APPENDIX F
Safe Additional Available Drawdown

APPENDIX F

SAFE ADDITIONAL AVAILABLE DRAWDOWN

Safe additional available drawdown is defined as the additional depth water within a pumping well could fall and still maintain that well's Allocated pumping rate. It is calculated as the additional drawdown that is available beyond the drawdown created by the Existing conditions pumping rate. To establish the safe additional available drawdown for each municipal well within the City of Guelph and the Township of Guelph/Eramosa (Rockwood and Hamilton Drive), the following components need to be evaluated or calculated for each well:

- **Safe water level elevations**: the lowermost elevation to which an operator can pump the water levels in municipal pumping well. This elevation may be related to the well screen elevation, pump intake elevation, depth of water bearing zones, or similar operational limitations.

- **Existing water level elevations in the pumping wells**: the elevation of the observed average annual pumped water level within each municipal well for 2008 (for Guelph) and a representative low operating water level determined for municipal wells in Rockwood and Hamilton Drive (Burnside 2015a) during periods of normal operation.

- **Estimated non-linear well losses at each well**: drawdown within the well in response to well inefficiencies (e.g., entrance losses or turbulent flow around pump fittings) created during groundwater extraction.

1 SAFE WATER LEVEL ELEVATION

The safe water level elevation at each municipal water supply well was developed with City of Guelph and the Township of Guelph/Eramosa staff and their consultants. The safe water levels or set points for operation are based on historical and recent testing and operation of the wells and have largely been determined based on pump intake levels or the top of the open borehole in bedrock wells. For wells where there is a lack of current operational data, set points were estimated from the depths of major producing fracture zones or aquifers. Safe water level elevations are summarized in Table F-1.

2 EXISTING WATER LEVEL ELEVATIONS

The average pumped water level elevation in each City of Guelph municipal well in 2008 was determined by examining water level hydrographs of each municipal pumping well. Operating low water levels were determined by consultants of the Township of Guelph/Eramosa for the existing Rockwood and Hamilton Drive municipal wells using automatic water level recorders (Burnside 2015a). Where necessary, professional judgement was used to determine a level that was representative of pumped conditions at a typical pumping rate where adjacent wells were also pumping at typical rates. Figures F1 to F24 illustrate the derivation of the existing water level elevations.

The safe additional available drawdown is a measure of the additional drawdown within a well, regardless of the non-linear head losses at each well due to turbulent flow of water through the well screen and casing to the pump intake. The safe additional available drawdown is calculated as the difference between the average pumped water level and the safe water level. Safe additional available

drawdown values are summarized in Table F-1. Figures F1 to F24 summarize the derivation of safe additional available drawdown in the Guelph, Rockwood, and Hamilton Drive wells. No transient water level and pumping data was available for Arkell Well 14, Arkell Well 15, Sacco Well, and Smallfield Well; therefore, no summary figures are provided for these wells.

TABLE F-1 Safe Additional Available Drawdown

Well	Safe Water Level (m asl)	Average Pumped Water Level (m asl)	Safe Additional Available Drawdown (m)[6]
City of Guelph			
Arkell 1	320.7[1]	322.9[3]	2.2
Arkell 14	304.7[1]	316.0[3]	11.3
Arkell 15	306.3[1]	317.6[3]	11.3
Arkell 6	298.5[1]	313.7[3]	15.2
Arkell 7	301.0[1]	313.9[3]	12.9
Arkell 8	303.4[1]	313.9[3]	10.5
Burke	313.1[1]	319.2[3]	6.1
Calico	291.8[1]	309.1[3]	17.3
Carter Wells	317.6[1]	320.2[3]	2.6
Clythe Creek	294.5[1]	321.4[3]	26.9
Dean Ave.	277.2[1]	289.7[3]	12.5
Downey Rd.	282.4[1]	297.0[3]	14.6
Emma	288.7[1]	293.2[3]	4.5
Helmar	295.5[1]	303.5[3]	8.0
Membro	274.4[1]	287.7[3]	13.3
Paisley	282.6[1]	299.1[3]	16.5
Park 1 and 2	283.1[1]	291.8[3]	8.7
Queensdale	278.3[1]	289.9[3]	11.6
Sacco	307.8[1]	337.9[3]	30.1
Smallfield	287.2[1]	334.2[3]	47.0
University	278.0[1]	293.0[3]	15.0
Water Street	276.8[1]	290.4[3]	13.6
Rockwood			
Rockwood Well 1	329.3[2]	344.0[4]	14.7
Rockwood Well 2	330.6[2]	345.0[4]	14.4
Rockwood Well 3	317.7[7]	331.0[4]	13.3
Rockwood Well 4	321.0[2]	355.1[5]	34.1
Hamilton Drive			
Cross Creek	303.7[2]	317.0[4]	13.3
Huntington	303.6[2]	314.0[4]	10.4

Notes:
[1] Defined by the City of Guelph.
[2] Selected as 1 m above pump intake (Burnside 2015a).
[3] Observed from water levels measured during periods of normal well operation and production (2008 - Guelph)
[4] Selected using operating low water levels from automatic water level recorder data (Burnside 2015a)
[5] Rockwood Well 4 was commissioned in 2016 and was not pumped during Existing conditions. Therefore, the water level used to determine the safe additional drawdown is the static water level determined during well completion (January 2015; Burnside 2015b).
[6] Relative to average observed water level
[7] Selected as 1 m above the bottom of the casing (top of open bedrock interval)

3 NON-LINEAR IN-WELL LOSSES

Well losses refer to the difference between the theoretical drawdown in a well and the observed drawdown and are due to factors such as turbulence in the well itself as water flows into the pump. These well losses need to be considered in the Tier Three Assessment as the safe additional available drawdown refers specifically to the water level in the well and not the average water level in the aquifer near the well. The in-well losses are calculated as the additional drawdown that is expected within the pumping well due to the incremental increase from the Existing to the Allocated pumping rates.

The two components of observed additional drawdown in a given pumping well are described in **Equation 1** (Bierschenk 1963; Hantush 1964; Jacob 1947):

$$s = BQ + CQ^2 \quad \text{.....Equation 1}$$

Where *s* is drawdown, *Q* is the pumping rate, *B* is the aquifer loss coefficient (Theis 1935), and *C* is the well loss coefficient, which is constant for a given pumping rate. The first term in the equation (*BQ*) describes the linear component of the drawdown (i.e., doubling the pumping rate leads to a doubling of the drawdown). This term accounts for the drawdown in the formation near the well. The second term of the equation (CQ^2) describes the non-linear well-loss component of drawdown (Jacob 1947) in the well itself; this is the additional component that was quantified in this assessment.

Well losses are estimated using step test results. Step tests are hydraulic tests where a well is pumped at a series of different pumping rates and the drawdown throughout the test is recorded. Non-linear well loss coefficients were estimated using the step test results presented in Stantec Consulting Ltd.'s (2009) Sacco and Smallfield Report, Jagger Hims Limited (1995, 1998a, 1998b, 1998c; i.e., the "Quadrant Reports"), Gartner Lee Limited (2003), Lotowater Geoscience Consultants Inc. (2005), R.J. Burnside and Associates Limited (2002, 2015b) and Well Initiatives Limited (2012). Where no step test data was available for the municipal wells, or where data was considered unreliable, a non-linear well loss coefficient of 3.82E-07 m/$(m^3/day)^2$ was selected based on the assumption that the well is mildly deteriorated (Walton 1962).

The loss coefficient, *C*, is calculated directly from step test data following the technique developed by Kasenow (1998):

$$C = \frac{s_2 Q_1 - s_1 Q_2}{Q_1 Q_2^2 - Q_2 Q_1^2} \quad \text{.....Equation 2}$$

Where:

s_1 is the total stabilized drawdown at the end of pumping step 1
Q_1 is the pumping rate for step 1

s_2 is the total stabilized drawdown at the end of pumping step 2
Q_2 is the pumping rate for step 2

For each step test, these coefficients were calculated for consecutive steps and then averaged to determine the loss coefficient for the well at the time of the step test. **Equation 2** after Jacob (1947) was

used to calculate drawdown due to in-well head losses for the increased pumping from Existing to the Allocated rates:

$$\Delta S_{inwell} = C\,[(Q_{EC} + \Delta Q)^2 - Q_{EC}^2] \quad \text{.....Equation 3}$$

Where: *C* is the well loss coefficient determined from step-test data,
Q_{EC} is the Existing Conditions (2008 - Guelph; 2009 to 2010 - Rockwood and Hamilton Drive) pumping rate used in the base case steady-state model,
ΔQ equal to the increase from Existing Conditions (2008 - Guelph; 2009 to 2010 - Rockwood and Hamilton Drive) pumping rate to the Allocated municipal pumping rate used in the Risk Assessment scenarios.

Drawdown from in-well head losses values were derived for two sets of Allocated municipal pumping rates for the City of Guelph wells:

- The Existing plus Committed Allocated municipal pumping rates used in the steady-state Risk Assessment scenarios G(1) and G(2), and as the minimum Allocated rates for the transient Risk Assessment scenarios H(1) and H(2).

- The maximum Allocated pumping rates used in the transient Risk Assessment scenarios H(1) and H(2) when the Glen Collector was not supplying its Allocated rate.

The amount of drawdown from in-well head losses was derived for a single set of Allocated pumping rates for Rockwood and Hamilton Drive municipal pumping wells. Minimum and maximum Allocated rates were not needed for these wells as their pumping is not tied to the demand at the Glen Collector.

Pumping rates used for the in-well head loss calculations are shown in Table F-2. Non-Linear head losses are summarized in Table F-3.

TABLE F-2 Pumping Rates for Non-linear Head Loss Calculations

Well	Typical Pumped Rates (2008)	Existing Plus Committed	ΔQ between Existing Conditions & Existing plus Committed	Maximum Allocated Rates for Long-Term Drought Scenarios	ΔQ between Existing Conditions & Maximum Allocated Rates
	m^3/day	m^3/day	m^3/day	m^3/day	m^3/day
City of Guelph					
Arkell 1	730	1,400	670	1,400	670
Arkell 14	-	3,300	3,300	4,400	4,400
Arkell 15	-	3,300	3,300	4,400	4,400
Arkell 6	3,774	4,900	1,126	5,300	1,526
Arkell 7	3,689	4,900	1,211	5,300	1,611
Arkell 8	3,694	4,900	1,206	4,900	1,206
Burke	5,385	6,000	615	6,300	915
Calico	748	1,100	352	1,100	352
Carter Wells	3,400[1]	4,000	600	4,400	1,000
Clythe Creek	-	2,200	2,200	2,200	2,200
Dean Ave.	1,215	1,500	285	1,500	285
Downey Rd.	3,940	5,100	1,160	5,236	1,296
Emma	2,600[1]	2,100	-500	2,400	-200
Helmar	800[1]	1,100	300	1,200	400
Membro	3,036	4,200	1,164	4,300	1,264
Paisley	762	800	38	1,000	238
Park 1 & 2	6,400[1]	6,400	-	6,900	500
Queensdale	702	2,000	1,298	2,000	1,298
Sacco	-	1,150	1,150	1,200	1,200
Smallfield	-	1,400	1,400	1,400	1,400
University	1,648	2,500	852	2,500	852
Water Street	1,184	2,300	1,116	2,400	1,216
Rockwood					
Rockwood Well 1	283[2]	396	112	n/a	n/a
Rockwood Well 2	262[2]	367	105	n/a	n/a
Rockwood Well 3	422[2]	572	150	n/a	n/a
Rockwood Well 4	0[3]	572	572	n/a	n/a
Hamilton Drive					
Cross Creek	87[2]	90	3	n/a	n/a
Huntington	92[2]	95	3	n/a	n/a

Notes:

[1] Rates used in the Risk Assessment Scenarios are based on the typical pumped rates for which a typical pumped water level has been observed, rather than the 2008 average pump rate used for the water demand calculations.

[2] Rates used in the Risk Assessment Scenarios are based on the 2009 to 2010 average pump rate.

[3] Rockwood Well 4 was commissioned in 2016 and was not pumped during the Study Period (2009 to 2010)

TABLE F-3 Estimated Drawdown due to Non-linear Head Losses

Well	Well Loss Coefficient (C)	Existing Conditions versus Existing Plus Committed		Existing Conditions versus Maximum Allocated Rates for Long-Term Drought Scenarios	
		Pumping Rate Increase (ΔQ)	Drawdown due to Non-Linear Head Losses	Pumping Rate Increase (ΔQ)	Drawdown due to Non-Linear Head Losses
	$m/(m^3/day)^2$	m^3/day	m	m^3/day	m
City of Guelph					
Arkell 1	2.38E-07	670	0.3	670	0.3
Arkell 14	1.88E-08	3,300	0.2	4,400	0.4
Arkell 15	1.12E-08	3,300	0.1	4,400	0.2
Arkell 6	5.83E-08	1,126	0.6	1,526	0.8
Arkell 7	1.66E-08	1,211	0.2	1,611	0.2
Arkell 8	6.87E-09	1,206	0.1	1,206	0.1
Burke	1.71E-07	615	1.2	915	1.8
Calico	2.91E-08	352	0.0	352	0.0
Carter Wells	1.74E-07	600	0.2	1,000	0.3
Clythe Creek	2.72E-06	2,200	13.2	2,200	13.2
Dean Ave.	3.28E-06	285	2.5	285	2.5
Downey Rd.	8.51E-08	1,160	0.9	1,296	1.0
Emma	1.92E-07	-500	-0.5	-200	-0.2
Helmar	1.36E-07	300	0.1	400	0.1
Membro	1.64E-07	1,164	1.4	1,264	1.5
Paisley	2.98E-06	38	0.2	238	1.3
Park 1 and 2	3.40E-08	-	0.0	500	0.2
Queensdale	5.58E-08	1,298	0.2	1,298	0.2
Sacco	4.59E-07	1,150	0.6	1,200	0.7
Smallfield	3.60E-06	1,400	7.1	1,400	7.1
University	4.46E-07	852	1.6	852	1.6
Water Street	9.91E-07	1,116	3.9	1,216	4.3
Rockwood					
Rockwood Well 1	3.82E-07	112	0.0	n/a	n/a
Rockwood Well 2	3.82E-07	105	0.0	n/a	n/a
Rockwood Well 3	3.22E-06	150	0.5	n/a	n/a
Rockwood Well 4	9.20E-06	572	1.4	n/a	n/a
Hamilton Drive					
Cross Creek	3.82E-07	3	0.0	n/a	n/a
Huntington	8.38E-06	3	0.0	n/a	n/a

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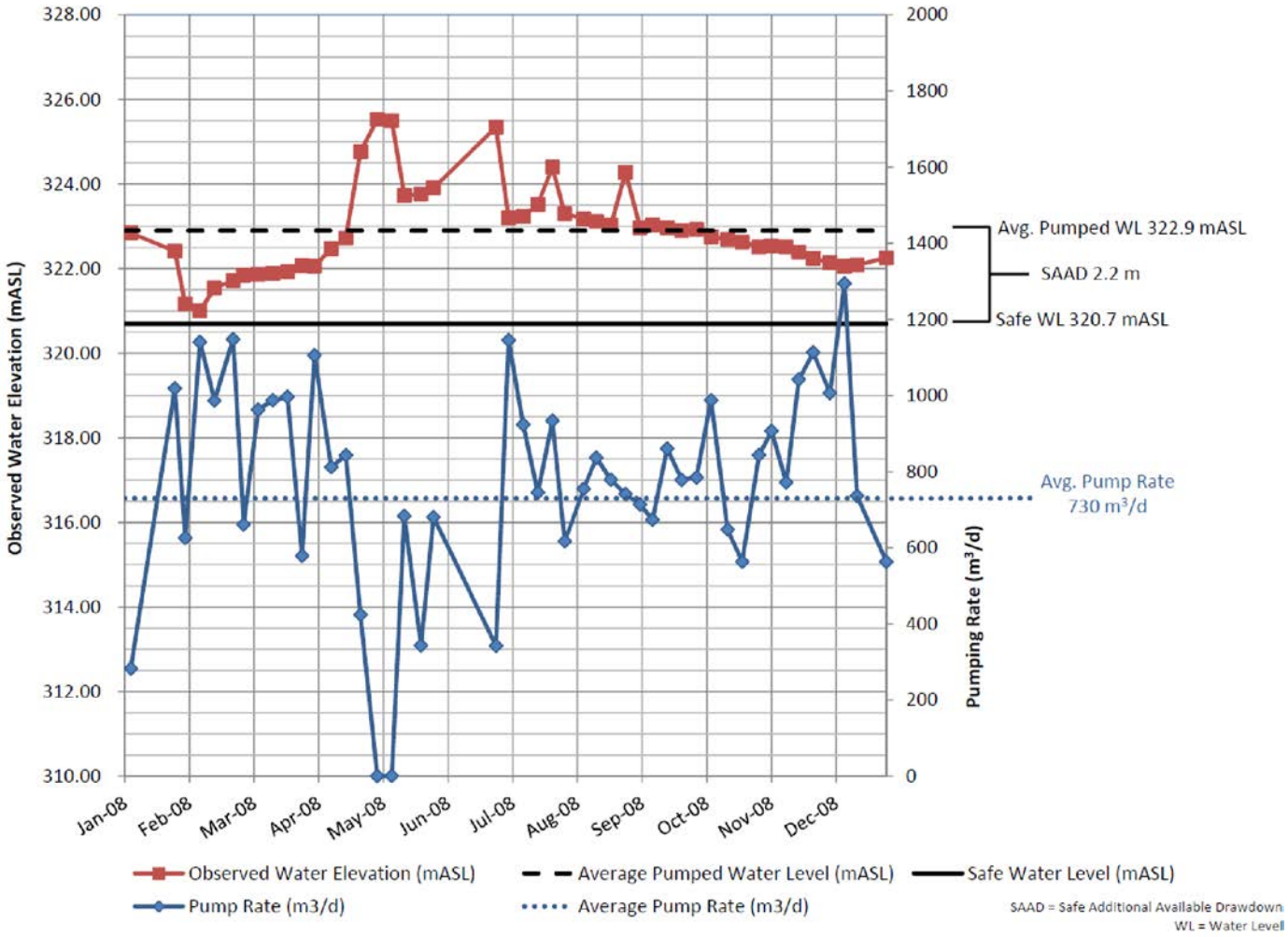

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Arkell 1

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Figure F1

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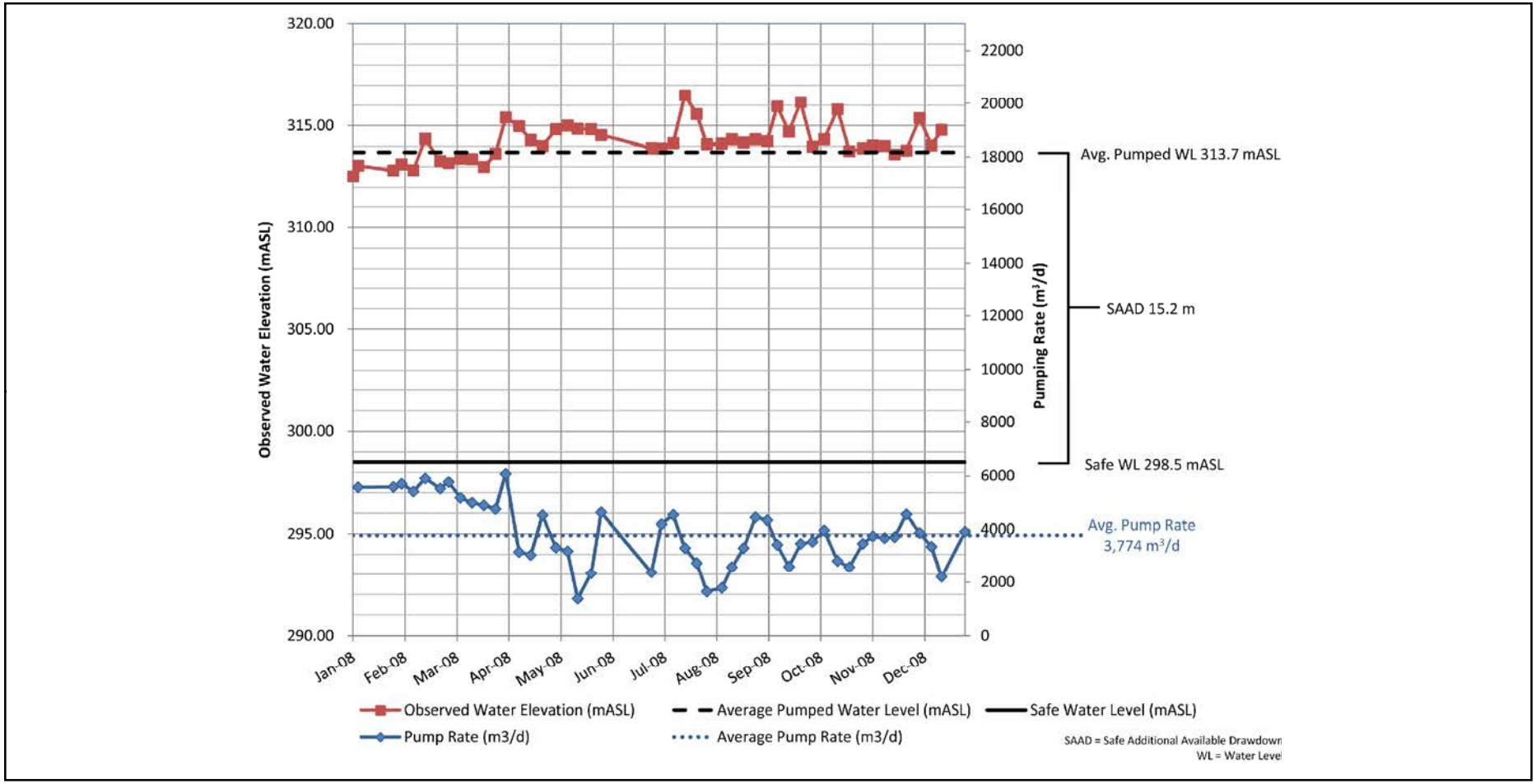

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Safe Additional Drawdown Calculation Arkell 6

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Figure F2

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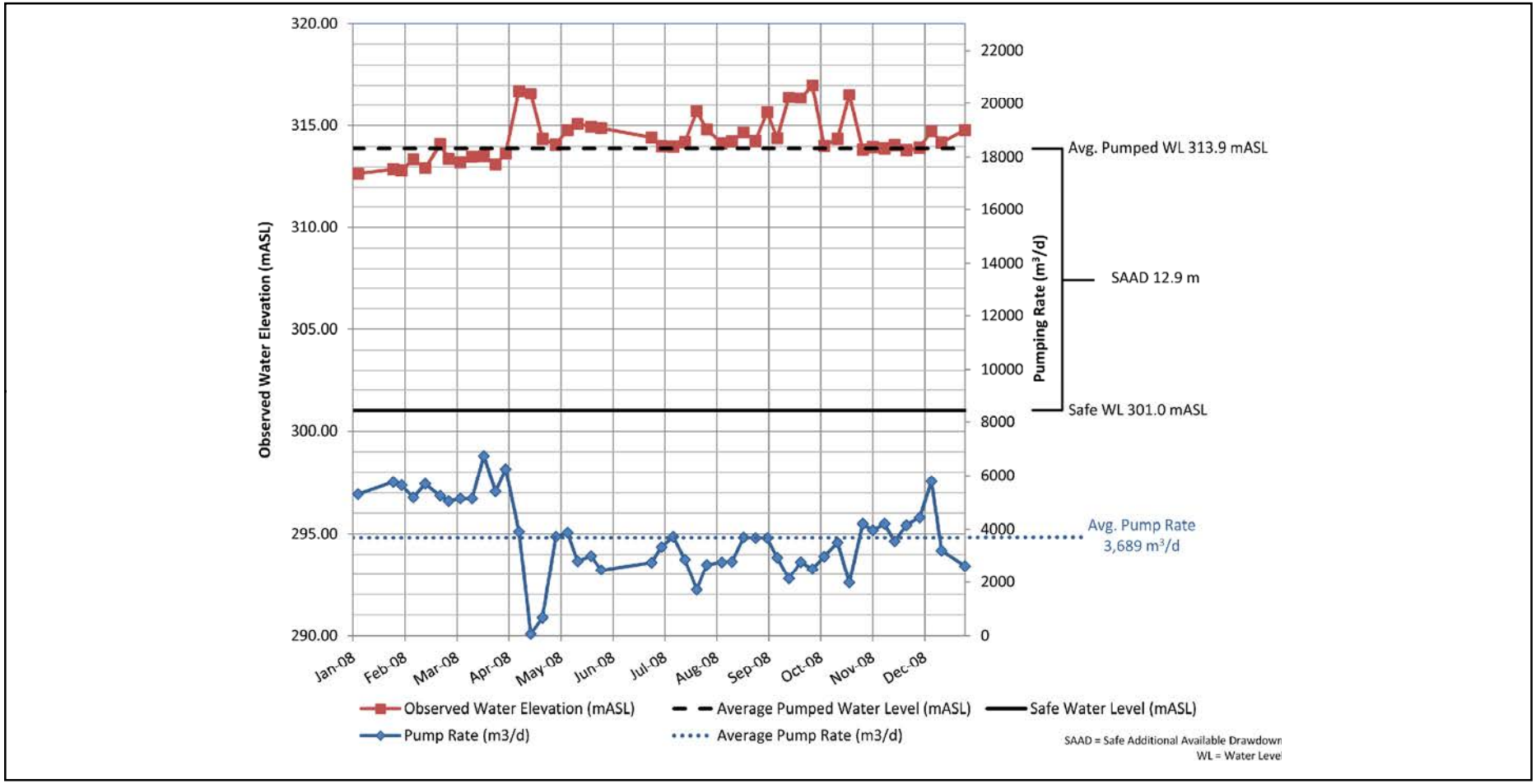

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Safe Additional Drawdown Calculation Arkell 7

