

## Cowichan River and Koksilah River: Water Quality Objectives Attainment (2012-2014)



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## **EXECUTIVE SUMMARY**

Water Quality Objectives (WQO's) were approved for the Cowichan and Koksilah Rivers in 2011 based on data collected in 2002, 2003, and 2008 (Obee and Epps, 2011). Attainment monitoring occurred from May 2012 through December 2014. Sampling was completed at ten sites on the Cowichan river mainstem, 15 sites in the lower Cowichan watershed including tributaries and storm drains, and at 17 sites in the Koksilah River watershed. Attainment data and changes that have occurred in the watershed between 2008 and 2014 are presented in this report.

Parameters that failed to meet WQO's in the Cowichan River watershed were: *E. coli*, dissolved oxygen, turbidity, total phosphorus, total copper, total zinc and temperature. WQO's were met in the Cowichan River watershed for: total suspended solids, ammonia, total lead.

Parameters that failed to meet WQO's in the Koksilah River watershed were: *E. coli*, dissolved oxygen, total suspended solids, turbidity, ammonia, total phosphorus, total copper, and total zinc. Only total lead and temperature met the WQO's in the Koksilah River watershed.

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## **1. INTRODUCTION**

As part of the Province of British Columbia, Ministry of Environment and Climate Change's (ENV) mandate to manage water bodies, Water Quality Objectives (WQO) have been created for a number of lakes, rivers and marine surface waters. The objectives set acceptable levels for water quality parameters that are of concern in a given waterbody. WQO's take into account natural local water quality, water uses, water movement, and waste discharges. While WQO's currently have no legal standing, they can direct resource managers aiming to protect the water body in question and are used as a standard against which to measure the water quality of that water body. Once objectives have been developed, periodic monitoring (every three to five years) is undertaken to determine whether they are being met.

The Cowichan and Koksilah Rivers, which support one of Vancouver Island's most valuable fisheries, lie within the Nanaimo Lowlands Ecoregion on the south-eastern portion of Vancouver Island (Figures 1 and 2). The Town of Lake Cowichan and the City of Duncan are located within the watershed. The Cowichan River is one of only three rivers in British Columbia designated as a Canadian Heritage River, based on its outstanding natural, cultural and recreational values. This watershed is used extensively for primary contact recreation such as swimming and kayaking, and is also a source of water for drinking, irrigation and industrial purposes (McKean, 1989).

WQO's were first developed for the Cowichan and Koksilah Rivers in 1989 (McKean, 1989). The objectives were updated in 2011 (Obee and Epps), based on attainment sampling conducted in 2002, 2003 and 2008 at five sites on each river. A second attainment monitoring program was then completed from May 2012 through December 2014. The results obtained from this program, as well as changes that have occurred in the watershed between 2008 and 2014, are presented in this report.

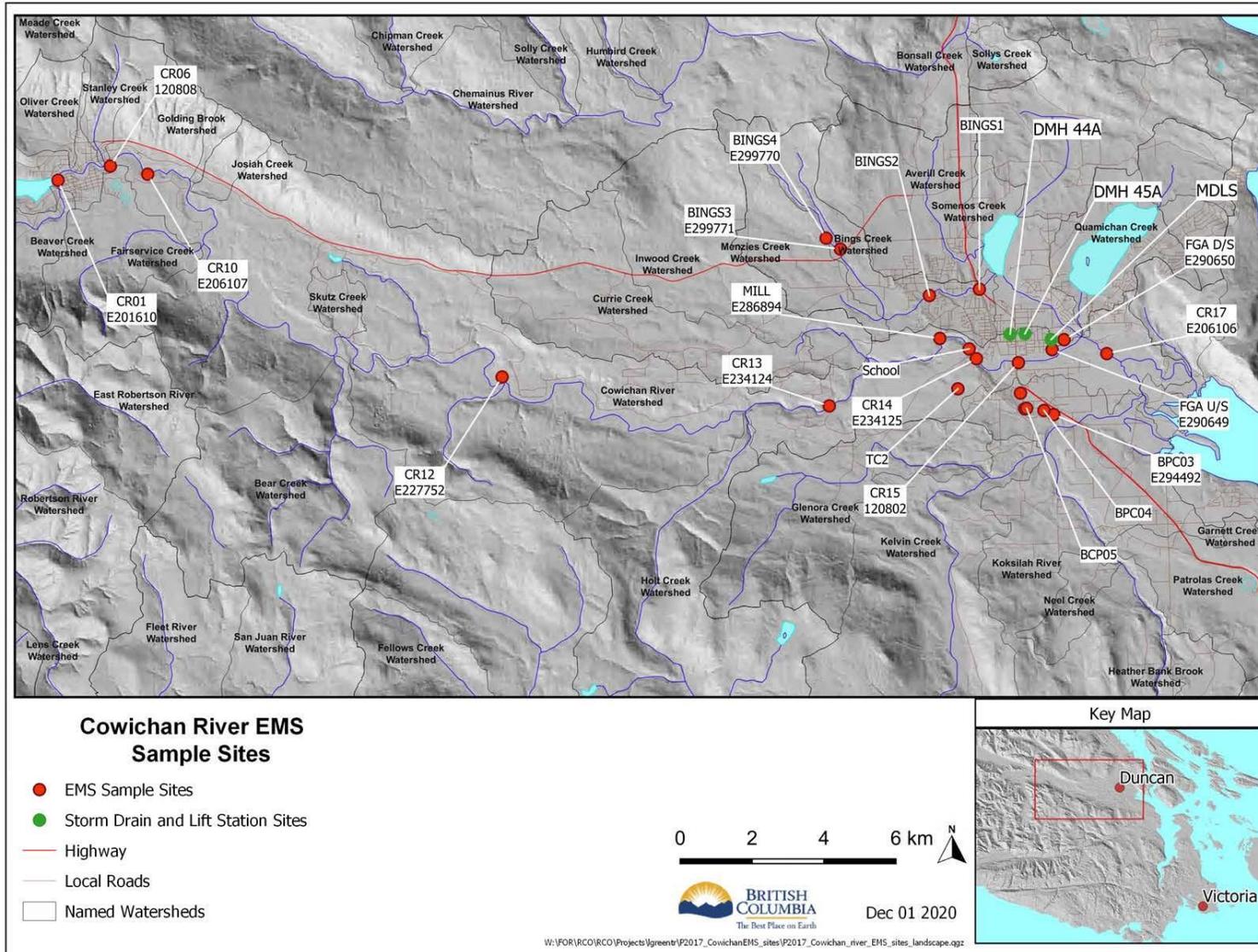


Figure 1. Cowichan River watershed and sampling sites

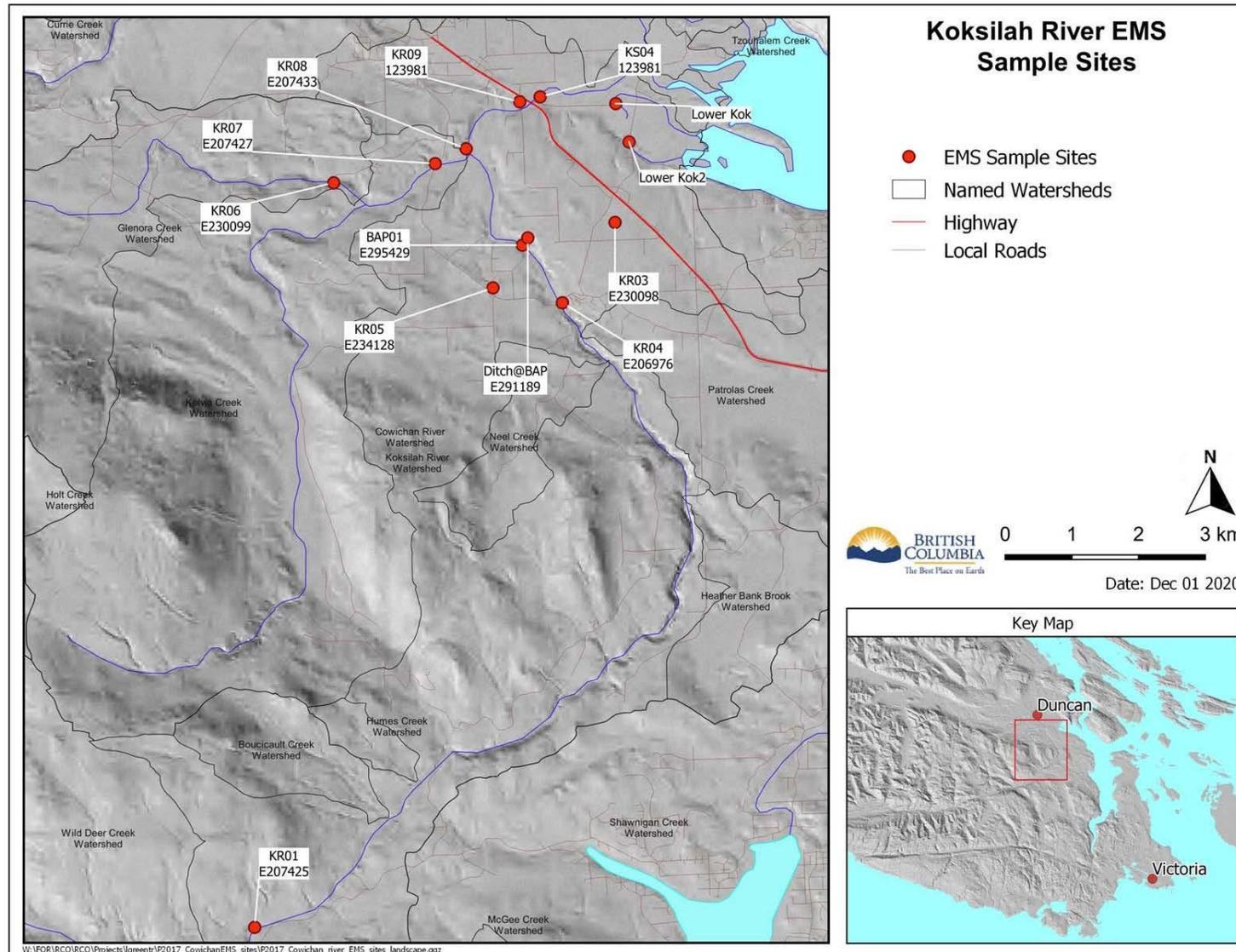


Figure 2. Koksilah River watershed and and sampling sites

## **2. CHANGES IN THE WATERSHED SINCE OBJECTIVES DEVELOPMENT**

The following is a list of known changes to the Cowichan and Koksilah River watersheds that occurred between 2008 and 2014:

- Land clearing and development occurred in the watershed potentially contributing to increased turbidity and phosphorus levels as soil is disturbed (Rutherford, *pers. comm.*, 2018).
- There was a shift towards aerial fertilization of agricultural crops and forestry operations that could increase nutrient loading in the watershed (Rutherford, *pers. comm.*, 2018).
- The quality of discharge coming from the North Cowichan/Duncan sewage lagoons has improved significantly in recent years (80% reduction in phosphorus) as a result of a new phosphorus removal system that was constructed to reduce the amount of phosphorus discharged to the Cowichan River. Typical phosphorus loadings have been reduced from water column concentrations averaging 4.5 ppm to less than 1 ppm (CVRD, 2010).
- The Cowichan Valley Regional District (CVRD) worked to take over, and bring up to provincial standard, more of the smaller sewage treatment plants, thus addressing some issues related to bacteriological inputs. However, many aging septic fields remain that continue to contribute to water quality issues in the region (CVRD, 2010).
- Slow population increase in the watershed is placing more demands on water resources. A local pulp mill uses a large percentage of the water licensed from the river system. Recent low flows have made it difficult for salmonid species to spawn in the river and also cause dilution issues for sewage discharges (CVRD, 2010).
- To decrease water usage, the CVRD and municipalities began providing incentives for homeowners to install water efficient technologies. They also legislated that water saving plumbing fixtures be installed in all new buildings (CVRD, 2015).
- The CVRD, forestry companies and municipalities implemented Best Management Practices (BMPs) for stormwater management and protection of ground water resources in the Cowichan Basin (CVRD, 2015).
- The Joint Utilities Board, the Town of Cowichan and the CVRD investigated and implemented strategies to avoid or minimize the release of treated effluent directly to the Cowichan River (e.g., by applying it to forest or farm land), particularly during the summer (CVRD, 2015).

- Between 2010-2014 there were four major gravel removal operations from the lower Cowichan river. Removal of gravel was intended to decrease the chance of flooding and lessen geomorphological changes to the main channel during high flow periods (Miller, *pers. comm.*, 2018).
- A trestle bridge providing access to the upper Koksilah watershed was rebuilt in 2010-2011. This greatly increased the number of recreational users accessing the area (Miller, *pers. comm.*, 2018).
- Initiatives to improve water quality by forestry companies working in the area included:
  - Island Timberlands instituted a program that allows managers to shut down hauling operations during extreme rainfall events to reduce high turbidity runoff (Epps, *pers. comm.*, 2018).
  - Continued road construction and improvement program. This included replacing old structures, installing base plates on bridges to stop runoff, and grass seeding (Epps, *pers. comm.*, 2018).
  - In 2009 Island Timberlands updated its practises for the upper watershed. They removed log jams and unused bridges and worked to decrease the amount of woody debris in the system (Miller, *pers. comm.*, 2018).

Important changes to the watersheds occurring outside of the study period:

- Stolz Bluff is an important part of the Cowichan River system. It is an eroding clay bluff on the upper Cowichan River which has added significant amounts of sediment to the river for many years. In 2006-2007 teams constructed a sediment collection system that successfully slowed the sediment inputs to the river. However, in 2017 sediment from the bluffs overwhelmed the system and added increased volume of sediment to the river (Rutherford, *pers. comm.*, 2018).
- The Koksilah watershed contains some large dairy farms which can contribute bacteriological contaminants to the river especially during periods of high flow where heavy precipitation events contribute to runoff events. Recently there has been outreach to farmers in the area and funding has been granted for farm improvement projects to reduce bacteria levels in runoff, including desiccation of manure and the building of sheds and rain covers for manure storage areas. A 2017 sampling program showed a decrease in bacteriological parameters that may be due these improvements (Rutherford, *pers. comm.*, 2018).

