SUMMER 2003 LOW FLOWS IN THE

SOUTHERN INTERIOR OF BRITISH COLUMBIA

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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. 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.

Table 1: July and August 2003 Monthly Precipitation 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

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. Significant rainfall in the middle of September east of Kamloops brought streams in the Shuswap area up substantially. General rainfall in mid-October ended the severe low flow conditions throughout the region. The lack of rainfall in July and August following the low snowpack runoff resulted in very low summer flows in the region. Table 2 provides the 2003 summer drought return periods for long-term natural flow stations in the study area. Note that once the 2003 preliminary flow data are approved, incorporating the 2003 rare low flow data in updated drought frequency analyses will reduce the rarity of the 2003 event in many cases because low flows are normally adjusted upward.

In August, Fisheries and Oceans Canada (DFO), the BC Ministry of Water, Land and Air Protection (WLAP), Fraser Basin Council (FBC), and Salmon River Watershed Roundtable (SRWR) staff began a systematic low flow monitoring program on select streams having important fisheries values to document the impacts of the intensifying drought on that resource. Stream temperatures were usually collected at the time of the discharge measurements. Flow measurements began in mid-August continuing through to mid- October in three sub-areas called Nicola, Shuswap, and North Thompson to the north, east, and south of Kamloops, respectively, at a frequency generally between two days and two weeks.

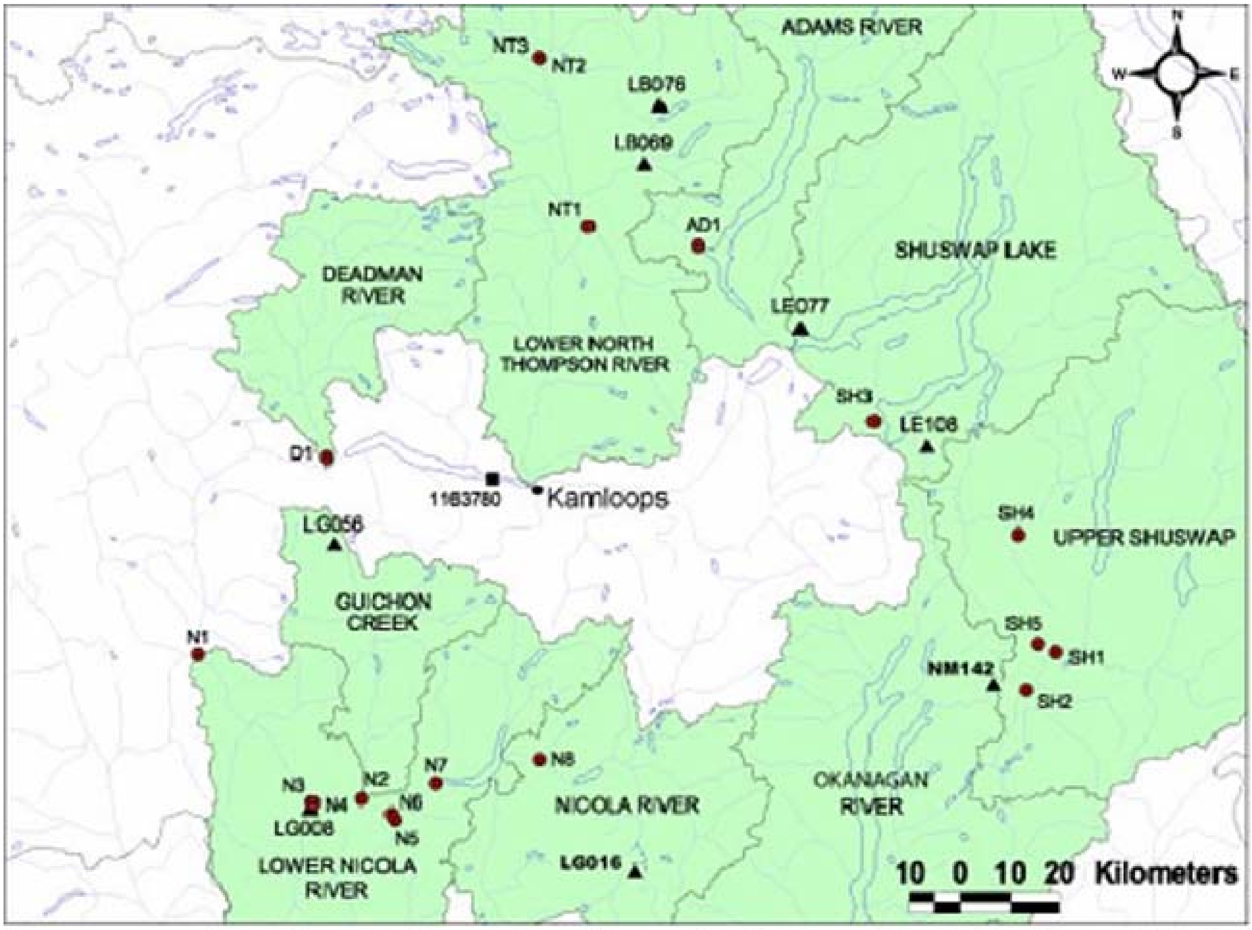
Table 2: 2003 Drought Return Periods for Natural Flow WSC Hydrometric Stations1 in the Region

Station Name	Station No.	Sub-basin	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	NTR	0.392	0.468	03-09 Sep	26	100
Barriere R bel. Sprague Ck	08LB069	NTR	1.08	0.873	07-13 Sep	34	75
East Canoe Ck	08LE108	Shuswap	0.0033	0.0029	03-09 Sep	16	50
Guichon Ck at Tunkwa Lk div.	08LG056	Nicola	0.0143	0.0047	03-09 Sep	31	5
Coldwater R nr. Brookmere	08LG048	Nicola	0.371	0.26	04-10 Sep	30	30
Corning Ck	08LE077	Shuswap	0.0081	0.006	03-09 Sep	21	30
Spius Ck[2]	08LG008	Nicola	0.292	0.46	02-08 Sep	34	90
Pennask Ck	08LG016	Nicola	0.044	0.014	02-08 Sep	35	5
Coldstream Ck abv mun. div.	08NM142	Shuswap	0.0018	0.007	25-31 Aug	24	>100

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

Two continuous stream flow gauges were also installed on the Nicola River as part of the project, one upstream of the Coldwater River and one upstream of Spius Creek on 14 August. Water level data were collected at 15-minute intervals at both sites until 11 November. Figure 1 is a location map showing the 2003 data collection sites (DFO sites) and WSC stations in the region. The Nicola Basin was given highest priority for flow data reduction and analyses.

The four objectives of this report are: (1) to provide a quick reference to summary DFO drought flow and water temperature data collected between July and October; (2) to quantify the severity of the 2003 drought within the three sub-areas in an historical and spatial context; (3) to explain some of the low flow variability along the Nicola River and its main tributaries; and (4) to provide recommendations to improve the efficiency of future low flow monitoring programs.



2003 Low Flow Transect Site	Site No.	WSC Stations	Site No.	AES Stations	Site No.
Lower Nicola	N1	Harper	LB076	Kamloops	1163780
Guichon	N2	E. Canoe	LE108		
Spius	N3	Corning	LE077		
Nicola above Spius	N4	Spius	LG008		
Coldwater	N5	Guichon	LG056		
Norgaard	N6	Coldwater	LG048		
Clapperton	N7	Barriere	LB069		
Beaks	N8	Coldstream	NM142		
Deadman	D1	Pennask	LG016		
Louis	NT1				
Lemeiux	NT2				
Sinmax	AD1				
Bessette	SH1				
Duteau	SH2				
Tappen	SH3				
Trinity	SH4				
Vance	SH5				
Eakin	NT3				

Figure 1: Location Map of 2003 WSC and DFO Low Flow Stations and AES Climate Stations

METHODOLOGY

Field data collection

Suitable measuring sections were established initially on selected biologically sensitive streams. Discharge in the Nicola Basin was measured using a Marsh-McBirney flow meter; in the other two basins, discharge was measured using Swoffer flow meters. Occasional checks of Marsh-McBirney discharge measurements were made using an OSS meter for a second measurement, but performance of the Swoffer meters was not investigated in detail until the field season had concluded. The metering sites were visited as often as crews could schedule trips. Number of measurements made at 31 metering sites ranged from 1 to 14.

Discharge rating tables for the two continuous recorders installed on the Nicola River were computed by WLAP staff from a series of discharge measurements made over the range of low flows encountered.

Air and water temperatures, often to the nearest 0.1-degree, and weather conditions were usually recorded each time a flow measurement was made.

Metering techniques were based on Provincial stream gauging standards; habitat observations were also recorded in some instances (T. Chestnut, pers. comm., 2004).

Analyses of Data

i) All 3 basins

WSC preliminary 2003 discharge data were compared to previously calculated return period flows for all long-term natural flow stations to determine the 2003 drought frequency for the minimum 7-day average summer low flows. Annual Basin Aggregate Drought Indices were also calculated incorporating all operating WSC stations (both regulated and non-regulated) that had suitable records for each of the past 20 years to put the 2003 drought in perspective on an entire sub-area basis.

Current and past low flow studies done in the Region and WSC records dating back to 1970 (the last well-known dry summer) were reviewed to help define the severity of the 2003 drought.

2003 preliminary WSC long-term station 7-day average low flows were compared to Mean Annual Flow (MAF) and September mean flows at each station for their entire periods of record and to prescribed fish conservation flows where known.

Some discrepancies between DFO data and nearby WSC preliminary data, and DFO data and WLAP data were brought to light, and, in most cases, will likely be resolved to everyone's benefit.

ii) <u>Nicola Basin only</u>

In addition to the above, Nicola Basin data underwent other analyses. The Basin Aggregate Drought Index analysis for the last 20 years was expanded to include 1-day minimum summer low flows at all long-term WSC stations. 7-day Basin Drought Index values were also calculated for only those stations that did not have summer flows augmented by reservoir releases. Lowest 1-day summer flows for all operating long-term basin stations were also ranked quantitatively for the previous 20 years of record and for the entire record at each station to compare the 2003 drought flows to recorded flows; this same comparison was also done using only those stations that did not have storage-augmented summer flows.

