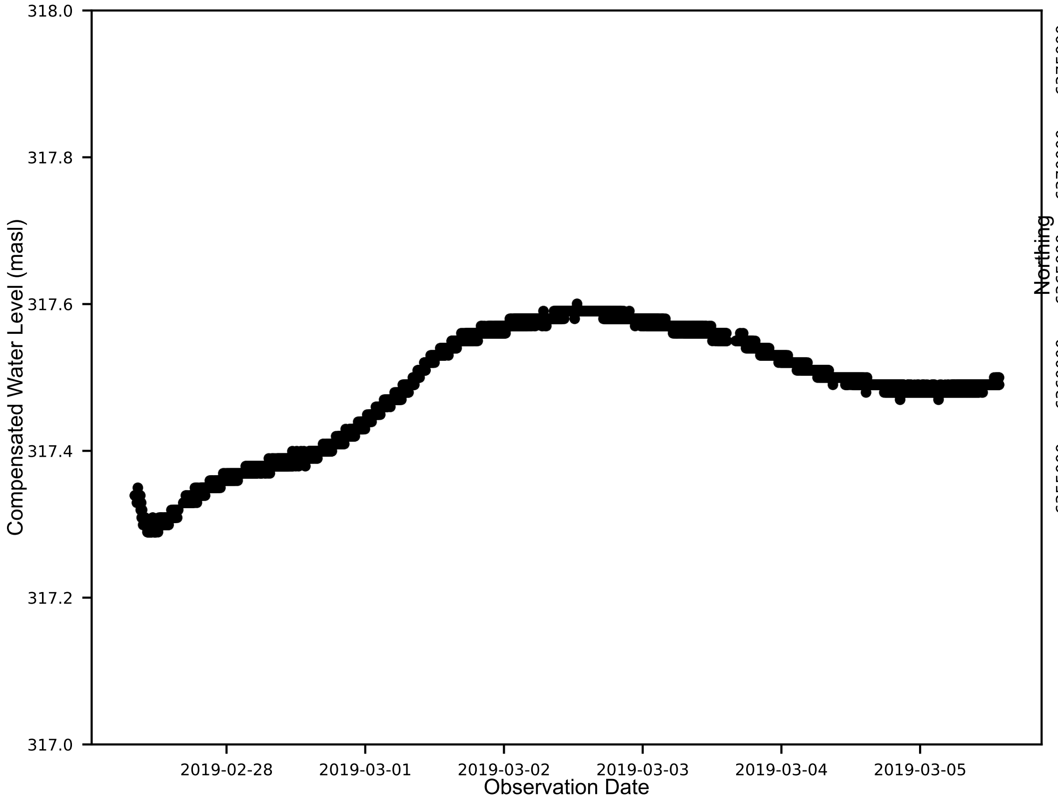
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

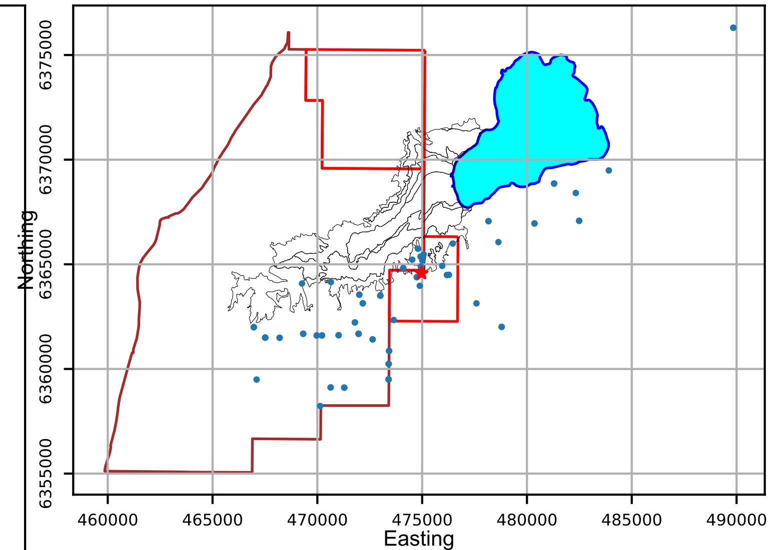
TITLE
FH19-ES672-SN3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-118

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 18.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

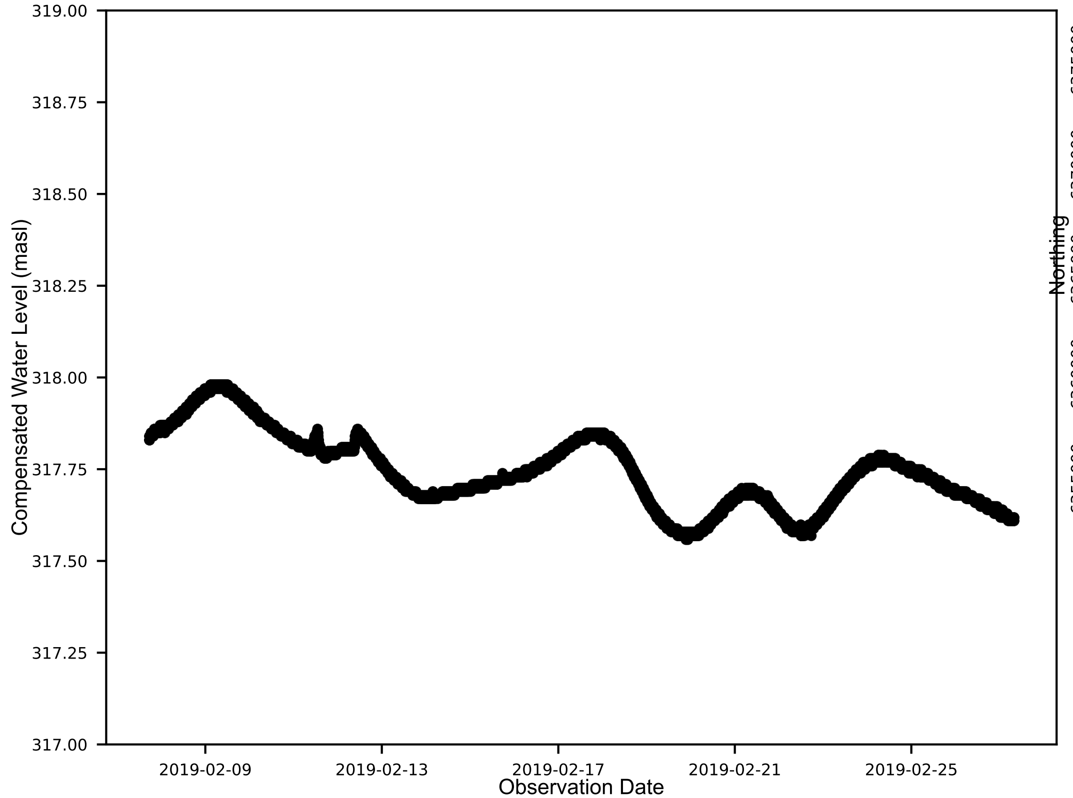
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

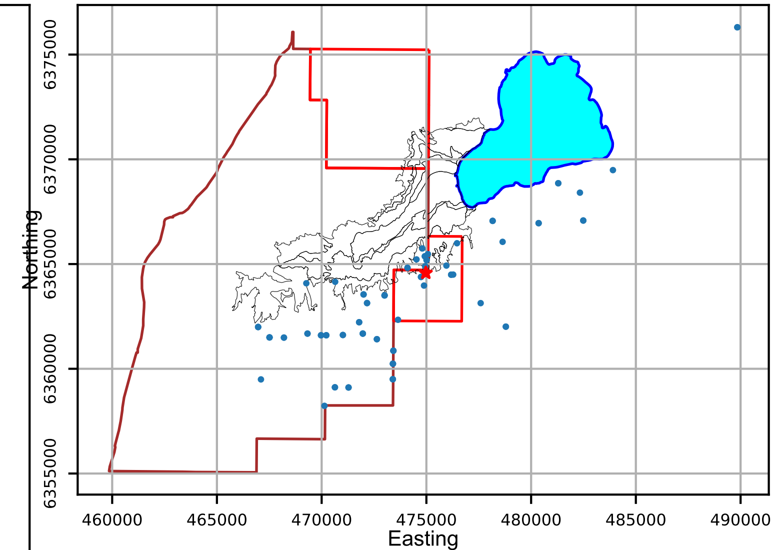
FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES672-SN3 - 18.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-119

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 01 Peat
Depth of Measurement: 18.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

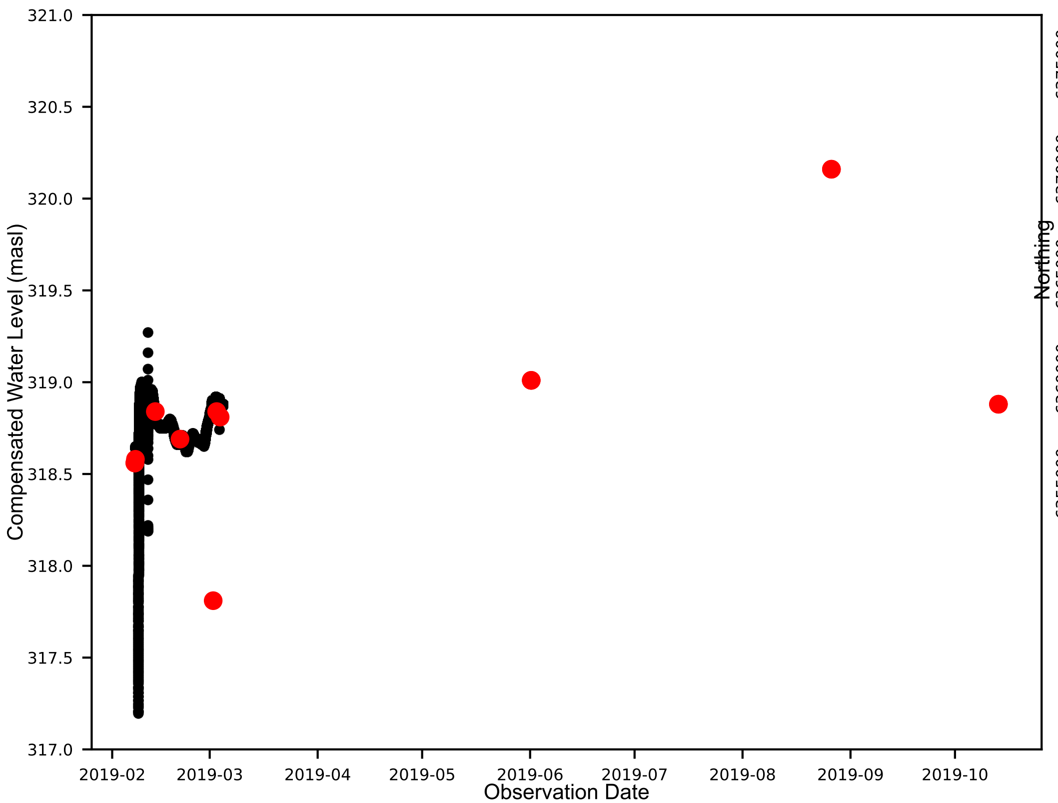
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

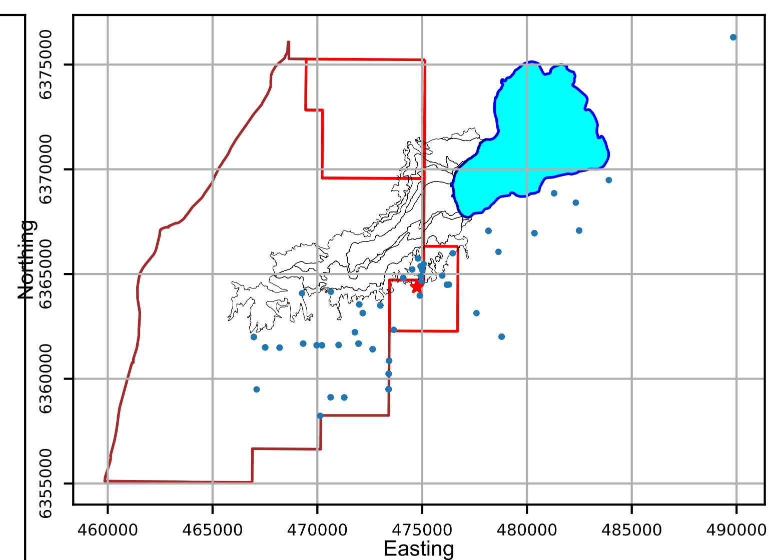
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES672-SN3 - 18.37 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-120

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

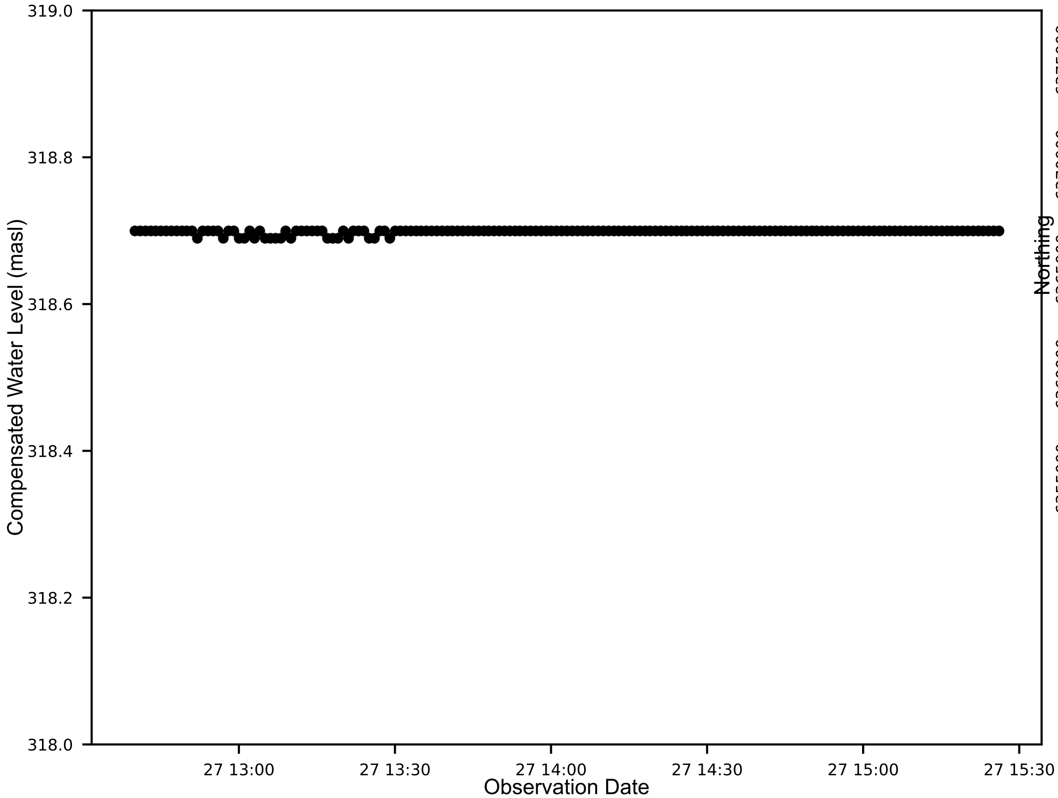
FORT HILLS
Operated by Suncor Energy

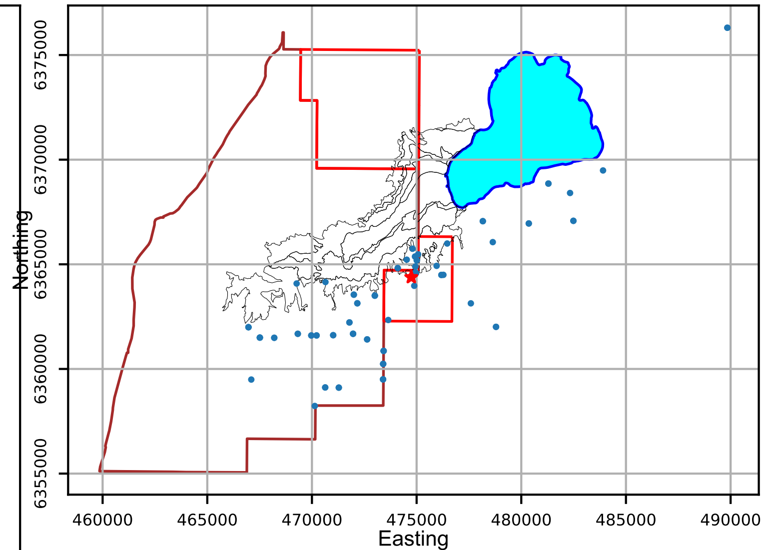
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES678-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-121

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH19-ES678-SN1 - 17.085 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-122

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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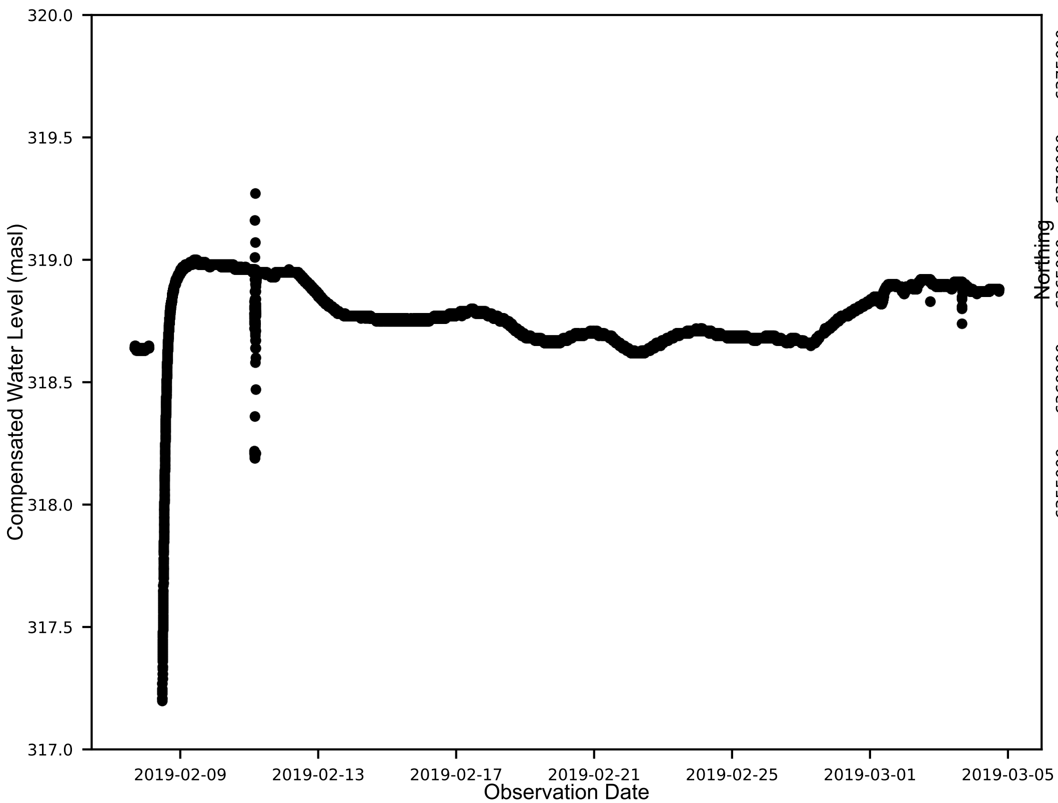

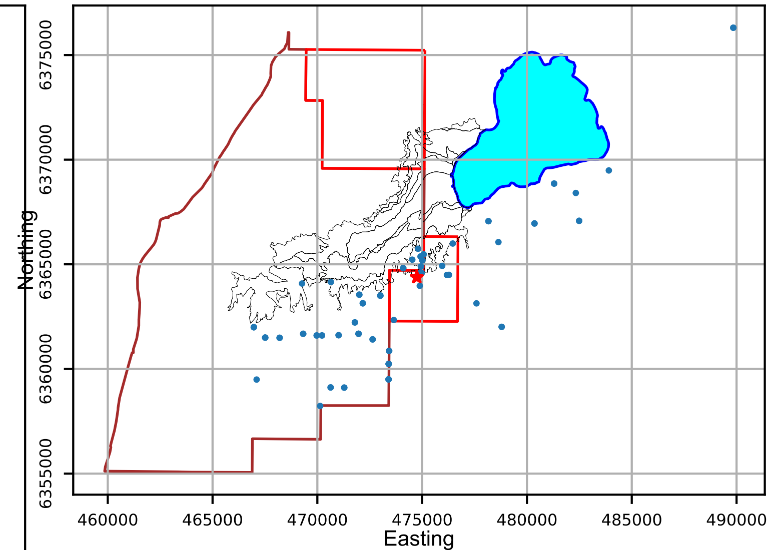

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES678-SN1 - 17.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-123

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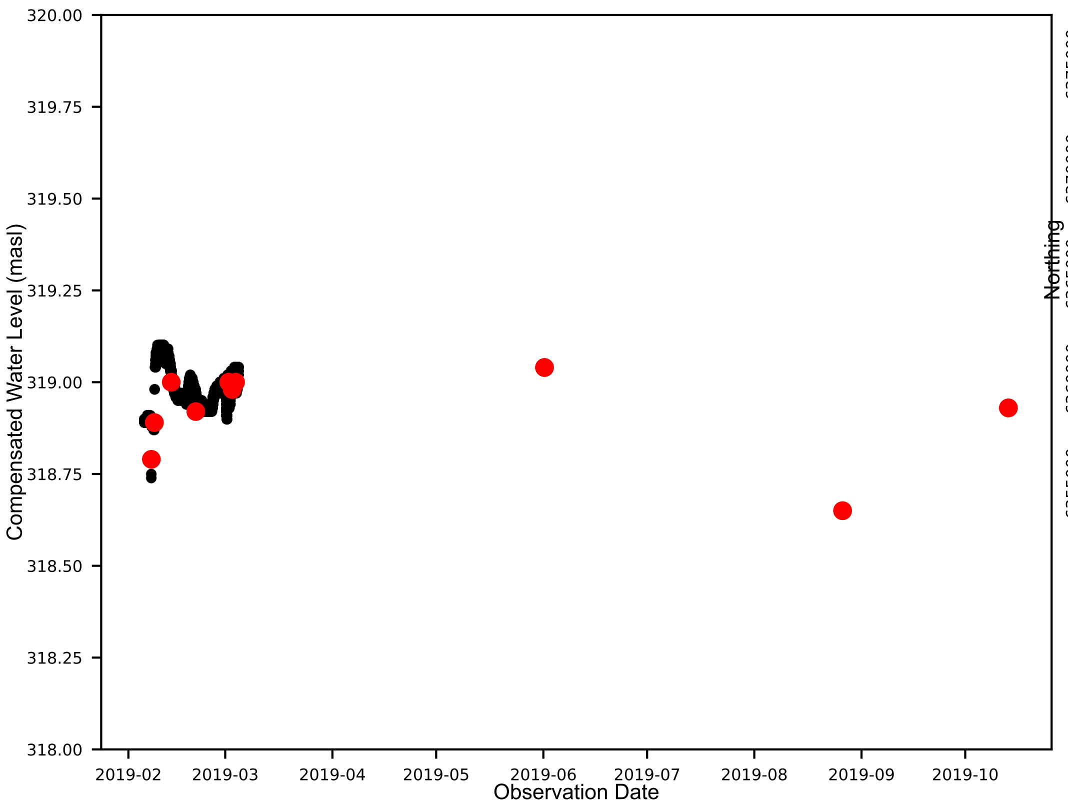
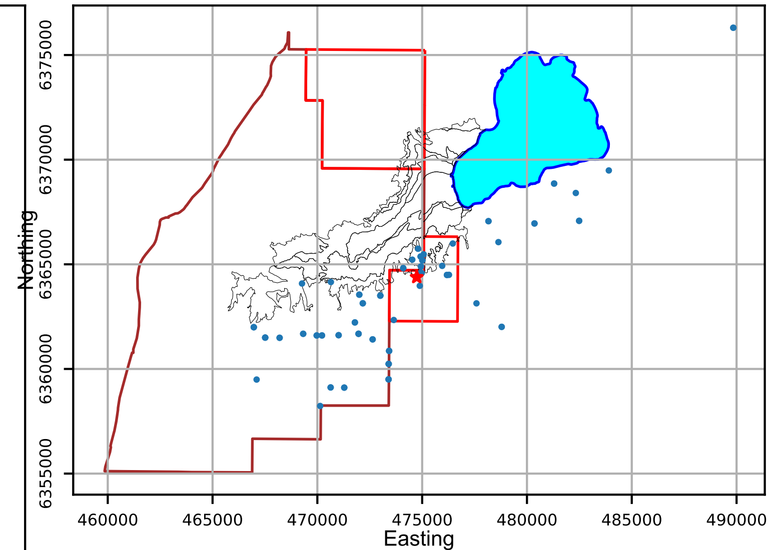




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 37.32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

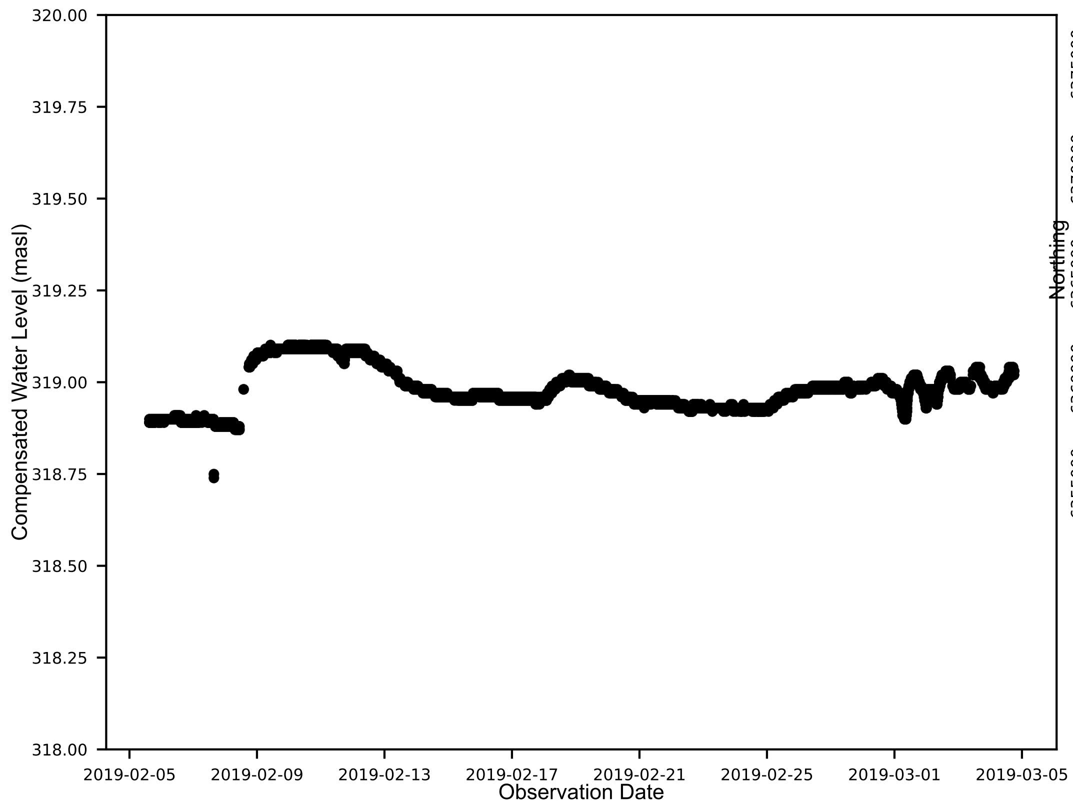
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

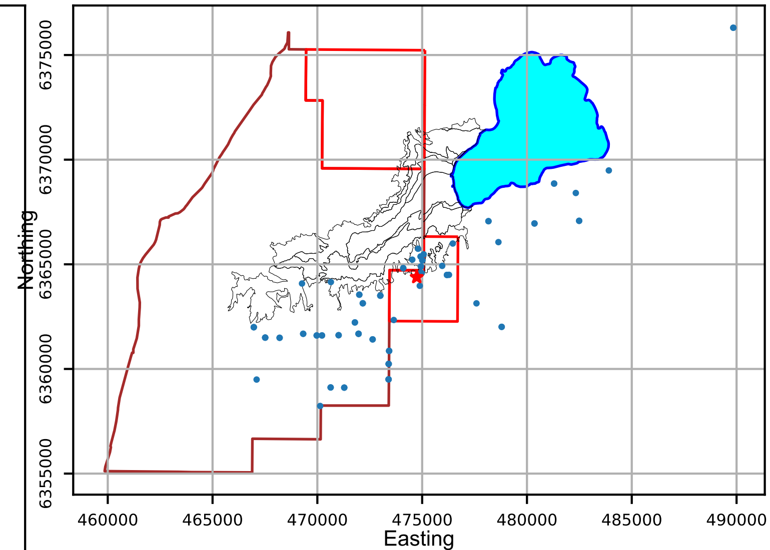
TITLE

FH19-ES678-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-124

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 37.32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

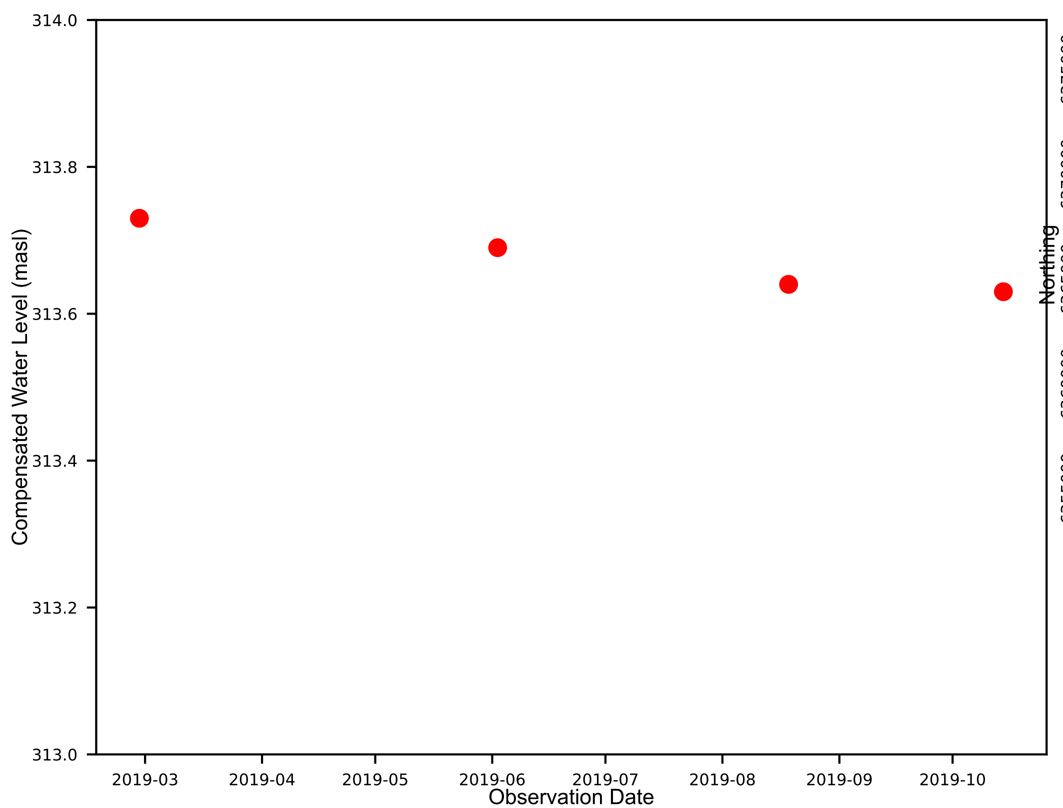
TITLE

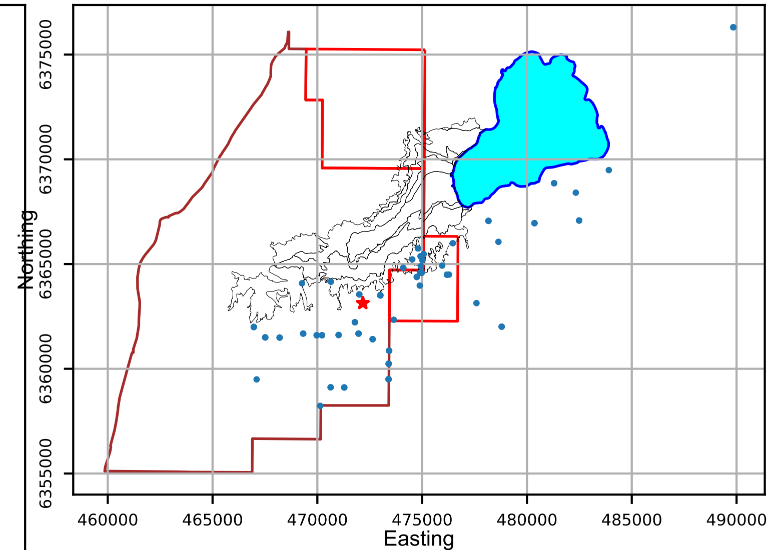
FH19-ES678-SN2 - 16.55 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-125

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 19.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

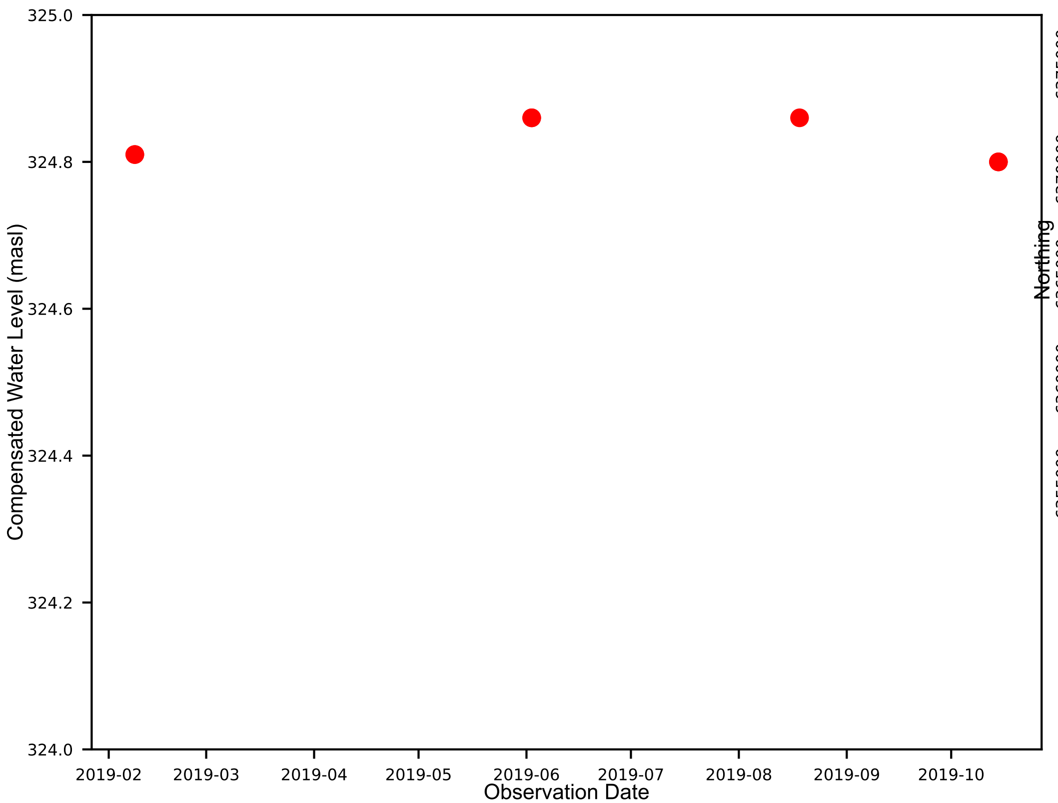
FORTHILLS
Operated by Suncor Energy

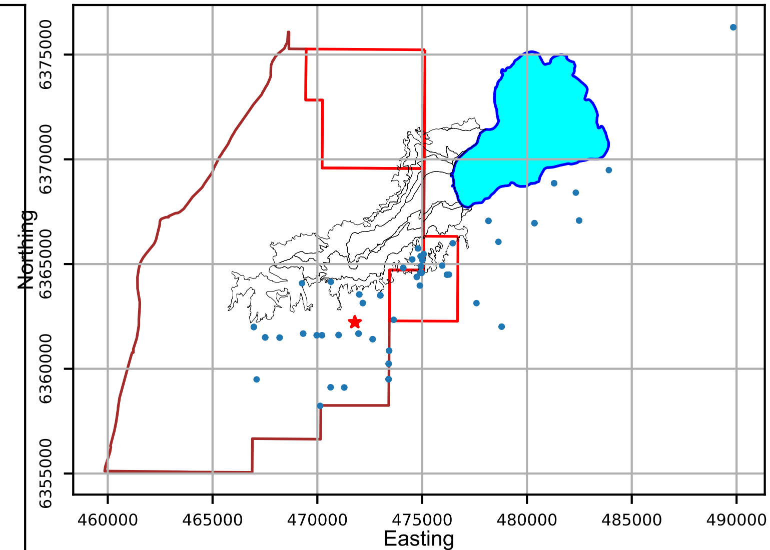
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES700-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-126

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 64 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES706-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-127

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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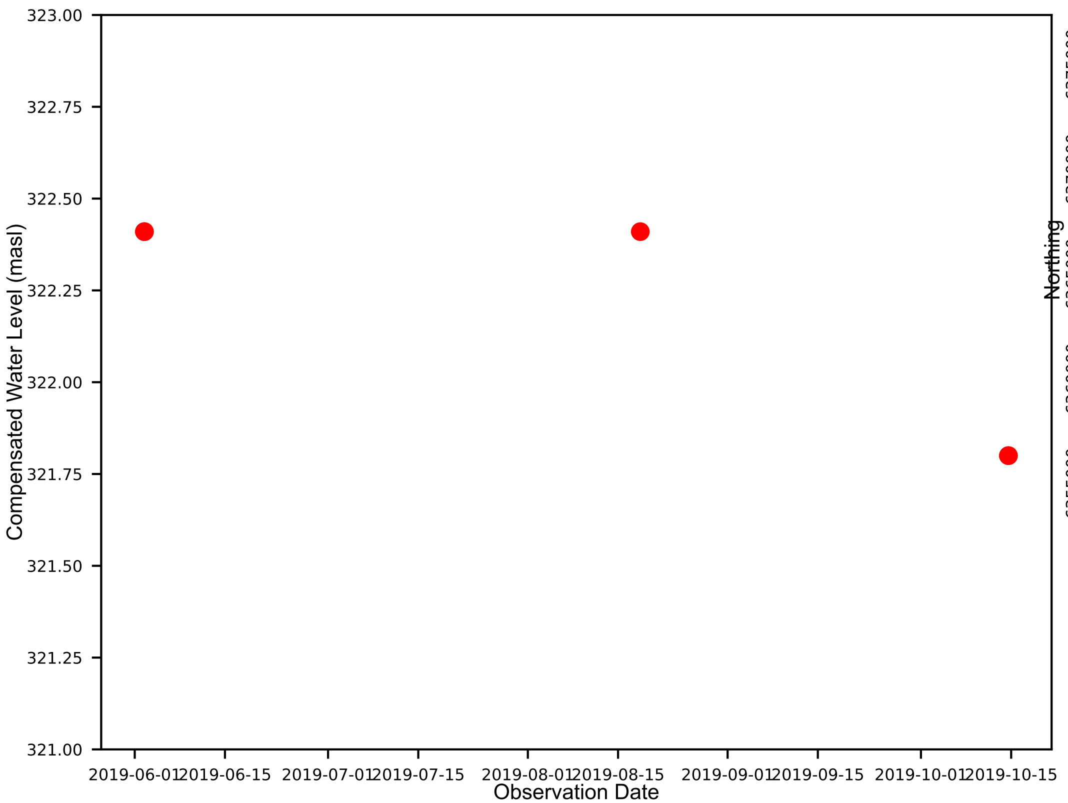

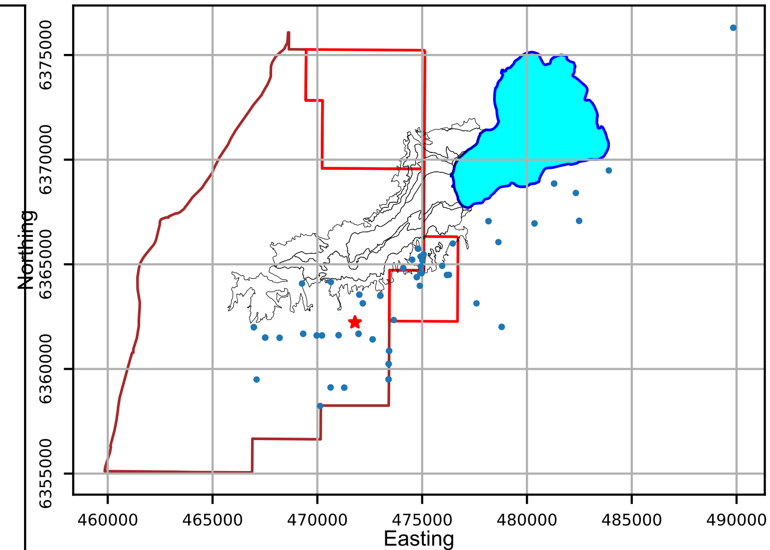

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 25 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES706-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
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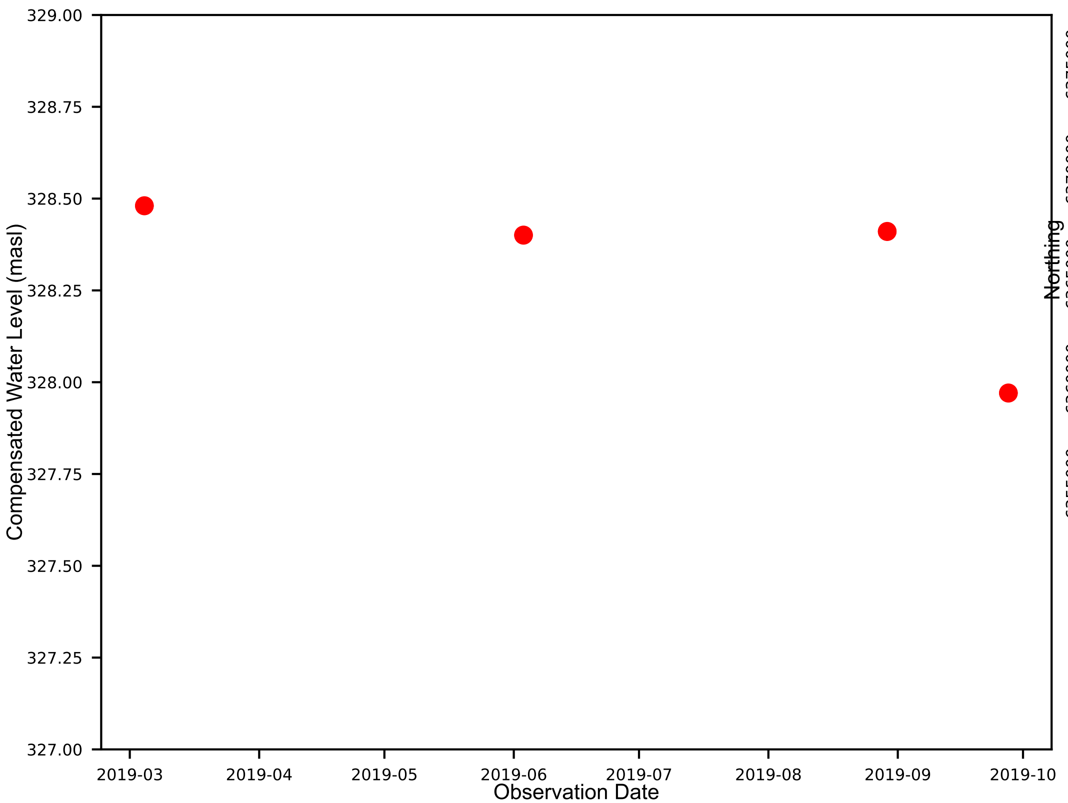

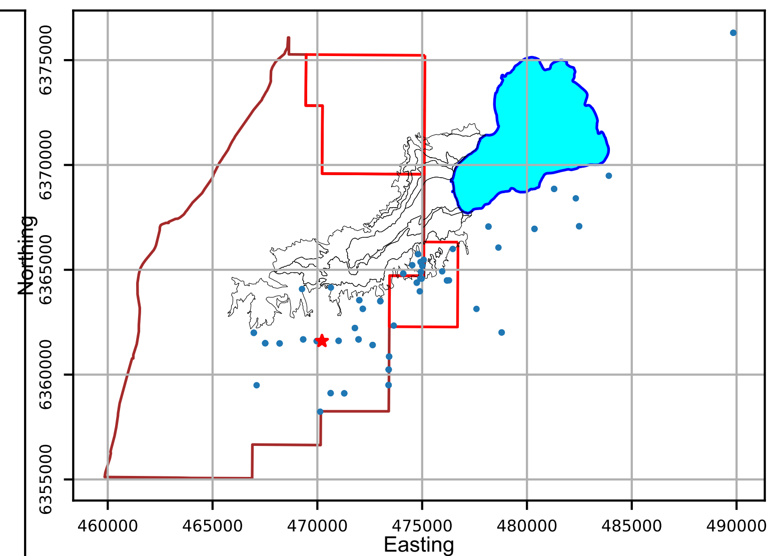

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 30.25 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES709-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-129

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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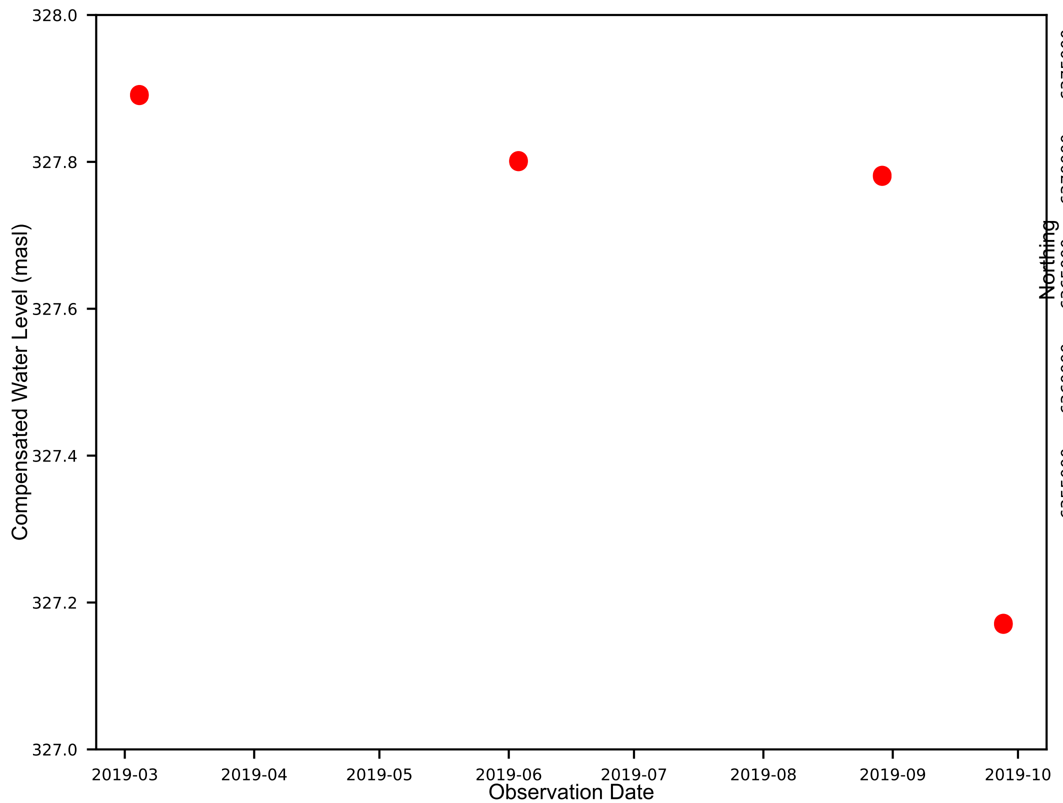

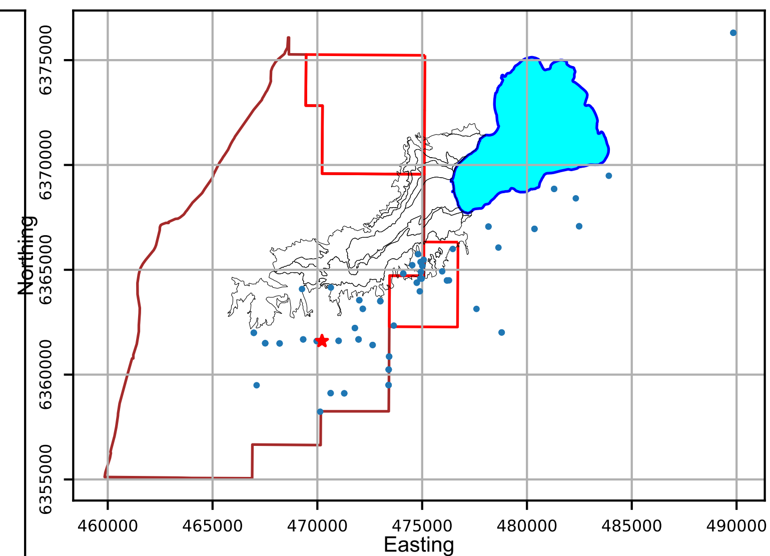

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 17.08 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES709-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-130

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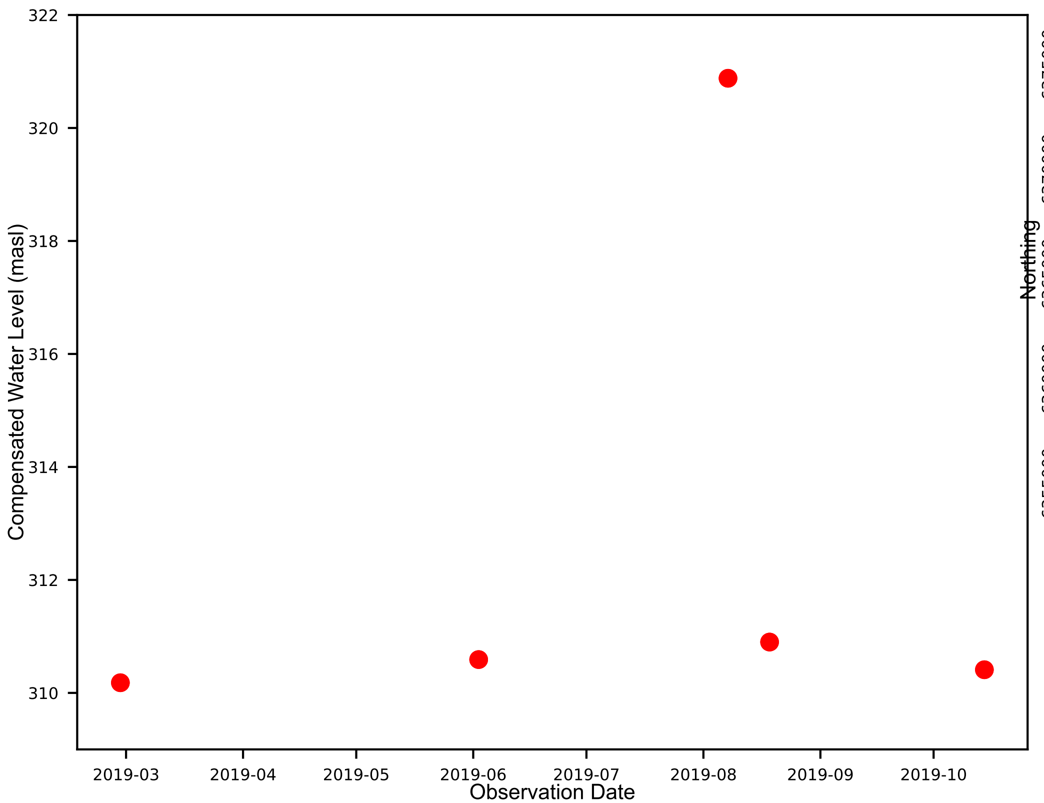

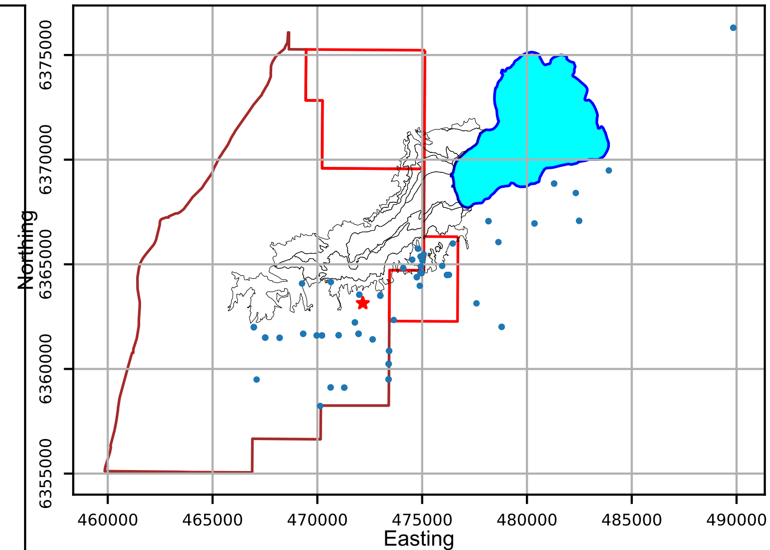

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 50.37 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL700-SN3

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-131

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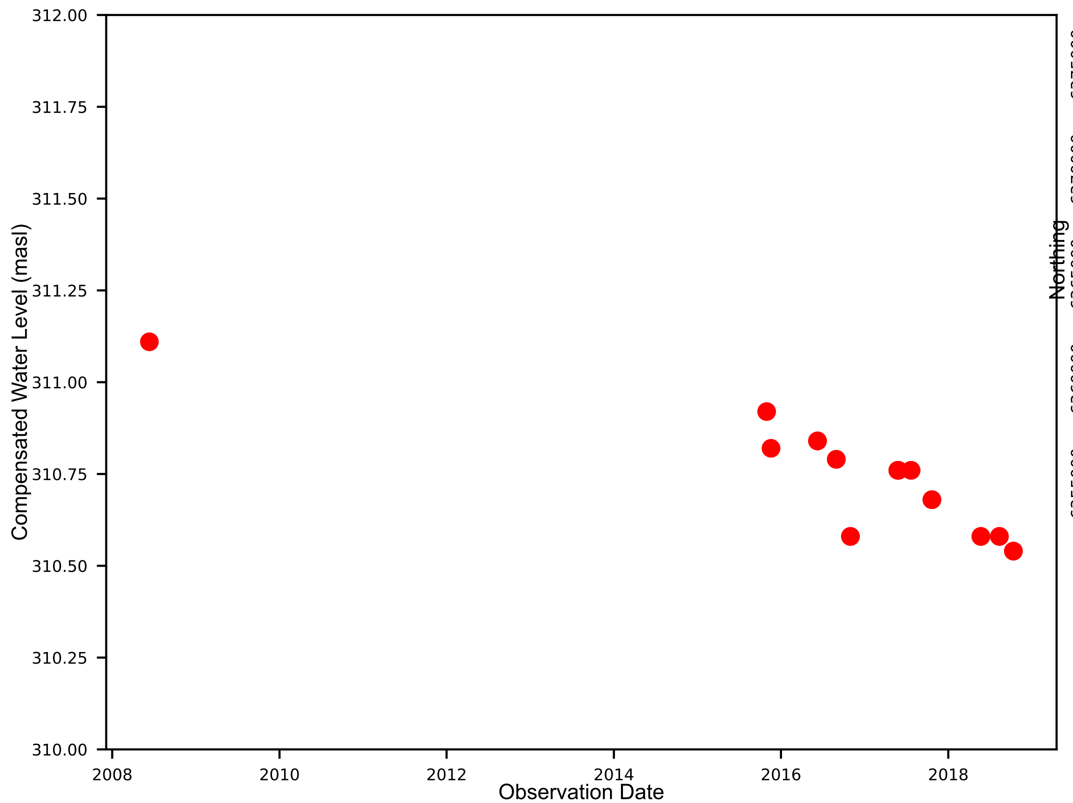
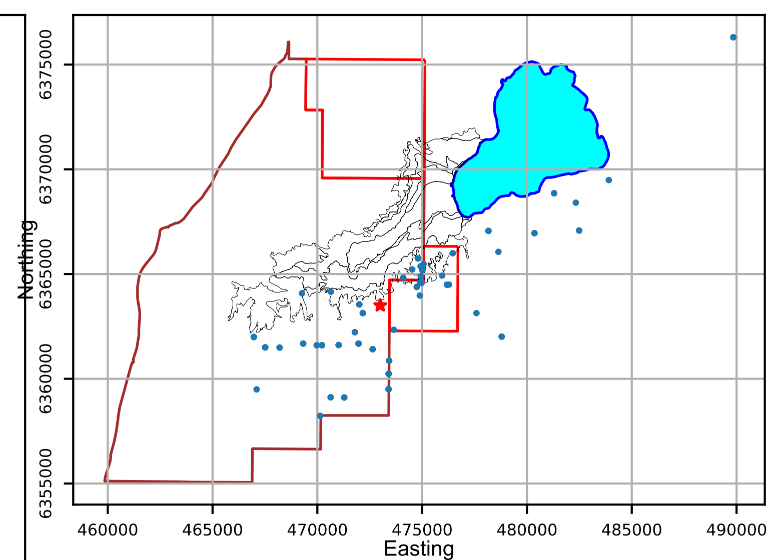




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 36.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

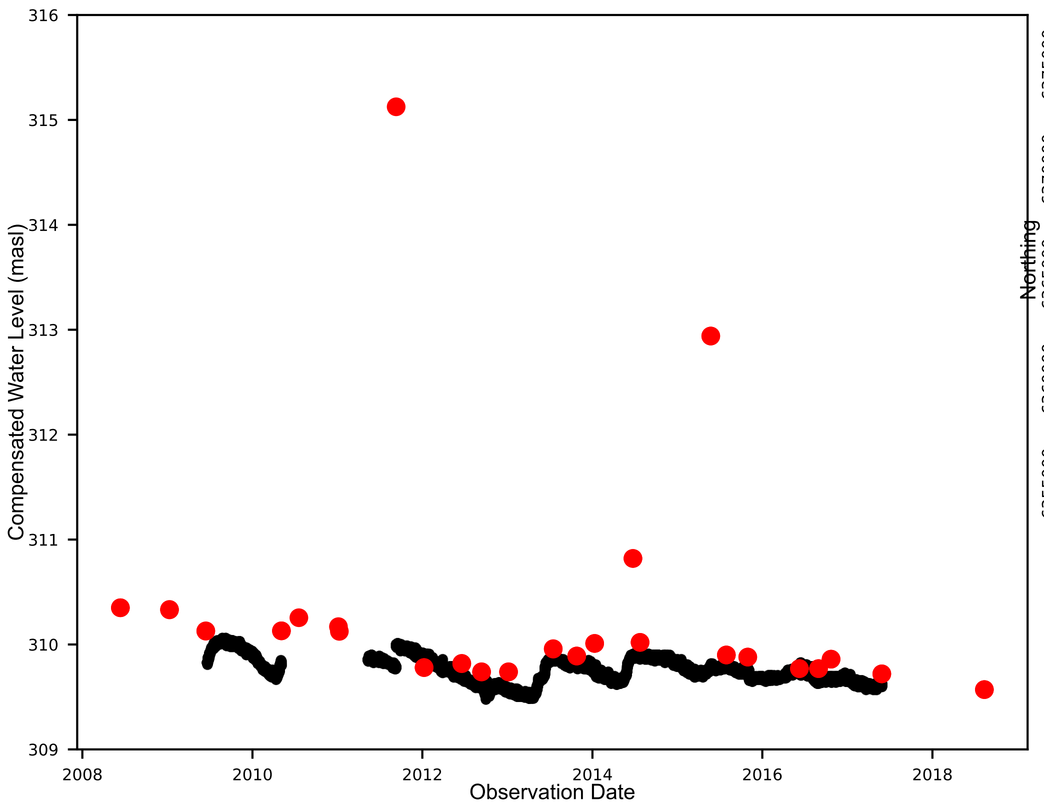
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

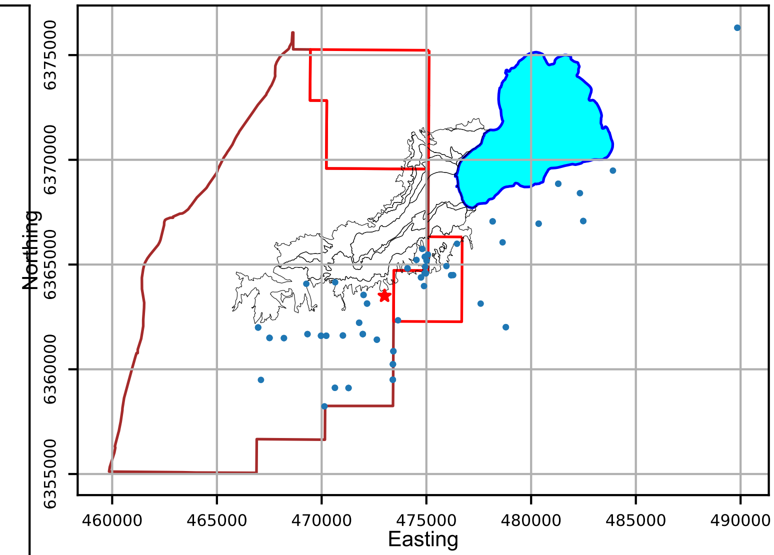
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-097A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-132





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 17.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

GT07-097B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-133

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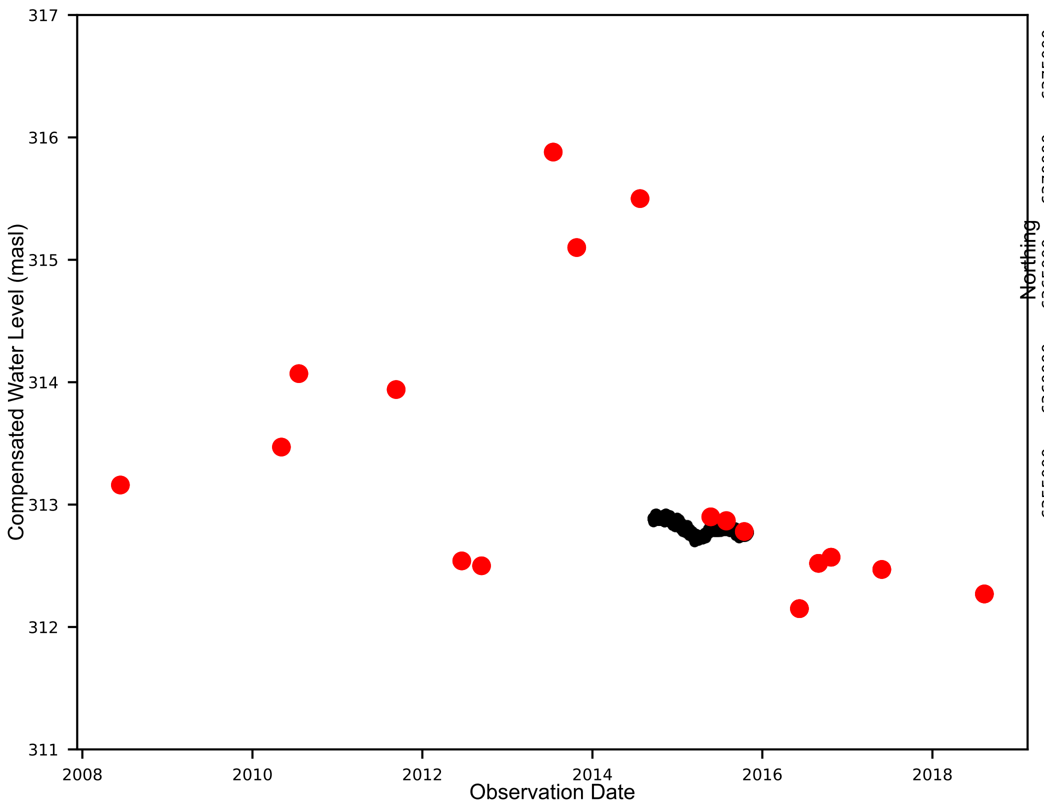
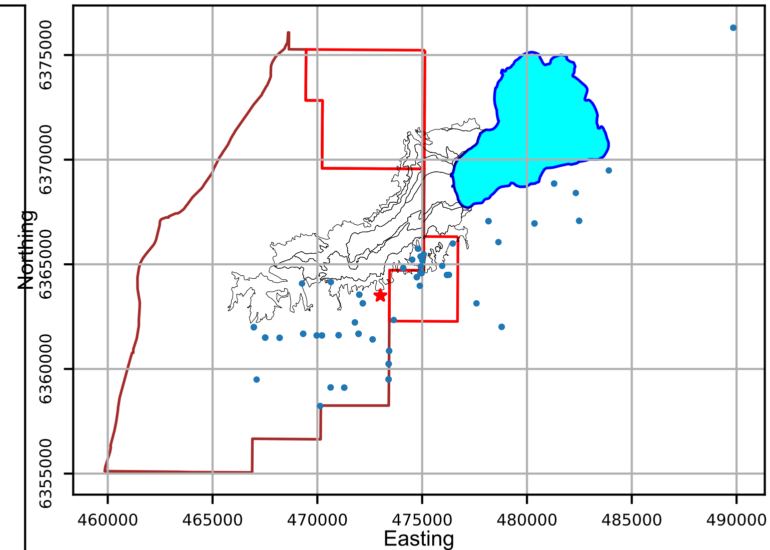




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 6.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

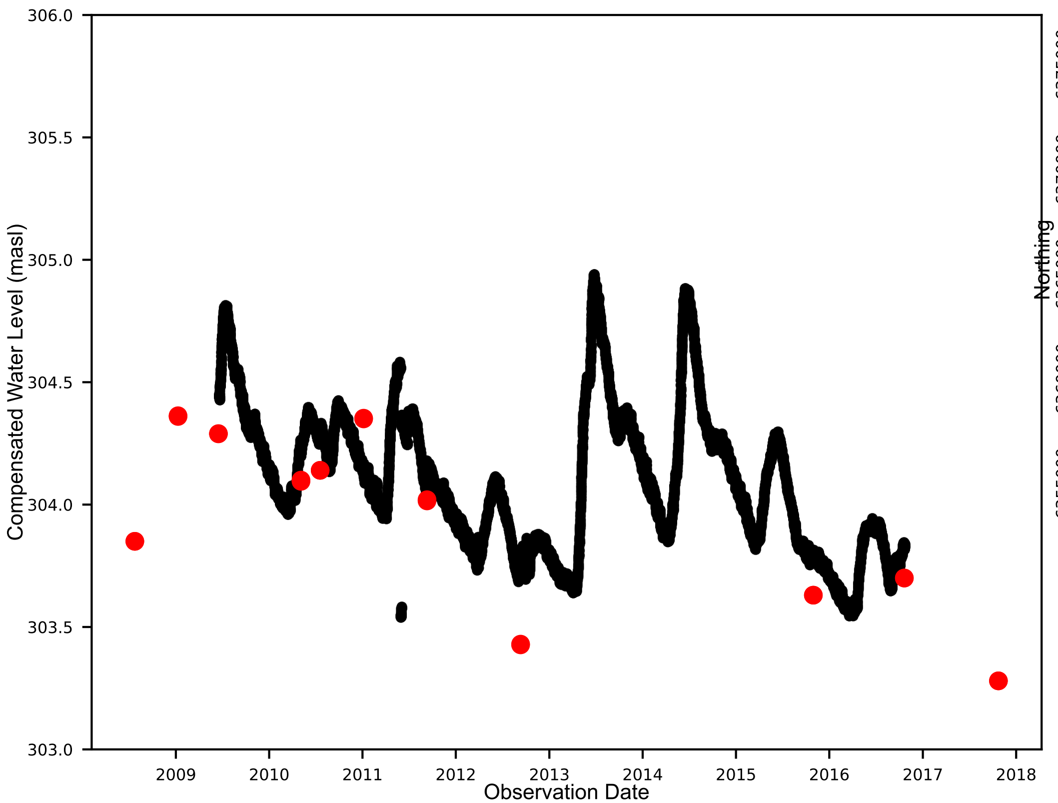
FORTHILLS
Operated by Suncor Energy

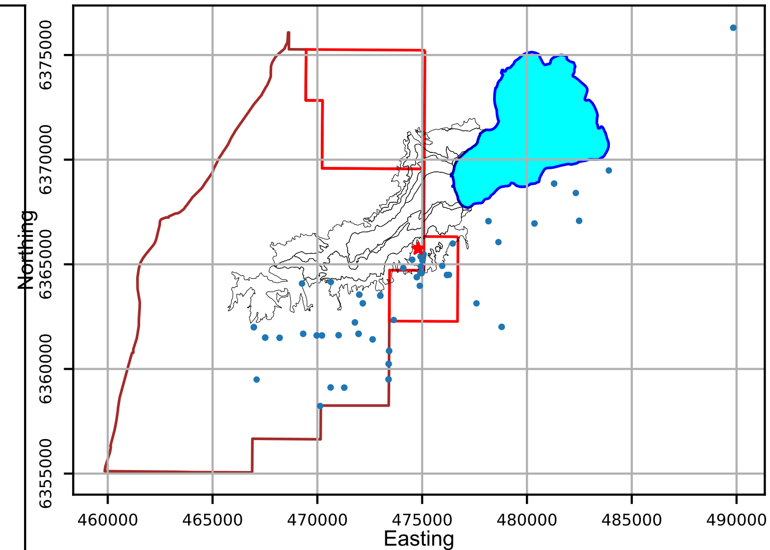
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-097C

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-134

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 26 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-100A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-135

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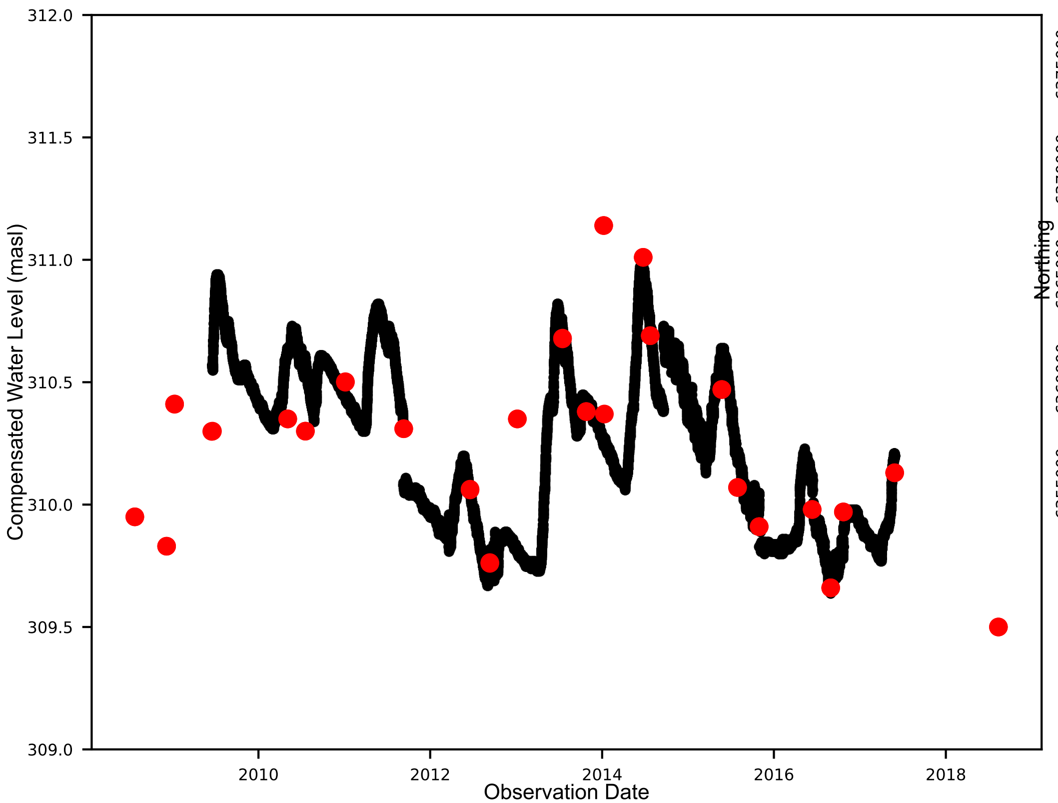

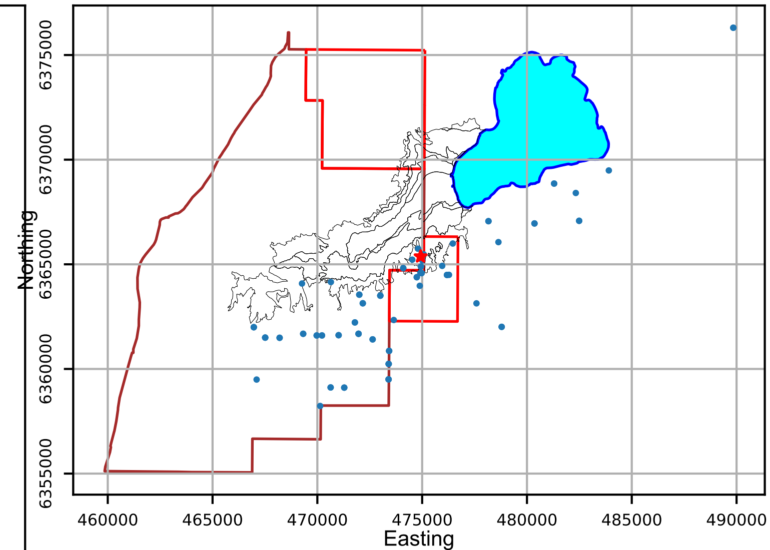

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 34.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-101A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-136

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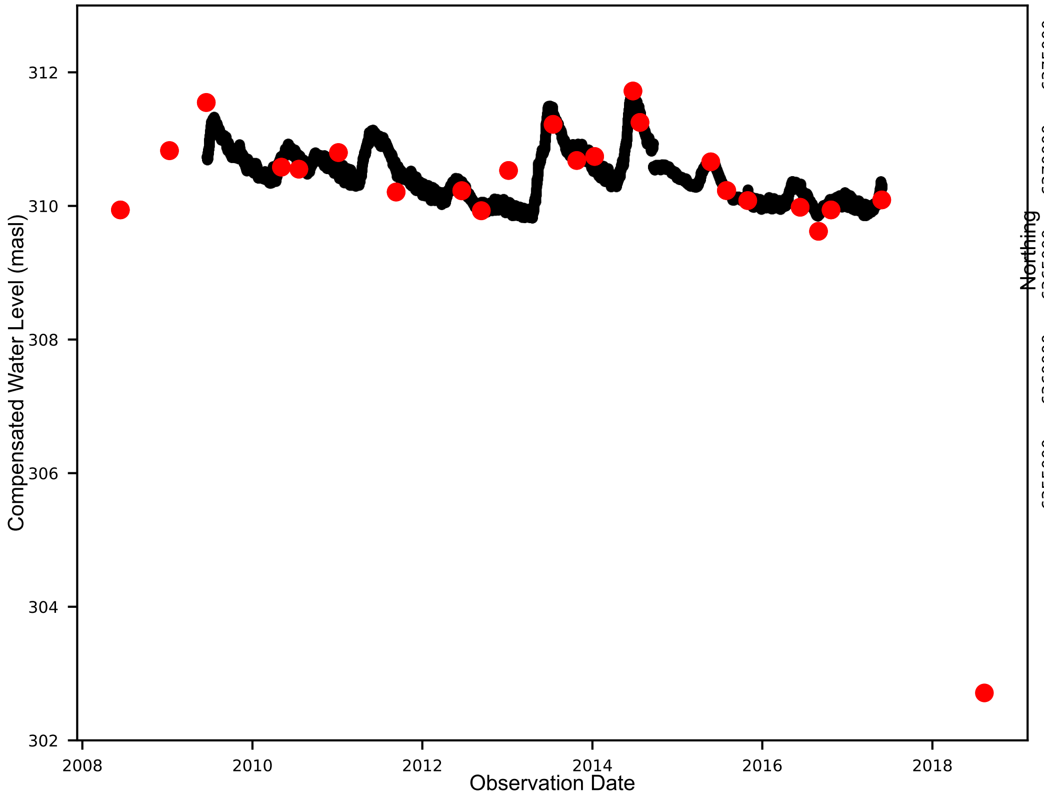

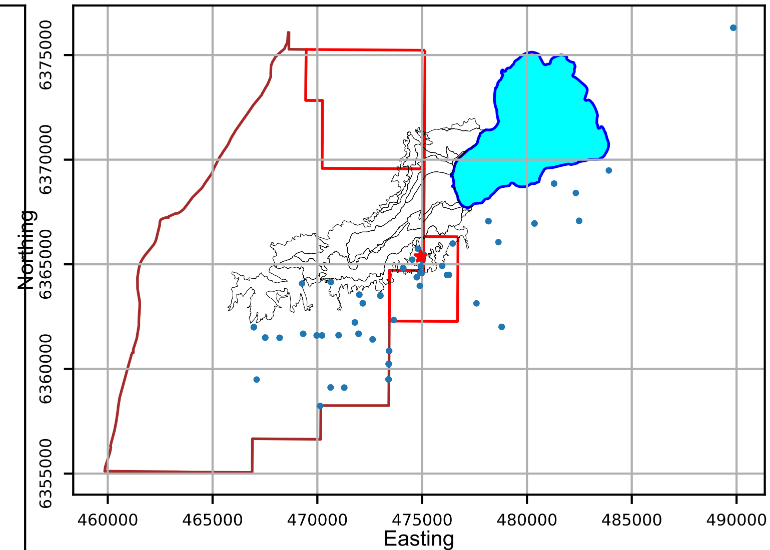

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 13.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-101B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-137

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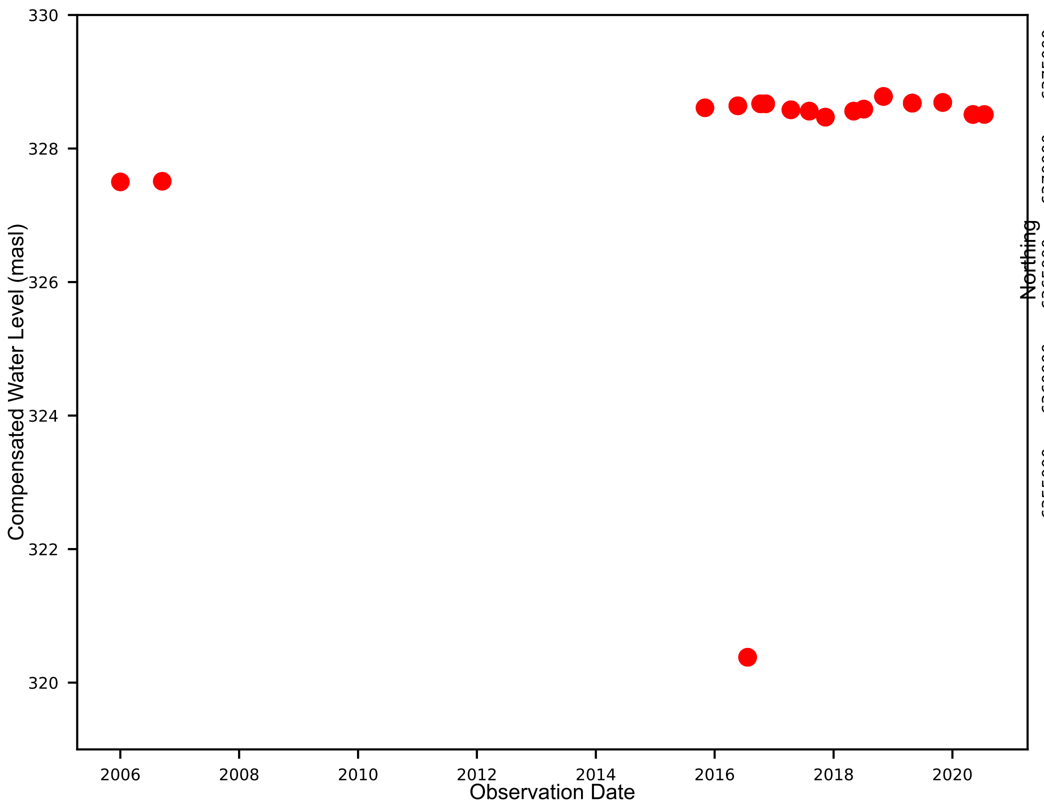

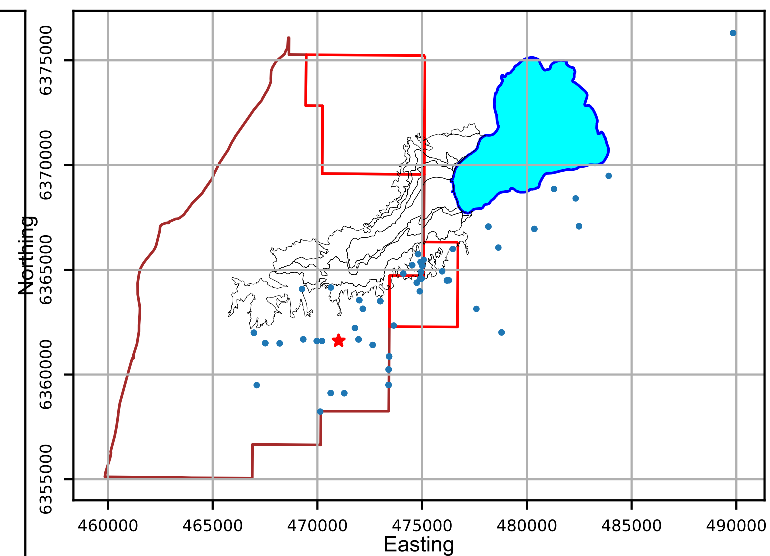

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 54.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

MW-06-076-A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-138

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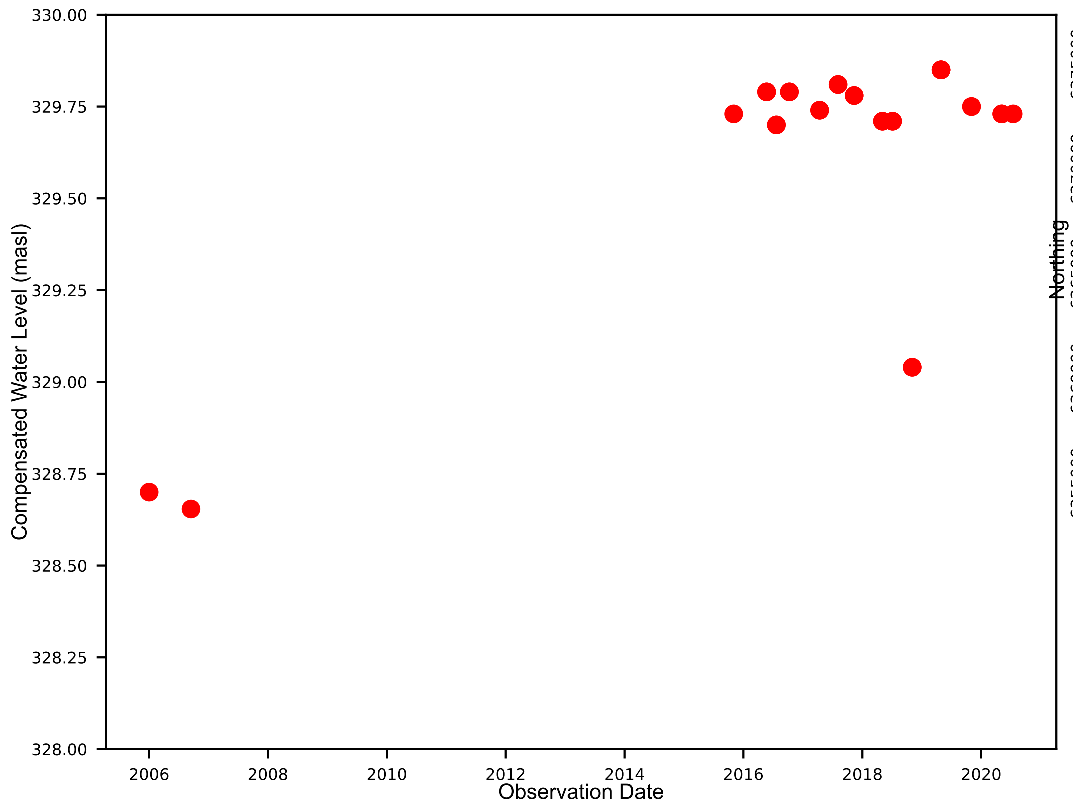

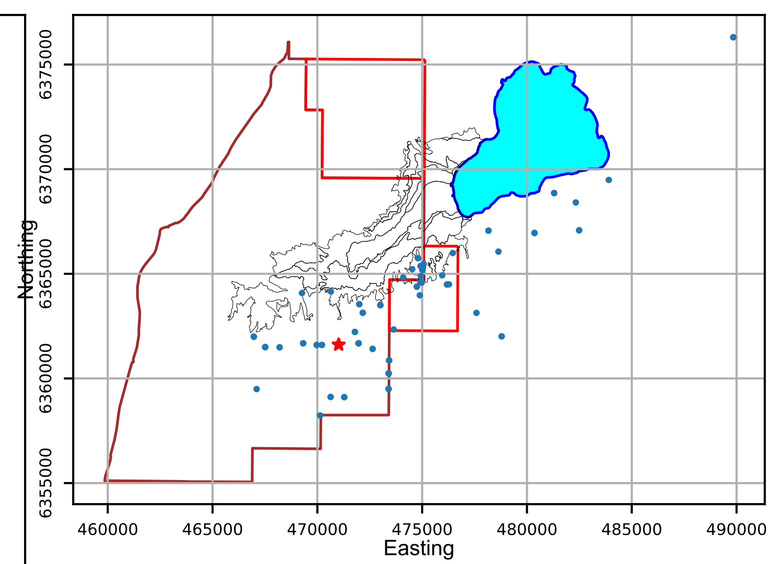

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 36.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW-06-076-B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-139

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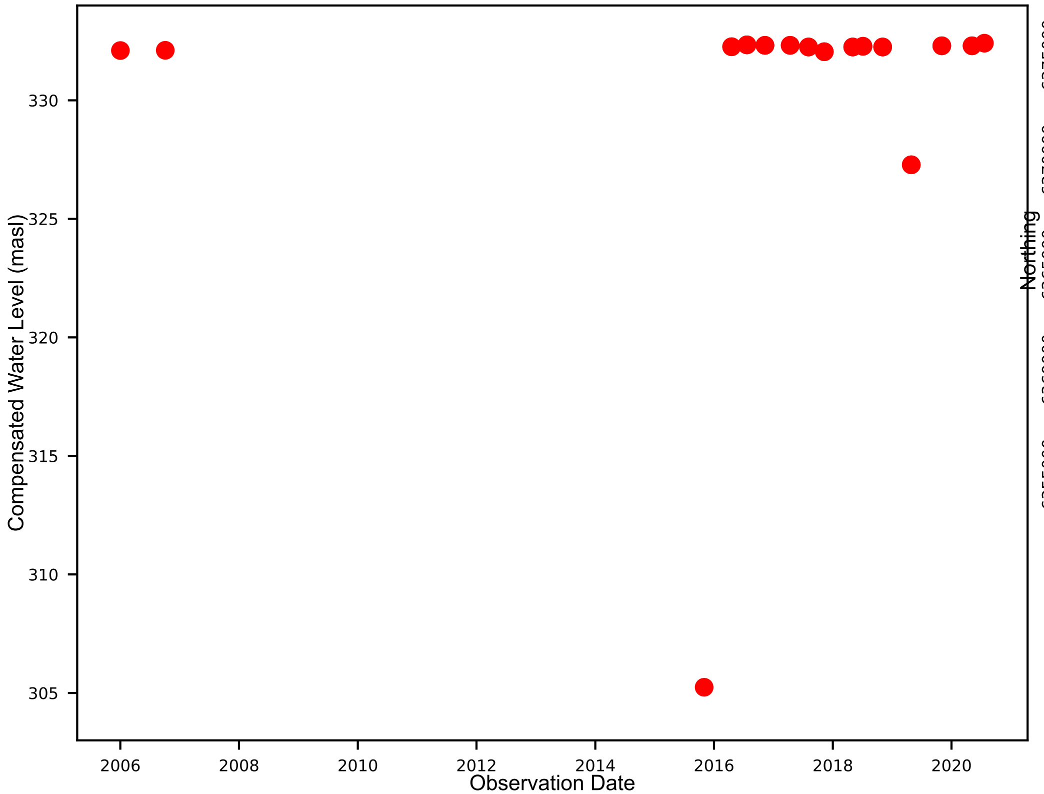

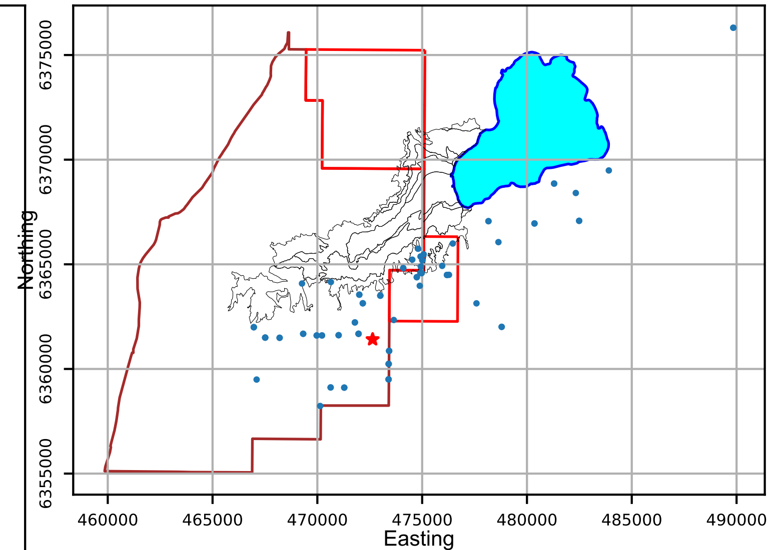

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 60.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW-06-077-A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-140

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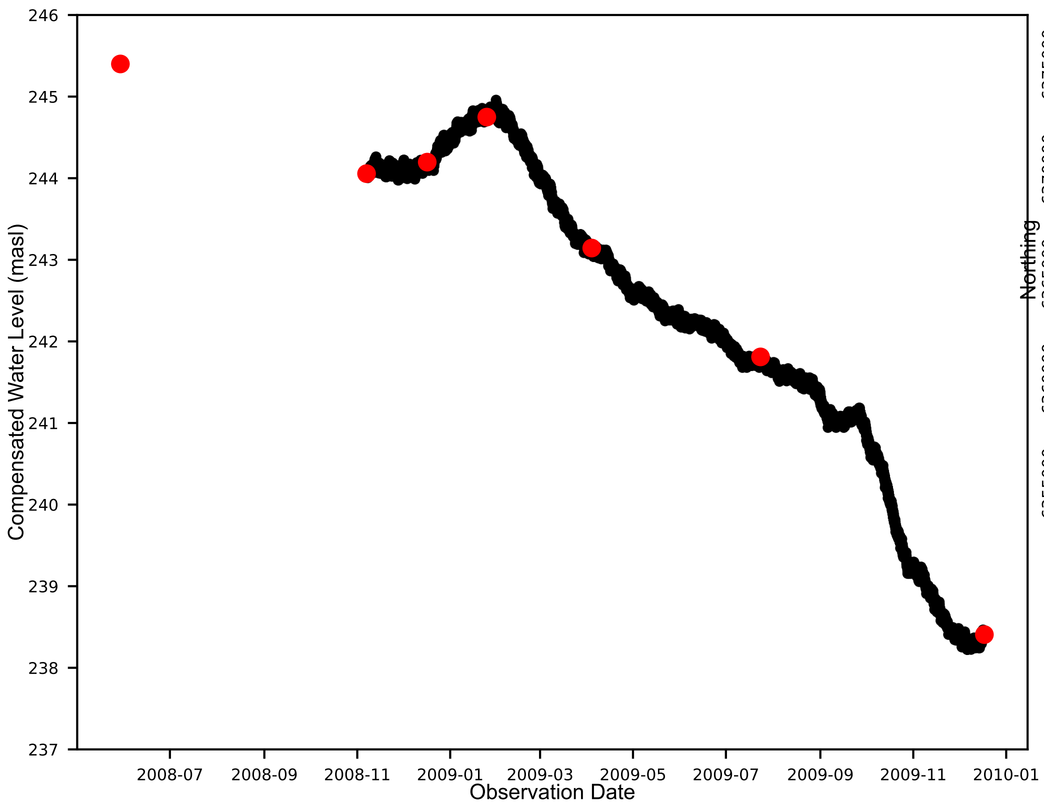

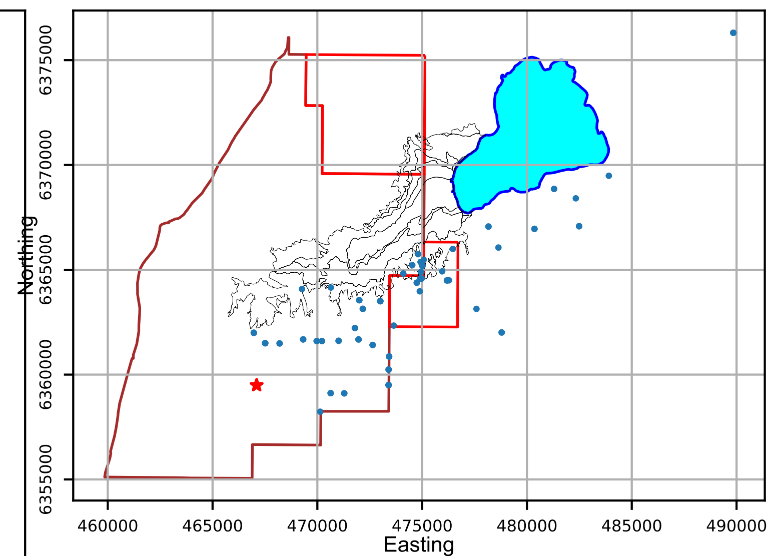

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 185.9 masl

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW-07-119

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-141

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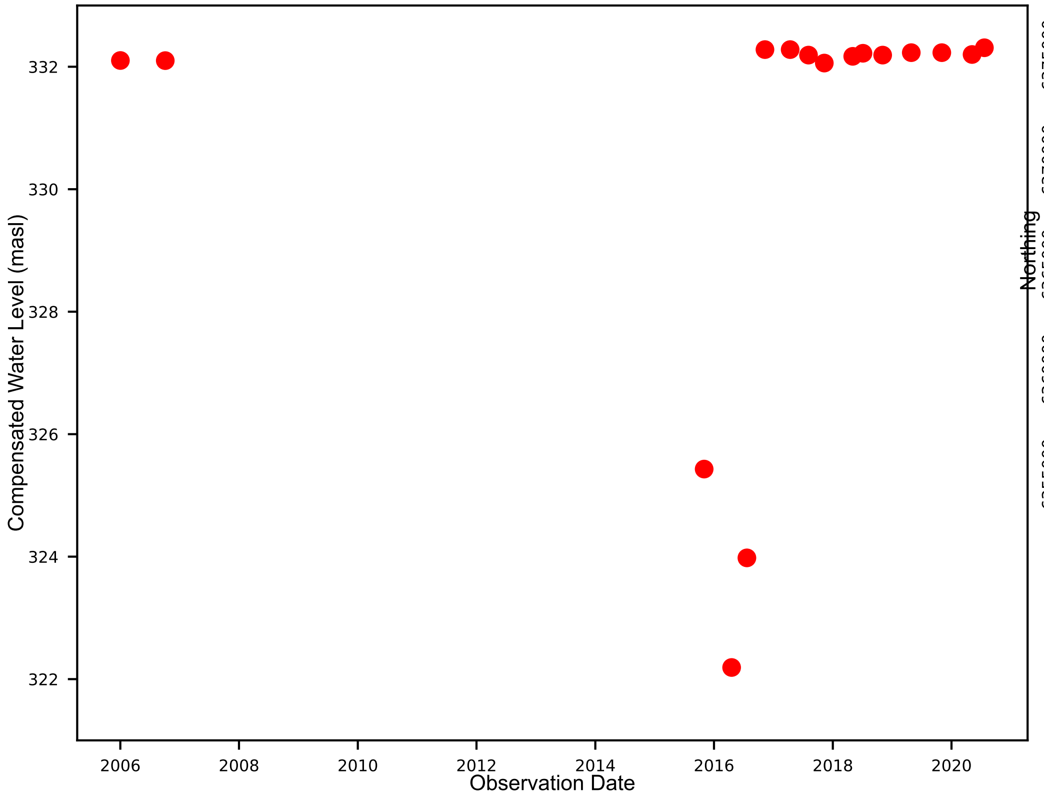

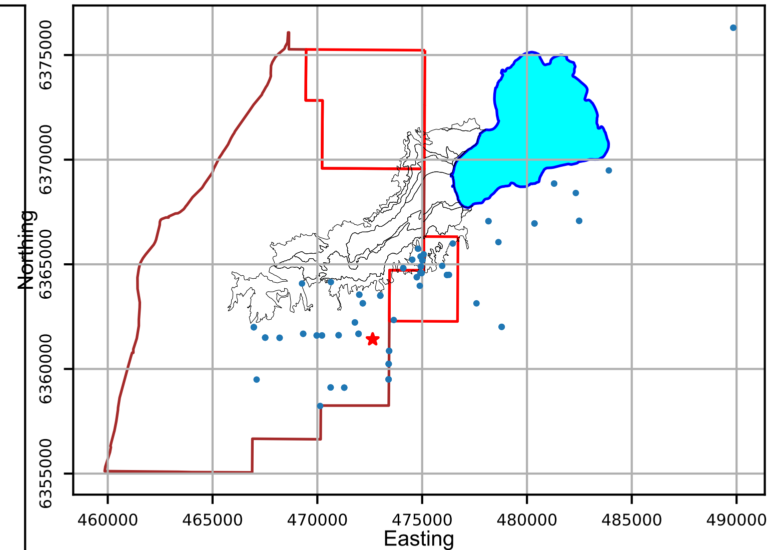

Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 09 Silty Sand AQ4
Depth of Measurement: 45.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

Manual measurement

Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
MW06-077B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B7-142

B8 Hydrographs for North Outwash Plain

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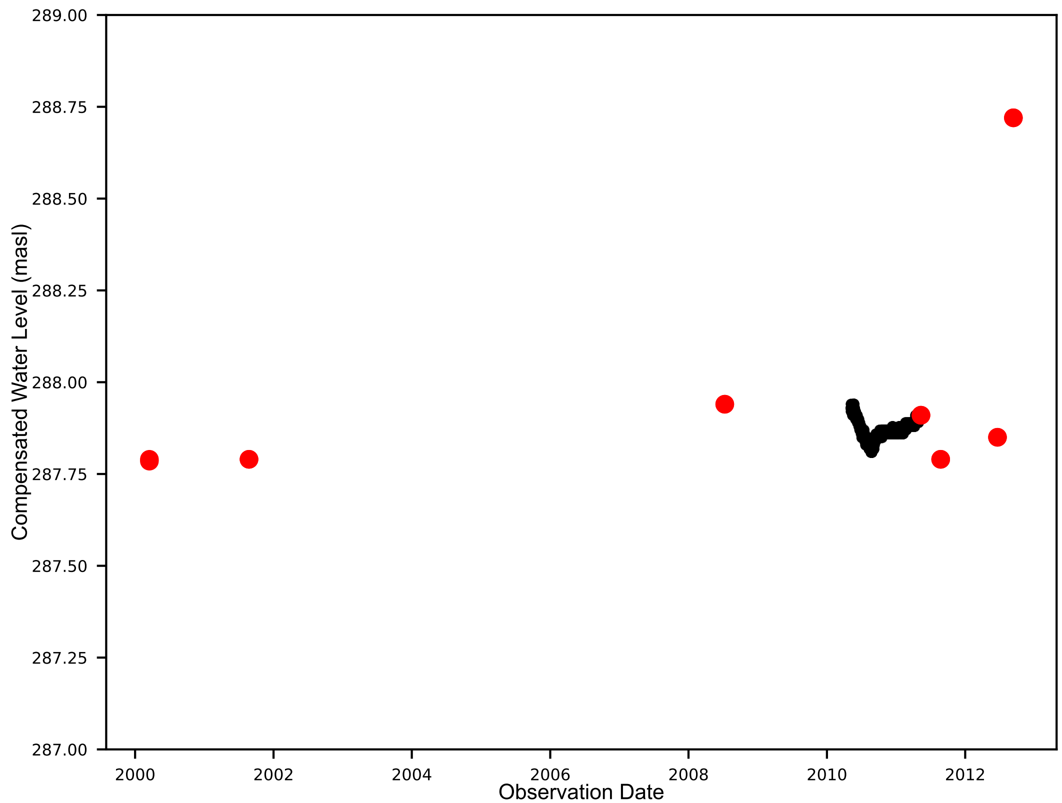

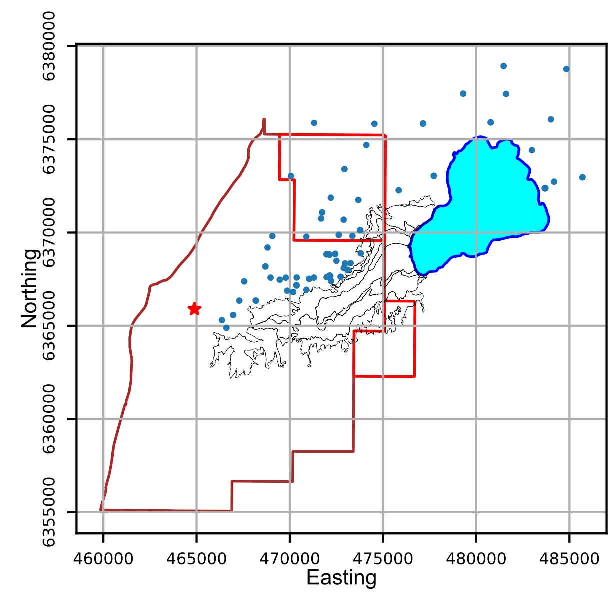

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 17.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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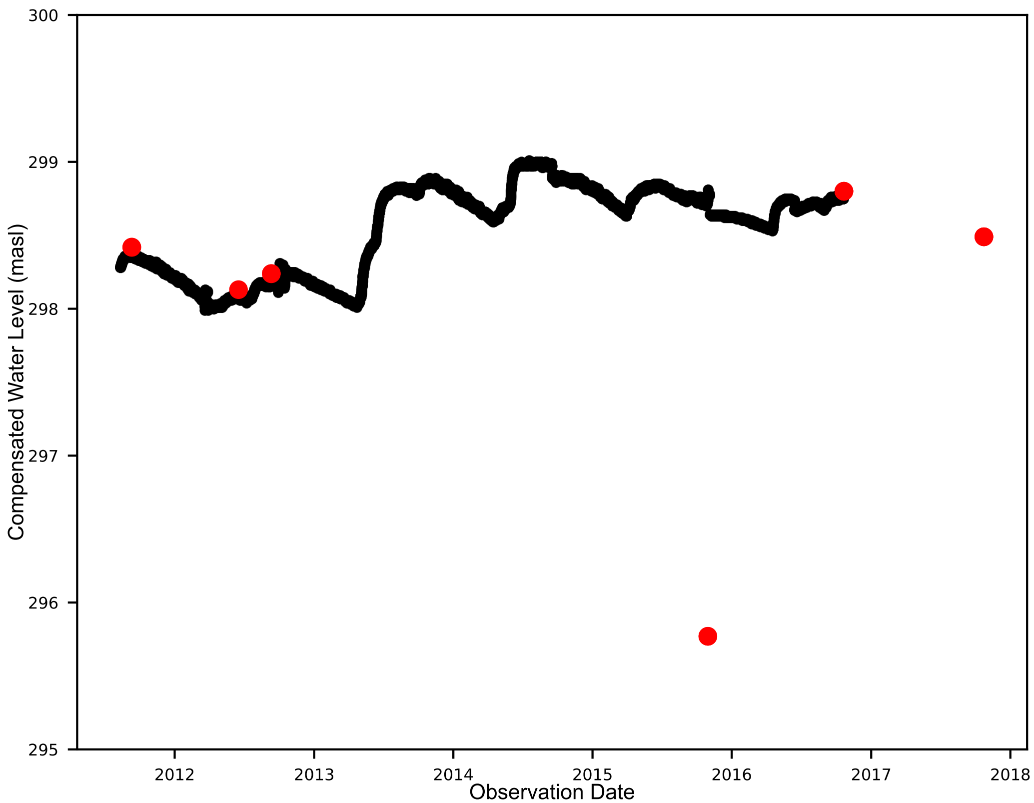
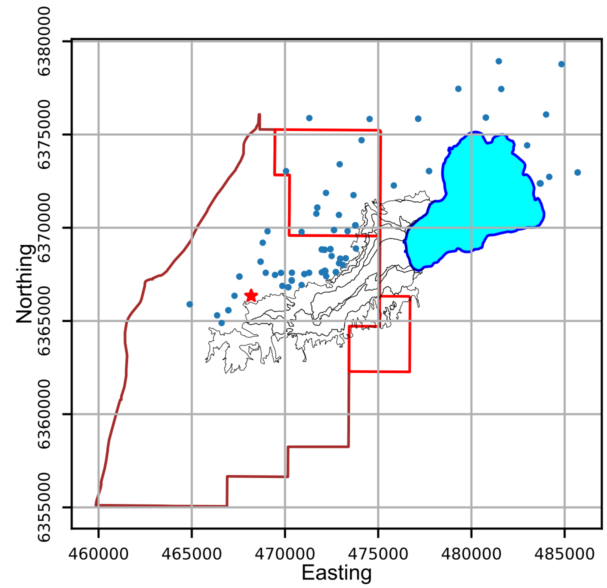
TITLE
AA-10-20-97-10

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-1

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

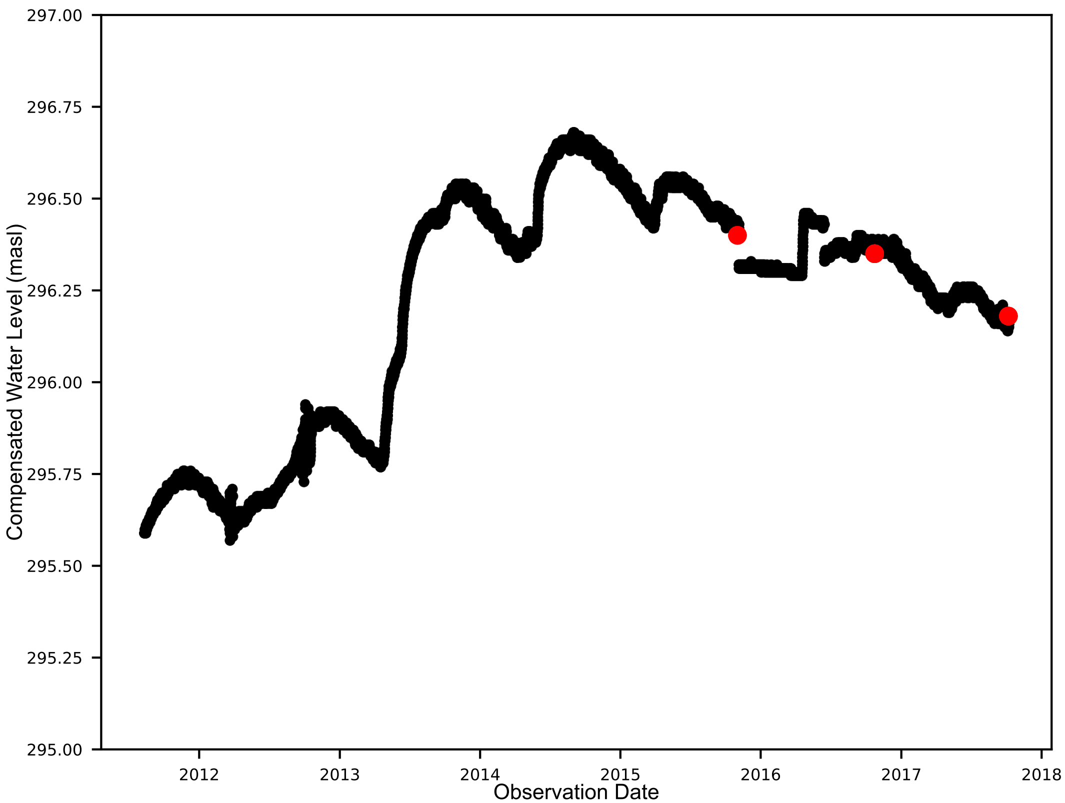
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

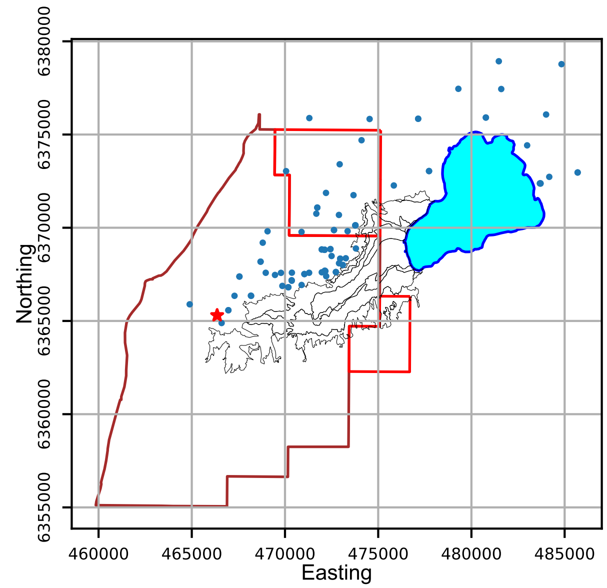
TITLE
FH11-MW-001

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-2

Operated by Suncor Energy

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH11-MW-002

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-3

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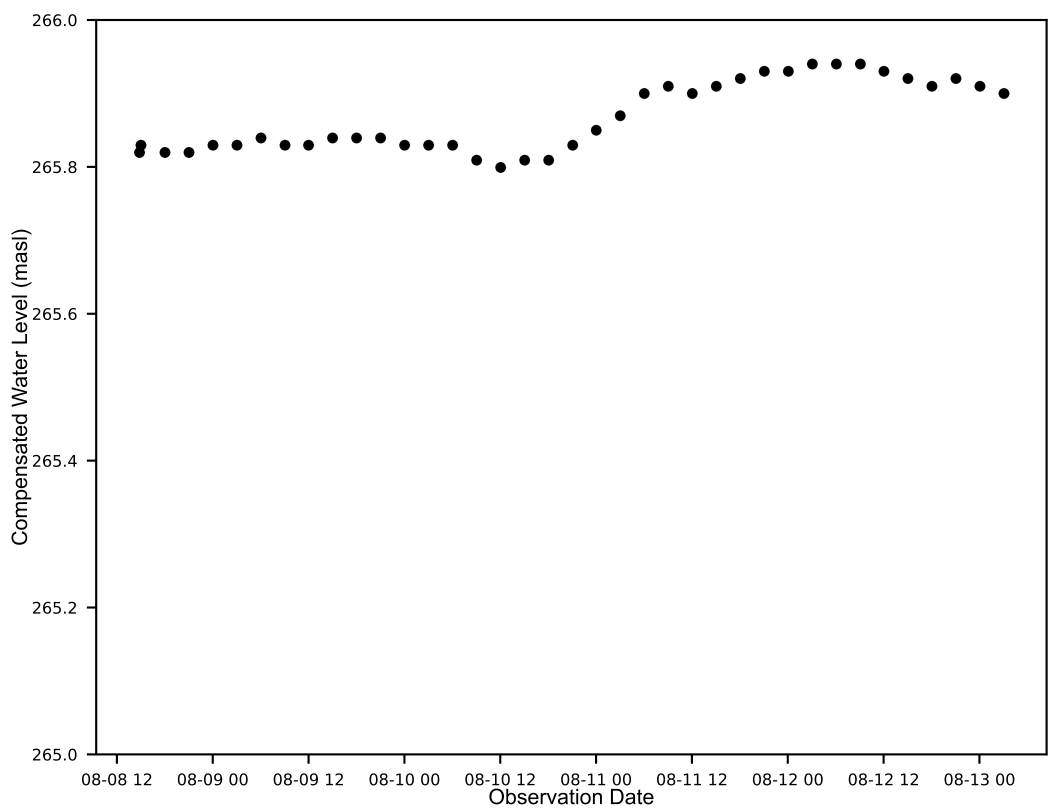

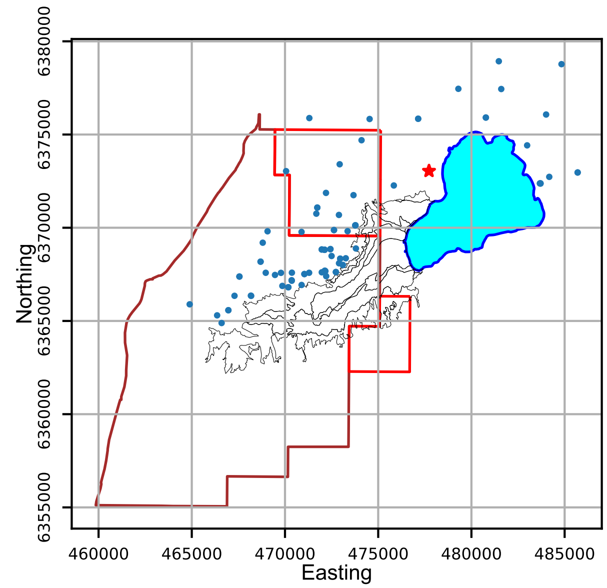

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 72.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
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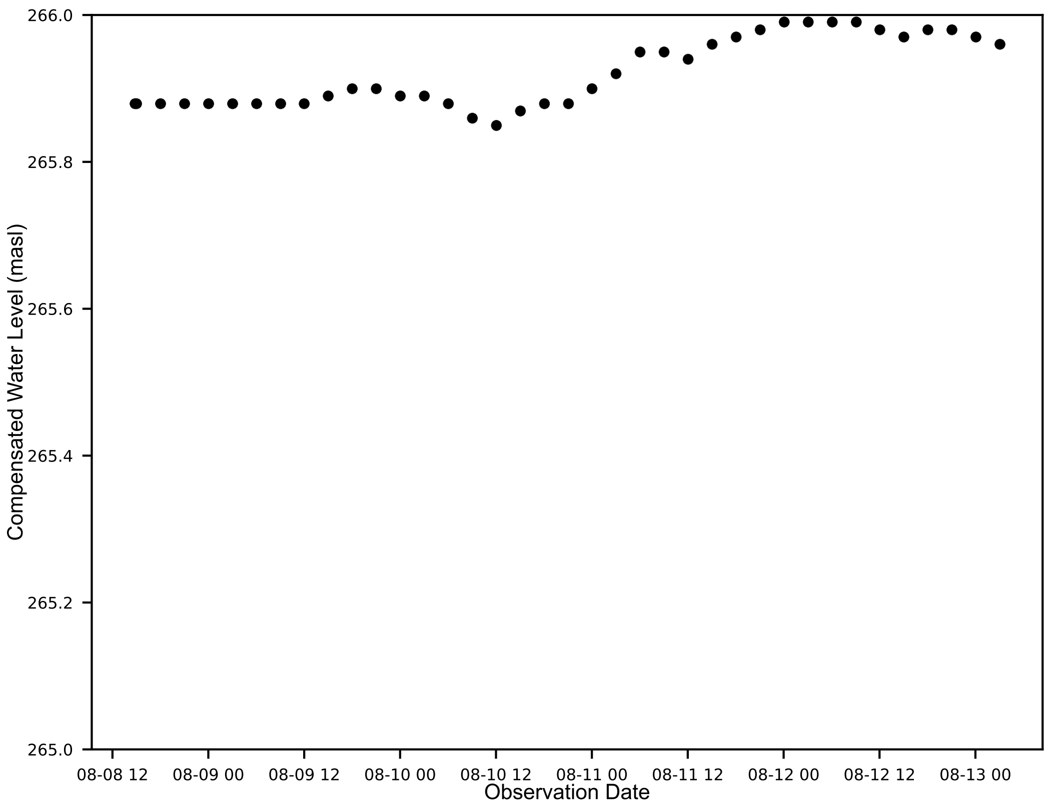
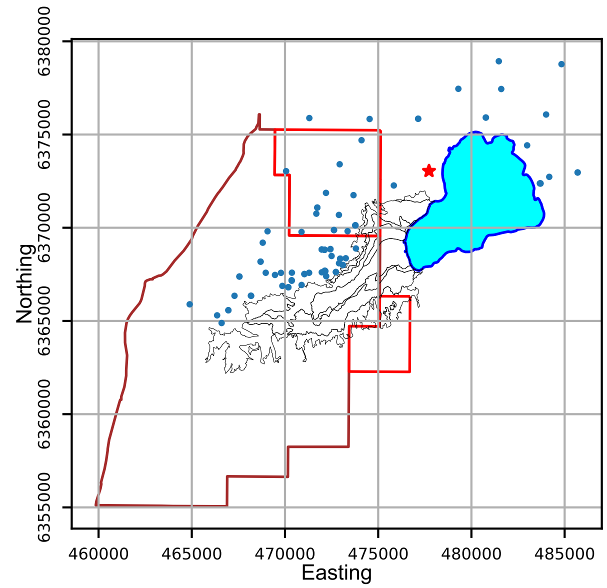
TITLE
FH17-WR407-MR1 - 72.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-4

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 83 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS

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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR407-MR1 - 83.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-5

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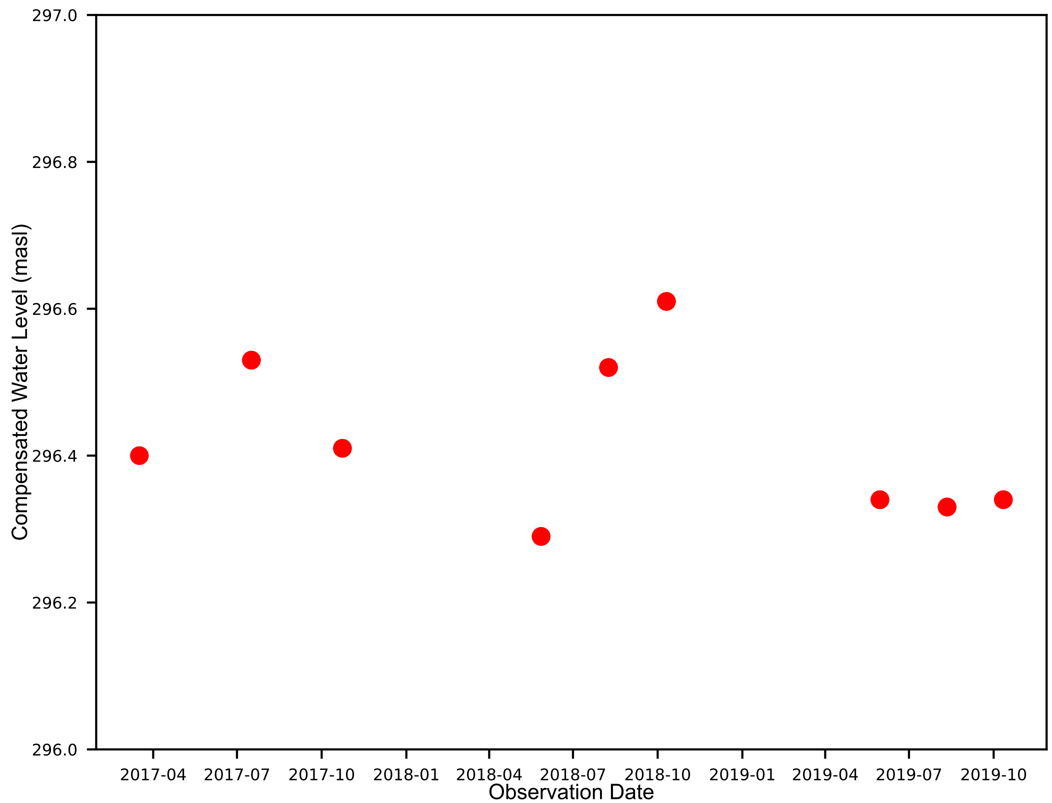
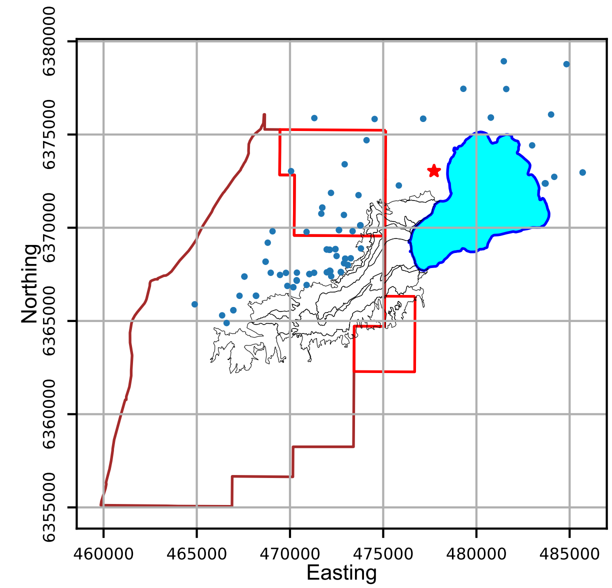




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 17 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

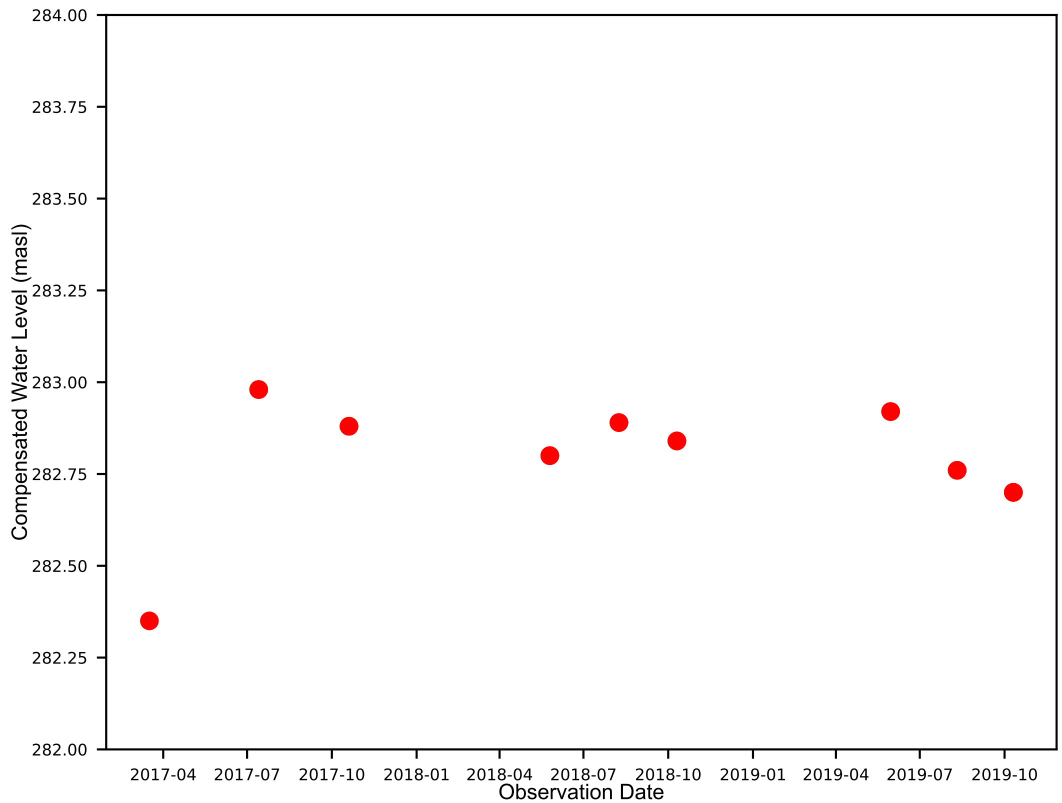
FORT HILLS
Operated by Suncor Energy

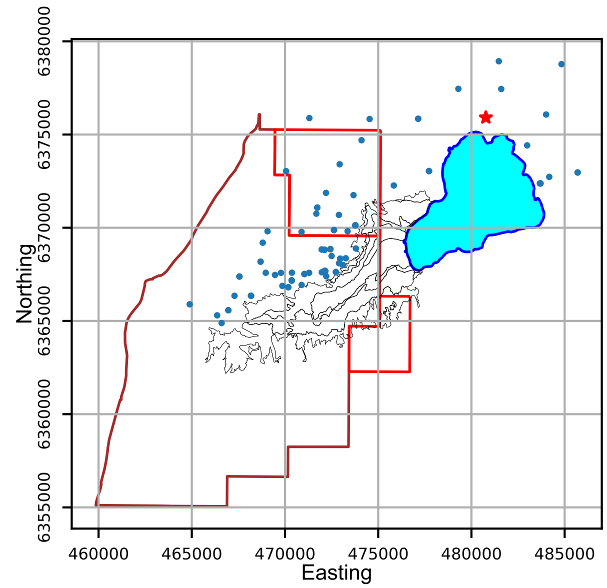
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR407-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-6

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 52.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

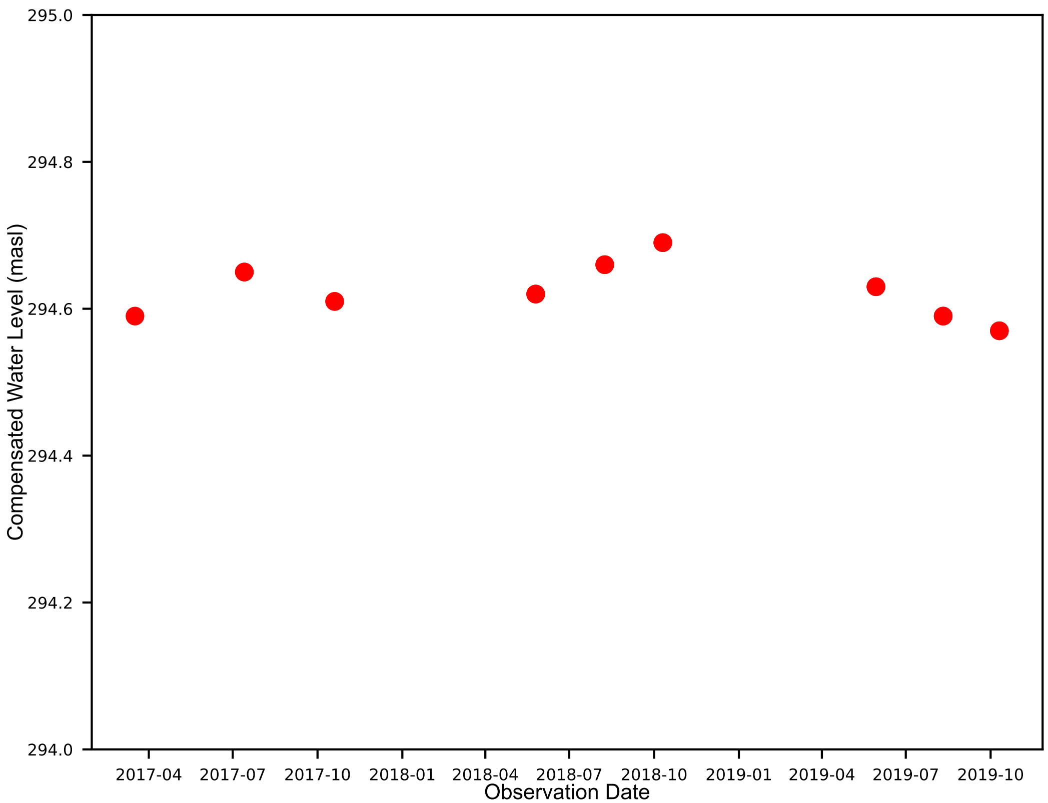
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

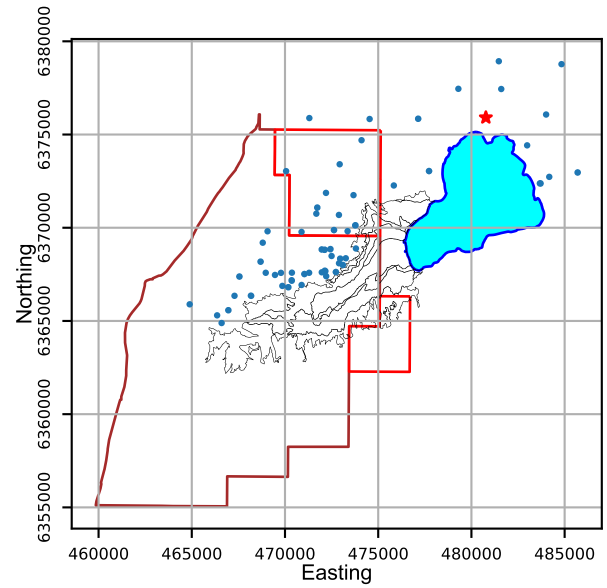
FORT HILLS
Operated by Suncor Energy

TITLE
FH17-WR412-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-7

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 19.81 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR412-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-8

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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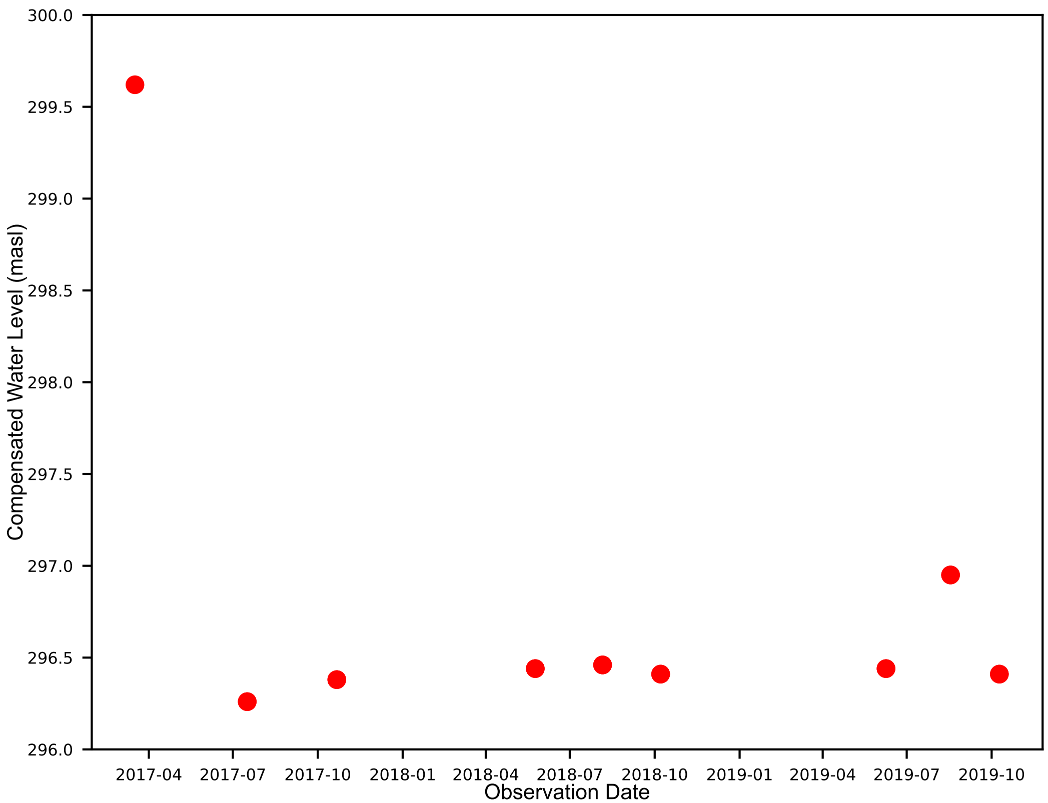

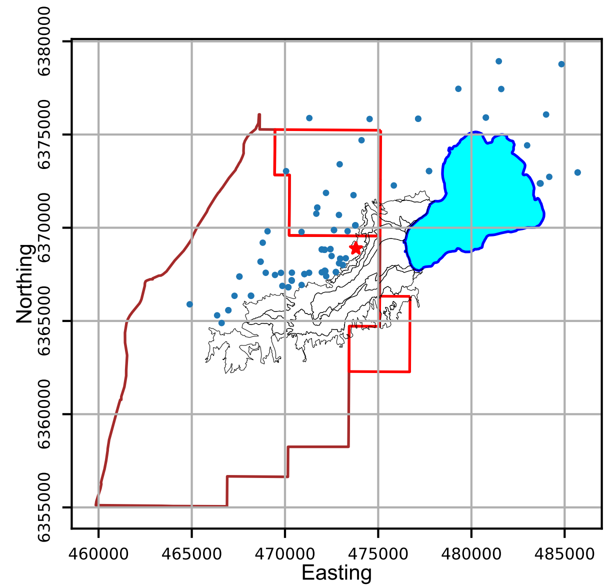

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 24.97 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR428-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-9

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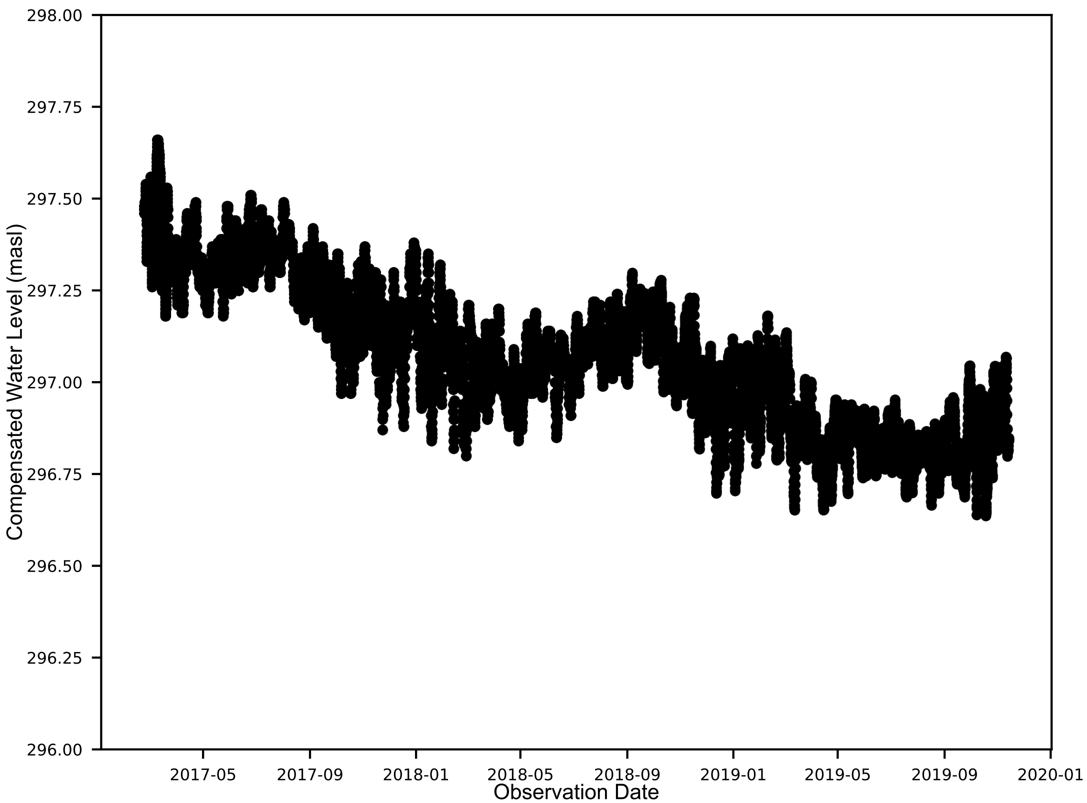

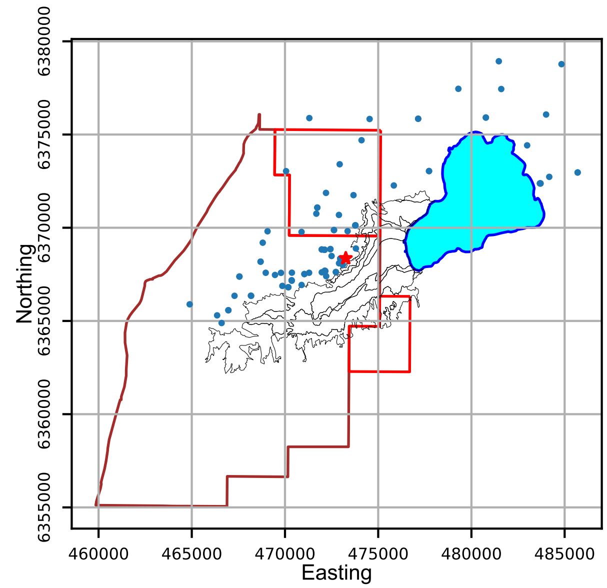

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 20 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH17-WR429-SN1 - 20.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-10

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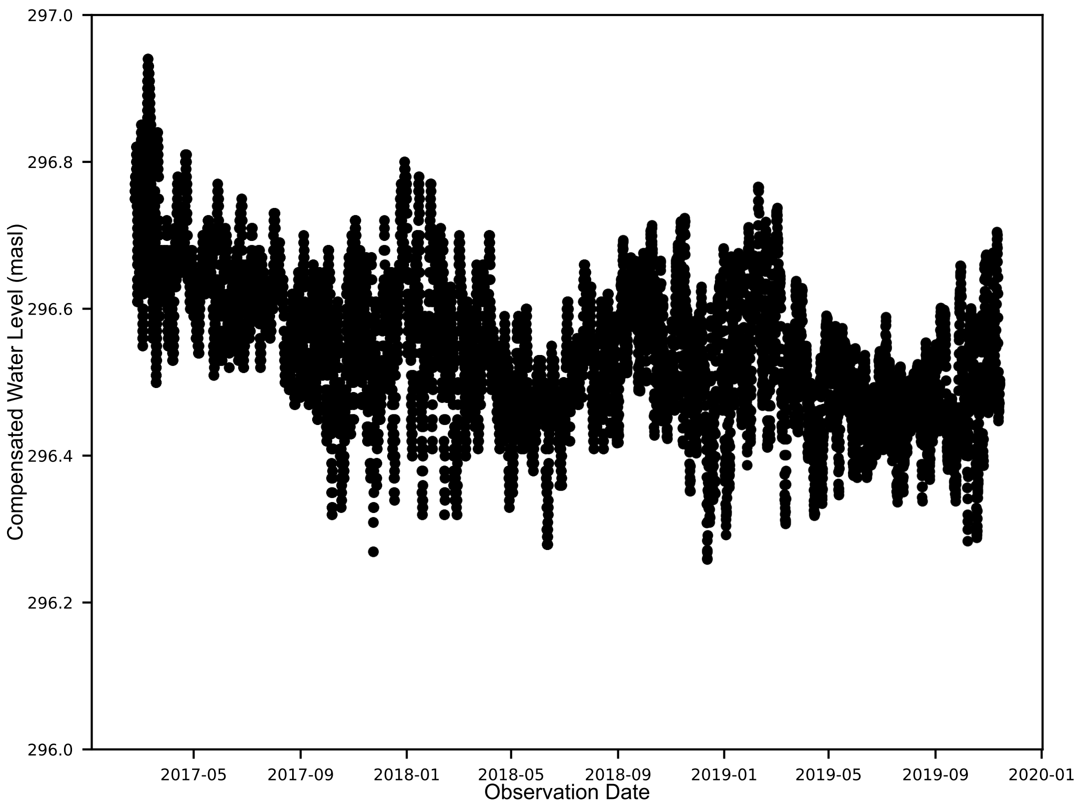

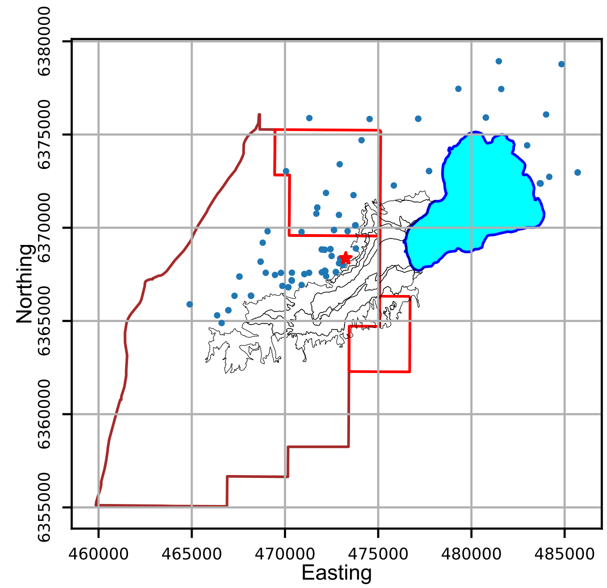

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 34 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR429-SN1 - 34.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-11

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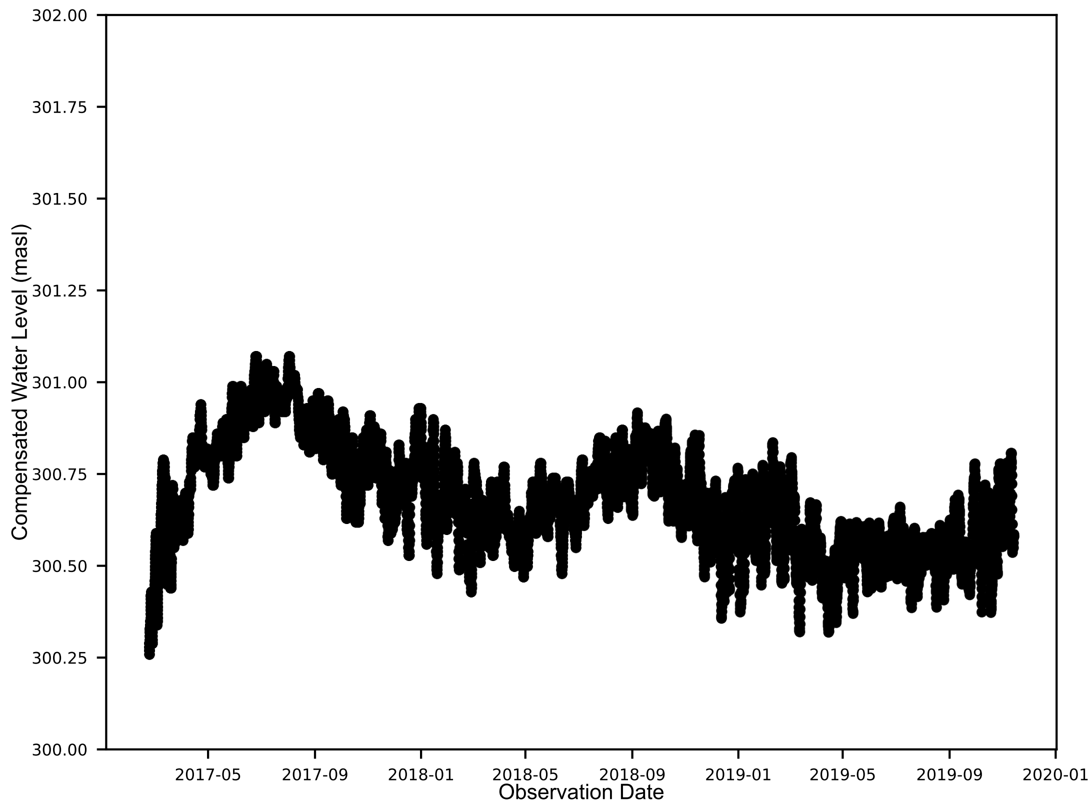

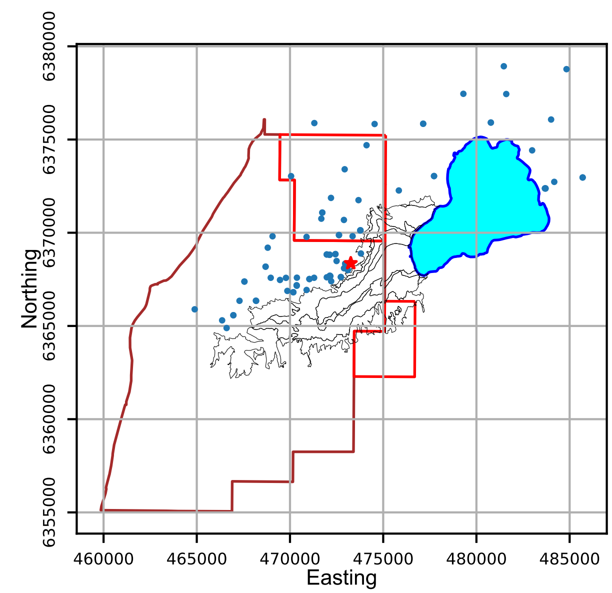

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR429-SN1 - 5.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
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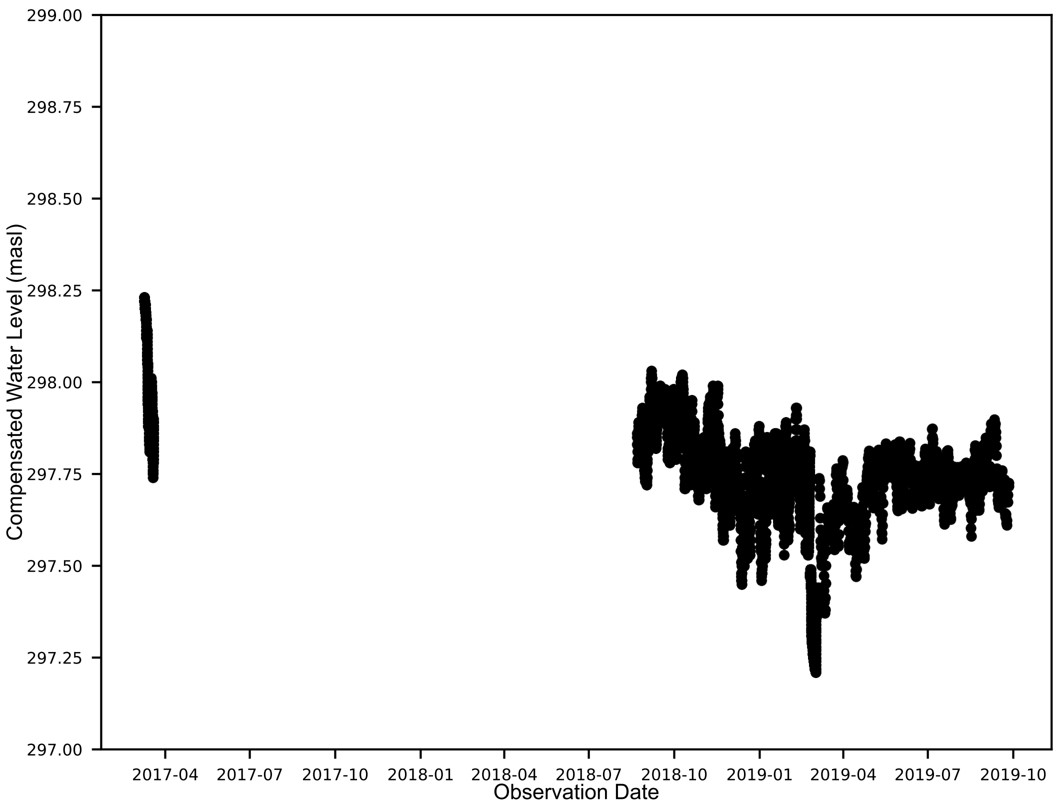
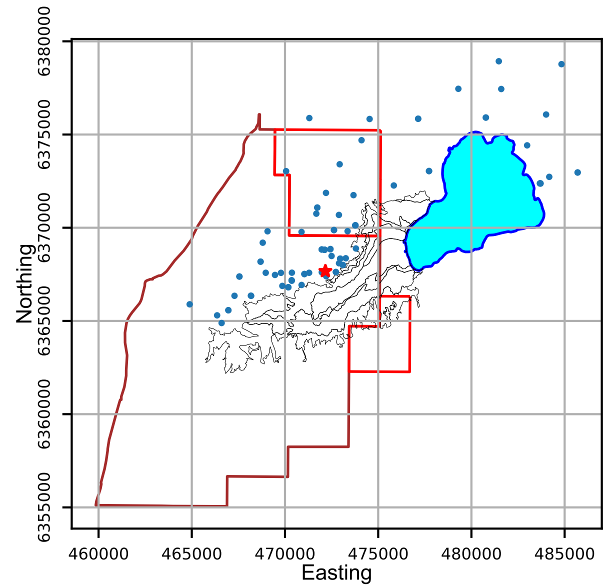




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

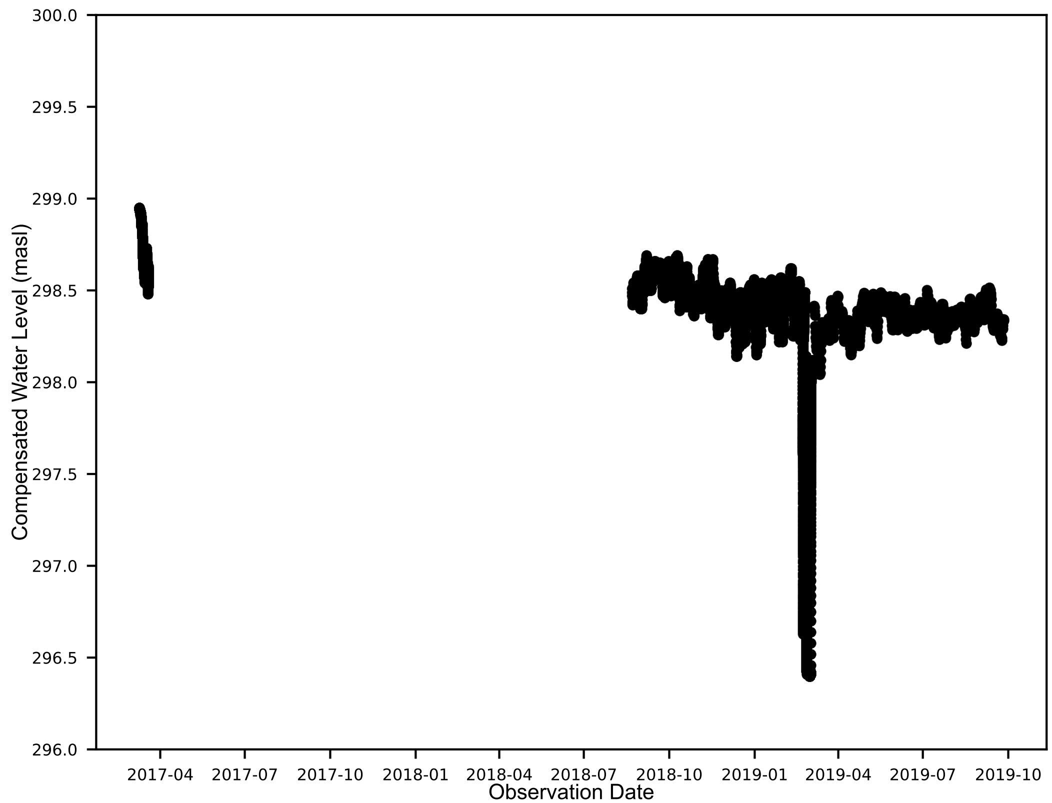
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

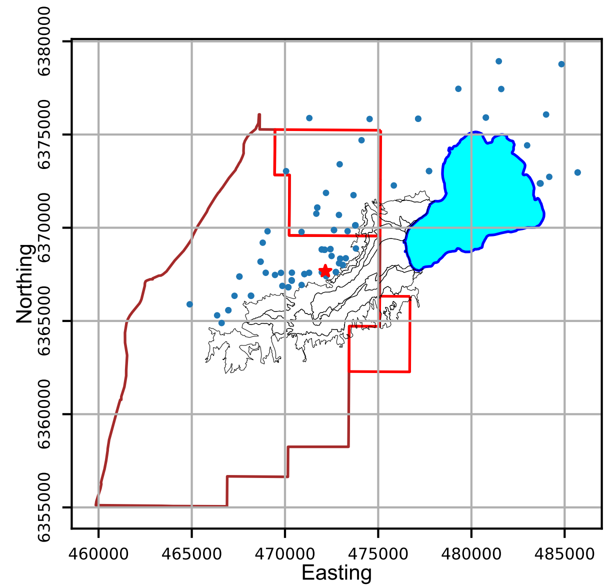
FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR430-SN1 - 10.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-13





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 21.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR430-SN1 - 21.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-14

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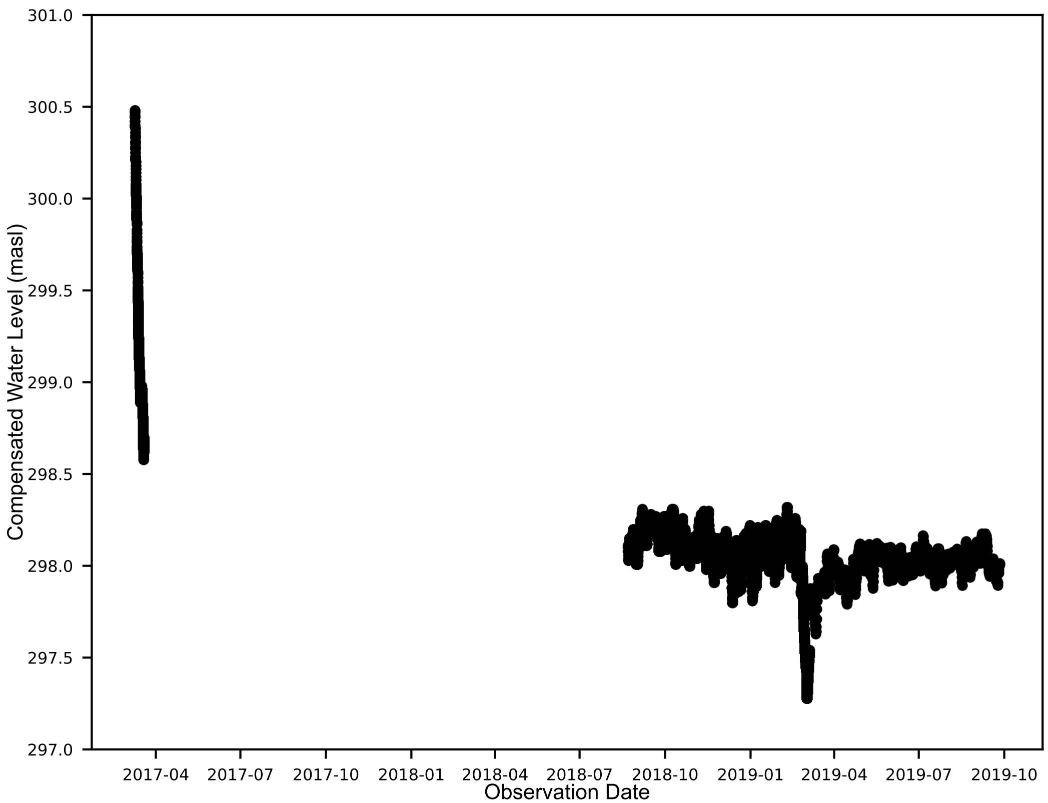
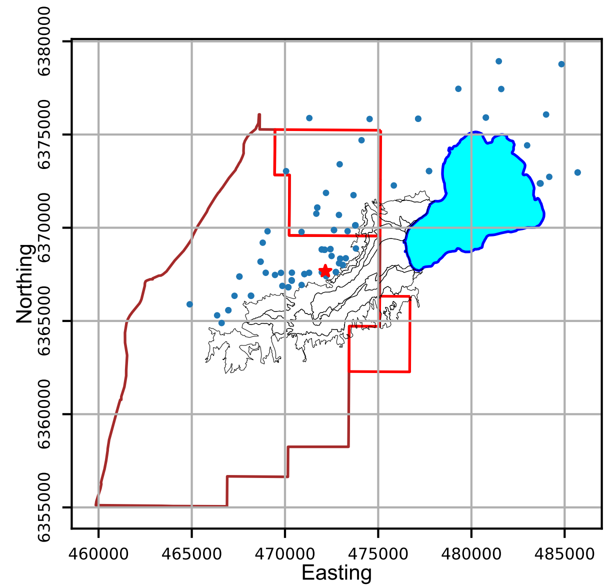




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

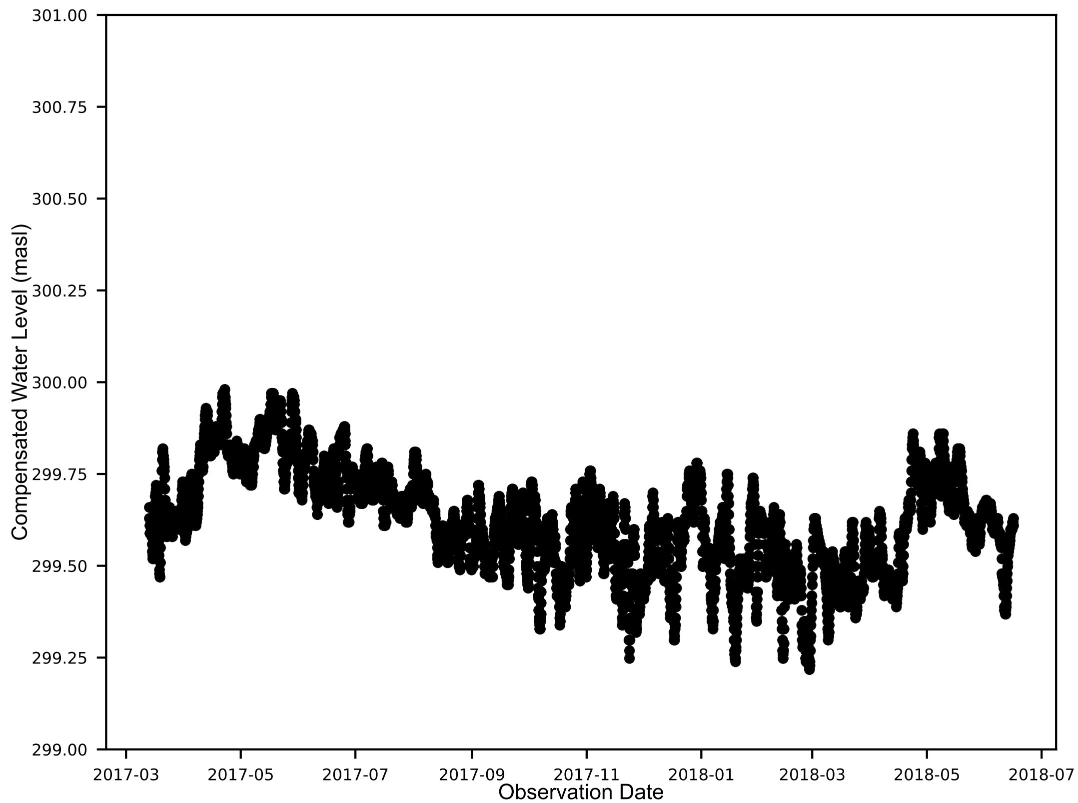
FORTHILLS
Operated by Suncor Energy

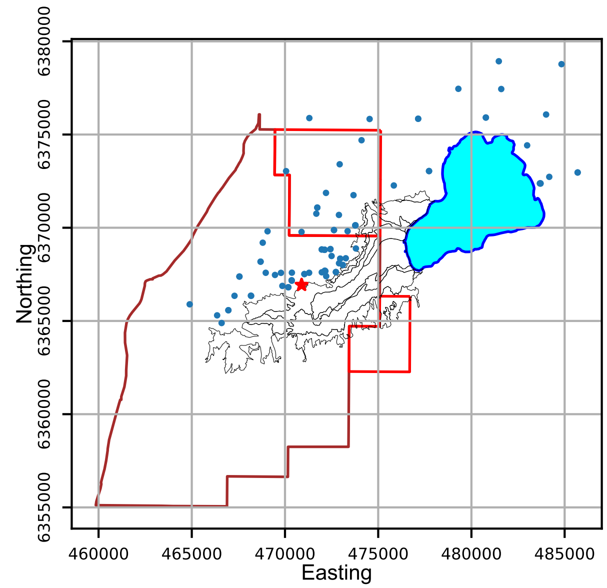
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR430-SN1 - 32.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-15





Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 15 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

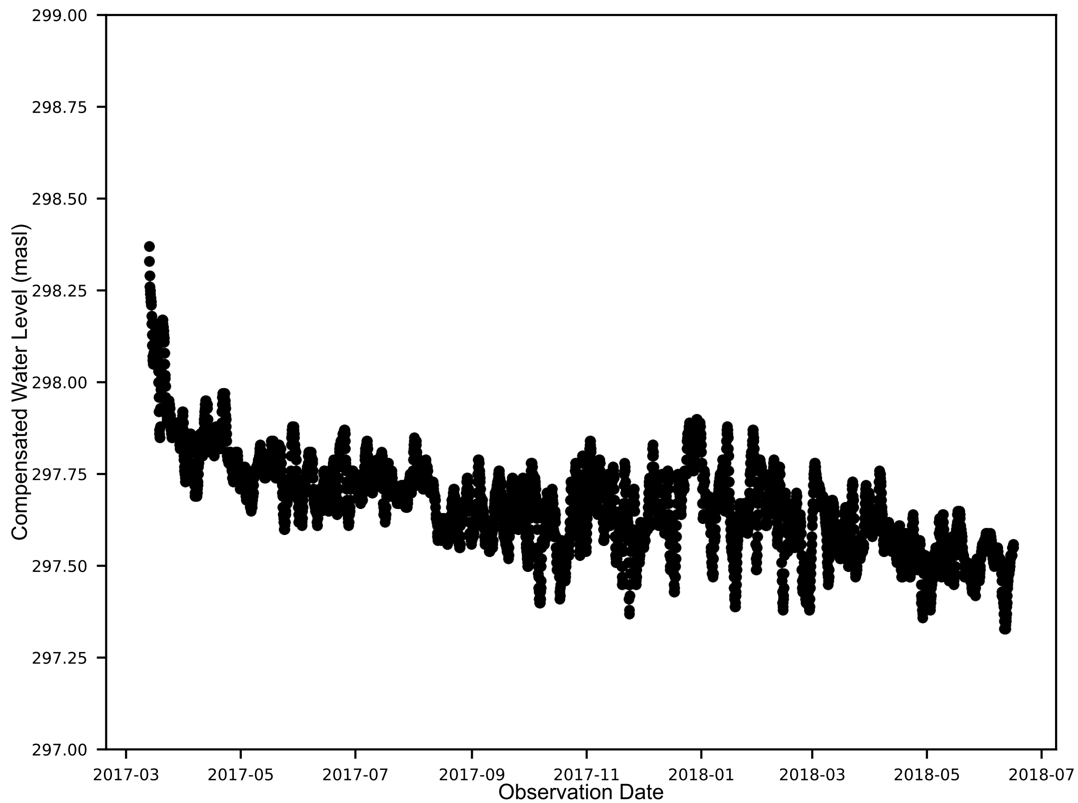
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

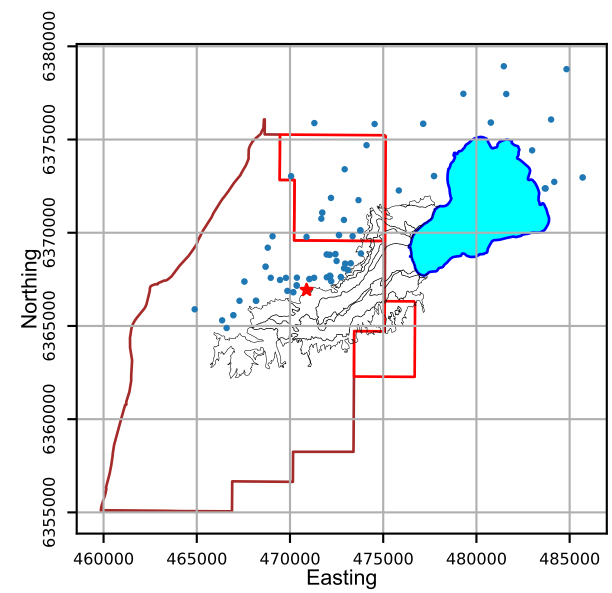
TITLE

FH17-WR431-SN1 - 15.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-16

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR431-SN1 - 32.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-17

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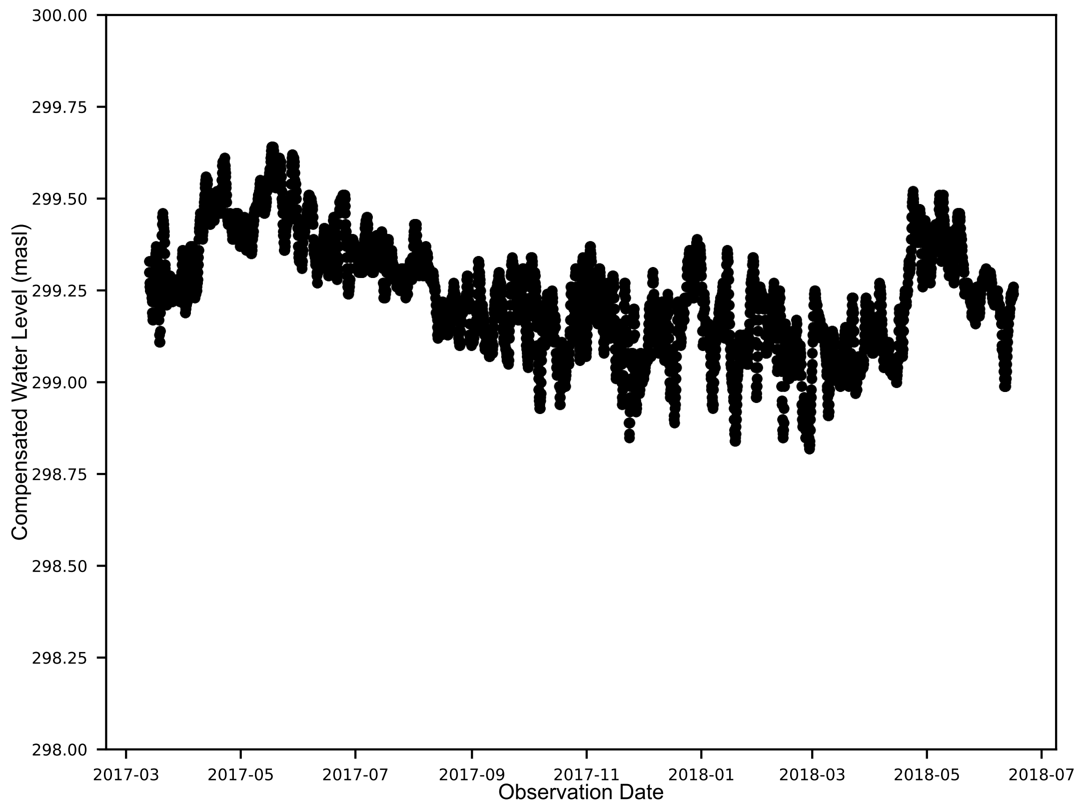

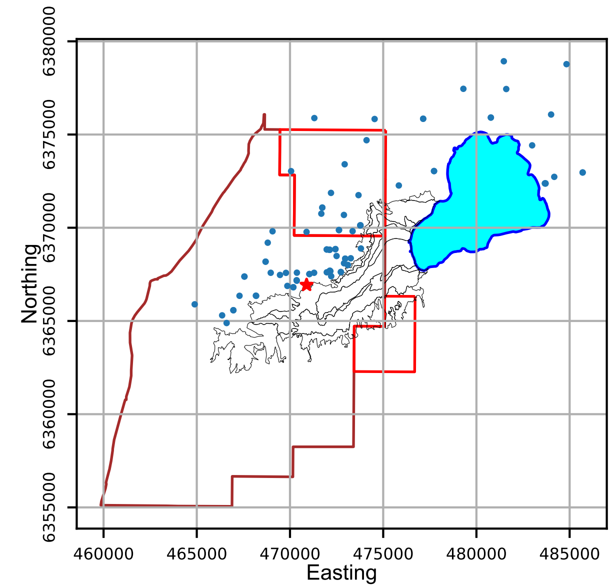

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR431-SN1 - 7.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-18

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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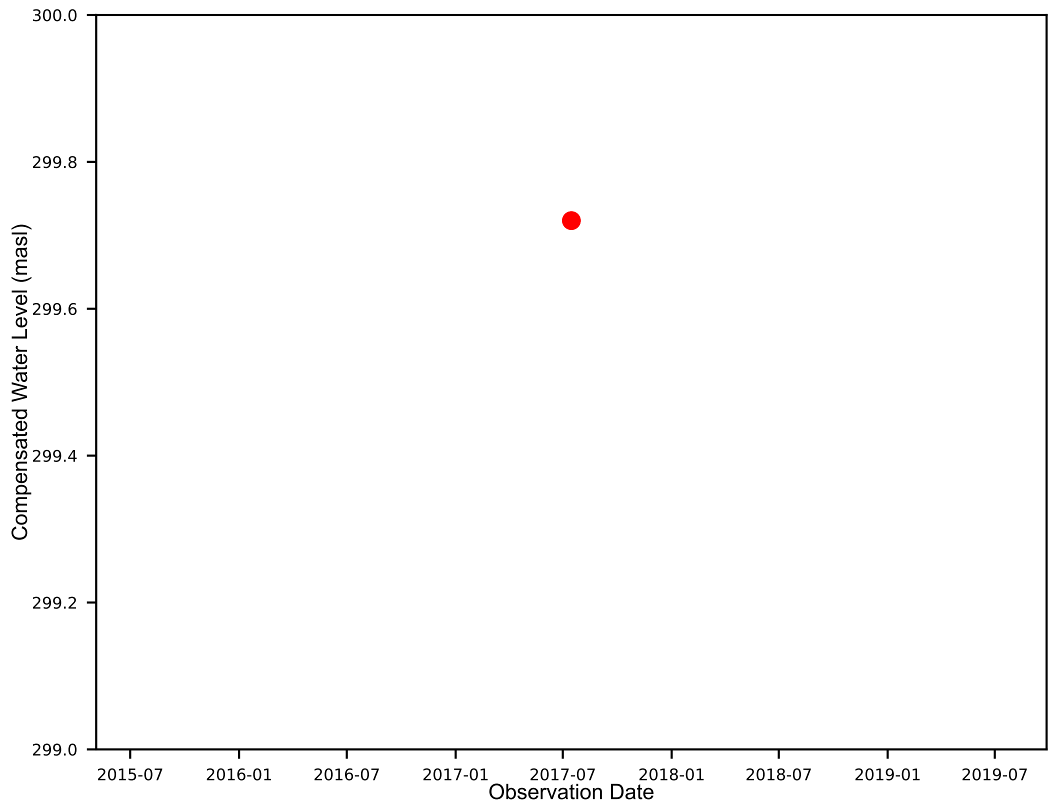

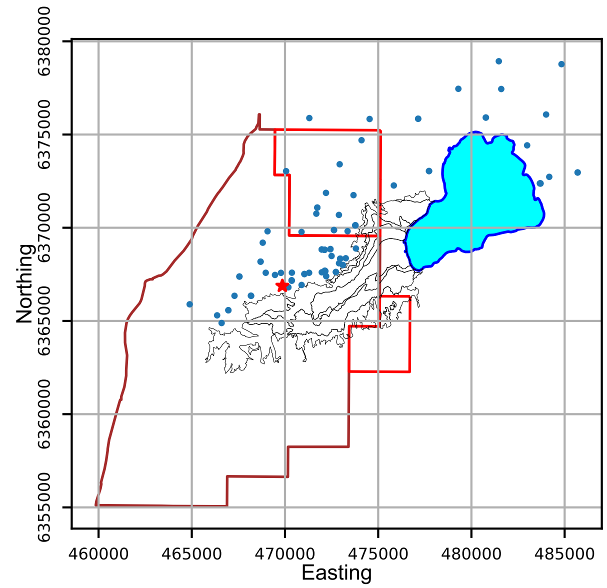

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR432-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-19

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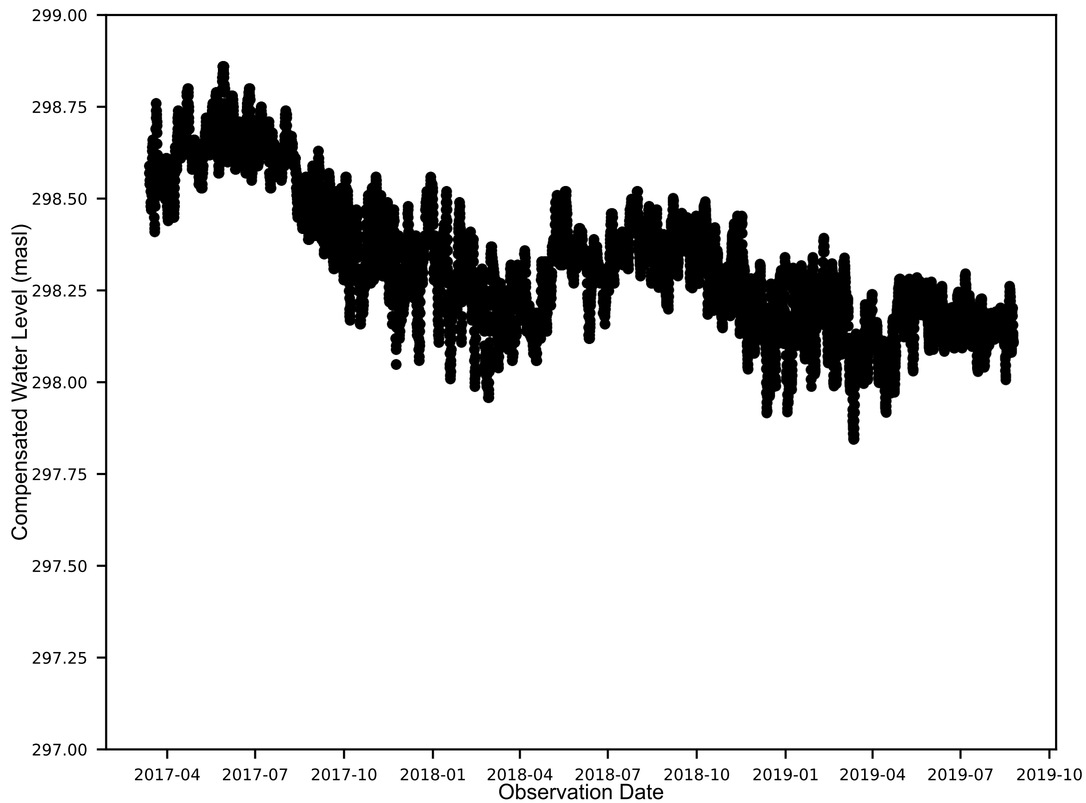
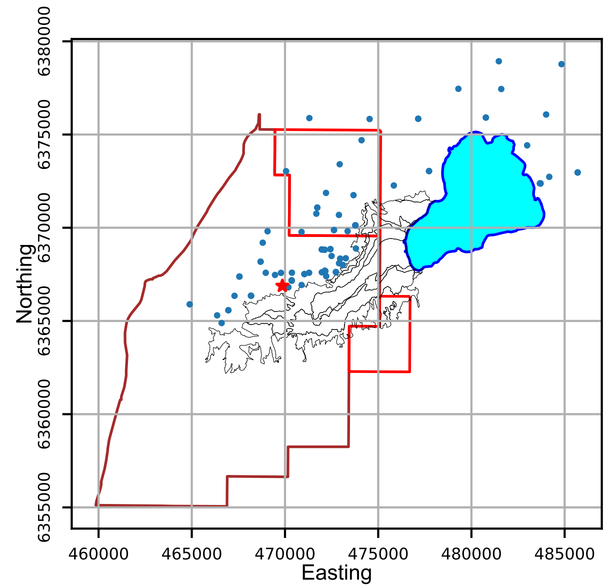




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

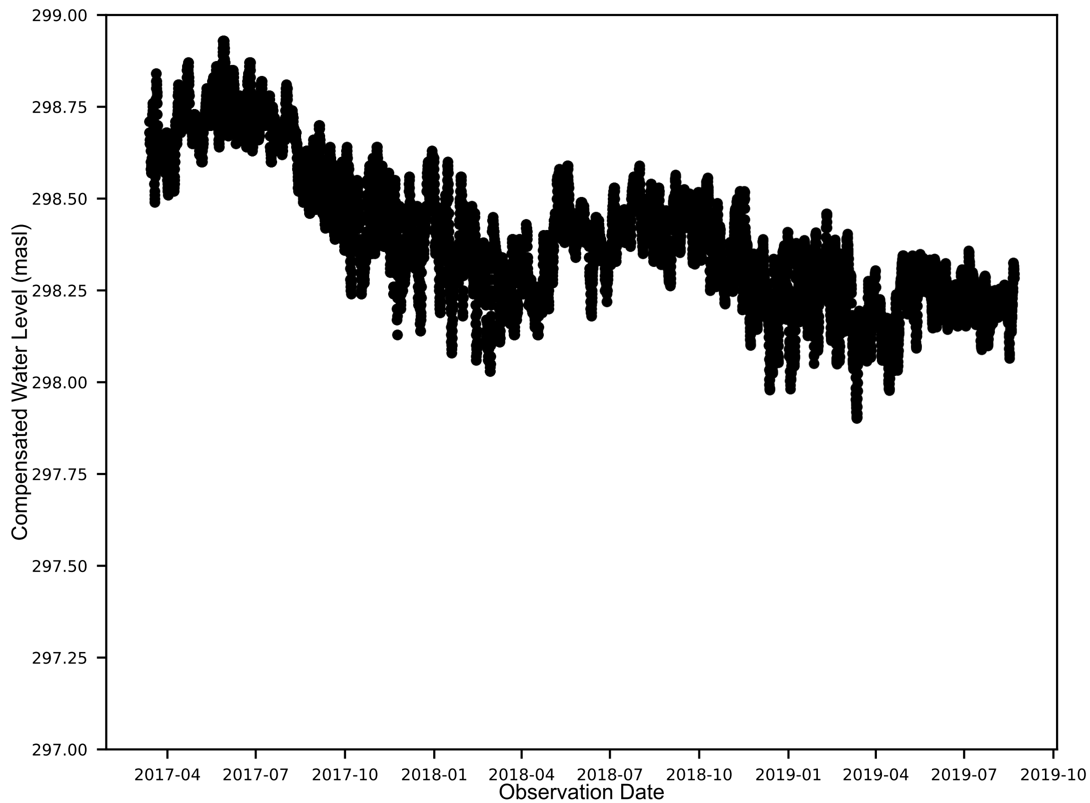
TITLE

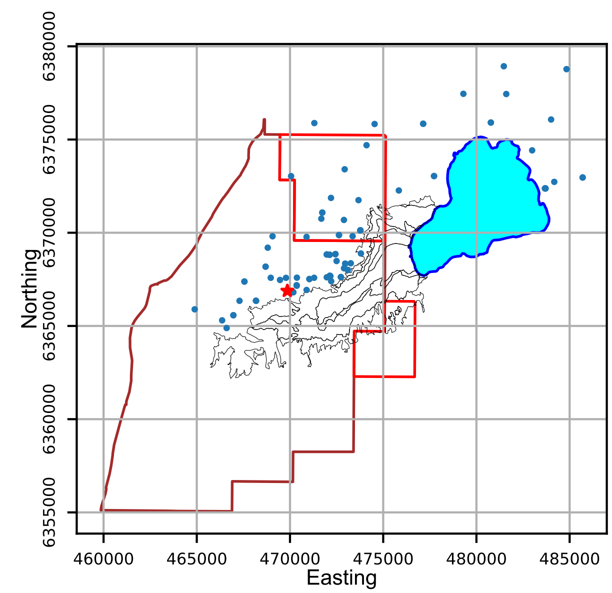
FH17-WR432-SN1 - 10.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-20

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well

Wells

Extension Areas as proposed in the Integrated Plan Amendment Application

McClelland Lake

Approved Project Area

Ecohydrology Zone

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

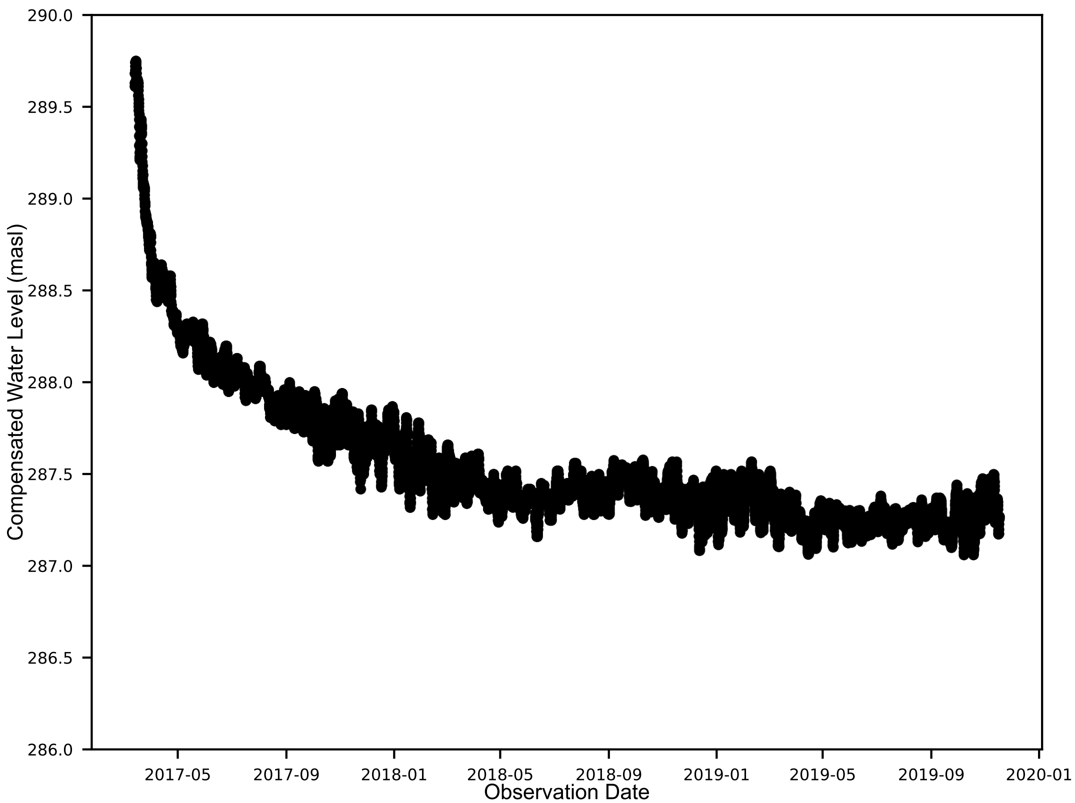
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

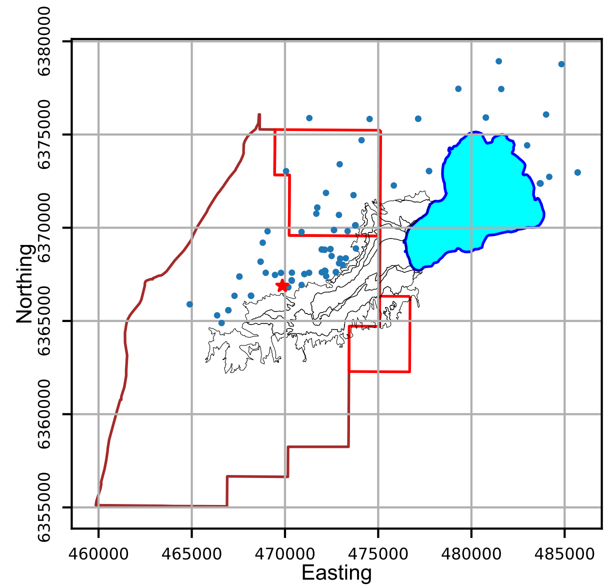
TITLE

FH17-WR432-SN1 - 16.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-21

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 35 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR432-SN1 - 35.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-22

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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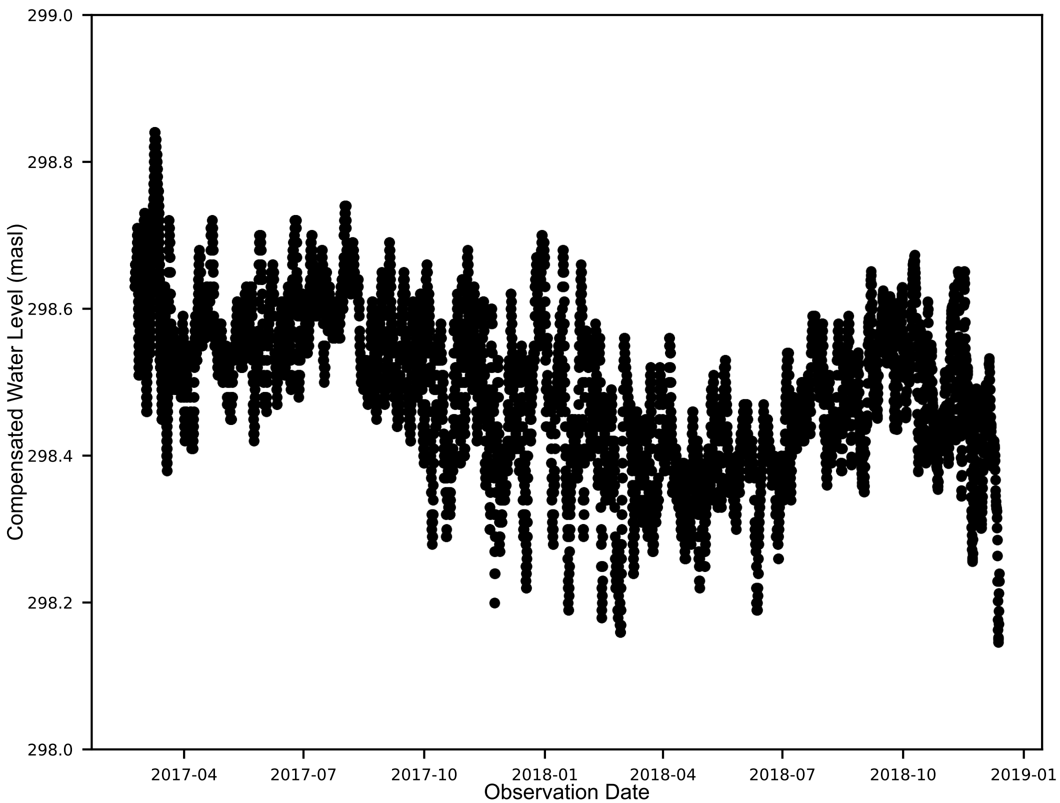
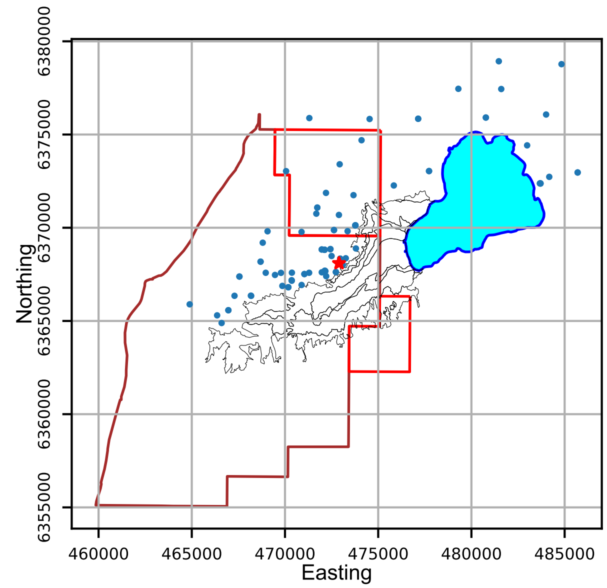




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 18 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

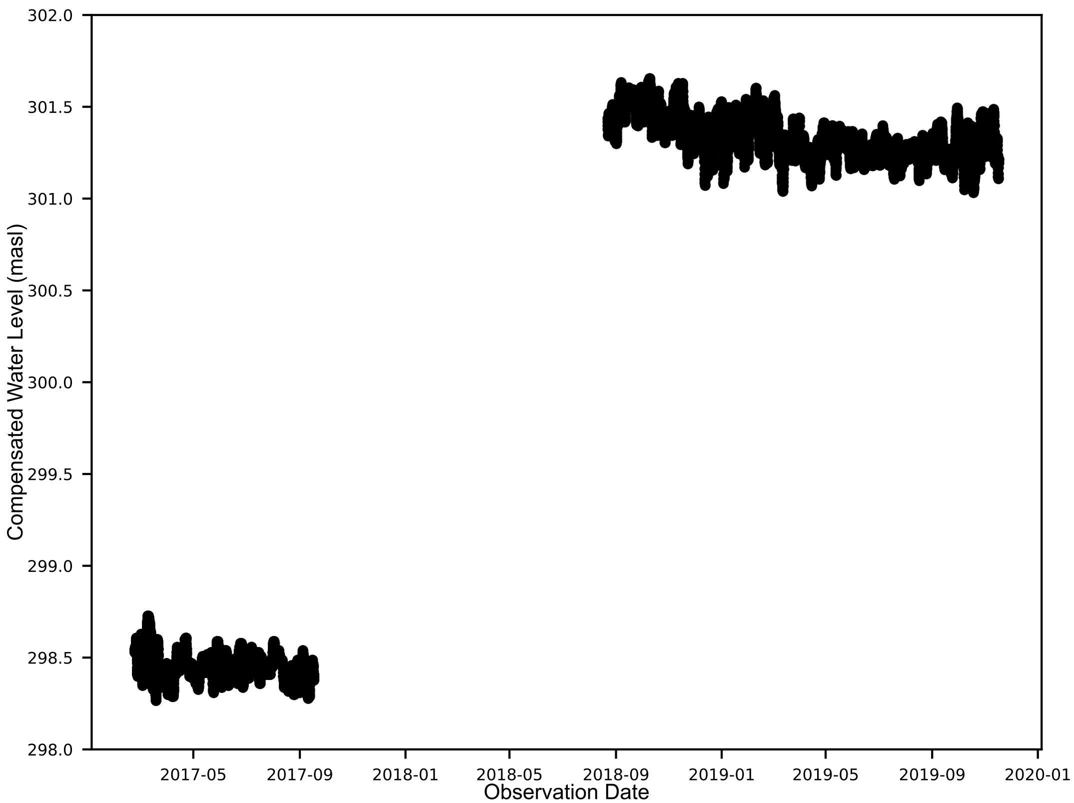
FORTHILLS
Operated by Suncor Energy

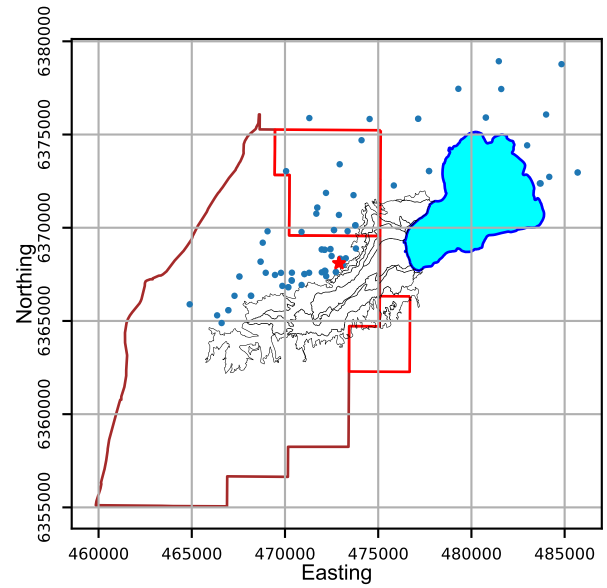
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR442-SN1 - 18.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-23

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 32 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR442-SN1 - 32.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-24

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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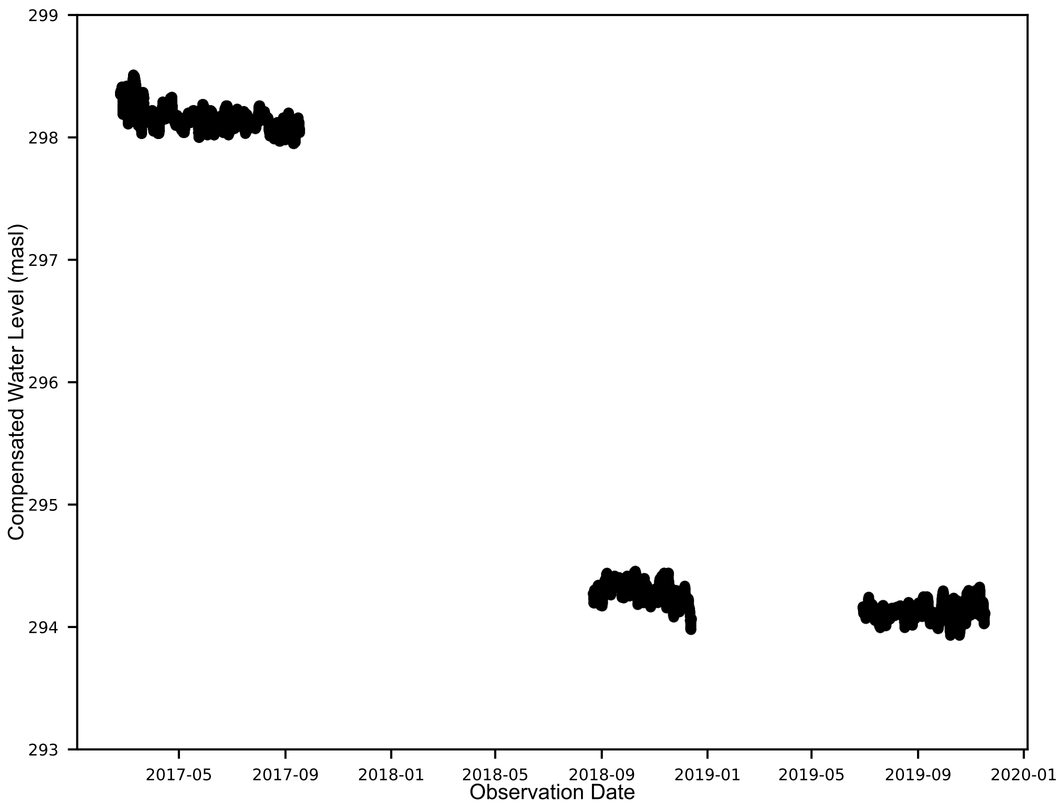
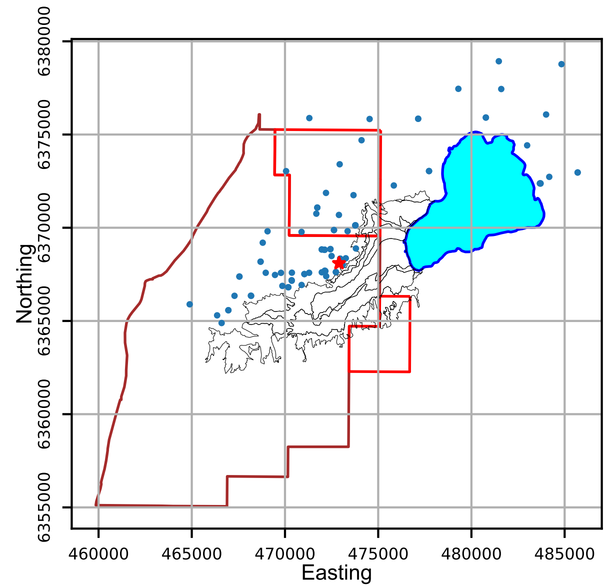




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 41.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

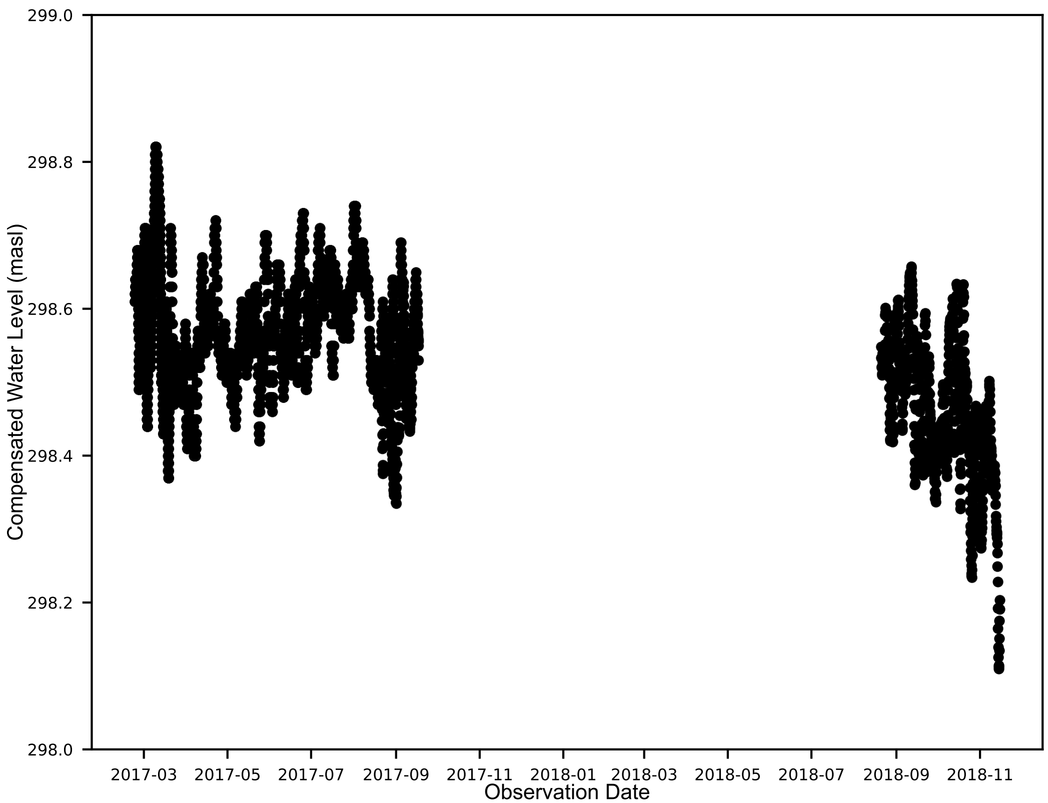
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

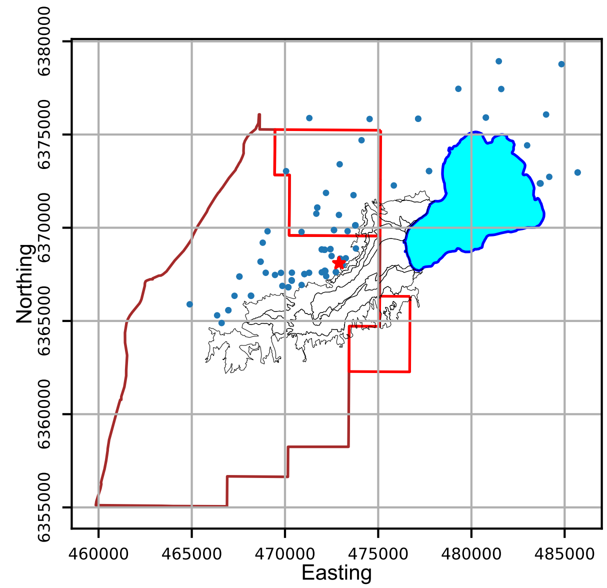
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR442-SN1 - 41.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-25





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR442-SN1 - 6.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-26

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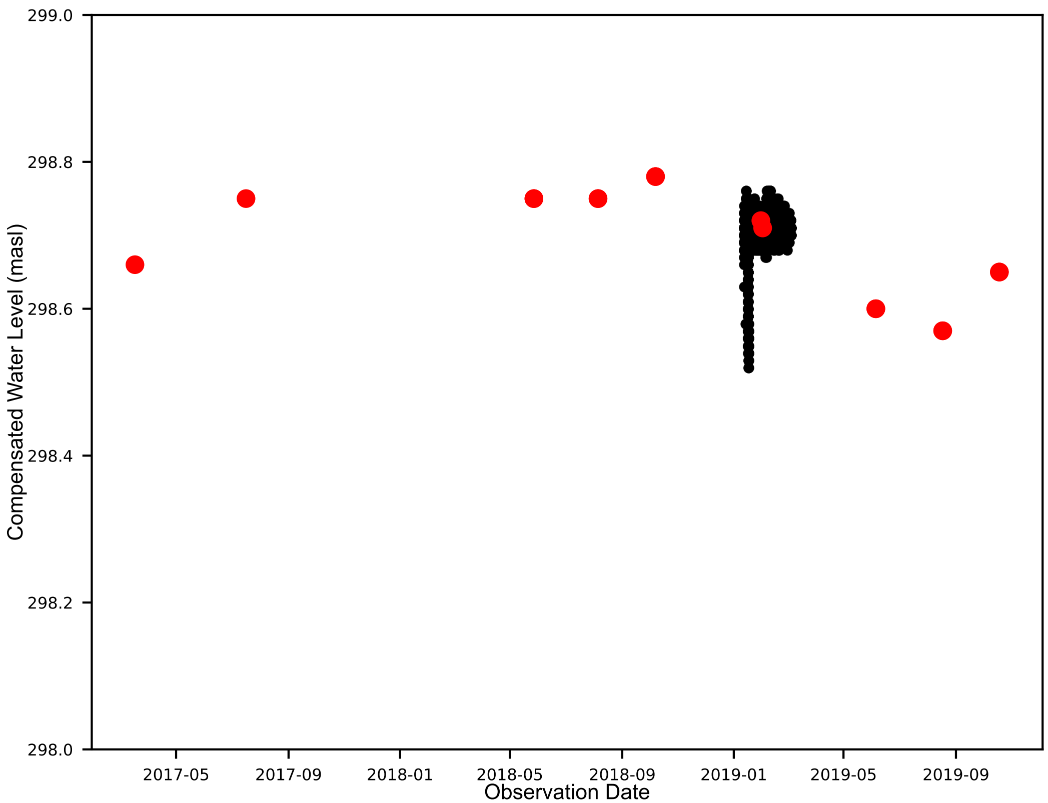

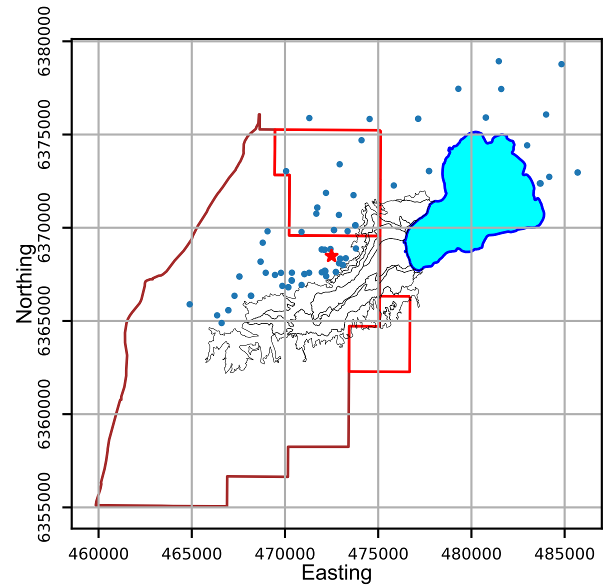

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.76 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR443-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-27

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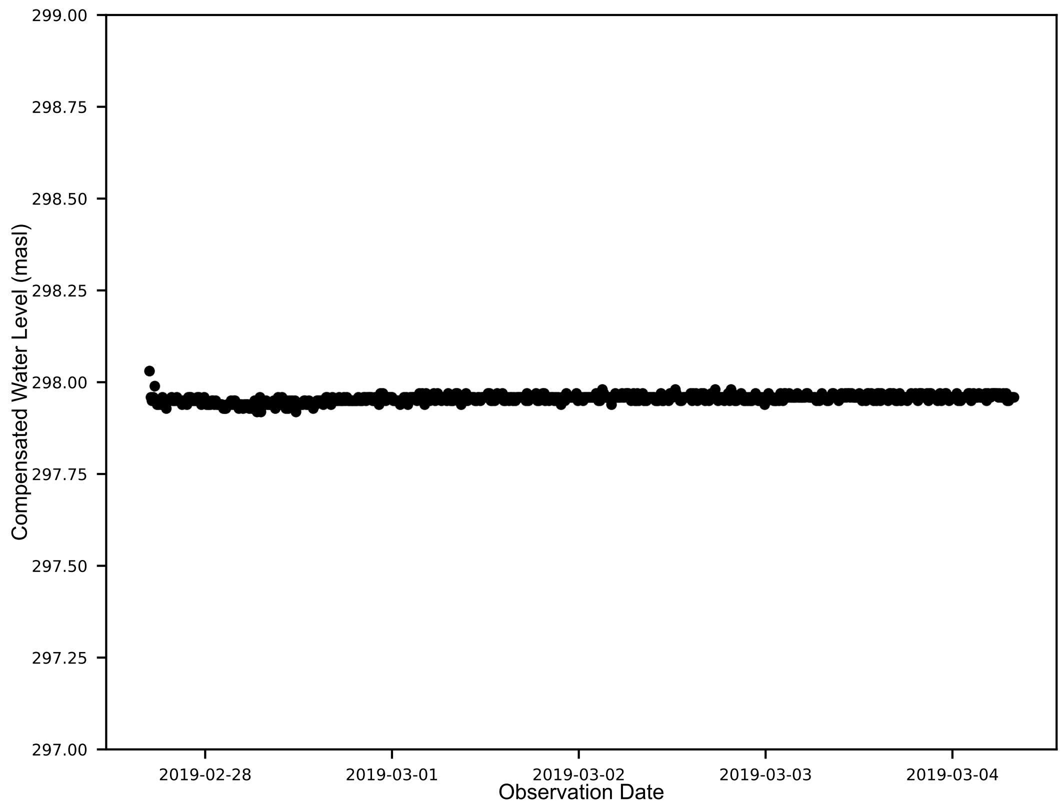
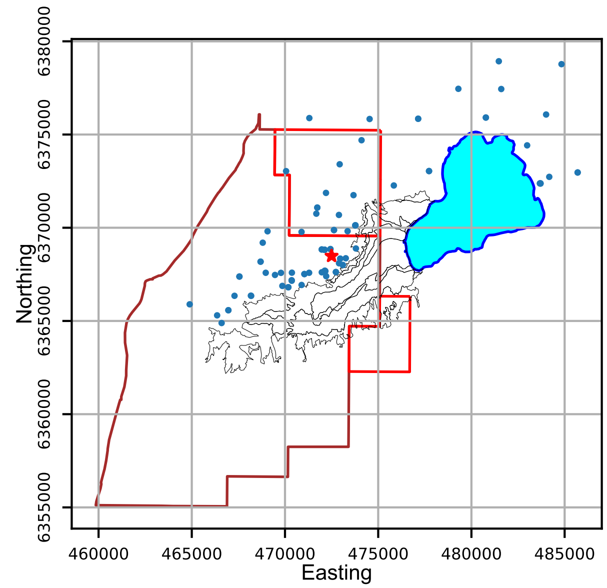




Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 16.76 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

Manual measurement

Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS

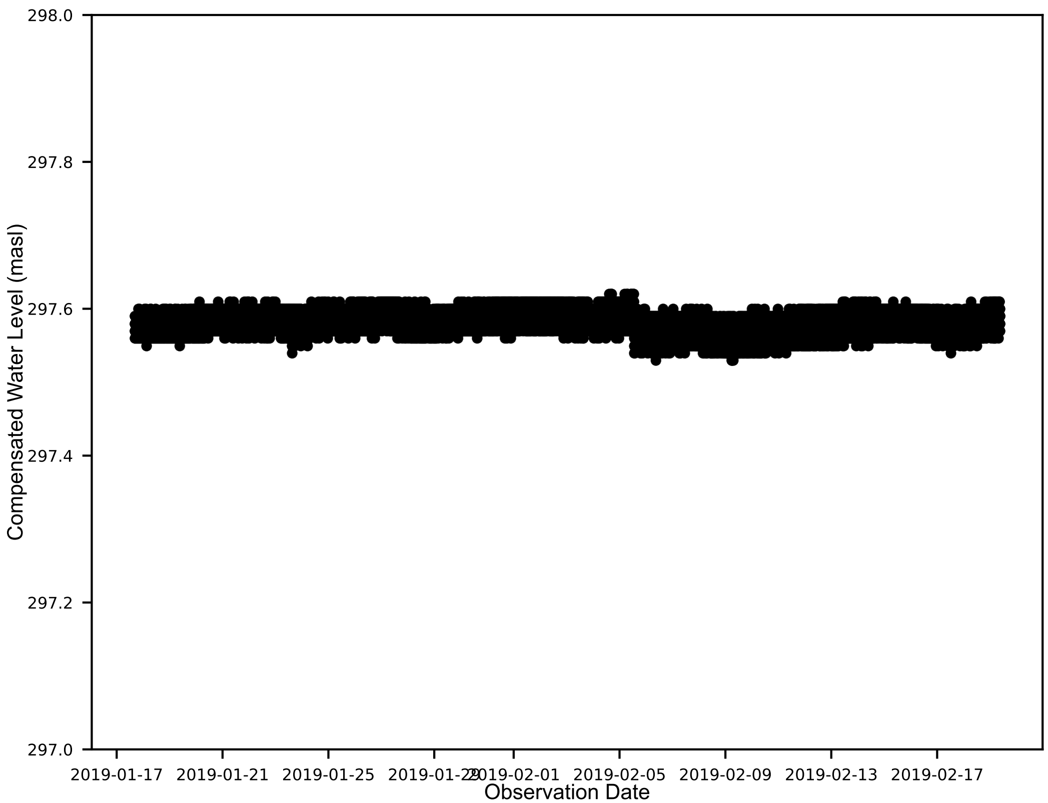
Operated by Suncor Energy

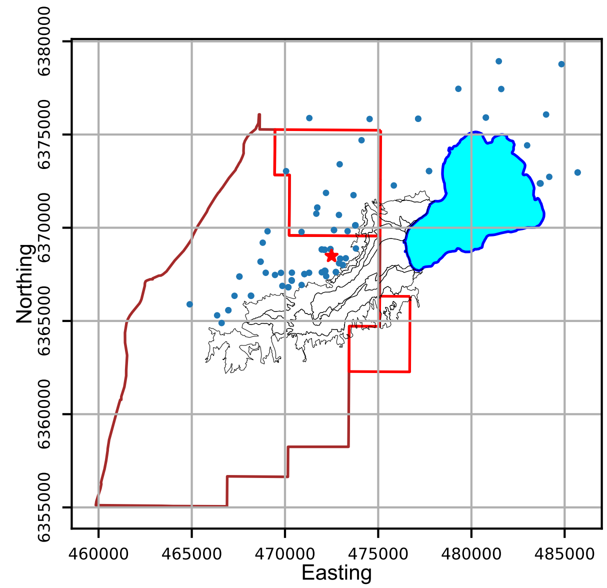
TITLE

FH17-WR443-SN1 - 13.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-28

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.76 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH17-WR443-SN1 - 14.16 M BELOW GROUND SURFACE

FORTHILLS
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PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-29

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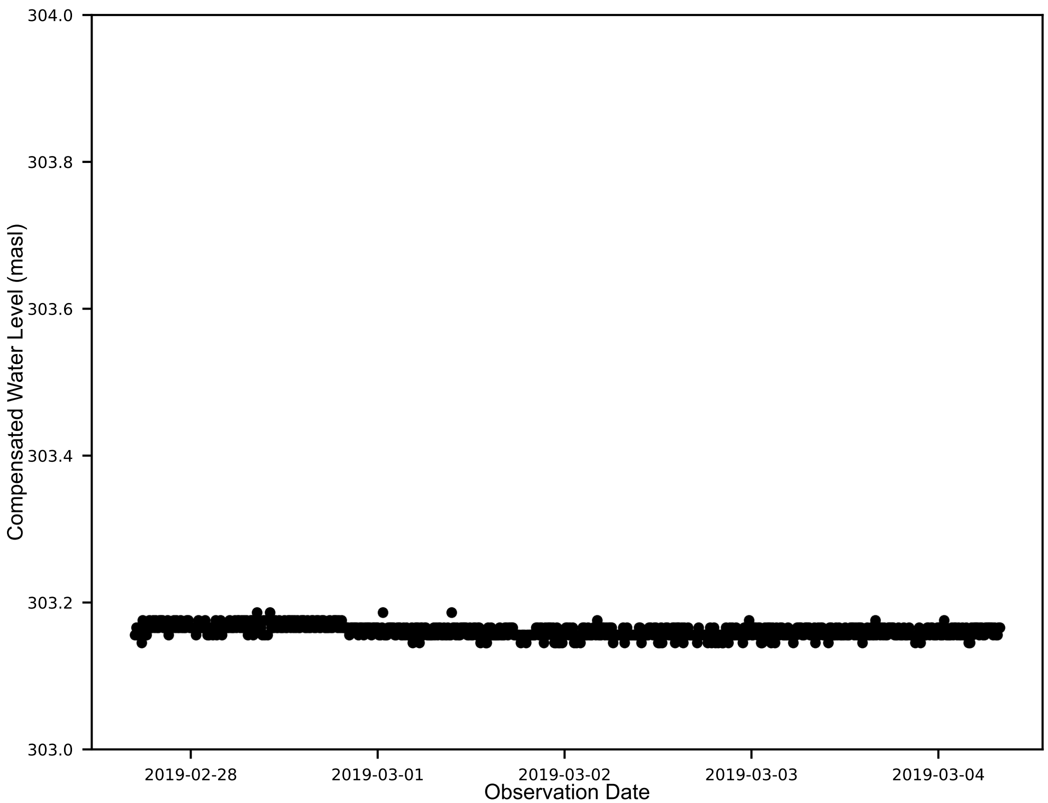

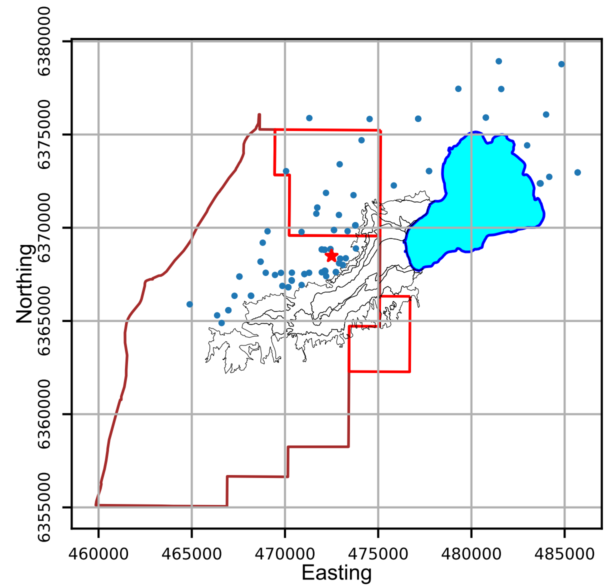

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.76 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR443-SN1 - 8.584 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-30

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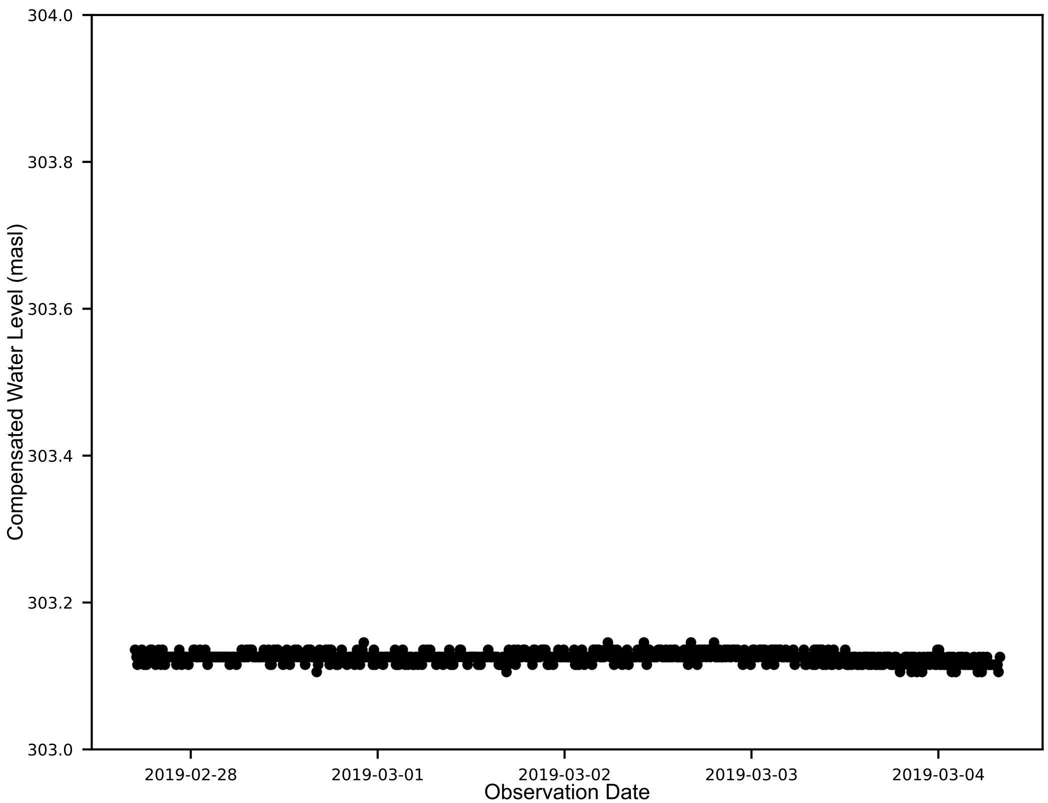

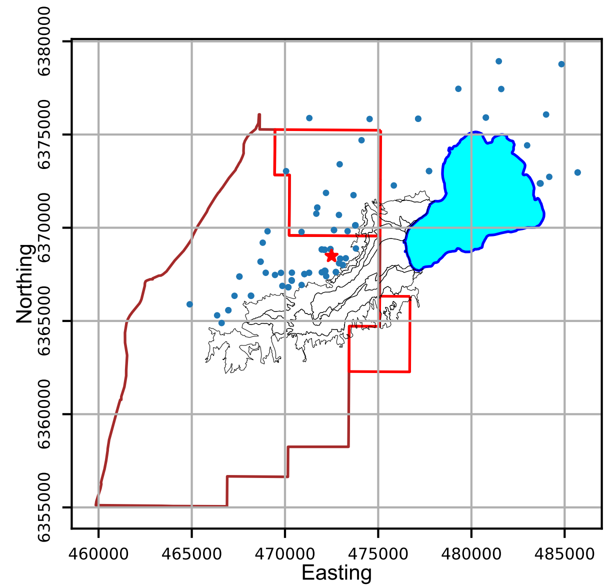

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.76 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH17-WR443-SN1 - 8.614 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-31

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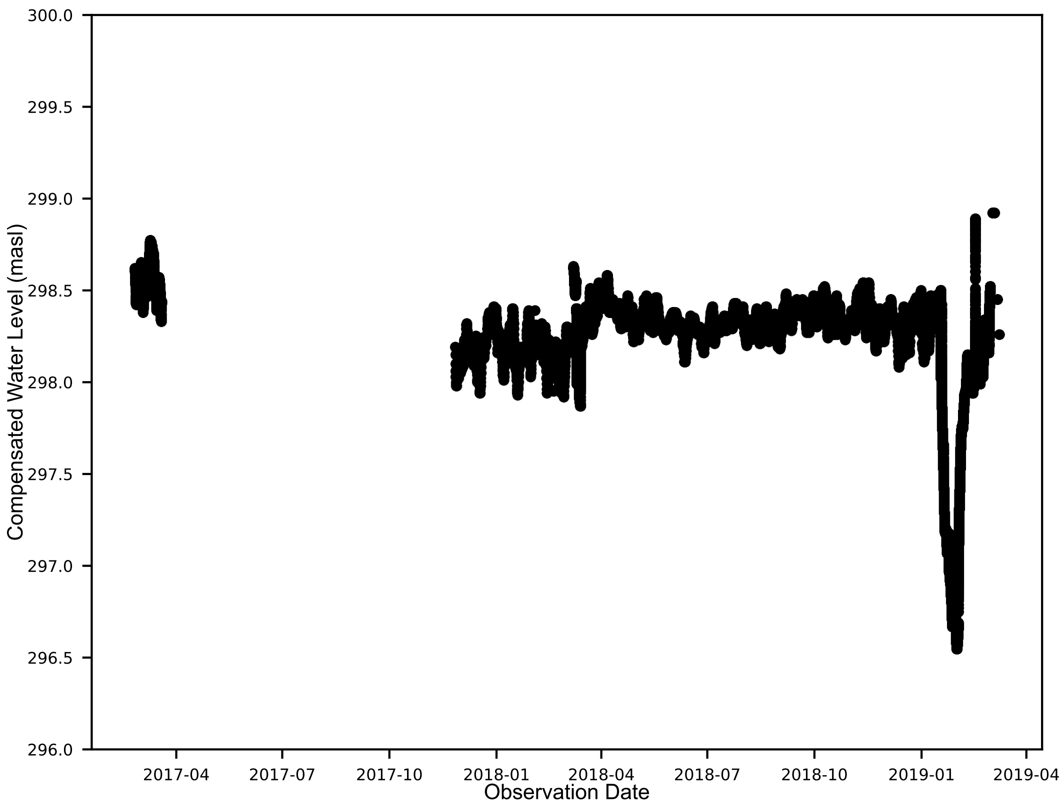
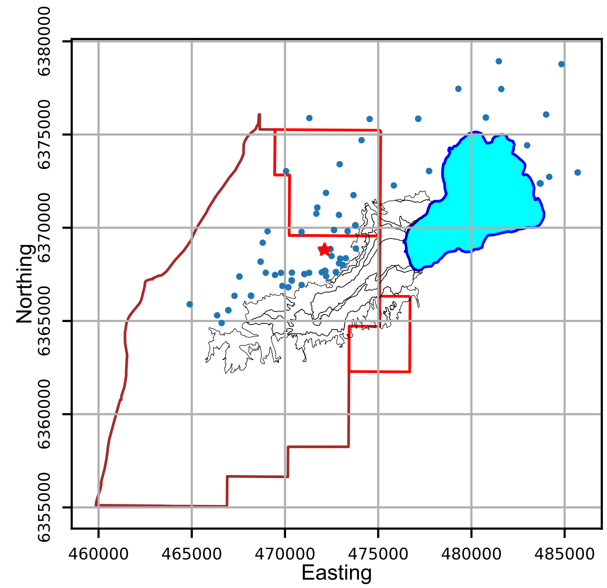




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

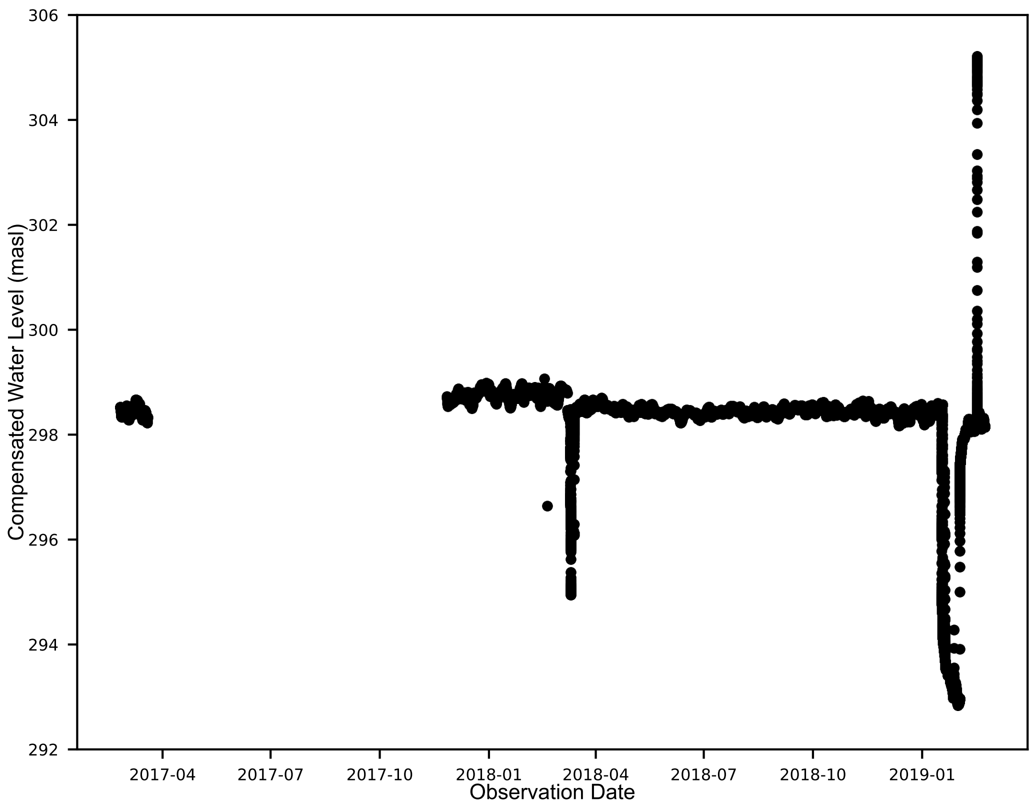
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

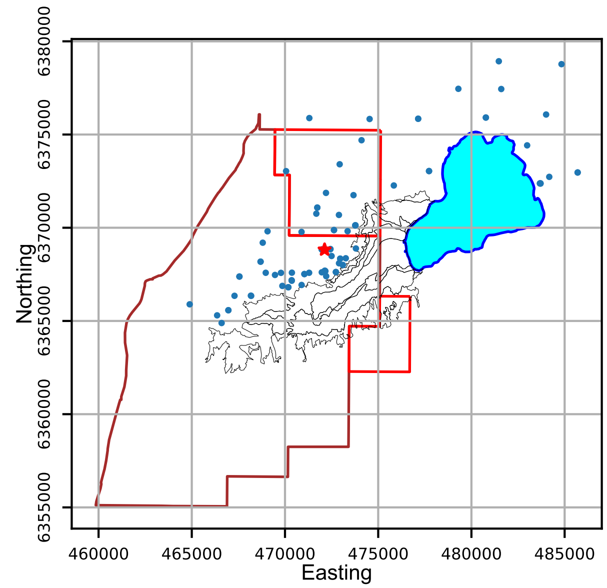
FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH17-WR444-SN1 - 14.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-32





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 33 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH17-WR444-SN1 - 33.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-33

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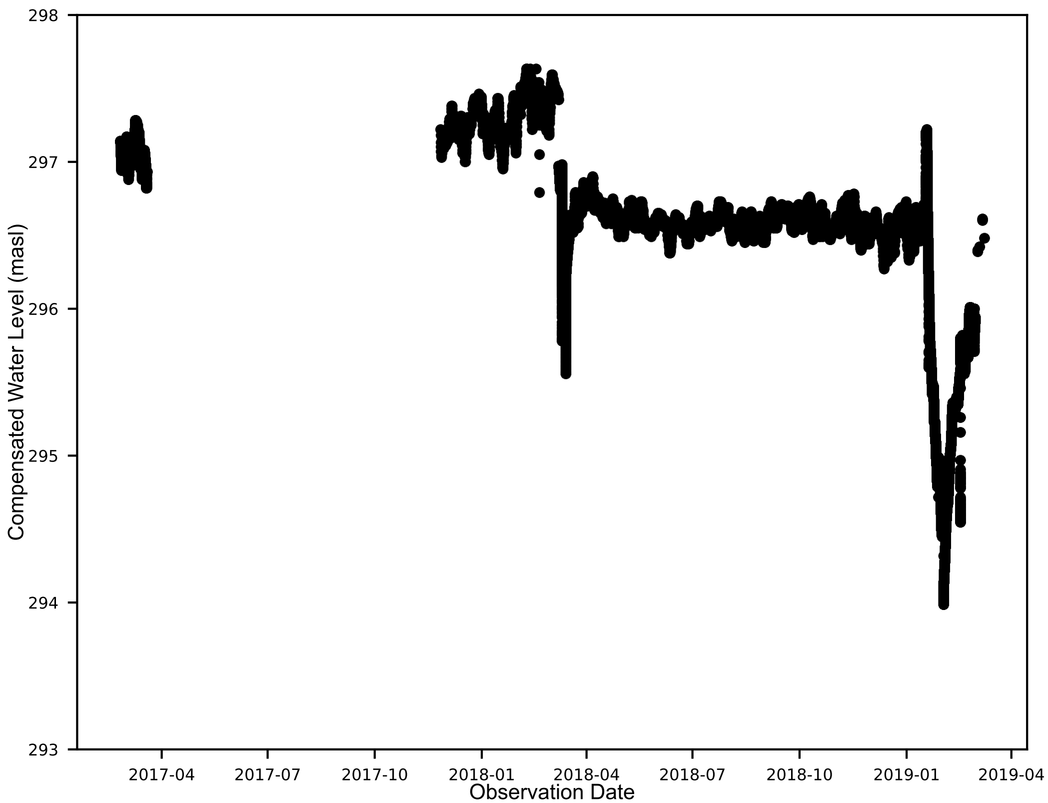
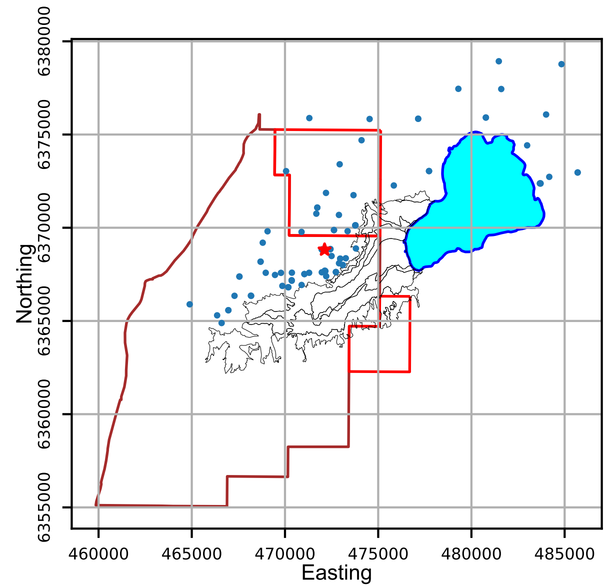




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 42 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

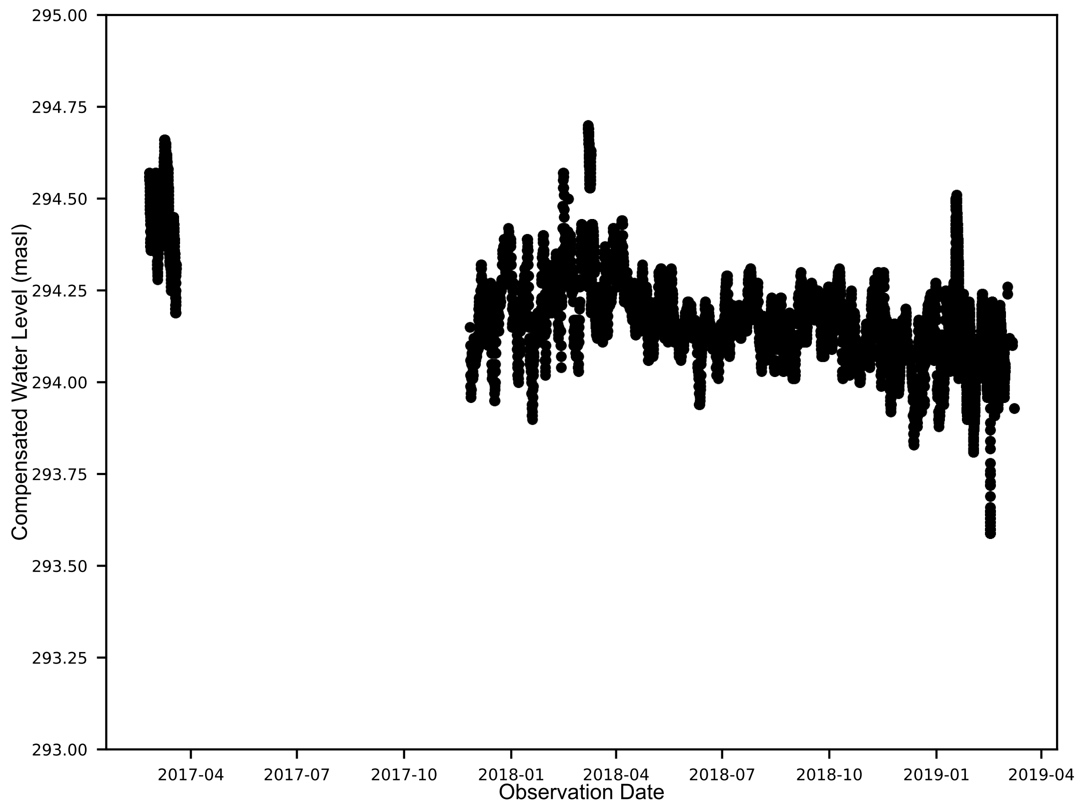
PROJECT

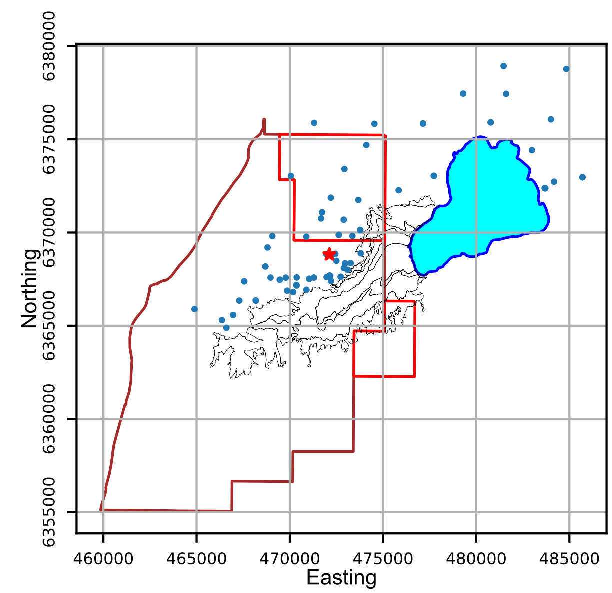
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH17-WR444-SN1 - 42.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-34





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquitard
Depth of Measurement: 51 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

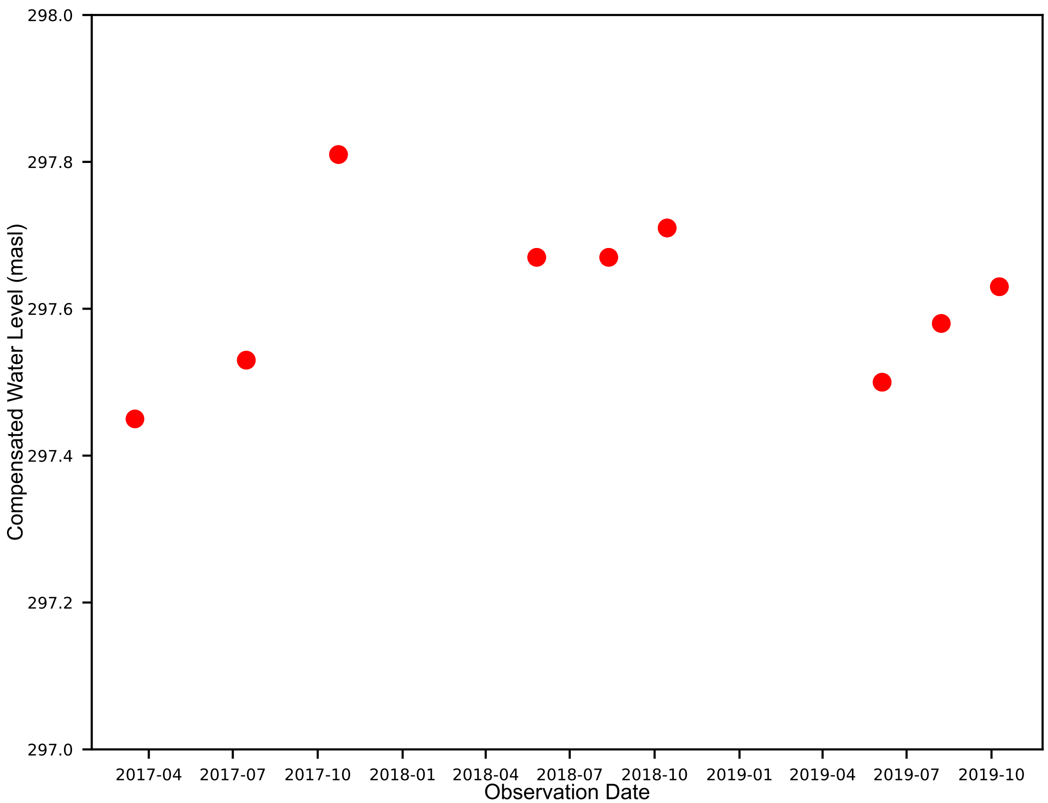
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

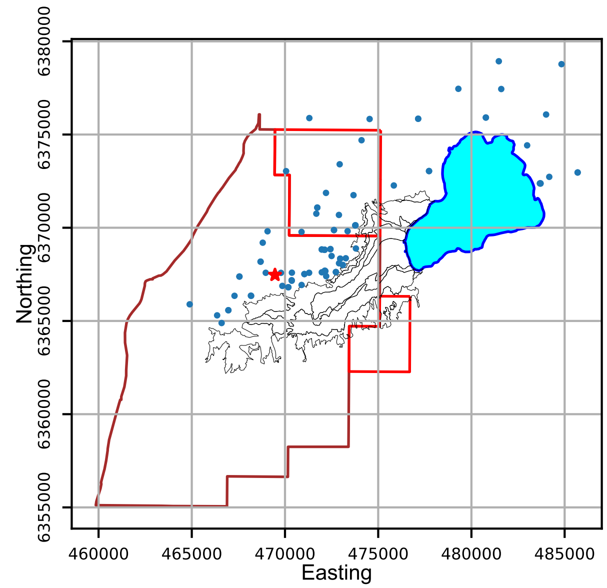
TITLE

FH17-WR444-SN1 - 51.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-35

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 12.35 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

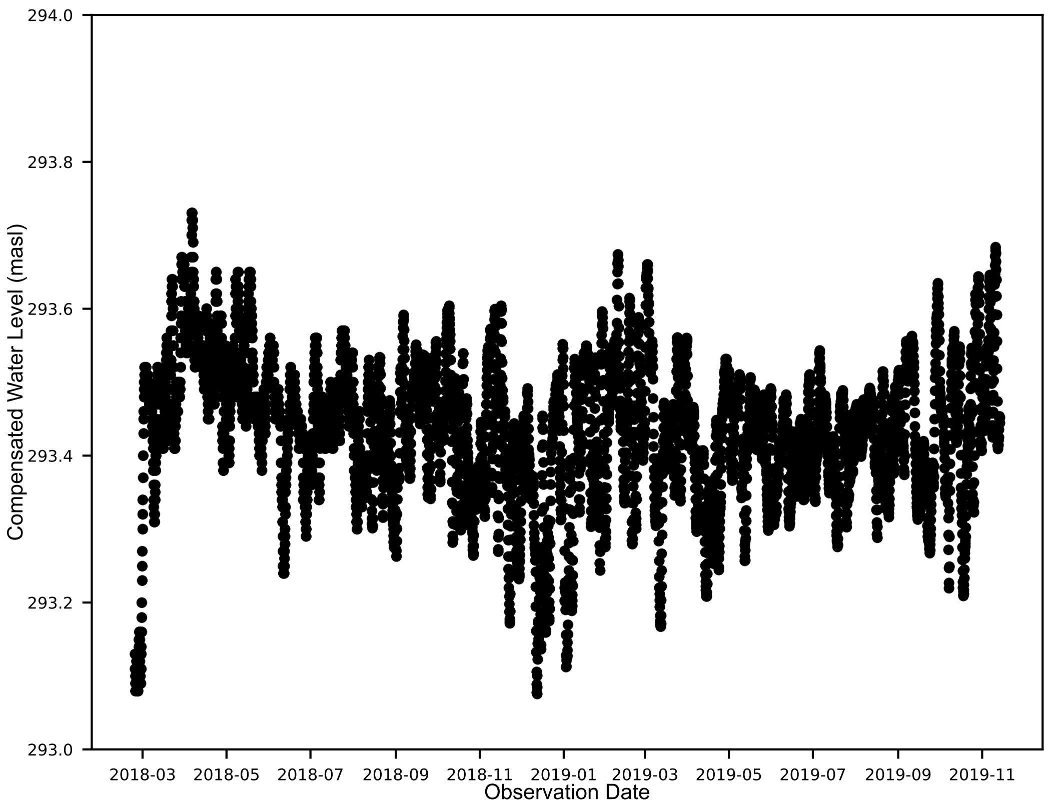
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

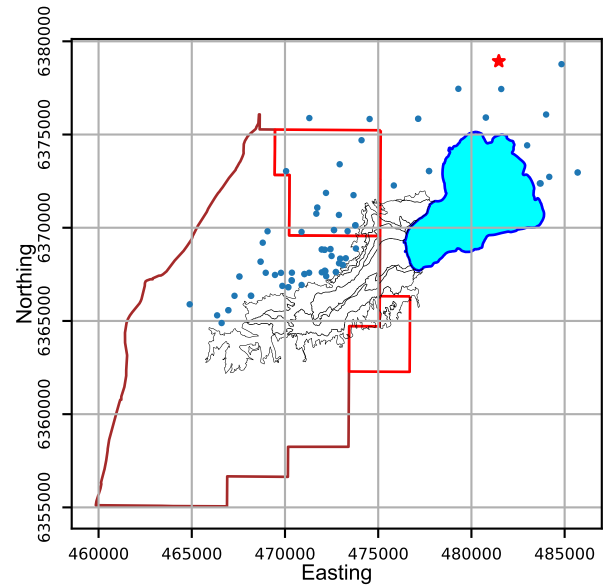
TITLE

FH17-WR452-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-36

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

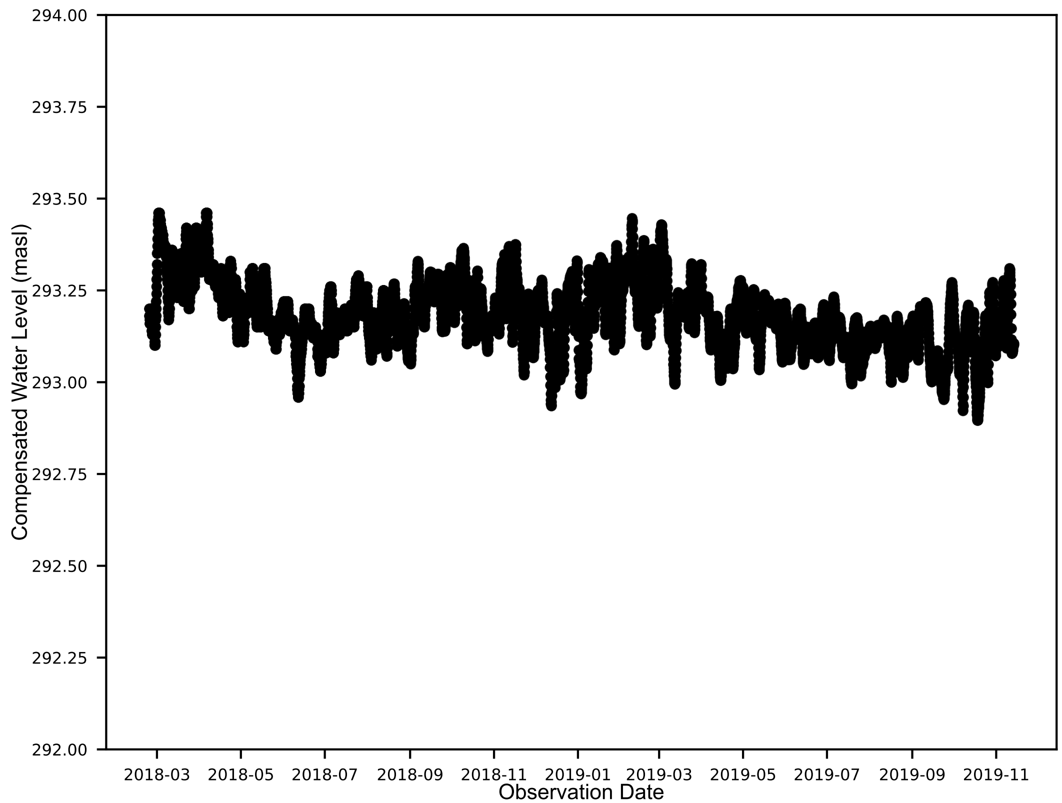
Operated by Suncor Energy

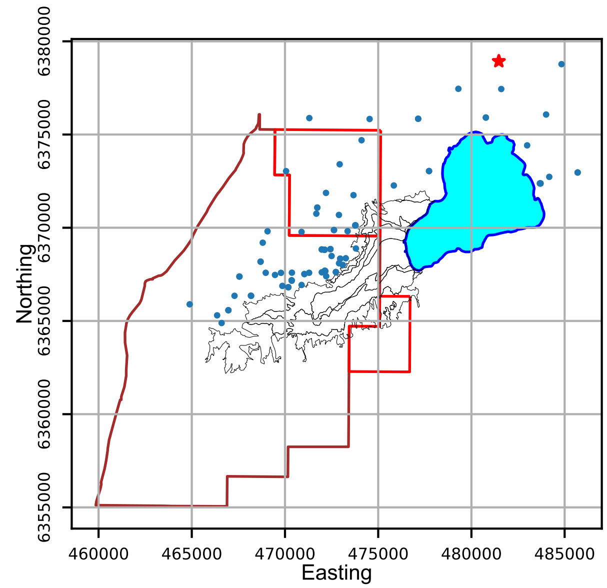
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES401-SN1 - 11.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-37





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 29.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

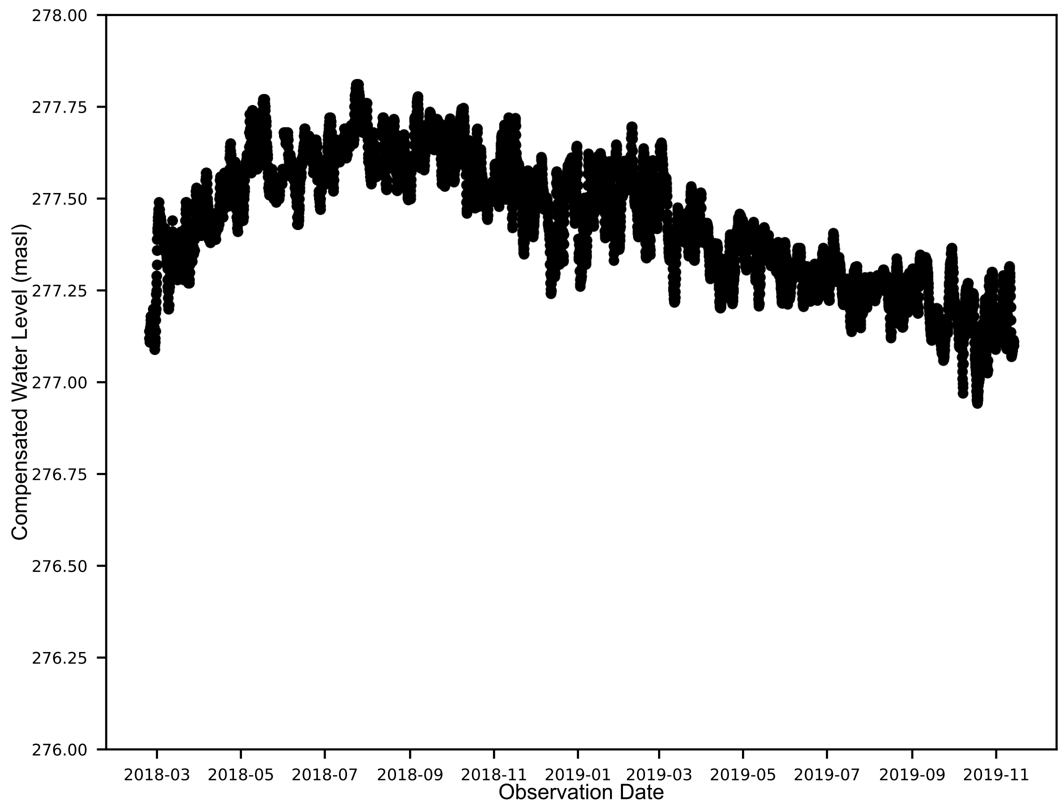
FORTHILLS
Operated by Suncor Energy

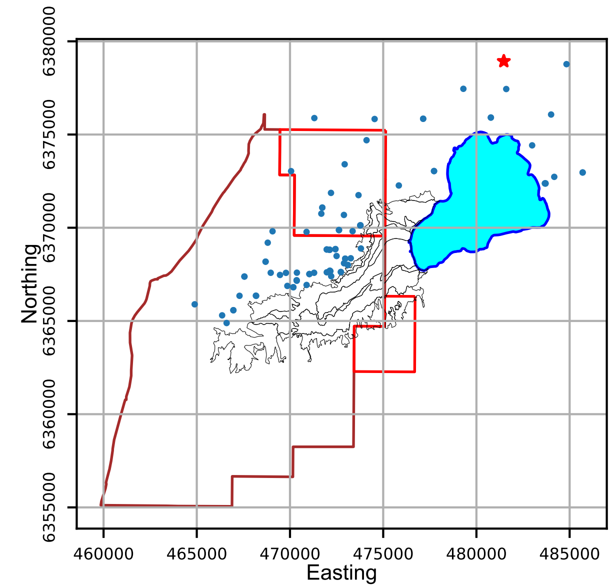
TITLE

FH18-ES401-SN1 - 29.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-38

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 70 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

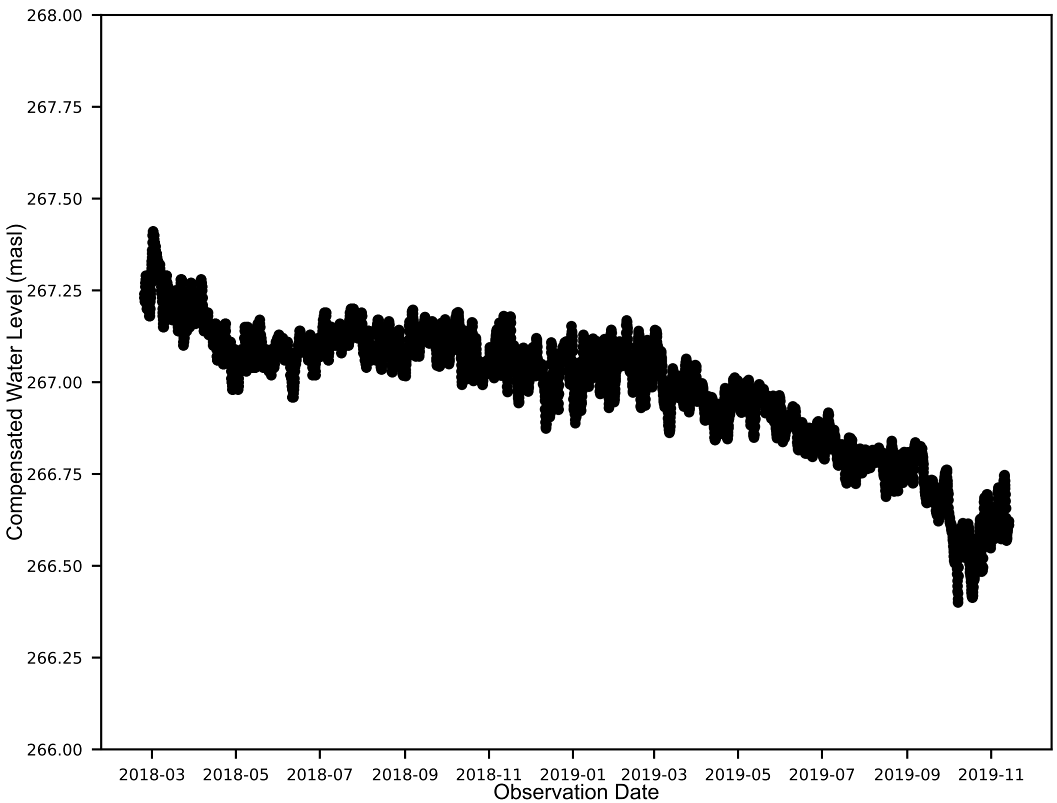
FORTHILLS
Operated by Suncor Energy

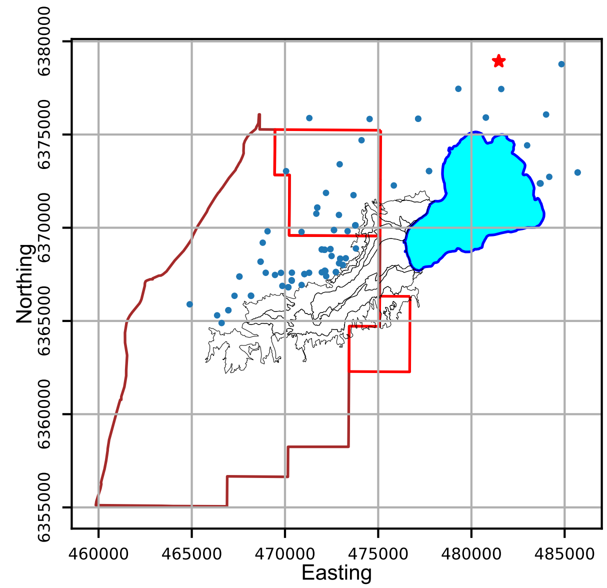
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES401-SN1 - 70.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-39

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 88.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
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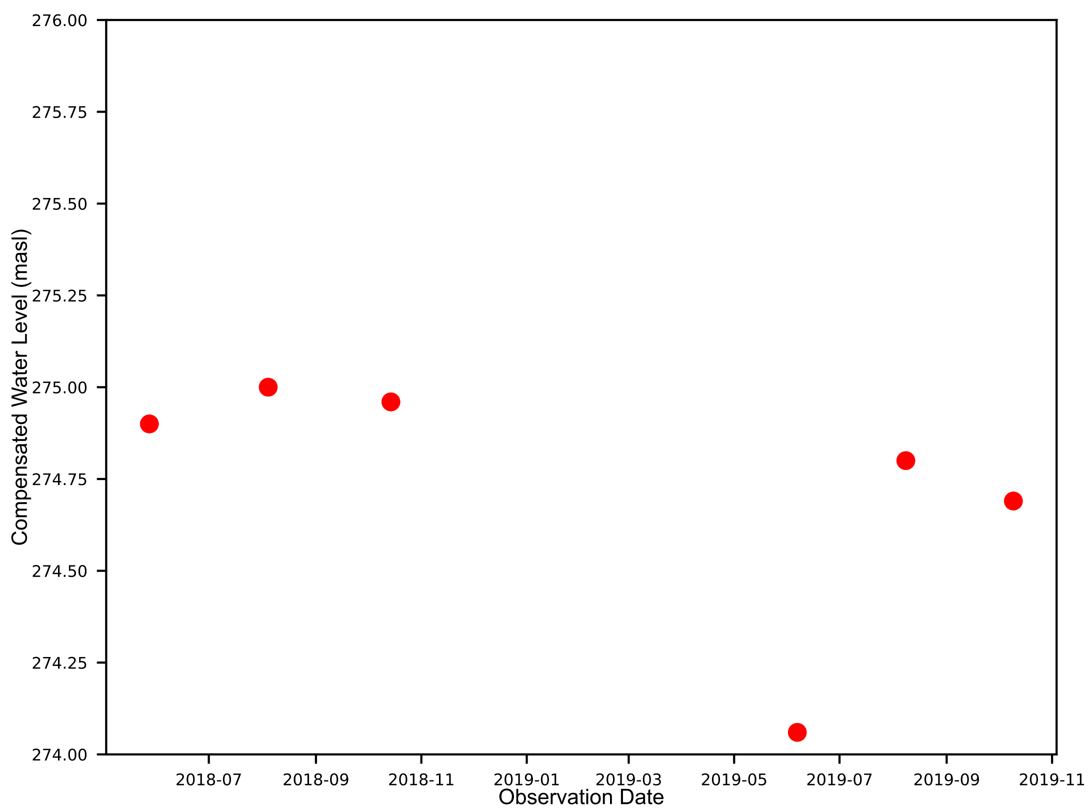
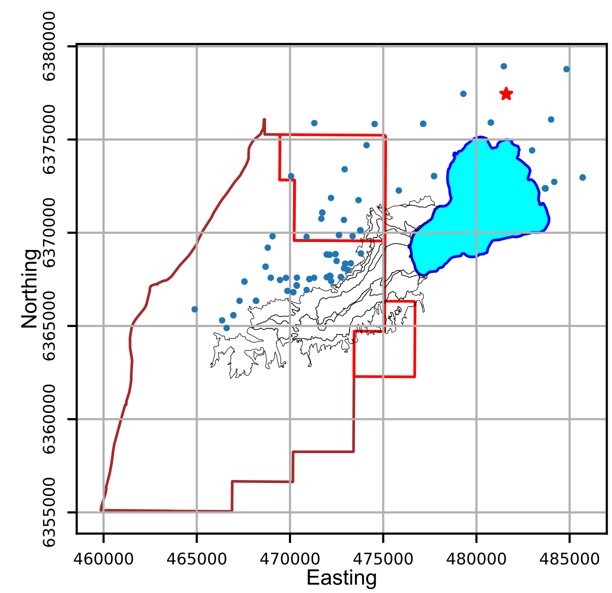
TITLE
FH18-ES401-SN1 - 88.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-40





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 75.07 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

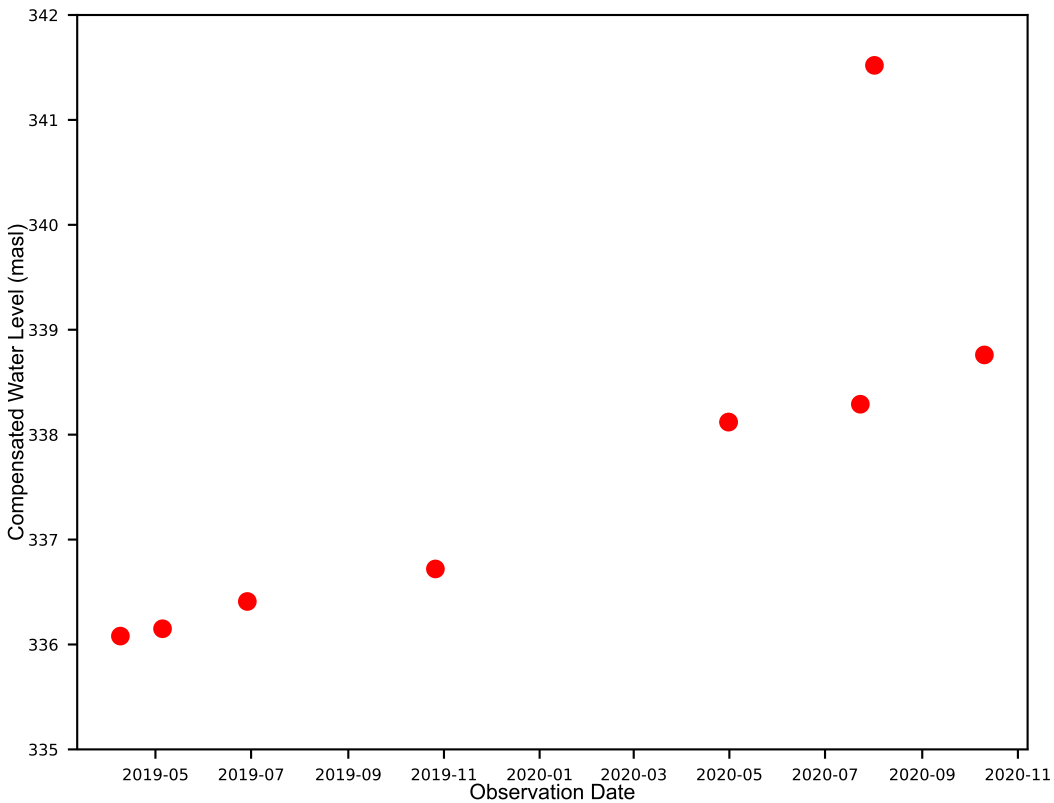
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

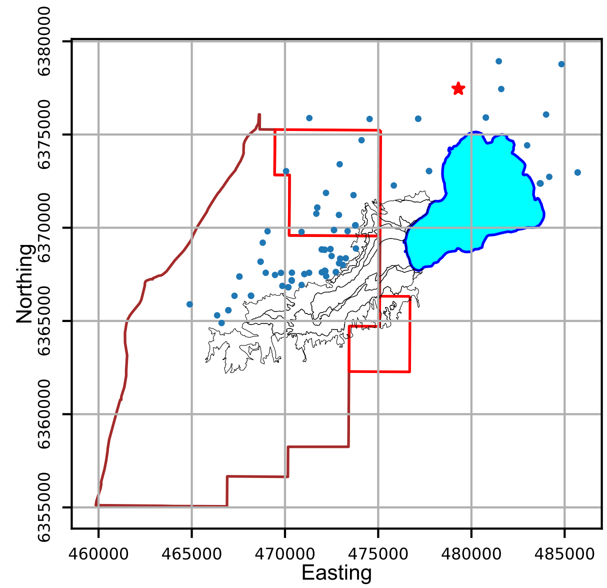
TITLE

FH18-ES403-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-41

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 26 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH18-ES404-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-42

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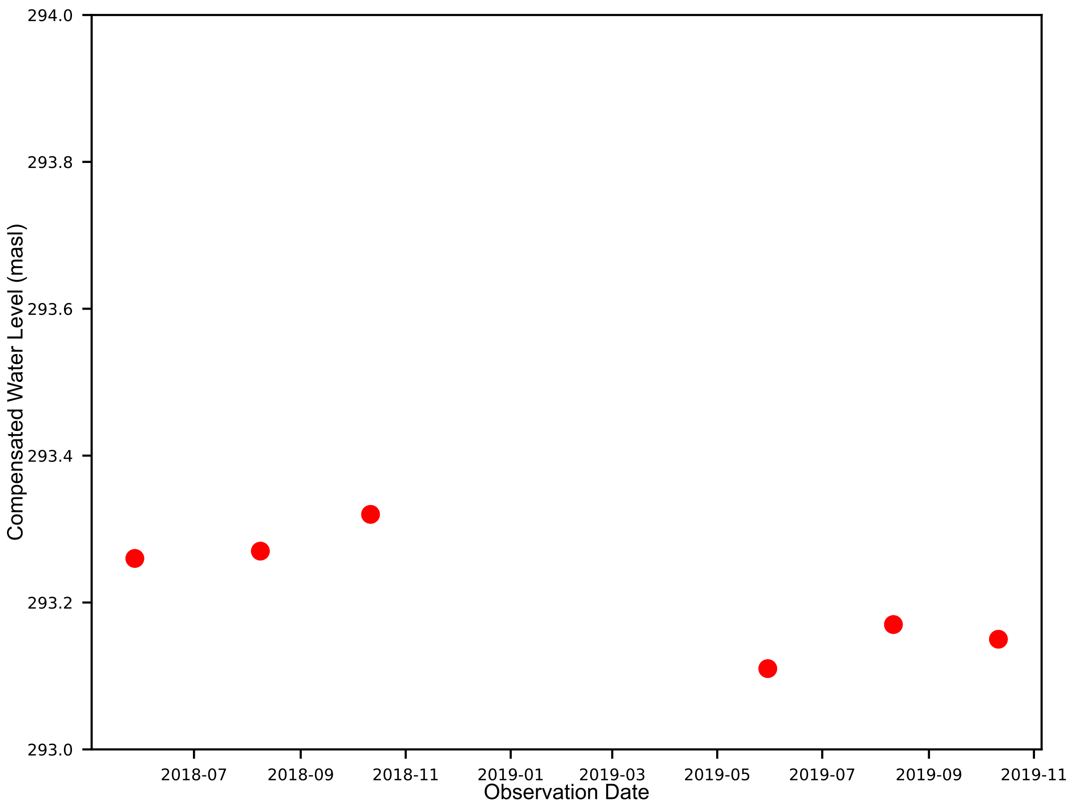

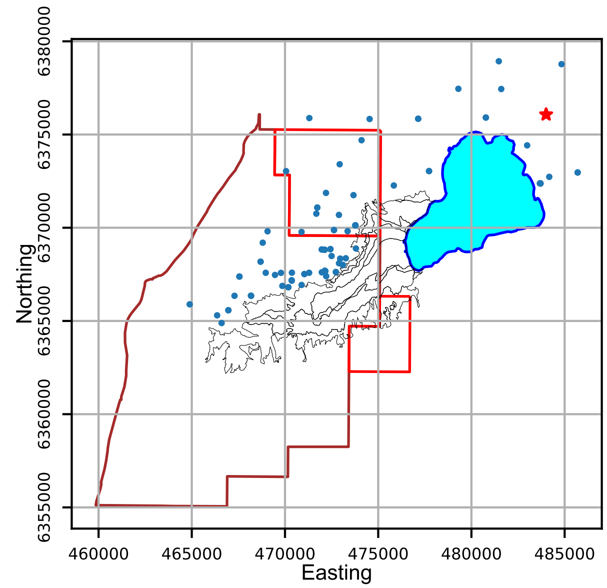

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 27.14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH18-ES405-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-43

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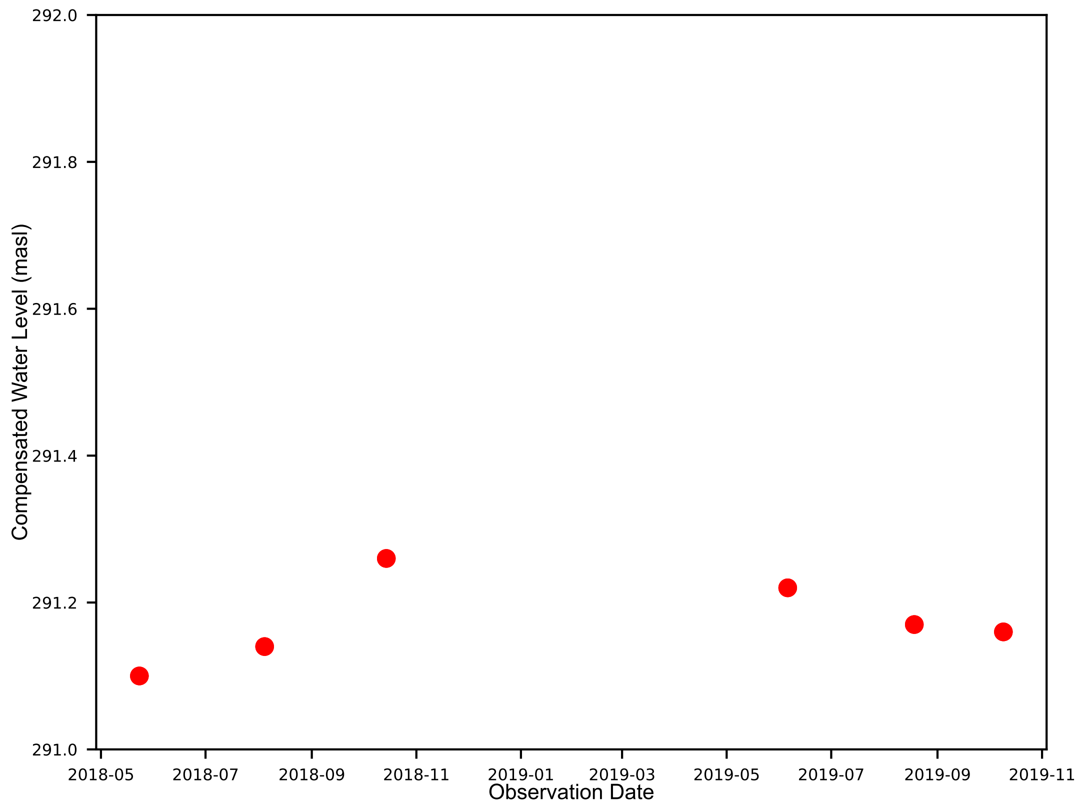

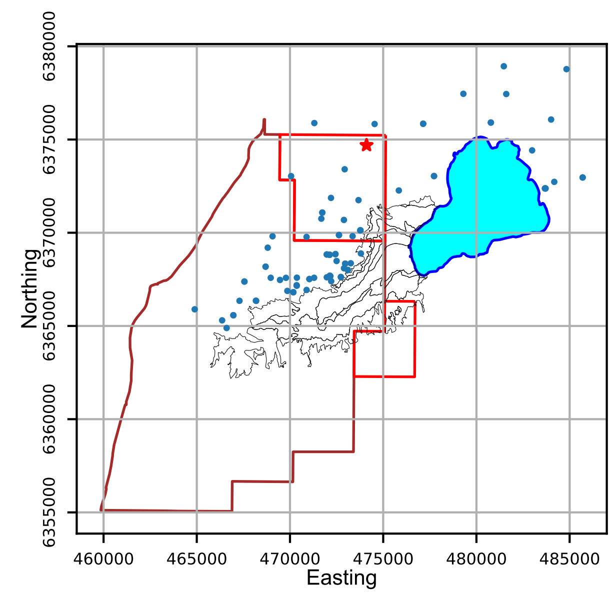

Map Legend

Plotted Well

Wells

Extension Areas as proposed in the Integrated Plan Amendment Application

McClelland Lake

Approved Project Area

Ecohydrology Zone

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 18.41 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES407-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-44

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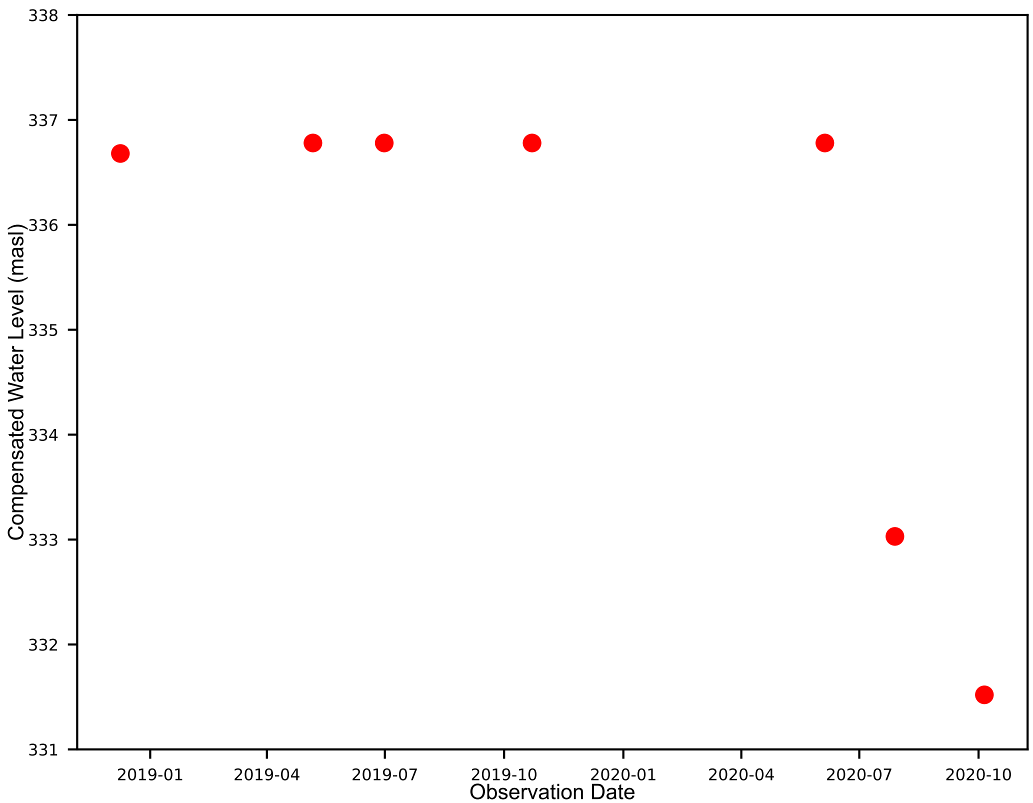

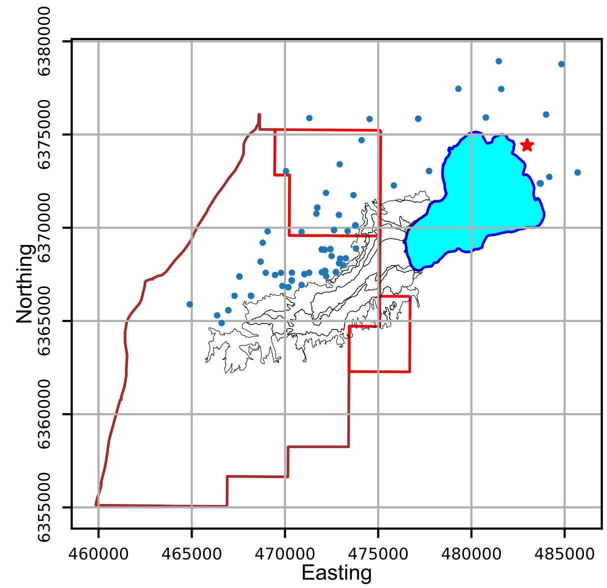

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES408-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-45

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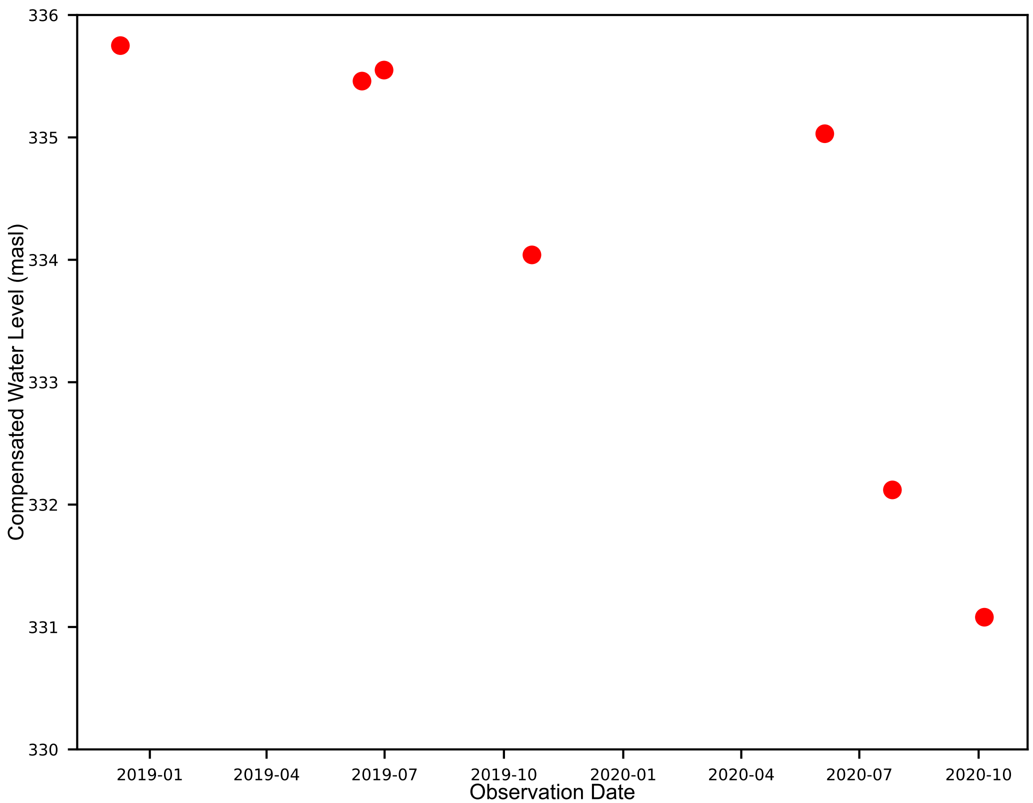
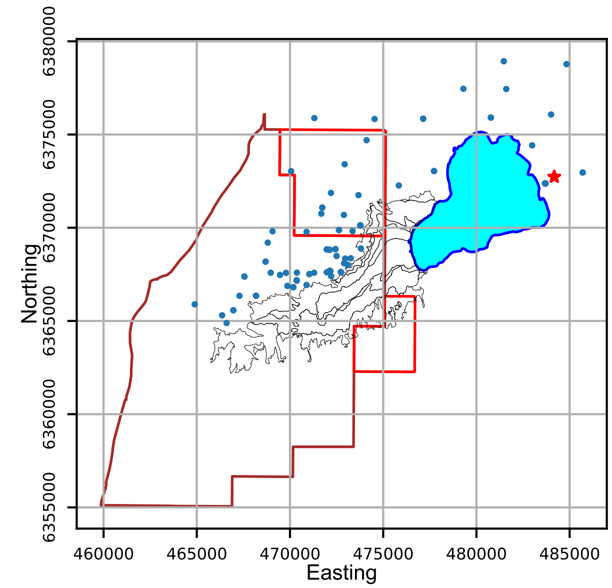




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

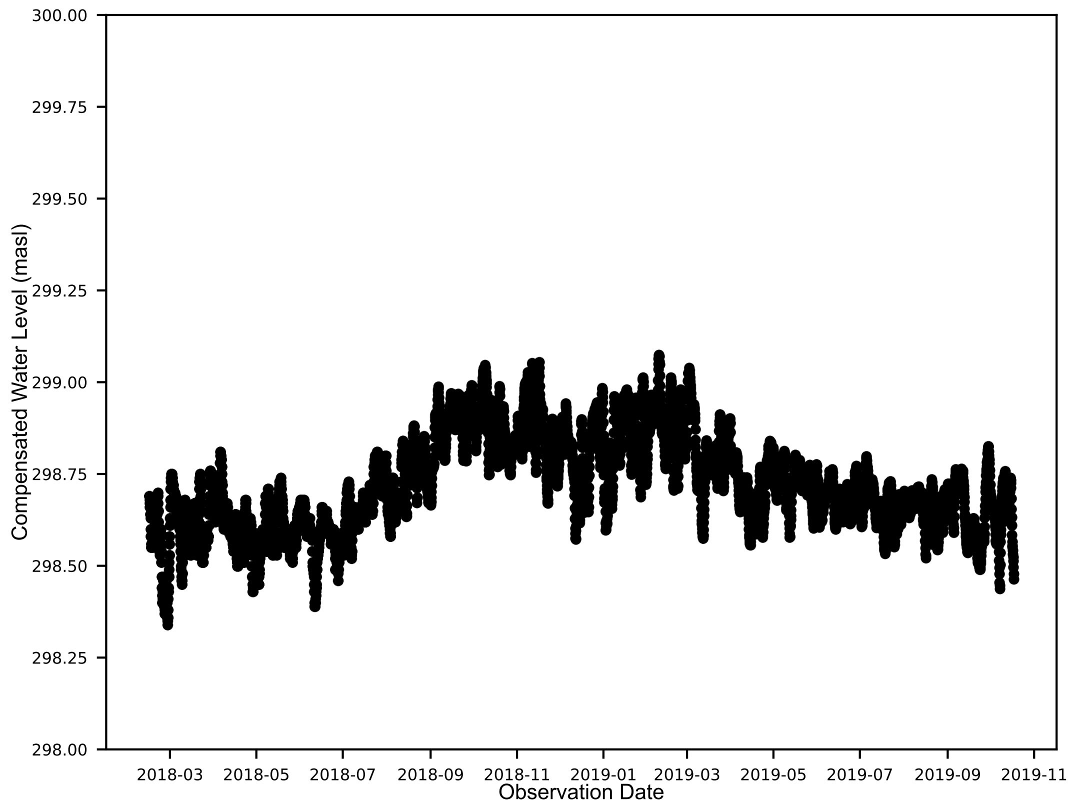
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

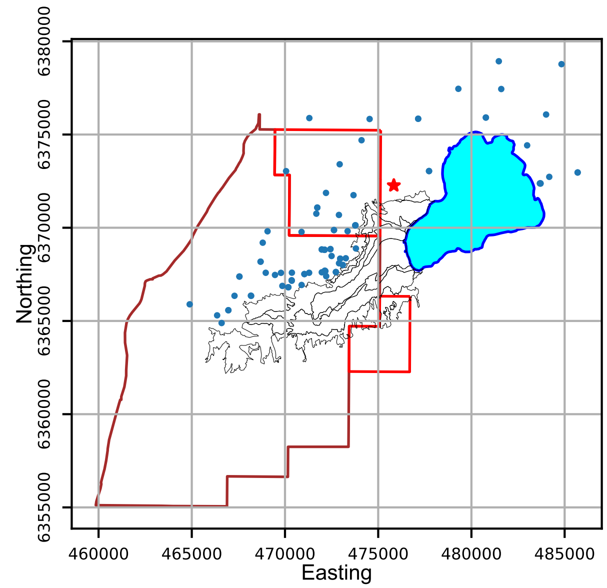
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES410-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-46





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

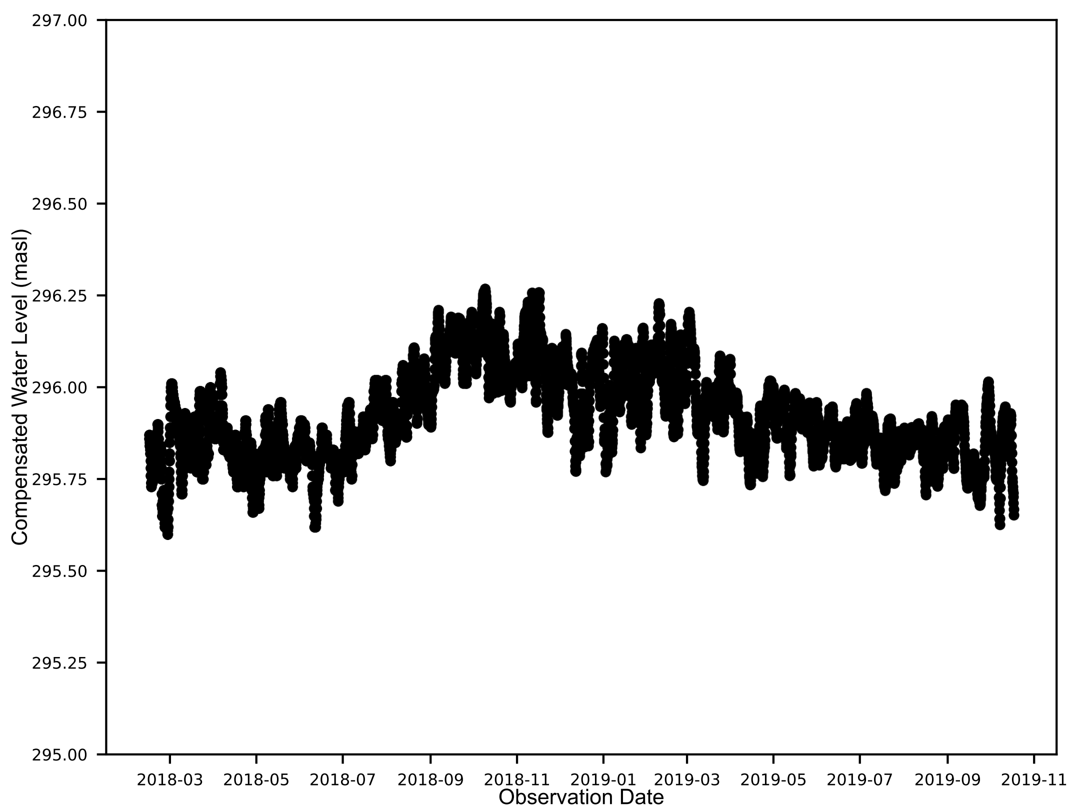
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

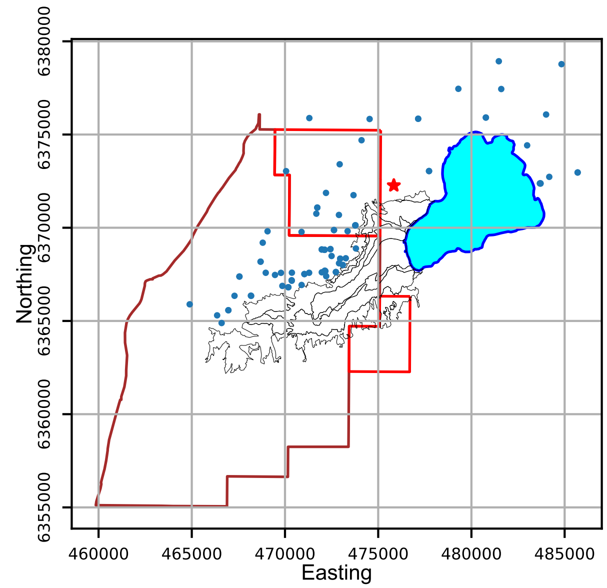
FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES411-SN1 - 10.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-47

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 22.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

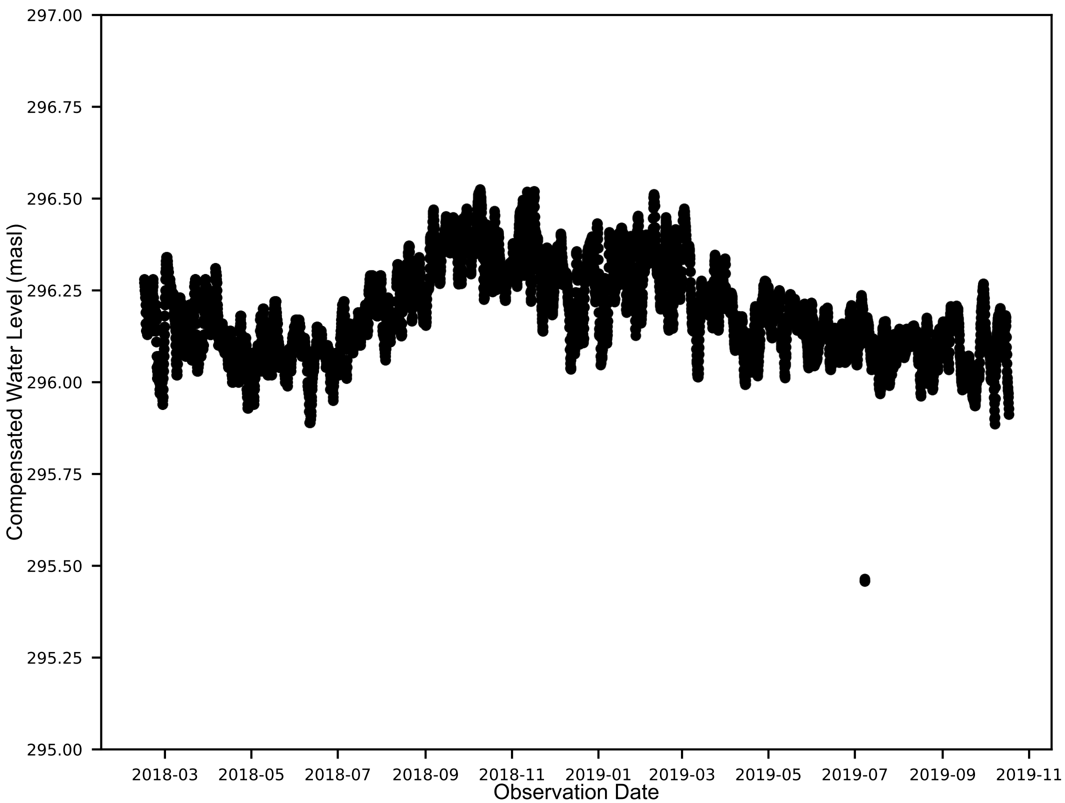
FORT HILLS
Operated by Suncor Energy

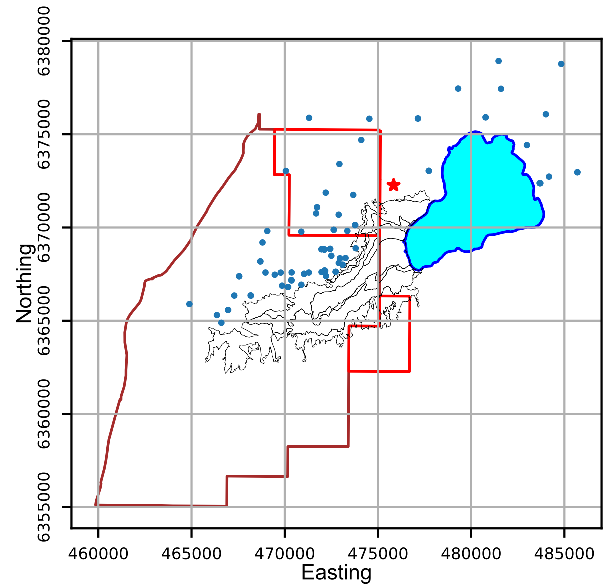
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES411-SN1 - 22.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-48

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 30 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS

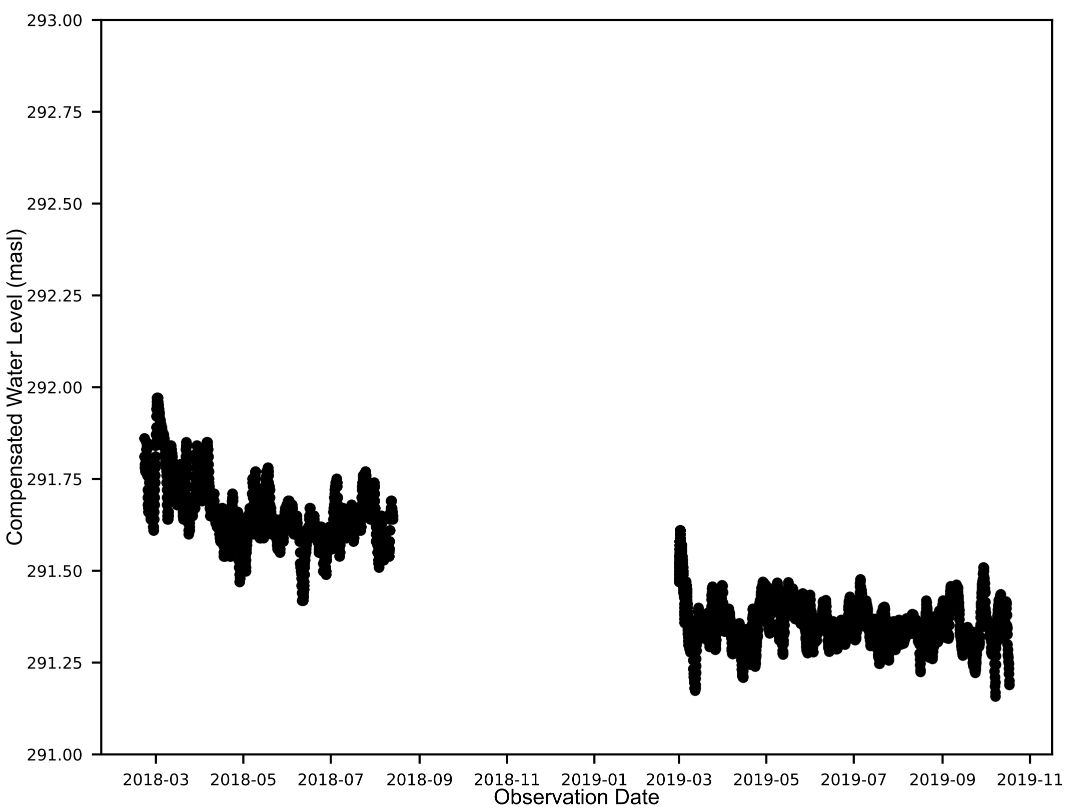
Operated by Suncor Energy

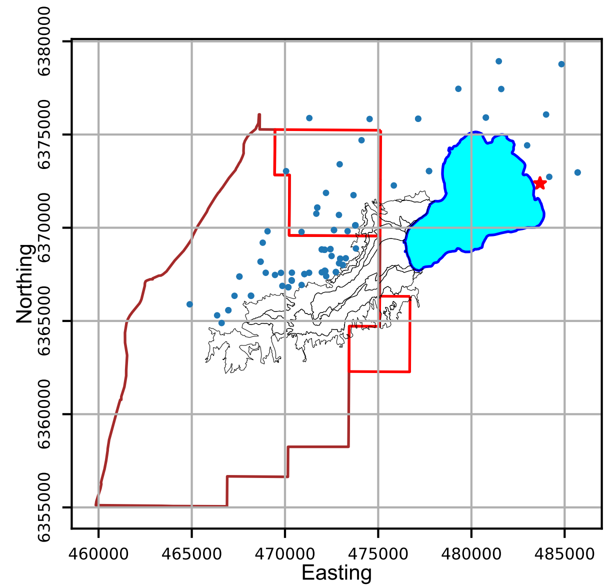
TITLE

FH18-ES411-SN1 - 30.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-49

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 10 Clay Till 2
Depth of Measurement: 42 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES412-MR1 - 42.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-50

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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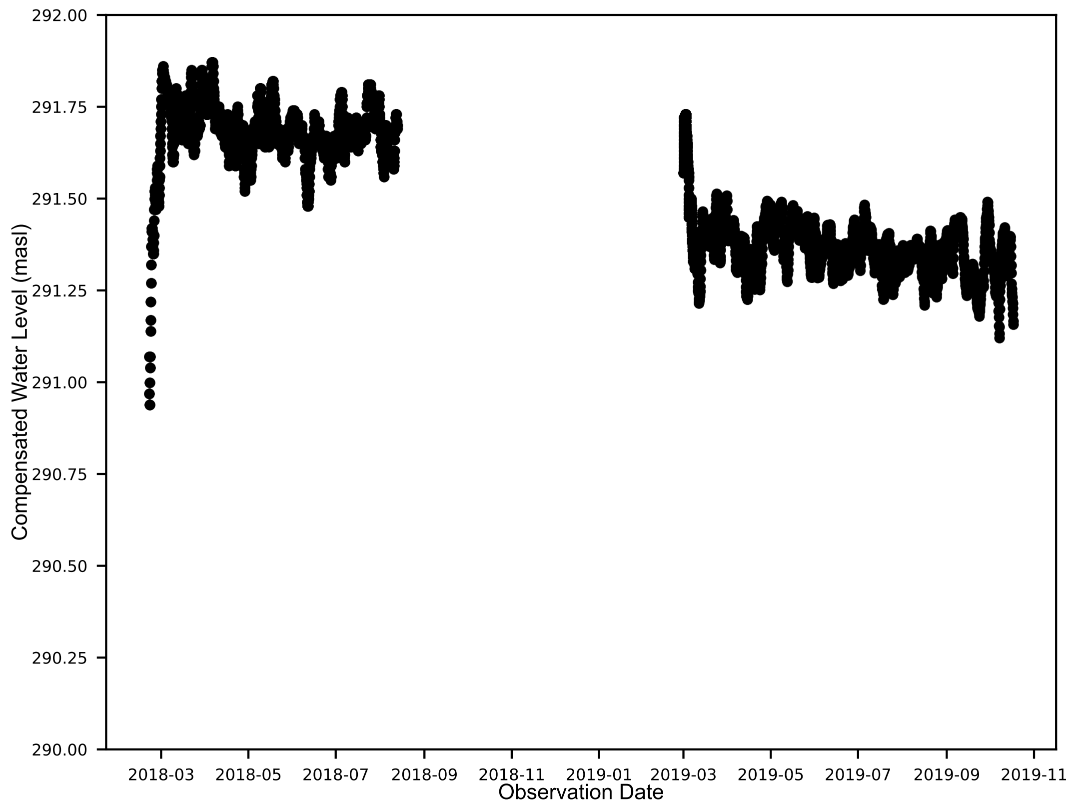

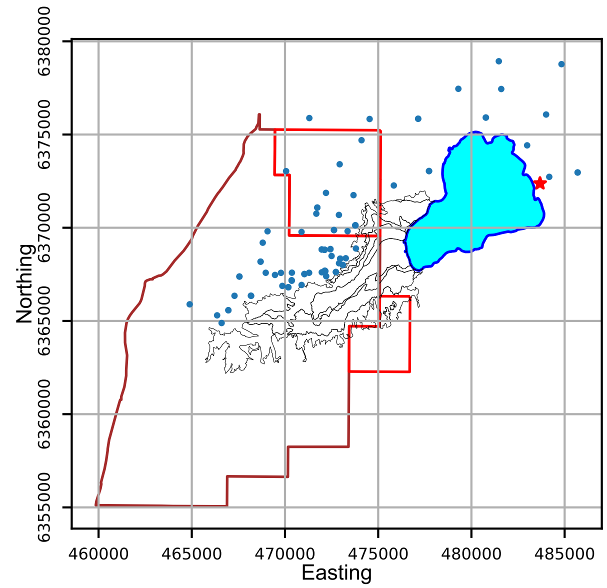

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 63 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH18-ES412-MR1 - 63.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-51

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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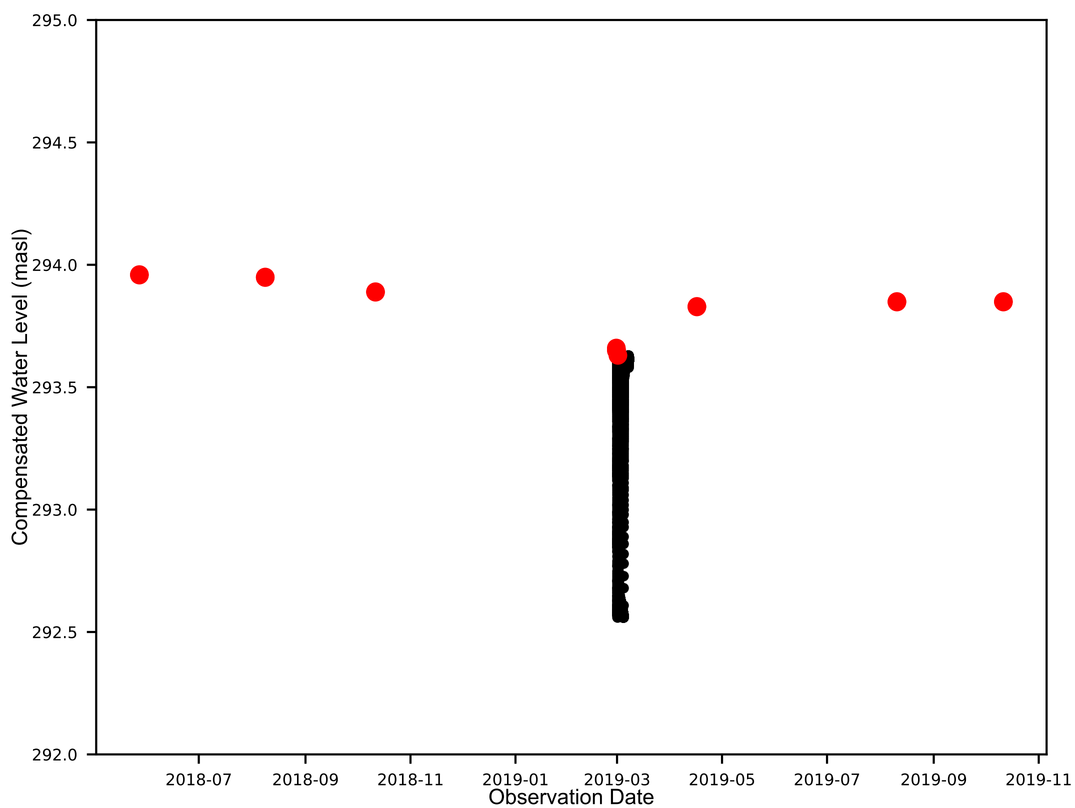

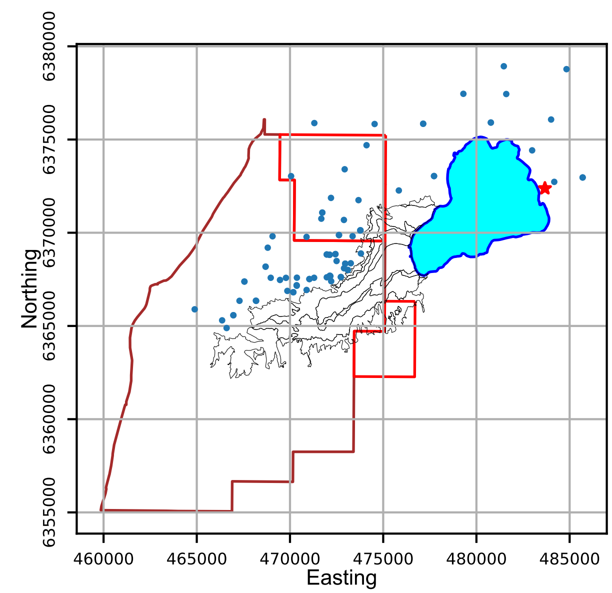

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 18 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES412-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-52

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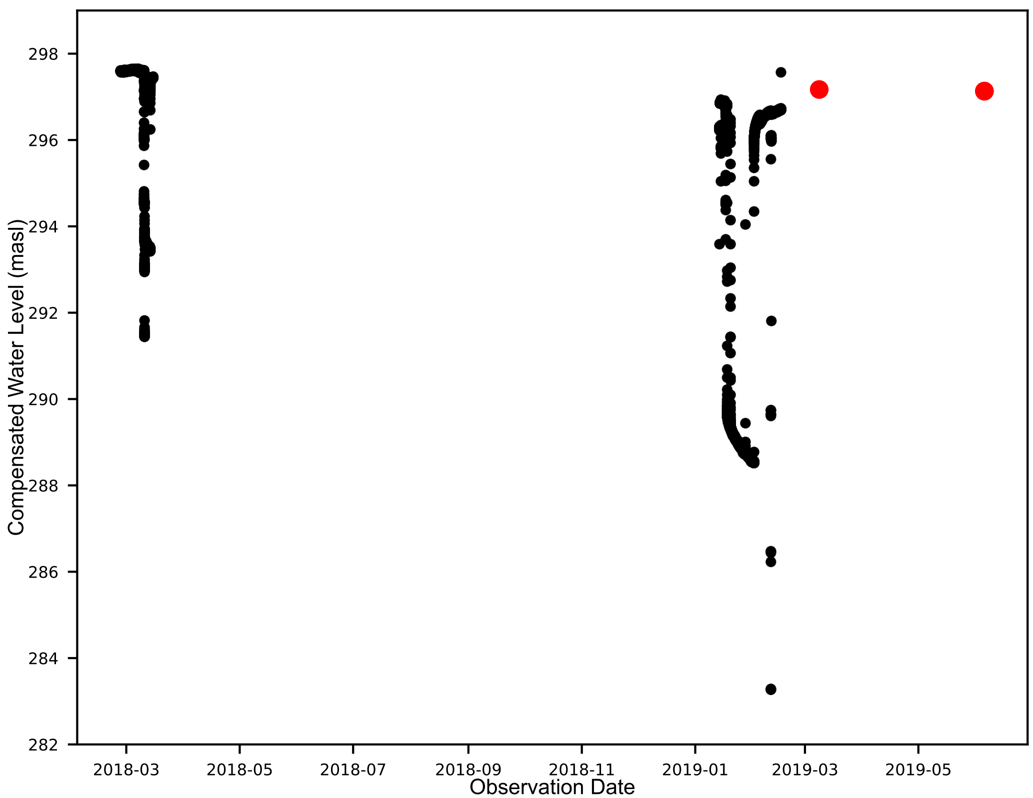
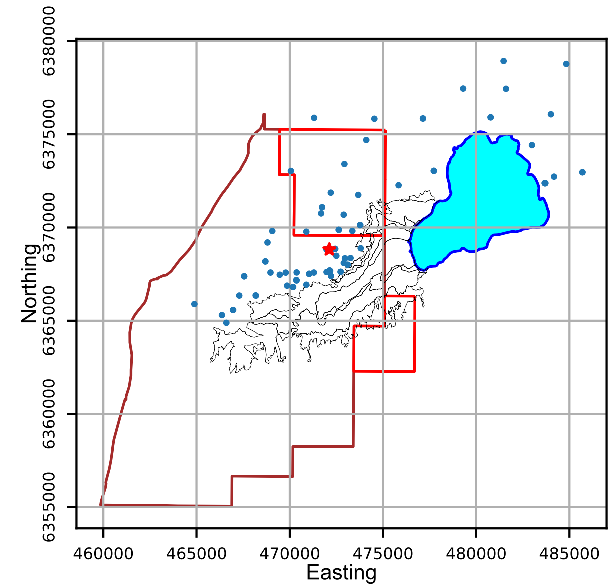




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

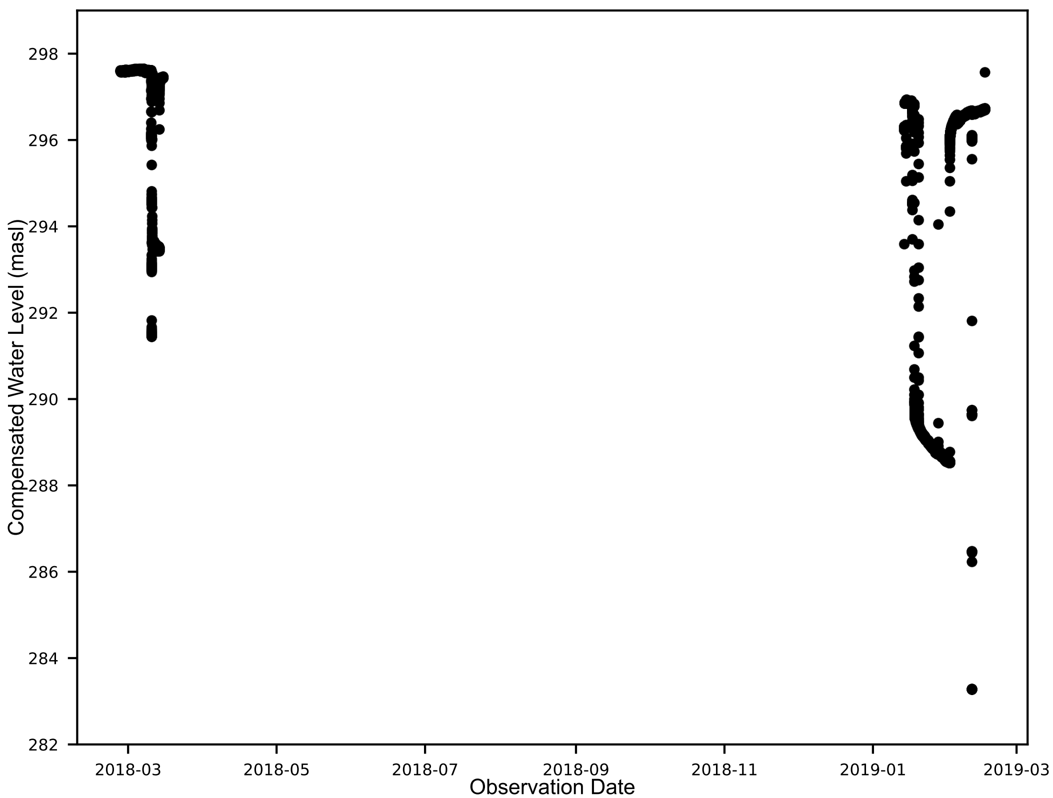
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

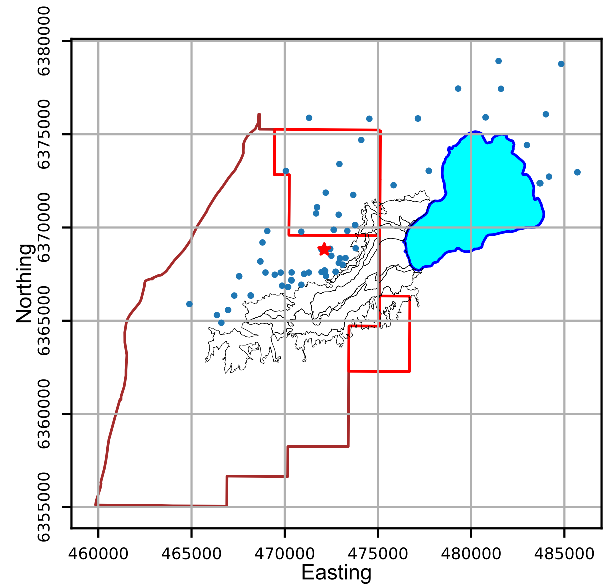
FORTHILLS
Operated by Suncor Energy

TITLE
FH18-ES419-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-53

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH18-ES419-DR1 - 24.269 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-54

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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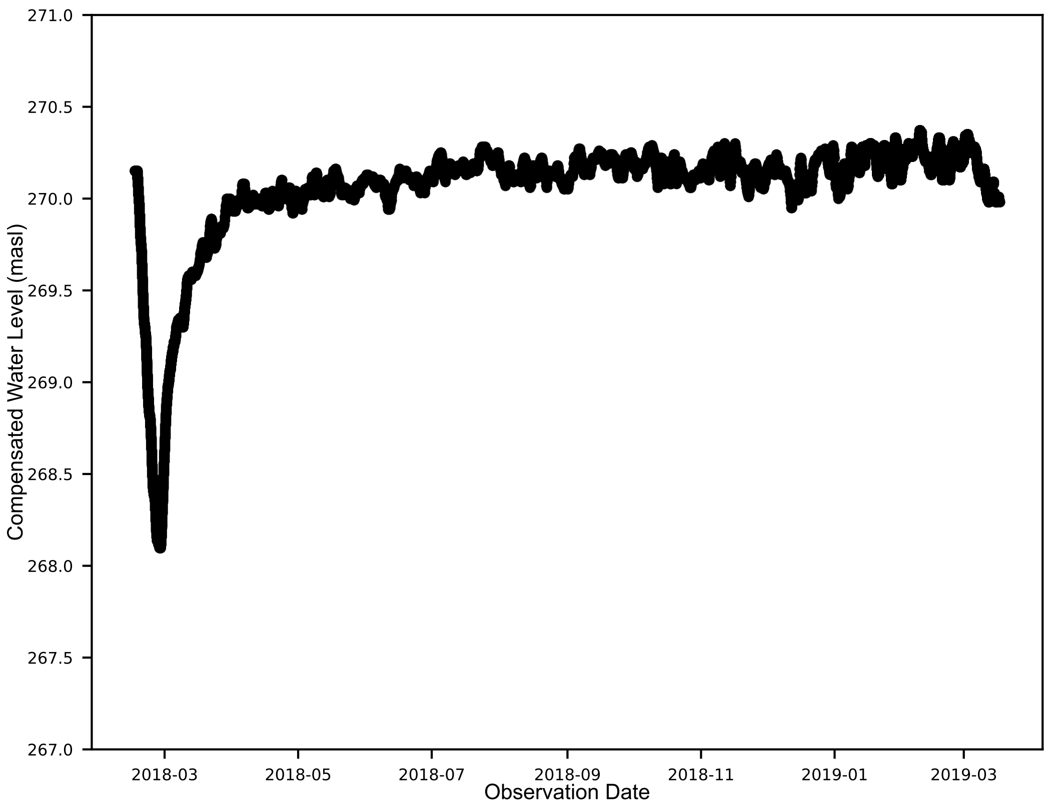
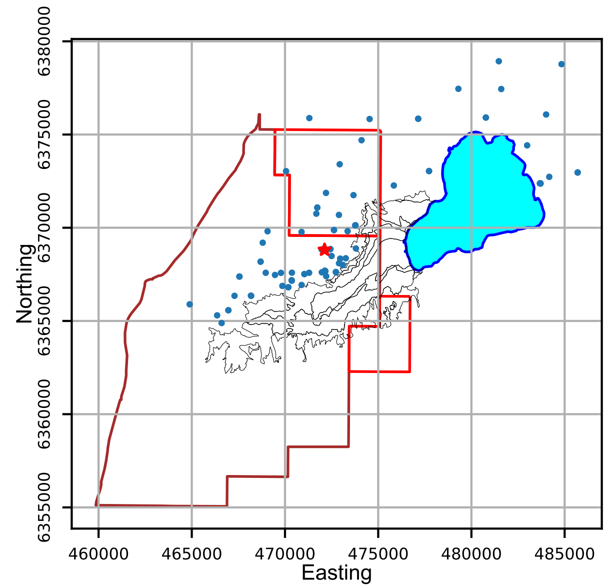




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 100 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

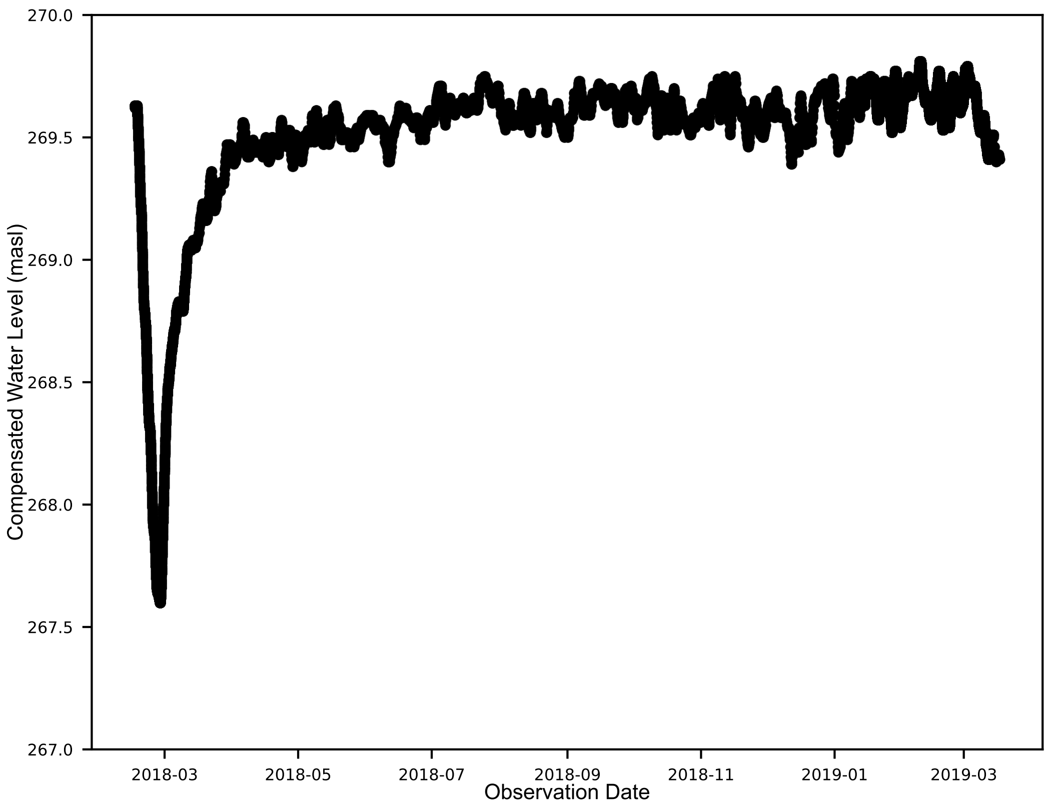
FORTHILLS
Operated by Suncor Energy

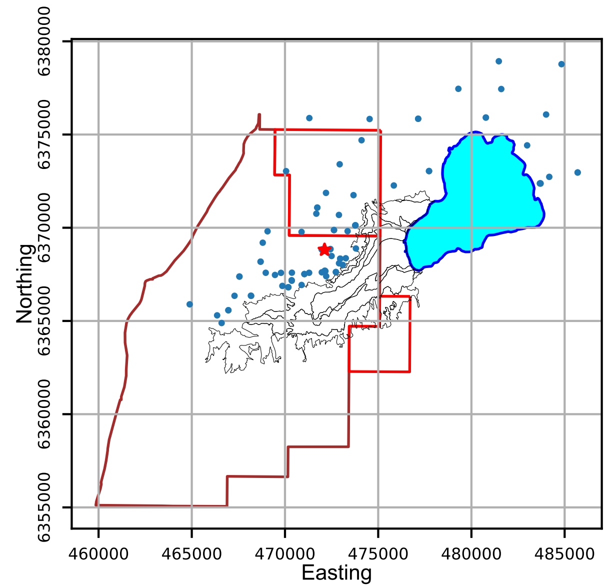
TITLE

FH18-ES419-MR1 - 100.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-55

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 109 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

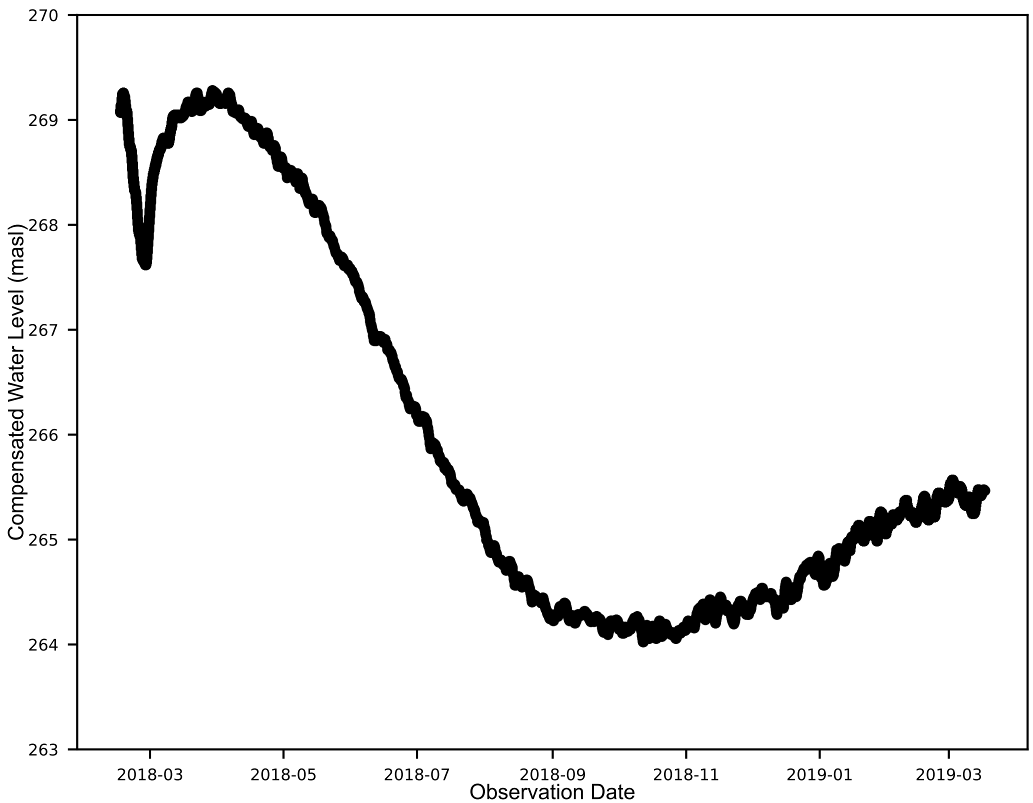
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

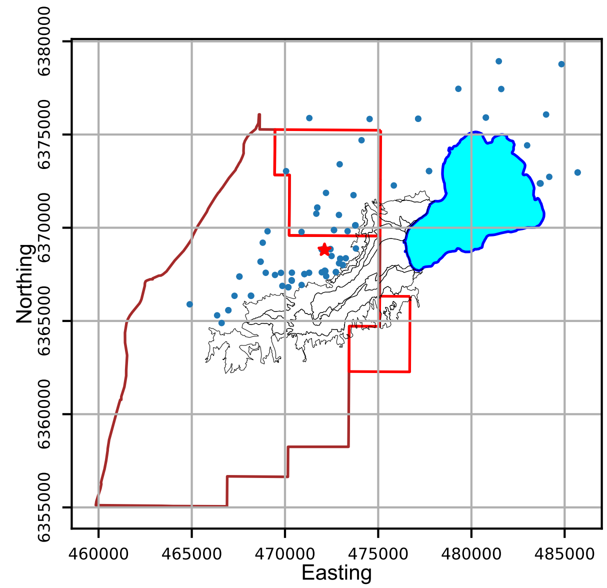
TITLE

FH18-ES419-MR1 - 109.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-56

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 121 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH18-ES419-MR1 - 121.0 M BELOW GROUND SURFACE
PROJECT No.	20140450
CONTROL	100
Rev.	A
FIGURE	B8-57

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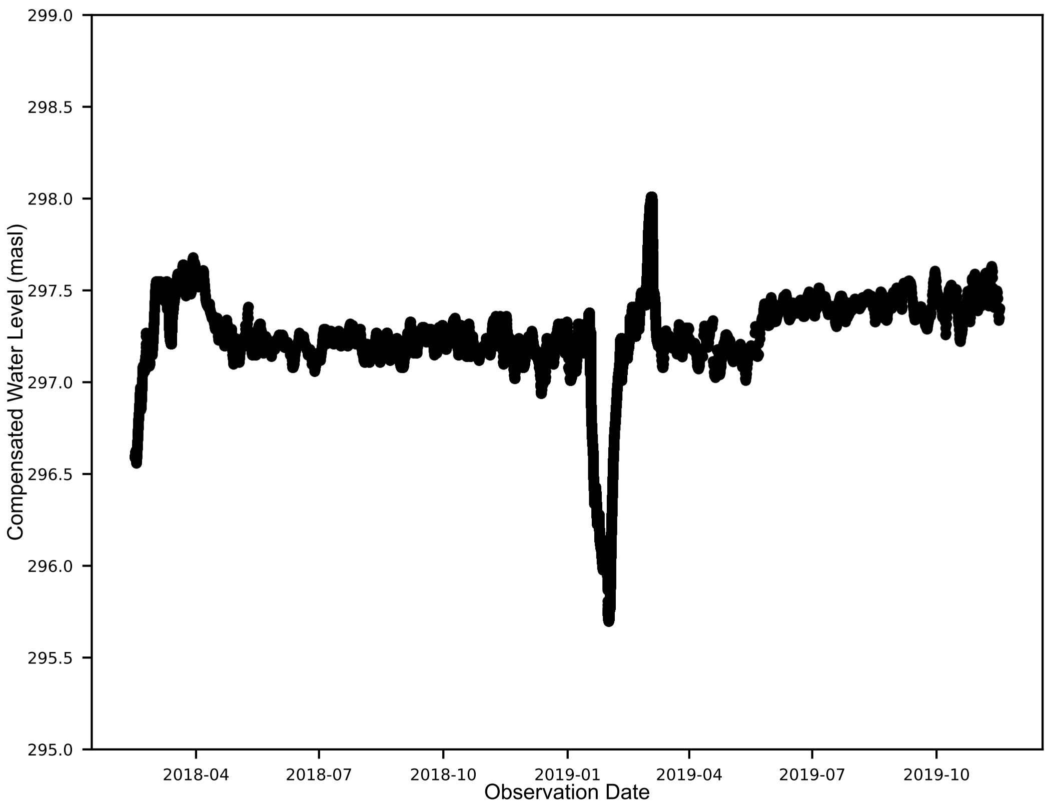

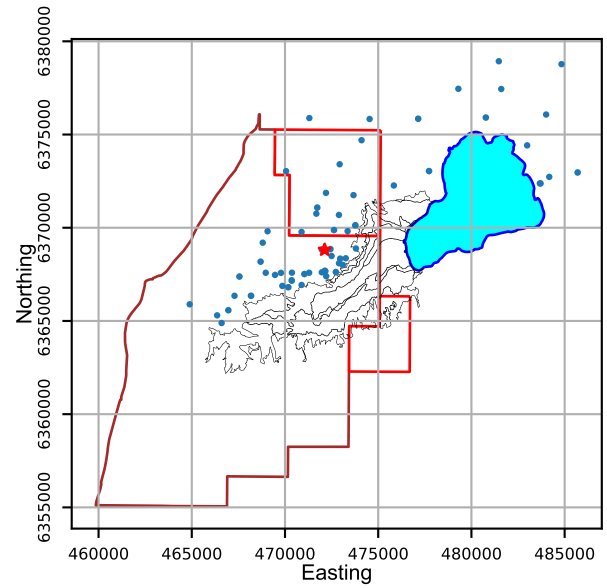

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES419-SN1 - 12.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-58

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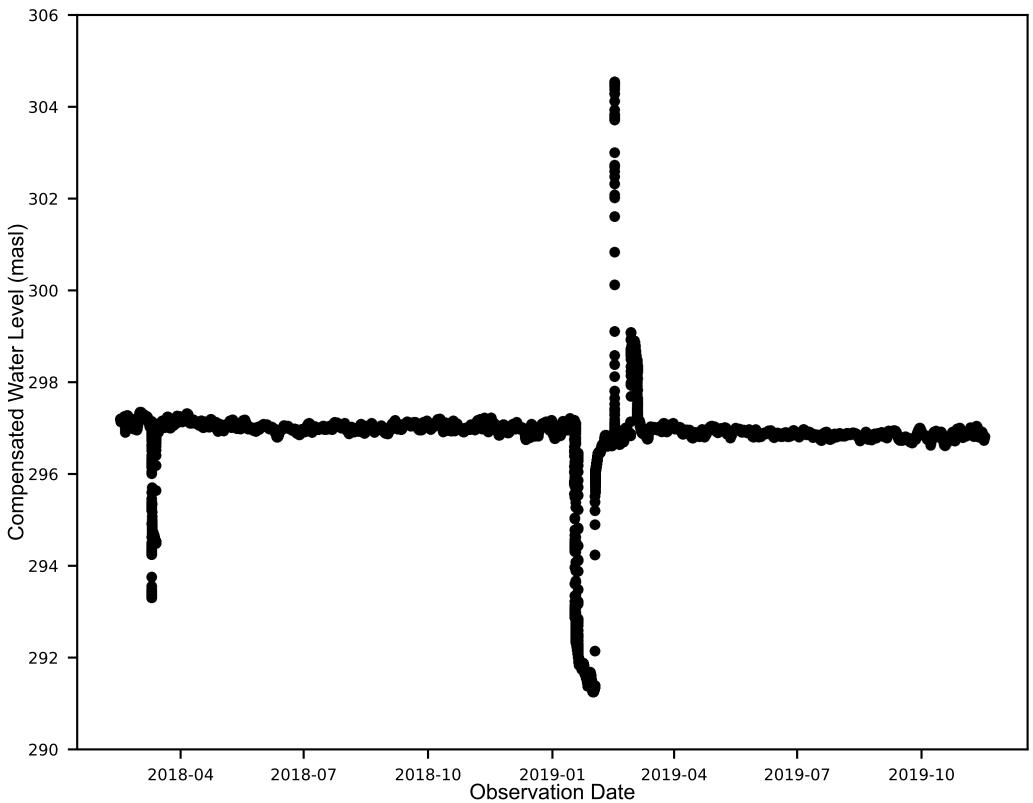

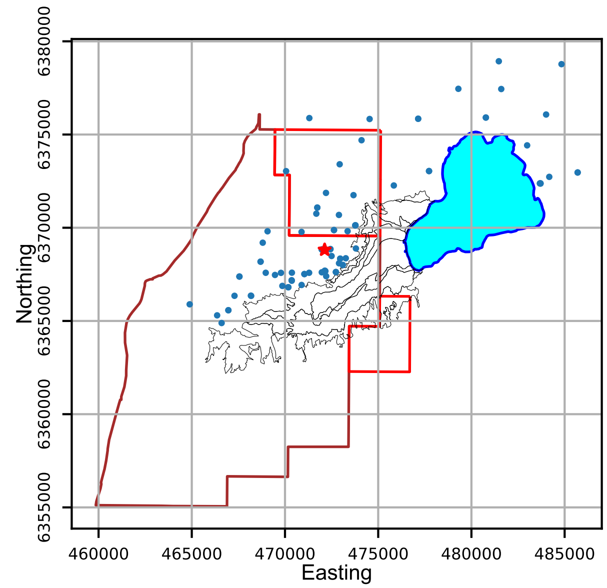

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 38.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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TITLE
FH18-ES419-SN1 - 38.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-59

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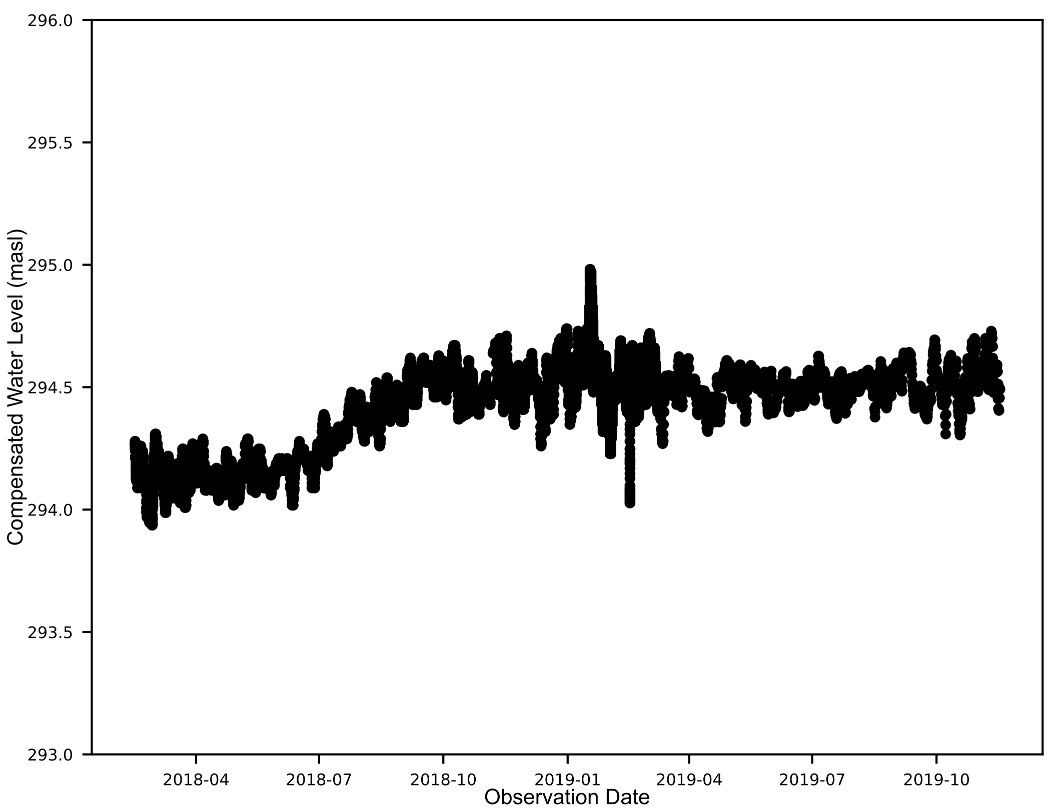

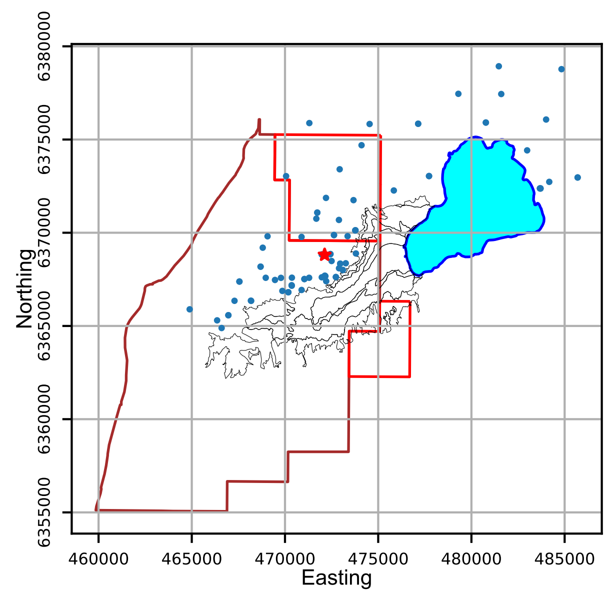

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH18-ES419-SN1 - 51.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-60

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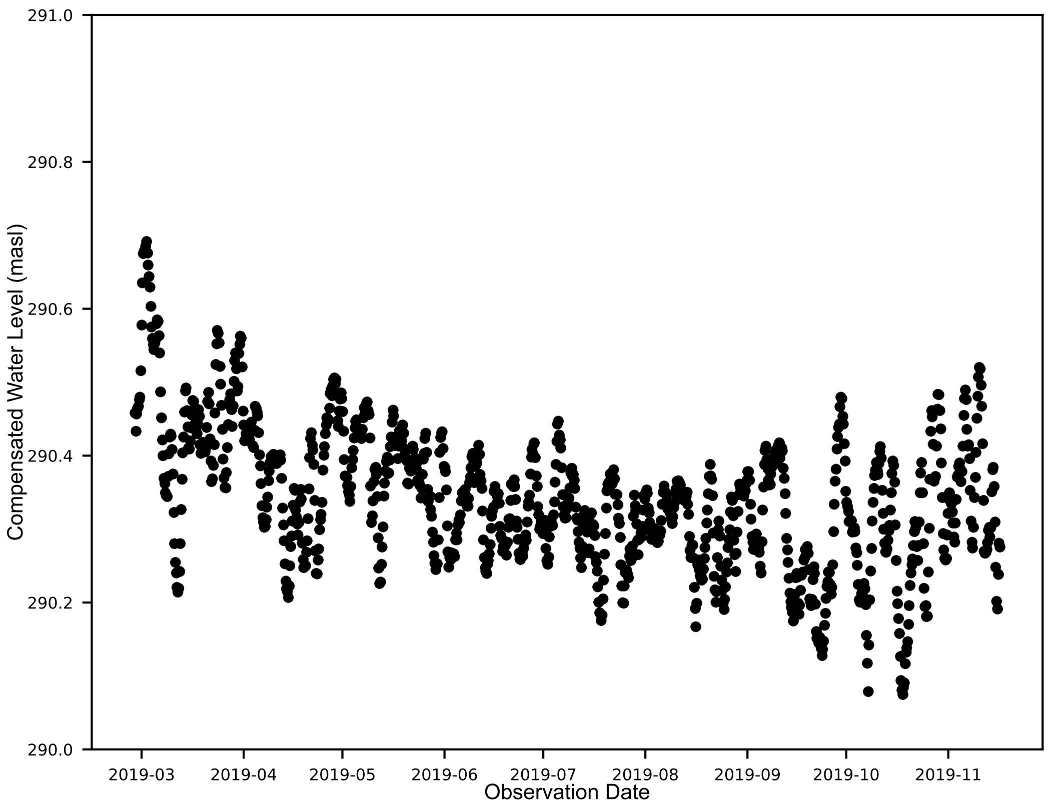

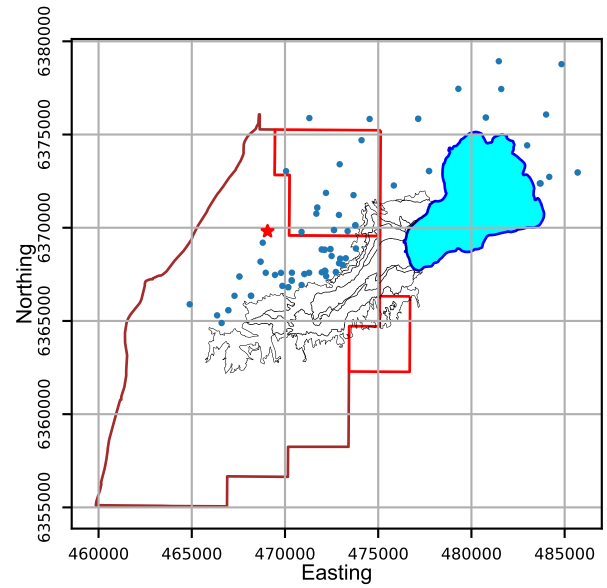

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 12 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES512-SN2 - 12.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-61

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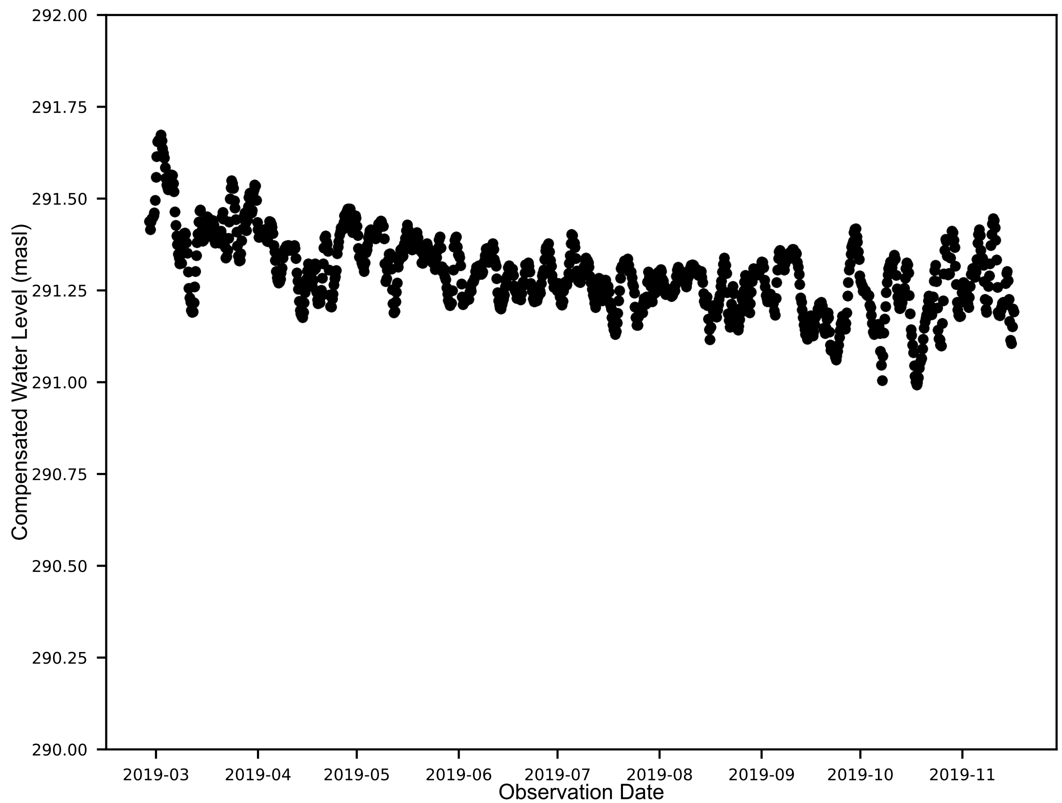

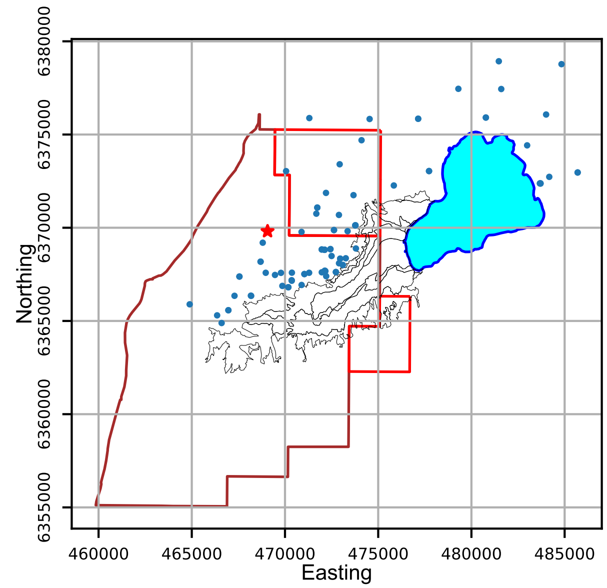

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 20.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES512-SN2 - 20.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-62

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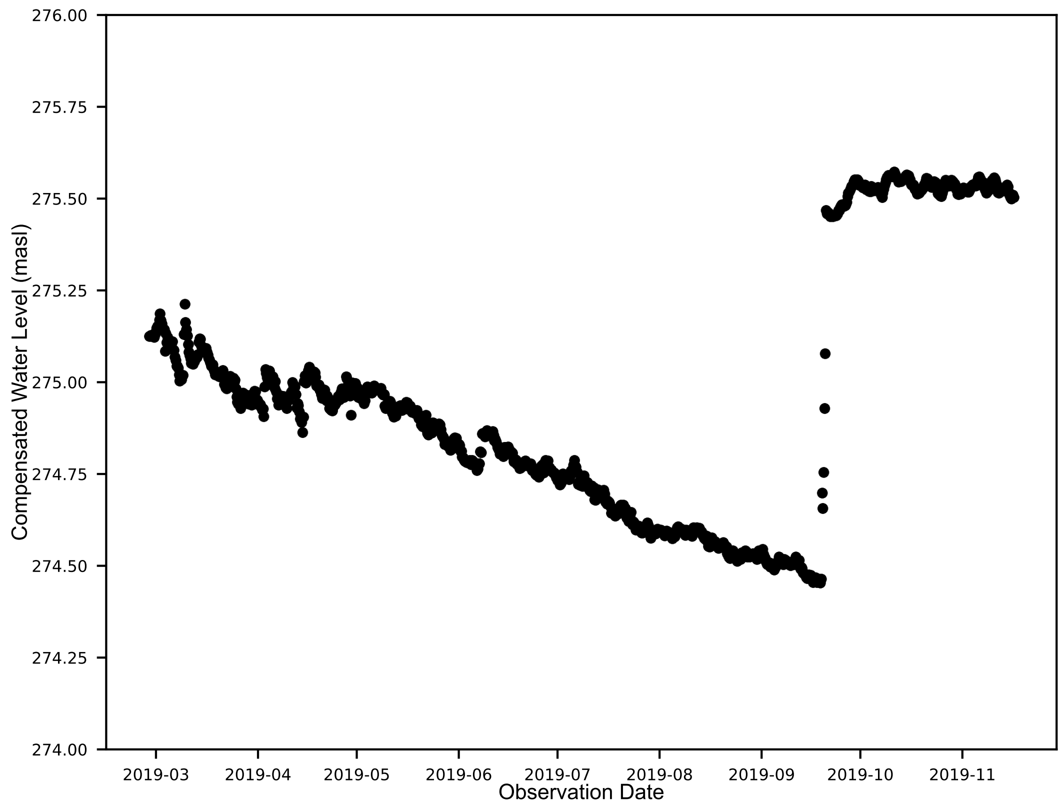

