BRITISH COLUMBIA | Ministry of Environment

ENVIRONMENTAL PROTECTION DIVISION

ENVIRONMENTAL SUSTAINABILITY AND STRATEGIC POLICY DIVISION

MINISTRY OF ENVIRONMENT

Water Quality Assessment and Objectives for the Chemainus River Watershed

TECHNICAL REPORT

JULY 2014

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EXECUTIVE SUMMARY

This document presents a summary of the ambient water quality of the Chemainus River, British Columbia, and proposes water quality objectives designed to protect existing and future water uses. The water quality assessment for the river and its tributaries and an evaluation of the watershed, as well as a comparison with the neighboring Cowichan and Koksilah Rivers, form the basis for the objectives.

The Chemainus River watershed, with an area of 35, 900 ha, is located near the community of Chemainus, British Columbia. Banon Creek (a designated community watershed and major tributary to the Chemainus River) provides Chemainus and the Town of Ladysmith with its drinking water. The designated water uses in the Chemainus River include drinking water, irrigation, primary and secondary contact recreation, aquatic life, and wildlife. Logging roads provide recreational access to the upper watershed, and hunting, ATV use and hiking occurs in those areas. Much of the upper watershed is privately owned by forestry companies and has had some forest harvesting, with second-growth harvesting ongoing. There is also a history of zinc and copper mining within the watershed boundaries. As well, there are agricultural uses and residential development throughout the lower watershed. These activities, as well as wildlife and cultural uses, all potentially affect water quality in the river.

Water quality monitoring was conducted from 2010 to 2012 (with some earlier sampling at one site). The results of this monitoring indicated that the overall state of the water quality is quite good, with turbidity and coliform levels slightly elevated on occasion. All chemical, physical and biological parameters met provincial water quality guidelines with the exception of pH, temperature, total suspended solids (TSS), copper and zinc, which exceeded the aquatic life guideline on occasion, and turbidity and *Escherichia coli*, which exceeded the drinking water guidelines on occasion. To support the maintenance and protection of the water quality in the Chemainus River watershed, ambient water quality objectives were set for these parameters and for total phosphorous in the watershed.

Future monitoring recommendations include attainment monitoring every 3 – 5 years, depending on available resources and whether activities, such as forestry or development,

are underway within the watershed. This monitoring should be conducted for one year during the summer low flow and fall flush period (five weekly samples in 30 days), and monthly from May through September for total phosphorous only, at the seven monitoring locations throughout the watershed.

Variable	Objective Value
pH	6.5 – 8.5 pH units
Turbidity	1 NTU max March - September 5 NTU max October – February 95% of samples ≤1 NTU at any intake
Temperature	Short term (< 5 years): 17°C maximum average weekly anywhere in watershed Long term (5 – 10 years): 15°C maximum instantaneous in lower Chemainus River and Bannon Creek
Total Suspended Solids (TSS)	26 mg/L max 6 mg/L average (based on a minimum of five weekly samples collected over a 30-day period)
Total Phosphorus	10 µg/L maximum 5 µg/L average (based on a minimum of monthly samples collected from May – Sept)
Escherichia coli	≤10 CFU/100 mL (90th percentile) (based on a minimum 5 weekly samples collected over a 30-day period)
Total cadmium (provisional)	≤ 0.007 µg/L average
Total copper (provisional)	≤ 3.5 µg/L maximum, ≤ 2 µg/L average (minimum 5 weekly samples collected over a 30-day period)
Total zinc (provisional)	≤ 33 µg/L maximum, ≤ 7.5 µg/L average (minimum 5 weekly samples collected over a 30-day period)

Designated water uses: drinking water, irrigation, primary and secondary contact recreation, aquatic life, and wildlife.

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AKNOWLEDGEMENTS

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1.0 INTRODUCTION

The British Columbia (BC) Ministry of Environment (MOE) is conducting a program to assess water quality in priority watersheds. The purpose of this program is to accumulate the baseline data necessary to assess both the current state of water quality and long-term trends, and to establish ambient water quality objectives on a watershed-specific basis. Water quality objectives provide goals that, if met, help to ensure protection of designated water uses. The inclusion of water quality objectives into planning initiatives can help protect watershed values, mitigate impacts of land-use activities, and protect water quality in the context of both acute and chronic impacts to human and aquatic ecosystem health. Water quality objectives provide direction for resource managers, serve as a guide for issuing permits, licenses, and orders by the MOE, and establish benchmarks for assessing the MOE's performance in protecting water quality. Water quality objectives and attainment monitoring results are reported out both to local stakeholders and on a province wide basis through forums such as State of the Environment reporting.

Vancouver Island's topography is such that the many watersheds of the MOE's Vancouver Island Region are generally small (<500 km^2). As a result the stream response times can be relatively short and opportunities for dilution or settling are often minimal. Rather than developing water quality objectives for these watersheds on an individual basis, an ecoregion approach has been implemented. The ecoregion areas are based on the ecosections developed by Demarchi (1996). However, for ease of communication with a wide range of stakeholders, the term "ecoregion" has been adopted by Vancouver Island MOE regional staff. Thus, Vancouver Island has been split into six terrestrial ecoregions, based on similarities in characteristics such as climate, geology, soils, and hydrology (Figure 1).

Fundamental baseline water quality should be similar in all streams and all lakes throughout each ecoregion. However, the underlying physical, chemical and biological differences between streams and lakes must be recognized. Representative lake and stream watersheds within each ecoregion are selected (initially stream focused) and a three year monitoring program is implemented to collect water quality and quantity data, as well as biological data. Standard base monitoring programs have been established for use in streams and lakes, to maximize data comparability between watersheds and among ecoregions, regardless of location. Watershed objectives will be developed for each of the representative lake and stream watersheds, and these objectives will also be applied on an interim basis to the remaining lake and stream watersheds within that ecoregion. Over time, other priority watersheds within each ecoregion will be monitored for one year to verify the validity of the objectives developed for each ecoregion and to determine whether the objectives are being met for individual watersheds. This report represents the application of this methodology to the Chemainus River, with the neighboring Cowichan and Koksilah rivers used as the representative watershed. The watersheds are all located in the Nanaimo Lowland Ecoregion of Vancouver Island. Water quality objectives were originally developed for the Cowichan and Koksilah rivers in 1989 (McKean, 1989). Attainment monitoring occurred in 2002, 2003 and 2008, and the objectives were updated in 2011 (Obee and Epps, 2011).

Partnerships formed between the MOE, local municipalities, aboriginal governments, stakeholders and stewardship groups are a key component of the water quality network. Water quality sampling conducted by the public works departments of local municipalities and stewardship groups has enabled the Ministry to significantly increase the number of watersheds assessed and the sampling regime within these watersheds. Stronger relationships with local government and interest groups provide valuable input, local support and, ultimately, a more effective monitoring program.

The Chemainus River provides a significant source of drinking water to the local community and has very high fisheries values, with steelhead, rainbow trout, cutthroat trout, coho salmon, chinook salmon and chum salmon all present at some point during the year. Occurances of pink and sockeye salmon and Dolly Varden have also been noted in the watershed (FISS, 2013). Anthropogenic land uses within the watershed include First Nations cultural use, timber harvesting, historical mining, agriculture, rural residential, urban residential (in the lower watershed) and recreation. These activities, as well as natural erosion and the presence of wildlife, all potentially affect water quality in Chemainus River.

Figure 1. Map of Vancouver Island Ecoregions.

This report examines the existing water quality of Chemainus River for 2010 – 2012 (as well as some additional historical data), and recommends water quality objectives for this watershed based on the water quality parameters of concern and potential impacts . Banon Creek, a tributary to the Chemainus River, was designated as a community watershed in 1995, as defined under the *Forest Practices Code of British Columbia Act* (“the drainage area above the downstream point of diversion and which are licensed under the *Water Act* for waterworks purposes”). This designation was grandparented and continued under the *Forest and Range Practices Act* (FRPA) in 2004 and infers a level of protection. As the majority of the Banon Creek community watershed is on private land, the FRPA does not apply to most of the watershed. However, the MOE uses other tools, such as water quality objectives, and legislation (*e.g.*, the *Private Managed Forest Land Act* and the *Drinking Water Protection Act*) to ensure that water quality within these watersheds is protected and managed in a consistent manner.

2.0 WATERSHED PROFILE AND HYDROLOGY

2.1 BASIN PROFILE

The Chemainus River is a fifth-order stream 64 km in length from its origins on El Capitan Mountain, Mount Whymper and Mount Landale (maximum elevation 1,541 m) to the outlet into Georgia Strait between the communities of Chemainus to the north and Crofton to the south (Kay and Blecic, 1996). The watershed is 35,900 ha in area, while the community watershed of Banon Creek within it is 3,450 ha in area.

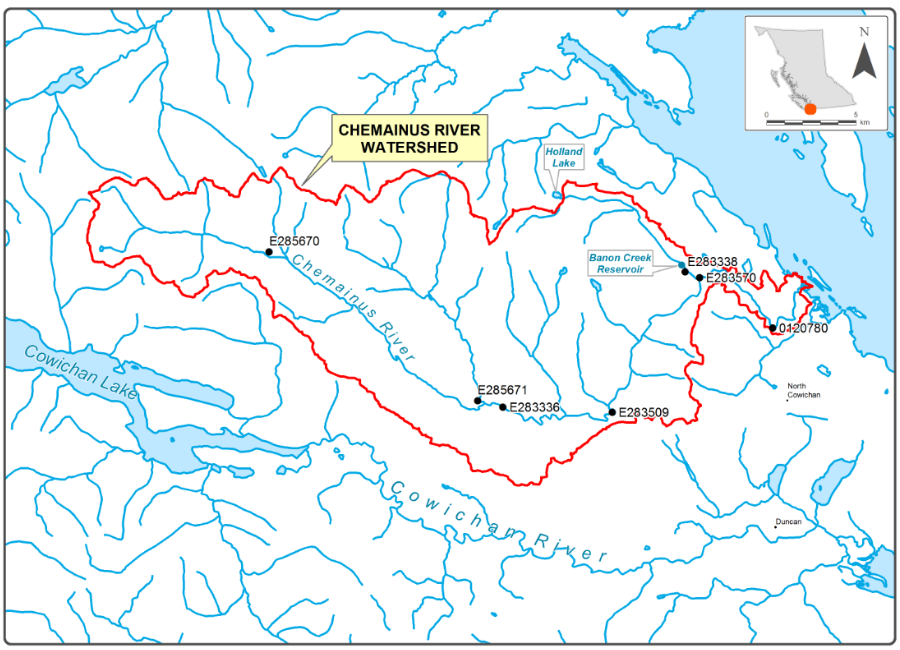

Figure 2. Chemainus River Watershed boundary and location of water quality monitoring sites.

There are a number of named tributaries to the Chemainus River including Reynard Creek, Harrison Creek, South Chemainus River, Reinhart Creek, Chipman Creek, Silver

Creek, Solly Creek, Humbird Creek, Banon Creek, West Banon Creek, Holyoak Creek and Venner Brook. Named lakes within the watershed include Sherk Lake, Brenton Lakes, Silver Lake and Holyoak Lake (Table 1).