After a review of rainfall records at the BC Ministry of Forests climate stations in the basin, daily stream discharge for dry weeks and weeks with some rainfall were investigated both at-a-station and between stations for impacts and unusual flow responses.

Discharge at different locations along the same stream was investigated for anomalies in 2003 low flows. Continuous record at and between the two dataloggers on the Nicola River was studied to find evidence of water withdrawal impacts.

FIELD DATA SUMMARY

Appendix A lists all the stream flow and water temperature data collected in the Nicola Basin during this study. Appendices B and C list the stream flow and water temperature data collected in the Shuswap and North Thompson Basins, respectively. The Shuswap and North Thompson flow data were collected using Swoffer meters; therefore, this data is presently unproven. The original field notes, including weather and habitat data, and photos of the channels at low flow are available in the DFO Kamloops office.

<u>Data Uncertainties</u>

Very small flows in steep natural channels can be difficult to measure accurately without artificial flow control, such as weirs or flumes. Pike and Scherer (2003) note that accurately metering very low flows is difficult for several reasons. The accuracy of individual current meter measurements depends on the type of meter used, the suitability of the measuring site, and the skill and experience of the individual streamgauger. All current meters are less accurate in very low-velocity streams (say < 0.15 m/s) and/or in very small cross-sectional areas where there are large edge effects on the meter performance. Figure 2 depicts a natural channel at very low flows where the metering location choice is between a shallow, narrow riffle and a pool having a negligible velocity.

Figure 2: Small stream channel in southern interior of BC at a very low flow.

During the field season, some comparisons were made between different flow meters at a few measuring sites. The Marsh-McBirney meter results were similar to the OSS meter results in these comparisons. However, streamgauging staff had reservations about the accuracy of the Swoffer meters, particularly at very low velocity sites. Swoffer meter results differed somewhat from those obtained with the March-McBirney in two field comparisons. After the field season, one of the Swoffer meters was tested under controlled conditions by the streamgaugers. It under-measured velocities, particularly when velocities were very low (< 0.2 m/s).

Swoffer meters were used exclusively in the Shuswap and North Thompson sub-areas. Confidence in the accuracy of the flow measurements conducted in these areas is thus lower than that in the Nicola data. Miscellaneous Price current meter measurements made on Sinmax and Eakin creeks in the same reaches during a 5-week period show the Swoffer meter always recorded less flow than the Price and not in a consistent manner.

One piece of information that would have helped relate miscellaneous flow measurements together by providing a check on the accuracy of each discharge measurement made is a water level reference. Very small water level changes were important during these extremely low flows in the smaller streams. A stage change of less than one cm could indicate a flow change that would not be recorded due to discharge measurement inaccuracy.

The decision to conduct an in-house drought-monitoring program in 2003 was made late in the summer. Staff had to fit in their stream-gauging duties amongst their regular heavy workloads. Crews still managed to collect a lot of valuable flow data by the end of the summer.

ANALYSIS OF DATA

Nicola Basin

Nicola Basin data was analysed in greater detail than the data from the other two sub-areas. There were more long-term WCS gauges operating in this basin than in the other two sub-areas, and the 2003 DFO flow data collected in the Nicola was thought to be more accurate. The two continuous recorders installed in the Nicola River for the study period also provided information on short-term discharge fluctuations in the river at these two locations and, in conjunction with the WSC recorders and miscellaneous measurements on tributaries, allowed documentation of losses in channel flow between an upper station and a lower station on a particular stream segment.

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 tributary watersheds. In the Nicola Basin, for instance, Guichon Creek in its natural upper watershed and Pennask Creek experienced modest 5-year droughts. At the other end of the scale, Spius Creek and Coldwater River at their mouths both recorded their lowest flows in 40 and 51 years of record, respectively.

i) Historical context

Table 3 provides a simple numeric ranking of the 2003 summer lowest daily discharge compared to the past 20 years of record and to the entire period of record at all operating Nicola Basin WSC stations. The 2003 drought severity rankings for individual stations in the table are then averaged

Table 3: Comparison of Summer 2003 WSC Nicola Basin Stations 1-day Minimum Flows to Previous 20 Years and to Entire Record.

Stream	WSC No.	2003 Compared to Record since 1984 or later		2003 Compared to Entire Record Available		Comments
		Drought rank	% Probability	Drought rank	% Probability	
Nicola R nr Merritt	LG007	3 of 18	17	16 of 50	32	Late summer flows increased after Nicola Dam rebuilt in 1986
Nicola R nr Spences Bridge	LG006	2 of 20	10	5 of 53	9	
Nicola R abv Nicola Lake	LG049	2 of 20	10	4 of 39	9	Location of gauge changed slightly in 2002
Nicola River at Nicola Lk. outlet	LG065	4 of 18	22	n/a	n/a	Late summer flows increased after Nicola Dam rebuilt in 1986
Nicola Lk (level only)	LG046	1 of 18	6	n/a	n/a	Minimum lake levels lowered when Nicola Dam rebuilt in 1986
Spius Ck nr Canford	LG008	1 of 20	5	1 of 40	2	
Spius Ck below Silver Ck	LG068	1 of 4	25	1 of 4	25	Station only running for last 4 years
Coldwater R nr Brookmere	LG048	2 of 20	10	2 of 38	5	
Coldwater R at Merritt	LG010	1 of 12	8	1 of 51	2	Station abandoned in 1995
Guichon Ck at Mamit Lk outlet	LG041	3 of 20	15	11 of 47	23	
Guichon Ck at mouth	LG067	7 of 20	35	18 of 43	42	Record prior to 1984 from WSC gauge LG004 from 1961 to 1983
Guichon Ck abv Tunkwa div	LG056	5 of 20	25	10 of 35	29	
Pennask Ck	LG016	3 of 20	15	8 of 49	16	
Avg. probability for all stations excluding LG068 short record			15		17	
Avg. probability for all stations excluding Nicola & Guichon d/s of dams			10		9	

for the two periods of record to provide a rough estimate of the severity of the 2003 summer drought on a basin-wide basis (with and without the stations having flow augmented by major storage releases over the summer) at the bottom of the table.

A modified aggregate stream flow index similar to that in Luecke et *al.* (2003) provides a second method of determining drought severity in 2003 in the Nicola. This method is referred to as the Basin Aggregate Drought Index method. Figure 3 provides 7-day average and 1-day aggregate summer minimum flow indexes calculated from the eleven currently operating long-term WSC stations in the basin for the past 20 years. The following table interprets the index values in Figure 3.

Index	1	2	3	4	5	6	7	8
Flow Percentile Range	1	2-9	10-24	25-49	50-74	75-89	90-99	100
Interpretation	Lowest on Record	Very Much Below Normal	Much Below Normal	Below Normal	Above Normal	Much Above Normal	Very Much Above Normal	Highest on Record

It is obvious, both visually and statistically, that there has been no trend in summer low flows over the last 20 years, although there has been a gradual drying trend from 1999 to 2003. Most of the eleven streams used to calculate the yearly aggregate index values have seen at least one lower flow over the previous 20 years of record. The years 1985, 1987, 1988, 1992, 1994, and 1998 saw low summer flows occur on most streams.

It is difficult to accurately assess the return period of flow events on heavily regulated streams such as most of those in the Nicola because water use can be significantly variable on regulated streams. Using long-term natural (or lightly regulated) WSC preliminary data (see Table 2) and WLAP drought network station 2003 data in the watershed from Doyle (2004), Nicola Basin streams experienced a summer drought ranging from a 5-yr recurrence interval to, perhaps, a 40-year recurrence interval. The Nicola encompasses parts of 4 hydrologic sub-zones that may explain some of the relative variation in the 2003 low flows within the basin (Obedkoff 1998). Based on Figure 3 and Tables 2 and 3 herein, and findings in Ministry of Environment and Parks (1986) and in Doyle (2004), the 2003 summer drought is thought to be a 10-to15-year natural flow event in the Nicola Basin as a whole. The fact that the Nicola Basin escaped the serious wildfires that plagued other parts of the region may be an indicator that the area did not get as dry in 2003 as other areas.

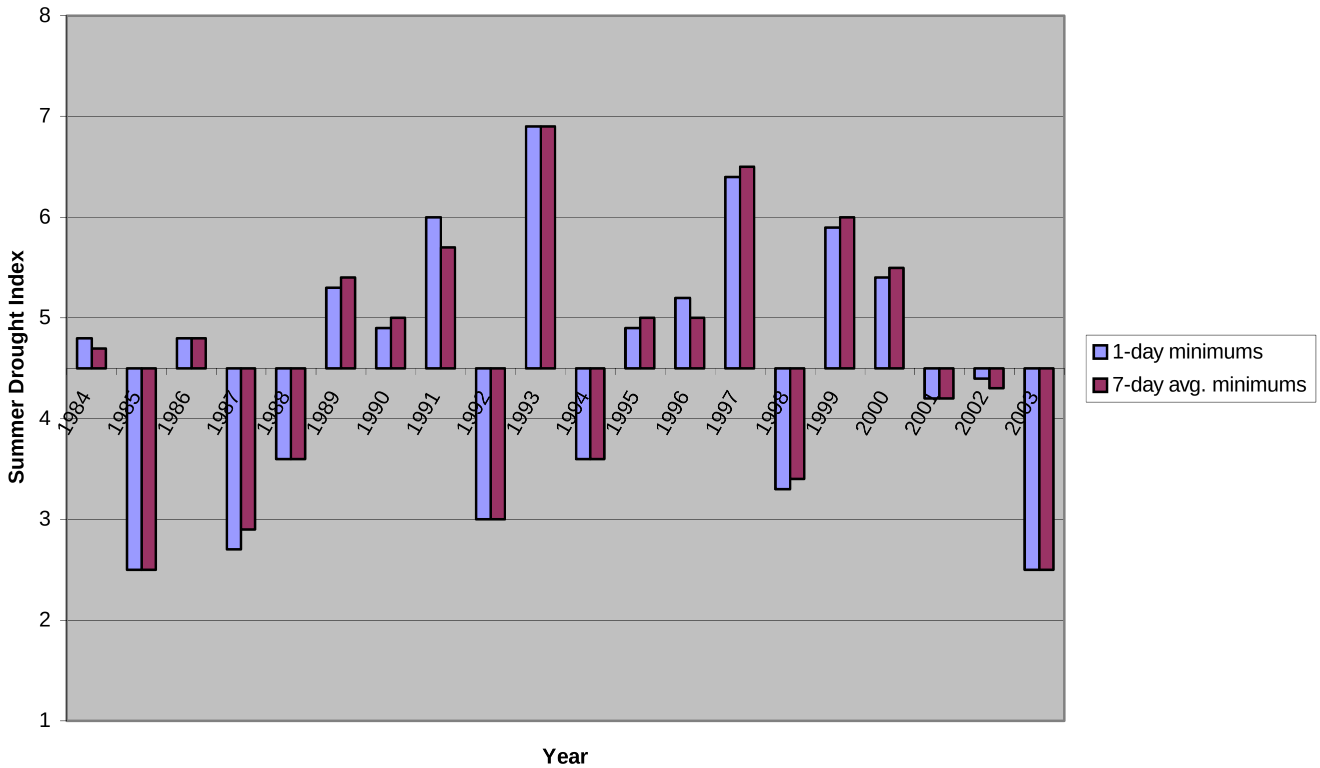


Figure 3: Aggregate Indexes of the Severity of the 1-day and 7-day Average Minimum Summer Low Flows (Level) in the Nicola Basin from 1984 to 2003.

