Slocan Valley Water Quantity and Quality Monitoring Program

Report for Year 5

November 30, 2000 – December 31, 2001

Presented by the Winlaw Watershed Committee

Summary

Community groups initiated the Slocan Valley Water Monitoring Program in 1996 with funding from Forest Renewal B.C and in partnership with the Ministry of Environment. The objectives of the program were to obtain baseline data on water quantity and quality on selected creeks and to develop stream flow measurement technique. In addition the program intended to increase community awareness of the creeks and watershed conditions. The data was intended to be used in conjunction with ecosystem based forest management in a working relation between community, government and the forest licensee.

To date, the program has compiled five years of data on flow, sediment, turbidity, and conductivity levels on twelve creeks and three years of data macro invertebrates, nutrients, and low level metals on four creeks. In addition, total and fecal coliform tests were done on 5 - 9 creeks over five years.

A review of the last five freshets shows 1997 as a record high flow year. Years 1998,1999, and 2000 had moderate spring flow events. In Fall, 1999, an unusual fall flood event brought some creeks to spring high flow levels. Spring 2001 was the lowest spring freshet for the majority of creeks. However, some creeks like Hasty, Elliot, Winlaw, and Airy show instantaneous peaks equivalent or higher than previous years. Low flows for 2001 were also the lowest recorded for the majority of study creeks.

All 12 creeks have excellent water quality for 5 years when related to Ministry Criteria **(1).** Generally, the lower valley creeks had higher percentage of samples with non-detectable levels of sediment. Seventy five percent of all samples collected were less than 5 NTU's for turbidity and 50% of samples were less than 1 NTU for the majority of creeks.

Over eighty percent of all temperatures readings for all creeks were less than 9°C and no creek had more than 8% of readings higher than 13°C. Creeks with higher percentages of warm

readings normally had higher fecal coliform counts; however, watershed conditions e.g. aspect, development, presence of wetlands influenced counts to some extent.

Regarding fecal coliforms, over 50% of samples had no detectable counts for the majority of creeks. Presumptive E. coli does occur in the creeks and approximately 50% of the organisms isolated from fecal cultures were positive for presumptive E.coli.

The Slocan Valley Water Quality and Quantity Year 5 Report

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1.0 Introduction

1.1 Background

This report documents the fifth year of a 5 year study to characterize water quality & quantity on 11 creeks in the Slocan Valley **(2).** The program was initiated in 1996 by local residents concerned about industrial logging in their watersheds. Funding was secured from Forest Renewal B.C. and the program was set up in partnership with Ministry of Environment.

People in the West Kootenays view maintenance of water quality as a top concern in forest management and numerous studies and polls attest to this fact. A recent survey done by the I.F.P.A. Socio-Economic Project for the Arrow Forest District found that "that water related concerns are of paramount importance to all the residents in the District and Nelson area"**(3).**

This water-monitoring program is a response to that concern and it also addresses local residents' concern that water users have no meaningful participation in watershed planning and development.

A recent government acknowledgement of the inadequacies of current legislation to address this problem is contained in the findings of a recent Forest Practices Board investigation. Regarding water-users input into planning processes the Board found " that the Forest Practices Code does not take adequate account of the importance of water-user involvement in forest planning in domestic watersheds" **(4).**

Bartlett and McFayden are Community Watersheds. They have legal status and are referenced in the Forest Practices Code. All the other study creeks except Grizzly are Domestic Watersheds. This means they provide water for human consumption.

The program also serves the goal of the Ministry of Environment to develop water quality criteria. These criteria focus on coliform, fecal coliform, low-level metals and benthic invertebrate analyses as well as sediment and discharge.

Residents who live near creek gauge sites are employed to read gauges, take temperature, record weather observations and collect samples. Testing of water samples for turbidity, suspended sediment and conductivity is done at Passmore Laboratory ltd. in the Slocan Valley. A trained person from the laboratory collects fecal coliform samples and tests are performed at the local laboratory.

1.2 Objectives: The Year Five Report

As the final report in a five year study, the purpose of this document is to present and summarize the data and findings for year 2001 and the last five years in a way that will assist in understanding the hydrology, physical and biological processes that operate in watersheds studied.

1.3 Acknowledgments

The Winlaw Watershed Committee is grateful to the community members who worked so hard make this program successful. Their names are listed below:

Denyse LaCroix	Chris Churchill	Peter Wood	Sally Hammond
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In addition to the office and field workers we are thankful to Forest Renewal B.C. for providing funds, the Innovative Forest Practices Board for supporting this project, Slocan Forest Products, and the Ministry of Environment for providing technical direction. Thank you to the Wolverton Creek Waterusers for providing data.
A local mining company, Crystal Graphite, provided flow information on the Little Slocan River.

2.0 Overview of Watersheds and Their Stations

The following table lists some of the physical characteristics of each of the watersheds and information about the monitoring stations.

All the watersheds lie with the boundaries and are sub- basins of the Slocan Valley Watershed:

2.2 Table 1. Summary of Watersheds and Stations

Creek	Area Sq. km	Aspe ct	Max. Elevation meters	Meters	% Gradient at Gauge Site*	Stream Type at Gauge Site	Gauge Size and Type	Added* Tests over 5 years	Location In Slocan Valley
Cadden	6.7	W	1800	720	14	SP	3 ft. weir	Fecal Coliforms 1997-98	Hills
Grizzly	N/A	E	2200**	570		SP	Meter		Hills
Bonanza	N/A	S	2200**	570	2	RP	Meter	Benthic Invertebrates , metals, nutrients 1998-2000	Hills
Harris	4.7	W	N/A	690	15	SP	3 ft. weir	Fecal Coliforms 1997-2001	New Denver
Bartlett	5.7	W	2000	645	15-20	SP	3 ft. weir	Fecal Coliforms 1997-2001	Silverton
Hasty	6.1	W	2000	940	3	CP	Meter	Fecal Coliforms 1997-2001	Silverton
Lemon	178.0	W	2200	590	2.5	CP	WSC	Benthic Invertebrates 1997-1998	Appledale
Jerome	2.9	SE	1800	740	15+	SP	3 ft. weir	Fecal Coliforms 1997-2001	Appledale
Elliot	2.0	SW	1750	730	15+	SP	18in. weir	Fecal Coliforms 1997-2001	Appledale
Winlaw	40.7	W	1700	665	3	RP	Meter	Benthic Invertebrates , metals, nutrients 1998-2000 Fecal Coliforms 1996-2001	Winlaw
McFayden	5.0	SE	2100	600	15+	SP	4ft. weir	Fecal Coliforms 1996-98	Vallican

Airy	**58.0**	**N**	**2600**	**490**	**2**	**RP**	**Meter**	**Benthic Invertebrates, metals, nutrients 1996-2001 Fecal Coliforms 1997-2001**	**Passmore**

***Gradient at gauge site only   ** Uncertain elevation   SP = Step – Pool, CP = Cascade – Pool**
RP = Riffle – Pool,   N/A = not available, WSC = Water Survey Canada

- **Added Tests indicates those done in addition to sediment, turbidity, conductivity**

MAP of THE VALLEY STATIONS

3.0 Methodology

3.1 Sample Collection and Analytical Tests

Gauge readings and water samples were collected daily during spring run-off events and major rainfall events. These "grab samples" are collected in accordance with methods outlined in Stednick **(5)** and tested for Suspended Sediment, Conductivity and Turbidity.

After spring, sample collection was reduced to 2 per month unless a rain event occurred. Please see the Gauge Reading and Sample Collection Schedule , pages 15,16. Spring runoff and heavy rainfall events are critical because they coincide with the main sediment transfer for the year. Gauge readings are continued on average at 3 per week all year.

Five samples for Fecal Coliform and presumptive E.coli bacteria were collected over one month during late summer and early fall on Harris, Bartlett, Hasty, Jerome, Winlaw and Airy Creeks. All test procedures remained as per the year 2 and analyses were done in accordance with the Standard Methods outlined in **(6)** .

3.2 Rainfall Data

Rainfall measurements for March through June 2001 have been incorporated into the data sheets for all creeks. This was done because of the importance of rainfall in interpreting sediment and discharge data.

Rain measurements from New Denver weather station were obtained from Environment Canada Atmospheric Environment Service. The New Denver rain data was inserted into the data sheets for Cadden, Bonanza, Harris, Bartlett and Hasty Creeks.

Rain data from the newly relocated Passmore/Vallican station has been inserted into data sheets for Elliot, Jerome, Winlaw, and Airy Creeks. These two weather stations are manually operated. Each rain reading represents 24 hours. New Denver readings are taken at 8:00AM. Passmore/Vallican measurements are taken at 7:45 and 16:45. The two readings are added to give a total for 24 hours. All data from the above stations for 2001 is unverified.

3.0 Methodology cont'

3.3 Data Input

The following is the list of inputs given in the Creek Data Sheets found in the data section.

1. Information obtained by the readers that includes date, time, weather, air and water temperatures, gauge readings and initials of reader.

2. Events related to metering and weir maintenance. E.g. dates the weirs were inspected and cleaned, dates when inspections/work was done by the Metering Team.

3. Flow data obtained from metering the creeks or weir readings.

4. Passmore Laboratory test results for Suspended Sediment, Conductivity, Turbidity, Fecal Coliforms

5. Rainfall from New Denver or Passmore/Vallican Stations (March - June)

6. Fecal Coliform Test Results

7. Quality Control: Duplicate and Replicate Results From ALS Environmental formerly known as Analytical Service Laboratory . Canadian Assoc. of Environmental Laboratories Check Sample Program results are listed in a separate table in the yearly report.

3.4 Sampling Schedule

Water Monitoring Program Gauge Reading and Sample Collection Schedule

Gauge Readings			Samples	
Month	Readings/week	Total/Month	Samples/week	Total/Month
January	1	4	1 every second week	2
February	2	8	1 every second week	2
March	3	12	1 sample/week	4
April	3	12	2 samples/week	8
May	4	16	3 or more/week	12
June	4	16	3 or more/week	12
July	3	16	1 sample/week	4
August	2	8	1 every second week	2
September	2	8	1 every second week	2
October	2	8	1 every second week	2
November	2	8	1 every second week	2
December	1	4	1 every second week	2

Total

Note: Sample extra if/when there are rain events. If events go on 2-3 days sample every day Try to coincide sampling with events (freshet of rain) which change gauge reading and/or bring down sediment

3.0 Methodology

3.5 The Metering of Creeks

Overview

The year of 2001 marks the 5th and final year of the FRBC program for all the metered creeks and thus warrants a hydrometric summary of the 5 years, with some reflection on what has occurred in the past 5 years.

Detailed descriptions of methods etc., are to be found in the reports for the individual years. For instance, weir installations, choice of gauge sites and the actual metering method as taught by John Harris is in Year I report (1997). The gradual evolution of the stage discharge equation was discussed in both Years I and II reports (1997 and 1998). Trends in the meterings and possible reasons for shifts and variability in the stage discharge curves are treated in Year III and Year IV reports (1999 and 2000). In the report for this year of 2001 (Year V) the treatment of the creek discussions will be more general with an emphasis on understanding the individuality of the creeks as shown by their behavior in the stage discharge curves over the past 5 years.

The most “ stable” or “least variable hydrometrically” creek is Airy Creek followed by Bonanza, Hasty and then Winlaw. Grizzly Creek has only 3 years data, and sparse data at that, so that it is not possible to draw any conclusions at this point. Further work needs to be done on this creek.

Not surprisingly, Airy, the largest creek is the most stable or least variable. In many ways it was the most physically difficult to measure because its size required the use of the 16 ft boom with the 75 lb lead fish at high water. Moreover, Airy has the most “unforgiving” bed to stand on in waders, as it is composed of mainly boulders; thus one is often either measuring water flowing above a rock or water flowing in a “hole” surrounded by rocks.