### 3. STUDY DETAILS

Water quality monitoring sites on the Cowichan and Koksilah rivers were sampled from May 2012 through November 2014 following recommendations in the WQO report shown in

Table 1 (Obee and Epps 2011). Sampling included water quality parameters and Microbial Source Tracking (MST) for selected sites (MST sites listed in Appendix 1 and 2).

*Table 1. Proposed schedule for water quality and benthic invertebrate monitoring in the Cowichan and Koksilah Rivers (Obee and Epps, 2011)*

<b>Frequency and Timing</b>	<b>Characteristic to be Measured</b>	<b>Sites</b>
August - September (low-flow season): once per week for five weeks	Hardness (once during 30 day period), temperature, pH, non-filterable residue/total suspended solids (NFR/TSS), turbidity, ammonia, phosphorus, total and dissolved metals, <i>Escherichia coli</i> , dissolved oxygen	All
October - November (high-flow season): once per week for five weeks	Hardness (once during 30 day period), temperature, pH, NFR/TSS, turbidity, ammonia, phosphorus, total and dissolved metals, <i>E. coli</i> , dissolved oxygen	All
Continuously	Temperature	At high-value rearing locations and C5
Once during low-flow season	Chlorophyll a	Downstream of PE-247, PE-1497
Once every five years	Benthic invertebrate sampling	All sites

Sampling was conducted during the summer low flow (August/September) and fall high flow (flush) periods (October/November). Monitoring focused on key environmental indicators for which five weekly samples were collected over 30 days during each period (5-in-30 sampling). Results from this sampling regime were used to calculate 30-day averages, maximum values, geometric means, and 90th percentiles, as recommended in the water quality objectives report (Obee and Epps, 2011).

Where the sampling regime met the criteria of five weekly samples in 30 days, these data were compared to the objectives/criteria. If fewer than five samples were collected over a 30-day periods, these data were included in the analysis but it was noted that the statistical calculations were based on fewer samples and could not be directly compared to WQO/criteria.

Metals were typically measured in only one to four samples over a 30-day period due to high analytical costs.

Table 2 and Table 3 provide lists of monitoring sites and years sampled in the Koksilah and Cowichan watersheds. Additional study details (e.g. who conducted sampling, laboratories used, list of parameters and sampling methodology) of 2012 and 2013 sampling are presented in separate summary reports (Maven Consulting, 2013; Smorong, 2014). Sampling in 2012 and 2013 included 5-in-30s in summer and fall as well as MST samples in the last week of fall sampling. Table 4 presents the details of 2014 sampling activities. All 2012-2014 data are summarized in this report as they relate to WQO attainment.

Analyses for MST was completed at Pacific Environmental Services Centre (PESC) in 2012 and 2013 and at the University of Victoria (UVIC) in 2013 to determine bacterial sources in the watershed. In 2012, 52 samples were collected for MST analysis but only the 33 samples (one Cowichan River site and 7 Koksilah River sites) meeting the required fecal coliform count of higher than 40 CFU/100ml were analyzed.

Table 2. Koksilah River Sampling stations

Site	Site description	EMS Number	Latitude	Longitude	Year Sampled:		
					2012	2013	2014
BAP01	Koksilah River d/s Bright Angel Park	E295429	48.73678	-123.6788		Yes	
Ditch@BAP	Ditch at Bright Angel Park	E291189	48.73774	-123.6777	Yes	Yes	
KR01	Koksilah at Renfrew	E207425	48.64596	-123.7377	Yes		
KR03	Patrolas Creek	E230098	48.73944	-123.6598	Yes	Yes	
KR04	Koksilah River at Koksilah Road	E206976	48.72884	-123.671	Yes	Yes	Yes
KR05	Howie Creek	E234128	48.73116	-123.6851	Yes	Yes	
KR06	Glenora	E230099	48.74602	-123.7168	Yes	Yes	
KR07	Kelvin Creek	E207427	48.74817	-123.696	Yes	Yes	Yes
KR08	Kosilah d/s Kelvin	E207433	48.75003	-123.6896	Yes	Yes	
KR09	Koksilah at Hwy	123981	48.75613	-123.6784	Yes		
KS04	Koksilah River at Hwy #1	123981	48.7567	-123.6742		Yes	
Lower Kok	Lower Koksilah	N/A	48.75546	-123.6588	Yes		
Lower Kok2	Lower Koksilah 2	N/A	48.75022	-123.6564	Yes		

Table 3. Cowichan River sampling stations

Area/Station	Station description	EMS Number	Latitude	Longitude	Year Sampled:		
					2012	2013	2014
<b><i>Cowichan River</i></b>							
CR01	Cowichan River south side at Cowichan Lake weir	E206108	48.8243	-124.0589	Yes	Yes	Yes
CR06	Cowichan u/s PE247	0120808	48.82748	-124.03897	Yes	Yes	
CR10	Cowichan d/s PE247	E206107	48.8252	-124.02495	Yes		
CR12	Cowichan at Stoltz	E227752	48.77195	-123.89321	Yes		
CR13	Cowichan River at Vimy Beach	E234124	48.7622	-123.77	Yes	Yes	Yes
CR14	Cowichan River at Allenby Bridge	E234125	48.77283	-123.71388	Yes	Yes	Yes
CR15	Cowichan River at HWY#1	0120802	48.77149	-123.69806	Yes		Yes
CR17	Cowichan d/s PE1497	E206106	48.77304	-123.66456	Yes		
MILL	Cowichan River at Mill Intake	E286894	48.778172	-123.727444			Yes
School	Cowichan River - Khowhemun School	NA	48.775333	-123.7165			Yes
<b><i>Tunnel Creek (tributary to Cowichan River)</i></b>							
TC2	Tunnel Creek Site 2	NA	48.765444	-123.721222			Yes
<b><i>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</i></b>							
BINGS1	Bings Creek Site 1	NA	48.790172	-123.711883	Yes	Yes	Yes
BINGS2	Bings Creek Site 2	NA	48.789	-123.730861			Yes
BINGS3	Bings Creek, approx 200 m u/s Drinkwater Rd d/s CVRD waste facility	E299771	48.801315	-123.763945			Yes
BINGS4	Bings Creek, approx 600 m u/s Drinkwater Rd u/s CVRD waste facility	E299770	48.804158	-123.769194			Yes
FGA D/S	Fish Gut Alley d/s Marchmont	E290650	48.77686	-123.6805	Yes	Yes	
FGA U/S	Fish Gut Alley u/s Marchmont	E290649	48.77446	-123.68516	Yes	Yes	
<b><i>Busy Place Creek (tributary to Cowichan River)</i></b>							
BPC01	Busy Place Creek - confluence of unnamed trib	E294493	48.759917	-123.696239		Yes	Yes
BPC02	Busy Place Creek at Hykawy Road	E294494	48.763858	-123.697647		Yes	Yes
BPC03	Busy Place Creek at Polkey Road terminus - a	E294492	48.758239	-123.685378		Yes	Yes
BPC04	Busy Place Creek at Polkey Road terminus - b	NA	48.759333	-123.689			Yes
BPC05	Busy Place Creek - Tributary confluence	NA	48.76	-123.6955			Yes
<b><i>Storm Drain and Lift Station sites</i></b>							
DMH 44A	Storm manhole 44A	NA	48.778694	-123.700833			Yes
DMH 45A	Storm manhole 45A	NA	48.778694	-123.695222			Yes
MDLS	Marchmont Storm Liftstation	NA	48.777028	-123.685389			Yes

Table 4. Details of 2014 sampling activities.

Area/Station	Station	5-in-30 sampling	Season	Sampler <sup>2</sup>	Parameters Measured
<b>Cowichan River<sup>1</sup></b>					
CR01	Cowichan River south side at Cowichan Lake weir	Yes <sup>3</sup>	Fall	ENV	Nutrients, conventionals, dissolved metals
CR14	Cowichan River at Allenby Bridge	Yes	Fall and summer	ENV, COD, CVRD	<i>E. coli</i> , total metals, turbidity, hardness, DO, temp
CR15	Cowichan River at HWY#1	Yes	Fall and summer	ENV, CVRD	<i>E. coli</i> , nutrients, conventionals, total metals, DO, temp
MILL	Cowichan River at Mill Intake	Yes	Summer	ENV	<i>E. coli</i> , turbidity, hardness, total metals
School	Cowichan River - Khowhemun School			CVRD	DO and temperature
<b>Bings Creek (tributary to Cowichan River)</b>					
BINGS1	Bings Creek Site 1	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
BINGS2	Bings Creek Site 2	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
BINGS3	Bings Creek, approx 200 m u/s Drinkwater Rd d/s CVRD waste facility	Yes	Fall	ENV, CVRD	<i>E. coli</i> , turbidity, hardness, total metals, DO, temp
BINGS4	Bings Creek, approx 600 m u/s Drinkwater Rd u/s CVRD waste facility	Yes	Fall	ENV, CVRD	<i>E. coli</i> , turbidity, hardness, total metals, DO, temp
<b>Busy Place Creek (tributary to Cowichan River)</b>					
BPC01	Busy Place Creek - confluence of unnamed trib	Yes	Fall	ENV, CVRD	<i>E. coli</i> , turbidity, hardness, total metals, DO, temp
BPC02	Busy Place Creek at Hykawy Road	Yes	Fall	ENV	<i>E. coli</i> , turbidity, hardness, total metals, DO, temp
BPC03	Busy Place Creek at Polkey Road terminus - a	Yes	Fall	ENV	<i>E. coli</i> , turbidity, hardness, total metals, DO, temp
BPC04	Busy Place Creek at Polkey Road terminus - b	Yes	Fall	CVRD	DO and temperature
BPC05	Busy Place Creek - Tributary confluence	Yes	Fall	CVRD	DO and temperature
<b>Storm Drain and Lift Station sites</b>					
DMH 44A	Storm manhole 44A	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
DMH 45A	Storm manhole 45A	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
MDLS	Marchmont Storm Liftstation	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
TC2	Tunnel Creek Site 2	Yes	Fall	COD	<i>E. coli</i> , turbidity, hardness, total metals
<b>Koksilah River</b>					
KR04	Koksilah River at Koksilah Road	Yes	Fall	ENV, CVRD	<i>E. coli</i> , turbidity, hardness, total metals
KR07	Kelvin Creek	No	Fall	CVRD	DO and temperature

<sup>1</sup>The following stations were also sampled on single dates in 2014 and analyzed for nutrients, conventional parameters and total or dissolved metals: CR01 - July 29; CR13 - July 29; CR15 - March 25; MILL - Oct 28. These results were not included in the attainment analysis.

<sup>2</sup>CVRD (Cowichan Valley Regional District) sampling included DO and temperature; COD = City of Duncan.

<sup>3</sup>Only four samples.

#### 4. OBJECTIVES ATTAINMENT

A summary of the WQO's and attainment results are included in Table 5 for the Cowichan River and tributaries and Table 6 for the Koksilah River. Results are then discussed in detail for individual parameters. Data showed that objectives were frequently exceeded for most parameters, for both the Cowichan and Koksilah Rivers.

Table 5. Attainment results for the Cowichan River and tributaries based on 2012-14 sampling compared to water quality objectives. Note metals often had limited data to allow direct comparison to mean objectives.

Revised Objectives (2011)			Objective met? (yes/no)					
Variable	Site	Objective	2012		2013		2014	
			Cowichan River and Tributaries		Cowichan River and Tributaries		Cowichan River and Tributaries	
			Fall	Summer	Fall	Summer	Fall	Summer
<i>Escherichia coli</i>	All	≤ 10 CFU/100 mL*	No	No	No	No	No	No
Dissolved Oxygen	All (Oct to May)	≥ 11.2 mg/L	ND	--	No	--	No	--
	All (June to Sept)	≥ 8 mg/L	--	ND	--	Yes	--	ND
Non-filterable Residue	All	≤ 7 mg/L (mean)	Yes	Yes	Yes	ND	ND	ND
		≤ 27 mg/L (max)	Yes	Yes	Yes	ND	ND	ND
Turbidity	All (Oct to Apr)	≤ 5 NTU (max)	Yes	--	No	--	No	--
	All (May to Sept)	≤ 2 NTU (max)	--	No	--	Yes	--	Yes
Ammonia	All (Oct to Apr)	≤ 1.31 mg/L (mean)	Yes	--	ND	ND	ND	ND
		≤ 6.83 mg/L (max)	Yes	--	ND	ND	ND	ND
	All (May to Sept)	≤ 0.49 mg/L (mean)	--	Yes	ND	ND	ND	ND
		≤ 3.61 mg/L (max)	--	Yes	ND	ND	ND	ND
Total Phosphorus**	All (May to Sept)	≤ 5 µg/L (mean)	ND	No	ND	ND	ND	ND
		≤ 7 µg/L (max)	ND	No	ND	ND	ND	ND
Chlorophyll a	d/s of PE-247 and PE-1497	≤ 5.0 µg/cm <sup>2</sup>	ND	ND	ND	ND	ND	ND
Total Copper***	All	≤ 2 µg/L (mean)	No	Yes	No	Yes	No	No
		≤ 4 µg/L (max)	No	Yes	No	Yes	No	No
Total Lead****	All	≤ 4 µg/L (mean)	Yes	Yes	Yes	Yes	Yes	No
		≤ 11 µg/L (max)	Yes	Yes	Yes	Yes	Yes	No
Total Zinc****	All	≤ 7.5 µg/L (mean)	Yes	Yes	No	Yes	No	No
		≤ 33 µg/L (max)	Yes	Yes	Yes	Yes	No	No
Temperature	All	≤ 17 °C (weekly mean)	ND	ND	Yes	No	Yes	ND

ND means no data; "--" means no WQO for that situation

\*90th percentile

\*\*Guideline is to be applied to the total phosphorous average, with samples collected monthly.

\*\*\*original objective was set for dissolved metal

note: unless otherwise specified, all calculations are based on five weekly samples in 30 days

Table 6. Attainment results for the Koksilah River and tributaries based on 2012-14 sampling compared to water quality objectives.

