2003 SUMMER DROUGHT

IN THE KAMLOOPS REGION

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDICES

INTRODUCTION

The summer of 2003 was exceptionally dry and hot in the southern interior of British Columbia (BC). The previous winter had been one of the driest on record. Numerous large, destructive forest fires in the region were evidence that the 2003 summer was remarkably dry. Table 1 compares July and August 2003 monthly mean temperature and total precipitation at three climate stations in the Region to 30-year climate normals at these stations. Environment Canada (2003) provides climate data on its website. A review of BC Ministry of Forests climate station data throughout the region confirms that rainfall, even at higher elevations, was virtually non-existent in July and relatively light and sporadic through early September in most of the Region. Some areas to the northwest of Kamloops received one relatively heavy rainfall in the middle of August. Significant rainfall in the middle of September east of Kamloops brought streamflow in parts of the Shuswap area up substantially. Rainfall in mid-October ended the severe low flow conditions throughout the region.

In early August, the BC Ministry of Water, Land and Air Protection (WLAP) and Land and Water BC Inc. (LWBC) decided to fund a low flow monitoring program on natural streams similar to previous monitoring programs that the BC government had carried out during past summer droughts (Doyle, 2000). Stream temperatures were recorded for all streams during each site visit. Wetted stream widths in the vicinity of the flow measurement sites were also recorded for some streams and were re-measured when flow changed significantly. Flow monitoring began on 12 August continuing through to 17 October on five circuits to the northwest, north, northeast, east, and south of Kamloops at

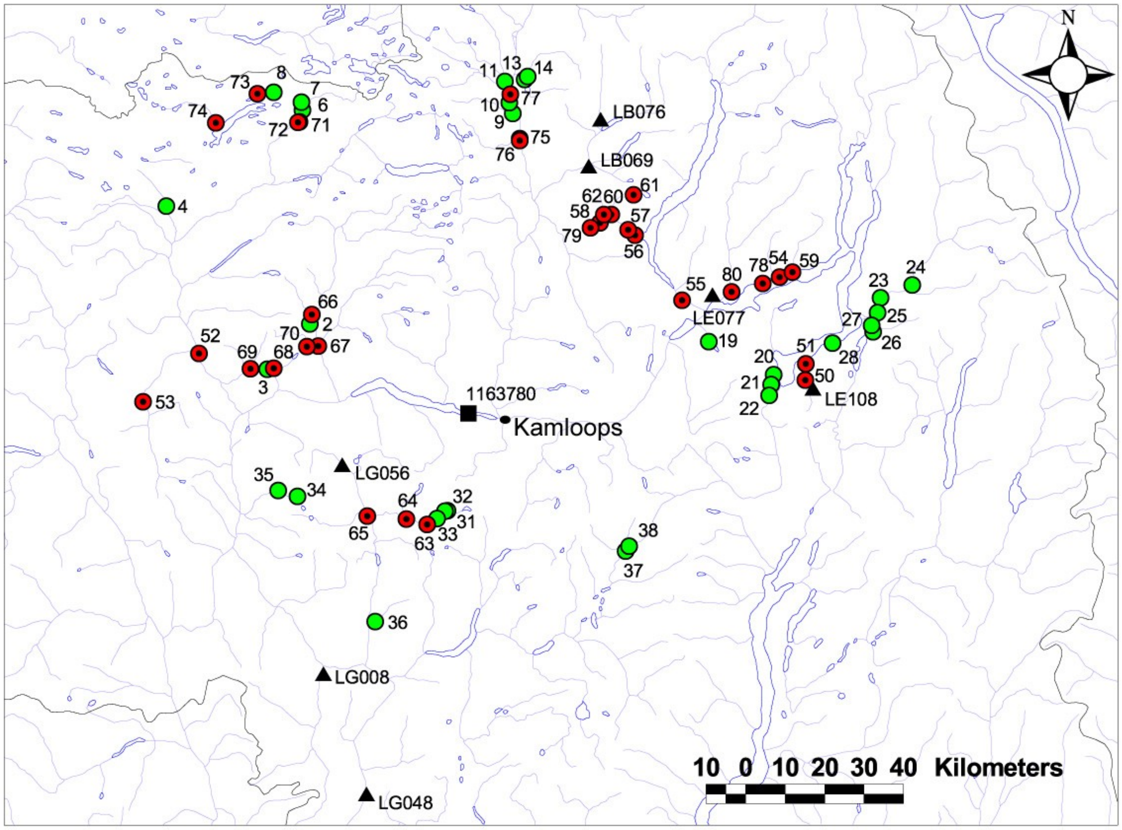
Table 1. July and August 2003 Monthly Precipitation Stations and Temperature and 30 year Normals at Regional Climate Stations.

Station	Station No.	Temperature (^{0}C)				Precipitation (mm)			
		Jul-03	July Normal	Aug-03	Aug Normal	Jul-03	July Normal	Aug-03	Aug Normal
Kamloops Airport	1163780	23.3	21	22.3	20.5	1.8	29.5	1.6	29.1
Penticton Airport	1126150	23.1	20.4	21.7	20.1	0	27.9	3.8	30.7
Williams Lake Airport	1098940	17.2	15.6	15.9	15.1	12.6	53.5	38.8	47.3

a frequency of between one and two weeks. Figure 1 is a location map showing 2003 data sites in the region and Environment Canada weather and streamflow stations. The primary objective of the program was to quantify the severity of the 2003 drought using natural flow measurements made on unregulated streams with prior drought flow records combined with analysis of Water Survey of Canada (WSC) natural stream flow records in the region. Secondary objectives were to expand the low flow database of stream water temperatures and determine the variation in wetted cross-sections of natural stream channels during critical low flows. A tertiary objective was to determine if water withdrawals measurably affected flow in selected streams.