However, in spite of all this, Airy produced the best data. Its variation from year to year was minimal for a mountain creek. The stage discharge curves for 1997 and 1998 varied only slightly (< 6%). The 1999 and 2001 stage discharge curves were almost identical, with a difference of as low as 1% at the 0.7 meter gauge height level. (SEE FIGURE 5, PAGE 234)

A small shift downward did occur in the curve from 97/98 to 1999, indicating a small loss in the downstream control. The word control used here refers to downstream conditions that impede flow and affect gauge height. The downward shift may be explained by speculating that the material gained in the control from the big flow year of 1997 was finally flushed through in 1999.

A significant gain in control occurred from 1999 to 2000. Again, it may be speculated that this was caused by sediment brought down by the torrent which occurred on November 12, 1999, giving Airy Creek its highest one- time flow in the 5 years of recorded data.

Finally, there was an almost identical shift back to the 1999 position in the year 2001, indicating that the material accumulated from November 1999 had washed through the downstream control, making the creek as clean again in 2001 as it was in 1999.

The equation describing the stage discharge curve for Airy creek for the year 2001 is:

Y=AX to the power of B where

A= 37.8997

B= 3.0775

correlation coefficient r = 0.9988

number of points n = 6

Bonanza Creek is the second largest creek and unlike Airy, contains significant stretches of a moving sandy bed interspersed with rock. There was sizeable shift in the stage discharge curve from 1997 to 1998 indicating a gain in control. This can be explained by the transport of sand in the high flow of 1997which remained imbedded downstream of the gauge. There was a further shift <u>in the same direction</u> from 1998 to 1999, leading one to think that even more material was deposited in the control. This might be explained by speculating that high alpine material dislodged in the big flow of 1997 took 2 years before fully affecting the control below the gauge. See FIGURE 1, PAGE 230 .

Finally, in 2000 and 2001, there was an incremental shift in the opposite direction, indicating that the material accumulated in the previous years of 1997, 1998 and 1999 were being released in 2000 and 2001. However, the position of the 2001 stage discharge curve is still above that of 1997, indicating that not all of the material accumulated from the 1997 big flow had washed out by 2001.

The equation for the stage discharge curve for Bonanza Creek for 2001 is:

Y = AX to the power of B

where constant A = 16.3399

constant B = 3.1286

correlation coefficient r = 0.9999

number of points n = 5

As mentioned previously, Y represents discharge in meters per second and X represents gauge height in meters.

Hasty Creek is unusual in that it not only originates in wetlands but is also fed by a diversion from Vevey Creek.. The Vevey Creek diversion makes up the bulk of the flow to Hasty Creek. It is also visually apparent if one walks to the diversion that Vevey contributes a fine granitic sand to Hasty Creek. This gradual infilling of Hasty Creek by sand is reflected in the 5 year discharge pattern of the creek. (SEE FIGURE 3 , PAGE 232).

After the big flow year of 1997, there was an apparent loss in the control indicated by the downshift of the stage discharge curve in going from 1997 to 1998. This may be explained by the flushing action of the big flow, which had a scouring effect on the bed. and removed sand from the creek. In the subsequent years of 1999, 2000 and 2001, the stage discharge curve incrementally shifts upwards, reflecting the gradual infilling of the creek by the fine sand contributed by Vevey Creek. Thus the stage discharge curve for Hasty is at its highest point in 2001 after 4 relatively low flow years following 1997.

The stage discharge equation for Hasty Creek for 2001 is:

Y = AX to the power of B
where constant A = 11.6357
constant B = 5.1195
correlation coefficient r = 0.9937
number of points n = 5

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Grizzly Creek is tributary to Bonanza Creek and was initiated after MacFayden Creek left the program in 1999. Consequently, it has only three years of metering data . It is the least accessible of all the creeks, requiring a short steep hike to reach the gauge station in the spring and summer months and is practically inaccessible in the winter months. There was also a lack of choice gauge sites because of the terrain; as a result the current site was somewhat of a compromise. The gauge is located almost midstream and secured onto a solid fallen log. Turbulence at high flow makes accurate reading of the gauge difficult. Few conclusions may be drawn about the creek except its apparent high variability, which may be due to the fact that it is a very small creek, poor gauge placement and/or the lack of a good downstream control. It may be wise to relocate the gauge to gain a more definite control if future work is to be done. See FIGURE 2, Page 231.

The stage discharge equation for Grizzly Creek for the year 2001 is:

Y = AX to the power of B, where
constant A = 15.68005
B = 6.1140
correlation coefficient r = 0.93602

number of points = 13

Winlaw Creek , as alluded to in the year IV report, was definitely the most unpredictable of all the creeks, mainly because of its active bedload and its tendency to braid and make new channels. Under the direction of John Harris, the very first gauge station was set up on 9/28/96 about 100 meters beyond the current site. By 5/12/97, a new channel had formed behind the gauge thus making the gauge site an island and therefore inaccessible.

On 5/23/97 a new gauge station was initiated at the first large left bank cedar tree upstream from the Popoff dam. The dam itself therefore served as a control for the gauge. This site remained useable for all of 1998 and 1999; the occasional side-stream was metered if they became significant in size. At high water when it was not possible to wade the creek at the gauge site, the boom with the 75 lb lead fish was used downstream at the Sutherland log bridge. This period from 5/24/97 to 11/2/98 marked the most stable metering period for the whole 5 years. The Popoff dam, which served as the control for this period, was still relatively stable, as shown by the curve correlation of that whole period (r= 0.9912 with n = 20 points) .

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From 11/2/98 to 12/4/99 the stage discharge curve shifted left and upwards, indicating an increase in the control. This was evidenced visually by the bedload slowly advancing toward the Popoff dam, putting pressure on the structure.

By 4/28/00 the top log of the dam had broken off and simultaneously the right bank directly downstream of the gauge was beginning to erode away. Thus the control for the gauge was changed .The gauge readings dropped 10 cms to reflect the new control. There was a further drop of 6.5 cms between 5/3/00 and 5/5/00 as the second log of the dam was removed.

Finally there was a increase of 5.5 cm on the gauge between 5/16/00 and 5/18/00, reflecting the repositioning of the bedload to the new position of the dam. After 5/19/00, the control appeared to stop shifting, as evidenced by no sudden changes in gauge readings. However the readings on the gauge were now much lower and the gauge ran the risk of running dry at low water. By 8/21/00 the gauge was out of water.

A new third gauge was installed on the right bank on 9/28/00 and serves Winlaw Creek up until the present. The last curve (2001) shows promise as it reflects an increase in the control and is in a similar position to the 1999 curve just before the dam broke. Hopefully the present dam structure allows for the movement of bedload through it without breaking apart.

The stage discharge equation for Winlaw Creek for the year 2001 is:

Y = AX to the power of B

where constant A = 157.5177

B = 5.1361

correlation coefficient = 0.9917

number of points = 7

What overall conclusions may be drawn about the 5 creeks ? It is apparent that size affects the variability of the creek. The bigger creeks give tighter stage discharge curves even though they may be more difficult to measure. However, they still do vary significantly from year to year so that it is wise to use the most current yearly stage discharge curve rather than relying on the previous year's data. Exceptions to this may occur in the case of very high variability in a particular year. In this case a recalculation using the previous years points may be necessary to obtain a reasonable and useable curve.

The positioning of the gauge is also important in minimizing variability from year to year. A fortunate gauge site has a good control downstream from it in the form of stable logs and other woody debris and/or rocks which won't move; these elements enhance the sensitivity of the gauge as the water rises and produce meaningful curves. A good case in point is Hasty creek which has quite an elaborate water intake directly below the gauge which serves as a control for the gauge. Although a small creek by any standards, in the 5 year study it has produced a series of curves which correlate with physical evidence, viz, sand building up in the channel.

4.0 Results and Discussion

4.01 Approach and Charts

The data collected by readers, technical experts and analytical test results to date represents the total inputs of information about each creek. The following descriptive summaries and charts can be considered outputs. The purpose of these outputs is to identify meaningful relations that characterize the creeks. Relations likely to be helpful in this regard are:

1. Chart 1 shows the monthly mean discharge and number of readings for each creek. The values are based on gauge readings taken by the readers throughout the year. The number of readings "n" varies throughout the year with numerous readings in spring and few in winter.

2. Chart 2 shows discharge vs. time for the 5 years of the study. It is based on readings from 1996 to 2001.

3. Chart 3 shows flow, sediment and rain in relation to each other for all the creeks from March to December, 2001. This time period encompasses the spring run-off and hence the time when most sediment transfer occurs. Rain data was entered every day from March to June and gauge readings were taken approximately every 3 days and when samples were collected. Daily readings were not taken and are not represented between July and March; *hence, this time period is compressed,* in some but not all of the charts.

4. Chart 4 shows flow, turbidity and rain in relation to each other for year 2001. This Chart is similar to Chart 3 and confirms or differs depending on the relation between the two parameters of turbidity and sediment. More often than not, the turbidity reading in chart 4 strengthens the sediment value presented in chart 3.

5. Chart 5 shows Sediment and Turbidity in relation to flow for 5 years. The points represent values
for analytical tests over five years. Chart 5 is the same scale for all creeks to allow for comparison between creeks. This chart is different to the other charts in that it is plotted on log-log paper and contains all the values of sediment and turbidity obtained for the same sample. Thus this chart is a visual representation of a statistical correlation between sediment and turbidity . Most creeks show some correlation of these two important parameters..

6. Chart 6 shows flow and conductivity of creek water over time for year 2001.

7. Chart 7 shows air and water temperature for year 2001.

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4.02 Freshet Summary

The 2000 - 2001 winter snow pack in the Kootenays was well below normal and at some recording stations it was a record low. In fact, at Koch Creek, the station nearest the Lower Slocan Valley Watersheds, the water equivalent for April, 2001 was 7% lower than the lowest reading for 42 years of record.

It is interesting to note that other areas including the northwest part of the province had above average snowpacks for winter 2001.

For the third year in a row, weather during the critical melt period was generally cool and unsettled. These unsettled conditions resulted in a later and slower melt of the snowpack. However, because of the low snowpack, very little residual snow was left by mid June.

The above information was obtained from Ministry of Environment Lands and Parks Web site for Columbia Basin Snow Survey Measurement :

www.elp.gov.bc.ca/wat/snow

4.03 Summary of Maximum & Minimum Values, Table 2, pg. 24

The following table summarizes maximum and minimum values for discharge, sediment, and conductivity for January 1, 2001 – December 31, 2001. In instances where low entries are noted for more than one day, the value nearest the spring high flow is recorded as the minimum value.

Comments Regarding Results and Discussion

The following observations are based on review of the data obtained by methods described above. As stated in the summary, the nature of the creeks and parameters studied are extremely variable and gauge readings and sampling frequency is limited. Hence, the values and observations reported represent the closest approximation of the actual maximum or minimum for an event. And, on some creeks, because events can happen so quickly, the entire event could actually have been missed.

The data record for April, 2001 is sparse or missing because of uncertainty about program funding during this period.