Table 1. Summary of named lakes within the Chemainus River watershed.

Lake name	Surface area (ha)	Maximum depth (m)	Mean depth (m)	Volume (dam^3)
Holyoak Lake	20.7	10	5	1030
Silver Lake	8.6	5.6	3.3	86.4
Brenton Lakes	7.4	N/A*	N/A*	N/A*
Sherk Lake	7.5	N/A*	N/A*	N/A*

*N/A indicates this information not available

The lower portion of the watershed falls within the Coastal Douglas-fir (moist maritime, CDFmm) biogeoclimatic zone, changing at about 200 m elevation to Coastal Western Hemlock (beginning with moist montane, CWHmm, then gradually transitioning with elevation to very dry maritime, CWHxm1 and CWHxm2), which in turn gives way to Mountain Hemlock (windward moist montane, MHmm1) biogeoclimatic zone above about 800-900 m. The Chemainus River lies entirely within the Nanaimo Lowland (NAL) eco-region (see Figure 1).

2.2 HYDROLOGY AND PRECIPITATION

The nearest climate station to the watershed for which climate normal data (1971 – 2000) are available is the Cowichan Lake Forestry station (elevation 177 m) (Environment Canada Climate Station 1012040). Average daily temperatures between 1971 and 2000 ranged from 2.6°C in January to 17.9°C in August. Average total annual precipitation between 1971 and 2000 was 2,170 mm, with only 112 mm (water equivalent) (6%) of this falling as snow (Figure 3). Temperatures at higher elevations in the watershed would be cooler than recorded at sea level, thus a larger portion of the annual total precipitation would have occurred as snowfall in the higher-elevation terrain of the watershed. Most precipitation (1,749 mm, or 81%) fell between October and March. Snowpack in the watershed reaches a maximum between April and May, and snowmelt contributes to spring freshet and summer flows.

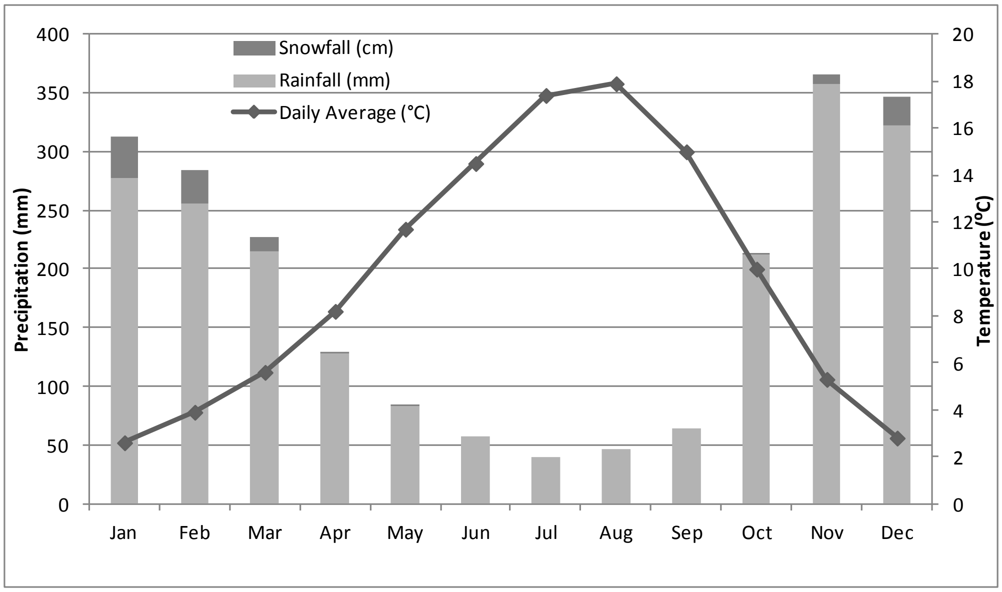

Figure 3. Climate data (1971-2000) for Cowichan Lake (Environment Canada Climate Station 1012040).

Water Survey Canada (WSC) operated a hydrometric station on Chemainus River near Westholme for about 62 years, from 1914 to 1917 and again from 1953 to 2011 (WSC, 2013). Minimum, maximum and average daily flows for this site are shown in Figure 4. Flows ranged between a low of 0.071 m^3/s on December 2, 1956 to a maximum of 537 m^3/s on February 11, 1983. Flows are highly variable during all seasons, and very sensitive to rainfall; the day before the maximum flow occurred (February 10, 1983) the average daily flow was only 38.8 m^3/s, and the day after the minimum flow (December 3, 1956) the flow was 18 m^3/s. Flows are very low during the summer months, especially August and September.

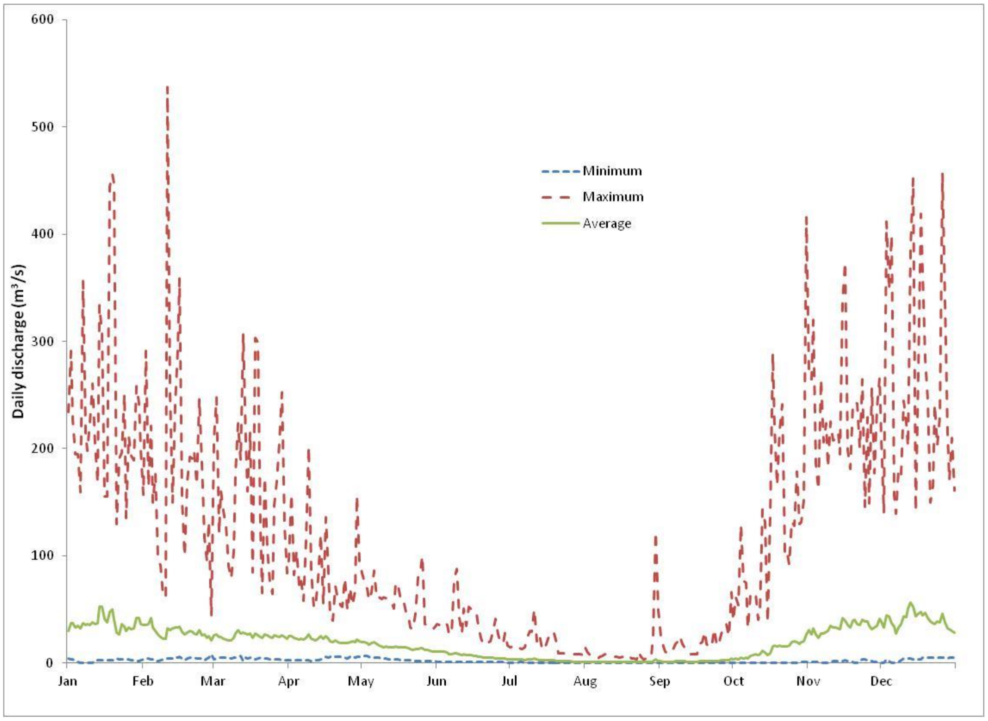

Figure 4. Minimum, maximum and average daily discharge data for Chemainus River near Westholme (WSC Station 08HA001) between 1914 and 2011 (WSC, 2013).

3.0 WATER USES

3.1 CULTURAL

The Chemainus River is important for current and historic traditional fisheries and cultural practices of First Nations in the local area. Protection of the Chemainus River aquifer and ecosystems are of utmost importance, and First Nations communities are actively engaged in salmon enhancement, habitat restoration, groundwater protection, and collaborative fisheries management planning to achieve the best possible outcome for the protection of these resources.

3.2 WATER LICENSES

Thirty-three water licenses have been issued for the Chemainus River and its tributaries (Table 2). The majority of the licensed volume (7,627.98 dam^3/year (cubic decametres/year, where 1 dam^3 = 1,000 m^3)) is for use by the Town of Ladysmith and the District of North Cowichan for waterworks purposes. The Town of Ladysmith diverts water from upper Banon Creek into the neighboring Holland Creek watershed between November and May (Pommen, 1996). The community of Chemainus is supplied with drinking water in part from a reservoir on Banon Creek (between June 15 and October 15 each year), and from groundwater wells for the remainder of the year (October 15 to June 15) (MNC, 2010). The remaining licenses are for other domestic use and irrigation, as well as a fire-protection license issued to Island Timberlands.

Table 2. Summary of licensed water withdrawals from within the Chemainus River watershed.

	Total volume of licences (dam^3/year)	No. Of licences	Primary licensee
Banon Creek			
Waterworks Local Auth	4,309.34	2	Town of Ladysmith/District of North Cowichan
Storage-Non Power	424.32	3	Various
Chemainus River			
Domestic	5.81	5	Various
Fire Protection	13.27	1	Island Timberlands
Irrigation	341.07	6	Various
Storage-Non Power	9.87	2	Various
Venner Brook			
Irrigation	111.69	10	Various
Storage-Non Power	8.76	2	Various
Holyoak Lake			
Waterworks Local Auth	3,318.65	1	District of North Cowichan
Storage-Non Power	1,233.48	1	District of North Cowichan
Total consumptive licences	8,099.82	25	

3.3 FISHERIES

The Chemainus River supports an extremely diverse and important fish population. Historically, it has been an important spawning and rearing ground for steelhead (*Oncorhynchus mykiss)*, although stock status is now considered to be at moderate to high risk due to low numbers since the 1990's. A project to increase rearing habitat in the Chemainus River by constructing large woody debris (LWD) structures was proposed in 2002 (Gaboury and McCulloch, 2002) and undertaken in 2004 (Craig, 2005). Surveys conducted on the river in 2010 showed marked increases in fish numbers between control (690 fish per linear km) and treated (1,201 fish per linear km) reaches (HCTF, 2011).

Other species utilizing the river include chinook (*O. tshawytscha*), coho (*O. kisutch*), and chum (*O. keta*) salmon, rainbow (*O. mykiss*) and cutthroat trout (*O. clarkii*). Observations of pink (*O. gorbuscha*) and sockeye (*O. nerka*) salmon and Dolly Varden (*Salvelinus malma malma*) have also been recorded (FISS, 2013). A 2002 report by Gaboury and McCulloch indicated coho populations at that time were below their historical averages, while chinook, chum and pink salmon appeared to be at or above their long term averages (Gaboury and McCulloch, 2002). Increased numbers of chinook, chum and pink were attributed in part to to hatchery augmentation, fry outplanting and/or artificial spawning channels (Gaboury and McCulloch, 2002). Recent stock assessments indicate these species are currently below average in Georgia Strait (DFO, 2013).

In addition to construction of LWD structures, other restoration and enhancement projects conducted within the Chemainus River watershed include the construction of the Westholme spawning channel in 1978, as well as a river fertilization project in 2009 to increase nutrients for salmonid production (Pellett, 2010).

3.4 RECREATION

Logging roads permit access to the upper watershed (although access is occasionally restricted during summer months due to forest fire hazards), and recreationalists utilize these areas for hiking, ATV use, hunting, and other activities. No specific studies have been conducted on recreational use in the upper watershed, so it is difficult to quantify or qualify this use.