ii) Effects of regulation on stream flow

The review of stream flow records on each stream since 1984 uncovered how dramatic the effects of flow regulation can be on a stream. In 1989, a summer in which all Nicola Basin flows were well above average, including upper Guichon Creek, Guichon Creek outflow from Mamit Lake at the dam was suddenly reduced to zero in late September. This curtailment of flow in Guichon Creek was evident all the way to the mouth.

Especially indicative of upstream regulation are jumps in discharge during rainless periods. Unusual increases or drops in discharge over short periods of time reflect some manipulation of the flow upstream. Flow data supplied by the two Nicola River dataloggers every 15 minutes between 15 August and 11 November suggests that there is a random diurnal discharge range during the extreme low flow period of up to 7%. Much of this diurnal fluctuation could be the result of heavier water use upstream during the cooler hours of darkness compared to daytime. Figure 4 depicts the diurnal cycle of flow over a 72-hour period in early September at the Nicola River recording gauges upstream of Coldwater River and upstream of Spius Creek. The daily hydrograph peak is believed to be close to the natural hydrograph recession curve, and the difference between an imaginary line connecting the daily peaks and the actual measured hydrograph reflects water losses from one day to the next at each station. It is also felt that **e**xtended hours of irrigation into daytime on 4 Sep resulted in little recovery of the hydrographs on the following day as the figure shows.

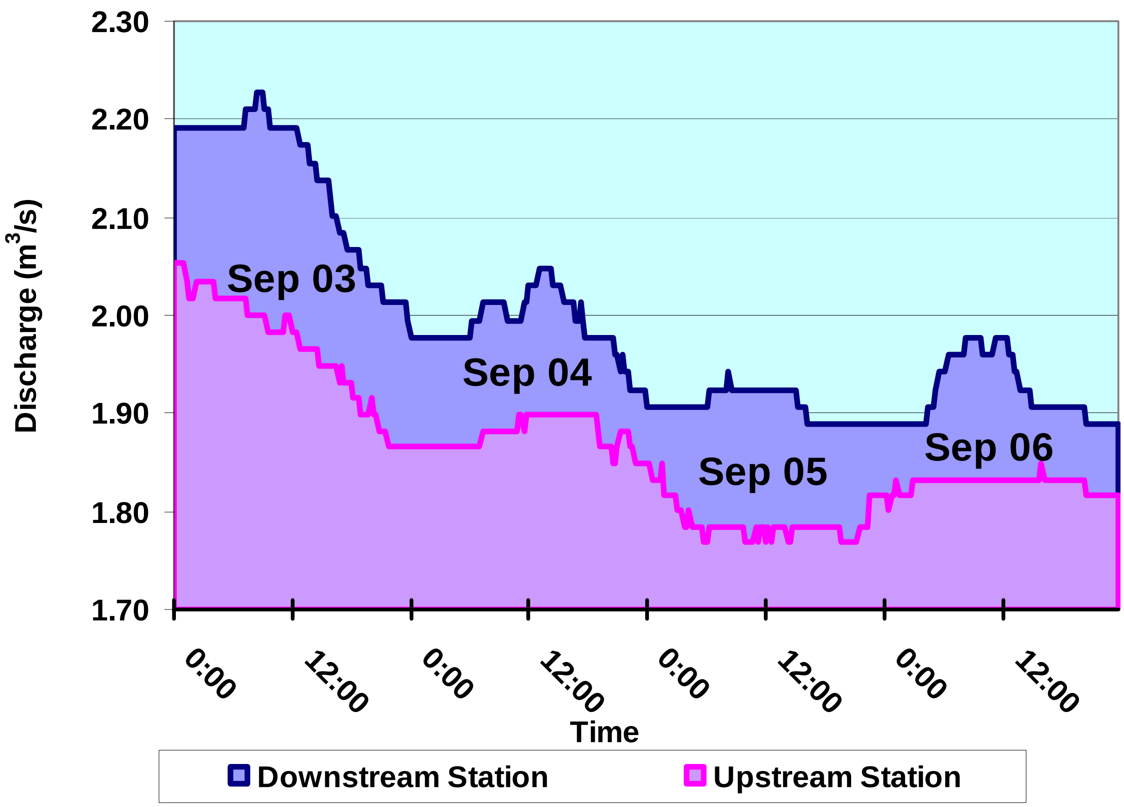


Figure 4: Diurnal Fluctuations in Discharge at the Temporary Dataloggers in Nicola River Upstream of Coldwater River and Upstream of Spius Creek Adjusted for Travel Time from 3 to 6 September.

The preliminary 2003 WSC data clearly show impacts of storage regulation. For example, the gate on Mamit Lake was lowered on 28 August reducing the outflow from the previous day by 75%. This flow decrease is reflected 3 days later at the gauge at the mouth of Guichon Creek about 40 km downstream by a similar amount.

Another good example of regulated flow changes is Clapperton Creek flow data in early September. During a rainless period when natural flow would be gradually diminishing, the discharge measured in Clapperton was 0.033 cms on 2 September, 0.062 cms on 4 September, and 0.039 cms on 8 September. Also, on 28 August, flow in Clapperton was measured at a robust 0.273 cms after 0.129 cms was measured on 25 August. Inspection of the channel on 28 August did not determine the cause of flow variation, but a momentary closure of an upstream diversion could be assumed (B. McFarlane, pers. comm., 2004).

Table 4 summarizes daily flows and miscellaneous measurements during the rain-free lowest flow week of the summer at all the Nicola gauging sites that were operating in 2003. This rainless period was ended by very light rainfall at some locations in the valley on 8 Sep. The very hot days ended on 6 Sep. Table 4 data allows one to make a few deductions about Nicola Basin flow during the lowest flow week of the summer: (1) at the four natural-flow stations located at the higher elevations, flow was approaching its nadir as the baseflow recession constant was approaching unity; (2) increases in daily flows at regulated stations are likely evidence of upstream regulation – fluctuations in Clapperton Creek flow being the most dramatic example of this; (3) there is little increase in Nicola River flow from Nicola Lake to the mouth other than small contributions of tributaries, and; (4) releases from Nicola Lake Dam sustain the bulk of flow in the Nicola River all the way to the Thompson River.

Table 4. Daily Flows at All Nicola Basin Gauging Sites During the Rain-free Lowest Flow Week of the 2003 Summer

Regulated Discharge Measurements

Date	Nicola abv Coldwater	Nicola abv Spius	Nicola at S. B.	Guichona t mouth	WSC Guichon at mouth[1]	Guichon at outlet lake	Coldwate nr mouth	Nicola nr Merritt	Nicola at outlet lk	Nicola abv Nicola Lk	Clapperton	Spius nr Canford	Spius at mouth
02-Sep	2.082	2.273	2.95	(DFO)	0.042	0.071		2.36	2.24	0.054	0.033	0.309	
03-Sep	1.923	2.139	2.88	0.052	0.042	0.065		2.23	2.04	0.054		0.308	
04-Sep	1.866	1.990	2.81		0.042	0.061	0.107	2.18	2.06	0.054	0.062	0.296	0.26
05-Sep	1.834	1.908	2.75	0.034	0.042	0.06		2.14	2.05	0.052		0.282	
06-Sep	1.856	1.921	2.72		0.042	0.059		2.09	2.04	0.052		0.282	
07-Sep	1.906	1.918	2.69		0.051	0.059		2.15	1.96	0.053		0.275	
08-Sep	1.894	1.944	2.7		0.051	0.058	0.079	2.13	1.92	0.053	0.039	0.294	0.336

Natural Discharge Measurements

Date	Guichon abv Tunkwa	Pennask	Spius bel Silver C	Coldwater nr Brookmere
02-Sep	0.016	0.044	0.057	0.4
03-Sep	0.015	0.043	0.057	0.38
04-Sep	0.015	0.043	0.058	0.37
05-Sep	0.014	0.044	0.056	0.365
06-Sep	0.014	0.044	0.056	0.37
07-Sep	0.014	0.045	0.055	0.375
08-Sep	0.013	0.045	0.055	0.37

[1]*Manual gauge - water level read once a day. These data expected to be revised*

Table 5 clearly shows how critically important releases from Nicola Lake are in augmenting low flow in the Nicola River during summer droughts when consumptive use throughout the watershed is very high. This is not to say that releases from the dam make it all the way to the mouth, since losses to evaporation and off-stream use must be weighed against gains from tributary flows and groundwater influx over the entire stream length.