Variable	Revised Objectives (2011)		2012		2013		2014	
	Site	Objective	Fall	Summer	Fall	Summer	Fall	Summer
<i>Escherichia coli</i>	All	≤ 10 CFU/100 mL*	No	No	No	ND	No	ND
Dissolved Oxygen	All (Oct to May)	≥ 11.2 mg/L	No	--	ND	--	No	--
	All (June to Sept)	≥ 8 mg/L	--	ND	--	ND	--	ND
Non-filterable Residue	All	≤ 7 mg/L (mean)	No	Yes	ND	ND	ND	ND
		≤ 27 mg/L (max)	No	Yes	ND	ND	ND	ND
Turbidity	All (Oct to Apr)	≤ 5 NTU (max)	No	--	ND	--	No	--
	All (May to Sept)	≤ 2 NTU (max)	--	No	--	ND	--	ND
Ammonia	All (Oct to Apr)	≤ 1.31 mg/L (mean)	No	--	ND	ND	ND	ND
		≤ 6.83 mg/L (max)	No	--	ND	ND	ND	ND
	All (May to Sept)	≤ 0.49 mg/L (mean)	--	Yes	ND	ND	ND	ND
		≤ 3.61 mg/L (max)	--	Yes	ND	ND	ND	ND
Total Phosphorus**	All (May to Sept)	≤ 5 µg/L (mean)	ND	No	ND	ND	ND	ND
		≤ 7 µg/L (max)	ND	No	ND	ND	ND	ND
Chlorophyll a	d/s of PE-247 and PE-1497	≤ 5.0 µg/cm <sup>2</sup>	ND	ND	ND	ND	ND	ND
Total Copper***	All	≤ 2 µg/L (mean)	No	ND	ND	ND	Yes	ND
		≤ 4 µg/L (max)	No	ND	ND	ND	Yes	ND
Total Lead***	All	≤ 4 µg/L (mean)	Yes	ND	ND	ND	Yes	ND
		≤ 11 µg/L (max)	Yes	ND	ND	ND	Yes	ND
Total Zinc***	All	≤ 7.5 µg/L (mean)	No	ND	ND	ND	Yes	ND
		≤ 33 µg/L (max)	Yes	ND	ND	ND	Yes	ND
Temperature	All	≤ 17 °C (weekly mean)	ND	ND	ND	ND	Yes	ND

\*90th percentile

\*\*Guideline is to be applied to the total phosphorous average, with samples collected monthly.

\*\*\*original objective was set for dissolved metal

'ND' means no data was available. "--" means no WQO for that situation.

note: unless otherwise specified, all calculations are based on five weekly samples in 30 days

## 4.1 Microbiology

### 4.1.1 *E. coli*

The WQO for the Cowichan and Koksilah Rivers states that the 90<sup>th</sup> percentile of at least five weekly samples collected in a 30-day period should not exceed 10 CFU/100 ml to protect raw drinking water sources receiving disinfection. Given that previous sampling results for *E. coli* were often in exceedance of this WQO it is recognized that many samples would exceed this

objective. However, it is intended to serve as a target for area-based watershed planning to address the sources of bacteriological contamination (Obee and Epps, 2011). The WQO was exceeded at almost all sites sampled in the fall and summer, for all three years of sampling.

Since the Cowichan and Koksilah Rivers are often used for recreation, the results were also compared to ENV Recreational Water Quality Guidelines (RWQG) (BC ENV, 2017) which state that the geometric mean value obtained from a minimum of 5 samples in 30 days should not exceed 200 CFU/100 mL of *E. coli* and maximum values from a single sample should not exceed 400 CFU/100 mL. Summary statistics are shown in Table 7 (2012 sampling), Table 8 (2013 sampling), and Table 9 (2014 sampling).

Table 7. 2012 summary statistics for *E. coli* (CFU/100 mL) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept). Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

EMS Number	Station	Fall				Summer			
		Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max	Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max
<b>Cowichan River</b>									
E206108	CR01	3	13.861	49.6	68	1	8.857	115	177
0120808	CR06	15	37.478	121.6	150	1	7.018	17.8	19
E206107	CR10	10	30.508	73.7	75.5	1	3.245	14.4	20
E227752	CR12	12	35.758	95.2	120	2	3.987	10.8	14
E234124	CR13	21	60.308	442	670	1	5.65	15.6	16
E234125	CR14	32	85.931	197	255	3	4.733	9	11
0120802	CR15	29	58.697	109.6	120	2	5.785	14.8	18
E206106	CR17	28	61.699	94.4	100	3	8.438	15.2	18
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>									
NA	BINGS1 <sup>3</sup>	--	--	--	--	70	219.6	392	400
E290650	FGA D/S <sup>3</sup>	--	--	--	--	30	48.721	124.4	180
E290649	FGA U/S <sup>3</sup>	--	--	--	--	1	4.573	10	10
<b>Koksilah River</b>									
E291189	Ditch@BAP	240*	<b>2793.92*</b>	63930*	90000*	--	--	--	--
E207425	KR01	6	41.728	234.4	340	6	11.596	24.8	32
E230098	KR03	43.5	249.39	1236	1500	40	144.5	660	1000
E206976	KR04	16	80.3488	222	270	17	47.4829	156.4	220
E234128	KR05	51	139.4	458	510	15	30.275	51.8	55
E230099	KR06	12	44.295	230	290	32	68.513	144.4	180
E207427	KR07	37	220.78	822	930	110	<b>701.9</b>	2120	2200
E207433	KR08	52	328.65	1584	2000	33	79.153	158	170
0123981	KR09	41	223.54	616	620	31	63.946	138.8	190
NA	Lower Kok	60	189.3	650	750	13	35.736	148.4	220
NA	Lower Kok2	100	332.15	3224	5200	--	--	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted geometric mean values exceed the British Columbia RWQG for *E. coli* of  $\leq 200$  CFU/100 mL; light grey shaded maximum values exceed the RWQG for *E. coli* of  $\leq 400$  CFU/100 mL.

<sup>2</sup>Light grey highlighted 90th percentile values exceed the WQO of  $\leq 10$  CFU/100 mL.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

Table 8. 2013 summary statistics for *E. coli* (CFU/100 mL) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept). Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

EMS Number	Station	Fall				Summer			
		Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max	Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max
<b>Cowichan River</b>									
E206108	CR01	<1	1.32	2.8	4	2	4.49	10.6	13
0120808	CR06	<1	2.3	10.4	16	4	7.35	13.8	17
E206107	CR10	<1	2.79	12.2	17	3	6.32	11.7	15.5
E234124	CR13	--	--	--	--	5	7.3	10.2	11
E234125	CR14	7*	20.5*	75*	90*	5	16.5	58.4	60
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>									
NA	BINGSI <sup>5</sup>	24*	76.2*	408*	540*	--	--	--	--
E290650	FGA D/S <sup>4</sup>	30*	78.2*	271.7*	350*	--	--	--	--
E290649	FGA U/S <sup>4</sup>	3*	6.77*	10*	10*	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01 <sup>3</sup>	5	23.7	118.8	140	--	--	--	--
E294494	BPC02 <sup>3</sup>	18	32.8	49.4	55	--	--	--	--
E294492	BPC03 <sup>3</sup>	1	1.7	5	7	--	--	--	--
<b>Koksilah River</b>									
E295429	BAP01	<1	2.55	7	9	--	--	--	--
E291189	Ditch@BAP	<1*	13.2*	199.6*	280*	--	--	--	--
E230098	KR03	4	23.9	122.3	150.5	--	--	--	--
E206976	KR04	3	15	38.8	44	--	--	--	--
E234128	KR05	7	26	70.3	87.5	--	--	--	--
E230099	KR06	<1	3.97	7	7	--	--	--	--
E207427	KR07	7	24.5	54.6	65	--	--	--	--
E207433	KR08	3	14.8	46	50	--	--	--	--
123981	KS04	<1	5.13	16.8	22	--	--	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted geometric mean values exceed the British Columbia RWQG for *E. coli* of < 200 CFU/100 mL; light grey shaded maximum values exceed the RWQG for *E. coli* of < 400 CFU/100 mL.

<sup>2</sup>Light grey highlighted 90th percentile values exceed the WQO of  $\leq 10$  CFU/100 mL.

<sup>3</sup>Sampling sites in Busy Place Creek.

<sup>4</sup>Sampling sites in, or downstream of, Fish Gut Alley.

<sup>5</sup>City of Duncan storm drain site located in lower Bings Creek

Table 9. 2014 summary statistics for *E. coli* (CFU/100 mL) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept). Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated by the sample count (n).

EMS Number	Station	Fall					Summer				
		n	Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max	n	Min	Geomean <sup>1</sup>	90th percentile <sup>2</sup>	Max
<b>Cowichan River</b>											
E206108	CR01	4	15	47.325	394.6	550	--	--	--	--	--
E234125	CR14	4	23	88.771	730	1000	5	5	9.109	17.2	22
E234125	CR14 <sup>3</sup>	5	10	99.311	302	350	--	--	--	--	--
0120802	CR15	4	10	75.023	663	900	5	4	10.537	17.8	20
E286894	MILL	--	--	--	--	--	5	4	8.841	19.8	25
<b>Tunnel Creek (tributary to Cowichan River)</b>											
NA	TC2 <sup>3</sup>	5	20	113.698	626	870	--	--	--	--	--
<b>Bings Creek (tributary to Cowichan River)</b>											
NA	BINGS1 <sup>3</sup>	5	30	209.979	1944	2900	--	--	--	--	--
NA	BINGS2 <sup>3</sup>	5	10	183.648	3152	4800	--	--	--	--	--
E299771	BINGS3	4	5	20.773	35.8	37	--	--	--	--	--
E299770	BINGS4	5	<1	9.746	31	37	--	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>											
E294493	BPC01	4	100	679.32	2200	2200	--	--	--	--	--
E294494	BPC02	5	39	261.308	6156	10000	--	--	--	--	--
E294492	BPC03	5	4	99.712	1236	1900	--	--	--	--	--
<b>Storm Drain and Lift Station sites</b>											
NA	DMH 44A <sup>3</sup>	5	200	1202.061	5720	8000	--	--	--	--	--
NA	DMH 45A <sup>3</sup>	5	100	570.56	1920	2600	--	--	--	--	--
NA	MDLS <sup>3</sup>	5	30	291.933	1572	2000	--	--	--	--	--
<b>Koksilah River</b>											
E206976	KR04	5	4	57.98	9020.8	15000	--	--	--	--	--

<sup>1</sup>Light grey highlighted geometric mean values exceed the British Columbia RWQG for *E. coli* of  $\leq 200$  CFU/100 mL; light grey shaded maximum values exceed the RWQG for *E. coli* of  $\leq 400$  CFU/100 mL.

<sup>2</sup>Light grey highlighted 90th percentile values exceed the WQO of  $\leq 10$  CFU/100 mL.

<sup>3</sup>Sampling conducted by the City of Duncan.

Though the Cowichan River sampling sites that have results from multiple sampling years showed no consistent trend for *E. coli* levels, the levels of *E. coli* in different areas showed distinctly different patterns (Tables 7-9 and Figure 3). Cowichan River and Bings Creek/Fish Gut Alley had relatively low levels of *E. coli* with only occasional exceedances of the RWQG geomean at sampling site 'BINGS1' and few exceedances of the maximum RWQG except for in the fall of 2014. Conversely, *E. coli* levels at sites sampled in Busy Place Creek (2014 sampling) and the Koksilah River (2012 sampling) consistently exceeded the RWQG's.

As expected, *E. coli* levels were relatively much higher at the storm drain and lift station sites sampled by the City of Duncan in 2014 ('DMH 44A' and 'DMH 45A'), where elevated levels of contaminants would be minimally diluted relative to samples from natural water courses.

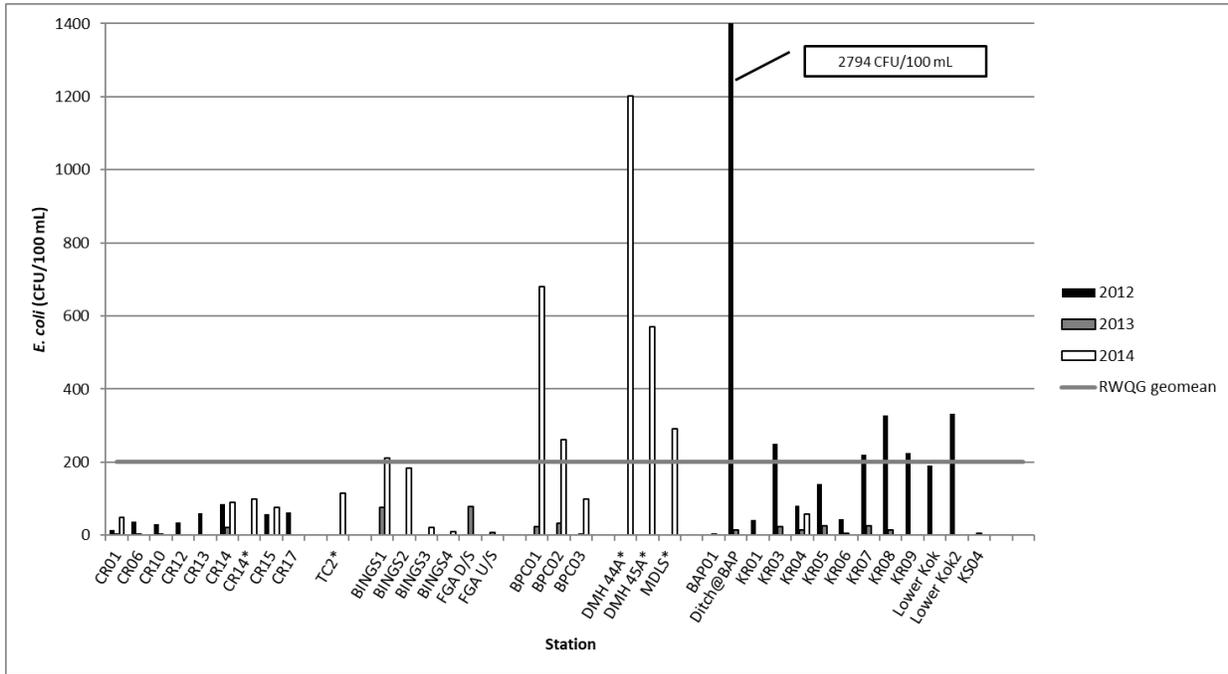


Figure 3. Summary of geometric mean values of *E. coli* (CFU/100 mL) in samples collected in the fall in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River, compared to the BC Recreational Water Quality Criteria ( $\leq 200$  CFU/100 mL). Asterisk (\*) indicates sites sampled by the City of Duncan.