The 119 ha Chemainus River Provincial Park, located about 3 km northwest of the City of Duncan, is a popular recreation destination, especially with locals (BC Parks, 2013). Park facilities are limited to day-use, with no camping or campfires permitted. There are no developed trails at the park, but there are a number of routes that follow the river. While there is no designated swimming or picnicking area at this park, there are numerous calm swimming holes and deep pools that are utilized for swimming and picnicking (BC Parks, 2013). Horseback riding is permitted in the park, but it is not known how common this practice is. Copper Canyon, located on the Chemainus River downstream from the Provincial Park, is a popular destination for kayakers, boasting Class III and IV+ rapids (LiquidLore, 2013).

3.5 FLORA AND FAUNA

The Chemainus River watershed provides habitat to a wide variety of species including Roosevelt elk (*Cervus canadensis roosevelti*), blacktail deer (*Odocoileus hemionus columbianus*), black bear (*Ursus americanus*), cougar (*Puma concolor*), wolves (*Canis lupis*) and numerous other small mammals and birds. The endangered (red-listed) Vancouver Island marmot (*Marmota vancouverensis*) has been found in the sub-alpine portions of Mt Whymper and Mount Landale (BCCDC, 2013). Another species of concern, the anguinae sub-species of ermine (*Mustela erminea anguinae*) (blue-listed), has been observed in the upper portion of the watershed (BCCDC, 2013). Other blue-listed species that have been found within the watershed boundaries include the white-tailed ptarmigan (saxatilis subspecies (*Lagopus leucura saxatilis*)), observed on Mt. Whymper; dwarf bramble (*Rubus lasiococcus*); Howell’s violet (*Viola howellii*); common bluecup (*Githopsis specularioides)* and California-tea (*Ruperta physodes*) (BC CDC, 2013).

A study conducted in 2009 to assess the suitability of a number of sites in the Chemainus River watershed (as well as three other watersheds on southern Vancouver Island) for marbled murrelet (*Brachyramphus marmoratus*) breeding sites found that the majority of the sites assessed on public land in the Chemainus River watershed had either very low or low habitat value as potential nesting sites. The primary reason for this low ranking was the lack of mature trees with suitable size, as well as epiphytes and moss necessary for nest building (Leigh-Spencer, 2009).

3.6 DESIGNATED WATER USES

Designated water uses are those identified for protection in a specific watershed or waterbody. Water quality objectives are designed for the substances or conditions of concern in a watershed so that their attainment will protect the most sensitive designated uses. The preceding discussion demonstrates that water uses to be protected include drinking water, irrigation, primary and secondary contact recreation, aquatic life, and wildlife.

4.0 INFLUENCES ON WATER QUALITY

Relatively little information is available for land use within the Chemainus River watershed. No Coastal Watershed Assessment Plan (CWAP) has been conducted, and no land ownership summary has been compiled to determine the ratio of privately owned lands versus Crown Land, as well as the amount of land used for forestry, agriculture, or rural and urban residential development, all of which can potentially impact water quality in the river.

4.1 LAND OWNERSHIP

Much of the upper watershed consists of forestry lands privately owned by Island Timberlands. In the lower portion of the watershed, land use is primarily agricultural (mostly small hobby farms), as well as rural residential. There is also some industrial use, primarily along Highway 1 (the Island Highway) that backs onto the river approximately 8 km from its mouth; downstream from this the river runs within a few hundred metres of Highway 1 for about 4 km. In the upper watershed (upstream from Highway 1), the MacMillan Bloedel Forest Service road parallels the river for much of its length, and there are a number of river crossings. Access to this road is restricted approximately 1.2 km upstream from Highway 1 during the summer months for fire prevention.

Agricultural activity occurs through a portion of the lower watershed, and sediment from cleared land, nutrients from fertilizer use, pesticides, and animal waste can all be transported from farmland into the river.

Rural residential development in the lower watershed, can impact water quality in many ways, including road runoff, stormwater, nutrients from lawn fertilizers, proliferation of impervious surfaces and increased sediment loadings from land disturbance. Thus, potential sources of contamination associated with households (such as septic fields), as well as fecal material from domestic animals, may affect water quality in the Chemainus River.

Finally, there are two highway crossings in the lower Chemainus River watershed: Highways 1 and 1A, (a major highway and local thoroughfare, respectively, both with high traffic volume), cross the Chemainus River approximately 4 km and 2 km, respectively, upstream from the mouth of the river. Runoff from the highways can also impact the lower portion of the Chemainus River with increased sediment loads and contaminants such as polycyclic aromatic hydrocarbons from vehicles.

4.2 LICENSED WATER WITHDRAWALS

The water allocation plan for the Chemainus River watershed (Kay and Blecic, 1996) summarizes the low flow licensed water demand for the Chemainus River (Table 3). Minimum flows required to avoid severe degradation to biotic communities are >10% of the mean annual discharge (MAD), where MAD in the Chemainus River is 1,900 L/s. These minimum lows are generally met all year except in August and September (Kay and Blecic, 1996). During these environmentally critically low flow months, the average withdrawal of 120 L/s (6% of MAD) could represent a significant portion of base flows, potentially creating severely degraded habitat conditions (values less than 10% MAD).

Water may only available for extractive uses between the months of October and May, when mean monthly flows are at least 60% of MAD (at least 11.3 m^3/s), resulting in an estimated volume of available water of approximately 334,000 dam^3 annually. As the

Town of Ladysmith only extracts water between November and May each year, only the District of North Cowichan withdrawals would potentially affect low flows.

Table 3. Summary of low-flow licensed water demand for Chemainus River watershed (from Kay and Blecic, 1996).

	Volume	
Use	litres/second	dam^3
Domestic	0.18	1.43
Industrial	0.42	3.27
Irrigation	45.27	352
Storage – Holyoak	-95.19	-1,234.00
Storage - other	-57.04	-443.66
Waterworks	226.25	1,759.30
Total Consumption	**119.89**	**438.34**

Based on an estimated 90 day period demand assuming that: irrigation and industrial demands are totally withdrawn over the 90 day period; domestic and municipal waterworks demand are the authorized licensed maximum daily for 90 days; storage balances demand, and therefore, is a negative demand over the 90 days; land improvement is non-consumptive and, therefore, has no demand. The storage demand on Holyoak Lake is based upon an estimated 150 day period.

4.3 FOREST HARVESTING AND FOREST ROADS

Forestry activities can impact water quality both directly and indirectly in several ways. The removal of trees can decrease water retention times within the watershed and result in a more rapid response to precipitation events and earlier and higher rain on snow events in spring. The improper construction of roads can change drainage patterns, destabilize slopes, and introduce high concentrations of sediment to streams.

Historical forest harvesting has occurred throughout much of the upper watershed, and current harvesting is primarily second-growth timber. No current estimate of equivalent clearcut area (ECA) is available (Epps, pers. comm., 2013).

Most streamside roadways within the watershed have a vegetated buffer between them and the river, reducing runoff and therefore decreasing the amount of turbidity and suspended solids entering the river. However, the relatively high density of roads within the watershed suggests that, in some areas, runoff from these roads has the potential to impact turbidity levels in the river, particularly during periods of road grading or road construction. Potential impacts from these roads will decrease as roads are deactivated and reclaimed.

It is likely the cumulative effect of the large number of small-scale disturbances associated with road construction and forest harvesting is impacting water quality to a certain degree, especially with respect to turbidity levels during rain events. Improvements in harvesting practices over the past 20 years, coupled with increased legislation (for example, the *Water Act* and the *Private Managed Forest Land Act*), should decrease the potential for impacts to water quality as hydrologic recovery continues.

4.4 RECREATION

Recreational activities can affect water quality in a number of ways. Erosion associated with 4-wheel drive and ATV vehicles, direct contamination of water from vehicle fuel, and fecal contamination from human and domestic animal wastes (*e.g*., dogs or horses) are typical examples of potential effects. As no specific studies have been conducted on recreation within the Chemainus River watershed, the relative impacts of recreational activities cannot be discussed. However, with the ease of access in the lower watershed, presence of a large Provincial Park within the watershed boundaries, and proximity to population centres, it is likely that some recreational impacts occur within the watershed.

The Chemainus River Provincial Park is a popular tourist destination, with several routes that follow the river and lead to various swimming holes (BC Parks, 2013). It is likely that some fecal coliforms will be shed by bathers. Recreational use of the upper river (Copper Canyon) is likely limited to kayakers due to fast flowing water and frequent canyons, although it is possible that ATV's are able to access the river at some point.

4.5 WILDLIFE

Wildlife can influence water quality through the deposition of fecal material which may include pathogens such as *Giardia lamblia*, which causes giardiasis or "beaver fever", and *Cryptosporidium* oocysts which cause the gastrointestinal disease cryptosporidiosis (Health Canada, 2004). Microbiological indicators, such as *Escherichia coli,* are used to assess the risk of fecal contamination to human health. Fecal contamination of water by animals is generally considered to be less of a concern to human health than contamination by humans because there is less risk of inter-species transfer of pathogens. However, without specific source tracking methods, it is impossible to determine the origins of coliforms.

The Chemainus River watershed contains valuable wildlife habitat and provides a home for a wide variety of warm-blooded species. Therefore, the risk of contamination from endemic wildlife exists.

4.6 MINING

Mining activities can impact water quality by introducing high concentrations of metals and other contaminants (*e.g.*, sulphate) to waterbodies. The leaching of waste rock or adit discharges can also contribute to acidification of the water. Mining activities generally include road construction and land-clearing, which can change water movement patterns and result in increased turbidity levels.

There are at four inactive metal mines (Lenora, Richard III, Tyee, Victoria) on Mount Sicker (about 7 km west of Crofton) (MINFILE, 2013; BC MEM, 2003), exploration of the old Laramide (Lara – metal prospect) property in the headwaters of Solly Creek, and two developed prospects (Lady A (Zone A and C) – iron magnetite prospects) in one of the tributaries to Chipman Creek (MINFILE, 2013). MINFILE (2013) also lists six additional prospects and 25 showings in the Chemainus River watershed.

Of the three inactive mines on Mt. Sicker (Lenora, Tyee and Richard III), potential impacts on water quality would likely be limited to the Lenora mine. It is located in the Nugget Creek watershed (a small tributary to the Chemainus River), and water sampled at a waste dump seep and a test-pit at the south-east end of the property showed acid rock drainage occurs at the site; low pH water (4.0 to 5.1 pH units) and very high conductivity (800 µS/cm), and a number of metals (including aluminum, chromium, cadmium, copper, cobalt, iron, lead, manganese, silver and zinc) were present at concentrations one to four orders of magnitude greater than water quality guidelines (BC MEM, 2003). Historical data (Martell, 1995) showed potential for exceedences of average water quality guidelines for zinc downstream of the old mine at the highway site. However, more recent and frequent data with lower detection limits for metals are considered in Section 6.8 of this report to evaluate the potential for mine site impacts to water quality in the Chemainus River. Generally, the amount of water coming off this site tends to be low, and concerns about acid drainage from existing inactive mines in the Chemainus River are minimal at this time. Activities regarding the future development of mines or prospects within the Chemainus River watershed are unknown, but any activities would have to undergo impact assessments to ensure that water quality is not impacted.