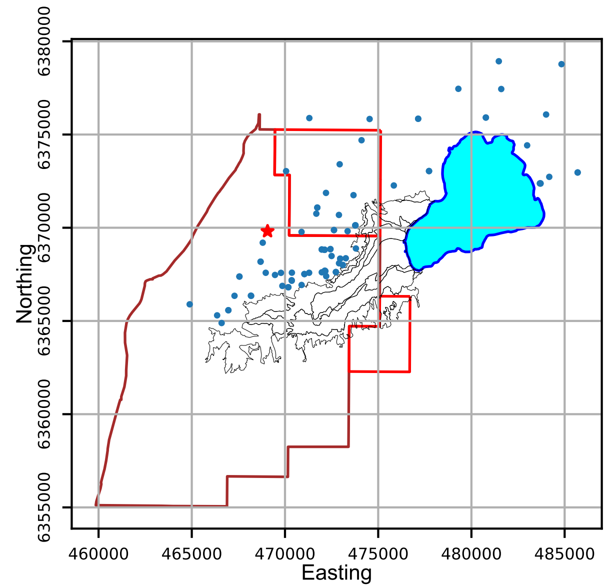

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 44.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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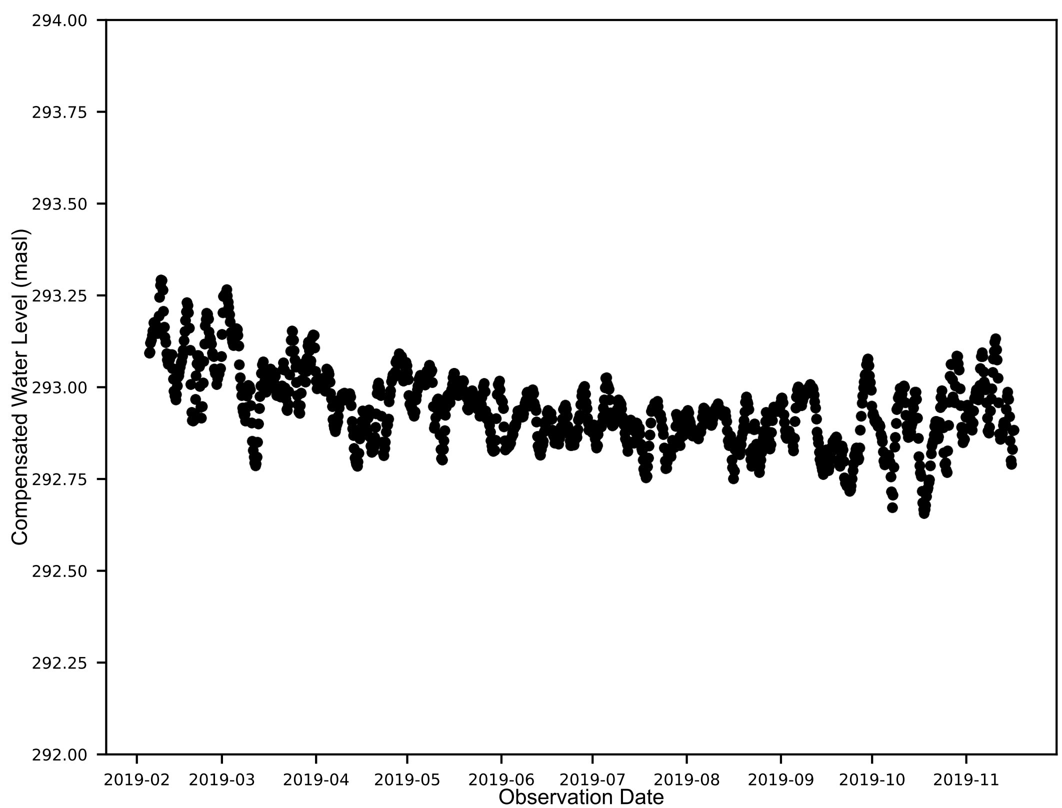
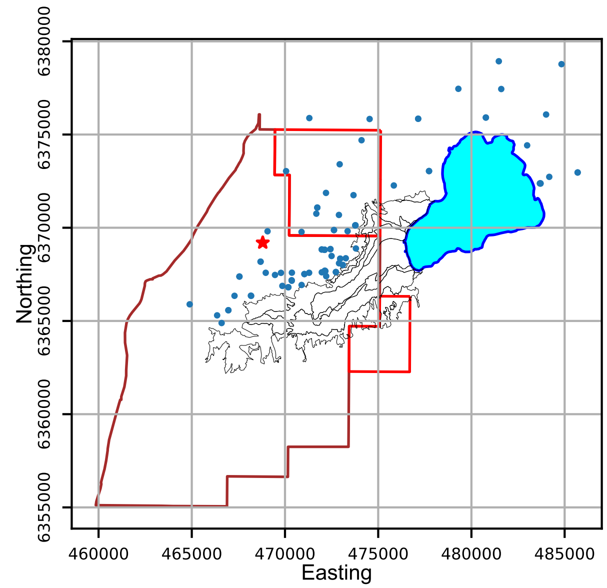
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES512-SN2 - 44.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-63

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH19-ES519-SN2 - 10.6 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-64

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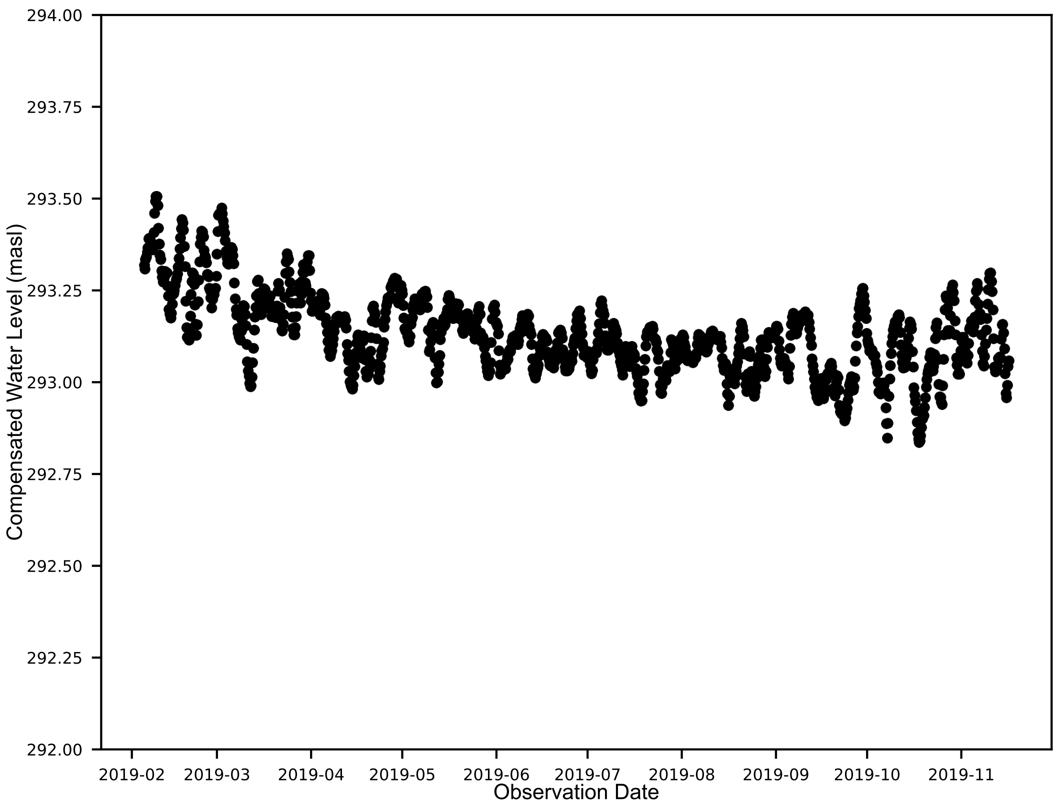

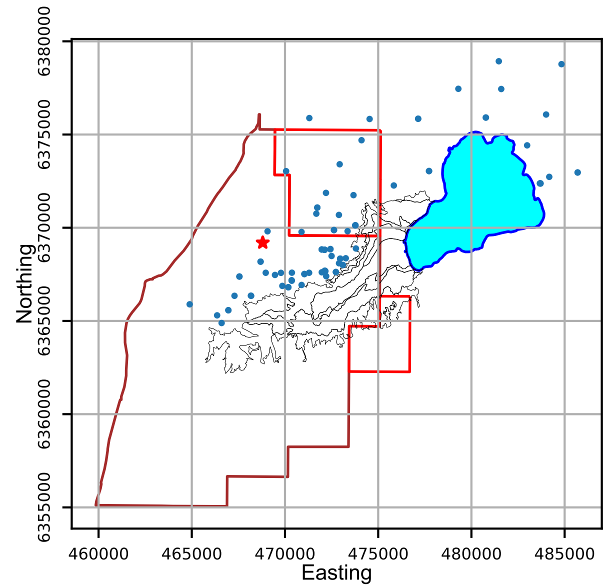

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 22.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES519-SN2 - 22.4 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-65

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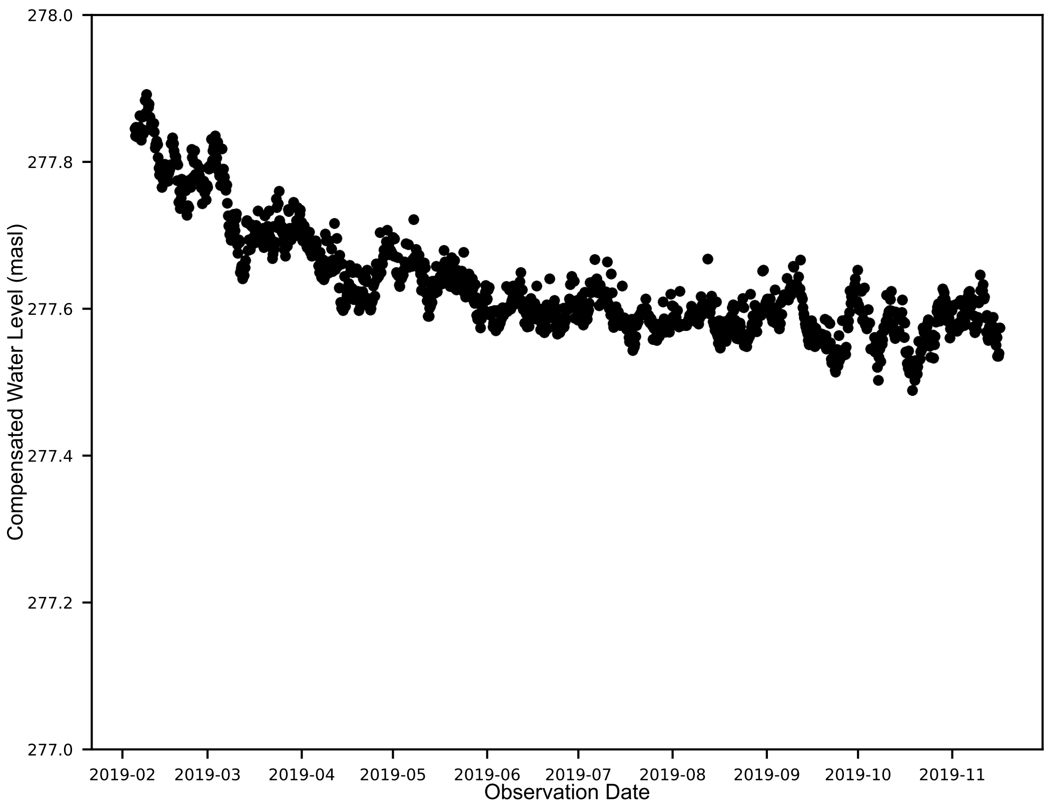

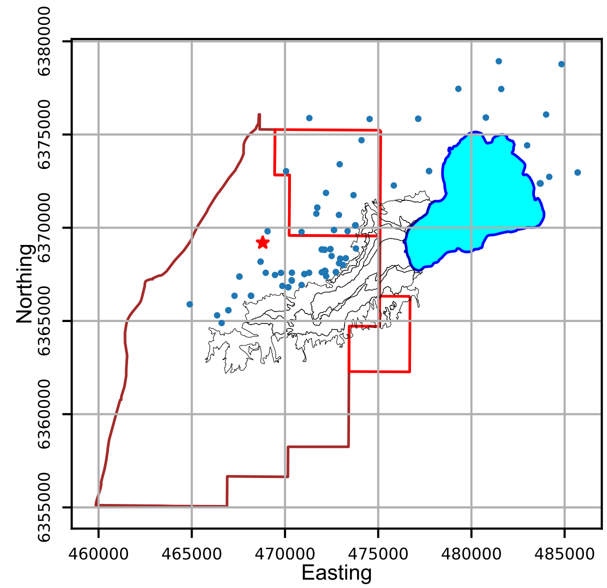

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 42.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES519-SN2 - 42.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-66

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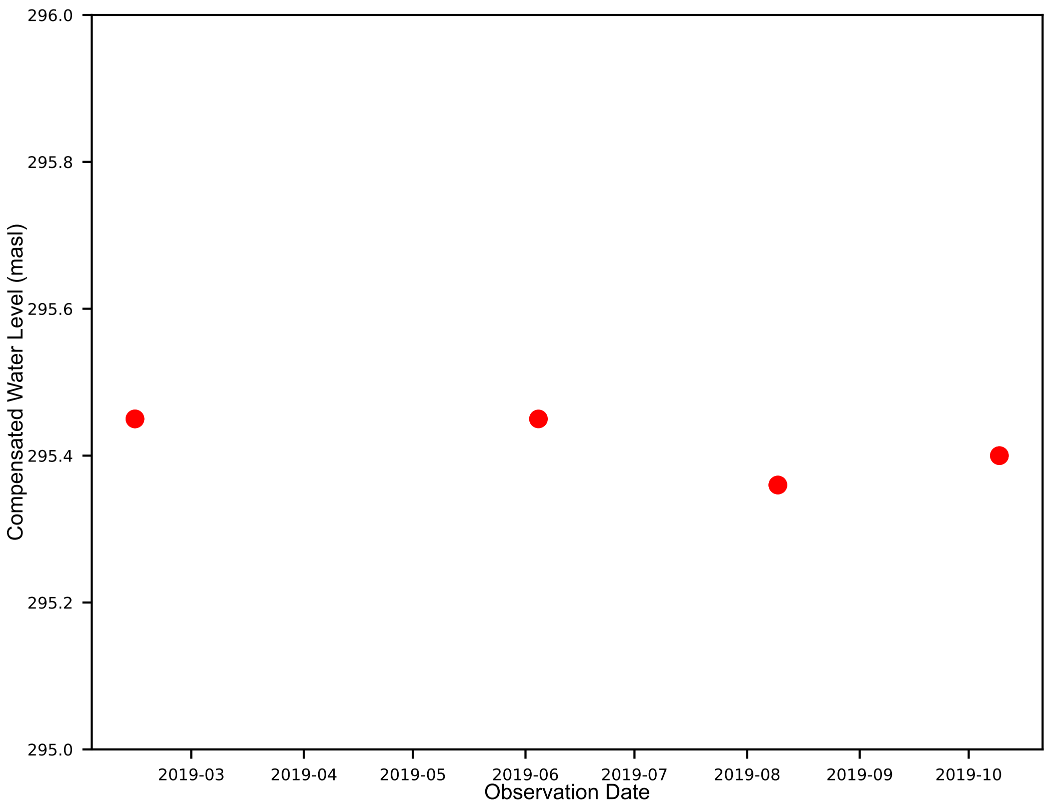
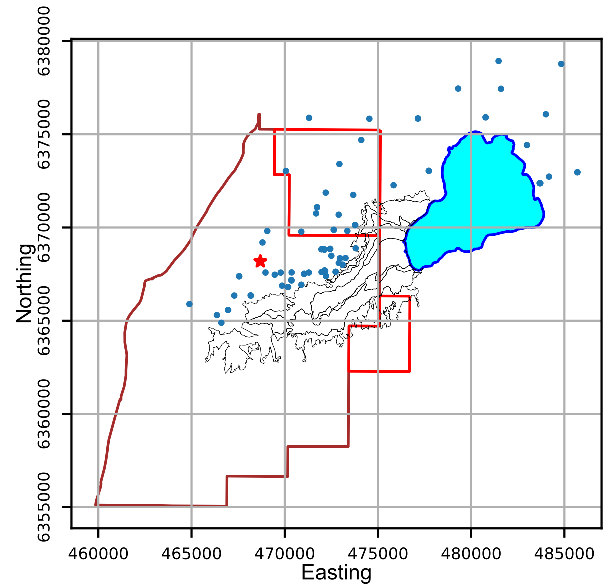




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

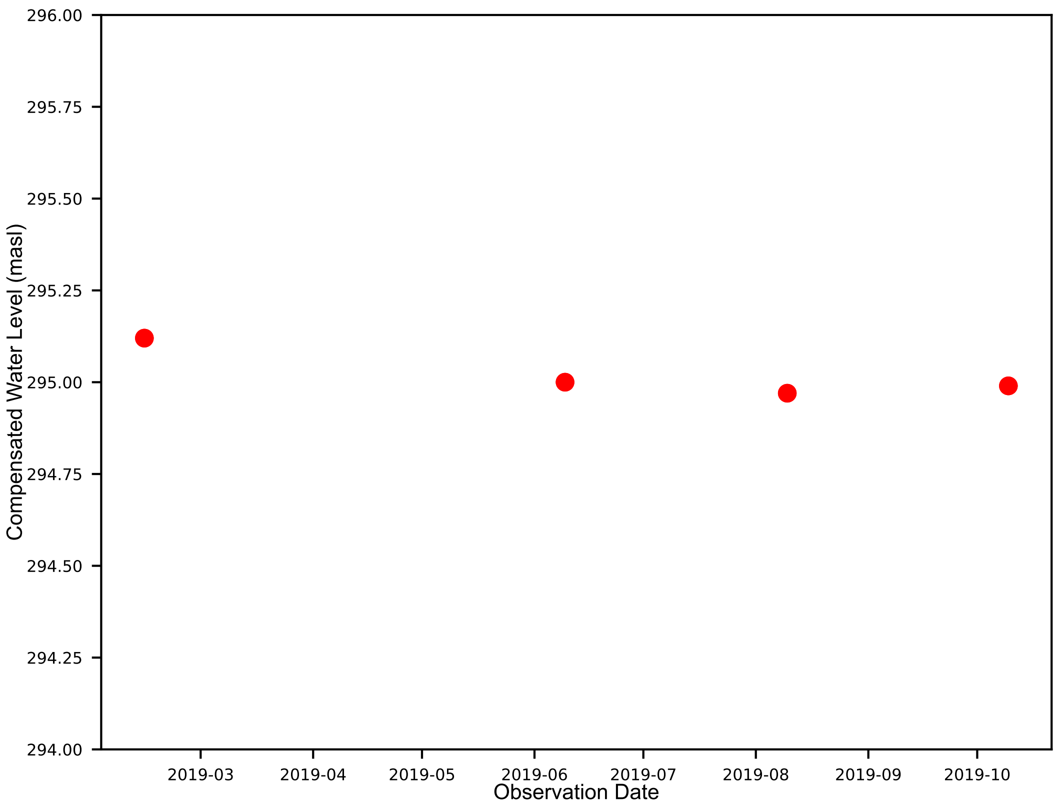
TITLE

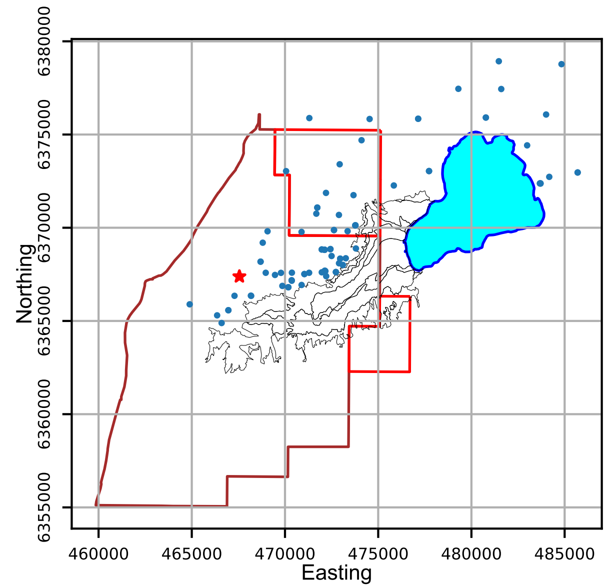
FH19-ES534-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-67

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.46 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

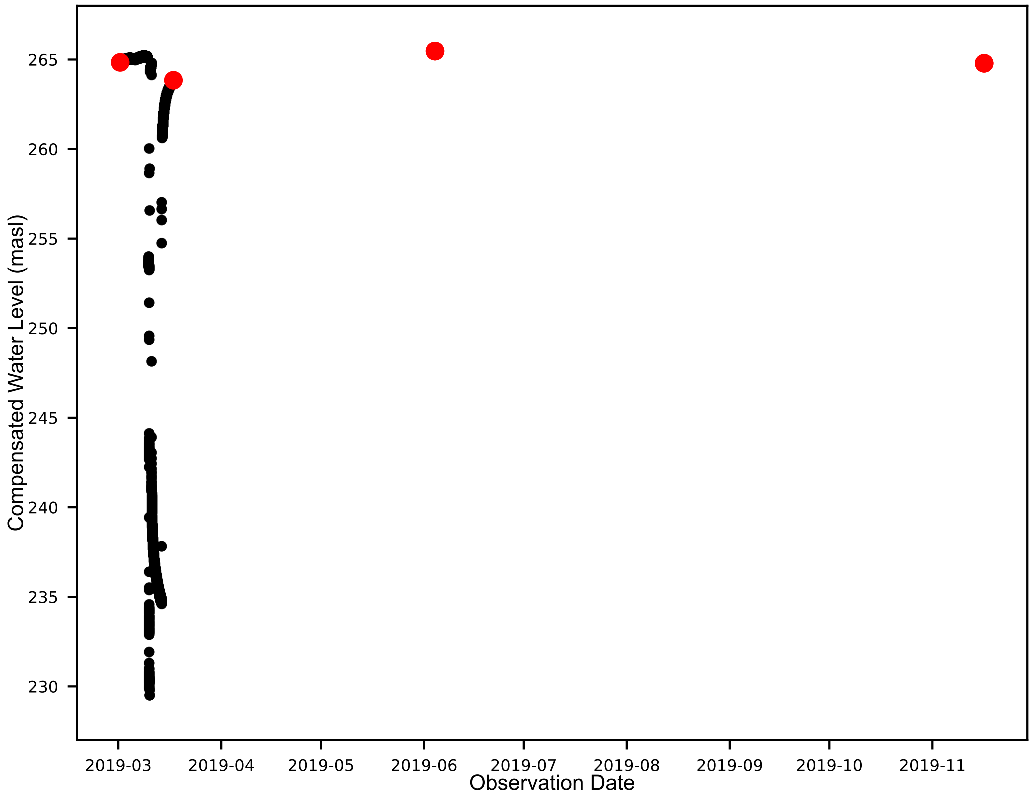
FORT HILLS
Operated by Suncor Energy

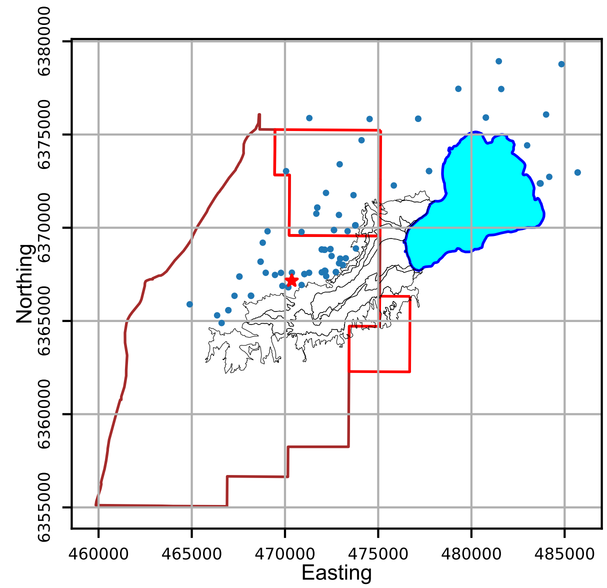
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES562-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-68

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer

Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

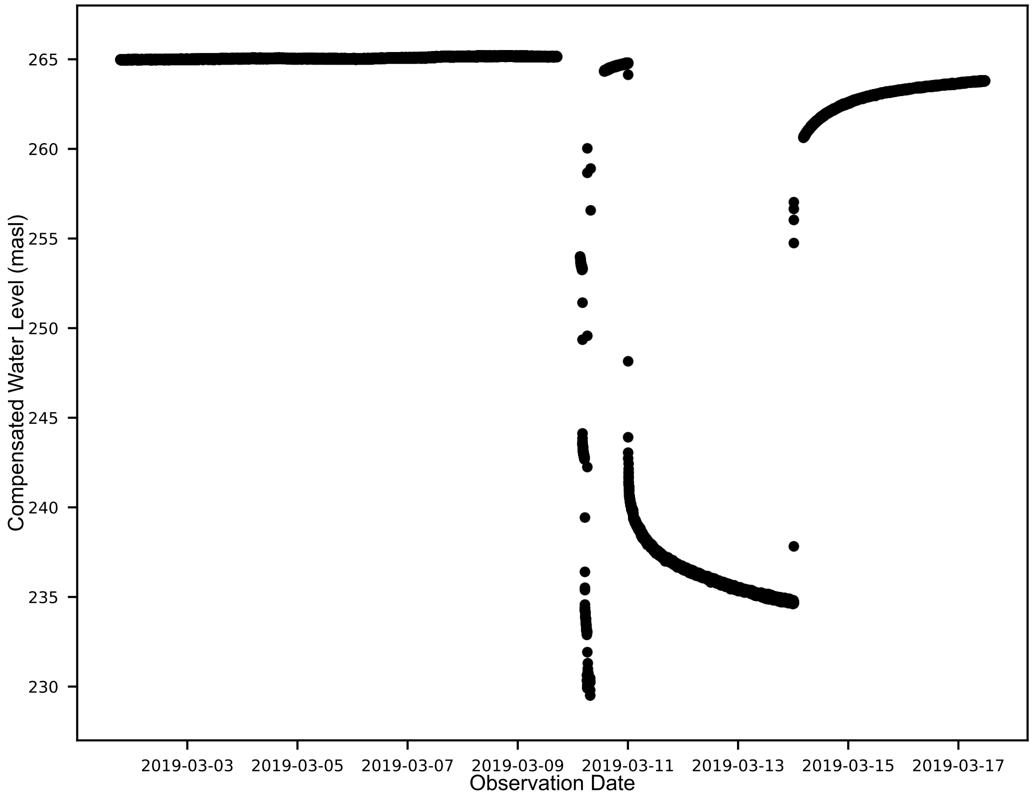
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

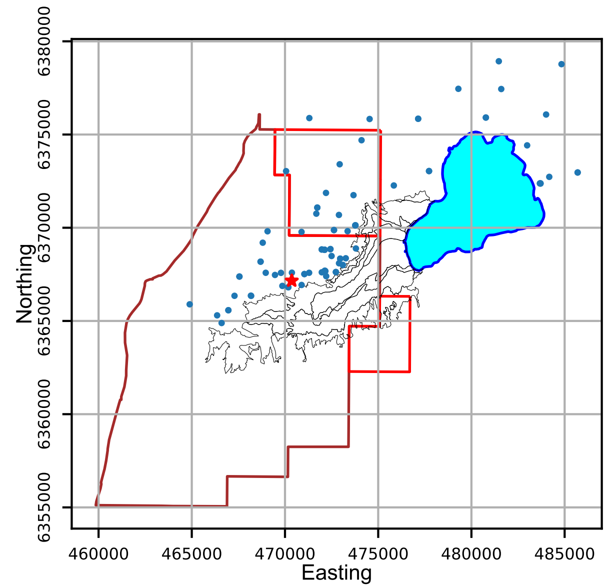
TITLE

FH19-ES565-MR2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-69

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

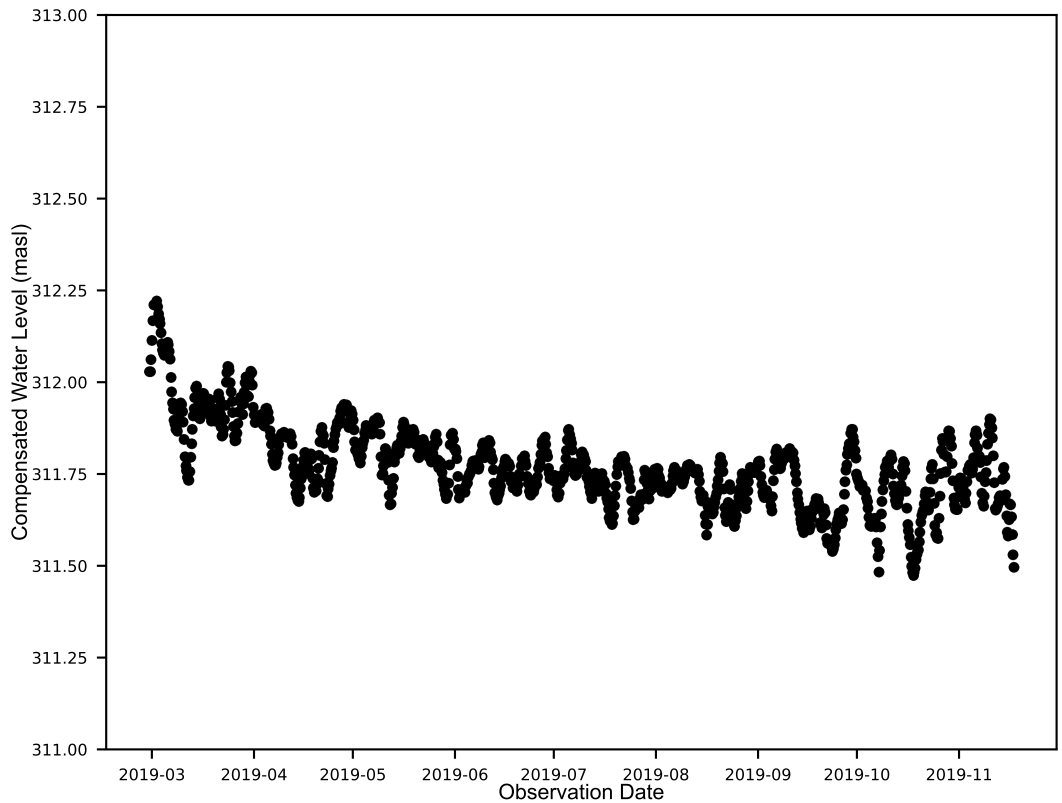
FORTHILLS
Operated by Suncor Energy

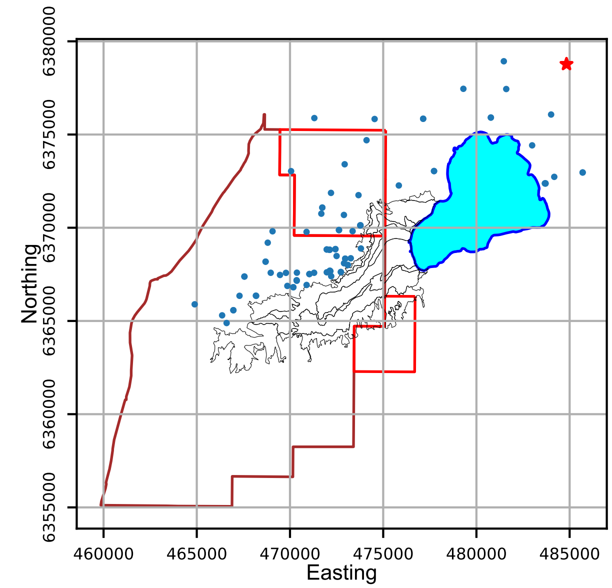
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES565-MR2 - 96.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-70

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 23.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

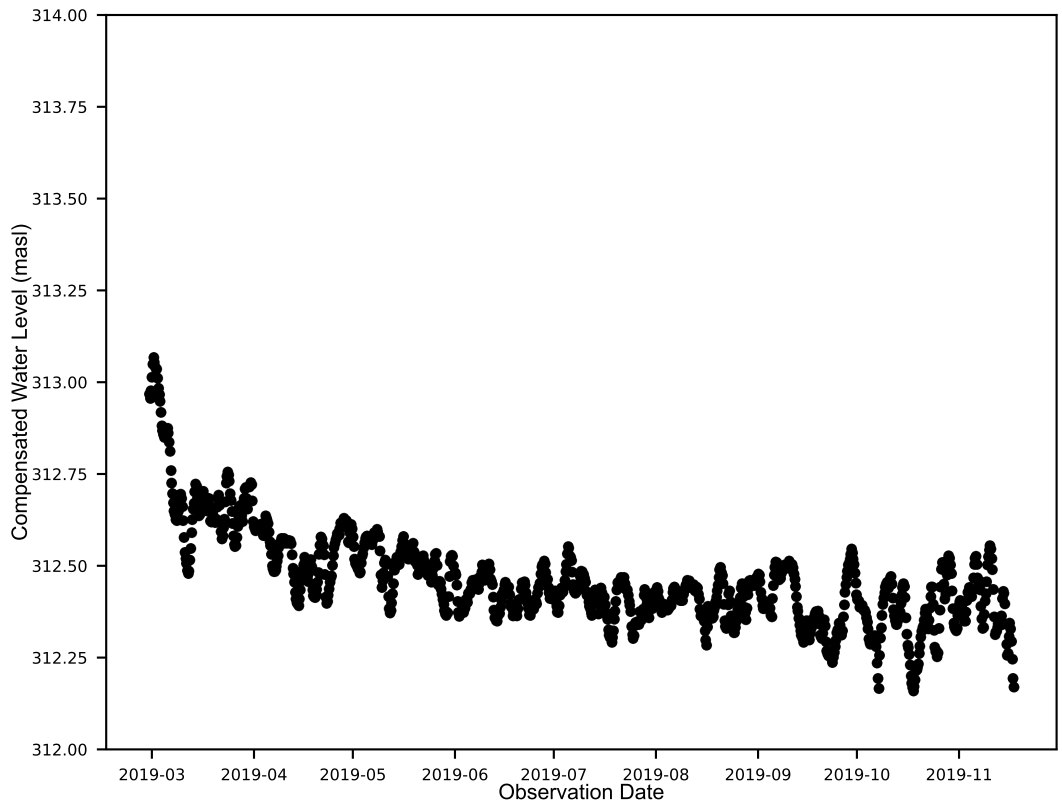
FORT HILLS
Operated by Suncor Energy

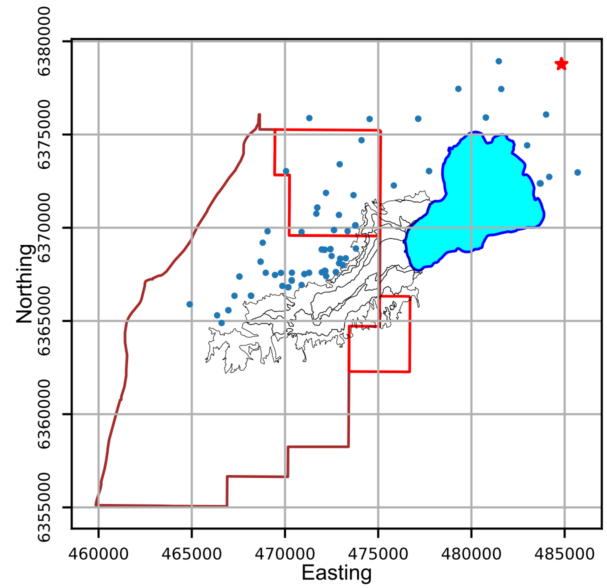
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES602-SN1 - 23.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-71

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 42.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES602-SN1 - 42.3 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-72

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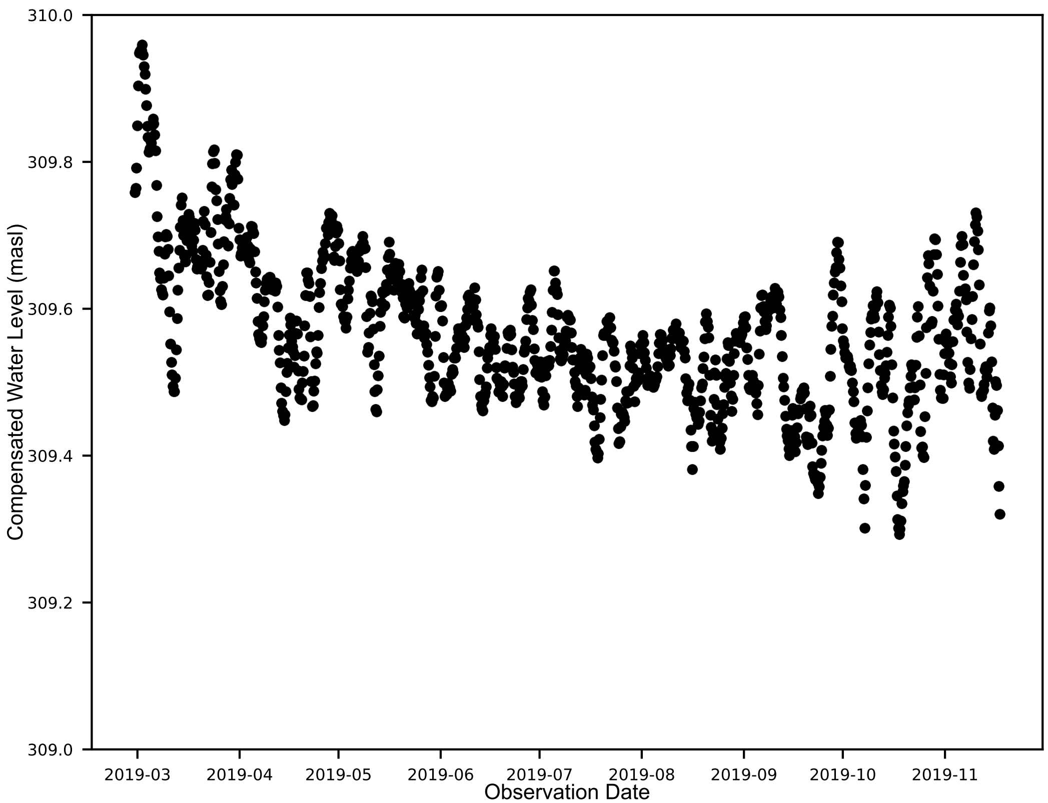

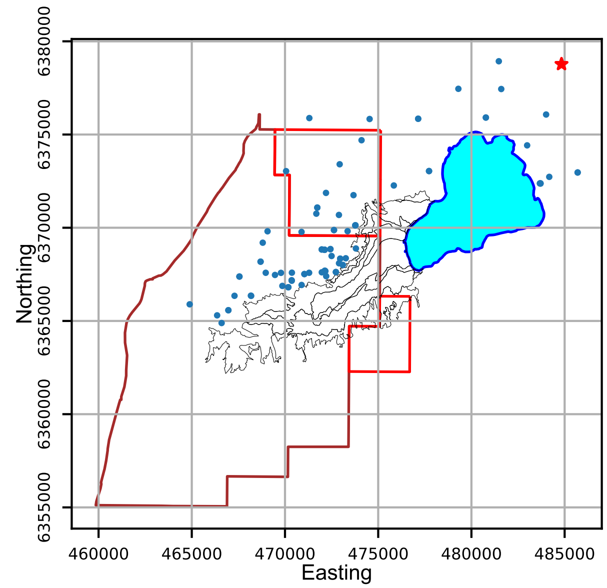

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES602-SN1 - 6.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-73

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A
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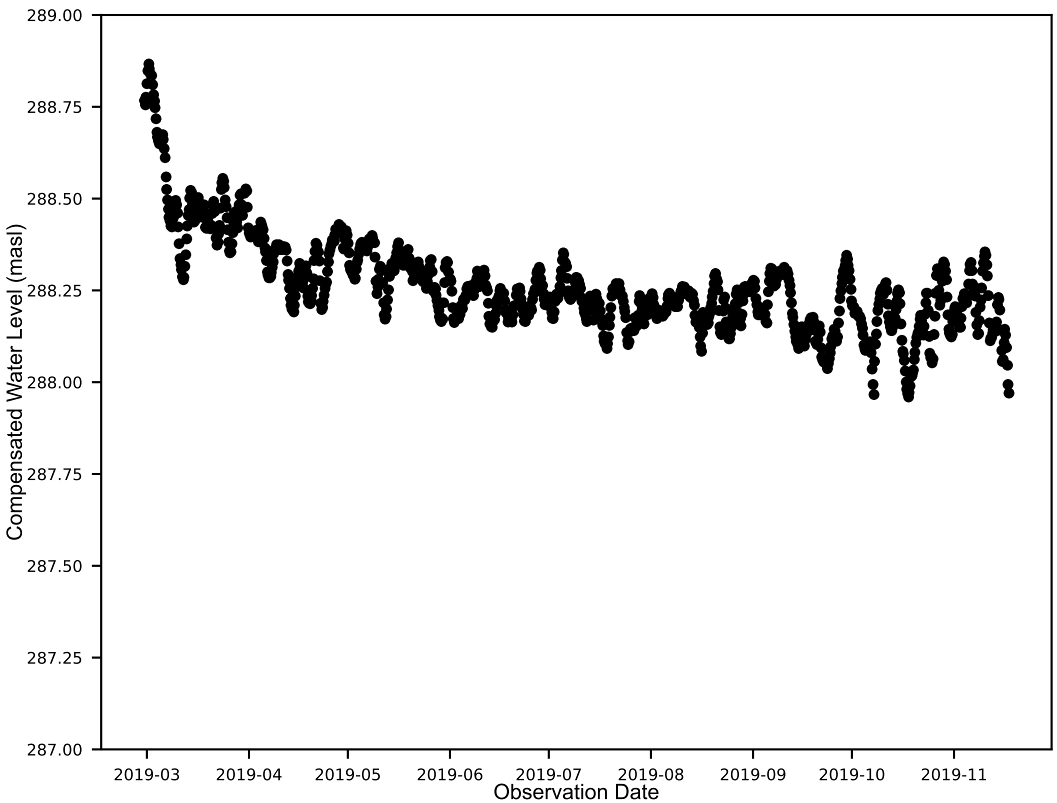

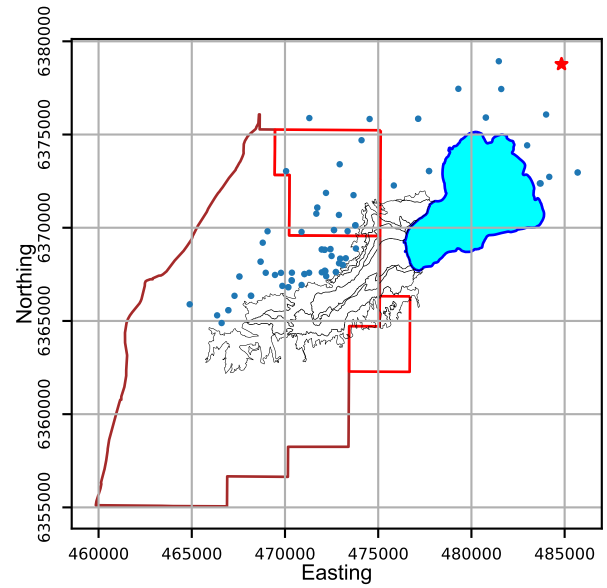

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 66.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES602-SN1 - 66.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-74

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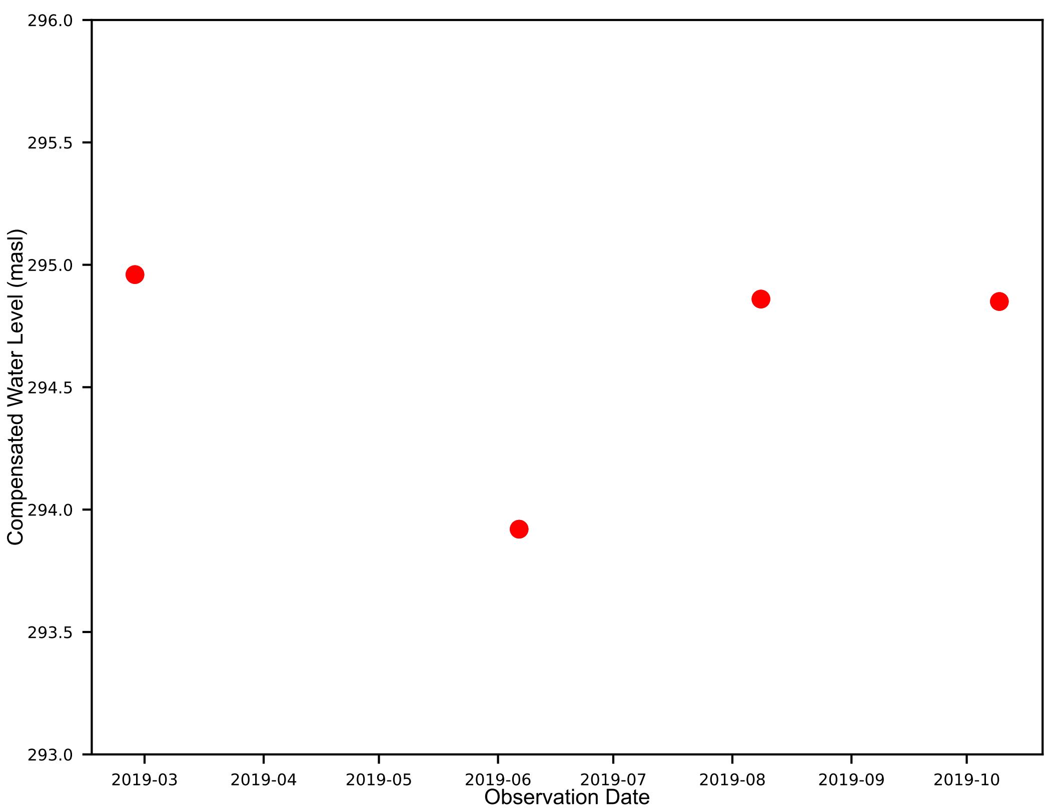
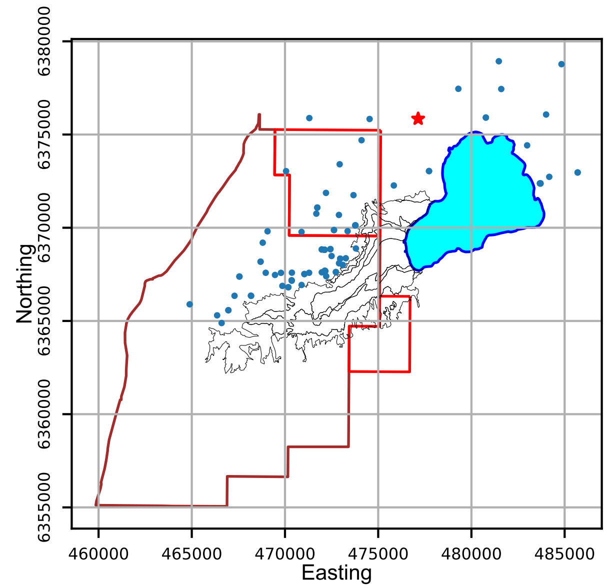




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 31.54 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS

Operated by Suncor Energy

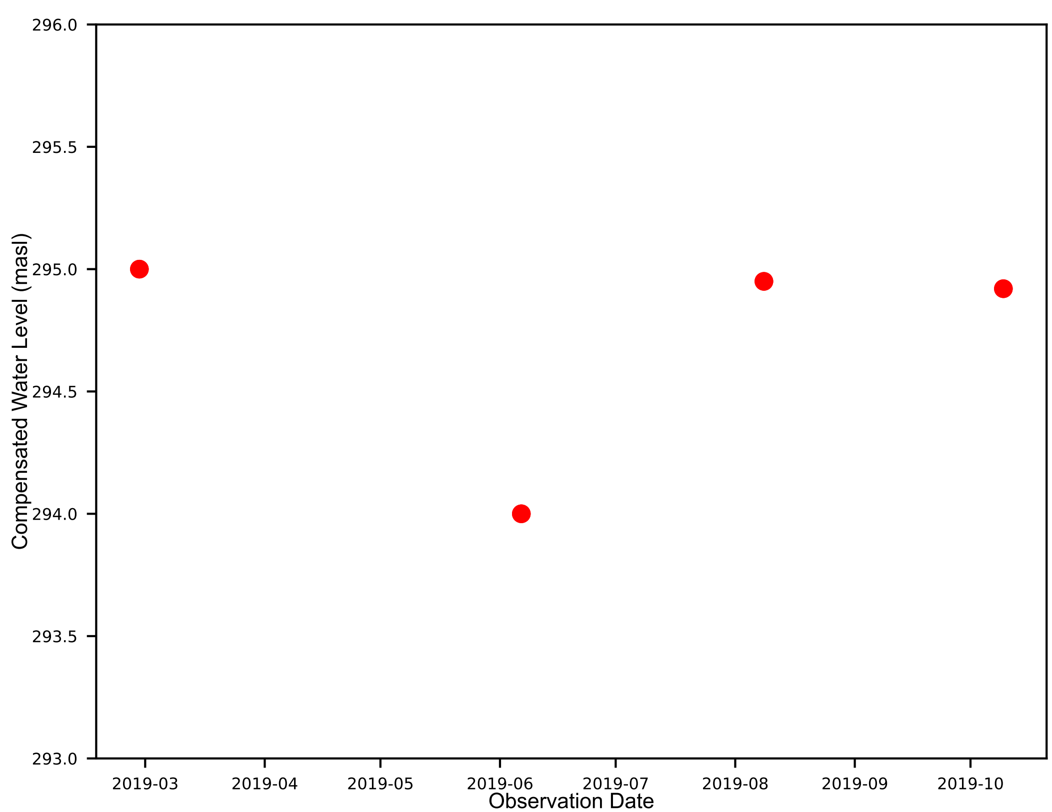
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

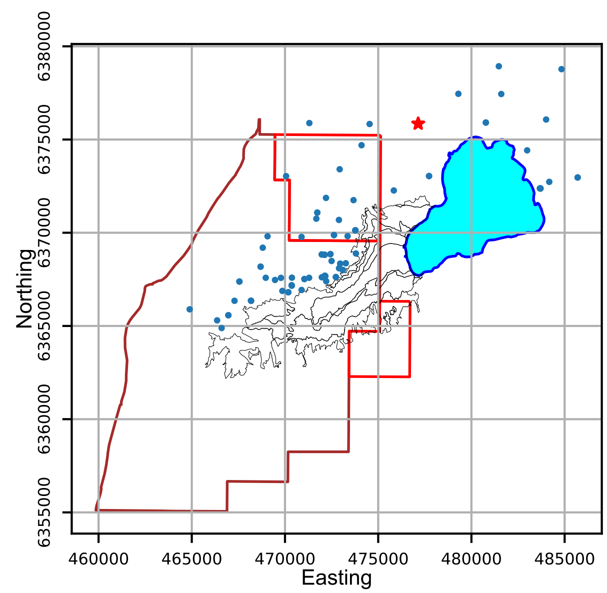
TITLE

FH19-ES603-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-75

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 13.05 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES603-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-76

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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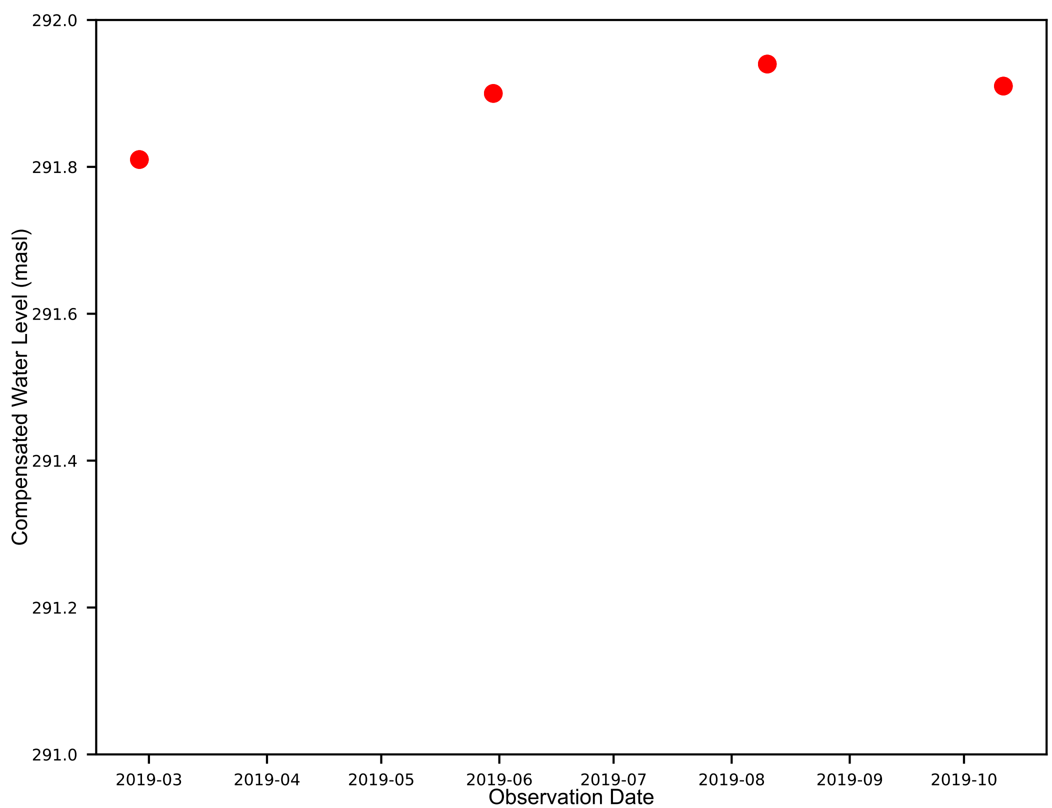

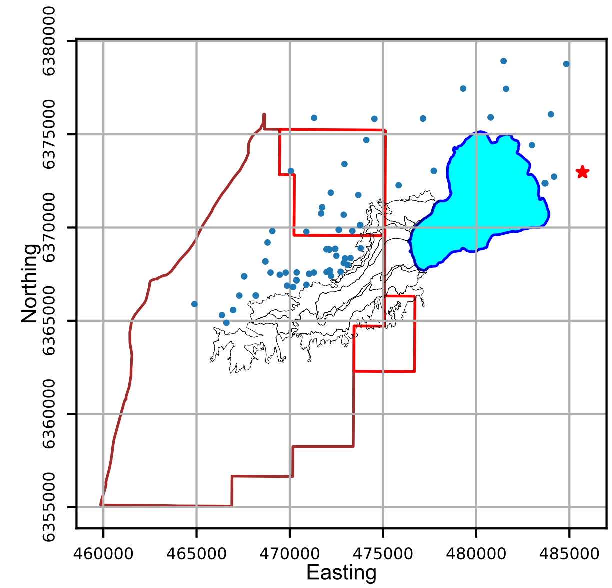

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 32.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH19-ES604-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-77

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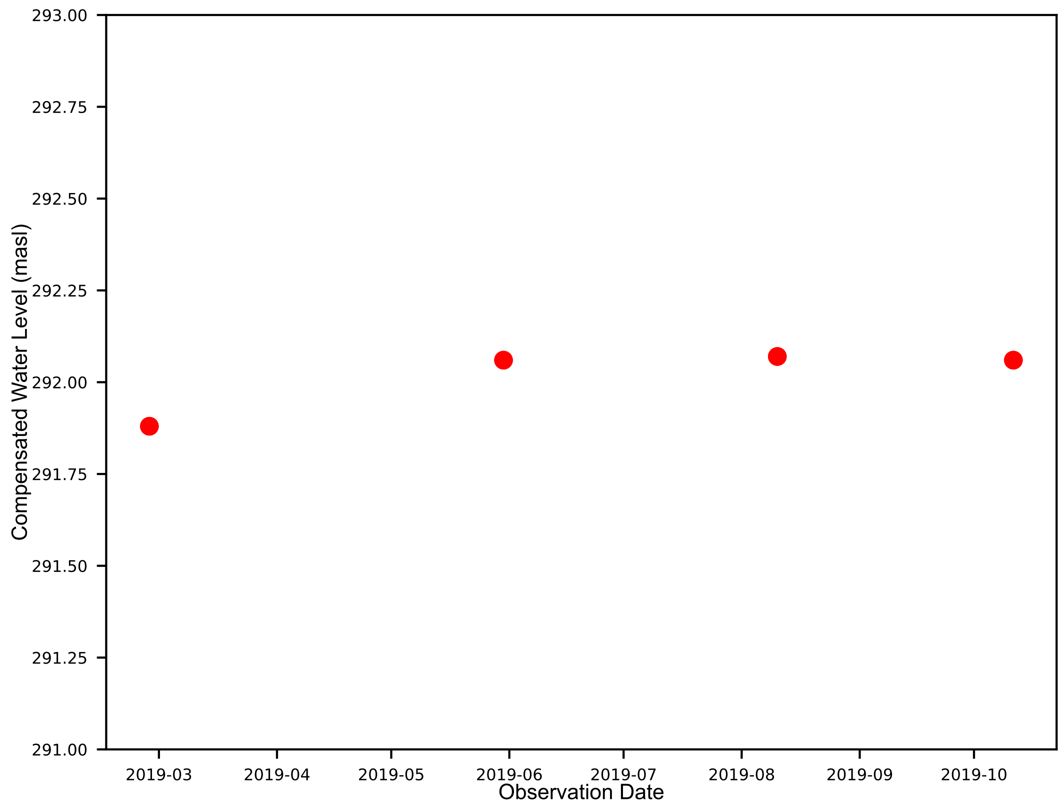
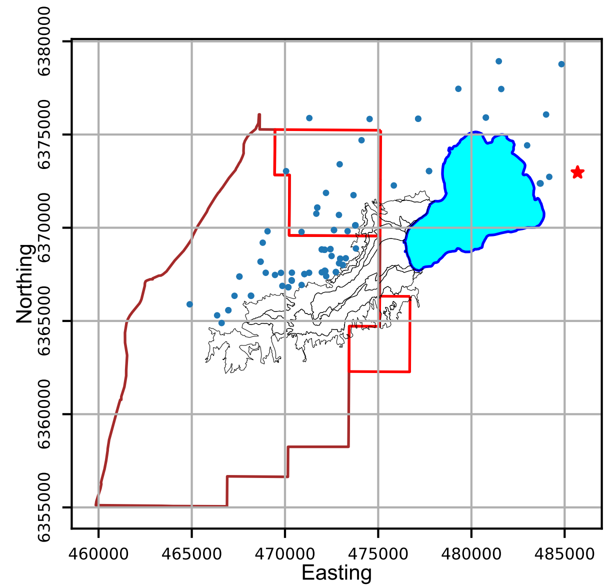




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 19.3 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

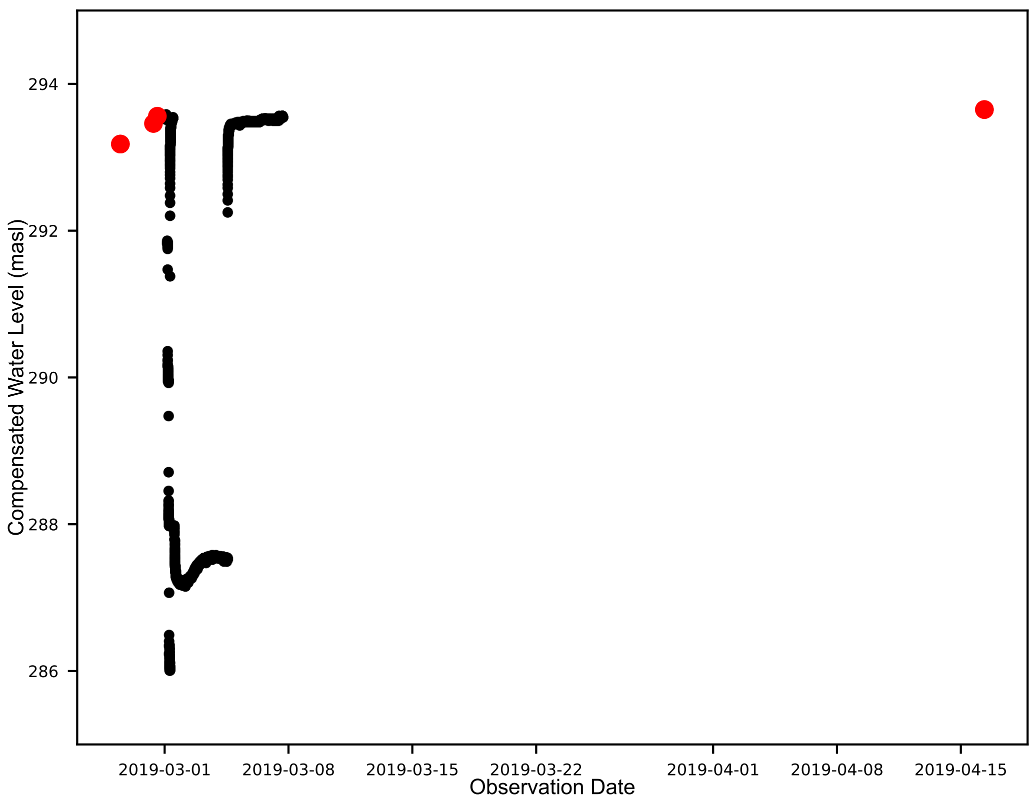
FORTHILLS
Operated by Suncor Energy

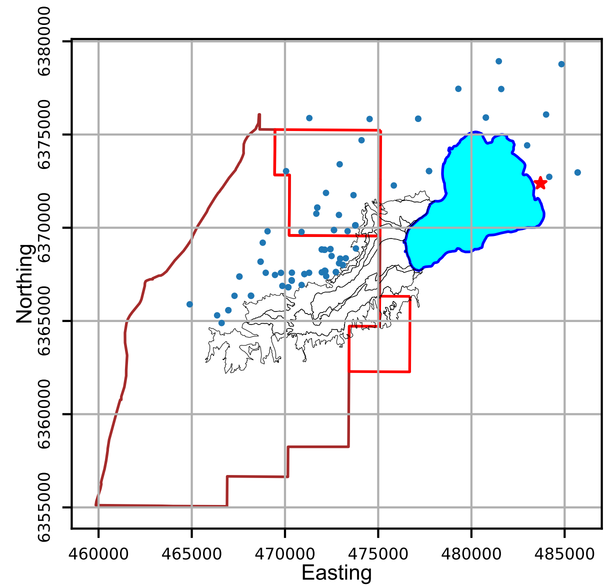
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES604-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-78

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

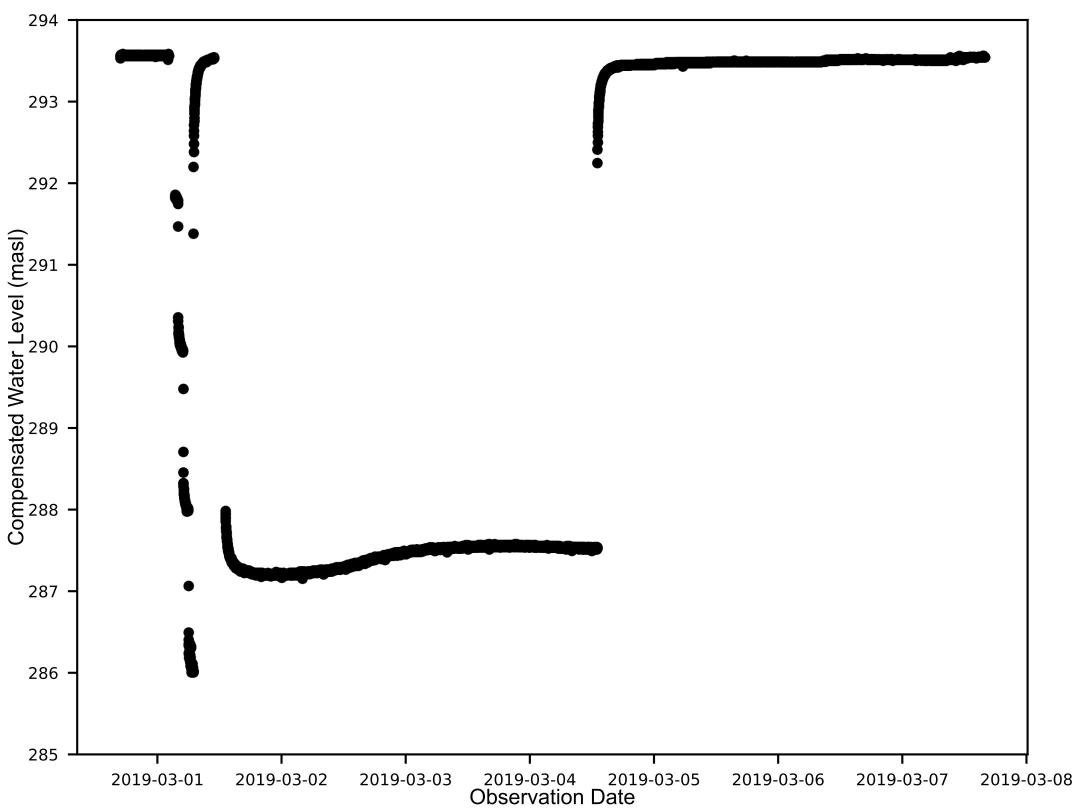
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

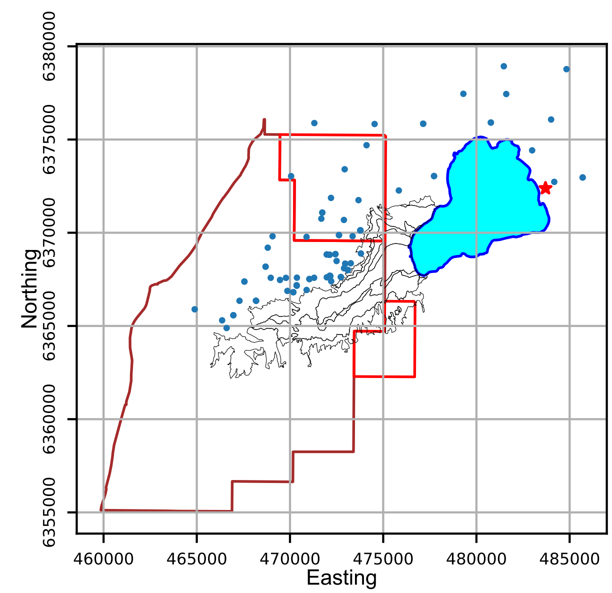
TITLE

FH19-ES605-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-79

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

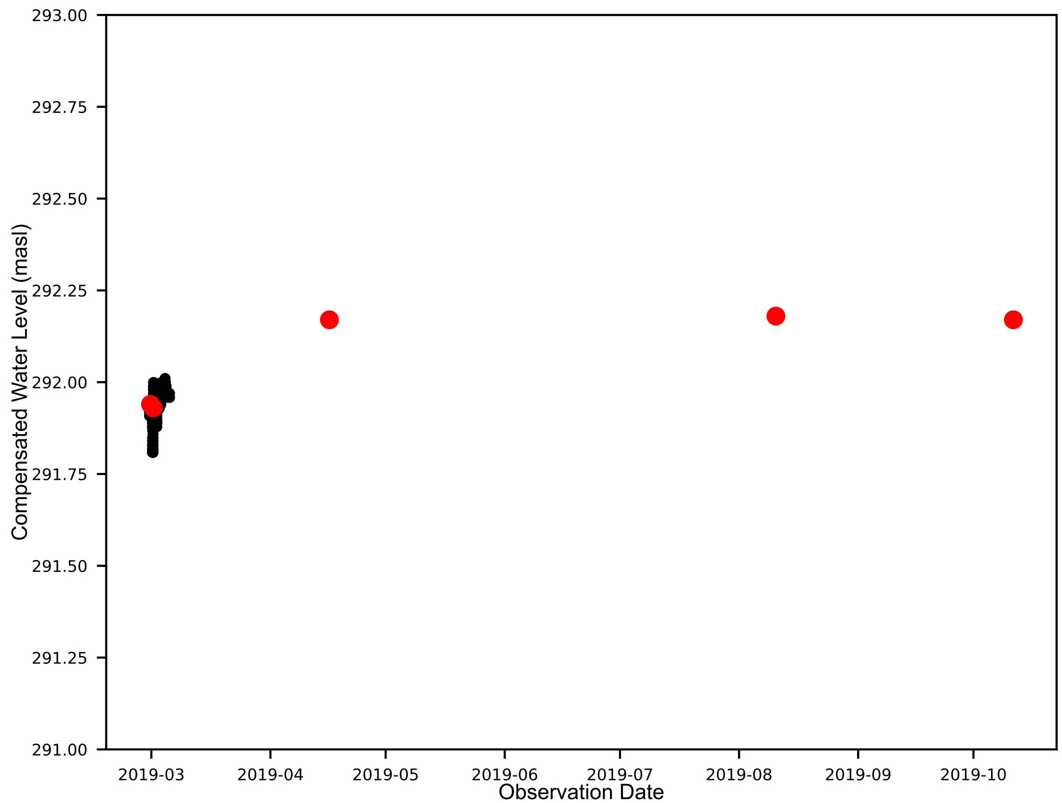
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

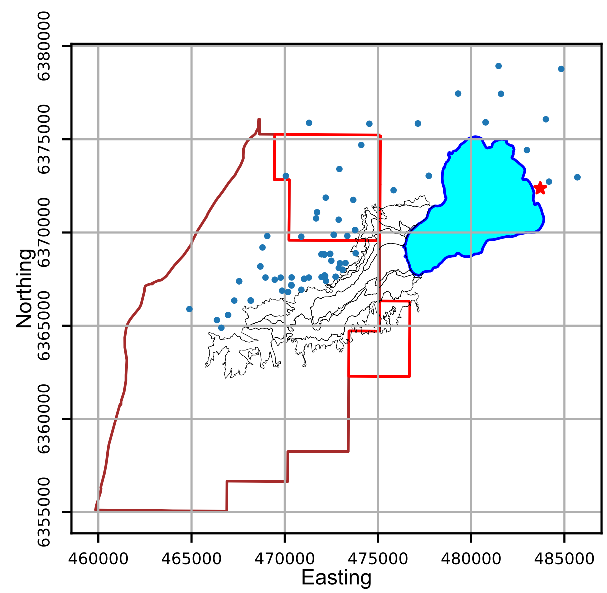
TITLE

FH19-ES605-DR1 - 12.53 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-80

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 39.85 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH19-ES605-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-81

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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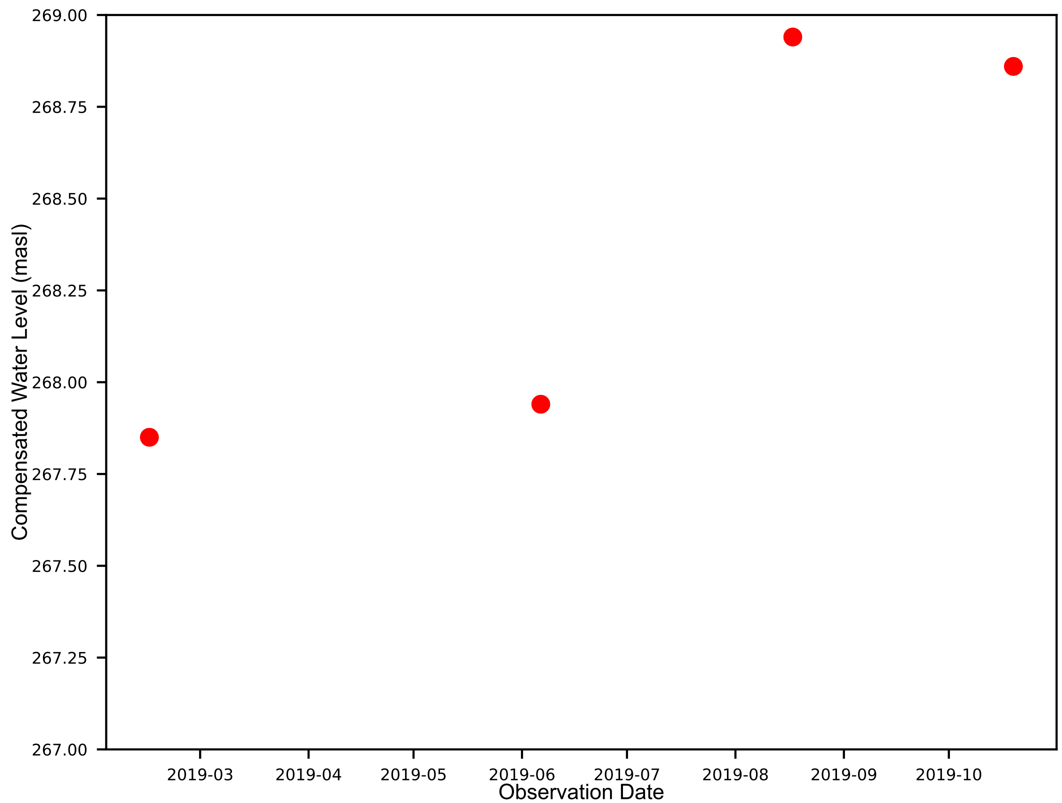

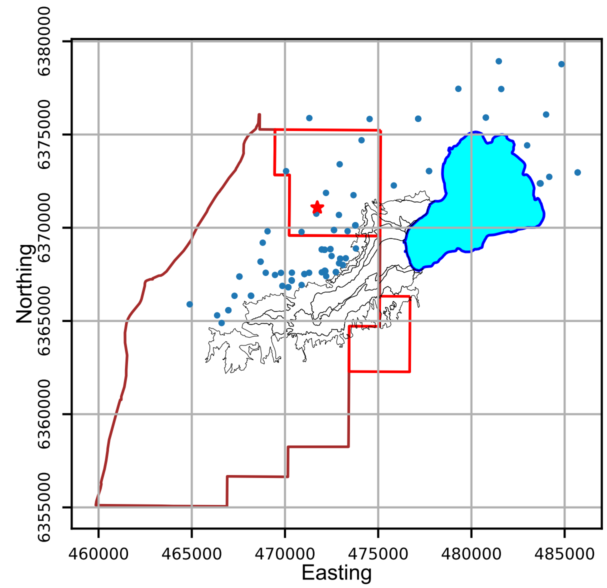

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 71.04 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH19-ES606-SN1
PROJECT No.	20140450
CONTROL	100
Rev.	A
FIGURE	B8-82

FORTHILLS
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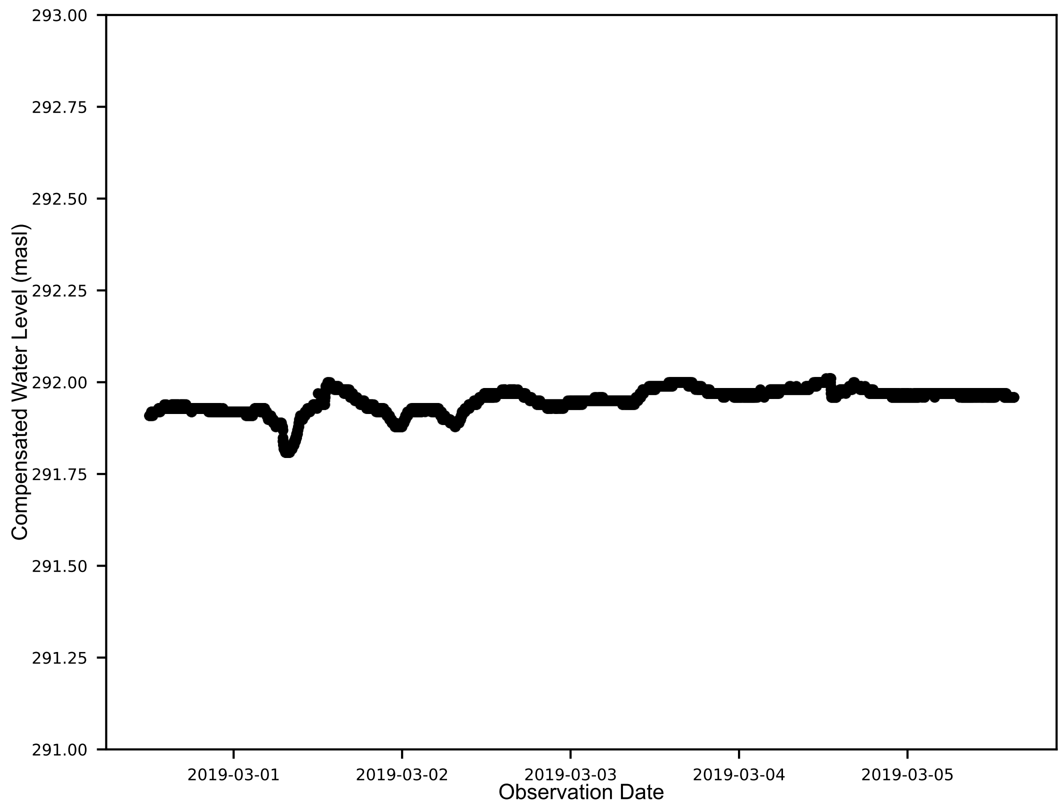

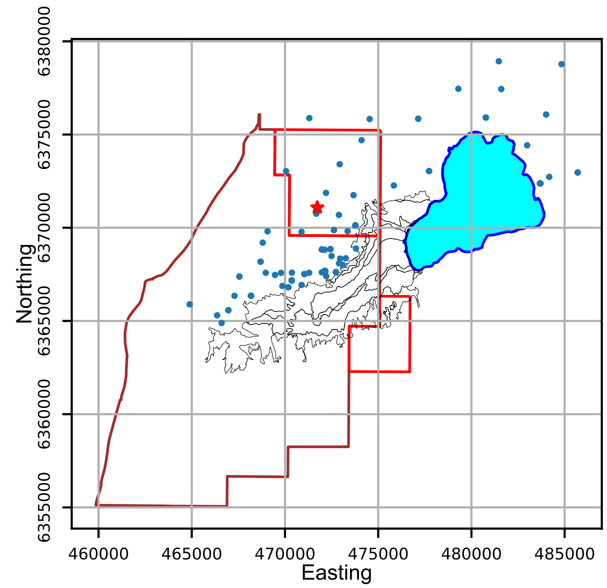

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 71.04 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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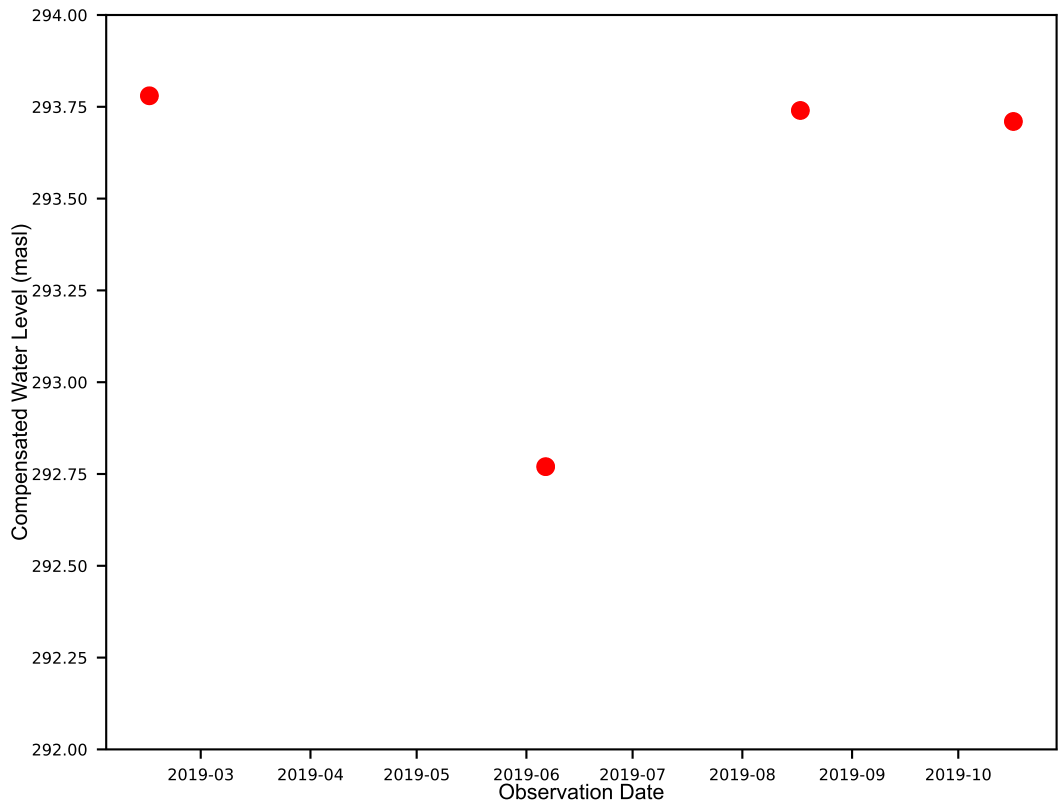
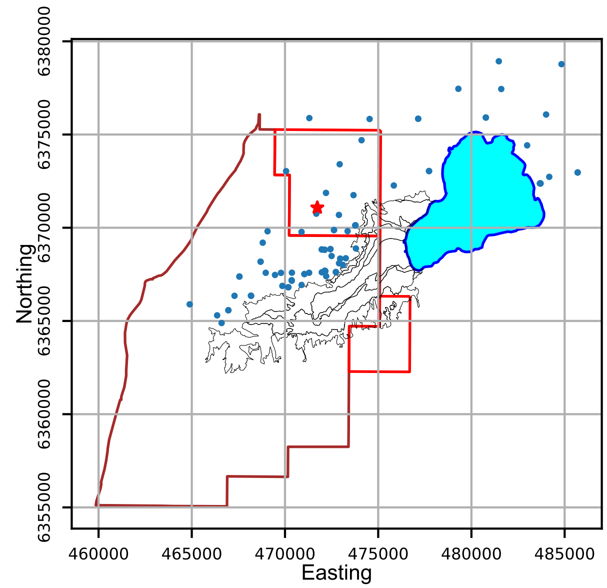
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES606-SN1 - 15.37 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-83

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 28.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

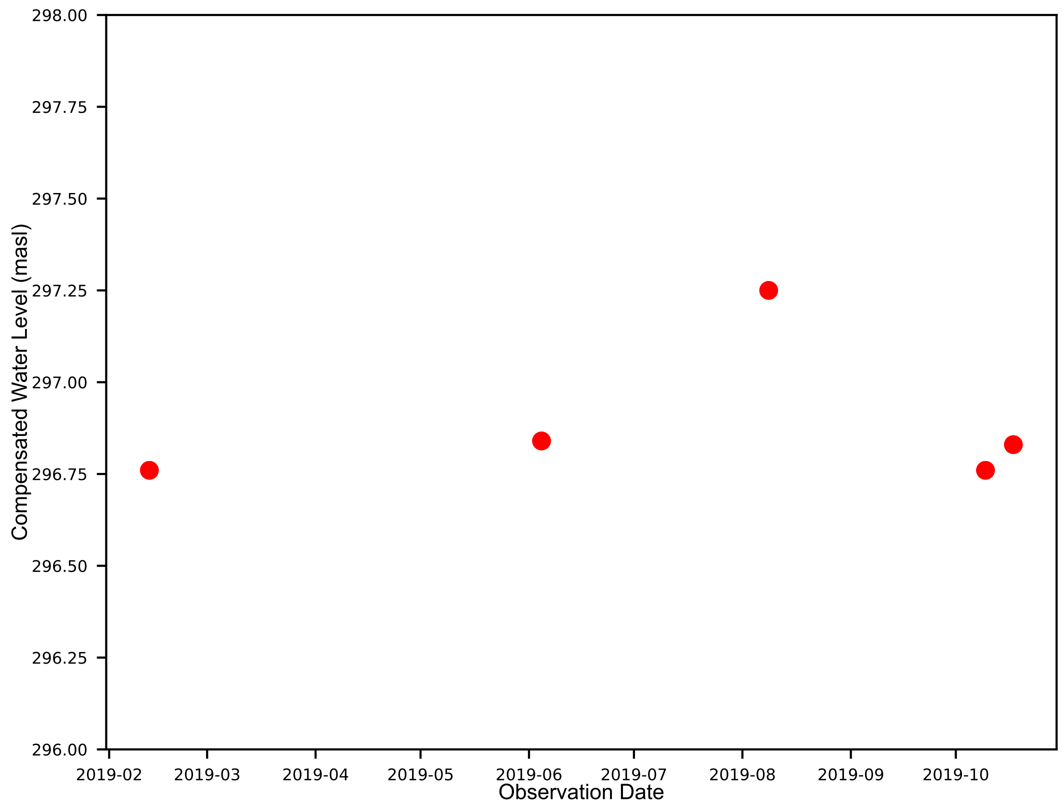
FORTHILLS
Operated by Suncor Energy

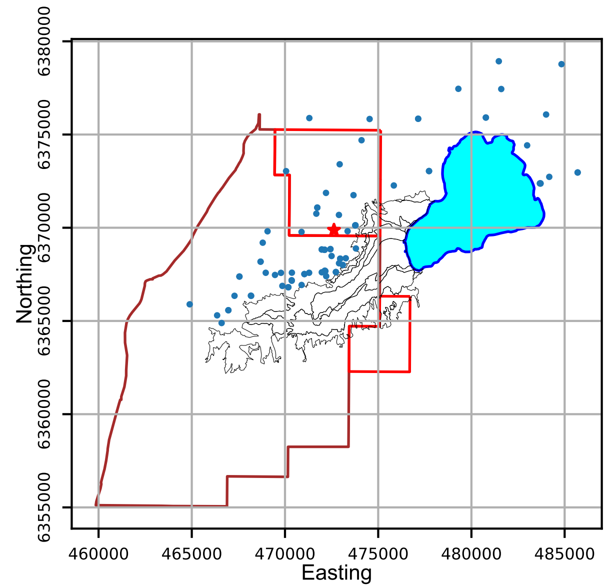
TITLE

FH19-ES606-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-84

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 49.42 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-ES607-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-85

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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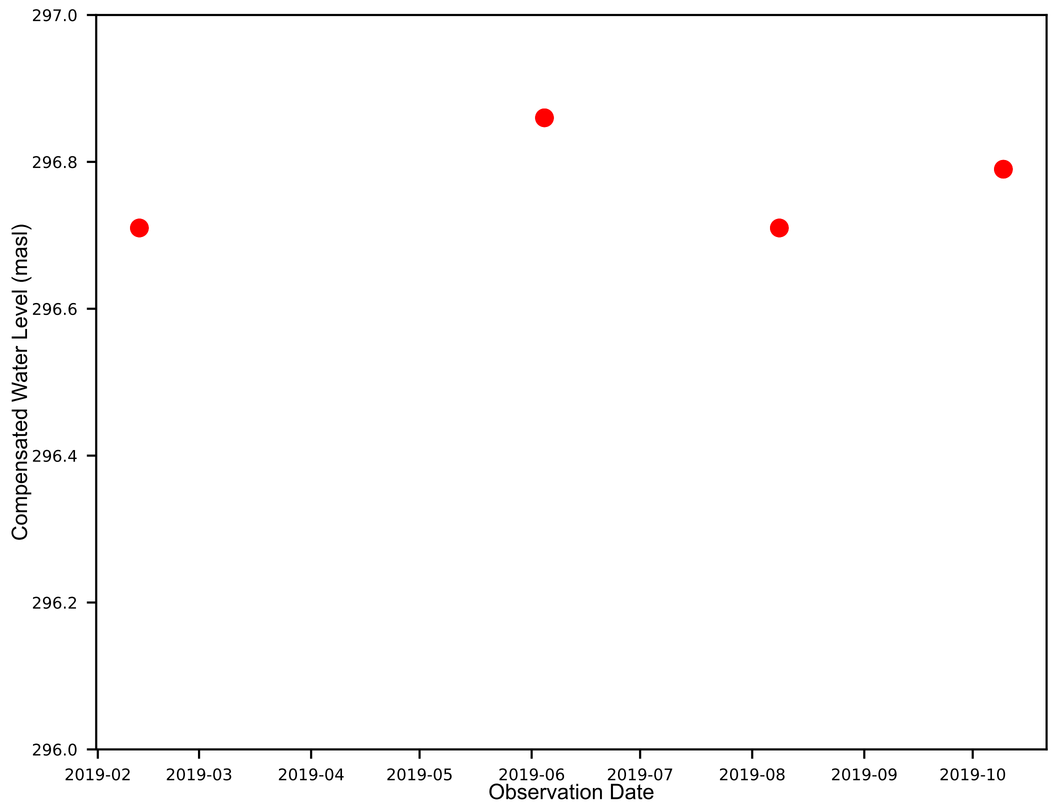
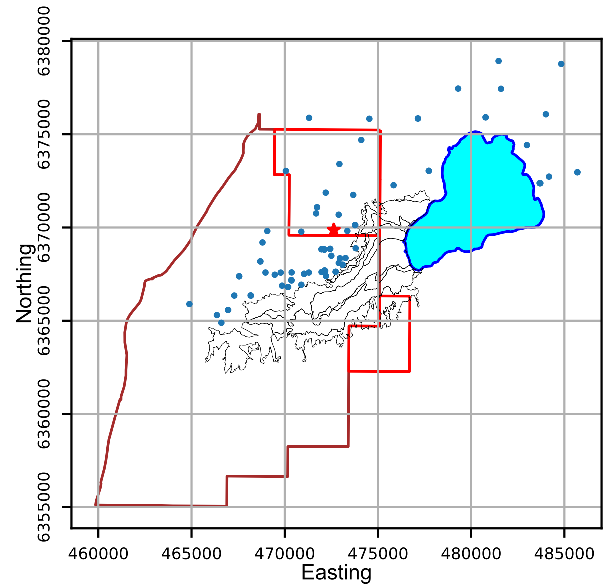
FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 27.68 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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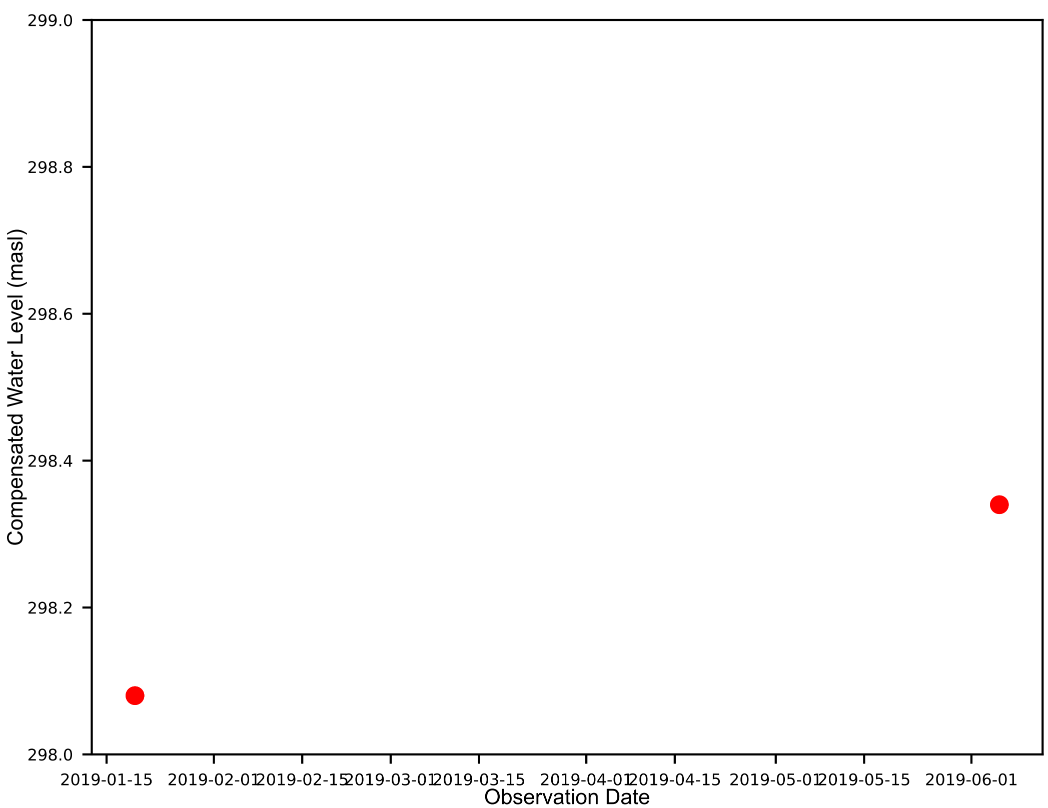
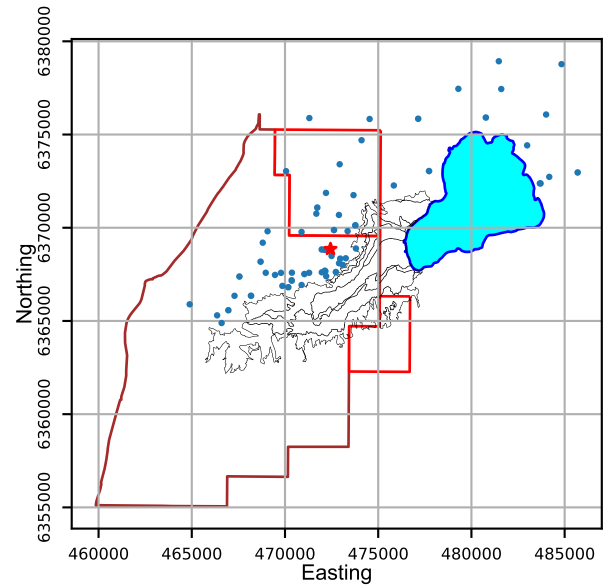
TITLE
FH19-ES607-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-86

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit:
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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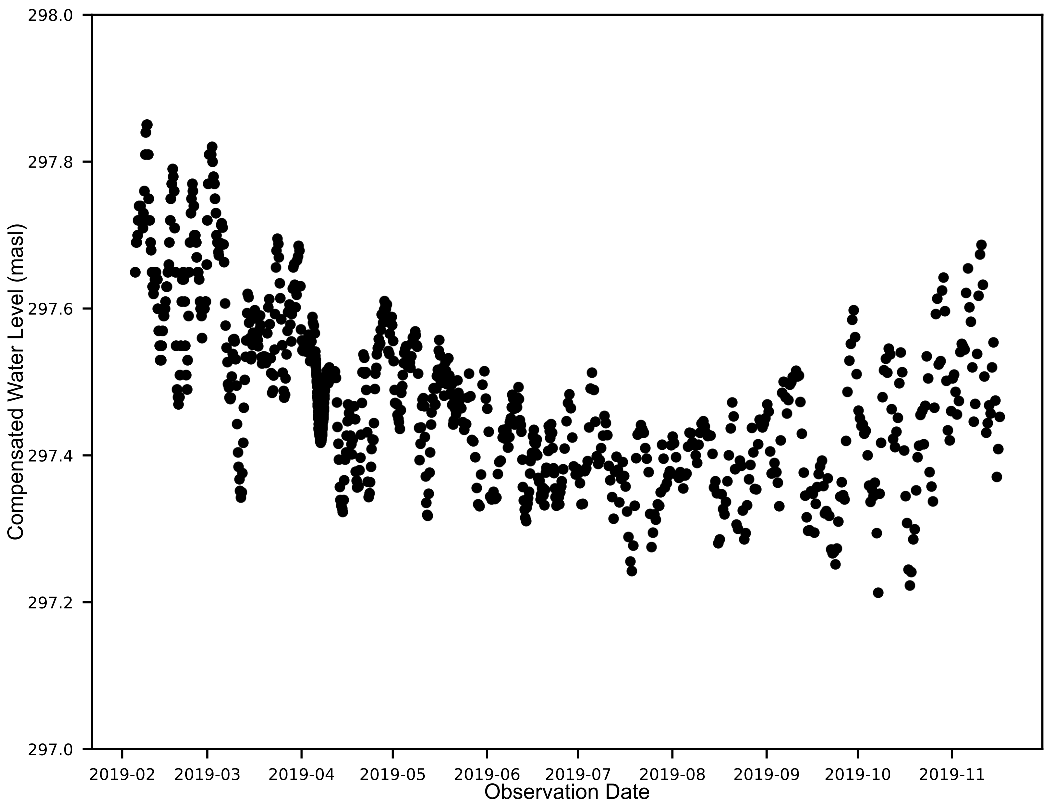
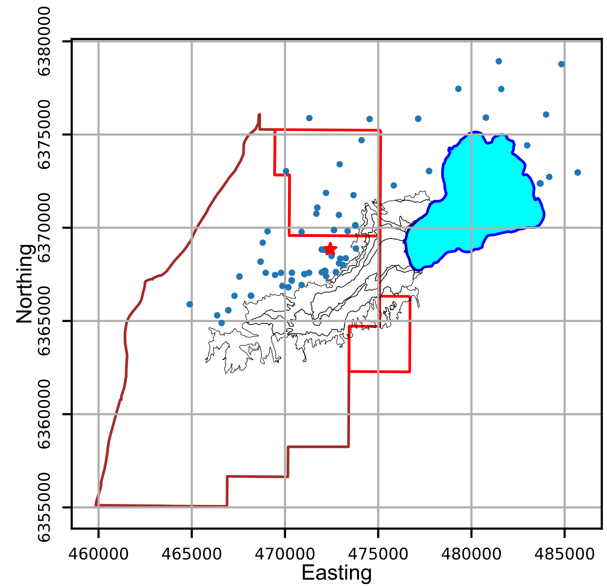
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES609-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-87





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
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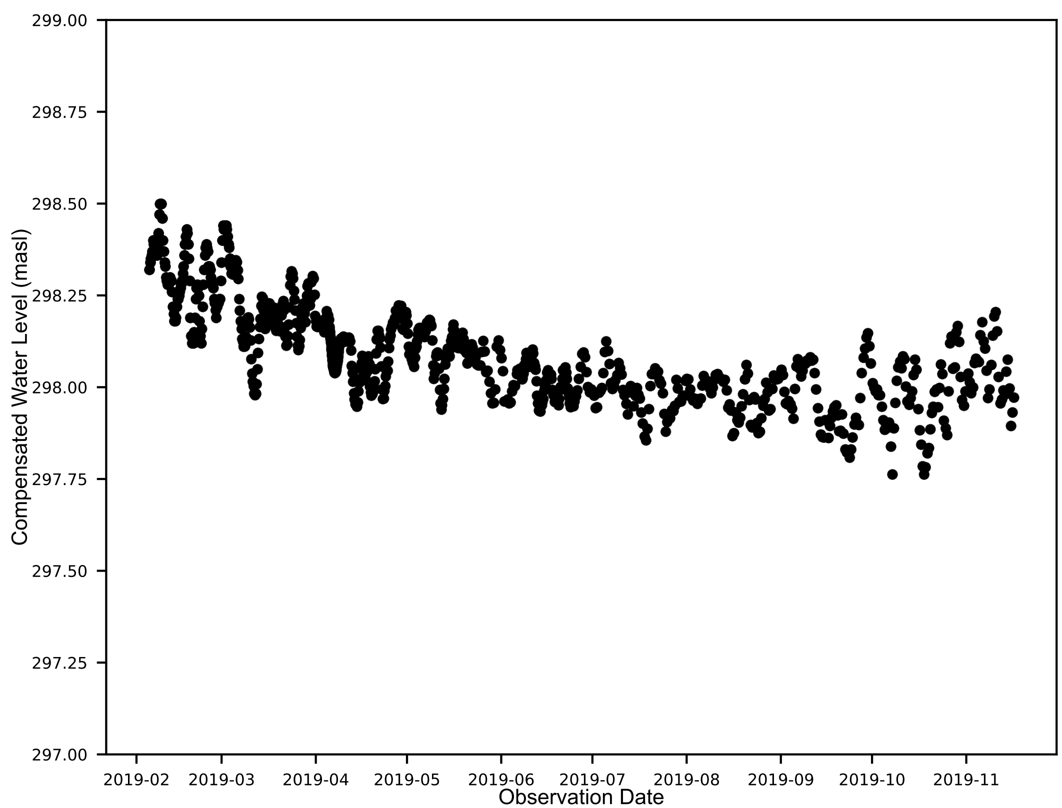
REVIEW	LW
APPROVED	RM

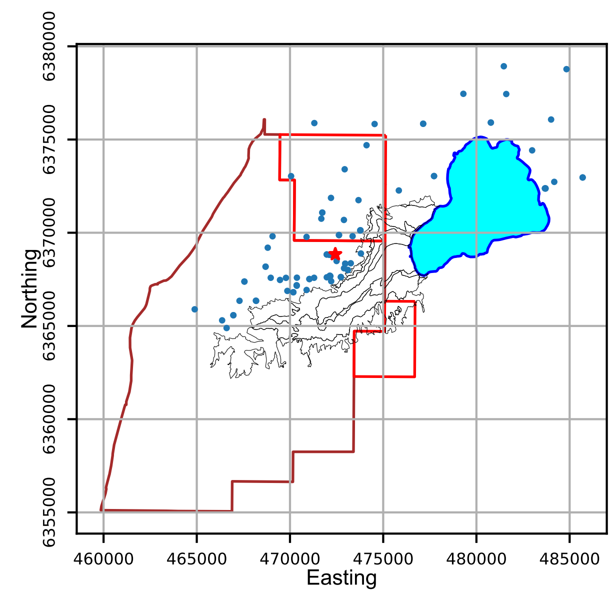
TITLE

FH19-ES609-SN1 - 10.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-88

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 28 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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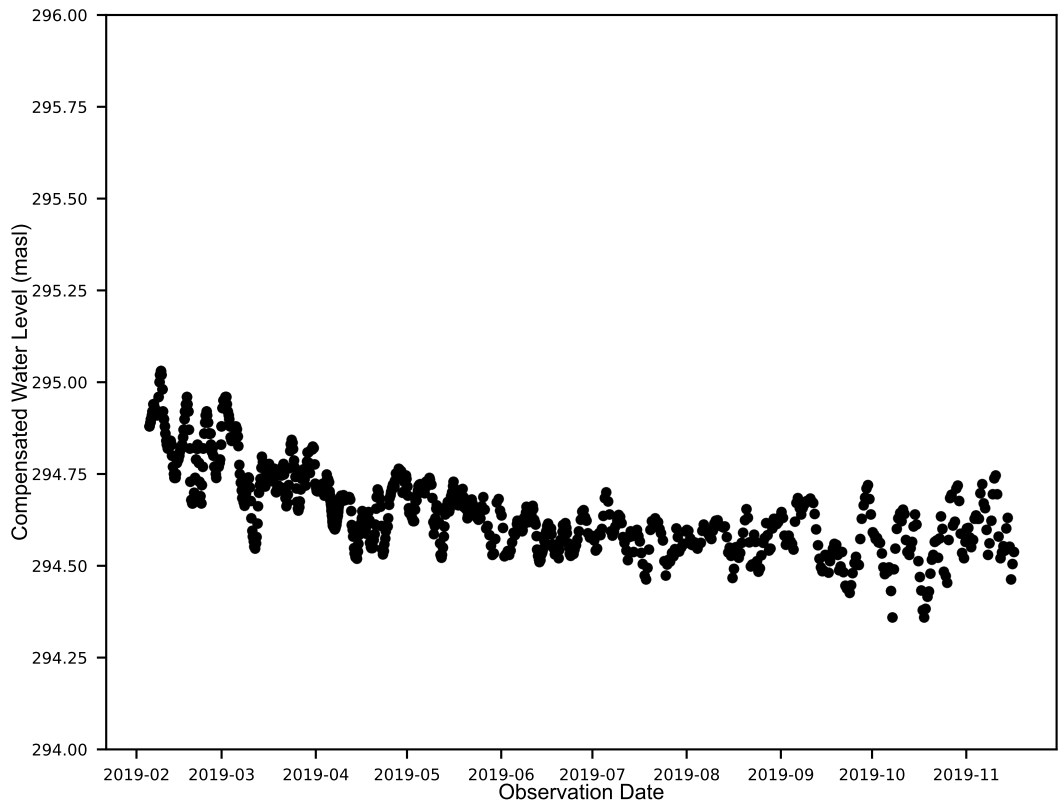
APPROVED	RM

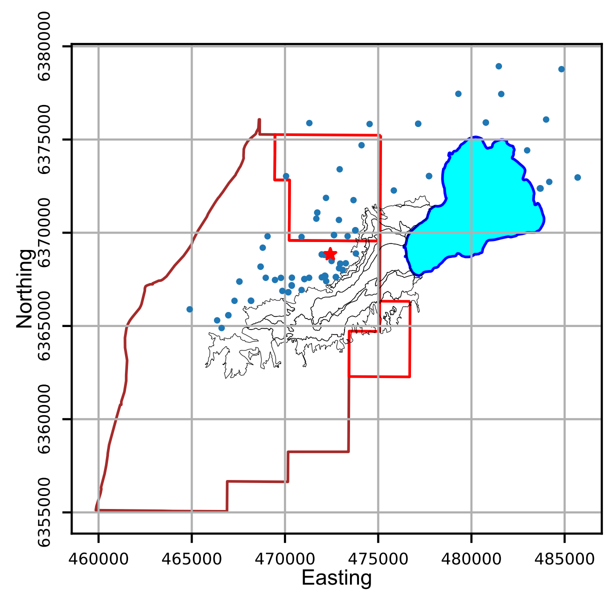
TITLE

FH19-ES609-SN1 - 28.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-89

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 51 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
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REVIEW	LW
APPROVED	RM

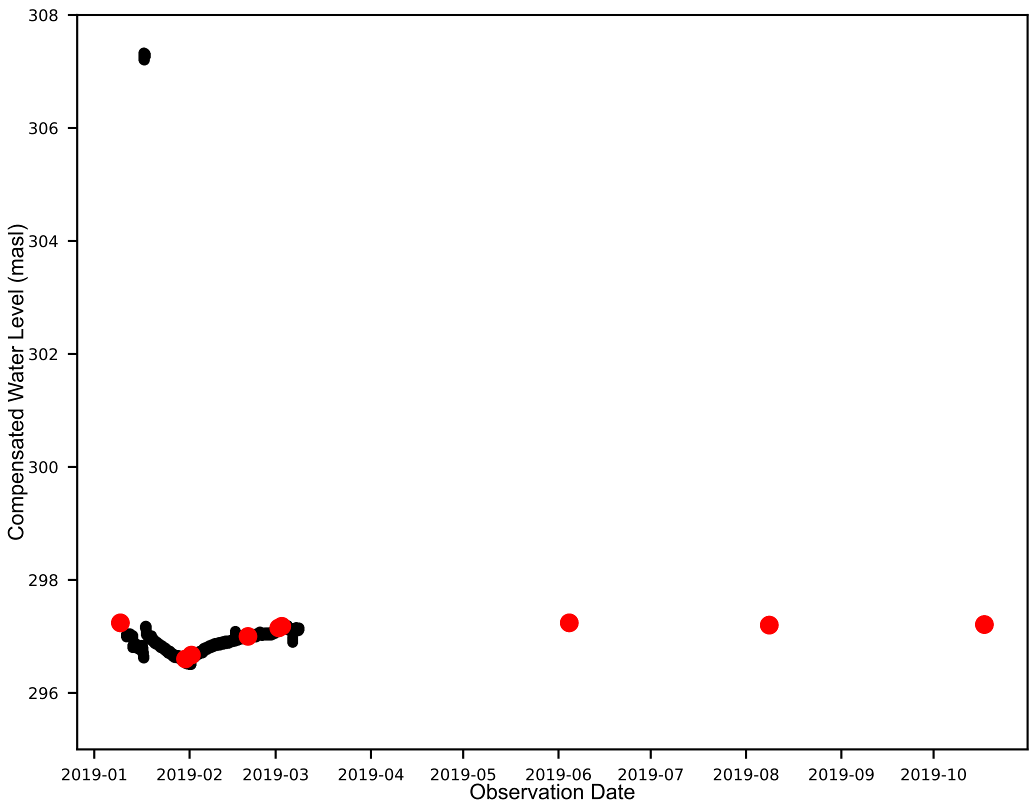
FORT HILLS
Operated by Suncor Energy

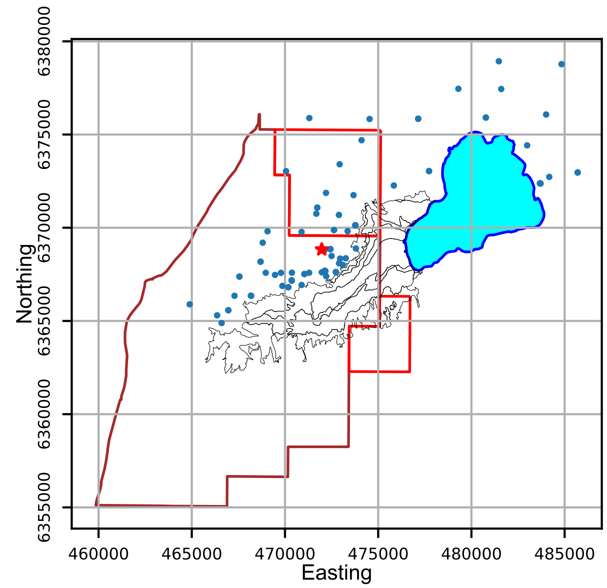
TITLE

FH19-ES609-SN1 - 51.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-90

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 28.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

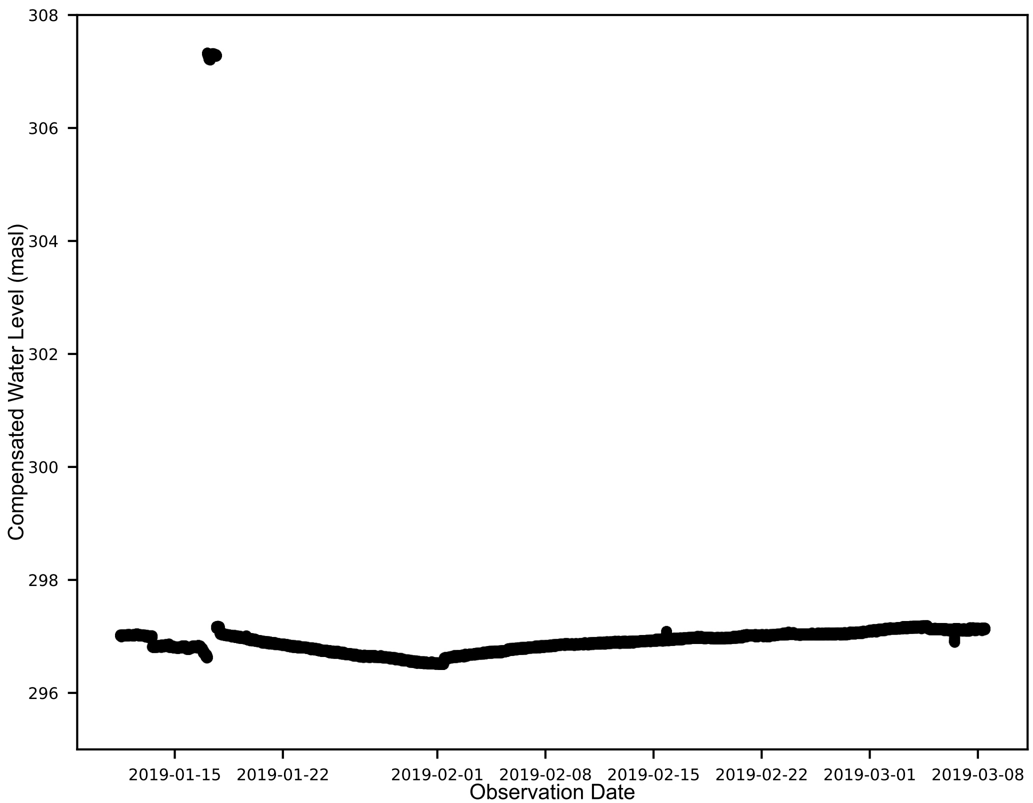
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

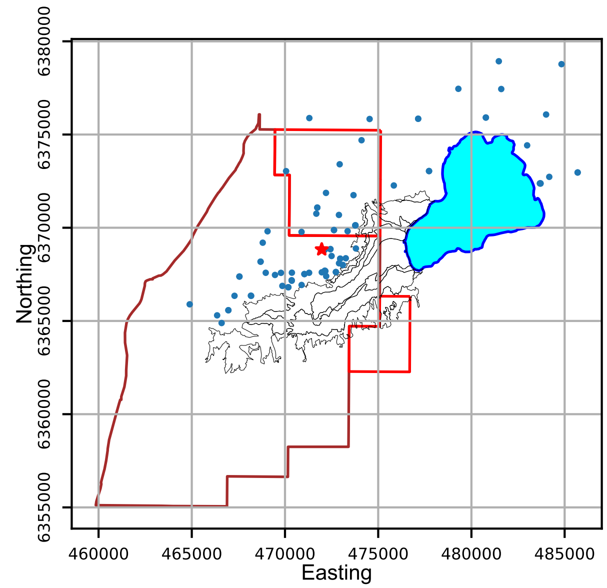
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH19-ES610-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-91





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 28.4 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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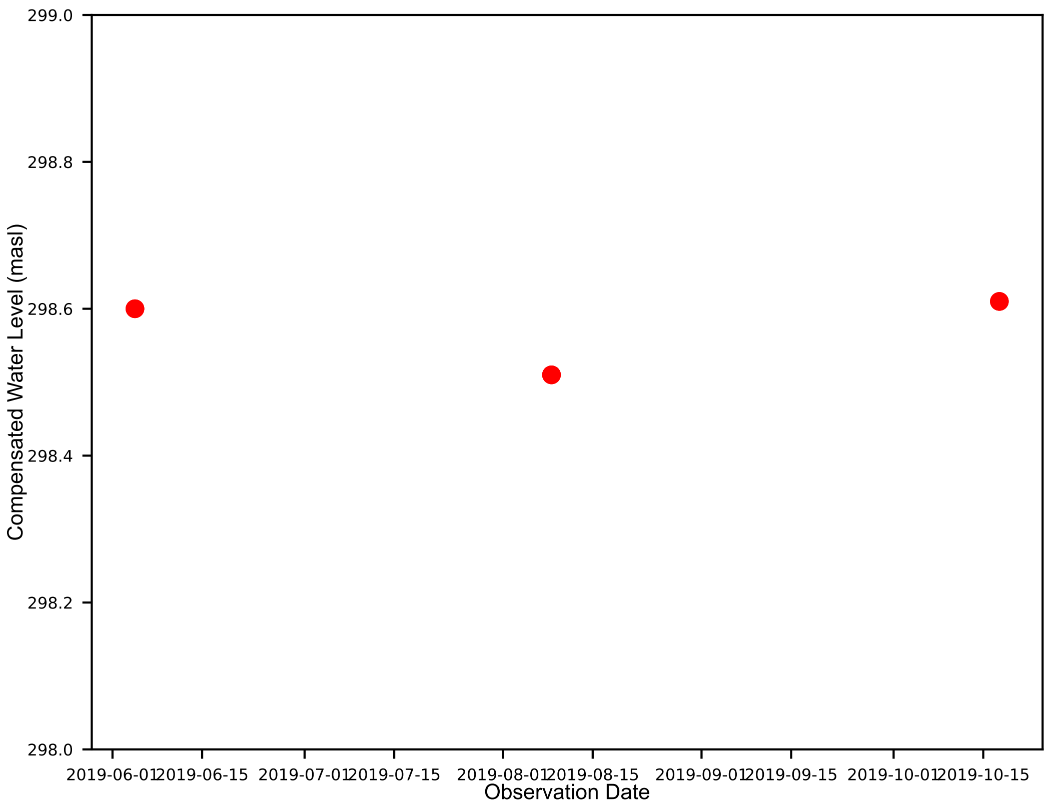
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

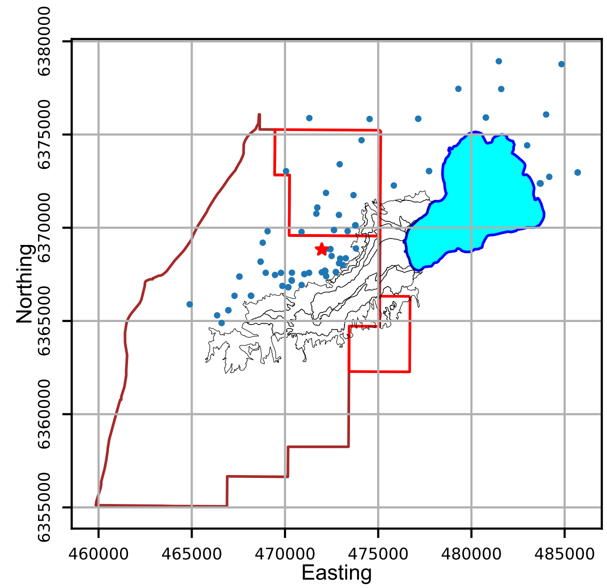
TITLE

FH19-ES610-SN1 - 17.03 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-92

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

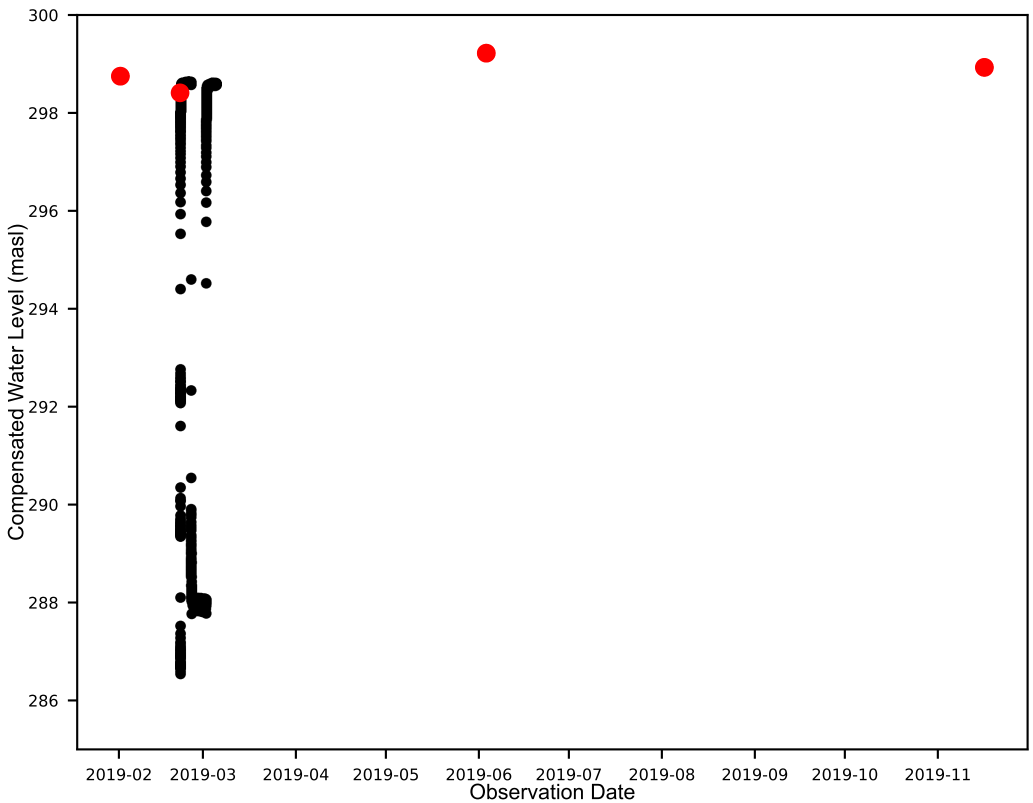
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

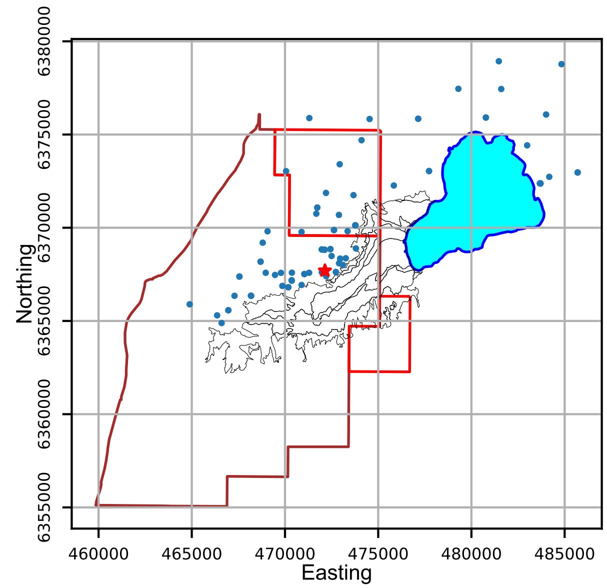
TITLE

FH19-ES610-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-93

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

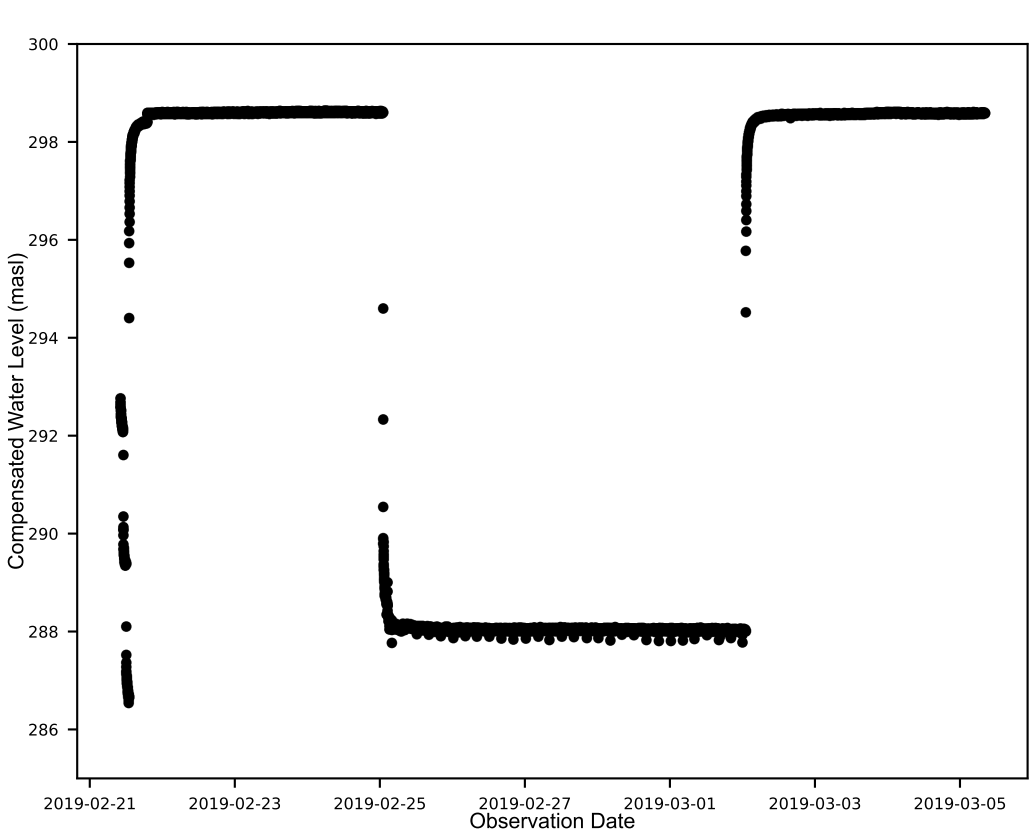
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

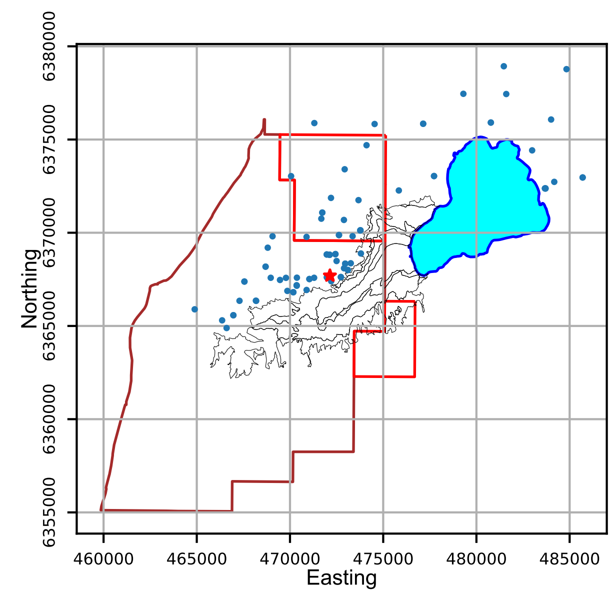
TITLE

FH19-ES612-DR1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-94

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement:

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
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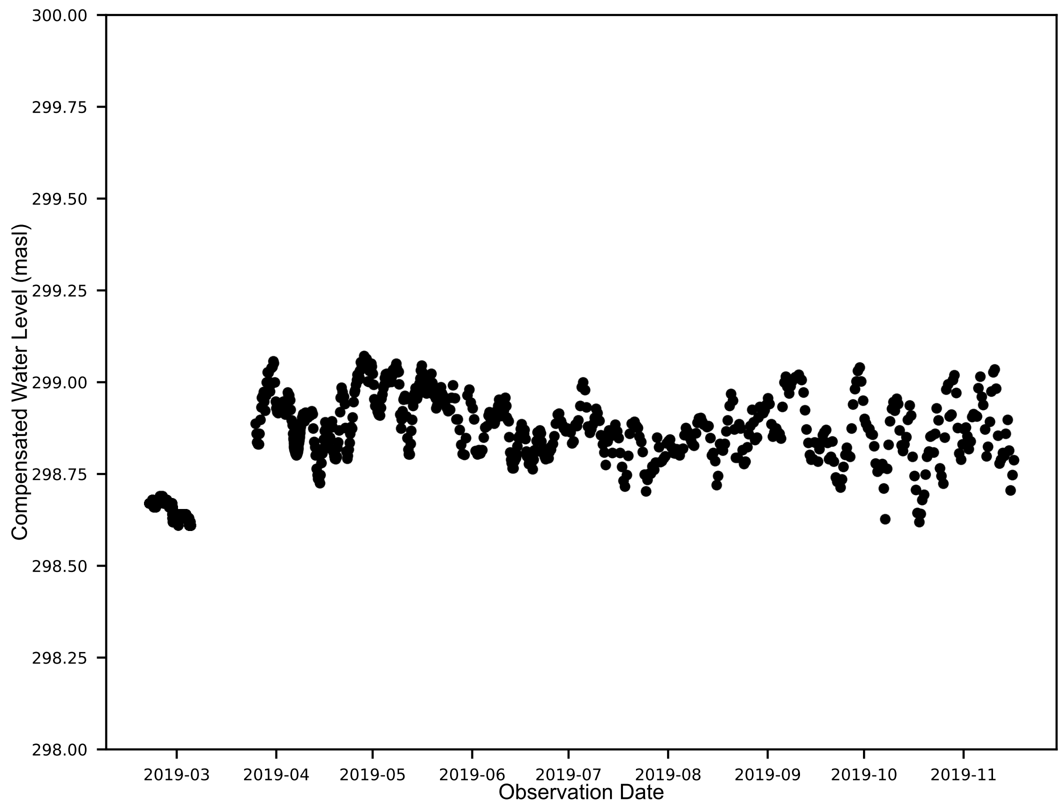
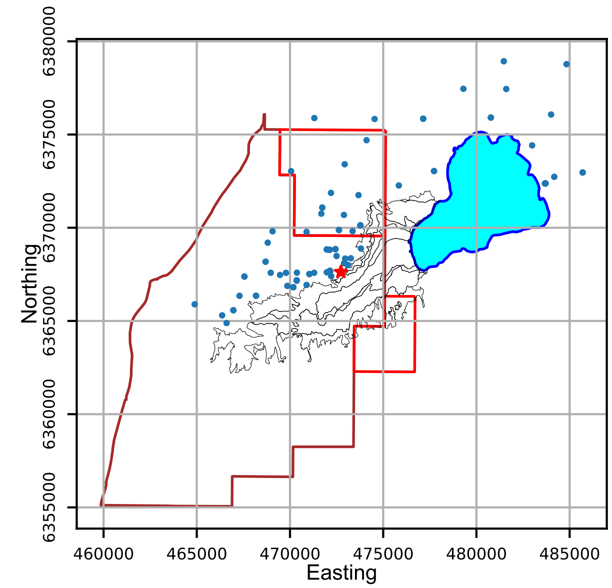
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES612-DR1 - 16.04 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-95

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well
Wells
McClelland Lake
Approved Project Area
Ecohydrology Zone
Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES
Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 17 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

Manual measurement
Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

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REVIEW	LW
APPROVED	RM

TITLE
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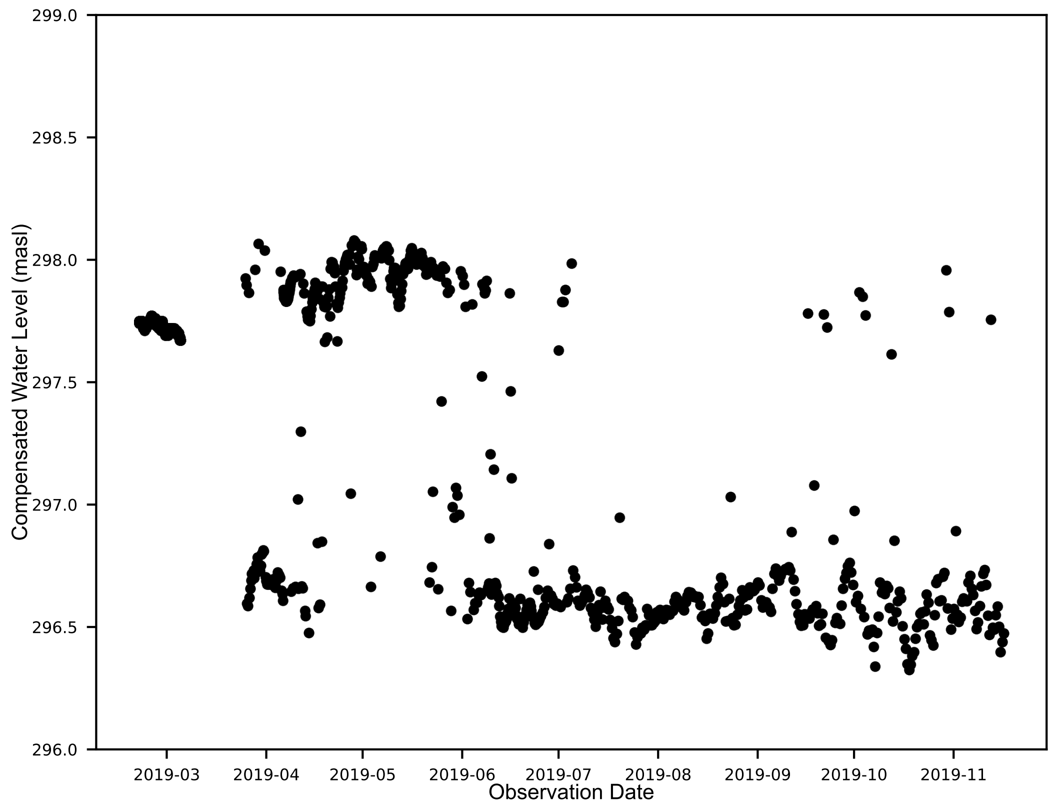
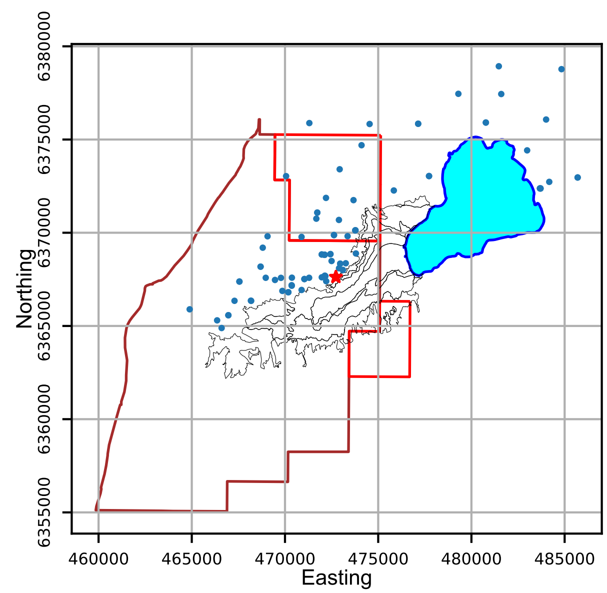
PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-96

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 30.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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FORT HILLS
Operated by Suncor Energy

TITLE

FH19-ES613-SN1 - 30.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-97

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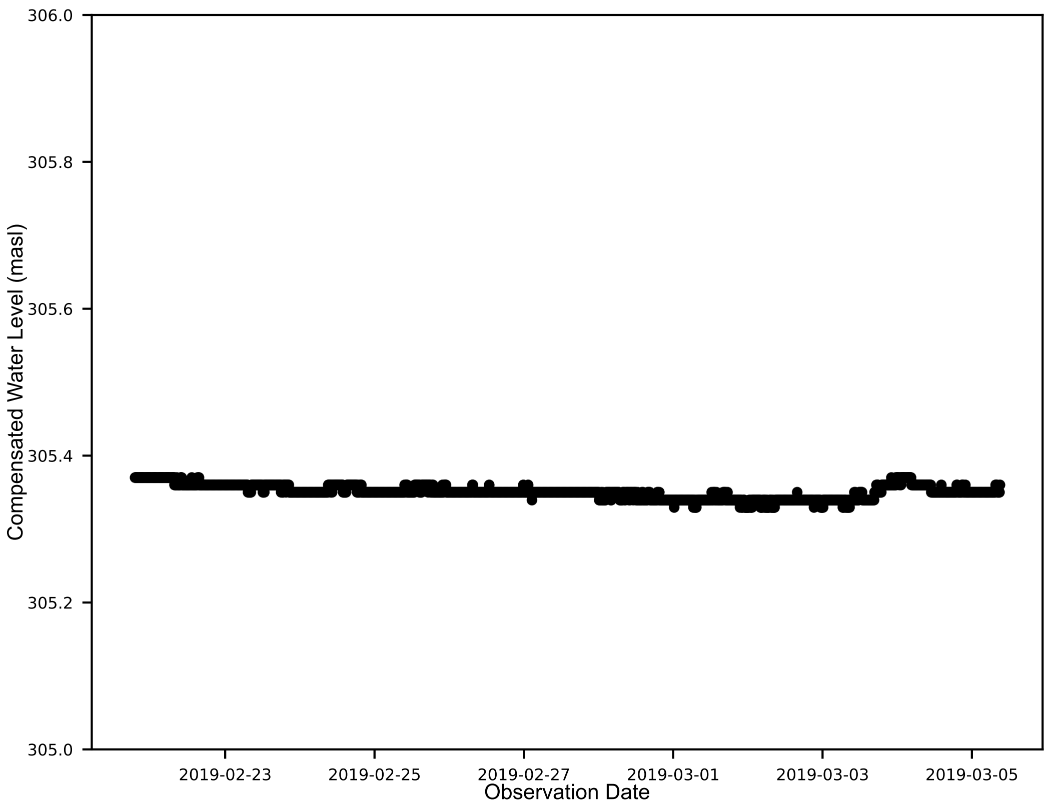

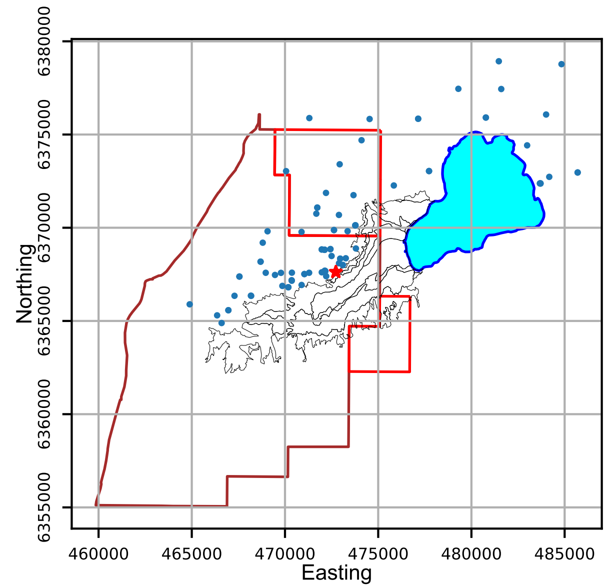

Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

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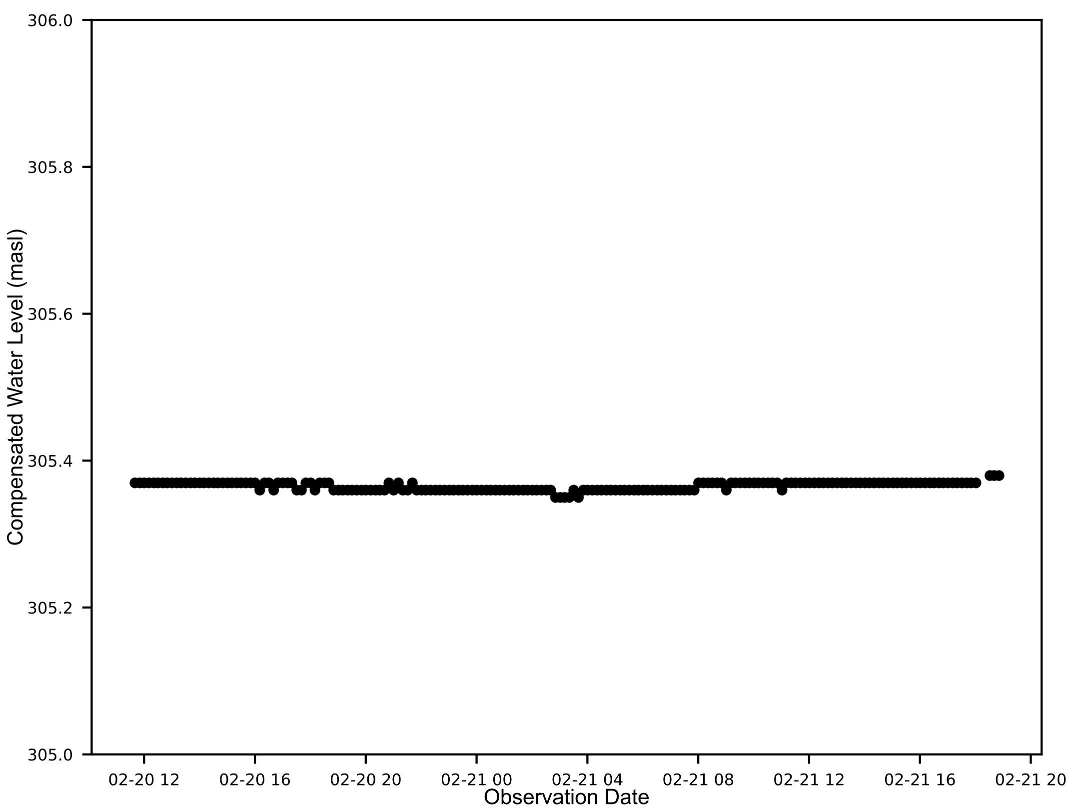
FORT HILLS
Operated by Suncor Energy

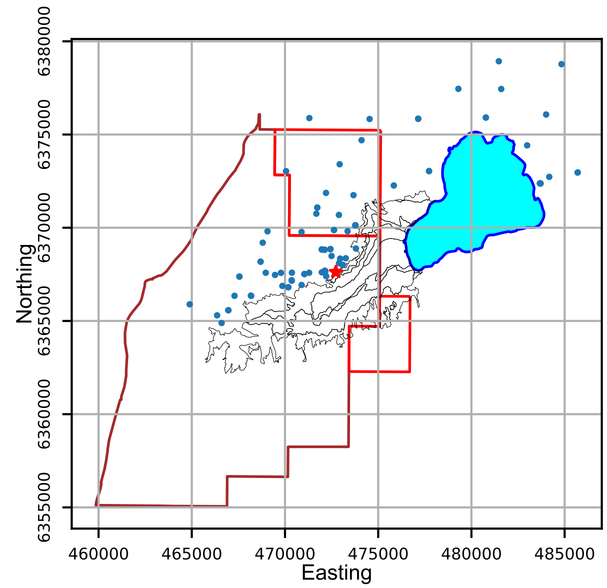
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES613-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-98





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

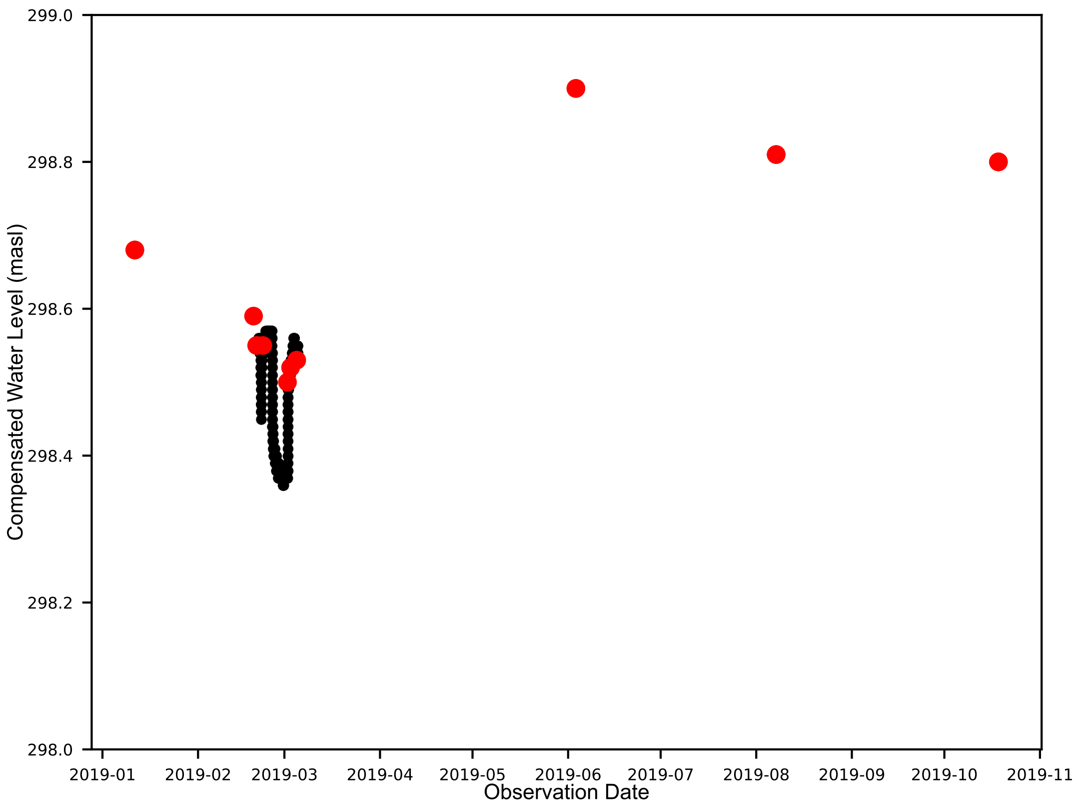
FORTHILLS
Operated by Suncor Energy

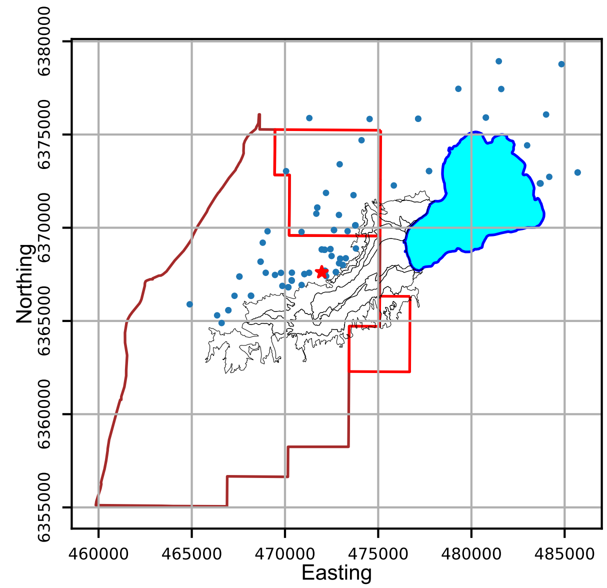
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES613-SN2 - -0.195 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-99

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

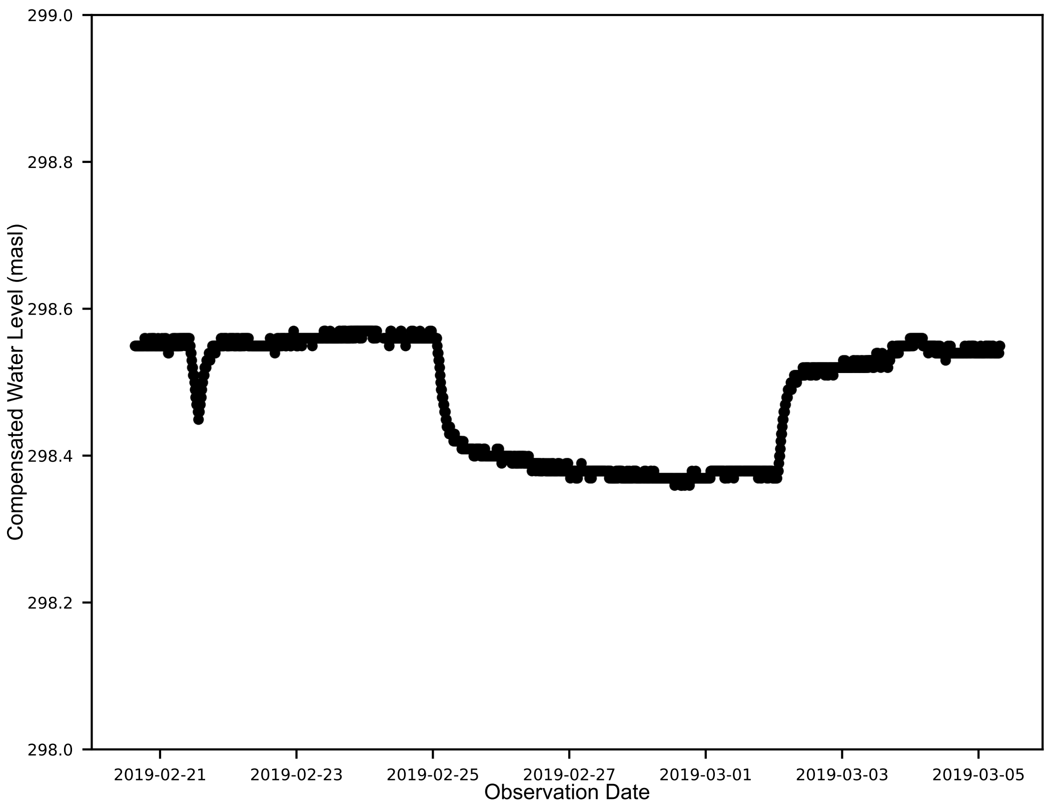
TITLE

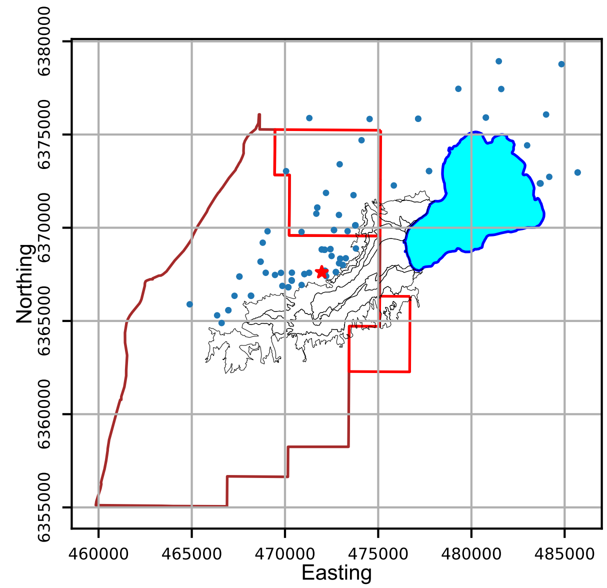
FH19-ES614-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-100

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

1 in





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

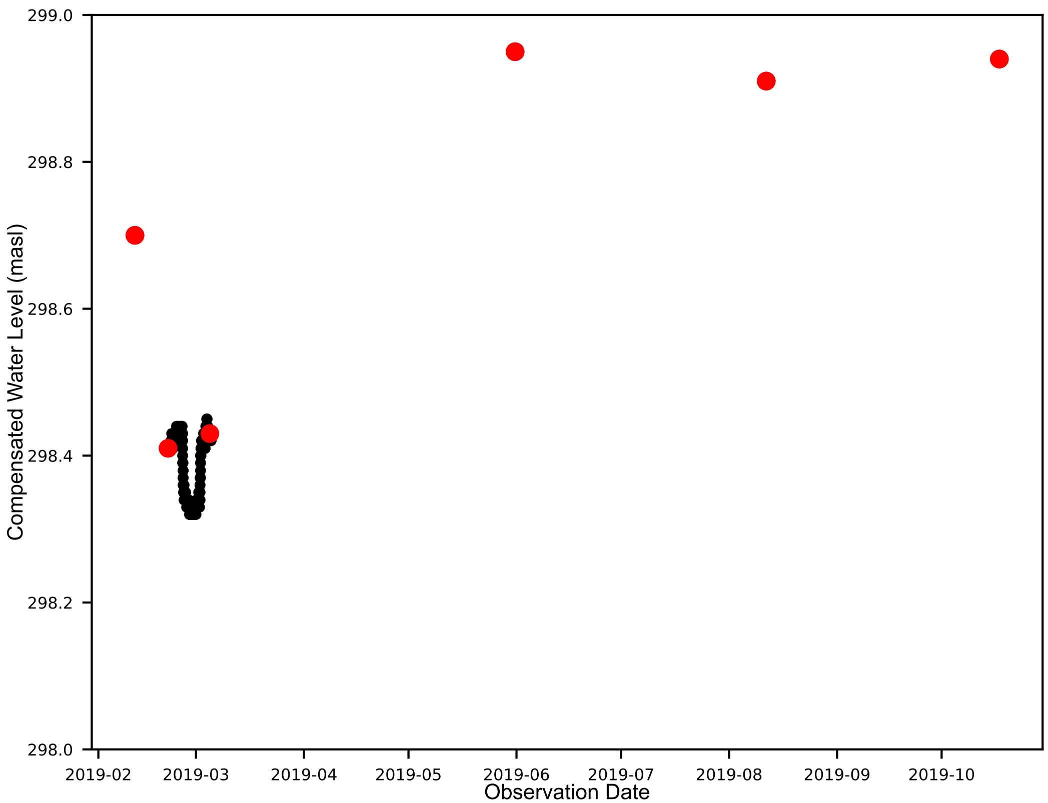
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

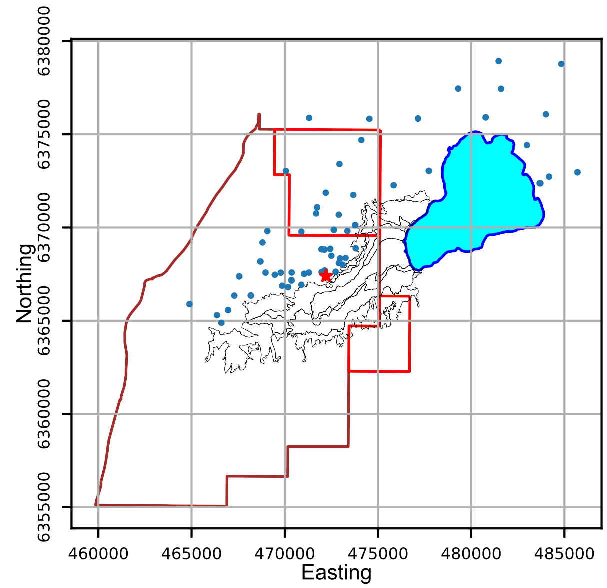
TITLE

FH19-ES614-SN1 - 12.49 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-101

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 17.53 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

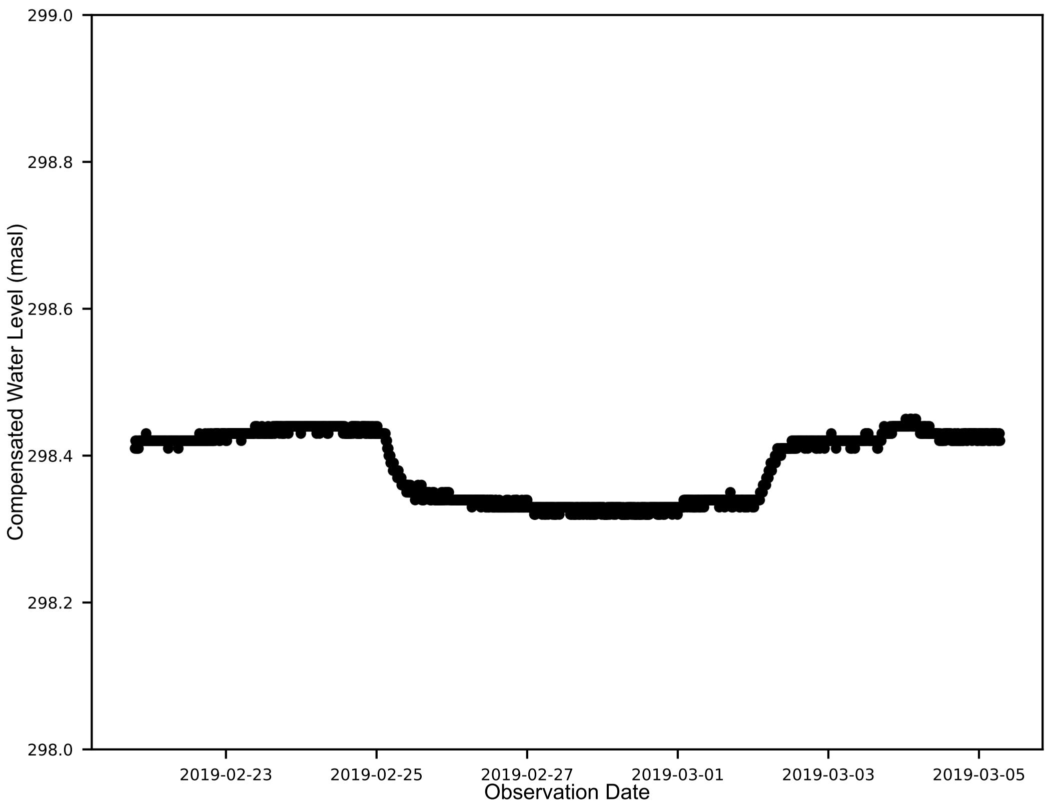
TITLE

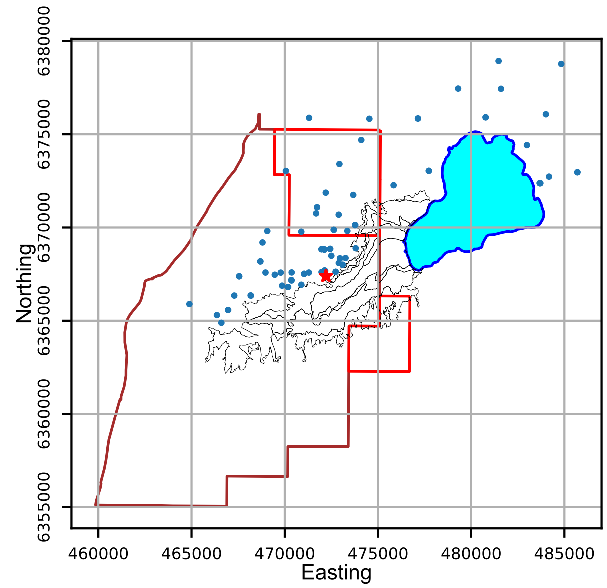
FH19-ES616-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-102

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 17.53 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

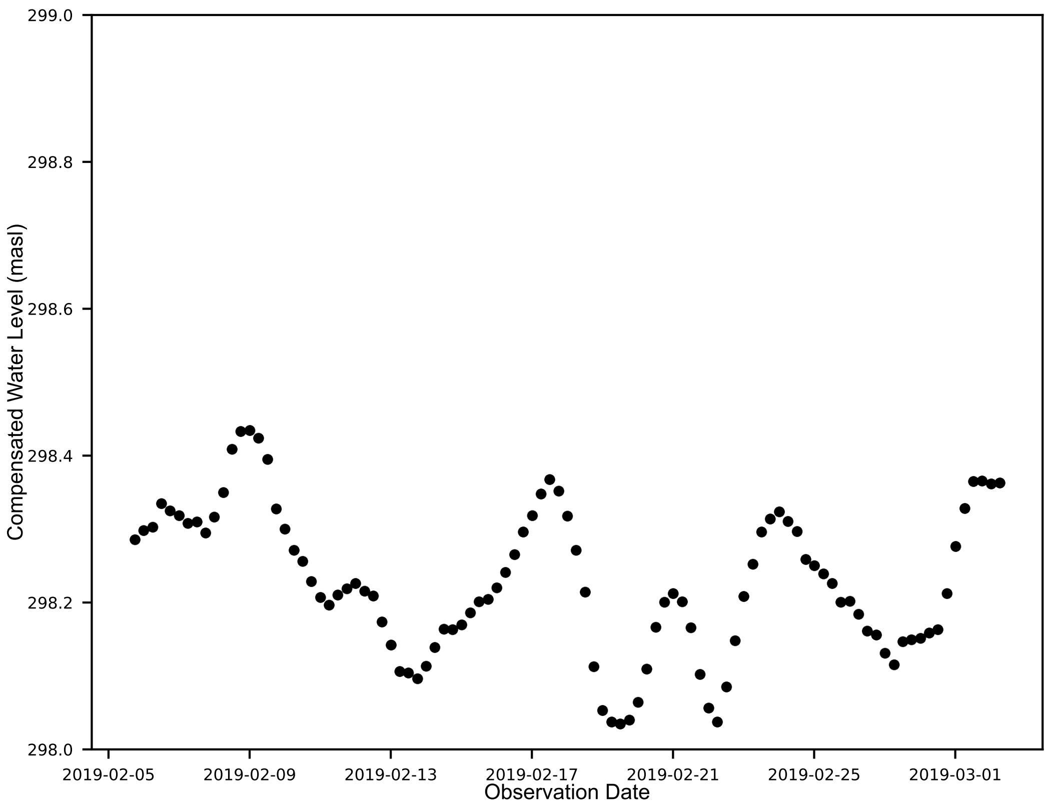
FORT HILLS
Operated by Suncor Energy

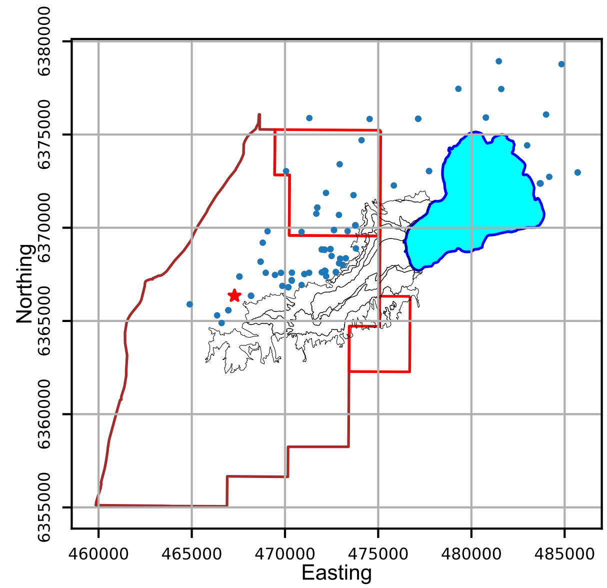
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES616-SN1 - 7.86 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-103

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

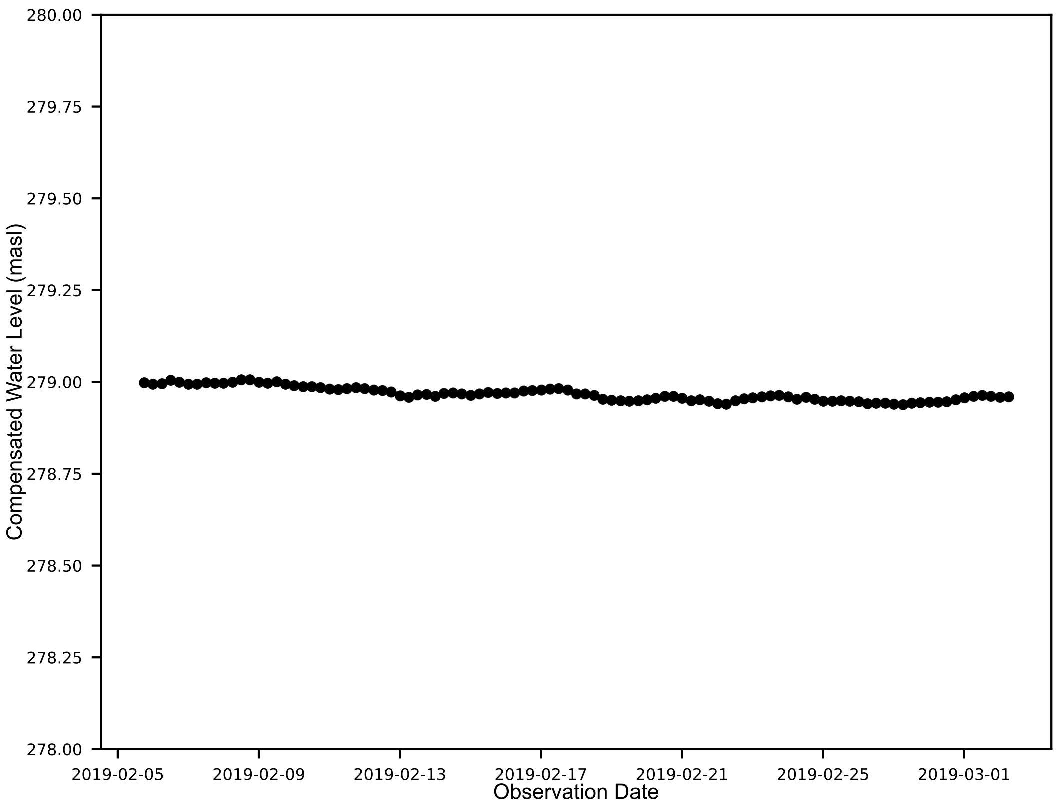
TITLE

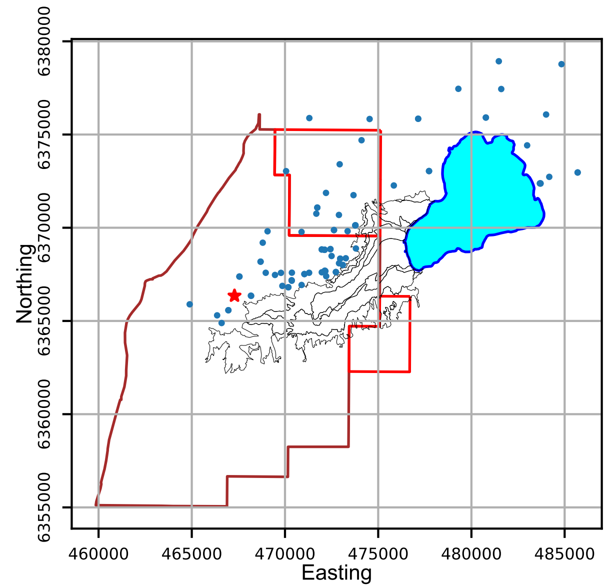
FH19-ES630-SN1 - 14.15 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-104

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 33.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

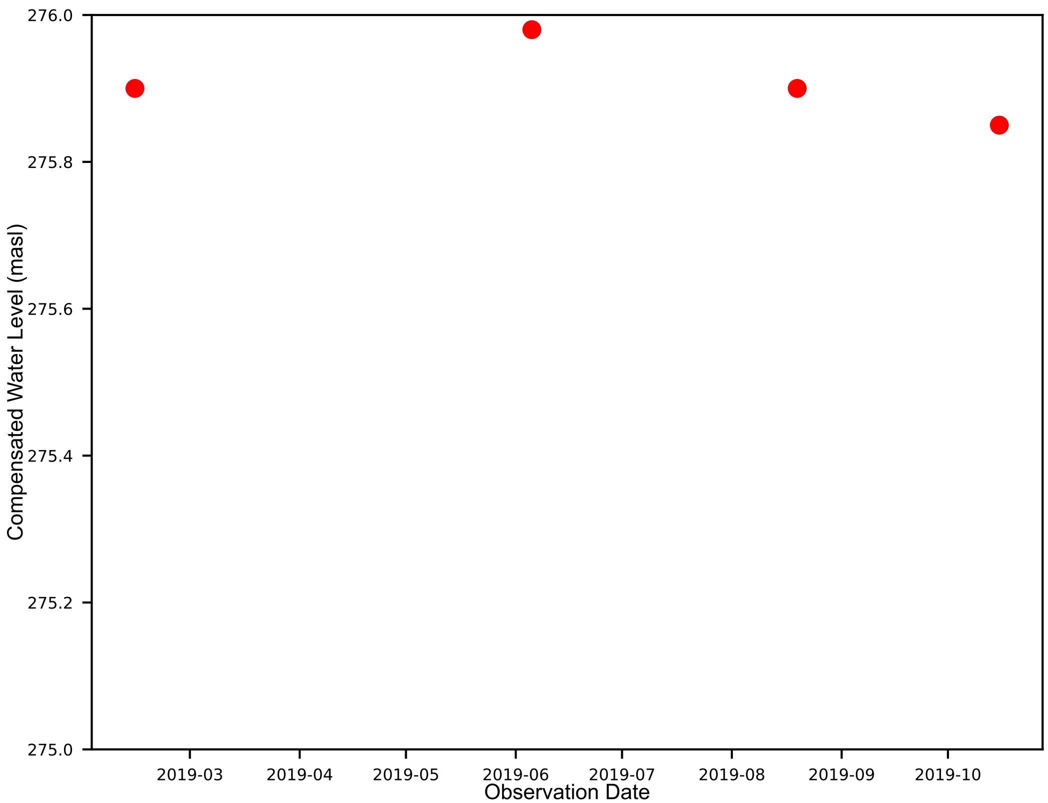
FORT HILLS
Operated by Suncor Energy

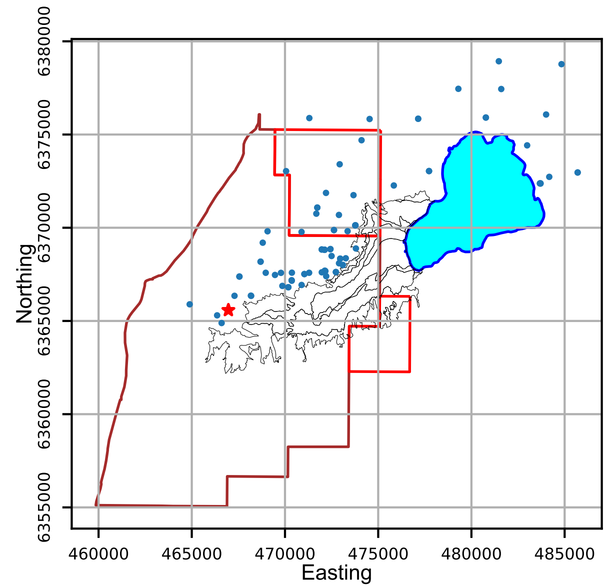
TITLE

FH19-ES630-SN1 - 33.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-105

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 40.29 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

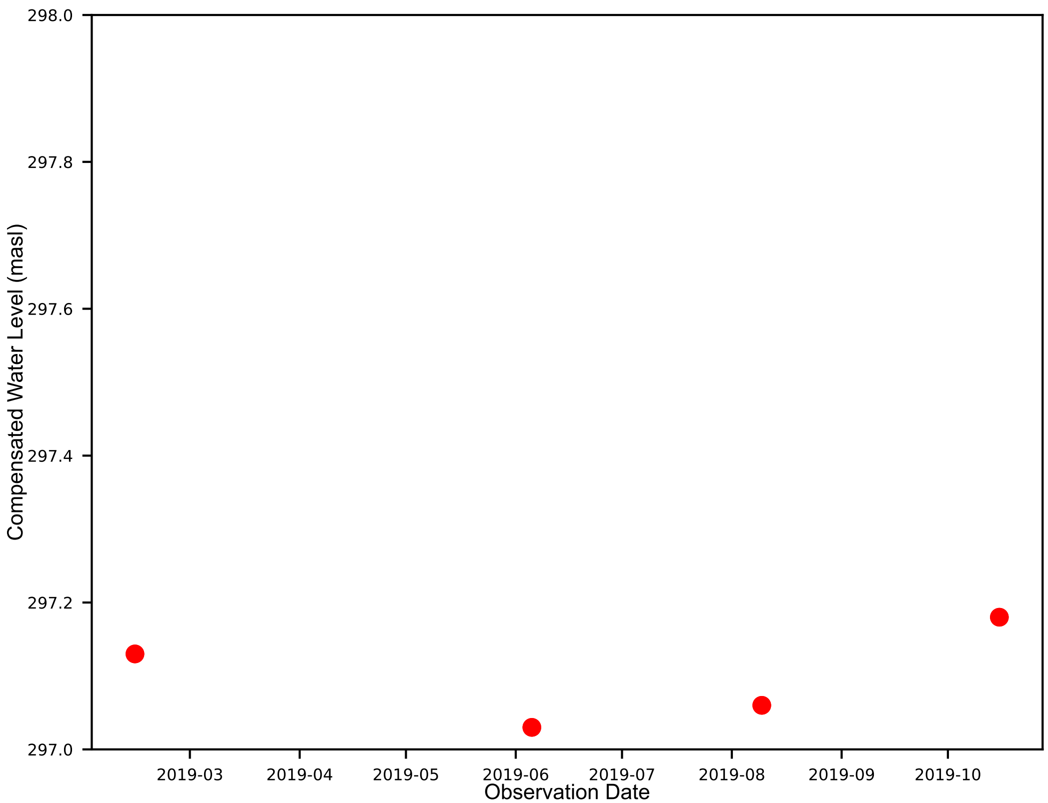
FORTHILLS
Operated by Suncor Energy

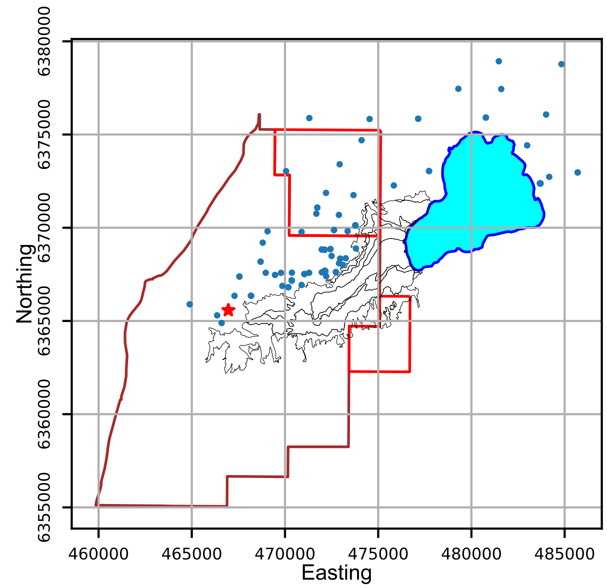
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-ES644-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-106





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 14 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

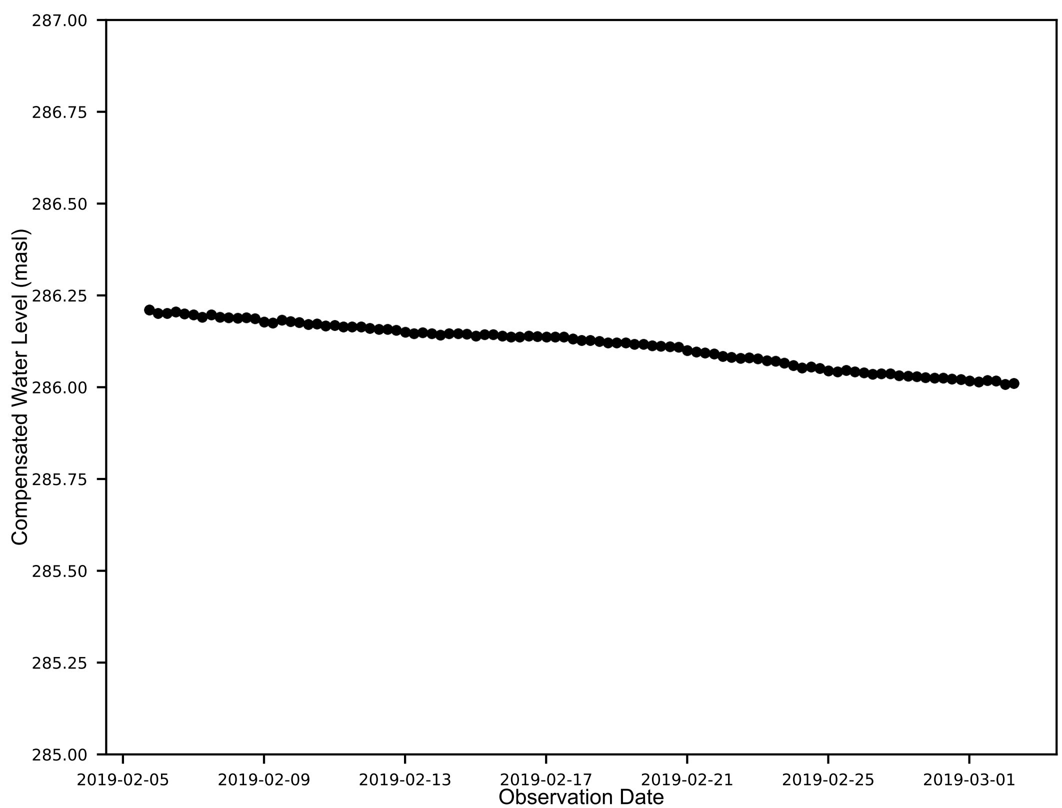
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

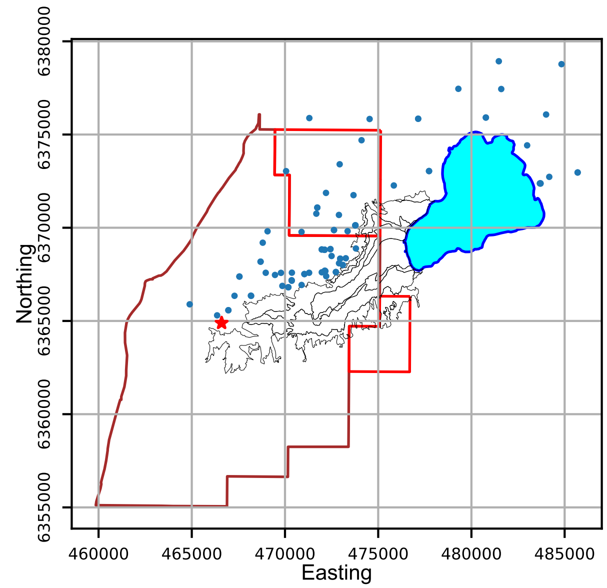
TITLE

FH19-ES644-SN2

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-107

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 27 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

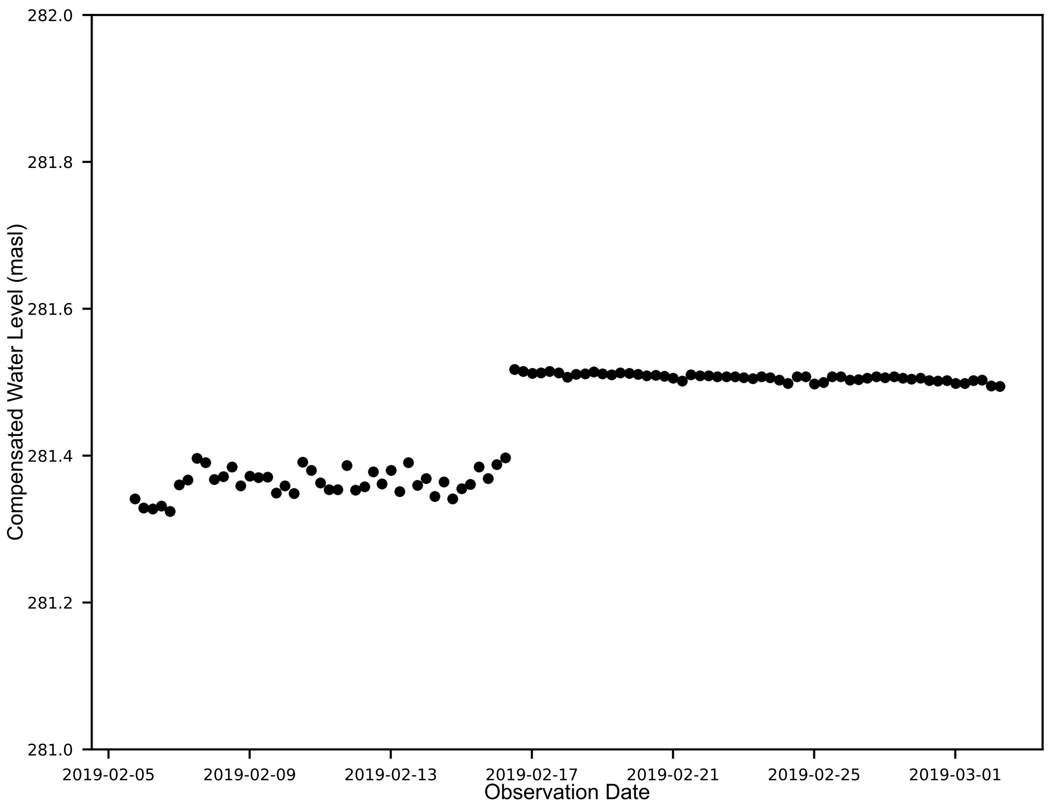
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

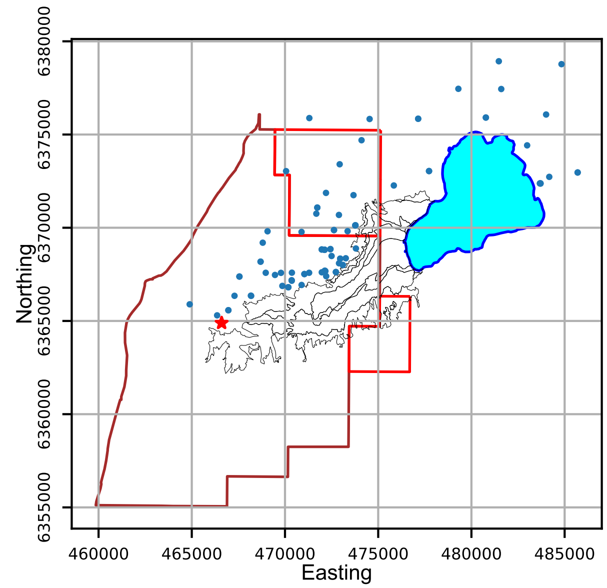
TITLE

FH19-ES664-SN1 - 27.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-108

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 31 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

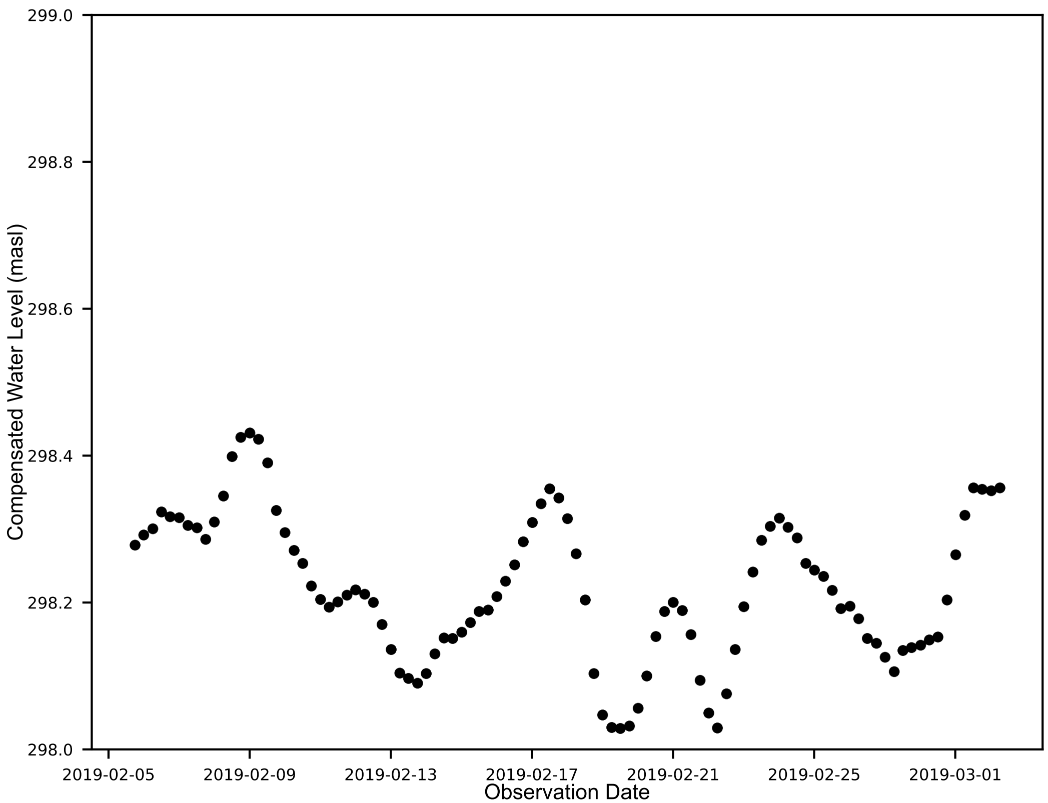
FORTHILLS
Operated by Suncor Energy

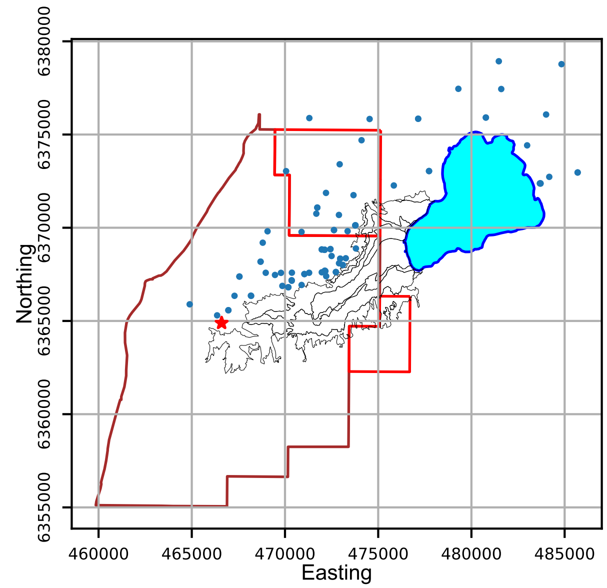
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES664-SN1 - 31.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-109

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 9.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

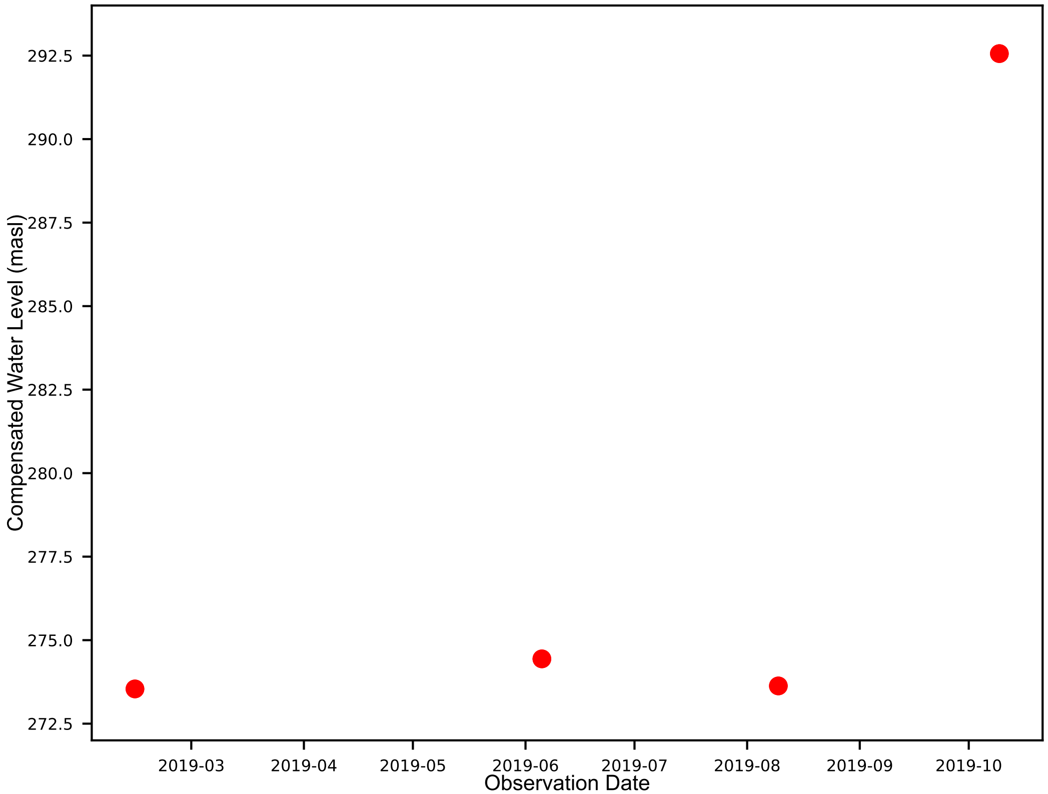
FORTHILLS
Operated by Suncor Energy

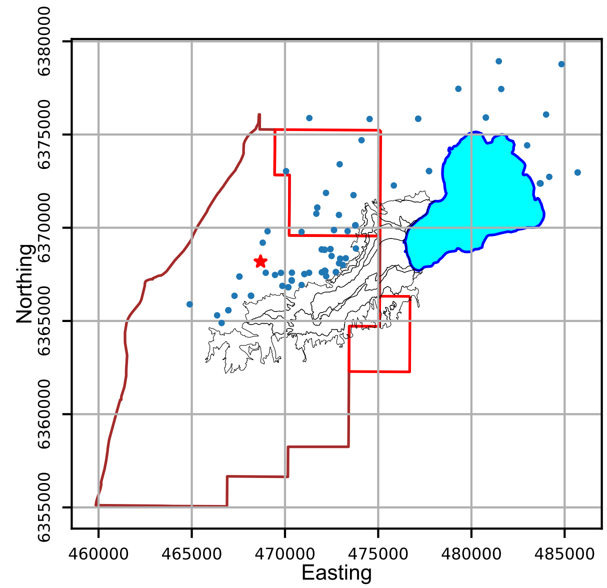
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-ES664-SN1 - 9.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-110

1 in





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 47.11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

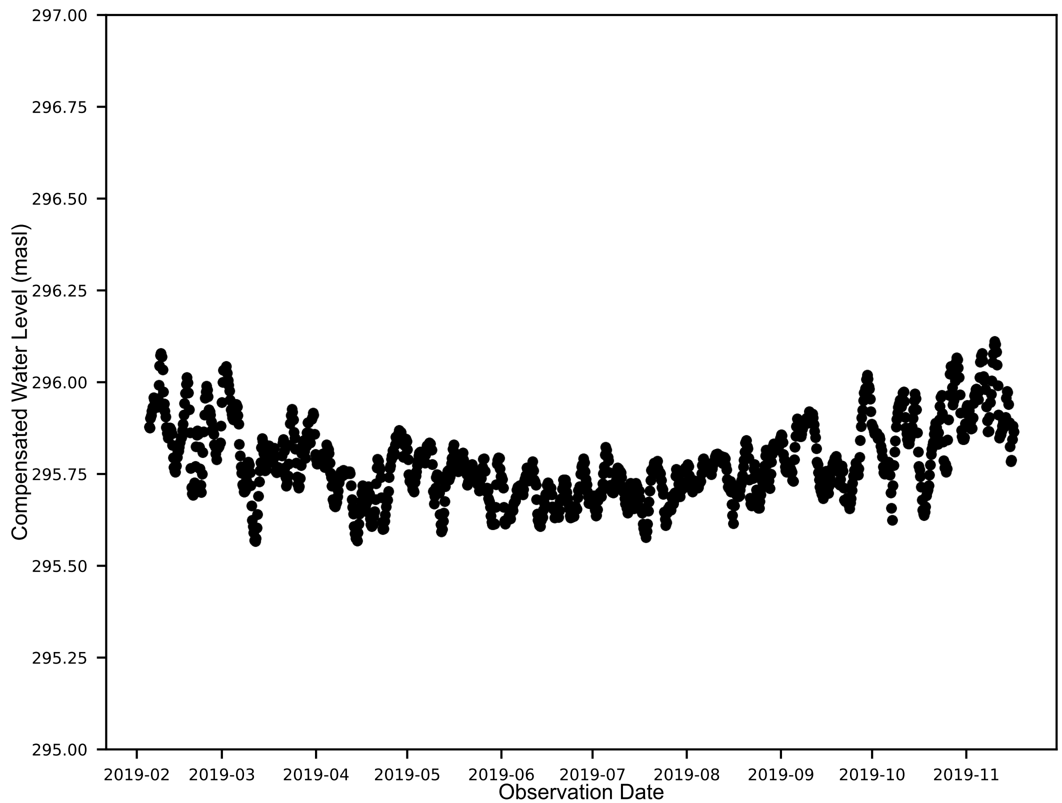
FORT HILLS
Operated by Suncor Energy

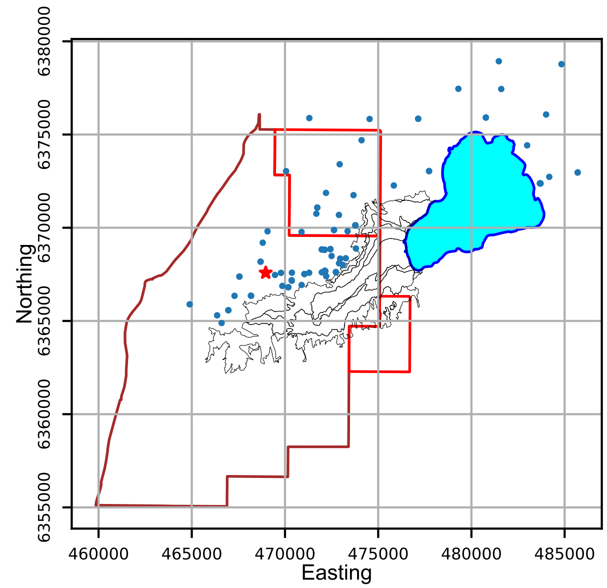
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL534-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-111

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

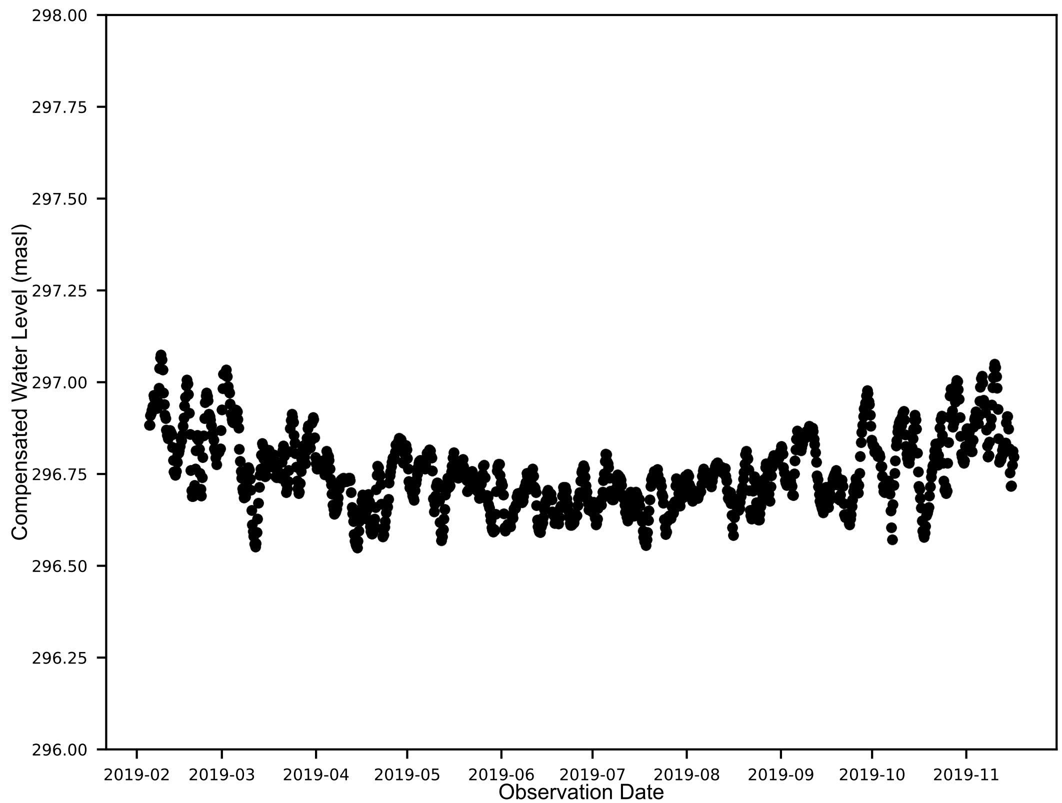
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

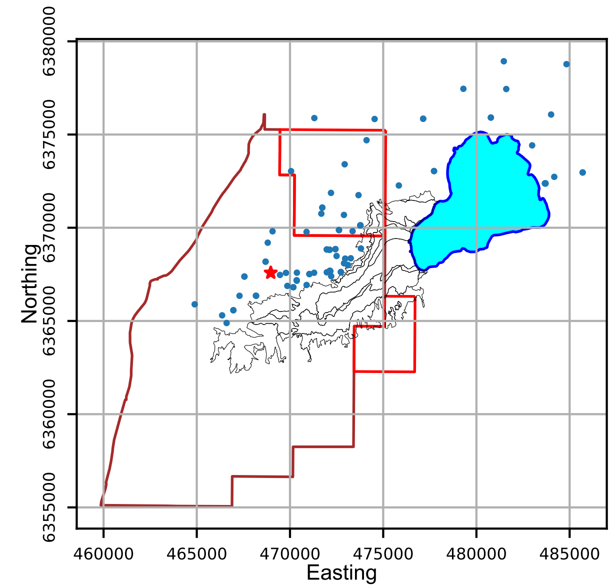
TITLE

FH19-GL547-SN1 - 10.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-112

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 16.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

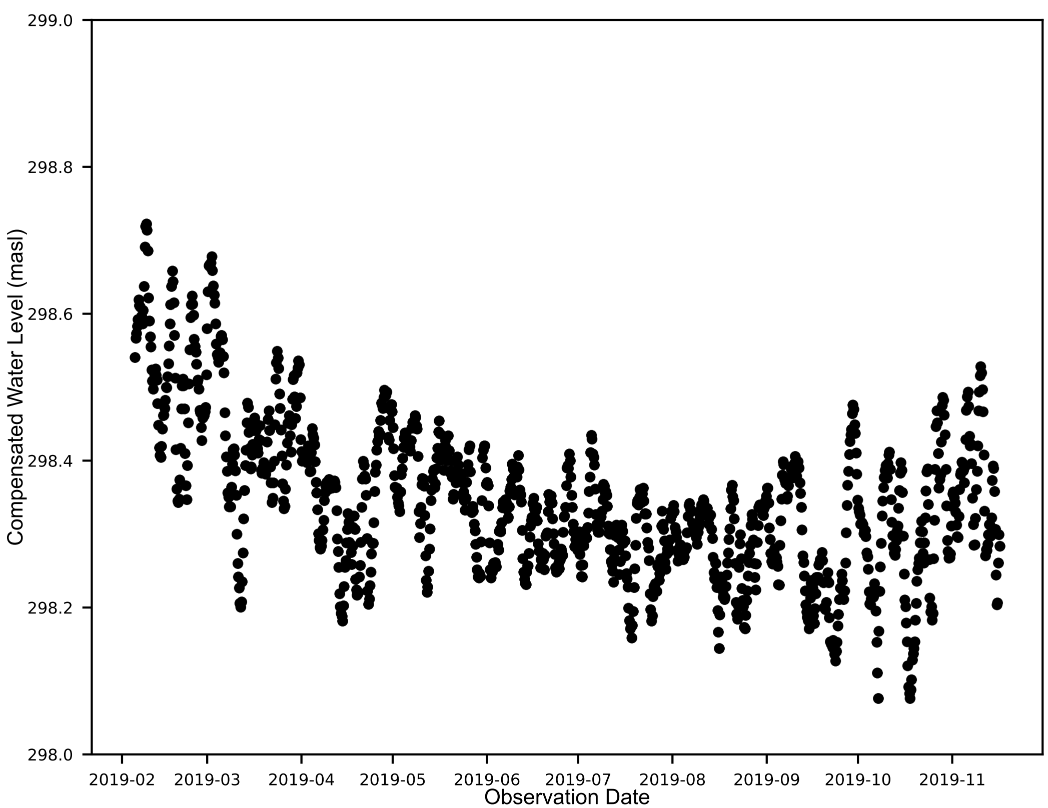
Operated by Suncor Energy

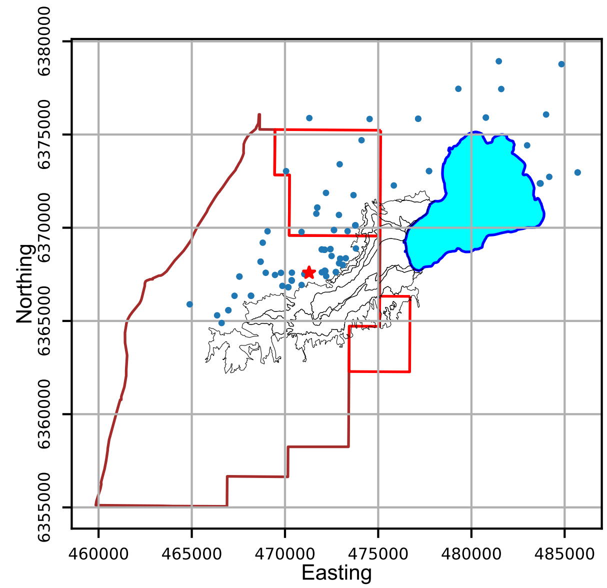
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-GL547-SN1 - 16.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-113





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 11.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL550-SN1 - 11.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-114

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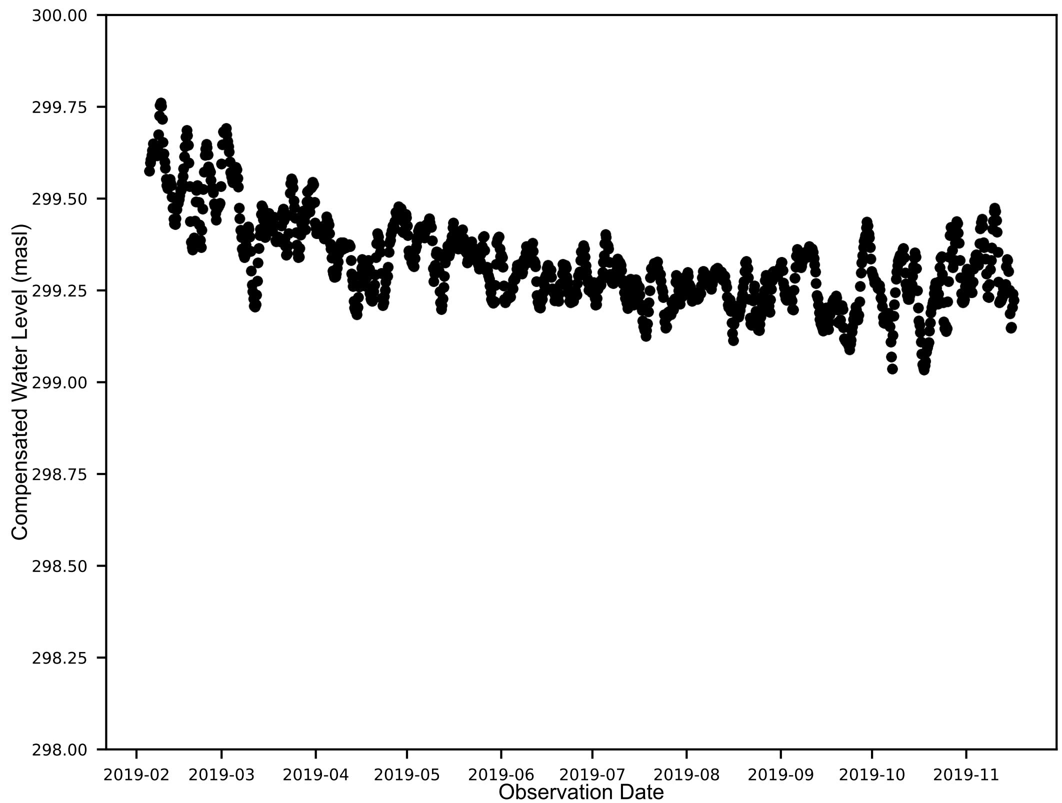
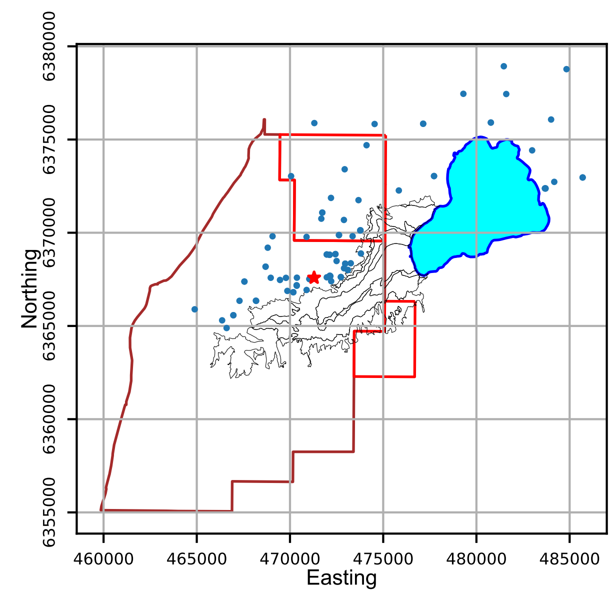




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 23.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

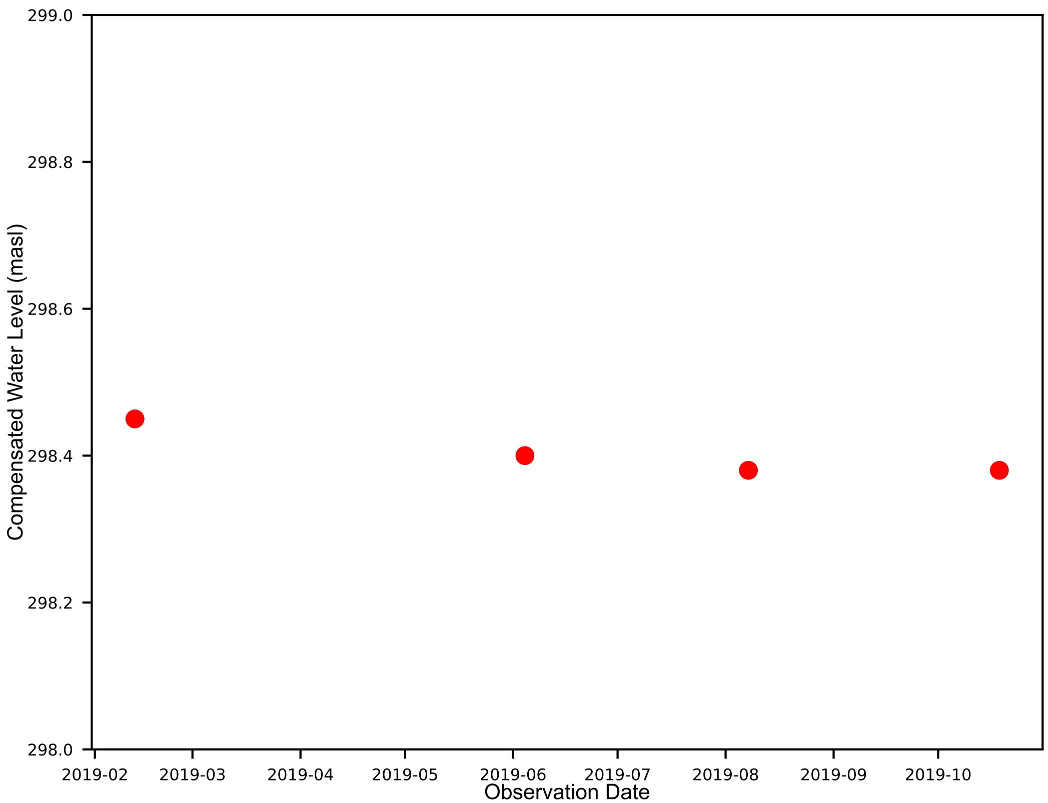
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

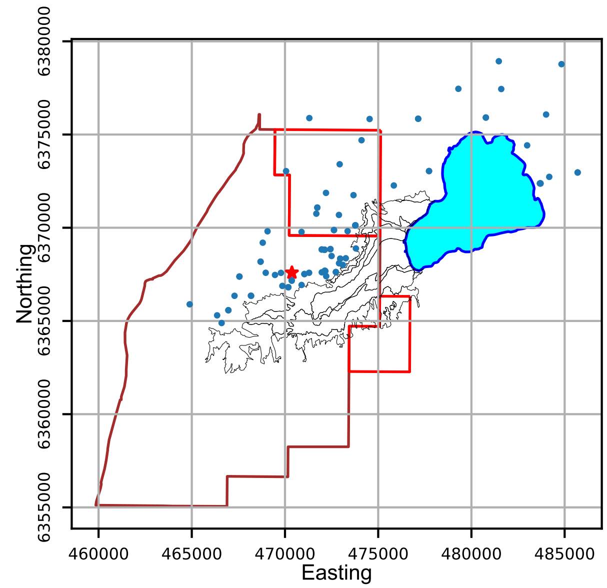
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH19-GL550-SN1 - 23.2 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-115





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 19.66 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

FH19-GL551-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-116

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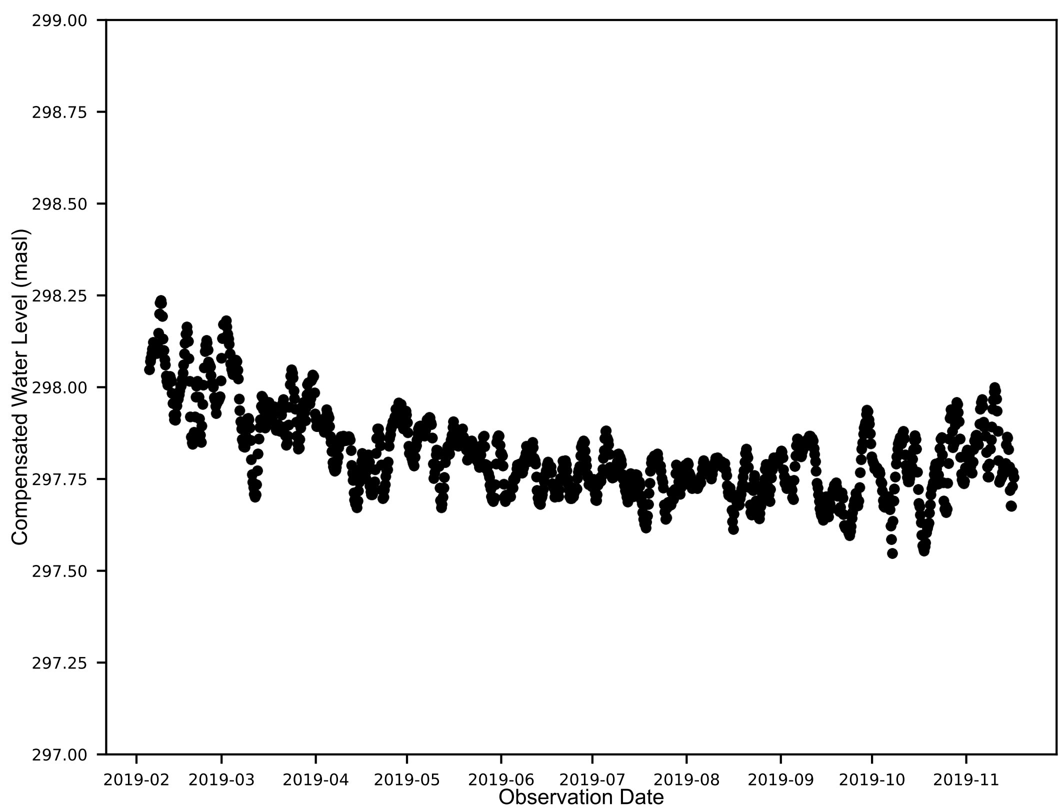

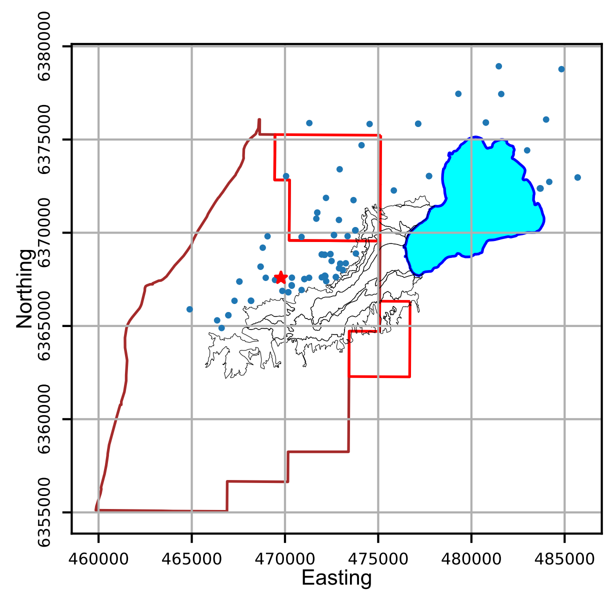

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 17.7 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE
FH19-GL553-SN1 - 17.7 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-117

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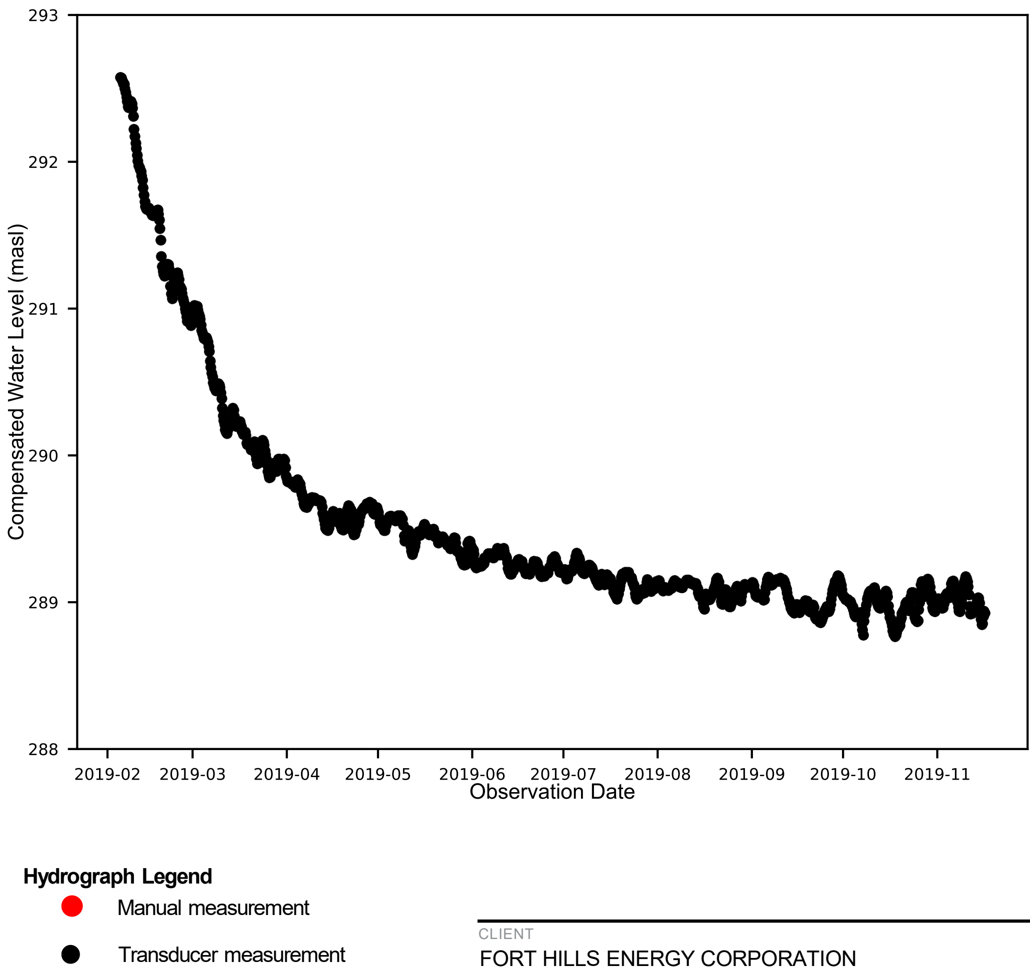

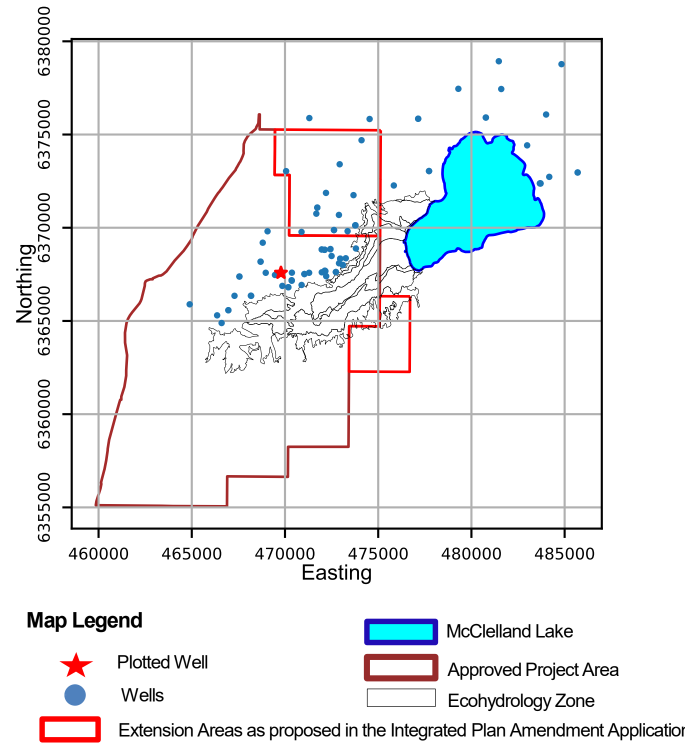

NOTES
Hydrostratigraphic Unit: 04 Clay Till
Depth of Measurement: 37.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

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PREPARED	RS
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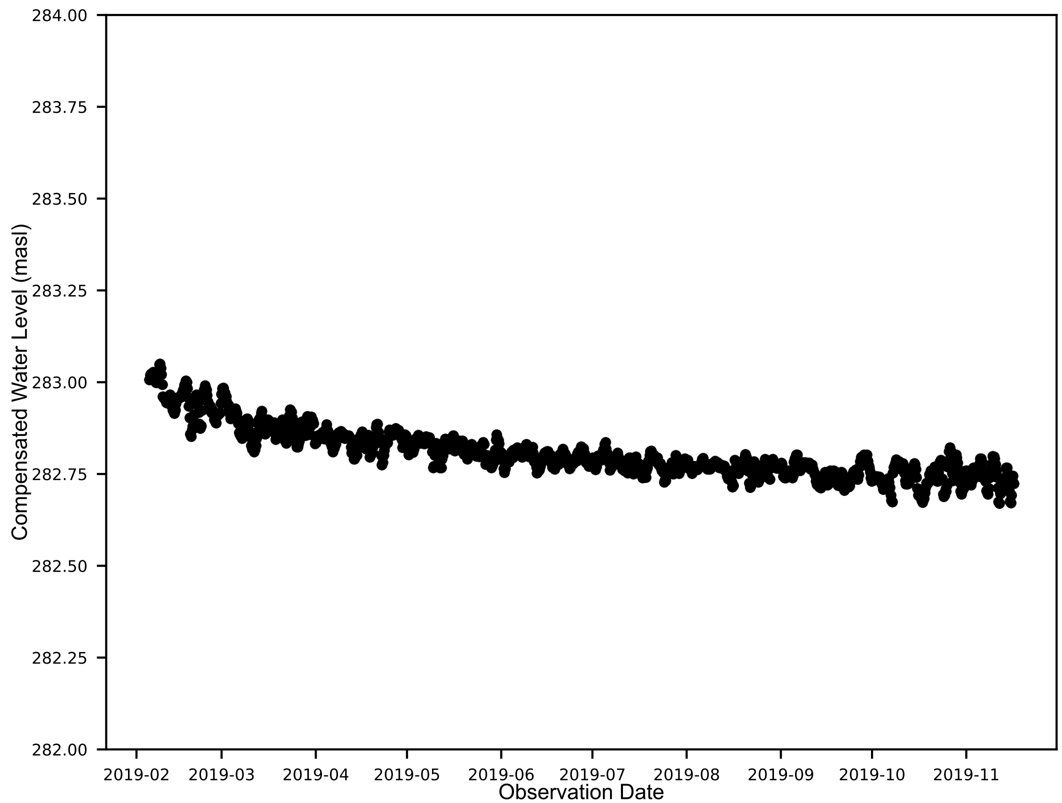
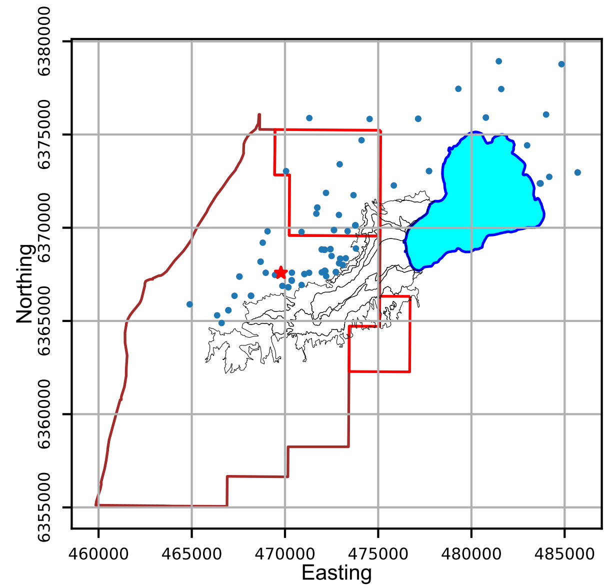
APPROVED	RM

TITLE
FH19-GL553-SN1 - 37.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-118





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 44.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

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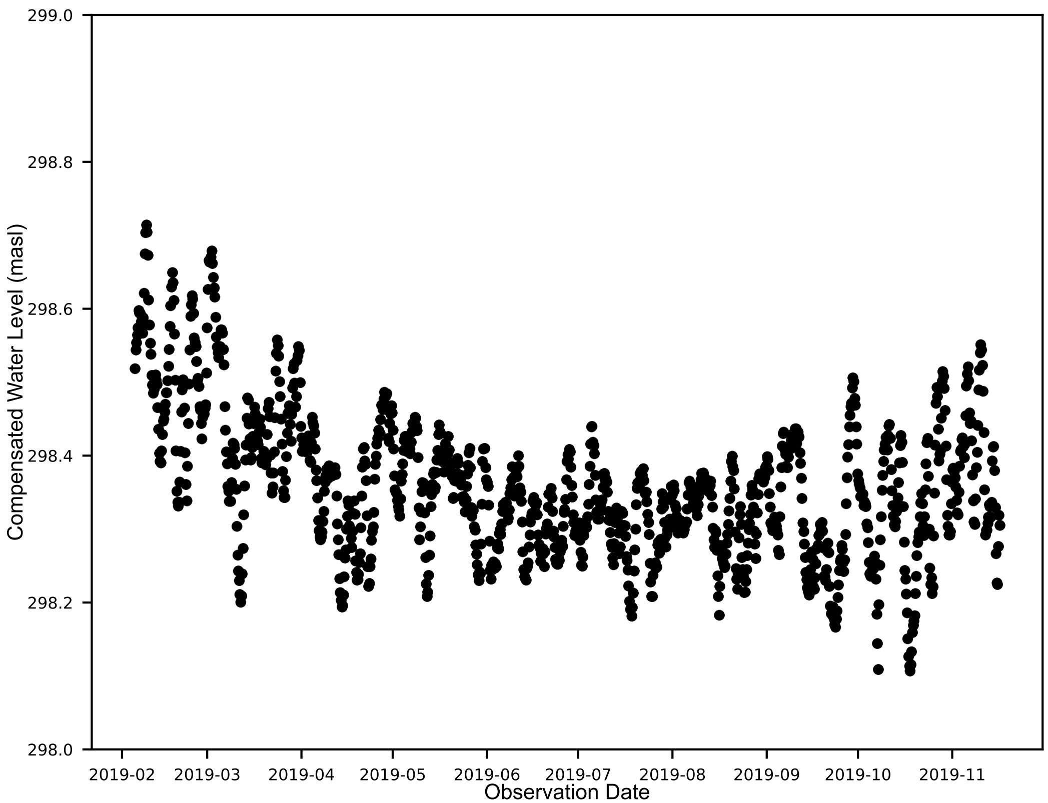
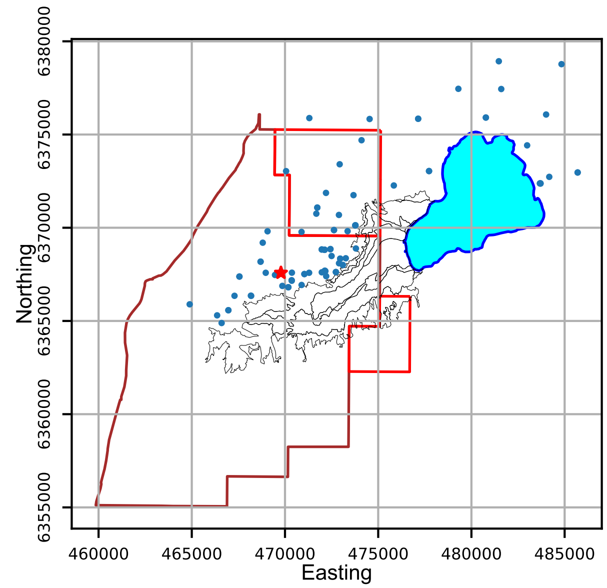
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL553-SN1 - 44.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-119

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 8.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS

Operated by Suncor Energy

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PREPARED	RS
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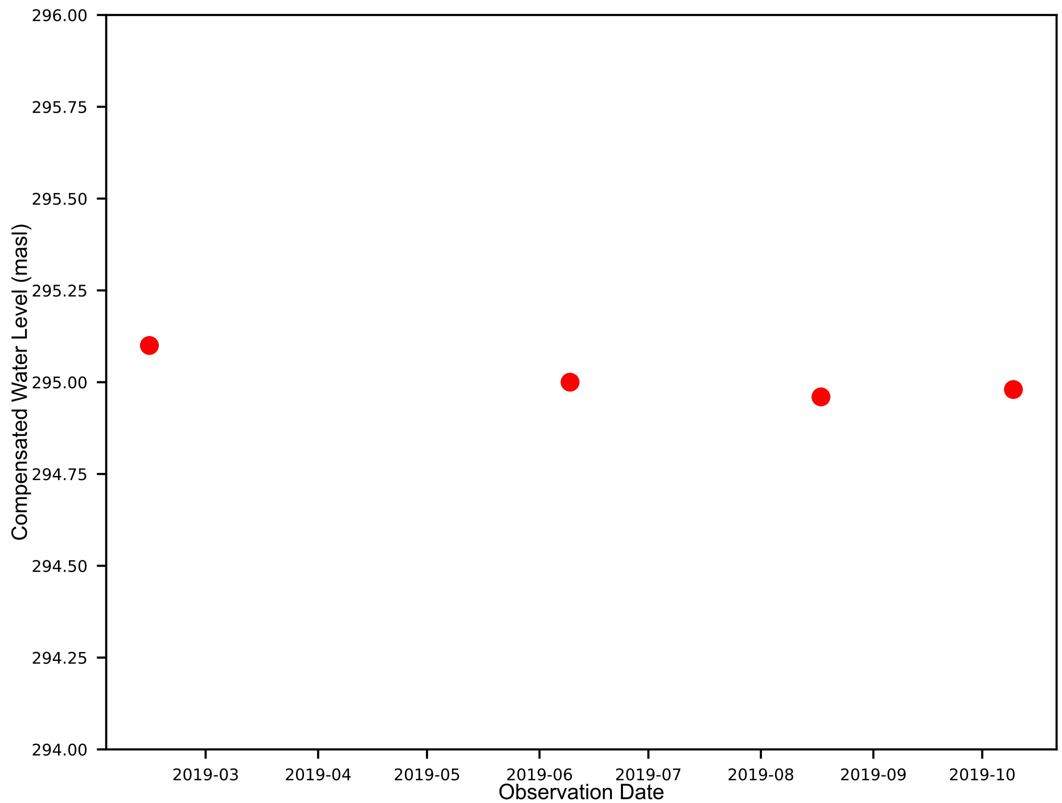
REVIEW	LW
APPROVED	RM

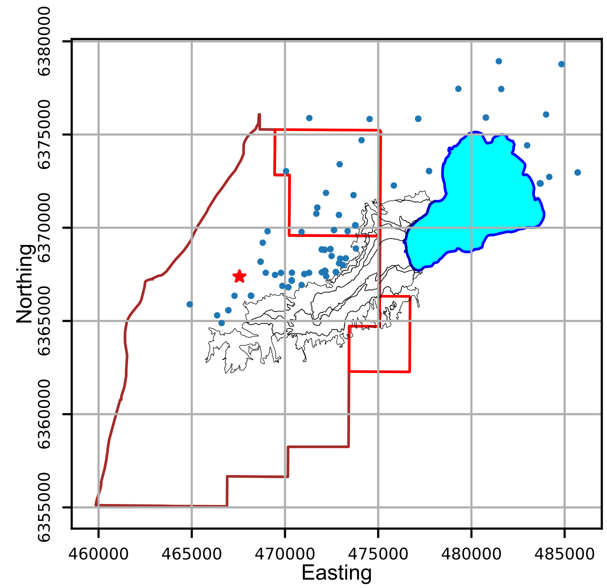
TITLE

FH19-GL553-SN1 - 8.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-120

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 16.26 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT	FORT HILLS ENERGY CORPORATION
PROJECT	MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM
TITLE	FH19-GL562-SN1

FORT HILLS
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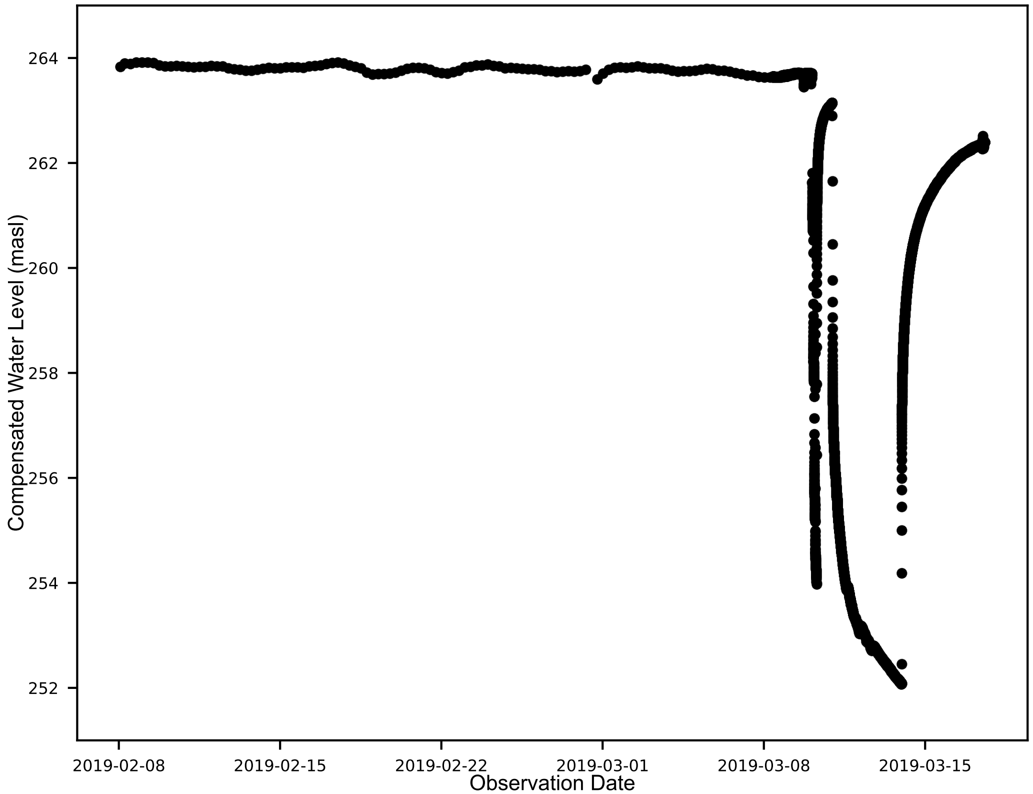
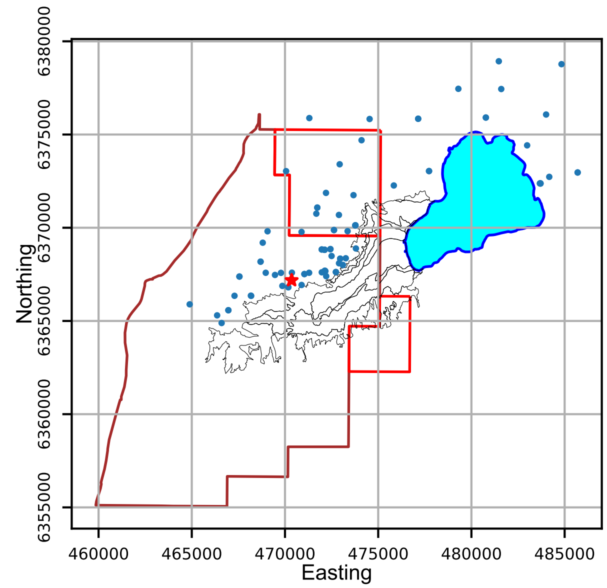
PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-121

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 106 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL565-MR1 - 106.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-122

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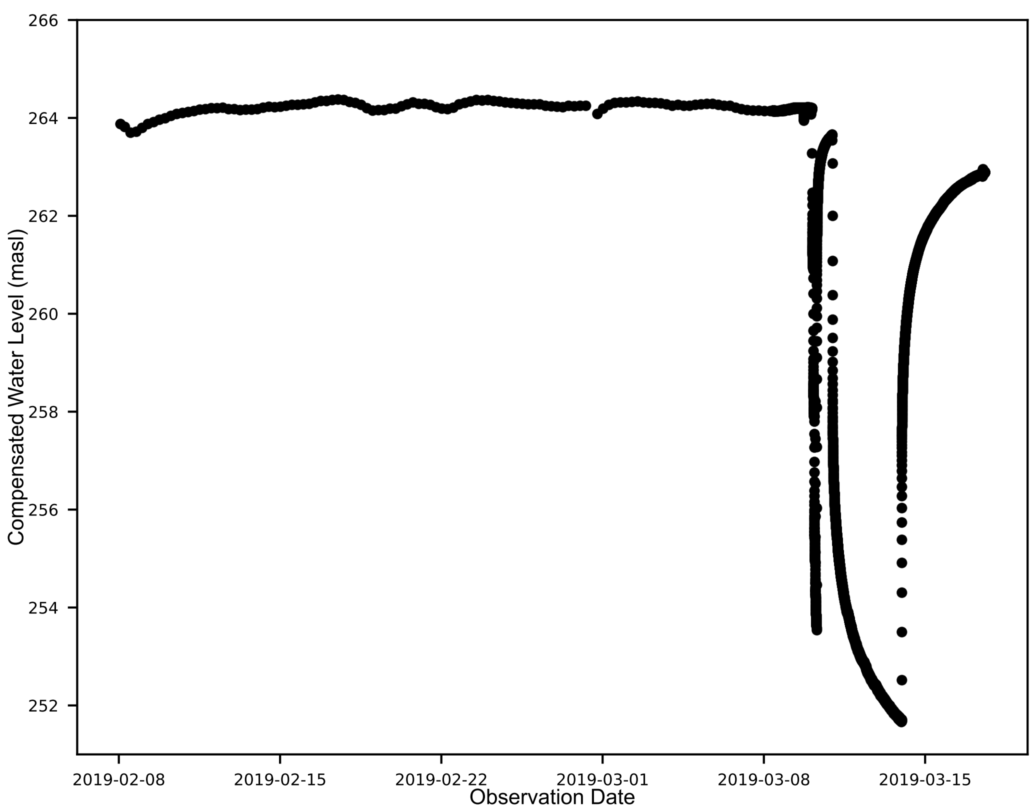

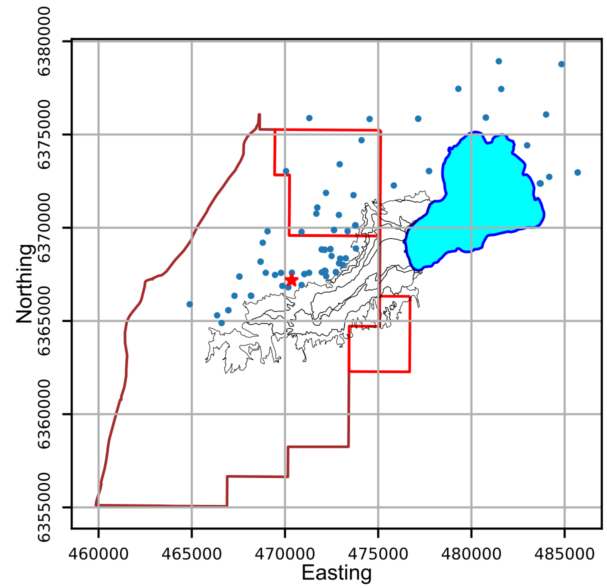

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 122 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
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DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

FH19-GL565-MR1 - 122.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-123

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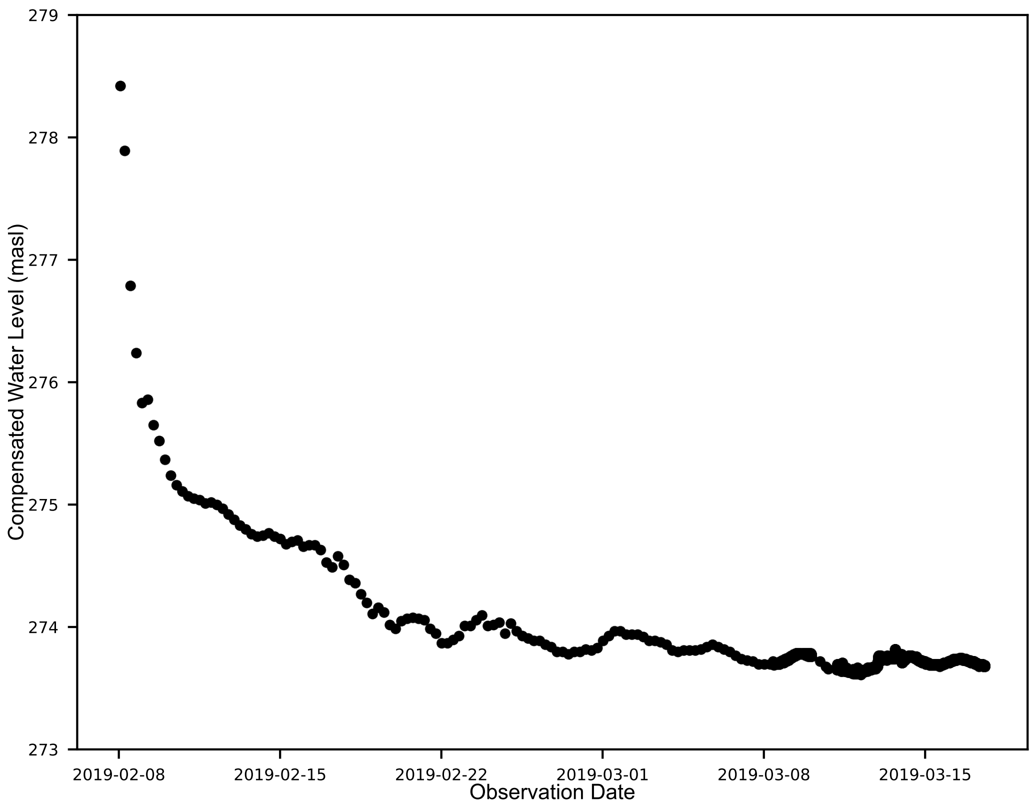

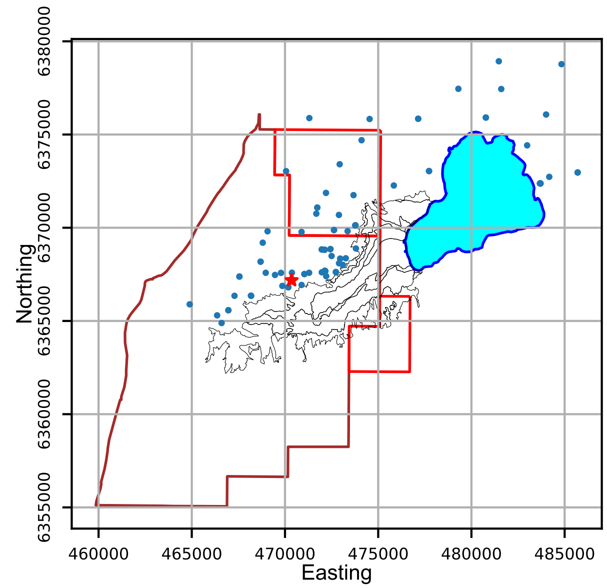

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 72 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL565-MR1 - 72.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-124

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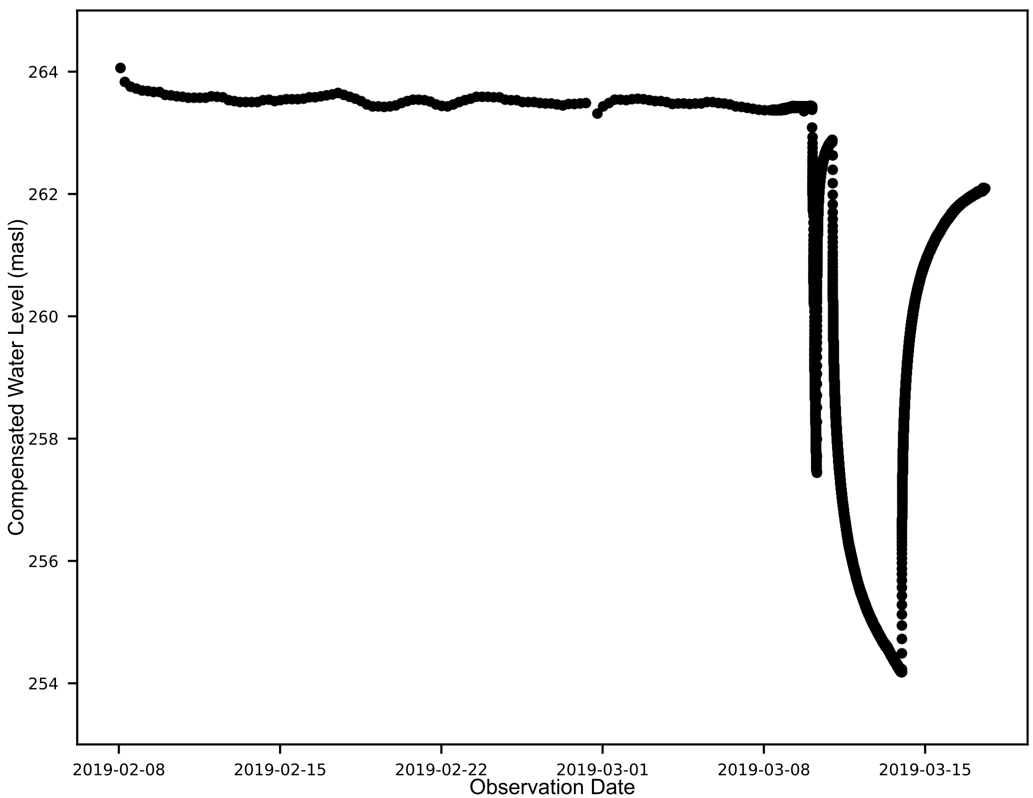

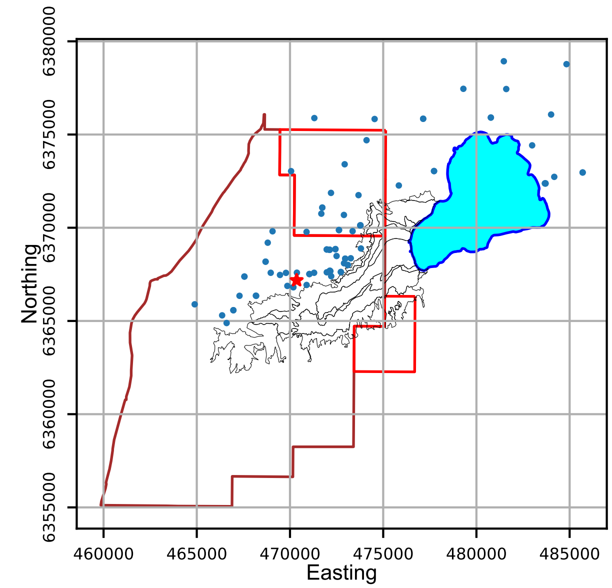

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 95 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH19-GL565-MR1 - 95.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-125

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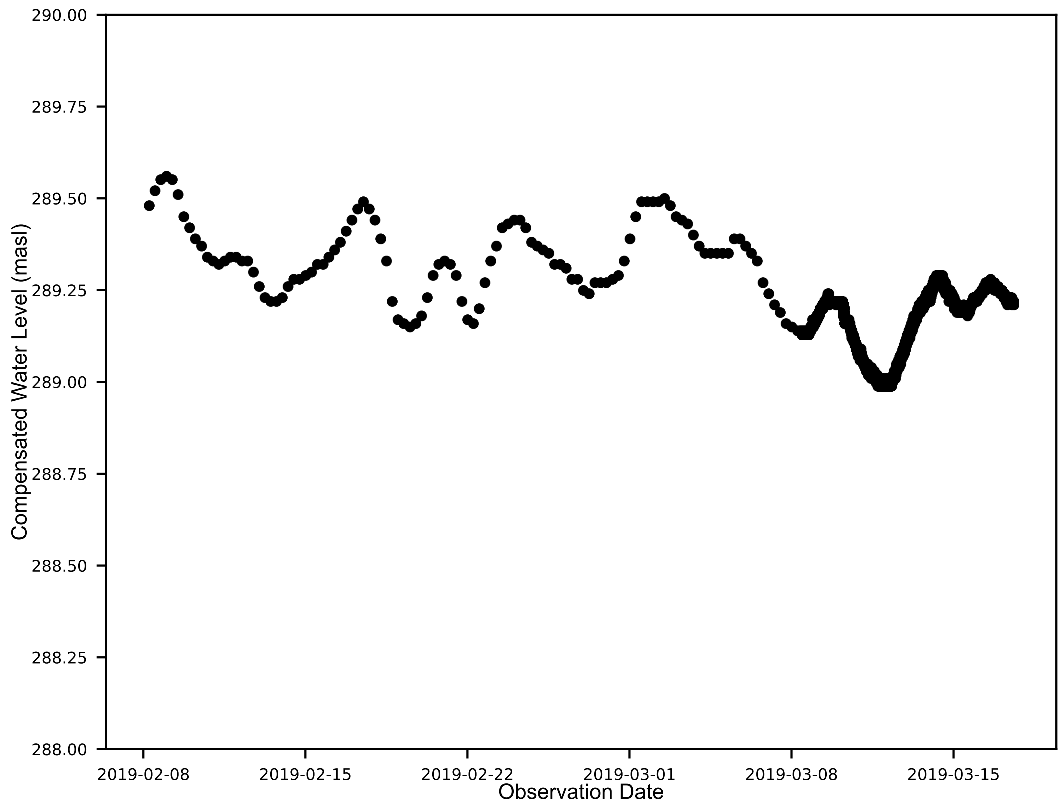

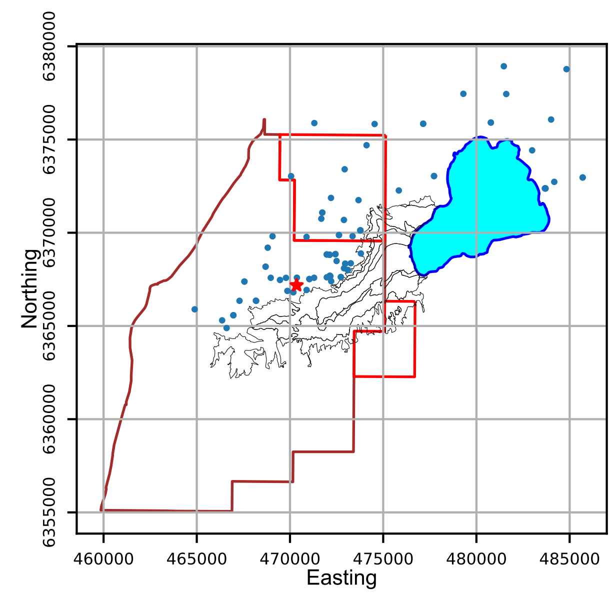

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Quaternary-Aquifer
Depth of Measurement: 27.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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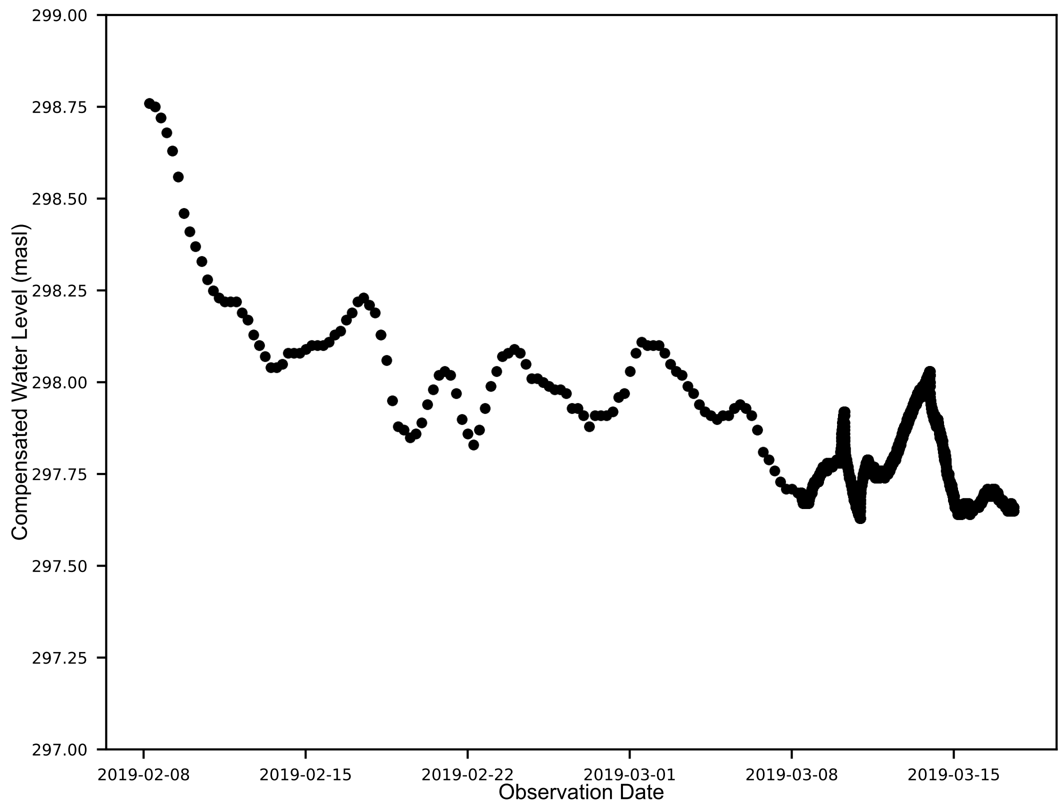
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

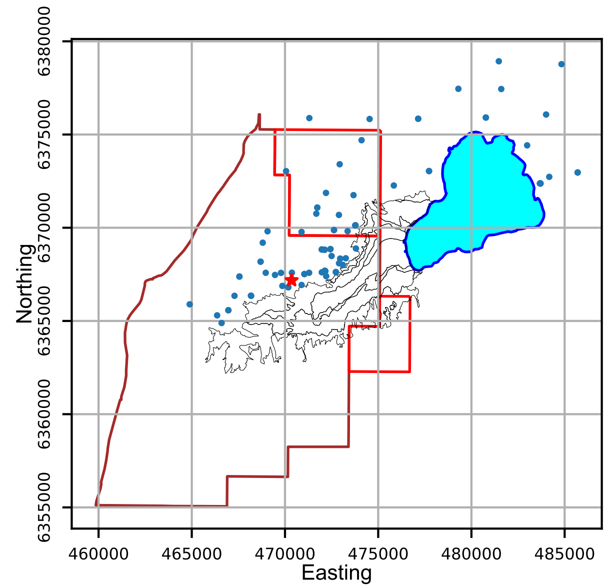
FORTHILLS
Operated by Suncor Energy

TITLE
FH19-GL565-SN1 - 27.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-126

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 36 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE
FH19-GL565-SN1 - 36.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-127

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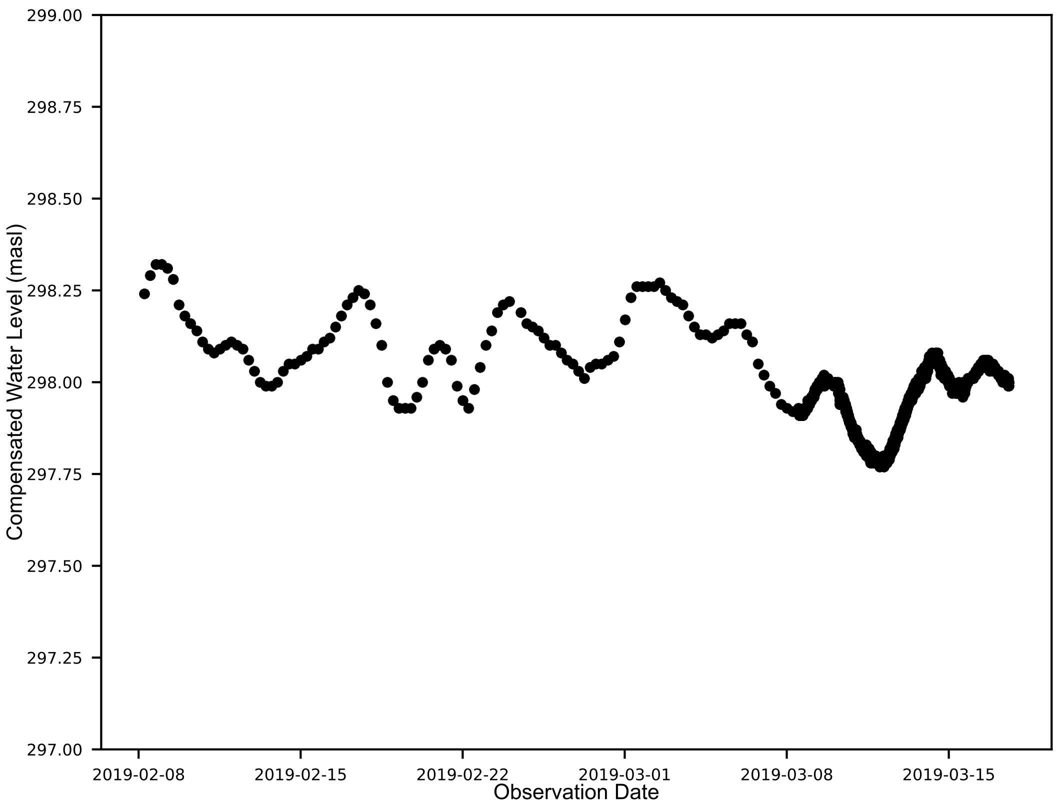

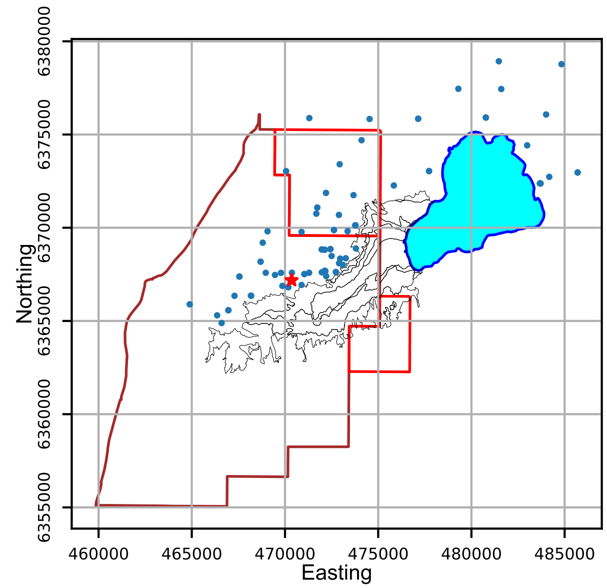

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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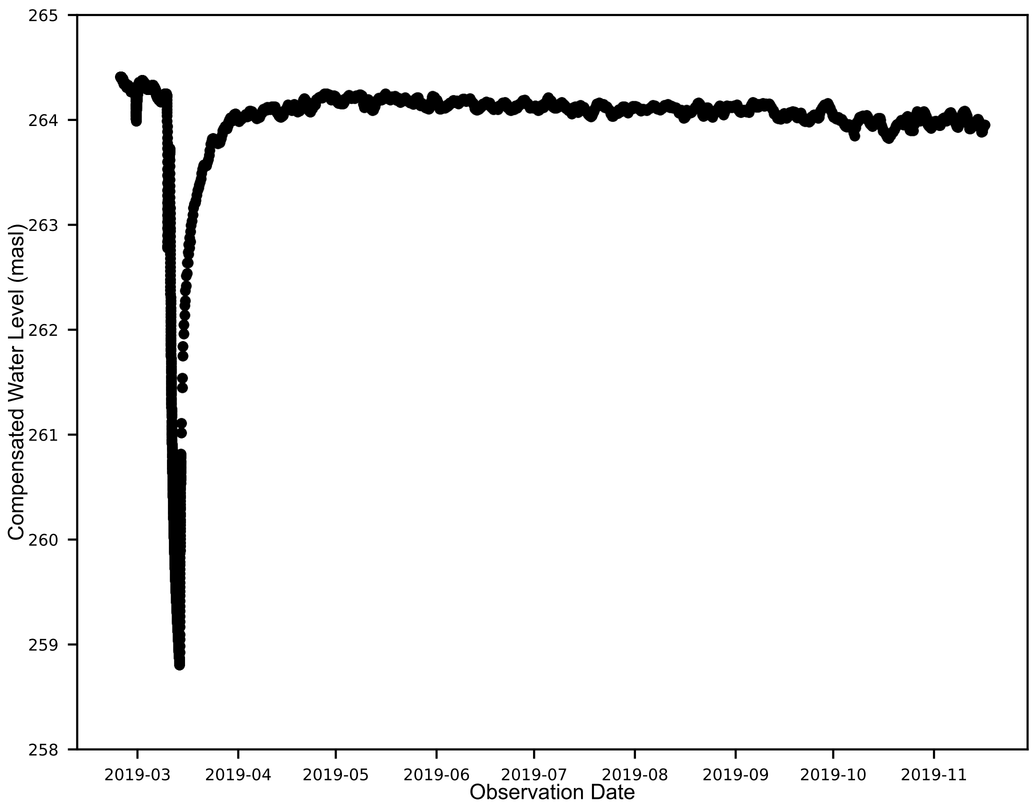
REVIEW	LW
APPROVED	RM

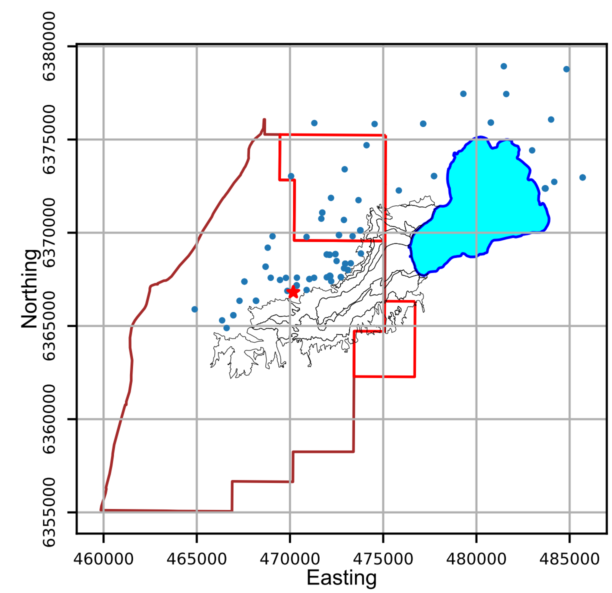
TITLE

FH19-GL565-SN1 - 8.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-128

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 111.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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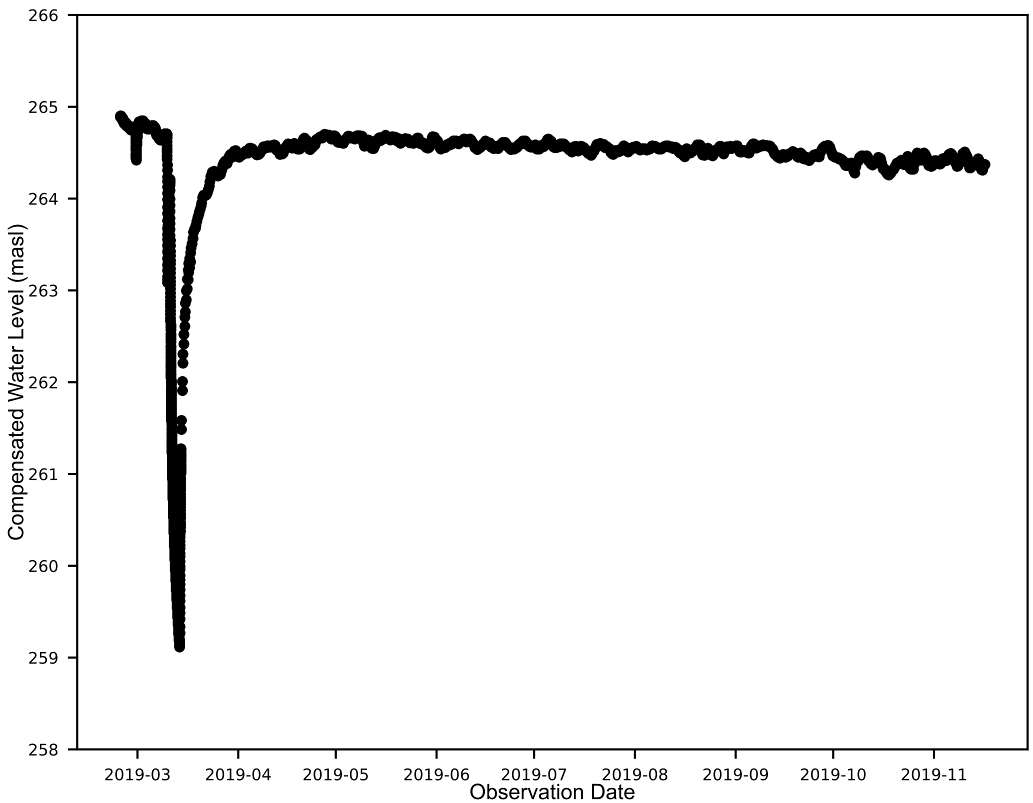
REVIEW	LW
APPROVED	RM

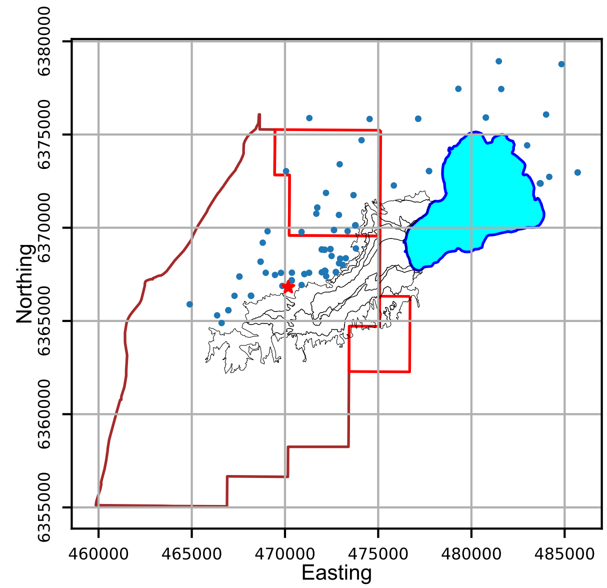
TITLE

FH19-GL570-MR1 - 111.1 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-129

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 123.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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REVIEW	LW
APPROVED	RM

TITLE

FH19-GL570-MR1 - 123.8 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-130

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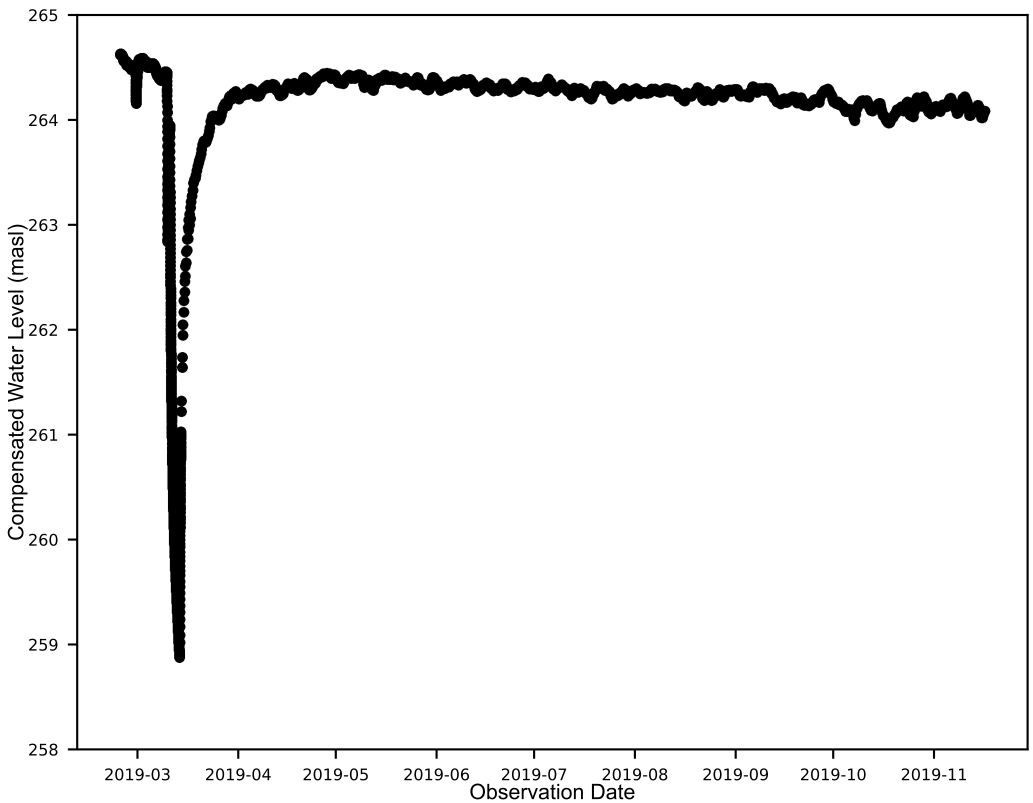
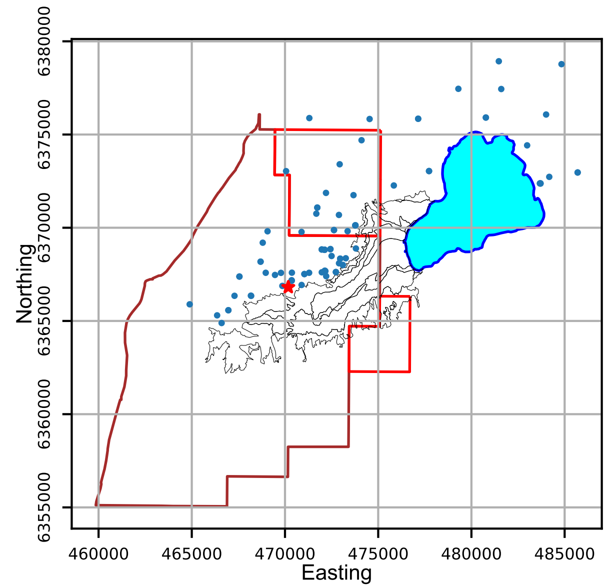




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 135 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

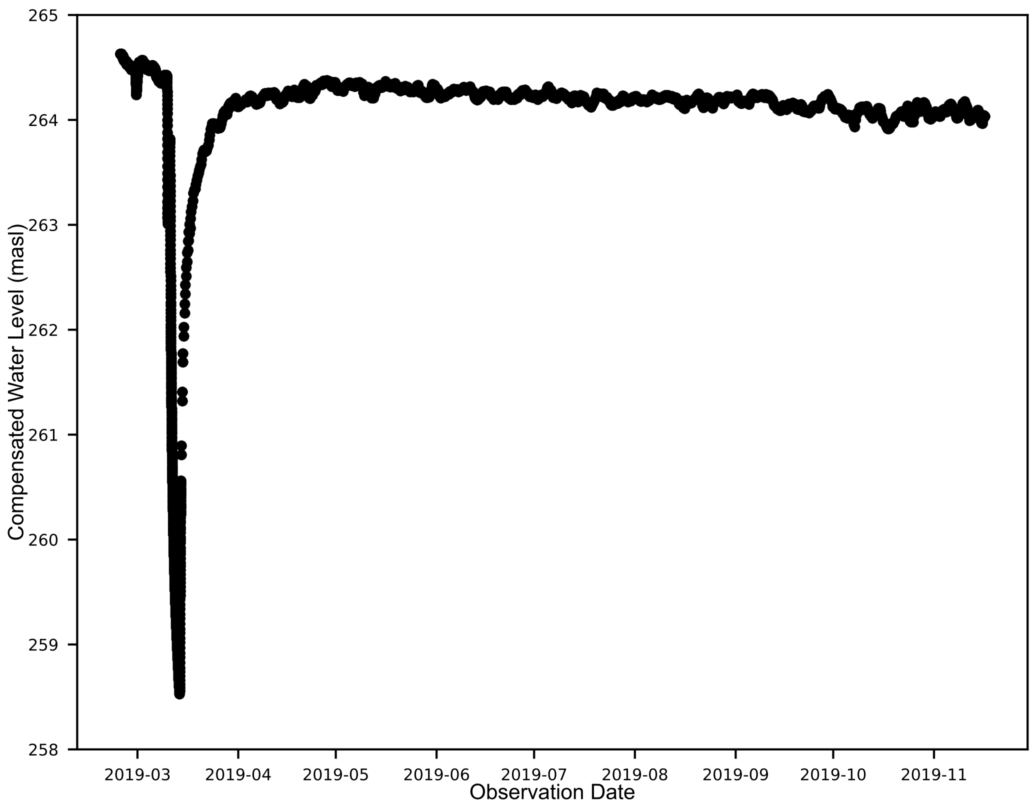
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

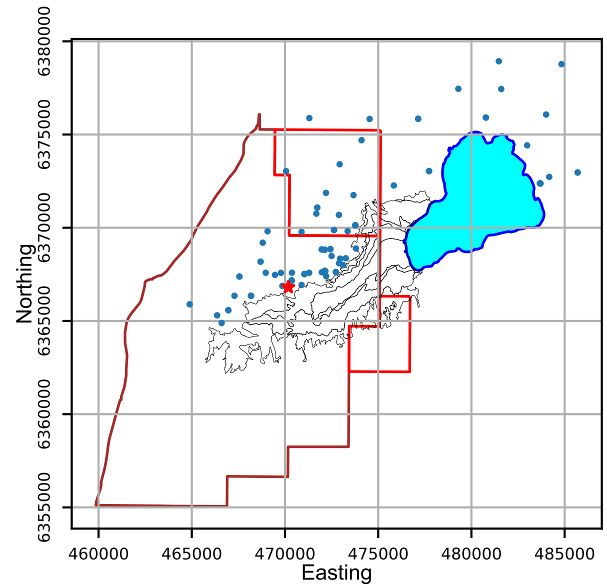
FORTHILLS
Operated by Suncor Energy

TITLE
FH19-GL570-MR1 - 135.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-131

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 90 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

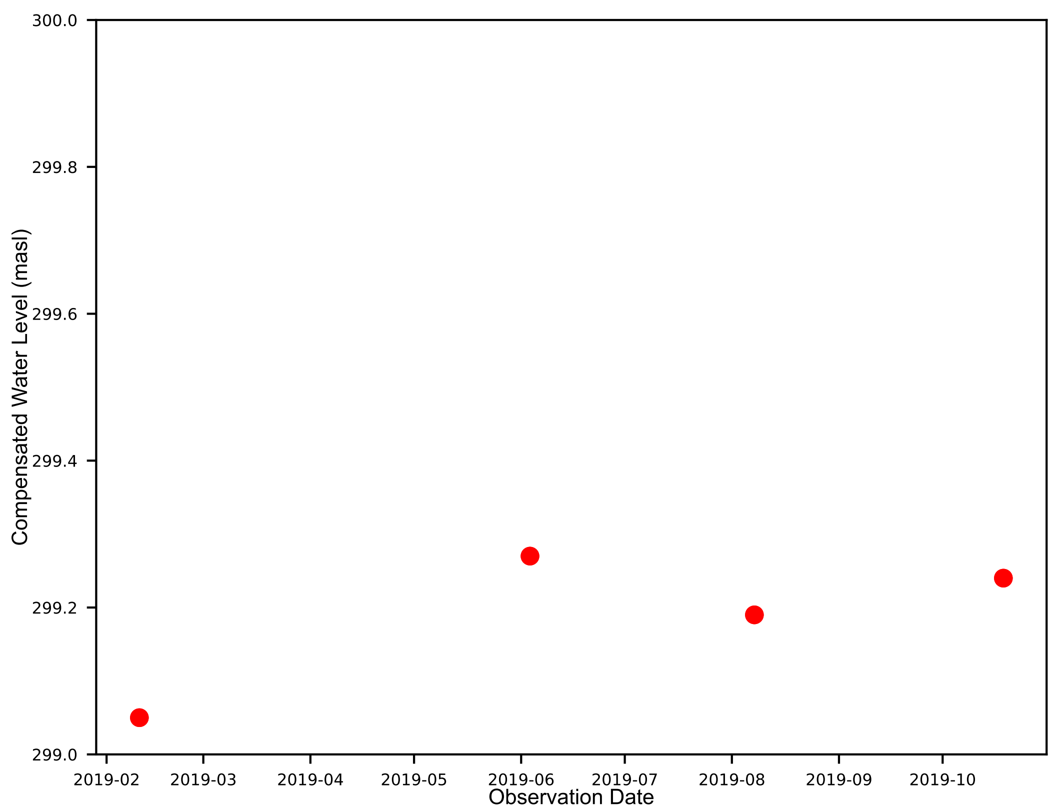
FORTHILLS
Operated by Suncor Energy

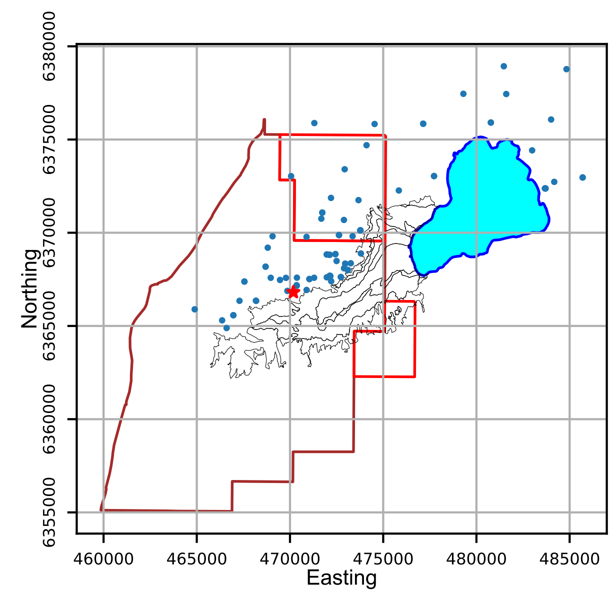
TITLE

FH19-GL570-MR1 - 89.9 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-132

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15.99 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

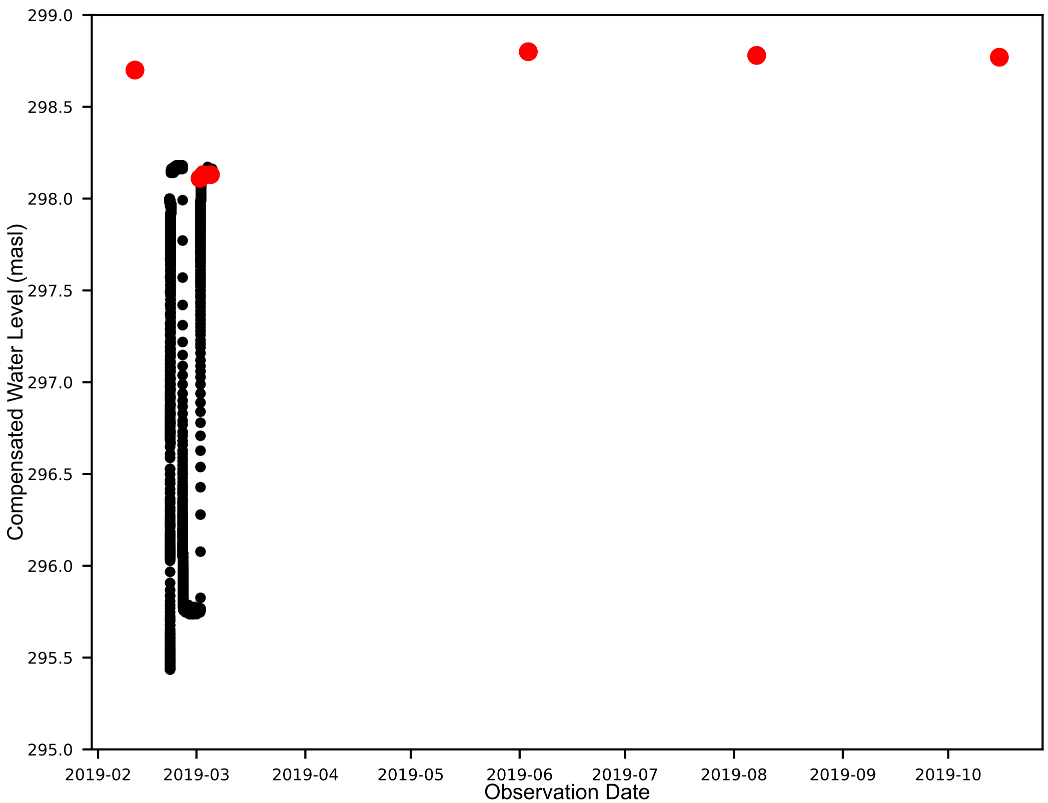
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

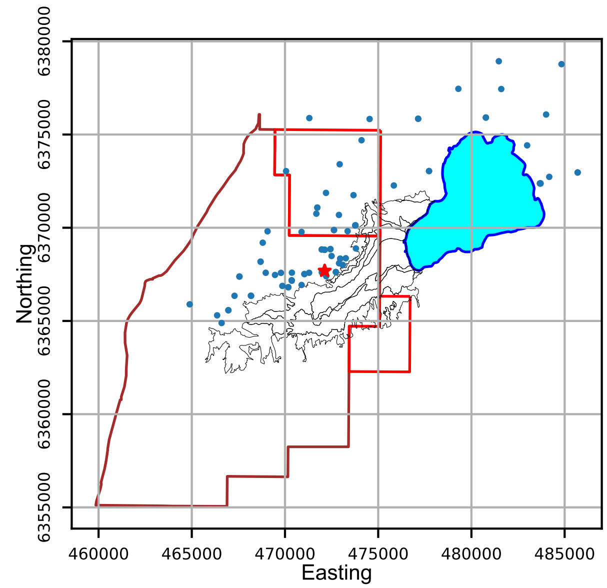
TITLE

FH19-GL570-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-133

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 22.77 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

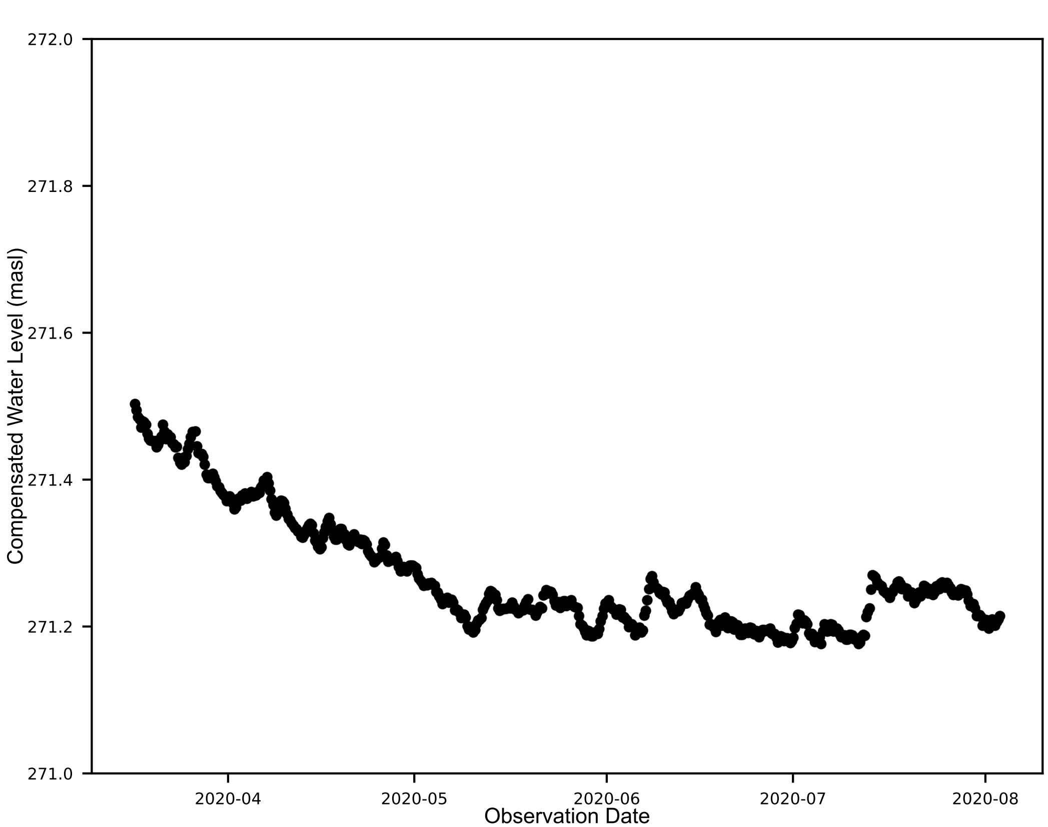
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
Operated by Suncor Energy

TITLE

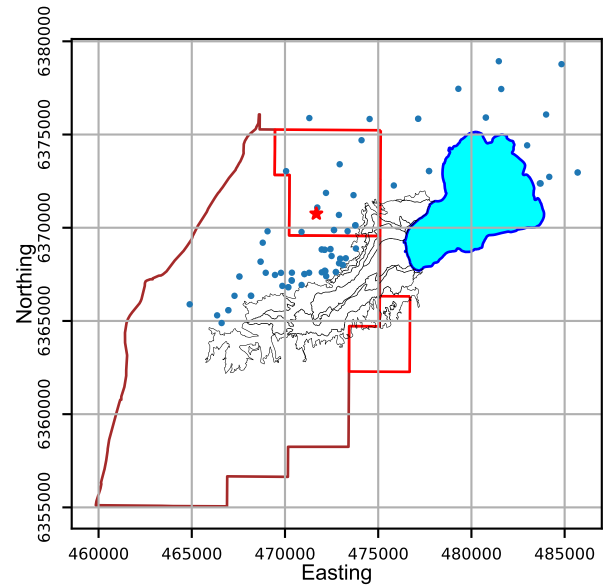
FH19-GL612-SN1

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-134



Hydrograph Legend

- Manual measurement
- Transducer measurement



Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 119 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

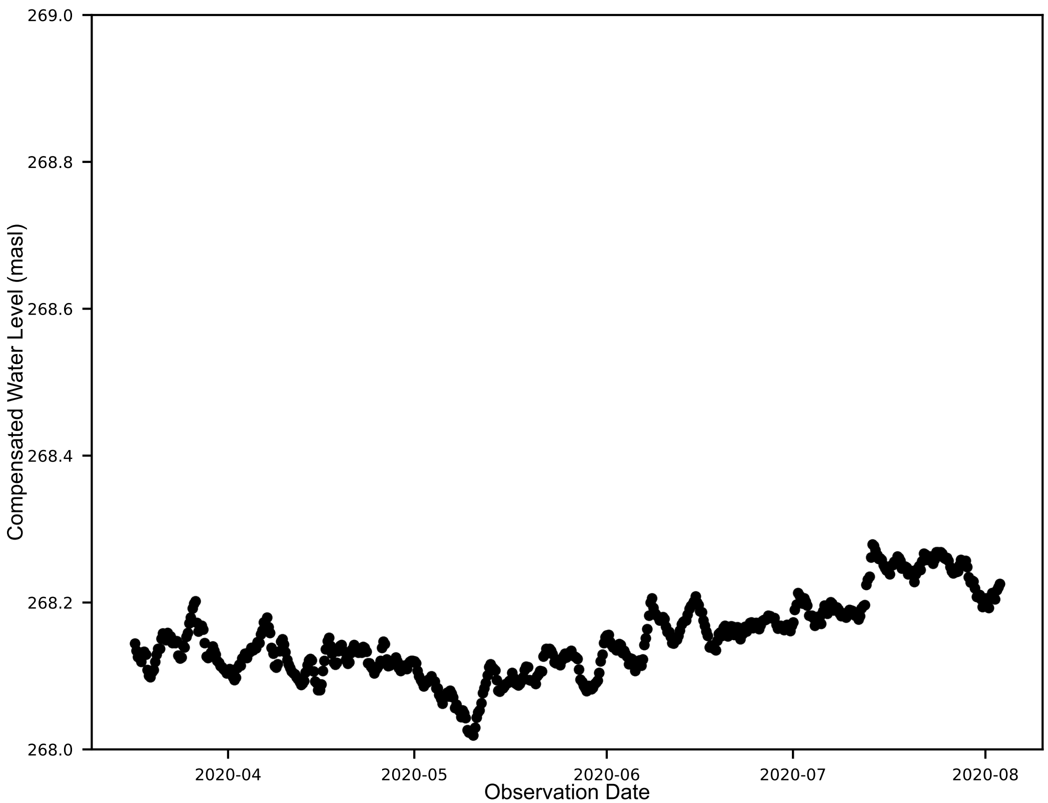
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

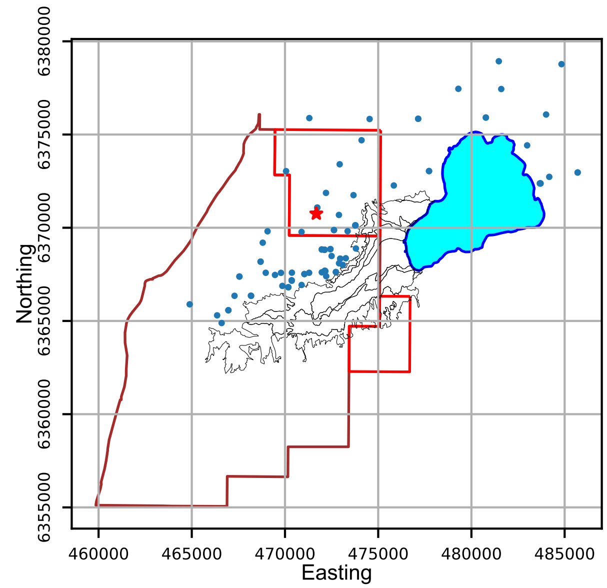
TITLE

FH20-WR620-MR1 - 119.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-135

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Beaver Hill
Depth of Measurement: 135 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

FH20-WR620-MR1 - 135.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-136

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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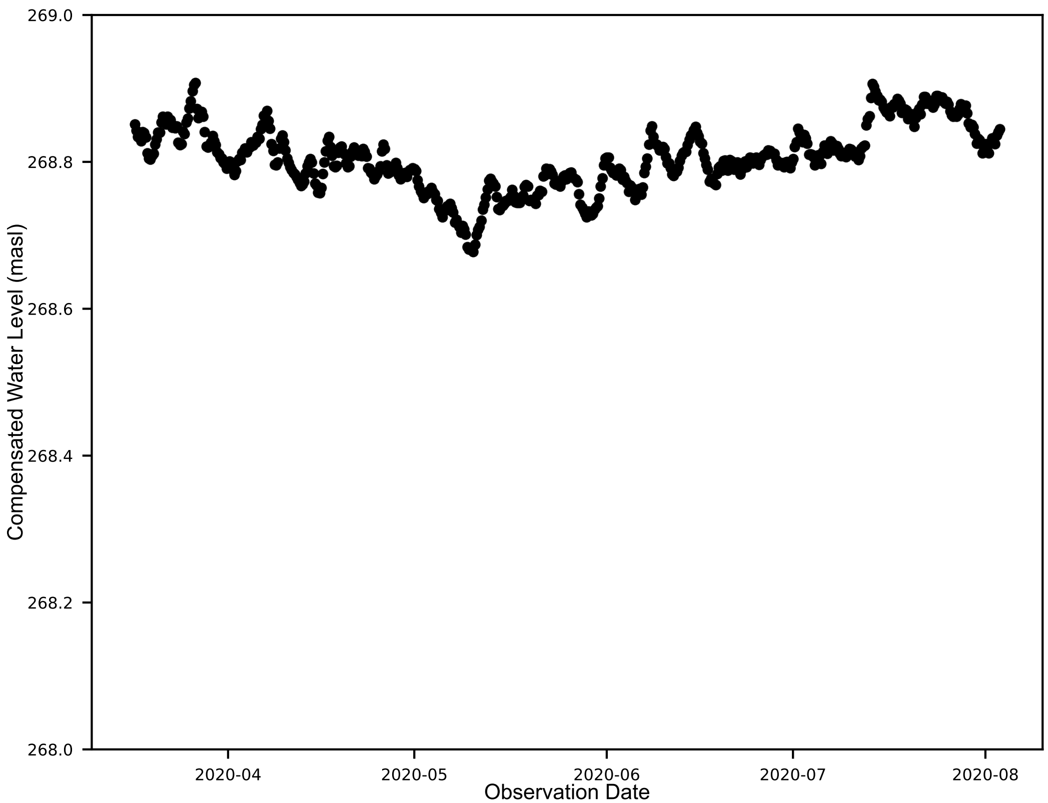
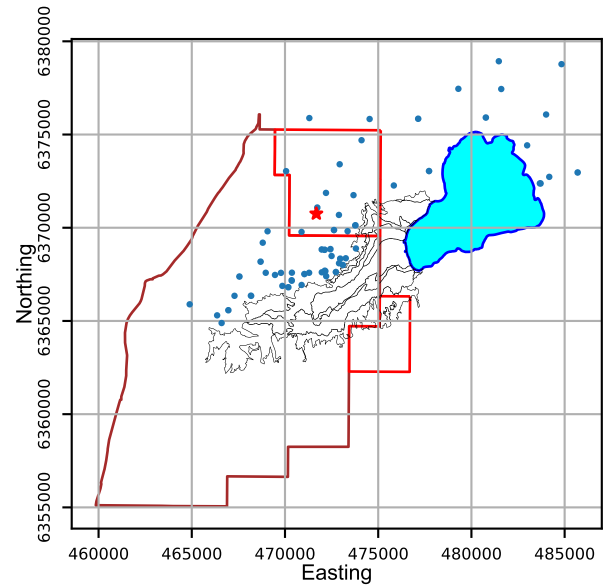




Map Legend

- Plotted Well
- Wells
- Extension Areas as proposed in the Integrated Plan Amendment Application
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 92 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

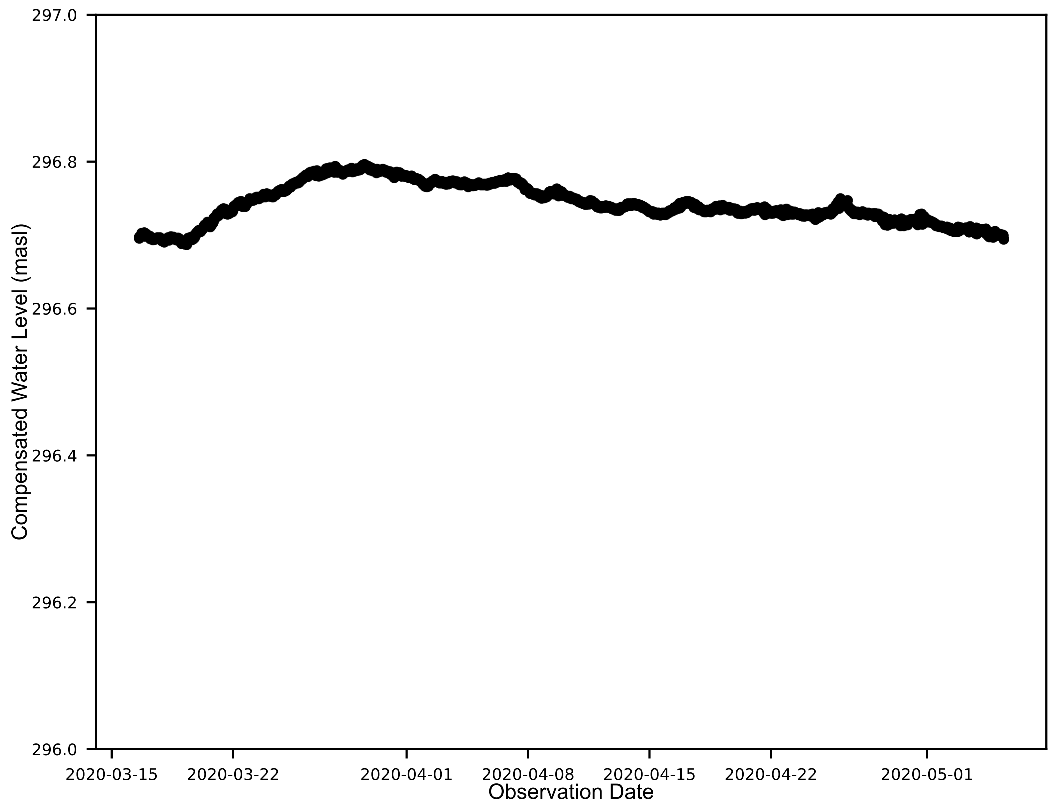
FORT HILLS
Operated by Suncor Energy

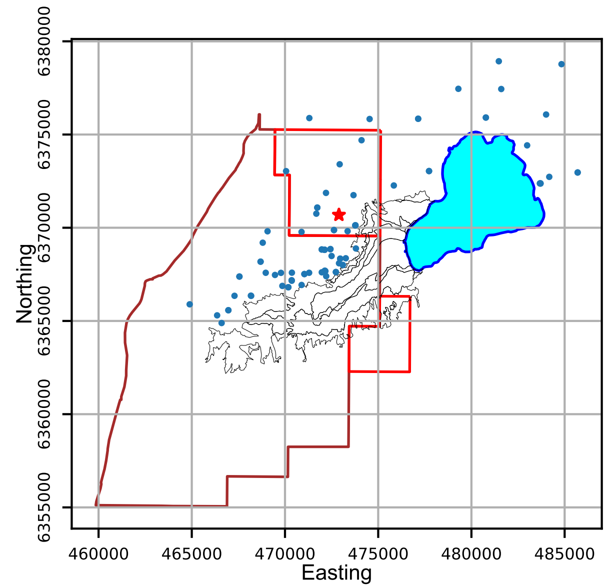
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH20-WR620-MR1 - 92.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-137

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 11 mbgs

masl = metres above sea level, mbgs = metres below ground surface

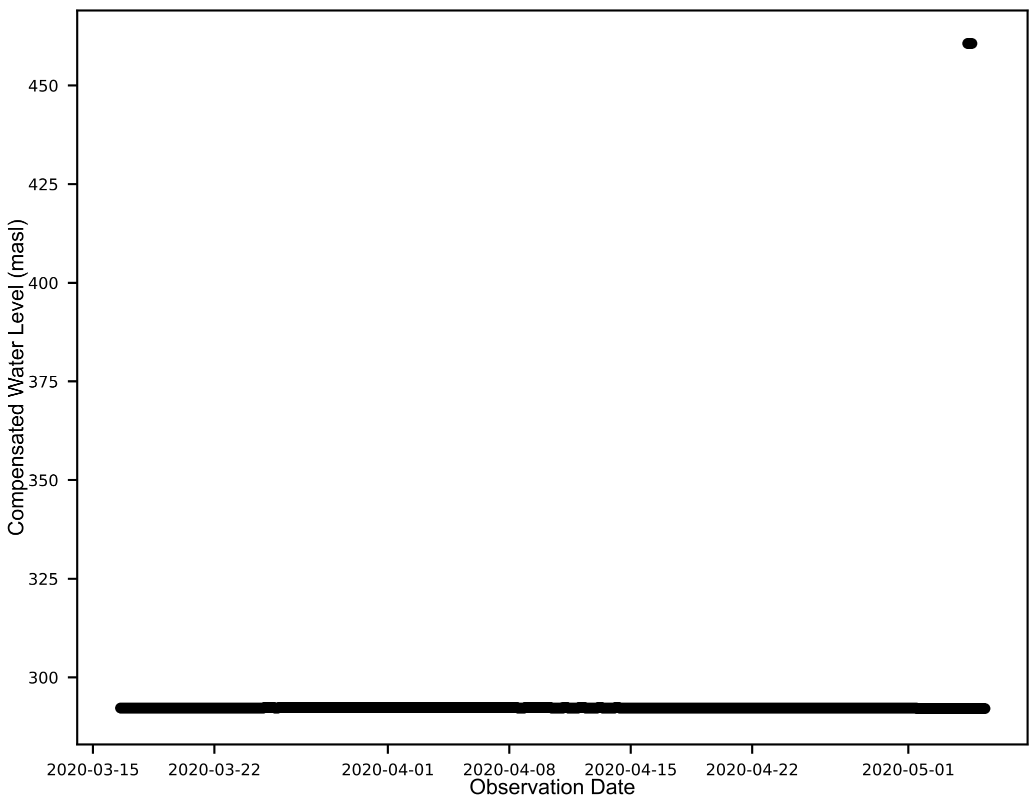
CLIENT
FORT HILLS ENERGY CORPORATION

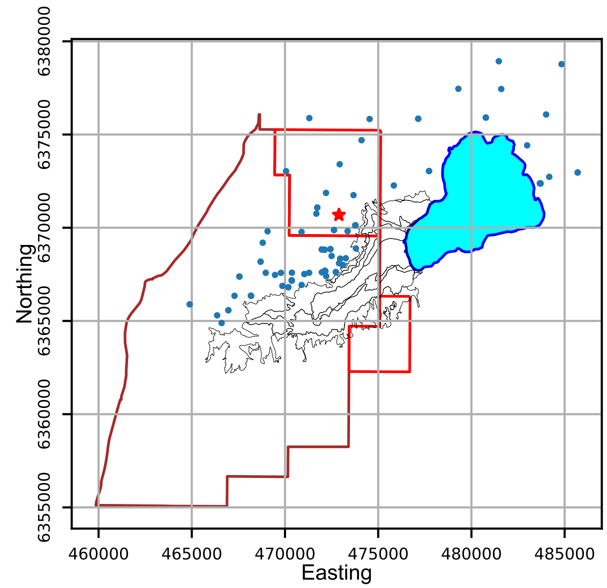
PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
FH20-WR623-SN1 - 11.0 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-138





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Rafted McMurray
Depth of Measurement: 52.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

FH20-WR623-SN1 - 52.5 M BELOW GROUND SURFACE

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-139

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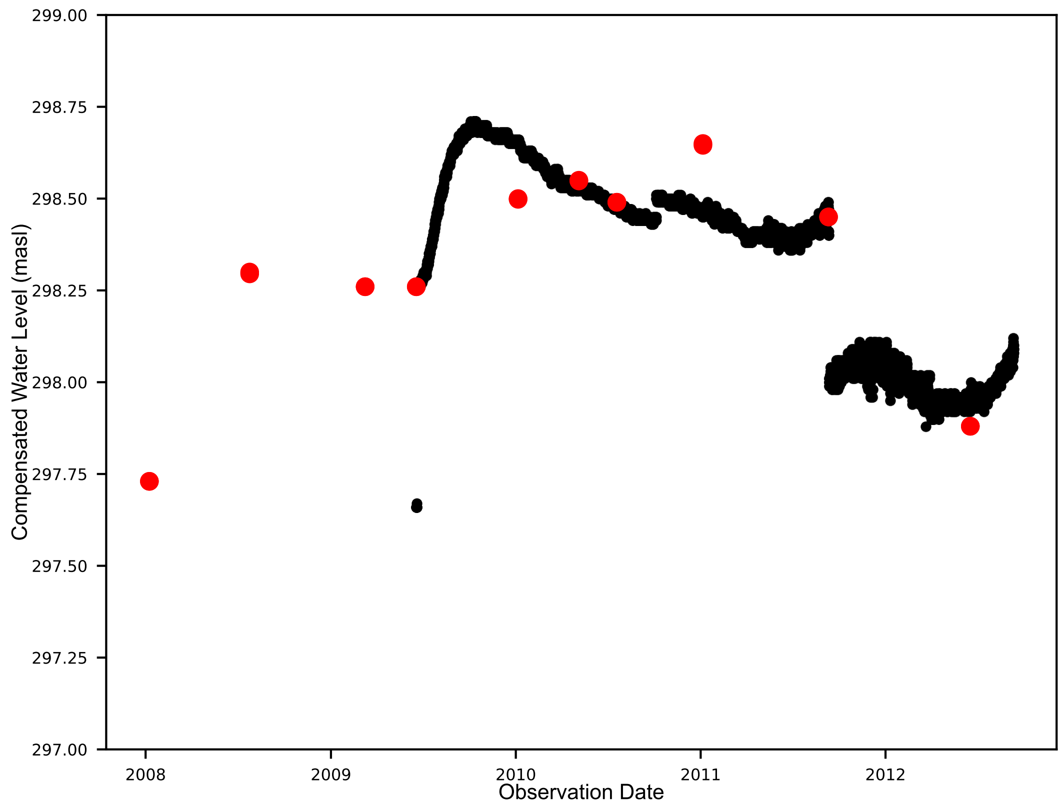

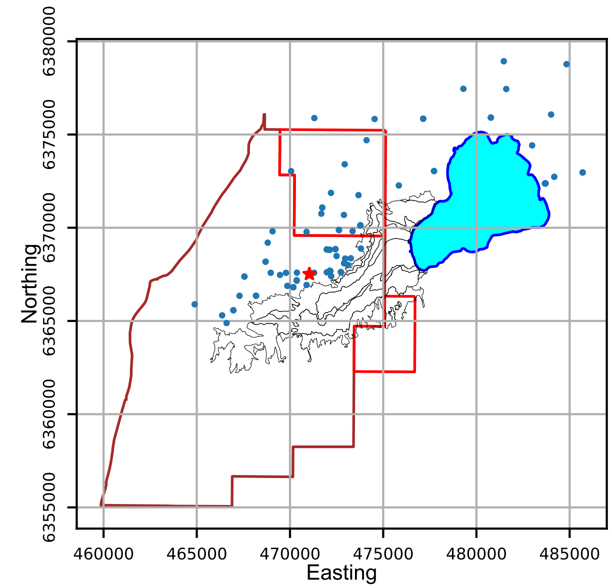

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 24.39 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-094A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-140

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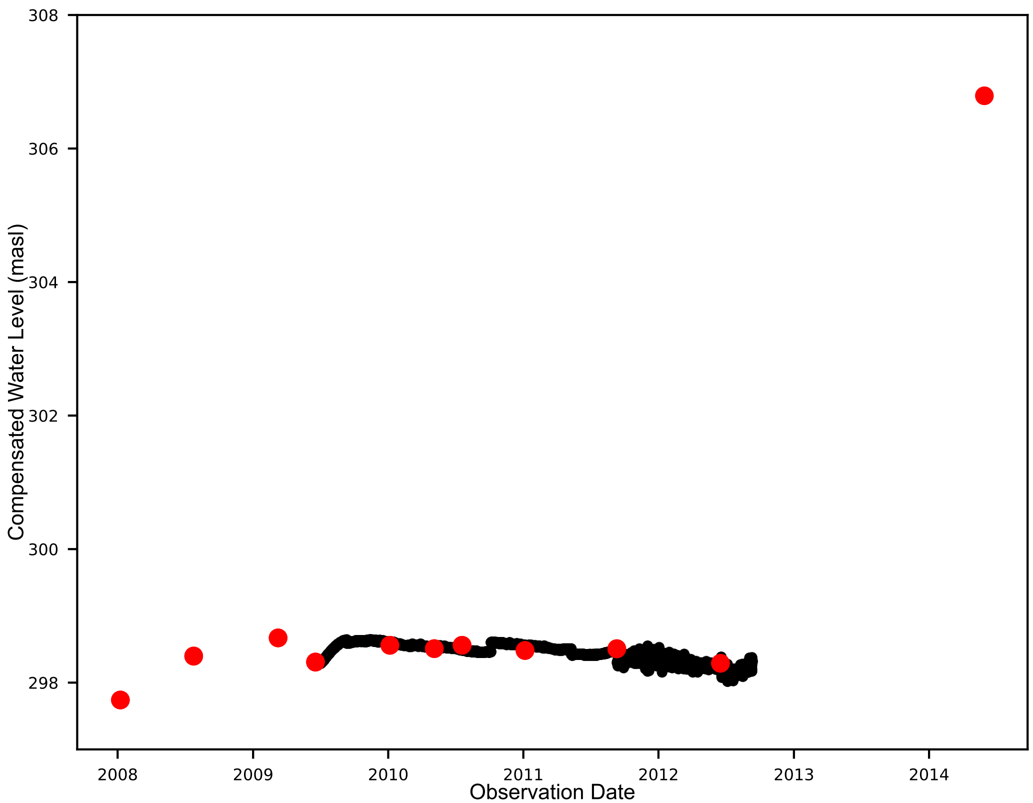
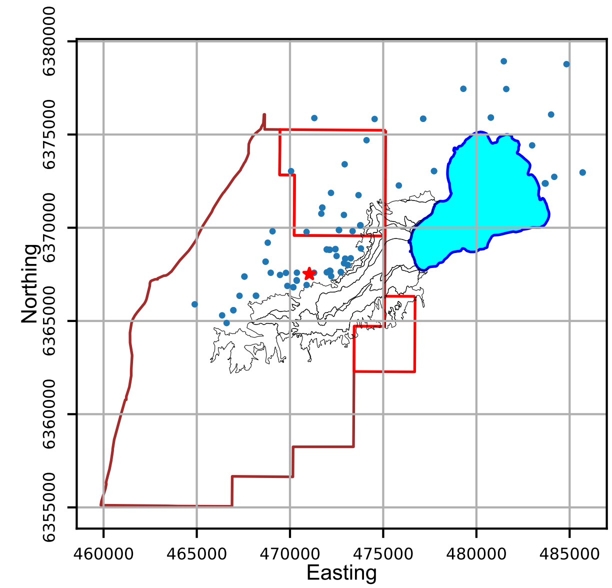




Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 10.37 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

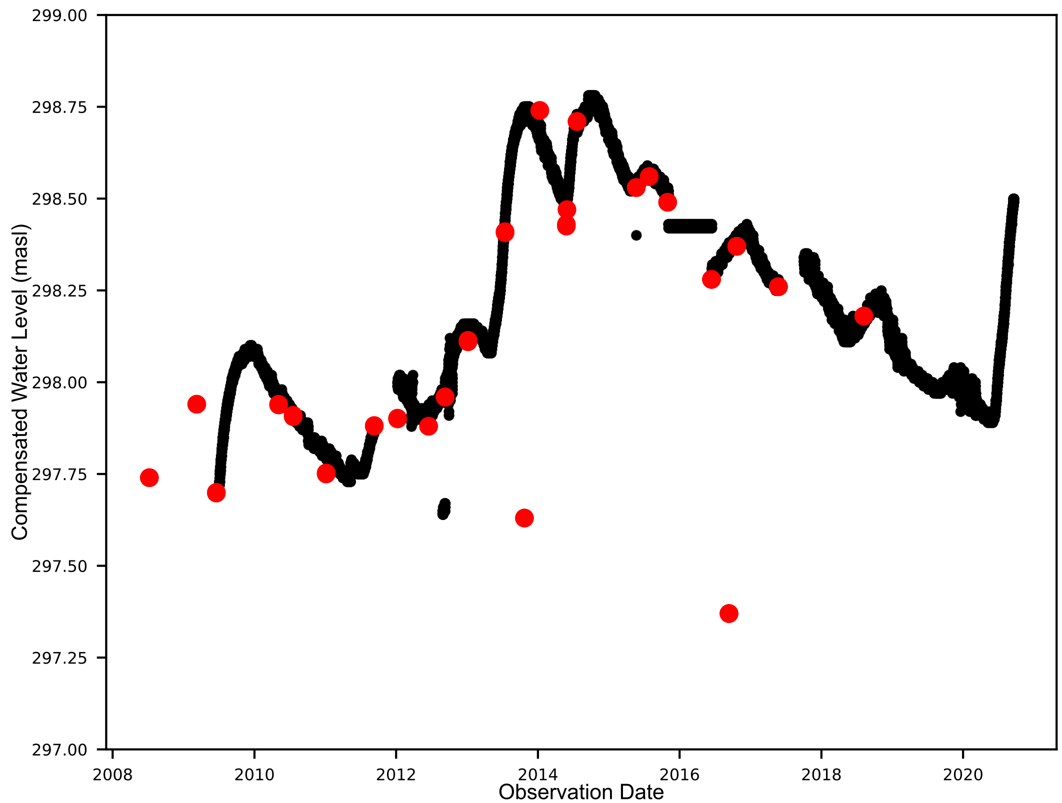
FORTHILLS
Operated by Suncor Energy

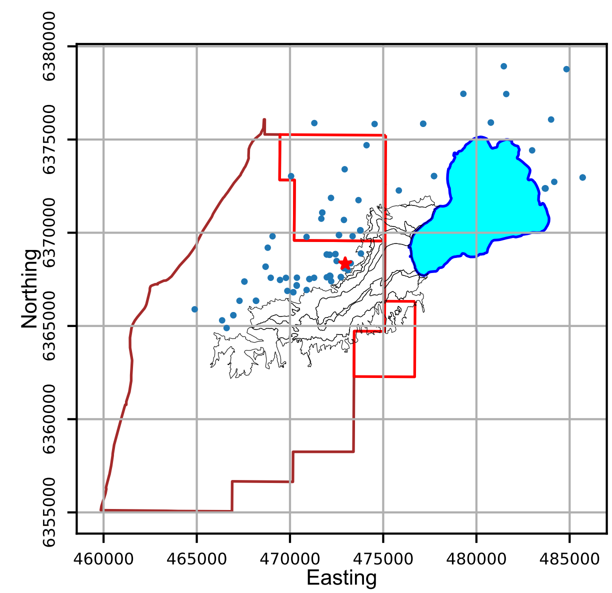
YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-094B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-141

FILE PATH: \\golder.gds\gal\Calgary\ComplexData\Suncor_2020\2020 FHX_OPTA_MLWC Hydrogeology Data\MLWC Data Assessment\DataProcessingFolder





Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 22.8 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORTHILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-098A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-142

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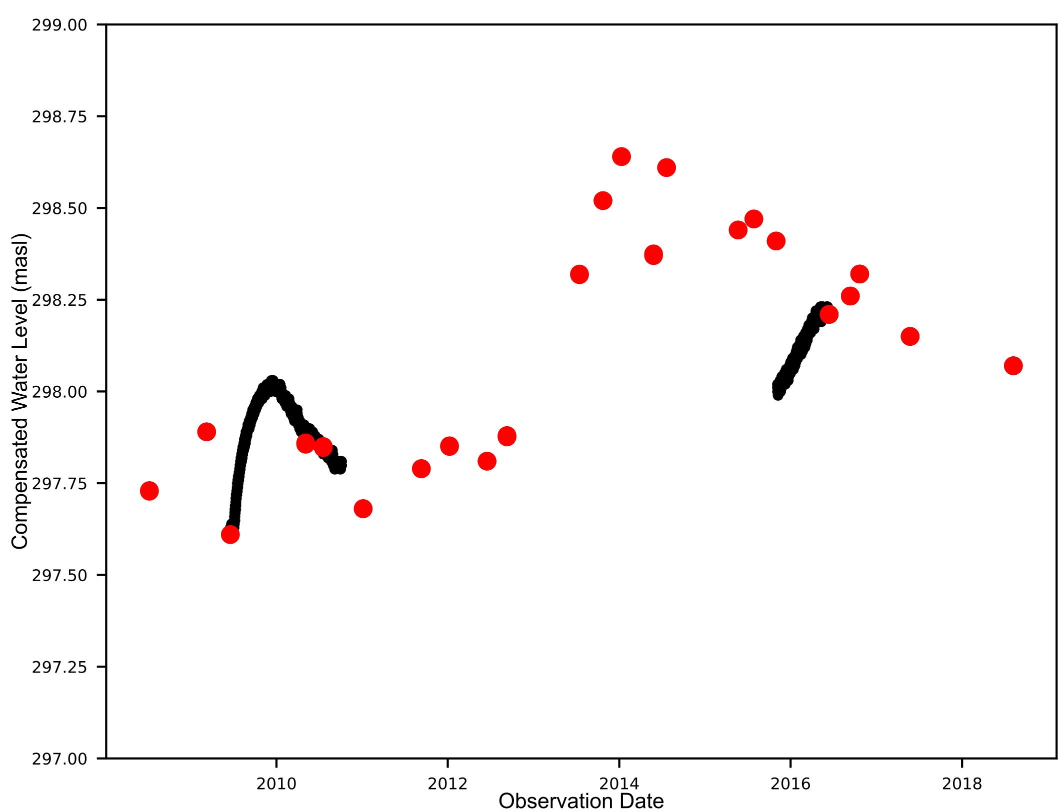

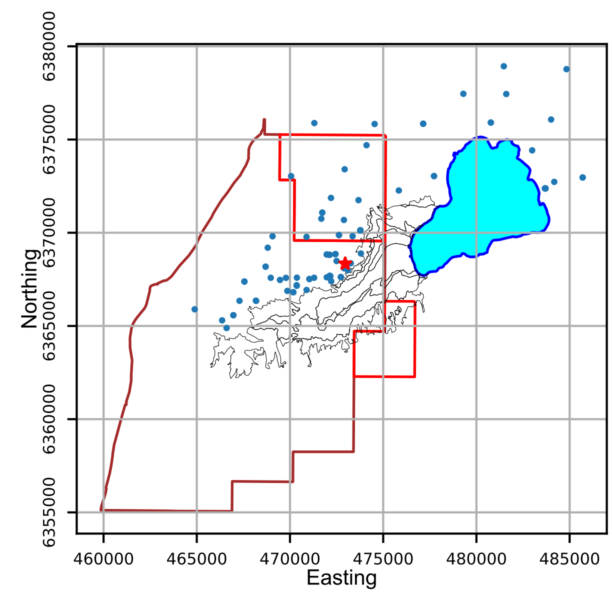

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 8.5 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

GT07-098B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-143

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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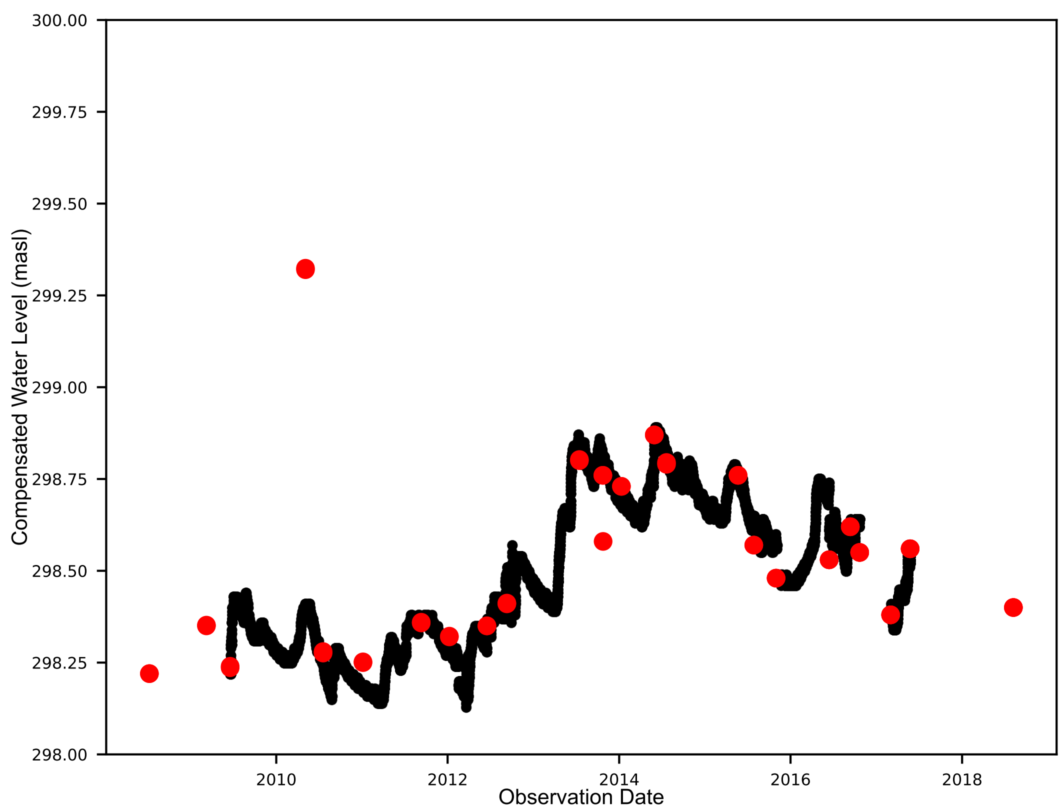

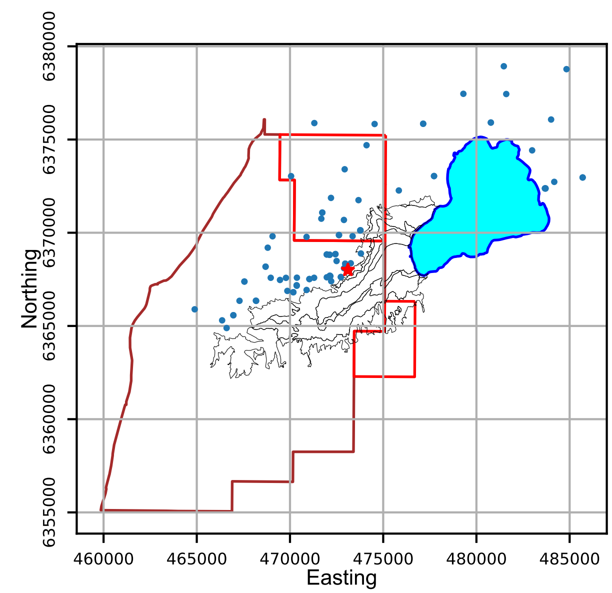

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
GT07-099A

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-144

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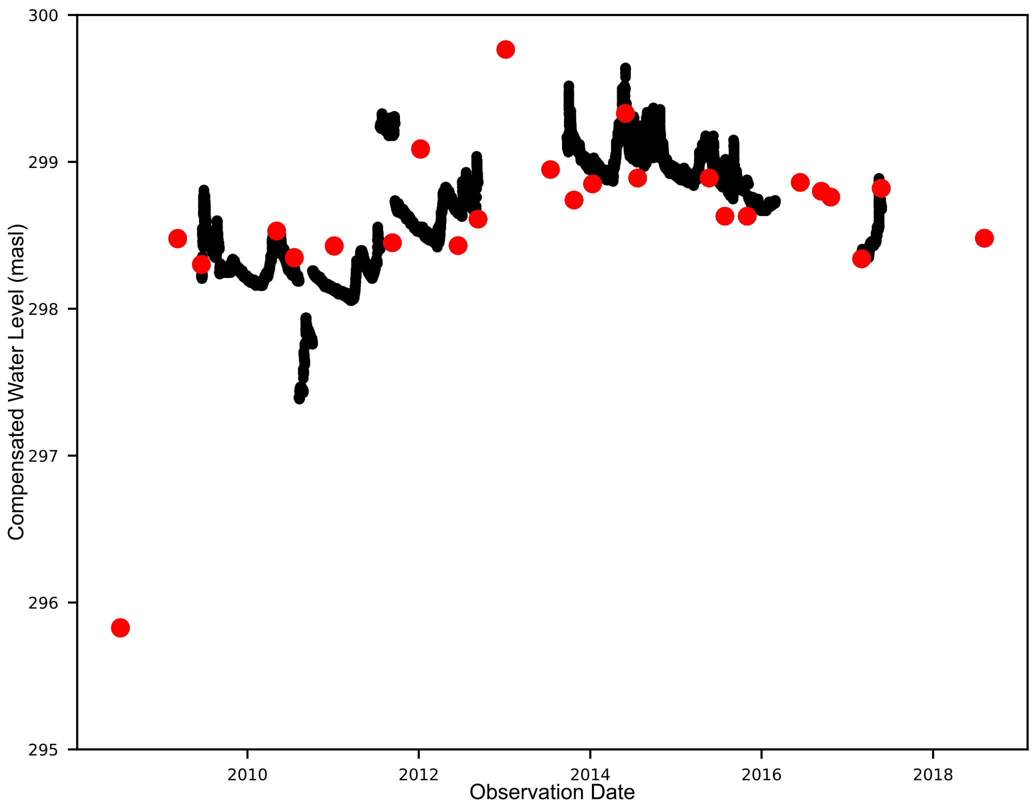

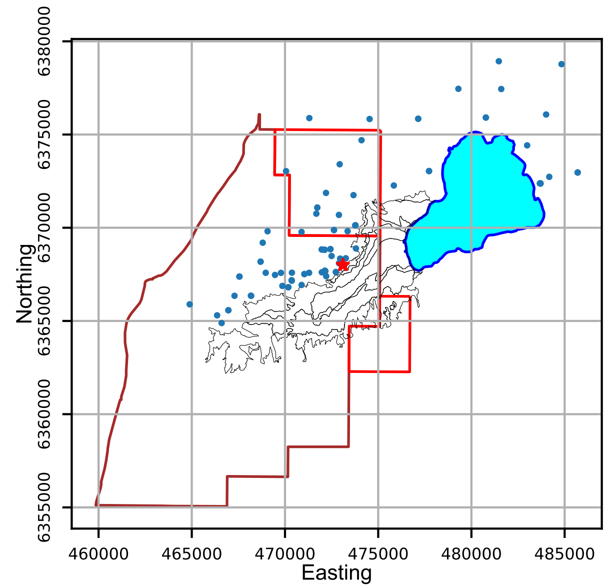

Map Legend

Plotted Well

Wells

McClelland Lake

Approved Project Area

Ecohydrology Zone

Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

Manual measurement

Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 1.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
Operated by Suncor Energy

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

GT07-099B

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-145

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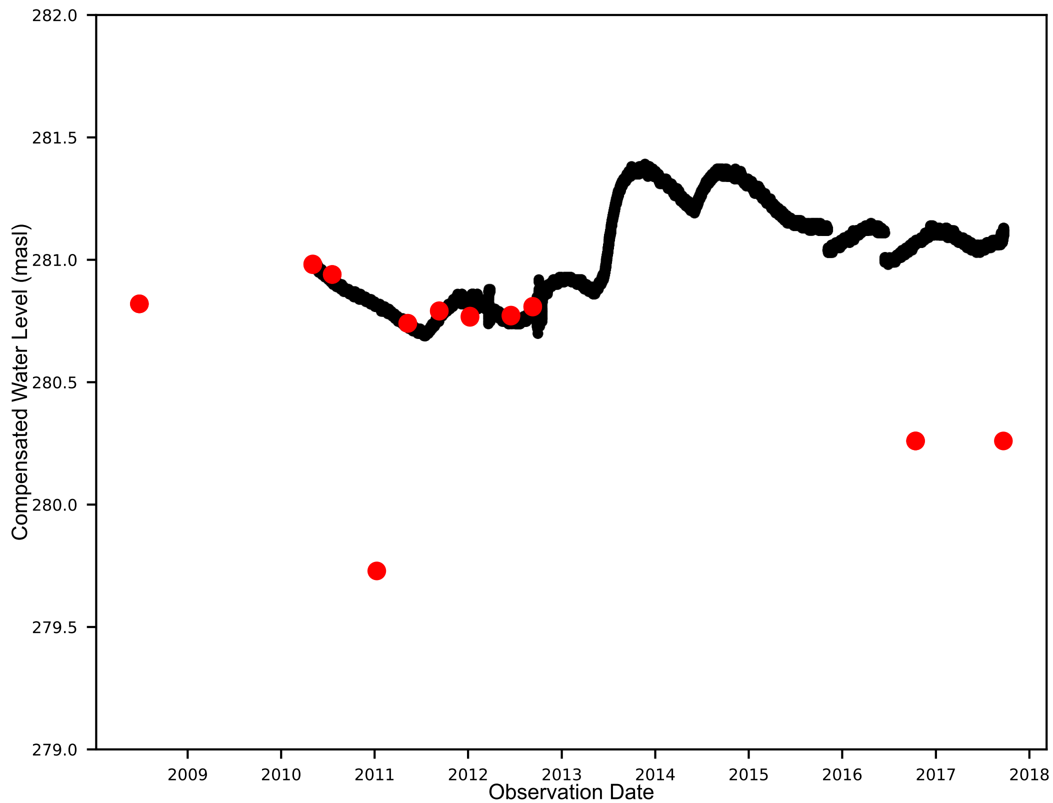

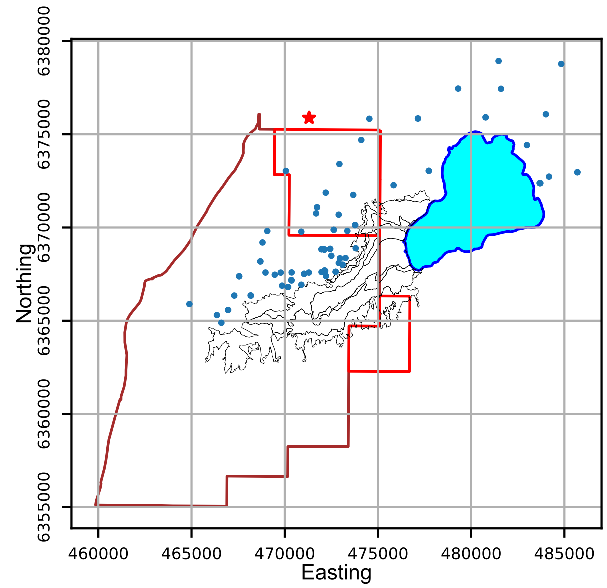

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 64.31 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

YYYY-MM-DD	2021-12-09
PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORTHILLS
Operated by Suncor Energy

TITLE

MW-08-02

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-146

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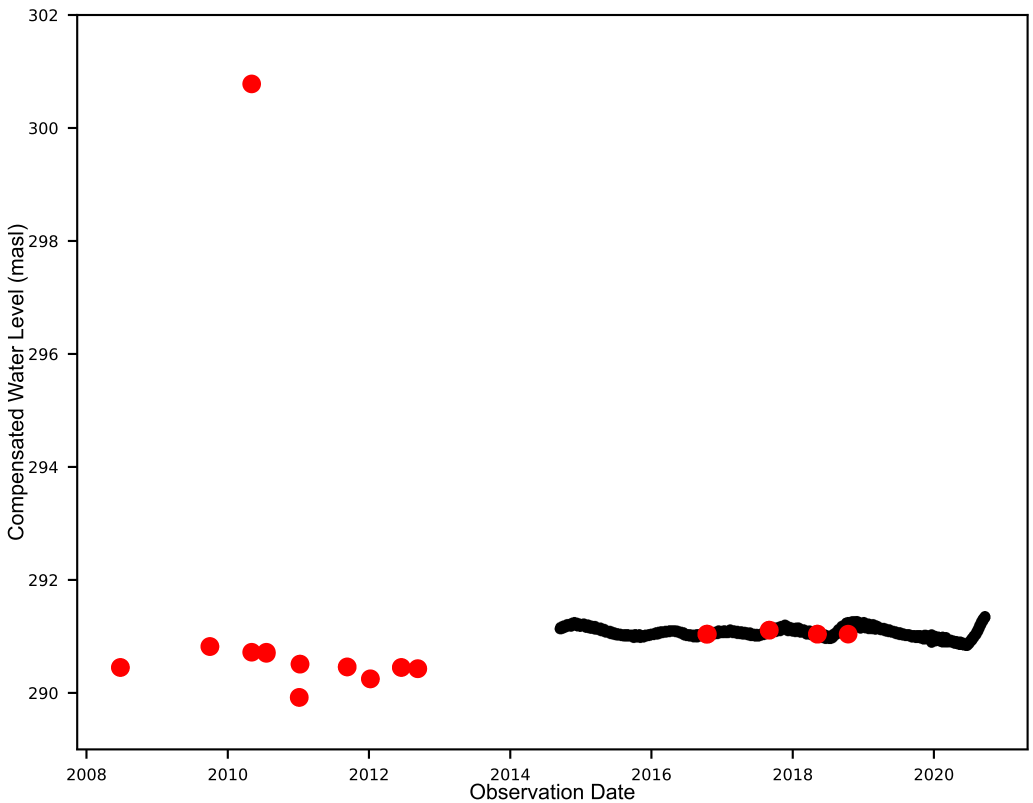

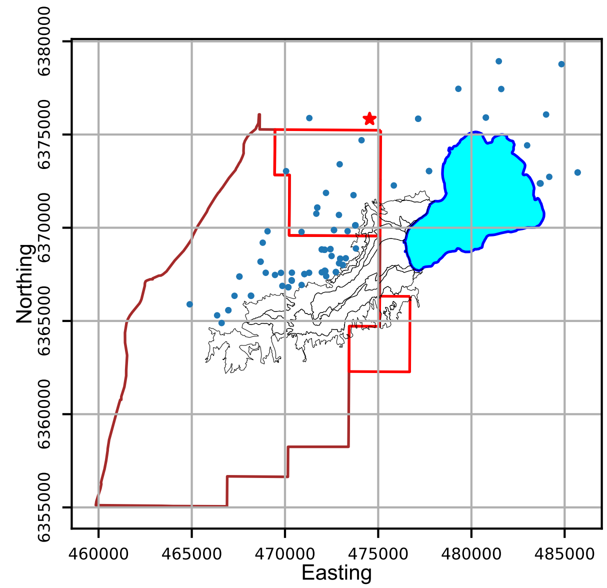

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 71.93 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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REVIEW	LW
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TITLE
MW-08-05

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-147

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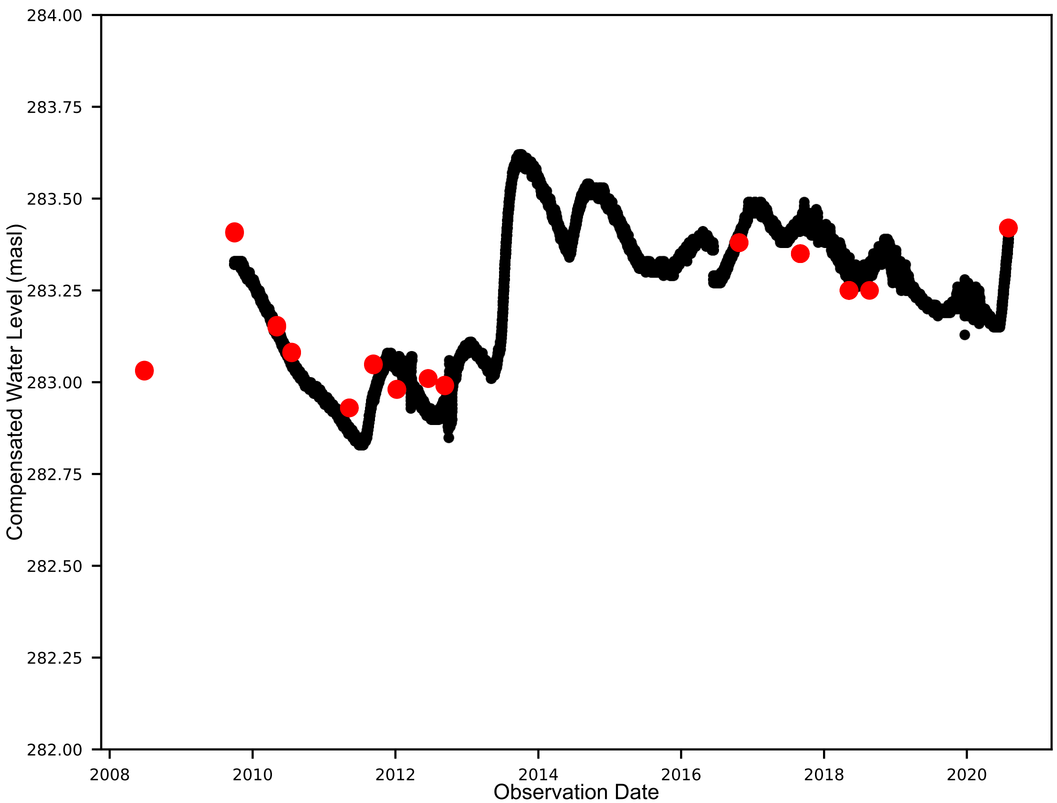

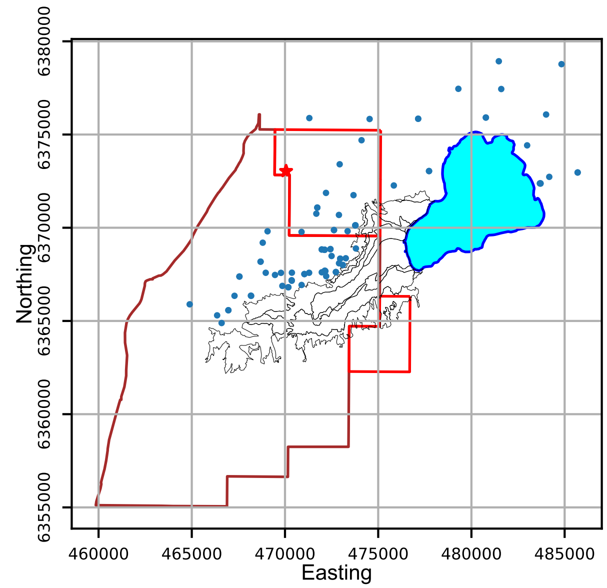

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand

Depth of Measurement: 56.39 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW-08-06

PROJECT No.	CONTROL	Rev.	FIGURE
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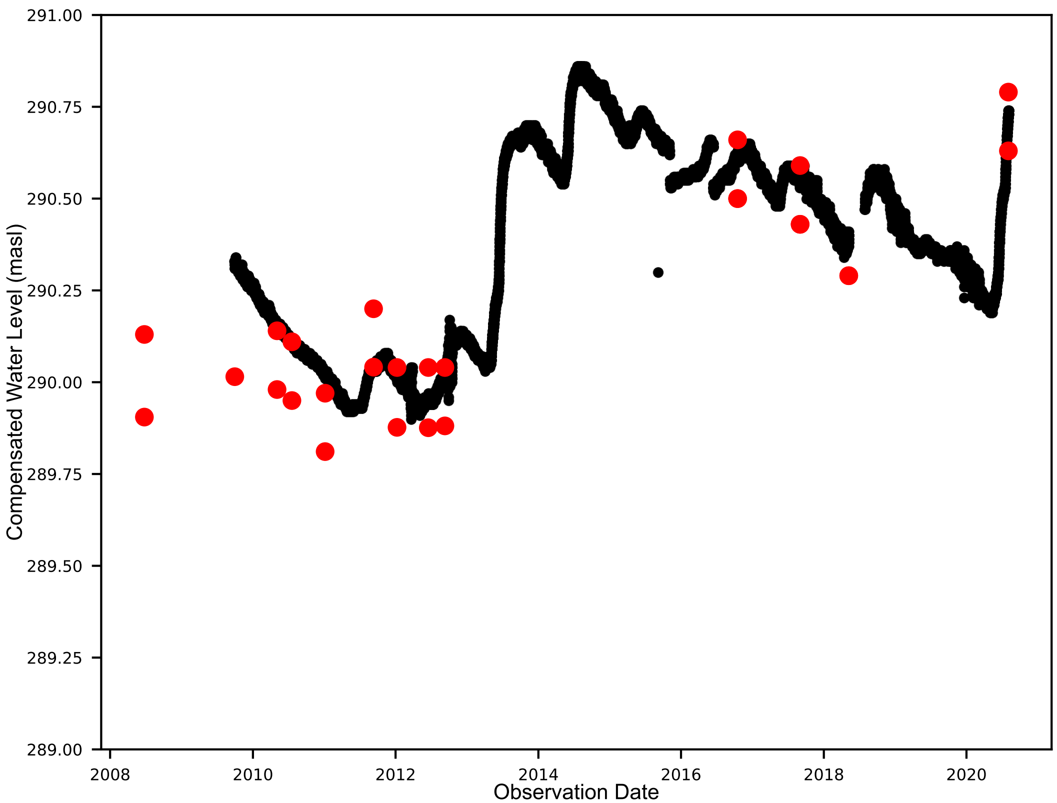

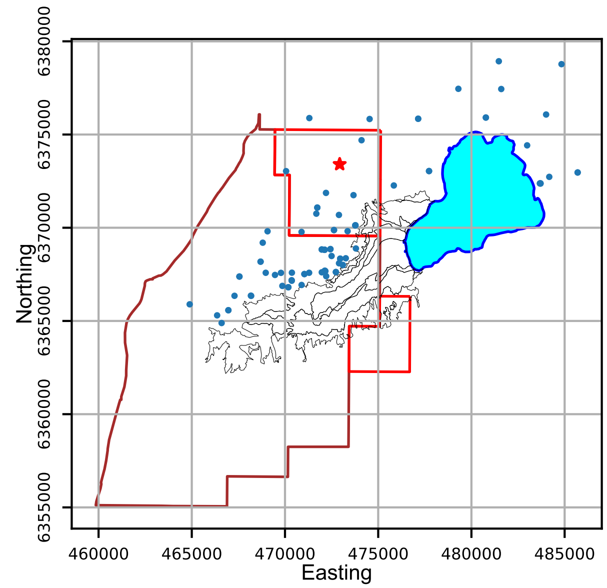

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 60.35 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

FORT HILLS
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TITLE

MW-08-07

PROJECT No.	CONTROL	Rev.	FIGURE
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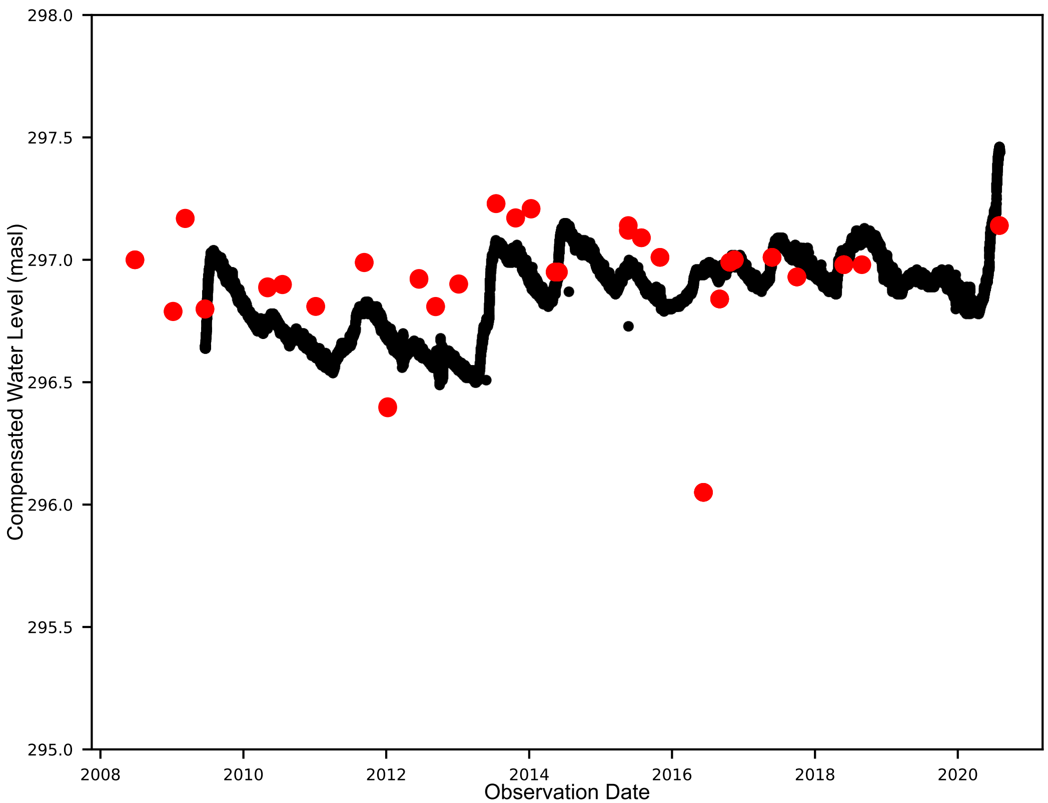

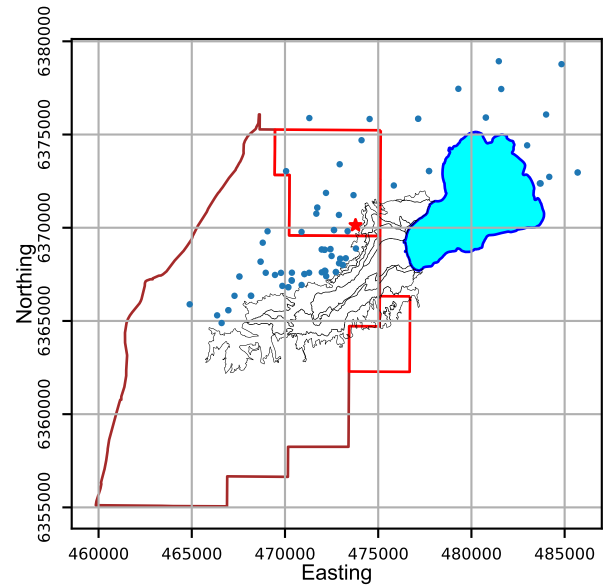

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 24.2 mbgs

masl = metres above sea level, mbgs = metres below ground surface

Hydrograph Legend

- Manual measurement
- Transducer measurement

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

FORT HILLS
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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW-08-13

PROJECT No.	CONTROL	Rev.	FIGURE
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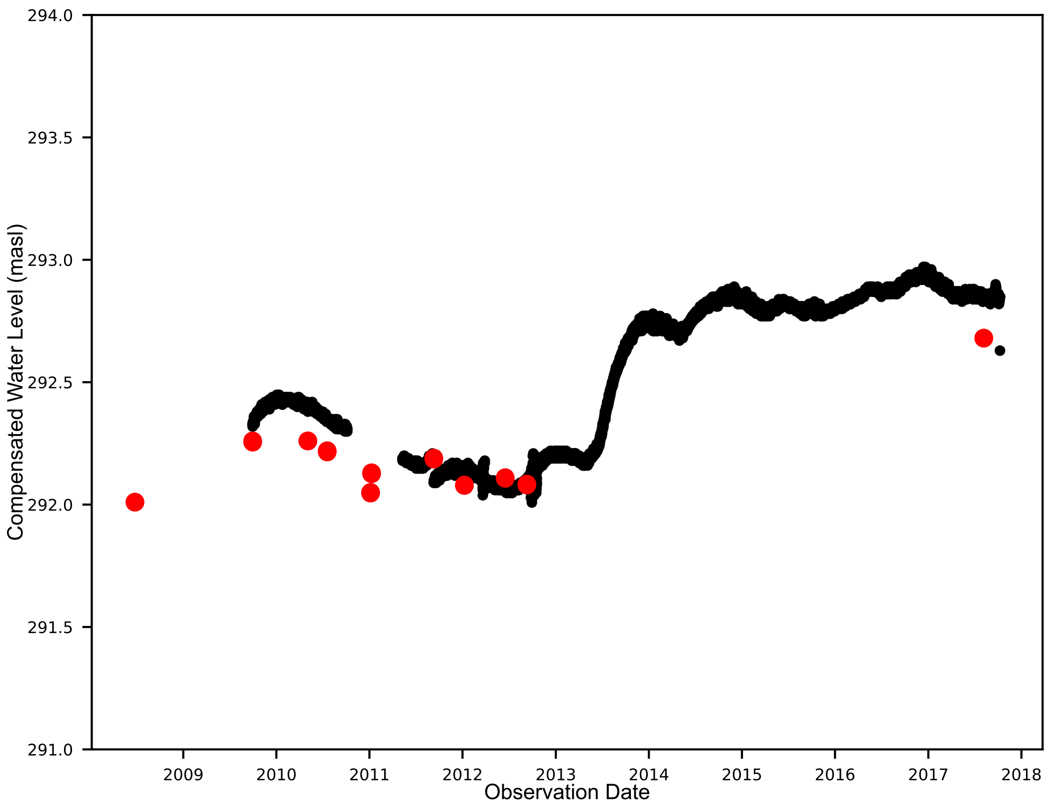

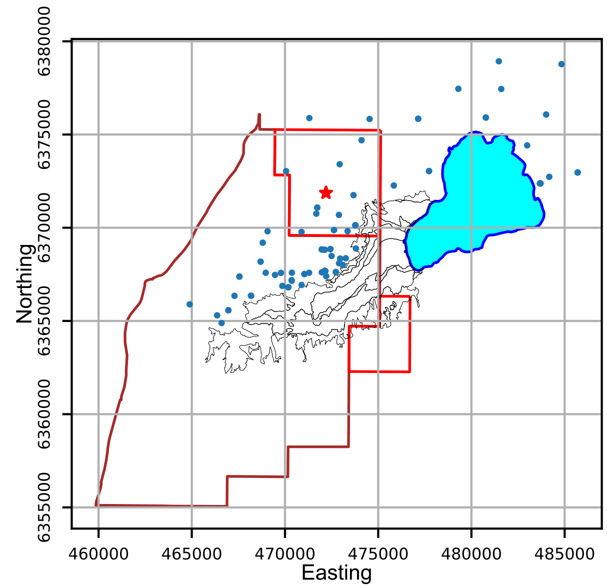

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 65.53 mbgs

masl = metres above sea level, mbgs = metres below ground surface

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-09

PROJECT No.	CONTROL	Rev.	FIGURE
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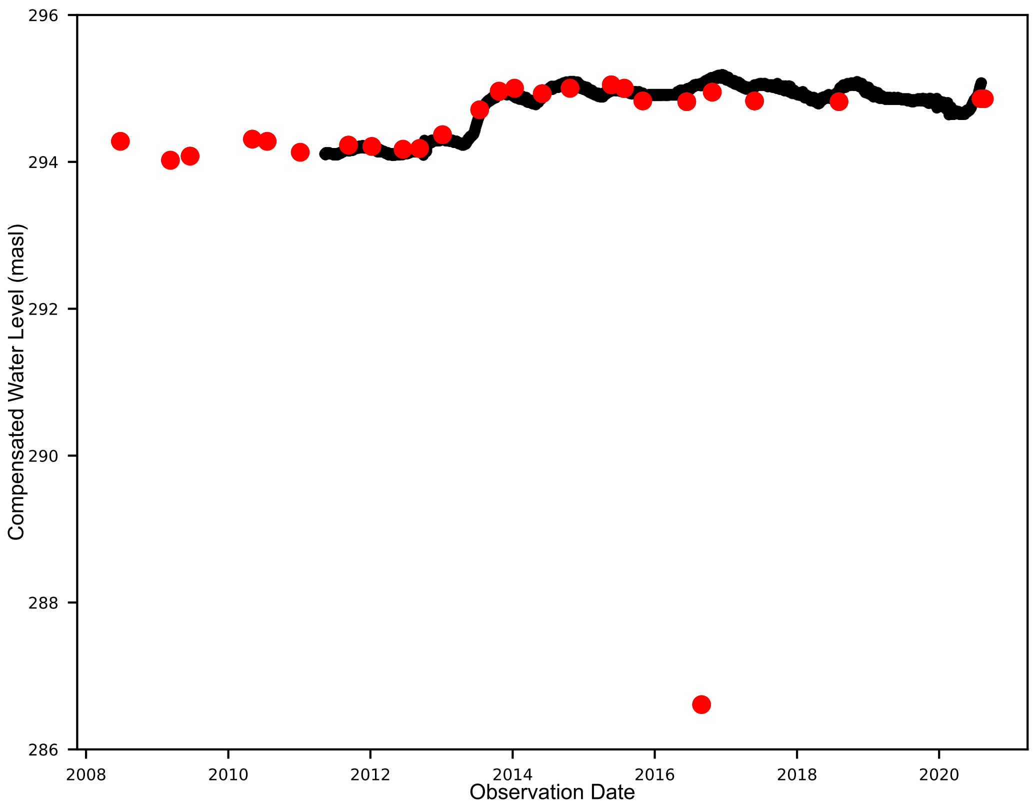

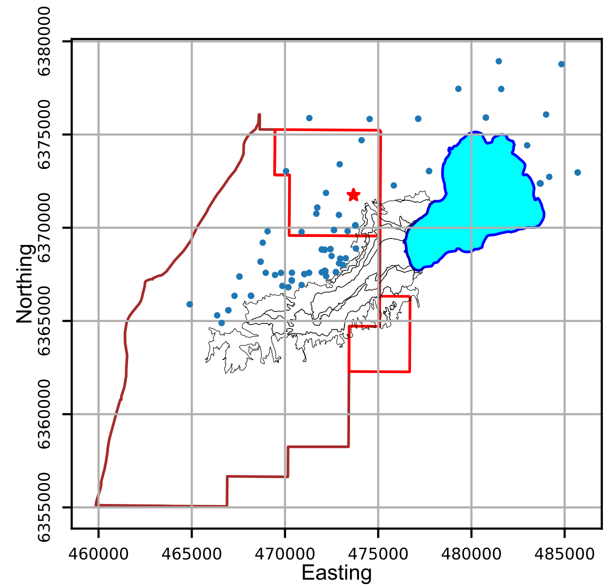

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 39.9 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

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MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-10

PROJECT No.	CONTROL	Rev.	FIGURE
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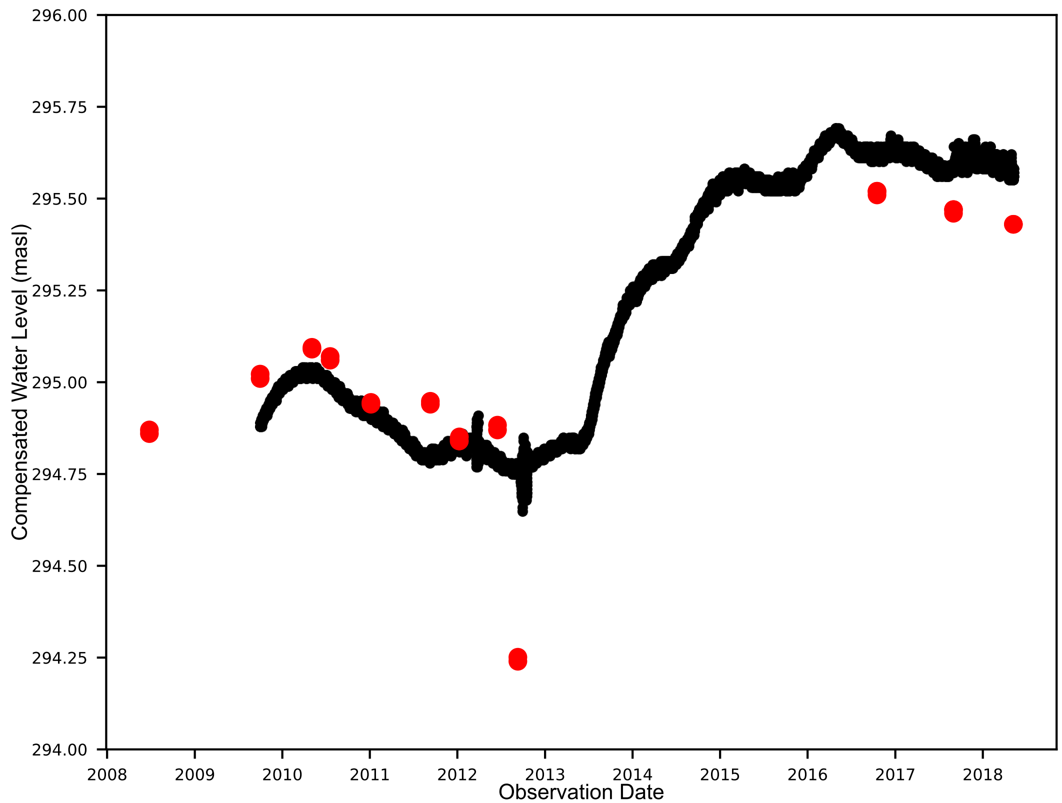

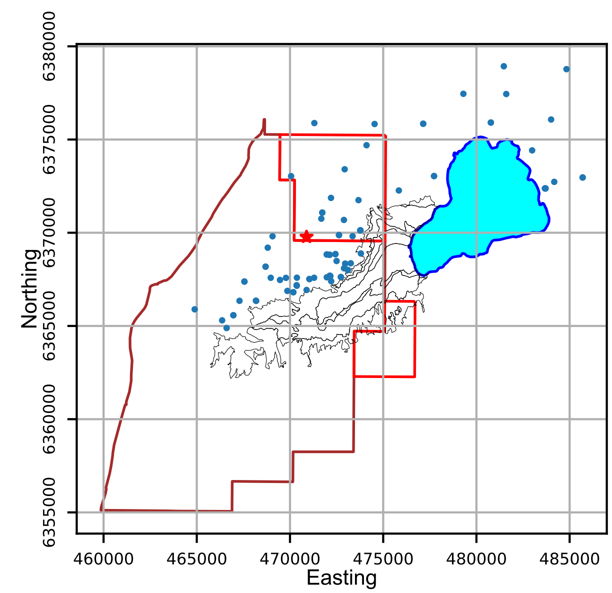

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES
Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 31.39 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT
FORT HILLS ENERGY CORPORATION

PROJECT
MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE
MW08-11

PROJECT No.	CONTROL	Rev.	FIGURE
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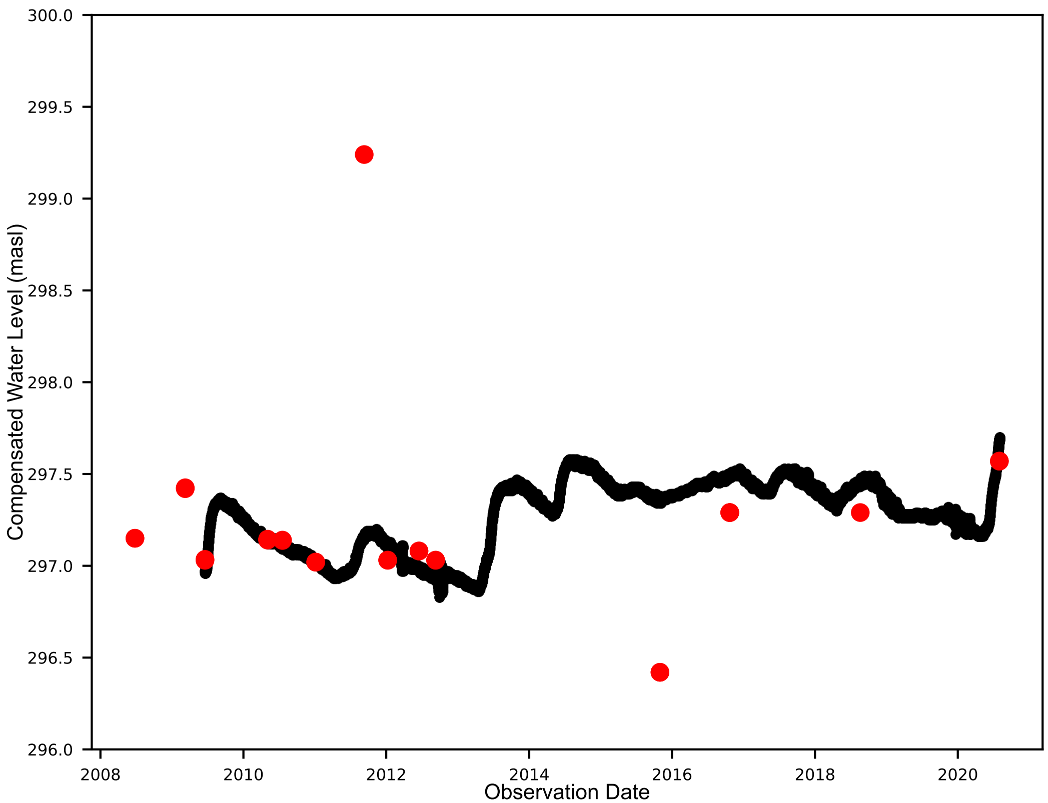

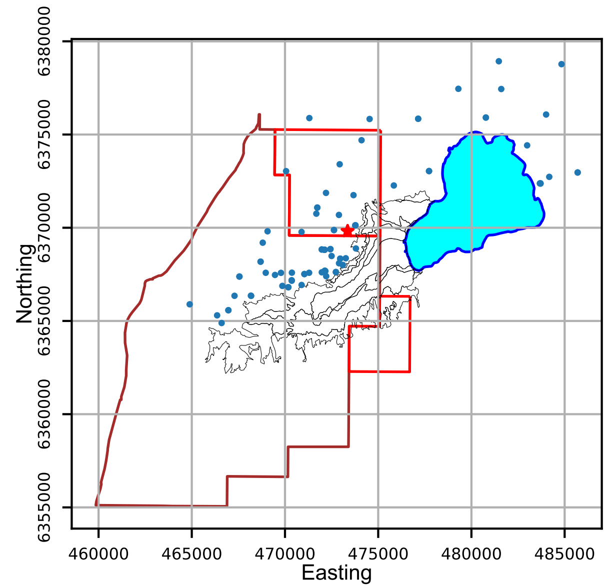

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 33.07 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

MW08-12

PROJECT No.	CONTROL	Rev.	FIGURE
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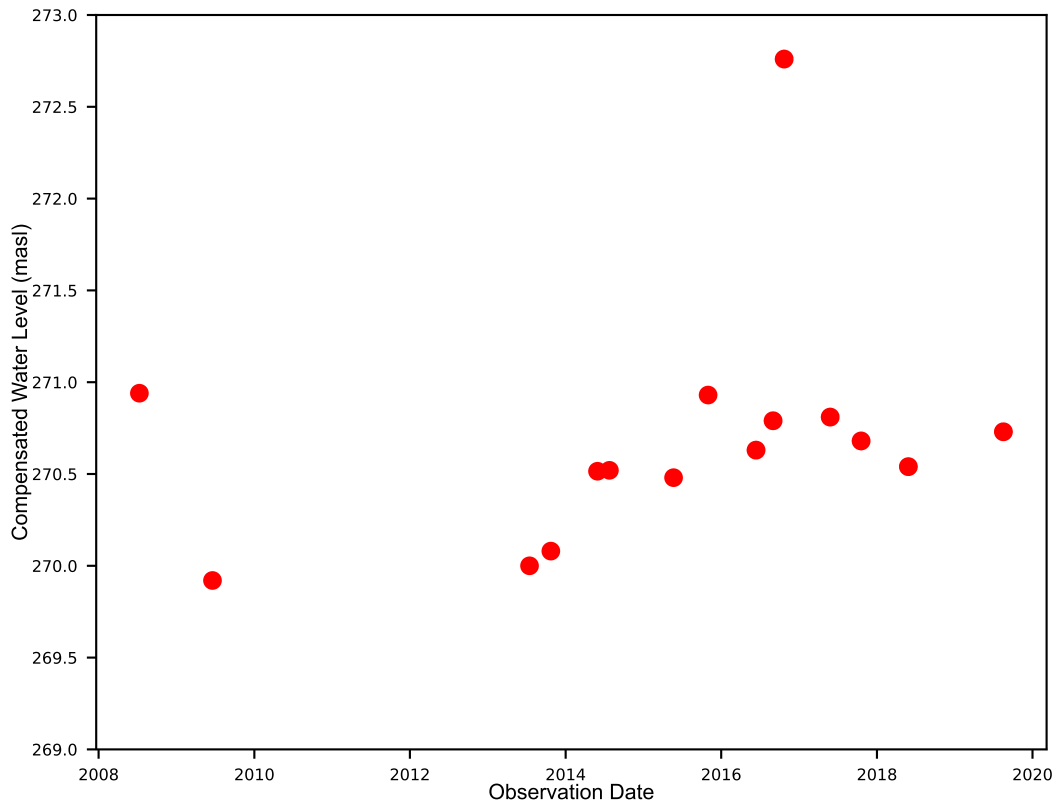

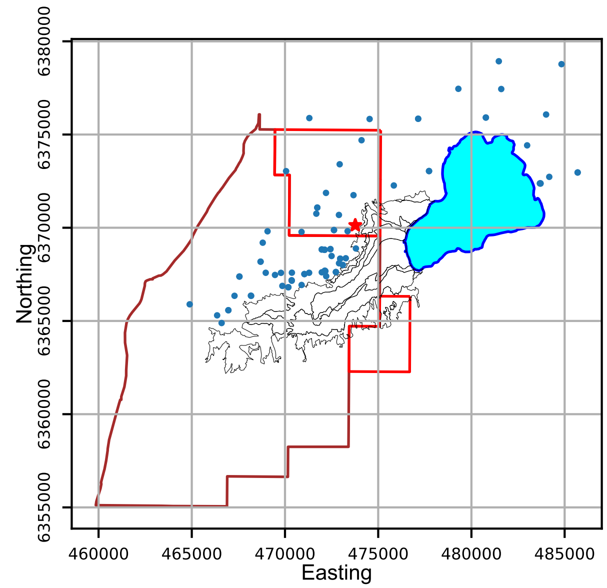

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 81.1 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

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YYYY-MM-DD	2021-12-09
PREPARED	RS
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REVIEW	LW
APPROVED	RM

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

TITLE

MW08-13BA

PROJECT No.	CONTROL	Rev.	FIGURE
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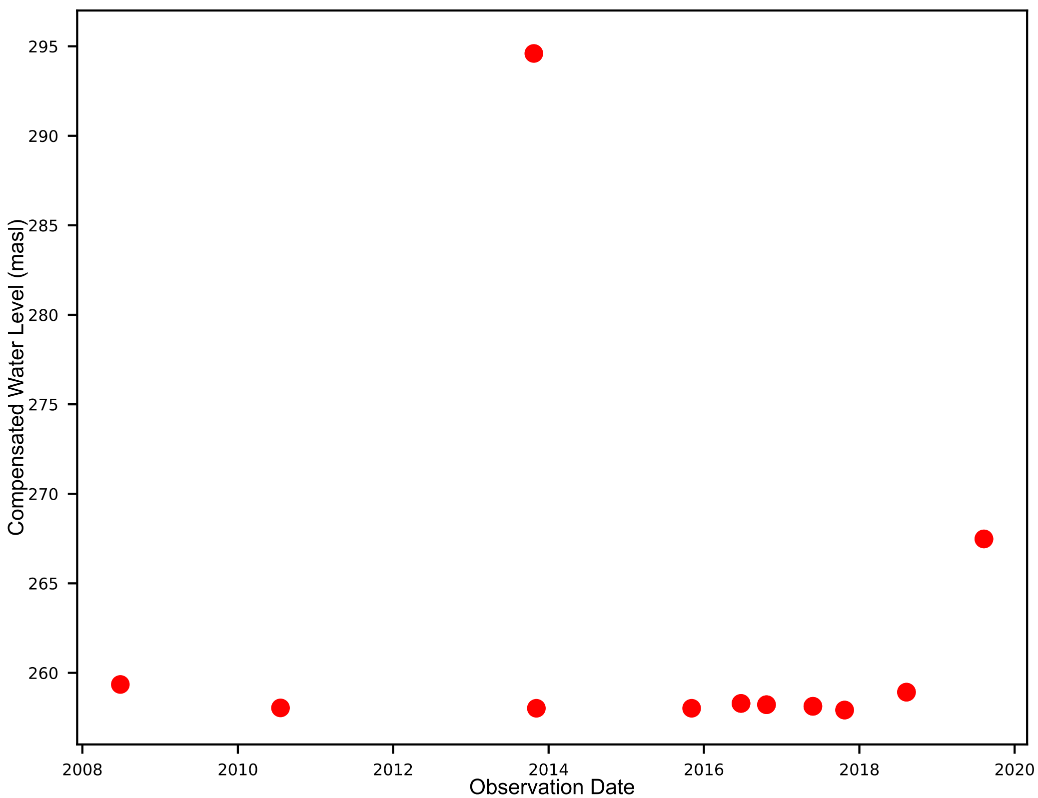

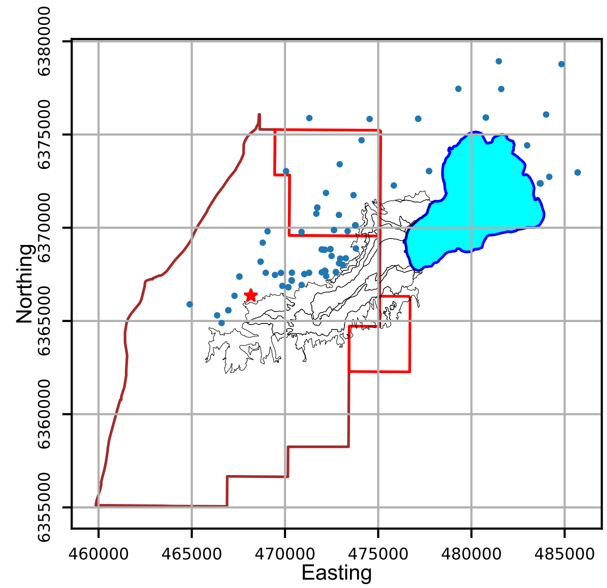

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: Basal Aquifer
Depth of Measurement: 120.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

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PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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PREPARED	RS
DESIGN	MO
REVIEW	LW
APPROVED	RM

TITLE

MW08-19BA

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-156

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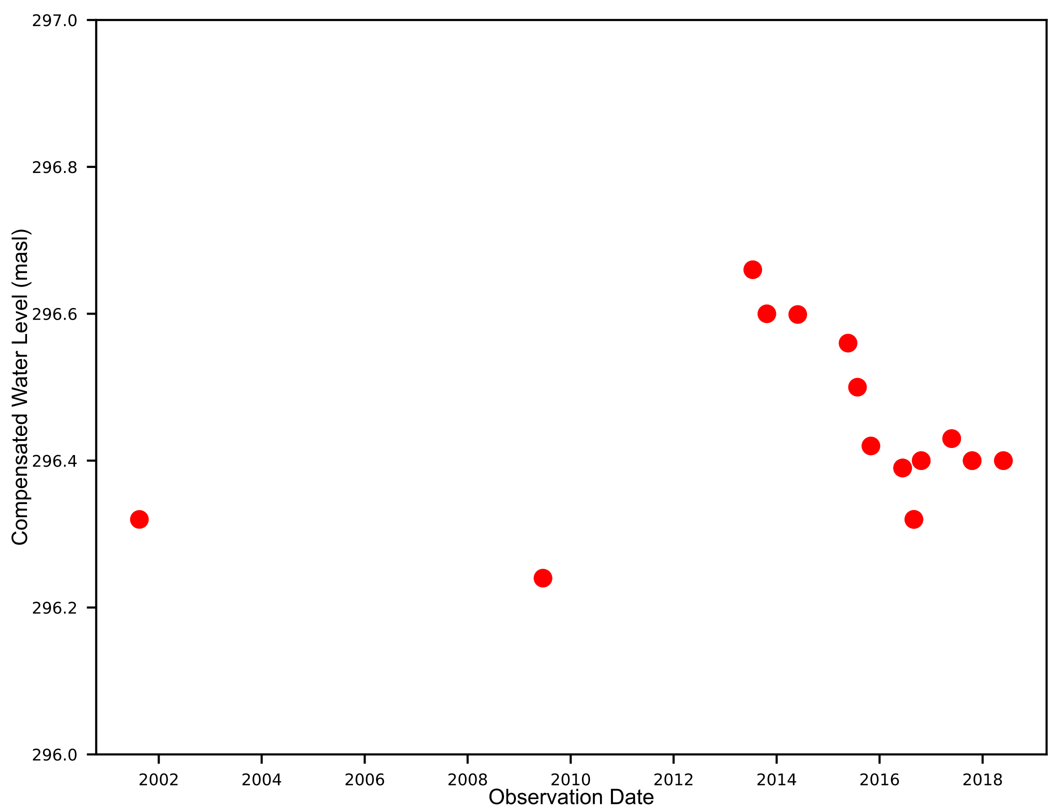

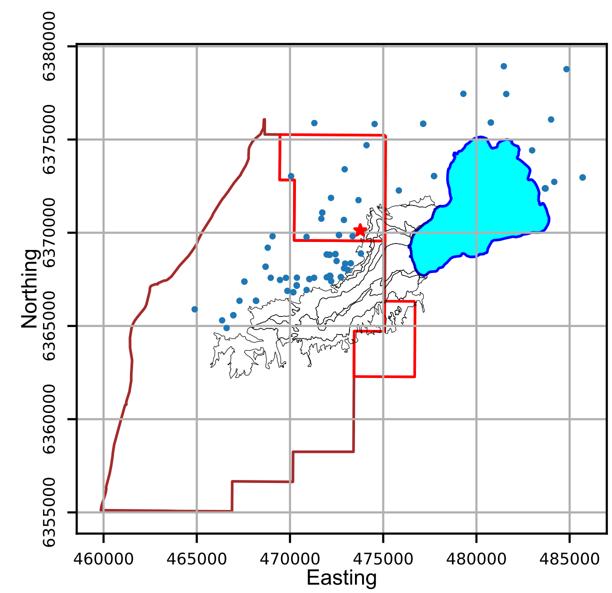

Map Legend

- Plotted Well
- Wells
- McClelland Lake
- Approved Project Area
- Ecohydrology Zone
- Extension Areas as proposed in the Integrated Plan Amendment Application

Hydrograph Legend

- Manual measurement
- Transducer measurement

NOTES

Hydrostratigraphic Unit: 03 Surface Sand
Depth of Measurement: 15.6 mbgs

masl = metres above sea level, mbgs = metres below ground surface

CLIENT

FORT HILLS ENERGY CORPORATION

PROJECT

MCCLELLAND LAKE WETLAND COMPLEX – OPERATIONAL PLAN

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REVIEW	LW
APPROVED	RM

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TITLE

PW-08-02

PROJECT No.	CONTROL	Rev.	FIGURE
20140450	100	A	B8-157

Appendix C

Summary Statistics of Surface and Groundwater Quality Parameters

C1 Surface Water Quality

Table C1-1a: Seasonal Water Quality Summary in Ecohydrology Zone 1, 2008 to 2010

Parameter	Unit	Seasonal Summary																										Summary								
		Spring									Summer									Fall									2008 - 2010								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (lab)	-	7.2	—	—	—	—	—	—	0	1	7.4	7.2	6.6	7.5	6.3	7.6	0.44	0	7	7.2	7.0	5.9	7.4	5.6	7.4	0.67	0	7	7.3	7.1	6.1	7.5	5.6	7.6	0.54	0	15
Electrical conductivity (lab)	µS/cm	—	—	—	—	—	—	—	0	0	215	210	176	237	170	240	29	0	4	170	173	152	197	150	200	25	0	3	200	194	156	234	150	240	32	0	7
Alkalinity (as $CaCO_3$)	mg/L	115	—	—	—	—	—	—	0	1	115	119	89	156	82	170	26	0	7	90	89	65	115	61	115	20	0	7	115	105	69	137	61	170	27	0	15
Total dissolved solids	mg/L	113	—	—	—	—	—	—	0	1	120	122	95	157	89	173	25	0	7	90	91	67	120	65	120	22	0	7	113	107	69	136	65	173	27	0	15
Calcium	mg/L	35	—	—	—	—	—	—	0	1	35	36	27	51	24	58	10	0	7	27	27	20	35	19	35	6.3	0	7	35	32	21	42	19	58	9.3	0	15
Magnesium	mg/L	7.1	—	—	—	—	—	—	0	1	6.5	6.8	5.5	9.0	5.2	10	1.5	0	7	5.5	5.4	3.7	6.5	3.4	6.5	1.1	0	7	6.5	6.1	4.2	8.0	3.4	10	1.5	0	15
Potassium	mg/L	0.20	—	—	—	—	—	—	0	1	1.0	1.7	0.41	4.3	0.25	5.3	1.7	0	7	<0.3	*	<0.3	0.55	<0.2	0.60	*	4	7	0.44	*	0.20	2.9	<0.2	5.3	*	4	15
Sodium	mg/L	1.8	—	—	—	—	—	—	0	1	2.0	2.2	1.5	2.9	1.5	2.9	0.61	0	7	1.7	1.7	1.5	1.9	1.5	2.0	0.16	0	7	1.7	1.9	1.5	2.9	1.5	2.9	0.48	0	15

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.
* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.