Notably, at almost all stations that have both fall and summer period *E. coli* data, summer low-flow period values are the same or lower than fall flush values indicating the *E. coli* levels may be associated with suspended solids in the water column. An exception to this pattern is that at site 'KR07', where the summer geometric mean value in 2012 sampling is much greater than the fall geometric mean value, suggesting a unique pattern of contamination at this location.

#### 4.1.2 Microbial Source Tracking

The results for the MST analysis can be found in Appendix 1 (note these raw data summaries include results for Cowichan Bay freshwater and marine sites; the Koksilah and Cowichan River sites are highlighted yellow and blue, respectively) and Appendix 2.

The 2012 PESC MST Analysis (Appendix 1) identified human markers in Patrolas Creek, a tributary to the Koksilah River. The human sources are likely linked to inputs from aging and poorly maintained septic systems. Ruminant markers were also identified in six of the Koksilah

sites: Patrolas Creek, Koksilah River d/s Koksilah Road, Kelvin Creek, Koksilah River d/s Kelvin Creek, Koksilah at the Highway and the ditch at Bright Angel Park. Pig markers were found at five sites in the Koksilah River. The PESC laboratory explained that the level of confidence in a positive pig result is not as high as other potential organisms as these results can be confused with other ruminant animals.

In 2013, only one sample at site 'KR04' was analyzed by PESC (Appendix 2a) as others samples did not meet the requirement of fecal coliforms greater than 40 CFU/100ml, likely due to not being collected during a worst-case scenario rainfall event. The Koksilah River site did not have any markers identified. In 2013 the UVIC MST method (Appendix 2b), which is capable of identifying a broader range of sources than the PESC method, was used to analyze samples from eight sites on the Koksilah River. This process was able to identify a large number of sources in the Koksilah River sites, including various types of wildlife including: black bear, marmot, mule deer, racoon, cow, horse, and elk. Coyote were also identified, but as it is known that coyote are not present on Vancouver Island, this may be indicative of dog sources. The analyses identified human sources at four of eight sites and cow sources at one site ('KR04').

## **5.2 Dissolved Oxygen**

The dissolved oxygen (DO) objectives are based on the minimum requirement for eyed or hatched fish eggs (October to May;  $\geq 11.2$  mg/L) or alevins and juvenile fish (June to September;  $\geq 8$  mg/L) (Obee and Epps, 2011). Due to a limited number for field instruments, DO was not measured at all sites or during both summer and fall in all years (Table 10). The minimum DO objective was not met in the fall samples except for at KR04 in 2014. Two sites on Busy Place Creek (at confluence with unnamed tributary - 'BPC01'; upstream of the CVRD waste facility - 'BPC04') had very low levels of DO, 2.5 mg/L and 2.6 mg/L, respectively.

## **4.2 Total Suspended Solids (TSS)**

The WQO for TSS or Non-Filterable Residue (NFR) for all sites states that levels should not exceed 27.0 mg/L at any time and that the mean of five weekly samples in 30 days should not exceed 7.0 mg/L. These objectives are intended to protect aquatic life. They were based on the observation that occasional high concentrations of TSS can occur, and the objective is meant to apply to situations which are not natural but may have been triggered by human activities (Obee and Epps, 2011).

Table 10. Summary statistics for dissolved oxygen (mg/L) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless indicated by sample count (n).

Year	EMS Number	Station	Fall				Summer			
			n	Min <sup>1</sup>	Mean	Max	n	Min <sup>1</sup>	Mean	Max
<b>Koksilah River</b>										
2012	NA	Lower Kok	5	8.58						
2012	NA	Lower Kok2	5	8.85						
2014	E206976	KR04	5	11.3	11.96	12.53				
2014	E207427	KR07	2	9.98	10.305	10.63				
<b>Cowichan River</b>										
2013	E2016108	CR01	4	10.1	10.525	10.9	2	8.05	8.19	8.33
2013	120808	CR06	4	10.3	10.925	11.5	2	8.46	8.625	8.79
2013	E206107	CR10	4	10.6	11.325	11.9	2	8.83	8.86	8.89
2014	E234125	CR14	4	10.04	10.33	10.77				
2014	120802	CR15	4	9.98	10.268	10.71				
2014	NA	School	4	10.16	10.398	10.8				
<b>Busy Place Creek (tributary to Cowichan River)</b>										
2013	E294493	BPC01	4	10.85	11.975	12.98				
2013	E294494	BPC02	4	1.12	2.95	5.08				
2013	E294492	BPC03	4	1.81	2.5225	3.3				
2014	E294493	BPC10	4	2.5	5.148	8.02				
2014	NA	BPC04	4	2.6	4.753	5.8				
2014	NA	BPC05	4	10.13	10.618	11.61				
<b>Bings Creek (tributary to Cowichan River)</b>										
2014	E299771	BINGS3	5	9.68	10.506	10.87				
2014	E299770	BINGS4	5	10.77	11.038	11.56				

<sup>1</sup>Light grey highlighted minimum values exceed the Cowichan and Koksilah River fall WQO for dissolved oxygen of  $\geq 11.2$  mg/L.

Summary statistics for 2012 TSS results are shown in Table 11. In 2012 concentrations of TSS ranged from below detectable limits (1 – 5 mg/L) to 31 mg/L. While results for most sites met the WQO there were some exceedances in the downstream locations of the Koksilah River during the fall season ('KR08' and 'Lower Kok2'). There were no exceedances of the WQO in any samples collected from the rivers during the 2012 summer low-flow season. In 2013 sampling, only three stations (CR01, CR06 and CR10) were sampled and concentrations of TSS at these Cowichan River sites ranged from below detectable limits (1 mg/L) to 3.65 mg/L (a fall sample) with no exceedances of the guidelines. No samples were analyzed for TSS during 2014 sampling.

Table 11. 2012 summary statistics for total suspended solids (TSS; mg/L) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

Year	EMS Number	Station	Fall			Summer		
			Min	Mean <sup>1</sup>	Max <sup>2</sup>	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>								
2012	E206108	CR01	1	3.62	13.3	1	5.01	9.6
2012	0120808	CR06	1	1.32	1.8	1	1	1
2012	E206107	CR10	1	1.1	1.2	1	1	1
2012	E227752	CR12	2.2	3.54	5.8	1	1.44	2.2
2012	E234124	CR13	1.7	3.64	9.1	1	1.49	2.1
2012	E234125	CR14	1.8	4.36	9.3	1	1.46	2.1
2012	0120802	CR15	3.3	6.12	11.3	1.3	1.58	1.9
2012	E206106	CR17	3.7	5.9	10.5	1	1.28	1.7
2013	E206108	CR01	<1	1	<1	--	--	--
2013	0120808	CR06	<1	1	<1	--	--	--
2013	E206107	CR10	<1	1.53	3.65	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>								
2012	NA	BINGS1 <sup>3</sup>	--	--	--	3	4.6	6
2012	E290650	FGA D/S <sup>3</sup>	--	--	--	1.95	3.09	5.5
2012	E290649	FGA U/S <sup>3</sup>	--	--	--	2	2.8	4
<b>Koksilah River</b>								
2012	E291189	Ditch@BAP	--	--	--	--	--	--
2012	E207425	KR01	1	1.14	1.5	1	1	1
2012	E230098	KR03	2.1	4.36	9.8	2.1*	3.4*	4.9*
2012	E206976	KR04	1	1.44	2.2	1*	1.55*	3*
2012	E234128	KR05	1	2.82	5.2	2.9	4.14	6.9
2012	E230099	KR06	1	4	13.3	1	1.54	2.6
2012	E207427	KR07	1.15*	1.3375*	1.8*	1	1.82	3.5
2012	E207433	KR08	1.3	7.64	31	1	1.62	3.1
2012	0123981	KR09	1.1	2.84	5.9	1	1.24	2.2
2012	NA	Lower Kok	5	5.33	7	--	--	--
2012	NA	Lower Kok2	5	13	28	--	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for TSS of  $\leq 7$  mg/L.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for TSS of  $\leq 27$  mg/L.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

### 4.3 Turbidity

The WQO for the Cowichan and Koksilah Rivers states that turbidity should not exceed a maximum of 5 NTU from October to April, the period when high turbidity flows typically occur; during the remainder of the year turbidity should not exceed a maximum of 2 NTU (Obbe and Epps, 2011), in order to protect drinking water not receiving treatment to remove turbidity.

During 2012 fall sampling the WQO for turbidity was not exceeded at any of the Cowichan River sampling locations (Table 12). Conversely, the Koksilah River showed high turbidity, exceeding the WQO at all but two sites ('KR04' and 'Lower Kok'). Turbidity measurements in samples collected in the summer of 2012 were lower than those measured in the fall; the summer WQO

for turbidity was exceeded in only four sampling locations in the Cowichan and Koksilah Rivers. Station ‘CR01’ (Cowichan River south side at Cowichan Lake weir) had one value that was slightly elevated (3.68 NTU) and may be a result of sampling collection error (i.e. disturbance of bottom in shallow area) as all other results in Cowichan River are below 1 NTU.

Table 12. 2012 summary statistics for turbidity (NTU) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons, showing exceedances of the Cowichan and Koksilah River Water Quality Objectives (WQO). Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

EMS Number	Station	Fall		Summer	
		Minimum	Maximum	Minimum	Maximum
<b>Cowichan River</b>					
E206108	CR01	0.32	0.62	0.49	3.68
120808	CR06	0.1	0.71	0.19	0.64
E206107	CR10	0.1	1.04	0.4	0.56
E227752	CR12	0.71	2.78	0.35	0.6
E234124	CR13	1.08	3.22	0.34	0.86
E234125	CR14	1.08	4.4	0.42	0.59
120802	CR15	1.32	4.68	0.42	0.78
E206106	CR17	1.66	4.07	0.48	0.84
<b>Koksilah River</b>					
E291189	Ditch@BAP	4.95*	74.3*	--	--
E207425	KR01	0.47	7.83		0.44
E230098	KR03	2.68	9.7		11.7
E206976	KR04	1.28	2.97		0.6
E234128	KR05	2.2	10.8		8.5
E230099	KR06	0.61	7.87		3.02
E207427	KR07	0.995	14.8		1.81
E207433	KR08	0.61	13.4		1.23
E123981	KR09	0.01	5.095		1.07
NA	LowerKok	0.7	4.2	--	--
NA	LowerKok2	2.9	20	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted maximum values exceed the Cowichan and Koksilah River fall WQO for turbidity  $\leq 5$  NTU.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River summer WQO for turbidity of  $\leq 2$  NTU.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

In 2013 sampling, turbidity measured at the headwaters to the Cowichan River (sites ‘CR01’, ‘CR06’ and ‘CR10’) were low and did not exceed the objectives (Table 13). However, elevated turbidity was measured further downstream (‘CR14’), in Bings Creek and at Fish Gut Alley D/S; notably, these three sites also had elevated *E. coli*. All exceedances were observed during the fall-flush season and were substantially greater than the maximum objective of 5 NTU.

Table 13. 2013 summary statistics for turbidity (NTU) for water samples collected at sites in the Cowichan River and Fish Gut Alley during the fall (Oct-Apr) and summer (May-Sept) seasons, showing exceedances of the Cowichan and Koksilah River WQO. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

EMS Number	Station	Fall			Summer		
		Minimum	Mean	Maximum <sup>1</sup>	Minimum	Mean	Maximum <sup>2</sup>
<b>Cowichan River</b>							
E206108	CR01	0.305	0.497	1.1	0.35	0.398	0.45
0120808	CR06	0.3	0.328	0.4	0.3	0.386	0.44
E206107	CR10	0.36	0.632	1.42	0.33	0.416	0.57
E234125	CR14	5.8*	12.975*	23*	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>							
NA	BINGS1	2.3*	5.375*	11*	--	--	--
E290650	FGA D/S	1.2*	88.7*	350*	--	--	--
E290649	FGA U/S	0.2*	0.6*	1.6*	--	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted maximum values exceed the fall Cowichan and Koksilah River WQO for turbidity of  $\leq 5$  NTU.

<sup>2</sup>Light grey highlighted maximum values exceed the summer Cowichan and Koksilah River WQO for turbidity of  $\leq 2$  NTU.

Four of the Cowichan River five sites sampled for turbidity in the fall of 2014 exceeded the maximum fall objective of  $\leq 5$  NTU (Table 14). The summer turbidity levels were low at all five sites sampled (although two of these sites were not based on 5-in-30 sampling) and there were no exceedances of the maximum summer objective of  $\leq 2$  NTU. The other samples analyzed for turbidity during 2014 sampling were collected during the fall from tributaries to the Cowichan River (n = 8), storm drain and lift station sites (n=3), and the Koksilah River (n = 1). In all but 3 samples, turbidity measurements exceeded the maximum fall objective.

Figure 4 shows the maximum concentrations for turbidity measured at all sites sampled in the fall, over all three years of sampling.

Table 14. 2014 summary statistics for turbidity (NTU) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated by the sample count (n).