5.0 STUDY DETAILS

Initially (between 1986 and 2001), one water quality monitoring site was established within the Chemainus River watershed: Environmental Monitoring System (EMS) Site 0120780 is the Chemainus River at Highway 1 (Kay and Blecic, 1996). In 2010, six additional sites were added to the monitoring program. Four sites are located on the Chemainus River mainstem: Site E285670 is located at the Meade Creek Main Line on the Chemainus River, in the upper watershed; Site E283336 is located on the Chemainus River upstream from Copper Canyon; Site E283509 is on the Chemainus River at the Provincial Park; and Site E283570 is located on the Chemainus River at Grace Road; (upstream from Site 0120780 at the Highway 1 crossing) (Figure 2). The remaining two sites are on tributaries to the Chemainus River: Site E285671 is on Chipman Creek upstream from its confluence with the Chemainus River (just upstream from Copper Canyon); and E283338 in Banon Creek, just upstream of its confluence with the Chemainus River (between the Grace Road and Highway 1 sites). The project consisted of four phases: collecting water quality data, gathering information on water use, determining land use activities that may influence water quality, and establishing water quality objectives.

Water quality data were collected between 1986 and 2001 at Site 0120780 (Chemainus River at Highway 1), in 2010 at four sites (0120780 Chemainus at Highway 1, E283336 Copper Canyon and E283570 Grace Road and at the E283338 Banon Creek site) and from 2011 to 2012 at all seven sites. Drinking water is one of the designated water uses in the Chemainus River and so water quality variables relevant to the protection of raw drinking water supplies were included. Based on the current knowledge of potential anthropogenic impacts to watershed (generally associated with timber harvesting, mining, agriculture, recreation, rural residential and industrial development), cultural uses, natural features (wildlife), and the lack of authorized waste discharges to the river, the following water quality variables were included at the 0120780 Chemainus River at Highway 1 site and a subset of them at the other six sites:

- Physical: pH, temperature, specific conductivity, true color, turbidity, total suspended solids
- Carbon: dissolved organic carbon, total organic carbon, total inorganic carbon
- Nutrients: total phosphorus, orthophosphate, nitrate, nitrite, ammonia, total Kjeldahl nitrogen
- Total and dissolved metals concentrations, hardness
- Microbiological indicators: fecal coliforms, *Escherichia coli*
- Biological: benthic invertebrates, chlorophyll *a*

Water samples were collected periodically between 1986 and 2010 (see Table 4), and again from April 2011 through March 2012, with sampling frequencies increased to five weekly samples in 30 days during the summer low-flow (August – September) and fall high-flow (October-November) periods.

Samples were collected in strict accordance with Resource Inventory Standards Committee (RISC) standards (BC MOE, 2003) by trained MOE personnel. Samples were sent to Maxxam Analytics Inc. in Burnaby, BC (and Cantest Laboratories for microbiological analysis prior to Cantest being purchased by Maxxam) for all laboratory analyses except taxonomic identification of benthic invertebrates which was done by Fraser Environmental Services of Surrey, B.C. Summary statistics were calculated on all available data, and, for applicable parameters, 90^{th} percentiles were calculated using data from a minimum of 5 weekly samples in 30 consecutive days for each site. Field measurement of temperature, dissolved oxygen, specific conductivity, and turbidity were also conducted using a YSI ProPlus handheld meter. Data are summarized in Appendix I.

Table 4. Sampling schedule for Site 0120780, Chemainus River at Highway 1*.

Year	Number of Samples	Month(s) samples collected
1986	1	March
1987	1	December
1988	13	Near-monthly, including 5-in-30 May-June
1989	10	Near-monthly
1990	1	May
1995	8	Mar - May, Sept - Nov
1999	2	Feb, Dec
2000	1	Nov
2001	1	Nov
2010	1	Sept
2011	16	Apr - Dec, incl 5-in-30 summer and fall
2012	3	Jan-Mar

*Sampling for Copper Canyon, Provincial Park, and Grace Road sites began in 2010 and remaining sites (Meade Creek FSR, Chipman Creek and Banon Creek) began in 2011.

HOBO temperature loggers were installed at two sites (E285670 Chemainus River at Meade and E283570 Chemainus River at Grace Road) in on June 14, 2011with data collected successfully for this report until Nov 10, 2011 and Aug 23, 2012, respectively, for the two sites. The HOBO loggers remain in the river to date. These temperature loggers collect hourly temperature data.

As well, data are compared with the nearby Cowichan and Koksilah rivers as part of the ecoregion approach to water quality objective development. The proximity of the three watersheds, the fact that they are in the same ecoregion (and therefore having similar climate, geology, soils and hydrology), and the similarity of land use (forestry in the upper watershed, agricultural use through portions of the watershed, and residential/urban/ industrial uses primarily in the lower watershed) makes the comparison of water quality in the two watersheds useful, especially considering the longer period of record for water quality data in the Cowichan River and Koksilah River watersheds.

6.0 WATER QUALITY ASSESSMENT AND OBJECTIVES

There are two sets of guidelines that are commonly used to determine the suitability of drinking water. The BC MOE water quality guidelines (available at http://www.env.gov.bc.ca/wat/wq/wq_guidelines.html) are used to assess water at the point of diversion of the natural stream into a waterworks system. These BC guidelines are also used to protect other designated water uses such as recreation and habitat for aquatic life. Water quality guidelines provide the basis for the development of water quality objectives for a specific waterbody, which can be integrated into an overall fundamental water protection program designed to protect all uses of the resource, including drinking water sources.

The BC *Drinking Water Protection Act* sets minimum disinfection requirements for all surface supplies, as well as requiring drinking water to be potable. The Vancouver Island Health Authority (VIHA) determines the level of treatment and disinfection required based on both the source and end-of-tap water quality. As such, VIHA requires all surface water supply systems to provide two types of disinfection processes. Both Ladysmith and Cowichan disinfect their drinking water with chlorination (MNC, 2010). To effectively treat the water for viruses and parasites, such as *Cryptosporidium* and *Giardia*, Ladysmith and Cowichan may be required to provide additional disinfection, such as UV or ozone, and/or treatment, such as filtration.

The following sections describe the characteristics considered in assessing the water quality of the Chemainus River.

6.1 PH

pH measures the concentration of hydrogen ions (H^+) in water. The concentration of hydrogen ions in water can range over 14 orders of magnitude, so pH is defined on a logarithmic scale between 0 and 14. A pH between 0 and 7 is acidic (the lower the number, the more acidic the water) and a pH between 7 and 14 is alkaline (the higher the number, the more basic the water). The aesthetic objective for drinking water is a pH between 6.5 and 8.5 (McKean and Nagpal, 1991). Corrosion of metal plumbing may occur at both low and high pH outside of this range, while scaling or encrustation of metal pipes may occur at high pH. The effectiveness of chlorine as a disinfectant is also reduced outside of this range.

The pH measured at most of the sites was slightly basic, with values ranging from 7.06 pH units to 8.7 pH units, and an average of between 7.26 pH units and 7.46 pH units at all of the sites (Table 5). There was no general directional trend in pH between the sites, but average pH was higher in the summer than at the winter at all of the sites (Table 5). Two of the sites had pH values slightly outside of the guideline range: 0120780 Chemainus River at Highway 1 had three pH measurements of 6.4 pH units collected between October 11, 1995 and November 7, 1995, and E283338 Banon Creek had a single pH measurement of 8.66 pH units measured on June 14, 2011.

Table 5. Summary of pH (pH units) measured at the five Chemainus River sites and in Chipman Creek and Banon Creek. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. Of Samples	Minimum	Maximum	Average	Std Dev	Summer Average	Winter average
E285670	Chemainus R. @ Meade Ck.	10	7.25	7.72	7.42	0.14	7.51	7.36
E283336	Chemainus R. @ Copper Canyon	13	7.18	7.87	7.46	0.22	7.57	7.40
E283509	Chemainus R. @ Provincial Park	13	7.24	7.6	7.39	0.10	7.45	7.35
E283570	Chemainus R. @ Grace Road	13	7.26	7.69	7.41	0.11	7.49	7.35
0120780	Chemainus R. @ Hwy 1	49	6.4	7.83	7.26	0.33	7.47	7.21
E285671	Chipman Ck. U/S from Chemainus R	12	7.26	7.66	7.43	0.14	7.48	7.40
E283338	Banon Ck. U/S from Chemainus R.	12	7.06	8.66	7.40	0.42	7.75	7.23

The low pH measured at the Highway 1 site (0120780) occurred during the months of October and November 1995, and were collected on days preceded by significant rainfall (212 mm of rainfall were measured at the Lake Cowichan weather station, and 111 mm of rainfall occurred on November 7, 1995). Rainfall tends to have a low pH (6.0 – 6.5 pH units), and therefore heavy rainfall can temporarily drive down the pH in a river, which possibly occurred at the Highway 1 site. Conversely, low rainfall can result in elevated pH, as likely occurred at the Banon Creek site in June 2011. The pH measured at the Banon Creek site one month before and one month after the high value was 7.22 pH units, and the pH range measured at the Highway 1 site for 2011-12 (the total period of record for the other sites, and therefore useful for comparison purposes) was 7.17 pH units to 7.83 pH units, suggesting that these occasional more extreme values are short-term and likely not of concern. The pH range measured in the neighboring Cowichan and Koksilah River watersheds between 2002 and 2008 was similar although a narrower range was observed (6.9-8.2 pH units) and site averages were slightly higher (averages between 7.44 and 7.85). No objective was proposed for pH in those watersheds (Obee and Epps, 2011). ***However, in order to monitor the situation in the Chemainus River and ensure that pH does not become a concern, an objective is proposed for the Chemainus River, as well as Chipman and Banon creeks: the pH should remain within the range of 6.5 to 8.5 pH units at all of the monitoring sites within these watersheds.***

6.2 TEMPERATURE

Temperature is considered in drinking water for aesthetic reasons. The aesthetic guideline is 15°C; temperatures above this level are considered to be too warm to be aesthetically pleasing (Oliver and Fidler, 2001). For the protection of aquatic life in streams, the allowable hourly change in temperature is +/-1°C from naturally occurring levels. The optimum temperature ranges for salmonids are based on species-specific life history stages such as incubation, rearing, migration, and spawning. For steelhead, which are present in the Chemainus River, the optimum temperature ranges are: 10 – 12°C for incubation; 16 – 18°C for rearing; and 10 – 15.5°C for spawning (Oliver and Fidler, 2001). Each salmon species also has its own optimum temperature range. Chum salmon, which are present in the Chemainus River, are the most sensitive salmonid to warmer temperatures (12 – 14°C for rearing). However, the juveniles are not present in the river during the summer months. Steelhead and coho, which have similar temperature thresholds, are the species present in the watershed for the longest periods of time, including the summer (McCulloch, pers. com., 2013). Maturation of the embryos is temperature-dependent, but coho typically emerge by mid-May and steelhead typically emerge by late June. Cutthroat trout (17°C guideline for rearing) are resident year-round.