METHODOLOGY

The same natural (no storage or significant diversion) drought flow gauging sites in four circuits near Kamloops that were first established during the 1985 summer drought and were still useable became the base 2003 flow measurement network. A fifth circuit to the



2003 WSC and WLAP Low Flow and AES Climate Stations

- New Low Flow Stations
- WSC Stations
- AES Stations
- Old Low Flow Stations

New Stations	Site No.	WSC Stations	Site No.	AES Stations	Site No.	Old Stations	Site No.
Upper Canoe	50	Harper	LB076	Kamloops	1163780	Barricade	2
Lower Canoe	51	E. Canoe	LE108			Upper Tsotin	3
Lower Hat	52	Corning	LE077			61	4
Upper Hat	53	Spius	LG008			Lower Orren B.	6
Onyx	54	Guichon	LG056			Upper Orren B.	7
Hihuill	55	Coldwater	LG048			Watch	8
Lower Sinmax	56	Barriere	LB069			Thuya	9
Middle Sinmax	57					Montigny	10
Upper Sinmax	58					Eakin	11
Ross	59					Dunn	13
Lower Johnson	60					Joseph	14
Upper Johnson	61					Chum	19
Lime	62					Gale	20
Hay	63					Palmer	21
Greenstone	64					Moutell	22
Guichon	65					Sims	23
Gorge	66					Yard	24
Criss	67					Owlhead	25
Upper Battle	68					Sicamous	26
Upper Cache	69					Gillis B.	27
Clemes	70					Enns	28
Graham	71					Walloper	31
Rayfield	72					Melba	32
Si	73					Neal	33
Eighty-Three Mil	74					Burr	34
Darlington	75					Woods	35
Lindquist	76					Steffans	36
Lemieux	77					Weyman	37
Hlina	78					Twig	38
Sinmax at Forest	79						
Scotch	80						

Figure 1. Location Map of 2003 WSC, WLAP Low Flow and the AES Climate Stations.

northeast of Kamloops was added to record drought flows in important fish bearing streams. Paired measuring sites were added in two of the five circuits to determine if water withdrawals had a measurable effect on stream flows. Flow at culvert sites with a free outfall was measured by bucket and stopwatch. Otherwise, flow was measured using either a Price or pygmy current meter at the most suitable location quickly accessible from nearby road. Corresponding water level was related to a fixed or temporary reference point. Occasional checks on accuracy of current meter discharge measurements were made using a second meter, a timed volume measurement or a Parshall flume. The accuracy of individual measurements depended on the type of measurement, the suitability of the measuring site, and the difficulty of making the measurement at the time of the sampling. At sites where stream flow was measured by current meter, a few discharges were estimated using the rough discharge rating curves developed for these sites.

Water temperatures were taken to the nearest 0.5 degree using a hand-held alcohol thermometer at each site visit when surface water was present. Bank-full stream widths and wetted widths were taken at four to five cross sections using a tape measure at a number of flow measurement sites. Wetted widths were re-measured each time the discharge changed significantly. Photos were taken of each site where cross sections were measured. Photos were taken again if flow changed markedly.

DATA SUMMARY

Table 2 summarizes the lowest flow measured during the summer of 2003 at each of the drought network sites. Appendix A lists all the stream flow data, temperature data, and cross section measurements collected during this study. Some of these sites were new in

Table 2. Summary of Lowest Summer 2003 Flows measured at all WLAP Drought Network stations.

Stream	Station No.	2003 Min. Flow measured (l/s)	Date	Lower Flow Previously recorded at site (Y or N)
61 Ck	4	0.7	22-Aug	N
Thuya Ck	9	3	11-Sep	N
Eakin Ck	11	47	09-Oct	Y
Dunn Ck	13	166	03-Oct	N
Joseph Ck	14	196	03-Oct	N
Chum Ck	19	3.6	04-Sep	N
Gale Ck	20	2.4	25-Aug	N
Moutell Ck	22	3	25-Aug	N
Yard Ck	24	183	05-Sep	N
Owlhead Ck	25	17	05-Sep	Y
Sicamous Ck	26	57	05-Sep	Y
Enns Ck	28	4.1	25-Aug	Y
Burr Ck + Woods Ck	34 & 35	7.7	01-Sep	N
Steffans Ck	36	1.3	12-Aug	N
Weyman Ck	37	16	01-Sep	N
Sims Ck	23	0	05-Sep	N
Gillis Bk	27	0	25-Aug	N
Upper Canoe Ck	50	41	14-Aug	N/A
Lower Canoe Ck	51	59	14-Aug	N/A
Melba Ck	32	0	01-Sep	N
Barricade Ck	2	0	29-Aug	N
Lower Hat Ck	52	16	22-Aug	N/A
Upper Hat Ck	53	24	12-Sep	N/A
Onyx Ck	54	0.3	04-Sep	N/A
Hiuihill Ck	55	36	30-Sep	N/A
Lower Sinmax Ck	56	148	15-Sep	N/A
Middle Sinmax Ck	57	0	04-Sep	N/A
Upper Sinmax Ck	58	35	30-Sep	N/A
Ross Ck	59	0	15-Aug	N/A
Lower Johnson Ck	60	2.5	30-Sep	N/A
Upper Johnson Ck	61	<1	30-Sep	N/A
Lime Ck	62	1.3	30-Sep	N/A

2003. The original field notes and photos of the channels at low flow are available in the WLAP Kamloops office. Figure 2 is an example of how the wetted channel widths in one stream (Dunn Creek) changed as the discharge changed at a representative site.