EMS Number	Station	Fall				Summer			
		n	Min	Mean	Max	n	Min	Mean	Max
<b>Cowichan River</b>									
E206108	CR01	4	1.29	4.948	13.9	1	0.48	0.48	0.48
E234124	CR13	--	--	--	--	1	0.46	0.46	0.46
E234125	CR14	5	1.37	5.174	15.8	5	0.31	0.408	0.54
E234125	CR14 <sup>3</sup>	5	3.9	11.09	23	--	--	--	--
0120802	CR15	5	0.51	5.602	15.5	6	0.3	0.399	0.54
E286894	MILL	1	4.72	4.72	4.72	5	0.34	0.388	0.44
<b>Tunnel Creek (tributary to Cowichan River)</b>									
NA	TC2 <sup>3</sup>	5	2.2	8.84	15	--	--	--	--
<b>Bings Creek (tributary to Cowichan River)</b>									
NA	BINGS1 <sup>3</sup>	5	2.7	7.5	16	--	--	--	--
NA	BINGS2 <sup>3</sup>	5	2.3	7.6	17	--	--	--	--
E299771	BINGS3	5	0.68	2.216	4.43	--	--	--	--
E299770	BINGS4	4	1.06	1.57	2.21	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	5	1.64	5.698	9.7	--	--	--	--
E294494	BPC02	5	3.4	10.91	31.4	--	--	--	--
E294492	BPC03	5	0.22	2.734	6.15	--	--	--	--
<b>Storm Drain and Lift Station sites</b>									
NA	DMH 44A <sup>3</sup>	5	3.2	13.3	40	--	--	--	--
NA	DMH 45A <sup>3</sup>	5	1.1	14.32	50	--	--	--	--
NA	MDLS <sup>3</sup>	5	0.7	2.98	7.6	--	--	--	--
<b>Koksilah River</b>									
E206976	KR04	5	0.39	3.036	11.1	--	--	--	--

<sup>1</sup>Light grey highlighted maximum values exceed the Cowichan and Koksilah River fall WQO for turbidity  $\leq 5$  NTU.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River summer WQO for turbidity of  $\leq 2$  NTU.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

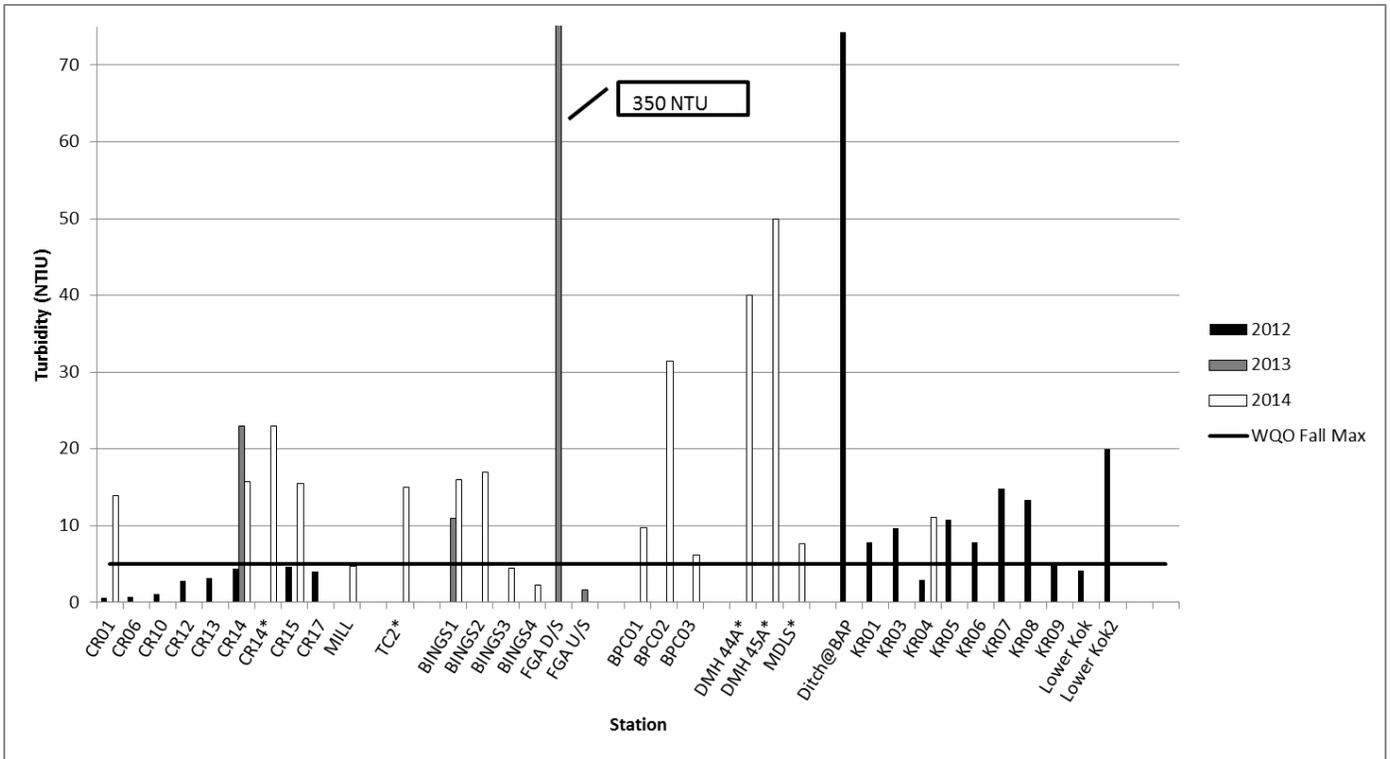


Figure 4. Summary of maximum values for turbidity (NTU) in samples collected in the fall in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River, compared to the fall Water Quality Objective (maximum value < 5 NTU). Asterisk (\*) indicates sites sampled by the City of Duncan.

#### 4.4 Nutrients

##### 4.4.1 Ammonia

The WQO for the Cowichan and Koksilah Rivers, for the protection of aquatic life, states that for the period of October to April total ammonia should not exceed a maximum of 6.83 mg/L, and the mean of 5-in-30 sampling should not exceed 1.31 mg/L; from May to September ammonia should not exceed a maximum of 3.61 mg/L and the mean of 5-in-30 sampling should not exceed 0.49 mg/L (Obee and Epps, 2011).

Ammonia was measured in 2012 sampling only (Table 15) and the WQO was met at all stations for both summer and fall, with the exception of one sampling location on the Koksilah River ('Ditch@BAP'). At this location, water samples collected in the fall had the potential to exceed both the mean and maximum WQO if levels stayed at observed levels consistently over five weekly samples (note calculation was based on only four weekly samples).

Table 15. 2012 summary statistics for total ammonia (mg/L) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on a minimum of five samples collected within a 30-day period, unless otherwise indicated.

EMS Number	Station	Fall			Summer		
		Min	Mean <sup>1</sup>	Max <sup>2</sup>	Min	Mean <sup>3</sup>	Max <sup>4</sup>
<b>Cowichan River</b>							
E206108	CR01	0.005	0.00958	0.015	0.0065	0.01186	0.019
0120808	CR06	0.005	0.00778	0.0097	0.005	0.00902	0.021
E206107	CR10	0.0095	0.0882	0.26	0.051	0.055	0.065
E227752	CR12	0.0187	0.02884	0.0382	0.005	0.00926	0.014
E234124	CR13	0.012	0.03748	0.0762	0.007	0.0095	0.014
E234125	CR14	0.014	0.03899	0.0741	0.0064	0.01024	0.022
0120802	CR15	0.02	0.04494	0.0706	0.005	0.00926	0.013
E206106	CR17	0.118	0.1756	0.33	0.22	0.264	0.33
<b>Koksilah River</b>							
E291189	Ditch@BAP	0.689*	3.451*	11.2*	--	--	--
E207425	KR01	0.005	0.00756	0.011	0.005	0.0125	0.034
E230098	KR03	0.0269	0.10863	0.169	0.013	0.028	0.042
E206976	KR04	0.0085	0.04566	0.141	0.0073	0.01106	0.015
E234128	KR05	0.0068	0.01424	0.0175	0.044	0.0686	0.089
E230099	KR06	0.0053	0.01286	0.0342	0.0053	0.00814	0.011
E207427	KR07	0.0054	0.01436	0.0241	0.015	0.0218	0.026
E207433	KR08	0.0068	0.01186	0.024	0.0093	0.01238	0.018
0123981	KR09	0.0055	0.01412	0.0261	0.033	0.0392	0.042
NA	Lower Kok	0.0082	0.0215	0.038	0.018	0.0356	0.076
NA	Lower Kok2	0.014	0.028	0.05	--	--	--

\*Based on 4 weekly samples in 30 days. Results are compared to the objective but as frequency is not met, results only reflect the potential for exceeding the WQO

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River fall WQO for ammonia of  $\leq 1.31$  mg/L.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River fall WQO for ammonia of  $\leq 6.83$  mg/L.

<sup>3</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River summer WQO for ammonia of  $\leq 0.49$  mg/L.

<sup>4</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River summer WQO for ammonia of  $\leq 3.61$  mg/L.

<sup>5</sup>Sampling sites in, or downstream of, Fish Gut Alley.

#### 4.4.2 Total Phosphorus

The WQO for phosphorus is a May to September mean of 5  $\mu\text{g/L}$  and maximum of 7  $\mu\text{g/L}$  (Obee and Epps, 2011) and varies slightly from the more recent ENV guidance document *Phosphorous Management in Vancouver Island Streams*, which specifies a mean of 5  $\mu\text{g/L}$  and maximum of 10  $\mu\text{g/L}$  (monthly samples from May through September) (BC ENV, 2014).

Total phosphorus was measured in 2012 only (Table 16), and concentrations in the Cowichan and Koksilah Rivers were generally within the same concentration range and consistently just above the mean and maximum WQO. Exceptions to this were the very high levels of phosphorus at sites in Fish Gut Alley and Bings Creek, though these concentrations could not be

directly compared to the objective as they were not based on monthly samples; however, if the very high levels were maintained over the May-Sept season, the WQO would be exceeded by a large margin at these sites. The WQO was also exceeded by a large margin at sites KR03, KR05 and KR06 on the Koksilah River. The elevated concentrations of total phosphorus at certain locations on the Koksilah suggest that there may be inputs to the river at certain points (e.g., tributaries or run-off from agricultural sources) that cause these concentration spikes.

Table 16. 2012 summary statistics for Total Phosphorus (mg/L) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the summer (May-Sept) season. Statistics were calculated based on monthly samples collected from May to September, unless otherwise indicated.

EMS Number	Station	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>				
E206108	CR01	0.0026	0.00802	<b>0.0192</b>
0120808	CR06	0.002	0.00292	0.0041
E206107	CR10	0.0045	0.00762	<b>0.0113</b>
E227752	CR12	0.0034	0.00644	<b>0.0125</b>
E234124	CR13	0.0032	0.00498	0.0067
E234125	CR14	0.0038	0.00482	0.0061
0120802	CR15	0.0033	0.00534	0.0068
E206106	CR17	0.0128	0.02038	<b>0.0286</b>
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>				
NA	BINGS1 <sup>3</sup>	0.104*	0.1234*	<b>0.148*</b>
E290650	FGA D/S <sup>3</sup>	0.0268*	0.03137*	<b>0.0445*</b>
E290649	FGA U/S <sup>3</sup>	0.0374*	0.0446*	<b>0.0515*</b>
<b>Koksilah River</b>				
E291189	Ditch@BAP	--	--	--
E207425	KR01	0.0021	0.00322	0.0048
E230098	KR03	0.0147	0.11074	<b>0.15</b>
E206976	KR04	0.0067	0.00832	<b>0.0118</b>
E234128	KR05	0.0287	0.07448	<b>0.143</b>
E230099	KR06	0.0289	0.04592	<b>0.0859</b>
E207427	KR07	0.0137	0.01616	<b>0.0178</b>
E207433	KR08	0.0065	0.00924	<b>0.0112</b>
0123981	KR09	0.0079	0.00926	<b>0.0109</b>
NA	Lower Kok	0.0083	0.01069	<b>0.013</b>
NA	Lower Kok2	--	--	--

\*Based on based on a minimum of five samples 5 collected within a 30-day period.

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River summer mean WQO for Total Phosphorus of  $\leq 0.005$  mg/L.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River summer maximum WQO of  $\leq 0.007$  mg/L. and ENV guidance for Total Phosphorus of  $\leq 0.010$  mg/L.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

## 4.5 Chlorophyll *a*

The WQO for chlorophyll *a* of 5.0 µg/cm<sup>2</sup> was set for specific locations downstream of both sewage treatment plants (sites 'CR10' and 'CR17') (Obee and Epps, 2011). Chlorophyll *a* was not measured at these locations as it is a specialized sampling technique for which trained personnel were not available. Chlorophyll *a* was only measured at sites 'FGA U/S' (2.65 µg/cm<sup>2</sup>) and 'FGA D/S' (0.10 µg/cm<sup>2</sup>) as part of a more intensive sampling program, with neither measurement exceeding the objective. Since the appropriate sites were not sampled WQO attainment cannot be assessed for Chlorophyll *a*.

## 4.6 Metals

### 4.6.1 Total Copper

The WQO states that total copper values should not exceed 2 µg/L based on 30-day average results and 4 µg/L based on maximum values at any time in the Cowichan and Koksilah Rivers (Obee and Epps 2011).

Mean objectives could not be compared for most sites in 2012 due to that only a few sites met the requisite sampling frequency of five samples in 30 days for metals. Sample results from 2012 sampling (Table 17) show Cowichan River mainstem sites were below maximum WQO's, but Cowichan tributary site Fish Gut Alley downstream of the Marchmont outfall ('FGA D/S') was above the maximum WQO. Mean WQO's had the potential to be exceeded if levels were maintained at the levels observed at Fish Gut Alley downstream of the Marchmont outfall ('FGA D/S') and Bings Creek ('BINGS1'), which is an area that is affected by a stormwater outfall from the City of Duncan. Sites in the Koksilah River in 2012 had total copper concentrations slightly above or below the mean concentration objective, with the exception of sampling location 'KR04', which exceeded both mean and maximum WQO's.

Table 17. 2012 summary of mean and maximum values for total copper ( $\mu\text{g/L}$ ) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on one to five samples collected within a 30-day period.