Water temperature was measured in 2011 – 2012 at all monitoring sites. Water temperatures in the Chemainus River and Chipman and Banon creeks varied seasonally, with maximum temperatures occurring in late July through the end of August. Maximum water temperatures decreased slightly between the Meade Creek FSR and the Provincial Park before increasing considerably at the Grace Road and Highway 1 sites (Table 6). Chipman Creek remained relatively cold throughout the summer with a maximum temperature of 13.3°C measured on August 29, 2011, and Banon Creek was warmer, with a maximum temperature of 18.5°C on August 16, 2011.

Table 6. Summary of water temperatures (°C) measured at the five Chemainus River sites as well as at Chipman and Banon creeks between 2011 and 2012. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. Of Samples	Minimum	Maximum	Average	Std Dev	Summer Average	Winter average
E285670	Chemainus R. @ Meade Ck.	14	3	16.3	9.1	5.0	14.4	5.1
E283336	Chemainus R. @ Copper Canyon	16	1.6	16.1	8.0	5.2	14.1	4.3
E283509	Chemainus R. @ Provincial Park	16	2	15.9	8.1	5.3	14.4	4.3
E283570	Chemainus R. @ Grace Road	16	3	17.6	9.1	5.9	16.1	5.0
0120780	Chemainus R. @ Hwy 1	16	3.2	20	10.0	6.6	18.0	5.3
E285671	Chipman Ck. U/S from Chemainus R.	16	1.7	13.3	7.2	4.3	12.2	4.2
E283338	Banon Ck. U/S from Chemainus R.	16	2.9	18.5	8.2	5.5	14.6	4.3

HOBO temperature logger data ranged from 4.7°C to 18.0°C at the Meade Creek site (Figure 5), with a maximum weekly average temperature of 14.0°C; at the Grace Road site, water temperatures ranged from 0°C to 21.1°C (Figure 6), with a maximum weekly average temperature of 18.1°C. The fact that the maximum temperatures measured at both of these sites is considerably higher than the maximum temperatures measured during field visits demonstrates the difficulty in measuring extreme values by relying on site visits alone.

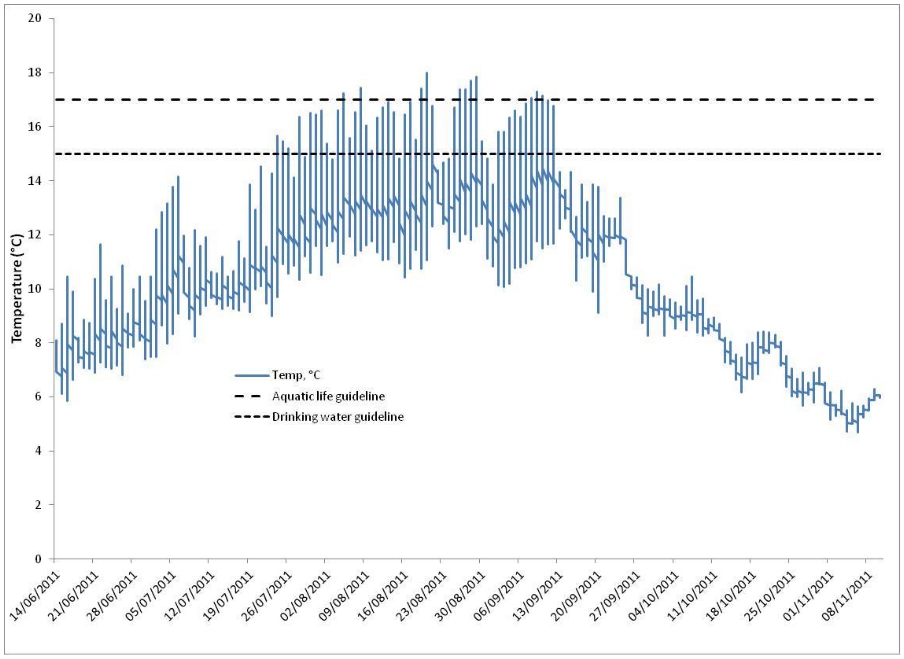

Figure 5. Hourly water temperature measured at E285670 Chemainus River at the Meade Creek Forest Service Road between June 14, 2011 and November 8, 2011.

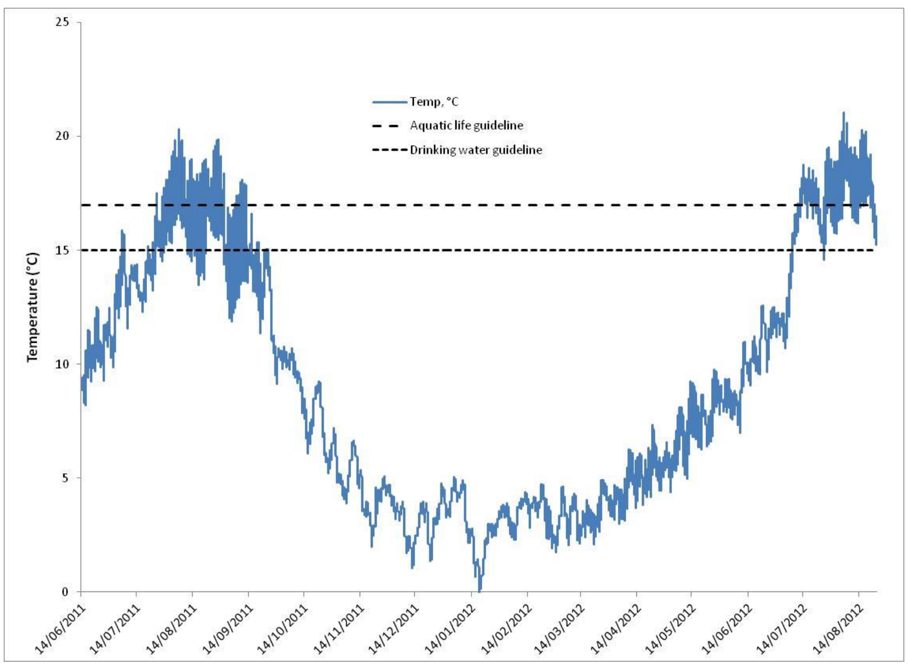

Figure 6. Hourly water temperature measured at E283570 Chemainus River at Grace Road between June 14, 2011 and August 14, 2012.

Water temperatures remained consistently below the aquatic life guidelines for the incubation and spawning period for salmonids. However, maximum summer water temperatures exceed the guideline for both coho, dolly varden and cutthroat (17°C) (at the Grace Road, Highway 1 and Banon Creek sites) and steelhead (19°C) (at the Highway 1 site) rearing. While adult steelhead typically return to the ocean after spawning, most juveniles spend one to two years in freshwater maturing into smolts before entering the ocean. Some salmon species, including coho, also utilize freshwater for up to three years before entering the ocean. The lower portion of the Chemainus River is generally wide and shallow, with little riparian cover, allowing considerable solar infiltration. Therefore, water temperatures in the lower reaches are likely considerably higher than at upstream locations. Maximum temperatures were slightly lower than those seen in the neighboring Cowichan and Koksilah River watersheds, which reached as high as 24°C (likely due to the residence time of Cowichan Lake, which allowed the water more time to warm up) (Obee and Epps, 2011). Chemainus River data support the application of the Cowichan and Koksilah Rivers temperature objective for the Chemainus River. Therefore, ***due to the high summer temperatures and the high fisheries values of the Chemainus River, a short-term (within five years) water quality objective is proposed to protect juvenile salmonids. The average weekly temperature at all sites should not exceed 17°C at any time during the year.*** While maximum temperatures may exceed the guideline in the lower portion of the river, as long as refuges remain with average temperatures below the guideline, juvenile fish should be protected during periods of elevated temperatures.

The aesthetic drinking water guideline (a maximum of 15°C) was exceeded by a considerable margin during the summer months at all of the sites except Chipman Creek. Many watersheds on the west coast of Vancouver Island, as well as throughout the Southern Interior, typically have elevated summer water temperatures. It is therefore likely that higher summer temperatures are, for the most part, a natural occurrence. However, it is possible that activities, such as forest harvesting, agriculture or urban development, that have the potential to decrease stream shading through removal of vegetation in riparian areas, and climate change, could exacerbate peak summer water temperature to the point where this guideline is occasionally exceeded. ***Therefore, a long-term (five to ten years) objective is also proposed for drinking water purposes whereby the maximum instantaneous water temperatures should not exceed 15°C during the summer months in the lower Chemainus River or in Banon Creek.*** This would protect the domestic water intakes on the Chemainus River, and ensure that water temperatures in Banon Creek would not impact the drinking water supply for the District of North Cowichan. In the Banon Creek system, releases of water from Holyoak Lake could augment low summer flows and decrease maximum temperatures, which would be beneficial both for aquatic life and for drinking water aesthetics.

6.3 CONDUCTIVITY

Conductivity refers to the ability of a substance to conduct an electric current. The conductivity of a water sample gives an indication of the amount of dissolved ions in the water. The more ions dissolved in a solution, the greater the electrical conductivity. As temperature affects the conductivity of water (a 1ºC increase in temperature results in approximately a 2% increase in conductivity), specific conductivity is used (rather than simply conductivity) to compensate for temperature. Coastal systems, with high annual rainfall values and typically short water retention times, generally have low specific conductivity (<80 microsiemens/centimeter (μS/cm)), while interior watersheds generally have higher values. Increased flows resulting from precipitation events or snowmelt tend to dilute the ions, resulting in decreased specific conductivity levels with increased flow levels. Therefore, water level and specific conductivity tend to be inversely related. However, in situations such as landslides, where high levels of dissolved and suspended solids are introduced to the stream, specific conductivity levels tend to increase. As such, significant changes in specific conductivity can be used as an indicator of potential impacts.

Specific conductivity was measured at the five Chemainus River sites, as well as in Chipman and Banon creeks. Values ranged from a minimum of 37 μS/cm in Banon Creek to a maximum of 85 μS/cm in the Chemainus River at Highway 1, and the average conductivity at all of the sites was similar, ranging from 46 μS/cm in Banon Creek to 66 µS/cm at the Chemainus River Grace Road site (Table 7). Conductivity was only measured during the summer at most of the sites, so no seasonal comparison can be made. At the Highway 1 site, where there is a considerably larger data set (36 measurements have been made between 1986 and 2011), the average conductivity during the summer (defined as June to September for this analysis) was slightly higher than the winter average (65 µS/cm versus 41 µS/cm), likely reflecting the increased dilution of ions by the increased rainfall occurring during the winter months. Specific conductivity values were similar to those measured in the neighboring Cowichan River (site averages ranging from 50 to 59 µS/cm) and slightly lower than those in the more impacted Koksilah River (site averages ranging from 106 to 145 µS/cm), where no specific conductance objective was recommended (Obee and Epps, 2011). As there is no BC Water Quality Guideline for specific conductivity and the average specific conductivity observed was typical of coastal systems, no objective is proposed for specific conductivity in the Chemainus River watershed.