Table C1-1b: Seasonal Water Quality Summary in Ecohydrology Zone 2, 2002 to 2019

Parameter	Unit	Seasonal Summary																										Summary								
		Spring									Summer									Fall									2002 - 2019								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.8	6.8	6.6	7.0	6.6	7.0	0.20	0	3	6.8	6.8	6.6	7.0	6.6	7.0	0.13	0	8	6.6	6.4	5.4	7.2	5.3	7.3	0.80	0	6	6.7	6.6	5.5	7.1	5.3	7.3	0.50	0	17
pH (lab)	-	7.8	7.8	7.5	8.3	7.5	8.3	0.31	0	7	7.5	7.5	7.0	8.0	7.0	8.1	0.30	0	21	7.7	7.6	7.0	7.9	7.0	8.0	0.26	0	23	7.6	7.6	7.0	8.1	7.0	8.3	0.30	0	51
pH (field + lab)	-	7.8	7.6	6.7	8.3	6.6	8.3	0.60	0	11	7.5	7.3	6.7	8.0	6.6	8.1	0.43	0	34	7.5	7.3	6.2	7.9	5.3	8.0	0.59	0	41	7.5	7.3	6.6	8.0	5.3	8.3	0.54	0	86
Specific conductivity (field)	µS/cm	726	704	637	755	627	758	68	0	3	689	734	648	910	636	969	106	0	8	704	673	516	793	484	820	114	0	6	700	707	587	850	484	969	102	0	17
Electrical conductivity (field)	µS/cm	554	510	427	562	413	563	84	0	3	559	583	490	680	470	692	76	0	8	457	456	392	518	381	530	51	0	6	530	526	407	664	381	692	88	0	17
Electrical conductivity (lab)	µS/cm	560	609	449	797	440	800	153	0	7	685	618	301	866	290	870	183	0	22	710	603	321	799	300	890	185	0	23	685	610	306	832	290	890	177	0	52
Alkalinity (as $CaCO_3$)	mg/L	262	292	185	447	124	451	95	0	11	361	333	161	477	156	492	103	0	33	320	316	164	434	151	508	96	0	41	320	319	164	464	124	508	98	0	85
Total dissolved solids	mg/L	260	286	181	425	121	430	90	0	11	350	323	156	468	150	480	101	0	33	310	307	170	420	140	470	90	0	40	315	311	160	456	121	480	94	0	84
Calcium	mg/L	79	81	49	115	38	120	23	0	11	100	91	44	140	41	140	31	0	33	82	83	53	120	37	120	22	0	41	82	86	46	120	37	140	26	0	85
Magnesium	mg/L	21	23	13	32	5.4	32	7.4	0	11	28	25	7.1	36	6.2	37	9.1	0	33	26	23	8.4	33	7.3	35	8.7	0	41	26	24	7.4	35	5.4	37	8.7	0	85
Potassium	mg/L	0.94	1.1	0.34	2.7	0.34	3.3	0.91	0	11	0.90	1.4	<0.3	3.9	<0.3	4.1	1.2	3	33	1.4	2.0	0.30	4.9	<0.3	5.4	1.5	2	41	0.96	1.6	0.30	4.4	<0.3	5.4	1.4	5	85
Sodium	mg/L	4.2	4.7	3.1	6.2	2.2	6.3	1.3	0	11	5.4	5.6	2.8	7.6	2.7	7.6	1.6	0	33	5.8	5.5	3.2	7.6	2.5	7.8	1.5	0	41	5.8	5.4	2.8	7.6	2.2	7.8	1.6	0	85

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C1-1c: Seasonal Water Quality Summary in Ecohydrology Zone 3, 2017 to 2019

Parameter	Unit	Seasonal Summary																	Summary								
		Summer									Fall									2002 - 2019								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	5.9	5.9	5.6	6.2	5.6	6.2	0.42	0	2	6.2	6.5	6.0	7.3	6.0	7.4	0.56	0	6	6.2	6.3	5.7	7.2	5.6	7.4	0.57	0	8
pH (lab)	-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH (field + lab)	-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Specific conductivity (field)	µS/cm	251	251	243	259	242	260	13	0	2	486	413	154	578	118	590	184	0	6	366	373	161	573	118	590	173	0	8
Electrical conductivity (field)	µS/cm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical conductivity (lab)	µS/cm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alkalinity (as $CaCO_3$)	mg/L	135	135	113	158	110	160	35	0	2	280	219	58	315	49	320	119	0	6	215	198	62	313	49	320	109	0	8
Total dissolved solids	mg/L	140	140	131	149	130	150	14	0	2	290	231	68	333	57	340	121	0	6	220	208	72	330	57	340	110	0	8
Calcium	mg/L	34	34	32	36	32	36	2.8	0	2	80	64	18	94	15	97	34	0	6	58	57	19	93	15	97	32	0	8
Magnesium	mg/L	9.2	9.2	8.8	9.5	8.8	9.5	0.49	0	2	22	17	5.3	23	4.6	23	8.4	0	6	15	15	5.5	23	4.6	23	7.9	0	8
Potassium	mg/L	5.7	5.7	2.6	8.7	2.3	9.0	4.7	0	2	1.4	1.8	0.48	3.6	0.35	3.6	1.4	0	6	1.9	2.8	0.54	7.1	0.35	9.0	2.8	0	8
Sodium	mg/L	3.5	3.5	3.0	3.9	2.9	4.0	0.78	0	2	5.8	5.6	3.5	7.1	3.1	7.1	1.5	0	6	5.2	5.1	3.0	7.1	2.9	7.1	1.6	0	8

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.
Data Source for Ecohydrology Zone 3: InnoTech (2021)

Table C1-1d: Seasonal Water Quality Summary in Ecohydrology Zone 4, 2017 to 2019

Parameter	Unit	Seasonal Summary																	Summary								
		Summer									Fall									2002 - 2019								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.4	*	6.4	6.4	—	—	*	0	1	6.2	6.3	6.0	6.9	6.0	7.1	0.36	0	8	6.2	6.3	6.0	6.8	6.0	7.1	0.34	0	9
pH (lab)	-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
pH (field + lab)	-	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Specific conductivity (field)	µS/cm	433	*	433	433	—	—	*	0	1	400	419	241	674	171	810	177	0	8	400	421	251	659	171	810	166	0	9
Electrical conductivity (field)	µS/cm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Electrical conductivity (lab)	µS/cm	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Alkalinity (as $CaCO_3$)	mg/L	230	*	230	230	—	—	*	0	1	215	231	112	393	65	480	114	0	8	220	231	119	380	65	480	107	0	9
Total dissolved solids	mg/L	230	*	230	230	—	—	*	0	1	220	231	115	377	69	450	104	0	8	220	231	121	366	69	450	97	0	9
Calcium	mg/L	63	*	63	63	—	—	*	0	1	62	64	30	104	16	120	28	0	8	62	64	32	101	16	120	26	0	9
Magnesium	mg/L	22.0	*	22.0	22.0	—	—	*	0	1	18	17	6.8	26	4.6	31	7.5	0	8	18	17	7.2	27	4.6	31	7.2	0	9
Potassium	mg/L	0.8	*	0.8	0.8	—	—	*	0	1	0.4	1.2	0.30	3.8	0.30	4.6	1.5	0	8	0.4	1.2	0.30	3.7	0.30	4.6	1.4	0	9
Sodium	mg/L	5.0	*	5.0	5.0	—	—	*	0	1	4.8	4.7	3.7	5.4	3.6	5.4	0.7	0	8	4.9	4.7	3.8	5.4	3.6	5.4	0.6	0	9

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.
* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.
Data Source for Ecohydrology Zone 4: InnoTech (2021)

Table C1-1e: Seasonal Water Quality Summary in Ecohydrology Zone 5, 2002 to 2019

Parameter	Unit	Seasonal Summary																										Summary								
		Spring									Summer									Fall									2002 - 2019								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.8	6.9	6.4	7.6	6.4	7.7	0.45	0	7	6.6	6.7	6.4	7.2	6.1	7.8	0.37	0	14	6.6	6.6	5.4	7.3	5.0	7.3	0.75	0	8	6.6	6.7	6.1	7.5	5.0	7.8	0.51	0	29
pH (lab)	-	7.4	7.3	6.4	8.1	6.1	8.2	0.57	0	25	7.2	7.1	6.6	7.7	6.3	7.9	0.35	0	52	7.1	7.1	6.4	7.6	6.1	7.7	0.36	0	45	7.2	7.1	6.4	7.8	6.1	8.2	0.41	0	122
pH (field + lab)	-	7.3	7.3	6.4	8.0	6.1	8.2	0.51	0	37	7.1	7.1	6.5	7.8	6.1	7.9	0.43	0	78	7.0	7.0	6.3	7.5	5.0	7.7	0.46	0	72	7.1	7.1	6.4	7.8	5.0	8.2	0.47	0	187
Specific conductivity (field)	µS/cm	349	303	88	559	83	607	208	0	7	510	470	95	731	77	799	227	0	14	511	473	84	754	69	815	259	0	8	487	430	79	757	69	815	235	0	29
Electrical conductivity (field)	µS/cm	242	203	55	368	53	389	140	0	7	380	357	71	580	61	615	177	0	14	326	295	53	472	43	510	161	0	8	337	303	55	549	43	615	171	0	29
Electrical conductivity (lab)	µS/cm	350	292	82	562	74	580	183	0	25	490	417	85	670	65	800	220	0	53	480	392	58	670	53	780	227	0	45	470	382	65	670	53	800	219	0	123
Alkalinity (as $CaCO_3$)	mg/L	189	165	39	303	34	320	97	0	37	262	220	41	354	31	459	119	0	77	246	204	28	360	23	418	120	0	72	238	203	32	352	23	459	117	0	186
Total dissolved solids	mg/L	190	161	47	286	42	320	92	0	37	260	225	48	354	38	440	116	0	77	240	207	33	382	26	430	120	0	69	240	205	38	359	26	440	115	0	183
Calcium	mg/L	55	48	16	85	13	92	26	0	37	73	64	14	102	9.5	120	33	0	77	68	58	10	105	8.5	120	33	0	72	68	59	11	100	8.5	120	32	0	186
Magnesium	mg/L	15	12	2.0	22	1.9	22	7.6	0	37	19	16	2.0	26	1.5	32	9.3	0	77	17	14	1.4	27	1.2	38	9.3	0	72	17	15	1.6	26	1.2	38	9.0	0	186
Potassium	mg/L	1.0	1.8	<0.3	5.3	<0.3	7.1	1.6	4	37	0.50	*	<0.3	3.0	0.25	9.2	*	29	77	0.32	*	<0.3	3.2	<0.3	5.6	*	35	72	0.53	*	<0.3	3.6	0.25	9.2	*	68	186
Sodium	mg/L	3.7	3.7	1.2	7.1	1.1	7.4	2.0	0	37	5.3	4.9	1.1	8.4	1.0	12	2.7	0	77	4.8	4.3	1.2	7.4	<0.5	8.1	2.2	2	72	4.7	4.4	1.1	7.4	<0.5	12	2.4	2	186

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.
* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.

Table C1-1f: Seasonal Water Quality Summary in Ecohydrology Zone 6, 2002 to 2019

Parameter	Unit	Seasonal Summary: Winter									Spring									Summer									Fall									Summary 2002 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	—	—	—	—	—	—	—	0	0	7.6	7.3	6.4	7.9	6.2	8.0	0.61	0	11	7.6	7.4	6.3	8.0	6.0	8.2	0.59	0	24	7.3	7.2	6.3	7.9	6.0	8.3	0.62	0	16	7.5	7.3	6.3	8.0	6.0	8.3	0.60	0	51
pH (lab)	-	8.0	8.0	—	—	7.9	8.1	0.14	0	2	7.9	7.6	6.6	8.2	5.1	8.3	0.67	0	33	7.8	7.5	5.8	8.2	4.4	8.3	0.81	0	55	7.7	7.4	6.0	8.1	4.1	8.3	0.80	0	43	7.8	7.5	5.9	8.2	4.1	8.3	0.77	0	133
pH (field + lab)	-	—	—	—	—	—	—	—	0	0	7.1	6.9	5.1	7.7	5.1	8.0	0.79	0	21	7.1	6.8	4.4	7.8	4.2	8.0	0.97	0	37	6.8	6.7	4.6	7.7	4.1	8.3	0.94	0	27	7.1	6.8	4.5	7.8	4.1	8.3	0.91	0	85
Specific conductivity (field)	µS/cm	—	—	—	—	—	—	—	0	0	259	259	80	478	75	494	161	0	11	373	315	77	514	46	522	159	0	24	421	371	90	619	66	743	198	0	16	372	321	76	552	46	743	174	0	51
Electrical conductivity (field)	µS/cm	—	—	—	—	—	—	—	0	0	222	225	57	430	54	458	147	0	11	337	273	57	431	33	475	145	0	24	254	223	55	370	43	407	116	0	16	266	247	55	430	33	475	136	0	51
Electrical conductivity (lab)	µS/cm	545	545	—	—	470	620	106	0	2	300	302	70	620	16	670	186	0	33	380	357	34	683	27	740	214	0	56	430	363	49	697	27	800	225	0	43	375	348	38	680	16	800	211	0	134
Alkalinity (as $CaCO_3$)	mg/L	—	—	—	—	—	—	—	0	0	50	62	1	172	1	238	55	0	21	78	87	7	254	6	262	72	0	33	57	87	6	287	5	311	84	0	25	59	81	6	255	1	311	72	0	79
Total dissolved solids	mg/L	285	285	—	—	240	330	64	0	2	150	154	24	345	8.5	390	105	1	46	190	185	17	372	<10	390	122	2	79	220	194	34	370	12	460	124	0	57	190	181	19	370	8.5	460	119	3	184
Calcium	mg/L	76	76	—	—	63	88	18	0	2	38	42	4.0	91	0.83	110	29	0	46	54	53	4.0	101	1.0	110	33	0	79	60	54	5.4	110	2.7	120	34	0	58	52	51	4.0	108	0.83	120	32	0	185
Magnesium	mg/L	26	26	—	—	22	30	5.7	0	2	12	12	0.90	28	<0.2	31	9.0	2	46	16	15	0.65	30	0.34	31	11	1	79	18	14	1.2	30	0.45	32	10	0	58	16	14	0.77	30	<0.2	32	10	3	185
Potassium	mg/L	2.4	2.4	—	—	2.3	2.4	0.071	0	2	2.2	2.2	<0.3	5.2	<0.3	5.5	1.7	8	46	1.4	1.6	<0.3	4.0	<0.3	4.6	1.2	18	79	2.0	1.8	<0.3	4.4	<0.3	6.1	1.5	12	58	1.9	1.9	<0.3	4.2	<0.3	6.1	1.4	38	185
Sodium	mg/L	5.5	5.5	—	—	3.8	7.2	2.4	0	2	2.5	2.9	1.1	6.3	1.0	6.9	1.6	0	46	3.3	3.8	0.82	7.7	<0.5	12	2.4	5	79	3.3	3.6	1.5	7.1	0.86	8.0	1.9	0	58	3.3	3.5	1.2	7.2	<0.5	12	2.1	5	185

Spring = April - May; Summer = June - August; Fall = September - October; Winter = November - March.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.

Table C1-1g: Seasonal Water Quality Summary in Lowland Fen, 2002 to 2017

Parameter	Unit	Seasonal Summary: Spring									Summer									Fall									Summary 2002 - 2017								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.9	—	—	—	—	—	—	0	1	6.6	6.7	6.6	6.9	6.6	6.9	0.17	0	3	7.0	—	—	—	—	—	—	0	1	6.9	6.8	6.6	7.0	6.6	7.0	0.19	0	5
pH (lab)	-	7.4	7.2	6.5	7.7	6.3	7.8	0.45	0	17	7.3	7.1	6.2	7.7	5.9	7.9	0.53	0	27	7.1	7.0	6.2	7.6	6.1	7.7	0.44	0	28	7.3	7.1	6.3	7.7	5.9	7.9	0.48	0	72
pH (field + lab)	-	7.3	7.2	6.3	7.7	6.3	7.8	0.44	0	26	7.1	7.1	6.1	7.7	5.9	7.9	0.54	0	44	7.0	7.0	6.3	7.6	6.1	7.7	0.40	0	40	7.1	7.1	6.3	7.7	5.9	7.9	0.47	0	110
Specific conductivity (field)	µS/cm	687	—	—	—	—	—	—	0	1	676	673	658	686	656	688	16	0	3	672	—	—	—	—	—	—	0	1	676	676	659	688	656	688	13	0	5
Electrical conductivity (field)	µS/cm	457	—	—	—	—	—	—	0	1	508	506	484	527	481	529	24	0	3	542	—	—	—	—	—	—	0	1	508	503	462	539	457	542	35	0	5
Electrical conductivity (lab)	µS/cm	410	367	61	690	54	770	271	0	17	220	383	58	778	50	960	277	0	29	425	424	102	787	45	820	283	0	28	350	395	60	784	45	960	275	0	74
Alkalinity (as $CaCO_3$)	mg/L	127	177	23	369	20	443	146	0	26	107	208	24	441	12	557	160	0	46	316	239	41	452	20	467	163	0	40	148	212	22	443	12	557	159	0	112
Total dissolved solids	mg/L	207	193	29	370	6.1	440	141	0	26	130	212	55	435	24	500	145	0	46	290	238	57	420	24	440	149	0	39	170	217	33	420	6.1	500	145	0	111
Calcium	mg/L	44	51	6.9	100	6.5	130	40	0	26	36	57	10	128	5.4	130	41	0	46	79	63	16	120	6.5	130	41	0	40	47	58	7.9	120	5.4	130	41	0	112
Magnesium	mg/L	13	14	2.0	30	2.0	31	11	0	26	9.8	16	2.3	32	1.3	34	11	0	46	23	18	3.9	33	1.4	34	12	0	40	14	16	2.0	33	1.3	34	12	0	112
Potassium	mg/L	2.4	2.4	0.87	5.4	<0.3	6.0	1.4	1	26	2.3	2.3	<0.3	5.0	<0.3	7.9	1.8	7	46	2.9	2.6	<0.3	6.3	<0.3	6.8	1.9	5	40	2.3	2.5	<0.3	6.0	<0.3	7.9	1.7	13	112
Sodium	mg/L	1.9	3.1	0.88	6.4	<0.5	6.4	2.2	2	26	4.6	4.0	0.81	7.7	<0.5	9.1	2.6	4	46	4.7	4.1	<0.5	7.1	<0.5	7.4	2.5	4	40	4.5	3.8	0.80	7.1	<0.5	9.1	2.5	10	112

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.

Table C1-1h: Seasonal Water Quality Summary in North Outwash Plains, 2016 to 2019

Parameter	Unit	Seasonal Summary: Spring									Summer									Fall									Summary 2016 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.7	7.7	7.3	8.2	7.3	8.2	0.44	0	4	7.5	7.7	6.8	8.6	6.6	8.6	0.73	0	11	7.4	7.3	6.9	7.7	6.9	7.7	0.33	0	7	7.5	7.6	6.9	8.6	6.6	8.6	0.59	0	22
pH (lab)	-	8.0	8.1	7.9	8.3	7.9	8.4	0.24	0	4	7.7	7.5	6.7	8.2	6.5	8.3	0.57	0	11	7.8	7.6	6.8	8.2	6.8	8.2	0.52	0	8	7.8	7.7	6.8	8.3	6.5	8.4	0.52	0	23
pH (field + lab)	-	7.7	7.7	7.3	8.2	7.3	8.2	0.46	0	4	7.5	7.7	6.8	8.6	6.6	8.6	0.74	0	11	7.5	7.4	6.9	7.7	6.9	7.8	0.34	0	8	7.5	7.6	6.9	8.6	6.6	8.6	0.58	0	23
Specific conductivity (field)	µS/cm	303	316	146	506	145	516	195	0	4	143	193	82	498	81	561	156	0	11	174	239	92	514	91	546	179	0	7	151	230	83	545	81	561	168	0	22
Electrical conductivity (field)	µS/cm	282	278	132	417	130	418	160	0	4	130	172	70	440	66	462	135	0	11	103	140	53	291	53	307	99	0	7	130	181	55	418	53	462	133	0	22
Electrical conductivity (lab)	µS/cm	300	315	142	510	140	520	198	0	4	140	196	79	525	78	550	166	0	11	160	229	95	522	93	560	175	0	8	150	228	79	547	78	560	172	0	23
Alkalinity (as $CaCO_3$)	mg/L	160	166	67	274	66	279	112	0	4	68	109	35	284	35	287	100	0	9	77	112	42	259	41	270	89	0	8	71	121	35	279	35	287	96	0	21
Total dissolved solids	mg/L	158	167	73	274	73	280	108	0	4	73	102	38	280	37	290	89	0	11	82	118	47	269	44	290	90	0	8	78	119	40	289	37	290	91	0	23
Calcium	mg/L	46	48	22	77	22	78	29	0	4	22	31	13	83	12	86	26	0	11	25	35	14	79	14	88	26	0	8	24	35	13	85	12	88	26	0	23
Magnesium	mg/L	11	12	3.6	21	3.6	22	9.6	0	4	3.8	6.5	1.6	22	1.5	23	7.5	0	11	4.0	8.0	1.9	22	1.9	23	8.7	0	8	3.9	7.9	1.6	23	1.5	23	8.1	0	23
Potassium	mg/L	0.76	1.0	0.71	1.7	0.71	1.9	0.58	0	4	0.75	0.83	<0.3	1.8	<0.3	2.4	0.60	2	11	0.76	1.0	0.64	2.4	<0.3	2.9	0.84	1	8	0.75	0.94	<0.3	2.4	<0.3	2.9	0.67	3	23
Sodium	mg/L	2.7	3.0	1.5	4.9	1.5	5.1	1.7	0	4	1.5	1.9	0.83	4.6	<0.5	4.8	1.4	1	11	1.6	2.4	1.1	5.4	0.94	5.7	1.8	0	8	1.6	2.3	0.84	5.1	<0.5	5.7	1.6	1	23

Spring = April - May; Summer = June - August; Fall = September - October.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C1-1i: Seasonal Water Quality Summary in Fort Hills Upland Complex, 2008 to 2019

Parameter	Unit	Seasonal Summary: Winter									Spring									Summer									Fall									Summary 2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	—	—	—	—	—	—	—	0	0	7.4	7.3	6.6	7.7	6.5	7.8	0.39	0	10	7.2	7.3	6.8	7.9	6.7	8.1	0.36	0	26	7.4	7.4	6.9	7.8	6.9	7.9	0.31	0	16	7.3	7.3	6.8	7.8	6.5	8.1	0.35	0	52
pH (lab)	-	7.9	7.9	7.7	8.1	7.7	8.1	0.28	0	2	7.9	7.8	7.3	8.1	6.9	8.2	0.30	0	25	7.8	7.7	6.9	8.1	6.7	8.3	0.37	0	43	7.8	7.7	6.6	8.2	6.5	8.3	0.43	0	39	7.8	7.8	6.9	8.2	6.5	8.3	0.38	0	109
pH (field + lab)	-	7.9	7.9	7.7	8.0	7.7	8.1	0.23	0	2	7.7	7.7	6.9	8.1	6.5	8.2	0.41	0	32	7.7	7.6	6.9	8.0	6.7	8.1	0.39	0	53	7.7	7.6	6.9	8.2	6.6	8.3	0.37	0	46	7.7	7.6	6.9	8.1	6.5	8.3	0.39	0	133
Specific conductivity (field)	µS/cm	—	—	—	—	—	—	—	0	0	322	393	112	723	39	727	245	0	10	283	354	42	730	38	753	234	0	26	323	388	55	739	50	746	245	0	16	288	372	44	734	38	753	236	0	52
Electrical conductivity (field)	µS/cm	—	—	—	—	—	—	—	0	0	258	289	98	514	41	537	154	0	10	238	304	39	611	32	693	198	0	26	208	240	34	463	28	487	146	0	16	238	281	37	581	28	693	175	0	52
Electrical conductivity (lab)	µS/cm	625	625	540	711	530	720	134	0	2	450	469	166	726	33	750	224	0	25	500	450	38	757	35	780	249	0	43	570	508	53	750	46	770	231	0	39	530	479	45	750	33	780	235	0	109
Alkalinity (as $CaCO_3$)	mg/L	324	324	276	372	270	377	75	0	2	234	252	75	410	10	410	125	0	32	295	262	14	420	12	443	138	0	53	332	281	22	424	16	434	130	0	46	295	267	16	418	10	443	131	0	133
Total dissolved solids	mg/L	325	325	276	375	270	380	78	0	2	235	252	91	400	15	400	120	0	32	260	252	16	424	9.2	430	137	0	53	320	279	25	408	21	430	122	0	46	290	262	18	410	9.2	430	127	0	133
Calcium	mg/L	91	91	74	108	72	110	27	0	2	64	68	25	110	3.3	110	33	0	32	80	72	3.7	114	3.3	120	37	0	53	88	75	5.2	110	4.5	120	33	0	46	82	72	4.4	110	3.3	120	34	0	133
Magnesium	mg/L	29	29	25	33	25	33	5.7	0	2	19	20	7.3	32	1.2	33	9.9	0	32	23	20	1.4	32	1.3	33	10	0	53	24	22	1.8	35	1.6	36	10	0	46	23	21	1.6	33	1.2	36	10	0	133
Potassium	mg/L	2.4	2.4	2.1	2.7	2.1	2.7	0.42	0	2	3.2	3.6	1.6	6.7	1.3	7.5	1.6	0	32	2.5	2.5	1.1	4.3	<0.3	5.1	1.0	2	53	2.7	2.8	1.5	4.8	1.2	5.2	0.87	0	46	2.7	2.8	1.3	4.9	<0.3	7.5	1.2	2	133
Sodium	mg/L	6.1	6.1	5.8	6.3	5.8	6.3	0.35	0	2	4.8	4.8	1.5	11	0.85	12	3.0	0	32	4.9	4.5	0.78	8.8	<0.5	16	3.0	2	53	5.2	5.1	1.4	11	0.87	17	3.1	0	46	5.0	4.8	0.88	11	<0.5	17	3.0	2	133

Spring = April - May; Summer = June - August; Fall = September - October; Winter = November - March.
$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no data or not applicable.

InnoTech (InnoTech Alberta). 2021. *Developing an Improved Understanding of Past and Present Hydrology and Ecosystem Processes in the McClelland Lake Wetland Complex: Phase 2 Final Report.* Submitted to Suncor Energy Inc. March 2021.

Table C1-2: Seasonal Water Quality Summary in McClelland Lake, 2000 to 2019

Parameter	Unit	Guideline for the Protection of Aquatic Life (Chronic)	Seasonal Summary: Winter									Spring									Summer										Fall										Summary 2000 - 2019									
			Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	% Above Guideline	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	% Above Guideline	Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count	% Above Guideline
pH (field)	-	6.5 - 9.0	—	—	—	—	—	—	—	0	0	7.3	7.4	6.8	8.1	6.8	8.2	0.66	0	4	7.0	7.3	6.4[a]	8.6	6.2[a]	8.6	0.90	0	7	14	8.3	8.1	6.6	9.1[a]	6.1[a]	9.1[a]	0.94	0	11	18	7.7	7.7	6.2[a]	9.0	6.1[a]	9.1[a]	0.93	0	22	14
pH (lab)	-	—	8.1	8.1	8.1	8.1	8.1	8.1	0	0	2	7.8	7.8	7.3	8.3	7.3	8.4	0.36	0	8	7.5	7.7	7.2	8.8	7.1	8.9	0.59	0	14	-	8.3	8.1	6.9	8.7	6.6	8.7	0.63	0	25	—	8.0	7.9	7.2	8.7	6.6	8.9	0.58	0	49	—
pH (field + lab)	-	—	8.1	8.0	7.9	8.1	7.9	8.1	0.11	0	3	7.9	7.7	6.8	8.3	6.8	8.4	0.48	0	13	7.4	7.5	6.6	8.7	6.2	8.9	0.71	0	24	—	8.2	7.9	6.5	9.0	6.1	9.1	0.77	0	32	—	7.7	7.8	6.6	8.8	6.1	9.1	0.71	0	72	—
Specific conductivity (field)	µS/cm	—	—	—	—	—	—	—	—	0	0	260	241	188	266	176	267	43	0	4	213	203	125	257	100	270	52	0	7	—	220	222	100	295	50	297	83	0	7	—	221	219	93	292	50	297	63	0	18	—
Electrical conductivity (field)	µS/cm	—	—	—	—	—	—	—	—	0	0	200	191	151	219	143	223	34	0	4	188	178	99	235	76	245	57	0	6	—	231	196	84	254	35	257	72	0	9	—	200	189	72	251	35	257	59	0	19	—
Electrical conductivity (lab)	µS/cm	—	—	—	—	—	—	—	—	0	0	260	246	177	291	150	300	47	0	7	230	226	195	255	190	260	23	0	11	—	220	195	77	286	59	290	75	0	10	—	230	220	118	287	59	300	54	0	28	—
Alkalinity (as $CaCO_3$)	mg/L	20[b]	197	191	160	219	156	221	33	0	3	139	131	103	148	73	148	20	0	13	123	118	90	132	90	140	15	0	19	—	115	109	43	141	27	156	32	0	19	—	123	122	72	156	27	221	30	0	54	—
Total dissolved solids	mg/L	—	230	230	194	266	190	270	40	0	3	130	134	95	178	79	190	28	0	13	125	126	95	169	95	180	21	0	22	—	142	134	59	184	29	230	43	0	32	—	132	136	79	192	29	270	40	0	70	—
Calcium	mg/L	—	33	33	31	34	31	34	1.5	0	3	27	26	22	29	18	29	2.8	0	12	24	23	18	29	13	29	3.9	0	20	—	20	20	11	25	7.4	26	4.4	0	28	—	23	23	13	29	7.4	34	5.1	0	63	—
Magnesium	mg/L	—	25	24	20	28	19	28	4.6	0	3	15	15	12	18	9.6	19	2.1	0	13	15	15	12	18	12	19	2.0	0	21	—	14	13	2.9	20	1.5	21	5.5	0	19	—	15	15	8.2	20	1.5	28	4.3	0	56	—
Potassium	mg/L	—	4.3	4.1	3.1	5.0	3.0	5.1	1.1	0	3	2.8	3.3	2.2	6.2	1.7	6.2	1.4	0	13	2.3	2.1	1.4	2.8	<0.3	3.1	0.71	2	21	—	2.8	2.4	<0.3	3.7	<0.3	4.5	1.2	3	19	—	2.7	2.6	0.77	4.7	<0.3	6.2	1.2	5	56	—
Sodium	mg/L	—	7.7	7.2	6.2	7.8	6.0	7.8	1.0	0	3	4.4	4.7	3.6	5.9	3.1	5.9	0.90	0	13	4.2	4.2	3.2	5.0	3.2	5.3	0.65	0	21	—	4.2	4.1	1.5	6.0	1.2	6.0	1.4	0	19	—	4.3	4.4	2.9	6.0	1.2	7.8	1.2	0	56	—
Chlorophyll *a*	µg/L	—	—	—	—	—	—	—	—	0	0	0.0058	*	<0.0045	0.020	<0.0005	0.022	*	2	5	0.011	0.073	0.0049	0.35	0.0024	0.51	0.15	0	11	—	0.011	0.063	0.0026	0.28	0.0021	0.43	0.13	1	10	—	0.0100	0.057	0.0022	0.37	<0.0005	0.51	0.13	3	26	—

[a] concentration is outside the recommended pH range for the protection of aquatic life (GOA/CCME guideline).
[b] guideline is a minimum value, unless the background concentration or value is lower (GOA 2018).
$CaCO_3$ = calcium carbonate; < = less than; µg/L = micrograms per litre; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units; — = no guidelines or data.

* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.

GOA (Government of Alberta). 2018. *Environmental Quality Guidelines for Alberta Surface Waters.* Water Policy Branch.

C2 Groundwater Quality

Table C2-1a: Groundwater Quality Summary for Peat in Ecohydrology Zone 1, 2009 to 2019

Parameter	Unit	Summary 2009 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.2	6.3	6.1	6.6	6.1	6.8	0.20	0	18
pH (lab)	-	7.0	7.0	6.7	7.5	6.6	7.6	0.24	0	65
pH (field + lab)	-	6.9	6.9	6.2	7.5	6.1	7.6	0.37	0	92
Specific conductivity (field)	µS/cm	309	281	149	363	135	417	81	0	18
Electrical conductivity (field)	µS/cm	201	199	105	298	88	303	59	0	18
Electrical conductivity (lab)	µS/cm	270	254	150	355	120	410	71	0	66
Alkalinity (as $CaCO_3$)	mg/L	139	130	68	172	57	213	35	0	90
Total dissolved solids	mg/L	140	134	73	180	61	210	36	0	90
Calcium	mg/L	46	43	23	61	20	67	12	0	90
Magnesium	mg/L	7.9	7.5	4.2	10	3.9	12	1.8	0	90
Potassium	mg/L	<0.3	*	<0.3	<0.3	<0.3	0.56	*	89	90
Sodium	mg/L	1.9	1.9	1.2	2.6	1.2	2.9	0.42	0	90

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.

Table C2-1b: Groundwater Quality Summary for Peat in Ecohydrology Zone 2, 2002 to 2019

Parameter	Unit	Summary 2002 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.7	6.7	5.6	7.0	5.4	7.4	0.36	0	86
pH (lab)	-	7.5	7.5	7.1	7.9	6.9	8.1	0.22	0	261
pH (field + lab)	-	7.4	7.3	6.6	7.8	5.4	8.1	0.44	0	362
Specific conductivity (field)	µS/cm	864	844	582	1,097	467	1,112	147	0	86
Electrical conductivity (field)	µS/cm	563	576	406	770	314	841	103	0	85
Electrical conductivity (lab)	µS/cm	830	816	541	1,100	100	1,100	144	0	262
Alkalinity (as $CaCO_3$)	mg/L	459	452	287	566	52	680	84	0	357
Total dissolved solids	mg/L	450	439	280	550	55	640	81	0	353
Calcium	mg/L	120	118	83	150	17	160	21	0	355
Magnesium	mg/L	32	33	20	50	2.3	65	8.7	0	355
Potassium	mg/L	2.5	2.4	<0.3	5.2	<0.3	6.4	1.4	28	355
Sodium	mg/L	8.5	8.7	4.4	15	1.2	25	3.5	0	355

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-1c: Groundwater Quality Summary for Peat in Ecohydrology Zone 3, 2002 to 2019

Parameter	Unit	Summary 2002 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.5	6.2	5.2	6.8	5.0	6.9	0.67	0	7
pH (lab)	-	7.0	7.1	6.7	7.6	6.7	8.2	0.33	0	30
pH (field + lab)	-	7.0	7.0	6.5	7.5	5.6	8.2	0.42	0	37
Specific conductivity (field)	μS/cm	505	509	497	529	496	530	14	0	7
Electrical conductivity (field)	μS/cm	309	311	289	342	289	352	22	0	7
Electrical conductivity (lab)	μS/cm	470	457	292	536	210	560	75	0	29
Alkalinity (as $CaCO_3$)	mg/L	262	251	123	305	107	368	51	0	37
Total dissolved solids	mg/L	270	253	120	300	110	300	46	0	39
Calcium	mg/L	70	69	32	88	32	105	15	0	39
Magnesium	mg/L	17	16	7.1	19	6.9	26	3.4	0	39
Potassium	mg/L	1.2	1.4	0.85	3.7	0.60	3.9	0.73	0	39
Sodium	mg/L	4.8	5.2	2.8	7.6	2.0	11	1.7	0	39

$CaCO_3$ = calcium carbonate; μS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-1d: Groundwater Quality Summary for Peat in Ecohydrology Zone 4, 2009 to 2019

Parameter	Unit	Summary 2009 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.6	6.6	6.5	6.8	6.4	7.1	0.15	0	18
pH (lab)	-	7.3	7.4	7.0	7.8	6.9	7.9	0.25	0	50
pH (field + lab)	-	7.3	7.2	6.5	7.8	6.4	7.9	0.41	0	71
Specific conductivity (field)	μS/cm	818	728	323	952	250	980	236	0	18
Electrical conductivity (field)	μS/cm	545	494	242	632	196	714	140	0	18
Electrical conductivity (lab)	μS/cm	755	667	306	920	220	970	228	0	52
Alkalinity (as $CaCO_3$)	mg/L	410	359	156	516	107	541	133	0	70
Total dissolved solids	mg/L	405	347	144	510	22	520	132	0	70
Calcium	mg/L	120	103	44	156	31	160	38	0	70
Magnesium	mg/L	24	23	15	30	9.3	32	5.0	0	70
Potassium	mg/L	0.68	0.77	<0.3	1.5	<0.3	1.9	0.47	13	70
Sodium	mg/L	5.2	4.9	2.8	6.6	2.0	9.5	1.5	0	70

$CaCO_3$ = calcium carbonate; < = less than; μS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-1e: Groundwater Quality Summary for Peat in Ecohydrology Zone 5, 2002 to 2019

Parameter	Unit	Summary 2002 - 2019								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.6	6.6	6.3	7.1	6.3	7.3	0.26	0	22
pH (lab)	-	7.2	7.3	6.9	7.7	6.7	7.8	0.26	0	77
pH (field + lab)	-	7.2	7.1	6.4	7.7	5.8	7.8	0.39	0	115
Specific conductivity (field)	µS/cm	487	447	187	575	167	597	133	0	22
Electrical conductivity (field)	µS/cm	314	296	110	418	110	430	97	0	22
Electrical conductivity (lab)	µS/cm	440	412	152	552	89	760	146	0	77
Alkalinity (as $CaCO_3$)	mg/L	238	219	61	310	34	402	83	0	113
Total dissolved solids	mg/L	240	222	62	320	28	400	85	0	108
Calcium	mg/L	70	65	19	90	16	120	24	0	113
Magnesium	mg/L	17	15	2.9	22	2.1	26	6.0	0	113
Potassium	mg/L	0.50	*	<0.3	<1.5	<0.3	2.6	*	42	113
Sodium	mg/L	4.6	4.5	1.7	6.6	0.50	8.4	1.5	0	113

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.
* = In cases where 25% or more of data were lower than the detection limit, no mean or standard deviation was calculated.

Table C2-1f: Groundwater Quality Summary for Peat in Ecohydrology Zone 6, 2009 to 2017

Parameter	Unit	Summary 2009 - 2017								
		Median	Mean	5^{th} Percentile	95^{th} Percentile	Min	Max	Standard Deviation	nd	Count
pH (lab)	-	7.8	7.8	7.5	8.1	7.4	8.1	0.17	0	50
Electrical conductivity (lab)	µS/cm	710	710	505	923	430	1,000	123	0	50
Alkalinity (as $CaCO_3$)	mg/L	406	415	276	583	238	664	85	0	70
Total dissolved solids	mg/L	380	391	273	550	230	600	75	0	70
Calcium	mg/L	100	104	73	150	60	180	23	0	70
Magnesium	mg/L	29	28	21	37	16	37	4.9	0	70
Potassium	mg/L	2.4	2.1	0.50	3.5	<0.3	3.6	1.0	4	70
Sodium	mg/L	5.3	5.5	3.7	8.1	3.0	8.3	1.4	0	70

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-1g: Groundwater Quality Summary for Peat in Fort Hills Upland Complex, 2002 to 2019

Parameter	Unit	Summary 2002 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.8	6.7	5.9	7.0	5.4	7.0	0.46	0	10
pH (lab)	-	7.6	7.6	7.2	8.0	7.2	8.1	0.25	0	46
pH (field + lab)	-	7.5	7.4	6.4	8.0	5.4	8.1	0.50	0	68
Specific conductivity (field)	µS/cm	924	913	852	949	826	949	40	0	10
Electrical conductivity (field)	µS/cm	630	646	533	779	533	798	87	0	10
Electrical conductivity (lab)	µS/cm	690	707	443	940	220	970	197	0	47
Alkalinity (as $CaCO_3$)	mg/L	389	380	199	525	90	574	117	0	68
Total dissolved solids	mg/L	370	376	213	520	120	550	111	0	64
Calcium	mg/L	96	103	51	150	32	160	35	0	68
Magnesium	mg/L	27	28	18	40	11	44	8.4	0	68
Potassium	mg/L	0.81	1.1	0.42	2.3	0.29	4.1	0.72	0	68
Sodium	mg/L	5.7	5.8	3.1	8.8	2.1	9.1	1.9	0	68

$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2a: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 1, 2017 to 2019

Parameter	Unit	Summary 2017 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.4	7.4	6.9	7.8	6.7	7.8	0.37	0	16
pH (lab)	-	8.0	7.9	7.4	8.4	7.3	8.4	0.32	0	14
pH (field + lab)	-	7.4	7.3	6.9	7.8	6.7	7.8	0.37	0	16
Specific conductivity (field)	µS/cm	714	754	574	1,020	568	1,025	161	0	16
Electrical conductivity (field)	µS/cm	449	485	358	664	351	692	116	0	16
Electrical conductivity (lab)	µS/cm	770	773	577	977	570	990	188	0	14
Alkalinity (as $CaCO_3$)	mg/L	402	406	306	506	295	516	91	0	14
Total dissolved solids	mg/L	435	443	317	567	310	580	116	0	14
Calcium	mg/L	60	62	21	110	20	110	42	0	14
Magnesium	mg/L	9.6	9.9	6.4	14	6.4	14	3.3	0	14
Potassium	mg/L	3.3	3.3	2.4	4.2	2.3	4.3	0.81	0	14
Sodium	mg/L	100	103	5.6	210	5.4	210	100	0	14

$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2b: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 2, 2008 to 2019

Parameter	Unit	Summary 2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.8	6.8	6.5	7.6	5.4	7.7	0.37	0	76
pH (lab)	-	7.5	7.5	7.2	7.9	7.0	8.2	0.22	0	207
pH (field + lab)	-	7.4	7.3	6.6	7.8	5.4	8.0	0.44	0	211
Specific conductivity (field)	µS/cm	867	866	362	1,191	354	1,278	227	0	76
Electrical conductivity (field)	µS/cm	566	566	230	813	220	913	161	0	76
Electrical conductivity (lab)	µS/cm	850	843	513	1,190	190	1,200	173	0	203
Alkalinity (as $CaCO_3$)	mg/L	467	470	277	648	82	746	103	0	209
Total dissolved solids	mg/L	460	465	274	646	110	720	97	0	209
Calcium	mg/L	120	117	63	150	20	170	25	0	203
Magnesium	mg/L	31	33	16	62	4.1	68	12	0	203
Potassium	mg/L	4.4	4.7	2.7	7.9	<0.3	11	1.6	1	203
Sodium	mg/L	17	17	5.5	30	4.3	67	8.1	0	203

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2c: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 3, 2008 to 2018

Parameter	Unit	Summary 2008 - 2018								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.6	6.5	6.0	6.7	5.9	6.7	0.26	0	14
pH (lab)	-	7.3	7.4	7.1	7.7	7.0	8.0	0.21	0	52
pH (field + lab)	-	7.3	7.1	6.5	7.7	5.9	7.8	0.42	0	52
Specific conductivity (field)	µS/cm	745	741	690	817	688	864	50	0	14
Electrical conductivity (field)	µS/cm	446	442	407	482	405	509	28	0	14
Electrical conductivity (lab)	µS/cm	670	657	450	710	370	720	78	0	50
Alkalinity (as $CaCO_3$)	mg/L	361	355	248	393	180	402	43	0	52
Total dissolved solids	mg/L	370	363	248	410	200	410	45	0	52
Calcium	mg/L	120	115	79	130	42	140	17	0	50
Magnesium	mg/L	16	16	11	18	7.7	19	2.3	0	50
Potassium	mg/L	2.0	2.0	1.3	2.8	<0.3	3.5	0.57	1	50
Sodium	mg/L	3.9	4.7	3.3	8.0	2.5	25	3.2	0	50

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2d: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 4, 2008 to 2019

Parameter	Unit	Summary 2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	6.8	6.9	6.5	7.5	5.7	9.2	0.51	0	39
pH (lab)	-	7.5	7.4	6.7	8.0	6.5	8.1	0.41	0	77
pH (field + lab)	-	7.0	7.1	6.5	7.8	5.7	9.2	0.50	0	79
Specific conductivity (field)	µS/cm	794	759	585	914	84	945	164	0	39
Electrical conductivity (field)	µS/cm	502	490	394	592	190	888	102	0	39
Electrical conductivity (lab)	µS/cm	800	626	82	890	61	930	301	0	75
Alkalinity (as $CaCO_3$)	mg/L	426	339	41	494	30	525	172	0	76
Total dissolved solids	mg/L	430	352	61	512	46	530	162	0	77
Calcium	mg/L	110	86	12	130	9.2	140	45	0	75
Magnesium	mg/L	22	19	2.2	29	1.2	30	9.6	0	75
Potassium	mg/L	3.4	3.1	1.0	6.1	<0.3	6.4	1.7	1	75
Sodium	mg/L	13	23	1.3	130	<0.5	140	37	1	75

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2e: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 5, 2009 to 2019

Parameter	Unit	Summary								
		2009 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.1	7.1	6.5	7.9	5.3	8.0	0.53	0	65
pH (field)	-	7.8	7.7	7.1	8.1	6.8	8.3	0.32	0	93
pH (field + lab)	-	7.4	7.3	6.6	8.0	5.3	8.1	0.54	0	102
Specific conductivity (field)	µS/cm	535	514	158	837	82	861	238	0	65
Electrical conductivity (field)	µS/cm	308	311	105	517	23	552	151	0	65
Electrical conductivity (lab)	µS/cm	270	409	140	840	48	860	260	0	93
Alkalinity (as $CaCO_3$)	mg/L	139	211	68	451	23	500	145	0	99
Total dissolved solids	mg/L	140	214	71	460	25	490	144	0	99
Calcium	mg/L	39	58	20	120	7.4	140	39	0	99
Magnesium	mg/L	6.9	13	3.0	34	1.5	38	10	0	99
Potassium	mg/L	1.4	1.6	0.42	4.2	<0.3	6.7	1.1	5	99
Sodium	mg/L	5.2	9.5	1.6	38	<0.5	48	12	2	99

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2f: Groundwater Quality Summary for Quaternary Aquifer in Ecohydrology Zone 6, 2008 to 2019

Parameter	Unit	Summary								
		2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.2	7.2	6.9	7.6	6.2	7.7	0.27	0	42
pH (lab)	-	7.8	7.8	7.5	8.1	7.2	8.2	0.21	0	64
pH (field + lab)	-	7.5	7.4	6.9	8.0	6.2	8.1	0.37	0	58
Specific conductivity (field)	µS/cm	656	779	228	1,591	208	1,936	458	0	42
Electrical conductivity (field)	µS/cm	412	502	120	1,114	27	1,544	346	0	42
Electrical conductivity (lab)	µS/cm	680	778	441	1,500	200	2,000	367	0	63
Alkalinity (as $CaCO_3$)	mg/L	369	348	236	412	98	451	72	0	56
Total dissolved solids	mg/L	365	432	240	870	100	1,300	227	0	64
Calcium	mg/L	90	85	55	110	26	130	22	0	63
Magnesium	mg/L	27	25	14	32	6.1	34	6.7	0	63
Potassium	mg/L	3.3	3.6	1.9	6.5	0.55	8.8	1.4	0	63
Sodium	mg/L	5.5	47	3.6	260	1.8	300	91	0	63

$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2g: Groundwater Quality Summary for Quaternary Aquifer in Fort Hills Upland Complex, 2006 to 2019

Parameter	Unit	Summary								
		2006 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.2	7.2	7.0	7.6	5.7	8.0	0.30	0	183
pH (lab)	-	7.8	7.8	7.3	8.1	6.8	8.3	0.23	0	280
pH (field + lab)	-	7.6	7.5	7.0	8.0	5.7	8.3	0.40	0	209
Specific conductivity (field)	µS/cm	623	597	276	810	62	1,016	171	0	184
Electrical conductivity (field)	µS/cm	384	372	168	515	119	618	103	0	184
Electrical conductivity (lab)	µS/cm	655	639	327	870	180	1,000	154	0	274
Alkalinity (as $CaCO_3$)	mg/L	328	326	156	484	76	516	93	0	204
Total dissolved solids	mg/L	360	350	170	490	98	600	89	0	281
Calcium	mg/L	90	90	52	130	23	150	22	0	274
Magnesium	mg/L	28	27	9.8	40	4.6	46	7.7	0	274
Potassium	mg/L	2.7	2.7	1.1	4.0	<0.3	5.9	0.97	1	274
Sodium	mg/L	6.7	10	2.6	28	1.3	120	14	0	274

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-2h: Groundwater Quality Summary for Quaternary Aquifer in North Outwash Plains, 2008 to 2019

Parameter	Unit	Summary								
		2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (filed)	-	7.7	7.7	6.8	8.4	5.5	9.3	0.57	0	141
pH (lab)	-	8.0	7.8	6.1	8.2	5.0	9.2	0.59	0	291
pH (field + lab)	-	7.9	7.7	6.0	8.3	5.0	9.3	0.65	0	300
Specific conductivity (field)	µS/cm	258	294	129	629	39	976	172	0	141
Electrical conductivity (field)	µS/cm	157	181	80	395	29	596	105	0	140
Electrical conductivity (lab)	µS/cm	220	250	79	608	44	1,000	149	0	286
Alkalinity (as $CaCO_3$)	mg/L	107	123	6	292	2	426	79	0	288
Total dissolved solids	mg/L	110	136	44	330	22	600	85	0	296
Calcium	mg/L	33	34	7.1	62	3.7	130	18	0	286
Magnesium	mg/L	5.3	6.5	1.5	14	0.82	23	4.4	0	286
Potassium	mg/L	0.99	1.4	0.44	3.4	<0.3	9.5	1.2	2	286
Sodium	mg/L	3.0	9.5	1.4	37	1.1	200	22	0	286

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-3: Groundwater Quality Summary for Quaternary Aquitard, 2006 to 2019

Parameter	Unit	Summary 2006 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.3	7.3	6.2	8.2	5.7	12	0.68	0	135
pH (lab)	-	7.8	7.8	7.5	8.1	7.2	12	0.41	0	132
pH (field + lab)	-	7.3	7.3	6.2	8.2	5.7	12	0.67	0	144
Specific conductivity (field)	µS/cm	645	665	192	1,220	4.8	2,575	323	0	135
Electrical conductivity (field)	µS/cm	390	470	118	775	40	9,016	768	0	135
Electrical conductivity (lab)	µS/cm	700	705	250	1,200	170	2,100	288	0	131
Alkalinity (as $CaCO_3$)	mg/L	361	367	127	603	69	672	133	0	130
Total dissolved solids	mg/L	375	388	140	715	89	770	158	0	132
Calcium	mg/L	74	76	27	120	6.1	130	27	0	131
Magnesium	mg/L	25	24	6.1	39	<0.2	44	9.9	1	131
Potassium	mg/L	3.6	3.8	1.6	7.2	0.52	9.3	1.8	0	130
Sodium	mg/L	16	42	3.5	220	1.8	260	63	0	131

$CaCO_3$ = calcium carbonate; < = less than; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Table C2-4: Groundwater Quality Summary for Basal, 2008 to 2019

Parameter	Unit	Summary 2008 - 2019								
		Median	Mean	5th Percentile	95th Percentile	Min	Max	Standard Deviation	nd	Count
pH (field)	-	7.3	7.4	7.1	8.2	7.0	9.3	0.58	0	13
pH (lab)	-	7.9	7.9	7.6	8.2	7.6	8.3	0.19	0	35
pH (field + lab)	-	7.7	7.7	7.1	8.2	7.0	9.3	0.43	0	36
Specific conductivity (field)	µS/cm	717	724	674	773	645	773	38	0	13
Electrical conductivity (field)	µS/cm	456	466	412	523	396	535	40	0	13
Electrical conductivity (lab)	µS/cm	780	774	700	832	700	1,100	71	0	33
Alkalinity (as $CaCO_3$)	mg/L	406	403	366	434	361	443	25	0	34
Total dissolved solids	mg/L	430	427	390	466	390	542	29	0	35
Calcium	mg/L	66	73	54	94	54	96	16	0	33
Magnesium	mg/L	21	24	17	31	17	32	5.7	0	33
Potassium	mg/L	6.9	8.8	5.3	16	5.0	17	3.6	0	33
Sodium	mg/L	67	62	40	87	39	99	20	0	33

$CaCO_3$ = calcium carbonate; µS/cm = microsiemens per centimetre; mg/L = milligrams per litre; Min = minimum; Max = maximum; nd = non-detected; - = no units.

Appendix D

Integrated Hydrological Modelling of the McCLelland Lake Wetland Complex - Report

Integrated Hydrologic Modelling of the McClelland Lake Wetland Complex

Support for the McClelland Lake Wetland Complex Operational Plan

Report Submitted to:

Water Resources
Geoservices & Mine Planning
Suncor Energy Inc.
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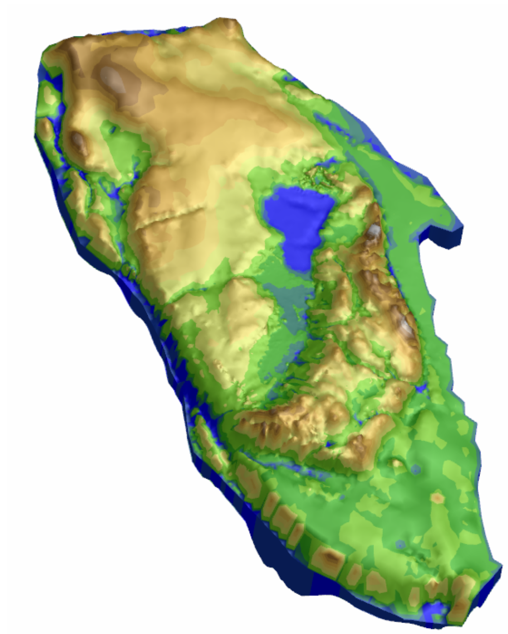

Final: 10 December 2021

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Date	Version	Revision Description
10 December 2021	V1.0	Final Issued to Client

1.0 TABLE OF CONTENTS

FIGURES

TABLES

ATTACHMENTS

ABBREVIATIONS

AER: Alberta Energy Regulator

AET: Actual evapotranspiration

Baseline Model: the 2020 MLWC HGS Baseline Model.

Calibration Model: the 2020 MLWC HGS Calibration Model

Closure Model: The 2020 MLWC HGS Closure Model

CPL: Centre Pit Lake

CPDDA: Centre Pit Dedicated Disposal Area

CPTA: Centre Pit Tailings Area

DEM: Digital elevation model

EOY: End of year

ECCC: Environment and Climate Change Canada

ET: Evapotranspiration

FEM: Finite element mesh

FHEC: Fort Hills Energy Corporation

FHUC: Fort Hills Upland Complex

GW: Groundwater

HGS: HydroGeoSphere

HRA: Hydrologic response area

IPA: Integrated Plan Amendment

K: Hydraulic conductivity (saturated)

LAI: Leaf area index.

LFH: Litter, fermenting\rotting, humus

mASL: Metres above sea level

MFT: Mature fine tailings

MLWC: McClelland Lake Wetland Complex

N.A.: Not applicable

NED: North External Dump

NOP: North Outwash Plains

NPDDA: North Pit Dedicated Disposal Area

NPL: North Pit Lake

NPTA: North Pit Tailings Area

OP: Operational Plan

Operations Model: the 2020 MLWC HGS Operations model.

OPTA: Out of Pit Tailings Area

PET: Potential evapotranspiration

PGKM: Pleistocene glacially rafted McMurray oil sand

QA/QC: Quality assurance and quality control

RAMP: Regional Aquatics Monitoring Program

R0 Scenario: Pre-development baseline scenario that include no Fort Hills mine development.

R1 Scenario: Full Fort Hills mine development scenario without mitigation (no water management design features).

S1 Scenario: Full Fort Hills mine development including mitigation (includes water management design features).

SED: South External Dump

SMS: Seepage Management System

SPDDA: South Pit Dedicated Disposal Area

SPL: South Pit Lake

SPTA: South Pit Tailings Area

SW: Surface water

Water Balance Model: The 2020 MLWC HGS Water Balance Model

WBF: Western Boreal Forest

WRF: Weather Research and Forecasting

1.0 INTRODUCTION

Aquanty Inc. (Aquanty) was commissioned by Fort Hills Energy Corporation (FHEC) to build an integrated surface-subsurface hydrologic model to support proposed water management design features to sustain the hydrologic functioning of the McClelland Lake Wetland Complex (MLWC) during mine operations and through closure of the Fort Hills Project. The area of the MLWC is illustrated in Figure 1-1. Hydrologic modelling was conducted using the fully-integrated surface-subsurface hydrologic model, HydroGeoSphere (HGS) to simulate pre-development, operations and closure hydrological conditions as part of the MLWC Operational Plan (OP) by incorporating the effects of proposed mining operations, water management design features, and the closure landscape on the non-mined portion of the MLWC and its surrounding watershed. Since 2017, the HGS model has undergone regular annual updates to include newly collected site data and to reflect the latest conceptual understanding of the hydrologic system.

This report documents the current state of the MLWC HGS Model in 2020 (herein referred to as the 2020 MLWC HGS Model) and its application for supporting the 2021 MLWC OP assessment. The 2020 MLWC HGS Model was previously applied in support of the 2021 Fort Hills Integrated Plan Amendment (IPA) assessment, recently submitted to the Alberta Energy Regulator (AER).

1.1 Objectives

The primary objectives of the development and application of the 2020 MLWC HGS model in supporting the 2021 MLWC OP assessment were:

- To simulate baseline (pre-development) hydrological conditions within the MLWC watershed;
- To simulate hydrological conditions during operations within the MLWC watershed using the 2021 IPA Mine Plan;
- To simulate hydrological conditions during active closure and far-future periods within the MLWC watershed;
- To conduct a climate change analysis in terms of hydrological conditions shortly into the active closure period (approximately mid-century) and again at a far-future period (approximately the end of the 21st century);
- To quantify how mine development in the MLWC and the surrounding landscape that contributes water to the MLWC could potentially impact the non-mined portion of the MLWC (as defined in Figure 1-1 of FHEC [2021]); and
- To simulate water management design features to sustain the hydrologic functioning of the non-mined portion of the MLWC, that includes a cutoff wall to maintain groundwater (GW) heads within the non-mined portion of the fen, surface water (SW) resupply to maintain SW flows (both magnitude and timing) and water levels within the patterned fen, and GW injection to maintain subsurface GW discharge into the northern portion of the patterned fen.

Accomplishing the above objectives required building a series of models from a common foundation. Flux and water level tracking was added to these models to facilitate evaluation of the water management design features. This document describes the 2020 MLWC HGS model construction, calibration, validation, and application to support the 2021 MLWC OP assessment.

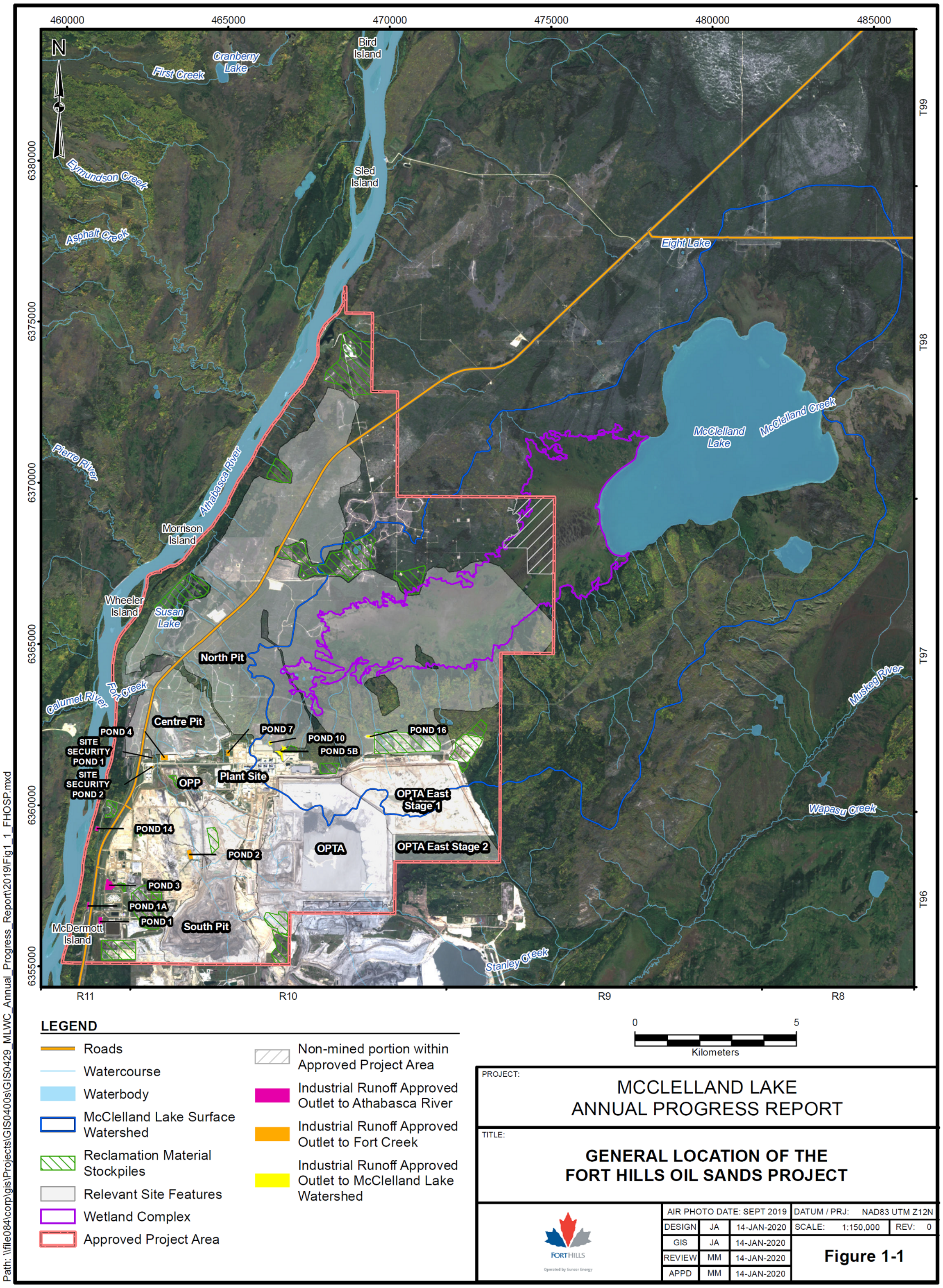


Figure 1-1: General location of the Fort Hills Oil Sands Project (source: FHEC 2021).

2.0 CONCEPTUAL MODEL IMPLEMENTATION

The MLWC system can be generalized as an area of complex SW-GW interaction fed from the sandy uplands of the North Outwash Plains (NOP) to the north and the Fort Hills Upland Complex (FHUC) situated to the south of an extreme-rich patterned fen. A second, moderately-rich patterned fen lies to the north of the extreme-rich one and both patterned fens drain eastwards towards McClelland Lake (Vitt and House 2020). In plain terms, the MLWC is hydrologically sustained by incoming precipitation and GW that either discharges to SW or sustains a high water-table resulting in SW runoff generation on near-saturated ground. High spatiotemporal variability in SW-GW interaction within the MLWC system makes the flow system difficult to analyze using traditional hydrologic modelling techniques, which typically employ separate SW and GW models and assumptions.

The conceptual understanding of the MLWC system (as of end of year [EOY] 2020) was used to guide the construction of the 2020 MLWC HGS Model using the HGS software program (Aquanty, 2021). The most current conceptual understanding of the MLWC hydrological system has been subsequently refined since EOY 2020 and is described in Appendix F of the MLWC OP. The main, relevant changes in conceptual understanding of the MLWC since EOY 2020 include higher observed ET rates, compared to simulated, for aspen stands based on literature values from Devito et al. (2017), and the degree and timing of substrate freezing during winter and thawing at the onset of the spring freshet. These new refinements to the conceptual understanding of the MLWC hydrology can be incorporated into a subsequent update of the MLWC HGS model.

The general workflow for HGS model construction is a bottom-up approach. A strong foundation using regionally relevant geomodel(s) and hydrological boundary conditions was first required before incorporating the local details of the surface and shallow subsurface flow systems. This concept of a bottom-up model design also facilitates incorporating system understanding into the HGS model construction process.

The 2021 MLWC CM was prepared by FHEC with input from Aquanty (Appendix F of the MLWC OP). The 2021 MLWC CM was developed using the five hydrologic response factors outlined in Devito et al. (2005) (plus land usage) that predominantly control the landscape's hydrologic response within the Western Boreal Forest (WBF) setting (which includes the MLWC):

- Climate;
- Bedrock geology;
- Surficial geology;
- Soil type and depth; and,
- Topography.

Sections 2.1 to 2.4 summarize some of the considerations made regarding these five key factors for their inclusion in the design and construction of the 2020 MLWC HGS model. Additional information on each of these factors as they pertain to the key hydrological processes occurring in the MLWC can be found in the 2021 MLWC CM (Appendix F of the MLWC OP).

2.1 Climate

The Fort Hills Project is located within a sub-humid climate setting characterized by long-term average potential evapotranspiration (PET) exceeding precipitation. This relatively high evapotranspiration demand results in a correspondingly large degree of interannual variability in shallow water availability, with dry years experiencing declining stores of soil water and GW. The short-term, multi-year wet and dry cycles occur superimposed upon longer-term decadal cycles of wet and dry precipitation periods (Figure 2-1).

The mid-1940’s through the mid-1950’s were relatively low in precipitation compared to the wetter climate of the mid-1950’s to the mid-1970’s. The recent period (the mid 1990’s onwards), wherein most of the existing site monitoring data resides, can be characterized as relatively dry in terms of annual precipitation coupled with a documented century-long temporal trend of increasing mean annual air temperature, which compounds the drying effect by concomitantly also increasing annual PET rates (Figure 2-1). The source of climate data used in this study was Environment and Climate Change Canada’s (ECCC) Fort McMurray Airport meteorological station (1945 to 2019), located approximately 90 km south of the project area.

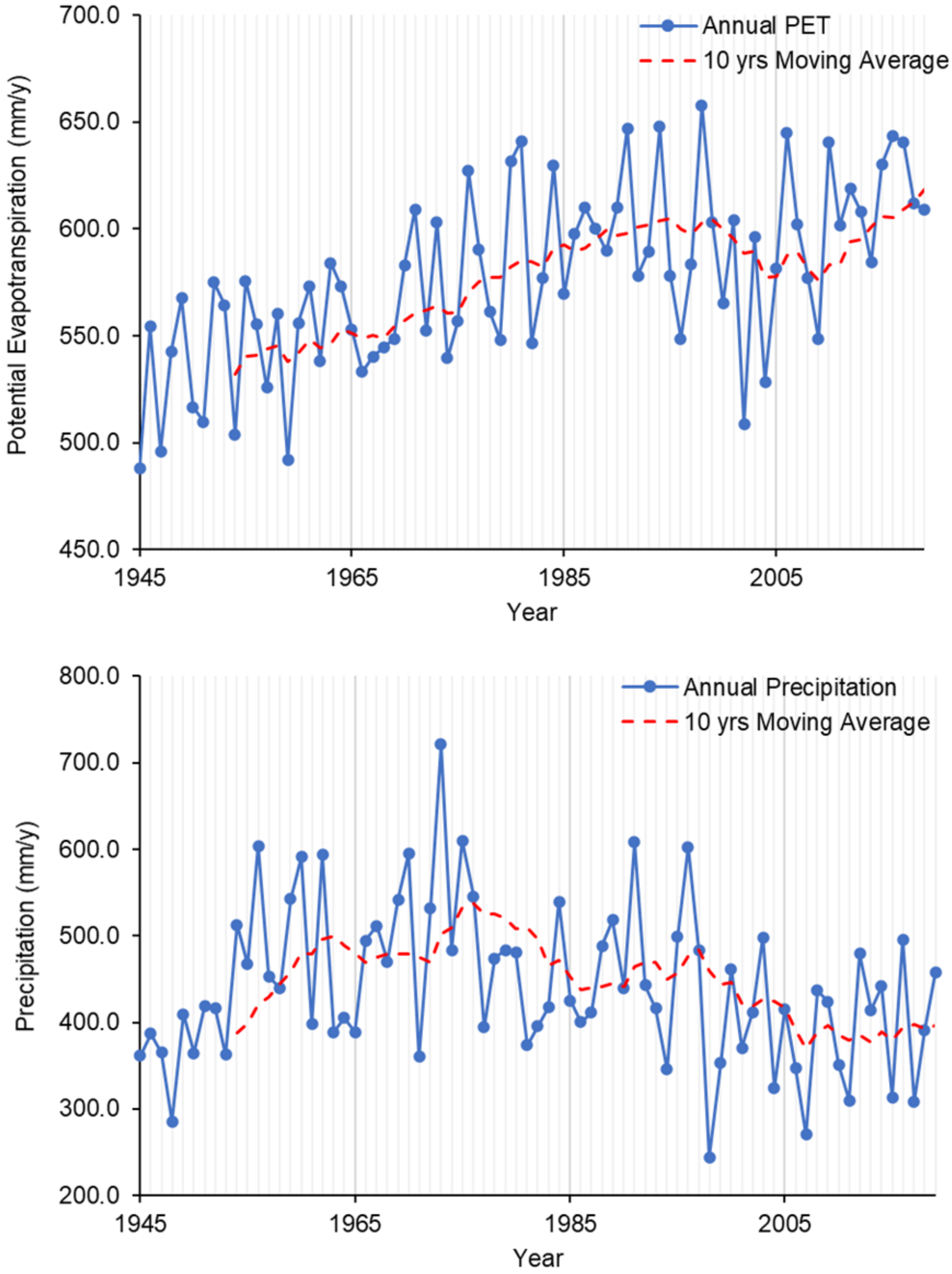


Figure 2-1. Historical record of annual precipitation and potential evapotranspiration recorded at the Fort McMurray airport climate station.

2.2 Geology

The following general hydrostratigraphic units were defined for the Fort Hills Lease and surrounding area, based on: (1) regional geologic data; (2) the geomodel of the Fort Hills Lease provided by FHEC and surrounding region (version FH19a); and, (3) recent drilling data collected during the 2019 to 2020 winter field program (Matrix, 2020):

- Muskeg;
- Surficial Sand Aquifer (North Outwash Plains [NOP] and Fort Hills Upland Complex [FHUC]);
- Clay Till 1 Aquitard;
- Intermixed sands and silty sands Aquifers/Aquitards (FHUC);
- Clay Till 2 Aquitard;
- Rafted McMurray Formation Till Aquitard (PGKM);
- Clearwater Formation Aquitard;
- Upper/Middle McMurray Oil Sands Aquitard;
- Lower McMurray (Basal) Sand Aquifers and Mud Aquitards:
- Weathered Beaverhill Lake Formation Aquifer:
- Intact Beaverhill Lake Formation Aquitard:
- Upper Prairie Evaporite Aquitard:
- Lower Prairie Evaporite Aquifer: and
- Keg River Aquifer.

The regional and local geological information from the three aforementioned data sets was used to generate a 3D hydrostratigraphic framework using the hydrostratigraphic units listed above (refer to Section 3.2 for details). This 3D hydrostratigraphic framework is designated as the 2020 Unified Geomodel and was used to help define the system conceptually. The vertical and lateral extents of the 2020 Unified Geomodel covers those of 2020 MLWC HGS model, and the hydrostratigraphy defined in the former guided the model layering definition in the latter (Figure 2-2). The primary focus of the 2020 MLWC HGS model is on shallow flow processes for conceptual pre-development understanding; however, deeper units have also been included as they play a role in assessing impacts while development occurs within the McClelland Lake watershed.

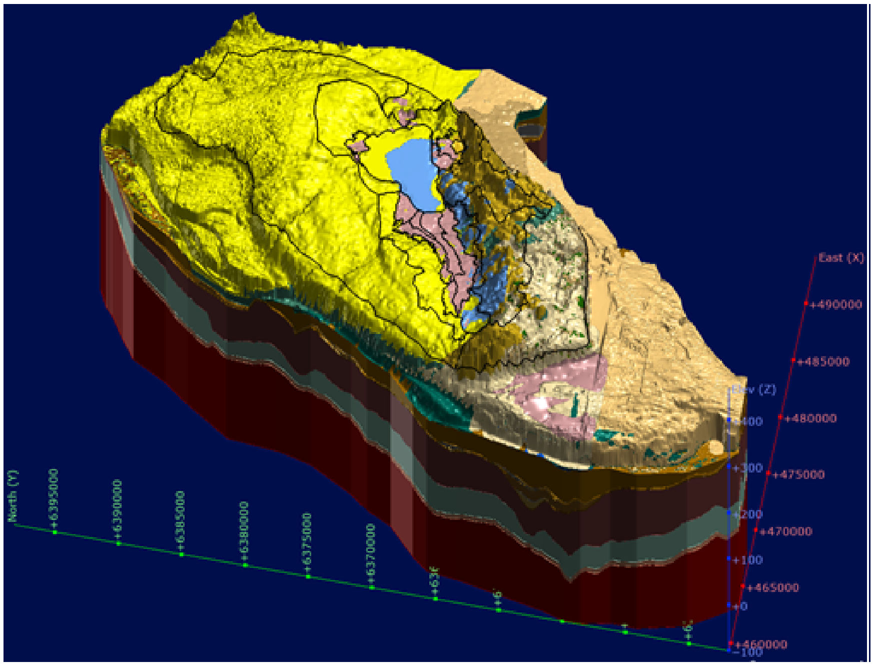


Figure 2 2. 3D Perspective view of the 2020 Unified Geomodel. Note: shown vertical exaggeration is 80:1.

2.2.1 Deeper Geology

The majority of the shallow GW flow system in the Fort Hills Lease (i.e., the Quaternary aquifers) is underlain by a nearly continuous aquitard designated Clay Till 2. A younger clay till unit (designated Clay Till 1) covers most of the northern portion of the model domain (shown in Figure 2-3). The presence of these continuous tills is conceptualized to hydraulically isolate the local (Quaternary) GW flow system from the deeper intermediate (Cretaceous) and regional (Devonian) flow systems. As such, the hydrostratigraphic units below these clay till aquitards are implicitly assumed to play little role in the pre-development local GW flow system in the MLWC watershed. However, proposed mine operations in the Fort Hills Lease (e.g., pit excavation) will remove these Quaternary tills, along with the bitumen-saturated ore, and create potential hydraulic pathways which could facilitate hydraulic connection between the shallow local GW flow system and the deeper intermediate (Cretaceous) and regional (Devonian) ones. Additionally, Basal McMurray Aquifer depressurization activities directly affect the intermediate (Cretaceous) flow system.

In terms of the Devito et al. (2005) characterization framework, the orientation of the bedrock geology is assessed to determine its influence on GW flow directions. As noted in the 2021 MLWC CM (Appendix F of the MLWC OP), the bedrock surface under the MLWC (the top of the Devonian) is overlain by an erosional unconformity. Moreover, there is a second erosional unconformity between the structural top of the Cretaceous deposits and the base of the overlying Quaternary sequence. Consequently, a composite surface of the clay till aquitards underlying the major MLWC Quaternary aquifers was instead used as a proxy for the assessment of the influence of bedrock orientation on local GW flows in and around the MLWC.

The clay till aquitards can be considered a low-permeability surface that limits vertical hydrologic connectivity between deeper aquifers (Cretaceous) below and the shallow aquifers (Quaternary) above. The northerly dip of the top surface of Clay Till 1 in the FHUC directs GW flow through thin surficial sands north towards the MLWC (shown in Figure 2-4). Sandy, more permeable sections in the Clay Till 1 Aquitard (aka hydraulic windows) are conceptualized to facilitate upward vertical GW flow from the sandy AQ4 units upwards, with Clay Till 2 below AQ4 limiting downward percolation. These upward flows through the hydraulic windows in the Clay Till 1 Aquitard manifest themselves on the surface of the Fort Hills portion of the MLWC watershed as GW springs or seeps that contribute SW flows to the MLWC and McClelland Lake.

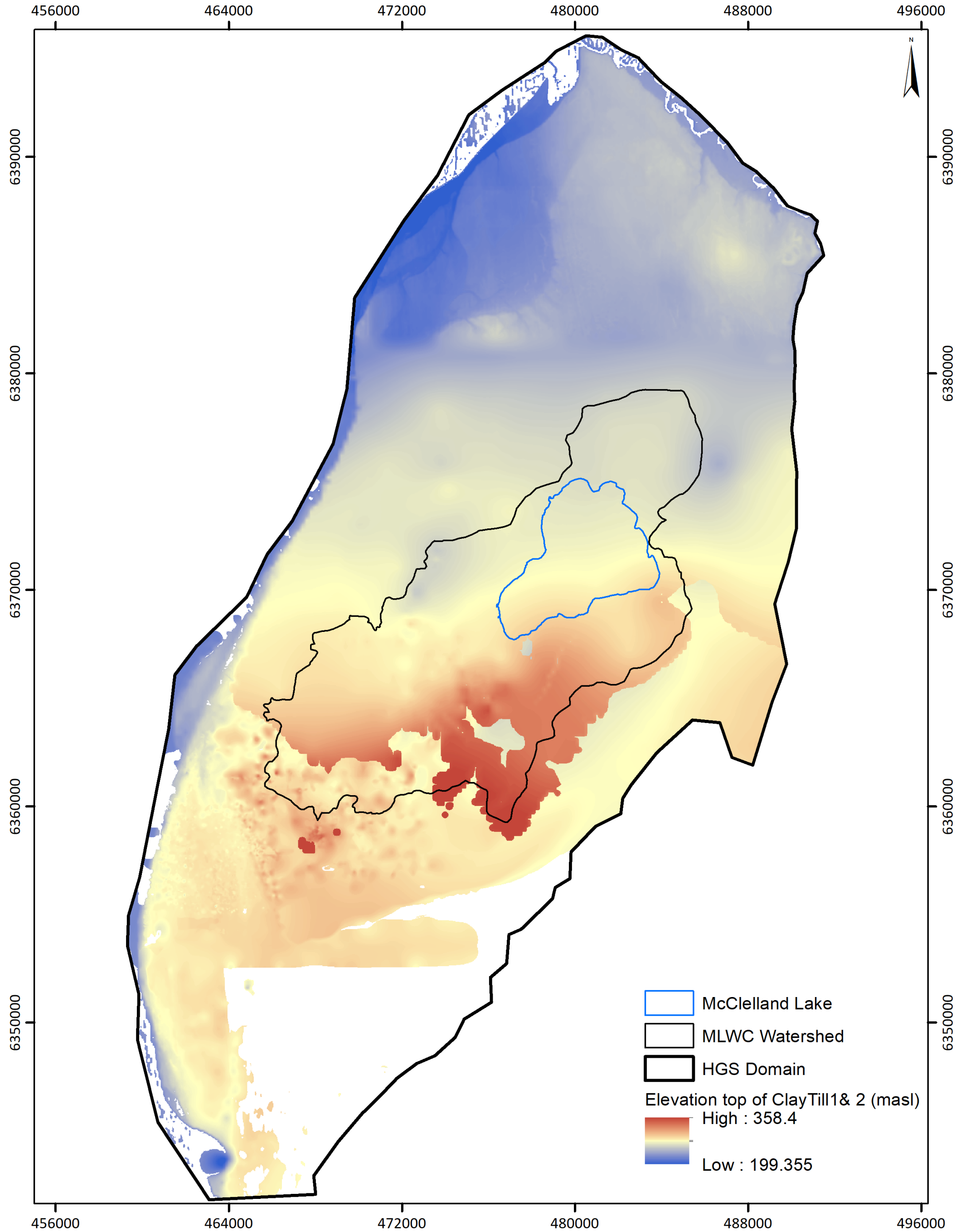


Figure 2-3. Composite Clay Till 1 and 2 structural tops.

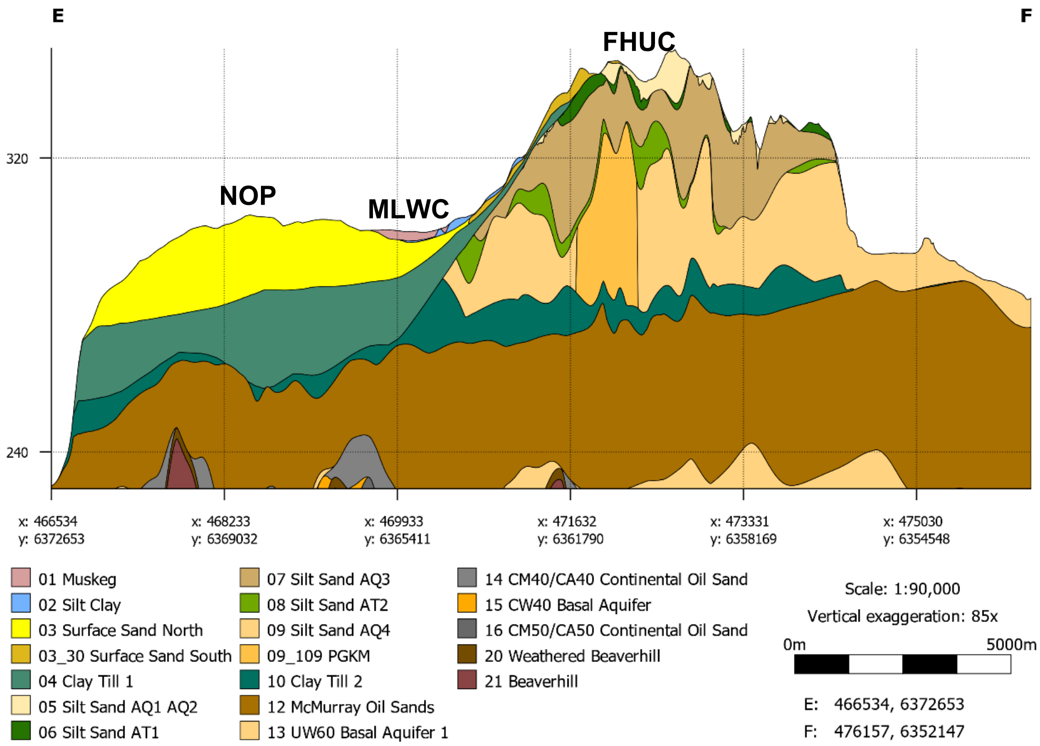


Figure 2-4. Cross-section through the Quaternary and Cretaceous hydrostratigraphy of the North Outwash Plain (NOP), McClelland Lake Wetland Complex (MLWC), and Fort Hills Upland Complex (FHUC). Note: cross-section location given in Figure 3-5.

2.2.2 Surficial Geology

Surficial geology is the third hydrologic response factor in the Devito et al. (2005) characterization framework. The 2021 MLWC CM considers the hydrostratigraphic units above the composite Clay Till 1 and 2 surface shown in Figure 2-3. For the majority of the MLWC watershed (Figure 2-4) the near surface geology is comprised of the surficial sand aquifers, which are a thin veneer (typically less than 5-m thick) over Clay Till 1 in the FHUC by the MLWC, and up to 51-m thick in the FHUC near the watershed boundary, 10 to 15-m thick under the fen, and up to 54-m thick in the NOP. The surficial sands are highly permeable units and are capable of rapidly delivering GW down gradient towards the MLWC and McClelland Lake.

Underneath the MLWC fen, the surficial sand aquifers are conceptualized to provide upward GW flow that is an important source of hydraulic support to the fen water levels during dry periods in the fall. These steady upward GW flows keep the water table near to or above the ground surface in the MLWC fen. The sustained high water table within the fen maintain the peatland ecohydrology and additionally serves to prime the fen system for large and rapid surface runoff over frozen ground during spring freshet. It is hypothesized that a high rate of surface flow during spring runoff over partially frozen peat is at least partially responsible for maintenance of the string and flark features that are characteristic of the patterned fen (Vitt and House, 2020).

The thick surficial sand underlying the NOP is of sufficiently high permeability that perennial surface drainage features are absent within that area. The NOP surficial sands, do however, serve as a source of diffuse GW discharge to the fen along the western side (Figure 2-5) of the moderately-rich fen (Ecozone 1; Vitt and House, 2020), which shows a distinctly different chemical signature than the water in the extreme-rich fen (Ecozone 2; Vitt and House, 2020). The water sources for Ecozone 2 are discussed below.

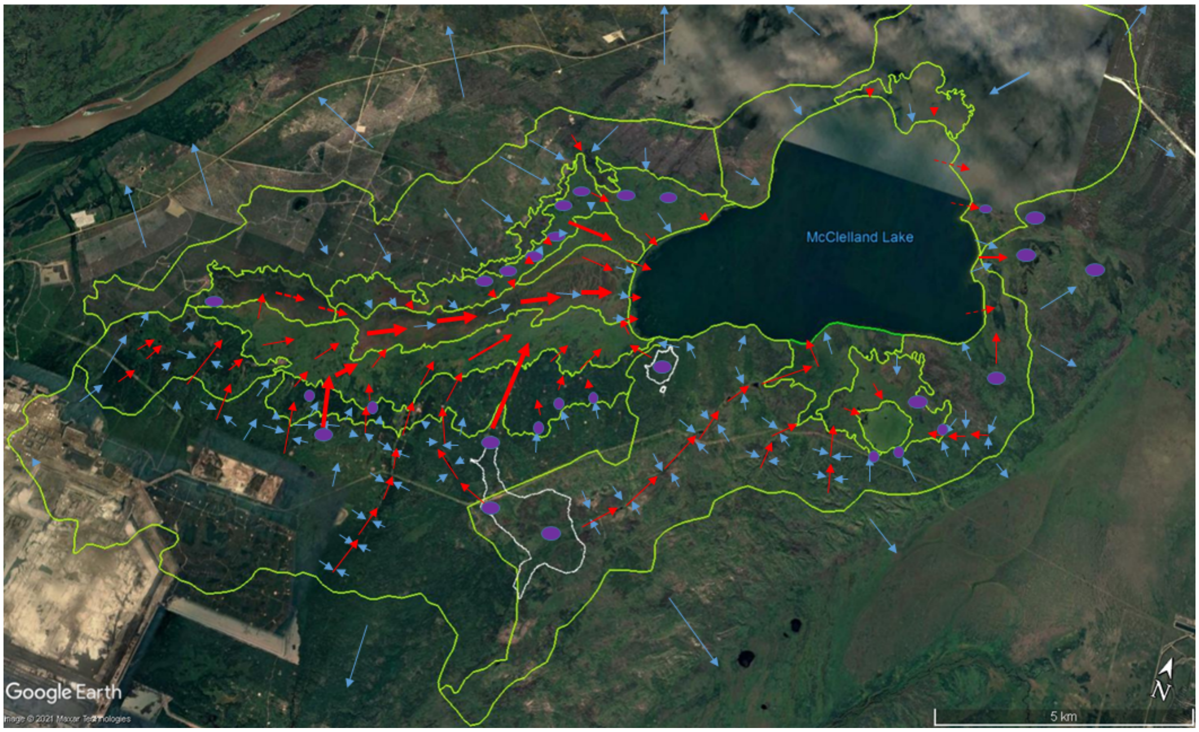


Figure 2-5. Conceptual SW and GW flow directions. The red arrows in the figure represent SW flows, the blue arrows represent GW flows and the purple ovals are areas of GW exfiltration to surface. The areas outlined in green are the MLWC HRAs (defined in Appendix F) and the areas outlined in white are mapped hydraulic windows. Image source: Google Earth/Maxar Technologies. Figure source: Appendix F of the MLWC OP.

Draping the north slope of the FHUC is a discontinuous silt clay layer that may be responsible for localized ponding evident along the toe of the FHUC in air photos taken in spring. These areas of ponded water could serve as source areas for saturation excess overland flow generation during spring freshet and large precipitation events.

Within the MLWC, the thickness of accumulated peat (or muskeg) ranges from a few metres up to 7-m thick in the eastern part of the fen towards McClelland Lake. The peat accumulation in its string and flark patterning is a defining characteristic of the MLWC fen. Maintenance of the present-day peat surface elevation within the non-mined portion of the MLWC is key to its long term ecohydrologic sustainability. Being comprised of organic material, the peat and its ecosystem is susceptible to decomposition and compaction, both of which would result in a reduction of peat thickness and a change in SW hydrologic behaviour and ecohydrological functioning of the fen.

Figure 2-6 illustrates a number of the major pathways by which GW originating from the silty sand aquifers in the FHUC uplands can create GW springs or seeps that contribute to SW flows in the MLWC watershed. Locations No. 1 and No. 4 in Figure 2-6 are examples of where GW is conceptualized to seep from the overlying silt sands aquifers of the FHUC and across the terminal edge of Clay Till 1 deposit, flowing downgradient (within the overlying surficial sands or at surface) and seeping out at the break in slope at the northern toe of the FHUC. Locations 2 and 3 in Figure 2-6 are examples of hydraulic windows in Clay Till 1 that are conceptualized to facilitate upward vertical GW flows originating within the underlying silt sand aquifers. This GW discharge either directly enters the SW system as springs or seeps, or serves to maintain a shallow water table, resulting in the generation of saturation excess overland flow. Four relatively large sources of SW flows into the MLWC were mapped by Vitt and House (2020) (Figure 2-7) and subsequently traced back to their GW origins in the 2021 MLWC CM. Location No. 1 in Figure 2-6 is hypothesized to be a source of GW seepage towards the north into the fen (source No. 2 in Figure 2-7). The hydraulic window No. 2 in Figure 2-6 is conceptualized as a potential GW source in the headwaters of South Creek, as well as a potential GW contributor to source area No. 3 in Figure 2-7. The hydraulic window at Location No. 3 in Figure 2-6 is a contributing GW source for the SW flows mapped by Vitt and House (2020) at source area No. 4 in Figure 2-7.

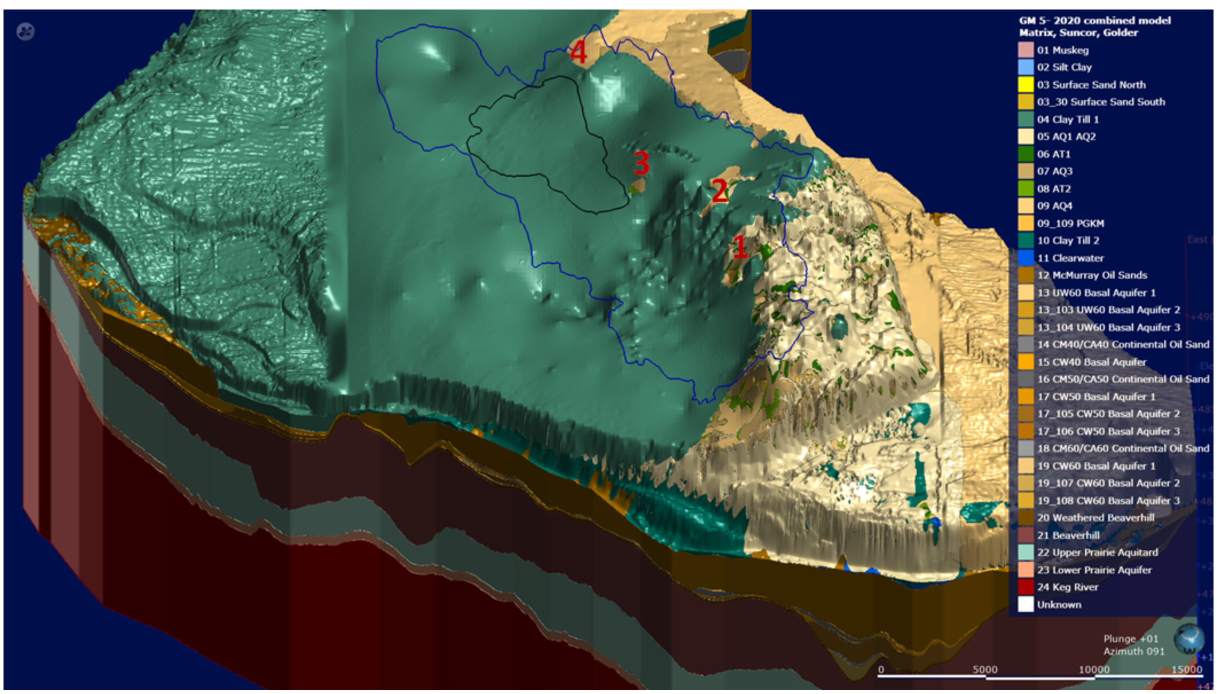


Figure 2-6. Mapped GW springs through Clay Till 1. Locations 1 to 4 are interpreted to be GW springs that contribute to the lower lying fen complex and lakes within the MLWC watershed. Note: vertical exaggeration is 80:1. Figure source: Appendix F of the MLWC OP.

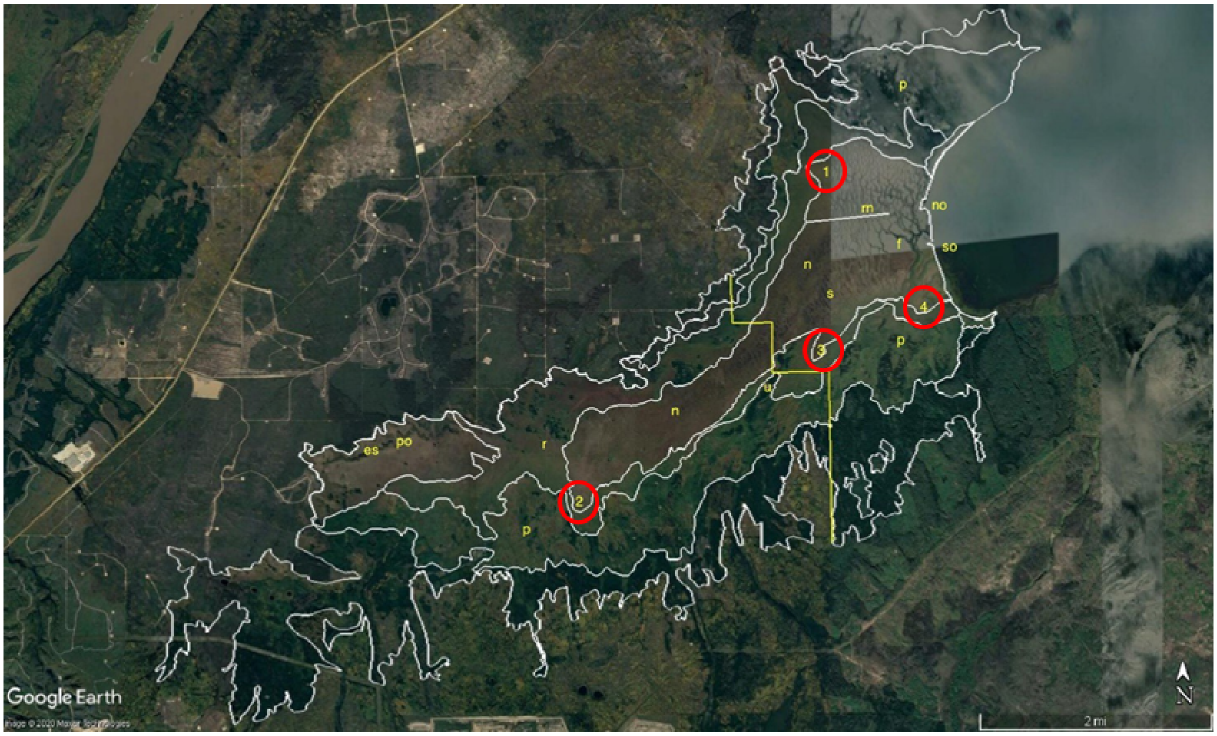


Figure 2-7. Four mapped source areas of incoming SW flows reporting to the wetland complex west of McClelland Lake, highlighted with red circles. Figure source: Appendix F of the MLWC OP-Modified from Figure 3.5 in Vitt and House (2020). Image source: Google Earth/Maxar Technologies.

2.2.3 Soils

The soils in the upland areas, the FHUC and NOP, are generally sandy and well drained resulting in relatively rapid infiltration of rain and snowmelt. Leaf litter and topsoil are very thin or absent in the NOP, which is observed as being locally bare medium-grained sand in field photos. The FHUC has a more well-developed soil profile (62 to 139 cm thick) and a litter, fermenting/rotting, humus (LFH) layer (2 to 23 cm thick) (Golder, 2018).

In the MLWC, the soil is organic (peat) and exhibit a layered structure due to the increase in peat's state of decomposition with depth. The consequence of this layered structure is high hydraulic conductivity at surface and decreasing with depth. Therefore, flow is highly dynamic in the top few to 10's of cm of the peat, and the lateral flow rate decreases with depth.

Between strings and flarks, hydraulic conductivity varies with lower hydraulic conductivity strings effectively acting like leaky dams holding back ponded water in the flarks. Details of the previous modelling work by Aquanty performed in 2019 to upscale the hydraulic behaviour of the peat in the fen are given in Attachment B. That upscaling study demonstrated that the ET and runoff rates and timings in the patterned fen could be accurately captured through calibration of its surface flow and ET properties, which justified calibrating those parameters during the automated calibration process (Section 4.0). The study also provided the benchmark upscaled parameter values which have helped in assigning the upper and lower bounds to these parameters in the automated calibration.

2.3 Topography

Typical catchment-based hydrological analysis relies on the watershed being defined by a topographic high (i.e., the SW divide). It is often assumed that the GW divide coincides with the SW divide and that neither divide will shift over time, however this is not always the case (Winter et al., 2003). Within the MLWC watershed, the SW divide is conceptualized to coincide with the watershed boundary and is essentially static with respect to time. Similarly, the southeastern GW divide is also coincident with the watershed boundary and essentially static with respect to time. However, the GW divide in the NOP, given its relatively flat topography and water table, is dynamic and shifts its position as a function of GW storage; as storage is added to the GW system, the divide shifts westward; as storage is consumed it shifts eastward. A conceptualized typical position of the GW divide in late winter is shown in Figure 2-8.

The surficial sand in the NOP is of sufficiently high permeability and the water table is sufficiently deep that neither infiltration excess nor saturation excess overland flow are conceptualized to occur with any regularity. Therefore, understanding the nature of the GW divide becomes relatively important in the NOP since such a large proportion of the flow in the NOP (nearly all of it) occurs as GW flow and not SW flow. As a consequence of the GW divide lying to the east of the SW divide, a portion of precipitation falling on the NOP leaves the MLWC watershed as GW flow draining W-NW towards the Athabasca River (or N-NE towards the Firebag River) and not towards the MLWC.

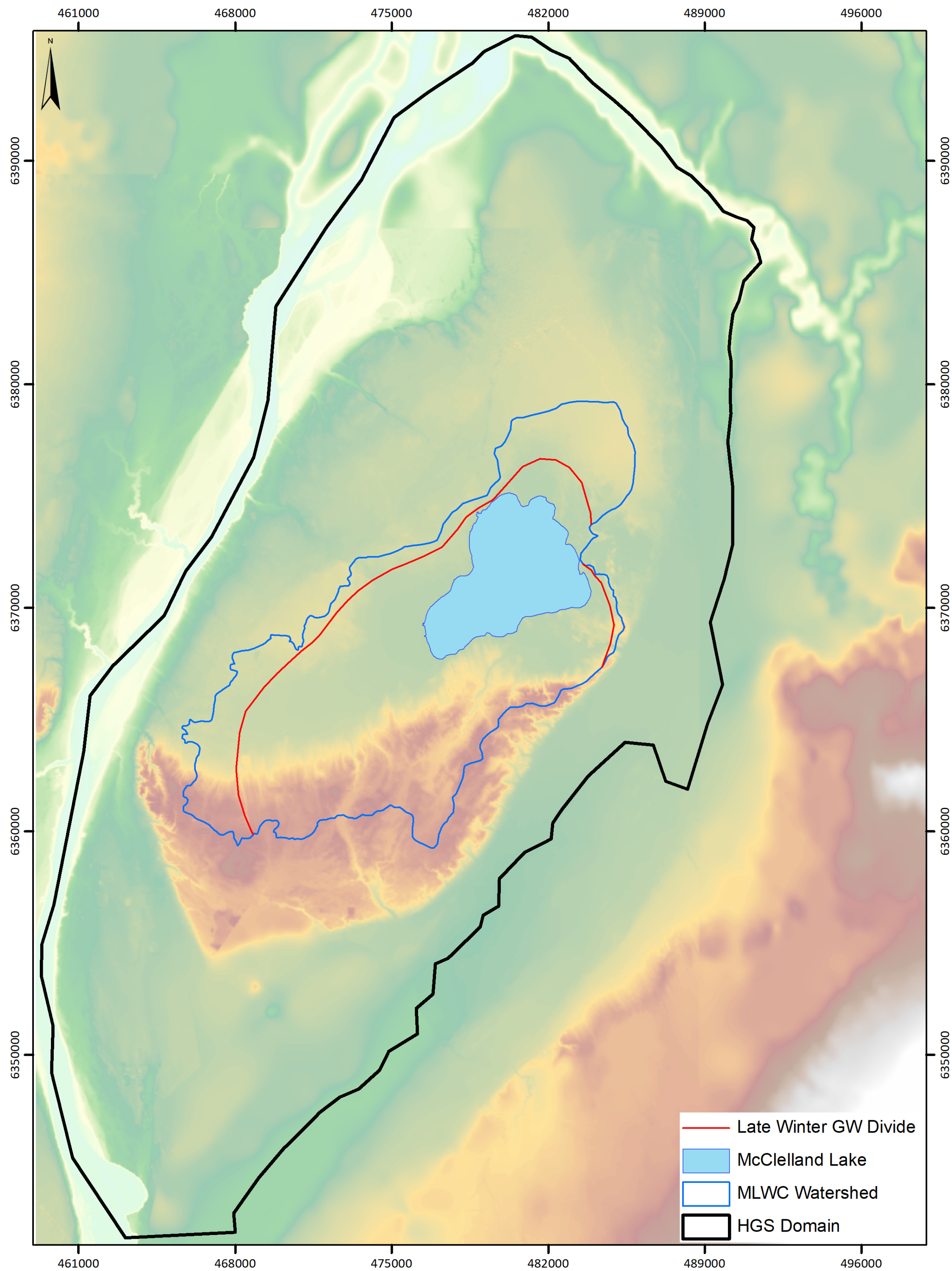


Figure 2-8. Conceptualized typical location of the GW divide in late winter within the MLWC watershed (the red line). The remainder of the GW divide coincides with the southern watershed boundary (shown in blue in the figure).

2.4 Land Cover

Land cover physical properties are required as input for the HGS model to parameterize the overland flow and evapotranspiration (ET) characteristics which affect hydrologic response. Land cover across the Fort Hills Lease is relatively varied, ranging from forested upland areas such as the FHUC and NOP, to the sparsely treed non-patterned and patterned fen areas. The land cover map for the HGS model domain was produced as an aggregate of two land cover datasets, one for within the surface watershed (Hatfield, 2018) and a second outside the surface watershed (Chowdhury and Chao, 2019). The land cover aggregation scheme is given in Table 2-1.

The land cover of the FHUC is comprised of conifers in the swampy areas at the toe of the north slopes (black and white spruce), aspen dominant in the western FHUC and along the north slopes and interspersed with mixedwood by the watershed divide. In the eastern FHUC, aspen occurs on the north slopes, with shrubland and mixedwood interspersed at higher elevations (Figure 2-9).

Prior to the Richardson Fire in 2011 the NOP was predominantly forested. Following the fire, and up to present day, the land cover is shrubby and presumed to be recovering vegetation, although the exact composition is unknown.

The fen is described as graminoid (sedges) in its westernmost area, with the non-patterned and patterned fen being primarily a mix of peat mosses and larch. In the patterned fen, the strings are dominated by bog birch in the western fen and larch in the eastern fen (D. Vitt, pers. comm.).

McClelland Lake comprises an area of 30 km^2 and represents a large source of evaporation from the system. With an average depth of ~2 m and a maximum depth of ~5.5 m, it can be characterized as a shallow lake for evaporation estimates.

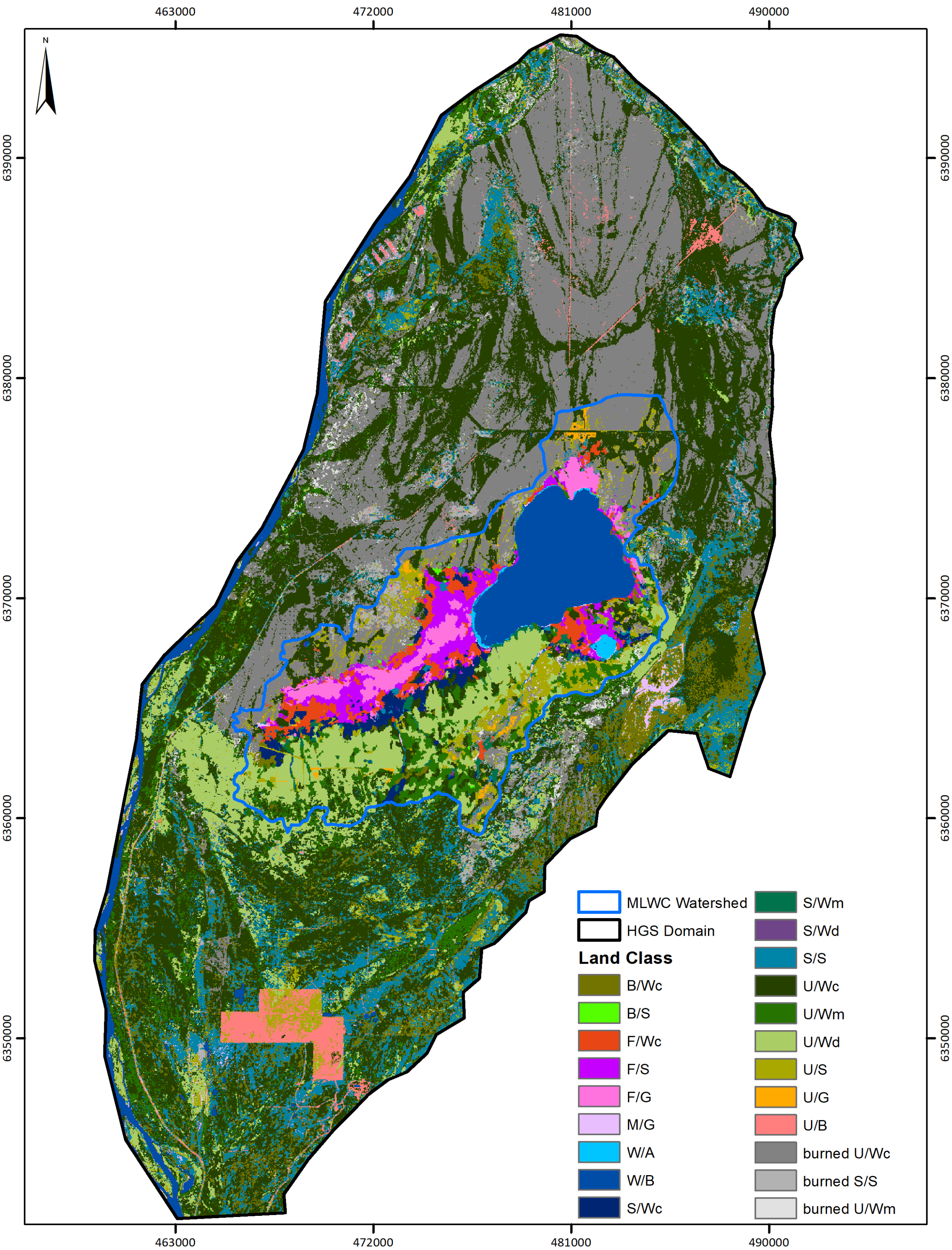


Figure 2-9. The merged land cover for the 2020 MLWC HGS Model domain which was reclassified using Hatfield (2018). Land cover classes are described in Table 2-1.

Table 2-1: Land cover classes in the 2020 MLWC HGS Model domain.

Data Source	HGS Zone	Classification		Hatfield Class (Zone)
Hatfield 2018	1	B/Wc	Bog Wooded Coniferous	-
	2	B/S	Bog Shrubby	-
	3	F/Wc	Fen Wooded Coniferous	-
	4	F/S	Fen Shrubby	-
	5	F/G	Fen Graminoid	-
	6	M/G	Marsh Graminoid	-
	7	W/A	Shallow Open Water Aquatic vegetation	-
	8	W/B	Shallow Open Water Bare	-
	9	S/Wc	Swamp Wooded Coniferous	-
	10	S/Wm	Swamp Wooded Mixedwood	-
	11	S/Wd	Swamp Wooded Deciduous	-
	12	S/S	Swamp Shrubby	-
	13	U/Wc	Upland/not wetland Wooded Coniferous	-
	14	U/Wm	Upland/not wetland Wooded Mixedwood	-
	15	U/Wd	Upland/not wetland Wooded Deciduous	-
	16	U/S	Upland/not wetland Shrubby	-
	17	U/G	Upland/not wetland Graminoid	-
	18	U/B	Upland/Bare	-
Chowdhury and Chao (2019); 1985 land usage	20	Coniferous - Closed Jack Pine		U/Wc (13)
	21	Coniferous - White Spruce		U/Wc (13)
	22	Broadleaf - Closed Deciduous		U/Wd (15)
	23	Coniferous Leading Mixedwood - Closed		U/Wc (13)
	24	Mixedwood - Closed		U/Wm (14)
	25	Shrub - Closed Upland		U/S (16)
	26	Wetlands - Graminoid		M/G (6)
	27	Wetlands - Shrubby		S/S (12)
	28	Coniferous - Black Spruce Bog		B/Wc (1)
	29	Wetland - Undifferentiated		S/S (12)
	30	Water		W/B (8)
	31	Exposed - Barren Land		U/B (18)
	32	Bare - Open Pine		U/Wc (13)
	33	Developed Footprints		U/B (18)
	34	Burned Areas - Little Biomass		U/B (18)
Chowdhury and Chao (2019); 2011 Richardson wildfire land usage	35	Burned Coniferous - Closed Jack Pine		Burned U/Wc (new 19)
	36	Burned Bare - Open Pine		Burned U/Wc (new 19)
	37	Burned Coniferous - White Spruce		Burned U/Wc (new 19)
	38	Burned Wetlands - Shrubby		Burned S/S (new 20)
	39	Burned Coniferous Leading Mixedwood - Closed		Burned U/Wc (new 19)
	40	Burned Mixedwood - Closed		Burned U/Wm (new 21)
	41	Burned Wetland - Undifferentiated		Burned S/S (new 20)

2.5 Key Hydrological Processes for Integrated Surface-Subsurface Hydrologic Modelling

Key hydrological processes and system features from the conceptual model were implemented within a fully-integrated modelling framework using the HGS software package. HydroGeoSphere uses a physics-based approach to solving tightly-coupled flow equations for surface flow (2D St. Venant equation, diffusive wave formulation) and variably saturated subsurface flow (3D Richards' equation). The tight coupling between surface and subsurface flow and water exchange between the surface and subsurface domains is a defining characteristic of the limited group of integrated hydrologic models to which HGS belongs (namely HGS and Parflow as detailed by Barthel and Banzhaf, 2016). Details of the numerical representation of the surface and subsurface flow equations and additional explanation of the conceptual basis for the HGS software package is included in Attachment A.

2.5.1 Climate Inputs

The implications of using a tightly-coupled integrated hydrologic model, such as HGS, from an application perspective, is the simplification of the modelling approach into a single model for both SW and GW modelling. The main water flux typically applied to a lease-scale HGS model is precipitation at the model surface. This is conceptually similar to rainfall being applied to traditional surface hydrological models, such as rainfall-runoff models, and very different from GW flow-only models that are driven with a user-specified recharge boundary condition. An HGS model therefore avoids subjective user input as to the distribution of recharge to GW, as all fluxes between atmosphere, SW, soil water, and GW are calculated internally to the model based on the physical state of the system at any given point in time.

Over the long term, ET is the second largest component of the water balance in the lease relative to precipitation, and in many years, ET exceeds rainfall. HydroGeoSphere calculates Actual ET (AET) from Potential ET (PET). The AET calculation is accomplished by accounting for many feedbacks between the hydrologic state of the model and ET (e.g., soil saturation, SW ponding, leaf area index [LAI]) for varying land covers (e.g., deciduous, or coniferous forest, shrubland, grassland, wetlands, open water, etc.) and for soils of varying physical properties (e.g., sandy, silty, clayey, peaty, etc.). The details of how HGS accounts for water available for ET and details of partitioning between evaporation and transpiration are contained in Attachment A.

2.5.2 Surface Flow

Surface flow generated within the MLWC watershed is marked by a high degree of seasonality (in Appendix F of the MLWC OP). Freshet during the spring months is marked by high SW flows along the fen margins, within the fen and into McClelland Lake. Saturation excess overland flow occurs over generally saturated subsurface conditions in the fen and along the northern toe of the FHUC. Following freshet, the SW levels in the fen drop through the summer and below the surface of the peat to depths on the order of 0.1 to 0.2 m below ground surface by late summer (Aug. to Sep). As PET wanes in the fall, GW continues to feed the fen through winter, raising water levels so that the fen is primed to generate runoff again in the following spring.

Summer rains can generate saturation excess overland flow when rain falls on the saturated fen in early summer. Early spring rain that falls on frozen ground can generate infiltration excess runoff, hypothesized to occur along the toe of the FHUC. Later in the summer, when there exists surface and subsurface storage capacity in the fen, long periods of rain or particularly intense rain events can fill the storage capacity and then generate runoff.

The FHUC generates surface flow in the vicinity of numerous ephemeral channels along the north slope of the FHUC flowing towards the fen, where locally saturated conditions can generate saturation excess overland flow, as a result of snowmelt. Following the freshet period, the streams likely dry substantially, although no streamflow data is available.

The broad sandy areas of the NOP do not exhibit substantial evidence of overland flow. Channelization is largely absent, and rapid infiltration into the sandy soil surface results in little surface flow generation.

In HGS, the partitioning of rainfall into infiltration and runoff is handled via the physical state of the surface and subsurface (e.g., the degree of soil saturation and surface depression storage levels), rather than through more traditional hydrologic modelling approaches using empirical runoff coefficients. In HGS, there is no prior assumptions regarding the runoff mechanism required (e.g., infiltration excess or saturation excess). Water begins to pool on the model surface when the infiltration capacity of the model surface is exceeded. The infiltration capacity is determined internally to the model using the input saturated hydraulic conductivity and soil water retention characteristics. Depending on the current soil moisture state of the model at any point in time and space, the 3D Richards' equation is used to calculate the infiltration capacity of the model surface. If the surface becomes saturated, then excess water pools on the surface in the model.

Runoff generation occurs when the water pooled on the model surface exceeds the small-scale storage capacity of the surface, called rill storage. Two-dimensional (depth averaged) overland flow is governed by a solution of the 2D St. Venant shallow water equations with the diffusive wave approximation. Surface water flow is additionally affected by obstruction storage effects (e.g., flow around vegetation) and the roughness friction of the model surface.

Winter processes were incorporated in the model through calculation of snow accumulation, snowmelt, and sublimation, as well as the freezing of the surface and shallow subsurface of the model during winter. The fen is not conceptualized to freeze deeply in winter (on the order of 20 cm) due to the observed upward GW seepage and resultant heat flux present throughout winter. GW that seeps to surface in Boreal fens during winter has been observed to freeze in situ (Price and Fitzgibbon, 1987). The timing of SW freezing was controlled in the model by recorded air temperature. The freezing effect was modelled through decreased mobility of SW during the winter period by increasing the friction coefficient to reduce lateral flow conductance.

Runoff in the patterned fen is controlled by the isolated nature of flarks delineated by raised peat ribs (Appendix F of the MLWC OP). Surface water flow from one flark to the next follows a so-called fill and spill process, whereby upstream flarks fill with SW and spill over and through ribs to downstream flarks. To accurately capture the relatively narrow peat ribs (approximately 10 to 20-m wide) in a finite element mesh would require elements on the order of 5 to 10-m in size. Given the lateral dimensions of the 2020 MLWC HGS model (nominally 50 by 20 km) it was prohibitive to use elements much smaller than 100-m in size within the fen to avoid excessively long model run times. To represent flow processes in the patterned fen as accurately as possible, an upscaling exercise was conducted to generate parameterization for a model with elements nominally 100-m in size (coarse model) using a model with elements of varying size, but on the order of 5 to 10 m within the ribs (fine model) (in Attachment B).

2.5.3 Subsurface Flow

Subsurface flow in the HGS model comprises not only saturated GW flow, but also includes variably saturated flow within the vadose zone. The 3D Richards' equation for variably saturated flow is used, which collapses to the 3D GW flow equation under saturated conditions. Processes such as GW recharge, and discharge are handled implicitly in the model without explicit definition being required. The rigorous 3D implementation does not require partitioning of water into separate user-defined fluxes. This implementation avoids arbitrary assignment of fluxes that are essentially unknown. HydroGeoSphere calculates these fluxes subject to the physics of flow and the water balance of the site conditions. GW recharge is an important process in the surficial sands of the NOP that have a high infiltration capacity and a thick vadose zone. Groundwater discharges from the NOP sands along the margins of the fen and McClelland Lake.

In HGS, GW recharge and discharge zones are not user-specified. Recharge occurs implicitly in the model as the net drainage to a dynamic water table as determined by internally calculated infiltration, soil evaporation, and plant transpiration. Similarly, to GW recharge, GW discharge zones do not require prior definition in HGS but occur implicitly in the model where the physics of flow defines the locations of discharge to occur. Numerically within the model, GW discharge to surface occurs where subsurface heads exceed surface heads (i.e., an upward hydraulic gradient to surface occurs). The rate of discharge is primarily governed by the hydraulic conductivity of the subsurface. Positive subsurface-surface exchange in HGS represents GW discharge to surface, while negative subsurface-surface water exchange represents infiltration. The resulting model output of subsurface to SW exchange output can be visualized as a 2D map. Within a highly dynamic SW-GW exchange environment like the MLWC, the ability to test model performance against known infiltration and discharge areas is a potential model validation tool.

Freezing of the shallow subsurface during winter occurs to varying depths within the lease. HydroGeoSphere has multiple methods for calculating subsurface freezing and thawing. Heat conduction (1D vertical) coupled with pore water-ice partitioning is included in HGS; however, the high computational effort for this option limits its application to soil column and field-scale simulations. For the 2020 MLWC HGS model build, soil freezing and thawing was implemented through a reduction in soil hydraulic conductivity tied to observed air temperature with a site-derived time lag. The freezing and thawing hydraulic conductivity reduction also incorporates an impedance factor to account for the effect of soil water saturation. Soils with higher soil water saturation at the onset of freezing experience a higher degree of reduction in hydraulic conductivity, which is reflected in the model. Sandy soil in the FHUC and NOP forested uplands will generally have low soil water saturations in fall prior to freeze-up relative to lowland soils at the toes of the slopes along the fen margin. Therefore, the areas with higher soil water saturation at the toes of the slopes are modelled to experience a greater decrease in hydraulic conductivity associated with the onset of freezing and generate more rapid snowmelt runoff during spring, compared to drier sandy upland soils.

High variability in annual precipitation results in large fluctuation in water available for runoff generation. Relatively permeable sediments in both the FHUC and NOP experience high infiltration rates that replenish GW. Changes in soil water storage affects the seasonal variability of runoff generation. Drawdown of water levels within the peat in the patterned fen are replenished by GW discharge over winter, priming the fen system for rapid runoff generation during spring freshet. Dynamic storage of soil water and GW in an HGS model is governed by the 3D Richards' equation for flow, the soil water characteristic curve for the relation between soil matric potential (or pressure head) and saturation, and variably saturated hydraulic conductivity.

The continuous physics-based formulation for soil water flow and storage across the water table in HGS allows the model to simulate the water table depth in a rigorous fashion and as a side benefit non-coincident with SW and GW divides are handled implicitly without user intervention. The phenomenon of non-coincident SW and GW divides occurs in the area of the NOP and is conceptualized to be a sink of GW from the MLWC surface watershed towards the Athabasca River and Firebag River.

Groundwater in the deeper intermediate (Cretaceous aquifers) and regional (Devonian aquifers) across the model domain generally flow east to west, with the Athabasca River acting as a regional drain, in locations where the Upper Devonian is hydraulically connected to the Athabasca River.

Surface water-GW interaction within the MLWC occurs across the landscape on a variety of scales from GW discharge at the sources of streams as seeps or springs to a continuous, highly spatially variable expression of GW in the fen just below the peat surface, providing hydraulic support to SW flow in the patterned and non-patterned fens. The definition of GW and SW is so indistinct in the fen that for modelling purposes it should be considered as one integrated reservoir of water which feeds ET, generates SW flow, and receives GW discharge. Additionally, the dynamics of SW-GW interaction are temporally variable, particularly within the fen, where the water table rises to surface at spring freshet and declines just below the pear surface during summer (in Appendix F of the MLWC OP). The fully coupled SW and GW domains within the HGS model capture the spatial variability and timing of SW-GW interaction without the need for prior definition of this process by the user, and the physics of flow between surface and subsurface govern the model result.

3.0 MODEL CONSTRUCTION

To simulate the hydrological processes in the MLWC during different time periods and operational stages (baseline, operations, active closure, and far-future) several HGS models were constructed. These models were built from a common data foundation which ensured consistent construction and parameterization across all model scenarios.

The model list includes:

- **Calibration Model**: Observed historical data were used as calibration targets and the physical parameters of the system controlling GW and SW regimes were calibrated.
- **Baseline Model**: Based on the **Calibration Model** and was used to simulate the historical period from 1945 to 2019.
- **Operations Model**: Simulates the mine operations period (2014 to 2063) and was used to assess the impact of mining and water management design features on the non-mined portion of the MLWC for the current 2021 IPA Mine Plan.
- **Active Closure and Far-Future Models**: Simulates the active closure period and far-future landscape post-closure, and was used to assess the hydrologic sustainability of the MLWC.
- **Water Budget Model**: This model uses the same settings as the **Baseline Model**, however, its geographic extent was trimmed to the MLWC watershed, and its purpose was to assess the long-term water balance of the MLWC watershed over the historical period (1945 to 2019).

3.1 Model Domain and 2D mesh

Depending on the scale and the objectives of the problem, two different strategies are commonly employed when selecting outer boundary extents for fully-integrated models: watershed divides (i.e., topographic highs), or SW features (i.e., topographic lows). For the Fort Hills Lease, the surrounding SW features provide appropriate boundary conditions given that it's location in the landscape is almost completely surrounded by SW features that form natural SW divides. As such, the outer boundary of the HGS model is defined by the Athabasca River to the west, the Firebag River to the north, and Muskeg River to the southeast. The lowlands between the MLWC and forested uplands to the east are also used as a boundary extent to the east of the MLWC. The model domain, as shown in Figure 3-1, covers 978 km^2.

The different MLWC HGS models have differing 2D numerical meshes, depending on the model application purpose. The 2D triangular prism finite element meshes (FEMs) were built using the multi-level optimisation algorithm implemented in the AlgoMesh software program (HydroAlgorithmics, 2016), which has been shown to produce triangular elements of higher quality than traditional Delaunay refinement alone (Merrick and Merrick, 2015). For the modelling work at MLWC, three 2D FEMs were built as follows:

1. Calibration Model: 8,857 nodes and 17,508 elements.
2. Baseline and Operations Models: 11,816 nodes and 23,407 elements.
3. Active Closure and Far-Future Models: 11,897 nodes and 23,565 elements.
4. Water Balance Model: 7,092 node and 13,709 elements.

More details on each 2D FEM including their constraints, node spacings, and their final mesh will be discussed and illustrated in the upcoming sections, where the details of each model are explained.

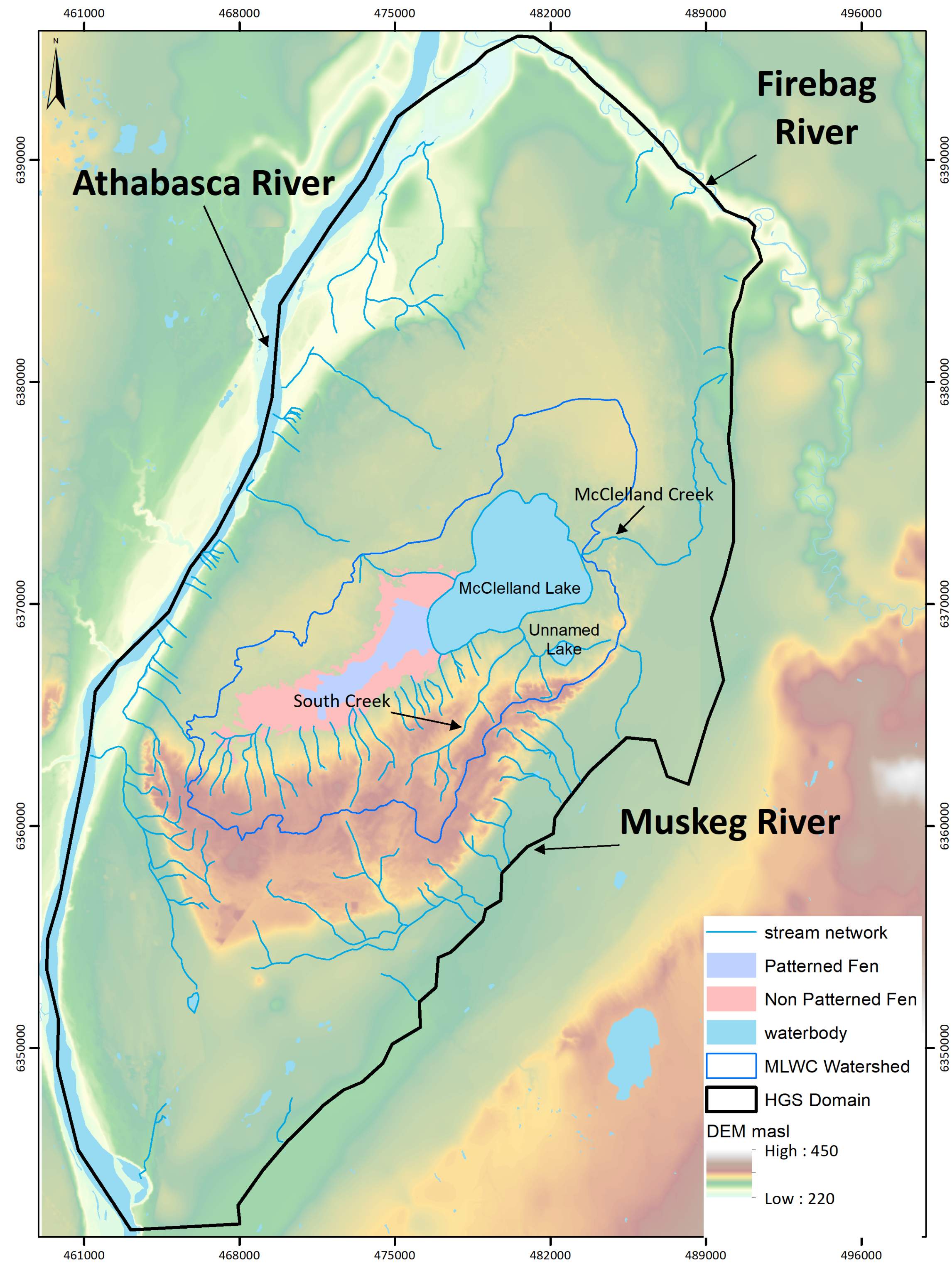


Figure 3-1: Model domain for the 2020 MLWC HGS model.

3.2 3D Model Construction and Subsurface Parameterization

For the 2020 MLWC HGS model builds, the 2020 Unified Geomodel was used, as described in Section 2.2. The hydrostratigraphy (i.e., deposit depth and lateral extent) defined in the 2020 Unified Geomodel (Figure 3-2) also defined the subsurface material zonation employed to initially parametrize and then calibrate the 2020 MLWC HGS model. In turn, each of these defined subsurface material zones were initially parameterized with a unique set of hydrogeological properties (Table 3-1 and Table 3-2), based largely on the calibrated results of the 2019 version of the MLWC HGS model. Within HGS, water retention and unsaturated flow relations (Table 3-2) are defined for each subsurface material zone but are only used by the model if the zone becomes unsaturated during a model run. In the current models, the deeper subsurface material zones in the model (below the base of the Quaternary sequence) remain saturated and were therefore assigned default water retention and unsaturated flow properties. Because these deeper units remain saturated, their assigned water retention and unsaturated flow relations are irrelevant in terms of the model output.

Figure 3-3 presents the subsurface material zonation in plan view and Figure 3-4 gives the corresponding isopachs of each subsurface material zone/hydrostratigraphic unit. Cross-sections of the zonation/hydrostratigraphy are shown in Figure 3-6 and locations of the cross-sections are given in Figure 3-5. Four additional model layers were added to represent soil horizons: LFH, A, B and C, in areas with mineral soils present. The depths assigned to the soil horizons for the various soils are given in Table 3-3. Soil zonation and thicknesses in the 2020 MLWC HGS model were based on mapped soil units from Golder (2018) within the MLWC watershed combined with the data in Turchenek and Lindsay (1982) for the remainder of the model domain (Figure 3-7). Hydraulic conductivity for each layer of each soil unit was determined from soil texture results reported in Golder (2018) input into the Rosetta software program (Schaap et al., 2001). The saturated hydraulic conductivity distributions for each of the four soil layers are shown in Figure 3-8. The assigned properties of the soils are presented in Table 3-4. The unsaturated hydraulic conductivity curves and soil water characteristic curves of the surficial soil units are illustrated in Figure 3-9. Within the MLWC fen boundary, the four surface soil layers represented peat soil layers with different degrees of decomposition in which the hydraulic conductivity decreased with depth.

Initial zone parameterization has evolved over four generations of MLWC HGS model and the initial values for the 2020 MLWC HGS model are tabulated in Table 3-1. Unsaturated soil water characteristic and hydraulic conductivity curves were assigned to the model based on soil classification using the Rosetta software program (Schaap et al., 2001) for near surface materials, which are expected to be variably saturated during simulation.

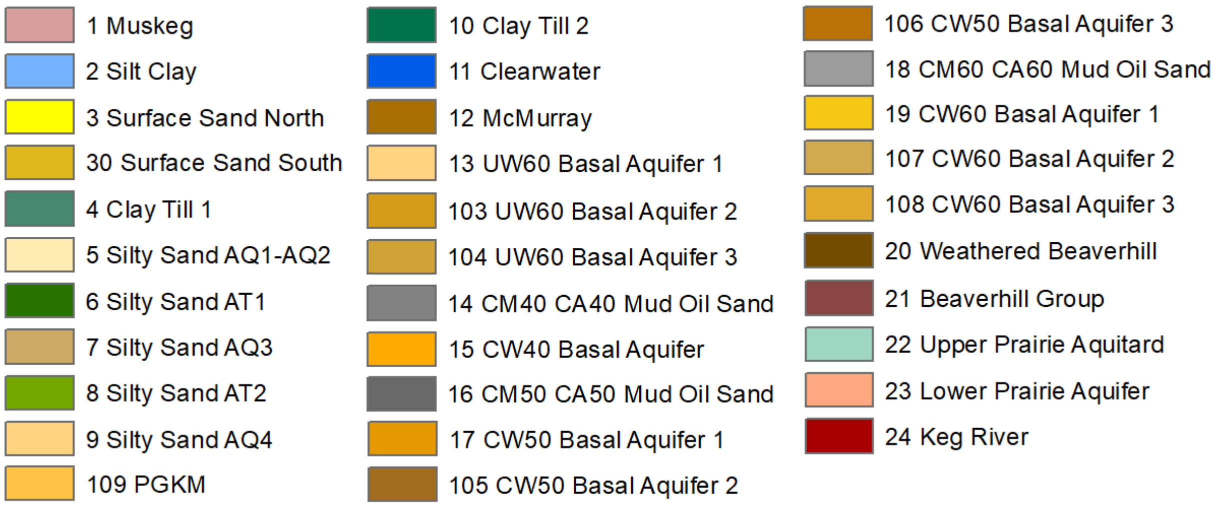


Figure 3-2: Legend of subsurface zonation and hydrostratigraphic definition for Figure 3-3.

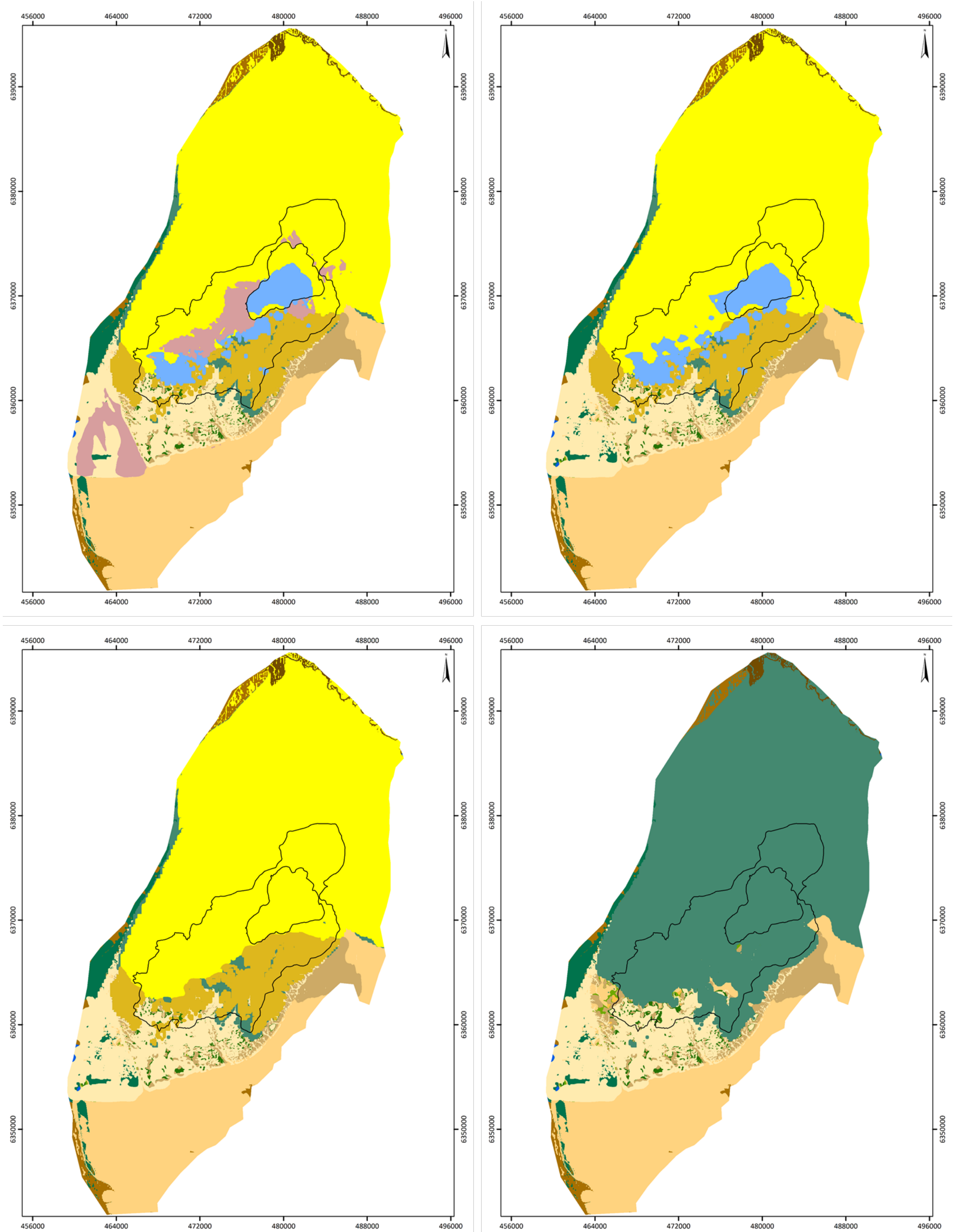


Figure 3-3a. The distribution of zonation/hydrostratigraphy within layers 1 (top left), 2 (top right), 3 (bottom left), and 4 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

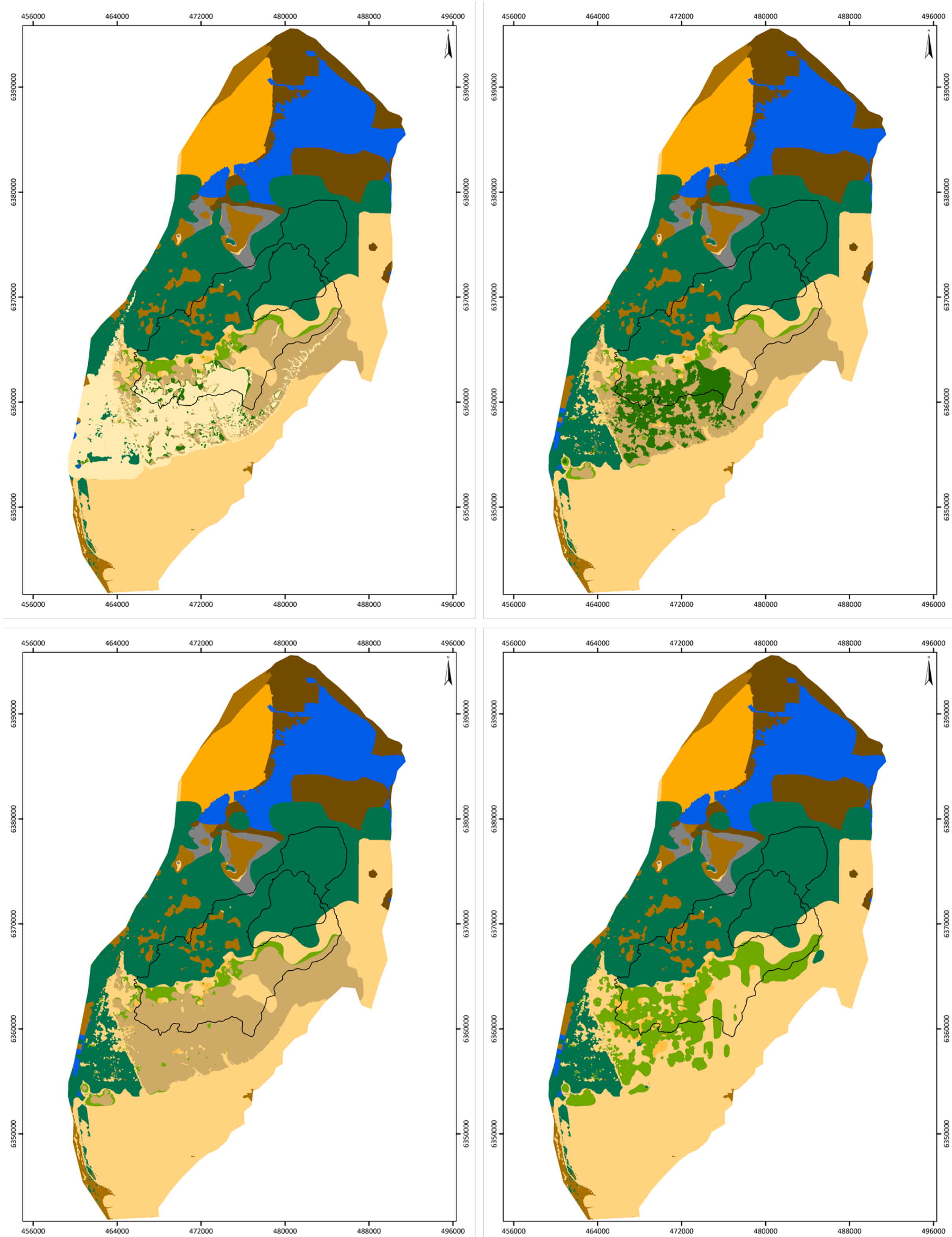


Figure 3-3b. The distribution of zonation/hydrostratigraphy in layers 5 (top left), 6 (top right), 7 (bottom left), and 8 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

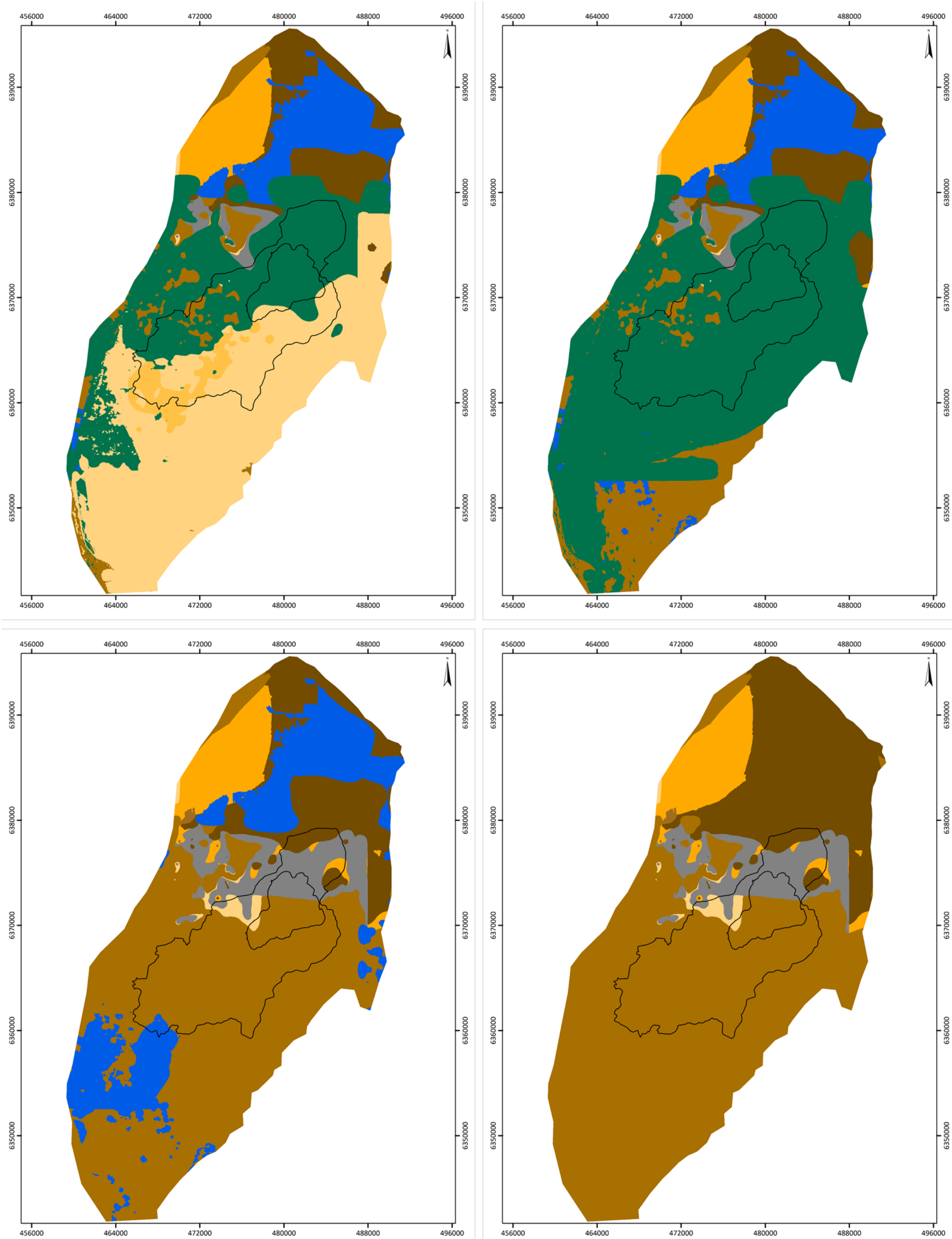


Figure 3-3c. The distribution of the zonation/hydrostratigraphy in layers 9 (top left), 10 (top right), 11 (bottom left), and 12 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

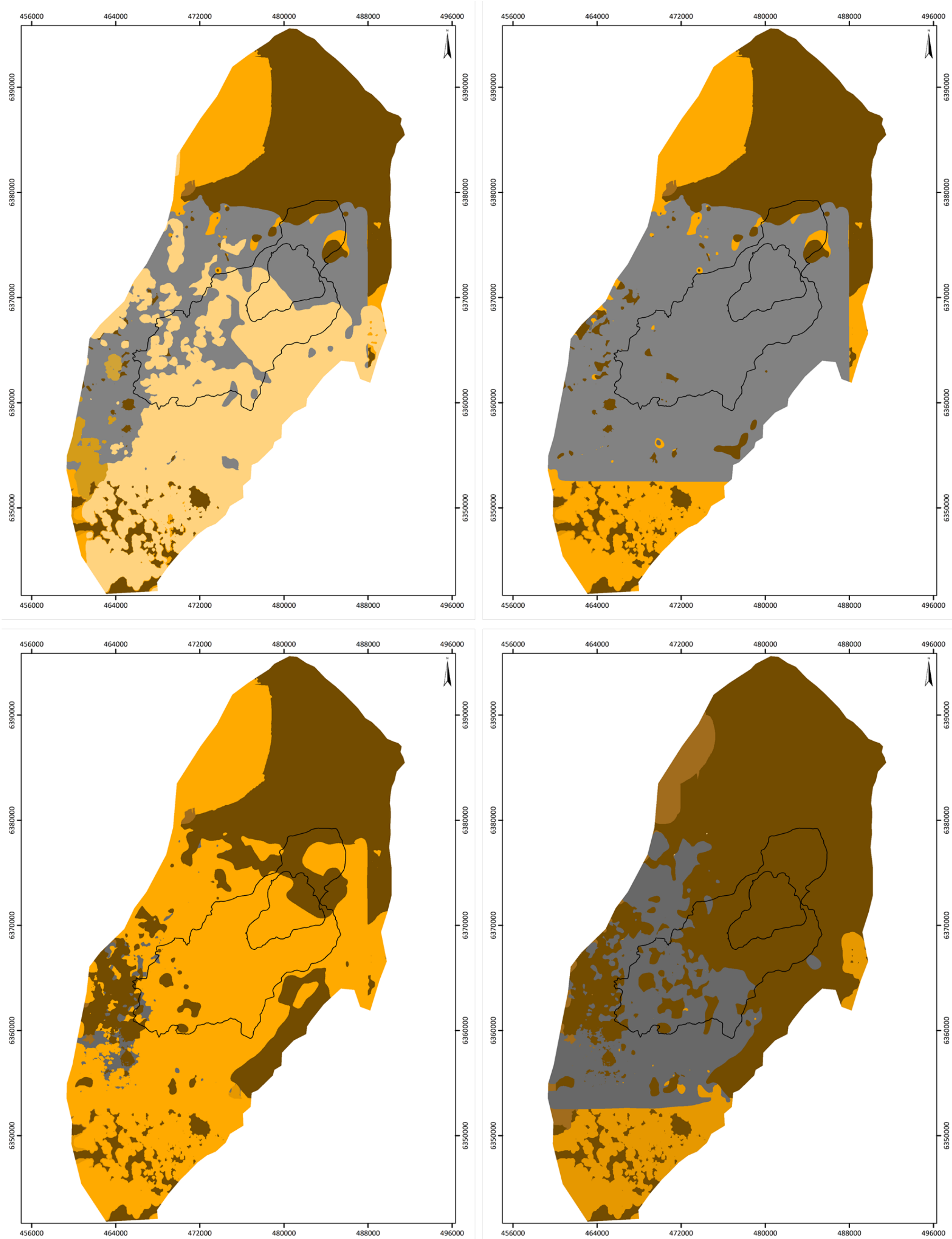


Figure 3-3d. The distribution of the zonation/hydrostratigraphy of layers 13 (top left), 14 (top right), 15 (bottom left), and 16 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

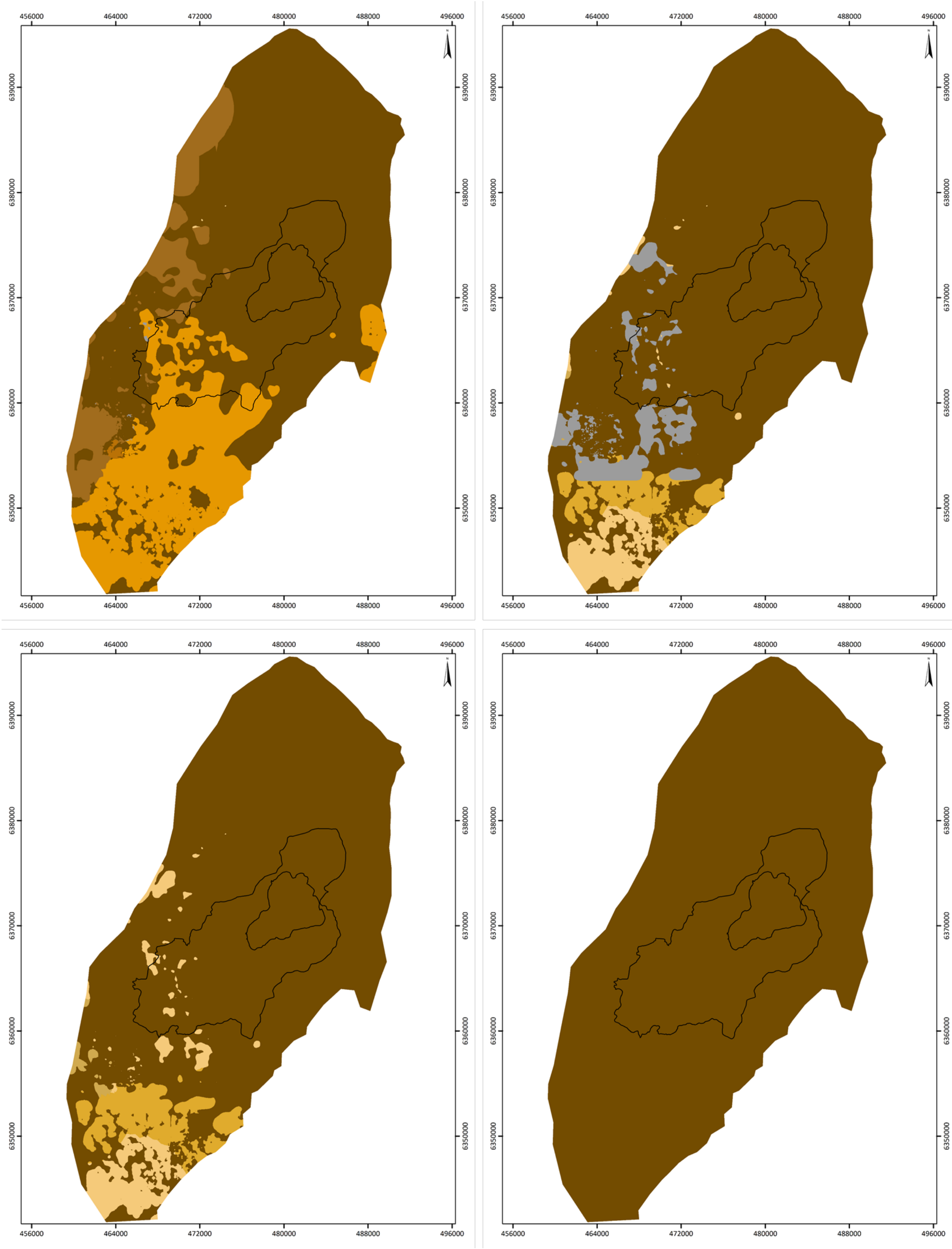


Figure 3-3e. The distribution of zonation/hydrostratigraphy in layers 17 (top left), 18 (top right), 19 (bottom left), and 20 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

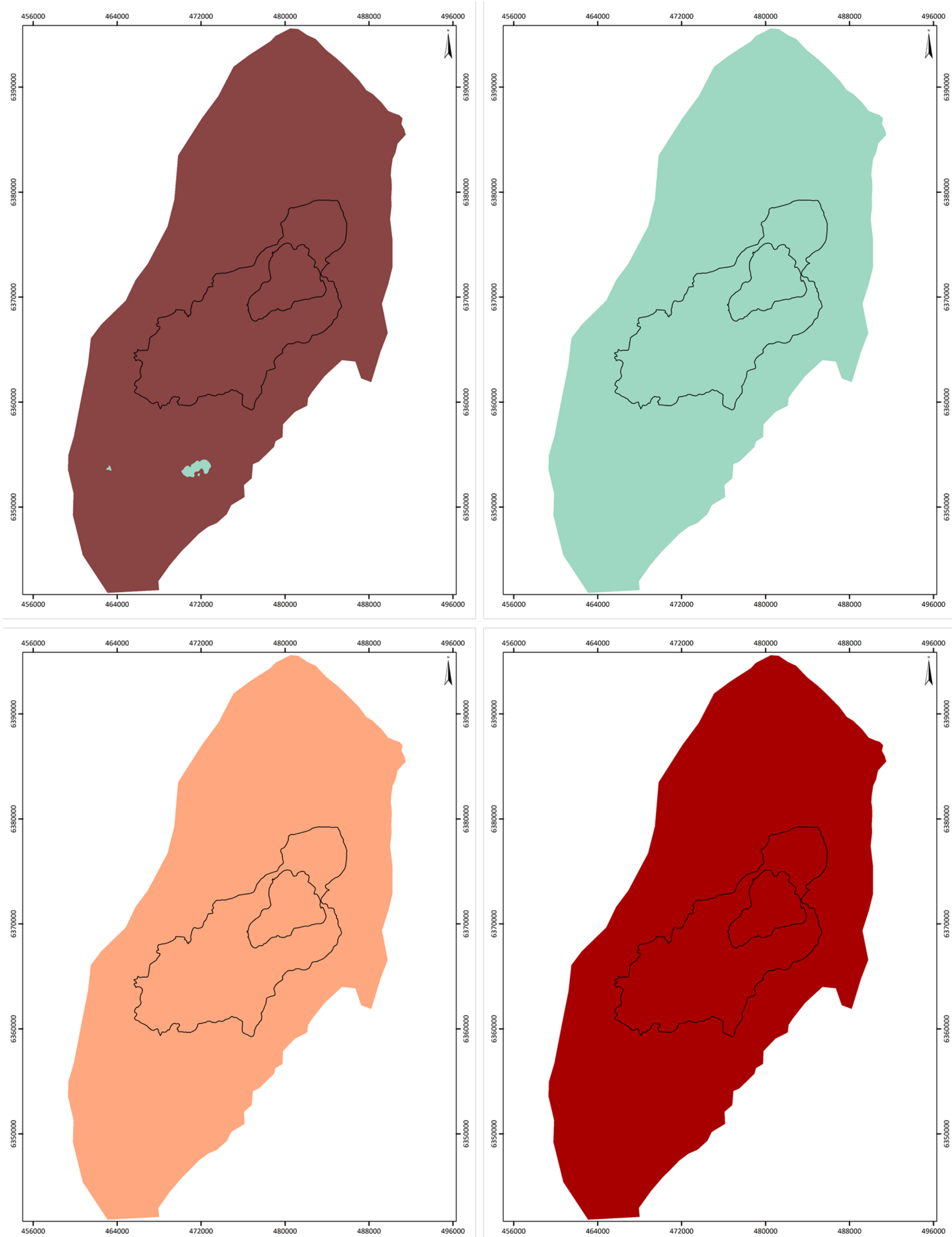


Figure 3-3f. The distribution of zonation/hydrostratigraphy of layers 21 (top left), 22 (top right), 23 (bottom left), and 24 (bottom right) in the 2020 Unified Geomodel. Definitions of the displayed zonation/hydrostratigraphy are given in Figure 3-2.

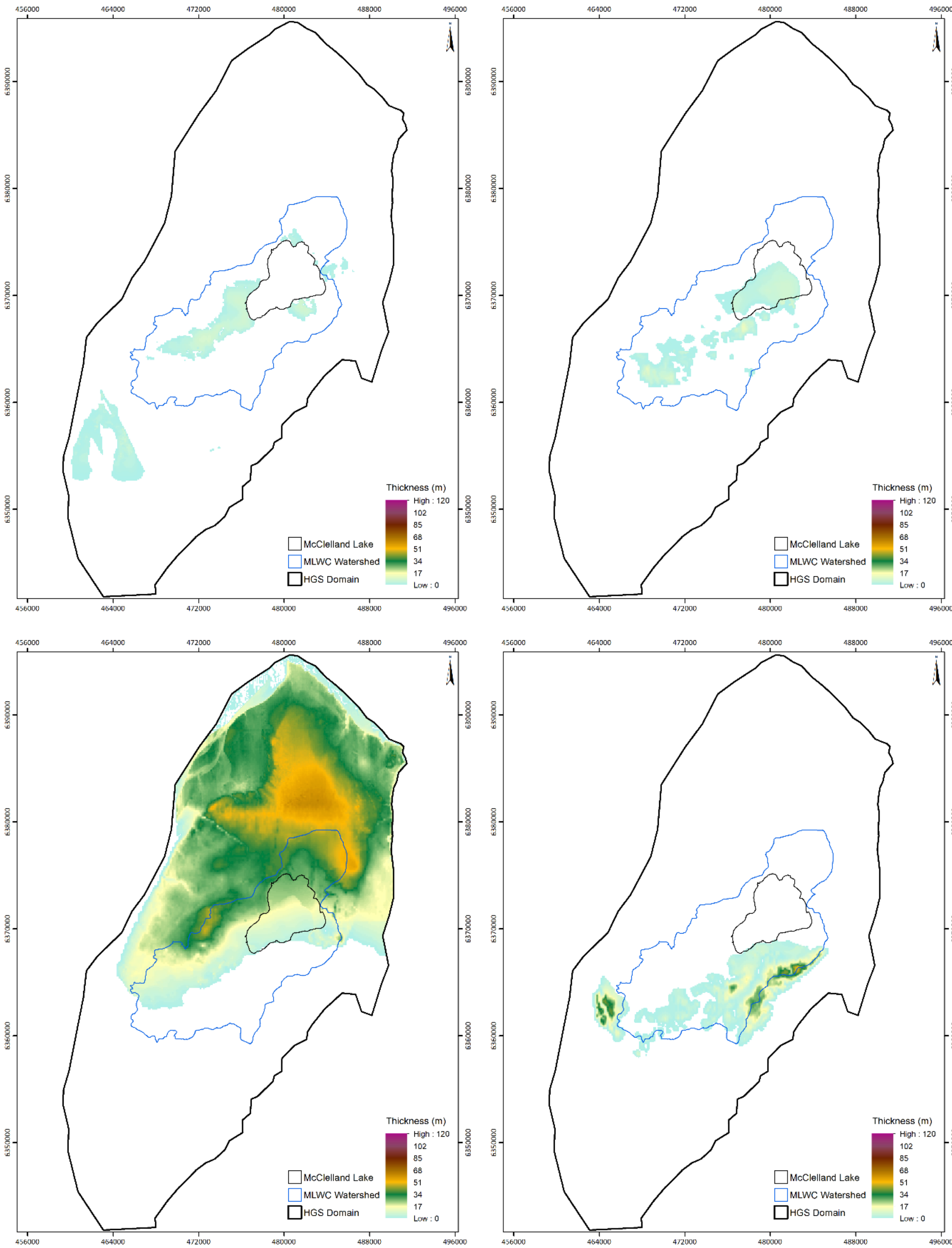


Figure 3-4a. Isopach (thickness) of the Muskeg (zone 1; top left), Silt Clay (zone 2; top right), Surface Sand North (zone 3; bottom left), and Surface Sand South (zone 30; bottom right) in the 2020 Unified Geomodel.

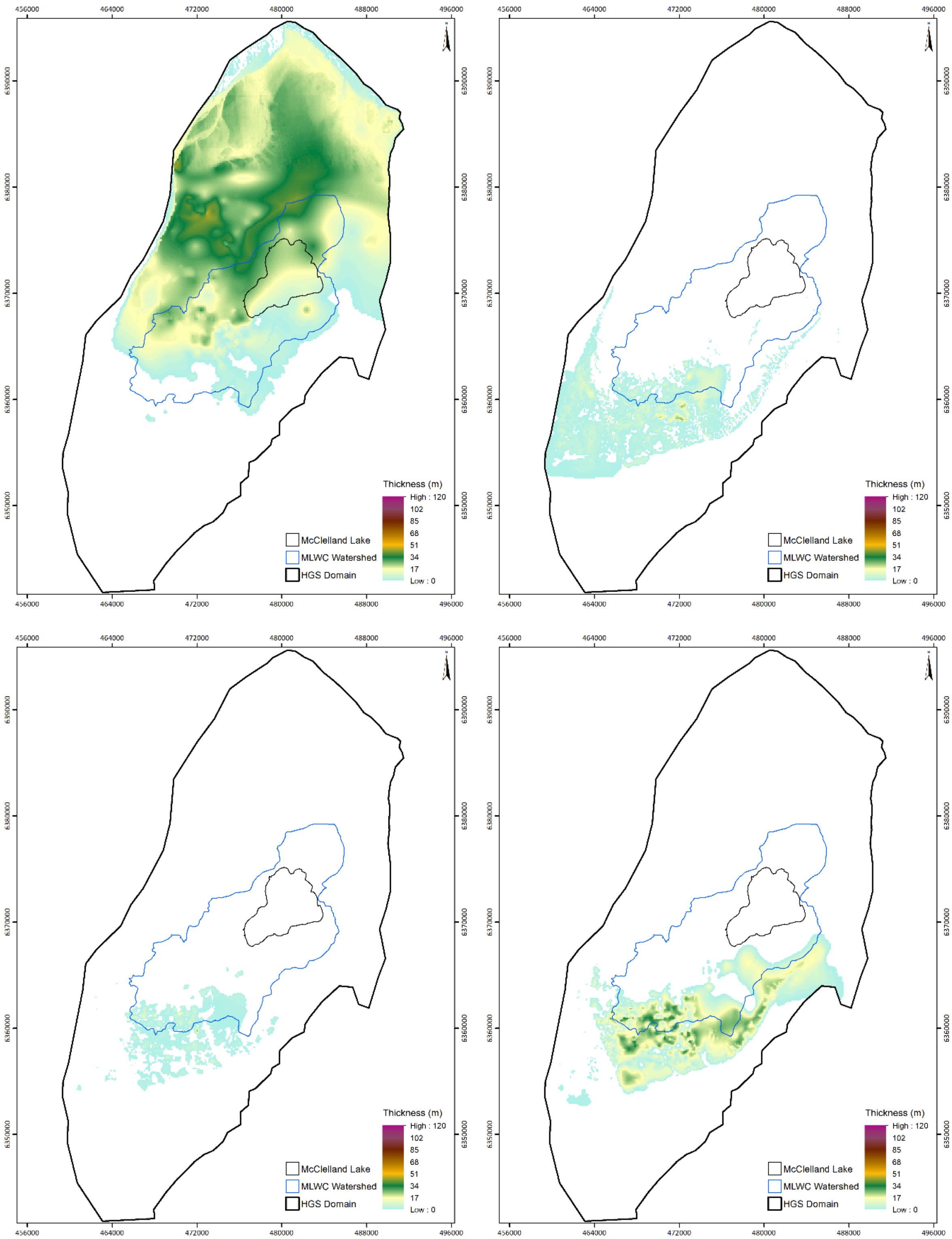


Figure 3-4b. Isopach (thickness) of Clay Till 1 (zone 4; top left), Silty Sand AQ1-AQ2 (zone 5; top right), Silty Sand AT1 (zone 6; bottom left), and Silty Sand AQ3 (zone 7; bottom right) in the 2020 Unified Geomodel.

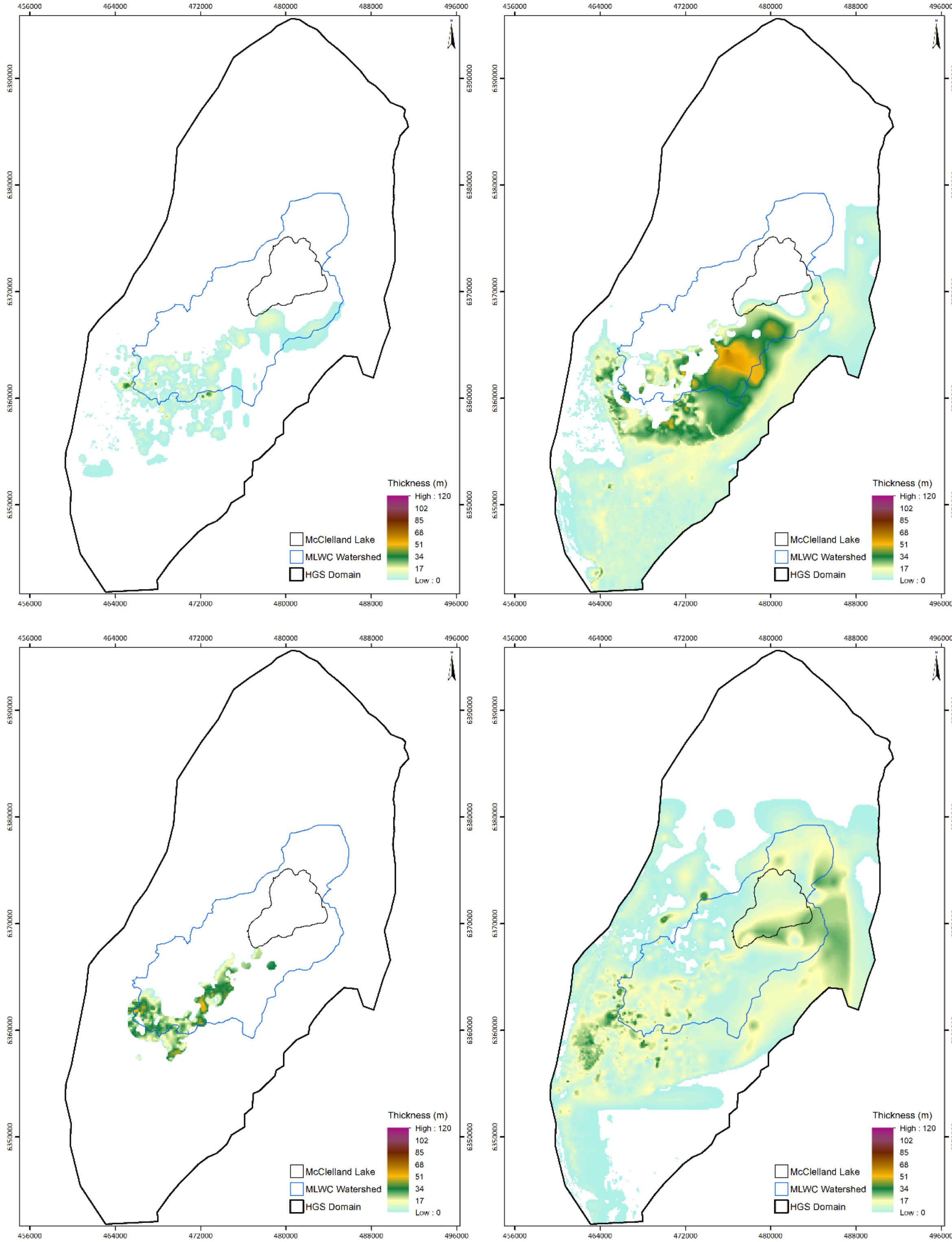


Figure 3-4c. Isopach (thickness) of Silty Sand AT2 (zone 8; top left), Silty Sand AQ4 (zone 9; top right), PGKM (zone 109; bottom left), and Clay Till 2 (zone 10; bottom right) in the 2020 Unified Geomodel.

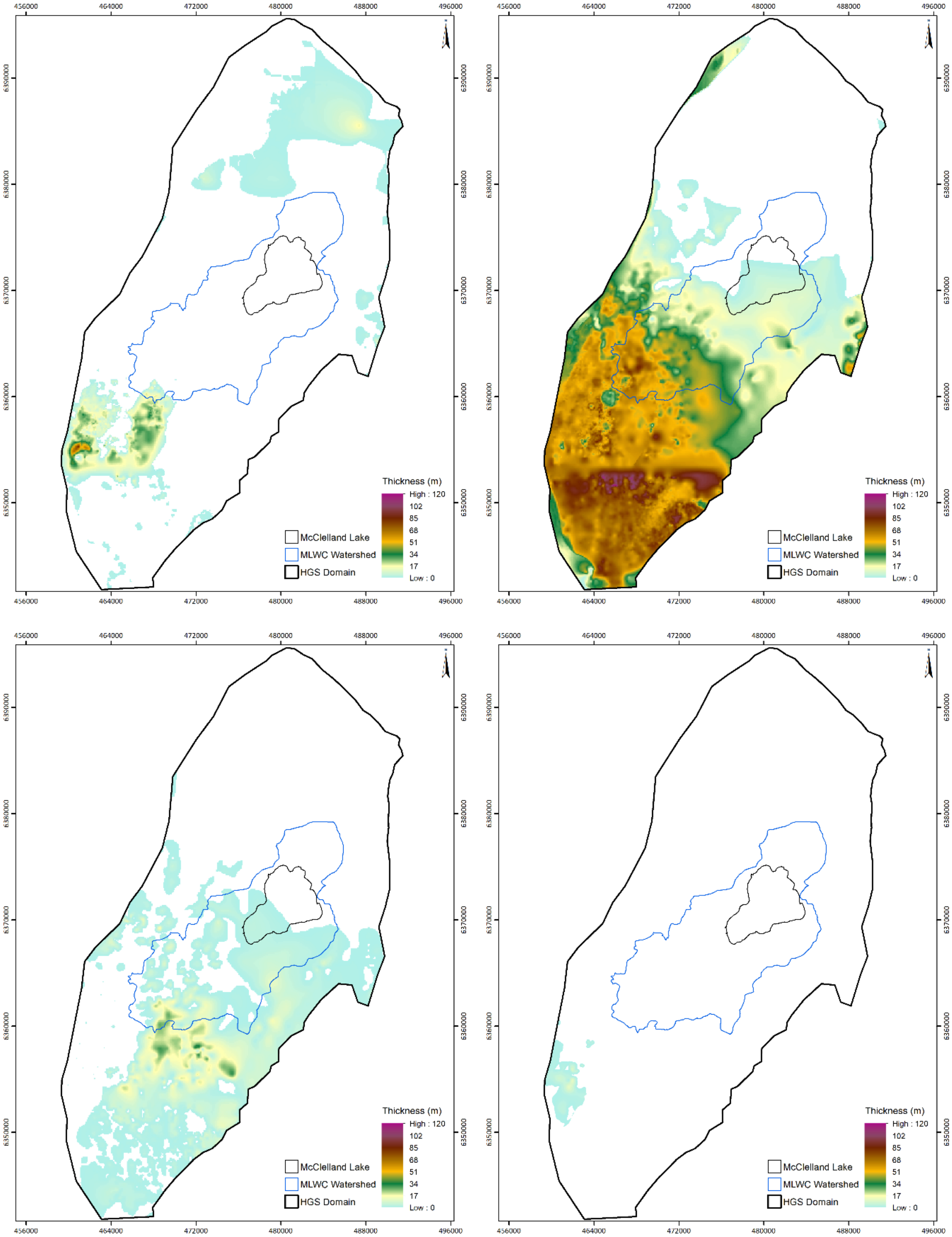


Figure 3-4d. Isopach (thickness) of Clearwater (zone 11; top left), McMurray (zone 12; top right), UW60 Basal McMurray Aquifer 1 (zone 13; bottom left), and UW60 Basal McMurray Aquifer 2 (zone 103; bottom right) in the 2020 Unified Geomodel.

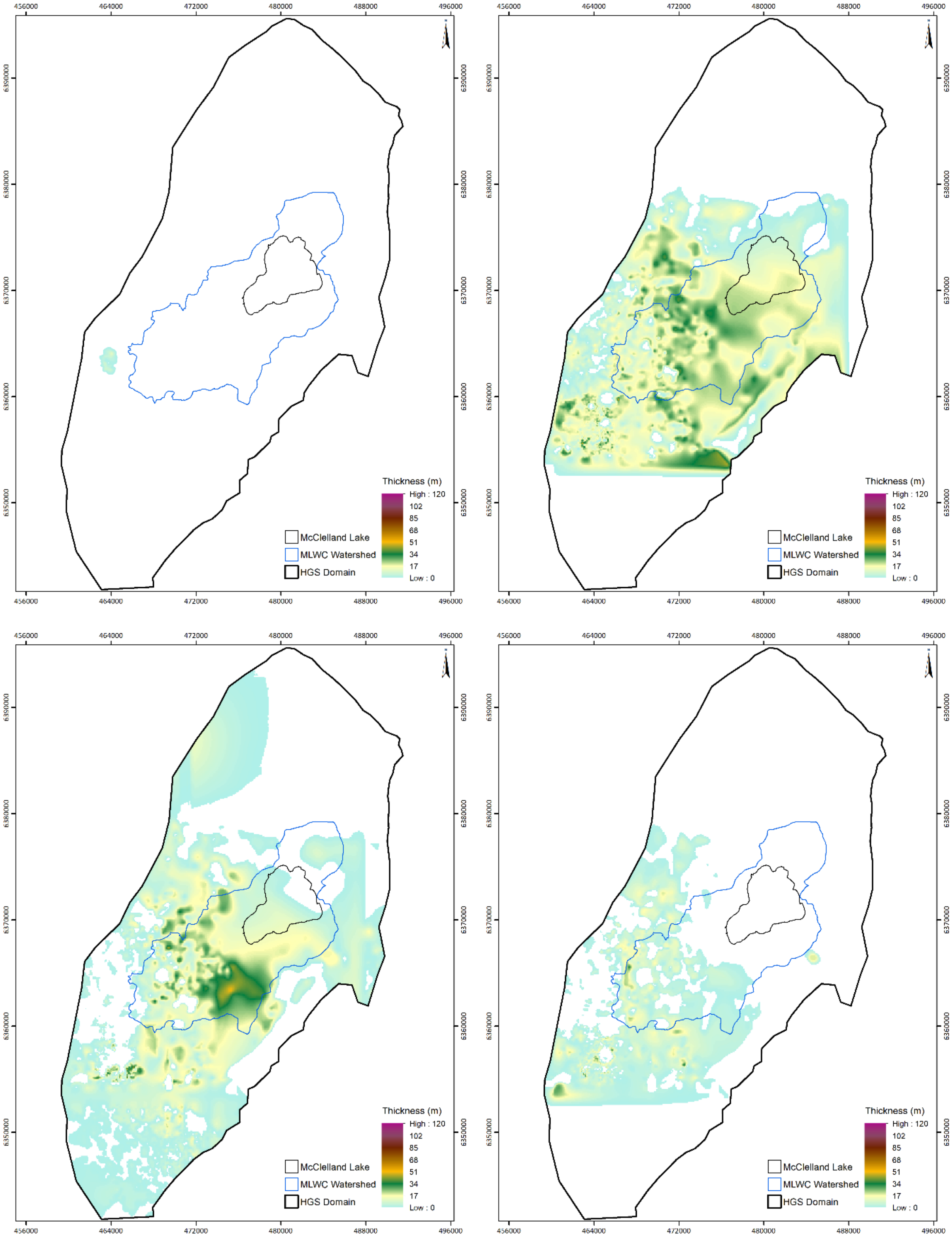


Figure 3-4e. Isopach (thickness) of UW60 Basal McMurray Aquifer 3 (zone 104; top left), CM40 CA40 Mud Oil Sand (zone 14; top right), CW40 Basal McMurray Aquifer (zone 15; bottom left), and CM50 CA50 Mud Oil Sand (zone 16; bottom right) in the 2020 Unified Geomodel.

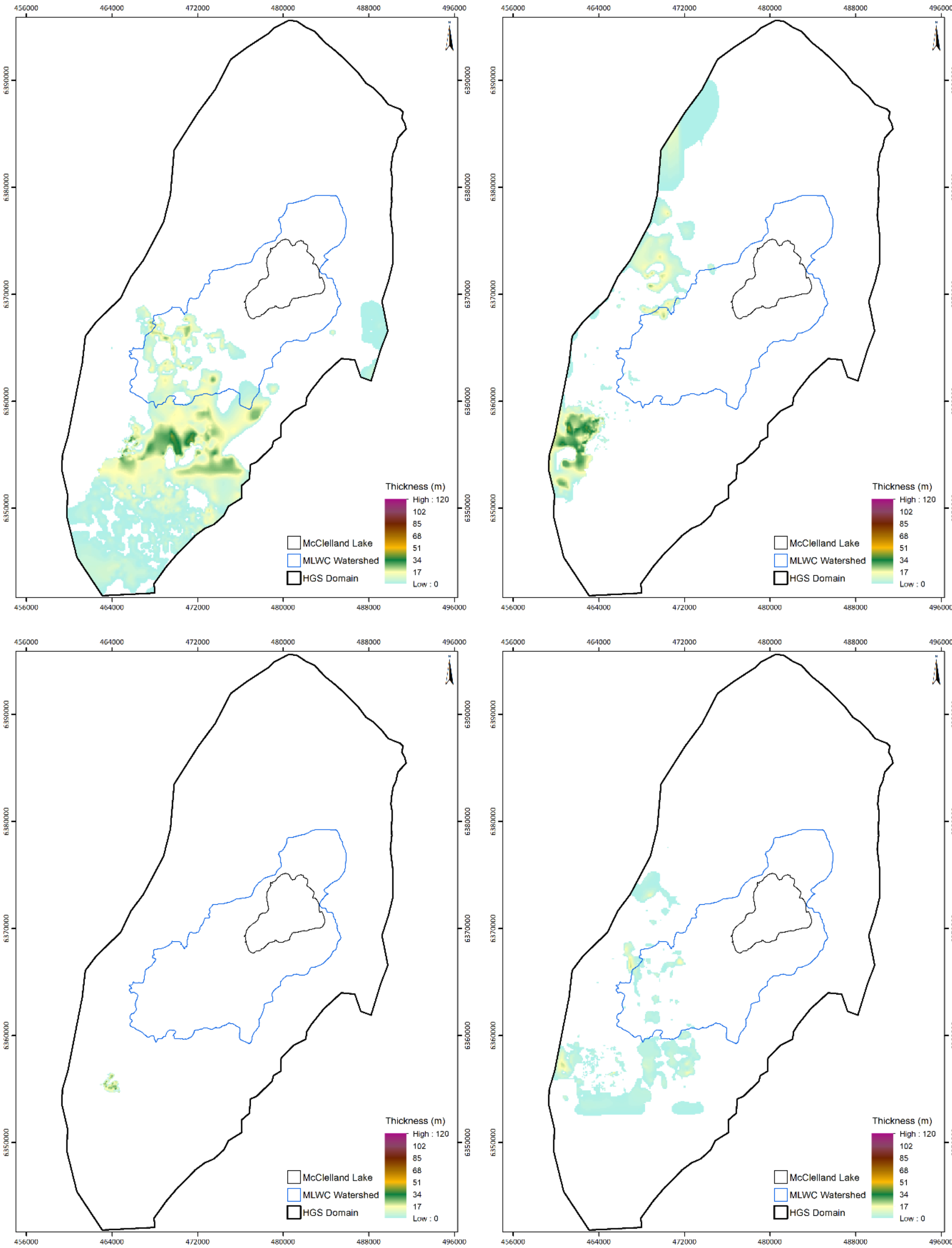


Figure 3-4f. Isopach (thickness) of CW50 Basal McMurray Aquifer 1 (zone 17; top left), CW50 Basal McMurray Aquifer 2 (zone 105; top right), CW50 Basal McMurray Aquifer 3 (zone 106; bottom left), and CM60 CA60 Mud Oil Sand (zone 18; bottom right) in the 2020 Unified Geomodel.

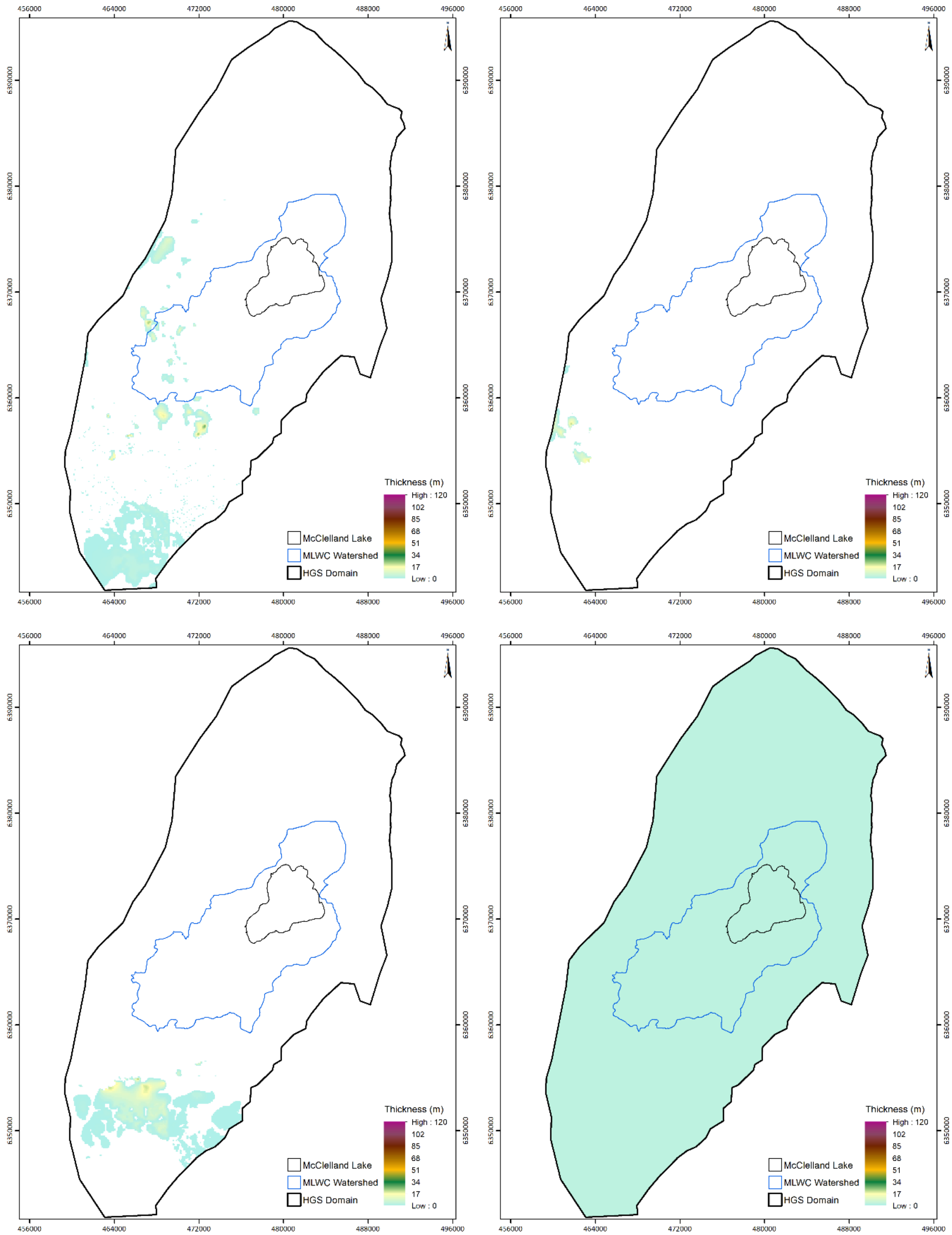


Figure 3-4g. Isopach (thickness) of CW60 Basal McMurray Aquifer 1 (zone 19; top left), CW60 Basal McMurray Aquifer 2 (zone 107; top right), CW60 Basal McMurray Aquifer 3 (zone 108; bottom left), and Weathered Beaverhill (zone 20; bottom right) in the 2020 Unified Geomodel.

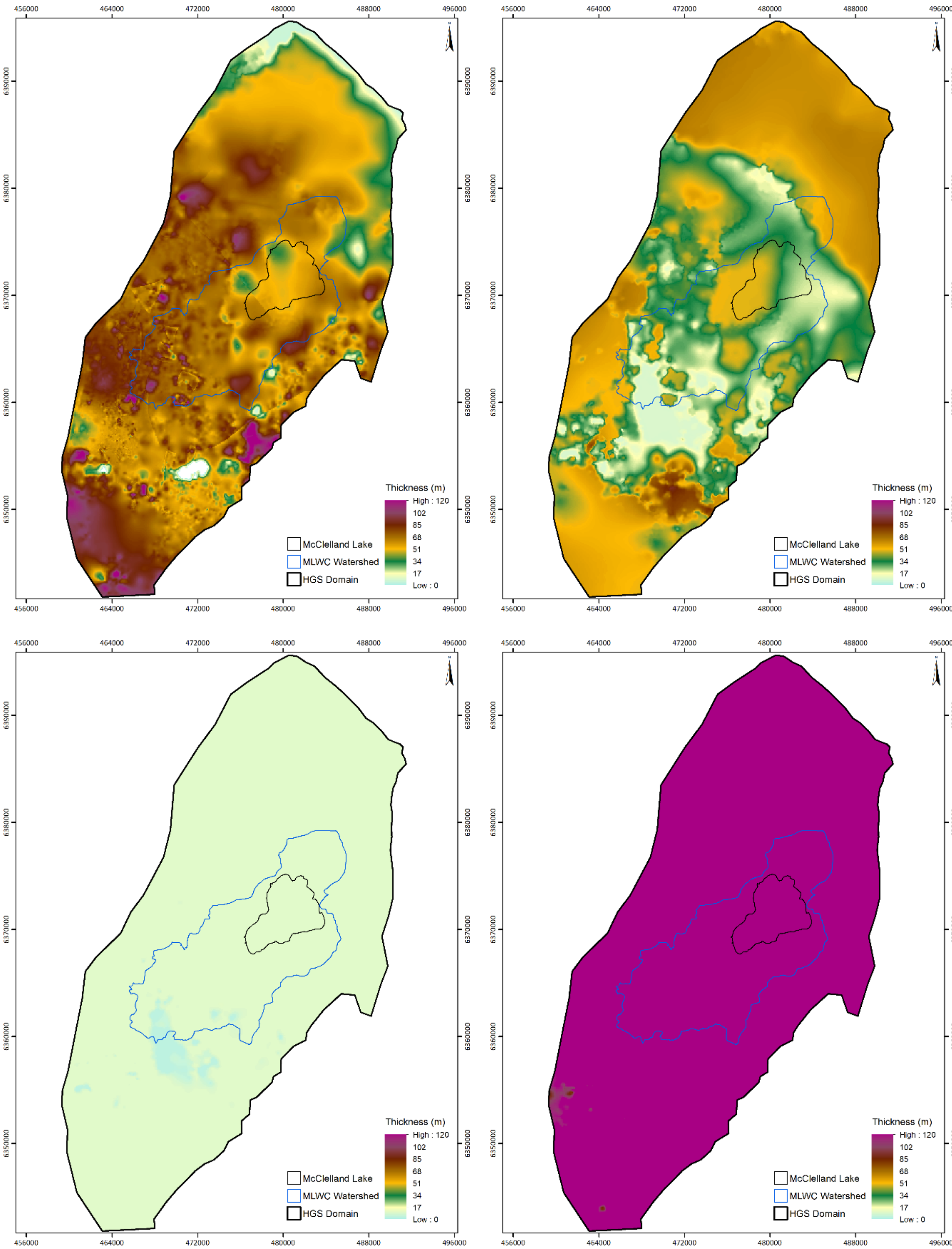


Figure 3-4h. Isopach (thickness) of Beaverhill Group (zone 21; top left), Upper Prairie Aquitard (zone 22; top right), Lower Prairie Aquifer (zone 23; bottom left), and Keg River (zone 24; bottom right) in the 2020 Unified Geomodel.

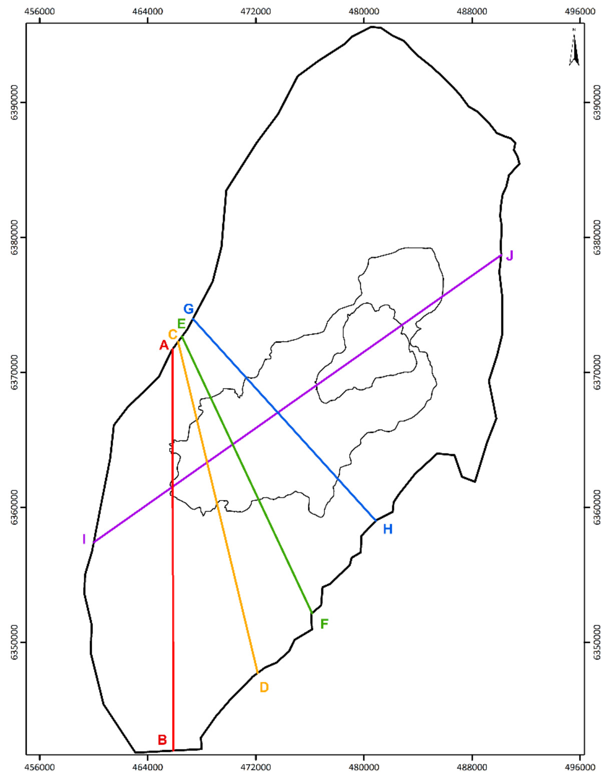
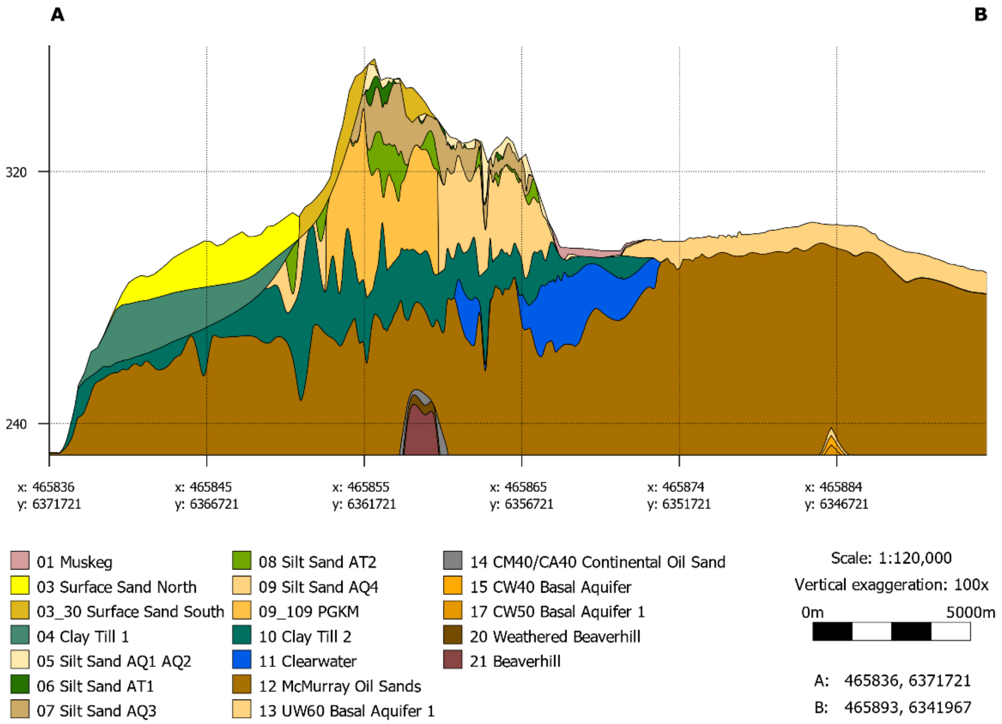


Figure 3-5: Locations of cross-sections taken through the 2020 Unified Geomodel.



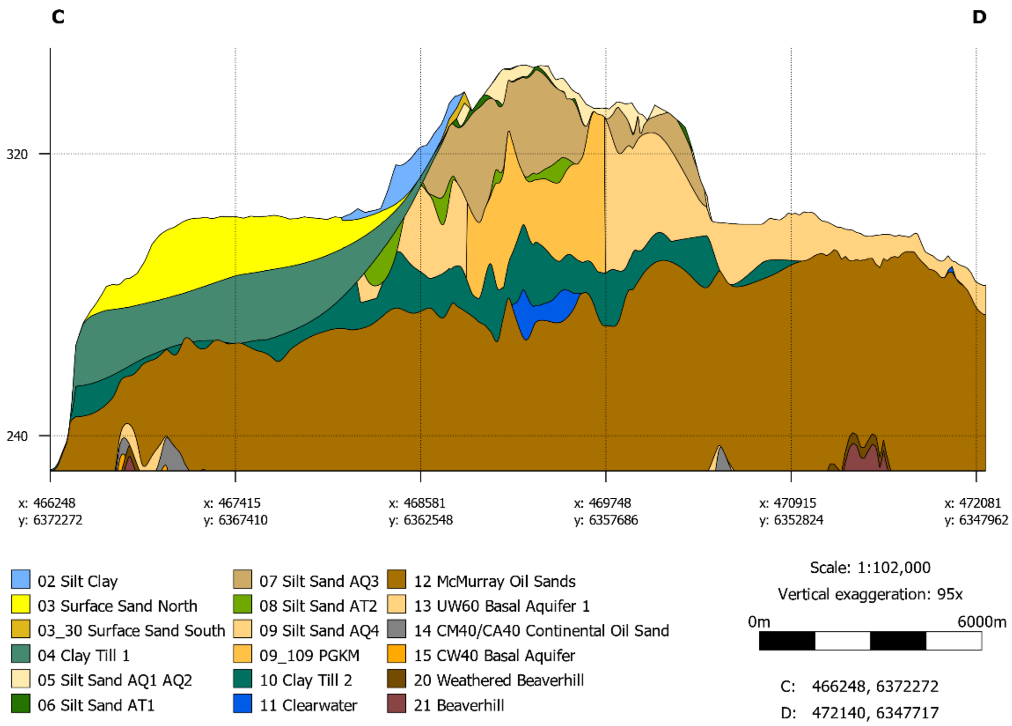


Figure 3-6a. Cross-sections A-B and C-D as shown in Figure 3-5.

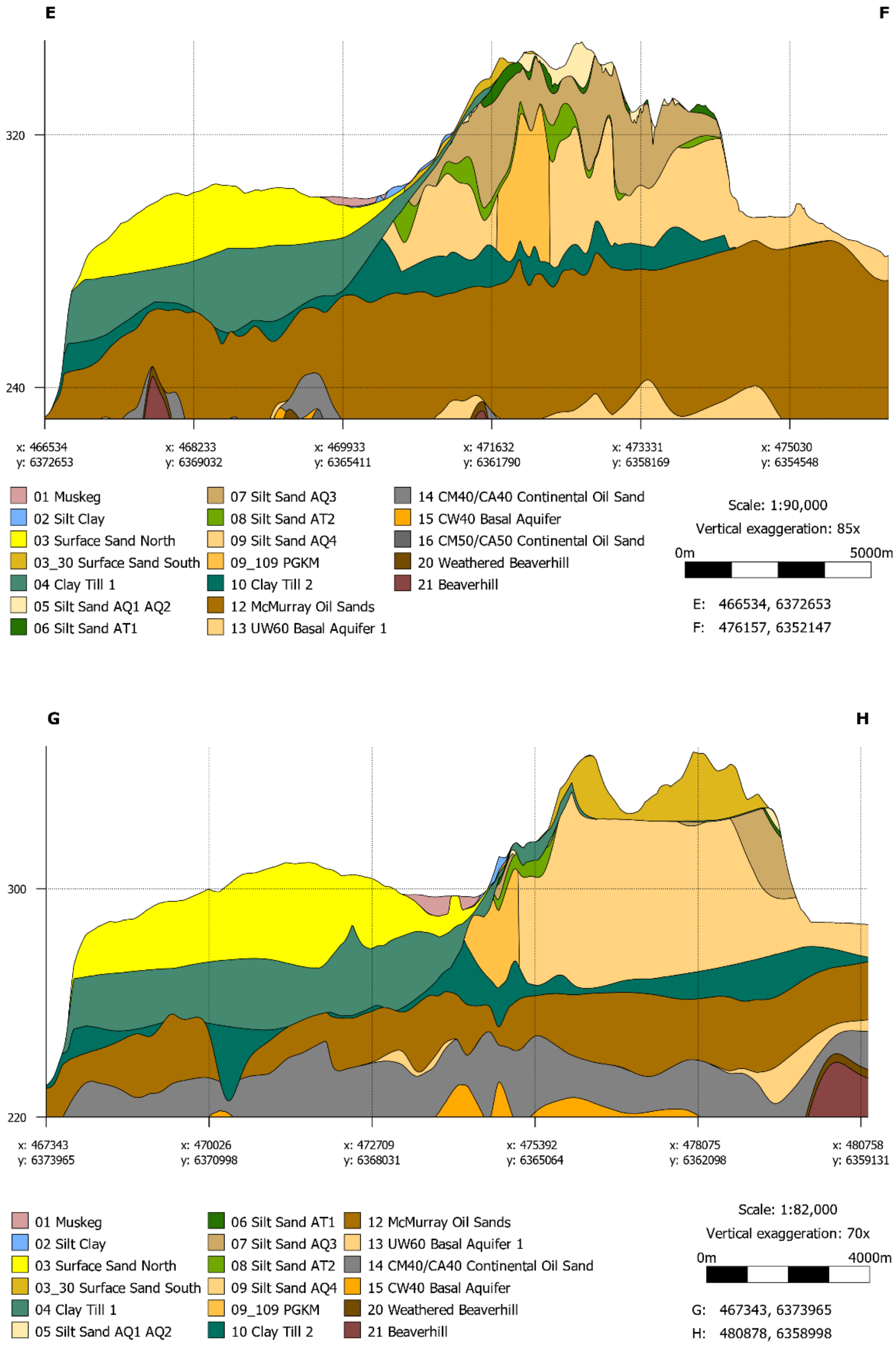


Figure 3-6b. Cross-sections E-F and G-H as shown in Figure 3-5.

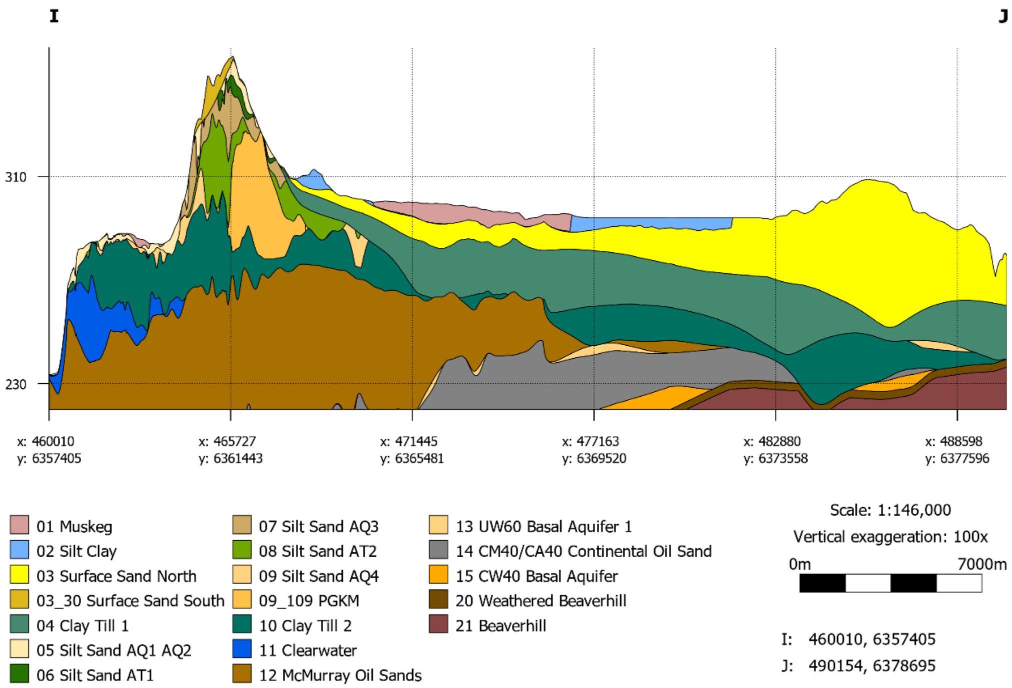


Figure 3-6c. Cross-section I-J as shown in Figure 3-5.

Table 3-1: Zonation and initial parameterization of the subsurface in the 2020 MLWC HGS model.

Hydrostratigraphy	Aquifer/ Aquitard	Model Zone	Geomodel Layer	K_h (m/s)	K_v (m/s)	Aniso. Ratio (Kh:Kv)	S_s (1/m)
Soil layer 1	-	31-48	n/a	9.2E-06 ~ 2.1E-04		1	-
Soil layer 2	-	49-66	n/a	9.2E-06 ~ 4.7E-05		1	-
Soil layer 3	-	67-84	n/a	7.3E-07 ~ 4.9E-05		1	-
Soil layer 4	-	85-102	n/a	7.5E-07 ~ 5.4E-05		1	-
Muskeg	AQ	1	1	1.1E-05	1.0E-06	10.3	1.00E-07
Silt Clay	AT	2	2	3.9E-08	7.4E-10	51.8	1.00E-07
Surface Sand North	AQ	3	3	4.2E-04	3.8E-05	10.8	1.00E-06
Surface Sand South	AQ	30	3	1.7E-04	8.5E-05	2.0	1.00E-06
Clay Till 1	AT	4	4	1.3E-07	3.3E-08	4.0	1.00E-07
Silty Sand AQ1-AQ2	AQ	5	5	1.7E-06	1.0E-07	16.8	1.00E-06
Silty Sand AT1	AT	6	6	1.5E-06	1.5E-08	98.8	1.00E-07
Silty Sand AQ3	AQ	7	7	9.3E-05	1.7E-06	54.8	1.00E-06
Silty Sand AT2	AT	8	8	3.3E-07	4.5E-09	72.9	1.00E-07
Silty Sand AQ4	AQ	9	9	1.8E-05	1.8E-06	9.6	1.00E-06
PGKM	AT	109	9	1.3E-07	1.3E-09	98.2	1.00E-06
Clay Till 2	AT	10	10	2.9E-07	2.9E-08	10.0	1.00E-07
Clearwater	AT	11	11	4.6E-09	4.6E-10	10.0	1.00E-07
McMurray	AT	12	12	6.0E-09	6.0E-10	10.0	1.00E-07
UW60 Basal Aquifer 1	AQ	13	13	7.5E-05	7.5E-06	10.0	1.00E-07
UW60 Basal Aquifer 2	AQ	103	13	9.4E-05	9.4E-06	10.0	1.00E-07
UW60 Basal Aquifer 3	AQ	104	13	1.3E-04	1.3E-05	10.0	1.00E-07
CM40 CA40 Mud Oil Sand	AT	14	14	9.0E-10	3.0E-10	3.0	1.00E-07
CW40 Basal Aquifer	AQ	15	15	7.5E-05	7.5E-06	10.0	1.00E-07
CM50 CA50 Mud Oil Sand	AT	16	16	2.3E-10	7.5E-11	3.0	1.00E-07
CW50 Basal Aquifer	AQ	17	17	1.3E-04	1.3E-05	10.0	1.00E-07
CW50 Basal Aquifer 2	AQ	105	17	5.0E-05	5.0E-06	10.0	1.00E-07
CW50 Basal Aquifer 3	AQ	106	17	2.1E-04	2.1E-05	10.0	1.00E-07
CM60 CA60 Mud Oil Sand	AT	18	18	2.3E-10	7.5E-11	3.0	1.00E-07

Hydrostratigraphy	Aquifer/ Aquitard	Model Zone	Geomodel Layer	K_h (m/s)	K_v (m/s)	Aniso. Ratio (Kh:Kv)	S_s (1/m)
CW60 Basal Aquifer 1	AQ	19	19	3.0E-05	3.0E-06	10.0	1.00E-07
CW60 Basal Aquifer 2	AQ	107	19	3.8E-05	3.8E-06	10.0	1.00E-07
CW60 Basal Aquifer 3	AQ	108	19	1.3E-04	1.3E-05	10.0	1.00E-07
Weathered Beaverhill	AQ	20	20	5.0E-06	5.0E-07	10.0	1.00E-07
Beaverhill Group	AT	21	21	3.0E-07	3.0E-08	10.0	1.00E-07
Upper Prairie Aquitard	AT	22	22	1.1E-09	1.1E-10	10.0	1.00E-07
Lower Prairie Aquifer	AQ	23	23	7.3E-05	7.3E-06	10.0	1.00E-07
Keg River	AQ	24	24	9.5E-06	9.5E-07	10.0	1.00E-07

Notes: K_v is vertical hydraulic conductivity; K_h is horizontal hydraulic conductivity and S_s is specific storage. The K_h:K_v anisotropy ratios were derived in consultation with FHEC.

Table 3-2: Unsaturated parameters of the subsurface zones.

Hydrostratigraphy	θ_s	α	*n*	S_r	Reference
Soil layer 1 Soil layer 2 Soil layer 3 Soil layer 4	Table 3-4				
Muskeg	0.7	Table 3-4			Price et al., (2010)
Silt Clay	0.33	0.13	1.34	0.05	Gerke and Köhne (2004)
Surface Sand North	0.37	3.53	3.18	0.14	Schaap et al., (2001)
Surface Sand South	0.37	3.53	3.18	0.14	Schaap et al., (2001)
Clay Till 1	0.33	0.13	1.34	0.05	Gerke and Köhne (2004)
Silty Sand AQ1-AQ2	0.37	3.53	3.18	0.14	Schaap et al., (2001)
Silty Sand AT1	0.33	0.13	1.34	0.05	Gerke and Köhne (2004)
Silty Sand AQ3	0.37	3.53	3.18	0.14	Schaap et al., (2001)
Silty Sand AT2	0.33	0.13	1.34	0.05	Gerke and Köhne (2004)
Silty Sand AQ4	0.37	3.53	3.18	0.14	Schaap et al., (2001)
PGKM	0.37	3.53	3.18	0.14	Schaap et al., (2001)
Clay Till 2	0.33	0.13	1.34	0.05	Gerke and Köhne (2004)
Clearwater	0.1	N.A.			
McMurray	0.1	N.A.			
UW60 Basal Aquifer 1	0.1	3.53	3.18	0.14	Schaap et al., (2001)

Hydrostratigraphy	θ_s	α	*n*	S_r	Reference
UW60 Basal Aquifer 2	0.1	3.53	3.18	0.14	Schaap et al., (2001)
UW60 Basal Aquifer 3	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CM40 CA40 Mud Oil Sand	0.1		N.A.		
CW40 Basal Aquifer	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CM50 CA50 Mud Oil Sand	0.1		N.A.		
CW50 Basal Aquifer	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CW50 Basal Aquifer 2	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CW50 Basal Aquifer 3	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CM60 CA60 Mud Oil Sand	0.1		N.A.		
CW60 Basal Aquifer 1	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CW60 Basal Aquifer 2	0.1	3.53	3.18	0.14	Schaap et al., (2001)
CW60 Basal Aquifer 3	0.1	3.53	3.18	0.14	Schaap et al., (2001)
Weathered Beaverhill	0.1		N.A.		
Beaverhill Group	0.2		N.A.		
Upper Prairie Aquitard	0.2		N.A.		
Lower Prairie Aquifer	0.2		N.A.		
Keg River	0.2		N.A.		

Notes: θ_s – saturated volumetric water content, the same as porosity
α – van Genuchten parameter related to the inverse of air entry pressure
n – van Genuchten parameter related to pore size distribution
S_r – residual saturation
N.A. – not applicable to fully saturated units.

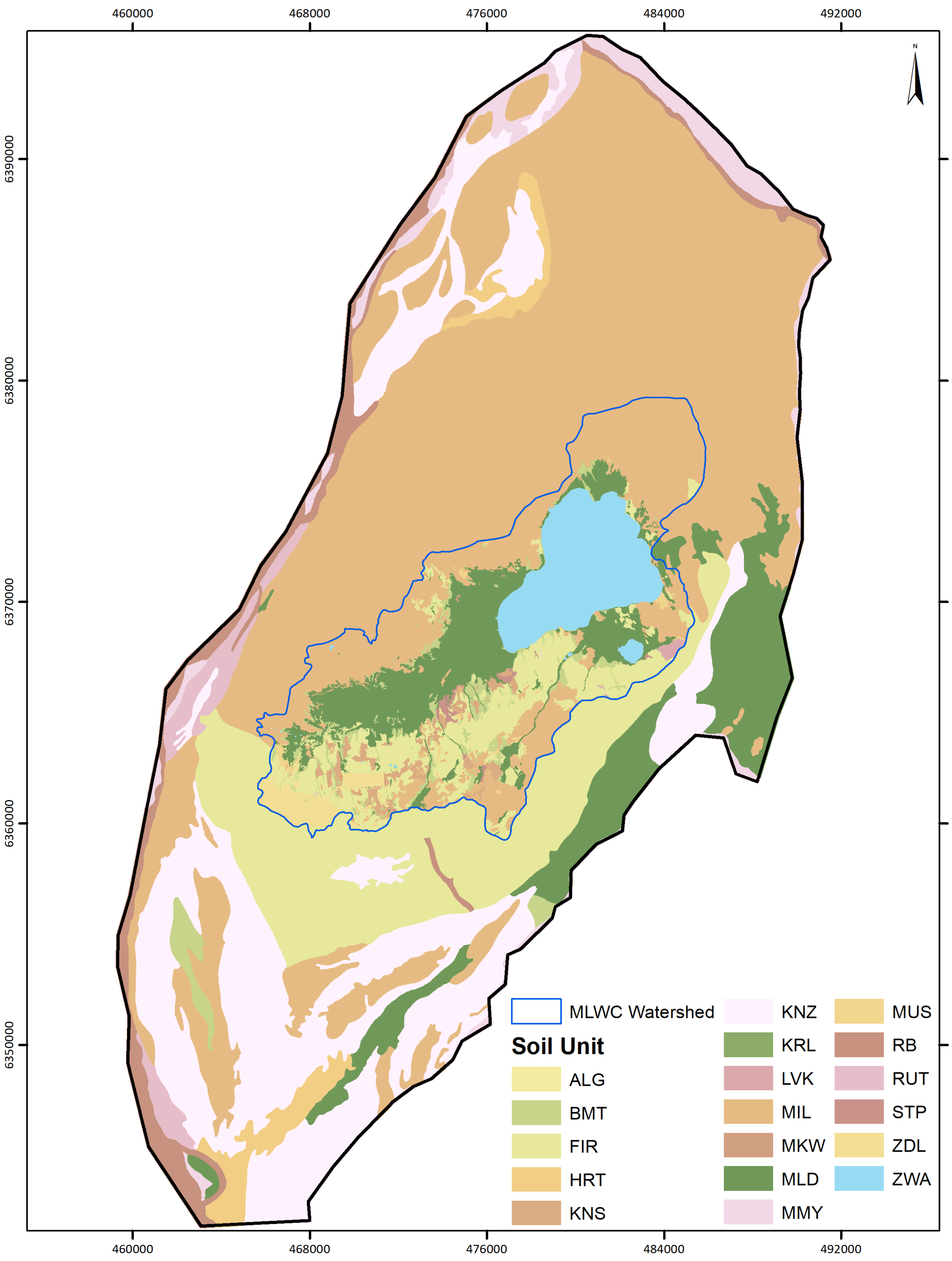


Figure 3-7: Soil zonation for 2020 MLWC HGS model based on Golder (2018) within the MLWC watershed and Turchenek and Lindsay (1982) outside of the watershed.

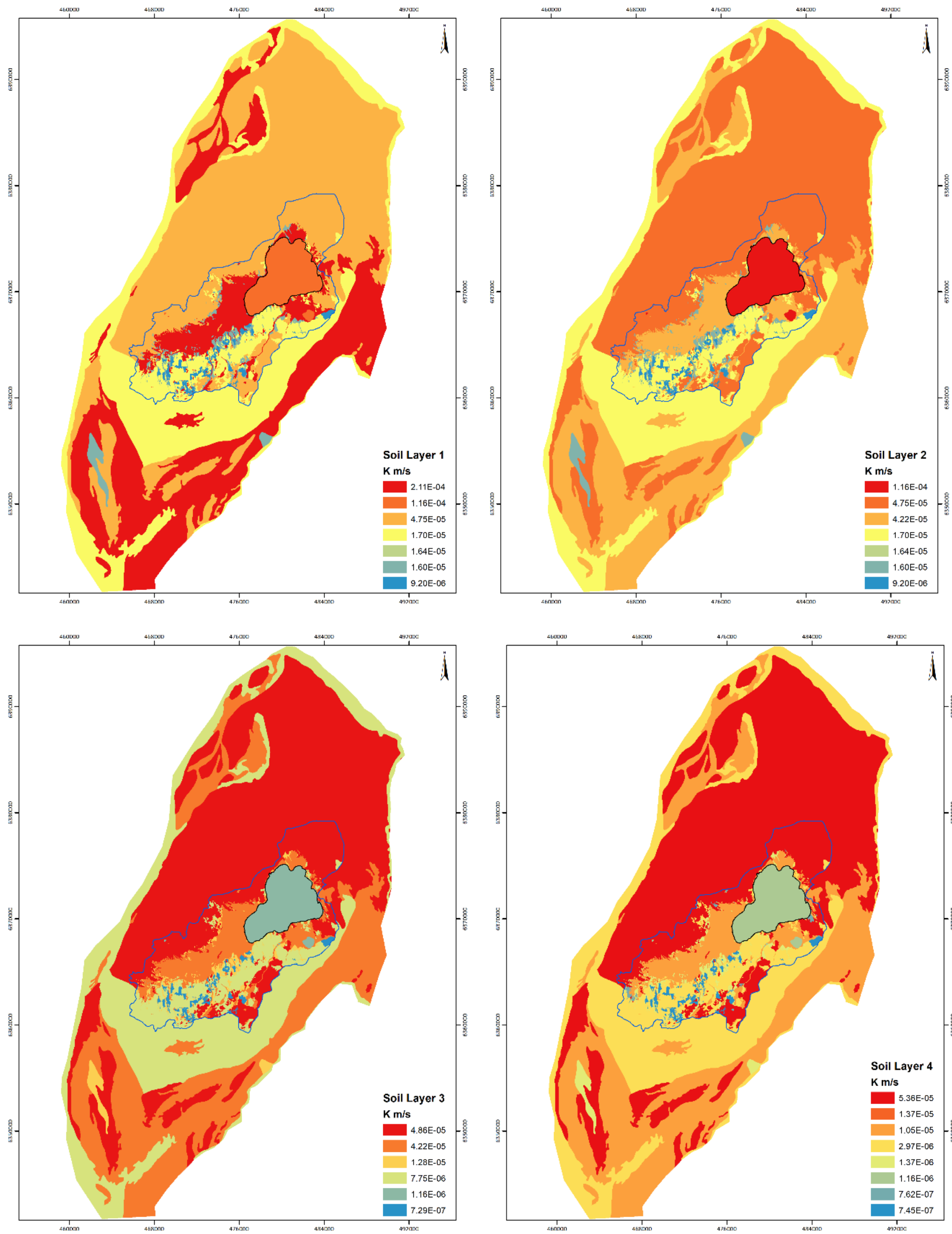


Figure 3-8: The hydraulic conductivities assigned to the surface soil layers in the 2020 MLWC HGS model.

Table 3-3: Soil unit names and corresponding horizon thicknesses.

ID	Soil Unit	Name	Layer 1 (cm)	Layer 2 (cm)	Layer 3 (cm)	Layer 4 (cm)
1	ALG	ALGAR	23	25	35	65
2	BMT	BITUMONT	12	16	39	79
3	FIR	FIREBAG	7	13	39	60
4	HRT	HEART	7	13	39	60
5	KNS	KINOSIS	7	14	41	62
6	KNZ	KENZIE	10	20	30	80
7	KRL	KEARL	8	10	26	83
8	LVK	LIVOCK	8	18	41	62
9	MIL	MILDRED	4	12	43	61
10	MKW	MIKKWA	10	20	30	80
11	MLD	MCLELLAND	10	20	30	80
12	MMY	MCMURRAY	7	28	<1	94
13	MUS	MUSKEG	10	20	20	61
14	RB	ROUGH BROKEN	7	13	39	60
15	RUT	RUTH LAKE	2	2	26	34
16	STP	STEEPBANK	8	18	33	88
17	ZDL	DEVELOPED	7	13	39	60
18	LB	LAKE BED	10	20	30	80

Table 3-4: Assigned soil units properties in the 2020 MLWC HGS model.

Soil Layer	Soil Unit	HGS Zone	K (m/s)	Porosity	Unsaturated Functions
1	ALG	31	1.64E-05	0.44	unsat_table_sandy_loam
	BMT	32	1.60E-05	0.44	unsat_table_sandy_loam
	FIR	33	1.70E-05	0.42	unsat_table_sandy_loam
	HRT	34	1.70E-05	0.42	unsat_table_sandy_loam
	KNS	35	9.20E-06	0.43	unsat_table_sandy_loam
	KNZ	36	2.11E-04	0.85	unsat_table_peat
	KRL	37	2.11E-04	0.85	unsat_table_peat
	LVK	38	9.20E-06	0.43	unsat_table_sandy_loam
	MIL	39	4.75E-05	0.43	unsat_table_fine_sand
	MKW	40	2.11E-04	0.85	unsat_table_peat
	MLD	41	2.11E-04	0.85	unsat_table_peat
	MMY	42	1.70E-05	0.42	unsat_table_sandy_loam
	MUS	43	2.11E-04	0.85	unsat_table_peat
	RB	44	1.70E-05	0.42	unsat_table_sandy_loam
	RUT	45	1.70E-05	0.42	unsat_table_sandy_loam
	STP	46	1.60E-05	0.44	unsat_table_sandy_loam
	ZDL	47	1.70E-05	0.42	unsat_table_sandy_loam
	LB	48	1.16E-04	-	-
2	ALG	49	1.64E-05	0.44	unsat_table_sandy_loam
	BMT	50	1.60E-05	0.44	unsat_table_sandy_loam
	FIR	51	1.70E-05	0.42	unsat_table_sandy_loam
	HRT	52	1.70E-05	0.42	unsat_table_sandy_loam
	KNS	53	9.20E-06	0.43	unsat_table_sandy_loam

	KNZ	54	4.22E-05	0.85	unsat_table_peat
	KRL	55	4.22E-05	0.85	unsat_table_peat
	LVK	56	9.20E-06	0.43	unsat_table_sandy_loam
	MIL	57	4.75E-05	0.43	unsat_table_fine_sand
	MKW	58	4.22E-05	0.85	unsat_table_peat
	MLD	59	4.22E-05	0.85	unsat_table_peat
	MMY	60	1.70E-05	0.42	unsat_table_sandy_loam
	MUS	61	4.22E-05	0.85	unsat_table_peat
	RB	62	1.70E-05	0.42	unsat_table_sandy_loam
	RUT	63	1.70E-05	0.42	unsat_table_sandy_loam
	STP	64	1.60E-05	0.44	unsat_table_sandy_loam
	ZDL	65	1.70E-05	0.42	unsat_table_sandy_loam
	LB	66	1.16E-04	-	-
3	ALG	67	1.28E-05	0.37	unsat_table_loamy_sand
	BMT	68	1.28E-05	0.37	unsat_table_loamy_sand
	FIR	69	7.75E-06	0.39	unsat_table_sandy_loam
	HRT	70	7.75E-06	0.39	unsat_table_sandy_loam
	KNS	71	7.29E-07	0.41	unsat_table_clay_loam
	KNZ	72	4.22E-05	0.85	unsat_table_peat
	KRL	73	4.22E-05	0.85	unsat_table_peat
	LVK	74	7.29E-07	0.41	unsat_table_clay_loam
	MIL	75	4.86E-05	0.40	unsat_table_fine_sand
	MKW	76	4.22E-05	0.85	unsat_table_peat
	MLD	77	4.22E-05	0.85	unsat_table_peat
	MMY	78	7.75E-06	0.39	unsat_table_sandy_loam
	MUS	79	4.22E-05	0.85	unsat_table_peat
	RB	80	7.75E-06	0.39	unsat_table_sandy_loam
	RUT	81	7.75E-06	0.39	unsat_table_sandy_loam
	STP	82	1.28E-05	0.37	unsat_table_loamy_sand
	ZDL	83	7.75E-06	0.39	unsat_table_sandy_loam
	LB	84	1.16E-06	-	-
4	ALG	85	1.37E-06	0.39	unsat_table_sandy_clay_loam
	BMT	86	1.37E-06	0.39	unsat_table_sandy_clay_loam
	FIR	87	2.97E-06	0.39	unsat_table_sandy_loam
	HRT	88	2.97E-06	0.39	unsat_table_sandy_loam
	KNS	89	7.45E-07	0.42	unsat_table_clay_loam
	KNZ	90	1.05E-05	0.85	unsat_table_peat
	KRL	91	1.37E-05	0.38	unsat_table_loamy_fine_sand
	LVK	92	7.45E-07	0.42	unsat_table_clay_loam
	MIL	93	5.36E-05	0.40	unsat_table_fine_sand
	MKW	94	1.05E-05	0.85	unsat_table_peat
	MLD	95	1.05E-05	0.85	unsat_table_peat
	MMY	96	2.97E-06	0.39	unsat_table_sandy_loam
	MUS	97	7.62E-07	0.42	unsat_table_clay_loam

RB	98	2.97E-06	0.39	unsat_table_sandy_loam
RUT	99	2.97E-06	0.39	unsat_table_sandy_loam
STP	100	1.37E-06	0.39	unsat_table_sandy_clay_loam
ZDL	101	2.97E-06	0.39	unsat_table_sandy_loam
LB	102	1.16E-06	-	-

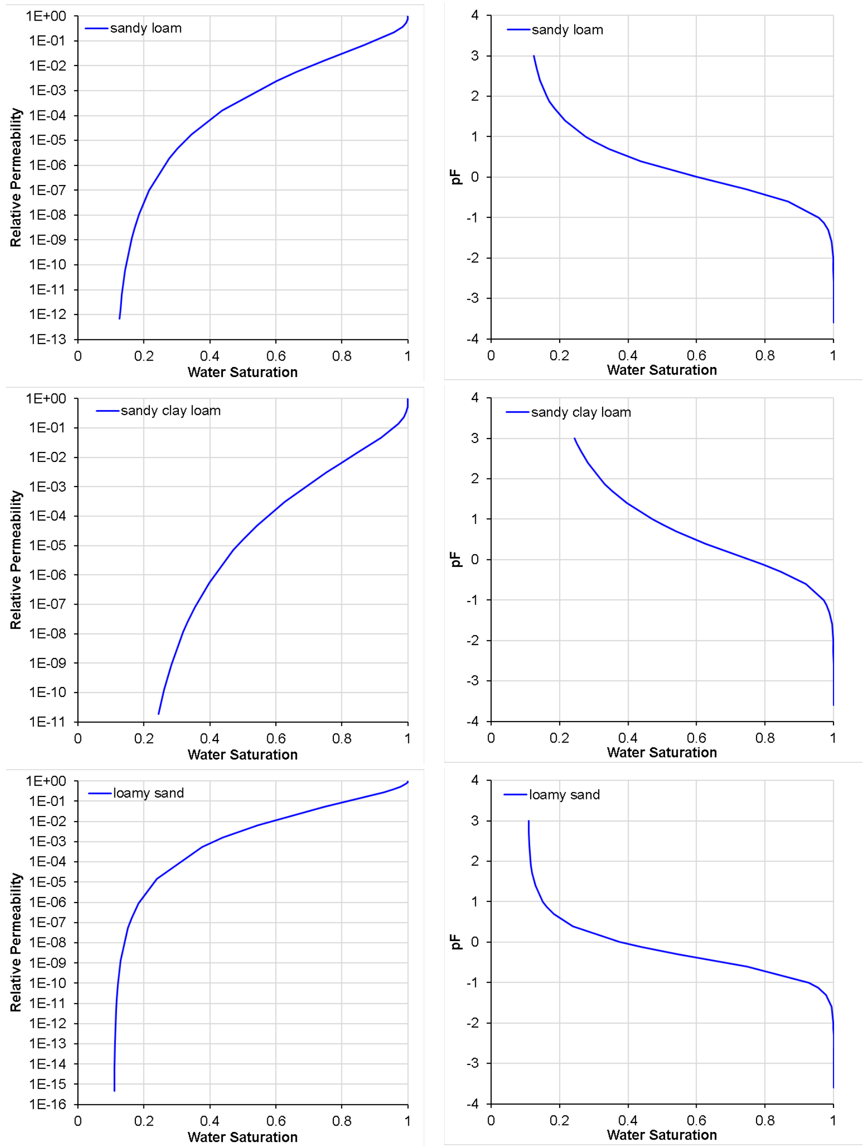


Figure 3-9: Unsaturated flow curves of the surface soils.

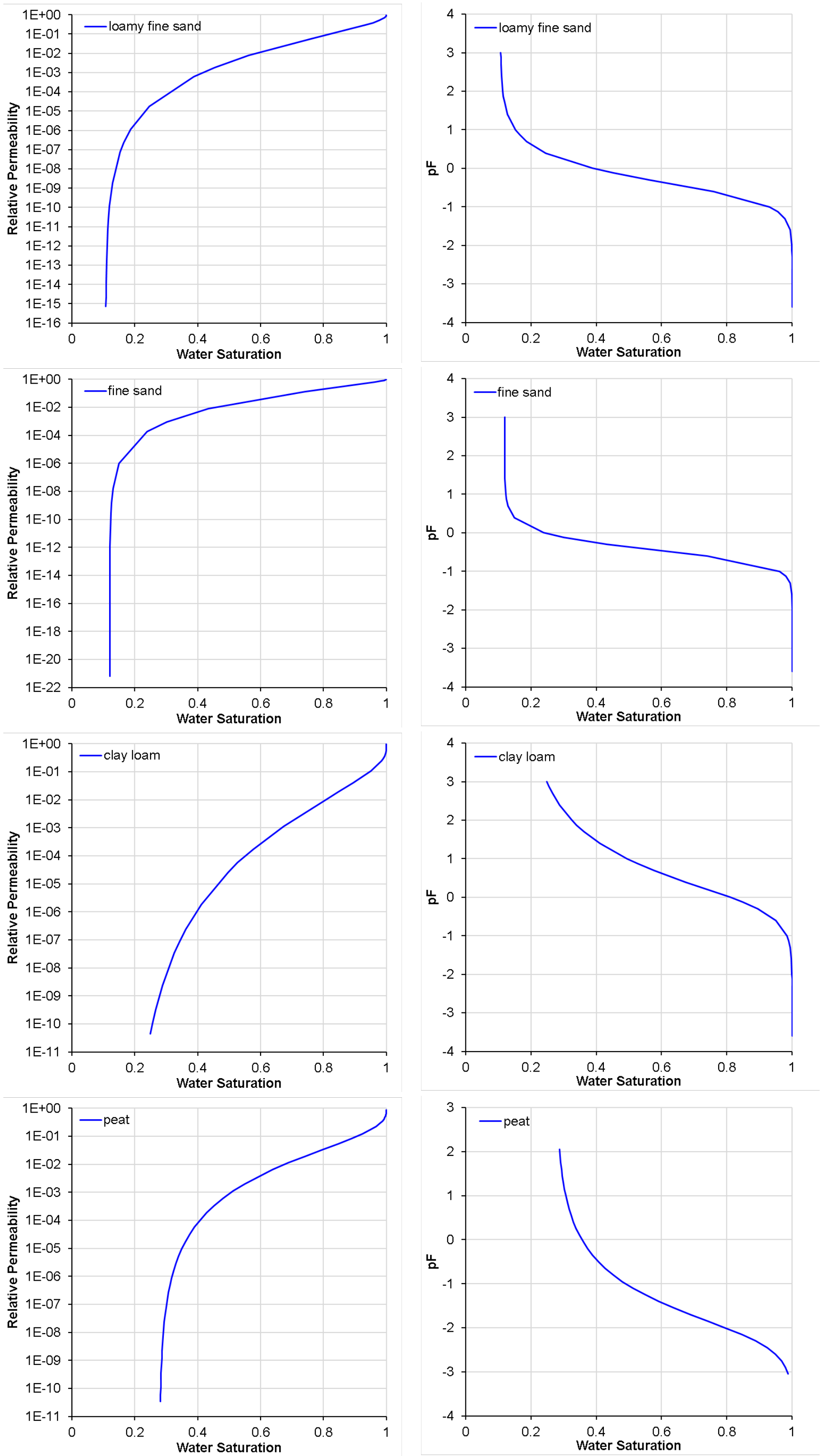


Figure 3-9: Unsaturated flow curves of the surface soils. (cont.)

3.3 Surface Parameterization

Overland flow properties in the 2020 MLCW HGS model were assigned based on land cover; Hatfield (2018) within the MLWC watershed and Chowdhury and Chao (2019) outside of the watershed. The data from these previous studies were merged and reclassified using the Hatfield (2018) land coverage schema as guidance (Table 2-1). A map of the merged land coverage is shown in Figure 2-9 which was used to define surface zonation in the 2020 MLWC HGS model. Literature values including Chow (1959), McCuen (2004), and Arcement and Schneider (1989) were used to parameterize the overland flow properties within the zones, given in Table 3-5.

Table 3-5. Overland flow properties for the 2020 HGS MLWC model.

Land Cover	HGS Zone	Prototype	Manning's n	OSH (m)	RSH (m)	CL (m)
Shallow open water, water	7, 8, 30	Water	0.030	0.001	0.001	0.01
Swamp-wooded, upland-wooded, closed-white spruce, closed-deciduous, closed-coniferous leading mixedwood	13, 14, 15, 20, 21, 22, 23, 24, 28, 35, 37, 39, 40	Forest	0.150	0.01	0.1	0.01
Swamp-shrubby, upland-shrubby, closed-upland shrub	16, 17, 25	Shrubland	0.100	0.01	0.1	0.01
Patterned fen	5	Patterned wetland	0.022	0.001	0.02	0.001
Bog, fen, marsh, graminoid, shrubby wetlands, black spruce bog, undifferentiated wetland	1, 2, 3, 4, 6, 9, 10, 11, 12, 26, 27, 29, 38, 41	Non-patterned wetland	0.022	0.001	0.038	0.001
Bare, commercial, new burn, ice and snow, exposed soil	18, 19, 31, 32, 33, 34, 36	Barren	0.040	0.01	0.1	0.01

Notes: Manning's n: Manning`s Roughness Coefficient (s $m^{-1/3}$)
OSH: Obstruction Storage Height
RSH: Rill Storage Height
CL: Surface-subsurface coupling length

3.4 Evapotranspiration Parameters

Seven evapotranspiration property categories were defined: five surface vegetation, one exposed ground, and one open water (Table 3-6) based on ET properties and the land cover shown in Figure 2-9. The assigned ET properties were derived from a combination of remotely sensed LAI values in the MLWC watershed (Myeni et al, 2015 and Hatfield, 2019) and the technical literature (Leskiw, 2004; Panday and Huyakorn, 2004; Novak and Havrila, 2006; and CEMA, 2006). Vegetation canopy evaporation is assumed to be lumped with the land surface evaporation term.

Remotely sensed time varying LAI were obtained from a MODIS dataset MCD15A3H V006 (Myneni et al., 2015) for 10 samples of each land cover type for 2002 to 2020 period. The monthly mean LAI time series were calculated from the raw data (Figure 3-10, left panel). For 2019, ground-truthed LAI data for the MLWC watershed was available from May to October (Hatfield, 2019) to benchmark the remotely sensed LAI. The calculated monthly mean LAI values from MODIS were compared to those of Hatfield for each land cover type and scaled to obtain a visual match to the Hatfield data (Figure 3-10, right panel). The adjustment factor was then propagated back to the monthly MODIS LAI time series for each land cover type back to 2002. The monthly mean LAI from 2000 to 2018 was calculated for each land cover type and was applied for the period prior to the MODIS remotely sensed data coverage (1945 to 1999). Note: the effect of the Richardson wildfire in 2011 is captured in this dataset and reflected in the LAI time series values.

Table 3-6: Evapotranspiration properties for the 2020 MLWC HGS model.

Land Class	LAI	RD (m)	E/T C1	E/T C2	C3	WP (m)	FC (m)	OL (m)	AL (m)	ED (m)	EP1 (m)	EP2 (m)
Open-water	0	NA	0	0.02	2	NA	NA	NA	NA	0.50	NA	NA
Deciduous Forest	time-varying	2.0	0.09	0.05	2	150.0	3.78	0	0	0.50	1.50	0.42
Mixed-woodland	time-varying	2.0	0.09	0.05	2	150.0	3.78	0	0	0.50	1.50	0.42
Shrubland	time-varying	0.6	0.27	0.11	2	150	4.4	0	0	0.50	1.43	0.67
Wetland	0	0.3	0	0.05	2	5.3	0.56	0.15	0.01	0.23	0.22	0
Exposed	0	NA	0	0	2	150	3.3	0	0	0.5	0.82	0.64
Coniferous Forest	time-varying	2.5	0.09	0.05	2	150.0	3.78	0	0	0.50	1.50	0.42

Notes: LAI: Leaf Area Index (average)
RD: Rooting depth
E/T C1-C2: Evaporation/Transpiration partitioning coefficients
WP: Wilting point pressure, FC: Field capacity pressure, OL/AL: Oxic and anoxic limit pressures
ED: Evaporation depth
EP1 and EP2: Evaporation limiting pressure heads

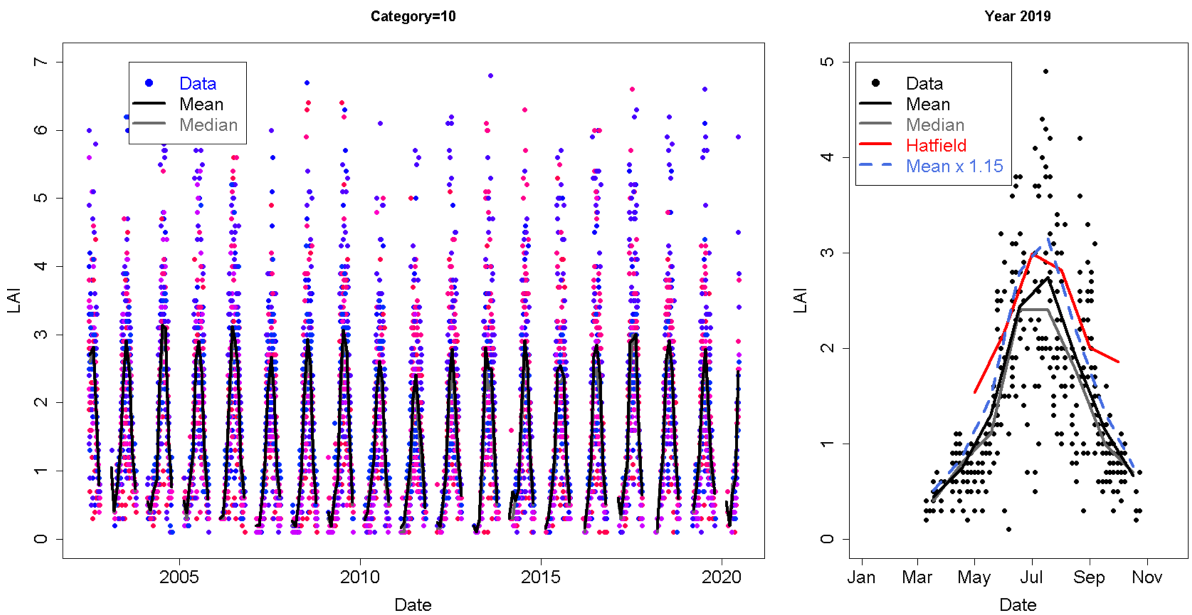


Figure 3-10: An example of resampled LAI extracted from satellite data for a land cover type and the calculated monthly mean (left); and adjusting the extracted monthly mean for 2019 to conform to the locally observed LAIs in Hatfield (2018).

3.5 Winter Processes-Surface and Subsurface

Snow accumulation and snowmelt were calculated external to HGS using a temperature-index approach from total precipitation. Sublimation of the snowpack and snowmelt rates during the winter season was accounted for by assuming a uniform sublimation rate of 15.5 %, using literature-derived values for sublimation for jack pine, black spruce, regenerating pine, mixedwood (all from Pomeroy et al. 1997) and open land cover (Gelfan et al., 2004). Sublimation was subtracted from the accumulated snowpack each winter season prior to calculation of snowmelt component**.** The resulting adjusted climate data was then used to force the 2020 MLWC HGS model with a combined rainfall plus snowmelt time series (liquid input).

Ground and surface freeze-thaw processes were also accounted for in the 2020 MLWC HGS model. Surface and subsurface freezing and thawing times were derived from observed air and soil temperature time series provided by FHEC. During the frozen period each year, the surface Manning's friction coefficient was increased by a factor of 30 to mimic SW freezing, thereby resulting reduced surface runoff. In the subsurface, the hydraulic conductivity of the two uppermost layers in the model was reduced via an impedance factor for the non-waterbody elements.

3.6 Boundary Condition Assignment

3.6.1 Climatology

Daily climate data (liquid water as rain plus snowmelt and PET) were used as climate forcing for the 2020 MLWC HGS model. Total precipitation was partitioned into rain and snowfall using a temperature-index approach. The source of climate data was Environment and Climate Change Canada's Fort

McMurray Airport meteorological station (1945 to 2019), located approximately 90 km south of the project area. Daily PET was calculated using the Hamon (1963) temperature-based method using air temperature recorded at Fort McMurray and was bias corrected on a monthly interval using Morton's long term average shallow lake evaporation rates (AB Gov., 2013). Details of the PET methodology used, and the monthly adjustment factors are provided in Attachment C.

Figure 3-11 shows annual precipitation rates from 1945 to 2019 with a maximum annual value of 721.4 mm in 1973 and a minimum of 244.6 mm in 1998. The average annual precipitation for this period is 442.5 mm shown with horizontal red line in the figure. Figure 3-12 shows the annual PET for the same period with a maximum annual PET of 658.0 mm in 1998 and a minimum annual PET of 487.9 mm in 1945. The average annual PET for this period is 577.7 mm which is indicated with the horizontal red line in the figure.

Depending on the model build and its purpose, climate data from the entire 1945 to 2019 period or a subset of it was used as climate forcing for the models. Details on climate forcing for each model are explained in the following sections, where the details of each model build are discussed.

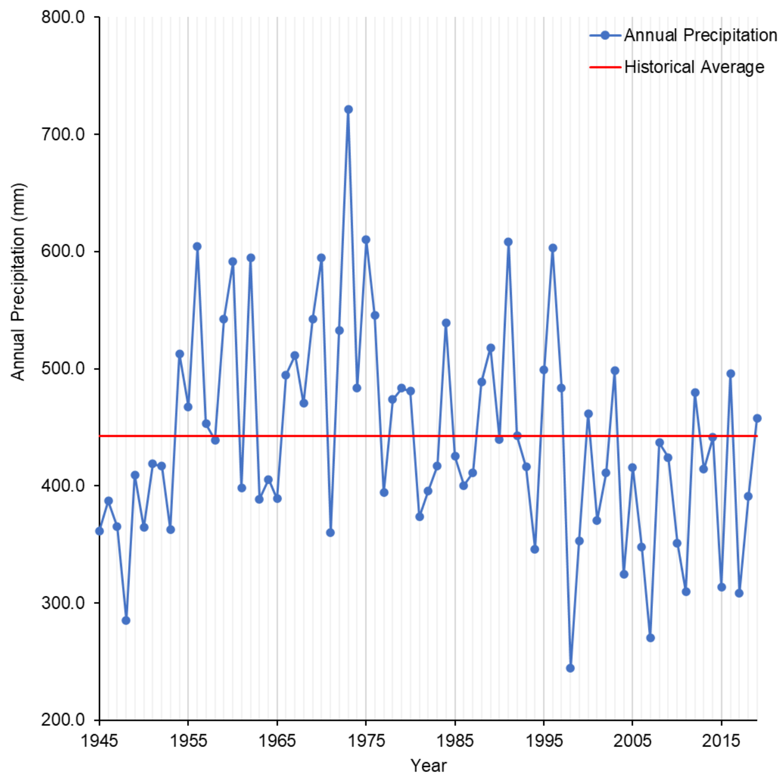


Figure 3-11: Annual precipitation rates from 1945 to 2019 at the Fort McMurray airport meteorological station.

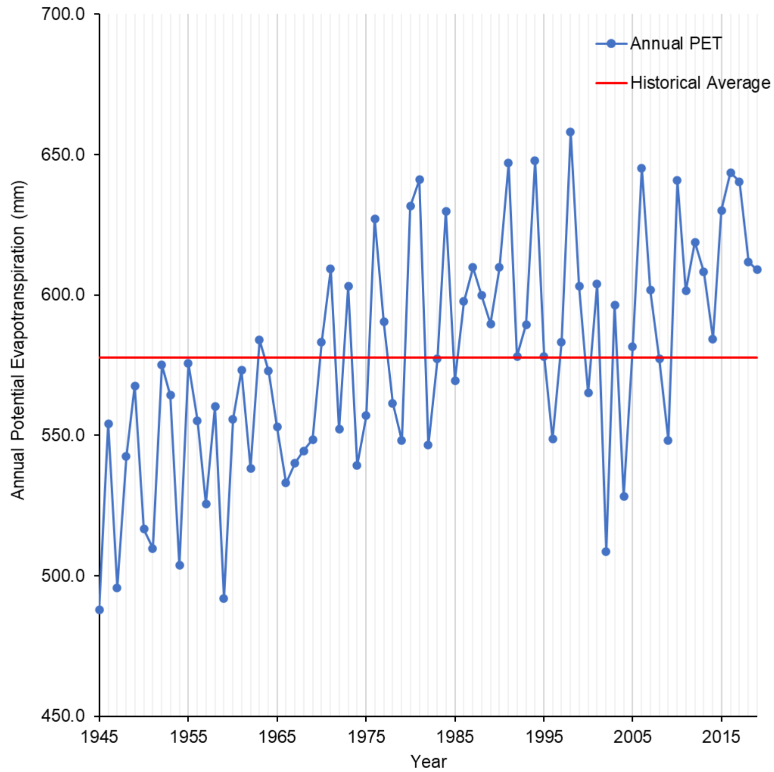
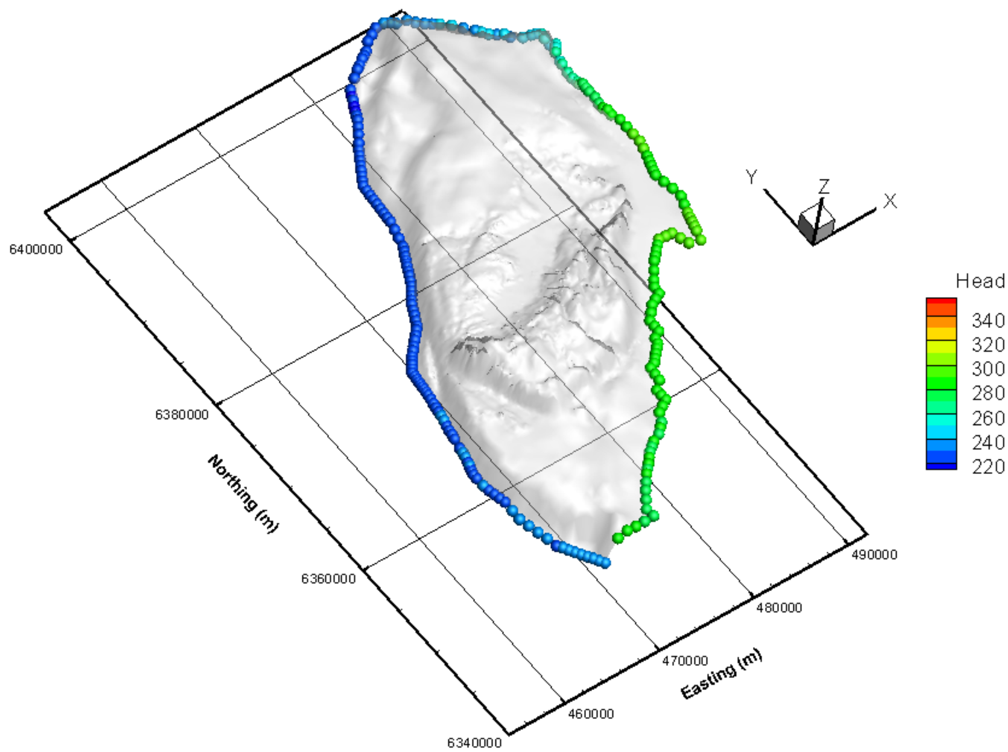


Figure 3-12: Annual PET rates from 1945 to 2019 at the Fort McMurray airport meteorological station.

3.6.2 Surface and Subsurface

The outer, upper perimeter of the 2020 MLWC HGS model was assigned a specified head boundary condition equal to either SW elevation or the land surface elevation, as applicable. Specified water levels along the western perimeter of the model domain were subsequently modified using the 2019 results from a 1D HEC-RAS hydraulic model of the Athabasca River, provided by FHEC, to reflect a 0.02% average slope along this reach of the river. These boundary conditions were applied downward to the base of the Quaternary hydrostratigraphy along the outer perimeter of the model. Groundwater levels at the model boundaries for the deeper Cretaceous and Devonian aquifers were determined using the regionally compiled GW data presented in WorleyParsons (2012). The WorleyParsons (2012) data were originally used to define specified head boundary conditions in a Fort Hills FEFLOW model with a similar model domain as the 2020 MLWC HGS model (but also extending to the west side of the Athabasca). The specified head boundary conditions applied to the Cretaceous and Devonian aquifers from the Fort Hills FEFLOW model were extracted and mapped onto the corresponding units in the 2020 MLWC HGS model. Figure 3-13 illustrates the applied boundary conditions in the surface and subsurface domains.



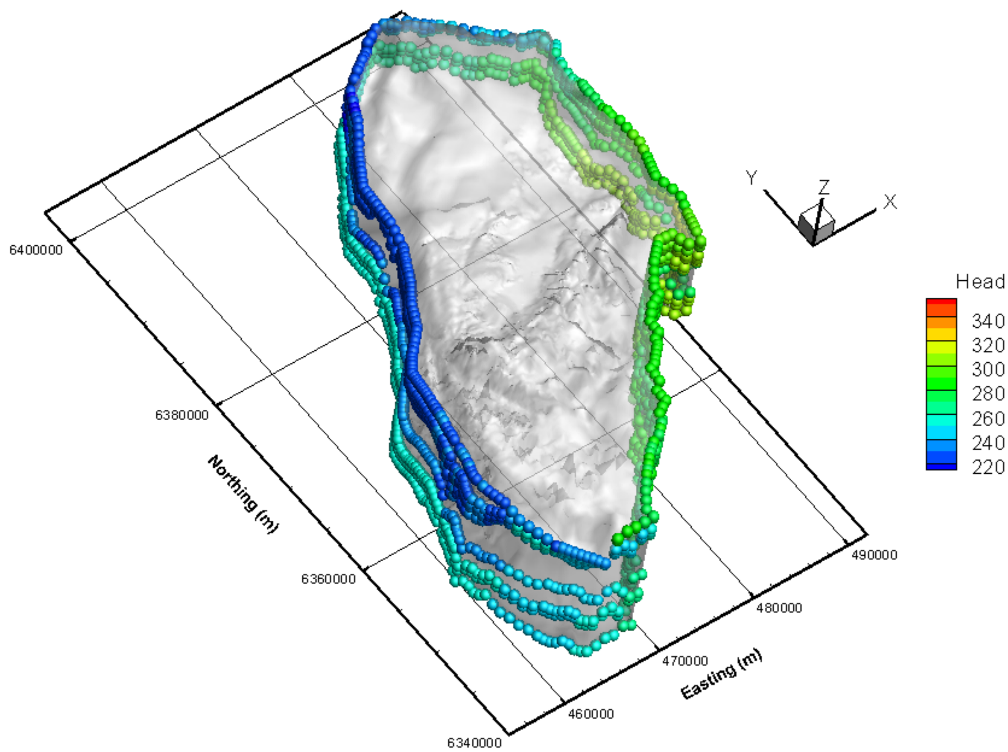


Figure 3-13: Lateral boundary condition definition in the 2020 MLWC HGS model.

3.6.3 McClelland Lake stage-discharge boundary condition

The poorly defined, ephemeral outflow channel (McClelland Creek) through the muskeg at the eastern end of McClelland Lake makes it challenging to accurately simulate channelized outflow from the watershed. To overcome this challenge, a prescribed boundary condition was incorporated to define lake outflow via a stage-discharge rating curve. The coefficients for the stage-discharge rating curve were considered during model calibration (Section 4.0), thus improving the fit between simulated and observed lake levels. The stage discharge relation was computed as follows:

$$Q = C \times (h - h_0)^n$$

in which Q is discharge rate [L^3T^{-1}], C is a multiplying constant [L^3T^{-1}], h_0 is the minimum water depth[L] required to induce discharge from the lake, h is the simulated lake level at a given time [L], and n [-] is the power constant. C, h_0 and n are the stage-discharge parameters calibrated during calibration.

3.6.4 Other internal boundary conditions

Additional internal boundary conditions were also used in some of the model builds. Most of these additional boundary conditions were related to mine development activities such as overburden dewatering, mining progression, Basal McMurray Aquifer depressurization, or SW routing. Where applicable, these additional boundary conditions are discussed in the model build sub-sections below.

3.7 2020 MLWC HGS Calibration Model Build Details

The 2020 MLWC HGS Calibration Model (Calibration Model) was built from the common model basis detailed in Sections 3.1 to 3.6. A climate forcing period from 1991 to 2017 was chosen because it overlapped with the bulk of the monitoring data available for calibration. Since most of the calibration targets were located within the Quaternary units or shallower (i.e., GW levels, ET rates, McClelland Lake levels); and given that the Quaternary is presumed to be hydraulically separated from the deeper units by the Clay Till (1 and 2) and Oil Sands aquitards, the Calibration Model was truncated at the bottom of the Quaternary units to reduce calibration model run times. The model had two extra node sheets in the surficial sand layer to vertically refine this geological layer and to represent the unsaturated zone more accurately in the forested uplands. As a result, the Calibration Model contained 17 node sheets and 16 layers starting from surface topsoil LFH layer down to Clay Till 2, the deepest Quaternary unit.

Truncating the Calibration Model at the base of Quaternary substantially reduced model run time, which facilitated the automated calibration via coupling PEST and HGS. The calibration process is discussed in more detail in Section 4.0. It should be noted that the calibrated parameter set (e.g., hydraulic conductivity of the Quaternary units) obtained from automated calibration were used to parameterize the other of the MLWC models (e.g., Baseline, Operations, Active Closure, and Far-Future).

The number of nodes per 2D node sheet was 8,857 and the number of elements in each layer was 17,508. Lateral nodal spacing varied from 100 to 800 m. Table 3-7 presents the AlgoMesh parameters used for generating and optimizing the Calibration Model mesh. Figure 3-14 and Figure 3-15 respectively show the mesh constraints and refinement zones used in building the 2D mesh. Figure 3-16 illustrates the 2D mesh built via AlgoMesh.

Initial heads in the Calibration Model were defined by importing the heads produced in a previous iteration of the MLWC HGS model. Subsequently, the Calibration Model was spun up using historical climate forcing data (1945 to 1990). The final head distribution from the spin-up run was then used as the initial condition for automated calibration.

The rest of model setting including its boundary conditions, subsurface, surface, and ET zones and parameter values were defined as discussed in Sections 3.1 to 3.6.

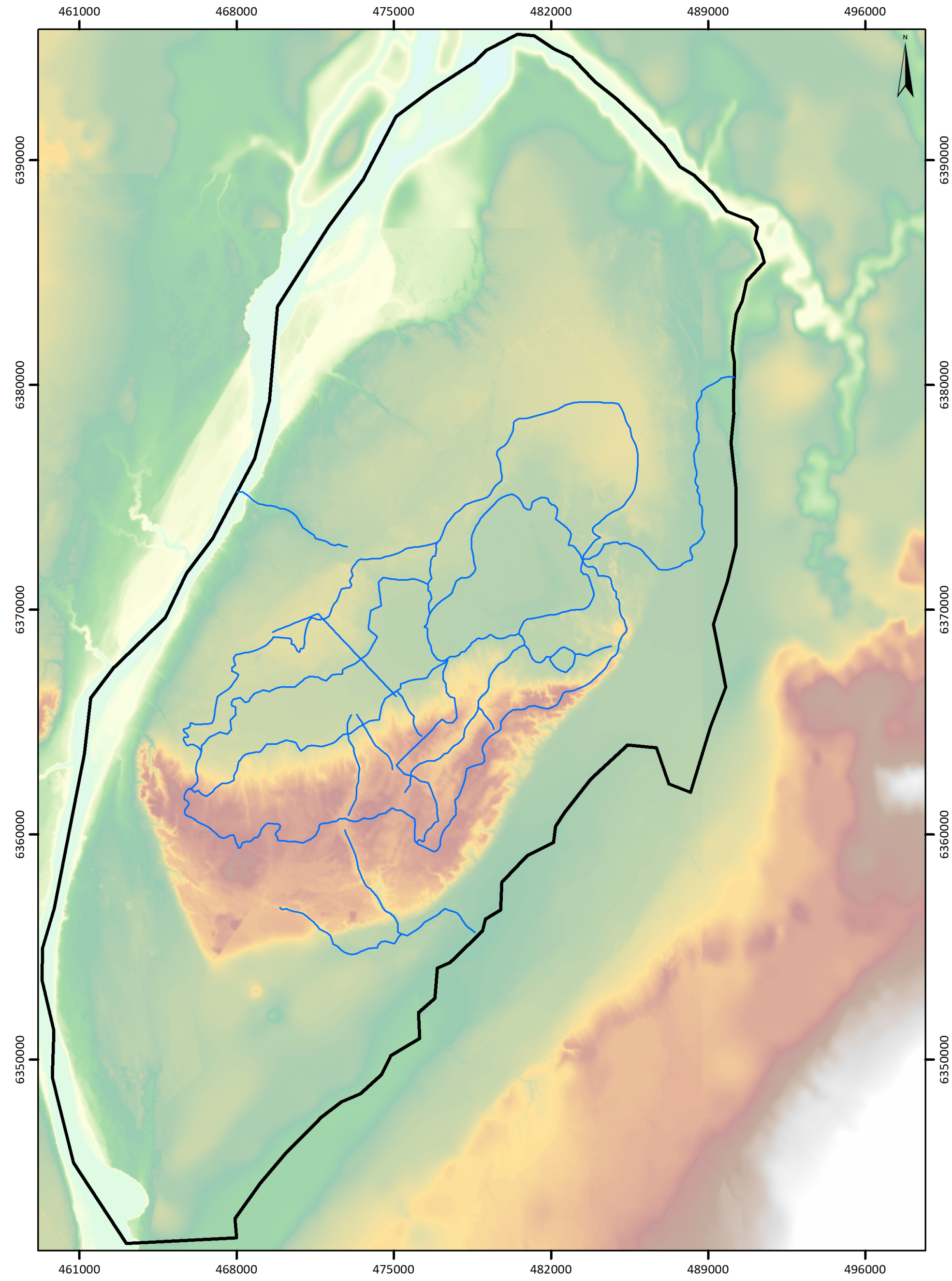


Figure 3-14: Mesh constraints for the Calibration Model's 2D mesh.

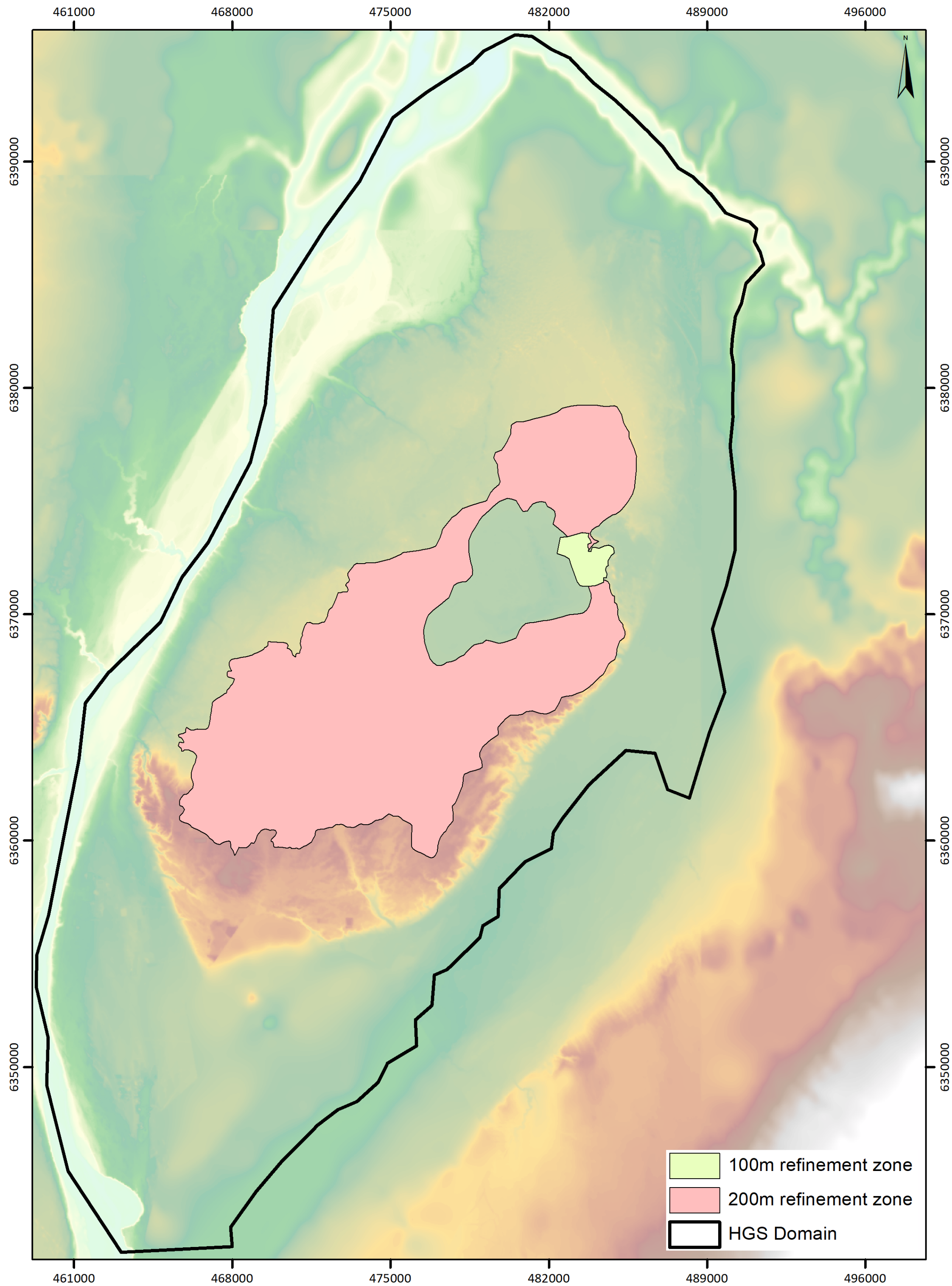


Figure 3-15: Mesh refinement control for the Calibration Model's 2D mesh.

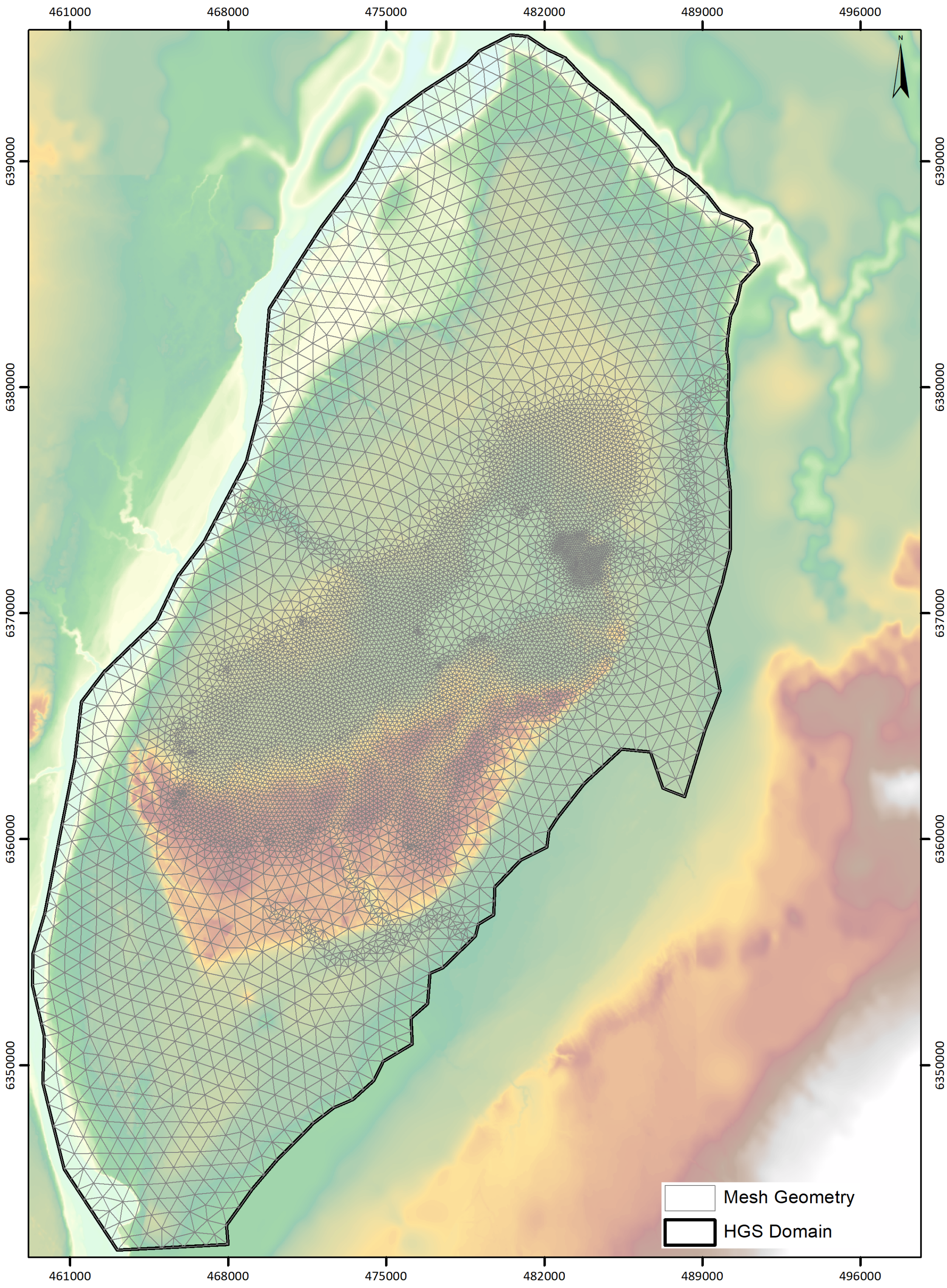


Figure 3-16: The 2D mesh for the Calibration Model.

Table 3-7: AlgoMesh settings to generate and optimize the Calibration Model's 2D mesh.

Distance (grading) factor	0.4
Boundary resampling factor	2
Min. resampling interval	100
Global max. edge length	1040 m
Sizing ratio reduction factor	0.95
max. refine iterations	no limit
max. Lloyd iterations (refine)	no limit
max. Lloyd iterations (final relax)	no limit
run Delaunay refinement after completion of optimization	yes
Min. angle in degree	25

3.8 2020 MLWC HGS Baseline Model Build Details

The 2020 MLWC HGS Baseline model (Baseline Model) was parameterized using the calibrated model parameters detailed in Section 3.7. A climate forcing period from 1945 to 2019 was used. The vertical extent of the Baseline Model extended from the land surface to the middle of the Keg River Formation. Two extra node sheets were added in the surficial sand layer to vertically refine this geological layer and to represent the unsaturated zone more accurately in the sandy uplands. The Baseline Model and the 2020 MLWC Mine Plan Operations Model (Section 3.9) were constructed using identical 3D meshes to ease the comparison of the results. Therefore, to match the vertical discretization used in the MLWC 2020 Mine Plan Operations Model to represent mining, two additional node sheets were added in the McMurray Oil Sands unit in the Baseline Model. As a result, the Baseline Model contains 33 node sheets and 32 layers.

The number of nodes per 2D nodal sheet was 11,816 and number of elements in each layer was 23,407. Lateral nodal spacing varied from 200 m to 800 m. Table 3-8 presents the AlgoMesh parameters used for generating and optimizing the Baseline Model mesh. Figure 3-17 and Figure 3-18 respectively show the mesh constraints and refinement zones used to build the 2D mesh. Figure 3-19 illustrates the 2D mesh built using AlgoMesh.

The initial (1945) condition for the Baseline Model was defined using results from a previous iteration of the model and was then run for the 1945 to 2019 period. It is assumed that 1945 was a very dry year for the region (Carrera-Hernández et al., 2011) and the initial condition used in the first run did not reflect this upon examination of the results. Pre-1945 climate data collected at the Fort McMurray airport station are considered less reliable; 1945 was the year the station was moved to its current location from an older location situated at a lower elevation. As such, the pre-1945 climate data were not used for model spin up. Instead, model output from 2008 (also a very dry year) was used as a proxy for the actual 1945 initial condition. The use of the relatively dry 2008 helped mitigate temporal boundary condition effects in the early portion of the simulation and provided a more representative initial condition for the Baseline Model simulations.

The remainder of the model set up, including boundary conditions, subsurface, surface, and ET zones and parameter values was as discussed in Sections 3.1 to 3.6.

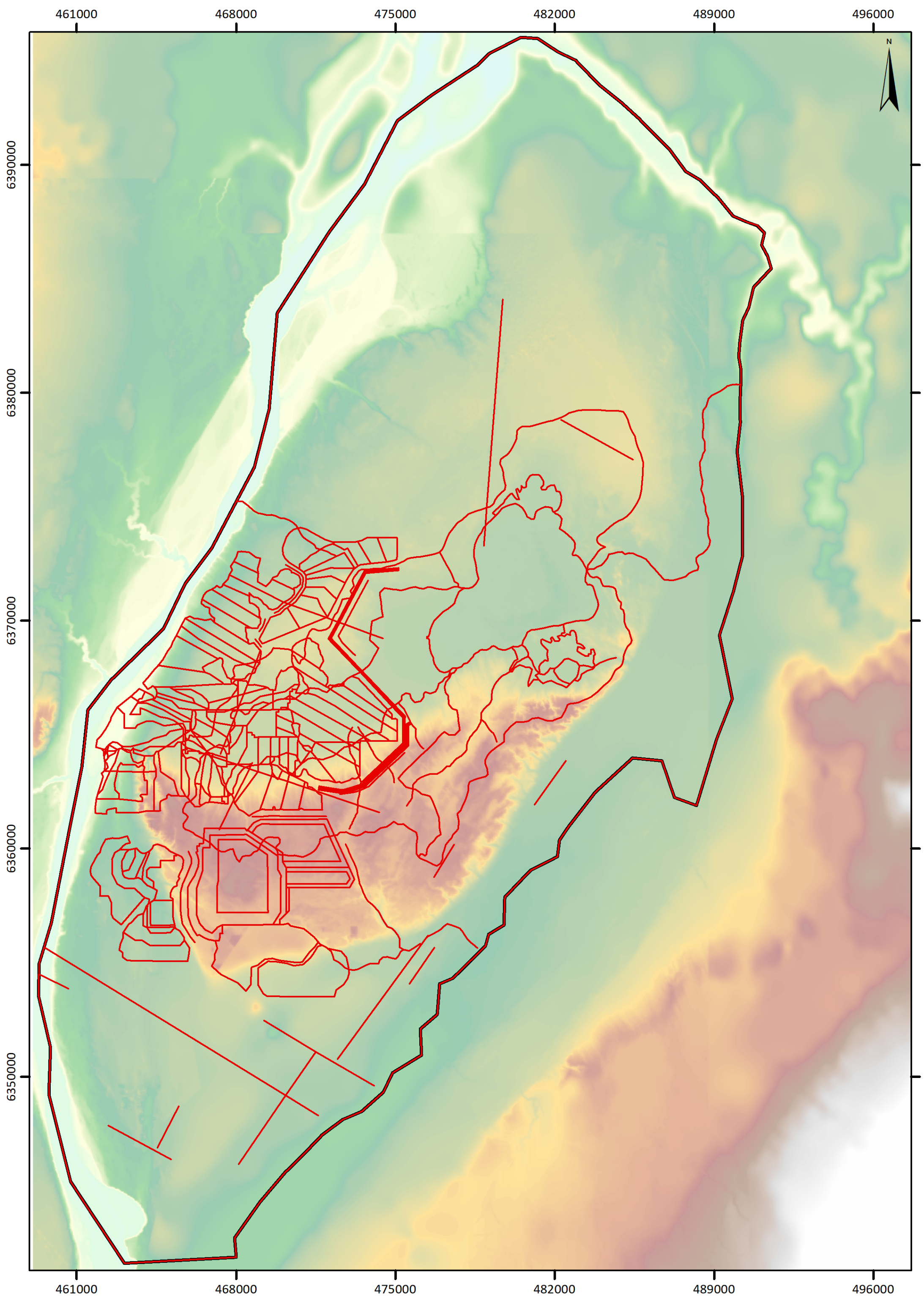


Figure 3-17: Mesh constraints for the Baseline Model's 2D mesh. Note that the Baseline Model mesh contains features identical to the Operations Model to ease differencing of model results during analysis.

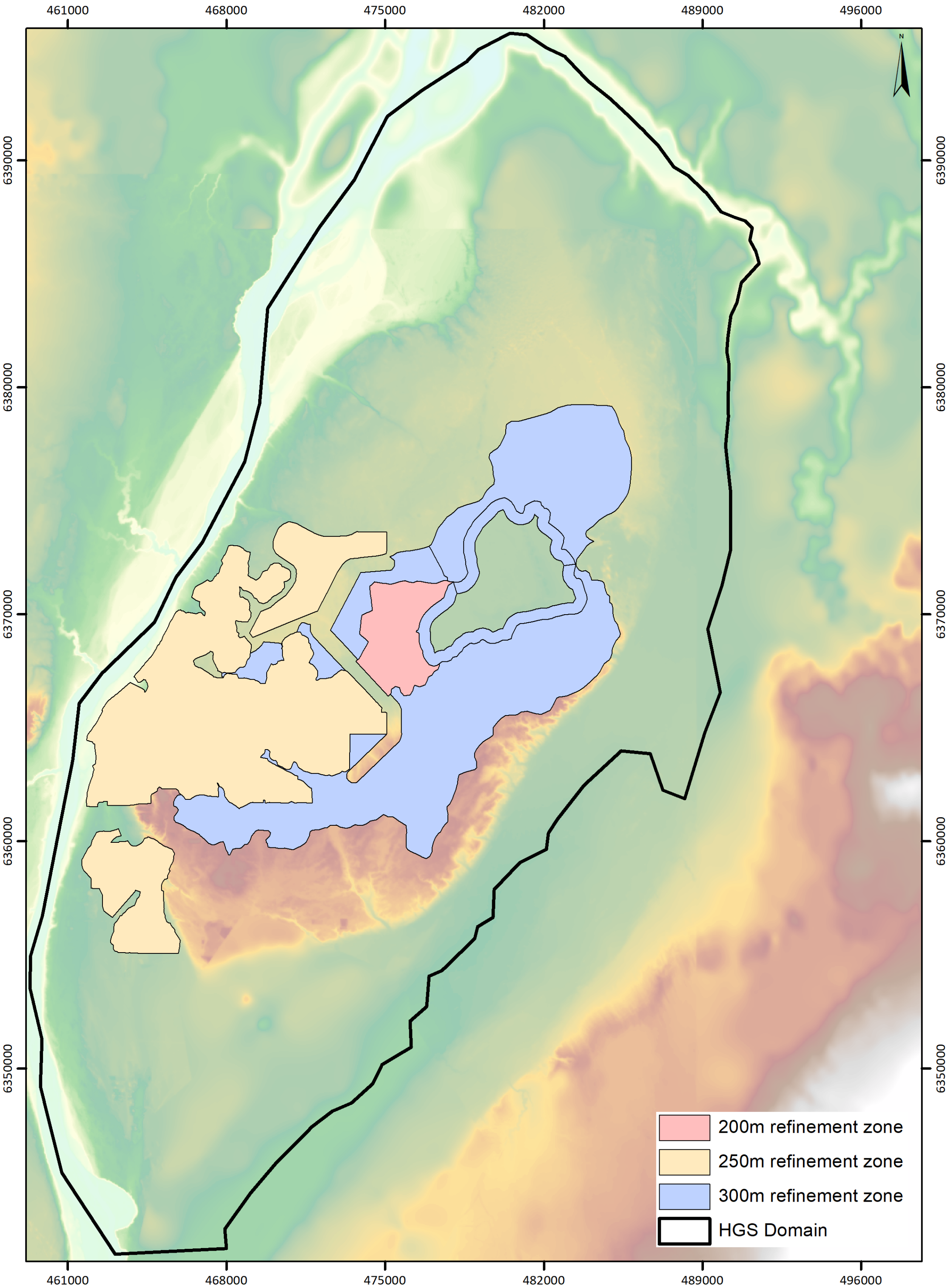


Figure 3-18: Mesh refinement control for Baseline Model's 2D mesh.

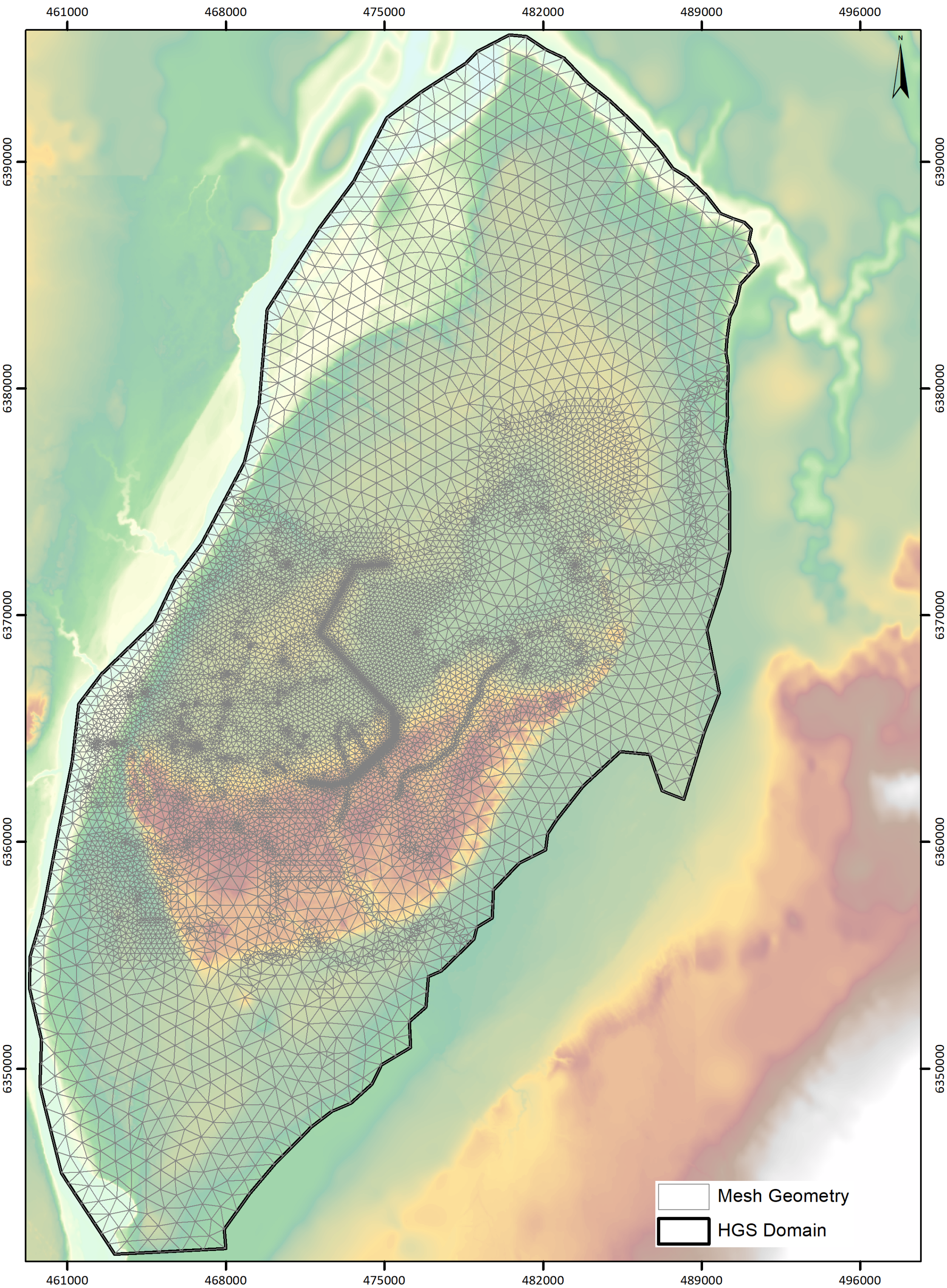


Figure 3-19: The 2D mesh for the Baseline Model.

Table 3-8: AlgoMesh settings to generate and optimize the Baseline Model's 2D mesh.

Distance (grading) factor	0.5
Boundary resampling factor	5
Min. resampling interval	500
Global max. edge length	1040 m
Sizing ratio reduction factor	0.95
max. refine iterations	no limit
max. Lloyd iterations (refine)	50
max. Lloyd iterations (final relax)	no limit
run Delaunay refinement after completion of optimization	yes
Min. angle in degree	23

3.9 2020 MLWC HGS Mine Plan Operations Model Build Details

The 2020 MLWC HGS Mine Plan Operations Model (Operations Model) was constructed using the 2021 IPA Mine Plan provided by FHEC. The Operations Model shared the same 2D mesh, 3D mesh, material distributions and outer boundary condition definitions as the Baseline Model (described in Section 3.8).

The 2020 Mine Operations Model was developed to simulate the period 2014 to 2064 during which active mining operations in the Fort Hills Lease occur, including: dewatering, depressurization, excavation, backfilling, and mitigating water management design features in the MLWC watershed. As such, the 2020 Mine Operations Model contains substantially more internal boundary conditions and model settings than the Baseline Model.

The planned evolution of the landscape from 2014 to 2063 was provided to Aquanty as a series of digital elevation models (DEMs) delineating mining progression over time. These DEMs included annual landscape DEMs from 2021 to 2030, 5-yr-interval landscape DEMs from 2030 to 2045, and a landscape DEM for 2055 and again for 2063. To allow for a more continuous evolution of the mine within the model, annual DEMs were created to infill gaps from the provided DEMs. Pre-2021 annual DEMs were created using satellite imagery to determine the extent of face advance and to replace the pit extents with pit shell elevation. Representation of this changing landscape is accomplished in the model using a combination of time varying parameterizations and boundary conditions to simulate the effects of the evolving landscape. This approach avoids mass balance and continuity issues because the simulation is run continuously without restarting to incorporate changes to the landscape.

Mine operations within the model incorporated water management strategies in addition to the features from the evolving landscape:

- Quaternary and Muskeg dewatering (i.e. Overburden dewatering) (Figure 3-20)
  - The dewatering occurs during the excavation period and while the mine panel is active to simulate Quaternary dewatering of the pit face. Dewatering is turned off in the model when backfilling occurs. The dewatering process is represented in the HGS model through drain node boundary conditions turned on one to two years (for Quaternary and Muskeg dewatering, respectively) before excavation and turned off when backfilling starts (Figure 3-20). Excavation and backfill timings were determined from the annual time-varying DEMs.

- Pit evolution (Figure 3-20)
    - To simulate mine pit face advance, the hydraulic conductivity of the excavated volume was increased in the model to a very high value (~0.01 m/s) (Figure 3-20), causing the system to behave as though the material were absent.
    - To simulate backfill material placement in the pit after mining is complete (Figure 3-20), the hydraulic conductivity in the area of the backfill is decreased to represent the lower hydraulic conductivity of backfill material.
- Out-of-Pit Tailings Area (OPTA) (Figure 3-21)
    - OPTA and OPTA-East structures were simulated using a specified head boundary condition equal to the designed pond level as provided by FHEC, with a low hydraulic conductivity layer below the base of OPTA and OPTA-East to simulate an effective sealing with mature fine tailings (MFT). The height of OPTA increases over time as specified by mine plans and was represented as a time varying specified head boundary condition. The hydraulic conductivity of the base of OPTA and OPTA-East was calibrated to produce seepage approximately equal to projections of seepage rates provided by FHEC (Figure 3-22). Neither precipitation nor ET was simulated within the footprint of these structures because their effects have been accounted for by the on-site IWW water balance.
    - The OPTA and OPTA-East seepage management system (SMS) was included in the model as time-varying flux boundary conditions. Individual wells were not included due to their spacing being at a sub-element scale in the finite element mesh. The SMS pumping wells were simulated using a series of nodal flux boundary conditions defined along the perimeter of OPTA. Similar to the field implementation, the depth of extraction was limited to the Quaternary aquifers underlying OPTA. Designed extraction rates provided by FHEC for the wells were used to guide the relative magnitude of the flux boundary conditions, which was controlled by a pressure head cutoff to limit drawdown to the top of the Clay Till 2.
- Stockpiles and Dumps (Figure 3-21)
    - The North External Dump (NED), South External Dump (SED), and Syncrude Aurora North Dump are above ground features and are expected to produce reduced recharge due to material compaction. It is expected that runoff from the dumps will be captured by surface collection ditches, and the dumps will release negligible runoff to the natural environment. To represent this behaviour in the model, the overland flow friction coefficient (Manning's n) was increased to an artificially high value to prevent overland flow across the footprint of the feature. Additionally, the hydraulic conductivity of the upper 1.2 m (equal to the top four soil layers in the model) underlying the feature was set to a low value representative of an effective hydraulic conductivity of random compacted material. Rain plus snowmelt and PET are applied to the dumps in a similar fashion to elsewhere in the model.
    - In-Pit Tailings Storage Facilities including South Pit Dedicated Disposal Area (SPDDA), South Pit Tailing Area (SPTA) Centre Pit Tailings Areas (CPTA) 1 and 2, and Centre Pit DDA, North Pit Tailings Areas (NPTA) 1 and 2 were modelled individually, using specified head boundary conditions equal to the designed pond elevation provided by FHEC.
- Basal McMurray Aquifer depressurization
    - Fort Hills Basal depressurization takes place one year ahead of excavating a mine panel; the aim is to reduce the head in the underlying Basal units and to prevent Basal

water breakthrough across the pit floor. Basal depressurization continues during excavation and turns off when the region being depressurized is backfilled. In the HGS model (Figure 3-20), Basal depressurization is represented with drain node boundary conditions defined below the mining panel in the top of Basal unit. The boundary condition turns on one year prior to excavation and turns off when backfilled.

- Syncrude Aurora North Basal depressurization started in 2000 and was projected to continue until the end of 2025. Given the relatively short distance between Syncrude Aurora North pits to the south of the FHUC, the pressure head decline induced by Syncrude Aurora North Basal depressurization impacts the Basal pumping volumes within the Fort Hills Lease. The initial head in 2014 (the first year of the 2020 Mine Operations Model run) in the Basal units was impacted by Syncrude Aurora North Basal depressurization. Thus, Syncrude Aurora North Basal Pumping was represented through flux nodes in the Basal units around the Syncrude Aurora North pits with time varying rates. The coordinates of the pumping wells and approximate rates were received from FHEC (Figure 3-23).

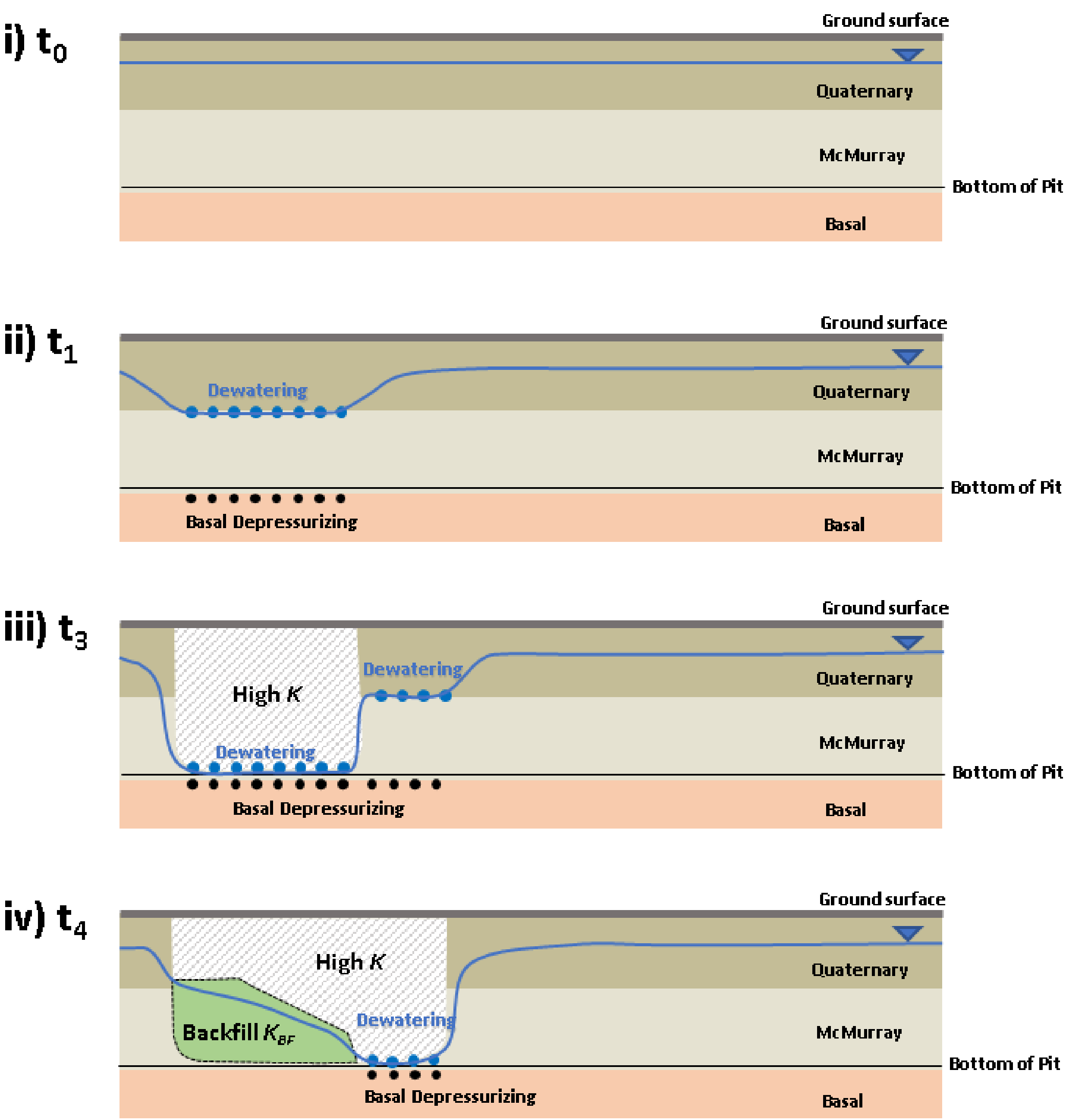


Figure 3-20 Conceptualization of mine pit evolution and backfill in the Operations Model.

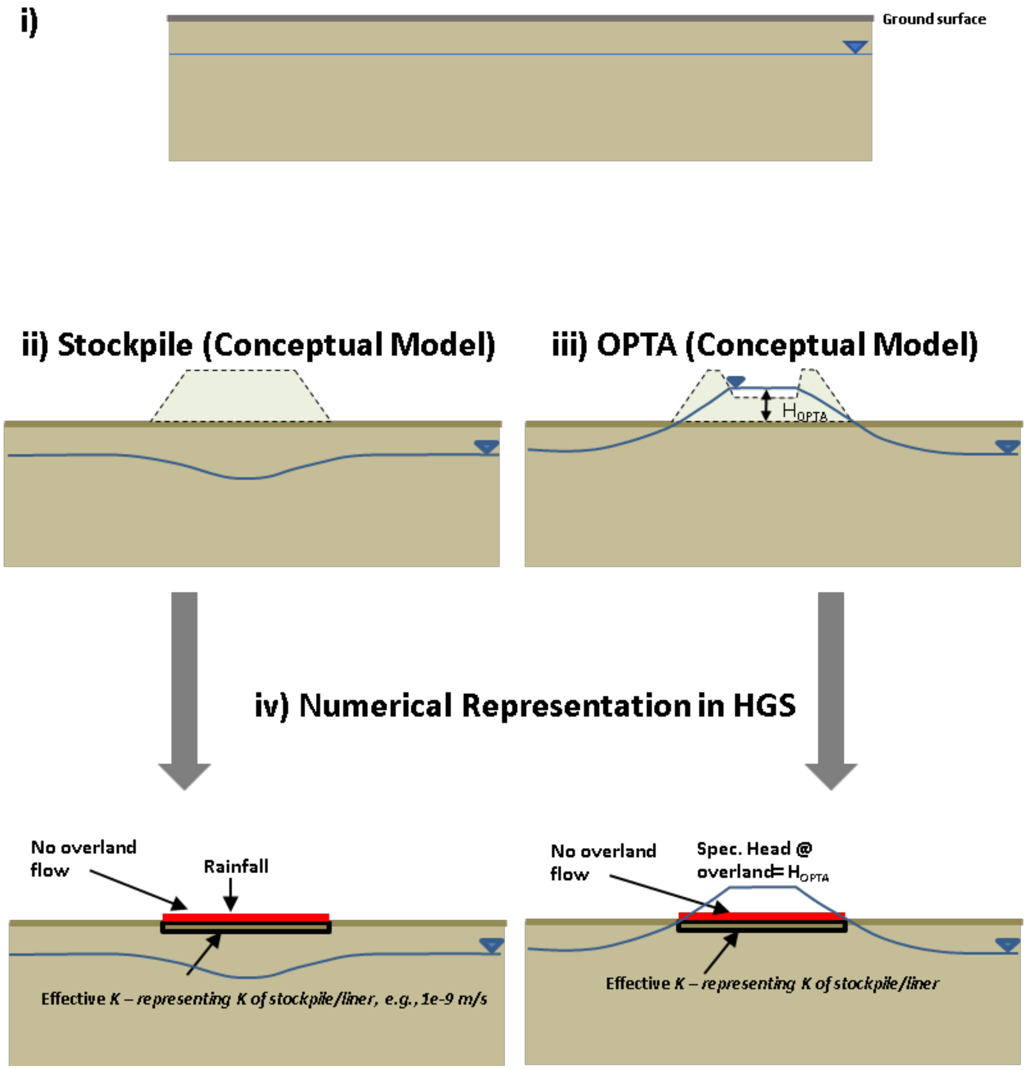


Figure 3-21 Representation of dumps and tailings storage facilities in the Operations Model.

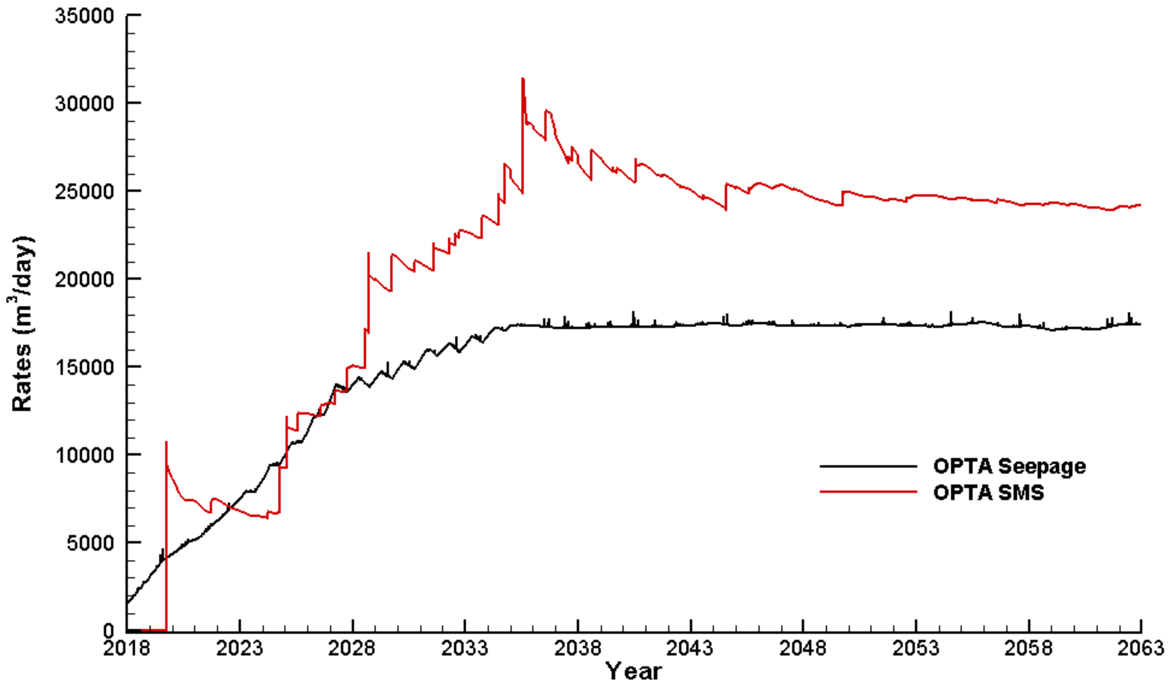


Figure 3-22: Rates of seepage in OPTA (black line) and seepage collection via the seepage management system (red line).

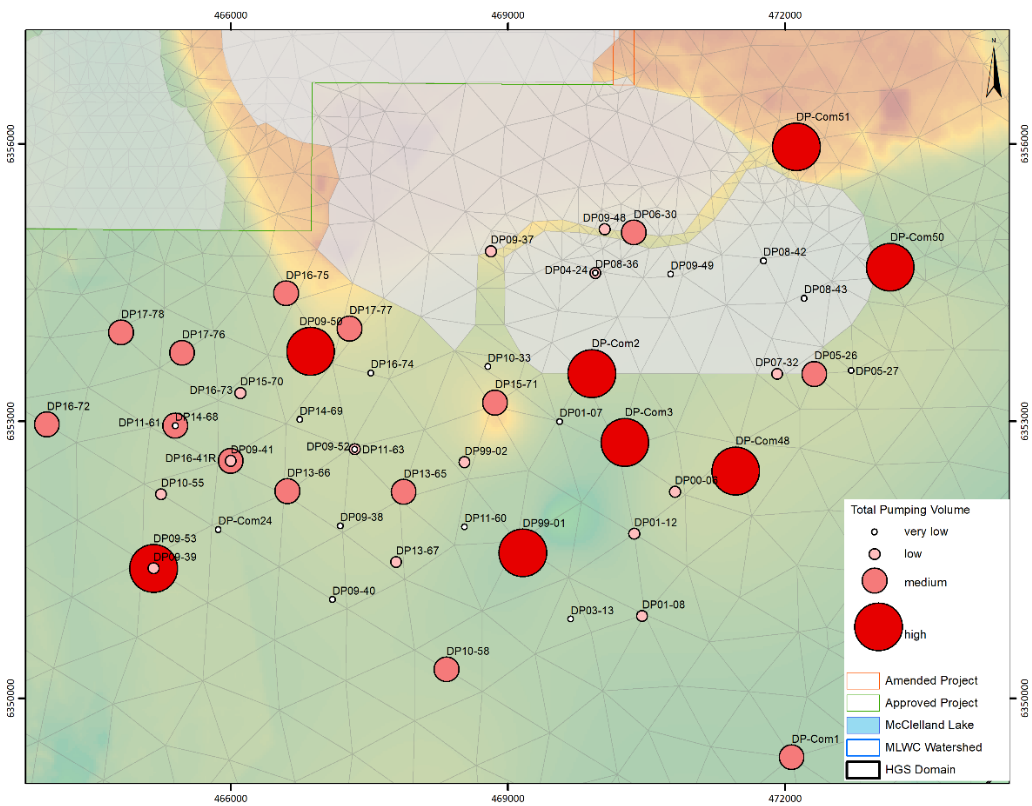


Figure 3-23: Estimated Syncrude Aurora North Basal depressurization volumes (2000 to 2025).

The 2020 Mine Operations Model was initialized in 2014 using an initial head condition mapped from the Baseline Model for 2014. Syncrude Aurora North Basal McMurray Aquifer Pumping was present in the Baseline Model starting in 2000, and its effect on the Basal heads was present in the head data used to map heads into the Mine Operations Model. This means the initial condition used in the 2020 Mine Operations Model also includes the influence of Basal depressurization at the Syncrude Aurora North Mine. The 2020 Mine Operations Model had additional internal boundary conditions to represent water management design features to mitigate the mining operations impact on non-mined portion of the MLWC:

- The design features include a cutoff wall, which was incorporated into the FEM construction (Figure 3-24). The cutoff wall was simulated in the model by reducing the hydraulic conductivity of the elements representing the wall to a low value starting in 2037, approximately 6 years before the effects of mining are simulated to cause GW to begin flowing from the fen and towards the advancing pit (if left unmitigated). Implementing this feature earlier than needed was done to conservatively account for model uncertainty and/or subsequent changes to the mine progression. The wall elements of the model are thicker than the presumed designed wall thickness of 1 m; as such, the hydraulic conductivity assigned to these elements was lowered to produce the same effective Darcy flux through the wall that would have been produced by a cutoff wall 1 m thick and an intended hydraulic conductivity of $1x10^{-9}$ m/s (refer to the cut off wall sensitivity analysis presented in Section 6.1 for more information). The cutoff wall is conceptualized to have a surface expression as a berm to restrict SW flow over the wall location.
- The fen SW resupply starts in 2025 and continues until the end of the simulation period (2063). The objective of the SW resupply is to provide the non-mined portion of the MLWC a similar volume and timing of water it would have received in the absence of development. The rate of resupply was determined as the difference of water discharge rates (sum of SW and GW) passing the proposed cutoff wall location in the fen with no mine operations (i.e. baseline) and with operations but with no mitigation (i.e. no SW resupply) (see Section 5.2.1); and,
- Supplemental GW injection takes place in the North Outwash Plain (NOP) starting in 2028 and continues until 2037, when the cutoff wall is constructed near the watershed boundary and the deficit of GW flow becomes minimal. The rate of injection was determined as the difference between GW discharge rates through the NOP with no mine operations (i.e. baseline) and with operations but with no mitigation (i.e. no GW injection). The aim of the GW injection was to replace the water that is being lost from the MLWC watershed through NOP surficial sands into the advancing North Pit.

It should be noted that historical climate forcing data was used to compute the required volumes and timing for the 2020 Mine Operations Model and this allows perfect knowledge of the needed resupply requirements within the modelling framework. When the water resupply system within the MLWC is operated in the field, the climate forcing will not be perfectly known, and some level of resupply forecasting (in addition to field data and possibly modelling) will be required to determine the resupply volumes and timings.

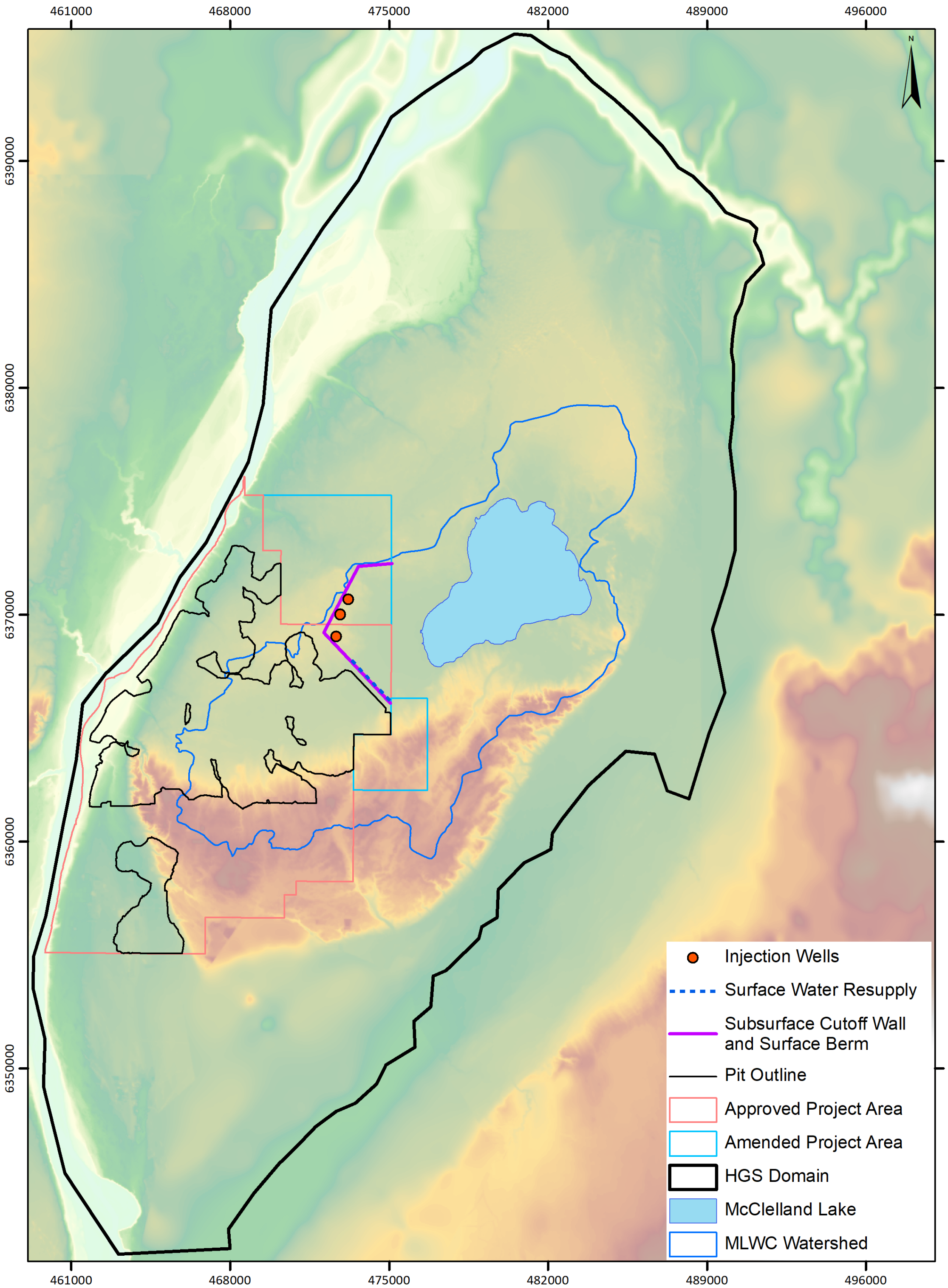


Figure 3-24: Location of water management design features in 2020 Mine Plan Operations Model.

Figure 3-25 illustrates the footprints of in-pit and out-of-pit mine features for the 2021 IPA Mine Plan as well as the MLWC watershed boundary and the Fort Hills Lease boundary. For representation in the model these features were classified as either in pit tailings areas (i.e., CPTA1, CPTA2, NPTA1, NPTA2, SPTA, and North Pit NE), out of pit tailings areas (i.e., OPTA and OPTA-East), in pit dedicated disposal areas (South Pit DDA, Centre Pit DDA), or External Dumps (NED, SED). Each of these mine features is represented uniquely within the numerical model as shown in Figure 3-20 and Figure 3-21. Figure 3-26 shows the pit advances map for the 2021 IPA Mine Plan. The map illustrates when excavation takes place in the model domain, and when the subsections of each in-pit feature appear in the 2020 Mine Operations Model.

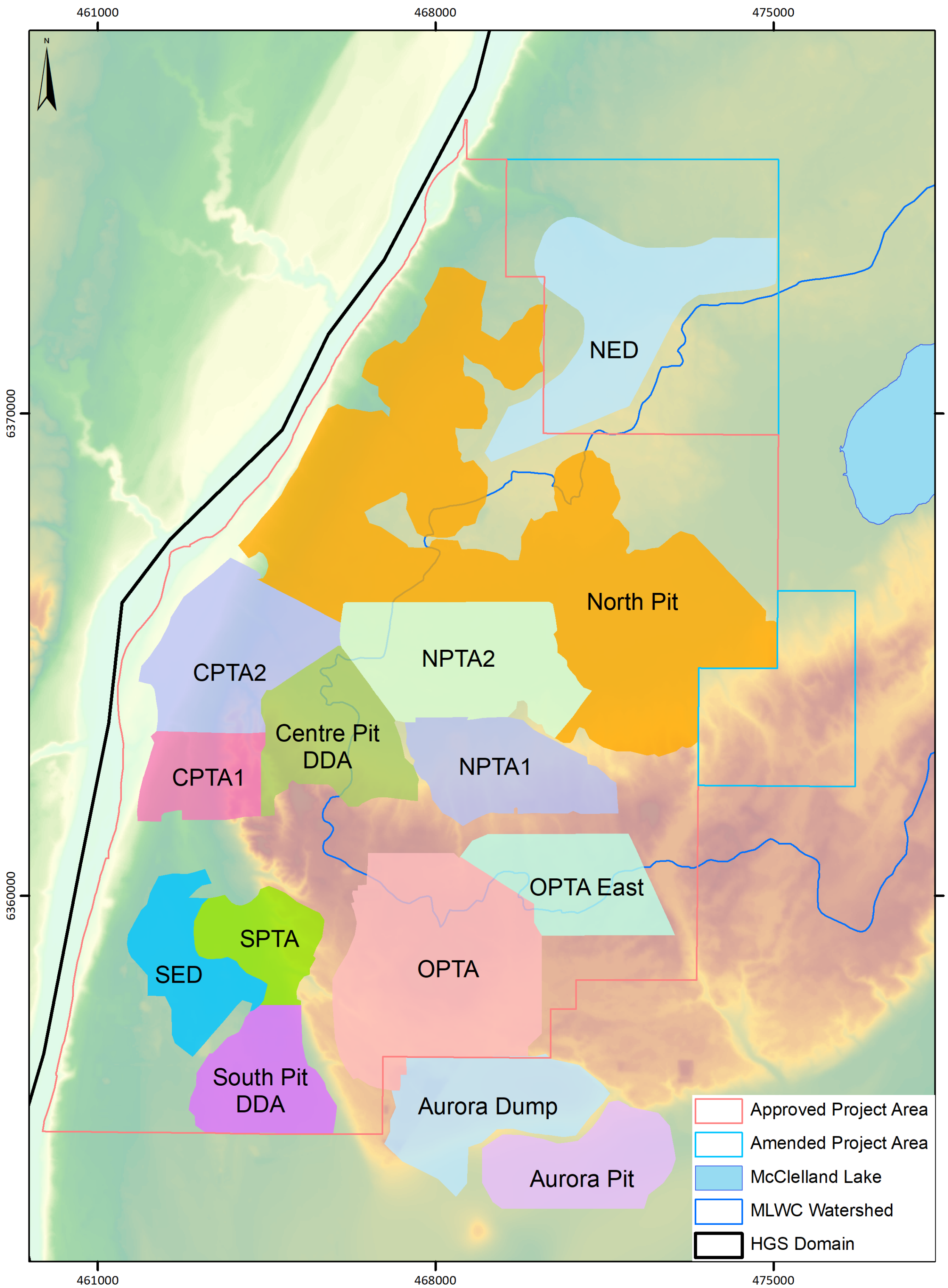


Figure 3-25: Mine features in the 2020 Mine Operations Model mesh.

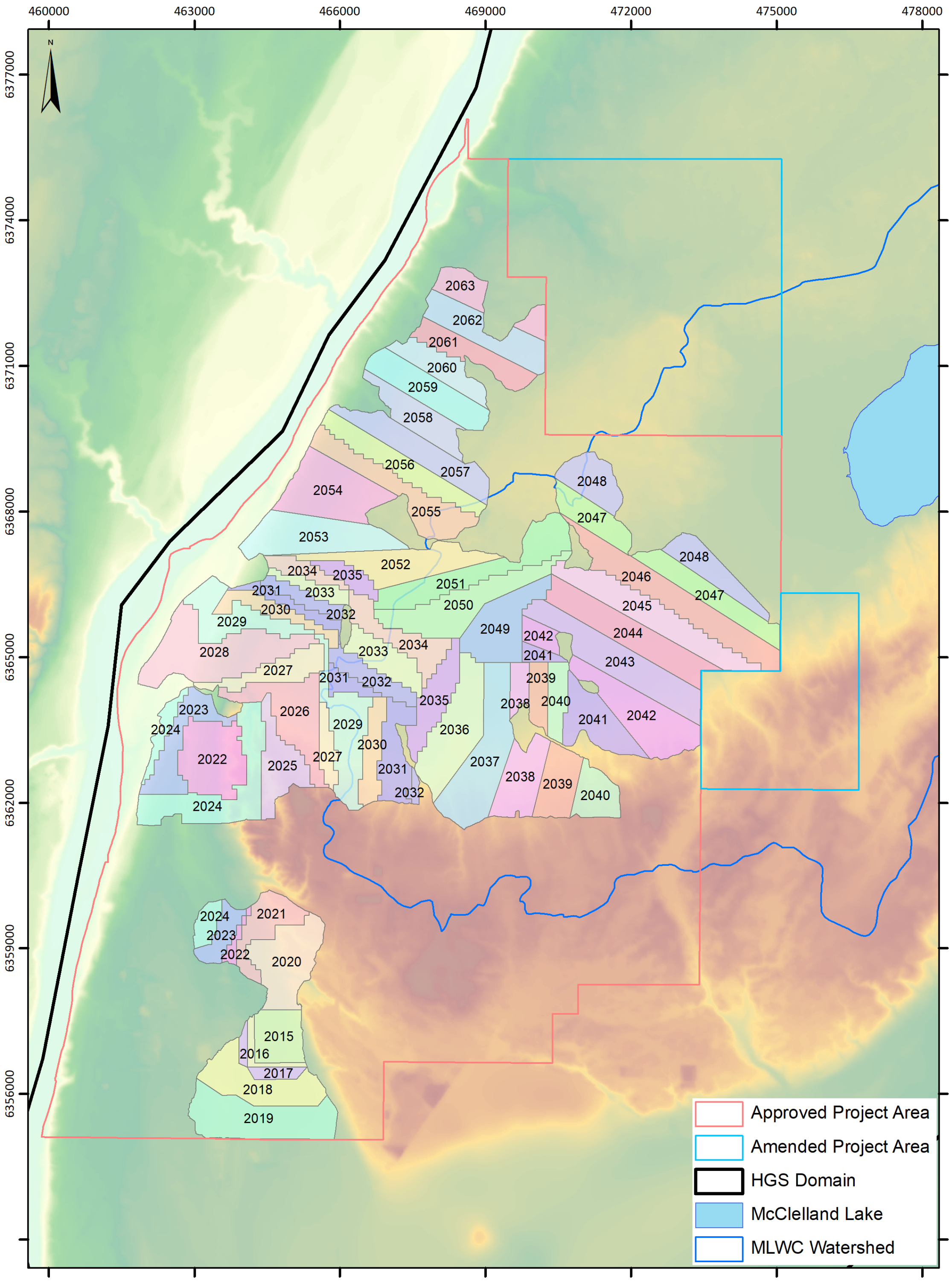


Figure 3-26: Fort Hills annual mining panels for the 2021 IPA Mine Plan.

3.10 2020 MLWC HGS Closure Model Build Details

The 2020 MLWC HGS Closure model (Closure Model) was constructed using the 2021 IPA Closure Plan provided by FHEC, shown in Figure 3-27. The Closure Model was used to simulate the closure landscape and to conduct the active closure period (approximately mid-century) and far-future (approximately end-century) climate change analyses presented in Sections 5.3 and 5.4, respectively. The Closure Model contains hydrostratigraphic units from the middle of the Keg River Formation to the uppermost soil layer. The closure landscape, and the prescribed soil placement within that landscape, was defined using the 2021 IPA Closure Plan provided to Aquanty by FHEC. Additional model layers were added to accommodate the merging of placed materials with undisturbed portions of native materials. The Closure Model has 37 nodal sheets and 36 element layers.

The number of nodes per 2D nodal sheet was 11,897 and number of elements in each layer was 23,565. Lateral nodal spacing varied from 200 m to 800 m. Table 3-9 shows the AlgoMesh parameters used to generate and optimize the Closure Model mesh. Figure 3-28 and Figure 3-29, respectively, show the mesh constraints and refinement zones used to build the 2D mesh. Figure 3-30 illustrates the Closure Model's 2D mesh. Closure material hydraulic properties are given in Table 3-10.

The remainder of model setup including its boundary conditions, subsurface, surface, and ET zones and parameter values were defined as discussed in Sections 3.1 to 3.6.