ANALYSIS OF DATA

The summer drought of 2003 was one of the most severe on record in the BC southern interior. Beeson and Doyle (2001) provided summer low flow frequency analysis tables for all natural flow WSC stations in the Kamloops region. Using these published frequencies for seven long-term natural flow WSC stations in the study area, the 2003 summer drought exceeded a 30-year event for the 7-day average low flow at six of the seven stations. Table 3 indicates the 2003 stream flow drought frequencies for the WSC stations used for historical comparison. The lowest summer flows ever recorded occurred in 2003 at three of the seven WSC stations that have periods of record ranging from 16 to 34 years. The WLAP stations have the 2003 flows factored into the drought frequency analyses while the WSC stations do not. New drought frequency analyses run with the 2003 WSC flow data included would undoubtedly reduce the return period of the 2003 drought at many of the stations.

Wetted widths at Dunn Creek (see Figure 2) consistently diminished as discharge decreased. All measurements were taken in a narrow range of low flows so overall changes in wetted width were small. A cursory review of all wetted width data collected during this project indicates a pattern similar to Dunn Creek wetted width changes.

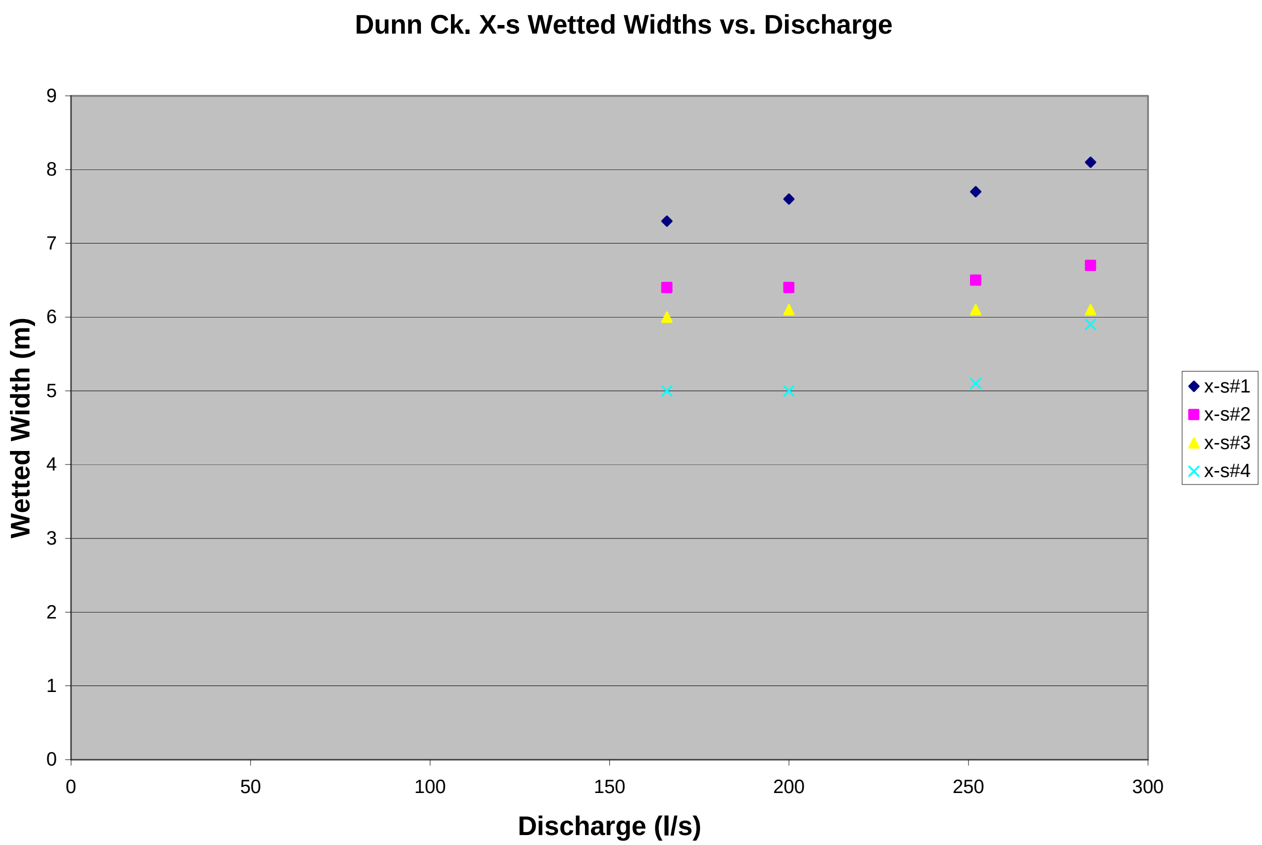


Figure 2. Example of Relationship Between Wetted Stream Width and Discharge.

Table 3. 2003 Drought Return Periods for Natural Flow WSC Hydrometric Stations[1] in the Region.

Station Name	Station No.	7-day Avg. Min. Q (m^3/s)	Previous Min. Q Recorded (m^3/s)	Dates	Years of Record	Return Period (years)
Harper Ck	08LB076	0.392	0.468	03-09 Sep	26	100
Barriere R below Sprague Ck	08LB069	1.08	0.873	07-13 Sep	34	75
East Canoe Ck	08LE108	0.0033	0.0029	03-09 Sep	16	50
Guichon Ck at Tunkwa Lk diversion	08LG056	0.0143	0.0047	03-09 Sep	31	5
Coldwater R near Brookmere	08LG048	0.371	0.26	04-10 Sep	30	30
Corning Ck	08LE077	0.0081	0.006	03-09 Sep	21	30
Spius Ck[2]	08LG008	0.292	0.46	02-08 Sep	34	90