Table 2: Summary of Maximum and Minimum Values

Slocan Valley Creeks January 2001 to December 2001	Peak Flow	Low Flow	Max Sed	Max Turb	Max Cond.	Min Cond.	Rnge. Cond.
	m3/sec	m3/sec	mg/l	NTU's	uS/cm	uS/cm	uS/cm
Cadden	0.188 5/15/01	0.040 1/23/01	45 2/08/01	5.5 2/08/01	284 4/6/01	195 5/15/01	89
Bonanza	7.63 5/25/01	0.564 10/8/01	54.3 4/28/01	6.5 4/27/91	156 2/6/01	107 4/28/01	49
Grizzly	0.690 4/29/01	0.320 10/5/01	103 5/25/01	27 5/25/01	261 9/16/01	133 11/17/01	128
Harris	0.119 5/24/01	0.001 2/23/01	36.0 5/25/01	5.0 5/25/01	288 2/28/01	201 5/24/01	87
Bartlett	0.052 4/28/01	0.009 12/27/01	14.4 8/18/01	3.2 8/18/01	323 2/28/01	209 4/28/01	114
Hasty	0.926 5/24/01	0.050 3/5/01	110 5/24/01	15 5/24/01	93.0 3/4/01	40.0 5/24/01	53

Elliot	0.110 4/28/01		0 4/15/01		69.6 3/13/01		21 3/13/01		216 9/21/01		96.0 4/29/01	120
Jerome	0.057 5/26/01		0.003 2/9/01		21.6 11/26/01		5.2 11/26/01		179 1/8/01		49.3 3/26/01	130
Winlaw	4.39 5/18/01		0.057 2/13/01		4.2 3/27/01		1.3 3/27/01		144 1/31/01		46.2 5/28/01	97.8
Airy	17.30 5/24/01		0.030 2/23/01		23.7 5/23/01		4.8 5/23/01		42.2 3/4/01		9.5 6/28/01	32.7

4.0 Results and Discussion

4.1 Cadden Creek

The Cadden Creek weir station is located approximately 1/2 kilometer east of highway 6 off the Old Hills road. The station was taken over from Water Survey Canada in 1997. Vera Depretto reads a weir gauge.

The west facing Cadden Watershed is 6.7 sq. km and ranges in elevation from 720 to 1800meters. The reach above the weir can be characterized as step - pool morphology controlled by large boulders and woody debris. Large woody debris is fairly plentiful and is important in defining the channel. The watershed is characterized by steep slopes with few flat benches and is sparsely treed. In the 1997 review (**7**) M. Carver noted "frequent signs of instability in the section of the creek above the weir."

No forestry operations are planned for Cadden at this time; however, a woodlot (**8**) is adjacent to the lower reach and private land logging has occurred up to the bank below the gauge.

The original weir installed by Water Survey Canada blew out on April 23rd , 2000. A gauge was installed and the creek was metered until a new weir was installed on September 26, 2000. Hence, hydrometric comparisons are only given for 2 years.

Hydrometric and Sediment Summary

As can be seen by the Hydrograph for Cadden, chart 2, pg 27, Spring 2001 flow was significantly lower than 2000. A peak flow of 0.188m3/sec on May 15th and mean monthly flow of 0.165m3/sec for May 2001 compares with a peak of 0.526m3/sec for 2000. The mean monthly flow for May, 2000 was 0.318m3/sec. Hence, the peak flow in 2001 was approximately half the volume of water seen in 2000. Although data for flow during March is sparse, there does not appear to be sharp, distinct discharge peaks in the flow record for 2001. Rather, a gentle rise is noted during April.

The high for the year on May 15th is characteristically early when compared with other north valley creeks. It is interesting to note that although high flows were meager in 2001, low water reported on January 23, 2001 @ 0.040m3/sec was higher than 2000 when flows dropped to 0.02m3/sec.

The peak sediment level at 45mg/l occurred on February 8th, 2001. The value was <u>not</u> related to a large rise in flow. The lack of sediment at high water likely indicates a "threshold" level for stored sediment was not reached in 2001. The second highest sediment reading at 16.5mg/l was recorded on December 9th. . See Cadden Chart 3, pg28.

Hydrometric & Sediment Summary Cadden Creek cont'

However, turbidity levels did rise at freshet with a high of 2.8 NTU's on 4/29/01 See Chart 3, pg28. There is a strong relation between sediment and turbidity as seen in Cadden Chart 5 pg. 29
The outlying sediment readings are seen to the left of the sediment rating curve given in chart 5. Regarding the sediment/turbidity relation, most of the outlying values are sediment rather than turbidity and most of the values lie to the left of the curve. Thus turbidity responds to flow more consistently than sediment in the case of Cadden Creek.

Regarding water quality for human consumption, 7.5% of samples were less than 0.5mg/l for sediment. For turbidity, 43.8% were less than 1 NTU and 84.0% were less than 5 NTU. This is based on 333 samples collected over 5 years. See Water Quality Charts 1 & 2., pg.

Conductivity and Temperature Summary

In previous years and especially in 1997 a sharp drop in Cadden's conductivity was noted at high water. At that time, the conductivity range was 129uS/cm. In 1998 the range was 106uS/cm. In 2001, conductivity readings only dropped by 89 uS/cm. This was approximately the same as 81uS/cm seen in 2000. The conductivity record for 2001 is notable because of a drop and rise before freshet followed by a rise and drop after freshet.
These values likely reflect rain events and dilution of creek water. See Cadden Chart 6, pg29.

Historically, Cadden's water temperature remains cool with a low number of readings over 13°C and most readings below 9°C. In 2001, this trend continued with only 3 readings 13°c
and over. See Cadden Chart 7 pg30.

A review of water temperature readings shows that 86.0% were less than or equal to 9°C
and 99.2% were less than or equal to 13°C. This is based on 774 readings over 5 years.
See Water Quality Chart 3 for Temperature, pg .

4.0 Results and Discussion

4.2 Bonanza Creek

Bonanza Creek flows from Summit lake on the north to Slocan lake on the south. It flows through a north-south valley where numerous smaller creeks including Cadden and Grizzly contribute to its flow. The ridges that border Bonanza rise from 570 to over 2000meters. Bonanza is gauged and metered. Eric Faulks of Hills reads the gauge at the station located just upstream from the Bonanza Creek Bridge.

As noted in previous years, Bonanza is the most important fish- spawning creek in the Slocan Valley Watershed. Kokanee and Rainbow are the two main varieties of fish that spawn in the fall and spring. In year 1999, over 20, 0000 Kokanee fish were counted by local residents working with a biologist. In year 2001 between 5,000 to 10,000 Kokanee were counted (**9**).

In the lower reach, the creek empties into Bonanza Marsh, one of the most significant wetland marshes in the Kootenays. The marsh is home to young fish, birds & a myriad of wildlife (**10**).

Logging continued on Bonanza's west slope in 2000 with the completion of road branch 5200 and 3 new cut blocks. In addition to Slocan Forest Products operations, 10 one-hectare clear cuts were completed under Ministries Small Business Development Program. These cuts are located just outside Hill near Highway 6. In 2001, 2.5 Hectares of land were logged on the Bonanza west slope (**11**).

Local residents continue to be concerned that reduction in forest cover and impacts from road building could alter water temperature and that changes in sediment load could impact Bonanza's spawning channels.

Hydrometric and Sediment Summary

In 2001, Bonanza Creek began to rise at the beginning of April. The first major peak was seen on April 24th. Historically, Bonanza shows 3 - 4 peaks during the spring season. In 2001 three peaks were seen. See Chart 2 pg34 . The high for the year was recorded on May 25th when water levels reached 7.63m3/sec. This is the lowest recorded peak flow in 5 years of study. March rains were seen at the same time as a rise in flow and were a factor in all four rises. Warm temperatures in late April and mid May helped push water levels higher.

.4.0 Results and Discussion cont'.

Hydrometric and Sediment Summary for Bonanza cont.

Low water for the year at 0.564m3/sec was reported on August 10. This is the lowest reading noted for low flow in 5 years of study. At 0.694m3/sec, the mean reading for September was the lowest recorded for that month.

In previous years except 2000, the major flux of sediment came during or just before the first major peak flow event. In 2001, sediment levels also peaked just before the first peak flow at 54.3 mg/l on April 28th.. Sediment levels rose again to 30.0mg/l during the yearly high flow. It is interesting to note that peak sediment levels were about the same as 1998 & 2000 while flow levels were significantly lower.

As expected , high turbidity levels accompanied the high flows for the year on May 25 and April29. However sediment was higher during the smaller peak event in April. This may reflect scouring in the April event. See Chart 4, pg35. Historically, Bonanza has shown a tight relation between sediment and turbidity. That trend continued in 2001. As with Cadden, outlying values tend to be to the right of the curve. See chart 5, pg 36..

Regarding historic sediment and turbidity levels, 9.4% of samples tested had less than 0.5mg/l. Samples tested for turbidity showed that 47.8% were lower than or equal to 1 NTU and 89.3% were lower or equal to 5 NTU's. This was based on 229 sediment and 326 turbidity samples over 5 years. These relatively high readings reflect on the high sediment contributed by Cadden and Grizzly – two tributaries of Bonanza. See Water Quality Sediment and Turbidity Charts 1 & 2 pg 118 & 119.

Conductivity and Temperature Summary

Although 2001 was a low flow year, Bonanza's Conductivity range at 50uS/cm was in line with previous years. In 2000 the range was 36 uS/cm. The minimum conductivity occurred at the same time as a high flow on April 28th at 107uS/cm. The typical pattern showing a drop in conductivity during peak flow events is recorded in chart 6 pg 36. Maximum Conductivity levels at 156 uS/cm were recorded on February 6, 2001.

Bonanza's close relation between Air and Water temperatures was seen again and is given on Chart 7, pg 37. Water temperatures rose to 15°C on July 24th and August 7th, 2001.

Regarding historic temperature readings, 65.3% of Bonanza's water temperature readings were less than or equal to 9 degrees and 92.8% were less than or equal to 13 degrees C. See Water Quality Chart 3, pg 120.

4.0 Results and Discussion

4.3 Grizzly Creek

Grizzly Creek is an S3 stream that originates in alpine terrain on the west slope of Bonanza Creek. With numerous branches and channels it flows through terrain that is currently being logged. Over the last 3 years three road crossings have been built over Grizzly (**12**). The creek is metered and the gauge is located just up from its confluence with Bonanza.. The Grizzly gauge is read by Ben Sopow.

Hydrometric and Sediment Summary

The peak discharge for Grizzly Creek was recorded as 0.690 m3/sec on April 29th, 2001. In 2000, the high flow of 0.761m3/sec was recorded on April 21st and in 1999 the peak flow was 1.64m3/sec on June 17th. Hence, the volume of water in the 2001 freshet, a low flow year, seems to be in line when compared with previous years. The timing of the flow is in line with high flow on Bonanza and the rise in Cadden. See Cadden Chart 2., pg 41.

High sediment levels accompanied the April and May high water. The highest sediment reading of 103mg/l occurred on May 25th. Timing for this event coincided with Bonanza's high flow. Anomalous readings occurred on August 9th when sediment levels rose to 25.2mg/l. Again on November 17th, they rose to 41.7mg/l and on November 28th levels rose to 35.1mg/l. See Grizzly Chart 3 pg 42. The turbidity values follow suit and echo the sediment values. See Grizzly chart 4, pg 43 .

The relation between sediment and turbidity as seen on Chart 5, pg 43, shows many outlying values. These high readings appear as anomalies in charts 3 & 4 and outlyers in Chart 5. Most of these values lie to the left and above the curve, indicating that they occur at low flow times. Note however, that there is a strong correlation between sediment & turbidity in Grizzly, in spite of the outlyers. This is to be expected, as Grizzly shares much the same type of sediment as Bonanza, and Bonanza has an excellent correlation between sediment and turbidity.

Conductivity and Temperature Summary

Grizzly's conductivity pattern in late summer and winter are not in line with the normal pattern of a drop at high water and rise during low water. Anomalies occur in August, October and November when drops in conductivity do not correspond with increased flow. On November 17th, sediment levels rose to 41.7mg/l and conductivity dropped to 140uS/cm

4.0 Results and Discussion cont'

Conductivity and Temperature Summary for Grizzly cont'

These anomalies may be initiated by light rain, which would allow runoff from topsoil and roads to enter the main channel.