Table 7. Summary specific conductivity (µS/cm) measured at the five Chemainus River sites as well as Chipman and Banon creeks, 1986-2011. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. Of Samples	Minimum	Maximum	Average	Std Dev	Summer Average	Winter average
E285670	Chemainus R. @ Meade Ck.	6	44	60	53	6	53	
E283336	Chemainus R. @ Copper Canyon	6	60	65	62	2	62	
E283509	Chemainus R. @ Provincial Park	6	52	73	63	7	63	
E283570	Chemainus R. @ Grace Road	6	56	74	66	6	66	
0120780	Chemainus R. @ Hwy 1	36	26	86	48	17	65	41
E285671	Chipman Ck. U/S from Chemainus R	5	46	66	59	7	59	
E283338	Banon Ck. U/S from Chemainus R.	5	37	56	46	7	46	

6.4 TURBIDITY

Turbidity is a measure of the clarity or cloudiness of water, and is measured by the amount of light scattered by the particles in the water as nephelometric turbidity units (NTU). Elevated turbidity levels can decrease the efficiency of disinfection, allowing microbiological contaminants to enter the water system. As well, there are aesthetic concerns with cloudy water, and particulate matter can clog water filters and leave a film on plumbing fixtures. The guideline for drinking water that does not receive treatment to remove turbidity is an induced turbidity over background of 1 NTU when background is less than 5 NTU, and a maximum of 5 NTU (during turbid flow periods) (Caux *et al*., 1997). VIHA's goal for surface drinking water sources with systems that do not receive filtration, such as the Chemainus River watershed, is that it demonstrate 1 NTU turbidity or less (95% of days) and not above 5 NTU on more than 2 days in a 12 month period when sampled at the intake (Enns, pers. comm., 2009).

The District of North Cowichan only utilizes water from Banon Creek during the summer months, due to elevated turbidity during the winter months (MNC, 2010). Water utilized from Banon Creek by Ladysmith between November and May is diverted into Holland Lake, where the residence time (and subsequent settling out of particulate matter), ameliorates to some extent, the elevated turbidity levels occurring during this time in Banon Creek. In a 2010 – 2011 study of four communities on southern Vancouver Island and the Gulf Islands with recent boil-water advisories (Tofino, Chemainus, Courtenay-Comox and Pender Island), the authors found that Chemainus had the largest proportion of residents reporting that their drinking water was poor (26%) or fair (23%), and the only community with respondents report having "very poor" (4%) water (Tromp-van Meerveld *et al*., 2011). However, 47% of respondents residing in Chemainus reported that their water was "good" or "very good". They also had the highest proportion of residents (33%) who thought their drinking water was inferior to that of other coastal communities in BC. The fact that Chemainus had 12 boil-water advisories between 2005 and 2010 (Tromp-van Meerveld *et al*., 2011) is likely responsible to a large part for this negative perception.

Turbidity is one of the factors that can lead to boil-water advisories. Turbidity events can result from non-point sources such as runoff from roads, ditches, farmland, etc., as well as from landslides (both natural and those resulting from anthropogenic impacts such as timber harvesting or road construction). A summary of turbidity measurements for the Chemainus River watershed is given in Table 8.

Average turbidity tended to increase in a downstream direction; it was highest at the highway site and lowest in the upper watershed. Four of the seven sites had maximum turbidity levels exceeding 1 NTU. Higher turbidity levels (those exceeding 1 NTU) at each of the sites occurred almost invariably in January and February, likely as a result of rainfall events washing suspended sediments into the rivers. The exception to this was the two higher values measured in Banon Creek (1.1 NTU, measured on both August 23, 2011 and September 6, 2011). The reason for these slightly elevated values is unclear, as no increase was seen at the other sites on these days. Values may have been influenced by low flows and difficulty filling sample bottle without slight sediment disturbance. The maximum turbidity value measured at the Highway 1 site (5.04 NTU) occurred on February 17, 1999, and no data were collected at the other sites on this day, so it is not known if the turbidity event occurred elsewhere in the watershed or solely at the intake site. Turbidity tended to be highest during the fall and winter (when rainfall is the highest), with the exception of Banon Creek, where, as mentioned, the maximum values occurred during the summer months and resulted in a higher average during that period.

Turbidity levels are generally low throughout the watershed, including at the Highway 1 site. Turbidity at the Meade Creek FSR site (the site most representative of natural conditions in the watershed) remained low (< 1 NTU) over the course of the monitoring program. In the neighboring Cowichan and Koksilah rivers, ambient turbidity was determined to be 1 NTU (Obee and Epps, 2011), thus a slightly more conservative objective than that proposed for these rivers is applicable to the Chemainus River.

It should be noted that turbidity values above 2 NTU are considered likely to affect disinfection in a chlorine-only system (Anderson, pers. comm., 2006). An alternative to the objective of 1.0 NTU would be to treat the raw water prior to chlorination to remove some of the turbidity and increase chlorine efficiency. In accordance with VIHA's protocol for whether filtration is required, the Town of Ladysmith and the District of North Cowichan, as water purveyors, should continue to sample turbidity levels at the water intake location to ensure that the appropriate treatment methods are applied.

To protect drinking water quality in the Chemainus River watershed, ***it is recommended that from October to February (when turbid flows can occur), turbidity measured at the Highway 1 site and in Banon Creek should not exceed 5 NTU; during the remainder of the year (clear flow periods, March to September), turbidity measured at these locations should not exceed 1 NTU (1 NTU above ambient levels, as measured at the Meade Creek FSR site). To align with VIHA criteria, turbidity at any intake in the watershed should be <1 NTU 95% of the time.***

Table 8. Summary of results of turbidity values (NTU) measured within the Chemainus River watershed. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. Of Samples	Minimum	Maximum	Average	Std Dev	Summer Average	Winter average
E285670	Chemainus R. @ Meade Ck.	16	< 0.1	0.31	0.15	0.08	0.14	0.16
E283336	Chemainus R. @ Copper Canyon	19	0.1	0.76	0.22	0.17	0.14	0.27
E283509	Chemainus R. @ Provincial Park	19	0.1	1.02	0.28	0.20	0.25	0.30
E283570	Chemainus R. @ Grace Road	19	0.1	1.07	0.32	0.24	0.28	0.35
0120780	Chemainus R. @ Hwy 1	23	0.14	5.04	0.56	1.01	0.25	0.72
E285671	Chipman Ck. U/S from Chemainus R	18	0.1	0.78	0.20	0.17	0.16	0.23
E283338	Banon Ck. U/S from Chemainus R.	17	0.1	1.1	0.36	0.33	0.65	0.21

6.5 TOTAL SUSPENDED SOLIDS

Total suspended solids (TSS), or non-filterable residue (NFR), include all of the undissolved particulate matter in a sample. TSSshould be closely correlated with turbidity; however, unlike turbidity, it is not measured by optics. Instead, a quantity of the sample is filtered, and the residue is dried and weighed so that a weight of residue per volume is determined. No guideline has been established for drinking water sources at this time. For the protection of aquatic life, the maximum concentration allowed is an induced TSS concentration over background of 25 mg/L at any one time in 24 hours when background is less than or equal to 25 mg/L (clear flows) and an induced TSS concentration of 5 mg/L over background concentrations at any one time for a duration of 30 days (clear flows). Initially, less frequent monitoring may be appropriate to determine the need for more extensive monitoring (Caux *et al.*, 1997).

Concentrations of TSS at all sites ranged from below detection limits (< 1 mg/L) for most samples (ranging from 63% of samples at the Highway 1 site to 95% of samples at the Grace Road site) to a maximum of 49 mg/L (at the Highway 1 site) (Table 9). TSS values were consistently low with elevated levels (> 10 mg/L) only occurring twice, both at the Highway 1 site, and both during the month of January (January 4, 1987 and January 12, 1989). Only one sample (the maximum value measured at the Highway 1 site, 49 mg/L) had a TSS concentration exceeding the 25 mg/L guideline. Average TSS concentrations were similar at most of the sites, increasing slightly at the Highway 1 site.

To determine average background values relative to impacted sites, a minimum of five weekly samples within 30 days were collected on two occasions (once for summer and once for fall) in 2011 (Table 9) . Average background summer TSS levels for both summer and winter were 1 mg/L at Meade Creek FSR site. Using these background values, BC Water Quality Guidelines for aquatic life in the watershed would specify a maximum of 26 mg/L (25 mg/L over background) at any one time in 24 hours, and of maximum of 6 mg/L (5 mg/L over background) at any one time for a duration 30 days. Average background TSS in the nearby Cowichan and Koksilah rivers was slightly higher at 2 mg/L in the summer and 3 mg/L in the fall (Obee and Epps, 2011).

Table 9. Summary of results of TSS analyses (mg/L) within the Chemainus River watershed. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. of Samples	No. of samples below detection limit (< 1 mg/L)	Min	Max	Avg	Std Dev	2011 Summer 5 in 30 Average	2011 Winter 5 in 30 average
E285670	Chemainus R. @ Meade Ck.	16	15	< 1	1	1.0	0.0	< 1	< 1
E283336	Chemainus R. @ Copper Canyon	19	16	< 1	10	1.5	2.1	< 1	< 1
E283509	Chemainus R. @ Provincial Park	19	17	< 1	3	1.2	0.5	1.4	< 1
E283570	Chemainus R. @ Grace Road	19	18	< 1	4.1	1.2	0.7	< 1	< 1
0120780	Chemainus R. @ Hwy 1	38	24	1	49	3.0	8.1	< 1	< 1
E285671	Chipman Ck. U/S from Chemainus R/	18	17	< 1	1.6	1.0	0.1	< 1	< 1
E283338	Banon Ck. U/S from Chemainus R.	18	16	< 1	1	1.0	0.0	1	< 1

In general, TSS concentrations showed trends similar to those shown by turbidity, with increases occurring in a downstream direction, generally after a rainfall event. As with turbidity, concentrations of TSS tended to be lowest in the upper watershed, and increased slightly at the Highway 1 site. While uncommon, it is evident that elevated concentrations of TSS can occasionally occur in the lower Chemainus River watershed, and for this reason a water quality objective for TSS is proposed that is slightly more conservative than the nearby Cowichan and Koksilah rivers. The objective is meant to apply to situations that are not natural and may have been triggered by human activities (agriculture, timber harvesting or urban runoff). ***It is recommended that TSS in the Chemainus River watershed (including Chipman and Banon creeks) should not exceed 26 mg/L (25 mg/L above clear flow background levels as measured in the Chemainus River at Meade Creek) at any time and the mean of five samples in 30-days should not exceed 6 mg/L (5 mg/L above clear flow background levels as measured in the Chemainus River at Meade Creek).*** Means of five weekly samples in 30 days were chosen (rather than maximum values of 30 samples in a 30 day period, as recommended in the guideline) considering the resources available for monitoring, as well as local hydrology and the fact that Vancouver Island streams have clear flows for most of the year.