EMS Number	Station	Fall			Summer		
		Min	Mean <sup>1</sup>	Max <sup>2</sup>	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>							
E206108	CR01	0.38	0.38	0.38	--	--	--
0120808	CR06	0.843	0.843	0.843	--	--	--
E206107	CR10	0.7865	0.7865	0.7865	--	--	--
E227752	CR12	0.586	0.9275	1.29	--	--	--
E234124	CR13	0.931	0.931	0.931	--	--	--
E234125	CR14	0.981	0.981	0.981	--	--	--
0120802	CR15	0.747	0.90375	1.06	--	--	--
E206106	CR17	0.796	1.1515	1.39	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>							
NA	BINGS1 <sup>3</sup>	3.94	3.94	3.94	1.19	1.4	1.87
E290650	FGA D/S <sup>3</sup>	7.99	7.99	7.99	0.42	0.5547	0.78
E290649	FGA U/S <sup>3</sup>	0.65	0.65	0.65	0.35	0.534	0.75
<b>Koksilah River</b>							
E291189	Ditch@BAP	--	--	--	--	--	--
E207425	KR01	1.12	1.12	1.12	--	--	--
E230098	KR03	2.13	2.13	2.13	--	--	--
E206976	KR04	1.03	6.21625	21.3	--	--	--
E234128	KR05	2.15	2.15	2.15	--	--	--
E230099	KR06	1.46	1.46	1.46	--	--	--
E207427	KR07	0.985	0.985	0.985	--	--	--
E207433	KR08	0.745	1.1	1.3	--	--	--
0123981	KR09	1.02	1.02	1.02	--	--	--
NA	Lower Kok	--	--	--	--	--	--
NA	Lower Kok2	--	--	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total copper of  $\leq 2 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total copper of  $\leq 4 \mu\text{g/L}$ .

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

For 2013 sampling (Table 18), concentrations exceeded the objectives at the single site sampled in the fall on Cowichan River ('CR14'; Allenby). The objectives were also exceeded in Fish Gut Alley downstream of the Marchmont outfall ('FGA D/S') and Bings Creek ('BINGS1'), an area affected by a stormwater outfall from the City of Duncan. At the 'BINGS1' site, the fall concentrations exceeded both the mean and maximum objective for total copper, whereas the 'FGA D/S' site exceeded only the maximum objective.

Table 18. 2013 summary of mean and maximum values for total copper ( $\mu\text{g/L}$ ) for water samples collected at sites in the Cowichan River, Fish Gut Alley, and Busy Place Creek during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were not calculated based a minimum of five samples collected within a 30-day period; sample count is indicated in the table (n).

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E234125	CR14	4	1.71	3.0275	5.13	--	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>									
NA	BINGS1	4	1.05	2.155	4.01	--	--	--	--
E290650	FGA D/S	4	0.34	1.9975	6.27	--	--	--	--
E290649	FGA U/S	4	0.26	0.4225	0.57	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	2	1.47	1.48	1.49	--	--	--	--
E294494	BPC02	2	1.07	1.71	2.35	1	0.183	0.183	0.183
E294492	BPC03	2	1.05	1.12	1.19	1	0.828	0.828	0.828

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total copper of  $\leq 2 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total copper of  $\leq 4 \mu\text{g/L}$ .

In the fall of 2014, four sites were sampled for total copper on Cowichan River mainstem (Table 19). Of these, only 'CR14'- Allenby, showed exceedances of the objective based on mean concentrations. The other samples analyzed for total copper during the fall of 2014 were collected from eight tributaries to Cowichan River, three storm drain and lift station sites, and one Koksilah River site. Three of these sites were below the WQO and the other nine sites exceeded both the mean and maximum fall objective.

In two of the three Cowichan River mainstem sites sampled during the summer of 2014, lower concentrations were seen in summer than the fall. However, summer samples at 'CR15' (Cowichan River at HWY#1) exceeded both objectives with a mean value of  $14.0 \mu\text{g/L}$  and maximum of  $27.5 \mu\text{g/L}$ . Notably, neither *E. coli* (Table 9) nor turbidity (Table 12) were elevated at this site during the summer, but total copper, lead, and zinc were elevated. This may indicate a site-specific situation related to the proximity to the highway, which is exacerbated during the summer months by low flows and thus low dilution of pollutants.

shows max concentrations for total copper measured at all sites sampled in the fall, over all three years of sampling, respectively.

Table 19. 2014 summary of mean and maximum values for total copper (µg/L) for water samples collected at sites in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on one to five samples collected within a 30-day period, unless otherwise indicated by the sample count.

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E206108	CR01	4	0.471	1.059	2.56	--	--	--	--
E234125	CR14	5	0.736	1.126	2.28	1	0.499	0.499	0.499
E234125	CR14 <sup>3</sup>	5	1.96	2.864	3.57	--	--	--	--
0120802	CR15	5	0.609	1.117	2.38	2	0.484	13.992	27.5
E286894	MILL	1	0.904	0.904	0.904	1	0.377	0.377	0.377
<b>Tunnel Creek (tributary to Cowichan River)</b>									
NA	TC <sup>3</sup>	5	1.29	2.95	4.31	--	--	--	--
<b>Bings Creek (tributary to Cowichan River)</b>									
NA	BINGS1 <sup>3</sup>	5	2.04	2.924	4.02	--	--	--	--
NA	BINGS2 <sup>3</sup>	5	1.28	2.876	5.7	--	--	--	--
E299771	BINGS3	5	0.785	1.123	1.65	--	--	--	--
E299770	BINGS4	4	0.82	0.933	1.19	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	5	2.37	3.946	6.04	--	--	--	--
E294494	BPC02	5	1.83	4.25	7.73	--	--	--	--
E294492	BPC03	5	0.904	4.277	12.7	--	--	--	--
<b>Storm Drain and Lift Station sites</b>									
NA	DMH 44A <sup>3</sup>	5	5.5	9.344	17.8	--	--	--	--
NA	DMH 45A <sup>3</sup>	5	9.35	14.47	19.5	--	--	--	--
NA	MDLS <sup>3</sup>	5	0.8	3.038	6.72	--	--	--	--
<b>Koksilah River</b>									
E206976	KR04	5	0.579	1.127	2.5	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total copper of ≤ 2 µg/L.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total copper of ≤ 4 µg/L.

<sup>3</sup>Sampling conducted by the City of Duncan.

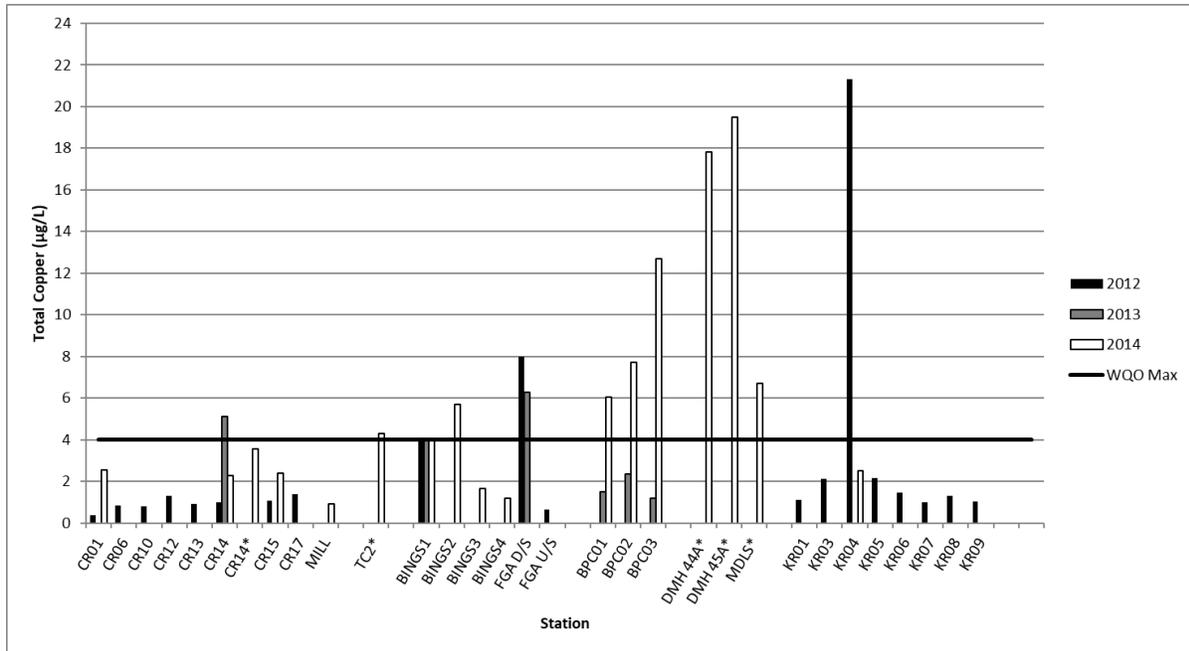


Figure 5. Summary of maximum values for copper ( $\mu\text{g/L}$ ) in samples collected in the fall in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River, compared to the fall Water Quality Objective (maximum value  $\leq 4 \mu\text{g/L}$ ). Asterisk (\*) indicates sites sampled by the City of Duncan.

#### 4.6.2 Total Lead

The WQO states that, for the protection of aquatic life, total lead values should not exceed  $4 \mu\text{g/L}$  based on 30-day average results and  $11 \mu\text{g/L}$  based on maximum values at any time in the Cowichan and Koksilah Rivers (Obee and Epps 2011).

Concentrations of total lead were well below objectives for all sites sampled over all three years of attainment monitoring (Table 20, Table 21, Table 22). The only exception to this trend is the samples collected in the summer of 2014 at 'CR15' (Cowichan River at HWY#1) which had a mean value of  $13.6 \mu\text{g/L}$  and maximum of  $27.1 \mu\text{g/L}$  total lead. See the discussion in the Copper section with regards to elevated metals levels at this station.

Table 20. 2012 summary of mean and maximum values for total lead ( $\mu\text{g/L}$ ) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on one to five samples collected within a 30-day period.

EMS Number	Station	Fall			Summer		
		Min	Mean <sup>1</sup>	Max <sup>2</sup>	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>							
E206108	CR01	0.013	0.013	0.013	--	--	--
0120808	CR06	0.031	0.031	0.031	--	--	--
E206107	CR10	0.0295	0.0295	0.0295	--	--	--
E227752	CR12	0.029	0.056	0.088	--	--	--
E234124	CR13	0.042	0.042	0.042	--	--	--
E234125	CR14	0.065	0.065	0.065	--	--	--
0120802	CR15	0.063	0.0755	0.083	--	--	--
E206106	CR17	0.053	0.0705	0.105	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>							
NA	BINGS1 <sup>3</sup>	0.26	0.26	0.26	0.21	0.39	0.85
E290650	FGA D/S <sup>3</sup>	0.81	0.81	0.81	0.1345	0.1889	0.21
E290649	FGA U/S <sup>3</sup>	0.2	0.2	0.2	0.2	0.2	0.2
<b>Koksilah River</b>							
E291189	Ditch@BAP	--	--	--	--	--	--
E207425	KR01	0.095	0.095	0.095	--	--	--
E230098	KR03	0.088	0.088	0.088	--	--	--
E206976	KR04	0.048	0.071	0.1	--	--	--
E234128	KR05	0.137	0.137	0.137	--	--	--
E230099	KR06	0.031	0.031	0.031	--	--	--
E207427	KR07	0.062	0.062	0.062	--	--	--
E207433	KR08	0.022	0.053625	0.067	--	--	--
0123981	KR09	0.054	0.054	0.054	--	--	--
NA	Lower Kok	--	--	--	--	--	--
NA	Lower Kok2	--	--	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 4 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 11 \mu\text{g/L}$ .

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

Table 21. 2013 summary of mean and maximum values for total lead ( $\mu\text{g/L}$ ) for water samples collected at sites in the Cowichan River, Fish Gut Alley, and Busy Place Creek during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were not calculated based on a minimum of five samples collected within a 30-day period; sample count is indicated in the table.

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E234125	CR14	4	<0.2	0.335	0.54	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	2	0.087	0.117	0.147	--	--	--	--
E294494	BPC02	2	0.026	0.2155	0.405	1	0.024	0.024	0.024
E294492	BPC03	2	0.008	0.0105	0.013	1	0.037	0.037	0.037
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>									
E290650	FGA D/S	4	<0.2	0.455	1.13	--	--	--	--
E290649	FGA U/S	4	<0.2	0.2	<0.2	--	--	--	--
NA	BINGS1	4	<0.2	0.2525	0.41	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 4 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 11 \mu\text{g/L}$ .

Table 22. 2014 summary of mean and maximum values for total lead ( $\mu\text{g/L}$ ) for water samples collected at sites in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on one to five samples collected within a 30-day period.

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E206108	CR01	4	0.026	0.115	0.351	--	--	--	--
E234125	CR14	5	0.036	0.1	0.287	1	0.029	0.029	0.029
E234125	CR14 <sup>3</sup>	5	<0.2	0.34	0.57	--	--	--	--
0120802	CR15	5	0.048	0.113	0.308	2	0.03	13.565	27.1
E286894	MILL	1	0.081	0.081	0.081	1	0.017	0.017	0.017
<b>Tunnel Creek (tributary to Cowichan River)</b>									
NA	TC2 <sup>3</sup>	5	<0.2	0.248	0.32	--	--	--	--
<b>Bings Creek (tributary to Cowichan River)</b>									
NA	BINGS1 <sup>3</sup>	5	<0.2	0.3	0.47	--	--	--	--
NA	BINGS2 <sup>3</sup>	5	<0.2	0.24	0.37	--	--	--	--
E299771	BINGS3	5	0.0344	0.062	0.109	--	--	--	--
E299770	BINGS4	4	0.036	0.05	0.063	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	5	0.0872	0.169	0.253	--	--	--	--
E294494	BPC02	5	0.0923	0.55	1.38	--	--	--	--
E294492	BPC03	5	0.0487	0.166	0.377	--	--	--	--
<b>Storm Drain and Lift Station sites</b>									
NA	DMH 44A <sup>3</sup>	5	0.68	1.106	2.29	--	--	--	--
NA	DMH 45A <sup>3</sup>	5	0.21	1.104	3.19	--	--	--	--
NA	MDLS <sup>3</sup>	5	<0.2	0.474	1.13	--	--	--	--
<b>Koksilah River</b>									
E206976	KR04	5	0.0155	0.076	0.234	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 4 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total lead of  $\leq 11 \mu\text{g/L}$ .

<sup>3</sup>Sampling conducted by the City of Duncan.

