CVC
CREDIT VALLEY CONSERVATION

Watershed Management

To:	**John Sinnige, Sr. Manager, Water Resources and Flood Risk**	**Date:**	**June 13, 2016**
From:	**Alex Pluchik, Hydrologist**	**Subject:**	**Update of Low Flow Assessment ($7Q_{20}$) for the West Credit River Assimilative Capacity Study (Erin SSMP)**
Cc:	**Neelam Gupta, Manager, Hydrology and Hydraulics**	**Our File:**	**Erin SSMP - ACS**
Cc:	**Jennifer Dougherty, Manager, Water Quality Protection**		

Introduction

This memo summarizes the revision of $7Q_{20}$ values for the West Credit River at 10th line to support the update of the West Credit River assimilative capacity study. The initial assessment was completed at the end of 2013 in support of the Town of Erin Servicing and Settlement Master Plan (SSMP) study and was based on stream flows for the period from July to October 2013 at 10th Line. A similar approach was used to update the $7Q_{20}$ values based on stream flows for the period from July 2013 to end of 2015 (refer to Memo from March 14, 2016). The present memo finalizes the results of $7Q_{20}$ value assessment for the West Credit River at 10th line.

The location of the streamflow stations and proposed location of the WWTP effluent discharge are shown in Figure 1.

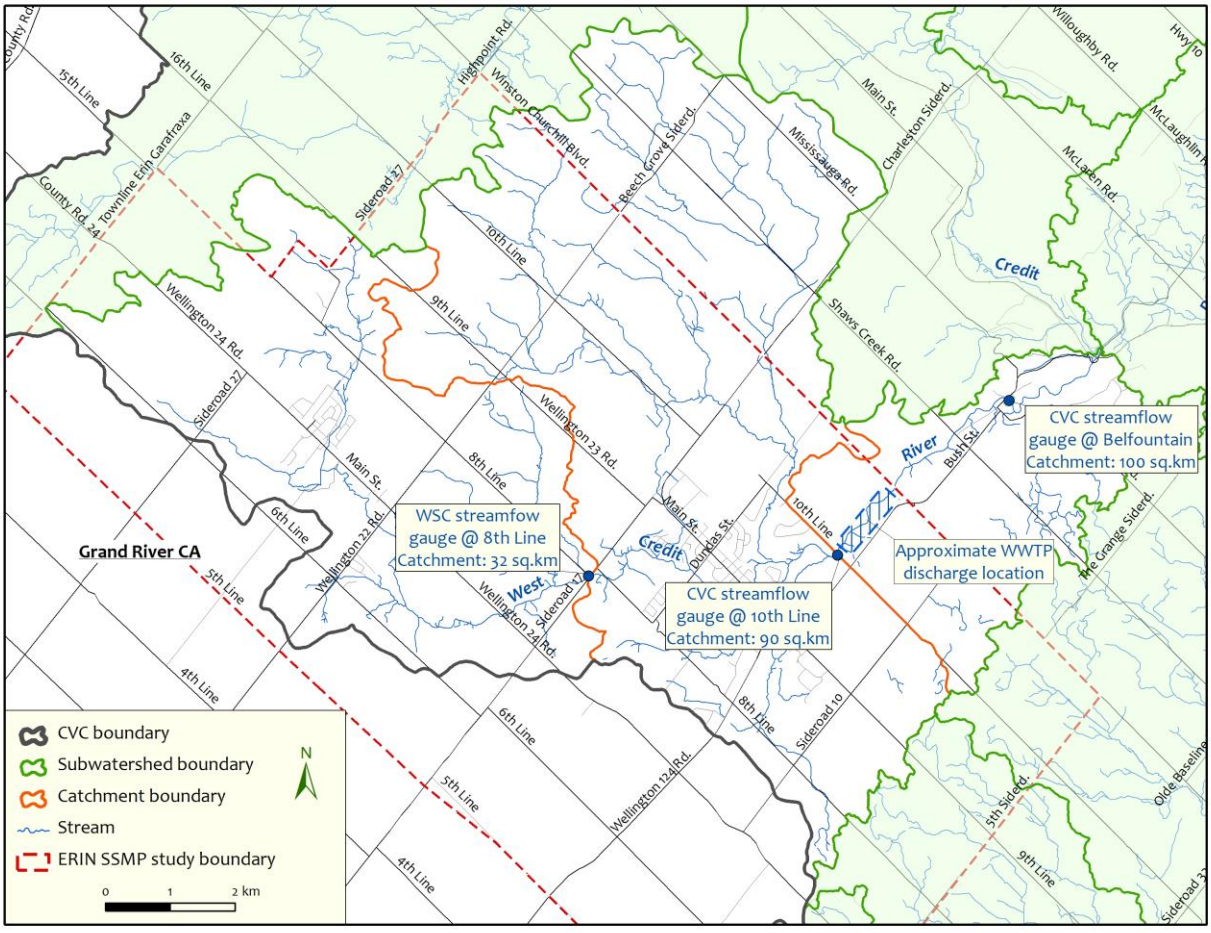

Figure 1: West Credit River watershed relative to the Assimilative Capacity Study limits for the Erin SSMP