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Figure F3

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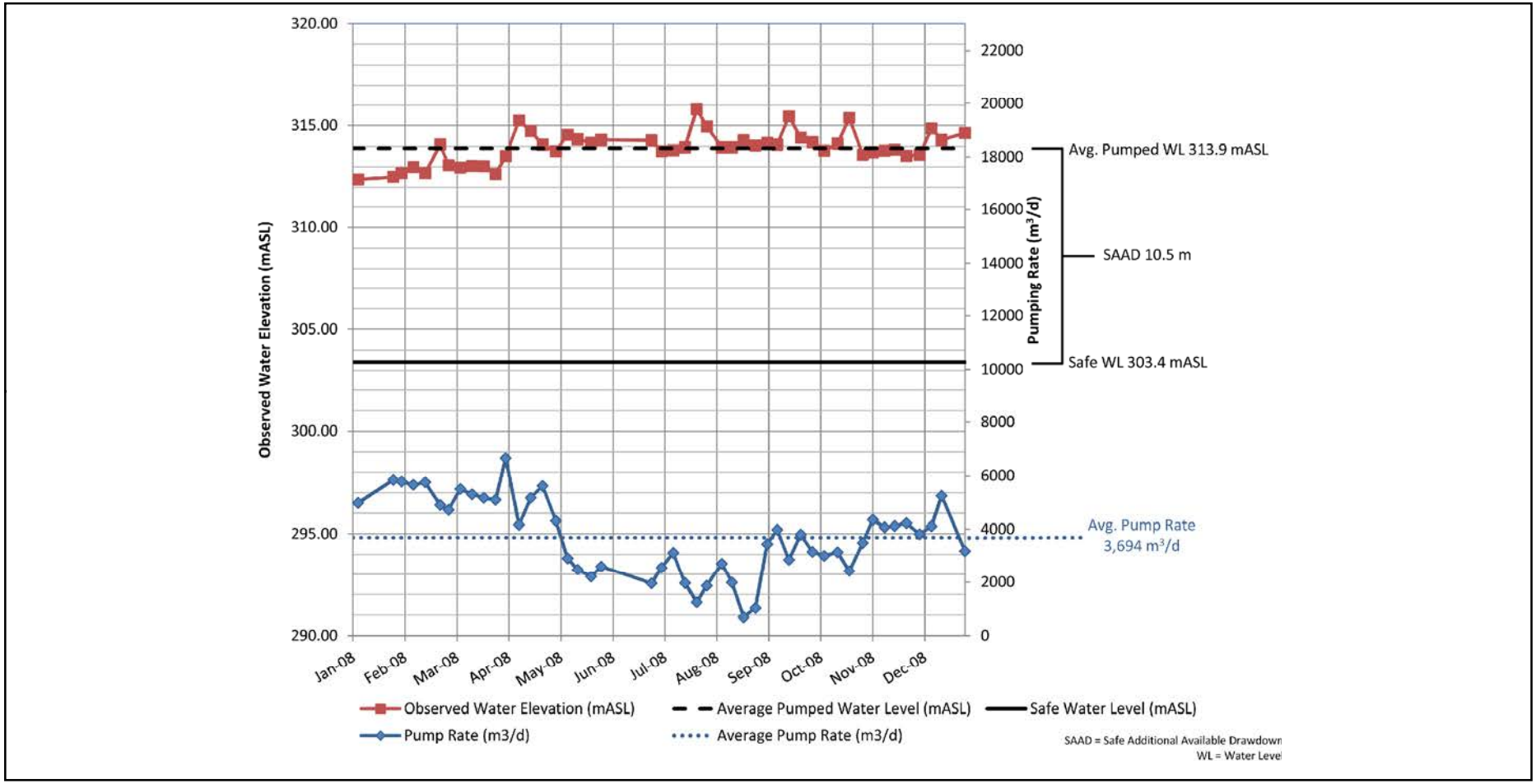

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Arkell 8

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Figure F4

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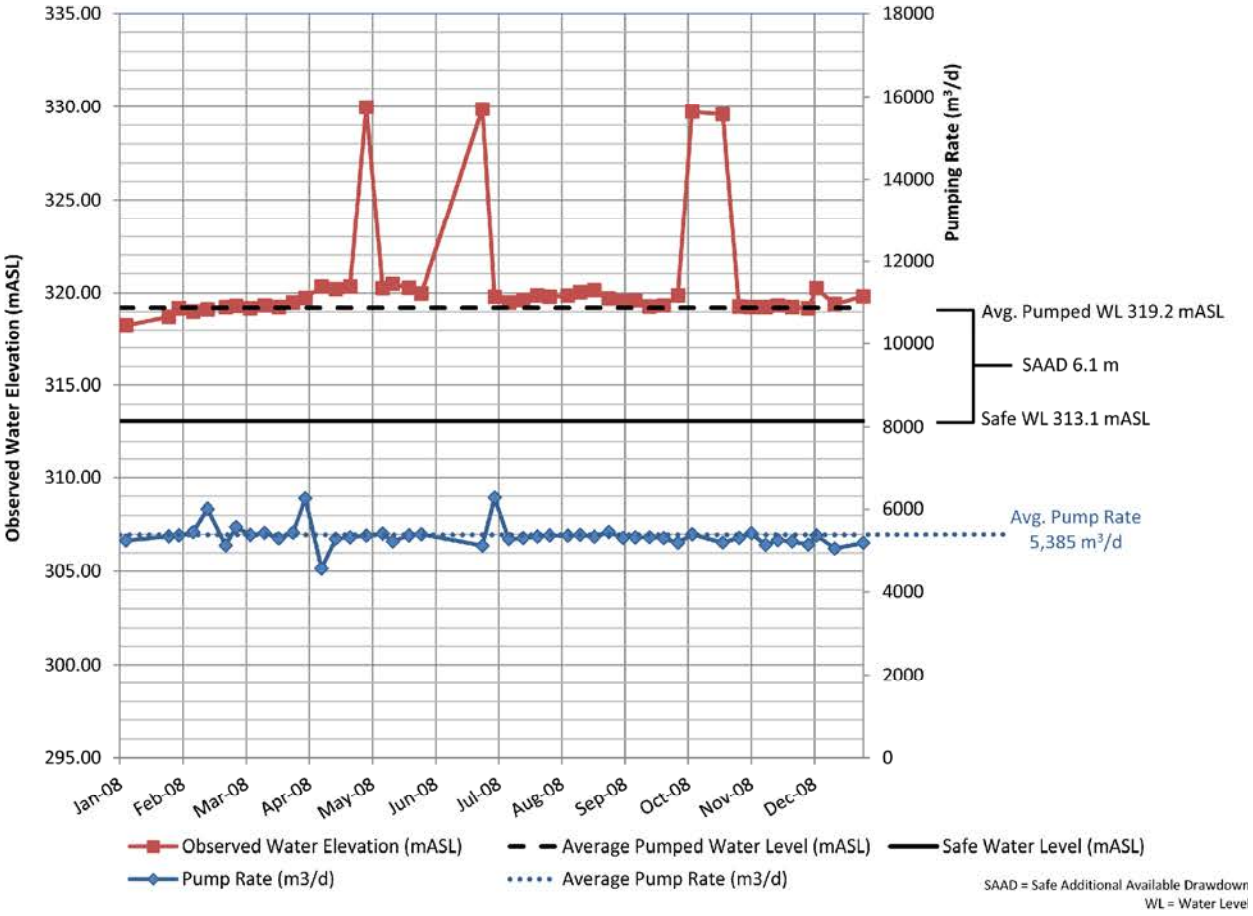

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Burke

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Figure F5

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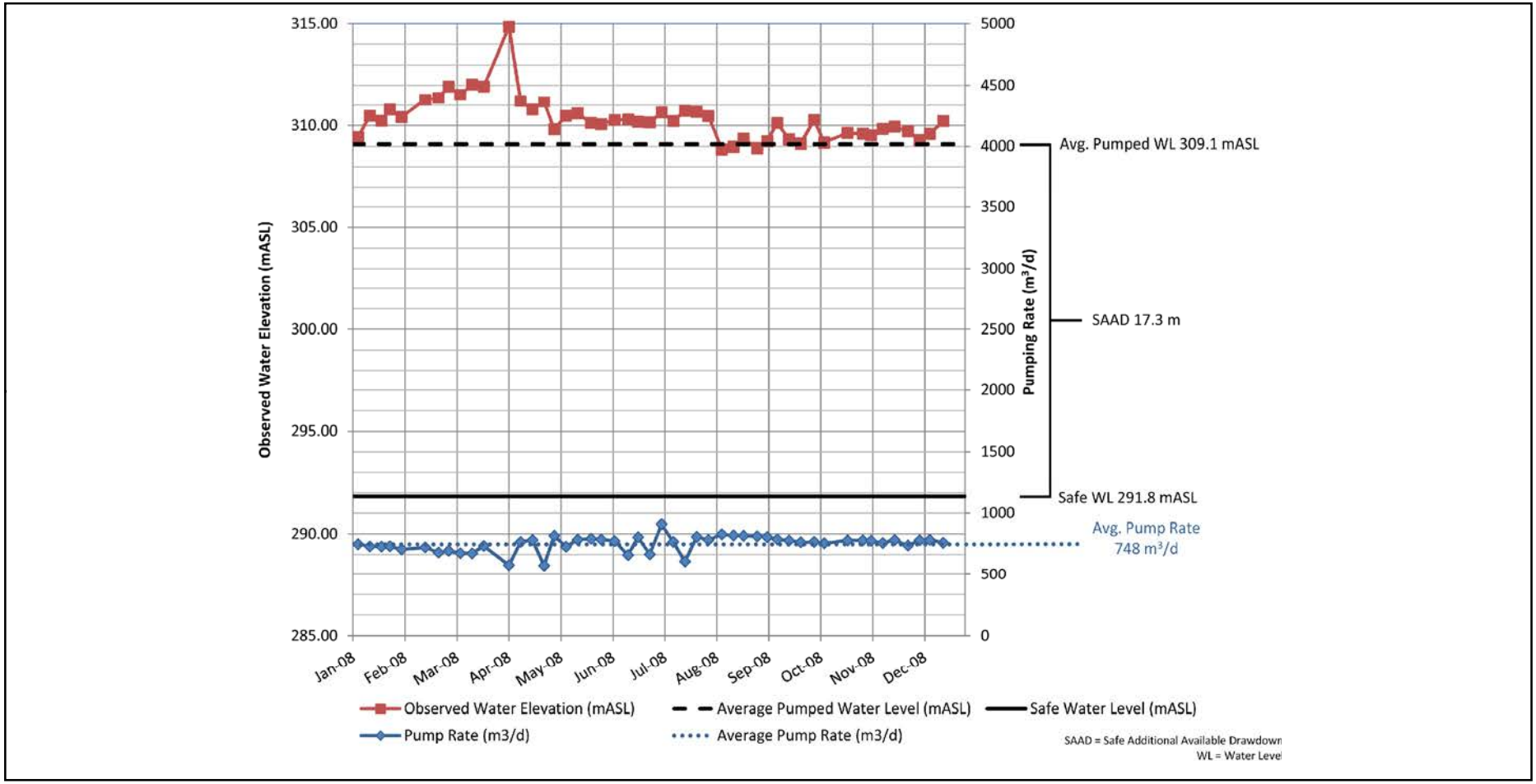

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Calico

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Figure F6

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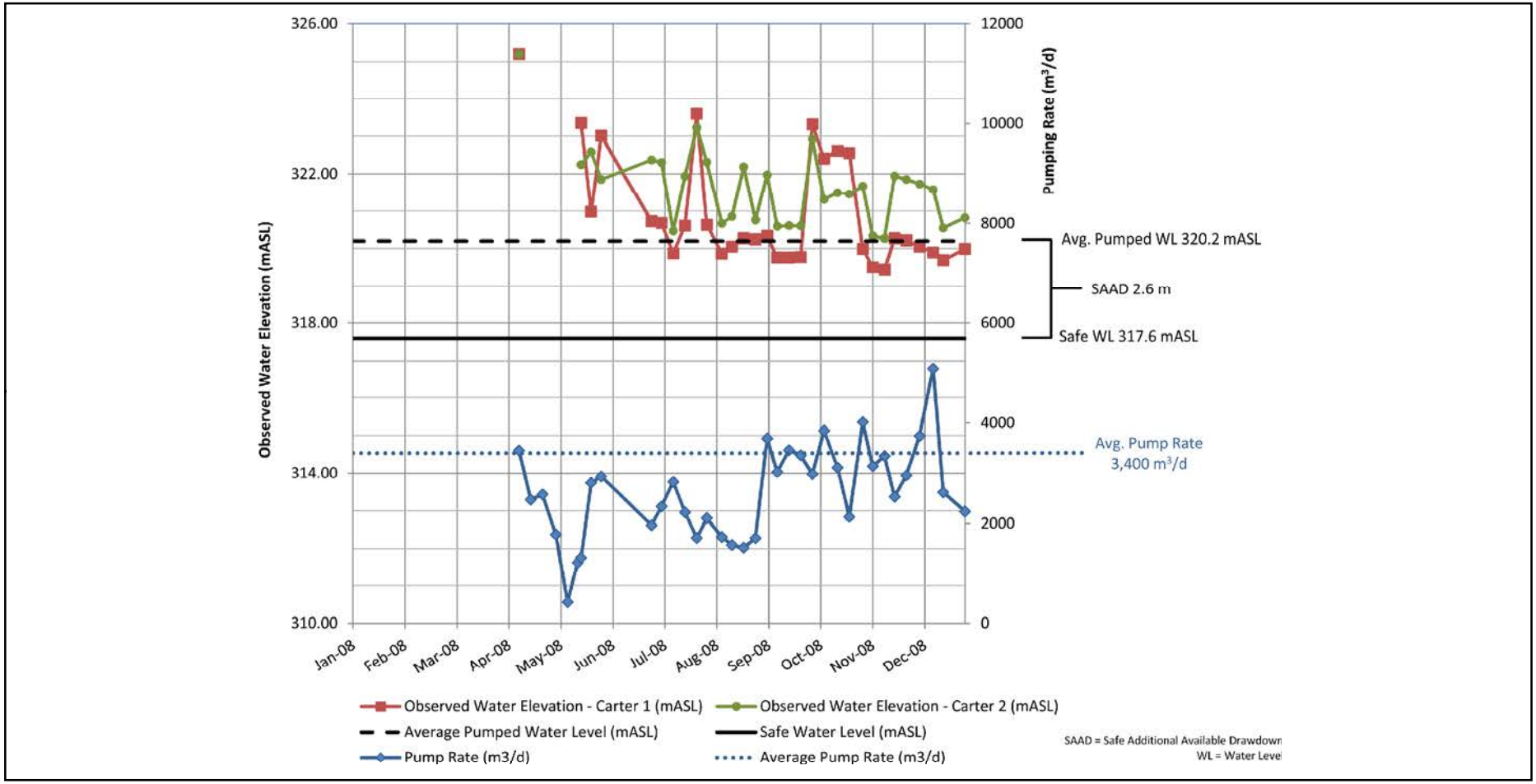

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Carter

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Figure F7

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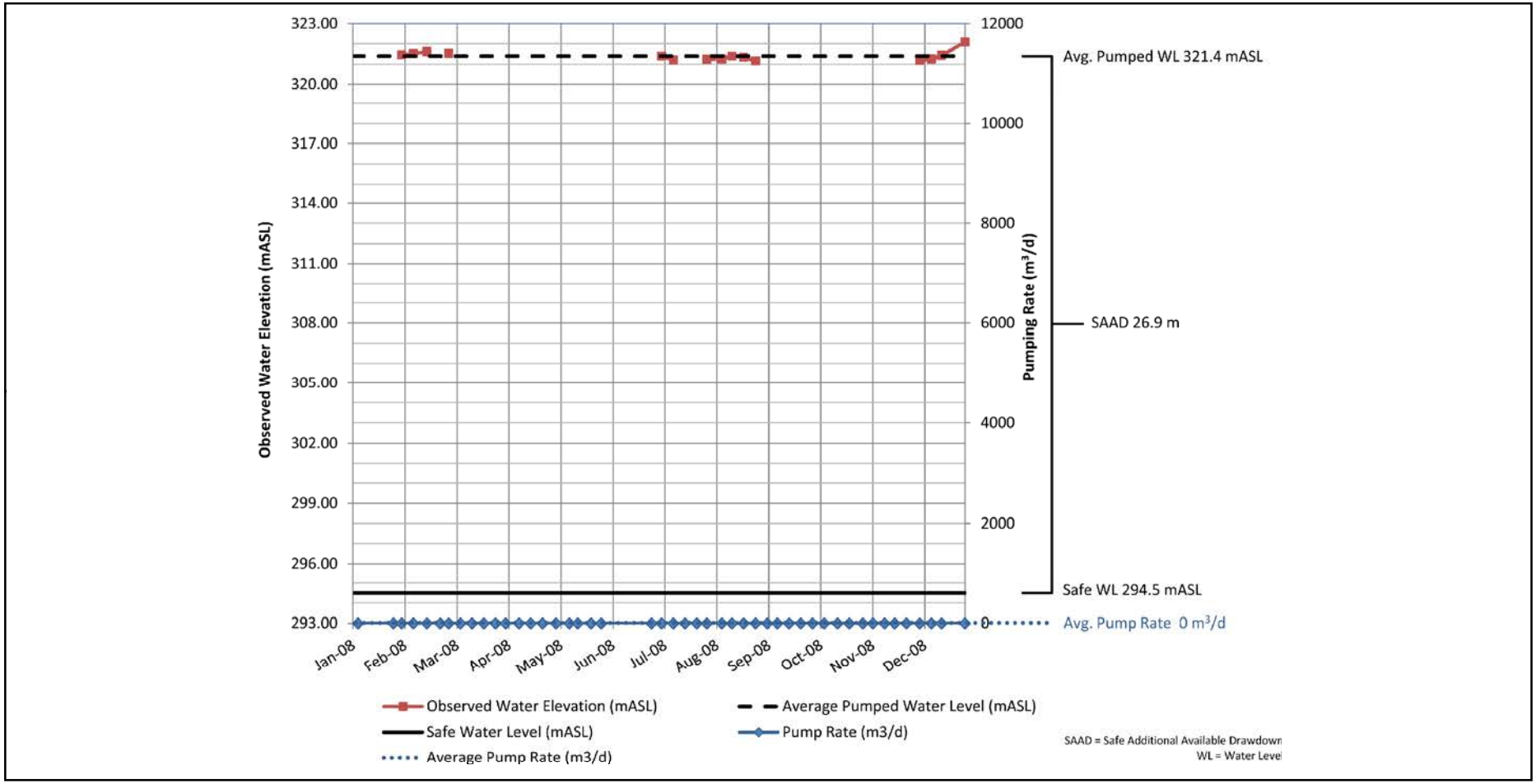

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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Clythe Creek

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Figure F8

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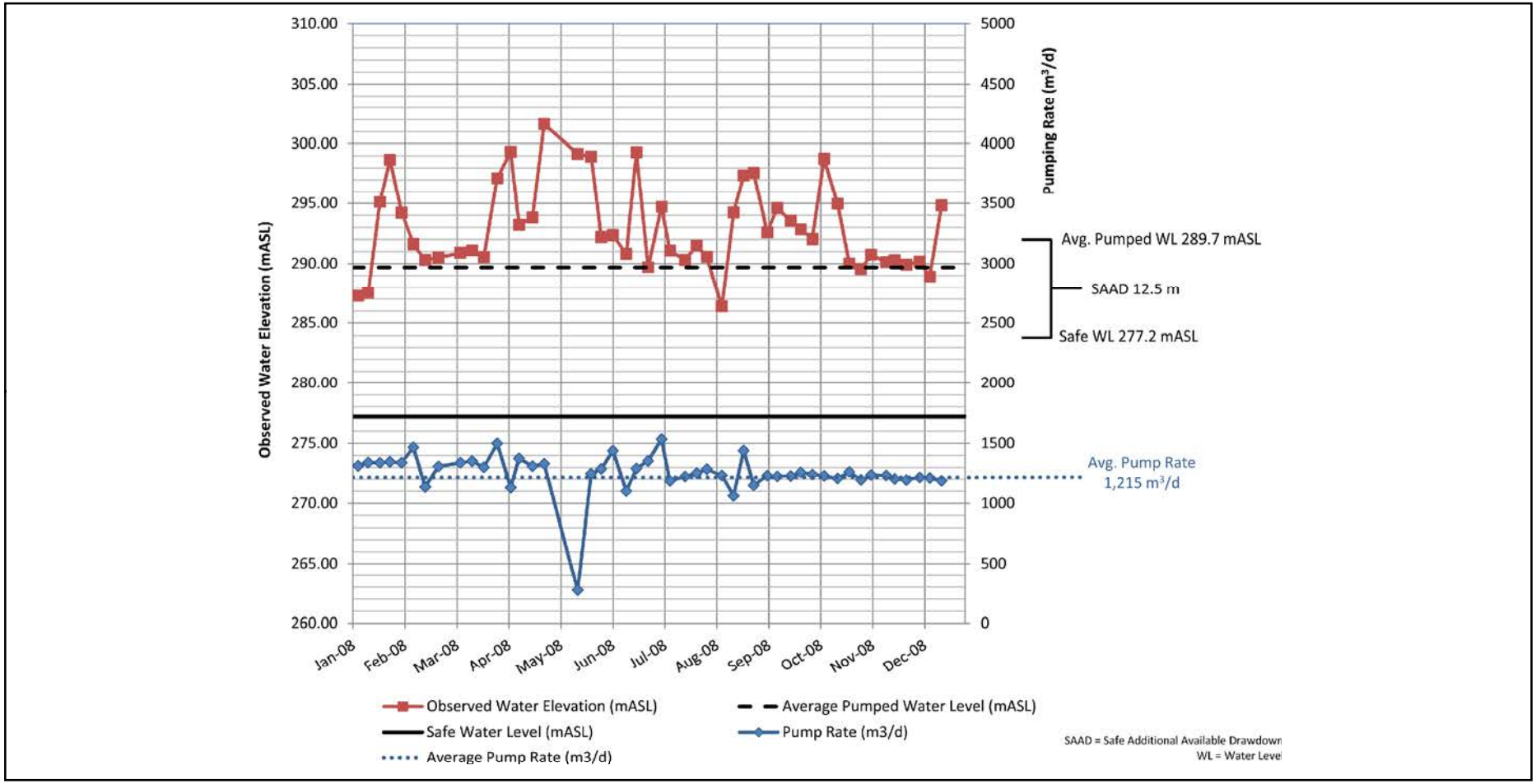

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Dean Ave.

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Figure F9

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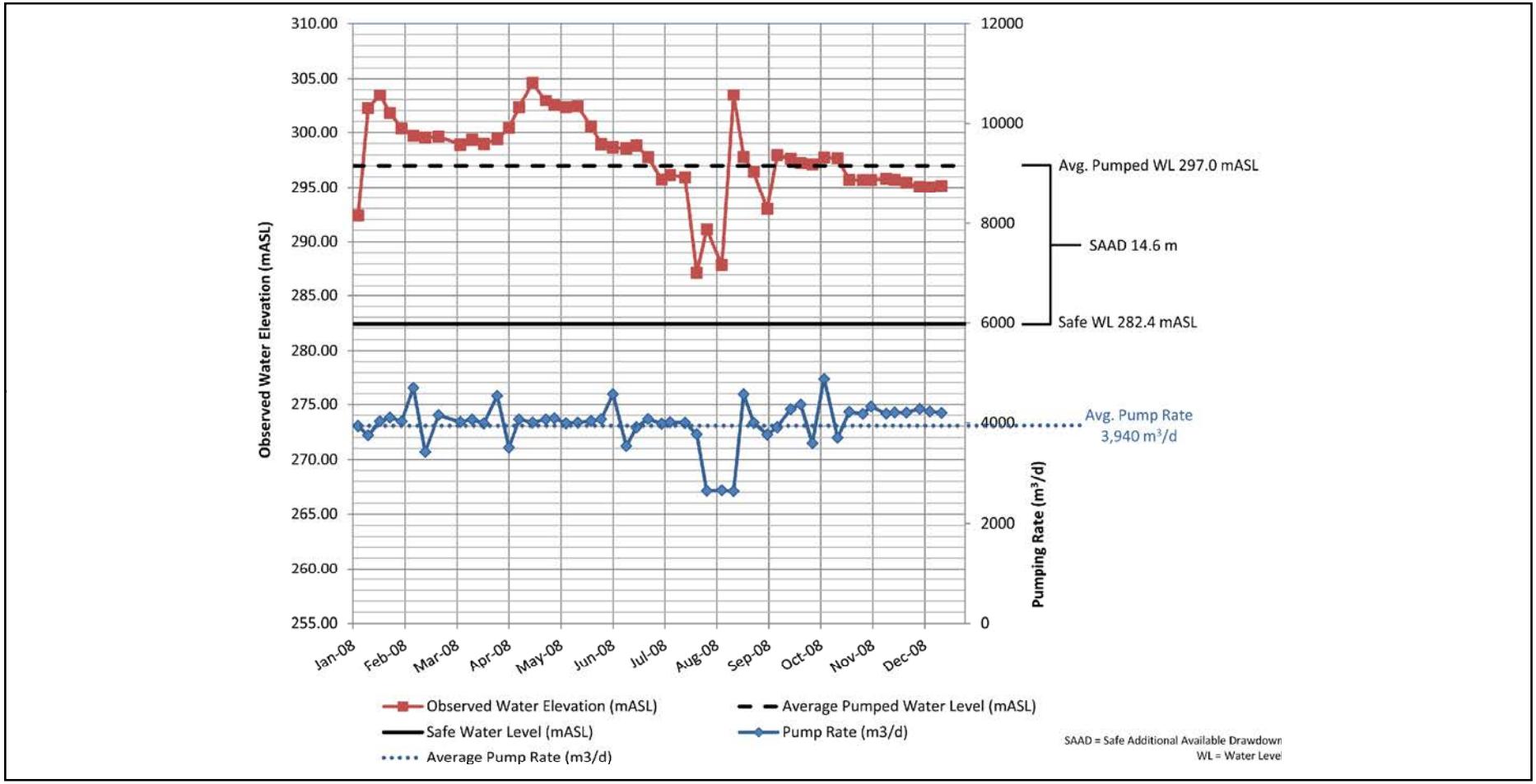

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Downey Road

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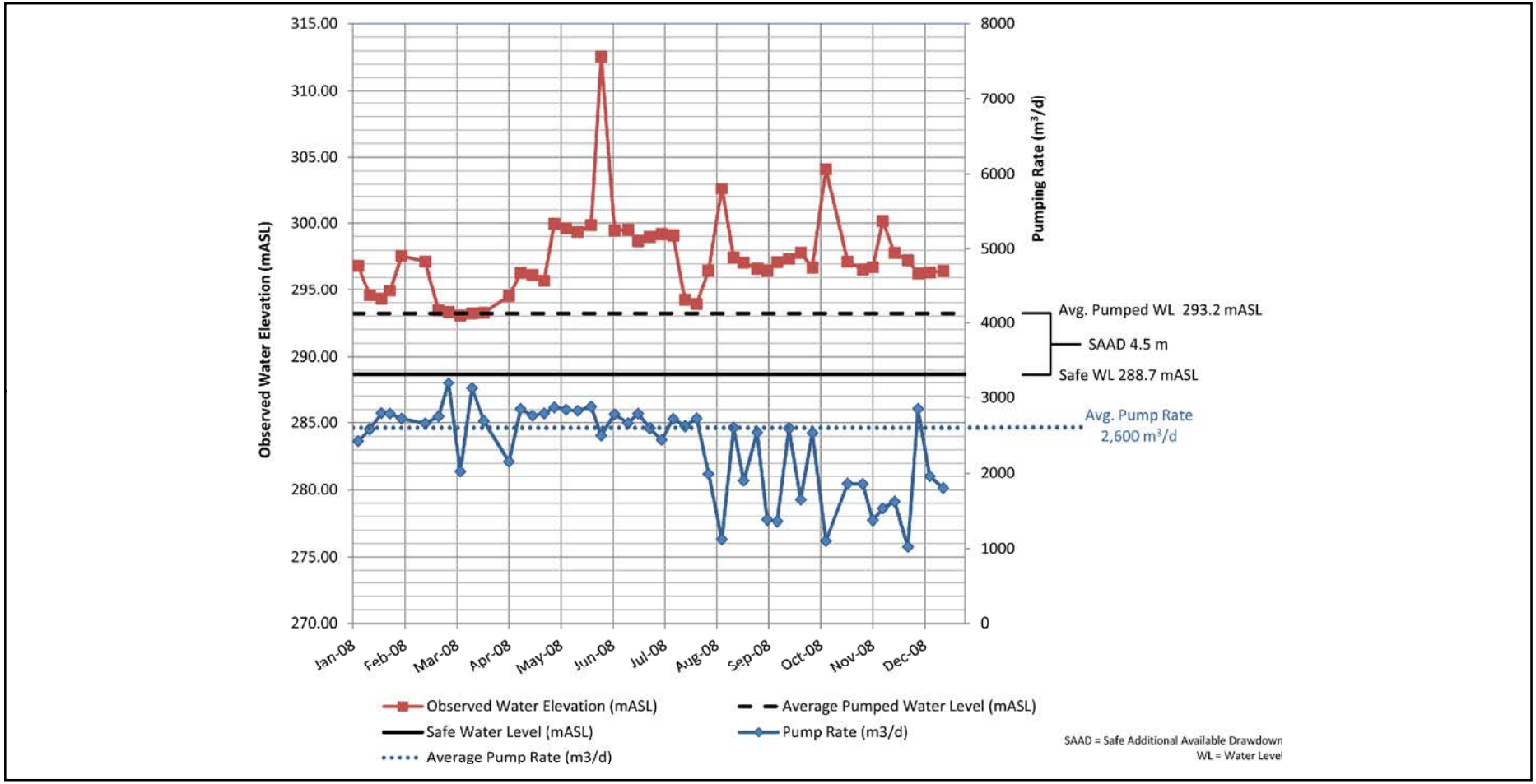
Figure F10