6.6 COLOUR AND TOTAL ORGANIC CARBON

Colour in water is caused by dissolved and particulate organic and inorganic matter. True colour is a measure of the dissolved colour in water after the particulate matter has been removed, while apparent colour is a measure of the dissolved and particulate matter in water. Colour can affect the aesthetic acceptability of drinking water, and the aesthetic water quality guideline is a maximum of 15 true colour units (TCU) (Moore and Caux, 1997). Colour is also an indicator of the amount of organic matter in water. When organic matter is chlorinated it can produce disinfection by-products (DBPs) such as trihalomethanes, which may pose a risk to human health.

Colour was measured once at three of the Chemainus River sites (E283336, E283509, E283570) and three times at the Highway 1 site (0120780). Colour was below detection limits (< 5 TCU) in all samples collected except one sample from the Highway 1 site that measured 10 TCU. The data are insufficient to make a definitive determination of whether colour may be a concern at any of the sites, and no true colour data were collected from the neighboring Cowichan and Koksilah river watersheds (Obee and Epps, 2011) for comparison. Therefore no objective is proposed for true colour in the Chemainus River watershed at this time. We recommend including true colour in future monitoring programs to determine if it is a potential concern.

The total organic carbon (TOC) guideline to protect drinking water is 4.0 mg/L; elevated TOC can result in higher levels of DBPs in finished drinking water if chlorination is used to disinfect the water (Moore, 1998). As the Town of Ladysmith and District of North Cowichan use chlorine to disinfect their drinking water, TOC concentrations should be monitored. Concentrations of TOC ranged from < 0.5 mg/L at the Meade Creek FSR and Provincial Park sites to 3.4 mg/L at the Banon Creek site (Table 10). None of the samples had TOC concentrations exceeding the guideline. Median TOC values tended to increase in a downstream direction. TOC was not measured in the neighboring Cowichan and Koksilah river watersheds, so no comparison can be made (Obee and Epps, 2011). It does not appear that TOC concentrations are a concern in the Chemainus River watershed, and no objective is proposed for TOC at this time.

Table 10. Summary TOC concentrations (mg/L) within the Chemainus River watershed. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	n	Min	Max	Median	90th percentile	Jun-Sep median	Oct-May median
E285670	Chemainus R. @ Meade Ck.	10	< 0.5	1.4	0.9	1.3	0.9 (n=4)	1.0 (n=6)
E283336	Chemainus R. @ Copper Canyon	12	0.7	2.1	1.0	2.0	0.8 (n=4)	1.0 (n=8)
E283509	Chemainus R. @ Provincial Park	12	< 0.5	1.5	1.2	1.5	1.2 (n=5)	1.1 (n=7)
E283570	Chemainus R. @ Grace Road	13	0.6	1.9	1.1	1.7	0.9 (n=5)	1.3 (n=8)
0120780	Chemainus R. @ Hwy 1	16	0.5	2.2	1.4	2.1	1.3 (n=4)	1.5 (n=12)
E285671	Chipman Ck. U/S from Chemainus R	12	0.5	1.8	1.0	1.7	0.8 (n=4)	1.4 (n=8)
E283338	Banon Ck. U/S from Chemainus R.	12	1.6	3.4	2.4	3.4	2.0 (n=4)	2.6 (n=8)

6.7 NUTRIENTS (NITRATE, NITRITE AND PHOSPHORUS)

Nitrogen (including nitrate and nitrite) and phosphorus are important parameters, since they tend to be the limiting nutrients in biological systems. Productivity is therefore directly proportional to the availability of these parameters. Nitrogen is usually the limiting nutrient in terrestrial systems, while phosphorus tends to be the limiting factor in freshwater aquatic systems. In watersheds where drinking water is a priority, it is desirable that nutrient levels in surface water remain low to avoid algal blooms and foul tasting water. Similarly, to protect aquatic life, nutrient levels should not be too high or the resulting plant and algal growth can deplete oxygen levels when it dies and begins to decompose, as well as during periods of low productivity when plants consume oxygen (*i.e.*, at night and during the winter under ice cover).

The guideline for the maximum concentration for nitrate in drinking water is 10 mg/L as nitrogen and the guideline for nitrite is a maximum of 1 mg/L as nitrogen. When both nitrate and nitrite are present, their combined concentration must not exceed 10 mg/L as N. For the protection of freshwater aquatic life, the nitrate guidelines are a maximum concentration of 32.8 mg/L and an average concentration of 3.0 mg/L (Meays, 2009). Nitrite concentrations are dependent on chloride; in low chloride waters (*i.e.*, less than 2 mg/L) the maximum concentration of nitrite is 0.06 mg/L and the average concentration is 0.02 mg/L. Allowable concentrations of nitrite increase with ambient concentrations of chloride (Nordin and Pommen, 1986).

Nitrogen concentrations were measured once at three of the Chemainus River sites and five to six times at the Highway 1 site, in terms of dissolved nitrite (NO_2) and dissolved nitrate (NO_3). Total nitrate concentrations ranged from 0.0081 mg/L as N to a maximum of 0.185 mg/L (both at the Highway 1 site), while dissolved nitrite concentrations were consistently below detection limits (<0.002 mg/L as N) at all of the sites. All values of both nitrate and nitrite species were well below the existing aquatic life guidelines, and therefore no guidelines are recommended.

The BC MOE has developed a phosphorus objective for Vancouver Island. This objective takes into consideration the fact that elevated phosphorus is primarily a concern during the summer low flow period when elevated nutrient levels are most likely to lead to deterioration in aquatic life habitat and aesthetic problems. The total phosphorus objective applies from May to September and is an average of 0.005 mg/L and a maximum of 0.010 mg/L, based on a minimum of five monthly samples (BCMOE, *in press*).

Summary statistics for all total phosphorus data are listed in Appendix I. In 2011, samples were collected each month from May to September (the primary growing season, when phosphorus uptake should be at its highest in-stream) (Table 11). In 1988 and 1989 several values were available from the months of May to September (1988 average: 0.004 mg/L (n=5); 1989 average: 0.003 mg/L (n=3)) but not every month was represented in each year. These data cannot be directly compared to the average objective but suggest that 2011 May to September levels of total phosphorous are similar to 1988-1989 levels . May to September average total phosphorous in 2011 was 0.003 mg/L at all of the sites except

Banon Creek, which had summer average of 0.010 mg/L. The maximum values at nearly all Chemainus watershed sites was 0.006 mg/L, well below the maximum objective of 0.010 mg/L The only exception to this was in Banon Creek where one sample on August 23, 2011 had a value of 0.010 mg/L, and another sample on August 29, 2011 had a very high value of 0.051 mg/L, that skewed the Banon Creek May to September average (removing this value results in a May to September average of 0.004 mg/L). The origin of this very high value is uncertain but appeared to be associated with slightly increased turbidity, which may have been a result of low flows and difficulty filling the sample bottle without disturbing sediment. Ambient growing season average total phosphorous in the neighboring Cowichan and Koksilah rivers was similar to the ambient Chemainus River at Meade site at 0.004 mg/L with a maximum ambient growing season value of 0.008 mg/L (Obee and Epps, 2011).

Table 11. Summary of results of total phosphorus analyses (mg/L) within the Chemainus River watershed. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	2011 May - Sept Average	# of 1986 – 2011 May-Sept max values higher than 0.010 mg/L
E285670	Chemainus R. @ Meade Ck.	0.003 (n=8)	0 (n=8)
E283336	Chemainus R. @ Copper Canyon	0.003 (n=9)	0 (n=9)
E283509	Chemainus R. @ Provincial Park	0.003 (n=9)	0 (n=9)
E283570	Chemainus R. @ Grace Road	0.003 (n=9)	0 (n=9)
0120780	Chemainus R. @ Hwy 1	0.003 (n=9)	0 (n=17)
E285671	Chipman Ck. U/S from Chemainus R	0.003 (n=8)	0 (n=8)
E283338	Banon Ck. U/S from Chemainus R.	0.010 (n=8)	1 (n=8)

These occasional elevated concentrations of total phosphorus at Banon Creek may not be cause for concern if potentially associated with sampling protocol, but sampling needs to continue to determine what the situation may be in Banon Creek. As increased phosphorous can result in increased algal productivity that can impact fish populations and decrease recreational values, and the land uses occurring in the Chemainus watershed can contribute to phosphorous loadings in the watershed, a water quality objective is proposed that is the same as that in Cowichan and Koksilah rivers. ***It is recommended that the May through September (based on a minimum of five monthly samples)***

average total phosphorous at any location in Chemainus River (including Chipman and Banon creeks) should not exceed 0.005 mg/L (5 µg/L) and maximum values should not exceed 0.010 mg/L (10 µg/L).

Chlorophyll *a* concentrations were measured on one occasion at each of the four downstream sites on the Chemainus River, in mid-September 2010. In streams (as opposed to lakes), concentrations of chlorophyll *a* rather than total phosphorus are used as a guideline, as a number of factors (including water velocity, substrate, light, temperature and grazing pressures) determine when phosphorus becomes a limiting factor (Nordin, 1985). The recreational guideline for chlorophyll *a* is 50m mg/m^2, and the guideline for aquatic life is 100 mg/m^2. Table 12 summarizes the concentration of total chlorophyll *a* measured at each of the sites. All average values (calculated from three replicates at the same site collected at the same time) were within guideline levels. Concentrations of chlorophyll *a* were moderate at the Copper Canyon site, dropped considerably at both the Provincial Park and Grace Road sites, and then increased to its maximum value at the Highway 1 site. The cause for the higher concentrations of chlorophyll *a* measured at the Copper Canyon site compared with the Provincial Park and Grace Road sites is not clear, as total phosphorus concentrations were similar between those three sites. However, it is likely that one of the other conditions mentioned above for growth was not met to the same extent at the Provincial Park and Grace Road sites.

Table 12. Summary of results of total chlorophyll a (mg/m^2) analyses within the Chemainus River watershed.

	Chemainus R. @ Copper Canyon	Chemainus R. @ Provincial Park	Chemainus R. @ Grace Road	Chemainus R. @ Hwy 1
Sample 1	19	2.1	1.6	84.7
Sample 2	34	5.6	5.6	6.25
Sample 3	9.0	4.4	1.9	14.2
Average	**20.7**	**4.0**	**3.0**	**35.1**

In the neighboring Cowichan River, the average chlorophyll *a* concentration upstream of sewage treatment plant discharges was 2.7 mg/m^2. This, at times, increased to levels above the recommended recreational guideline in the lower watershed. For this reason, an objective (5 µg/cm^2, or 50 mg/m^2) was proposed for the Cowichan and Koksilah watersheds (Obee and Epps, 2011). As chlorophyll *a* concentrations remained within guideline levels in the Chemainus watershed, and because the objective proposed for total phosphorus should protect from elevated chlorophyll *a* concentrations, no objective is recommended for chlorophyll *a* at this time.