Low Flow Analysis

The following methodology was applied to update the $7Q_{20}$ values for the West Credit River at 10th line:

1. Mean daily flow series of the West Credit River at 8th Line (WSC gauge, 1984-2015) were converted to the 7-day mean flows (7-day moving average).
2. Lowest 7-day mean flows for each year of record were collected for the Water Year (October 1-September 30), Summer (July-September), Fall-Winter-Spring (October-June) and for each month of year.
3. Mean daily flow series of the West Credit River at Belfountain (CVC gauge, 2002-2015) were converted to the 7-day mean flows (7-day moving average).
4. Lowest 7-day mean flows for each year of record were collected for the Water Year (October 1-September 30) and Summer (July-September).
5. The CVC real-time streamflow gauge at 10th Line became active and fully operational at the end of July 2013. The development of a rating curve started at the same time. Since then, CVC field staff has measured 20 discharges (16 of them were used for the building of rating curve). The lowest discharges were measured at the end of July 2015; however the 2015 low flows were significantly higher than the low flows of summers 1995-2003 (excepting 1997), 2007 and 2012.

   Continuous water level data (15-min intervals) were converted to a continuous flow record using a rating curve fit equation (Shifted Power Law) developed in the WISKI module SKED (refer to Appendix, Figure A.1).
6. Mean daily and 7-day mean (moving average) flow series for the West Credit River at 10th Line were produced using TSM module of WISKI. 7-day mean flows at the 8th Line (WSC gauge) were paired with corresponding flows at the 10th Line (CVC gauge) for the period of July 2013 – November 2015. These series were sorted by the ratio of 10th Line flows to 8th Line flows in ascending order. To remove outliers, values that lie outside of a band around the mean with a width of two standard deviations were not included for drawing the scatter graph and performing the regression analysis (refer to Appendix A, Figure A.2).
7. Similarly, 7-day mean flows at the Belfountain CVC gauge were paired with corresponding flows at the 10th Line (CVC gauge) for the period of July 2013 – November 2015. These series were sorted by the ratio of Belfountain flows to 10th Line flows in ascending order. Data that was obviously affected by freezing of the CVC Belfountain station were removed. Then values that lie outside of a band around the mean with a width of two standard deviations were not included for drawing the scatter graph and performing the regression analysis (refer to Appendix A, Figure A.3).
8. A regression analysis was executed to explore the relationships between streamflows at 8th Line and 10th Line and also Belfountain and 10th Line. A linear trendline forced to intercept at nil was chosen as the best fit to observed data for both relations (refer to Appendix A, Figures A.2 and A.3). The quality of the regression equations was examined using the following indices: standard deviation of the criterion variable and standard error of estimate, coefficient of determination and F-test. Both regressions were deemed to be significant

given that the computed F-test is greater than F value extracted from the F values distribution table (level of significance = 0.05).

9. The low-flow frequency analysis was performed using the "Low Flow Frequency Analysis Package – LFA" (Environment Canada, September 1988). The program methodology is based on the Gumbel III distribution. This distribution has been recommended by Environment Canada as the best fit for extreme value analysis of low flows in the streams of South Ontario (Condie, Cheng, "Low Flow Frequency Analysis", 1987). Also, the LFA application includes the Cunnane plotting-position formula for estimation the empirical exceedance probability.

10. The low-flow frequency analysis of the West Credit River at 8th Line data was performed for two data sets: 1984-2015 and 2002-2015. Also, the 7-day minimum flows of the West Credit River at Belfountain were processed for period of 2002-2015. The results of calculations ($7Q_{20}$ values) are presented in the Table 1 below and in the Appendix A, Table A.1 and Figures A.4, A.5 and A.6 (Gumbel III and Cunnane frequency curves).

Table 1: $7Q_{20}$ stream flows for the West Credit River gauges of WSC and CVC

(Water Year: Oct 1-Sep 30)

Station location/name	Data Set Period	$7Q_{20}$ (m^3/sec)	$7Q_{20}$ Ratio for 8th Line
8th Line (WSC)	1984-2015	0.123	
8th Line (WSC)	2002-2015	0.172	1.4
Belfountain (CVC)	2002-2015	0.428	

The significant difference between the $7Q_{20}$ values at 8th Line for the different periods (almost 40%) can be explained by the length of analysed data sets. The driest year of the 2002-2015 data set (2003) is positioned at 7th place in 1984-2015 data set, i.e. the 6 years with smallest 7-day minimum flows observed at the 8th Line gauge (flow record from 1981 to 2015) were not measured in the Belfountain gauge (flow record from 2002 to 2015).