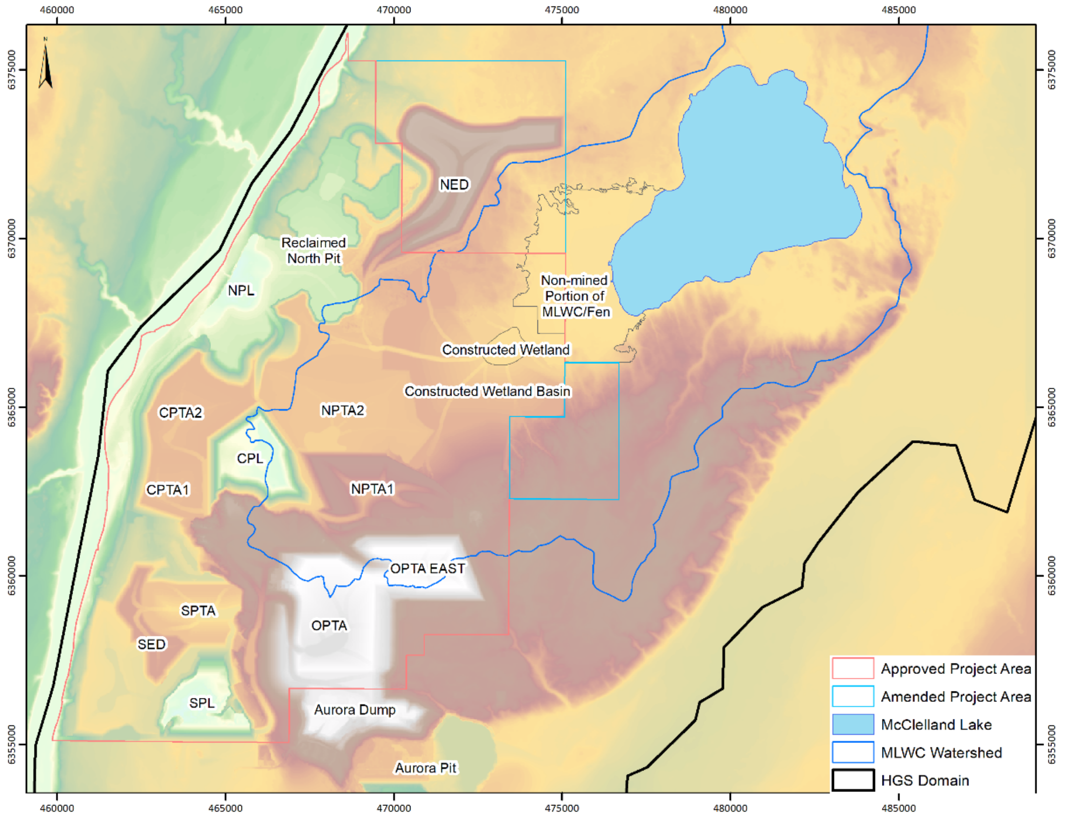


Figure 3-27. Constructed and natural landscape features in the Closure Model

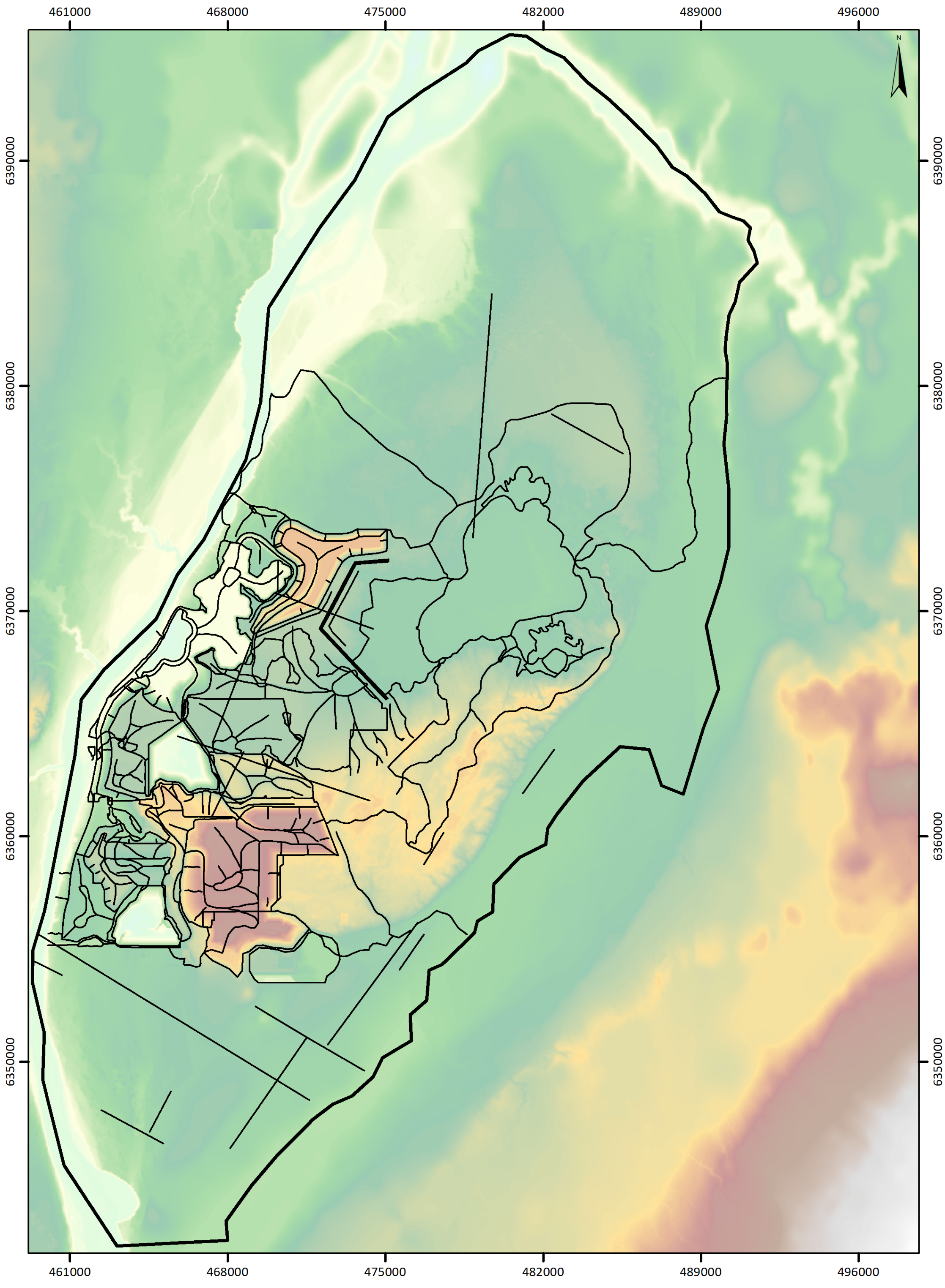


Figure 3-28: Mesh constraints for the Closure Model's 2D mesh.

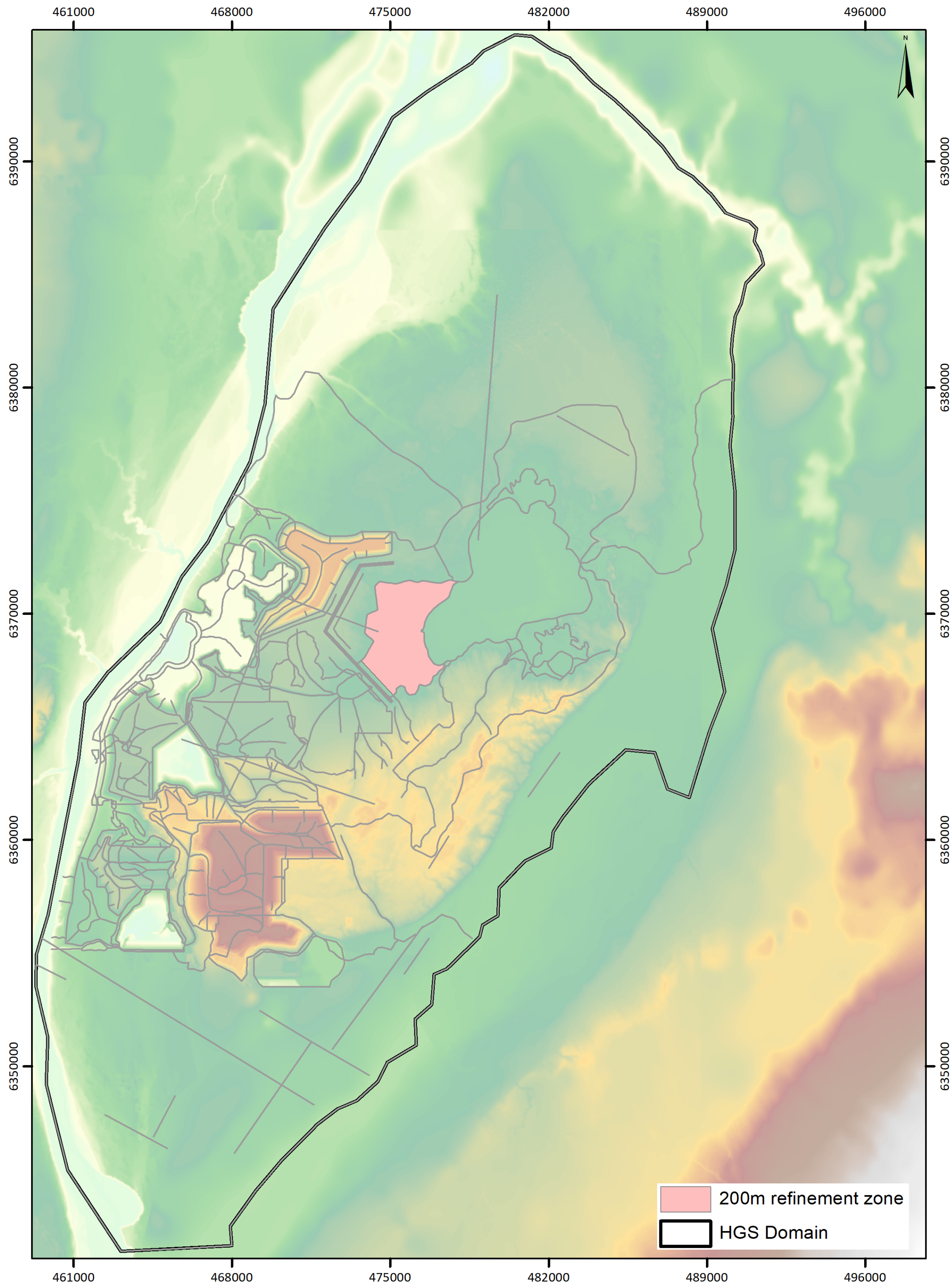


Figure 3-29: Mesh refinement control for the Closure Model's 2D mesh (200 m refinement within the non-mined portion of the MLWC fen).

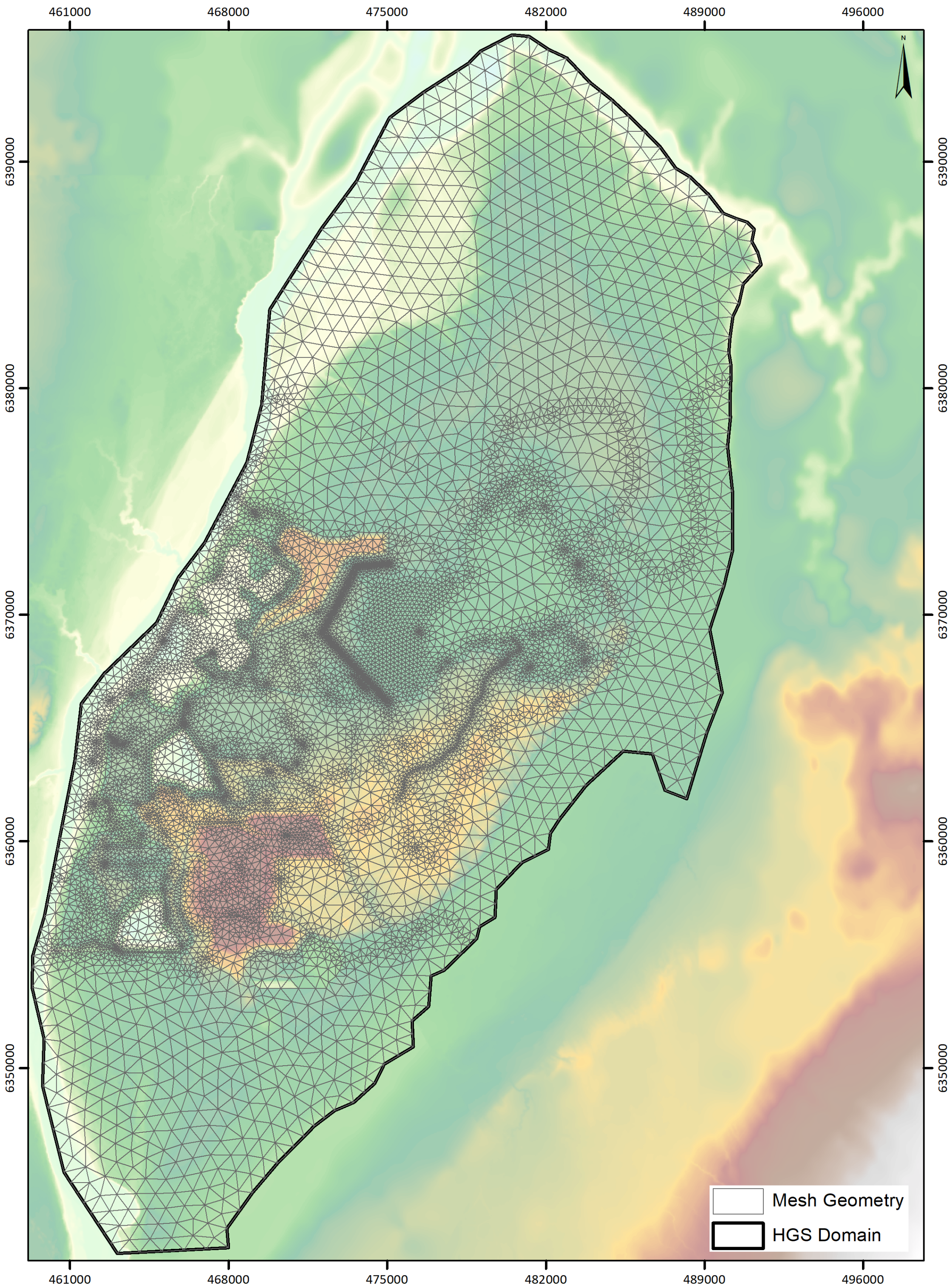


Figure 3-30: The 2D mesh for the Closure Model.

Table 3-9: AlgoMesh settings used to generate and optimize the Closure Model's 2D mesh.

Distance (grading) factor	0.55
Boundary resampling factor	4
Min. resampling interval	500
Global max. edge length	1040 m
Sizing ratio reduction factor	0.95
max. refine iterations	no limit
max. Lloyd iterations (refine)	No limit
max. Lloyd iterations (final relax)	no limit
run Delaunay refinement after completion of optimization	No
Min. angle in degree	n/a

Table 3-10: Closure material hydraulic properties.

	Material Name	K_h (m/s)	K_v (m/s)	Porosity (%)	Explanation
Closure material below surface layer	MSM B-Spec	5.00E-09	5.00E-10	0.35	Source: "Compacted Fill (B/KSpec)" from FHEC
	MSM Random OB	5.00E-09	5.00E-10	0.35	Source: "Compacted Fill (B/KSpec)" from FHEC
	Tailings Sand	2.00E-05	1.00E-06	0.41	Source: "Tailings Sand (capping)' from FHEC
	Overburden Dump (Random Uncompacted OB)	7.00E-07	2.00E-07	0.46	Source: "Un-compacted Fill (GSpec)" from FHEC
	Clean Sand	8.25E-05	8.25E-06*	0.43	Source: "Sand" from Carsel and Parrish (1988)**
	Compacted OB (clay liner under Clean Sand)	5.00E-09	5.00E-10*	0.35	Source: "Compacted Fill (B/KSpec)" from FHEC
	Suitable OB Capping	2.00E-07	1.00E-07	0.5	Source: "Cap Soil" from FHEC
	Treated FT	5.00E-09	1.00E-09	0.5	Source: "Mature Fine Tailings MFT" from FHEC.
Closure soil material within surface layer	Upland Surface Soil Coarse (SSC)	1.23E-05	1.23E-06*	0.41	SSC is coarse sandy soil (e.g. sandy loam). Source: "Sandy loam" from Carsel and Parrish (1988)
	Upland Surface Soil Fine (SSF)	7.22E-07	7.22E-08*	0.41	SSF is fine soil; source: "Clay loam" from Carsel and Parrish (1988)
	Peat-Mineral Mix (PMM)	5.00E-07	5.00E-07	0.55	Source: Ketcheson and Price (2016)

Note: Kh and Kv represent the horizontal and vertical saturated hydraulic conductivity, respectively.

3.11 2020 MLWC HGS Water Balance Model Build Details

The lateral domain of the 2020 MLWC HGS Water Balance Model (Water Balance Model) is the MLWC surface watershed divide. The 2D FEM of the Water Balance Model was extracted out of the identical mesh as the Baseline Model, and therefore shares the same nodal locations and elements as the Baseline Model within the watershed. The geology considered in the Water Balance Model extends from the land surface (the LFH soil layer) down to the middle of the Keg River Formation.

The Water Balance Model contains 7,092 nodes per nodal sheet and 13,709 elements per model layer. Nodal spacing varied from 200 m to 800 m. Table 3-7 shows the AlgoMesh parameters used to generate and optimize the Water Balance Model mesh. Identical mesh constraints (Figure 3-17) and refinement zones (Figure 3-18) were used in the Water Balance Model mesh, as were used in the Baseline Model. Figure 3-31 illustrates the 2D mesh for the Water Balance Model extracted from the Baseline Model's mesh.

The rest of model settings including subsurface, surface, and ET zones and parameter values were identical to those of the Baseline Model.

Groundwater levels extracted along the MLWC watershed boundary in the Baseline Model were applied as specified head boundary conditions along the subsurface perimeter of the Water Balance Model. This was done on a monthly basis which allowed the applied boundary conditions to vary in space and in time. This strategy is commonly referred to as a nested modelling approach, and it ensures the flow solution computed in the (larger) Baseline Model is accurately replicated in the (smaller) Water Balance Model. This nested approach also accommodates for the movement of the western GW divide (within the MLWC watershed) in the subsequent water balance calculations. The perimeter of the surface domain in the Water Balance Model was assigned a no flow boundary condition with the exception of the lake outlet which employed the stage-discharge boundary condition described in Section 3.6.3.

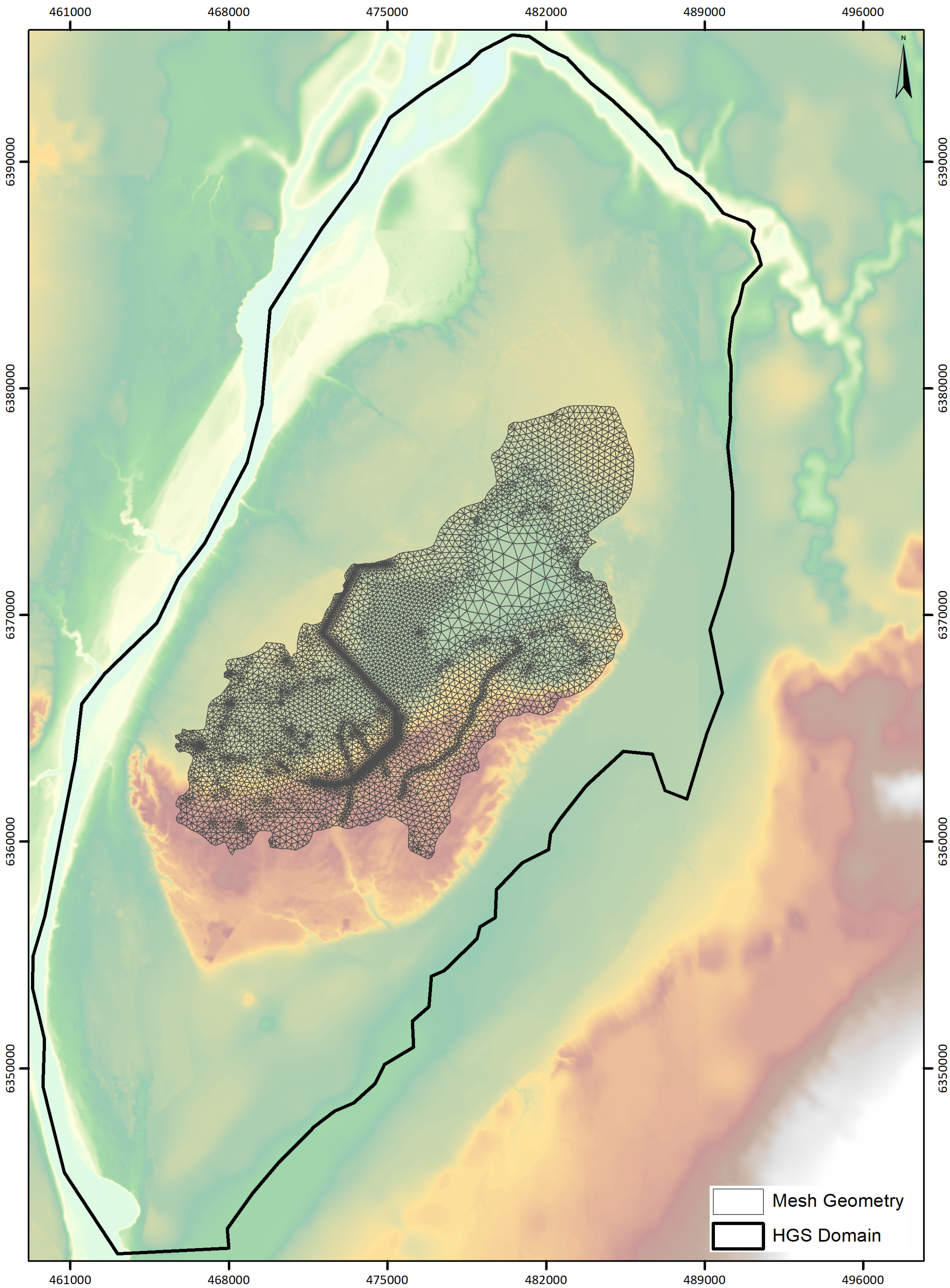


Figure 3-31: The 2D mesh for the Water Balance Model.

4.0 INTEGRATED HYDROLOGIC MODEL CALIBRATION AND VALIDATION

The workflow for the calibration and validation of the 2020 MLWC HGS model is overviewed below and then discussed in more detail later in this section. Calibration and validation of the 2020 MLWC HGS model was a multi-step process. Initial steps involved identifying the available calibration and validation data and screening the monitoring points/data that could be affected by active mining. For the subsurface data, emphasis was placed on calibrating the hydraulic parameters of the Quaternary units. This separation of shallow and deep model calibration was undertaken due to the computational burden the full thickness model places on the automated calibration process.

The available calibration and validation data was categorized by type and screened for anomalous values or indications that the data had been influenced by development or mine operations. For the Quaternary GW data, calibration targets were determined by temporally averaging manual and time series level data at the targeted locations. The calibration period spanned 1991 to 2017 (the first 5 years are a spin up period for the model in every calibration run). As such, the definition of the calibration targets emphasized, to the degree feasible, data collected before the end of 2017. However, the bulk of the available GW data was collected since 2017. Consequently, some GW data collected post-2017 was also included in the definition of the GW calibration targets after being screened for any obvious development impacts. This procedure defined 497 shallow GW targets for use during automated calibration.

Initial parameterization of the 2020 MLWC HGS model was taken from calibrated values from previous generations of the model. The model was truncated at the base of the Quaternary sequence during this automated calibration step. After the initial automated calibration, a manual transient calibration was performed to reproduce the drawdown responses of Quaternary pumping tests conducted within and adjacent to the Fort Hills Lease. Based on the results of those simulated Quaternary pumping tests, a zone delineating the extent of glacially-rafted McMurray (estimated from textural data) was added to the hydrostratigraphy in the 2020 MLWC HGS model (the PGKM unit in Figure 3-2, shown in plan-view in the top left panel of Figure 3-3c), and it was assigned a lower initial hydraulic conductivity than the surrounding silty sands. Prior to this model modification, the PGKM unit was lumped in as part of the Silt Sand Aquifer 4 unit at the base of the FHUC (which overlies the Clay Till 2 Aquitard). Once this modification was implemented, the model was subjected to a second round of automated calibration.

Following calibration, the hydrostratigraphy below the Quaternary sequence was added back into the model and those deeper units were subsequently parameterized using the previously calibrated hydraulic conductivity and storativity parameters extracted from the Fort Hills FEFLOW model, discussed in Section 3.6.2. The full model was run and the simulated heads for the calibration targets established for the deeper GW units were then checked against the levels simulated by the 2020 MLWC HGS model containing the entire hydrostratigraphic sequence down the Keg River unit (the Quaternary heads and other targets were also re-examined and found to remain relatively unchanged). The imported calibrated parameterization of the deeper units was also tested against available Basal McMurray Aquifer pumping test data near or within the MLWC watershed.

4.1 Calibration and Validation Data Types

Several historical observation types within the model boundaries were used either in the calibration or in the validation of the 2020 MLWC HGS models. The first data group is historical GW levels monitored by FHEC at wells and piezometers across the Fort Hills Lease. These monitoring points span from the near surface units (e.g., < 1 m depth) down to the Devonian units, with the majority of the data considered in the analysis screened in the Quaternary units.

The second data group is the McClelland Lake stage data which has been monitored since 1997. Outflow rates from McClelland Lake's outlet into McClelland Creek are also available from 1996 to 2006. However, the overall quality of the outflow data has been questioned in previous studies (e.g., Golder, 2018). Given this uncertainty, the McClelland Lake outflow observations were not used as model calibration targets but were instead retained to validate simulated lake outflow timing and, to a lesser degree, the outflow rates. Even when considering the uncertainties in the McClelland Lake outflow data, it was still judged valid enough to be combined with the overlapping lake stage data to validate the stage-discharge relationship at the lake outflow in the 2020 MLWC HGS models.

The third data group is the flow data for the SD-8 station (2018 to 2019), located near where South Creek discharges into the south side of McClelland Lake (Figure 4-1). This flow data is of a short (two-year) duration and therefore was of limited use for calibrating the simulated channel flows in South Creek. As such, the South Creek discharge data was not used during model calibration but was used in model validation.

The fourth data group are AET rates measured between 2018 and 2019 at two eddy covariance flux towers within the MLWC watershed for the fen and NOP forested upland (Figure 4-1). The reported annual AET rates were used as calibration targets for the corresponding land types in the models, while the seasonal trends served as a validation dataset.

The fifth data group are representative annual evaporation and AET rates determined for a range of land covers using eddy covariance tower data compiled from a number of sites in the Athabasca Oils Sands region.

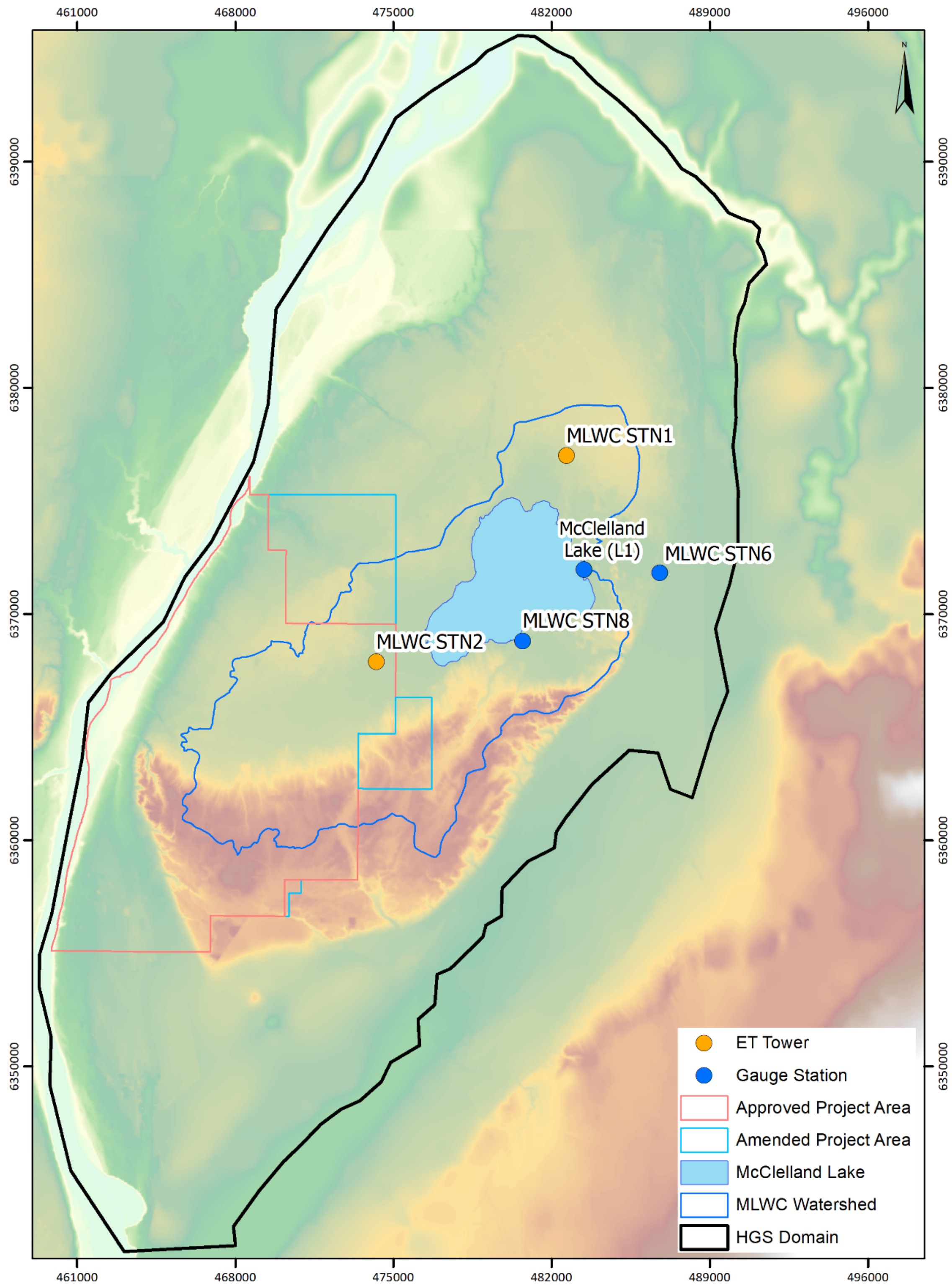


Figure 4-1: ET flux tower and gauging stations locations in the HGS model domain.

4.2 Transient Automated Calibration and Well Testing

4.2.1 Manual Quaternary Well Testing Calibration

Well testing simulation included manually calibrating the HGS model to 13 individual pumping tests and two injection tests (locations shown on Figure 4-2). This separate, manual calibration exercise consisted of six tests (four pumping and two injection tests) conducted in the Surface Sand North unit, four in the AQ4-Silty Sand unit, seven in the AQ3- Silty Sand unit, and one in the Clay Till 2. Among these tests, four tests (two pumping and two injection) were in the vicinity of the NOP, two in the vicinity of the MLWC, seven in the vicinity of OPTA and OPTA-East, one at the McClelland Lake outlet, and one on the north slope of the FHUC. Table 4-1 presents the summary of each Quaternary well tests considered in the manual calibration.

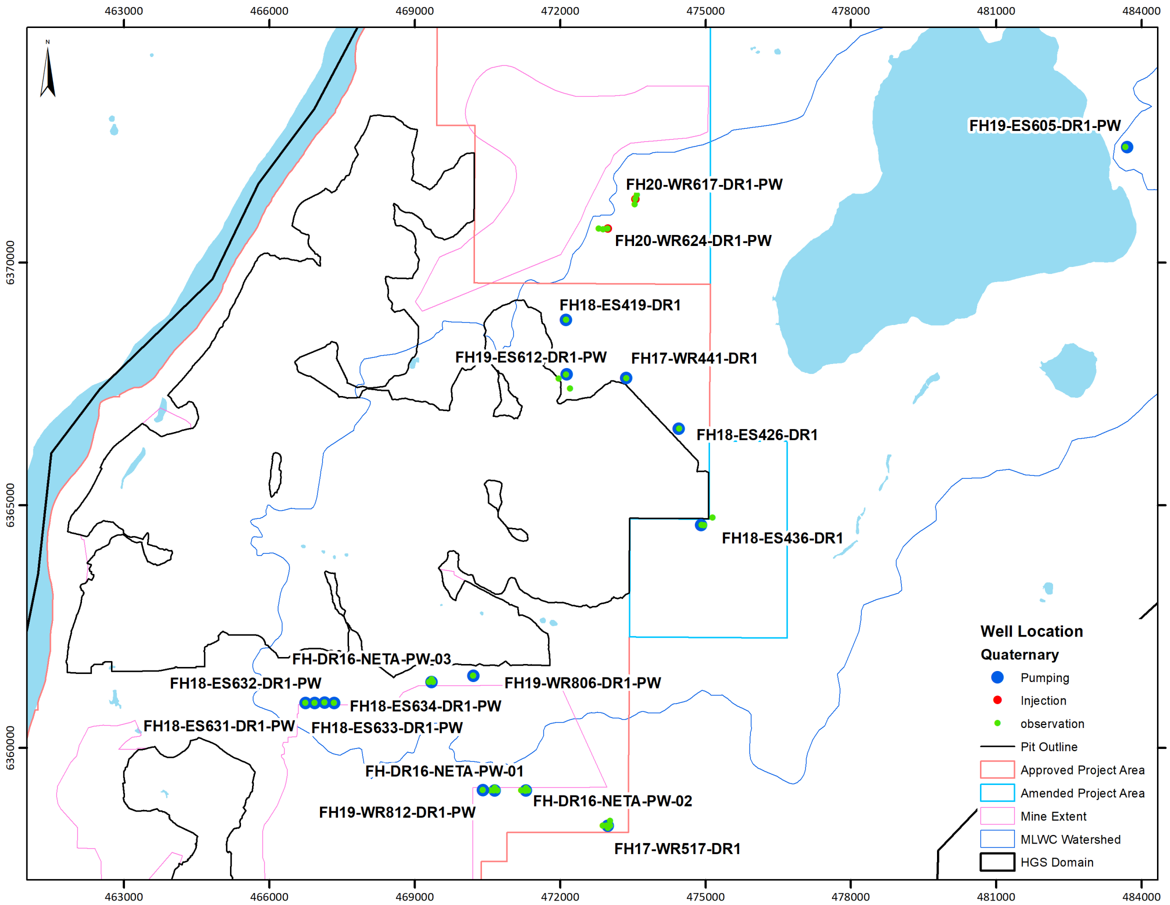


Figure 4-2: Quaternary well testing locations.

Table 4-1: Summary of well tests evaluated in manual calibration of the 2020 MLWC HGS model.

Pumping Well ID	Pumping well Diameter (in.)	Observation well ID	Date of the test	Duration	Pumping Rate (m^3/day)
FH18-ES419-DR1[a]	8	ES444-SN1 VWP-C ES419-SN1 VWP-B	17-Jan 2019 to 2-Feb-2019	15 days	1000
FH18-ES426-DR1	8	FH18-ES426-SN1	8-Mar-2018	8.2 hours	5.8-14.4
FH18-ES436-DR1[b]	8	FH18-ES436-SN1 FH19-ES672-SN2 FH19-ES672-SN1 FH19-ES668-SN1	12-Feb-2019 to 27-Feb-2019	15 days	700
FH18-ES631-DR1-PW FH18-ES632-DR1-PW FH18-ES633-DR1-PW FH18-ES634-DR1-PW	10	FH17-ES631-SN1-MW FH17-ES632-SN1-MW FH17-ES633-SN1-MW FH17-ES634-SN1-MW FH17-ES635-SN1-MW FH17-ES636-SN1-MW FH17-ES636-SN2-MW FH17-ES637-SN1-MW FH17-ES638-SN1-MW FH17-ES638-SN2-MW FH17-ES638-SN3-MW FH17-ES639-SN1-MW FH17-ES640-SN1-MW FH17-ES641-SN1-MW FH17-ES642-SN1-MW FH17-ES643-SN1-MW	1-Aug-2018 to 8-Aug-2018	7 days	396 144 151.2 43.2
FH17-WR517-DR1	8	FH17-WR513-SN1 FH17-WR514-SN1 FH17-WR515-SN1 FH17-WR516-SN1 FH17-WR516-SN2 FH17-WR518-SN1	20-Sep-2017 to 23-Sep-2017	3 days	500
FH-DR16-NETA-PW-01	8	FH-SO16-NETA-OW-01 FH-SO16-NETA-OW-02 FH-SO16-NETA-OW-03A FH-SO16-NETA-OW-10 A-25-AQ1 A-25-AQ3	11-Aug-2016 to 14-Aug-2016	3 days	518.4
FH-DR16-NETA-PW-02	8	FH-SO15-DDA1-OW-04 FH-SO16-NETA-OW-05 FH-SO16-NETA-OW-06 FH-SO16-NETA-OW-11 A-26-AQ1 A-26-AQ3	1-Aug-2016 to 4-Aug-2016	3 days	86.4
FH-DR16-NETA-PW-03	8	FH-SO16-NETA-OW-07 FH-SO16-NETA-OW-08 FH-SO15-DDA1-OW-09	6-Aug-2016 to 9-Aug-2016	3 days	230.4
FH20-WR617-DR1-PW[c]	8	FH20-617-SN1-VW FH20-616-SN1-VW FH20-619-SN1-VW	24-Feb-2020 to 15-Mar-2020	20 days	300
FH20-WR624-DR1-PW[c]	8	FH20-624-SN1-VW FH20-623-SN1-VW FH20-622-SN1-VW	18-Mar-2020 to 28-Mar-2020	10 days	800

Pumping Well ID	Pumping well Diameter (in.)	Observation well ID	Date of the test	Duration	Pumping Rate (m^3/day)
FH17-WR441-DR1	8	FH17-WR441-SN1	13-Mar-2017 to 17-Mar-2017	3 days	180
FH19-ES605-DR1-PW	8	FH18-ES412-SN1	1-Mar-2019 To 4-Mar-2019	3 days	1,000
FH19-ES612-DR1-PW	8	FH19-GL612-SN1 FH19-ES614-SN1-MW FH19-ES616-SN1-MW	25-Feb-2019 To 2-Mar-2019	5 days	400
FH19-WR806-DR1-PW	10	FH19-WR806-SN1-VW1 FH19-WR806-SN1-VW2	21-Sept-2019 To 24-Sept-2019	3 days	748
FH19-WR812-DR1-PW	10	FH19-WR812-SN1-VW1 FH19-WR812-SN1-VW2	10-Mar-2019 To 13-Marc-2019	3 days	1,656

Notes:

a. Initially well FH18-ES419-DR1 was pumped at a rate of 500 m^3/day for 3 days in March 2018; however, it was retested in 2019 and re-assessed in 2020 as presented in the table.

b. Initially well FH18-ES436-DR1 was pumped at a rate of 500 m^3/day for 5 days in March 2018; however, it was retested in 2019 and re-assessed in 2020 as presented in the table.

c. Injection tests

The regional scale of the 2020 MLWC HGS model is large relative to the scale of the radius of influence of the pumping tests; therefore, it was necessary to build a new 2D mesh with refinement appropriate for representing the pumping and observation wells (Figure 4-3). Quaternary well testing locations are shown in Figure 4-4 and cross sections are shown in Figure 4-5. It should be noted that despite refinement in the finite element mesh around the pumping tests, no attempts were made to refine the hydrostratigraphy to match the drawdown observations. This is because any local refinement would likely be below the resolution of the 2020 MLWC HGS model. In a process of manual calibration (through trial-and-error), the 2020 MLWC HGS model was used to determine the hydraulic conductivity and specific storage values to provide a best-fit for each of the pumping/injection tests. Plots showing the observed (points) versus simulated (lines) fits obtained during the manual calibration of the Quaternary well tests are presented in Attachment G.

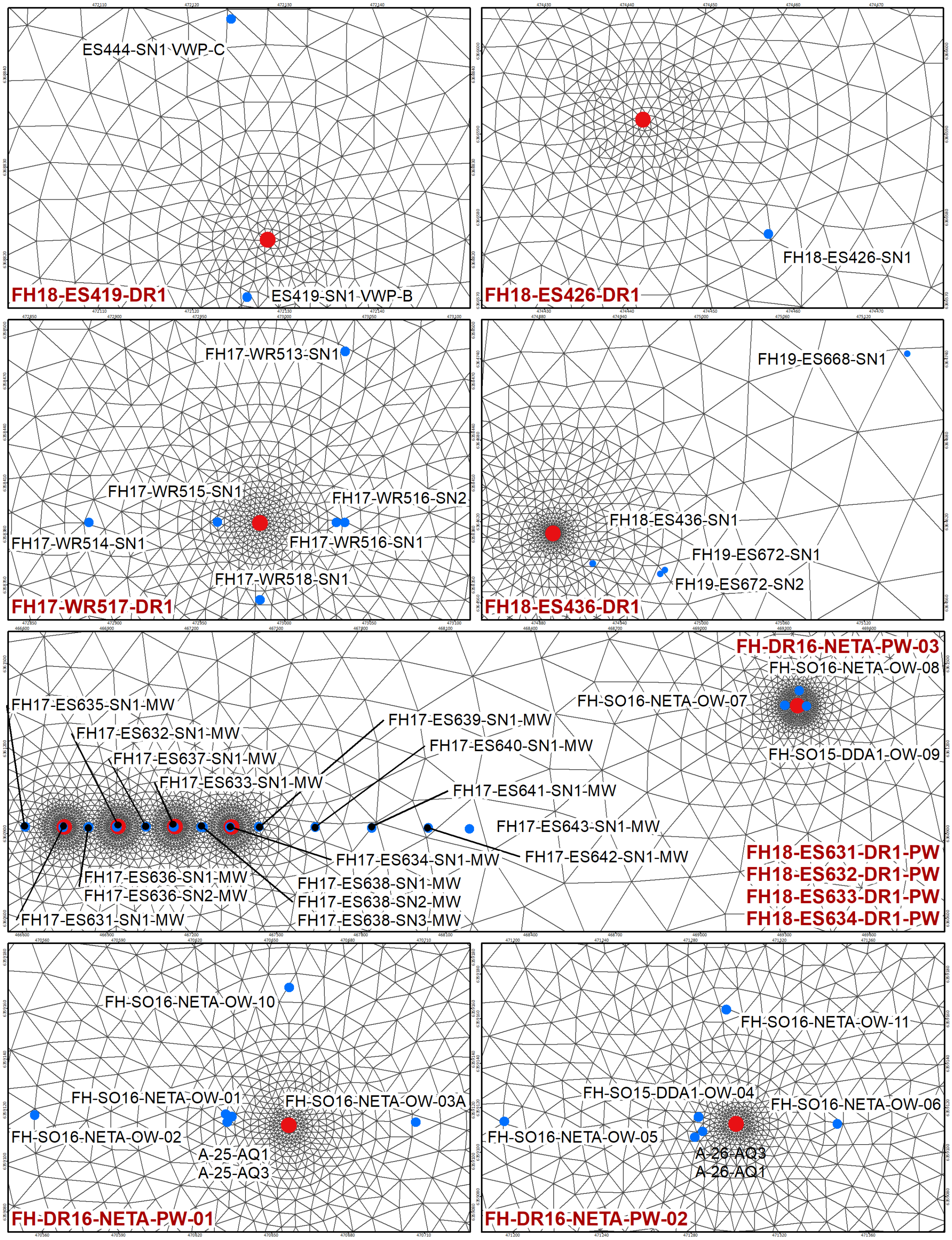


Figure 4-3a: Pumping (red) and observation wells (dark blue) in the locally refined 2D mesh of the transient calibration model.

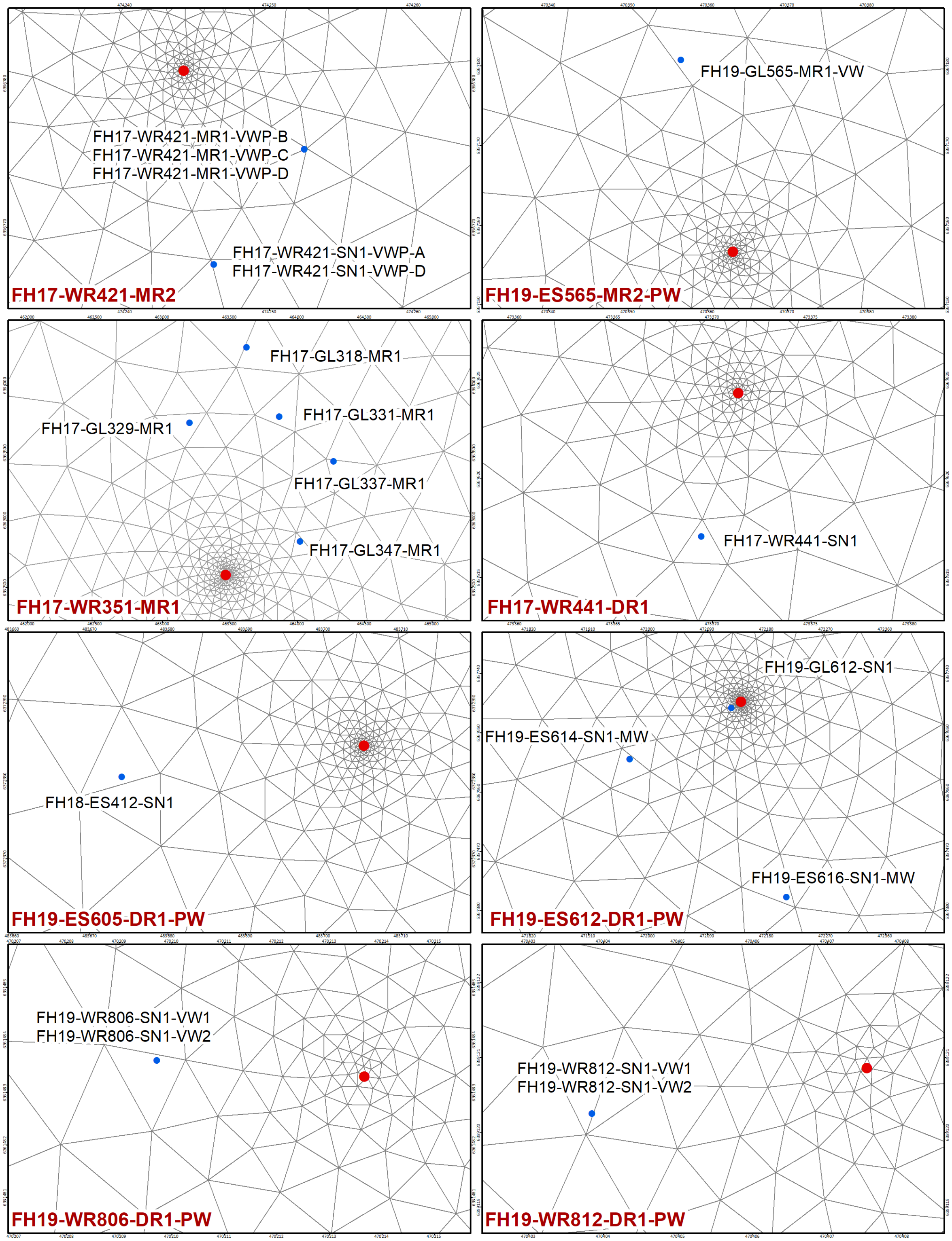


Figure 4-3b. Pumping (red) and observation wells (dark blue) in the locally refined 2D mesh of the transient calibration model.

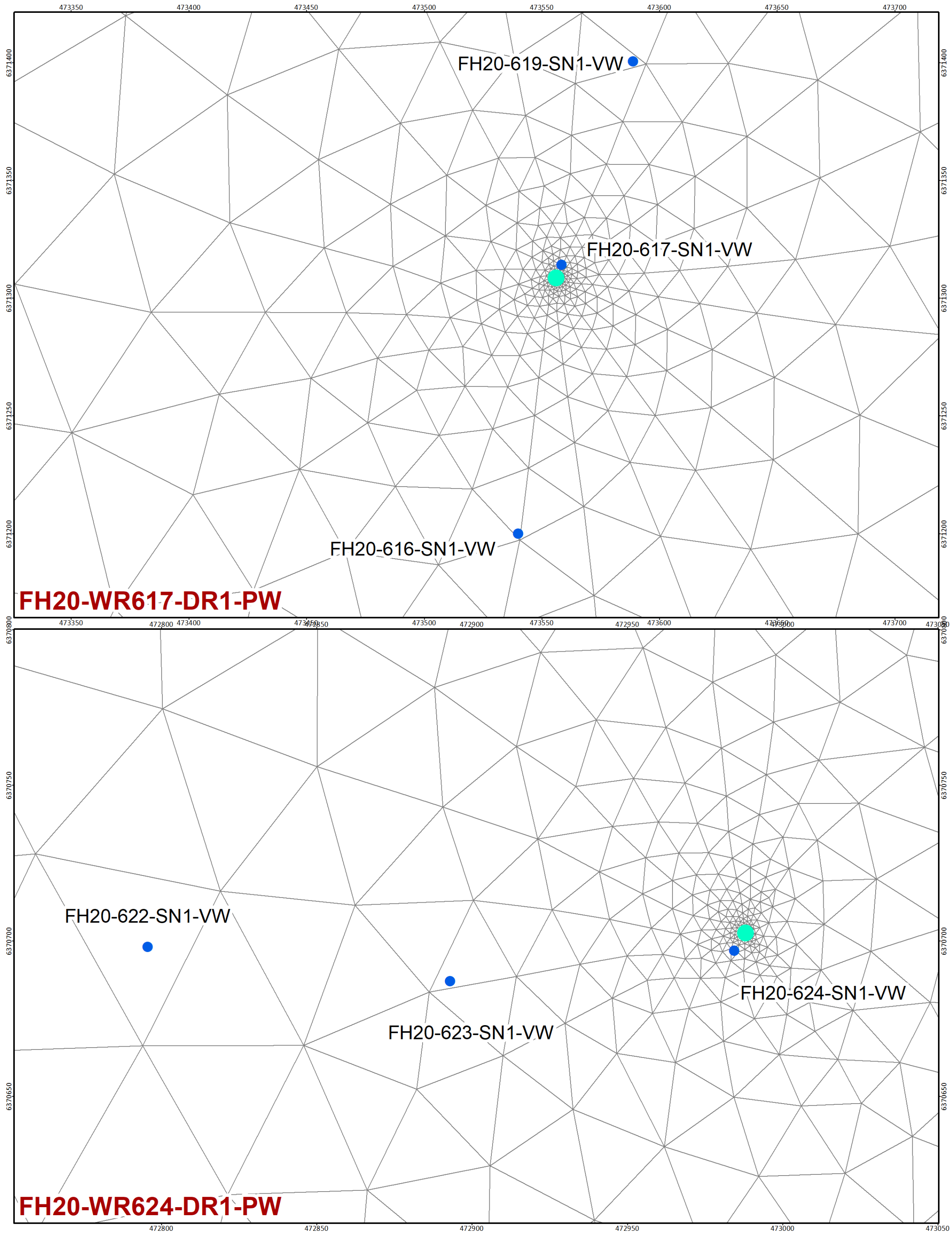


Figure 4-3c: Injection (light blue) and observation wells (dark blue) in the locally refined 2D mesh of the transient calibration model.

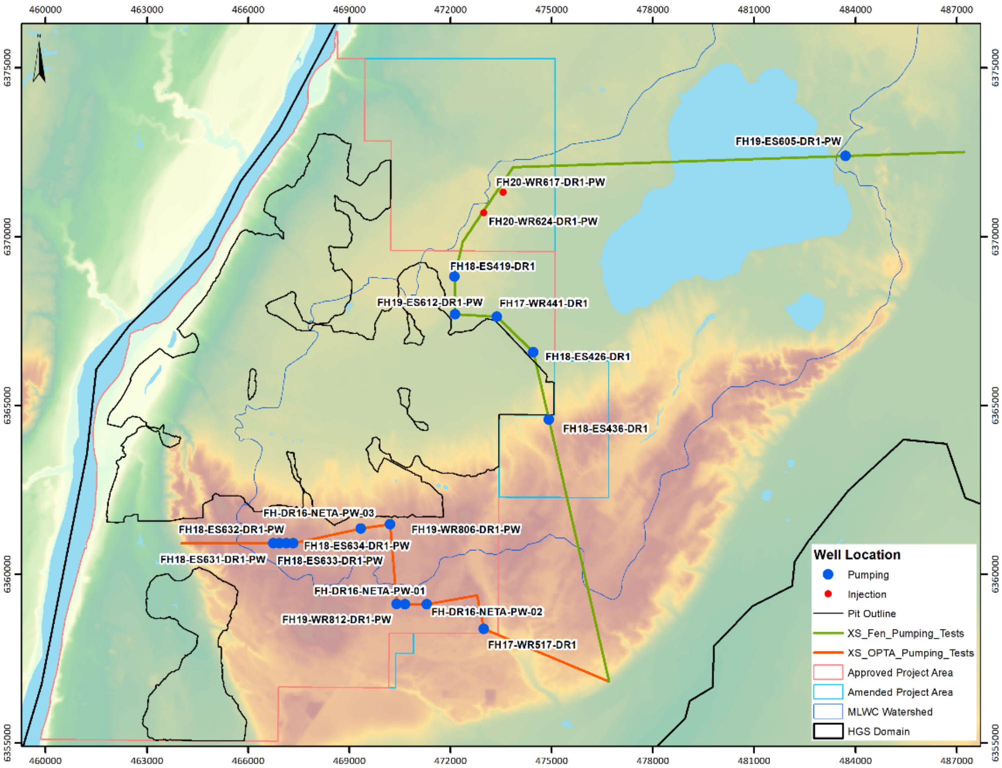
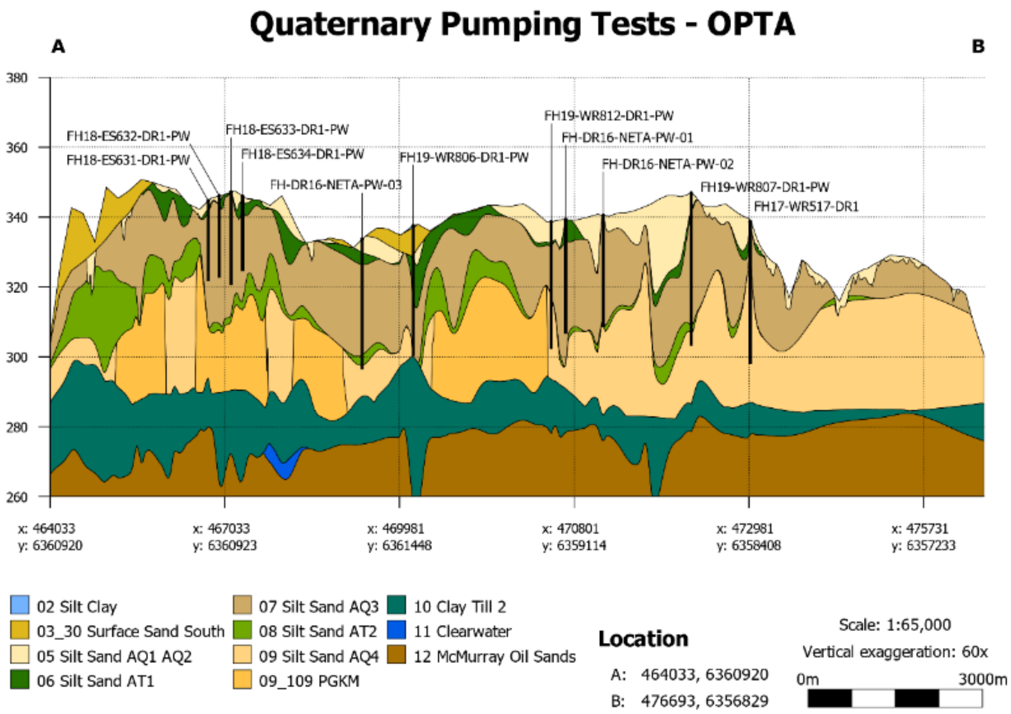


Figure 4-4: Location of the OPTA and Fen Quaternary well tests.



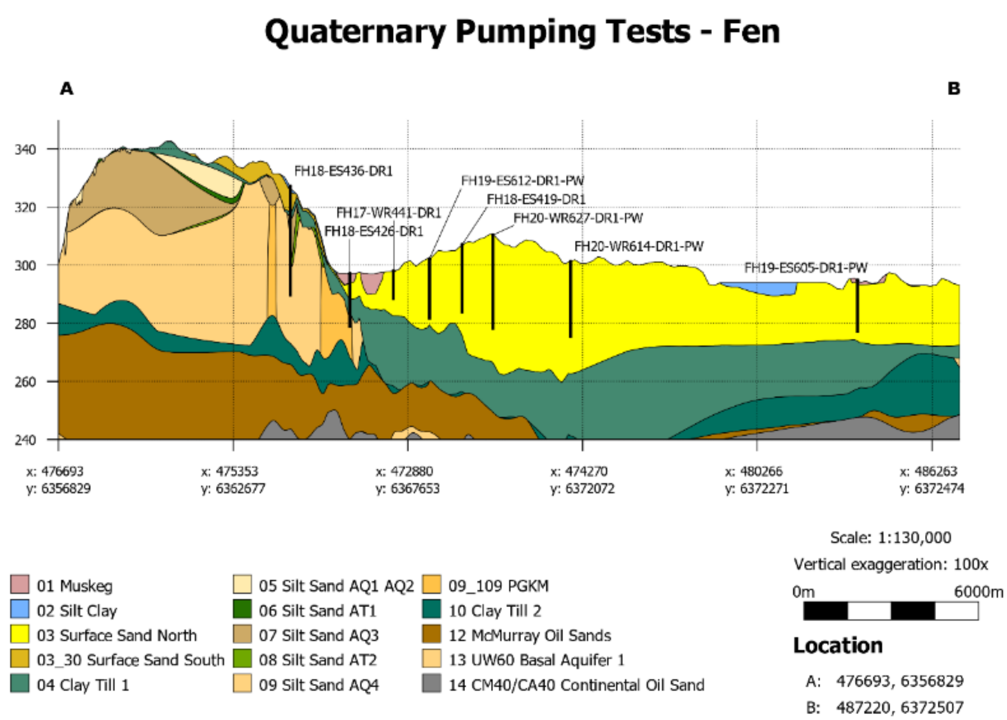


Figure 4-5: Cross-section of the OPTA (top panel) and Fen (bottom panel) well testing locations.

Table 4-2. Comparison of Quaternary well testing calibration results.

Test Area	Pumping Well	Screened Hydrostratigraphic Unit	No. of Obs. Wells	Manually Calibrated *K* (m/s)	Manually Calibrated S_s (1/m)
NOP	FH18-ES419-DR1	Quaternary- Surface Sand North	2	1.30E-04	1.00E-03
FEN	FH18-ES426-DR1	Quaternary Silty Sand-AQ4	1	3.47E-07	1.00E-06
Fort Hills N. Slope	FH18-ES436-DR1	Quaternary Silty Sand-AQ4	1	7.79E-06	1.00E-05
OPTA	FH18-ES631-DR1-PW FH18-ES632-DR1-PW FH18-ES633-DR1-PW FH18-ES634-DR1-PW	Quaternary Silty Sand-AQ3	16	1.74E-05	4.00E-04
OPTA	FH17-WR517-DR1	Quaternary Silty Sand-AQ4	6	2.31E-05	9.00e-05
OPTA	FHDR16-NETA-PW-01	Quaternary Silty Sand-AQ3	6	3.40E-05	5.00E-05
OPTA	FHDR16-NETA-PW-02	Quaternary Silty Sand-AQ3	4	2.96E-05	5.00E-05
OPTA	FHDR16-NETA-PW-03	Quaternary Silty Sand-AQ3	3	7.87E-06	2.50E-05
NOP	FH20-WR617-DR1-PW	Quaternary - Surface Sand North	3	5.21E-05	1.00E-05
NOP	FH20-WR624-DR1-PW	Quaternary- Surface Sand North	3	5.79E-05	1.00E-06
Fen	FH17-WR441-DR1	Quaternary- Surface Sand North	1	2.78E-05	5.00E-05
Lake Outlet	FH19-ES605-DR1-PW	Quaternary- Surface Sand North	1	1.39E-04	5.00E-04
NOP	FH19-ES612-DR1-PW	Quaternary- Surface Sand North	3	5.21E-05	1.00E-05
OPTA-East SMS	FH19-WR806-DR1-PW	Quaternary - Clay Till 2	2	1.97E-05	5.00E-08
OPTA-East SMS	FH19-WR812-DR1-PW	Quaternary Silty Sand-AQ4	2	1.04E-04	4.00E-05

Textural data for these FHUC deposits were obtained from FHEC and analyzed in terms of their sand, silt and clay content across the FHUC. Figure 4-6 demonstrates the sand content in AQ4 unit. The results from the analysis were plotted and interpreted to indicate that the deeper silty sand units in the FHUC contain a region of lower permeability material that was later identified as glacially-rafted McMurray Formation (designated the PGKM unit). In the original conceptualization of the 2020 MLWC HGS model, this rafted McMurray deposit was combined with the surrounding silty sands as one unit. However, based on the well testing versus automated calibration results and the subsequent textural analysis, the model's hydrostratigraphy was modified and the relatively lower hydraulic conductivity PGKM material was added in as a distinct and separate hydrostratigraphic unit located at the base of the FHUC, above Clay Till 2. Once the modifications were completed, the 2020 MLWC HGS model was subjected to a second and final round of automated calibration. All subsequent automated calibration results presented in this report refer to the results achieved in this second and final round of automated calibration of the 2020 MLWC HGS model.

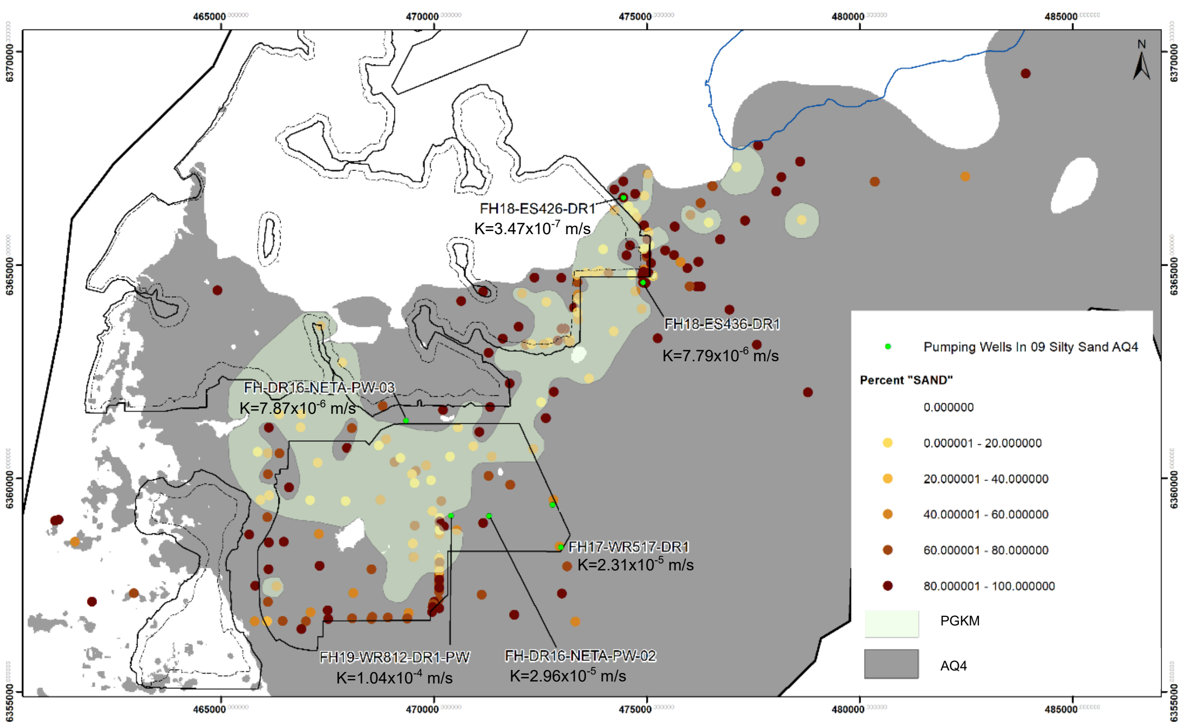


Figure 4-6. Plan view illustrating the sand fraction in borehole logs in the Fort Hills with silty sand PGKM unit sub-divided from the silty sand AQ4 unit.

4.2.2 Automated transient calibration

4.2.2.1 Automated calibration targets

The available historical GW head data were initially screened to exclude wells near mine operations, leaving 612 monitoring wells/piezometers for potential use in model calibration. Of those, 534 were screened within Muskeg and Quaternary units, with the remaining 78 screened below the Quaternary and excluded from the automated calibration dataset. The remaining GW calibration data were screened for mining impacts and 37 out of 534 wells/piezometers contained anomalously low heads, indicating the heads were likely influenced by mine operations. These 37 wells were excluded from the calibration dataset. The remaining 497 observation points, consisting of manual GW measurements and time series data, were included in the automatic calibration process. The long-term mean head at each of the 497 points were used to define the first set of calibration targets.

A second set of calibration targets consisted of the observed McClelland Lake levels from 1997 to 2017. Note that lake levels are not recorded during the winter. To reduce the number of lake level targets to a tractable number, inter- and intra-annual highs and lows within the dataset from 1997 to 2017 were chosen as targets (Figure 4-7). The post-2017 lake level data was excluded from the calibration data and was instead used for model validation.

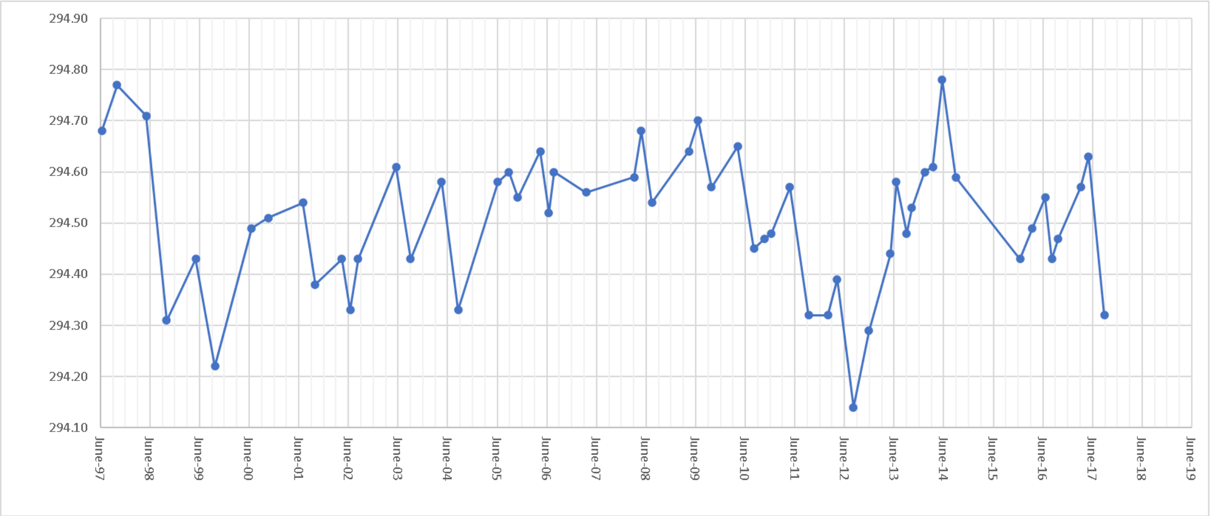


Figure 4-7: Inter and intra-annual highs and lows of McClelland Lake levels used in the long-term automatic calibration.

The third and final set of calibration targets were long term annual evaporation and AET rate targets for McClelland Lake, the fen, the NOP and the FHUC. Figure 4-8 shows the extent of each MLWC AET target zone and the associated annual AET rate target used during automated calibration. Long-term evaporation rates from Morton's shallow lake evaporation for Fort McMurray were used as the evaporation target for McClelland Lake (ABGOV, 2013). 2018 AET rates recorded at the eddy covariance flux tower located in the NOP were used for the AET target for the NOP West and NOP North regions shown in Figure 4-8. The 2018 AET rates observed at the fen eddy covariance flux tower were used as the AET target for the fen zone (Figure 4-8). FHEC provided long term statistics on the annual AET rates of different land covers within the Athabasca Oil Sands region. The mean AET of the land covers was combined with the weighted areal distribution of those landcovers within the MLWC watershed to determine the annual AET target rates for the Fort Hills and Unnamed Lake regions shown in Figure 4-8.

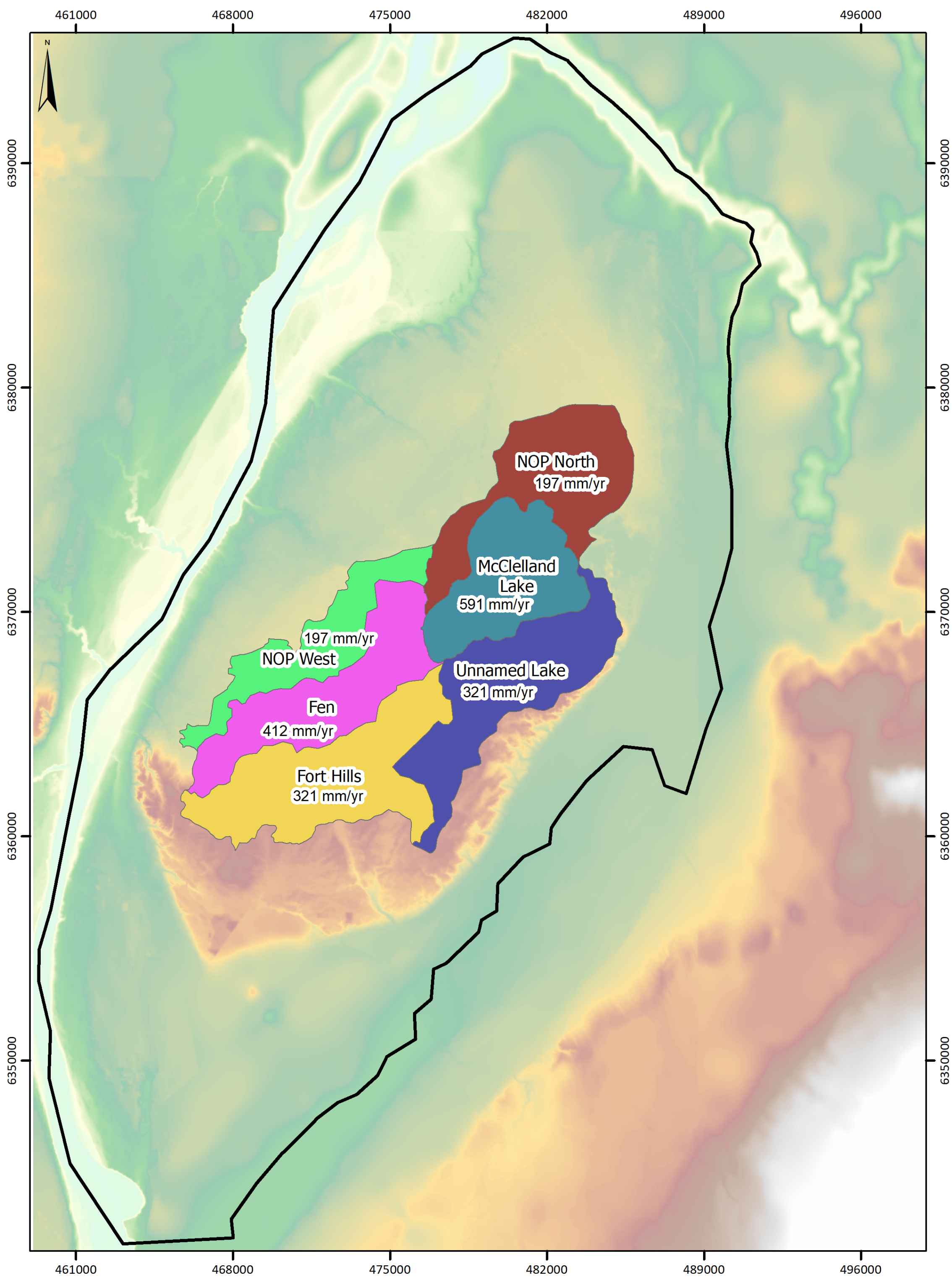


Figure 4-8: Actual Evapotranspiration (AET) zones and calibration targets.

4.2.2.2 Automated calibration setup

For the initial round of automated calibration, the results of 3 previous calibrations performed on earlier generation MLWC HGS models (Aquanty, 2018; 2019; 2020a) were used to inform which specific model parameters were to be included in the automated calibration (i.e., based on the most sensitive parameters as indicated from previous calibrations), their initial values, and potential value ranges.

The automated calibration involved running the model in a transient state with daily climate forcing for 25 years (1991 to 2017). The results were then compared to the calibration targets set for GW levels, AET, and McClelland Lake level over this period. Each individual calibration run includes a run-in period of 5 years prior to the calibration period (1996 to 2017) to allow for the effect of changes in parameter values made by the calibration software to stabilize. In total, 497 average GW head levels, 56 extremums (highs and lows) in McClelland Lake levels, and 6 long-term AET values were included as targets in the objective function for the automatic calibration. Automated calibration was performed using the parameter estimation code, PEST_HP (WNC, 2017). PEST_HP is a version of PEST (Doherty, 2005) that has been optimized for parameter estimation in highly parallelized environments. Additional details on the PEST calibration approach are presented in Attachment E. PEST_HP was coupled with HGS to run the Calibration Model iteratively and to calibrate the model parameters by minimizing PEST_HP's computed objective function. Each observation group (GW level, lake level, and AET) had a different number of entries (as mentioned above). The calibration weights for the members of each observation group were adjusted so that the objective functions of the calibration target groups lay within a similar range.

Three parameter groups were also included in the calibration process; 1) horizontal saturated hydraulic conductivity and anisotropy ratio for 11 key subsurface material zones (22 parameters in total); 2) McClelland Lake's stage-discharge rating curve parameters discussed in Section 3.6.3 (3 parameters in total); 3) ET parameters including evaporation depth, transpiration depth, and their limiting pressure heads in the wetland and forested upland land covers (15 parameters total), and 4) overland flow parameters including rill storage height and Manning's friction coefficient for the patterned and non-patterned fens (4 parameters total). Table 4-3 shows the model parameters considered during the automated calibration process.

Table 4-3. Model input parameters used in the automated model calibration.

Parameter	Group	Description	Scope of Calibration	Units
C2_Peat	etparams	Transpiration fitting parameter C2 for Peat	AET in the wetland-lowland surface zone (fen)	-
E_d_Peat	etparams	Evaporation depth interval	AET in the wetland-lowland surface zone (fen)	-
HminPeat	etparams	Minimum evaporation limiting pressure head for Peat	AET in the wetland-lowland surface zone (fen)	m
HmaxPeat	etparams	Maximum evaporation limiting pressure head for Peat	AET in the wetland-lowland surface zone (fen)	m
Hol_Peat	etparams	Oxic limiting pressure head for transpiration for Peat	AET in the wetland-lowland surface zone (fen)	m
Hal_Peat	etparams	Anoxic limiting pressure head for transpiration for Peat	AET in the wetland-lowland surface zone (fen)	m
C1_Shrb	etparams	Transpiration fitting parameter C1 for Shrubland	AET in the land cover "shrubland"	-

Parameter	Group	Description	Scope of Calibration	Units
C2_Shrb	etparams	Transpiration fitting parameter C2 for Shrubland	AET in the land cover “shrubland”	-
HminShrb	etparams	Minimum evaporation limiting pressure head for Shrubland	AET in the land cover “shrubland”	m
HmaxShrb	etparams	Maximum evaporation limiting pressure head for Shrubland	AET in the land cover “shrubland”	m
C1_Frst	etparams	Transpiration fitting parameter C1 for Forest	AET in the upland forest land covers	-
C2_Frst	etparams	Transpiration fitting parameter C2 for Forest	AET in the upland forest land covers	-
HminFrst	etparams	Minimum evaporation limiting pressure head for Forest	AET in the upland forest land covers	m
HmaxFrst	etparams	Maximum evaporation limiting pressure head for Forest	AET in the upland forest land covers	m
C2_Water	etparams	Transpiration fitting parameter C2 for Water	AET in the open water surface zone (lake)	-
KhPeatU	k_scaling	K_h for Peat (upper)	GW flow in the muskeg peat	m/s
AR_Peat	k_scaling	Anisotropy ratio for Peat (upper)	GW flow in the muskeg peat	-
KhSSN	k_scaling	K_h for Surficial Sand North	GW flow in the surficial sand aquifer (NOP)	m/s
AR_SSN	k_scaling	Anisotropy ratio for Surficial Sand North	GW flow in the surficial sand aquifer (NOP)	-
KhSSS	k_scaling	K_h for Surficial Sand South	GW flow in the surficial sand aquifer (Fort Hills)	m/s
AR_SSS	k_scaling	Anisotropy ratio for Surficial Sand South	GW flow in the surficial sand aquifer (Fort Hills)	-
KhTill	k_scaling	K_h for ClayTill1 and ClayTill2	GW flow in the clay till 1 layer	m/s
AR_Till	k_scaling	Anisotropy ratio for ClayTill1 and ClayTill2	GW flow in the clay till 1 layer	-
KhSiC	k_scaling	K_h for Silty Clay	GW flow in the silty clay layer	m/s
AR_SiC	k_scaling	Anisotropy ratio for Silty Clay	GW flow in the silty clay layer	-
KhSiS	k_scaling	K_h for Silty Sand (AQ1+AQ2)	GW flow in the silty sand layer	m/s
AR_SiS	k_scaling	Anisotropy ratio for Silty Sand	GW flow in the silty sand layer	-
KhSiS_AQ4	k_scaling	K_h for Silty Sand AQ4	GW flow in the AQ4 layer	m/s
AR_SiS_AQ4	k_scaling	Anisotropy ratio for Silty Sand AQ4	GW flow in the AQ4 layer	-
Kh_PGKM	k_scaling	K_h for PGKM	GW flow in the PGKM zone	m/s
AR_PGKM	k_scaling	Anisotropy ratio for PGKM	GW flow in the PGKM zone	-
KhSiS_AQ3	k_scaling	K_h for Silty Sand AQ3	GW flow in the AQ3 layer	m/s
AR_SiS_AQ3	k_scaling	Anisotropy ratio for Silty Sand AQ3	GW flow in the AQ3 layer	-
KhSiS_AT1	k_scaling	K_h for Silty Sand AT1	GW flow in the AT1 aquitard layer	m/s
AR_SiS_AT1	k_scaling	Anisotropy ratio for Silty Sand AT1	GW flow in the AT1 aquitard layer	-
KhSiS_AT2	k_scaling	K_h for Silty Sand AT2	GW flow in the AT2 aquitard layer	m/s
AR_SiS_AT2	k_scaling	Anisotropy ratio for Silty Sand AT2	GW flow in the AT2 aquitard layer	-
Frc_Pat	surface	Manning's friction coefficient for the patterned fen	Overland flow in the patterned wetland surface zone	$s/m^{1/3}$

Parameter	Group	Description	Scope of Calibration	Units
Ril_Pat	surface	Surface rill storage for the patterned fen	Overland flow in the patterned wetland surface zone	m
Frc_Non_Pat	surface	Manning's friction coefficient for the non-patterned fen	Overland flow in the non-patterned wetland surface zone	$s/m^{1/3}$
Ril_Non_Pat	surface	Surface rill storage for the non-patterned fen	Overland flow in the non-patterned wetland surface zone	m
stg_dis_cnst	stage_disch	Stage-discharge constant for McClelland Lake outlet	Discharge from McClelland Lake	m^3/s
min_flw_dpth	stage_disch	Minimum flow depth for the stage-discharge for McClelland Lake outlet	Lake outlet elevation adjustment	m
stg_dis_pwer	stage_disch	Stage discharge power coefficient for McClelland Lake outlet	Discharge from McClelland Lake	-

Note: K_h is the horizontal saturated hydraulic conductivity and AR is the anisotropy ratio, which is defined as ratio of vertical saturated hydraulic conductivity to horizontal saturated hydraulic conductivity.

4.2.2.3 *Automated calibration results*

Figure 4-9 shows a scatterplot and diagnostic sub-plots of simulated and measured GW heads in all Quaternary units. The figure shows a strong grouping of data points about the 1:1 line between the observed and the simulated data points and reasonable overall fit. The results in Figure 4-9 exhibit a minor overprediction bias in that more data points are falling above the 1:1 line than below it. This minor bias in the simulated GW levels results is attributed to three possible causes (or a combination thereof):

1. The simulated scatterplot fit within the surficial, relatively shallower, unconfined Quaternary units (e.g., Surface Sand South) show little predictive bias. However, the confined/semi-confined silty sand deposits in the FHUC, a significant fraction of which lie beneath Clay Till 1, do exhibit a degree of overprediction bias. This behavior could be due to the presence of unmapped hydraulic windows in Clay Till 1, which are therefore not currently represented in the model; GW in the underlying silty units is conceptualized to be slightly over pressured because GW is attempting to discharge upwards through these unmapped hydraulic windows and cannot. Future work to further improve these results could involve additional characterization of Clay Till 1, additional characterization of the PGKM and silty sand deposits making up the core of the FHUC, or manually creating additional hydraulic windows in the Clay Till 1 aquitard within the model to relieve the simulated pressure buildup in the underlying units (a trial-and-error process); and,
2. The 2020 MLWC HGS model is a regional-scale simulator that was designed and parameterized using a zoned hydrostratigraphic approach. Each defined (subsurface) zone in the model corresponds to a specific hydrostratigraphic unit in the model and each of those zones were parametrized using uniform sets of hydraulic properties. This procedure implicitly assumes that the hydrogeological properties in each hydrostratigraphic unit are homogeneous, whereas it is certain these units contain a degree of heterogeneity not currently represented in the model. A potential avenue of exploration would be to introduce a higher degree of heterogeneity into the model to see whether an appreciable improvement in simulated heads could be gained. However, there exists a trade off between added resolution of heterogeneity (including

increased FEM refinement) and maintaining a tractable model run time. Therefore, it may not be a practical solution for a regional scale HGS model, such as the 2020 MLWC HGS model.

3. The simulated AET for the aspen stands in the FHUC is underpredicted (data not shown), based on values reported in comparable settings and discussed in Devito et al. (2017). As such, there is likely an overprediction of recharge occurring in this area of the model. Additional work on parameterizing the transpiration process in the FHUC for aspen dominated areas has the potential to reduce recharge and thereby reduce the overprediction of groundwater heads in the hydrostratigraphic units underlying the FHUC.

A plan view map of the spatial distribution of the calibration residuals is illustrated in Figure 4-10. More details on the observed versus simulated GW levels are available in Attachment D and Attachment F.

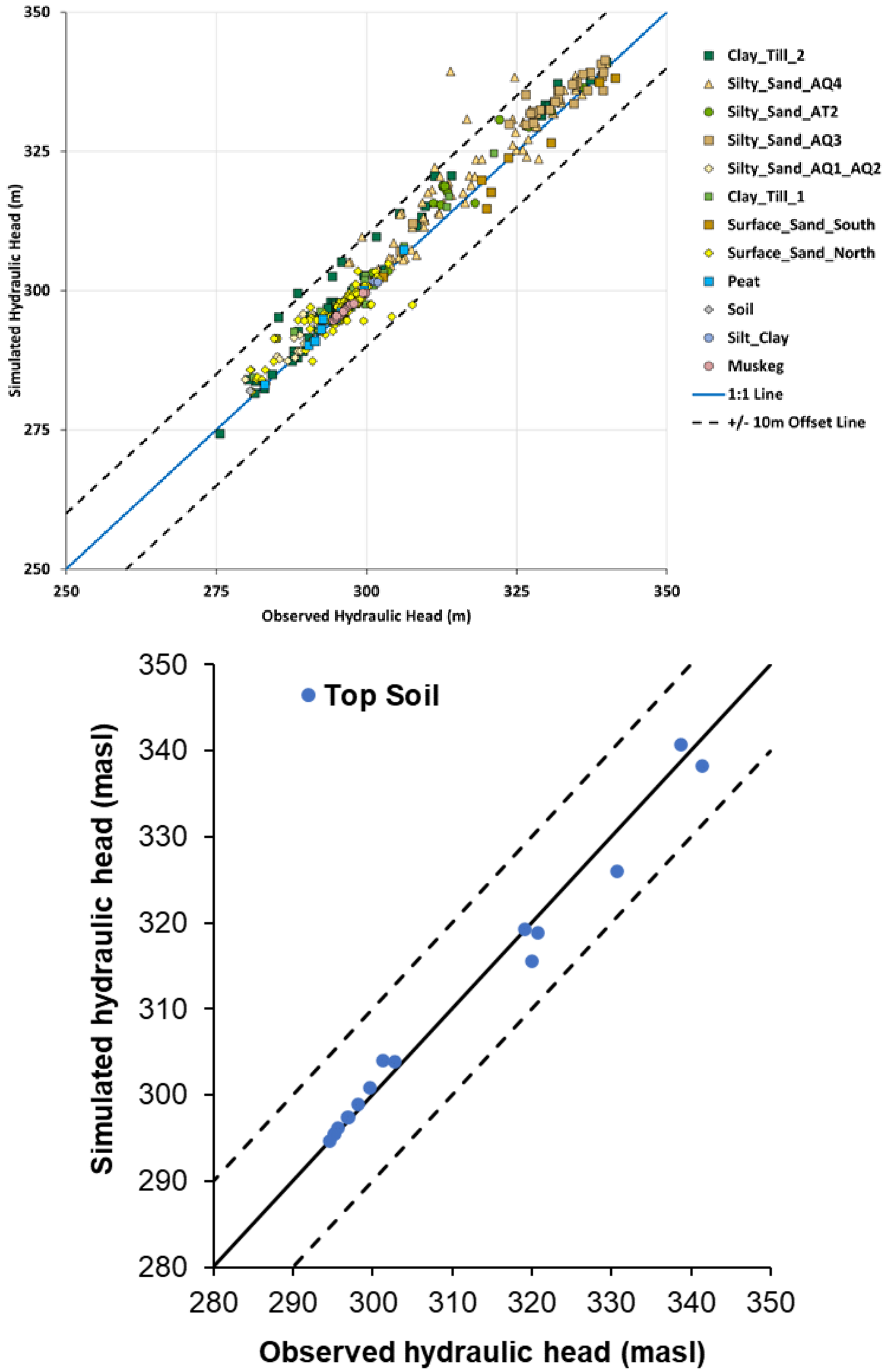


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model.

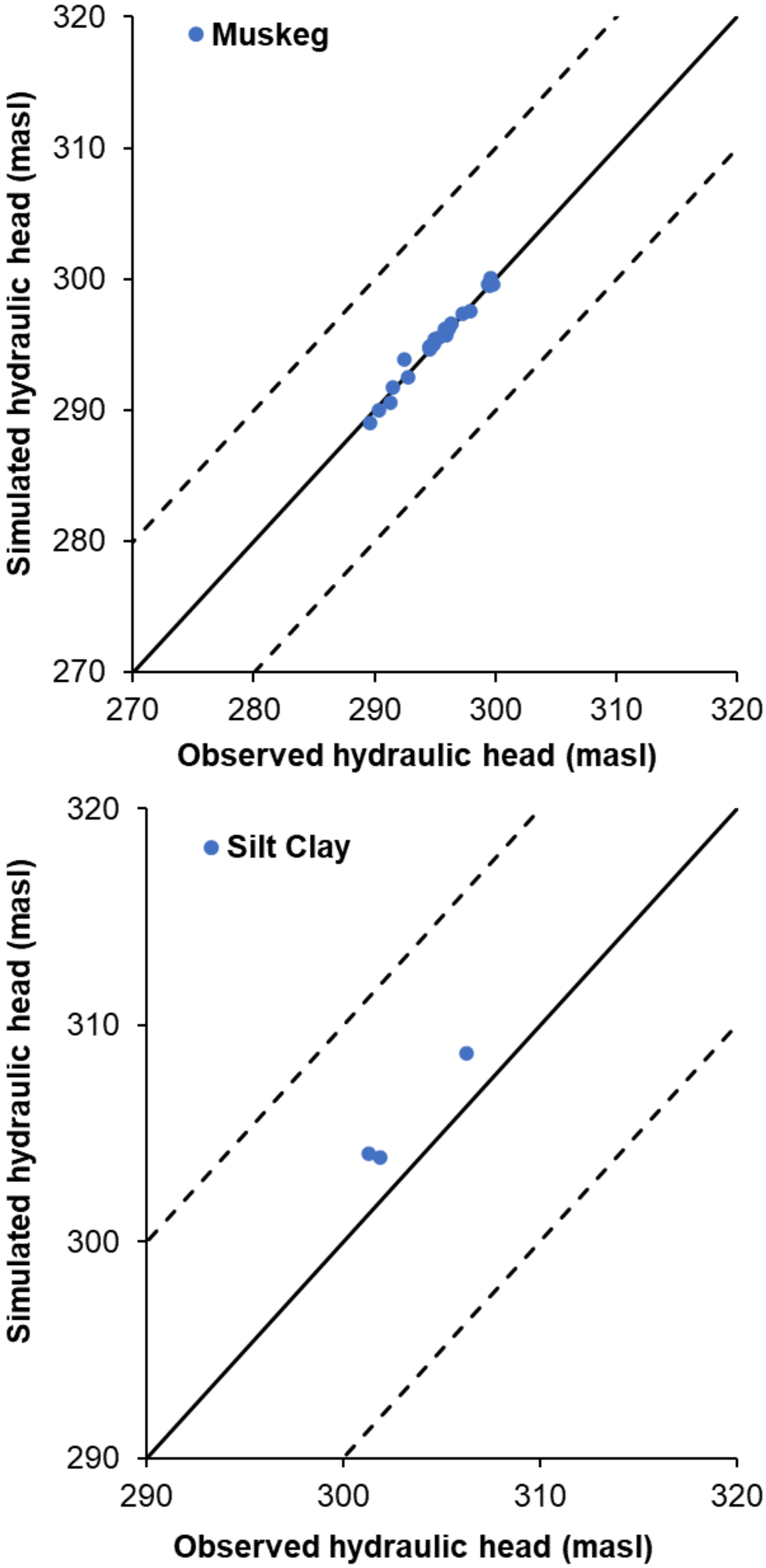
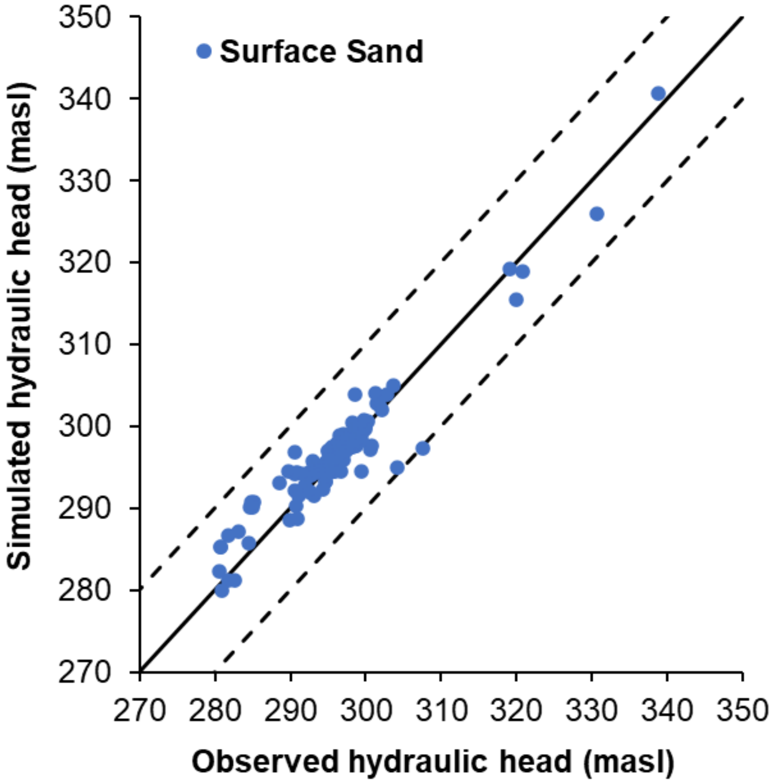


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model. (cont.'d)



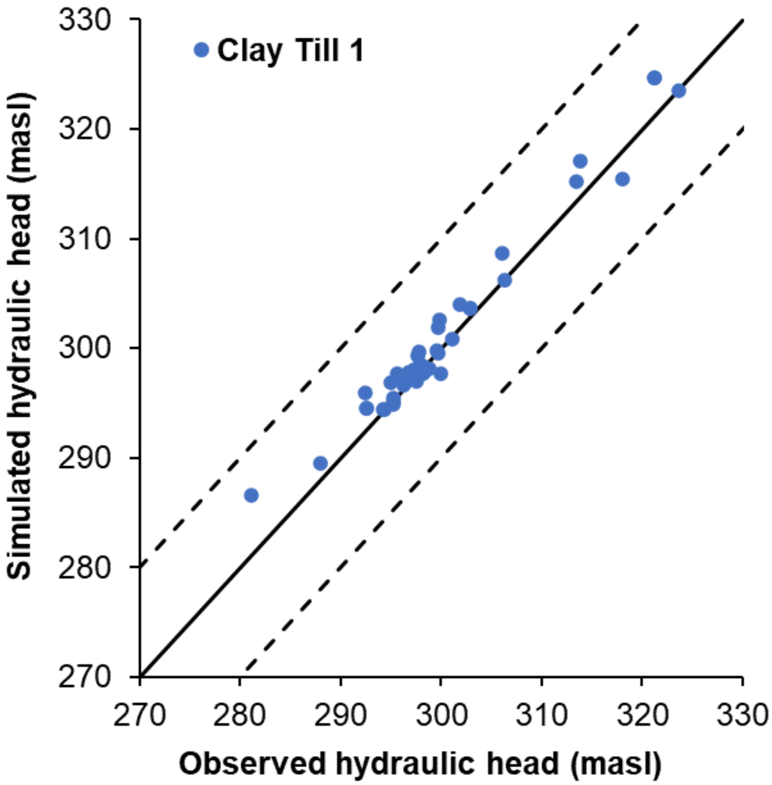


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model. (cont.'d)

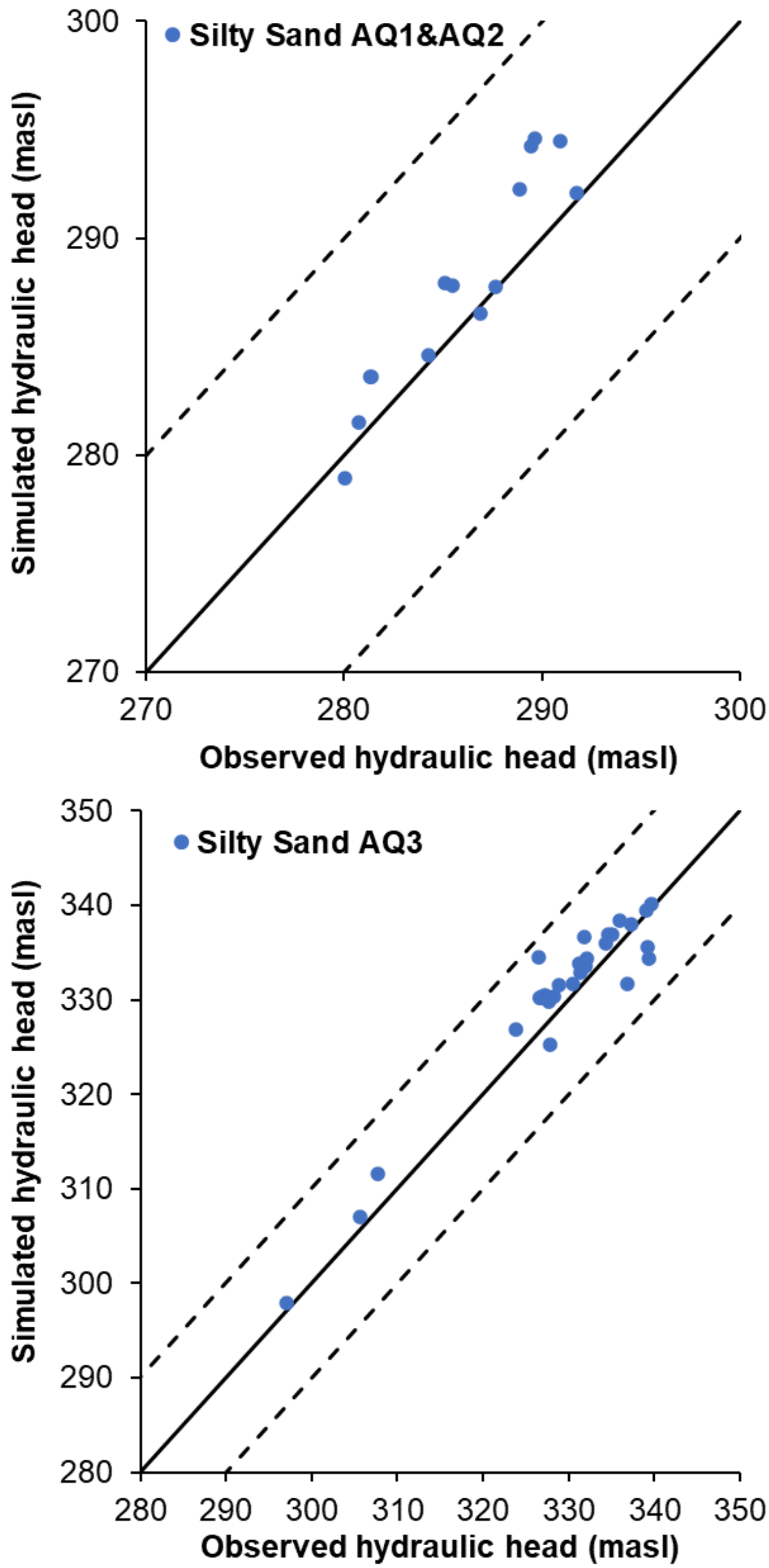
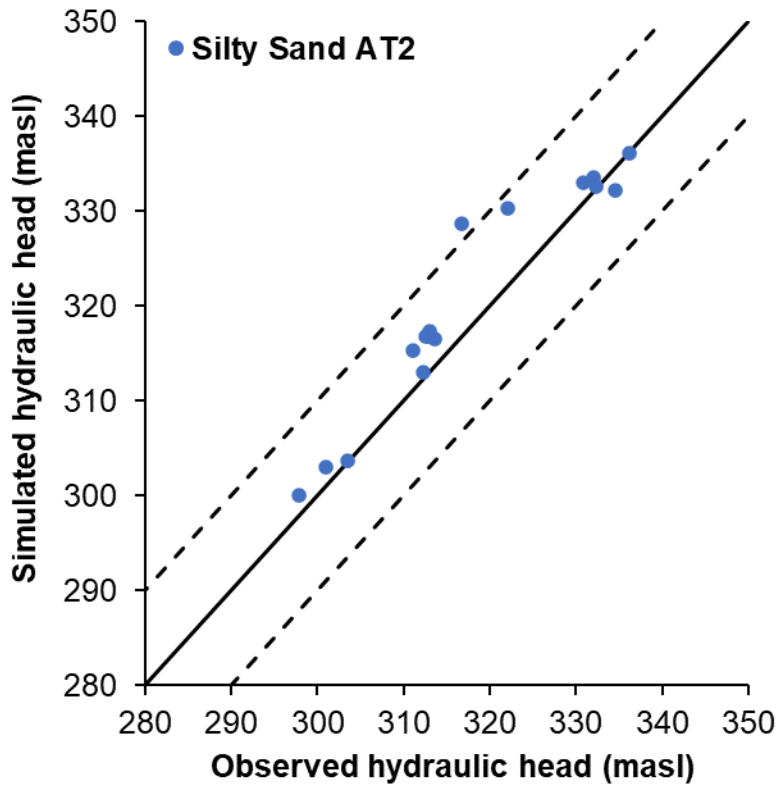


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model. (cont.'d)



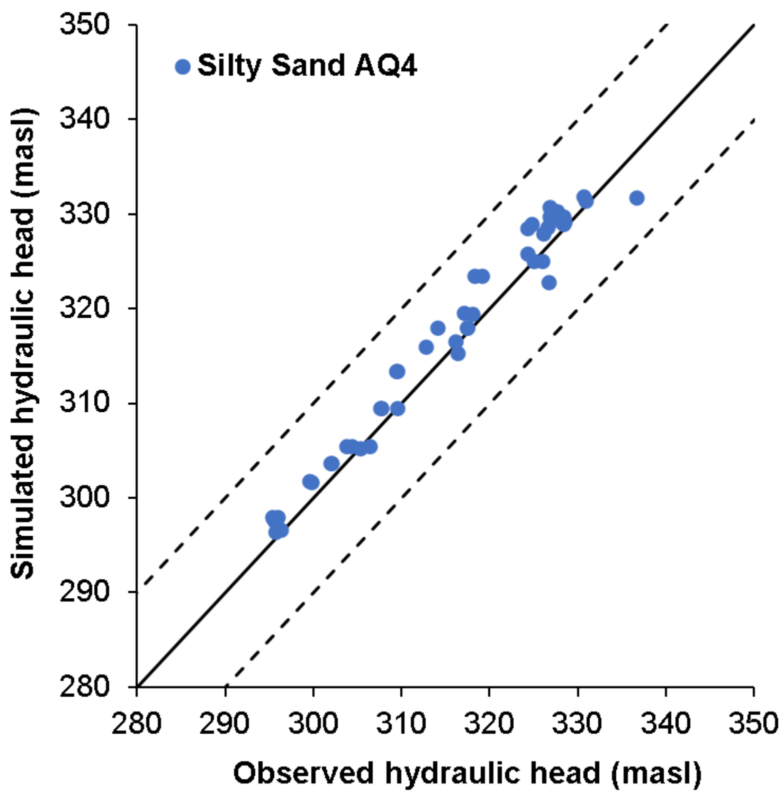
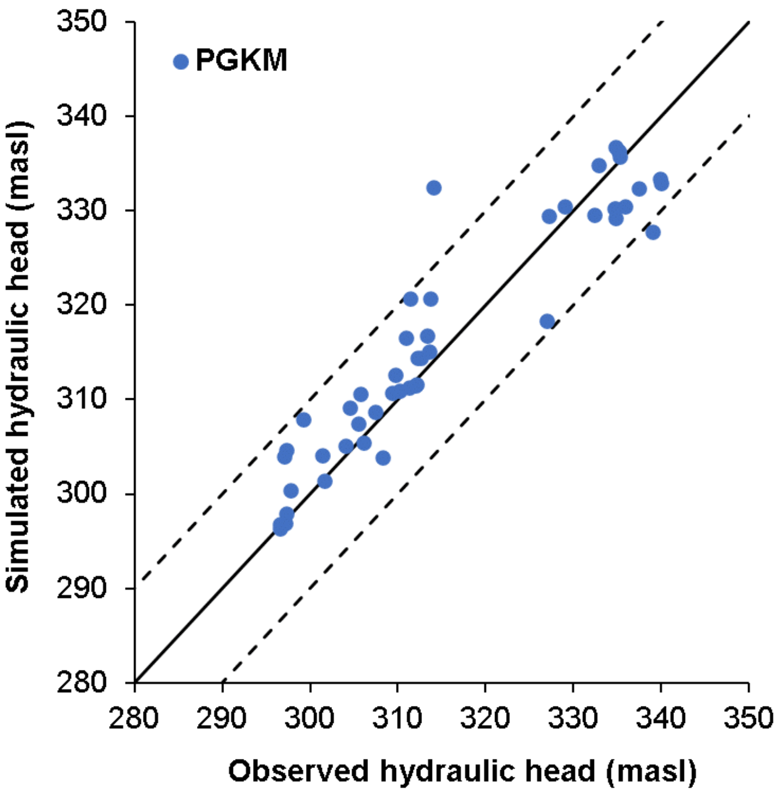


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model. (cont.'d)



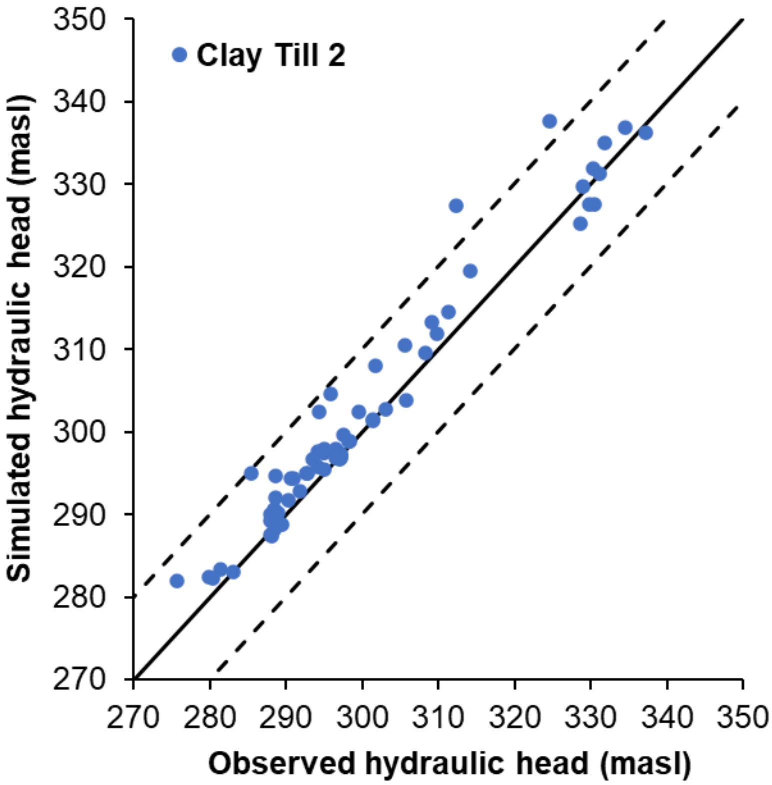


Figure 4-9: Composite scatterplot of the computed versus observed long-term GW levels used in the calibration of the model. (cont.'d)

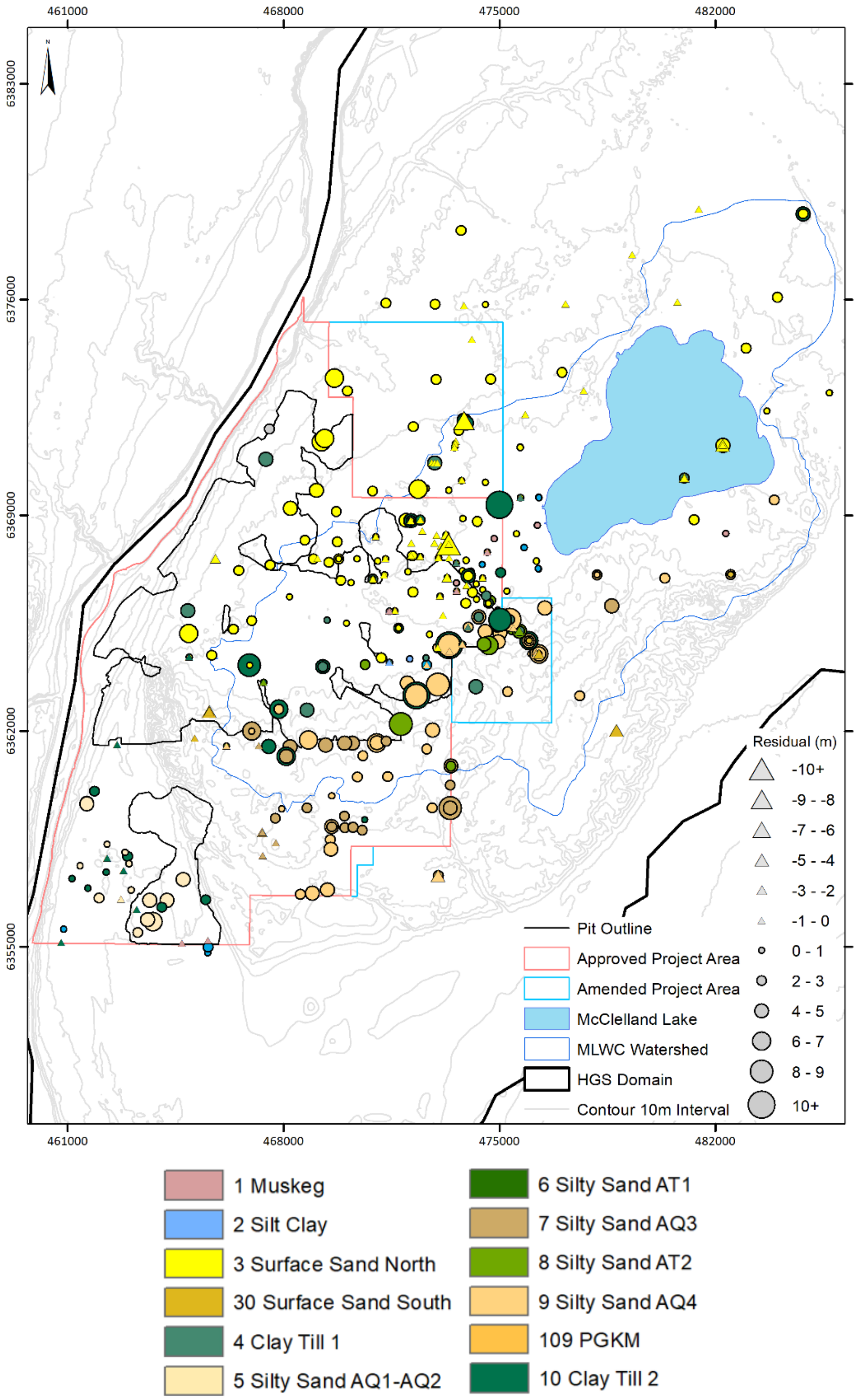


Figure 4-10: Plan view of the average GW level calibration residuals.

Table 4-4 presents the simulated and observed McClelland Lake levels and residual of each targeted lake level obtained from the automated calibration. Figure 4-11 presents simulated lake level time series and compares it to the observed time series. The results show a good match between the simulated and observed values.

Table 4-4. McClelland Lake observed vs. simulated levels from the automated calibration.

Date	Observed Level (mASL)	Simulated Level (mASL)	Residual (m)
1-Jul-1997	294.68	294.74	-0.06
20-Oct-1997	294.77	294.76	0.01
23-May-1998	294.71	294.70	0.01
19-Oct-1998	294.31	294.40	-0.09
23-May-1999	294.43	294.50	-0.07
11-Oct-1999	294.22	294.32	-0.10
7-Jul-2000	294.49	294.45	0.04
5-Nov-2000	294.51	294.55	-0.04
20-Jul-2001	294.54	294.51	0.03
18-Oct-2001	294.38	294.45	-0.07
30-Apr-2002	294.43	294.51	-0.08
2-Jul-2002	294.33	294.55	-0.22
30-Aug-2002	294.43	294.57	-0.14
4-Jun-2003	294.61	294.69	-0.08
20-Sep-2003	294.43	294.56	-0.13
6-May-2004	294.58	294.81	-0.23
4-Sep-2004	294.33	294.50	-0.17
23-Jun-2005	294.58	294.54	0.04
12-Sep-2005	294.60	294.55	0.05
16-Nov-2005	294.55	294.55	0.00
3-May-2006	294.64	294.64	0.00
3-Jul-2006	294.52	294.47	0.05
11-Aug-2006	294.60	294.43	0.17
5-Apr-2007	294.56	294.39	0.17
22-Mar-2008	294.59	294.21	0.38
13-May-2008	294.68	294.31	0.37
1-Aug-2008	294.54	294.10	0.44
30-Apr-2009	294.64	294.55	0.09
6-Jul-2009	294.70	294.48	0.22
14-Oct-2009	294.57	294.48	0.09
24-Apr-2010	294.65	294.61	0.04
22-Aug-2010	294.45	294.35	0.10
10-Nov-2010	294.47	294.40	0.07
28-Dec-2010	294.48	294.41	0.07
13-May-2011	294.57	294.52	0.05
30-Sep-2011	294.32	294.27	0.05
18-Feb-2012	294.32	294.30	0.02
25-Apr-2012	294.39	294.42	-0.03
23-Aug-2012	294.14	294.24	-0.10
15-Dec-2012	294.29	294.47	-0.17
22-May-2013	294.44	294.62	-0.18
4-Jul-2013	294.58	294.63	-0.05
19-Sep-2013	294.48	294.47	0.01
28-Oct-2013	294.53	294.52	0.01
31-Jan-2014	294.60	294.55	0.05
1-Apr-2014	294.61	294.56	0.05

Date	Observed Level (mASL)	Simulated Level (mASL)	Residual (m)
8-Jun-2014	294.78	294.70	0.08
17-Sep-2014	294.59	294.49	0.10
3-Jan-2016	294.43	294.42	0.01
1-Apr-2016	294.49	294.43	0.06
5-Jul-2016	294.55	294.37	0.18
23-Aug-2016	294.43	294.35	0.08
8-Oct-2016	294.47	294.52	-0.05
24-Mar-2017	294.57	294.64	-0.07
20-May-2017	294.63	294.62	0.01
14-Sep-2017	294.32	294.30	0.02

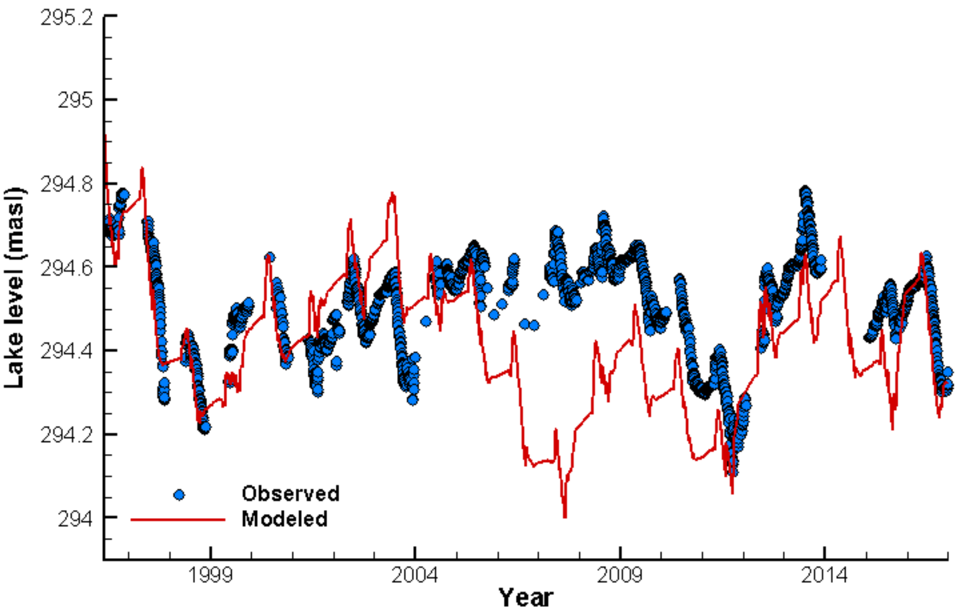


Figure 4-11: Computed McClelland Lake levels versus observed levels in the calibration period. Note: See Figure 6-8 for simulated lake level results produced using Bitumont precipitation data for the 2004 to 2010 period.

The simulated lake level deviates from the observed lake level to a larger degree between approximately 2005 to 2009. This discrepancy is attributed to the recorded precipitation at Environment Canada's (ECCC) Fort McMurray Airport meteorological station not capturing one or more local storms (e.g., localized convective storms) which occurred in the vicinity the Fort Hills Lease and McClelland Lake but not at the Fort McMurray airport meteorological station. A future improvement to the model could look at correcting this mismatch by spinning up the model using historical Fort McMurray airport meteorological data (to imbue the system with hydrologic memory) and then switching over to local meteorological data during the last several years of the simulation (at the point in time where complete/reliable local meteorological data are available). Further details on this issue are discussed in Section 6.2.5, with respect to model uncertainty attributable to climate data.

Table 4-5 presents the simulated and targeted AET rates of the selected ET zones in the MLWC model, which shows a good match between simulated values and targeted AETs. The largest error is in the Unnamed Lake zone, which is ~4%. AET of the lowlands in MLWC including the fen and McClelland Lake are nearly matched identically with ~0.5% difference.

Table 4-5: Simulated AET vs. targeted AET.

AET zone	Targeted AET (mm/y)	Simulated AET (mm/y)	Residual (mm/y)
Fen	412	410	2
McClelland Lake	591	588	3
FHUC	321	309	12
Unnamed Lake	321	308	13
NOP West	197	207	-10
NOP North	197	200	-3

Summary statistics of the subsurface automated calibration results were produced using the following standard statistical metrics:

- $Max\ E = max|C_i - O_i|_{i=1}^{N}$
- $Min\ E = min|C_i - O_i|_{i=1}^{N}$
- $MRE = \frac{1}{N}\sum_{i=1}^{N}(C_i - O_i)$
- $MARE = \frac{1}{N}\sum_{i=1}^{N}|C_i - O_i|$
- $RMSE = \left[\frac{1}{N}\sum_{i=1}^{N}(C_i - O_i)^2\right]^{0.5}$
- $R^2 = \frac{\left(\sum_{i=1}^{N}(C_i-\bar{C})(O_i-\bar{O})\right)^2}{\sum_{i=1}^{N}(C_i-\bar{C})^2\sum_{i=1}^{N}(O_i-\bar{O})^2}$

where *N* is the total number of observations, *C* is the calculated value, $\bar{C}$ is the mean of the calculated values, *O* is the observed (target) value, $\bar{O}$ is the mean of the observed values, *Max E* is the maximum residual error, *Min E* is the minimum residual error, *MRE* is the mean residual error, *MARE* is the mean absolute residual error, *RMSE* is the root mean squared residual error; and R^2 is the goodness-of-fit. The summary statistics for the Quaternary GW level targets are presented in Table 4-6. Units of *Max E*, *Min E*, *MRE*, *MARE*, and *RMSE* for the GW levels are in meters. R^2 is dimensionless.

The *Max E* between simulated GW levels and targeted ones in Quaternary units is 25.44 m with an *MARE* of 2.01 m. The *MRE* is 1.56 m, which shows the model to be very slightly overpredicting the observed GW levels. R^2 of the GW heads are 0.97, showing a good correlation between simulated and observed GW levels.

Table 4-6: Summary calibration statistics for Quaternary GW.

Assessment criteria	Quaternary GW level targets
Max E	25.44
Min E	0.00
MRE	1.56
MARE	2.01
RMSE	3.20
R^2	0.97

Figure 4-7 presents the initial and calibrated values of each parameter considered during the automated calibration process, along with the normalized composite sensitivity for each parameter. Descriptions of each of the parameters is given in Table 4-3. The results in Table 4-7 indicate that the HmaxPeat (maximum evaporative limiting pressure head for the peat) is the most sensitive parameter in the model. Other relatively sensitive parameters in the model are primarily related to ET parameters assigned to the peat and forested landcovers (e.g., C1_Frst) and the horizontal hydraulic conductivity of Surface Sand North hydrostratigraphic unit (KhSSN). The results also indicate that the final calibrated parameter values all fall within defined ranges set for each of the calibrated model parameters.

Table 4-7: Starting and calibrated values, lower and upper bounds, and normalized composite sensitivity values of the calibration parameters.

Parameter	Initial Estimate	Lower bound	Upper Bound	Final Value	Units	Normalized Composite Sensitivity
C2_Peat	5.24E-02	5.00E-02	3.00E-01	5.24E-02	-	1.4E-02
E_d_Peat	5.10E-02	1.60E-01	5.10E-01	1.70E-01	-	4.0E-03
HminPeat	2.27E-01	-8.00E-01	-2.00E-01	-2.10E-01	m	3.6E-03
HmaxPeat	6.33E-03	-1.90E-01	-1.00E-03	-3.86E-03	m	6.2E-01
Hol_Peat	9.38E-02	-3.50E-01	-1.50E-01	-1.60E-01	m	3.7E-03
Hal_Peat	2.42E-01	-1.40E-01	-1.00E-03	-2.51E-03	m	6.4E-02
C1_Shrb	1.70E-01	1.00E-02	4.00E-01	2.42E-01	-	7.4E-03
C2_Shrb	2.10E-01	5.00E-02	4.00E-01	2.27E-01	-	5.6E-03
HminShrb	3.86E-03	-1.50E+00	-7.00E-01	-1.43E+00	m	4.7E-04
HmaxShrb	1.60E-01	-6.90E-01	-1.00E-02	-6.80E-01	m	1.7E-03
C1_Frst	2.51E-03	1.00E-02	2.50E-01	9.38E-02	-	5.6E-02
C2_Frst	1.49E+00	5.00E-02	3.00E-01	5.10E-02	-	2.8E-02
HminFrst	5.24E-01	-1.50E+00	-7.00E-01	-1.49E+00	m	2.1E-03
HmaxFrst	1.43E+00	-6.90E-01	-1.00E-02	-5.24E-01	m	1.1E-02
C2_Water	6.80E-01	1.00E-04	3.00E-01	6.33E-03	-	6.1E-02
KhPeatU	3.47E-04	1.16E-04	1.16E-03	2.31E-04	m/s	1.9E-03
AR_Peat	1.06E-01	5.00E-02	5.00E-01	1.00E-01	-	1.8E-03

Parameter	Initial Estimate	Lower bound	Upper Bound	Final Value	Units	Normalized Composite Sensitivity
KhSSN	2.00E-04	5.00E-06	5.00E-04	3.47E-04	m/s	1.6E-02
AR_SSN	5.55E-01	1.00E-02	1.00E+00	1.06E-01	-	1.5E-03
KhSSS	2.31E-04	5.00E-06	5.00E-04	2.00E-04	m/s	2.5E-03
AR_SSS	1.00E-01	1.00E-02	1.00E+00	5.55E-01	-	1.2E-03
KhTill	1.35E-07	1.00E-08	1.00E-06	1.35E-07	m/s	1.7E-03
AR_Till	2.58E-01	1.00E-02	1.00E+00	2.58E-01	-	1.6E-03
KhSiC	4.24E-08	1.00E-08	1.00E-06	4.24E-08	m/s	1.5E-03
AR_SiC	2.28E-02	1.00E-02	1.00E+00	2.28E-02	-	2.2E-03
KhSiS	1.73E-06	1.00E-07	1.00E-05	1.73E-06	m/s	1.6E-03
AR_SiS	6.48E-02	1.00E-02	1.00E+00	6.48E-02	-	1.8E-03
Kh_PGKM	1.53E-07	1.00E-07	1.00E-05	1.53E-07	m/s	1.9E-03
AR_PGKM	1.10E-02	1.00E-02	1.00E+00	1.10E-02	-	1.8E-03
KhSiS_AQ4	2.00E-05	9.95E-08	1.00E-04	2.00E-05	m/s	1.7E-03
AR_SiS_AQ4	1.00E-01	1.00E-02	1.00E+00	1.00E-01	-	1.4E-03
KhSiS_AQ3	1.05E-04	1.00E-06	5.00E-04	1.05E-04	m/s	2.5E-03
AR_SiS_AQ3	1.89E-02	1.00E-02	1.00E+00	1.89E-02	-	1.8E-03
KhSiS_AT1	1.65E-06	1.00E-08	1.00E-05	1.65E-06	m/s	1.9E-03
AR_SiS_AT1	1.10E-02	1.00E-02	1.00E+00	1.10E-02	-	1.6E-03
KhSiS_AT2	3.56E-07	1.00E-08	1.00E-05	3.56E-07	m/s	1.4E-03
AR_SiS_AT2	1.38E-02	1.00E-02	1.00E+00	1.38E-02	-	1.8E-03
Frc_Pat	2.25E-02	2.20E-02	1.50E-01	2.25E-02	$s/m^{1/3}$	1.7E-03
Ril_Pat	3.00E-02	2.00E-02	1.00E-01	3.00E-02	m	2.9E-02
Frc_Non_Pat	2.25E-02	2.20E-02	1.50E-01	2.25E-02	$s/m^{1/3}$	1.9E-03
Ril_Non_Pat	1.00E-02	5.00E-03	1.00E-01	1.00E-02	m	2.8E-02
stg_dis_cnst	2.04E+03	1.16E+01	1.16E+04	2.04E+03	m^3/s	2.0E-03
min_flw_dpth	3.32E-02	1.00E-03	1.00E+00	3.32E-02	m	1.5E-03
stg_dis_pwer	4.83E+00	1.00E+00	1.00E+01	4.83E+00	-	7.6E-04

4.3 Testing Basal targets and Basal pumping tests

Based on the automated calibration results presented in Section 4.2, the overall simulated versus calibration-target fit achieved with the 2020 MLWC HGS model was judged satisfactory in the truncated Calibration Model. To investigate the effect of the deeper hydrostratigraphy, below the Quaternary, on the model results, the deeper hydrostratigraphic units were added back into the Calibration Model. The deeper units (Cretaceous and Devonian) were subsequently parameterized using the previously calibrated hydraulic conductivity and storage properties extracted from the Fort Hills FEFLOW model discussed in Section 3.6.2. The full model was then spun up and run once again with 1945 to 2019 climate forcing. The 79 GW heads for the calibration targets established for the deeper GW units were then checked against the head simulated by the 2020 MLWC HGS model containing the entire hydrostratigraphic sequence down the Keg River Formation. As can be seen in Figure 4-12, the Cretaceous and Devonian GW levels simulated by the 2020 MLWC HGS model using the imported calibrated hydraulic conductivities of the FEFLOW model discussed in Section 3.6.2 were able to achieve a modest fit. The remaining calibration targets were checked as well, and the achieved fits were very comparable to those achieved with the truncated model. A table providing details regarding the computed versus observed GW levels achieved during this process using the full 2020 MLWC HGS model is given in Attachment D.

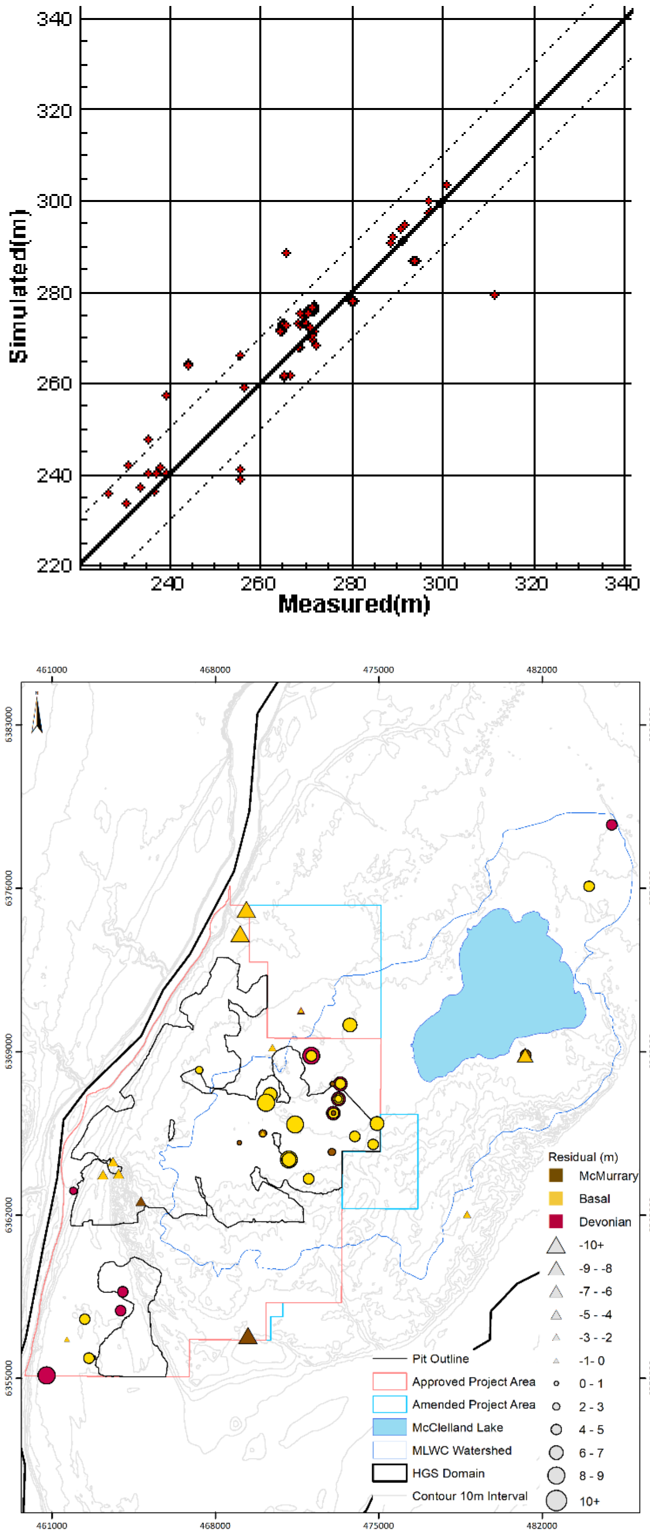


Figure 4-12: A cross-plot (top) and residual map (bottom) of the 2020 MLWC HGS model computed GW level data versus observed for the Cretaceous and Devonian Formations.

Table 4-8: Summary calibration statistics for the Basal and Devonian GW levels.

Assessment criteria	GW levels
Max E	32.03
Min E	0.16
MRE	2.99
MARE	5.87
RMSE	8.06
R^2	0.83

The imported parameterization of the deeper units was also tested by manually calibrating the model to three Basal McMurray Aquifer well tests (pumping), shown in Figure 4-13. For the Basal pumping tests, one test (FH17-WR421-MR2) was done in the basal units below MLWC fen, one test (FH19-ES565-MR2-PW) was in the vicinity of NOP, and one test (FH17-WR351-MR1) in the Centre Pit area (Table 4-9 and Table 4-10). Plots showing the observed versus simulated drawdowns obtained for Basal well tests are presented in Attachment H.

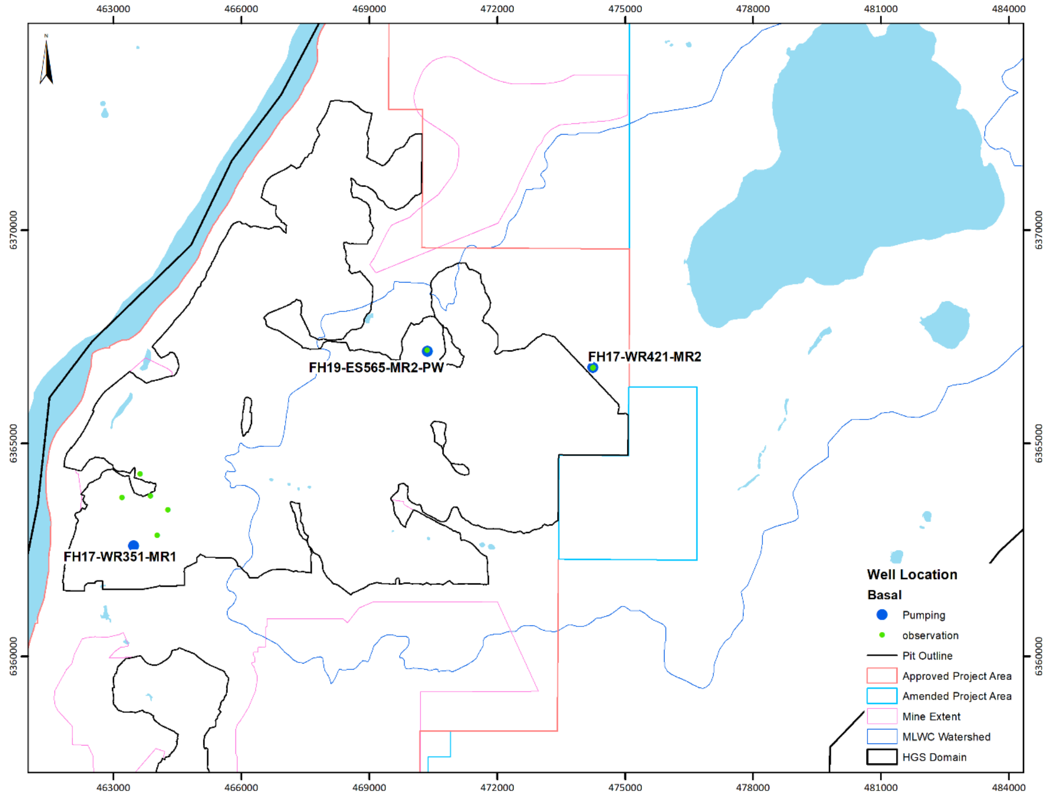


Figure 4-13: The location of Basal McMurray Aquifer well testing locations.

Table 4-9: Summary of well tests used to evaluate the 2020 MLWC HGS model in the Basal McMurray Aquifer.

Pumping Well ID	Pumping well Diameter (in.)	Observation well ID	Date of the test	Duration	Pumping Rate (m^3/day)
FH17-WR421-MR2	8	FH17-WR421-MR1-VWP-B FH17-WR421-MR1-VWP-C FH17-WR421-MR1-VWP-D FH17-WR421-SN1-VWP-A FH17-WR421-SN1-VWP-D	15-Feb-2018 to 25-Feb-2018	10 days	2,400
FH19-ES565-MR2-PW	8	FH19-GL565-MR1-VW	10-Mar-2019 to 13-Mar-2019	3 days	1,990
FH17-WR351-MR1	8	FH17-GL337-MR1 FH17-GL347-MR1 FH17-GL331-MR1 FH17-GL318-MR1 FH17-GL329-MR1	3-Mar-2017 to 6-Mar-2017	3 days	400

Table 4-10: Comparison of Basal McMurray Aquifer well testing calibration results.

Test Area	Pumping Well	Screened Hydrostratigraphic Unit	No. of Obs. Wells	Manually Calibrated *K* (m/s)	Manually Calibrated S_s (1/m)
Fen	FH17-WR421-MR2	Basal- CW 40	5	1.21E-04	1.00E-07
NOP	FH19-ES565-MR2-PW	Basal - CW 40	1	1.30E-04	8.00E-05
Centre Pit	FH17-WR351-MR1	Basal - UW 60	5	3.7E-05	1.00E-06

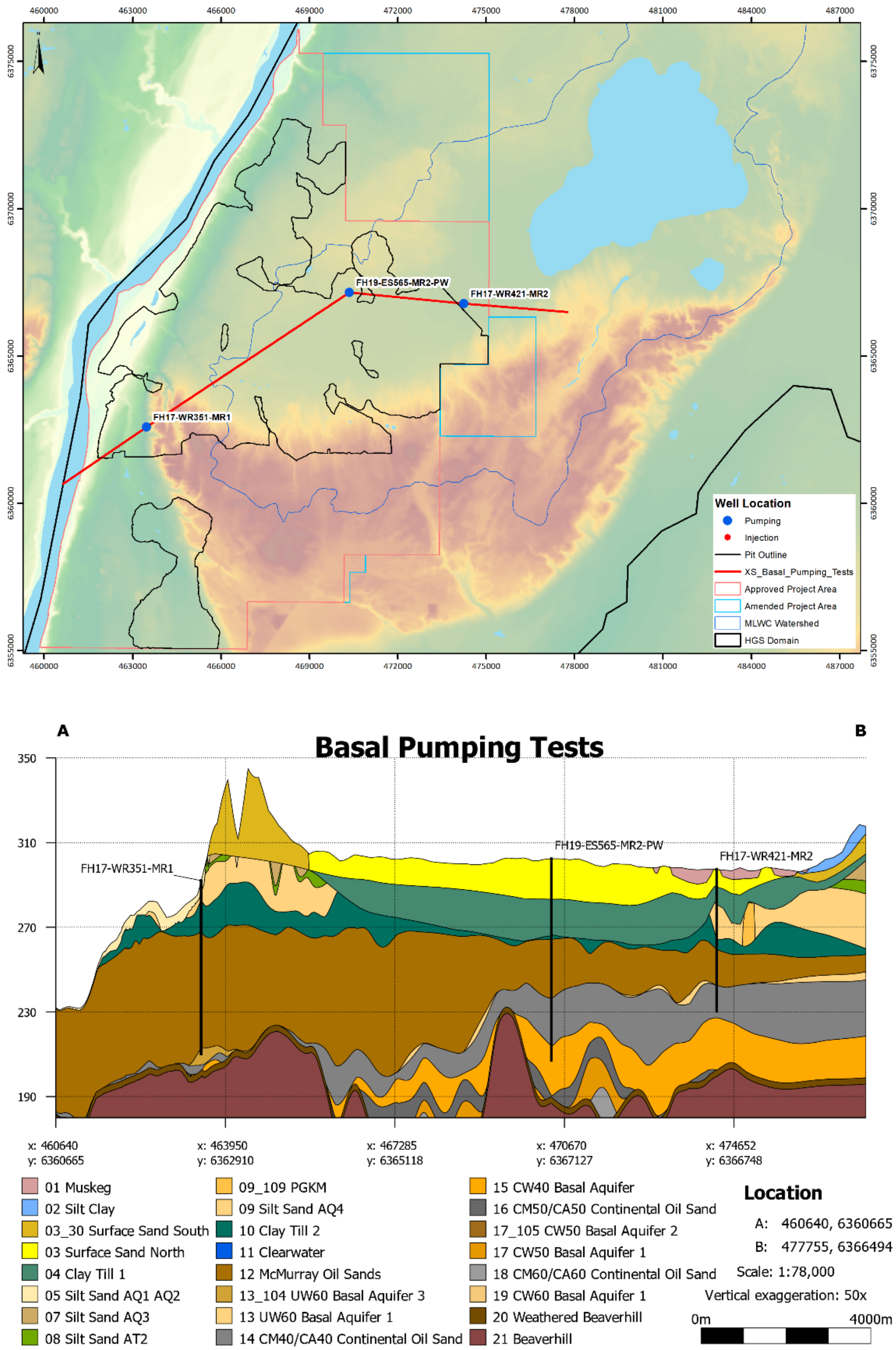


Figure 4-14: Cross-section along the Basal McMurray Aquifer well testing locations.

4.4 Quantitative Model Validation

Historical observations that were not used in the automatic calibration were used as part of model validation to evaluate the performance of the full thickness 2020 MLWC HGS model that contains all previously discussed Quaternary, Cretaceous and Devonian layers.

Vertical hydraulic gradients between the Quaternary aquifers and the Basal McMurray Aquifers determined from field data were compared to simulated vertical gradients computed by the 2020 MLWC HGS model. Vertical gradient data was not considered during the automated calibration process due to the exclusion of the deeper hydrostratigraphy from that process. The simulated vertical gradients were evaluated using the Baseline Model, which contains the deeper units (Cretaceous and Devonian), and therefore, could be used to evaluate the vertical gradients between Quaternary and Basal units. Figure 4-15 shows the comparison between the observed and simulated vertical gradients for 22 nested wells (nested vibrating wire piezometers) and shows that the 2020 MLWC HGS model captured the direction and magnitude of the gradients moderately well. Table 4-11 presents the pairs of the monitoring wells in the Basal and Quaternary units that were used to compute the vertical gradients illustrated in Figure 4-15.

Table 4-11: Pairs of Basal and Quaternary wells used to compute the vertical gradient.

Quaternary Well Name	Basal Well Name
FH17-WR401-SN1	FH17-WR401-MR1
FH17-WR402-SN2	FH17-WR402-MR1
FH17-WR403-SN1	FH17-WR403-MR1
FH17-WR404-SN2	FH17-WR404-MR1
FH17-WR405-SN1	FH17-WR405-MR1
FH17-WR406-SN1	FH17-WR406-MR1
FH17-WR409-SN1	FH17-WR409-MR1
FH17-WR421-SN1	FH17-WR421-MR1
FH17-WR441-SN1	FH17-WR441-MR1
FH17-WR445-SN1	FH17-WR445-MR1
FH17-WR446-SN1	FH17-WR446-MR1
FH17-WR450-SN1	FH17-WR450-MR1

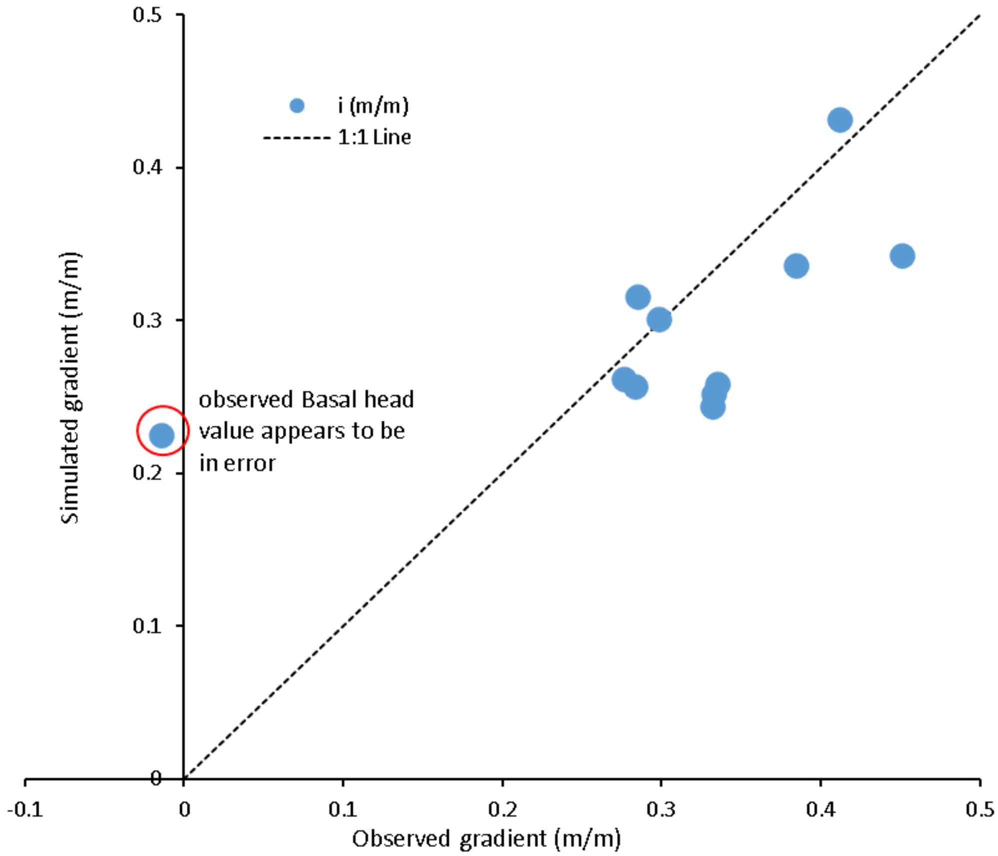


Figure 4-15. Simulated vs observed vertical gradients between the surficial sands and the Basal McMurray Aquifers in the 2020 MLWC HGS model.

McClelland Lake level data was available for the 1997 to 2019 period; however, model calibration used a subset of 20 years, up to mid-2017, leaving slightly more than two years of observed lake data for use in model validation. Figure 4-16 demonstrates the comparison between the modelled lake level and the observed data and exhibits a good visual match between them from 2017 to 2019, indicating the model can continue to simulate lake levels reasonably well beyond the calibration period (provided representative climate forcing data is driving the simulation).

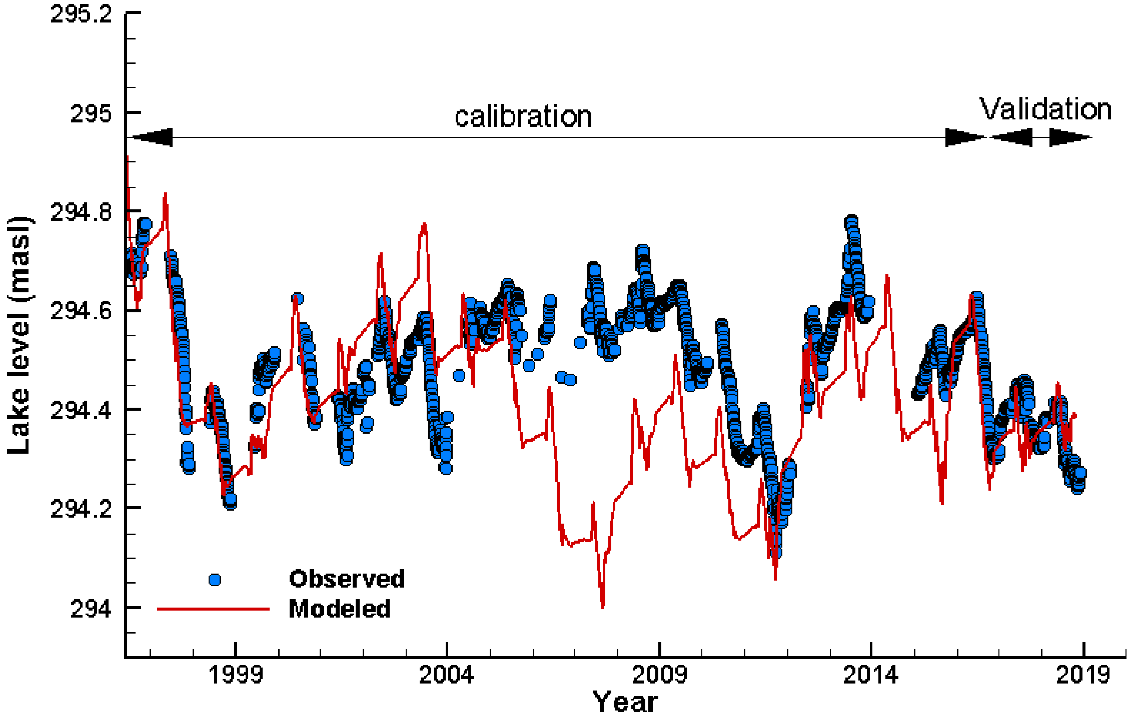


Figure 4-16. Computed McClelland Lake levels versus observed levels using the 2020 MLWC HGS model.

Figure 4-17shows the computed versus observed stage-discharge data at the outlet of McClelland Lake. Note that stage-discharge data were not considered during calibration. The observed data (blue circles in Figure 4-17) were used to validate the success of the calibration of the stage-discharge relation for McClelland Lake generated through automatic calibration. Figure 4-17 shows a very similar pattern between the observed stage discharge data and that obtained from calibration of the 2020 MLWC HGS model.

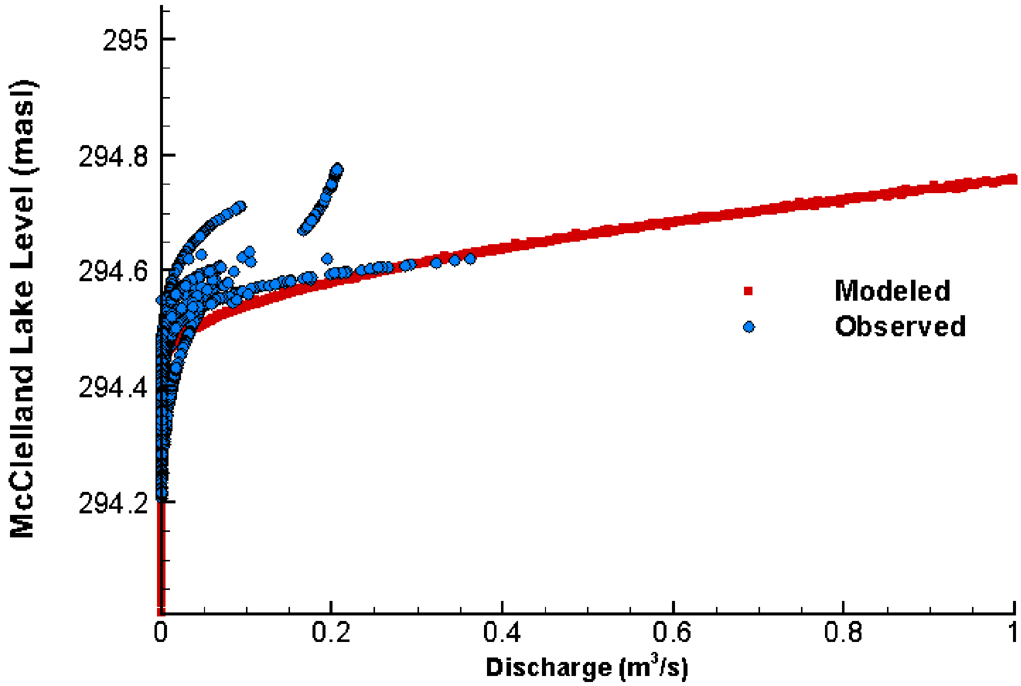


Figure 4-17: Simulated stage-discharge values using the 2020 MLWC HGS model versus the observed, for the open water season.

Gauged SW flows are a common calibration target used in hydrological modelling. For the Fort Hills Lease and surrounding area, the outlet from McClelland Lake represents a logical SW outflow monitoring point. Indeed, the outlet from McClelland Lake was monitored on a semi-regular basis between 1997 and 2005 by the Regional Aquatics Monitoring Program (RAMP) at the L1 gauge station location shown in Figure 4-1. Following 2006, McClelland Lake outflow monitoring was discontinued until 2018, when monitoring was re-initiated by FHEC in the McClelland Creek outlet channel (discharging from the lake), approximately 4 km downstream from the RAMP monitoring point (monitoring station STN6 shown in Figure 4-1). The lake outlet monitored by RAMP at the L1 station is a poorly defined channel through muskeg with known seepage bypassing the monitoring point, and previous hydrological assessments have deemed the gauged flow rates to be of questionable quality (Golder, 2018). Given the relatively small proportion of outflow from McClelland Lake (representing approximately 2% of the total incoming annual precipitation in the watershed) and the known uncertainty in the gauged flow rates from 1997 to 2005, the lake discharge data were not used during model calibration. However, these data can be used to qualitatively validate the model in terms of lake discharge rates and seasonal timing of those discharges.

As can be seen in Figure 4-18, the model is matching observed peak/trough discharge timing reasonably well but is also predicting a flashier rainfall-lake discharge response than is apparent in the observed data. This overprediction of the modelled discharge rates primarily coincides with spring freshet to early summer period and is thought, in part, to be related to the model settings dictating how hard and how long the ground freezes in the MLWC watershed. Updating these ground freezing settings in the model is a targeted future model improvement. Known uncertainty in the simulated lake outflow introduced by the regional versus local differences in climate forcing is also likely contributing factor to the peaks exhibited in the simulated discharge response. This latter topic is covered further in Section 6.2.5 in the discussion on model uncertainty. With respect to the observed data quality, it is worth noting that the data was generally recorded during the open water season and therefore large data gaps exist. Therefore, modelled flows that occur during data gaps in the observations cannot be validated or refuted. The observed flows are known to underestimate the true flows due to the inability of the flow gauging to capture diffuse outflow through the muskeg surrounding the outlet (Golder, 2018). Therefore, some degree of computed versus observed mismatch is expected. Overall, however the modelled lake discharge rates shown in Figure 4-18 demonstrate that the model generally captures the timing of flow events as well as no flow periods and is in general agreement with the magnitude of outflows from the lake outside of the freshet period. The observed discharge data in Figure 4-18 indicate an intermittent rainfall-runoff response at the lake outlet (consistent with the regional understanding of this setting as discussed in Devito et al., 2012) and the simulated response exhibits this behavior as well.

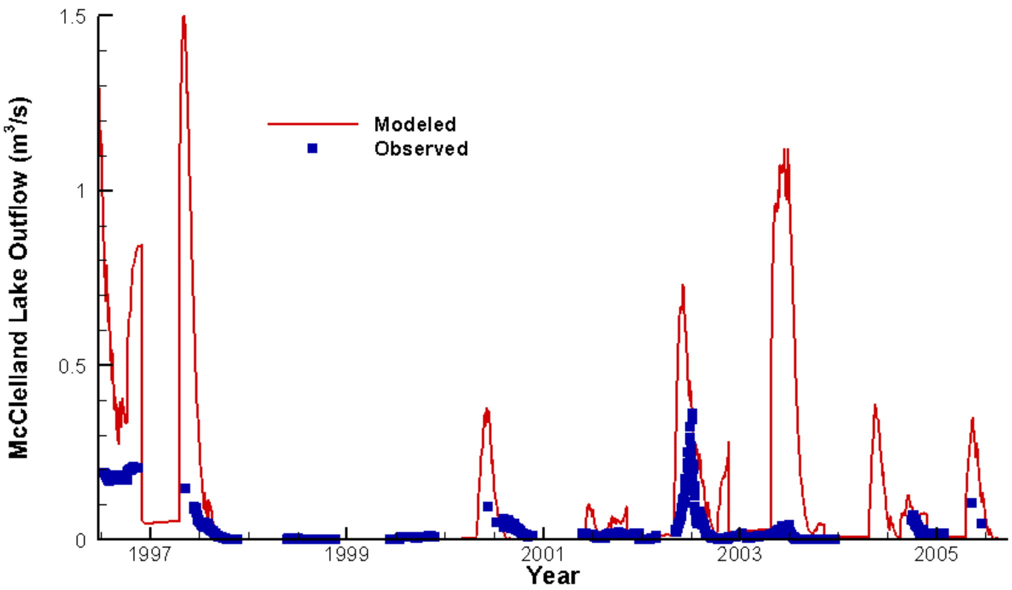


Figure 4-18: Measured and modelled outflowing rates of the McClelland Lake.

A limited amount of gauged streamflow data was also available for South Creek (STN 8, location shown in Figure 4-1). South Creek drains the eastern portion of the FHUC uplands into a wetland south of McClelland Lake (and subsequently discharges into the lake itself). The simulated versus observed streamflow at STN 8 are shown in Figure 4-19. The monitoring period covers 2018 to 2019 and the previously discussed uncertainties between the regional meteorological data driving the model and the local meteorological data precluded its use during calibration. As indicated on Figure 4-19, timings of the simulated peak flow events at STN 8 are in general agreement with the recorded data. However, the magnitude and duration of the simulated flow peaks are higher and shorter, respectively, than those observed. Moderate flow periods appear to be fit relatively well, although baseflow recession rates for the simulated hydrograph are too rapid and result in large periods of zero baseflow that are not as frequent or as prolonged in the observed data. However, a similar strategy to that described above for future improvements to modelled lake discharge data (spinning the model up with regional meteorology and calibrating with local) could also potentially be used to calibrate the model to the STN 8 stream gauge data in a future iteration of the MLWC HGS model (especially after more data have been collected). Similarly, improvements to the duration and degree of ground freezing in the model (affecting runoff) will likely also improve the simulated versus observed fit.

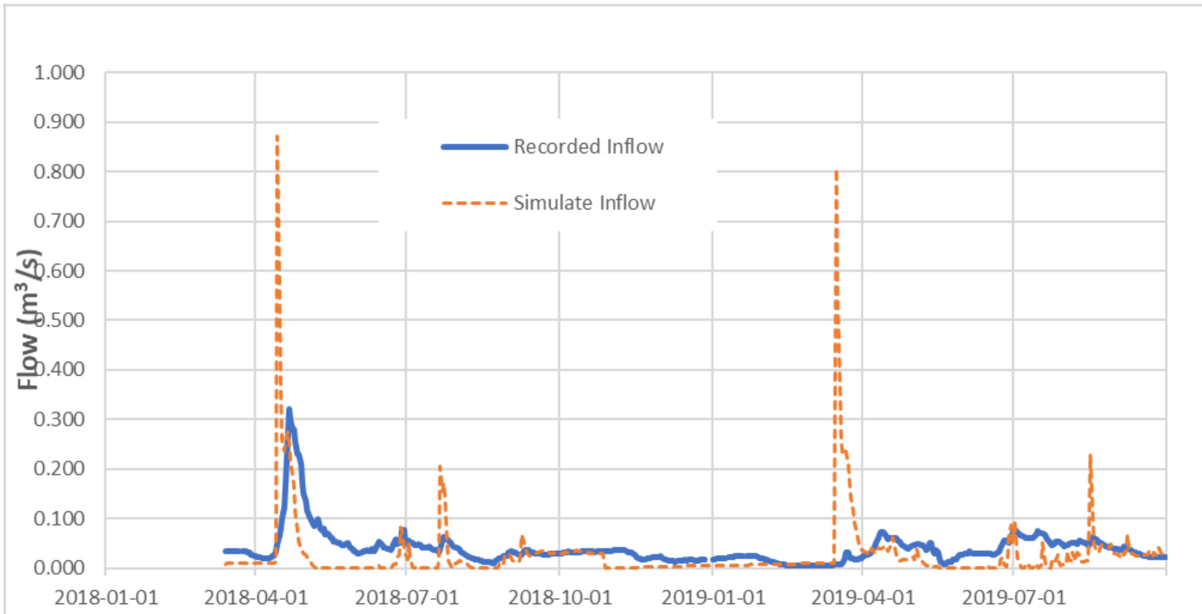
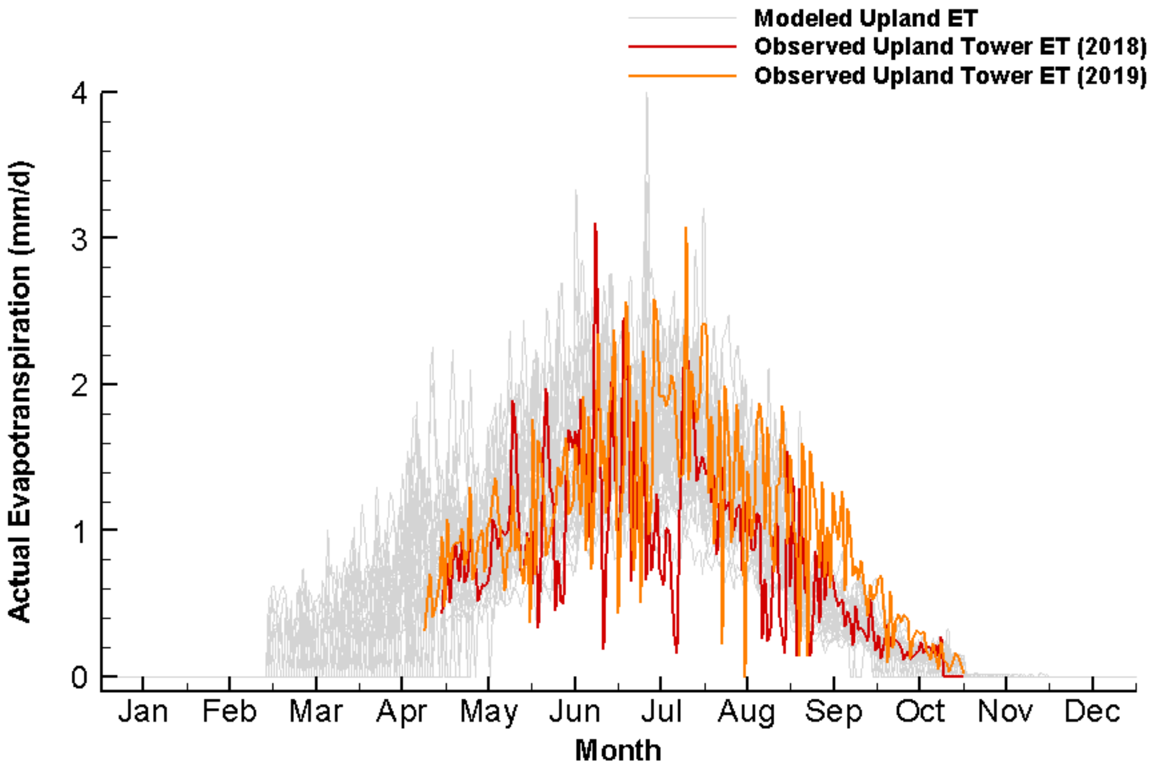


Figure 4-19: Observed and simulated discharge of South Creek.

AET data were also used for model validation. The AET time series data recorded at two ET flux tower (Figure 4-1) were recorded in 2018 and 2019, respectively. Stacks of intra-annual variations of simulated AET in the fen and NOP West are shown in comparison to observed ET time series in Figure 4-20. Observed ET was available for the growing season only and started in each April for the two years. Figure 4-20 indicates the 2020 MLWC HGS model was able to capture the seasonality, timing and magnitude of the observed AET data at these two locations quite well. The 2020 MLWC HGS model is driven with spatially uniform PET and through parameterization of the surface and subsurface and the internal soil moisture regime, the model can simulate the much lower observed AET at the NOP flux tower location, which is approximately half of that observed at the fen tower location in the fen. The physical basis for the lower AET in the NOP is relatively low SW availability (negligible) coupled with low soil moisture availability in the thick unsaturated surficial sands. In contrast the fen contains appreciable standing water and a very shallow water table depth, on the order of 10's of cm during dry periods and at or above surface during wet periods.



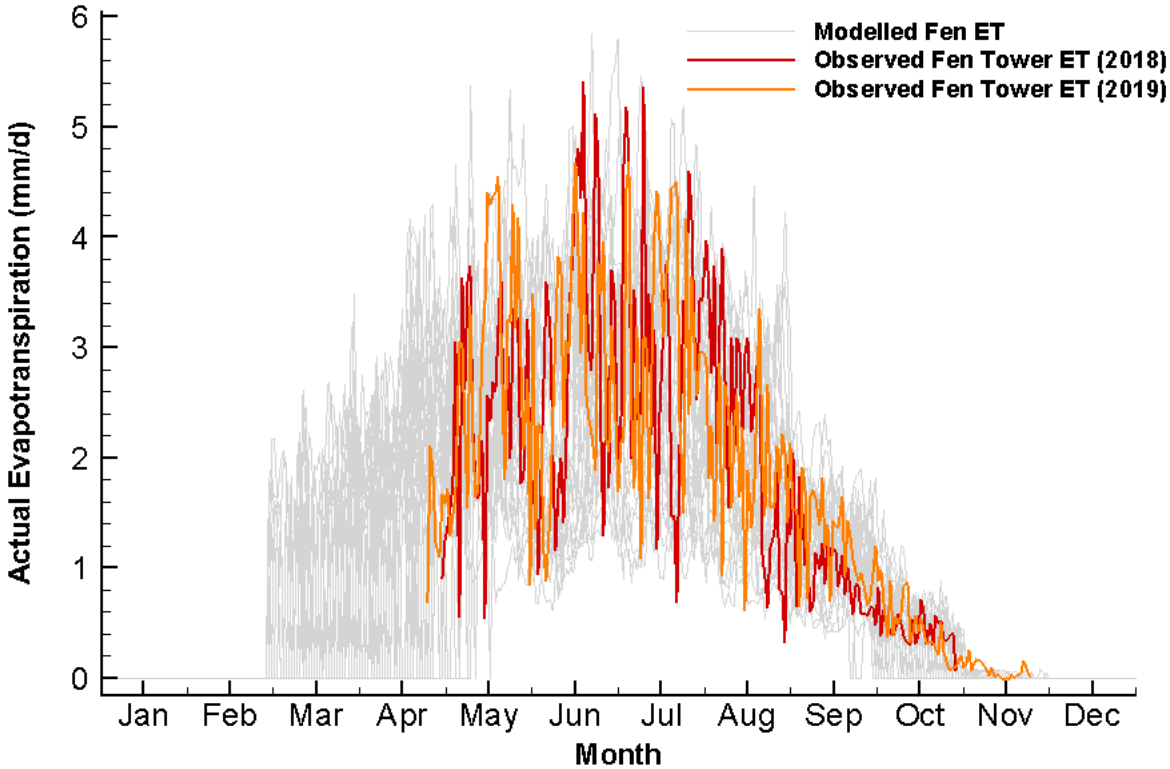
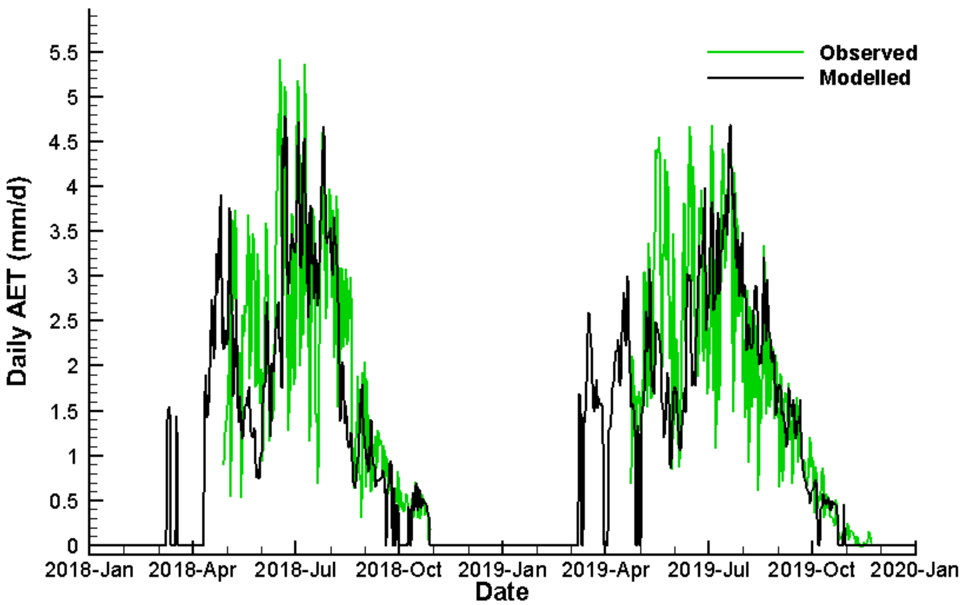


Figure 4-20: Observed AET from the ET flux towers compared to the modelled AET in forested upland and fen areas.

A more direct comparison between simulated and observed AET at the fen and NOP eddy covariance flux tower locations (Figure 4-21) confirms the quality of the match between the measured and the modelled data in timing and magnitude of daily AET values.



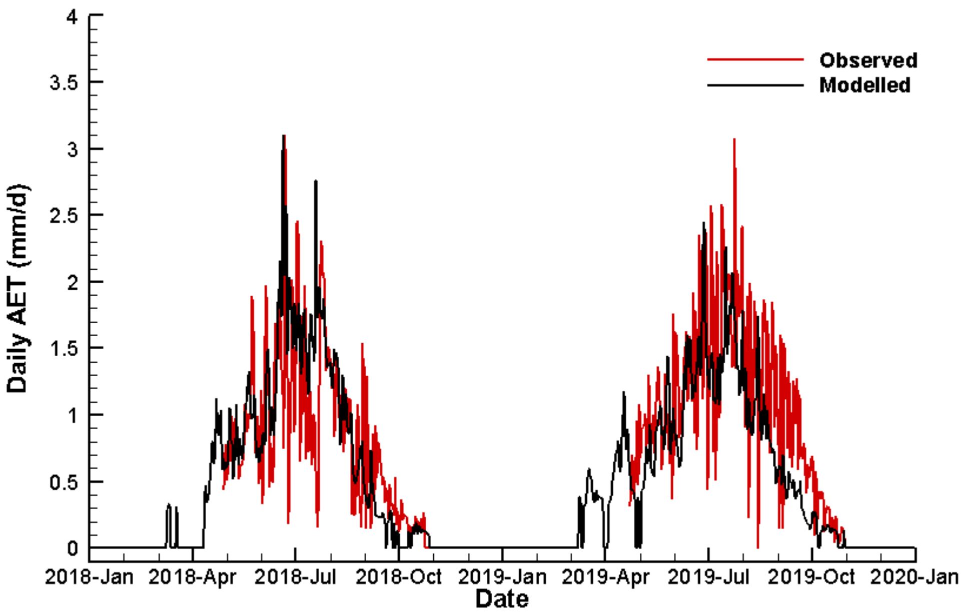


Figure 4-21: Observed AET from the eddy covariance flux towers versus modelled AET in the fen (top) and forested upland (bottom) during 2018 and 2019.

5.0 INTEGRATED HYDROLOGIC MODEL APPLICATION AND RESULTS

5.1 2020 MLWC HGS Baseline Model Results

5.1.1 Description of Scenarios Considered

One scenario was simulated using the 2020 MLWC HGS Baseline Model (model build described in Section 3.8): the historical period from 1945 to 2019, which was simulated using historical climate data from the ECCC Fort McMurray airport meteorological station. From 2000 to 2019, Basal McMurray Aquifer depressurization was being conducted at the Syncrude Aurora North Mine and was incorporated into the simulation as an internal boundary condition to account for impacts of depressurization activity within the Fort Hills Lease.

The primary objective in the application of the Baseline Model was to provide benchmark values for the GW and SW levels and fluxes across the MLWC and surrounding area. These benchmark values can be used as reference values in the assessment of hydrologic changes in other scenarios (e.g., during Operations or the Active Closure and Far-Future time periods).

5.1.2 Results

Simulated flow rates and levels for the non-mined portion of the MLWC fen area and the lake are presented in Figure 5-1, which summarizes the computed average GW fluxes through the Quaternary units into the edges of the non-mined portion of the fen. The figure indicates that the largest GW flux into the non-mined portion of the fen area occurs through the west side, where the NOP area delivers an average of approximately 2,890 m^3/d during the 75-year simulation.

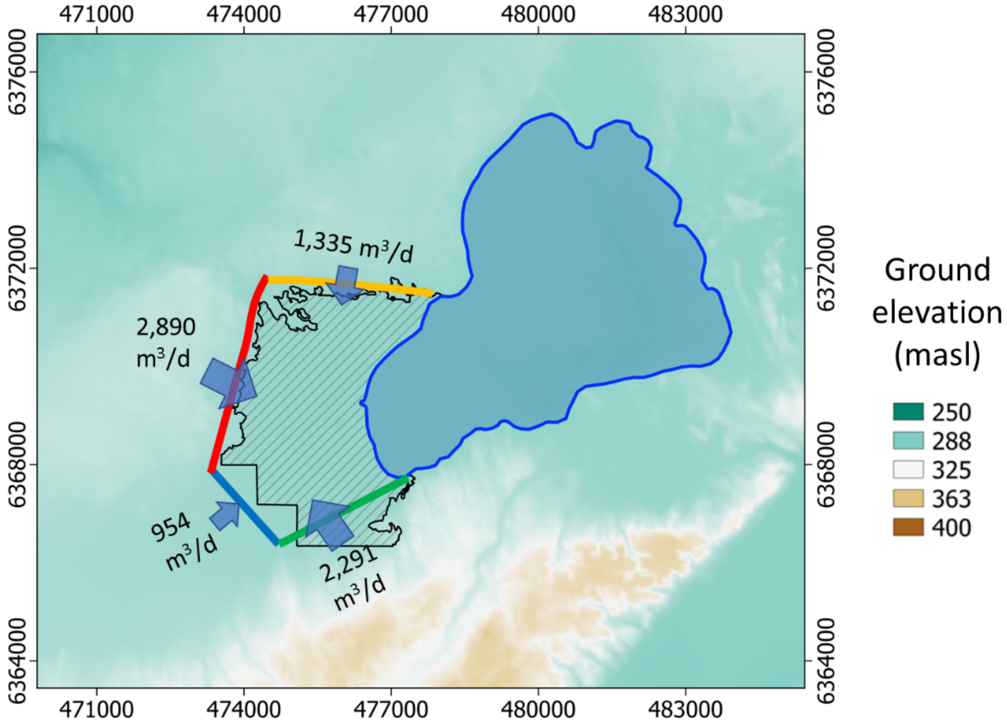


Figure 5-1: Simulated GW fluxes through the Quaternary units and into the non-mined portion of the MLWC using the Baseline Model.

Figure 5-2 shows the corresponding computed average surface runoff rates into or out of the non-mined portion of the fen through its boundaries. The largest inflows occur through the upgradient fen area into the non-mined portion of MLWC fen, at an average rate of approximately 12,000 m^3/d over the simulation period. SW leaves the non-mined portion of the fen into the lake at an average daily rate of approximately 20,000 m^3/d. These data computed using the Baseline Model were subsequently used as benchmark values to assess the hydrologic conditions of the Operations, Active Closure, and Far-Future scenarios.

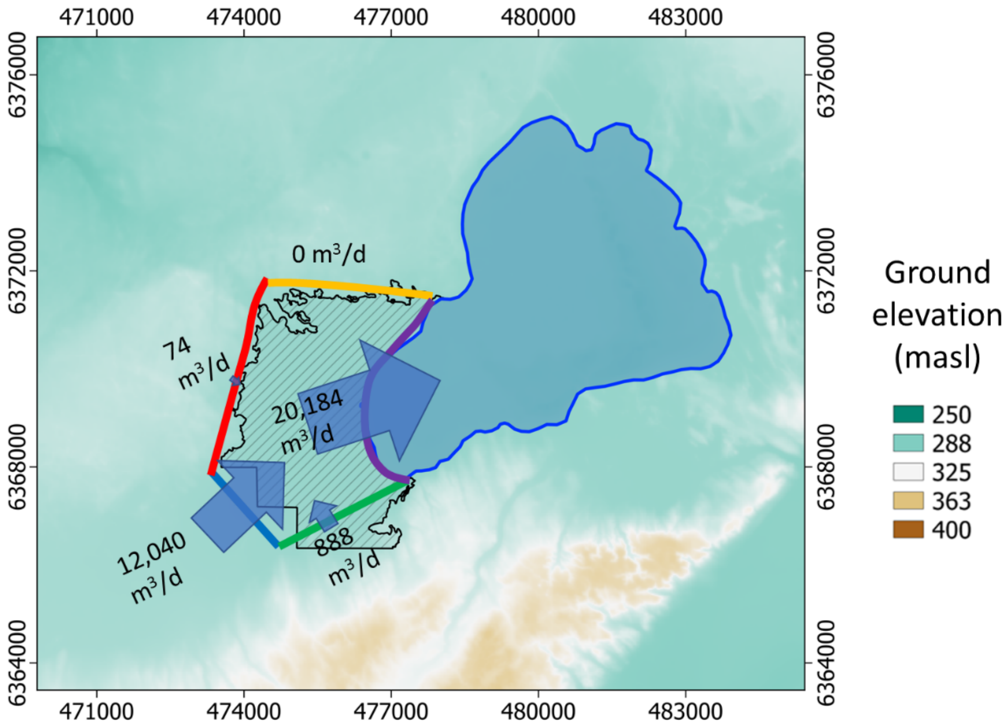


Figure 5-2: Simulated SW flows into and out of the non-mined portion of the fen using the Baseline Model.

The GW table in the non-mined portion of the MLWC fen area was monitored through a network of synthetic monitoring points in the HGS model. These synthetic monitoring points were added to the simulation to provide the average water table depth across the non-mined portion of the fen. Figure 5-3 shows the locations of these synthetic monitoring points, and their associated average water table depths for the period of the simulation. The results show that for most of the fen area, the average water table depth was either at or slightly above surface, or was 0 to 10 cm below ground surface, a typical range found in fen-type peatlands. The results shown in Figure 5-3 illustrate that the Baseline Model can simulate water table depths consistent with the expected conditions of a fen. Shallow water table depths are needed to sustain the non-mined portion of the fen's peat layer and to maintain anoxic conditions. Maintenance of a shallow water table in this area will also be required during the operations, active closure and far-future periods to ensure the viability of the non-mined portion of the fen.

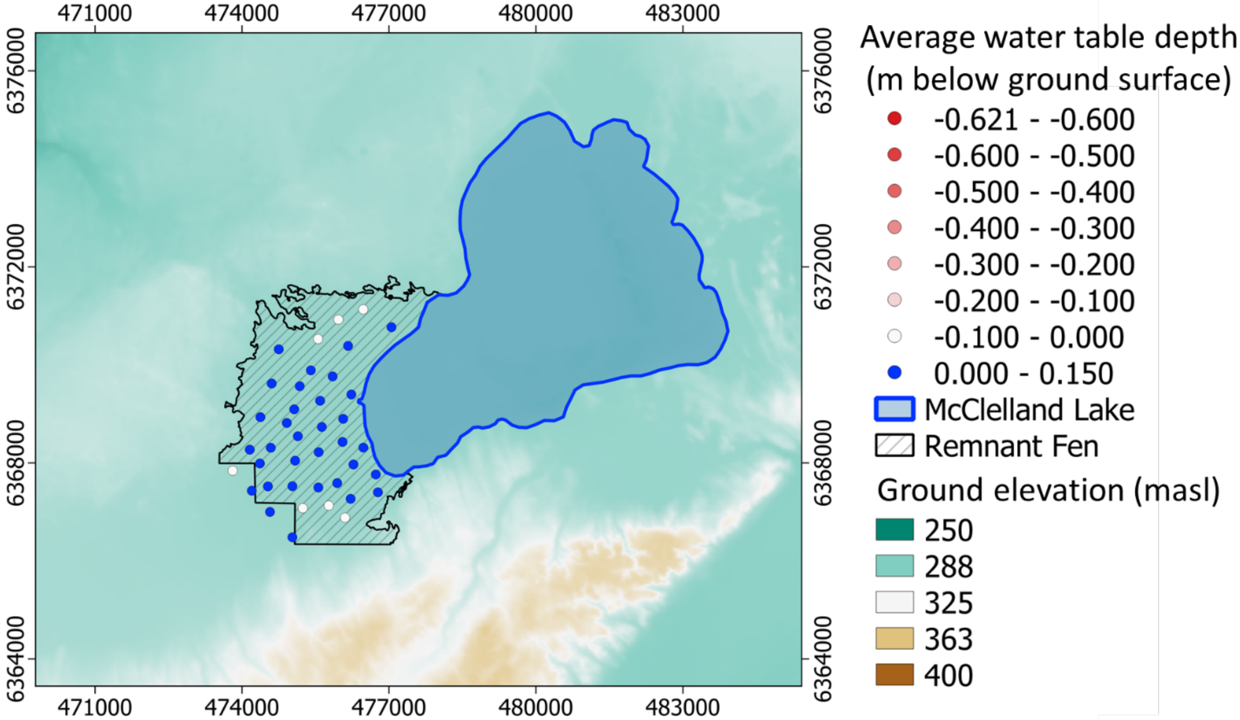


Figure 5-3: Simulated average depth to water table in the non-mined portion of the MLWC fen using the Baseline Model. Note: Negative values are below ground surface.

5.2 2020 MLWC HGS Mine Plan Operations Model Results

5.2.1 Description of Scenarios Considered

As discussed in Section 3.9, the effects of mining and water management design features on the hydrologic functioning of the MLWC was simulated using the 2020 MLWC HGS Mine Plan Operations Model (Operations Model) which shared the same mesh and surface and subsurface material distributions as the Baseline model. The principal modifications made to Operations Model (in contrast to the Baseline Model) consisted of the addition of key aspects of mine operations, including pit excavation, dump construction, and tailings area operations, and the water management design features to preserve the non-mined portion of the MLWC fen during development of the Fort Hills Project. The water management design features consist of a cutoff wall (to create a hydraulic barrier), fen SW resupply system, and GW injection wells located in the NOP, west of McClelland Lake (Figure 3-24). Given that mine operation features and the water management design features were built into the model at the meshing stage for the Baseline Model, the identical model mesh was also used for the Operations Model. The state of a mining features or water management design features being present in the model or 'turning on' in the model depended on the simulation scenarios, which are discussed below.

Three scenarios were simulated using the Operations Model:

1. **R0 scenario (no mining operations)**: no mining features or mining boundary conditions were applied to the model; only Syncrude Basal pumping was included as an internal boundary condition which ceases at 2025. The R0 scenario would be considered a best-case scenario,

where by the MLWC's hydrologic response (with the exception of Aurora North Basal depressurization) is controlled by natural conditions.

2. **R1 scenario:** This scenario was built upon the R0 scenario, and included the addition of mining features and mining internal boundary conditions to simulate the effects of mining on the MLWC; however, water management design features to mitigate drawdown effects on the non-mined portion of the MLWC were not included. The R1 scenario is considered a worst-case scenario, in that it simulates full development of the Fort Hills Project without any mitigations in place to sustain the functionality of the non-mined portion of the MLWC; and,
3. **S1 scenario:** This scenario was built upon the R1 and included the water management design features (the cutoff wall, fen SW resupply system, and GW injection wells in the NOP). The S1 scenario would be considered the mitigated scenario and is used to judge the effectiveness of the proposed water management design features to preserve the hydrologic condition of the non-mined portion of the MLWC fen

The simulated period from 2014 to 2063 was used for all three scenarios. In turn, these scenarios were used to assess the impact of the proposed mine operations and the effectiveness of the water management design features. Each 50-year simulation was driven using historical climate data from 1989 to 2013 using climate data recorded at the Fort McMurray meteorological station, repeated twice. The 1989 to 2013 period is considered representative of a recent, relatively dry climate period at the MLWC and judged a moderately conservative dataset to use in assessing the impact of development on the MLWC as well as the effectiveness of the proposed water management design features.

5.2.2 2020 MLWC HGS Operations Model Results

5.2.2.1 R1 Scenario – Water Levels in the Non-mined Portion of the Fen and McClelland Lake

R0-simulated water table elevations are shown for selected years in Figure 5-4; which provide the benchmark data to determine water table drawdowns during Fort Hills mine operations in the R1 scenario (mining without water management design features), shown in Figure 5-5. The panels in Figure 5-5 show the progression of simulated drawdown of the water table during mining operations calculated relative to the unimpacted R0 scenario. Thus, the general temporal behaviour of the drawdown associated with mine advance (dewatering and excavation) is communicated. The 2023 results in Figure 5-5 show water table drawdown associated with operations in South Pit, Centre Pit, and of a lesser magnitude due to OPTA, OPTA-East, and Syncrude Aurora North Pit. Drawdown under the footprint the NED, which is due to decreased recharge under the dump, appears in 2025 and increases in magnitude through 2030 and beyond. For the R1-scenario, drawdown associated with the North Pit advance, co-mingled with pre-existing drawdown associated with the presence of NED, reaches the western edge of the remnant fen (adjacent to the NOP) in the mid-2030's. The drawdown progressively increases in the remnant fen with maximum drawdown reached in mid-2050's. The distribution of drawdown in the fen is not uniform across the fen but is highest in the western portion of the fen and decreases in magnitude towards McClelland Lake.

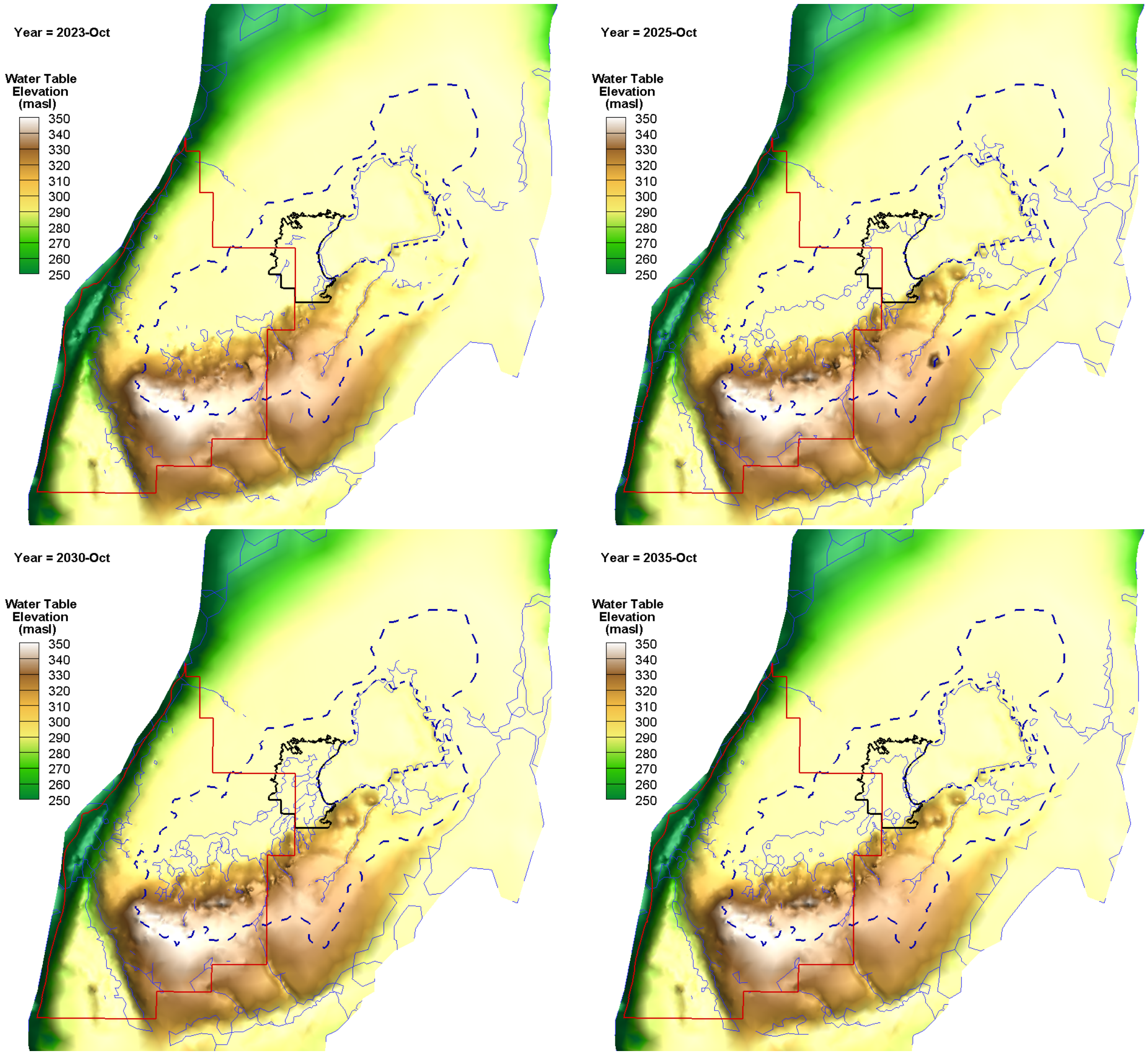


Figure 5-4: Water table elevations at selected times in the R0 scenario.

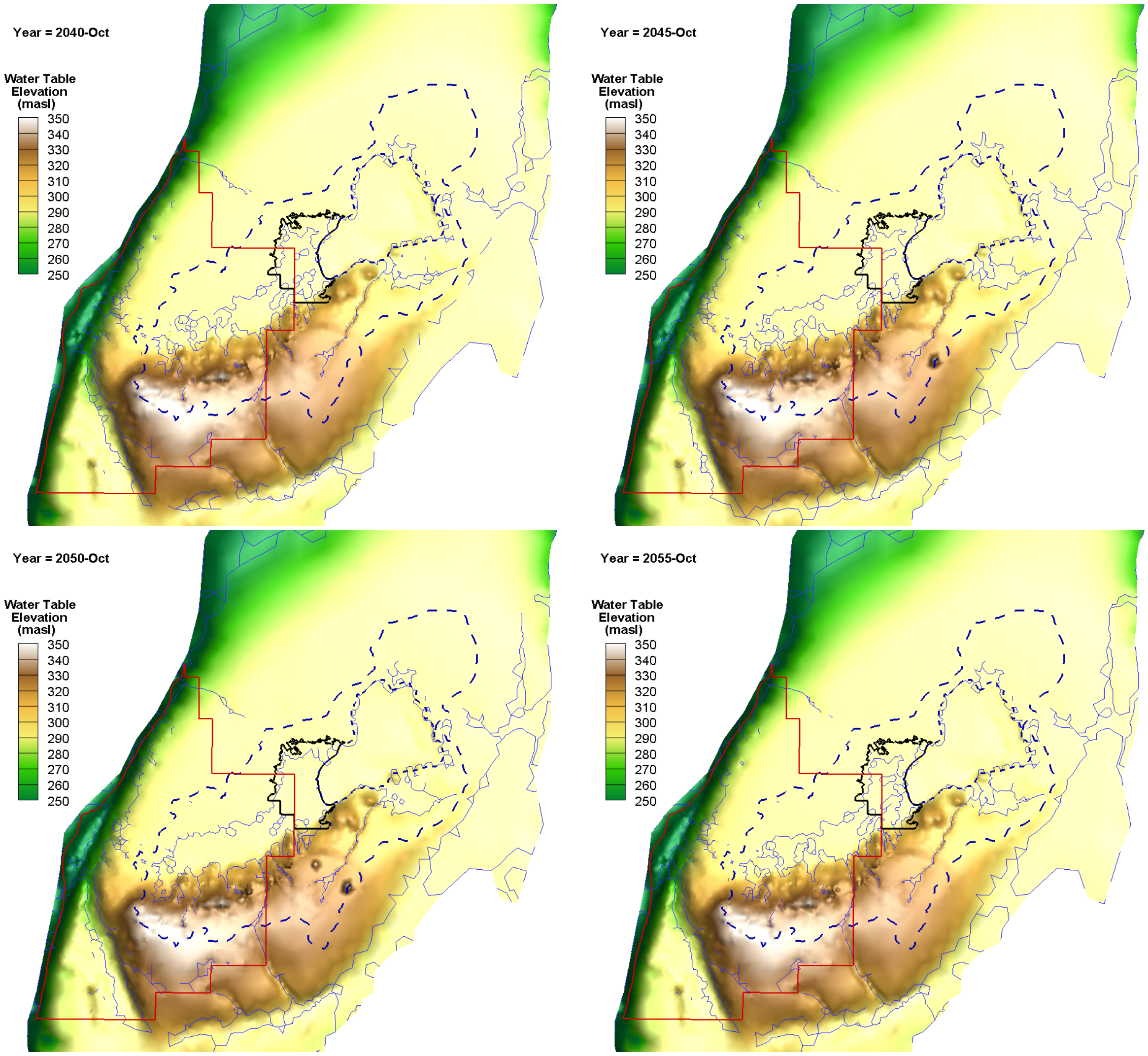


Figure 5-4: Water table elevations at selected times in the R0 scenario.(cont'd)

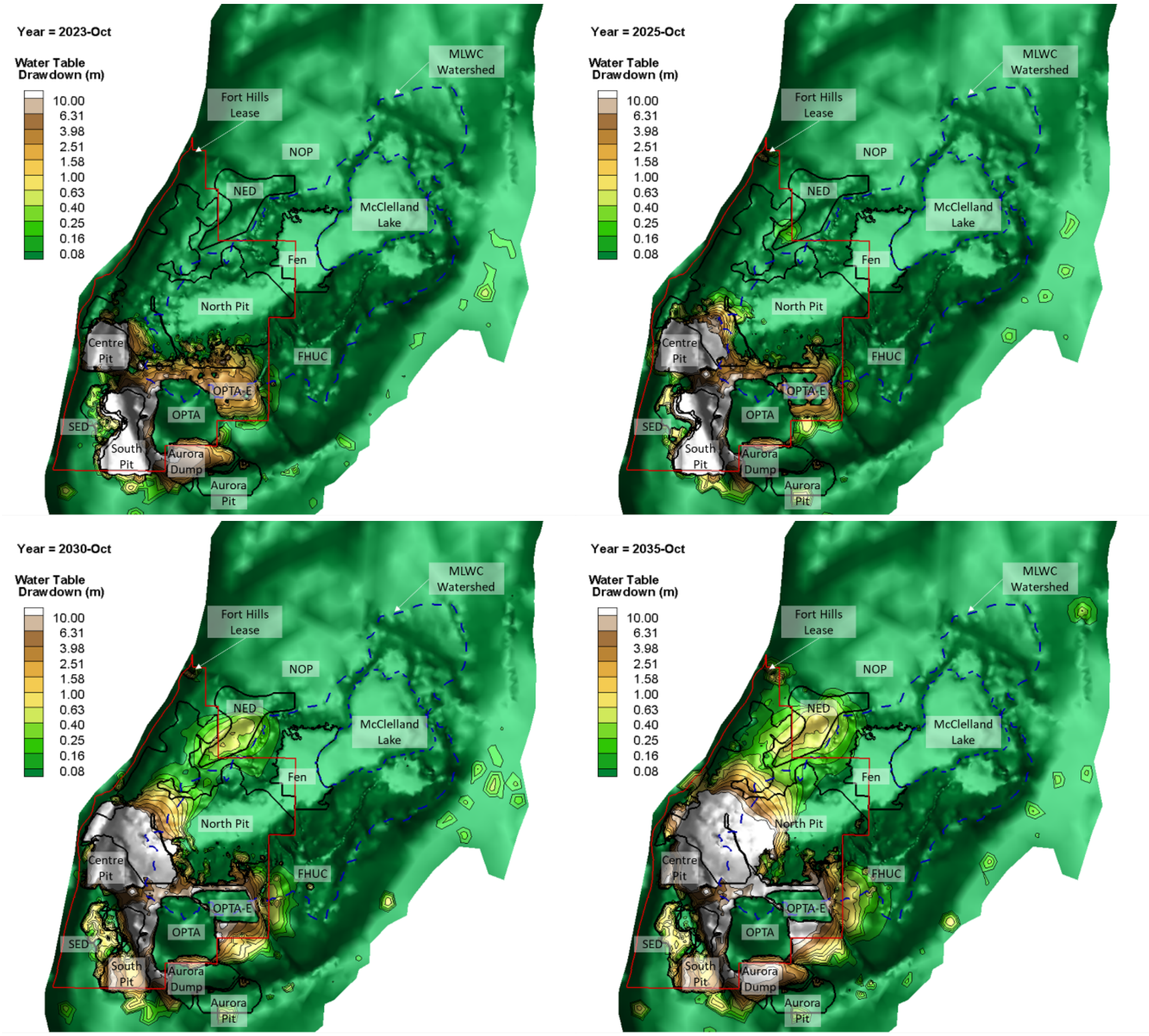


Figure 5-5: Water table drawdown during mining operations at selected times in the R1 scenario.

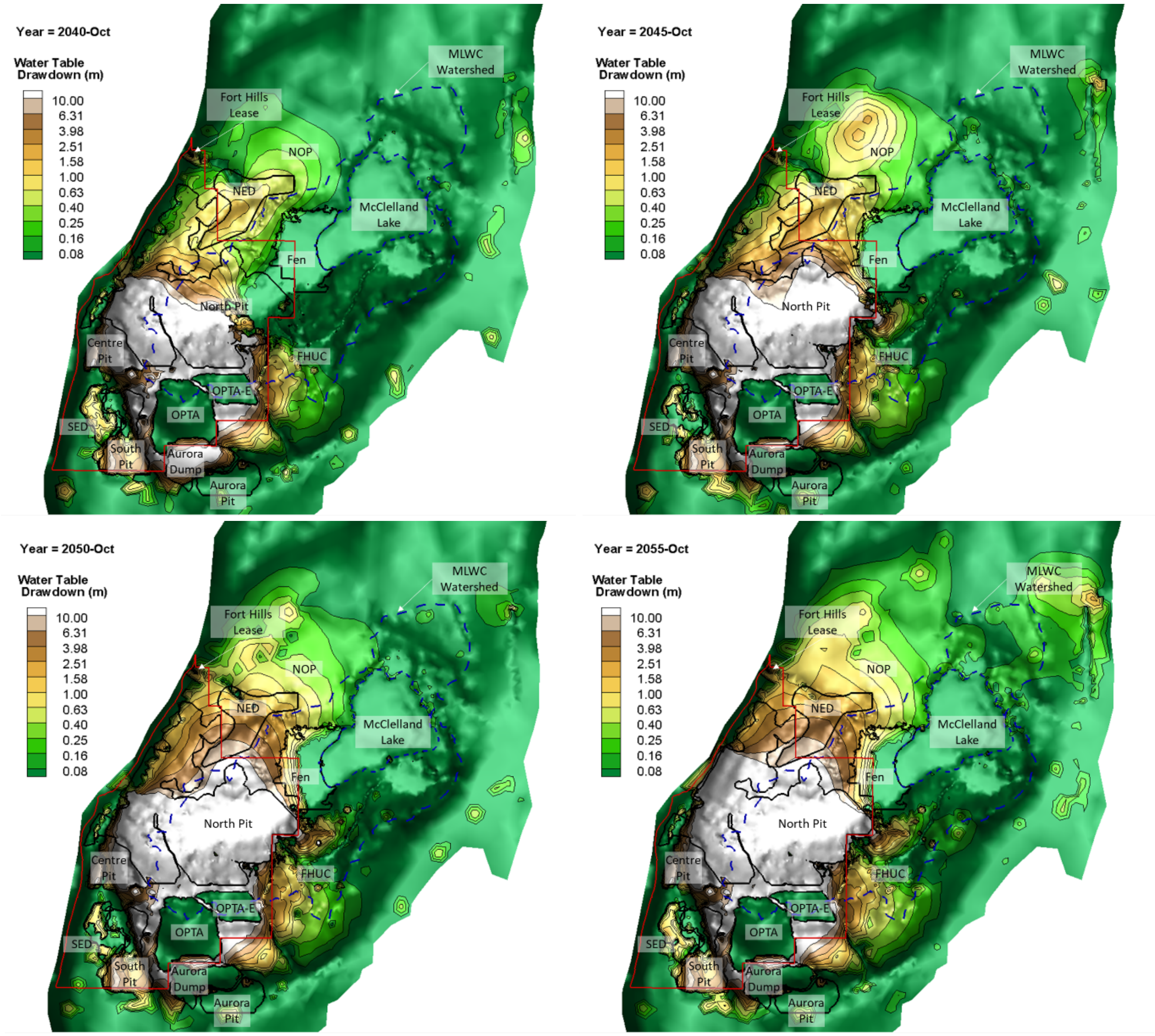


Figure 5-5: Water table drawdown during mining operations at selected times in the R1 scenario (cont'd).

Figure 5-6 plots the average water table depths (2014 to 2063) at the synthetic monitoring points across the non-mined portion of the MLWC fen for the R0 and R1 scenarios, for comparison. The results show water levels are near or above ground surface in the R0 scenario, aligning with the conceptual expectations for the undisturbed fen system (Figure 5-6; top panel). Average water table depths dropped approximately 30 to 40 cm along the western side of the non-mined portion of the MLWC fen in the R1 scenario (Figure 5-6; bottom panel). The R1 scenario results in Figure 5-5 and Figure 5-6 demonstrate that, if left unmitigated, mine operations are simulated to have a detrimental impact on GW levels within the non-mined portion of the MLWC, and could result in drawdown of the water table beyond that typically associated with fen peatlands.

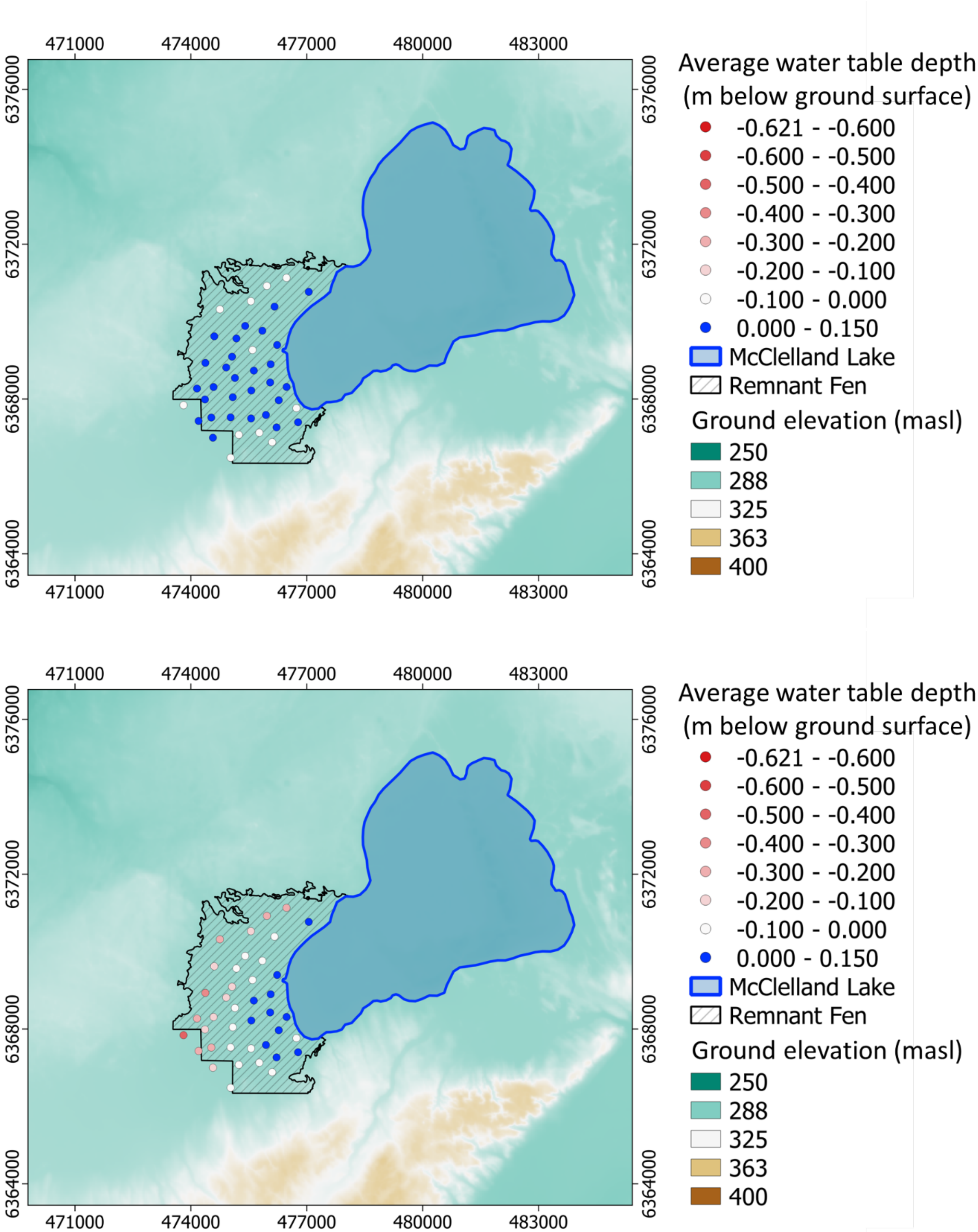


Figure 5-6: Simulated average (2014 to 2063) depth to water table in the R0 (top) and R1 (bottom) operations scenarios in the non-mined portion of the MLWC fen area.

Simulated GW levels for individual observation wells are a useful hydrologic indicator for examining the timing of drawdown effects in the non-mined portion of the fen. The location of three monitoring wells, between the proposed cutoff wall location and McClelland Lake, are shown in Figure 5-7. Simulated GW levels at these three locations are shown in Figure 5-8 for the R0 and R1 scenarios over the period 2014 to 2063. Water levels closest to the cutoff wall are the most sensitive to mine operations in the R1 scenario, as demonstrated by the sharp drop of >1 m in water levels at location GT-07-093C upon encroachment of North Pit towards the cutoff wall at approximately year 2047 (Figure 5-8, bottom). Location GT-07-093C is approximately 1200 m from the edge of the maximum extent of North Pit. In the R1 results, upon backfilling North Pit, the water level at GT-07-093C begins a steady recovery starting around year 2053 that returns to its pre-disturbance value by 2063. Simulated fen water levels for the R1 scenario (Figure 5-8, bottom) at location MW08-308C (2100-m distance from North Pit) show more moderated effects of the pit encroachment, compared to location GT-07-093C. Average water levels at MW08-308C are maintained close to the R0 levels; however, noticeable modification of the peak simulated fen water levels, relative to R0, is evidence of reduced hydrologic function of the fen at this location. For the most distal observation point from North Pit (2950-m distance), MLWC1-P100, which is also the closest of the three points to McClelland Lake (300-m distance), the effect of mine operations on the fen water level is to reduce the magnitude and frequency of high peaks relative to R0.

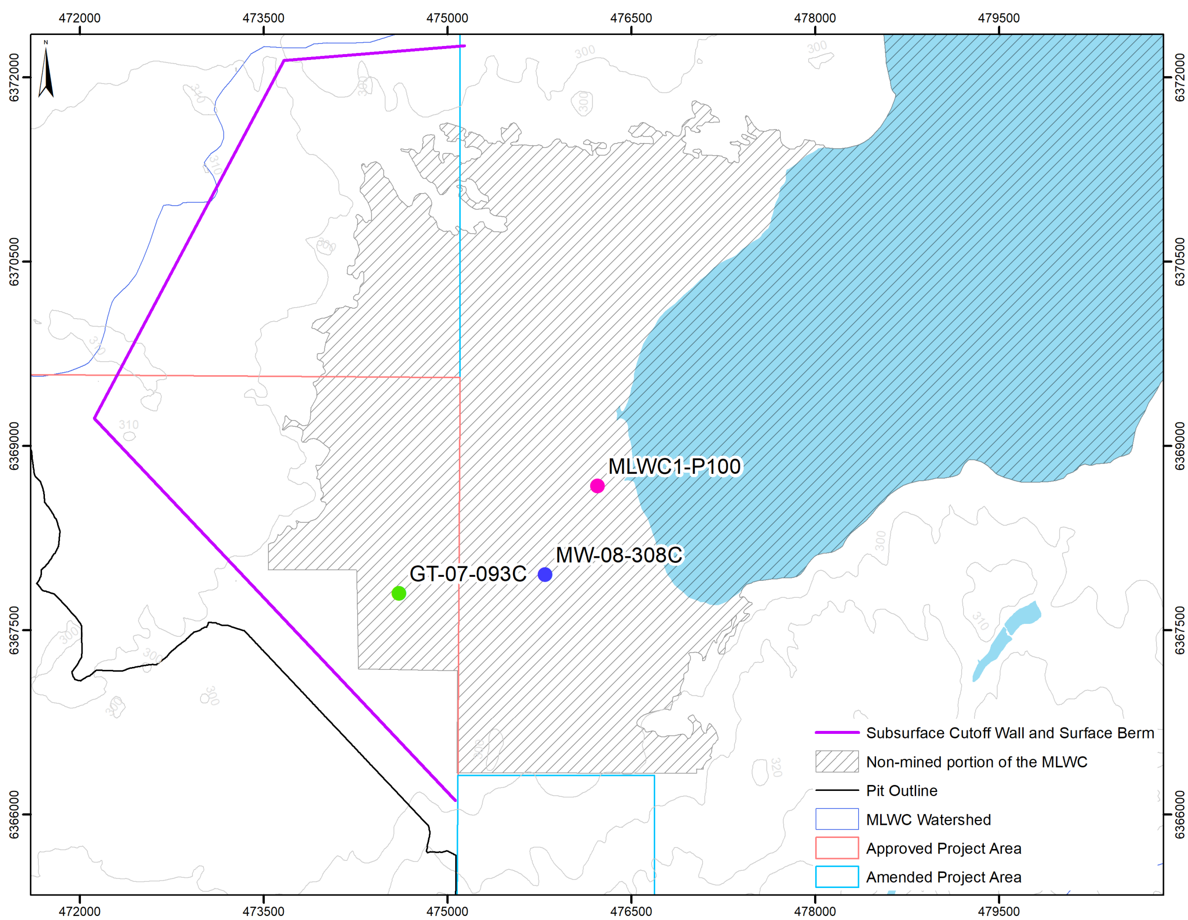
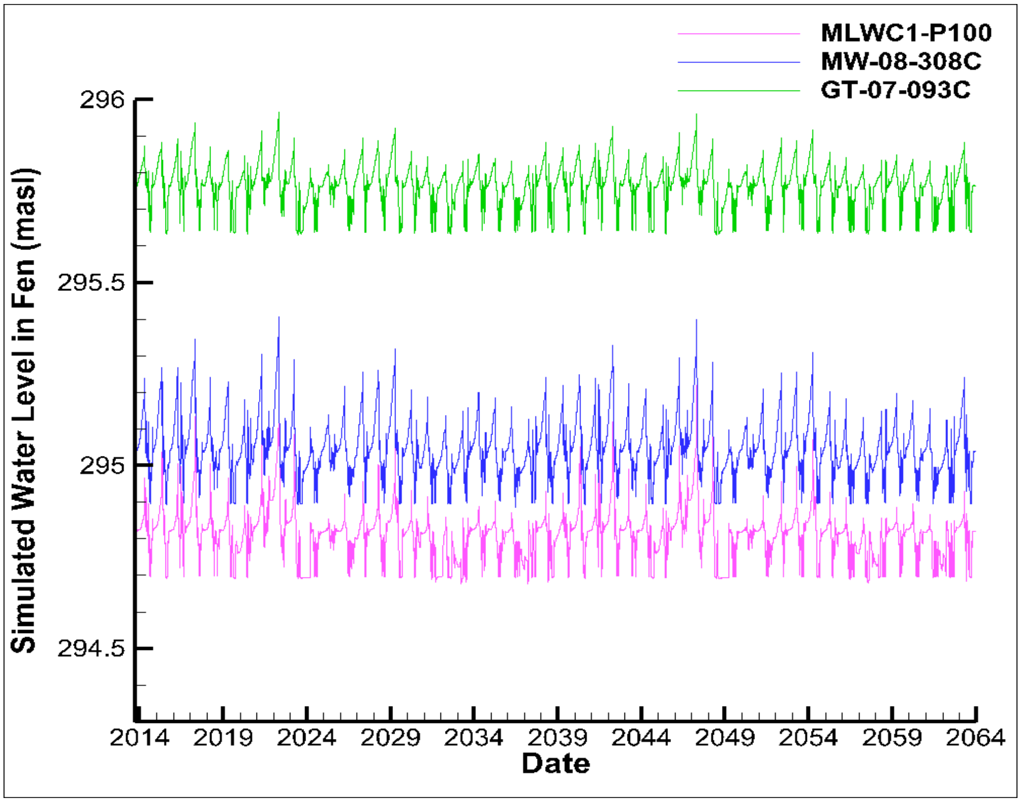


Figure 5-7: Locations of fen GW monitoring wells used in the operations scenarios.



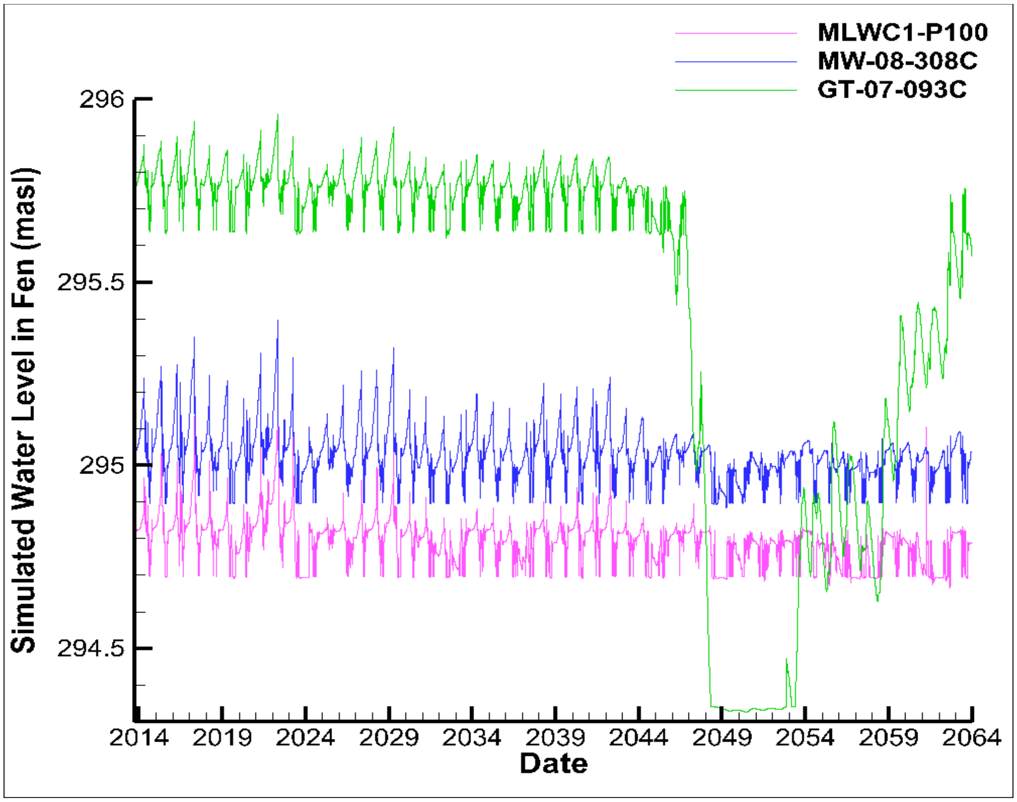


Figure 5-8: Simulated GW levels in the non-mined portion of the MLWC fen for R0,(i.e. no development) (top) and S1 (i.e., operations no mitigation) scenarios (bottom), respectively.

Simulated McClelland Lake levels between 2014 and 2063 are shown in Figure 5-9. Over the simulated period, the lake levels for the R0-scenario are maintained between 294.1 and 294.9 mASL. Under mine operations, in the R1-scenario, the lake level starts to decline around year 2033, decreasing 0.04 m by 2040. As mining progresses the R1 lake levels continue to decline relative to the R0 levels, achieving a maximum difference of 0.72 m lower by 2063.

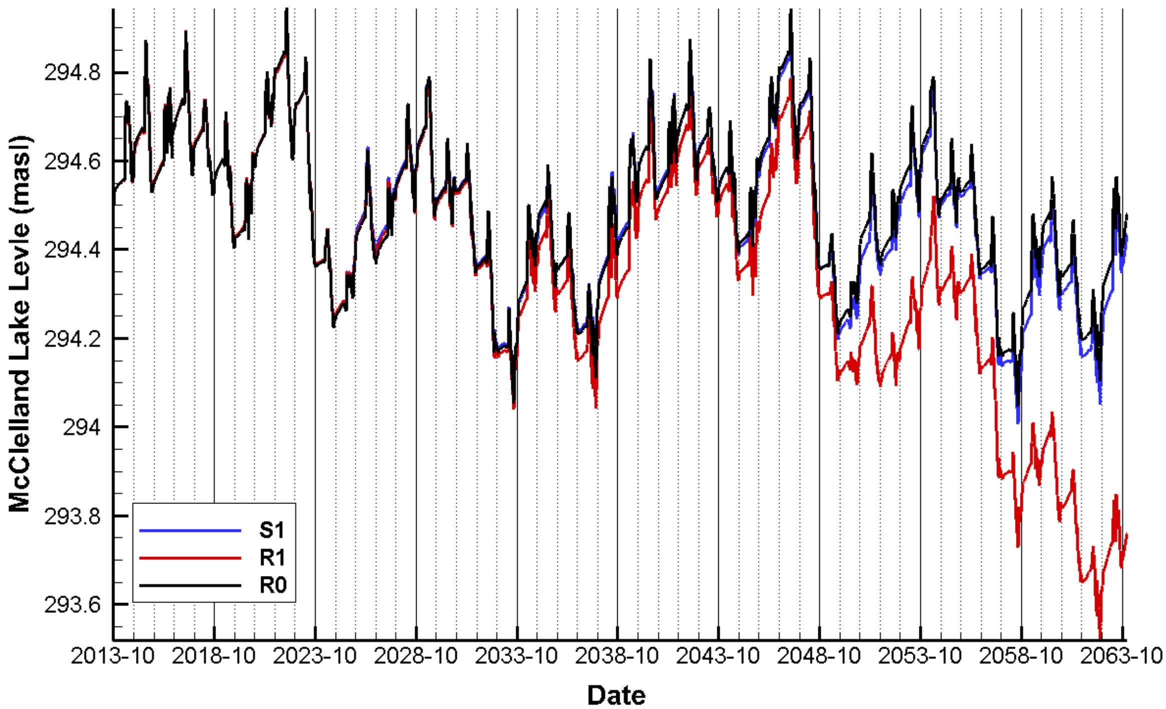


Figure 5-9: Simulated McClelland Lake levels in the R0, R1 and S1 operations scenarios.

5.2.2.2 S1 Scenario – Water Levels in the Non-mined Portion of the Fen and McClelland Lake

The water management design features included in the S1 scenario were: a cutoff wall with a coincident surface berm, a fen SW resupply system operating from 2025 through 2063, and a GW injection system operating from 2025 to 2037. The cutoff wall was implemented in the model in 2037, using an effective hydraulic conductivity of 1 x 10^{-9} m/s. The overall effectiveness of the water management design features is evident in the time panels presented in Figure 5-10. The figure shows the drawdown in the water table in the S1-scenario relative to the no-development R0 scenario. The effect of the water management design features present in the S1 model are evident as the difference between water table drawdown in the S1 and R1 scenarios (respectively, shown in Figure 5-10 and Figure 5-5). As mentioned previously, in the R1 scenario, the drawdown reached the edge of the fen in the mid-2030's and moved into the fen afterwards, reaching a maximum drawdown extent in the fen in the mid-2050's (Figure 5-5). In comparison, drawdown in the S1-scenario is effectively limited to outside the western and northern margins of the fen (Figure 5-10, mid-2030's onwards). By the time of peak drawdown in 2055, the drawdown at the western margins is negligible, and at the northern margin of the non-mined portion of the MLWC fen is minor. Future engineering work on the proposed water management design features is anticipated to further mitigate these predicted small impacts during development along the northern and western margins of the non-mined portion of the MLWC fen.

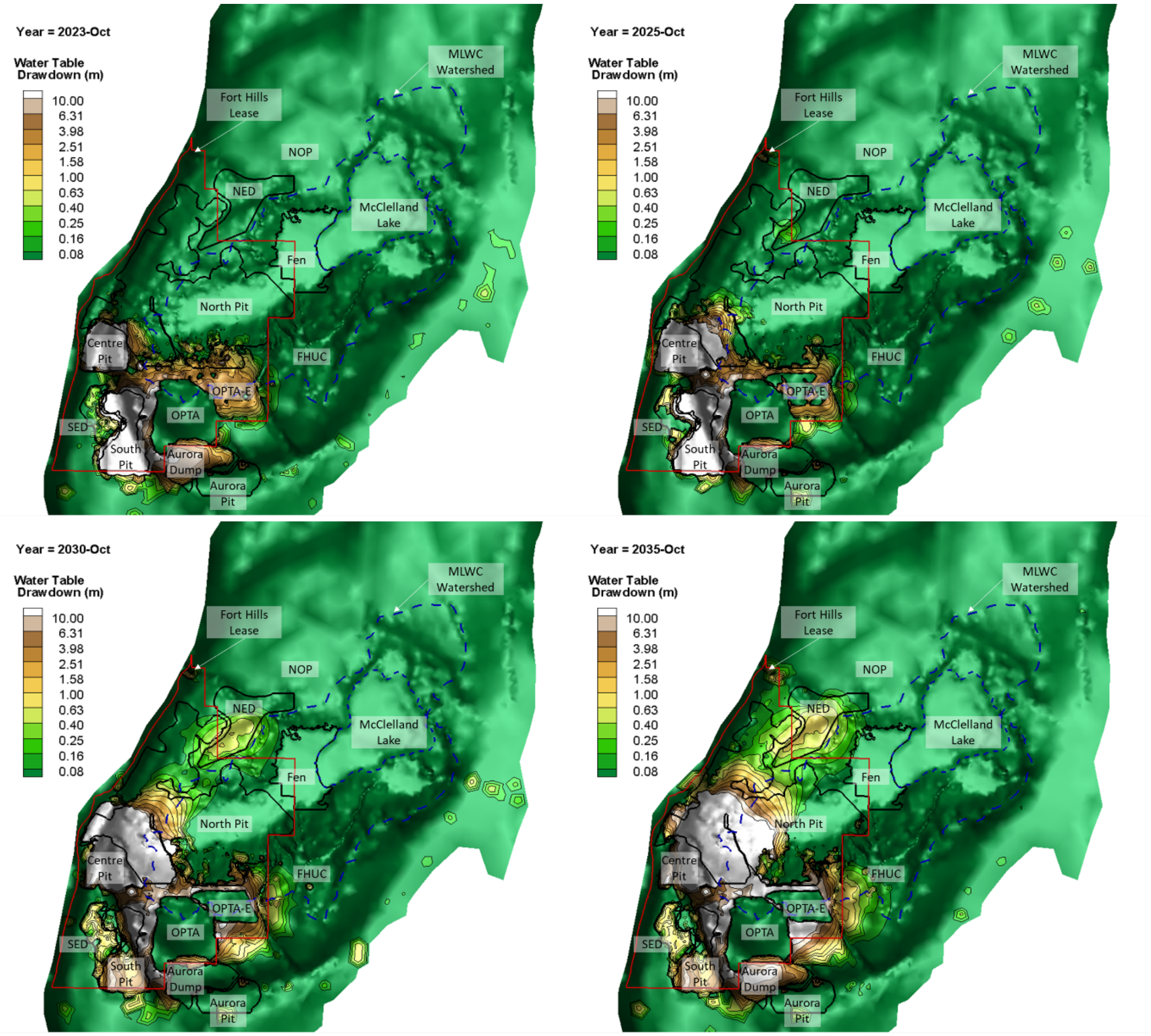


Figure 5-10: Water table drawdown during mining operations at selected times in the S1 scenarios.

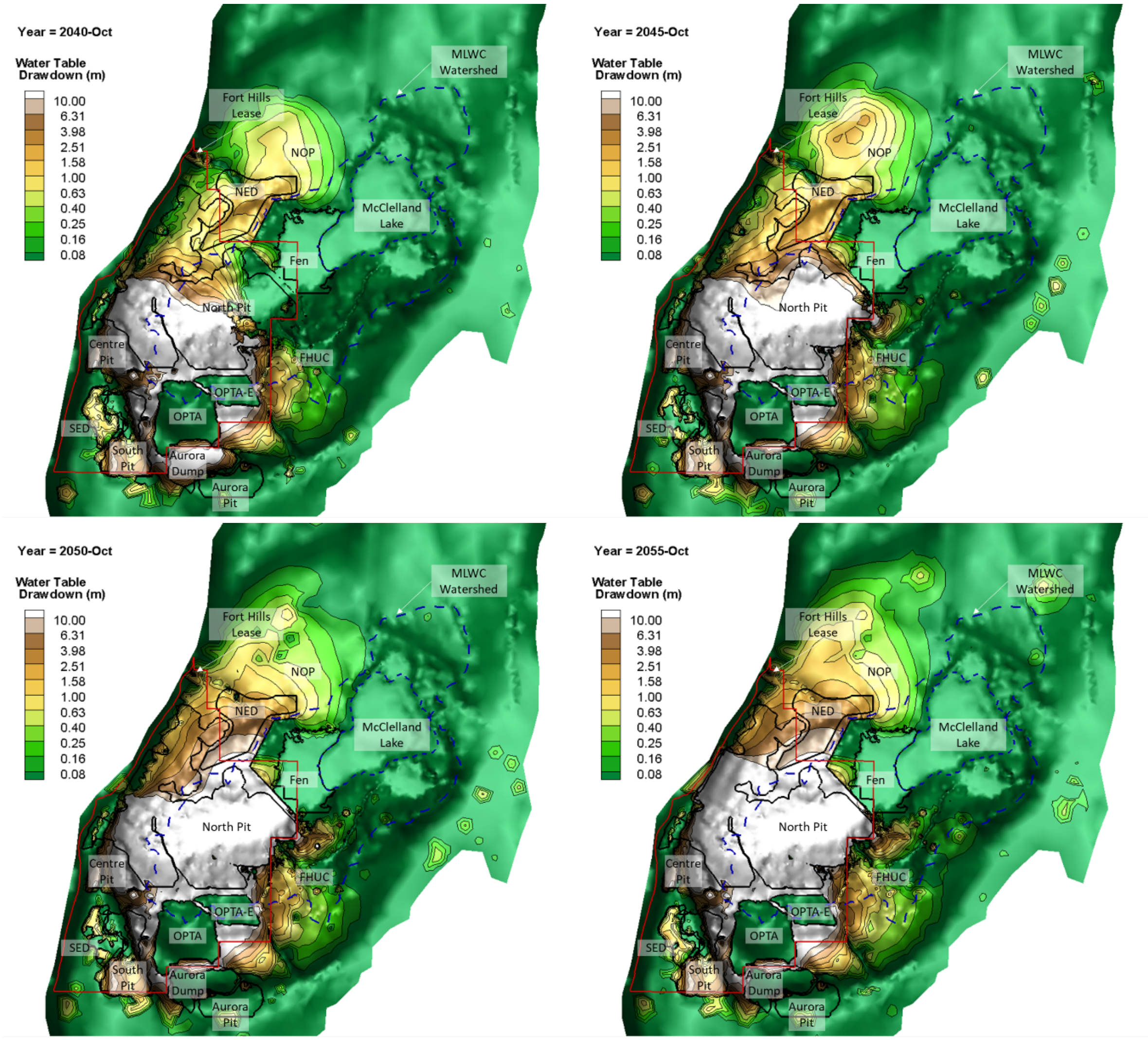
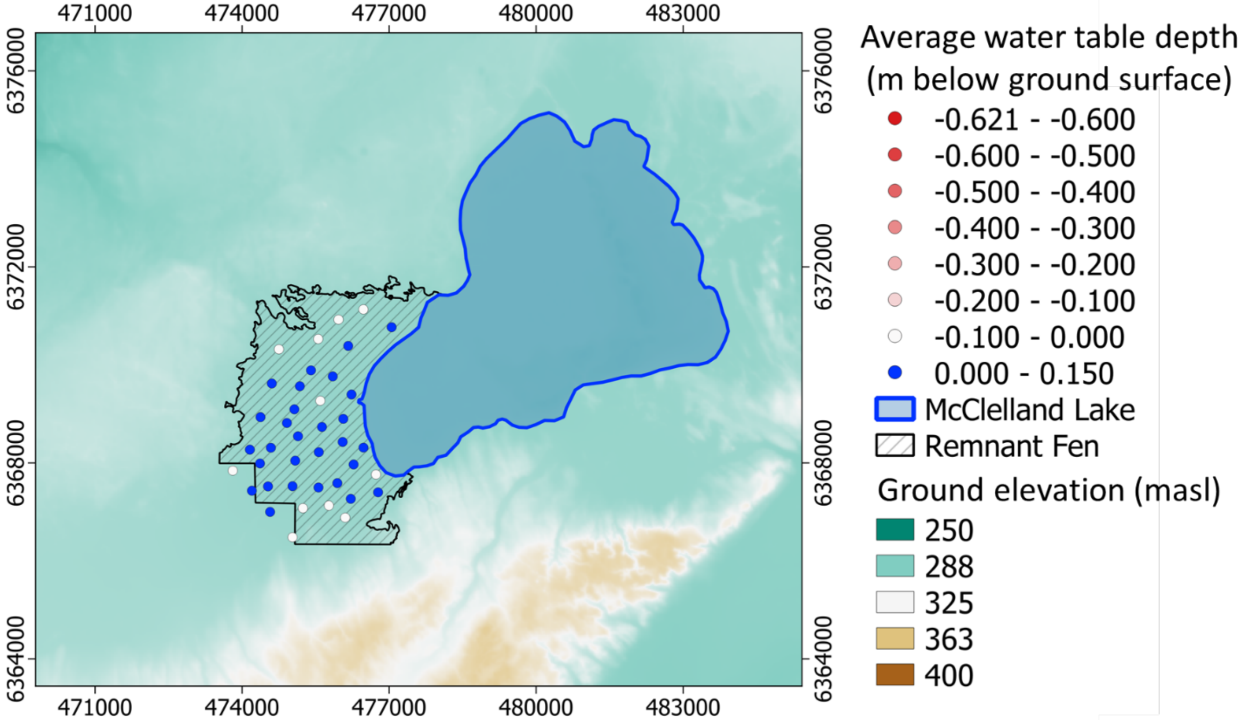


Figure 5-10: Water table drawdown during mining operations at selected times in the S1 scenarios (cont'd).

Figure 5-11 plots the average water depths (2014 to 2063) at the simulated monitoring points across the non-mined portion of the MLWC fen for the R0 and S1 scenarios. The results show water levels are at or above ground surface in the R0 scenario, aligning with the conceptual expectations for the undisturbed fen system (Figure 5-11; top). The S1 scenario results (Figure 5-11; bottom) indicate that the water management design features is able to mitigate the impacts of development on the GW levels within the non-mined portion of the fen with the exception of an approximately 10 cm drop in GW levels at two monitoring locations along the northern margin of the non-mined portion of the MLWC fen. Further engineering work to optimize the water management design features is anticipated to mitigate these predicted minor GW impacts. Overall, however, the S1 scenario results simulate that the proposed water management design features will maintain the GW levels in the non-mined portion of the MLWC fen at their pre-development levels, thereby preserving the shallow GW conditions (i.e., a high water table) required for maintenance of fen peatlands.



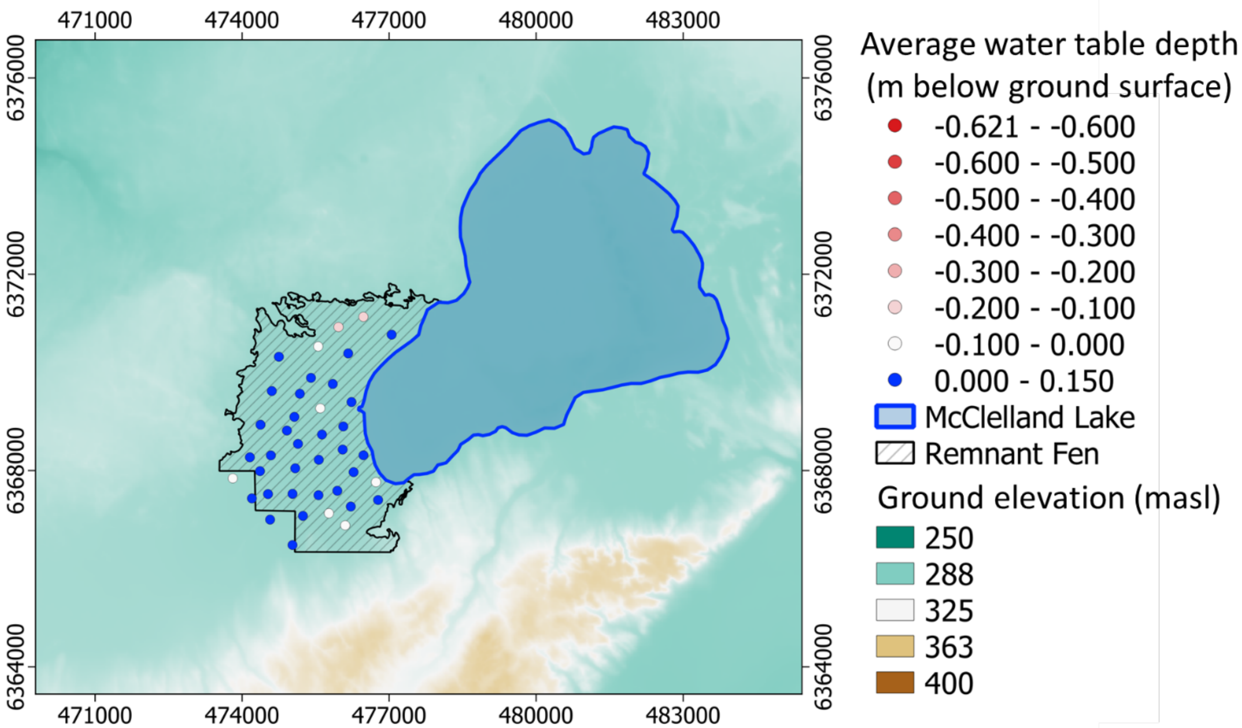
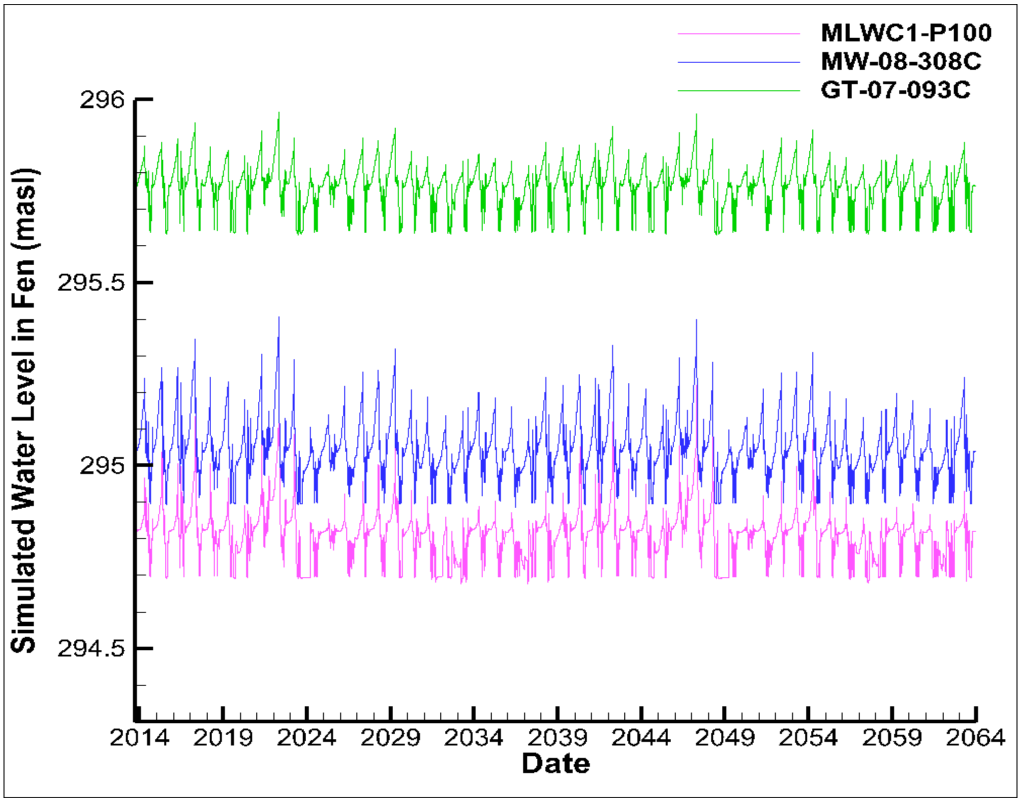


Figure 5-11: Simulated average (2014 to 2063) depth to water table in the R0 (top) and S1 (bottom) operations scenarios in the non-mined portion of the MLWC fen area.

Simulated fen GW water levels (Figure 5-12) at three monitoring well locations (Figure 5-7) during the S1-scenario do not exhibit a similar sharp drop at location GT-07-093C as was evident in the unmitigated R1-scenario (Figure 5-8). The water levels at locations GT-07-093C, MW08-308C, and MLWC1-P100 show no overall ascending or descending trends for the duration of the simulation. Additionally, the S1-predicted water level at all three well locations show very similar seasonal peaks relative to the R0 simulation (Figure 5-12).



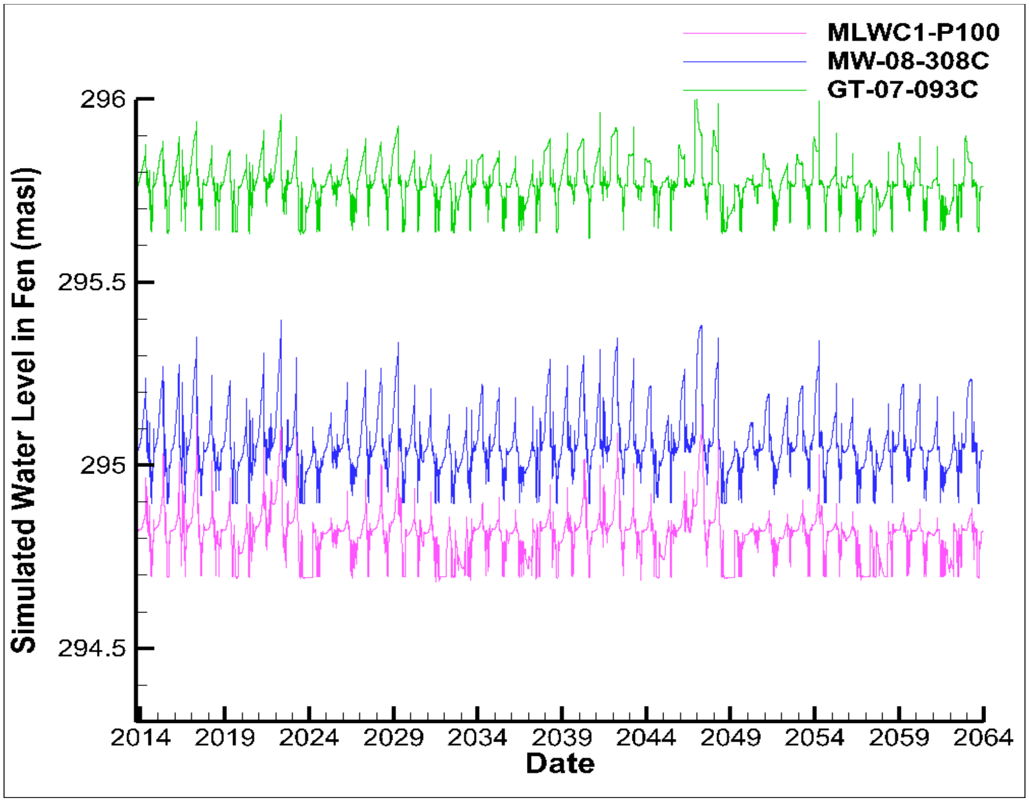


Figure 5-12: Simulated GW levels in the non-mined portion of the MLWC fen for R0, (i.e. no development) (top) and S1 (i.e., operations with water management design features) scenarios (bottom), respectively.

5.3 2020 MLWC HGS Active Closure Model Results (Mid-century)

5.3.1 Scenario Description

The Active Closure scenario work assesses the hydrologic performance of the Fort Hills Lease system shortly after mine operations end (2064) and while the landscape is being reclaimed. The objective was to assess hydrologic performance of the system under different projected climate conditions in the active closure period (approximately mid-century), which are discussed below. An additional closure scenario, far-future climate change analysis (approximately end-century), the Far-Future Model, is presented in Section 5.4.

Early testing of the closure landscape using the Active Closure Model indicated that the northwest extension (NOP portion) of the cutoff wall (Figure 3-24) would need to remain in place in perpetuity to prevent GW losses from this region of the non-mined portion of the MLWC fen to the surrounding landscape. The Active Closure Model results discussed below explicitly assume this northwest extension of the cutoff wall remains in place. Tests conducted with the Active Closure Model also indicated that the remainder of the cutoff wall (fen portion) can be removed or perforated as soon as the reclaimed landscape is ready to be hydraulically reconnected to the surrounding landscape.

5.3.1.1 Discussion of Climate Projection Scenarios

The projected changes in the climate of western Canada due to anthropogenic greenhouse gas emissions, based on two Weather Research and Forecasting (WRF) model (Skamarock et al., 2008) initial condition ensembles, are detailed in Erler and Peltier (2017). Figure 5-13 illustrates the change in the precipitation in western Canada by the end of century in these two WRF ensembles. Note that the climate change results presented are identical to those reported in Appendix C of the Fort Hills IPA document recently submitted to the AER.

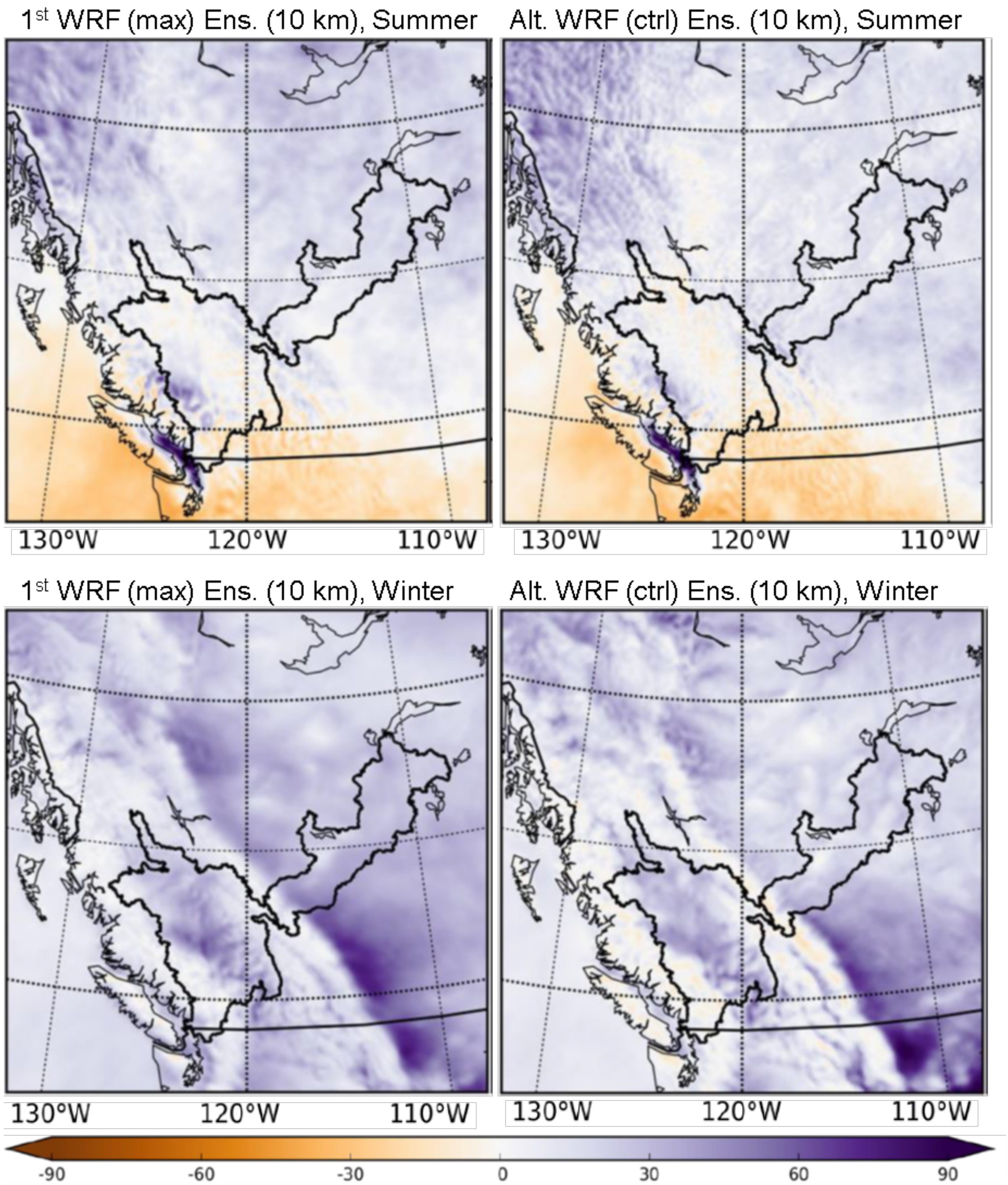


Figure 5-13. Ensemble average precipitation changes (percent) at the end of the 21st century in summer (top row) and winter (bottom row), based on two regional WRF ensembles. Relative changes with respect to the corresponding historical ensemble are shown. Outlines of the Fraser and Athabasca River basins as well as coast lines and major lakes are illustrated with solid black lines (Aquanty, 2020b).

The projected increase in temperature in western Canada at end-century under the RCP8.5 scenario is nearly 4.8 °C for the WRF ensembles (Aquanty, 2020b)). Warming in mid-century in two WRF ensembles is 2.6 to 2.8 °C. Projected changes in annual total precipitation in the 1st WRF and Alt. WRF ensembles are respectively 9% and 7% at mid-century, and 17% and 14% at end-century.

Figure 5-14 demonstrates the monthly average PET and precipitation of bias-corrected projected scenarios in two WRF ensembles for historical, mid-century, and end-century conditions.

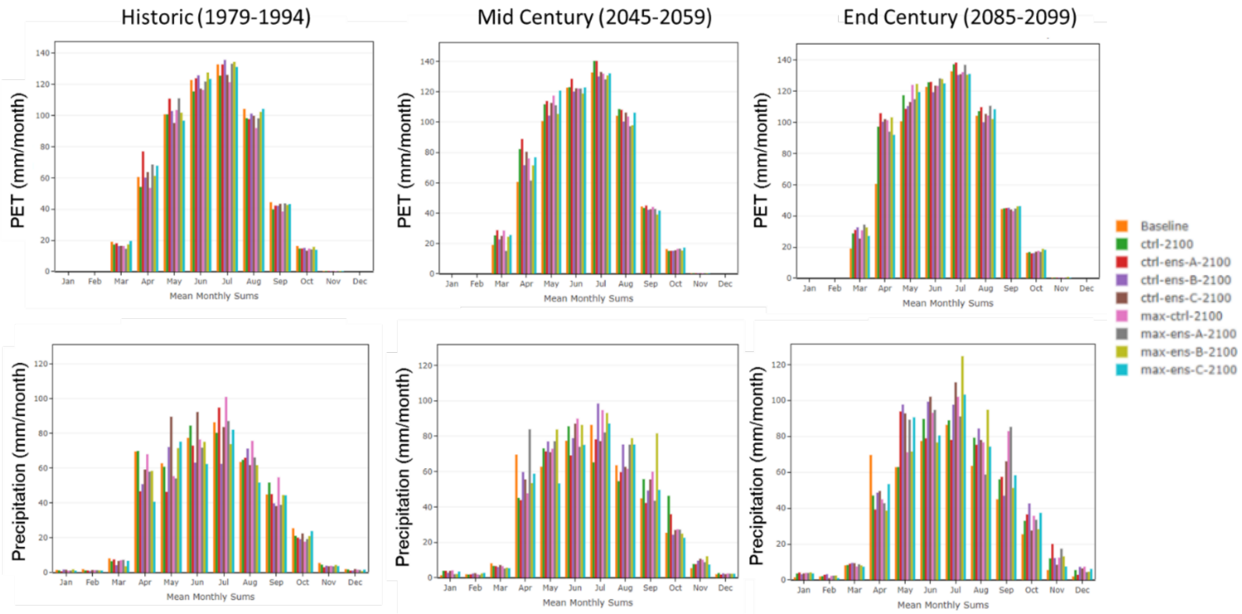


Figure 5-14. Monthly average climate forcing after bias correction in the members of 1st WRF and Alt. WRF ensembles compared to the historical period (i.e., Baseline).

From the two WRF ensembles, five different realizations were selected representing warm-wet, warm-dry, median, cold-wet, and cold-dry scenarios for mid-century and end-century. The realizations for these categories were determined by assessing changes in precipitation compared to the changes in air temperature and changes in estimated AET. Figure 5-15 illustrates the change in precipitation versus change in air temperature for the 1st WRF (scenarios with “max” in their title) and Alt. WRF (scenarios with “ctrl” in their title) for mid-century and end-century conditions. Earlier testing with the Closure Model indicated an AET/PET ratio of ~55%. This ratio was used to estimate AET values from the projected average PET of the ensemble members and to plot precipitation versus AET (Figure 5-16). The 1:1 line in this plot helps in selecting the wet and dry scenarios; for example, if a projection scenario is above the 1:1 line in Figure 5-16, the increase in its precipitation is higher than the increase in ET, and thus the model is wetter compared to the historical period. Conversely, if a projected climate scenario is below the 1:1 line, the increase in its ET is greater than the increase in precipitation and the scenario is drier compared to the historical benchmark. These analyses using Figure 5-16 and the change in air temperature from Figure 5-15 allowed for the selection of warm-wet, warm-dry, median, cold-wet, and cold-dry scenarios for mid-century and end-century conditions as shown with green labels in these two figures. Figure 5-17 shows the precipitation versus PET of the ensembles’ members and the selected scenarios for both mid-century and end-century conditions (end-century results discussed in Section 5.4). Table 5-1 presents the five projected climate scenarios that were selected from two WRF ensembles for mid-century and end-century conditions.

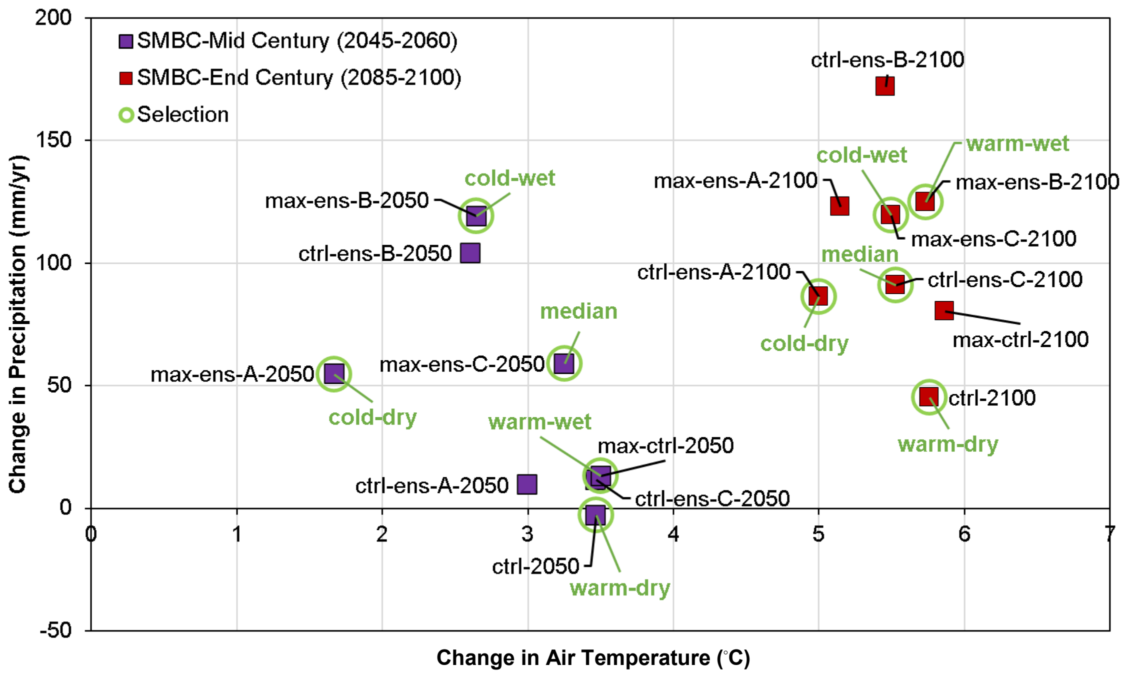
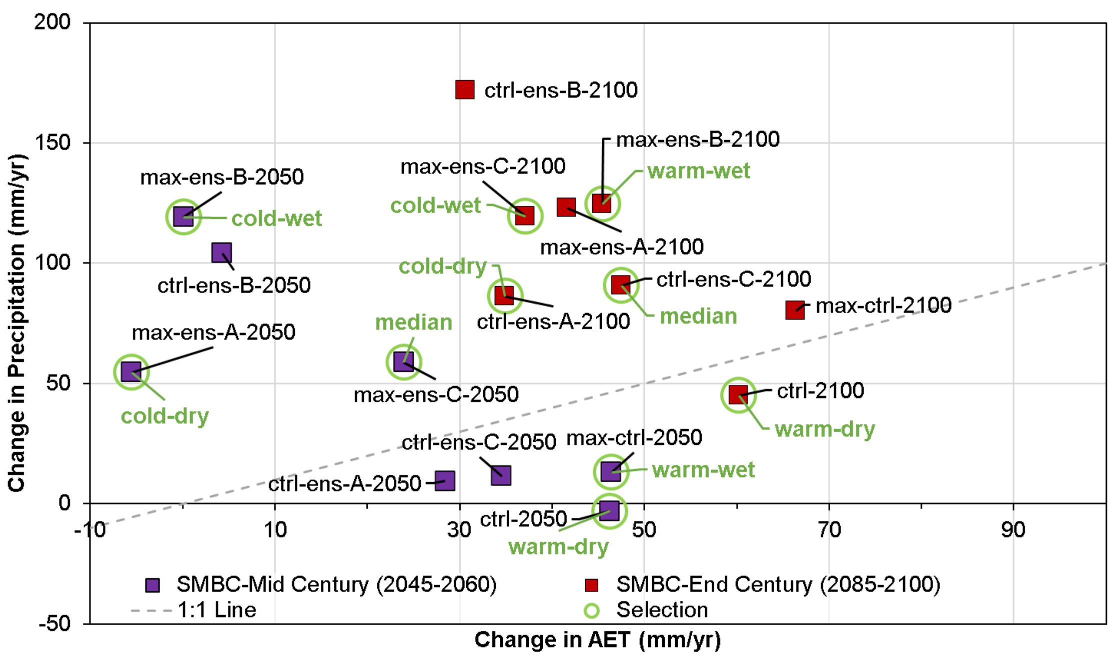


Figure 5-15. Change in air temperature vs. change in precipitation in the ensemble mid-century and end-century climate projection scenarios and the selected HGS scenarios in each ensemble.



*assuming AET is 55% of PET (watershed approximation)

Figure 5-16. Change in estimated AET vs. change in precipitation in the ensemble mid-century and end-century climate projection scenarios and the selected HGS scenarios in each ensemble.

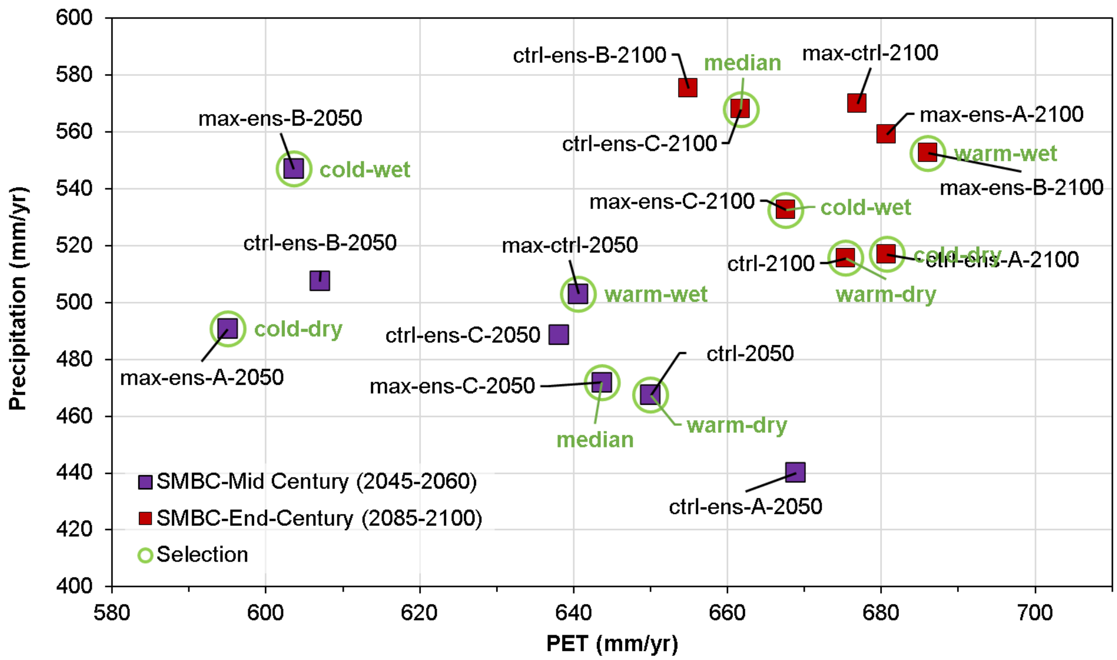


Figure 5-17. PET vs. precipitation in the ensemble mid-century and end-century climate projection scenarios and the selected HGS scenarios in each ensemble.

Table 5-1: Selected projected climate scenarios for mid-century and end-century conditions.

Climate scenario	Mid-Century	End-Century
cold-wet	max-ens-B-2050	max-ens-C-2100
cold-dry	max-ens-A-2050	ctrl-ens-A-2100
median	max-ens-C-2050	ctrl-ens-C-2100
warm-wet	max-ctrl-2050	max-ens-B-2100
warm-dry	ctrl-2050	ctrl-2100

5.3.2 Initial Condition Spin-up Strategy

The Active Closure Model represents conditions in the early post-mining period when the site is being reclaimed and pit lakes are either empty or partially filled. Since the different pit lakes, shown in Figure 3-27, are generally reclaimed near mid-century, climate projection scenarios from the mid-century were used as forcing data to drive the (mid-century) Active Closure Model. The initial conditions were assumed to include the South Pit Lake and Centre Pit Lake being partially filled, and the North Pit Lake being empty.

Outside of the reclaimed area, initial SW and GW hydraulic heads were defined in the Active Closure Model by importing those heads from the Baseline Model. Within the reclaimed area, the native, undisturbed soil materials were also initialized with heads from the Baseline Model. In addition, the reclaimed (placed) materials within this area (except within the pit lakes) were given initial head (water level) values equal to the ground surface elevation. This latter step was taken to provide enough water in the reclaimed material pore space for gravity drainage to establish physically meaningful water tables and surface flows within the reclaimed materials during the spin up period.

Once initialized, the Active Closure Model was spun up for 25 years. The climate forcing that was used for this spin up period was obtained through averaging the daily forcing (1945 to 2019) for each Julian day over 75 years. For example, the 75 historical precipitation data contains 75 values for 1st January; those 75 values were averaged to provide the precipitation on 1st January in the spin up climate forcing data. This was done for all the days of the year providing the precipitation and PET for 365 days. Subsequently, this data set was looped 25 times to provide a 25-year spin-up period. During this 25-year spin-up period, the reclaimed area hydraulically re-equilibrated with the surrounding landscape within the model. The results of this spin-up run were then used as the initial conditions for the final Active Closure Model runs, including: 1) a 25-year run with the same climate forcing of the spin up run, and 2) an ensemble of five projected climate scenarios for mid-century climate projections, discussed in Section 5.3.1.1, Table 5-1, and Figure 5-15 to Figure 5-17.

Each of the five selected climate projections for mid-century were used to drive the Active Closure Model for 15 years. Because of the hydrological memory of the system, the first few years of the results of these runs could be impacted by the initial condition (Note: the initial condition was identical for all five runs). Therefore, to remove the effect of the initial condition, the final head distribution in each of the five runs was looped back and used as its initial condition (for areas outside of the pit lakes). Within the pit lakes the head was defined as described earlier. Each model was subsequently run for a second 15-year period with the same climate projection forcing. The results of the second 15-year runs are analyzed in the remainder of this section.

5.3.3 Active Closure Model Results with Historical and Projected Climate

Figure 5-18 presents the mean monthly rainfall plus snowmelt rates (liquid forcing) applied over the historical 25-year period (average year) as well as the five 15-year climate simulations. As indicated in Figure 5-18, the liquid forcing rates for the climate scenarios are generally projected to be higher during the freshet than have been observed historically, even when compared to the dry climate scenarios.

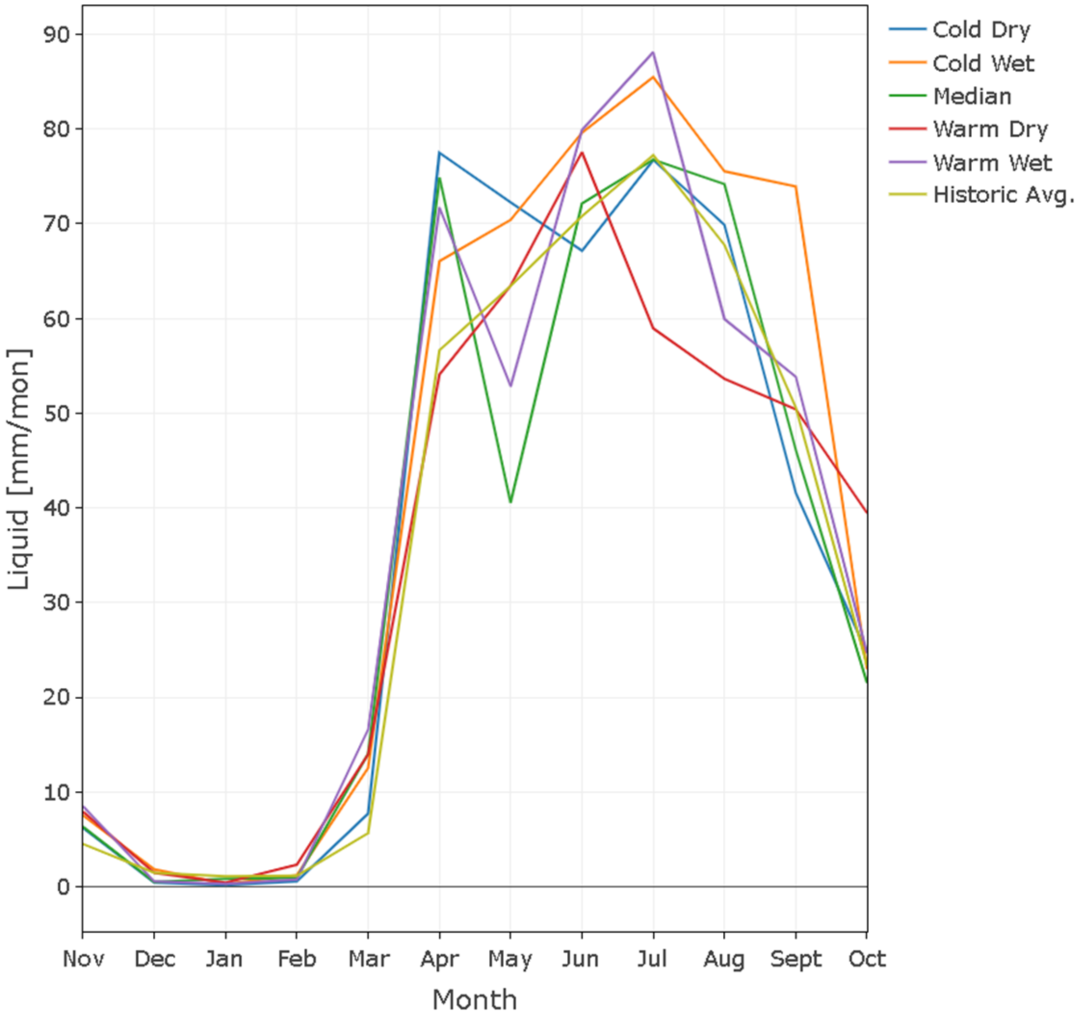


Figure 5-18. Average monthly average precipitation rates used in the Active Closure Model for the 25-year average historical run and as well as five projected 15-year mid-century climate scenarios.

Figure 5-19 presents a comparable plot of AET for the climate scenarios. The results in Figure 5-19 indicate that AET increases more rapidly after freshet (approximately March and April) at mid-century for the climate change scenarios than is the case for the historical (Average Year) scenario.

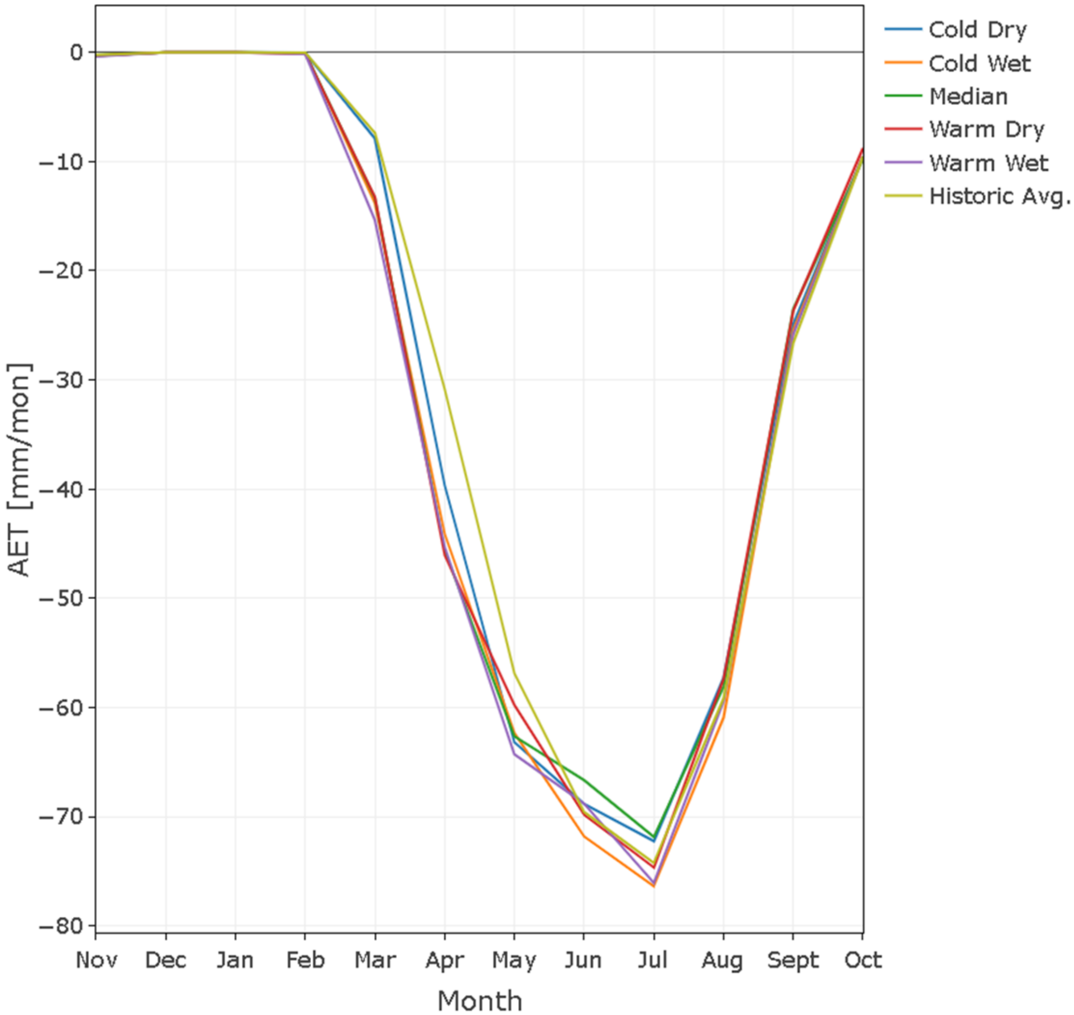


Figure 5-19. Simulated average monthly average AET of the Active Closure Model for the 25-year average historical run as well as five projected 15-year mid-century climate scenarios. Note: AET is given as a negative flux out of the HGS model.

Projected average monthly lake levels for McClelland Lake are shown in Figure 5-20 for the historical (Average Year) and the mid-century climate projection scenarios. The cold-dry, cold-wet and warm-wet results in Figure 5-20 predict lake levels comparable to, or greater than, the historical (Average Year) results, while the median and warm-dry results predict lower lake levels. The range of variation across the results is ~0.3 m between all the runs, which is within the historical temporal variability of the observed McClelland Lake levels. Peak lake level during freshet generally occurs one month earlier in the projected climate scenarios compared to the historical run result.

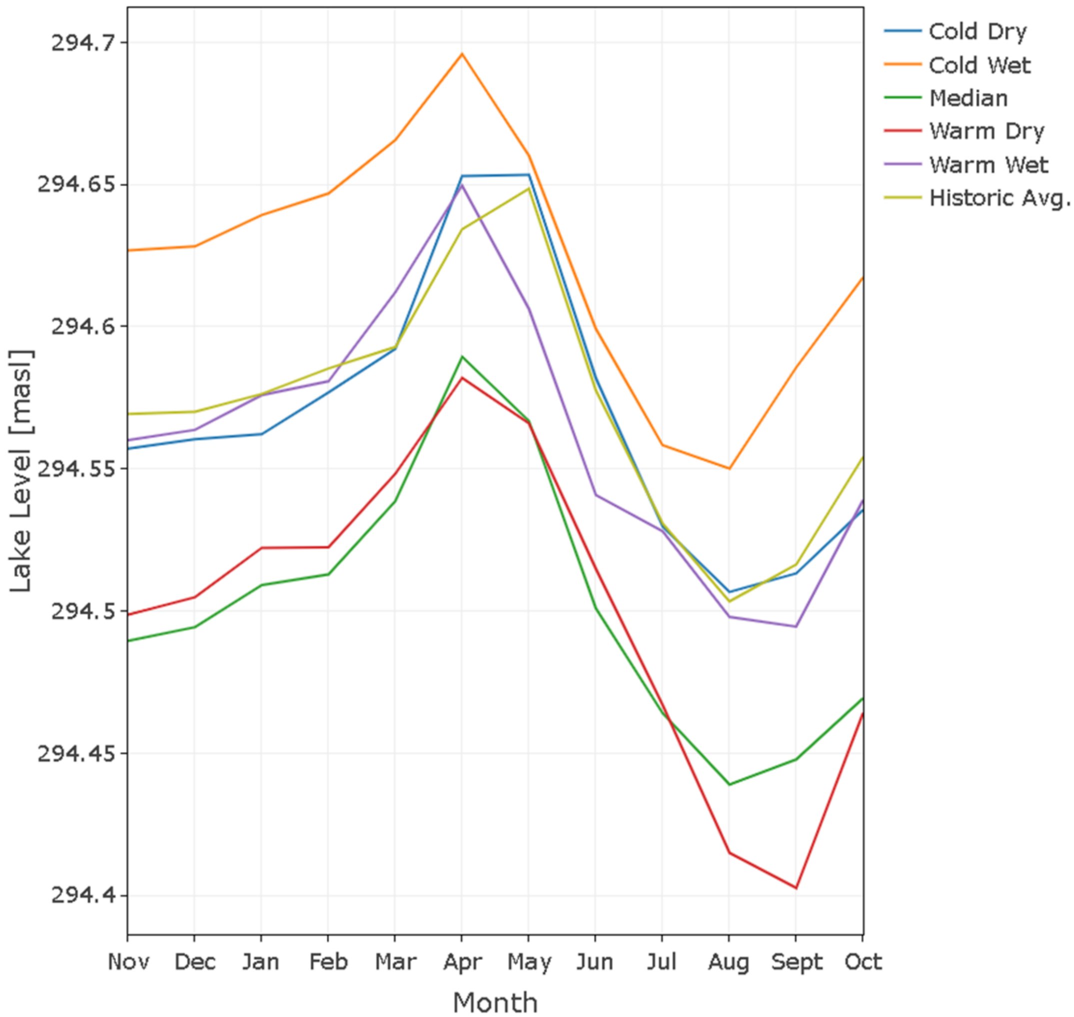


Figure 5-20. Simulated average monthly levels of McClelland Lake in the Active Closure Model with the 25-year historical average daily forcing as well as five projected 15-year mid-century climate scenarios.

Figure 5-21 and Figure 5-22 present water level exceedance curves for McClelland Lake, and the non-mined portion of the MLWC fen. The exceedance curves for McClelland Lake (Figure 5-21) for the projected mid-century climate span a range of approximately 0.15 m at the 50th percentile, which increases to approximately 0.2 m at the 90th percentile. In general, at lower percentiles, the projected lake level lies above the level simulated with historical average climate, while at higher percentiles, the project lake level lies below the level simulated with historical average climate. These model results indicate that McClelland Lake will likely not experience large declines its level, provided the mid-century climate stays within the bounds of the ensemble of projected climate scenarios.

The exceedance curves for the fen (Figure 5-22) do not exhibit a wide range of projected fen water levels, showing a range in projected water levels of 0.02 m at the 50th percentile

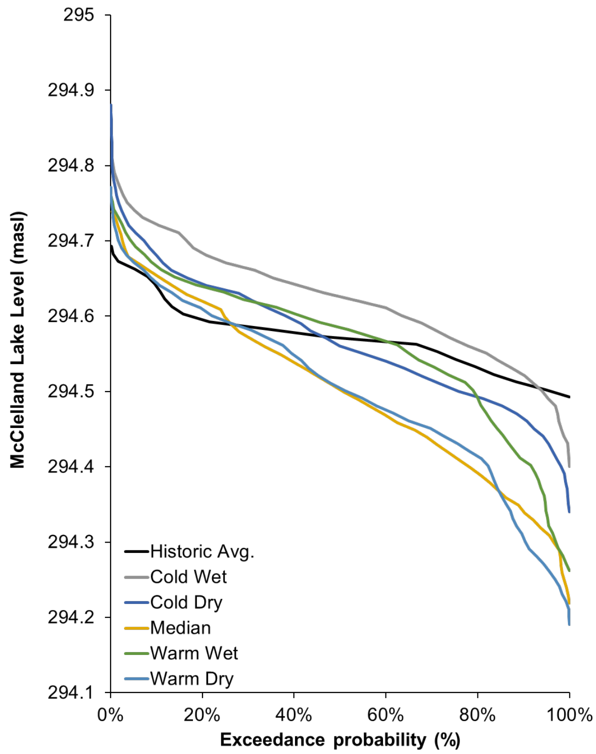


Figure 5-21. Exceedance curves of water levels in McClelland Lake in the Active Closure Model for the historical climate and mid-century projected climate.

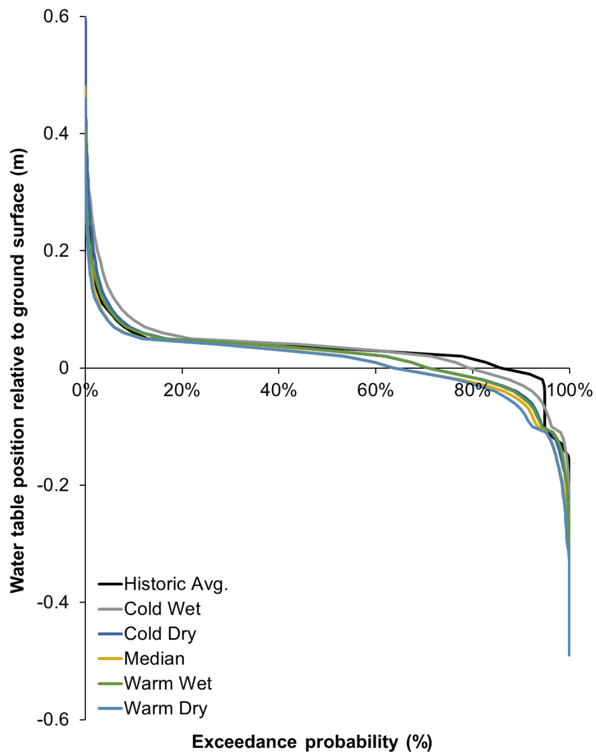


Figure 5-22. Exceedance curves of water levels in the non-mined portion of the MLWC fen in the Active Closure Model for the historical climate and mid-century projected climate.

5.4 2020 MLWC HGS Far-Future Results (End-century)

5.4.1 Scenario Description

The far-future period represents a time period for the closure landscape wherein the pit lakes are filled, the flow regimes around them have fully established, and the reclaimed area has reached a hydrological and hydrodynamical equilibrium. This far-future closure period is represented by a time snapshot at the end of the 21st century (end-century).

The far-future scenario assesses MLWC system hydrologic performance during a timeframe near the end of the century and beyond, after the site has been reclaimed and the landscape has been hydrologically reconnected to the surrounding landscape. The primary objective of the assessment was to compare SW and GW flows in and out of the non-mined portion of the MLWC fen predicted for far-future conditions to those predicted under pre-development conditions using the Baseline Model. The Baseline Model results being compared to are presented in Figure 5-1and Figure 5-2. The 2020 MLWC HGS Far-Future Model used the same historical climate forcing as the Baseline Model (1945 to 2019).

Early testing of the closure landscape using the Closure Model indicated that the northwest extension of the cutoff wall (location shown in Figure 57) would be need to remain in place in perpetuity to prevent GW losses from this region of the non-mined portion of the MLWC fen to the surrounding landscape (results not shown). The Far-Future Model explicitly includes this northwest extension of the cutoff wall. The remainder of the cutoff wall in the fen was assumed to be removed immediately following the active closure period.

The (end-century) Far-Future Model results include: 1) a 75-year historical run that uses the same historical climate forcing used in the Baseline Model (1945 to 2019) but applied to the far-future, post-closure landscape, and 2) an ensemble of five projected climate scenarios (warm-wet, warm-dry, median, cold-wet and cold-dry, respectively) for end-century conditions discussed in Section 5.3.1.1, Table 5-1, and Figure 5-15 to Figure 5-17.

5.4.2 Initial Condition Spin-up Strategy

The initial head distribution for these models was mapped from the Active Closure Model, which used average daily forcing for 25 years (as discussed in Section 5.3.2). Next, a reference run for the (end-century) Far-Future Model was conducted using 1945 to 2019 historical forcing. Fifteen-years of end-century climate data for each ensemble member was then used in the (end-century) Far-Future Model to generate the end-century climate projection simulations. For each climate projection simulation, the end-century climate data was looped over the Far-Future Model twice. The intended purpose of the first 15-year loop is to dissipate the initial condition effects in the model. The results from the second 15-year loop for each climate projection simulation were then compared to those of the aforementioned reference run (See Section 5.4.4).

5.4.3 Far-Future Model Results with Historical Climate

Figure 5-23 presents the simulated average GW fluxes (over the 75-year simulation period) through the Quaternary units into the non-mined portion of the MLWC fen using the Far-Future Model. A comparison of the far-future GW fluxes presented in Figure 5-23 to the corresponding baseline results shown in Figure 5-1 indicated that GW fluxes originating upgradient from the west-southwest and east-southeast sections of the non-mined portion of the fen are quite comparable to one another during the far-future and baseline periods. In contrast, the GW fluxes predicted to enter the non-mined portion of the fen along its western and northern margins are predicted to be considerably larger (> 3,500 m^3/d) during the far-future period (Figure 5-23) than the comparable GW fluxes predicted during the Baseline period (Figure 5-1). This difference in the predicted GW fluxes along the northern and western margins of the non-mined portion of the MLWC fen during the baseline and closure periods is largely attributed to the presence of the northwest section of the cutoff wall during closure which is preventing GW losses to the surrounding landscape.

Figure 5-24 shows the averaged SW fluxes in and out of the non-mined portion of the MLWC fen over the far-future period. The far-future simulation results presented in Figure 5-24 were then compared to the baseline SW fluxes shown in Figure 5-2. Surface water entering the non-mined portion of the MLWC fen along the northern and western margins is approximately comparable in both cases, as are the net SW fluxes into McClelland Lake. However, the SW fluxes entering the non-mined portion of the MLWC fen from the west-southwest are lower by approximately 26% for the far-future period (Figure 5-24) than fluxes predicted during the baseline period (Figure 5-2), (8,864 m^3/day vs. 12,040 m^3/day, respectively). Moreover, the predicted SW fluxes entering the non-mined portion of the MLWC fen along its east-southeast margin are predicted to be approximately 135% higher during the far-future period (Figure 5-24) than the comparable fluxes predicted during the baseline period (Figure 52),(1,896 m3/day vs. 888 m3/day, respectively). These differences in the far-future vs. baseline SW fluxes are assumed to be attributed to a reduced topographic gradient (when compared to baseline topography) and smaller contributing area from the surrounding landscape supplying SW to the non-mined portion of the MLWC fen following closure.

The predicted far-future and baseline SW flows into McClelland Lake are similar in both cases. The total volume of water (SW+GW fluxes) entering the non-mined portion of the MLWC fen during the far-future period is comparable to the volumes entering this area during the baseline period (about 8% greater for the far-future, 22,179 m^3/d versus 20,494 m^3/day, respectively). Predicted annual AET rates over the non-mined portion of the MLWC fen averaged 465 mm/yr during the closure simulation period (higher than the average rate of 428mm/y mm/yr computed for baseline), indicating that the closure landscape will have sufficient water to sustain evaporative demand during periods of maximum evaporative stress (the summer months or during dry periods).

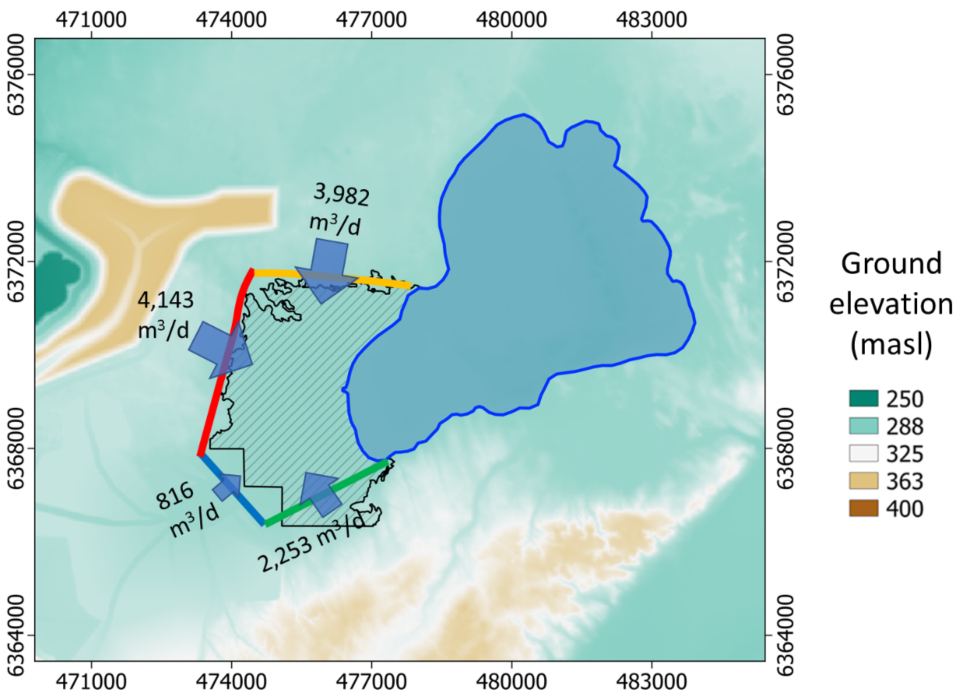


Figure 5-23: Groundwater fluxes through Quaternary units into the non-mined portion of the fen area in the Far-Future Model.

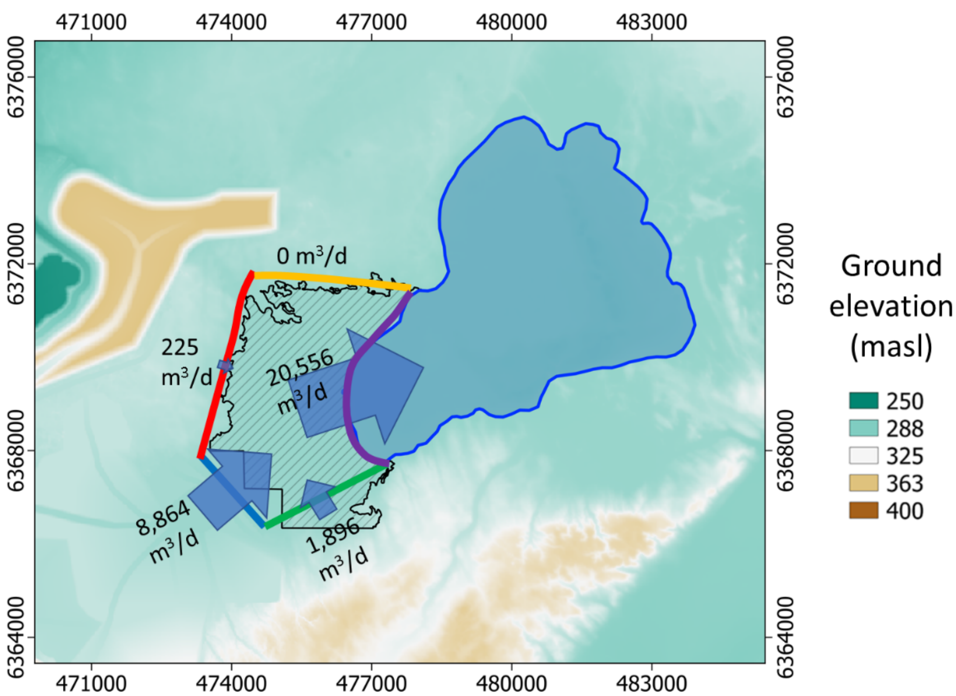


Figure 5-24: Surface water fluxes into and from the non-mined portion of the MLWC fen in the Far-Future Model.

Figure 5-25 plots the average water table depths during the closure period at the simulated monitoring locations located across the non-mined portion of the MLWC fen. A comparison of these results to those given for the baseline period (Figure 5-3) indicates the results are quite comparable. In both cases, water levels were above surface to 0 to10-cm below surface, indicating the water tables achieved during the far-future period are simulated to be compatible with water table conditions typically associated with fen type peatlands (as is the case for the baseline period).

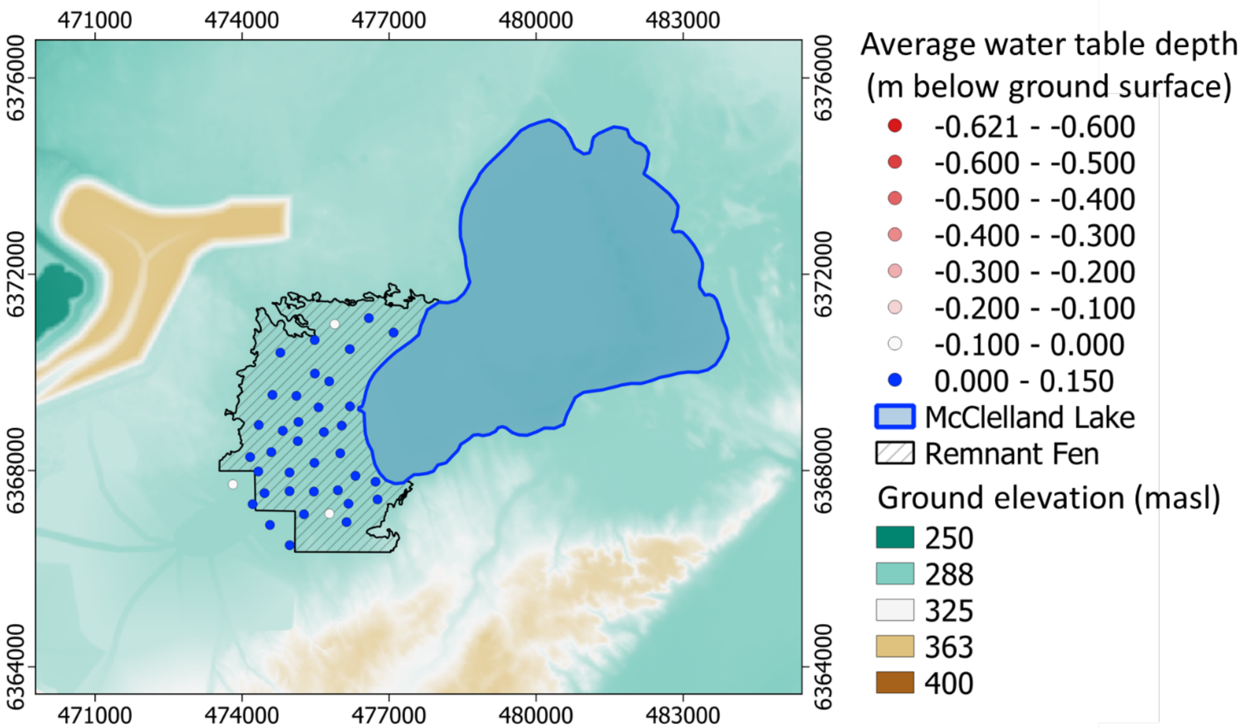


Figure 5-25: Spatial distribution of the average depth to GW table in the non-mined portion of the MLWC fen in the Far-Future Model.

5.4.4 Far-Future Model Results with Projected Climate

The monthly summary results of the rainfall plus snowmelt (liquid forcing) for the end-century historical climate run (75 years) and for the 15-year end-century climate projection runs are presented in Figure 5-26. Similar to the results shown in Figure 5-18 for the mid-century, the end-century climate projection results indicate a general increase in liquid forcing when compared to the historical climate run. Also, precipitation in the summer months (with the exception of the cold-dry scenario) are higher in the end-century results compared to the historical reference run values.

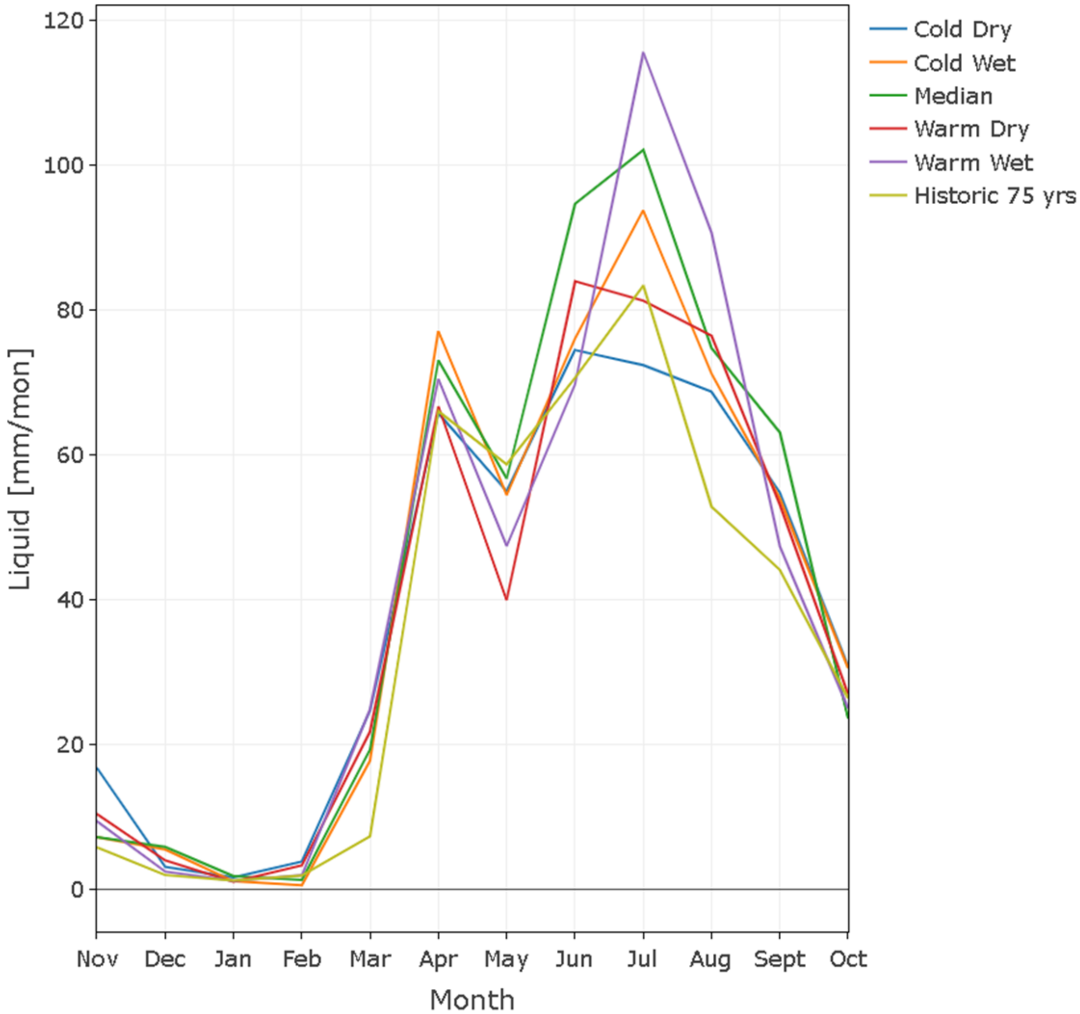


Figure 5-26. Simulated average monthly liquid water forcing (rain+snowmelt) in the Far-Future models for the 75 years historical run with daily forcing as well as five projected 15-year end-century climate scenarios.

Comparison of AET results reveal that the AET after freshet in March and April rises in magnitude more sharply in the end-century climate projection scenarios compared to the historical reference run (Figure 5-27). The AET in summer months is also of greater magnitude.

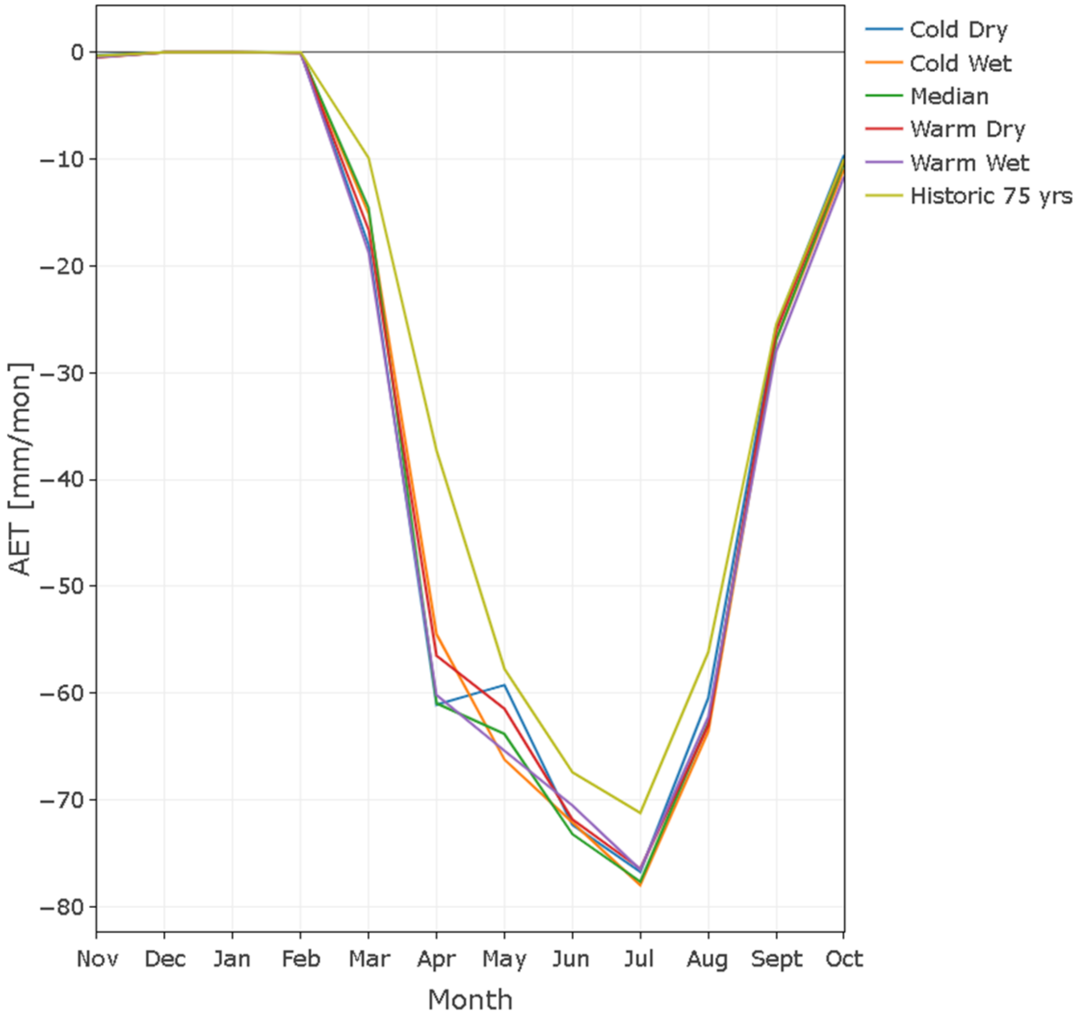


Figure 5-27. Simulated average monthly AET in the Far-Future Model in the 25-year average run and in five projected 15-year end-century climate scenarios. Note: AET is given as a negative flux out of the HGS model.

Figure 5-28 shows the monthly average McClelland Lake levels in the historical climate (75 years) run and the end-century climate projections. The results indicate that McClelland Lake levels at the end of the 21st century could be ~5 to10-cm lower than the levels being simulated using the historical reference run.

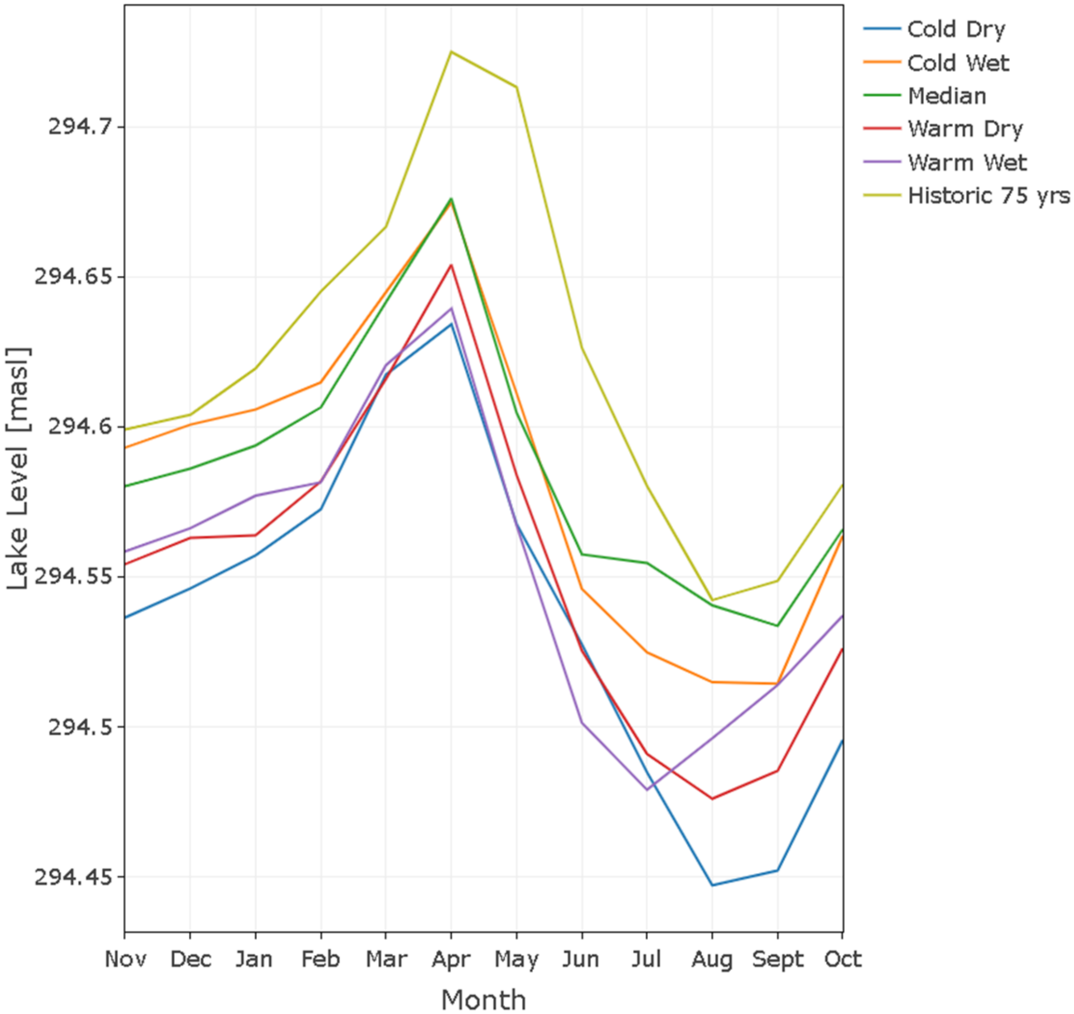


Figure 5-28: Simulated average monthly levels of McClelland Lake in the Far-Future Model with 75 years historical daily forcing and five projected 15-year end-century climate scenarios.

Figure 5-29 and Figure 5-30 show the exceedance curves of water levels in McClelland Lake and the non-mined portion of the MLWC fen in the Far-Future Model (end-century) simulations. The exceedance curves for McClelland Lake (Figure 5-29) for the projected end-century climate generally lie at or below that of the historical climate scenario. The offset between the envelope of lowest exceedance curve and the historical curve is 0.06 m (lower lake level) up to the 50th percentile and increases to 0.18 m by the 90th percentile. This indicates marginally lower average lake levels were projected under end-century climate compared to historical climate. These model results indicate that McClelland Lake will likely not experience large declines in its level, provided the end-century climate stays within the bounds of the ensemble of projected climate scenarios.

The exceedance curves for the fen (Figure 5-30) do not exhibit a wide range of projected fen water levels, showing negligible difference in range between projections at the 50th percentile

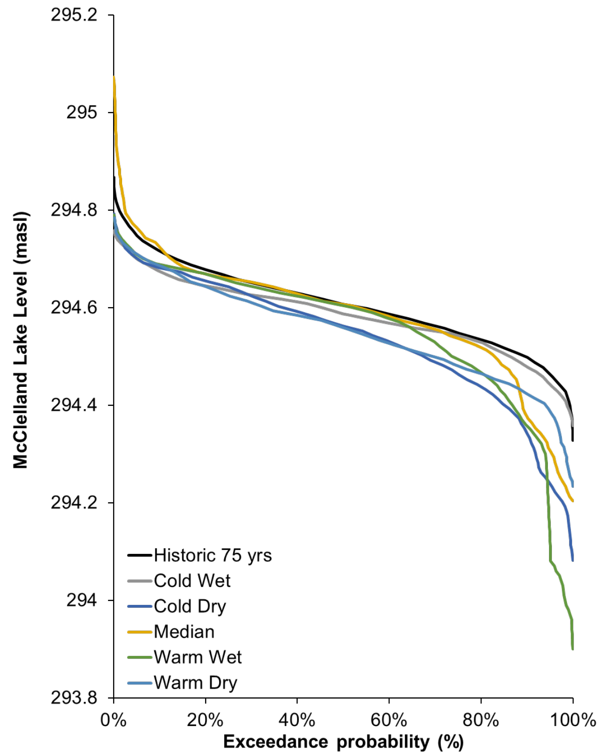


Figure 5-29. Exceedance curves of water levels in McClelland Lake in the Far-Future Model for historical climate and end-century projected climate.

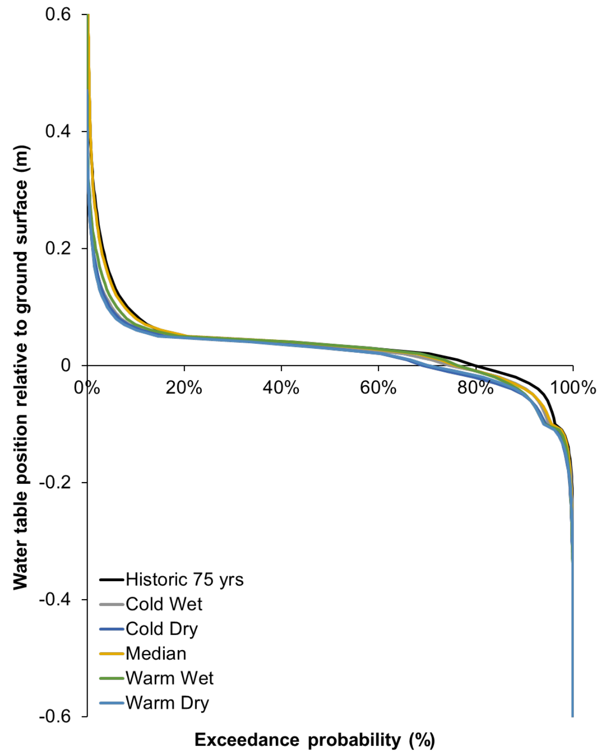


Figure 5-30. Exceedance curves of water levels in the non-mined portion of the MLWC fen in the Far-Future Model for historical climate and end-century projected climate.

5.5 2020 MLWC HGS Watershed Water Balance Model

5.5.1 Scenario Description

The 2020 MLWC HGS Watershed Water Balance model (Water Balance Model) was constructed to provide supporting water balance information for the baseline hydrogeological and hydrological analyses performed for Objective 1 in the MLWC OP and to provide supplementary water balance information used to support conceptual interpretations of landscape hydrologic response areas (HRAs) (Section 1.3 of Appendix F of the MLWC OP). The MLWC surface watershed was used as the area of analysis for the water balance results shown in Table 5-2.

5.5.2 Results

Table 5-2 presents annual water balances over the time period 1945 to 2019 in addition to an overall long-term average water balance for the MLWC watershed. The dynamic nature of the western GW divide is fully accounted for in the computation of these water balances. As can be seen in Table 5-2, the water balance results are in good general agreement with the conceptual understanding of the system in that AET is typically the largest water sink term in a given year. As well, the water balance results clearly indicate that predicted SW losses (runoff) occurring primarily through the lake outlet into McClelland Creek peaked in the mid 1970's and have been declining since approximately 2000.

Table 5-2: Summary annual water balances (1945 to2019) computed using the Water Balance Model.

Year	ΔGW storage (mm/yr)	ΔSW storage (mm/yr)	ΔTotal storage (mm/yr)	Precip (mm/yr)	AET (mm/yr)	Net GW (mm/yr)	NET Runoff (mm/yr)	Total Flux (mm/yr)
1945	123.1	54.0	177.0	365.0	264.1	53.5	-3.3	151.2
1946	25.1	2.0	27.1	379.5	316.8	-13.6	-24.1	24.9
1947	-0.6	-0.2	-0.8	350.4	282.0	-43.8	-28.2	-3.6
1948	-38.6	-19.9	-58.5	288.4	274.7	-51.0	-15.2	-52.5
1949	17.4	4.8	22.3	401.3	319.0	-56.5	-1.3	24.5
1950	-19.9	1.7	-18.2	335.6	278.8	-55.3	-12.9	-11.3
1951	23.1	14.9	38.0	443.3	298.0	-68.2	-41.5	35.6
1952	1.7	-3.6	-1.9	403.1	322.8	-89.8	-19.0	-28.6
1953	-17.1	-4.7	-21.8	352.5	292.5	-65.1	-12.9	-17.9
1954	49.3	28.5	77.8	508.2	317.6	-93.7	-43.5	53.4
1955	5.6	-7.6	-2.0	460.3	338.7	-61.0	-57.3	3.3
1956	63.6	34.3	97.9	584.6	349.6	-66.9	-70.5	97.6
1957	-26.0	-30.2	-56.2	423.1	325.7	-71.5	-88.5	-62.6
1958	14.2	3.4	17.7	490.6	319.3	-62.9	-82.9	25.4
1959	41.2	28.3	69.5	524.8	313.2	-78.1	-75.1	58.4
1960	42.2	5.0	47.2	602.6	353.4	-66.0	-131.0	52.2
1961	-64.0	-45.0	-109.0	396.2	341.2	-68.9	-98.9	-112.8
1962	54.9	25.7	80.6	587.7	345.9	-72.8	-90.9	78.1
1963	-46.9	-26.7	-73.5	406.9	335.3	-65.0	-76.6	-69.9
1964	-27.5	-6.8	-34.4	400.1	333.9	-70.6	-32.5	-36.8
1965	-23.9	2.7	-21.3	374.4	306.7	-63.1	-19.0	-14.4
1966	26.1	18.4	44.5	490.1	327.7	-71.4	-47.7	43.3

Year	ΔGW storage (mm/yr)	ΔSW storage (mm/yr)	ΔTotal storage (mm/yr)	Precip (mm/yr)	AET (mm/yr)	Net GW (mm/yr)	NET Runoff (mm/yr)	Total Flux (mm/yr)
1967	12.1	-0.1	12.0	493.7	333.7	-74.8	-77.0	8.2
1968	14.8	8.8	23.6	481.8	329.7	-86.7	-64.8	0.5
1969	11.4	8.1	19.5	488.5	323.5	-63.1	-75.3	26.6
1970	64.6	20.7	85.3	663.5	383.9	-74.7	-127.0	77.9
1971	-87.2	-60.2	-147.4	344.6	342.2	-63.5	-84.6	-145.7
1972	18.4	21.7	40.2	492.5	340.9	-67.5	-43.3	40.7
1973	96.0	43.3	139.3	727.6	398.2	-83.5	-123.3	122.7
1974	-19.9	-28.8	-48.7	511.8	349.0	-56.3	-149.8	-43.3
1975	25.5	22.5	48.0	573.9	359.8	-65.1	-102.6	46.4
1976	-1.9	-11.8	-13.7	544.0	379.1	-70.8	-115.0	-20.9
1977	-61.5	-38.2	-99.7	410.8	350.9	-71.3	-93.7	-105.1
1978	7.6	29.7	37.3	460.7	318.3	-90.6	-37.2	14.6
1979	-5.1	-5.5	-10.5	476.9	333.4	-69.0	-82.5	-8.0
1980	3.9	8.1	12.0	495.8	353.2	-65.4	-61.2	16.0
1981	-97.5	-56.6	-154.1	315.2	352.2	-69.8	-50.8	-157.6
1982	5.5	12.5	18.0	435.4	314.3	-64.7	-32.0	24.4
1983	-35.6	-13.2	-48.7	359.9	319.4	-88.2	-17.9	-65.7
1984	50.1	28.8	78.9	552.0	371.3	-75.1	-32.7	73.0
1985	-13.7	-8.2	-21.9	441.8	330.9	-70.9	-61.7	-21.8
1986	-25.3	-9.8	-35.1	404.4	336.8	-76.2	-33.7	-42.4
1987	-19.2	-9.0	-28.2	394.9	335.7	-90.0	-21.5	-52.3
1988	32.7	23.8	56.5	505.8	357.5	-79.1	-22.5	46.5
1989	20.1	10.1	30.2	503.7	358.2	-66.6	-50.0	28.9
1990	-25.0	-20.4	-45.5	440.9	358.1	-66.8	-58.8	-42.9
1991	56.5	26.8	83.4	600.5	396.5	-66.1	-52.9	85.0
1992	-15.0	-6.7	-21.7	447.4	340.9	-70.3	-64.3	-28.1
1993	-27.2	-16.7	-43.9	405.0	341.7	-63.2	-40.4	-40.3
1994	-55.1	-25.3	-80.4	351.8	341.6	-71.2	-19.4	-80.5
1995	31.0	28.5	59.4	464.5	328.2	-75.0	-8.0	53.3
1996	81.2	48.3	129.6	621.4	355.3	-85.1	-70.3	110.6
1997	-9.3	-18.5	-27.8	475.2	356.3	-65.6	-81.9	-28.5
1998	-125.2	-68.7	-193.9	245.4	323.3	-93.4	-48.3	-219.5
1999	-22.8	-16.1	-38.9	337.3	303.9	-68.5	0.0	-35.1
2000	42.5	27.2	69.7	460.0	322.9	-72.8	0.0	64.2
2001	-56.9	-12.6	-69.4	326.8	324.2	-61.1	-5.6	-64.1
2002	18.6	26.8	45.4	412.4	301.1	-76.8	-1.3	33.1
2003	19.2	14.0	33.2	466.8	343.6	-69.8	-19.3	34.2
2004	-34.9	-15.2	-50.1	357.3	291.0	-73.4	-43.2	-50.2
2005	9.3	4.1	13.4	416.5	320.7	-78.7	-10.5	6.6
2006	-52.8	-31.7	-84.5	343.2	346.5	-68.1	-8.5	-79.9
2007	-59.1	-28.5	-87.6	258.6	270.8	-72.7	0.0	-84.9
2008	24.2	1.5	25.7	388.5	287.5	-75.6	0.0	25.4
2009	33.8	32.4	66.3	451.5	316.5	-91.5	0.0	43.5
2010	-24.5	-9.8	-34.3	360.7	321.3	-65.8	-0.5	-27.0
2011	-33.7	-22.8	-56.5	300.2	283.2	-72.9	0.0	-55.9

Year	ΔGW storage (mm/yr)	ΔSW storage (mm/yr)	ΔTotal storage (mm/yr)	Precip (mm/yr)	AET (mm/yr)	Net GW (mm/yr)	NET Runoff (mm/yr)	Total Flux (mm/yr)
2012	60.0	18.3	78.2	460.5	310.3	-70.4	0.0	79.8
2013	4.7	24.4	29.1	427.3	325.2	-69.4	-2.9	29.7
2014	8.5	10.4	18.9	414.4	316.4	-64.7	-8.9	24.4
2015	-42.8	-25.3	-68.1	323.9	306.3	-66.7	-11.3	-60.4
2016	47.5	15.2	62.7	463.8	329.4	-67.6	0.0	66.8
2017	-71.0	-26.0	-97.0	286.9	302.7	-60.2	-8.6	-84.5
2018	31.7	13.4	45.1	437.7	319.6	-61.7	0.0	56.4
2019	15.8	5.6	21.4	417.8	324.0	-64.0	0.0	29.7
Average (1944-2019)	0.6	0.4	1.0	437.5	328.5	-68.2	-42.6	-1.8

Note: Δ indicates a change in water storage.

6.0 MODEL VERACITY

The 2020 MLWC HGS model is a series of hydrological models developed to simulate a complex natural hydrological system in addition to anthropogenic modifications made to that system due to the proposed development of the Fort Hills Lease. All models are simplified representations of the system or features that they are used to simulate. All models, including numerical models of hydrological processes, require some degree of simplifying assumptions pertaining to the system they are simulating and the underlying physical processes. These necessary simplifications and assumptions inevitably introduce a degree of uncertainty into the results of the model. Qualitatively and quantitatively assessing modelling uncertainty provides information that can be used to gauge the level of confidence to be placed in the results during decision making.

In the following sub-sections, information is provided to gauge the level of confidence to be placed in the results of the 2020 MLWC HGS model (the model veracity). This is accomplished by means presenting additional model sensitivity, model uncertainty and model validation testing work performed using the 2020 MLWC HGS model but not discussed in previous sections of this document. These additional model results also provide more insight into some of the model parameter values used and the basis for some of the assumptions made in building, calibrating, and applying the 2020 MLWC HGS model.

6.1 Model Sensitivity

A sensitivity analysis was conducted on the cutoff wall implemented in the operations scenario conducted using the Operations Model. Preliminary work commissioned by FHEC by others and conducted for the water management design features design indicated that the hydraulic conductivity of the proposed cutoff wall at the MLWC, consisting of mixed soil/grout bentonite, would have a targeted operational hydraulic conductivity of $1x10^{-9}$ m/s and 1-metre thick. Cutoff walls are made of low permeability materials but are not impermeable, some degree of GW flow through the cutoff wall is to be expected. The purpose of the sensitivity analysis was to better understand how much GW flow can be expected through the cutoff wall as a function of its hydraulic conductivity. This was done to better understand how much GW might seep through the cutoff wall, if its hydraulic conductivity target is not achieved during construction or if a different type of cutoff with a higher targeted hydraulic conductivity were constructed instead. The section of the cutoff wall considered (cutoff wall location shown in Figure 6-1) is the portion crossing the MLWC fen. The simulation period in all three cases described below was 2014 to 2063.

A 1-m thick cutoff wall is beneath the resolution of the Operation Model's numerical mesh (element size along the cutoff in the mesh was on the order of 50 m) and this had to be accounted for in the sensitivity analysis. Effective hydraulic conductivities, that yield the same Darcy flux as would be derived with a 1-m thick cutoff wall and the targeted hydraulic conductivity, were assigned to the wall elements in the model to account for the difference in targeted versus simulated cutoff wall thickness. Three separate sensitivity runs were conducted to determine the GW flux through a cutoff wall with targeted hydraulic conductivities of $1x10^{-9}$ m/s, $1x10^{-8}$ m/s, and $1x10^{-7}$ m/s.

Groundwater fluxes simulated using the three hydraulic conductivities are shown in Figure 6-1. The results for a cutoff wall with a hydraulic conductivity of $1x10^{-9}$ m/s indicate that near negligible GW will pass through the wall, even as North Pit begins to approach this part of the wall in late 2043, causing the GW gradient to flip and inducing GW flow from the fen towards North Pit. The results for a cutoff wall with a hydraulic conductivity of 1x10^{-8} m/s, shown in Figure 6-1, indicate that after 2043 GW flow rates from the fen, across the wall and into North Pit could peak at rates of approximately 200 to 300 m^3/d along the fen section of the cutoff wall. A cutoff wall with a hydraulic conductivity of 1x10^{-7} m/s could allow as much as 2000 m^3/d to drain from the fen into North Pit post-2043.

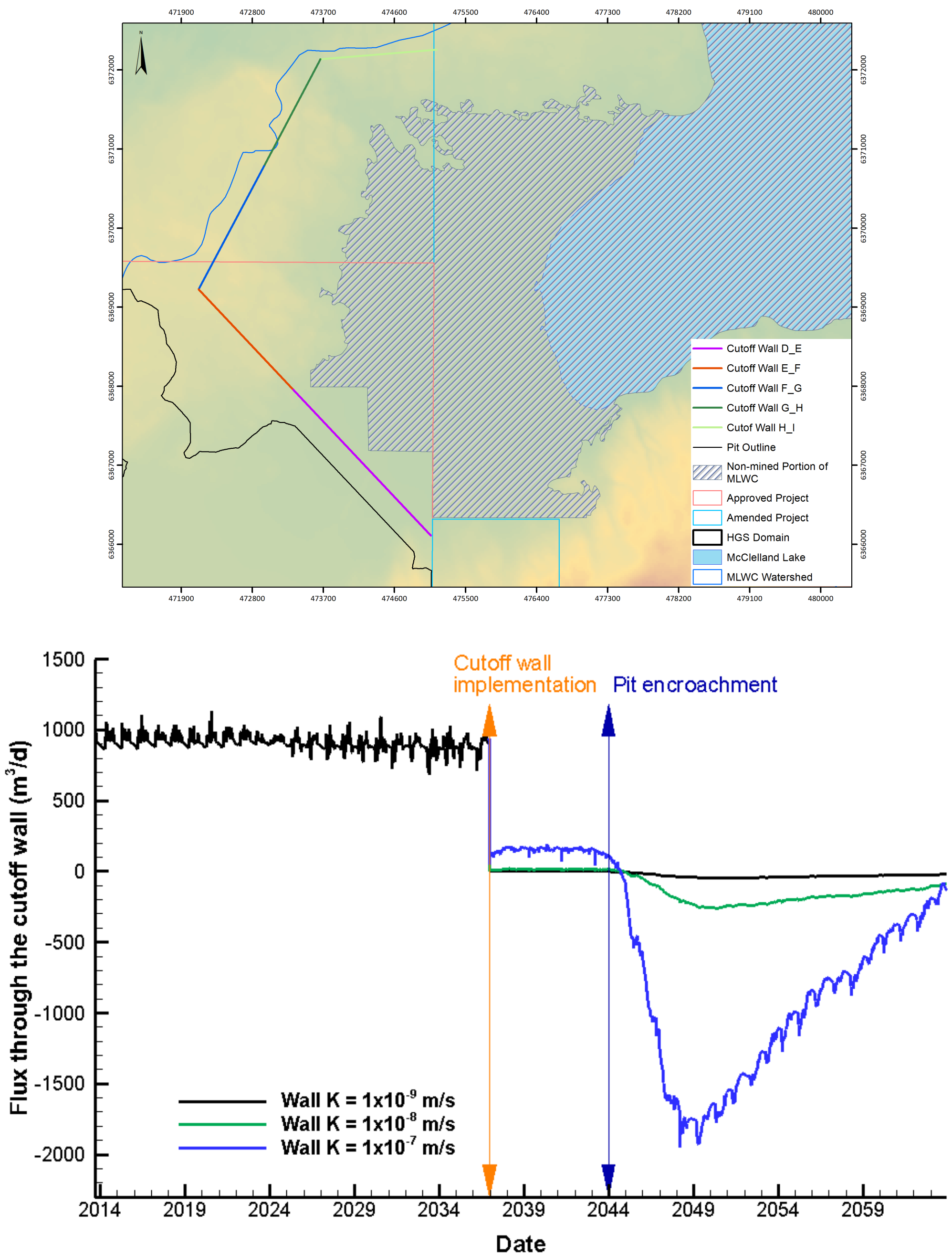


Figure 6-1: GW flux (bottom panel) through the cutoff wall in the fen area (i.e., D_E segment in the top panel)

A sensitivity analysis was also conducted to investigate the relationship between the peat hydraulic conductivity and the corresponding degree to which the model predicts the propagation of mining impacts (reductions in GW levels) into the non-mined portion of the MLWC fen. The mining impacts as a function of peat hydraulic conductivity were assessed with mine operations but no mitigation measures (no cutoff wall, no SW resupply, and no NOP GW injection). A comparable no mining simulation was also conducted to establish the non-disturbance GW levels used to produce the drawdown maps shown in Figure 6-2. Two peat hydraulic conductivity profiles were tested: 1) the calibrated peat hydraulic conductivity profile (which was based on laboratory measurements from MLWC peat cores and field hydraulic conductivity tests); and, 2) a second profile that assumed the peat hydraulic conductivity is two orders of magnitude higher. The peat hydraulic conductivity profiles are shown in Figure 6-3. The simulated impacts from mining in the absence of mitigation are shown in Figure 6-2. The results indicate that increasing the peat hydraulic conductivity by two orders of magnitude above its calibrated value will cause an additional (but relatively moderate) 8 cm drop in the water table along the margins of the non-mined portion of the MLWC fen, and the simulated drawdown would extend slightly further into the non-mined portion of the MLWC.

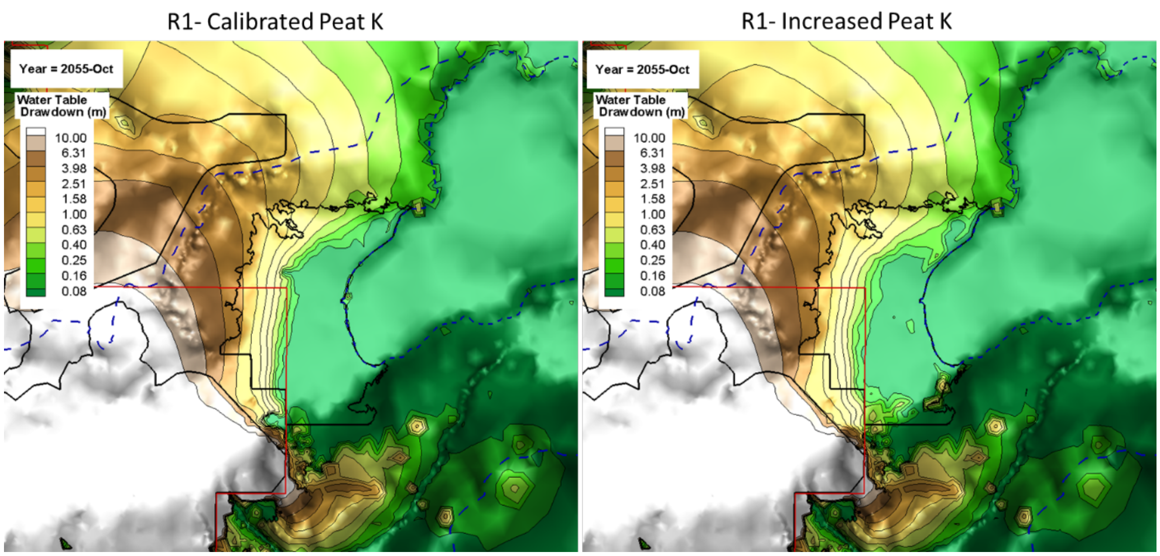


Figure 6-2: Simulated water table drawdown within the fen peat hydraulic conductivity for the calibrated peat hydraulic conductivity scenario (left panel) and the peat hydraulic conductivity increased by two-orders-of-magnitude scenario.

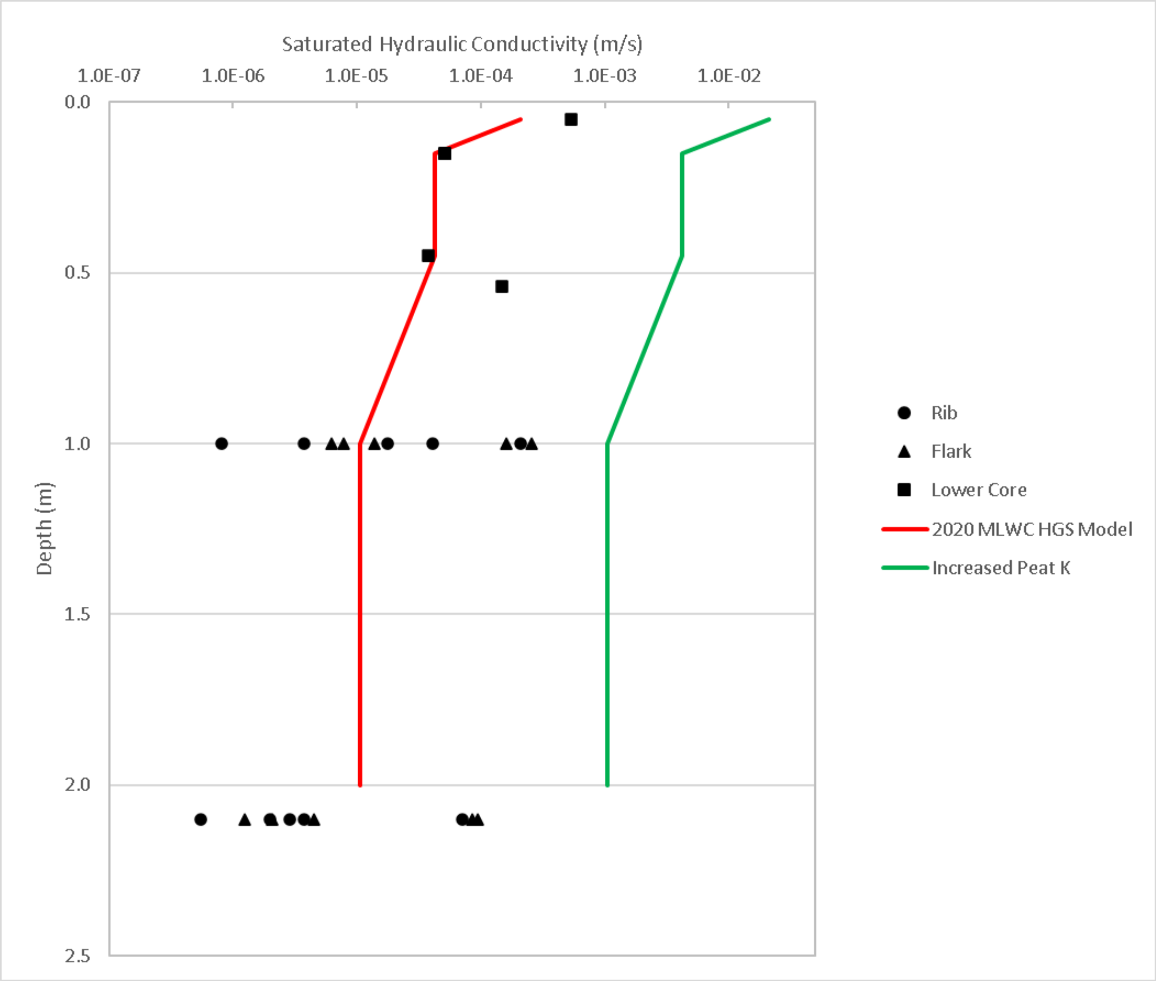


Figure 6-3: Measured peat hydraulic conductivity (black markers) versus the calibrated hydraulic conductivity profile (red curve) and increased peat hydraulic conductivity profile used in peat hydraulic conductivity sensitivity runs (green curve).

A sensitivity analysis was conducted with respect to the degree of physical rigour required for simulating winter processes in the model and the influence on the simulated results. Previous generations of the MLWC HGS model implemented simpler representations of winter processes and this was identified as an area of model improvement in 2019, particularly the addition of the freeze-thaw process (Aquanty, 2019). As discussed in Section 3.5, the freeze-thaw process was added to the 2020 MLWC HGS model by adjusting the surface domain conductivity and near surface soil hydraulic conductivity over the winter to mimic the reduced hydraulic conductivity due to freezing. Figure 6-4 presents modelled vs. observed head levels in the fen (in well GT07-97C), illustrating one case where the freeze-thaw process was implemented and a second where it was not. The observed data (the red and orange lines) in Figure 6-4 illustrate how GW levels at this location in the fen increase during winter and then drop again with the onset of the freshet. This behavior is thought to be consistent with the white ice buildup during winter observed at a different patterned fen in the WBF and reported in Price and Fitzgibbons (1987). Similarly, the simulated GW heads in the scenario that included the freeze-thaw process also predict a buildup in GW head over winter and a decline after the freshet, and with similar magnitudes as the observed data. Conversely, the scenario that does not consider the freeze-thaw process does not predict the observed

GW head build up during winter. The results shown in Figure 6-4 were used, in part, to justify the inclusion of freeze-thaw processes in the 2020 MLWC HGS model.

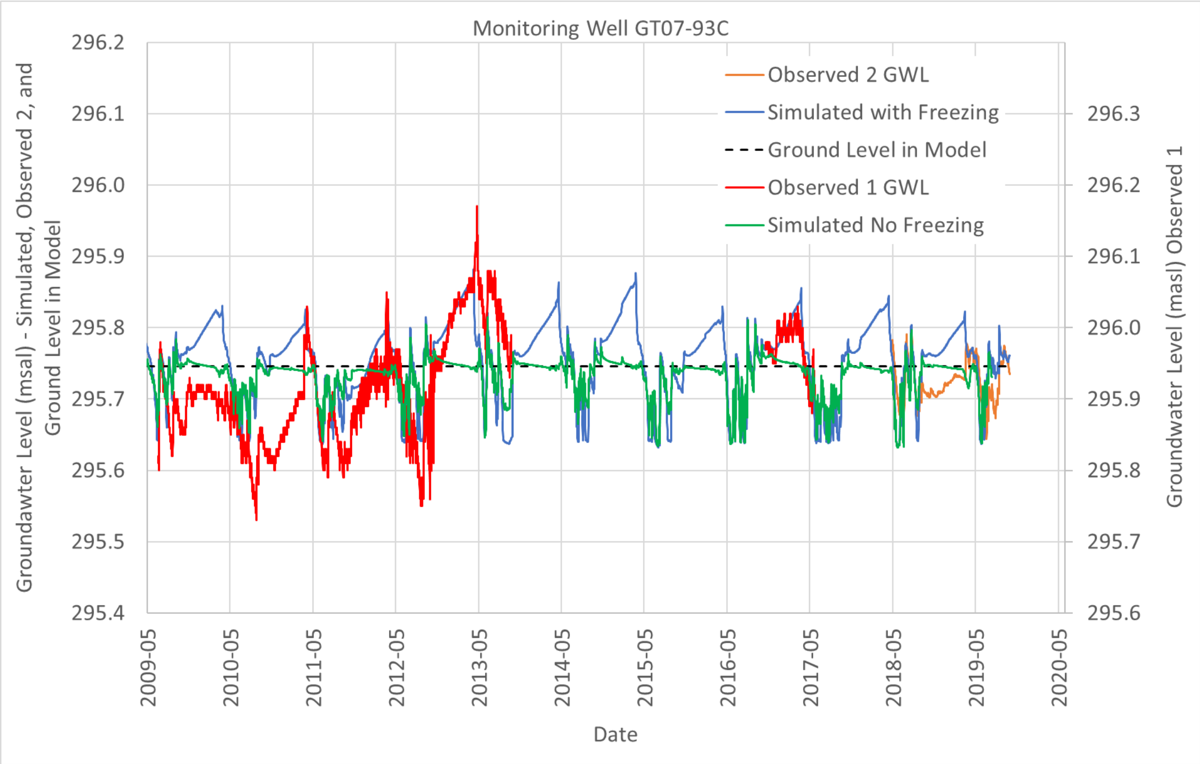


Figure 6-4: Simulated and observed hydraulic head levels in GT-07-093C well in the fen when surface/near surface freezing over the winter is included/excluded in the 2020 MLWC HGS model. Note: A vertical datum offset error of 0.2 m was present in the observations prior to 2018 is adjusted for by plotting the pre-2018 levels on the righthand y-axis.

6.2 Model Assumptions and Limitations

Uncertainty in model results, especially models that simulate complex hydrological settings, can come in many forms, all of which have the potential to influence the predictive veracity of the model and therefore the interpretation of its results both by the modeller and the end users of the work. In this section, different sources of uncertainty in the 2020 MLWC HGS model are identified, along with the steps that were taken to mitigate that uncertainty.

6.2.1 Numerical Model Accuracy

HydroGeoSphere uses numerical schemes to solve the non-linear partial differential equations for surface (2D St. Venant equation, diffusive wave approximation) and subsurface water levels (3D Richards' equation for variably saturated flow). The solution of the numerical approximations of these flow equations is completed to a user-specified tolerance. Post-simulation, the accuracy of the results can be evaluated by calculating the water balance error that is introduced by the numerical solution. In

HGS, the water balance error is calculated as the ratio of the net water flux of all model boundaries relative to the net change of water storage of the model. The water balance error for the family of 2020 MLWC HGS models is summarized in Table 6-1 below. A water balance closure error of <1% was considered adequate based on the recommended threshold for acceptable model error by Anderson et al. (2015).

Table 6-1: Summary of numerical water balance errors for the suite of 2020 MLWC HGS models.

Model Build Name	Water Balance Error (%)
Baseline	0.02%
Operations (R0)	0.5%
Operations (R1)	0.4%
Operations (S1)	0.4%
Closure	0.2%
Watershed Water Balance	0.6%

Calculation of water balance components for sub-areas within the 2020 MLWC HGS is associated with a higher closure error than reported in Table 6-1. This is a result of the complexities of calculating fluxes within sub-areas of a control volume finite element model. Therefore, to mitigate this uncertainty, the 2020 MLWC HGS Watershed Water Balance model was constructed with model boundaries coincident with the watershed divide (thereby facilitating a more accurate watershed-wide water balance). The average annual mass balance error for the 2020 MLWC HGS Watershed Water Balance model, 1944 to 2019, was 0.6%, and calculated as follows:

$$WB\ Error = \frac{ABS(Net\ Flux\ In\ and\ Out - Change\ in\ Storage)}{MAX(\sum Flux\ In\,, ABS(\sum Flux\ Out))}$$

6.2.2 Mesh Resolution

Finer mesh resolution increases model realism by enabling capture of more detail in surface or subsurface features. However, integrated surface-subsurface models such as HGS are computationally expensive and can require a prohibitively long model run time, if the number of computational nodes in the model are too high due to a high degree of spatial refinement of the mesh. Therefore, a trade-off must be made between the total number of computational nodes that can be included in a model and an acceptable model run time. For the 2020 MLWC HGS model, a nominal model run time of 1 to 2 weeks, for simulations spanning up to 75 years, was considered acceptable. Process complexity that contributed to model run time included: surface and subsurface freezing and thawing processes as well as mine operations (excavation, dewatering and depressurization).

It is important to note that the 2020 MLWC HGS models for the Fort Hills Lease were designed to address large scale water balance questions under different conditions/periods (i.e., historical, operations, closure). Since the model is ~ 1,000 km2, the mesh resolution is relatively coarse in some areas; for instance, the horizontal mesh resolution varied between 100 to 1200 m with the finer resolution being applied in the fen and coarser resolution applied to areas distal to the MLWC watershed; as such, the model should be interpreted as a high-level water balance model to provide insights on how water is moving through the system. The hydrologic behaviour of local features including ribs and flarks of the patterned fen were upscaled to provide an equivalent hydrologic response of the patterned fen using a coarser mesh, and using nominal 100-m node spacing in the fen was justified via the upscaling approach. Details of the approach used to upscale fen parameterization is available in Attachment B.

In addition, it was not practical from a computational runtime point of view to have a large number of vertical layers to allow the inclusion of finer scale heterogeneities within individual hydrostratigraphic units. Such heterogeneities, which are likely present in the field, were instead implicitly lumped by assigning each hydrostratigraphic unit a unique but uniform set of hydrogeological properties. As a result, the calibrated hydraulic properties for individual hydrostratigraphic units should be considered effective properties, lumping the influence of localized heterogeneity into their respective calibrated values. This is a standard simplification common to three-dimensional physics-based environmental models, regardless of the chosen numerical code used to perform the work.

6.2.3 Geological Heterogeneity

Structural uncertainty relates to the conceptual model and represents uncertainty in the conceptualization of the system itself. For example, what is the impact of an aquitard not being present in the model, or a fault that is unaccounted for. In some cases, the inability to calibrate a certain portion of the model may indicate that there is a structural problem with the model conceptualization.

While structural uncertainty is undoubtedly important, there are currently no efficient tools/methodologies available to systematically mitigate structural uncertainty when using complex physics-based hydrologic models. As such, the approach taken in the 2020 MLWC HGS model was to identify potential sources of structural uncertainty and, if warranted, perform deterministic simulations to investigate the potential impacts on the predictive veracity of the model.

One example of the geologic heterogeneity within the FHUC involves the presence of low and high hydraulic conductivity zones within the Silty Sand AQ4 hydrostratigraphic unit. The initial interpretation of this unit was based solely on field data consisting of borehole logs and well testing data which suggested that Silty Sand AQ4 should be conceptualized as consisting of a moderately low hydraulic conductivity silty sand matrix with local pockets of higher hydraulic conductivity sand (See Figure 6-5).

Silty Sand AQ4 proved challenging to calibrate because it was relatively insensitive during the initial long-term automated calibration. Moreover, when the well testing results were used to manually calibrate the Silty Sand AQ4 as a check on the automated calibration value assigned to AQ4, it was discovered that the manually calibrated Silty Sand AQ4 conductivities required much higher hydraulic conductivities to successfully replicate the well testing results. It should be noted however, that the well testing results were conducted at locations in Silty Sand AQ4 that specifically targeted high hydraulic conductivity pockets of materials within this hydrostratigraphic unit.

The original conceptualization of Silty Sand AQ4's hydrostratigraphy was revisited due to the challenges encountered when calibrating this unit. Specifically, the sand fraction at each borehole was used to define zones of high conductivity and low conductivity material within the Silty Sand AQ4 (see Figure 4-6). These distinct zones within Silty Sand AQ4 could now be parameterized independently, allowing the model to reproduce the pumping tests in the high conductivity zone (AQ4) while maintaining the mapped low conductivity zone in the siltier regions (PGKM). The approach taken to break up the original Silty Sand AQ4 unit was relatively simplistic and additional pumping tests and drilling in the region may yield an improved delineation of these high and low conductivity zones.

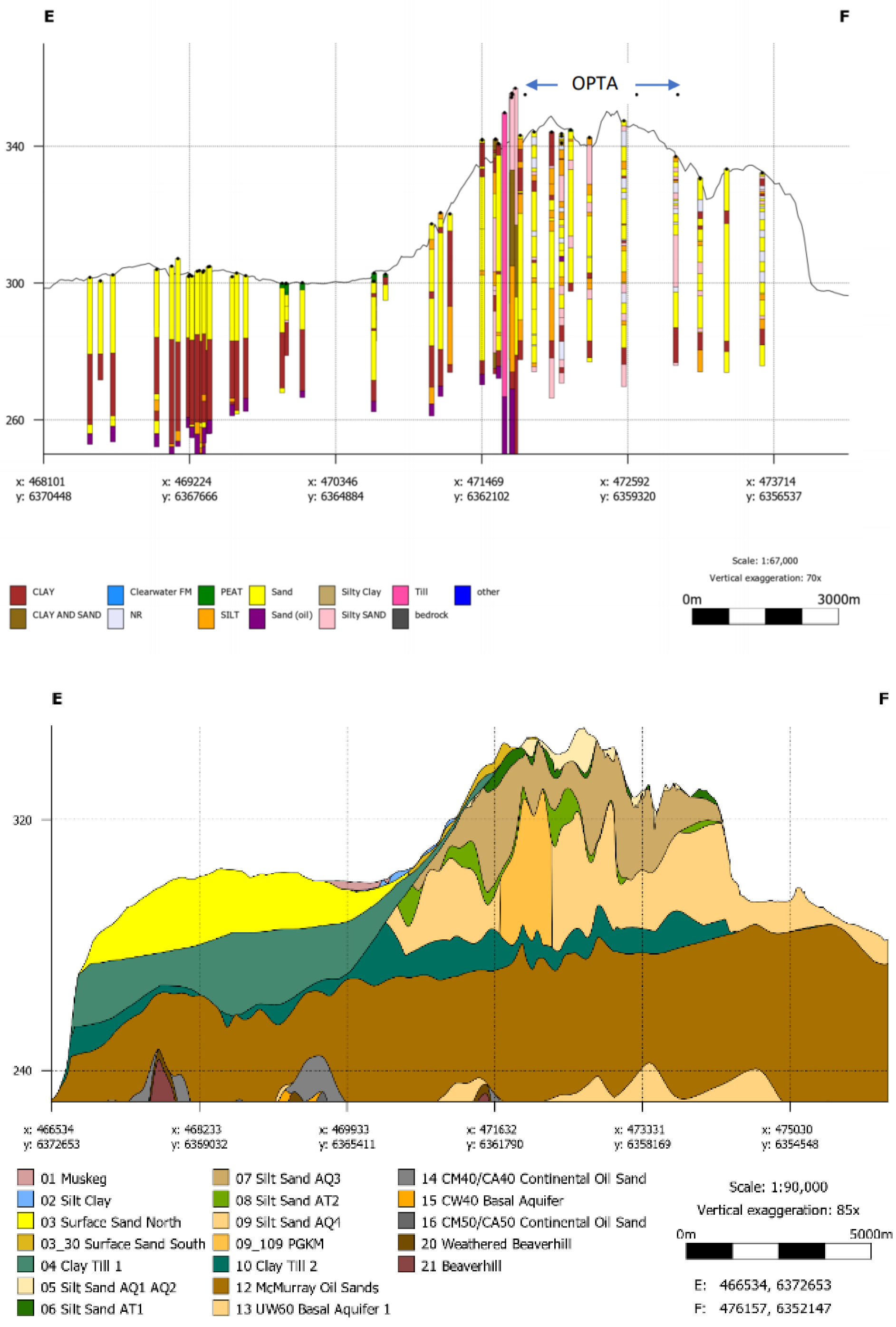


Figure 6-5. Cross-sections: illustrating the degree of heterogeneity in borehole logs (top panel) relative to the interpreted hydrostratigraphy in the 2020 Unified Geomodel (bottom panel). Also note the modification of the Silt Sand AQ4 hydrostratigraphy to include a separate PGKM layer.

6.2.4 Parametric Uncertainty

The best available data and conceptual understanding of the system were used at the time of model construction and calibration. However, subsurface data is inherently uncertain. A formal parametric uncertainty quantification has not been performed with the 2020 MLWC HGS model. The complexity of the model, the long model runtimes, the requirement for a large numbers of runs (in the hundreds to thousands for uncertainty quantification methods like Latin Hypercube), precluded its use.

Associated with the degree of geologic heterogeneity present in naturally deposited materials, in particular in glaciated landforms, there exists some uncertainty in the calibrated hydraulic conductivity of the subsurface units. Figure 6-6 shows the relative sensitivity of the calibration targets (thus, the objective function of the automatic calibration) to the calibration parameters. The sensitivity corresponding to the subsurface hydraulic conductivity parameters is relatively less in comparison to the other parameters controlling surface ET or runoff processes. These sensitivity results make intuitive sense given that a large portion of the calibration targets incorporate near-surface or surficial hydrologic processes and inevitably the objective function will be more sensitive to the parameters controlling those phenomena (e.g., AET and McClelland Lake Level).

The assumed wetting and drying properties within the unsaturated zone, which help control soil moisture storage have associated uncertainties as do the specific storage values assigned to the confined aquifers. Both sources of uncertainty have the potential to impact calculated overburden dewatering and basal depressurization volumes.

Uncertainty in the simulated cutoff wall hydraulic conductivity is present given that the wall hydraulic conductivity cannot be known with certainty before the wall is built. The actual hydraulic conductivity of the cutoff wall will be a function of the material used and the construction methods employed. The cutoff wall sensitivity analysis results discussed in Section 6.1 indicate that if the constructed hydraulic conductivity of the cutoff wall is too high, its effectiveness in sustaining the non-mined portion of the MLWC fen could be affected, even if the remaining water management design features work as designed.

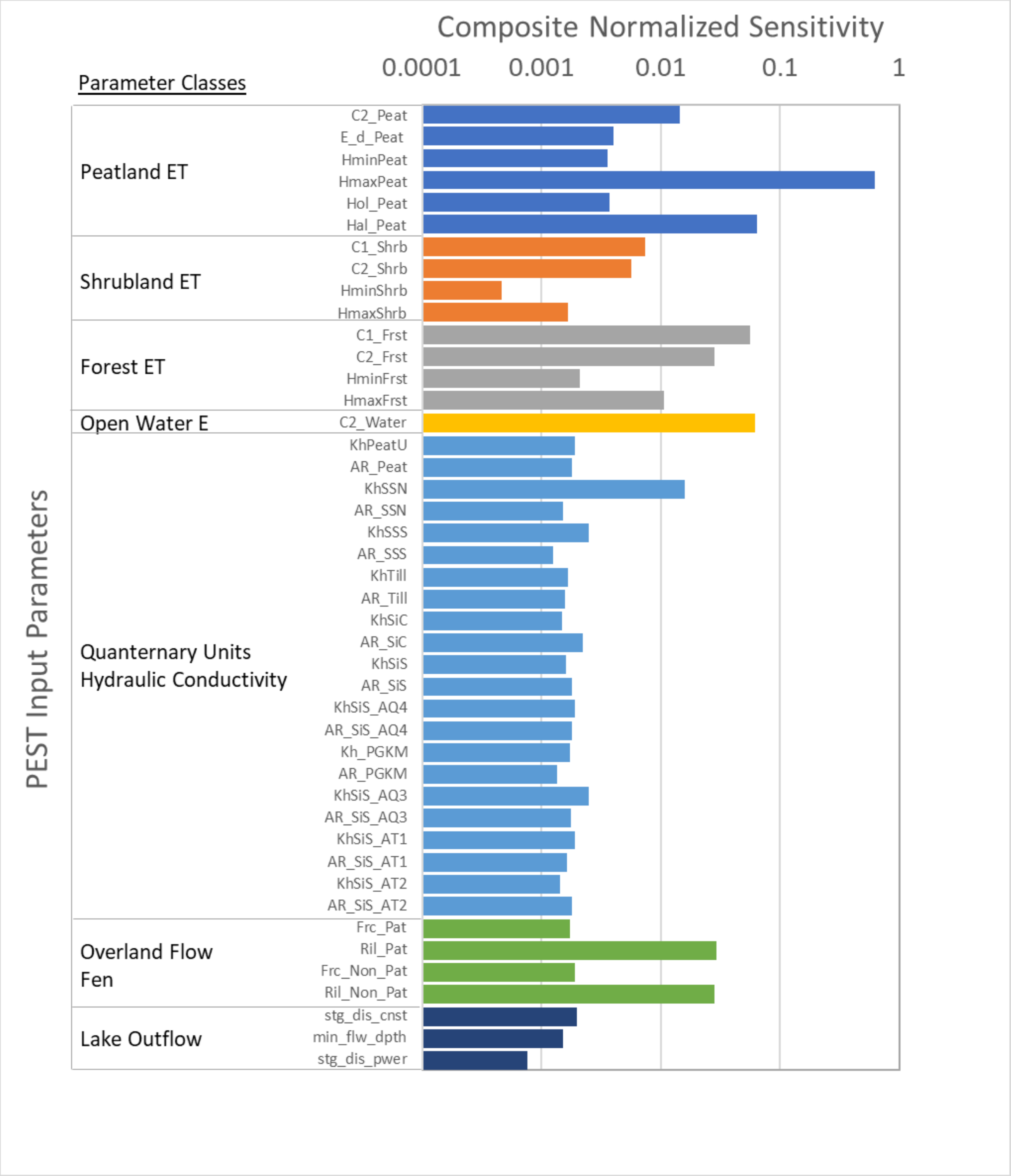


Figure 6-6: Composite normalized sensitivity of the calibration parameters in the automated calibration with PEST. Individual parameter descriptions are given in Table 4-3.