[1]Preliminary WSC Data
[2]Likely affected by diversions

Doyle (2000) developed a second method of determining the frequencies of summer droughts in the Kamloops area. This technique makes use of natural low flow data collected at the same sites during summer droughts since 1985 and incorporates the most recent drought flows into the bottom end of a frequency curve covering a 24 year time span since 1980. The five and in some areas, six most severe droughts that have resulted in the lowest summer stream flows around Kamloops since 1980 have been measured at the same sites each drought year, allowing for construction of an improved frequency curve with each drought occurrence. Table 4 provides return periods of the WLAP natural flow stations for 5 or 6 years of non-zero drought flows using this method. For the sixteen natural flow stations used in the study, the 2003 drought return period ranged from 10 to 50 years with most (eleven) between 20-30 years. The 2003 minimum flow recorded at twelve of the sixteen WLAP sites was the lowest on record. Other streams that were dry at the measuring sites during some or all of the visits such as Melba and Sims creeks were sinking into their respective streambeds farther upstream than ever observed in previous drought years. Summer water levels in the Salmon River groundwater well in Westwold declined to the lowest levels recorded over the past 34 years (WLAP, 2003). This observation well is considered representative of the groundwater conditions in the Thompson watershed. Minimum water levels in observation wells during 2003 around the region varied widely from the lowest on record (in some cases nearly 40 years) to not much below normal (D. Anderson, pers. comm., 2004).

Table 4. 2003 Drought Return Periods for Non-Zero Natural Flow WLAP Drought Network Stations.

Station	Station Number	Measured Low Flow (l/s)	Date	Return Period (years)
Dairy Ck (Upper Tsotin)	3	0.9	15-Aug	30
61 Ck	4	0.7	22-Aug	25
Thuya Ck	9	3	11-Sep	25
Eakin Ck	11	47	09-Oct	16
Dunn Ck	13	166	03-Oct	23
Joseph Ck	14	196	03-Oct	22
Gale Ck	20	2.4	25-Aug	50
Moutell Ck	22	3	25-Aug	25
Sicamous Ck	26	57	05-Sep	16
Enns Ck	28	4.1	05-Sep	12
Burr + Woods Cks[1]	34 & 35	7.7	01-Sep	20
Steffans Ck[2]	36	1.3	13-Sep	25
Weyman Ck[3]	37	16	01-Sep	25
Yard Ck	24	183	05-Sep	30
Owlhead Ck[4]	25	17	05-Sep	10
Chum Ck	19	3.6	04-Sep	30

[1]Woods Ck apparently partially diverted into Burr Ck between 1992 and 1998

[2]Affected by upstream withdrawals and storage release

[3]Earlier low flow measurements adjusted based on 2003 measurements

[4]May be affected by upstream diversions

DISCUSSION

Low flows on a unit runoff basis can vary widely, even between adjacent watersheds. As in the past, 2003 low flow return periods varied amongst watersheds. For instance, Guichon Creek in its upper watershed stood out amongst all others by experiencing a modest 5-year drought. Lower down in the watershed, casual observations at the same site during previous dry summers indicated that Guichon Creek had never been as dry as it was in 2003. At the other end of the scale, Spius and Harper creeks both recorded extremely rare low flows. Low Spius Creek flows may be reduced even further in very dry years by upstream withdrawals.

This summer's monitoring program on the WLAP network allowed some comparisons to be made between different flow measurement methods at measuring sites where the measurement accuracy has been questioned. As a result, a few of the flow measurements published previously were revised to better reflect the results of these check measurements.

Flow measurements in the adjacent Woods and Burr creeks confirmed that between 1992 and 1998, flow was somehow diverted from Woods Creek into Burr Creek. Doyle (2000) had noted that low flow ratios between the two watersheds had changed at some time after 1992 but prior to 1998. The only way to keep historical comparisons on the two creeks valid was to combine the flows in the two creeks for all the years that they have been monitored.

In 2001, it was learned that Steffans Creek was not a "natural" flow stream but was, in fact, highly regulated. However, Steffans has been kept in the shrinking portfolio of "natural" streams both in the WSC network and in the WLAP drought flow network as an indicator stream for summer drought comparisons. The stream flow measurements at the Steffans Creek site are very accurate and are a good indicator of drought conditions in the area, and, in the absence of rain, can also show how upstream regulation affects flow. There is no doubt that 2003 was an extremely dry year on all five WLAP circuits. Non-monitored streams on the circuit routes were observed by the author to be dry for the first time in 24 years of casual observations including summer droughts. Monitored streams on the WLAP circuits that previously had zero flow yet maintained pools of water in their channels or damp channels became “bone dry” in 2003. The importance of the “long-term” WLAP natural drought flow network in determining the severity of regional droughts increases as the natural flow long-term WSC station network diminishes in size. Five of the thirteen WSC natural flow stations that were used to document the 1998 drought are no longer operating. A sixth, Fishtrap Creek, was destroyed by one of the summer’s forest fires that eliminated all flow data at the gauge beyond mid-July. That left only seven WSC natural flow stations that could be used for calculating drought frequencies and one of those seven, Spius Creek, appears to be significantly affected by water withdrawals upstream of the gauge.

The rapid decision to organize a drought-monitoring program in 2003 resulted in a few glitches in an expanded data collection program. One of the new sites, Hiuihill Creek, was metered to determine flow impacts of water withdrawals between a location near the mouth and a long-term WSC gauge upstream that had been operating through 2002. Only after the new site data had been collected did the author learn that the Hiuihill WSC station did not operate in 2003.

Sites with zero flow could provide more useful historical information if the exact location of where the surface flow sank into the bed was determined each time that the site was visited. This year the sinking fronts retreated so far upstream of the measuring site in some cases that it took more time to get to the sinking front on the stream than was available on a tight circuit schedule.

More time and care should have gone into getting accurate water level reference points. Since water level changes of less than one cm were important during these extreme low flows, it became apparent that some reference points were not well enough marked and described to be sure of getting such accuracy. Precise marking and description of each temporary reference point should be done in the future to prevent uncertainty in measuring water levels.