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F11-Safe_Additional_Drawdown_Calculation_Emma.mxd



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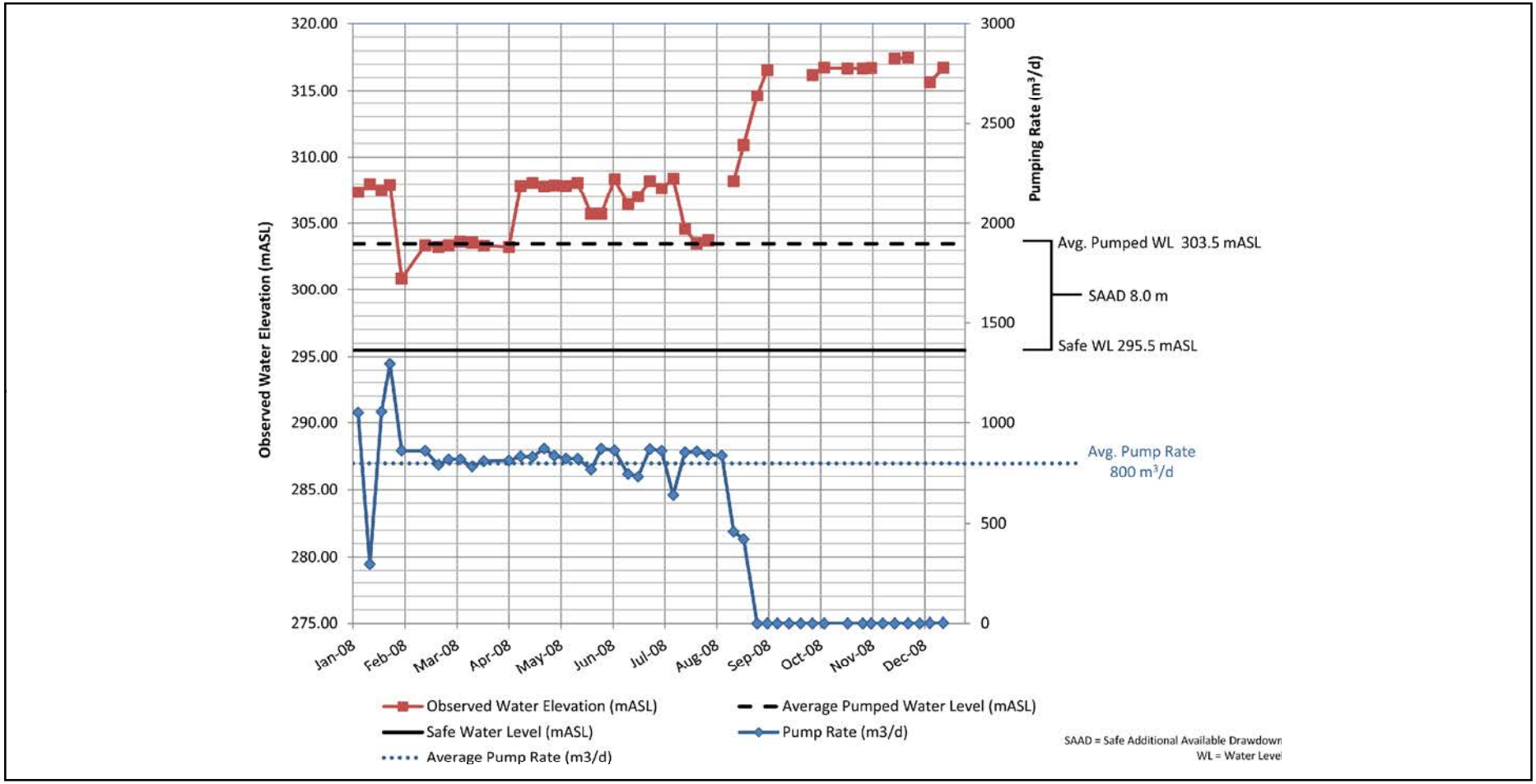
Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Emma

Date:	Project:	Technical:	Reviewer:	Drawn:
17 Jan 2017	15072	J. Melchin	P. Chin	C. Curry

Figure F11

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F12-Safe_Additional_Drawdown_Calculation_Helmar.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Helmar

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Figure
F12

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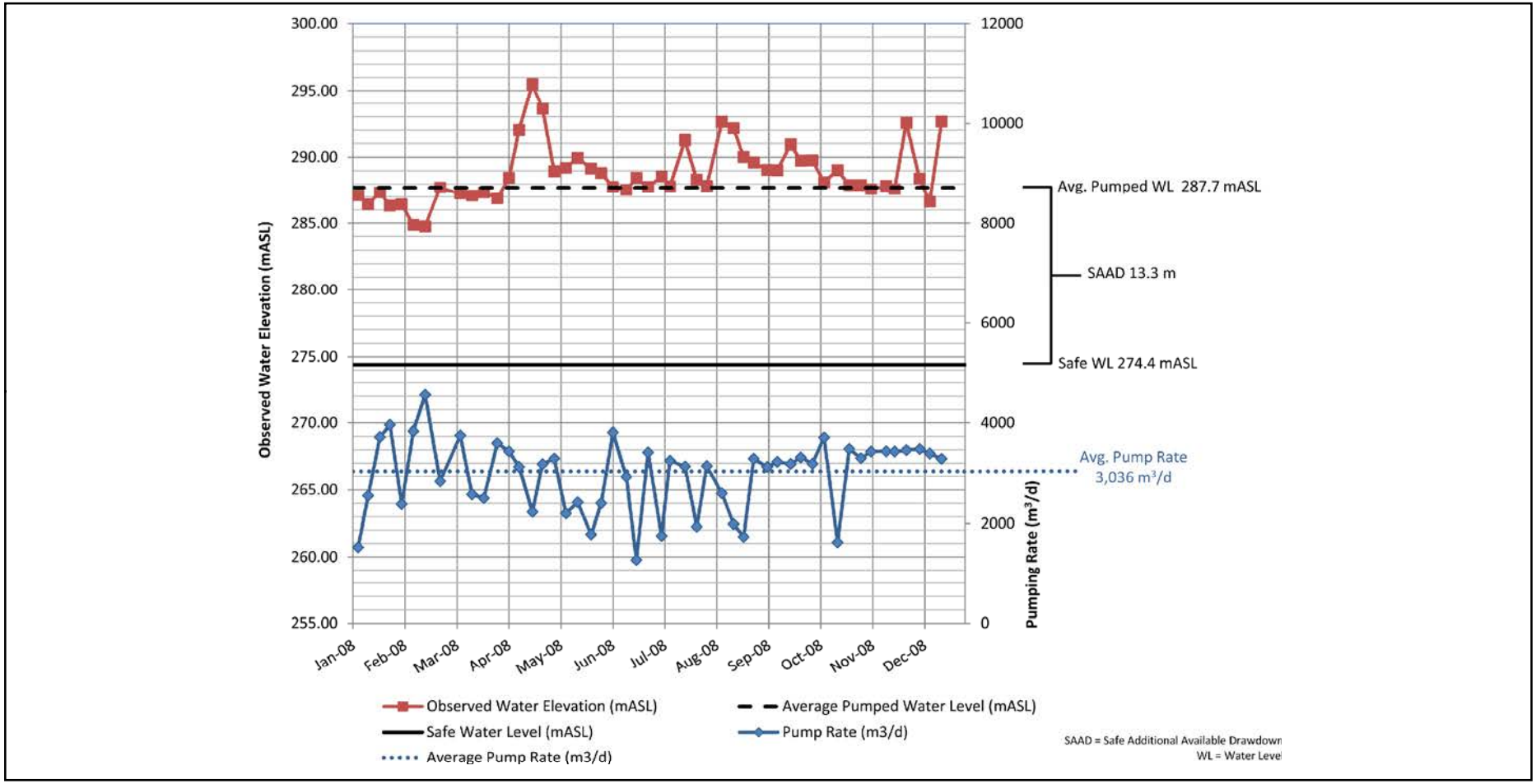

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Membro

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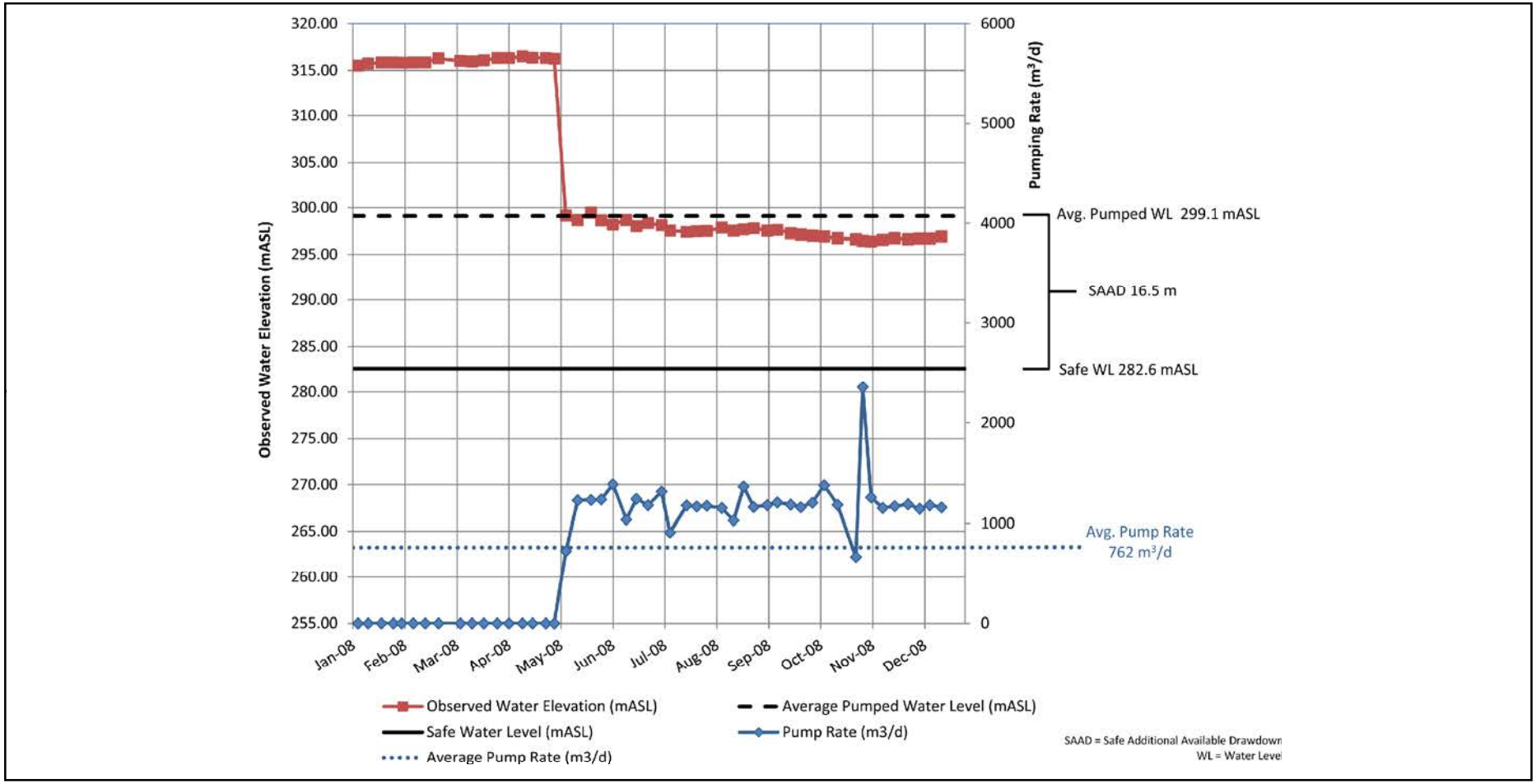
Figure
F13

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F14-Safe_Additional_Drawdown_Calculation_Paisley.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Paisley

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Figure F14

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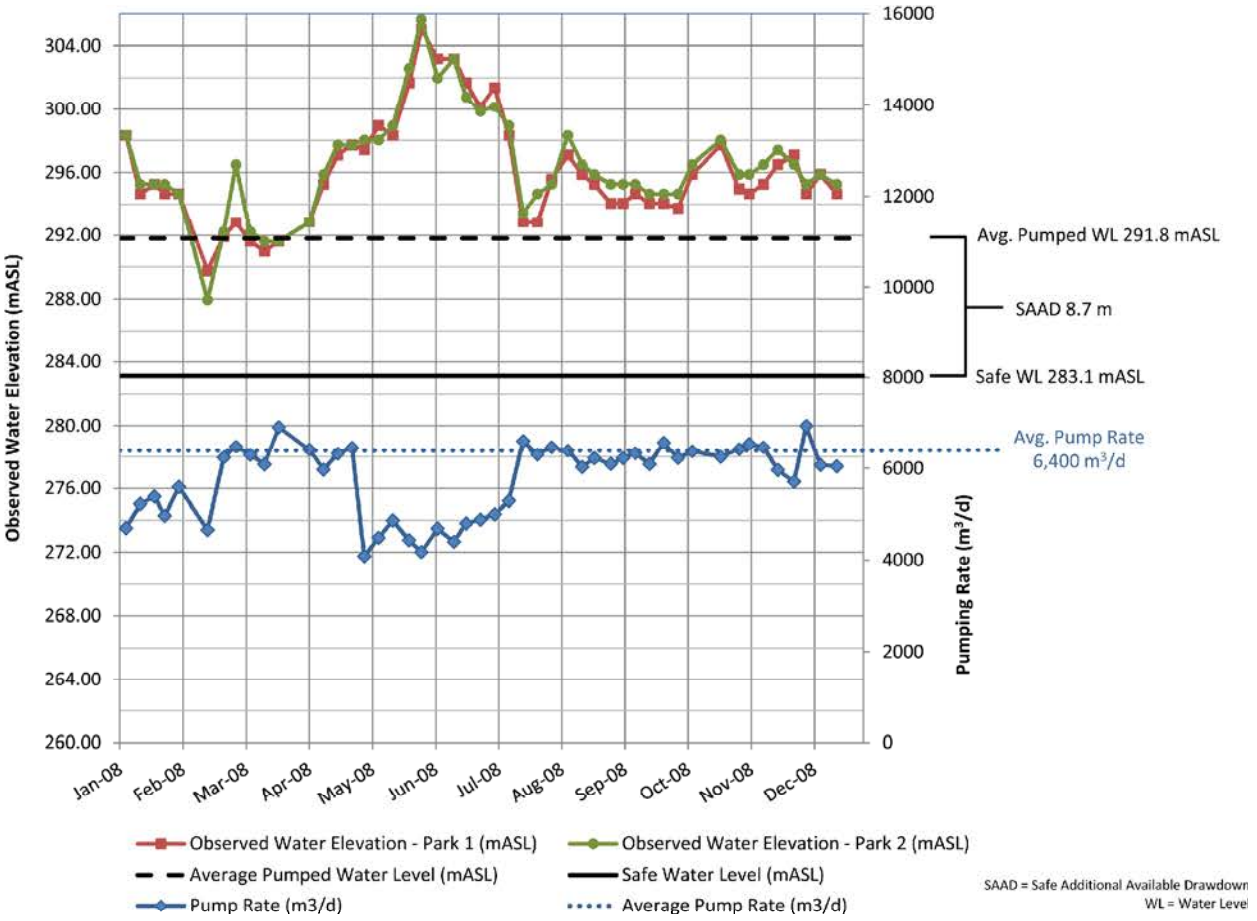

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Park 1 and 2

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Figure F15

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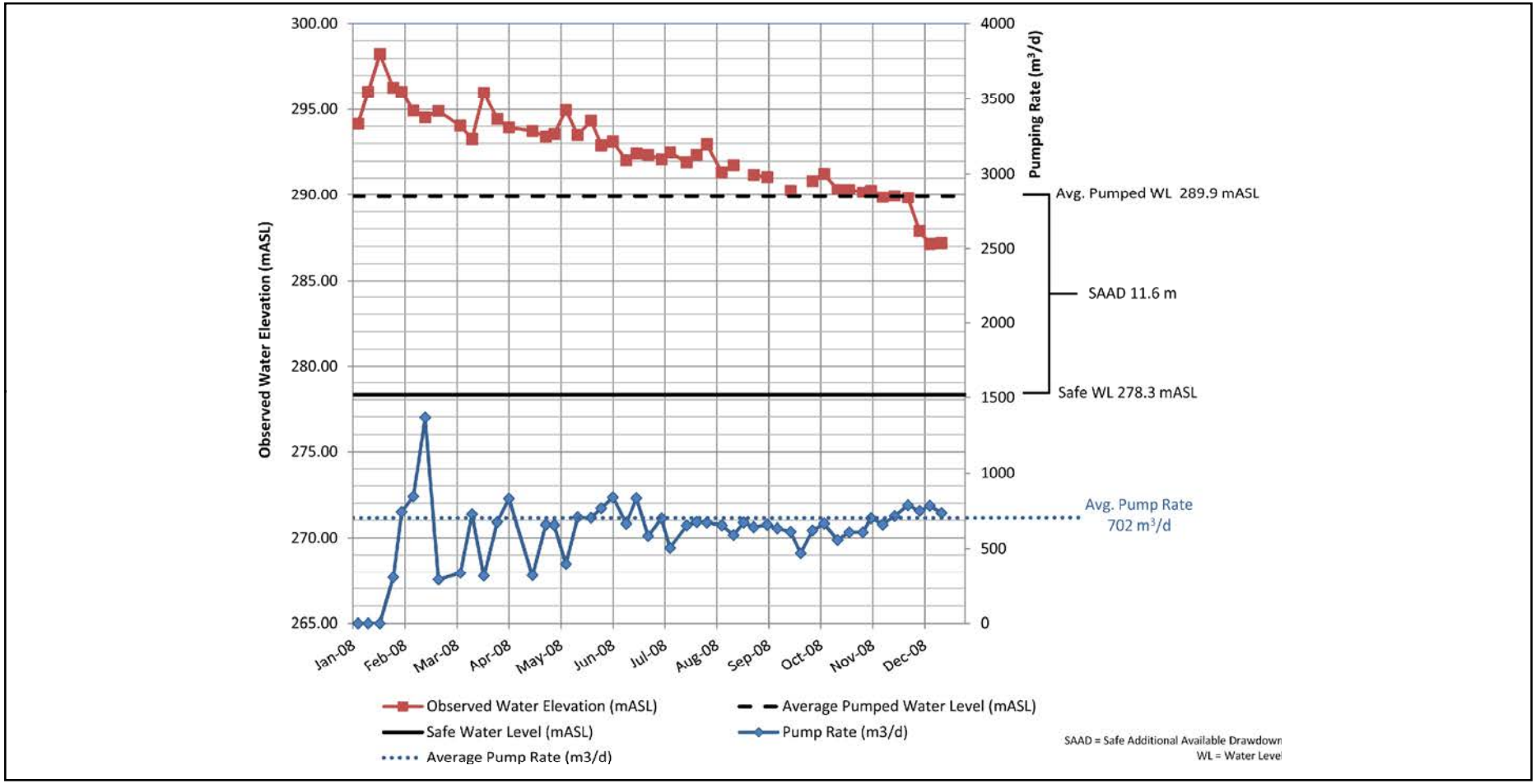

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Queensdale

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Figure F16

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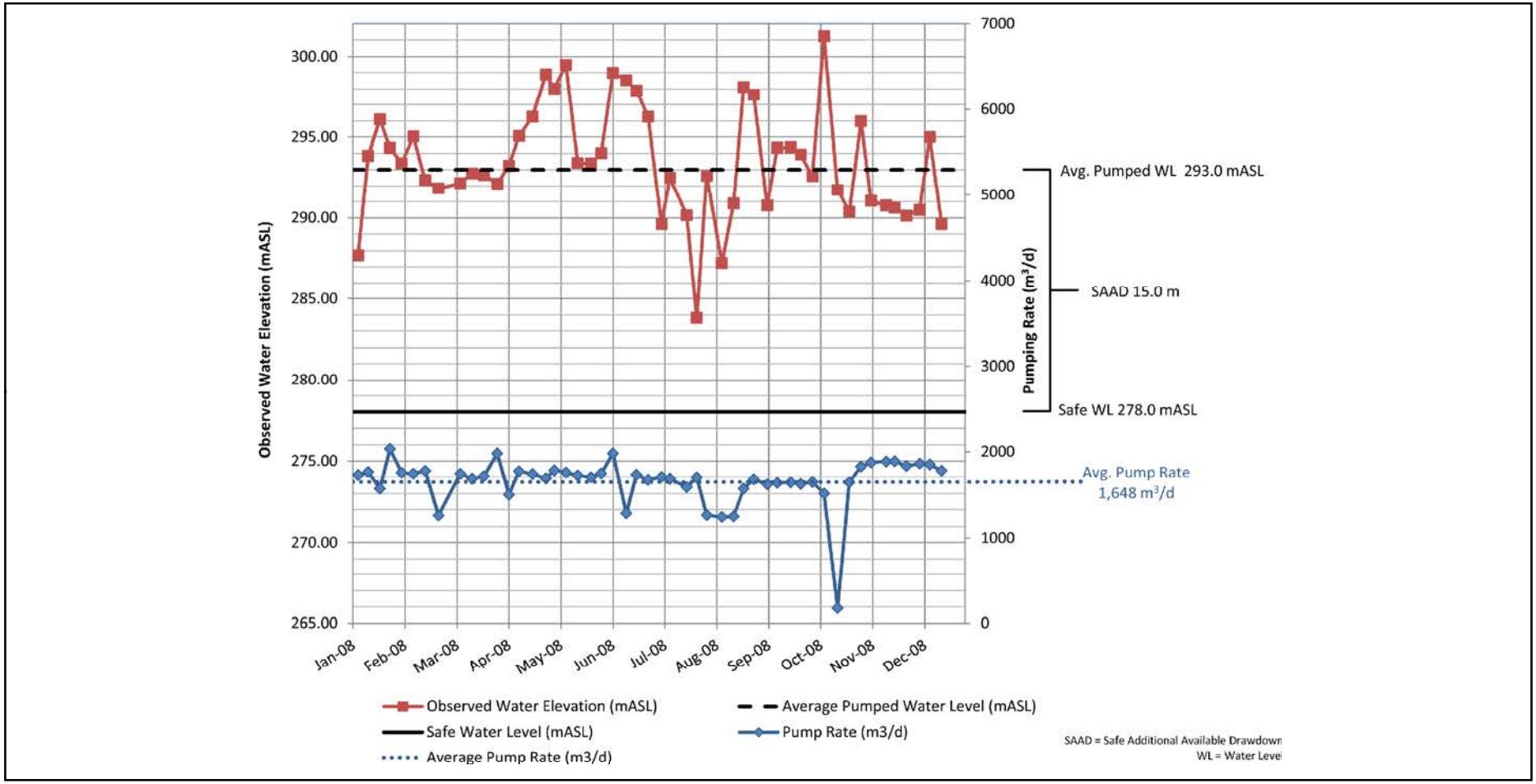

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation University

Date:	Project:	Technical:	Reviewer:	Drawn:
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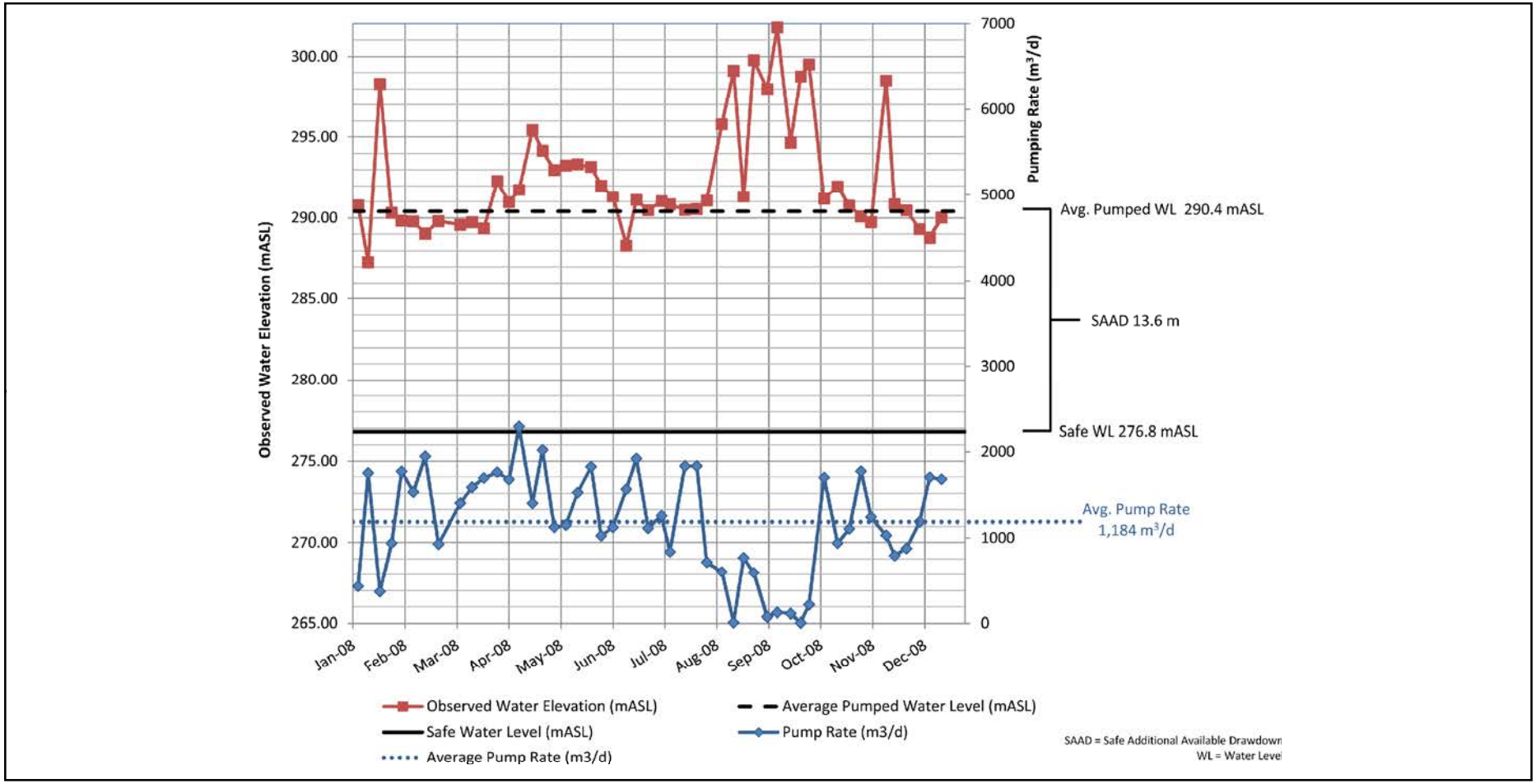
Figure F17