As noted in previous years, Grizzly is an important source of cool water for Bonanza, especially in mid summer when water temperatures can reach critical high levels for fish. This is illustrated by the fact that in over three years with 101 readings on Bonanza above Grizzly, *30% of readings were equal to or above 13°C while only 7.1% of readings on Bonanza at the Bridge below Grizzly were 13°C or higher.*

This implies that Grizzly contributes a significant amount of cold water to the lower reaches of Bonanza creek.

Grizzly's cool temperatures in relation to Bonanza are <u>also</u> shown in Water Quality Temperature Chart 3 pg.   Note that Bonanza tends to be warm (i.e. lower percentage of readings less than 9°C) when compared with other valley creeks. In fact, it is the warmest of all the creeks in the valley, even <u>with</u> the mitigating effect of the Grizzly input.

Cool water input from Grizzly and readings for Bonanza <u>above</u> Grizzly is also illustrated in Chart 7 , pg 44.

4.0 Results and Discussion

4.4 Harris Creek

Harris Creek is a small drainage that flows through the area known as New Denver Flats. New Denver Flats is a mid elevation bench located at the base of Idaho Peak and between the towns of Silverton and New Denver. Water flowing from the slope of Idaho Peak surfaces in the Flats. The flats contain streams and marshes with an array of wildlife and large trees. As with Bonanza marsh, this area shows a great diversity of life.

Harris Creek is a debris flow creek that originates in the high alpine and flows subsurface down the slopes of Idaho Peak It surfaces at an elevation of 1200 meters in the Flats. In his report on New Denver Flats, Al Isaacson states that Harris creek is in a "perennial avalanche path" (**13).**
Harris Creek services the Harris Heritage Ranch and during dry summers is fully utilized for irrigation & domestic needs.

The creek alternates between step - pool morphology to a low gradient meandering stream through wetlands. Woody debris is plentiful, especially on the steeper sections and plays an important role in determining channel structure.

The station site is just down from a small bench and has a 15% slope. The station elevation is 690 meters. The creek bottom is gravel, and rock composed mainly of gray slate.

Logging began in the Flats in 1997. In 2000, Forestry operations continued on the Flats and two cut blocks were logged in the Harris Creek watershed. Logging operations are now completed for this pass. In 2001, the bridge over Harris Creek was removed and local residents are concerned that mountain bikes and all terrain vehicles now cross through the creek. The station, a 3 ft. weir, is read by Norm and Joe Matthews.

4.0 Results and Discussion

Hydrometric and Sediment Summary for Harris Creek

Year 2001 saw the lowest volume of water and lowest spring freshet for five years of study on Harris Creek. Water levels began to rise after April 20th and the first peak was seen on April 28th. High water for the year came on May 25th at 0.119m3/sec. This is slightly lower than May, 1998 , another low year, when high water was 0.180m3/sec. See Harris Chart 2, page 48. Rain followed by warm temperatures initiated the peak event. The mean flow in May 2001 was 0.04m3/sec. In 2000 the mean for May was 0.124 m3/sec.

Harris's tendency to rise and fall quickly was seen in 2001 when water levels rose from 0.01m3/sec to 0.119m3/sec overnight on May 24 – 25th. See Harris Charts 3 & 4 pg 49.

Low water also set a 5-year record at 0.001m3/sec on February 23, 2001.

Sediment levels rose from 9.9mg/l on May 24th to 36mg/l on May 25th. This is the lowest quantity of sediment recorded at peak flow in 5 years of study. Raised levels of sediment and turbidity were observed on August 17th (8.1mg/l), November 10th (8.7mg/l) and on November 17th , 2000 (36.9 mg/l) with no corresponding increase in flow. These anomalous readings were not accompanied by a corresponding drop in conductivity or increase in flow. These sediment spikes have never been observed in previous years. They may indicate disturbance of the creek at the road in New Denver Flats. See Harris Charts 3 & 4 pg 49.

The relation between sediment and turbidity is shown on chart 5 pg 50. Note the extended range of sediment values at high flows indicating access to new sediment sources as flow increases. Outlying points occur to the left of the curve.

Regarding Harris Creek's acceptability for drinking water – 21% of samples tested over 5 years were less than or equal to 0.5mg/l for sediment, 73.1% of samples were less or equal to 1.0 NTU for turbidity and 92.4% were less than or equal to 5.0 NTU's
These values are based on 227 samples for sediment and 276 for turbidity. Samples were usually taken on the same day as Bartlett. Both creeks have similar origins and they are also similar in water quality. See Water Quality Charts 1 & 2, pg .

Conductivity and Temperature Summary

Despite the very low flow year, conductivity levels showed a characteristic drop in spring and rise in fall and winter in 2001. The range of conductivity at 87uS/cm over the year is close to 78uS/cm reported in 2000 and 89uS in 1999. In 1997, an extremely high year, the range was 121uS/cm. That year, conductivity levels dropped to 173uS/cm, the lowest recorded for Harris Creek. See Harris Chart 6 pg.50.

The relation between air and water in 2001 shows a characteristic pattern whereby water temperatures rise with warming air values to about 10°C in late June. After this time, despite increasing air temperatures, the water remains cool. See Chart 7 pg 51.. Water temperatures were slightly higher than in 2000. The pattern is similar to Bartlett. See Bartlett Chart 7, page . This tendency to remain cool likely reflects the fact that flow for both is sub-surface at higher elevations.

A review of five years of temperature data for Harris shows that 83.6% of samples were 9°C or lower while only 0.35% were 13°C or more. This is based on 568 readings. See Water Quality Chart 3, page
.

4.0 Results and Discussion

4.5 Bartlett Creek

Bartlett Creek is located on the south side of the mid elevation bench between Silverton and New Denver. The entire area is called New Denver or Hartney Flats. The mid zone of the bench drains westward into Harris while the south end drains into Bartlett. The Bartlett branch, which originates high above the Flats, initially flows west, then changes and flows south. The south section is susceptible to impacts from old logging cuts. As Bartlett leaves the flats another tributary that runs west from Idaho Peak joins it. This tributary runs from slopes that ascend to over 2,000 meters.

The Bartlett Creek station is located in a fairly steep v- shaped gully approximately 10 meters up from the Silverton community reservoir. Bartlett is the back –up water source for the town of Silverton. The channel has a step - pool morphology and a 15 - 20% slope. Large woody debris is plentiful above the creek and logs in the channel do affect the shape of the channel. Bartlett is the neighbor watershed to Harris and it is a 6th order creek.

Although Bartlett's lesser channel could have been impacted from logging operations on New Denver Flats, the work on the Flats is now finished for this pass and no logging activity occurred during year 2001.

Concern remains about the accessibility of New Denver Flats to motor bikes, hikers and all terrain vehicles. Norm Matthews also reads the Bartlett Creek weir.

Hydrometric and Sediment Summary

Bartlett's discharge pattern for 2001 follows a trend that reflects its relation to Harris. That trend shows that Bartlett's higher discharge levels off in the fall and winter, and rises to about the same level as Harris in spring. This pattern reflects Bartlett's larger storage capacity and the fact that it has two sources as noted above. The peak discharge for the year was recorded on April 28th at 0.052m3/sec. See Bartlett Chart 3, pg 57, and Harris Chart 3, pg 49..

In year 2001, Bartlett had its lowest peak flow recorded in 5 years of study. Timing of the flow is in line with Harris's first spring peak and occurred after a period of warm temperatures and rain. A second broader rise was reported at the beginning of June. See Bartlett Charts 1 & 2, pg. 56.

The low water level reported for the year at 0.009m3/sec on February 13th was the lowest recorded in 5 years of study. See Bartlett Chart 1, pg 56.

The maximum sediment reading at 14.4 mg/l was taken on August 18th . It was also the lowest peak sediment reading seen in 5 years and it was also not in line with past years when high sediment levels accompanied high flow. See Chart 3, page 57. This occurrence may reflect the fact that a threshold flow level to access stored sediment was not reached in 2001. See Charts 3 & 4 page 57 . Bartlett also had an anomalous sediment reading on August 18 at 14.4mg/l .

The relation between sediment and turbidity for Bartlett has always been close. In Bartlett Chart 5, pg. 58 the only definite outlying values are the two high sediment/low flow points reported in 2001. As with Harris, a steepening of the sediment curve is noted as flow increases. This reflects a tendency for sediment levels to rise quickly with increased flow.

A review of sediment samples for Bartlett shows that 19% are less than 0.5mg/l. Eighty two percent of the samples are lower than1.0 NTU and 93.8% are less than 5 NTU's. This is based on analyses of 277 samples over 5 years. See Water Quality Chart 1 & 2.

Conductivity and Temperature Summary

In 2001 the range for conductivity at 114uS/cm is slightly lower than previous years.
See Summary table page 24. In the high flow year of 1997, Bartlett's conductivity range was 151uS/cm. At that time conductivity levels dropped to 173uS/cm. In 2001, the lowest reading was 209uS/cm. The cyclic pattern of conductivity dips for high water seen in previous years was repeated in 2001. See Bartlett Chart 6 pg 58.

Bartlett's water temperatures accompanied rising air temperatures at the beginning of April. However, at the end of June when air temperatures continued to rise, water temperatures stayed low – below 12°C. Then they began dropping even lower at the beginning of October. Bartlett is slightly cooler than Harris in winter and slightly warmer than Harris in summer. Its record of low readings confirms Bartlett's suitability as a drinking water source.
Over 5 years 85% of samples was 9°C or lower and no sample was above 13°C. This is based on 606 samples. See Water Quality Chart 3.

4.0 Results and Discussion

4.6 Hasty Creek

Hasty Creek is one of a number of streams that originate in a range of high mountains south Silverton. The other creeks from north to south are: Vevey, Babe Ruth, Fingland, Congo and Alwin. All the Red Mountain creeks are small . In their lower reaches, they flow through a mixed terrain of marshes and wetlands.

The Hasty Creek Watershed ranges in elevation from 500 meters at Slocan Lake to 1,900 meters at the height of land. The creek had 20 registered licensees as of 9/1995.

The station is located above all user intakes at an altitude of 940 meters. It is the highest station in the program and winter access is limited due to snow and weather conditions. The creek just above the station is a cascade - pool morphology with a 2 - 3% slope.

Approximately 100 meters upstream from the monitoring station the terrain opens up into a wetland and an old beaver pond that has filled in. The wetland is overgrown with sedge grasses. Here, the soil is black and organic in origin. The banks of the stream are also a dark, soft peat material. A number of smaller streams pass through this wetland before they converge and descend from the wetlands.

The largest Hasty tributary flows from the Vevey Watershed via a diversion that was built in the early 1900's. This diversion channel contains abundant coarse "granitic" sand. This channel also shows evidence of movement and instability. Material on the bottom of the creek at the gauge is a combination of dark wetlands "peat" and coarse white sand from the Vevey Channel.

The local residents who take water directly from Red Mt. creeks for domestic supply have expressed concern for a number of years regarding road building and logging in their watersheds. Logging operations commenced in the winter of 2000 and continued in the fall and winter of 2001. Road 200 that cuts across the numerous streams above the wetland has been cleared and partially constructed. The bridge across Hasty and above the wetlands was built. Six small cut blocks with 30 - 40% retention were completed in 2001 **(12)** .
Thirty-seven hectares of wood were removed from the Hasty watershed in 2001 **(11).**
The creek is metered and the gauge is read by Denyse La Croix

4.0 Results and Discussion

Hydrometric and Sediment Summary for Hasty Creek

A large number and variety of tributary streams and the wetlands influence the Hasty Creek cyclic discharge pattern. Hasty's discharge pattern for 2001 was similar to the 4 previous years in that multiple peaks were noted during the late April – June freshet time. Year 2001 was exceptional in that the overall volume of water during this time was down.