Two people were much more efficient than one at measuring cross section widths with a tape. A second person also generally made discharge measurements faster by taking the field notes and doing other tasks.

Accuracy of measurements varies. Very small flows in steep natural channels can be difficult to measure accurately without artificial flow control. Installation of flow control devices often creates excessive sediment disturbance, takes time, and sometimes is ineffective in these types of channels. Price and pygmy current meters are less accurate in very low velocity streams and in very small cross-sectional areas where there are large edge effects on the meter.

Anecdotal observations of fish behaviour and habitat change during varying discharges and documented impacts of water withdrawals on stream flow collected during this program were noted in the field. Observations are included in Appendix B. Often, culvert scour holes are some of the deepest scour pools (and sometimes are the last to go dry) in a reach and fish congregate in them. This may ensure some survival, but the trapped fish are easy for predators to catch. These same culverts may become barriers to upstream migration. Generally, fish will move upstream or downstream in descending flows or even into stream gravel/cobble/boulder cover and may become stranded as sections completely dewater. (A. Caverly, pers. comm., 2004).

Suggestions to improve the accuracy and efficiency of future low flow monitoring programs are noted in a companion drought report (Doyle, in prep.). The question of how to get accurate measurements of small flows in steep streams in a reasonable time at little expense for short, infrequent durations without further stressing already stressed fish remains. Complete discharge, water temperature, and stream cross-section data contained in Appendix A is available to others for further analyses. This data combined with additional discharge and water temperature data presented in the companion 2003 drought report (Doyle, in prep.) provides a good 2003 drought data set for future investigations. Finally, tracking the expanding extent of dry channel sections by GPS referencing the receding surface flow would add a useful, spatial impact reference during future droughts.

CONCLUSIONS

The very hot dry summer of 2003 following a mild, dry winter led to record low summer flows on many natural flow streams that have flow records extending up to 35 years in the Kamloops region. All streams, regulated and natural, with very few exceptions experienced summer drought flows of less than 10 percent probability. The large majority of the natural flow streams in the region with documented flows during the late summer experienced summer drought flows of less than 5 percent probability. For the region as a whole, late summer season flows were the lowest on record in 35 years. The value of the existing Kamloops region natural drought flow network increases with each documented drought because (1) the WSC network has shrunk drastically over the years, and (2) the ever-lengthening natural flow WLAP network record of summer droughts will provide a better estimate of the severity of each drought as it occurs. More preparation time in getting drought network sites ready for use and more staff and resources committed to collecting stream flow, water temperature, and stream channel data such as receding surface flow or wetted width and observed fish impacts at selected network sites during summer droughts would provide a more accurate and comprehensive documentation of these events.

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APPENDICES

Appendix A. All 2003 Discharge, Temperature and Cross-section Data Collected on WLAP Low Flow Network Sorted by Stream and Date Within Each of the Five Circuits.

i.) Merritt Circuit

						X-S#1			X-S#2			X-S#3			X-S#4			X-S#5			Average
STATION	No.	DATE	STAGE	FLOW	TEMP	BANKFULL	W.P.	% Wetted	BANKFULL	W.P.	% Wetted	BANKFULL	W.P.	% Wetted	BANKFULL	W.P	% Wetted	BANKFULL	W.P.	% Wetted	% Wetted
			negative (-)	(l/s)	deg. C	m	m		m	m		m	m		m	m		m	m		for all x-s's
Merritt Circuit																					
Melba C	32	12-Aug	n/a	sinks 28m u/s fl	n/a	no x-secs															
		20-Aug	n/a	sinks > 120m u/s fl	n/a																
		01-Sep	n/a	sinks > 200m u/s fl	n/a																
		13-Sep	n/a	sinks>120m u/s fl	n/a																
		04-Oct	n/a	sinks u/s fl	n/a																
		15-Oct	n/a	sinks>120m u/s fl	n/a																
Burr C	34	12-Aug	n/a	6.8	9.5	4	2.5	N/A	4	3.6	N/A	4	3.5	N/A	4	3.2	N/A	3	2.3	N/A	65
		20-Aug	n/a	4.7	10		2.5	60		3.6	65		3.3	35		3.2	55		1.4	50	55
		01-Sep	n/a	4.1	9		2.2	50		3.5	65		3.3	20		2.6	50		1.4	50	45
		13-Sep	n/a	7.2	6.5	no x-secs	this date														
		04-Oct	n/a	6.4	7	no x-secs	this date														
		15-Oct	n/a	7.9	2	no x-secs	this date														
Woods C	35	12-Aug	n/a	4.8	11.5	5	1.8		5	1.4		4.4	2.3		5	3		6	3.4		60
		20-Aug	n/a	4.2	12.5		1.8	60		1.4	80		2.1	70		2.8	50		2.7	30	60
		01-Sep	n/a	3.6	11		1.5	80		1.2	80		2.1	45		2.7	40		2.6	30	55
		13-Sep	n/a	5.0	8	no x-secs	this date														
		04-Oct	n/a	4.9	8.5	no x-secs	this date														
		15-Oct	n/a	8.4	3.5	no x-secs	this date														
Steffens C	36	12-Aug	n/a	1.3	n/a	no x-secs															
		20-Aug	n/a	1.9	15																
		01-Sep	n/a	3.9	12.5																
		13-Sep	n/a	1.8	10																
		04-Oct	n/a	28	8																
		15-Oct	n/a	8.7	4																
Weyman C	37	12-Aug	-32	22	15	10	1.6		10	6.7		7	3		8	2.6		10	5		80
		20-Aug	-33	20	14		1.6	90		5.6	80		3	95		2.6	80		5	50	80
		01-Sep	-33.5	16	12.5	no x-s's	this date														
		13-Sep	-32	22	9	no x-secs	this date														
		04-Oct	-33	20	9	no x-secs	this date														
		15-Oct	-31.5	24 (est)	3	no x-secs	this date														
Walloper C	31	Dry at all 6 visits																			
Hay B	63	Flowing at all 6 visits																			
Greenstone	64	Dry at all 6 visits																			
Guichon C	65	Dry at all 6 visits																			
L. Chartrand	66	Flowing on 12 Aug, dry at all 5 visits thereafter																			
Twig C	38	Dry at all 6 visits																			