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F18-Safe_Additional_Drawdown_Calculation_Water_Street.mxd



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Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Water Street

Date:	Project:	Technical:	Reviewer:	Drawn:
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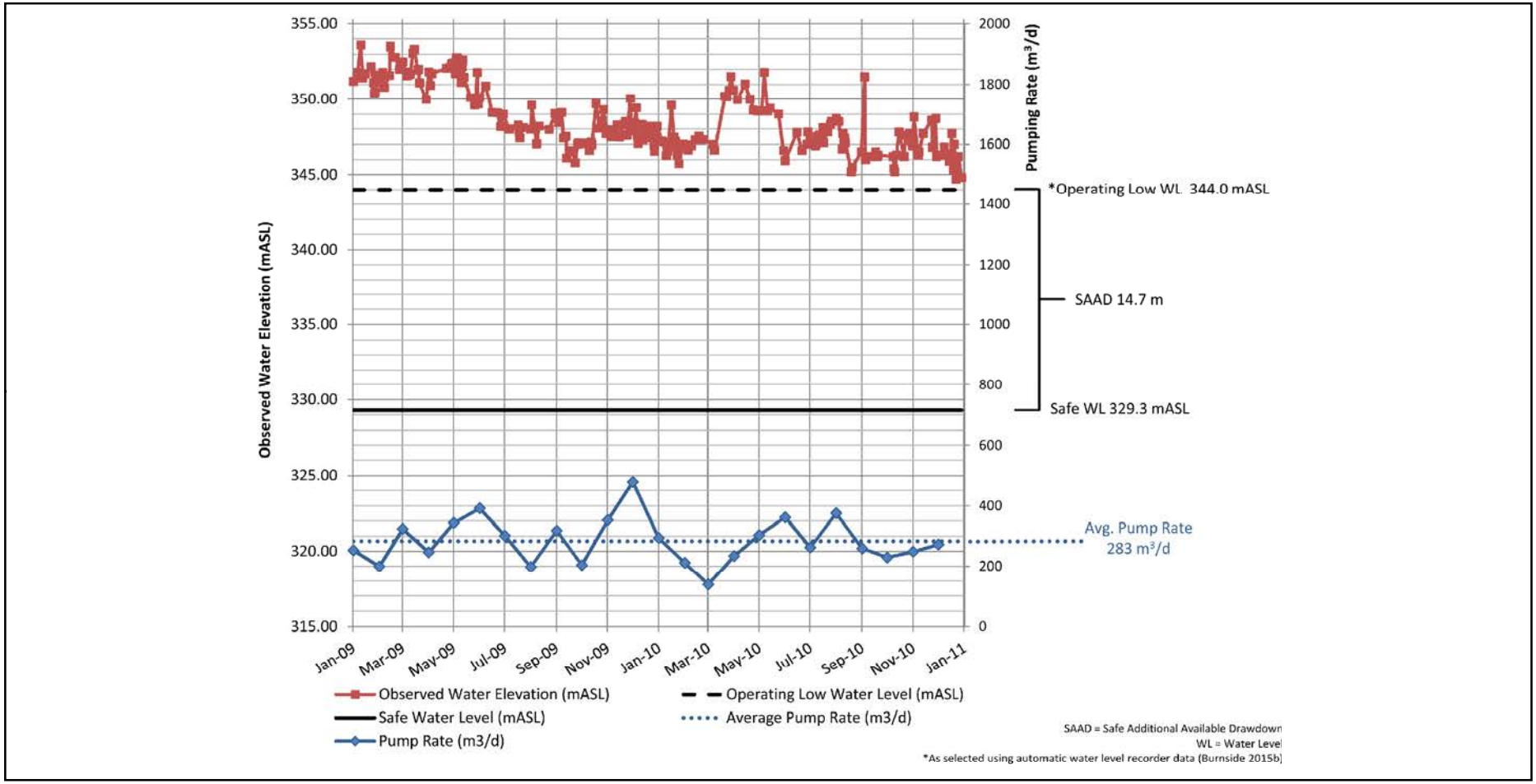
Figure F18

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F19-Safe_Additional_Drawdown_Calculation_Station_Street_1.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Rockwood 1

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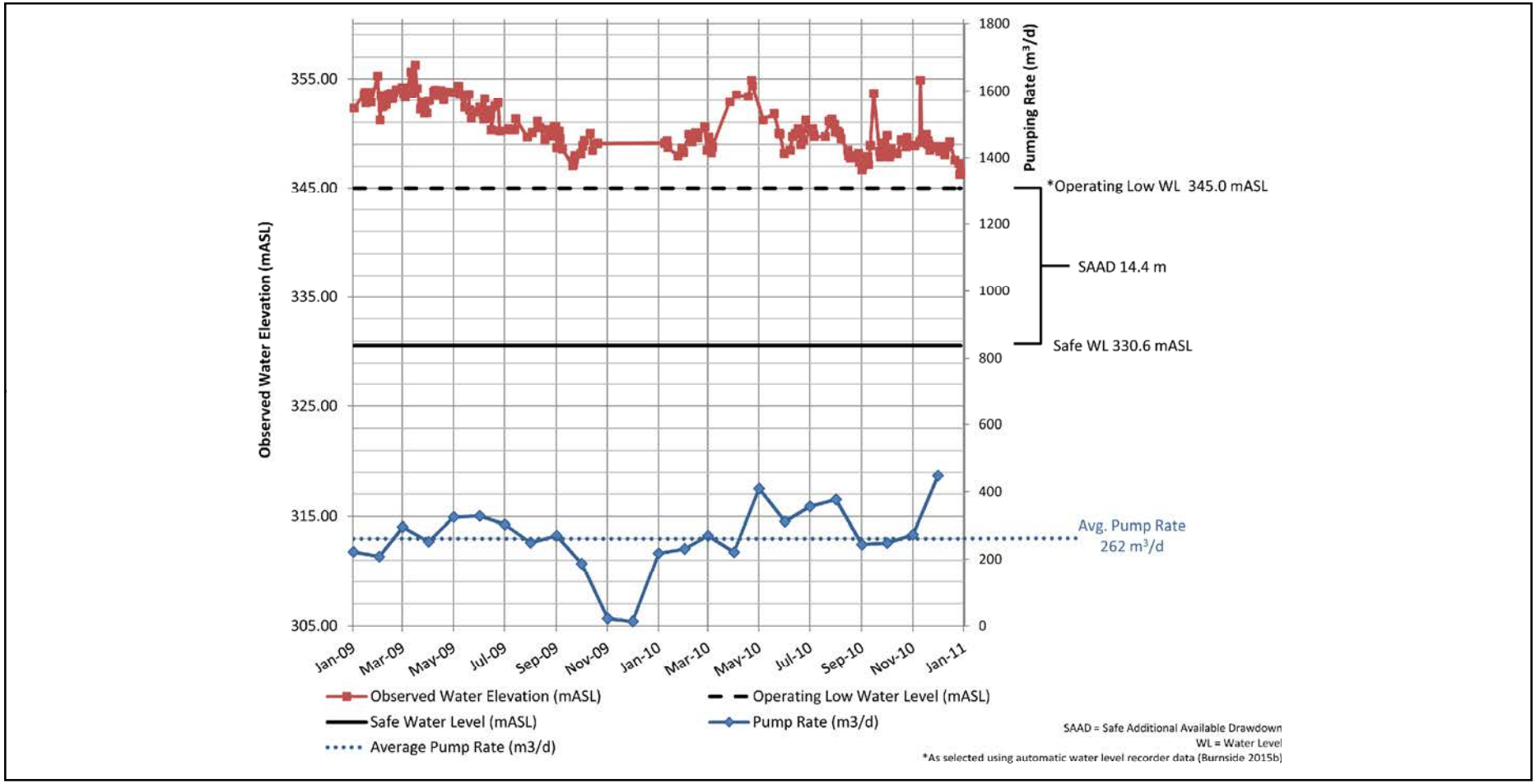
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure
F19

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F20-Safe_Additional_Drawdown_Calculation_Station_Street_2.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Rockwood 2

Date:	Project:	Technical:	Reviewer:	Drawn:
07 Mar 2017	15072	J. Melchin	P. Chin	C. Curry

Figure F20

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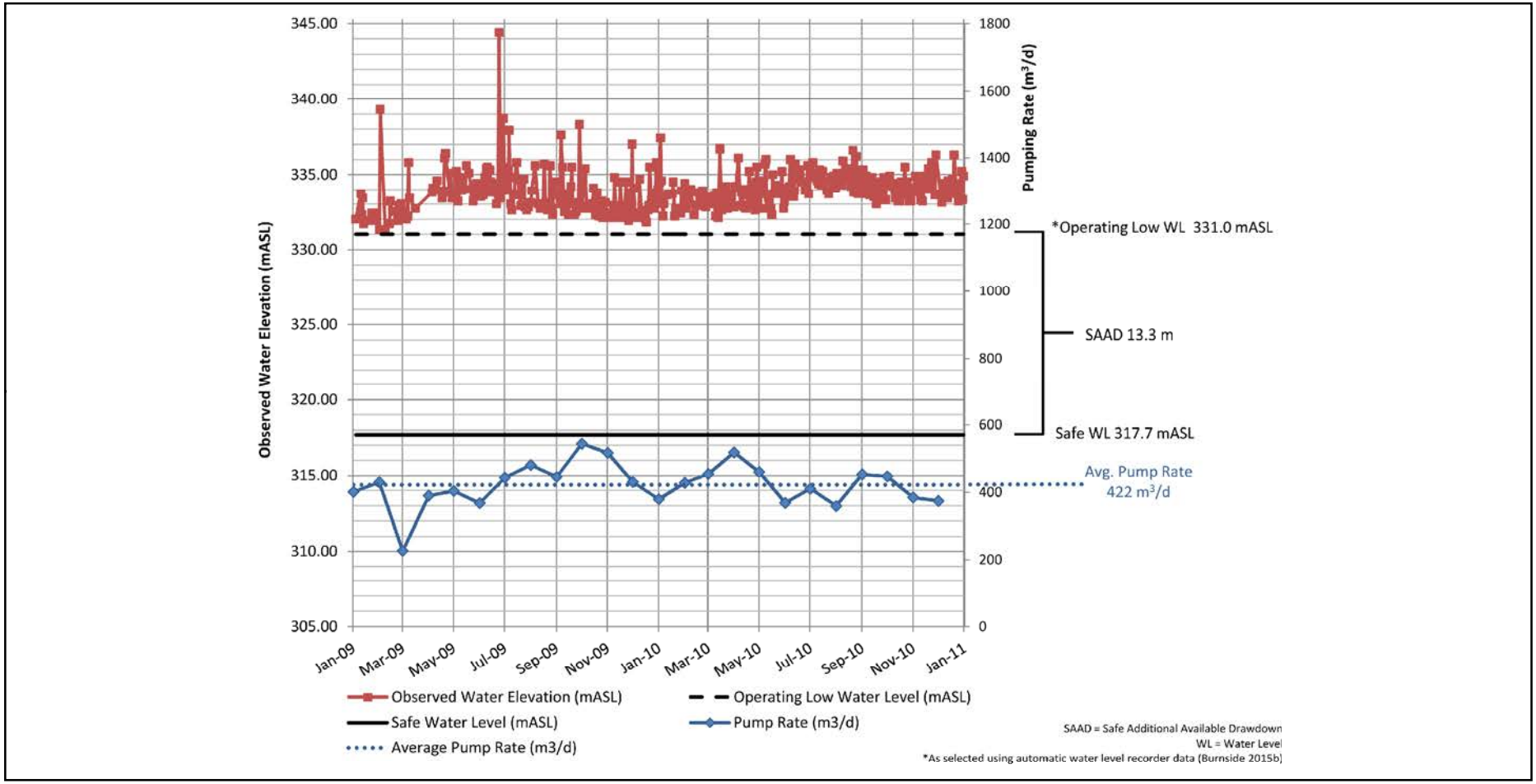

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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Rockwood 3

Date:	Project:	Technical:	Reviewer:	Drawn:
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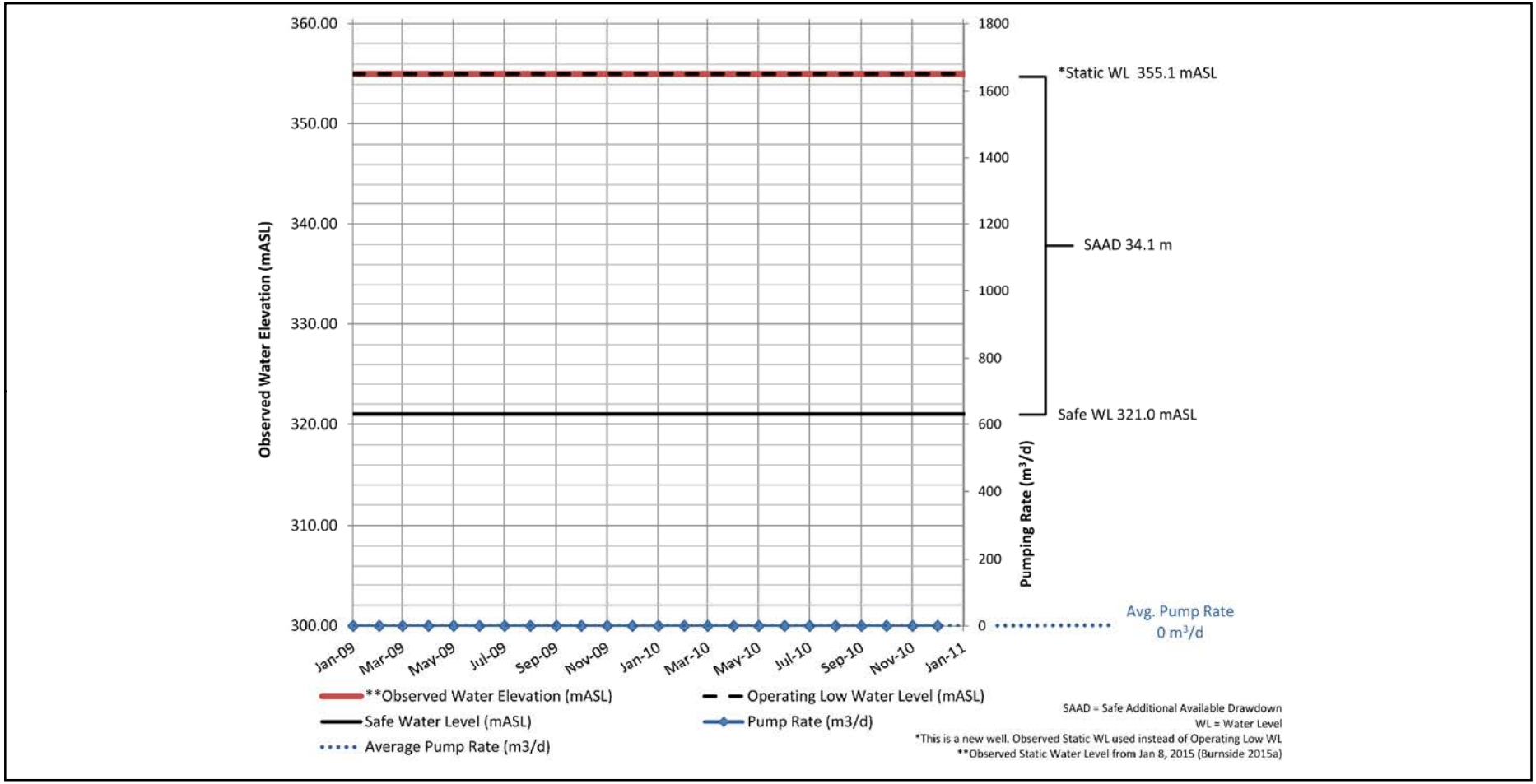
Figure F21

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F22-Safe_Additional_Drawdown_Calculation_Rockwood_4.mxd



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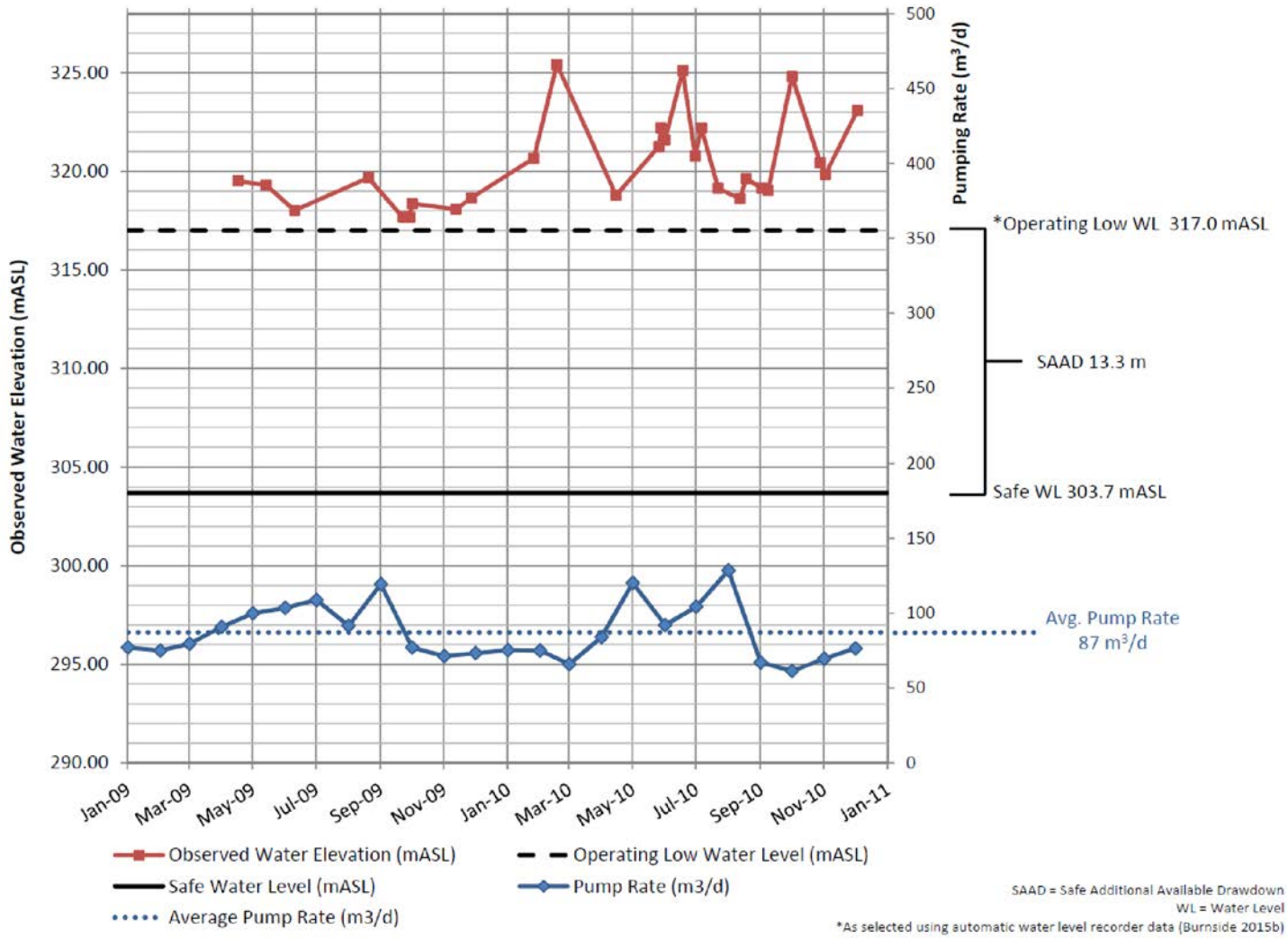
Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Rockwood 4

Date:	Project:	Technical:	Reviewer:	Drawn:
17 Jan 2017	15072	J. Melchin	P. Chin	C. Curry

Figure F22

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F23-Safe_Additional_Drawdown_Calculation_Cross_Creek.mxd



SAAD = Safe Additional Available Drawdown
WL = Water Level
*As selected using automatic water level recorder data (Burnside 2015b)

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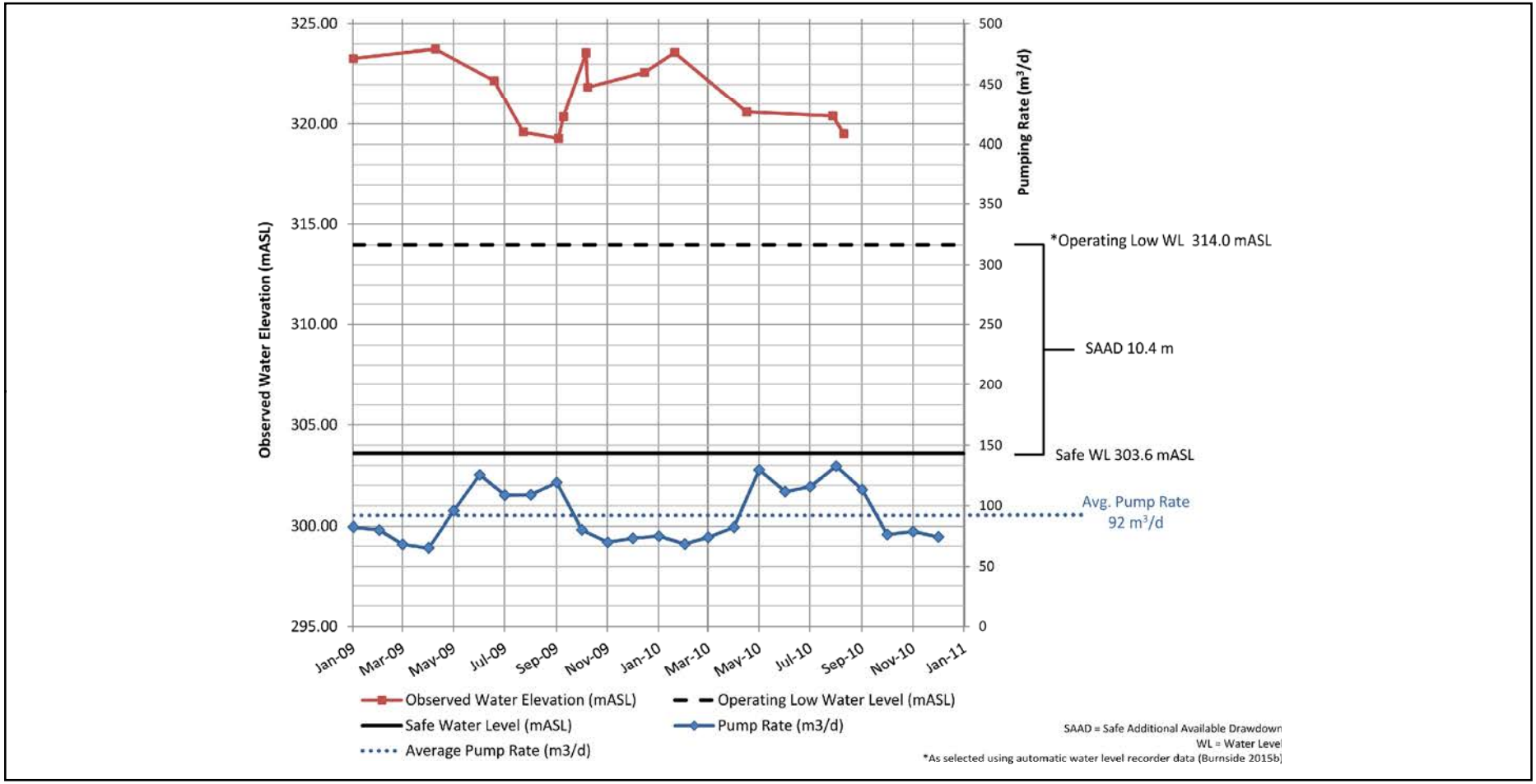
Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Cross Creek

Date:	Project:	Technical:	Reviewer:	Drawn:
17 Jan 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure F23

I:\CityofGuelph\15072\FiguresandTables\QHG\2014\Report\AppendixF_SafeAdditionalAvailableeDrawdown\Figure-F24-Safe_Additional_Drawdown_Calculation_Huntington.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix F Safe Additional Available Drawdown

Safe Additional Drawdown Calculation Huntington

Date:	Project:	Technical:	Reviewer:	Drawn:
17 Jan 2017	15072	J. Melchin	P. Chin	C. Curry