Table 5: Nicola Dam Release as Percentage of Nicola River Flow from Nicola Dam to Mouth During Lowest Flow Week of 2003 Summer

Location on River	**7-day Avg. Low Flow (cms)**	**Reservoir Release as % of Discharge (%)**
Nicola River at Nicola Dam	2.04	100
Nicola River below Coldwater River	2.18	94
Nicola River near mouth	2.72	75

iii) Effects of rainfall on stream flow

The preliminary 2003 WSC data also shows the influence of small amounts of rainfall on streamflow. The varying amounts of rainfall during 6-11 August recorded at all 5 Ministry of Forests meteorological stations in the basin and smaller amounts of rain at 4 of the 5 sites between 26 – 28 August are reflected in small increases in flow at most WSC stations. Table 6 illustrates the bump in daily discharges at those Nicola Basin stations unaffected by major storage releases during two separate weeks in August when rain showers moved through the watershed at times of steadily diminishing flows. In most cases, stream flows increased by only a few percent but increases of up to 25 % were recorded.

iv) Data inconsistencies between WSC and DFO data

Some inconsistencies are apparent between preliminary 2003 WSC data and DFO data. Since all the 2003 WSC data are preliminary, internal review of this data will likely result in data revisions prior to publishing the data. Two such examples are: (1) at the WSC gauge at the outlet of Nicola Lake (08LG065) where the preliminary data show a rising outflow for a few days at the end of August while the lake level continued to drop and the dam gates were stationary, and; (2) at the Guichon Creek WSC gauge at the mouth (08LG067) where 2003 preliminary data indicate a steady discharge of 0.042 cms from 1-6 September. The Guichon gauge is a manual one with a single water level reading taken each morning. At the Guichon site, DFO miscellaneous discharge measurements made on 3 September and on 5 September were 0.052 cms and 0.034 cms, respectively. The difference in flows between the WSC and DFO Guichon data may be partly reconciled when the WSC data is reviewed prior to approval, may reflect the difficulties of measuring extreme low flow accurately, or

Table 6: Daily Discharge Changes at Nicola Basin WSC Stations Unaffected by Storage Releases During Weeks When Rain Recorded in Basin.

Stream	WSC #	Daily Flow During First August Period of Showers						
		Aug 6	Aug 7	Aug 8	Aug 9	Aug 10	Aug 11	Aug 12
Spius Ck bel Silver Ck	08LG068	0.12	0.12	0.116	0.119	0.122	0.145	0.125
Spius Ck nr Canford	08LG008	1.01	1.01	0.987	1.08	1.09	1.16	1.1
Coldwater R nr Brookmere	08LG048	0.712	0.705	0.678	0.732	0.746	0.764	0.738
Guichon Ck abv Tunkwa div.	08LG056	0.021	0.023	0.025	0.027	0.029	0.031	0.028
Nicola R abv Nicola Lk	08LG049	0.222	0.19	0.179	0.164	0.153	0.15	0.134
Pennask Ck	08LG016	0.057	0.057	0.057	0.058	0.058	0.058	0.058
Stream	**WSC #**	**Daily Flow During Second August Period of Showers**						
		Aug 24	Aug 25	Aug 26	Aug 27	Aug 28	Aug 29	Aug 30
Spius Ck bel Silver Ck	08LG068	0.059	0.06	0.073	0.08	0.077	0.065	0.058
Spius Ck nr Canford	08LG008	0.318	0.316	0.334	0.378	0.43	0.392	0.34
Coldwater R nr Brookmere	08LG048	0.447	0.44	0.435	0.425	0.425	0.42	0.421
Guichon Ck abv Tunkwa div.	08LG056	0.019	0.019	0.02	0.019	0.02	0.019	0.018
Nicola R abv Nicola Lk	08LG049	0.057	0.059	0.06	0.062	0.06	0.06	0.059
Pennask Ck	08LG016	0.049	0.048	0.049	0.049	0.049	0.049	0.048

could be evidence of changes in water diversion(s) upstream on those days. WSC staff expects that these preliminary flow data in both these instances will be revised during normal reviews (R. Ellis, pers. comm., 2004). No obvious errors were evident during review of the transcribed DFO field notes at the Guichon site.

v) <u>Spatial comparisons</u>

Within-basin and along-stream variability in the severity of a drought suggest that vulnerable tributaries or different reaches of an acknowledged sensitive main stream may suffer lesser or greater resource losses than the main stream or other reaches of the main stream during a drought which record is captured only at gauged locations. Certainly Coldwater River, and possibly Spius Creek, flows are reduced more than usual in very hot, dry summers by larger than normal upstream withdrawals as the streams pass through irrigated ranch lands.

An extreme case of water loss is demonstrated by the Coldwater River. Flows at the mouth during the driest week of the 2003 summer were only about one quarter of the natural flow upstream at the Brookmere gauge. A review of past years when there was concurrent WSC record on the Coldwater at the mouth and at Brookmere indicate that the lowest summer flows at the mouth were usually between one-half and two-thirds of the flow at Brookmere. In general, the Coldwater River experiences higher flow losses with increasing summer drought severity.

Shuswap Basin

A modified Basin Aggregate Drought Index computed in the same way as was done in the Nicola, provides a method of determining drought severity in 2003 in the Shuswap. Figure 5 provides 7-day average summer minimum flow indexes calculated from nine long-term WSC stations operating in the basin for the past 20 years. The table previously shown for the Nicola Basin drought index interprets the index values in Figure 5.

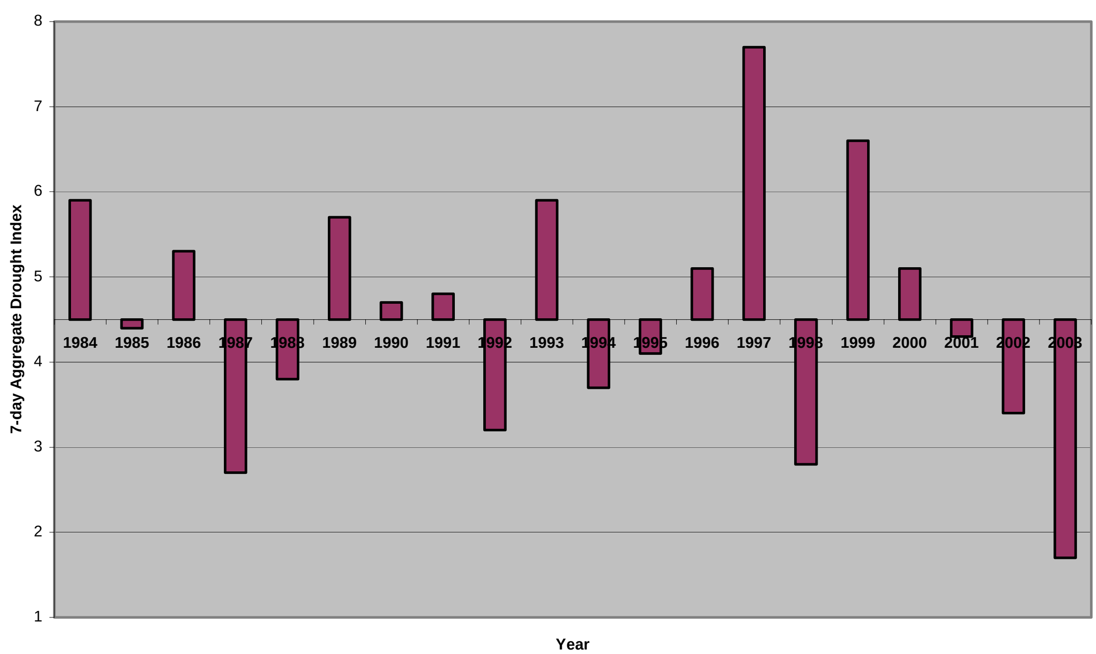


Figure 5: Aggregate Index of the Severity of the 7-day Average Minimum Summer Low Flows in the Shuswap Basin from 1984 to 2003.

As in the Nicola Basin, there has been no observable trend in summer low flows in relation to the 20 year period of record examined, but there has been a steady decline in summer low flows since the wet summer of 1999. Only three of the nine streams used to calculate the yearly aggregate summer drought index values have seen lower flows over the previous 20 years of record. The years 1987, 1988, 1992, 1994, 1998, and 2002 saw low summer flows occur on most streams. Based on Figure 5 and Table 2 herein, and findings in Doyle (2004), the 2003 summer drought is thought to be greater than a 25-year natural flow event in the Shuswap sub-area. Furthermore, a review of summer flow records for the past 35 years indicates that 2003 flows were the lowest in this sub-area over that time span.

North Thompson Basin

A modified Basin Aggregate Drought Index again computed in the same way as for the Nicola and Shuswap basins provides a method of determining drought severity in 2003 in the lower North Thompson. Figure 6 provides 7-day average summer minimum flow indexes calculated from five long-term WSC stations operating in the basin for the past 20 years. The table previously shown to interpret the Nicola Basin index values can be used to interpret the values in Figure 6.

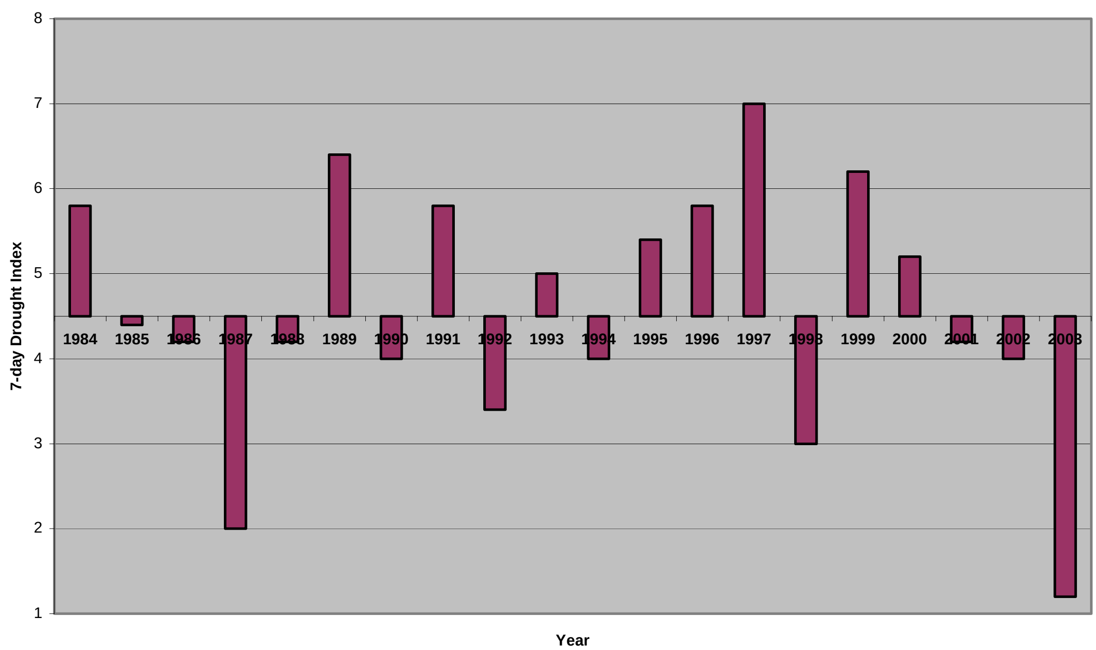


Figure 6: Aggregate Index of the Severity of the 7-day Average Minimum Summer Flows in the North Thompson Basin from 1984 to 2003.