ii.) Green Lake Circuit

STATION	No.	DATE	STAGE negative (-)	FLOW (l/s)	TEMP deg. C	X-S#1 BANKFULL m	W.P. m	% Wetted	X-S#2 BANKFULL m	W.P. m	% Wetted	X-S#3 BANKFULL m	W.P. m	% Wetted	X-S#4 BANKFULL m	W.P m	% Wetted	X-S#5 BANKFULL m	W.P. m	% Wetted	Average % Wetted for all x-s's
Green Lake Circuit																					
Barricade C	2	13-Aug	-193	1	15.5	4	0.8		3	1		3	1		2	0.8		3	1.3		60
		22-Aug	-198.5	0	15		0.8	50		0.9	50		1	70		0.8	90		1.3	50	60
		29-Aug	dry	0	17.5	no change															
		12-Sep	dry	0	12	no x-secs	this date														
		26-Sep	dry	0	11	no change															
		10-Oct	-198.5	0	4	no x-secs	this date														
61 Ck	4	13-Aug	n/a	1.5	n/a	no x-secs															
		22-Aug	n/a	0.7	13																
		29-Aug	n/a	1.1	9																
		12-Sep	n/a	1.4	7.5																
		26-Sep	n/a	1.6	5																
		10-Oct	n/a	2.3	4.5																
Lower Hat C	52	22-Aug	-125.5	16	16	7	1.9	100	7	2.8	100	7	4	100	5	3.6	100	7	5.5	60	90
		29-Aug	-122	76	15		2.1	100		4.2	80		4.5	100		3.9	100		5.7	85	95
		12-Sep	-122.5	57	12	no x-s's	this date														
		26-Sep	-122.5	57 (est.)	9.5	no x-s's	this date														
		10-Oct	-121.5	98	6.5	no x-s's	this date														
Upper Hat C	53	22-Aug	-17	30	16	7	4.9	90	8	5.1	90	10	5.6	95	9	7.4	80	7	5.6	80	85
		29-Aug	-16	37	16		4.9	90		5.5	90		5.7	100		7.5	90		5.8	85	90
		12-Sep	-17.5	24	13.5	no x-s's	this date														
		26-Sep	-14	64	9		5.1	95		5.7	95		5.7	100		7.9	90		5.8	95	95
		10-Oct	-12.5	72	6		5.1	95		5.7	95		5.8	100		7.9	95		5.9	95	95
Gorge C	66	Flowing on 13 Aug and 10 Oct																			
U. Battle C	67	Flowing on 13 Aug and 22 Aug																			
U. Cache C	68	Flowing on 13 Aug and 22 Aug																			
Clemes C	69	Flowing on 13 Aug and 22 Aug																			
U. Orren B	7	Dry on 13 Aug, skipped on 22 Aug, and dry last 4 visits																			
L. Orren B	6	Zero flow with pools on 13 Aug, skipped on 22 Aug, bone dry next 3 visits, and tiny puddle in downstream scour hole on final visit on 10 Oct																			
Watch C	8	Zero flow with pool upstream of culvert on 13 Aug that gradually dried up until bone dry on 25 Sep and on 10 Oct																			
Criss C	70	Flowing on 13 Aug, sinks at bridge on 22 Aug and 29 Aug, sinks 20 m downstream of bridge on 12 Sep, sinks at bridge again on 26 Sep, and apparently reconnected to Deadman R on 10 Oct																			
Graham C	71	Dry at first notice on 29 Aug and 3 visits thereafter																			
Rayfield R	72	Trickle at Green Lk-Bridge Lk Rd at first notice on 12 Sep and same on final two visits																			
Si C	73	Dry at first notice on 29 Aug and 3 visits thereafter																			
83 C	74	Trickle at first notice on 29 Aug and 3 visits thereafter																			