6.2.5 Role of Climate Data

Climate has the biggest relative effect on the modelled levels and flows as it is both the largest water source (precipitation) and water sink (evapotranspiration) in the Fort Hills Lease. As such, climate drives the overall water balance of the system. As with any form of measured data, the climate forcing data used in this study contains uncertainties. Specific to the 2020 MLWC HGS model, the major uncertainties include:

- Potential differences between the regional climate data (Fort MacMurray in Figure 6-7) used in the 2020 MLWC HGS model and local climate experienced at the Fort Hills Lease. As an example, annual precipitation rates recorded at the Bitumont station (located near the MLWC) were compared to those recorded at the Fort McMurray airport meteorological station (Figure 6-7). Differences in the annual precipitation rates recorded at the two stations are apparent during the overlapping time period spanned by the data. For instance, from 2005 to 2009 more precipitation was recorded at the Bitumont station compared to that recorded at the Fort McMurray station, and this difference was reflected in the simulated McClelland Lake levels during this period (Figure 4-16).
- The process of snow redistribution was not represented in the 2020 MLWC HGS model work, and relative importance of its exclusion in the final simulated results is currently unknown. Rigorous representation of winter processes in hydrological models is an ongoing challenge in general, especially for complex codes like HGS. Snow depths and densities before the freshet and thus the corresponding snowmelt rates and runoff volumes during the freshet were assumed to be uniform over the model domain. These simplifying assumption regarding winter processes introduce uncertainty into the simulation results in that snow does redistribute during the winter and snow depths on different landforms likely varies widely.
- Snow sublimation rates were included based on literature values for the WBF; however, to the best of our knowledge, sublimation measurements have never been performed in the Fort Hills Lease. As such, there is uncertainty in the assumed sublimation rates used.
- The net effect of the simplifying assumptions made for these winter processes is a degree of additional uncertainty in the computed timing and magnitude of snowmelt runoff during the freshet.

To assess and to confirm that the difference in precipitation shown in Figure 6-7 is the source of the mismatch between simulated and observed McClelland Lake level for the 2005 to 2009 period (Figure 4-11 and Figure 4-16) the calibrated model was run with a new precipitation time series which contained the Fort McMurray ECCC meteorological station (90 km from the model center) precipitation up to the end of 2003 and for 2011 to 2019, and precipitation from Bitumont ECCC station (13 km from the model center) for the 2004 to 2010 period. The simulated McClelland Lake level for this specific model run is compared to the observed data in Figure 6-8 showing a closer agreement between observed and simulated lake levels for the 2005 to 2009 period. These results confirm the that it is the difference between the precipitation at the Fort McMurray ECCC station and that of MLWC that has caused the mismatch for this period in the calibrated model. The motivation behind using the Fort McMurray climate data as model input was to have a relatively long and continuous historical dataset that is less susceptible to statistical variations that can complicate interpretation of model results.

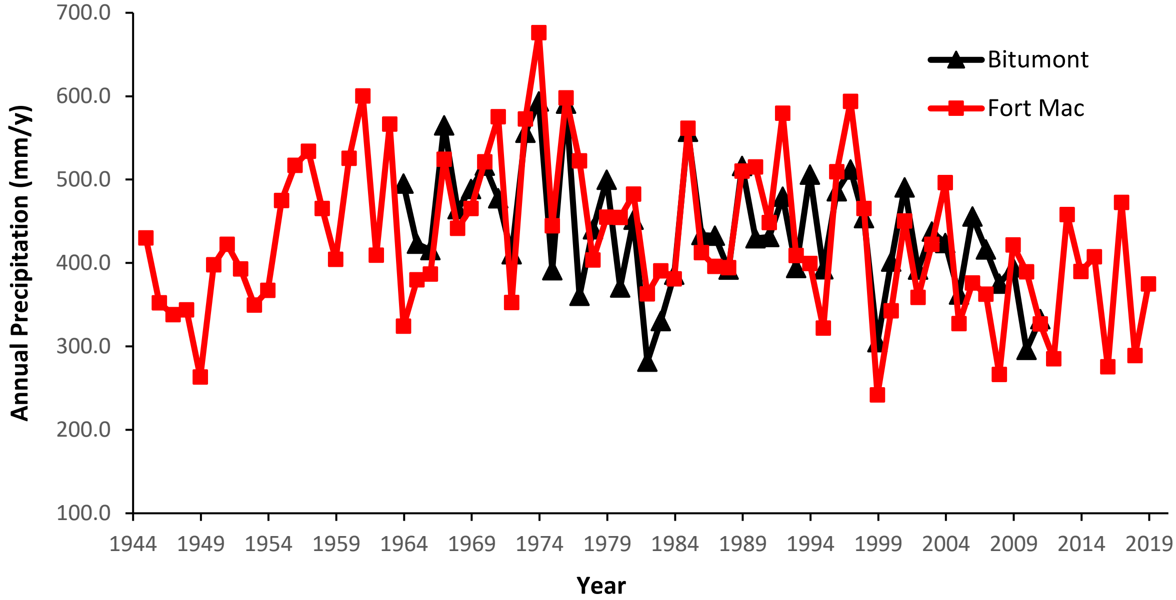


Figure 6-7: Comparison between annual average precipitation from the Fort McMurray Airport and Bitumont ECCC climate stations.

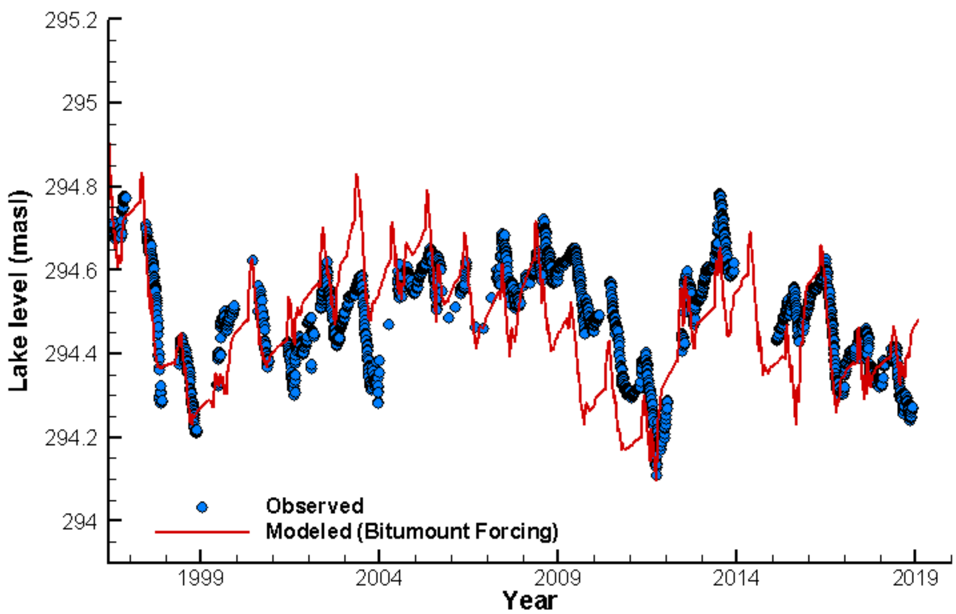


Figure 6-8: Computed McClelland Lake levels versus observed levels using the 2020 MLWC HGS model and Bitumont precipitation for 2004 to 2010 period with Fort McMurray precipitation outside of this period.

6.2.6 Data Available for Model Calibration

The models were calibrated to field observed data. This included 497 average GW head levels, 56 extremums (highs and lows) in McClelland Lake levels, and 6 long-term annual average AET values that were used as targets in the objective function for the transient automated calibration. All of these calibration targets rely on field measurements which have their own sources of uncertainty. Some of the key sources of uncertainty that could affect the 2020 MLWC HGS model calibration include:

- Of the available calibration targets, AET is one of the most difficult to reliably measure; leading to some uncertainty in the calibration targets. Despite this uncertainty, it represents one of the largest water sinks in the system and was included in the calibration to ensure that the relative AET for different hydrological response areas agreed with the conceptual understanding of the system.
- Uncertainty in the GW levels used for model calibration may arise from logger datum errors relative to manual measurements. The QA/QC process attempted to remove or reduce the obvious errors; however, it may not have been possible to identify and correct them all.
- Since the surface of the fen moves up and down over the period of a year due to peat swelling and shrinkage, this adds another level of uncertainty to the observed GW levels as the reference datum for the loggers may not be consistent during the recording period.
- Gauged SW flows are a common calibration target used in hydrological modelling. For the MLWC watershed, the outlet from McClelland Lake represents a logical SW outflow monitoring point. Indeed, the outlet from McClelland Lake was monitored on a semi-regular basis between 1997 and 2005 by RAMP. Following 2006, McClelland Lake outflow monitoring was discontinued until 2018, when monitoring was re-initiated by FHEC in the McClelland Lake outlet channel approximately 4 km downstream from the original RAMP L1 monitoring point. The lake outlet monitored by RAMP is a poorly defined channel through muskeg with known seepage bypassing the monitoring point, and hydrological assessments have deemed the gauged flow rates to be unreliable (Golder, 2018). Given the relatively small outflow from McClelland Lake (representing approximately 2% of the total precipitation falling on the watershed) and the known uncertainty in the gauged flow rates, it was decided to not use the data as model calibration targets.
- Due to computational constraints, model calibration was performed using a zonal approach, whereby all material properties are uniform within a given zone. A calibrated value for a zone should be interpreted as an effective value and should not be viewed as meaning that the entire zone is uniform in reality. As such, there is uncertainty in the exact distribution of material properties within the system.

6.2.7 Mine Plan Evolution

The representation of the 2021 IPA Mine Plan evolution within the 2020 MLWC HGS Model required simplifications and assumptions which will necessarily introduce uncertainty into the simulations. For the operational models presented in this report, a continuous mine evolution approach was represented by changing material properties and boundary condition values over time. While being able to run a continuous simulation of the mine is a significant improvement relative to classical snap-shot approach, it also means that not every surface feature is explicitly built into the model (e.g., roads or small stockpiles). Some of the uncertainties associated with the representation of the mine plan include:

- While the advance of the mine face and backfilling are continuous processes, the mine plan itself must be discretized in time to allow it to be represented within the numerical model. Initially the 5-year panels for the later years in the mine plan provided by FHEC were directly incorporated into the model; however, these 5-year steps were found to be too coarse and unable to accurately capture the maximum pit extents sequentially over time. To overcome this limitation, annual mine panel were interpolated from the provided 5-year status maps, potentially introducing a minor amount of predictive uncertainty in terms of simulated mine progression.

- Above ground features are not explicitly represented within the mesh, but rather represented using boundary conditions and material property changes.
- Laboratory or field-measured hydrogeological properties of tailings and backfill material were not available and were parameterized based on best available estimates.

6.3 Qualitative Model Validation

In addition to the quantitative model validation results presented in Section 4.4, a number of comparisons to secondary datasets are presented here as further evidence of the adequacy of the model performance.

6.3.1 Groundwater head levels in 2020 and 2021

2020 and 2021 GW head data from the Fort Hills Lease were used to perform a qualitative validation of the subsurface calibration of the model. None of the GW level data considered in this qualitative validation were used during the previous calibration work. Figure 6-9 illustrates the comparison between the average observed and average simulated hydraulic heads at each of the monitoring points for 2020 to 2021 period. The results show a good agreement between the observed and simulated heads, which confirms that the 2020 MLWC HGS Model is performing adequately out of its calibration period.

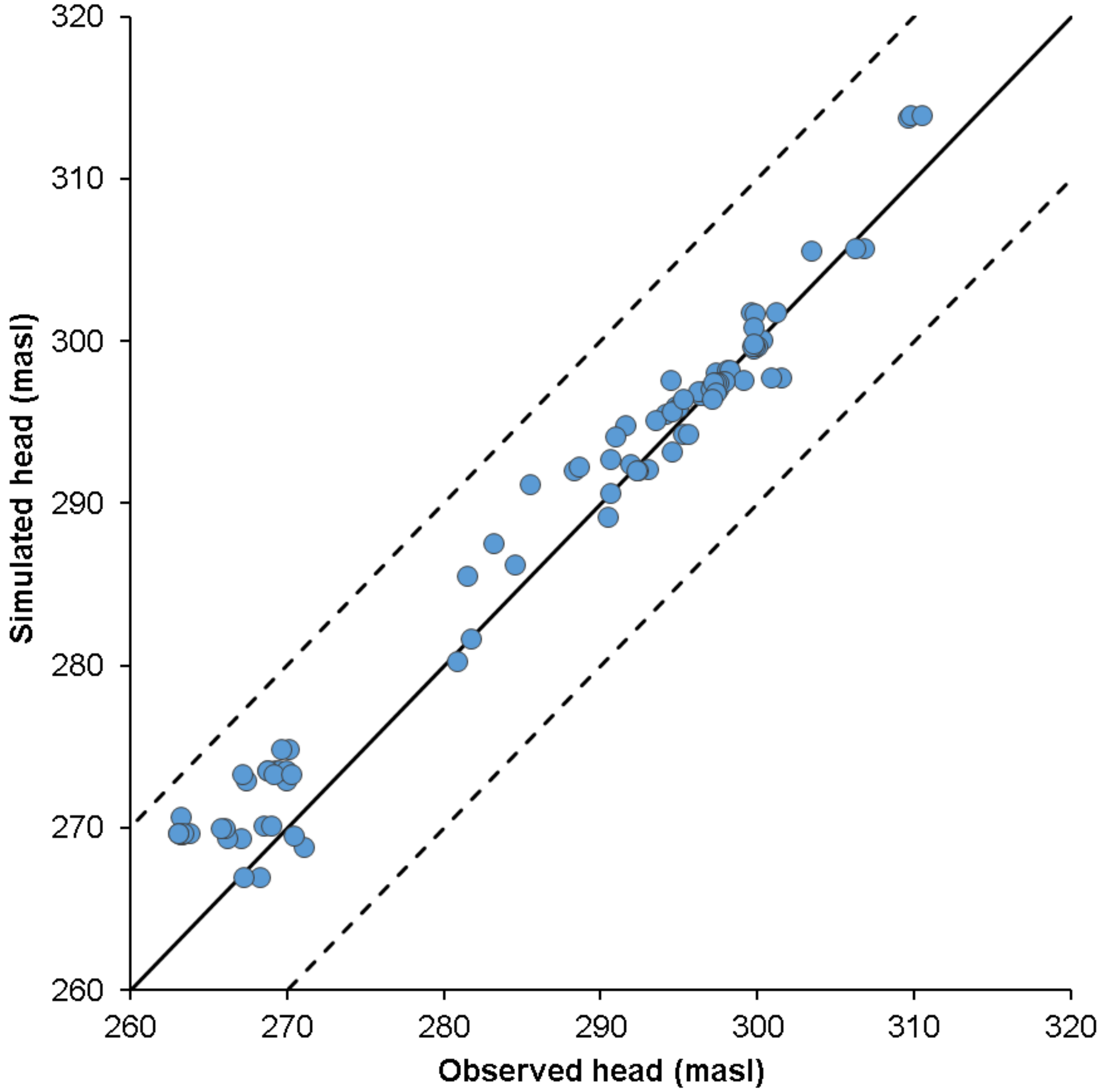


Figure 6-9: Observed vs. simulated heads in the MLWC in years 2020 and 2021.

6.3.2 Flow Patterns and Source Areas

Figure 6-10 shows the direction of surface flow streamlines in the fen and the lake. The direction of the streamlines in the fen clearly agrees with the conceptualized understanding of these flow directions (Figure 2-5). Also, the SW flow directions are, as expected, perpendicular to the orientation of the patterned fen strings at the MLWC, indicating the model accurately captures the salient surface flows required to help preserve the strings.

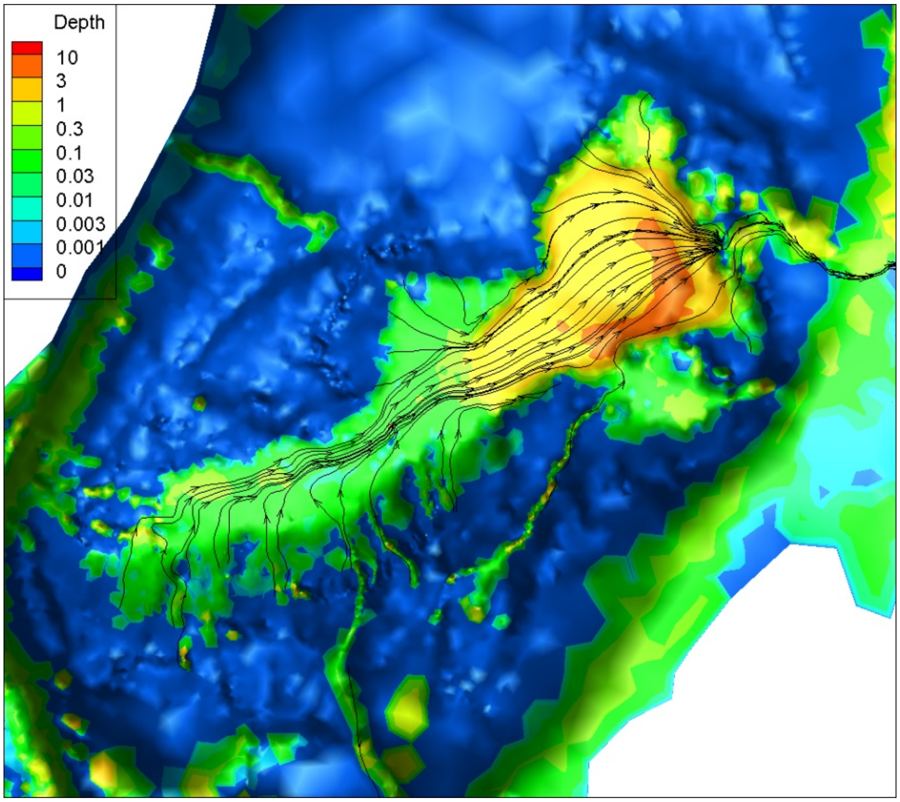


Figure 6-10: Simulated overland flow streamlines in the fen and the lake.

Another model validation criterion is the exchange flux rate between surface and subsurface domains in the model, shown in Figure 6-11. The exchange flux is positive (exfiltration) at the margins of McClelland Lake, indicating the lake receives GW input along its edges, which agrees with physical expectations and the conceptual understanding. Moreover, positive exchange fluxes are predicted to occur along the western margins of the patterned fens (HRA 05 as discussed in Appendix F). This location is where GW flowing from the NOP surficial sand deposits daylights at the margin of the MLWC, discharging to surface. This GW discharge location is consistent with the conceptual understanding of flow processes in that area.

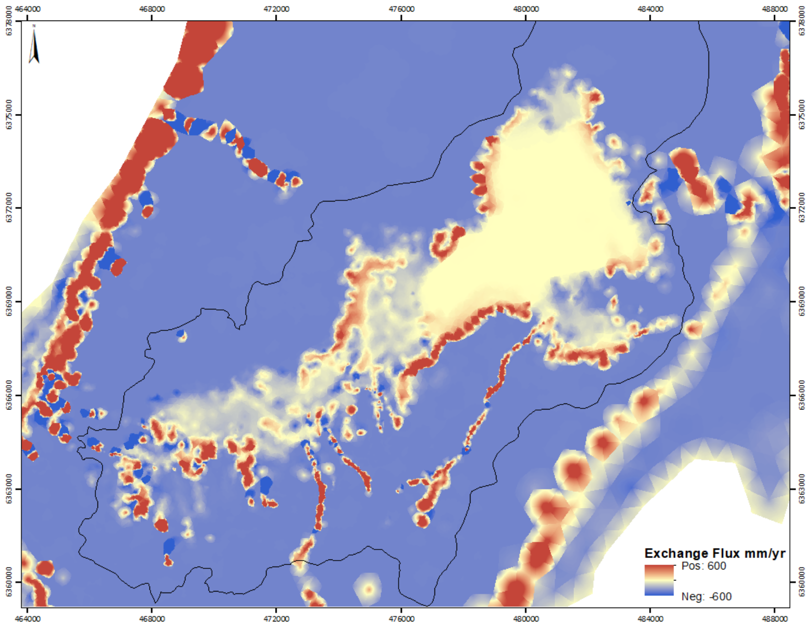


Figure 6-11: Surface-subsurface exchange in the fen and lake and along the natural steams in MLWC. GW discharge areas are shown in red and infiltration areas in blue.

6.3.3 Fen Hydrology

The water table in the fen peatlands is generally shallow and does not typically drop significantly below the ground surface. Based on the Canadian Wetlands Classification, water tables in fen peatlands lie at or near surface (Warner and Rubec, 1997). The average predicted water table position shown in Figure 5-3 for the non-mined portion of the MLWC fen confirms that the average water table is at and near surface. An exceedance curve of the water table position developed using the same simulated monitoring points shown in Figure 5-3. This exceedance curve (Figure 6-12) was developed for the baseline period (1945 to 2019) and shows that the water table, on average, was simulated to remain near or above surface. The exceedance curve results indicate the model is maintaining the simulated water table variation in the non-mined portion of the MLWC fen within a narrow range of approximately 0.2-m above the peat surface to 0.1-m below for the simulated 5th and 95th percentile fen water levels, respectively.

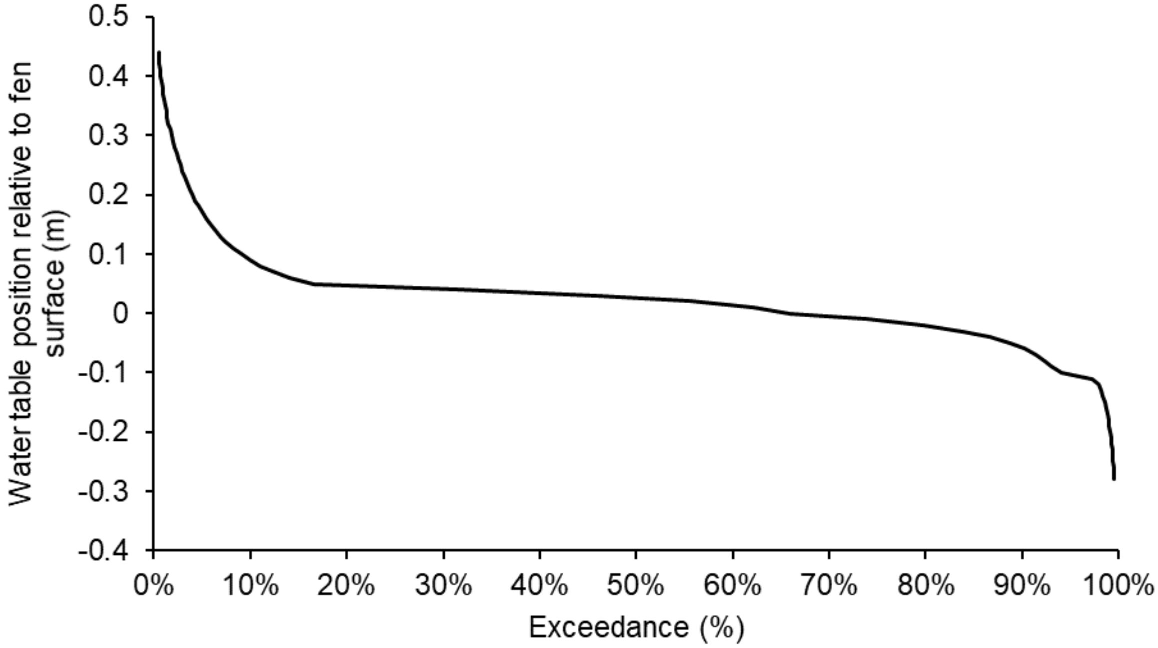


Figure 6-12: Exceedance curve of average water table position in the non-mined portion of the MLWC fen (positive values are above ground surface and negative values below ground surface).

Another qualitative validation of the fen hydrology is the effect of antecedent moisture contents within the peat in terms of runoff generation (Figure 6-13). illustrates the upper soil saturation and also the SW depth (in meters) above ground surface before and after two rainfall events in September 2012 (of similar magnitudes and which are shown in the bottom panel of the the figure). Before the first rainfall event (September 2nd and 3rd, 2012) the upper soil is partially saturated (top left) and there is no water ponding at the surface (top right). After the first rain event, the top soil in the fen is mostly saturated with water and the nearby uplands also show increases in their moisture content (middle left); however, surface runoff does not happen in the fen (middle right panel). In contrast, once the second rain event takes place (September 10th and 11th, 2012), considering that the upper soil was now nearly fully saturated before the event, its saturation rises very little (bottom left), and substantial saturation excess overland flow is generated (bottom right). The sequence of snapshots in the figure show the impact of antecdent moisture content on runoff generation in the fen and confirm that this phenomenon has been captured in the 2020 MLWC HGS model.

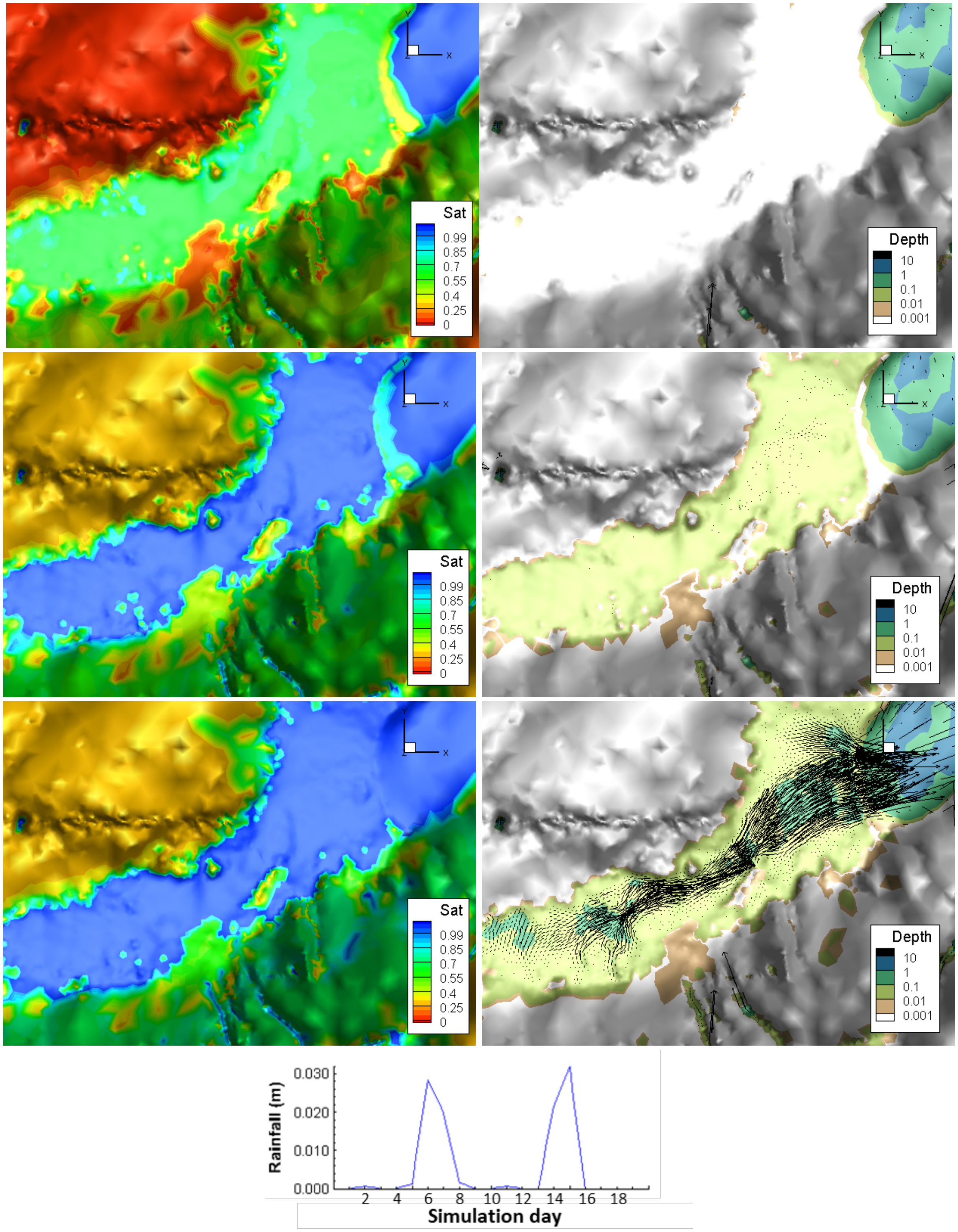


Figure 6-13: Effect of antecedent moisture content of the soil in the fen on runoff generation; panels on the left show upper soil saturation before (top panel) and after two rainfall events (middle and bottom panels). Hyetographs of the two rain events are shown in the bottommost panel. The panels on the right show the depth of water accumulation at the surface and plots of surface flow vectors (representing runoff) before and after these events.

6.3.4 Seasonality of Flows and Levels

Historical observed and simulated levels of the McClelland Lake are illustrated in annually stacked form in Figure 6-14. This form of presenting the data compares the seasonality of the McClelland Lake levels between the observed and simulated data. The results show that the lake level over late fall, winter, and early spring months (October to March) rise very smoothly in both the observed and simulated data. Next, the lake level rises at a relative sharp rate during the freshet in both the observed and simulated data, and then begin to decrease until September. The figure clearly shows that the rate of increase in the lake level over the winter and the rate of the decline in the lake level over the summer months are similarly captured in both the observed data and simulated data, indicating the 2020 MLWC HGS model has properly captured the seasonality in the McClelland Lake levels.

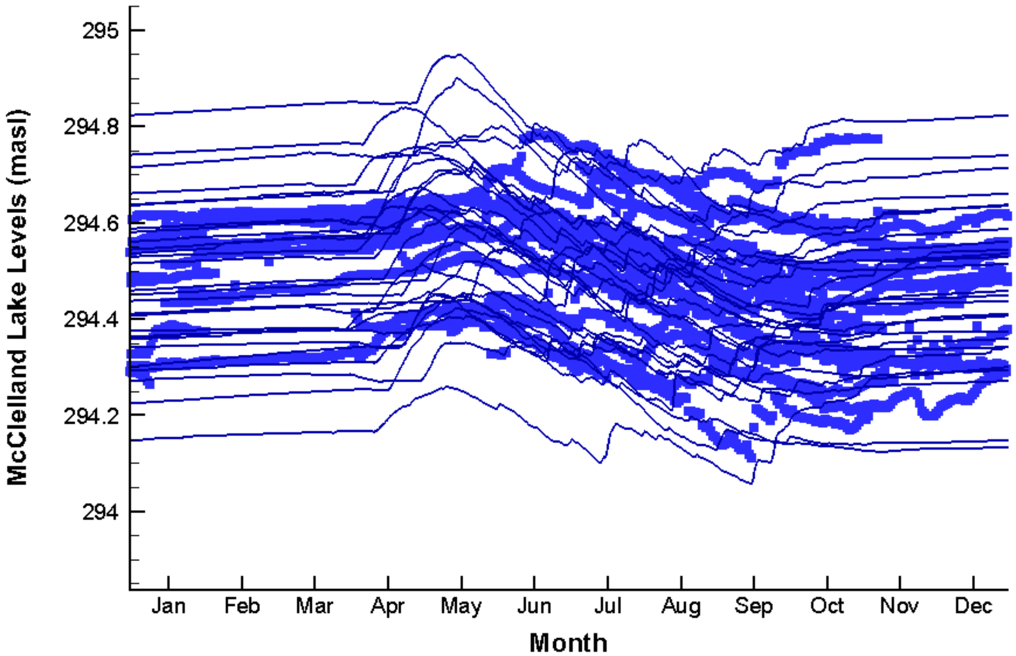


Figure 6-14: Seasonality in the observed (markers) and the simulated (lines) McClelland Lake levels between 1997 to 2019.

In addition, an example of the seasonality in water table position in the fen is shown in Figure 6-4 which shows the match between simulated head in GT-07-093C well in the fen and the observed data. The figure indicates that the head in the fen rises over the winter and drops after the freshet in both observed and simulated data, which means that the intra-annual variations and seasonality of the fen hydraulic head has been reasonably captured in the MLWC HGS model.

Seasonality of surface runoff rate within the fen in the 2020 MLWC HGS model is demonstrated at the location of proposed cutoff wall in the Baseline Model; Figure 6-15 illustrates the simulated runoff rate between 1990 to 2019 in a stacked form. The results in Figure 6-15 indicate that large runoff rates will occur during freshet, and the simulated timing of the freshet is also consistent with the conceptual understanding of peak flows in patterned fens located at this latitude in the WBF. Figure 6-15 also shows that the model predicts a reduction in SW runoff after the freshet with additional peaks during the summer months due to rain events.

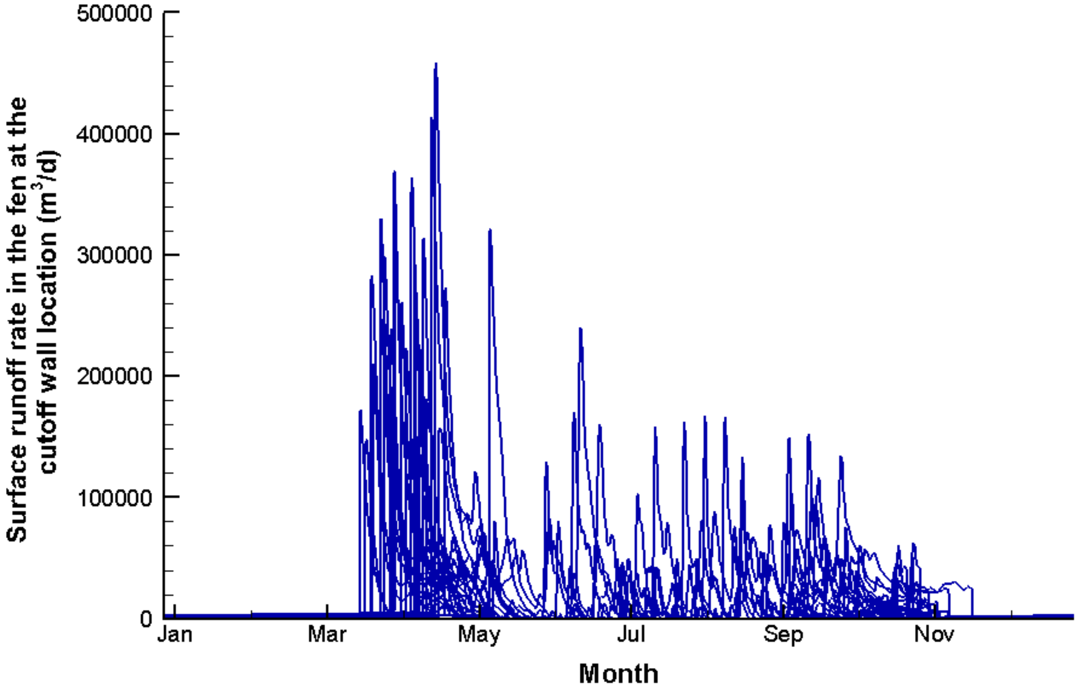


Figure 6-15: SW flow through the fen at the proposed cutoff wall location over the 1990 to 2019 period in the Baseline Model.

6.3.5 Groundwater-divide versus surface water-divide

The GW divide and its location relative to the MLWC watershed boundary are conceptualized to vary with time as a function of GW storage capacity. Section 2.3 discusses how the western GW divide within the MLWC watershed shifts with time; when storage is added to the GW system it moves westward, and when the storage is consumed it shifts eastward. Figure 6-16 presents the simulated GW divide during three fall time periods and highlights how the 2020 MLWC HGS model captures this dynamic hydrological feature of the system for a wet fall period (1970), a median fall period (1986) and a dry fall period (2007).

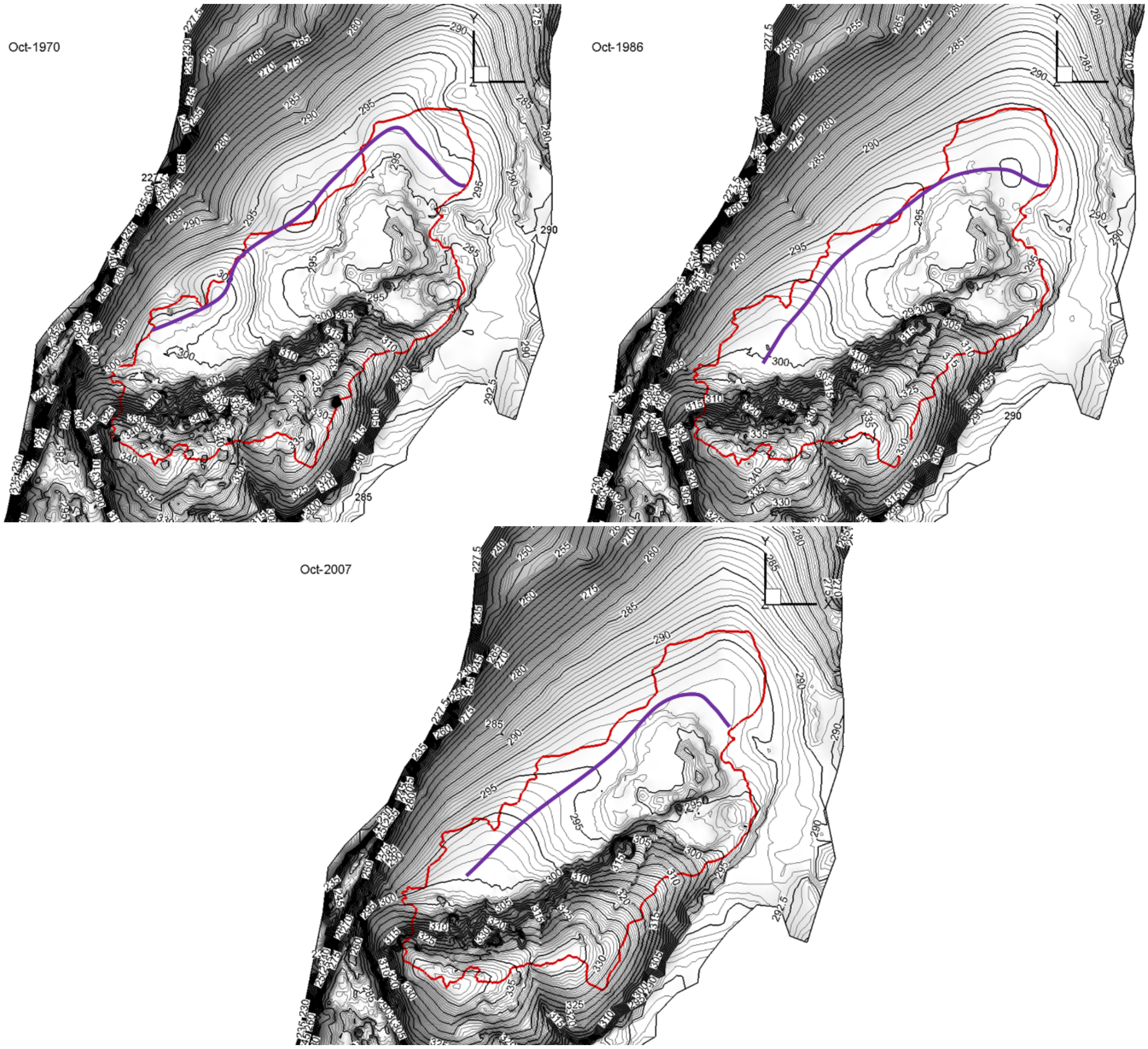


Figure 6-16: Examples of western GW divide (purple line) in the NOP relative to the SW divide (red line) in a wet period (top left), a normal period (top right) and a relatively dry period (bottom).

7.0 CONCLUSIONS

The 2020 MLWC HGS Model includes individual model builds and simulations of baseline, mine operations (2021 IPA Mine Plan), active closure and post-closure far-future conditions. Additionally, active closure and far-future simulations were conducted with an ensemble of climate projections, both mid and end-century. The preceding report sections: 6.0 (Model Veracity), 6.1 (Model Sensitivity), 6.2 (Model Assumptions and Limitations), and 6.3 (Qualitative Validation), provide a detailed justification that the 2020 MLWC HGS Model is capable of representing highly dynamic hydrological and mine plan evolution interactions within the MLWC watershed, fen, and McClelland Lake. The 2020 MLWC HGS Model is therefore considered an appropriate simulation tool for supporting the MLWC OP assessment.

It is recognized that all models are simplified representations of reality. Therefore, the modelling results presented in this report have been interpreted with an understanding of the limitations associated with data quality/availability, resolution, process representation, and other sources of uncertainty. The following discussion highlights some of the known limitations of the 2020 MLWC HGS Model that have been considered in the MLWC OP. Sources of uncertainty were discussed in Section 6.2.

1. **Model Resolution:** The 2020 MLWC HGS Model was designed to address large scale water balance questions under different conditions (i.e., historical, operations, active closure and far-future). Since the model domain covers an area of approximately 1,000 km^2, the mesh resolution is relatively coarse in some areas, and as such the modelling results have been interpreted with this in mind.
2. **Winter Processes:** The current implementation of winter processes in the models uses simplified methods designed to capture the primary effects of winter on hydrologic processes (i.e., soil/surface freeze thaw and snow accumulation/melt). Specifically:
    - Surface and subsurface freezing turn on and off instantaneously without a smooth transition;
    - Snowmelt is modelled using the degree-day method and does not explicitly account for the energy balance; and,
    - Snow redistribution by wind is not included.
3. **Equifinality**: This is a limitation of all environmental models, where more than one parameter set may provide acceptable calibration performance. Mitigation of equifinality was undertaken by using a multi-target objective function that accounted for SW, GW, and ET targets. Additionally, many quantitative and qualitative post-calibration verification data sets were assessed to ensure that the calibrated model agreed with the conceptual understanding of the system (Sections 4.3 and 6.3). It should be noted that equifinality can only be mitigated but never fully eliminated in complex environmental models.
4. **Limited SW data available for calibration**: There is a small amount of SW flow data available for model calibration: 1) the outflow from McClelland Lake is through a poorly defined channel in muskeg with known seepage bypassing the monitoring point and was previously deemed unreliable; and, 2) the only other SW flow data is for South Creek, but it is of very limited duration (two years). As such, SW flow data was not included as a calibration target, but rather it was used as a qualitative verification metric.
5. **AET in aspen forestlands is too low:** The simulated AET rates in the aspen forested areas of the FHUC appear to be too low in the current model, based on values reported in comparable settings and discussed in Devito et al.(2017). An update to the model parameterization may be required in this area of the model to retain soil moisture in the soil column to supply additional aspen transpiration.

6. **Homogeneous hydrostratigraphic units:** Due to computational constraints, model calibration was performed using a zonal approach whereby all material properties are uniform within a given zone or hydrostratigraphic unit. This means that intra-unit heterogeneity is not included in the model. It is also worth noting that in some cases, the regionally calibrated hydraulic conductivity values are higher than measured values or values from calibrated pumping tests. This is a well-known phenomenon called the “scale-effect” and is due to the fact that each method samples a different volume of material. Additionally, the amount of hydrostratigraphic detail that can be included is limited by the mesh resolution of the model.
7. **Parametric uncertainty**: Formal quantification of parametric uncertainty has not been performed. The best available data and interpretations were used at the time of model construction and calibration. However, subsurface data is inherently uncertain. The large number of runs necessary to do a formal parametric uncertainty quantification such as Monte Carlo, Latin Hypercube, or Polynomial Chaos Expansion, may preclude its use with the current model runtimes.
8. **Refinement of Hydrostratigraphic Unit AQ4**: Simulated pumping tests were used to improve the initial hydrostratigraphic zonation of the AQ4 unit (the addition of a PGKM unit). It is understood that further characterization of these units will likely result in improved model performance.
9. **Definition of the peat as a rigid porous medium**: The peat has been modelled as a rigid porous medium, which is a standard assumption of groundwater flow models. Peat is known to shrink on drying and swell on wetting and is subject to continuous growth and decomposition. These shrink-swell and growth-decomposition processes have not been modelled using HGS.

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9.0 SCOPE OF REPORT

This report has been prepared by Aquanty Inc., for the exclusive use of Fort Hills Energy Corporation, and its authorized agents (collectively, "FHEC") in connection with certain professional hydrogeological modelling services. FHEC acknowledges that the information contained in this report, including, without limitation, the factual information, descriptions, interpretations, plans, specifications, calculations, notes, electronic files and similar material, comments, conclusions and recommendations contained herein with respect to the hydrogeological model are based on the hydrogeological investigations specific to the project described in this report and do not apply to any other project or site.

The professional hydrogeological modelling services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by members of the engineering and science professions currently practicing under similar conditions, subject to the quantity and quality of available data, the time limits and financial and physical constraints applicable to the services. Unless otherwise specified, the results of previous or simultaneous work provided by sources other than Aquanty Inc. and quoted and/or used herein are considered as having been obtained according to recognized and accepted professional rules and practices, and therefore deemed valid. This model provides a predictive scientific tool to evaluate the impacts on a real hydrogeological system of specified hydrological stresses and/or to compare various scenarios in a decision-making process.

This report must be read in its entirety as some sections could be falsely interpreted when taken individually or out-of-context. As well, the final version of this report and its content supersedes any other text, opinion or preliminary version produced by Aquanty Inc.

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Attachment A

Detailed Description of HydroGeoSphere

Integrated Hydrologic Approaches and *HydroGeoSphere* (*HGS*)

A diverse group of problems exists that requires quantification of the entire hydrologic cycle by integrated simulation of water flow and contaminant migration in the surface and subsurface regimes. Increased demand on limited resources for potable water and other purposes has driven the development of innovative management practices including water recycling, drainage water reuse for salt-tolerant crops, conjunctive use of surface and subsurface water resources, and artificial recharge of subsurface aquifers during wet periods. A quantification of available water within the hydrologic system and the impacts of withdrawals is essential for addressing these complex water supply issues. The complex cycle of irrigation; evaporation; infiltration; discharge to nearby lakes, rivers, and streams, and pumping needs to be quantified in these cases to resolve supply and demand issues. Concerns over drying and restoration of wetlands or the effects of subsurface water withdrawals on surface water features (which may fluctuate across land surface or layering features in an unsaturated zone) also require an integrated, fully-coupled analysis of the various flow regimes. Ecosystems of lakes, rivers, and bays depend on certain minimum flows as do hydropower generation, recreational use, and downstream water districts, states, and countries for their water needs. Regulating water use in hydraulically connected watershed and surficial aquifer systems necessitates an understanding of surface/subsurface water interactions and overall seasonal hydrologic cycle behavior.

Since the early 1970s, there has been an evolution of hydrologic models for single-event and continuous simulations of rainfall-runoff processes. Earlier models quantify various hydrologic components using simplified procedures (including a unit hydrograph method, empirical formulas, system lumping, and analytical equations) that are incapable of describing flow physics and contaminant transport in any detail. In the past, numerical models based on complex multi-dimensional governing equations have not received much attention because of their computational, distributed input and parameter estimation requirements. Today, with the availability of powerful personal computers, efficient computational methods, and sophisticated GIS, remote sensing and advanced visualization tools, the hydrologic community is realizing the tremendous potential and utility of physically-based numerical simulators.

The *HydroGeoSphere* (*HGS*) model (Aquanty, Inc., 2015) is a three-dimensional control volume finite element simulator which is designed to simulate the entire terrestrial portion of the hydrologic cycle. It uses a globally-implicit approach to simultaneously solve the 2D diffusion wave equation and 3D form of Richards' equation. It also dynamically integrates key components of the hydrologic cycle such as evaporation from bare soil and water bodies, vegetation-dependent transpiration with root uptake, snowmelt and soil freeze/thaw. As with the solution of the coupled water flow equations, *HGS* solves the contaminant transport and energy transport equations over the land surface and in the subsurface, thus allowing for surface/subsurface interactions. The *HGS* platform uses a robust and efficient nonlinear solver, and has been parallelized to utilize high performance computing facilities to address large-scale problems.

2. Key Features and Formulations

Overland Flow

In the *HGS* model, areal overland flow is represented by a two-dimensional depth-integrated flow equation which is the diffusion-wave approximation of the Saint Venant equation for surface water flow:

$$\nabla \cdot d_o K_o \cdot \nabla h_o \pm Q_o + \Gamma_o = \frac{\partial h_o}{\partial t}$$

where d_o is the depth of flow, h_o is the water surface elevation ($= d_0 + z$), and K_o is the surface conductances that are changed with the friction slopes of the surface and is approximated by the Manning's equation in *x*- and *y*- directions as:

$$K_{ox} = \frac{d_o^{2/3}}{n_x} \frac{1}{\left[\partial h_o / \partial s\right]^{1/2}}; \qquad K_{oy} = \frac{d_o^{2/3}}{n_y} \frac{1}{\left[\partial h_o / \partial s\right]^{1/2}}$$

where n_x and n_y are the Manning's roughness coefficients and s is the direction of maximum surface-water slope. The surface conductances K_{ox} and K_{oy} are complex functions of the dependent variables d_0 or h_0 ($= d_0 + z$), and the complex relationship makes the governing equation highly nonlinear.

Groundwater Flow

The modified form of Richards' equation describing three-dimensional transient subsurface flow under variably-saturated conditions is given by:

$$\nabla \cdot k_r \mathbf{K} \cdot \nabla h \pm Q + \Gamma = \frac{\partial}{\partial t}\left(\theta_s S_w\right)$$

where k_r is the relative permeability of the medium as a function of the water saturation S_w or the pressure head ψ, $\mathbf{K}$ is the hydraulic conductivity tensor, h is the total head as $\psi + z$ where z is the elevation, θ_s is the saturated water content, Q is an externally applied source or sink of water. The fluid exchange between the surface and subsurface is represented by Γ. The storage term can be expanded to account for both the change in storage in the saturated zone through compressibility effects and a change in saturation in the unsaturated zone (Cooley, 1971; Neuman, 1973):

$$\frac{\partial}{\partial t}\left(\theta_s S_w\right) \approx S_w S_s \frac{\partial h}{\partial t} + \theta_s \frac{\partial S_w}{\partial t}$$

where S_s

h), saturation (S_w), and relative

permeability (k_r), which is commonly described through expressions such as the van Genuchten (1980) or Brooks and Corey (1964) relations.

Surface Water and Groundwater Interaction

Separate surface and subsurface flow models can be combined by explicitly coupling the variably-saturated flow and the surface flow equations. In *HGS*, it is assumed that the two domains are separated by a thin boundary layer. Thus, Γ_o in the governing flow equation represents a first-order exchange between subsurface and surface domains as follows:

$$\Gamma_o = (k_r)_{exch} K_{exch} (h - h_o) / l_{exch}$$

$$\int_V \Gamma dV = -\int_{A_{\text{interf}}} \Gamma_o dA_{\text{interf}}$$

where $(k_r)_{exch}$ is the relative permeability for fluid exchange, K_{exch} is the surface/subsurface conductance, and l_{exch} is the thickness of the interface layer between surface and subsurface domains. In the coupling equation, a positive Γ_0 indicates movement from the subsurface to the surface domain through the interface (A_{interf}). Note that the *HGS* model is referred to as a fully-integrated globally-implicit model, opposed to linked or iteratively coupled simulators because the governing equations are solved simultaneously with the above coupling equation.

Canopy Interception and Evapotranspiration

The *HGS* model simulates interception and evapotranspiration as mechanistic processes governed by plant and climate conditions as noted by Kristensen and Jensen (1975) and Wigmosta et al. (1994). Interception is the process involving retention of a certain amount of precipitation on the leaves, branches, and stems of vegetation or on buildings and structures in urban areas. The interception process is simulated by the bucket model, wherein precipitation in excess of interception storage and evaporation from interception reaches the ground surface. The interception storage varies between zero and S_{int}^{Max}, the interception storage capacity such that

$$S_{\text{int}}^{Max} = c_{\text{int}} LAI$$

where *LAI* is the dimensionless leaf area index and c_{int} is the canopy storage parameter. Note that *LAI* represents the cover of leaves over a unit area of ground surface, and may be prescribed in a time-dependent manner.

Evapotranspiration is rigorously modeled as a combination of plant transpiration and evaporation, and affects both surface and subsurface flow domains. Transpiration from vegetation occurs within the root zone of the subsurface which may be above or below the watertable. The rate of transpiration (T_p) is estimated using the following relationship that distributes the net capacity for transpiration among various factors (Kristensen and Jensen, 1975).

$$T_p = f_1(LAI) f_2(\theta) RDF[E_p - E_{can}]$$

where $f_1(LAI)$ is a function of leaf area index, $f_2(\theta)$ is a function of nodal water content, *RDF* is the root distribution function, E_p is the potential evapotranspiration, and E_{can} is the canopy evaporation. The vegetation term is expressed as

$$f_1(LAI) = \max\{0, \min[1, (C_2 + C_1 LAI)]\}$$

and the moisture content dependence term is expressed as

$$f_2(\theta) = \begin{cases} 0 & \text{for } 0 \le \theta \le \theta_{wp} \\ f_3 & \text{for } \theta_{wp} \le \theta \le \theta_{fc} \\ 1 & \text{for } \theta_{fc} \le \theta \le \theta_o \\ f_4 & \text{for } \theta_o \le \theta \le \theta_{an} \\ 0 & \text{for } \theta_{an} \le \theta \end{cases}$$

where:

$$f_3 = 1 - \left[\frac{\theta_{fc} - \theta}{\theta_{fc} - \theta_{wp}}\right]^{C_3/E_p} \text{ and } f_4 = 1 - \left[\frac{\theta_{an} - \theta}{\theta_{an} - \theta_o}\right]^{C_3/E_p}$$

where C_1, C_2, and C_3 / E_p are dimensionless fitting parameters, θ_{fc} is the moisture content at field capacity, θ_{wp} is the moisture content at the wilting point, θ_0 is the moisture content at the oxic limit, θ_{an} is the moisture content at the anoxic.

The evaporation mode used in *HGS* assumes that evaporation occurs along with transpiration, resulting from energy that penetrates the vegetation cover and is expressed as

$$E_s = \alpha^*(E_p - E_{can})[1 - f_1(LAI)]EDF$$

where α^* is a wetness factor given by

$$\alpha^* = \begin{cases} \frac{\theta - \theta_{e2}}{\theta_{e1} - \theta_{e2}} & \text{for } \theta_{e2} \le \theta \le \theta_{e1} \\ 1 & \text{for } \theta > \theta_{e1} \\ 0 & \text{for } \theta < \theta_{e2} \end{cases}$$

where θ_{e1}

θ_{e2} is the limiting moisture content below unity which evaporation is zero. The equation expresses the moisture availability term for the subsurface domain. For the overland flow domain, α^* is calculated as varying between unity when the elevation of flow is at or above depression storage and zero for a flow elevation at the land surface, thus representing the reduced evaporative area of available water in the overland flow domain within the depressions. The term *EDF* is the evaporation distribution function that includes the overland and subsurface flow domains. It is assumed that the capacity for evaporation decreases with depth below the surface due to the reduction of energy penetration in the soil.

Snowmelt and Porewater Freezing and Thawing

In order to consider both solid and liquid phases of water in the surface flow domain, the governing overland flow equation needs to be expanded to include both water and snow mass ($\rho_w d_w$ and $\rho_{snow} d_{snow}$). The solid phase snow is assumed to be immobile and the mass balance of the total water is formulated as the following:

$$\frac{\partial}{\partial t}(\rho_w d_w + \rho_{snow} d_{snow}) = \frac{\partial}{\partial x}\left(\rho_w k_m d_w K_{ox} \frac{\partial h_o}{\partial x}\right) + \frac{\partial}{\partial y}\left(\rho_w k_m d_w K_{oy} \frac{\partial h_o}{\partial y}\right) - \rho_w \Gamma_{ex} + \rho_w Q_o + \rho_{snow}(Q_{snow} - \mu)$$

where Q_{snow} and μ represent the rates of snow precipitation and sublimation per unit surface area. The depth of snow is determined by the rates of snow precipitation, sublimation, and melting (always sink) which is caused by temperature change.

$$\frac{\partial}{\partial t}(\rho_{snow} d_{snow}) = \rho_{snow} Q_{snow} - \eta(T_{air} - T_{threshold}) - \mu$$

where the depth of snow is always positive and the rate of melting is assumed to be proportional to a melting constant (η) and the difference between air temperature (T_{air}) and threshold temperature ($T_{threshold}$) when $T_{air} > T_{threshold}$.

By combining the total water balance equation with the snow balance equation, *HGS* solves the balance equation for the liquid phase water.

$$\frac{\partial}{\partial t}(\rho_w d_w) = \frac{\partial}{\partial x}\left(\rho_w k_m d_w K_{ox} \frac{\partial h_o}{\partial x}\right) + \frac{\partial}{\partial y}\left(\rho_w k_m d_w K_{oy} \frac{\partial h_o}{\partial y}\right) - \rho_w \Gamma_{ex} + \rho_w Q_o + \rho_{snow} Q_{melt}$$

When the liquid phase of porewater can be transformed into the solid phase ice (freezing) or vice versa (melting), the total mass of water in the subsurface system is $\rho_w \theta_s S_w + \rho_{ice} \theta_s S_{ice}$ where the subscript ice represents the solid phase ice. The ice is assumed to be immobile and thus, the balance of the total water mass can be described by the following equation:

$$\frac{\partial}{\partial t}(\rho_w \theta_s S_w + \rho_{ice} \theta_s S_{ice}) = -\nabla \cdot \rho_w \mathbf{q} + \rho_w Q_w$$

The partitioning of water between solid and liquid phases is assumed to be determined by the temperature (which is a function of time at a given point) such that

$$\frac{\rho_{ice}S_{ice}}{\rho_w S_w + \rho_{ice}S_{ice}} = \left(\frac{T_f - T_{pm}}{T_f - T_m}\right)^{\beta} \text{ when } T_m < T_{pm} < T_f$$

where T_m and T_f are the melting and freezing temperatures. A simple one-dimensional analytical model is employed in *HGS* to determine the vertical temperature distribution of bulk porous medium

$$\frac{\partial}{\partial t}(T_{pm} - T_b) = \frac{\partial}{\partial z}\left(\frac{k_{pm}}{c_{pm}}\frac{\partial(T_{pm} - T_b)}{\partial z}\right)$$

where k_{pm} and c_{pm} are the bulk thermal conductivity and heat capacity, respectively and it is assumed that the temperature at depth is given as T_b and the surface temperature is same as the atmospheric temperature (T_{atm}). The analytical solution of the equation is given as follows:

$$T_{pm}(z,t) = T_b + \frac{z}{\sqrt{4\pi\kappa}}\int_{\tau=0}^{t}\frac{\partial T_{atm}(\tau)}{\partial \tau} erfc[\frac{z}{\sqrt{4\kappa(t-\tau)}}]d\tau$$

where the thermal diffusivity of bulk porous medium κ is defined as k_{pm} / c_{pm} .

Solute Transport

In *HGS*, three-dimensional transport of solutes in a variably-saturated porous matrix is described by the following advection-dispersion equation:

$$-\nabla \cdot w_m(\mathbf{q}C - \theta_o S_w \mathbf{D}\nabla C) + [w_m \theta_o S_w R\lambda C]_{par} + \sum \Omega_{ex} \pm Q_c = w_m\left[\frac{\partial}{\partial t}(\theta_o S_w RC) + \theta_o S_w R\lambda C\right]$$

where *C* is the solute concentration of the current species amongst possibly multiple species and λ is a first-order decay constant. The subscript *par* designates parent species for the case of a decay chain. For the case of a straight decay chain, there is only one parent species, as might be the case for a radioactive decay chain; however, for degrading organic species, a particular species may have several parent sources through a complex degradation process. Solute exchange with the outside of the simulation domain, as specified from boundary conditions, is represented by Q_c which represents a source (positive) or a sink (negative) to the system. The dimensionless retardation factor, *R*, is given as:

$$R = 1 + \frac{\rho_b}{\theta_s S_w}K'$$

where ρ_b

saturation appears in the definition of *R*. Ω_{ex} represents the mass exchange rate of solutes per unit volume between the subsurface domain and all other types of domains supported by the model. Currently, these additional domains are surface, wells, tile drains, discrete fractures, immobile second continuum and mobile dual continuum.

The equation for two-dimensional transport of solutes along the surface domain is written as

$$-\overline{\nabla}(\mathbf{q}_o C_o - \mathbf{D}_o \phi_o d_o \overline{\nabla} C_o) + [\phi_o d_o R_o \lambda C_o]_{par} - \phi_o d_o \Omega_o = \frac{\partial}{\partial t}(\phi_o d_o R_o C_o) + \phi_o d_o R_o \lambda C_o$$

where C_o is the concentration in water on the surface domain, $\mathbf{D}_o$ is the hydrodynamic dispersion tensor of the surface flow domain and $\overline{\nabla}$ is the vertically integrated two-dimensional gradient operator. An expression similar to the equation used for a two-dimensional fracture is used to represent the dispersion coefficient $\mathbf{D}_o$ and the retardation factor R_o.

Solute exchange between surface and subsurface $d_o\Omega_o$ is calculated by advective-dispersive equation:

$$\left(d_o\Omega_o\right)_{total} = \left(d_o\Omega_o\right)_{adv} + \left(d_o\Omega_o\right)_{disp}$$

Advective solute exchange flux is computed from fluid exchange flux and upstream concentration and dispersive flux is accounted for by one-dimensional mechanical dispersion and diffusion.

$$\left(d_o\Omega_o\right)_{adv} = \left(d_o\Gamma_o\right)C_{up}$$

where:

$$C_{up} = \begin{cases} C_o & \text{for } h_o > h \\ C & \text{for } h_o \le h \end{cases} \text{ and } \left(d_o\Omega_o\right)_{disp} = \left|(d_o\Gamma_o)\right|\alpha_{ex} + \frac{D_{free}\theta_{ex}S_{ex}\tau}{l_{ex}}(C - C_o)$$

where α_{ex} is the exchange dispersivity, θ_{ex} and S_{ex} are the geometric mean for surface and subsurface porosities and saturations, respectively, τ is the subsurface tortuosity, and l_{ex} is the effective mass transfer scale which represents the dimension of an interface layer. In *HGS*, dispersive flux can be optionally neglected if it is considered to be much smaller than advective flux.

Thermal Energy Transport

The equation describing thermal energy transport in the unsaturated zone is similar to that for the saturated zone, with the inclusion of a saturation term in the bulk transport parameters. The general equation for variably-saturated subsurface thermal energy transport following Molson et al. [1992] is given by:

$$\left[\frac{\delta \rho_b c_b T}{\delta t}\right] = -\nabla[q\rho_w c_w T - (k_b + c_b \rho_b D)\nabla T] \pm Q_T + \Omega_o$$

where ρ is the density, c is the heat capacity, T is the temperature, t is time, q is the Darcy flux in the subsurface, k_b is the bulk thermal conductivity term, D is the dispersion term, Q_T is a source sink and Ω_o is the surface/subsurface interaction term, which will be discussed in a following section. The subscript b denotes a bulk term, whereas w represents the aqueous phase.

The surface water thermal energy transport equation is similar to the surface water contaminant transport equation. The equation used for surface water thermal transport is given by:

$$\frac{\delta \rho_w c_w h_o T_o}{\delta t} = -\nabla[q_o \rho_w c_w T_o - (k_b + D_o \rho_w c_w d_o)\nabla T_o] \pm Q_{T_o} - d_o \Omega_o + E_{atm}$$

where h is the elevation of the surface water, d is the depth of flow, and the subscript o denotes overland flow. The inclusion of atmospheric thermal inputs (E_{atm}) is necessary to properly simulate the surface and subsurface thermal regimes. Currently the atmospheric inputs from CLASS (Verseghy, 1991) are used to determine the surface heat fluxes in HydroGeoSphere. The atmospheric input included in HydroGeoSphere has four components, shortwave radiation (K*), longwave radiation (L*), sensible heat flux (QH) and latent heat flux (QE). The sum of these components represents the atmospheric input to the surface thermal energy system.

$$\mathrm{E_{atm}} = \mathrm{K_*} + \mathrm{L_*} + \mathrm{Q_H} + \mathrm{Q_E}$$

The coupling of the surface and subsurface thermal continua is similar to that used for advective-dispersive contaminant transport in HydroGeoSphere. There are two methods of coupling the surface and subsurface continua, the common node and the dual node approach. The common node approach is based on superposition where continuity of thermal energy is assumed between the two domains concerned, which correspond to instantaneous equilibrium between the two domains. The dual node approach does not assume continuity of thermal energy between two domains but uses a first-order flux relation to transfer heat from one domain to the other. The equation for the dual-node coupling of the surface and subsurface thermal equations is given by:

$$\Omega_o = \rho_w c_w T_{ups} \Gamma_o + \alpha_o \rho_w c_w (T - T_o)$$

Where Γo represents the aqueous exchange flux between the surface and subsurface (the amount of water flowing between the two regimes), and α is an energy transfer coefficient.

3. Numerical Methods

Control Volume Finite Element Method

The control volume finite element (CVFE) method is based on the concept of combining the finite element and finite difference methods. Specifically, the CVFE method takes advantage of the finite element method, which is computationally efficient and geometrically flexible, and the cell-centered finite difference method, which has continuous interfacial fluxes across the element interfaces and thus, the fluid mass in each single local element is conserved. For the discretization of the variably-saturated flow equation, the finite element method uses a weighted residual method combined with a trial solution ($\hat{h}$ and $\hat{S}_w$) to solve for unknown nodal values of head and saturation within a domain V. The final form of discretized equation for surface and subsurface flow is as follows:

$$\frac{a_{oi}}{\Delta t}\left(h_{oi}^{t+\Delta t} - h_{oi}^{t}\right) = \sum_{oj\in\eta_{oi}} (\lambda)_{oioj+1/2}^{t+\Delta t}\ \gamma_{oioj}\ \left(h_{oj}^{t+\Delta t} - h_{oi}^{t+\Delta t}\right) \pm Q_{oi}^{t+\Delta t} + \Gamma_{oi}^{t+\Delta t}$$

$$\frac{v_i (S_w)_i^{t+\Delta t} S_s}{\Delta t}\left(h_i^{t+\Delta t} - h_i^{t}\right) + \frac{v_i\theta_s}{\Delta t}\left((S_w)_i^{t+\Delta t} - (S_w)_i^{t}\right) = \sum_{j\in\eta_i} \lambda_{ij+1/2}^{t+\Delta t}\ \gamma_{ij}\ \left(h_j^{t+\Delta t} - h_i^{t+\Delta t}\right) \pm Q_i^{t+\Delta t} + \Gamma_i^{t+\Delta t}$$

where the control area and control volume associated with surface node *oi* and subsurface node *i* is defined as

$$a_{oi} = \int N_{oi} dA \text{ and } v_i = \int N_i dv$$

and $(\lambda)_{oioj+1/2}^{t+\Delta t}\ \gamma_{oioj}\ \left(h_{oj}^{t+\Delta t} - h_{oi}^{t+\Delta t}\right)$ and $(\lambda)_{ij+1/2}^{L+1}\gamma_{ij}(h_j^{L+1} - h_i^{L+1})$ represent the surface and subsurface flux from node *oj* to *oi* and from *j* to *i*, respectively. The fluid exchange terms $\Gamma_{oi}^{t+\Delta t}$ and $-\Gamma_i^{t+\Delta t}$ are given as

$$a_{oi}(k_r)_{exch}K_{exch,oi}(h_i^{t+\Delta t} - h_{oi}^{t+\Delta t})/l_{exch,oi}$$

where the dual nodes *oi* and *i* represent surface and subsurface nodes, respectively.

The discretized equation presented above is independent of the choice of element type. Of the numerous types of three-dimensional elements that can be used to discretize the porous blocks, both 8-node rectangular block elements (Huyakorn et al., 1986) and 6-node prism elements are implemented here. The user also has the option of subdividing rectangular block or prism elements into 4-node tetrahedral elements, which permits the discretization of highly irregular domains. The two-dimensional fracture planes and the surface flow are discretized using either rectangular or triangular elements (Huyakorn et al., 1984). This choice of simple elements allows use of the influence coefficient technique (Huyakorn et al., 1984) to analytically evaluate the integrals appearing in finite element discretization in an efficient manner.

Newton-Raphson Successive Linearization

One of the challenges of simulating integrated surface-subsurface flow is to solve the nonlinear discrete equations. Specifically, the discrete mass balance equations for surface-subsurface flow become nonlinear because the terms $(S_w)_i^{t+\Delta t}$ and $\lambda_{ij+\frac{1}{2}}^{t+\Delta t}\gamma_{ij}$ for subsurface flow and h_o and $(\lambda_o)_{ij+\frac{1}{2}}^{t+\Delta t}\gamma_{oij}$ for surface flow are nonlinear functions of the dependent variables h and h_o, respectively. To linearize the discrete equations, the HGS model applies the Newton-Raphson (NR) iterative method. In the NR procedure for subsurface flow, the residual value at each NR iteration level *L* can be defined as:

$$\begin{aligned} R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L}) &= \frac{v_i(S_w)_i^{t+\Delta t,L} S_s}{\Delta t}\left(h_i^{t+\Delta t,L} - h_i^t\right) + \frac{v_i\theta_s}{\Delta t}\left((S_w)_i^{t+\Delta t,L} - (S_w)_i^t\right) \\ &- \sum_{j\in\eta_i}(\lambda_{ij+1/2}^{t+\Delta t}\ \gamma_{ij})^L\ \left(h_j^{t+\Delta t,L} - h_i^{t+\Delta t,L}\right) \mp Q_i - \Gamma_i^L(h_i^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L}) \end{aligned}$$

where R_i^L represents the residual for node *i* at the iteration level *L*. To minimize the residual for a given $h_{i,j\in\eta_i}^{t+\Delta t}$, a Taylor expansion technique is used such that

$$\begin{aligned} &R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L} + \Delta h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L} + \Delta h_{oi}^{t+\Delta t,L}) = \\ &R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L}) + \frac{\partial R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L})}{\partial h_{i,j\in\eta_i}^{t+\Delta t,L}}\Delta h_{i,j\in\eta_i}^{t+\Delta t,L} + \frac{\partial R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L})}{\partial h_{oi}^{t+\Delta t,L}}\Delta h_{oi}^{t+\Delta t,L} = 0 \end{aligned}$$

HGS uses numerical differentiation to construct the Jacobian matrix (Forsyth and Simpson 1991). With a Jacobian matrix being defined as

$$J_{ij}^L = \partial R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}) \big/ \partial h_{i,j\in\eta_i}^{t+\Delta t,L} \text{ and } J_{ioi}^L = \partial R_i^L(h_{i,j\in\eta_i}^{t+\Delta t,L}, h_{oi}^{t+\Delta t,L}) \big/ \partial h_{oi}^{t+\Delta t,L}$$

a set of linearized discrete equations can be obtained to update the dependent variables such that

$$J_{ij}^L \Delta h_{i,j\in\eta_i}^{t+\Delta t,L} + J_{ioi}^L \Delta h_{oi}^{t+\Delta t,L} = -R_i^L$$

$$\Delta h_{i,j\in\eta_i}^{t+\Delta t,L} = h_{i,j\in\eta_i}^{t+\Delta t,L+1} - h_{i,j\in\eta_i}^{t+\Delta t,L} \text{ and } \Delta h_{oi}^{t+\Delta t,L} = h_{oi}^{t+\Delta t,L+1} - h_{oi}^{t+\Delta t,L}$$

A similar procedure can be applied to linearize the surface flow equation, with the residual for a surface node *oi* given as

$$\begin{aligned} R_{oi}^L(h_{oi,oj\in\eta_{oi}}^{t+\Delta t,L}, h_i^{t+\Delta t,L}) &= \frac{a_{oi}}{\Delta t}\left(h_{oi}^{t+\Delta t,L} - h_{oi}^t\right) \\ &- \sum_{oj\in\eta_{oi}}((\lambda)_{oioj+1/2}^{t+\Delta t}\ \gamma_{oioj})^L\ \left(h_{oj}^{t+\Delta t,L} - h_{oi}^{t+\Delta t,L}\right) - \Gamma_{oi}^{\ L} - Q_{oi} \end{aligned}$$

Convergence is assumed to be achieved when either $\max_i\left|R_i^{L+1}\right|$ or $\max_i\left|\Delta h_i^{t+\Delta t,L}\right|$ becomes smaller than pre-specified convergence criteria.

Adaptive Time Stepping/Sub-Time Stepping

For transient integrated surface and subsurface simulations, *HGS* uses an adaptive time stepping strategy to optimize the computational cost for a given tolerance controlling the simulation accuracy. In this adaptive time stepping approach, the time step size is determined by the maximum nodal change in the hydraulic head, saturation, water depth, and/or concentration from the previous time step such that

$$\Delta t^{L+1} = \frac{\Delta h_{allowed}}{\max_j(\Delta h_j^L)} \cdot \Delta t^L$$

where Δt^L and Δt^{L+1} are the time step sizes used in the previous and current time marching levels, $\Delta t_{allowed}$ is a given tolerance in head (saturation, depth, concentration, or the number of NR iterations), and $\max_j(\Delta h_j^L)$ is the maximum nodal change in the previous time step with given Δt^L.

Sub-time stepping in HGS is a fully-implicit numerical strategy that applies different time step sizes to one or more sub-domains with each having different accuracy requirements. By applying smaller sub-time steps to the sub-domains with relatively rapid responses and utilizing larger time steps in the remainder of the domain, the accuracy requirement is satisfied in the entire domain with minimal temporal over-discretization. This approach is most suitable for problems where the system response is high in only a small portion of the computational domain such as in integrated surface and subsurface simulations. In an implicit sub-time stepping procedure, the global time step size (Δt^{L+1}), the number of sub-timed nodes (n_s), and the number of sub-time steps (M) can be determined from the previous time step results such that

$$z\, \Delta t^{L+1} = \frac{\Delta h_{allowed}^{\Delta t}}{\max_j(\Delta h_j^L)} \cdot \Delta t^L$$

$$M = \min\left[M_{\max}, \frac{\max_j(\Delta h_j^L)}{\Delta h_{allowed}^{\Delta t_s}} \right] \text{ and } \Delta h_{allowed}^{\Delta t_s} < M_{\max} \Delta h_{allowed}^{\Delta t_s}$$

where $\Delta h_{allowed}^{\Delta t}$ and $\Delta h_{allowed}^{\Delta t_s}$ are prescribed accuracy tolerance that are defined as the maximum allowed nodal change during a global time step Δt and sub-time step Δt_s, $M_{\max}$ is the maximum number of sub-time steps, and a node *j* is sub-timed when $\Delta h_j \geq \Delta h_{allowed}^{\Delta t_s}$. Sub-time stepping becomes most efficient when $n_s(M-1)$ is small compared to the number of nodes and thus a larger $M_{\max}$ does not necessarily guarantee higher efficiency.

Parallel High Performance Computing using OpenMP

The main numerical tasks for the integrated surface-subsurface flow and transport simulators can be divided into initialization, simulation time looping, and finalization. For initialization, it reads the discretization information and the initial and boundary conditions and initializes the simulation variables and time loops. During time looping, the model repeatedly solves water flow, solute and heat transport at each current time step based on the results from the previous time step until it reaches the final target time. Analysis of computational cost in integrated hydrologic simulations indicates that more than 90 % of the total computing time is consumed by the tasks that deal with a system of linear equations (matrix assembly and matrix solution) for most of the cases.

When the Jacobian matrix is assembled in parallel, communications among threads are not required and each thread can work independently. However, an appropriate scheduling is necessary because the parallel matrix assembly can cause data racing conditions. Specifically, the racing conditions in matrix assembly occur when values computed by threads are simultaneously updated to one matrix entry that is shared by two or more threads. Thus, a static scheduling that avoids the conditions is applied to HGS.

The matrix solver used in *HGS* (BiCGSTAB) consists of four operational components: forward and backward substitutions (or LUs), dot products (DPs), and matrix-vector (MVs) and scalar-vector (SVs) multiplications: LU solve takes more than 50 % of total solver computing time and thus the efficiency of parallel matrix solver is highly dependent on the efficiency of parallel LU solution and the other operations (DPs, MVs, and SVs) are straightforward to be parallelized due to the data independency. The parallelization of preconditioned BiCGSTAB uses two schemes: a multiblocking scheme with coordinate nested dissection and a privatization scheme. For the multiblocking scheme, nodes consisting of a simulation domain are reordered for dissecting a simulation domain with the number of CPUs applied. In the multiblocking method, each of the computing processors can perform computational tasks for each of the smaller sub-domains. The privatization scheme was implemented for reducing competitions among CPUs when CPUs access to shared memory locations. The process of privatization scheme is to chop the matrix and arrays used in the matrix solving to fit with the computing for each CPU and to designate all the variables as private in the parallel loop.

Attachment B

Wetland Reclamation 2019 Memo

Memorandum

Date: January 9, 2020
Project: Wetland Reclamation (00010009)
Document 00010009_WetlandRecl_2019_Final
Version: Final

To: Jon P. Jones, PhD, P.Geo.
(FHELP)

From: Behrad Gharedaghloo, PhD, P.Eng (Aquanty)
Steven Berg, PhD., P.Geo (Aquanty)
Michael Callaghan, PhD, P.Eng (Aquanty)

Subject: Wetland Reclamation Modelling of the McClelland Lake Watershed – 2019 Interim Technical Memo

This project was commissioned by Fort Hills Energy Limited Partnership (FHELP) as part of the Fort Hills Project operated by Suncor to inform mine plans within the patterned fen region of the McClelland Lake Wetland Complex (MLWC). This project combines Aquanty Inc.'s (Aquanty) expertise in fully-integrated surface and subsurface numerical modelling, with DRH2O Inc.'s (DRH2O Inc.) expertise in peatland hydrology, to improve the current understanding of the patterned fen system in the MLWC and inform FHELP's reclamation and closure design.

This interim technical memorandum provides an update on modelling activities completed for calendar year 2019. Specifically, this memo focuses on the simulation and analysis of four different reclamation designs for the mined portion of the McClelland Lake Watershed. All of the reclamation designs were evaluated by comparing the hydrologic function and water balance of the unmined portion of the fen (remnant fen) to pre-mining conditions. The purpose of these design evaluations was to identify potential reclamation designs that can maintain sustainable functioning of the remnant fen.

All numerical simulations were completed using a fully-integrated hydrologic model of the McClelland Lake Wetland Complex (MLWC) and surrounding area using HydroGeoSphere (Aquanty, 2019a). The regional MLWC model used in this study is referred to as the "2018 MLWC HGS model" (Aquanty, 2019b) in other projects currently being completed by Aquanty for FHELP.

The reader is advised that the results provided herein are solely based on the results of numerical simulations.

1 OVERVIEW

The objective of this study is to assess different end-of-mine closure and reclamation designs by comparing changes in the water balance of the remnant portion of the patterned fen (Figure 1) to pre-mining conditions. A calibrated regional-scale model, the 2018 MLWC HGS model (Aquanty 2019b), previously built by Aquanty, was the reference model used for comparison to asses the pre-mining water balance of the system. Four potential reclamation designs created by Suncor were merged into the 2018 MLWC HGS model to assess their relative post-closure water balance and hydrologic function within the remnant portion of the fen.

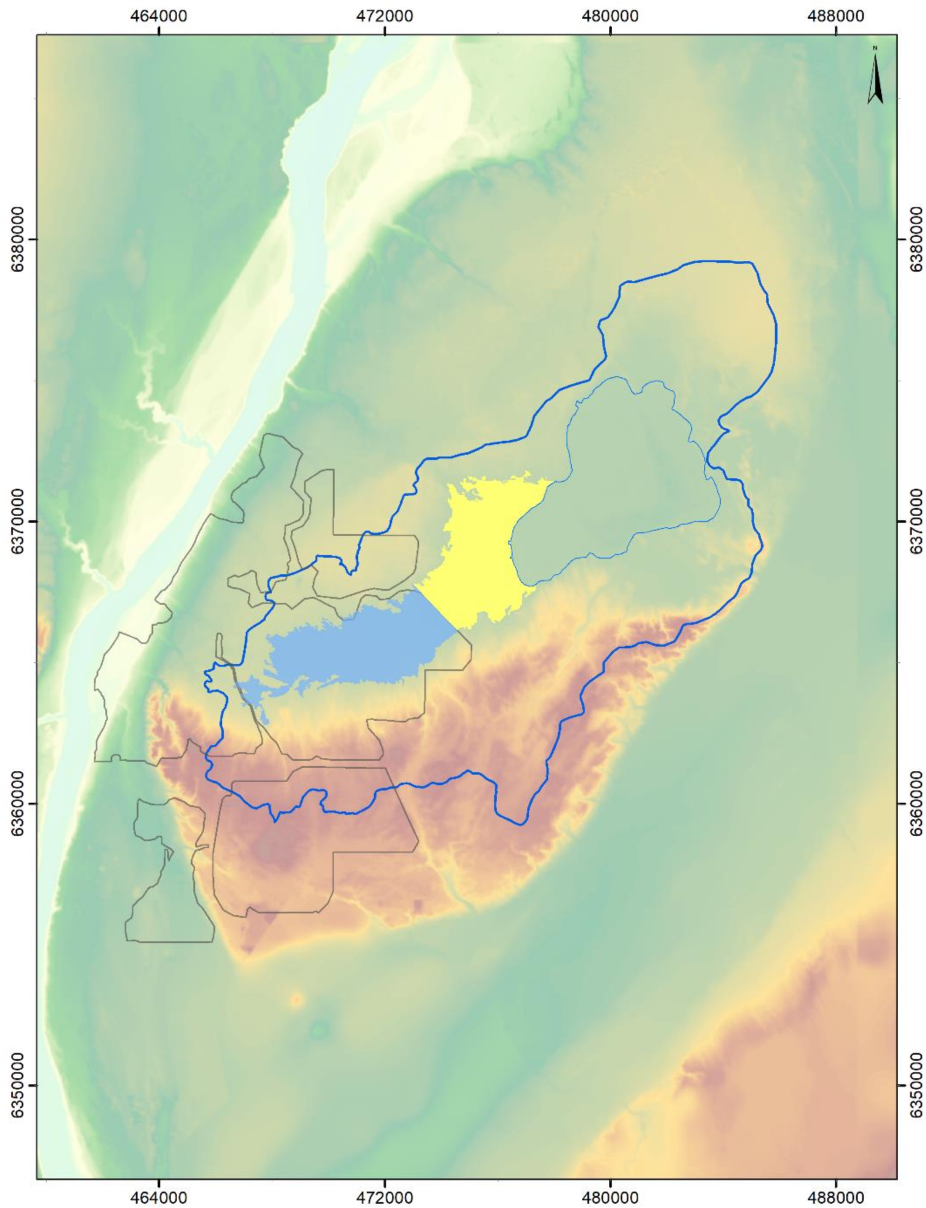


Figure 1: McClelland Lake Watershed (thick blue line) relative to Suncor operations (black likes). The mined (blue shading) and unmined or remnant fen (yellow shading) are also shown.

The patterned fen in the MLWC (Figure 2) consists of a series of flarks (pools) and ribs (ridges) (Figure 2), the dimensions of which control the storage and redistribution of water as it moves through the fen towards McClelland Lake. Explicit representation of the ribs and flarks within a large-scale numerical model (e.g., 2018 MLWC HGS model) is computationally prohibitive because the node count required to represent them in detail would lead to excessively long run times. Therefore, it was necessary to develop an upscaling scheme which can represent the water balance of the patterned fen within a regional scale model with coarse resolution in the fen. This required developing a local-scale to regional-scale workflow in which the properties of the patterned fen are upscaled from a high-resolution local model (explicitly containing the ribs and flarks) into the regional-scale model, which does not contain this level of detail. This parametric upscaling was the primary focus of the work completed in 2018 and is reported in detail in (Aquanty, 2018). **A brief summary of the upscaling methodology and new results from 2019 are presented in Section 2 of this memo.**

The objective of mine reclamation is to return the land to the equivalent capability of the pre-mined environment (Conservation and Reclamation Regulation, AR 115/93). This means from hydrological point of view (which is the focus of this study), the effective hydrological function of the system under reclamation should be equivalent to the hydrological function of pre-mining conditions. The hydrological functioning can be quantified and evaluated based on hydrological components and indicators of the surface water/groundwater system, including water influxes and outfluxes, or changes in water table elevation. The pre-mining hydrologic function of the McClelland Lake Watershed is evaluated using the 2018 MLWC HGS model (Aquanty 2019b) and serves as a reference for assessing the hydrologic function of various reclamation designs. A total of four different reclamation designs are evaluated in 2019 by modifying the 2018 MLWC HGS model to include reclamation design surfaces and material distributions provided by Suncor. The goal of this study is to identify the reclamation design(s) that can potentially reproduce a hydrologic function for the remnant portion of the fen similar to that of pre-mining conditions. Of the four reclamation designs provided by Suncor in 2019, two were identified as showing promise and will be further refined and evaluated in 2020. **A summary of the evaluation of the different reclamation designs completed in 2019 is presented Section 3 of this memo.**

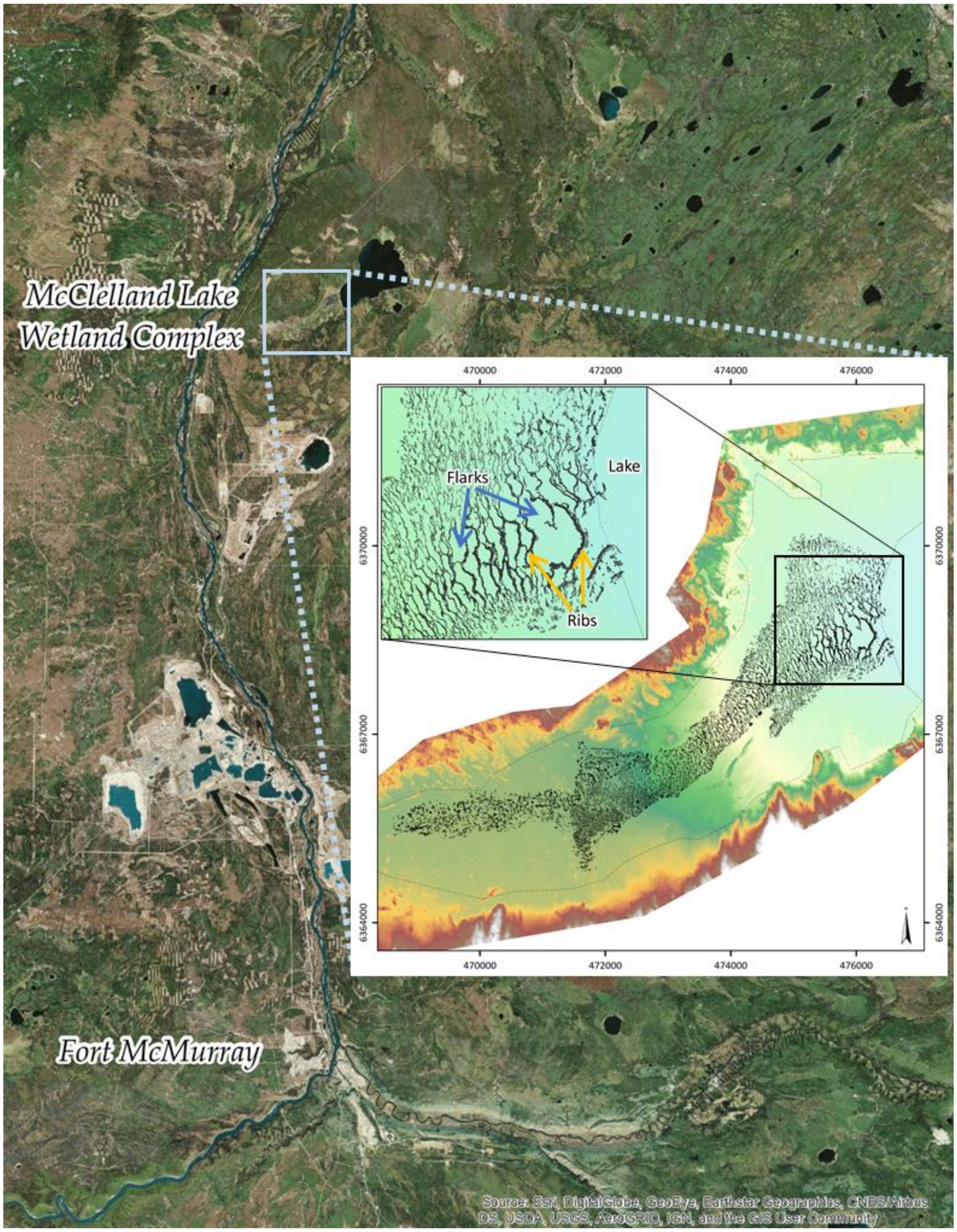


Figure 2: Location of the McClelland Lake Wetland Complex located of Fort McMurray. The inset image shows the rib and flark pattern of the patterned fen within the MLWC.

2 FEN REPRESENTATION IN THE REGIONAL-SCALE MODEL

The ribs and flarks in the patterned fen have widths parallel to the primary flow direction that range from ~5 to ~20 m and ~50 to ~200 m respectively. These features are too small to be explicitly represented within a regional scale HGS model (e.g., 2018 MLWC HGS model, which has node spacing of ~100 m in the fen), as such, it was necessary to develop upscaled parameters values such that the overall water balance of the patterned fen can be represented within a regional model. A detailed 2D upscaling of the patterned fen was completed in 2018 (Aquanty, 2019b). Section 2 of this memo reports the results of 3D upscaling that was completed in 2019 to verify the performance of the upscaling parameterization prior to inclusion in the regional scale numerical model for assessing the reclamation designs.

2.1 High-resolution Fen Simulations

A high-resolution 3D model was constructed covering a portion of the patterned fen to the south-west of McClelland Lake. The red dashed line in Figure 3a shows the model boundary of the chosen patterned fen area for the high-resolution 3D HGS model.

LiDAR elevation data received from Suncor was used to define the topography of the high-resolution 3D model. The vertical layering of the 3D high-resolution model contained variable thickness of peat (based on available borehole data) and the underlying quaternary layer. The LiDAR data had a lateral resolution of 0.5 m and allowed for capturing the precise shape and topographic profiles of the ribs and flarks within a triangular prism mesh developed using AlgoMesh (HydroAlgorithmics, 2016). This ensured appropriate representation of both the ribs and flarks, which control the lateral distribution and storage of water, in the 3D high-resolution model.

Daily climatology datasets (liquid water [rain plus snowmelt] and potential evapotranspiration [PET]) provided by Suncor were used to drive the 3D high-resolution HGS model. Total precipitation was partitioned by Suncor into rain and snowfall using air temperature, and snowmelt was generated using a temperature-index approach. The primary source of climate data was Environment Canada’s Fort McMurray meteorological station (1944 to present) located approximately 90 km south of the project area. Climatology for the years 2006-2015 were used to drive the model. Note: At the time of modelling, 2015 was the most recent complete data set available.

Figure 3b illustrates an example of ponding of water in the flarks during a simulation with the high-resolution 3D HGS model. The pattern of standing water in the flarks agrees well with the water distribution seen in the aerial photo shown in Figure 3a.

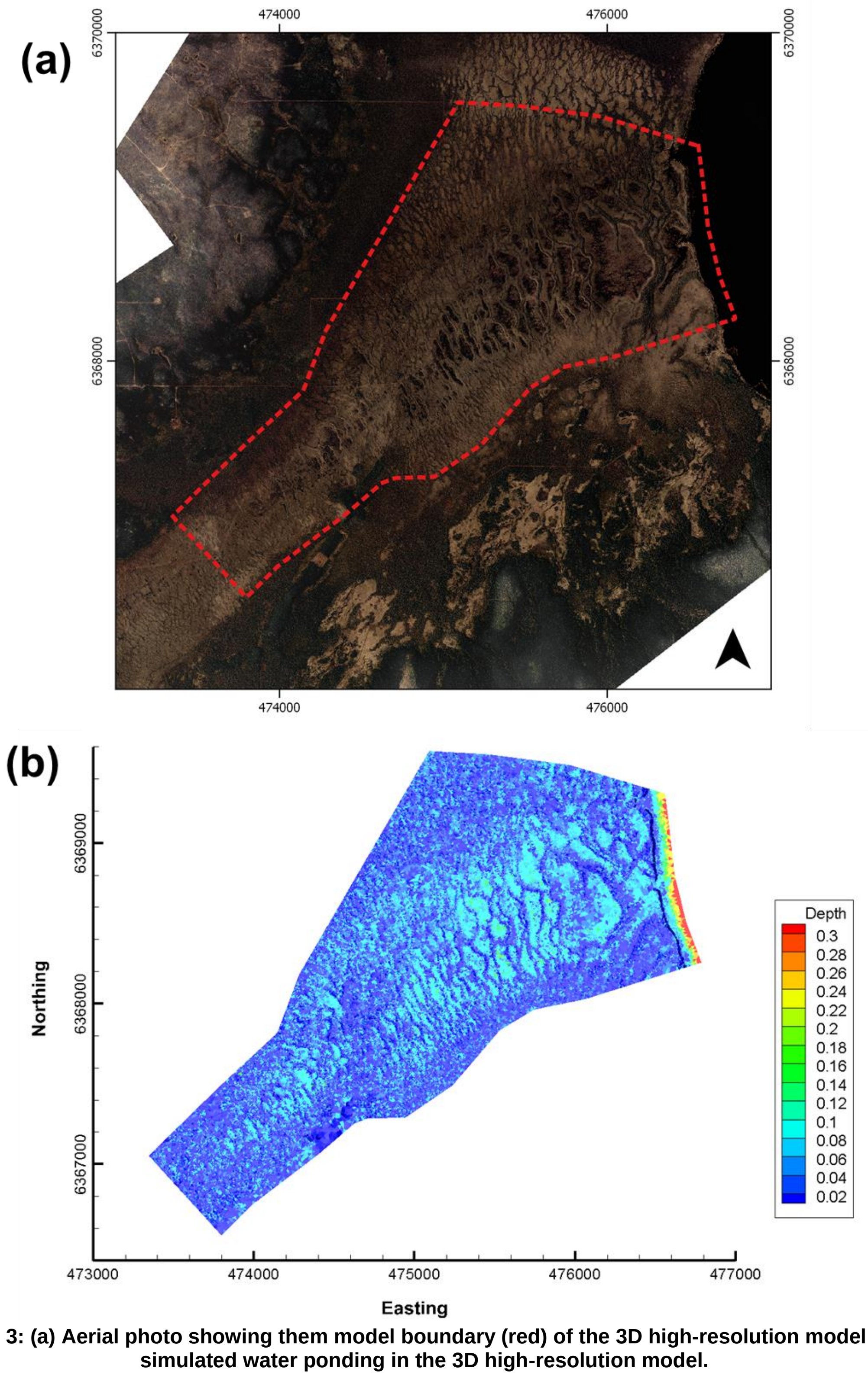


Figure 3: (a) Aerial photo showing them model boundary (red) of the 3D high-resolution model; and, (b) simulated water ponding in the 3D high-resolution model.

The performance of the 3D high-resolution model was assessed by comparing the simulated actual evapotranspiration (AET) of the fen from 2006 to 2015 to observed AET for 2018 and 2019 as measured by a meteorological tower located within the fen (Hatfield, 2019). The simulated and observed daily AET rates, as presented in Figure 4, show good agreement with the timing and magnitude of the seasonal AET cycle for 2018 and 2019. This suggests that the evapotranspiration (ET) and storage properties used to parameterize these processes in the 3D high-resolution HGS model were able to reasonably represent AET, which is the primary outflux component of the fen's water balance.

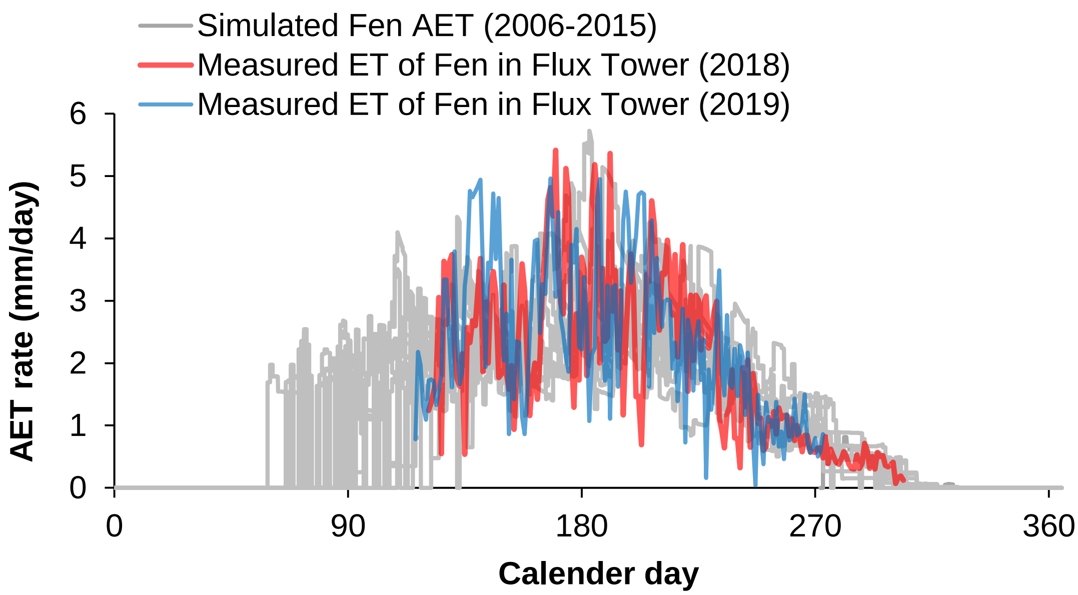


Figure 4: Simulated daily AET rate from 2006-2015 for the fen from the high-resolution model compared to measured AET in the fen for 2018 and 2019.

2.2 Parametric upscaling of fen properties

Since using a relatively small node spacing (e.g., ~5-10 m) in the fen (similar to that of the high-resolution model) is not practical for regional-scale models, it was necessary to derive parameters for a coarse mesh that preserve the hydrologic behaviour of the 3D high-resolution model; this is referred to as parametric upscaling. Parametric upscaling was completed by constructing a 3D low-resolution model with the same dimensions as the 3D high-resolution model. This low-resolution model was designed to approximate the triangular mesh resolution in the patterned fen portion of the regional-scale 2018 MLWC HGS model. As such, the triangular mesh did not explicitly include the rib and flark features of the patterned fen. Instead, to obtain similar surface water storage (i.e. an equivalent of water ponding in the flarks) in the 3D low-resolution model, the rill storage parameter in HGS was included in the calibration (the rill storage parameter in HGS is designed to mimic the effects of sub-grid microtopography, i.e. to what level does surface water need to rise before it can move laterally). The aim of the calibration was to parameterize the 3D low-resolution model such that it mimics the hydrologic function and water balance of the 3D high-resolution model. The calibration target was cumulative AET from the fen, since the AET of the fen is the largest outflux of water from the fen and its variation indicates the state of water availability in the fen. In addition to the rill storage height, parameters controlling the ET of the fen were calibrated in the low-resolution model; these include minimum evaporation pressure, evaporation depth, and the evaporation/transpiration partitioning coefficient (C2). Table

1 compares the parameterization of the high-resolution 3D model to the calibrated upscaled parameters for the low-resolution 3D model.

Figure 5 compares (a) the simulated cumulative AET (as the primary calibration target), and (b) the simulated cumulative surface water discharge from the fen into McClelland Lake (as a secondary indicator), for the 3D low-resolution and 3D high-resolution models over 10 years of simulation (2006-2015). The results show a good agreement between two models, suggesting that the calibrated (upscaled) parameters should be able to effectively represent the hydrologic function and water balance behaviour of the patterned fen within a region-scale model with coarse resolution in the fen; such as, the 2018 MLWC HGS model.

Table 1: Assigned Evaporation and Storage Parameters in High-resolution 3D Model and Estimated Parameter Values in the Low-resolution 3D Model During Calibration.

Model and surface feature		Minimum evaporation pressure (m)	Evaporation depth (m)	C_2	Rill storage height (m)
High resolution 3D Model	Flarks	-1	0.300	0.05	0.010
	Ribs	-1	0.500	0.35	0.010
Low resolution 3D model		-0.542	0.335	0.172	0.044

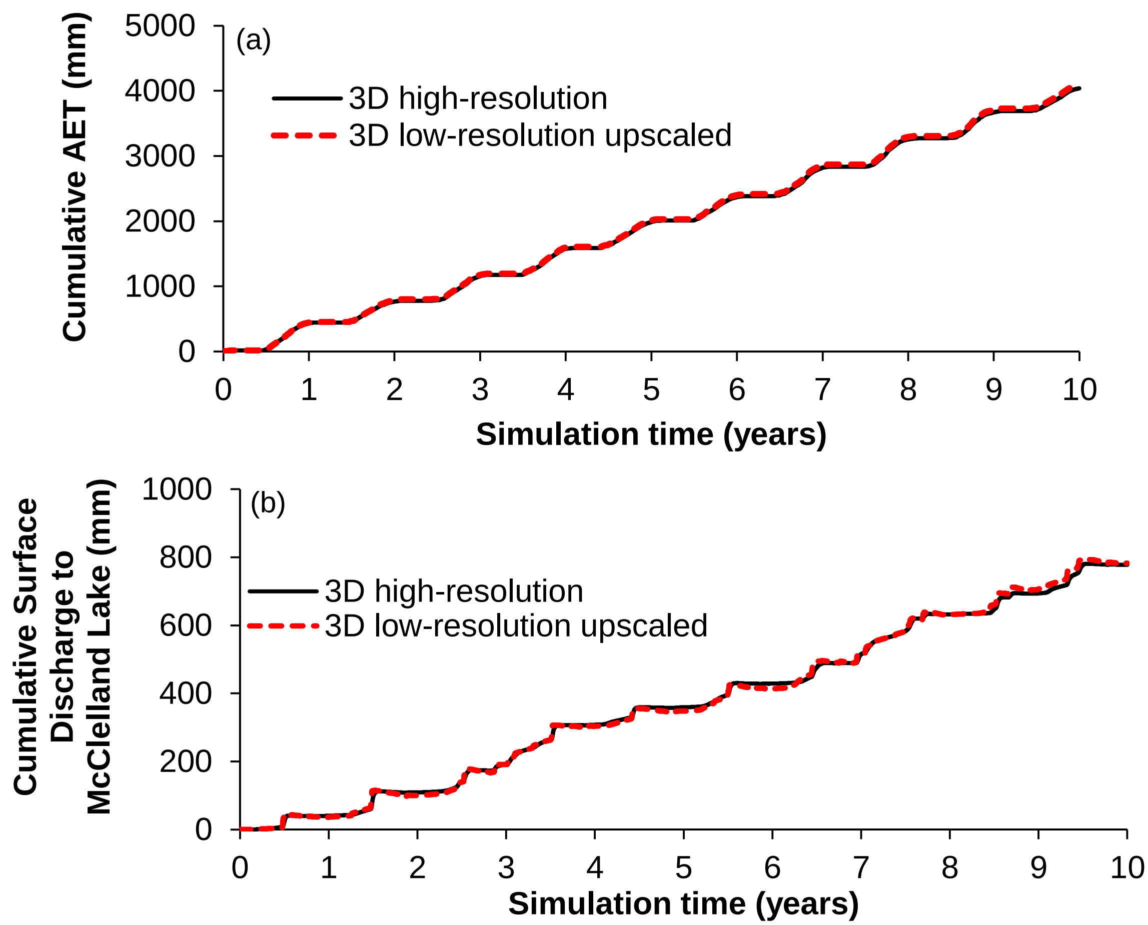


Figure 5: (a) Cumulative AET, and (b) cumulative surface discharge from the fen to McClelland Lake for the 3D high-resolution and 3D low-resolution models.

2.3 Validation of the Updated Regional Model

The upscaled fen parameters were incorporated into the 2018 MLWC HGS model, creating a version of the 2018 MLWC HGS model with upscaled fen parameterization (hereafter referred to as Upscaled 2018 MLWC HGS model). The pre-mining simulation was repeated with the Upscaled 2018 MLWC HGS model to assess the impact of the upscaled parameters on the model results. The result was an improvement in the simulated McClelland Lake water level, in particular between 2013 to 2015, (Figure 6) without any degradation of the groundwater calibration (not shown). Additionally, simulated AET rates from 1996-2015, for both the upland and the fen, were in good agreement with the observed daily rates from 2018 and 2019 years (Figure 7). The Upscaled 2018 MLWC HGS model is the base model for incorporating and simulating the reclamation scenarios presented in Section 3.

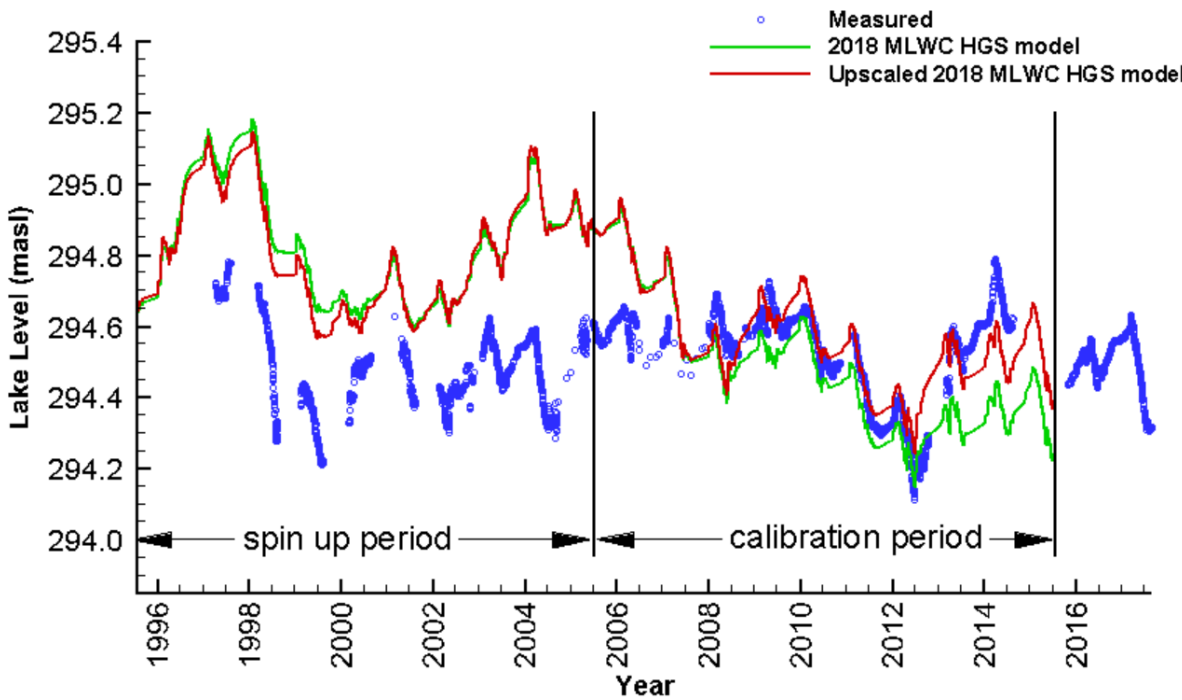


Figure 6: Simulated McClelland Lake level in the 2018 MLWC HGS model (with no upscaled fen parameterization) (Green) and Upscaled 2018 MLWC HGS model (with upscaled fen parameterization) (Red) vs. observed lake levels (blue). Note: The spin up period shown in the figure is included to allow initial condition effects to dissipate.

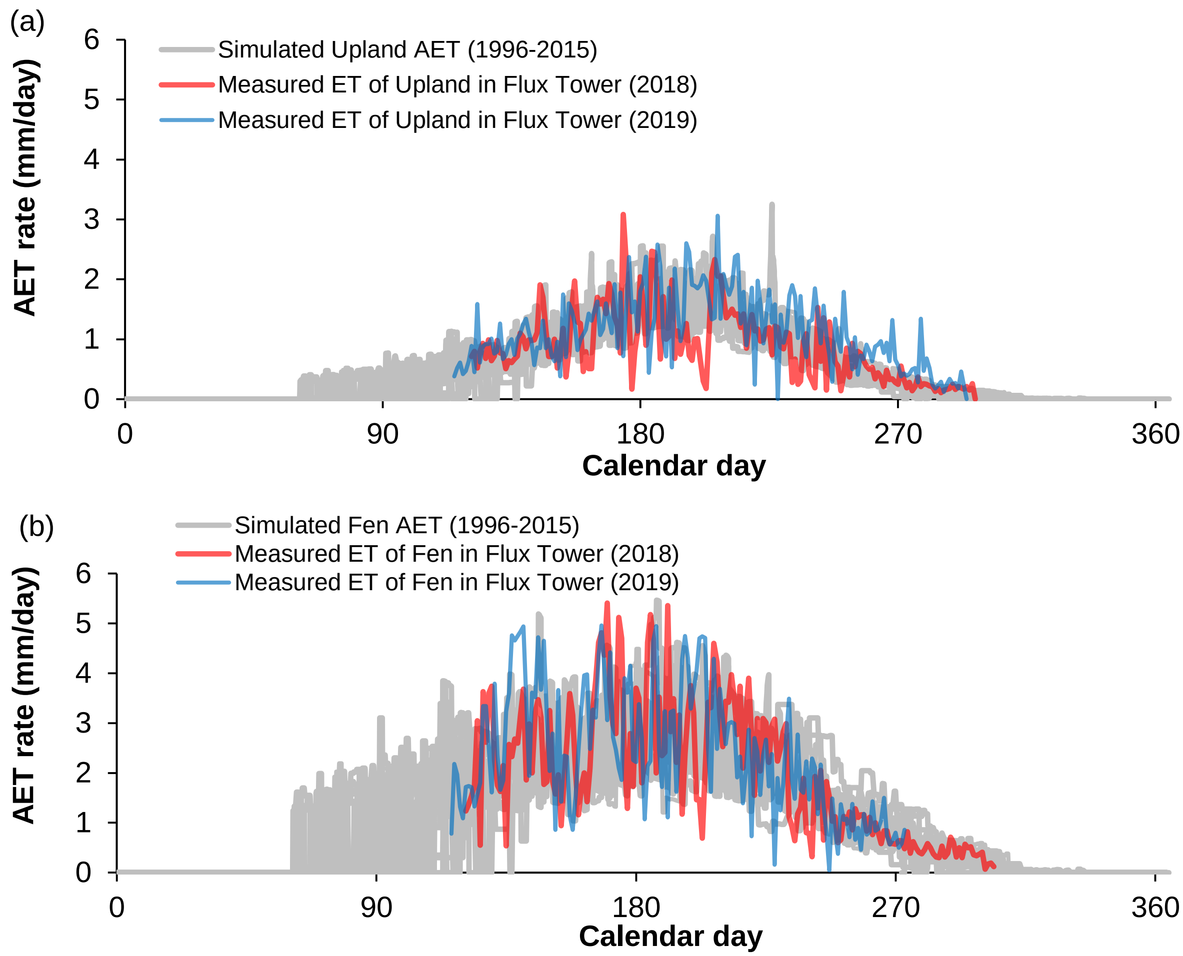


Figure 7: Simulated daily AET rates versus observed tower AET for (a) upland tower (MLWC1) and (b) fen tower (MWLC2)

3 RECLAMATION DESIGNS

3.1 Conceptualization

In 2019, Suncor developed four different mine reclamation concepts for the mined portion of the fen. These cases were originally named Base Case, Case 1, Case 2, and Case 3. **Since "Base Case" is a design case, we are renaming it to "Case 0" for the purposes of this memo to avoid possible misinterpretation of Base Case being understood as a pre-mining scenario**. Figure 8 shows the reclamation area (black outline) and the unmined portion of the fen. The black dashed line on this figure indicates the approximate orientation of the cross-section used to compare the different designs as shown in Figure 9 (a-d). The primary difference between the reclamation designs are the slope of reclaimed area southwest of the remnant fen, which is toward the northeast in all cases except Case 1. The other key difference between the designs is the presence of an upland of sandy soil for Cases 2 and 3 in the reclaimed area upgradient of the remnant fen.

3.2 Model Construction

The Upscaled 2018 MLWC HGS model was used as the base model into which the four different reclamation cases were incorporated based on the designed surfaces of reclaimed material provided by Suncor. A layer of surface soil with a minimum thickness of 50 cm was placed on top of all reclamation material in the reclaimed area. The soil type and hydraulic properties of subsurface reclamation material (e.g. compacted clay liner, sandy overburden, uncompacted overburden, tailings, *etc*.) and surface soil were determined in consultation with Suncor (Table 2). Figure 10 a-d shows a detailed cross-section for each reclamation design after it was incorporated into the Upscaled 2018 MLWC HGS model.

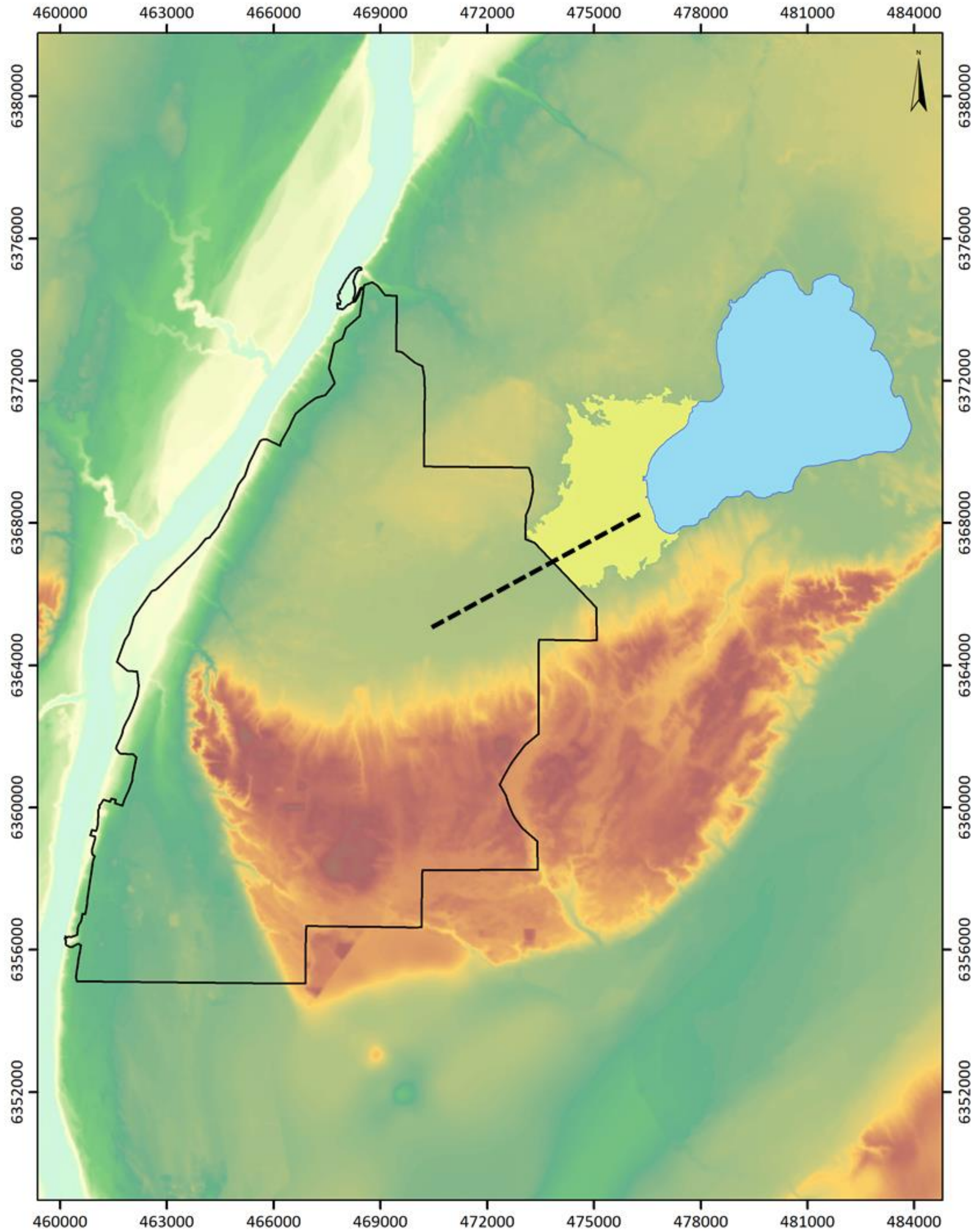


Figure 8: Reclamation design area (solid black line) and remnant fen (solid green) and approximate orientation of the cross-section (dashed black line) for comparing the different reclamation cases in Figure 9.

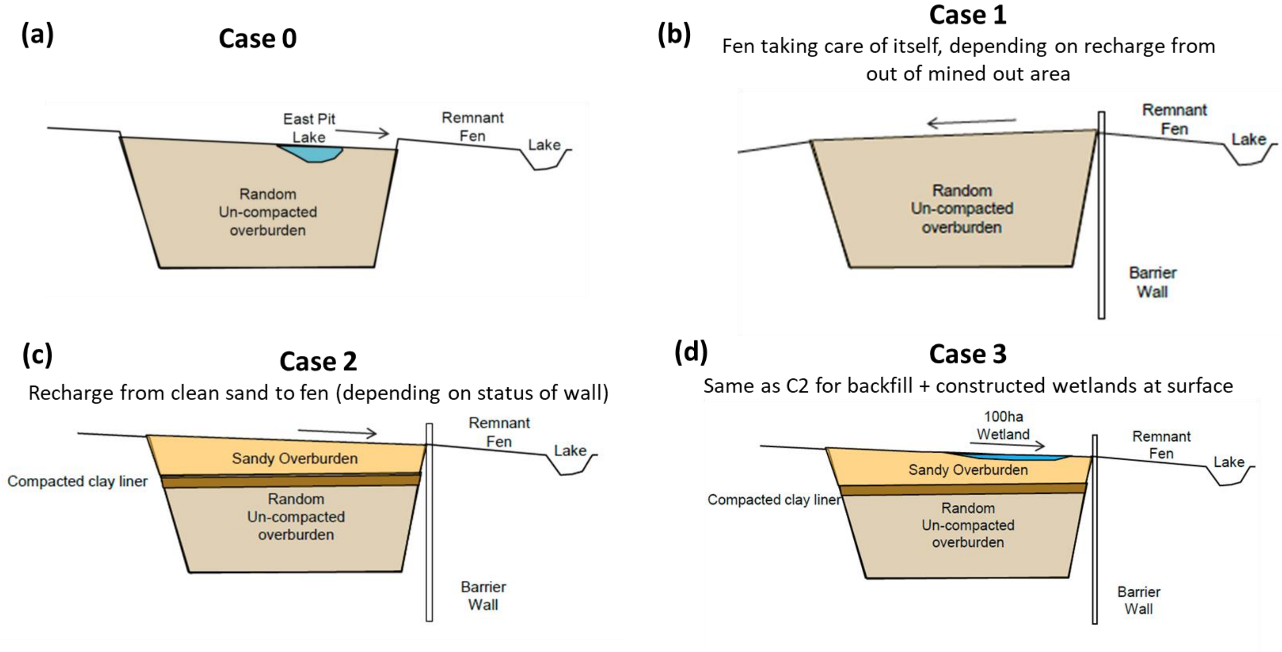


Figure 9: Cross-sections through four different reclamation design cases (Images source: Suncor).

Table 2: Hydraulic Properties Assigned to Reclamation Materials

Material Name	K_h (m/s)	K_{vs} (m/s)	Porosity (%)	Explanation
B-Spec	5.00E-09	5.00E-10	0.35	Source: “Compacted Fill (B/KSpec)” from Suncor
Semi Compacted OB	5.00E-09	5.00E-10	0.35	Source: “Compacted Fill (B/KSpec)” from Suncor
Tailings Sand	2.00E-05	1.00E-06	0.41	Source: "Tailings Sand (capping)' from Suncor
Random Uncompacted OB	7.00E-07	2.00E-07	0.46	Source: "Un-compacted Fill (GSpec)" from Suncor
Sandy Overburden	8.25E-05	8.25E-06*	0.43	Source: “Sand” from Carsel and Parrish (1988)
Compacted Clay Liner	5.56E-07	5.56E-08*	0.38	Source: “Clay” from Carsel and Parrish (1988)
Compacted OB	5.00E-09	5.00E-10	0.35	Source: “Compacted Fill (B/KSpec)” from Suncor
Upland Surface Soil Coarse (SSC)	1.23E-05	1.23E-06*	0.41	SSC is coarse sandy soil (e.g. sandy loam). Source: “Sandy loam” from Carsel and Parrish (1988)
Upland Subsoil Coarse (SBC)	1.23E-05	1.23E-06*	0.41	SBC is coarse sandy soil (e.g. sandy loam). Source: “Sandy loam” from Carsel and Parrish (1988)
Upland Surface Soil Fine (SSF)	7.22E-07	7.22E-08*	0.41	SSF is fine soil; source: “Clay loam” from Carsel and Parrish (1988)
Upland Subsoil Fine (SBF)	7.22E-07	7.22E-08*	0.41	SBF is fine soil; source: “Clay loam” from Carsel and Parrish (1988)
Peat-Mineral Mix (PMM)	7.22E-07	7.22E-08*	0.41	PMM is just a random soils mixed with peat. Source: “Clay loam”

* assuming $k_v = k_h \times 0.1$

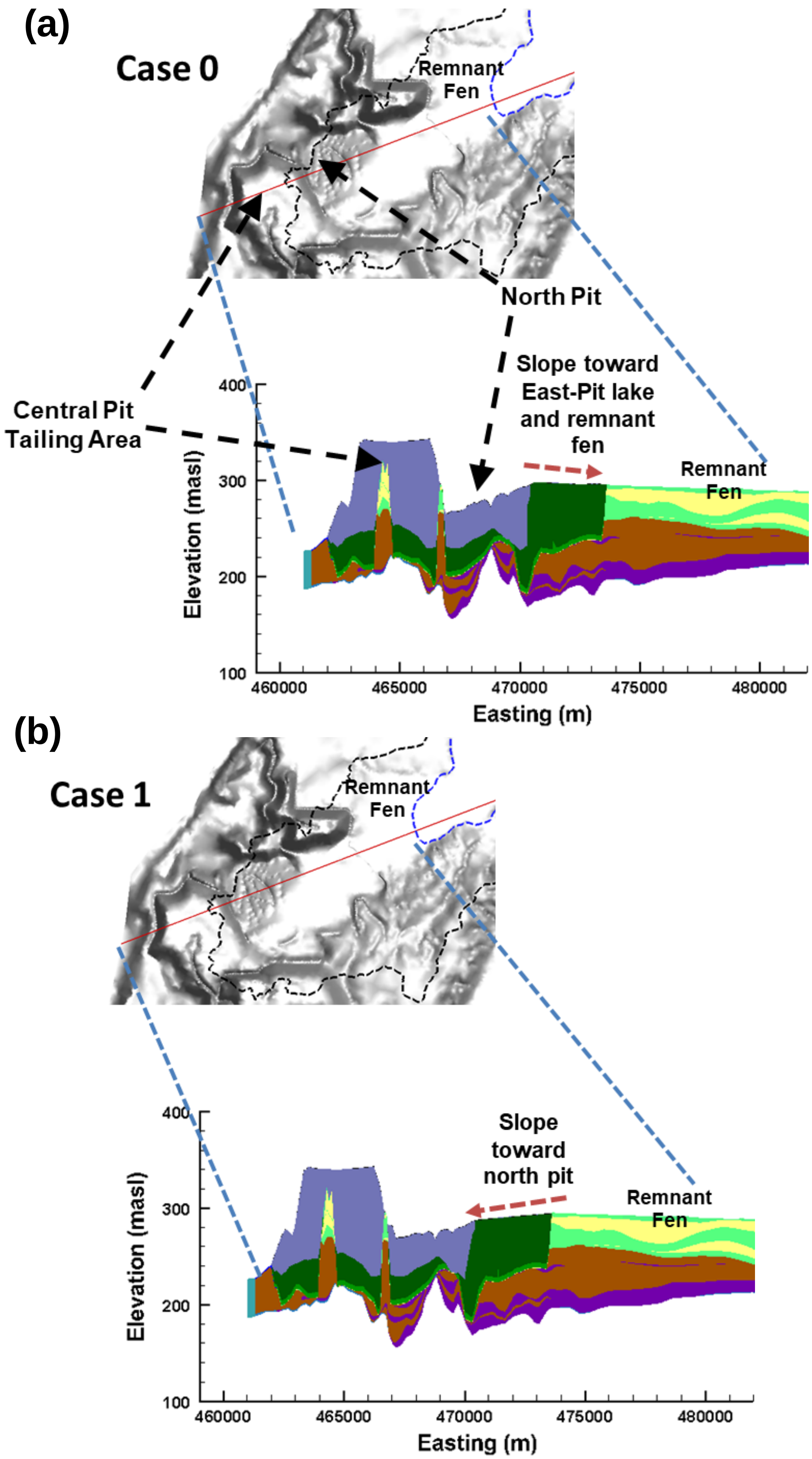
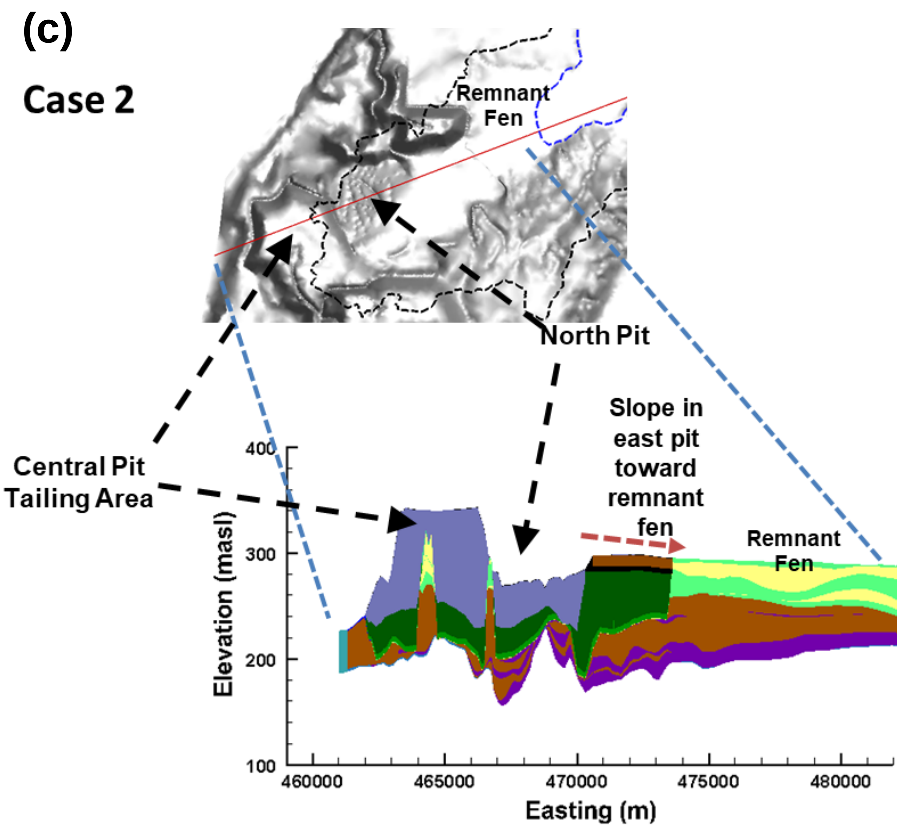


Figure 10: Surface topography and subsurface layering of the reclamation areas in (a) Case 0, and (b) Case 1.



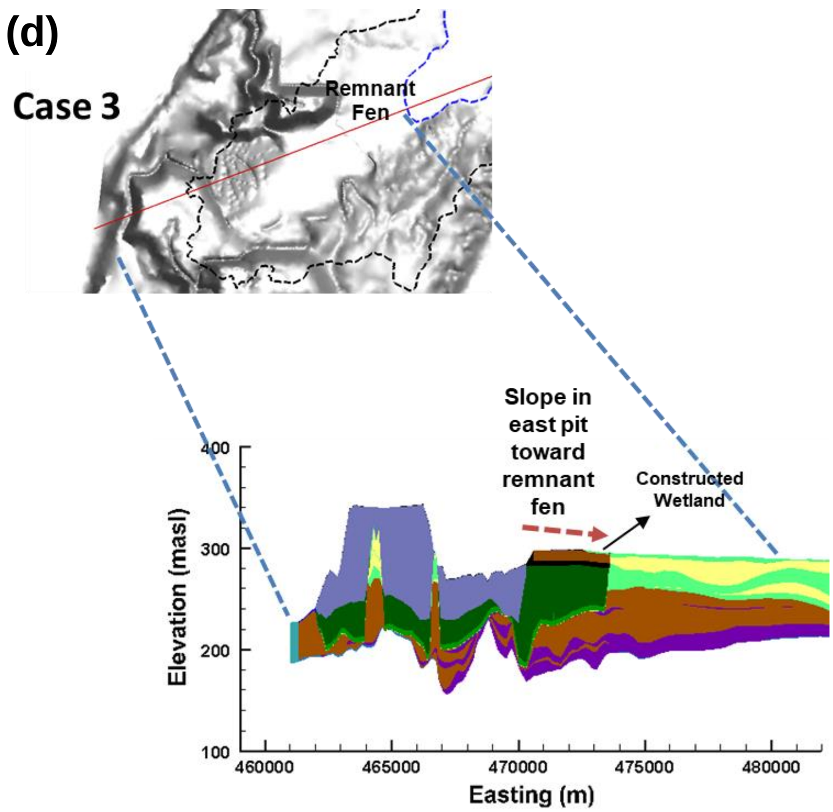


Figure 10 (continued): Surface topography and subsurface layering of the reclamation areas in (c) Case 2, and (d) Case 3.

As part of the engineered solutions to mitigate the drawdown effects of the pit excavation on the remnant fen, a surface berm and cut-off wall were included in the simulation of mine operations scenarios with the 2018 MLWC HGS model (Aquanty, 2019). As these reclamation scenarios represent the post-operations time period (post 2064), the performance of each reclamation design was evaluated for two conditions: 1) leaving the berm and cut-off wall in place (i.e. with wall scenarios) and, 2) with the berm and cut-off wall removed (i.e. no wall scenarios). Similar to the operational scenarios performed with the 2018 MLWC HGS model (Aquanty, 2019), the cut-off wall was represented by reducing the hydraulic conductivity of subsurface elements and by increasing the surface friction in the surface domain along the location of the wall. The net effect of these adjustments is to mimic the cut-off wall behaviour by minimizing the surface and subsurface connection between the reclaimed and remnant areas of the fen. These conditions represent extreme end members, and most likely, the solution will be a partial removal of the cut-off wall at some point after the reclamation construction is complete. The timing of cut-off wall removal will be further evaluated as part of the continuation of this project in 2020.

All reclamation simulations were run using the climate forcing data from 1996-2015, which is the same used to assess the performance of the Upscaled 2018 MLWC HGS model (described in section 2.3). Therefore, it is feasible to make a direct comparison of the hydrological function in the remnant portion of the fen between Upscaled 2018 MLWC HGS model and the reclamation models.

3.3 Reclamation Design - Evaluation Criteria

The performance of reclamation design Cases 0-3 were evaluated relative to simulation results from the Upscaled 2018 MLWC HGS model by comparing the following evaluation criteria between them:

- **Criteria 1:** Water table depth exceedance vs frequency relationship (i.e., duration curves);
- **Criteria 2:** Average vertical discharge from the quaternary sand aquifer into the peat soil in the remnant fen area (Figure 11a);
- **Criteria 3:** The average rate of lateral groundwater discharge from the to-be-mined portion of the fen into the remnant portion of the fen (under pre-mining conditions) versus the average rate of lateral groundwater discharge from the reclaimed area into the remnant portion of the fen (under reclamation conditions) (Figure 11b); and
- **Criteria 4:** Comparison of average rate of surface water discharge from the to-be-mined portion of the fen into the remnant portion of the fen (under pre-mining conditions); and, the average rate of surface water discharge from the reclaimed area into the remnant portion of the fen (under reclamation conditions) (Figure 11b).

McClelland Lake levels were compared as a secondary indicator.

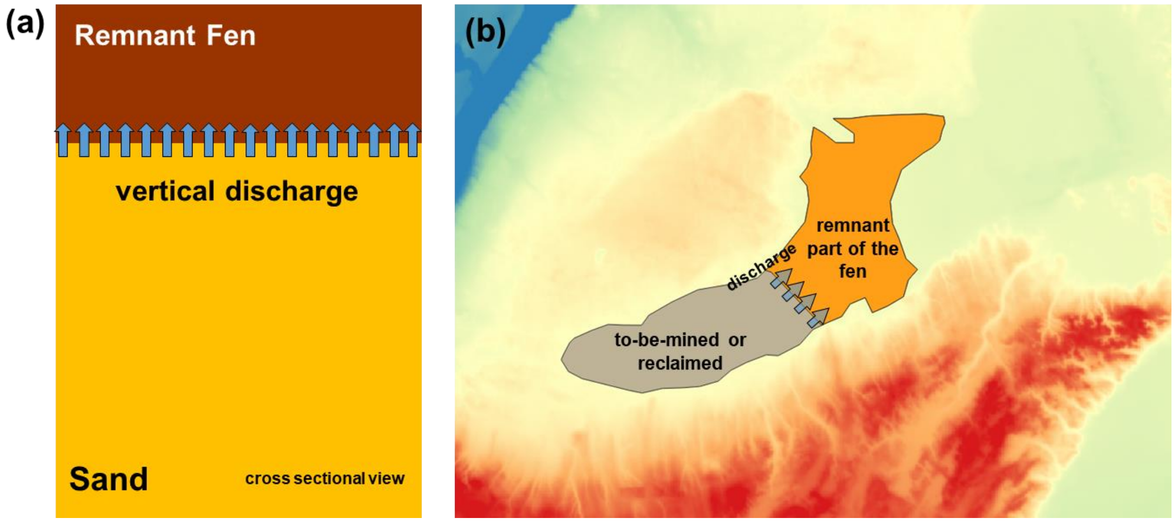


Figure 11: (a) vertical recharge from quaternary sand layer into the peat layer of the remnant part of the fen; (b) lateral surface and subsurface discharge from to-be-mined or reclaimed portion of the fen into the remnant fen area.

To provide the data for the first evaluation criteria, observation points which cover the entire remnant fen, as shown in Figure 12, were added to the models. The observation points used to quantify the spatial and temporal water table variations in the models and to generate the data required for evaluation Criteria 1.

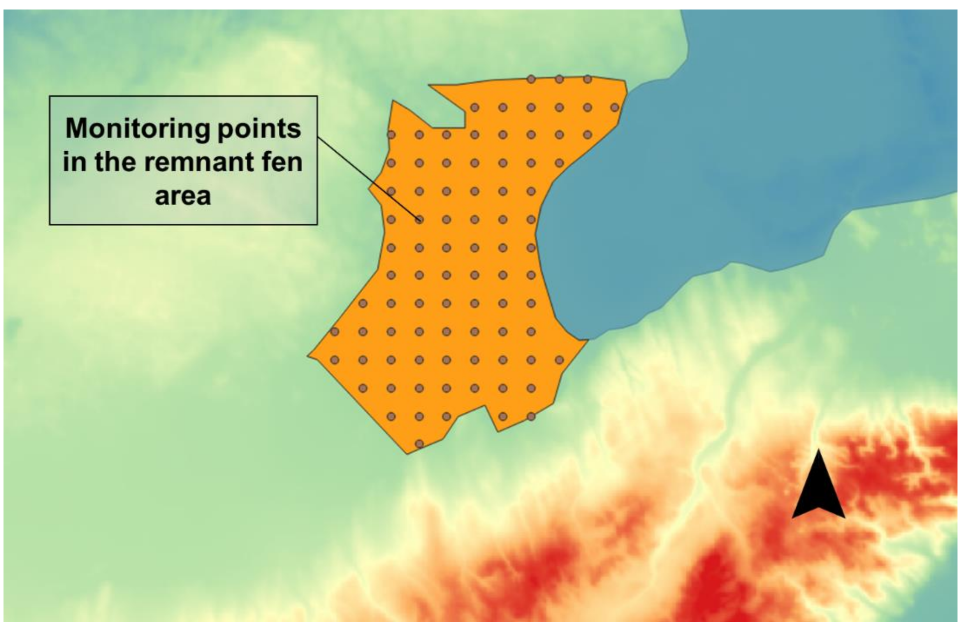


Figure 12: Observation points in used to track the temporal variations of water table depth in the remnant fen area during the simulations.

3.4 Results

The simulated results for each of the four evaluation criteria are presented in Figure 13 and Table 3.

3.4.1 Criteria 1 - Water Table Depth Exceedance vs Frequency Relationship

The water table depth duration curves for the remnant fen (Figure 13) show that the frequency of water table below both 20- and 30-cm depth (below ground surface [bgs]) is higher for all reclamation cases relative to the Upscaled 2018 MLWC HGS model. This means that the cumulative duration of dry events in which the water table is deeper than 20 cm bgs and 30 cm bgs is higher after the reclamation relative to the pre-mining conditions. The average annual duration of dry events (in days) of all models is presented in Table 3.

For severely dry conditions, where the water table is deeper than 40 cm bgs, the exceedance of all reclamation models, with the exception of Case 2 (no wall) and Case 3 (no wall), have increased relative to pre-mining conditions. The average annual duration of dry periods, when the water table is deeper than 40 cm bgs, were 6.0 and 5.9 days for Case 2 (no wall) and Case 3 (no wall) respectively, which is similar to 6.1 days for pre-mining conditions (Table 3).

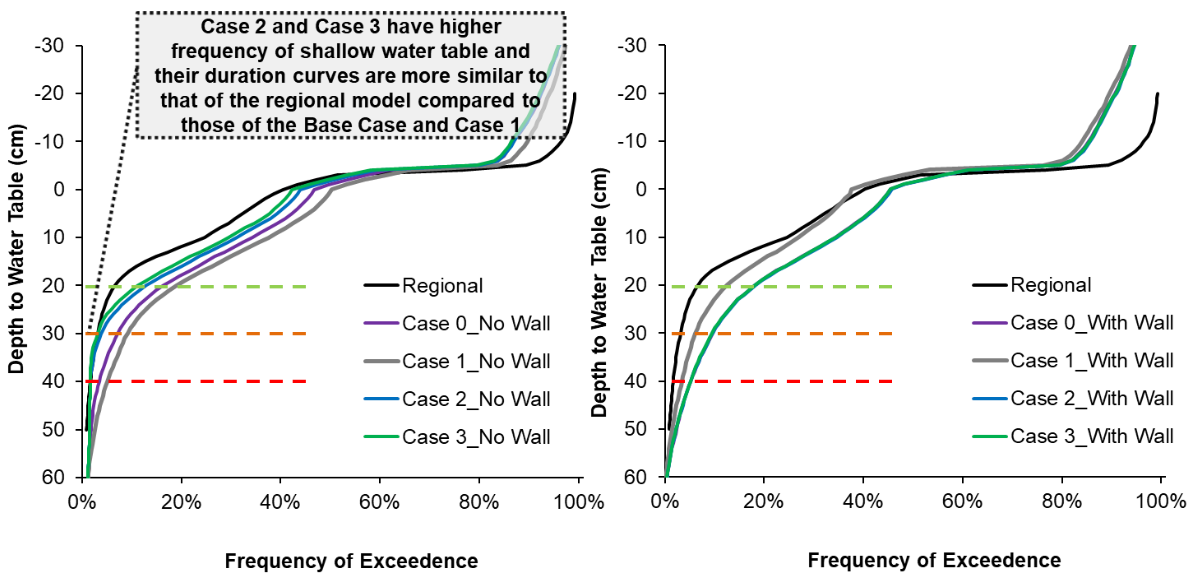


Figure 13: Depth-duration curves of the regional model and reclamation cases with and without the cut-off wall; in cases with wall, the curves of Case 0 and Case 2 are behind that of Case 3.

3.4.2 Criteria 2 - Average Vertical Dscharge from the Quaternary Sand Aquifer into the Peat Soil in the Remnant Fen Area

The vertical discharge into the remnant fen area in the Upscaled 2018 MLWC HGS model is 79 mm/y. For all reclamation cases, excluding Case 1 with wall, the vertical discharge rates into the peat layer of the remnant fen are reduced and range between 36 mm/y to 55 mm/y. The results show that the vertical discharge into the fen generally decreases for all reclamation cases.

3.4.3 *Criteria 3 and 4 - Surface and Groundwater Water Flux to the Remnant Fen*

The results show that the rates of surface and subsurface water discharge from to-be-mined portion of the fen into the remnant fen area are 136 mm/y and 30 mm/y respectively (Table 3) in the Upscaled 2018 MLWC HGS model. The rates of surface and groundwater discharge from the reclaimed area into the remnant fen area for the reclamation cases range between -1 to 13 mm/y and -9 to 20 mm/y (Table 3). Negative values indicate water discharge from the remnant portion of the fen into the reclamation area. The reduction in surface and subsurface discharge suggests that the average annual surface water and groundwater discharge into the remnant fen area during post-reclamation conditions may be considerably less than that of the pre-mining conditions. This might be one of the reasons that the durations of dry periods in the reclamation models were generally longer than those in the Upscaled 2018 MLWC HGS model.

Table 3: Tracking Results in Calibrated Regional Model Compared to the Results of Closure Models Without the Cut-Off Wall (No-Wall Scenarios)

		Upscaled 2018 MLWC HGS model	Case 0		Case 1		Case 2		Case 3	
			With Wall	No Wall	With Wall	No Wall	With Wall	No Wall	With Wall	No Wall
Average duration of WT lower than 20cm (Criteria 1)	(days/year)	24.2	66.1	59.8	45.6	69.4	66.9	47.2	66.3	41.3
Average duration of WT lower than 30cm (Criteria 1)	days/year)	11.5	35.2	26.3	22.5	33.4	35.1	14.2	34.5	11.2
Average duration of WT lower than 40cm (Criteria 1)	days/year)	6.1	19.1	12.6	12.6	18.5	19.1	6.0	18.7	5.9
Vertical discharge from underlying sand aquifer into remnant fen (Criteria 2)	(mm/y)	79	49	46	94	36	51	52	52	55
Surface flux (Mined to Remnant) (Criteria 3)	Daily rate (m^3/day)	4976.2	144.5	492.5	-21.2	-0.4	299.1	484.1	473.1	485.3
	Equivalent annual rate (mm/yr)	136	4	13	-1	0.0	8	13	13	13
GW flux (Mined to Remnant) (Criteria 4)	Daily rate (m^3/day)	1101.4	-80.3	-67.4	-341.9	-324.0	120.2	459.9	65.1	738.8
	Equivalent annual rate (mm/yr)	30	-2	-2	-9	-9	3	13	2	20

3.4.4 *Lake Level as a Secondary Indicator*

As a secondary indicator, the water level in the McClelland Lake was monitored during the simulation period in the reclamation models (Figure 14 and Figure 15). The results show similar simulated lake level for all reclamation cases.

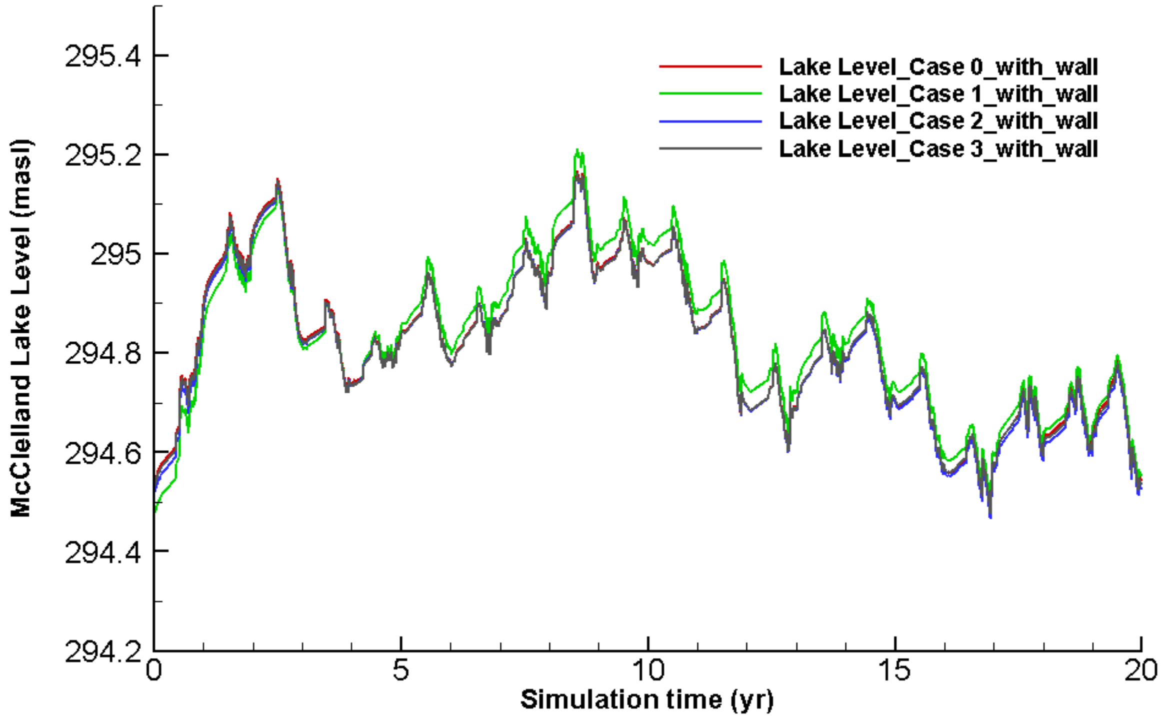


Figure 14: Comparison of simulated lake levels in the different closure cases with the cut-off wall

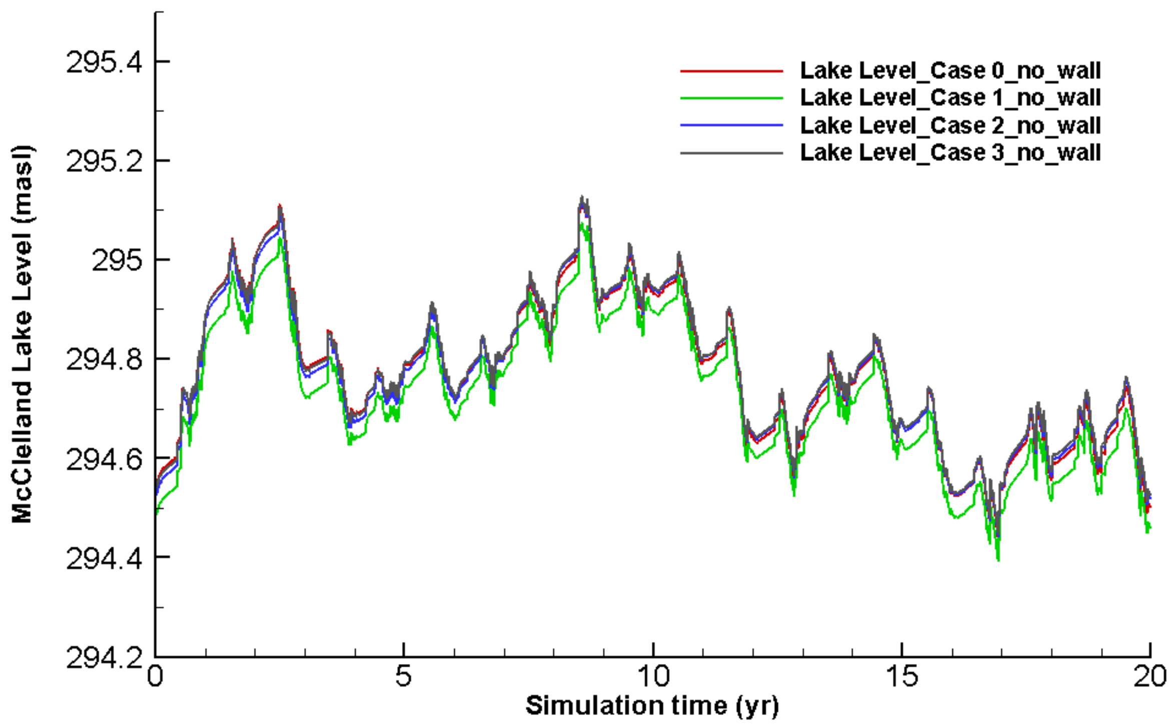


Figure 15: Comparison of simulated lake levels in the different closure cases without the cut-off wall

4 SUMMARY AND CONCLUSION

The simulation results show that while the reclamation designs might not a have significant effect on the water level of McClelland Lake, they have the potential to increase the duration of dry periods in the remnant fen and decrease surface water and groundwater fluxes into the remnant fen.

Based on these results, Cases 2 and 3 show the most promise for continued design refinement and optimization. Both Cases 2 and 3 (no wall) did not show a significant increase in the duration of water table depth below 40 cm bgs. The lower frequencies of water table below 40 cm bgs (compared to the other reclamation designs) are possibly due to the sandy upland layer present upgradient of the remnant fen in these reclamation designs, which will function to store surplus water and regulate discharge to the remnant fen.

While Cases 2 and 3 (no-wall) show that the amount of water discharging from the reclaimed area into the remnant fen will likely be reduced relative to pre-mining conditions, they still perform better than Case 0 and Case 1. This also could be a result of the sandy upland (in the reclaimed area) upgradient of the remnant fen. There may be opportunities to further improve the performance of Cases 2 and 3 (no-wall) by performing a sensitivity analyses on the shape and dimension of the sandy upland.

The absence of any significant impact to the McClelland Lake levels, despite clear changes in the hydrologic function of the fen, indicates that the fen itself is more sensitive to the final reclamation design relative to the lake. This highlights the need for a specific focus on the fen when optimizing the reclamation designs in 2020.

In 2020, these simulations will be repeated with the most current geology as included in the 2020 HGS Model. Additional iterations of the reclamation designs are expected to be generated in 2020, which will be evaluated using the same methodology presented in this memo. The impact of cut-off wall removal timing will also be evaluated as part of the work to be completed in 2020.

5 REFERENCES

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6 LIMITATIONS

This memo has been prepared by Aquanty Inc., for the exclusive use of Fort Hills Energy Limited Partnership, and its authorized agents (collectively, “FHELP”) in connection with certain professional hydrogeological modelling services. FHELP acknowledges that the information contained in this memo, including, without limitation, the factual information, descriptions, interpretations, plans, specifications, calculations, notes, electronic files and similar material, comments, conclusions and recommendations contained herein with respect to the hydrogeological model are based on the hydrogeological investigations specific to the project described in this report and do not apply to any other project or site.

The professional hydrogeological modelling services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by members of the engineering and science professions currently practising under similar conditions, subject to the quantity and quality of available data, the time limits and financial and physical constraints applicable to the services. Unless otherwise specified, the results of previous or simultaneous work provided by sources other than Aquanty Inc., and quoted and/or used herein are considered as having been obtained according to recognised and accepted professional rules and practices, and therefore deemed valid. This model provides a predictive scientific tool to evaluate the impacts on a real hydrogeological system of specified hydrological stresses and/or to compare various scenarios in a decision-making process.

This memo must be read in its entirety as some sections could be falsely interpreted when taken individually or out-of-context. As well, the final version of this report and its content supersedes any other text, opinion or preliminary version produced by Aquanty Inc.

LIMITATIONS OF LIABILITY

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Attachment C

Description of the Potential Evapotranspiration Methodology

Memorandum Date	Wednesday, July 7, 2021
To	Aquanty Inc.
From	Ranjeet Nagare, Ph.D., P.Eng.; Ali Kiyani, P.Eng.; Rob Wirtz, P.Eng.
Copy to	
Project Name	Fort Hills Mine Closure Modelling Support
Project Number	20-028
File No.	20-028-CE-MEM-0001-REVA

Aquanty Inc. (Aquanty) retained ARKK Engineering Corporation (ARKK) to provide technical support and review of surface water and groundwater modelling for Fort Hills Mine Closure ("closure water modelling"). The modelling is being conducted using HydroGeoSphere (Aquanty 2015), a fully coupled surface water and groundwater, solute and heat transport code. HydroGeoSphere uses potential evapotranspiration (PET) based formulation to calculate actual evapotranspiration. As part of ARKK's support, Aquanty requested information on methodology used to estimate potential evapotranspiration (PET) time series used in the closure water modelling. This memorandum briefly describes the methodology used to calculate PET time series used in the modelling.

PET can be estimated using energy balance or empirical methods. The energy balance methods (e.g., Penman-Monteith) need comprehensive meteorological data and their application is limited when required climate data are not available. Empirical approaches (e.g., Hamon, Thornthwaite) use most readily available meteorological variables (e.g., air temperature) for PET calculation. Empirical PET methods typically require development of location specific equations and calibration to be reliable. Long-term time series of required meteorological data (e.g., net radiation, wind speed, and humidity) are not available for the Fort McMurray region. Therefore, estimating PET with Penman-Monteith method with high confidence is not possible.

For closure water modelling, Hamon (1963) method was used to calculate PET based on air temperature measured at Environment Canada's Fort McMurray Airport Weather Station. Hamon's (1963) PET equation (Dingman 2002) is stated as:

$$ET\ (\frac{mm}{day}) = 29.8D\,\frac{e_a^*}{T_a + 273.15}$$

where e_a^* is the saturation vapor pressure (kPa) at the mean daily temperature T_a (°C), and D is day length (hours). Published monthly PET and shallow lake evaporation data calculated using Morton's complementary areal evapotranspiration relationship for different locations in Alberta (Alberta Government 2013) are available for 1972-2009 period. These monthly PET and shallow lake evaporation data from 1972-2009 were used to calculate adjustment factors to correct the PET values calculated using Hamon's (1963) method. The monthly adjustment factors were used to correct the daily PET values for each month. The adjustment factors for different months are given in Table 1.

Table 1 – Adjustment Factors of Calculated PET for Each Month

Month	Adjustment Factor
Jan	1
Feb	1
Mar	2.2
Apr	1.8
May	1.5
Jun	1.4
Jul	1.3
Aug	1.2
Sep	0.9
Oct	0.7
Nov	0.1
Dec	1

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Dingman, S. L. 2002. Physical Hydrology (Second Edition), Waveland Press Inc., Englewood, Long Grove, IL, 646 pages.

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Attachment D

Groundwater Levels Calibration Targets and Results

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
1	AA-01-20-97-10-L	464919	6365159	292.845	288.61	293.088	4.478	included
2	AA-11-32-97-09-L	474275.6	6368800	288.67	292.97	295.809	2.839	included
3	FH08-OB-004-L	463271.4	6355452	289.42	291.77	292.074	0.304	included
4	FH08-OB-006-L	463240	6356208	286.42	288.53	290.636	2.106	included
5	FH08-OB-010-L	463757.8	6355816	291.73	289.46	294.248	4.788	included
6	FH08-OB-013-L	464216.3	6356509	287.39	287.9	290.067	2.167	included
7	FH08-OB-014-L	463656.2	6356508	289.81	288.89	292.246	3.356	included
8	FH08-OB-016-L	464737.4	6357176	285.445	285.13	287.916	2.786	included
9	FH11-MW-001-L	468185.6	6366346	290.745	298.71	299.397	0.687	included
10	FH11-MW-002-L	466360.4	6365301	286.765	296.58	298.89	2.31	included
11	FH11-MW-003-L	466542.6	6367206	285.975	293.08	294.414	1.334	included
12	FH11-MW-004-L	476012.1	6364497	310.065	324.95	325.101	0.151	included
13	FH11-MW-005-L	464930	6364396	278.42	298.34	298.923	0.583	included
14	FH11-MW-006-L	474228.1	6363441	322.455	321.21	324.66	3.45	included
15	FH11-MW-007-L	477028.1	6373638	274.895	294.43	294.967	0.537	included
16	FH11-MW-008-L	470992.3	6368298	291.685	298.98	298.586	-0.394	included
17	FH11-MW-009-L	469104.3	6367599	292.935	299.5	298.409	-1.091	included
18	FH11-MW-010-L	468217.5	6369223	290.905	290.92	294.312	3.392	included
19	FH11-MW-012-L	469215.7	6371389	277.41	285.15	290.732	5.582	included
20	FH11-MW-015-L	469644.5	6373456	272.44	280.78	285.353	4.573	included
21	FH17-WR414-SN2-L	478160.4	6367061	298.57	305.67	306.967	1.297	included
22	FH17-WR416-SN1-L	475549.5	6368393	285.75	294.83	295.027	0.197	included
23	FH17-WR418-SN2-L	474990.9	6369347	281.395	295.06	295.147	0.087	included
24	FH17-WR420-SN1-L	476197.2	6367509	287.92	295.08	295.234	0.154	included
25	FH17-WR440-SN1-L	473794.1	6367187	287.92	296.8	296.873	0.073	included
26	FH17-WR451-SN2-L	475028.3	6367135	285.89	295.7	295.842	0.142	included
27	FH18-ES412-SN1-L	483674.1	6372381	278.66	294.01	294.288	0.278	included
28	FH19-ES647-SN1-MW-L	475072.9	6365477	287.17	309.3	310.723	1.423	included
29	FH19-ES656-SN1-MW-L	475006.1	6365188	274.69	312.81	315.999	3.189	included
30	FH19-ES663-SN2-MW-L	474943.8	6364892	293.92	314.1	318.002	3.902	included
31	FH19-GL612-SN1-MW-L	472127.3	6367688	281.23	298.59	298.539	-0.051	included
32	FH19-GL667-SN1-VW-L	474650	6364771	299.81	312.64	316.738	4.098	included
33	FH-MW14-06-SS-L	461134	6357212	278.6	281.32	283.634	2.314	included
34	FH-MW14-20-SS-L	462935.9	6357927	284.16	287.94	289.313	1.373	included
35	FH-MW14-21-SS-L	462838.8	6357685	256.49	258.54	288.742	30.202	excluded
36	GT07-090A-L	469399.8	6365600	291.395	299.73	300.038	0.308	included
37	GT-07-090B-L	469401.4	6365600	295.835	299.86	300.038	0.178	included
38	GT07-091A-L	471608.9	6365900	288.215	299.64	299.498	-0.142	included
39	GT-07-091B-L	471607.3	6365899	292.765	299.6	299.498	-0.102	included
40	GT07-091C-L	471605.8	6365899	296.195	299.54	299.487	-0.053	included
41	GT07-092A-L	473606.3	6366800	285.185	297.43	297.399	-0.031	included
42	GT-07-092B-L	473604.7	6366800	287.99	297.39	297.399	0.009	included
43	GT-07-092C-L	473603.2	6366800	291.675	297.32	297.398	0.078	included
44	GT-07-093A-L	474607.6	6367800	288.26	295.85	295.748	-0.102	included
45	GT07-093B-L	474606.2	6367800	292.03	295.84	295.748	-0.092	included
46	GT-07-093C-L	474604.5	6367800	294.36	295.91	295.751	-0.159	included
47	GT07-094A-L	471041.6	6367517	284.615	298.53	299.189	0.659	included
48	GT07-094B-L	471039	6367516	298.645	298.55	299.19	0.64	included
49	GT-07-095A-L	471259	6367060	285.405	299.44	299.357	-0.083	included
50	GT-07-095B-L	471256	6367058	297.145	299.53	299.359	-0.171	included
51	GT07-096A-L	472642.9	6364137	294.49	307.44	308.655	1.215	included
52	GT-07-097B-L	473003.6	6363503	299.835	310.92	316.559	5.639	included
53	GT07-097C-L	473006.3	6363506	311.085	312.96	317.294	4.334	included
54	GT07-098A-L	472962.2	6368342	283.74	298.73	297.605	-1.125	included
55	GT07-098B-L	472960	6368342	298.015	298.36	297.746	-0.614	included
56	GT07-099A-L	473106.7	6368002	283.61	298.59	297.622	-0.968	included
57	GT07-099B-L	473105.2	6368001	297.635	298.3	297.98	-0.32	included
58	GT-07-100A-L	474807.6	6365745	282.885	304.07	305.072	1.002	included
59	GT-07-101A-L	474927.3	6365372	283.535	312	311.501	-0.499	included
60	GT-07-101B-L	474925.9	6365371	304.03	312.12	311.569	-0.551	included
61	MW06-046A-L	469559.3	6358894	291.395	334.79	330.248	-4.542	included
62	MW-06-074-A-L	469358	6361541	287.495	329.03	329.751	0.721	included

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
63	MW-06-074-B-L	469355.7	6361541	314.985	328.3	330.408	2.108	included
64	MW-06-085-B-L	472817.6	6359500	314.345	327.01	330.416	3.406	included
65	MW-06-096-A-L	473009.5	6357300	286.45	328.65	325.186	-3.464	included
66	MW-08-01-L	473750.4	6378239	272.595	281.69	281.157	-0.533	included
67	MW-08-02-L	471306.4	6375883	271.775	280.89	279.974	-0.916	included
68	MW-08-05-L	474539.5	6375833	270.055	290.84	290.305	-0.535	included
69	MW-08-06-L	470059.4	6373036	275.26	283.15	287.211	4.061	included
70	MW-08-07-L	472933.4	6373405	273.02	290.6	292.162	1.562	included
71	MW08-09-L	472198.6	6371869	271.255	292.73	294.057	1.327	included
72	MW08-10-L	473675.4	6371749	261.475	294.42	295.18	0.76	included
73	MW08-11-L	470888.4	6369775	280.585	295.17	296.532	1.362	included
74	MW08-12-L	473358.1	6369816	271.355	296.16	296.453	0.293	included
75	MW-08-13-L	473783.6	6370133	273.1	296.61	296.113	-0.497	included
76	A-18-M	465656	6364454	296.36	298.18	300.442	2.262	included
77	A-20-AQ1-M	473425.5	6360863	331.32	331.88	336.63	4.75	included
78	A-20-AQ2-M	473424	6360861	323.85	331.9	333.55	1.65	included
79	A-20-AQ3-M	473422.7	6360863	318.5	331.99	333.55	1.56	included
80	A-21-AQ2-M	473401.7	6360240	329.07	331.28	333.873	2.593	included
81	A-21-AQ3-M	473401.6	6360242	320.72	331.4	332.871	1.471	included
82	A-22-AQ1-M	473397.9	6359502	324.44	326.51	334.499	7.989	included
83	A-22-AQ2-M	473396.8	6359502	316.83	326.65	330.188	3.538	included
84	A-22-AQ3-M	473398.7	6359503	312.4	326.62	330.188	3.568	included
85	A-27-AQ2-M	466966.6	6361994	318.17	323.77	326.843	3.073	included
86	A-27-AQ3-M	466967.2	6361997	284.83	326.92	318.328	-8.592	included
87	A-28-AQ1-M	467513.4	6361497	326.66	330.77	333.039	2.269	included
88	A-28-AQ2-M	467512.4	6361500	289.07	330.52	327.623	-2.897	included
89	A-28-AQ3-M	467510	6361497	290.09	329.78	327.623	-2.157	included
90	A-29-AQ2-M	468200.4	6361489	325.95	328.9	331.594	2.694	included
91	AA-06-10-98-10A-M	467534.7	6371806	281.46	280.65	282.306	1.656	included
92	AA-06-19-096-10-M	462771.5	6355879	156.62	239.16	240.142	0.982	excluded
93	AA-10-20-97-10-M	464887.3	6365893	279.495	287.97	289.529	1.559	included
94	AA-10-35-97-10B-M	469701.7	6369122	303.745	301.46	302.751	1.291	included
95	AA-11-03-98-10A-M	467408.1	6370828	284.54	281.82	286.647	4.827	included
96	AA-11-03-98-10B-M	467419.8	6370822	273.115	281.15	286.604	5.454	included
97	AA-11-28-97-10-M	465783.3	6367585	282.93	291.01	288.682	-2.328	included
98	AA-12-11-97-10-M	468753.7	6362676	311.335	313.78	317.12	3.34	included
99	AA-12-30-97-09-M	472022	6367164	293.21	298.85	298.995	0.145	included
100	AA-12-36-97-10-M	470460.7	6369166	191.67	271.37	269.704	-1.666	excluded
101	FH08-OB-015-M	465121	6357173	282.92	288.55	294.624	6.074	included
102	FH11-MW-005-M	464930	6364396	278.42	298.17	298.923	0.753	included
103	FH11-MW-006-M	474228.1	6363441	322.455	321.21	324.66	3.45	included
104	FH11-MW-007-M	477028.1	6373638	274.895	294.15	294.967	0.817	included
105	FH11-MW-008-M	470992.3	6368298	291.685	298.83	298.586	-0.244	included
106	FH11-MW-010-M	468217.5	6369223	290.905	290.69	294.312	3.622	included
107	FH11-MW-012-M	469215.7	6371389	277.41	284.77	290.732	5.962	included
108	FH11-MW-015-M	469644.5	6373456	272.44	280.68	285.353	4.673	included
109	FH16-A-2-M	460871.6	6355572	282.955	283.03	281.917	-1.113	included
110	FH16-A-7-M	464931.6	6364401	298.06	298.17	298.931	0.761	included
111	FH16-B-4-M	460789.9	6355135	272.78	283	283.057	0.057	included
112	FH17-GL318-MR1-M	463627.9	6364281	201.73	266.38	261.638	-4.742	excluded
113	FH17-GL329-MR1-M	463203.7	6363723	202.1	265.11	261.171	-3.939	excluded
114	FH17-GL331-MR1-M	463868.6	6363766	203.76	265.4	261.876	-3.524	excluded
115	FH17-GL340-MR1-M	461923	6363036	184.83	230.59	233.501	2.911	excluded
116	FH17-GL350-MR1-M	464831	6362596	212.08	272.47	268.206	-4.264	excluded
117	FH17-GL368-SN1-MW-M	462605.9	6361552	264.805	275.59	282.025	6.435	included
118	FH17-WR366-SN2-M	465120.4	6361761	342.125	338.78	340.711	1.931	included
119	FH17-WR402-SN2-M	472732.8	6365129	293.025	300.2	300.633	0.433	included
120	FH17-WR404-SN1-M	471721.5	6365334	265.67	297.55	299.692	2.142	included
121	FH17-WR404-SN2-M	471722	6365339	291.8609	299.82	299.801	-0.019	included
122	FH17-WR406-SN1-M	470037.8	6365498	292.5841	299.78	300.014	0.234	included
123	FH17-WR407-SN1-M	477728.3	6373039	286.5472	296.37	295.102	-1.268	included
124	FH17-WR412-SN1-M	480774.1	6375911	244.555	282.89	294.215	11.325	excluded
125	FH17-WR412-SN2-M	480774.1	6375911	277.545	294.92	294.267	-0.653	included
126	FH17-WR414-SN1-M	478165.6	6367061	271.69	305.34	305.229	-0.111	included
127	FH17-WR418-SN1-M	474995.5	6369344	253.77	285.38	295.022	9.642	included

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
128	FH17-WR425-SN1-M	470645.5	6364153	293.6588	301.03	303.078	2.048	included
129	FH17-WR427-SN1-M	472185.6	6366509	280.4312	297.83	298.988	1.158	included
130	FH17-WR428-SN1-M	473804.4	6368888	279.1214	296.45	296.394	-0.056	included
131	FH17-WR441-SN1-M	473369.5	6367617	285.03	297.57	297.359	-0.211	included
132	FH17-WR443-SN1-M	472498.9	6368484	291.4182	298.68	297.865	-0.815	included
133	FH17-WR446-SN1-M	473616.5	6366541	286.892	297.7	297.554	-0.146	included
134	FH17-WR449-SN1-M	473171.9	6365743	291.8126	298.81	298.814	0.004	included
135	FH17-WR451-SN1-M	475031.6	6367138	262.4874	294.09	295.839	1.749	included
136	FH17-WR452-SN1-M	469463.4	6367468	293.2248	297.89	298.826	0.936	included
137	FH17-WR491-SN1-MW-M	465587.8	6362630	315.87	319.98	315.535	-4.445	included
138	FH18-ES403-SN1-M	481599.9	6377441	226.9535	274.74	293.236	18.496	excluded
139	FH18-ES405-SN1-M	484006.3	6376073	279.895	293.21	294.4	1.19	included
140	FH18-ES407-SN1-M	474106.2	6374695	281.3629	291.18	291.495	0.315	included
141	FH18-ES426-SN1-M	474457	6366578	276.55	296.62	296.854	0.234	included
142	FH18-ES426-SN2-M	474456.6	6366576	291.89	296.84	296.903	0.063	included
143	FH18-ES427-SN1-M	478638.9	6366060	297.67	307.71	311.608	3.898	included
144	FH18-ES430-SN1-M	476461.4	6365994	284.765	304.5	309.166	4.666	included
145	FH18-ES437-SN1-M	477591.3	6363134	278.475	324.31	325.779	1.469	included
146	FH19-ES534-SN2-MW-M	468690.4	6368181	291.535	295.46	297.491	2.031	included
147	FH19-ES562-SN2-MW-M	467554	6367384	295.57	295.02	297.042	2.022	included
148	FH19-ES603-SN1-MW-M	477143.7	6375844	269.44	294.65	293.192	-1.458	included
149	FH19-ES603-SN2-MW-M	477144.6	6375849	287.78	294.72	293.194	-1.526	included
150	FH19-ES604-SN1-MW-M	485700.9	6372965	262.6	291.89	292.857	0.967	included
151	FH19-ES604-SN2-MW-M	485695.2	6372963	275.3	292.02	292.856	0.836	included
152	FH19-ES606-SN1-MW-M	471732.5	6371083	237.79	268.4	294.418	26.018	excluded
153	FH19-ES606-SN2-MW-M	471732.6	6371079	280.89	293.5	295.323	1.823	excluded
154	FH19-ES607-SN1-MW-M	472627.3	6369877	260.09	296.89	296.733	-0.157	included
155	FH19-ES607-SN2-MW-M	472628.7	6369873	281.81	296.77	296.733	-0.037	included
156	FH19-ES609-DR1-PW-M	472440.5	6368858	278.66	298.21	297.569	-0.641	included
157	FH19-ES610-SN2-MW-M	471973.9	6368832	300.92	298.57	303.865	5.295	included
158	FH19-ES621-SN1-MW-M	480357.9	6366954	278.035	304.29	305.464	1.174	included
159	FH19-ES623-SN1-MW-M	473932.2	6366721	269.01	297.26	296.922	-0.338	included
160	FH19-ES623-SN2-MW-M	473928.6	6366723	284.59	297.4	297.014	-0.386	included
161	FH19-ES631-SN1-MW-M	474251.1	6366273	263.9	297	296.715	-0.285	included
162	FH19-ES631-SN2-MW-M	474257.6	6366272	291.51	297.1	297.436	0.336	included
163	FH19-ES634-SN1-MW-M	474704.8	6366230	282.5	297.23	297.896	0.666	included
164	FH19-ES634-SN2-MW-M	474702.4	6366227	287.58	297.03	297.893	0.863	included
165	FH19-ES640-SN1-MW-M	482489.6	6367076	269.915	295.68	297.384	1.704	included
166	FH19-ES640-SN2-MW-M	482489.9	6367080	292.33	295.57	296.131	0.561	included
167	FH19-ES644-SN1-MW-M	466963.2	6365578	264.52	275.91	298.863	22.953	excluded
168	FH19-ES644-SN2-MW-M	466961.7	6365573	290.81	297.1	299.017	1.917	included
169	FH19-ES651-SN1-MW-M	475442.7	6365338	278.08	316.4	315.33	-1.07	included
170	FH19-ES651-SN2-MW-M	475438.1	6365338	300.61	311.12	315.376	4.256	included
171	FH19-ES659-SN1-MW-M	475799.7	6365067	267.41	317.38	318.028	0.648	included
172	FH19-ES659-SN2-MW-M	475794.9	6365067	279.6	317.38	318.022	0.642	included
173	FH19-ES670-SN1-MW-M	476181.9	6364490	269.75	326.69	322.861	-3.829	included
174	FH19-ES670-SN2-MW-M	476185.1	6364493	318.25	326.01	325.101	-0.909	included
175	FH19-ES676-SN1-MW-M	473375.3	6364593	272.66	306.43	305.492	-0.938	included
176	FH19-ES676-SN2-MW-M	473379.9	6364593	289.685	303.76	305.471	1.711	included
177	FH19-ES682-SN1-MW-M	466891.1	6364132	268.84	294.33	302.369	8.039	included
178	FH19-ES682-SN2-MW-M	466896	6364132	298.13	301.74	302.622	0.882	included
179	FH19-ES700-SN2-MW-M	472168	6363134	306.765	313.67	320.656	6.986	included
180	FH19-ES702-SN1-MW-M	467847.8	6362713	285.71	309.78	311.846	2.066	included
181	FH19-ES702-SN2-MW-M	467843.3	6362714	303.19	309.69	312.679	2.989	included
182	FH19-ES706-SN1-MW-M	471787.9	6362222	280.55	324.82	328.985	4.165	included
183	FH19-ES706-SN2-MW-M	471792.9	6362224	319.12	322.11	330.371	8.261	included
184	FH19-ES709-SN1-MW-M	470220.3	6361602	309.061	328.32	329.791	1.471	included
185	FH19-ES709-SN2-MW-M	470220.9	6361600	321.412	327.66	329.85	2.19	included
186	FH19-GL534-SN1-MW-M	468690.4	6368181	259.08	278.54	297.148	18.608	excluded
187	FH19-GL551-SN1-MW-M	470370.5	6367589	288.79	298.4	299.181	0.781	included
188	FH19-GL562-SN1-MW-M	467557.3	6367381	288.785	295.01	297.041	2.031	included
189	FH19-GL570-SN1-MW-M	470181.5	6366809	288.47	299.19	299.577	0.387	included
190	FH19-GL612-SN1-MW-M	472127.3	6367688	281.23	298.76	298.539	-0.221	included
191	FH19-GL700-SN3-MW-M	472167.5	6363141	275.805	312.59	314.467	1.877	included
192	FHA00012-M	469967.9	6361600	307.2	327.26	330.49	3.23	included

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193	FHA99031-M	467747	6358369	333.58	339.24	335.577	-3.663	included
194	FHA99033-M	467728	6359158	324.68	339.12	339.403	0.283	included
195	FHALG227-M	461861.9	6360043	281.03	281.46	283.293	1.833	included
196	FHALG228-M	461621.9	6359642	268.58	280.3	282.206	1.906	included
197	FHALG229-M	461619.4	6359642	278.18	279.82	282.433	2.613	included
198	FHALG231-M	461210.7	6358956	279.68	280.05	278.945	-1.105	excluded
199	FHALG233-M	462853	6358057	286.3766	288.48	288.187	-0.293	included
200	FHALG234-M	462982.9	6357692	287.985	288.98	290.168	1.188	included
201	FHALG235-M	462732.2	6356543	285.12	288.1	287.349	-0.751	included
202	FHALG236-M	462008.1	6356573	283.76	285.51	287.807	2.297	included
203	FHALG237-M	461657.5	6356902	282.28	284.28	284.584	0.304	included
204	FHALG238-M	462244.8	6357420	286.545	287.98	287.575	-0.405	included
205	FHALG239-M	462271.2	6357864	287.16	287.67	287.728	0.058	included
206	FHALG240-M	462271.7	6358321	285.485	286.86	286.529	-0.331	included
207	FHALG241-M	462696.7	6357618	290.625	289.62	288.974	-0.646	excluded
208	FHALG242-M	461401.6	6357630	281.62	283.25	281.518	-1.732	included
209	FHALG243-M	461189.2	6357848	280.07	280.73	281.514	0.784	excluded
210	FHALG245-M	463046.7	6356843	289.2969	289.63	294.613	4.983	included
211	FHC01238-M	468605.8	6371616	178.6	235.46	247.892	12.432	excluded
212	FHC02032-M	462585.5	6355872	173.32	237.11	240.14	3.03	excluded
213	FHC98019-M	462804.7	6357469	276.25	289.44	288.857	-0.583	included
214	FHC98034-M	463581.4	6355871	291.64	290.89	294.477	3.587	included
215	FHC98042-M	464040.8	6356274	283.39	290.32	291.719	1.399	included
216	FHC98044-M	464041.3	6358707	146.317	238.05	241.543	3.493	excluded
217	FHC99107-M	465470	6356522	291.59	295.06	298.009	2.949	included
218	FHC99141-M	465580.2	6362627	320.5	320.74	318.859	-1.881	included
219	FHC99165-M	467308.8	6368207	203.85	256.39	258.969	2.579	excluded
220	FHC99190-M	467534.7	6371806	204.27	231.17	241.885	10.715	excluded
221	FHC99192-M	469348.4	6375094	195.6	255.42	241.035	-14.385	excluded
222	FH-MW14-06-SS-M	461134	6357212	278.6	281.39	283.634	2.244	included
223	FHSO16NETA-OW01-M	470632	6359118	287.4	337.26	336.297	-0.963	included
224	FHSP-08-003-M	464700	6355103	290.315	290.32	289.979	-0.341	included
225	FHSP-08-004-M	465539.7	6354802	292.88	292.46	293.838	1.378	included
226	FHSP-08-005-M	465541.4	6354981	292.895	292.77	292.511	-0.259	included
227	FHSP-08-006-M	465542.2	6355200	292.29	291.47	291.704	0.234	included
228	FHSP-08-007-M	465001.8	6354701	292.18	291.29	290.533	-0.757	excluded
229	FHSP-08-008-M	464249.2	6354745	292.81	284.38	297.229	12.849	excluded
230	GT07-090C-M	469403.1	6365600	298.6	299.57	300.038	0.468	included
231	GT07-097A-M	473002.1	6363501	281.07	310.24	310.922	0.682	included
232	MLWC1-P100-M	476225.3	6368672	293.19	294.59	294.802	0.212	included
233	MLWC1-P250-M	476225.7	6368672	291.736	294.65	294.802	0.152	included
234	MLWC1-P460-M	476226.6	6368671	288.81	294.58	294.801	0.221	included
235	MLWC1-P530-M	476227.5	6368670	291.77	294.57	294.802	0.232	included
236	MLWC2-P100-M	457000	6352000	295.057	296.42	229.903	-66.517	excluded
237	MLWC2-P250-M	474073.6	6367174	293.572	296.38	296.58	0.2	included
238	MLWC2-P560-M	474074.9	6367175	290.672	296.35	296.6	0.25	included
239	MLWC3-P100-M	469401.7	6365600	273.49	299.56	299.79	0.23	included
240	MLWC3-P50-M	469035.3	6365085	264.02	299.62	299.779	0.159	excluded
241	MLWC4-P100-M	475660.5	6371206	268.28	295.31	295.476	0.166	included
242	MLWC4-P250-M	475662.5	6371207	254.58	295.26	295.086	-0.174	included
243	MLWC4-P360-M	475664.4	6371205	291.26	295.33	295.45	0.12	included
244	MLWC5-P100-M	475237.9	6366535	294.62	295.97	296.82	0.85	included
245	MLWC5-P200-M	475238.2	6366537	293.73	296.12	296.821	0.701	included
246	MW06-014A-M	466137.9	6359599	295.475	313.98	332.522	18.542	excluded
247	MW06-014B-M	466137.9	6359601	306.135	313.99	332.522	18.532	included
248	MW06-018A-M	466109.4	6360594	297.465	324.69	337.605	12.915	included
249	MW06-022C-M	466144.4	6361509	307.93	335.88	330.436	-5.444	included
250	MW06-022D-M	466144.2	6361510	329.18	336.21	336.12	-0.09	included
251	MW-06-028-B-M	467193.6	6361516	320.245	334.57	332.188	-2.382	included
252	MW-06-031-A-M	468080.4	6361175	289.715	331.82	334.942	3.122	included
253	MW-06-031-B-M	468083	6361175	317.67	332.08	334.391	2.311	included
254	MW06-032A-M	468753.3	6359497	292.475	340	332.955	-7.045	included
255	MW06-032B-M	468753.3	6359501	317.89	339.71	340.169	0.459	included
256	MW06-043A-M	469548.9	6359885	291.655	339.01	327.782	-11.228	included
257	MW06-044A-M	469969	6359234	299.66	337.49	332.398	-5.092	included

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258	MW06-044B-M	469966.7	6359233	325.325	337.28	338.038	0.758	included
259	MW06-046B-M	469559.6	6358890	321.645	336.02	338.344	2.324	included
260	MW06-047A-M	469978.7	6358865	290.105	334.62	330.274	-4.346	included
261	MW06-047B-M	469982.6	6358865	327.33	335.08	336.879	1.799	included
262	MW06-048A-M	470239.2	6358870	290.505	334.51	336.809	2.299	included
263	MW06-048B-M	470242.6	6358870	315.305	334.59	336.881	2.291	included
264	MW06-049A-M	469508	6358469	292.935	334.81	329.174	-5.636	included
265	MW06-049B-M	469507.7	6358471	313.675	334.82	336.725	1.905	included
266	MW06-051B-M	469536.1	6358155	315.545	332.88	334.883	2.003	included
267	MW06-053A-M	469415.5	6356846	252.61	311.28	279.249	-32.031	excluded
268	MW06-053B-M	469415.3	6356844	272.53	312.4	327.487	15.087	excluded
269	MW06-053C-M	469415.3	6356843	302.09	326.1	327.953	1.853	included
270	MW06-055A-M	468928	6356737	302.14	326.62	328.612	1.992	included
271	MW06-057B-M	468542.8	6356702	318.93	326.78	329.741	2.961	included
272	MW06-069A-M	467934.2	6359469	303.79	339.89	333.337	-6.553	included
273	MW06-070B-M	467306.6	6358698	327.505	339.38	334.403	-4.977	included
274	MW06-070C-M	467309.7	6358698	338.535	339.41	341.907	2.497	included
275	MW06-072A-M	467323.4	6357948	300.41	336.71	331.721	-4.989	included
276	MW06-072B-M	467325.3	6357948	321.55	336.78	331.72	-5.06	included
277	MW06-075C-M	470568.3	6361193	287.67	332.42	329.54	-2.88	included
278	MW06-075D-M	470570.6	6361194	309.11	332.32	332.659	0.339	included
279	MW-06-076-A-M	471013.3	6361612	284.8	327.15	329.492	2.342	included
280	MW-06-076-B-M	471016	6361614	302.945	328.97	330.494	1.524	included
281	MW-06-077-A-M	472635.7	6361412	281.45	330.27	331.896	1.626	included
282	MW-06-077-B-M	472638.1	6361414	296.5	330.71	331.896	1.186	included
283	MW-06-078-B-M	472822.4	6362027	300.57	327.6	330.299	2.699	included
284	MW06-079A-M	470383.6	6360508	306.225	335.11	336.335	1.225	included
285	MW06-079B-M	470384.2	6360505	312.81	335.18	336.335	1.155	included
286	MW06-080A-M	471365.8	6360512	297.525	335.3	335.682	0.382	included
287	MW-06-085-A-M	472816.9	6359497	293.07	326.83	330.704	3.874	included
288	MW06-087A-M	470548.5	6358784	312.55	334.3	335.962	1.662	included
289	MW06-096B-M	473013	6357300	323.19	327.82	325.26	-2.56	included
290	MW-07-113-M	461647.9	6356676	153.31	236.87	236.117	-0.753	excluded
291	MW-07-114-M	460771.5	6355135	92.2	226.81	235.703	8.893	excluded
292	MW-07-115-M	462418.5	6357539	138.43	233.75	237.206	3.456	excluded
293	MW-07-117-M	463949.7	6357906	150.23	235.41	240.327	4.917	excluded
294	MW-07-119-M	467102	6359493	166.8	244.31	264.324	20.014	excluded
295	MW-07-121-M	466454.1	6356647	153.42	239.38	257.563	18.183	excluded
296	MW-07-122-M	467347.7	6364011	160.8936	255.57	266.326	10.756	excluded
297	MW-07-123-M	469164.6	6358673	152.97	244.14	264.002	19.862	excluded
298	MW-08-01-M	473750.4	6378239	272.595	282.58	281.157	-1.423	included
299	MW08-03-M	472902.9	6375844	269.99	284.56	285.836	1.276	included
300	MW08-04-M	473852.8	6375794	268.185	289.86	288.593	-1.267	included
301	MW08-08-M	474711.3	6373419	272.11	292.43	294.295	1.865	included
302	MW-08-13BA-M	473769.6	6370132	216.82	270.71	276.279	5.569	excluded
303	MW-08-15BA-M	469079.4	6374052	193.26	255.69	238.769	-16.921	excluded
304	MW08-301A-M	474613.5	6366167	297.53	296.81	297.442	0.632	included
305	MW08-301B-M	474613.3	6366166	297.39	296.98	297.442	0.462	included
306	MW08-302A-M	474638	6366143	294.96	296.64	297.469	0.829	included
307	MW08-302B-M	474637.7	6366142	295.88	297.08	297.468	0.388	included
308	MW08-302C-M	474638.2	6366141	296.63	297.04	298.55	1.51	included
309	MW08-303A-M	472644.5	6364140	304.94	306.12	308.66	2.54	included
310	MW08-303B-M	472644.5	6364140	306.52	306.25	308.68	2.43	included
311	MW08-304A-M	476260.7	6367266	295.185	295.19	295.479	0.289	included
312	MW08-304B-M	476254.1	6367271	294.765	295.29	295.479	0.189	included
313	MW08-305A-M	476271.9	6369577	288.21	294.5	294.872	0.372	included
314	MW08-305B-M	476271.7	6369578	292.11	294.53	294.624	0.094	included
315	MW08-305C-M	476272.4	6369576	294.32	294.55	294.623	0.073	included
316	MW08-306A-M	472613.2	6364373	301.59	302.9	303.632	0.732	included
317	MW08-306B-M	472614	6364372	301.2	302.92	303.632	0.712	included
318	MW08-307A-M	474826.9	6368247	292.13	295.38	295.359	-0.021	included
319	MW08-308A-M	475796.2	6367952	289.19	294.83	295.041	0.211	included
320	MW08-308B-M	475796.5	6367951	292.51	294.89	295.034	0.144	included
321	MW-08-308C-M	475797	6367951	294.24	294.93	295.033	0.103	included
322	MW08-309A-M	474441.1	6367403	291.33	296.12	296.228	0.108	included

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
323	MW08-309B-M	474441.3	6367402	295.32	295.8	296.228	0.428	included
324	PW-08-02-M	473768.2	6370123	282.115	295.63	296.113	0.483	included
325	SP06-1-20-M	474506.9	6374205	222.19	265.54	288.699	23.159	excluded
326	FH17-WR401-MR1-VW-A	473071.8	6366365	183.37	269.08	275.092	6.012	excluded
327	FH17-WR401-MR1-VW-C	473071.8	6366365	208.37	270.27	275.091	4.821	excluded
328	FH17-WR401-SN1-VW-A	473066.4	6366365	262.58	297.32	298.007	0.687	excluded
329	FH17-WR401-SN1-VW-B	473066.4	6366365	275.58	298.06	298.176	0.116	included
330	FH17-WR401-SN1-VW-C	473066.4	6366365	289.08	298.23	298.176	-0.054	included
331	FH17-WR403-MR1-VW-A	473975.9	6365366	182.97	271.34	276.005	4.665	excluded
332	FH17-WR403-MR1-VW-B	473975.9	6365366	195.97	271.55	275.994	4.444	excluded
333	FH17-WR403-MR1-VW-C	473975.9	6365366	205.97	271.79	275.989	4.199	excluded
334	FH17-WR403-SN1-VW-A	473979.7	6365364	265.14	301.34	301.354	0.014	included
335	FH17-WR403-SN1-VW-B	473979.7	6365364	274.94	301.61	301.399	-0.211	included
336	FH17-WR403-SN1-VW-D	473979.7	6365364	294.94	301.15	300.886	-0.264	included
337	FH17-WR405-MR1-VW-A	472003.3	6363549	171.35	268.91	272.718	3.808	excluded
338	FH17-WR405-MR1-VW-B	472003.3	6363549	181.35	268.67	272.718	4.048	excluded
339	FH17-WR405-MR1-VW-C	472003.3	6363549	191.35	268.5	273.238	4.738	excluded
340	FH17-WR405-MR1-VW-D	472003.3	6363549	202.35	269.2	273.238	4.038	excluded
341	FH17-WR405-SN1-VW-A	471998.4	6363550	271.51	309.2	313.274	4.074	included
342	FH17-WR405-SN1-VW-B	471998.4	6363550	281.21	309.57	313.38	3.81	included
343	FH17-WR405-SN1-VW-C	471998.4	6363550	309.21	309.45	313.382	3.932	included
344	FH17-WR406-MR1-VW-A	470042.6	6365498	227.02	271.96	271.524	-0.436	excluded
345	FH17-WR406-MR1-VW-C	470042.6	6365498	268.52	297.03	299.838	2.808	excluded
346	FH17-WR409-MR1-VW-B	481293.5	6368858	215.12	293.36	286.933	-6.427	excluded
347	FH17-WR409-MR1-VW-C	481293.5	6368858	222.12	294.2	286.933	-7.267	excluded
348	FH17-WR409-MR1-VW-D	481293.5	6368858	235.12	293.87	286.933	-6.937	excluded
349	FH17-WR409-SN1-VW-A	481298.4	6368858	255.13	291.64	294.944	3.304	excluded
350	FH17-WR409-SN1-VW-B	481298.4	6368858	266.33	292.63	294.949	2.319	included
351	FH17-WR409-SN1-VW-C	481298.4	6368858	278.83	292.77	294.977	2.207	included
352	FH17-WR409-SN1-VW-D	481298.4	6368858	288.53	293.16	294.983	1.823	included
353	FH17-WR421-SN1-VW-A	474246.2	6366767	278.49	296.27	296.681	0.411	included
354	FH17-WR421-SN1-VW-B	474246.2	6366767	281.49	296.22	296.681	0.461	included
355	FH17-WR421-SN1-VW-C	474246.2	6366767	287.49	296.41	296.856	0.446	included
356	FH17-WR421-SN1-VW-D	474246.2	6366767	291.49	296.49	296.856	0.366	included
357	FH17-WR422-SN1-VW-A	472998.5	6364693	264.94	300.75	303.649	2.899	excluded
358	FH17-WR422-SN1-VW-B	472998.5	6364693	274.64	302.02	303.696	1.676	included
359	FH17-WR422-SN1-VW-C	472998.5	6364693	283.44	301.92	303.679	1.759	included
360	FH17-WR422-SN1-VW-D	472998.5	6364693	300.24	302.07	302.086	0.016	included
361	FH17-WR423-SN1-VW-A	472080.5	6364334	284.98	301.39	304.112	2.722	included
362	FH17-WR423-SN1-VW-B	472080.5	6364334	298.58	301.32	304.048	2.728	included
363	FH17-WR423-SN1-VW-C	472080.5	6364334	299.58	301.27	304.048	2.778	included
364	FH17-WR424-SN1-VW-A	471425.2	6364217	295.55	301.81	303.936	2.126	included
365	FH17-WR424-SN1-VW-B	471425.2	6364217	298.55	302.77	303.892	1.122	included
366	FH17-WR424-SN1-VW-C	471425.2	6364217	300.55	301.86	303.892	2.032	included
367	FH17-WR426-SN1-VW-A	469267.7	6364082	281.63	299.54	302.413	2.873	included
368	FH17-WR426-SN1-VW-B	469267.7	6364082	290.78	299.8	302.536	2.736	included
369	FH17-WR426-SN1-VW-C	469267.7	6364082	296.88	299.72	301.876	2.156	included
370	FH17-WR429-SN1-VW-A	473260	6368363	269.15	296.59	297.141	0.551	included
371	FH17-WR429-SN1-VW-B	473260	6368363	283.15	297.04	297.225	0.185	included
372	FH17-WR429-SN1-VW-C	473260	6368363	298.15	300.61	297.226	-3.384	included
373	FH17-WR430-SN1-VW-A	472167	6367672	269.68	297.86	298.539	0.679	included
374	FH17-WR430-SN1-VW-B	472167	6367672	280.08	298.11	298.539	0.429	included
375	FH17-WR430-SN1-VW-C	472167	6367672	291.68	297.43	298.54	1.11	included
376	FH17-WR431-SN1-VW-A	470890.8	6366931	268.42	297.67	299.322	1.652	included
377	FH17-WR431-SN1-VW-B	470890.8	6366931	285.42	299.62	299.477	-0.143	included
378	FH17-WR431-SN1-VW-C	470890.8	6366931	292.92	299.24	299.478	0.238	included
379	FH17-WR432-SN1-VW-A	469858	6366880	267.87	287.41	299.11	11.7	excluded
380	FH17-WR432-SN1-VW-B	469858	6366880	286.87	298.39	299.567	1.177	included
381	FH17-WR432-SN1-VW-C	469858	6366880	292.87	298.33	299.567	1.237	included
382	FH17-WR434-SN1-VW-A	476279.6	6364497	269.56	318.23	323.487	5.257	included
383	FH17-WR434-SN1-VW-B	476279.6	6364497	295.26	319.17	323.535	4.365	included
384	FH17-WR434-SN1-VW-C	476279.6	6364497	319.96	323.62	323.535	-0.085	included
385	FH17-WR434-SN1-VW-D	476279.6	6364497	341.26	341.43	338.22	-3.21	included
386	FH17-WR435-SN1-VW-A	475955.6	6364926	262.9	314.14	319.458	5.318	included

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387	FH17-WR435-SN1-VW-B	475955.6	6364926	272.9	317.1	319.623	2.523	included
388	FH17-WR435-SN1-VW-C	475955.6	6364926	304.9	318.02	319.47	1.45	included
389	FH17-WR435-SN1-VW-D	475955.6	6364926	319.4	319.15	319.283	0.133	included
390	FH17-WR436-SN1-VW-A	475647.6	6365234	278.23	316.08	316.565	0.485	included
391	FH17-WR436-SN1-VW-B	475647.6	6365234	290.83	313.55	316.565	3.015	included
392	FH17-WR436-SN1-VW-C	475647.6	6365234	296.43	318.05	315.473	-2.577	included
393	FH17-WR436-SN1-VW-D	475647.6	6365234	305.63	313.4	315.2	1.8	included
394	FH17-WR437-SN1-VW-A	475329.8	6365604	264.63	305.52	310.52	5	included
395	FH17-WR437-SN1-VW-B	475329.8	6365604	275.63	305.78	310.577	4.797	included
396	FH17-WR437-SN1-VW-C	475329.8	6365604	291.63	305.53	307.503	1.973	included
397	FH17-WR437-SN1-VW-D	475329.8	6365604	299.63	306.29	306.241	-0.049	included
398	FH17-WR438-MR1-VW-A	474933.4	6365925	199.21	271.94	277.108	5.168	excluded
399	FH17-WR438-MR1-VW-B	474933.4	6365925	213.21	271.75	277.109	5.359	excluded
400	FH17-WR438-MR1-VW-D	474933.4	6365925	262.51	301.42	301.522	0.102	included
401	FH17-WR439-SN1-VW-A	474566.9	6366384	277.95	296.52	296.34	-0.18	included
402	FH17-WR439-SN1-VW-B	474566.9	6366384	288.45	297.22	296.917	-0.303	included
403	FH17-WR439-SN1-VW-C	474566.9	6366384	290.95	294.95	296.888	1.938	included
404	FH17-WR441-MR1-VW-A	473366.7	6367621	192.56	270.28	275.348	5.068	excluded
405	FH17-WR441-MR1-VW-B	473366.7	6367621	204.56	270.62	275.348	4.728	excluded
406	FH17-WR441-MR1-VW-C	473366.7	6367621	231.56	291.3	291.023	-0.277	excluded
407	FH17-WR442-SN1-VW-A	472897.9	6368095	261.73	298.16	297.714	-0.446	included
408	FH17-WR442-SN1-VW-B	472897.9	6368095	271.23	298.35	297.844	-0.506	included
409	FH17-WR442-SN1-VW-C	472897.9	6368095	285.23	298.49	297.844	-0.646	included
410	FH17-WR442-SN1-VW-D	472897.9	6368095	297.23	298.52	297.845	-0.675	included
411	FH17-WR444-SN1-VW-A	472123.4	6368823	255.94	294.11	297.65	3.54	included
412	FH17-WR444-SN1-VW-B	472123.4	6368823	263.94	295.67	297.653	1.983	included
413	FH17-WR444-SN1-VW-C	472123.4	6368823	273.94	298.1	297.77	-0.33	included
414	FH17-WR444-SN1-VW-D	472123.4	6368823	292.94	298.02	297.772	-0.248	included
415	FH17-WR445-MR1-VW-A	473288.3	6366970	189.76	268.93	275.257	6.327	excluded
416	FH17-WR445-MR1-VW-B	473288.3	6366970	197.76	270.68	275.257	4.577	excluded
417	FH17-WR445-MR1-VW-C	473288.3	6366970	212.76	270.35	275.257	4.907	excluded
418	FH17-WR445-MR1-VW-D	473288.3	6366970	229.26	288.43	290.911	2.481	excluded
419	FH17-WR445-SN1-VW-A	473293	6366971	258.87	296.78	297.535	0.755	excluded
420	FH17-WR445-SN1-VW-B	473293	6366971	263.67	296.64	297.563	0.923	included
421	FH17-WR445-SN1-VW-C	473293	6366971	277.87	299.9	297.697	-2.203	included
422	FH17-WR445-SN1-VW-D	473293	6366971	289.87	300.81	297.697	-3.113	included
423	FH17-WR447-SN1-VW-A	473894.1	6366138	282.93	296.59	297.966	1.376	included
424	FH17-WR447-SN1-VW-B	473894.1	6366138	287.43	297.32	298.013	0.693	included
425	FH17-WR447-SN1-VW-C	473894.1	6366138	290.93	296.21	298.014	1.804	included
426	FH17-WR448-SN1-VW-A	474325.8	6365706	287.31	297.71	300.369	2.659	included
427	FH17-WR448-SN1-VW-B	474325.8	6365706	290.81	297.86	300.074	2.214	included
428	FH17-WR448-SN1-VW-C	474325.8	6365706	294.31	297.78	299.706	1.926	included
429	FH18-ES401-SN1-VW-A	481469.4	6378931	216.53	267.32	291.393	24.073	excluded
430	FH18-ES401-SN1-VW-B	481469.4	6378931	235.03	277.55	291.394	13.844	excluded
431	FH18-ES401-SN1-VW-C	481469.4	6378931	275.53	293.16	291.483	-1.677	included
432	FH18-ES401-SN1-VW-D	481469.4	6378931	294.03	285.39	291.485	6.095	excluded
433	FH18-ES404-SN1-VW-B	479299.9	6377453	223.66	257.25	292.18	34.93	excluded
434	FH18-ES404-SN1-VW-C	479299.9	6377453	241.66	284.34	292.184	7.844	excluded
435	FH18-ES404-SN1-VW-D	479299.9	6377453	273.66	294.4	292.277	-2.123	included
436	FH18-ES408-SN1-VW-A	482988.8	6374419	237.71	258.4	294.588	36.188	excluded
437	FH18-ES408-SN1-VW-B	482988.8	6374419	270.21	293.36	294.625	1.265	included
438	FH18-ES408-SN1-VW-C	482988.8	6374419	284.21	309.6	294.627	-14.973	excluded
439	FH18-ES411-SN1-VW-A	475837.6	6372267	272.8	296.26	295.444	-0.816	included
440	FH18-ES411-SN1-VW-B	475837.6	6372267	280.3	296.01	295.444	-0.566	included
441	FH18-ES411-SN1-VW-C	475837.6	6372267	292.8	296.24	295.445	-0.795	included
442	FH18-ES415-SN1-VW-A	474540	6370073	281.5	294.87	295.566	0.696	included
443	FH18-ES415-SN1-VW-B	474540	6370073	286.6	295	295.566	0.566	included
444	FH18-ES415-SN1-VW-C	474540	6370073	293.4	294.74	295.566	0.826	included
445	FH18-ES417-SN1-VW-A	483905.6	6369485	254.2	295	297.533	2.533	included
446	FH18-ES417-SN1-VW-B	483905.6	6369485	284.1	295.4	297.735	2.335	included
447	FH18-ES417-SN1-VW-C	483905.6	6369485	292	295.34	297.978	2.638	included
448	FH18-ES417-SN1-VW-D	483905.6	6369485	296.3	295.89	297.978	2.088	included
449	FH18-ES419-MR1-VW-A	472121.1	6368816	185.77	265.25	273.427	8.177	excluded
450	FH18-ES419-MR1-VW-B	472121.1	6368816	197.77	269.66	273.427	3.767	excluded

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
451	FH18-ES419-MR1-VW-C	472121.1	6368816	206.77	270.22	273.428	3.208	excluded
452	FH18-ES419-SN1-VW-A	472126.2	6368816	255.73	294.52	297.649	3.129	included
453	FH18-ES419-SN1-VW-B	472126.2	6368816	268.33	296.78	297.77	0.99	included
454	FH18-ES419-SN1-VW-C	472126.2	6368816	294.83	297.23	297.772	0.542	included
455	FH18-ES421-SN1-VW-A	482330.2	6368408	259.78	294.98	295.402	0.422	included
456	FH18-ES421-SN1-VW-B	482330.2	6368408	287.98	295.24	295.412	0.172	included
457	FH18-ES421-SN1-VW-C	482330.2	6368408	291.18	295	295.412	0.412	included
458	FH18-ES424-MR1-VW-A	471421	6365878	173.81	270.69	272.373	1.683	excluded
459	FH18-ES424-MR1-VW-B	471421	6365878	180.31	270.85	272.373	1.523	excluded
460	FH18-ES424-MR1-VW-C	471421	6365878	193.81	264.65	273.066	8.416	excluded
461	FH18-ES424-SN1-VW-A	471420.6	6365884	270.52	299.76	299.518	-0.242	included
462	FH18-ES424-SN1-VW-B	471420.6	6365884	284.32	299.94	299.614	-0.326	included
463	FH18-ES424-SN1-VW-C	471420.6	6365884	296.12	299.85	299.615	-0.235	included
464	FH18-ES424-SN1-VW-D	471420.6	6365884	297.32	299.43	299.617	0.187	included
465	FH18-ES431-MR1-VW-A	471164.3	6364367	170.46	264.99	272.677	7.687	excluded
466	FH18-ES431-MR1-VW-B	471164.3	6364367	180.46	265	272.678	7.678	excluded
467	FH18-ES431-MR1-VW-C	471164.3	6364367	188.46	265.74	272.678	6.938	excluded
468	FH18-ES431-SN1-VW-A	471164.1	6364372	279.98	299.57	301.746	2.176	included
469	FH18-ES431-SN1-VW-B	471164.1	6364372	290.28	299.77	301.668	1.898	included
470	FH18-ES431-SN1-VW-C	471164.1	6364372	297.98	299.68	300.795	1.115	included
471	FH18-ES440-MR1-VW-A	478796.2	6362011	191.29	279.72	277.876	-1.844	excluded
472	FH18-ES440-MR1-VW-B	478796.2	6362011	201.29	280.53	277.876	-2.654	excluded
473	FH18-ES440-MR1-VW-C	478796.2	6362011	209.29	280.09	277.876	-2.214	excluded
474	FH18-ES440-SN1-VW-A	478790.4	6362012	278.09	306.29	323.086	16.796	excluded
475	FH18-ES440-SN1-VW-B	478790.4	6362012	302.39	308.87	323.197	14.327	excluded
476	FH18-ES440-SN1-VW-C	478790.4	6362012	331.89	330.71	326.036	-4.674	included
477	FH19-ES512-SN2-VW-A	469059	6369805	257.1	275.12	294.174	19.054	excluded
478	FH19-ES512-SN2-VW-B	469059	6369805	280.8	291.66	294.268	2.608	included
479	FH19-ES512-SN2-VW-C	469059	6369805	289.6	290.52	294.269	3.749	included
480	FH19-ES565-MR2-PW-VW-A	470363.2	6367157	205.68	264.98	271.668	6.688	excluded
481	FH19-ES602-SN1-VW-A	484832.1	6378775	242.8	288.64	292.028	3.388	included
482	FH19-ES602-SN1-VW-B	484832.1	6378775	266.91	292.58	292.052	-0.528	included
483	FH19-ES602-SN1-VW-C	484832.1	6378775	286.16	292.5	292.053	-0.447	included
484	FH19-ES602-SN1-VW-D	484832.1	6378775	303.25	303.59	305.034	1.444	included
485	FH19-ES608-SN1-VW-B	475682.4	6369568	266.13	295.3	294.922	-0.378	included
486	FH19-ES608-SN1-VW-D	475682.4	6369568	287.13	294.89	294.92	0.03	included
487	FH19-ES609-SN1-VW-A	472431.3	6368848	255.16	294.84	297.487	2.647	included
488	FH19-ES609-SN1-VW-B	472431.3	6368848	278.16	297.85	297.617	-0.233	included
489	FH19-ES609-SN1-VW-C	472431.3	6368848	296.16	297.92	297.619	-0.301	included
490	FH19-ES615-SN1-VW-A	473599.7	6367450	259.26	296.52	296.868	0.348	included
491	FH19-ES615-SN1-VW-B	473599.7	6367450	272.56	297.51	296.984	-0.526	included
492	FH19-ES615-SN1-VW-C	473599.7	6367450	288.06	296.86	296.984	0.124	included
493	FH19-ES620-SN1-VW-A	473976.6	6367024	266.11	293.51	296.76	3.25	included
494	FH19-ES620-SN1-VW-B	473976.6	6367024	287.61	295.68	296.849	1.169	included
495	FH19-ES625-SN1-VW-A	473610.3	6366528	286.91	296.69	297.554	0.864	included
496	FH19-ES625-SN1-VW-B	473610.3	6366528	292.41	297.9	297.553	-0.347	included
497	FH19-ES627-SN1-VW-A	474117.6	6366501	264.79	297.02	297.204	0.184	included
498	FH19-ES627-SN1-VW-B	474117.6	6366501	269.79	297.15	297.303	0.153	included
499	FH19-ES627-SN1-VW-C	474117.6	6366501	289.79	296.3	297.392	1.092	included
500	FH19-ES652-SN1-VW-A	474529	6365222	265.44	308.3	309.555	1.255	included
501	FH19-ES652-SN1-VW-B	474529	6365222	271.94	309.56	309.555	-0.005	included
502	FH19-ES652-SN1-VW-C	474529	6365222	286.94	307.7	309.555	1.855	included
503	FH19-ES652-SN1-VW-D	474529	6365222	298.94	307.63	309.467	1.837	included
504	FH19-ES691-SN1-VW-A	467346.7	6363573	271.34	303.06	302.779	-0.281	included
505	FH19-ES691-SN1-VW-B	467346.7	6363573	283.21	321.57	302.887	-18.683	excluded
506	FH19-ES691-SN1-VW-C	467346.7	6363573	290.21	303.58	303.653	0.073	included
507	FH19-ES696-SN1-VW-A	475260.4	6363278	272.63	328.37	328.989	0.619	included
508	FH19-ES696-SN1-VW-B	475260.4	6363278	302.63	328.47	329.138	0.668	included
509	FH19-ES696-SN1-VW-C	475260.4	6363278	327.73	328.17	329.138	0.968	included
510	FH19-ES707-SN1-VW-A	468804.1	6361700	278.59	303.54	328.265	24.725	excluded
511	FH19-ES707-SN1-VW-B	468804.1	6361700	289.59	324.33	328.502	4.172	included
512	FH19-ES707-SN1-VW-C	468804.1	6361700	309.09	316.73	328.673	11.943	included
513	FH19-ES708-SN1-VW-A	471326.2	6361672	281.69	331.19	331.361	0.171	included

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
514	FH19-ES708-SN1-VW-B	471326.2	6361672	301.69	330.94	331.374	0.434	included
515	FH19-ES708-SN1-VW-C	471326.2	6361672	325.69	330.46	331.661	1.201	included
516	FH19-GL504-SN2-VW-A	469323.6	6371487	273.39	285.07	290.209	5.139	included
517	FH19-GL504-SN2-VW-B	469323.6	6371487	283.29	284.59	290.209	5.619	included
518	FH19-GL547-SN1-VW-A	468966.8	6367584	285.1	296.94	298.408	1.468	included
519	FH19-GL547-SN1-VW-B	468966.8	6367584	291.7	317.46	298.408	-19.052	excluded
520	FH19-GL550-SN1-VW-A	471294.2	6367584	282.25	299.27	299.105	-0.165	included
521	FH19-GL550-SN1-VW-B	471294.2	6367584	293.95	298.46	299.106	0.646	included
522	FH19-GL553-SN1-VW-A	469783.2	6367580	259.05	283.01	298.367	15.357	excluded
523	FH19-GL553-SN1-VW-B	469783.2	6367580	266.45	289.19	298.367	9.177	excluded
524	FH19-GL553-SN1-VW-C	469783.2	6367580	285.85	297.92	298.946	1.026	included
525	FH19-GL553-SN1-VW-D	469783.2	6367580	295.05	298.48	298.947	0.467	included
526	FH19-GL570-MR1-VW-A	470176.4	6366810	167.04	264.5	271.694	7.194	excluded
527	FH19-GL570-MR1-VW-B	470176.4	6366810	178.24	264.76	271.694	6.934	excluded
528	FH19-GL570-MR1-VW-C	470176.4	6366810	190.94	264.29	271.695	7.405	excluded
529	FH19-GL570-MR1-VW-D	470176.4	6366810	212.14	264.48	271.547	7.067	excluded
530	FH19-GL667-SN1-VW-A	474650	6364771	277.47	313.59	315.101	1.511	included
531	FH19-GL667-SN1-VW-B	474650	6364771	287.47	313.36	316.738	3.378	included
532	FH19-GL667-SN1-VW-C	474650	6364771	299.97	313.02	316.738	3.718	included
533	FH20-WR602-MR1-VW-A	484992.6	6378711	226.23	288.76	292.253	3.493	excluded
534	FH20-WR606-MR1-VW-A	484012	6376077	229.01	290.78	293.877	3.097	excluded
535	FH20-WR610-MR1-VW-B	474110.7	6374699	234.41	271.4	290.156	18.756	excluded
536	FH20-WR613-SN1-VW-A	473791.4	6372141	278.12	293.92	294.867	0.947	included
537	FH20-WR614-SN1-VW-A	473853.4	6372063	238.13	291.02	294.35	3.33	included
538	FH20-WR614-SN1-VW-B	473853.4	6372063	264.13	294.8	294.992	0.192	included
539	FH20-WR614-SN1-VW-C	473853.4	6372063	282.13	304.18	294.994	-9.186	included
540	FH20-WR615-SN1-VW-A	473922.5	6371991	238.37	290.64	294.338	3.698	included
541	FH20-WR615-SN1-VW-B	473922.5	6371991	269.37	294.58	295.019	0.439	included
542	FH20-WR615-SN1-VW-C	473922.5	6371991	282.37	294.64	295.021	0.381	included
543	FH20-WR616-SN1-VW-A	473588.9	6371400	268.7	295.99	295.387	-0.603	included
544	FH20-WR616-SN1-VW-B	473588.9	6371400	278.2	295.94	295.387	-0.553	included
545	FH20-WR616-SN1-VW-C	473588.9	6371400	290.2	296.24	295.388	-0.852	included
546	FH20-WR617-SN1-VW-A	473558.4	6371314	269.15	295.56	295.441	-0.119	included
547	FH20-WR617-SN1-VW-B	473558.4	6371314	284.15	295.97	295.442	-0.528	included
548	FH20-WR617-SN1-VW-C	473558.4	6371314	294.15	296.22	295.443	-0.777	included
549	FH20-WR618-SN1-VW-A	482233.4	6371267	276.517	294.2	294.449	0.249	included
550	FH20-WR618-SN1-VW-B	482233.4	6371267	276.517	294.32	294.449	0.129	included
551	FH20-WR618-SN1-VW-C	482233.4	6371267	284.32	299.48	294.449	-5.031	included
552	FH20-WR618-SN1-VW-D	482233.4	6371267	279.22	294.37	294.449	0.079	included
553	FH20-WR618-SN1-VW-E	482233.4	6371267	279.22	289.67	294.449	4.779	included
554	FH20-WR618-SN1-VW-F	482233.4	6371267	284.32	294.58	294.449	-0.131	included
555	FH20-WR619-SN1-VW-A	473540.1	6371200	263.9	295.93	295.498	-0.432	included
556	FH20-WR619-SN1-VW-B	473540.1	6371200	276.9	295.91	295.499	-0.411	included
557	FH20-WR619-SN1-VW-C	473540.1	6371200	292.9	295.24	295.5	0.26	included
558	FH20-WR620-MR1-VW-A	471680.2	6370754	170.92	268.8	267.803	-0.997	excluded
559	FH20-WR620-MR1-VW-B	471680.2	6370754	186.92	268.14	267.803	-0.337	excluded
560	FH20-WR620-MR1-VW-C	471680.2	6370754	213.92	271.24	270.438	-0.802	excluded
561	FH20-WR622-SN1-VW-A	472795.7	6370698	267.47	295.9	296.013	0.113	included
562	FH20-WR622-SN1-VW-B	472795.7	6370698	278.97	296.31	296.014	-0.296	included
563	FH20-WR622-SN1-VW-C	472795.7	6370698	290.97	296.57	296.015	-0.555	included
564	FH20-WR623-SN1-VW-A	472893	6370687	253.93	292.39	295.888	3.498	included
565	FH20-WR623-SN1-VW-B	472893	6370687	295.43	296.74	296.022	-0.718	included
566	FH20-WR624-SN1-VW-A	472984.4	6370697	265.9	296.99	295.978	-1.012	included
567	FH20-WR625-SN1-VW-A	480986.4	6370201	277.975	292.57	294.579	2.009	included
568	FH20-WR625-SN1-VW-B	480986.4	6370201	277.975	292.62	294.579	1.959	included
569	FH20-WR625-SN1-VW-C	480986.4	6370201	282.775	295.86	294.579	-1.281	included
570	FH20-WR625-SN1-VW-D	480986.4	6370201	282.775	296.73	294.579	-2.151	included
571	FH20-WR625-SN1-VW-E	480986.4	6370201	286.58	295.6	294.579	-1.021	included
572	FH20-WR625-SN1-VW-F	480986.4	6370201	286.58	295.34	294.579	-0.761	included
573	FH20-WR626-SN1-VW-A	472265.9	6369828	270.86	295.1	296.875	1.775	included
574	FH20-WR626-SN1-VW-B	472265.9	6369828	280.86	295.79	296.875	1.085	included
575	FH20-WR626-SN1-VW-C	472265.9	6369828	290.86	296.32	296.876	0.556	included
576	FH20-WR627-SN1-VW-A	472364.2	6369845	266.4	290.66	296.849	6.189	included
577	FH20-WR627-SN1-VW-B	472364.2	6369845	276.4	281.91	296.849	14.939	excluded

No.	Well label	Easting (m)	Northing (m)	Monitoring elevation (masl)	Observed head (masl)	Simulated head (masl)	Residual (m)	Included in or Excluded from Automatic Calibration
578	FH20-WR627-SN1-VW-C	472364.2	6369845	286.4	286.49	296.849	10.359	excluded
579	FH20-WR630-SN1-VW-A	469741.3	6368135	255.48	272.01	297.756	25.746	excluded
580	FH20-WR630-SN1-VW-B	469741.3	6368135	284.08	297.32	298.452	1.132	included
581	FH20-WR630-SN1-VW-C	469741.3	6368135	293.58	297.37	298.453	1.083	included
582	FH20-WR634-SN1-VW-B	471340.5	6368095	293.44	323.01	298.709	-24.301	excluded
583	FH20-WR636-SN1-VW-A	472140.8	6368093	277.74	299.24	298.321	-0.919	included
584	FH20-WR636-SN1-VW-B	472140.8	6368093	290.24	298.74	298.321	-0.419	included
585	FH20-WR638-SN1-VW-A	473349.4	6368053	257.7	297.17	297.174	0.004	included
586	FH20-WR638-SN1-VW-B	473349.4	6368053	282.9	307.63	297.306	-10.324	included
587	FH20-WR638-SN1-VW-C	473349.4	6368053	293	297.78	297.307	-0.473	included
588	FH20-WR642-SN1-VW-A	472434.2	6367650	259.05	298.84	298.179	-0.661	included
589	FH20-WR642-SN1-VW-B	472434.2	6367650	277.15	298.14	298.344	0.204	included
590	FH20-WR642-SN1-VW-C	472434.2	6367650	287.65	298.92	298.344	-0.576	included
591	FH20-WR645-SN1-VW-A	473018.3	6367624	257.79	297.03	297.569	0.539	included
592	FH20-WR645-SN1-VW-B	473018.3	6367624	286.89	298.13	297.78	-0.35	included
593	FH20-WR657-SN1-VW-A	473907.4	6367537	283.71	296.63	296.539	-0.091	included
594	FH20-WR657-SN1-VW-B	473907.4	6367537	289.71	296.51	296.538	0.028	included
595	FH20-WR664-SN1-VW-A	474457.7	6366956	267.68	295.69	296.435	0.745	included
596	FH20-WR664-SN1-VW-B	474457.7	6366956	288.18	296.73	296.505	-0.225	included
597	FH20-WR674-SN1-VW-A	475013.6	6365603	264.1	301.65	307.966	6.316	included
598	FH20-WR674-SN1-VW-B	475013.6	6365603	278.3	299.21	307.966	8.756	included
599	FH20-WR680-SN1-VW-A	473365.3	6364772	268.3	295.86	304.681	8.821	included
600	FH20-WR680-SN1-VW-B	473365.3	6364772	277.8	297.31	304.697	7.387	included
601	FH20-WR680-SN1-VW-C	473365.3	6364772	283.8	297	303.971	6.971	included
602	FH20-WR681-SN1-VW-A	473794.4	6364817	267	305.77	303.841	-1.929	included
603	FH20-WR681-SN1-VW-B	473794.4	6364817	276.6	308.3	303.916	-4.384	included
604	FH20-WR681-SN1-VW-C	473794.4	6364817	289.6	306.11	305.501	-0.609	included
605	FH20-WR684-SN1-VW-A	474494.6	6364811	278.7	311.26	311.272	0.012	included
606	FH20-WR684-SN1-VW-B	474494.6	6364811	301.7	312.34	313.029	0.689	included
607	FH20-WR697-SN1-VW-A	472303.7	6363144	272.9	311.34	314.467	3.127	included
608	FH20-WR697-SN1-VW-B	472303.7	6363144	291.9	312.19	314.467	2.277	included
609	FH20-WR697-SN1-VW-C	472303.7	6363144	307.4	311.34	320.656	9.316	included
610	FHEC20-WR700-MR1-VW-A	474760.7	6365020	185.1	272.06	276.452	4.392	excluded
611	FHEC20-WR700-MR1-VW-B	474760.7	6365020	196.1	271.97	276.521	4.551	excluded
612	FHEC20-WR700-MR1-VW-C	474760.7	6365020	214.1	271.59	276.521	4.931	excluded

Attachment E

Detailed Description of PEST

Parameter estimation model (PEST)

In this investigation, we used a model-independent parameter estimation package, PEST (Parameter ESTimation). PEST has been used for various fields to estimate (or calibrate) numerical models [*Doherty, 2005*]. The theory of the inverse algorithm implemented into the PEST model is summarized based on the PEST manual [*Doherty, 2005*]. For a linear model, X denotes the model matrix, which acts on parameters encapsulated in the vector p to generate a set of outputs $\hat{\mathrm{y}}$. X has a size of *m x n*, where *m* represents the number of observations in the calibration dataset and *n* corresponds to the number of parameters to be calibrated in p.

$$\hat{\mathrm{y}} = X\mathrm{p}$$

During the calibration process, the model outputs are fitted to the observation dataset encapsulated in an m-dimensional vector y with a noise (ϵ) associated with the observation. The true measurement set of the model parameters are represented by p^*, the following relationship therefore holds for a model without structural defects,

$$\mathrm{y} = X\mathrm{p}^* + \epsilon$$

The best fits of parameters related to the model are obtained by minimizing the weighted residual sum of squares (RSS):

$$\mathrm{RSS} = \sum_{i=1}^{n} \left[\frac{\mathrm{y} - \hat{\mathrm{y}}}{\omega_i}\right]^2$$

where n is the number of observations, ω_i is the weighting factor that is proportional to the uncertainty in the measured dataset. Alternatively, the fitness of the model calibration can be characterized by a weighted sum-of-squared residuals objective function (Φ),

$$\Phi = (\mathrm{y} - \hat{\mathrm{y}})^{\mathrm{T}}\mathrm{W}(\mathrm{y} - \hat{\mathrm{y}})$$

where the superscript t denotes matrix transpose and W represents a *m* × *m* weight matrix which is chosen depending on the data quality. Through the model calibration the objective function Φ decreases with increasing the number of iterations. In the weighted Levenberg–Marquardt (LM) method, a simple update form of parameters to be estimated can be expressed as:

$$\mathrm{p}^{k+1} = \mathrm{p}^k + \Delta\mathrm{p}^k$$

where p^{k+1} is the vector of *n* parameters at iteration level $k+1$ and $\Delta\mathrm{p}^k$ is the update vector computed from the weighted LM method. $\Delta\mathrm{p}^k$ in non-linear models can be obtained from:

$$\Delta\mathrm{p}^k = (\mathrm{J}^T\mathrm{W}\mathrm{J})^{-1}\mathrm{J}^T\mathrm{W}(\mathrm{y} - \hat{\mathrm{y}})$$

The Jacobian matrix (J) is defined as:

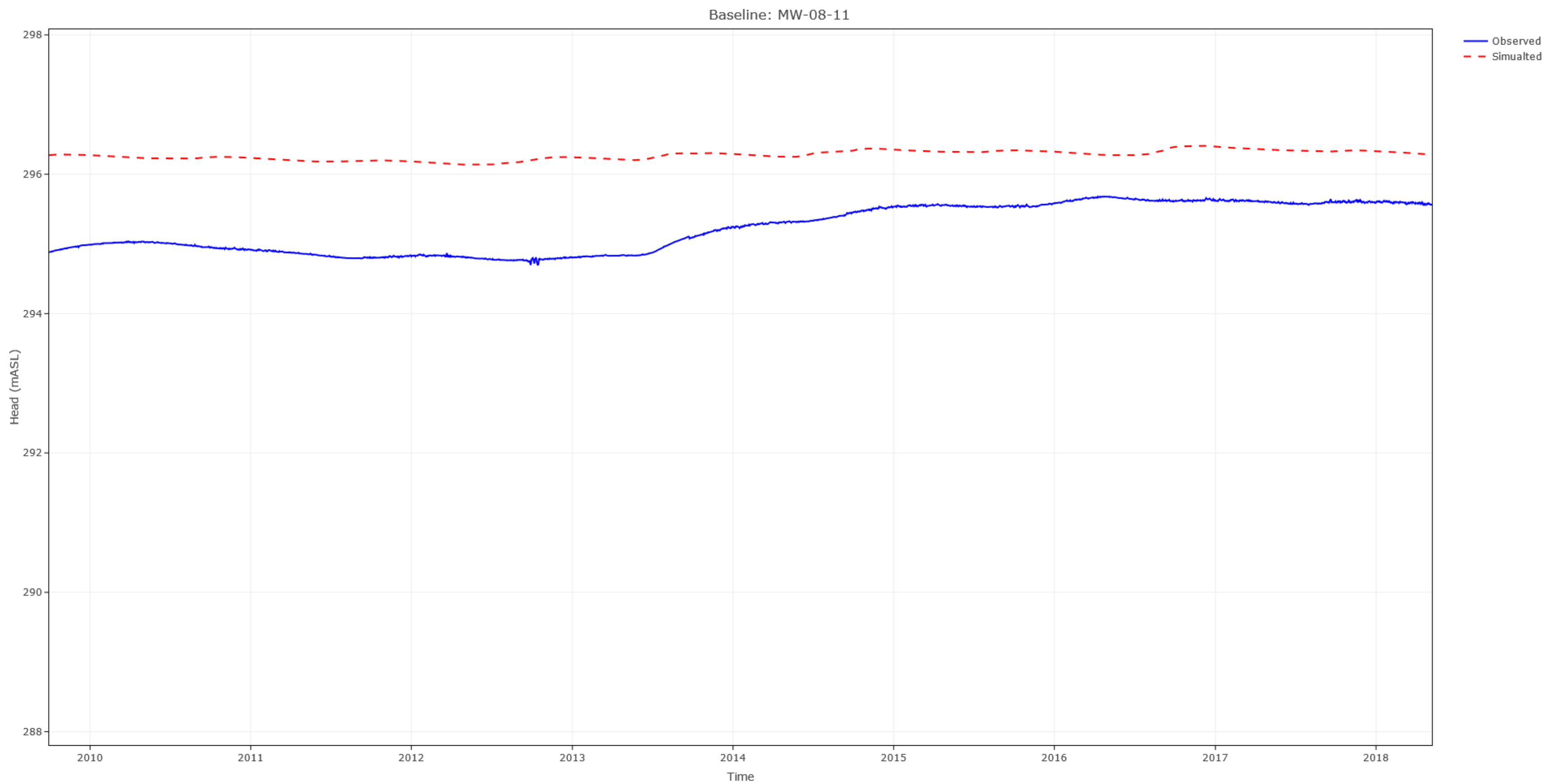
$$\mathrm{J} = \frac{\partial \hat{\mathrm{y}}}{\partial \mathrm{p}}$$

At each iteration, the calculated step $\Delta \mathrm{p}^k$ is essentially an interpolation between a Gauss-Newton step and a gradient descent step. Finally, the LM method may only converge to a local minimum or a saddle point. In other words, it is not guaranteed to find a global minimum. The iteration will stop when an acceptable residual is achieved.

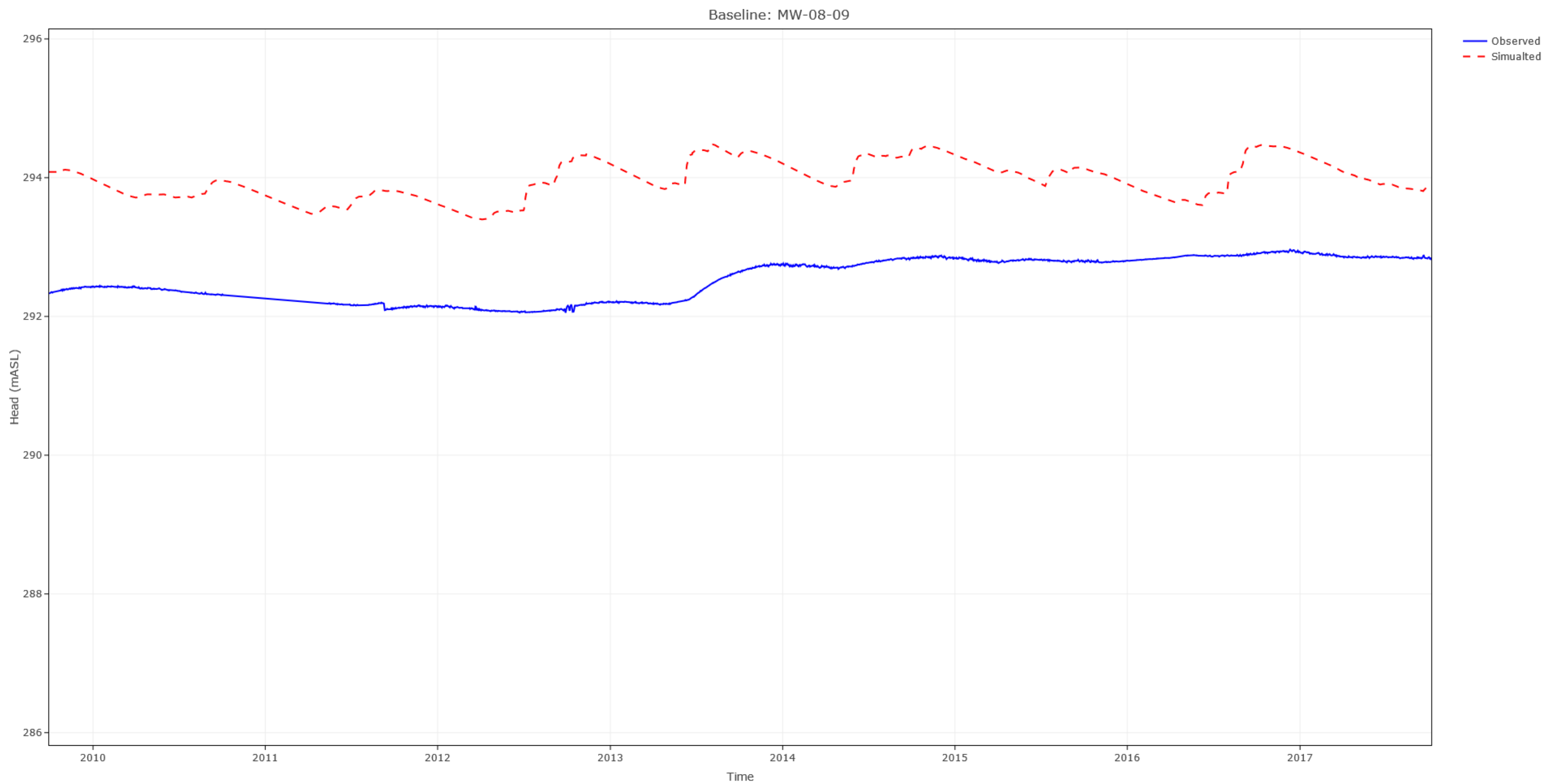
Attachment F

Simulated vs. Observed Groundwater Level Time Series

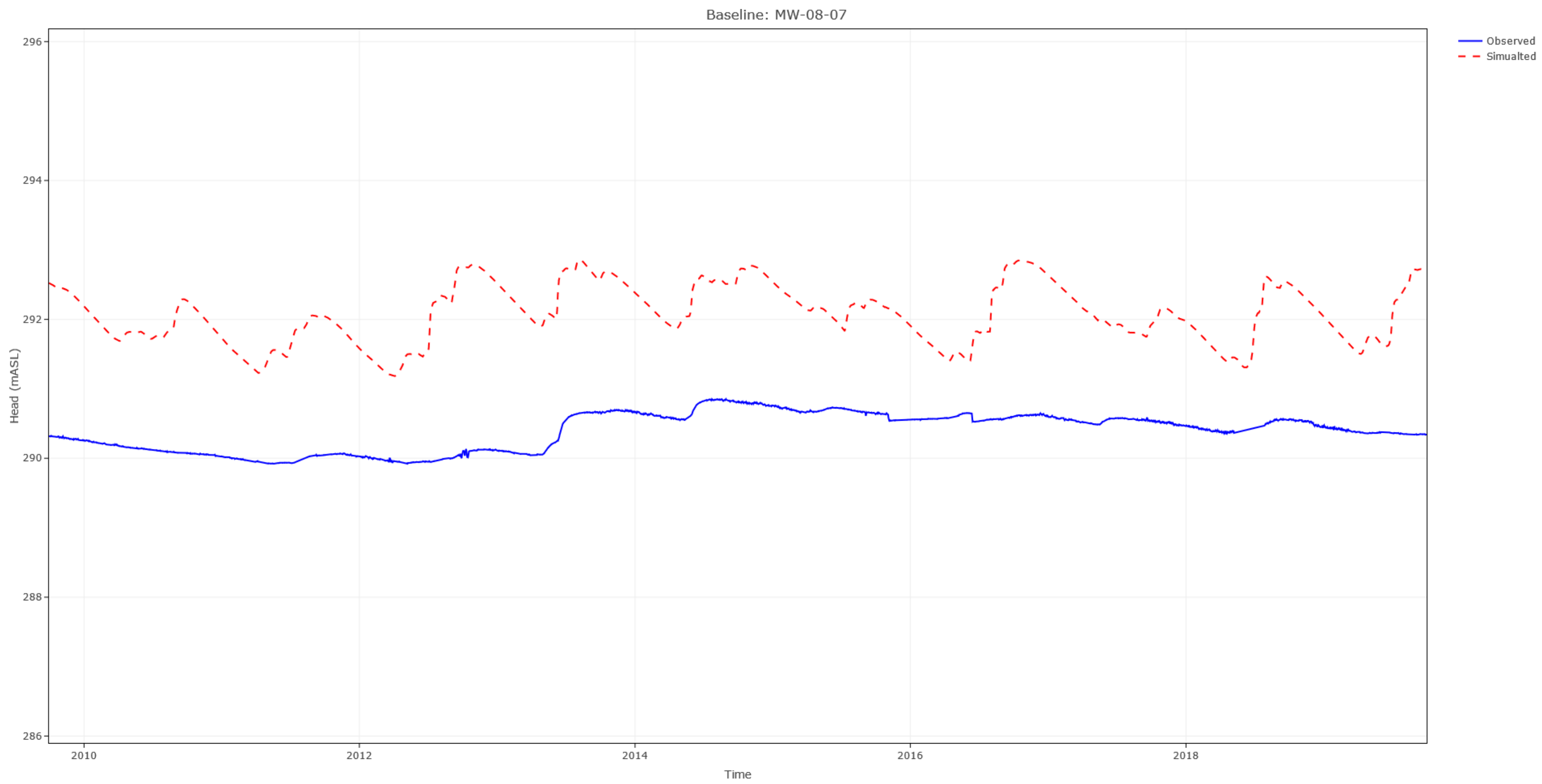
Baseline: MW-08-12
Observed
Simualted
Head (mASL)
300
298
296
294
292
290
2010
2012
2014
2016
2018
Time

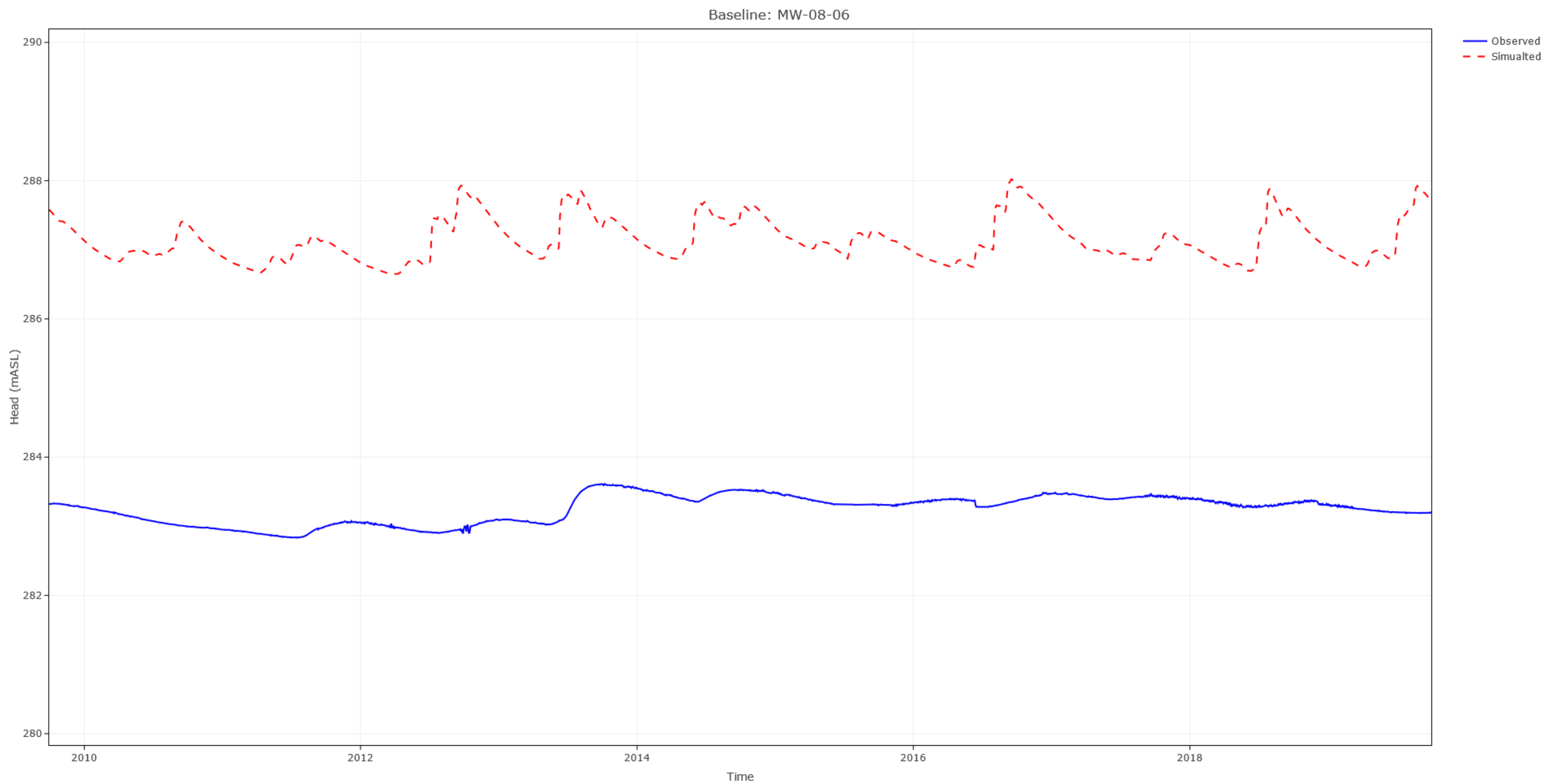

Baseline: MW-08-11
298
296
294
292
290
288
Head (mASL)
2010
2011
2012
2013
2014
2015
2016
2017
2018
Time
Observed
Simualted

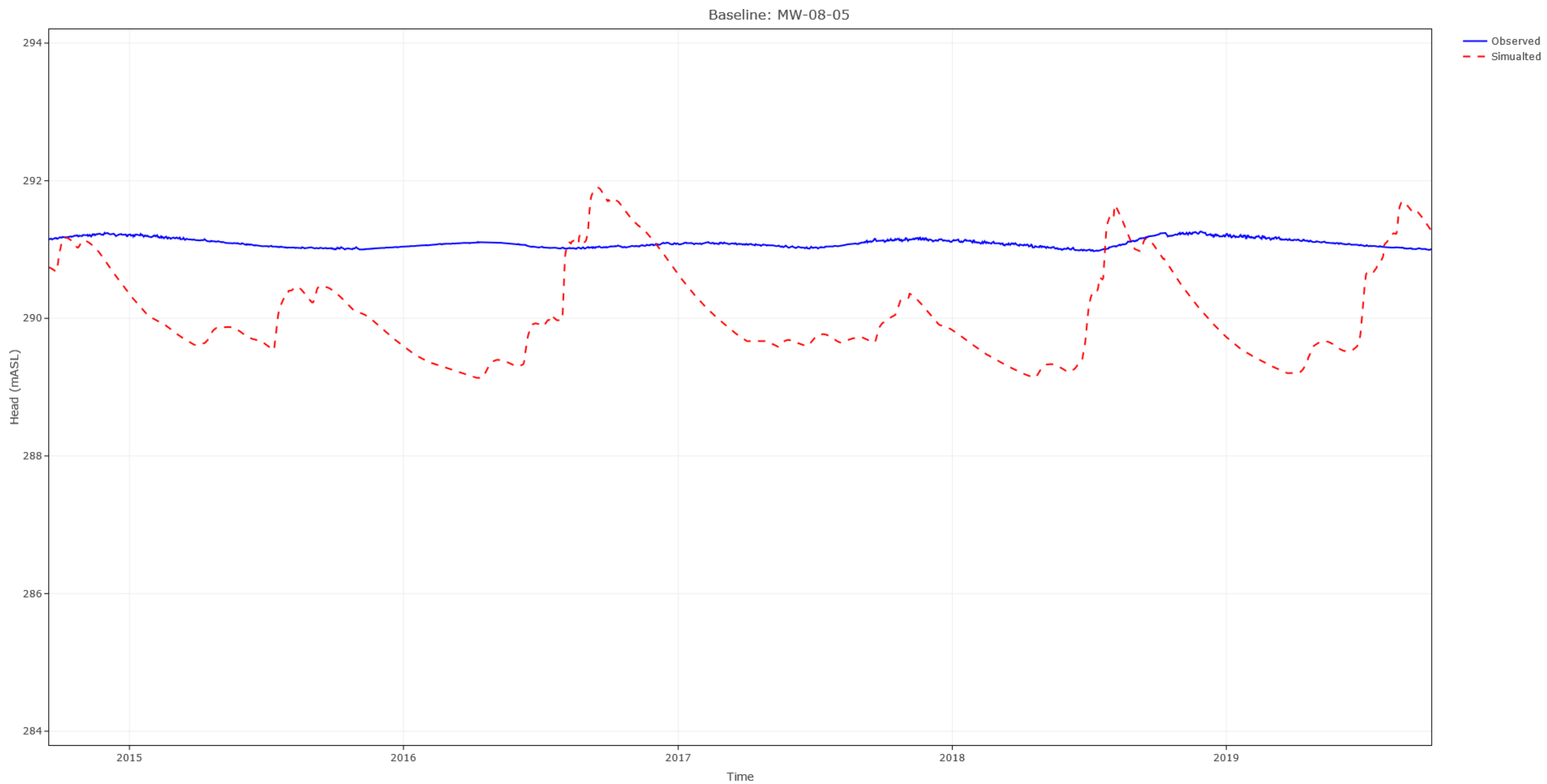
Baseline: MW-08-10
Observed
Simualted
Head (mASL)
298
296
294
292
290
288
2012
2013
2014
2015
2016
2017
2018
2019
Time

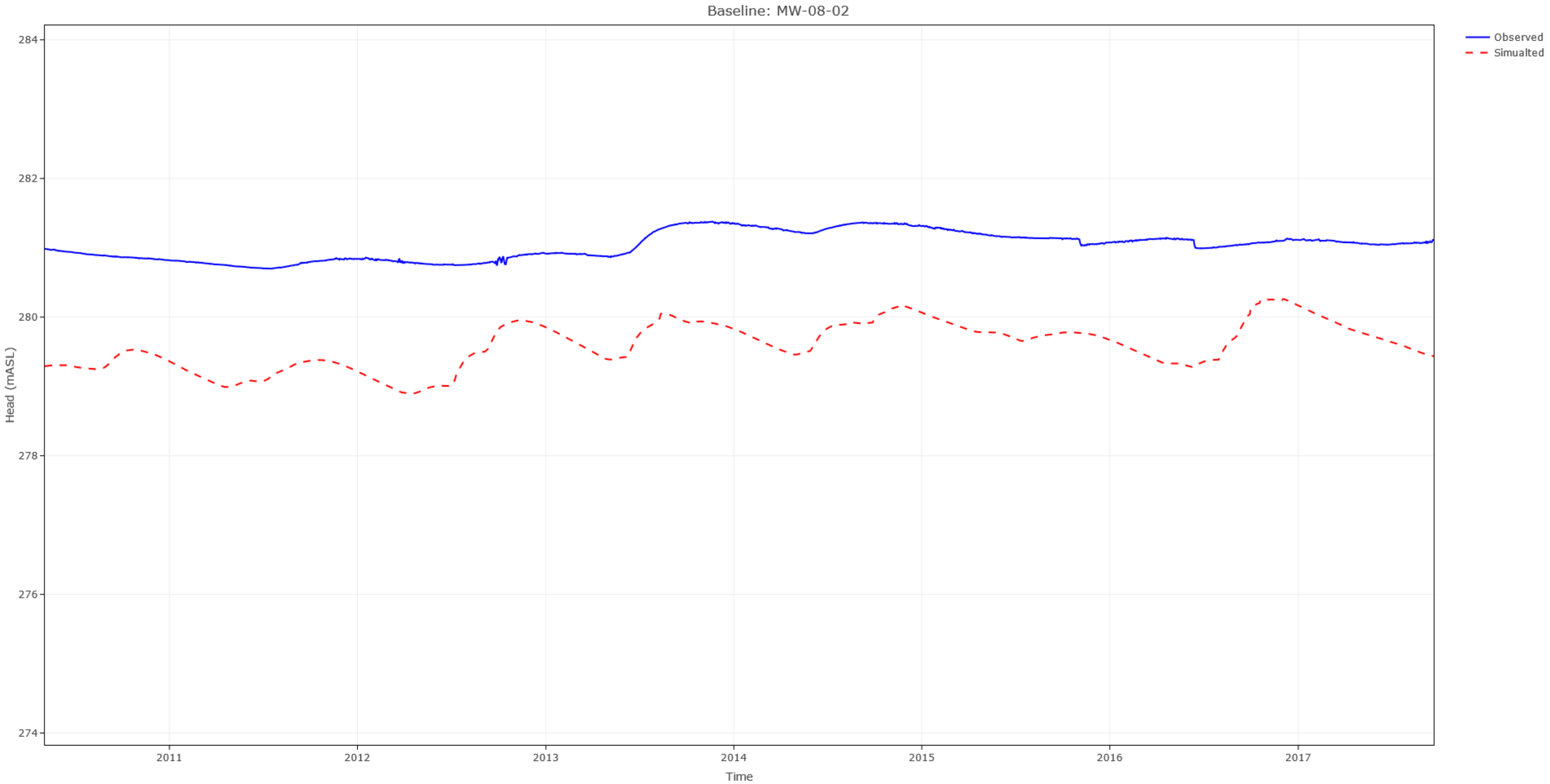


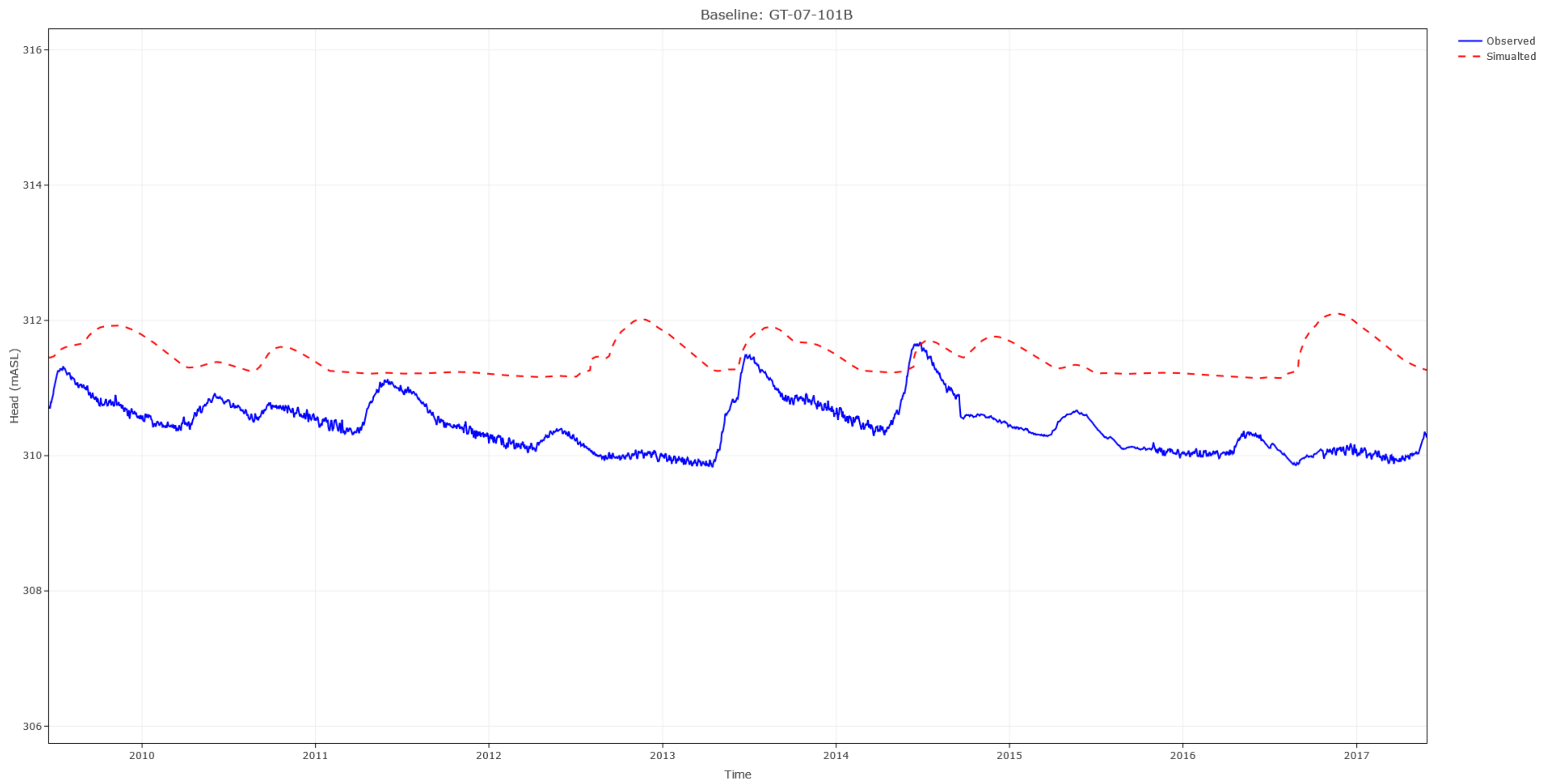
Baseline: MW-08-09
Observed
Simualted
296
294
292
290
288
286
Head (mASL)
2010
2011
2012
2013
2014
2015
2016
2017
Time


Baseline: MW-08-07
Head (mASL)
296
294
292
290
288
286
2010
2012
2014
2016
2018
Time
Observed
Simualted

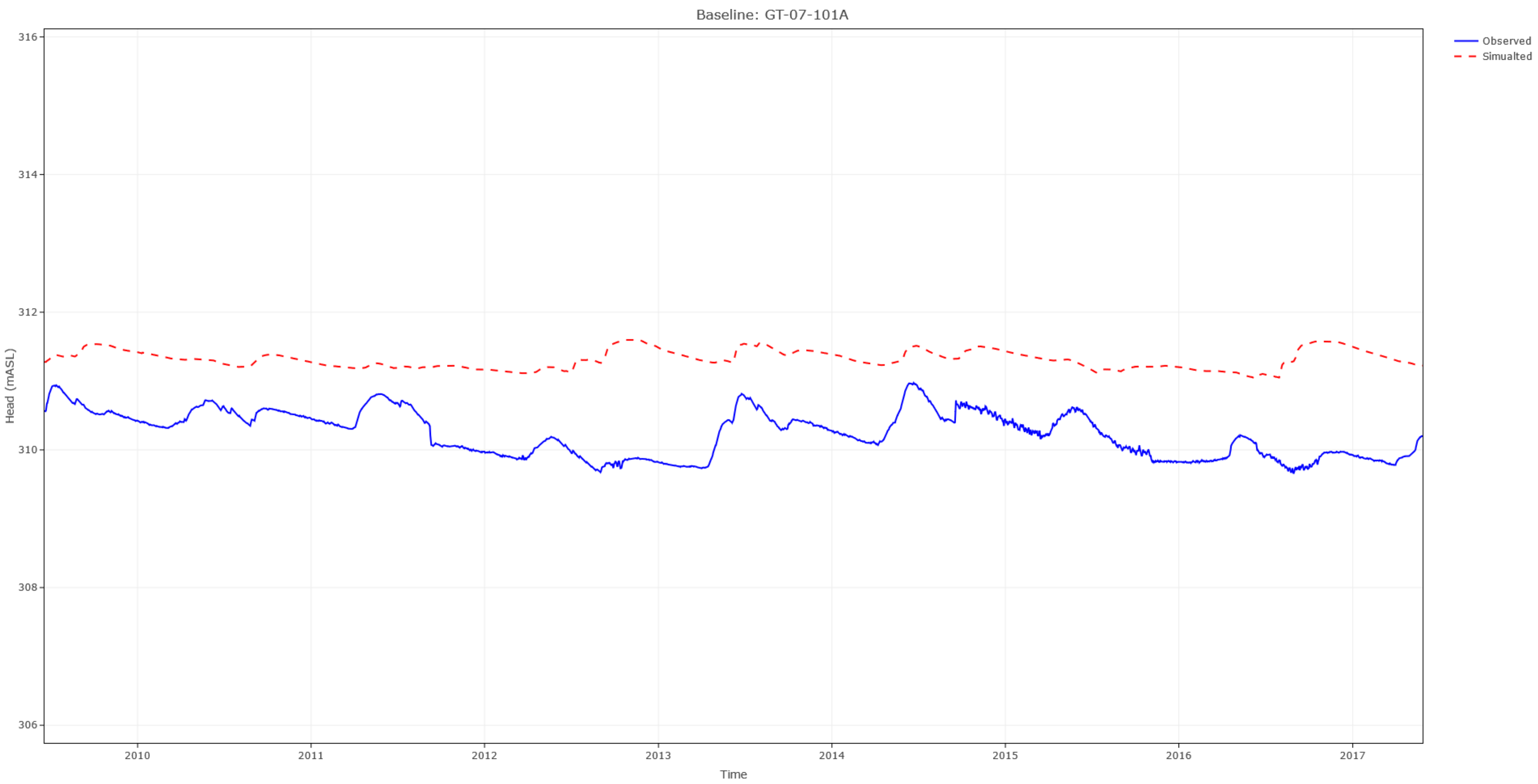

Baseline: MW-08-06
Observed
Simualted
Head (mASL)
290
288
286
284
282
280
2010
2012
2014
2016
2018
Time


Baseline: MW-08-05
Observed
Simualted
294
292
290
288
286
284
Head (mASL)
2015
2016
2017
2018
2019
Time

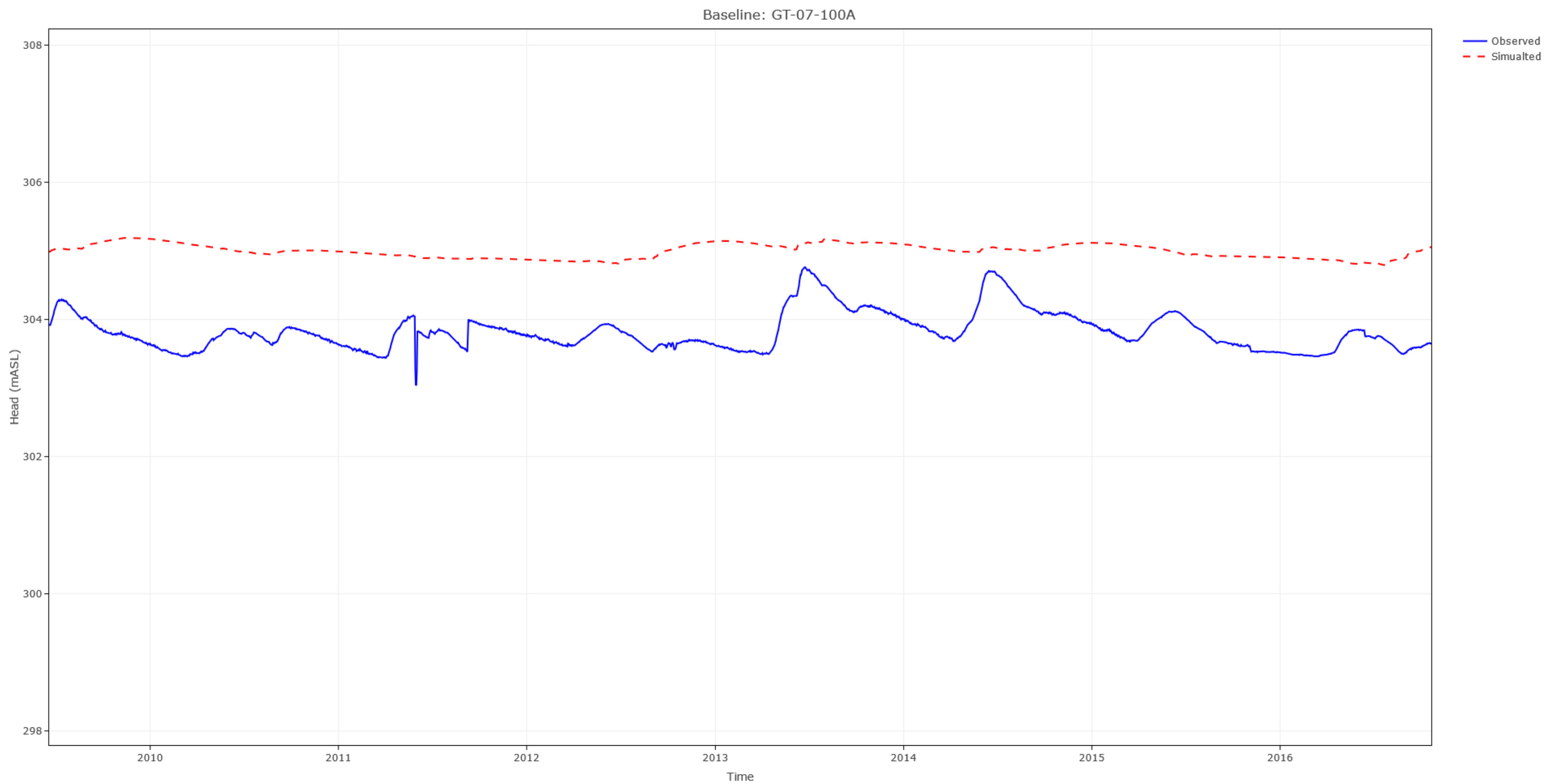

Baseline: MW-08-02
284
282
280
278
276
274
Head (mASL)
2011
2012
2013
2014
2015
2016
2017
Time
Observed
Simualted



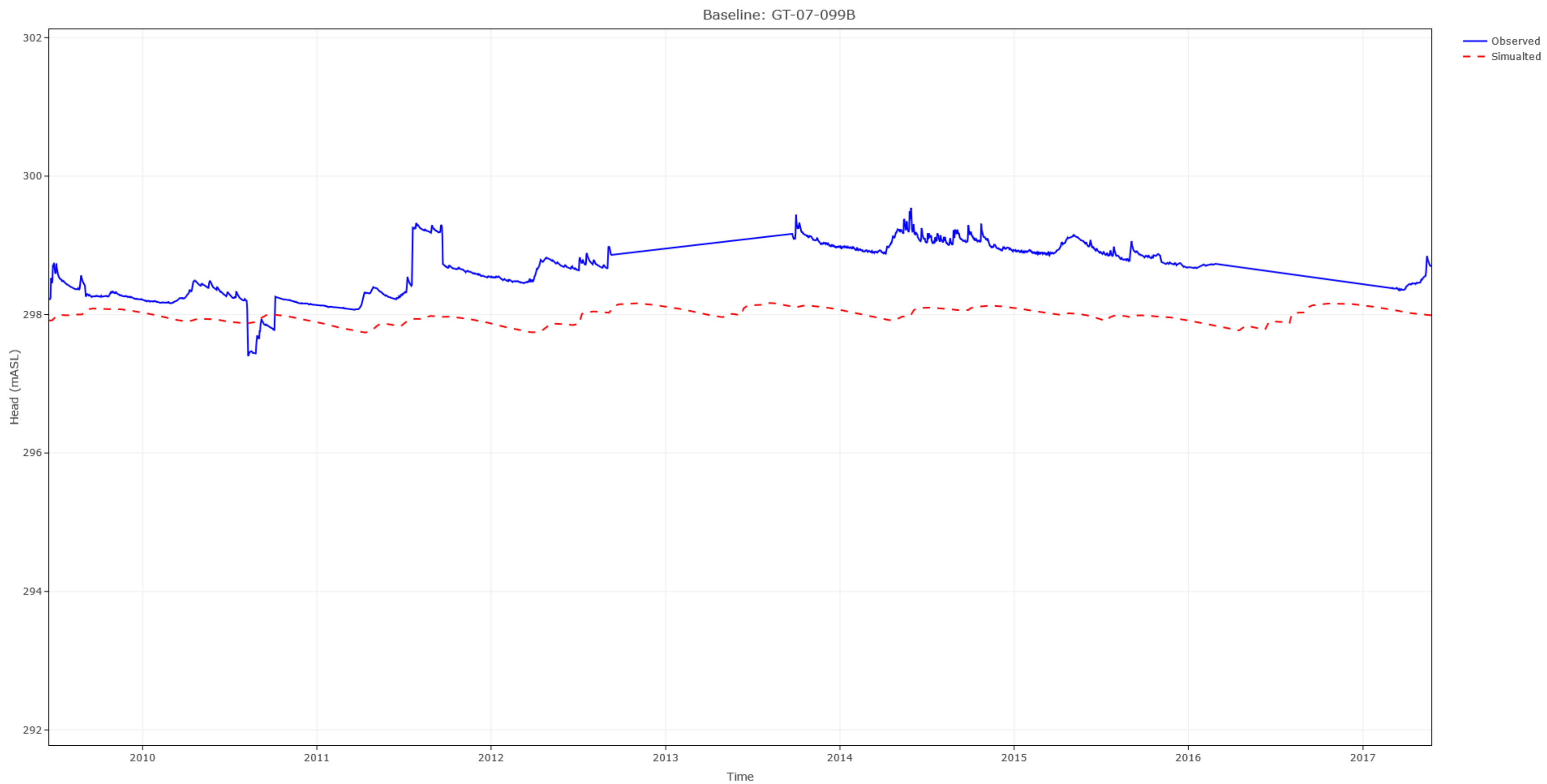
Baseline: GT-07-101B
Observed
Simualted
Head (mASL)
316
314
312
310
308
306
2010
2011
2012
2013
2014
2015
2016
2017
Time



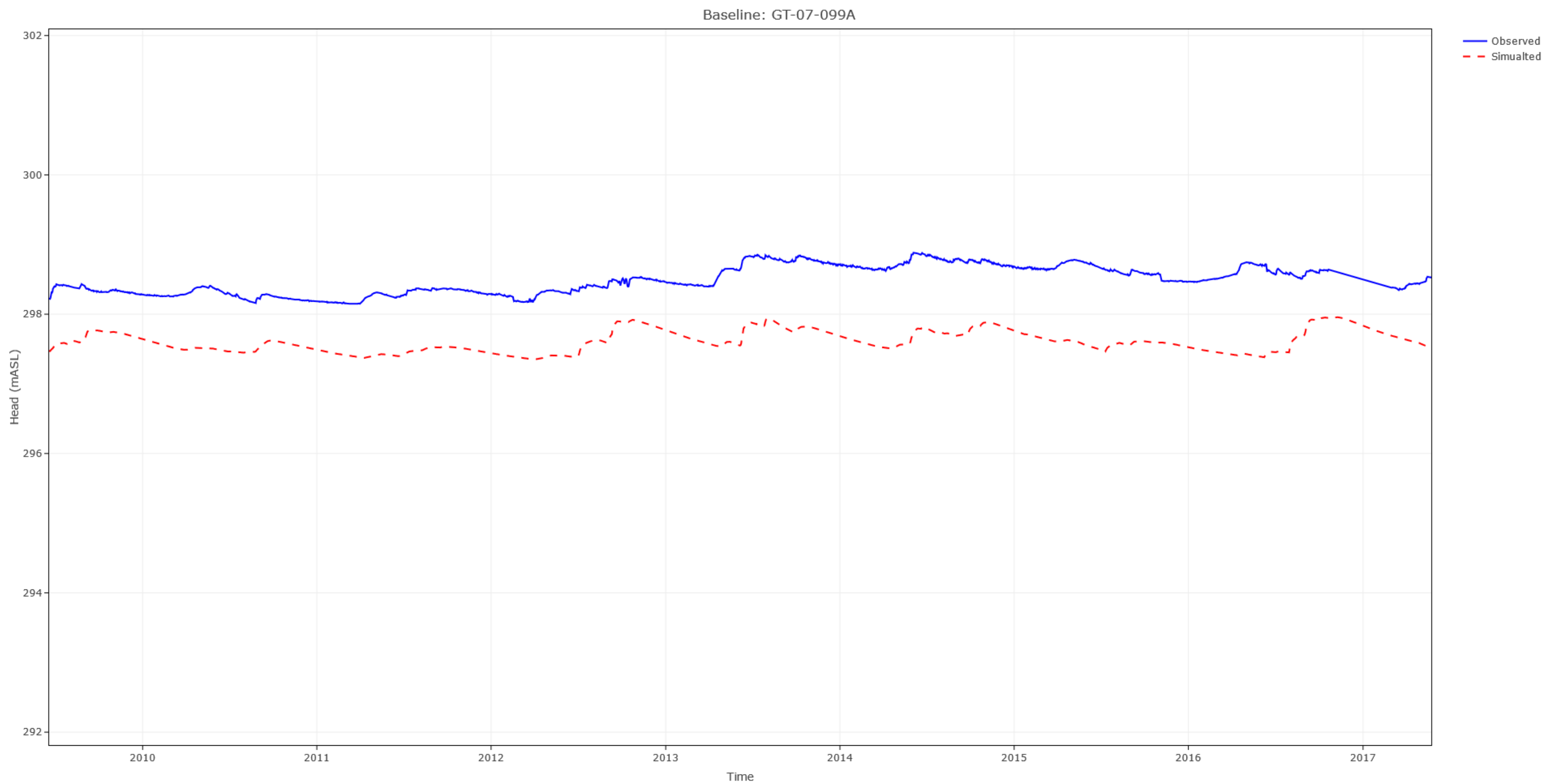
Baseline: GT-07-101A
Observed
Simualted
Head (mASL)
316
314
312
310
308
306
2010
2011
2012
2013
2014
2015
2016
2017
Time

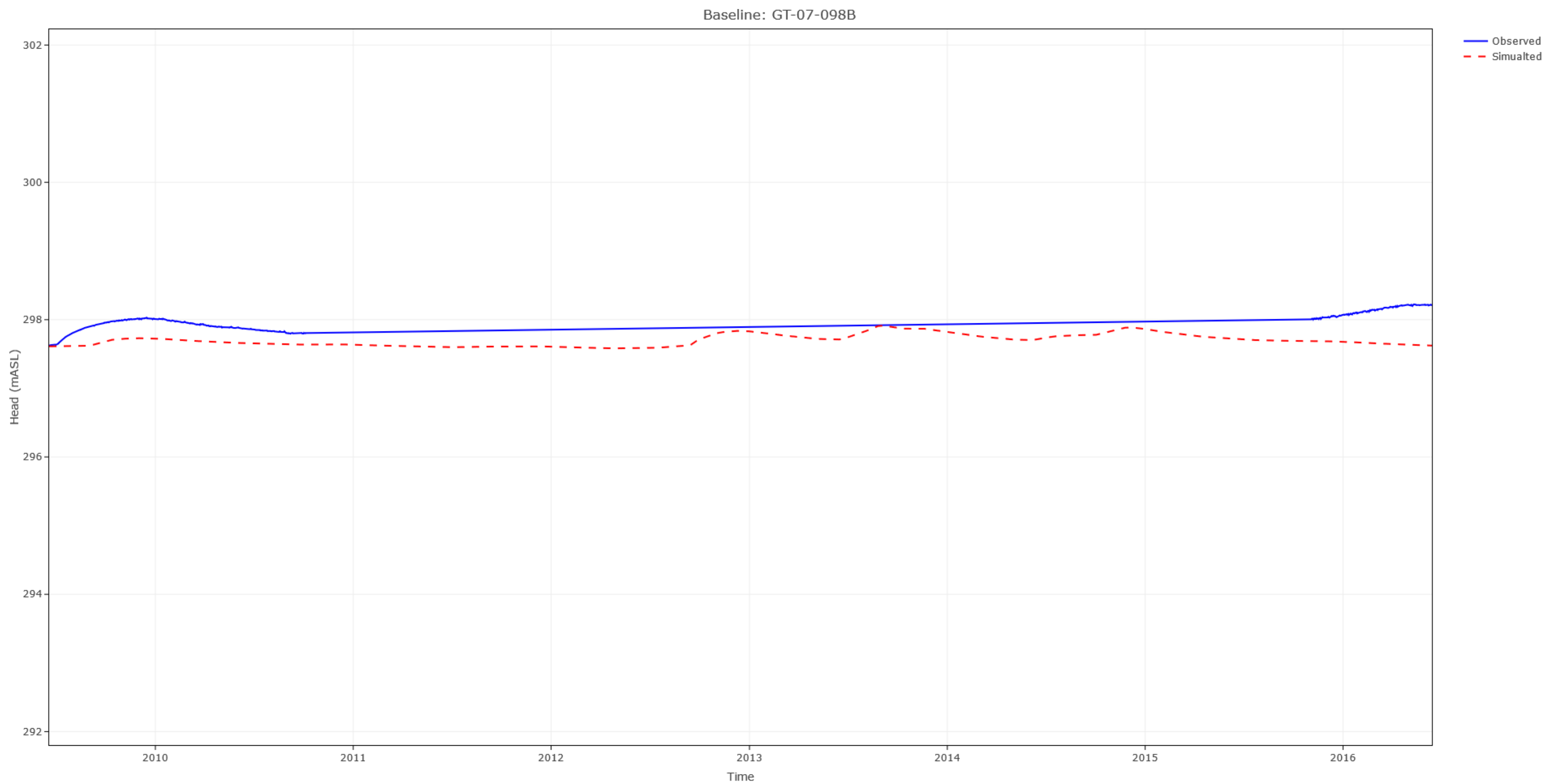


Baseline: GT-07-100A
Observed
Simualted
Head (mASL)
308
306
304
302
300
298
2010
2011
2012
2013
2014
2015
2016
Time

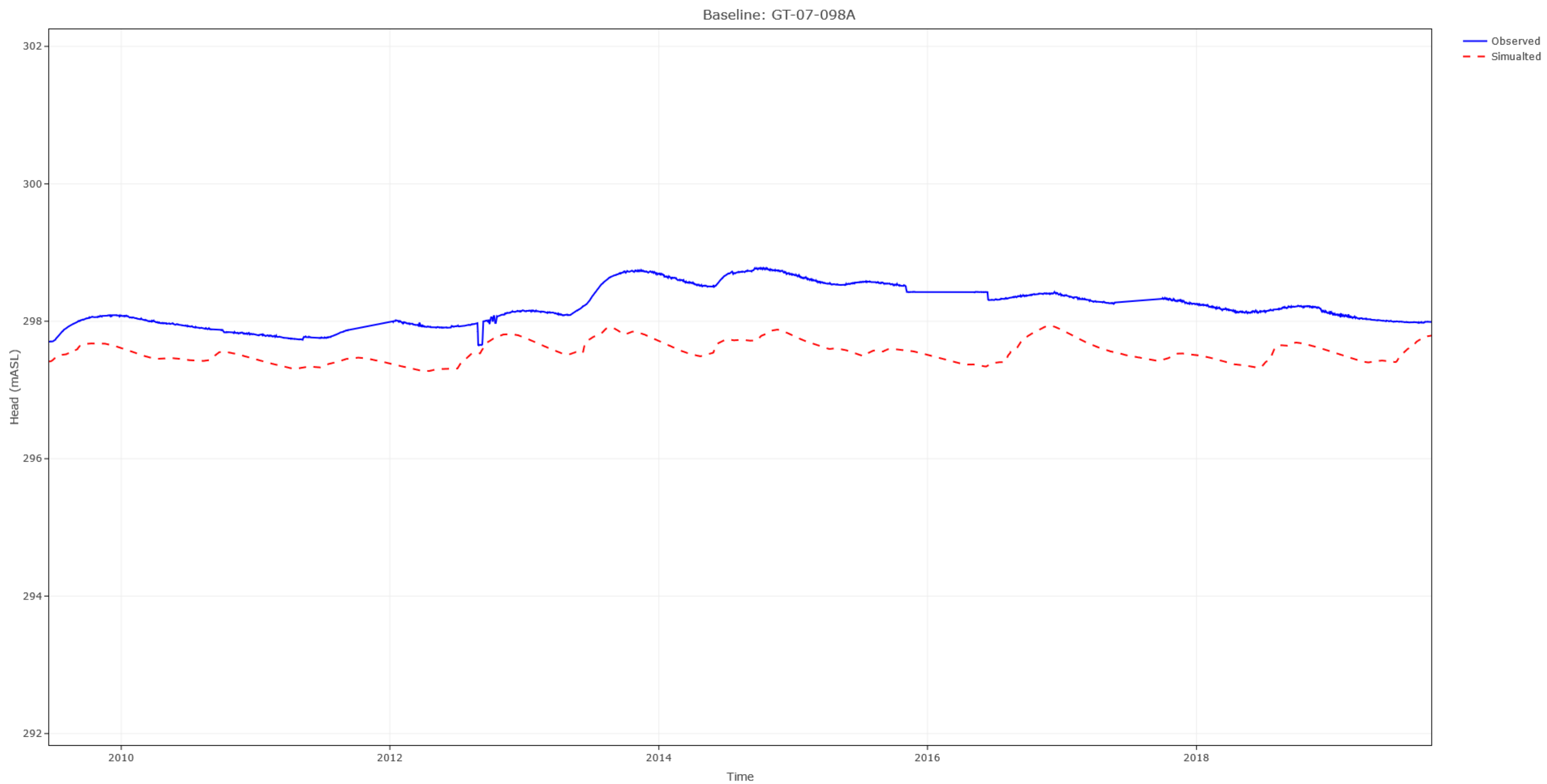


Baseline: GT-07-099B
Observed
Simualted
Head (mASL)
302
300
298
296
294
292
2010
2011
2012
2013
2014
2015
2016
2017
Time

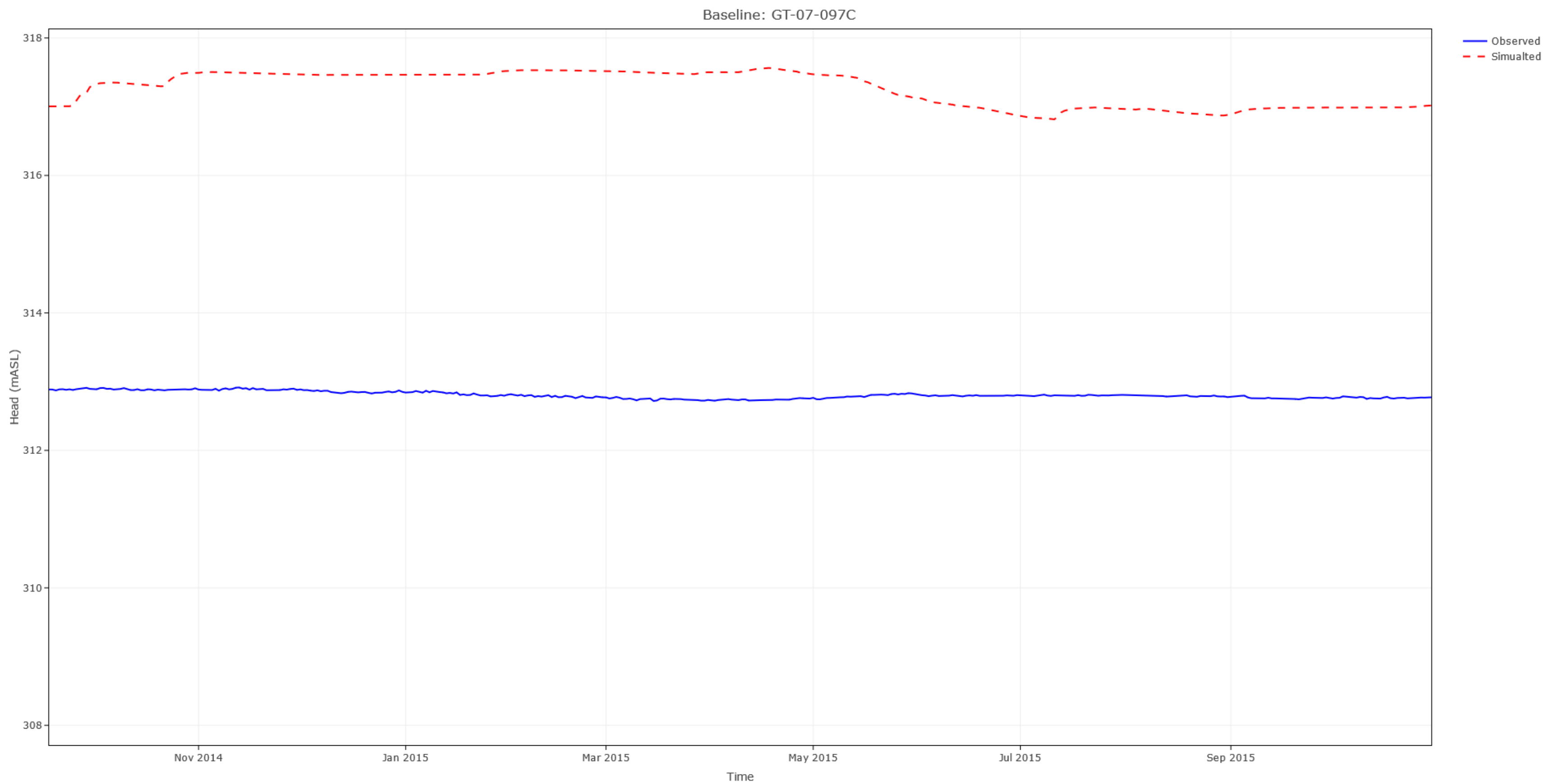

Baseline: GT-07-099A
302
300
298
296
294
292
Head (mASL)
2010
2011
2012
2013
2014
2015
2016
2017
Time
Observed
Simualted

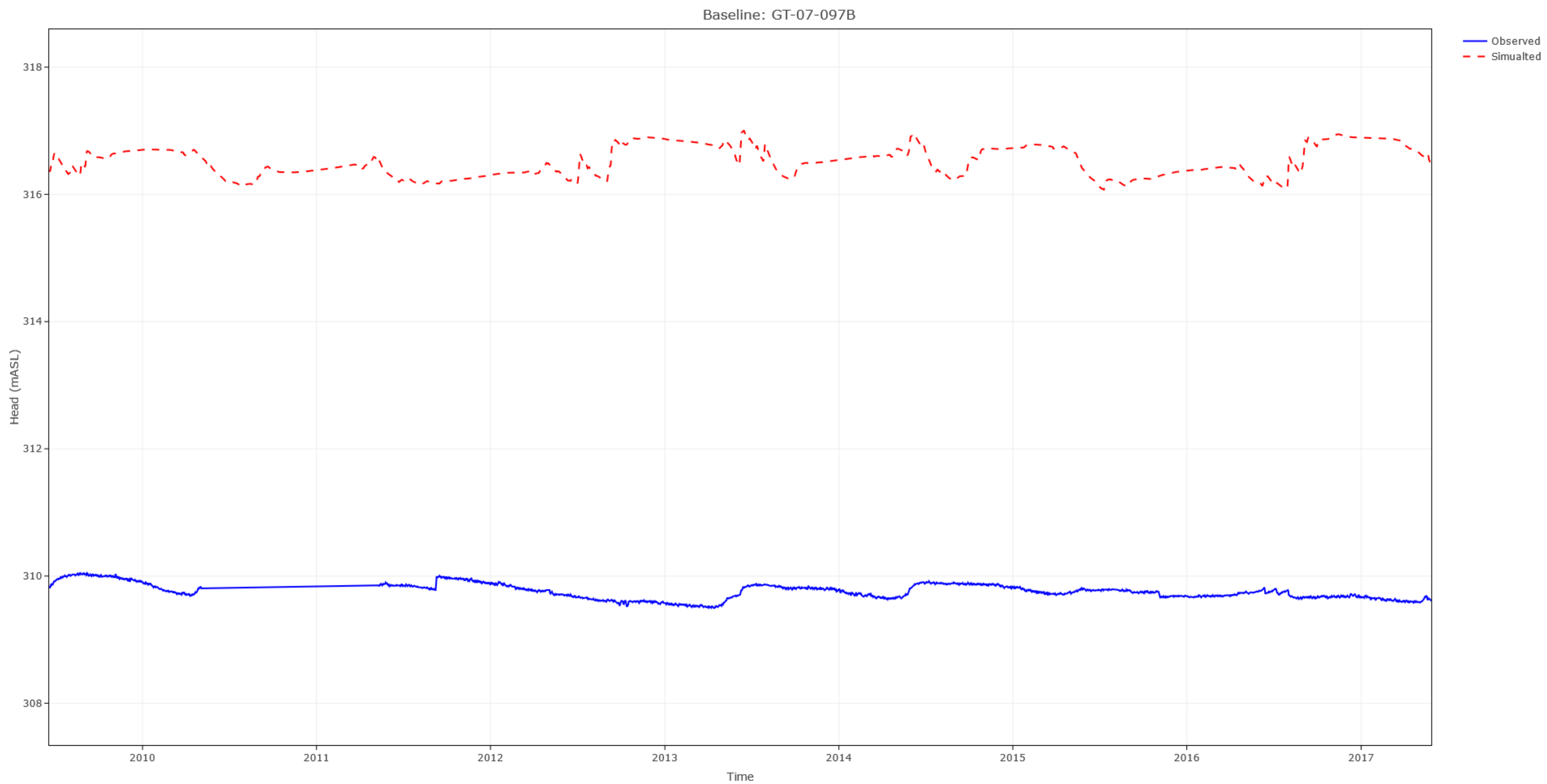


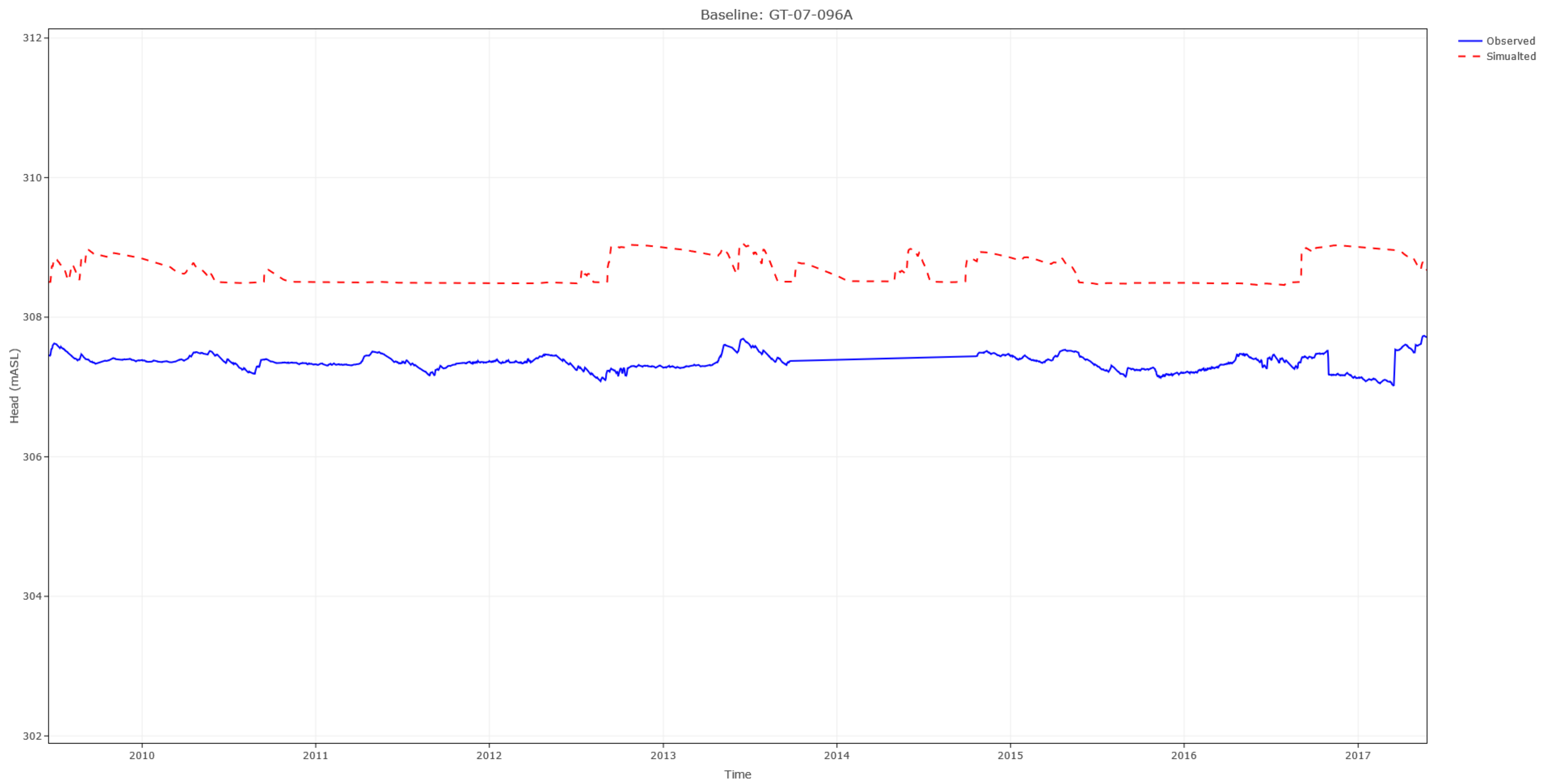
Baseline: GT-07-098B
Observed
Simualted
Head (mASL)
302
300
298
296
294
292
2010
2011
2012
2013
2014
2015
2016
Time



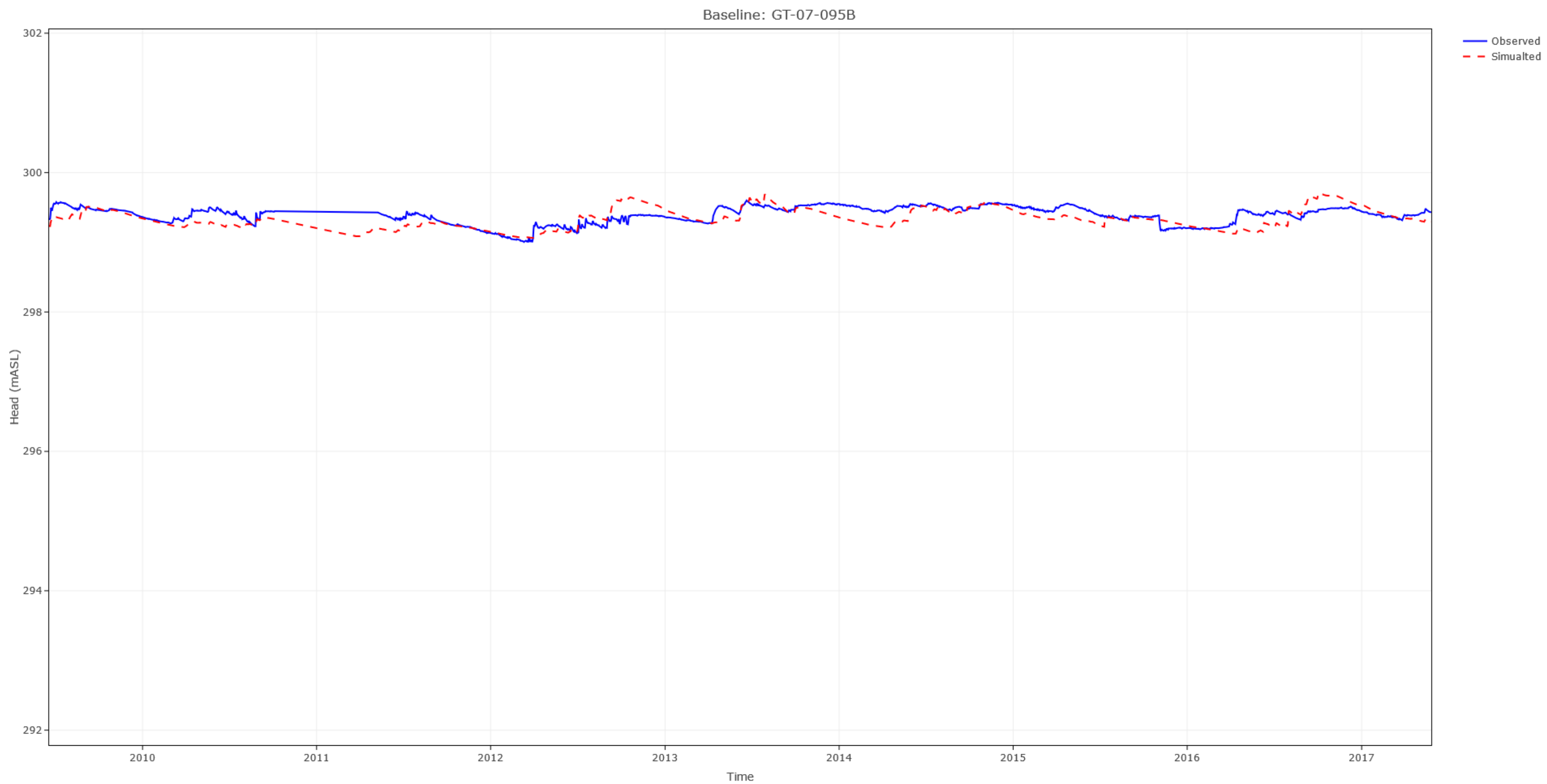
Baseline: GT-07-098A
Observed
Simualted
Head (mASL)
302
300
298
296
294
292
2010
2012
2014
2016
2018
Time

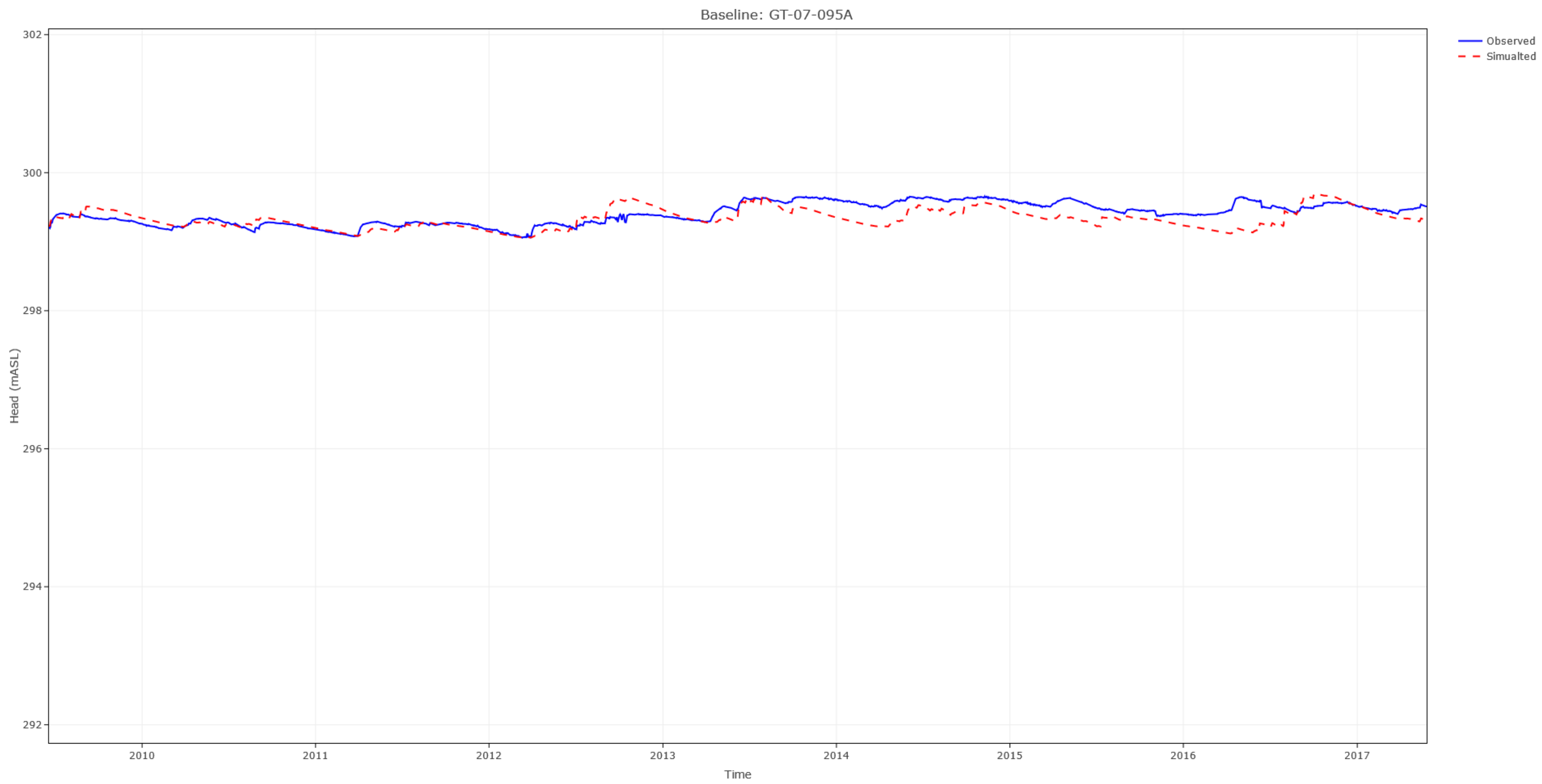

Baseline: GT-07-097C
Observed
Simualted
318
316
314
312
310
308
Head (mASL)
Nov 2014
Jan 2015
Mar 2015
May 2015
Jul 2015
Sep 2015
Time


Baseline: GT-07-097B
Observed
Simualted
318
316
314
312
310
308
Head (mASL)
2010
2011
2012
2013
2014
2015
2016
2017
Time

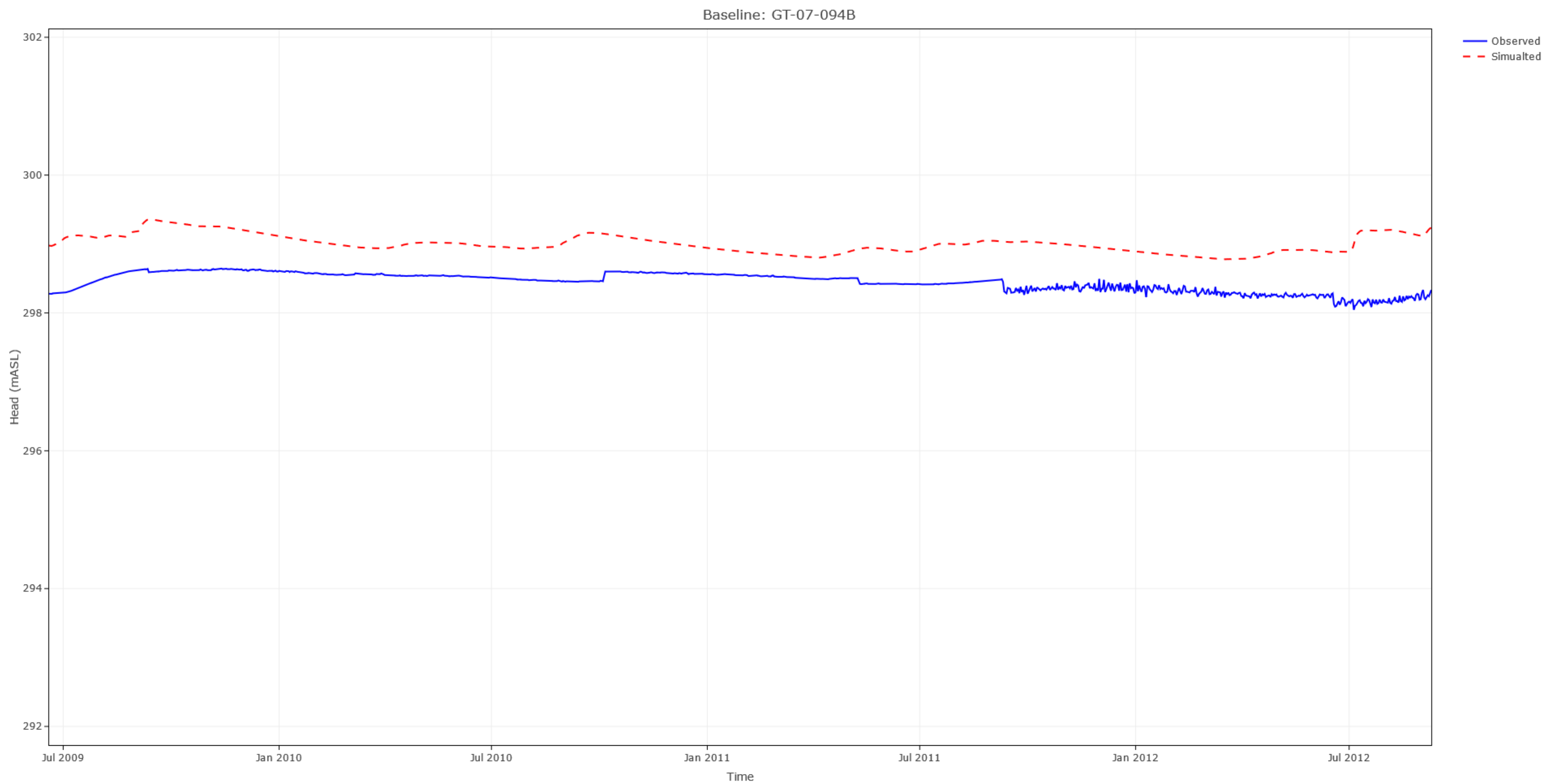


Baseline: GT-07-096A
Observed
Simualted
Head (mASL)
312
310
308
306
304
302
2010
2011
2012
2013
2014
2015
2016
2017
Time

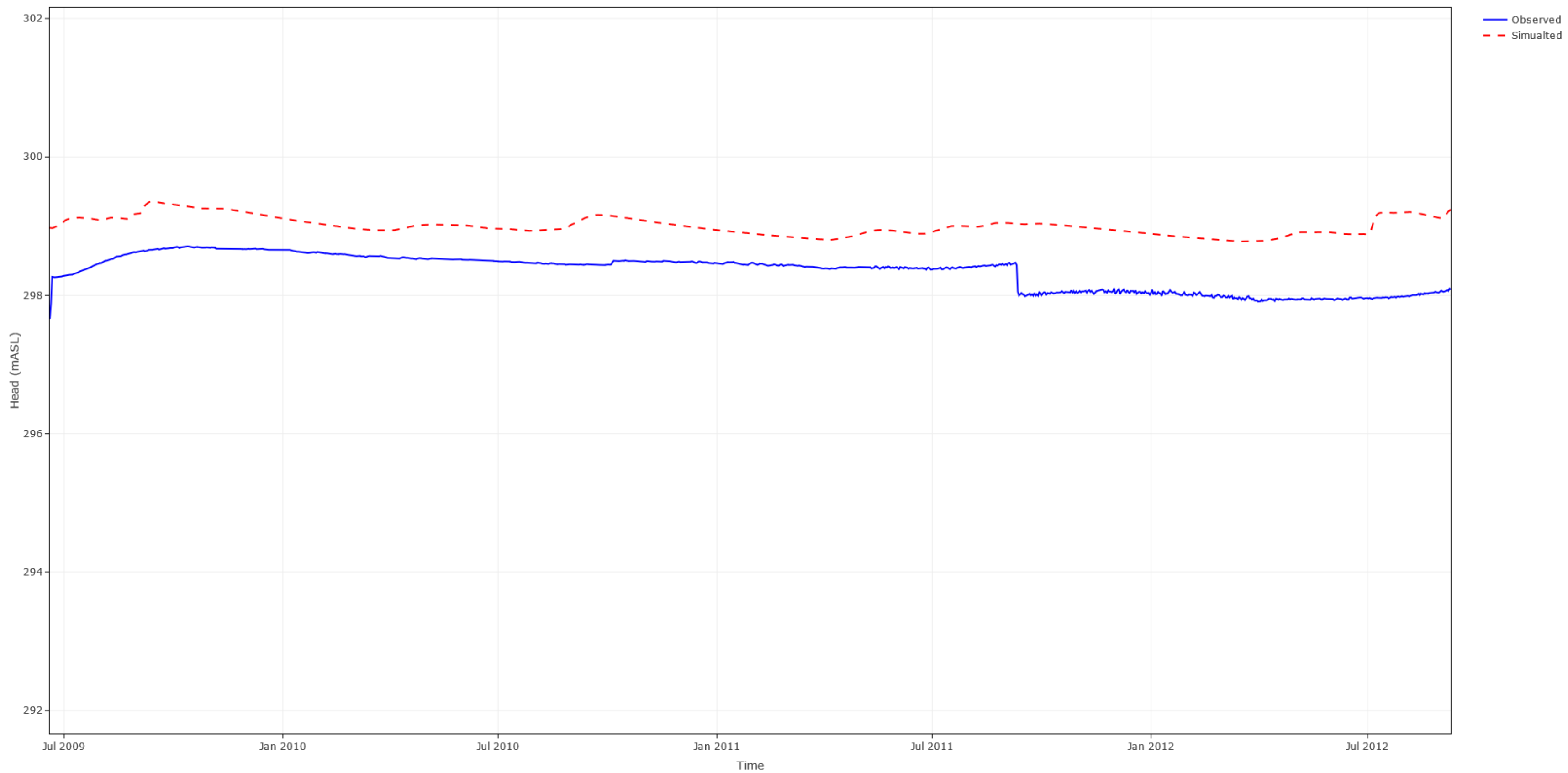

Baseline: GT-07-095B
302
300
298
296
294
292
Head (mASL)
2010
2011
2012
2013
2014
2015
2016
2017
Time
Observed
Simualted

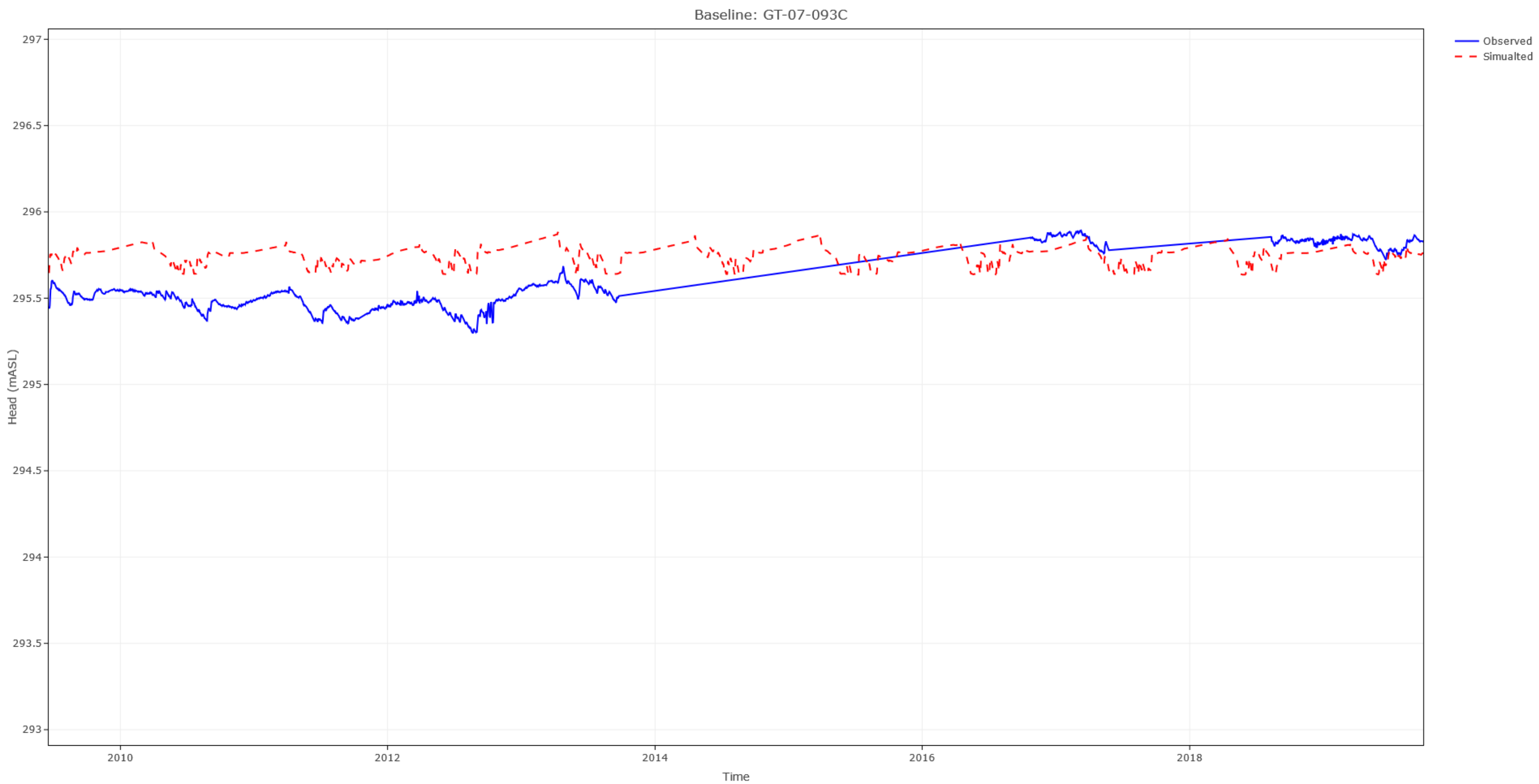


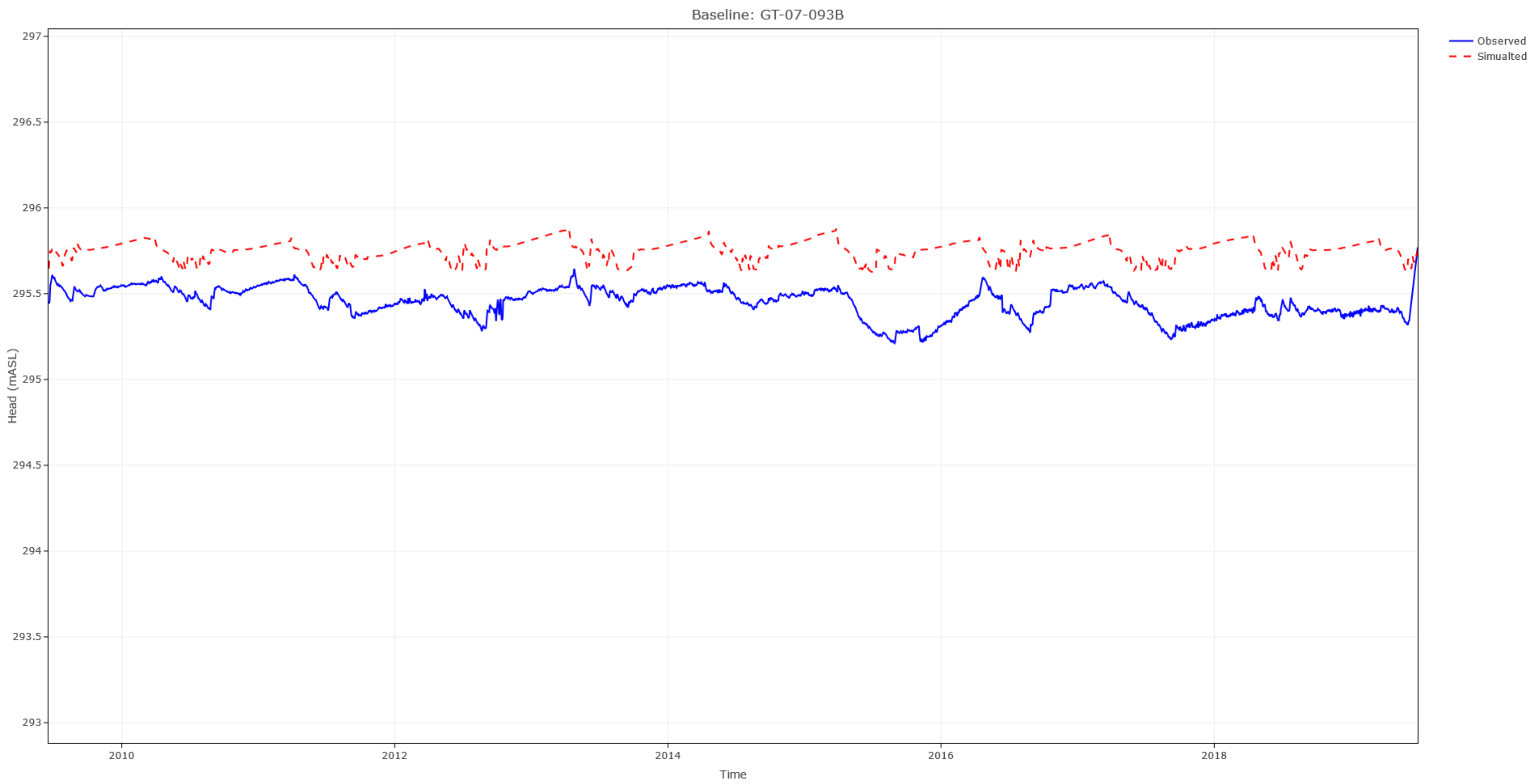
Baseline: GT-07-095A
Head (mASL)
302
300
298
296
294
292
2010
2011
2012
2013
2014
2015
2016
2017
Time
Observed
Simualted

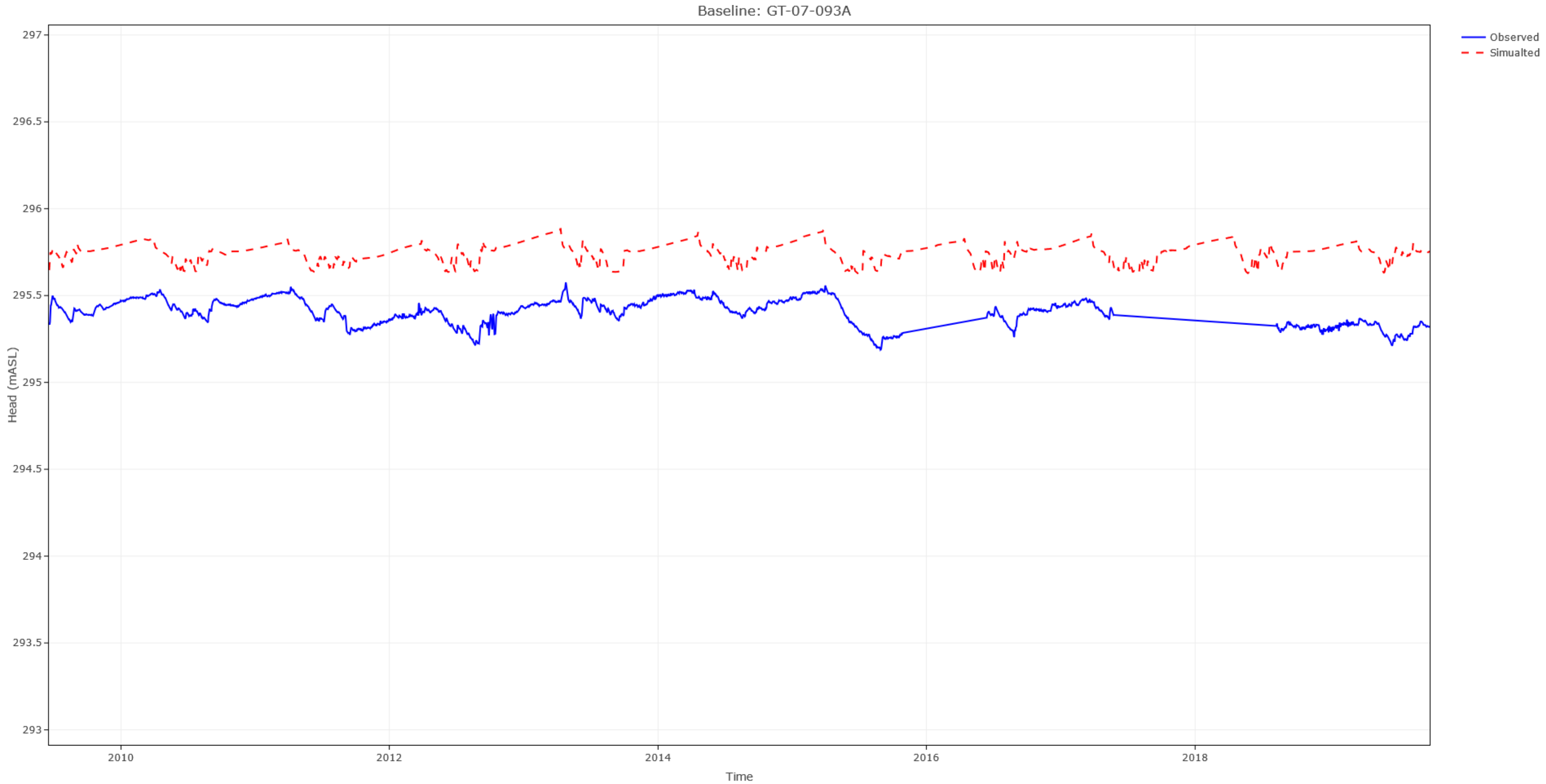

Baseline: GT-07-094B
Observed
Simualted
Head (mASL)
302
300
298
296
294
292
Jul 2009
Jan 2010
Jul 2010
Jan 2011
Jul 2011
Jan 2012
Jul 2012
Time

Baseline: GT-07-094A

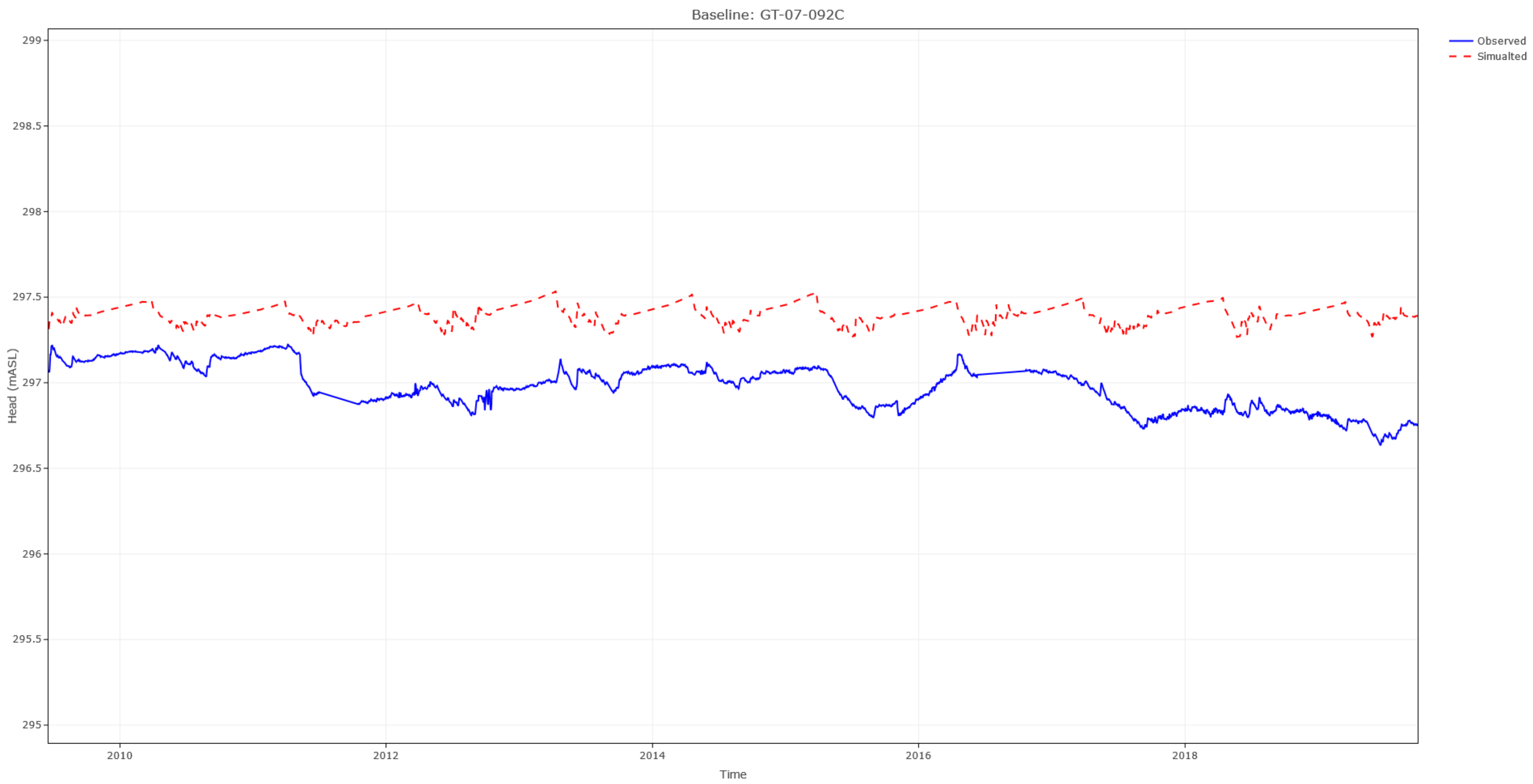



Baseline: GT-07-093C
Head (mASL)
297
296.5
296
295.5
295
294.5
294
293.5
293
2010
2012
2014
2016
2018
Time
Observed
Simualted


Baseline: GT-07-093B
Observed
Simualted
Head (mASL)
297
296.5
296
295.5
295
294.5
294
293.5
293
2010
2012
2014
2016
2018
Time



Baseline: GT-07-093A
Observed
Simualted
Head (mASL)
297
296.5
296
295.5
295
294.5
294
293.5
293
2010
2012
2014
2016
2018
Time



Baseline: GT-07-092C
Observed
Simualted
Head (mASL)
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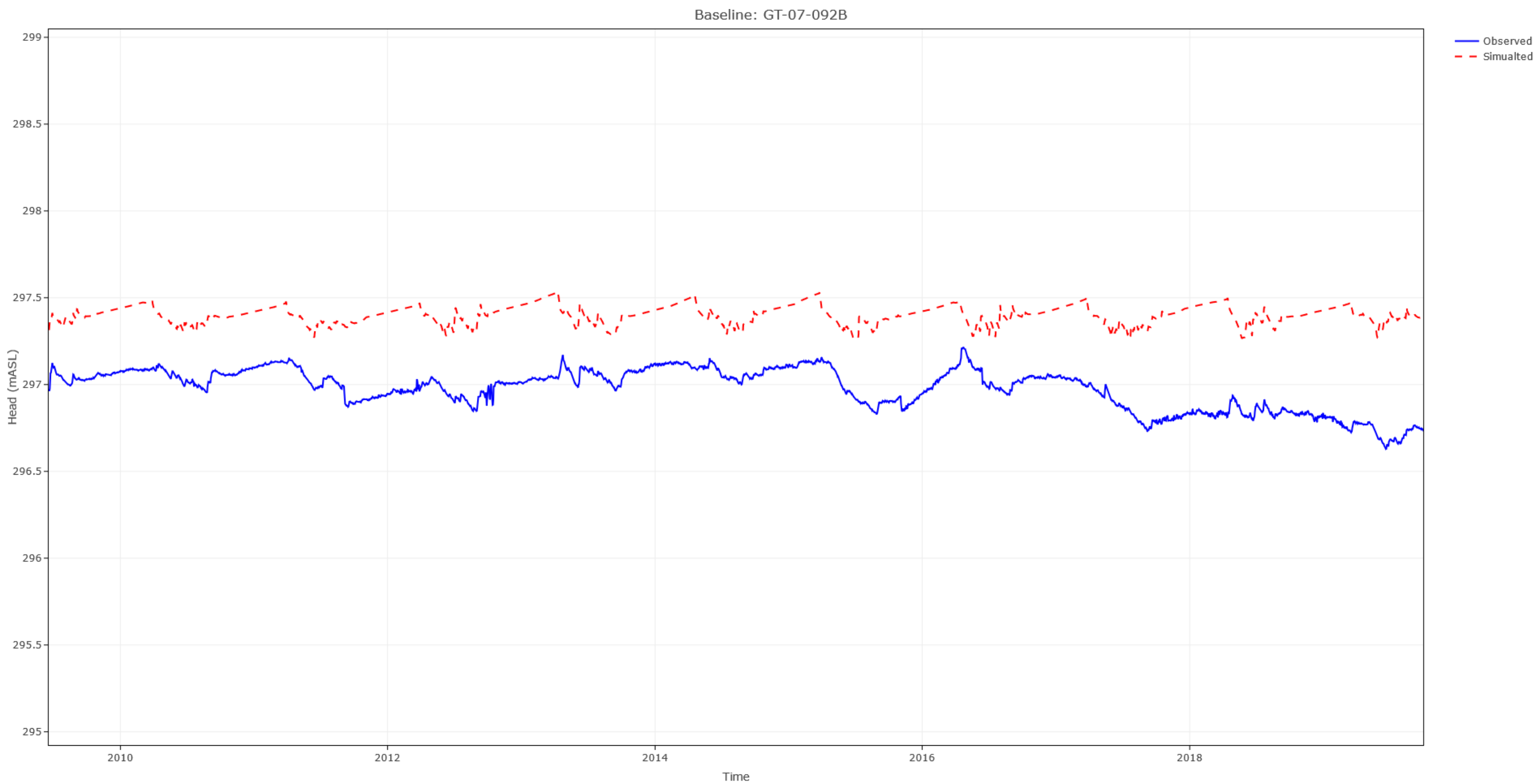
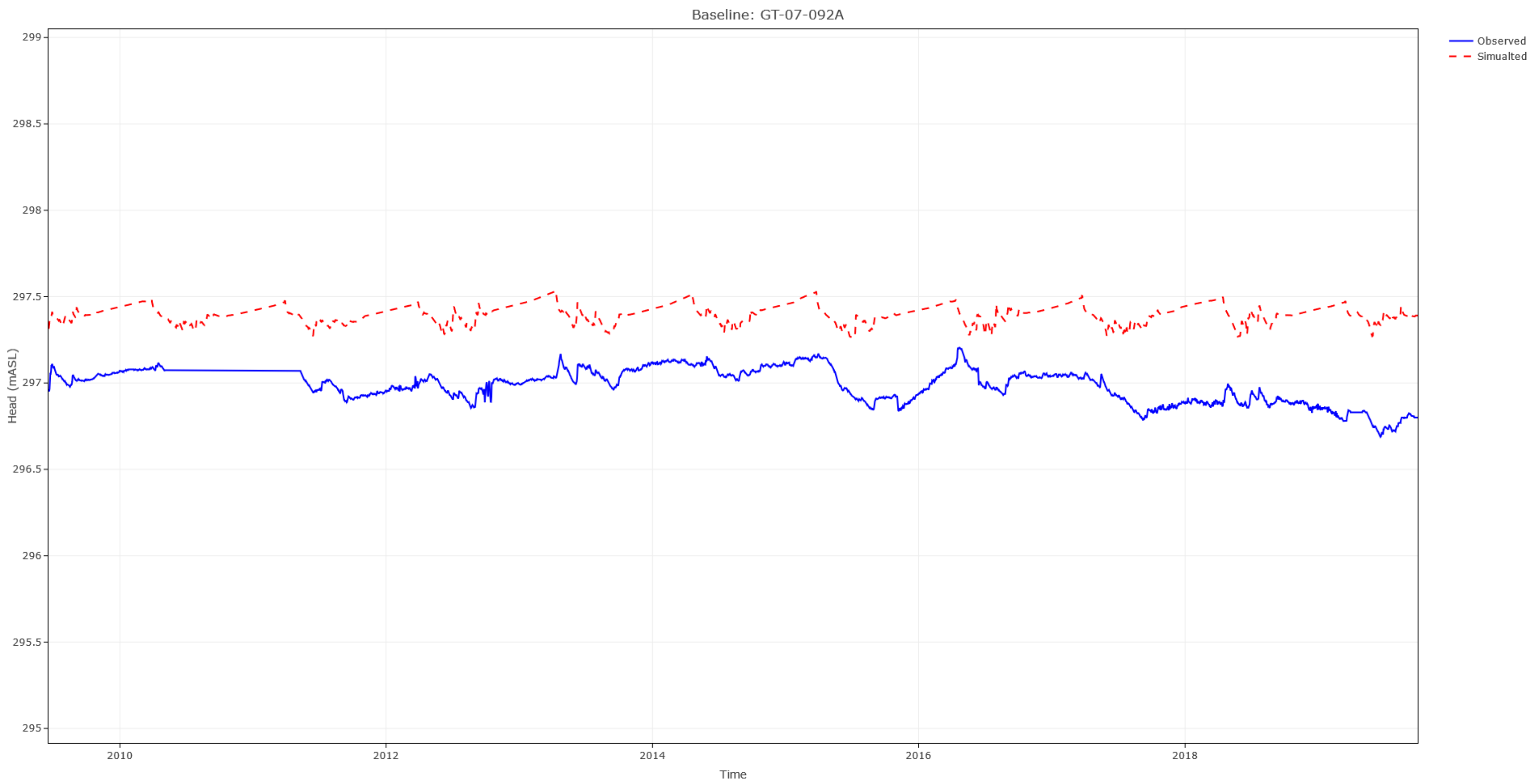
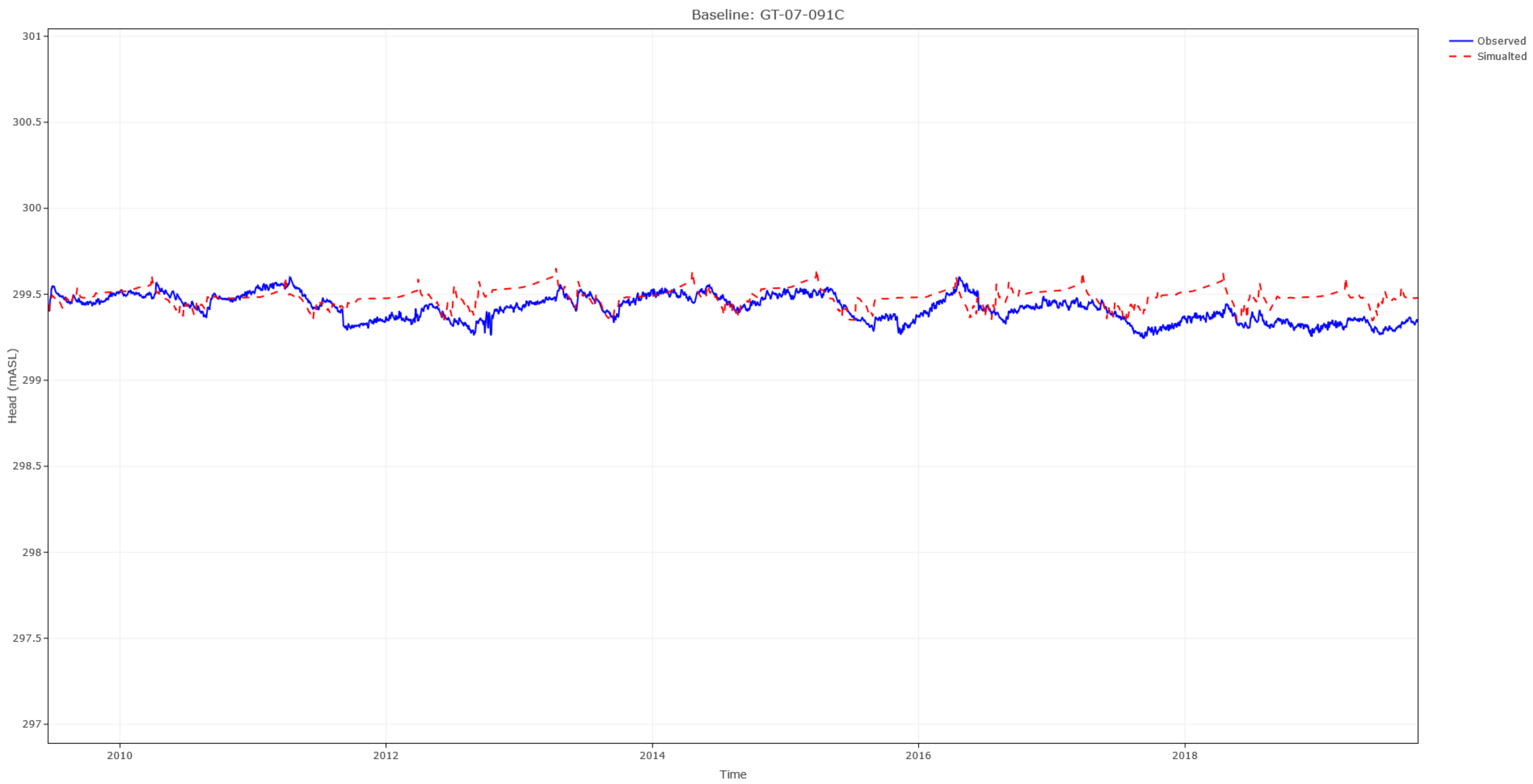
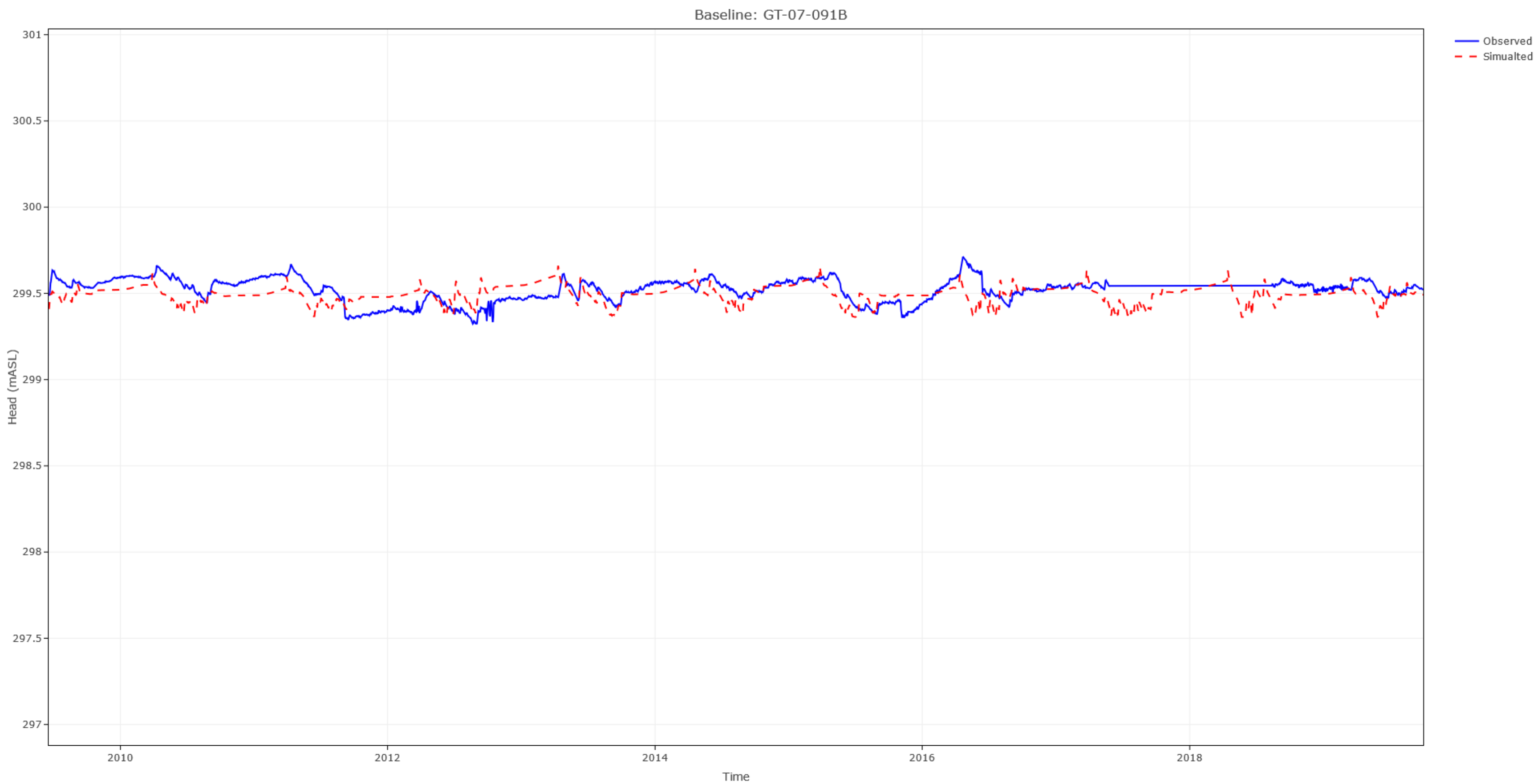
298.5
298
297.5
297
296.5
296
295.5
295
2010
2012
2014
2016
2018
Time



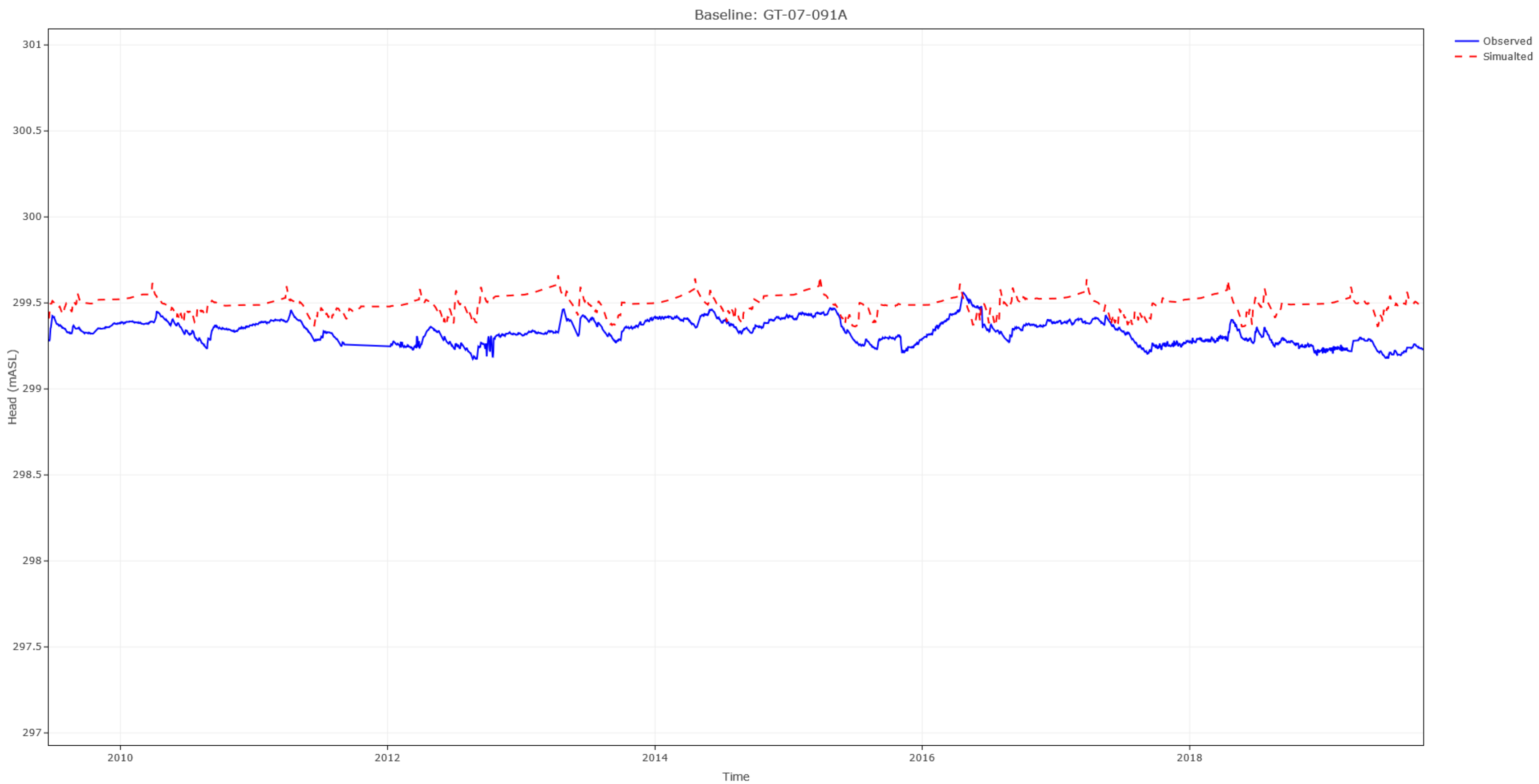
Baseline: GT-07-092B
Observed
Simualted
Head (mASL)
299
298.5
298
297.5
297
296.5
296
295.5
295
2010
2012
2014
2016
2018
Time


Baseline: GT-07-092A
Observed
Simualted
299
298.5
298
297.5
297
296.5
296
295.5
295
Head (mASL)
2010
2012
2014
2016
2018
Time


Baseline: GT-07-091C
Observed
Simualted
Head (mASL)
301
300.5
300
299.5
299
298.5
298
297.5
297
2010
2012
2014
2016
2018
Time

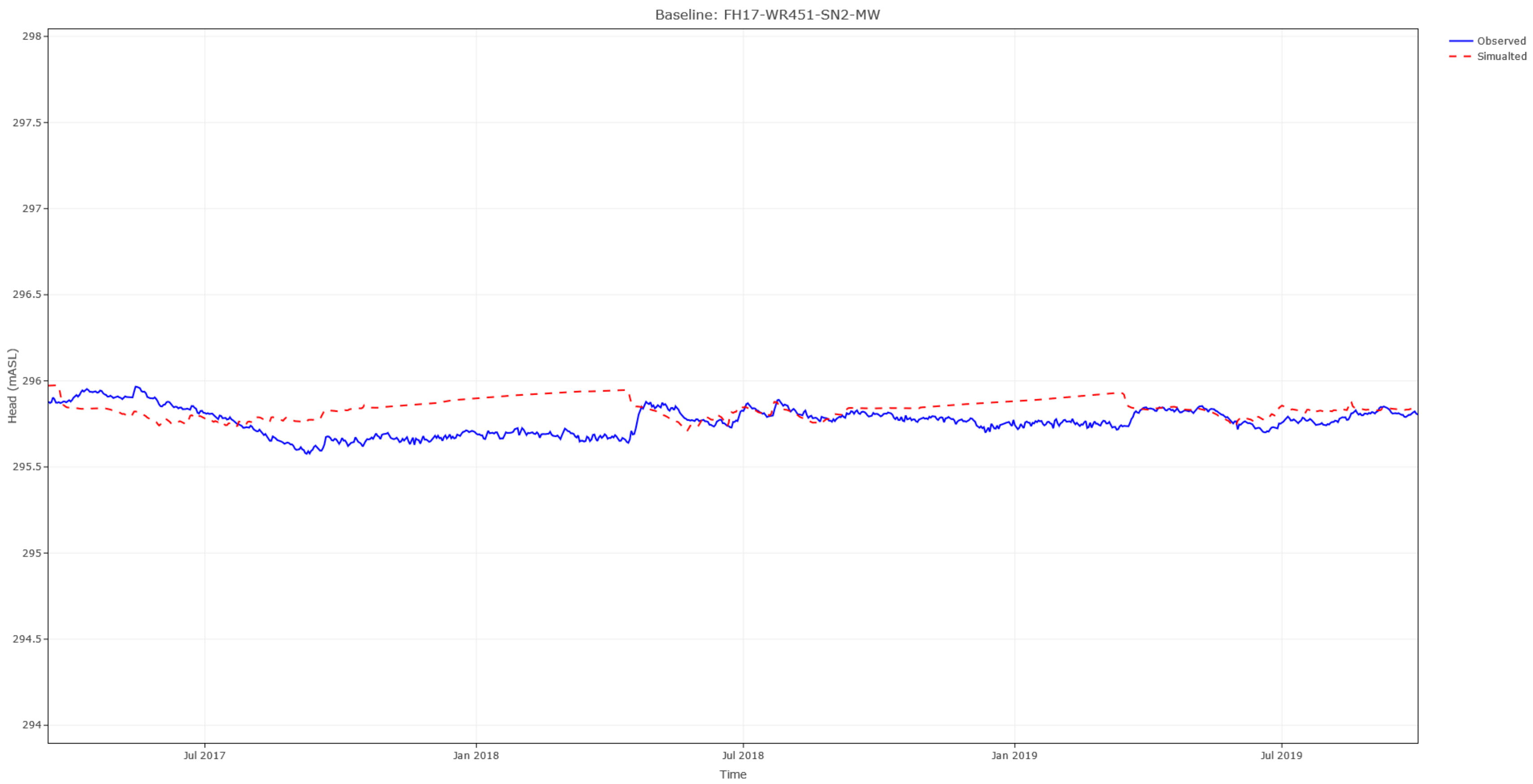


Baseline: GT-07-091B
Observed
Simualted
Head (mASL)
301
300.5
300
299.5
299
298.5
298
297.5
297
2010
2012
2014
2016
2018
Time


Baseline: GT-07-091A
Observed
Simualted
Head (mASL)
301
300.5
300
299.5
299
298.5
298
297.5
297
2010
2012
2014
2016
2018
Time


Baseline: GT-07-090B
Observed
Simualted
Head (mASL)
302
301.5
301
300.5
300
299.5
299
298.5
298
2010
2012
2014
2016
2018
Time

Baseline: GT-07-090A
Observed
Simualted
Head (mASL)
302
301.5
301
300.5
300
299.5
299
298.5
298
2010
2012
2014
2016
2018
Time