As in the Nicola and the Shuswap sub-areas, there has been no trend in summer low flows over the last 20 years for North Thompson, but there has been a steady decline in summer low flows since the wet summer of 1999. Only one of the five streams used to calculate the yearly aggregate summer drought index values has had a lower flow over the previous 20 years of record. The years 1987, 1992, and 1998 saw low summer flows occur on most streams. Based on Figure 6 and Table 2 herein, and findings in Doyle (2004), the 2003 summer drought is thought to be greater than a 25-year natural flow event in the North Thompson sub-area. Moreover, a review of summer flow records for the past 35 years indicates that 2003 flows were the lowest in this sub-area over that time span.

FISH CONSERVATION FLOWS

General

A summer drought, such as that which occurred in 2003, tests whether there is enough water at non-lethal temperatures left in affected streams for fish to survive and provides context to existing minimum conservation flows for fish. Determining what the minimum flows for fish should be in a particular stream during different species life cycles is a complex task and government scientists in BC are in the process of developing an acceptable methodology to do this (D. Watts, pers. comm., 2004). Doyle (2004) provides changes in wetted stream widths for numerous small streams in the Kamloops region as the extreme low flows varied during 2003. A separate report focusing on the biological aspects of the 2003 summer drought is anticipated (D. Watts, pers. comm., 2004). For the purposes of comparisons drawn in this report, a 20 % MAF calculation was used for minimum fish flow requirements where conservation flows specific to a stream were not available (B. McFarlane, pers. comm., 2004).

Nicola Basin

Table 7 compares existing summer minimum fish flow requirements in Nicola Basin streams from BC Ministry of Environment (1983) to the 7-day average low flows recorded at long-term stations in 2003. BC Ministry of Environment (1983) relied on Kosakoski and Hamilton (1982) for many of its fish flow requirements and the 20% MAF Tennant method (Tennant 1976) for the remainder. Kosakoski and Hamilton (1982) also used the 20% MAF Tennant method (MAF calculated from existing record at the time) as a default method to calculate minimum flows in streams where more detailed assessments had not been conducted. For comparison purposes, Table 7 also lists the 20% MAF and September mean flow for all long-term WSC gauges in the Basin. Drought flows exceeding a 10-yr recurrence interval, as occurred in 2003, are very much less than present minimum fish flow requirements on any Nicola Basin streams (both natural and regulated), except for the reach of the Nicola River from Nicola Dam to Coldwater River confluence.

Table 7: Comparison of Possible Fish Flow Requirements in Nicola Basin Streams at Long-term Gauging Stations to 7-day Average Low Flows Recorded in 2003 Summer

Stream	WSC #	**20% MAF** (cms)	**Min. Fish Flow Required** (cms)	**2003 7-day Avg. Low Flow** (cms)	**2003 Low Flow % MAF** (%)	**Mean Sept. Flow** (cms)	**2003 LF % Mean Sept. Flow** (%)
Pennask Ck.	08LG016	0.151	0.151	0.044	5.8	0.207	21
Coldwater R. nr Brookmere	08LG048	1.37	1.42	0.371	5.4	1.16	32
Coldwater R. at Merritt	08LG010	1.62	1.42	~0.10	1.2	1.26	7.9
Guichon Ck. abv Tunkwa div.	08LG056	0.026	0.026	0.014	11	0.053	26
Guichon Ck. at outlet Mamit L.	08LG041	0.16	0.16	0.047	5.9	0.424	11
Guichon Ck. at mouth	08LG067	0.148	0.2	0.042	5.7	0.377	11
Spius Ck. at Canford	08LG008	2.04	2.22	0.292	2.9	1.71	17
Nicola R. abv Nicola L.	08LG049	0.856	0.78	0.053	1.2	0.993	5.3
Nicola R. at outlet Nicola L.	08LG065	1.06	1.69	1.52	28	2.44	62
Nicola R. nr Merritt	08LG007	2.82	3.12	2.11	15	3.93	54
Nicola R. nr Spences Bridge	08LG006	5.36	5.66	2.71	10	6.48	42
Clapperton Ck.[1]	08LG015	~0.7	0.14	~0.05	~6	n/a	n/a

[1] ***Based on very limited data***

Table 8 compares mean September discharge vs. 20 % MAF for nine long-term natural flow WSC stations in the 3 sub-areas for all years of record through 2001. The natural monthly mean flow for September often falls below this threshold, including Pennask Creek, Guichon Creek, and Coldwater River, which are tributary to the Nicola River.

Shuswap Basin

Table 9 compares default (20% MAF) minimum fish flow requirements in Shuswap Basin streams and also September mean flows to the 7-day average low flows recorded at long-term stations in 2003. Drought flows exceeding a 25-yr recurrence interval (as occurred in 2003) are very much less than default minimum fish flow requirements for Shuswap Basin streams - both natural and regulated - in Table 9, except for the glacier-fed Eagle River and the large South Thompson River draining the entire watershed. September flow may offer a much better starting point to establish summer fish conservation

Table 8: Comparison of Annual Recorded September Mean Discharges vs. 20 % MAF at Long-term Natural Flow WSC Stations.

Station	WSC #	20 % MAF (cms)	Total Yr of Sept. Record	No. of Yr Sept. Mean Q < 20 % MAF	% of time Sept. Mean Q < 20 % MAF
Pennask Ck	08LG016	0.151	45	24	53
Guichon Ck abv Tunkwa div.	08LG056	0.026	34	4	12
Coldwater R nr Brookmere	08LG048	1.37	36	26	72
Corning Ck	08LE077	0.076	24	16	67
E. Canoe Ck	08LE108	0.024	19	7	37
Coldstream Ck	08NM142	0.052	34	14	41
Harper Ck	08LB076	0.822	29	2	7
Barriere R bel Sprague Ck	08LB069	2.34	37	4	11
Fishtrap Ck	08LB024	0.154	34	10	34

flows than MAF in these streams. Refer to Corning Creek, East Canoe Creek, and Coldstream Creek data in Table 8 to see how frequently September mean flows are less than 20 % MAF in natural flow streams in this sub-area.

Table 9: Comparison of Possible Fish Flow Requirements in Shuswap Basin Streams at Long-term Gauging Stations to 7-day Average Low Flows Recorded in 2003 Summer.

Stream	WSC #	**20% MAF** (cms)	**Min. Fish Flow Required** (cms)	**2003 7-day Avg. Low Flow** (cms)	**2003 Low Flow % MAF** (%)	**Mean Sept. Flow** (cms)	**2003 LF % Mean Sept. Flow** (%)
Vance Ck. bel Deafies Ck.	08LC040	0.101	?	0.019	3.7	0.144	13
Bessette Ck. abv Lumby lagoon	08LC042	0.636	?	0.151	4.7	1.34	11
Bessette Ck. abv Beaverjack Ck.	08LC039	0.736	?	0.16	4.3	1.53	10
Salmon R. at Falkland	08LE020	0.58	?	0.291	10	1.25	23
Salmon R. nr Salmon Arm	08LE021	1.03	0.6	0.25 (tentative)	4.9	1.89	13
Corning Ck.	08LE077	0.076	?	0.0081	2.1	0.062	13
Eagle R. nr Malakwa	08LE024	7.68	?	10.2	27	23.7	43
E. Canoe Ck.	08LE108	0.024	?	0.0033	2.8	0.033	10
Coldstream Ck. abv Mun. intake	08NM142	0.052	?	0.0018	0.7	0.083	2.2
South Thompson River	08LE031	58.6	?	104	35	220	47

North Thompson Basin

Table 10 compares default (20% MAF) minimum fish flow requirements in North Thompson Basin streams, September mean flows, and the 7-day average low flows recorded at long-term stations in 2003. Drought flows exceeding a 25-yr recurrence interval, as occurred in 2003, are very much less than default minimum fish flow requirements for lower North Thompson Basin streams - both natural and regulated - in Table 10, except for the large glacier-fed North Thompson River draining the entire watershed. As in the other two basins, September flow may offer a much better starting point to establish summer fish conservation flows than MAF in small streams in the North Thompson Basin. Although September mean flows for the three natural flow streams in this sub-area that are shown in Table 8 - Harper Creek, Barriere River, and Fishtrap Creek - compare more favourably to 20 % MAF as a group than the three streams in each of the other two other basins, a larger sample may show otherwise.

Table 10: Comparison of Possible Fish Flow Requirements in N. Thompson Basin Streams at Long-term Gauging Stations to 7-day Average Low Flows Recorded in 2003 Summer.