iii.) Sicamous Circuit

STATION	No.	DATE	STAGE negative (-)	FLOW (l/s)	TEMP deg. C	X-S#1 BANKFULL m	W.P. m	% Wetted	X-S#2 BANKFULL m	W.P. m	% Wetted	X-S#3 BANKFULL m	W.P. m	% Wetted	X-S#4 BANKFULL m	W.P m	% Wetted	X-S#5 BANKFULL m	W.P. m	% Wetted	Average % Wetted for all x-s's
Sicamous Circuit																					
Gale C	20	14-Aug	n/a	2.9	n/a	no x-secs															
		25-Aug	n/a	2.4	14																
		05-Sep	n/a	2.6	14																
		17-Sep	n/a	3.3	9.5																
		05-Oct	n/a	2.6	9																
Moutell C	22	14-Aug	n/a	4	13	no x-secs															
		25-Aug	n/a	3	13																
		05-Sep	n/a	3	14																
		17-Sep	n/a	5	9.5																
		05-Oct	n/a	4	9.5																
Sims C	23	14-Aug	-13	6.5	17.5	15	1.3		15	2.9		15	4.7		15	3.2		15	4.2		50
		25-Aug	n/a	sinks 25m u/s bridge	15.5		dry			dry			dry			n/a			n/a		n/a
		05-Sep	n/a	sinks 40m u/s bridge	17.5		dry			dry			dry			dry			dry		
		17-Sep	-2.5	est. 40	8		2.2	75		4	75		5.2	75		3.9	95		6.6	45	75
		05-Oct	n/a	sinks 30m u/s bridge	11.5		no x-secs	this date													
Yard C	24	14-Aug	-24	450 (est.)	15	16	8.5	100	16	12.2	95	21	18.6	75	34	31.6	50	n/a			80
		25-Aug	-27	230	14		8.3	100		12.2	95		18.5	50		30.2	40				70
		05-Sep	-28.5	183	14		8.3	99		11.9	95		18.5	50		30.2	40				70
		17-Sep	-18.5	1000 (est.)	8.5		10.6	90		13.1	95		19.7	60		30.6	55				75
		05-Oct	-28	215	9		no x-secs	this date													
Owlhead C	25	14-Aug	n/a	26	15	no x-secs															
		25-Aug	n/a	23	14																
		05-Sep	n/a	17	14																
		17-Sep	n/a	65 (est.)	9																
		05-Oct	n/a	34	9																
Sicamous C	26	14-Aug	-18	130	15	16	6.6		16	5.3		16	5.7		16	7.7		n/a			n/a
		25-Aug	-22	72	13		4.2	100		5.2	85		5.4	90		7.7	85				90
		05-Sep	-24.5	57	13.5		4.2	100		5.2	85		5.1	95		7.6	75				90
		17-Sep	-9.5	350	8		6.9	95		7.5	90		7.9	85		8.3	90				90
		05-Oct	-20.5	95 (est.)	8		no x-secs	this date													
Gillis B	27	14-Aug	n/a	3 drops/sec.	n/a	no x-secs															
		25-Aug	n/a	dry	n/a																
		05-Sep	n/a	dry	n/a																
		17-Sep	n/a	small trickle	n/a																
		05-Oct	n/a	dry	n/a																
Enns C	28	14-Aug	n/a	6.8	13	no x-secs															
		25-Aug	n/a	5.2	12.5																
		05-Sep	n/a	4.1	12																
		17-Sep	n/a	7.3	10																
		05-Oct	n/a	4.5	9																
Upper	50	14-Aug	n/a	41	14.5	no x-secs															
Canoe C		25-Aug	n/a	46	12																
		05-Sep	n/a	49	11.5																
		17-Sep	n/a	60	10																
		05-Oct	n/a	43	8																
Lower	51	14-Aug	-12	59	16.5		no x-secs	this date													
Canoe C		25-Aug	-9	60	14	4	2.1	100	3	2.7	95	4	2	100	8	2.5	100				100
		05-Sep	-8	65	13		2.3	100		2.8	100		2.1	100		2.5	100				100
		17-Sep	-3	81	10.5		3	95		2.8	100		2.2	100		2.5	100				99
		05-Oct	-4	75 (est.)	8		no x-secs	this date													
Palmer C	21	Dry all 5 visits																			

iv. Little Fort Circuit

STATION	No.	DATE	STAGE negative (-)	FLOW (l/s)	TEMP deg. C	X-S#1 BANKFULL m	W.P. m	% Wetted	X-S#2 BANKFULL m	W.P. m	% Wetted	X-S#3 BANKFULL m	W.P. m	% Wetted	X-S#4 BANKFULL m	W.P m	% Wetted	X-S#5 BANKFULL m	W.P. m	% Wetted	Average % Wetted for all x-s's
Little Fort Circuit																					
Thuya C	9	18-Aug	-117.5	7	15	no x-secs															
		28-Aug	-118	6	13.5																
		11-Sep	-118.5	3	12.5																
		25-Sep	-118	6	9																
		03-Oct	-118	4	9.5																
		09-Oct	-118	4	9																
Eakin C	11	18-Aug	-12	73	14.5	10	5.5	95	8	4.8	80	8	5.9	90	8	5.8	90	7	5.5	50	80
		28-Aug	-12.5	61	13		5.1	95		4.8	90		5.7	80		5.8	90		5.3	40	80
		11-Sep	-14	52	11.5		5.1	95		4.8	80		5.6	80		5.8	90		5.3	40	75
		25-Sep	-13.5	52	8.5	no x-secs	this date														
		03-Oct	-14	50	9	no x-secs	this date														
		09-Oct	-14	47	9	no x-secs	this date														
Dunn C	13	18-Aug	-87	284	22	12	8.5	95	12	6.8	99	13	6.4	95	15	6.2	95				95
		28-Aug	-89	252	20.5		8.1	95		6.5	100		6.4	95		6	85				95
		11-Sep	-91.5	200	18		8	95		6.5	99		6.4	95		5.6	90				95
		25-Sep	-91.5	200 (est.)	14.5	no x-secs	this date														
		03-Oct	-93	166	14.5		7.7	95		6.5	99		6.3	95		5.5	90				95
		09-Oct	-92	179	13	no x-secs	this date														
Joseph C	14	18-Aug	-17	388	15	13	7.3	95	n/a			n/a			n/a						
		28-Aug	-19	322	14		6.4	100													
		11-Sep	-21.5	220	12		5.9	100													
		25-Sep	-19.5	252	8		6.4	99													
		03-Oct	-22.5	196	9		5.8	100													
		09-Oct	-19	322	8		6.4	99													
Montigny C	10	Dry on all 6 visits																			
Darlington C	75	Flowing on all 6 visits																			
Lindquist C	76	Trickle on first 5 visits and then dry on final visit on 9 Oct																			
Lemieux C	77	Connected to N. Thompson R on 18 Aug, sinks 20 m upstream on 28 Aug, 60 m upstream on 11 Sep, same on 25 Sep, 80 m upstream on 3 Oct, and 120 m upstream on 9 Oct																			