Baseline: FH17-WR451-SN2-MW
Observed
Simualted
Head (mASL)
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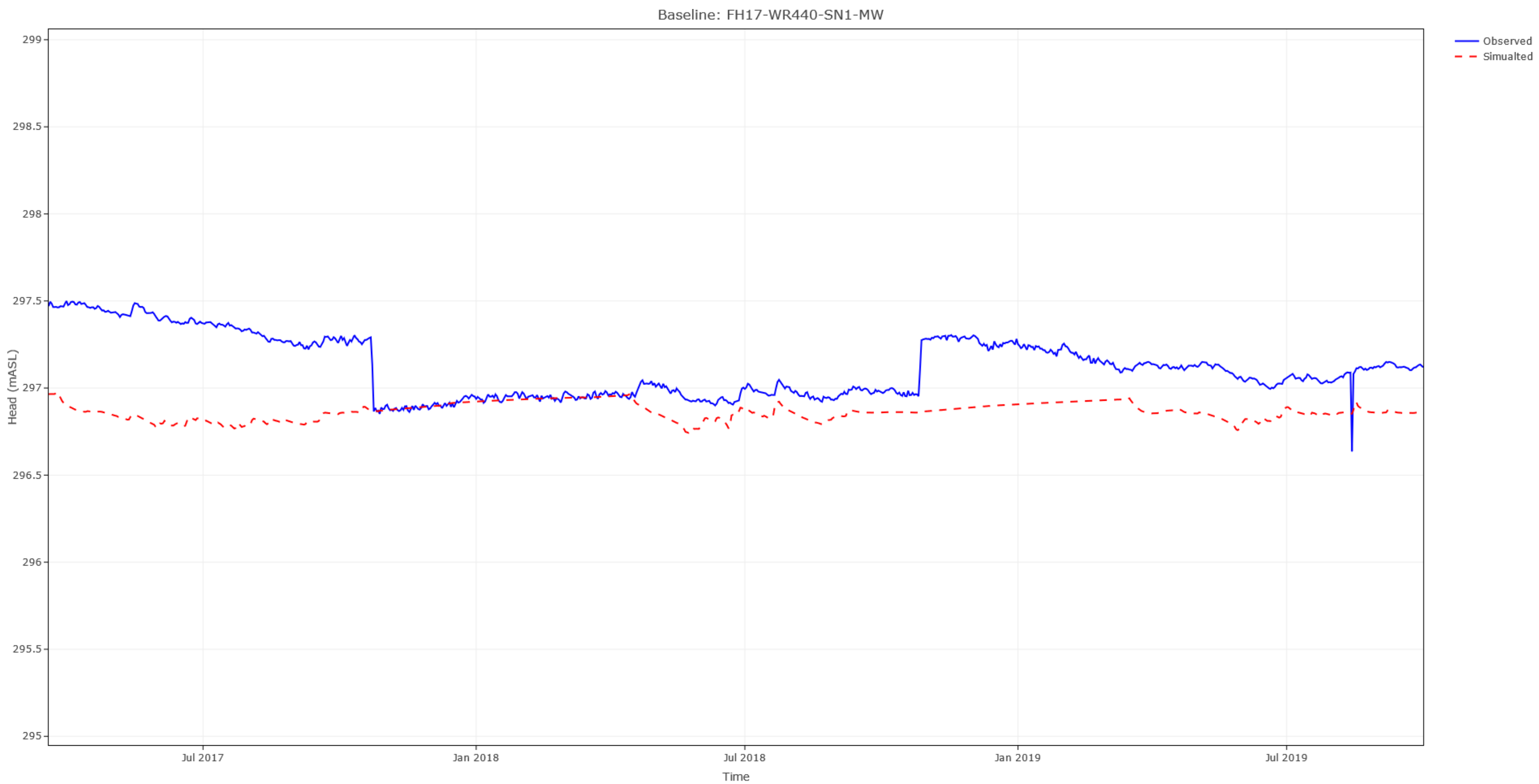
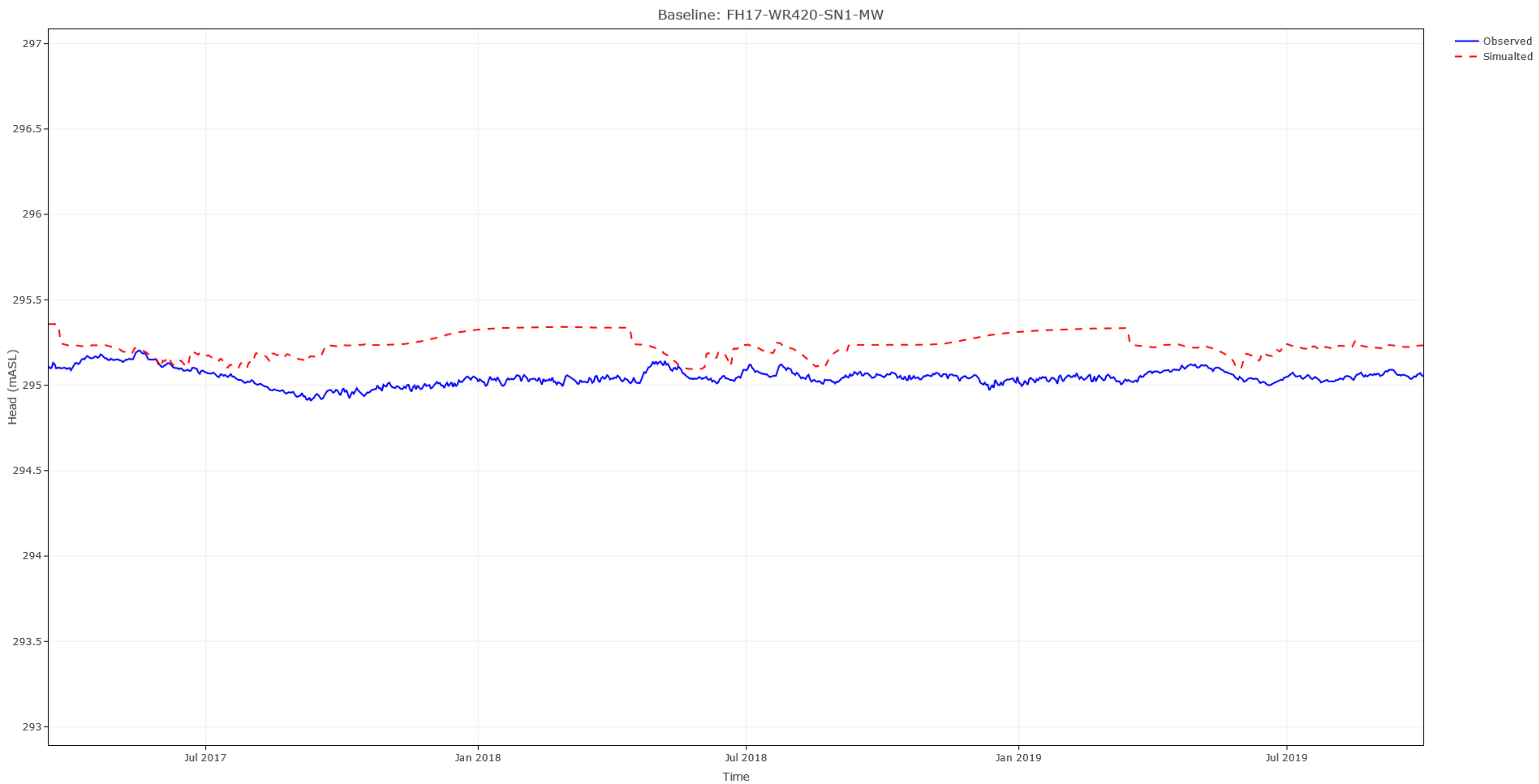
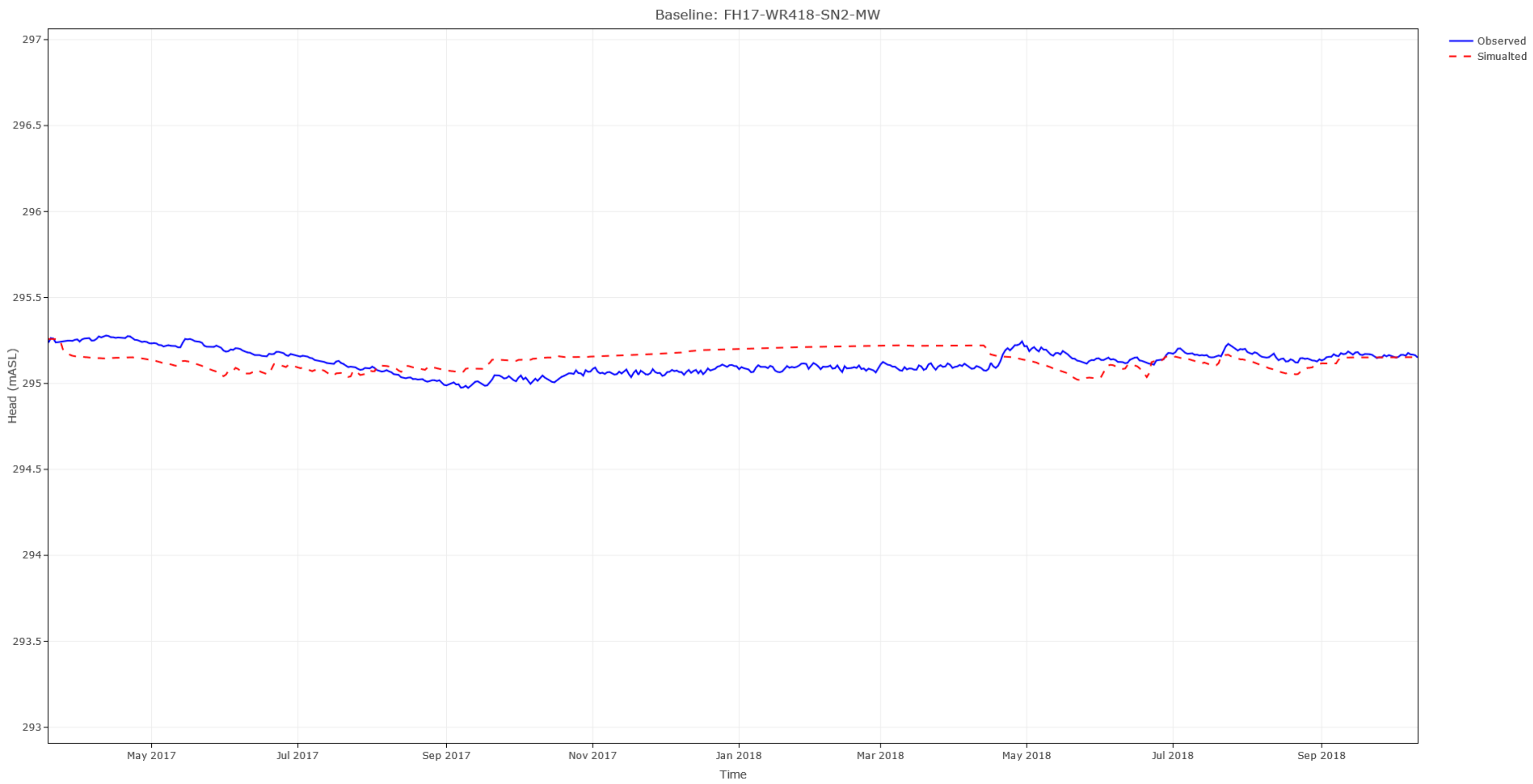
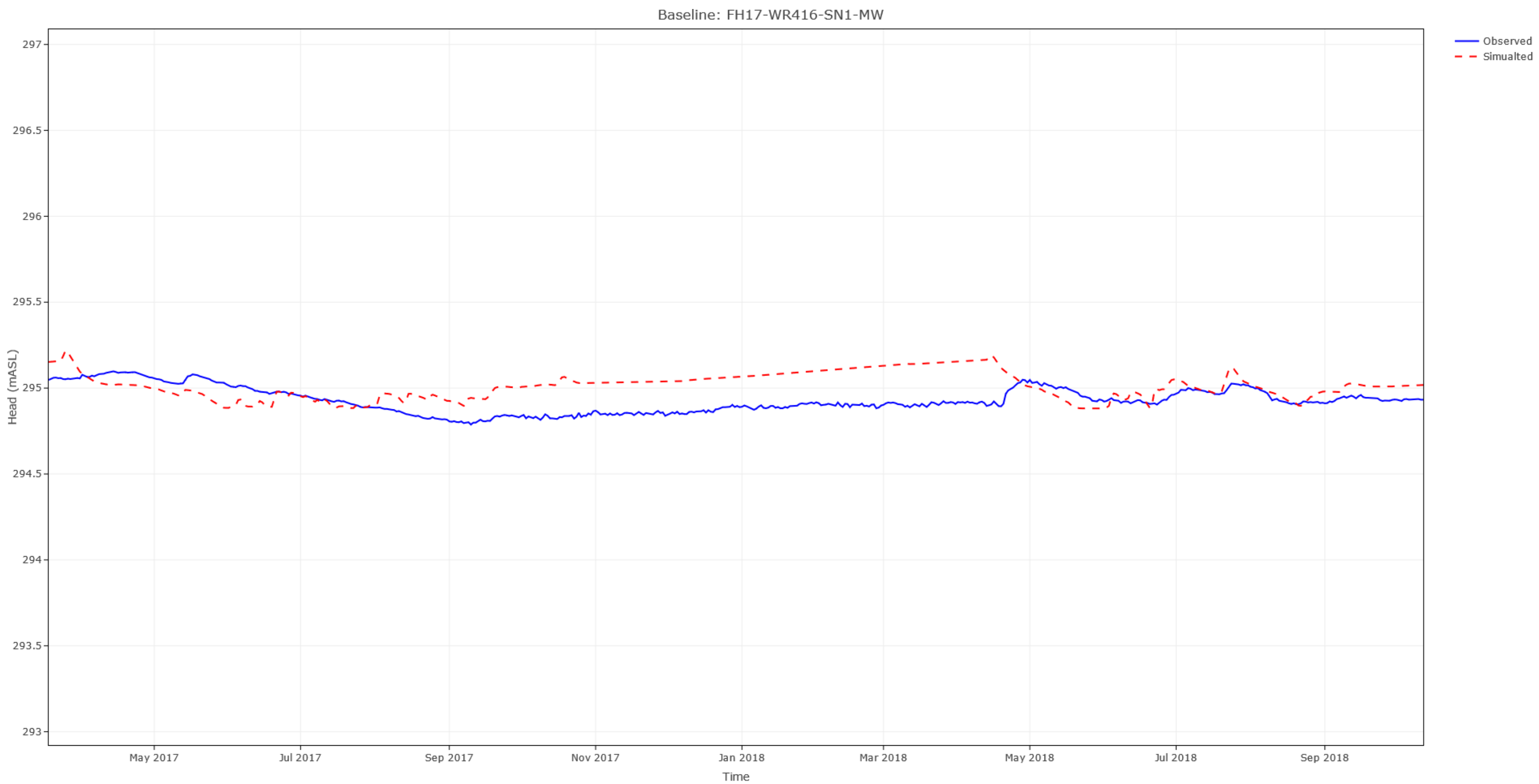
297.5
297
296.5
296
295.5
295
294.5
294
Jul 2017
Jan 2018
Jul 2018
Jan 2019
Jul 2019
Time

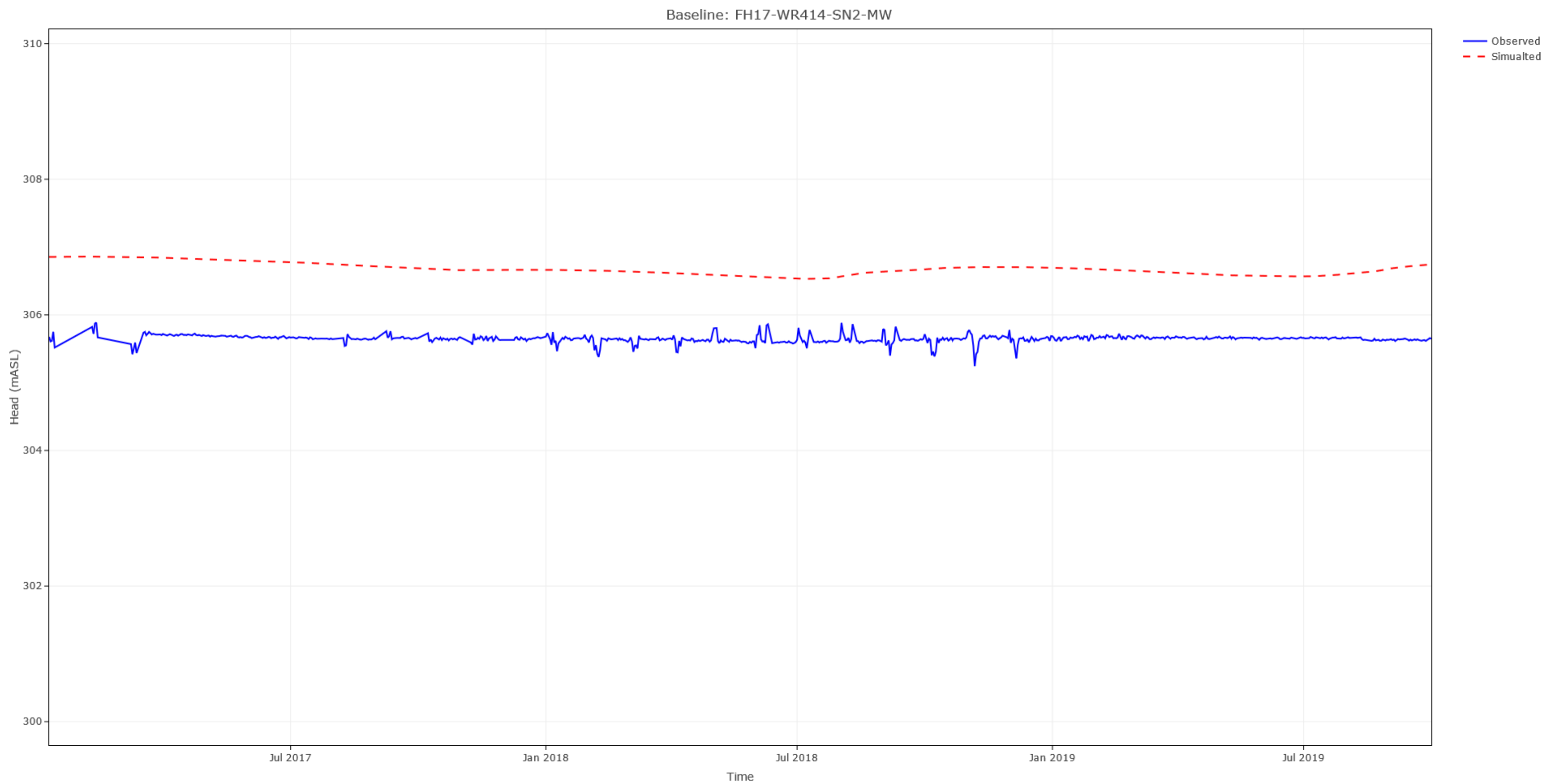

Baseline: FH17-WR440-SN1-MW
Observed
Simualted
Head (mASL)
299
298.5
298
297.5
297
296.5
296
295.5
295
Jul 2017
Jan 2018
Jul 2018
Jan 2019
Jul 2019
Time



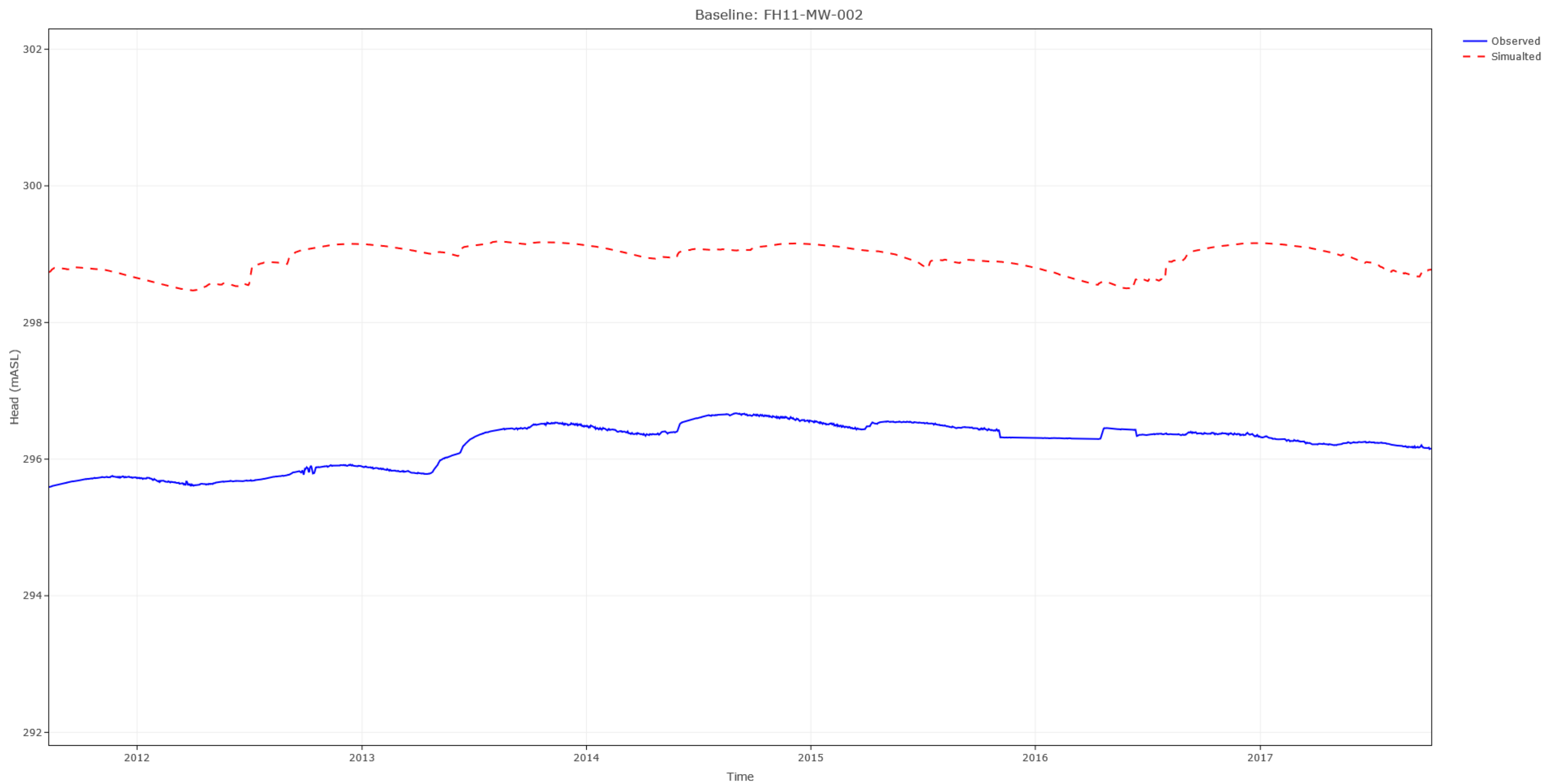
Baseline: FH17-WR420-SN1-MW
Observed
Simualted
Head (mASL)
297
296.5
296
295.5
295
294.5
294
293.5
293
Jul 2017
Jan 2018
Jul 2018
Jan 2019
Jul 2019
Time


Baseline: FH17-WR418-SN2-MW
Observed
Simualted
Head (mASL)
297
296.5
296
295.5
295
294.5
294
293.5
293
May 2017
Jul 2017
Sep 2017
Nov 2017
Jan 2018
Mar 2018
May 2018
Jul 2018
Sep 2018
Time

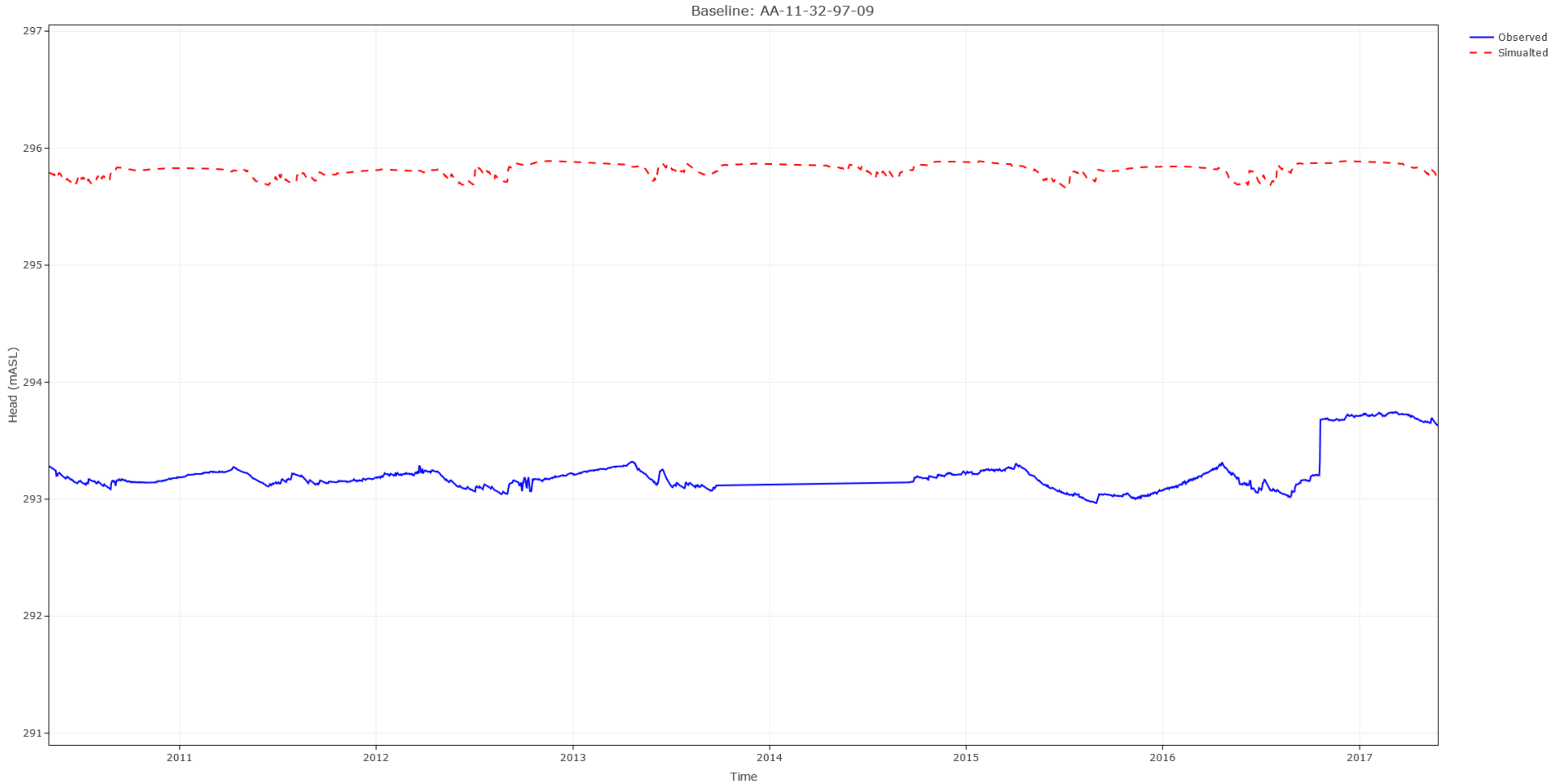

Baseline: FH17-WR416-SN1-MW
Observed
Simualted
297
296.5
296
295.5
295
294.5
294
293.5
293
Head (mASL)
May 2017
Jul 2017
Sep 2017
Nov 2017
Jan 2018
Mar 2018
May 2018
Jul 2018
Sep 2018
Time



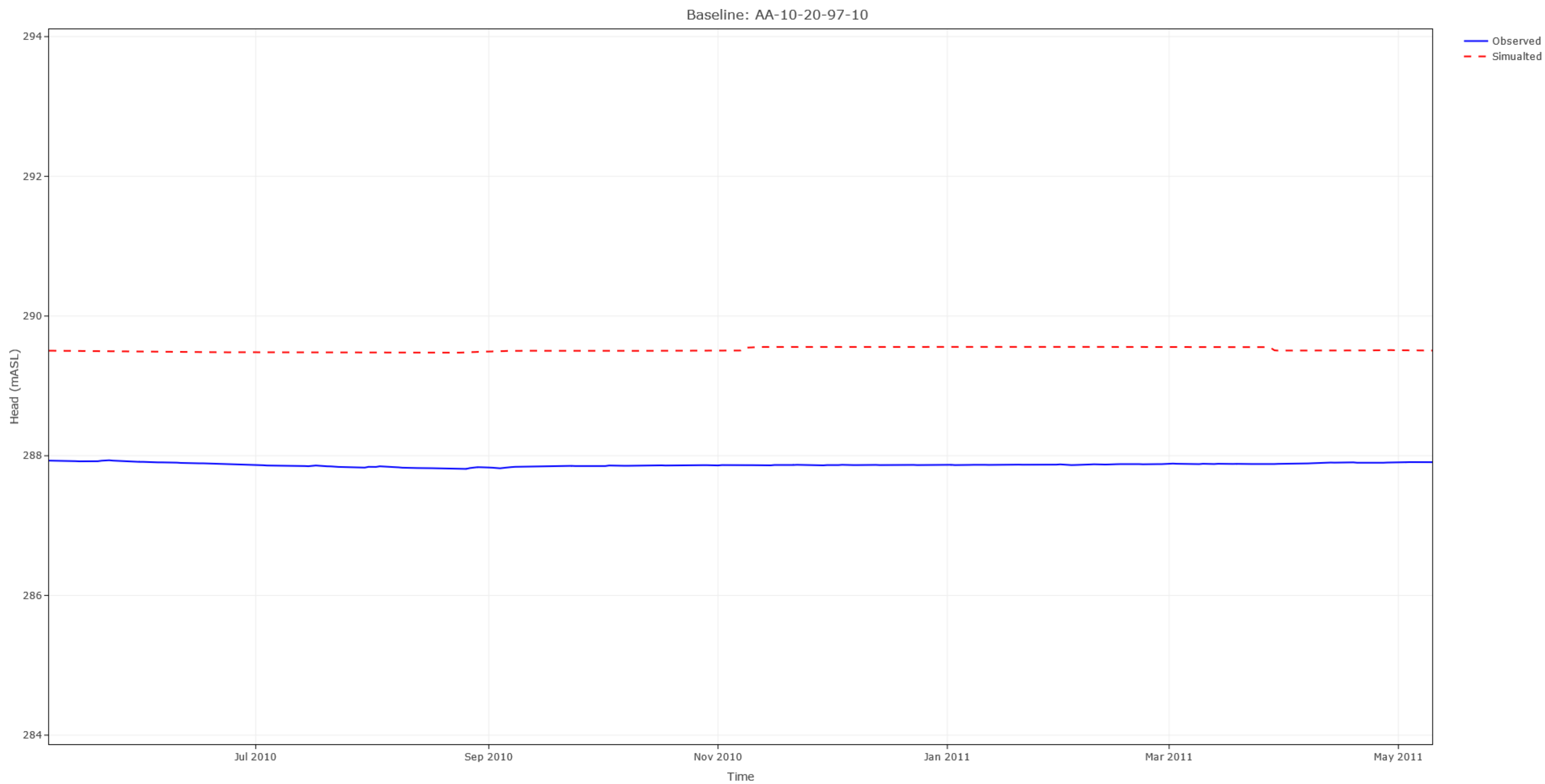
Baseline: FH17-WR414-SN2-MW
Observed
Simualted
Head (mASL)
310
308
306
304
302
300
Jul 2017
Jan 2018
Jul 2018
Jan 2019
Jul 2019
Time


Baseline: FH11-MW-002
Observed
Simualted
Head (mASL)
302
300
298
296
294
292
2012
2013
2014
2015
2016
2017
Time

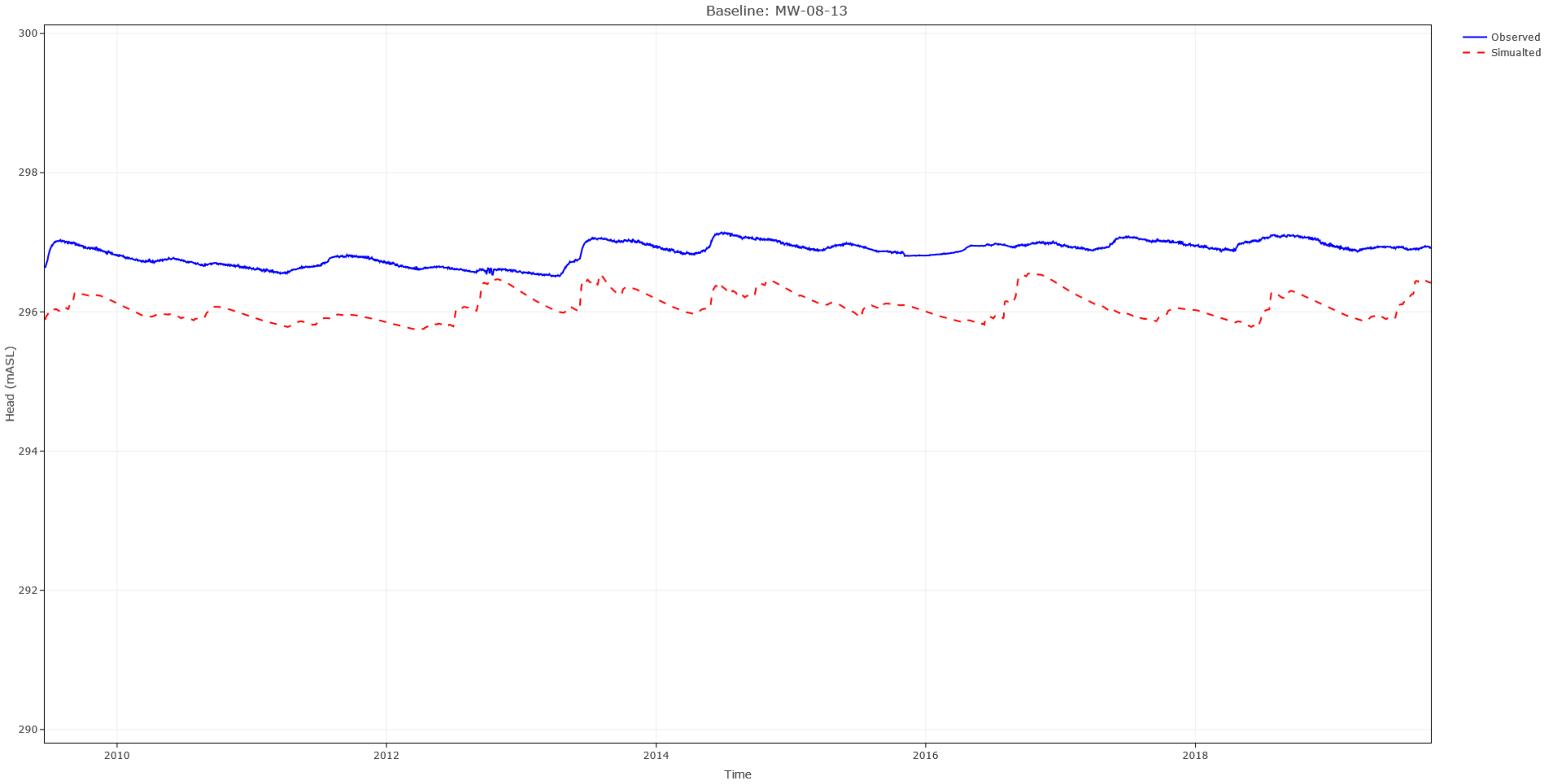
Baseline: FH11-MW-001
Head (mASL)
304
302
300
298
296
294
2012
2013
2014
2015
2016
Time
Observed
Simualted



Baseline: AA-11-32-97-09
Observed
Simualted
Head (mASL)
297
296
295
294
293
292
291
2011
2012
2013
2014
2015
2016
2017
Time



Baseline: AA-10-20-97-10
Observed
Simualted
Head (mASL)
294
292
290
288
286
284
Jul 2010
Sep 2010
Nov 2010
Jan 2011
Mar 2011
May 2011
Time

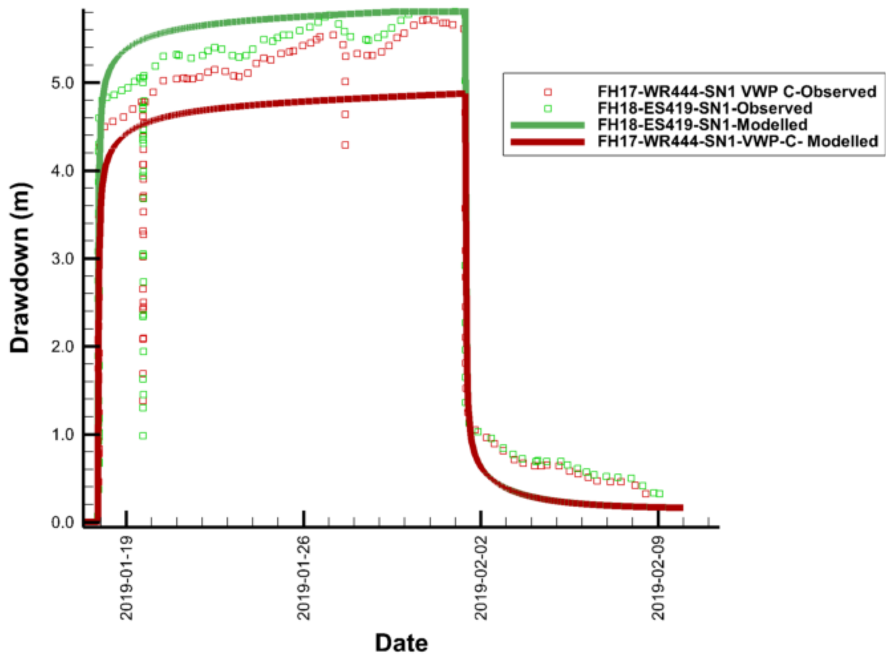


Baseline: MW-08-13
Observed
Simualted
300
298
296
294
292
290
Head (mASL)
2010
2012
2014
2016
2018
Time

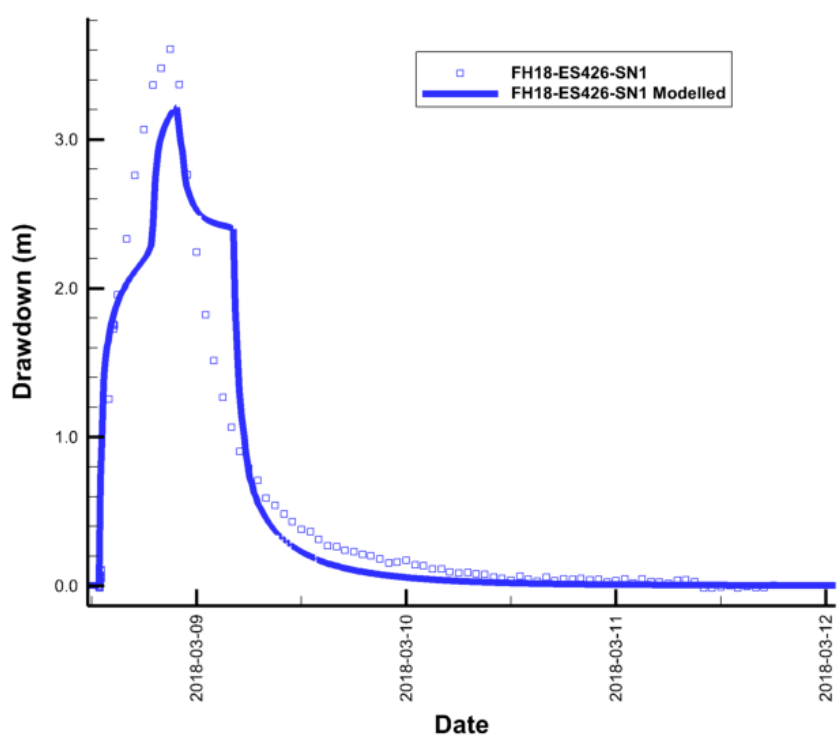
Attachment G

Simulated vs. Observed Drawdown in the Quaternary Aquifer Well Tests

Pumping well ID was FH18-ES419-DR1

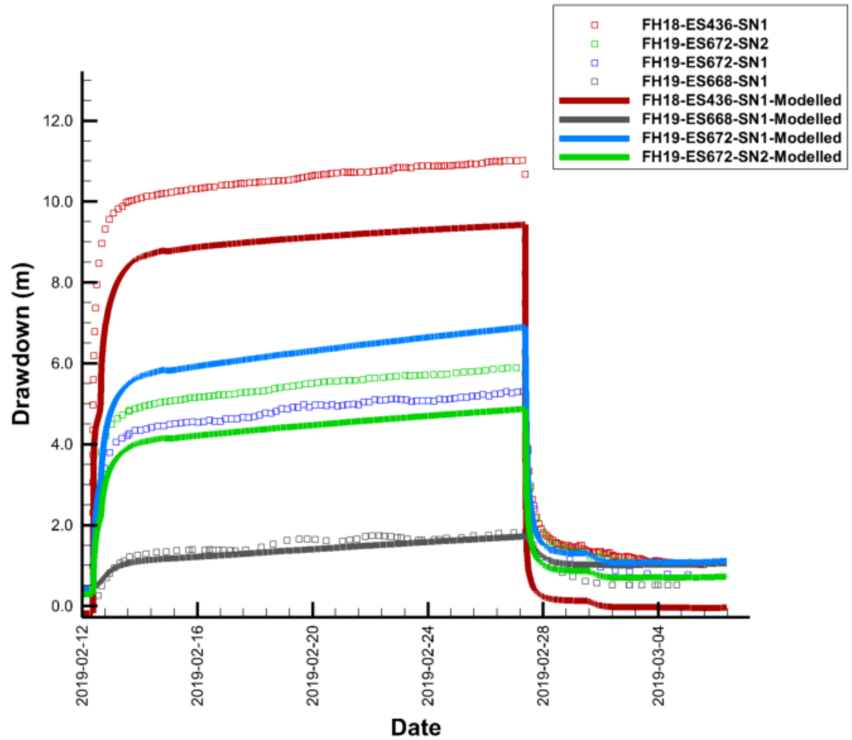


Pumping well ID was FH18-ES426-DR1

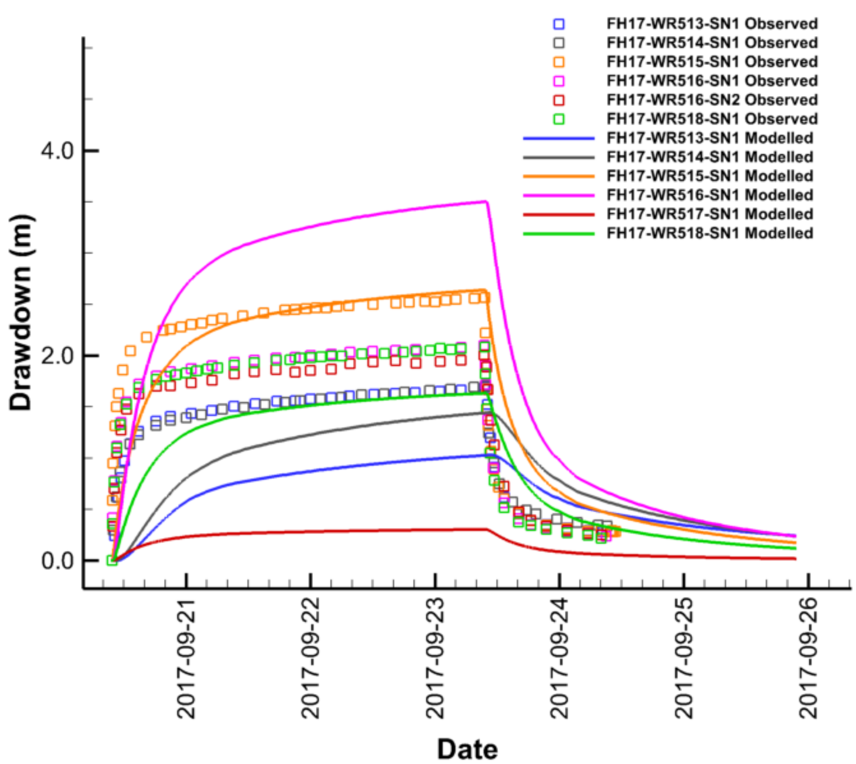


: Quaternary well testing transient calibration results

Pumping well ID was FH18-ES436-DR

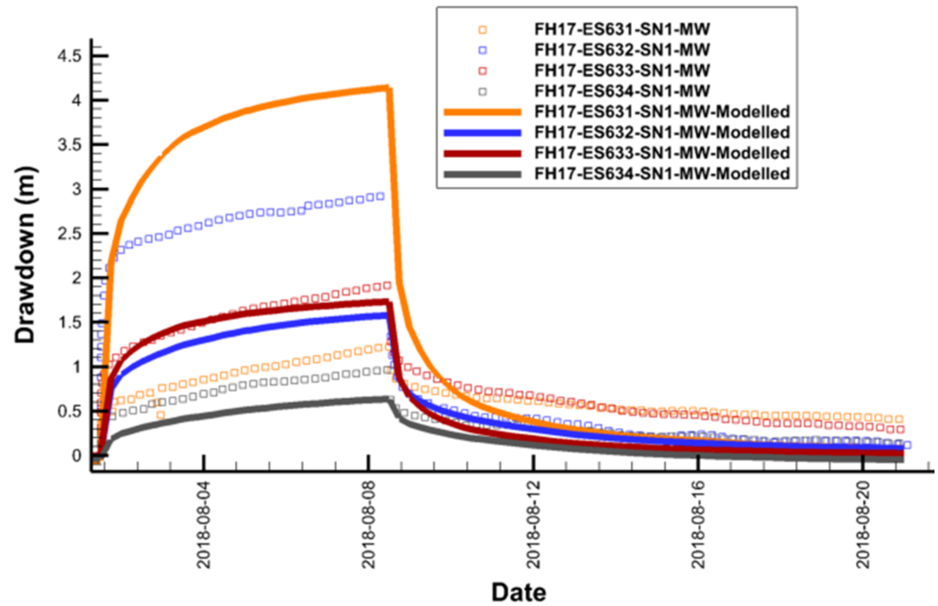


Pumping well ID was FH17-WR517-DR1

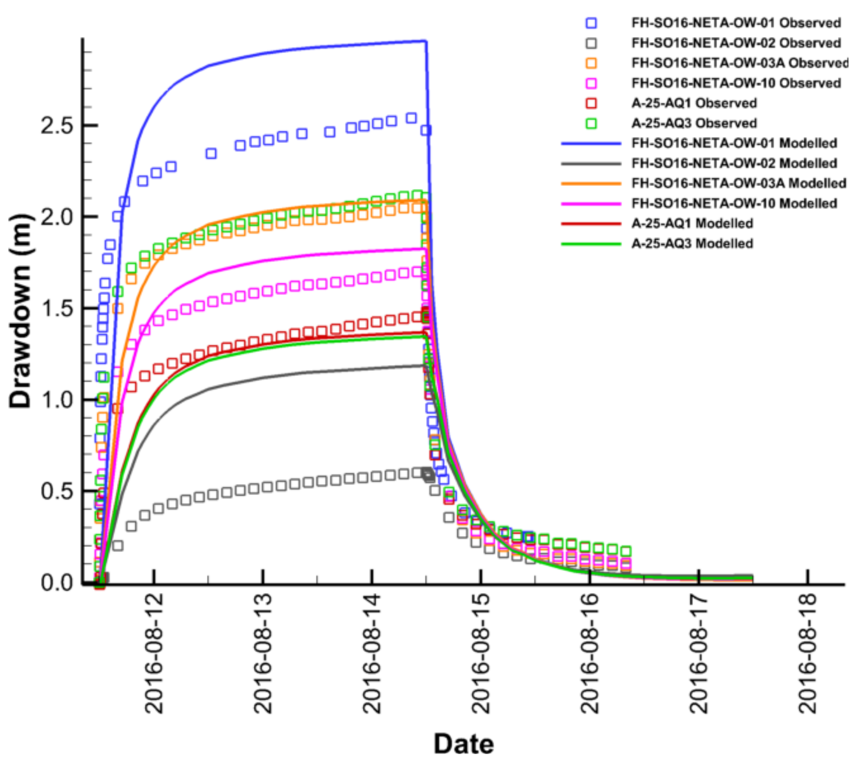


Quaternary well testing transient calibration results

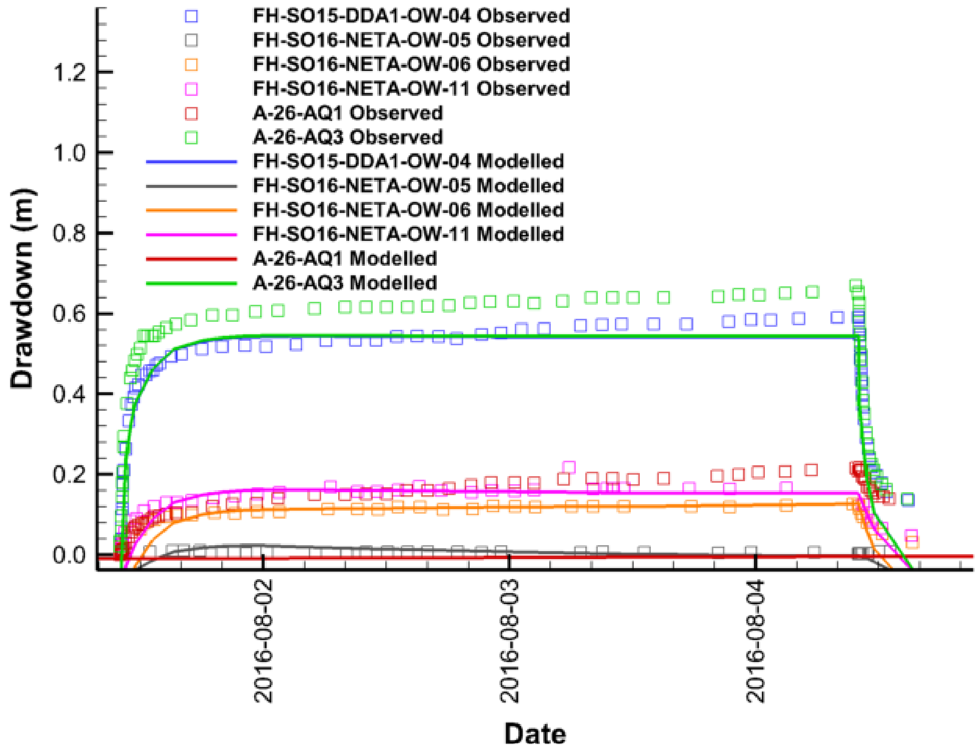
Pumping well IDs were FH18-ES631-DR1-PW, FH18-ES632-DR1-PW, FH18-ES633-DR1-PW, FH18-ES634-DR1-PW



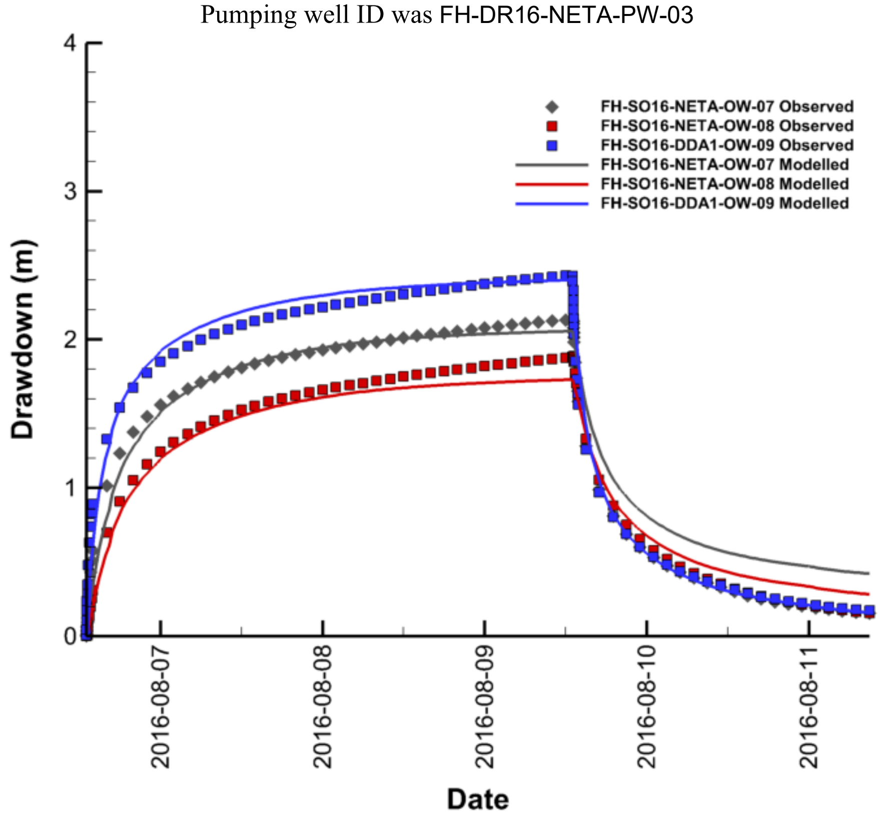
FH-DR16-NETA-PW-01



: Quaternary well testing transient calibration results

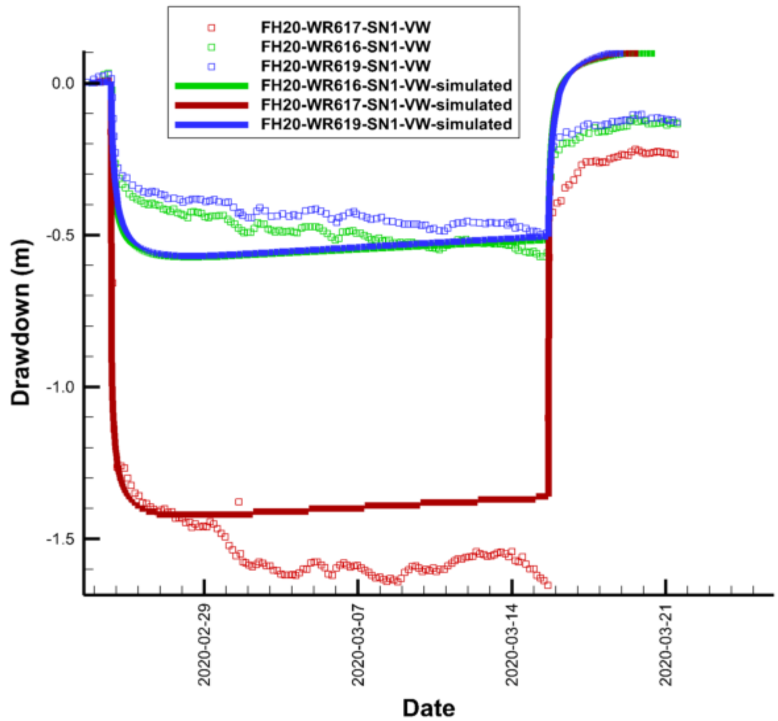


Pumping well ID was FH-DR16-NETA-PW-03

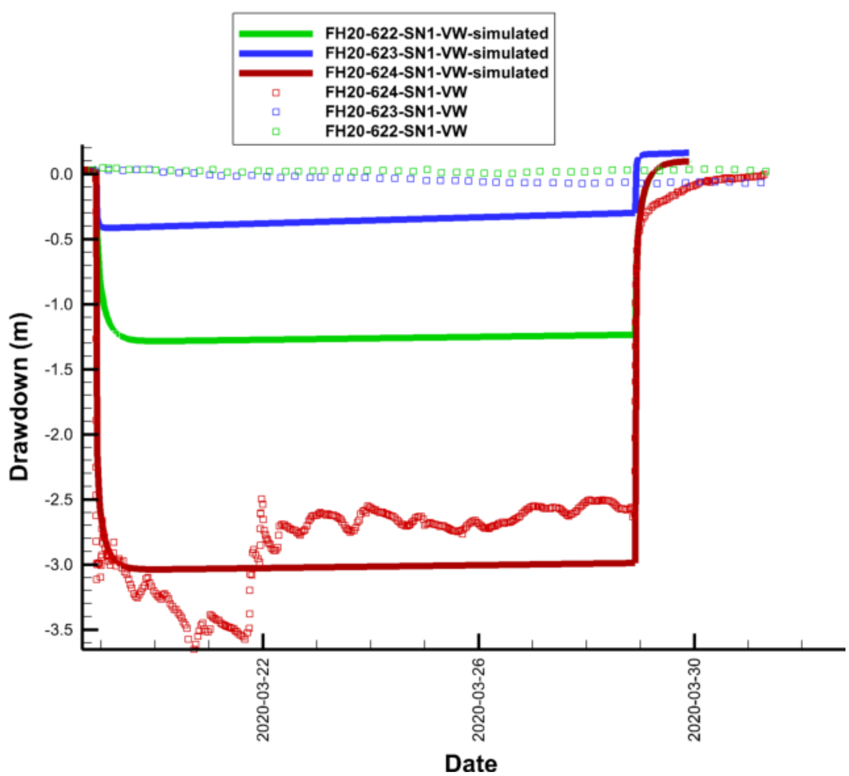


Quaternary well testing transient calibration results

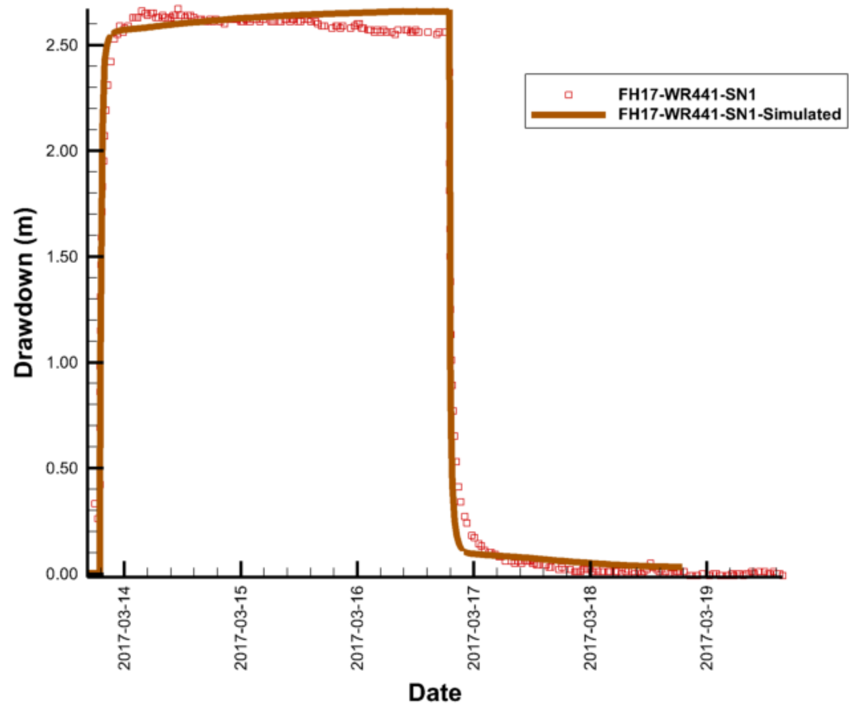
Injection well ID was FH20-WR617-DR1-PW



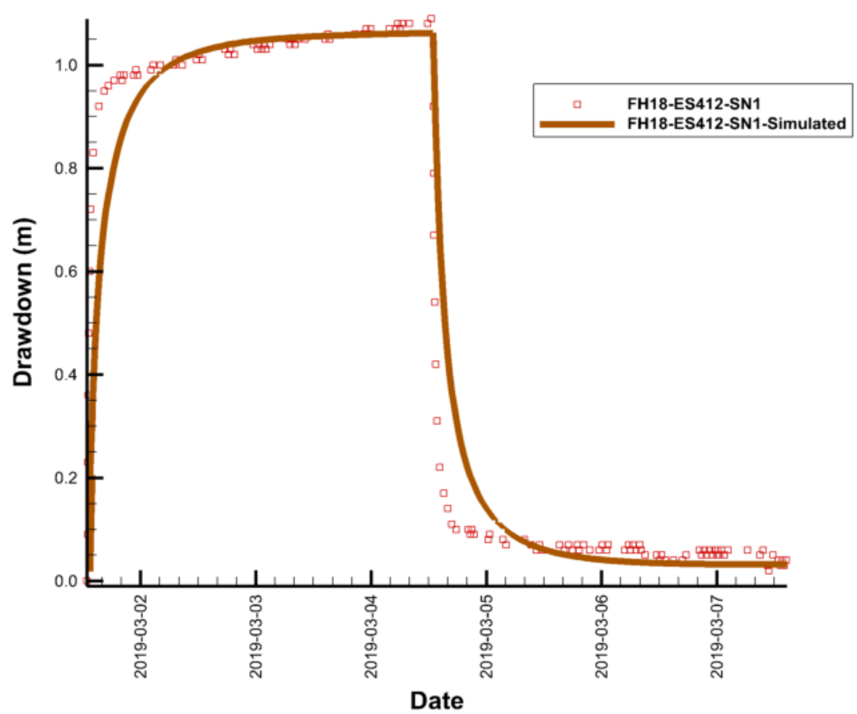
Injecting well ID was FH20-WR624-DR1-PW



Quaternary well testing transient calibration results

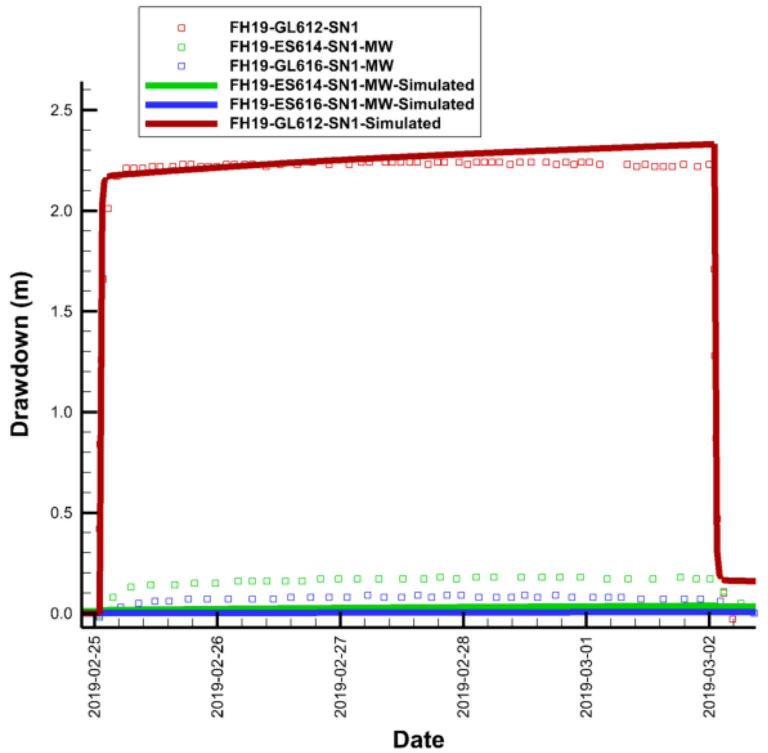


Pumping well ID was FH19-ES605-DR1-PW

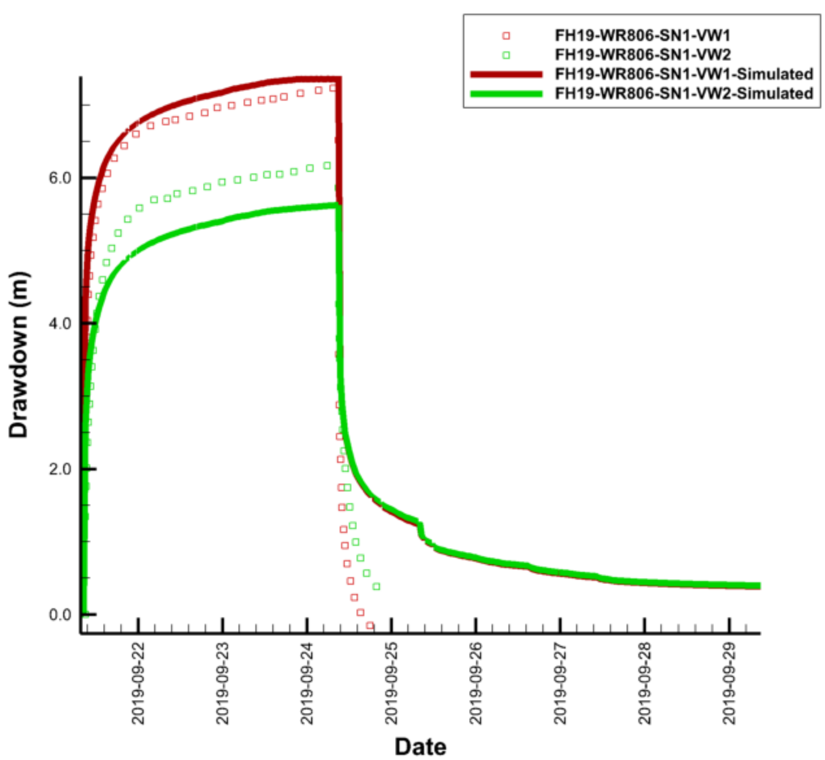


Quaternary well testing transient calibration results

Pumping well ID was FH19-ES612-DR1-PW

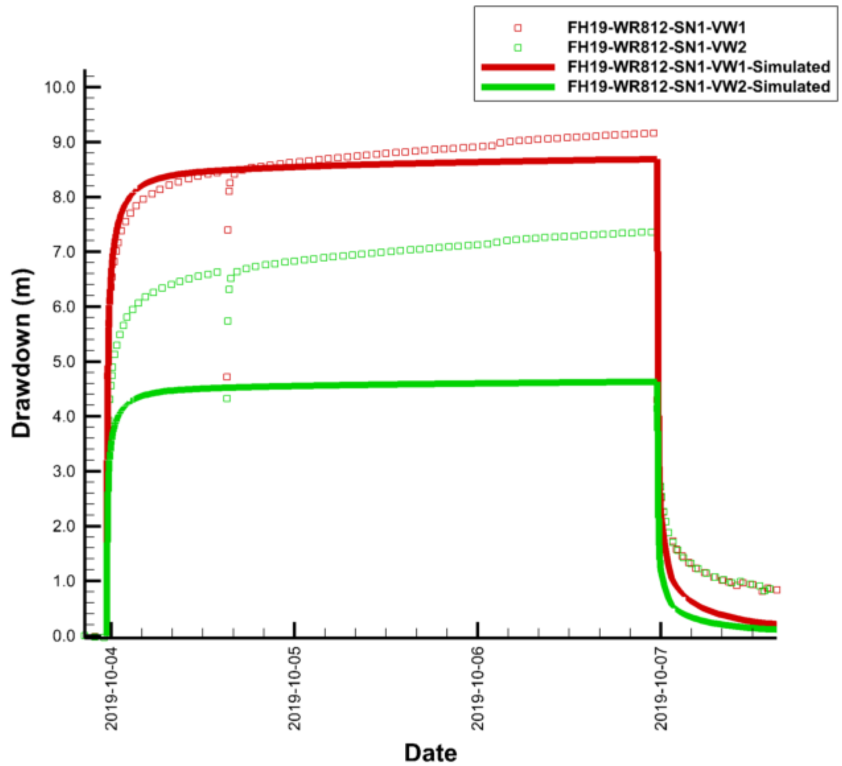


Pumping well ID was FH19-WR806-DR1-PW



Quaternary well testing transient calibration results

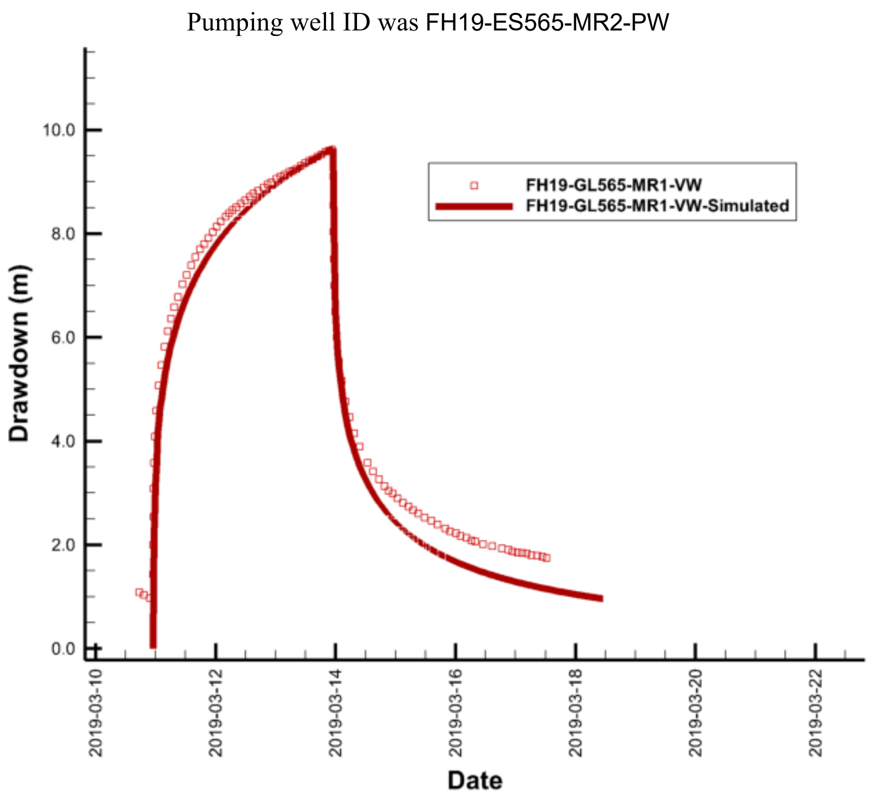
Pumping well ID was FH19-WR812-DR1-PW

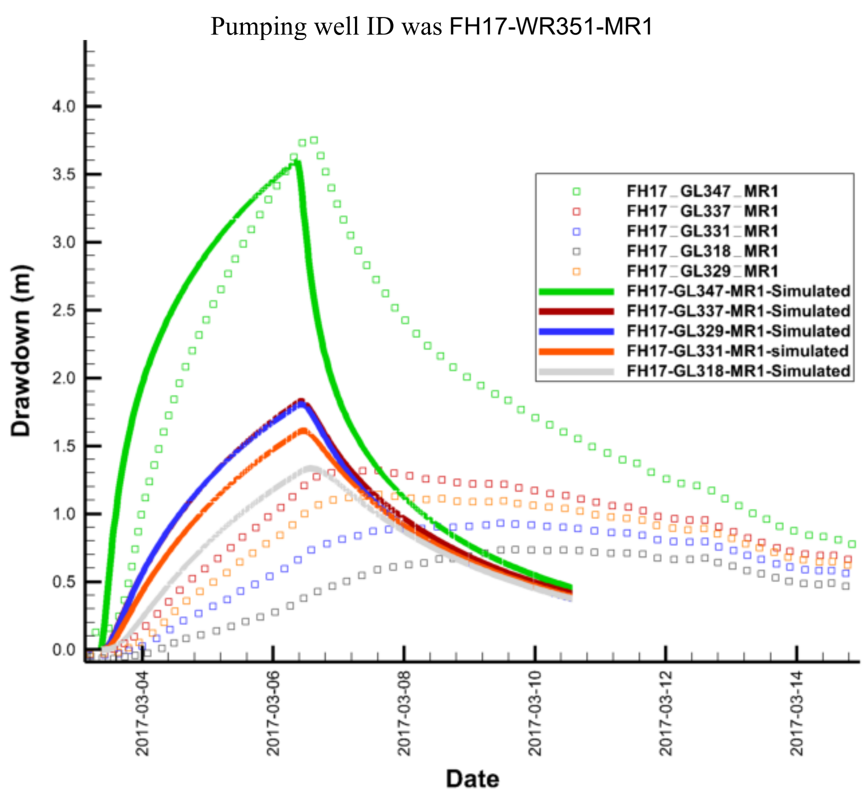


Quaternary well testing transient calibration results

Attachment H

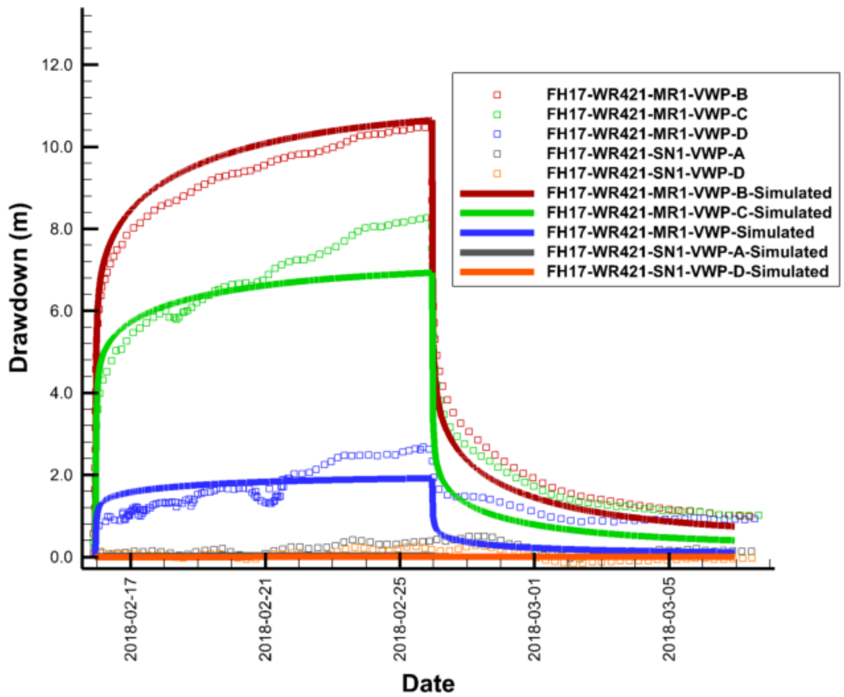
Simulated vs. Observed Drawdown in the Basal McMurray Aquifer Well Tests





Basal well testing transient calibration results.

Pumping well ID was FH17-WR421-MR2



Basal well testing transient calibration results.

Appendix E

Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed - Report

EVALUATION OF WATER CHEMISTRY FOR MCCLELLAND LAKE WETLAND COMPLEX MITIGATION SCENARIOS

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LIST OF DEFINITIONS

Acidic	Water chemistry with a relatively dilute signature is more acidic (lower pH). This is a result of hydrologic flowpaths via clean sandy substrates made of quartz, which is not very erodable and has higher hydraulic conductivity resulting in short contact time for dissolution processes to occur, and thus water chemistry signatures with similarities to precipitation (pH range 5 - 6).
Alkaline	Water chemistry with relatively higher concentrations of base cations is more alkaline (higher pH) due to lengthened contact times of hydrologic flowpaths with the high alkalinity silty sands and clays forming glacial till deposits.
Capillary Fringe	Saturated zone above the water table where water is affected by capillary forces.
Cryoconcentration	Increased concentration of water from the formation of ice where constituents are excluded from the ice mass, resulting in increased concentration in the remaining lake water.
Depression Storage	Depression storage refers to small low points in undulating terrain that can store water on the surface that otherwise would become runoff.
Detention Storage	Detention storage refers to water that is held at or near the ground surface until sufficient water storage is available for the detended water to move through the shallow subsurface towards the lake.
EFDC	Environmental Fluid Dynamic Code, a 3-dimensional surface water model.
Evapoconcentration	Concentration of constituents in the water due to evaporation decreasing the volume of water the constituents are dissolved in.
Groundwater	Groundwater is considered as shallow groundwater, at depths greater than 1 m below ground.
HRA	Hydrologic Response Areas - classified by geology, vegetation, topography, substrate (peat) thickness, and potential response to climate. HRA's distinguish areas of the watershed with different water storage and redistribution capacities, leading to differences in water-chemistry and eco-hydrology among different HRAs.
Humified	More decomposed organic material with lower hydraulic conductivity.
Infiltration-excess Overland Flow	When water enters a soil system faster then the soil can absorb or move it, such as when precipitation exceeds the infiltration capacity of the soil, or infiltrating precipitation reaches a substrate with lower hydraulic conductivity and generates interflow.
MLWC	The McClelland Lake Wetland Complex, including the Fen and McClelland Lake
MLWC watershed	The McClelland Lake Wetland Complex, including the Fen, McClelland Lake and upland portions of the watershed such as the North Outwash Plains and Fort Hills Upland Complex.
Minerogenic	Minerogenic means water sourced from mineral substrates. As the hydrologic pathways in silty sands and clays forming glacial till deposits are lengthened with greater opportunity for accumulation of solutes, the water chemistry is considered minerogenic.

Near-surface Water	Near-surface water is considered as shallow subsurface flow at depths ranging from 0 to 1 m below ground and includes stagnated water in surface depressions that presents up to 30 cm above the ground surface.
Ombrogenic	Ombrogenic means water sourced from precipitation. As the hydrologic pathways in sandy substrates are relatively short with little opportunity for dissolution processes to occur, water chemistry signatures in sandy substrates are conceptualized to be more similar to precipitation, and thus more ombrogenic in nature.
Return Flow	Where the rate of inflow entering a saturated area from upslope exceeds the capacity for interflow to leave the area by continuing to flow down-hill through the shallow subsurface and excess interflow returns to the surface as runoff.
Saturation Overland Flow	When the soil becomes saturated, and any additional precipitation causes runoff.
Surface Water	Surface water is considered as flow above the ground surface which has not stagnated and is fresh from recent snow-melt or precipitation.
Water Chemistry	Water chemistry parameters include base cations (Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^{+}) & Sodium (Na^{+})) and Total Dissolved Solids (TDS).
Wetland Water	Wetland water is considered as near-surface (shallow subsurface) flow at depths ranging from 0 to 1 m below ground within the MLWC and includes stagnated water in surface depressions that presents up to 30 cm above the ground surface. It does not include surface water in the MLWC.

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AMENDMENT RECORD

This report has been issued and amended as follows:

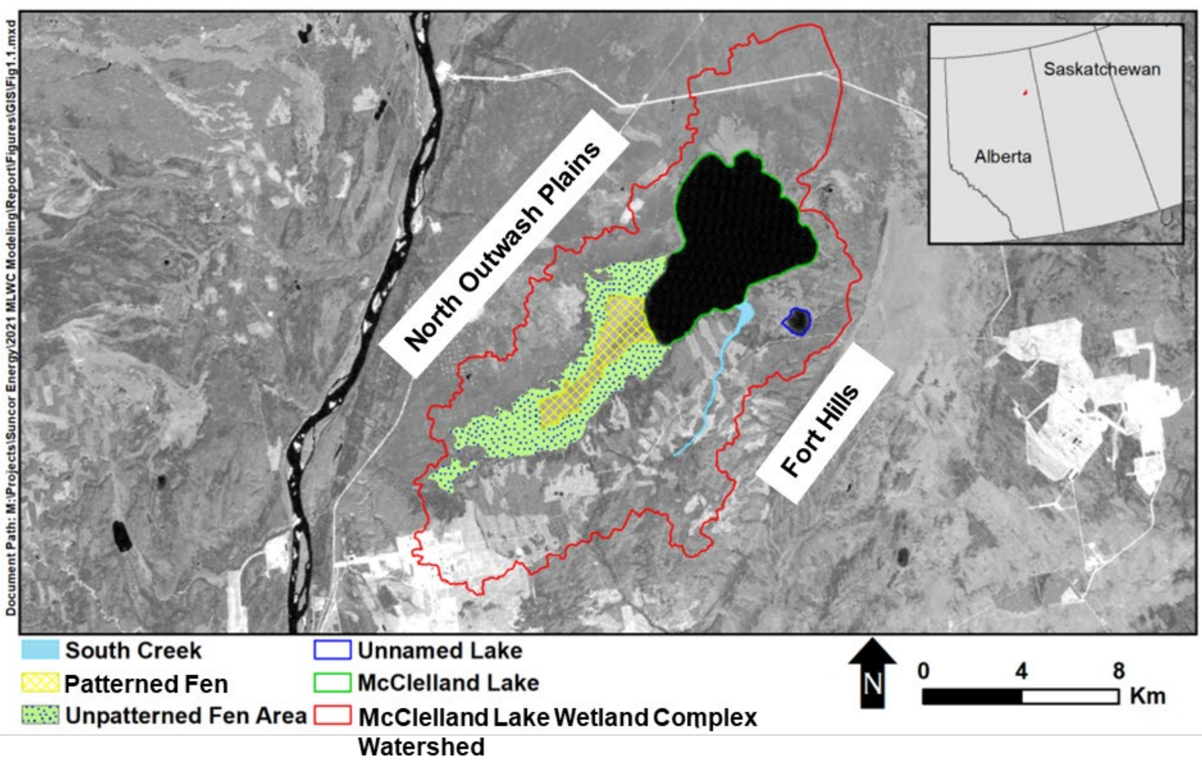
Issue	Description	Date	Approved by	
1	First draft of Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed	20211119	Steven Guenther Project Director	Steven Guenther Project Manager
2	Second draft of Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed	20211125	Steven Guenther Project Director	Steven Guenther Project Manager
3	Third draft of Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed	20211210	Steven Guenther Project Director	Steven Guenther Project Manager
4	Fourth version of Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed	20211213	Steven Guenther Project Director	Steven Guenther Project Manager
5	Fifth version of Evaluation of Water Management and Wetland Mitigation Scenarios for the McClelland Lake Wetland Complex Watershed	20211214	Steven Guenther Project Director	Steven Guenther Project Manager

1.0 INTRODUCTION

This report by Hatfield Consultants LLP (Hatfield) provides a summary of the Environmental Fluid Dynamics Code (EFDC+) surface water and water chemistry modelling of the McClelland Lake Wetland Complex (MLWC) watershed to evaluate the water management strategy associated with mining in the MLWC watershed.

The conceptual and numerical modelling described in this report is intended to provide water chemistry results of the MLWC watershed using a primarily surface water and conservative constituent (non reactive) transport approach. For the purposes of this report, water chemistry parameters include base cations (Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Potassium (K^+) & Sodium (Na^+)) and Total Dissolved Solids (TDS). Understanding gained from this work will be incorporated into future initiatives to further refine modelling efforts that better represent the MLWC watershed as a system and its complexities. This work builds on existing hydrologic understanding of the MLWC watershed and incorporates non-reactive (conservative) constituents to characterize the hydrologic flow paths. Building an understanding of the hydrological processes within the MLWC watershed that are characterized appropriately within modelling efforts is required as a basis for future complexities to be incorporated. Future work is intended to incorporate further refinement of wetland water chemistry constituents, reactive transport modelling of constituents, and inclusion of nutrient cycling within the MLWC watershed.

Figure 1.1 General location of McClelland Lake Wetland Complex (MLWC) watershed in Northern Alberta, approximately 90 km north of Fort McMurray.



The purpose of the EFDC modelling is to determine the potential impacts of continued development of the Fort Hills Project on the water chemistry of the non-mined portion of the MLWC watershed (Figure 1.2). Fort Hills is proposing to build water management design features to maintain ecosystem diversity and function of the non-mined portions of the MLWC watershed during continued development of the Project. These features will manage and control future changes to the water quantity and chemistry in the non-mined portion of the MLWC watershed during the operational and reclamation periods, as well as post-closure.

The proposed MLWC watershed design features include operational water management and closure drainage facilities. The operational phase features include:

- Surface and groundwater water resupply systems and associated infrastructure to maintain flows with suitable water chemistry; and
- A cutoff wall and associated working pad to hydrologically isolate the active mining areas from the non-mined portion of the MLWC watershed.

The EFDC+ model has been developed to support evaluation of the effects of mining in the MLWC watershed on the non-mined portion of the fen, and the effects of proposed mitigation measures.

1.1 PREVIOUS WORK (SUPPORTING STUDIES)

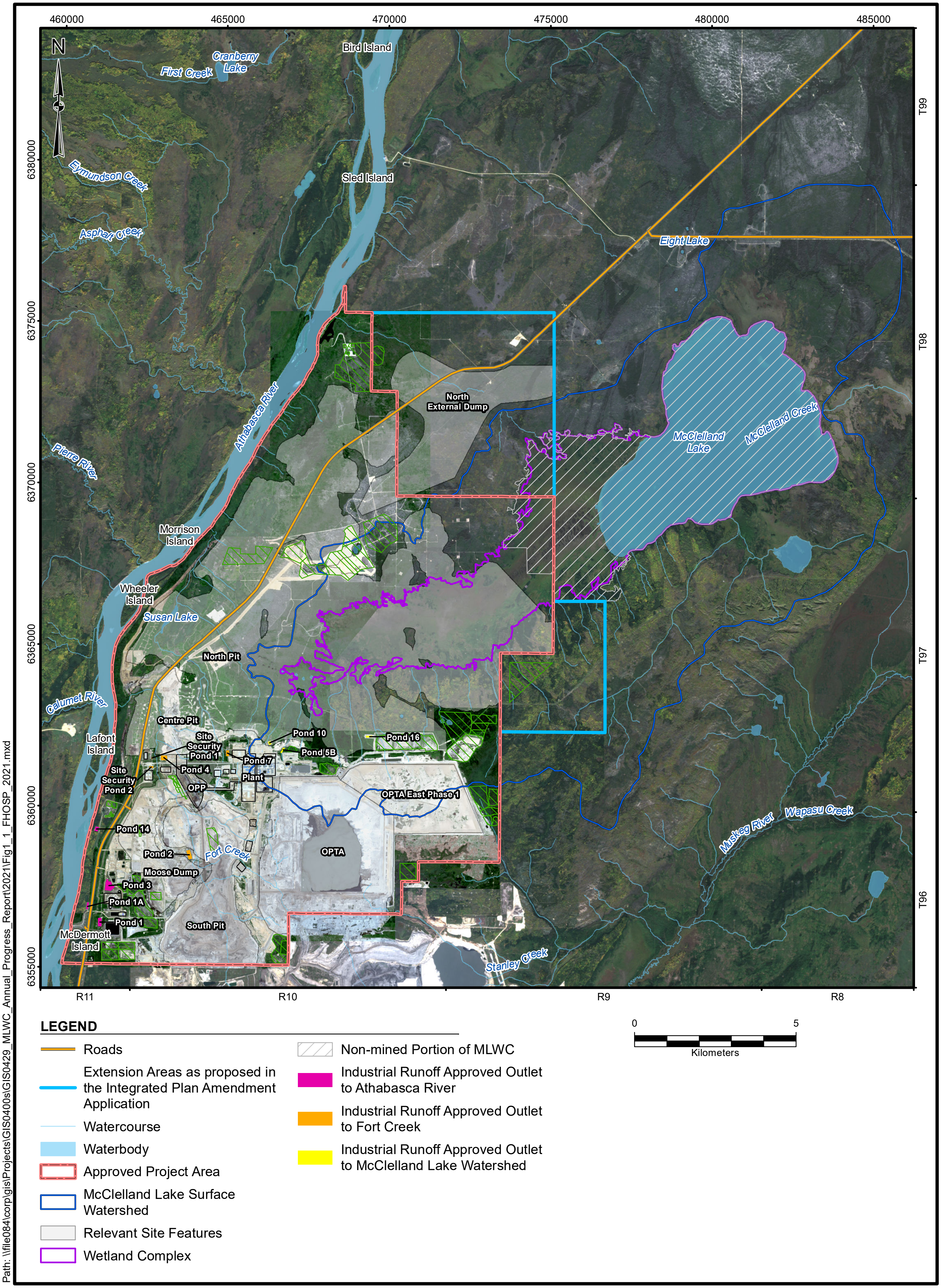
The EFDC+ modelling builds on several MLWC watershed focused supporting studies. The Hydrogeosphere (HGS) model used was developed by Aquanty and is detailed in the McClelland Lake Wetland Complex Operational Plan (OP) Appendices. Furthermore, Objective 1 of the OP presents previous work documenting the natural historic variability of hydrological and biogeochemical conditions at the MLWC watershed, while Objective 4 of the OP discusses water resupply options for the fen.

1.2 REPORT ORGANIZATION

This report is organized as follows:

- Section 2.0: describes the conceptual understanding of the physical and other controls on surface water chemistry at the MLWC, which required context for interpreting EFDC+ model outputs.
- Section 3.0: describes the EFDC+ model construction, including key data sources and associated model inputs, as well as model assumptions and limitations.
- Section 4.0: describes the EFDC+ model simulation results regarding the proposed Suncor Fort Hills mining activities and water management strategy, including an evaluation of whether it is capable of maintaining existing hydrology and water chemistry conditions of the MLWC watershed under operational and closure conditions.

Figure 1.2 Fort Hills mine layout and non-mined portion of MLWC.



2.0 CONCEPTUAL MODEL AND DATA

To address the EFDC+ modelling objectives, a conceptual understanding of the physical and other controls on surface water chemistry at the MLWC is required to compare and provide context for interpreting model outputs. Details of the conceptual model for understanding the controls on water chemistry at the MLWC are presented in the following sections.

2.1 STUDY AREA

This section is a summary of the study area and a more in-depth description can be found in Objective 1 of the OP. The MLWC watershed covers an area of approximately 200 km^2, and is located 90 km north of Fort McMurray, Alberta (Figure 1.1). The region has a sub-humid climate, typical of the Western Boreal Forest, where potential evapotranspiration is often equal to or greater than precipitation.

The MLWC watershed is generally perched above the surrounding landscape, surrounded by low-lying areas. The Athabasca River lies to the West, the Firebag River to the northeast and the Muskeg River to the south of the MLWC watershed. Watershed elevations range from approximately 295 to 350 meters above sea level (masl). Higher elevations are predominantly in the southwestern Fort Hills Upland Complex portion (Figure 1.1), sloping down to the northeast, with the low point in the watershed occurring in the central area flowing towards McClelland Lake in the northeastern portion. Lower elevations in the north and northeast portion of the watershed are comprised of the North Outwash Plains and slope down towards the south and southeast portions of the watershed.

The Fort Hills Upland Complex and North Outwash Plains are predominantly forested upland areas, with wetlands, such as swamps, at the base of hillslopes. In the central to central-eastern portion of the watershed there is a non-patterned fen and patterned fen that connect to McClelland Lake in the eastern portion of the watershed. The non-patterned and patterned fen are peat-forming wetlands. The patterned fen occurs where alternating ridges of peat (strings) and depression areas, sometimes with shallow pools (flarks), have formed perpendicular to the surface water flow path. The relatively drier strings support trees, shrubs, and other types of wetland vegetation. However, the flarks have a water table near the surface and typically only support wetland vegetation. Soils are predominately peat and organics in low-lying areas (27% of total area), moderately permeable Firebag soils to the south along the mid-elevations (21% of total area), and permeable Mildred soils to the north and south bordering the edge of the watershed (34% of total area; soil characterization based on data collected by Paragon in 2016 and mapped by Hatfield in 2018). Based on the 2019 hydrogeology drilling program, peat thickness in the MLWC (where it occurs), ranges up to 7 metres with an average of about 2 to 3 metres.

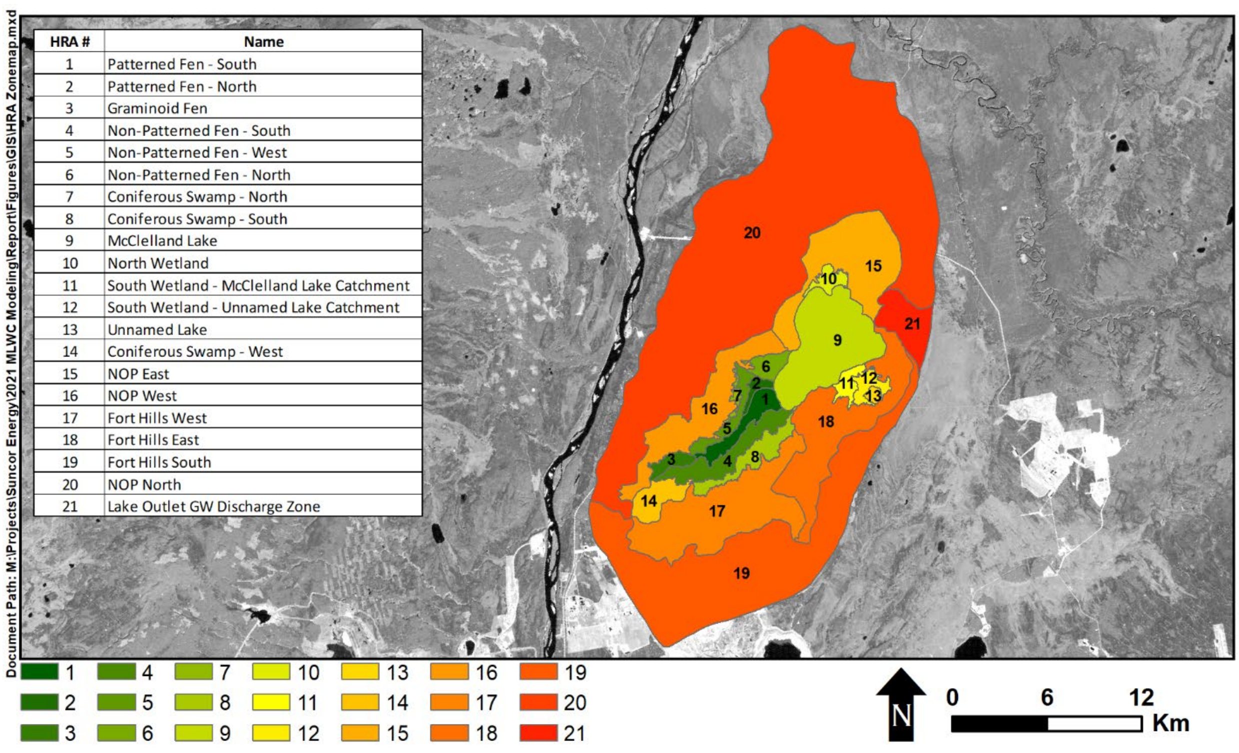
McClelland Lake, located east of the Fort Hills Lease, is approximately 30 km^2 in size and has an average depth of approximately 2.2 m, with a maximum depth of 5.9 meters. Over two thirds of McClelland Lake has depths of 2 m or less and thus in a wetland classification would be considered a shallow open water wetland, which is important for understanding that this water body will have characteristics of both shallow open water wetlands and lakes. A geophysical survey conducted in 2017 found that the eastern portion of the lake is characterized by coarse material that grades into a possible channel to the south-west. Finer-grained material characterizes the central-north portion of McClelland Lake. The geophysical survey also revealed that the deepest portions of the lake are located on the eastern and south-eastern sides of the lake.

The MLWC watershed is characterized by thick heterogeneous glacial substrates from the Quaternary period overlying Cretaceous marine deposits including the Clearwater and McMurray bedrock formations. The surficial geology comprises coarse-textured glaciofluvial deposits in the north and northeast regions of the watershed (associated with the North Outwash Plains) and fine-textured glacial till deposits towards the southwestern portion of the watershed (associated with the Fort Hills Upland Complex region).

2.2 HYDROLOGIC RESPONSE AREAS

The watershed was classified into 21 distinct hydrologic response areas (HRAs) based on factors including geology, vegetation, topography, substrate (peat) thickness, and potential response to climate (Figure 2.1; Appendix D of the OP). These HRA's distinguish areas of the watershed with different water storage and redistribution capacities, leading to differences in water-chemistry and eco-hydrology among different HRAs. Both the Fort Hills Upland Complex (FHUC) and North Outwash Plains (NOP) are distinguished by their surficial geology which determines the dominance of distinct hydrologic flow paths and are described in detail in Section 2.3.

Figure 2.1 Hydrologic Response Areas (HRAs) in the McClelland Lake Wetland Complex Watershed.



2.3 WATER CHEMISTRY DATA

Water chemistry samples in the MLWC watershed have been collected through a variety of programs over the past twenty years. The data used for this study were compiled from these historical programs and summarized, along with sampling locations and analysis of trends within the MLWC watershed described in Objective 1 of the OP. Within this dataset, three sampling sources have been included: groundwater, wetland water (shallow subsurface), and near-surface water. Groundwater and surface water samples were collected quarterly as part of Suncor's Surface and Groundwater Monitoring program. The number of available water chemistry observations were spatially summarized by 18 of the 21 HRAs that are defined for the MLWC watershed (Figure 2.1) and presented in Table 2.1 below. These data have been used for advancing conceptual understanding of water movement and surface water chemistry at the MLWC watershed (Section 2.4) and as well as for defining EFDC+ model inputs (Section 3.5.3).

Table 2.1 Water Chemistry samples and hydrological source in each HRA in the MLWC watershed.

Hydrologic Response Area (HRA)	Number of Samples		
	Near-Surface Water	Wetland Water	Groundwater
Patterned Fen South	74 to 81	25 to 68	497 to 499
Patterned Fen North	0	9 to 29	82 to 83
Graminoid Fen	0	8	100 to 103
Non- Patterned Fen South	81 to 84	19 to 22	207 to 210
Non- Patterned Fen West	0 to 1	3 to 5	75
Non- Patterned Fen North	63 to 66	3 to 5	39
Coniferous Swamp North	66	0	0
Coniferous Swamp South	24 to 25	0	190
McClelland Lake	30 to 44	NA	0
North Wetland	0	1 to 3	15
South Wetland - McClelland Lake Catchment*	0	0	0
South Wetland - Unnamed Lake Catchment	0	0	2
Unnamed Lake	1	NA	0
Coniferous Swamp West	35 to 36	0	20
NOP East	1	NA	20
NOP West	70	NA	274 to 278
Fort Hills West	165 to 169	NA	469
Fort Hills East	0	NA	35

Note: Range in number of samples associated with differences in the number of samples for each water chemistry constituent. In general, only one water chemistry constituent showed a difference in the number of samples per hydrological source. However, the water chemistry constituent with a different number of samples varied among hydrological sources.

2.4 WATER MOVEMENT & SURFACE WATER CHEMISTRY AT MCCLELLAND LAKE WETLAND COMPLEX WATERSHED

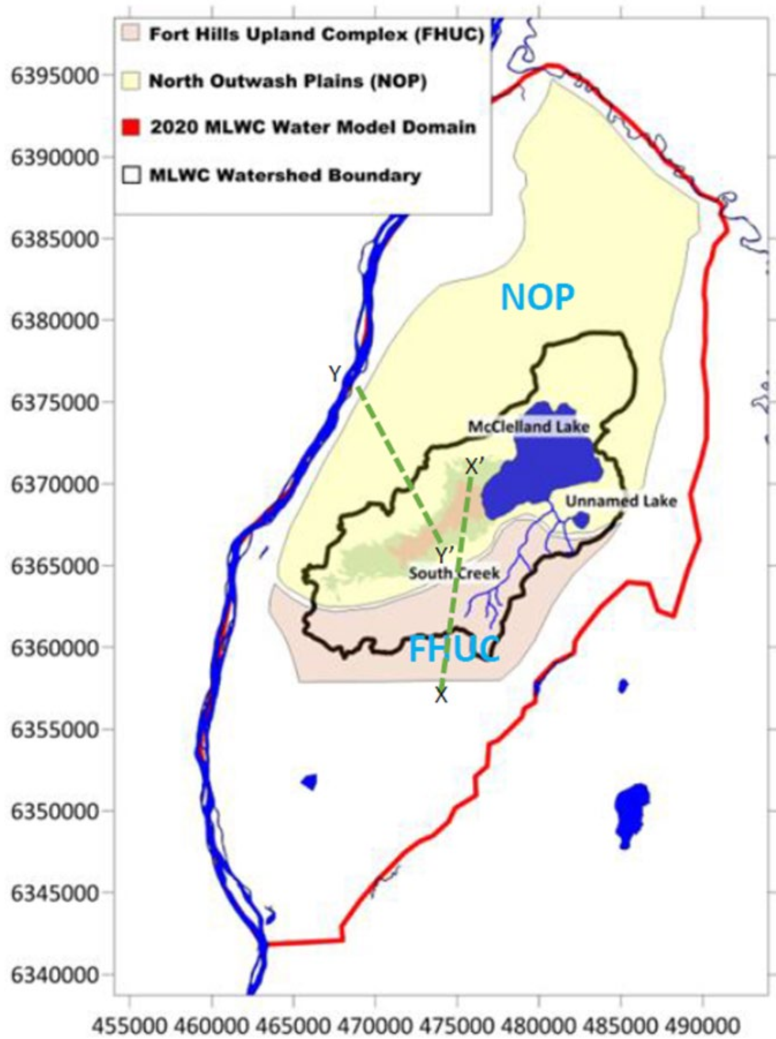
2.4.1 Conceptual framework overview

Surface water flows within the MLWC watershed are entirely derived from precipitation (rainfall and snowmelt), saturation-excess overland flow and groundwater exfiltration originating from localized precipitation-sourced water at the base of hillslopes (discharge). Although groundwater exfiltration plays an important role in determining the water chemistry reaching McClelland Lake, it is a relatively small component of the water balance, where precipitation was found to be an order of magnitude higher than other components in the water balance.

Groundwater exfiltration originates from two distinct areas, the North Outwash Plains (NOP) and Fort Hills Upland Complex (FHUC), that comprise different HRAs classified within the MLWC watershed each with generally similar geology and therefore water chemistries (Figure 2.1; Figure 2.2). Furthermore, it is interpreted that the MLWC watershed is connected to a relatively localized groundwater flow system where short groundwater travel times and distances along subsurface flow paths result in lower base cation concentrations and water chemistry signatures. However, the MLWC may receive exfiltrated groundwater from relatively longer flow paths (not anticipated to be regional groundwater), in addition to the local precipitation sourced groundwater. Both the NOP and FHUC contain HRAs with similar characteristics regarding relative dominance of surface and groundwater flow paths, and atmospheric exchange of water (evapotranspiration).

At both the NOP and FHUC, coniferous swamp wetland areas are present at the base of the hillslope. The water table is conceptualized to intersect or be close to the ground surface at the base of the NOP and FHUC, thus maintaining saturated conditions. Therefore, these are areas of potential ice formation during winter and rapid overland flow during spring-melt and summer precipitation events. These areas are also likely important regions for mixing of exfiltrated groundwater at the ground surface with water from shallow subsurface and interflow, overland flow, and precipitation, representing important water chemistry sources to the MLWC.

Figure 2.2 Plan view of Fort Hills Upland Complex (FHUC) and North Outwash Plains (NOP) within the McClelland Lake Wetland Complex Watershed.



Further descriptions of the NOP and FHUC at the MLWC watershed and characterization of their respective water chemistry are provided below.

2.4.1.1 North Outwash Plains (NOP)

The North Outwash Plains (NOP) is formed by HRA 15, 16 and 20 (North Outwash Plains – North) and adjacent lowland HRAs (i.e., HRA 03, 05, 06, 07, 09 & 10): The NOP is comprised of coarse-textured, deep, permeable uplands adjacent to coarse-textured lowlands, also permeable with high hydraulic conductivity.

The water chemistry exfiltrated from the NOP is conceptualized to be relatively dilute (ombrogenic) and more acidic. This is a result of the substrate being clean sands made of quartz, which is not very erodible and this material having higher hydraulic conductivity resulting in short contact time for dissolution processes to occur, and thus water chemistry signatures with similarities to precipitation. However, it is possible that the sandy substrates may contain deposits of feldspars, and hydrologic pathways via these pathwasy could increase TDS concentrations exfiltrated from the NOP.

2.4.1.2 Fort Hills Upland Complex (FHUC)

The Fort Hills Upland Complex (FHUC) is formed by HRA 17 (Fort Hills West) and adjacent lowlands (i.e., HRA 04, 08 and 14): The upland portion of the FHUC is comprised of a thin veneer of coarse-textured permeable sand deposits overlying fine-textured and lower permeability glacial till. The slopes towards the lowlands are also comprised of glacial till intersected by high hydraulic conductivity sand windows. Compared to the NOP, water exfiltrated from the FHUC generally has higher concentrations of base cations and is more alkaline due to lengthened contact times of groundwater with the high alkalinity silty sands and clays forming the glacial till deposits. Due to the relatively steeper topography and complex geology of the FHUC, there are three distinct subsurface flow paths distinguished with different associated water chemistry.

Shallow subsurface flow (pathway 1) with moderate base cation concentrations and alkalinity, and considered to be more intermediate between more ombrogenic and minerogenic water chemistry. Interactions of infiltrated precipitation with the tills at the coarse-fine-textured surficial geology interface result in water chemistry with moderate base cation concentrations and alkalinity. This water then rapidly preferentially flows along the coarse-fine-textured surficial geology interface to exfiltrate at the patterned fen.

Deeper subsurface flow (pathway 2) through the thick silty sand unit with higher base cation concentrations and alkalinity (more minerogenic) due to lengthened contact time between infiltrated precipitation and glacial tills. The proportion of groundwater exfiltrated from the shallower subsurface flow paths (pathway 1) is conceptualized to be greater than those from deeper subsurface flow paths (pathway 2).

High hydraulic conductivity windows located along the hillslopes are conceptualized to contribute a significant proportion of water to the patterned fen and subsequently McClelland Lake (pathway 3). These windows are essentially sand lenses that intersect the glacial tills of the Fort Hills and have higher hydraulic conductivities that allow for groundwater exfiltration and the generation of surface flow paths via rills (shallow channels formed by the erosive force of flowing water) to the patterned fen. The water chemistry of groundwater exfiltrated from the high hydraulic conductivity windows is currently unknown. However, water chemistry will likely be more ombrogenic and more acidic than the water from flow pathway 1 and 2, due to adsorption processes that act to exchange base cations. Therefore, the water chemistry will likely be similar to that found at the NOP. An examination of the hydrologic role played by the high hydraulic windows and an assessment of their water chemistry is scheduled for Winter 2021/2022.

2.4.2 Spring Freshet

During the winter months, ground freezing hydrologically isolates the subsurface flow system (groundwater exfiltration) from surface flow systems with the establishment of a concrete frozen layer in saturated areas such as the fen and lowland swamps (Figure 2.3). In spring, the concrete frozen layer does not thaw immediately, and is often present through to June. This layer creates an impermeable surface that prevents snowmelt from infiltrating into the subsurface. Instead, the concrete freezing structure of the fen and lowland swamps provides an opportunity for snowmelt, and any precipitation that falls while the ground remains frozen, with low TDS and major ion concentrations to rapidly enter McClelland Lake and 'clean' the lake via lateral runoff (Figure 2.3). Once the water storage capacity of McClelland Lake is full from snow-melt, the fen stores water via detention storage (where water is held in the fen until the lake level lowers and more lake storage is available) and depression storage (where water is stored in depressions created by the microtopography of the fen).

Upland forested areas, such as the NOP and FHUC, develop a honeycomb freezing structure in sediments during winter which allows for snowmelt to infiltrate and recharge the groundwater for deeper subsurface flows and discharge at spring locations during snowmelt (Figure 2.3). Shallow subsurface flows at the coarse-fine textured substrate interface in the FHUC are expected to be greater during spring-freshet, when infiltration of snowmelt is limited by lower permeability silty sand that underly a coarse-textured sand veneer and allow for rapid preferential shallow subsurface flow down the hillslope towards the fen and South Creek Inlet, and subsequently McClelland Lake (Figure 2.3).

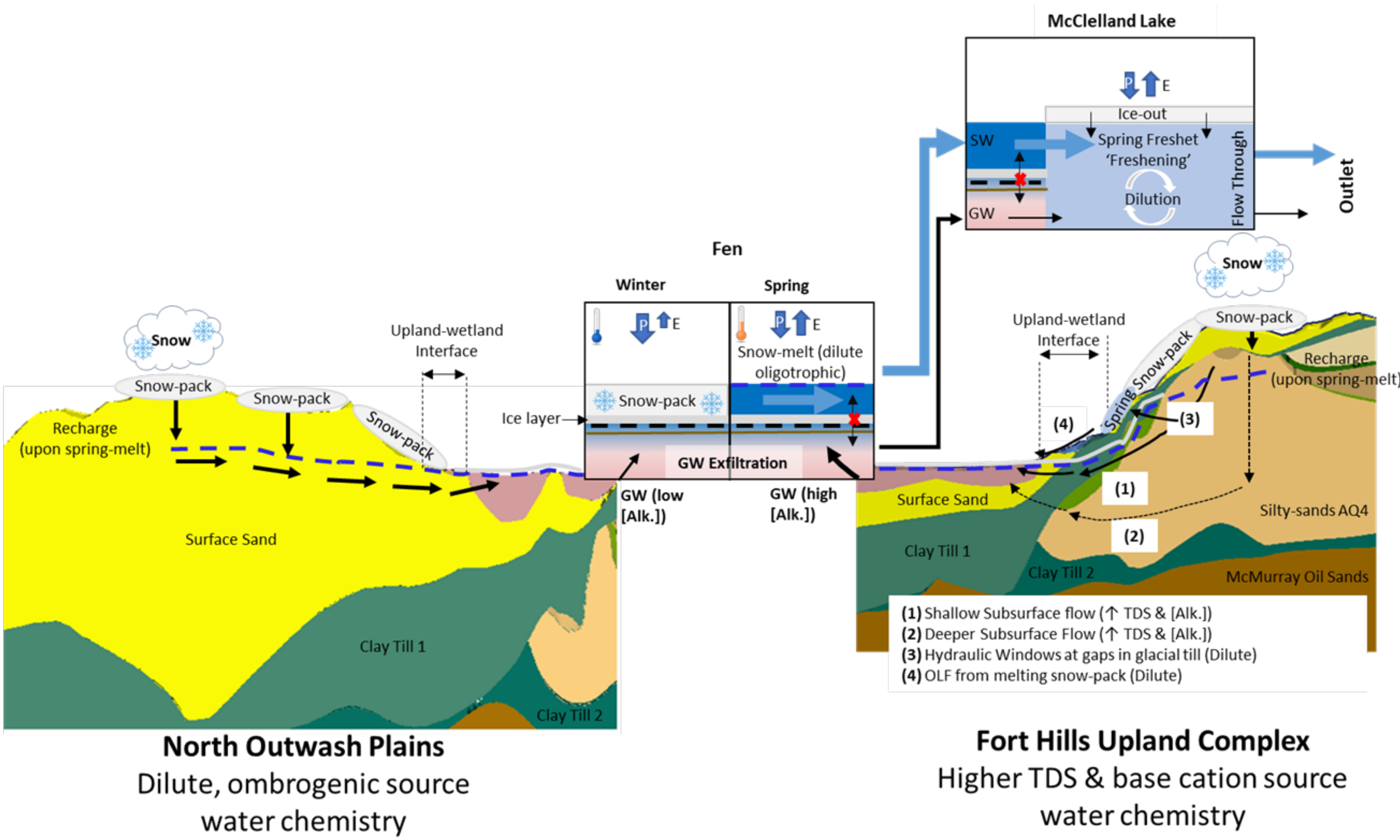
When ice-out occurs at McClelland Lake, the lake is conceptualized to rapidly 'freshen' and additions of low TDS and base cation snow and ice-melt could counter cryoconcentration effects that took place under the ice during winter (Figure 2.3). Furthermore, lake water levels are typically higher following spring melt, allowing for surface water fluxes to be greater than groundwater fluxes out of McClelland Lake as the water level exceeds the sill height at the lake outlet (Figure 2.3). This suggests that McClelland Lake is a flow-through system, which limits the extent of concentration effects occurring in the lake, further facilitating low TDS and base cation concentrations.

The extent of lateral runoff in the fen portion and groundwater recharge in upland forest portions of the watershed in spring will be dependent on antecedent moisture conditions at the MLWC watershed:

- Under wet antecedent conditions, the water table may freeze at a relatively shallower position in the fen during winter, limiting any interaction of snowmelt with soils and vegetation. As a result, major ion and TDS concentrations entering McClelland Lake may be lower following wet antecedent conditions. In the upland forest, the water table will likely be shallower under wet antecedent conditions and could be close to the surface, promoting surface runoff to McClelland Lake. This could either (a) result in shallow runoff entering the fen and, subsequently, McClelland Lake with very dilute water chemistry; or (b) flush nutrients and TDS from the leaf fibric humic layer of the forest floor to the fen and McClelland Lake, thereby increasing TDS and major ion concentrations.

- During dry antecedent conditions, the concrete frozen layer forms at greater depth, into potentially more humified layers of the fen. Therefore, upon spring snowmelt there is increased opportunity for melt water interactions with soil and vegetation, and although subsurface and surface flow paths remain isolated, higher TDS water could enter McClelland Lake from the fen. In the upland forest, dry antecedent moisture conditions result in deeper water tables. During dry antecedent conditions, groundwater recharge rates and therefore groundwater exfiltration and the loading of TDS and base cations may be reduced in the MLWC. The decrease in groundwater exfiltration at the fen could also increase the amount of surface water infiltration, thereby reducing lateral flow to the lake and potentially increasing evapoconcentration within the lake. Alternatively, given the reduced groundwater exfiltration potential during dry antecedent conditions, the surface water to groundwater ratios entering McClelland Lake may remain similar to that of relatively wetter years, which may explain the more static year-to-year trends observed in lake water chemistry.

Figure 2.3 Conceptual model for water movement & surface water chemistry at McClelland Lake Wetland Complex Watershed. Spring freshet condition.



2.4.3 Maintenance of McClelland Lake water chemistry under dry conditions during summer

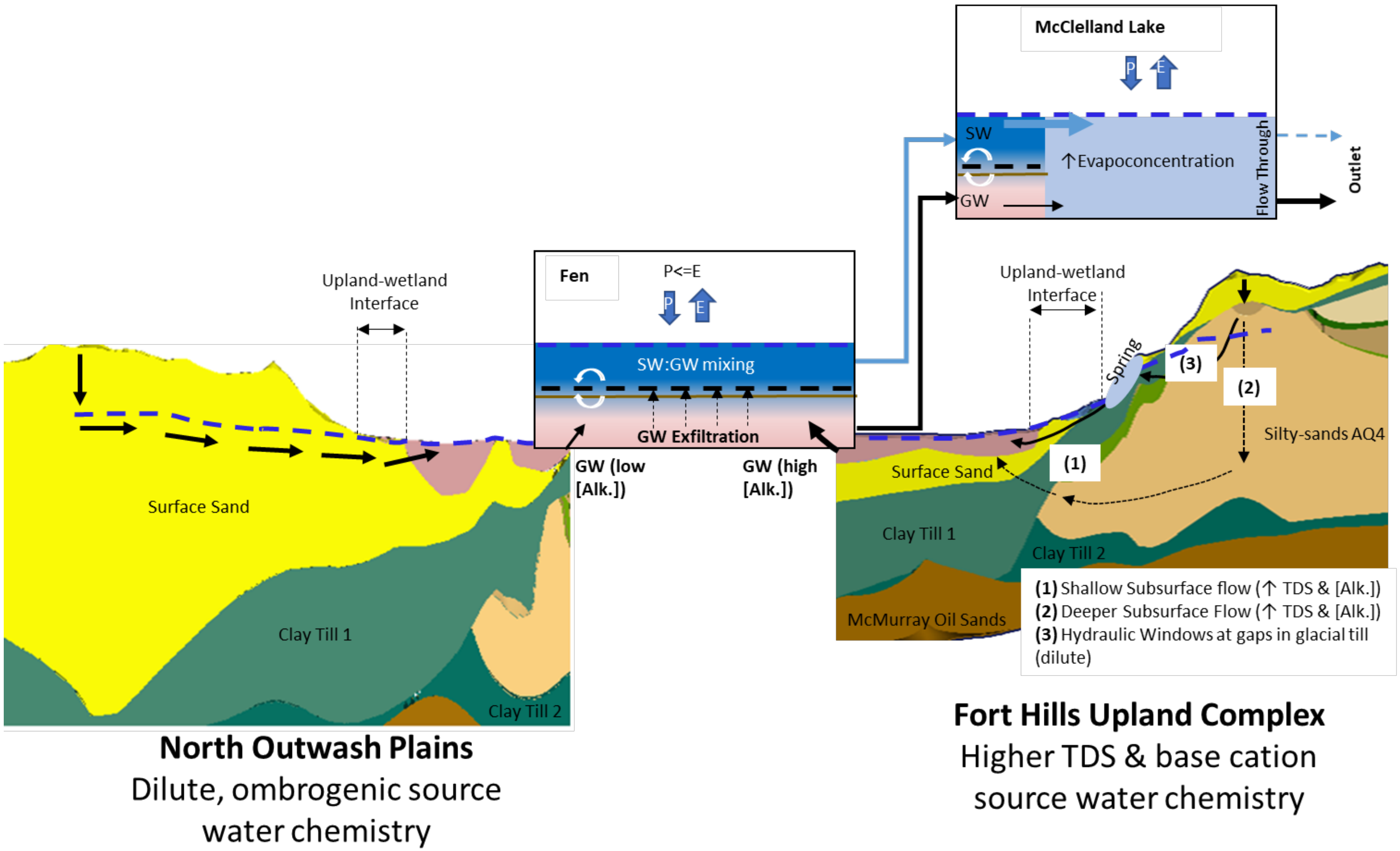
Under dry conditions during summer, precipitation (in the form of rainfall; long-term precipitation 316 mm/year; ECCC, 2021) is typically less than or equal to evapotranspiration (actual evapotranspiration from land 315 mm/year; potential evapotranspiration from lakes 590 mm/year; AESRD 2013). During this time the MLWC system relies on continual groundwater exfiltration and stored surface water in small depressions resulting from previous spring-melt or precipitation events as its water sources.

As groundwater exfiltrates at the patterned fen and creates saturated conditions, the majority of stored surface water in small depressions mounds at the fen surface rather than infiltrating into the ground (Figure 2.4). At this groundwater-surface water interface, mixing processes are conceptualized to occur between exfiltrated groundwater (higher TDS and major ion concentrations) and surface water stored from previous spring-melt or precipitation events (low TDS and major ion concentrations) (Figure 2.4). However, because under dry conditions during the summer, the ratio of groundwater to surface water is similar, and this mixing only has a small dilution effect on the exfiltrated groundwater (Figure 2.4). As a result, the water entering McClelland Lake under normal conditions is expected to have relatively higher TDS and base cation concentrations.

The relative dominance of groundwater exfiltration and stored surface water in mixing processes at the groundwater-surface water interface likely varies between wet versus dry years. During wetter years, where there may be greater snowpack and subsequently a larger spring-melt event, there is likely more detention storage in the fen (i.e., the fen is able to hold onto more water originating from spring-melt as the lake is full and excess spring-melt is unable to move into the lake). Therefore, during wetter years, it is likely that surface water stored in the fen from spring-melt overwhelms groundwater exfiltration at the groundwater-surface water interface, with larger dilution effects on exfiltrated groundwater. As a result, during wet years, McClelland Lake is expected to freshen with relatively lower TDS and base cation concentrations entering from the fen.

McClelland Lake is conceptualized to function as a well-mixed flow-through system, whereby groundwater, conceptualized as shallow subsurface flow, leaving the lake is greater than surface water outputs. It is thought to be well-mixed due to its shallow nature (< 2 m) and large fetch with poor-stratification. The extent of surface water leaving McClelland Lake is dependent on the lake water level and whether the lake water level exceeds the elevation of the sill at the outlet. Under dry summer conditions, in a 'normal' climate year, when water levels are likely lower, the water level of McClelland Lake is unlikely to overcome the sill height and surface water outputs are conceptualized to be minimal. Therefore, it is likely that evapoconcentration processes in McClelland Lake (Figure 2.4) are greater during dry summer conditions resulting in increased TDS and base cation concentrations over time until a precipitation event effectively 'cleans' the system. Temporal events such as spring-melt and summer storms interact differently with groundwater exfiltration to effectively "freshen" water chemistry in the patterned fen and subsequently McClelland Lake (Figure 2.5), as outlined further below.

Figure 2.4 Conceptual model for water movement & surface water chemistry at McClelland Lake Wetland Complex. Maintenance of system condition.



2.4.4 Intense summer precipitation

Following spring freshet, evaporation from McClelland Lake is expected to be high and with minimal surface outflow, suggesting that TDS and major ions would evapoconcentrate in the absence of large dilute post-freshet water sources. However, available water chemistry data from McClelland Lake shows that TDS and major ion concentrations remain stable or slightly decrease during summer. Conceptual water chemistry process models (using data from 2000 to 2020) were used to test the importance of precipitation events on lake water chemistry. These results suggests that large summertime precipitation events quickly deliver substantial volumes of low-TDS water to McClelland Lake and can therefore maintain low TDS. As an example, a relatively large precipitation event in July 2018 contributed to a lake level rise of 0.03 m within four hours. Given the lake size and precipitation depth falling on the area, only two-thirds of the water level rise can be attributed to direct precipitation on McClelland Lake, with the remaining third conceptualized to be delivered by shallow runoff (low TDS and base cation water chemistry) flow paths from the surrounding watershed.

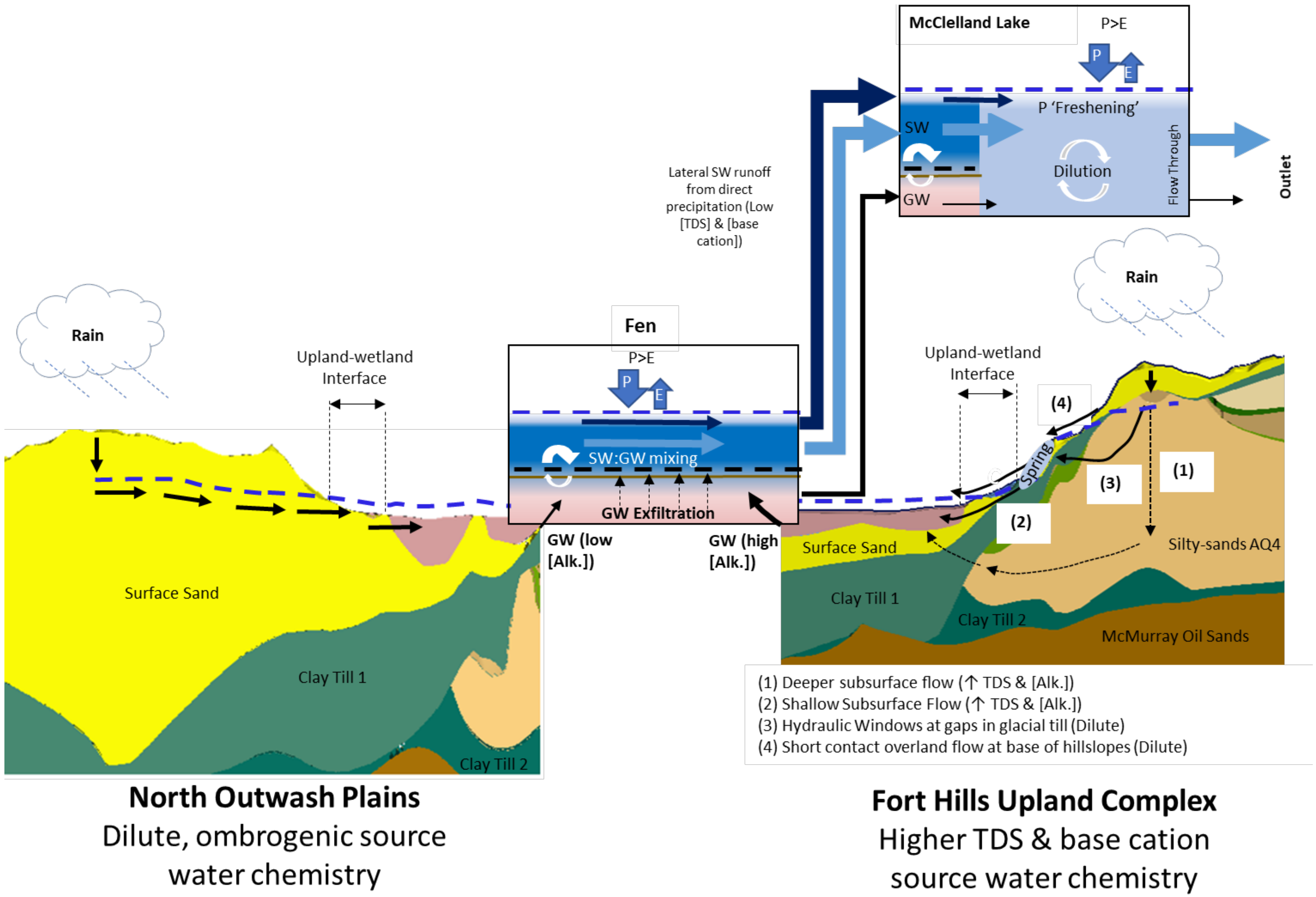
Water delivered from the NOP and FHUC likely undergoes slightly different hydrologic processes that determine the chemistry of water reaching the fen and subsequently McClelland Lake. In the NOP, intense precipitation during a summer storm results in infiltration and groundwater recharge. Upon reaching the capillary fringe (saturated zone above the water table where water is affected by capillary forces), infiltrating precipitation displaces air in the void space of the unit and the groundwater table rises (Appendix D in OP; Figure 2.5). The fresh infiltrating water, therefore, sits at the top of the capillary fringe which rises with the water table. The water table in the coarse-textured NOP is relatively flat, and does not necessarily follow the topography, therefore infiltrating water will reach the capillary fringe at different rates in different parts of the NOP (Figure 2.5). Once the infiltrating water reaches the water table, a mound of fresh water (originating from precipitation) will form and migrate either towards the Athabasca River or towards the interior of the watershed (i.e., the fen). Meanwhile, the water table continues to rise. Therefore, during times of intense precipitation, complex hydrodynamic interactions occur within and beneath the unsaturated zone (Appendix D in OP).

For the Fort Hills Upland Complex, during intense precipitation events, it is conceptualized that overland flow via infiltration excess is generated (Figure 2.5). As intense precipitation falls on the FHUC, the fine-textured nature of glacial tills limits rapid infiltration and promotes overland flow. Subsequently, the precipitation-induced runoff is short-contact water with minimal interactions with soils, and therefore low TDS and base cation water rapidly enter the fen (Figure 2.5).

Return flow is also a likely hydrologic process occurring at the MLWC watershed during intense precipitation events. During intense precipitation events, the rate of interflow and overland flow entering saturated fen and swamp areas downslope of the NOP, and in particular the FHUC, will likely exceed the ability for interflow to leave the fen and swamp areas. Subsequently, the excess interflow returns to the surface as return flow and moves with overland flow towards McClelland Lake as runoff. This hydrologic process can continue to occur after the intense precipitation event, until interflow excess dissipates, and is expected to comprise of lower TDS and base cation water chemistry concentrations.

Upon reaching the fen, low TDS and base cation water rapidly exfiltrated from the NOP, and originating from overland flow at the FHUC, flows laterally across the saturated fen and quickly enters McClelland Lake with little to no mixing occurring in the fen (Figure 2.5). Therefore, it is conceptualized that intense summertime precipitation events are capable of maintaining low TDS and major ion concentrations in McClelland (Figure 2.5).

Figure 2.5 **Conceptual model for water movement & surface water chemistry at McClelland Lake Wetland Complex Watershed. Intense precipitation condition.**



2.4.5 Effects of biogeochemical processes on water chemistry at McClelland Lake – Calcium (Ca^{2+})

The Fort Hills Upland Complex is considered the dominant source of base cations and alkalinity, to the fen portion of the MLWC (Figure 2.4; Figure 2.6). However, alkalinity and Ca^{2+} concentrations decrease from approximately 400 mg/L and 100 mg/L, respectively, at the southern edge of the Fort Hills-fen interface, to 50 mg/L and 20 mg/L, respectively, at the fen-McClelland Lake interface. Traditionally, the relatively dilute and non-alkaline water chemistry of McClelland Lake has been conceptualized to be mainly driven by the dominance of terrestrial flow paths (i.e., surface runoff). However, this chemistry could be partially attributed to biogeochemical processes modifying the alkalinity of water reaching McClelland Lake. Within the fen portion of the MLWC, and particularly at the fen-McClelland Lake interface, a series of carbon cycling processes appear to control base cation concentrations, and thus alkalinity, within the peat (Figure 2.6; Figure 2.7).

Figure 2.6 Summary of the updated conceptual model for the MLWC showing main water flow paths and geochemical processes in the MLWC.

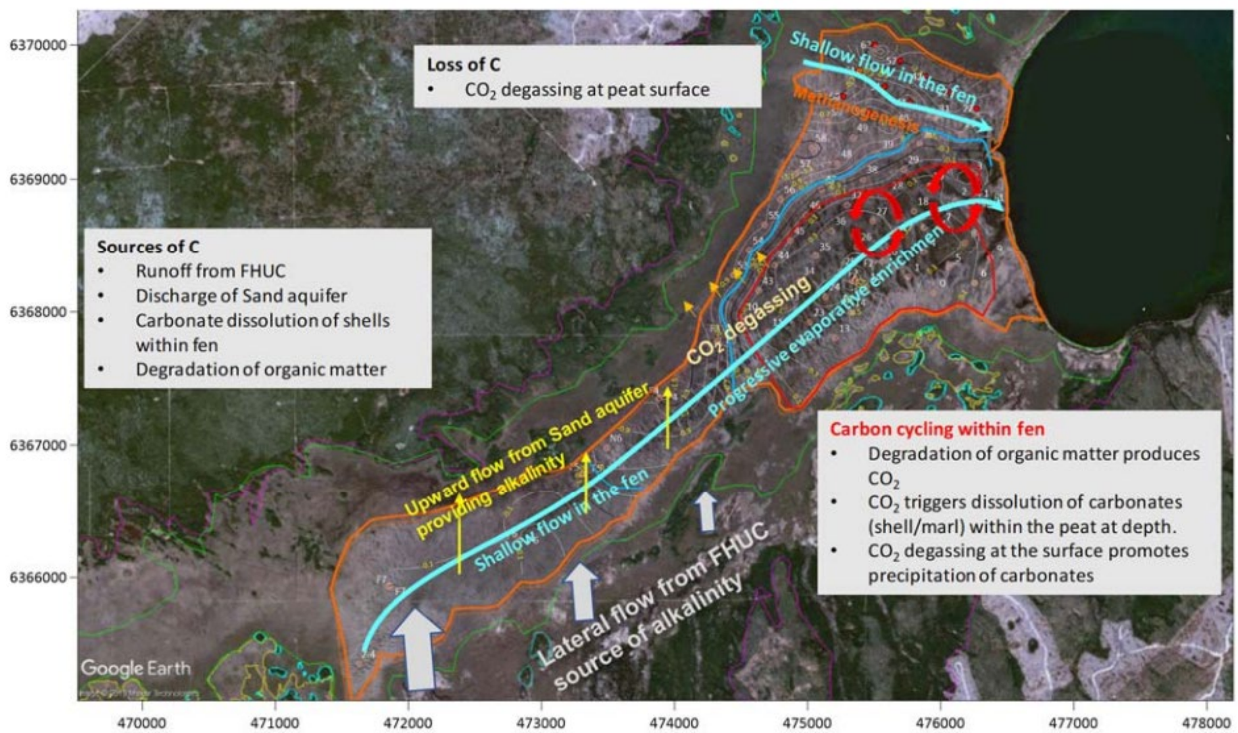
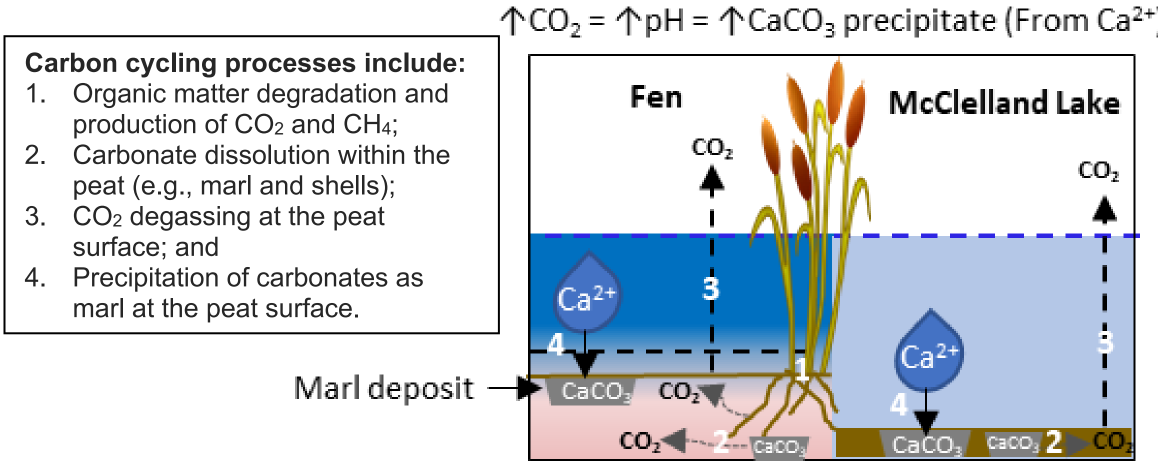


Figure 2.7 Schematic diagram of carbon cycling processes controlling base cation concentrations (i.e., alkalinity) at the fen and fen-McClelland Lake Interface.



Within the top 0.2 m of peat in the fen where hydraulic conductivity is highest, concentrations of alkalinity, Ca^{2+} and other base cations are lower than samples collected at 1 m peat depths. This supports the conceptual understanding that mixing groundwater exfiltration and surface water has a dilution effect on the water chemistry of the fen and this dilution is greater at shallower peat depths. Additionally, more dilute concentrations in the upper portions of the peat are likely associated with mineral precipitation of Ca^{2+} to $CaCO_3$ (calcium carbonate) as a result of CO_2 (carbon dioxide) degassing and a subsequent increase in pH (Cole & Caraco, 1998).

At depths of 1 m into the peat, the extent of mixing between exfiltrated groundwater and surface water is reduced and the extent of CO_2 degassing, which promotes mineral precipitation of Ca^{2+}, is limited. Together, the lack of source water mixing and the presence of mineral precipitation results in higher alkalinity and Ca^{2+}, and lower pH values in deeper layers of peat at the fen. Furthermore, respiration of vegetation in the root zone and degradation of organic matter will generate CO_2, which, combined with lower pH values, results in the dissolution of calcium carbonate marls that have been buried as the fen continues to accumulate organic matter, thus also increasing alkalinity and Ca^{2+}.

2.5 CONCEPTUAL MODEL SUMMARY

The conceptual model for water chemistry at the MLWC watershed that is presented provides a current understanding of the water sources, flow paths, and hydrologic processes that influence surface-groundwater interactions within the MLWC watershed. Key points from the current conceptual understanding that are incorporated into numerical model development for this initial step in the modelling of water chemistry within the MLWC watershed are as follows:

1. Precipitation is the primary source of water volume input at the MLWC watershed.
2. The NOP and FHUC both represent upland recharge zones and their water chemistry signatures are controlled by their surficial geology and flow paths:

a. NOP – Surface sands are primarily made of quartz and only weather minimally and water sourced from this area is considered to be ombrogenic (low TDS and base cations).

b. FHUC – Moraine silts are believed to be a source of alkalinity and water sourced from this area is considered minerogenic (high TDS and base cations).

3. Groundwater from the two uplands (NOP & FHUC) exfiltrates at the fen and from hydraulic windows on the lower slop areas of the FHUC.

4. During dry periods in the summer, the MLWC system relies on groundwater exfiltration and stored water in depressions at the fen (from spring-melt and previous precipitation) to sustain water demands at McClelland Lake.

5. During wet periods (i.e., spring-melt and intense summer precipitation events), there are large freshwater inputs to the fen and lake via surface runoff which both replenish any moisture storage deficits and freshen the lake.

This initial step provides a robust conceptual framework for understanding hydrological processes at the MLWC watershed and subsequently the hydrochemical mass balance. This framework can now incorporate more complexity into future conceptualizations. For the next phase of work, to better the holistic understanding of the MLWC watershed, the following recommendations should be considered:

- Generate a conceptual model for McClelland Lake, with a focus on external and internal processes, including the functional role of McClelland Lake as a sink, source, or conveyor of nutrients and TDS.
- Incorporate nutrient cycling and transport into the existing conceptual model.
- Incorporate water table-redox relationships into the existing conceptual model.

3.0 NUMERICAL MODEL DEVELOPMENT

3.1 MODELLING PLATFORM AND RELEVANT FEATURES

The Environmental Fluid Dynamics Code (EFDC+) model was used to model surface water chemistry dynamics for different potential mitigation strategies proposed to maintain the hydrology and water chemistry of the non-mined portion of MLWC watershed, both during mining activities and following mine closure. The original version of the model was developed at the Virginia Institute of Marine Science for estuarine and coastal applications and has since been expanded and updated by DSI.

EFDC+ simulates many hydrological aspects of the MLWC watershed, including multi-dimensional flow, transport, and biogeochemical processes in surface water systems, including lakes and wetlands. EFDC+ has several capabilities that make this model an appropriate choice for application at the MLWC watershed. For example, the EFDC+ model allows for spatial differences in the concentration of water balance inputs and other physical properties, and offers functions that enable robust prediction of continuous hydrologic flow paths and associated chemical compositions of water. In addition to hydrodynamic, salinity, and temperature transport simulation capabilities, EFDC+ includes sub-modules to simulate sediment transport, eutrophication, and the transport and fate of toxic contaminants in the water and sediment bed. The EFDC+ code is widely used by federal agencies, including the United States Army Corps of Engineers (USACE), the United States Environmental Protection Agency (USEPA), and the United States Geological Survey (USGS). EFDC+ is one of the only currently supported public domain modelling systems that incorporates fully linked, user-transparent hydrodynamics, sediment transport, water chemistry, and sediment diagenesis simulation capabilities.

Although the EFDC+ model has many applications that are relevant to surface water chemistry modelling of the MLWC watershed, this stage of modelling focuses on the application of hydrodynamics and the general water quality module. Specifically conservative dye tracers, which were used as a proxy for major ions and TDS. The EFDC+ version used for this modelling task includes some enhancements that are specific to the Suncor McClelland Lake Wetland Complex project, to facilitate the coupling to the integrated surface and groundwater model HGS. Potential improvements of this current phase of modelling work are listed in Section 6.0 and outline potential ways to add complexity to this work, such as the modelling of biogeochemical processes, including nutrient cycling.

3.2 SCOPE & OBJECTIVES

The overall objective of the EDFC+ modelling approach is to evaluate the ability of the water resupply strategy to maintain water level and water chemistry conditions in the non-mined portion of the MLWC watershed. To meet this objective, a computational model for surface water chemistry dynamics was implemented to assess the natural variability in water chemistry of the MLWC using a baseline scenario comprising the 1944 to 2019 historical period.

Subsequent scenarios were simulated to predict surface water chemistry entering the non-mined portion of the MLWC under operational (i.e., during mining activities) and closure conditions and changes in water chemistry at the MLWC relative to baseline conditions. This was done through:

- An operational model scenario (S1) that includes mining activities, the cutoff wall and resupply water, simulating the period 2025-2075. This scenario (S1) is compared to a parallel simulation over the same period that incorporates no development (R0). R0 is therefore a baseline simulation, representing no impact from mining, but with different hydroclimatic conditions from the historical baseline simulation as it runs from 2025-2075 (i.e., during mining activities).

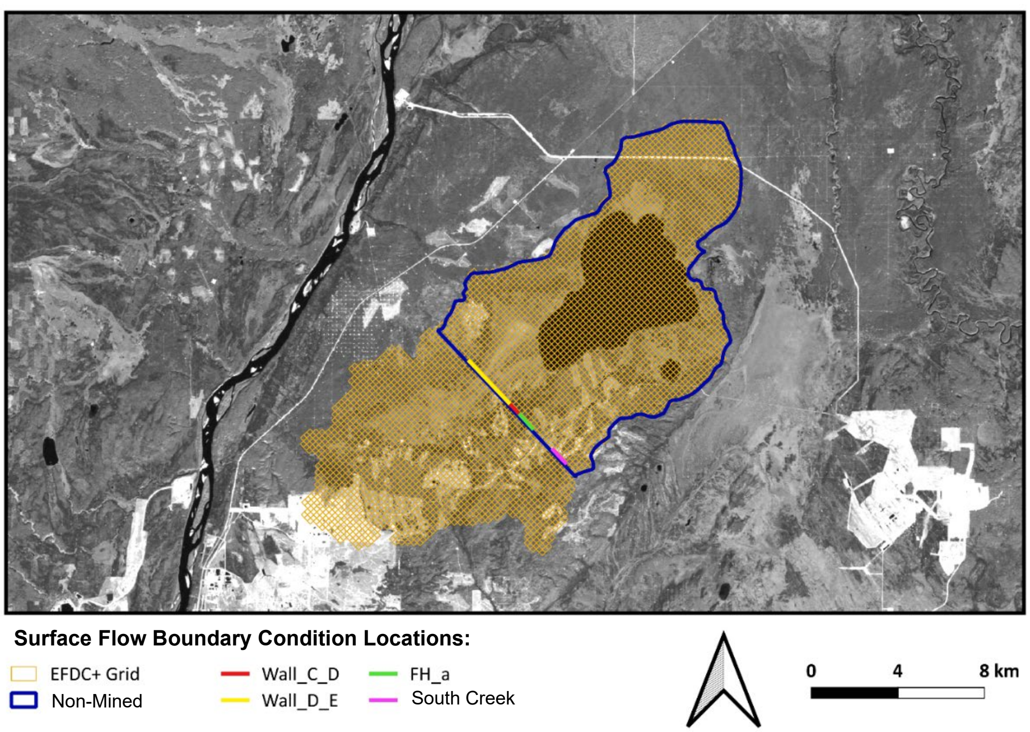
- A scenario representing the period directly after mining but with continued water resupply (Active Closure), from 2075 to 2100.
- A 75-year "Far Future Closure" simulation (2100 to 2175) using the same climate forcing data as the historical baseline simulation. This scenario evaluates water chemistry results for the reclaimed landscape, with a reduced watershed area due to cutoff wall and absence of resupply water, to the baseline period (fully non-mined watershed area).

3.3 MODEL DOMAIN AND GRID

A model grid (200 m × 200 m; 5,113 cells) was developed to support the simulation of surface water chemistry scenarios for the MLWC watershed (Figure 3.1). The grid was rotated to orient with the proposed alignment of the cutoff wall. One version of the grid (the MLWC watershed grid), shown in Figure 3.1, covers the entire spatial extent of the MLWC watershed; this was used for the Baseline Simulation Period (1944 to 2019).

For the model simulations in the operational and closure phases of the project, cells upstream of the cutoff wall alignment were deactivated so that only the area downstream of the cutoff wall was included in the simulation (200 m × 200 m: 3,095 cells). This is referred to as the non-mined area model.

Figure 3.1 MLWC watershed EFDC+ model domain and grid showing the non-mined area and the surface flow boundary condition locations.



3.4 DATA SOURCES AND ASSOCIATED MODEL INPUTS

The data sources used to generate the EFDC+ model are described and analyzed in previous reports prepared by other parties, as listed in Table 3.1. Corresponding model inputs (boundary conditions) are described in subsequent sections.

Table 3.1 Summary of purpose, variables, and sources of data used for EFDC+.

Purpose	Variable	Role for EFDC+ modelling development	Location Applied	Available Record	Data Source
Boundary conditions for the EFDC+ model water balance	Surface-subsurface Flux (Qgs)	Estimates surface water infiltration and groundwater exfiltration fluxes	Spatially distributed	1944 to far-future closure scenario	Computed by HGS model see DSI 2021 for further details.
	Precipitation	Water input to the model domain			
	Evaporation	Water loss from the model domain			
	Surface flow	Water input and loss to/from the model domain	South Creek, Fen cutoff wall, McClelland Lake outlet on east side		
	Water Resupply quantity	Enables assessment of different resupply water quantities & chemistries for maintenance of eco-health at the MLWC watershed	North Outwash Plain, Fort Hills (South Creek) and Fen downstream of cutoff wall	Fen surface water resupply: 2025 to 2063 Routing of water over cutoff wall 2037 to 2063 NOP Injection: 2028 to 2037*	Provided for HGS model from Wood 2021 recommendations and made available along with other water balance variables.
EFDC+ model computations e.g., lake mixing	Wind speed, wind direction, relative humidity or dew point temperature, mean air temperature, weather, and atmospheric pressure	Enables characterization of potential historical variability and ranges of conditions of the MLWC watershed	Watershed	1944 to 2019	Environment Canada Fort McMurray A/AWOS A Climate Station
Water chemistry concentration inputs and observations	Surface, fen, ground, and lake water chemistry (TDS, Ca, K, Mg, Na)	Variables represent key constituents for maintaining ecosystem health of the MLWC	Specific value in each HRA in the watershed	2000 to 2020	Suncor, InnoTech Alberta 2019, and RAMP 2018

* Not used in EFDC model, provided for context.

3.5 BOUNDARY CONDITIONS

3.5.1 Meteorological boundary conditions

Atmospheric data was compiled for the Fort McMurray Climate Station A from November 1, 1944, and October 31, 2019, and data gaps were filled using nearby Government Station data (i.e., Mildred Lake). These data are required for the EFDC+ lake mixing computations and included: wind speed, wind direction, relative humidity or dew point temperature, mean air temperature, weather, and atmospheric pressure.

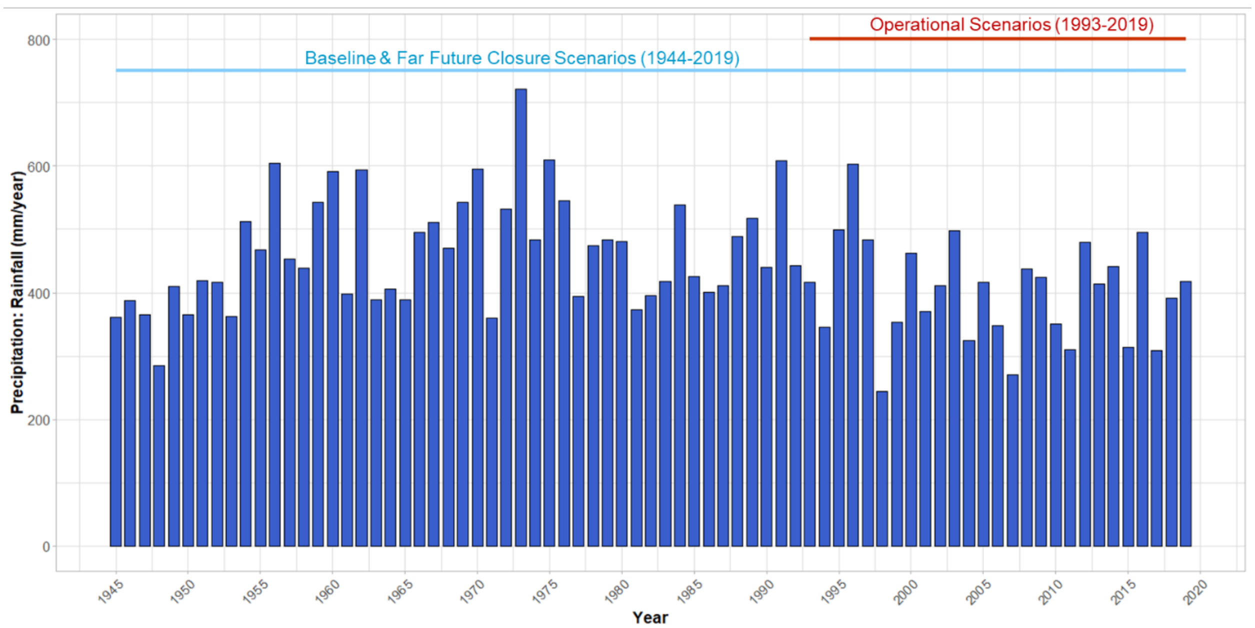
To retain consistency with the HGS integrated groundwater-surface water model, key meteorological variables were derived directly from that model to ensure no water balance misalignment would occur between the models from these variables. This included precipitation inputs and evaporation outputs (Table 3.1). The HGS-EFDC+ linkage is described further below.

Table 3.2 shows the period of climate forcing data used for the different MLWC modelling scenarios and Figure 3.2 provides the annual total precipitation along with the climate forcing period for context.

Table 3.2 Climate forcing period used in each simulated scenario.

Scenario	Simulation Length	Simulation Period	Climate Forcing Period
Baseline	75 years	1944 to 2019	1944 to 2019
R0	50 years	2025 to 2075	1993 to 2019 (looped)
S1	50 years	2025 to 2075	1993 to 2019 (looped)
Active Closure	25 years	2075 to 2100	Average daily conditions for all years
Far Future Closure	75 years	2100 to 2175	1944 to 2019

Figure 3.2 Annual precipitation (mm/year) derived from the HGS model and periods of climate forcing used in different simulation scenarios represented by horizontal blue and red lines.



3.5.2 Linking HGS boundary conditions to EFDC+

Hydrologic boundary conditions for the EFDC+ MLWC model scenarios were based on a loose coupling with the HGS model, with additional input data provided by observed meteorological conditions. The HGS model for the MLWC watershed was developed as a separate project and the results are reported in the OP. The HGS model was used to predict the transport of water among surface and groundwater systems in a tightly coupled framework. Precipitation and the groundwater exchange flux (Qgs) were provided as a boundary condition to EFDC+ based on the HGS model results.

Precipitation is the predicted sum of rainfall and snow melt, and evaporation is the surface evaporation computed for open water areas. Transpiration is computed within HGS and is accounted for in the subsurface water balance and was not explicitly modelled in EFDC+ but incorporated in the Qgs term. For additional information on these terms used in the HGS model, refer to the theoretical documentation listed in the OP.

Surface-subsurface flux (Qgs) is provided as a boundary condition for each EFDC+ model simulation (Table 3.1) as a spatially and temporally varying field file. The surface-subsurface flux (Qgs) used in the EFDC+ is a term computed by the HGS model and represents an estimate of the movement of water from the land surface into the ground (infiltration) and movement of water from the ground to the surface (exfiltration).

Surface water flow inputs were provided for the cutoff wall and South Creek cross-sections, while lake outlet discharge was also obtained from the HGS model. These terms were used as boundary conditions for the MLWC EFDC+ simulations. In the R0 (no development) and Far Future Closure (75 years) scenarios, the boundary condition along the cutoff wall cross-section and South Creek reflect an estimate of natural flow conditions, whereas for the S1 and Active Closure scenarios the flows reflect surface water resupply for the cutoff wall and an estimate of natural flow for South Creek. Downstream wall flow in S1 is the natural flux that is occurring at the wall from the unaffected portion of the watershed that is not mined yet and routed over the wall once it is constructed on January 1, 2037, while the fen water resupply is the additional flux to supplement the natural flows to McClelland Lake from the fen that have been stopped by mining.

3.5.2.1 Model Linkage Analysis Methods and Adjustments

Mass Balance Calculation

Because the HGS model is a finite element model using nodes and the EFDC model is a finite difference model and uses cells for computation the data from the HGS model needed to be transformed. A quality assurance check was performed to ensure the transformation for each scenario (Baseline, R0, S1, Active Closure, and Far Future Closure) did not cause a change in the overall volume for each boundary condition type (precipitation, evaporation, and Qgs). As an example of the transformation difference, Table 3.3 provides a summary of the volume change breakdown for each water source in the R0 scenario and was on the order of one-thousandth of a percent.

Table 3.3 R0 Volume differences (m^3) between node and cell transformations.

	Node	Cell	Difference (%)
Precipitation	1.29E+09	1.29E+09	-0.002
Evaporation	-5.96E+08	-5.96E+08	-0.001
Qgs	-8.02E+08	-8.02E+08	-0.009

Total Volume Change Prediction and Adjustment

As another model linkage check prior to running the EFDC+ model, a volume time series for all water sources was generated, then aggregated into a cumulative change of volume time series over the modelling period. This change of volume time series provided a general indication of what the EFDC+ lake water surface elevation would be before running the simulation and could be compared to the HGS model predicted lake level elevation. This approach suggests that the boundary conditions provided by HGS do not fully align with the predicted lake level from the HGS model. It is believed that this discrepancy is from the Qgs term and was corrected as described below.

To adjust for the HGS linkage, the total volume difference near the end of the simulation was estimated and applied as a constant volume/velocity rate to the main outlet node time series. This mass balance adjustment was relatively small compared to the total estimated annual inflow to McClelland Lake and ranged from removing 3.4% (negative term) to adding 0.5% of the total inflow volume (Table 3.4). Overall, this adjustment approach did not affect the concentration input loading and distribution through the Qgs term in the watershed, since the correction was applied to the lake by scaling the lake outflow volumes which included the associated constituent concentrations of the lake for each time interval.

Table 3.4 EFDC+ mass balance adjustment for the HGS linkage.

	Baseline	R0	S1	Active Closure	Far Future Closure
Annual Volume Adjusted (m^3)	-1,118,667	105,600	-1,108,000	-141,200	160,000
Annual Volume Adjusted Percent of Lake Inflow	-3.4%	0.3%	-3.4%	-0.4%	0.5%

3.5.3 Water Chemistry Concentration Inputs

3.5.3.1 Precipitation

Concentration of the constituents in precipitation is very low (median concentrations (mg/L) – Ca: 0.56; K: 0.05; Mg: 0.14; Na: 0.07; TDS: 3). Therefore, precipitation inputs to the model were tagged with a concentration of 0 mg/L for all constituents.

3.5.3.2 Groundwater Exfiltration (Qgs)

The primary source of concentration constituents to the model is from the groundwater flux through the HGS Qgs term. The water that is exfiltrating is tagged with concentrations that were observed in the field for each HRA, discussed further below. Near-surface water samples were the preferred source of concentration data to assign to the Qgs exfiltration volumes. Once water is exfiltrated the EFDC+ model uses the volume and concentration to calculate mixing with precipitation and surface runoff from upslope areas of the model and this volume is computed as runoff and/or infiltration.

Near-surface concentrations as the preference is based on the conceptual understanding of the MLWC system (outlined in Section 2.4), where groundwater exfiltration across the fen is highly variable.

The MLWC watershed generally has near-surface, wetland and groundwater quality sampling focused along the western portion. Different near-surface, wetland and groundwater samples were collected as part of separate programs with a specific purpose unique to the scope of each sampling program (Section 2.3). Therefore, samples for near-surface water are not available across each of the identified HRAs for input to the EFDC+ model. To address this lack of data and based on the conceptual understanding of the system, a dilution factor was introduced to adjust groundwater quality samples to represent near-surface water concentrations within each specific HRA. However, using a HRA-specific approach for water chemistry inputs to the model requires surface-groundwater pairings that are relatively close to one another. Since the sampling program was not designed with surface-groundwater parings in mind, there is insufficient data to develop HRA-specific water chemistry inputs suitable for the conceptual understanding of the MLWC watershed. Subsequently, for HRAs with no near-surface water samples a watershed-spanning 'average' dilution factor for each water chemistry constituent was applied to the available groundwater concentration data and used as an input/boundary condition to the EFDC+ model.

3.5.3.3 Surface Water

For the full watershed model domain, surface water is computed in the EDFC+ model from input volumes and concentrations of the Qgs term and precipitation and then routed through watershed. In the non-mined model domain (Figure 3.1), used for the R0, S1, Active Closure, and Far Future Closure scenarios, the routing of surface water generated by EFDC+ surface water is also added as a boundary condition. Surface flow and water chemistry concentration boundaries were set at locations where the model domain intersects the fen along the cutoff wall and South Creek. These locations are where the surface flow was computed in the Baseline simulation of the entire watershed domain model and HGS.

Flow across these boundaries was provided from the HGS model simulation for the downstream wall inflow (natural flow prior to cutoff wall construction and after cutoff wall removal) and South Creek. The water chemistry concentrations for the downstream wall inflow and South Creek were derived from the seasonal average concentrations from the 75-year Baseline simulation and represent an estimate of the seasonally varying concentrations (Table 3.5 and Table 3.6).

3.5.3.4 Water Resupply

Water resupply, used to represent estimated water volumes that are calculated as required to maintain the fen and McClelland Lake during mining operations, was provided from the HGS model simulation. The water chemistry concentrations for the water resupply inflow were derived from the seasonal average concentrations from the 75-year Baseline simulation and represent an estimate of the seasonally varying concentrations (Table 3.6).

Water Resupply volumes that are injected in the NOP to maintain water table elevations in the NOP are not explicitly modelled in EFDC+. Volumes were added to the HGS models and therefore incorporated in the EFDC+ model through the Qgs term and water chemistry concentration was assumed to be the same as in situ concentrations, and therefore it was assumed that no change to concentrations would occur from the injection.

Table 3.5 Seasonal Major ion and TDS Concentrations for the Cutoff Wall and Water Resupply boundary conditions

Cutoff Wall	TDS (mg/L)	Ca^{++} (mg/L)	K^{+} (mg/L)	Mg^{++} (mg/L)	Na^{+} (mg/L)
Fall	14.89	1.02	0.23	1.28	0.63
Winter	22.32	2.28	0.30	2.03	1.21
Freshet	10.33	0.88	0.18	1.04	0.50
Summer	5.81	0.37	0.12	0.55	0.30

Table 3.6 Seasonal Major ion and TDS Concentrations for the South Creek boundary conditions.

South Creek	TDS (mg/L)	Ca^{++} (mg/L)	K^{+} (mg/L)	Mg^{++} (mg/L)	Na^{+} (mg/L)
Fall	20.70	3.03	0.26	2.70	0.42
Winter	28.05	4.13	0.35	3.67	0.55
Freshet	17.93	2.63	0.20	2.27	0.34
Summer	11.19	1.52	0.12	1.42	0.30

3.6 INITIAL CONDITIONS

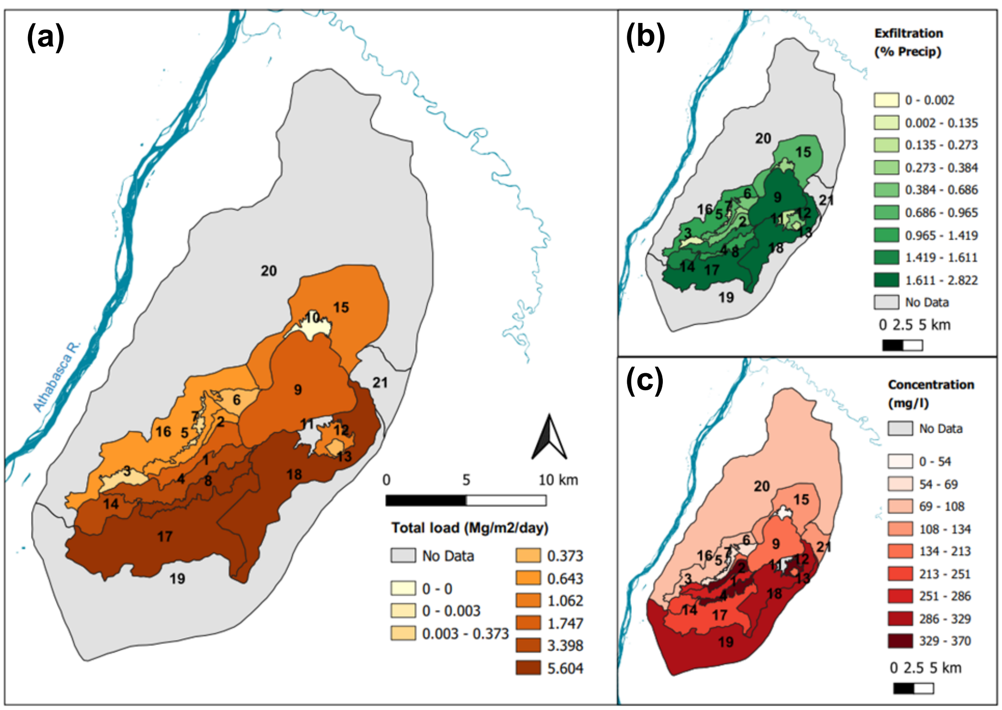
The initial conditions of the EFDC+ model scenarios applied to the MLWC watershed were based upon the observed data or a spin-up model to reduce the sensitivity of the model to initial conditions. The initial water level for all the cells in the EFDC+ model domain was based on the HGS simulated lake level. Since all the cells outside the lake were at a greater elevation than the set initial water level, they were defined as dry at the start of the simulation. Generally, these surface cells are more dynamic and go through the process of rapid wetting and drying with rain events, and there is no long-term effect to the results of setting these cells as dry. When the cells are dry, the concentration of water chemistry constituents in the cells is also set to zero.

4.0 MODEL SCENARIOS AND RESULTS

This section provides the purpose, setup, scenario details, and model performance results for each of the five (5) scenarios that were conducted in the EFDC+ model. It should be noted that results in the Baseline simulations for both McClelland Lake and the Patterned Fens are expressed as the raw 6-hourly data. The remaining plots for McClelland Lake and Patterned Fen results are expressed as 1-month moving averages to dampen the noise in the raw 6-hourly data, with the exception of operational scenario plots for McClelland Lake (footnotes confirm the data used in each plot).

As an initial point of comparison of the conceptual and numerical model, a simple assessment of the average exfiltration and observed TDS concentrations from each HRA was used to compute a spatial loading of TDS across the watershed. This is presented graphically in Figure 4.1 and shows greater exfiltration and TDS loadings at the HRAs within the southern portion of the MLWC watershed. This supports the conceptualization of water sources to the fen, suggesting that the Fort Hills Upland Complex contributes larger groundwater exfiltration volumes to the fen in comparison to the North Outwash Plains. TDS loadings and concentrations originating from the Fort Hills Upland Complex are therefore larger than those that originate from the North Outwash Plains.

Figure 4.1 Colour maps representing (a) relative total dissolved solids (TDS) loadings of each HRA; (b) relative groundwater exfiltration contributions of each HRA to lake inflows; and (c) relative TDS concentrations of each HRA within the McClelland Lake Wetland Complex Watershed.



4.1 BASELINE SCENARIO (1944 - 2019)

Description: Represent baseline conditions in the pre-mining/operation period of the MLWC watershed. Used to test whether the model is able to reproduce observed data collected in the watershed primarily from 2000 to 2020. Also used to establish/estimate water chemistry at boundary conditions for scenarios that use the non-mined model domain.

Simulation Period: 1944 to 2019

Model Domain: MLWC watershed.

Climate Forcing: Historical data from 1944 to 2019.

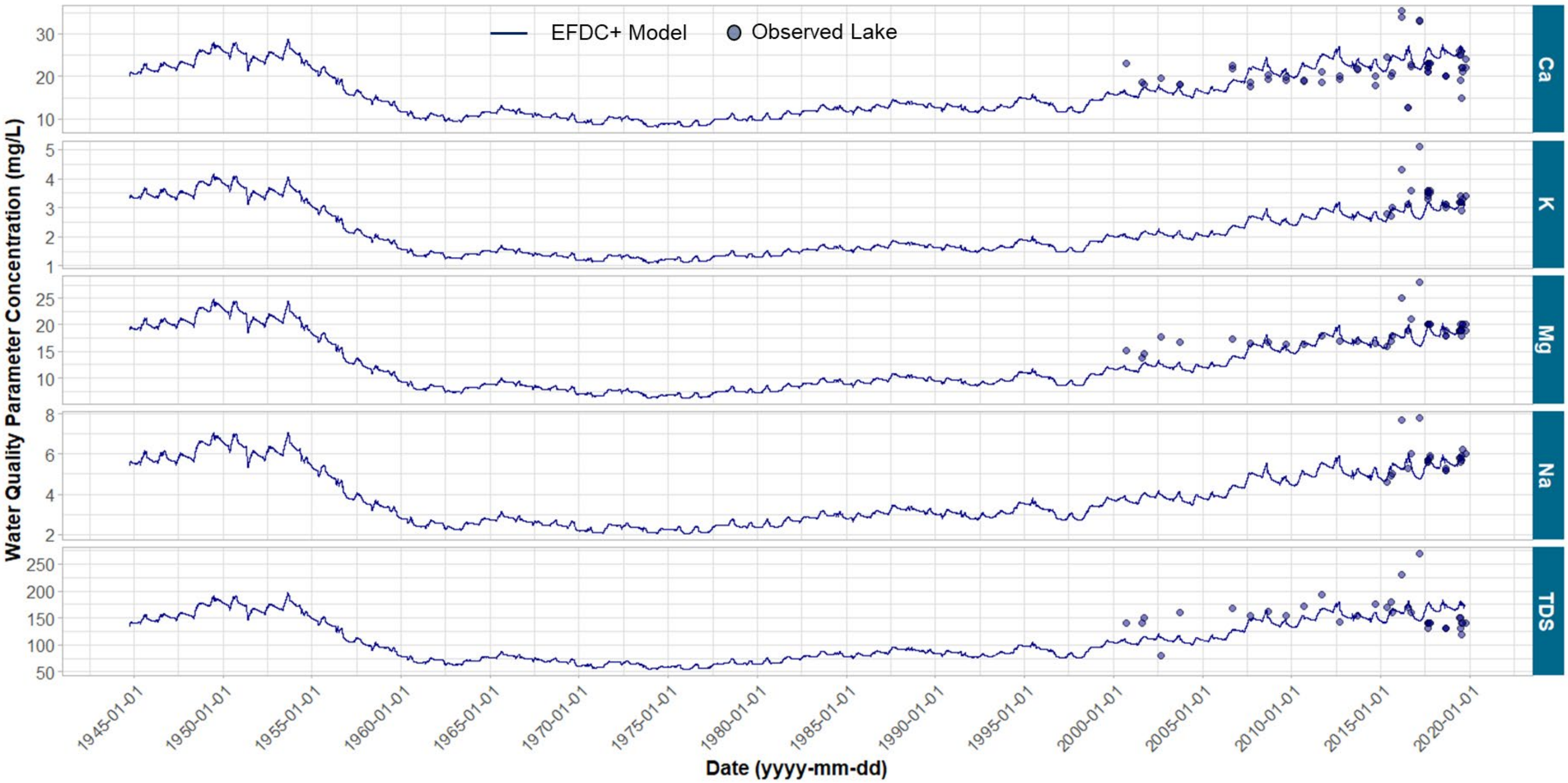
Boundary Conditions:

- Groundwater infiltration and exfiltration (Qgs) provided by HGS model.
- Lake outflow volume provided by HGS model.
- Water chemistry concentrations applied to exfiltration values are from observed near-surface water chemistry samples collected within each HRA.

4.1.1 McClelland Lake Water Chemistry Results

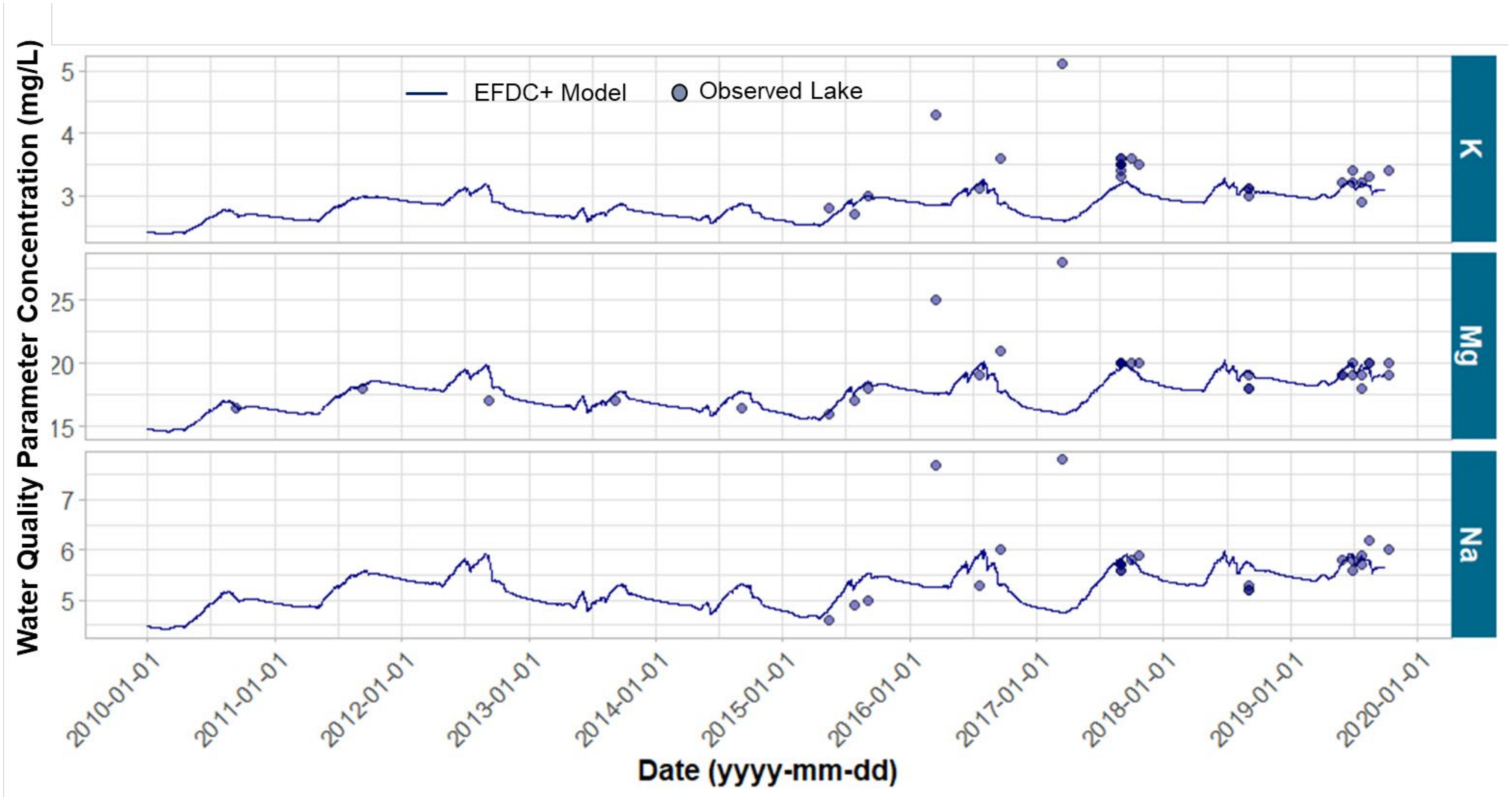
- Simulated lake water chemistry exhibits similar concentration ranges to observed water chemistry for all five water chemistry constituents (Ca, K, Mg, Na & TDS) (Figure 4.2).
- Simulated lake water chemistry follows seasonal variability that is similar in magnitude to observed data, especially seen in K, Mg, and Na (Figure 4.3), showing that the simulation results can represent seasonal processes driving the observed concentrations at McClelland Lake.
- Simulation results align with the current conceptual understanding of McClelland Lake and show that simulated water chemistry of McClelland Lake responds to wet and dry climatic periods:
    - Wet period (~1955 to 1995; Figure 3.2) shows decreased concentration from increased lake flushing of fresh rainwater and short residence time of water in the lake.
    - Dry period (~1995 to 2019; Figure 3.2) shows increasing concentration due to reduced lake flushing of fresh rainwater and increased evaporative enrichment.

Figure 4.2 Timeseries of simulated McClelland Lake concentrations from the EFDC+ Baseline scenario and observed field sample data.



Note: Darker points represent overlapping observed field sample data from McClelland lake. Using raw 6-hourly data.

Figure 4.3 **Timeseries (selected from 2010 to 2020) of simulated McClelland Lake concentrations from the EFDC+ Baseline scenario and observed field sample data.**



Note: Darker points represent overlapping observed field sample data from McClelland lake. Using raw 6-hourly data.

4.1.2 Patterned Fen North and South Water Chemistry Results

- There is large variability in the concentrations of water chemistry constituents across different areas and at different depths within the fen (Figure 4.4). The observed sample dataset was compiled from different studies with different purposes and geographic extents and are generally more representative of shallow groundwater or near-surface water chemistry (taken from shallow wells and boot wells; n = 148), and not true surface water (n = 6) (Figure 4.5).

- Fen water chemistry for both Patterned Fen North and South is simulated as surface runoff water and presents lower than the majority of observed near-surface sample data (Figure 4.6). However, as noted, observed data generally includes shallow well and bootwell samples that are more representative of shallow groundwater or near surface water chemistry and do not represent the surface water chemistry the EFDC+ model is simulating (Figure 4.4; Figure 4.5; Figure 4.6).

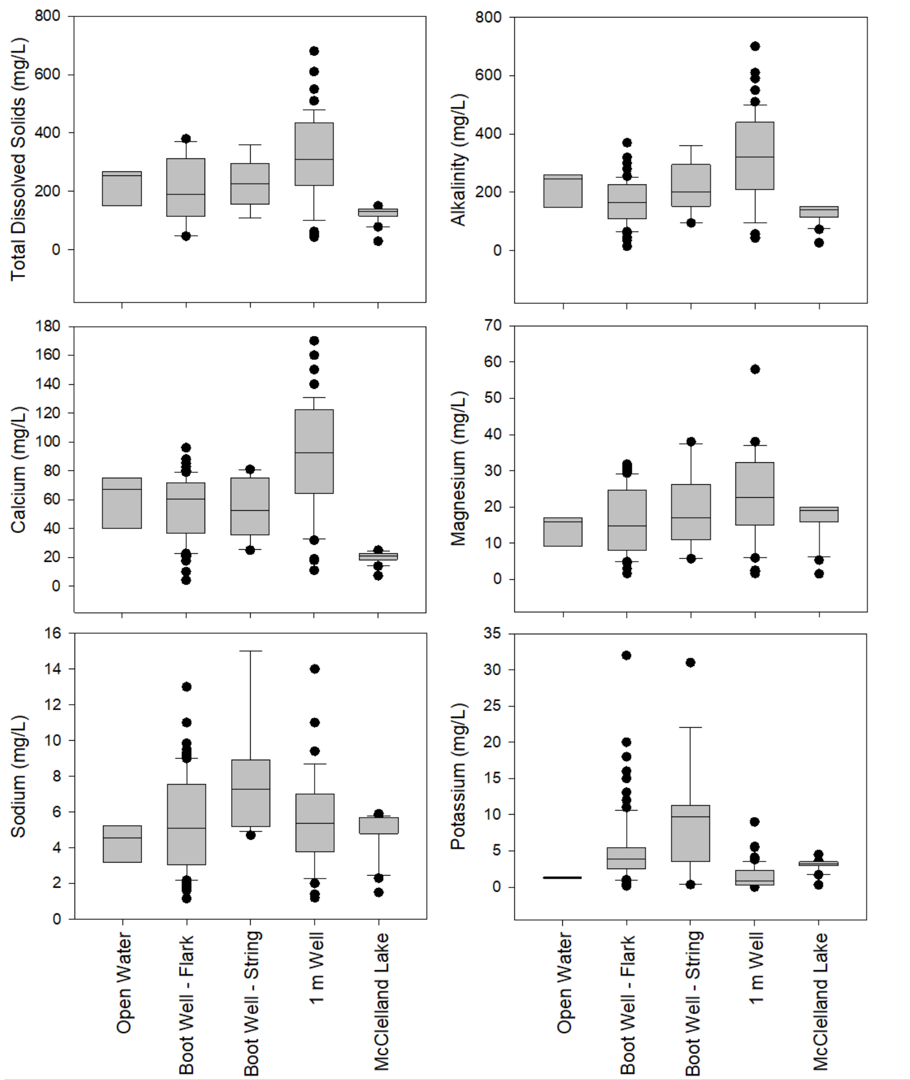
- Subsampling the observed data to only present open water samples collected in the Patterned Fen shows better alignment to the simulated fen water chemistry results, and are considered a better representation of the surface runoff simulated in the EFDC+ model (Figure 4.7). The EFDC+ model used in this phase of modelling is only a transport model and no reactive processes were included in the simulation, which is why the simulated water chemistry constituents for Ca and TDS deviate from the simulated results due to the biogeochemical processing (i.e., reactive behaviour) of Ca and therefore TDS were not being captured in the simulated data.

- During dry periods and with larger exfiltration events from the HGS model fen water concentration results are at a similar range to observed near-surface water concentrations (Figure 4.6).

- Water volume in the MLWC is conceptualized to be approximately ten (10) parts precipitation to one (1) part exfiltrated water and simulated fen concentration are on average an order of magnitude lower than observed/exfiltrated concentrations supporting this conceptualization.

- Patterned Fen South concentrations are generally higher than Patterned Fen North concentrations (Figure 4.6). This is due to the Fort Hills supplying water to the Patterned Fen South and being richer in dissolved ions compared to the North Outwash Plains (NOP) which supplies more ombrogenic water to the Patterned Fen North. This pattern supports the conceptual model of the water sources and major ion loadings.

Figure 4.4 Boxplots showing water chemistry results from field samples collected from 2009 to 2019



Open Water: free water sampled in the fen by Isobrine in 2009-2010 (n=6)

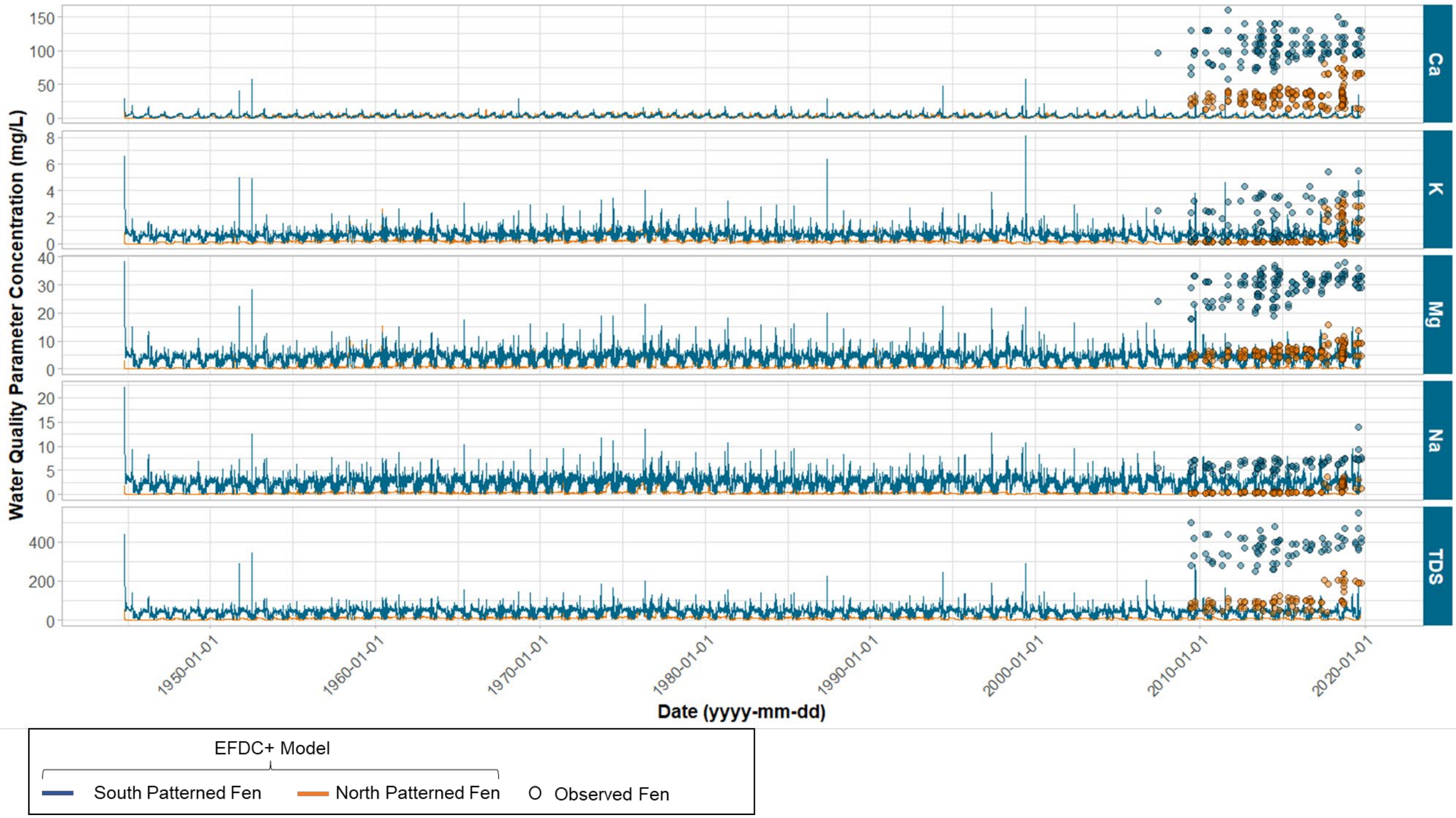
Bootwell Flark: assumed free water sample collected from flark by InnoTech 2017-2018 (n= 82)

Bootwell String: String water sample may have required some shallow digging by InnoTech 2017 (n=14)

1 m Well: Water sample collected from a 1 m below the fen surface by Isobrine 2009-2010 (n=9) and InnoTech 2018-2019 (n=52)

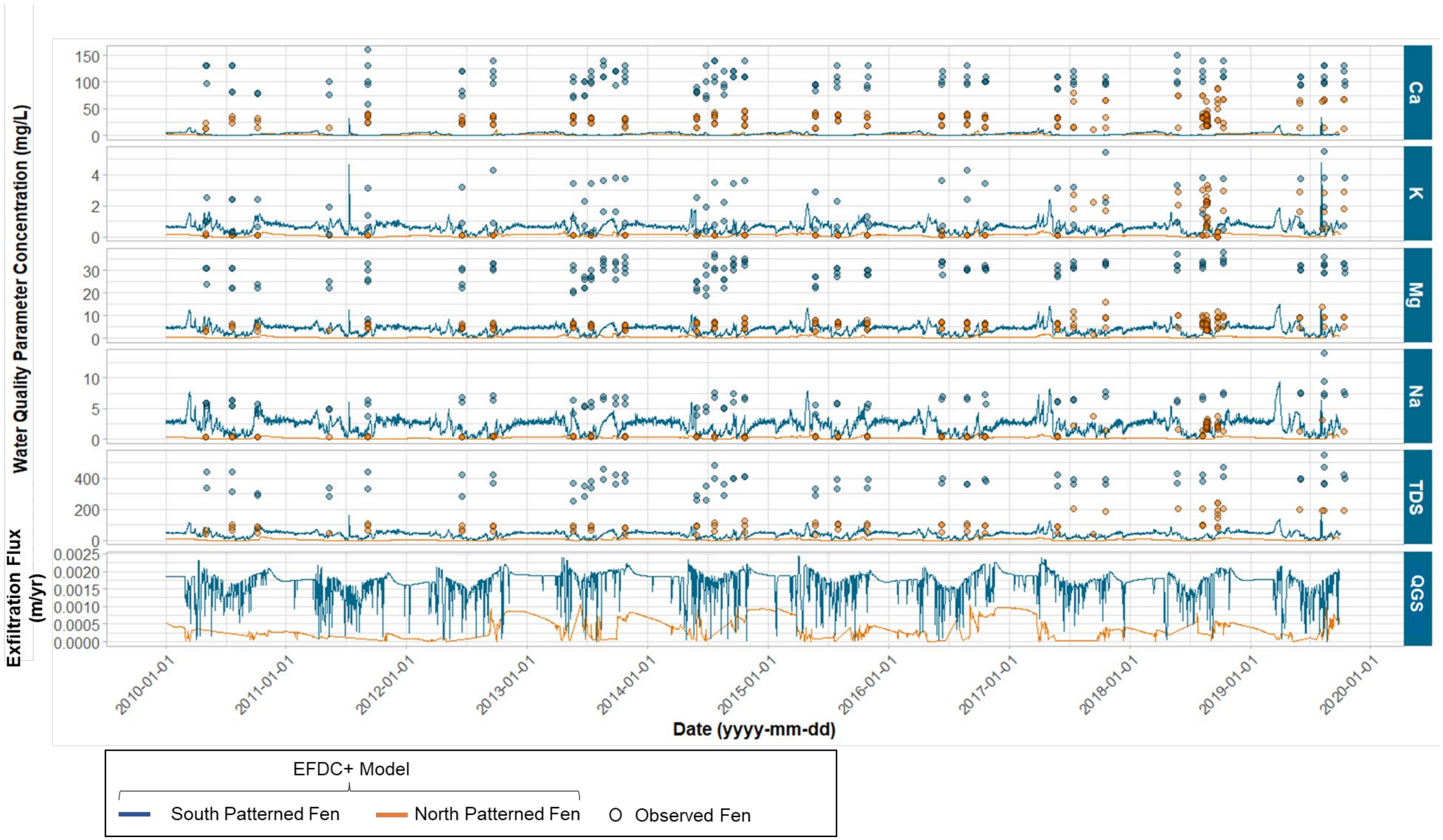
McClelland Lake: surface water samples collected by InnoTech 2017-2019 (n=25)

Figure 4.5 Timeseries of simulated McClelland Lake Wetland Complex Patterned Fen North and South concentrations from the EFDC+ Baseline scenarios and observed field sample data.



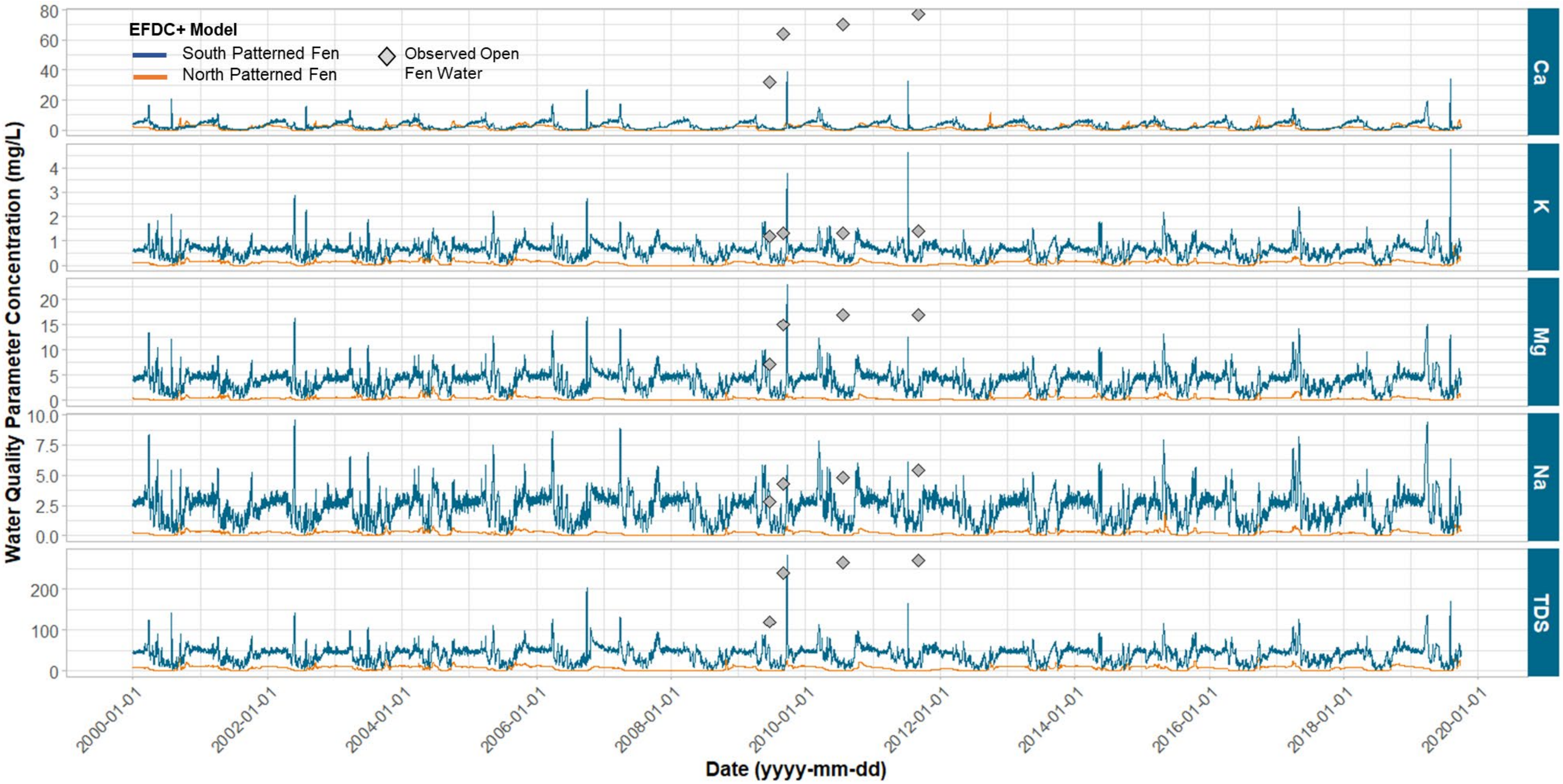
Note: Darker points represent overlapping observed field sample data from McClelland lake. Using raw 6-hourly data.

Figure 4.6 **Timeseries (selected from 2010 to 2020) of simulated concentrations and exfiltration fluxes in the North and South Patterned Fen from the EFDC+ Baseline scenario and observed field sample data.**



Note: Using raw 6-hourly data.

Figure 4.7 Timeseries (selected from 2000 to 2020) of simulated concentrations in the North and South Patterned Fen from the EFDC+ Baseline scenario and observed field sample data collected from open water areas in the Patterned Fen.



Note: Using raw 6-hourly data.

4.2 OPERATIONAL SCENARIO (2015 TO 2065)

Description: S1 simulates conditions during the mining/operational period that includes mitigation/resupply water and groundwater injection. R0 is intended to represent a baseline simulation that can be compared to the S1 simulation. The R0 simulation uses the same climate, geographic extent, and the same infiltration and exfiltration as S1 but uses values from the baseline simulation to represent conditions with no mining/operations.

Simulation Period: 2015 to 2065

Model Domain: Non-mined portion of MLWC watershed, east of the cutoff wall alignment.

Climate Forcing: 1993 to 2019 (25 years) looped twice and repeats at 2040.

Boundary Conditions:

- Groundwater infiltration and exfiltration provided by HGS model.
- Lake outflow volume provided by HGS model.
- Surface flow at the cutoff wall alignment and South creek provided by HGS model.
- Water chemistry concentrations applied to exfiltration values are from observed near-surface water chemistry samples collected within each HRA.
- Seasonal average water chemistry concentrations at the cutoff wall alignment and South Creek were derived from water chemistry concentrations applied to exfiltration values (described above) for the whole watershed and computed at these locations with the Baseline scenario model.

4.2.1 McClelland Lake Water Chemistry Results

- Generally, simulated lake water chemistry concentrations between the R0 (no development) and S1 (water resupply) scenarios show the same trends and magnitudes of concentration over time (Figure 4.8; Figure 4.9; Figure 4.10).
- There is major variation in concentrations due to climatic variability through wet and dry cycles (Figure 4.8; Figure 4.9; Figure 4.10).
- S1 concentrations are slightly lower compared to the R0 concentrations, which is a result of the resupply water volumes. However, the shift in the magnitude of concentration observed in S1 due to resupply water is relatively small compared to the long-term trend caused by natural variability that is driven by wet and dry cycles (Figure 4.10).
- The simulation shows that the increase in concentration from relatively dry climatic forcing from 2030 to 2037 of the simulation is reduced during the wetter period from ~2037 to 2047 (Figure 4.10).

Figure 4.8 Timeseries of simulated McClelland Lake concentrations from the EFDC+ R0 operational scenario.

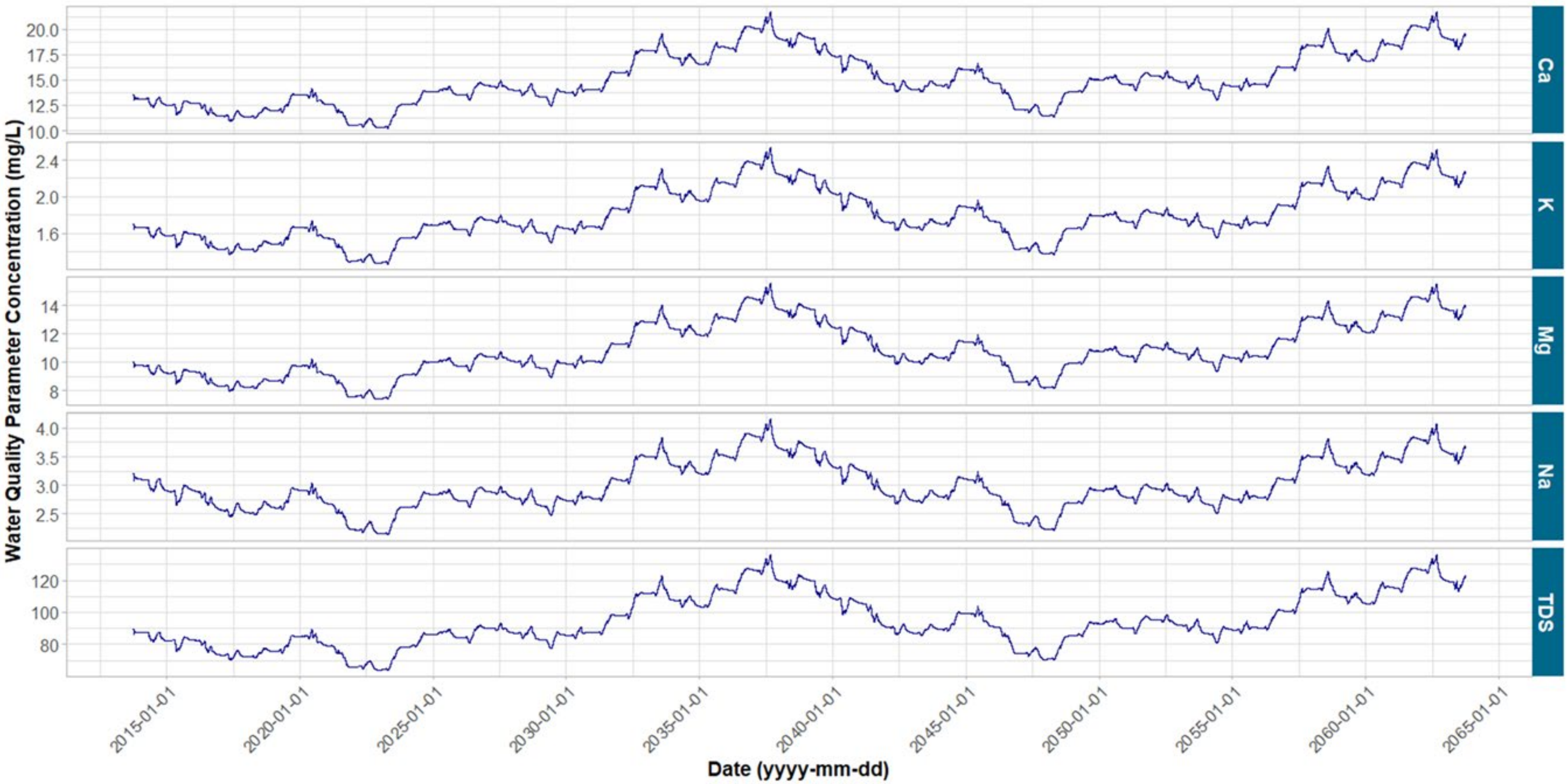


Figure 4.9 Timeseries of simulated McClelland Lake concentrations from the EFDC+ S1 operational scenario.

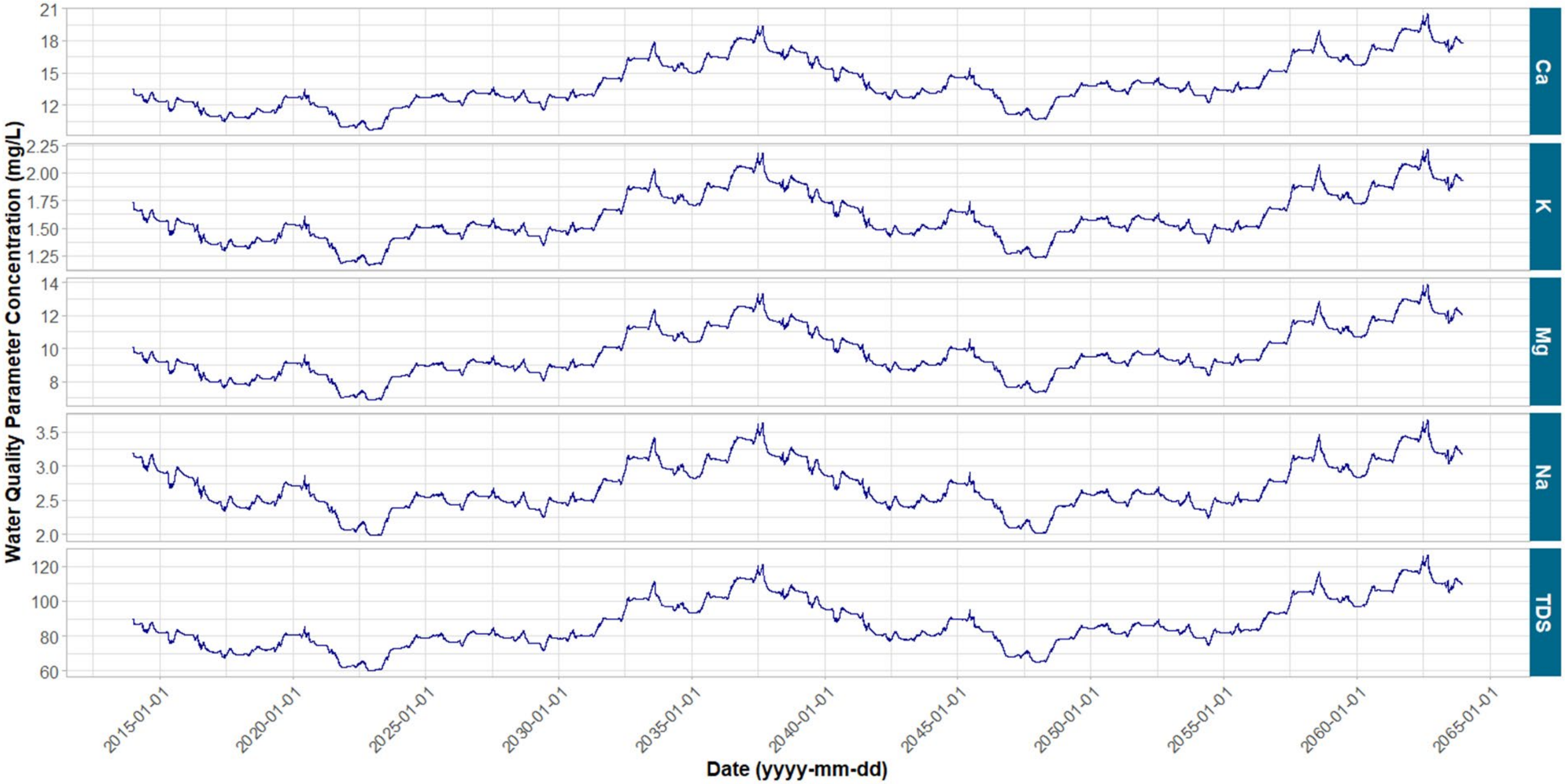
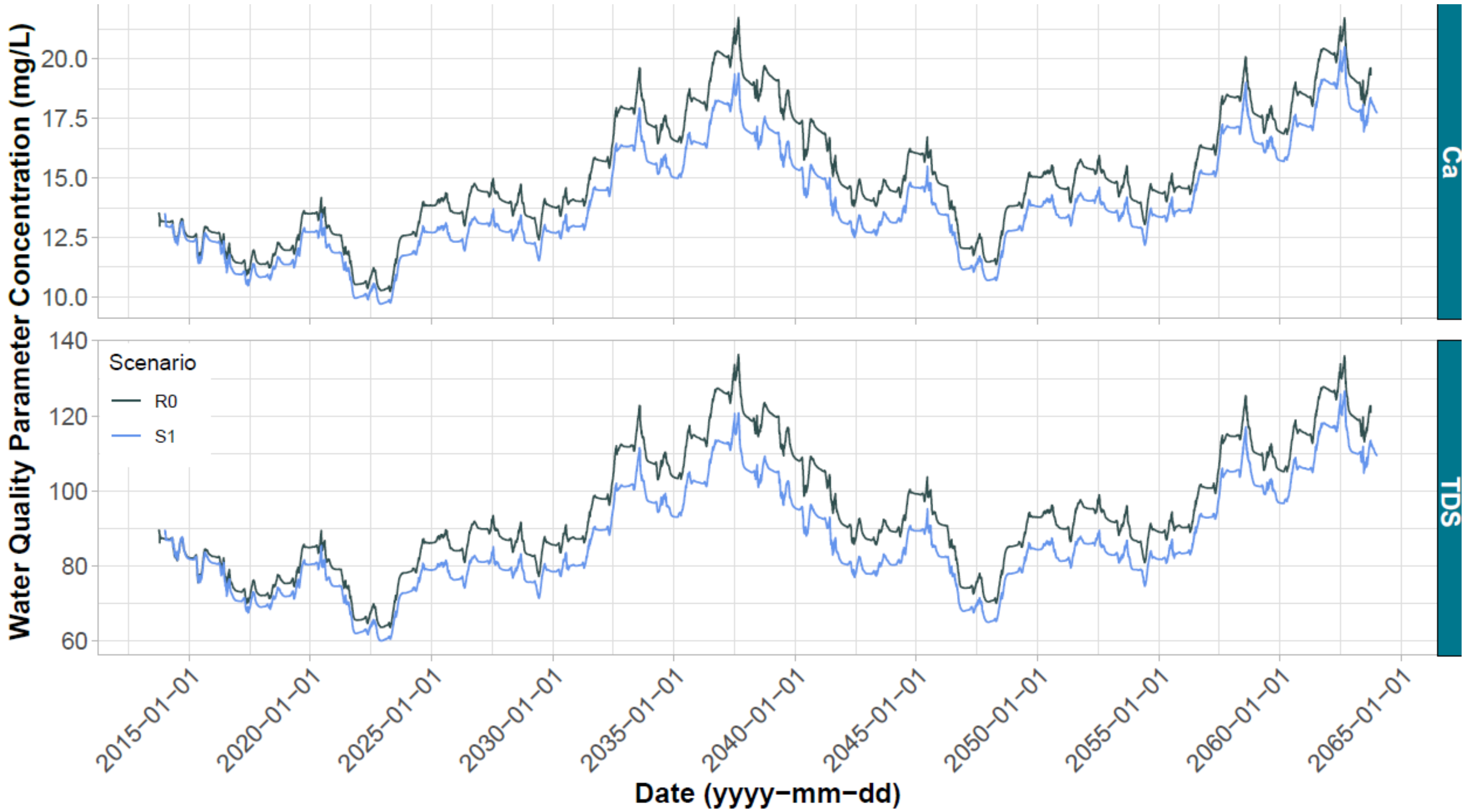


Figure 4.10 Timeseries of simulated McClelland Lake concentrations from the EFDC+ Operational scenarios.



Note: Using raw 6-hourly data.

4.2.2 Patterned Fen North and South Water Chemistry Results

- Overall simulated fen water concentration results don't appear to differ substantially between the R0 and S1 simulations for either water chemistry constituents (Figure 4.11; Figure 4.12; Figure 4.13).

- Simulated fen concentrations for Operational Scenarios R0 and S1 show that concentrations between the Patterned Fen North and South have more similar magnitudes compared to the Baseline simulation results where the Patterned Fen North presents as more dilute compared to the Patterned Fen South (Figure 4.5 and Figure 4.6). This pattern is a result of the combination of using the smaller model domain resulting in a reduced fen area and the large amount of low concentration surface water (flow and concentration) that is added at this smaller fen area downstream of the cutoff wall both resulting in diluting the Patterned Fen South more than in the Baseline simulation.

Figure 4.11 Timeseries of simulated patterned fen concentrations from the EFDC+ R0 Operational scenario.

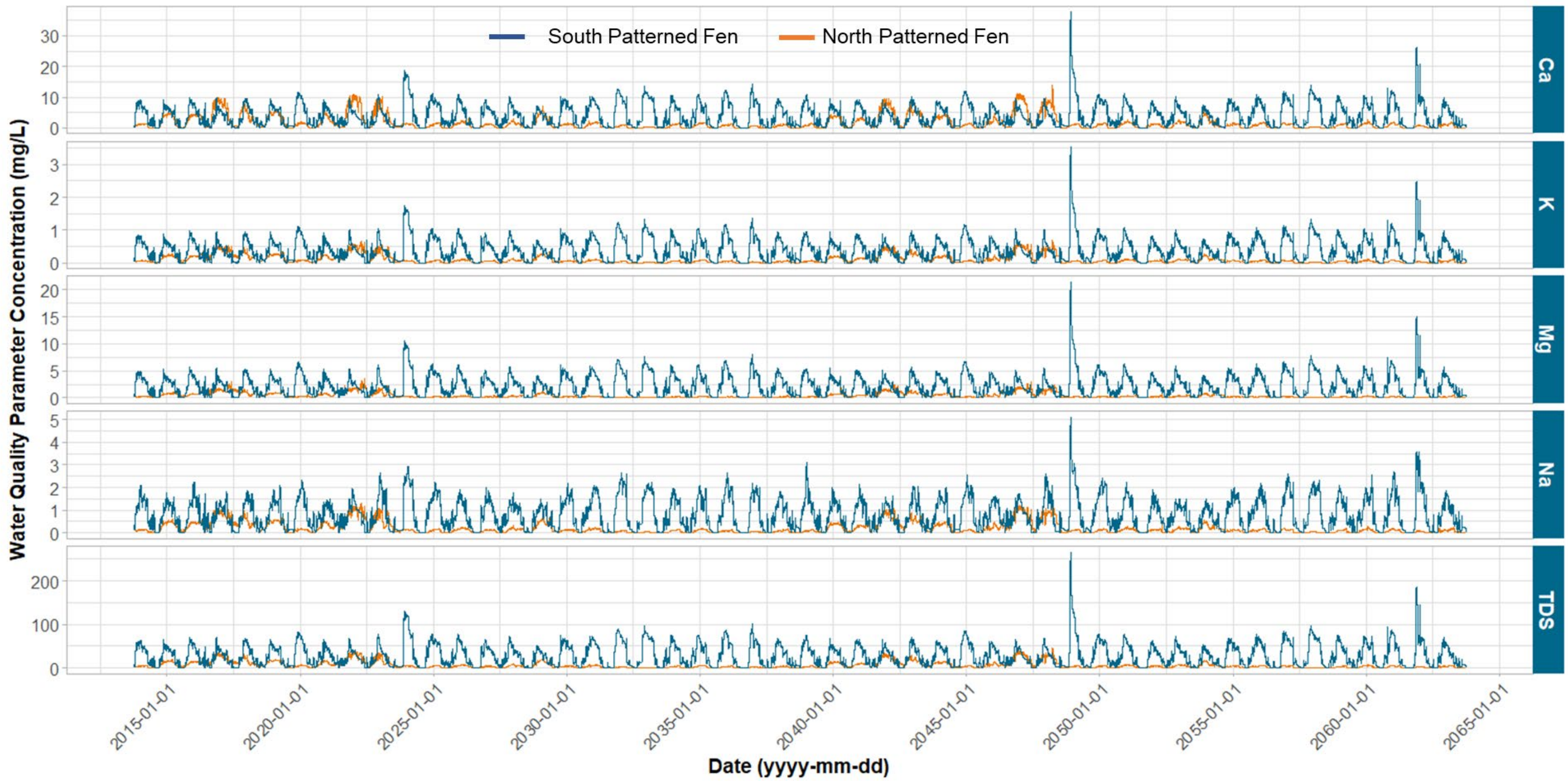


Figure 4.12 Timeseries of simulated patterned fen concentrations from the EFDC+ S1 Operational scenario.

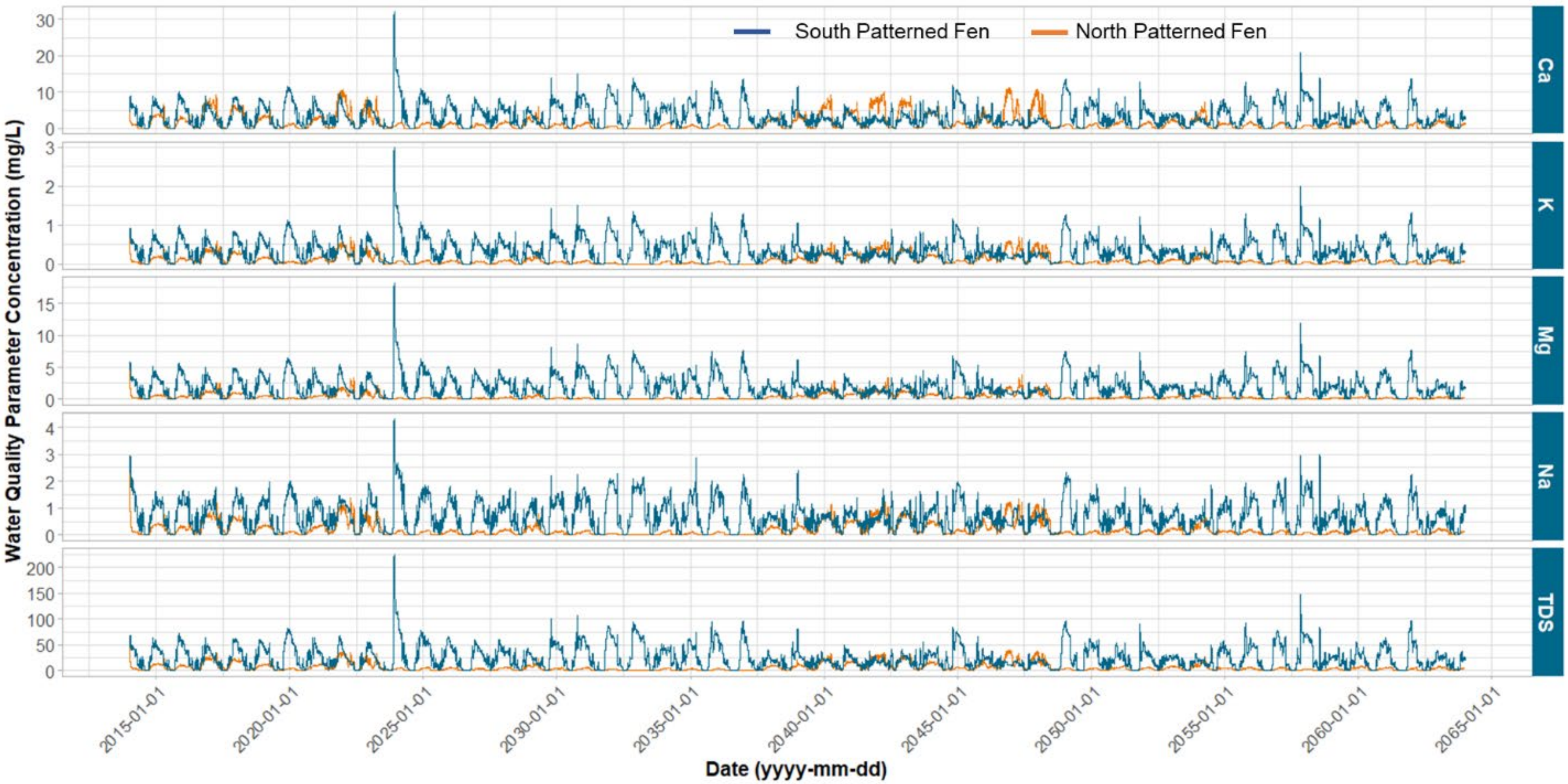
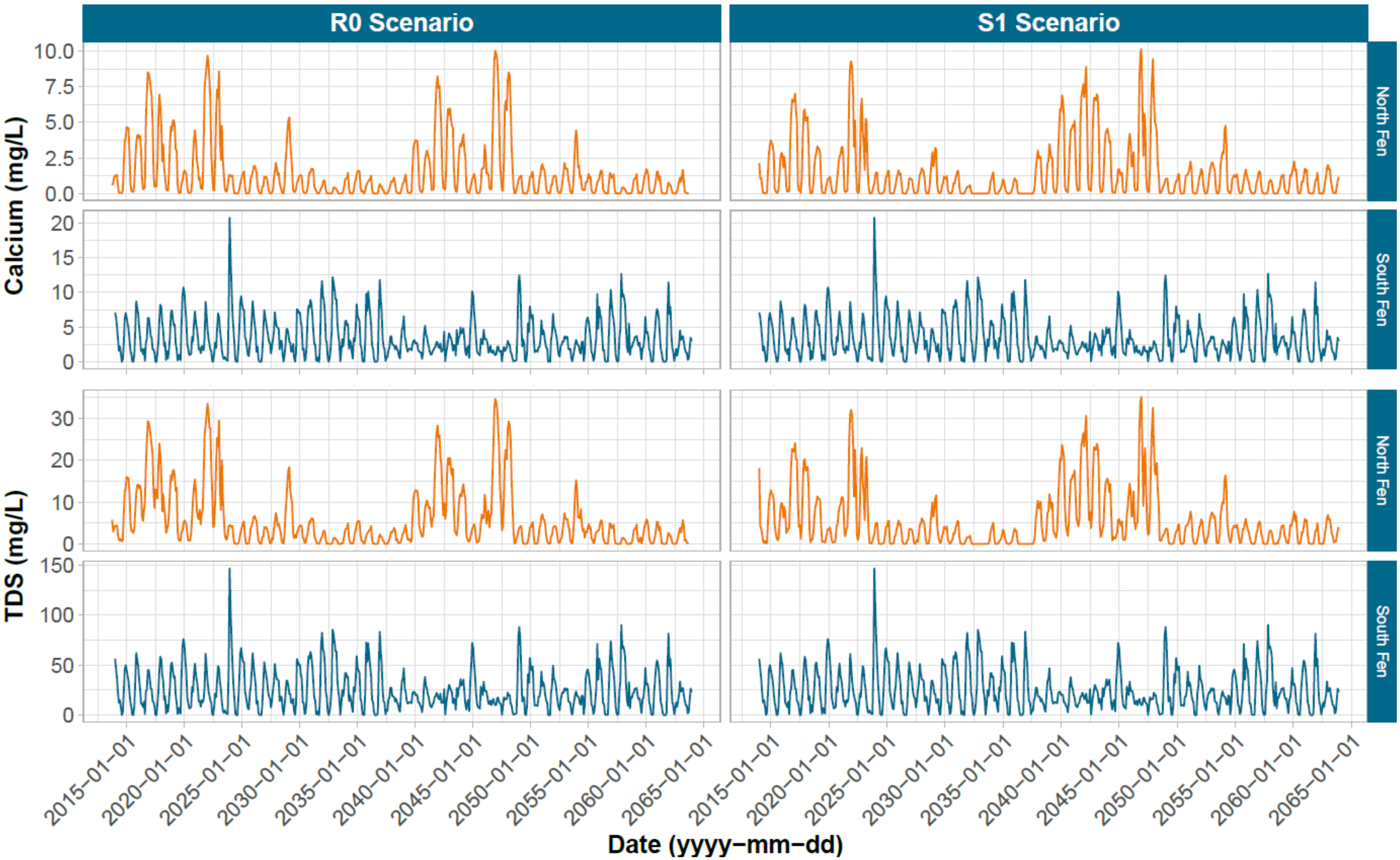


Figure 4.13 Timeseries of simulated McClelland Lake Wetland Complex Patterned Fen North and South concentrations from the EFDC+ Operational scenarios.



Note: Using 1-month moving average data.

4.3 ACTIVE CLOSURE SCENARIO (2075 TO 2100)

Description: Simulates period from end of mine life, while closure is being conducted, and closure conditions are stabilizing.

Simulation Period: 2075 to 2100

Model Domain: Non-mined portion of MLWC watershed, east of the cutoff wall alignment.

Climate Forcing: Julian calendar day average values for 1944 to 2019, repeated for each year of the 25-year simulation.

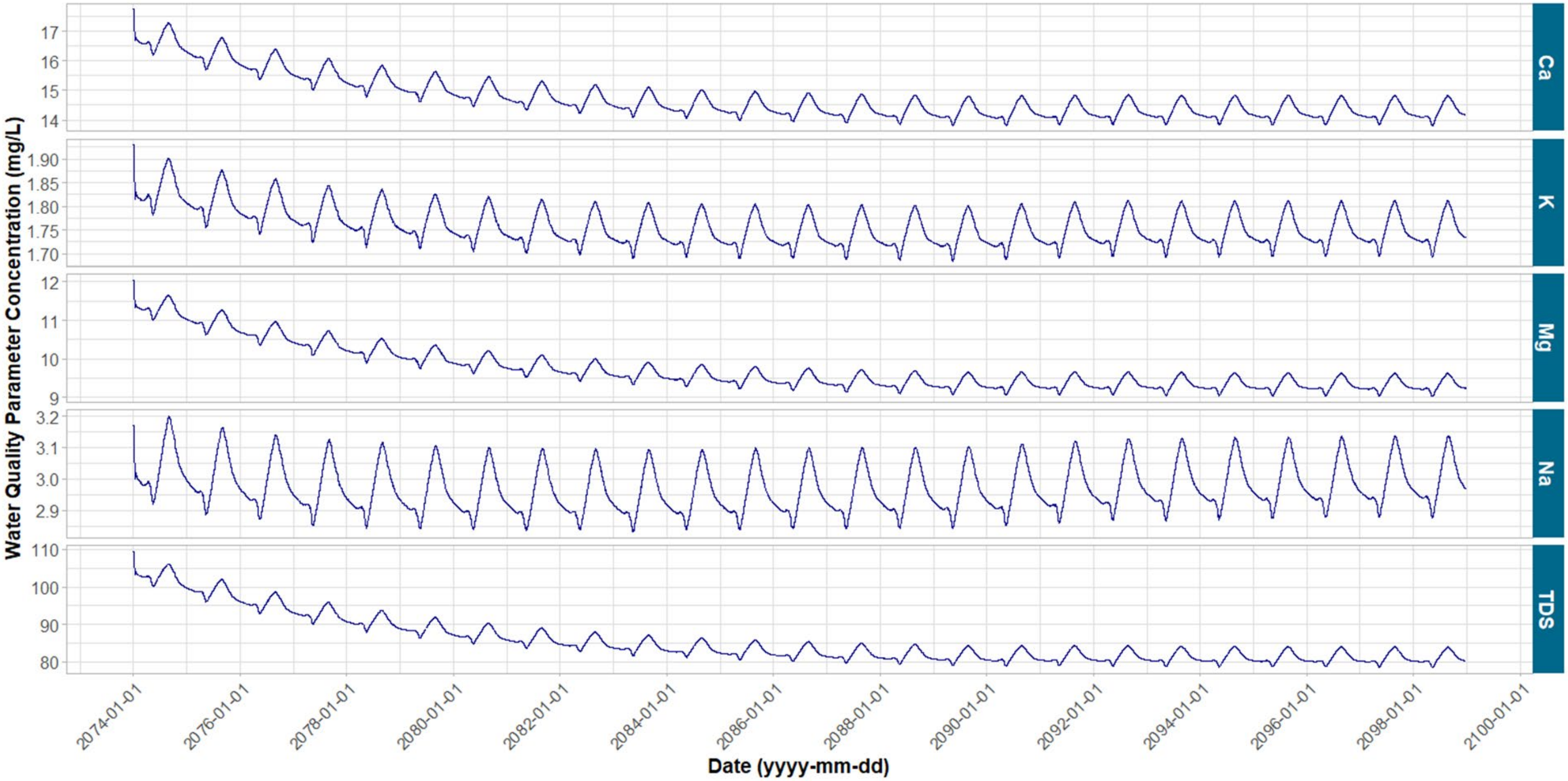
Boundary Conditions:

- Groundwater infiltration and exfiltration provided by HGS model.
- Lake outflow volume provided by HGS model.
- Surface flow at the cutoff wall alignment and South creek provided by HGS model.
- Water chemistry concentrations applied to exfiltration values are from observed near-surface water chemistry samples collected within each HRA.
- Seasonal average water chemistry concentrations at the cutoff wall alignment and South Creek were derived from water chemistry concentrations applied to exfiltration values (described above) for the whole watershed and computed at these locations with the Baseline scenario model.

4.3.1 McClelland Lake Water Chemistry Results

- Simulated lake water chemistry concentrations for the Active Closure scenario present the same annual pattern over time, as would be expected from the annually repeating climate condition (Figure 4.14).
- Overall, there is a downward trend for both Ca and TDS for the first 15 years of the simulation and a generally stable annual trend in concentration for the remainder of the simulation.
- This pattern indicates that the precipitation for the scenario was wetter than average, and the initial concentration condition of the model set at the end of the S1 simulation is reduced over time and the model stabilized on what would be the new normal condition for the applied climate condition.

Figure 4.14 Timeseries of simulated McClelland Lake concentrations from the EFDC+ active closure scenario.



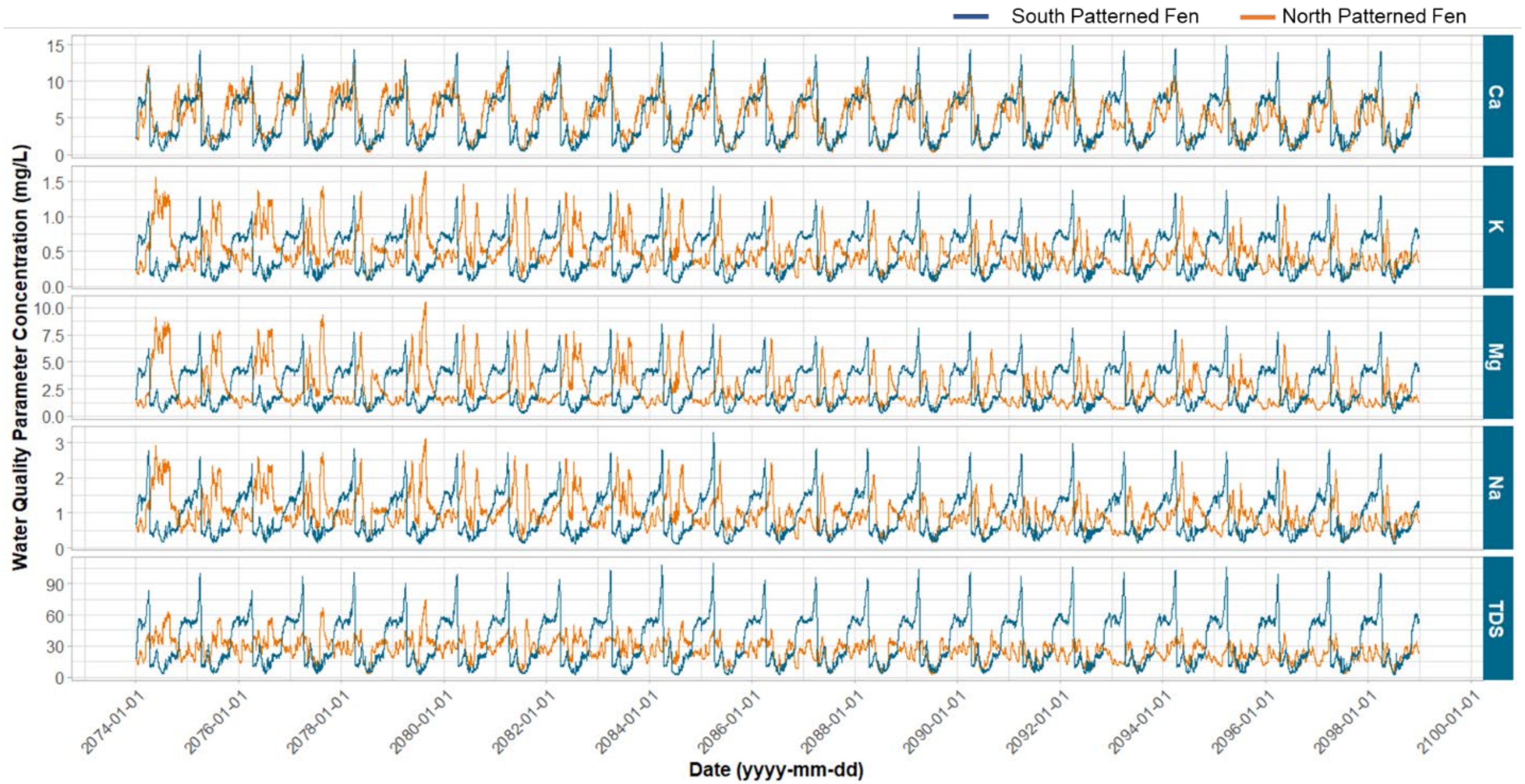
Note: Using 1-month moving average data.

4.3.2 Patterned Fen North and South Water Chemistry Results

Simulated fen water chemistry concentrations for the Active Closure scenario presents generally the same annual pattern over time for both the Patterned Fen North and South, as would be expected from the annually repeating climate condition (Figure 4.15).

- Overall, the results appear to be stable over time with a slight downward trend in concentration throughout the simulation, which is more apparent in the Patterned Fen North results.
- Simulated fen concentrations for the Active Closure Scenario show that concentrations between the Patterned Fen North and South have more similar concentrations compared to the Baseline simulation results where the Patterned Fen North presented as more dilute compared to the Patterned Fen South (Figure 4.5). The reason for this result is the influence of low concentration flow across the cutoff wall boundary combined with the smaller model domain used in the Active Closure Scenario, which appears to have a stronger influence on the Patterned Fen South water chemistry compared to the Patterned Fen North.

Figure 4.15 Timeseries of simulated McClelland Lake Wetland Complex Patterned Fen North (FN) and South (FS) concentrations from the EFDC+ Active Closure scenarios.



Note: Using 1-month moving average data.

4.4 FAR FUTURE CLOSURE SCENARIO (2100 TO 2175)

Description: Simulates conditions in the far future scenario, where closure landscape has stabilized and no water resupply is required. The reclaimed portion of the watershed is smaller compared to the pre-mining watershed and will result in reduced natural flow to the non-mined portion of the watershed. This model scenario simulates if the reduced flow to the fen and McClelland Lake has an impact on the non-mined portion of the watershed. Because this simulation uses the same climate forcing as the baseline scenario, the Far Future Closure and Baseline scenarios can be compared.

Simulation Period: 2100 to 2175 (75 years)

Model Domain: Non-mined portion of MLWC watershed, east of the cutoff wall alignment.

Climate Forcing: Historical data from 1944 to 2019.

Boundary Conditions:

- Groundwater infiltration and exfiltration provided by HGS model.
- Lake outflow volume provided by HGS model.
- Surface flow at the cutoff wall alignment and South creek provided by HGS model.
- Water chemistry concentration applied to the infiltration and exfiltration values from observed water chemistry samples collected within each HRA.
- Seasonal average water chemistry concentrations at the cutoff wall alignment and South Creek were derived from water chemistry concentrations applied to exfiltration values (described above) for the whole watershed and computed at these locations with the Baseline scenario model.

4.4.1 McClelland Lake Water Chemistry Results

- The Far Future Closure simulation, similar to the Baseline simulation, shows that during the wetter period in the early part of the simulation the lake concentration reduces while the drier conditions in the later part of the simulation result in increasing concentrations. (Figure 4.16; Figure 4.17)
    - However, it should be noted that simulated lake water concentrations for Baseline and Far Future Closure scenarios follow more similar patterns during the relatively wet climate forcings (Baseline: 1955 – 1995; Far Future: 2110 - 2150) and deviate from each other during drier climate forcings (i.e., Baseline: 1945 – 1955 and 1995 – 2020; Far Future: 2100 – 2110 and 2150 - 2175).
    - In general, the Far Future Closure scenario lake concentrations are dampened compared to the Baseline simulation (Figure 4.17). This is caused by the influence of boundary condition at the former cutoff wall combined with the smaller model domain used in the Far Future Closure Scenario.

Figure 4.16 Timeseries of simulated McClelland Lake concentrations from the EFDC+ far-future closure scenario.

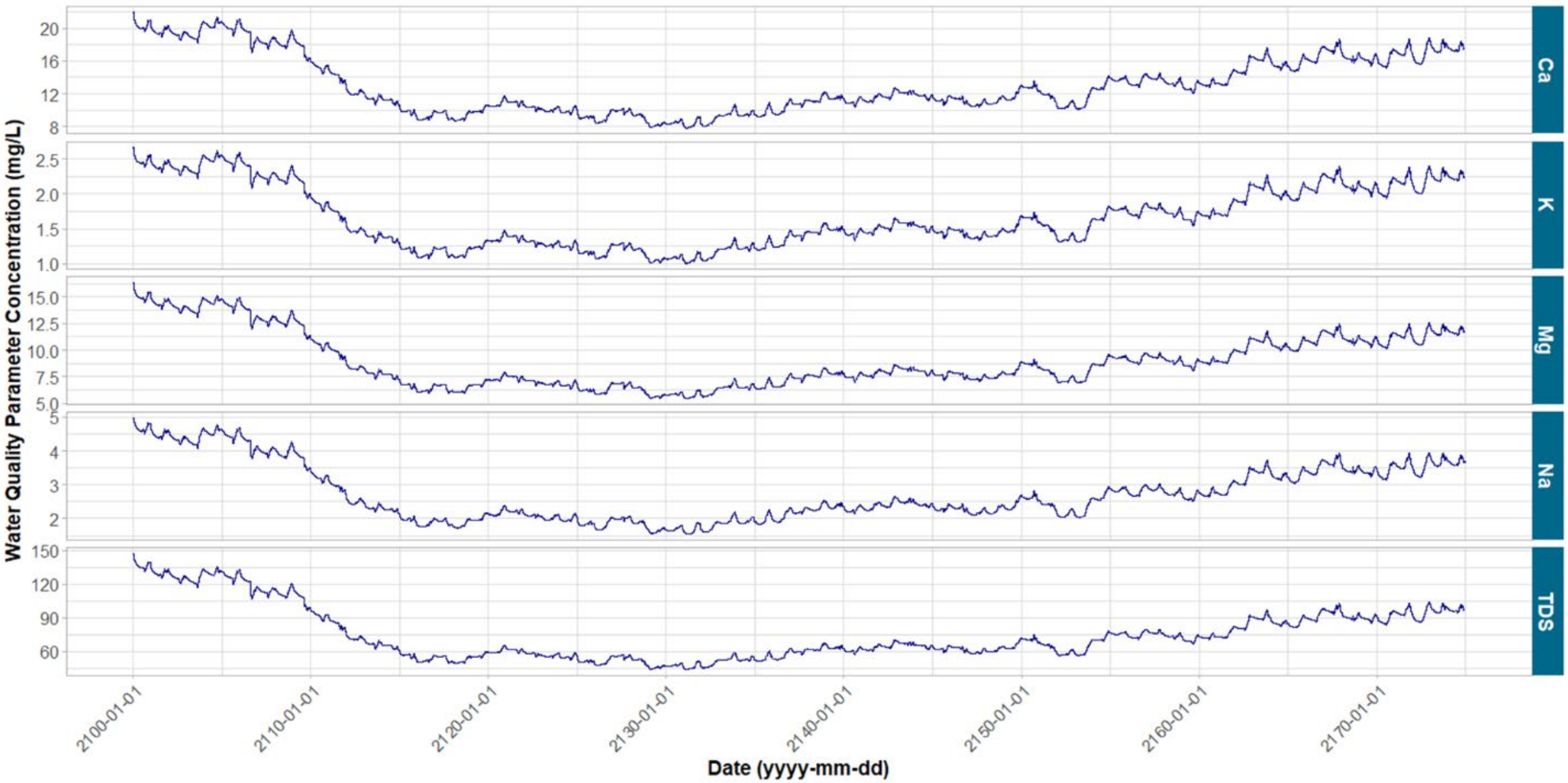
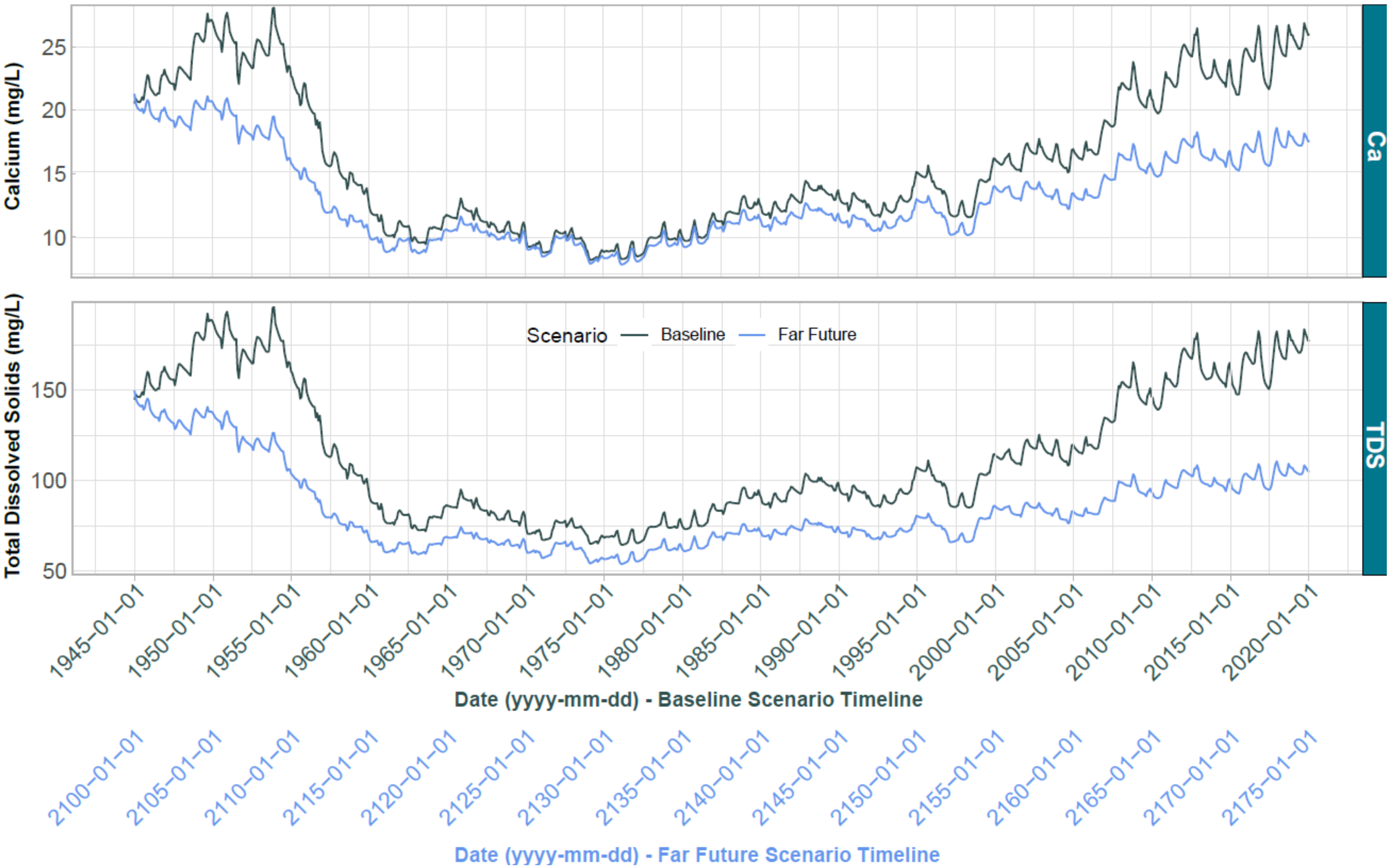


Figure 4.17 Timeseries of simulated McClelland Lake concentrations from the EFDC+ Baseline and Far Future Closure scenarios.



Note: Using 1-month moving average data.

4.4.2 Patterned Fen North and South Water Chemistry Results

- Overall simulated fen concentration results for the Far Future Closure Scenario are in the same general range of water chemistry constituent concentrations between the Baseline and Far Future Closure scenarios, however Ca concentrations are higher for both Patterned Fen North and South in the Far Future Closure scenario (Figure 4.18; Figure 4.19).

- Simulated fen concentrations for the Far Future Closure Scenario show that concentrations between the Patterned Fen North and South have more similar concentrations compared to the Baseline simulation results (where the Patterned Fen North presented as more dilute compared to the Patterned Fen South (Figure 4.19)). This is caused by the influence of boundary condition at the former cutoff wall combined with the smaller model domain used in the Far Future Closure Scenario. This boundary condition has an effect on the Far Future Closure simulation fen results where the natural processes that are present are diluted by the fresh nature of the boundary condition flow volumes, thus reflecting similar water chemistry signatures between the Patterned Fen North and South.

Figure 4.18 Timeseries of simulated patterned fen concentrations from the EFDC+ Far Future Closure scenario.

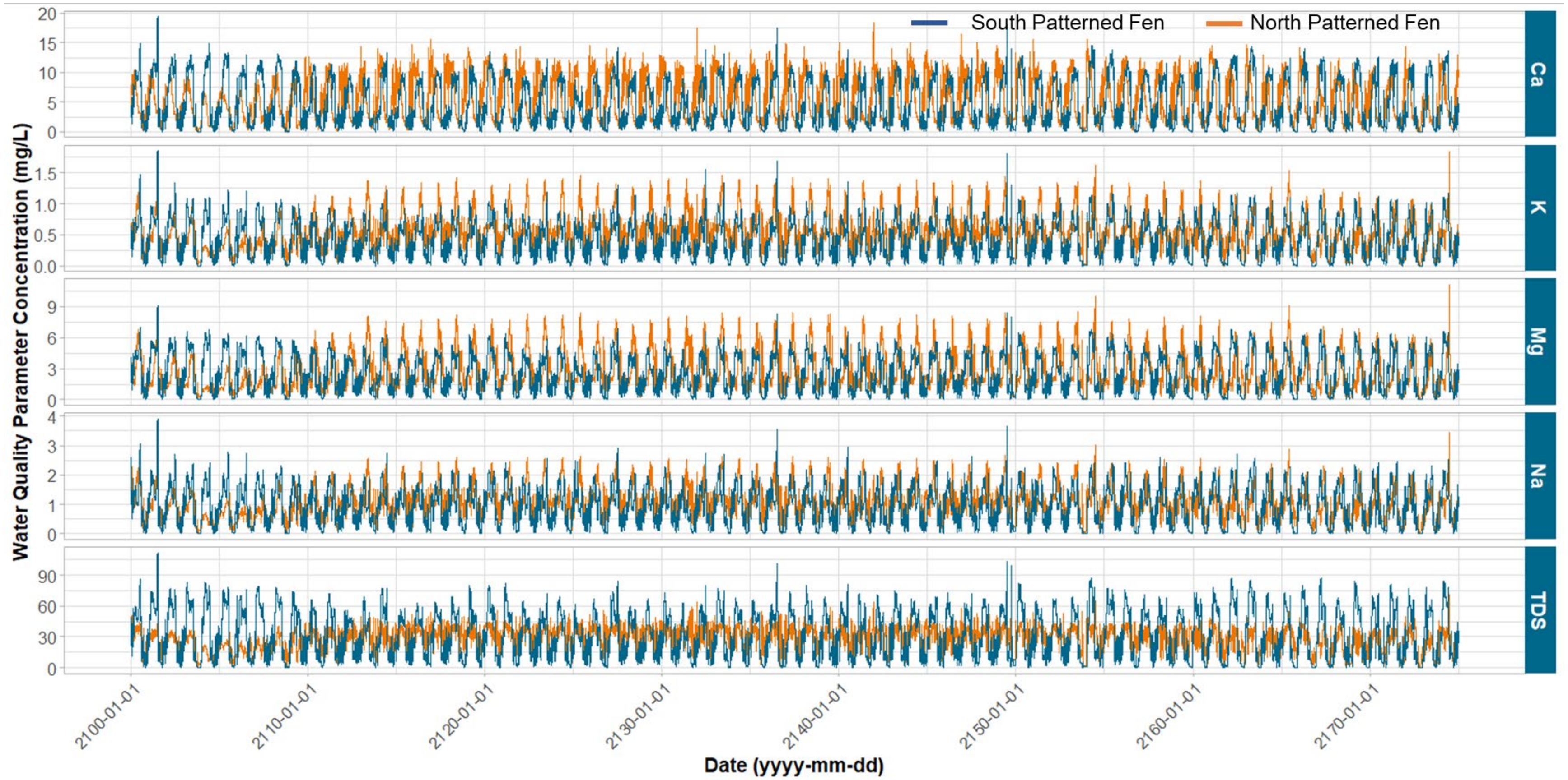
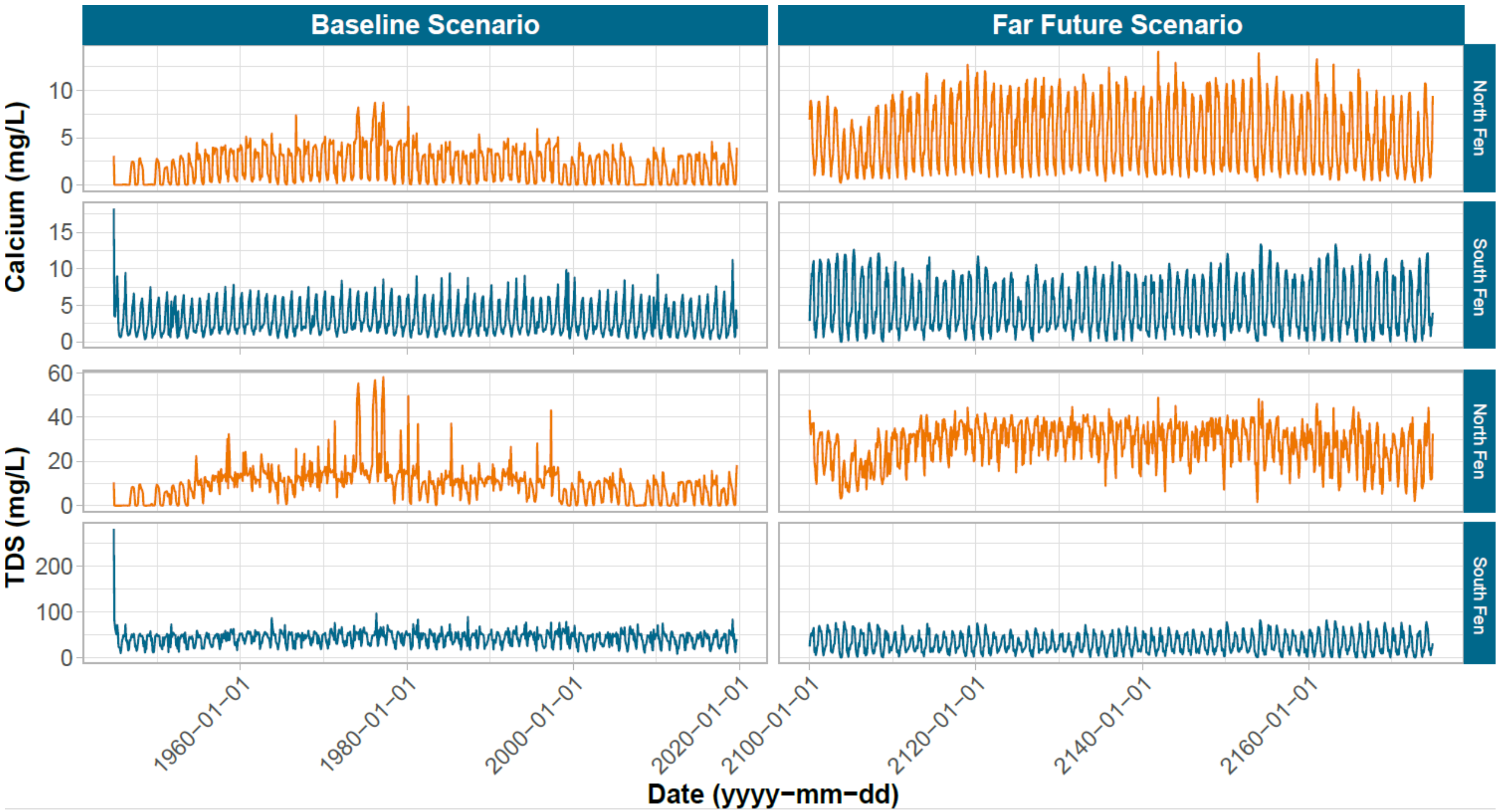


Figure 4.19 Timeseries of simulated McClelland Lake Wetland Complex Patterned Fen concentrations North (FN) and South (FS) from the EFDC+ Baseline and Far Future Closure scenarios.



Note: Using 1-month moving average data.

5.0 SUMMARY & KEY FINDINGS

The conceptual model development and numerical modelling results outlined in this report provides an important first step in the modelling of water chemistry within the MLWC watershed. This work builds on numerous studies and modelling efforts conducted by Suncor, InnoTech Alberta, Aquanty, DSI, and Hatfield. Modelling of water chemistry of the MLWC watershed is required to evaluate the ability of the water resupply strategy to maintain water level and water chemistry conditions in the non-mined portion of the MLWC watershed.

Overall, these modelling efforts were an important first step in evaluating the ability of a simplified numerical model (only non reactive constituents) to simulate the surface water chemistry conditions in the non-mined portion of the MLWC watershed, specifically:

- Climate variability (i.e., wet and dry periods) is the primary driver for water chemistry changes in McClelland Lake and able to be simulated across the scenarios.
- Lake water chemistry conditions were generally able to be represented by the EFDC+ model in the Baseline scenario, including intra-annual observed lake water chemistry variations, which were able to be simulated for most of the five modelled constituents.
- The EFDC+ model was able to simulate water chemistry in the Patterned Fen for flowing surface water. However, it should be noted that comparisons of simulated Patterned Fen results to observed near-surface water chemistry samples is not a valid assessment of the model performance since the EFDC+ model simulates chemistry of flowing surface water and there are limited true surface water samples to compare simulated results with. Of the few true surface water samples available, there is better alignment with the simulated Patterned Fen results, suggesting that the Patterned Fen modelled results are a reasonable first step and should be compared with a larger true surface water dataset. Additionally, the simulated lake water chemistry matched the smapled data quite closely and suggests that the model was aple to represent the runoff from the fen system quite well.
- The pattern of concentration between the Patterned Fen North and South represented the water source conceptualization (Patterned Fen North – suppled by dilute NOP; Patterned Fen South – supplied by enriched FHUC), suggesting that the underlying hydrologic processes are able to be represented and future work can improve these results.
- The integration of the HGS and EFDC+ models was acheived and with further refinement of this linkage approach a reduce uncertainty in the modelled results can be achieved.
- Following this stage of modelling, that focusses on application of hydrodynamics and the general water quality module, improvements can be made to add more complexity at the MLWC watershed, as listed in Section 6.0.

6.0 POTENTIAL IMPROVEMENTS

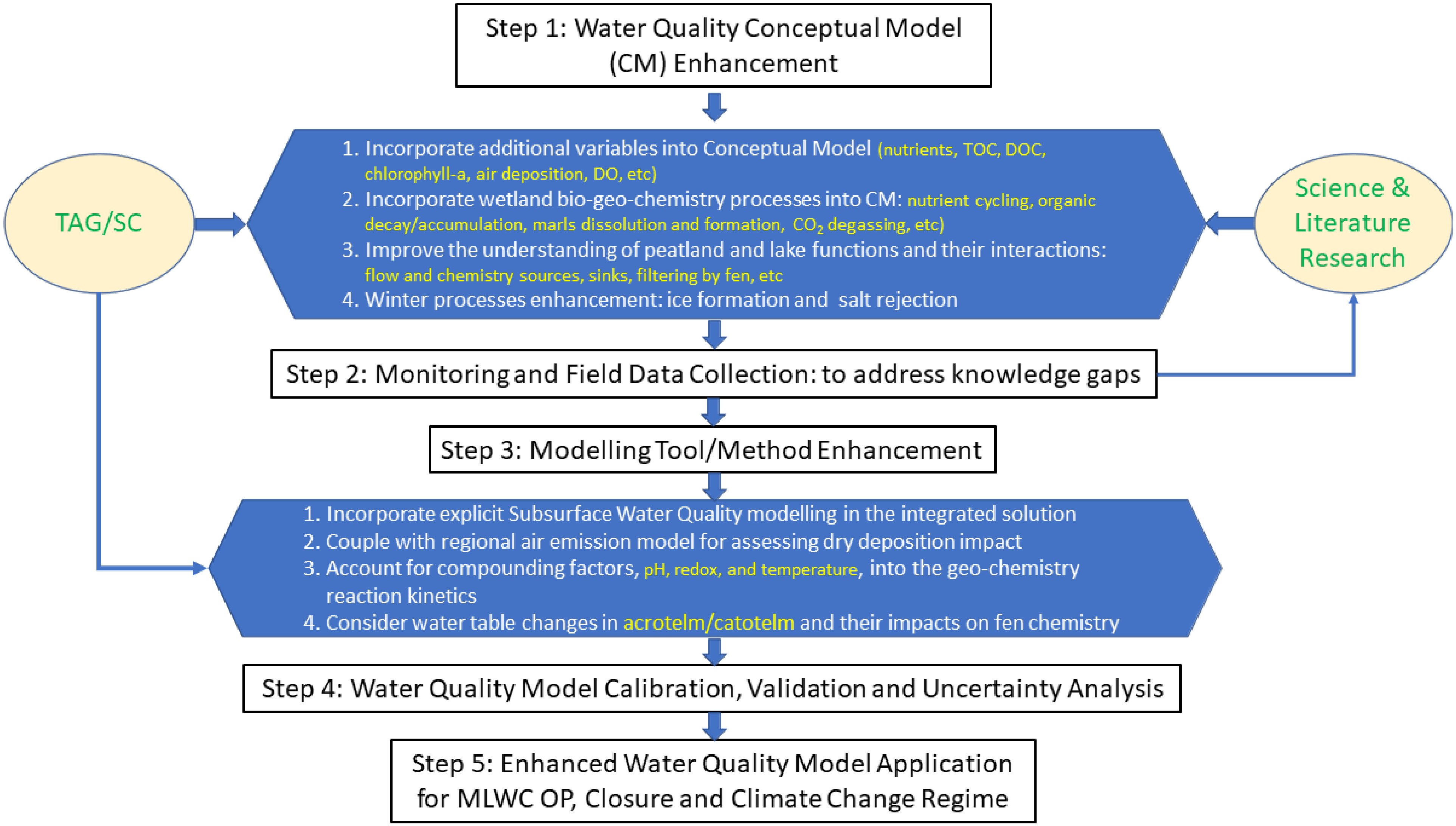
This stage of the surface water chemistry modelling of the MLWC watershed focused on using a simplistic approach to align the water chemistry of the MLWC and trying to ensure that the primary aspects of the conceptual framework could be represented in a numerical model. This was partially successful and allows for a conceptualization of the requirements to improve the current modelling of the MLWC watershed. Figure 6.1 provides a visualization of a workflow to enhance the modelling and meet the objective of being able to assess the impacts of the development on the MLWC watershed and proposed closure and mitigation measures. The extent and timing of technical refinements will be discussed further with the TAG and AAG, as shown in the road map included in Objective 3.

Below is a list of potential improvements that would support improved understanding and model results:

- It is recommended that a more robust loose coupling approach between HGS and EFDC+ for future phases of modelling should be developed to improve modelling results and reduce uncertainty.
- Additional water chemistry field sampling and investigation is required to increased confidence in spatial and temporal variability in the MLWC watershed to help develop and refine the conceptual model understanding and increase spatial representation for model inputs. This is especially important for near surface water and flowing/ephemeral locations during the full year and in general in areas in the eastern portion of the watershed.
- Model grid refinements to represent the patterned and unpatterned fen in greater detail should be incorporated in future phases of work to resolve flow patterns on the scale of individual strings and flarks. Current modelling efforts implemented a coarsened grid resolution to support efficient long-term simulations, but this limited the model's ability to simulate portions of the fen.
- This modelling phase assumed non-reactive (conservative) behaviour of constituents and produced scientifically reasonable results of the lake water concentrations, a full consideration of the biogeochemical processes taking place in the MLWC watershed is important to more effectively assess water management and mitigation alternatives for mine development, reclamation, and closure. Coupling of EFDC+ with PhreeqC-RM and should incorporate:
    - Reactive transport of constituents including pH, alkalinity, and Calcium;
    - Nutrient dynamics (Nitrogen, Phosphorus & Dissolved Organic Carbon); and
    - Aerial loadings of constituents from dry deposition.
- Future modelling efforts should incorporate explicit groundwater and soil water chemistry modelling for more accurate representation of hydrological and biogeochemical processes occurring in the shallow substrate of the fen. This is especially true in the NOP where injection of groundwater and water resupply/injection could have effects on water chemistry on the fen and lake. This could include expansion of the HGS model capability or using a specific soil model such as Hydrus to conduct these simulations.

- It is known that several factors contribute to the observed water chemistry in the MLWC. These could include groundwater exfiltration/infiltration, precipitation, evaporative enrichment, cryoconcentration, and biogeochemical reactions. Integration of these processes should be considered and evaluated during future phases of work.
- Future predicted weather patterns available form global climate models should be included as the atmospheric forcing data to provide a better understanding of possible future concerns and trends. In current modelling efforts, the atmospheric forcing data for simulations were based on historical conditions rather than projected future conditions, and therefore does not consider cumulative effects of mining activities and climate change.

Figure 6.1 Draft MLWC watershed water chemistry modelling workflow.



7.0 REFERENCES

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Appendix F

The 2021 MLWC Conceptual Model Report

The 2021 MLWC Conceptual Model

In support of the McClelland Lake Wetland Complex Operational Plan

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1. COMMONLY USED ABBREVIATIONS OR ACRONYMS:

AAG: Aboriginal Advisory Group

AET: Actual evapotranspiration

AGS: Alberta Geological Survey

ET: Evapotranspiration

FHEC: Fort Hills Energy Corporation

FHUC: Fort Hills Upland Complex

GW: Groundwater

HGS: HydroGeoSphere

HU: Wetland and forestland hydrologic units

IEOLF: Infiltration excess overland flow

ITK: Indigenous Traditional Knowledge

LAI: Leaf area index.

MASL: Metres above sea level

MBGS: Metres below ground surface

MLWC: McClelland Lake Wetland Complex

MLWC OP: MLWC Operational Plan

NED: North east dump

NOP: North outwash plains

OLF: Overland flow

PET: Potential evapotranspiration

SC: McClelland Lake Wetland Complex Sustainability Committee

SIR: Supplemental Information Request

SW: Surface water

TAG: Technical Advisory Group

WBF: Western Boreal Forest

WS: Western Science

2. Section 1.0: The 2021 MLWC Conceptual Model

Over the course of various McClelland Lake Wetland Complex (MLWC) Sustainability Committee (SC) meetings and workshops, Indigenous Traditional Knowledge (ITK) holders and land users have shared some of their perspectives, concerns and knowledge about the MLWC. ITK from Indigenous land users has been braided together with the scientific knowledge in the development of the MLWC conceptual model. Some of the braided core teachings related to water in the MLWC are (in no particular order):

- Everything is connected. The health of the people depends on the health of the land and water. Water is life
  - This unique ecological area is known for clean water and an abundance of wildlife.
  - People have been living around MLWC for thousands of years, has a rich oral history and spiritual importance.
- Surface water and groundwater feed McClelland Lake and other wetland areas, creeks and lakes.
- The fen plays a central role in keeping the entire watershed healthy. The way water moves through the fen, various wetlands and McClelland Lake influences the water levels and water quality in many different wetlands, creeks, lakes and muskeg areas and ultimately the Firebag River and Athabasca River.
- All areas, from the fen to the lake (McClelland Lake) to the river (Firebag River) need to be considered in the development of water models, mitigation and management strategies.
- Water levels have historically fluctuated in the MLWC. Changes in water levels and flows caused by seasonal weather and natural cycles that result in ice jams, frost heave, high water and periodic flooding are good – they help cleanse the land and waters in the MLWC replacing stagnant waters, and scrubbing out river banks and creek beds.
- The MLWC watershed resides atop hummocky, glaciated terrain located within the Western Boreal Forest (WBF). The watershed experiences a semi-humid climate. As noted in Devito et al. (2005), this WBF setting tends to produce poorly-correlated rainfall-runoff responses and complex surface water – groundwater interactions.

Through the integration of ITK and Western Science (WS), we hope to demonstrate a fulsome understanding of the connection to the region and broader landscape, how water flows through the watershed, the interconnectedness of the surface water and groundwater systems, and how water quality and water levels influence the watershed.

The following sections outline the conceptual understanding developed for the MLWC region to support the construction and application of a numerical water model of the system. Emphasis is placed on conceptualizing water cycling behavior within the MLWC watershed itself as well as any portion of the surrounding landscape that may contribute to flows within it. Development of the 2021 MLWC

Conceptual Model was a collaborative effort between Fort Hills Energy Corporation (FHEC) personnel and Aquanty; FHEC provided conceptual interpretations and data while Aquanty provided simulation support and aid in final definition of the HRAs. Note that the HGS simulation results presented herein are meant to be supplementary information to the conceptual model. The core of the 2021 MLWC Conceptual Model itself is based entirely on field data, observations, analysis and the professional judgment of the practitioners alone (as all conceptual models should be). Also note that the MLWC Technical Advisory Group (TAG), the MLWC Aboriginal Advisory Group (AAG) and the MLWC SC provided substantial feedback and guidance on the conceptual model of the MLWC through a series of workshops and made recommendations as its development evolved. The feedback from all of these groups greatly improved Project understanding of the hydrological processes occurring within the watershed.

Each successive generation of the MLWC HydroGeo Sphere (HGS) model discussed in Appendix D has been built and designed based on the current MLWC Conceptual Model. The current MLWC HGS model (the 2020 MLWC HGS model described in Appendix D) was based upon conceptual knowledge of the MLWC as of the end of 2020. The next generation of the MLWC HGS model will be based upon the 2021 MLWC Conceptual Model (both models will continue to be refined after the MLWC OP submission to support ongoing engineering work taking place in the MLWC).

The remainder of this document will overview the methodology, WS and ITK used to develop the 2021 MLWC Conceptual Model, apply that methodology to the MLWC watershed and then discuss how water is conceptualized to cycle within it.

3. Section 1.1: Technical Background and Justification of Approach

The conceptual model of a hydrological system is essentially the embodiment of the understanding of how water (and possibly chemistry and nutrients) cycles through that system, based largely on available site information and the professional judgment of the practitioner. Hydrologists typically focus conceptual model development efforts on the surface water flow system while hydrogeologists primarily just consider the groundwater flow system. The hydrological setting in the MLWC watershed indicates that strong surface water – groundwater interactions are present (significant amounts of open water on the surface, no apparent incoming surface water sources).

ITK holders understand that water (groundwater and surface water) is connected through the entire area. The groundwater, fen, lakes (including McClelland Lake, Baby Lake [aka Unnamed Lake], little round lakes), creeks (including McClelland Creek), rivers (including Firebag River) are all connected and valued.

*“My understanding of McClelland, those big lakes, they are all connected somehow. Water seeping through the ground, through the muskeg. I do believe with all my heart that all of those lakes with the hanging muskeg, they are all connected. I got that information from two very smart scientific men, Pat Marcel and Charlie Voyageur. Pat used to work out there, he verified that all those wetlands are connected to one another. He told me at one time, he said, "If you get through the ground and get to where the water is..." He said, "That water down there is so clean and so cold."” (*FMFN ITK holder, March 3, 2021 workshop*)*

*“I would say that there’s—well, there is some creeks feeding the Moose Creek, and—but there is a lot of underground water that also feeds it. And I don’t know if you would—because Moose Creek got a tint. It’s got a tint in its water. Whenever there’s tint in water—well, Firebag has too. So I would say that would have—that’s probably underground water through muskeg for that—where it gets its—that tint. Because the Athabasca don’t have it on clear. I don’t know why. There is a lot of muskeg feeding in there, just like the lake. But down in this kind of light coloured tea, that’s how the Firebag looks. And Moose Creek is the same way.” (*FCM ITK holder, FCM 2019*)*

Developing a conceptual model of a complex system such as the one in the MLWC watershed requires a framework that considers the entire hydrologic cycle; the movement of surface water and groundwater, how those waters interact, and how they are affected by climate (Winter, 1999).

The work of Devito et al. (2005) provides such a framework, based on a modification of the Fundamental Hydrological Landscape Unit (FHLU) concept proposed earlier by Winter (2001). A FHLU is defined by: a) a landform that contains an upland separated from a lowland by a steeper slope, b) the geological architecture and c) the climate setting. The FHLU concept is applicable from the site-scale to the continental-scale. The Devito et al. (2005) framework is a systematic approach to understand and characterize hydrologic behavior within the WBF (and other settings). The framework de-emphasizes classical, topographically-based landscape definitions (Dooge, 1968) and instead emphasizes a broader definition that considers the entire hydrologic cycle and conservation of mass (Dooge, 1986). The Devito et al. (2005) conceptual framework considers a hierarchical series of five factors which are (listed in descending order of consideration):

- **Factor 1: Climate.** This factor can range from dry conditions (precipitation is less than potential evapotranspiration) to wet conditions (precipitation is greater than potential evapotranspiration);
- **Factor 2: Bedrock Geology.** This factor ranges from permeable to impermeable;
- **Factor 3: Surficial Geology.** This factor ranges from deep to shallow substrates;

- **Factor 4: Soil Type and Depth.** This factor can range from mineral soils to organic soils; and
- **Factor 5: Topography**. This factor can range from gentle slopes to steep slopes.

A key observation noted in Devito et al. (2005) was an example of water residing within the boundaries of a watershed at the Utikuma Research Study Area (URSA) (near Fort McMurray, Alberta in the WBF) which originated from the surrounding landscape (as opposed to originating from within the watershed). In that example, groundwater exfiltrated to surface within a watershed boundary which had originated from outside of that watershed boundary. This is possible because watershed boundaries and the groundwater divides in the underlying groundwater catchment(s) are often not coincident, contrary to assumptions commonly made in hydrological practice. This misalignment of the groundwater and surface water divides has been observed or proposed in other jurisdictions as well (Bouaziz et al., 2018; Jones et al., 2008; Haitjema and Mitchell-Bruker, 2005; Winter et al., 2003; Holzbecher, 2001 and Tiedeman et al., 1998). Consequently, an initial step in understanding water movement in the landscape, especially the glaciated WBF landscape, is to understand where the water originates from.

The system characterization framework described in Devito et al. (2005) was subsequently expanded upon in Devito and Mendoza (2006) and then formalized into the synthesis document Devito et al. (2012). This latter work argues for a shift in focus from primarily considering system rainfall-runoff responses to instead considering processes like precipitation, evapotranspiration and water storage as the dominant hydrological processes to appraise while characterizing flow system behavior (i.e., the major source, sink and storage terms). It also requires practitioners to stop thinking of surface water processes and groundwater processes as distinct hydrologic regimes with limited hydraulic connectivity and to alternatively consider the land phase of the hydrologic cycle as a single, potentially hydraulically connected and dynamically interactive continuum.

The Devito et al. (2012) synthesis conceptualizes the WBF setting as commonly experiencing extended dry or drought periods punctuated by short wet periods that replenish the supply of water stored in the landscape. Sporadic runoff is possible during wet periods or cycles in this setting; more commonly, net excess precipitation (precipitation minus actual evapotranspiration (AET)) replenishes landscape storage deficits in the form of groundwater recharge and/or surficial depression storage. During drier periods, this stored water is drawn upon to supply water to the surrounding landscape.

As part of the Devito et al. (2012) synthesis work, the authors introduced some new terminology to reduce confusion between classical, topographically-defined HRU's (hydrologic response units) used by some hydrologists and ones developed using the Devito et al. (2005) characterization framework: Hydrologic Response Areas (HRAs) and Wetland and Forestland hydrologic units (HUs). HRAs and HUs are arrived at while considering the five criteria in Devito et al. (2005) and perform the dual hydrologic functions of:

1) water storage and redistribution to the surrounding landscape during dry or drought periods; and
2) the transmission of significant volumes of water through the landscape during wet periods or cycles (drainage).

The practical application of the Devito et al. (2005) characterization framework to develop HRAs for the 2021 MLWC Conceptual Model requires identifying and considering all the contributing landscape storage, redistribution and transmission components and then determining how these hydrological components interact with one another. Note that the MLWC Project generically uses the term HRA to describe the functions of both the HRAs and HUs in the context of the Devito et al. (2005) characterization framework.

4. Section 1.2: Application of the Devito et al. (2005) Characterization Framework to the MLWC Project

The five factors in the Devito et al. (2005) characterization framework were assessed using relevant field data gathered as part of the MLWC Project.

5. Section 1.2.1: Factor 01: Climate

A climate setting is considered drier if, most years, precipitation is less than potential evapotranspiration and wetter if precipitation is greater than potential evapotranspiration. The MLWC watershed is situated in a glaciated, sub-humid setting in the WBF where annual potential evapotranspiration rates exceed precipitation rates most years; as such, the MLWC watershed would be considered a relatively drier setting within the Devito et al. (2005) characterization framework.

Using the guidelines provided in Devito et al. (2005), drier settings:

- Tend to exhibit a poorly correlated rainfall-runoff response. Runoff after a rain event can occur, but only sporadically. Incoming precipitation tends to either be absorbed into storage by the system or be lost to evapotranspiration. However, in situations where system storage capacity is limited, incoming precipitation can manifest hydrological processes such as saturation excess overland flow (SEOLF), resulting in runoff generation;
- Preferentially store water as opposed to generating runoff in response to incoming precipitation; and

- Have a greater tendency to produce vertical flows as opposed to lateral flows.

Figure 1 shows a hyetograph of daily precipitation rates (1945-2020) recorded at the Fort McMurray Airport climate station plotted against McClelland Lake water levels measured from approximately 1997 to 2019. Visual inspection of Figure 1 indicates that water levels in McClelland Lake appear to be stable and somewhat insensitive to recorded daily incoming precipitation rates over the recorded period (indirectly indicating a poorly correlated rainfall-runoff response). As discussed in Objective 1 of the MLWC OP (Section 2), historical climate long-term trends indicate annual precipitation rates in the region have been decreasing while mean annual temperatures have been increasing, which implies that the MLWC region has getting progressively drier. . These observed trends are consistent with observations by ITK holders of the area who have noted that weather patterns, beaver activity and climate change are affecting the MLWC and that current, average water levels have gotten noticeable lower than was the case historically.

> *"When Elder Emma Faichney was interviewed in 2001, she spoke of a time when she was a girl and the water in McClelland Lake was very low – so low there was a fairly wide sand beach almost all the way around the lake, but especially on the north and east shores. Emma was born in 1934, so this memory supports the notion that water levels were lowest in the 1940s. Emma believed that around that same time, it was McClelland Lake that "kept baby lake alive" – she said that McClelland Lake and Baby Lake are connected underground."* (C. Oloriz, personal communication, April 12, 2021)

> *"I remember my mother used to tell me about it. She said, "That's why there's no more fish in the lake because when the water was low, it all froze and the fish population didn't come back." I don't know, if groundwater was filling the lake back up to be McClelland Lake again. But my mother used to tell me the stories because her dad told her the stories. Because as far as I know, the way it have looked, it looked like there was just a hole in the... I saw the photo that you're talking about because, way back, years ago Pat Marcel brought it to one of our meetings one time, him and Charlie Voyager had it. There was that picture. But it was just like, I don't know, just a hole in the middle of the lake. And Pat Marcel and then Charlie [Voyager] was saying, that year, it was really different to us. There was a drought, there was no water anywhere. The creeks were drying up, even the Athabasca River, I guess was in trouble."* (FMFN ITK holder, , March 3, 2021 workshop)

> *"The water changing, we're losing water from somewhere, and the moose all the survivors that are living, depending on the water, all moved away. Cuz you know, the water is getting kind of low." (*MCFN ITK holder, MCFN 2019*)*

"Back where we parked, up to there – you couldn't walk. it used to be just straight water. Remember? Just water up to here (hitting his leg just above the knee) Now... well you can walk out here. There's no water. It used to be standing water. I haven't been out here for three, maybe four years.....that used to be right full of water and now its dried up...even with the amount of rain we had this year...." (FMMN ITK holder, FMMN 2017)

Figure 2 is an additional example illustrating the sporadic nature of runoff observed in the MLWC system. The recorded data exhibit extended periods of extremely low or no flow, punctuated by discrete periods of higher flow, at least within the available data. Figure 2 also shows that, for the roughly 20 years of available recorded data, McClelland Lake`s water levels have remained within a fairly stable 70 cm range, with an average level of approximately 294.5 masl over this time period. McClelland Lake is a relatively shallow lake whose average water levels are on the order of about 2m with a maximum depth of about 5.5m. Seventy centimeters could be considered a modest amount of overall water level change for a given lake over 20 years, but nonetheless represents a significant portion McClelland Lake`s average depth. MCFN ITK holders have also noted that MLWC water levels have historically fluctuated and attribute these fluctuations as being caused by seasonal weather and natural cycles that result in ice jams, frost heave, high water and periodic flooding and that these fluctuations help cleanse the land and waters in the MLWC replacing stagnant waters, and scrubbing out river banks and creek beds (MCFN 2019). Knowledge holders have also expressed that water levels have gone down in the McClelland Lake area since nearby industrial projects became active (IEG 2021).

"I found out it [McClelland Lake] was low. It was not as—not where the water used to be. You can tell by the land where the water used to be….For one thing, how far the cattails—I can't remember cattails in that area. But I noticed that there was a lot of cattails. There was, like—just like a little channel where it never used to be a little channel. Used to be, like, water was right up to the—to pretty well the main ground where you could just step from the main ground into your boat." (FCM ITK holder about water levels in 2019; FMC 2019)

Figure 3 plots recorded annual precipitation rates from 1945-2019 against simulated annual surface water fluxes (SW), groundwater fluxes (GW) and changes in water storage for the MLWC watershed. As can be seen in Figure 3, the MLWC watershed exhibits a regular cyclical oscillation between periods of water deficit and water surplus. Figure 3 also indicates that predicted total annual storage rates (sw + gw) strongly correlate to total annual flows (aka system sources and sinks which are comprised of the sum of [Precip + AET + Incoming surface water runoff (which is zero) + Outgoing Runoff + Net Groundwater]).

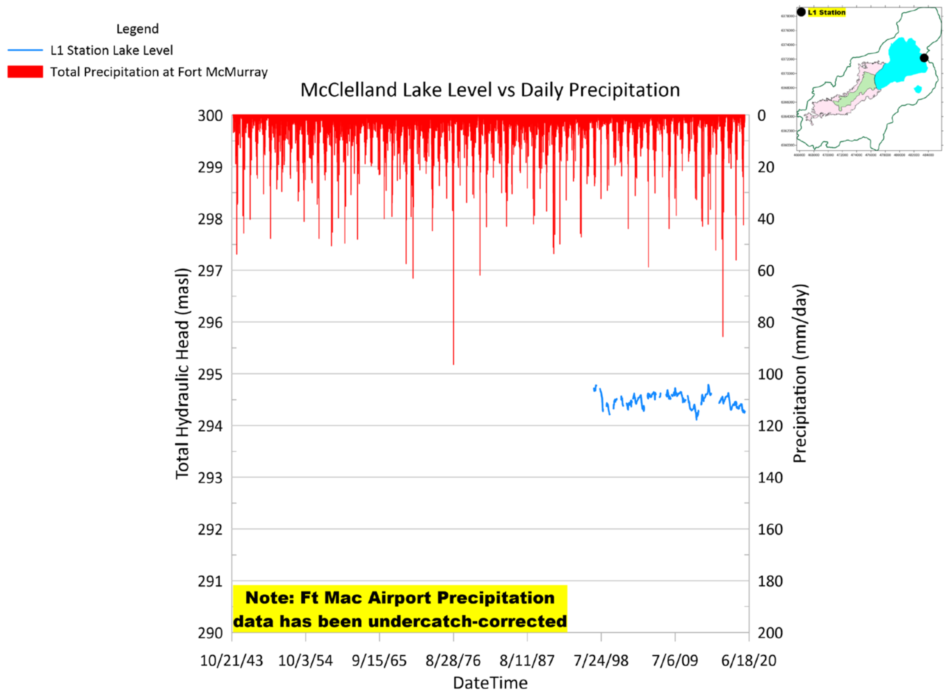

Figure 1 Daily precipitation rates plotted against recorded McClelland Lake levels at the L1 gauge station (location shown in upper right inset).

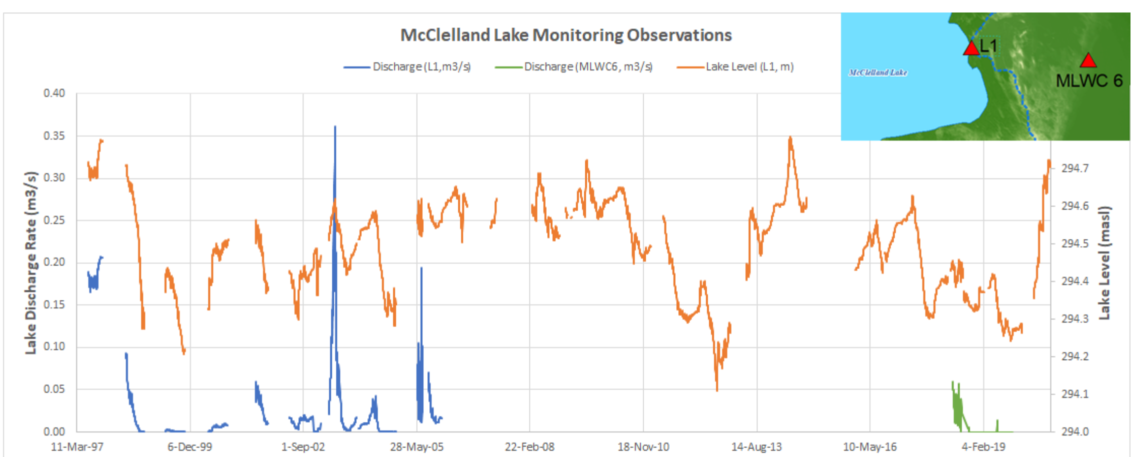

Figure 2 Recorded McClelland Lake levels versus discharge at the L1 and MLWC 6 stations. Station locations shown in inset. Discharge is often negligible at these locations and punctuated by sporadic, relatively higher runoff events. Note that the lake data span a ~70 cm range over the available recorded data.

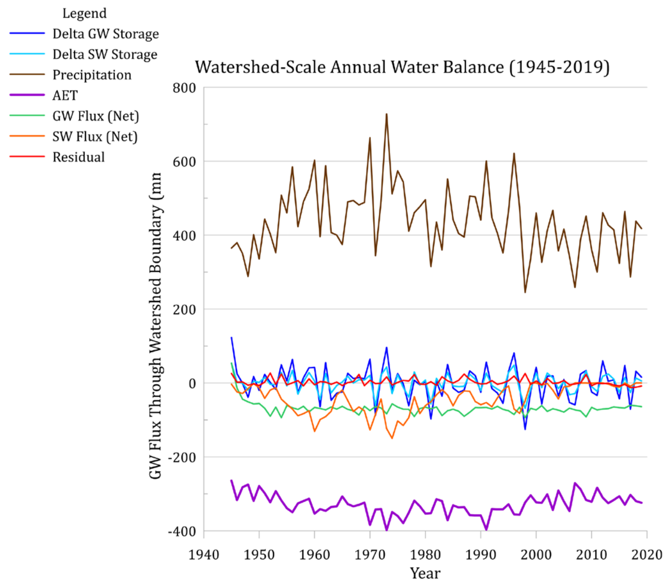

Figure 3 Annual MLWC watershed-scale water budget components from 1945-2019 (simulated). The McClelland Lake Watershed experiences regular cycles between adding and shedding water stored in the system. Negative storage values indicate that the system is consuming stored water while positive values indicate the system is replenishing stored water.

6. Section 1.2.2: Factor 02: Bedrock Geology

The Devito et al. (2005) characterization framework classifies a system`s bedrock geology as being permeable or impermeable. It is implicitly assumed that the orientation of the bedrock surface will have a predominant influence on groundwater flow directions and assessing the degree of bedrock permeability will help characterize this influence. An initial step in considering this factor is to determine the orientation of the bedrock surface, followed by assessing the relative degree of permeability. ITK holders have observed limestone outcrops along the Firebag River valley and noted that it continues deep beneath McClelland Lake and fen. Any observed limestone in this region would be Devonian-age bedrock (likely the Waterways Formation). ITK holders provided input on subsurface geology along the Firebag River valley and noted that it continues deep beneath McClelland Lake and fen:

> *"I know there's a lot of limestone through there. Now the water, course, is sitting on this limestone. It… some little creeks that don't fall through the limestone, maybe some places. And there's clay in there too, and water don't go through clay..... [underneath the fen] There's water. Because I know the limestone from there runs right to Fort McMurray, past Fort McMurray. The*

furthest north I've seen it was at the Firebag, …It could be further north yet too, but I know the Firebag. So the water then, it's sitting... Okay, it's limestone, tar sand, water, and the floating muskeg on top." (FCM ITK holder, March 3, 2021 workshop)

Figure 4 is conceptual cross-section of the regional geology underlying the MLWC watershed. As illustrated in the figure, the Devonian Period bedrock surface at the MLWC (the top of the Waterways Formation shown in the figure) has been previously interpreted as being quite uneven and undulating and whose orientation exhibits a general southwest dip between the Firebag River and the Athabasca River (WorleyParsons, 2015). It is also apparent in Figure 4 that the overlying Cretaceous Period deposits (labeled the Clearwater Formation and the McMurray Formation in Figure 4, respectively) do not dip in the same orientation as the underlying Devonian bedrock. This is because there is an erosional unconformity between the Devonian strata and the Cretaceous sediments. As well, a second erosional unconformity exists between the Cretaceous sediments and the overlying Quaternary sediments (labeled Mixed Overburden in Figure 4). The orientation of the Devonian bedrock geology underlying the MLWC watershed has no influence on local (Quaternary) groundwater flow directions within the MLWC watershed. Nor does the orientation of the underlying Cretaceous sediments. The deeper (Cretaceous and Devonian) geology was excluded from further consideration in the application of the Devito et al. (2005) methodology.

Based on the above, it is likely that groundwater flows within the MLWC watershed are being influenced by the architecture of the system`s Quaternary geology, which consists of a series of sand and till deposits. Geological characterization of the Fort Hills Lease and the MLWC Project has been an evolving process. Earlier efforts were primarily focused on the relatively deeper geology and characterization of the bitumen ore body. Additional drilling work was carried out from 2017-2020 to help better characterize the Quaternary and Cretaceous geology within and around the MLWC watershed. Geological data (to define the hydrostratigraphy) is foundational to the integrated water modelling discussed later in this document (just as it would be for a classical groundwater flow model). The geological data used to construct the 2020 MLWC HGS model (Appendix D) is overviewed below, followed by a description of the Quaternary sequence and a discussion of applying this information to finish assessing Factor 2 in the Devito et al. (2005) characterization framework.

The geological data used to construct the 2020 MLWC HGS model combines three distinct data sets: 1) regional geologic data; 2) a lease-scale geomodel developed by FHEC (version FH19a); and 3) refinement of the Quaternary geology using the drilling data collected in and around the MLWC watershed from 2017-2020. These three data sets were merged using the geomodelling software Leapfrog and then vertically discretized into 24 layers. These 24 layers, the upper 10 of which define the Quaternary sequence, also define the hydrostratigraphy of the MLWC geology (assigning geological units as aquifers and aquitards). This same layering was used in the 2020 MLWC HGS model (with minor modifications). The hydrostratigraphic base of the system is assumed to be within the Devonian Keg River Aquifer. The resulting Leapfrog hydrostratigraphic model is referred to as the 2020 Unified Geomodel. The Quaternary hydrostratigraphic sequence within the MLWC watershed is described next.

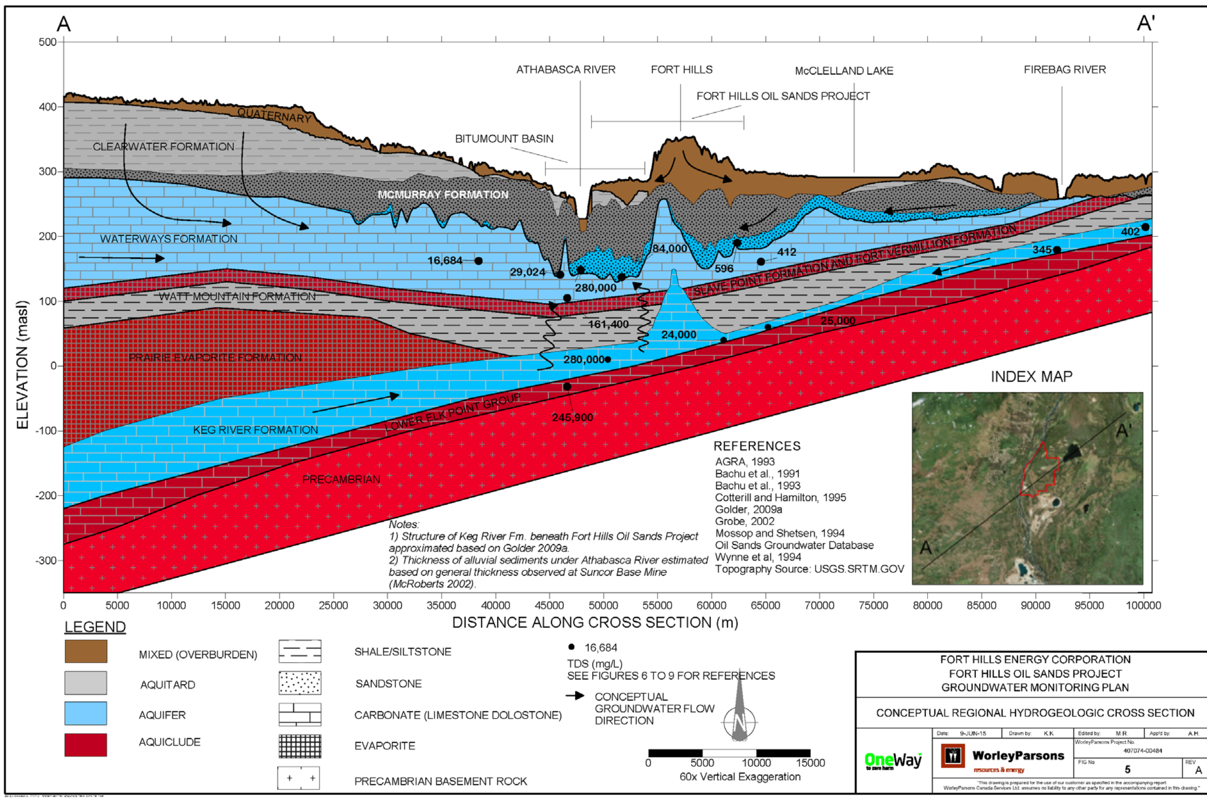

Figure 4 Conceptual cross-section illustrating the regional geology under the McClelland Lake area and the 2015 Fort Hills lease. Regional surface water – groundwater interactions can be inferred from this conceptual cross-section as well. Note that the oil sands deposits reside within the upper part of the McMurray Formation. Data source: Figure 5 in WorleyParsons (2015).

The Quaternary deposits overlying the Clearwater Formation and McMurray Formations are composed of fluvial sands, fluvial gravely sands, lacustrine clays and glacial tills of Holocene and Pleistocene age. The legend for the MLWC watershed hydrostratigraphy, as defined in the 2020 Unified Geomodel, is shown in Figure 5.

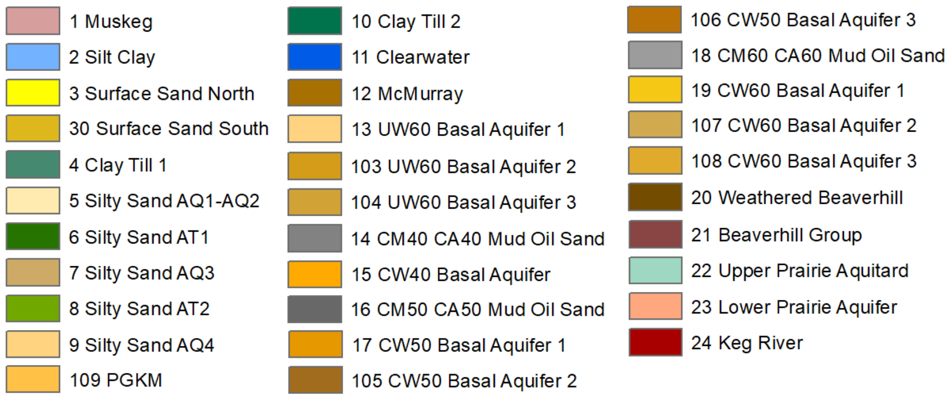

Figure 5 The hydrostratigraphy and corresponding water model zonation defined in the 2020 Unified Geomodel. The numbers beside each hydrostratigraphic material type are the corresponding zones in the 2020 MLWC HGS model (and which represent the hydraulic conductivity zonation). This legend is applicable to the maps of hydrostratigraphy shown in Figures 6-11 and Figures 13-16 below.

The base of the Quaternary hydrostratigraphy underlying the MLWC watershed is shown in Figure 6. The basal hydrostratigraphic unit in the sequence is a laterally extensive glacial till unit designated Clay Till 2. As can be seen in Figure 6, Clay Till 2 contains hydraulic windows (discontinuities such as sandy sections) west of McClelland Lake. Clay Till 2 unit primarily overlies bitumen- saturated McMurray Formation (Cretaceous) deposits over approximately the southern two-thirds of the watershed and deeper Cretaceous deposits elsewhere.

Continuing upwards hydrostratigraphically, Figure 7 shows the lateral extents of the Silty Sand AQ4 and PGKM deposits (the latter being interpreted as rafted McMurray material mixed with Pleistocene deposits). Figure 8 shows the patchiness of the Silty Sand AT2 unit overlying the PGKM and Silty Sand AQ4 deposits. Figure 9 shows the extents of the Silty Sand AQ2 unit that is partially overlain by the Silty Sand AT1 unit shown in Figure 10. Figure 11 shows the extents of the Silty Sand AQ1 AQ2 deposit that covers the top of the Fort Hills Upland Complex (FHUC; location shown in Figure 12).

A second laterally extensive and continuous till unit designated Clay Till 1 covers most (but not all) of the FHUC slopes that face McClelland Lake (Figure 13). Clay Till 1 continues extending northward, overlying most of the remaining 2020 Unified Geomodel domain (Figure 13). Deposited directly above Clay Till 1 are clean, fine- to medium-grained Surface Sands, primarily associated with the deposits the North Outwash Plains (NOP) physiographic unit shown in Figure 12. Overlying portions of these surface sand deposits are a smaller Silt Clay unit deposit and Muskeg (Figure 14 and Figure 15 respectively).

Cross-sections taken across 2020 Unified Geomodel domain are presented in Figures 18 – 22 (cross-section locations shown in Figure 17). These cross-sections all indicate that there are aquitards (tills) or oils sands ore between the deeper intermediate and regional groundwater flow systems and the shallow local groundwater flow system (Quaternary aquifers) within the MLWC watershed.

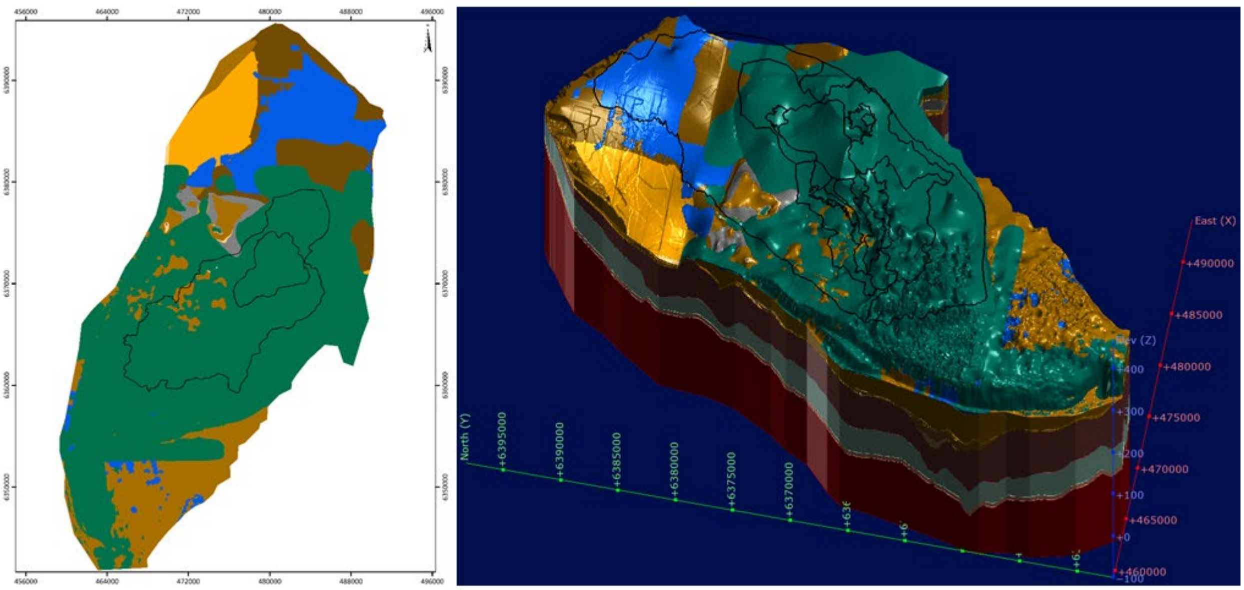

Figure 6 2020 Unified Geomodel layer 10. Clay Till 2 lateral extent (dark green). 3-D vertical exaggeration for the panel on the right is 80:1.

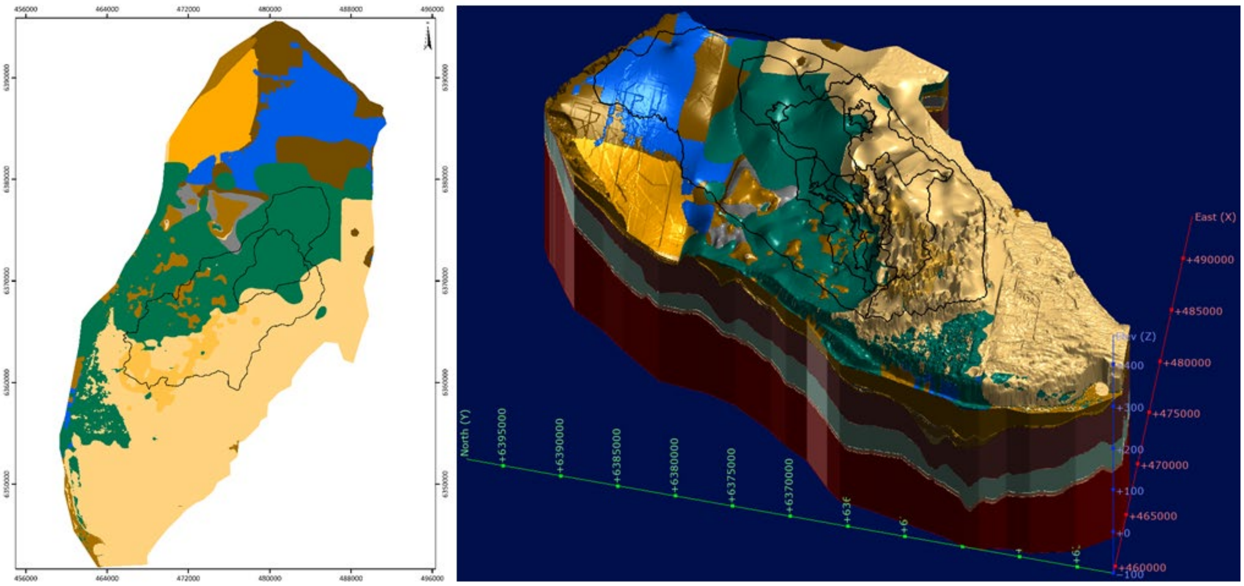

Figure 7 2020 Unified Geomodel layer 09. Silt Sand Aquifer 4 (lighter yellow) and PGKM (darker yellow; interpreted as rafted McMurray material). 3-D vertical exaggeration for the panel on the right is 80:1.

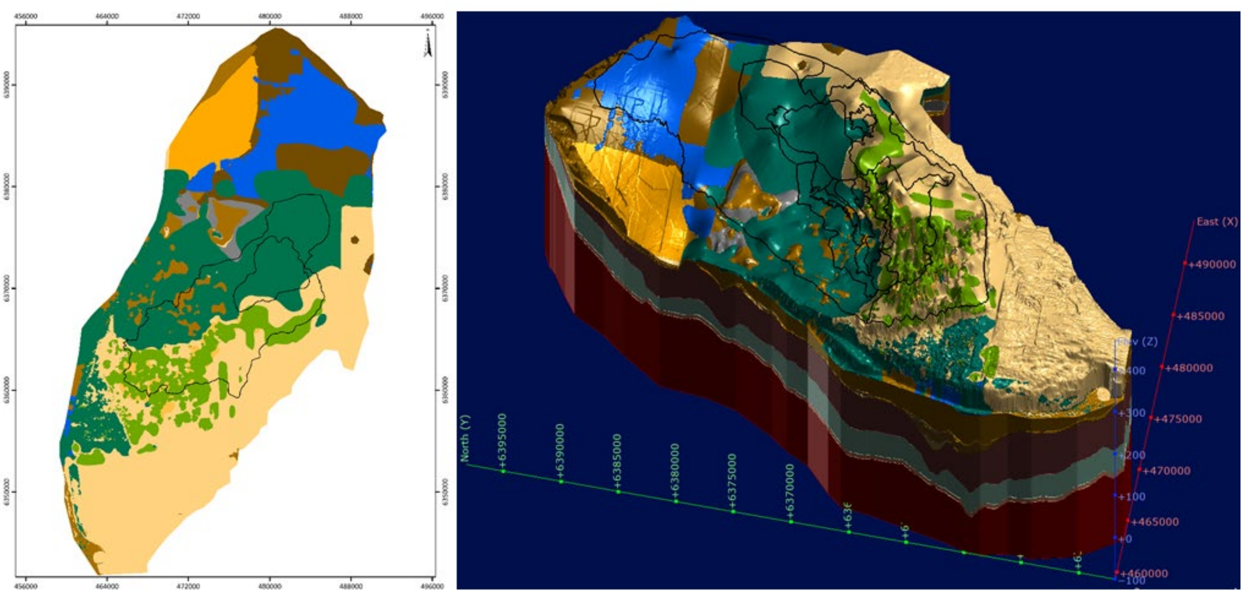

Figure 8 2020 Unified Geomodel layer 08. Silt Sand Aquitard 2 (patchy bright green). 3-D vertical exaggeration of the panel on the right is 80:1.

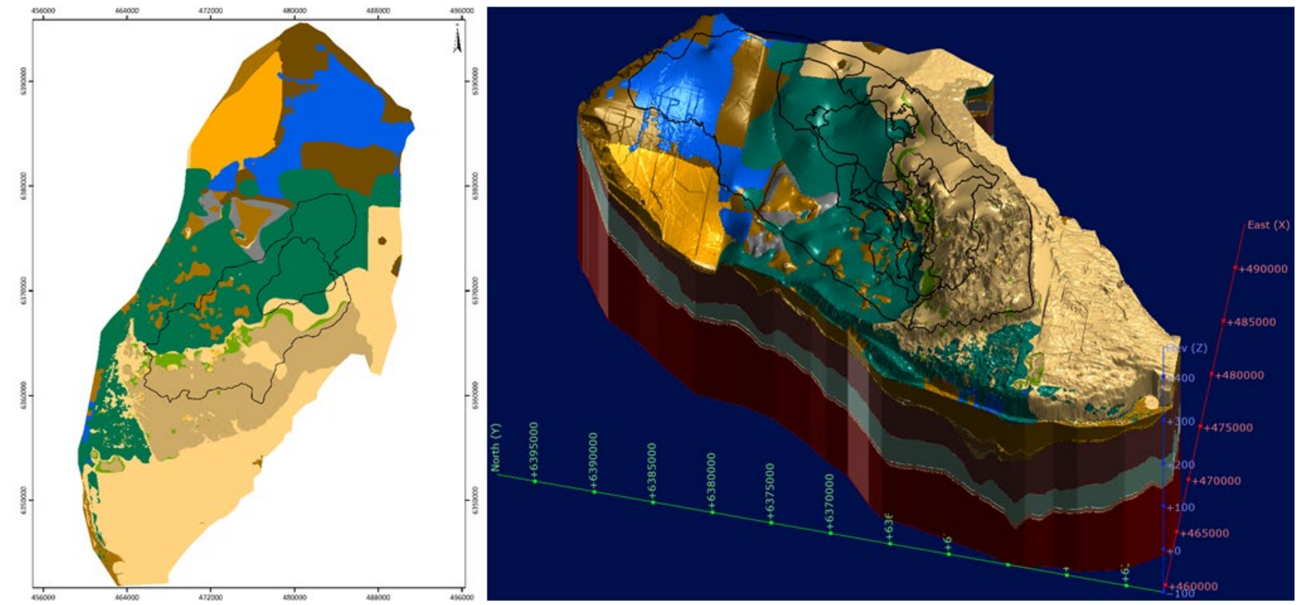

Figure 9 2020 Unified Geomodel layer 07. Silt Sand Aquifer 2 (dark yellow). 3-D vertical exaggeration of the panel on the right is 80:1.

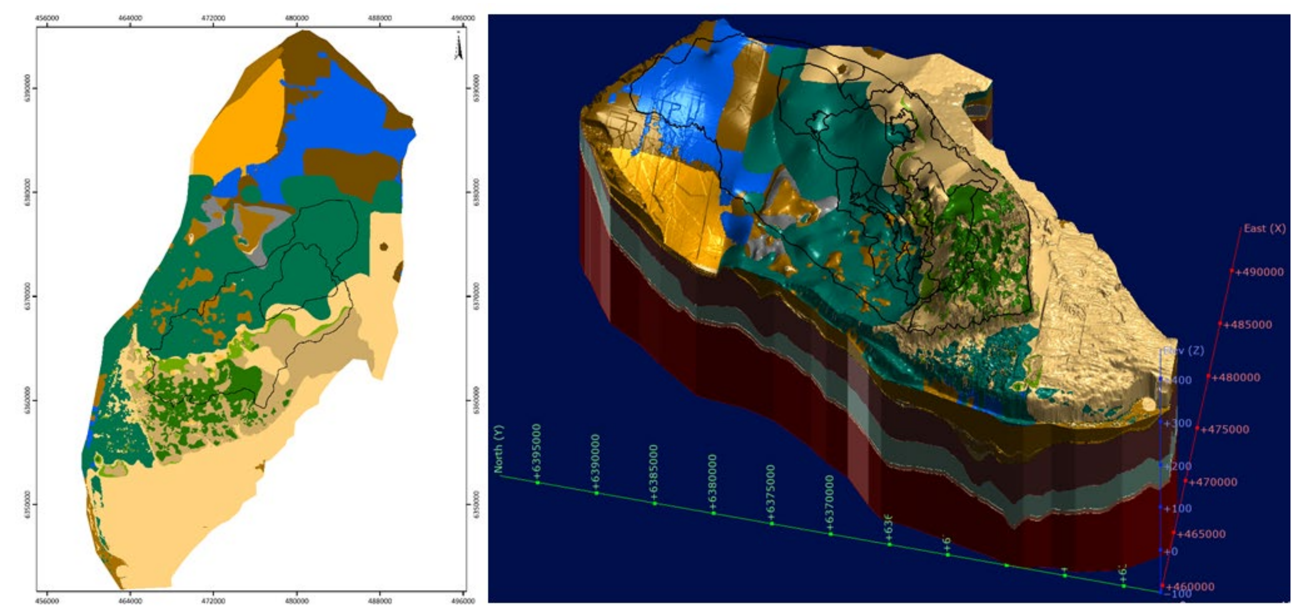

Figure 10 2020 Unified Geomodel layer 06. Silt Sand Aquitard 1 (patchy green material). 3-D vertical exaggeration for the panel on the right is 80:1.

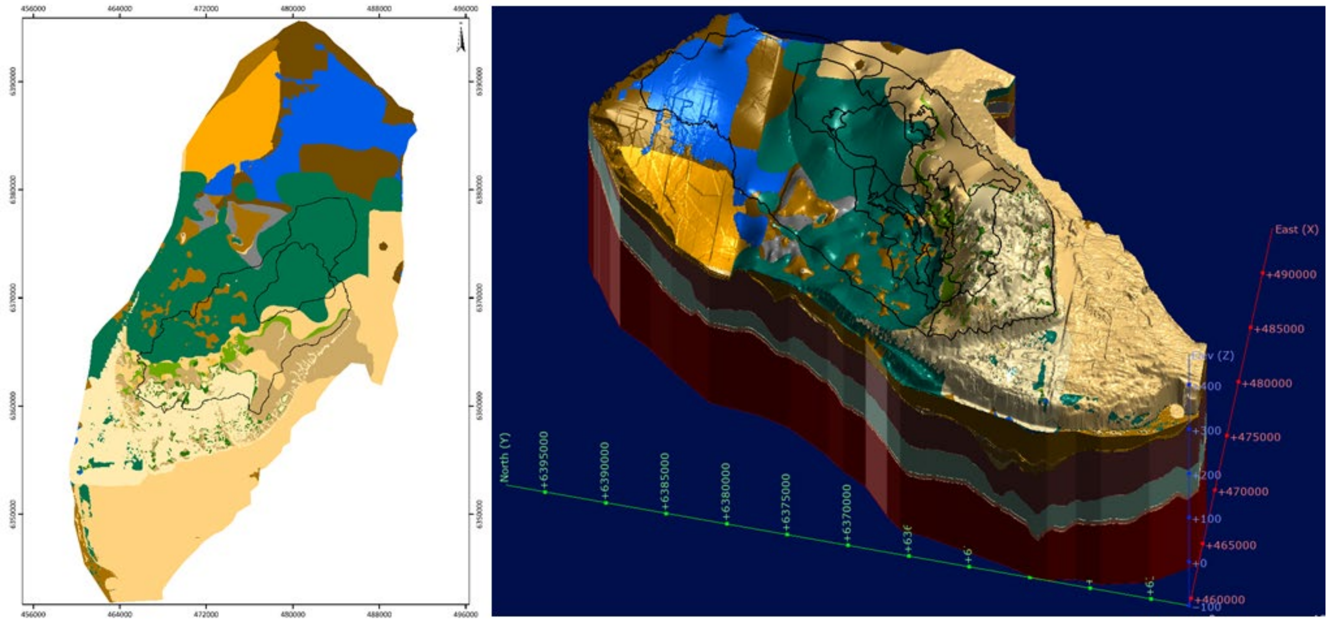

Figure 11 2020 Unified Geomodel layer 05. Silt Sand Aquifer 1-2 (light yellow). 3-D vertical exaggeration for the panel on the right is 80:1.

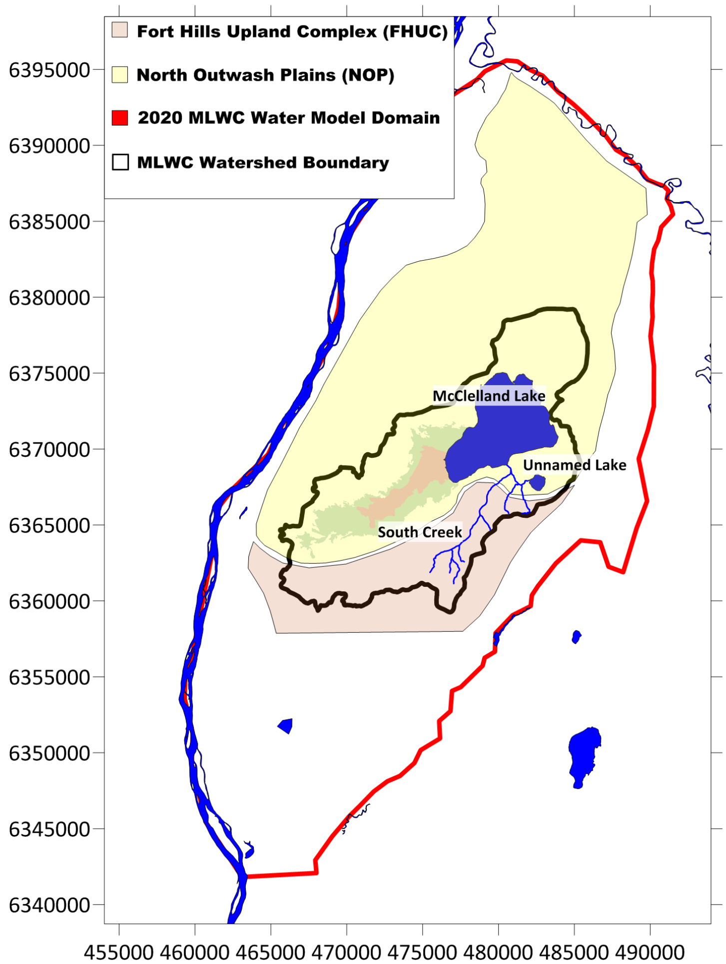

Figure 12 The approximate extents of the NOP and FHUC landforms. The combined NOP and FHUC regions roughly coincide with the extent of the Firebag Moraine which the McClelland Lake watershed sits on top of.

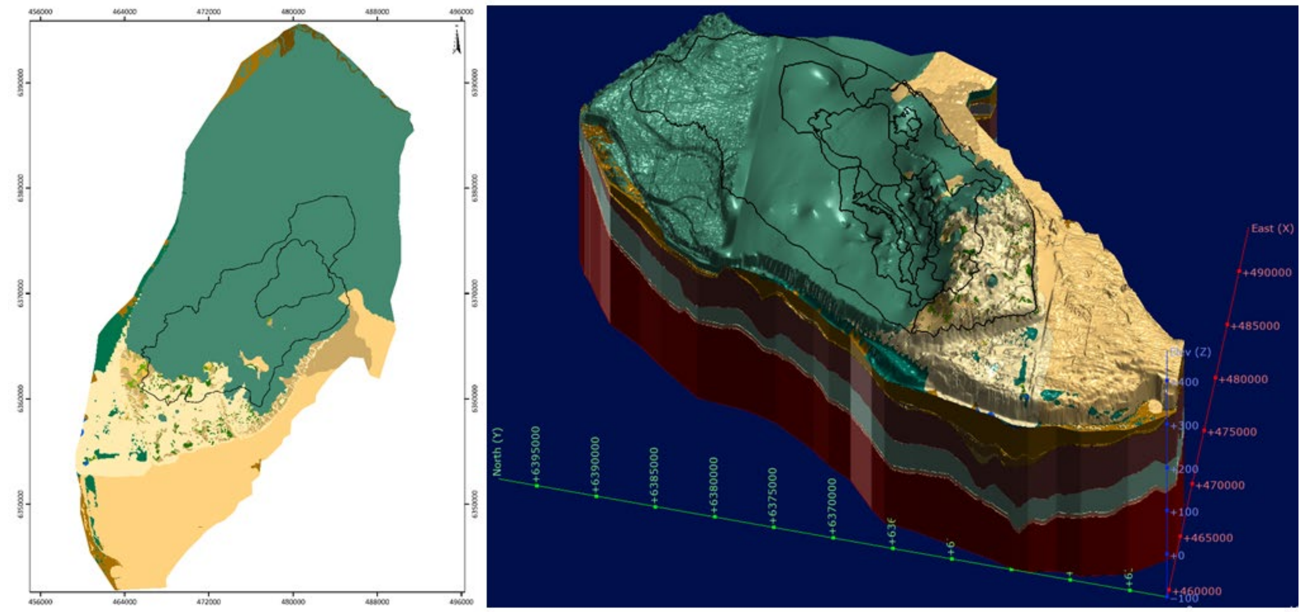

Figure 13 2020 Unified Geomodel layer 04. Clay Till 1 (light green). 3-D vertical exaggeration for the panel on the right is 80:1.

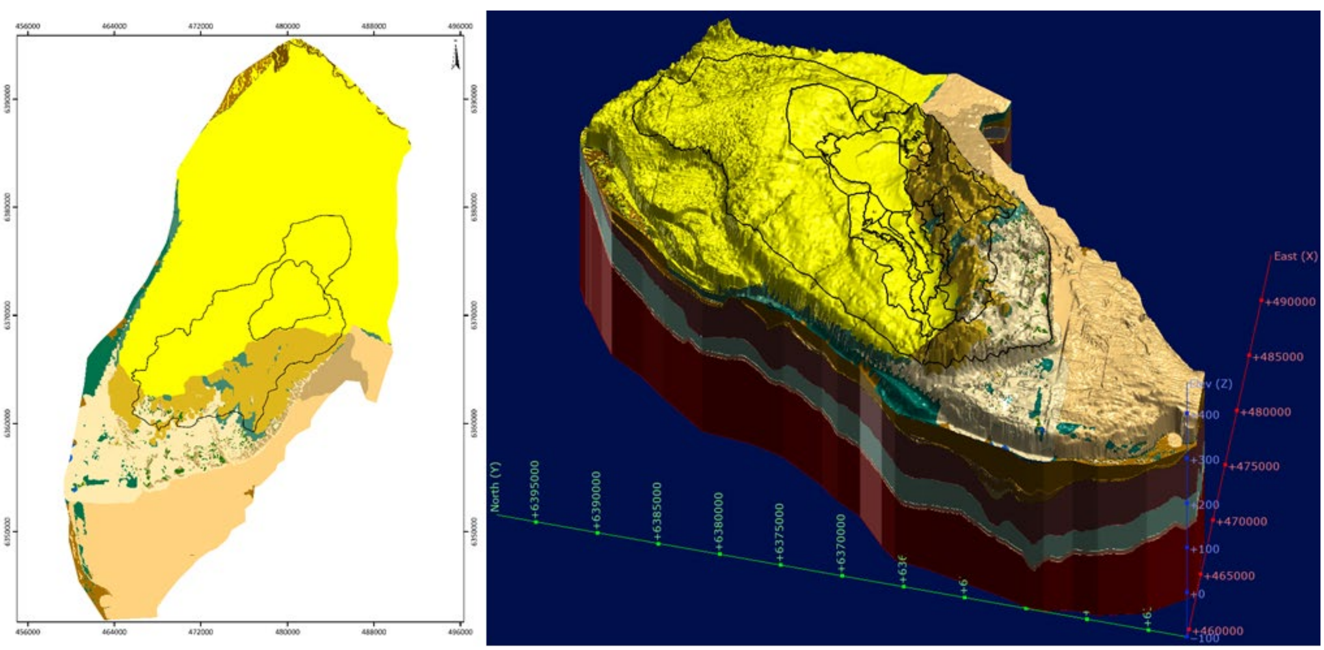

Figure 14 2020 Unified Geomodel layer 03. Surface Sands North and South (darker yellow and brighter yellow, respectively). 3-D vertical exaggeration for the panel on the right is 80:1.

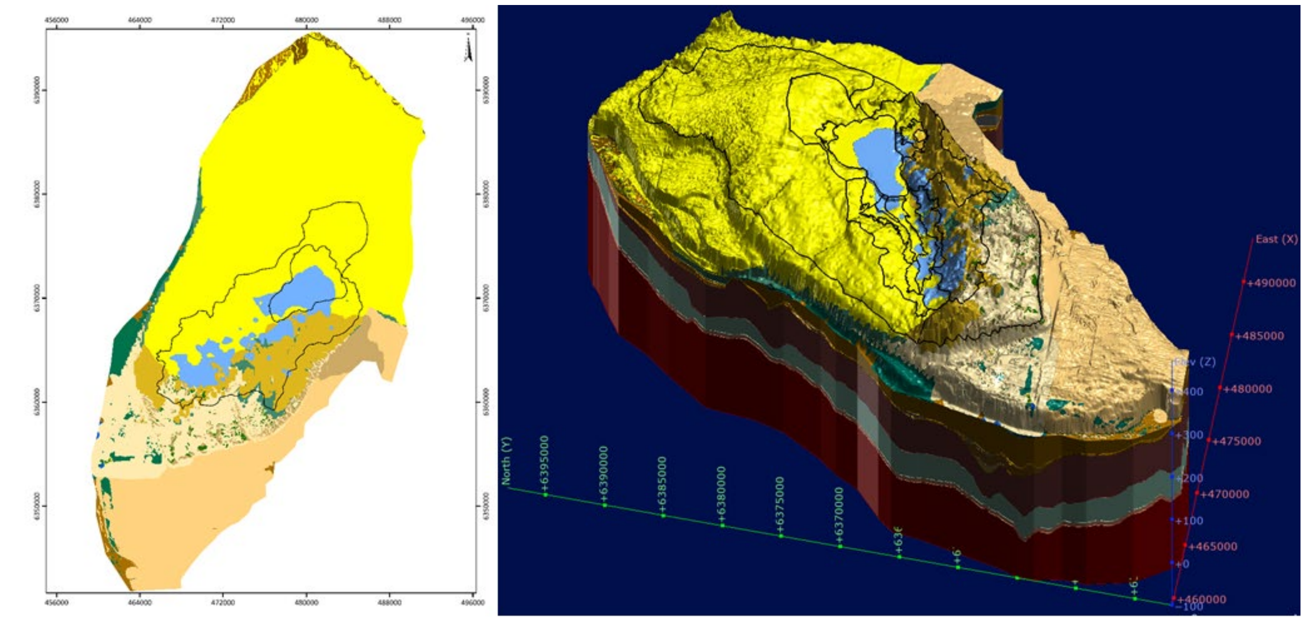

Figure 15 2020 Unified Geomodel layer 02. Silt Clay (light blue). 3-D vertical exaggeration for the panel on the right is 80:1.

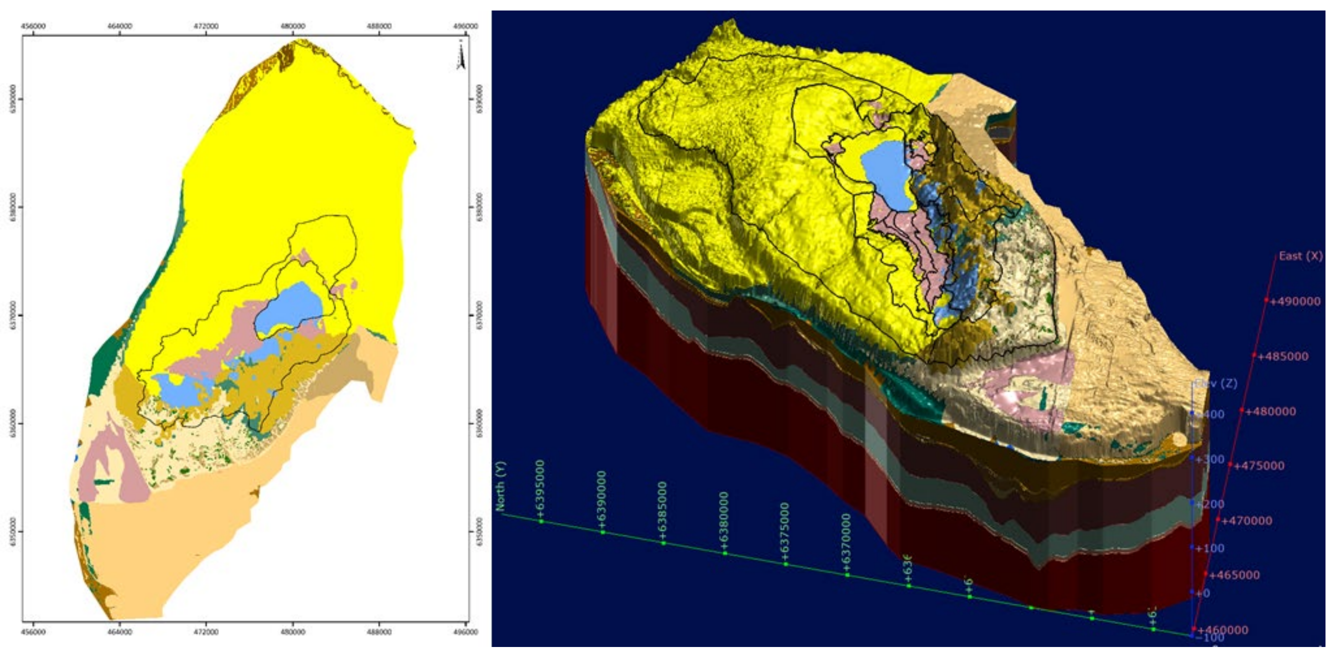

Figure 16 2020 Unified Geomodel layer 01. Muskeg (pink). 3-D vertical exaggeration for the panel on the right is 80:1.

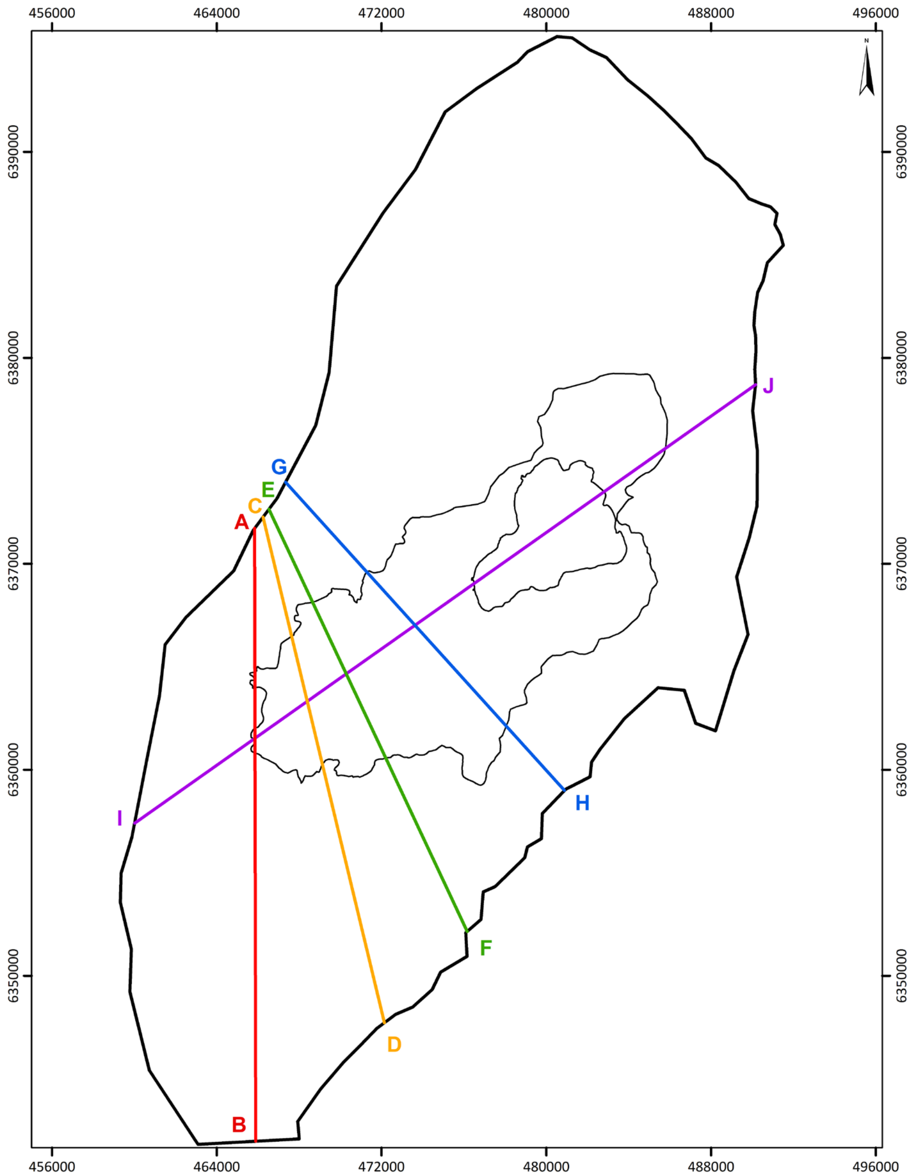

Figure 17 Locations of cross-sections taken through the 2020 Unified Geomodel.

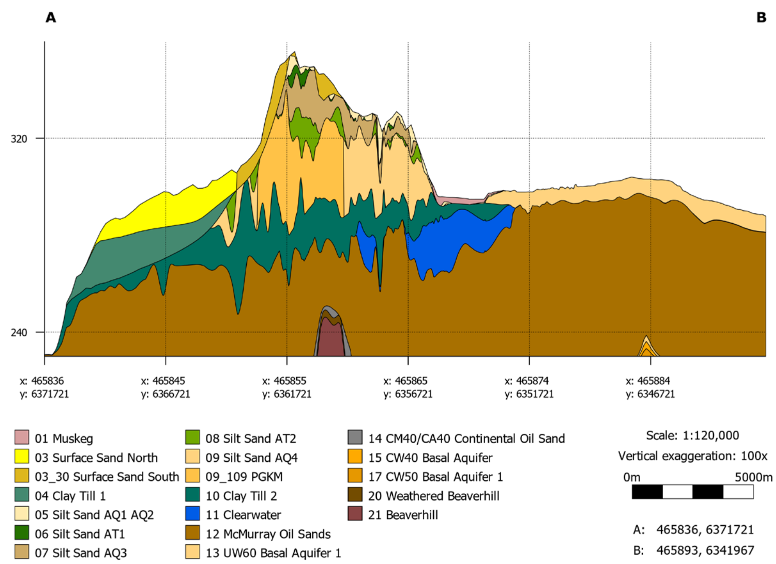

Figure 18 Cross-section A-B through the 2020 Unified Geomodel (section location shown in Figure 17). Vertical exaggeration is 80:1.

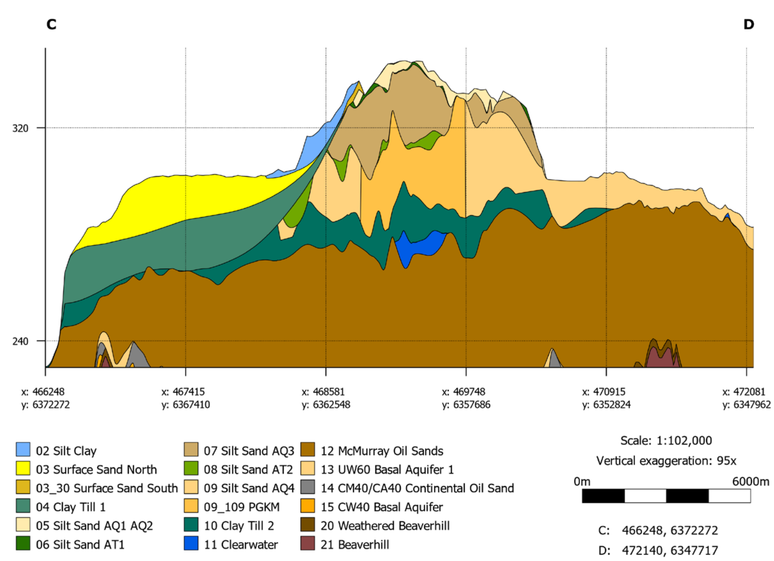

Figure 19 Cross-section C-D through the 2020 Unified Geomodel (section location shown in Figure 17). Vertical exaggeration is 80:1.

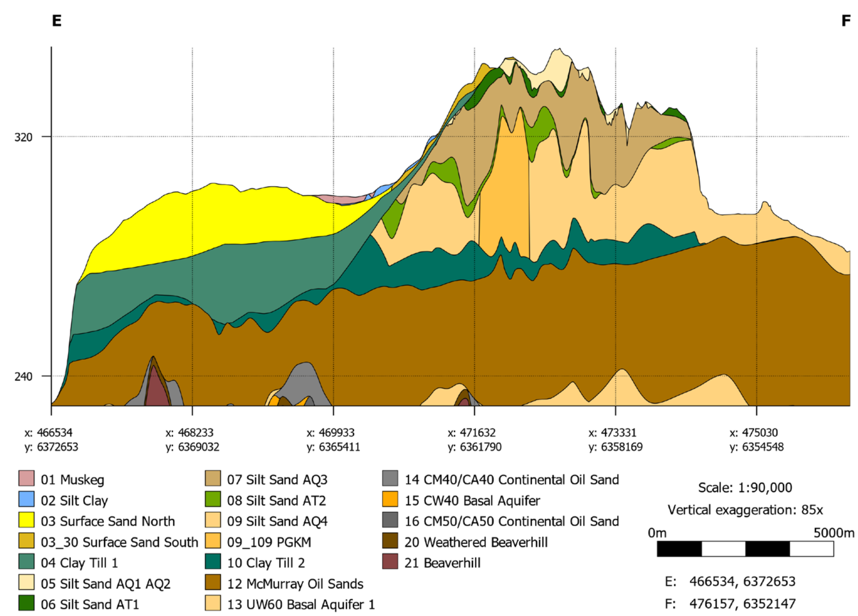

Figure 20 Cross-section E-F through the 2020 Unified Geomodel (section location shown in Figure 17). Vertical exaggeration is 80:1.

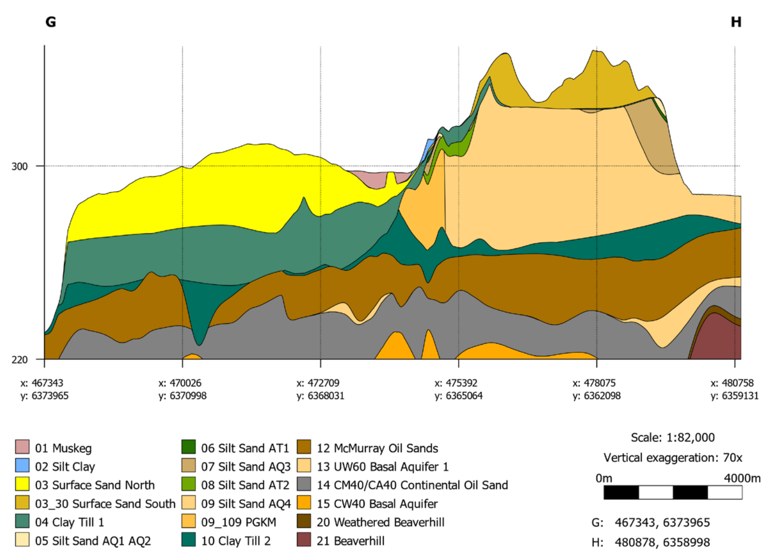

Figure 21 Cross-section G-H through the 2020 Unified Geomodel (section location shown in Figure 17). Vertical exaggeration is 80:1.

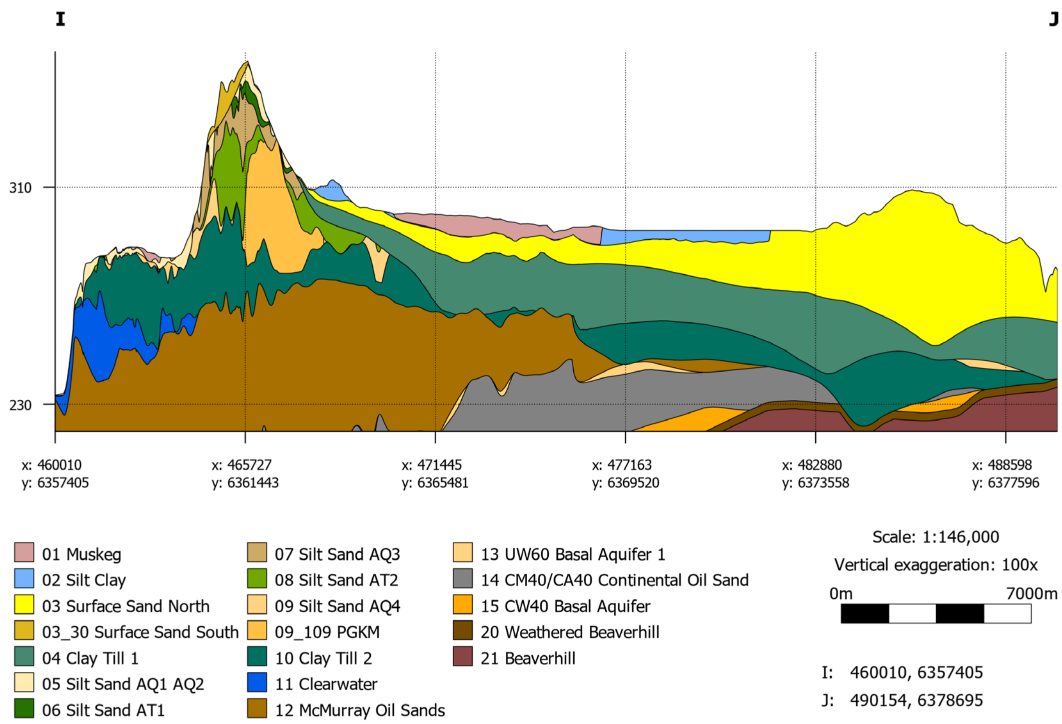

Figure 22 Cross-section I-J through the 2020 Unified Geomodel (section location shown in Figure 17). Vertical exaggeration is 80:1.

As noted previously, there is an erosional unconformity between the MLWC watershed area`s underlying Devonian bedrock and Cretaceous sediments; and an additional unconformity between the Cretaceous and Quaternary sediments. As a consequence, the topographic gradient of the deeper geology of the area exerts no influence on shallow groundwater flow directions within the Quaternary hydrostratigraphy. Instead, the orientation of the structural tops of the laterally extensive (Quaternary) clay till deposits exert this influence on flows in the sand aquifers within the Quaternary sequence. More specifically, Clay Till 2 acts as proxy bedrock geology with respect to flows in the overlying silt sand sequence within the FHUC, whereas Clay Till 1 fulfills this role for the Surface Sand deposits across the NOP and also the slopes of the FHUC that face McClelland Lake. Figure 23 combines the structural tops of these two till surfaces to create a single (somewhat) composite 'bedrock surface'. As can be seen in Figure 23, the composite surfaces both dip in a general northwest orientation. Of note, the cross-section shown in Figure 21 also indicates a 'bowl shape' in the Clay Till 1 surface under McClelland

Lake that likely facilitates a component of northeastern groundwater flows towards the southern, extreme-rich patterned fen and ultimately McClelland Lake.

Clay tills are generally presumed to be composed of low permeability materials. The system characteristics associated with impermeable bedrock geology in the Devito et al. (2005) methodology include:

- characterized by local to intermediate flow systems;
- topographic control on the direction local flow;
- lateral flow dominates in surface substrate;
- bedrock slope parallel to land surface; and
- simple watershed boundaries.

An overview of the geologic setting and observed hydrologic processes in operation at the MLWC indicates general agreement with the characteristics listed above: local flow systems present; groundwater runoff generated from the FHUC or the NOP surface sands flows downgradient towards the fen (mimicking the 'bedrock' gradient); topographic watershed divides easily defined; lateral flows commonly occur in the muskeg.

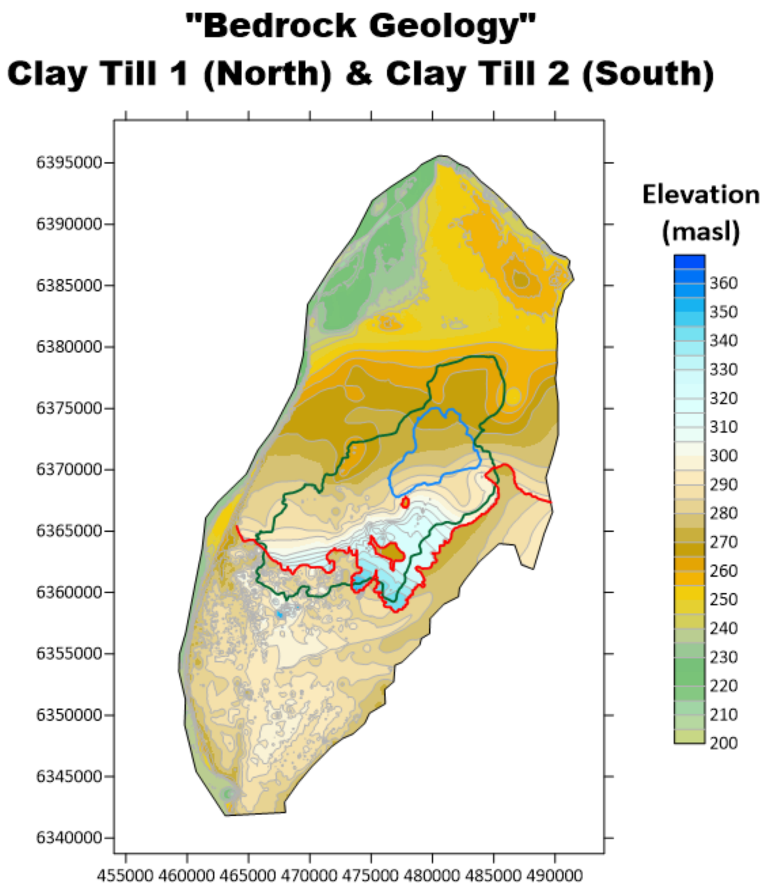

Figure 23 A composite 'bedrock' surface comprised of Clay Till 2 (generally south of the red line in the figure) and Clay Till 1 (north of the red line). The green and blue features on the map outline the topographic watershed and McClelland Lake, respectively. Two hydraulic windows interpreted to be present in Clay Till 1 are also outlined in red on the figure.

7. Section 1.2.3: Factor 03: Surficial Geology

Figure 24 presents the isopach of the deposits overlying Clay Till 1 as well as over Clay Till 2. As can be seen in the figure, the isopach overlying Clay Till 1 is quite thin on its southern margins where it overlies the FHUC and then gets progressively thicker towards the north. The bulk of the material overlying Clay Till 1 is comprised of the Surface Sands which also underlie deposits of silt clay and muskeg (refer to Figure 16) in the vicinity surrounding McClelland Lake. Vertical to sub-lateral flows would be expected to dominate in the southeastern, steeper sloped regions above Clay Till 1 that transition to predominately lateral flows.

In terms of the Devito et al. (2005) classification framework, the surficial geology of the site falls somewhere between the deep and shallow substrate end members listed in the classification system.

ITK holders have shared ITK around clay, sand and muskeg, including:

> *"At McClelland Lake we would cross, but that would be December and January and more on the north side – from around where the boat launch is now, across on the higher country – pretty well straight across there."* (FCM ITK holder, March 3, 2021 workshop)

And with respect to limestone and clay:

> *"I know there's a lot of limestone through there. Now the water, course, is sitting on this limestone. It doesn't fall through the limestone, maybe some places. And there's clay in there too, and water don't go through clay..... What about the fen? What's underneath the fen? There's water. There's tar sand under the fen and then the limestone? Because I know the limestone from there runs right to Fort McMurray, past Fort McMurray. The furthest north I've seen it was at the Firebag, and I could be wrong. It could be further north yet too, but I know the Firebag. So the water then, it's sitting... Okay, it's limestone, tar sand, water, and the floating muskeg on top. That's the way I'm picturing it."* (FCM ITK holder, March 3, 021 workshop).

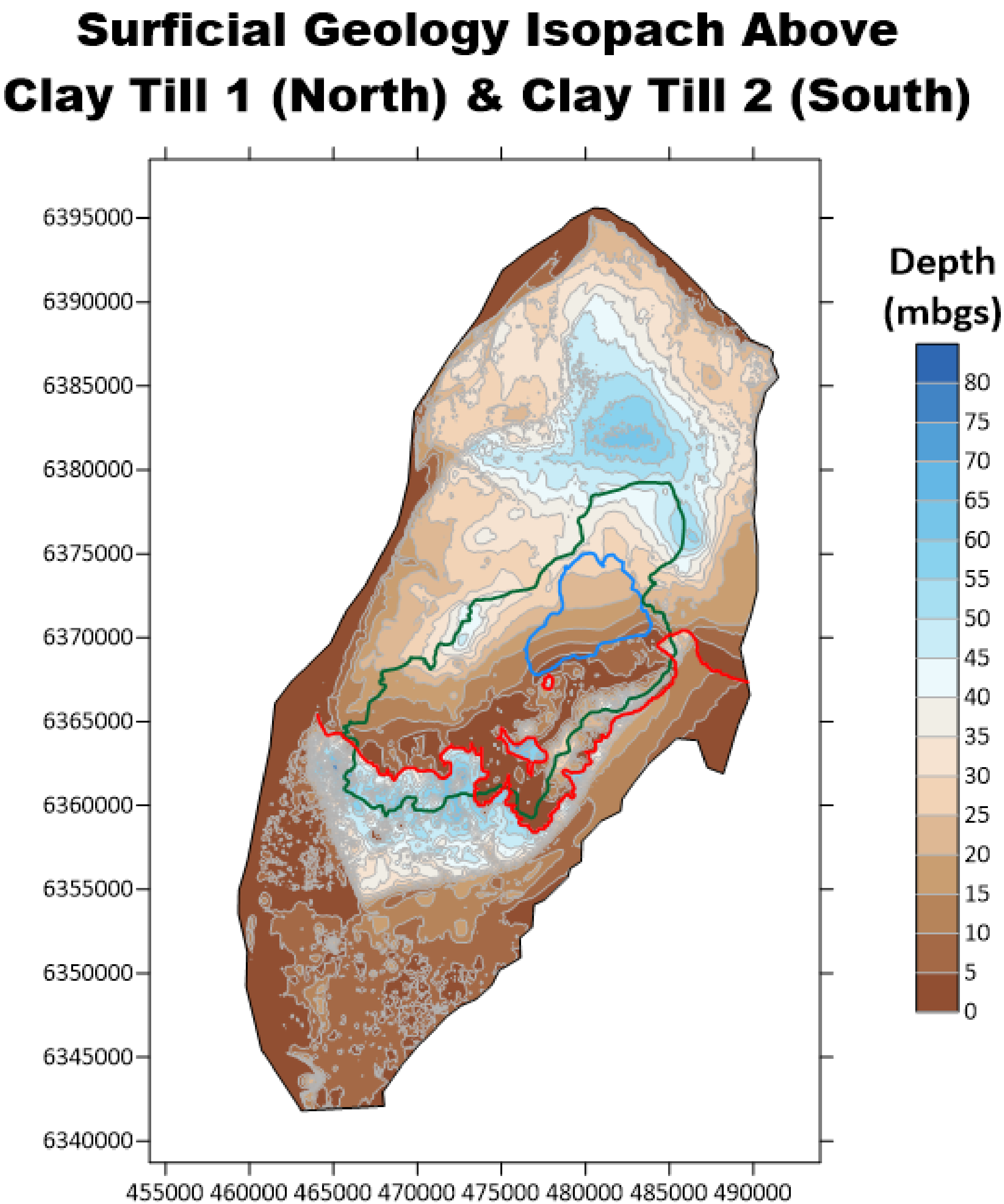

Figure 24 An isopach depth map of the NOP materials lying above Clay Till 1 (the area north of the red line) and the FHUC materials overlying Clay Till 2 (the area south of the red line). Two hydraulic windows interpreted to be present in Clay Till 1 are also outlined in red on the figure.

8. Section 1.2.4: Factor 04: Soil

Figure 25 presents the soils distribution across the 2020 Unified Geomodel domain. The distribution merges local (MLWC watershed) soil information presented in Golder (2018) with the more regional data presented in Soundarapandian et al. (2019) for areas outside of the watershed. Table 1 presents the names of the different soil types, their associated drainage class and the surveyed horizon depths of these soils within the MLWC watershed.

ITK holders have shared ITK around sandy soil types that influence runoff or infiltration. For example:

> *"Yeah, because it's right in the middle of the sand hills, right? And all through here, even here where we're sitting right here [pothole lake by Victor Amiot's cabin], this is all sand hills right through. And for miles this way, right up to Firebag, I think there's sand hills."* (FMFN ITK holder, FMMN 2017).
>
> *"It's nice to kill Moose over here (north/east side) cause it's sandy"* (FMMN ITK holder, FMMN 2017).
>
> *And, with respect to the bottom of McClelland Lake, "...But I know from boating around, the bottom is like quicksand. Maybe it's because it just sits there for so long, turn everything in to quicksand, that part is dangerous too. We would get in trouble if went too far in to the lake."* (FMFN ITK holder, March 3, 2021 workshop).

As might be expected, the soils are a mixture of well-draining mineral soils that tend to be deposited at (relative to the elevation of the lake) higher elevations and poor-draining organic soils that tend to be deposited at relatively lower elevations.

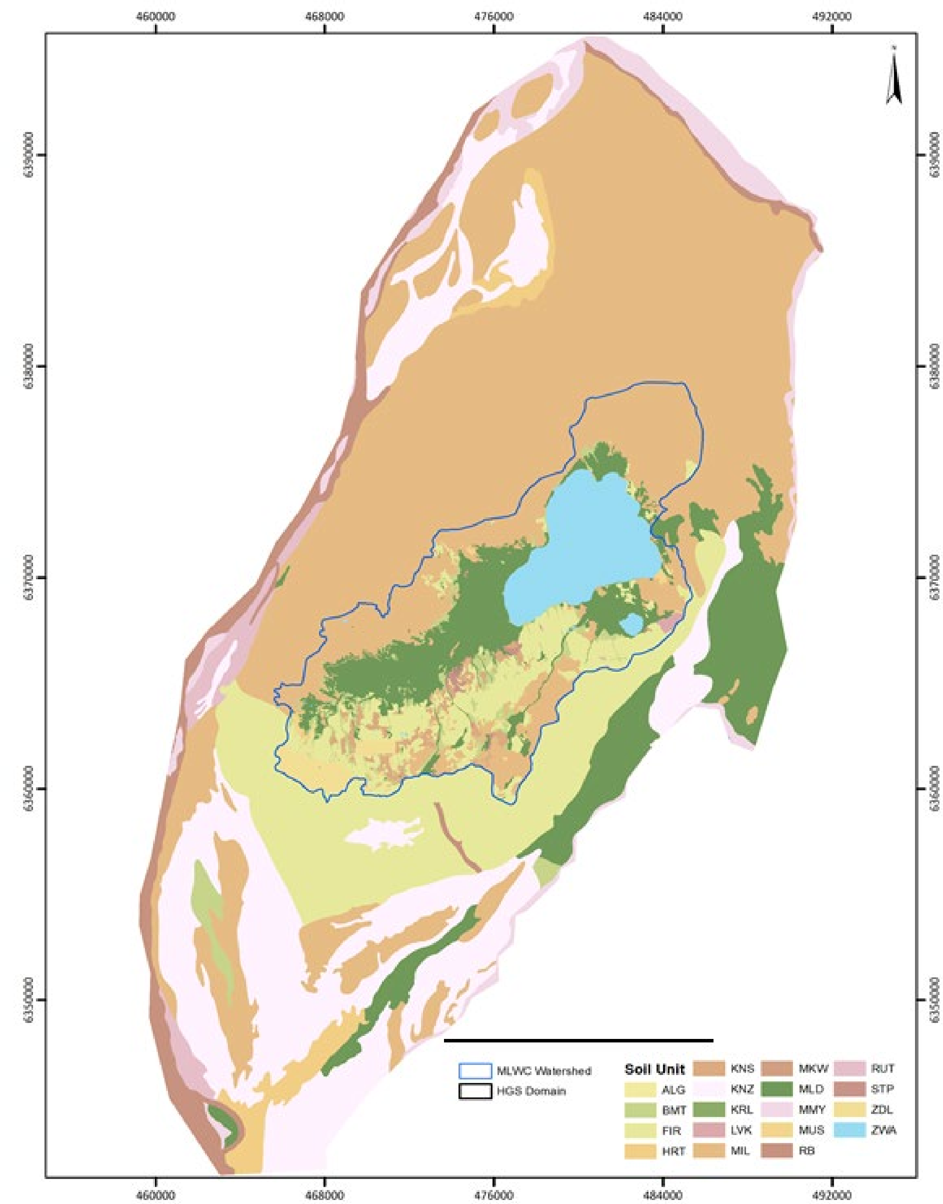

Figure 25 Topsoil distribution across the 2020 Unified Geomodel domain. As might be intuited, well-draining mineral soils dominate at higher elevations while poorly draining organic soils at lower locations.