11. $7Q_{20}$ values for the West Credit River at 10th Line were computed for period of 2002-2015 using described above two regression equations (one - based on 8th Line data set, second - based on Belfountain gauge data) and are presented in the Table 2 below.

Table 2: 7Q20 stream flows of the West Credit River at 10th line (2002-2015)

Station	$7Q_{20}$ by LFA (m^3/sec)	$7Q_{20}$ at 10th Line by Regression Equation (m^3/sec)	Difference (%)
8th Line (WSC)	0.172	0.350	2.8
Belfountain (CVC)	0.428	0.360	

Comparison of results, which are very close (difference is less than 3%), verifies accuracy of methodology used to calculate streamflow at 10th Line.

12. $7Q_{20}$ values for the West Credit River at 10th Line were computed using the results of the low-flow frequency analysis of 8th Line data for period 1984-2015 and described above regression equation between streamflows at 8th Line and 10th Line (refer to Appendix A, Table A.1). Using this time period, a water year $7Q_{20}$ of 0.250 m^3/sec was calculated, which is very similar to the water year $7Q_{20}$ of 0.246 m^3/sec calculated in the March 2016 memo.

Review of Results

1. A slight increase was found between the $7Q_{20}$ values for the West Credit River at 10th Line computed for Water Year, Summer Season and September and provided in present and previous memos: 1.9%, 5.2% and 5.5 % respectively (refer to Appendix A, Table A.1). However, for the rest of year the $7Q_{20}$ increase is varying from 10% (August and Fall-Winter-Spring Season) to 19% (November, December and May). This increase can be clarified by using more statistically valid approach of selecting data for performing the regression analysis (refer to paragraphs 6 and 7). It allowed developing new linear regression equation between 7-day streamflows at 8th Line and 10th Line. Accuracy of this approach was verified by using streamflow data of Belfountain gauge (refer to paragraph 11).
2. The $7Q_{20}$ values calculated for the West Credit River at 10th Line in the previous memos have included a climate change impact factor. Therefore, the calculated value of $7Q_{20}$ was reduced by 10%. For consistency results the same approach was used to **update the $7Q_{20}$ value for the Water Year at 10th Line, which equals to 0.225 m^3/sec (Table A.1)**, i.e. deviation from the March 2015 value is less than 2%.