For example, in 1999 (another low flow year) the mean discharge for June was 0.627m3/sec. In 2001, June's mean reading was 0.263m3/sec. High water for 2001 was reported on May 24th at

0.926m3/sec. This is close to the 0.966m3/sec high reported in 2000. The event came without rain or exceptionally warm temperatures.   See Hasty Charts 1 & 2 pg. 64.

A low flow of 0.05m3/sec was reported on March 5, 2001. This is the lowest low flow reported in 5 years of study.   The monthly mean for March at 0.064m3/sec compares with 0.107m3/sec seen in 2000.   See Hasty Charts 1 & 2 pg. 64.

The yearly high sediment reading of 110mg/l came on the same day as the peak flow of 0.926 m3/sec. This level of sediment is high when compared with previous years. For example, in 2000, at approximately the same flow (0.966m3/sec), sediment was recorded at 26.7mg/l.

Hasty sediment and turbidity values show a close relation.. See Chart 5 pg. 66. The few outlying values appear to the left and above the curve.   These values represent samples taken in fall, when sediment tends to rise with rain but without a large increase in flow.

A review of 5 years of sediment data shows the percentage of sediment samples reported as being less than 0.5mg/l was 13.3%. This is based on 339 samples. For turbidity, a total of 74.9% of samples were less than or equal to 1 NTU and 97.2% were less than 5 NTU's. This is based on 319 readings. See Water Quality Charts 1 & 2, pg   .

4.0 Results and Discussion

Conductivity and Temperature Summary for Hasty Creek

Hasty's conductivity values are relatively low when compared with other upper valley creeks. This is likely due to the low mineral content water from the Vevey watershed. A sudden drop in conductivity was recorded on May 24th when levels went from 60.2 to 40.2 uS/cm in two days. The overall range of conductivity at 52.3 uS/cm in 2001 is in line with values seen in previous years when the flow was higher.

Historically, Hasty's water temperatures have been low because of the high elevation of the gauge and the high mountain source of the Vevey tributary. See Hasty chart 7, page 67. Hasty does not have a consistent yearly trend in its relation to air temperatures when all 5 years of data is reviewed. In years 1, 3 and 5 there appears to be a lag between rising air and water temperatures.
In years 2 and 4 water temperatures do follow air temperatures fairly close.

A review of temperature data for 5 years shows that 86.4% of samples are 9°C or lower. Samples at 13°C and higher were 2.8%. This is based on 603 readings. See Water Quality Chart 3, page

4.0 Results and Discussion

4.7 Lemon Creek

When data was collected, Lemon Creek was the largest creek in this program. It has 8 major tributaries and encompasses an area of over 170 sq. km. Lemon flows off Slocan Ridge located on the east side of the Slocan River near Appledale.

During the past 10 years, Lemon has been heavily logged and much of the lower elevation forest now contains trees less than 3 meters in height. The headwaters of Lemon originate in high elevation alpine terrain.

One branch of the creek flows from Sapphire lake which is located within Kokanee Glacier Park. One of the main north tributaries of Lemon called Chapleau Creek has very steep unstable slopes on its northern side. A number of serious slides entered the creek in 1998. The road that traverses Chapleau's slope has recently been deactivated and access is restricted. See Lemon Map 1, Appendix 9.8 pg. 427.

Lemon has an automated flow measuring station owned and operated by Water Survey Canada. The station is located 4km up the Lemon Logging Road. Ten water licensees are reported; however, all residents now obtain water from shallow wells rather than the creek.

The sample collection site is located approximately 4.5 km downstream from the automated station. Water and air temperature and weather observations are currently taken by Peter Leach at his house. Over the last 5 years, Peter has carefully observed Lemon and noted changes in turbidity and flow. He collects samples strategically and so we have a reasonably good record of events on Lemon. Unfortunately, there is a lengthy delay in obtaining flow data from the Lemon Station and for this reason records have not been updated.

4.0 Results and Discussion

4.8 Elliot Creek

The Elliot Creek Watershed is located on the east side of Slocan River adjacent the Perry's Siding bridge in Appledale. It is a small (195.6 ha) domestic watershed with two main channels that come together in the middle of the watershed. Below the confluence of the two channels the creek flows under a rock slide and emerges just above the monitoring station.

In May, 1995, Al Isaacson performed a hydrological review of Elliot (**14**) and adjacent Watersheds. He noted that the Elliot watershed had a small flat area with steep sides of talus rock . This area collects water while the slopes remain dry. Isaacson noted that the small size of the watershed, steep nature of the channel, broken slopes and unstable geology made this watershed unsuitable to manage for both water quality and timber production.

Two reviews of the Elliot Creek watershed were performed in 1998 with local residents and the following observations were made:

- The watershed is low elevation; hence, it experiences peak flow in March – April.
- Abundant old wood debris was noted in sections of the channel and abundant larger logs were lodged above the channel awaiting recruitment.
- The small bench referred to by Isaacson, contained streams, a marshy area and wet indicator plants. The stream cascaded off the bench into the main channel
- The main sources of sediment appeared to be uprooted root masses and eroded stream bank

The Elliot Creek station is located at an old Water Survey site approximately 15 meters up from the highest user intake. It is read by Shemmaho, a local resident. The elevation is 730 meters.

Just below the weir the creek drops quickly forming a step-pool morphology with woody debris playing an important role in channel integrity.

Regarding forestry operations, in year 2001, two hectares of land was cleared to build a road (**11**). The road is located on the north ridge of the watershed.

4.0 Results and Discussion cont.

Hydrometric and Sediment Summary for Elliot Creek

The fact that measurements could not be taken at the Elliot weir between December to February and August to December and water was flowing below the weir indicates that Elliot flow increases below the weir. This fact was observed by Dr. Tony Salway (**15**) in 1984 in a study where measurements were taken at the weir and at the point of diversion (approximately 15 meters downstream). The readings at the point of diversion were significantly higher than the weir, especially at low flows.

The lack of readings also relates to the fact that 2001 was an extremely low flow year. Although flow may increase downstream form the gauge station, the weir did not leak. Hence, comparisons with previous years are valid.

The peak flow reported at 0.110 m3/sec on April 28th was short in duration and it was medium height compared to previous years. Only one main peak was noted. The mean for the month of May was 0.019m3/sec. This is the lowest May mean recorded in 5 years of study, the second lowest being 0.024m3/sec in 1998. Elliot's remarkably consistent flow is illustrated on Chart 2 pg 74.

Elliot's high sediment reading for the year was reported on March 13th, 2001. The lack of connection between high flow & high sediment is characteristic of Elliot. In 1998, the yearly peak sediment value of 28.8mg/l came in December and in 1999 the highest recorded sediment reading of 52.2mg/l came during a big rain event in November. Four samples taken during the freshet near April 28th did have elevated sediment and turbidity. Warm temperatures and heavy rain accompanied this time. See Chart 3 & 4 pg. 75.

Unlike most of the other valley creeks, Elliot's sediment readings do <u>not</u> show a strong relation to turbidity. See previous years charts and Chart 5, page 76. Turbidity has a slightly stronger relation to flow than sediment. This is likely due to fine sediment particles in the Elliot's clay soils and abundant functioning woody debris that traps larger particles. Outlyers for both sediment and turbidity fall to the left of the curve and indicate a tendency for Elliot to show occasional high sediment/turbidity without an accompanying increase in flow.

Fifteen percent of samples were less than 0.5mg/l for sediment, 38.4% were less than 1 NTU and 88.2% were lower than 5 NTU. This is based on 720 readings taken over 5 years. See Water Quality Charts 1 & 2, page .

4.0 Results and Discussion

Conductivity and Temperature Summary for Elliot Creek

Historically, Elliot's Conductivity range has been one of the highest in the program. Year 2001 was no exception. With a drop from 148 to 96 uS/cm on April 24 – 29th, Elliot's conductivity levels reach a low one day after the high flow for the year. The maximum reading of 216 uS/cm in September, 2001 is the highest recorded in 5 years of study. This large range reflects a strong dilution effect in spring – possibly from surface run off entering the channel. See Chart 6, pg. 76.

The Watershed has abundant forest cover. This fact and the abundant ground water results in low water temperatures. Readings rarely rise above 10°C or fall below 4°C. Year 2001 follows this same trend. See Chart 7 pg. 77. The percent of readings that were less than or equal to 9°C was 94.2% and none of the readings were higher or equal to 13°C. This is based on 720 readings over 5 years. See Water Quality Chart 3, page .

4.0 Results and Discussion

4.9 Jerome Creek

Jerome is a 1st order creek that flows from a 2.85 square kilometer watershed. It is located on the north east slope of Perry's Ridge in Appledale. Jerome's channel alternates between alluvial and non- alluvial origin. It is characterized by flat terrain in the headwaters and a steeply descending cascade channel.

The watershed covers an elevation of 600 to 1,800 meters at the ridge- top headwaters. It has two main tributaries that converge at 1,500 meters elevation. A Stream Channel Assessment was performed on Jerome during the fall, 1998 by Steve Chatwin (**16**). A summary of his findings helps to characterize the creek, to quote:

1. The creek channel is unconfined over the alluvial fan and tends to avulse.
2. The channel above the fan is confined by steep valley sides consisting of rock and colluvium. Old slide scars on the north slope indicate high debris flow hazard.
3. The upstream channel alternates between alluvial and non- alluvial origin, is sub-surface in places and contains no mobile bedload.

4. The upper reaches of Jerome are step-pool with small woody debris jams and evidence of recent accumulations of bedload (likely 1997 high flows).

Jerome has a large alluvial fan that extends far below the limit of the surface creek. Subsurface flow from underground streams fed by Jerome likely supply numerous wells for downstream residents. The flow measurement station is located at the break between the fan and the steep slope above. Chris Cowern reads the gauge on a 3 ft. weir.

Hydrometric and Sediment Summary

In years 1998 – 2000, Jerome's peak flow ranged from 0.180 – 0.262m3/sec. In year 2001, the recorded high flow for the year on May 26th was 0.057m3/sec. Three peaks were observed between May 2nd and the high on May 26th. The monthly mean for May was 0.044m3/sec. In previous years the monthly mean averaged 0.13m3/sec. As noted in the hydrograph, Jerome rises quickly and descends to low water levels by September.

The high came during a period of warm temperatures but no rain. The low for the year was reported on February 9th at 0.003m3/sec. This is the lowest level reported in 5 years of study. See Charts 1 & 2, page 81.

4.0 Results and Discussion

Hydrometric and Sediment Summary for Jerome Creek cont.

The maximum sediment level at 21.6mg/l was recorded on November 26, 2001. This reading was taken on one of 4 samples collected 3 days after reported rain. Historically, two creeks – Cadden and Elliot had peak sediment readings during rain events in Fall, 1999. This is the first fall high- sediment reading for Jerome.

Jerome has reported relatively low sediment readings for 5 years. However, 2001 is the lowest. This low sediment reading during a low flow year may indicate that water levels did not reach a threshold level. See Chart 3 & 4 pg. 82.

It is interesting to note the high turbidity readings taken during the first flow event on May 2, 2001. These readings did <u>not</u> correspond with elevated sediment levels. The relation between sediment and turbidity is seen on Chart 5, pg. 83. Outlying sediment and turbidity values are seen above and to the left of the curve.

Regarding Jerome's water quality, 19.2% of samples were less than 0.5mg/l for sediment. Fifty five percent were less than 1 NTU and 95.2% were less than 5 NTU based on 276 sample readings. See Water Quality Charts 1 & 2, page .