Figure F24

APPENDIX G
Drought Scenario Results

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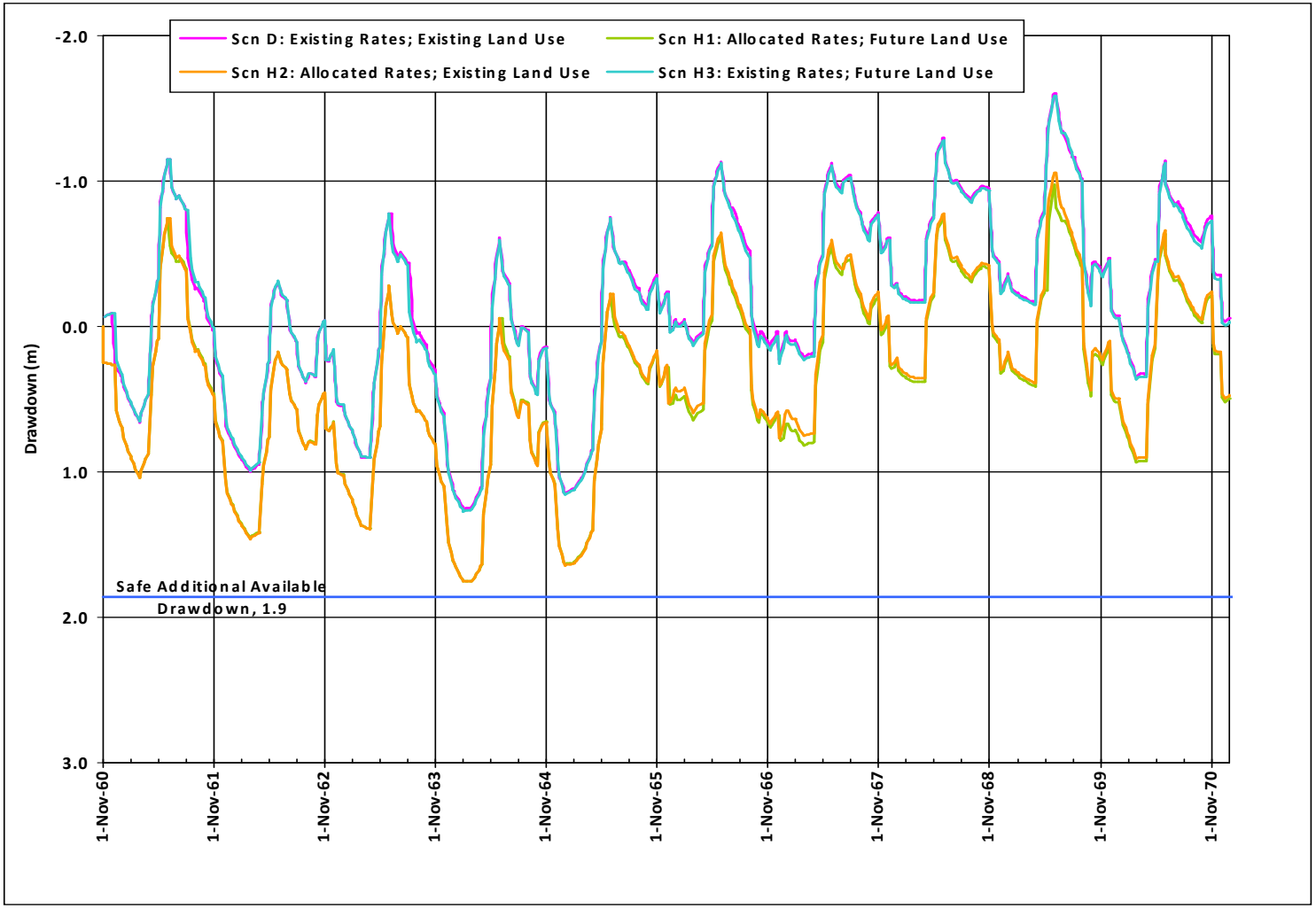

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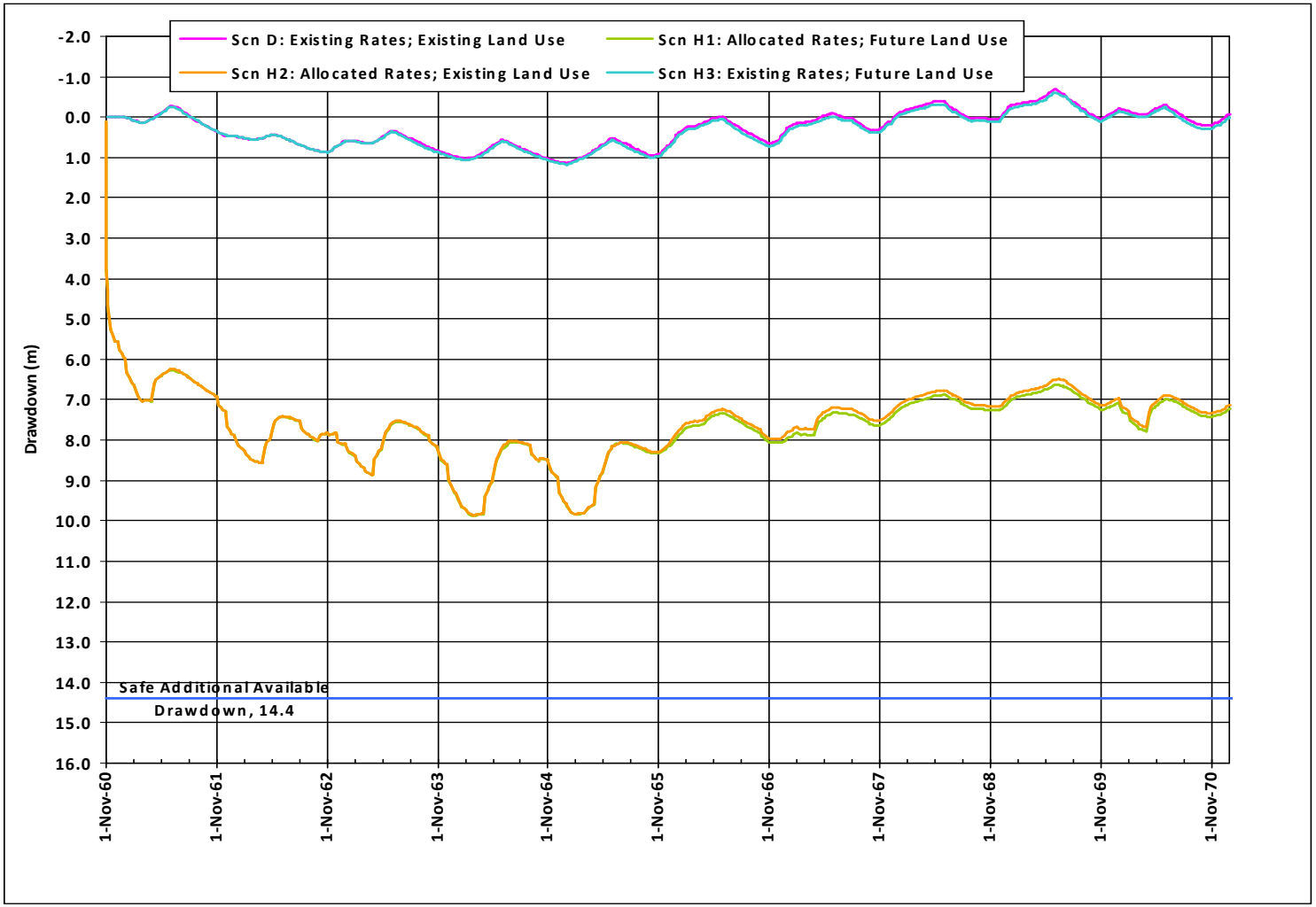
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 1

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G1

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G2_Scenario_H_Drought_Series_Predicted_Drawdown_Arkell6.mxd



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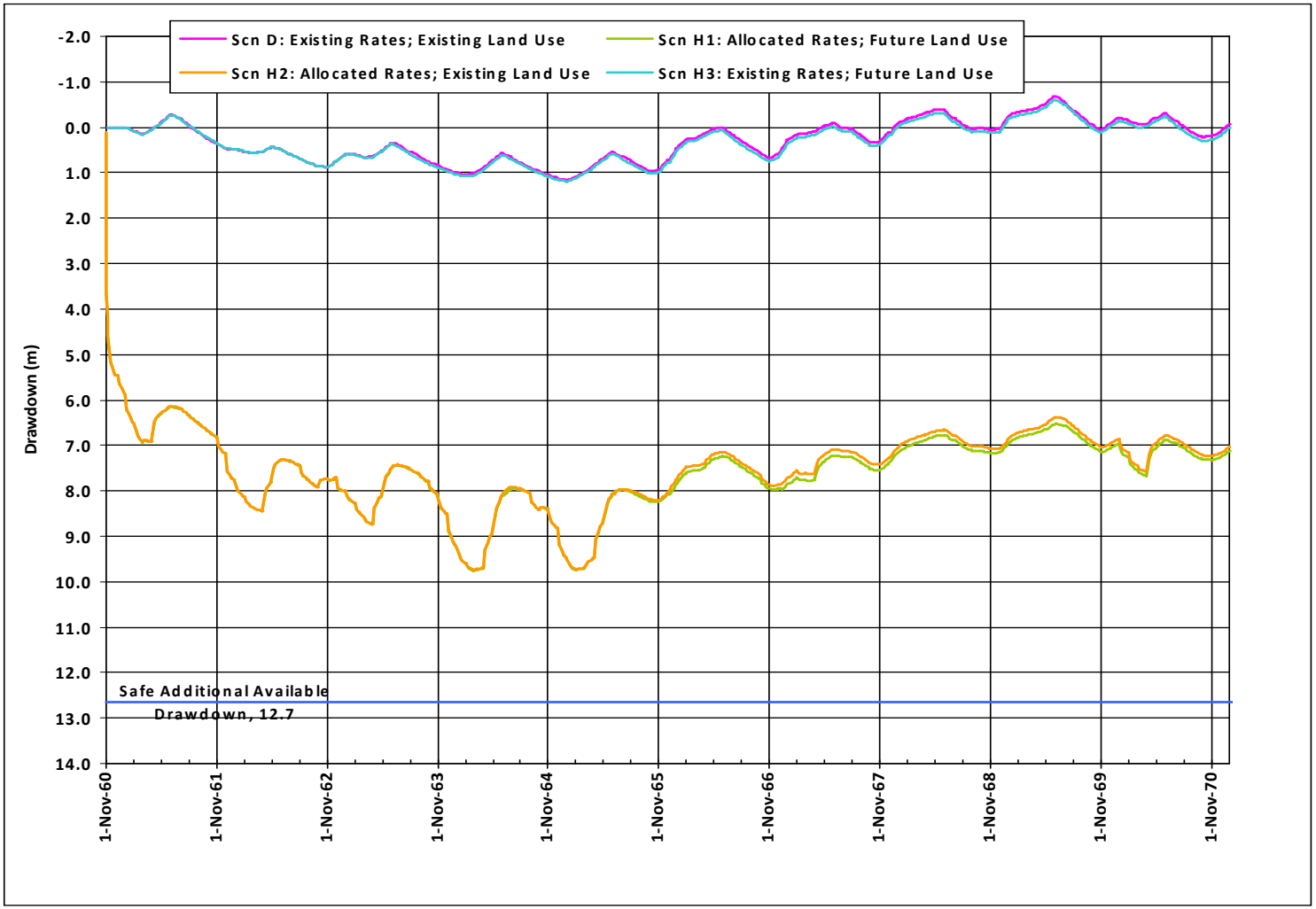
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 6

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G2

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G3_Scenario_H_Drought_Series_Predicted_Drawdown_Arkell7.mxd



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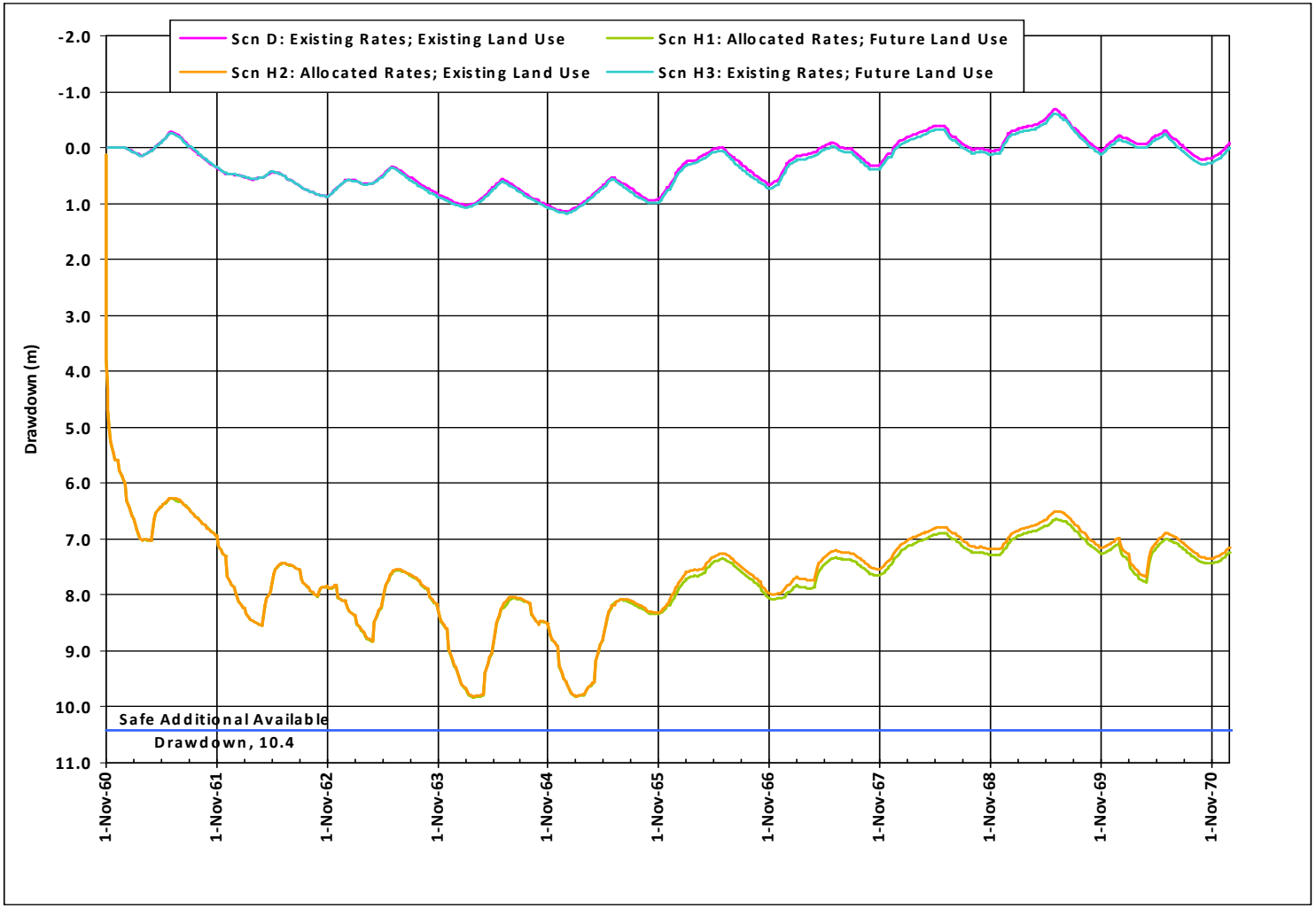
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 7

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G3

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G4_Scenario_H_Drought_Series_Predicted_Drawdown_Arkell8.mxd



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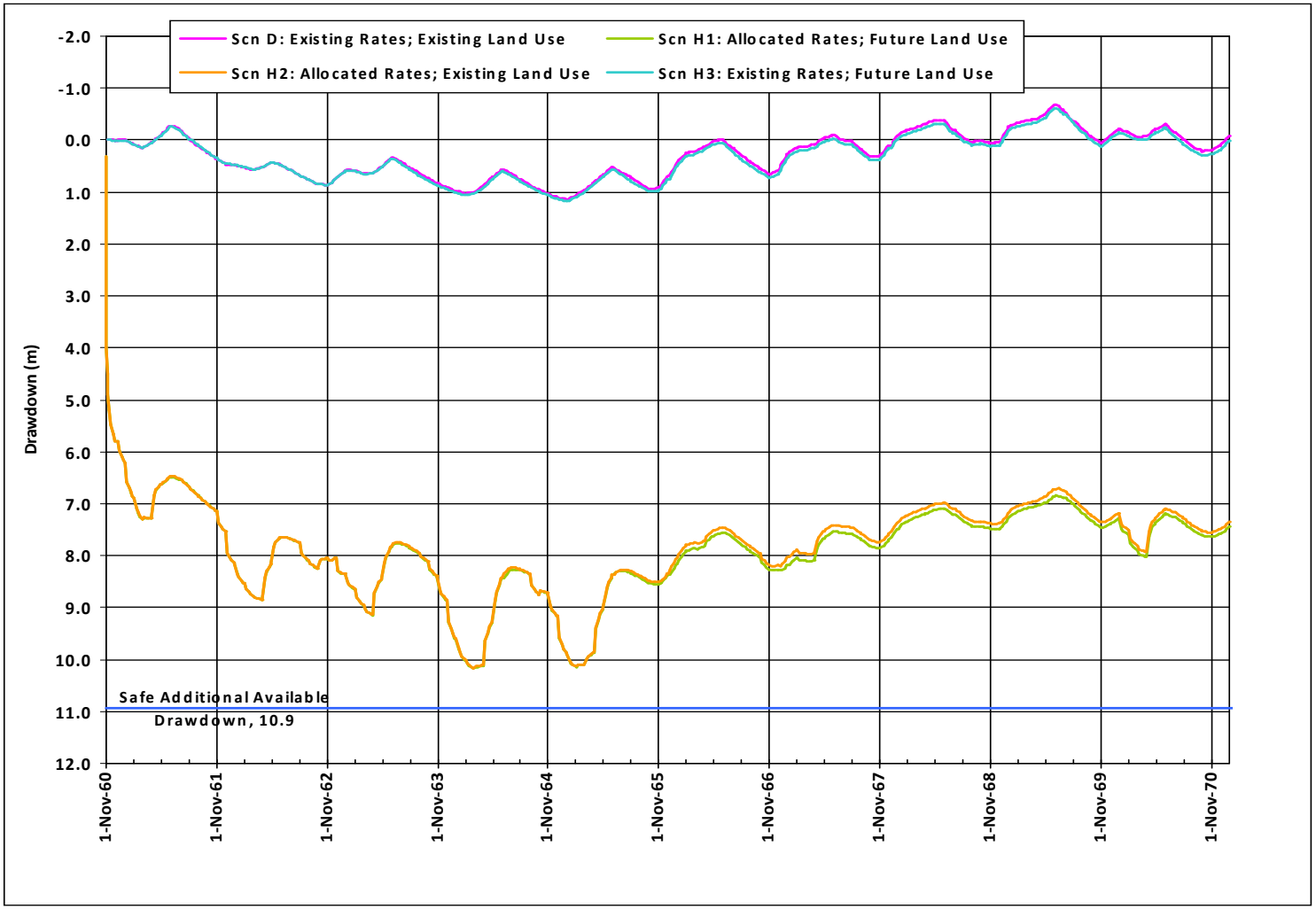
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 8

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G4

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G5_Scenario_H_Drought_Series_Predicted_Drawdown_Arkell14.mxd



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Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 14

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G5

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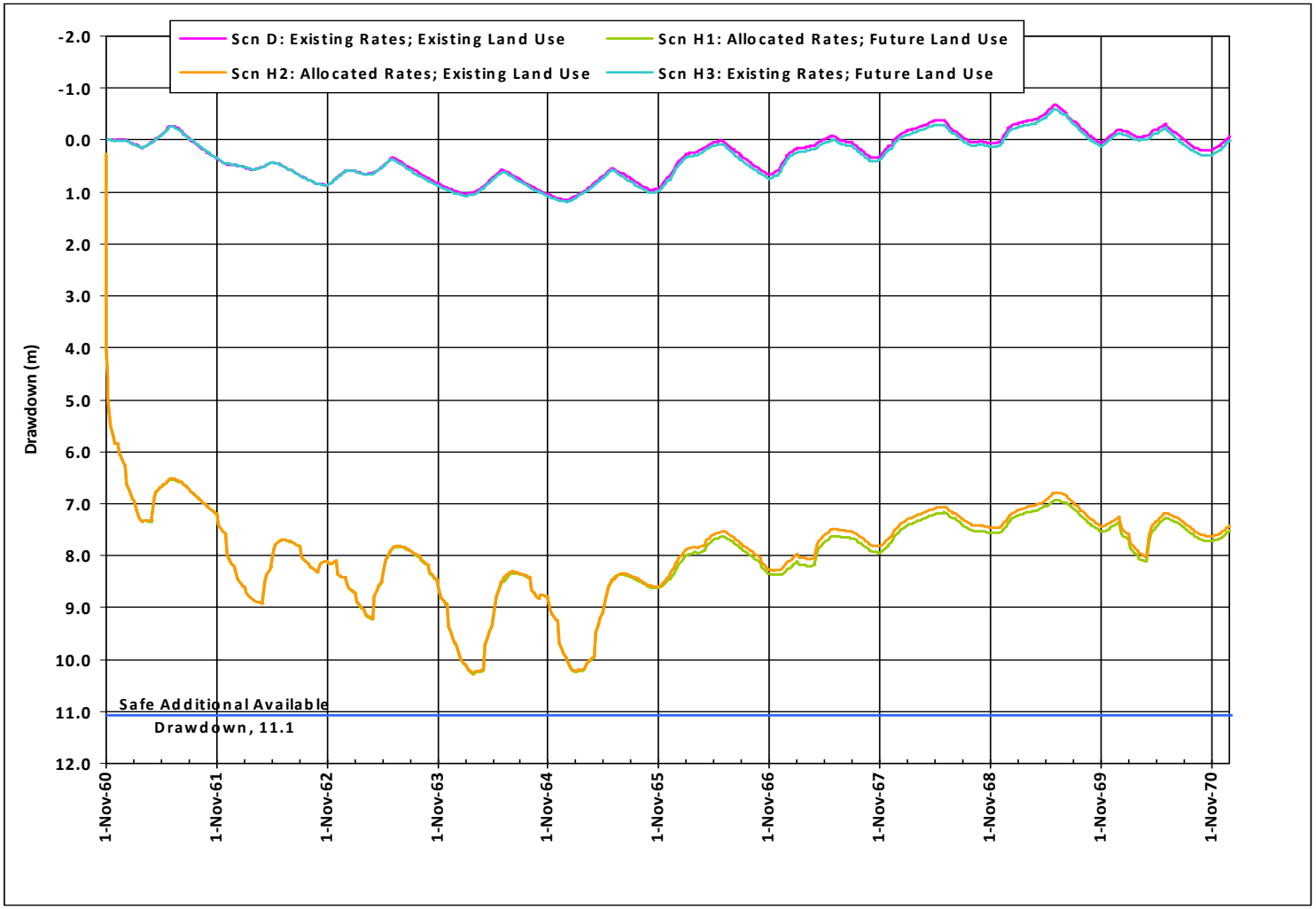

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Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Arkell 15

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G6

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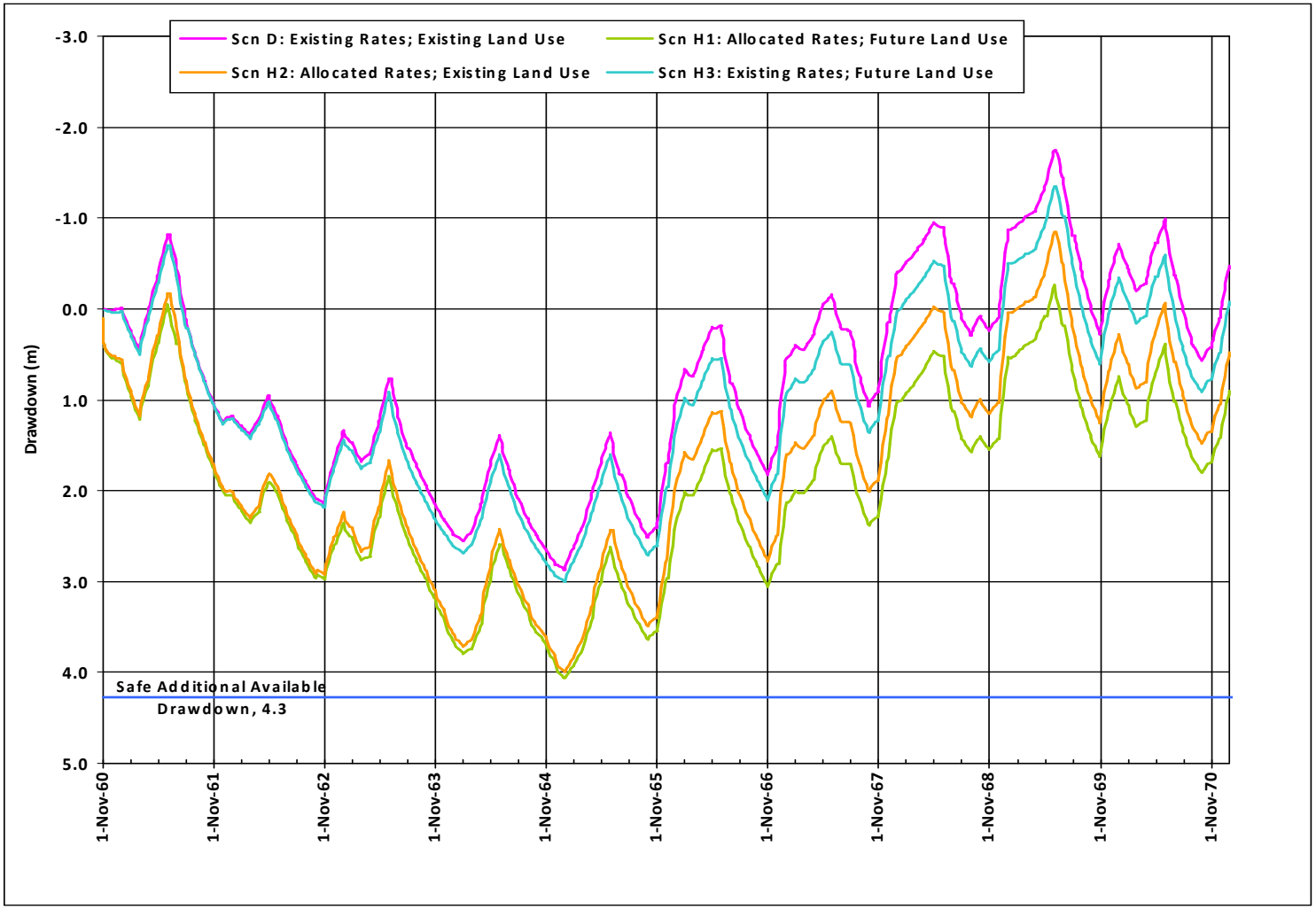