APPENDIX A

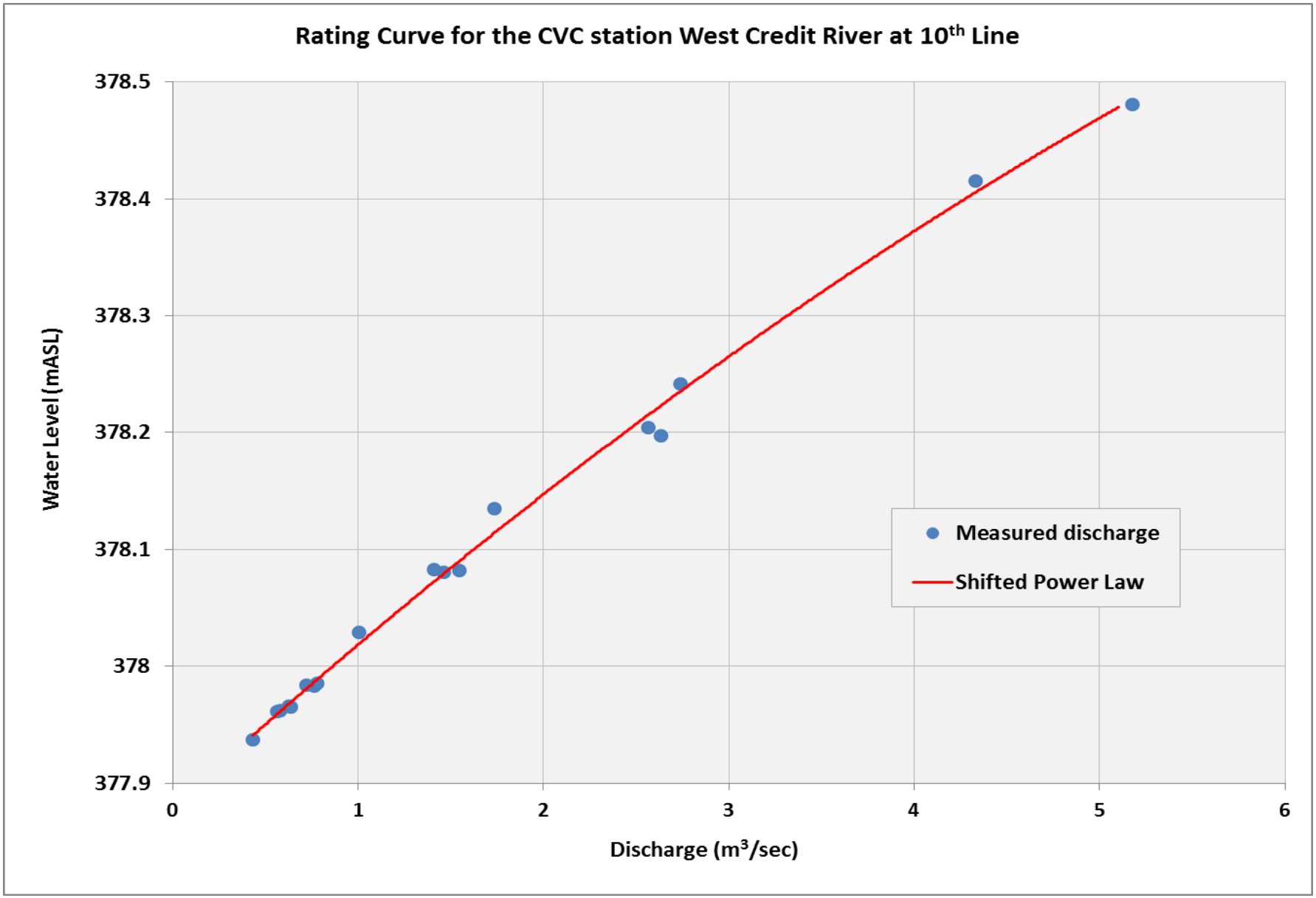

Figure A.1 Rating Curve for the CVC station West Credit River at 10th Line

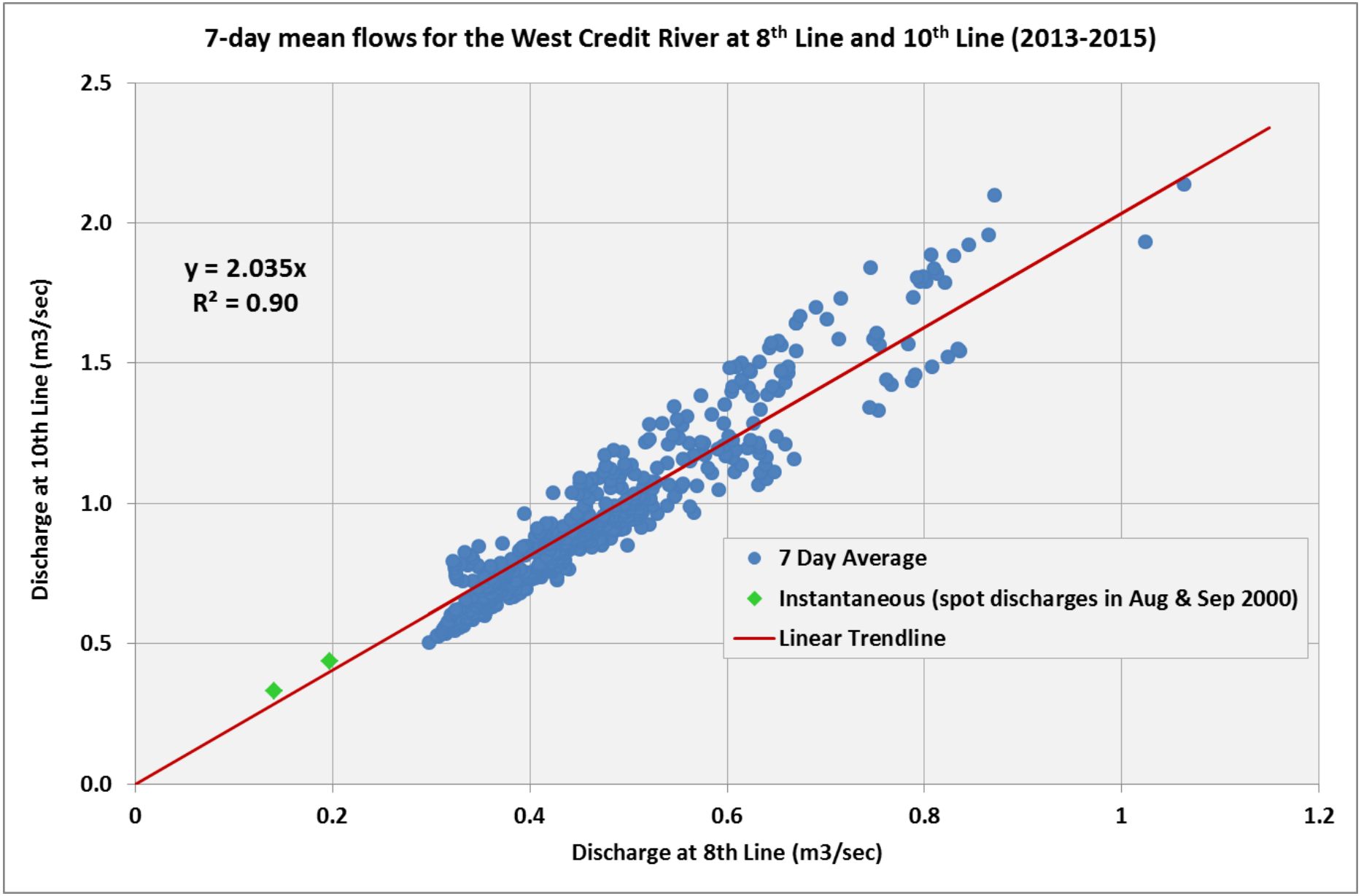

Figure A.2 Scatter graph of 7-day mean flows for the West Credit River at 8th Line and 10th Line (July 2013 - November 2015)