Conductivity and Temperature Summary

Jerome's Conductivity dropped from 165 uS/cm on March 19 to 49.3uS/cm on March 26th .This large drop was accompanied by a slight increase in flow and occurred at the same time as a rain event. The drop is likely due to a rain- on- snow event resulting in a sudden flush of dilute water into the channel. Over the year, the range in conductivity at 130uS/cm was exceptionally large when compared to previous records. The maximum high conductivity reading at 179uS/cm is in line with previous years. See Chart 6 pg. 83.

Historically, the relation between air and water for Jerome is not close i.e. Jerome's water temperature remains cool all year. This trend continued in 2001. Jerome's water temperature rarely reaches 9°C . See Jerome Chart 7, page 84

Drinking water quality as judged by temperature is excellent. Over 97% of Jerome's temperature readings were below 9°C degrees and none were over 13°C. This tendency for Jerome to stay cool helps keep fecal bacteria counts low.

4.0 Results and Discussion

4.10 Winlaw Creek

The Winlaw Creek watershed is located on the east side of the Slocan River adjacent to the community of Winlaw in the Slocan Valley. The main creek runs southeast to northwest and ranges in elevation from 520 meters where it enters the Slocan River to over 1,700 meters at the ridge tops.

Winlaw Creek contains 4 smaller basins and one class three sub-basin. The north side of the watershed is south facing and it is characterized by dry, open terrain. Fire suppression here has promoted dense shrub and ground cover. The south slope, which is north facing is steep and densely wooded with deeply incised tributary channels. One channel flows from a small lake.

The Winlaw watershed has only one road that traverses the north slope. This old road was used to access a mine on the north slope. Though largely overgrown and stable along most of its length, a section that crosses the north tributary is prone to landslides.

Some clear cut logging has occurred in the upper reaches of the south slope accessible from the Pedro Creek watershed. Two woodlots have been established on the northwest slope and cutting within Winlaw is contemplated under the Small Business Forestry Program. Winlaw serves 43 registered licensees as of 1995.

Historical flow data from the 1970's does exist for Winlaw. However gauging and metering the creek has been a challenge. To date, three gauges have been installed over the last 5 years. New gauges were installed because of channel shifts.

4.0 Results and Discussion

Winlaw Creek cont.

In 1997, the Winlaw Watershed Committee commissioned Apex Geoscience to look at channel conditions in Winlaw Creek (**17**).

The study was done to assess the likelihood that in-stream restoration works would restore fish habitat and stabilize the channel. The report provides useful information that helps in understanding the current condition of Winlaw Creek in relation to hydrometric/sediment data. Some relevant findings are listed, to quote:

- Winlaw's active channel pattern is altered by frequent flood events. The channel changes from irregular to confined meanders as one progresses upstream.

- These occasional flood events bring large quantities of bedload from tributaries into lower reaches. Here, the lack of large woody debris means the transport rate is higher than under natural conditions.

- A large undercut kame terrace (approx 3km up the creek) was the only significant sediment source noted in the report. Here, sediment is from surface erosion.

Hydrometric and Sediment Summary

Due to the fact that only 34 readings were reported between April and June, the high flow record for year 5 for Winlaw is not strong. In the period between April 28th to June 17th, three peak events were reported. At 4.39m3/sec, the high flow for the year on May 15 was lower than the 5.5 m3/sec reported in 1998, another low flow year. By comparison, the peak for 1997, an extreme high year, was 14.9m3/sec.

The monthly mean gives an indication of water volume over time. The June monthly means for 1998, 1999 and 2000 were 1.04, 2.96, and 2.07m3/sec. while June, 2001 reported
0.982 m3/sec.

The high came just after rain but warming temperatures were not a factor. As noted in Charts 3 & 4, pg. 90, water levels dropped quickly in early June, and rose to 3.555m3/sec for a day in mid June.

The low for the year at 0.057 m3/sec was reported on February10th. This is the second lowest low water reported in the 5 years of study. The lowest was 0.021 m3/sec on 11/2/98.

4.0 Results and Discussion

Hydrometric and Sediment Summary Winlaw Creek cont.

Historically Winlaw's sediment levels have not been closely linked to flow. In 2001, this trend continued. The high sediment reading at 4.2mg/l on March 27th likely reflects incomplete sample coverage rather than the actual high for the year. Turbidity is also scattered in relation to flow as seen in Chart 5, pg.91.

Winlaw's generally good water quality is illustrated by the fact that 28.7% of samples tested for sediment were less than 0.5mg/l, 68.6% of turbidity samples were less than 1NTU, while 95.6% of samples were less than 5NTU. This is based on 306 samples over 5 years. See Water Quality Charts 1 & 2, page

Conductivity and Temperature Summary

Historically, the relation between conductivity and flow has not shown the predictable highs and lows seen in the upper valley creeks. Winlaw is subject to unexplained drops and fluctuating highs in conductivity. There is mention of the existence of salt/high mineral banks in the north fork. Supposedly, ungulates frequent them and disturb them. If true, this would explain the erratic conductivity pattern sometimes seen in Winlaw creek. Year 2001 was similar to year 2000 in that no large drops or rises in conductivity were reported. At 97.8uS/cm, the conductivity range was comparable to previous years. See Chart 6 pg 91.

Winlaw's water temperature historically stays low in relation to rising air temperatures and year 2001 saw this trend continue. See Chart 7, pg. 92. Low temperatures are desirable for drinking water and Winlaw had 83.4% of temperature readings less than or equal to 9°C. Only 2.3% were greater than 13°C. This is based on 815 readings over 5 years.

4.0 Results and Discussion

4.11 McFayden Creek

The McFayden Watershed is located on the south end of Perry's Ridge in Vallican. The 5.0 sq. km drainage is south- facing and therefore called a "high energy" watershed. This community watershed is characterized by high snowmelt spring flows & very low summer flows.

According to Al Isaacson (**14a**), the critical area for water storage and regulation is approximately 100 meters down from the top of the ridge. Here, the soil and "organic layering" is best for holding water and releasing it slowly during the dry months. Most of the lower elevation terrain is steep and the entire watershed drops 5,200 feet in a distance of 2.5 miles.

The stream channel assessment done by Steve Chatwin in the fall, 1998 (**16**) is helpful in characterizing McFayden. Some relevant findings include, to quote:

1. Very high debris flow hazard which results from steep gradient channel, abundant boulders from talus/rock slopes and snow avalanche conditions in mid to upper slopes. (at least 3 debris flows since deglaciation.).

2. Little functional woody debris in lower reaches

3. Channel avulsion that is prominent on the fan, constrained by terraces.

4. Upper reaches are steep gradient step-pool channels and low gradient tributaries with detrital organic beds subject to scour.

In 1999, the reader for McFayden quit in protest to forestry activities in the Slocan Valley and the way this monitoring program was funded. The reader continues to read the gauge at the weir; however, the information obtained is not available to the public.

4.0 Results and Discussion

4.12 Airy Creek

Airy Creek is the most southern creek in the monitoring program. The watershed is 58 sq Kilometers. It has a north – north east aspect, granitic soils and it contains three main sub- basins; Tindale, Airy and one unnamed. All three sub-basins have a history of development that began in the early 1940's when the watershed supplied wood to a mill in Passmore.

The Tindale basin ranges from 800 to 2,000 meters in elevation. Steep slopes, small streams and a network of logging roads that are stacked across the slopes characterize the basin. The Tindale sub-basin has numerous debris flow slides which originate from older roads. Most of these slides extend to Tindale Creek.

The headwaters of both Airy and Tindale have been heavily cut with roads and tree removal to the stream banks. The lower reaches of Airy were horse- logged selectively in the 1940's and a riparian reserve is still intact. The Airy sub-basin ranges from 500 to 2,600 meters in elevation.

The Airy Creek monitoring station is located on the downstream side of the lowest bridge on the creek. It is below the user intakes. However, this is not a major concern because of the large size of the creek and relatively small water withdrawal volume.

In 1995, public concern and available funding from Forest Renewal B.C. was put towards deactivating and recontouring old roads. In 2000, some of the roads were upgraded and logging activities were resumed in the Airy creek drainage. In 2001, 44.7 hectares were logged in the Airy sub-basin (**11**).

4.0 Results and Discussion

Hydrometric and Sediment Summary for Airy Creek

The hydrograph for Airy creek is the most comprehensive of all the creeks in the program, Credit for the excellent coverage of this creek goes to the reader, Kuris Raits. Airy showed six distinct discharge peaks during the spring and summer of 2001 and one smaller rises in the fall. The peak flow at17.3m3/sec was reported on May 24th. This is slightly higher than 13.039m3/sec reported in 2000, but lower than 25.37m3/sec reported in November, 1999. Water levels began to rise at the end of April and stayed high through June. The high was accompanied by warming temperatures but rain had not fallen for 9 days.

Because of its north aspect and high elevation Airy's high water is usually later than other south valley creeks. In 2001, the timing for high flow was in line with other valley creeks.
The lowest gauge reading was entered at 0.03m3/sec on March 4th, 2001. This is the lowest reading in 5 years of study.

Airy's flow is subject to sudden rises and drops. This tendency is graphically illustrated in Chart 2 page 98 . In November, 1999 fall rains brought Airy water levels to the highest recorded level in the 5 year study. See Chart 2 pg. 98.

At 23.7 mg/l on May 23, 2001, Airy's peak sediment level was in line other low flow years. The lack of sediment with increased flow in late April relates to lack of samples, because of the uncertainty of the program. The peak sediment characteristically came at the beginning of the high flow i.e. one day before the high flow was reported. Turbidity readings rise at the same time as sediment but remain elevated longer as fine particles take longer to settle out. See Charts 3 & 4 pg.99.

The relation between flow, sediment and turbidity is less scattered than Winlaw, see Chart 5 pg.100. Airy's flow is largely confined as it passes over boulder & rock while Winlaw's channel is braided with unstable banks and backwash areas where sediment can be trapped.

Regarding the quality of water as it relates to sediment, 33.4% of Airy's samples were measured at less than 5mg/l. Seventy seven percent were lower than 1 NTU and 95.6% were less than or equal to 5 NTU's. This is based on 356 samples for sediment and 366 samples for turbidity over 5 years. See Water Quality Charts 1 & 2, page .

4.0 Results and Discussion

Conductivity and Temperature Summary for Airy Creek

Historically, Airy shows the lowest conductivity of all the creeks in the study. It also has the lowest range in conductivity. See Airy Chart 6 pg. 100. Year 2001 followed trends of previous years with the main conductivity drop occurring in early spring with increasing flow.

The cyclic yearly pattern of high conductivity in fall and a rapid drop in the spring can be seen on chart 6, page 100. It is interesting to note that conductivity drops sharply at the beginning of spring with the first rise in discharge then continues to drop slowly as spring progresses. Occasional drops during fall rain events are seen.

Airy's air and water temperatures are strongly linked. Water temperatures remain low all winter and slowly rise with rising air temperatures in March. Water temperatures then respond quickly to high air temperatures in summer as seen in Chart 7 pg. 101.

Regarding Airy's water quality as it relates to temperature, 83.5% of readings were less than 9°C, while 7.0% were equal to or greater than 13°C. This is based on 815 readings. Airy compares with McFayden and Bonanza in its tendency to become warm with rising air temperatures, even though it is not south-facing.

4.0 Results and Discussion

4.13 Total and Fecal Coliforms

Background and Methodology

The former Ministry of Environment, Air, Lands and Parks Water Quality Objectives for Bacteriological Quality for drinking water were recently revised to place greater emphasis on Fecal Coliforms and E.coli. (**1**). In line with this directive, the Monitoring Program dropped the Total Coliform Test in 1998 and has focused on Fecal and E.coli counts.