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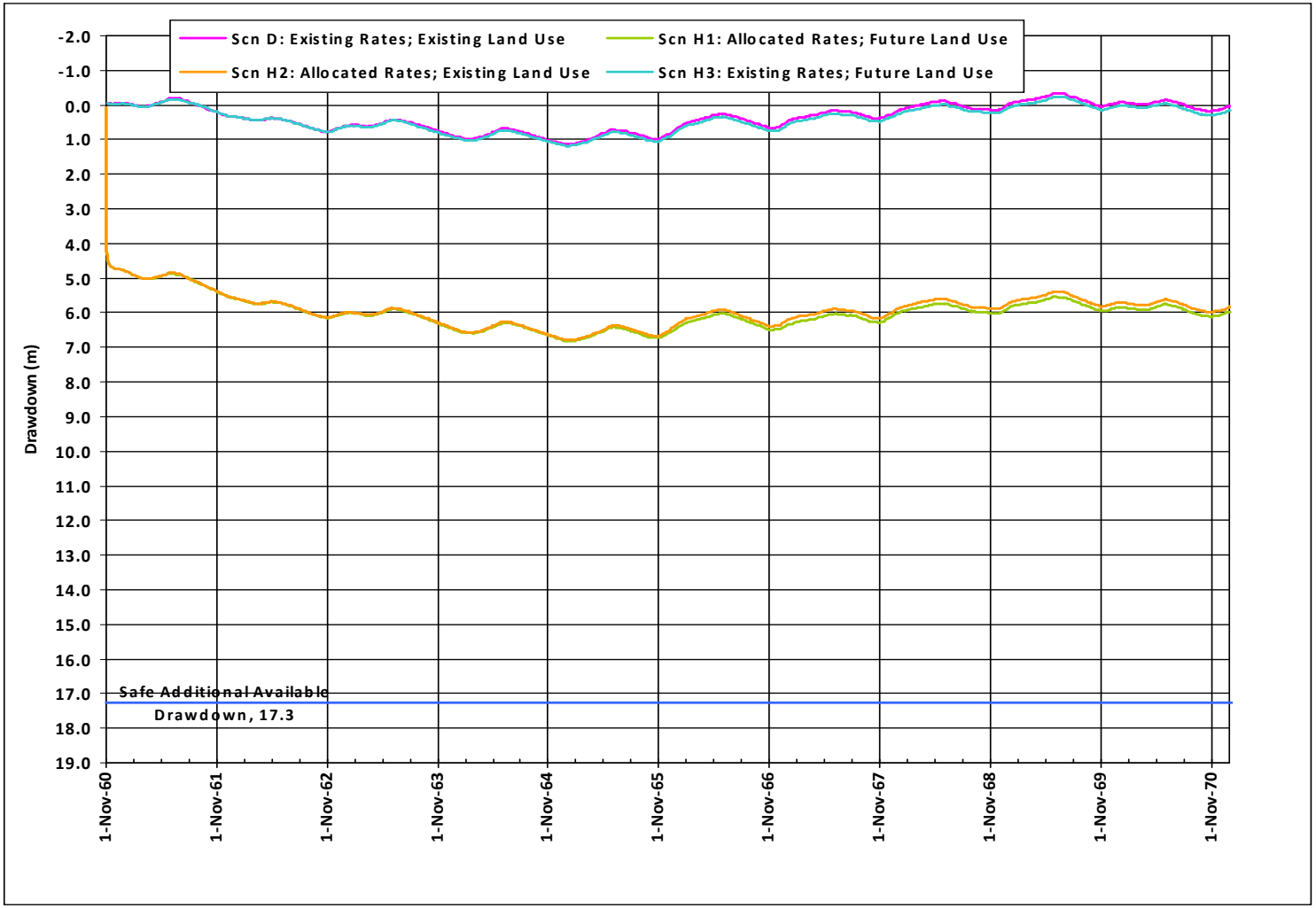
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Burke

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G7

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G8_Scenario_H_Drought_Series_Predicted_Drawdown_Calico.mxd



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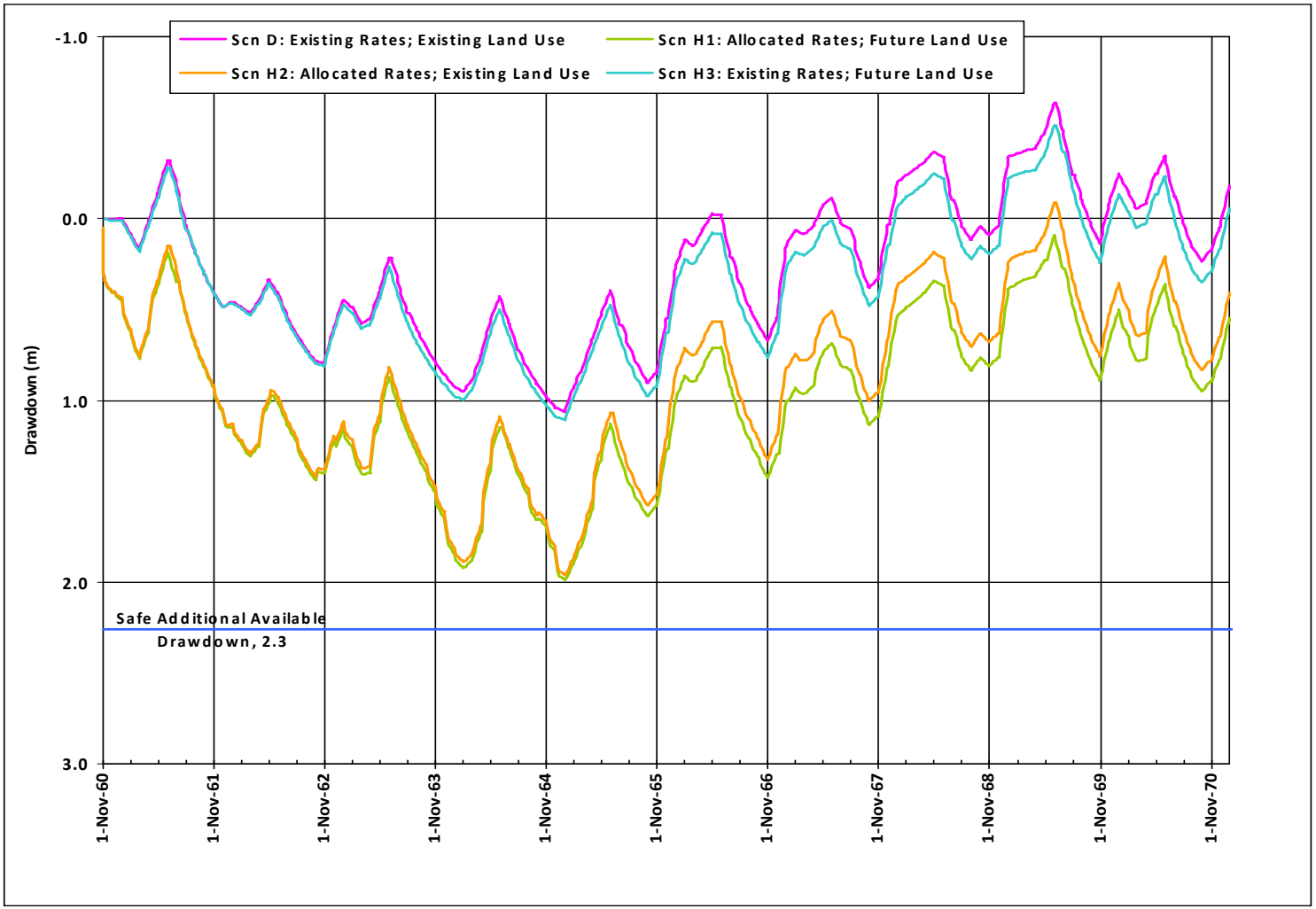
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Calico

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G8

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G9_Scenario_H_Drought_Series_Predicted_Drawdown_Carter.mxd



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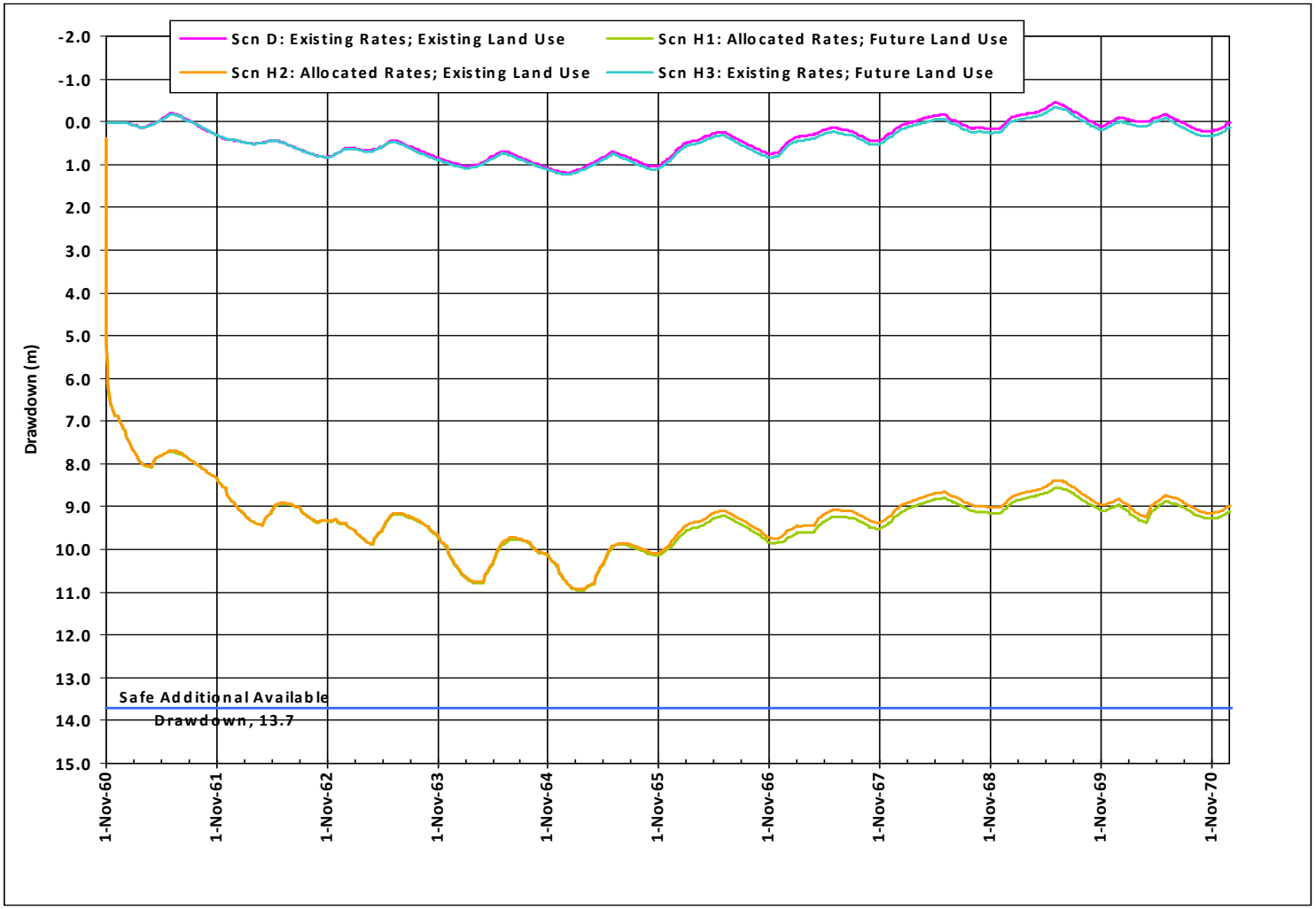
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Carter Wells

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G9

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G10_Scenario_H_Drought_Series_Predicted_Drawdown_ClytheCreek.mxd



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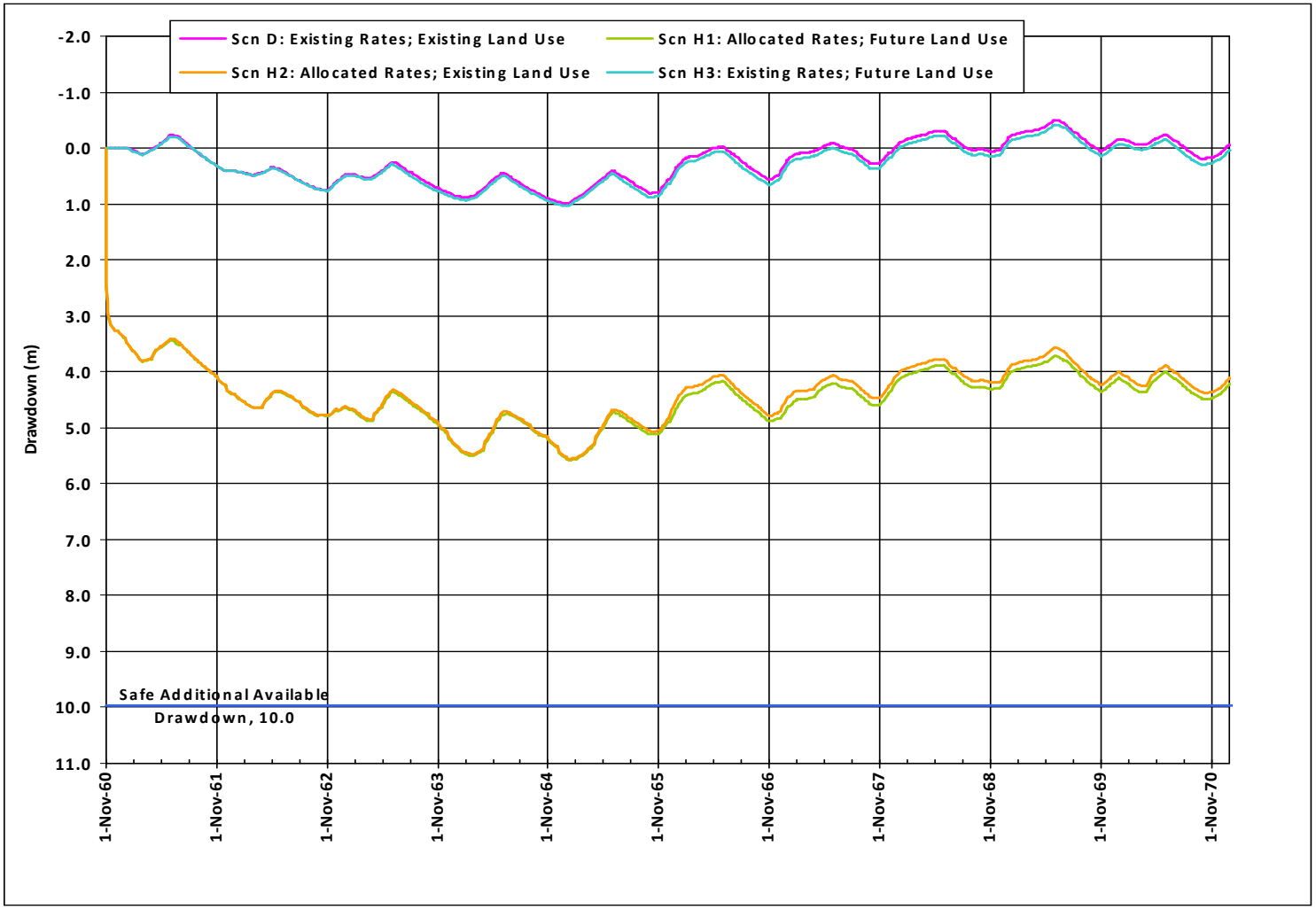
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Clythe Creek

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G10

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G11_Scenario_H_Drought_Series_Predicted_Drawdown_DeanAve.mxd



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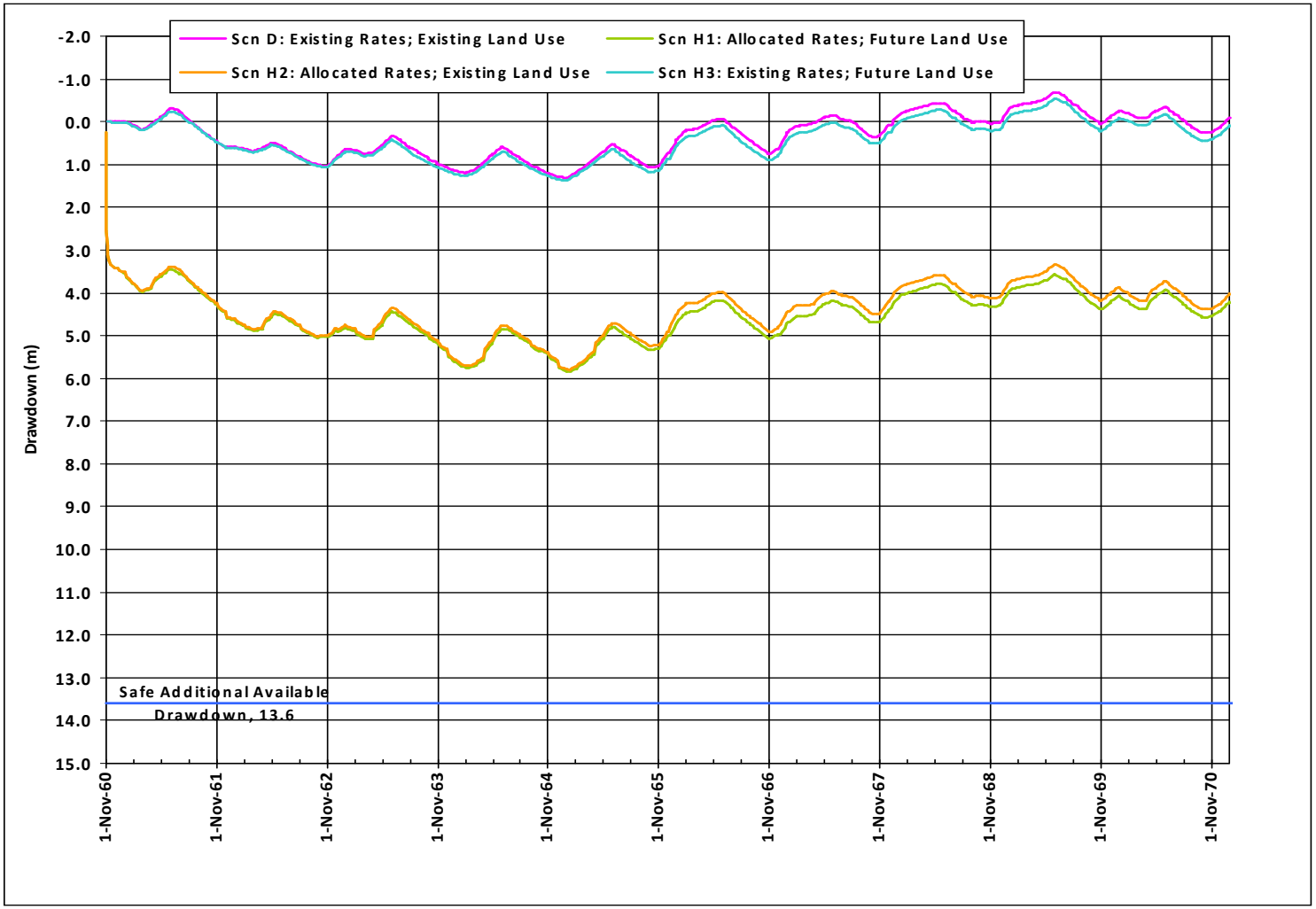
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Dean Ave.

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G11

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G12_Scenario_H_Drought_Series_Predicted_Drawdown_DowneyRd.mxd



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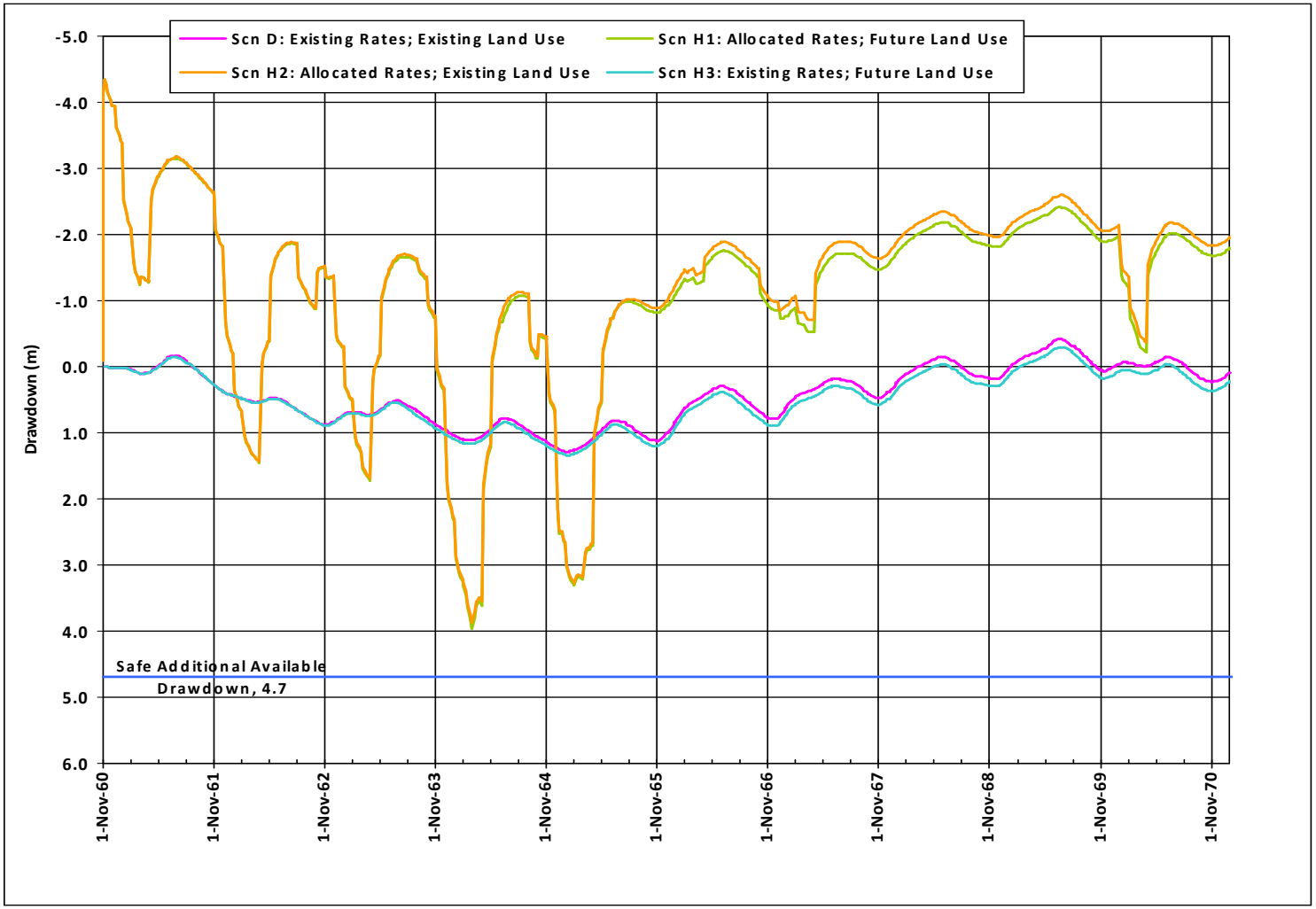
Drought Scenarios Predicted Drawdown - Downey Rd.

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G12

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G13_Scenario_H_Drought_Series_Predicted_Drawdown_Emma.mxd



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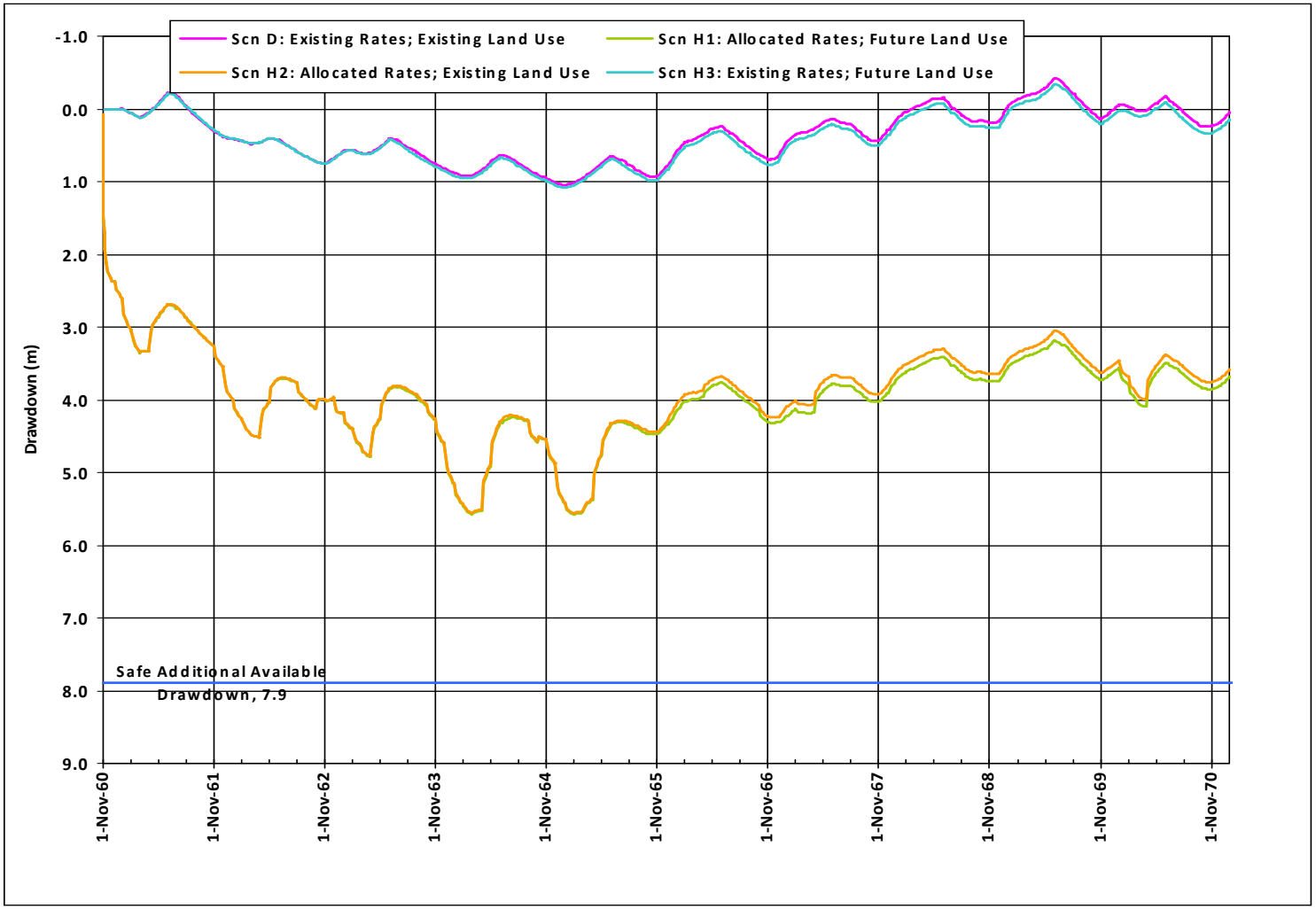
Drought Scenarios Predicted Drawdown - Emma

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G13

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G14_Scenario_H_Drought_Series_Predicted_Drawdown_Helmar.mxd