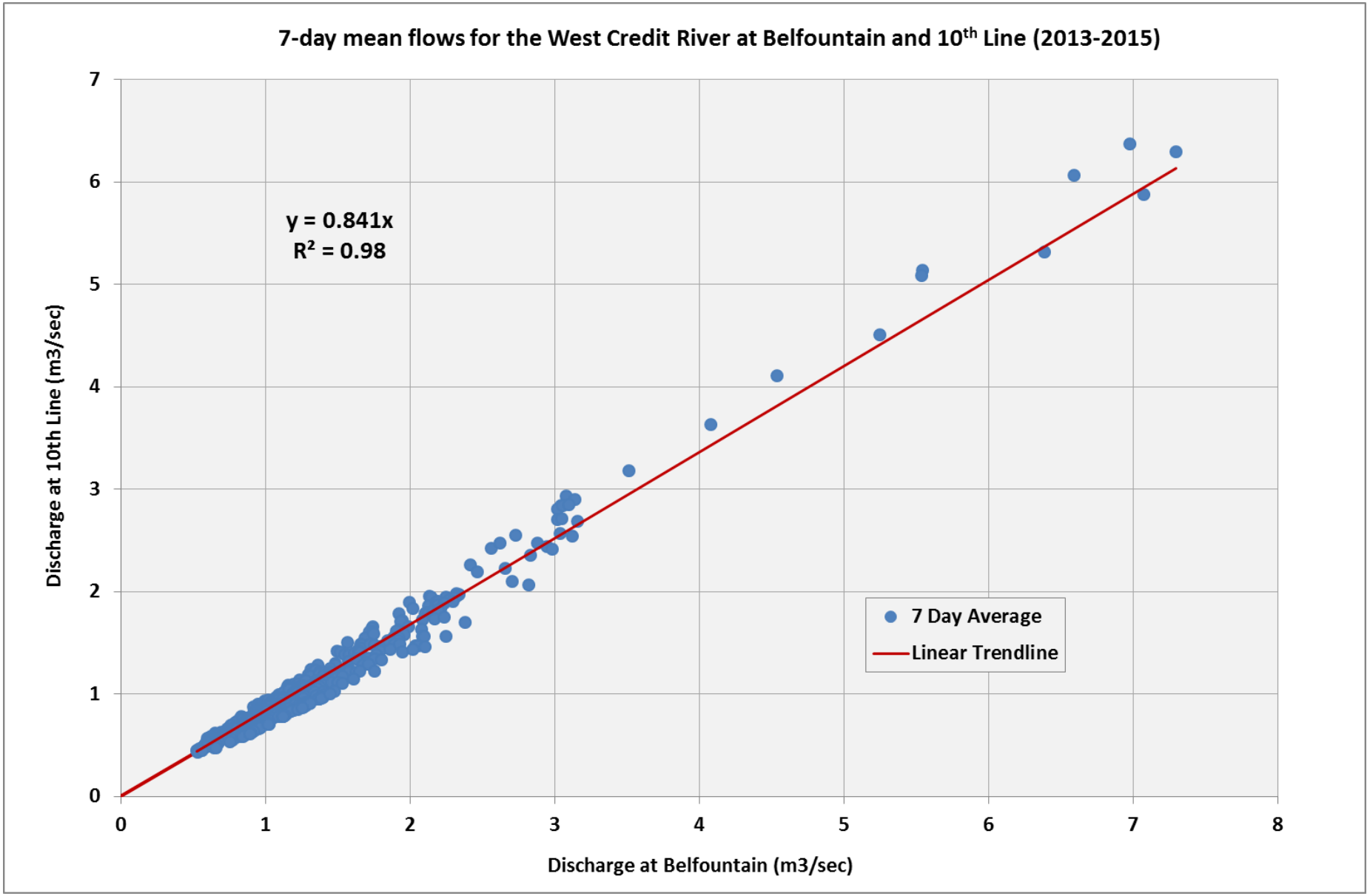

Figure A.3 Scatter graph of 7-day mean flows for the West Credit River at Belfountain and 10th Line (July 2013 - November 2015)