Stream	**WSC #**	**20% MAF** (cms)	**Min. Fish Flow Required** (cms)	**2003 7-day Avg. Low Flow** (cms)	**2003 Low Flow % MAF** (%)	**Mean Sept. Flow** (cms)	**2003 LF % Mean Sept. Flow** (%)
Harper C	08LB076	0.822	?	0.392	9.5	1.77	22
Paul C at Pinantan Lk outlet	08LB012	0.036	?	0	0	0.029	0
Lemieux C nr mouth	08LB078	0.616	?	0.005	0.2	1.03	0.5
Barriere R bel Sprague C	08LB069	2.34	?	1.08	9.2	4.54	24
Barriere R at mouth	08LB020	2.96	?	1.6	11	5.39	30
North Thompson R at McLure	08LB064	86.2	?	149	35	354	42

DISCUSSION

The two continuous stream gauges temporarily installed on the Nicola River allow detailed analysis of flows at those locations. The miscellaneous measurements made on major tributaries to the Nicola River in combination with WSC record allow tracking of flow contributions from measured streams to the Nicola and flow variation on the tributaries and mainstem in space and time to permit calculations of storage release, rainfall, and water withdrawal impacts on stream flows at measured points.

Diurnal fluctuations in stream flow may be critical to fish survival in streams that are heavily used and daily mean flows are close to zero. Minimum flows in these streams could be significantly less than mean flows and may go undetected even though miscellaneous flow measurements are made.

Discharge data collected at 10 sites on the Salmon River in the Shuswap Basin by SRWR staff remain largely unexplored due to lack of time and pending confirmation of data accuracy. Unfortunately, the WSC gauge at the mouth malfunctioned during the summer, but WSC and WLAP both have timely discharge measurements that support the SRWR data. There is little doubt that the Salmon River experienced a remarkable summer drought that worsened with closer proximity to the mouth. Low flows recorded at the mouth of the Salmon River were no more than half the lowest summer minimum flow recorded in 44 years of data and may yet be determined to have been even lower than that.

The Salmon data also dramatically indicate the effect of heavy water withdrawals on stream flow along the length of the river. This aspect of the flow data set is beyond the scope of this report but should be studied in detail.

Apparent inconsistencies uncovered between DFO flow measurements and preliminary WSC data collected in close proximity to each other may be resolved during further reviews of the 2003 data.

It is worth noting that 5 of the 14 natural flow WSC stations operating in 1998 in this region have been discontinued and a sixth was destroyed by wildfire during the summer leaving only 8 stations for drought frequency analysis of natural flows in 2003.

The issue of obtaining accurate measurements of small flows in steep natural channels in a reasonable time at little expense for short, infrequent durations without further strain on highly-stressed fish remains unresolved. Preliminary testing and comparisons of limited flow measurement checks indicate that Swoffer meters may under-register discharge when velocities are very low without frequent calibration. Other types of meters/methods may be preferred when measuring very low velocity flows.

All project data are available to others to conduct further analyses on the understanding that the Shuswap and North Thompson DFO flow data are unproven, and Nicola data are preliminary as of the date of this report. Project data combined with additional discharge and water temperature data in Doyle (2004) provides a full 2003 summer drought data set for future investigations. This report provides a solid basis for more detailed analyses of the 2003 summer drought data in all its features.

CONCLUSIONS

A wealth of 2003 summer drought flow and temperature data was collected at 31 DFO sites in the Kamloops area from mid-August to mid-November to augment the WSC flow data and WLAP drought flow network data already available.

All streams, regulated and natural, in the Nicola Basin with the exception of lower Guichon Creek, experienced summer drought flows exceeding a 1-in-5 year recurrence interval. (Higher flows in Guichon Creek below Mamit Lake in recent years may be a result of improved operation of the Mamit Lake dam and more conservative irrigation practices.)

Coldwater River and Spius Creek draining the north flank of the Cascades recorded their lowest flows in 40 and 51 years of record, respectively, in their regulated lower reaches. The upper Nicola watershed, between the very dry Cascades and the somewhat wetter plateau to the north, experienced a 10-to 20-year drought. Overall, the Nicola Basin experienced a 10-to15-year summer drought.

The Shuswap and North Thompson sub-areas both experienced at least 25-year summer droughts in 2003 and, collectively, the lowest summer stream flows in the past 35 years. Most of the streams in these two areas had exceptionally low summer flows.

A method of setting fish conservation flows for small streams in the Kamloops region is needed that acknowledges natural low flow conditions frequently encountered. Average September flows may offer a much better starting point to establish meaningful summer fish conservation flows than MAF in these streams.

RECOMMENDATIONS FOR FUTURE DROUGHT MONITIORING

General

Capturing the essence of hydrologic drought is always a balancing act among resource availability, geographic coverage, accuracy, and focus, all for consideration by the resource manager while he or she is poignantly aware that the drought will end, perhaps too quickly for capturing sufficient data. Resources are always limited, so emphasis on any one of the three components of data collection - area coverage, data accuracy, and data intensity - will result in a reduction in at least one of the other two if not both. Therefore, it is highly desirable and promotes efficiency to carry out as many of the following recommendations as possible before and during a drought monitoring project:

1. Clearly state reasons for selecting streams to gauge and objectives of the gauging at the beginning of the project.

   Examples of criteria for stream selection are:
   - historically water-short stream;
   - important resources in stream subject to losses during drought, and;
   - natural flow site in area lacking discharge records.

   Examples for objectives are:
   - to tie known or suspected drought problems to measured flows;
   - to document changes in flow along a stream, to develop a base gauging site for repeat drought flow measurements, and;
   - to quantify potential effects of specific water uses on stream flow.

2. Select location(s) of gauging site(s) for specific reasons and for utility. (For example, ease of access, good measuring characteristics, surface flow continues even during drought, flow comparison to other existing gauges, contentious site).

3. Identify a project co-ordinator, particularly if multiple agencies are involved in the effort, to check on progress of work and to insure that data collected meets quality standards. Refresh coordination from time to time.

4. Train, equip, and motivate field staff to do the work properly and free them from other duties so that they can focus on documenting the drought.

5. Match staff, equipment, and objectives with an approved project budget that allocates enough funds for data reduction, checking, permanent storage, and analysis in a timely fashion.

6. Ensure that at least one individual in each field crew knows the gauging site(s) being visited, once the site has been established.

7. Review and reduce field notes promptly as a top priority using knowledgeable staff.

8. Calibrate metering equipment annually and clearly mark interchangeable moving parts for identification. Insure that are all moving parts of meter are clean and functioning properly prior to each measurement.

9. Skilfully establish and uniquely describe water level reference points at each site, and carefully reference them each time the discharge is measured. As an example, on the first visit to each measuring site, affix a small section of a retractable measuring tape to a stable article in the channel, which should be inconspicuously located if the site is prone to recreational use; alternatively, fix the level gauge to an embedded stake if no suitable natural base found. This will serve as a precise temporary water level reference over the expected range of low water levels.

   (To provide a more permanent water level reference and a backup reference for the temporary one, select an enduring item in the channel, if such exists, and very carefully reference the prevailing water level to it at the same time as the temporary one. Water level references do not need to be right at the measuring cross-section.

   Adequately mark cross-sections for measuring flow or for any other reasons in the field and carefully measure stream widths at the measuring section each time since changes in depth and width are small at very low flows and small errors can be significant in discharge calculations.)

10. Document field observations of water diversions and use, precipitation in area, channel changes that might affect the stage or discharge at the measuring site related to previous measurements, and other factors potentially affecting data quality to provide the most accurate calculation of flow and permit a better analysis of the whole data spectrum at a later date.

11. Make multiple measurements at sites over the life of a project rather than only a single measurement because each additional measurement boosts confidence in the entire data set and facilitates future analyses of various kinds.

12. Establish temporary gauging sites near existing WSC stations only for very specific reasons. Instead of taking discharge measurements, use existing WSC gauge benchmarks to obtain prevailing water levels and use the station stage-discharge relationship from WSC to compute discharge. This should improve efficiencies while achieving near real-time measurements.

13. If at all possible, schedule miscellaneous measurements made at different sites on the same stream to allow for flow travel time from the upstream station.

14. If at all possible, make repeat same site measurements at roughly the same time of day each time – especially on the smaller streams - to minimize diurnal effects.

15. Exploit presence of free-fall outlets of culverts to accurately measure volume per unit time when flows are sufficiently small.

The following three sub-sections provide recommendations that emphasize each of the three components of a drought data collection program.

Emphasis on intensity of data collection

Concentrate on only a few critical streams that can be serviced by staff dedicated to the project. To determine effects of water withdrawal on low flow, saturate a system for 24-48 hours with flow measurements made at all major flow confluences with appropriate timing lags at least once when withdrawals are heavy and repeat at least once when withdrawals light or absent. This will more accurately determine water balance on a temporal scale. Concurrently, measure flows in diversion ditchs and/or count sprinklers where time and accessibility permits. Record water levels at least every 3 hours at each site and make discharge measurement at least every 6 hours to define the diurnal variation in flow.

Consider installing dataloggers at key locations to greatly increase data intensity and duration of data collection or as a substitute for manual readings when streamgauging staff is insufficient.
Use only reliable flow meters.

Emphasis on accuracy of data collection

Purchase state-of-the-art meters that are tailored for measuring minimal flows in natural channels and train people in their use and maintenance.

Consider installing and leaving measuring weirs (flumes) or dam and pipe in place for the duration of drought where environmental concerns allow it and the risk of losing them to vandalism or sudden high flows over the course of the project is acceptable.

Use temporary weirs (flumes) or pipe-and-bucket dams to improve accuracy of flow measurements where installation of the weir is accommodated by stream substrate and morphology, and environmental concerns allow it.

Recruit local observers to record daily (or even more frequently) water levels at nearby staff gauges or flow measuring devices. These observers could also alert program staff to problems with equipment or significant changes in weather or stream flow at their sites.

Establish the core drought network prior to serious summer drought by setting up water level reference points – gauge plates on bridge piers (abutments where feasible – and making measurements at moderate flows to begin developing rating curves and also to obtain average summer discharge records, even if drought conditions do not develop.

Continue to measure at existing long-term drought monitoring sites – such as the WLAP Regional Low Flow Network - during all droughts.

Emphasis on geographic area of data collection

Plan the drought network now and review the plan each spring in the office and early summer in the field if indications are that a drought is possible.

Make use of all available meters and staff on short notice and be prepared to accept reduced accuracy and intensity of monitoring for the broader coverage gained.

The final two sub-sections deal with recommendations that (1) help ensure that data are readily available for reference and analysis in the future, and (2) are specific to improved coverage of future droughts in the Nicola Basin.