In year 1997, testing was initially done using the Multiple Tube Fermentation method. The results of the initial testing was kept separate from this study because of a difference in method . This 4 year study uses the Membrane Filtration Method.

In the years 1998 and 1999, five sets of samples were taken in spring and fall and testing was done by Membrane Filtration from here on. In years 2000 & 2001, one set of 5 samples was collected over 30 days during late summer. In the first 3 years, Cadden and McFayden creeks were tested in addition to Harris, Bartlett, Hasty, Jerome, Winlaw and Airy. In 1999, 2000 and 2001 testing on Cadden and McFayden was discontinued.

In 2001, the normal 30 day period was extended to 46 days to include warm summer temperatures and a Fall rain event. As in previous years, an attempt was made to sample strategically e.g. immediately after heavy rain or during warm temperatures. All samples were collected by an experienced bacteriologist from Passmore Laboratory Ltd. The samples were held on ice during transport. They were taken to the laboratory and tested the same day.

Analytical test methodology followed procedures outlined in the American Public Health Association publication (A.P.H.A.): "Standard Methods for the Examination of Water and Wastewater" Membrane Filtration Method For Fecal Coliforms (**6**). All plates were read after 24 hours and incubated for a total of 48 hours to confirm original counts.

In 2000, the tests for presumptive E.coli were done using standard I.M.ViC. biochemical tests. In 2001 the tests for presumptive E.coli were done using Enterotube ll as recommended in the A.P.H.A. document cited above.

Enterotube ll is a self-contained, compartmentalized plastic tube manufactured by Becton Dickinson. It contains twelve different media. The tube is inoculated with a purified culture and the results of 15 different biochemical tests are recorded after 24 hr. The resulting color/gas reactions are compared to known specimens. See Table 3, page 109.

4.0 Results and Discussion

Review of Findings Fecal Coliforms 1997 - 2001

1. HARRIS CREEK: Between 1998 and 2001 thirty samples were collected from Harris Creek. Samples were taken during spring and fall. During this period, fecal coliform counts ranged from 1 – 8 cells/100ml. In 2001, fecal counts ranged from 2 – 7 cells/100ml for 5 samples. This is higher than in 2000 when fecal counts ranged from 1 – 3 cells/100ml. The average water temperatures in 2001 at the time of sample collection were 1°C higher than in the previous year and was the highest in 5 years of testing. See Harris Fecal Coliform Chart 1 page 110. In 2000, three of the five samples tested were positive for presumptive E.coli. In 2001, one sample was tested for E.coli and found to be positive.
   For the sake of completeness, in Fall of the first year 1997, 6 Harris samples were tested for fecal coliform using MPN methods and 1 sample had a count of 1.1MPN.

2. BARTLETT CREEK: Between 1998 and 2001, thirty samples were collected from Bartlett Creek. Counts ranged from 1 – 3 over this 3 year period. Samples were taken on the same day as the Harris Creek sampling. Of the 5 samples tested in 2001, two had counts of 1 – 2 cells/100ml for

Fecal Coliforms. As with Harris, water temperatures were higher than in all previous samplings. See Bartlett Fecal Coliform Chart 2, page 110.

For the sake of completeness, in Fall 1997, 6 samples from Bartlett creek were tested using MPN methods and only 1 sample had a count of 1.1 MPN.

3. HASTY CREEK: Between 1998 and 2001, thirty samples were collected from the Hasty Creek gauge site. Samples were taken on the same day as Harris and Bartlett Creek sampling. Of the samples tested, twenty three were positive for Fecal Coliforms. Nine of the twenty three samples had counts of 1 – 2 cells/100ml. The highest count was greater than 300 cells/100ml in August, 2000. That sample was taken after a rain event and during warm weather. However, the water temperature at that time was only 8.5° C. See Hasty Fecal Coli Chart 3, pg 111.

   In Fall 1997, 6 samples from Hasty were tested using MPN methods and 4 had counts between 1.1 and 2.2MPN.

4. HASTY_VEVEY CHANNEL & WETLANDS: Water samples taken at the Hasty Creek gauge represent input from two main sources. The first is the Hasty wetlands that contain numerous ponds and marshy terrain. Input from the Vevey watershed represents the second source. This channel originates on high alpine mountain slopes. In 2000 and 2001, water samples were

   collected upstream from the gauge at the wetlands channel and from the Vevey channel. On July 14^{th} when fecal counts read 3/100ml at the gauge site, samples from the wetlands read 14 and 13 cells per 100ml. Water temperatures at the wetlands were also one and a half-degrees higher than temperatures at the gauge readings . The Hasty- Vevey channel count for that same day was 1 cell/100ml. On August 8^{th} the wetland fecal counts were 4/100, the Vevey channel counts were 0/100ml and the gauge counts were 8/100ml. Regarding the incidence of E. coli in Hasty - in 2000, only 2 IMViC tests were reported and both were negative for pres. E.coli. In 2001, three Hasty gauge samples were tested using the enterotube technique. The gauge samples had 1 E.coli, 1 atypical E. coli & 1 Shigella genus. Four wetland samples were tested. They showed 3 E.coli and 1 atypical E. coli. All colonies including the ones that showed atypical reactions were a normal blue color on m-FC agar.

5. JEROME CREEK: Between 1998 and 2001 thirty two samples were collected on Jerome Creek. Early tests done in 1996 – 97 indicated that Jerome has low Fecal counts. See report for year 2 . Of 52 samples collected over 5 years, only 7 have shown fecal coliforms and only three samples had counts higher than 2 cells/100ml. In 2001, none of the 5 samples collected between July 14th and August 24th contained Fecal Coliforms. See Jerome Fecal Coli Chart 4, pg 111. Water temperatures at collection were low at 8 – 9°C. Jerome's water temperatures are not highly influenced by air temperatures. See Jerome Chart 4 page 111.

   In 1996 – 1997, eighteen samples were tested using the MPN method. Only two had detectable fecal coliforms with counts of 2 and 2.2MPN.

6. WINLAW CREEK: Between 1998 and 2001 thirty four samples were collected at the Winlaw Creek gauge site. Nineteen were positive for Fecal Coliforms. In year 2001, three of the five samples were positive for fecal coliforms. Counts ranged from 1 – 2 cells/100ml. See Winlaw Fecal Coliform Chart 5, page 112.

   Regarding the incidence of pres. E.coli, in 2001 two cultures were tested using the Enterotube technique. One sample was positive. The second was negative.

   Between 1996 and 1997 twenty samples were tested using the MPN method. Six were positive for fecal coliforms with counts between 1.1 and 3.6MPN

7. AIRY CREEK: Between 1998 and 2001, thirty four samples were collected from Airy Creek at the gauge site. Nineteen were positive for Fecal Coliforms. Most counts were less than 3; however, the higher counts were all seen when water temperatures were above 10°C. See Airy Creek Fecal Chart 6, page 112. In 2000, 4 samples were checked for presumptive E.coli and 2 were positive. In 2001, 4 samples were tested using the Enterotube technique. Three were positive, one negative. Airy's water temperature is greatly affected by air temperatures. It tends to be unbuffered, ie., very cold in Winter and warm in Summer. The highest counts of 7 and 10 cells/100 ml were seen in 2001 when water temperatures were above 12°C.

   Between 1996 and 1997 twenty-one samples were tested using the MPN method. Twelve were positive for fecal coliforms with counts between 1.1 and 9.2 MPN.

8. In year 1998, McFAYDEN CREEK was tested for Fecal Coliforms (see Chart 7 pg.113).

McFayden consistently showed fecal coliform counts in the fall and no counts in spring. This may be due to the fact that water temperatures warm considerably in the fall and drop low in winter and spring.

This same trend was seen when samples were tested using MPN methodology in 1996 and 1997.

9. ELLIOT CREEK was tested between 1998 and 2000. During this period, twenty samples were taken and only 4 had counts. The fecal counts ranged from 1 – 4/100m and were noted when water temperature for Elliot was high e.g. 9°C. See Elliot Coliform Chart 8 pg 114. Eighteen samples were tested for fecal coliforms between 1996 – 1997 using MPN methodologies and none were detected.

The chart for WOLVERTON CREEK in Slocan Park is included for comparison.
The Wolverton watershed is similar to McFayden in that it is geographically near by, is approximately the same size, has steep slopes and, as an east facing watershed, it drains quickly. It does, however, have a small lake in its headwaters and like McFayden, it tends to get warm in summer with frequent readings of 12 - 13°C. In 2001, six samples were taken in July – August. Four had fecal counts between 1 to 10 cells/100ml. The samples with counts were all taken when water temperatures were 13°C or higher. See Wolverton Chart 9 pg 113.

4.11 Fecal Coliforms cont.

Biochemical Tests for Presumptive E.coli

Atypical reactions where E. coli was the likely Genus/species were encountered in six of the isolates. Two other isolates with atypical biochemical patterns may have been Enterobacter. Eighteen isolates were tested from the six creeks. Atypical E.coli are known to occur in natural stream waters and have been found to comprise 70% of the colonies on m-FC agar **(18)**. The final determination for E. coli type I or II was not performed. Hence, results are reported as Presumptive E.coli. Regarding the incidence of presumptive E..coli the following limited observations can be made on the study creeks:

1. Presumptive E.coli can occur in any creek occasionally, normally at low (1-2 cells/100ml) levels.

2. Within a population of Fecal Coliforms and for the creeks that showed higher levels of these organisms (like Harris and Airy), 50% percent of organisms tested were positive for Presumptive E. coli. There does not appear to be a correlation between Presumptive E.coli presence and increased water temperature

   See Charts Biochemical identification – Slocan Valley Creeks, Fecal Coliforms 2001

Summary of Fecal Coliforms and Presumptive E.coli

A review of the data for Fecal Coliforms and Presumptive E.coli indicates the trends noted in previous years continued in 2001. These trends are stated:

1. Increased counts after rain events.

2. Slightly increased counts with warmer temperatures. This trend was especially evident in the sampling series where water temperatures were warmer than previous years.

3. The tendency for each creek to have consistently low or high counts i.e each creek has its own range Fecal Coliforms counts.

4.0 Results and Discussion

Summary of Fecal Coliforms and Presumptive E.coli cont.

Regarding the incidence of presumptive E.coli the following limited observations can be made on the study creeks:

1. Presumptive E.coli are common isolates from Fecal Coliform populations in all the creeks in the study

2. Within a population of Fecal Coliforms and for the creeks that show higher levels of these organisms (like Hasty and Airy), over 50% percent of organisms tested were positive for Presumptive E. coli

5.0 Water Quality Summary

Background

The test parameters of temperature, sediment, turbidity, and fecal coliforms studied for 5 years on the Slocan Valley creeks are useful in assessing the current water quality of each creek and in establishing baseline information. The significance of these parameters is summarized:

- Temperature determines biological activity. Increases result in higher bacteria counts and change in water temperature can adversely affect aquatic life.

- Sediment and Turbidity are indicators of active erosion in a watershed. Both can relate to particles in water that can harbor bacteria, clog filters and damage water systems.

- Fecal Coliform Bacteria are direct indicators of contamination due to wild life and human activity in a watershed. They are also indicators of the efficiency of the natural filtration system in a watershed.

An interpretation of data is based on the following guidelines set forth by Provincial R.I.C. Committee **(1)**:

- Temperature - 15°C maximum
- Turbidity – < 1 NTU for health and < 5 NTU for aesthetics
- Suspended Solids – no objective
- Fecal Coliforms – 0/10

It is important to state that *the overall water quality of all the creeks in the Slocan Valley is very good and generally meets the above standards most of the time.* These observations are supported by the fact that samples were taken strategically i.e. readers collected more samples during rain events and high water. Hence, overall water quality would likely be even higher if samples were taken at regular intervals rather than during events.