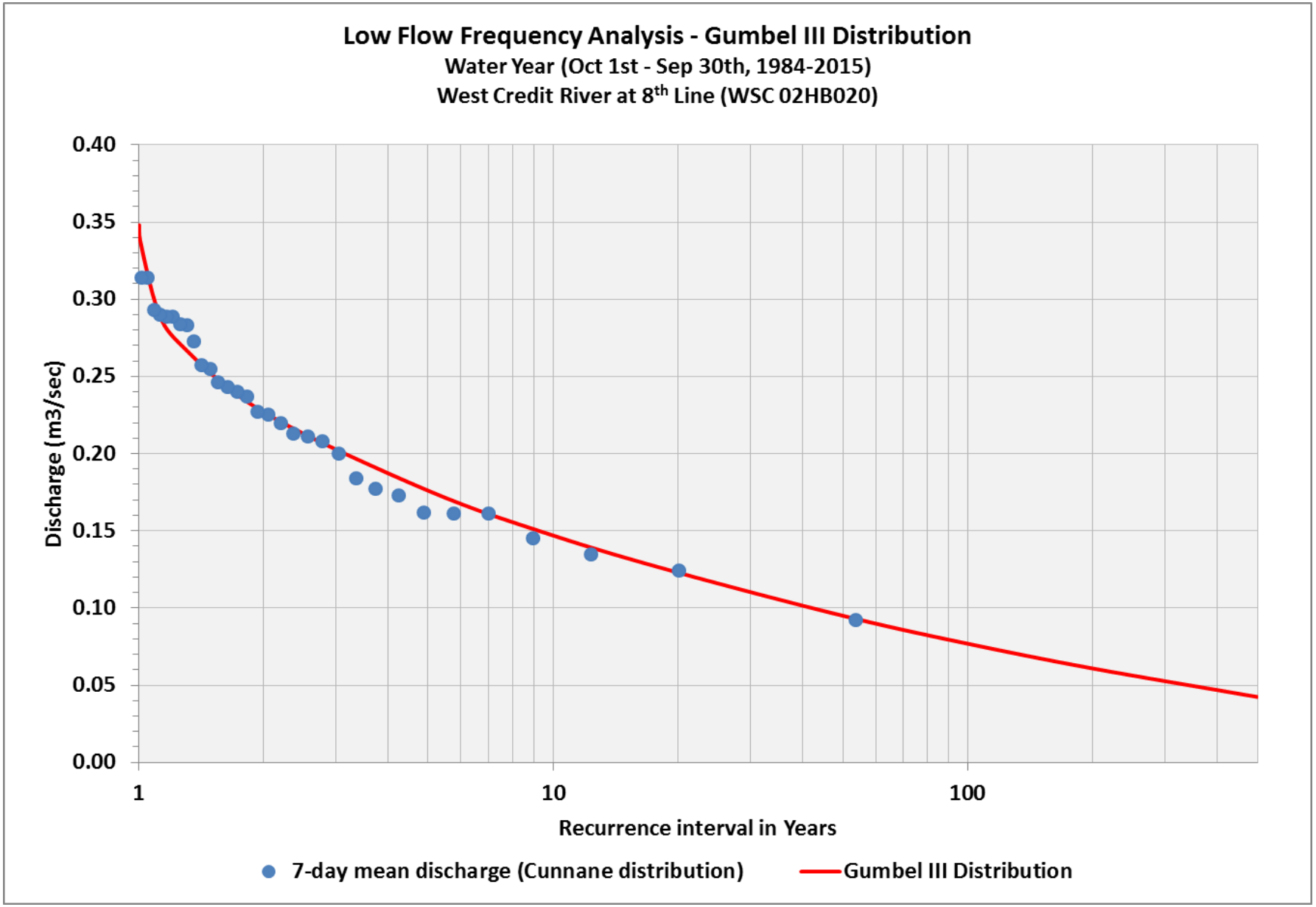

Figure A.4 **Gumbel III and Cunnane frequency distributions of minimum 7-day discharges for the West Credit River at 8th Line (WSC gauge 02HB020) for Water Year (1984-2015)**