				Horizon Thickness (cm)			
Soil ID	Soil_Unit	Name	Drainage Class	LFH	A	B	C
1	ALG	ALGAR	Poorly	23	25	35	65
2	BMT	BITUMOUNT	Poorly	12	16	39	79
3	FIR	FIREBAG	Rapidly - Very Rapidly	7	13	39	60
4	HRT	HEART	Rapidly - Very Rapidly	7	13	39	60
5	KNS	KINOSIS	Well	7	14	41	62
6	KNZ	KENZIE	Poorly - Very Poorly	10	20	30	80
7	KRL	KEARL	Rapidly	8	10	26	83
8	LVK	LIVOCK	Well	8	18	41	62
9	MIL	MILDRED	Rapidly	4	12	43	61
10	MKW	MIKKWA	Very Poorly	10	20	30	80
11	MLD	MCLELLAND	Very Poorly	10	20	30	80
12	MMY	MCMURRAY	Imperfect - Poorly	7	28	0	94
13	MUS	MUSKEG	Poorly	10	20	20	61
14	RB	ROUGH BROKEN	Rapidly	7	13	39	60
15	RUT	RUTH LAKE	Moderately Well - Rapidly	2	2	26	34
16	STP	STEEPBANK	Poorly	8	18	33	88
17	ZDL	DEVELOPED		7	13	39	60

Table 1 Soil classes, drainage characteristics and horizon depths of the soils deposited within the 2020 Unified Geomodel domain.

9. Section 1.2.5: Factor 05: Topography

Figure 26 presents the topography across the domain of the 2020 Unified Geomodel. As can be seen in the figure, the topography exhibits relatively steeper slopes along the sides of the FHUC that become more gradual and flatter at the toes of the landform where it intersects the fen-lake complex margins. The extent of the Firebag Moraine upon which the MLWC watershed sits is apparent in the figure. Overall, the topographic gradient is relatively steeper along the slopes of the FHUC facing McClelland Lake, relatively flat in the lowland fen complex adjoining the lake, and more gently sloped between McClelland Lake and the adjoining fen complex and the sand dunes in the North Outwash Plains deposits to the north and west, whose vertices define the western MLWC watershed boundary.

ITK has been provided with respect to topographic and landscape changes including traditional trails and access routes and increasing anthropogenic linear disturbances and physical barriers. This is important not only for characterizing the pre-development and pre-mining conditions but as well for closure and reclamation planning:

> *"FCM Knowledge Holders have said cutlines were made in the early 1970s, following and significantly widening, the old dog team trails around areas of McClelland Lake that were made before mining in the region"* (FCM ITK holder,FCM 2019).
>
> *"With the increased competition for resources and opening of roads to allow access by outsiders, habitation sites have been damaged through vandalism, theft, garbage dumping, and illicit activities"* (FMMN and FMFN ITK Holders, IEG 2021).
>
> *"Participants have already observed changes to transportation network within the McClelland Lake Wetland Complex and surrounding area. Members are concerned about their continued ability to travel within the area, as they have already felt the effects of restricted access to traditional routes due to gates and fences. They have witnessed the clearing of new paths and roads that overrun older routes or which are now confusing to navigate, increased disturbances, and increased access for recreational users and/or non-Indigenous hunters. Currently, members are still able to travel within the fen and on McClelland Lake, but often use trails via the north end of the watershed to access the fen and the lake. This is because industry has already created disturbances in the south of the watershed, preventing them from using the area the way they would like."* (FMMN and FMFN ITK Holders, IEG 2021).
>
> *IK holders have also said that changes to the topography will also have impacts on how sound travels and visual disturbances.* (IEG 2021).

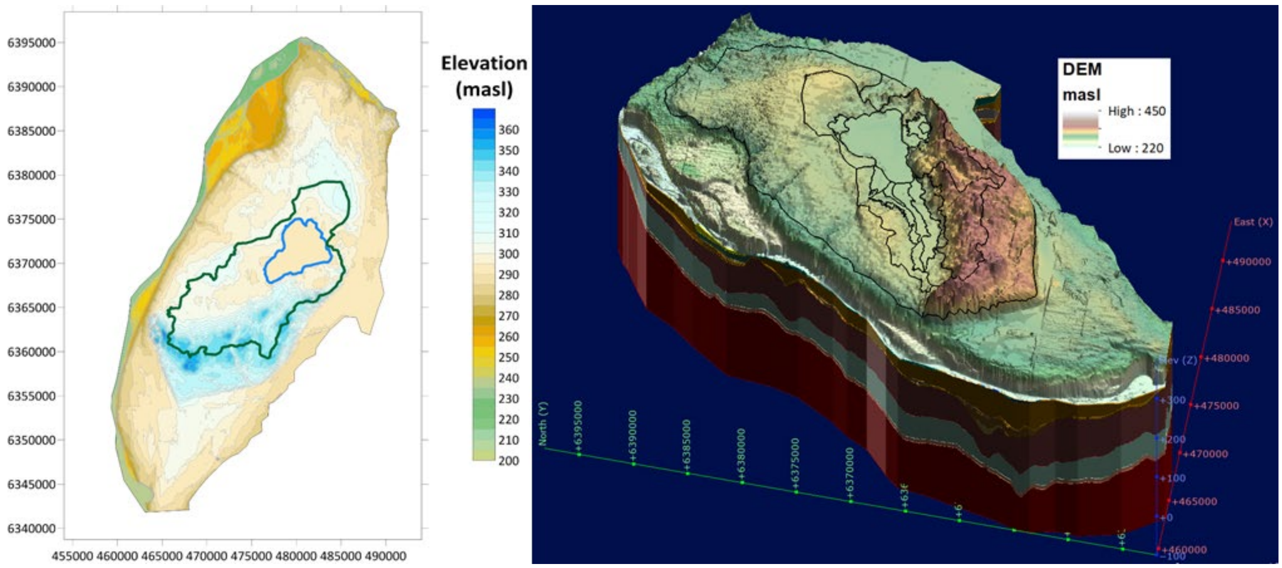

Figure 26 Topography across the 2020 Unified Geomodel domain in plan view (left) and in three-dimensions (right). 3-D vertical exaggeration is 80:1. The Hydrologic Response Areas (HRAs) outlined in black on the right-hand panel are discussed in Section 1.3.

10. Section 1.2.6: Land Cover

Land coverage is not one of the explicit factors in the Devito et al. (2005) characterization framework (but is part of the wetland and forestland HU concept discussed near the end of Section 1.1) but was nonetheless considered in the 2021 MLWC Conceptual Model due the influence that vegetative cover has on the hydrological functionality within the MLWC watershed.

Higher resolution land coverage data obtained within the MLWC watershed (Hatfield, 2018) was merged with regional land coverage data (Chowdhury and Chao, 2019) that incorporated the effects of the recent wildfires. The three land coverage schema that were merged are shown in Table 2 and the resulting merged land usage schema is shown in Table 3. The resulting merged land usage map is shown in Figure 27. The merged land coverage map in Figure 27 indicates the MLWC system has a wide range of land covers, some of which are still recovering from wildfire damage.

ITK holders have expressed the linkage of water levels and quality to vegetation, including that water levels are critical for understanding the health of the MLWC and surrounding area. Changes in water quantity can include changes to the lake and stream levels, vegetation, and/or flow connectivity within and surrounding the fen (IEG 2021).

"There are more willows growing where it is drier on the trapline. Sphagnum moss is important for water retention on the land through warmer drier months and a natural fire retardant. "You know, water doesn't do any good unless there's something there to bind it together to keep it moist during the dry periods, you know? …Well, you let it dry out, it's dead. That's it. So that moss gives it a buffer zone. Not a buffer zone, but a slow release of moisture over dry periods. So you drain the stuff out, it dies. Then you have one—peat moss, it's—when it's dry, it's a bad fire hazard, but when it's wet, keep it wet, you got a natural fire barrier." (FCM ITK holder, FCM 2019).

On another extensive visit to the area in 2009, Barb noted the condition of the balsam trees on the Firebag River bank. This was used as a place by Barb and her mother for harvesting balsam bark medicine. "At that time the balsam trees weren't big, as I could remember. Now they were—they're growing, they're big ones. But the bark looks dry. Don't look like the way a balsam bark should look. Balsam bark is kind of smooth and then there's bumps, pebbles where the pitch is in, eh. I looked at it and I said, well, the roots reach the river, so they can't be dry, like with no water. But what was in the water that made the tree like that, is what I thought. Those trees didn't look right. They just looked like they were—I didn't take the bark because it didn't look healthy. Who knows where I got to go now for balsam bark." (FCM ITKholder, FCM 2019).

Barb Hermansen returned to the trapline area, currently owned by Victor Amiot, several times for periods of time in the 1990s. "I found out it [McClelland Lake] was low. It was not as—not where the water used to be. You can tell by the land where the water used to be." Barb noted cat tails where they weren't before. "For one thing, how far the cattails—I can't remember cattails in that area. But I noticed that there was a lot of cattails. There was, like—just like a little channel where it never used to be a little channel. Used to be, like, water was right up to the—to pretty well the main ground where you could just step from the main ground into your boat" (FCM ITK Holder, FCM 2019).

*"Harebell (Blue-eyed grass?) is an important medicinal plant and a good indicator found in high ground/sandy soils. Indigenous people carefully harvest the root of this plant - the length of the root is an indicator of how low the water table is." (*Several ITK Holders, December 12, 2020 Workshop).

Data Source	Zone	Classification		Hatfield Class (Zone)
Hatfield 2018	1	B/Wc	Bog Wooded Coniferous	-
	2	B/S	Bog Shrubby	-
	3	F/Wc	Fen Wooded Coniferous	-
	4	F/S	Fen Shrubby	-
	5	F/G	Fen Graminoid	-
	6	M/G	Marsh Graminoid	-
	7	W/A	Shallow Open Water Aquatic vegetation	-
	8	W/B	Shallow Open Water Bare	-
	9	S/Wc	Swamp Wooded Coniferous	-
	10	S/Wm	Swamp Wooded Mixedwood	-
	11	S/Wd	Swamp Wooded Deciduous	-
	12	S/S	Swamp Shrubby	-
	13	U/Wc	Upland/not wetland Wooded Coniferous	-
	14	U/Wm	Upland/not wetland Wooded Mixedwood	-
	15	U/Wd	Upland/not wetland Wooded Deciduous	-
	16	U/S	Upland/not wetland Shrubby	-
	17	U/G	Upland/not wetland Graminoid	-
AER 1985	20	Coniferous - Closed Jack Pine		U/Wc (13)
	21	Coniferous - White Spruce		U/Wc (13)
	22	Broadleaf - Closed Deciduous		U/Wd (15)
	23	Coniferous Leading Mixedwood - Closed		U/Wc (13)
	24	Mixedwood - Closed		U/Wm (14)
	25	Shrub - Closed Upland		U/S (16)
	26	Wetlands - Graminoid		M/G (6)
	27	Wetlands - Shrubby		S/S (12)
	28	Coniferous - Black Spruce Bog		B/Wc (1)
	29	Wetland - Undifferentiated		S/S (12)
	30	Water		W/B (8)
	31	Exposed - Barren Land		U/B (new 18)
	32	Bare - Open Pine		U/Wc (13)
	33	Developed Footprints		U/B (new 18)
	34	Burned Areas - Little Biomass		U/B (new 18)
AER 2011	35	Burned Coniferous - Closed Jack Pine		Burned U/Wc (new 19)
	36	Burned Bare - Open Pine		Burned U/Wc (new 19)
	37	Burned Coniferous - White Spruce		Burned U/Wc (new 19)
	38	Burned Wetlands - Shrubby		Burned S/S (new 20)
	39	Burned Coniferous Leading Mixedwood - Closed		Burned U/Wc (new 19)
	40	Burned Mixedwood - Closed		Burned U/Wm (new 21)
	41	Burned Wetland - Undifferentiated		Burned S/S (new 20)

Table 2 Local land usage (Hatfield, 2018) and pre- and post-2011 wildfire schema that were merged for the MLWC Project.

No.	Classification	
1	B/Wc	Bog Wooded Coniferous
2	B/S	Bog Shrubby
3	F/Wc	Fen Wooded Coniferous
4	F/S	Fen Shrubby
5	F/G	Fen Graminoid
6	M/G	Marsh Graminoid
7	W/A	Shallow Open Water Aquatic vegetation
8	W/B	Shallow Open Water Bare
9	S/Wc	Swamp Wooded Coniferous
10	S/Wm	Swamp Wooded Mixedwood
11	S/Wd	Swamp Wooded Deciduous
12	S/S	Swamp Shrubby
13	U/Wc	Upland/not wetland Wooded Coniferous
14	U/Wm	Upland/not wetland Wooded Mixedwood
15	U/Wd	Upland/not wetland Wooded Deciduous
16	U/S	Upland/not wetland Shrubby
17	U/G	Upland/not wetland Graminoid
18	U/B	Upland/Bare
19	Burned U/Wc	Burned Upland/not wetland Wooded Coniferous
20	Burned S/S	Burned Swamp Shrubby
21	Burned U/Wm	Burned Upland/not wetland Wooded Mixedwood

Table 3 Merged land usage classification schema for the MLWC Project.

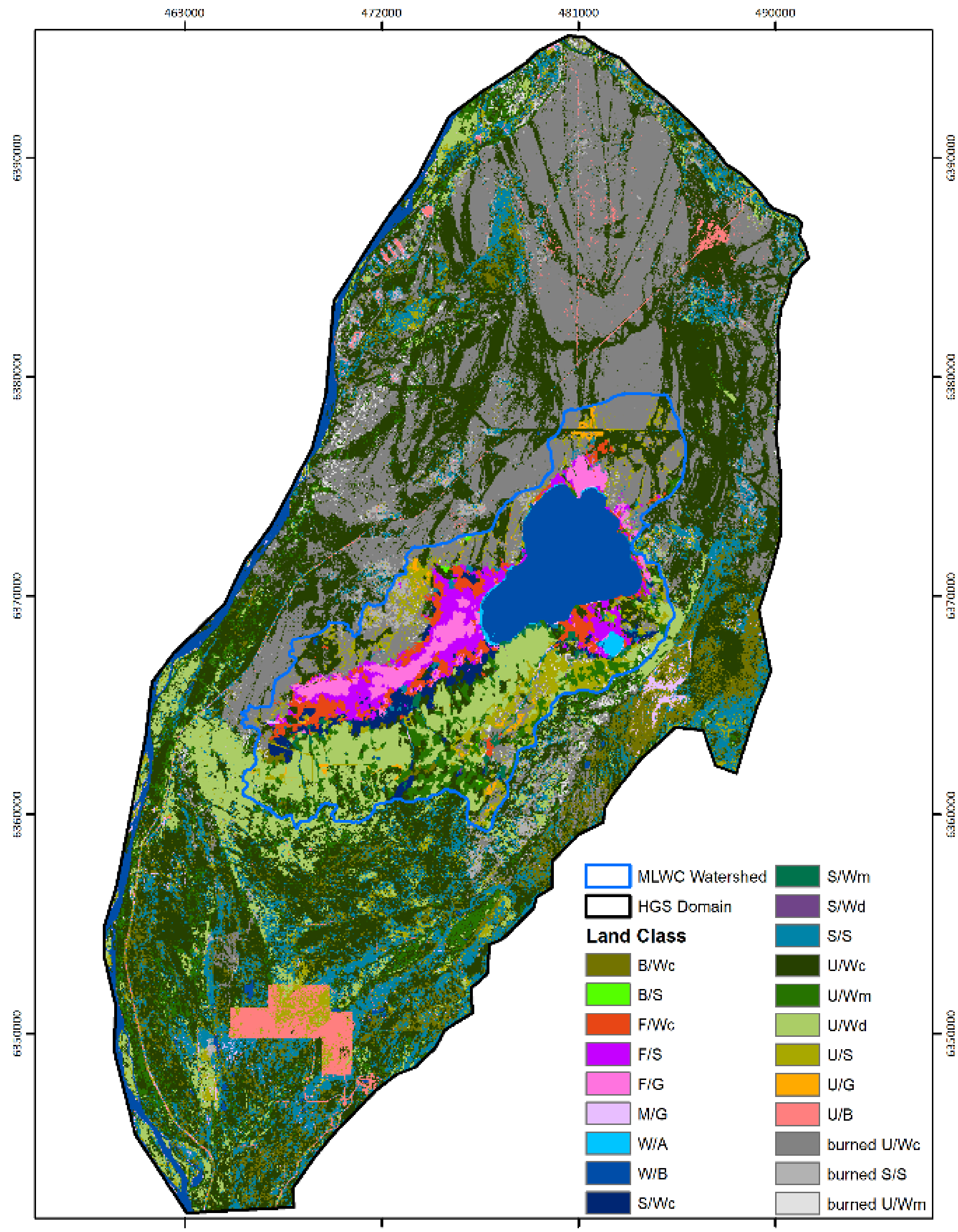

Figure 27 Regional land usage. The land usage shown in the figure corresponds to circa 2016.

11. Section 1.3: Definition and Delineation of the MLWC HRAs

The system insight gained using the Devito et al. (2005) characterization framework was subsequently merged with additional insight gained from analysis of collected field data and previous MLWC Project technical work. The ecohydrological work of Vitt and House (2020) was particularly useful in that regard; that study included mapped surface water flows in the west lowland fen complex west of McClelland Lake. Vitt and House (2020) also defined a series of ecohydrological zones that were used as the initial starting point for the subsequently delineated HRAs described below. The ecohydrological zones (EHZs) developed for the ecohydrology conceptual model in Objective 1 are distinct from the hydrological response areas (HRAs) developed for the 2021 MLWC Conceptual Model (and implemented in the 2020 MLWC HGS model). This is because the EHZs primarily consider ecohydrological considerations in their delineation whereas the HRAs take into account those factors and additional ones such as bedrock topography, bedrock permeability, substrate depth, climate, etc. As well, the application of the EHZs and HRAs differ as well; EHZs provide a framework to generate deeper ecological understanding of a system (often with a focus on vegetative concerns) whereas HRAs are developed to generate a deeper understanding of overall system hydrological functioning. Because of the different factors considered in their delineation, EHZs and HRAs developed for the same site can be differently shaped. In the context of the MLWC system, the developed HRAs largely overlap and subdivide the EHZs developed by Vitt and House (2020) (Table 4). The MLWC HRAs

A diagram overviewing the MLWC HRA derivation process is shown in Figure 28. The resulting 21 MLWC HRA's are presented in Figure 29. The EHZs developed by Vitt and House (2020) for the MLWC are shown in Figure 30 and their proportions within the HRAs are listed in Table 4. The areas and orientation of each MLWC HRA are tabulated in Table 5. The distribution of land usage within each MLWC HRA is presented in Table 6. The relative proportions of the soils types in each HRA are shown in Table 7. As can be seen in Table 7, the developed HRAs exhibit a wide degree of variation. Figure 31 presents conceptualized surface and subsurface flow directions and magnitudes across the MLWC watershed system. The information in Tables 5-7 will be discussed in more detail in the sections below that discuss each HRA individually.

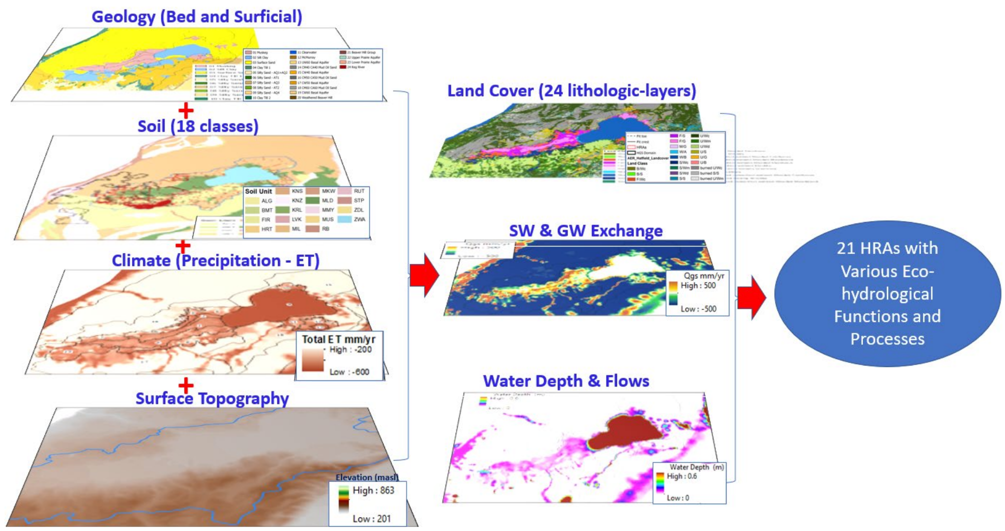

Figure 28 Summary diagram illustrating the HRA derivation process.

The 2020 MLWC HGS model was used to compute water budgets for each of the HRAs over the time period 1988-2013. The results were broken down into the long-term annual water budget for the MLWC watershed, temporally-averaged average monthly budgets over those 25 years and continuous monthly water budgets for all 25 years of the simulation period. Doing so allows for the assessment of each HRAs mean, seasonal and inter-annual water budget behavior based on simulation results that can be compared to conceptualized HRA behavior. Simulated average annual water budget components (1988-2013) for each HRA are shown in Table 8. Note that the computed water budget information was used to complement and enhance the conceptual understanding of each HRA's hydrologic functioning but not used to develop the conceptual understanding itself.

The computed water budgets were determined using the Water Balance Model (described in the modelling appendix of Objective 3 in the MLWC OP). Flux planes along the MLWC watershed edges and interior tracking polygons were added to the watershed interior to track water flows in and out of each HRA. Tracking polygons were also added to the top and bottom of each HRA (datum was Clay Till 2). The Water balance Model was setup using a nested mesh approach that was used to accommodate the any shifts to the groundwater divide location in the watershed. Watershed-scale and HRA-scale budgets were produced.

Calculation of water balance components for sub-areas within HGS (such as individual HRA balances computed using tracking polygons) are associated with a higher mass balance errors than would be generally be realized with a water balance of the global model domain. This greater degree of uncertainty in the sub-areas water balances is an outcome of complexities related to HGS's numerical discretization scheme (control volume finite element method) and an area of future model enhancement. The issue is generally negligible but is exasperated the more irregular the tracking polygon (or model sub-area) is shaped. Regularly-shaped tracking polygons produce much better results. As a consequence, the water balance results produced for the individual HRAs are only used as supplementary information to gain additional insight into the hydrological functioning of the MLWC HRAs.

Simulated long-term actual evapotranspiration rates, depths to the water table, saturations and exchange fluxes (the rate that water moves across the land surface) averaged over the period 1988-2013 are shown in Figures 30-33, respectively. The results shown in these figures are discussed in the individual HRA sections (Sections 1.3.1 to 1.3.21). These temporally-averaged maps can also be used to assess model-predicted long-term hydrologic behavior of each HRA. Sections 1.3.1 to 1.3.21 to present descriptions of the unique characteristics of each MLWC HRA, discuss conceptualized HRA behavior and summarize predicted behavior based off of the water balance and long-term behavior results.

HRA ID		HRA Name
1	Within MLWC Watershed	Patterned Fen - South
2		Patterned Fen - North
3		Graminoid Fen
4		Non-Patterned Fen - South
5		Non-Patterned Fen - West
6		Non-Patterned Fen - North
7		Coniferous Swamp - North
8		Coniferous Swamp - South
9		McClelland Lake
10		North Wetland
11		South Wetland - to McClelland Lake
12		South Wetland - to Unnamed Lake
13		Unnamed Lake
14		Coniferous Swamp - West
15		NOP East
16		NOP West
17		Fort Hills West
18		Fort Hills East
19	Outside MLWC	Fort Hills South
20		NOP North
21		Lake Outlet

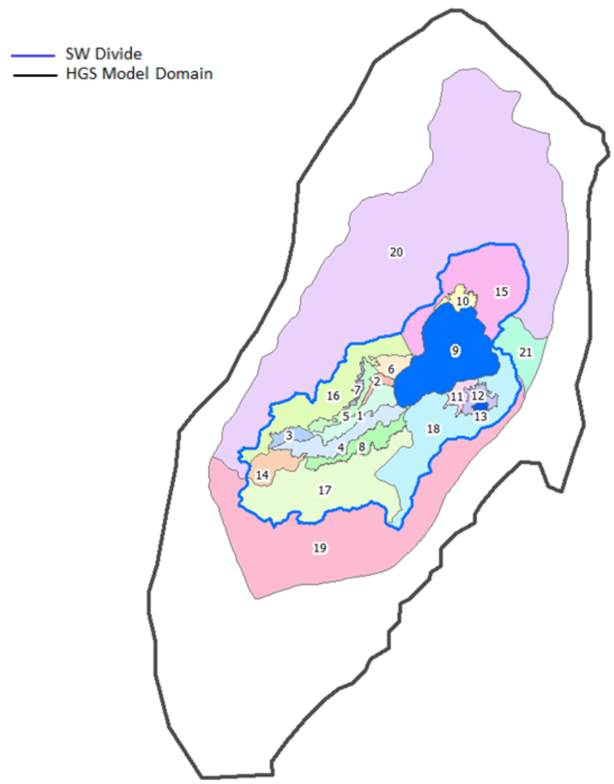

Figure 29 The HRAs developed for MLWC watershed (HRAs 1-18) and the surrounding extents of the FHUC (HRA 19), the NOP (HRA 20) and the discharge area from the McClelland Lake (HRA 21). The blue outline in the figure denotes the MLWC watershed boundary and the black line represents the extent of the 2020 MLWC HGS model domain.

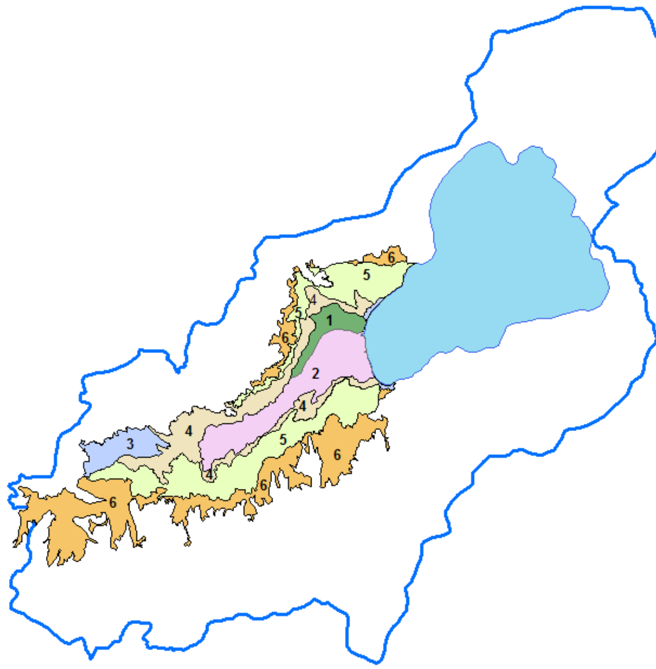

Figure 30 The EHZs (ecohydrological zones) developed for the MLWC in Vitt and House (2020).

HRA	Proportion of EHZ(s) within HRA
1	90% within EHZ 2 and 10% in EHZ 4
2	100% within EHZ 1
3	80% within EHZ 3 and 15% in EHZ 4
4	30% within EHZ 4 and 70% in EHZ 5
5	40% within EHZ 5 and 60% in EHZ 4
6	90% within EHZ 5 and 10% in EHZ 4
7	100% within EHZ 6
8	80% within EHZ 6
14	70% within EHZ 6

Table 4 Correspondence between the EHZs in Vitt and House (2020) and the HRAs developed for the 2021 MLWC Conceptual Model.

HRA ID	Area (km^2)	Elevation (masl)	Aspect (degrees azimuth)	Slope (degrees)	Slope (%)
1	6.32	296.65	90.37	0.05	0.09
2	1.33	294.99	102.24	0.03	0.05
3	2.42	300.08	154.19	0.08	0.14
4	9.42	298.55	162.04	0.11	0.19
5	4.07	297.33	115.43	0.11	0.20
6	3.19	295.24	163.40	0.09	0.16
7	1.03	297.27	116.11	0.58	1.00
8	6.72	305.44	222.61	1.24	2.16
9	30.46	292.72	176.14	0.20	0.35
10	2.54	294.65	150.96	0.21	0.38
11	2.55	295.74	171.78	0.43	0.74
12	2.93	295.73	190.83	0.28	0.48
13	0.83	295.27	177.83	0.03	0.05
14	6.22	305.40	152.63	0.58	1.01
15	29.33	302.43	195.36	0.60	1.04
16	23.39	303.20	160.35	0.64	1.12
17	37.62	334.02	189.31	1.66	2.90
18	32.53	319.42	194.60	2.13	3.72
19	85.58	332.27	175.71	2.39	4.18
20	222.63	297.55	183.59	0.67	1.17
21	10.03	296.07	155.47	1.25	2.18

Table 5 MLWC HRA areas and orientation.

HRA ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
B/Wc				0.01	0.47	0.02	0.36	1.09			1.40	0.28		8.52		0.05	1.20	0.71	4.94	0.64	4.25
B/S					0.83	2.24						1.42				0.35	0.05	0.04			
F/Wc	2.09	0.71	8.83	33.03	36.24	35.86	7.99	1.00	0.07	3.86	51.11	13.12	0.08	18.19	2.63	1.03		1.38			
F/S	29.71	74.58	16.65	33.66	35.11	38.75	1.75	0.11	0.09	14.76	16.26	47.18	0.46	2.92	1.60	0.56		0.89			
F/G	67.30	25.54	68.17	6.34	11.50	1.05		0.03	0.02	72.27	1.19	3.78	0.43	0.99	1.35	0.08		0.74			0.01
M/G	0.14			0.20				0.09	0.06	0.64	1.21	0.47	3.24	1.04	0.06	0.03	0.12	0.42	0.09	0.05	1.45
W/A	0.26	0.25		0.05		0.46			1.81	1.03		1.07	92.49		0.05			0.03			
W/B	0.02					0.01		0.05	97.88	0.34	1.72	0.32	2.46	0.27	0.16	0.17	0.17	0.23	0.02	0.01	0.21
S/Wc	0.14			22.12	4.96	8.32	0.63	29.50			2.20	11.81		25.13	0.01	0.01	1.53	1.36			
S/Wm				0.21				5.07	0.03		8.91	0.84	0.05	4.32	0.04		0.68	3.04			
S/Wd								0.23									0.08	0.07			
S/S	0.42			2.74	2.04	5.73	0.31	1.18	0.06	0.57	0.04	7.68	0.82	0.95	1.21	0.17	0.89	1.73	12.05	2.50	15.31
U/Wc			1.62	1.61	1.64	3.97	25.06	26.03		1.30	12.58	4.09		10.86	24.76	20.34	15.96	9.20	42.23	41.67	42.75
U/Wm				0.06			3.83	11.50	0.03	2.23	3.32	0.13	0.04	6.06	1.32	0.22	22.63	14.76	6.30	0.93	2.48
U/Wd								20.16						6.17	0.22		53.41	21.79	22.78	0.69	9.15
U/S			0.85	0.03	0.64	0.17	8.84	4.02	0.03	1.79	0.05	5.69		5.98	9.69	18.34	2.20	26.88	2.90	0.27	4.51
U/G							1.91	0.02						0.65	2.45	1.83	0.89	1.52			
U/B															0.01				0.06	1.36	0.20
Burned/Wc			3.26		6.42	3.35	44.39			0.88	0.08	2.18		6.82	52.10	48.93	0.22	10.90	4.11	49.26	15.29
Burned Wetland			0.65		0.12	0.06	0.61			0.32		0.01		0.15	2.06	7.58	0.05	2.07	3.68	2.36	3.88
Burned/Wm			0.06		0.09	0.09	4.41			0.70	0.01			1.05	0.36	0.39		2.31	0.92	0.33	0.59

Table 6 MLWC HRA land usage proportions. The tabulated numbers are percentages of a given land usage type within that HRA.

HRA ID	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
ALG														1.00							
BMT	0.05		3.45	2.14	7.86	0.62	58.58	23.04	0.02	5.44	2.19	0.59		20.10	1.80	0.75	5.95	5.56		0.66	
FIR				0.02			2.09	19.06			6.89	6.84		11.61	3.26	4.00	46.77	43.63	94.98	0.03	25.91
HRT																					
KNS				0.04				14.73						2.88			11.72	0.72			
KNZ																			3.74		1.29
KRL														0.60			0.01				
LVK																		2.20		99.18	46.33
MIL	0.01		13.67	1.01	4.59	1.01	34.06	2.25	0.03	0.69	5.12	1.29		14.14	90.68	92.62	13.77	37.15	0.14		
MKW					0.83	0.45														0.12	26.48
MLD	99.73	99.92	82.88	96.55	86.72	95.23	5.26	26.09	0.11	90.77	85.45	90.47	1.55	40.23	3.76	2.06	3.27	8.24			
MMY																		0.04			
MUS				0.01		2.02		0.98						9.14	0.05	0.43	1.21	1.51			
RB																			1.12		
RUT																	0.03				
STP				0.06				13.82									0.35	0.26			
ZDL																	16.83		0.02		
ZWA	0.21	0.08		0.17		0.66		0.03	99.84	3.09	0.34	0.80	98.45	0.32	0.44	0.15	0.09	0.70			

Table 7 MLWC HRA soil cover proportions. The tabulated numbers are percentages of a given soil cover within that HRA.

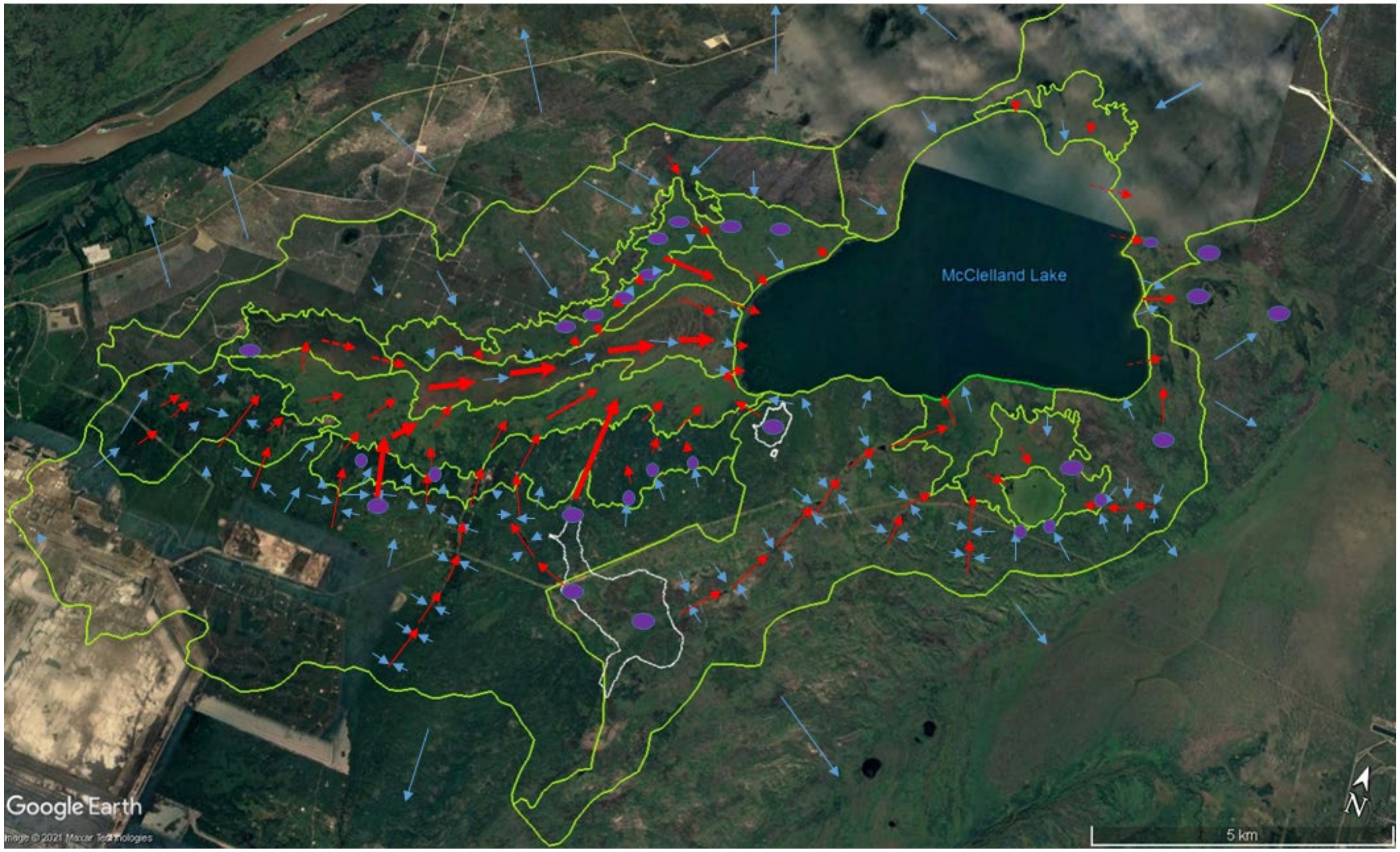

Figure 31 Conceptual surface water and groundwater flow directions. The red arrows in the figure represent surface water flows, the blue arrows represent groundwater flows and the purple ovals areas of groundwater exfiltration to surface. The areas outlined in green are the MLWC HRAs and the areas outlined in white are mapped hydraulic windows. Image source: Google Earth and Maxar Technologies.

HRA ID	Precipitation (mm/yr)	AET (mm/yr)	SW Storage (mm/yr)	GW Storage (mm/yr)	GW $Vert_{in}$ (mm/yr)	GW $Vert_{out}$ (mm/yr)	GW $Vert_{total}$ (mm/yr)	GW $Horz_{in}$ (mm/yr)	GW $Horz_{out}$ (mm/yr)	GW $Horz_{total}$ (mm/yr)	SW_{in} (mm/yr)	SW_{out} (mm/yr)	SW_{total} (mm/yr)	Residual
1	413.2	-443.4	1.4	0.3	0.0	-3.8	-3.8	162.8	-42.5	120.3	1074.0	-1146.8	-72.8	11.7
2	413.2	-461.6	1.2	0.2	0.0	-3.2	-3.2	452.6	-110.3	342.2	1961.7	-2210.0	-248.3	40.9
3	413.2	-362.3	0.9	0.3	0.0	-9.6	-9.6	135.6	-207.5	-71.9	762.5	-720.8	41.6	9.8
4	413.2	-432.3	0.9	0.3	8.2	-4.9	3.2	212.0	-43.5	168.6	949.4	-1075.7	-126.4	25.0
5	413.2	-345.8	0.3	0.3	0.0	-6.8	-6.8	388.0	-230.0	158.0	944.0	-1155.5	-211.5	6.4
6	413.3	-315.5	0.5	0.2	0.0	-8.2	-8.2	183.6	-91.1	92.5	296.4	-465.8	-169.4	12.1
7	413.3	-361.8	0.0	0.2	0.0	-7.4	-7.4	1110.4	-1118.0	-7.6	0.1	-148.8	-148.7	-112.5
8	413.3	-411.6	0.3	0.7	29.6	-8.5	21.0	355.1	-148.6	206.5	368.2	-559.0	-190.9	37.3
9	413.3	-580.0	1.7	0.0	0.2	-2.6	-2.4	78.5	-9.3	69.2	278.5	-171.7	106.8	5.1
10	413.3	-335.2	0.7	-0.7	0.0	-2.0	-2.0	204.3	-259.9	-55.6	132.6	-137.8	-5.1	15.3
11	413.3	-417.4	0.7	0.5	0.1	-1.3	-1.2	97.7	-47.2	50.5	1083.6	-1089.1	-5.5	38.4
12	413.3	-372.9	0.7	0.5	0.1	-1.5	-1.4	268.1	-48.1	220.0	259.5	-461.7	-202.2	55.7
13	413.3	-581.7	1.5	0.2	0.1	-0.8	-0.8	242.2	-2.1	240.1	658.2	-702.8	-44.6	24.5
14	413.3	-442.0	0.6	0.6	37.0	-7.8	29.2	354.2	-157.6	196.6	149.4	-304.6	-155.1	40.7
15	413.3	-183.9	0.0	-3.5	0.0	-3.2	-3.2	31.1	-277.1	-246.0	25.9	-47.2	-21.4	-37.8
16	413.6	-197.4	0.0	0.1	0.0	-16.0	-16.0	82.8	-335.4	-252.6	44.2	-36.1	8.1	-44.4
17	413.6	-243.7	0.1	-0.1	7.3	-15.5	-8.2	27.3	-138.5	-111.3	0.1	-63.3	-63.2	-12.7
18	413.6	-275.2	0.1	-0.1	0.6	-9.3	-8.7	35.3	-108.6	-73.2	36.6	-124.6	-88.0	-31.5
19	413.6	-219.6	0.1	-0.6	4.8	-13.8	-9.1	21.4	-75.1	-53.7	0.3	-137.1	-136.8	-5.1
20	413.6	-146.7	0.0	-4.4	0.2	-8.2	-8.0	54.8	-334.5	-279.7	22.7	-32.7	-10.1	-26.4
21	413.6	-311.0	0.3	0.1	0.6	-0.4	0.2	107.2	-98.3	8.8	557.9	-702.6	-144.7	-33.5

Table 8 HGS-predicted annual water budgets (1988-2013) for the MLWC HRAs generated using tracking polygons. Please note that negative values in the table represent fluxes leaving individual HRAs while positive ones represent fluxes entering the individual HRAs.

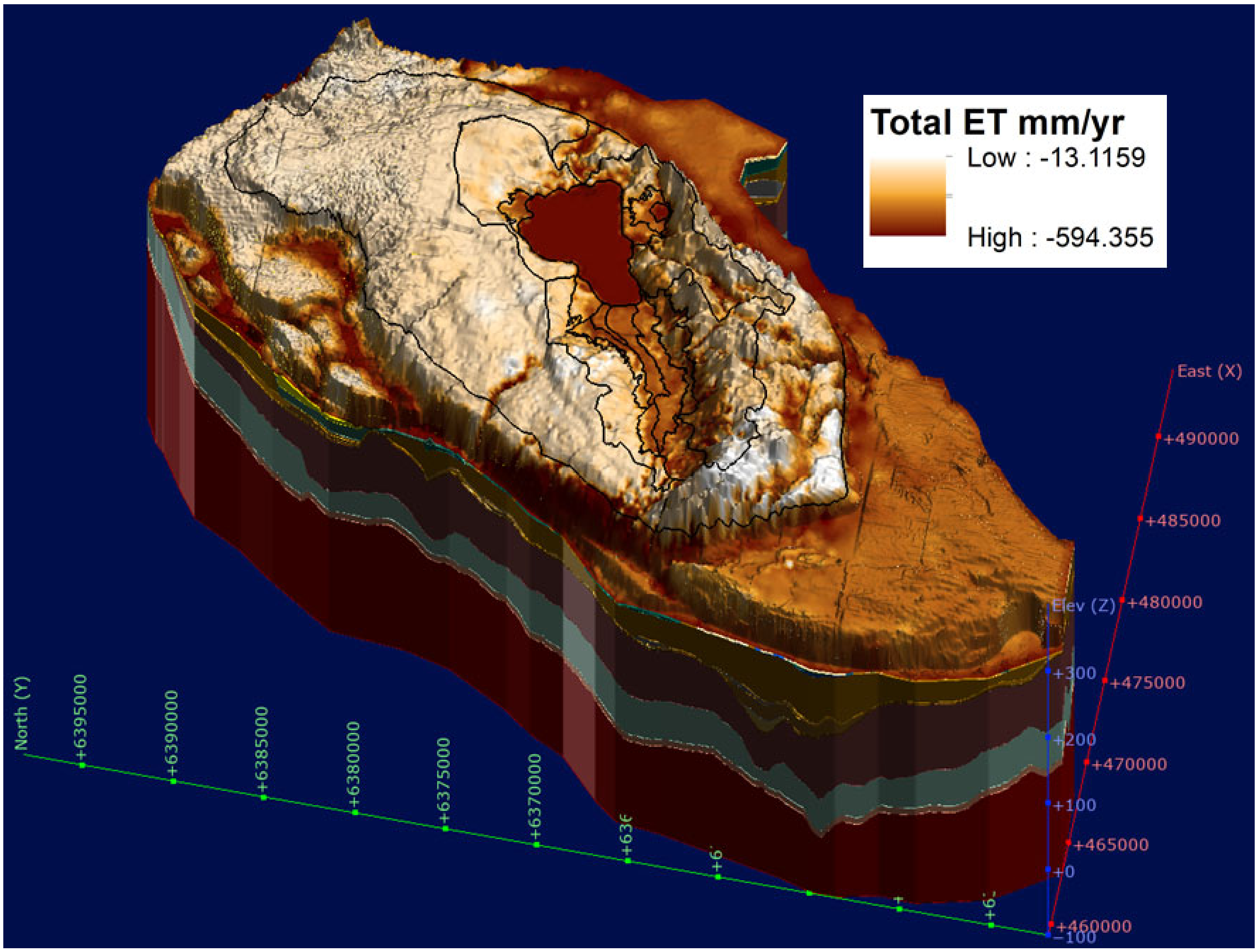

Figure 32 Simulated results of effective (temporally-averaged) actual evapotranspiration rates across the MLWC HRAs (1988-2013). Vertical exaggeration is 80:1.

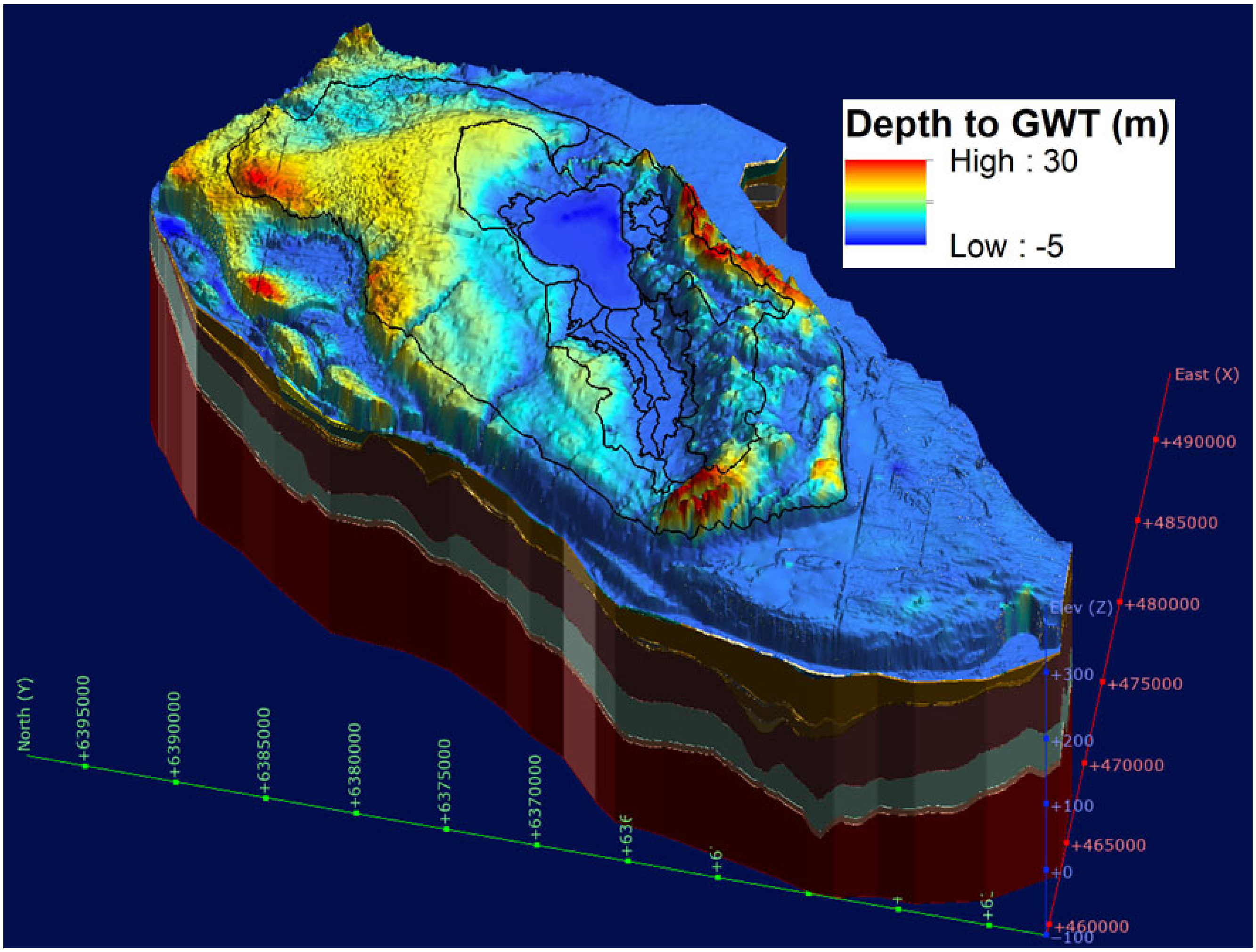

Figure 33 Simulated results of effective (temporally-averaged) depth to groundwater (the water table) across the MLWC HRAs (1988-2013). Vertical exaggeration is 80:1.

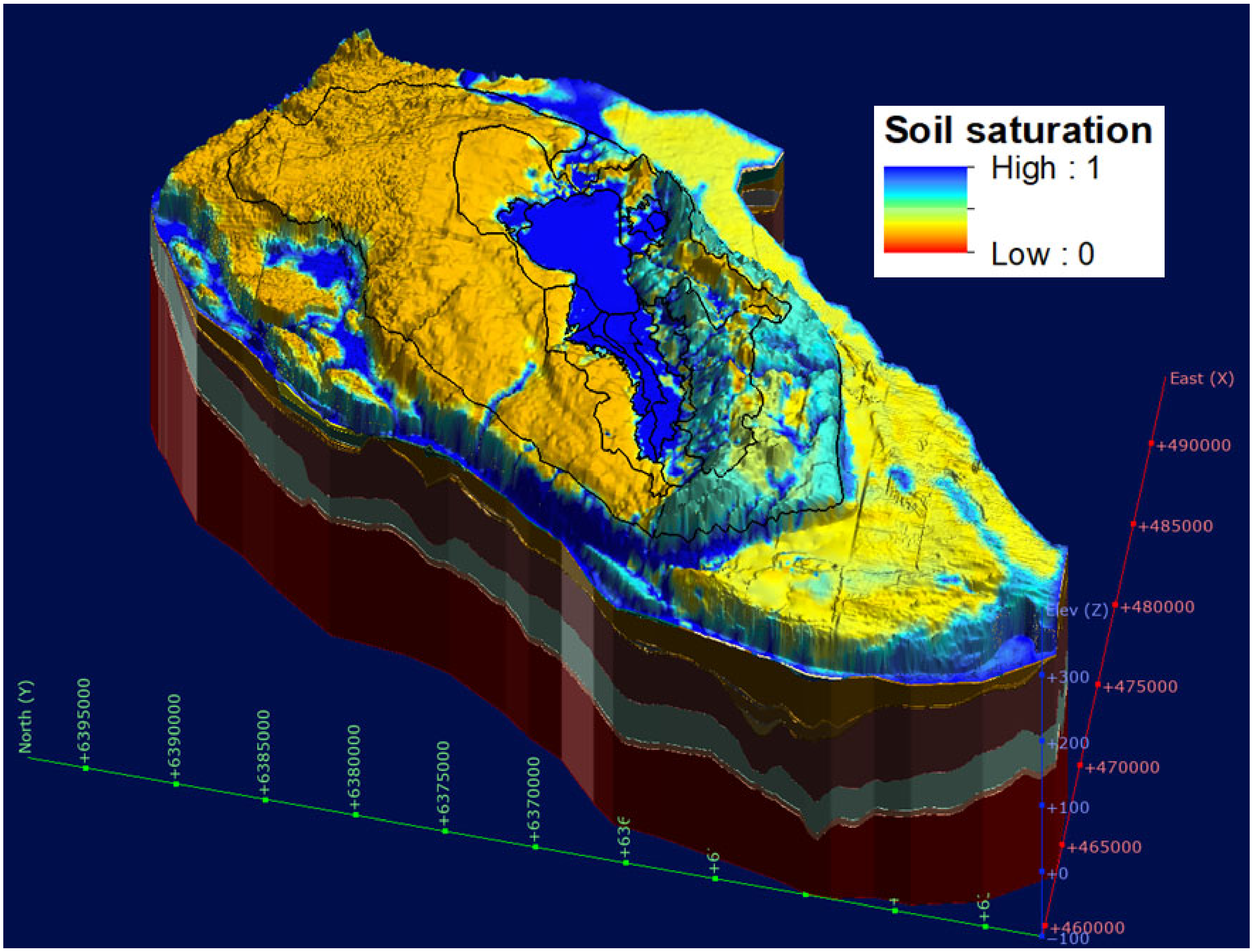

Figure 34 Simulated results of effective (temporally-averaged) topsoil saturation across the MLWC HRAs (1988-2013). Vertical exaggeration is 80:1.

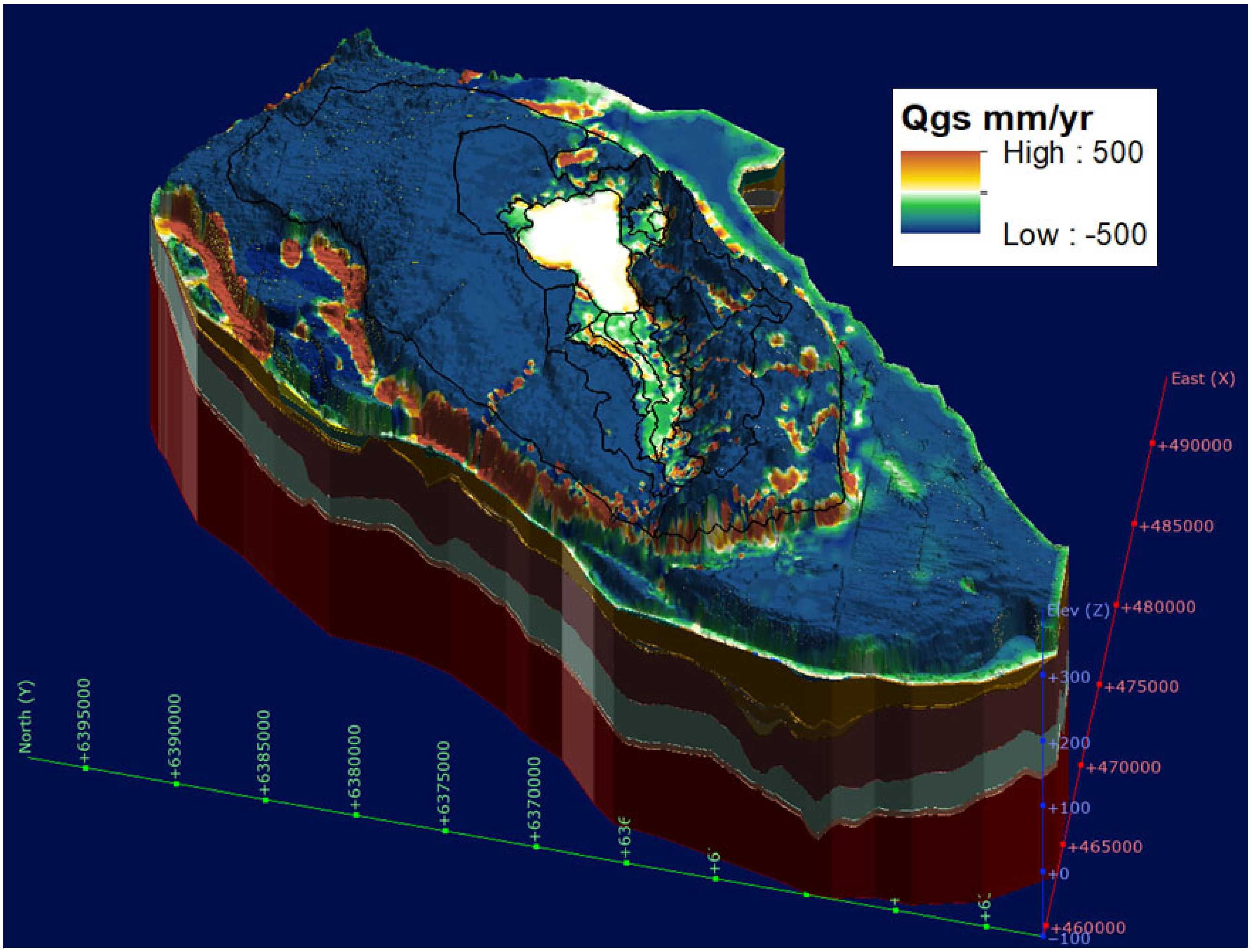

Figure 35 Simulated results of effective (temporally-averaged) exchange flux across the MLWC HRAs (1988-2013). Note that exchange flux is a measure of water movement (up or down) across the land surface; positive exchange flux values indicate groundwater discharge to surface while negative ones indicate surface water infiltration to subsurface. Vertical exaggeration is 80:1.

12. Section 1.3.1: HRA 01: Patterned Fen – South

HRA 01 is designated Patterned Fen – South and cross-sections taken through this HRA are shown in Figure 36. HRA 01 covers an area of approximately 6.3 km^2 that has a mean slope of 0.09%, an aspect of 90.37 degrees azimuth and a mean elevation of 296.65 masl. The dominant land usages classes and forms present in HRA 01 are shrubby fen (29.71%) and graminoid fen (67.3%), respectively. The dominant soil is McClelland (99.73%) which is classified to drain very poorly. Precipitation rates on this HRA average 422.7 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) described this area eco-hydrologically as a patterned extreme rich fen.

Substrate depths above Clay Till 1 in HRA 01 range from 7.3 to 21.5 m (Figure 37). The substrate in HRA 01 is composed of topsoil, Muskeg, Silt Clay and Surface Sands North deposits. Bedrock topography in HRA 01 (Clay Till 01) ranges from 278.0 to 288.3 masl and exhibits an elevated region in its surface in the western central portion of the HRA (Figure 38). Post-development, approximately 60% of the HRA will remain intact.

HRA 01 is conceptualized to receive water from precipitation and flows from HRA 04 (Non-patterned Fen – South), HRA 05 (Non-patterned Fen – West) and seasonally from HRA 03 (Graminoid Fen) (refer to Figure 29, Figure 31 and Figure 36). Contributions from HRA 04 are conceptualized to be primarily composed of surface water flows. Water inputs from HRA 03 are primarily conceptualized to occur during the spring freshet, when snowmelt runoff in the form of sheet flow moves down the topographic gradient over the impermeable, frozen muskeg. The remainder of the ice-free season most years, the flows from the eastern half of HRA 03 are conceptualized to be minimal. The southwestern half of HRA 05 is conceptualized to contribute more groundwater to HRA 01 than surface water. There is a natural surface water flow divide hydraulically isolating HRA01 surface water from HRA 02 (Patterned Fen – North). The water table is conceptualized as being at or near the land surface most times in HRA 01.

Water is conceptualized to leave HRA 01 (in ascending order of conceptualized relative contribution) as groundwater discharge into McClelland Lake, as evapotranspiration and as surface water discharge into McClelland Lake through one of three inlets (Figure 31). During the onset of the spring freshet, snowmelt runoff is conceptualized to flow over the frozen flarks in HRA 01 and discharge into McClelland Lake; any additional inputs of snowmelt or incoming precipitation would continue to generate runoff into the lake until the flarks thawed, potentially weeks after the freshet starts. This input of snowmelt runoff is conceptualized to flush McClelland Lake with very fresh water each spring. For the remainder of the ice-free period, the hydrogeochemistry of waters discharging from HRA 01 to

McClelland Lake (HRA 09) is conceptualized to be a mixture of non-alkaline and cation-poor water from the western margins of the watershed and alkaline and cation-enriched waters originating from the FHUC slopes.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 01 was simulated to receive 25%, 65% and 10% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 01 was simulated to discharge 27%, 70% and 3% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 01 indicates that annual AET rates (443.4 mm/yr) are slightly greater than precipitation rates (413.2 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface (Figure 33); the HRA is simulated to remain near saturated on average (Figure 34) and the exchange of water across the land surface interface is approximately net neutral (Figure 35).

Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves the HRA in the form of surface water. Proportionally more water exits the system in the form of surface water than enters it annually. Proportionally less water exits the system in the form of groundwater than enters it annually.

Figure 39 presents predicted average monthly water balance components over the period 1988-2013. HRA 01 is predicted to produce peak incoming and outgoing flows during the month of April. This HRA adds to surface water storage from approximately September-March and then starts shedding surface water storage with the onset of the spring freshet in April. Peak rainfall rates occur in the month of June and peak AET rates occur in July. Groundwater flows into the HRA at an approximately constant rate May-October and then begins to decline, reaching a minimum during February, before beginning to increase again. Groundwater discharges from the HRA at approximately the same rate most of the year but discharge rates also tend to increase as groundwater inflows decrease during the winter. The HRA sheds groundwater storage each May and gains storage through most of the remainder of the year with the bulk of storage being added June-October.

The timing and the magnitude of incoming and outgoing groundwater flows is predicted to remain relatively consistent from year to year with more groundwater entering the HRA than leaving each year.

August is typically the month when the HRA sees its largest gains in groundwater storage but this can occur anytime June-September. May is the month with that typically consumes the most groundwater storage but this can also occur in August some years.

Figure 40 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 01. Peak monthly precipitation can occur anytime May-August but typically happens in June. Maximum monthly AET rates can happen May-August but usually occur in July. Figure 41 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water inflow can happen March-May but usually occurs in April. Peak monthly surface water discharge can occur March-September but usually happens in April. The largest monthly gain in surface water storage occurs January-October but usually happens in January. The peak monthly consumption of surface water storage can occur anytime March to May but typically happens in April. Figure 42 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur anytime between May to October but typically peaks in July. Peak monthly outgoing groundwater rates occur in March and exhibit strong seasonality. The largest monthly gain in groundwater storage can happen between June and October but usually occurs in September. The largest consumption of groundwater storage usually happens between May to August but usually occurs in May.

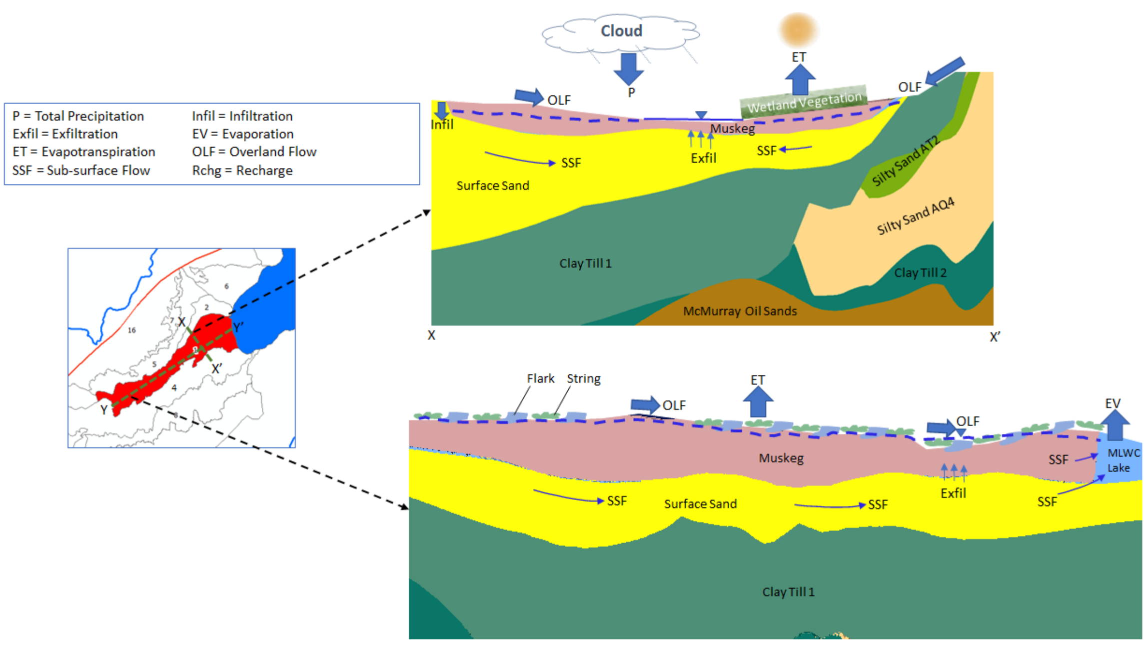

Figure 36 HRA 01: Patterned Fen – South. Vertical exaggeration is 80:1.

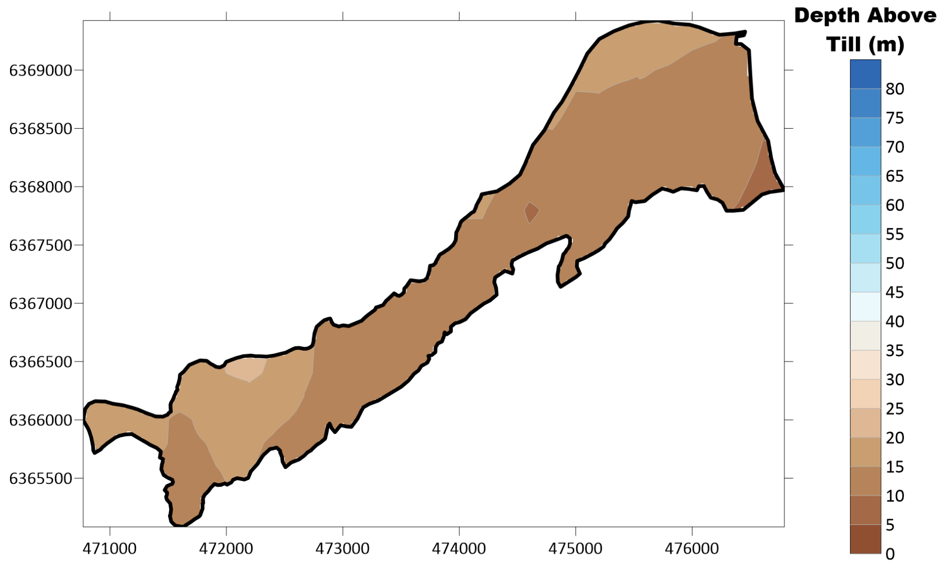

Figure 37 Substrate depths in HRA 01: Patterned Fen – South.

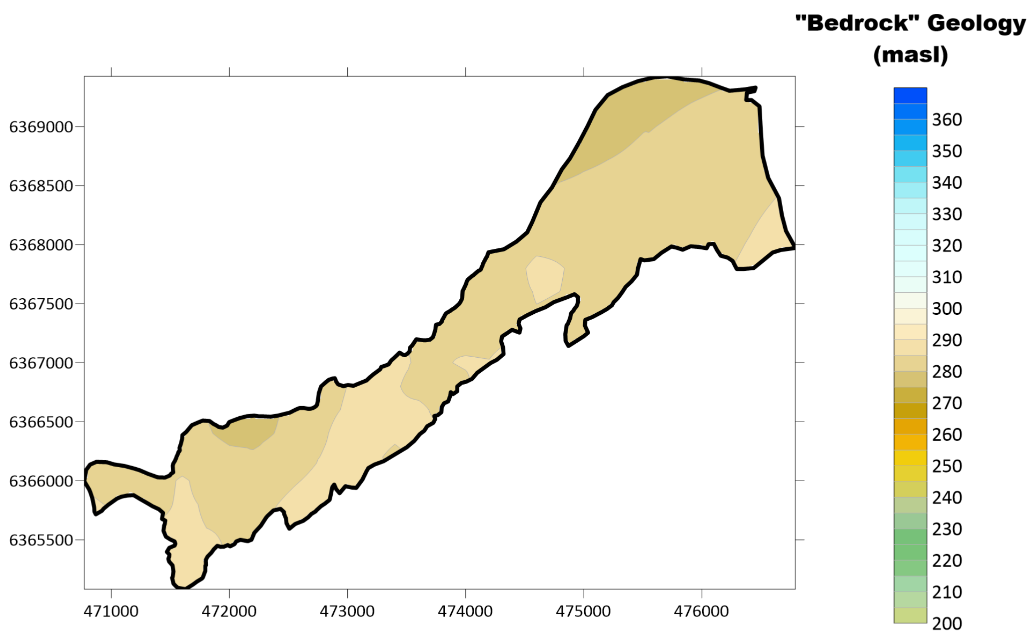

Figure 38 Bedrock topography in HRA 01: Patterned Fen – South.

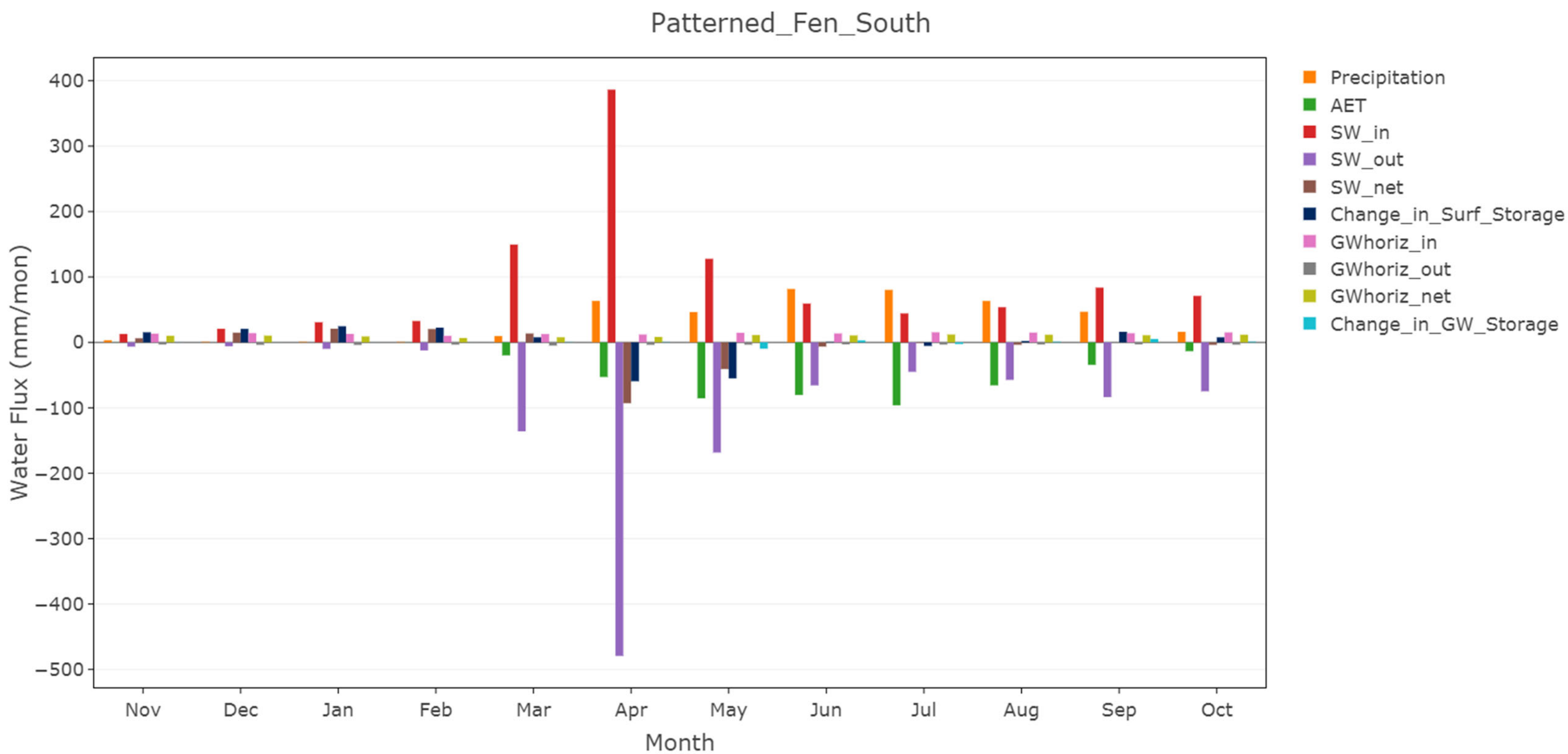

Figure 39 Mean monthly water budget components (1988-2013) for HRA 01: Patterned Fen - South. Note: Inflows are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

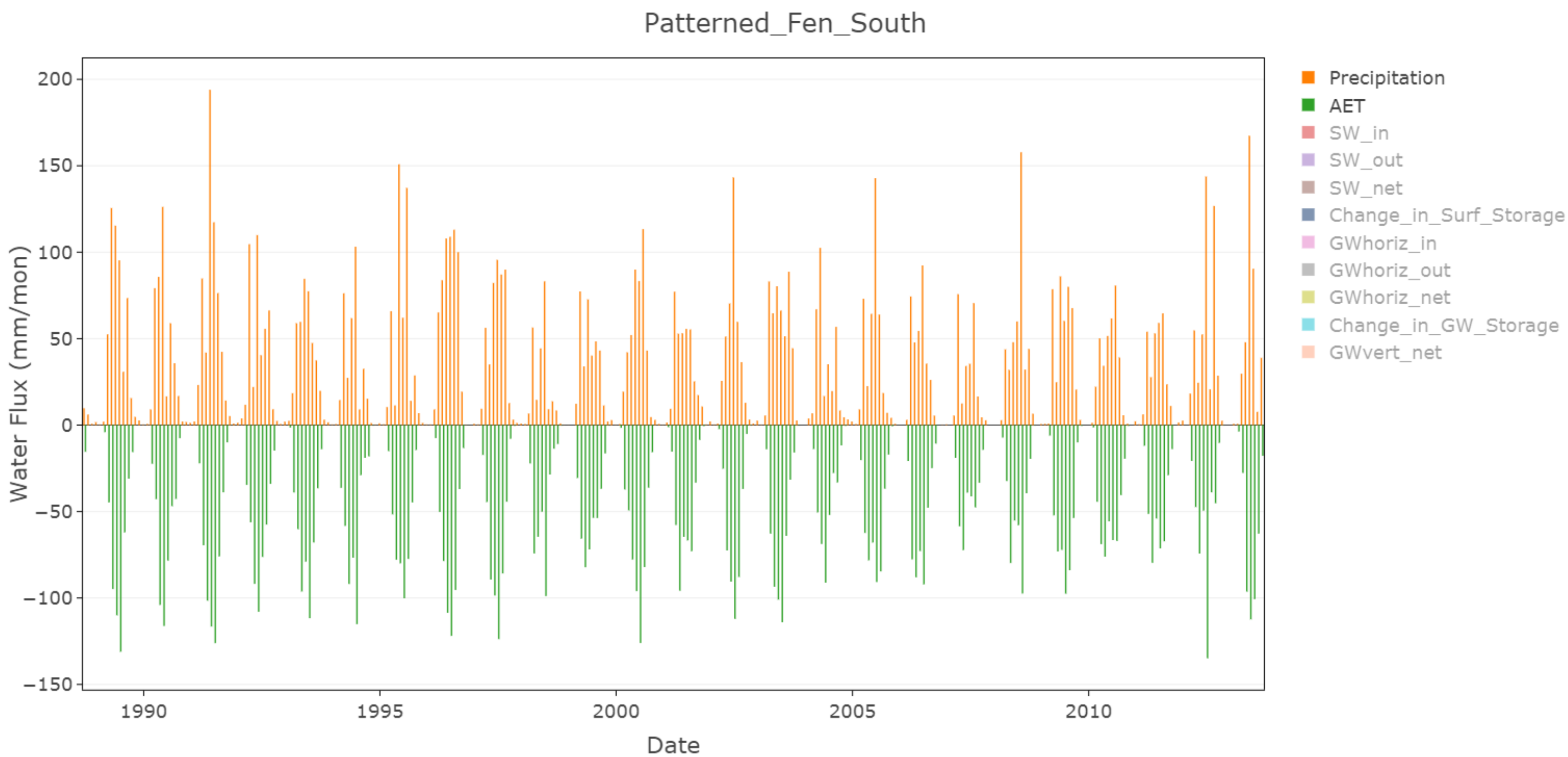

Figure 40 Predicted monthly precipitation and AET rates within HRA 01 from 1988-2013.

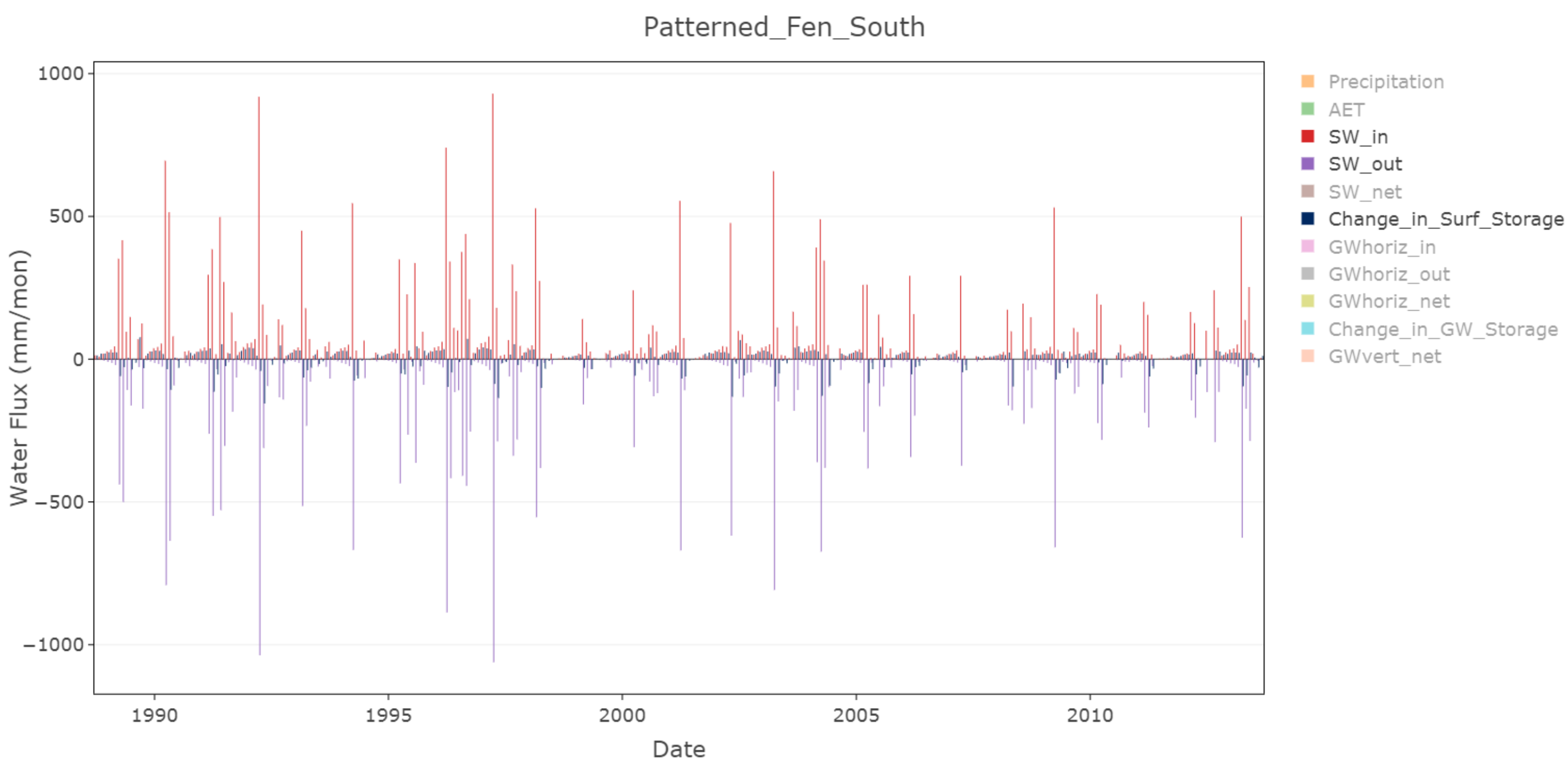

Figure 41 Predicted monthly surface water flows and storage within HRA 01 from 1988-2013.

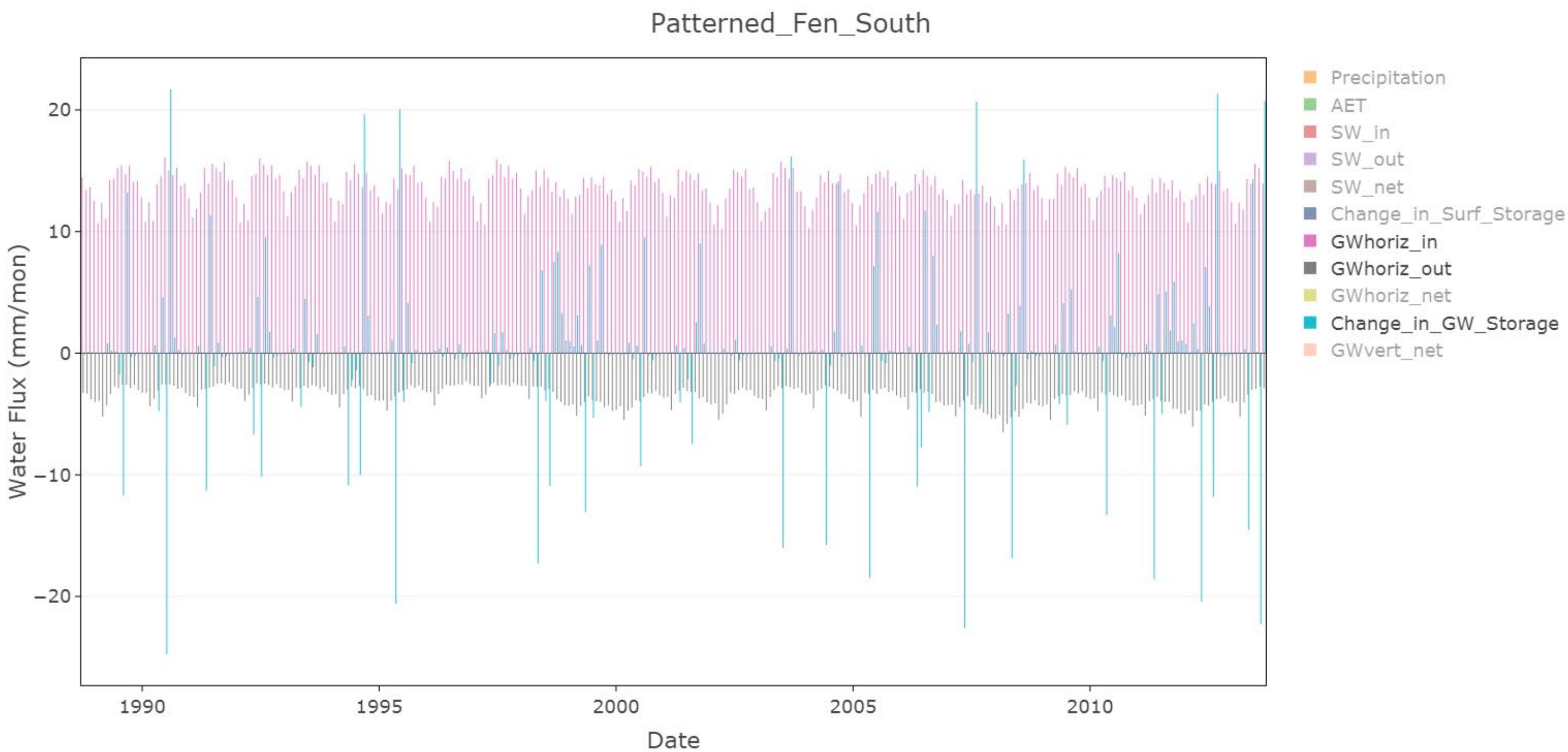

Figure 42 Predicted monthly groundwater flows and storage within HRA 01 from 1988-2013.

13. Section 1.3.2: HRA 02: Patterned Fen - North

HRA 02 is designated Patterned Fen – North and a cross-section taken through this HRA is shown in Figure 43. HRA 02 covers an area of approximately 1.33 km^2 that has a mean slope of 0.05%, an aspect of 102.24 degrees azimuth and a mean elevation of 294.99 masl. The dominant land usages classes and forms present in HRA 02 are shrubby fen (74.58%) and graminoid fen (25.54%), respectively. The dominant soil is Mildred (99.92%) which is classified to drain rapidly. Precipitation rates on this HRA average 422.7 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe the HRA 02 area eco-hydrologically as a moderate-rich patterned fen.

Substrate depths above Clay Till 1 in HRA 02 range from 13.2 to 25.0 m (Figure 44). The substrate is composed of topsoil, Muskeg, Silt Clay and Surface Sands North deposits. Bedrock topography in HRA 02 (Clay Till 01) ranges from 272.9 to 281.8 masl and tends to trend higher closer to McClelland Lake (Figure 45). Post-development, 100% of the HRA will remain undisturbed.

HRA 02 is conceptualized to receive water from precipitation and flows from HRA 05 (Non-patterned Fen – West) (refer to Figure 29, Figure 31 and Figure 43). Contributions from HRA 05 are conceptualized to be composed primarily of incoming surface water with smaller contribution of incoming groundwater (Figure 31). There is a natural surface water flow divide hydraulically isolating HRA02 surface waters from those of HRA 01 (Patterned Fen – South). The water table is conceptualized as being at or near the land surface most times in HRA 02.

Water is conceptualized to leave HRA 02 (in ascending order of conceptualized relative contribution) in the forms of groundwater discharge into McClelland Lake, evapotranspiration and surface water discharge into McClelland Lake through the northernmost inlet shown in Figure 31. During the spring freshet, snowmelt runoff is conceptualized to flow over the frozen flarks and discharge into McClelland Lake; any additional inputs of snowmelt or incoming precipitation would continue to generate runoff into the lake until the flarks have thawed, potentially weeks after the freshet. The hydrogeochemistry of the waters entering HRA 02 is conceptualized to be non-alkaline and cation-poor year-round.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 02 was simulated to receive 15%, 69% and 16% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 02 was simulated to discharge 17%, 79% and 4% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 02 indicates that annual AET rates (461.6 mm/yr) are greater than precipitation rates (413.2 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface (Figure 33); the HRA is simulated to remain near saturated on average (Figure 34) and the exchange of water across the land surface interface is approximately net neutral (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 46 presents predicted average monthly water balance components over the period 1988-2013. HRA 02 is predicted to produce peak incoming and outgoing flows during the month of April that subside somewhat during early summer with a secondary peak in the early fall (September). This HRA typically adds to surface water storage from approximately September to February and sheds surface water storage March to July. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA at an approximately constant rate May through October and then begins to decline through winter, reach a minimum rate in February and then increases again during the spring freshet. Groundwater discharges exhibit a similar seasonal pattern that lags the incoming flows pattern by two months. The HRA sheds groundwater storage in May and gains most of its additional groundwater storage from June through September. There are few predicted changes to groundwater storage November to April.

Figure 47 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 02. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occurs in July. Figure 48 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can happen April-September but usually occurs in April. Peak surface water out can occur March-September but usually happens in April. The largest monthly gain in surface water storage can occur July-December but most often happens in December. The maximum monthly consumption of surface water storage can occur March-May but typically happens in April. Figure 49 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur May-October but typically peaks in July. Peak monthly groundwater discharge rates occur in March. The largest monthly gain in groundwater storage can happen June-October but usually occurs in September. The largest consumption of groundwater storage happens July-December but usually occurs in December.

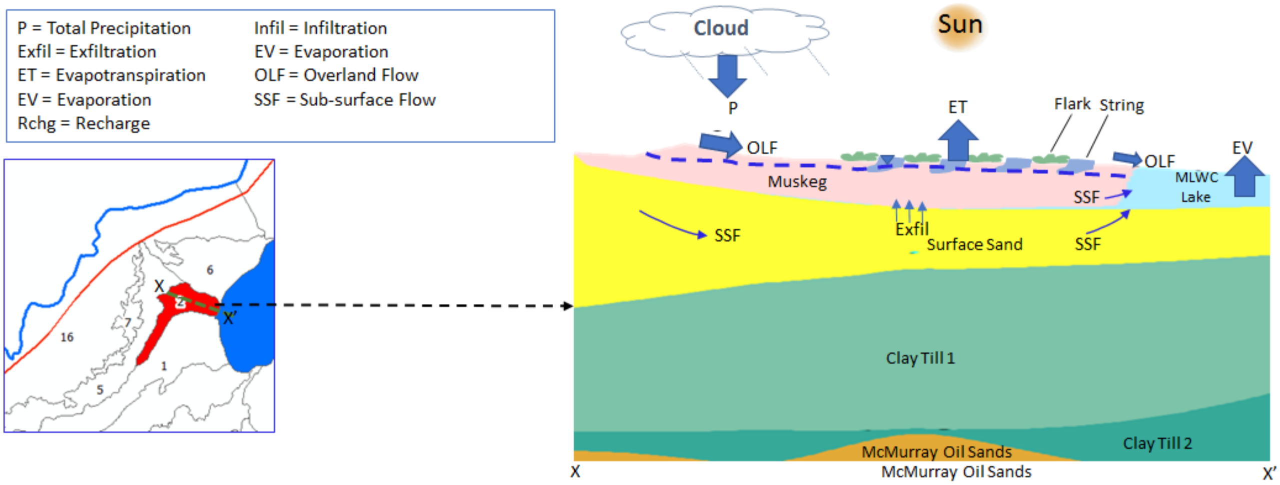

Figure 43 HRA 02: Patterned Fen – North. Vertical exaggeration is 80:1.

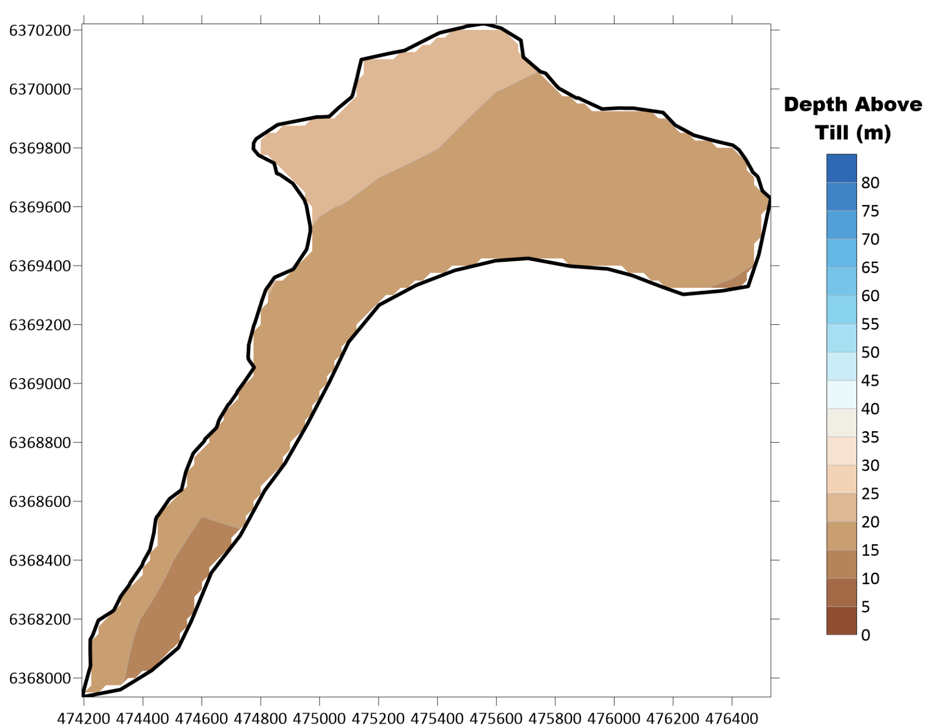

Figure 44 Substrate depths in HRA 02: Patterned Fen – North.

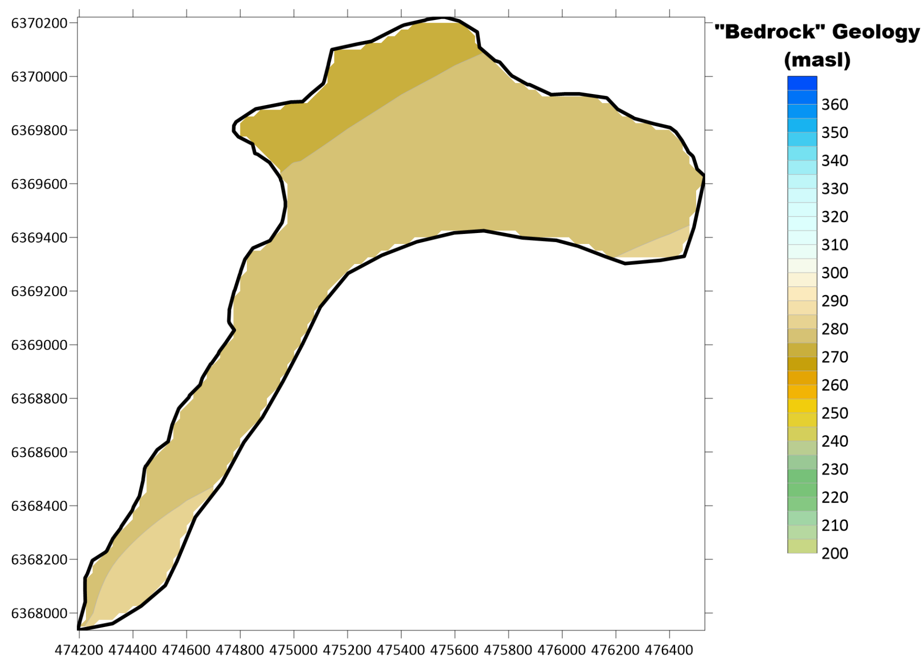

Figure 45 Bedrock topography in HRA 02: Patterned Fen – North.

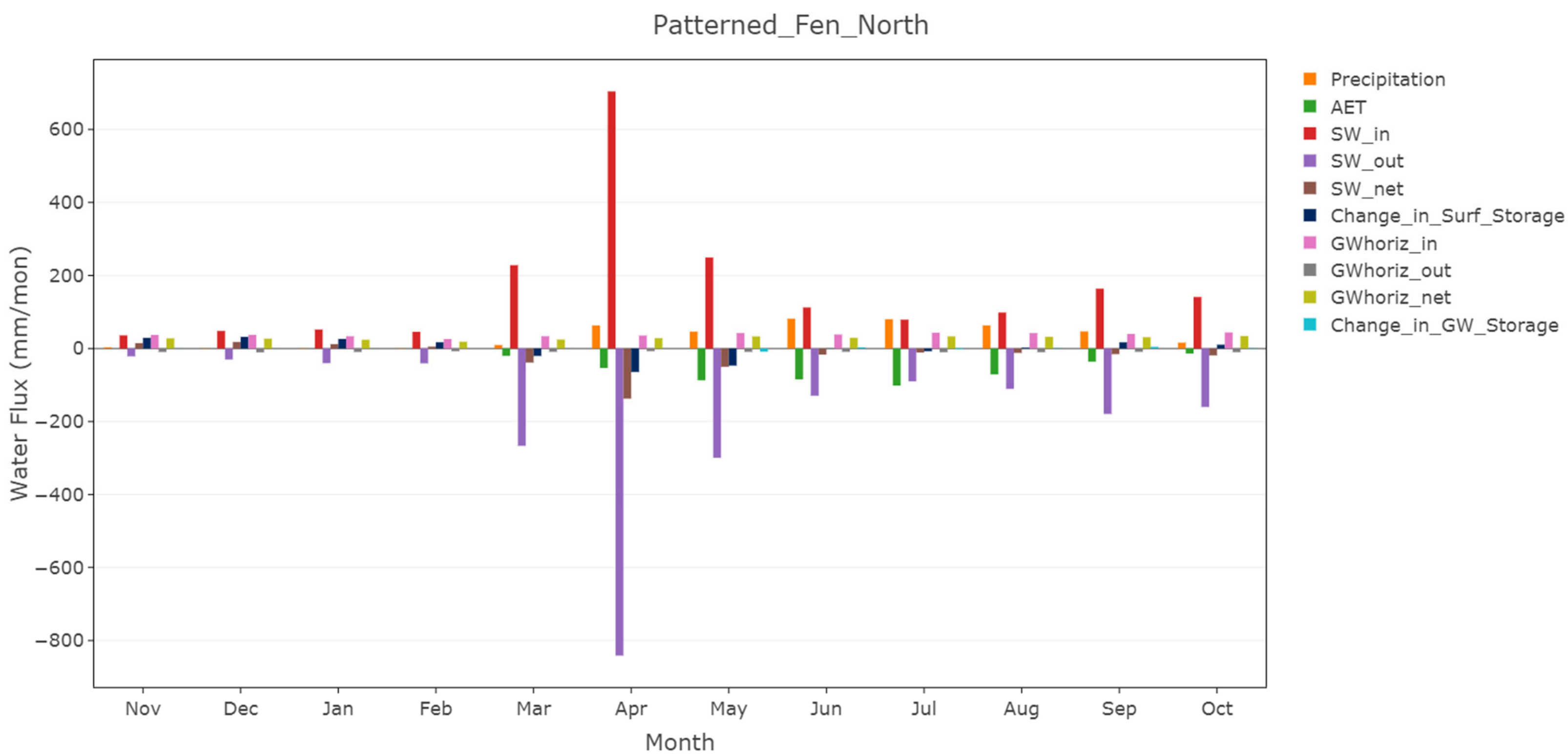

Figure 46 Mean monthly water budget components (1988-2013) for HRA 02: Patterned Fen - North. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

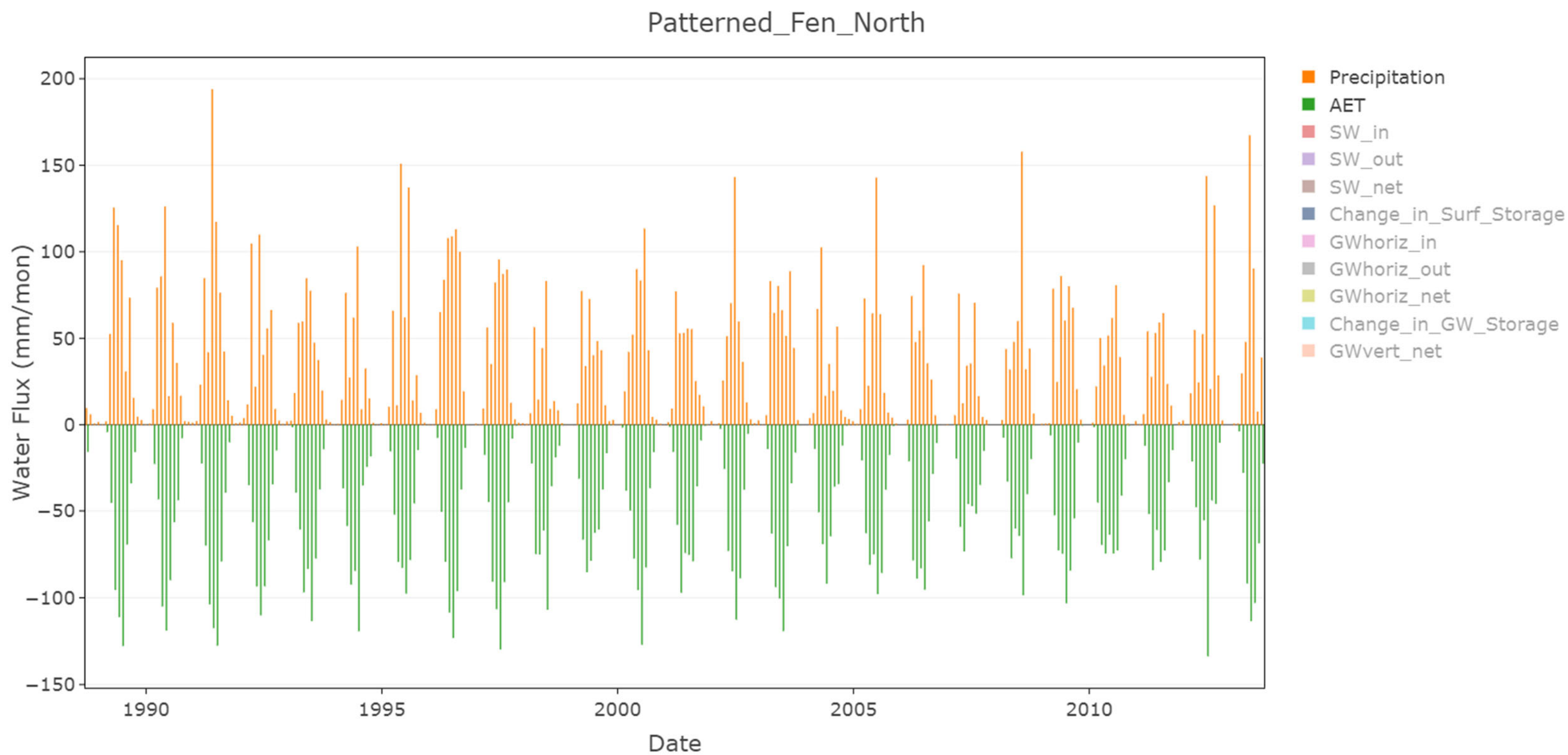

Figure 47 Predicted monthly precipitation and AET rates within HRA 02 from 1988-2013.

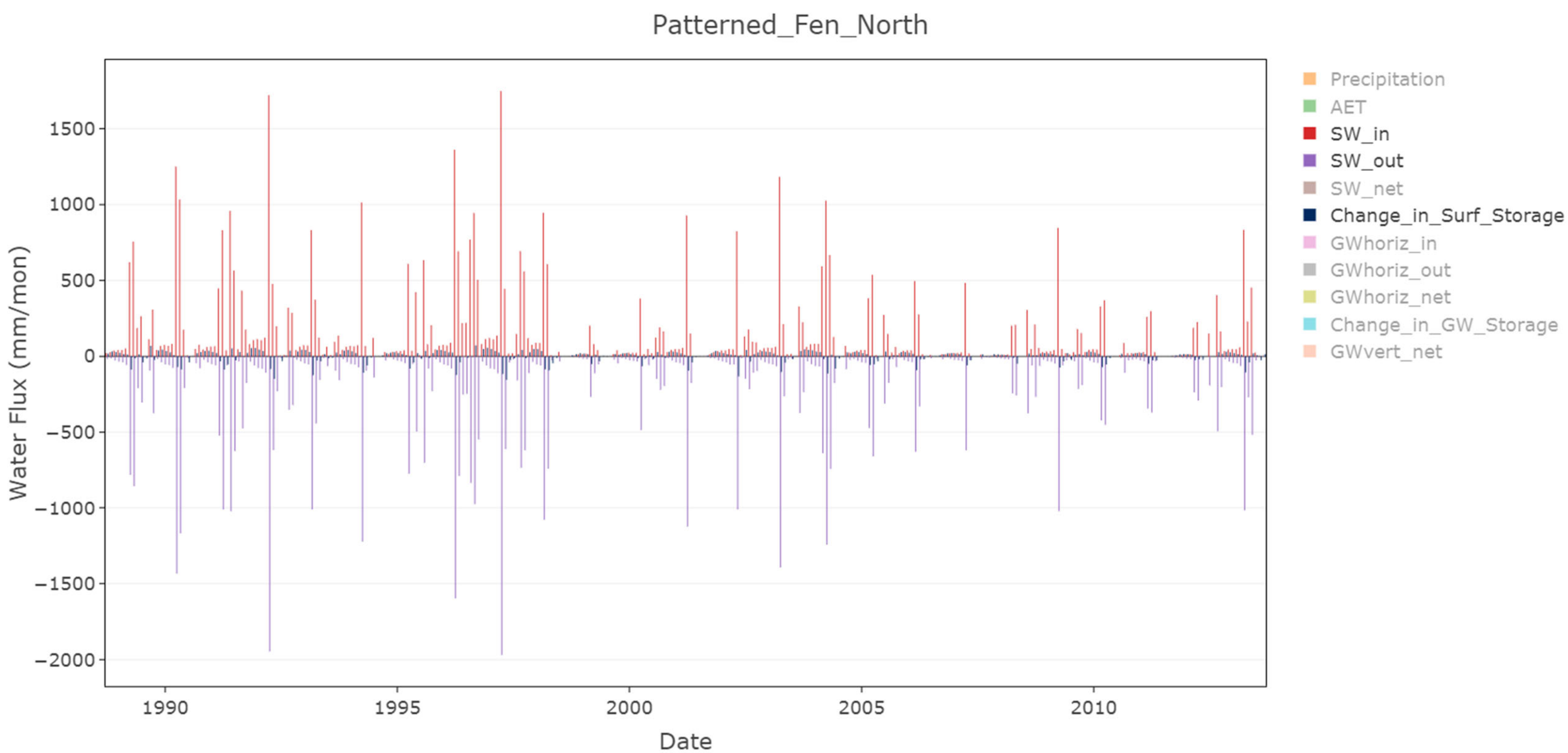

Figure 48 Predicted monthly surface water flows and storage within HRA 02 from 1988-2013.

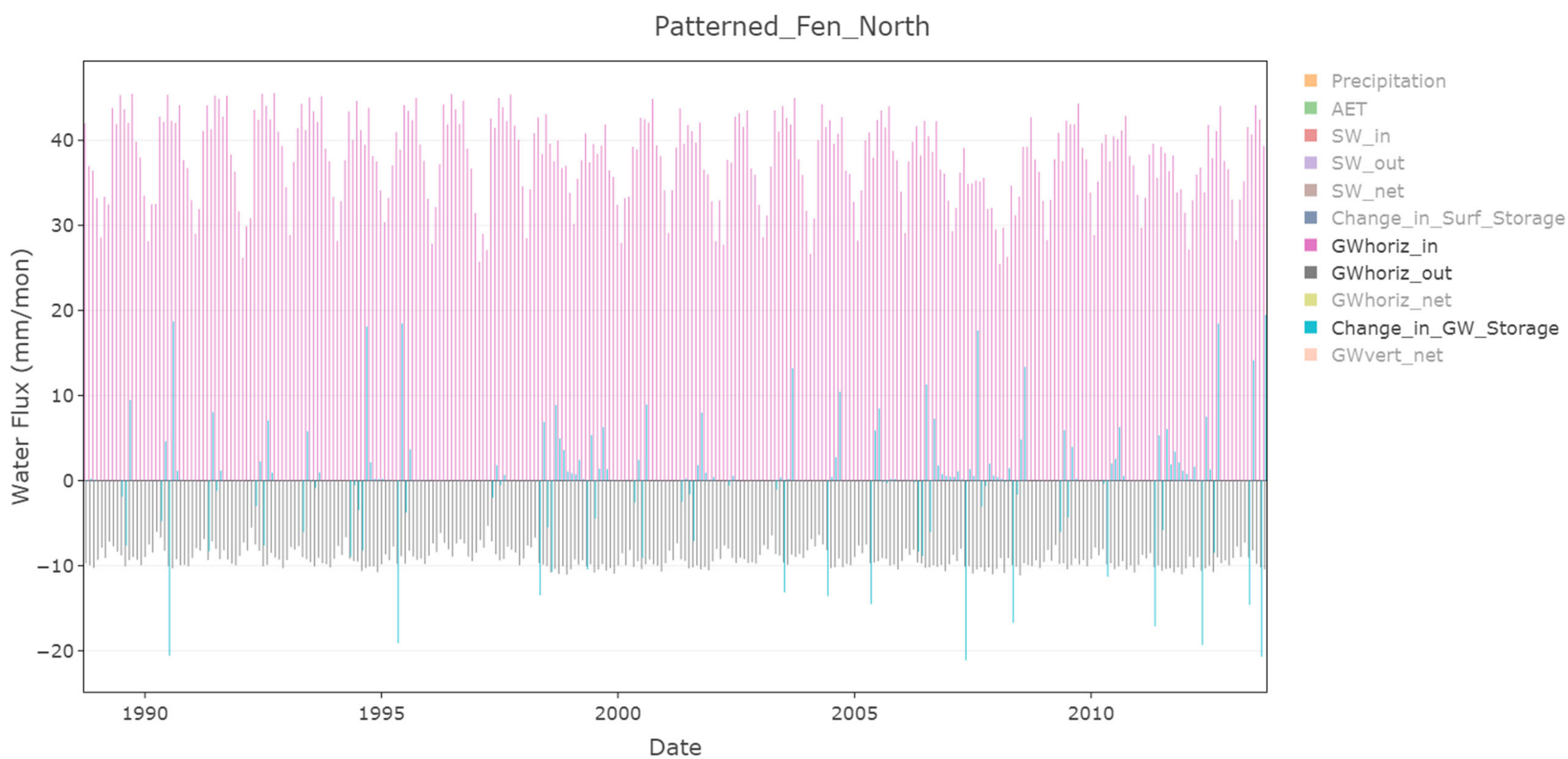

Figure 49 Predicted monthly groundwater flows and storage within HRA 02 from 1988-2013.

14. Section 1.3.3: HRA 03: Graminoid Fen

HRA 03 is designated Graminoid Fen and a cross-section taken through this HRA is shown in Figure 50. HRA 03 covers an area of approximately 2.42 km^2 that has a mean slope of 0.14%, an aspect of 154.19 degrees azimuth and a mean elevation of 300.08 masl. The dominant land usages classes and forms present in HRA 03 are shrubby fen (16.65%) and graminoid fen (68.17%), respectively. The dominant soil is McClelland (82.88%), which is classified to drain very poorly. Precipitation rates on this HRA average 422.7 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe the HRA 03 area eco-hydrologically as a moss/graminoid fen.

Substrate depths above Clay Till 1 in HRA 03 range from 10.2 to 16.5 m (Figure 51). The substrate is composed of topsoil, Muskeg, Silt Clay and Surface Sands North deposits. Bedrock topography in HRA 03 (Clay Till 01) ranges from 284.5 to 291.5 masl (Figure 52). Post-development, 0% of this HRA will remain undisturbed.

HRA 03 is conceptualized to receive water from precipitation and flows from HRA 16 (North Outwash Plains West), HRA 04 (Non-patterned Fen – South) and HRA 14 (Coniferous Swamp – West) (refer to Figure 29, Figure 31 and Figure 50). HRA 16 and HRA 14 both provide groundwater flows to HRA 03 while HRA 04 is conceptualized to provide surface water flows. There is a slight topographic hump in the topography within HRA 03 that generates different hydrologic behavior on the east and west sides of the HRA. On the west side of the topographic hump, water enters the HRA from the surrounding landscape just south of a large esker located in the northern extents of the HRA. The eastern half of HRA 03 tends to remain drier than the western half most years. The water table is conceptualized as being at or slightly below the land surface most times.

Water is conceptualized to leave HRA 03 primarily through evapotranspiration. Water entering the western half of HRA 03 will tend to pool on the surface by the esker and evaporate. Water can also exit the HRA during the freshet; snowmelt runoff over frozen muskeg will flow down the topographic gradient into HRA 01. The muskeg can potentially remain frozen for weeks after freshet, continuing to produce runoff. During wetter ice-free periods, sporadic surface water flows can also occur from the eastern half of HRA 03 into HRA 01. The string and flark orientations near the joint boundary of HRA 03 and HRA 01 are fairly random, indicating that there is not a preferential water flow direction in this region. The hydrogeochemistry in HRA 03 is conceptualized to be a dominated by alkaline and (relatively) cation-rich waters from the FHUC as evidenced by the presence of Scorpidium scorpioides in this HRA; a moss species associated with alkaline environments (Dale Vitt, personal communication).

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 03 was simulated to receive 32%, 58% and 10% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 03 was simulated to discharge 28%, 55% and 17% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 03 indicates that annual AET rates (362.3 mm/yr) are less than precipitation rates (413.2 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface except along the northern edge where substrates get deeper (Figure 33); the HRA is simulated to remain near saturated on average except near the northern edge (Figure 34) and the exchange of water across the land surface interface is approximately net neutral over most of the southern portion with two zones of exfiltration to the west and recharges along its northern flank (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves in the form of surface water and more groundwater is exiting the HRA than entering it. Proportionally slightly less water exits the HRA in the form of surface water than enters it annually. Proportionally more water exits the HRA in the form of groundwater than enters it annually.

Figure 53 presents predicted average monthly water balance components over the period 1988-2013. HRA 03 is predicted to produce peak incoming and outgoing flows during the month of April that subside somewhat during early summer with a secondary peak in the early fall (September). This HRA adds to surface water storage from approximately August to March and sheds surface water storage primarily in April and May. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA at an approximately constant rate through most of the year. Groundwater flows out of the HRA peak in April and then decline through October before starting to increase again in November. The HRA gains groundwater storage March-April, has its peak consumption of groundwater storage in May and then resumes gaining storage June through September. Groundwater storage is again consumed November through February.

Figure 54 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 03. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occurs in July. Figure 55 shows the surface water balance components (flow in, flow out and change in storage). Peak surface water in can happen March-May but usually occurs in April. Peak surface water out can occur March-October but usually happens in April. The largest monthly gain in surface water storage can occur March-

October but most often happens in March. The maximum monthly consumption of surface water storage occurs April-August but typically happens in May. Figure 56 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly groundwater discharge rates occur March-May but usually happen in April. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest consumption of groundwater storage happens May-August but usually occurs in May.

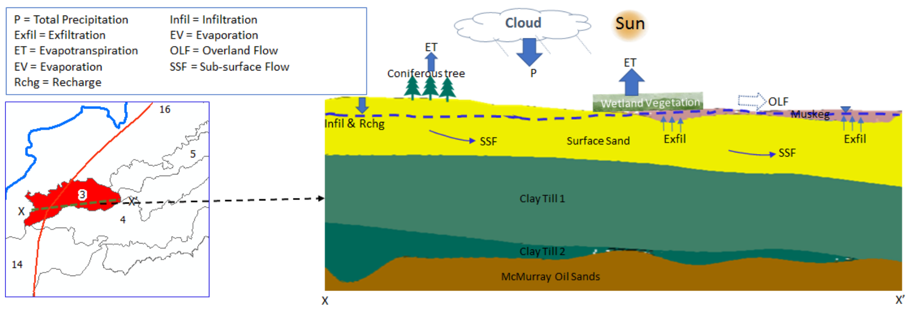

Figure 50 HRA 03: Graminoid Fen. Vertical exaggeration is 80:1.

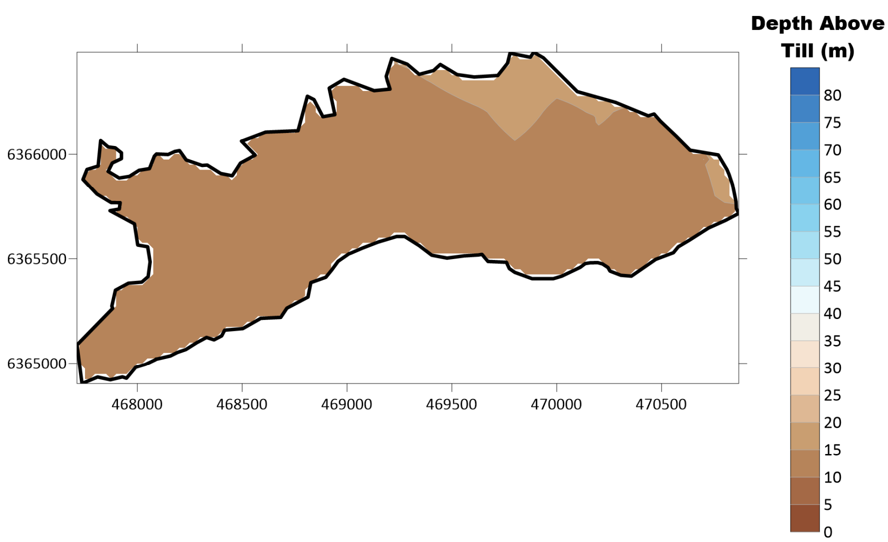

Figure 51 Substrate depths in HRA 03: Graminoid Fen.

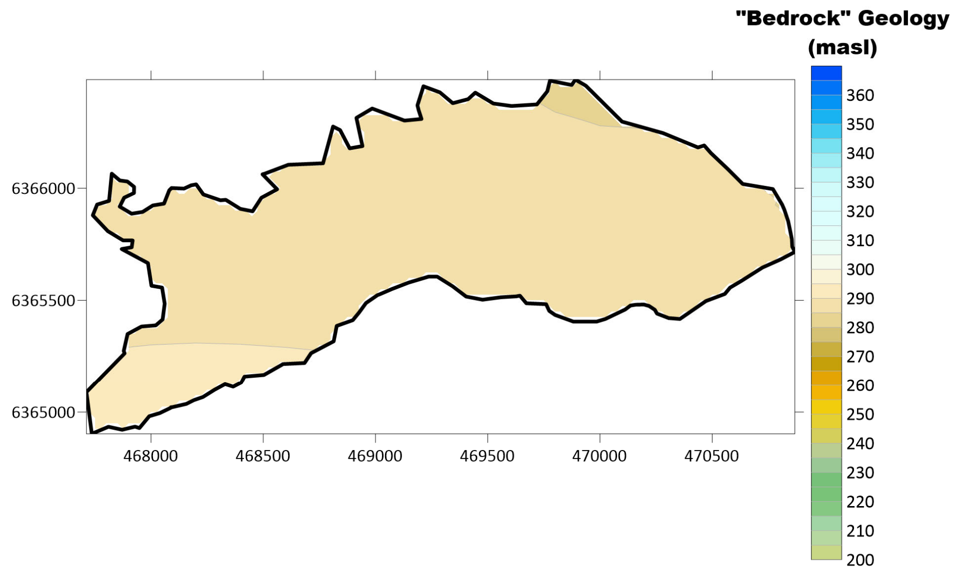

Figure 52 Bedrock topography in HRA 03: Graminoid Fen.

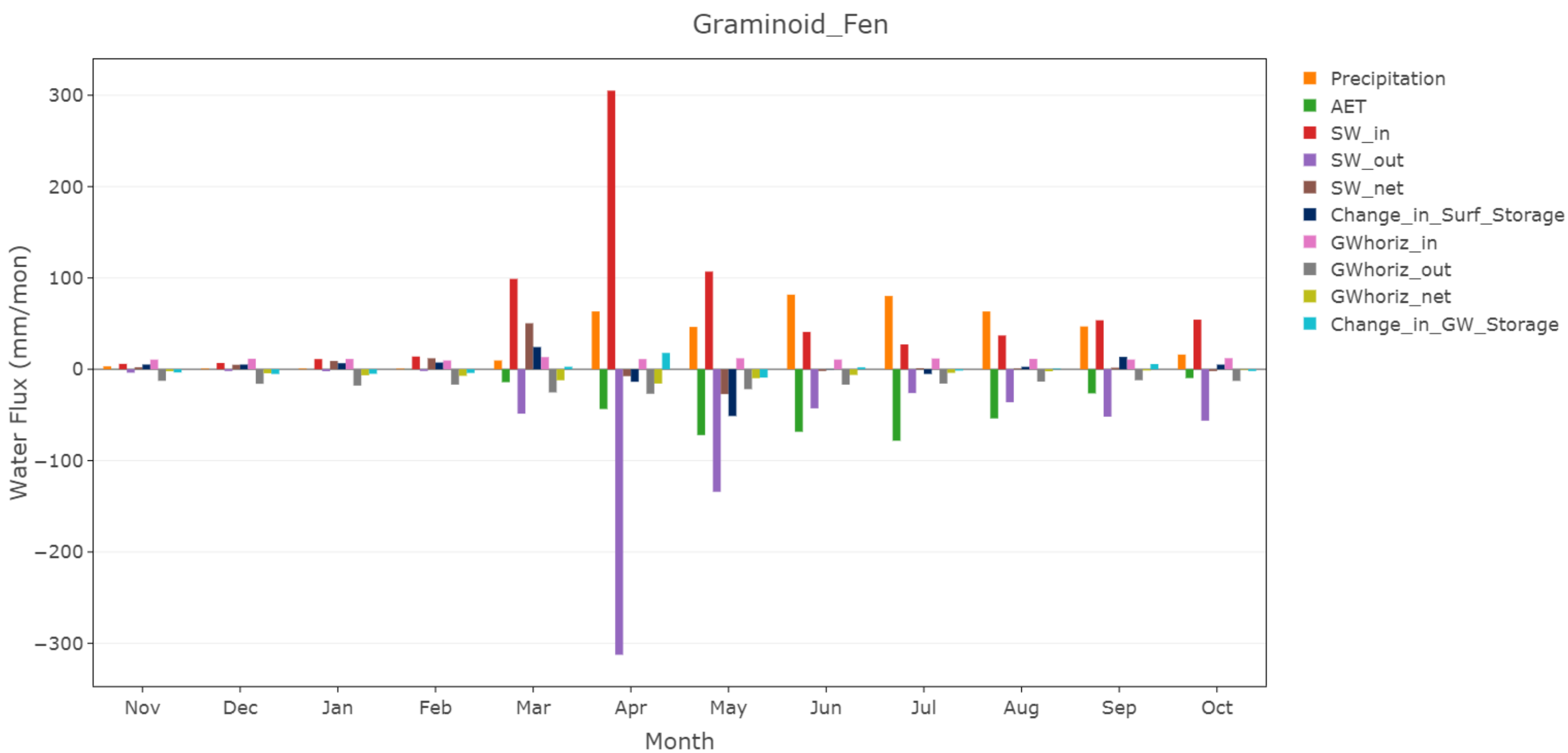

Figure 53 Mean monthly water budget components (1988-2013) for HRA 03: Graminoid Fen. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

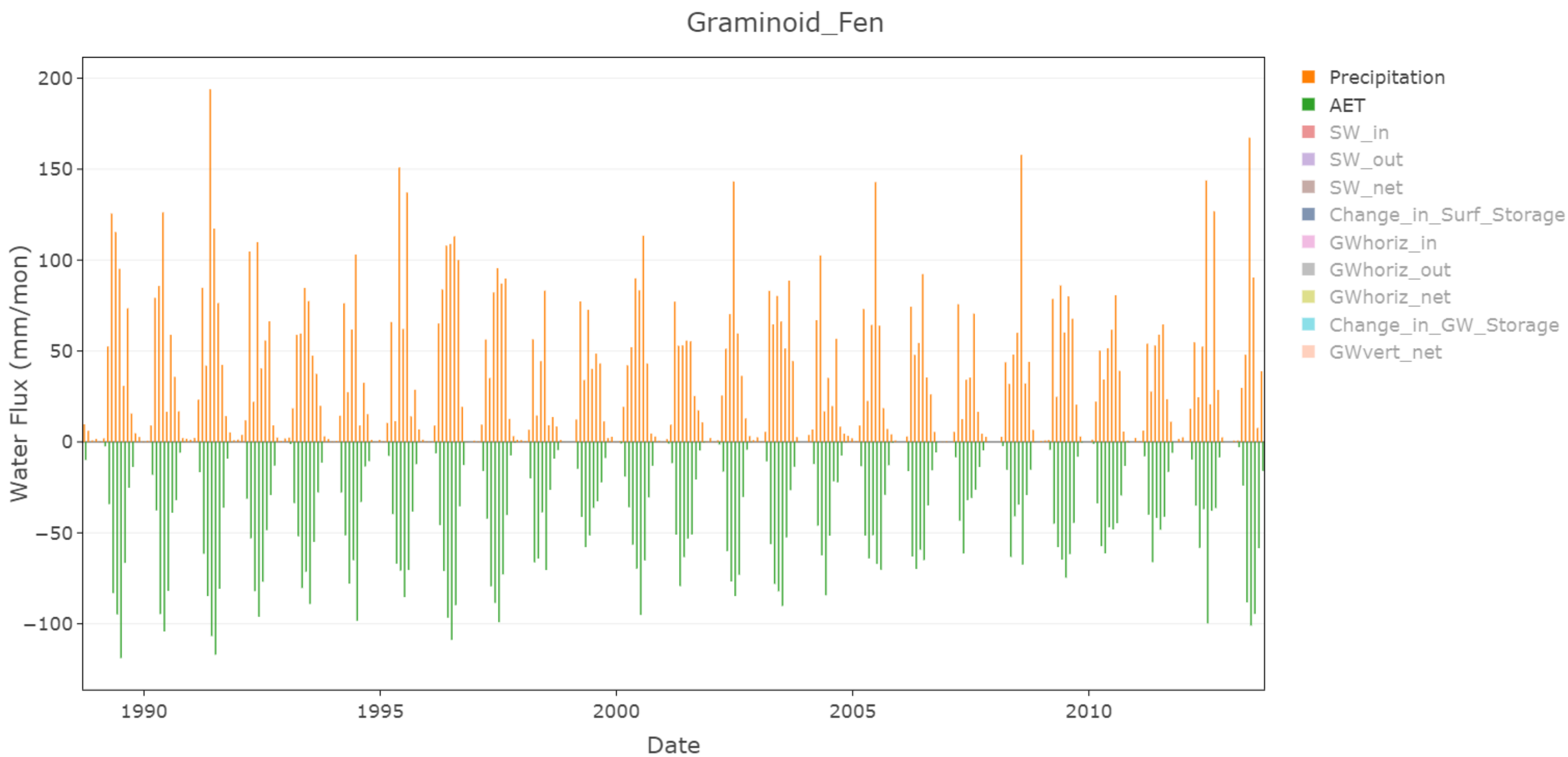

Figure 54 Predicted monthly precipitation and AET rates within HRA 03 from 1988-2013.

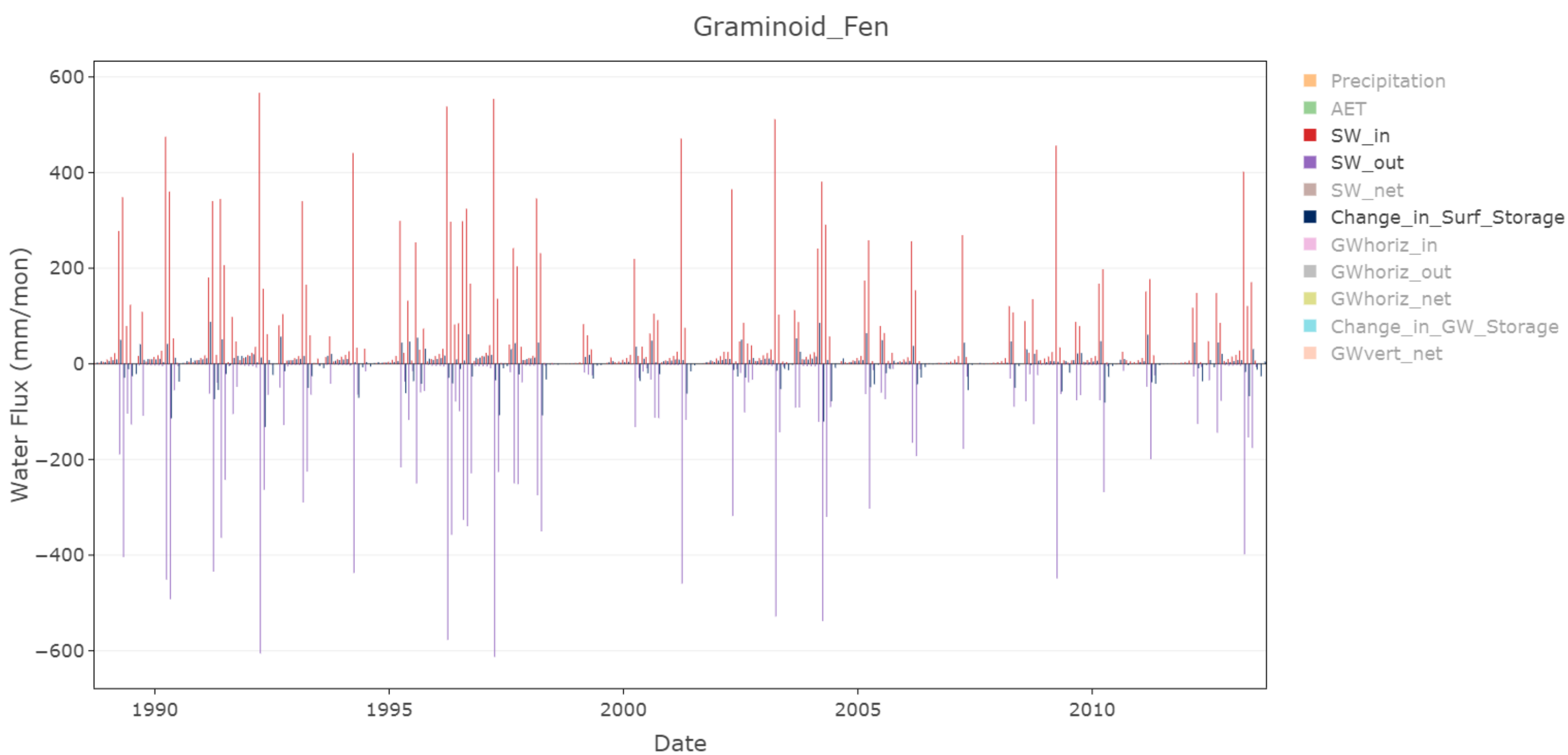

Figure 55 Predicted monthly surface water flows and storage within HRA 03 from 1988-2013.

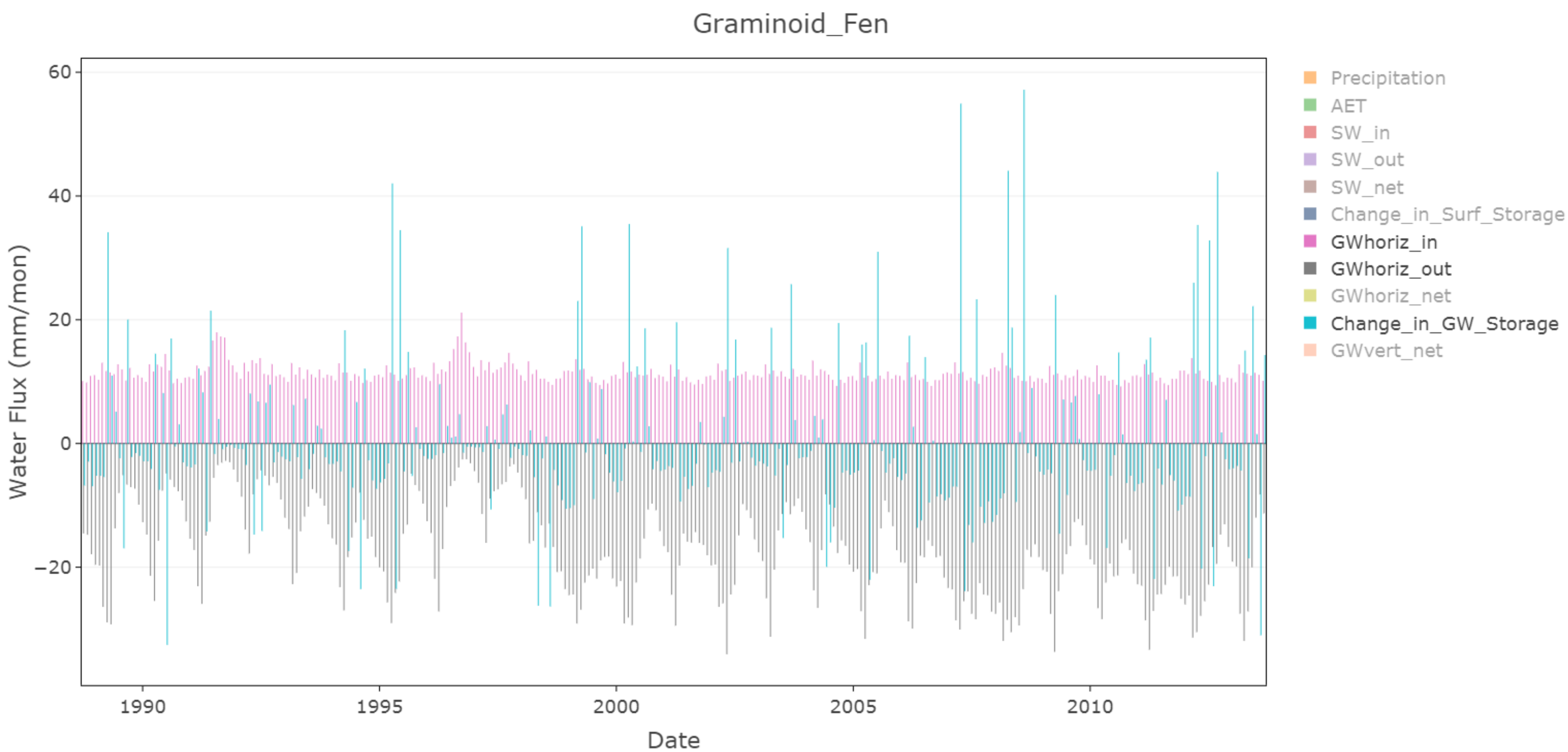

Figure 56 Predicted monthly groundwater flows and storage within HRA 03 from 1988-2013.

15. Section 1.3.4: HRA 04: Non-patterned Fen – South

HRA 04 is designated Non-patterned Fen – South and cross-sections taken through this HRA are shown in Figure 57. HRA 04 covers an area of approximately 9.42 km^2 that has a mean slope of 0.19%, an aspect of 163.4 degrees azimuth and a mean elevation of 298.55 masl. The dominant land usages classes and forms present in HRA 04 are wooded coniferous fen (33.03%), shrubby fen (33.66%) and wooded coniferous swamp (22.12%), respectively. The dominant soil is McClelland (96.55%) which is classified to drain very poorly. Precipitation rates on this HRA average 422.7 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a mix of Larix-dominated rich fen and permafrost/bog/fen/swamp complex.

Substrate depths above Clay Till 1 in HRA 04 range from 0.5 to 18.1 m (Figure 58). The substrate is composed of topsoil, Muskeg, Silt Clay, Surface Sands North and Surface Sands South deposits. The substrate depths generally become thicker south to north. Bedrock topography in HRA 04 (Clay Till 01) ranges from 279.4 to 303.2 masl and trends lower south to north in the HRA (Figure 59). Post-development, 35% of the HRA will remain undisturbed.

HRA 04 is conceptualized to receive water from precipitation and flows from HRA 14 (Coniferous Swamp - West), HRA 08 (Coniferous Swamp - South) and HRA 17 (Fort Hills West) (refer to Figure 29, Figure 31 and Figure 57). HRA 14 primarily contributes surface water flows while HRA 17 is conceptualized to contribute minor groundwater flows directly to HRA 04. HRA 08 is conceptualized to be the source for the bulk of HRA 04's incoming flows, transmitting groundwater and surface water that originated upslope. The water table is conceptualized as being at or near the land surface most times.

Water is conceptualized to leave HRA 04 (in ascending order of conceptualized relative contribution) as outgoing groundwater, evapotranspiration and outgoing surface water. Although HRA 04 discharges surface water and groundwater to HRA 03, the bulk of the runoff generated from this area flows into HRA 01. The northeastern-most extent of HRA 04 also acts as a transmission route for a portion of runoff generated from a nearby hydraulic window in HRA 18 that flows through HRA 04 and into McClelland Lake through the southern inlet (Figure 31). During the spring freshet, snowmelt would be expected to flow over the frozen muskeg, down the topographic gradient, and discharge into HRA 03 and HRA 01. The muskeg can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains. The hydrogeochemistry in HRA 04 is conceptualized to be (relatively) alkaline and cation-rich and originating from the FHUC.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 04 was simulated to receive 26%, 60% and 14% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 04 was simulated to discharge 28%, 69% and 3% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 04 indicates that annual AET rates (432.3 mm/yr) are slightly greater than precipitation rates (413.2 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface most times (Figure 33); the HRA is simulated to remain near saturated where the muskeg is present (Figure 34) and the exchange of water across the land surface interface is a patchwork of zones of exfiltration along the southern margin, large areas where exchange is net neutral and isolated regions of infiltration (Figure 35).

Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 60 presents predicted average monthly water balance components over the period 1988-2013. HRA 04 is predicted to produce peak incoming and outgoing flows during the month of April that continue to remain at relatively higher rates through October. This HRA sheds surface water storage from March to May (peak in April) and again in July. The remainder of the year, the HRA adds to surface water storage with peak rates occurring during the winter months (ice buildup). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA at an approximately constant rate through most of the year. Groundwater discharges from the HRA at slightly higher rates November through March than during the remainder of the year. The HRA mainly adds to groundwater April through September except for the month of May which is the only month predicted to consume groundwater storage.

Figure 61 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 04. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occurs in July. Figure 62 shows the surface water balance components (flow in, flow out and change in storage). Peak surface water in can happen March-August but usually occurs in April. Peak surface water out can occur March-September but usually happens in April. The largest monthly gain in surface water storage can occur August-January but most often happens in December. The maximum monthly consumption of surface water storage can occur March-May but typically happens in April. Figure 63 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly groundwater discharge rates occur March-May but usually happen in March. The largest monthly gain in groundwater storage can happen June-October but usually occurs in September. The largest consumption of groundwater storage happens May-August but usually occurs in May.

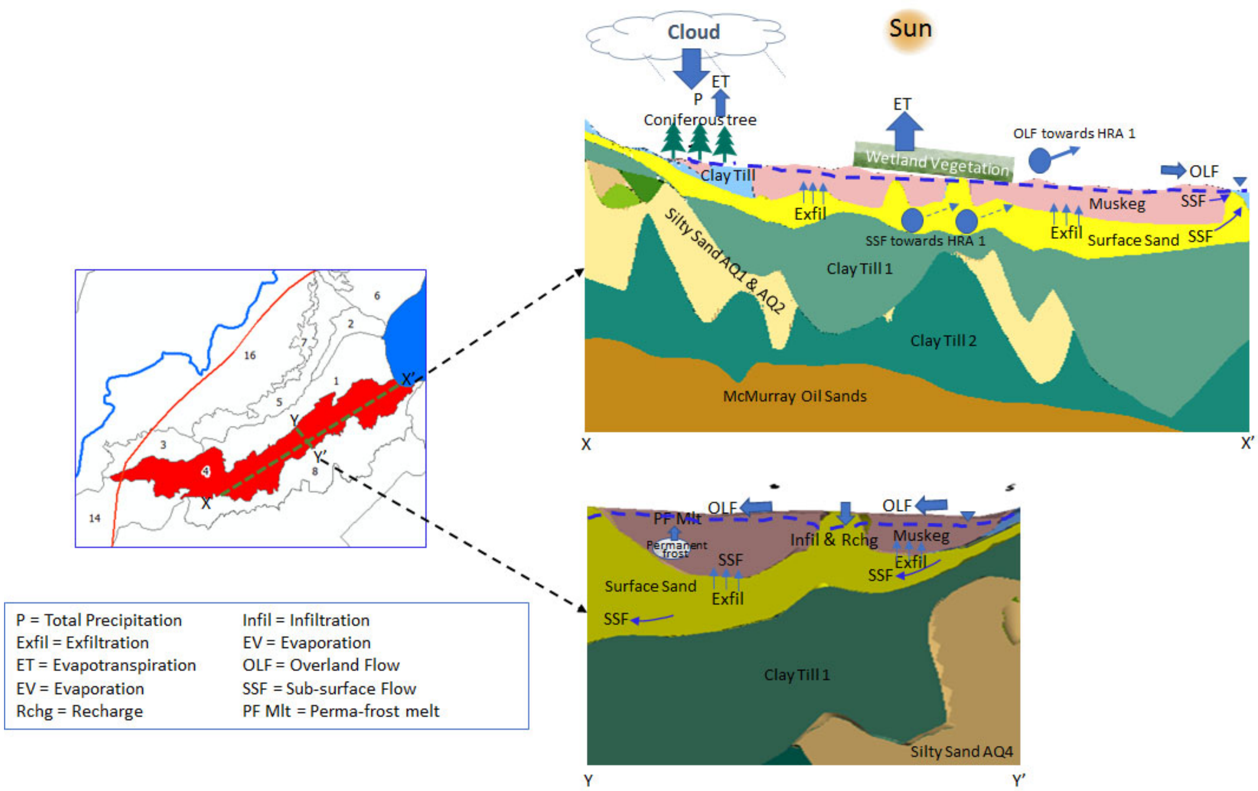

Figure 57 HRA 04: Non-patterned Fen – South. Vertical exaggeration is 80:1.

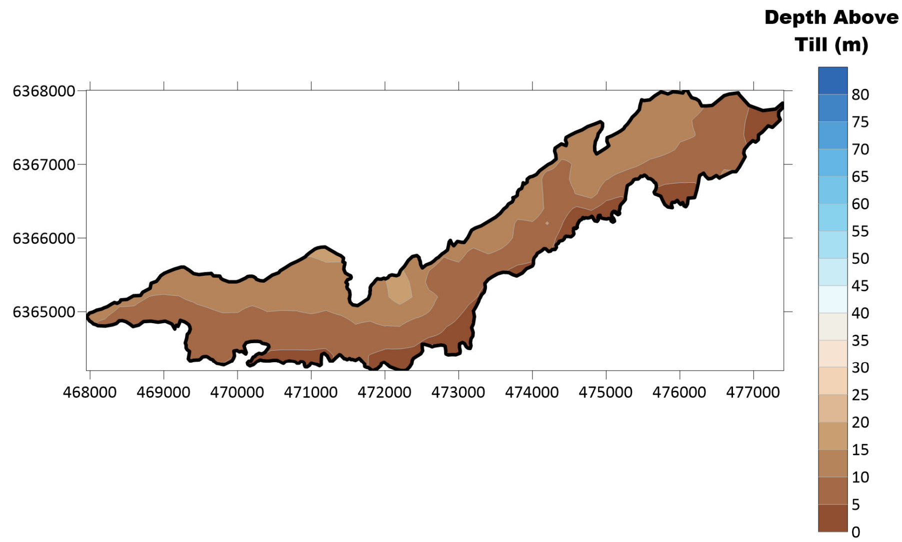

Figure 58 Substrate depths in HRA 04: Non-patterned Fen – South.

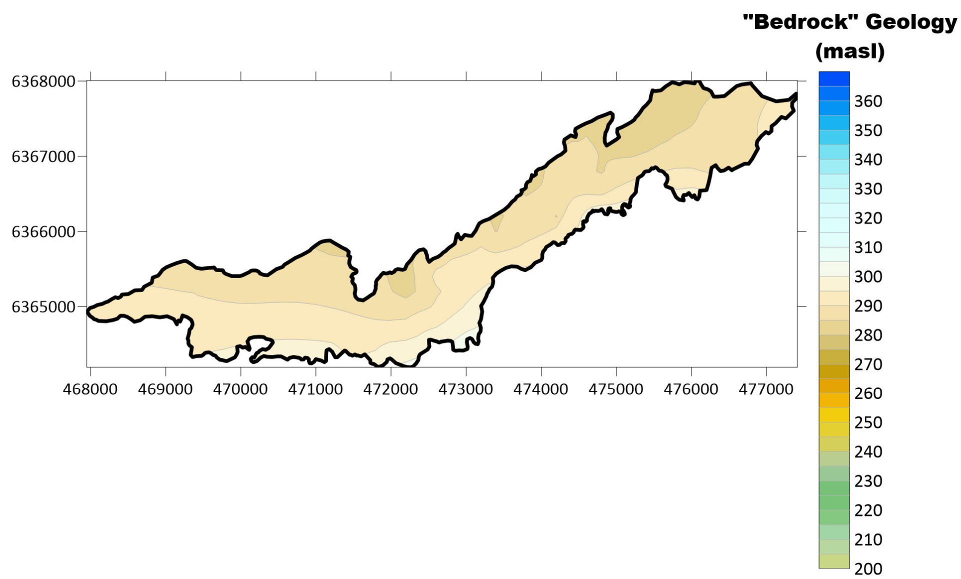

Figure 59 Bedrock topography in HRA 04: Non-patterned Fen – South.

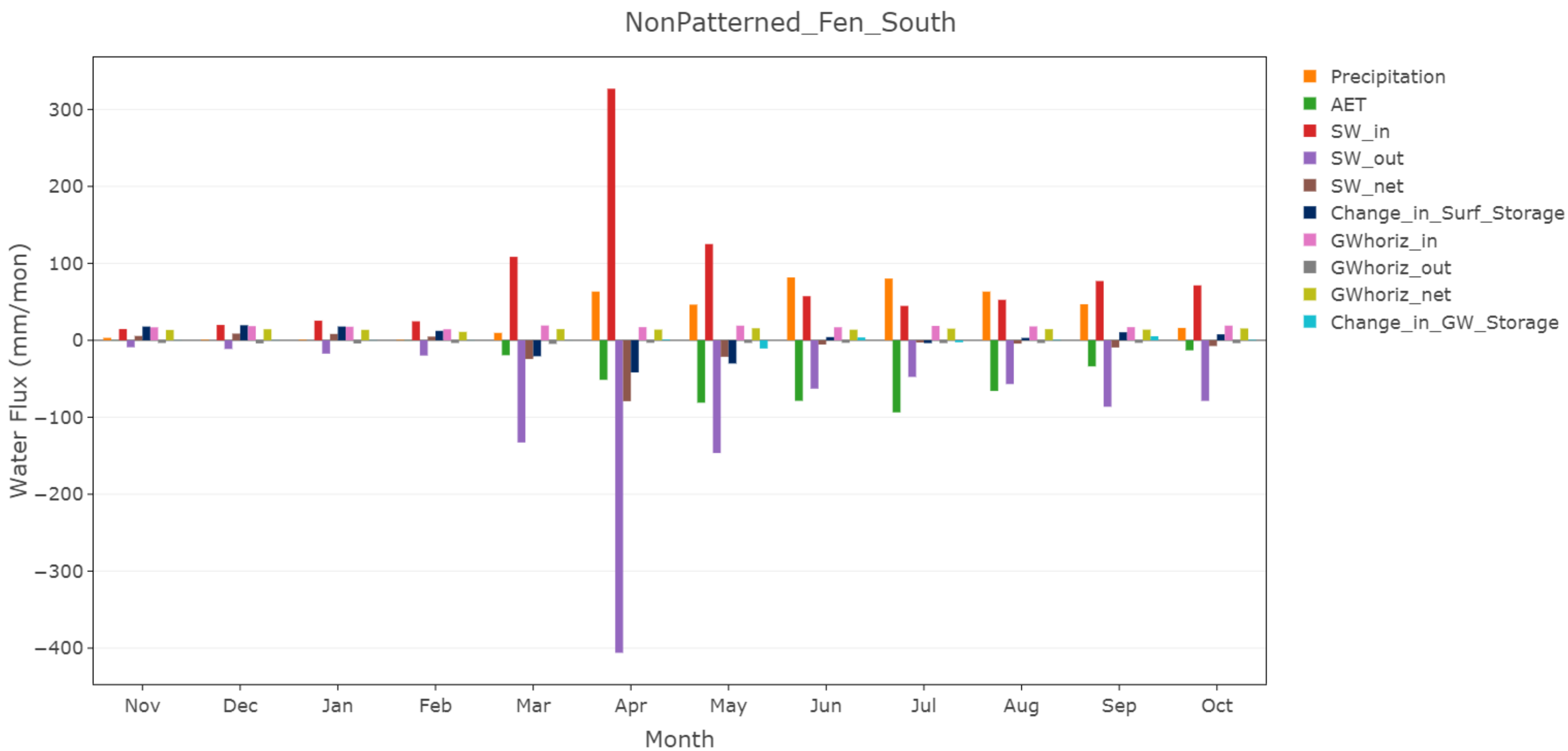

Figure 60 Mean monthly water budget components (1988-2013) for HRA 04: Non-patterned Fen - South. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

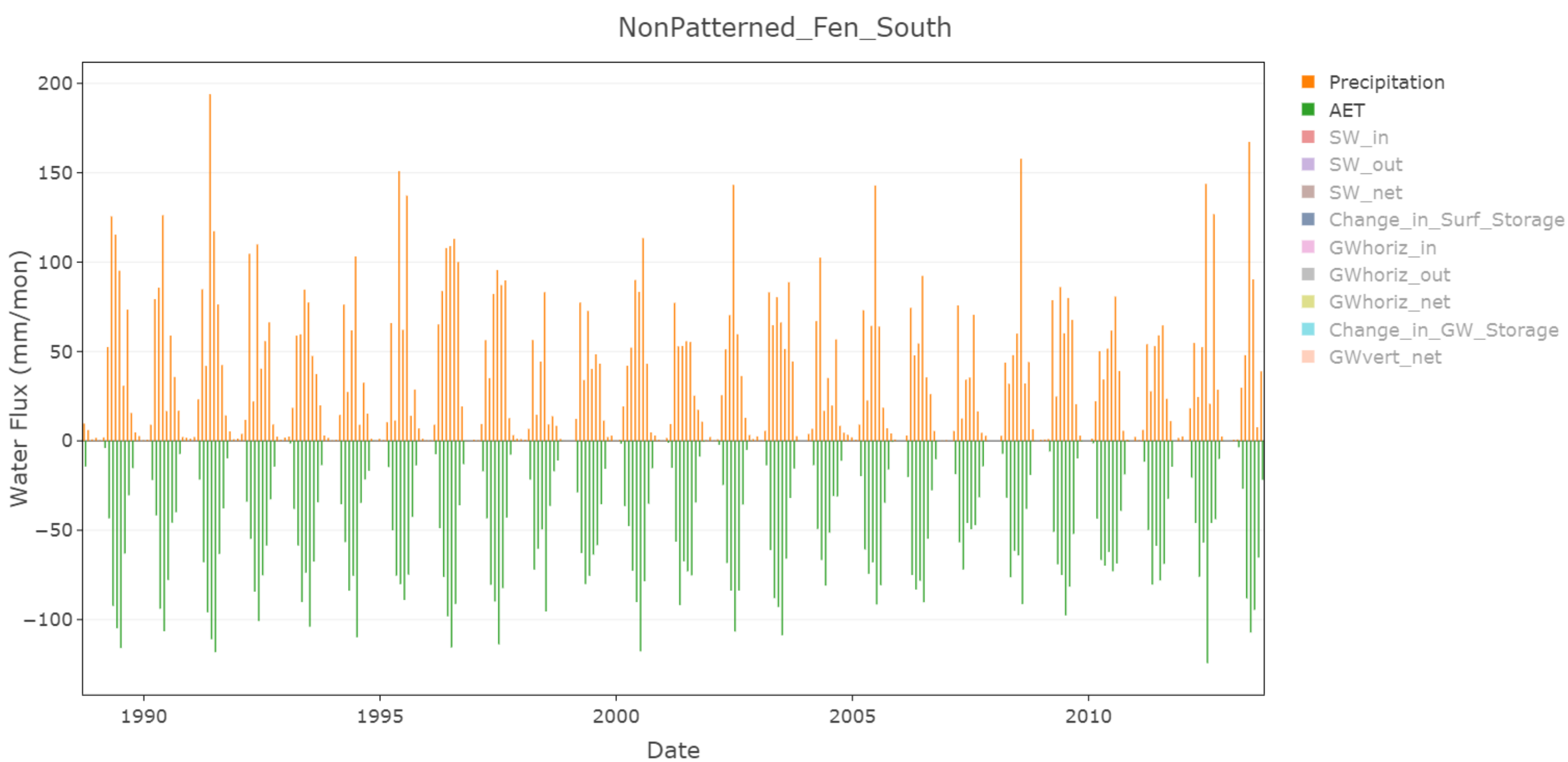

Figure 61 Predicted monthly precipitation and AET rates within HRA 04 from 1988-2013.

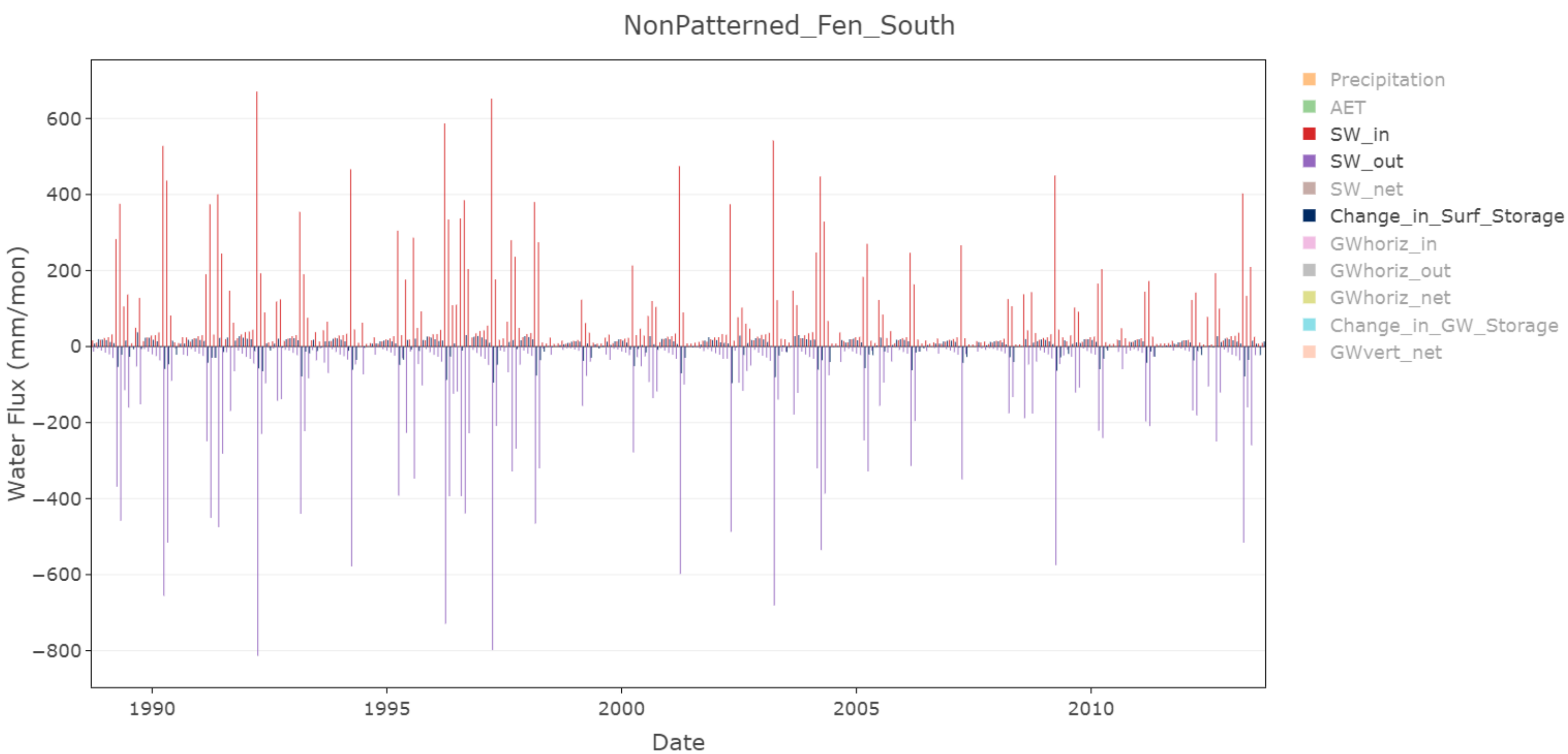

Figure 62 Predicted monthly surface water flows and storage within HRA 04 from 1988-2013.

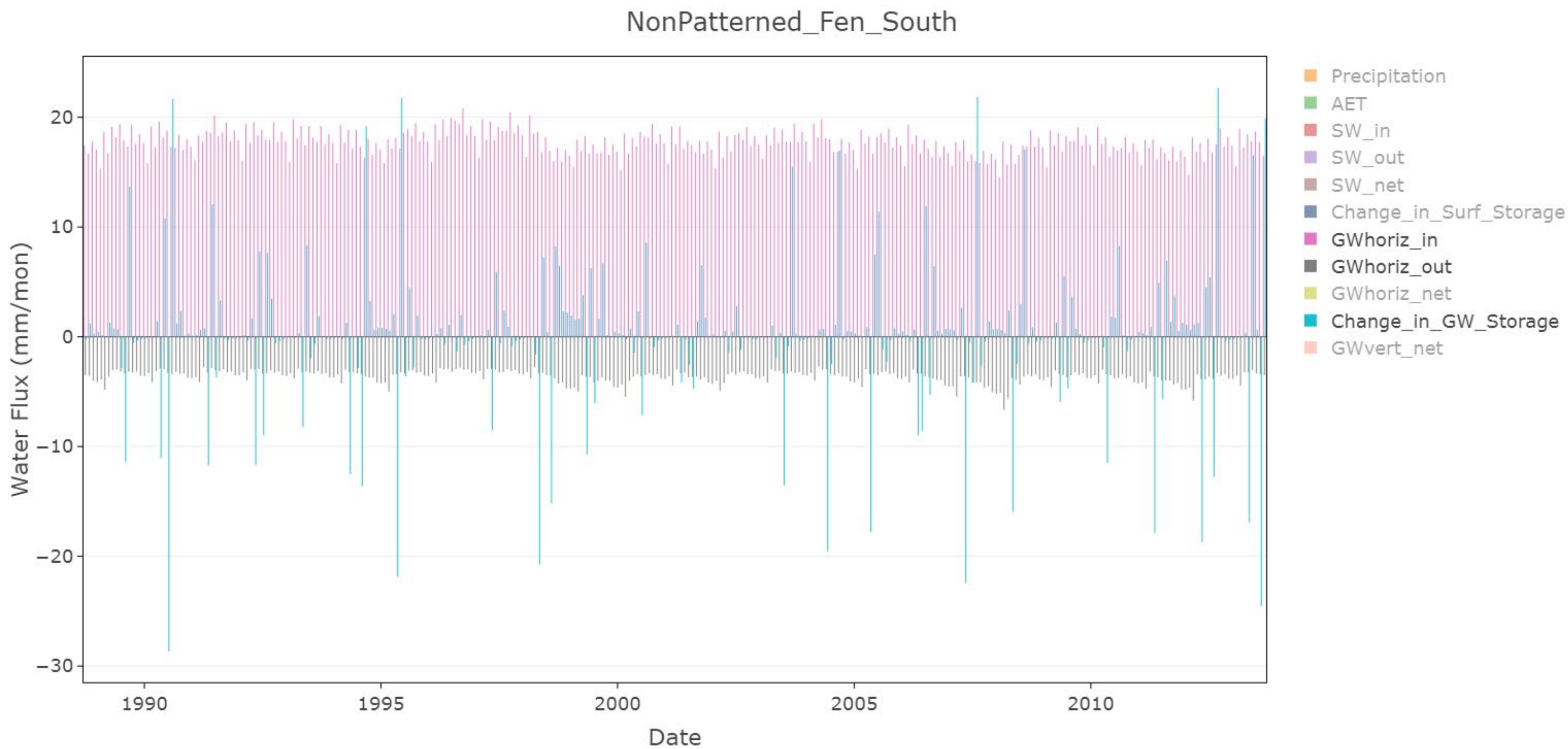

Figure 63 Predicted monthly groundwater flows and storage within HRA 04 from 1988-2013.

16. Section 1.3.5: HRA 05: Non-patterned Fen - West

HRA 05 is designated Non-patterned Fen – West and cross-sections taken through this HRA are shown in Figure 64. HRA 05 covers an area of approximately 4.07 km^2 that has a mean slope of 0.2%, an aspect of 115.43 degrees azimuth and a mean elevation of 297.33 masl. The dominant land usages classes and forms present in HRA 05 are wooded coniferous fen (36.24%) and shrubby fen (35.11%), respectively. The dominant soil is McClelland (86.72%) which is classified to drain very poorly. Precipitation rates on this HRA average 422.7 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a mix of Larix-dominated rich fen and permafrost/bog/fen/swamp complex.

Substrate depths above Clay Till 1 in HRA 05 range from 11.4 to 32.8 m (Figure 65). The substrate is composed of topsoil, Muskeg, Silt Clay and Surface Sands North deposits. The substrate depths generally become thicker south to north and east to west. Bedrock topography in HRA 05 (Clay Till 01) ranges from 264.5 to 286.8 masl and trends downward south to north in the HRA (Figure 66). Post-development, 57% of the HRA will remain undisturbed.

HRA 05 is conceptualized to receive water from precipitation and flows from HRA 16 (North Outwash Plains West) and HRA 07 (Coniferous Swamp - North) (refer to Figure 29, Figure 31 and Figure 64). HRA 16 primarily contributes groundwater to the southwestern half of HRA 05 and HRA 07 supplies mostly surface water to the northeastern half of HRA 05.

Water table position in this HRA strongly influences the hydrologic processes transmitting water to the adjacent lowlands. Seepage face development is conceptualized to commonly occur along the southeastern margins of this HRA where substrate depths become shallower and there is a shift from more permeable mineral soils to less permeable organic ones (muskeg). During relatively drier periods when the water table is lower (e.g., more than ~ 2 mbgs at the transitional margin), groundwater would be expected to simply flow under the margin and either discharge to surface at a lower elevation or eventually discharge into McClelland Lake.

During periods when the water table resides a few meters or less below the surface along this transitional margin, the capillary fringe would extend to the land surface. Under these conditions, incoming precipitation falling on this tension-saturated seepage face and would cause the underlying water table to immediately rise to surface and produce rapid groundwater exfiltration via a process called groundwater ridging (e.g., Gillham, 1984). The ridging would eventually subside and the water table would retreat back below the ground surface. The process would continue to happen during precipitation events so long as the capillary fringe in this HRA extends to the land surface.

During relatively wet periods, when the water table is at or above the land surface along the transitional margin, an advective seepage face would form and exfiltrating groundwater would be converted to saturation excess overland flow onto the muskeg.

Water is conceptualized to leave HRA 05 (in ascending order of conceptualized relative contribution) as outgoing groundwater, evapotranspiration and outgoing surface water. Outflows from HRA 05 contribute to HRA's 01, 02 and 06. HRA 06 primarily receives surface water. HRA 05 contributes both groundwater and surface water to the patterned fens (HRAs 01-02). Only the southwestern half of HRA 05 contributes waters to HRA 01 and only the northeastern half contributes to HRA 02. A surface water flow divide naturally separates the waters in HRA 02 from those in HRA 01. HRA 05 is the only part of the landscape that directly provides water to HRA 02. The hydrogeochemistry of this HRA is conceptualized to be non-alkaline and cation-poor.

The position of the water table during the onset of winter will also influence spring freshet behavior in this HRA. The ground will freeze solid in areas where muskeg is present. The ground will also freeze solid where the water table or the capillary fringe extends to surface at the onset of winter. The frozen solid zones can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains. Portions of HRA 05 where the surface is covered with deeper, permeable substrates and the water table is deeper will freeze in a permeable, honeycomb structure. Regions of the HRA that freeze solid will generate snowmelt runoff during the spring freshet whereas regions that freeze honeycomb are not expected to generate any snowmelt runoff most years (the snowmelt would infiltrate instead).

The water budget results shown on
Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 05 was simulated to receive 24%, 54% and 22% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 05 was simulated to discharge 20%, 66% and 14% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA

05 indicates that annual AET rates (345.8 mm/yr) are much lower than precipitation rates (413.2 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface by the transitional margin and deeper where the substrate thickens (Figure 33); the HRA is simulated to remain near saturated across the bulk of the HRA while saturation levels decline in areas with deeper substrates (Figure 34) and the exchange of water across the land surface interface is a patchwork of zones of exfiltration where the water table is near surface, large areas where exchange is approximately net neutral and isolated regions of infiltration (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 67 presents predicted average monthly water balance components over the period 1988-2013. HRA 05 is predicted to produce peak incoming and outgoing flows during the month of April that remain at relatively higher rates through October. This HRA sheds surface water storage from March to May (a small amount is also shed in July). The HRA adds to surface water storage June-December (except July). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA peak in October and are at their minimum in April. Groundwater flows out of the HRA reach their peak in May and their minimum in February. The HRA adds to groundwater storage in April (the peak) and June through September. The HRA consumes groundwater storage in May (peak consumption) and October through March.

Figure 68 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 05. Peak monthly precipitation can occur between April-August but typically happens in June. Maximum monthly AET rates can happen May-August but usually occurs in July. Figure 69 shows the surface water balance components (flow in, flow out and change in storage). Peak surface water in can happen March-August but usually occurs in April. Peak surface water out can occur April-September but usually happens in April. The largest monthly gain in surface water storage can occur June-November but most often happens in November. The maximum monthly consumption of surface water storage can occur March-May but typically happens in May. Figure 70 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur July-October but typically peaks in October. Peak monthly groundwater discharge rates occur March-August but usually happen in May. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest consumption of groundwater storage usually happens May-August but usually occurs in May.

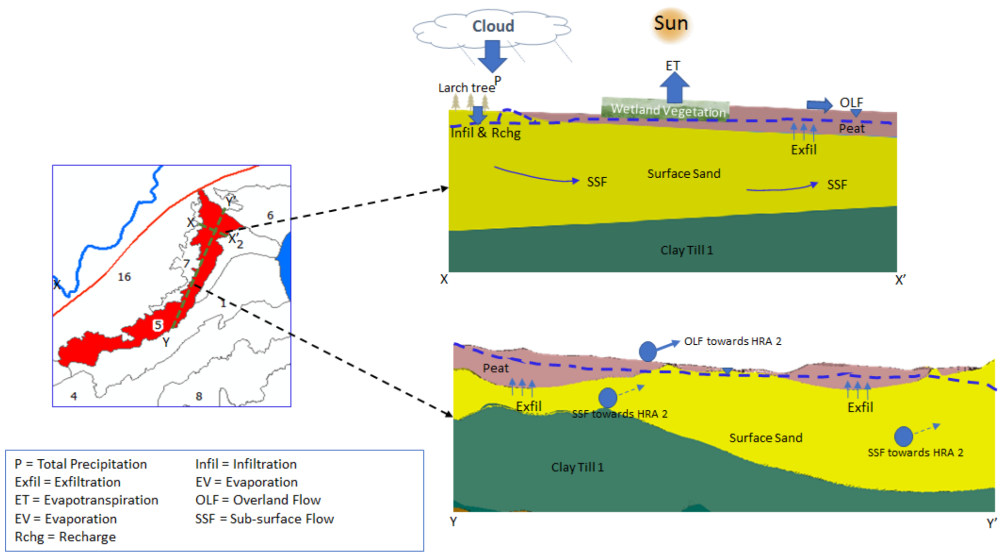

Figure 64 HRA 05: Non-patterned Fen – West. Vertical exaggeration is 80:1.

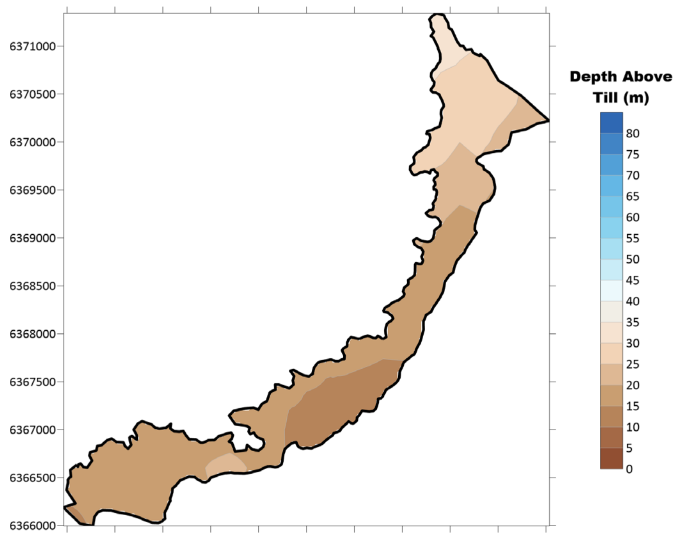

Figure 65 Substrate depths in HRA 05: Non-patterned Fen – West.

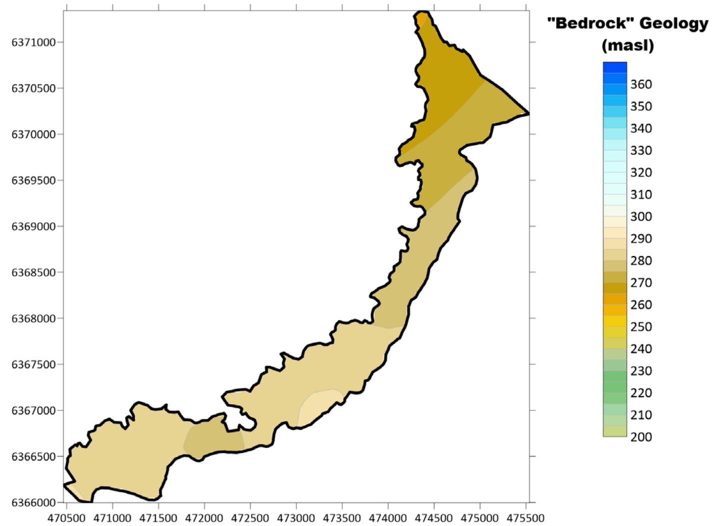

Figure 66 Bedrock topography in HRA 05: Non-patterned Fen – West.

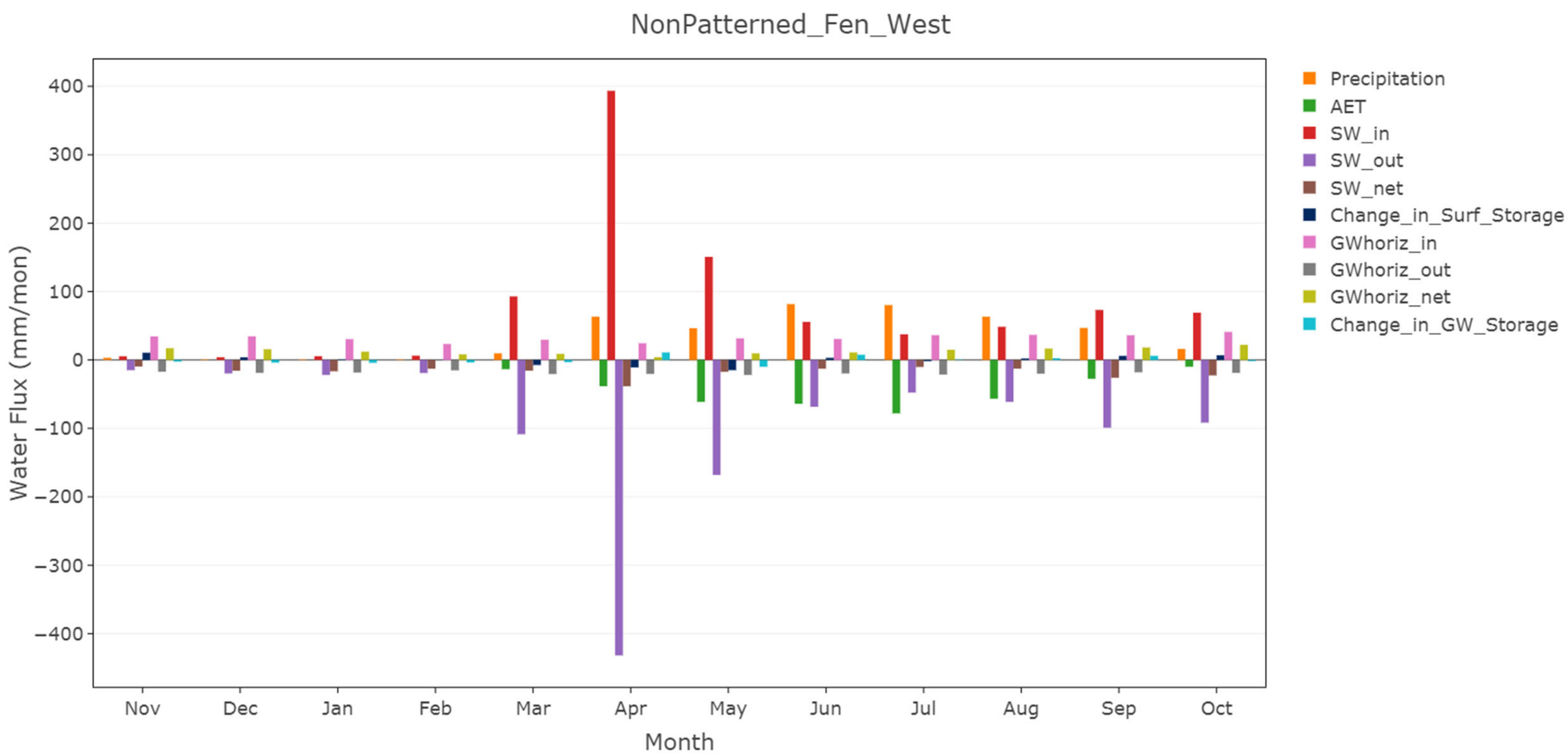

Figure 67 Mean monthly water budget components (1988-2013) for HRA 05: Non-patterned Fen - West. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

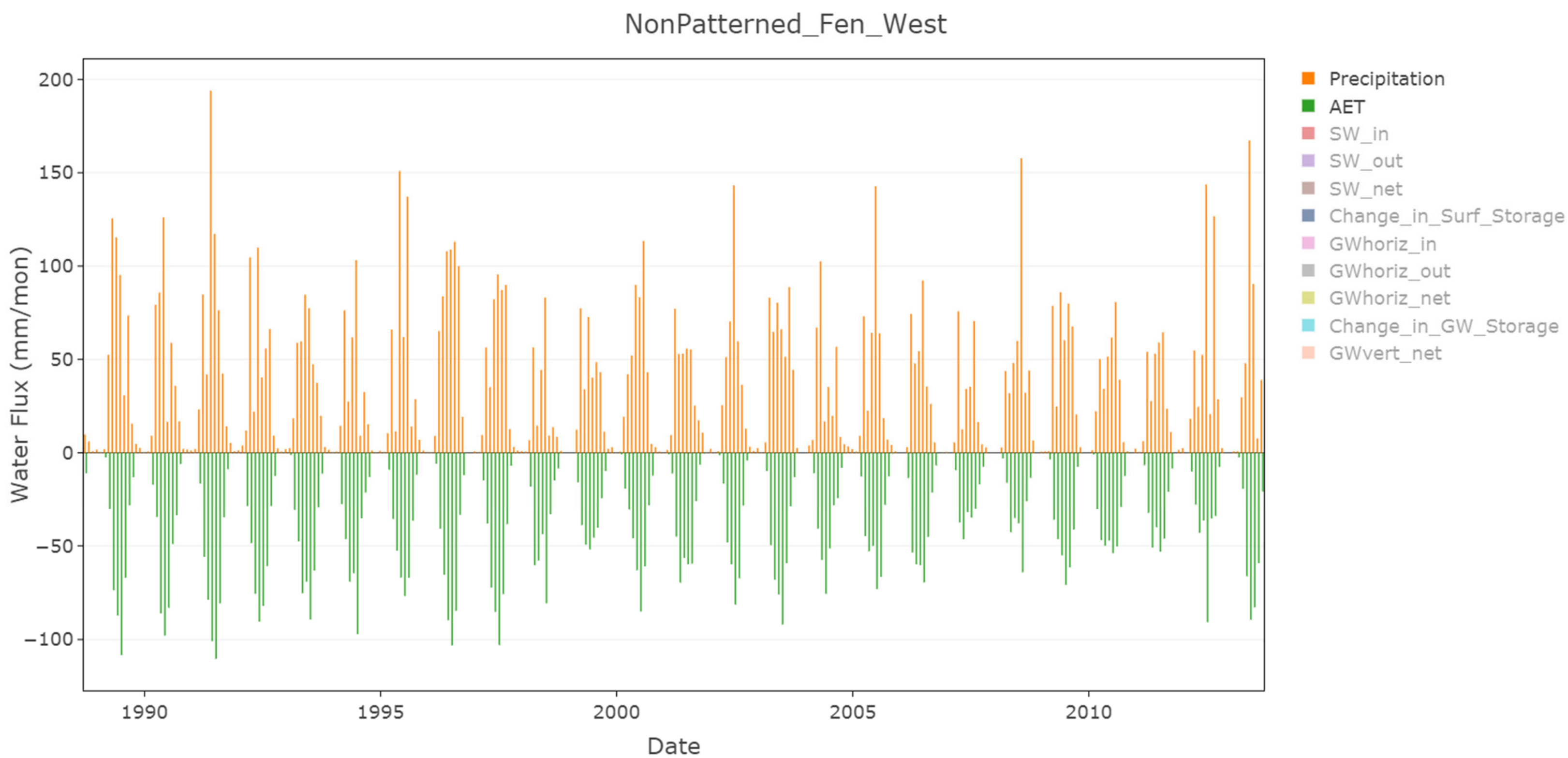

Figure 68 Predicted monthly precipitation and AET rates within HRA 05 from 1988-2013.

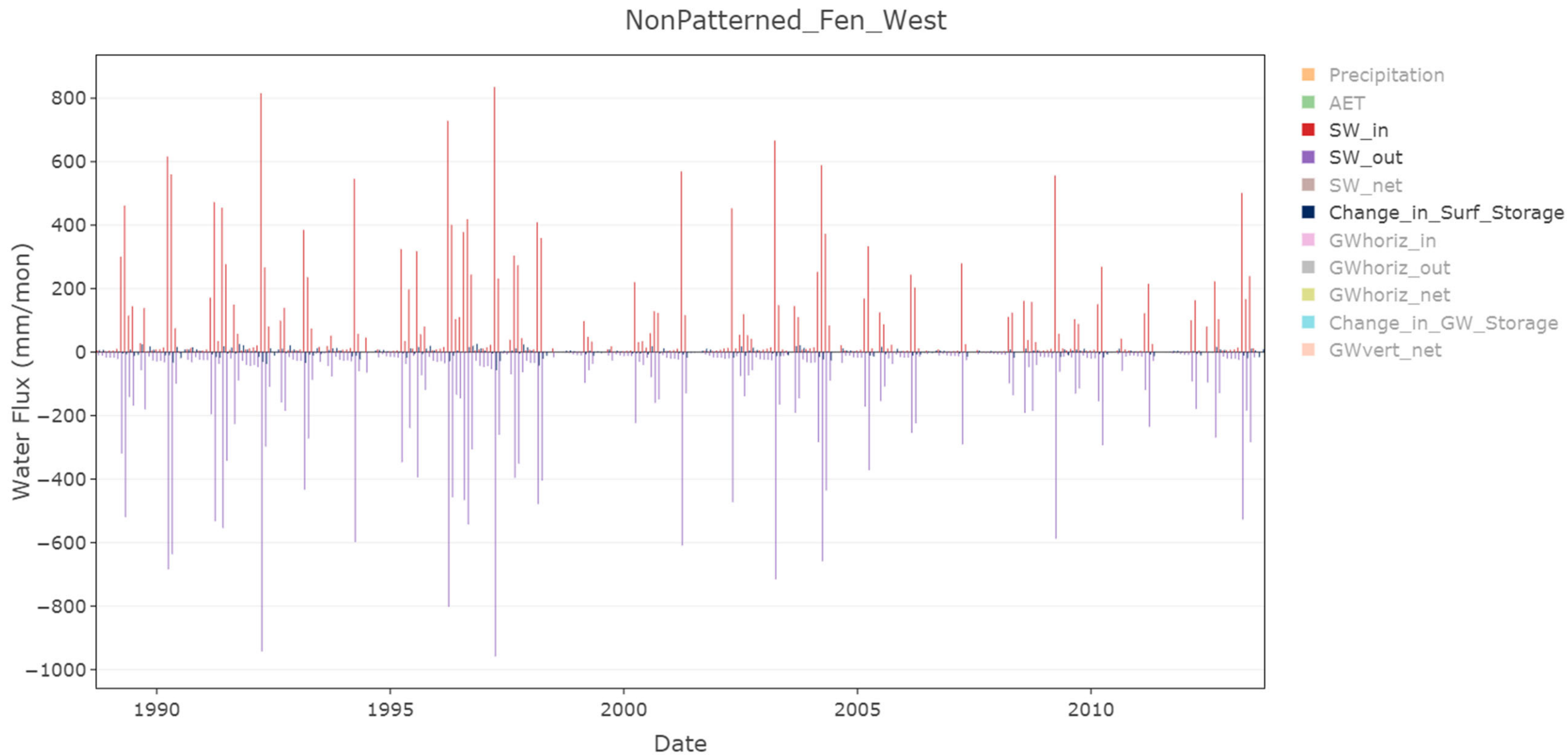

Figure 69 Predicted monthly surface water flows and storage within HRA 05 from 1988-2013.

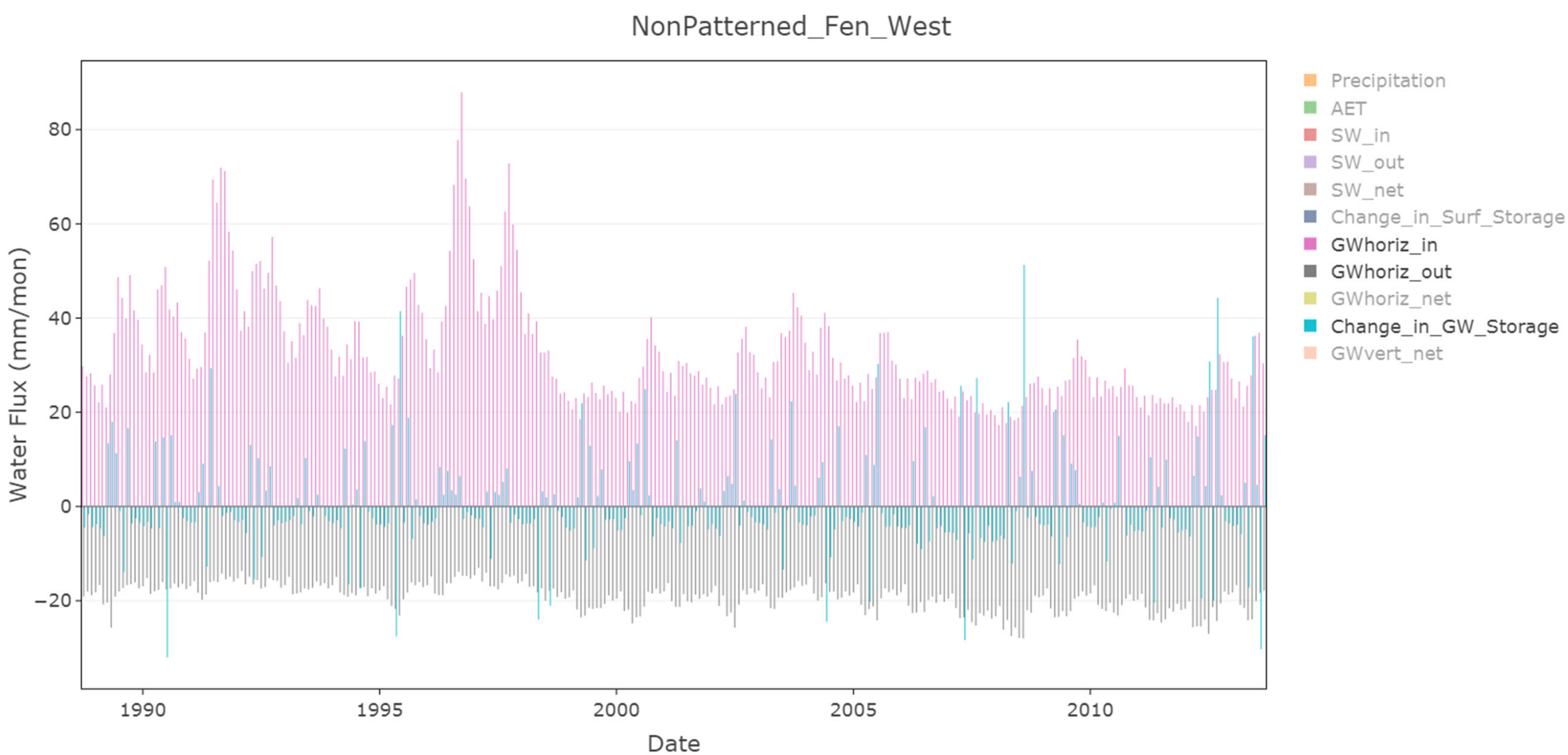

Figure 70 Predicted monthly groundwater flows and storage within HRA 05 from 1988-2013.

17. Section 1.3.6: HRA 06: Non-Patterned Fen - North

HRA 06 is designated Non-patterned Fen – North and a cross-section taken through this HRA is shown in Figure 71. HRA 06 covers an area of approximately 3.19 km^2 that has a mean slope of 0.16%, an aspect of 163.40 degrees azimuth and a mean elevation of 295.24 masl. The dominant land usages classes and forms present in HRA 06 are wooded coniferous fen (35.86%) and shrubby fen (38.75%), respectively. The dominant soil is McClelland (95.23%) which is classified to drain very poorly. Precipitation rates on this HRA average 422.6 mm per year, approximately 100% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a permafrost/bog/fen/swamp complex.

Substrate depths above Clay Till 1 in HRA 06 range from 15.5 to 30.8 m (Figure 72). The substrate is composed of topsoil, Muskeg, Silt Clay and Surface Sands North deposits. The substrate depths decline from west to east. Bedrock topography in HRA 06 (Clay Till 01) ranges from 266.2 to 279.1 masl and trends higher west to east (Figure 73). Post-development, 100% of the HRA will remain undisturbed.

HRA 06 is conceptualized to receive water from precipitation and flows from HRA 05 (Non-patterned Fen – West) and HRA 16 (North Outwash Plains West) (refer to Figure 29, Figure 31 and Figure 71). Contributions from HRA 05 are primarily in the form of incoming surface water while contributions from HRA 16 are primarily in the form of incoming groundwater. The water table is conceptualized to be at or near the land surface most times in HRA 06.

Water is conceptualized to leave HRA 06 (in ascending order of conceptualized relative contribution) in the forms of groundwater discharge into McClelland Lake, evapotranspiration and surface water discharge into McClelland Lake. During the spring freshet, snowmelt runoff in HRA 06 is conceptualized to flow over the frozen muskeg and discharge into McClelland Lake; any additional inputs of snowmelt or incoming precipitation would continue to generate runoff into the lake until the muskeg thawed, potentially weeks after the freshet. The hydrogeochemistry of the waters entering HRA 06 are conceptualized to be non-alkaline and cation-poor.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 06 was simulated to receive 46%, 33% and 21% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 06 was simulated to discharge 36%, 53% and 11% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 06 indicates that annual AET rates (315.5 mm/yr) are much lower than precipitation rates (413.3 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface (Figure 33); the HRA is simulated to remain near saturated on average (Figure 34) and the exchange of water across the land surface is a patchwork of near neutral and infiltration areas with a prominent exfiltration zone predicted to be located in the northeast corner of the HRA (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 74 presents predicted average monthly water balance components over the period 1988-2013. HRA 06 is predicted to produce peak incoming and outgoing flows during the month of April that remain at relatively higher rates through October. This HRA sheds surface water storage from March to July. The HRA adds to surface water storage September to February. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA peak in October and are at their minimum in April. Groundwater flows out of the HRA reach their peak in April and their minimum in November. The HRA adds to groundwater storage in April and June (the peak) through September. The HRA consumes groundwater storage in May (peak consumption) and October through March.

Figure 75 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 06. Peak monthly precipitation can occur between April-August but typically happens in June. Maximum monthly AET rates can happen May-August but usually occurs in July. Figure 76 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can happen March-September but usually occurs in April. Peak surface water out occurs March-September but usually happens in April. The largest monthly gain in surface water storage can occur June-November but most often happens in November. The maximum monthly consumption of surface water storage can occur March-October but typically happens in May. Figure 77 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur May-October but typically peaks in October. Peak monthly groundwater discharge rates occur between March and October but usually happen in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest consumption of groundwater storage happens March-August but usually occurs in March.

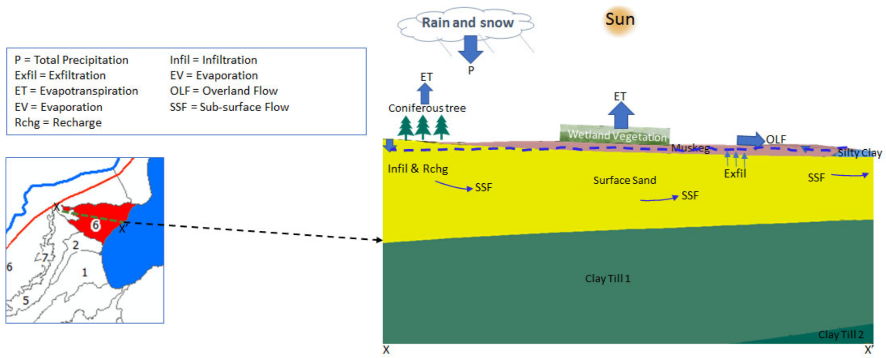

Figure 71 HRA 06: Non-patterned Fen – North. Vertical exaggeration is 80:1.

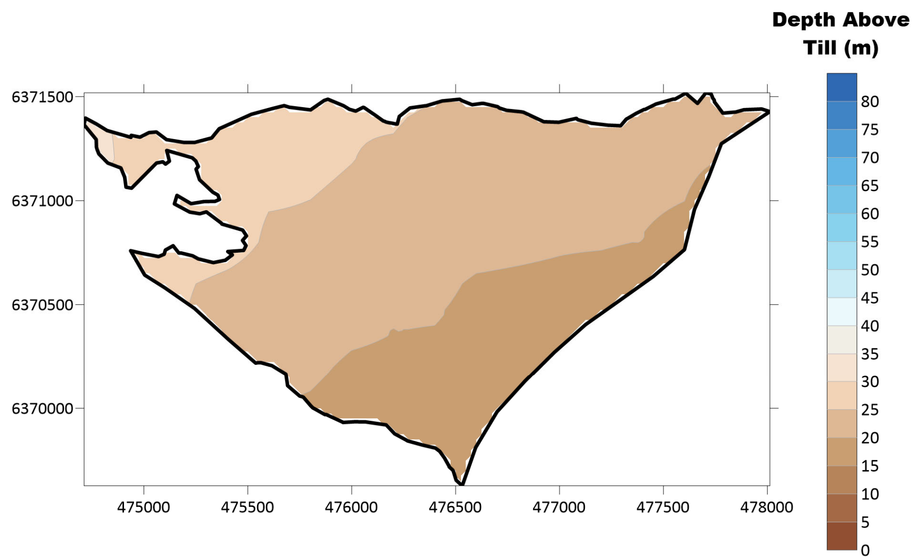

Figure 72 Substrate depths in HRA 06: Non-patterned Fen – North.

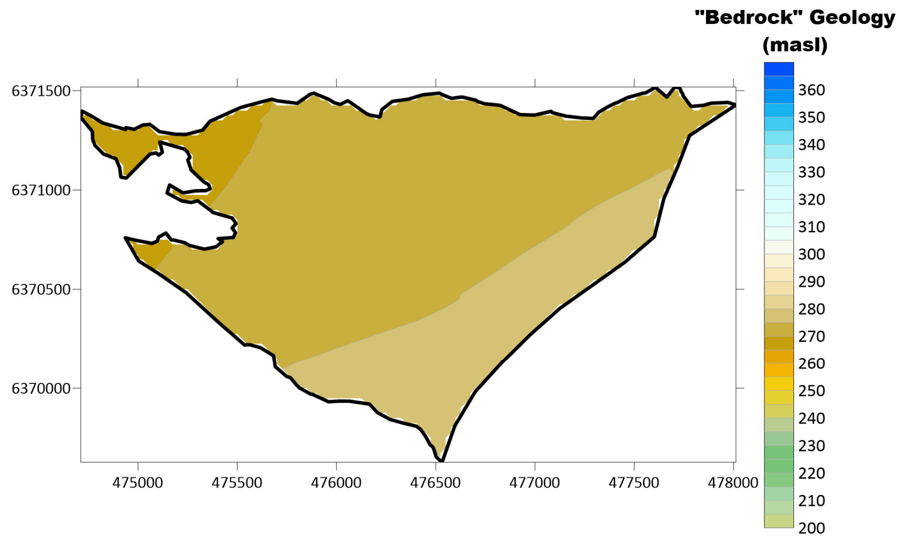

Figure 73 Bedrock topography in HRA 06: Non-patterned Fen – North.

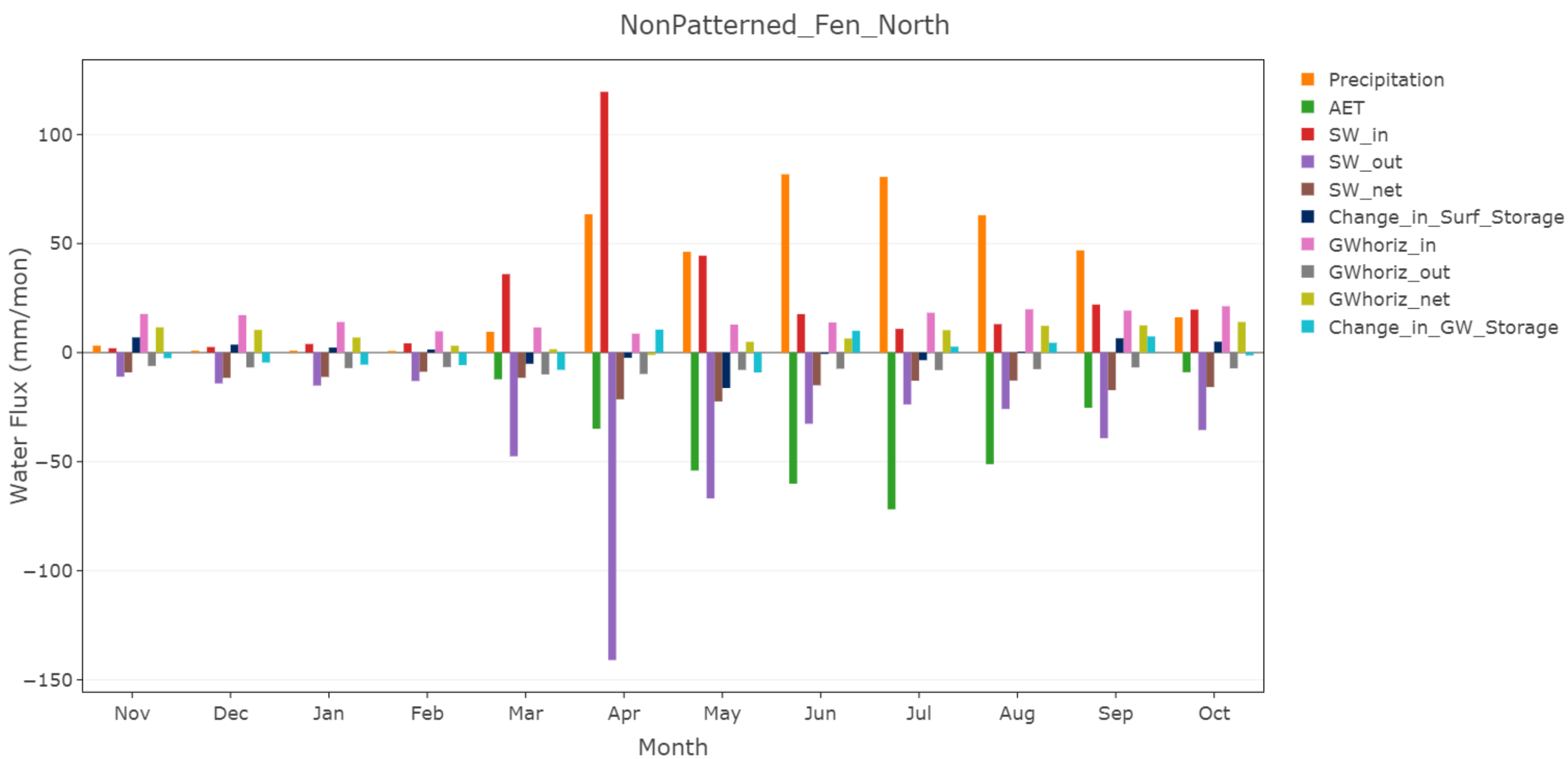

Figure 74 Mean monthly water budget components (1988-2013) for HRA 06: Non-patterned Fen - North. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

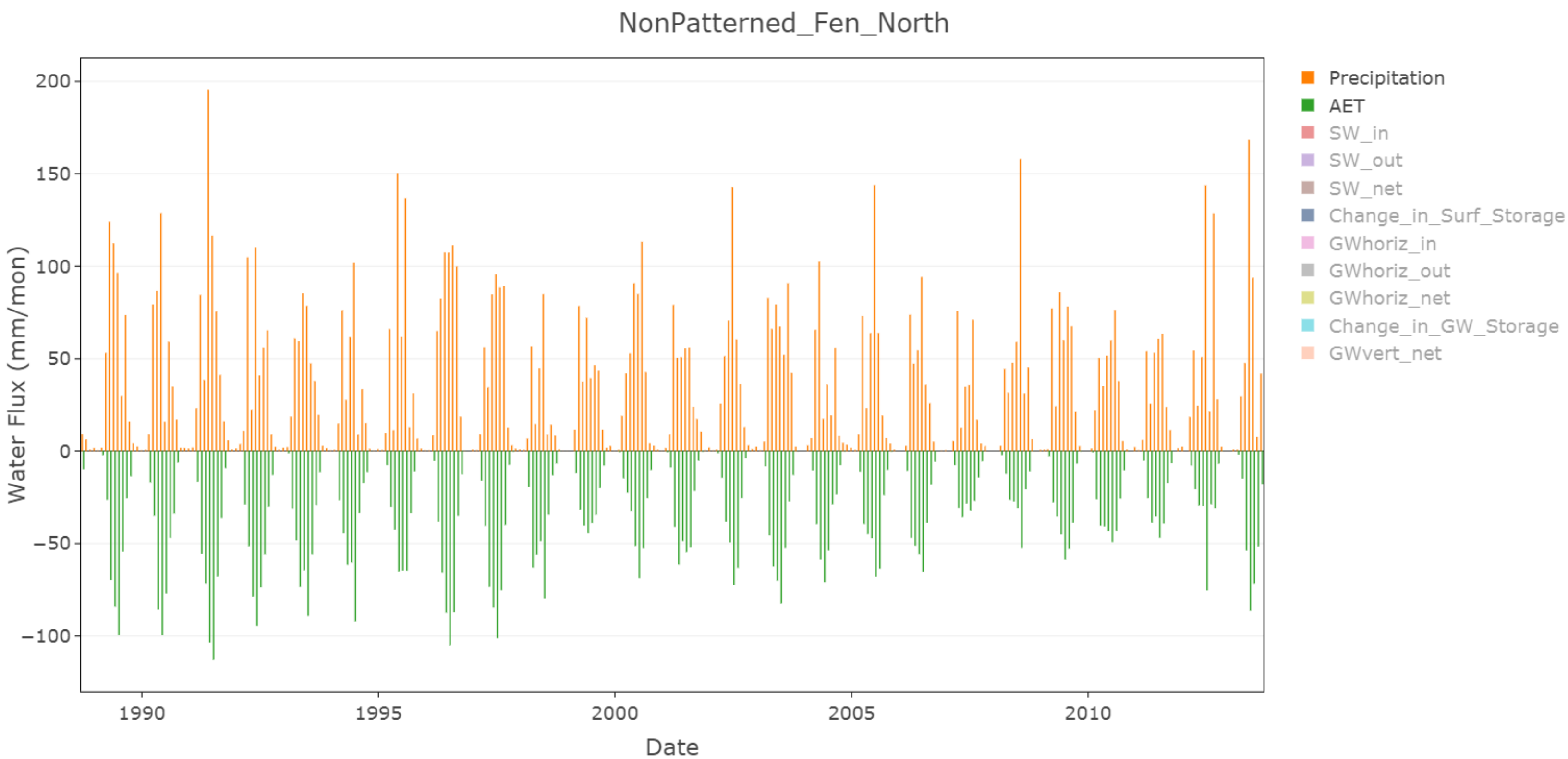

Figure 75 Predicted monthly precipitation and AET rates within HRA 06 from 1988-2013.

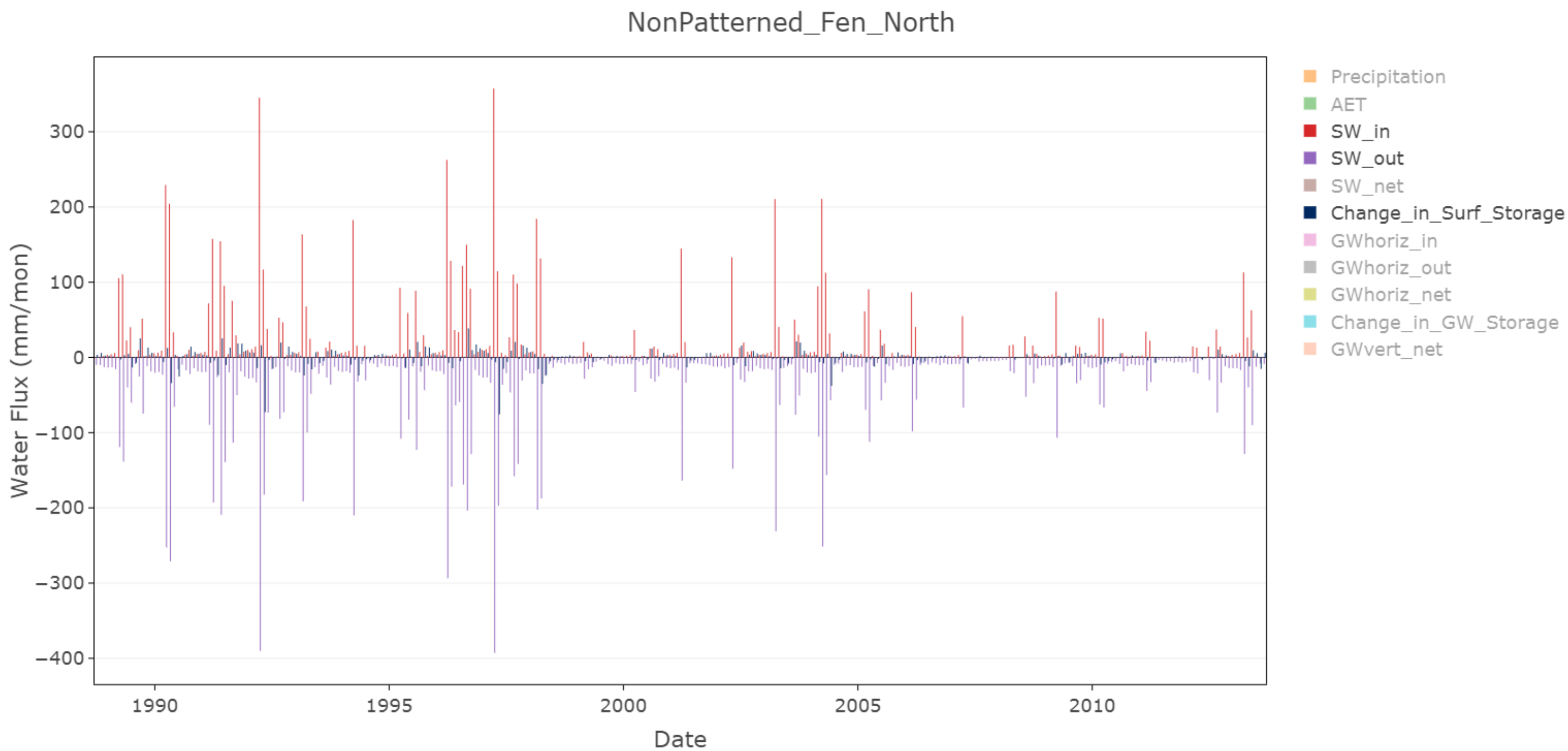

Figure 76 Predicted monthly surface water flows and storage within HRA 06 from 1988-2013.

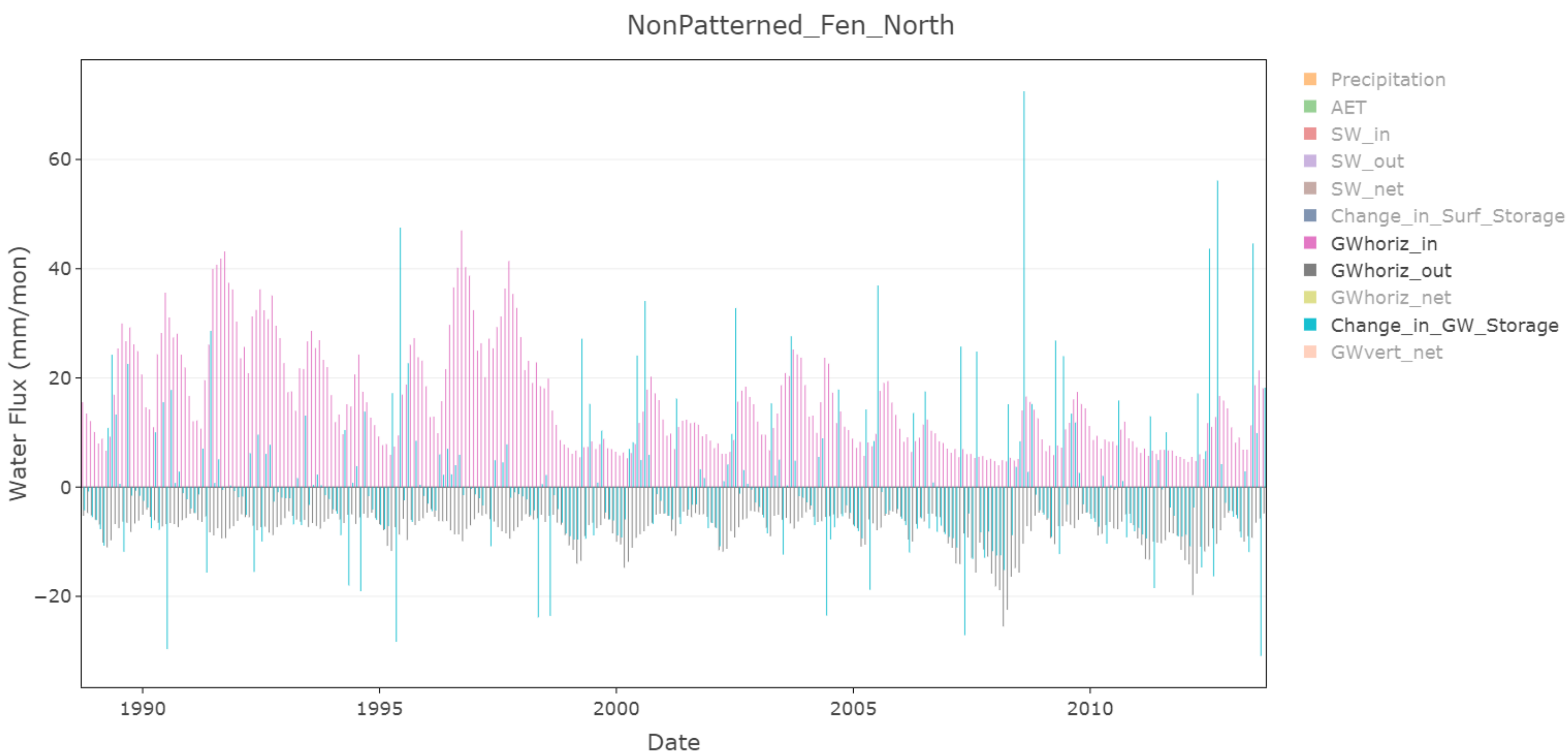

Figure 77 Predicted monthly groundwater flows and storage within HRA 06 from 1988-2013.

18. Section 1.3.7: HRA 07: Coniferous Swamp – North

HRA 07 is designated Coniferous Swamp – North and cross-sections taken through this HRA are shown in Figure 78. HRA 07 covers an area of approximately 1.03 km^2 that has a mean slope of 1.0%, an aspect of 116.11 degrees azimuth and a mean elevation of 297.27 masl. The dominant land usages classes and forms present in HRA 07 are wooded coniferous upland (non-wetland) (25.06%) and wooded coniferous burned (44.39%), respectively. The dominant soils are Bitumount (58.58%) and Mildred (34.06%) which are classified to drain poorly and rapidly, respectfully. Precipitation rates on this HRA average 422.6 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as riparian margin.

Substrate depths above Clay Till 1 in HRA 07 range from 16.3 to 36.3 m (Figure 79). The substrate is composed of topsoil and Surface Sands North deposits. The substrate depths decline from west to east. Bedrock topography in HRA 07 (Clay Till 01) ranges from 264.5 to 282.2 masl and the topography trends lower south to north (Figure 80). Post-development, 100% of the HRA will remain undisturbed.

HRA 07 is conceptualized to receive its water from precipitation and incoming groundwater from HRA 16 (North Outwash Plains West) (refer to Figure 29, Figure 31 and Figure 78). The water table is conceptualized to be somewhat deeper in this HRA. The deep and permeable surface sand deposits making up this HRA would be expected to freeze in a permeable, honeycomb structure during the winter and snowmelt runoff would be presumed to be minimal or non-existent.

Water is conceptualized to leave HRA 07 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, evapotranspiration and outgoing groundwater. During winter, the deep permeable sands in this HRA would be expected to freeze in a permeable honeycomb configuration and generate little if any runoff. The hydrogeochemistry of the waters entering HRA 07 are conceptualized to be non-alkaline and cation-poor.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 07 was simulated to receive 27%, 0% and 73% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 07 was simulated to discharge 22%, 9% and 69% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 07 indicates that annual AET rates (361.8 mm/yr) are lower than precipitation rates (413.3 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the land surface most times (Figure 33); the HRA is simulated to remain variably-saturated on average (Figure 34) and the exchange of water across the land surface is mostly downward infiltration (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of groundwater and leaves in the form of groundwater. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 81 presents predicted average monthly water balance components over the period 1988-2013. HRA 07 is not predicted to receive any appreciable incoming surface water flows. Outgoing surface water peaks in September and is at its minimum in May. This HRA sheds surface water storage from December to May (peak rates in March). The HRA adds to surface water storage August to November and in the month of June (peak rate in October). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA peak in August and are at their minimum in April. Groundwater flows out of the HRA reach their peak in October and their minimum in February. The HRA adds to groundwater storage in April (the peak) and June through September. The HRA consumes groundwater storage November to March (the peak) and in the month of May.

Figure 82 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 07. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occurs in July. Figure 83 shows the surface water balance components (flow in, flow out and change in storage). Incoming surface water inputs are negligible in this HRA. Peak surface water out can occur April-October but usually happens in September. The largest monthly gain in surface water storage can occur April-November but most often happens in October. The maximum monthly consumption of surface water storage can occur January-October but typically happens in March. Figure 84 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur May-October but typically peaks in October. Peak monthly groundwater discharge rates occur May-October but usually happen in October. The largest monthly gain in groundwater storage can happen April-September but usually occurs in September. The largest consumption of groundwater storage usually happens March-September but usually occurs in May.

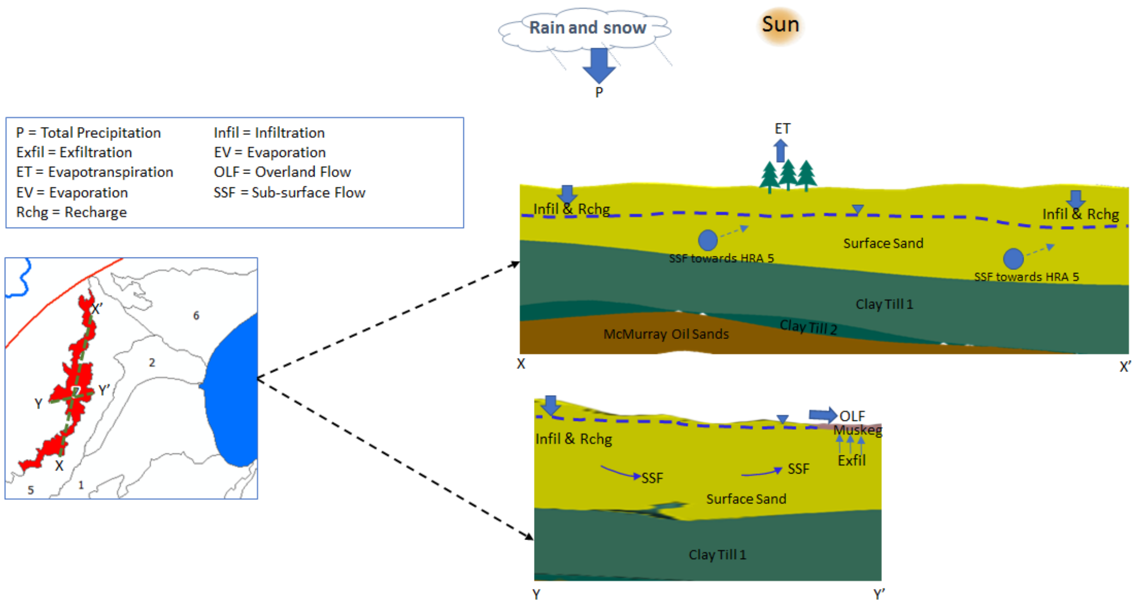

Figure 78 HRA 07: Coniferous Swamp – North. Vertical exaggeration is 80:1.

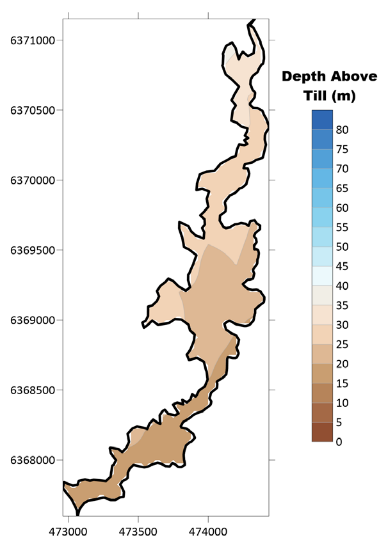

Figure 79 Substrate depths in HRA 07: Coniferous Swamp – North.

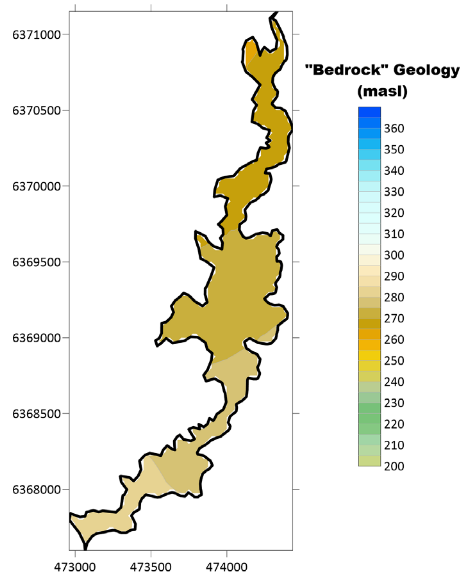

Figure 80 Bedrock topography in HRA 07: Coniferous Swamp – North.

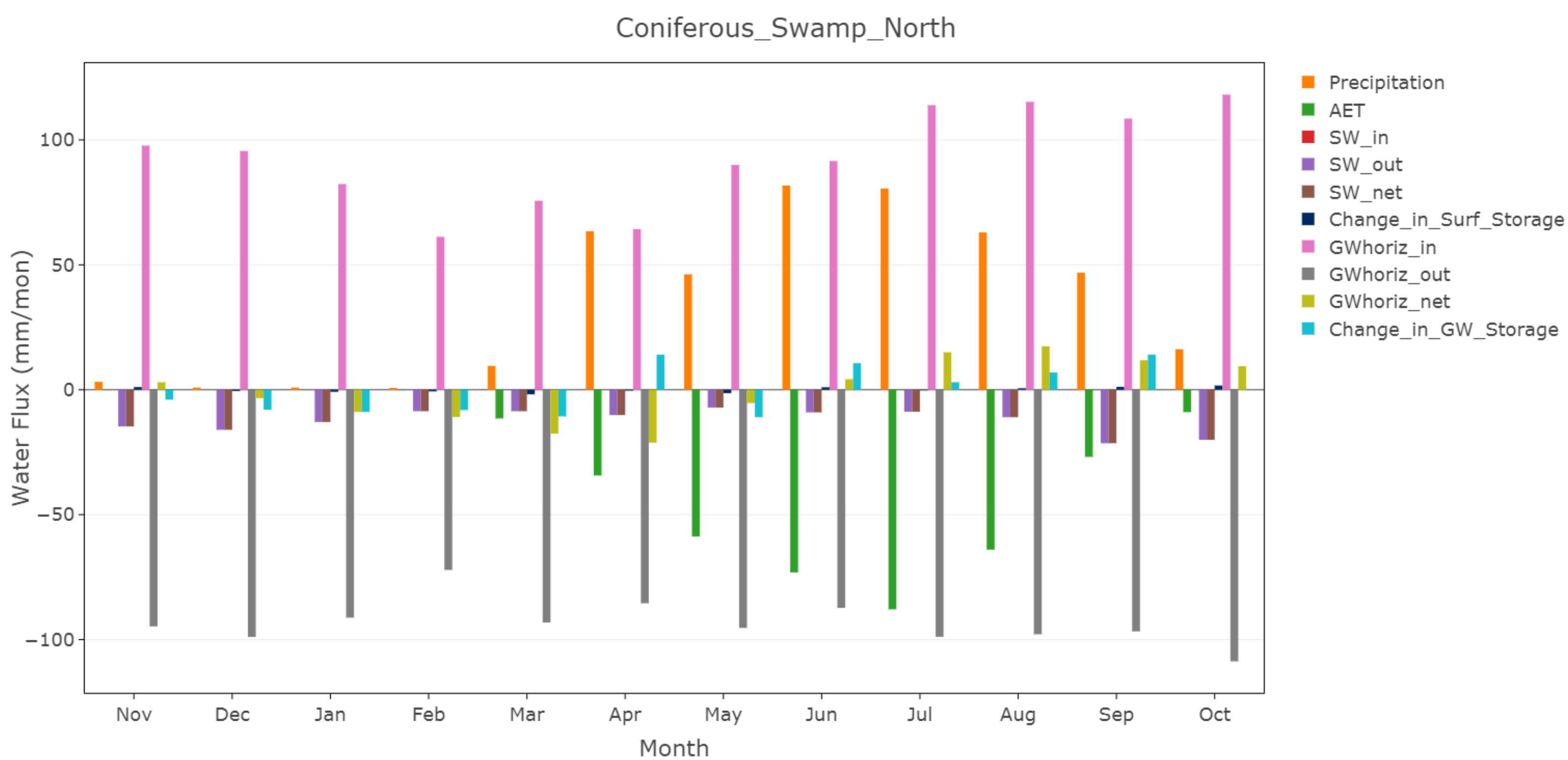

Figure 81 Mean monthly water budget components (1988-2013) for HRA 07: Coniferous Swamp - North. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

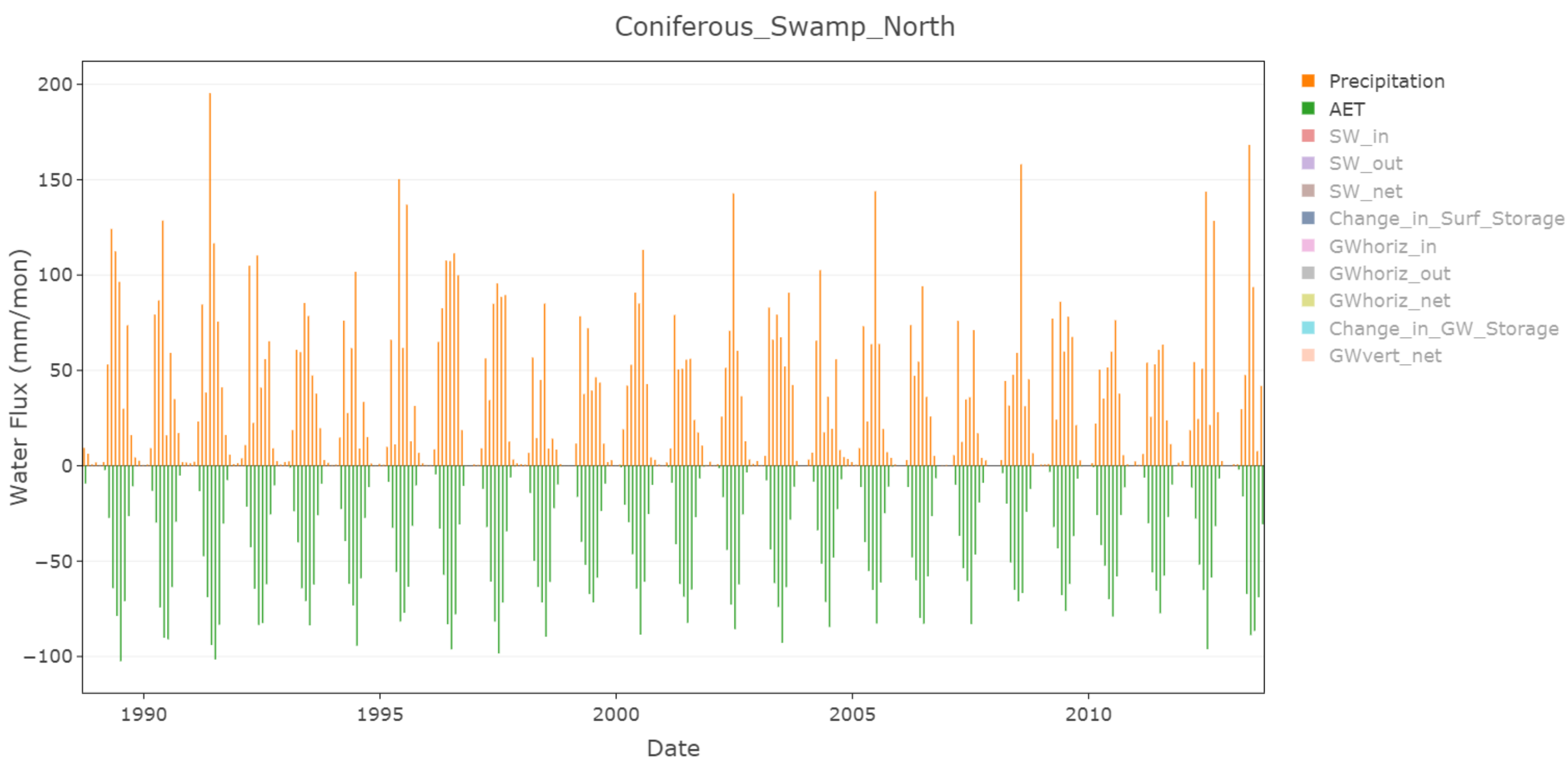

Figure 82 Predicted monthly precipitation and AET rates within HRA 07 from 1988-2013.

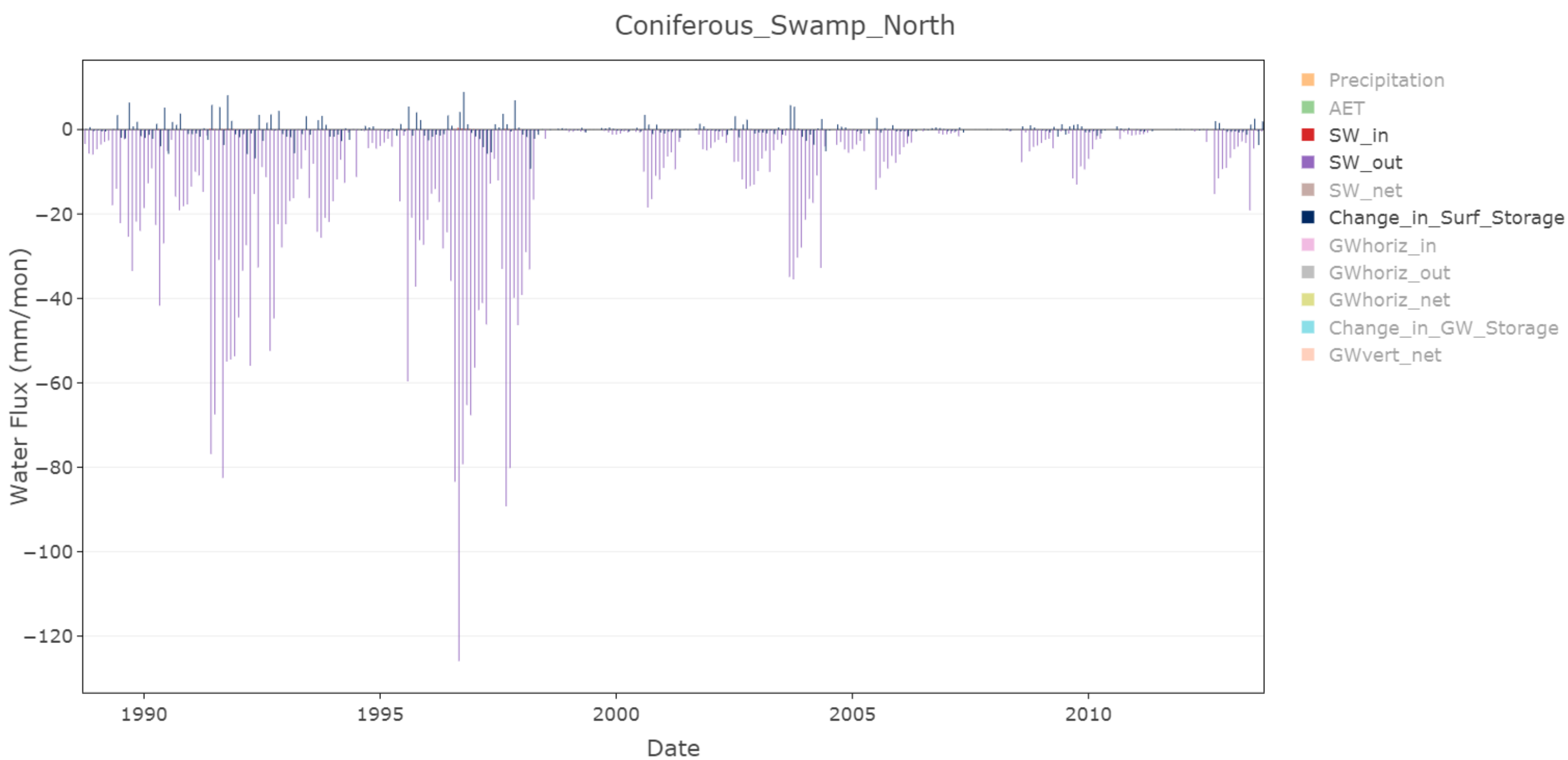

Figure 83 Predicted monthly surface water flows and storage within HRA 07 from 1988-2013.

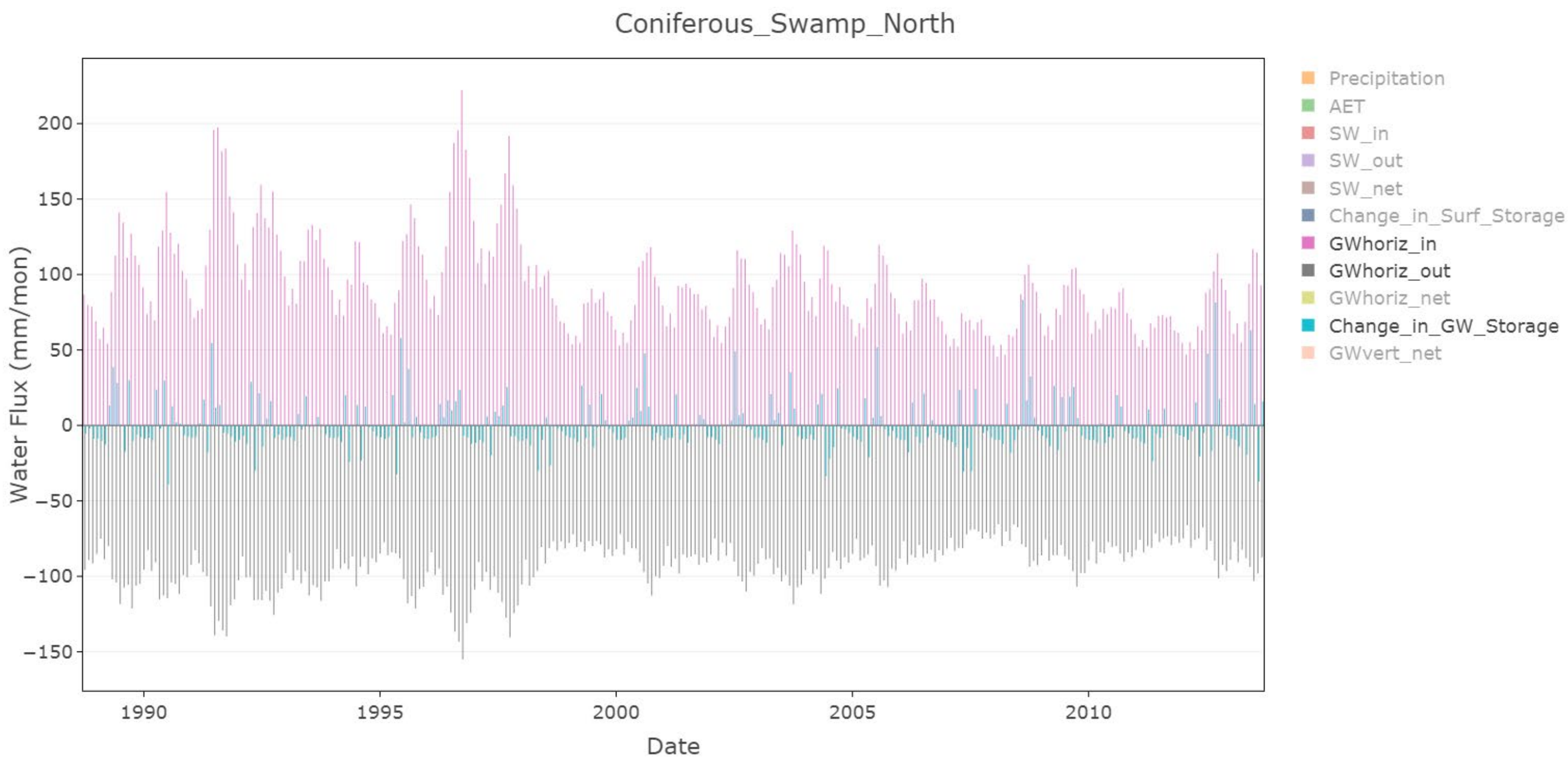

Figure 84 Predicted monthly groundwater flows and storage within HRA 07 from 1988-2013.

19. Section 1.3.8: HRA 08: Coniferous Swamp – South

HRA 08 is designated Coniferous Swamp – South and cross-sections taken through this HRA are shown in Figure 85. HRA 08 covers an area of approximately 6.72 km^2 that has a mean slope of 2.16%, an aspect of 222.61 degrees azimuth and a mean elevation of 305.44 masl. The dominant land usages classes and forms present in HRA 08 are wooded coniferous swamp (29.5%), wooded coniferous upland (non-wetland) (26.03%) wooded deciduous upland (non-wetland) (20.16%), respectively. The dominant soil types are Bitumount (23.04%), Firebag (19.06%) and Mildred 26.09%), which are classified to drain poorly, rapidly to very rapidly and rapidly, respectively. Precipitation rates on this HRA average 422.6 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as riparian margin and permafrost/bog/fen/swamp complex.

Substrate depths above Clay Till 1 in HRA 08 range from 0.0 to 13.6 m and are under 5m deep across the majority of the HRA (Figure 86). The substrate is composed of topsoil, Surface Sands North, Surface Sands South, Muskeg, Silt Clay and Clay Till 1 deposits. Beneath the muskeg, the majority of this HRA is covered in either Silt Clay or Clay Till 1 deposits. There is a small hydraulic window interpreted to be in this HRA (Figure 86). Substrate depths above Clay Till 2 in the hydraulic window are up to 52 m deep and are composed of silt sands and Surface Sand South deposits. Bedrock topography in HRA 08 (Clay Till 01) ranges from 266.3 to 322.9 masl and the trends lower south to north (Figure 87). Post-development, 50% of the HRA will remain undisturbed.

HRA 08 is conceptualized to receive its water from precipitation and flows from HRA 17 (Fort Hills West) and HRA 18 (Fort Hills East) (refer to Figure 29, Figure 31 and Figure 85). Water from HRA 18 transits the northeast end of HRA 08 from a flowing hydraulic window located by the southwestern shores of McClelland Lake (Figure 31). Runoff generated from HRA 17 enters HRA 08 in the forms of incoming surface water and groundwater. The water table in HRA 08, where present, is conceptualized to be at or near surface in this HRA most times due to the shallow substrate depths, sloping surfaces and its position in the landscape at the base of a large upland structure (the FHUC). The clay deposits at surface in HRA 08, coupled with its position in the landscape (down-gradient where it can receive flows from overlying groundwater springs) strongly indicates that HRA08 is a major runoff-producing HRA in the MLWC watershed outside of the winter period.

Water is conceptualized to leave HRA 08 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, evapotranspiration and outgoing surface water. Runoff from

HRA 08 enters HRA 04. The majority of the ground in HRA 08 is covered in clay or tills that are expected to freeze solid and impermeable in the winter; while the remainder is covered in surface sand deposits that will instead freeze into a permeable honeycomb structure. During the spring freshet, snowmelt will infiltrate in those areas of the HRA covered in permeable sands. Conversely, snowmelt runoff into HRA 04 will occur over the frozen solid clay or till deposits at surface during the spring freshet. These less permeable deposits can remain frozen for weeks after the spring freshet has concluded, generating further runoff into HRA 04 each time a precipitation event happens. The hydrogeochemistry of waters entering HRA 08 are conceptualized to be (relatively) alkaline and cation-rich.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 08 was simulated to receive 35%, 32% and 33% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 08 was simulated to discharge 36%, 50% and 14% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 08 indicates that annual AET rates (411.6 mm/yr) approximately equal precipitation rates (413.3 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near surface where substrates are shallow and below the land surface where they are deeper (Figure 33); the HRA is simulated to remain variably-saturated on average (Figure 34) and the exchange of water across the land surface is a mosaic of infiltration, exfiltration and neutral exchange regions (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in nearly equal parts of precipitation, surface water and groundwater and approximately half leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 88 presents predicted average monthly water balance components over the period 1988-2013. HRA 08 is predicted to produce peak incoming and outgoing flows during the month of April. This HRA sheds surface water storage from March to May (peak rate) and then a small amount again in July. The HRA adds to surface water storage August to February and the month of June (peak rate in November). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA at a fairly constant rate throughout the year. Groundwater flows out of the HRA reach their peak in July and do not occur November through February. The HRA adds to groundwater storage in April (the peak), June and September through November. The HRA consumes groundwater storage in May (peak consumption), July through August and December to March.

Figure 89 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 08. Peak monthly precipitation occur April-August but typically happens in June. Maximum monthly AET rates can happen June-August but usually occur in July. Figure 90 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-May but usually happens in April. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur June-November but most often happens in November. The maximum monthly consumption of surface water storage can occur March-May but typically happens in May. Figure 91 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly outgoing groundwater rates occur March-October but usually happen in April. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest consumption of groundwater storage usually happens May-August but usually occurs in May.

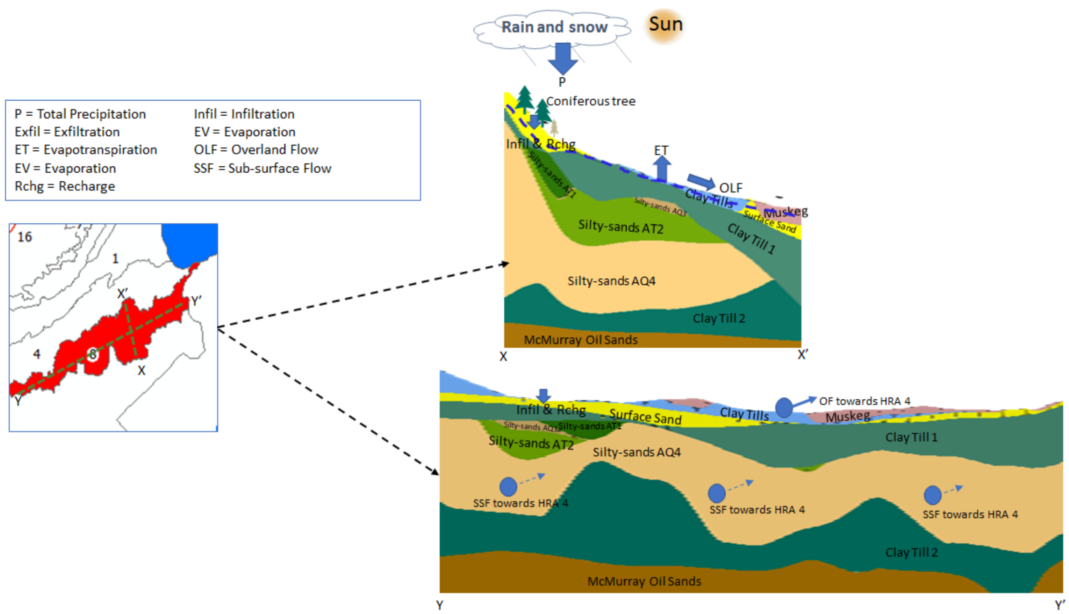

Figure 85 HRA 08: Coniferous Swamp – South. Vertical exaggeration is 80:1.

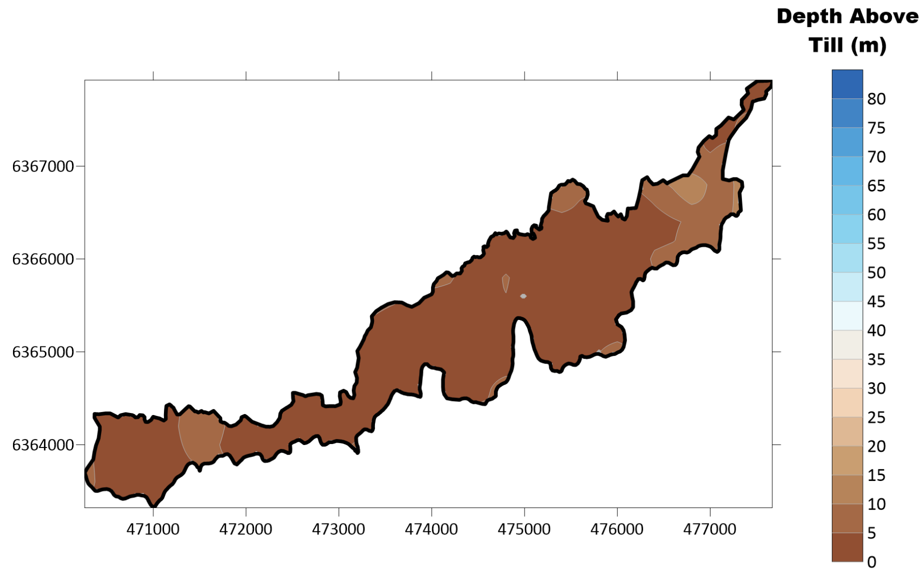

Figure 86 Substrate depths in HRA 08: Coniferous Swamp – South. Note the small hydraulic window present in the eastern central portion of the figure.

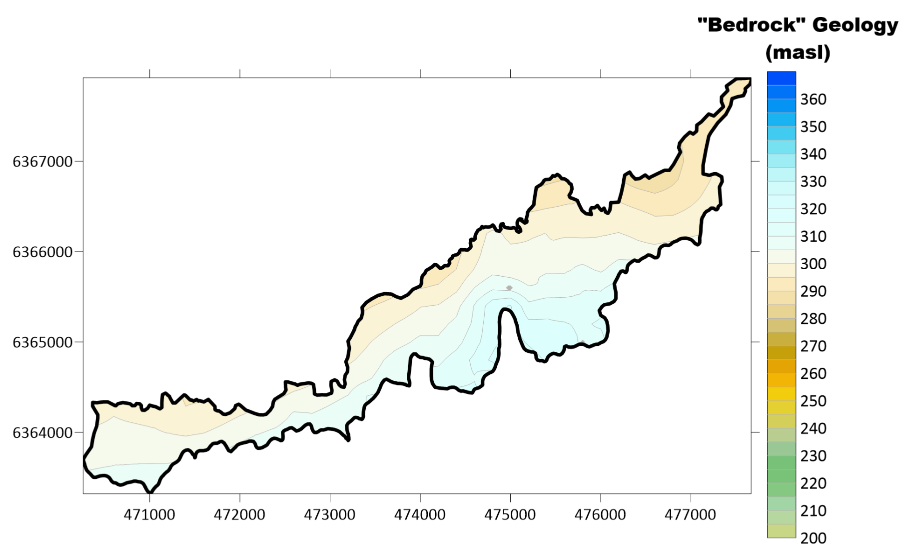

Figure 87 Bedrock topography in HRA 08: Coniferous Swamp – South.

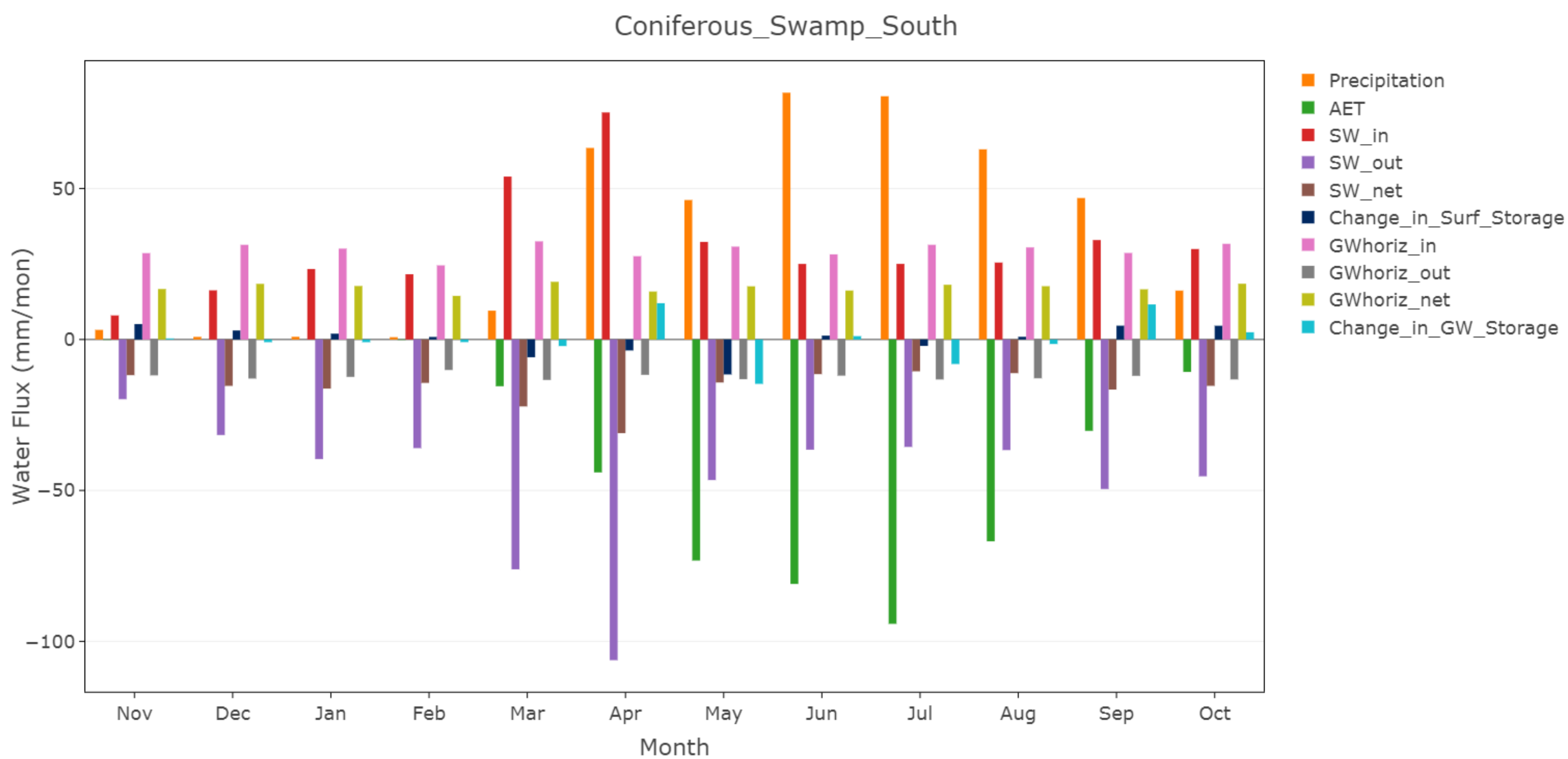

Figure 88 Mean monthly water budget components (1988-2013) for HRA 08: Coniferous Swamp - South. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

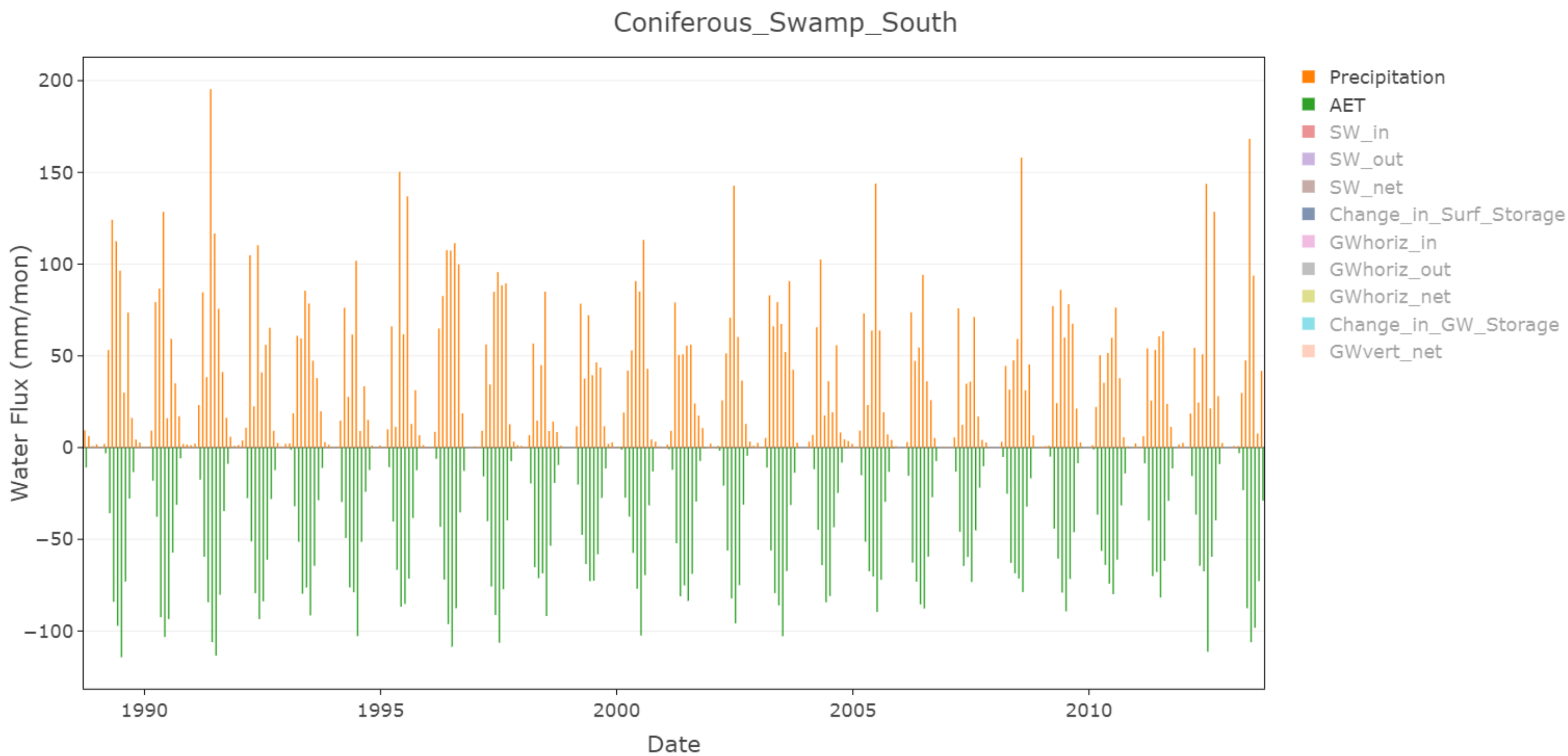

Figure 89 Predicted monthly precipitation and AET rates within HRA 08 from 1988-2013.

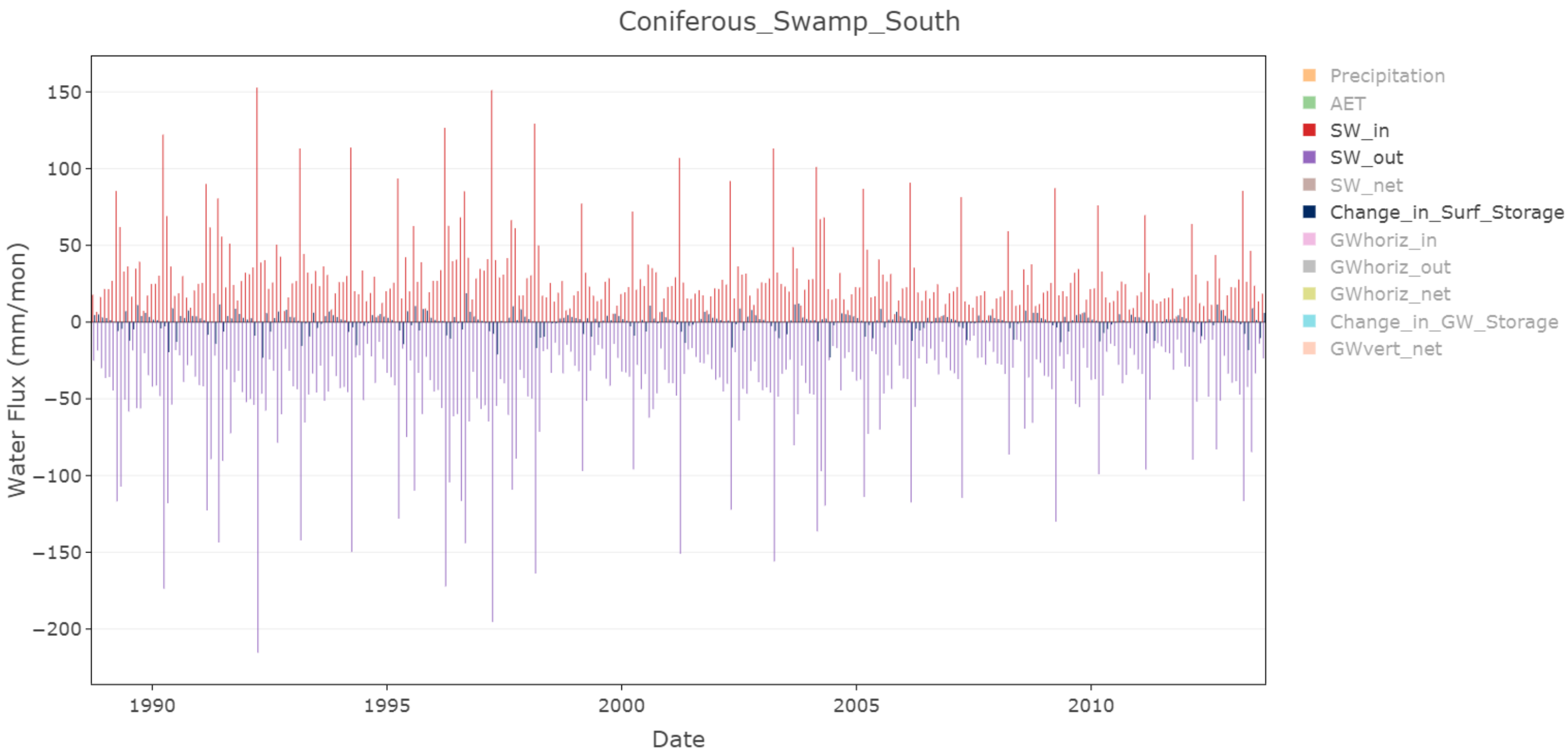

Figure 90 Predicted monthly surface water flows and storage within HRA 08 from 1988-2013.

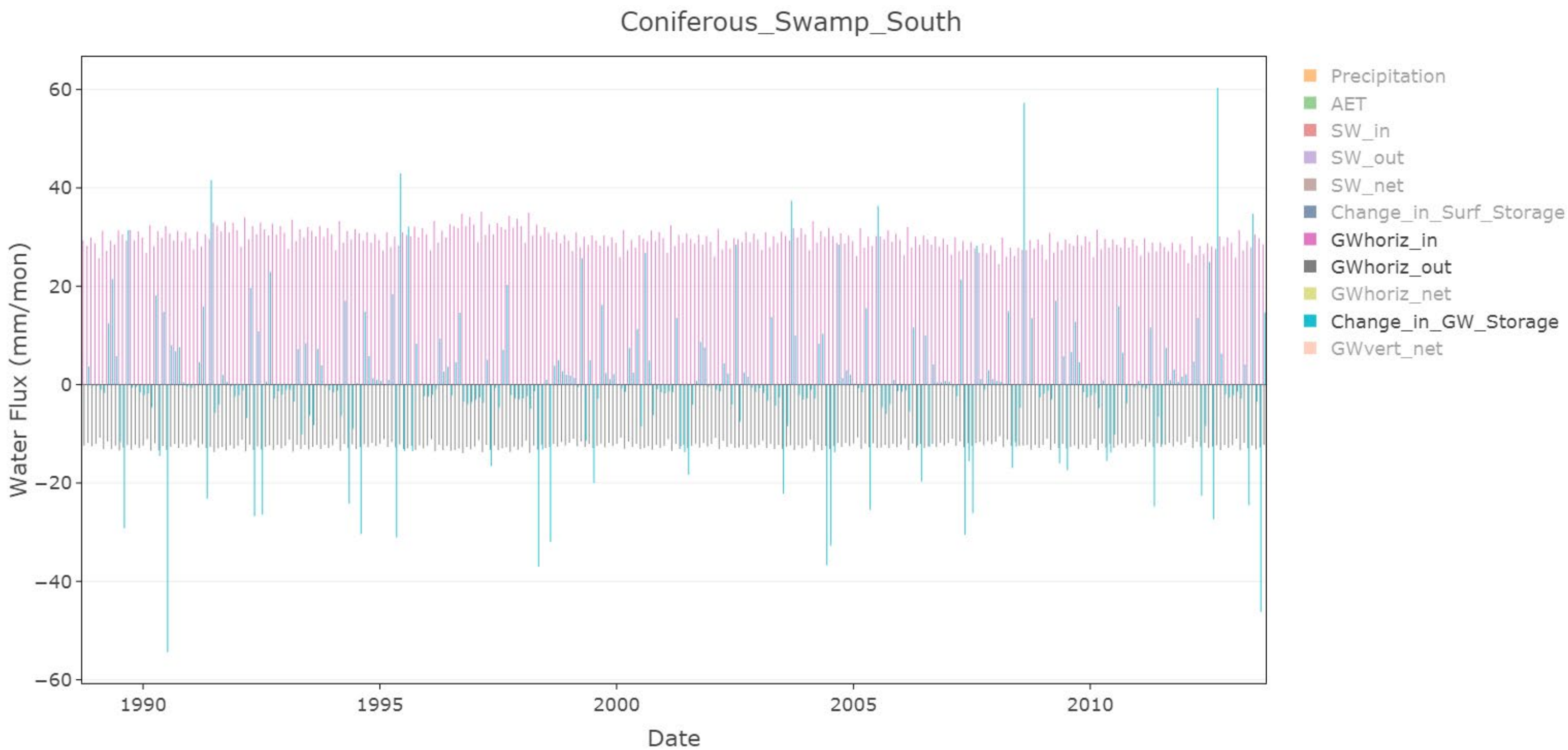

Figure 91 Predicted monthly groundwater flows and storage within HRA 08 from 1988-2013.

20. Section 1.3.9: HRA 09: McClelland Lake

HRA 09 is McClelland Lake and a cross-sections taken through this HRA is shown in Figure 92. HRA 09 covers an area of approximately 30.46 km^2 that has a mean slope of 0.35%, an aspect of 176.14 degrees azimuth and a mean elevation of 292.72 masl. The dominant land usages class present in HRA 09 is bare shallow open water (97.88%). Precipitation rates on this HRA average 422.6 mm per year, approximately 25% of which is in the form of snow (1988-2013).

Substrate depths above Clay Till 1 in HRA 09 range from 0.1 to 31.7 m (Figure 93). The substrate is composed of Surface Sands North and Silt Clay deposits. Bedrock topography in HRA 09 (Clay Till 01) ranges from 265.7 to 293.9 masl and the trends lower south to north (Figure 94). Post-development, 100% of the HRA will remain undisturbed.

HRA 09 is conceptualized to receive its water from precipitation and flows from HRA 11 (South Wetland – to McClelland Lake), HRA 15 (North Outwash Plains East), HRA 01 (Patterned Fen – South), HRA 02 (Patterned Fen – North), HRA 06 (Non-patterned Fen – North) and HRA 18 (Fort Hills East) (refer to Figure 29, Figure 31 and Figure 92). Flows from HRA 11 are a combination surface water inflows from South Creek discharge and lateral groundwater inputs. The patterned fen HRAs (01 and 02) primarily discharge surface water to the lake with proportionally smaller groundwater contributions. HRA's 06 and 10 are also conceptualized to primarily discharge surface water into the lake. The lake experiences year-round lateral groundwater inflows from nearly all sides, except the area by the outlet to McClelland Creek (east-northeastern shoreline area of the lake) where groundwater is discharging from underneath the lake towards the Firebag River.

In wintertime, the surface of the lake freezes but still continues to receive lateral groundwater inputs. Lake levels rise during the ice covered period. Lake levels continue to rise in the spring as snowmelt runs of over frozen muskeg and ultimately discharges to the lake. The hydrogeochemistry of the snowmelt entering the lake is presumed to be very dilute and non-alkaline. The remainder of the year the lake is conceptualized to receive a blend of the non-alkaline and cation-poor waters associated with the NOP surface sand deposits and also the (relatively) alkaline and cation-rich waters originating from the FHUC.

This very dilute volume of water the lake receives each spring is conceptualized as the primary reason solute concentrations stay low in the lake. It is also presumed that the fresh flush of snowmelt each spring is what prevents McClelland Lake from evapo-concentrating over time because more water exits the lake via evaporation than via discharge.

Water is conceptualized to leave HRA 09 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evaporation. Surface water discharge primarily leaves the lake via the outlet to the mouth of McClelland Creek (HRA 21) but can also leave through additional outlets during higher lake levels (Figure 31). Water can also discharge from the lake as outgoing groundwater discharge into the muskeg deposits downstream of the lake (HRA 21: Lake Outlet). ITK holders of the area have observed that discharge from the lake into McClelland Creek can be quite different year-to-year, consistent with available recorded data. ITK holders have stated within the year-to-year variation, since the 1960's, the water level has lowered:

> *"McClelland Creek, it varies, one year it will be dry and one year there's abundance of water. And years ago, there had seemed to be more water in that creek than the later years. And then when I say more water, probably I would say in the '50s, there was a lot more water, but then in the '60s, sometimes you can just walk across there with just your rubber boots. Sometimes, you've got to walk across, just about up to your neck because I've done that"* (FCM ITK holder, March 3, 2021 workshop).
>
> Water at the outflow also depended on beaver activity: "*But I guess maybe it varies again, because it depends on the beavers' _dams on the creek*," (FCM ITK holder, March 3, 2021 workshop).

ITK holders have expressed that there used to be a beaver lodge at the landing and now that beaver lodge is gone and they don't know where the beaver went.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 09 was simulated to receive 54%, 36% and 10% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 09 was simulated to discharge 76%, 22% and 2% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 09 indicates that annual AET rates (580.0 mm/yr) greatly exceed precipitation rates (413.3 mm/yr) most years (Table 8 and Figure 32); the simulated water table is at or near surface (Figure 33); the HRA is simulated to remain completely saturated (Figure 34) and the exchange of water across the lake is predicted to be negligible with active zones of exfiltration along most of the lakes near shore regions (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in the form of precipitation and leaves in the form of evaporation. Proportionally less water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 95 presents predicted average monthly water balance components over the period 1988-2013. HRA 09 is predicted to produce peak incoming flows during April and peak outgoing flows in May. This HRA adds most of its surface water storage in April, sheds storage from May to August, then begins adding to storage again the remainder of the year. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA peak in August and are at their minimum in April. Groundwater flows out of the HRA reach their peak in July and do not occur November through February. Changes to predicted groundwater storage are negligible throughout the year.

Figure 96 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 09. Peak monthly precipitation can occur April-August but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 97 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-September but usually happens in April. Peak monthly surface water out can occur April-May but usually happens in May. The largest monthly gain in surface water storage can occur anywhere between March-August but most often happens in April. The maximum monthly consumption of surface water storage can occur May-August but typically happens in May. Figure 98 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur July-October but typically peaks in October. Peak monthly outgoing groundwater rates occur March-May but usually happen in April. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest consumption of groundwater storage happens March-August but usually occurs in April.

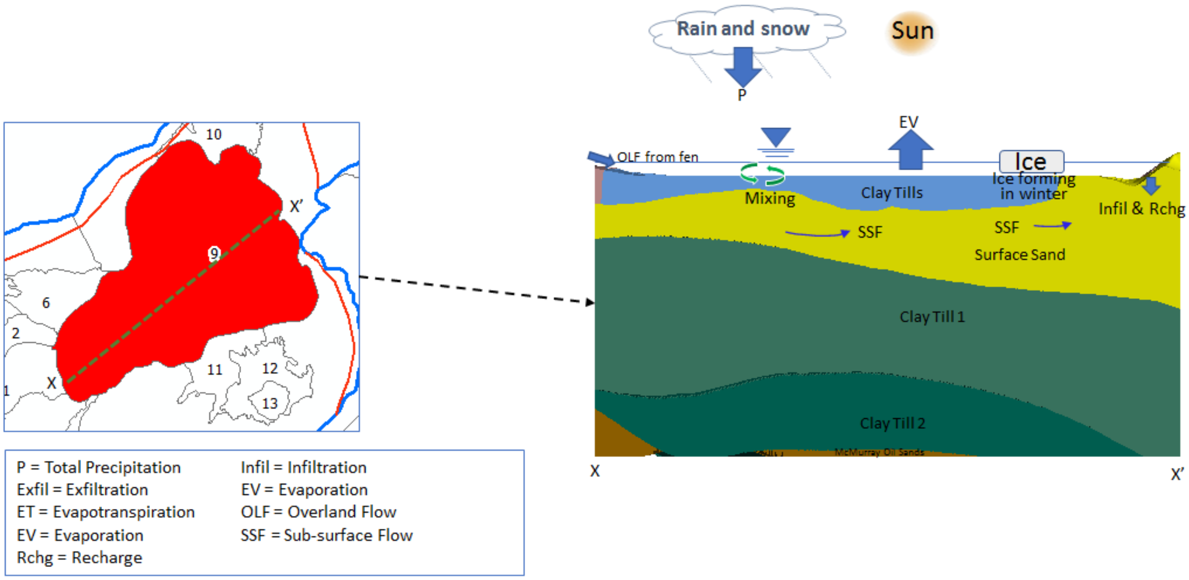

Figure 92 HRA 09: McClelland Lake. Vertical exaggeration is 80:1.

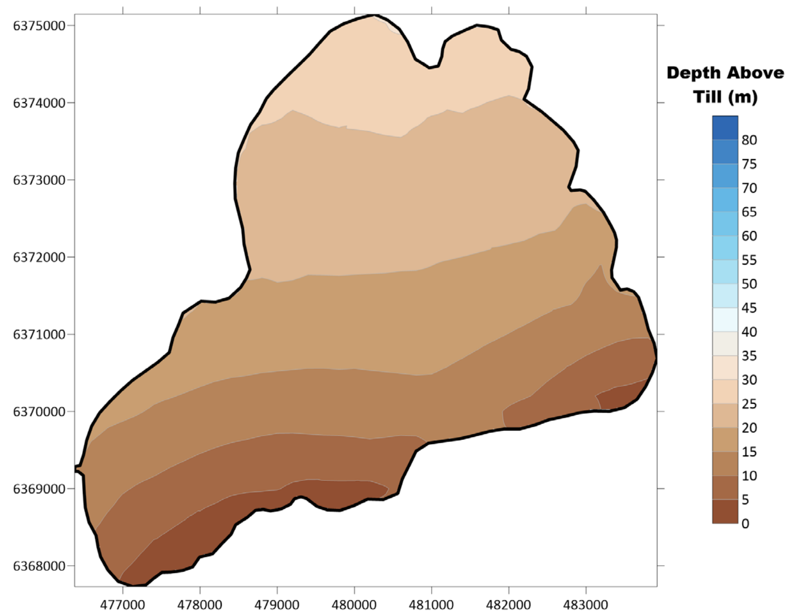

Figure 93 Substrate depths in HRA 09: McClelland Lake.

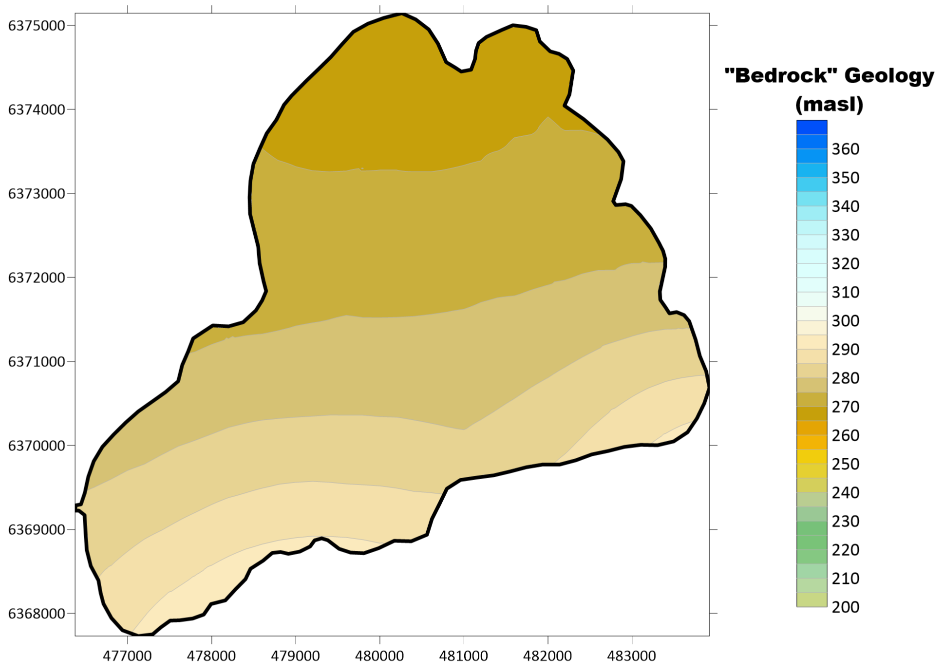

Figure 94 Bedrock topography in HRA 09: McClelland Lake.

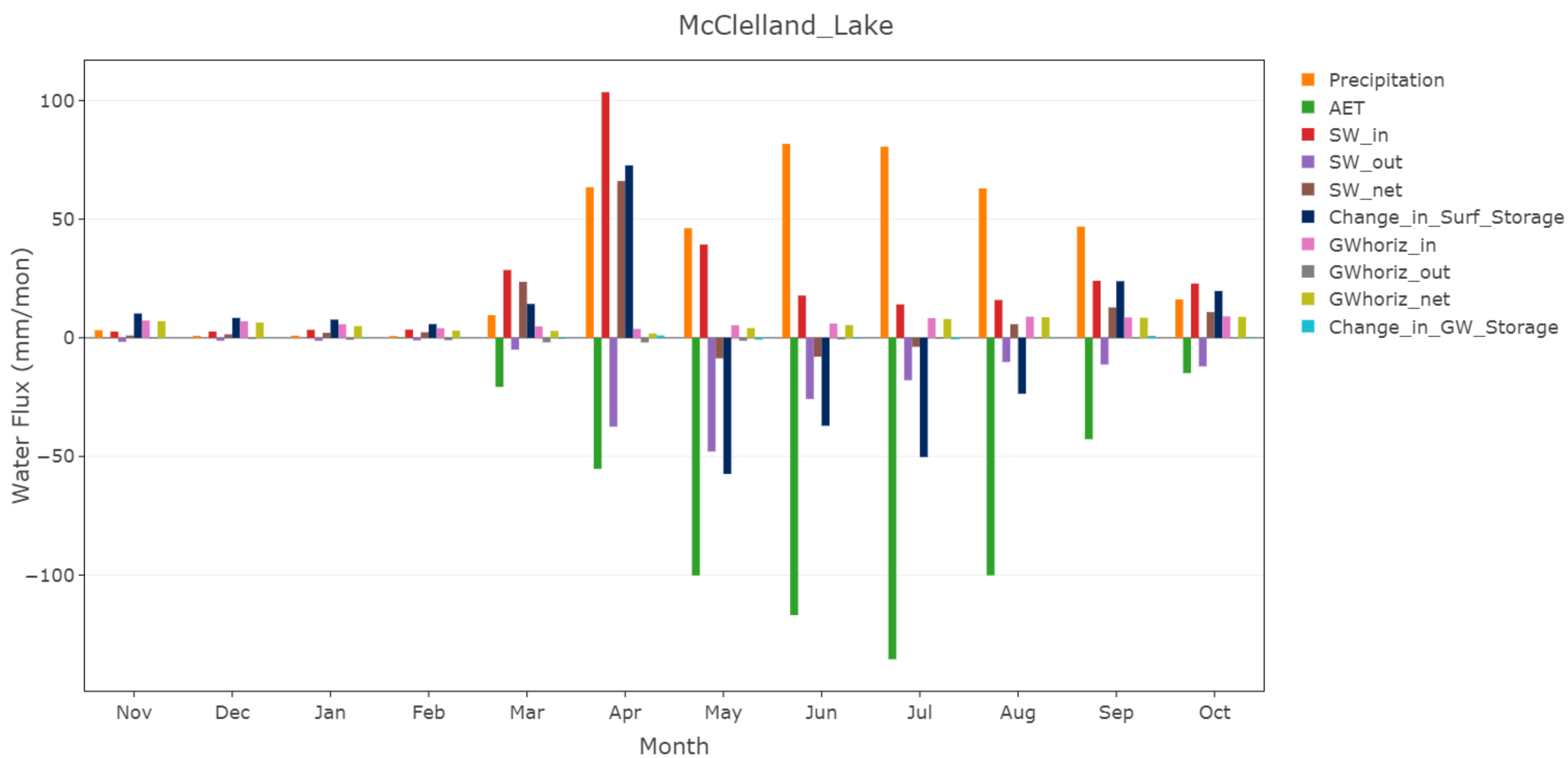

Figure 95 Mean monthly water budget components (1988-2013) for HRA 09: McClelland Lake. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

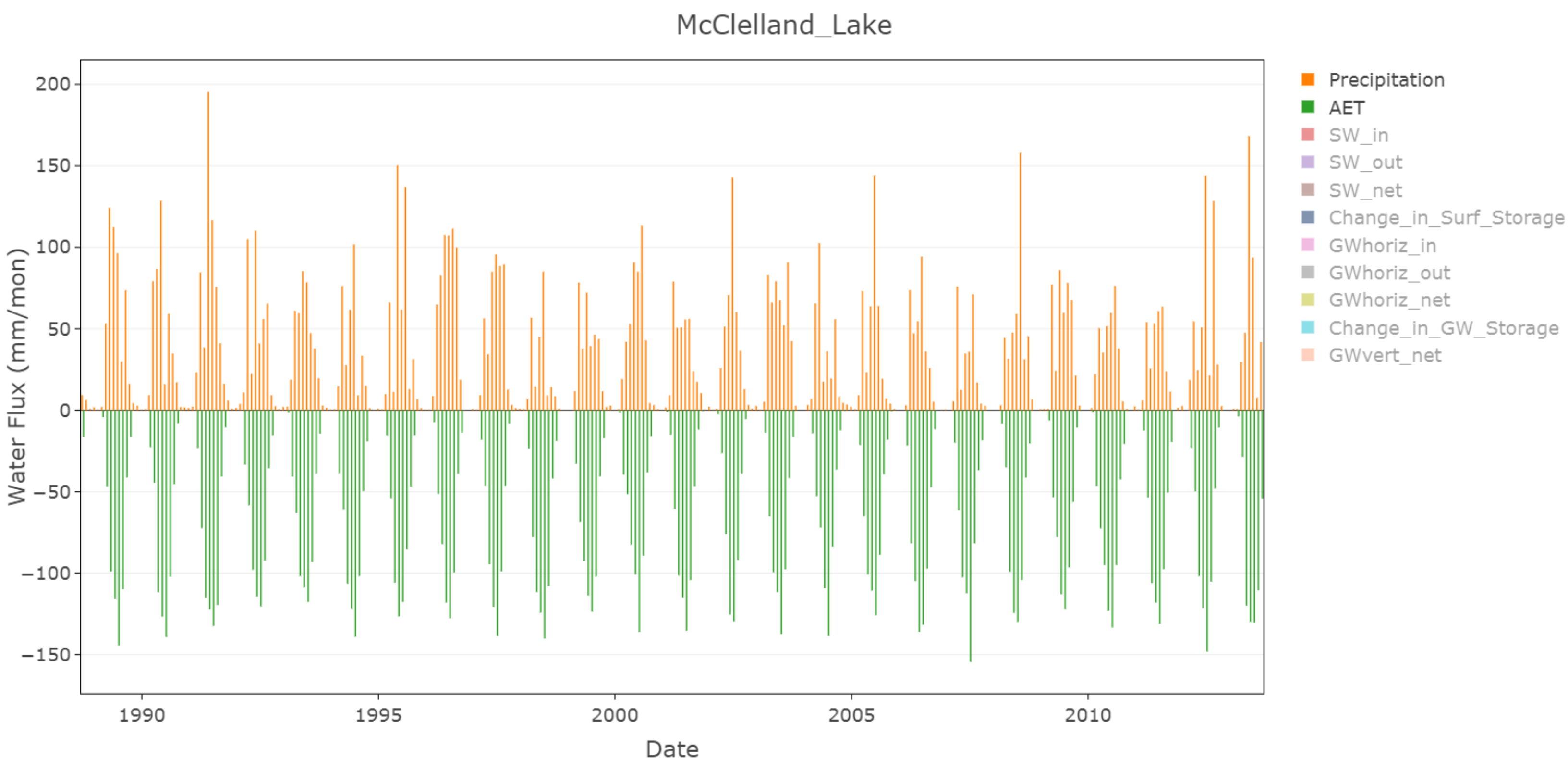

Figure 96 Predicted monthly precipitation and AET rates within HRA 09 from 1988-2013.

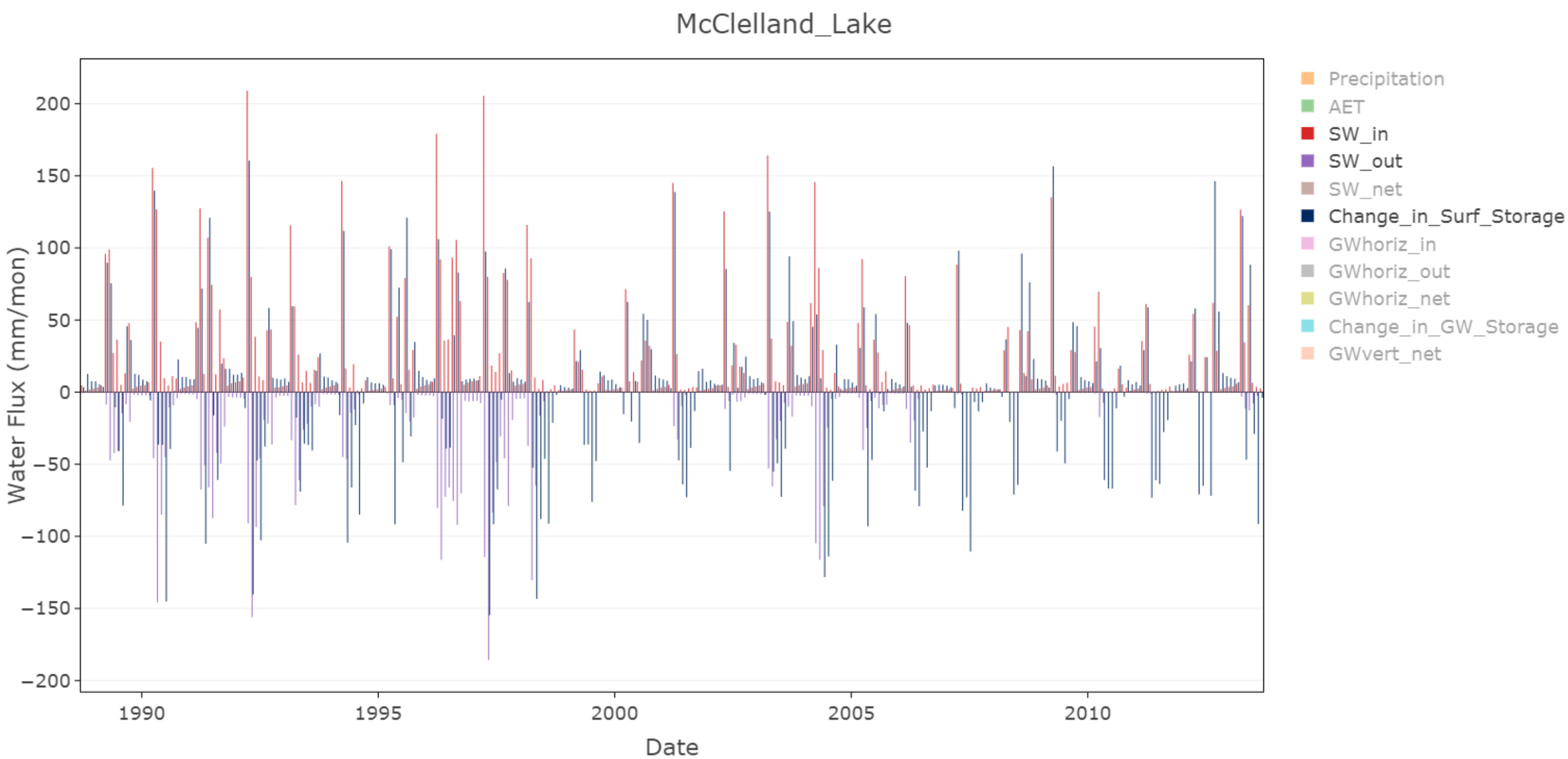

Figure 97 Predicted monthly surface water flows and storage within HRA 09 from 1988-2013.

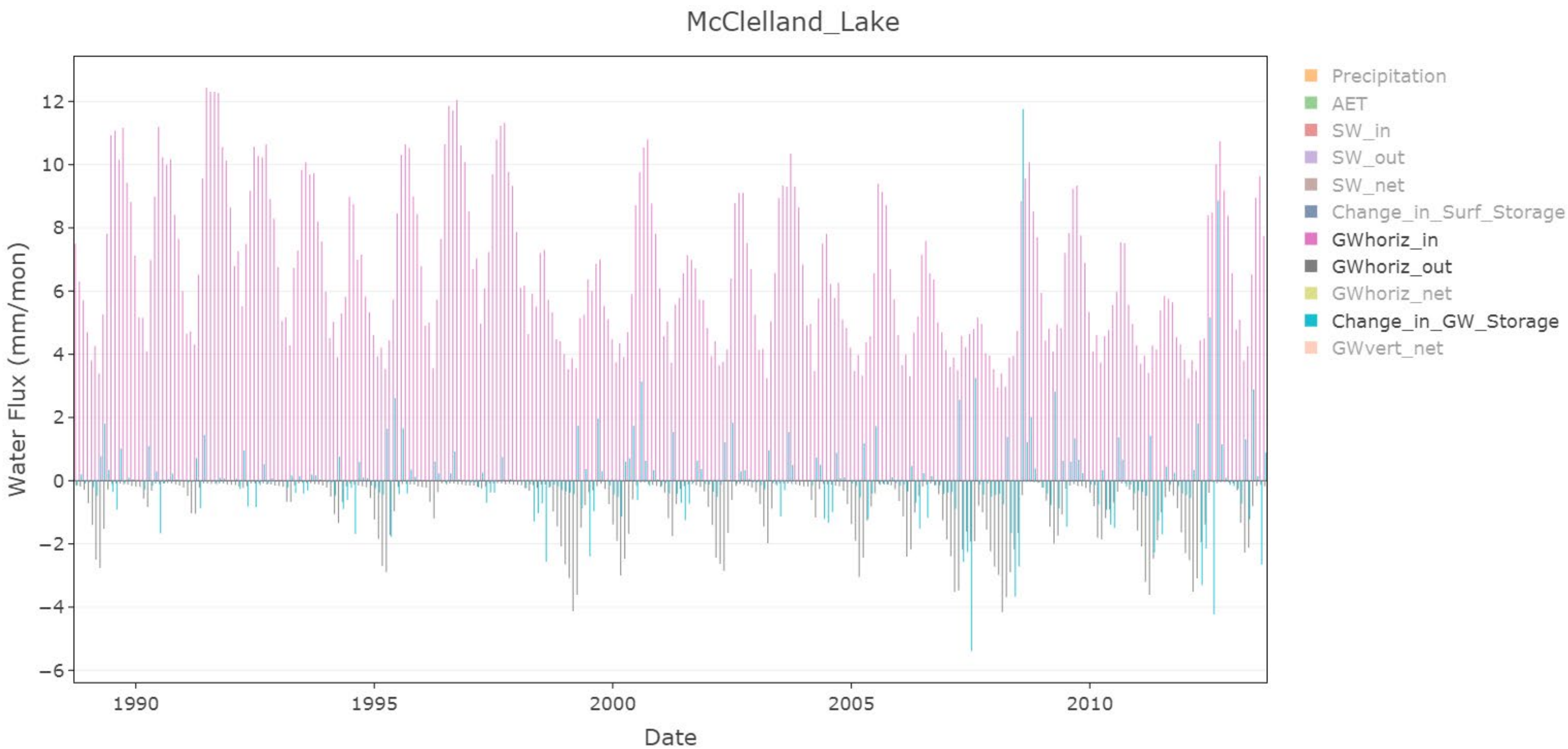

Figure 98 Predicted monthly groundwater flows and storage within HRA 09 from 1988-2013.

21. Section 1.3.10: HRA 10: North Wetland

HRA 10 is designated North Wetland and a cross-sections taken through this HRA is shown in Figure 99. HRA 10 covers an area of approximately 2.54 km^2 that has a mean slope of 0.19%, an aspect of 150.96 degrees azimuth and a mean elevation of 294.65 masl. The dominant land usages classes and forms present in HRA 10 are shrubby fen (14.76%) and graminoid fen (72.27%), respectively. The dominant soil is Mildred (90.77%) which is classified to drain rapidly. Precipitation rates on this HRA average 422.6 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a wetland containing bogs and swamps.

Substrate depths above Clay Till 1 in HRA 10 range from 26.5 to 34.6 m (Figure 100). The substrate is composed of topsoil, Surface Sands North and Muskeg. Substrate depths tend to decline west to east. Bedrock topography in HRA 10 (Clay Till 01) ranges from 264.5 to 267.9 masl and the trends slightly lower south to north (Figure 101). Post-development, 100% of the HRA will remain undisturbed.

HRA 10 is conceptualized to receive its water from precipitation and flows from HRA 15 (North Outwash Plains East) (refer to Figure 31 and Figure 99). Flows from HRA 15 are a combination incoming surface water and groundwater. The water table in HRA 10 would expected to remain at or near the land surface most times. The waters in HRA 10 originate from surface sand deposits and are conceptualized to be non-alkaline and cation-poor.

Water is conceptualized to leave HRA 10 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evaporation. Surface water and groundwater runoff from HRA 10 flows into McClelland Lake. The ground would be expected to freeze solid in the wintertime in HRA 10 and snowmelt would runoff into the lake during the freshet. The muskeg can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 10 was simulated to receive 55%, 18% and 27% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 10 was simulated to discharge 46%, 19% and 36% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8. The simulated average long-term behavior of HRA 10 indicates that annual AET rates (335.2 mm/yr) are much lower than precipitation rates (413.3 mm/yr) most years (Table 8 and Figure 32); the simulated water table is at or near surface (Figure 33); the HRA is simulated to remain nearly saturated most times (Figure 34) and the exchange of water across the land surface is primarily near neutral with a zone of exfiltration on the HRA's east side (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in the form of precipitation and leaves in the form of evaporation. Proportionally about the same volume exits the HRA in the form of surface water than enters it annually. Proportionally more water exits the HRA in the form of groundwater than enters it annually.

Figure 102 presents predicted average monthly water balance components over the period 1988-2013. HRA 10 is predicted to produce peak incoming flows during April and peak outgoing flows in July. Nearly all of the surface water entering this HRA does so during April and May with muted incoming surface water the remainder of the year. This HRA adds most of its surface water storage in April, sheds storage from May to August, then begins adding to storage again from September to December and then shedding again January to March. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into the HRA peak in August to October and reach their minimum in February. Groundwater flows out of the HRA reach their peak in April and their minimum in October. The HRA adds to groundwater storage April (the peak) to September and consumes groundwater storage October to March (peak consumption).

Figure 103 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 10. Peak monthly precipitation occurs April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occur in July. Figure 104 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-May but usually happens in April. Peak monthly surface water out can occur May-October but usually happens in July. The largest monthly gain in surface water storage can occur May-September but most often happens in April. The maximum monthly consumption of surface water storage can occur May-August but typically happens in April. Figure 105 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in October. Peak monthly groundwater discharge rates occur March-June but usually happen in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage happens February-July but usually occurs in March.

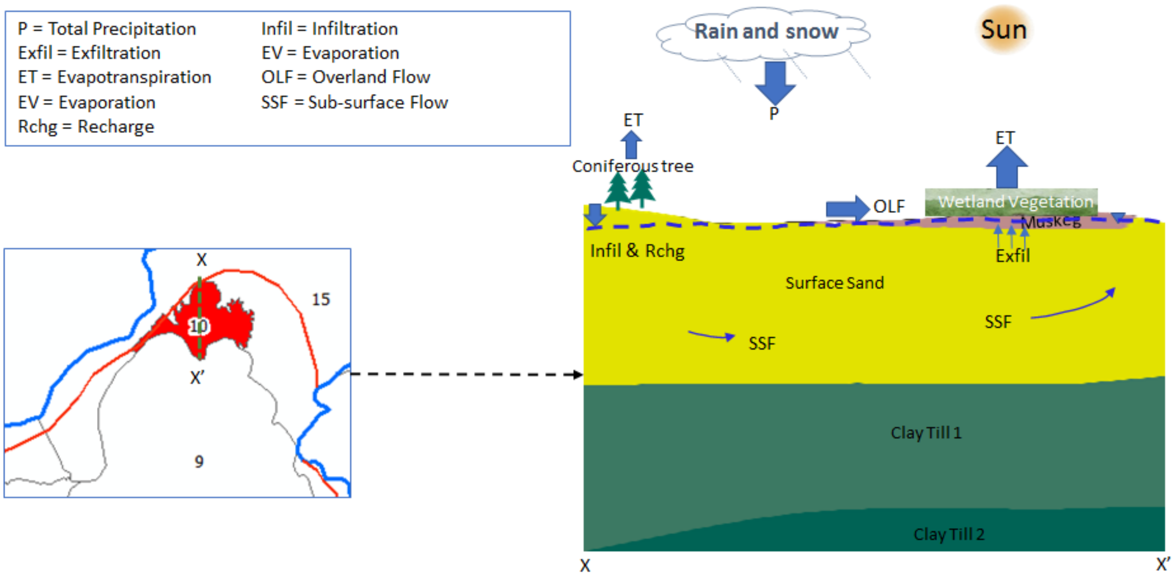

Figure 99 HRA 10: North Wetland. Vertical exaggeration is 80:1.

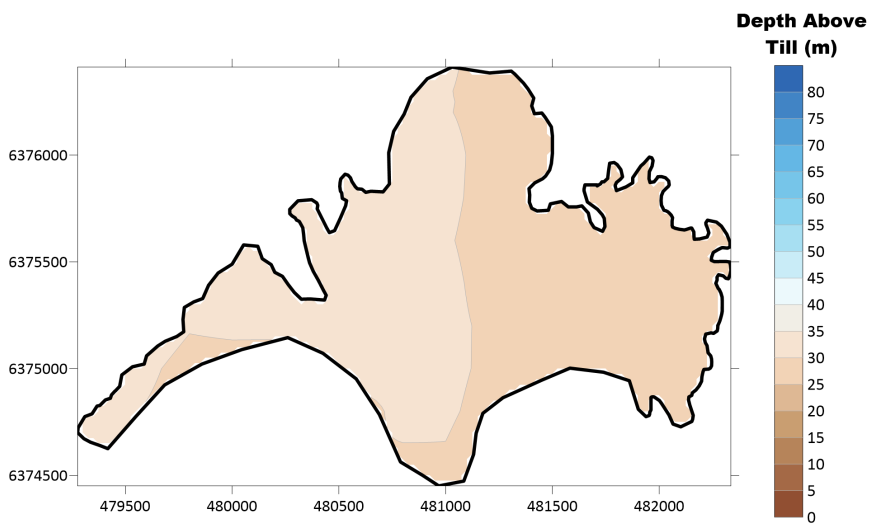

Figure 100 Substrate depths in HRA 10: North Wetland.

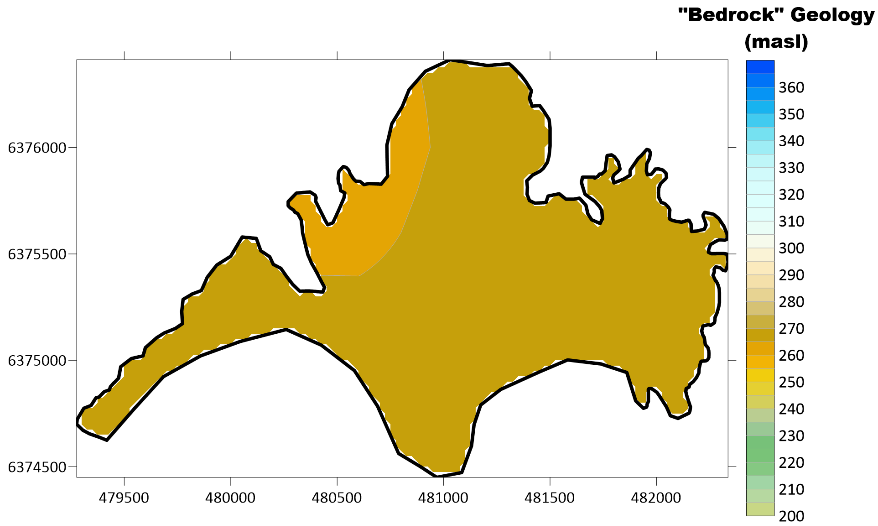

Figure 101 Bedrock topography in HRA 10: North Wetland.

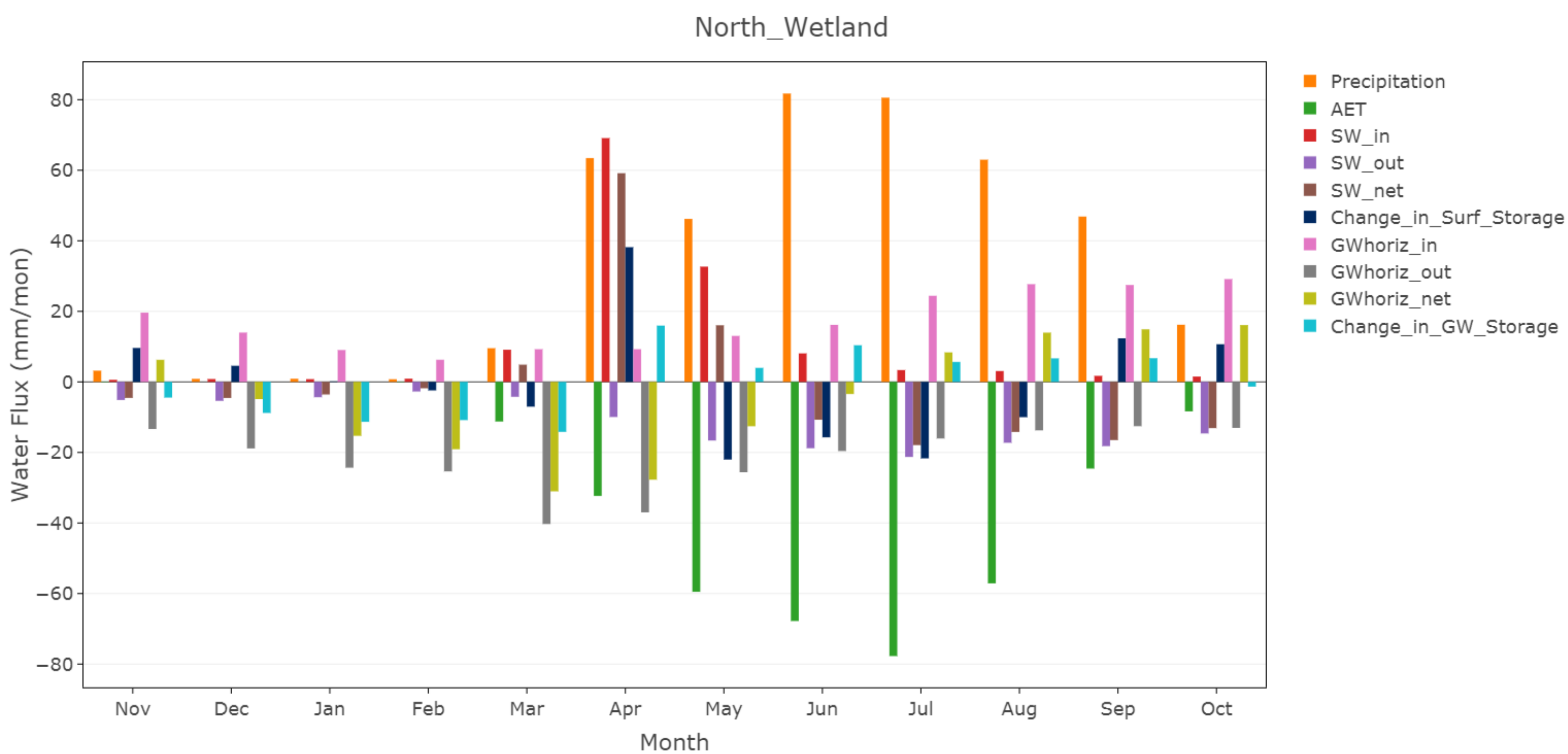

Figure 102 Mean monthly water budget components (1988-2013) for HRA 10: North Wetland. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

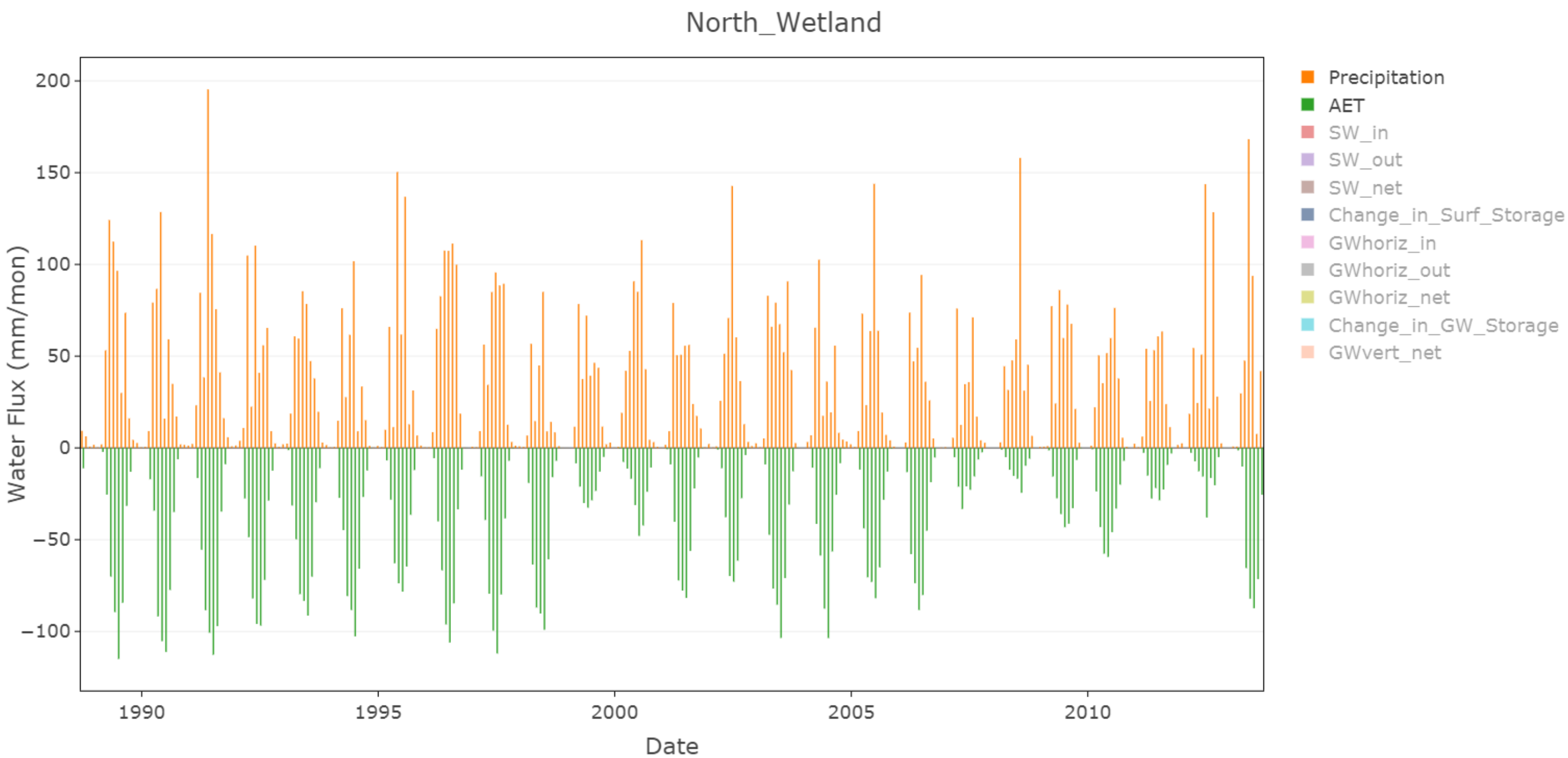

Figure 103 Predicted monthly precipitation and AET rates within HRA 10 from 1988-2013.

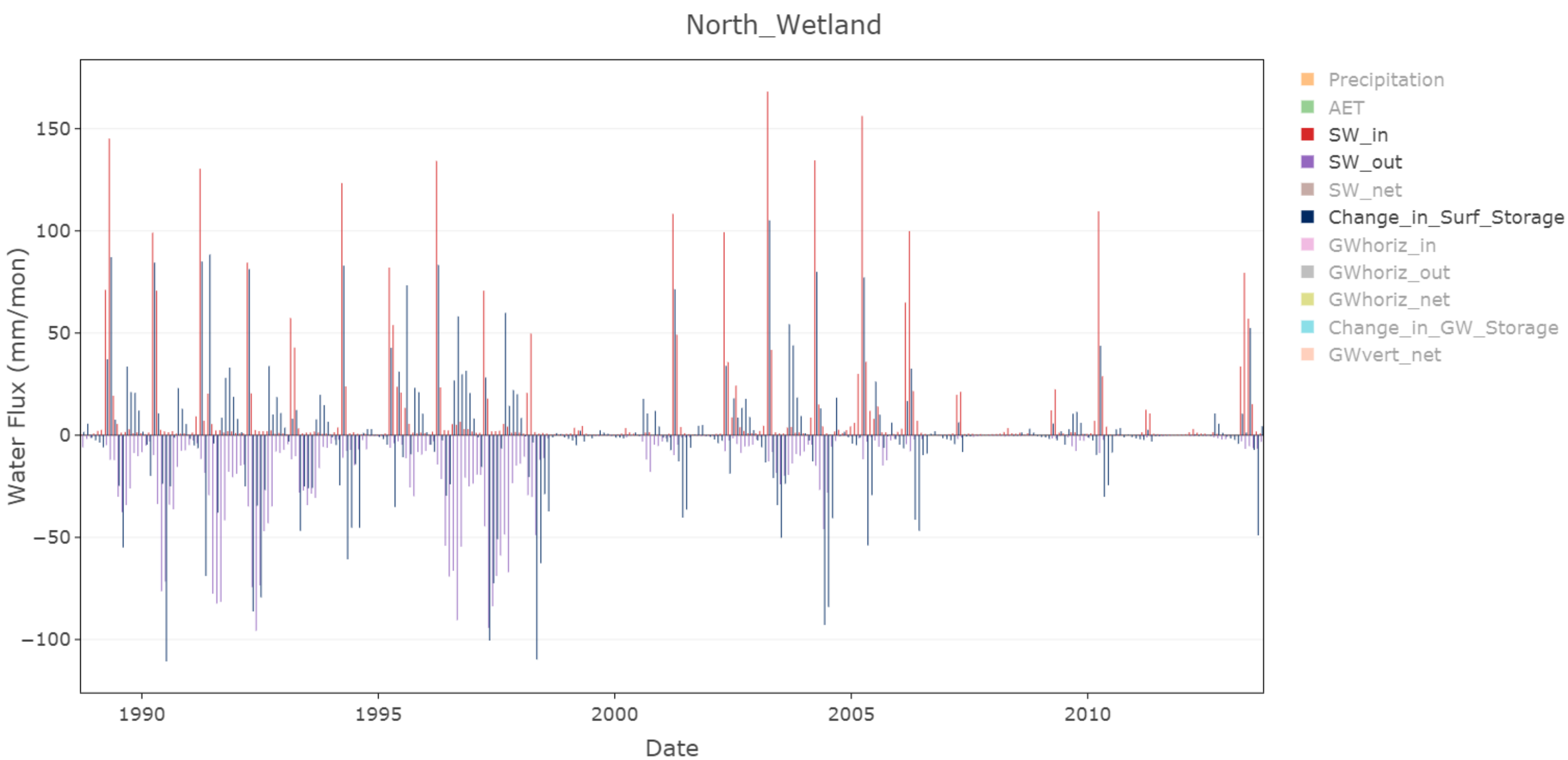

Figure 104 Predicted monthly surface water flows and storage within HRA 10 from 1988-2013.

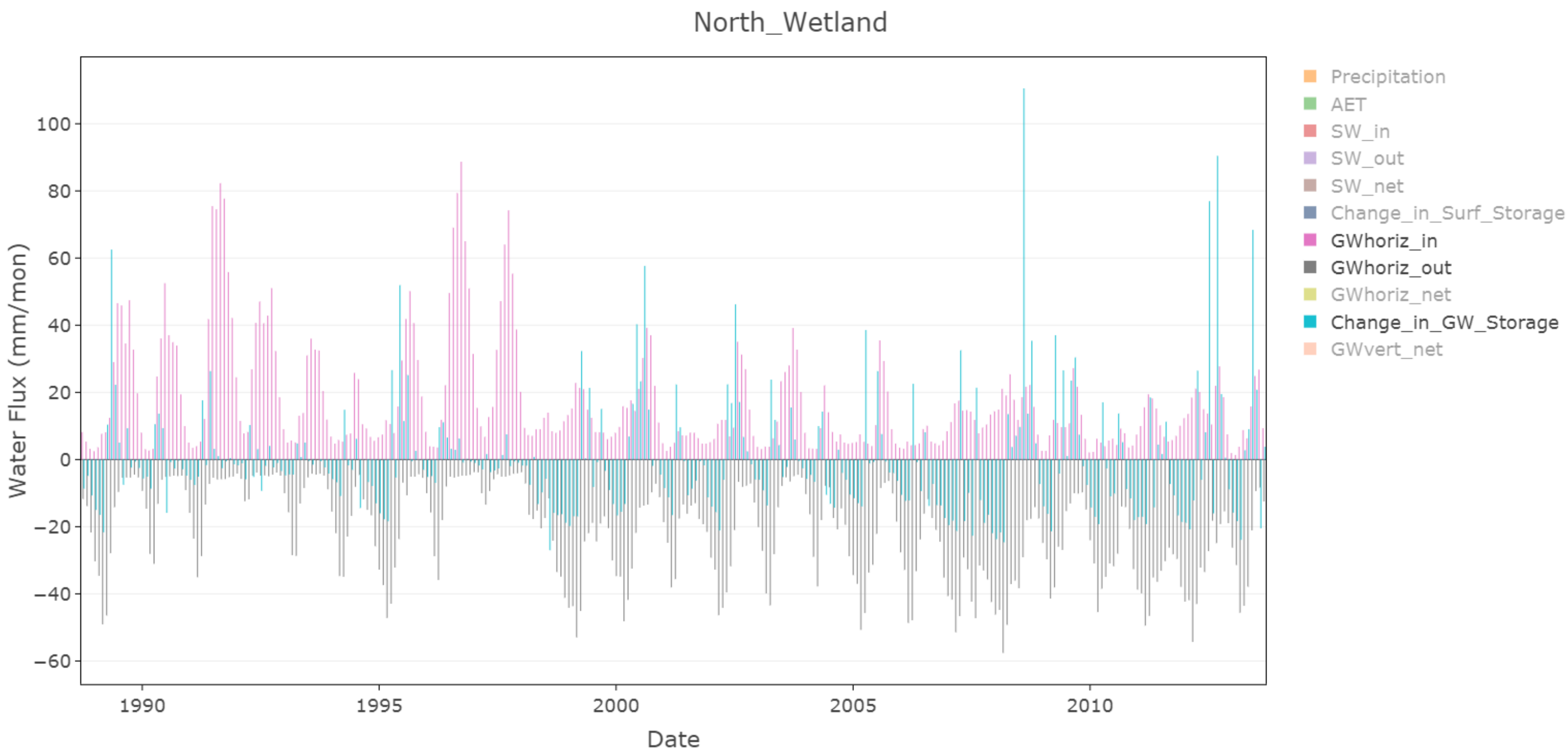

Figure 105 Predicted monthly groundwater flows and storage within HRA 10 from 1988-2013.

22. Section 1.3.11: HRA 11: South Wetland – to McClelland Lake

HRA 11 is designated South Wetland – to McClelland Lake and a cross-sections taken through this HRA is shown in Figure 106. HRA 11 covers an area of approximately 2.55 km^2 that has a mean slope of 0.74%, an aspect of 171.78 degrees azimuth and a mean elevation of 295.74 masl. The dominant land usages classes and forms present in HRA 11 are wooded coniferous fen (51.11%) and shrubby fen (16.26%), respectively. The dominant soil is McClelland which is classified to drain very poorly. Precipitation rates on this HRA average 422.5 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a wetland containing a swamp delta and Larix woodland.

Substrate depths in HRA 11 range from 0.0 to 11.1 m (Figure 107). The substrate is composed of topsoil, Surface Sands North, Surface Sands South, Silt Clay and Muskeg deposits. Substrate depths tend to increase south to north. ITK holders of the area have observed that the muskeg deposits overlying clay in this area can be treacherous to traverse by foot (FMFN ITK holder, March 3, 2021 workshop and FMMN 2017). Bedrock topography in HRA 11 (Clay Till 01) ranges from 283.7 to 300.1 masl and trends lower south to north (Figure 108). Post-development, 100% of the HRA will remain undisturbed.

> *"the wetness, like ... It's all the way on that side, it's all the way like, it's a hanging muskeg all the way to the lake.... You know where the nesting area is on that lake. Where we had our cabin. Off our cabin, about half a mile where the herons live, they nest there... around here (NW part of lake and then straight across from my dad's cabin.) where the nesting area is, up that way... that's where all that clay, that hanging clay, everything, it's all up through there. And in the south part too. Because we used to get lickings for going on down, so I always remember that hanging clay. Back then I thought I was always getting a licking for nothing, but it wasn't for nothing because it's dangerous to go in there."* (FMFN ITK holder, FMMN 2017)

> *"[the area south/east of McClelland Lake, including Baby Lake] my dad, my mom, they would never let us walk alone, we had to carry a stick, because of all the hanging muskeg in there. It hangs - about 4 feet of ground, then straight water underneath. then it was that thick clay. .... but there's lots of other places like that.... My grandfather used to say, if we sunk in that muskeg, we weren't coming back up, which I think it's true. Because when I went fire fighting after I grew up, you can see after where the muskeg gets burned, that its deep. Because ,we were on fire watch we had to put out smoldering ashes and stuff. Yeah. And there it was, you could see that*

in some places, it [muskeg] was like about eight feet deep... Well, I guess there is some danger in not listening to your mum and dad anyways” (FMFN ITK holder, March 3, 2021 workshop)

“We would have to wait until freeze up to go around the back of those lakes. You would need an Argo otherwise. Glen had told me about the water levels being low or high certain years.” (FMMN ITK holder, March 3, 2021 workshop)

With respect to muskeg deposits, ITK has provided understanding of how water moves through the wetland complex and the relationship between the wetland and hanging muskeg:

“It's a muskeg, but under that muskeg, the muskeg goes on clayish type layer, but under it there's water. The water travels all under there... traveling under and through the muskeg. And it's very dangerous to walk through. If you fall in, nobody ain't never going to find you, you're gone. So it's a very dangerous game to play, to go out there.... It's floating but it's connected. It's connected with all the rest of the pieces around the fen, but it's still got water under it. Remember where my mom's cabin was? Okay, my mom's cabin... If you stayed on the left side of the road going down there, you're fine. But if you went to the right side, the right side is where the hanging muskeg starts. If you were to get stuck there, you dig yourself out about four feet and then you hit straight water. And it's like that all over (FMFN ITK holder, September 13, 2021 AAG meeting).

HRA 11 is conceptualized to receive its water from precipitation and flows from HRA 18 (Fort Hills East) and HRA 12 (South Wetland – to Unnamed Lake) (refer to Figure 29, Figure 31 and Figure 106). Flows from HRA 18 are incoming surface water flows from South Creek, which discharges into the western side of HRA 11 (Figure 31). Flows from HRA 12 are a combination incoming surface water and groundwater. Patterning in the vegetation is present in HRA 11 and the orientation of the strings indicates a component of surface water flow from Unnamed Lake to McClelland Lake. The water table in HRA 11 would expected to remain at or near the land surface most times. The ground in this HRA would be expected to freeze solid in the winter and generate snowmelt runoff discharging into McClelland Lake in the spring. The muskeg can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains. HRA 11 receives runoff originating from the FHUC and its hydrogeochemistry is conceptualized to be (relatively) alkaline and cation-rich.

Water is conceptualized to leave HRA 11 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, evapotranspiration and outgoing surface water. All discharge from HRA 11 reports to McClelland Lake.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 11 was simulated to receive 26%, 68% and 6% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 11 was simulated to discharge 27%, 70% and 3% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 11 indicates that annual AET rates (420.5 mm/yr) are approximately equal to precipitation rates (422.6 mm/yr) most years (Table 8 and Figure 32); the simulated water table is at or near surface most times (Figure 33); the HRA is simulated to remain nearly saturated most times (Figure 34) and the exchange of water across the land surface is primarily near neutral with a zone of exfiltration on the HRA's west side and infiltration zones were substrate depths increase (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally slightly more volume exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 109 presents predicted average monthly water balance components over the period 1988-2013. HRA 11 is predicted to produce peak incoming and outgoing flows during April. This HRA adds to surface water storage September to March (peak rate in February) and consumes it April to August (May is peak consumption). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year-round. The HRA adds to groundwater storage April (the peak), June and September to November. The HRA consumes groundwater storage in May (peak consumption), July and December to March.

Figure 110 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 11. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occur in July. Figure 111 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-May but usually happens in April. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur anywhere between February-October but most often happens in January. The maximum monthly consumption of surface water storage can occur March-July but typically happens in May. Figure 112 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in July. Peak monthly outgoing groundwater rates occur March-October but usually happen in October. The largest monthly gain in groundwater storage can happen April-September but usually occurs in September. The largest monthly consumption of groundwater storage happens May-November but usually occurs in May.

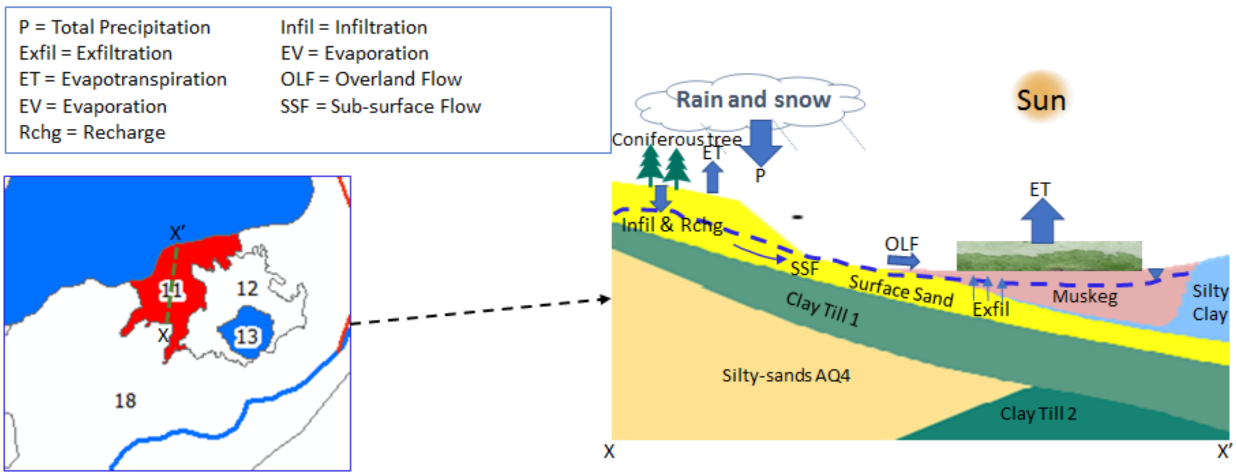

Figure 106 HRA 11: South Wetland – to McClelland Lake. Vertical exaggeration is 80:1.

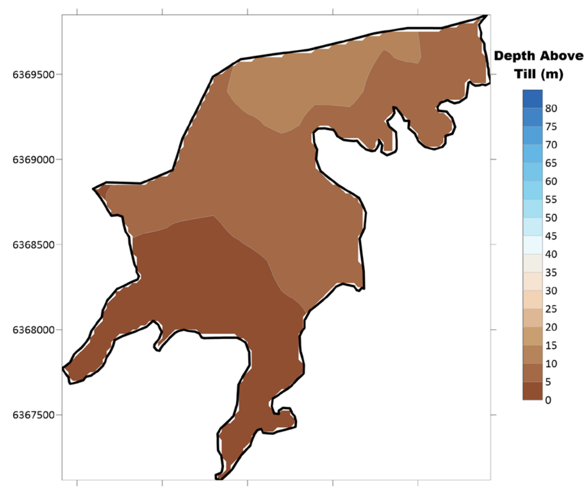

Figure 107 Substrate depths in HRA 11: South Wetland.

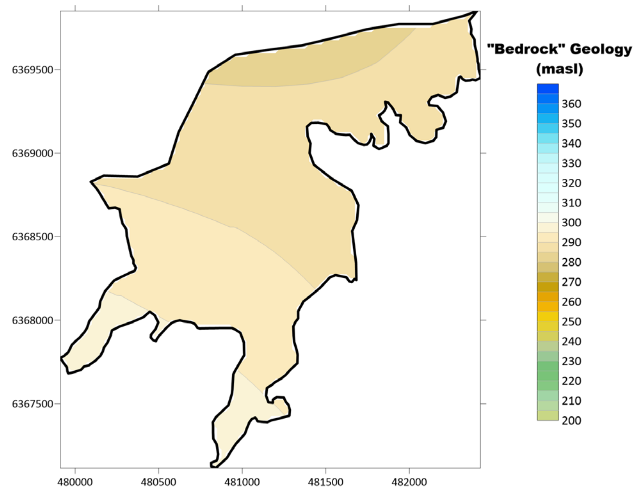

Figure 108 Bedrock topography in HRA 11: South Wetland.

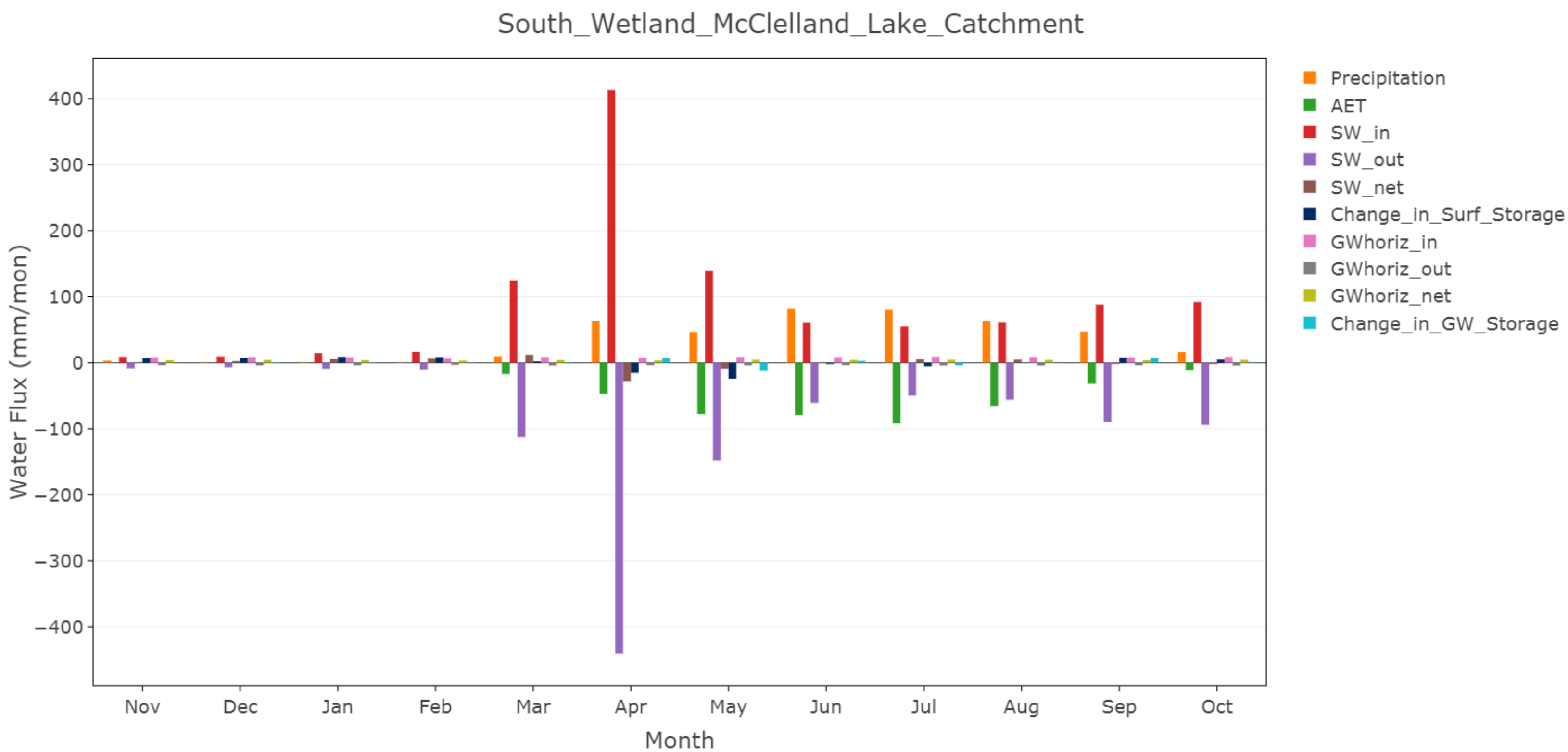

Figure 109 Mean monthly water budget components (1988-2013) for HRA 11: South Wetland. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

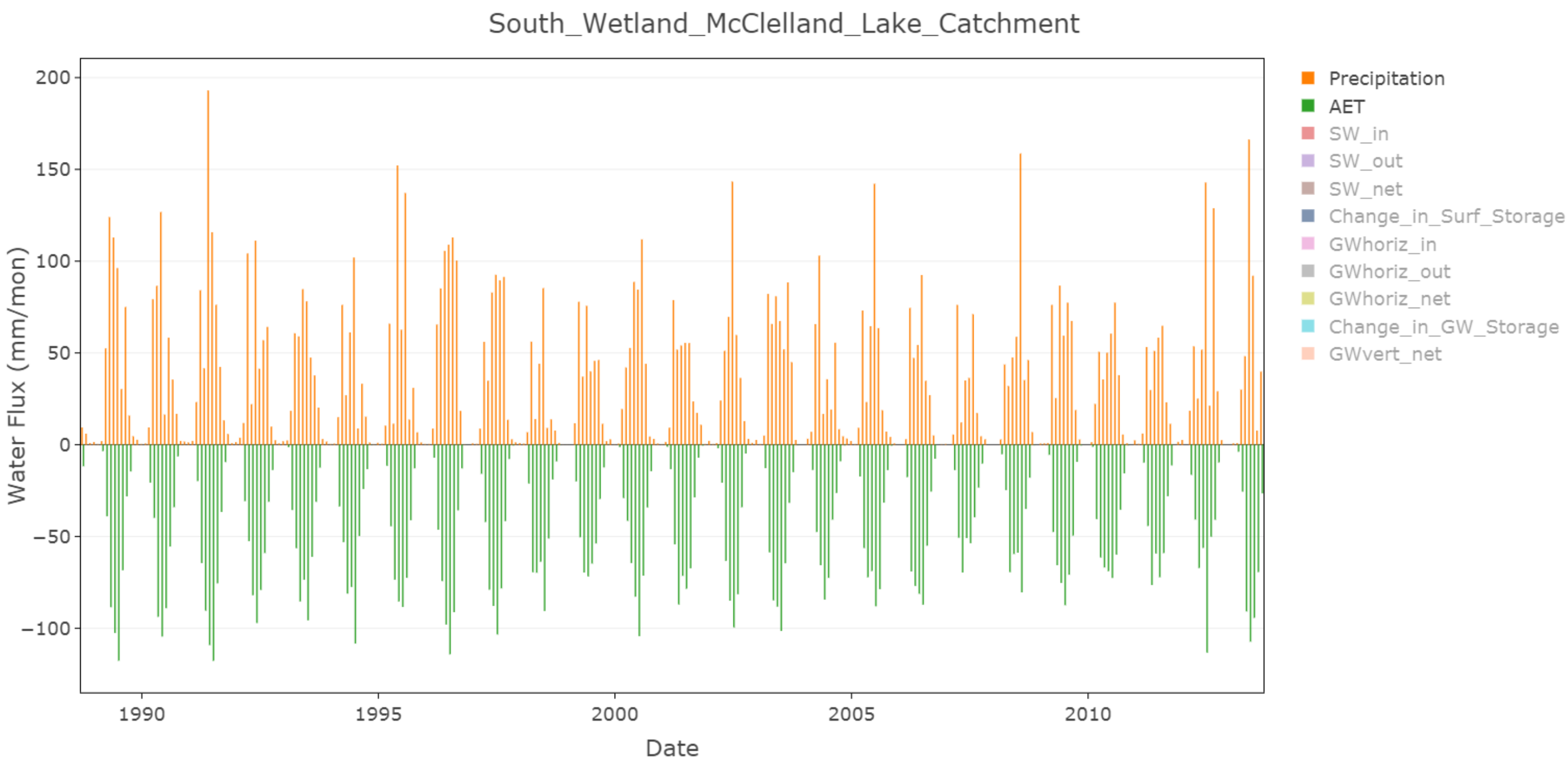

Figure 110 Predicted monthly precipitation and AET rates within HRA 11 from 1988-2013.

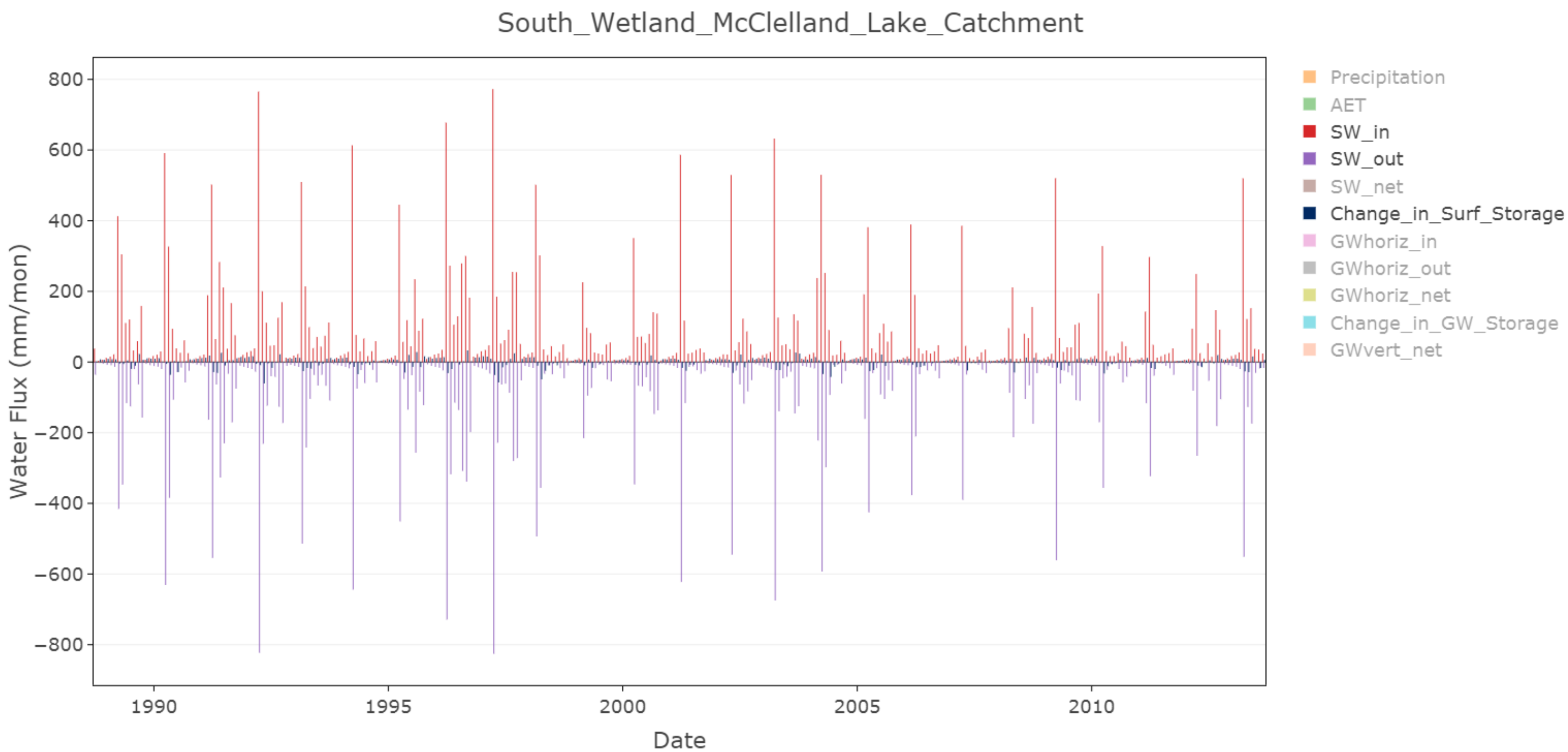

Figure 111 Predicted monthly surface water flows and storage within HRA 11 from 1988-2013.

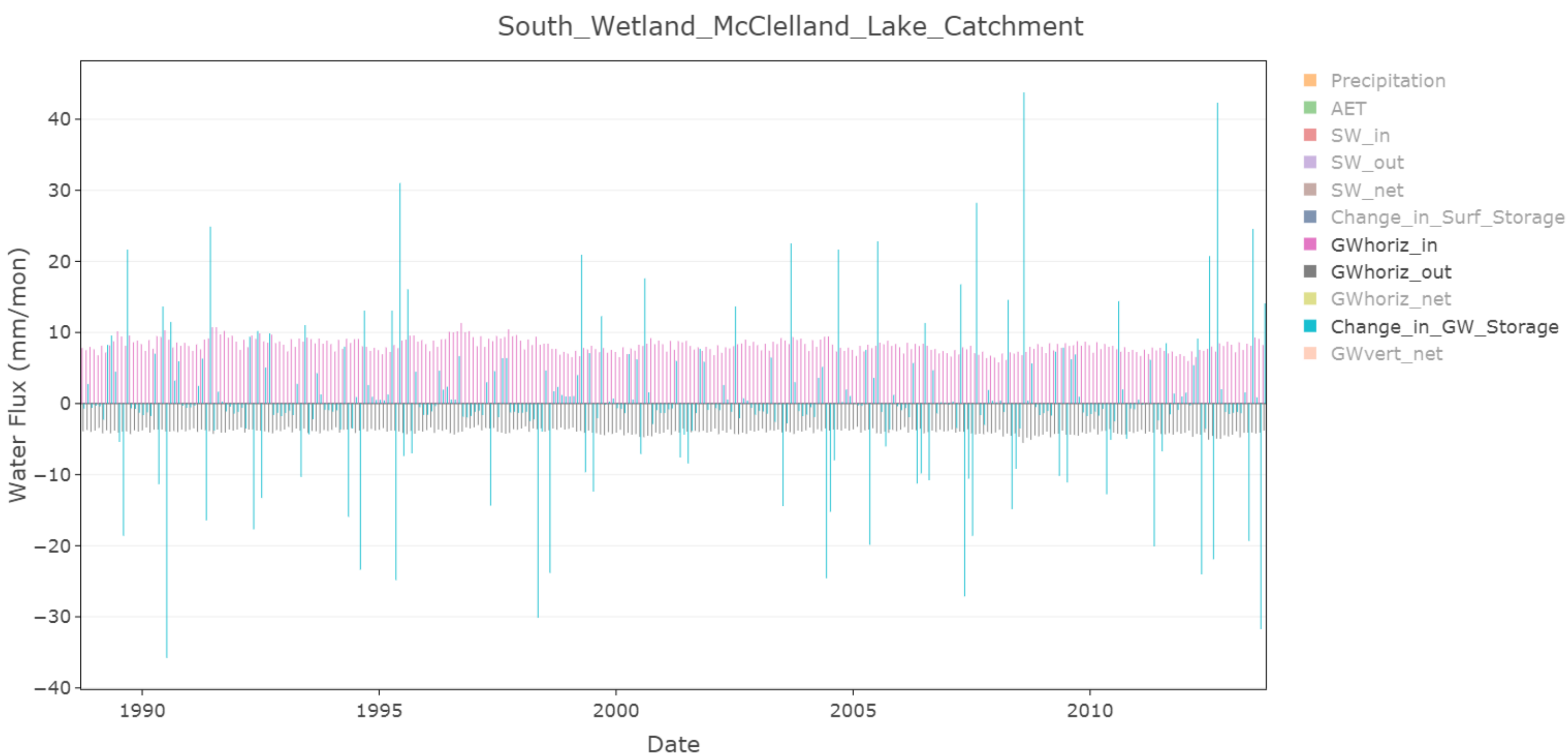

Figure 112 Predicted monthly groundwater flows and storage within HRA 11 from 1988-2013.

23. Section 1.3.12: HRA 12: South Wetland – to Unnamed Lake

HRA 12 is designated South Wetland – to Unnamed Lake and a cross-section taken through this HRA is shown in Figure 113. HRA 12 covers an area of approximately 2.93 km^2 that has a mean slope of 0.48%, an aspect of 190.83 degrees azimuth and a mean elevation of 295.73 masl. The dominant land usages classes and forms present in HRA 12 are wooded coniferous fen (13.12%) and shrubby fen (47.18%), respectively. The dominant soil is McClelland (90.47%) which is classified to drain very poorly. Precipitation rates on this HRA average 422.5 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as a wetland with bog-permafrost and Larix woodland.

Substrate depths in HRA 12 range from 1.0 to 9.4 m (Figure 114). The substrate is composed of topsoil, Surface Sands North, Surface Sands South, Silt Clay and Muskeg deposits. Substrate depths tend to increase south to north. Bedrock topography in HRA 12 (Clay Till 01 is a proxy for bedrock in this HRA) ranges from 286.1 to 294.9 masl and exhibits higher elevations on its western and eastern margins than elevations in the middle of the HRA (Figure 115). Post-development, 100% of the HRA will remain undisturbed.

HRA 12 is conceptualized to receive its water from precipitation and flows from HRA 18 (Fort Hills East) and HRA 13 (refer to Figure 29, Figure 31 and Figure 113). Flows from HRA 18 are primarily groundwater and surface water drainage from the permeable surface sand deposits on the FHUC slopes to the southeast (Figure 29). HRA 13 contributes groundwater water flows into HRA 12 along its northern shoreline. HRA 12 receives runoff originating from the FHUC and the hydrogeochemistry is conceptualized to be (relatively) alkaline and cation-rich.

Water is conceptualized to leave HRA 12 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, evapotranspiration and outgoing surface water. Flow from HRA 12 essentially drains into Unnamed Lake and there is some light patterning in the vegetation in this area indicating flow direction into the lake. Figure 3.2 in Vitt and House (2020) shows mapped elevations and drainage divides for this HRA which indicate the HRA primarily drains inward with no obvious flows into HRA 11. The ground in HRA 12 would be expected to freeze solid in the winter where muskeg is present and the water table is near surface and alternatively freeze honeycomb and permeable along its southern and northern margins where the substrates are composed of surface sands and the water table is deeper. The muskeg can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains. Snowmelt over frozen muskeg during the freshet would be expected to primarily runoff into Unnamed Lake.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 12 was simulated to receive 44%, 28% and 28% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 12 was simulated to discharge 42%, 52% and 6% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 12 indicates that annual AET rates (372.9 mm/yr) are much less than precipitation rates (413.3 mm/yr) most years (Table 8 and Figure 32); the simulated water table is at or near surface most times where muskeg is present (Figure 33); the HRA is simulated to remain nearly saturated in the muskeg and variably-saturated in the thicker surface sand deposits (Figure 34) and the exchange of water across the land surface is primarily near neutral in the interior of the HRA with zones of exfiltration along its southern and eastern margins (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in the form of precipitation and leaves in the form of surface water. Proportionally more volume exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 116 presents predicted average monthly water balance components over the period 1988-2013. HRA 12 is predicted to produce peak incoming and outgoing flows during April. This HRA adds to surface water storage August to February (November peak) and sheds storage March to May (April peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round reaching its peak in August and its minimum in February; outflows exhibit a similar pattern. The HRA adds to groundwater storage April (the peak) and August through October. The HRA consumes groundwater storage in May (peak consumption), July and November to March.

Figure 117 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 12. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen May-August but usually occur in July. Figure 118 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-October but usually happens in April. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur February-December but most often happens in November. The maximum monthly consumption of surface water storage can occur March-May but typically happens in April. Figure 119 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in October. Peak monthly outgoing groundwater rates occur March-October but usually happen in October. The largest monthly gain in groundwater storage can happen April-October but usually occurs in September. The largest monthly consumption of groundwater storage happens May-October but usually occurs in May.

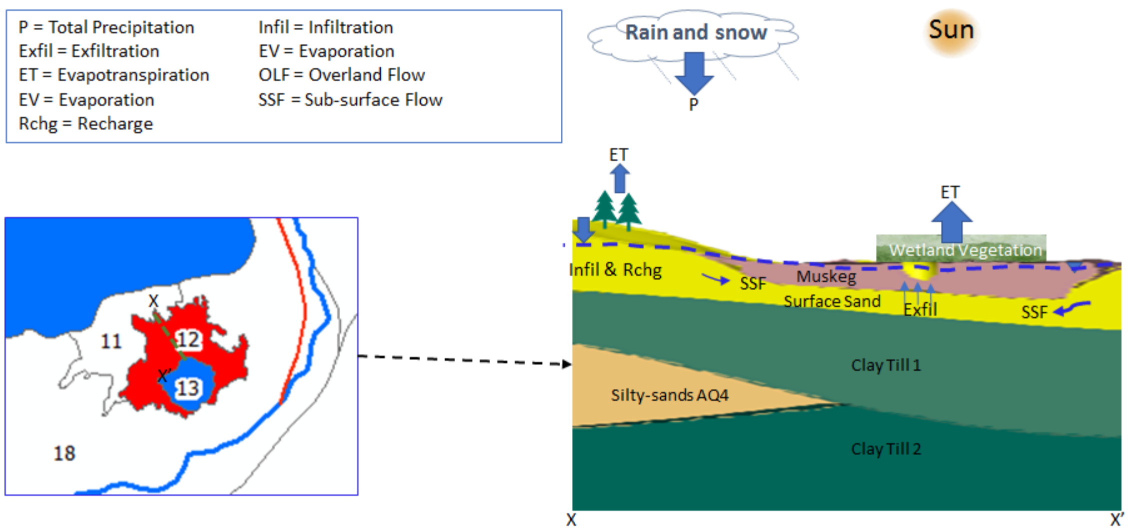

Figure 113 HRA 12: South Wetland – to Unnamed Lake. Vertical exaggeration is 80:1.

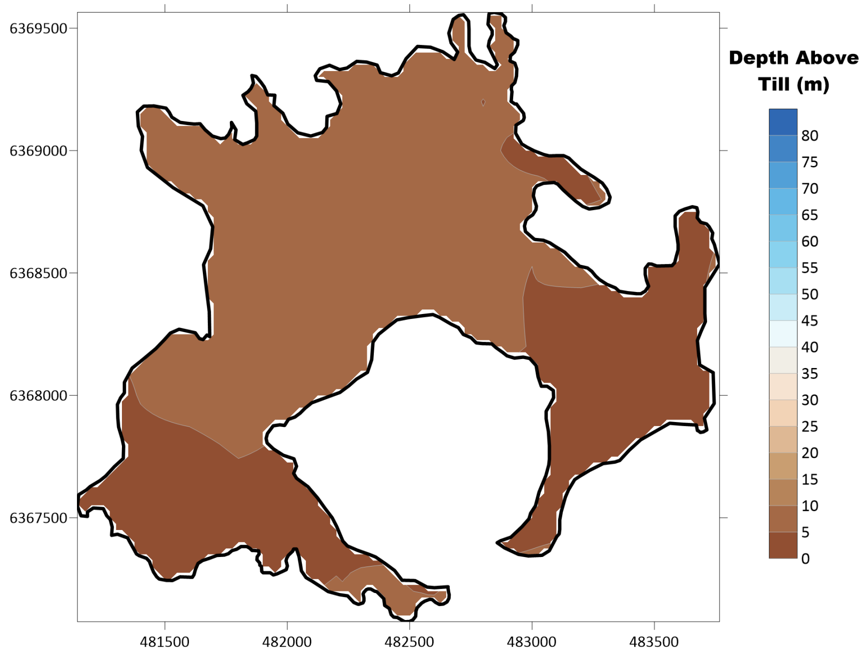

Figure 114 Substrate depths in HRA 12: South Wetland - to Unnamed Lake.

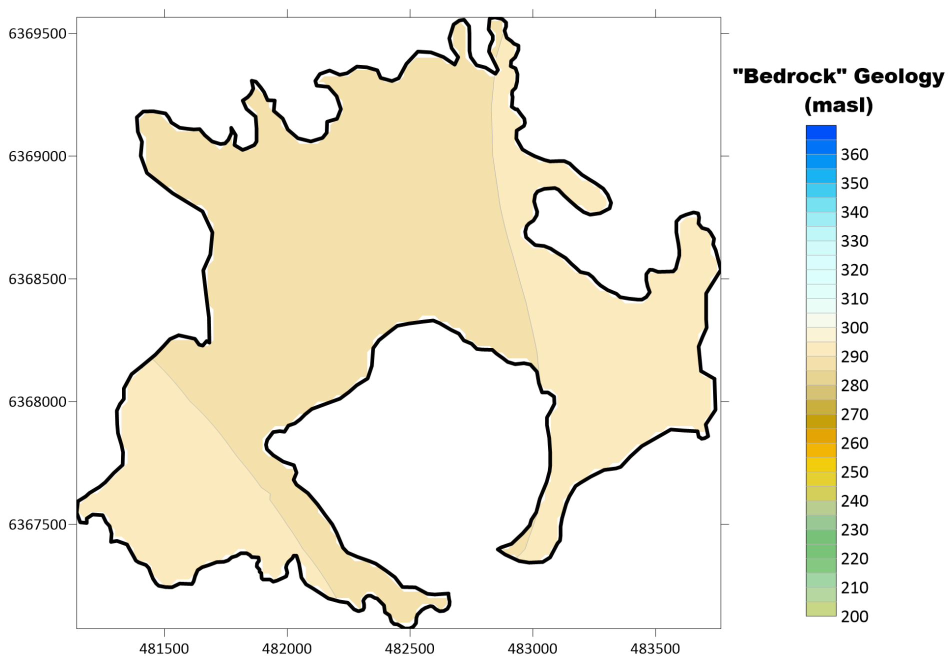

Figure 115 Bedrock topography in HRA 12: South Wetland – to Unnamed Lake.