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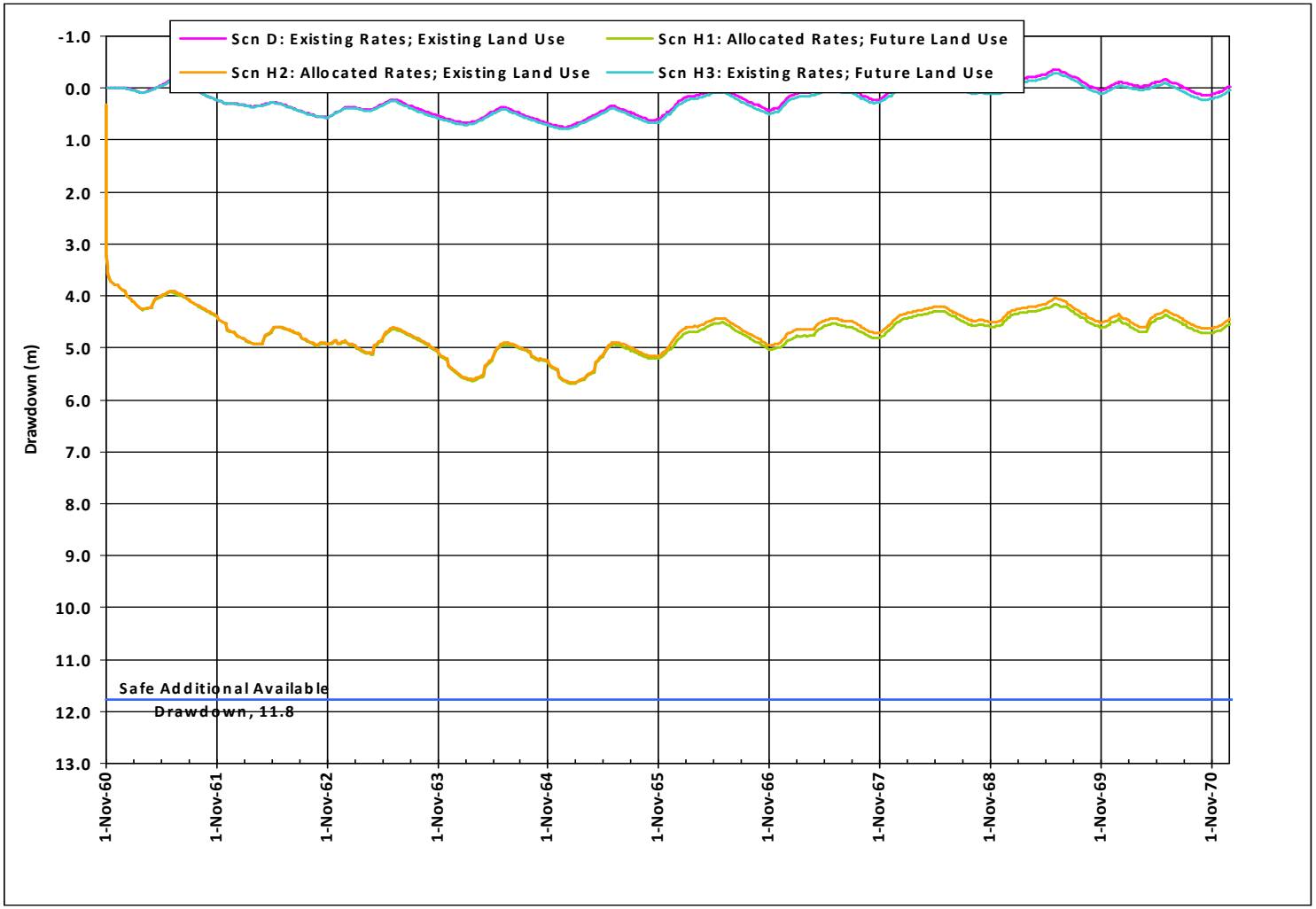
Drought Scenarios Predicted Drawdown - Helmar

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G14

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G15_Scenario_H_Drought_Series_Predicted_Drawdown_Membro.mxd



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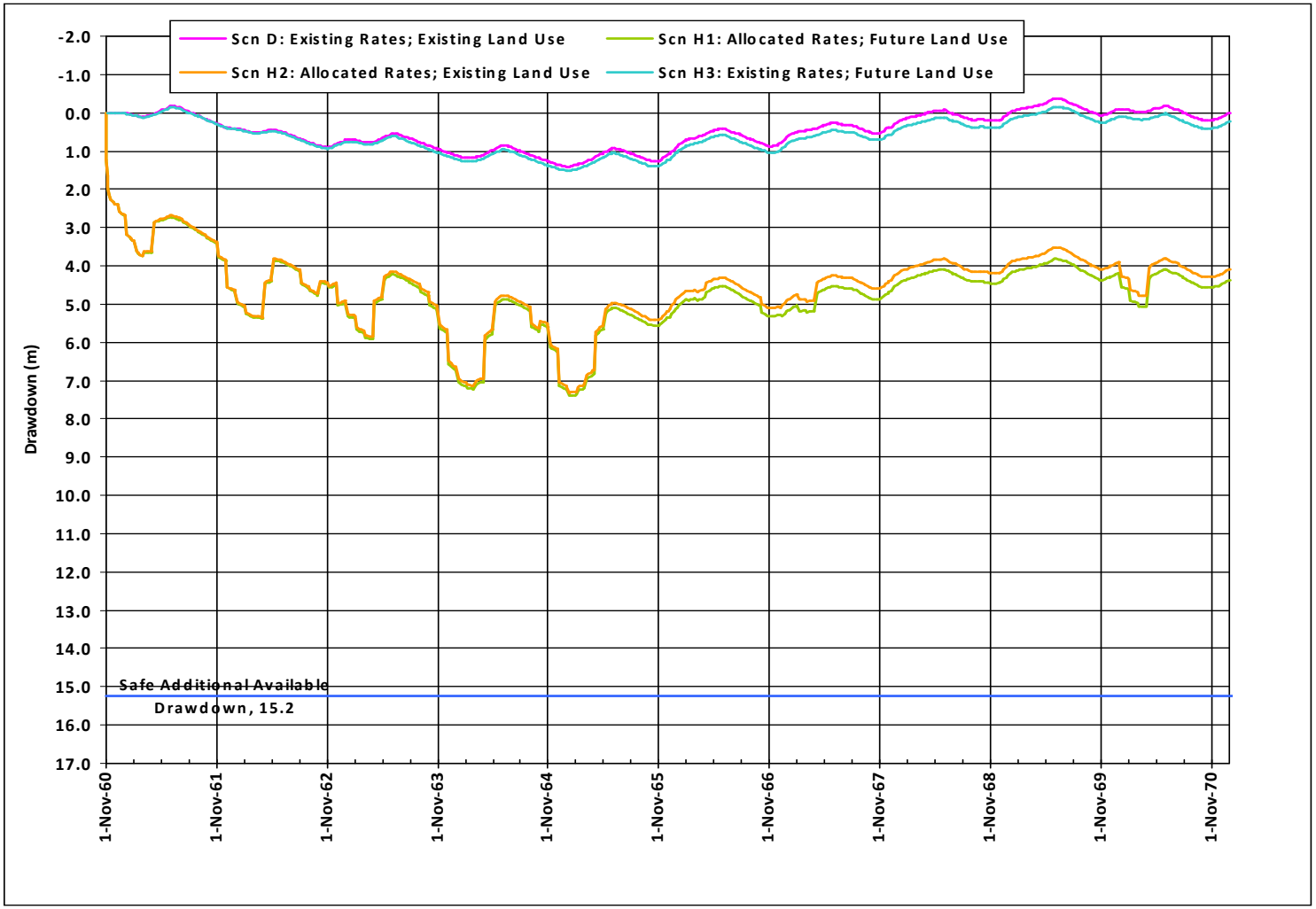
Drought Scenarios Predicted Drawdown - Membro

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G15

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G16_Scenario_H_Drought_Series_Predicted_Drawdown_Paisley.mxd



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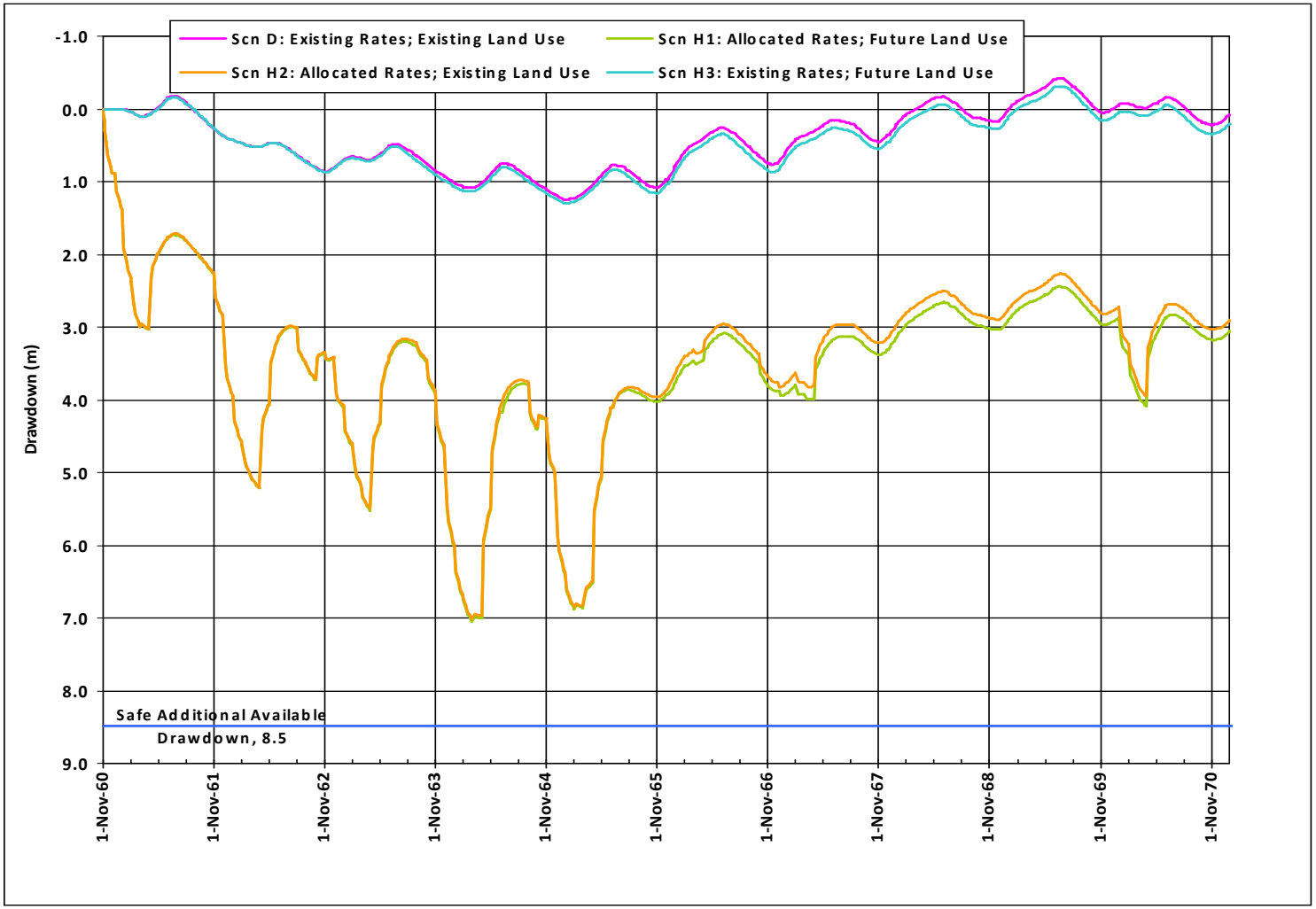
Drought Scenarios Predicted Drawdown - Paisley

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G16

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G17_Scenario_H_Drought_Series_Predicted_Drawdown_Park1and2.mxd



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Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Park 1 and 2

Date:	Project:	Technical:	Reviewer:	Drawn:
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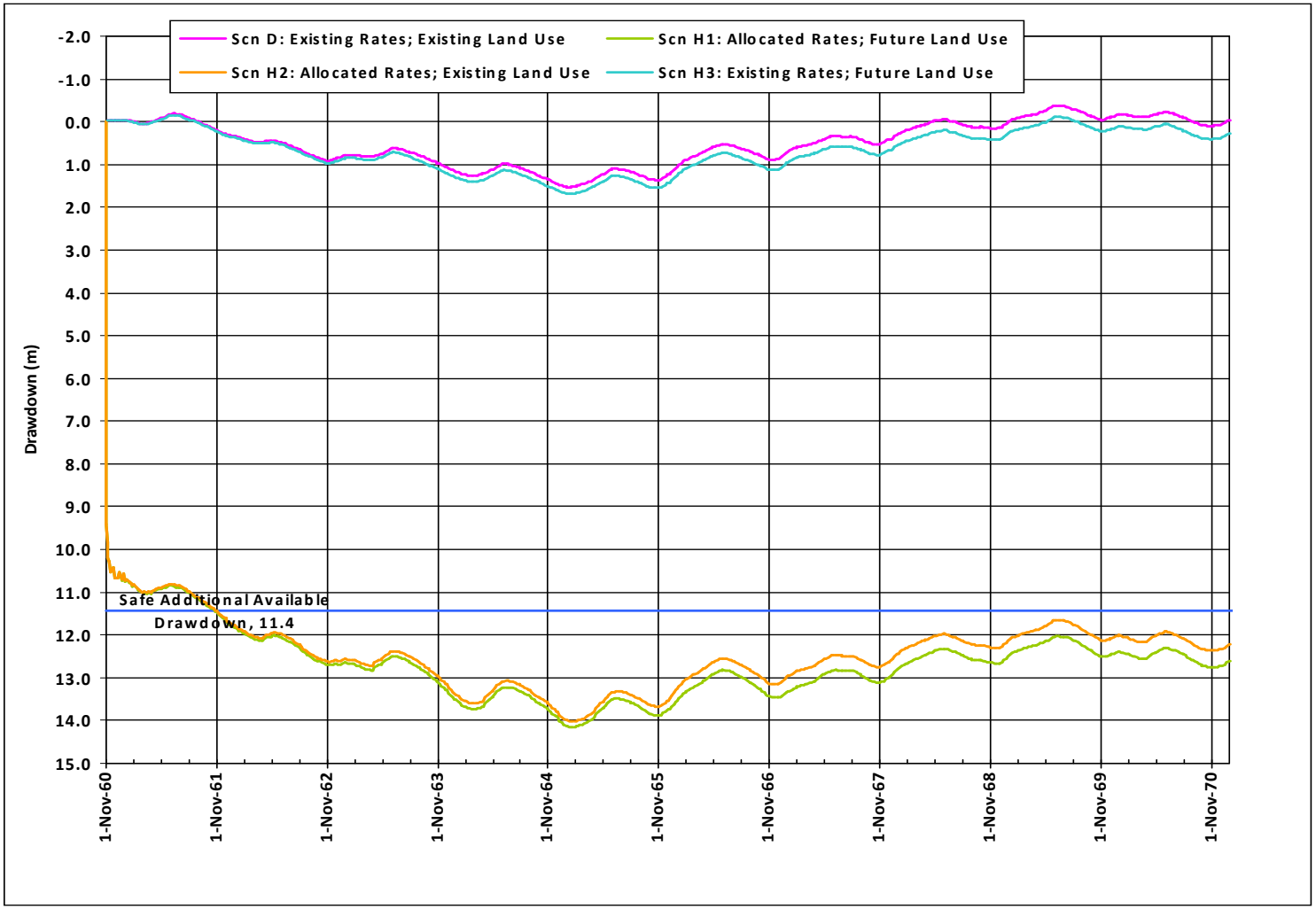
Figure G17

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G18_DroughtSeries_Predicted_Drawdown_Queensdale.mxd



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Drought Scenarios Predicted Drawdown - Queensdale

Date:	Project:	Technical:	Reviewer:	Drawn:
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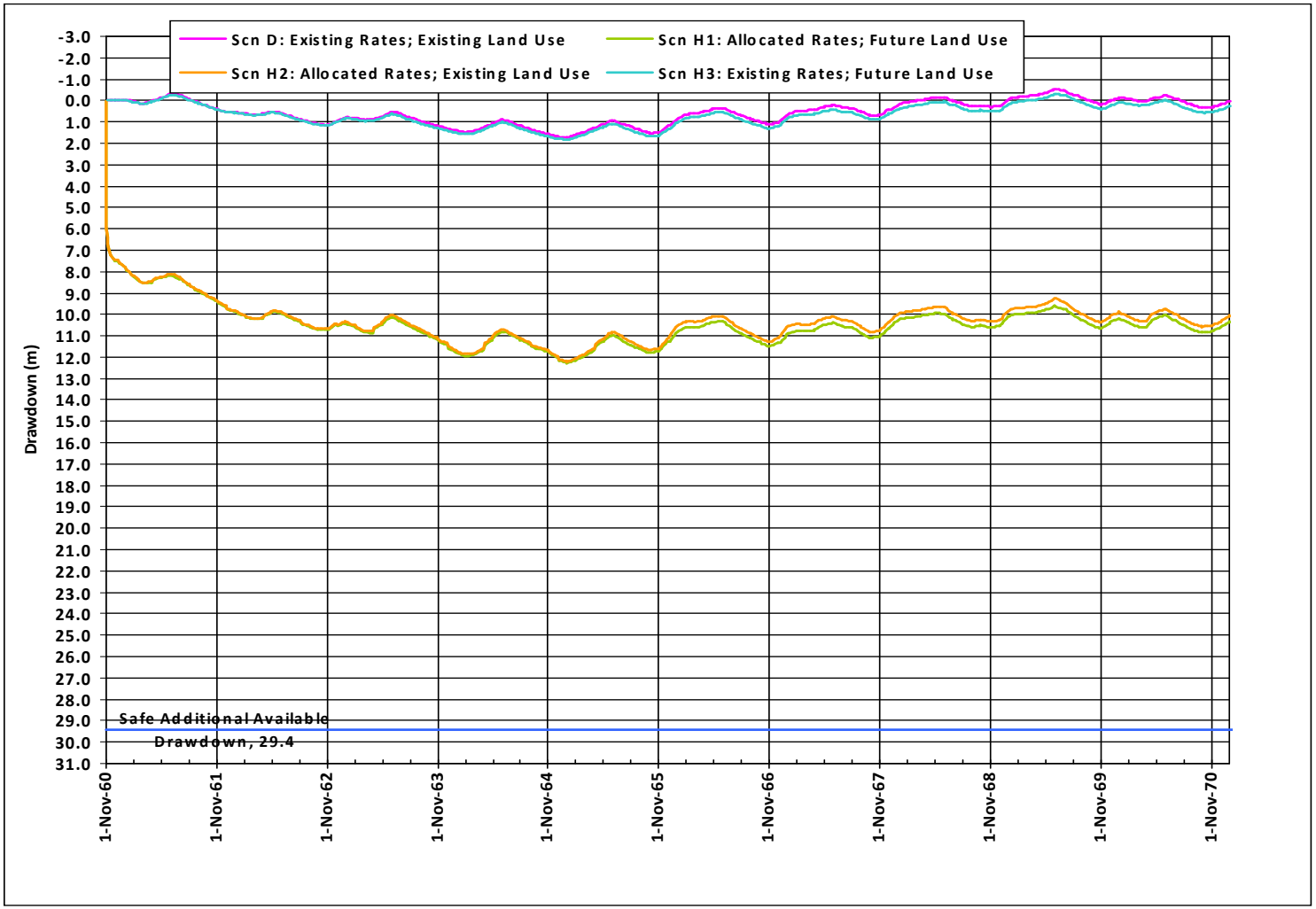
Figure G18

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G19_DroughtSeries_Predicted_Drawdown_Sacco.mxd



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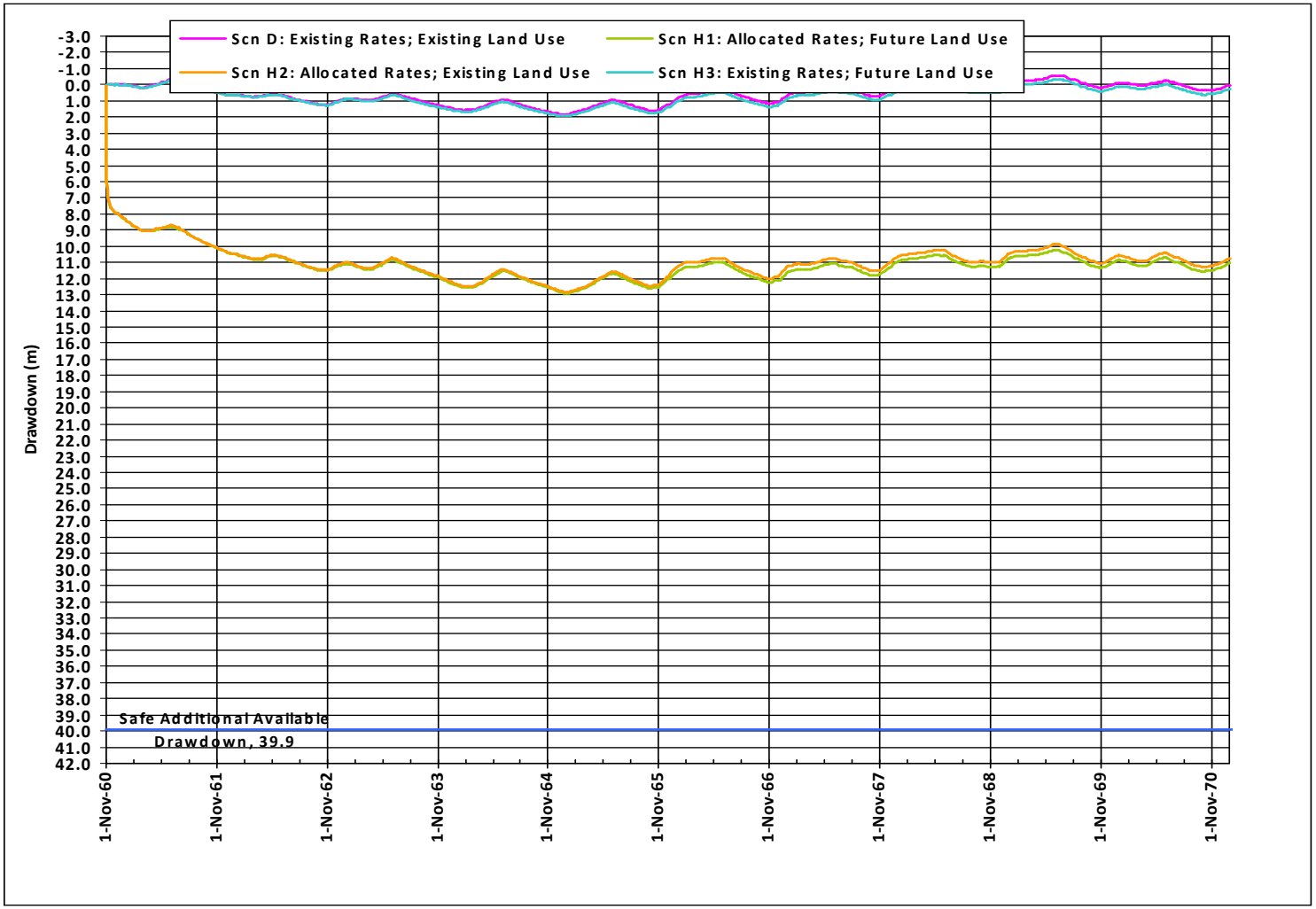
Drought Scenarios Predicted Drawdown - Sacco

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G19

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G20_Scenario_H_Drought_Series_Predicted_Drawdown_Smallfield.mxd



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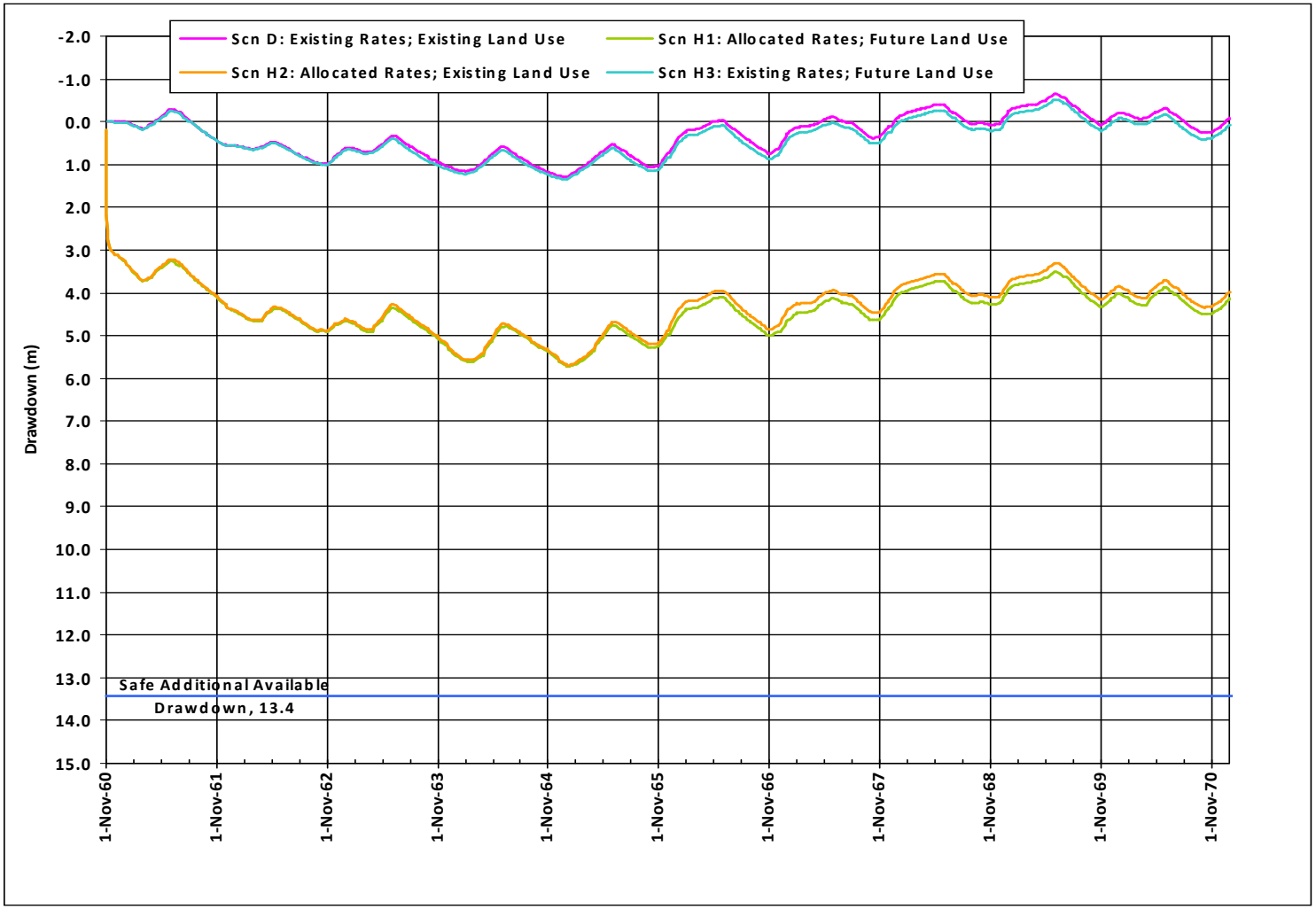
Drought Scenarios Predicted Drawdown - Smallfield

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G20

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G21_Scenario_H_Drought_Series_Predicted_Drawdown_University.mxd