Analysis and archiving of data

Faithfully maintain a master “Summer Drought” file (both paper and electronic) split into drought years to store all data and analyses.

Update summer drought frequency analyses for all streams in this report, both regulated and natural, that have more than 12 years of summer WSC record using the entire record (including 2003) and perhaps shorter lengths of concurrent record.

Create and carry out a precise methodology that directly relates low stream flow to reduced habitat quantity and quality in a reproducible manner.

Nicola River Basin

Measure discharge at the mouths of all tributaries likely to contribute surface flow to Nicola River below the dam.

Make use of all continuous data provided by the 5 recorders on the Nicola River downstream of Nicola Lake in 2003 to understand diurnal fluctuations in flow during the entire low flow period over the entire reach. Enlist cooperation of major water users to provide withdrawal schedules that help relate this information to observed water level changes at and between stations. Where data gaps exist in this information, collect in the future.

As recommended above, measure discharge in the vicinity of an operating WSC gauge only when there is compelling rationale to do so.

Concentrate making frequent measurements and stage recordings (every few hours) on streams where the flow is close to zero and withdrawals are heavy (such as Coldwater River at mouth and Guichon Creek at mouth) to determine diurnal variation in flow.

Forego one or both Nicola dataloggers if 2003 provided enough information on Nicola River withdrawals and redirect effort to other critically low streams such as Coldwater and Guichon.

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Staff of the BC Ministry of Water, Land and Air Protection, Fisheries and Oceans Canada, Fraser Basin Council, and Salmon River Watershed Roundtable carried out the data collection program. WLAP and DFO staff also provided reduced and checked data for summary and analysis. WSC staff provided preliminary 2003 data and yet-to-be published 2002 data. A. Morris produced Figure 1. T. Chestnut reviewed a draft of this report and made several suggestions that improved it. B. McFarlane contributed many useful comments and suggestions throughout reviews of multiple drafts of this report.

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DISCLAIMER

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APPENDIX A

All 2003 Discharge and Temperature Data Collected on DFO Low Flow Network in Nicola Basin.

Summary of All 2003 Discharge and Water Temp. Data in Nicola Basin (including Deadman R.)

Miscellaneous Discharge Measurement Sites

Clapperton Ck. 100 m d/s Hwy 5A bridge and just d/s of domestic intake

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
25-Aug	0.129	MMcBirney	12.3	1120
28-Aug	0.273	MMcBirney	15.5	1605
02-Sep	0.033	MMcBirney	16.7	1600
04-Sep	0.062	MMcBirney	13.6	1040
08-Sep	0.039	MMcBirney	13.5	1510
16-Sep	0.076	MMcBirney	8.5	1040
19-Sep	0.041	MMcBirney	n/a	1030
22-Sep	0.058	MMcBirney	10.4	1055
29-Sep	0.078	MMcBirney	n/a	1255
06-Oct	0.028	MMcBirney	n/a	1100
17-Oct	0.06	MMcBirney	n/a	1255
27-Oct	0.041	MMcBirney	n/a	1045

Coldwater R. 50 m d/s Voght St. Bridge

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
21-Aug	0.219	MMcBirney	19.5	1030
25-Aug	0.185	MMcBirney	15.9	1235
28-Aug	0.208	MMcBirney	16.4	1015
04-Sep	0.107	MMcBirney	19.4	1130
08-Sep	0.079	MMcBirney	15	1025
16-Sep	0.247	MMcBirney	11.4	1140
19-Sep	0.422	MMcBirney	13.6	1120
22-Sep	0.459	MMcBirney	n/a	1210
24-Sep	0.362	MMcBirney	12	1120
25-Sep	0.317	MMcBirney	16.8	1330
25-Sep	0.329	OSS	16.8	1350
29-Sep	0.277	MMcBirney	15.1	1320
06-Oct	0.282	MMcBirney	n/a	1145
27-Oct	7.714	MMcBirney	n/a	1210

Deadman R. 200 m d/s Hwy 1 bridge and just d/s of fish fence

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
22-Aug	0.521	MMcBirney	15.5	1015
27-Aug	0.426	MMcBirney	14.8	1045
27-Aug	0.49	Swoffer	14.8	1140
03-Sep	0.386	MMcBirney	20.5	1515
05-Sep	0.409	MMcBirney	16	930
17-Sep	0.5	MMcBirney	13.5	1425
24-Sep	0.45	MMcBirney	11.5	1505

Guichon Ck. 10 m d/s of Marshall Rd. Bridge

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
22-Aug	0.139	MMcBirney	18	1335
27-Aug	0.154	MMcBirney	17.7	1615
27-Aug	0.131	Swoffer	17.7	1645
03-Sep	0.052	MMcBirney	14.8	1120
05-Sep	0.034	MMcBirney	19	1410
17-Sep	0.093	MMcBirney	9.6	1115
24-Sep	0.092	MMcBirney	11	1210

Nicola R. d/s of last Hwy 8 bridge nr. the mouth

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
27-Aug	3.144	MMcBirney	19.2	1430
03-Sep	2.605	MMcBirney	19.7	1240
05-Sep	2.592	MMcBirney	16	1140
17-Sep	3.223	MMcBirney	12.4	1245
24-Sep	2.855	MMcBirney	12.6	1320

Nicola R. 80 m u/s of CPR bridge u/s of Coldwater R.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
15-Aug	2.536	MMcBirney	n/a	1400
21-Aug	2.124	MMcBirney	22.2	1520
04-Sep	1.82	MMcBirney	21.9	1510
16-Sep	1.78	MMcBirney	11.3	1535
22-Sep	1.511	MMcBirney	n/a	1515
25-Sep	1.737	MMcBirney	13.5	1100
26-Sep	1.766	OSS	13.5	1150
06-Oct	1.408	MMcBirney	n/a	1320
12-Nov	1.415	MMcBirney	n/a	1100

Nicola R. 100 m u/s of Spius Ck.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
15-Aug	2.834	MMcBirney	n/a	1530
21-Aug	2.608	MMcBirney	22	1410
26-Aug	2.839	MMcBirney	n/a	1310
02-Sep	2.24	MMcBirney	20.2	1345
04-Sep	2.013	MMcBirney	20.4	1310
08-Sep	2.12	MMcBirney	17	1130
16-Sep	2.521	MMcBirney	13.5	1330
06-Oct	2.164	MMcBirney	n/a	1430
27-Oct	9.797	MMcBirney	n/a	1345
04-Nov	5.581	MMcBirney	0	1450

Spius Ck. 100 m u/s of old CPR bridge

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
21-Aug	0.484	MMcBirney	18.4	1315
25-Aug	0.435	MMcBirney	15.8	1345
28-Aug	0.532	MMcBirney	16.5	1405
04-Sep	0.26	MMcBirney	18.7	1355
08-Sep	0.336	MMcBirney	15.5	1330
16-Sep	0.737	MMcBirney	11.7	1425
19-Sep	0.617	MMcBirney	13.1	1235
22-Sep	0.538	MMcBirney	n/a	1355
29-Sep	0.446	MMcBirney	12.7	1420

Nicola R. 10 to 50 m u/s of Beaks Bridge u/s of Douglas Lake

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
25-Aug	0.078	MMcBirney	15	1020
04-Sep	0.072	MMcBirney	15.7	920
17-Sep	0.082	MMcBirney	8.5	1010
19-Sep	0.084	MMcBirney	n/a	920
24-Sep	0.092	MMcBirney	9.4	1010
29-Sep	0.088	MMcBirney	n/a	1110

Nicola R. 40 m d/s Hwy 5A bridge where it enters Nicola Lake

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
29-Sep	0.01	MMcBirney	n/a	1015

Continuous Discharge Measurement Sites

Nicola R. u/s of Spius Ck.

Date	Q (cms)	Date	Q (cms)	Date	Q (cms)	Date	Q (cms)
15-Aug	2.918	01-Sep	2.310	01-Oct	2.286	01-Nov	n/a
16-Aug	2.881	02-Sep	2.273	02-Oct	2.286	02-Nov	n/a
17-Aug	2.810	03-Sep	2.139	03-Oct	2.293	03-Nov	6.245
18-Aug	2.809	04-Sep	1.990	04-Oct	2.299	04-Nov	5.740
19-Aug	2.778	05-Sep	1.908	05-Oct	2.302	05-Nov	5.591
20-Aug	2.643	06-Sep	1.921	06-Oct	2.273	06-Nov	5.904
21-Aug	2.582	07-Sep	1.918	07-Oct	2.240	07-Nov	n/a
22-Aug	2.530	08-Sep	1.944	08-Oct	2.223	08-Nov	n/a
23-Aug	2.489	09-Sep	1.851	09-Oct	2.334	09-Nov	n/a
24-Aug	2.516	10-Sep	1.820	10-Oct	2.574	10-Nov	n/a
25-Aug	2.590	11-Sep	1.847	11-Oct	2.960	11-Nov	5.643
26-Aug	2.616	12-Sep	1.876	12-Oct	2.979		
27-Aug	2.516	13-Sep	2.047	13-Oct	2.887		
28-Aug	2.586	14-Sep	2.189	14-Oct	3.657		
29-Aug	2.560	15-Sep	2.465	15-Oct	3.704		
30-Aug	2.458	16-Sep	2.613	16-Oct	3.625		
31-Aug	2.331	17-Sep	2.603	17-Oct	n/a		
		18-Sep	2.625	18-Oct	n/a		
		19-Sep	2.694	19-Oct	n/a		
		20-Sep	2.583	20-Oct	n/a		
		21-Sep	2.642	21-Oct	n/a		
		22-Sep	2.628	22-Oct	n/a		
		23-Sep	2.493	23-Oct	n/a		
		24-Sep	2.525	24-Oct	n/a		
		25-Sep	2.532	25-Oct	n/a		
		26-Sep	2.310	26-Oct	n/a		
		27-Sep	2.196	27-Oct	n/a		
		28-Sep	2.211	28-Oct	n/a		
		29-Sep	2.211	29-Oct	n/a		
		30-Sep	2.268	30-Oct	n/a		
				31-Oct	n/a		

Nicola R. u/s of Coldwater R.