v.) North Shuswap Circuit

						X-S#1			X-S#2			X-S#3			X-S#4			X-S#5			Average
STATION	No.	DATE	STAGE	FLOW	TEMP	BANKFULL	W.P.	% Wetted	BANKFULL	W.P.	% Wetted	BANKFULL	W.P.	% Wetted	BANKFULL	W.P	% Wetted	BANKFULL	W.P.	% Wetted	% Wetted
			negative (-)	(l/s)	deg. C	m	m		m	m		m	m		m	m		m	m		for all x-s's
North Shuswap Circuit																					
Chum C	19	15-Aug	-71	5.6	10	no x-secs															
		20-Aug	-71.5	4.3	12																
		04-Sep	-72	3.6	10																
		15-Sep	-71.5	4.3	7.5																
		30-Sep	-71.5	4.3	6.5																
		17-Oct	-71	5.6 (est)	7.5																
Onyx C	54	15-Aug	-46	8	13	14	1.5	100	11	2.1	80	14	4.9	70	12	6.2	40	9	3.8	95	75
		26-Aug	-47.5	4	13		1.5	100		1.9	60		3.7	70		6.1	30		3.8	95	65
		04-Sep	-50	0.3	14		1.5	100		0.9	60		2.4	60		dry	n/a		dry	n/a	n/a
		15-Sep	-45	7.3	10		1.5	100		2.8	60		5	70		6.2	40		4.2	99	75
		30-Sep	-47.5	4	8.5	no x-secs	this date														
		17-Oct	-27	370	7.5		4	100		3.9	100		6.6	100		7.7	99		6.7	100	100
Scotch C	80	15-Aug	717.5	n/a, stage only	n/a	no x-secs															
		26-Aug	716	n/a, stage only	14																
		04-Sep	714.5	n/a, stage only	12.5																
		15-Sep	715.6	n/a, stage only	9																
		30-Sep	713.8	n/a, stage only	8																
		17-Oct	728	n/a, stage only	5.5																
Hiuihill C	55	15-Aug	-63	73	15	9	6.1	70	8	6.5	80	9	4.3	100	10	5.2	95				85
		26-Aug	-63	73	14	no x-secs	this date														
		04-Sep	-65	44	13		2.4	100		6.4	70		4.3	99		5	90				90
		15-Sep	-62.5	74	10		6.3	70		6.5	70		4.4	100		5.3	95				85
		30-Sep	-67	36	7.5		2.4	100		6.4	70		4.3	100		5	95				90
		17-Oct	-61	100	8		6.6	80		6.7	85		4.7	100		5.5	95				90
L. Sinmax Ck.	56	15-Aug	0.18	170	14	7	4	100	13	3.4	100	19	6.7	70	17	6.2	100				90
		26-Aug	0.18	172	14	no x-secs	this date														
		04-Sep	0.18	169	13		4	100		3.4	100		6.6	70		6.3	100				90
		15-Sep	0.175	148	11		4	100		3.4	100		6.7	70		6.3	100				90
		30-Sep	0.18	170	11	no x-secs	this date														
		17-Oct	0.25	200 (est)	9		4.2	100		3.4	100		3.8	100		6.3	100				100
Mid Sinmax Ck.	57	26-Aug	n/a	nks 70m d/s Smith brid	n/a	no x-secs															
		04-Sep	n/a	ıks 120m u/s Smith brid	20-22																
		15-Sep	n/a	nks 90m d/s Smith brid	13.5																
		30-Sep	n/a	inks 5m d/s Smith bridg	13.5																
		17-Oct	n/a	ıks 170m d/s Smith brid	8																
L. Johnson Ck.	60	04-Sep	n/a	26	14	no x-secs															
		15-Sep	n/a	9.7	9.5																
		30-Sep	n/a	2.5	8.5																
		17-Oct	n/a	29	7																
U. Johnson Ck.	61	04-Sep	est 0.34	25	19	no x-secs															
		15-Sep	0.31	5.1	13																
		30-Sep	0.29	<1	11.5																
U. Sinmax Ck.	58	04-Sep	n/a	39	15	no x-secs															
		15-Sep	n/a	40	12																
		30-Sep	n/a	35	12																
Lime C	62	15-Sep	n/a	1.5	n/a	no x-secs															
		30-Sep	n/a	1.3	n/a																
		17-Oct	n/a	2	n/a																

North Shuswap Circuit (cont.)

Ross C	59	Dry all visits until flow resumed on last vist on 17 Oct at estimated 650 l/s
Hlina C	78	Flowing on 26 Aug, dry on 4 Sep, flowing again on 15 Sep
Sinmax C	79	At outlet of Forrest Lk, flowing at all 6 visits

Appendix B. Anecdotal Information on Fish Behaviour, Wetted Stream Width and Irrigation Use and Impacts on Flow.

Stream	Date	Observation	Comments
Sinmax Ck	05-Sep	Fish kill	Dozens of small dead fish (and very few live ones) in 20^0C pool where surface flow ended. Surface flow reappeared a few m d/s at 21^0C ending completely in a 22^0C pool further d/s.
Many	Many	Fish presence	Many culvert exit scour holes contained fish up to 15 cm long for duration of project.
Joseph Ck	Oct	Fish in gravel	As water temperatures cooled, fish less noticeable. Disturbance of channel bottom near edge of water on Joseph and one other creek caused small fish to emerge from gravel.
Most	All	Wetted width fairly constant until flow approaches zero	A detailed examination of the project wetted width data is necessary to draw any meaningful conclusions from it.
Sinmax Ck	15-Sep	Irrigation withdrawal reduces stream flow	Diversion running 63 sprinklers turned on for the first time between two gauging sites. This sole water use reduced the previously steady stream flow at d/s site by 20 l/s, about 12%, despite an increase in flow at the u/s site.
All	Oct	Not much irrigation	Little irrigation use observed after end of licensed irrigation season. Only casual observation while driving the 5 low flow circuits.
Many	Aug-Sep	Irrigation use less than expected	Perhaps due to dry sources as much as anything. Only casual observation.