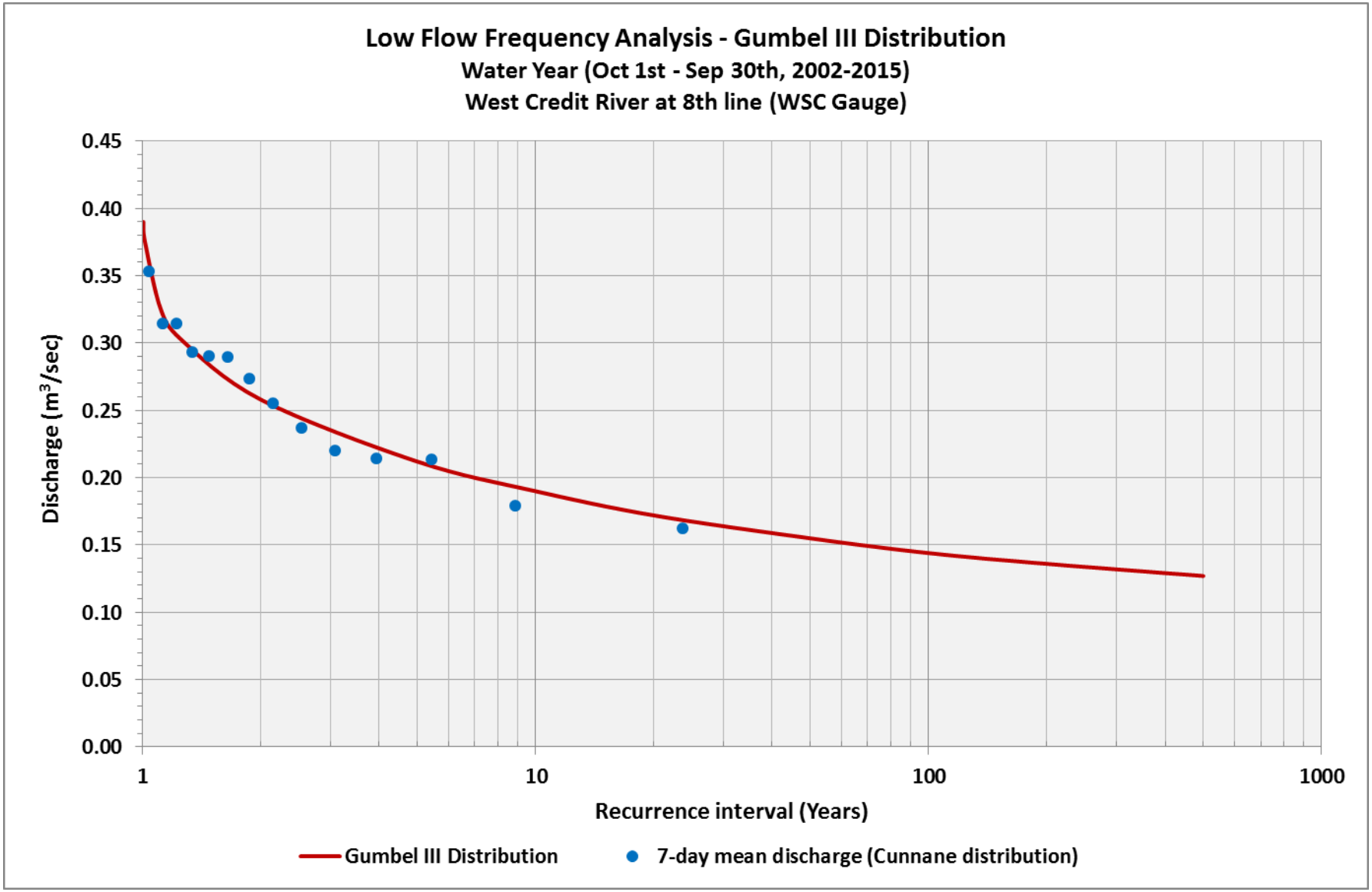

Figure A.5 Gumbel III and Cunnane frequency distributions of minimum 7-day discharges for the West Credit River at 8th Line (WSC gauge 02HB020) for Water Year (2002-2015)