### 4.6.3 Total zinc

The WQO states that, for the protection of aquatic life, total zinc values should not exceed 7.5 µg/L based on 30-day average results and 33 µg/L based on maximum values at any time in the Cowichan and Koksilah Rivers (Obee and Epps 2011).

Mean objectives could not be compared for most sites in 2012 due to that only a few sites met the requisite sampling frequency of five samples in 30 days for metals. For 2012 sampling (

Table 23), the pattern of elevated concentrations of total zinc is similar to that of total copper (Table 16). The Cowichan River mainstem sites had low total zinc concentrations while tributary sites 'BINGS1', 'FGA D/S', and 'KR05' (Howie Creek), had the potential to exceed mean WQO if levels observed were maintained over a 5 in 30 period. Site 'KR04' (Koksilah River at Koksilah Road) exceeded the mean WQO with a value of 7.6 ug/L; the maximum total zinc concentration of 27.4 ug/L at this site was dramatically higher than the maximum concentrations at any of the other sampling sites on this river, but still below the maximum WQO.

Table 23. 2012 summary of mean and maximum values for total zinc (µg/L) for water samples collected in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on one to five samples collected within a 30-day period.

EMS Number	Station	Fall			Summer		
		Min	Mean <sup>1</sup>	Max <sup>2</sup>	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>							
E206108	CR01	0.51	0.51	0.51	--	--	--
0120808	CR06	1.22	1.22	1.22	--	--	--
E206107	CR10	0.665	0.665	0.665	--	--	--
E227752	CR12	0.34	0.7425	1.41	--	--	--
E234124	CR13	1.55	1.55	1.55	--	--	--
E234125	CR14	0.9	0.9	0.9	--	--	--
0120802	CR15	0.76	0.8575	0.94	--	--	--
E206106	CR17	0.8	1.38	2.16	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>							
NA	BINGS1 <sup>3</sup>	9.5	9.5	9.5	5	8.12	13.4
E290650	FGA D/S <sup>3</sup>	31.5	31.5	31.5	3.175	4.635	5
E290649	FGA U/S <sup>3</sup>	5	5	5	5	5	5
<b>Koksilah River</b>							
E291189	Ditch@BAP	--	--	--	--	--	--
E207425	KR01	0.88	0.88	0.88	--	--	--
E230098	KR03	1.29	1.29	1.29	--	--	--
E206976	KR04	0.685	7.57625	27.4	--	--	--
E234128	KR05	8.63	8.63	8.63	--	--	--
E230099	KR06	0.67	0.67	0.67	--	--	--
E207427	KR07	0.55	0.55	0.55	--	--	--
E207433	KR08	0.485	0.87625	1.58	--	--	--
0123981	KR09	0.56	0.56	0.56	--	--	--
NA	Lower Kok	--	--	--	--	--	--
NA	Lower Kok2	--	--	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 7.5$  ug/L.

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 33$  ug/L.

<sup>3</sup>Sampling sites in, or downstream of, Fish Gut Alley.

For 2013 sampling (Table 24), samples from Fish Gut Alley (site 'FGA U/S') had exceedances of the total zinc objective for the mean value, while the other two sites (that had copper exceedances; 'BINGS' and 'FGA D/S') met the objectives. Busy Place Creek (BPC02) had the potential to exceed mean WQO if levels observed were maintained over a 5 in 30 period.

Table 24. 2013 summary of mean and maximum values for total zinc ( $\mu\text{g/L}$ ) for water samples collected at sites in the Cowichan River, Fish Gut Alley, and Busy Place Creek during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were not calculated based on a minimum of five samples collected within a 30-day period; sample count is indicated in the table.

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E234125	CR14	4	<5	5.2	5.8	--	--	--	--
<b>Bings Creek/Fish Gut Alley (tributary to Cowichan River)</b>									
NA	BINGS1	4	<5	5.75	8	--	--	--	--
E290650	FGA D/S	4	<5	5	<5	--	--	--	--
E290649	FGA U/S	4	<5	11.3	29.7	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	2	2.1	6.25	10.4	--	--	--	--
E294494	BPC02	2	1.96	10.53	19.1	1	2.08	2.08	2.08
E294492	BPC03	2	0.83	1.045	1.26	1	1.48	1.48	1.48

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 7.5$   $\mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 33$   $\mu\text{g/L}$ .

For 2014 fall sampling (Table 25), there were no exceedances of the objectives at the four sites sampled on the Cowichan River mainstem. The other samples analyzed for total zinc during 2014 sampling were collected during the fall from eight Cowichan tributaries sites, three storm drain and lift station sites, and one Koksilah River site. The mean objective was exceeded at six of these sites and the maximum objective was exceeded at four.

Two of the three Cowichan River sites sampled in the summer of 2014 had lower concentrations in the summer than the fall. The remaining site, 'CR15' (Cowichan River at HWY#1), exceeded both mean and maximum WQO for zinc with a mean value of 25.7  $\mu\text{g/L}$  and a maximum value of 50.8  $\mu\text{g/L}$ . See the discussion in the Copper section with regards to elevated metals levels at this station.

Figure 7 shows summaries of the maximum concentrations for total zinc measured at all sites sampled in the fall over all three years of sampling.

Table 25. 2014 summary of mean and maximum values for total zinc ( $\mu\text{g/L}$ ) for water samples collected at sites in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River during the fall (Oct-Apr) and summer (May-Sept) seasons. Statistics were calculated based on five samples collected within a 30-day period, unless otherwise indicated by the sample count.

EMS Number	Station	Fall				Summer			
		n	Min	Mean <sup>1</sup>	Max <sup>2</sup>	n	Min	Mean <sup>1</sup>	Max <sup>2</sup>
<b>Cowichan River</b>									
E206108	CR01	4	0.28	0.933	2.8	--	--	--	--
E234125	CR14	5	0.55	2.212	7.9	1	0.41	0.41	0.41
E234125	CR14 <sup>3</sup>	5	<5	5.18	5.9	--	--	--	--
0120802	CR15	5	0.56	1.29	2.5	2	0.6	25.7	50.8
E286894	MILL	1	0.55	0.55	0.55	1	0.29	0.29	0.29
<b>Tunnel Creek (tributary to Cowichan River)</b>									
NA	TC2 <sup>3</sup>	5	<5	5	<5	--	--	--	--
<b>Bings Creek (tributary to Cowichan River)</b>									
NA	BINGS1 <sup>3</sup>	5	<5	7.62	11.8	--	--	--	--
NA	BINGS2 <sup>3</sup>	5	<5	6.1	10.5	--	--	--	--
E299771	BINGS3	5	0.39	0.942	1.57	--	--	--	--
E299770	BINGS4	4	0.32	0.426	0.57	--	--	--	--
<b>Busy Place Creek (tributary to Cowichan River)</b>									
E294493	BPC01	5	4.71	6.122	8.47	--	--	--	--
E294494	BPC02	5	39.8	72.06	130	--	--	--	--
E294492	BPC03	5	1.76	7.7	11.9	--	--	--	--
<b>Storm Drain and Lift Station sites</b>									
NA	DMH 44A <sup>3</sup>	5	30.1	46.72	60.8	--	--	--	--
NA	DMH 45A <sup>3</sup>	5	26.6	48.42	76.4	--	--	--	--
NA	MDLS <sup>3</sup>	5	7	28.57	72.75	--	--	--	--
<b>Koksilah River</b>									
E206976	KR04	5	0.37	0.95	2.45	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 7.5 \mu\text{g/L}$ .

<sup>2</sup>Dark grey highlighted maximum values exceed the Cowichan and Koksilah River WQO for total zinc of  $\leq 33 \mu\text{g/L}$ .

<sup>3</sup>Sampling conducted by the City of Duncan.

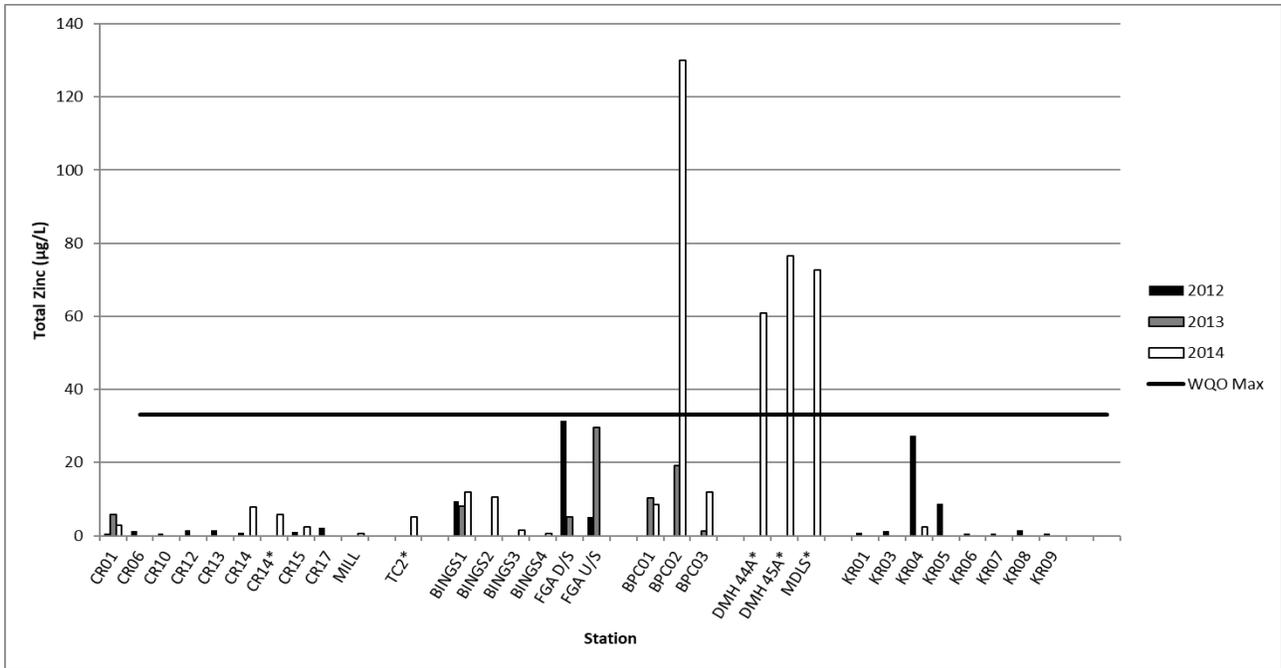


Figure 6. Summary of maximum values for zinc ( $\mu\text{g/L}$ ) in samples collected in the fall in the Cowichan River, tributaries to the Cowichan River, and the Koksilah River, compared to the fall Water Quality Objective (maximum value  $\leq 33 \mu\text{g/L}$ ). Asterisk (\*) indicates sites sampled by the City of Duncan.

#### 4.7 Temperature

The water temperature objective for the Cowichan and Koksilah Rivers is meant to protect trout and juvenile salmonids; the average weekly temperature should not exceed  $17\text{ }^{\circ}\text{C}$  at any time during the year (Obee and Epps, 2011)

Temperature data was acquired during 2013 and 2014 (Table 26). Fall data showed no exceedances of the water temperature objective. Only three sites were sampled in the summer of 2013, all in the Cowichan River mainstem; all three exceeded the objective by approximately  $4\text{ }^{\circ}\text{C}$ , representing a threat to fish stocks during the summer months unless refuges of cooler water are present.

Table 26. 2013 and 2014 summary statistics for temperature (°C). Statistics were not calculated based on a minimum of five samples collected within a 30-day period; sample count is indicated in the table.

Year	EMS Number	Station	Fall				Summer			
			n	Min	Mean	Max	n	Min	Mean <sup>1</sup>	Max
<b><i>Cowichan River</i></b>										
2013	E206108	CR01	4	8.9	10.75	12.8	2	20.7	21.45	22.2
2013	0120808	CR06	4	8.9	10.65	12.6	2	20.6	21.45	22.3
2013	E206107	CR10	4	8.9	10.7	12.7	2	20.5	21.35	22.2
2014	E234125	CR14	4	9.5	12.275	13.7	--	--	--	--
2014	0120802	CR15	4	9.6	12.4	13.8	--	--	--	--
2014	NA	School	4	9.5	12.225	13.8	--	--	--	--
<b><i>Busy Place Creek (tributary to Cowichan River)</i></b>										
2013	E294493	BPC01	4	3.6	6	9.2	--	--	--	--
2013	E294494	BPC02	4	4.6	6.875	9.6	--	--	--	--
2013	E294492	BPC03	4	11.2	12.25	13.4	--	--	--	--
2014	E294493	BPC01	4	6	10.925	13.1	--	--	--	--
2014	NA	BPC04	4	11.2	12.65	14.1	--	--	--	--
2014	NA	BPC05	4	5.6	10.45	13	--	--	--	--
<b><i>Bings Creek (tributary to Cowichan River)</i></b>										
2014	E299771	BINGS3	5	6.9	8.46	10.6	--	--	--	--
2014	E299770	BINGS4	5	5.4	7.94	10.5	--	--	--	--
<b><i>Koksilah River</i></b>										
2014	E206976	KR04	5	2.9	5.7	9.8	--	--	--	--
2014	E207427	KR07	2	10.8	11.4	12	--	--	--	--

<sup>1</sup>Light grey highlighted mean values exceed the Cowichan and Koksilah River WQO for temperature of  $\leq 17^\circ\text{C}$ .

## 5. CONCLUSIONS AND RECOMMENDATIONS

As attainment monitoring showed consistent exceedances of water quality objectives for which sample data were available, it is recommended that regular attainment monitoring continue to measure progress towards achieving these objectives.

Elevated *E. coli* in the tributaries to Cowichan River and the Koksilah River is a significant concern. Levels are lower in the mainstem Cowichan River, perhaps due to a dilution effect, but monitoring should continue for all water courses, and more sites should be targeted for summer sampling. Microbial source tracking analyses should continue, targeting sites on the Koksilah River that have shown human and ruminant indicators; sites on Busy Place Creek and Bings Creek/Fish Gut Alley should also be targeted to inform source control efforts.

Attainment monitoring has demonstrated that dissolved oxygen concentrations are often low in the Cowichan River, tributaries to the Cowichan River, and Koksilah River. Therefore, attainment monitoring should be continued with more sites targeted for summer sampling.