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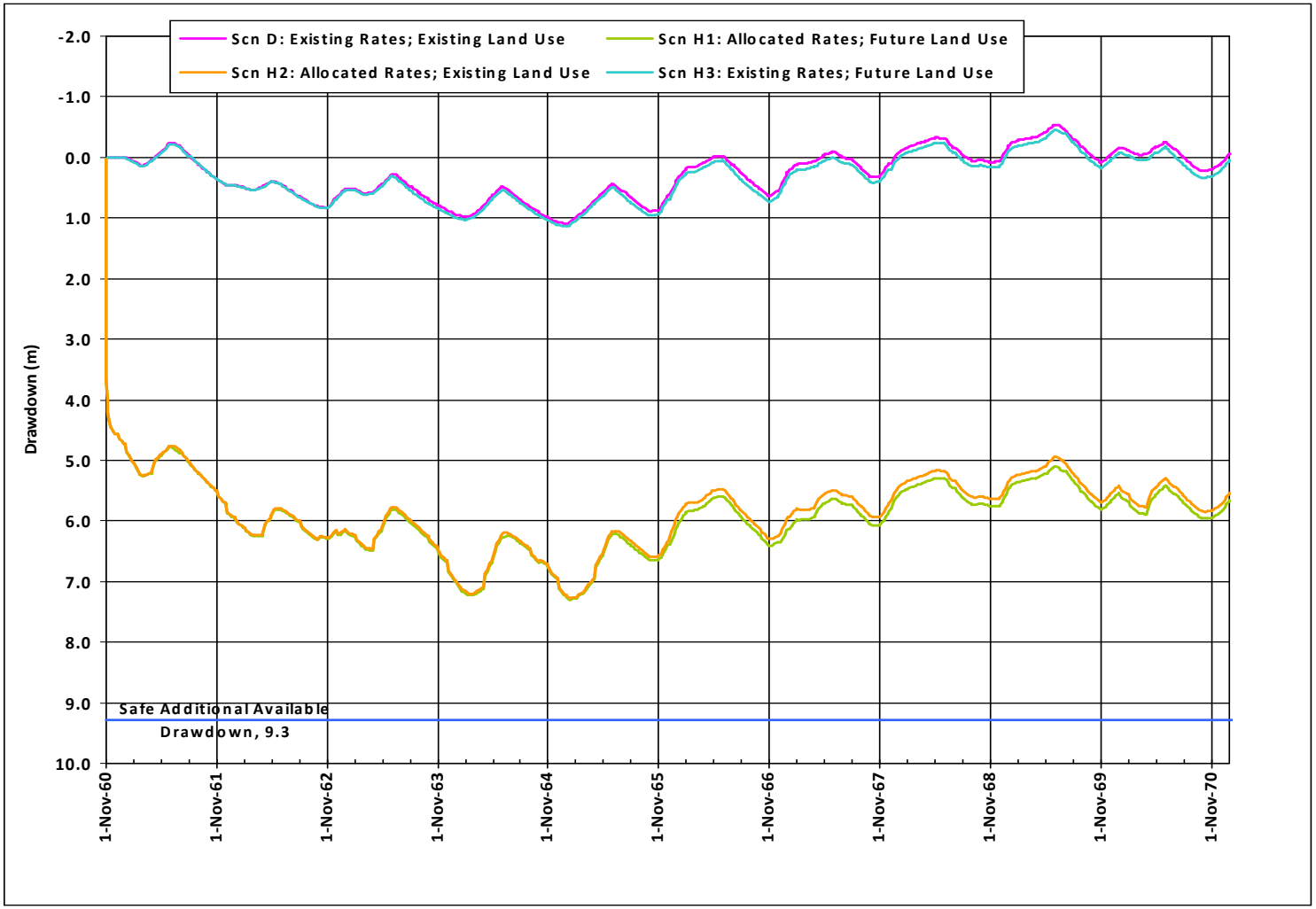
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - University

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G21

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G22_Scenario_H_Drought_Series_Predicted_Drawdown_WaterSt.mxd



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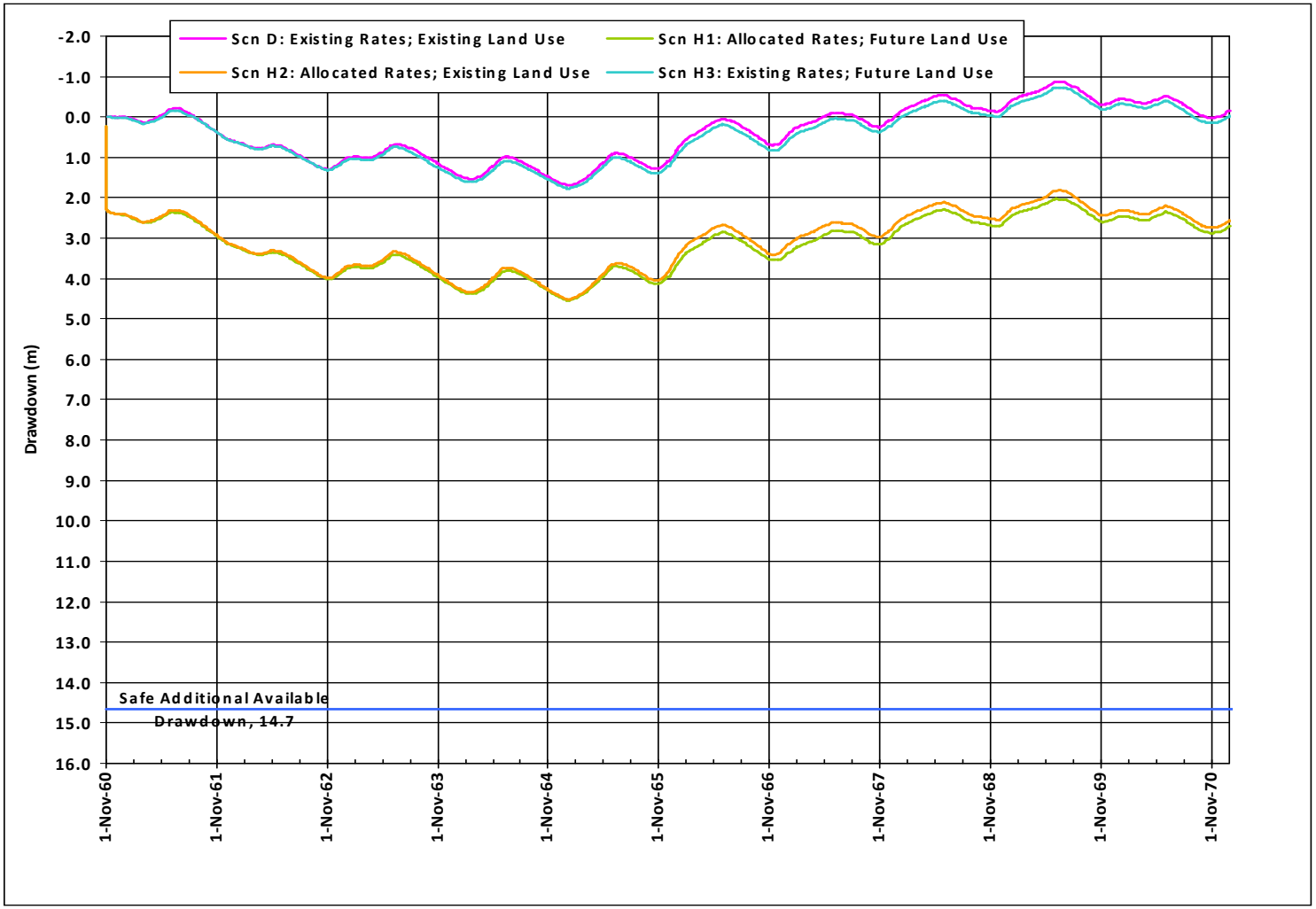
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Water St.

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G22

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G23_Scenario_H_Drought_Series_Predicted_Drawdown_StationSt1.mxd



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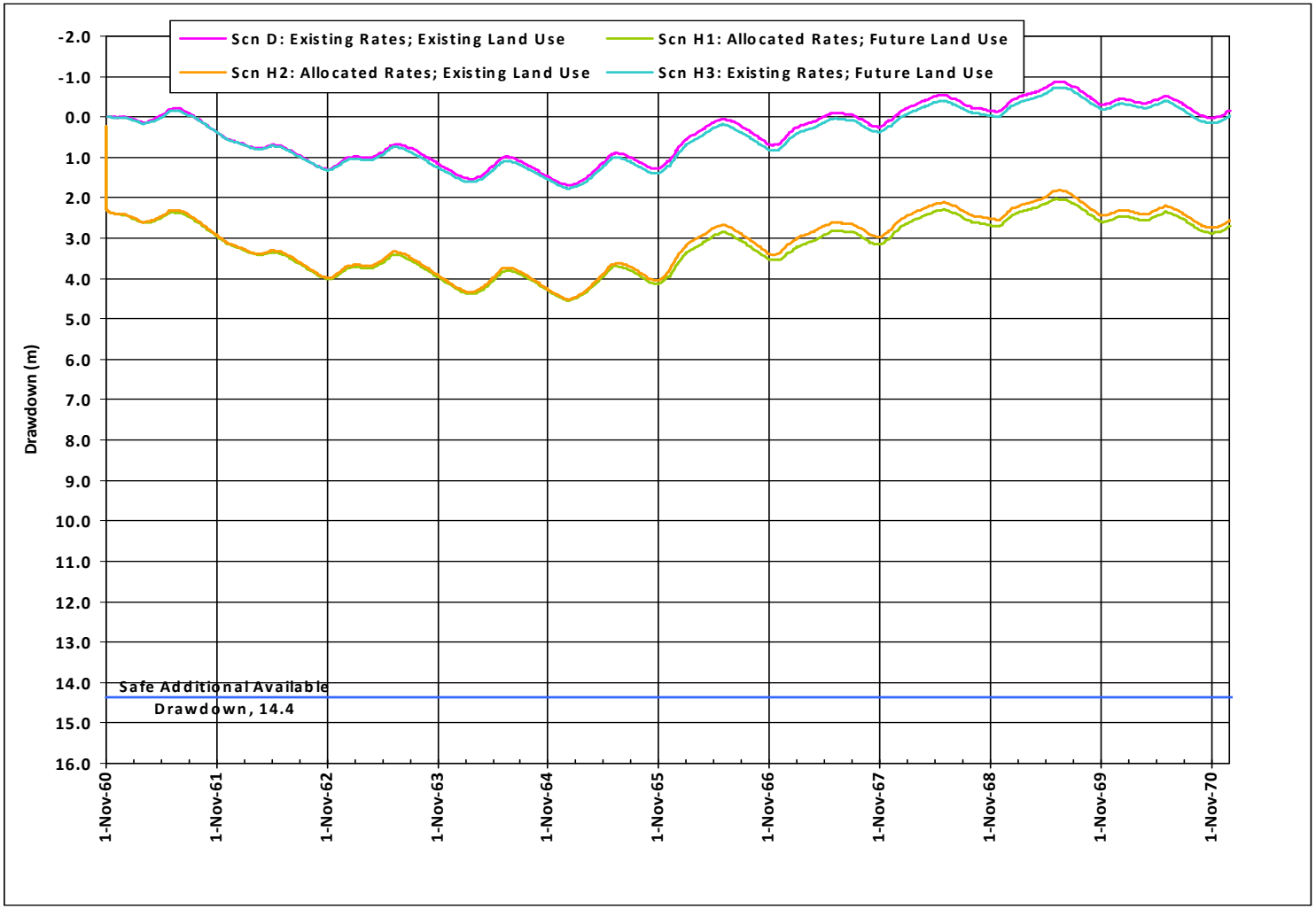
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Rockwood 1

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G23

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G24_Scenario_H_Drought_Series_Predicted_Drawdown_StationSt2.mxd



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Tier Three Water Budget and Local Area Risk Assessment
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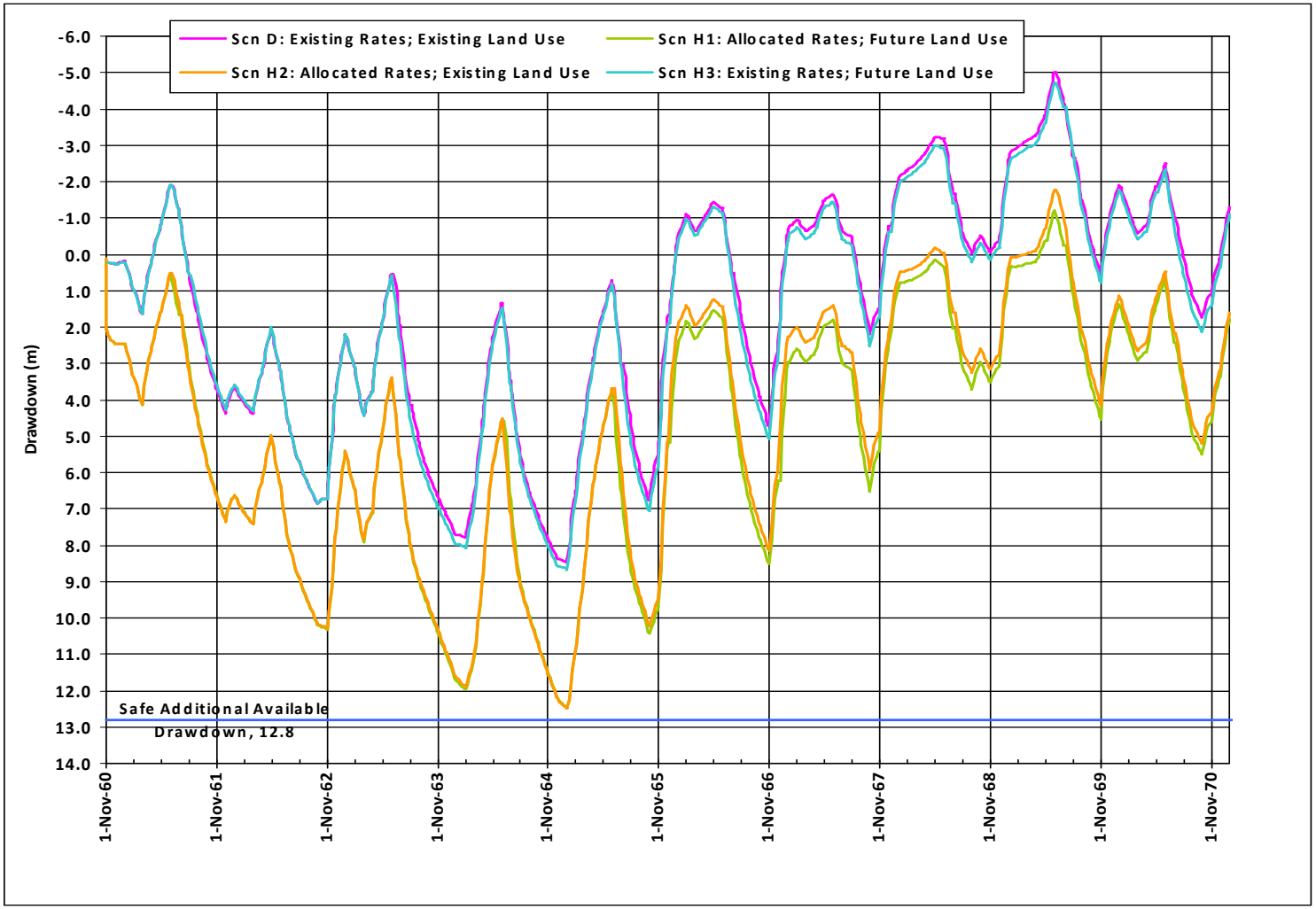
Drought Scenarios Predicted Drawdown - Rockwood 2

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G24

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G25_Scenario_H_Drought_Series_Predicted_Drawdown_Bernardi3.mxd



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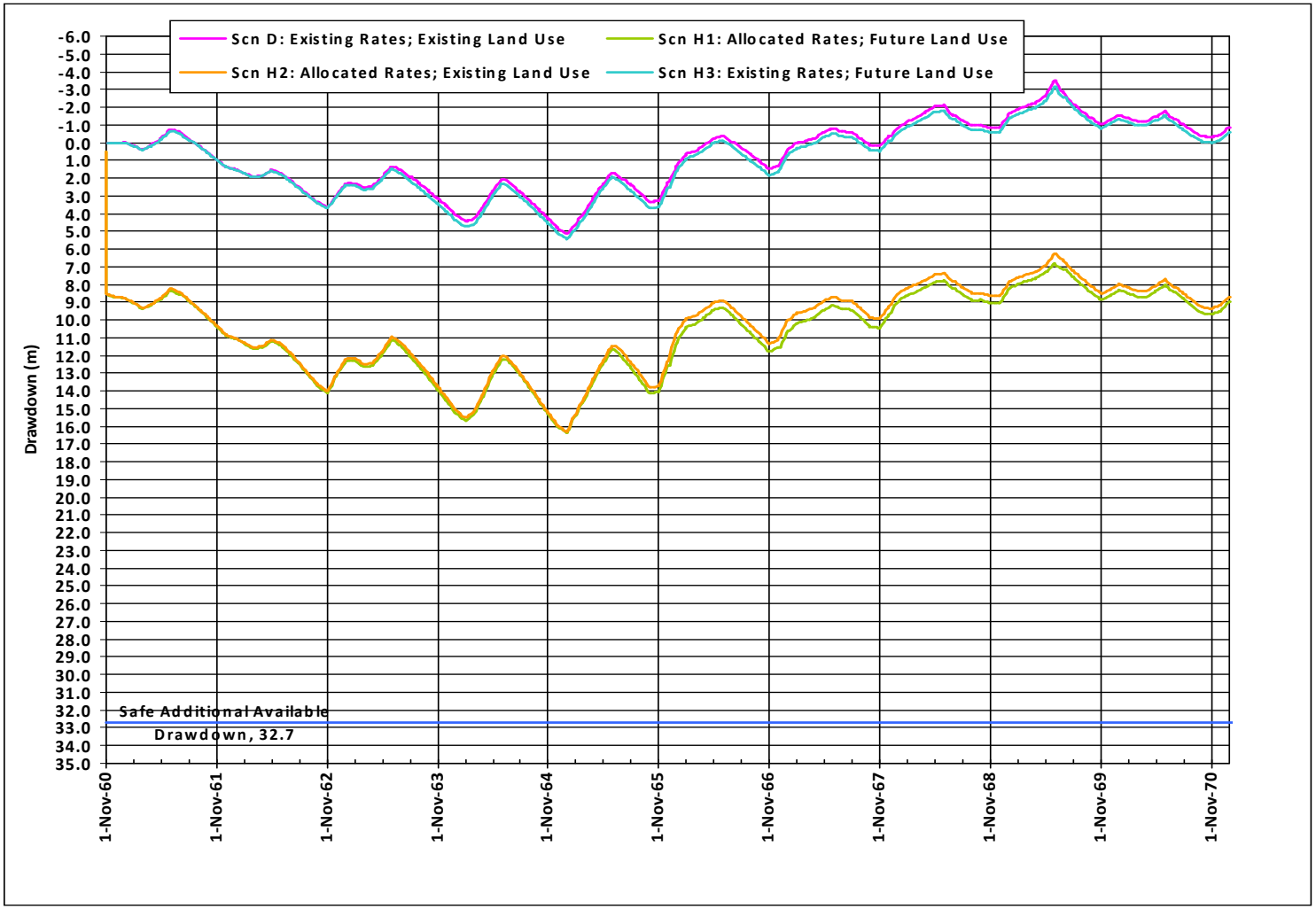
Drought Scenarios Predicted Drawdown - Rockwood 3

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G25

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G26_Scenario_H_Drought_Series_Predicted_Drawdown_Rockwood4.mxd



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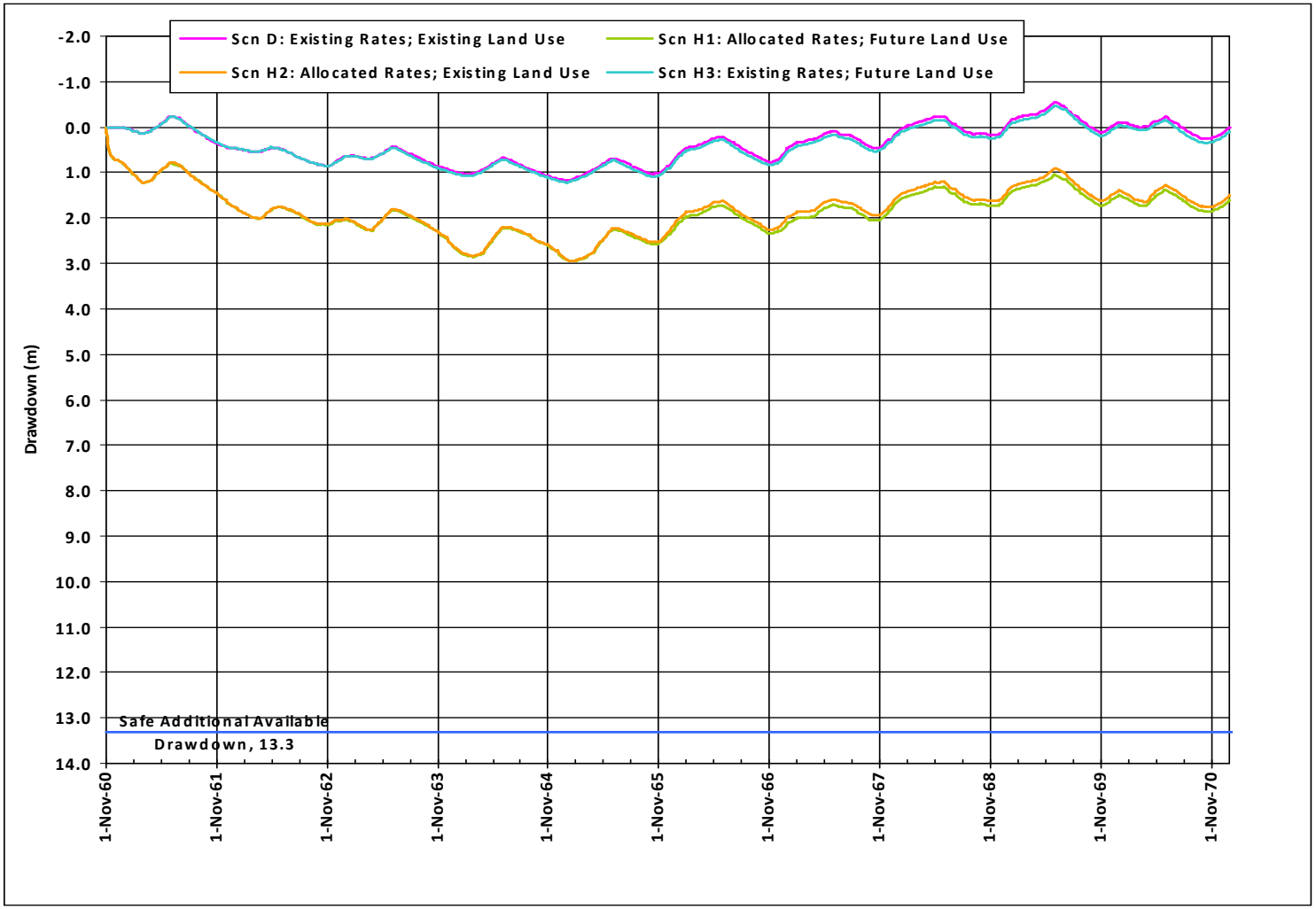
Drought Scenarios Predicted Drawdown - Rockwood 4

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G26

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G27_Scenario_H_Drought_Series_Predicted_Drawdown_CrossCreek.mxd



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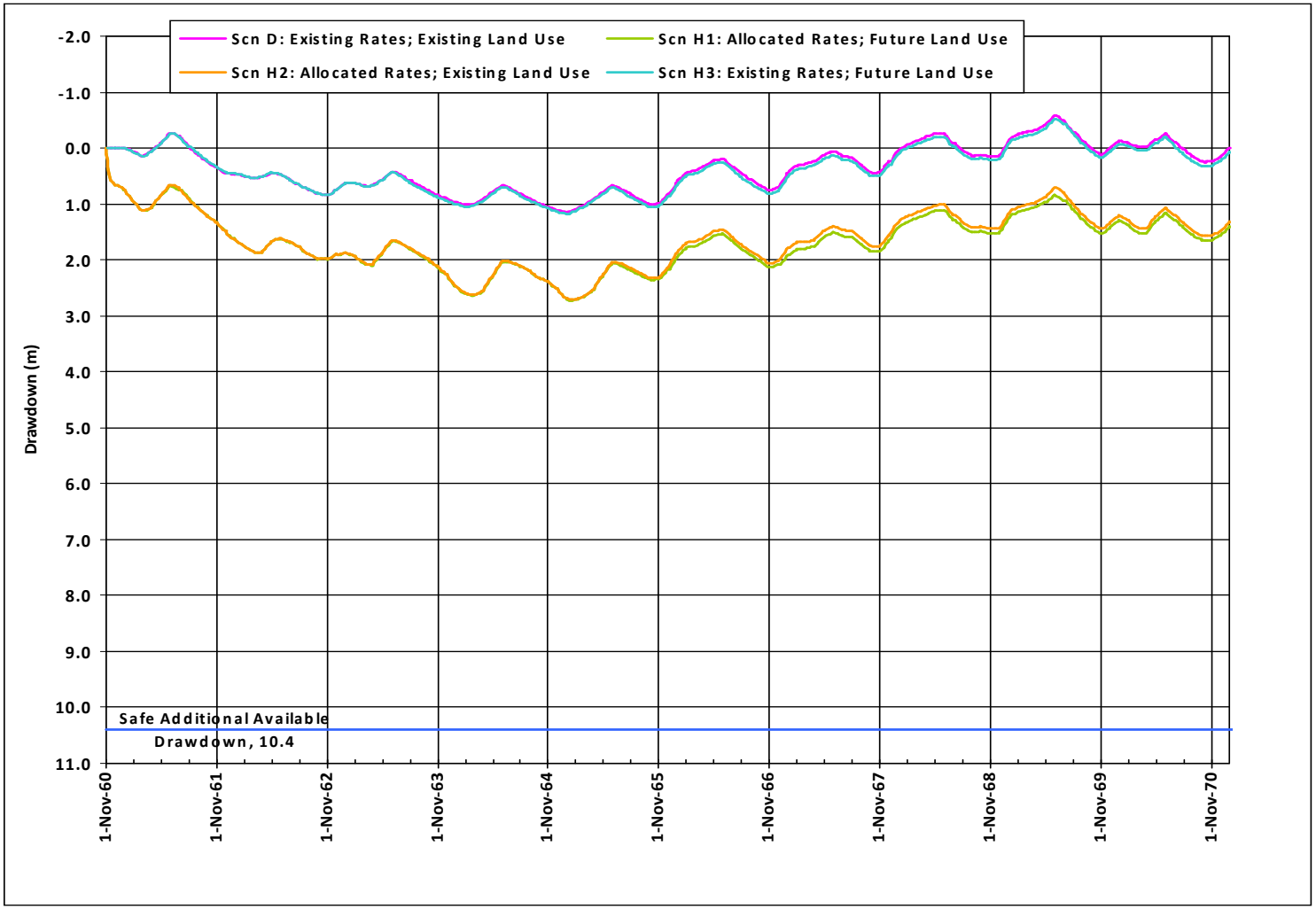
Tier Three Water Budget and Local Area Risk Assessment
Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Cross Creek

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G27

I:\CityofGuelph\15072\FiguresandTables\QHG\2016\Report\Appendix G - Drought Scenario Results\Figure_G28_Drought_Series_Predicted_Drawdown_Huntington.mxd



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Appendix G Drought Scenario Results

Drought Scenarios Predicted Drawdown - Huntington

Date:	Project:	Technical:	Reviewer:	Drawn:
7 Mar 2017	15072	J. Melchin	P. Chin	M. Urtheil

Figure G28