Date	Q (cms)	Date	Q (cms)	Date	Q (cms)	Date	Q (cms)
15-Aug	2.460	01-Sep	2.091	01-Oct	1.442	01-Nov	1.398
16-Aug	2.482	02-Sep	2.059	02-Oct	1.446	02-Nov	1.412
17-Aug	2.503	03-Sep	1.897	03-Oct	1.436	03-Nov	1.392
18-Aug	2.518	04-Sep	1.839	04-Oct	1.419	04-Nov	1.211
19-Aug	2.481	05-Sep	1.807	05-Oct	1.393	05-Nov	1.271
20-Aug	n/a	06-Sep	1.829	06-Oct	1.362	06-Nov	1.231
21-Aug	2.250	07-Sep	1.880	07-Oct	1.368	07-Nov	1.144
22-Aug	2.223	08-Sep	1.867	08-Oct	1.362	08-Nov	1.262
23-Aug	2.253	09-Sep	1.736	09-Oct	1.376	09-Nov	1.319
24-Aug	2.317	10-Sep	1.642	10-Oct	1.332	10-Nov	1.332
25-Aug	2.319	11-Sep	1.596	11-Oct	1.328	11-Nov	1.354
26-Aug	2.257	12-Sep	1.642	12-Oct	1.357		
27-Aug	2.177	13-Sep	1.687	13-Oct	1.328		
28-Aug	2.131	14-Sep	1.691	14-Oct	1.286		
29-Aug	2.097	15-Sep	1.805	15-Oct	1.307		
30-Aug	2.089	16-Sep	1.838	16-Oct	1.381		
31-Aug	2.083	17-Sep	1.695	17-Oct	n/a		
		18-Sep	1.673	18-Oct	n/a		
		19-Sep	1.642	19-Oct	n/a		
		20-Sep	1.543	20-Oct	n/a		
		21-Sep	1.536	21-Oct	n/a		
		22-Sep	1.512	22-Oct	n/a		
		23-Sep	1.480	23-Oct	n/a		
		24-Sep	1.609	24-Oct	n/a		
		25-Sep	1.643	25-Oct	n/a		
		26-Sep	1.401	26-Oct	n/a		
		27-Sep	1.365	27-Oct	n/a		
		28-Sep	1.390	28-Oct	1.399		
		29-Sep	1.411	29-Oct	1.296		
		30-Sep	1.446	30-Oct	1.354		
				31-Oct	1.368		

APPENDIX B

All 2003 Discharge and Temperature Data Collected on DFO Low Flow Network in Shuswap Basin. (The discharge data are unverified.)

Summary of All 2003 Discharge and Water Temp. Data in Shuswap Basin

Duteau Ck. At Lion's CG Bridge

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
22-Aug	0.123	Swoffer 2100	17.1	1730
29-Aug	0.118	Swoffer 2100	17	1830
04-Sep	0.082	Swoffer 2100	15.4	1420
18-Sep	0.275	Swoffer 2100	10.8	1740
25-Sep	0.214	Swoffer 2100	11.1	1130

Tappen Ck. 11 m u/s of TCH culvert

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
29-Aug	0.244	Swoffer 2100	9.8	815
05-Sep	0.222	Swoffer 2100	10.4	1000
18-Sep	0.302	Swoffer 2100	9.4	1040
25-Sep	0.243	Swoffer 2100	9	1120

Vance Ck. 14 m u/s of Mabel Lake Rd.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
29-Aug	0.009	Swoffer 2100	14.4	1735
04-Sep	0.014	Swoffer 2100	12.5	1130
18-Sep	0.037	Swoffer 2100	9.3	1630
25-Sep	0.034	Swoffer 2100	8.3	950

Canoe Ck. at CPR crossing d/s of Canoe Beach Dr.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
29-Aug	0.07	Swoffer 2100	n/a	1115
18-Sep	0.102	Swoffer 2100	9.8	1145
25-Sep	0.069	Swoffer 2100	9.7	1240

Brash Ck. 30 m u/s of Mabel Lake Rd.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
29-Aug	0.014	Swoffer 2100	16.6	1500
25-Sep	0.025	Swoffer 2100	12.1	1525

Bessette Ck. d/s of WSC bridge at gauge

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time

22-Aug	0.154	Swoffer 2100	17.2	1830
29-Aug	0.122	Swoffer 2100	16.8	1905
04-Sep	0.148	Swoffer 2100	16	1300
18-Sep	0.515	Swoffer 2100	11	1700
25-Sep	0.411	Swoffer 2100	11.4	1055

Trinity Ck. u/s of Trinity Valley Rd.

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
18-Sep	0	Swoffer 2100	9.6	1440

Salmon R. at Hwy 1 Site (# 1)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
25-Jul	0.324	Swoffer	16.1	710
29-Jul	0.238	Swoffer	23.1	1230
12-Aug	0.186	Swoffer	21.8	1305
19-Aug	0.192	Swoffer	20.4	1550
26-Aug	0.228	Swoffer	19.1	1325
28-Aug	0.274	Swoffer	18.9	1300
02-Sep	0.289	Swoffer	20	1725
05-Sep	0.242	Swoffer	19.5	1635
06-Sep	0.267	Swoffer	14.1	735
08-Sep	0.345	Swoffer	15.4	1050
09-Sep	0.487	Swoffer	13.1	955
10-Sep	0.499	Swoffer	15.4	1720
12-Sep	0.472	Swoffer	16.8	1350
23-Sep	0.693	Swoffer	13.3	1050

Salmon R. at Vivian Site (# 2)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
12-Aug	0.25	Swoffer	24	1600
06-Sep	0.235	Swoffer	13.7	810
08-Sep	0.332	Swoffer	16.4	n/a
09-Sep	0.552	Swoffer	16.5	1240
12-Sep	0.449	Swoffer	18.4	1430
23-Sep	0.554	Swoffer	18.4	1150

Salmon R. at Willis/Davey Site (# 3)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
12-Aug	0.229	Swoffer	21.2	1635
06-Sep	0.249	Swoffer	13.4	905
08-Sep	0.351	Swoffer	15.8	1230
09-Sep	0.437	Swoffer	17.1	1330
12-Sep	0.394	Swoffer	16.9	1510
23-Sep	0.621	Swoffer	15.4	1230

Salmon R. at Johnson Site (# 4)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
12-Aug	0.198	Swoffer	22.4	1705
06-Sep	0.127	Swoffer	14.1	1000
08-Sep	0.293	Swoffer	16.6	1300
09-Sep	0.409	Swoffer	17.8	1400
12-Sep	0.292	Swoffer	16.9	1540
23-Sep	0.517	Swoffer	15.4	1300

Salmon R. at Puetz Site (# 5)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
12-Aug	0.125	Swoffer	20.1	1215
06-Sep	0.259	Swoffer	15.1	1035
08-Sep	0.366	Swoffer	16.7	1330
09-Sep	0.433	Swoffer	18.0	n/a
12-Sep	0.429	Swoffer	17.6	n/a
23-Sep	0.554	Swoffer	15.8	1330

Salmon R. at Felhauer Site (# 6)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
12-Aug	0.121	Swoffer	16.6	1130
06-Sep	0.107	Swoffer	16.5	1135
08-Sep	0.24	Swoffer	18.1	1425
09-Sep	0.238	Swoffer	20.2	1455
12-Sep	0.245	Swoffer	16	1740
23-Sep	0.443	Swoffer	16.5	1410

Salmon R. at Kaiser Rd. Site (# 7)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
06-Sep	0.079	Swoffer	19	1220
08-Sep	0.274	Swoffer	17.4	1500
09-Sep	0.284	Swoffer	19.4	1515
12-Sep	0.296	Swoffer	15.6	1805
23-Sep	0.408	Swoffer	18.8	1445

Salmon R. at Schwebs Bridge Site (# 8)

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
06-Sep	0.092	Swoffer	18.3	1310
08-Sep	0.164	Swoffer	16.1	1530
09-Sep	0.164	Swoffer	16.7	1540
12-Sep	0.227	Swoffer	14	1830
23-Sep	0.338	Swoffer	13.2	1520

Salmon R. at Bolean Site (# 9)

Date	Q (cms)	Meter type	Temp. (^0C)	Time
19-Aug	0.254	Swoffer	15	850
06-Sep	0.231	Swoffer	16.9	1420
08-Sep	0.205	Swoffer	16	1745
09-Sep	0.207	Swoffer	15	1620
12-Sep	0.263	Swoffer	13.4	1630
23-Sep	0.392	Swoffer	13.8	1630

Salmon R. at Lapierre Site (#10)

Date	Q (cms)	Meter type	Temp. (^0C)	Time
12-Aug	0.308	Swoffer	14.6	900
06-Sep	0.176	Swoffer	19.3	1330
08-Sep	0.23	Swoffer	16.7	1605
09-Sep	0.259	Swoffer	16.6	1605
12-Sep	0.33	Swoffer	14.6	1900
23-Sep	0.403	Swoffer	14.8	1900

APPENDIX C

2003 Discharge and Temperature Data Collected on DFO Low Flow Network in North Thompson Basin. (The discharge data are unverified.)

Summary of 2003 Discharge and Water Temp. Data in N. Thompson Basin.

Eakin Ck at Hwy 24

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
19-Aug	0.064	Swoffer 3000	14	1435

Sinmax Ck at the mouth

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
27-Aug	0.129	Swoffer 3000	13	1600
29-Aug	0.119	Swoffer 3000	15	1425
11-Sep	0.088	Swoffer 3000	12.5	1345
16-Sep	0.087	Swoffer 3000	11.2	1330
18-Sep	0.114	Swoffer 3000	11	1325
23-Sep	0.085	Swoffer 3000	12.8	n/a
25-Sep	0.085	Swoffer 3000	10.5	1320
03-Oct	0.085	Swoffer 3000	15	1435

Louis Ck at Hwy 5

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
23-Sep	0.408	MMcBirney	13.1	P.M.

Lemieux Ck at Hwy 24

Date	Q (cms)	Meter type	Temp. (^{0}C)	Time
23-Sep	0.101	MMcBirney	15.2	P.M.