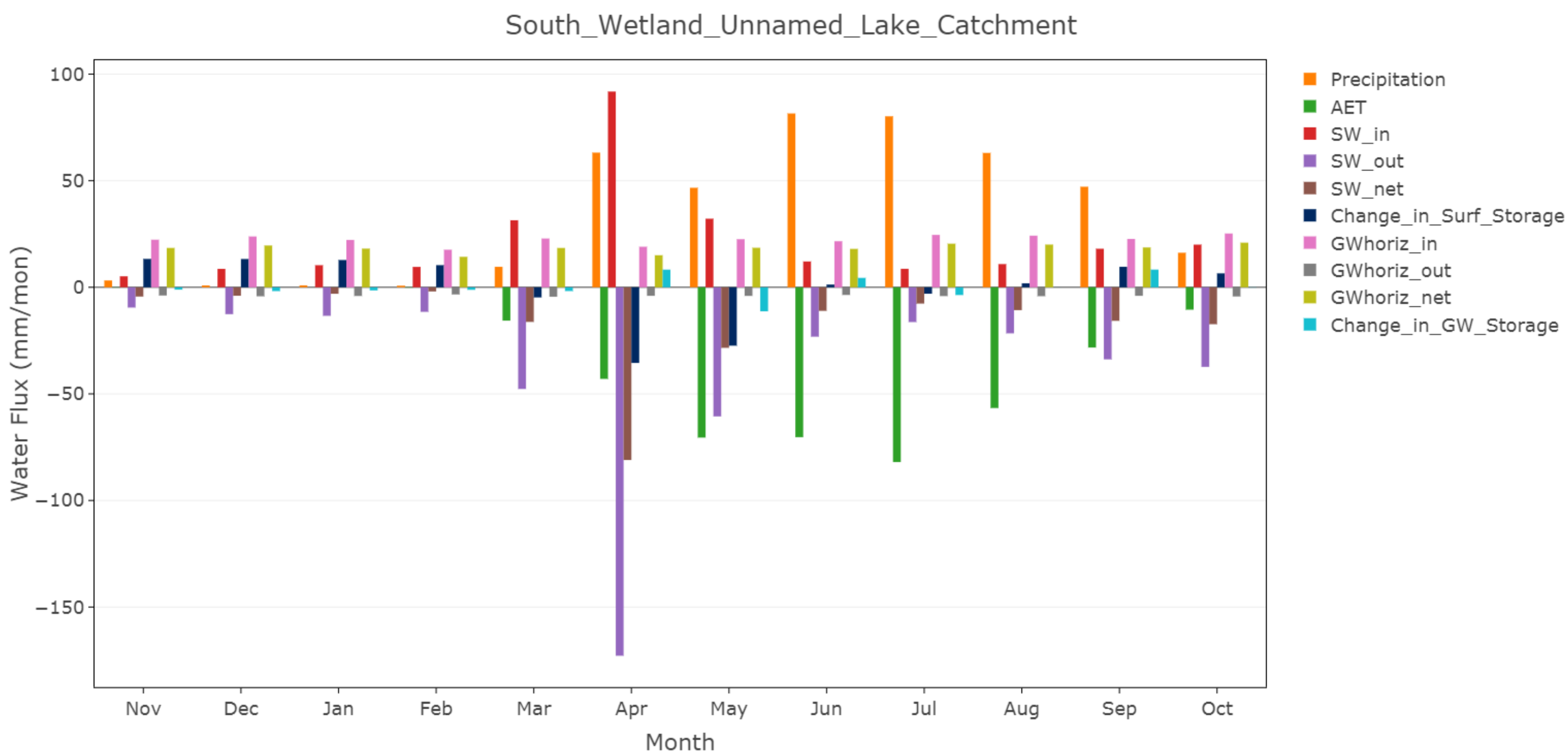

Figure 116 Mean monthly water budget components (1988-2013) for HRA 12: South Wetland – to Unnamed Lake. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

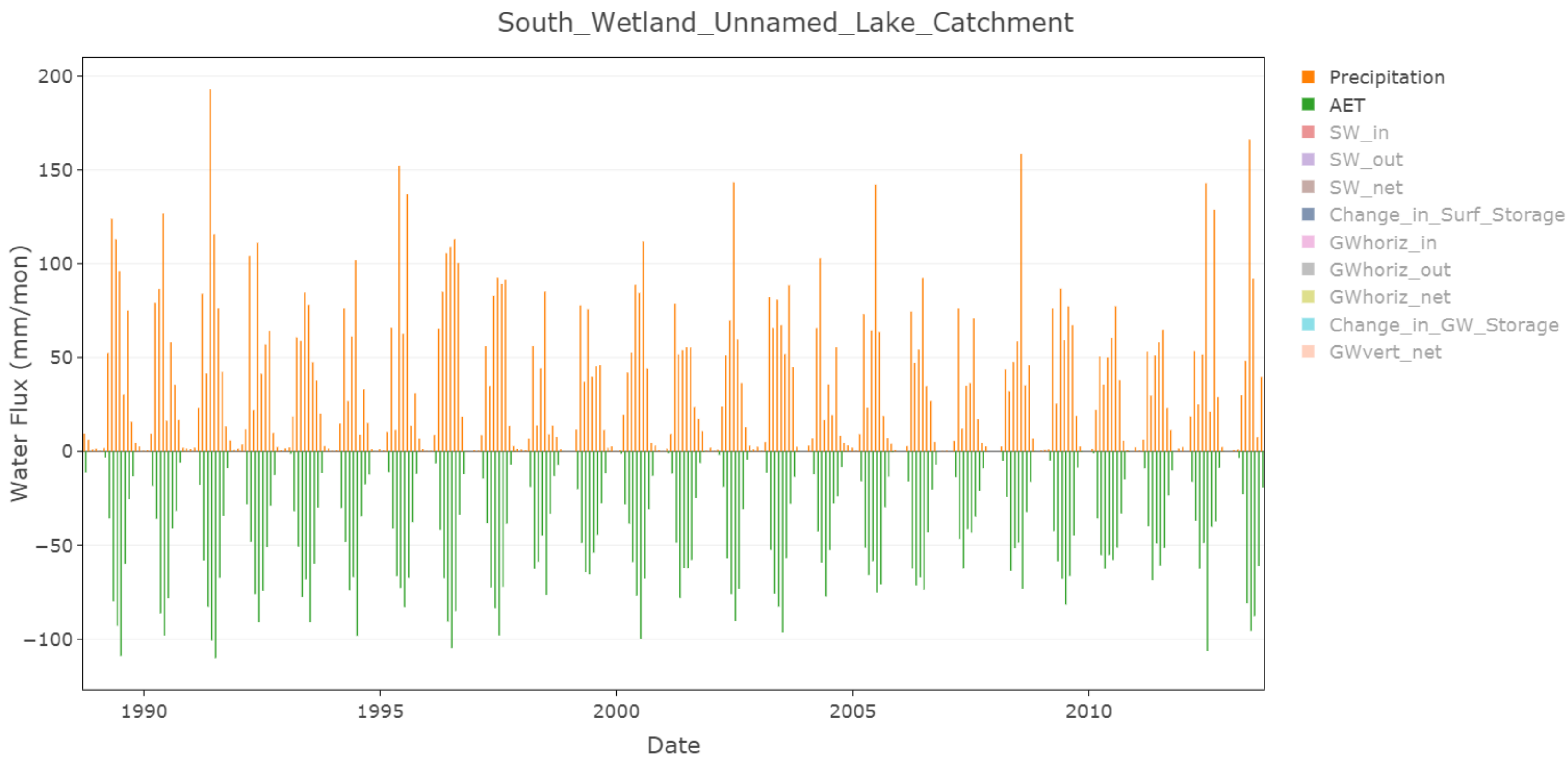

Figure 117 Predicted monthly precipitation and AET rates within HRA 12 from 1988-2013.

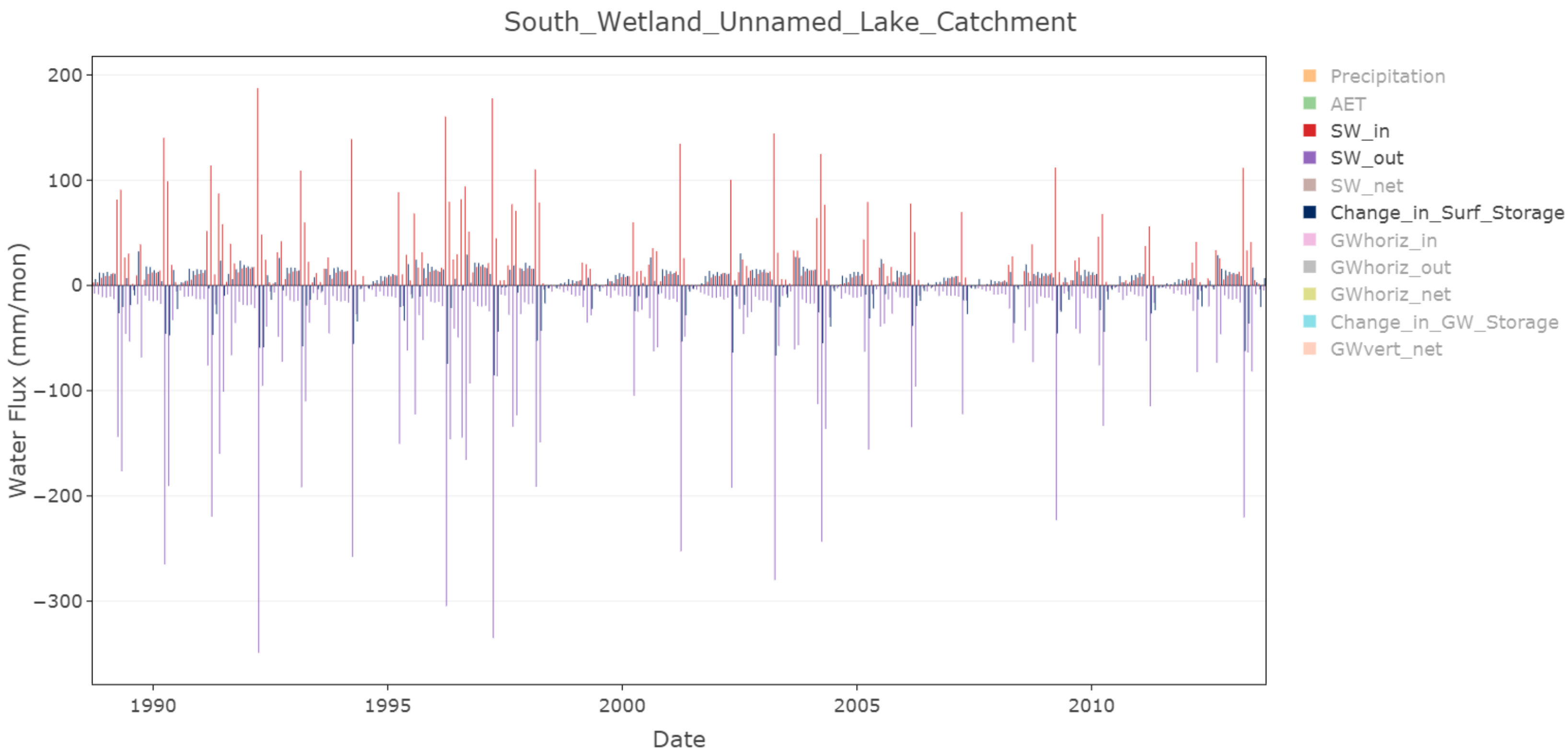

Figure 118 Predicted monthly surface water flows and storage within HRA 12 from 1988-2013.

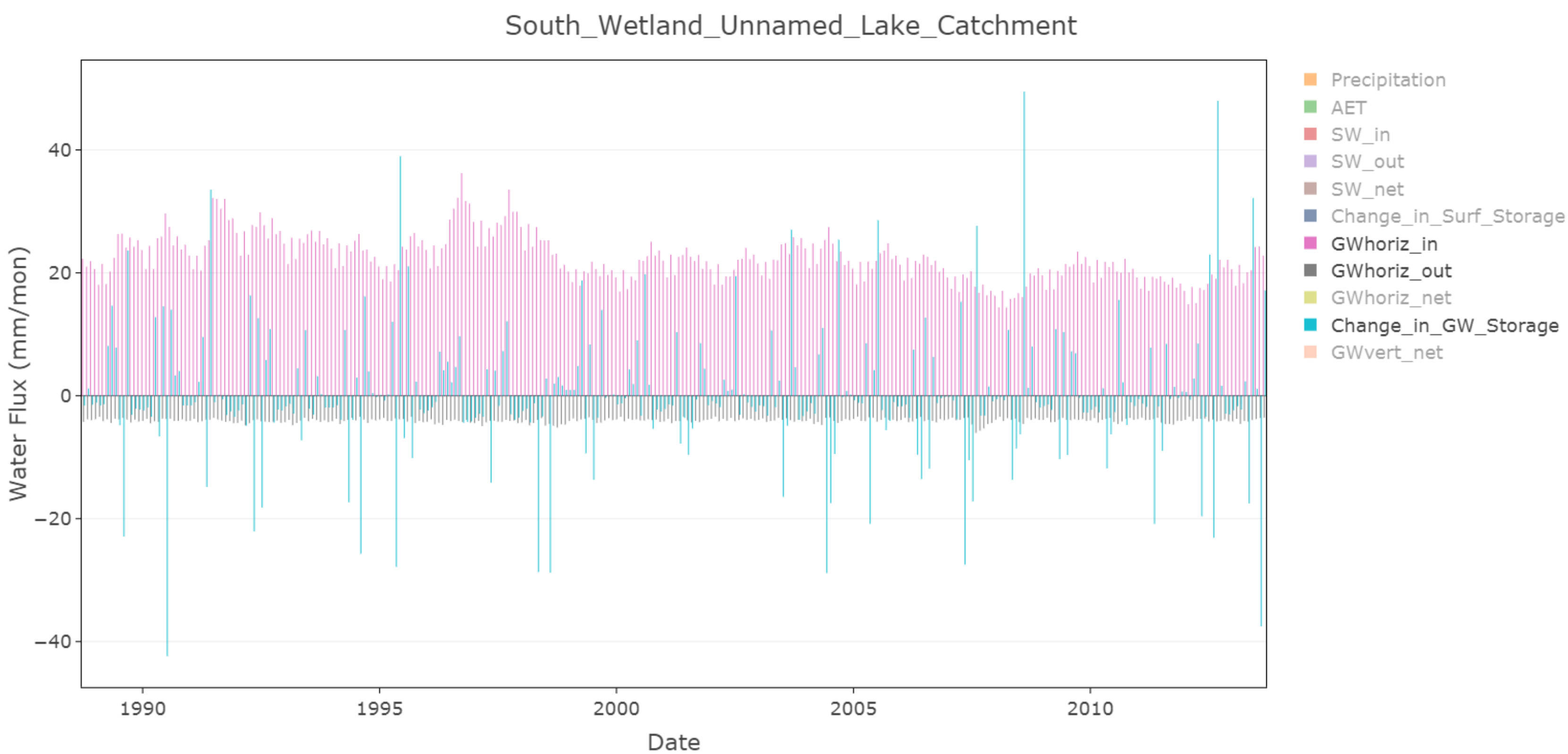

Figure 119 Predicted monthly groundwater flows and storage within HRA 12 from 1988-2013.

24. Section 1.3.13: HRA 13: Unnamed Lake

HRA 13 is designated Unnamed Lake and a cross-section taken through this HRA is shown in Figure 120. HRA 13 covers an area of approximately 0.83 km^2 that has a mean slope of 0.05%, an aspect of 177.83 degrees azimuth and a mean elevation of 295.27 masl. The dominant land usage class and form present in HRA 13 is aquatic vegetation shallow open water (92.49%). Precipitation rates on this HRA average 422.5 mm per year, approximately 25% of which is in the form of snow (1988-2013).

Substrate depths above Clay Till 1 in HRA 13 range from 2.6 to 7.4 m (Figure 121). The substrate is composed of topsoil, Surface Sands South and Silt Clay deposits. Substrate depths tend to increase south to north. Bedrock topography in HRA 13 (Clay Till 01) ranges from 287.4 to 290.2 masl and trends slightly higher south to north (Figure 122). Post-development, 100% of the HRA will remain undisturbed.

HRA 13 is conceptualized to receive its water from precipitation and flows from HRA 18 (Fort Hills East) and HRA 12 (refer to Figure 29, Figure 31 and Figure 120). Flows from HRA 18 are primarily groundwater drainage from the FHUC. Flows from HRA 12 include surface water flows discharging into Unnamed Lake and groundwater contributions along the lake's southern margins. HRA 13 receives runoff originating from the FHUC and the hydrogeochemistry is conceptualized to be a blend (relatively) alkaline and cation-rich from nearby groundwater spring inputs and non-alkaline and cation-poor drainage from the surface sand deposits lying south and east of Unnamed Lake; drainage form the surface sand deposits would be presumed to dominate the signature based on conceptualized inputs from these two parts of the contributing landscape.

It should be noted that ITK holders refer to this lake as Baby McClelland Lake or just Baby Lake and this naming convention will be adopted in future MLWC documentation (post the MLWC OP submission). A FCM ITK holder indicated that some of the area around Baby Lake that does not fully freeze (FCM ITK holder, October 14, 2020 meeting).

> *"[the area south/east of McClelland Lake, including Baby Lake] my dad, my mom, they would never let us walk alone, we had to carry a stick, because of all the hanging muskeg in there. It hangs - about 4 feet of ground, then straight water underneath. then it was that thick clay. .... but there's lots of other places like that.... My grandfather used to say, if we sunk in that muskeg, we weren't coming back up, which I think it's true. Because when I went fire fighting after I grew up, you can see after where the muskeg gets burned, that its deep. Because ,we were on fire watch we had to put out smoldering ashes and stuff. Yeah. And there it was, you could see that*

in some places, it [muskeg] was like about eight feet deep... Well, I guess there is some danger in not listening to your mum and dad anyways” (FMFN ITK holder, March 3, 2021 workshop).

“We’ve always been told that Baby Lake is connected through the stream and wetlands, but it is also connected to McClelland Lake by groundwater” (FCM ITK holder, October 14, 2020 meeting).

Water is conceptualized to leave HRA 13 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evapotranspiration. HRA 12 acts somewhat like a drainage basin around HRA 13 but the lake can discharge some groundwater into HRA 12. The surface of Unnamed Lake is expected to freeze solid in the wintertime.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 13 was simulated to receive 31%, 50% and 18% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 13 was simulated to discharge 45%, 55% and 0% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 13 indicates that annual AET rates (581.7 mm/yr) are much less than precipitation rates (413.3 mm/yr) most years (Table 8 and Figure 32); the simulated water table is at or near surface most times where muskeg is present (Figure 33); the HRA is simulated to remain nearly saturated in the muskeg and variably-saturated in the thicker surface sand deposits (Figure 34) and the exchange of water across the land surface is primarily near neutral in the interior of the HRA with zones of exfiltration along its southern and eastern margins (Figure 35). Table 8 indicates that, over the long term, most water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally more volume exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 123 presents predicted average monthly water balance components over the period 1988-2013. HRA 13 is predicted to produce peak incoming and outgoing flows during April. This HRA adds to surface water storage September to February (December peak) and sheds storage March to August (April peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round reaching its peak in August and its minimum in February;

groundwater outflows do not occur. The HRA adds to groundwater storage September (the peak) to March. The HRA consumes groundwater storage in April to August with peak consumption in May.

Figure 124 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 13. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 125 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-September but usually happens in April. Peak monthly surface water out can occur April-October but usually happens in April. The largest monthly gain in surface water storage can occur June-December but most often happens in December. The maximum monthly consumption of surface water storage can occur March-May but typically happens in April. Figure 126 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur July-October but typically peaks in October. Peak monthly groundwater discharge rates occur March-April but usually happen in March. The largest monthly gain in groundwater storage can happen June-October but usually occurs in September. The largest monthly consumption of groundwater storage usually happens May-August but usually occurs in May.

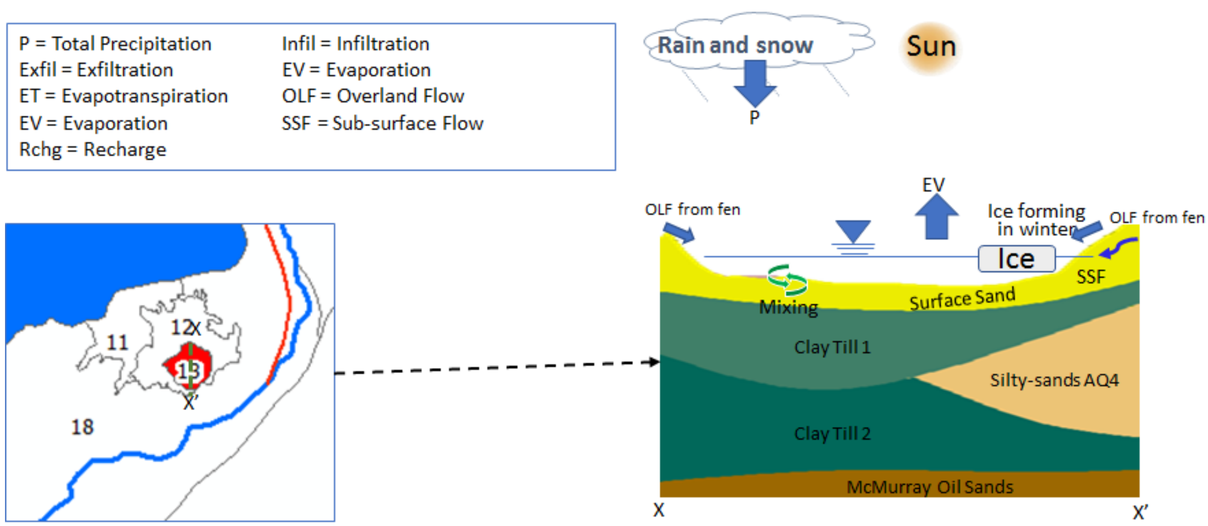

Figure 120 HRA 13: Unnamed Lake. Vertical exaggeration is 80:1.

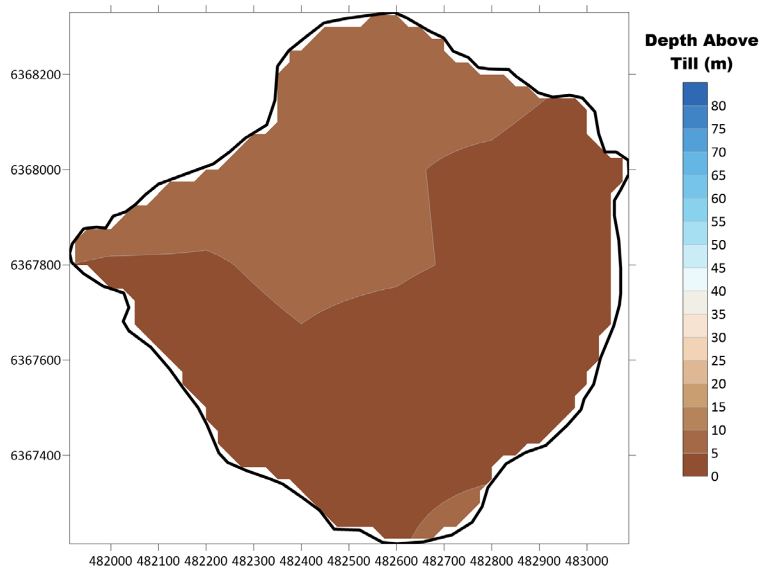

Figure 121 Substrate depths in HRA 13: Unnamed Lake.

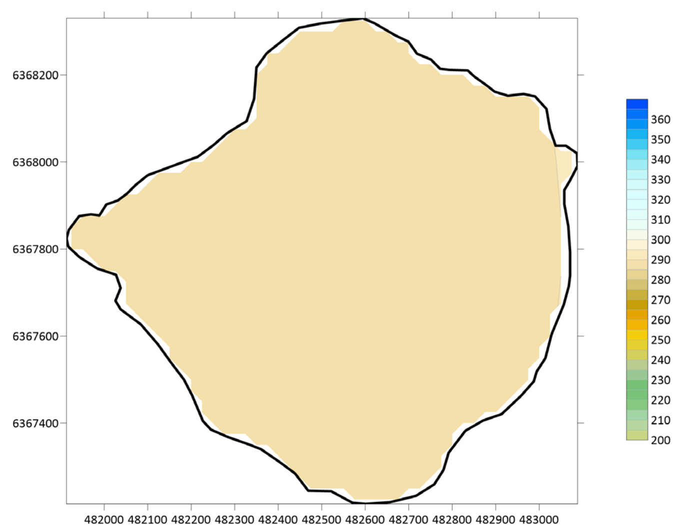

Figure 122 Bedrock topography in HRA 13: Unnamed Lake.

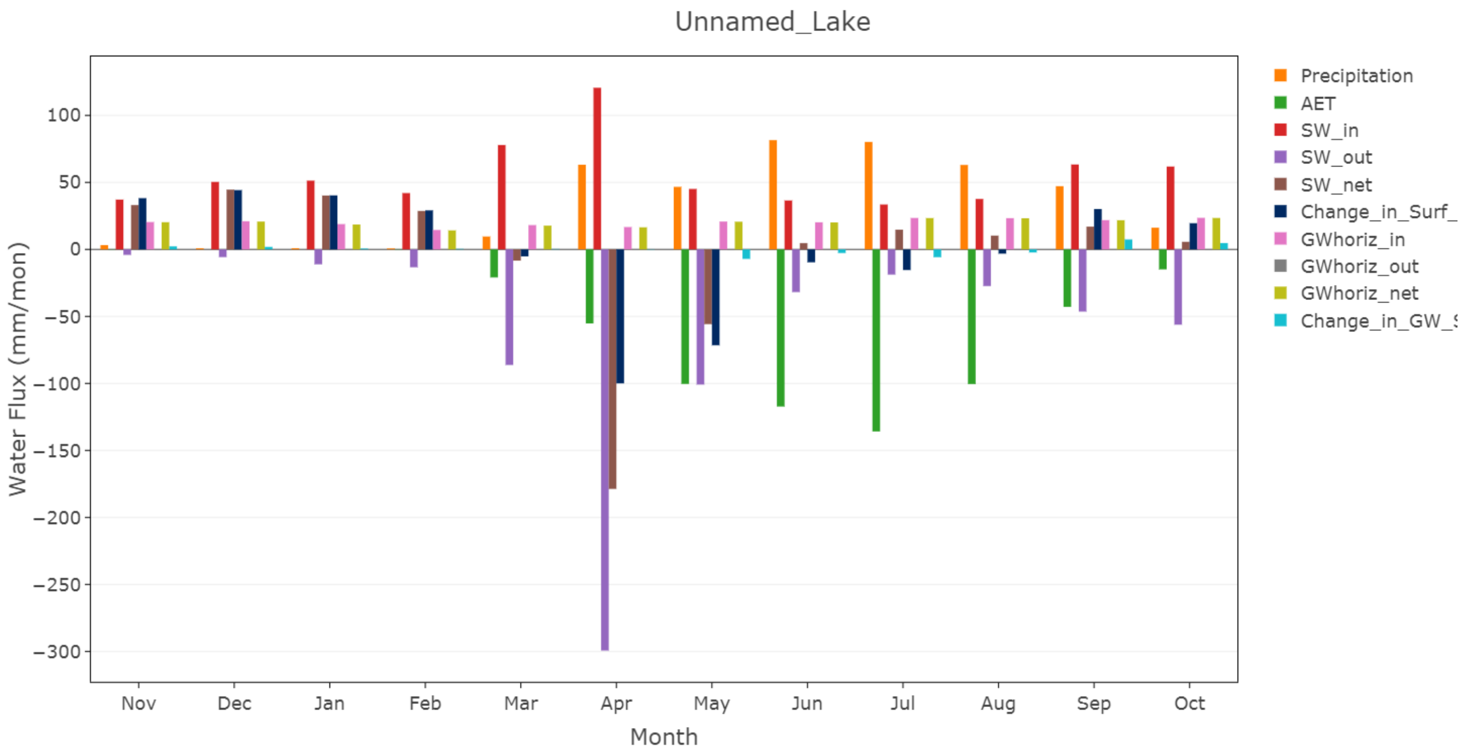

Figure 123 Mean monthly water budget components (1988-2013) for HRA 13: Unnamed Lake. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

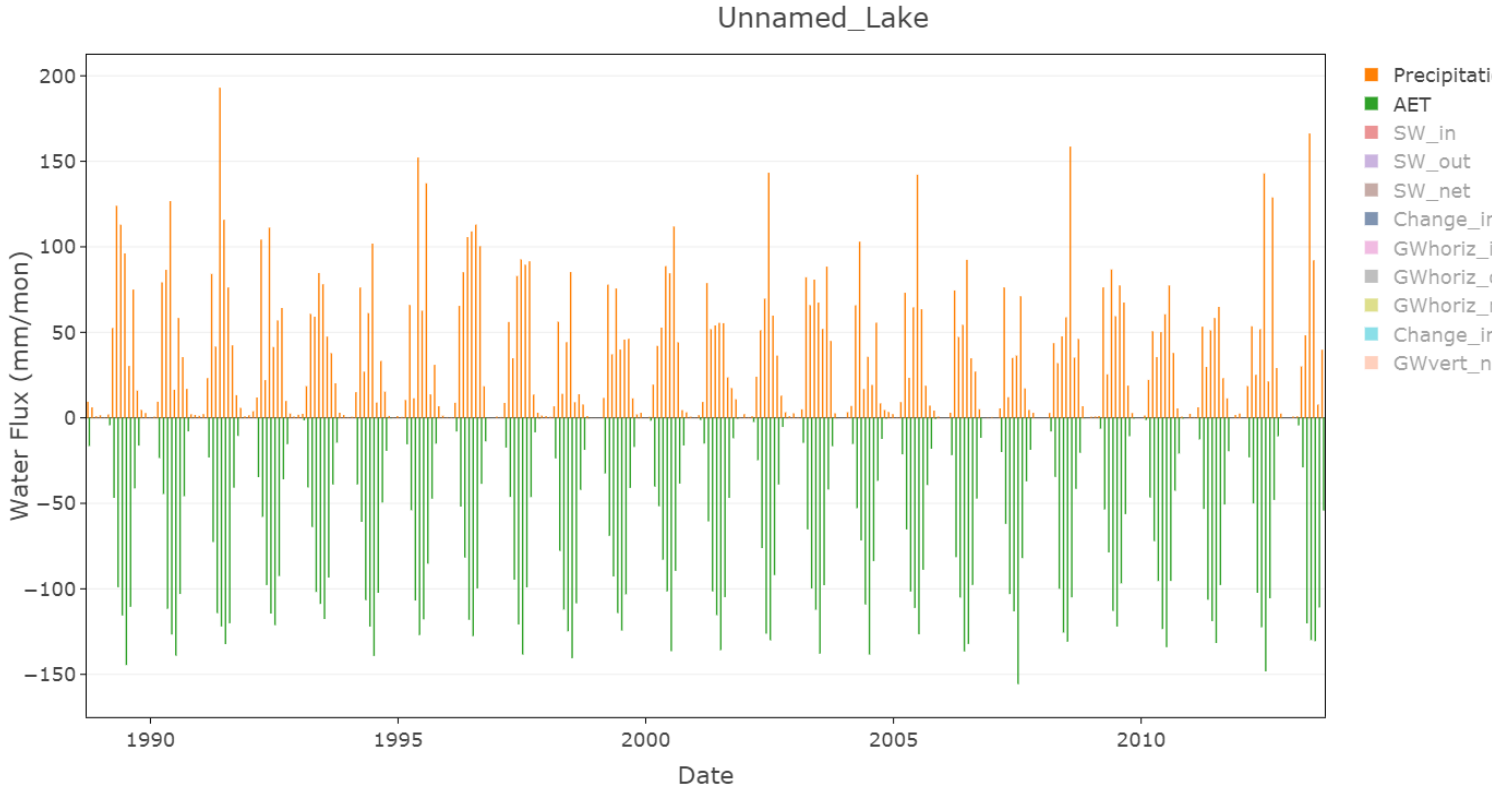

Figure 124 Predicted monthly precipitation and AET rates within HRA 13 from 1988-2013.

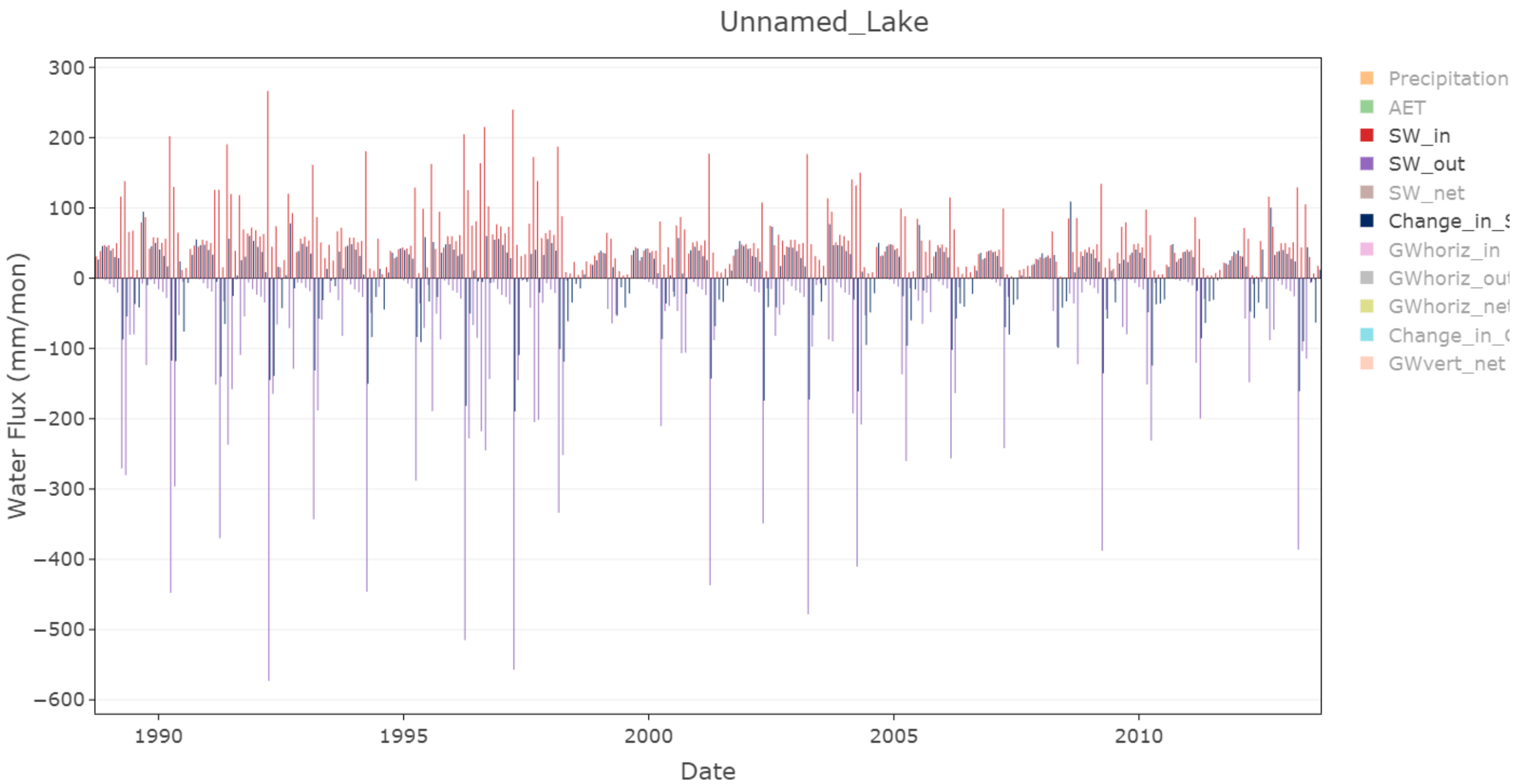

Figure 125 Predicted monthly surface water flows and storage within HRA 13 from 1988-2013.

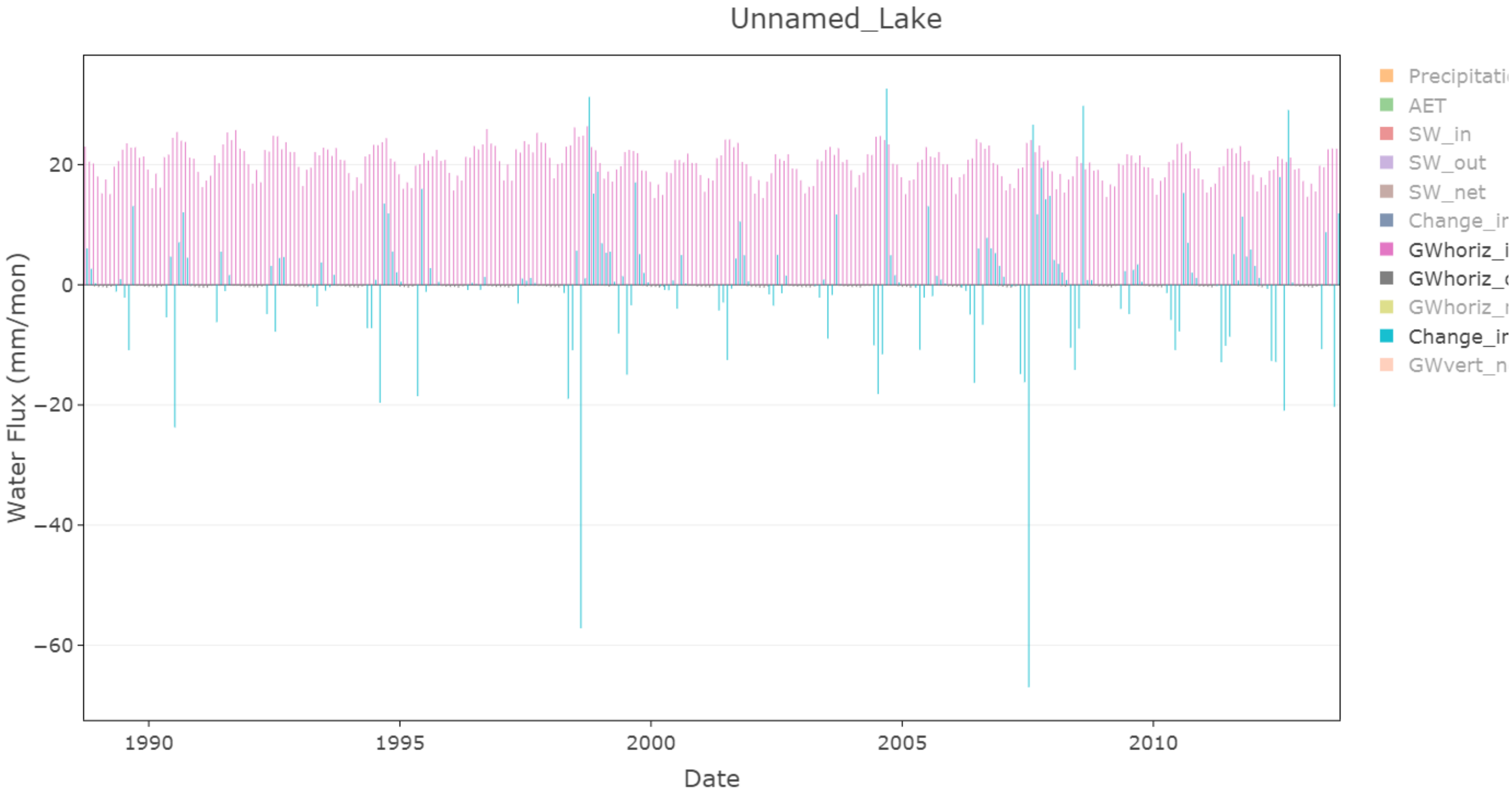

Figure 126 Predicted monthly groundwater flows and storage within HRA 13 from 1988-2013.

25. Section 1.3.14: HRA 14: Coniferous Swamp – West

HRA 14 is designated Coniferous Swamp - West and a cross-section taken through this HRA is shown in Figure 127. HRA 14 covers an area of approximately 6.22 km^2 that has a mean slope of 1.01%, an aspect of 152.63 degrees azimuth and a mean elevation of 305.4 masl. Land usages varies in HRA 14 and is dominated by wooded coniferous fen (18.19%), wooded coniferous swamp (25.13%) wooded coniferous upland (non-wetland) (10.86%) land usage classes and forms. The dominant soils are Bitumount (20.1%) and McClelland (40.23%) which are classified to drain poorly and very poorly, respectively. Precipitation rates on this HRA average 422.5 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) describe this area eco-hydrologically as riparian margin.

Substrate depths above Clay Till 1 in HRA 14 range from 0.0 to 11.4 m (Figure 128). The substrate is composed of topsoil, Surface Sands South, Surface Sands North, Muskeg and Silt Clay deposits. Substrate depths in HRA 14 beyond the terminal edge of Clay Till 1 range up to 42.1 m above Clay Till 2 and consist primarily of silt sand deposits. Substrate depths tend to increase north to south. Bedrock topography in HRA 14 ranges from 291.6 to 317.5 masl above Clay Till 1 Trending downward north to south) and ranges from 276.8 to 285.0 masl above Clay Till 2 (with higher elevations in the northwestern and southeastern flanks and lower elevations between the flanks (Figure 129). Post-development, 5% of the HRA will remain undisturbed.

HRA 14 is conceptualized to receive water from precipitation and flows from HRA 17 (Fort Hills West (refer to Figure 29, Figure 31 and Figure 127). Groundwater runoff from the FHUC south of HRA 17 will tend to exfiltrate into rills or gullies that will then discharge into HRA 14. Groundwater can also flow directly into HRA 14 from HRA 17. The water table is conceptualized as being well under the land surface on the western side of the HRA and at or near the surface on its eastern side where muskeg is present. The waters entering HRA 14 originate from the FHUC and are conceptualized to be (relatively) alkaline and cation-rich.

Water is conceptualized to leave HRA 14 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evapotranspiration. Water exiting HRA 14 in the form of surface water generally flows into HRA 04. During wintertime, the ground in HRA 14 would be expected to freeze permeable and honeycomb on its western side where the water table is relatively deep and then freeze progressively more solid to the east where the water table is closer to the surface. The center of HRA 14 is overlain by Silt Clay which would also be expected to freeze solid in the winter. The solid freezing zones can potentially remain frozen for weeks after freshet, continuing to produce runoff each time it rains. During the freshet, snowmelt runoff generated on the eastern side of the HRA would runoff into HRA 04. On the western side of the HRA, this snowmelt will infiltrate into the deeper substrate.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 14 was simulated to receive 43%, 16% and 41% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 14 was simulated to discharge 48%, 33% and 18% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 14 indicates that annual AET rates (442.0 mm/yr) are less than precipitation rates (413.3 mm/yr) (Table 8 and Figure 32); the simulated water table is at or near the land surface along the eastern side of the HRA (Figure 33); the HRA is simulated to remain variably saturated, becoming saturated where muskeg is present (Figure 34) and the exchange of water across the land surface interface is a mosaic of exfiltration, infiltration and approximately net neutral regions (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of evapotranspiration. Proportionally slightly more water exits the HRA in the form of surface water than enters it annually. Proportionally less water exits the HRA in the form of groundwater than enters it annually.

Figure 130 presents predicted average monthly water balance components over the period 1988-2013. HRA 14 is predicted to produce peak incoming and outgoing flows during April. This HRA adds to surface water storage August to February plus June (November peak) and sheds storage March to May plus July (April peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round. The HRA adds to groundwater storage September (the peak) to March plus the month of June. The HRA consumes groundwater storage in May (the peak) and the month of July.

Figure 131 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 14. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-August but usually occur in July. Figure 132 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur April-June but usually happens in April. Peak monthly surface water out can occur April-June but usually happens in April. The largest monthly gain in surface water storage can occur

July-December but most often happens in November. The maximum monthly consumption of surface water storage can occur anytime March-May but typically happens in April. Figure 133 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly groundwater discharge rates occur in March. The largest monthly gain in groundwater storage can happen April-October but usually occurs in September. The largest monthly consumption of groundwater storage usually happens May-October but usually occurs in May.

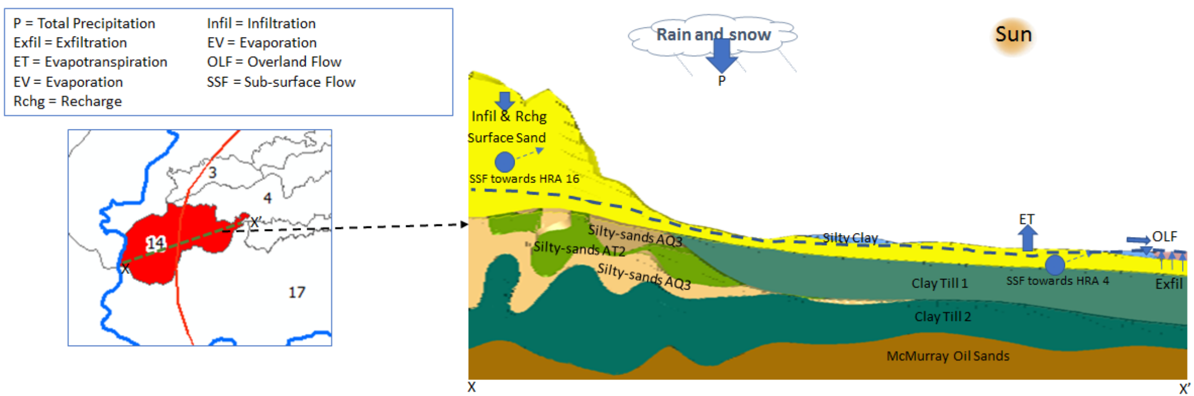

Figure 127 HRA 14: Coniferous Swamp – West. Vertical exaggeration is 80:1.

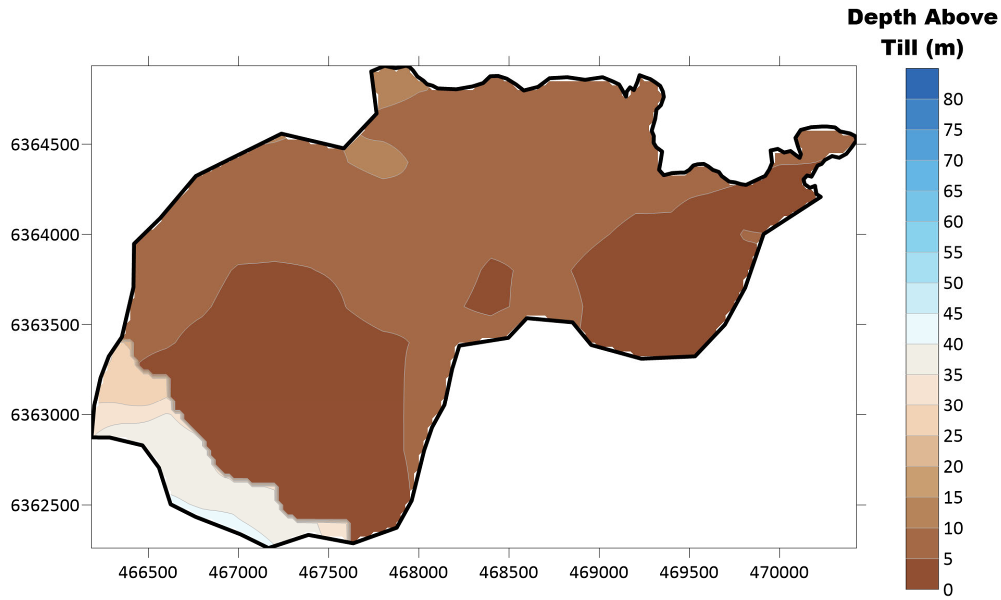

Figure 128 Substrate depths in HRA 14: Coniferous Swamp - West.

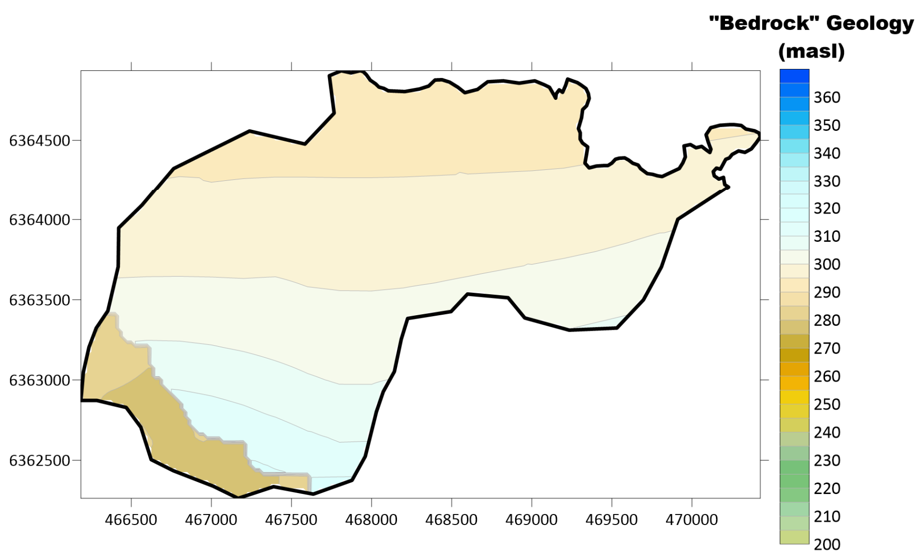

Figure 129 Bedrock topography in HRA 14: Coniferous Swamp - West.

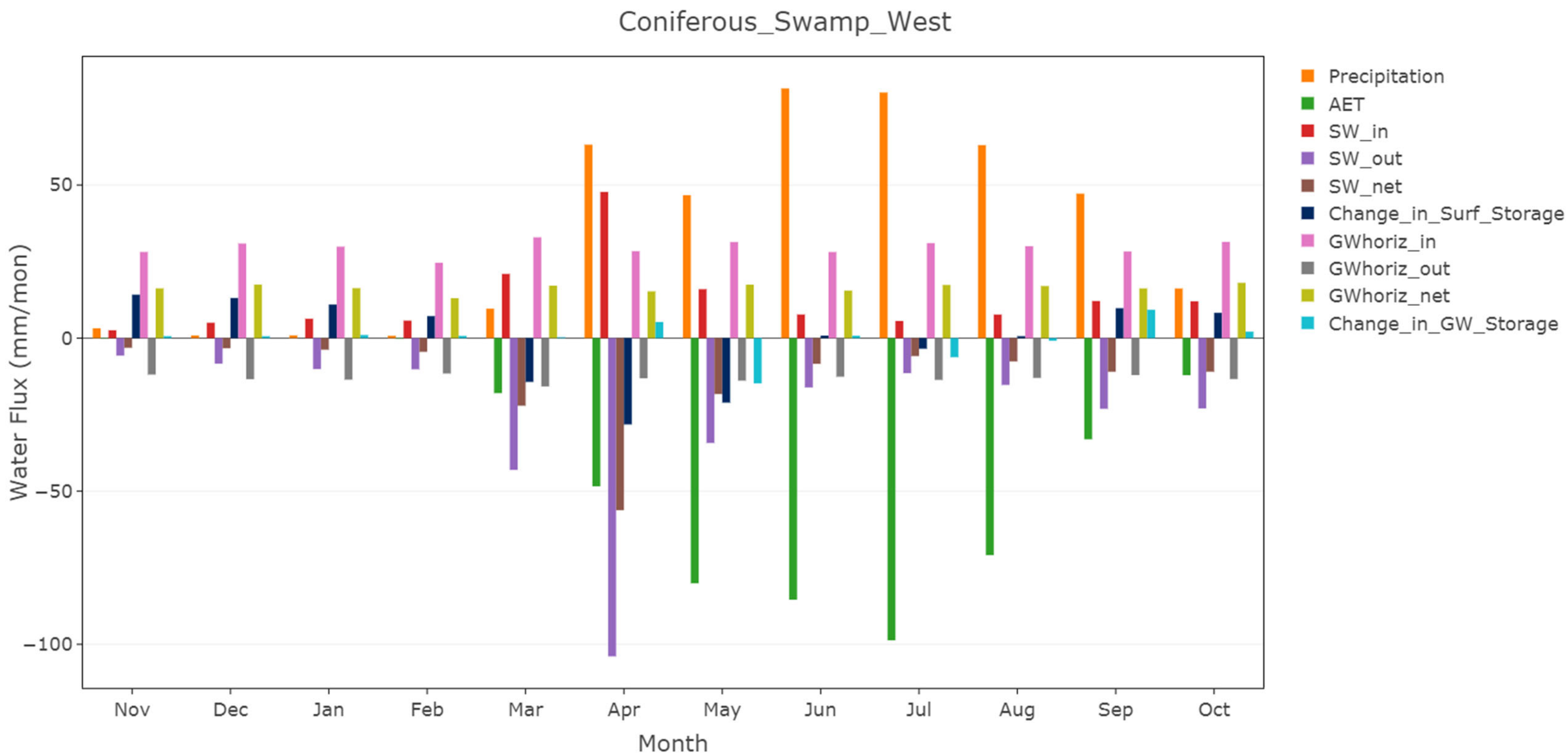

Figure 130 Mean monthly water budget components (1988-2013) for HRA 14: Coniferous Swamp - West. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

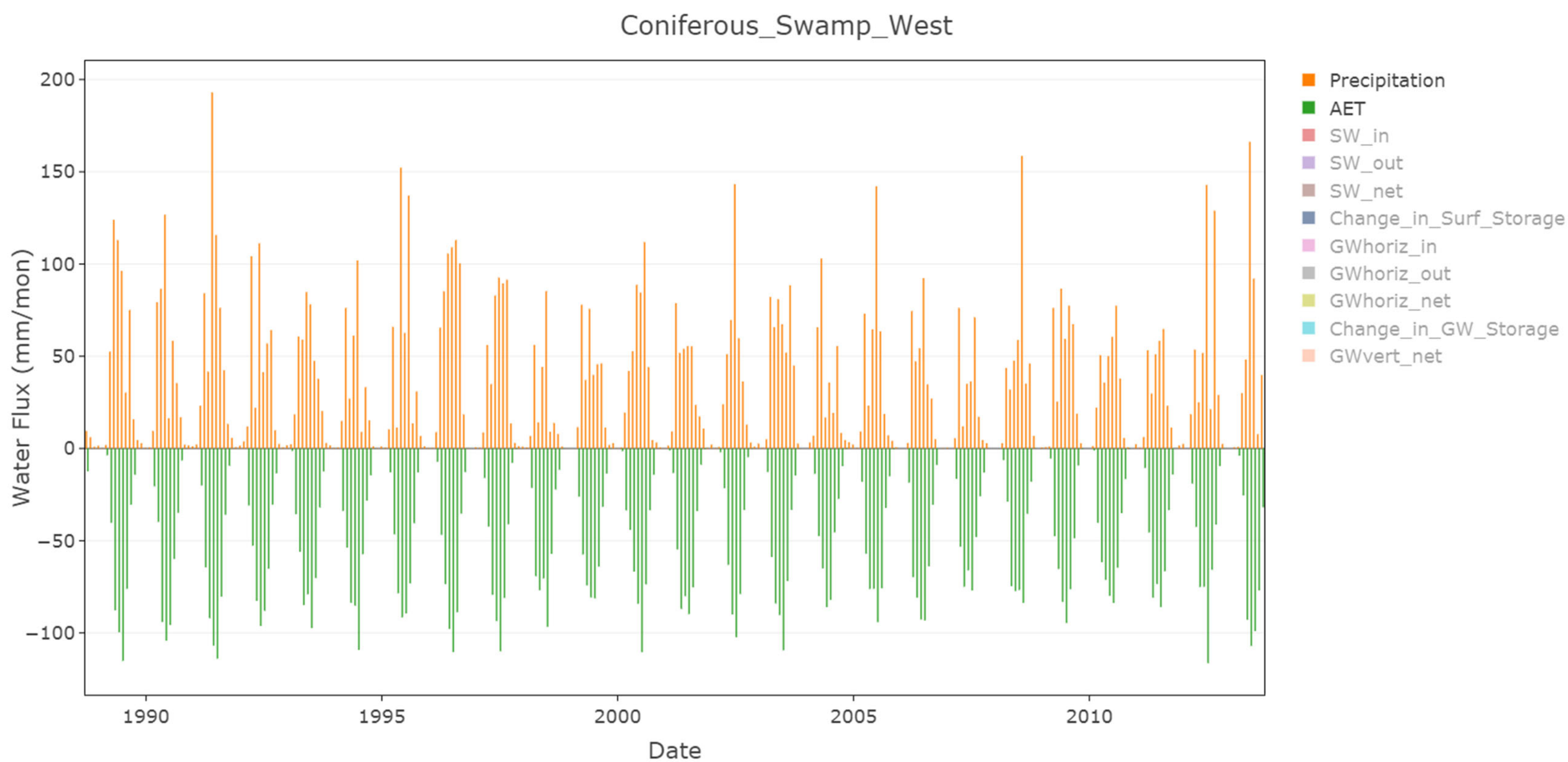

Figure 131 Predicted monthly precipitation and AET rates within HRA 14 from 1988-2013.

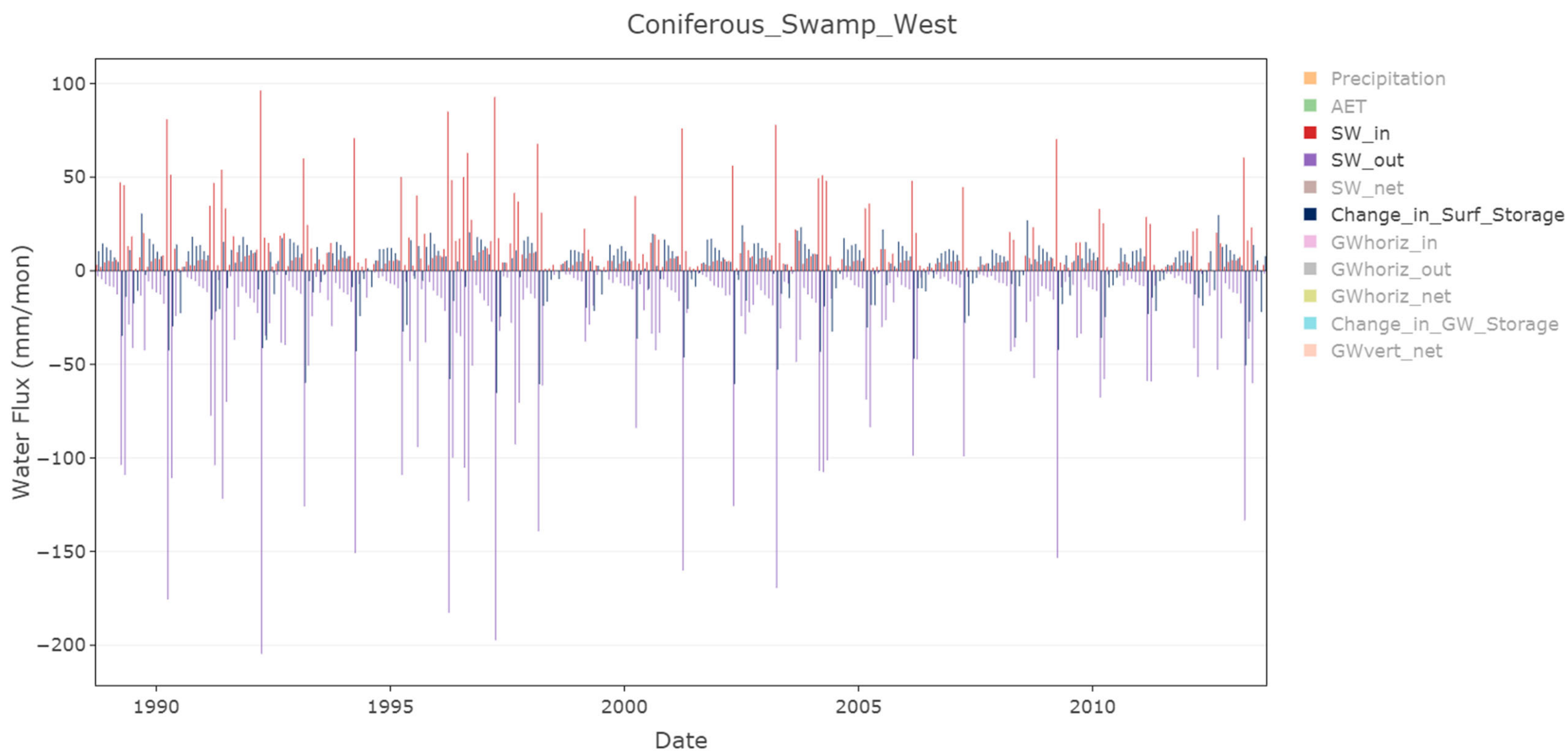

Figure 132 Predicted monthly surface water flows and storage within HRA 14 from 1988-2013.

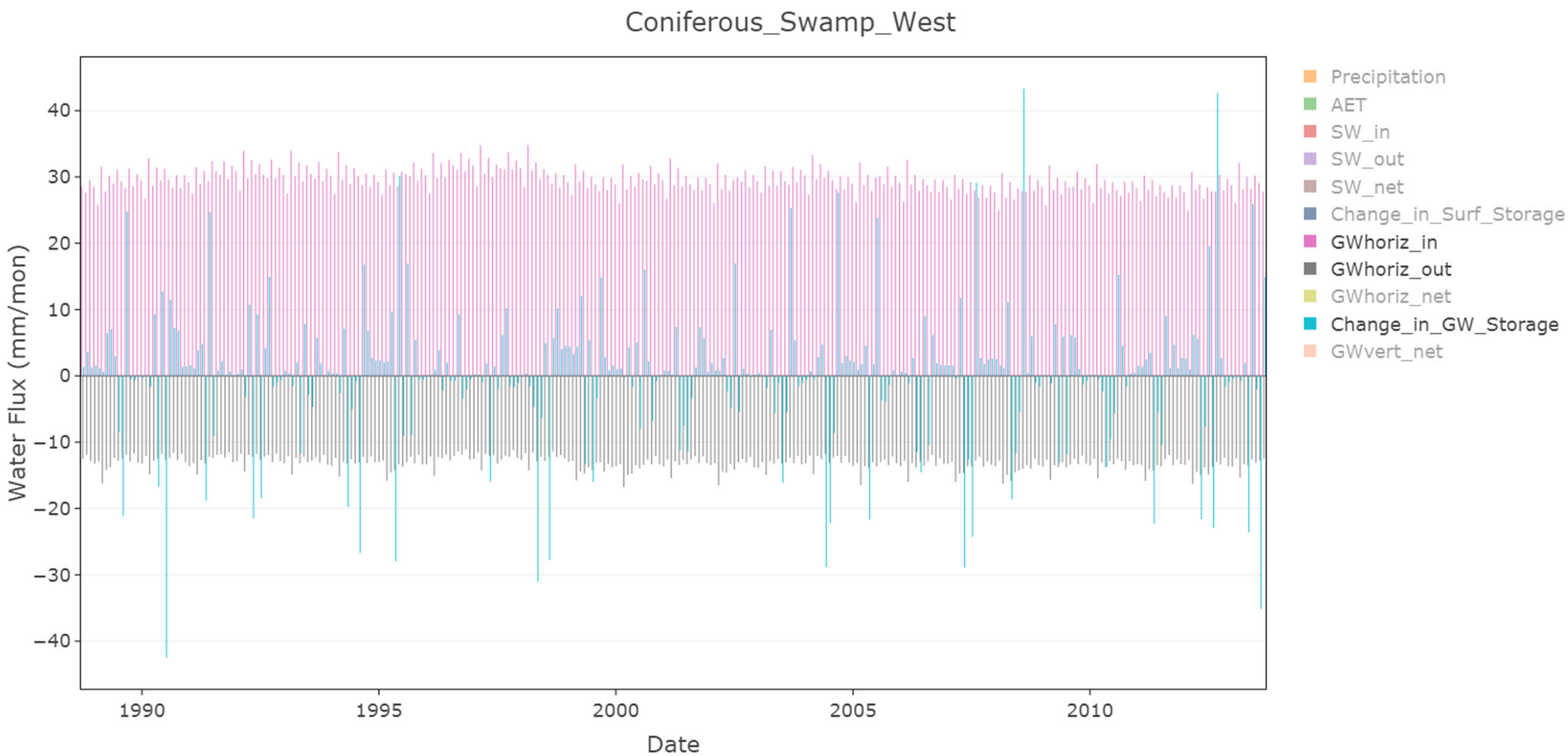

Figure 133 Predicted monthly groundwater flows and storage within HRA 14 from 1988-2013.

26. Section 1.3.15: HRA 15: North Outwash Plains – East

HRA 15 is designated North Outwash Plains – East and a cross-section taken through this HRA is shown in Figure 134. HRA 15 covers an area of approximately 29.33 km^2 that has a mean slope of 1.04%, an aspect of 195.36 degrees azimuth and a mean elevation of 302.43 masl. The dominant land usages classes and forms present in HRA 15 are wooded coniferous upland (non-wetland) (24.76%) and wooded coniferous burned (52.1%), respectively. The dominant soil is Mildred (92.62%) which is classified to drain rapidly. Precipitation rates on this HRA average 422.5 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 15 range from 19.3 to 52.1 m (Figure 135). The substrate is composed of topsoil, Surface Sands North and Muskeg deposits. Substrate depths increase going southwest to northeast. Bedrock topography in HRA 15 (Clay Till 01) ranges from 255.8 to 274.8 masl and elevations become progressively lower southwest to northeast (Figure 136). Post-development, 100% of the HRA will remain undisturbed.

HRA 15 is conceptualized to primarily receive water from precipitation and sporadically from HRA 09 (refer to Figure 29, Figure 31 and Figure 134). During periods of relatively higher water levels, McClelland Lake (HRA 09) can discharge surface water directly into HRA 15. The lake also perennially would be expected to discharge groundwater into HRA 15 as well. The hydrogeochemistry of waters in HRA 15 are conceptualized to be non- alkaline and cation-poor.

Water is conceptualized to leave HRA 15 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, evapotranspiration and outgoing groundwater. Groundwater from 15 discharges into McClelland Lake along its northern shores where the two HRAs share a common boundary (and also receives water from the lake’s eastern shores). As can be inferred from Figure 135, substrate depths are noticeably deeper along the northern and eastern margins of the HRA and shallower to the east and south. This aquifer geometry would generally be expected to focus groundwater return flow from the deeper substrates towards HRA 10 and McClelland Lake. The water table in HRA 15 would be expected to be near surface along its shared margin around HRA 10 and in its south-southeastern portions and well below ground surface elsewhere where substrate depths are greater. The ground in this HRA would be expected to freeze honeycomb and permeable in the winter and freshet runoff would be expected to be minimal except near HRA 10 or where the HRA shares a boundary with the eastern shores of McClelland Lake.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 15 was simulated to receive 88%, 5% and 7% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 15 was simulated to discharge 36%, 9% and 55% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 15 indicates that annual AET rates (183.9 mm/yr) are much less than precipitation rates (413.3 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface except near the lake and HRA 10 (Figure 33); the HRA is simulated to have low saturation rates where substrate depths are deeper and higher saturation rates where shallower (Figure 34) and the exchange of water across the land surface indicates most of the HRA is an infiltration region (again, except near HRA 10 and the eastern shores of McClelland Lake) (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of groundwater. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally more water exits the HRA in the form of groundwater than enters it annually.

Figure 137 presents predicted average monthly water balance components over the period 1988-2013. HRA 15 is predicted to produce peak incoming flows during April and peak outgoing flows in May. This HRA adds to surface water storage September to November plus the month of April (the peak). The HRA sheds surface water December to March and May to August (May peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round; outflow rates are consistently greater than inflow rates. The HRA adds to groundwater storage April through September (April peak). The HRA consumes groundwater storage October to March (December peak).

Figure 138 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 15. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-August but usually occur in July. Figure 139 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur April-May but usually happens in April. Peak monthly surface water out can occur April-October but usually happens in May. The largest monthly gain in surface water storage can occur April-September but most often happens in April. The maximum monthly consumption of surface water storage can occur May-August but typically happens in April. Figure 140 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly groundwater discharge rates occur in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage usually happens May-December but usually occurs in December.

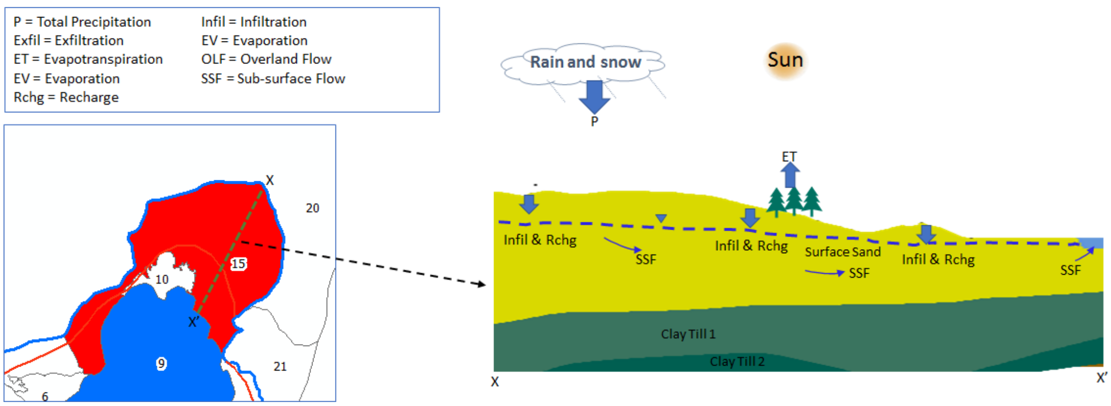

Figure 134 HRA 15: North Outwash Plains - East. Vertical exaggeration is 80:1.

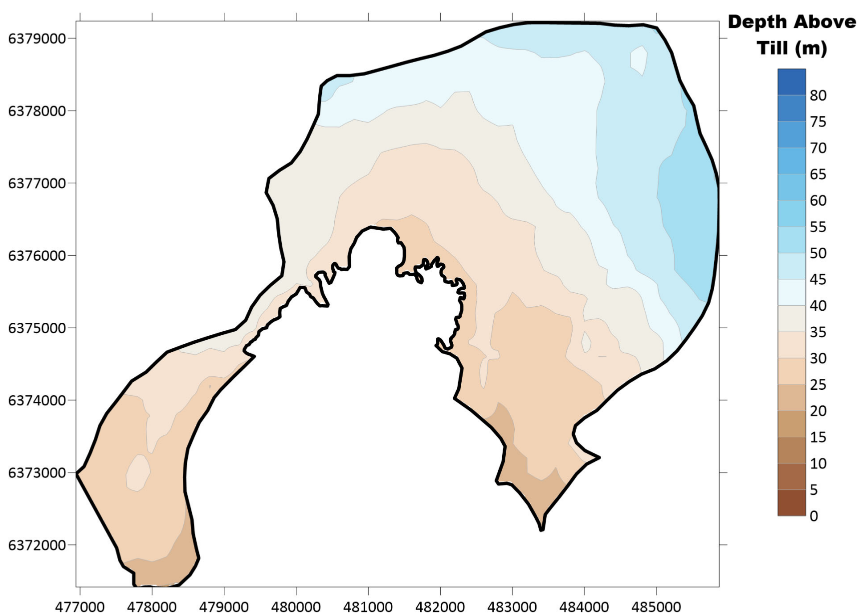

Figure 135 Substrate depths in HRA 15: North Outwash Plains - East.

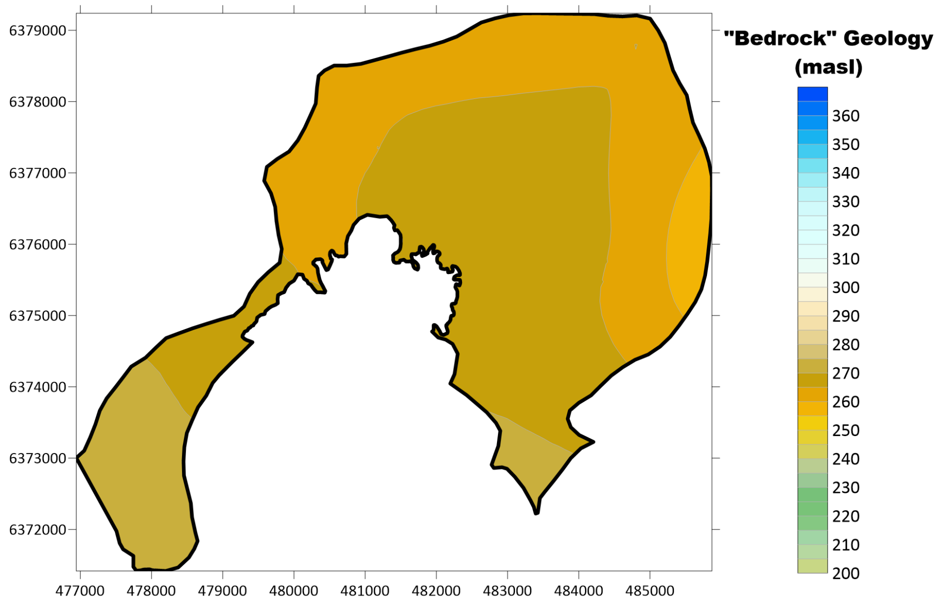

Figure 136 Bedrock topography in HRA 15: North Outwash Plains - East.

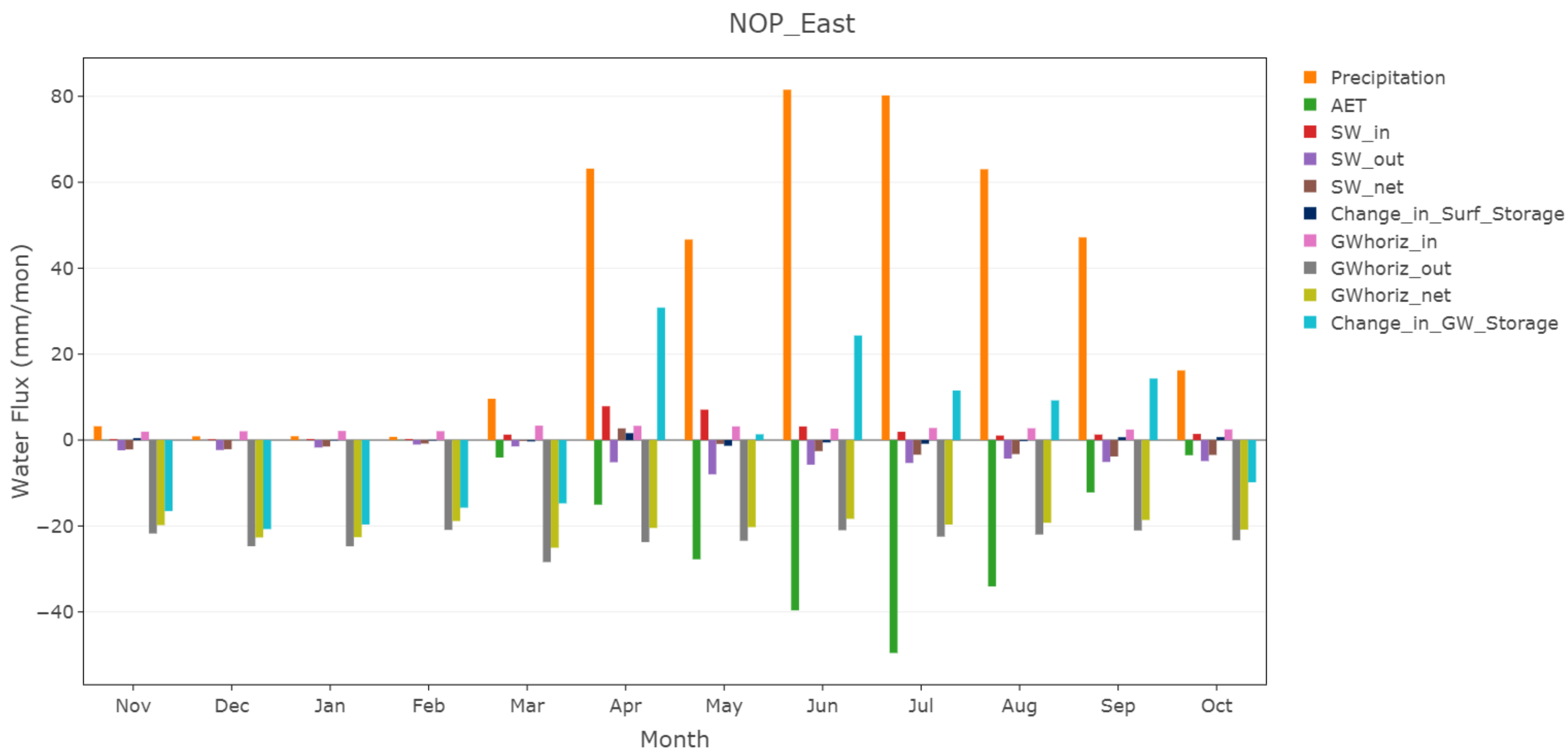

Figure 137 Mean monthly water budget components (1988-2013) for HRA 15: North Outwash Plains - East. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

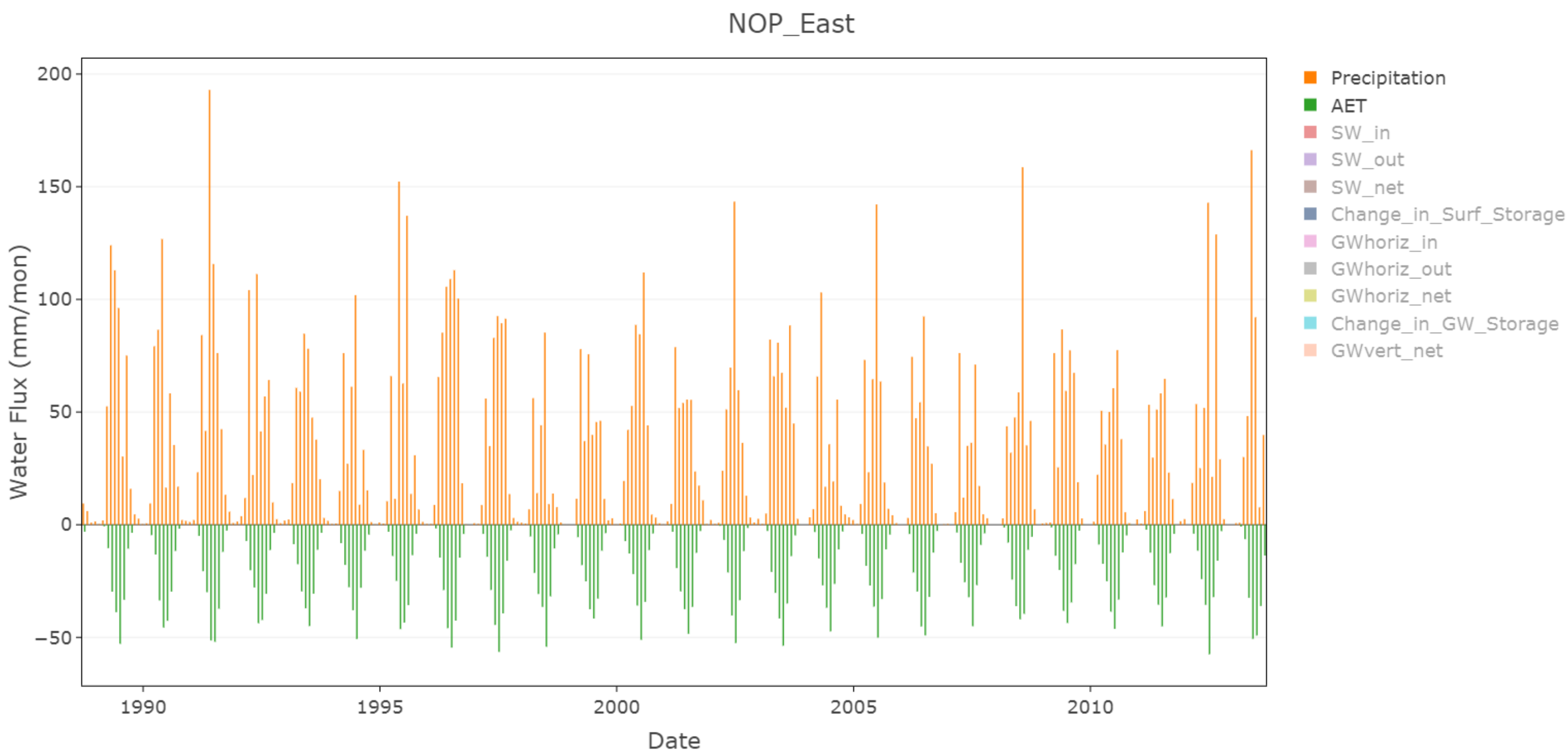

Figure 138 Predicted monthly precipitation and AET rates within HRA 15 from 1988-2013.

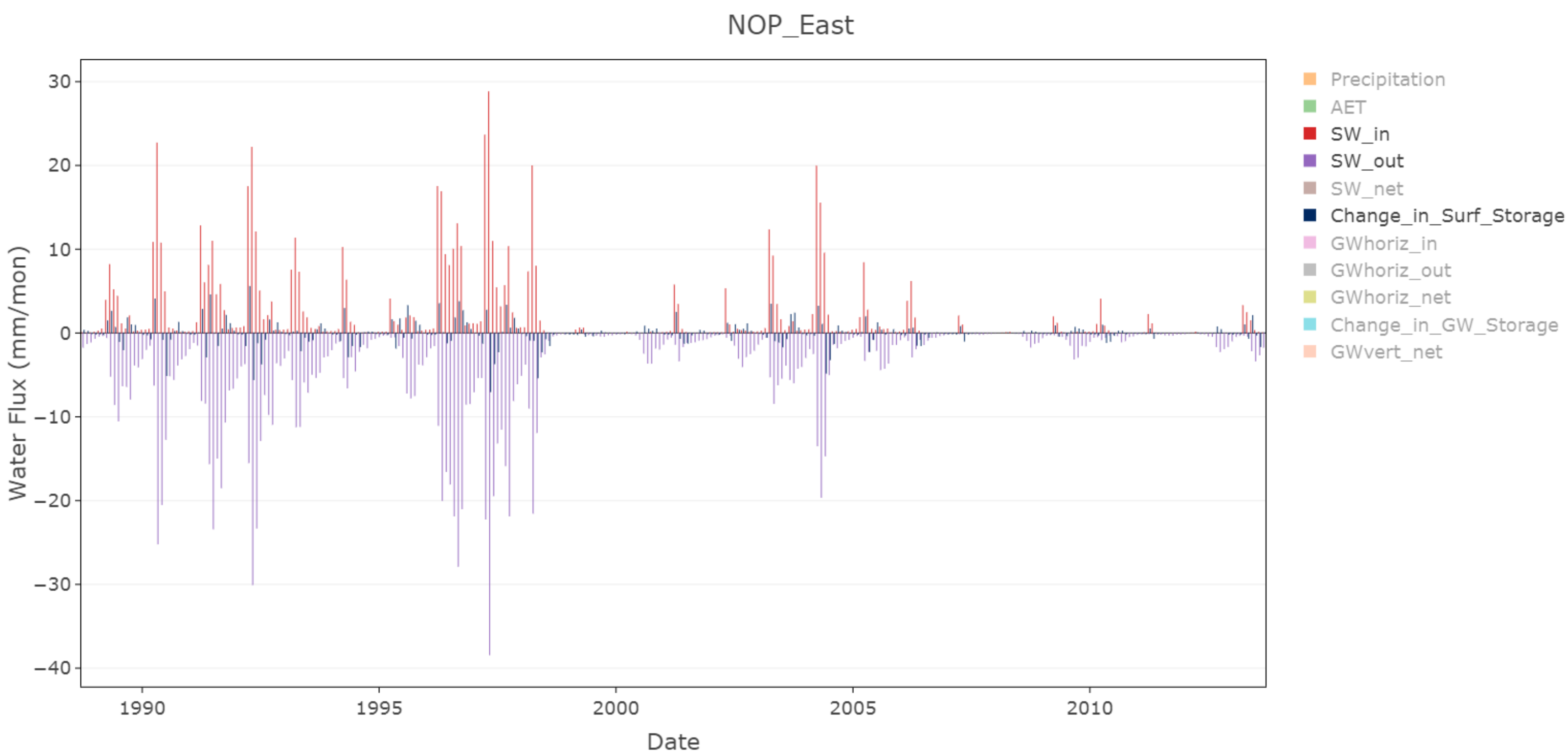

Figure 139 Predicted monthly surface water flows and storage within HRA 15 from 1988-2013.

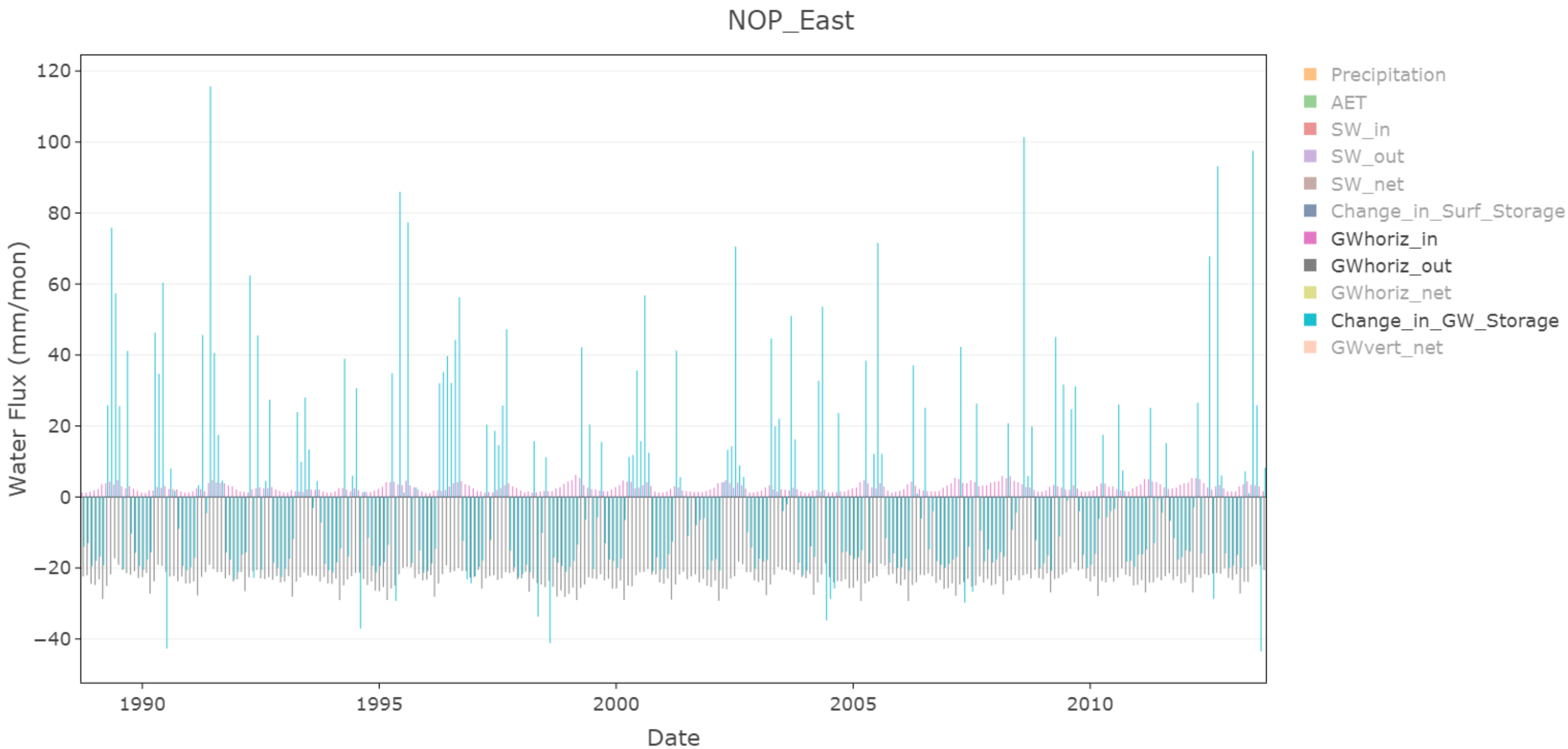

Figure 140 Predicted monthly groundwater flows and storage within HRA 15 from 1988-2013.

27. Section 1.3.16: HRA 16: North Outwash Plains West

HRA 16 is designated North Outwash Plains – West and a cross-section taken through this HRA is shown in Figure 141. HRA 16 covers an area of approximately 23.39 km^2 that has a mean slope of 1.12%, an aspect of 160.35 degrees azimuth and a mean elevation of 303.2 masl. The dominant land usages classes and forms present in HRA 16 are wooded coniferous upland (non-wetland) (20.34%) shrubby wetland (18.34%) and wooded coniferous burned (48.93%), respectively. The dominant soil is Mildred (92.62%) which is classified to drain rapidly. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 16 range from 6.9 to 47.9 m (Figure 142). The substrate is composed of topsoil, Surface Sands North and Silt Clay deposits. Substrate depths increase going southwest to northeast and there is a prominent deeper deposit north of HRA 16's circumcentre. Bedrock topography in HRA 16 (Clay Till 01) ranges from 259.3 to 298.7 masl and elevations become progressively lower southwest to northeast (Figure 143). Post-development, 64% of the HRA will remain undisturbed.

HRA 16 is conceptualized to primarily receive water from precipitation (refer to Figure 29, Figure 31 and Figure 141). The hydrogeochemistry of water in HRA 15 is conceptualized as being non-alkaline and cation-poor.

Water is conceptualized to leave HRA 16 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, evapotranspiration and outgoing groundwater. Groundwater from 16 discharges into HRAs 03, 05, 07, and 06. A small component of ephemeral drainage is conceptualized to exit into HRA 05 in the form of surface water. This HRA is composed primarily of surface sand deposits with a relatively deep water table and so the HRA would be expected to freeze honeycomb and permeable in the winter. Snowmelt runoff from this HRA during the spring freshet would be expected to be minimal. The hydrogeochemistry of this HRA would be expected to be dilute and non-alkaline in nature.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 16 was simulated to receive 77%, 8% and 15% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 16 was simulated to discharge 34%, 6% and 60% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 16 indicates that annual AET rates (197.4 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface (Figure 33); the HRA is simulated to have low saturation rates, corresponding to a deep water table (Figure 34) and the exchange of water across the land surface indicates HRA is primarily an infiltration region (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of groundwater. Proportionally slightly less water exits the HRA in the form of surface water than enters it annually. Proportionally much more water exits the HRA in the form of groundwater than enters it annually.

Figure 144 presents predicted average monthly water balance components over the period 1988-2013. HRA 16 is predicted to produce peak incoming and outgoing flows during April. This HRA adds to surface water storage August to October plus the month of June (September peak). The HRA sheds surface water November to March (December peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round. The HRA adds to groundwater storage April through September (April peak). The HRA consumes groundwater storage October to March (December peak).

Figure 145 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 16. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 146 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur March-June but usually happens in April. Peak monthly surface water out can occur March-June but usually happens in April. The largest monthly gain in surface water storage can occur anywhere March-September but most often happens in September. The maximum monthly consumption of surface water storage can occur March-December but typically happens in May. Figure 147 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-May but typically peaks in March. Peak monthly outgoing groundwater rates occur March-October but usually happen in October. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage usually happens May-December but usually occurs in December.

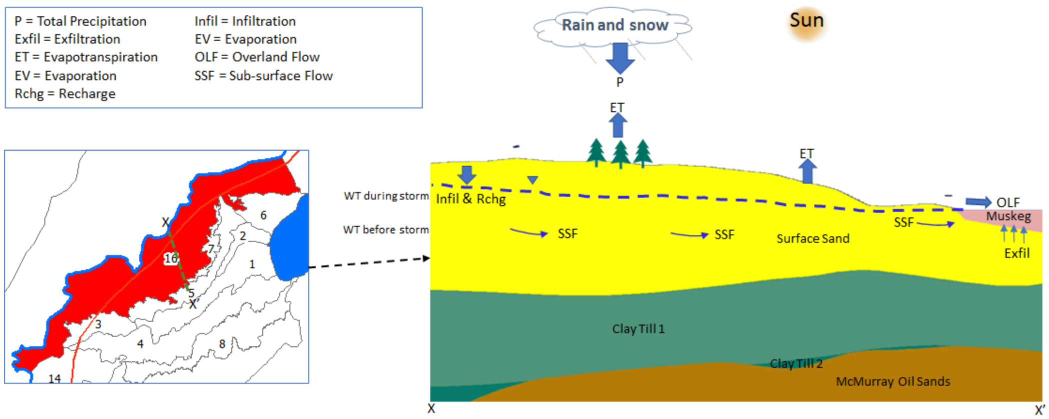

Figure 141 HRA 16: North Outwash Plains West. Vertical exaggeration is 80:1.

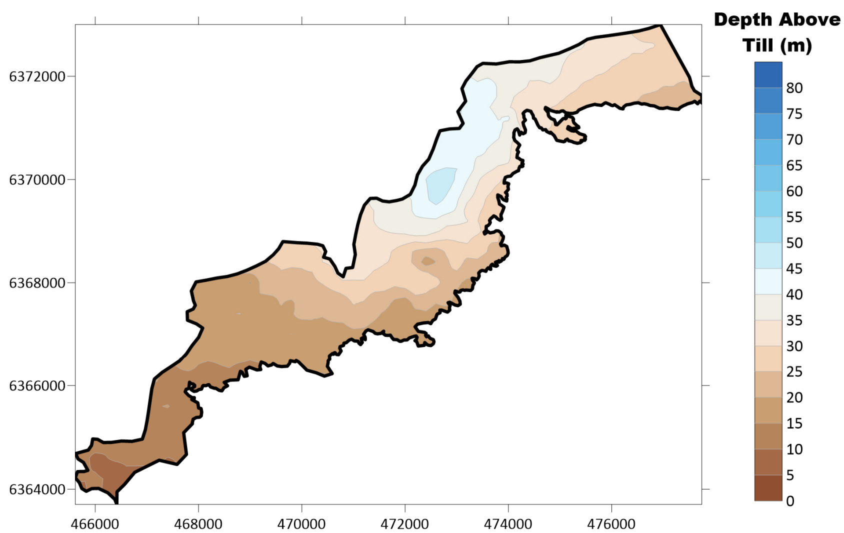

Figure 142 Substrate depths in HRA 16: North Outwash Plains West.

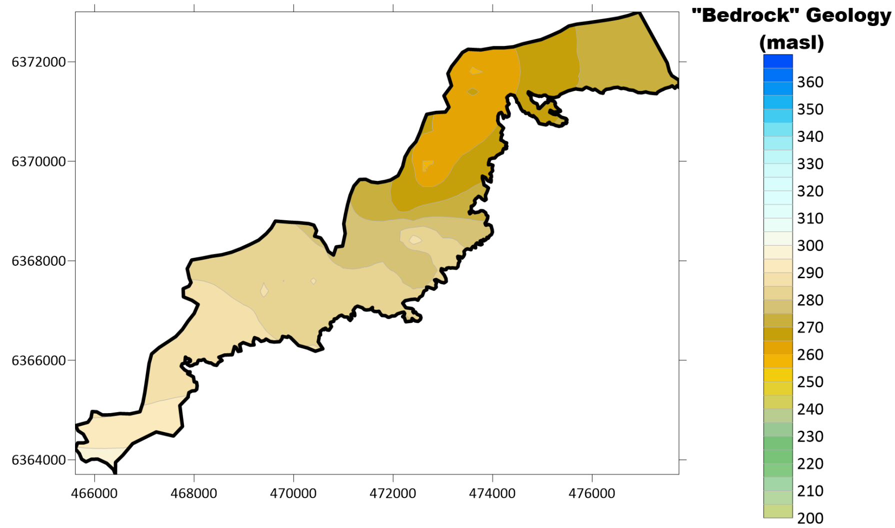

Figure 143 Bedrock topography in HRA 16: North Outwash Plains West.

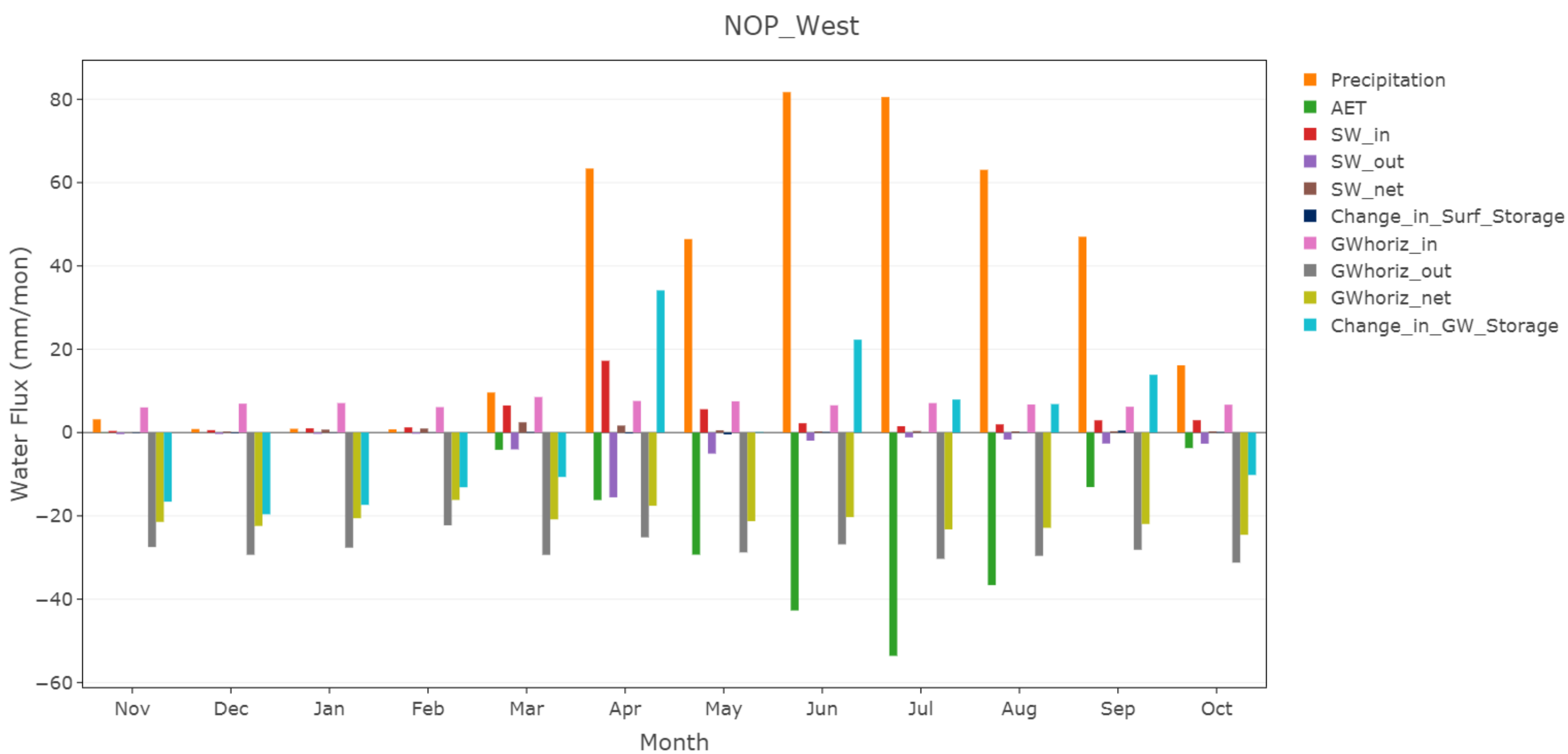

Figure 144 Mean monthly water budget components (1988-2013) for HRA 16: North Outwash Plains West. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

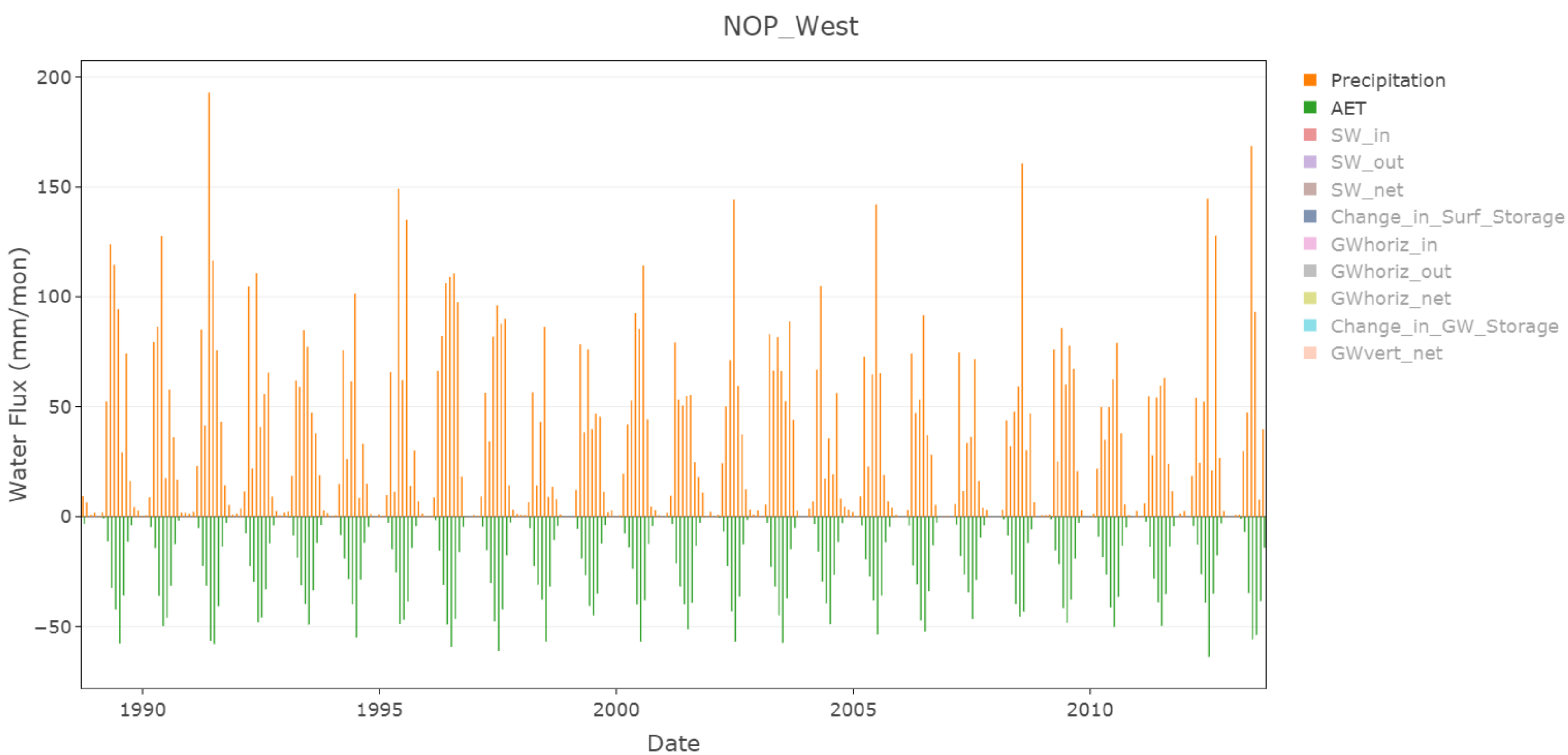

Figure 145 Predicted monthly precipitation and AET rates within HRA 16 from 1988-2013.

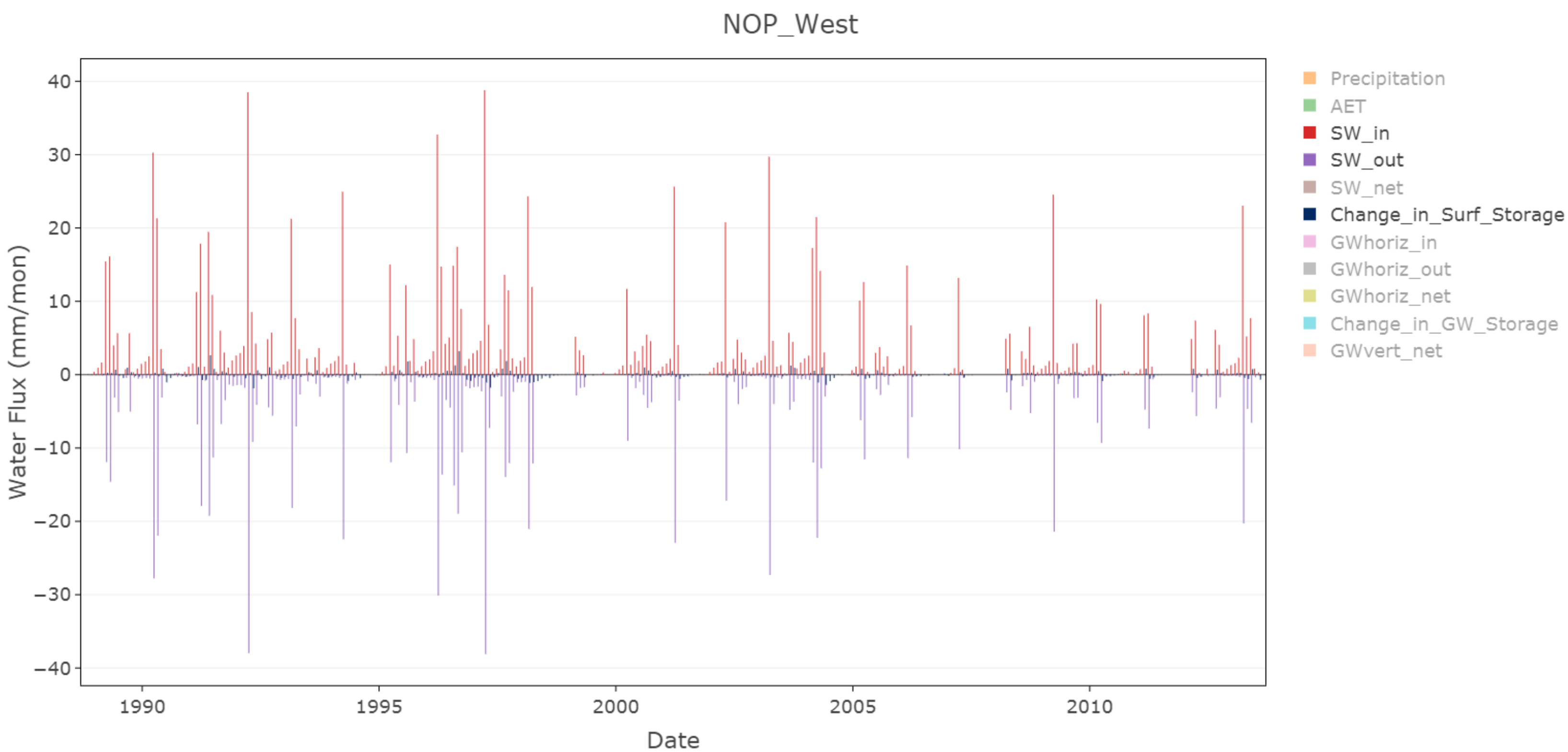

Figure 146 Predicted monthly surface water flows and storage within HRA 16 from 1988-2013.

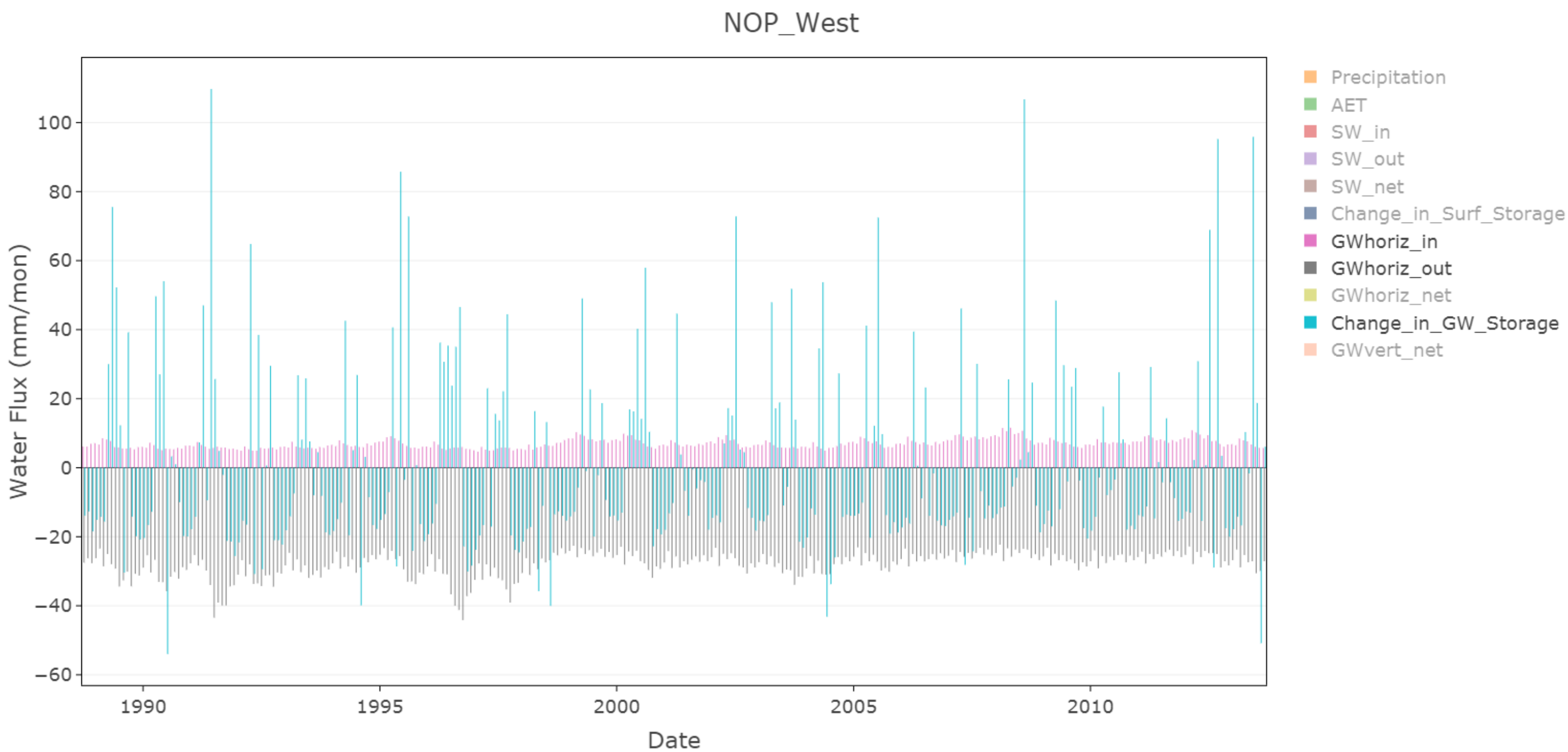

Figure 147 Predicted monthly groundwater flows and storage within HRA 16 from 1988-2013.

28. Section 1.3.17: HRA 17: Fort Hills West

HRA 17 is designated Fort Hills West and a cross-section taken through this HRA is shown in Figure 148. HRA 17 covers an area of approximately 37.62 km^2 that has a mean slope of 2.9%, an aspect of 189.31 degrees azimuth and a mean elevation of 334.02 masl. The dominant land usages classes and forms present in HRA 17 are wooded coniferous upland (non-wetland) (15.96%), mixed woods upland (non-wetland) (22.63%) and wooded deciduous upland (non-wetland) (53.41%), respectively. The dominant soil types are Firebag (46.77%), Kinosis (11.72%), Mildred 13.77%) and developed (16.83%), which are classified to drain rapidly – very rapidly, well, rapidly, respectively. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 17 range from 0.0 to 31.1 m, trending deeper south to north Figure 149). The substrate is composed of topsoil, Surface Sands North and Silt Clay deposits. Substrate depths in HRA 17 beyond the terminal edge of Clay Till 1 and above Clay Till 2 range between 22.3 to 76.0 m and consist primarily of silt sand deposits, trending deeper north to south. The Clay Till 1 “bedrock” topography in HRA 17 ranges from 298.9 to 349.2 masl, trending upward north to south (Figure 150). The Clay Till 2 “bedrock” topography in HRA 17 ranges from 270.3 to 327.0 masl and is undulating. Post-development, 59% of the HRA will remain undisturbed.

HRA 17 is conceptualized to receive water from precipitation and flows from HRA 19 and 18 (refer to Figure 29, Figure 31 and Figure 148). Groundwater flows originating from HRA 19 can flow into the western edge of HRA 17. Surface water flow from a spring above a hydraulic window located in HRA 18 and HRA 17 flows into HRA 08. The location of this hydraulic window in is outlined in white and shown in Figure 31.

Water is conceptualized to leave HRA 17 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, outgoing groundwater and evapotranspiration. Surface water from HRA 17 discharges into HRAs 14 and 08 while groundwater discharges into HRAs 14, 08 and 04. The origin of surface water flows from HRA 17 is a combination of groundwater discharging into the rills and gullies located along the lower slopes of the FHUC coupled with advective groundwater flows from the silt sand deposits over the terminal edge of the Clay Till 1 deposit. Seepage faces are assumed to form along the joint boundary of HRA 08 and 17 where the stratigraphy transitions from permeable sands to the tills or the silt clay lying at surface in HRA 08. The hydrogeochemistry of the water in HRA 17 is conceptualized to be (relatively) alkaline and cation-rich. The ground in HRA 17 would be expected to freeze solid in regions covered at surface with Silt Clay or Clay Till 1 (e.g., the areas of the HRA sitting over the eastern half of HRA 14 and the western third of HRA 08, respectively). Conversely, the remainder of the HRA is covered with surface sands or silt sands and those regions would be expected to freeze more honeycomb and permeable in the winter. The ground in HRA 17 that freezes solid would also be expected to generate runoff into the MLWC lowlands during the spring freshet, whereas snowmelt would be expected to infiltrate into the ground in the remainder of the HRA.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 17 was simulated to receive 92%, 0% and 8% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 17 was simulated to discharge 53%, 14% and 33% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 17 indicates that annual AET rates (243.7 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface across most of the HRA and gets near surface along portions of it southern margin (Figure 33); the HRA is simulated to have low saturation rates except near surface drainage features (Figure 34) and the exchange of water across the land surface indicates HRA is primarily an infiltration region with localized areas of exfiltration where there is a surface drainage feature or a shift to less permeable materials at surface (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of evapotranspiration. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally much more water exits the HRA in the form of groundwater than enters it annually.

Figure 151 presents predicted average monthly water balance components over the period 1988-2013. HRA 17 is predicted to produce peak outgoing surface water flows during April; there are no incoming surface water flows. This HRA adds to surface water storage August to February (November peak). The HRA consumes surface water March to July (April peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round; outflow rates are consistently larger than inflow rates of groundwater. The HRA adds to groundwater storage in April (the peak) and June through September. The HRA consumes groundwater storage in May and October to March (December peak).

Figure 152 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 17. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen between June-August but usually occur in July. Figure 153 shows the surface water balance components (flow in, flow out and change in storage). There is no appreciable incoming surface water in this HRA. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur September-November but most often happens in November. The maximum monthly consumption of surface water storage can occur anytime March-May but typically happens in April. Figure 154 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur anytime between March-October but typically peaks in March. Peak monthly groundwater discharge rates occur between March-October but usually happen in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage usually happens March-December but usually occurs in December.

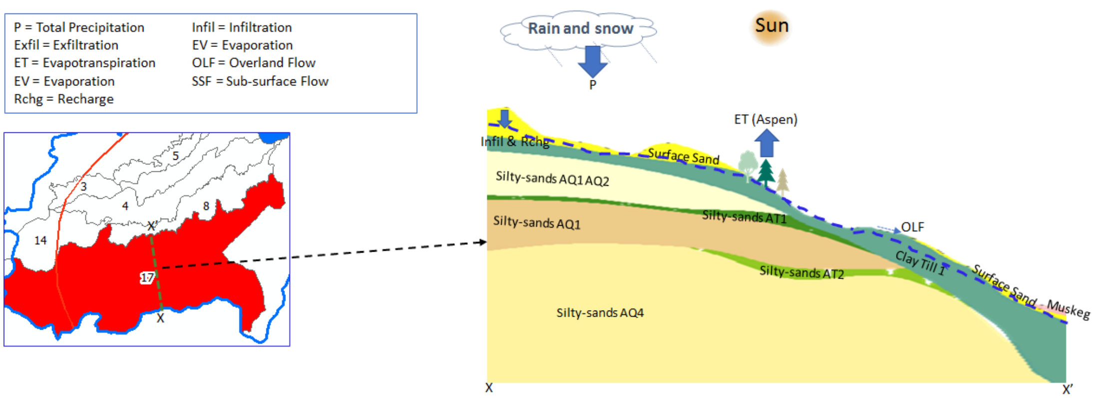

Figure 148 HRA 17: Fort Hills West. Vertical exaggeration is 80:1.

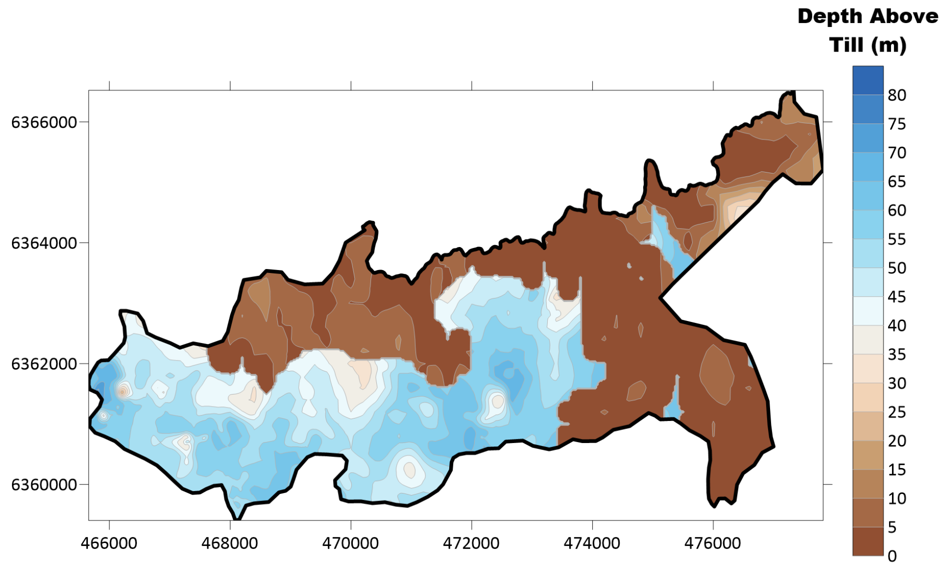

Figure 149 Substrate depths in HRA 17: Fort Hills West.

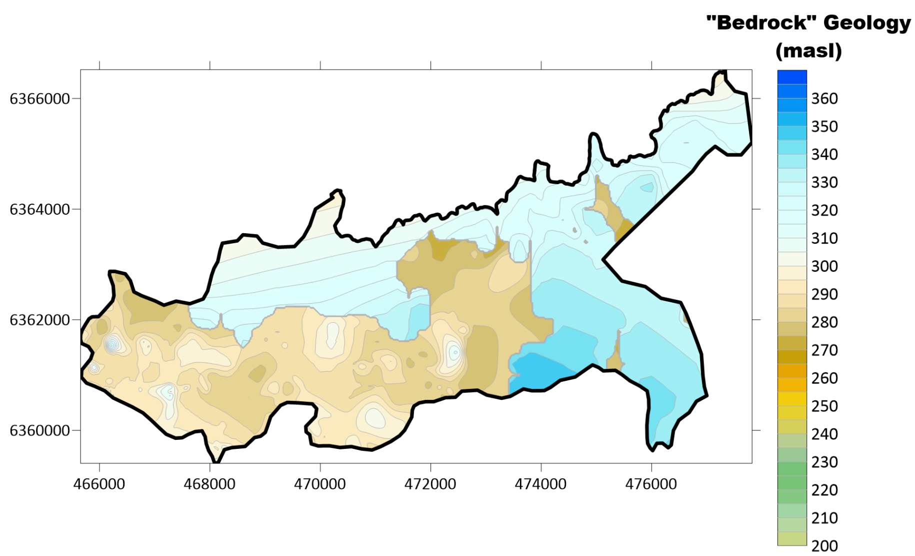

Figure 150 Bedrock topography in HRA 17: Fort Hills West.

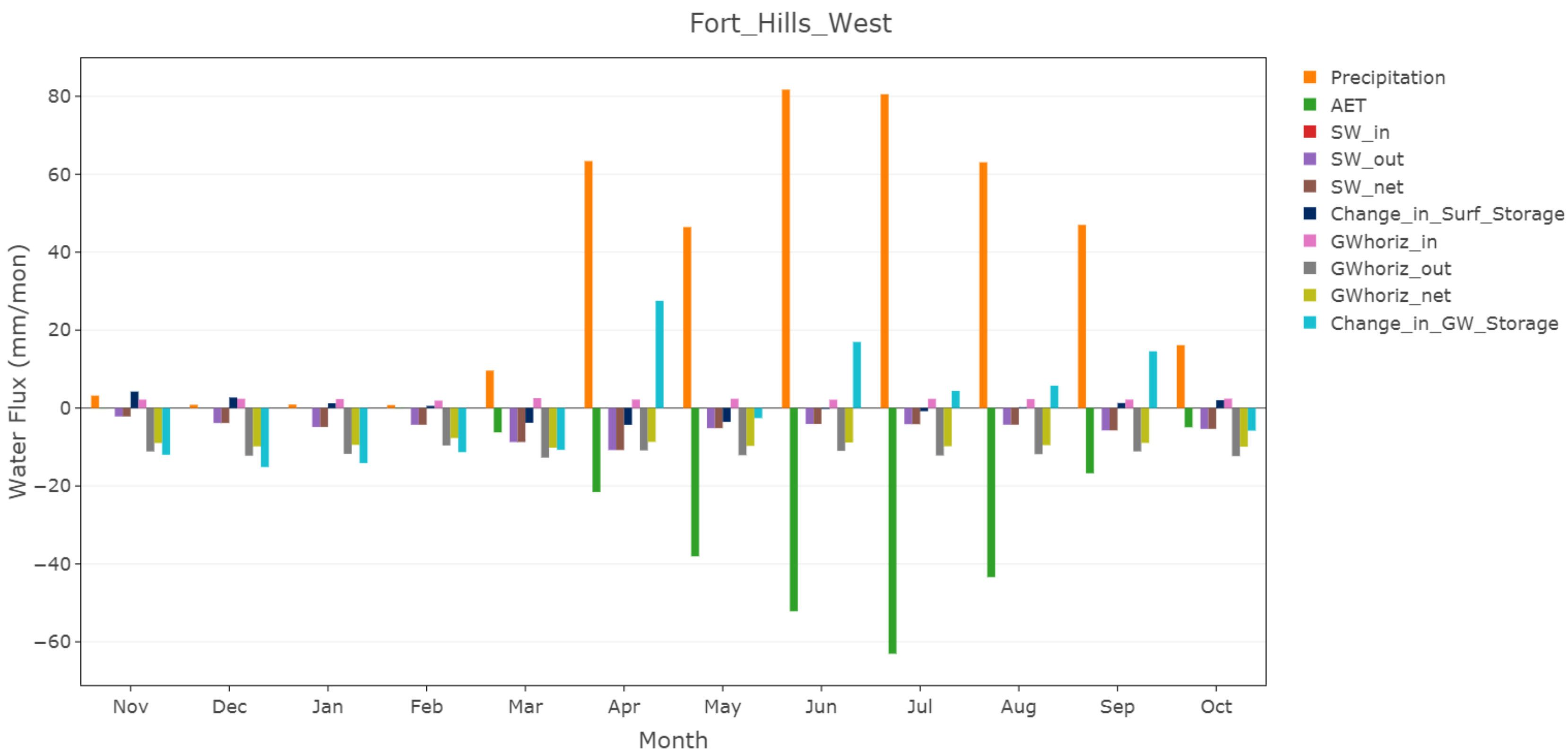

Figure 151 Mean monthly water budget components (1988-2013) for HRA 17: Fort Hills West. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

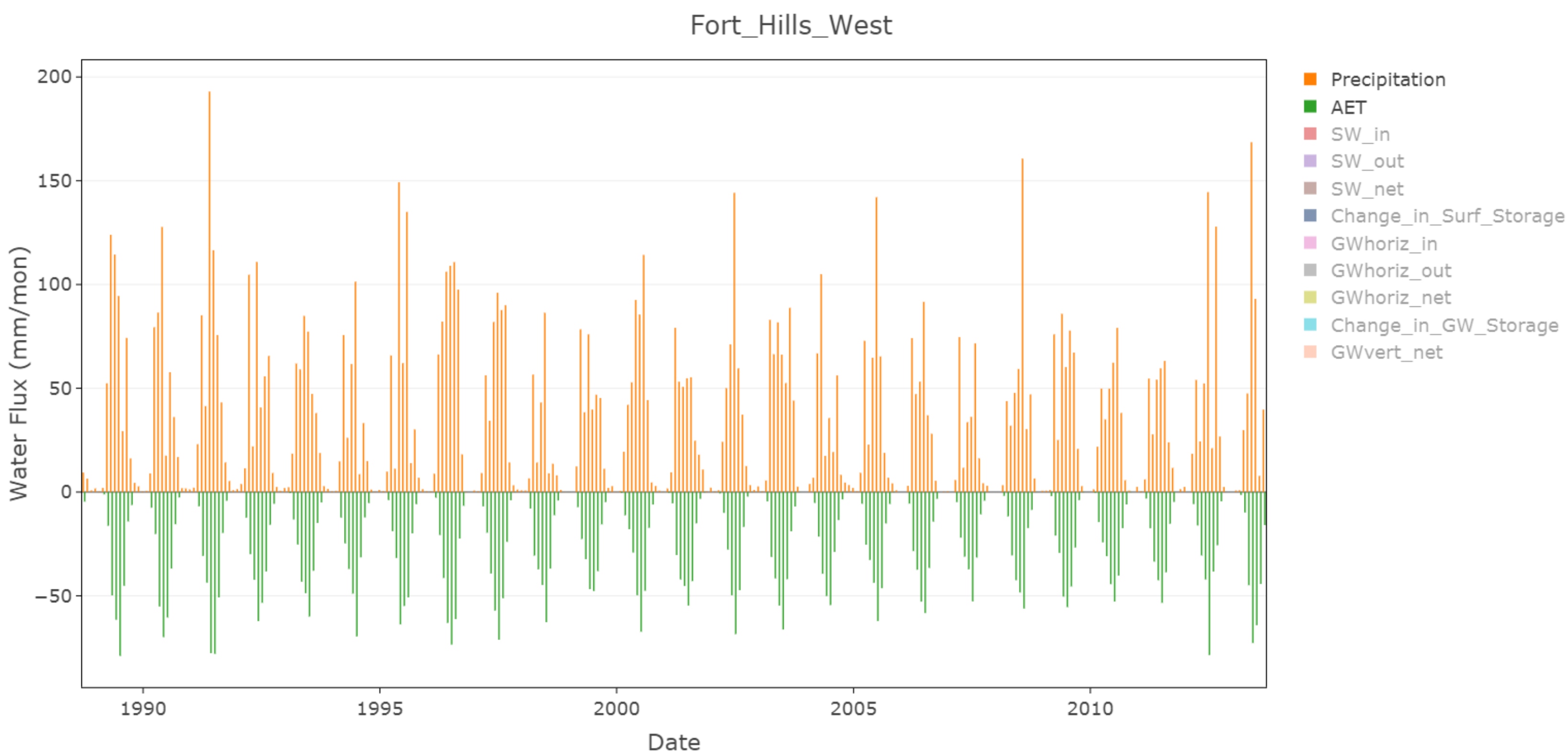

Figure 152 Predicted monthly precipitation and AET rates within HRA 17 from 1988-2013.

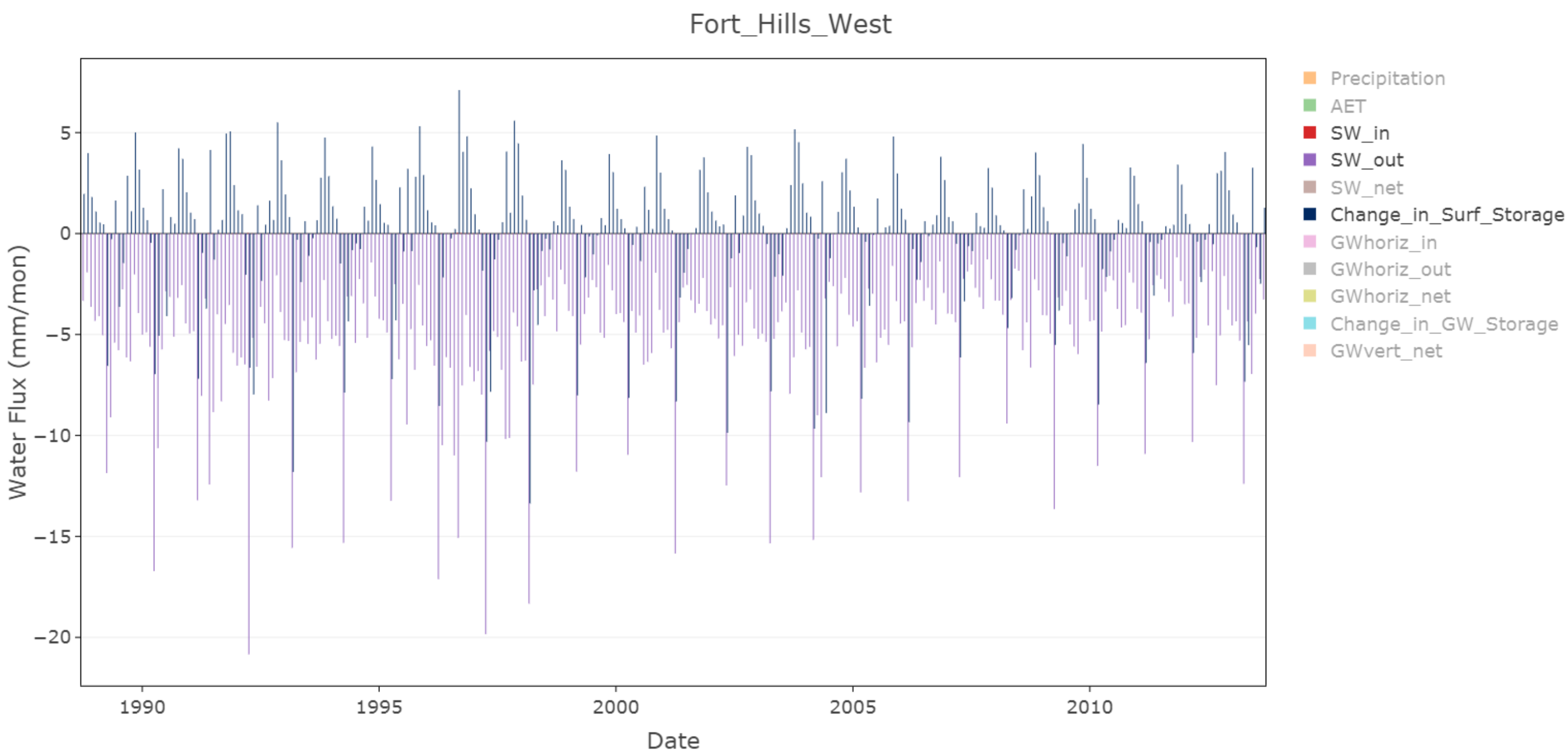

Figure 153 Predicted monthly surface water flows and storage within HRA 17 from 1988-2013.

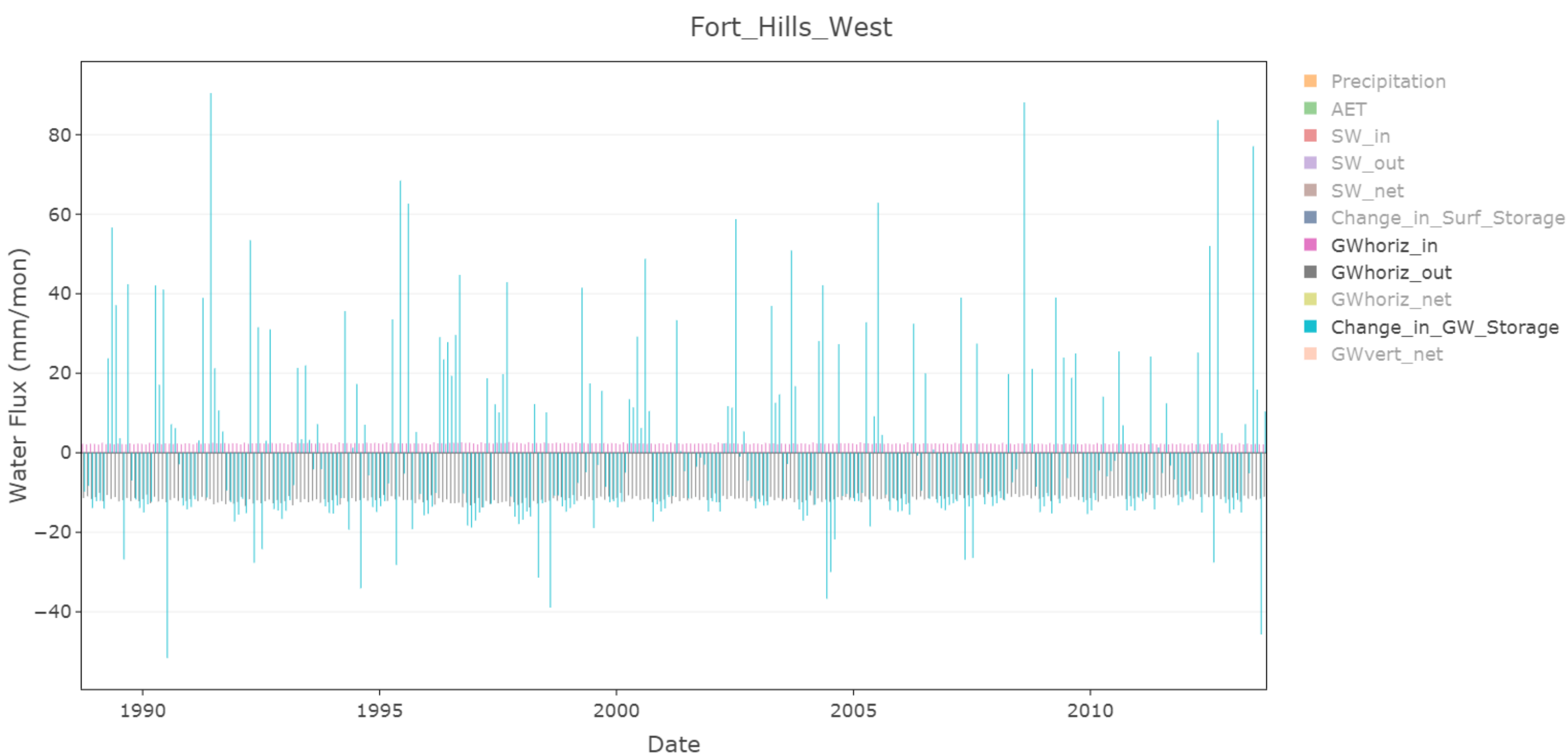

Figure 154 Predicted monthly groundwater flows and storage within HRA 17 from 1988-2013.

29. Section 1.3.18: HRA 18: Fort Hills East

HRA 18 is designated Fort Hill East and a cross-section taken through this HRA is shown in Figure 155. HRA 18 covers an area of approximately 32.53 km^2 that has a mean slope of 3.729%, an aspect of 194.6 degrees azimuth and a mean elevation of 319.42 masl. The dominant land usages classes and forms present in HRA 18 are mixed woods upland (non-wetland) (14.76%), wooded deciduous upland (non-wetland) (21.79%) and shrubby upland (non-wetland) (26.88%), respectively. The dominant soils are Bitumount (43.63%) and Mildred (37.15%) which are classified to drain poorly and rapidly, respectively. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 18 range from 0.0 to 31.6 m, trending deeper south to north (Figure 156). The substrate is composed of topsoil, Surface Sands North, Surface Sands South, Muskeg and Silt Clay deposits. Substrate depths in HRA 18 above Clay Till 2 range between 19.0 to 78.1 m and consist primarily of silt sand deposits, generally trending shallower south to north. Similar to HRA 11, ITK holders have also observed that the clay deposits in this area can be deep and a safety concern to traverse (FMFN ITK holder, March 3, 2021 workshop). The Clay Till 1 "bedrock" topography in HRA 18 ranges from 298.9 to 349.2 masl, trending upward north to south (Figure 157). The Clay Till 2 "bedrock" topography in HRA 18 ranges from 270.3 to 327.0 masl and is undulating. Post-development, 100% of the HRA will remain undisturbed.

> *"Like that area I took [industry rep] that first time in 2003, I think, or 2002 – he was like "I have a 4x4" - and his tires just spin and start bringing up water right away! Yeah and that place was exactly the same as the one by dad's [Ian Faichney] cabin [SW shore of McClelland Lake], about the same size waterhole too...That whole area is dangerous, and you need to watch your footing, watch your kids, where you walk. Be observant"* (FMFN ITK holder, March 3, 2021 workshop)

HRA 18 is conceptualized to receive water from precipitation and flows from HRA 09 (refer to Figure 29, Figure 31 and Figure 155). Surface water and groundwater can enter HRA 18 from the southeastern shores of McClelland Lake.

Water is conceptualized to leave HRA 18 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evapotranspiration. Discharge from HRA 18 flows into HRAs 17, 11, 12, and 13. Discharge from the large hydraulic window in HRA 18 shown in Figure 31 that flowing either west-northwest or north enters HRA 17 in the form of surface water.

Flows from the same large hydraulic windows that flow north-northeast enter South Creek and eventually discharge into HRA 11 by McClelland Lake. Discharge from the smaller hydraulic window located by the southwest shoreline of McClelland Lake flows into HRA 08 as surface water. Groundwater discharging into rills located along the central eastern FHUC slopes in HRA 18 enters HRAs 11 and 12 from the south. Seepage faces are expected to form along the southern shores of Unnamed Lake where it meets HRA 18 that contribute waters to that lake. An additional rill receiving groundwater in HRA 18 flows into HRA 12 from the east. The hydrogeochemistry of waters in HRA 18 are conceptualized to be (relatively) alkaline and cation-rich. The majority of HRA 18 has relatively thick surface sand deposits at surface and that ground would be expected to freeze honeycomb and permeable in the winter. Substrate thicknesses are quite thin along South Creek, which meanders within its channel and contains a number of wetlands along its extent. In these areas of HRA 18, the ground would be expected to freeze more solid and also generate a degree of runoff during the freshet.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 17 was simulated to receive 85%, 8% and 7% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 17 was simulated to discharge 53%, 24% and 23% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 17 indicates that annual AET rates (275.2 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface across most of the HRA except by South Creek (Figure 33); the HRA is simulated to have relatively low saturation rates near surface except by South Creek (Figure 34) and the exchange of water across the land surface indicates HRA is primarily an infiltration region with localized areas of exfiltration along South Creek and near Unnamed Lake where substrate depths are shallow (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of evapotranspiration. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally more water exits the HRA in the form of groundwater than enters it annually.

Figure 158 presents predicted average monthly water balance components over the period 1988-2013. HRA 18 is predicted to produce peak incoming and outgoing surface water flows during April. This HRA adds to surface water storage September to February (November peak). The HRA consumes surface water storage March to July (April peak). Peak rainfall rates occur in June and peak AET rates in July.

Groundwater flows into and out of the HRA at a fairly constant rate year round; outflow rates are consistently larger than inflow rates of groundwater. The HRA adds to groundwater storage in April (the peak) and June through September. The HRA consumes groundwater storage in May and October to March (December peak).

Figure 159 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 18. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 160 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur April-July but usually happens in April. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur September-November but most often happens in November. The maximum monthly consumption of surface water storage can occur anytime March-May but typically happens in April. Figure 161 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur anytime March-October but typically peaks in March. Peak monthly groundwater discharge occur March-October but usually happen in October. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage usually happens May-December but usually occurs in December.

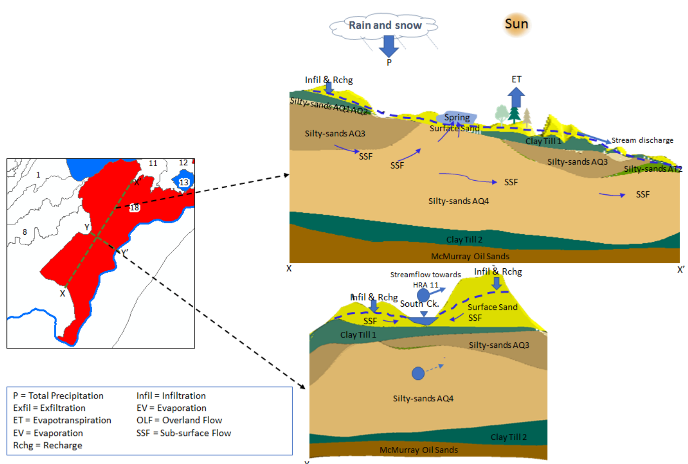

Figure 155 HRA 18: Fort Hills East. Vertical exaggeration is 80:1.

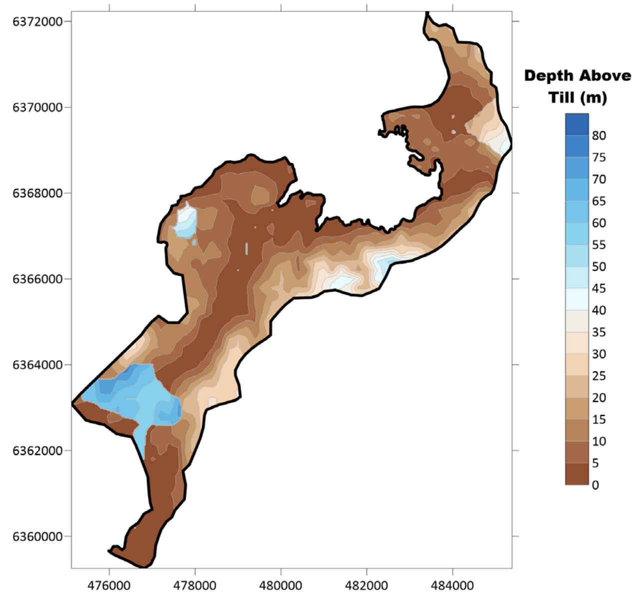

Figure 156 Substrate depths in HRA 18: Fort Hills East.

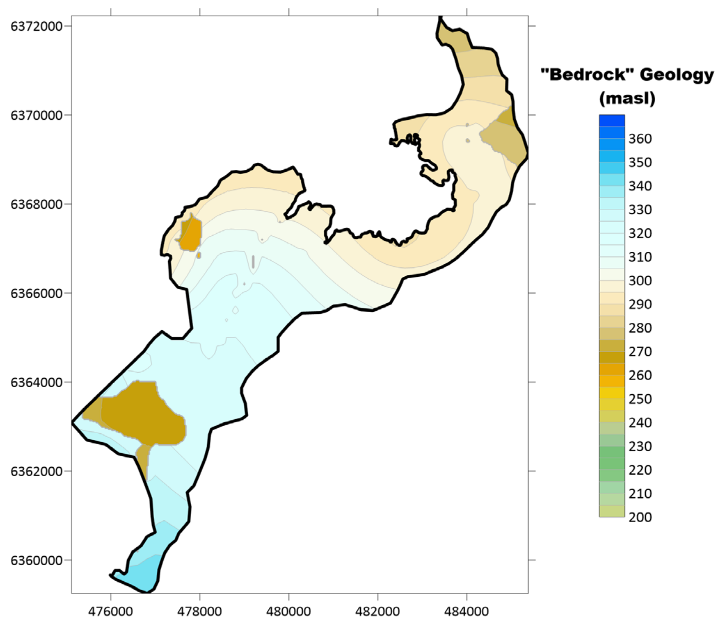

Figure 157 Bedrock topography in HRA 18: Fort Hills East.

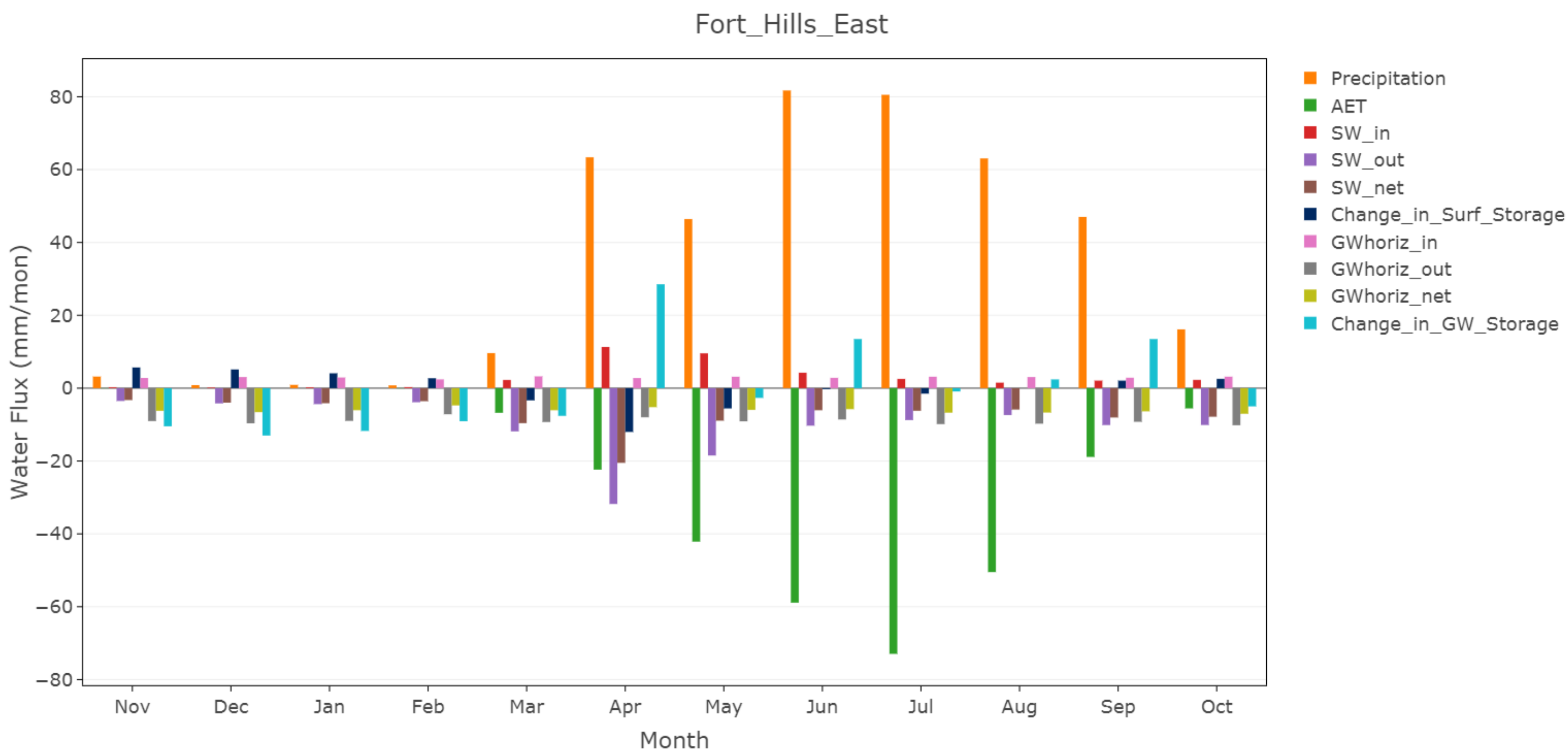

Figure 158 Mean monthly water budget components (1988-2013) for HRA 18: Fort Hills East. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

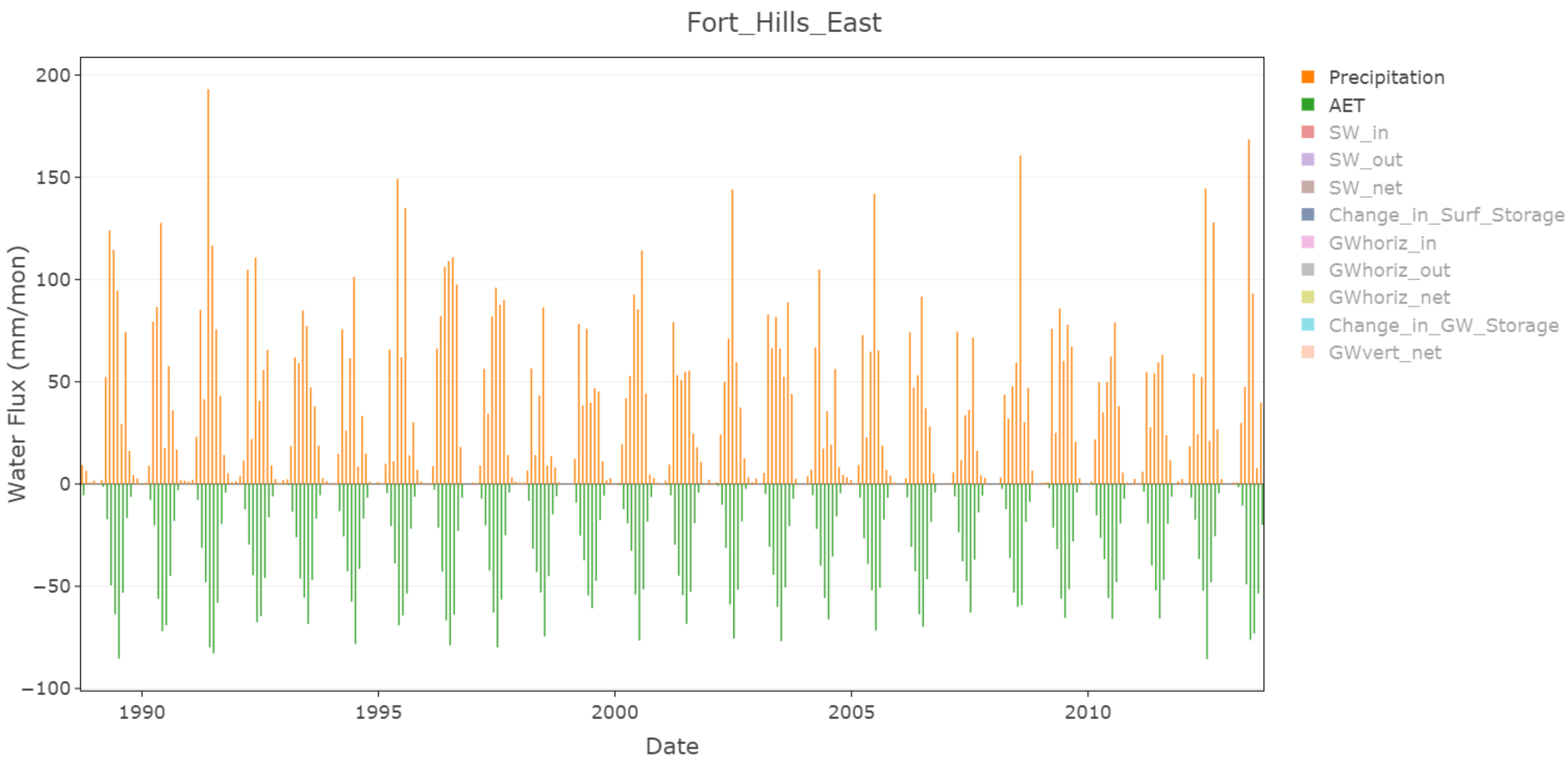

Figure 159 Predicted monthly precipitation and AET rates within HRA 18 from 1988-2013.

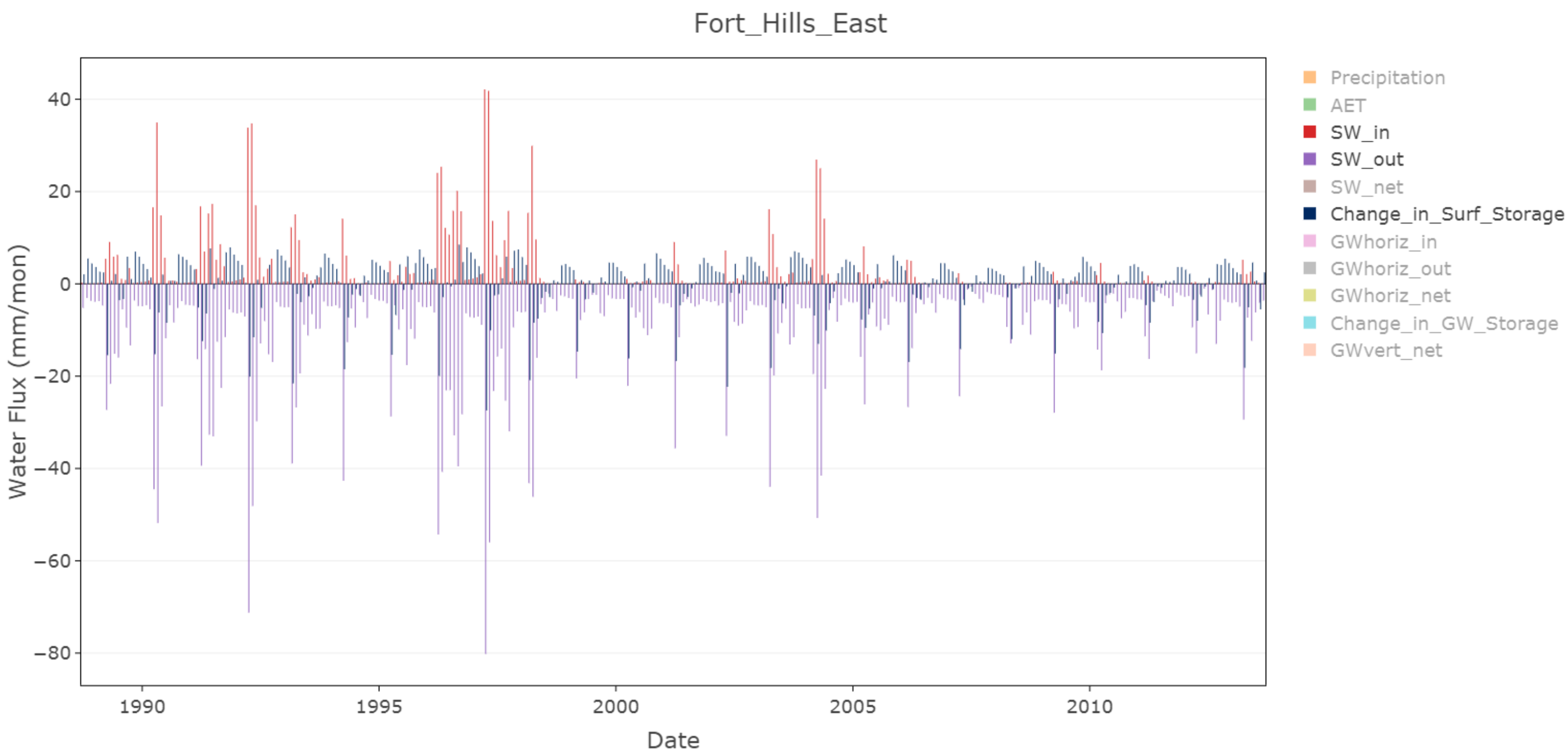

Figure 160 Predicted monthly surface water flows and storage within HRA 18 from 1988-2013.

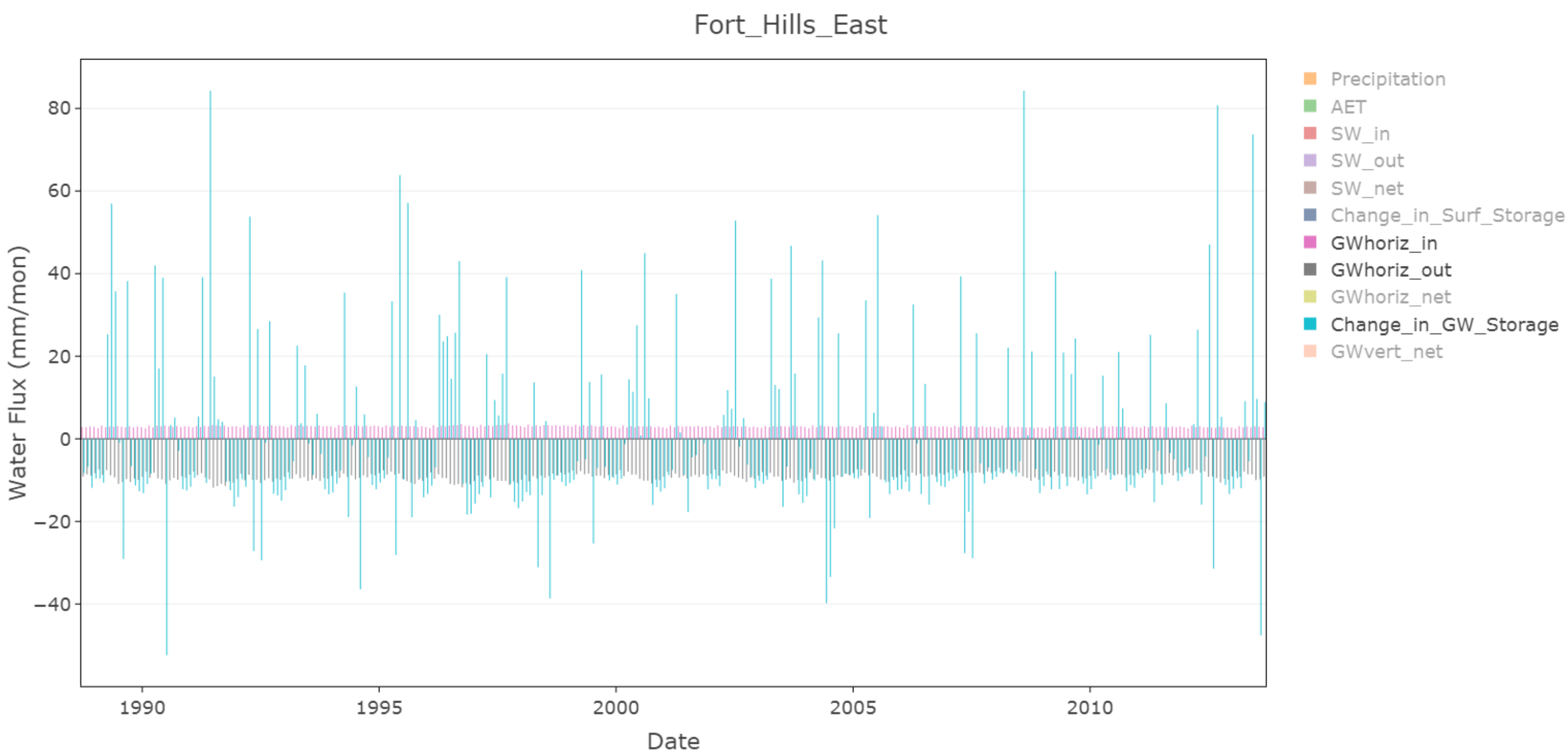

Figure 161 Predicted monthly groundwater flows and storage within HRA 18 from 1988-2013.

30. Section 1.3.19: HRA 19: Fort Hills South

HRA 19 is designated Fort Hills South and a cross-section taken through this HRA is shown in Figure 162. HRA 19 covers an area of approximately 85.58 km^2 that has a mean slope of 4.18%, an aspect of 175.71 degrees azimuth and a mean elevation of 332.27 masl. The dominant land usages classes and forms present in HRA 19 are wooded coniferous upland (non-wetland) (42.23%) and wooded deciduous upland (non-wetland) (22.78%), respectively. The dominant soil is Firebag which is classified to drain rapidly – very rapidly. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 19 range from 0.0 to 47.1 m, trending shallower southwest to northeast where present (Figure 163) and are composed of topsoil, Surface Sands South and Silt Clay deposits. Substrate depths in HRA 19 above Clay Till 2 range between 0.1 to 80.6 m. This substrate consists primarily of silt sand deposits, generally trending shallower south to north. The Clay Till 1 “bedrock” topography in HRA 19 ranges from 273.3 to 358.4 masl, trending downward west to east (Figure 164). The Clay Till 2 “bedrock” topography in HRA 19 ranges from 268.2 to 329.0 masl and is undulating. Post-development, 70% of the HRA will remain undisturbed.

HRA 19 is conceptualized to primarily receive water from precipitation (refer to Figure 29, Figure 31 and Figure 162). The hydrogeochemistry of HRA 19 waters are conceptualized to be (relatively) alkaline and cation-rich.

Water is conceptualized to leave HRA 19 (in ascending order of conceptualized relative contribution) in the forms of outgoing groundwater, outgoing surface water and evapotranspiration. A small component of groundwater is conceptualized to flow into HRA 17 from the northwestern extent of HRA 19 (and then continue north). For the bulk of HRA 19 however, precipitation recharges the groundwater system and then exits the HRA by advective groundwater flows to the south, either: a) discharging into the Muskeg River system at the base of the Firebag Moraine, b) discharging onto the southern portion of the Fort Hills Lease near the Athabasca River valley or c) exfiltrating as seepage along the southern slopes of the moraine before running off into either the Muskeg River valley or the Fort Hills lease. HRA 19 contains portions Stanley Creek which discharges into the Muskeg River valley. Snowmelt in this HRA is conceptualized to infiltrate and recharge the groundwater system.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 19 was simulated to receive 94%, 0% and 6% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 19 was simulated to discharge 49%, 31% and 20% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 19 indicates that annual AET rates (219.6 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface (Figure 33); the HRA is simulated to have low saturation rates across most of its extent (Figure 34) and the exchange of water across the land surface indicates HRA is primarily an infiltration region except in the vicinities of surface drainage features where exfiltration is predicted to often occur (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of evapotranspiration. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally more water exits the HRA in the form of groundwater than enters it annually.

Figure 165 presents predicted average monthly water balance components over the period 1988-2013. HRA 19 is predicted to produce peak outgoing surface water flows during April; there are no incoming surface water flows in this HRA. This HRA adds to surface water storage September to February (November peak). The HRA consumes surface water storage March to July (April peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round; outflow rates are consistently larger than inflow rates of groundwater. The HRA adds to groundwater storage in April (the peak) through September. The HRA consumes groundwater storage October to March (December peak).

Figure 166 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 19. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-August but usually occur in July. Figure 167 shows the surface water balance components (flow in, flow out and change in storage). There is no appreciable surface water entering this HRA. Peak monthly surface water out can occur March-May but usually happens in April. The largest monthly gain in surface water storage can occur anywhere June-November but most often happens in November. The maximum monthly consumption of surface water storage can occur anytime March-May but typically happens in April. Figure 168 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates can occur March-October but typically peaks in March. Peak monthly groundwater discharge rates occur March-October but usually happen in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage happens May-December but usually occurs in December.

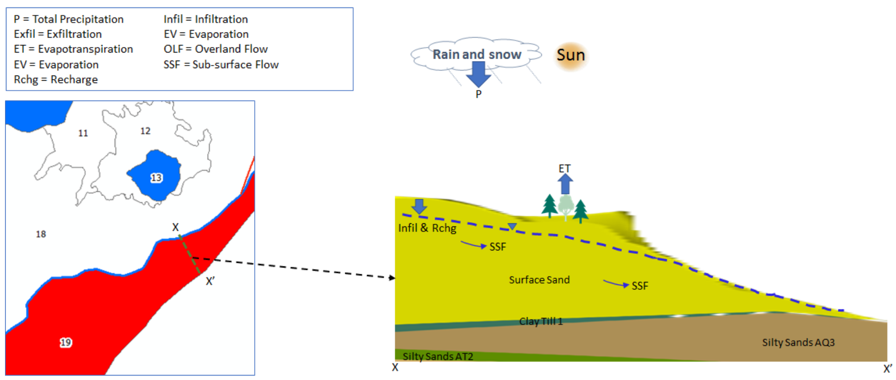

Figure 162 HRA 19: Fort Hills South. Vertical exaggeration is 80:1.

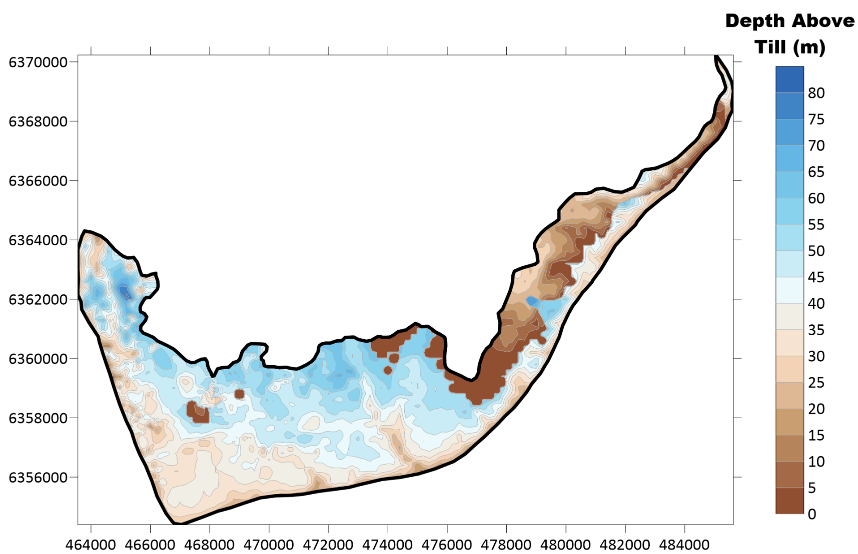

Figure 163 Substrate depths in HRA 19: Fort Hills South.

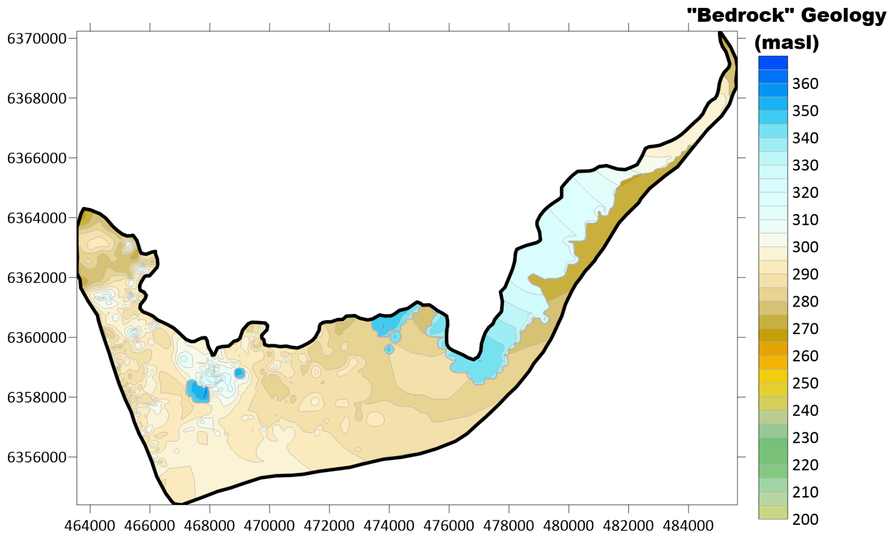

Figure 164 Bedrock topography in HRA 19: Fort Hills South.

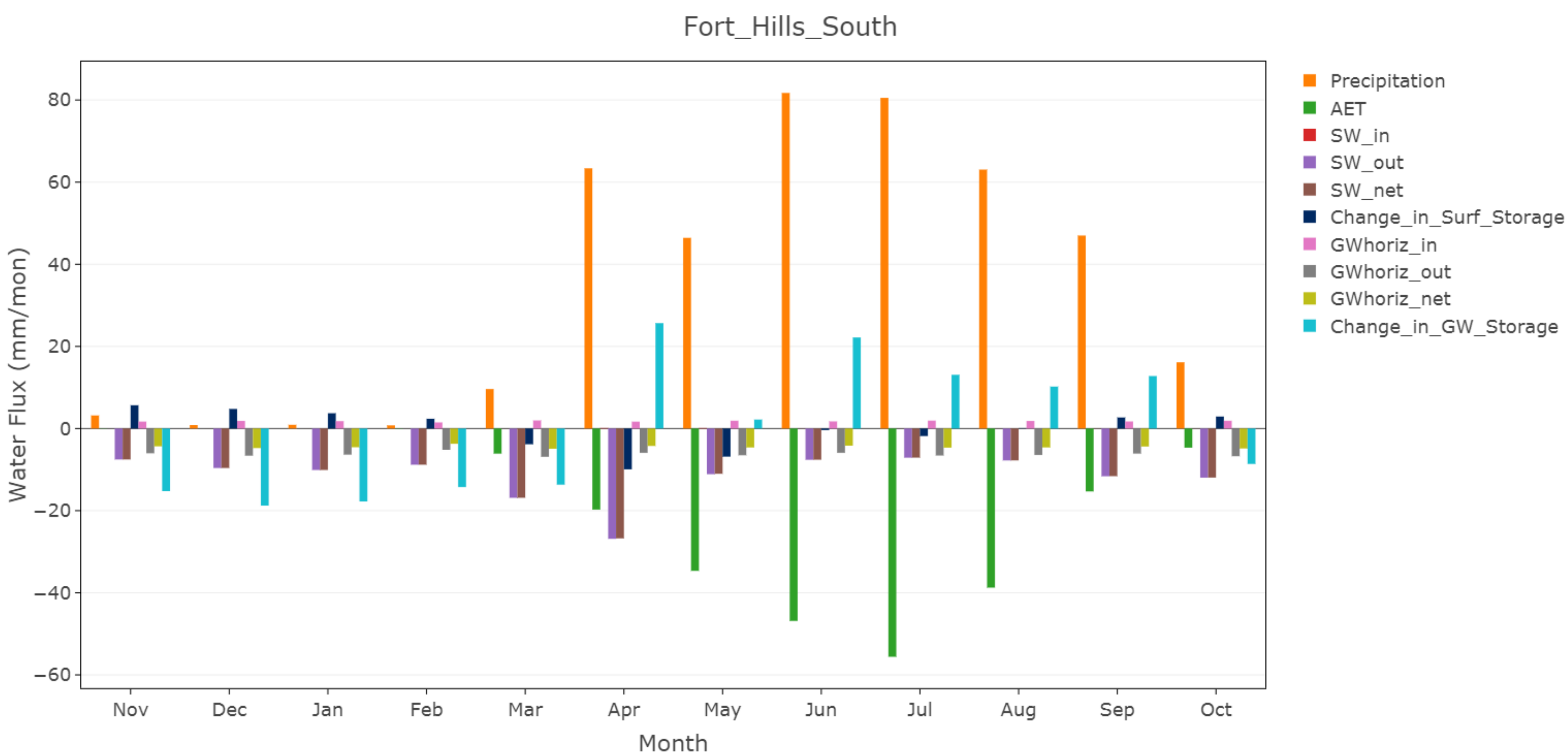

Figure 165 Mean monthly water budget components (1988-2013) for HRA 19: Fort Hills South. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

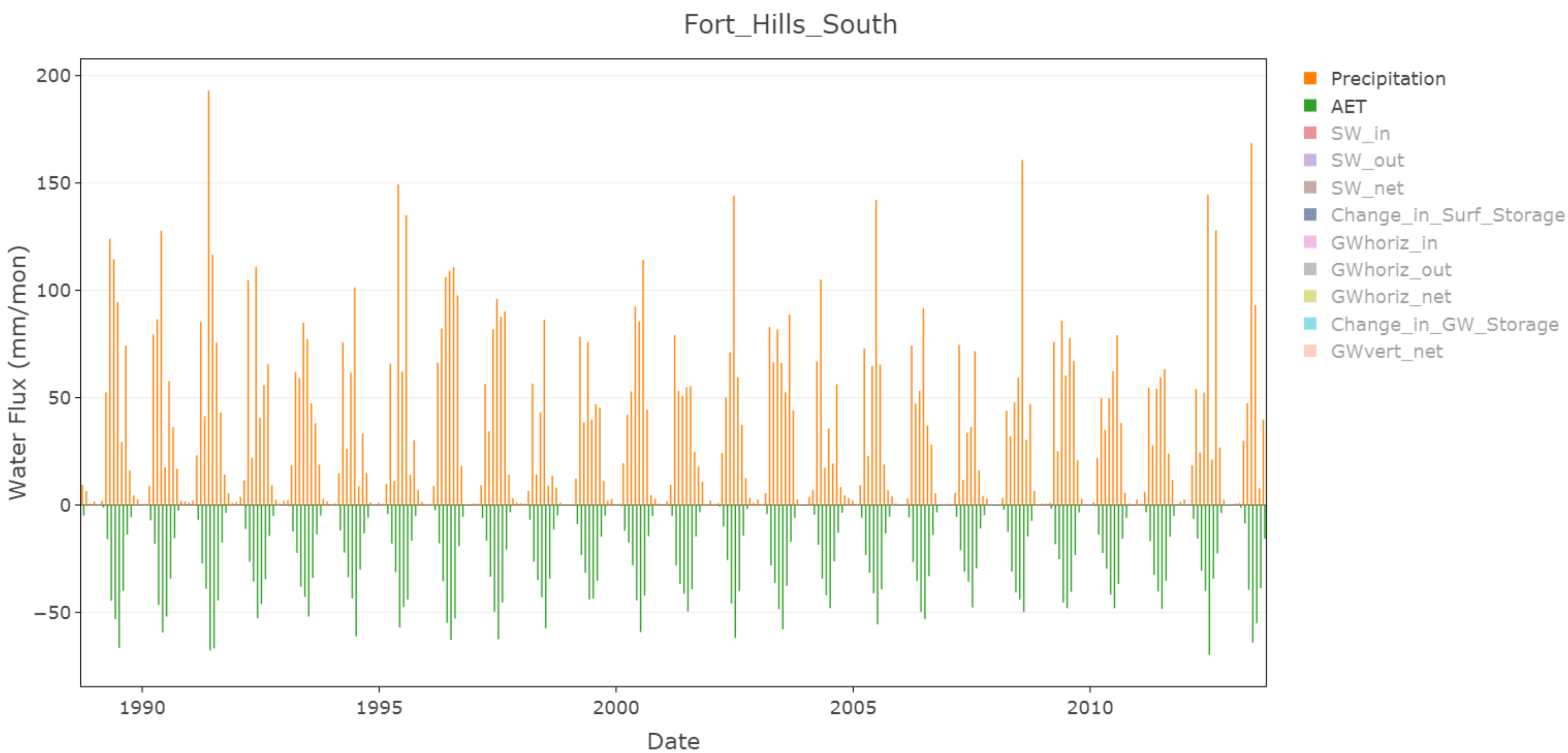

Figure 166 Predicted monthly precipitation and AET rates within HRA 19 from 1988-2013.

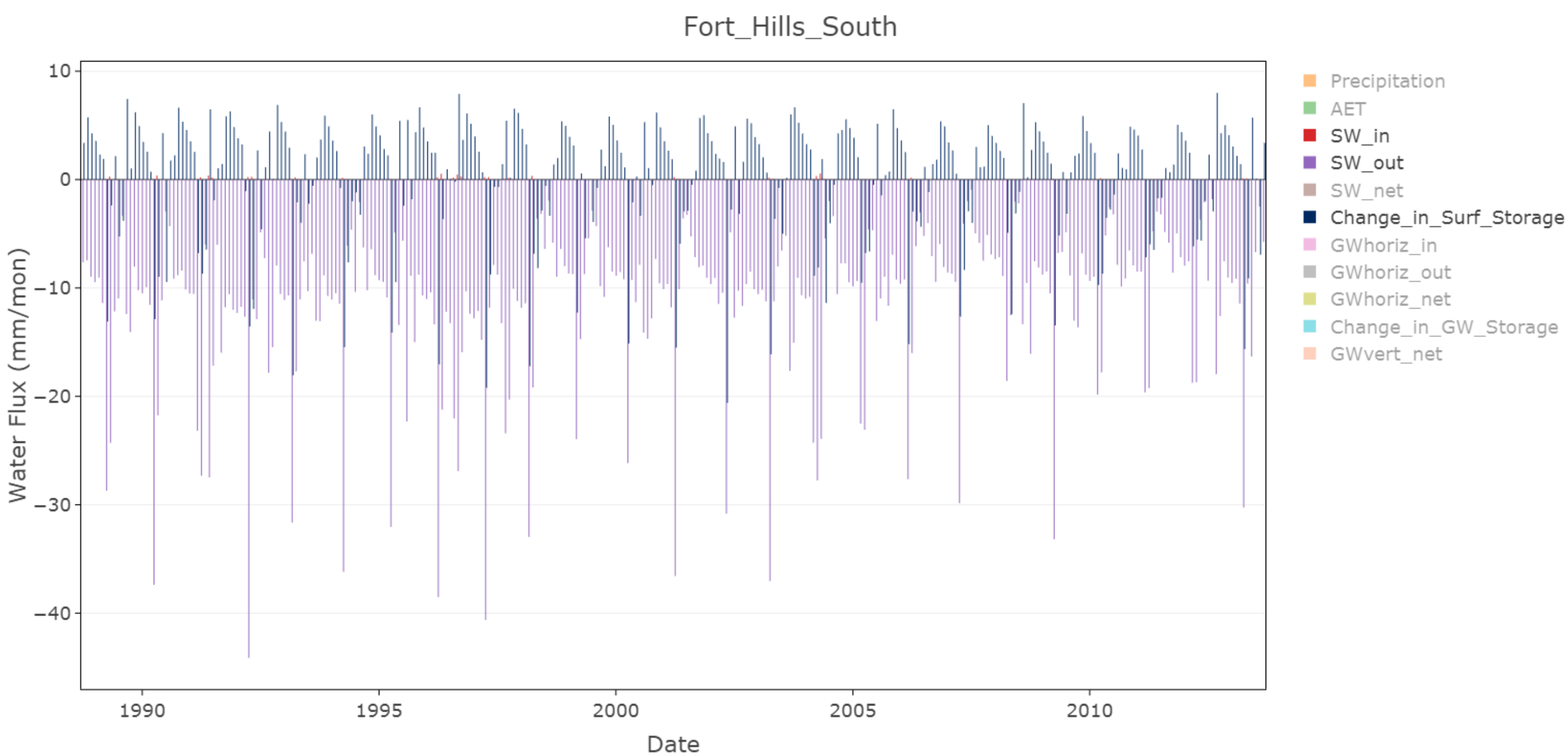

Figure 167 Predicted monthly surface water flows and storage within HRA 19 from 1988-2013.

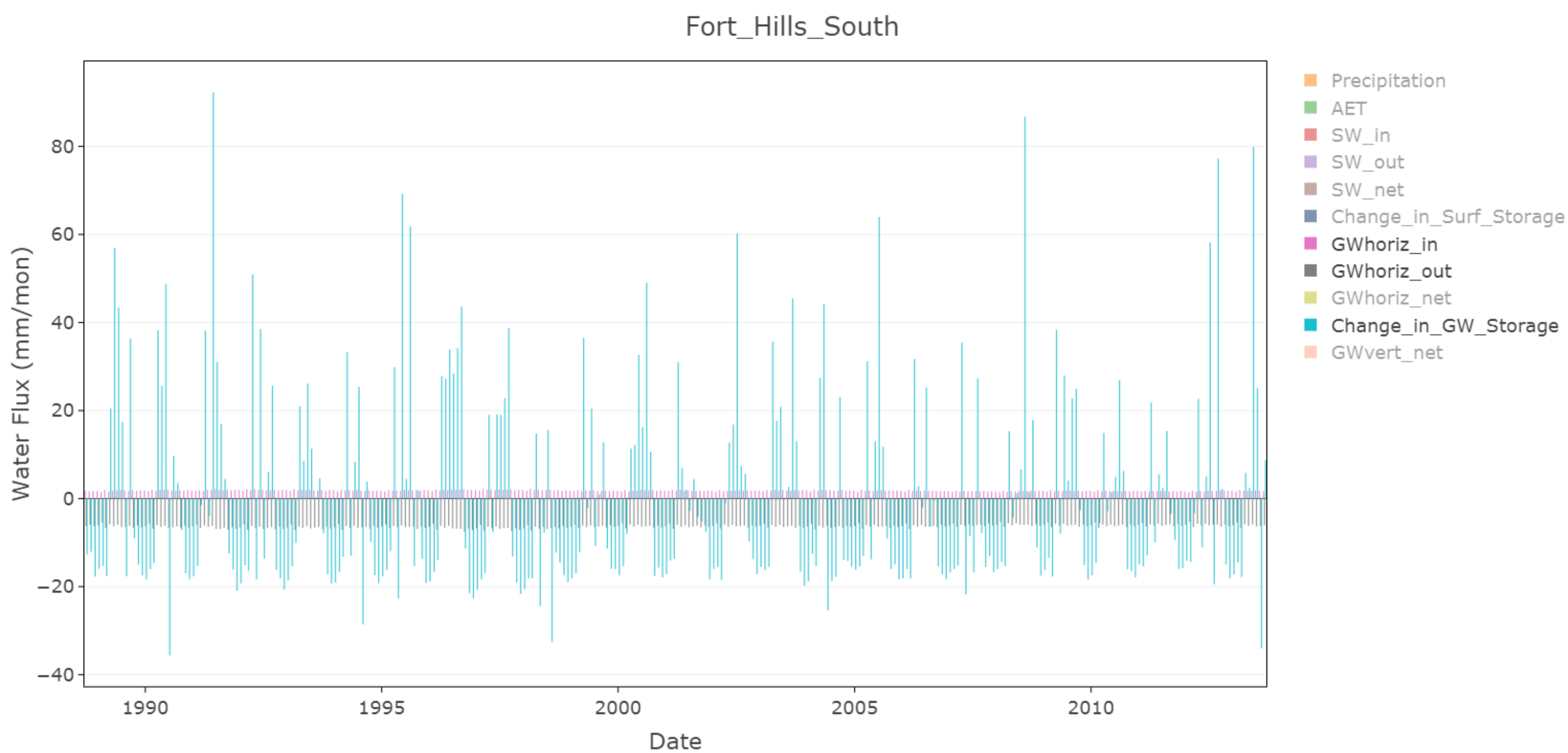

Figure 168 Predicted monthly groundwater flows and storage within HRA 19 from 1988-2013.

31. Section 1.3.20: HRA 20: North Outwash Plains North

HRA 20 is designated North Outwash Plains North and a cross-sections taken through this HRA is shown in Figure 169. HRA 20 covers an area of approximately 222.63 km^2 that has a mean slope of 1.17%, an aspect of 183.59 degrees azimuth and a mean elevation of 297.55 masl. The dominant land usages classes and forms present in HRA 20 are wooded coniferous upland (non-wetland) (41.67%) and wooded coniferous burned (49.26%), respectively. The dominant soil is Livock which is classified to drain well. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 20 range from 1.5 to 66.1 m, trending deeper southwest to northeast (Figure 170) and are composed of topsoil, Surface Sands South and Surface Sands North deposits. Substrate depths in HRA 20 above Clay Till 2 range between 7.4 to 43.8 m. This substrate consists primarily of silt sand and Surface Sands South deposit. The Clay Till 1 "bedrock" topography in HRA 20 ranges from 237.5 to 301.8 masl, trending deeper from the southwest to the northeast (Figure 171). The Clay Till 2 "bedrock" topography in HRA 20 ranges from 270.2 to 303.1 masl and is undulating. Post-development, 88% of the HRA will remain undisturbed.

ITK holders also discuss the depth and extent of the surface sand deposits, making note of an especially deep section just north and east of McClelland Lake.

> *"You want to go over, past McClelland Creek? No. You will never get there at this time of year. Yes, you can go quite a ways on the Synenco Road to a powerline, but there you'll come up to a big sand hill, before McClelland Creek. You'll never make it up there in a truck now. It's just sand – deep – like up to here (showing up, past his knees). I know because I've walked over that hill many times. I'd walk from there to the cabin at Mile 14, one time with 24 beaver skins on my back. That time I was 14 years old. Oh I tell you boy, that's deep sand."* (FMFN ITK holder, FMMN 2019)

> *"Yeah, because it's right in the middle of the sand hills, right? And all through here, even here where we're sitting right here [west of boat launch], this is all sand hills right through. And for miles this way, right up to Firebag, I think there's sand hills."* (FMFN ITKholder, FMMN 2017)

HRA 20 is conceptualized to primarily receive water from precipitation and HRAs 19, 16 and 15 (refer to Figure 29, Figure 31 and Figure 169). The hydrogeochemistry of HRA 20 waters is conceptualized to be non-alkaline and cation-poor.

Water is conceptualized to leave HRA 20 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, evapotranspiration and outgoing groundwater. Discharges from HRA 20 are conceptualized to drain to either the Athabasca or Firebag River valleys, primarily in the form of advective groundwater flow. Substrate depths are relatively deep across most of the HRA and the water table would be expected to be well below surface in most portions. HRA 20 is composed entirely of surface sand deposits that, when combined with deep water tables, would be expected to freeze honeycomb and permeable in the winter. Runoff from this HRA during the spring freshet is anticipated to be minimal or nonexistent.

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 20 was simulated to receive 84%, 5% and 11% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 20 was simulated to discharge 28%, 6% and 66% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 20 indicates that annual AET rates (146.7 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is well below the surface (Figure 33); the HRA is simulated to have low saturation rates across most of its extent (Figure 34) and the exchange of water across the land surface indicates HRA is primarily an infiltration region except along the sides of the moraine where seepage faces are predicted to develop (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of precipitation and leaves in the form of groundwater. Proportionally about the same volume of water exits the HRA in the form of surface water than enters it annually. Proportionally much more water exits the HRA in the form of groundwater than enters it annually.

Figure 172 presents predicted average monthly water balance components over the period 1988-2013. HRA 20 is predicted to produce peak incoming surface water flows during May and peak outflows in April. This HRA adds to surface water storage September to November (November peak). The HRA consumes surface water storage December to May (March peak) plus the month of July. Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round; outflow rates are consistently much larger than inflow rates of groundwater. The HRA adds to groundwater storage in April (the peak) through September. The HRA consumes groundwater storage October to March (December peak).

Figure 173 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 20. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 174 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur April-October but usually happens in May. Peak monthly surface water out can occur March-October but usually happens in May. The largest monthly gain in surface water storage can occur anywhere April-November but most often happens in November. The maximum monthly consumption of surface water storage can occur March-August but typically happens in April. Figure 175 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates occurs in March. Peak monthly groundwater discharge rates occur March-October but usually happen in December. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage happens May-December but usually occurs in December.

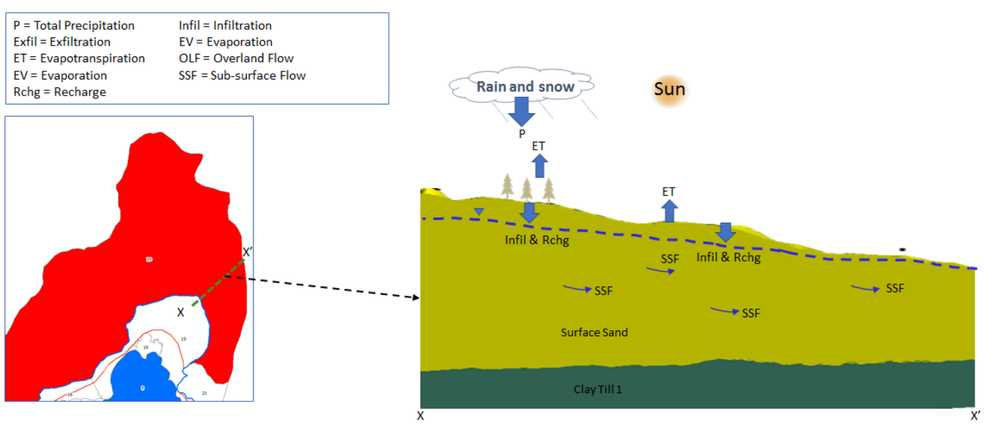

Figure 169 HRA 20: North Outwash Plains North. Vertical exaggeration is 80:1.

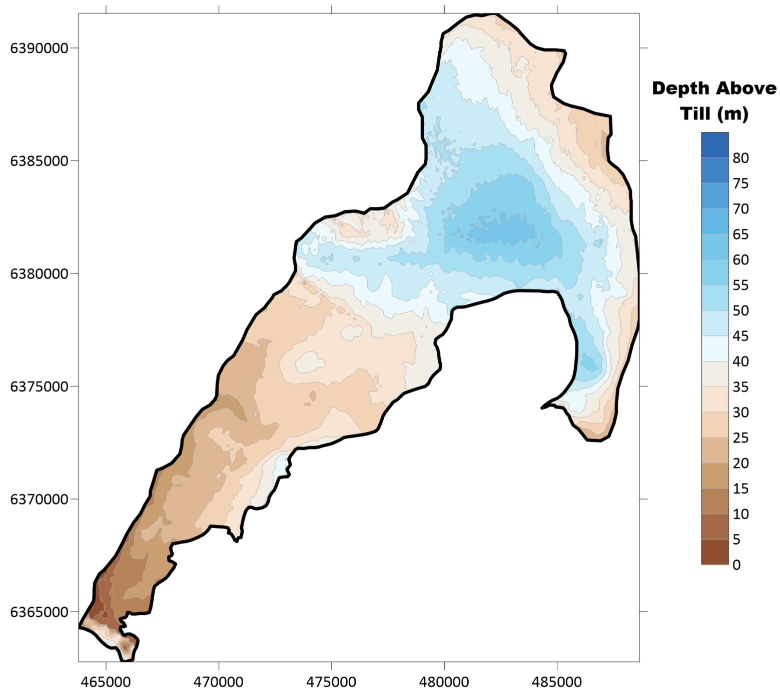

Figure 170 Substrate depths in HRA 20: North Outwash Plains North.

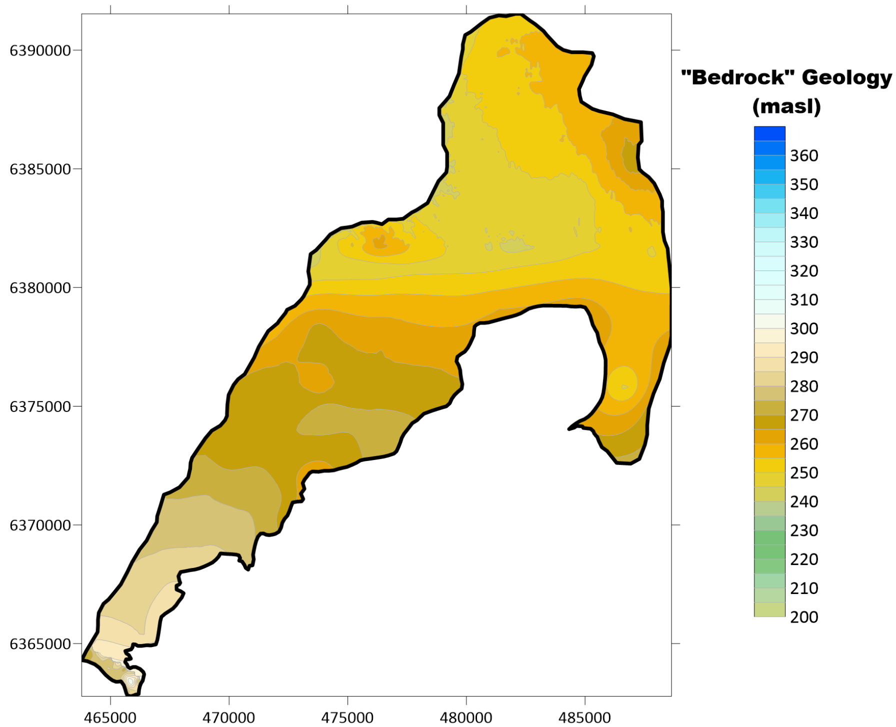

Figure 171 Bedrock topography in HRA 20: North Outwash Plains North.

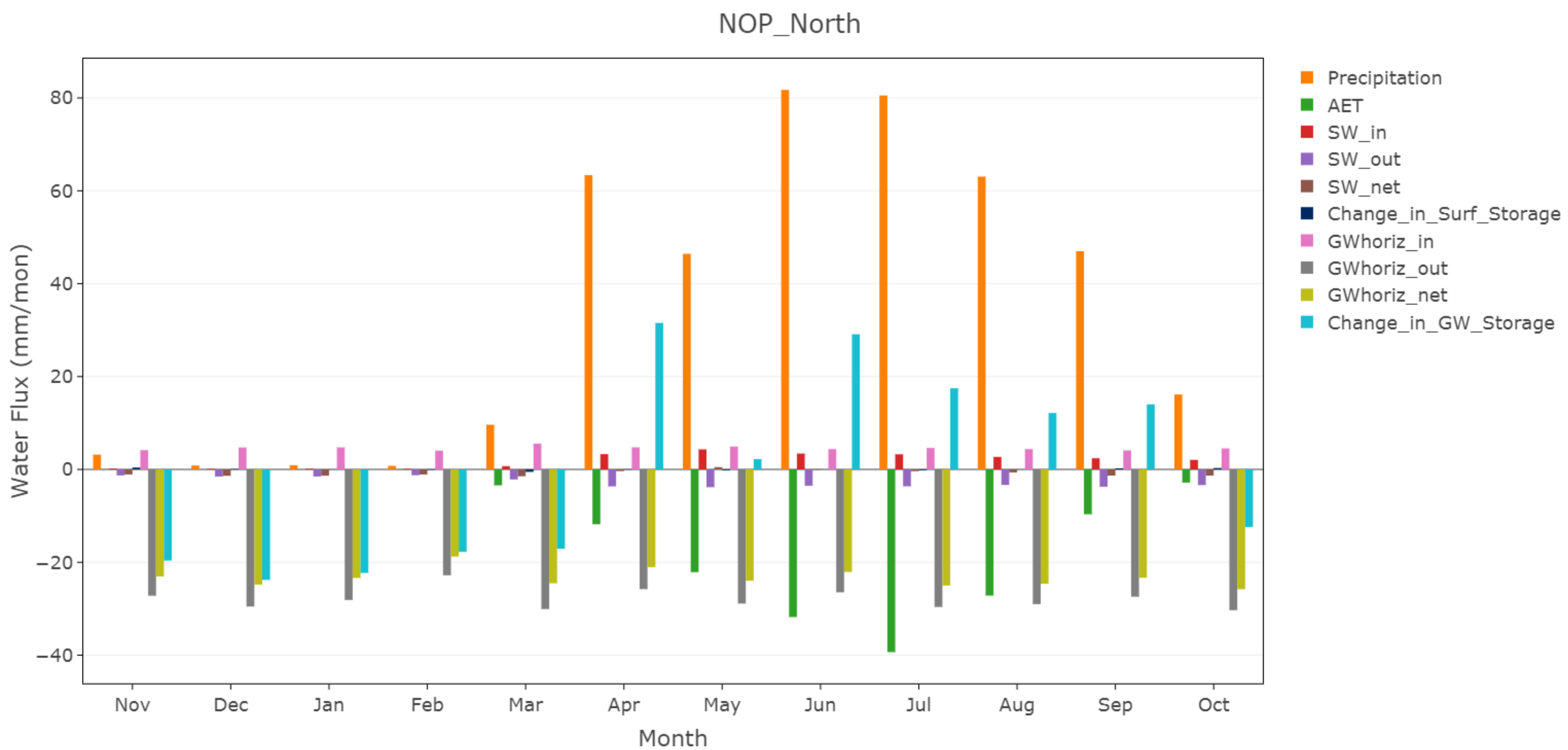

Figure 172 Mean monthly water budget components (1988-2013) for HRA 20: North Outwash Plains North. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

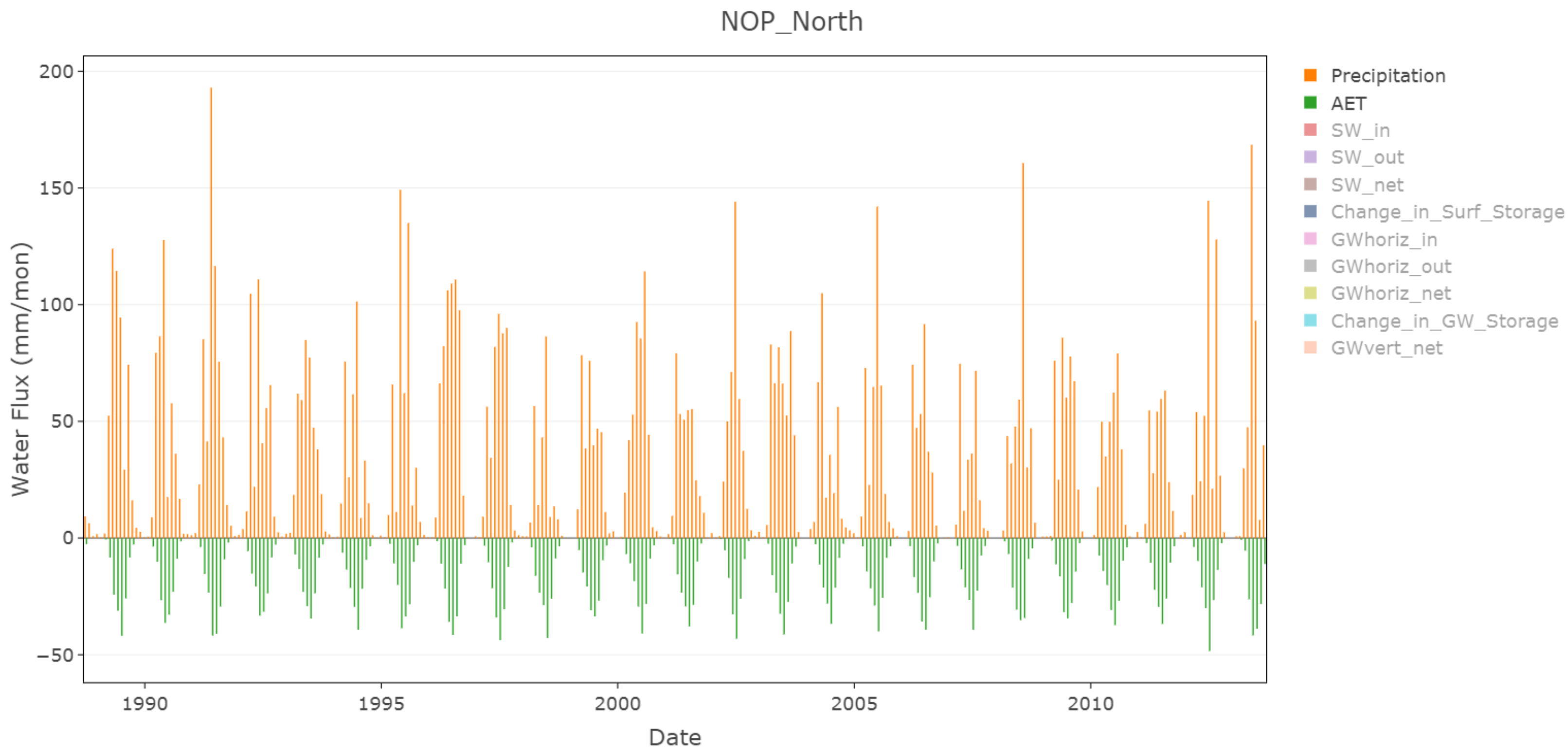

Figure 173 Predicted monthly precipitation and AET rates within HRA 20 from 1988-2013.

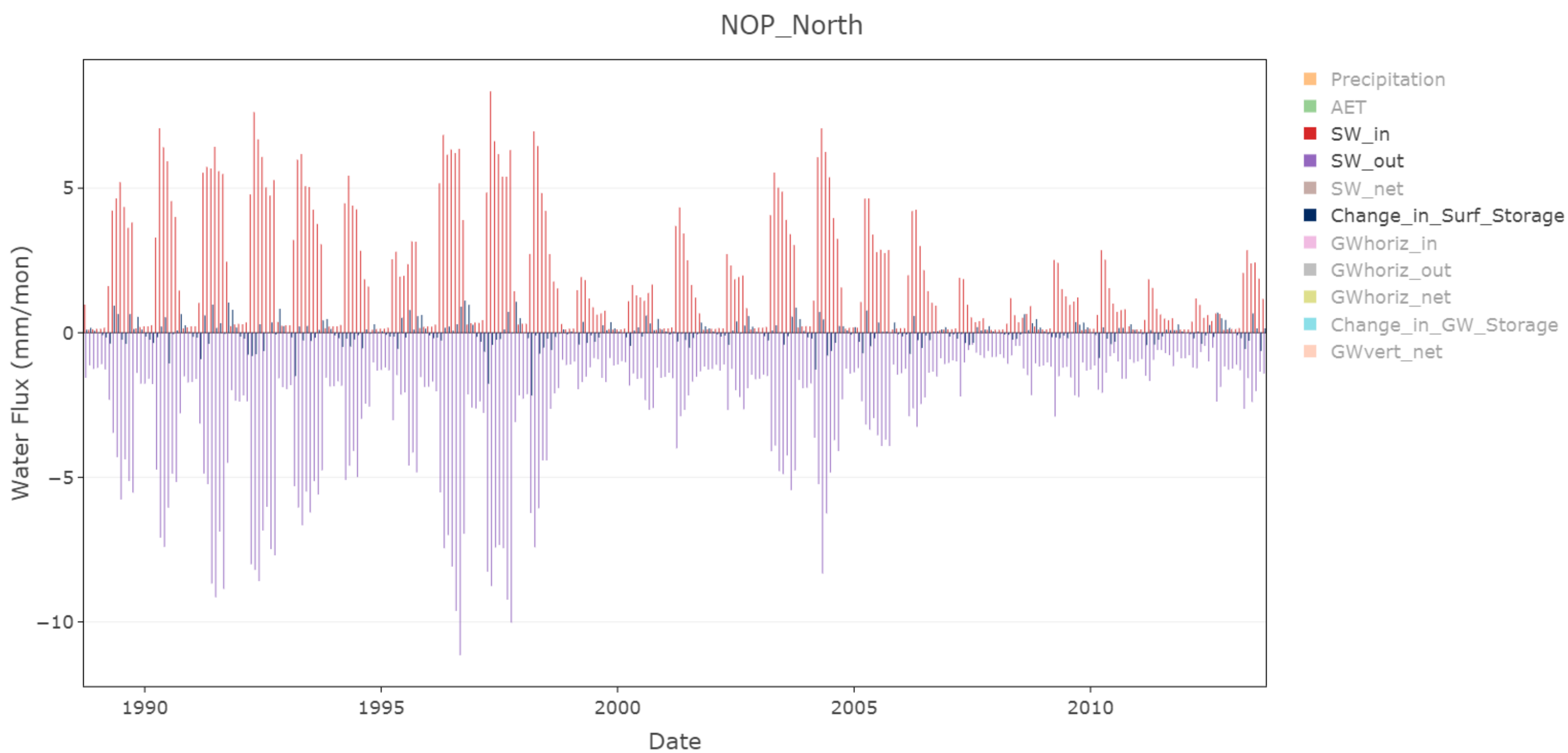

Figure 174 Predicted monthly surface water flows and storage within HRA 20 from 1988-2013.

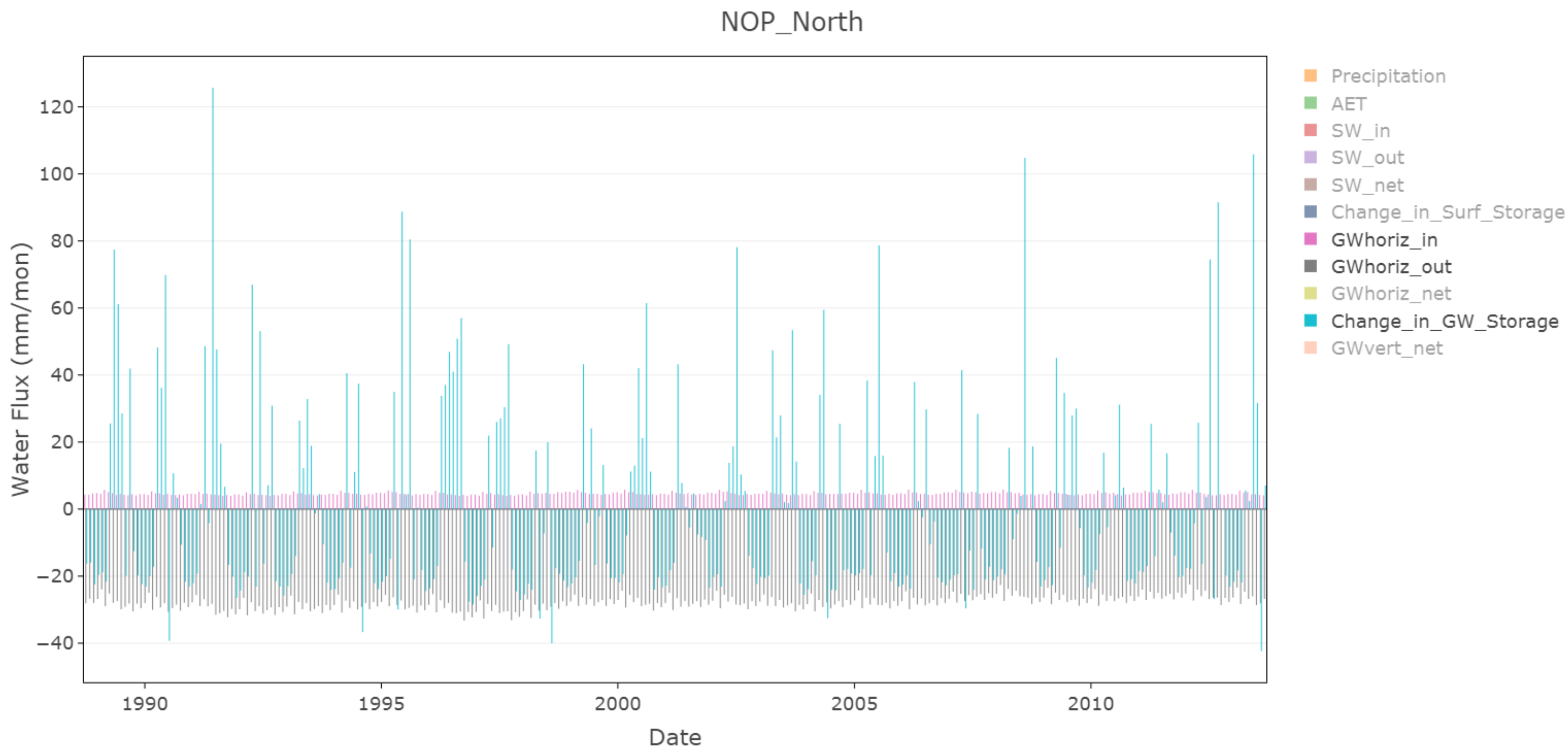

Figure 175 Predicted monthly groundwater flows and storage within HRA 20 from 1988-2013.

32. Section 1.3.21: HRA 21: McClelland Lake Outlet

HRA 21 is designated Lake Outlet and a cross-section taken through this HRA is shown in Figure 176. HRA 01 covers an area of approximately 10.03 km^2 that has a mean slope of 2.18%, an aspect of 155.47 degrees azimuth and a mean elevation of 296.07 masl. The dominant land usages classes and forms present in HRA 21 are shrubby swamp (15.31%), wooded coniferous upland (non-wetland) (42.75%) and wooded coniferous burned (15.25%), respectively. The dominant soils are Firebag (25.91%), Livock (46.33%) and Mikkwa (26.48%) which are classified to drain rapidly – very rapidly, well and very poorly, respectively. Precipitation rates on this HRA average 422.3 mm per year, approximately 25% of which is in the form of snow (1988-2013). Vitt and House (2020) did not describe this area eco-hydrologically.

Substrate depths above Clay Till 1 in HRA 21 range from 4.4 to 35.9 m, trending deeper south to north and is composed of topsoil, Surface Sands North and Muskeg deposits (Figure 177). Substrate depths in HRA 21 above Clay Till 2 range between 15.8 to 27.5 m. This substrate consists primarily of silt sand and Surface Sands North deposits. The Clay Till 1 "bedrock" topography in HRA 21 ranges from 264.5 to 289.3 masl, trending downward from the south to the north (Figure 178). The Clay Till 2 "bedrock" topography in HRA 21 ranges from 271.3 to 277.6 masl, trending downward from the south to the north. Post-development, 100% of the HRA will remain undisturbed.

HRA 21 is conceptualized to primarily receive water from precipitation and HRAs 09 and 18 (refer to Figure 29, Figure 31 and Figure 176). Flows from HRA 09 are surface water into McClelland Creek and groundwater discharges from the lake while flows from HRA 18 are groundwater flows that originated from McClelland Lake. The hydrogeochemistry of HRA 21 waters would be expected to be a mixture of the non-alkaline and cation-poor waters originating from the clean surface sands and the (relatively) alkaline and cation-rich waters originating from the FHUC.

> *"McClelland Creek, it varies, one year it will be dry and one year there's abundance of water. And years ago, there had seemed to be more water in that creek than the later years. And then when I say more water, probably I would say in the '50s, there was a lot more water, but then in the '60s, sometimes you can just walk across there with just your rubber boots. Sometimes, you've got to walk across, just about up to your neck because I've done that."* (FCM ITK holder, March 3, 2021 workshop)

Water is conceptualized to leave HRA 21 (in ascending order of conceptualized relative contribution) in the forms of outgoing surface water, evapotranspiration and outgoing groundwater. Discharges from

HRA 21 are conceptualized to drain to Moose Creek and then ultimately to the Firebag River. There are muskeg deposits immediately east of McClelland Lake in the discharge zone. The water table would be expected to be at or near land surface by muskeg deposits and wetlands portions of this HRA and somewhat deeper elsewhere. The ground would be expected to freeze solid where the water table is near the land surface and honeycomb and permeable elsewhere. An FCM ITK holder indicated *that Moose Creek is likely fed from groundwater through muskeg to get that tint of tea colour* (FCM ITK holder, FCM 2019).

> *"McClelland Creek will go dry sometimes but then get high again the next year. Moose Creek levels are more consistent"* (FCM ITK Holder, January 26, 2021 Workshop).
> An FCM ITK holder have shared that Moose Creek is likely fed from groundwater through muskeg to get that tint of tea colour. McClelland Creek will go dry sometimes but then get high again the next year. Moose Creek levels are more consistent.
> *"I've always noticed Moose Creek always seem to keep its level quite high..... I was born in '54, I can only remember probably from about '58 maybe. I have a long memory. The reason why I have good memory of water, because whenever there was water to cross that was deep, my mother had to piggyback me on her back to take me across. That's how I know – I had to hang on for dear life. Yeah. And then that was McClelland Creek and Moose Creek. It used to happen that it was high*." (FCM ITK holder, March 3, 2021 workshop)

The water budget results shown on Table 8 are meant to reflect the long-term average annual budget wherein inflows approximately equal outflows and changes in water storage are essentially assumed negligible. The results are also assessed in terms of long-term hydrologic behavior. From 1988-2013, HRA 21 was simulated to receive 38%, 52% and 10% of its average annual inflows in the forms of precipitation, incoming surface water and incoming groundwater (horizontal), respectively. HRA 21 was simulated to discharge 28%, 63% and 9% of its outflows in the forms of AET, outgoing surface water and outgoing groundwater, respectively, during the 1988-2013 simulation period (Table 8). The simulated average long-term behavior of HRA 21 indicates that annual AET rates (311.0 mm/yr) are much less than precipitation rates (413.6 mm/yr) (Table 8 and Figure 32); the simulated water table is near surface where wetlands/muskeg is present and deeper elsewhere (Figure 33); the saturation patterns also reflect water table position (Figure 34) and the exchange of water across the land surface is a mosaic of infiltration, exfiltration and near net neutral areas (Figure 35). Table 8 indicates that, over the long term, the bulk of water enters the HRA in the form of surface water and leaves in the form of surface water. Proportionally more water exits the HRA in the form of surface water than enters it annually. Proportionally similar amounts of water exits the HRA in the form of groundwater than enters it annually.

Figure 179 presents predicted average monthly water balance components over the period 1988-2013. HRA 21 is predicted to produce peak incoming and outgoing surface water flows during May. This HRA adds to surface water storage September to February (November peak). The HRA consumes surface water storage March to August (May peak). Peak rainfall rates occur in June and peak AET rates in July. Groundwater flows into and out of the HRA at a fairly constant rate year round. The HRA adds to groundwater storage in April (the peak) through September. The HRA consumes groundwater storage October to March (December peak).

Figure 180 illustrates the predicted inter-annual variability of monthly precipitation and AET rates from 1988-2013 in HRA 21. Peak monthly precipitation can occur April-September but typically happens in June. Maximum monthly AET rates can happen June-July but usually occur in July. Figure 181 shows the surface water balance components (flow in, flow out and change in storage). Peak monthly surface water in can occur May-September but usually happens in May. Peak monthly surface water out can occur April-October but usually happens in May. The largest monthly gain in surface water storage can occur June-November but most often happens in November. The maximum monthly consumption of surface water storage can occur March-May but typically happens in May. Figure 182 lists the groundwater balance components from 1988-2013. Peak monthly incoming groundwater rates occur May-October but usually happen in October. Peak monthly groundwater discharge rates occur March-July but usually happen in March. The largest monthly gain in groundwater storage can happen April-September but usually occurs in April. The largest monthly consumption of groundwater storage usually happens May-December but usually occurs in December.

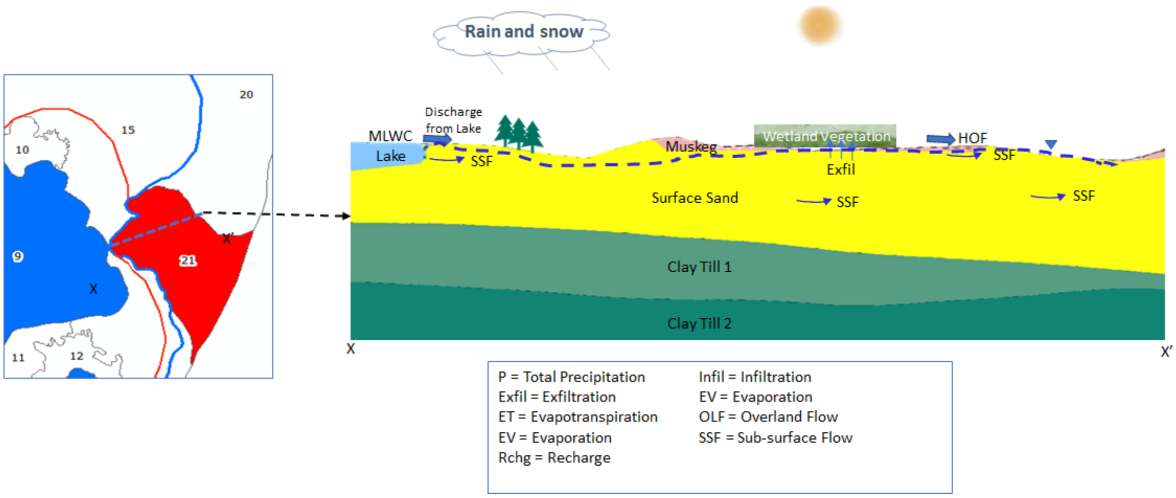

Figure 176 HRA 21: McClelland Lake Outlet. Vertical exaggeration is 80:1.

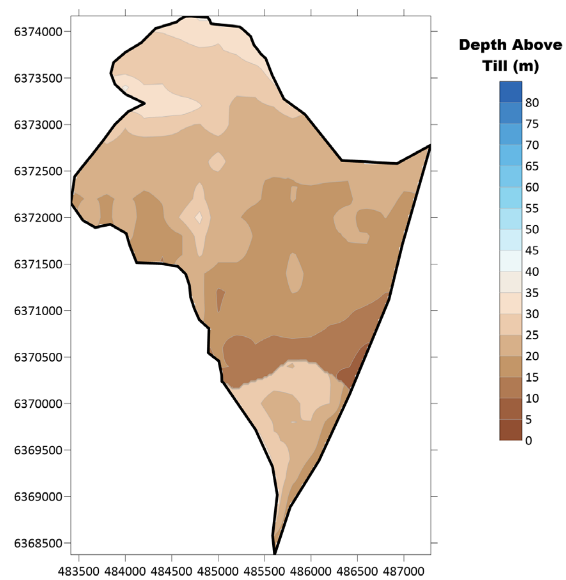

Figure 177 Substrate depths in HRA 21: McClelland Lake Outlet.

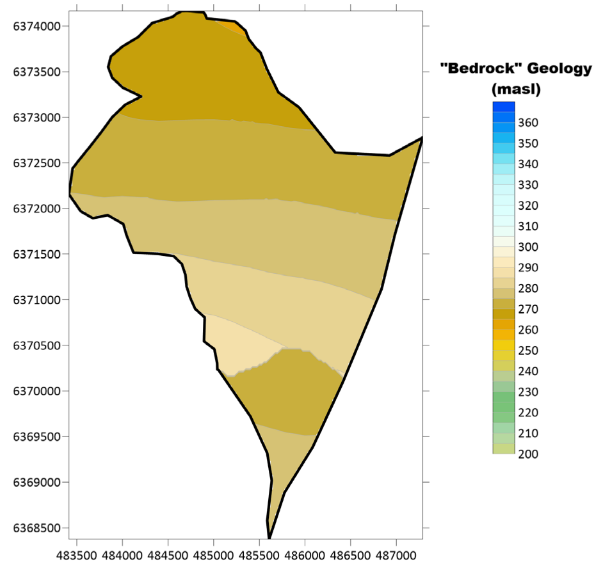

Figure 178 Bedrock topography in HRA 21: McClelland Lake Outlet.

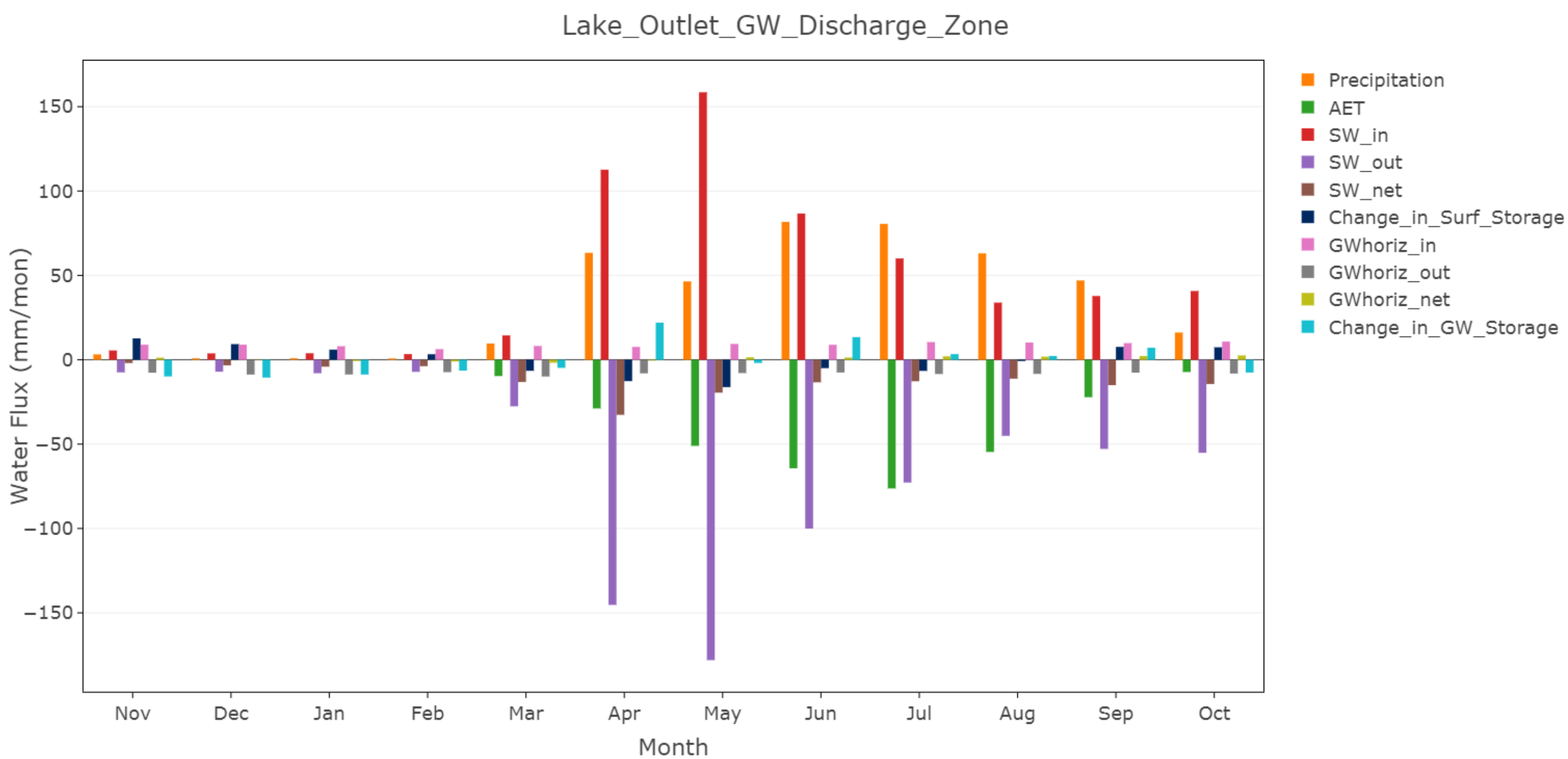

Figure 179 Mean monthly water budget components (1988-2013) for HRA 21: McClelland Lake Outlet. Note: Inflows to the HRA are positive (above 0 on the Y-axis) and outflows are negative (below 0 on the Y-axis), while net fluxes are given as: e.g., SW_net = SW_in + SW_out.

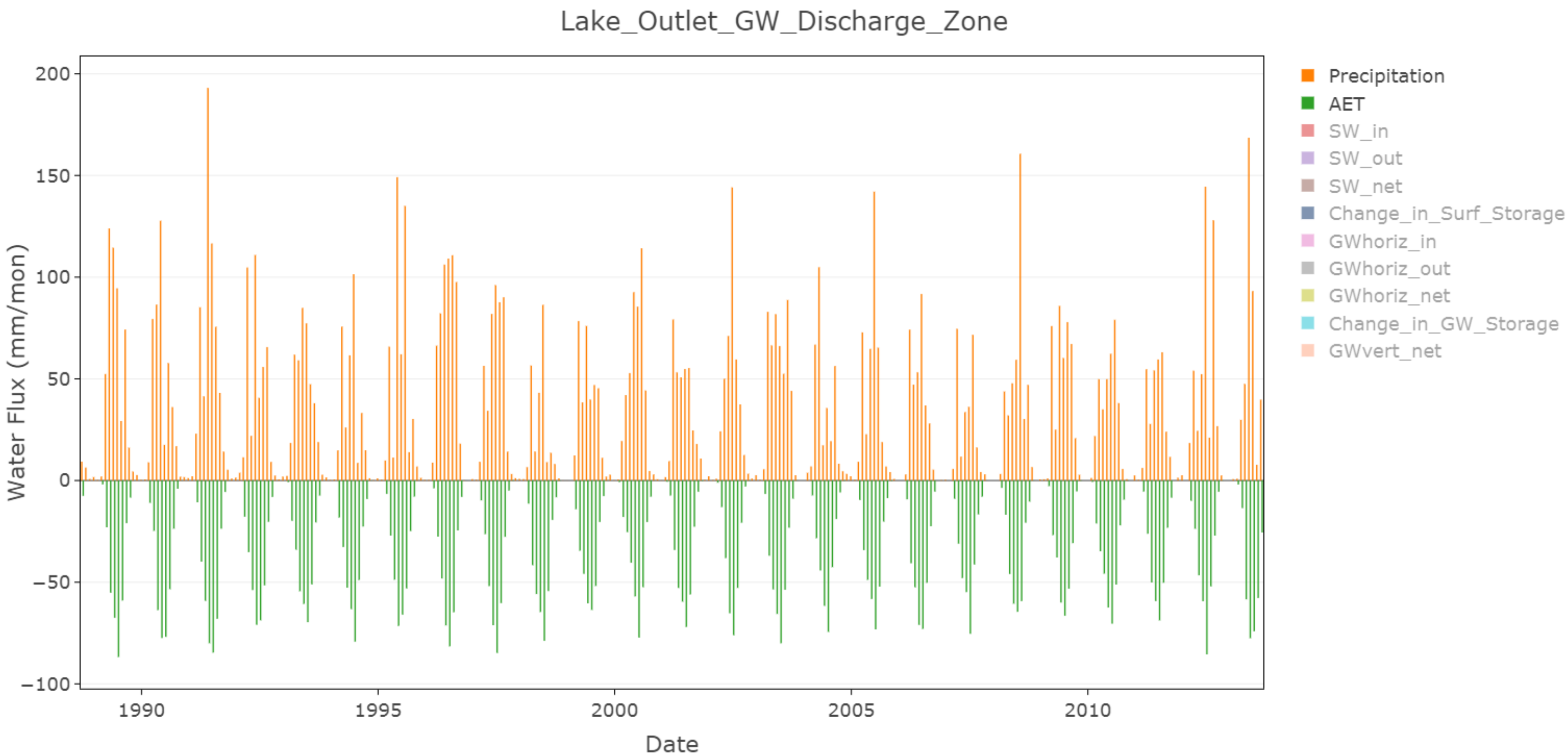

Figure 180 Predicted monthly precipitation and AET rates within HRA 21 from 1988-2013.

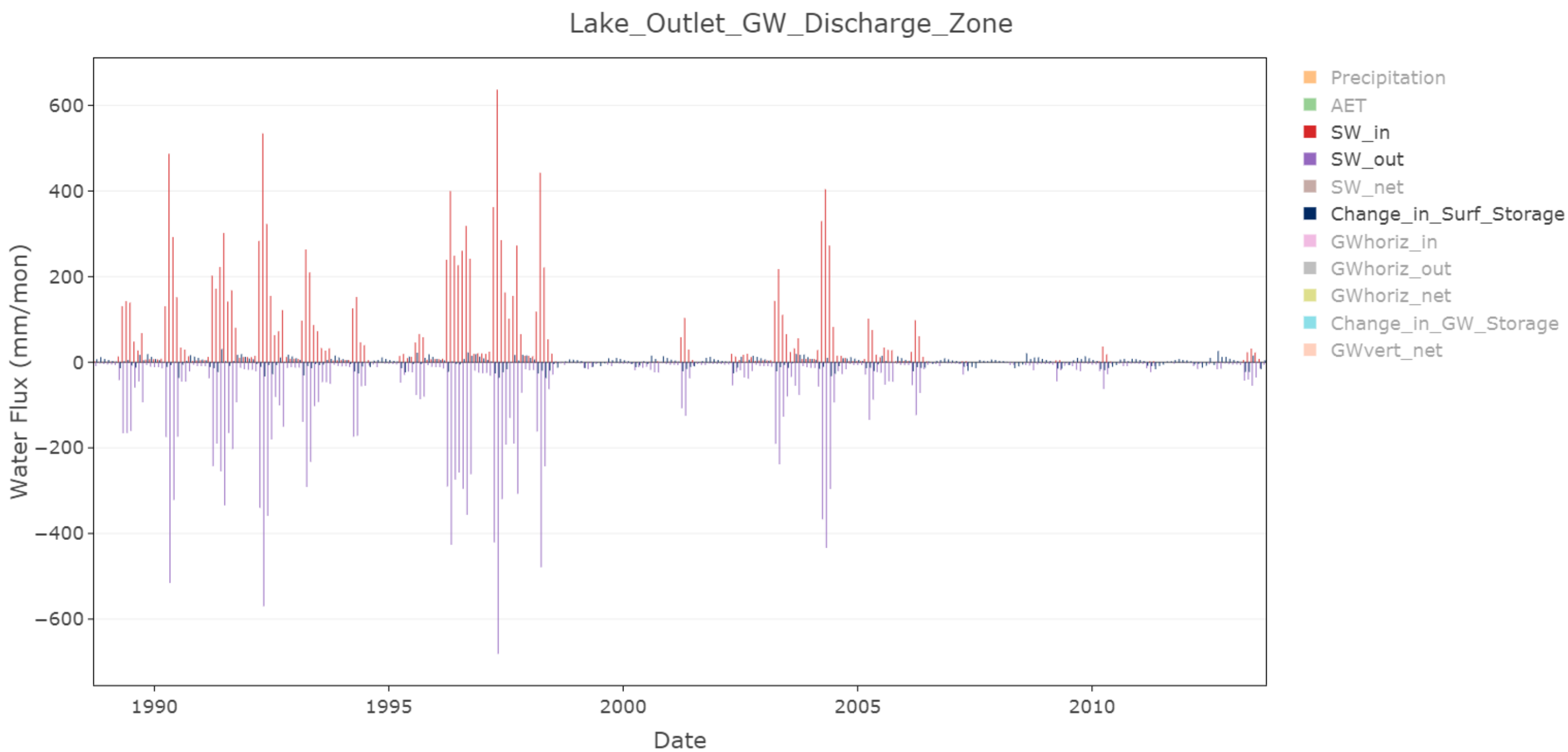

Figure 181 Predicted monthly surface water flows and storage within HRA 21 from 1988-2013.

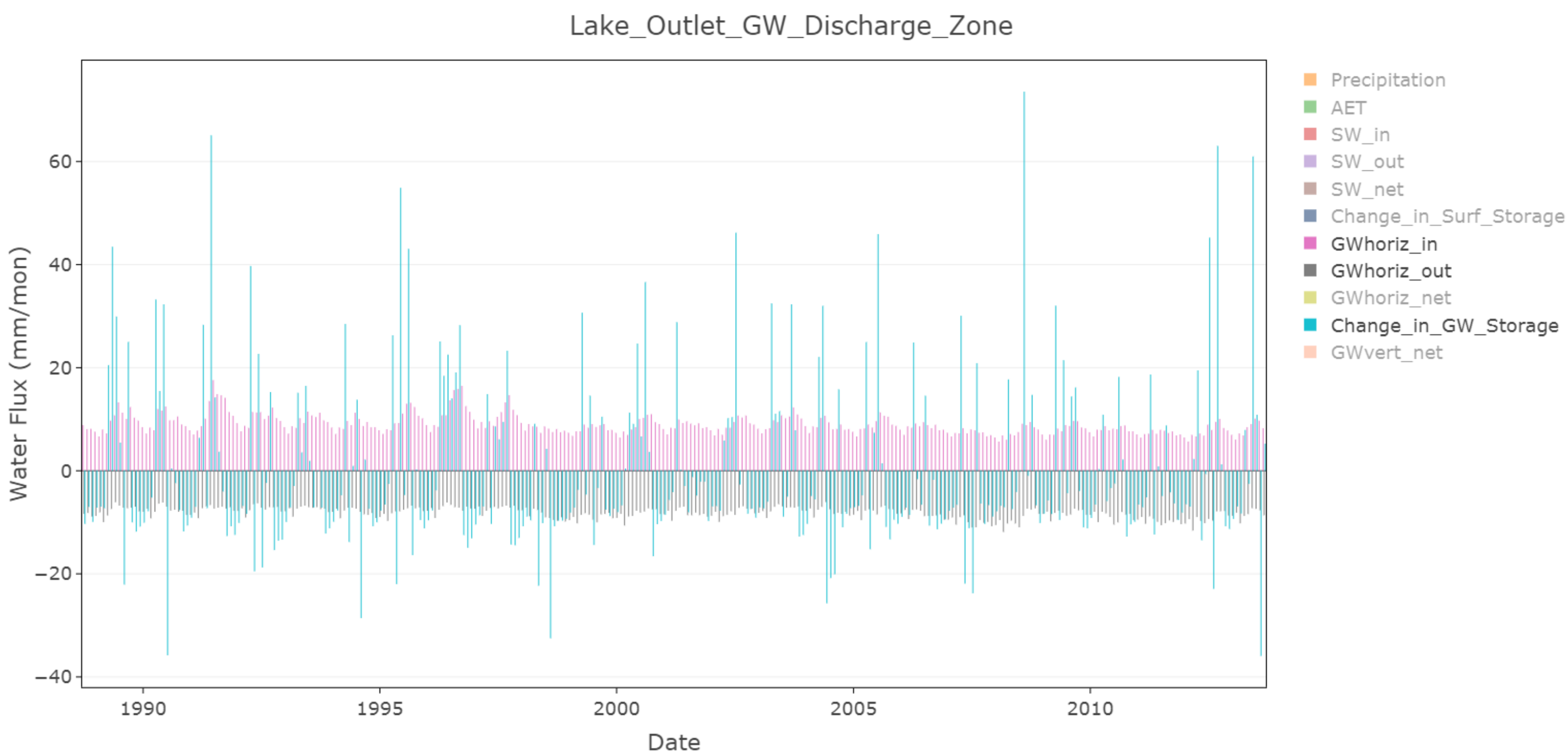

Figure 182 Predicted monthly groundwater flows and storage within HRA 21 from 1988-2013.

33. Section 1.4: Synthesis: The 2021 MLWC Conceptual Model

The results from the application of the characterization framework presented in Devito et al. (2005) indicate that the climate of the MLWC watershed is relatively dry, the bedrock impermeable (relatively), the surficial geology contains both shallow and deeper substrates, the system has a wide variety of soil covers and the topography is gently sloped in some regions of the watershed and more steeply sloped in others. This information, coupled with field data and the findings of previous technical work conducted for the MLWC Project, was used to develop the 21 HRAs presented in Section 2.3 and to conceptually describe the expected hydrologic functioning within each HRA. The purpose of this section is to analyze the MLWC watershed and the surrounding landscape that may contribute waters to it more holistically and to provide further conceptual insight on system-wide hydrological functioning.

As noted in the MLWC OP Objective 1 (Section 2), an examination of historical climate data (collected at the Fort McMurray airport) indicates that the last century in the region has experienced an increasing annual mean temperature trend coupled with a concomitant decrease in annual average precipitation rates (at least since the 1970's for the latter). Taken together, these trends indicate the MLWC region has been progressively drying out since at least the 1970's. Exasperating this drying trend is a third long-term trend in increasing annual PET rates over time. These observations are consistent with a large body of ITK of the region. Examples include several comments about how the area seems drier now than in the past, water levels are lower, how the ice used to freeze harder and for longer and how the now-ephemeral outlet channel for the lake (McClelland Creek) used to be so water-filled at times that it was difficult to cross, times when McClelland Lake's level was much higher (although ITK of the area also notes the lake level varies frequently).
ITK holders also identified that within these fluctuations, the levels are generally getting lower. It is recommended that this IK should be added to inform all relevant aspects of the "Pre-development, water levels were high enough that members of FMFN and FMMN regularly were able to travel by water to preferred hunting sites or other preferred areas within the McClelland Lake Wetland Complex and surrounding area. Since the 1960s, participants have observed changes to water quantity and quality within the McClelland Lake Wetland Complex and surrounding area. Members expressed that water levels have gone down in the McClelland Lake area since nearby industrial projects became active."(FMFN and FMMN ITK holders, IEG 2020)

ITK of the MLWC area also contains a number of findings and observations regarding beaver in and around the MLWC watershed. A 2019 beaver survey was conducted within the MLWC watershed and along Moose Creek to its confluence with the Firebag River (LGL Limited, 2019). The survey was conducted by helicopter over a one-day period. The LGL Limited (2019) results indicated that at the time of the survey, beaver activity was relatively low with increasing evidence of activity around the perimeter of McClelland Lake. One beaver lodge was found near an inlet to McClelland Lake but none near the outlet. ITK indicates that historically, the lake outlet may also have been a site of beaver activity (FCM ITK holder, September 13, 2019 Workshop). The survey also indicated much more beaver activity along Moose Creek than was found within the MLWC watershed. As the region continues to dry during this current climate period, it is anticipated that beaver activity will remain lower than was the case historically.

ITK holders have explained that there are seasonal fluctuations in the water levels which are controlled by beavers in the area (beavers let old water out through their dams in the spring and in the fall they dam the lake to keep the fresh water in).

> *"You can't understand changes to lake levels without also understanding beaver activity and weather (rain and snow levels)."* (FCM and FMFN ITK holders, March 12, 2020 workshop)

> *"In the 1950s there was a beaver dam across McClelland Creek that helped keep water levels in the lake high."* (FCM ITK holder, September 13, 2019 workshop)

> *"The beavers open the dams, and the water drops as the fresh water comes in. After the fresh water comes in the beavers drop their dams again." (ITK holders, Garibaldi 2021)*

> *"But then the wet years there's so much water the beavers will open the dams. So we go up to a lake and we measure it and it's a really wet year and it's like I've never seen it this low." (ITK holders, Garibaldi 2021)*

> *"Yeah, that's right, because the beavers open the dams because there's too much water for their house, so they open the dams and drop the water after it goes down to a certain level then they plug it again." (ITK holders, Garibaldi 2021)*

The MLWC watershed (and the hydrologically contributing landscape surrounding it) taken as a whole, is essentially a wetland complex with lakes and streams that is situated upon a hummocky, glacial terrain, underlain by a permeable substrate and whose sole source of water is incoming precipitation. Because the system's sole source of water is just incoming precipitation, it is particularly vulnerable to changes in the climate, although the presence of a permeable substrate is a mitigating factor (Winter, 2000). As the region continues to experience this current drying trend, the overall hydrologic functioning of the MLWC system will likely change over time. However, recent regional climate change analysis work indicates that this current drying trend may reverse sometime before mid-century (Aquanty, 2020).

The rate at which net precipitation is converted to storage in the landscape and eventually is transmitted to the lowlands and discharges into the fen-lake complex is the primary factor determining the general hydrologic state of the lowland fen-lake system. During historic, extensively wet periods when landscape water storage was replenished and annual net precipitation rates were high, discharge rates to the MLWC watershed’s lowlands increased. Low system storage capacity coupled with incoming flows exceeding the rate they can cycle through the lowlands (via discharge at the lake outlet or via ET) will cause water levels in the MLWC and the lake to rise and McClelland Creek would be expected to again become perennial until incoming flows declined again. McClelland Creek is ephemeral now and it is very likely that the elevation of the lake outlet at its mouth currently controls the level of McClelland Lake. Over the past few decades, McClelland Lake has received enough water to maintain its levels within a very stable ~ 70 cm range (with a mean level of ~ 292.34 masl) and McClelland Creek has remained ephemeral since discharges started being recorded (Figure 2). An FCM ITK holder noted that flows in McClelland Creek vary from year to year from being dry to having an abundance of water, but overall there seemed to be more water in the 1950s than in the last several decades (FCM ITK holder, March 3, 2021 workshop). During a visit in the fall of 2019, FCM ITK holders observed that McClelland Creek had less flow than previously, and attributed this to the lower lake levels and absence of beaver on the creek(FCM ITK holders, October 14, 2021 workshop)

> *The reason why I have good memory of water, because whenever there was water to cross that was deep, my mother had to piggyback me on her back to take me across. That’s how I know – I had to hang on for dear life. Yeah. And then that was McClelland Creek and Moose Creek. It used to happen that it was that high. (*FCM ITK holder, March 3, 2021 workshop*)*

As the storage capacity of the MLWC watershed changes so do the hydrological mechanisms driving the movement of water in the landscape. HRA 05 (refer to Figure 29) would be an example of this at a smaller scale. During very wet periods, when water tables are high and GW storage capacity is low, incoming rain falling on the saturated ground along the HRA’s eastern margin would just runoff as SW flow into HRA 01 and/or HRA 02. Under slightly drier conditions, where the water table is beneath the surface but the capillary fringe intersects it (so very low storage capacity), incoming rain would generate groundwater ridging which would subsequently runoff into the patterned fens. Under even drier conditions when storage capacity of the MLWC groundwater system is much higher and the water table is well below (>2 m) the surface, groundwater would simply pass through HRA 05 advectively flowing towards the patterned fens.

These hydrological changes with changing storage capacity can also happen at larger scales in the MLWC. If water levels on the fen side of lake were to drop below the lake inlets, flows in the lake could reverse towards the fen through the inlets. Similarly, the MLWC fen typically has water entering it along its margins and originating from the uplands. During extended dry periods, the water tables in the

MLWC lowlands would retreat to some very shallow level beneath the ground surface. In contrast, ET would continue to drawdown water stored in the uplands until the wilting point in the vegetation is reached. When the uplands are this dry, flow reversal can happen wherein water is lost at the fen margins.

Within the MLWC watershed boundaries, significant volumes of surface water are generated annually as evidenced by the streams, wetlands and a lake that spans in excess of 30 km^2 in area. There are no incoming streams originating from outside the watershed. With the exception of a large southwest portion of HRA 17 (Fort Hills – West), the entire MLWC watershed is underlain by a single, continuous surficial sand deposit (segregated into Surface Sand South and Surface Sand North and whose extents are shown in Figure 14). Groundwater levels within these surficial sands, upslope of either side of the MLWC's lowlands, would generally be presumed to be higher than the groundwater levels in the lowlands themselves (providing potential for the upslope groundwater to flow towards the lowlands). Underlying the surface sand deposits is Clay Till 1 which acts as an aquitard (extent shown in Figure 13). Clay Till 1 has mapped hydraulic windows (imperfections or erosional features in the till surface that facilitate water to flow vertically across this unit in these localized areas). These hydraulic windows have manifested flowing groundwater springs on the MLWC watershed surface, allowing groundwater from the underlying silt sand deposits to discharge to McClelland Lake and the adjoining wetland complex. The underlying silt sand deposits are interpreted to be separated by two patchy aquitards (aquitard extents shown in Figure 8 and Figure 10, respectively) and mixed with rafted McMurray material (PGKM) near the base (Figure 7). Underlying the silt sand deposits is Clay Till 2 which also contains mapped hydraulic windows (aquitard extent shown in Figure 6). Clay Till 2 is the base of the Quaternary sequence of hydrostratigraphy within the MLWC watershed.

As previously noted, the MLWC system is highly interconnected. Figure 29 presents the configuration of the HRAs developed within the MLWC watershed and Figure 31 shows the conceptual water flow directions. As can be inferred from Figure 31, the surface and subsurface flow systems are highly interactive with several groundwater spring locations where groundwater is exfiltrating to surface and flowing as surface water towards the MLWC fen and lakes. The dominant flow paths in the watershed (and the key hydrological processes connected to the flow paths) are annotated at 9 locations on Figure 183 below. Summary descriptions of these key flow paths are as follows:

- Location 1 (Figure 183): Locations 1-3 in Figure 183 are groundwater springs emanating from a large hydraulic window in Clay Till 01 (window location outlined in white, surrounding Locations 1-3 in Figure 183). The extent of Clay Till 1 is shown in Figure 187. The elevation of the Clay Till 01/Silty Sand AQ4 interface at Location 1 in Figure 183 is approximately 320.3 masl which indicates that when potentiometric levels in Silty Sand AQ4 exceed this level, the spring will flow. The groundwater spring at Location 1 is presumed to produce more water than the other two locations in the hydraulic window given that it sets at a lower elevation, thereby presumably making it more sensitive to changes in groundwater levels in the aquifers feeding it. Once at surface, any exfiltrated groundwater would be converted to surface water overland flow that will migrate downgradient across HRA 08 (Coniferous Swamp – South) and through the melted permafrost zones of HRA 04 (Non-patterned Fen – South) before ultimately discharging into HRA 01 (Patterned Fen – South). This location would be anticipated to produce alkaline and cation-rich waters.

- Location 2 (Figure 183): There is another groundwater spring at Location 2 in Figure 183. The elevation of the Clay Till 01/Silty Sand AQ4 interface at Location 2 in Figure 183 is approximately 328.2 masl which indicates that when potentiometric levels in Silty Sand AQ4 exceed this level, the spring will contribute flows to the adjacent (ephemeral) drainage channel. The reach of the drainage channel traverses HRAs 08 (Coniferous Swamp – South) and 04 (Non-patterned Fen – South) before discharging into HRA 01 (Patterned Fen – South). This location would be anticipated to produce alkaline and cation-rich waters.

- Location 3 (Figure 183): Location 3 is a third groundwater spring interpreted to emanate from the large hydraulic window shown in Figure 183 (outlined in white). Groundwater advectively discharging to surface at Location 3 is converted to channelized flow in South Creek (the stream exiting the hydraulic window to the east). South Creek flows along HRA 18 (Fort Hill – East) in a shallow valley whose base is supported by a zone of shallowly subcropped Clay Till 1 (refer to Figure XX) and with deep sand deposits on either side of this valley (which also contribute baseflows to Unnamed Creek). Unnamed Creek discharges to HRA 11 (South Wetland – To McClelland Lake) and then into McClelland Lake itself (HRA 09). This location would be anticipated to produce alkaline waters but the drainage into South Creek from the surrounding surface sand deposits would be anticipated to be of non-alkaline and cation-poor quality (so the discharge from South Creek into McClelland Lake would be expected to be a mixture of these distinct two water qualities).

- Location 4 (Figure 183): Location 4 is a surface water divide that impedes surface water in HRA 02 (Patterned Fen North) from mixing with surface waters entering HRA 01 (Patterned Fen South). The evidence for the existence of this surface water divide is apparent both in the orientation of the strings in this region and also in the hydrogeochemical signatures of the surface waters of HRAs 01 (Patterned Fen South) and 02 (Patterned Fen North) (refer to Figure 188 and Figure 189 below). The water quality north of Location 4 would be expected to be non-alkaline and cation-poor (originating from the surface sands deposited on the west. The water quality south of location 4 would be expected to be a blend of the non-alkaline and cation-poor and (relatively) alkaline and cation-rich waters entering HRA 01 (Patterned Fen – South).

- Location 5 (Figure 183): Location 5 is the easternmost point in the MLWC system where nutrient depleted groundwater flows originating from the relatively deep surface sand deposits along the western margin of the watershed boundary can enter HRA 01 (Patterned Fen – South). East of Location 5, all groundwater flowing towards the MLWC fen would enter HRA 02 (Patterned Fen – North) or discharge towards McClelland Lake in HRA 06 (Non-patterned Fen – North). So while HRA 02 (Patterned Fen – North) only receives these non-alkaline and cation-poor groundwater inputs from the surrounding landscape, HRA 01 (Patterned Fen – South) receives a blend of non-alkaline and cation-poor as well as (relatively) alkaline and cation-rich water originating from the Fort Hills (refer to Section 1.4.3). The hydrological processes governing these groundwater flows originating from HRA 05 (Non-patterned Fen – West) that subsequently convert to surface water flows entering HRA 01 (Patterned Fen – South) at Location 1 are a function of the water table position. When the water table is deep (drier conditions), groundwater from HRA 05 (Non-patterned Fen – West) advectively flows into HRA 01 (Patterned Fen – South). When the water table is less than a few metres below ground surface, its capillary fringe will extend to and intercept the land surface. Under these conditions, incoming precipitation will result in groundwater ridging which will, in effect, pump groundwater out of the ground via capillary action and convert it to IEOLF towards HRA 01 (Patterned Fen – South). Under very wet antecedent moisture conditions, where the water table is at or above land surface, groundwater from HRA 05 05 (Non-patterned Fen – West) will flow advectively towards HRA 01 (Patterned Fen – South) and 'daylight' as surface water before entering HRA 01. This latter set of hydrologic processes are conceptualized to govern water flows from HRA 05 05 (Non-patterned Fen – West) to HRA 01 (Patterned Fen – South) most times in regions west of Location 5 in Figure 183.

- Location 6 (Figure 183): Location 6 is where nutrient depleted groundwater flows originating from the relatively deep surface sand deposits along the North Outwash Plains edge of the watershed boundary can enter HRA 02 (Patterned Fen – North) from HRA 05 (Non-patterned Fen – West) directly or alternatively enter HRA 06 (Non-patterned Fen – North) before discharging to McClelland Lake. Similar to Location 5, the water table position will govern the specific hydrological processes driving the flow from HRA 05 (Non-patterned Fen – West) to either HRA 02 (Patterned Fen – North) or HRA 06 (Non-patterned Fen – North).

- Location 7 (Figure 183): Location 7 is a region is significant groundwater drainage towards Unnamed Lake. The surrounding surface sand deposits can be in excess of 50 m deep (primarily to the south of Location 7 but also the southeast and southwest) and drain towards Unnamed Lake (HRA 11 [South Wetland – Towards McClelland Lake], HRA 12 [South Wetland – Towards Unnamed Lake] and HRA 13 [Unnamed Lake]). The surface sand deposits in this region and within the confines of the MLWC watershed will drain towards HRAs 11-13 while those outside of the watershed will drain eastward towards the Muskeg River valley at the base of the moraine. Groundwater return flow from these deep sand deposits to HRAs 11-13 would be expected to experience a degree of hydraulic lag (it will take time for recharge to reach the water table in these deposits and drainage to HRAs 11-13 occurring today would be driven by groundwater recharge that occurred several months ago or earlier. Given that this drainage is originating from the same surface sand deposit that occurs along the western margin of the watershed (i.e., Surface Sand North/Surface Sand South), it is presumed that the hydrogeochemical signature of this groundwater is non-alkaline and cation-poor. One exception to this presumption would be incoming flows into HRA 12 (South Wetland – Towards Unnamed Lake) from the east. As can be seen in Figure 187, there is a groundwater spring located east of HRA 12 (South Wetland – Towards Unnamed Lake) (groundwater spring location 4 in Figure 187) which is assumed to contribute (relatively) alkaline and cation-rich waters. These groundwater spring contributions flow into HRA 12 (South Wetland – Towards Unnamed Lake) and subsequently HRA 13 (Unnamed Lake).

- Location 8 (Figure 183): Location 8 in Figure 183 coincides with the location of groundwater spring 1 in Figure 187. Unlike the groundwater springs at Locations 1-3 in Figure 183, the groundwater spring at Location 8 does not manifest through a hydraulic window. Instead, the Clay Till 1 unit terminates right below Location 8 and groundwater in Silt Sand Aquifer 1-2 advectively flows over the terminal edge of Clay Till 1/Silt Clay, converting to surface water overland flow, and downgradient over HRA 08 (Coniferous Swamp – South) and HRA 04 (Non-patterned Fen – South) before discharging into HRA 01 (Patterned Fen – South). Silty Sand AQ4 subcrops at an elevation of approximately 311.1 masl against the terminal edge of the Clay Till 1/Silt Clay deposit at this location. The water quality flowing from this spring would be anticipated to be (relatively) alkaline and cation-rich.

- Location 9 (Figure 183): The groundwater flows emanating from Locations 1, 2, 3 and 8 could be broadly classified as focused flows because they all originate from very definable point sources. Location 7 is a mix of focused and diffuse flows; some water is entering HRAs 11-13 via groundwater drainage discharging into ephemeral channels that drain to these HRAs while the remainder is groundwater advectively exfiltrating to surface just south of Unnamed Lake (HRA 13). Location 9 in Figure 183 is also an example of a diffuse flow generating region in the MLWC watershed. Location 9 corresponds to HRA 08 (Coniferous Swamp – South) and is located at the base of the Fort Hills slopes. A very large portion of HRA 08 (Coniferous Swamp – South) is covered with low permeability tills or silt clays (refer to Figure 16 to see the surface hydrostratigraphy) which will facilitate runoff of any incoming surface water draining off of the FHUC slopes or entering the system as exfiltrated groundwater. Although the vegetation above

HRA 08 (Coniferous Swamp – South), coupled with thin permeable substrates, would not be expected to generate significant runoff most years, any groundwater drainage to rills above HRA 08 (Coniferous Swamp – South) will pass over HRA 08 (Coniferous Swamp – South) on its way downgradient. HRA 08 (Coniferous Swamp – South) also contains some smaller hydraulic windows that could also generate runoff.

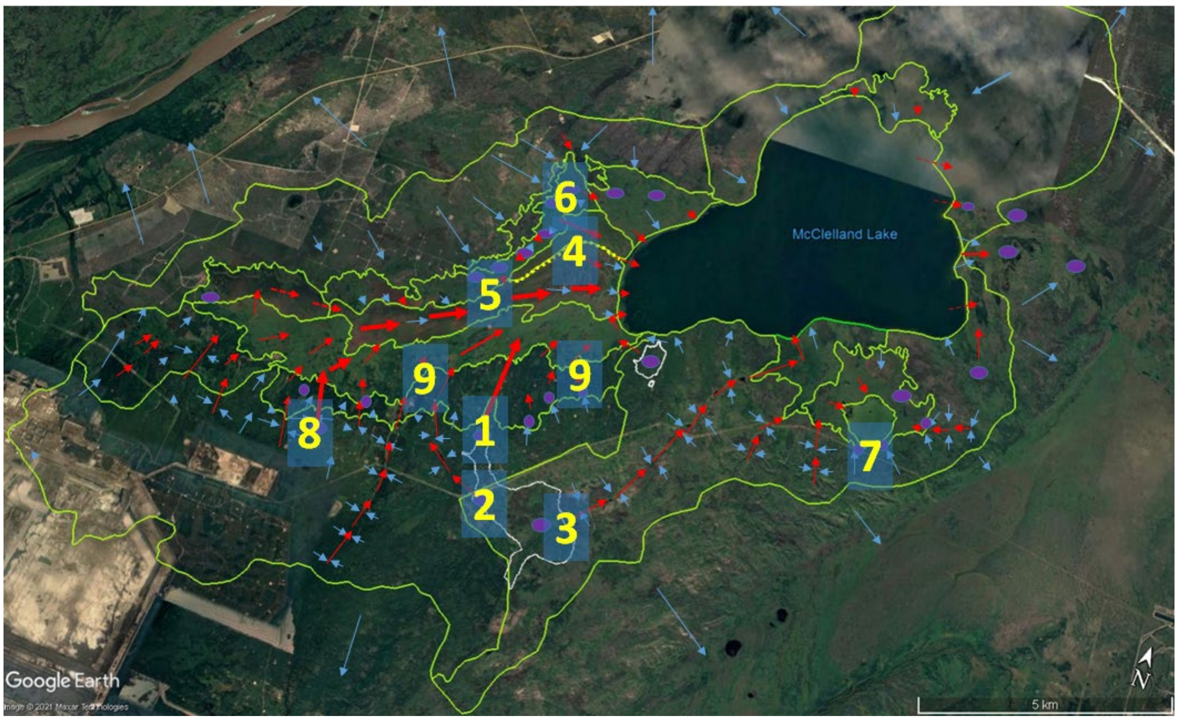

Figure 183 Conceptualized dominant flow paths within the MLWC: 1) groundwater spring flow from the FHUC reporting into HRA 01; 02) groundwater spring flow from the FHUC reporting into HRA 01; 03) groundwater spring flow from the FHUC into the headwaters of South Creek and then to McClelland Lake; 04) a surface water divide separating the patterned fens; 05) the location where oligotrophic water from the NOP can enter HRA 01; 06) the portion of the landscape contributing oligotrophic groundwater to HRA 02; 07) region of significant seepage from the overlying eastern FHUC towards Unnamed Lake; 08) groundwater spring flow from the FHUC reporting to the western margin of HRA 01; and 09) region (HRA 08) of significant runoff generation from the overlying FHUC towards the MLWC fen area. Image source: Google Earth/Maxar Technologies.

From the preceding work and the above observations, a number of initial conceptual statements can be made regarding the MLWC watershed flow system:

- The presence of Clay Till 1 essentially bifurcates the MLWC`s flows into upper (above Clay Till 1) and lower (below Clay Till 1 but above Clay Till 2) local groundwater flow systems. The lower portion of this bifurcated local groundwater flow system extends to the north and west within the MLWC watershed where these silty sand deposits exist (extent of the silt sand deposits shown in Figure 11). North and east of the silt sand deposits, Clay Till 1 directly overlies Clay Till 2 and continues extending northward. Cross-sections illustrating the bifurcation of the local groundwater flow system are shown in Figure 21 and Figure 22.
- The origin of the water generating surface water flows is a combination of precipitation and groundwater that discharged to surface within the boundaries of the MLWC watershed.
- The MLWC watershed is a groundwater dominated flow system. A substantial portion of that groundwater becomes surface water as it flows towards the MLWC lowlands.
- The origin of the water generating local groundwater flows within the Quaternary deposits of the MLWC watershed is likely just precipitation recharging the watershed`s aquifers. The potential for intermediate or regional groundwater inputs contributing to shallow Quaternary groundwater flows in the MLWC watershed is discussed next.

34. Section 1.4.1: The Potential for Regional or Intermediate Groundwater System Inputs

Regarding the origins of the waters flowing on the surface of the MLWC watershed, the potential for regional (Devonian) or intermediate (Cretaceous) groundwater inputs into the local (Quaternary) groundwater flow system was examined. Recorded undifferentiated Devonian water levels around the MLWC watershed (2014-2018) are presented in Figure 184. Although these data were recorded after industrial development of the region started, the levels are assumed to still be reasonably representative of pre-development conditions. As can be seen in Figure 184, Devonian groundwater levels range from approximately 250-260 masl around the footprint of the MLWC watershed and appear to trend higher to the southeast. Devonian bedrock outcrops in the Firebag River valley north and west of the MLWC (Schneider et al. 2014; Schneider et al. 2018; and ITK holders). As evidenced by the Lower McMurray Member (Basal water sands) groundwater well hydrographs discussed in MLWC OP Objective 1 (Section 2), Cretaceous groundwater levels can range up to nearly 300 masl under the MLWC watershed footprint.

ITK holders have noted limestone outcrops along the Firebag River and are known to underlie the sands and muskeg beneath MLWC:

> *"I know there's a lot of limestone through there. Now the water, course, is sitting on this limestone. It's some little creeks that don't… some places. And there's clay in there too, and water don't go through clay..... What about the fen? What's underneath the fen? There's water. There's tar sand under the fen and then the limestone? Because I know the limestone from there*

runs right to Fort McMurray, past Fort McMurray. The furthest north I've seen it was at the Firebag, and I could be wrong. It could be further north yet too, but I know the Firebag. So the water then, it's sitting... Okay, it's limestone, tar sand, water, and the floating muskeg on top. That's the way I'm picturing it." (FCM ITK holder, March 3, 2021 workshop) (Note that in this region limestone is the Devonian-aged rock and is referred to as the Devonian in the remainder of the document)

Ground surface elevations near McClelland Lake and the adjoining wetland complex to the west span approximately 294-300 masl. Regional Devonian groundwater cannot reach this elevation but intermediate Cretaceous groundwater can, provided a hydraulic pathway to do so exists. Roof elevations of the Clay Till 2 aquitard that sits at the base of the Quaternary sequence range from approximately 290-230 (masl), sloping downward in a general southwest to northeast orientation. Both regional Devonian and intermediate Cretaceous groundwater can reach this elevation range, provided a hydraulic pathway to do so exists. An obvious potential hydraulic pathway would be the hydraulic windows present in Clay Till 2 shown in Figure 11. Figure 11 also shows these hydraulic windows in Clay Till 2 are underlain by either bitumen-saturated McMurray oil sands (aquitard), or mudstone (CM40 Aquitard) (Figure 11), or are overlain by Clay Till 1 (Figure 13). Based on this hydrostratigraphic information, the mapped hydraulic windows present in Clay Till 2 do not present a likely hydraulic pathway upwards for regional or intermediate groundwater inputs. However, other potential hydraulic pathways could exist; for example, unmapped hydraulic windows in Clay Till 1 or sinkhole lakes hydraulically connected to the underlying Cretaceous or Devonian strata. A FCM ITK holder noted that sinkhole lakes in the MLWC area tend to maintain steady water levels (FCM ITK holder, March 3, 2021 workshop). Regional and intermediate groundwater inputs to the local MLWC Quaternary groundwater flow system are presumed unlikely but cannot be definitively precluded conceptually with currently available data.

"The little round lakes seem to keep their levels" (FCM ITK holder, March 3, 2021 workshop)

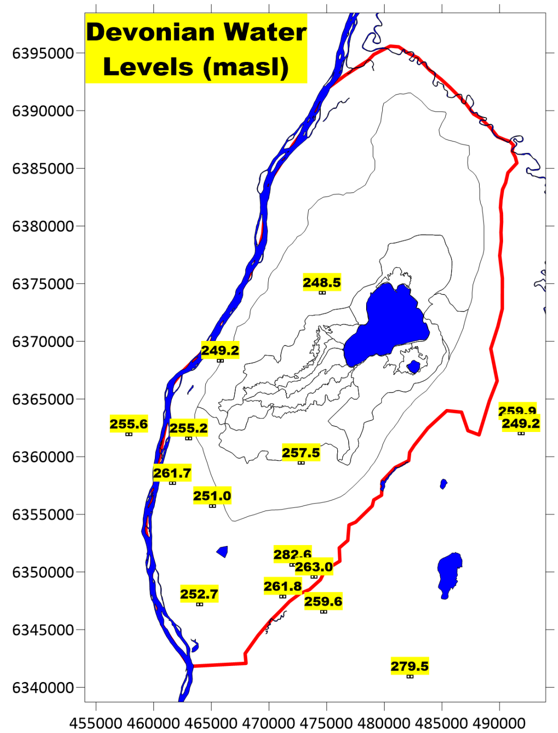

Figure 184 Regional undifferentiated Middle and Upper Devonian water levels. Note that the data spans a time range from approximately 2014 to 2018.

35. Section 1.4.2: The Groundwater Origins of Surface Water Flows in the MLWC Watershed

As noted in Section 1.4.1, the MLWC watershed has no incoming source of surface water originating from outside the watershed and is presumed to be hydraulically isolated from underlying regional or intermediate groundwater inputs. Based on available evidence, all water residing in the MLWC watershed appears to solely originate from incoming precipitation, with some potential for occasional, additional groundwater contributions from the surrounding landscape outside of the watershed boundaries (refer to Figure 191).

On the land surface of the MLWC watershed, most water is stored in the lakes, creeks, the muskeg and the flarks of the patterned fens (depression and channel storage). In the subsurface, groundwater is stored in the clean surface sand deposits (actually a single continuous unit but segregated into Surface Sands North and Surface Sands South in the 2020 Unified Geomodel to account for a slight trend in hydraulic conductivity) and the silt sand hydrostratigraphic sequence that underlies the FHUC (soil moisture and groundwater storage).

With no surface water coming into the MLWC watershed, direct precipitation and groundwater contributions are presumed the source of the relatively large volumes of surface water being produced. Vitt and House (2020) mapped four areas where surface water flows enter either the northern, moderate-rich patterned fen (the northwestern source in Figure 185) and the southern, extreme-rich patterned fen (the southwestern, southcentral and southeastern sources, respectively, in Figure 185). However, that study but did not trace the groundwater origins of these incoming surface water flows.

The northwestern source in Figure 185 is groundwater originating from the deep, fine- to medium-grain surface sand deposits lying on the western margins of the watershed. The three remaining mapped incoming surface water flows shown in Figure 185 all appear to originate south of the southern extreme-rich patterned fen (HRA 01). Southwestern and southcentral surface water sources in Figure 185 lie between HRA 01 (Patterned Fen – South) and HRA 17 (Fort Hills West), which is somewhat indicative that the surface water flows being generated at these locations likely originate from the uplands in HRA 17. Under the presumption that there are no intermediate or regional groundwater inputs to the MLWC watershed, then the surface water flows generated at locations 2 and 3 in Figure 185 have to be originating upslope in HRA 17 and flowing across HRAs 08 and 04.

Large portions of the forested upland slopes of HRA 17 are vegetated with Aspen which primarily overly a thin veneer of relatively permeable substrate with sections of low permeable silt clay or till. The study by Devito et al (2017) indicated the of Aspen in this type of setting (provided the area is not influenced by fine textured hummocky terrain) experience long term median AET rates ranging between 459 to 470 mm/yr and AET/Precipitation ratios on the order of .91 to .96 and runoff rates in the range of four to nine percent of precipitation. If runoff rates in the aspen forested HRA 17 are presumably this low, it is not immediately apparent how this HRA could be the origin of the southwestern and southcentral surface water flows shown in Figure 185.

Figure 186 shows the surface stratigraphy of the MLWC watershed taken from the 2020 Unified Geomodel and Figure 187 shows the setting again with hydrostratigraphy above Clay Till 1 turned off. The locations of four groundwater springs are also indicated in Figure 187. Groundwater springs 1 and 4 develop whenever the groundwater level in the silt sands at these locations is higher than the terminal edge of Clay Till 1, subsequently advectively flowing over that terminal edge. Groundwater spring 1 (Figure 187) is the primary origin of the mapped southwestern surface water flows shown in Figure 185.

Groundwater springs 2 and 3 (Figure 187) are located above hydraulic windows in Clay Till 1 that allow the passage of groundwater originating from the underlying silt sand deposits into the upper local groundwater flow system, subsequently exfiltrating to the land surface (based on the likely groundwater levels in the underlying silt sand deposits). Groundwater spring location 2 in Figure 187 is the primary source of the mapped southcentral surface water flows (location 3) shown in Figure 185 via a drainage channel originating from this hydraulic window and flow towards the southcentral source location (Figure 31). Moreover, groundwater spring 2 in Figure 187 contributes water to South Creek (which discharges into McClelland Lake by the area near Unnamed Lake). Groundwater spring location 3 shown in Figure 187 is a second flowing hydraulic window in the Clay Till 1 deposit whose discharge to surface reports to McClelland Lake directly through an inlet or indirectly by wrapping around the southern tip of the lake, entering Patterned Fen – South (HRA 01) and then discharging to the lake. Groundwater spring location 3 in Figure 187 is the primary origin of the mapped southeastern surface water source shown in Figure 185. The groundwater sources of any remaining water reporting to MLWC lowlands are mainly groundwater return flows from the deep, sandy deposits comprising the upland landforms surrounding the MLWC watershed (Figure 185) or simply groundwater advective flow from the uplands to the lowlands that can potentially continue to infiltrate or exfiltrate repeatedly along its flowpath to McClelland Lake.

Important observations of springs has been shared by ITK holders, including locations of springs and the importance of these underground springs connections to surface waters. ITK holders are familiar with most creeks, lakes and underground springs – places where shallow ground water comes up to the surface. Areas of thin ice or areas slow to freeze can represent the presence of springs.

> *“when you come from Mile 14, you'll come walkin straight up that hill there, there's ice cold water springs in there. And we used the pool right beside my granny's house (MaryAnn Beaver’s cabin). And I mean, that water was so cold you could just drink it there. But there was a lot of hanging muskeg past there...” (*FMFN ITK holder, March 3, 2021 workshop*)*

> *“And there is some little creeks that don't freeze in the winter the, but those are probably more like springs that are heading towards the river and on the river. But there's no really big creeks on towards the Athabasca River, from between McLennan Lake and Athabasca River, except for springs.”* (FCM ITK holder, March 3, 2021 workshop)

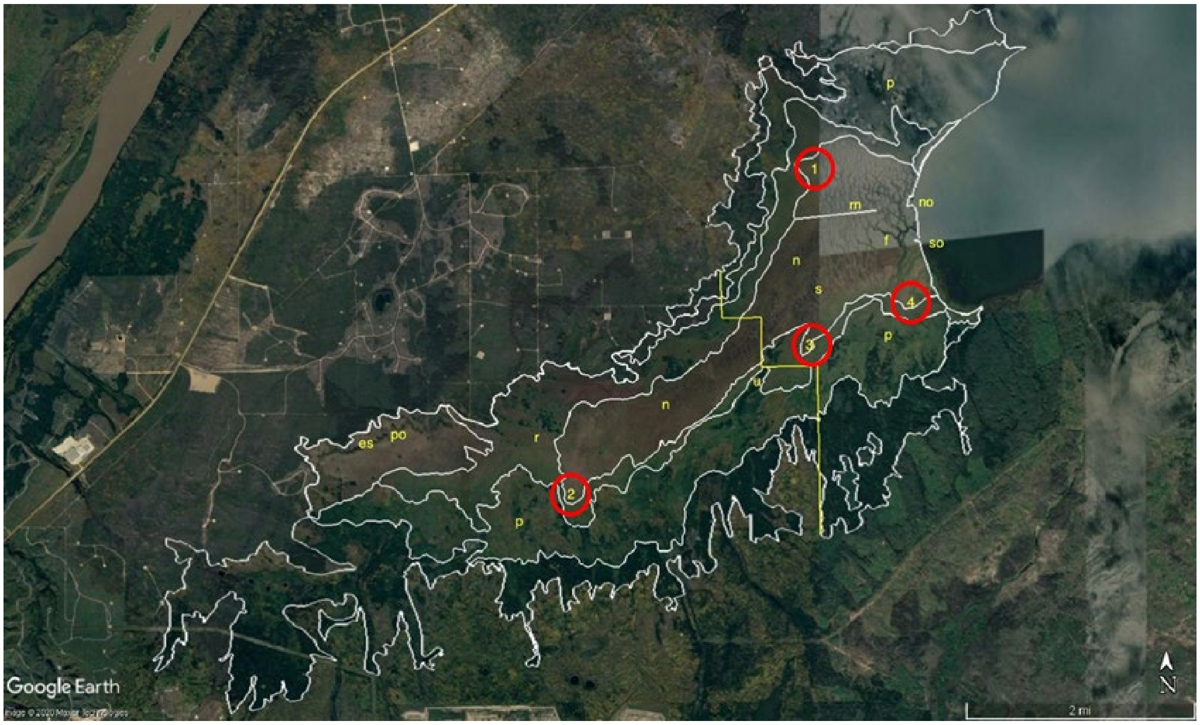

Figure 185 Four mapped areas of incoming surface water flows reporting to the wetland complex west of McClelland Lake, highlighted with red circles: 1) a northwestern source; 2) a southwestern source; 3) a southcentral source and 4) a southeastern source. Figure source: Modified from Figure 3.5 in Vitt and House (2020). Image source: Google Earth and Maxar Technologies.

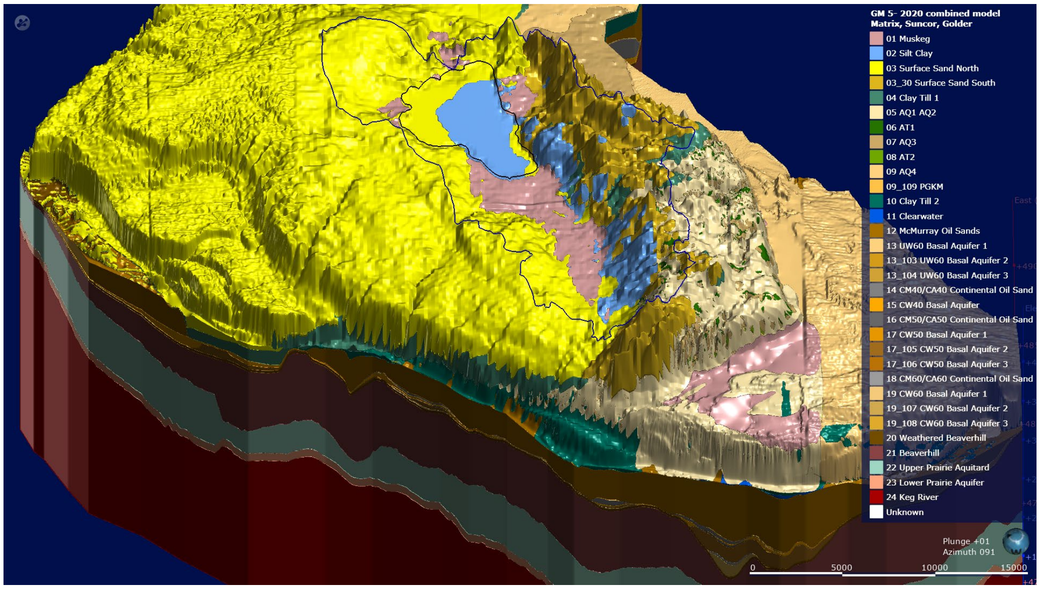

Figure 186 The surface hydrostratigraphy of the MLWC watershed. Note that the MLWC watershed and McClelland Lake are outlined in the figure. Note: vertical exaggeration is 80:1.

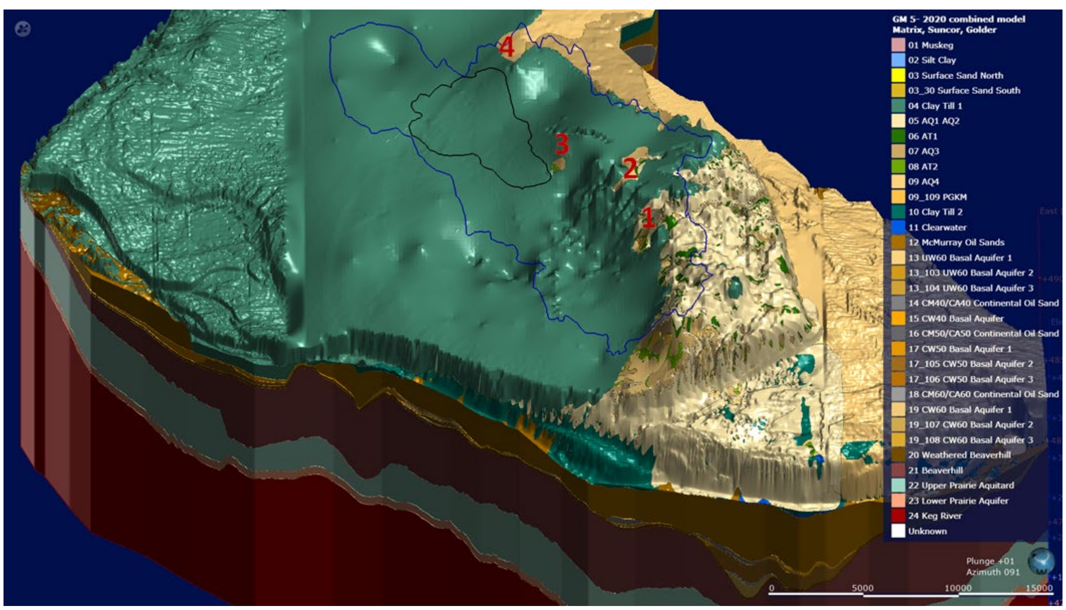

Figure 187 The MLWC watershed with the hydrostratigraphy above Clay Till 1 turned off. Locations 1-4 are interpreted to be groundwater springs that contribute flows to the MLWC lowlands. Note: the watershed and the lake are outlined in the figure and vertical exaggeration is 80:1.

36. Section 1.4.3: The Hydrogeochemical Regimes of the MLWC Watershed

All of the water within the MLWC's Quaternary deposits is conceptualized to ultimately originate from incoming precipitation and that incoming precipitation would be expected to have a relatively uniform, dilute and non-alkaline hydrogeochemical signature. This incoming precipitation is the source of all groundwater within the Quaternary deposits in the MLWC watershed. Groundwater exfiltration and incoming precipitation are the sources of all surface water within the MLWC watershed. However, as documented by field data and by Vitt and House (2020), by the time surface water drainage arrives at the moderate-rich and extreme-rich patterned fens (HRA 02 and HRA 01, respectively, Figure 29), the hydrogeochemistry has bifurcated into two distinct signatures: 1) non-alkaline water and cation-poor and 2) (relatively) alkaline and cation-rich waters. The moderate-rich patterned fen (HRA 02) solely receives the non-alkaline and cation-poor water while HRA 01 receives a blend of both waters. Vitt and House (2020) notes there is a shallow surface water drainage divide hydraulically isolating surface water flows reporting to HRA 02 from surface water flows reporting to HRA 01. The presence of this surface water drainage divide is what keeps the hydrogeochemical signatures of the two patterned fens distinct. Figure 188 and Figure 189 illustrate the distribution of these two hydrogeochemical streams (across the patterned fens) using plots of spatial variation with respect to calcium and magnesium, respectively.

All surface water present within the MLWC watershed originated as precipitation or groundwater that was subsequently converted to surface water along its flowpath. As such, it can be inferred that groundwater (the mineralogy of the porous medium's matrix) is the source of the observed variations in the surface water hydrogeochemistry within the MLWC watershed.

Groundwater flows reporting to the moderate-rich patterned fen (HRA 02; Figure 29 and Figure 31) originate from the surface sands deposits located north and west of this HRA (designated Surface Sands North in the 2020 Unified Geomodel; Figure 16). These surface sand deposits are present, to some degree, in all 21 HRAs (refer to the Surface Sand North and Surface Sand South deposit extents; Figure 16). These surface sand deposits were initially described by Bayrock (1970) as a continuous Aeolian sand layer sitting above till but beneath the muskeg deposits. Matrix (2020) classified the deposit as an aquifer and described them as being composed of fine- to coarse-grained quartz rich sand, containing low silt and clay content with traces of reworked bituminous sand/silt. Matrix (2020) also notes the unit likely originates from reworked outwash sands from the elevated areas of the Fort Hills that was deposited after being transported onto the lower lying area currently occupied be the MLWC in the early deglacial environment. Water residence times in this deposit (before exiting in the form of groundwater exfiltration) are conceptualized to be less than a few years (shorter residence times on the western side of the watershed where the water table is shallow and longer times in the deeper surface sands on top of the Fort Hills). Quartz is a relatively slow weathering and insoluble mineral and there is little other mineralogy present in these surface sand deposits to significantly alter the hydrogeochemical signature of infiltrating precipitation. The surface sand deposits are presumed to be the source of the non-alkaline and cation-poor hydrogeochemistry measured by Vitt and House (2020) in HRA 02.

As noted in Glaser et al. (1990), the main source of alkalinity in wetlands in the Lake Agassiz region is typically loamy or clayey ground moraines. The FHUC is a moraine deposit within the Lake Agassiz region (Fisher et al., 2009). Figure 16 shows that a relatively significant proportion of the lower slopes of the FHUC are covered with either Silt Clay or Clay Till 01. It is possible that that these clay and till deposits at surface in the FHUC are the source of both the alkalinity and the elevated level of base cations (such as dissolved calcium) that flow into the extreme-rich patterned fen (HRA 01). Alternatively, the glacially-rafted Upper McMurray unit (PGKM) at the base of the Pleistocene aquifers making up the core of the FHUC (the PGKM deposit extent is shown in Figure 7) is hypothesized as an additional potential source of the alkalinity and elevated cation levels observed in water coming from the FHUC. As well, the addition of calcite saturated groundwater entering the muskeg could contribute to the availability of alkalinity and base cations to the fen. It is also worth noting that tills and clays are not present at surface in the HRAs on the western and northern sides of the MLWC watershed. Alberta InnoTech (2020) noted that carbonate precipitation and dissolution, and the variations in base cation concentrations, seem to vary as a function of the partial pressure of carbon dioxide and pH fluctuations. As such, processes such as photosynthesis and seasonal fluctuations in the water table (both of which can cause these fluctuations in pH and the partial pressure of carbon dioxide), are also possible contributing factors to the alkalinity found in these waters. It should also be noted that the groundwater entering the MLWC lowlands from the Pleistocene silty sand deposits comprising the core of the FHUC (via groundwater springs shown in Figure 187) could also potentially contribute to the base cations of this (relatively) alkaline and cation-rich water.

It is conceptualized that the hydrogeochemical nature of the waters discharging to McClelland Lake also exhibit a degree of seasonality. During the spring freshet, the pulse of water received by the lake would essentially consist of snowmelt runoff which will have a hydrogeochemical signature quite similar to precipitation or the non-alkaline and cation-poor being produced by the system's surface sand deposits. As noted in available ITK, this snowmelt runoff freshens up the hydrogeochemical profile of the lake each spring (displacing higher TDS waters in the lake), which helps prevent the lake from evapo-concentrating over time (MCFN ITK Holders, MCFN 2019). As the system continues to thaw, McClelland Lake would resume receiving a blend of the non-alkaline cation-poor and the (relatively) alkaline and cation-rich waters until the onset of the next winter season.

Water levels in the MLWC vary. In the spring water levels are high. Water levels remain high until mid-summer. Water levels are lower in the fall. Spring water levels depend on the amount of winter snow, ice quality and strength and the amount of spring precipitation (MCFN ITK Holders, MCFN 2019).

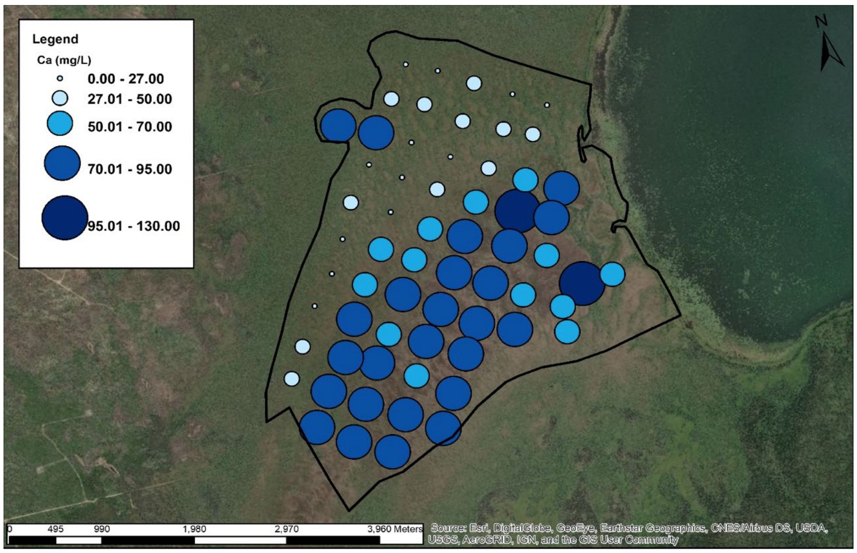

Figure 188 Recorded variation in surface water calcium (mg/l). Figure Source: Figure 7.5 in Vitt and House (2020).

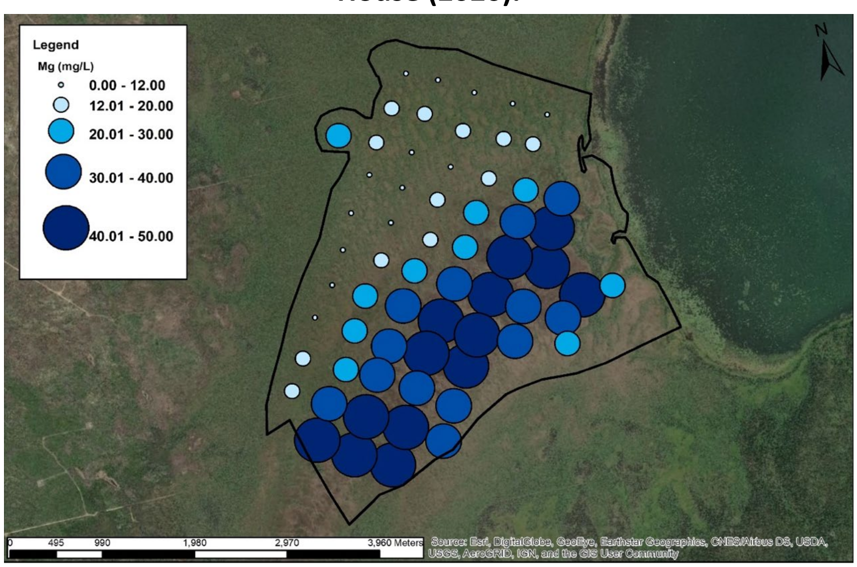

Figure 189 Recorded variation in surface water magnesium (mg/l). Figure Source: Figure 7.6 in Vitt and House (2020).

37. Section 1.4.4: The Role of the Patterned Fens in the MLWC

The patterned fens at MLWC control the magnitude and timing of surface water flows entering the southwestern shores of McClelland Lake. Annual peak flows within a patterned fen located in the southern WBF typically occur during the spring freshet. Within the MLWC extents, any runoff wanting to discharge into McClelland Lake has to cycle through one of the patterned fens first. Water levels in the flarks in late fall are typically at or near ground surface and the substrates in the flarks will freeze solid, with little excess storage capacity. Over winter, a degree of ice buildup is conceptualized to occur in the flarks similar to the white ice mechanism described in Price and Fitzgibbon (1987), due to groundwater redistribution from the MLWC uplands to the lowlands (towards to patterned fens) that still occurs during winter.

Once the freshet arrives and the winter snowpack begins to melt, the snowmelt will runoff where it can from the surrounding landscape, flow down gradient and converge towards the patterned fens (primarily the extreme-rich southern patterned fen), eventually discharging into the lake (Figure 190). Post-freshet, the flarks would thaw and drain water into the lake, leaving storage capacity in the flarks to store the incoming June and July rains, which typically constitute the peak precipitation rates encountered in a typical year at the MLWC. As a consequence, peak rainfall at the MLWC occurs during the summer but peak flow rates from the patterned fens to the lake occur earlier in the spring. This is typical of patterned fen behavior in the WBF. This precipitation-storage-runoff relationship of patterned fens is a function of a given flark's storage capacity and the degree to which the flarks are hydraulically interconnected to each other. Downstream flarks in patterned fens tend to be larger than upstream, younger flarks. At the MLWC, the largest flarks are the ones closest to the lake (Figure 190). Once the storage capacity of an upstream flark is depleted, water will begin to runoff into an adjacent downstream flark. This mechanism is sometimes colloquially referred to as a fill and spill process.

With some exceptions (such as string fens found in the Florida Everglades), patterned fens tend to only form in a relatively narrow latitudinal band globally falling between the subarctic permafrost and the more southerly WBF where the ice goes out early in the spring (Dale Vitt, personal communication). Patterned fens also typically form at locations in the landscape that receive groundwater discharge. These locations will tend to have water tables that facilitate the runoff to occur that patterned fens rely upon for their maintenance (among other mechanisms). These locations in the landscape also will tend to generate snowmelt runoff during the freshet that helps maintain the growing moss tips above the surface of the frozen peat. These mosses need this fresh cool water to quickly grow in the spring before more deeply rooted vascular plants start to grow and produce shade (Dale Vitt, personal communication).

Figure 190 Photo of the MLWC when the flarks are full during freshet. Note photo was taken from the McClelland lake side of the MLWC. Figure Source: Dale Vitt (used with permission).

38. Section 1.4.5: The Importance of Snowmelt in the MLWC Watershed

In a typical year at the MLWC, approximately one-quarter to one-half of all runoff cycling through the MLWC system will occur during the spring freshet. Freshet at the MLWC typically happens in a 2–6-week period between late March and early May most years. During the freshet most of this runoff arrives in the form of snowmelt running off over frozen ground. Runoff over frozen ground can also occur for a number of weeks after the freshet. Portions of the landscape that freeze solid during the winter (due to high water tables or low permeability land soils at surface) can remain frozen for several weeks after the freshet and continue to produce runoff each time incoming precipitation hits the frozen surface and runs off downgradient.

A substantial portion of the snowmelt runoff occurring within the MLWC landscape would eventually discharge into McClelland Lake. The hydrogeochemical nature of that freshet runoff would be non-alkaline and cation-poor (with a signature similar to that of precipitation). As noted by ITK holders and their observations in the area, this fresh pulse of snowmelt runoff each spring would serve to keep the water in the lake fresh (MCFN ITK Holders, MCFN 2019). Another way to describe this process would be that the snowmelt pulse received by the lake would displace less fresh water in the lake's storage which is presumed a major factor as to why McClelland Lake does not evapo-concentrate over time. Regions downstream would also rely on the on this lake discharge each spring to help support their maintenance. As the MLWC continues to thaw post-freshet, the lake would resume receiving a blend of the two distinct MLWC hydrogeochemistries discussed in Section 1.4.3.

39. Section 1.4.6: How Water Is Transmitted From The MLWC Uplands to the Lowlands

The FHLU concept of Winter (2001) can be used to describe how water cycles through the MLWC at larger scales. A FHLU consists of an upland adjacent to a lowland separated by a relatively steeper intervening slope and can contain one or more of the MLWC HRA's developed using the Devito et al. (2005) characterization framework. Delineating the hydrologic system of a FHLU consists of: 1) describing its surface water movement, 2) describing its groundwater movement and 3) describing the exchange of atmospheric water controlled by climate (Winter, 2001). The MLWC watershed arguably has two broad, general types of FHLU's:

1) **MLWC FHLU 1**: Uplands containing deep, permeable substrates adjacent to shallower, lowland permeable substrates, separated by a moderate intervening slope (also composed of the same permeable substrate). This FHLU is in a semi-humid climatic setting. This FLHU would generally apply to majority of the MLWC watershed, with the exception of the region between HRA 17 and HRA 01 (where the 2nd FHLU is situated).
2) **MLWC FHLU 2**: Uplands containing deep, (relatively less) permeable substrates adjacent to lowlands covered by a thin permeable substrate, separated by slopes covered of either a thin veneer of permeable substrates or by silt clay and till deposits. This FHLU is in a semi-humid climatic setting. This FHLU is applicable to the portion of the MLWC landscape between HRAs 17 and 01.

40. Section 1.4.6.1: MLWC Fundamental Hydrologic Landscape Unit 1

How water generally cycles through MLWC FHLU 1 can be illustrated using HRA 16 (North Outwash Plains – West) and the sequentially adjacent lowland HRAs (e.g., HRAs 07, 05 and 01) as an example. The locations of these HRAs is shown in Figure 29. MLWC FHLU 1 is also considered representative of the landform settings found in HRAs 15 and 18 and their respective adjacent lowland HRAs. The water cycling behavior across HRAs 15, 16 and 18 will vary somewhat but is presumed similar enough that it can be described using a single FHLU.

Substrate depths in the uplands of MLWC FHLU 1 (HRA 16) range between 6.9 to 47.9 m and are comprised of permeable surface sand deposits which trend deeper from the southwest to the northeast and shallower from the watershed boundary towards the interior. Substrate depths and generally decrease from the watershed boundary into its interior. Depth to the water table across HRA 16 can range from approximately 10 mbgs near the MLWC watershed boundary to near land surface along its interior lowland edge. Water table depths in HRAs 07, 05 and 01 tend to become progressively closer to or above land surface as one goes further into the interior of the watershed.

When an infiltration event resulting in recharge occurs in HRA 16 (e.g., snowmelt infiltration during the spring freshet or rainwater during a summer storm), upon reaching the capillary fringe the infiltrating water displaces all of the air in the void space and the water table begins to rise (Fetter, 2001). This process results in the freshest recharge lying at the top of the capillary fringe (which will rise with the water table). The water table in HRA 16 (and in the FHLU it is a part of) is assumed to be relatively flat and infiltrating water will reach the underlying capillary fringe in different parts of the landscape at different rates. In the interior of the watershed, where the water table is near or at the land surface, infiltration will reach the water table rapidly, causing a the water table to temporarily mound laterally towards the (now) lower-lying water table in the uplands (where infiltration has not reached the water table yet). Once infiltration in the uplands reaches the water table, a mound will form, migrating laterally towards the watershed interior. While all of this is happening, the water table is rising. During this transitory period of complex hydrodynamic interactions within and beneath the vadose zone, and before the system re-equilibrates, groundwater flow reversals are possible. As noted in Winter (1983), these flow reversals would be presumed to only affect groundwater movement at the top of the variably-saturated flow system.

The substrates underlying HRAs 16, 07, 05 and 01 are largely composed of clean fine- to medium-grain sands and are relatively permeable; the periods of complex and transitory flow processes during recharge events (described above) would be expected to dissipate quickly. In situations where understanding the timing of these groundwater flow reversals is needed, techniques to estimate travel times through the unsaturated zone using just basic field information or literature estimates are available, for example, in Sousa et al. (2013).

These complex transitory processes also contribute to the fluctuation of the groundwater divide position within the watershed. The divide position is relatively fixed by landscape geometry on the eastern and southern boundaries of the MLWC watershed; elsewhere, the divide position fluctuates constantly as a function of groundwater storage levels. As water enters storage in the underlying groundwater catchment in the MLWC area, the divide will shift outward. As groundwater storage is consumed, the divide will shift inward. For this fundamental hydrologic landscape unit, the presence of a flat water table, coupled with differential recharge rates due to variable substrate depths, results in a groundwater divide that is constantly moving. When groundwater mounding occurs near the watershed boundary, the groundwater divide will shift to the vertices of those mounds and then continue to recede inward as the system re-equilibrates. During winter, when groundwater recharge has ceased, the western groundwater divide will incrementally recede to the east as groundwater storage is consumed, reversing once infiltration from the spring freshet reaches the water table. A typical groundwater divide position near the end of winter is shown in Figure 191. The dynamic portion of the groundwater divide moves in concert with changes in groundwater storage within the groundwater catchment (the red line in Figure 191). Under unusually wet conditions with low groundwater storage capacity, additional incoming precipitation can push the divide temporarily past the western watershed boundary (the region outside of the watershed shaded in blue Figure 191).

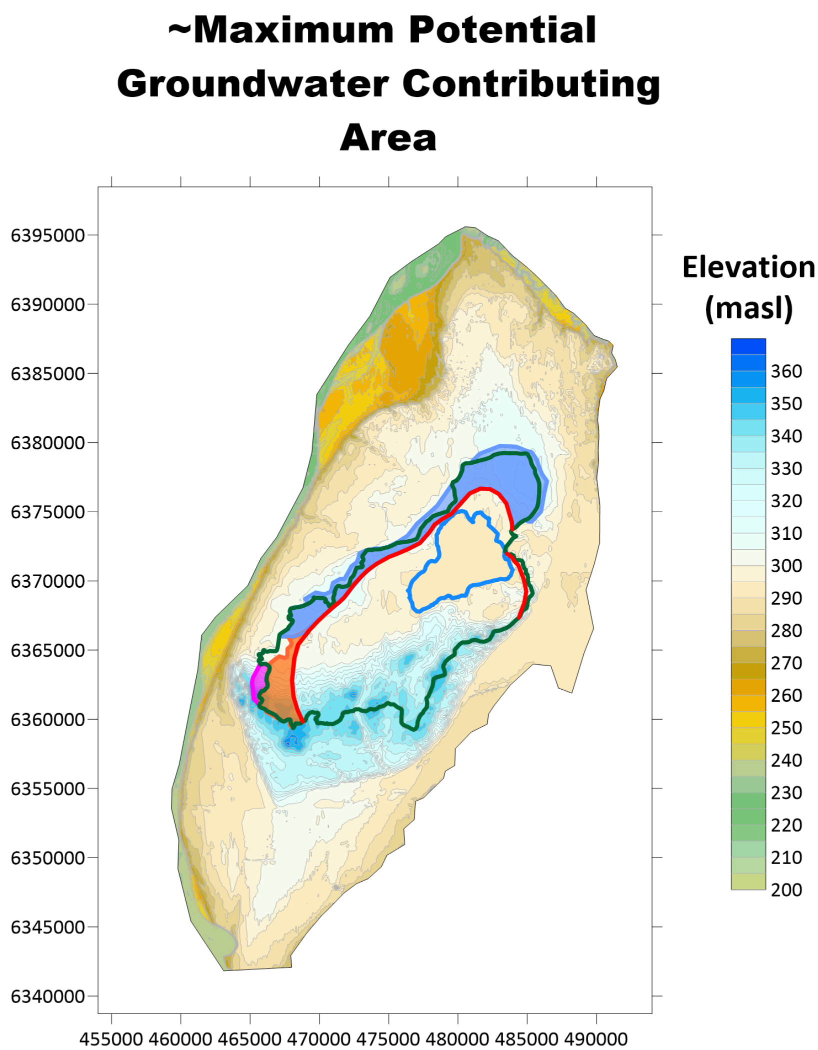

Figure 191 Approximate maximum potential area that can contribute groundwater to the MLWC lowlands. The pink region flows into the watershed from outside of the watershed, the orange region is where groundwater can enter the fen by discharging to surface even, when the groundwater divide is west of this region and the blue shaded region is the approximate area over which the groundwater divide can shift under wet and low storage conditions. The red line on the figure is conceptualized as a typical, minimal groundwater divide position near the end of winter. The groundwater divide can extend beyond the western and northern boundaries of the watershed under wet and low storage capacity conditions.

The intersectional margin of HRAs 07 (Coniferous Swamp – North) and HRA 05 (Non-patterned fen – West) is a region where the water table would be presumed to reside at or near the land surface under wet conditions, perhaps 1-2 mbgs under standard conditions and at some greater depth under dry conditions. Substrates depths decrease steeply from the watershed boundary (HRA 16) to the interior (HRA 05 and HRA 01) in this area. The surface sand deposits making up the aquifer in FHLU 1 have a fine to medium-grain texture that would be capable of producing a substantial capillary fringe. The HRA 05 setting has been previously conceptualized as generating significant volumes of runoff (the northwest surface water source shown in Figure 185). Runoff generated from HRA 05 would follow the topography downgradient into HRA 01 (Patterned Fen – South) and/or HRA 02 (Patterned Fen – North), before transpiring into the atmosphere or discharging to McClelland Lake. Evapotranspiration losses can occur all along the runoff flow path of FHLU 1, on its way to the lake.

The summertime hydrologic response to incoming precipitation in FHLU 1 is a function of the position of the water table during the precipitation event. Under dry conditions, when the water table is at some depth, precipitation at this margin would be expected to result in infiltration into the permeable substrate. Under very wet conditions, when the water table is at or near the land surface, incoming precipitation will generate runoff in the form of saturation excess overland flow. However, under expected average conditions in the MLWC watershed, when the water table in this region is less than a few meters below the ground surface in HRA 05, the capillary fringe above the water table will extend to or above the land surface. Under these conditions, the shallow subsurface is tension-saturated and the groundwater storage capacity over the tension-saturated zone is zero. Any incoming precipitation under these conditions will yield groundwater ridging, resulting in runoff generation. Groundwater ridging occurs when precipitation hits the tension-saturated ground, resulting in an instantaneous rise in the water table to the land surface and concomitant runoff generation. Further details on the groundwater ridging mechanism can be found in Gillham (1984). Field experiments on groundwater ridging in a comparable substrate setting as the MLWC's (Canadian Forces Base Borden) can be found in Abdul and Gillham (1989). Numerical simulations of these field experiments can be found in Jones et al. (2006).

The intersectional margin of HRAs 07 and 05 and the interior of HRA 05 would be assumed to be an area of the MLWC system that converts significant volumes of groundwater originating from HRA 16 to surface water runoff in HRA 05 via groundwater ridging and advective groundwater flows, among other hydrological mechanisms. More to the south, where HRA 16 intersects HRA 05 directly, and advective groundwater flow is the more dominant mechanism for conveying groundwater from the MLWC watershed boundary to its interior.

During winter, when ground freezing has effectively hydraulically isolated the subsurface flow system from the surface, the groundwater will incrementally re-equilibrate, redistributing water from regions of higher total hydraulic head (e.g., by the watershed boundary) to regions of lower total hydraulic head (e.g., the watershed interior), rates dictated by the existing hydraulic potential field. This redistribution process progressively slows over winter as the system state continues to approach equilibrium. After the spring freshet, the surface and subsurface flow systems regain hydraulic connection, both receive additions to storage from the freshet water pulse (depression storage gains on the surface and groundwater storage in the subsurface) and the ice-free period of water redistribution begins anew, driven by areas of water surplus flowing to areas of water deficit.

The upland portion of FHLU (HRA 16) is vegetated with a mix of conifer (dominant and mainly pine) and deciduous tree stands. The topsoils are classified as being relatively permeable and well-draining. This HRA is also still recovering from the effects of wildfires from 2011 and 2016 and the vegetation is relatively sparse and sits on a deep, permeable substrate with a relatively deep water table. Under these conditions (sparse vegetation, low canopy interception, deep and permeable substrate), both summer rainstorms generating infiltration and snowmelt infiltration during the spring freshet will typically be expected to capture large fractions of the infiltrating water as recharge.

In the wintertime, the ground in HRA 16 would be expected to freeze in a honeycomb-like structure (where the water table is well below land surface), remaining permeable and containing a high groundwater storage capacity which can absorb any snowmelt during the winter season. During the freshet, most snowmelt would be expected to infiltrate past the vegetative root zones and become groundwater recharge. Contrarily, the ground in HRAs 07, 05 and 01, where the water table is at or near the land surface, would be expected to freeze solid. During the spring freshet snowmelt would be generally expected to just infiltrate into the ground into the upland portion of fundamental hydrologic landscape unit 1 (HRA 16). Snowmelt runoff would be expected to occur over the frozen ground of the lowland HRAs (07, 05 and 01) that quickly discharges into McClelland Lake. Runoff from the lowlands could continue to be generated as that ground could remain frozen into early June, any incoming precipitation during this frozen period would generate infiltration excess overland flow until the ground thaws. A conceptual diagram indicating water flow directions, relative magnitudes and the primary hydrological processes involved in FHLU 1 is shown in Figure 192.

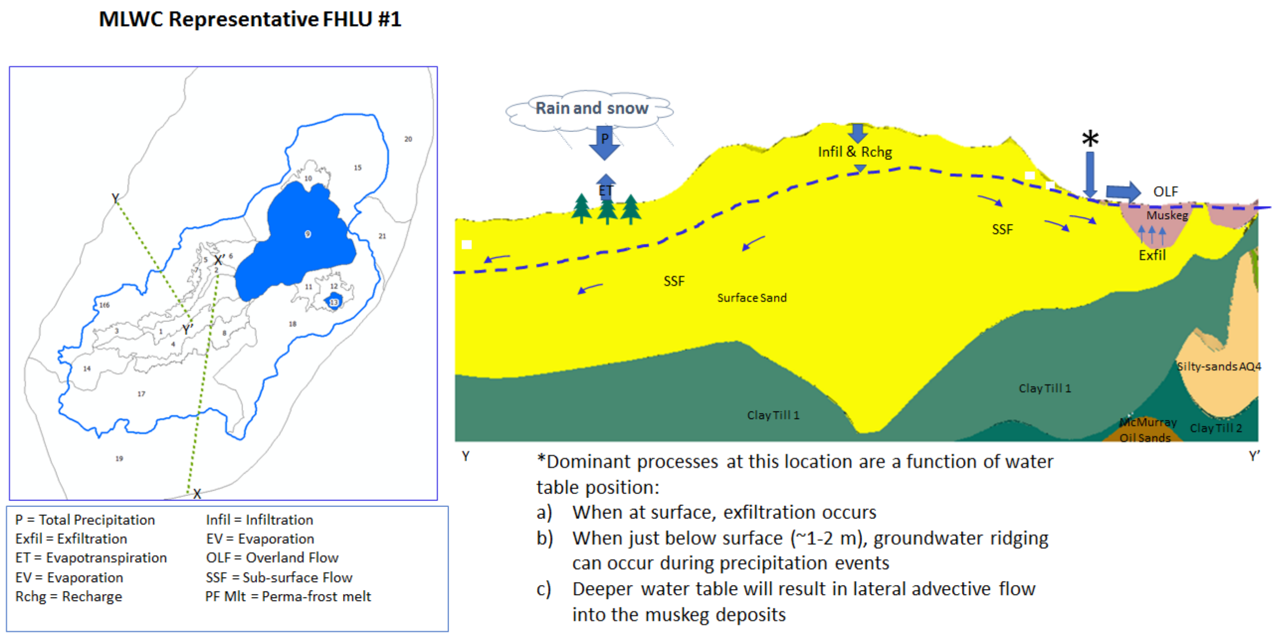

Figure 192 Conceptual flow processes diagram for FHLU #1.

41. Section 1.4.6.2: Fundamental hydrologic landscape unit 2

HRA 17 (Fort Hills – West) and the nearby lowlands (e.g., HRAs 14, 08, 04 and 01) are, when considered as a single unit, assumed representative of fundamental hydrologic landscape unit 2 in the MLWC watershed. The locations of the HRAs in fundamental hydrologic landscape unit 2 are shown in Figure 184. The upland slopes within HRA 17 are generally comprised of a thin veneer of surface sand deposits overlying Clay Till 1 where present (terminal edge of Clay Till 1 shown as the red line Figure 24). Large portions of the FHUC slopes in HRA 17 also have low permeability deposits (Clay Till 1 or Silt Clay) at surface (Figure 16); an indication of the HRA's runoff generation potential. Further south, a deep sequence of silt sand deposits overlying Clay Till 2 lay beyond the terminal edge of Clay Till 1.

Most runoff generated from HRA 17 would flow into HRA 08 (Conifer Swamp – South) which lies directly downslope along the majority of HRA 17's breadth. The existence of a conifer swamp near the base of the FHUC is also an indicator that runoff is being generated from HRA 17. Runoff generated from HRA 08 would flow into HRA 04 (Non-Patterned Fen – South) and then into HRA 01 (Patterned Fen – South), before discharging to McClelland Lake or transpiring into the atmosphere. Within each HRA, on the water's way to the lake, evapotranspiration losses are occurring along the flowpath.

HRA 08 is conceptualized to be a major source of runoff within the MLWC watershed. A substantial portion of the HRA surface is covered in till or Silt Clay which would help facilitate runoff. HRA 08 also overlies groundwater spring locations 1 and 2 shown in Figure 186. Given that the surface of HRA 08 is covered with less permeable material, little of the runoff generated by the springs would be expected to infiltrate within this HRA and would instead be expected to continue flowing downgradient into the MLWC. As discussed in Section 1.4.3, these less permeable materials at surface in HRA 08 also likely contribute to the less dilute and alkaline chemistry that is generated from FHUC runoff. These less permeable materials are absent at surface in MLWC FHLU 1. HRA 08 also sits at the base of the FHUC and would be expected to convey runoff from its slopes downgradient. HRA 08 also contains a number of rills (small drainage channels) along its base which indicate that this region of the landscape experiences episodic runoff that drains downgradient through these rill features.

A regional diagram of conceptual flow in FHLU 2 is shown in Figure 193. As can be seen in the figure, the slopes of MLWC FHLU 2 are draped with spotty and thin regions of permeable substrates. Little runoff would be expected from these permeable regions most years. Runoff can occur in the less permeable portions of the slopes and the ground would be expected to freeze more solid in these regions, which indicates that the FHUC slopes may contribute snowmelt runoff to the MLWC during freshet at some locations along the FHUC slopes.

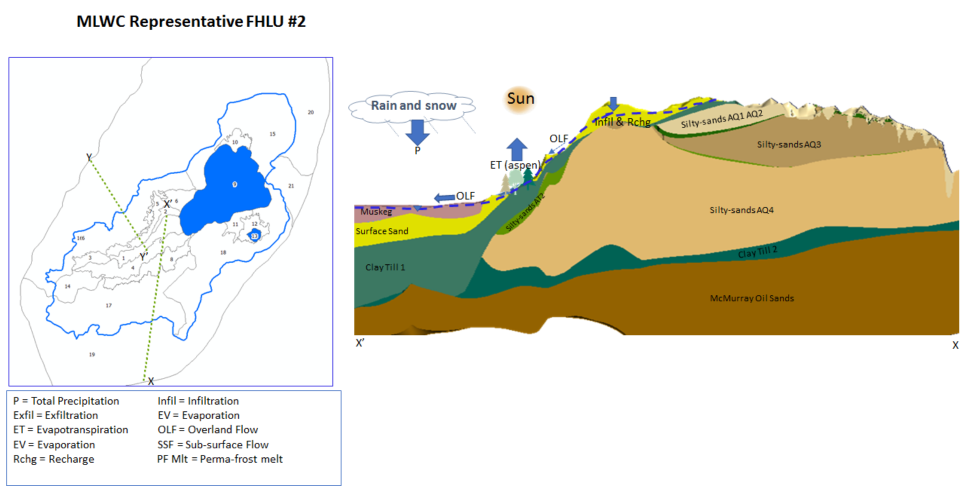

Figure 193 Conceptual flow processes diagram for FHLU #2.

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Appendix G

Plain Language Summary

Plain Language Summary of the 2021 MLWC Conceptual Model and the 2020 MLWC HGS model

A conceptual understanding of how water and nutrient move through the McClelland Lake Wetland Complex (MLWC) landscape was developed using Indigenous Knowledge (IK), Western Science (WS) and field data collected in the MLWC area and regionally. The resulting conceptual model is presented in Appendix F ("*The 2021 MLWC Conceptual Model*"). This conceptual model was, in turn, used to construct a water model. The water model's documentation is given in Appendix D ("*Integrated Hydrological Modelling of the McClelland Lake Wetland Complex*") of the MLWC Operational Plan (OP). This water model (computer code) is referred to throughout the MLWC OP as the 2020 MLWC HGS model.

Both the MLWC Conceptual Model and the MLWC HGS Model have gone through several generations (about one generation a year) since 2017 as the Project's understanding of the MLWC hydrological system improved. Along the way, the work on improving the conceptual and water models has been guided by feedback from the MLWC TAG (Technical Advisory Group), the MLWC AAG (Aboriginal Advisory Group) and the MLWC SC (Sustainability Committee). The feedback from all these groups greatly helped improve the Project's understanding of the MLWC system and to create successively better and more realistic MLWC HGS models.

Each successive generation of the MLWC Conceptual Model was used as the basis to create the next generation of the MLWC HGS model. For the MLWC OP, the 2020 MLWC HGS model was based on the conceptual understanding of the MLWC at the end of 2020. In contrast, the 2021 MLWC Conceptual Model was last updated in August 2021; so, the 2021 MLWC Conceptual Model presented in the MLWC OP is one generation ahead of the 2020 MLWC HGS model. The main updates in the 2021 MLWC Conceptual Model were regarding the rates that aspen trees transpire and how hard and how long various types of soils freeze in a typical year. These updates will be incorporated into the next generation of the MLWC HGS model.

Water in the MLWC landscape is conceptualized to be very interconnected and dynamic, consistent with all of the IK of the area. These connections are through streams, lakes, wetlands, springs, open water and groundwater flows; they are all interconnected to the land and each other at the MLWC. The water within the MLWC watershed is always in motion; even in the wintertime when the ground surface is frozen, deeper groundwater below the frostline still flows from the uplands to lowlands. The Project's understanding of typical flow patterns for the MLWC (around mid-year) are shown in Figure 1. Details about some of the major water flow paths in the watershed are discussed below. The outline of the MLWC watershed is shown in green on Figure 1. The figure also shows that the watershed has been broken up into a series of regions called Hydrological Response Areas (HRAs) that are also outlined in green. The names of each of these HRAs are shown in Figure 2. The 2021 MLWC Conceptual Model describes water and nutrient movement through each of these HRAs in detail.

Figure 1 indicates that groundwater (the blue arrows) flows away from (as opposed to towards) the MLWC watershed boundary. A further examination of Figure 1 indicates there are not any streams coming from outside the watershed and flowing into the watershed. If there is no incoming surface water and groundwater flows away from the watershed, then all the water residing in the MLWC must have come originally from rain or snow falling on the watershed. If the MLWC only gets replenished by rain or snow, that makes the MLWC vulnerable to climate change. Temperature and evapotranspiration rates in the region have been slowly increasing for the last century, while annual rain and snowfall rates have been declining since the early 1970's. If annual rain and snow rates have been trending down since the early

1970's (and the MLWC gets all its replenishing water from rain and snow), this means the MLWC has been slowly getting drier since the early 1970's. This conclusion also aligned with numerous IK comments about how water levels in streams and the fen and the lake all seemed higher historically than they do currently (while also acknowledging that these levels vary a lot year to year).

Figure 3 shows the surface aquifer and aquitard materials within the MLWC. The pink materials in Figure 3 are muskeg deposits, the blue and green materials are silt clay and clay till aquitards (respectively) and the yellowish materials are different types of sandy aquifers. As can be seen in Figure 3, the slopes of the Fort Hills and a large portion of McClelland Lake are underlain by silt clay or tills, there is muskeg at surface and, just under the muskeg and the clays and tills, nearly the entire watershed has a sand deposit at or near surface. In Figure 4, the muskeg, silt clay and surface sand deposits are removed, exposing the extent of the underlying till layer (the green material in Figure 4). This till deposit, called Clay Till 1, covers most of the watershed apart from a portion of the Fort Hills uplands. This portion of the Fort Hills uplands where there is no Clay Till 1 present is also where the aquifers in the Fort Hills get recharged when snowmelt or rainfall occurs. The locations of four relatively larger groundwater springs in the Fort Hills are also indicated in Figure 4. Groundwater in the sands at the spring locations can come up to surface and flow over Clay Till 1 or the land surface on its way to the MLWC fen or the lakes. Their existence was hypothesized in earlier (~ 2010) hydrological work in the area but never verified. MLWC IK also mentioned the existence of groundwater springs in the area. Both pieces of evidence prodded the Project to examine the geology (and satellite photos) of the Fort Hills more closely to see if the springs did exist and where they were located.

Groundwater springs 1 and 4 (Figure 4) develop whenever the groundwater level in the silt sands at these locations is higher than the upper edge of Clay Till 1, subsequently flowing over that edge. Groundwater springs 2 and 3 are located above hydraulic windows (holes) in Clay Till 1 that allow the passage of groundwater originating from the underlying silt sand deposits into the upper local groundwater flow system, subsequently discharging to the land surface. Moreover, groundwater spring 2 contributes water to South Creek (which discharges into McClelland Lake by the area near Unnamed Lake). Groundwater spring location 3 shown in Figure 4 is a second flowing hydraulic window in the Clay Till 1 deposit whose discharge to surface reports to McClelland Lake directly through an inlet or indirectly by wrapping around the southern tip of the lake, entering the southern patterned fen and then discharging to the lake.

The groundwater springs shown in Figure 4 supply water to the MLWC fen, streams and the lakes. The water coming out of these springs has a different quality than the water quality elsewhere in the MLWC watershed. The water from the springs is more alkaline and has more dissolved minerals in it. This difference in water quality is either a reflection of the different mineralogy of the Fort Hills aquifers (which are siltier than the other sand deposits in the watershed) or alternatively, the water is picking up this chemistry as it flows over the clay tills along the slopes of the Fort Hills.

Figure 5 shows nine locations across the MLWC watershed which highlight major water flow paths or features:

- Location 1 (Figure 5): groundwater can come to the ground surface at this groundwater spring location through an underlying hydraulic window (hole; outlined in white in Figure 5)) in the till and flow overland across HRAs 08 and 04 before entering the southern patterned fen (HRA 01). HRA locations shown in Figure 2.

- Location 2 (Figure 5): an additional groundwater spring location from the same hydraulic window feeding water to Location 01 (Figure 5) that also ultimately discharges into HRA 01. In contrast to Location 01, the groundwater spring flows at Location 02 flow in a more defined channel on the ground surface. HRA locations shown on Figure 2.
- Location 3 (Figure 5): a third groundwater spring emanating from the same hydraulic window as Locations 01 and 02 and which contributes flows into South Creek. In turn, South Creek discharges into HRA 11 (Figure 2) by McClelland Lake. HRA locations are shown in Figure 2.
- Location 4 (Figure 5): there is a natural surface water divide at this location that prevents the surface water in HRA 02 (Patterned Fen North) from mixing with surface waters entering HRA 01 (Patterned Fen South) before discharging into McClelland Lake. HRA locations are shown in Figure 2.
- Location 5 (Figure 5): this location is the easternmost point where nutrient poor water originating from the sand deposits on the western side of the watershed can enter the southern patterned fen (HRA 01). HRA 01 receives alkaline water from the Fort Hills and nutrient poor groundwater from these sand deposits west of Location 5. East of Location 5, the surface water divide at Location 4 prevents the nutrient poor water from entering the southern patterned fen (HRA 01). HRA locations are shown in Figure 2.
- Location 6 (Figure 5): nutrient poor groundwater flows originating from this location supply water to the northern patterned fen (HRA 02) or alternatively the north non-patterned fen (HRA 06) before discharging into McClelland Lake. HRA locations are shown in Figure 2.
- Location 7 (Figure 5): significant groundwater drainage from the deep sand deposits on the eastern part of Fort Hills flow towards Unnamed Lake at this location. HRA locations are shown in Figure 2.
- Location 8 (Figure 5): groundwater spring 1 (Figure 4) is at this location. When water flows from this spring, it will flow on the watershed surface across HRAs 08 and 04 before entering the very northwestern tip of HRA 01. HRA locations are shown in Figure 2.
- Location 9 (Figure 5): this is a region in the watershed that is mostly covered in low permeability tills that also receives groundwater flows from the overlying springs and runoff (drainage) from the FHUC slopes. These groundwater inputs are converted to surface water here that then flow downslope across HRA 04 and into the southern patterned fen (HRA 01). HRA locations are shown in Figure 2.

As noted above, IK was used, in part, to help the Project understand how water cycles through the MLWC (which, in turn, informed the construction of the MLWC HGS model). In some cases, IK was a primary source for this understanding (like in identifying the locations of the groundwater springs). In most cases however, MLWC IK was used in combination with field data and WS to help understand or verify understanding of various features of the MLWC:

- IK on historical water levels and rates in the MLWC completely aligns with the Project understanding of the MLWC climate for the last 75 years (higher temperatures and evapotranspiration rates, less annual rainfall).
- IK descriptions of deep and slippery clays are consistent with the geological characterization of the MLWC system at surface (for example, the silt clays and tills at the base of the Fort Hills slopes).

- IK descriptions of limestone outcrops along the Firebag River Valley are consistent with similar descriptions by the Alberta Government and helped verify the Project's conceptualization/characterization of the system's deeper geology (below the oilsands ore). The limestone is Devonian aged rock (specifically, the upper part of the Devonian aged deposits). Earlier work at the Fort Hills mine visualized these Devonian deposits as being tilted downward from the Firebag River and towards the Athabasca River. The IK comment on seeing limestone in the Firebag River valley (along with similar reports by the Alberta Government) helped build confidence that the Devonian stratigraphy (geological layering) is being represented properly.
- The IK comments on the depths and difficulty in traversing the surface sand deposits in the MLWC are consistent with how these sands are being characterized conceptually and in the water model.
- MLWC IK observations on seasonal flow behavior helped the Project understand and verify the importance of snowmelt (and the spring freshet) to the maintenance of the lakes and the vegetation. These observations also helped verify that the patterned fens (connected to the western shores of McClelland Lake) produce peak flows to McClelland Lake during the spring freshet and not during peak rainfall (which often happens in June or July). The conceptualized seasonal flow behavior of the patterned fens can also be used as a benchmark for the water model to see if it is able to replicate this feature of the MLWC system.

More detailed examples of how IK was used to help understand or verify understanding of how water and nutrients flow through the MLWC can be found throughout the 2021 MLWC Conceptual Model appendix. The IK used to help the Project develop the MLWC Conceptual Model is also implicitly embedded in the MLWC HGS model too (because the HGS model was built and designed using the conceptual model information). That being said, additional IK can still be used to help benchmark/validate the predictions of the MLWC HGS model (the water model) by extracting historical and seasonal water trends from the IK and seeing if the MLWC HGS model can replicate these trends. The MLWC HGS model will continue to be updated after the MLWC OP has been submitted (as will the MLWC Conceptual Model) and it is hoped that MLWC AAG and others can assist in incorporating IK into the MLWC HGS model in 2022 after the water model has been updated again (Post the MLWC OP submission).

The extent of the 2020 MLWC HGS model is shown in Figure 6. As can be seen in Figure 6, the model domain (extent) is much larger than the watershed itself and covers an area of about 978 km^2. The base of the model is the (Devonian) Keg River Aquifer, which is situated well below all the oil sands deposits. The geological layers included in the 2020 MLWC HGS model are shown in Figure 3. Within the MLWC watershed, the geological definition was supported using FHELP drilling data. Outside of the watershed, the geology was also defined using FHELP drilling information coupled with available regional geological information available from the Alberta Government and from industry. Topography was determined using Lidar surveys, FHELP data and publicly available data published in maps. Land usage (mostly vegetation and water features but also including any infrastructure) within the watershed was obtained from previous FHELP surveys and remote sensing data. Land usage outside of the watershed also used FHELP surveys as well as regional land usage maps produced by the Alberta Government. Soil distribution within the MLWC watershed (depth and coverage) was defined using a soil survey conducted within the watershed and regional data outside of the watershed. The effects of recent and historical wildfires were accounted for when defining land usage (lots of burnt and recovering areas in and around the watershed). Water level and flow rate information (surface water and groundwater) was entirely obtained from monitoring data (at Fort Hills and regionally). Properties were assigned to the geology, soils and land surface (like evaporation rates for different kinds of vegetation or hydraulic conductivity rates for different kinds of soils) were derived through a combination of field measurements where available and literature values or the results of previous work. These initially assigned properties were refined during model calibration to improve the fit between model-predicted water flows and levels and observed flows and levels.

Once the 2020 MLWC HGS model was built and calibrated, it was applied to the MLWC system to help provide information on 4 water-related themes/questions (among the other ways the model was used):

1. How did water move through the MLWC landscape historically (1945 to currently)?
2. How will development of the Fort Hills project impact water flows/levels in the unmined portion of the MLWC if left unmitigated?
3. How effective are various proposed mitigation options (like a cutoff wall) at preserving the water flows and levels in the non-mined portion of the MLWC while the Fort Hills mine is operating?
4. After mining at Fort Hills has ceased and the mined landscape has been reclaimed, what will water flows and levels in the MLWC look like in the future?

As the 2020 MLWC HGS model runs, it uses the climate (weather) applied at its surface to compute the water levels and rates across the landscape. Water levels/rates are user-defined at the boundaries (sides, top and bottom of the model domain) of the water model, but the HGS calculates what these levels and rates are within its interior. The model prediction results can then be compared against both measured water level flows and rates to benchmark its performance at specific locations or at specific times.

The Operational period of the Fort Hills mine will be used as an example of how the MLWC HGS model was applied in the MLWC OP. The Operational period at Fort Hills spans from the beginning of the mine (around 2014) to the end of the life of the mine (around 2063). Assessing MLWC impacts during the Operational period (water-related themes 2 and 3) using the model basically involves using 3 different kinds of model scenarios:

1) R0 Scenario: The R0 scenario assumes natural conditions. In this scenario there is no development of the Fort Hills mine and therefore no impacts. The MLWC HGS model uses the R0 scenario to figure out what the natural MLWC system response should be. The R0 results should be considered the best-case scenario and are used to benchmark the other scenario results.
2) R1 Scenario: The R1 scenario assumes the development of the MLWC watershed takes place (a portion of the watershed is mined) but no steps (mitigations, like a cutoff wall) are used to prevent mining from impacting water levels and flows within the non-mined portion of the watershed. The R1 scenario results should be considered the worst-case scenario (maximum predicted impacts).
3) S1 Scenario: The S1 scenario assumes that development of the MLWC watershed occurs and also that mitigation steps are taken (like installing a cutoff wall) to keep the impacts of development from occurring within the non-mined portion of the MLWC. The S1 scenario results should fall somewhere between the R0 and R1 scenario results and, if the mitigation steps taken in the watershed are adequate, S1 results should be much closer to the R0 results (the best-case scenario) than the R1 results (the worst-case scenario).

The majority of these simulations consider the future, and we cannot know what the weather will be in advance. Therefore, historical climate (1988-2013) was used to drive these future simulations under the assumption that weather in the future will be reasonably similar to weather in the recent past. These model scenario results were then used to **design** the mitigation measures in the watershed needed to mitigate the impacts of development on the non-mined portion of the MLWC: ranges of seasonal and annual water resupply volumes were calculated, the timing and size of the various mitigation features (for example, the cutoff wall or when groundwater injection will be needed) were determined. The scenario results for McClelland Lake levels for the current mitigation design (consisting of a cutoff wall, an injection system and a surface water resupply system) are shown in Figure 7. As can be seen in Figure 7, the model predicts that the mitigation measures planned for the MLWC will maintain lake levels quite close to their natural (R0) levels.

When the Project actually **operates** the water resupply system, a different approach will be required (because we will not know what the weather will be before it happens). **Operating** the system will require the Project to use a combination of field data, weather forecasting and modelling to determine how much water needs to be added to the non-mined portion of the MLWC and when.

In summary, a conceptual model of the MLWC was developed using a combination of IK, WS and field data. The conceptual model illustrates that the surface water system and the groundwater system are highly interconnected within the MLWC watershed. The conceptual model was then used to design and build a water model (the MLWC HGS model) and this model was used to help understand: 1) baseline (undisturbed) conditions at the MLWC before development took place, 2) the impacts that development of the Fort Hills mine could have on water flows and levels in the MLWC watershed, 3) the effectiveness of proposed measures to mitigate those development impacts and 4) what water flows and levels would look like after mining has ceased and the landscape has been reclaimed (both right after mining stops and into the far future).

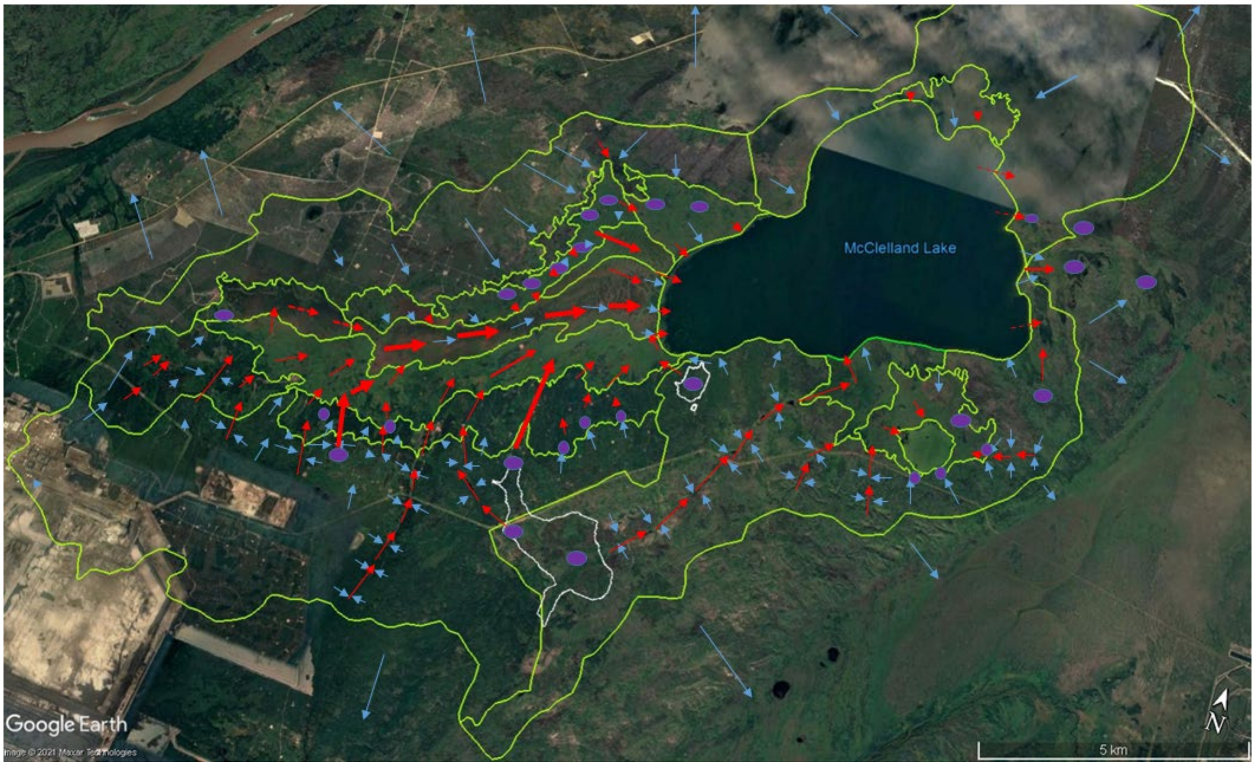

Figure 1 Conceptual surface water and groundwater flow directions. The red arrows in the figure represent surface water flows, the blue arrows represent groundwater flows and the purple ovals areas of groundwater discharge to surface (springs). Dashed arrows are where flow sometimes occurs. The areas outlined in green are the MLWC HRAs and the areas outlined in white are mapped hydraulic windows. Image source: Google Earth/Maxar Technologies.

HRA ID		HRA Name
1	Within MLWC Watershed	Patterned Fen - South
2		Patterned Fen - North
3		Graminoid Fen
4		Non-Patterned Fen - South
5		Non-Patterned Fen - West
6		Non-Patterned Fen - North
7		Coniferous Swamp - North
8		Coniferous Swamp - South
9		McClelland Lake
10		North Wetland
11		South Wetland - to McClelland Lake
12		South Wetland - to Unnamed Lake
13		Unnamed Lake
14		Coniferous Swamp - West
15		NOP East
16		NOP West
17		Fort Hills West
18		Fort Hills East
19	Outside MLWC	Fort Hills South
20		NOP North
21		Lake Outlet

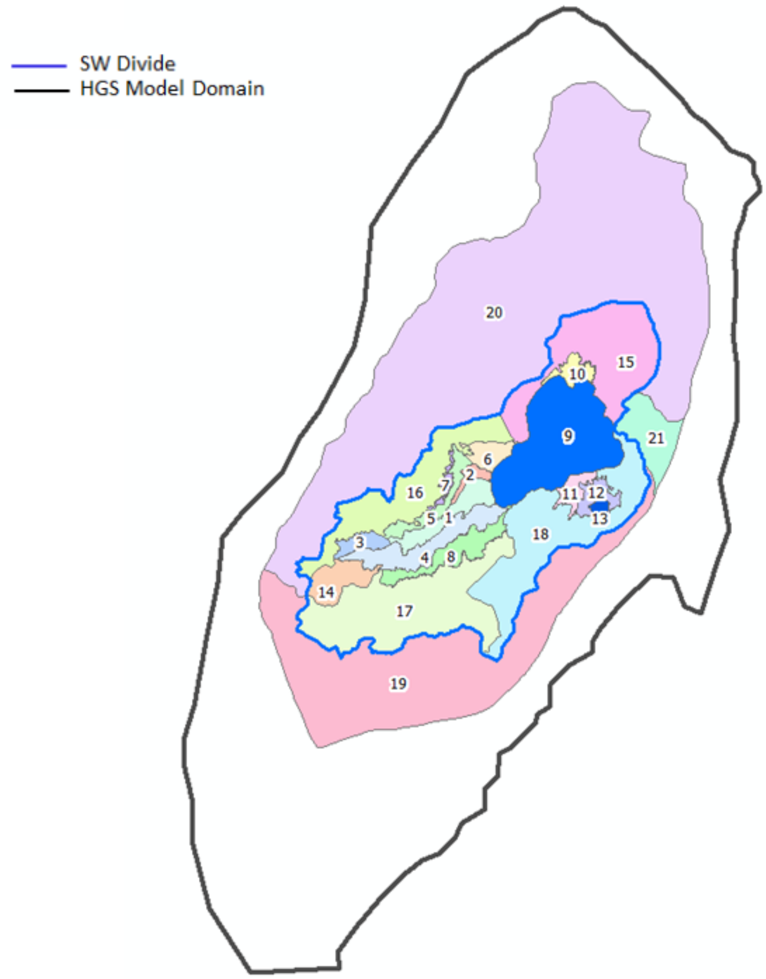

Figure 2 The HRAs developed for MLWC watershed (HRAs 1-18) and the surrounding extents. The blue outline in the figure denotes the MLWC watershed boundary and the black line represents the extent of the 2020 MLWC HGS model domain.

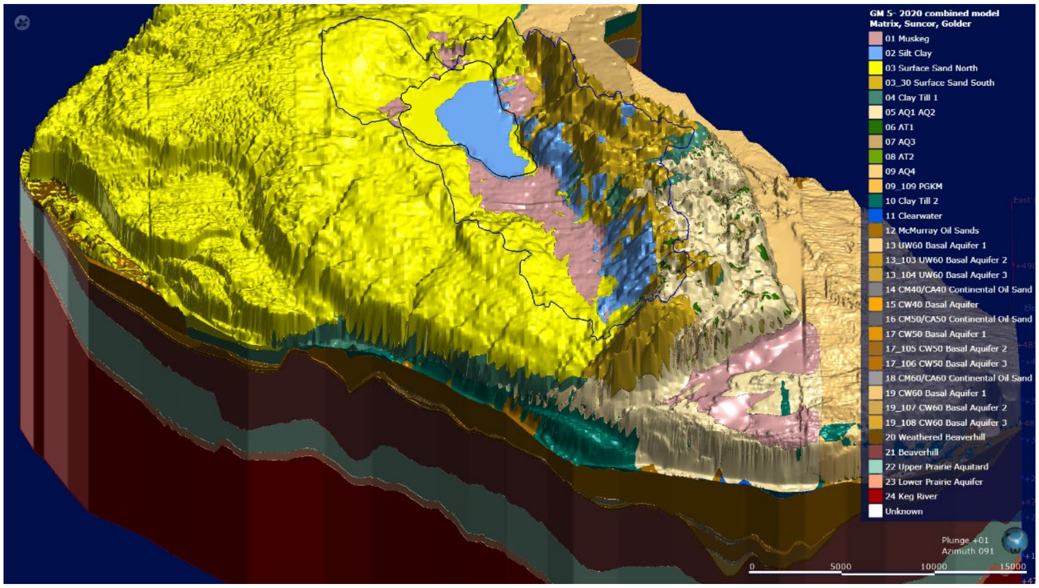

Figure 3 The surface hydrostratigraphy of the MLWC watershed. Note that the MLWC watershed and McClelland Lake are outlined in the figure. Note: vertical exaggeration is 80:1.

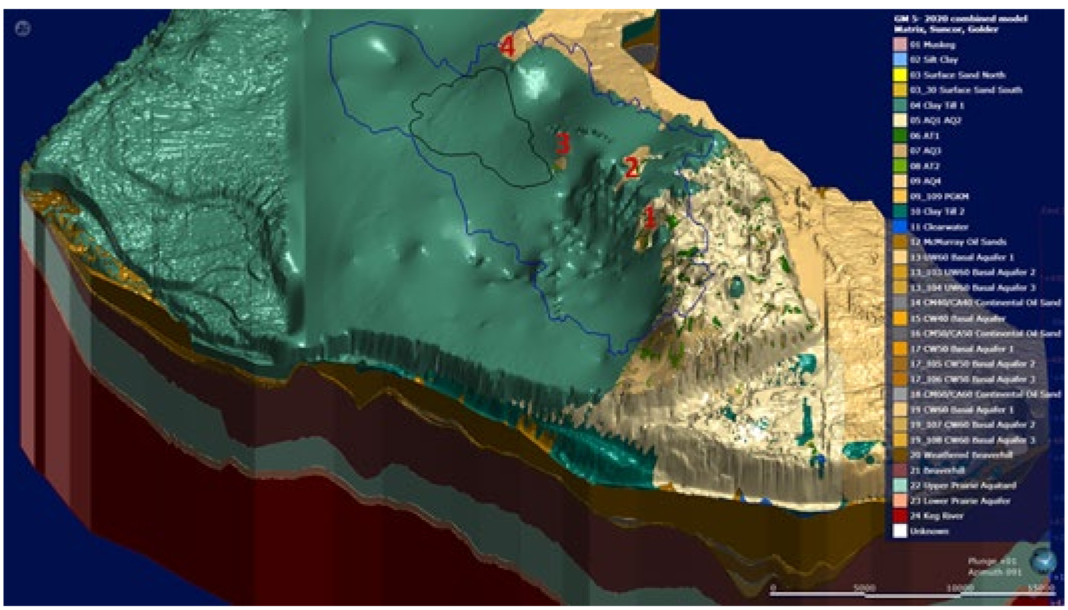

Figure 4 The MLWC watershed with the hydrostratigraphy above Clay Till 1 turned off. Locations 1-4 are interpreted to be groundwater springs that contribute flows to the MLWC lowlands. Note: the watershed and the lake are outlined in the figure and vertical exaggeration is 80:1.

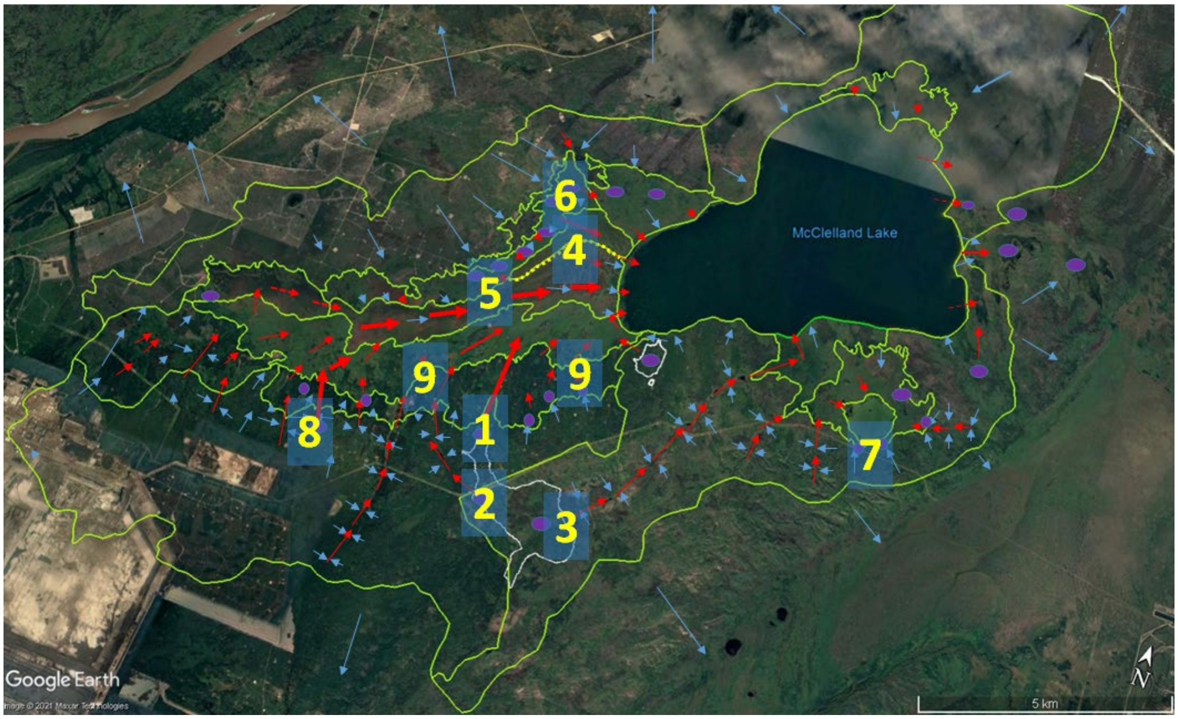

Figure 5 Conceptualized dominant flow paths within the MLWC: 1) groundwater spring flow from the FHUC reporting into HRA 01; 02) groundwater spring flow from the FHUC reporting into HRA 01; 03) groundwater spring flow from the FHUC into the headwaters of South Creek and then to McClelland Lake; 04) a surface water divide separating the patterned fens; 05) the location where oligotrophic water from the NOP can enter HRA 01; 06) the portion of the landscape contributing oligotrophic groundwater to HRA 02; 07) region of significant seepage from the overlying eastern FHUC towards Unnamed Lake; 08) groundwater spring flow from the FHUC reporting to the western margin of HRA 01; and 09) region (HRA 08) of significant runoff generation from the overlying FHUC towards the MLWC fen area. Image source: Google Earth/Maxar Technologies.

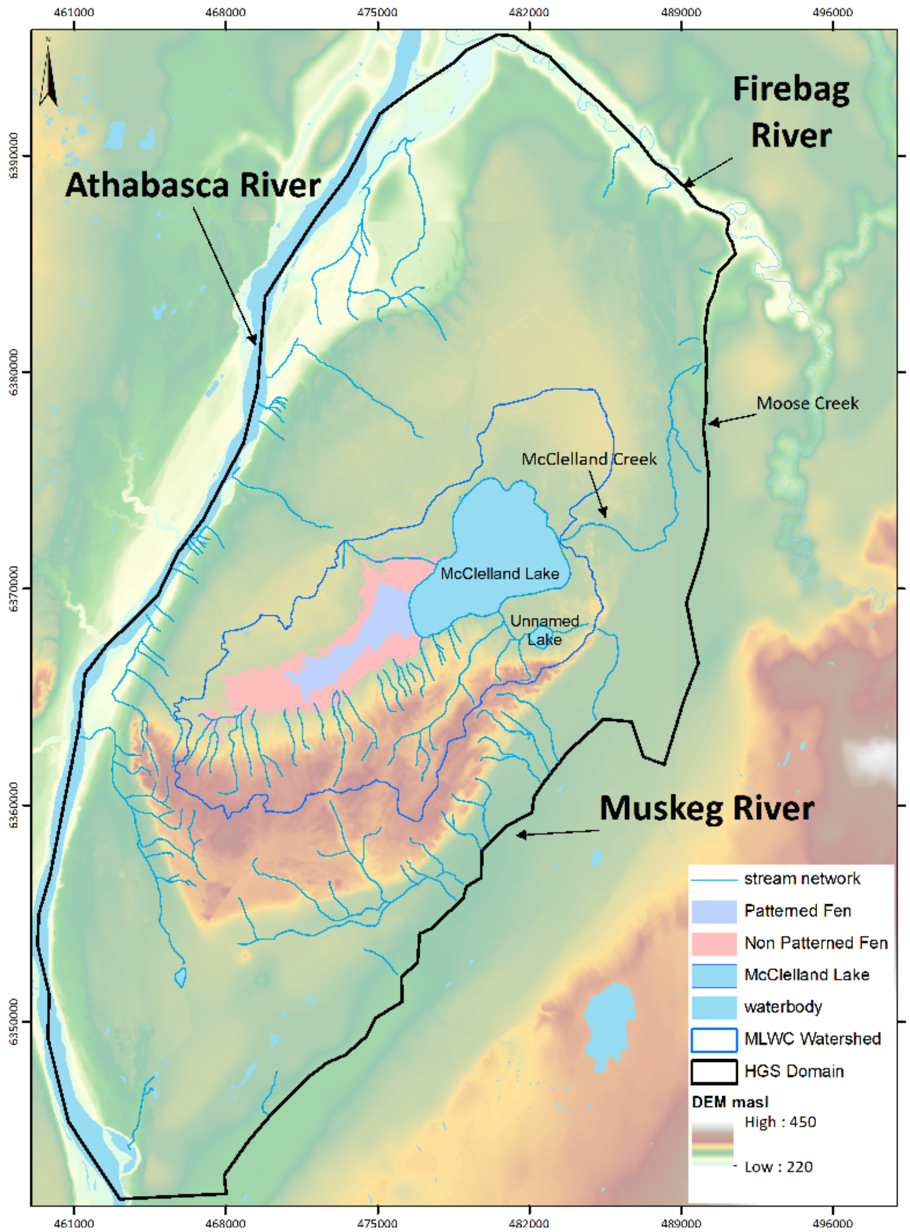

Figure 6 The 2020 MLWC HGS model domain. The water model also covers a large area outside of the MLWC watershed (watershed boundary shown in figure).

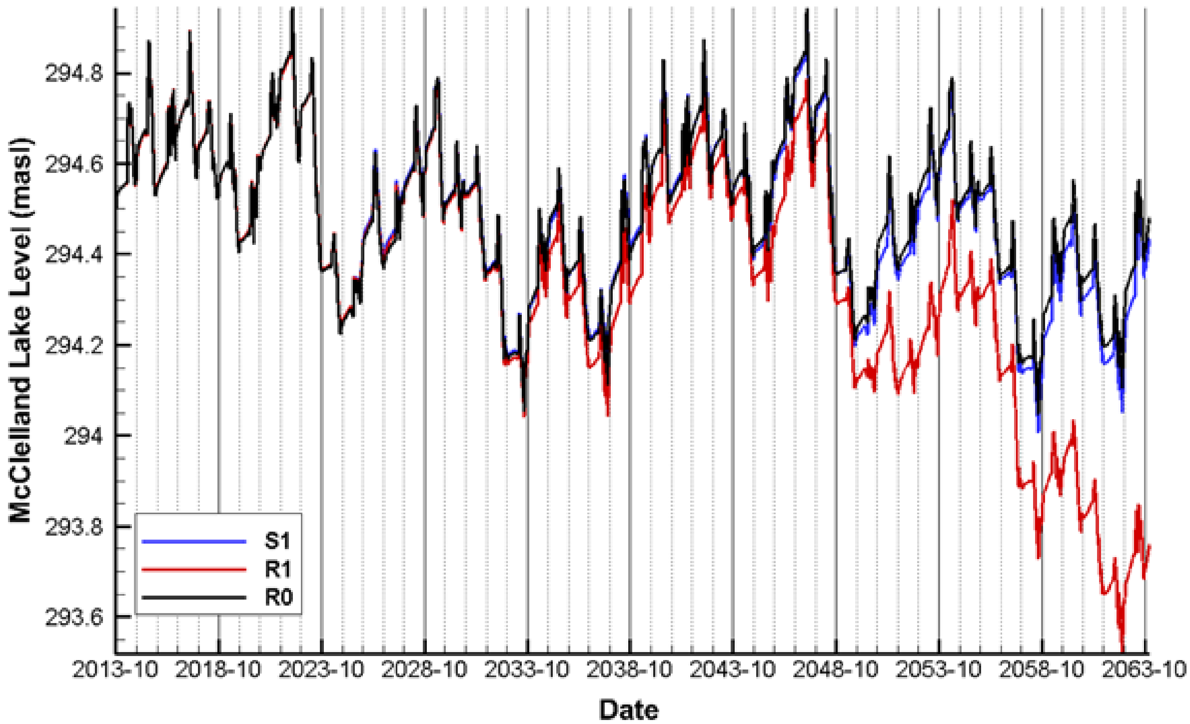

Figure 7: Simulated McClelland Lake levels in the R0, R1 and S1 operations scenarios.