The following discussion will relate the factors that affect water quality with the percentage of samples or readings that fall within the guidelines listed above. A summary of the data is given in the Water Quality Charts 1 – 4, pg. 118 – 121.

5.0 Water Quality Summary

Background cont'

Some of the factors that affect water quality in the study creeks are:

- Soil types and geology of the watershed
- Morphology and drainage pattern of watershed – volume of surface vs. ground water
- Aspect and elevation of the watershed
- Extent of development e.g. roads, cutblocks, and recreation access
- Forest cover and vegetation near stream banks
- Character and condition of headwaters e.g. marsh, lake or stream

Discussion on Sediment and Turbidity

A review of the Water Quality Sediment Charts 1, page 118, shows a higher percentage of detectable sediment levels in the upper valley when compared with lower valley creeks. Harris and Bartlett, however, rate similar to Lemon, Elliot and Jerome. This tendency for higher sediment in north valley samples may reflect a different bedrock geology. In the north valley, the Slocan group of rock includes slate, limestone and argillite as compared to the granodiorite rock of the Nelson batholith seen in the lower valley.

Grizzly and Cadden, the two tributaries of Bonanza, have a low percentages of clean sediment samples. Bonanza itself has a high number of samples with detectable sediment. Hence, these three creeks characterize active erosion processes in the Bonanza watershed.

Regarding turbidity, Harris, Bartlett and Hasty creeks have higher water quality than other upper valley creeks and the lower valley creeks Lemon, Elliot, and Winlaw.
These 3 creeks flow through wetlands which may trap the smaller particles measured as turbidity.

The higher number of samples with elevated turbidity seen in Elliot likely reflects its clay soils and conditions at the weir where sediment is stored in the pool.

McFayden's pristine watershed with intact soil may account for its clean water as noted by high number of samples with no sediment and low turbidity readings.
As noted in the Turbidity Charts 2 pg 119, all the valley creeks have very clear water with over 75% of their samples equal to or less than 5 NTU's.
Airy has a high percentage of low sediment samples. The water in Airy's upper channels flows through coarse mineral soil. The main channel is confined, flowing over boulder and bedrock with few areas of stored sediment.

Discussion on Temperature and Fecal Coliforms

A review of the water temperature data shows that 80% of readings for all the creeks except Bonanza are less than 9°C. See Temperature Chart 3, pg 120. Bonanza is probably warmer because of its lake origins and surface flow.
The three creeks with highest percentage of temperature readings greater than 13°C that were tested for coliforms had the highest number of detected readings for fecal coliforms. These creeks were Hasty, McFayden and Airy. See Temperature Chart 3 pg 120 & Coliform Chart 4, pg 121.

Hasty has organic soils, wetland ponds and marshes above the collection site. Water temperatures in the wetlands also rise. This combination contributes to high bacteria counts in the water.

McFayden is a south-facing watershed and its water temperatures are responsive to air. Hence, it gets warm in summer, allowing bacteria to grow.

Airy has a north aspect and no wetlands. It does, however, have a large network of roads.
Lack of forest cover in the headwaters of this watershed may contribute to water temperature rise during warm summer months.
Roads may also channel water directly into the main Airy creek the without cooling affect of ground filtration.

Winlaw and Bartlett have approximately the same percentage of water temperature readings below 9°c. Winlaw does have slightly higher percentage of warm temperatures readings.
Regarding fecal coliforms, the percentages of non-detected samples are similar for both creeks. Both creeks have good forest cover, pristine headwaters and they remain cool all year.
Bartlett is slightly cooler than Harris and, correspondingly has fewer coliforms.

Elliot and Jerome are the coolest creeks that were tested for fecal coliforms. They also had the lowest number of samples that were positive for fecal coliforms.
The relation between temperature and fecal coliforms cited above appears to be predictable for all the study creeks, especially when watershed factors are taken into consideration.

5.1 Quality Control

Summary of Quality Issues for Five Years

The Slocan Valley Water Monitoring Program was initiated before the Resource Inventory Committee (R.I.C.) Standards were fully in effect. The program was also begun before other regional water monitoring projects were under way. Hence, a number of issues regarding methodology and hydrometric standards had to be addressed. Because this report encompasses 5 years of work, a summary of quality control issues is appropriate.

1. Hydrometric Methodology.

Assistance was sought from John Harris, retired Water Survey Canada Employee, who lives in Nelson. John had worked for the Federal Agency for 30 years and had developed the Harris "drop in" weir used in the study.

John taught all aspects of stream flow measurement including metering, weir construction, benchmark installation and data analysis. His basic recommendations are still carefully followed today.

The only deviation from his methods occurs in the use of statistical formulas to calculate the stage discharge curve. This technique enables the use of a computer to convert gauge readings to flow measurements and handle large amounts of data.

The formula used was determined empirically and was instituted in the second year. It is noted that this same type of log-log formula is used to calculate conversion tables for weirs.

2. Laboratory Accreditation

Because of the large number of samples, the requirement for standardized analytical test procedures, the time that elapsed between sample collection and analysis, and the transport costs, it was essential that testing be done locally by a recognized laboratory.

This issue was addressed by working with Passmore Laboratory Ltd. through its accreditation with the Canadian Association of Environmental laboratories (CAEAL) using check samples. .An updated summary of performance is given in table 5, page 125.

Problems relating to transport time of check samples for fecal coliforms were experienced 2000 – 2001. These problems were resolved in October, 2001.
Differences in test results for suspended sediment were addressed by changes in analytical technique i.e. using the entire sample and rinsing the plastic containers.

Further in-house accreditation was achieved through the use of duplicate/replicate testing with the following reference laboratories: ALS Analytical Services, Cantest Laboratory Ltd., and the Kootenay Lake Hospital laboratory.

The main variation between laboratories occurred in the turbidity readings; this was not surprising since this test is generally acknowledged among laboratories as having high variability. All the other comparative tests generally conformed well with each other.
The results of these comparative tests with other laboratories ware extensively tabulated and graphed in the years II, III and IV reports.

3. <u>Chain of Custody for Water Samples</u>

To insure that samples would be definitely identified with individual who took it, a system was initiated whereby all sample tags showing date, creek and initials were removed from the bottles after testing and kept in a laboratory work-book as a permanent record with the analytical test results.

4. <u>Use of Recycled Sample Bottles</u>

A decision to recycle bottles was made at the beginning of the program because of the clean nature of the samples. In the laboratory, used bottles were treated to four rinses – three with low conductivity water and a fourth with distilled water. No soap was used.
When these recycled bottles were filled with distilled water and tested they invariably tested lower than detection limits for turbidity, suspended sediment and conductivity.
In addition to cleaning in the laboratory, samplers are told to rinse each bottle <u>three</u> times with creek water before filling as recommended in Stednick **(5)** sampling protocol**.**

5. <u>Weir Accuracy</u>

Right in the beginning, John Harris had informed us that for weir installations where the water did not attain zero velocity before exiting the pool, gauge readings would not be accurate and metering would be required in some cases. At that time, it was assumed the main interest in monitoring flow was its relative trends over time and not the actual quantitation of flow values. However, after 5 years of monitoring, it appears that accurate quantitation is an issue, especially if the flow data is to be used for licensing purposes.

In 2001, spot checks on Cadden confirmed deficiencies viz., the weir gauge readings converted to lower values than metered values. Hence, the Cadden flow values for 2001 were adjusted. Readings for the Harris Creek weir were comparable to metered values.

6.0 Recommendations

The following recommendations are based on a review of the program over the past five years. They cover both the personnel and the technical aspects of the work:

- Continue monitoring on creeks where community interest and willingness exists and where logging /road building is eminent.

- Offer training, services and funding to water user groups and community forest licensees intent on establishing their own program.

- Meter weirs 5 – 7 times during the year at existing installations to improve accuracy of flow data.

- Continue collecting Benthic Invertebrate, nutrient and metals data on one – two selected creeks for the purpose of establishing baseline information.

- Continue collecting Fecal Coliform data – 5 samples over 45days during late summer to early fall to establish trends relating to temperature and flow/rain events.

- Offer training to new groups who are committed and interested in inventory/basic data relating to flow, sediment, conductivity and fecal coliforms.

- Develop methodology and perform initial studies on the presence of Giardia and other protozoan cysts in consumptive use water sheds.

5.2 References

1. Cavanagh. N et al 1998. "Guidelines for Interpreting Water Quality Data" Published by Resources Inventory Committee (RIC) , Province of B.C

2. Slocan Valley Water Quantity and Quality Monitoring Program - Reports for Year 1,2,3 and 4 Winlaw Watershed Committee. Published by Winlaw Watershed Committee, RR#1, Winlaw., BC. VOG 2JO.

3. Meitner, Sheppard, Harshaw & Wilson, Arrow Forest District Innovative Forest Practices Agreement Socio-Economic Technical Report published by CALP, Dept. of Forest Resources Management, Faculty of Forestry, U.B.C., June 27, 2001

4. Forest Practices Board, Domestic Water-user Input in Forest Development Planning in the Nelson Forest Region, Special Report FPB/SR/06, October 2001

5. Stednick.J.D. 1991. "Wildland water quality sampling and analysis" Published by Academic Press Inc., San Diego.

6. American Public Health Association, American Water Works Association, Water Pollution Control Federation. 1989. "Standard Methods for the Examination of Water and Wastewater" Published by American Public Health Association, Fifteenth St, Wash DC 20005

7. Year II Report, Slocan Valley Water Monitoring Program, see above, page 13

8. Woodlot information from Ministry of Forests, Arrow Forest District Office, Castlegar

9. Gebhart. D.J. 2000. "Kokanee Spawner Assessment in Bonanza Creek Watershed Fall , 2000", Aquatic Resources Ltd.

10. Nancy Anderson, 1997, The Problems Arising as a Result of Lost Wetlands in the Kootenays and their Importance and Value, Specifically as Found at Bonanza Marsh at the Headwaters of Slocan Lake. Public Information Article

11. Slocan Forest Products , 705 Delaney St, Slocan V0G 2C0.

12. Pettiitt.C., Forest Watch Coordinator, Sierra Legal Defence Foundation

13. Isaacson, J.A. May, 1995, Hydrology Report for Denver Flats

14. Isaacson, J.A. 1995, Hydrology Report for Anderson/Elliot/Christian/Trozzo Creeks

14a. Isaacson, J.A. 1996, Hydrology Report for Perry's Ridge

15. Anthony A. Salway, Hydrological, Terrain and Geomorphic Processess Data Presentation for the Elliot/Christian Slope, 1984, for Slocan Forest Products

16. S. Chatwin Geoscience Ltd. Perry Ridge Stream Channel Survey, 1999, Arrow Forest District, Ministry of Forests, Castlegar

17. Apex Geoscience Consultants Ltd. Winlaw Creek Channel Conditions and Prescriptions Assessment, August, 1998, Winlaw Watershed Committee

References

18. Rychert and Stephenson, Atypical Escherichia coli in Streams, Applied and Environmental Microbiology, May 1981

19. Clark.G.McG. et al 1997. "Manual of Standard Operating Procedures for Hydrometric Survey in B.C. (RIC)."

Bibliography

MacDonald.L.H. et al 1991. "Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska" EPA Publication #910/9-91-001 US Environmental Protection Agency, Region 10, NPS Section,WD-139, 1200 Sixth ave, Seattle, Washington 98101

APPENDIX for Year 2001

Slocan Valley Quantity & Quality Monitoring Program

Year 5, 2001

November 30, 2000 to December 31, 2001

Presented by the Winlaw Watershed Committee

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