Ammonia results have only been obtained during 2012 sampling and there were no exceedances of the objective, with the exception of the 'Ditch@BAP' site. More thorough characterization of ammonia levels during future attainment monitoring would be beneficial.

Total phosphorus results were only obtained in 2012 sampling and showed many WQO exceedances in Cowichan River, Bings Creek/Fish Gut Alley, and Koksilah River. More thorough characterization of total phosphorus during future attainment monitoring would be beneficial.

Chlorophyll *a* measurements were not obtained during the 2012-2014 sample period at the sites to which the objective applies, and should be included in future attainment monitoring.

Total copper and zinc levels suggest localized areas of concern associated with storm drain inputs and road runoff, and monitoring should continue for these metals to inform source control efforts. Total lead showed no exceedances of the objective with the exception of the 'CR15' site (Cowichan River at HWY#1) which also had elevated concentrations of copper and lead; future attainment monitoring should target this site (fall and summer sampling) to better characterize risks of metals to aquatic life at this site.

Temperature values exceeded the WQO with very few recorded values. Temperature results should continue to be recorded regularly. It is important to obtain readings at a greater number of sites with emphasis on summer sampling.

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**APPENDIX 1. 2012 MICROBIAL SOURCE TRACKING RESULTS - PESC**

**Appendix. Bacterial Source Tracking (BST) - *Bacteroides* Method, Analysis Sheet - UPDATED 21-Feb-2013**  
 Environment Canada, Environmental Toxicology Section, Pacific Environmental Science Centre

<b>Client and Sample Information:</b>	
Name	Deb Epps
Affiliation	BCMOE
Project:	Cowichan Bay
Sampling Date:	13-Nov-12

Arrival at PESC:	14-Nov-12
Folder number:	201200791,-793,-794,-795
Analyst(s):	LB,MLS
Results checked by:	LB,MLS
Results updated:	26May2013 - LB

<u>Legend:</u>
- = absent
+ = all possible markers present (1 of 1 for pig, horse, dog, elk; 2 of 2 for human, ruminant animal, result is bolded)
** = 1 of 2 possible markers present
+f or **f = faint
? = unsure (potentially present)

PESC sample #	Client's Sample Description	Fecal Count (per 100mL)	Human	Ruminant Animal	Pig	Horse	Dog	Elk	General <i>Bacteroides</i>	Summary of fecal pollution source identification evidence by BST:
257525	18P3 Cowichan Bay between CB039 and 11P3 10:10	79	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257526	19P3 Cowichan Bay between CB013 & CB015 11:08	49	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257527	20P3 Cowichan Bay at Boatwain Bank 10:41	79	++	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257531	CB059 Cowichan Bay 400m E of breakwater 10:13	350	+	+	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257537	CB009 Cowichan Bay-small bay east of Genoa Bay 10:30	79	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257538	CB013 Cowichan Bay mouth 11:04	79	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257539	CB014 Cowichan Bay - Cherry Point Marina 10:22	79	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257540	A CB015 Cowichan Bay - between Skimmer and Cherry Points 11:13	49	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257541	B CB015 Cowichan Bay - between Skimmer and Cherry Points 11:14	79	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257542	CB038 Cowichan Bay - N of dolphins at Skimmer point 11:48	240	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257543	CB039 Cowichan Bay - Botwood lane storm drain 10:07	130	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257544	CB040 - Waldy Creek 10:17; CB040 Cow Bay @ Waldy Ck	70	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257545	CB041 - Cowichan Bay - S wecan terminal 11:58	350	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257546	1P3 - Cowichan Bay - out from boat launch A 10:00	280	+	+	+f	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257547	1P3 - Cowichan Bay - out from boat launch A 10:01	240	++	+	+	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257549	10P3 Cowichan bay - above Lambourn outfall 10:25	79	+	++	+f	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257575	<b>Patrols Creek at Moss Rd 12:05; E230098</b>	1,300	++f	+	+	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257576	<b>Koksilah River at Koksilah Rd 12:15; E206976</b>	95	-	+	+f	-	-	-	+	ruminant animal, general <i>Bacteroides</i>
257577	<b>Howie Creek at Koksilah Rd 12:40; E234128</b>	71	-	-	-	-	-	-	+	general <i>Bacteroides</i>
257579	<b>Kahin Creek at Koksilah Rd A 12:55; E207427</b>	45	-	++	-	-	-	-	+	ruminant animal, general <i>Bacteroides</i>
257581	<b>Koksilah River d/s Kahin Creek 1:20; E207433</b>	85	-	+	+f	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>

COWICHAN RIVER AND KOKSILAH RIVER ATTAINMENT REPORT 2012-2014

PESC sample #	Client's Sample Description	Fecal Count (per 100mL)	Human	Ruminant Animal	Pig	Horse	Dog	Elk	General <i>Bacteroides</i>	Summary of fecal pollution source identification evidence by BST:
257582	Koksilah River at highway 1 1:35; E123981	720	-	+	+	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>
257583	Ditch/stream across Bright Angel Park 12:30; E291189	1,100	-	++	+	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>
257585	Cowichan River 300 m w/s PE247 9:15; 0120808	180	-	-	-	-	-	-	-	no <i>Bacteroides</i> detected
257591	Manley Creek at Manley Creek park 9:50; E291149	1,800	-	-	-	-	-	-	+	general <i>Bacteroides</i>
257592	Garnett Creek at Cherry Point Beach 10:05; E291150	1,100	-	+	+f	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>
257593	Garnett Creek at Telegraph Road 10:16; E291151	600	+f	+	+f	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257594	Storm drain at Cherry Point Marina 10:30; E291152	250	+	++	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257595	Waldy Creek foreshore and Waldy Rd 10:55; E291153	980	++f	+	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257597	Storm drain at Botwood Lane 11:22; E291155	97	-	-	-	-	-	-	-	no <i>Bacteroides</i> detected
257598	Wessox Creek at Wessox Inn 11:35; E291158	810	++f	+	-	-	-	-	+	human, ruminant animal, general <i>Bacteroides</i>
257599	Wessox Creek at Wilmet Road 12:25; E291159	1,900	-	+	+f	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>
257600	Spiers Creek at Cowichan Bay Rd A 11:45; E291160	1,600	+	+	+	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257601	Spiers Creek at Hillbank Rd 12:36; E291161	4,100	++	+	+	-	-	-	+	human, ruminant animal, pig, general <i>Bacteroides</i>
257602	Treffery Creek at Cowichan Bay Rd 11:58; E291163	1,400	-	+	+	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>
257604	Treffery Creek at HWY; E291162	2,000	-	+	+	-	-	-	+	ruminant animal, pig, general <i>Bacteroides</i>

Note: The system of scoring is as follows: '+' denotes a definitively positive result (all markers possible for a particular species are present, clear and sufficiently bright). '+f' denotes a sample for which 1 out of 2 markers was detected (for those species with more than one marker), which is not as definitive as if both markers were present, but is still a positive result with one well-defined band. The occurrence of 1 out of 2 markers, or a faint or unsure result, may be due to a few reasons: 1. the method is at the edge of detection for this sample with respect to the amount of fecal matter present for a particular species. 2. not every single organism may carry both markers but in a herd (or larger number) of animals, you would expect to find both markers represented. In cases like this then, it is probable that an individual organism, possibly two organisms, caused this fecal pollution and that this particular individual did not have both markers. 3. the fecal material inoculation is old or other sample conditions (eg. protocol, temperature) are allowing the bacteria and DNA to degrade (bands can become unsharp; i.e. there appears to be 'something' in the area of interest but it is blurry).

Note: A positive result for general *Bacteroides* only indicates fecal contamination without implicating a specific source. If a sample also tests positive for markers from one or more specific animal group tested, then this is likely the, or definitely one of the contributors of the general *Bacteroides*. We do not have specific primers for other potential contributors (eg birds, seals, bears) at this time. If a sample tests positive for only general *Bacteroides*, it could be interpreted as "other species of animal" and the fecal contamination in the sample could not be attributed to human, ruminant animal, pig, horse, dog or elk sources.

QA/QC passed: All three negative controls (equipment blank, extraction blank and PCR blank) tested clear, and the PCR positive control reference test worked well.

**APPENDIX 2A. 2013 MICROBIAL SOURCE TRACKING RESULTS - PESC**

Bacterial Source Tracking (BST) Analysis Sheet											 Environment Canada	Environnement Canada
Environment Canada, Environmental Toxicology Section, Pacific and Yukon Laboratory for Environmental Testing (PYLET)												
<b>Client and Sample Information:</b> Name Deb Epps Affiliation BCMOE Project Cowichan Bay Sampling Date 03-Dec-13			Arrival at PESC: 04-Dec-13 Folder number: 201300780, 201300781 Analyst(s): LB, MLS Results checked by: LB, MLS Report date: 28-Jan-14				<b>Legend:</b> - = absent + = all possible markers present (1 of 1 for pig, horse, dog, elk; 2 of 2 for human, ruminant animal; result is <b>bolded</b> ) *+ = 1 of 2 possible markers present +f or *+f = faint ? = unsure (potentially present)					
PYLET Sample #	Client's Sample Description	Fecal Count	Human	Ruminant Animal	Pig	Horse	Dog	Elk	Gull	General <i>Bacteroides</i>	Summary of fecal pollution source identification	
276210	E291151 - Garnett Creek at Telegraph Road	91	*+f	*+f	-	-	?	-	-	+	human, ruminant animal, dog?, general <i>Bacteroides</i>	
276219	E291161 - Spiers Creek at Hillbank Road	64	-	-	-	-	-	-	-	+	general <i>Bacteroides</i>	
276224	E206976 - Koksilah River at Koksilah Road	44	-	-	-	-	-	-	-	+	general <i>Bacteroides</i>	
<b>QA/QC passed:</b> All three negative controls (equipment blank, extraction blank and PCR blank) tested clear, and the PCR positive control reference test worked well.												
<b>Note:</b> The system of scoring is as follows: '+' denotes a definitively positive result (all markers possible for a particular species are present, clear and sufficiently bright). '*+*' denotes a sample for which 1 out of 2 markers was detected (for those species with more than one marker), which is not as definitive as if both markers were present, but is still a positive result with one well-defined band. The occurrence of 1 out of 2 markers, or a faint or unsure result, may be due to a few reasons: 1. the method is at the edge of detection for this sample with respect to the amount of fecal matter present for a particular species. 2. not every single organism may carry both markers but in a herd (or larger number) of animals, you would expect to find both markers represented. In cases like this then, it is probable that an individual organism, possibly two organisms, caused this fecal pollution and that this particular individual did not have both markers. 3. the fecal material inoculation is old, or other sample conditions (eg protozoa, temperature) are allowing the bacteria and DNA to degrade (bands can become smeared; i.e. there appears to be 'something' in the area of interest but it is blurry).												
<b>Note:</b> A positive result for general <i>Bacteroides</i> : only indicates fecal contamination without implicating a specific source. If a sample also tests positive for markers from one or more specific animal group tested, then this is likely the, or definitely one of the contributors of the general <i>Bacteroides</i> . We do not have specific primers for other potential contributors (eg birds, seals, bears) at this time. If a sample tests positive for only general <i>Bacteroides</i> , it could be interpreted as "other species of animal" and the fecal contamination in the sample could not be attributed to human, ruminant animal, pig, horse, dog or elk sources.												
<b>Note:</b> The level of confidence in a positively pig result is not as high as any of the other organisms because the pig primers for one of the markers have been noted to cross-prime with ruminant animal. If it is considered impossible that the sample contains pig fecal material, we would appreciate being told.												
<b>Note:</b> When analyzed in the standard manner there is no evidence of <i>Bacteroides</i> presence. Given the pure genomic DNA gel following the extraction and knowing the FC result (forwarded by you), the lack of evidence of <i>Bacteroides</i> is surprising and it is suspected PCR inhibition is at play. It is likely a property or condition of the sample interfering with being able to isolate or amplify the target DNA. Compounds with high ionic content, chelating metals or some particular organic makeup might be to blame, and there are some strategies that I will try that I hope might take care of these to allow me to determine the source of the high FC seen for this (200700045, Jul07) and a previous sample of yours (200601278, Nov06) that resulted in a similar pattern. I'll let you know as soon as I have anything illuminating, but in the meantime "no <i>Bacteroides</i> detected" is the answer.												

**APPENDIX 2B. 2013 MICROBIAL SOURCE TRACKING RESULTS – UVIC**

Sampling Site	Sample Type (i.e., Raw Water, Pond Water, Storm	Internal Lab ID	E.coli (CFU/100ml)			Numbers of True E.Coli	Non- E.coli Colliforms (CFU/100ml)			Dilution Factor	Probable Sources											
			Plate 1	Plate 2	Mean		Plate 1	Plate 2	Mean													
Patrolas Creek at Moss Road	Fresh water	15	18	14	16	6/10	110	130	120		Black bear	Human	NI	NI	Marmot	Human						
Koksilah River at Koksilah Road	Fresh water	16	15	8	12	9/10	148	124	136		Mule deer	Black bear	Marmot	Mule deer	Human	Mule deer	Black bear	Human	Black bear			
Howie Creek at Koksilah Road	Fresh water	17	6	4	5	5/6	38	41	40		Mule deer	Mule deer	Black bear	Black bear	Black bear							
Glenora Creek at Doupe Road	Fresh water	18	8	7	8	8/8	100	110	105		Black bear	Black bear	Black bear	Black bear	Black bear	Black bear	NI	Black bear				
Kelvin Creek at Koksilah Road	Fresh water	19	38	31	35	10/10	37	48	43		Black bear	Black bear	Marmot	Black bear	Black bear	Horse	Cow	Mule deer	NI	Mule deer		
Koksilah River d/s Kelvin Creek	Fresh water	20	17	18	18	8/10	98	115	107		Mule deer	Human	Black bear	Human	Human	NI	Marmot	Human				
Koksilah River at Hwy	Fresh water	21	5	5	5	3/5	115	120	118		Raccoon	Horse	NI									
Koksilah River d/s Bright Angel Park	Fresh water	22	1	7	4	7/7	50	43	47		Elk	NI	Human	Raccoon	Coyote	Mule deer	NI					