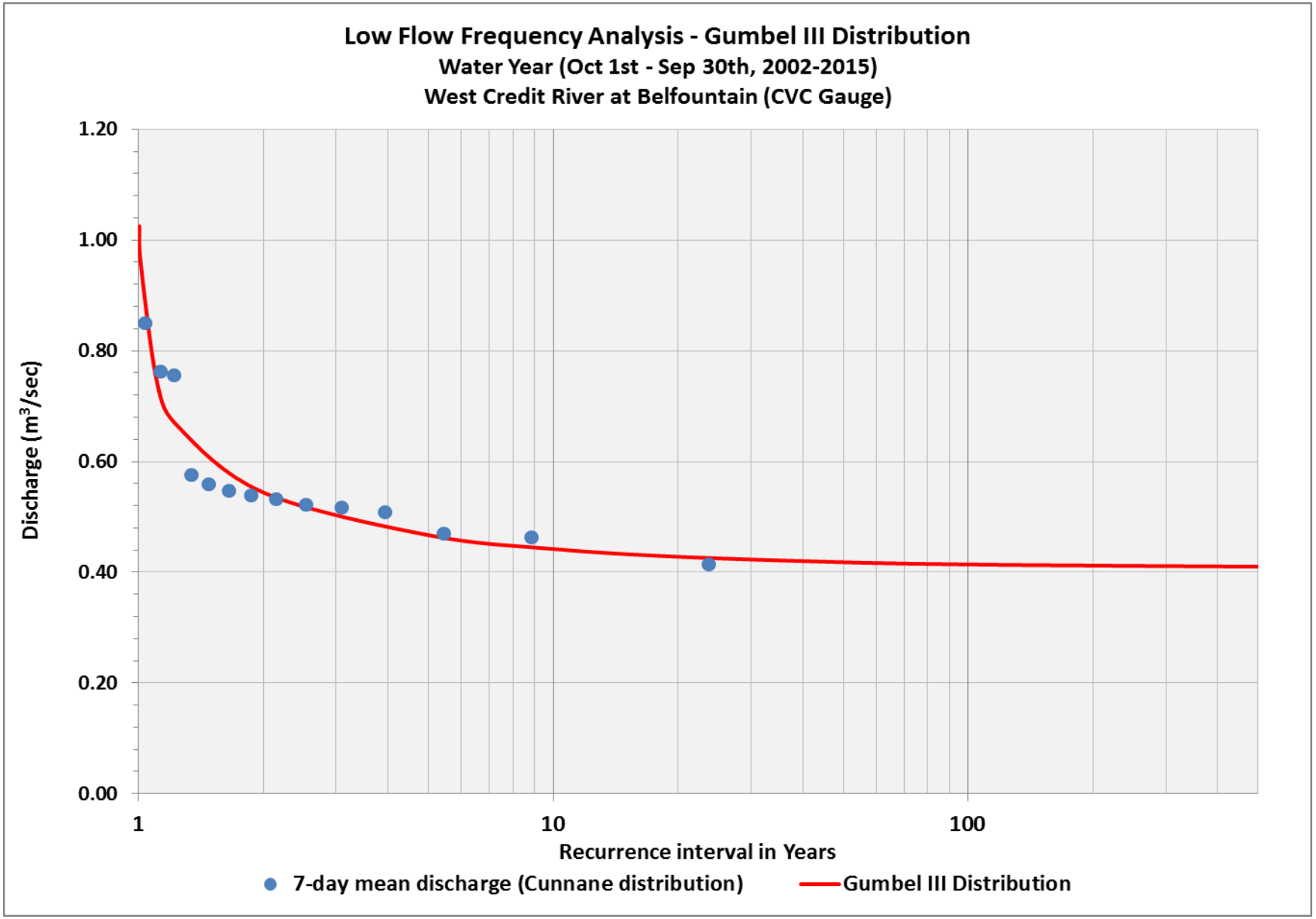

Figure A.6 Gumbel III and Cunnane frequency distributions of minimum 7-day discharges for the West Credit River at Belfountain (CVC gauge) for Water Year (2002-2015)

Table A.1 7Q20 monthly, seasonal and Water Year flows for the West Credit River at 8th Line and 10th Line (m^3/sec) - June 2016

Site/ Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Summer Min (Jul-Sep)	Fall-Winter-Spring Min (Oct-Jun)	Water Year Min (Oct 1-Sep 30)	Including 10% CC factor
8th Line (WSC Gauge)*	0.185	0.251	0.253	0.204	0.195	0.253	0.310	0.227	0.167	0.174	0.150	0.133	**0.132**	**0.151**	**0.123**	**0.111**
10th Line (CVC Gauge)**	0.376	0.511	0.515	0.415	0.397	0.515	0.631	0.462	0.340	0.354	0.305	0.271	**0.269**	**0.307**	**0.250**	**0.225**
Difference (%) * **	16.1	19.2	19.1	17.8	17.1	19.1	16.8	18.9	13.6	14.7	10.2	5.5	5.2	10.4	1.9	1.9

Notes:

* $7Q_{20}$ low flows (monthly, seasonal and yearly values) at 8th Line were estimated by frequency analysis of long-term streamflow data of the WSC gauge (1984-2015).

** $7Q_{20}$ low flows (monthly, seasonal and yearly values) at 10th Line were estimated by linear trendline equation defining relationship between streamflows at 8th Line and 10th Line. The ratio of 10th Line flow to 8th Line flow equal to 2.035.

*** Difference between present 7Q20 values (Jun 2016) and 7Q20 values from the March 14th Memo, calculated for the West Credit at 10th Line.

Table A.2 7Q20 monthly, seasonal and Water Year flows for the West Credit River at 8th Line and 10th Line (m3/sec) - March 2016

Site/ Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Summer Min (Jul-Sep)	Fall-Winter-Spring Min (Oct-Jun)	Water Year Min (Oct 1-Sep 30)	Including 10% CC factor
8th Line (WSC Gauge)	0.185	0.251	0.253	0.204	0.195	0.253	0.310	0.227	0.167	0.174	0.150	0.133	**0.132**	**0.151**	**0.123**	**0.111**
10th Line (CVC Gauge)	0.316	0.413	0.416	0.341	0.329	0.416	0.525	0.375	0.294	0.302	0.274	0.256	**0.255**	**0.275**	**0.246**	**0.221**
Ratio (10th Line/ 8thLine)	1.7	1.6	1.6	1.7	1.7	1.6	1.7	1.7	1.8	1.7	1.8	1.9	**1.9**	**1.8**	**2.0**	**2.0**