6.8 METALS

Increasing water hardness can decrease the toxicity of copper and some other metals to some organisms, hardness values are an important component water quality guidelines for certain metals. Hardness values in the Chemainus River were relatively consistent throughout the watershed. However, this observation was based on relatively few values: Chemainus River at Meade (one value of 16 mg/L), Chemainus River at Copper Canyon (average 21 mg/L (n=2)) , Chemainus River at Provincial Park (one value of 16 mg/L), Chemainus River at Grace Road (one value of 17 mg), Chemainus River at Highway 1 (average 15 mg/L (n=9)), Chipman Creek (one value of 16 mg/L), Banon Creek (one value of 10 mg/L). It is important to understand site specific hardness as it can be influenced by anthropogenic factors in the watershed. A water hardness of 16 mg/L, based on background conditions (Chemainus River at Meade) was used to calculate metal concentrations relative to water quality guidelines.

Total and dissolved metals concentrations were measured two to three times at each of the upper sites, the tributaries and at the Highway 1 site in 2011-12, and 40 additional occasions at the Highway 1 site between 1986 and 2009 (Appendix 1). Metals data collected prior to 1999 at the highway site were generally disregarded for this analysis because detection limits have improved in recent years, and therefore, the accuracy of earlier analyses cannot reasonably be compared with recent data. Most metals concentrations were below detection limits, and well below guidelines for drinking water and aquatic life. However, three metals (total cadmium, total copper and total zinc) either exceeded their respective guidelines, or were found at high enough concentrations to warrant further discussion.

The maximum concentration for total cadmium measured at the Highway 1 site between 1999 and 2011 was 0.06 µg/L (collected on February 17, 1999). If concentrations were to remain at these levels there may be a potential to exceed the aquatic life working water quality guideline (average 0.007 µg/L at a hardness of 16 mg/L), but the detection limit used at that time was only <0.01 µg/L, and a detection limit of no more than 1/10th the guideline is recommended in order to properly assess compliance. For samples collected in 2011-12, the detection limit decreased to < 0.005 µg/L, and the maximum concentration of total cadmium measured at that time was 0.013 µg/L. Though insufficient samples were collected to compare to the average guideline, if values were to remain at these levels, cadmium could be a concern in the lower watershed. In the neighboring Cowichan and Koksilah rivers, ambient total cadmium occasionally exceeded the aquatic life working water quality guideline in the lower watersheds (data within 10% of minimum detection limits and therefore interpreted with caution) (Obee and Epps, 2011).

Two samples at the Highway 1 site had total copper concentrations exceeding the maximum guideline of 3.5 µg/L (at a hardness of 16 mg/L) (4.7 µg/L and 8 µg/L, both collected on February 17, 1999). However, more recent sampling (from 2000-2011, when a lower detection limit was used for the analyses), showed a maximum of only 0.82 µg/L for the five samples collected. Total copper in the neighbouring Cowichan and Koksilah rivers (at a hardness of 20 mg/L) occasionally exceeded both the average guideline of 2 µg/L and maximum of 4 µg/L (up to a maximum of 7.13 µg/L) (Obee and Epps, 2011).

There were no exceedences of maximum zinc guidelines, however at the Highway 1 site, there were 12 values (ranging from 8.0 – 17.0 µg/L) between 1986 and 1999 that showed the potential for average guidelines for aquatic life of 7.5 µg/L to be exceeded (at a hardness of 16 mg/L). As the detection limit used at that time was <5.0 µg/L, and a detection limit of no more than 1/10th the guideline is recommended in order to properly assess compliance, these values were considered with caution. For samples collected in 2011-12, the detection limit decreased to <0.1 µg/L, and the maximum concentration of total zinc measured at that time was 1.8 µg/L. In the neighboring Cowichan and Koksilah river watersheds, objectives have been established for zinc due to occasional exceedances (Obee and Epps, 2011).

Table 13 provides a summary of average total cadmium, copper and zinc concentrations at the five Chemainus Creek sites for 2011. Even when disregarding pre-1999 data (due to the higher detection limits used for those analyses), the averages for all metals measured between 1999 and 2011 were higher than those measured in 2011 alone. This may be due to the larger sample size capturing elevated levels that were otherwise missed (*e.g*,. there was very little rainfall during the fall flush sampling period in 2011, and only two samples at each site were collected in 2011), but may also be due to a refinement in laboratory analytical methods and therefore the more recent data may be more accurate. This issue made a seasonal comparison of the Chemainus at Hwy 1 site (Table 13) challenging to interpret; however, it appeared that higher metal values occurred during the winter months associated with rainfall events.

The natural geology of the Chemainus Creek watershed (evidenced by several metal prospects) and the existence of old metal mine sites could contribute to increased metal concentrations in the watershed. As well, increased metals from rainwater runoff from roadways and developed areas could occur in the lower watershed. Therefore, just as in the neighboring Cowichan and Koksilah rivers, continued monitoring for metals is recommended, and provisional objectives are proposed for total copper and total zinc. A provisional cadmium objective is also proposed based on the slightly elevated concentrations in the lower watershed compared to upstream sites.

The proposed water quality objectives for Cd, Cu, and Zn are provisional until more data is collected to determine if they are a concern. *Provisional water quality objectives* are proposed when there is evidence that a substance is a concern but not sufficient information to support a water quality objective. Future metals monitoring should include five weekly samples in 30 days (during rainfall events) to enable comparison to average water quality guidelines. Lead, for which an objective was proposed in Cowichan and Koksilah rivers (Obee and Epps, 2011), was not a concern in the Chemainus River watershed. An updated water quality guideline for Cd is currently underway; this will be applied to future monitoring and assessments of Cd in the Chemainus Creek Watershed.

Table 13. Average total cadmium, copper and zinc (µg/L) at various Chemainus River monitoring sites (based on two samples) collected in 2011 (except where noted). Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	Cd - T	Cu - T	Zn - T
E285670	Chemainus at Meade Creek	0.006	0.39	0.6
E283336	Chemainus at Copper Canyon	<0.005	0.37	0.13
E283509	Chemainus at Park	<0.005	0.67	0.6
E283570	Chemainus at Grace Road	0.007	0.55	1.4
0120780	Chemainus at Hwy 1: 1999-2011	0.025	2.29	7.2
0120780	Chemainus at Hwy 1: 2011	0.011	0.675	1.35
0120780	Chemainus at Hwy1 1999-2011: Summer (June - Sept)	0.014	0.75	6.66
0120780	Chemainus at Hwy1 1999-2011: Winter (Oct - May)	0.030	2.81	10.43
E285671	Chipman Ck u/s Chemainus River	0.005	0.36	0.2
E283338	Banon Cd u/s Chemainus River	<0.005	0.53	0.2

Provisional: Average total cadmium concentrations should not exceed 0.007 µg/L. This is based on the equation *10 exp (0.86[log{hardness}]-3.2)* where hardness is reported as mg/L $CaCO_3$ and was 16 mg/L at Chemainus River at Meade (background). Ideally, detection limits that are no more than 10% of the working guideline level should be used to ensure accuracy, which in this case would mean using an analytical method with a detection limit of 0.001 µg/L for total cadmium. Currently detection limits of only 0.005 µg/L are available. The BC aquatic life water quality guideline for cadmium is will be updated in 2015; future monitoring and assessments will apply the most up-to-date guideline.

Provisional: Maximum total copper concentrations should not exceed 3.5 µg/L, and average concentrations (based on a minimum of five weekly samples collected within a 30-day period) should not exceed 2 µg/L. Maximum concentration is based on the equation *0.094(hardness)+2* where hardness is reported as mg/L $CaCO_3$ and was 16 mg/L at Chemainus River at Meade (background).

Provisional: Maximum concentrations of total zinc should not exceed 33 µg/L in any single sample, and the average of at least five weekly samples collected in a 30-day

period should not exceed 7.5 µg/L. Maximum concentration is based on the equation *33 + 0.75 x (hardness -90)* where hardness is reported as mg/L $CaCO_3$ and was 16 mg/L at Chemainus River at Meade (background).

Metal speciation determines the biologically available portion of the total metal concentration. Only a portion of the total metals level is in a form which can be toxic to aquatic life. Naturally occurring organics in the watershed can bind substantial proportions of the metals which are present, forming metal complexes that are not biologically available. The relationship will vary seasonally, depending upon the metal under consideration (*e.g.*, copper has the highest affinity for binding sites in humic materials). Levels of organics as measured by dissolved organic carbon (DOC) vary from ecoregion to ecoregion. To aid in future development of metals objectives, DOC has been included in the Chemainus River monitoring program. As increasing water hardness can decrease the toxicity of copper and some other metals to some organisms, hardness has also been included in the Chemainus River monitoring program.

Comment [KJR1]: How would you use DOC in deriving WQOs?

6.9 MICROBIOLOGICAL INDICATORS

Fecal contamination of surface waters used for drinking and recreating can result in high risks to human health from pathogenic microbiological organisms as well as significant economic losses due to closure of beaches (Scott *et al*., 2002). The direct measurement and monitoring of pathogens in water, however, is difficult due to their low numbers, intermittent and generally unpredictable occurrence, and specific growth requirements (Krewski *et al*., 2004; Ishii and Sadowsky, 2008). To assess risk of microbiological contamination from fecal matter, resource managers commonly measure fecal indicator bacteria levels (Field and Samadpour, 2007; Ishii and Sadowsky, 2008). The most commonly used indicator organisms for assessing the microbiological quality of water are the total coliforms, fecal coliforms (a subgroup of the total coliforms more appropriately termed thermotolerant coliforms as they can grow at elevated temperatures), and *E. coli* (a thermotolerant coliform considered to be specifically of fecal origin) (Yates, 2007).

There are a number of characteristics that suitable indicator organisms should possess. They should be present in the intestinal tracts of warm-blooded animals, not multiply outside the animal host, be nonpathogenic, and have similar survival characteristics to the pathogens of concern. They should also be strongly associated with the presence of pathogenic microorganisms, be present only in contaminated samples, and be detection and quantifiable by easy, rapid, and inexpensive methods (Scott *et al*., 2002; Field and Samadpour, 2007; Ishii and Sadowsky, 2008).

Total and fecal coliforms have traditionally been used in the assessment of water for domestic and recreational uses. However, research in recent years has shown that there are many differences between the coliforms and the pathogenic microorganisms they are a surrogate for, which limits the use of coliforms as an indicator of fecal contamination (Scott *et al*., 2002). For example, many pathogens, such as enteric viruses and parasites, are not as easily inactivated by water and wastewater treatment processes as coliforms are. As a result, disease outbreaks do occur when indicator bacteria counts are at acceptable levels (Yates, 2007; Haack *et al*., 2009). Additionally, some members of the coliform group, such as *Klebsiella*, can originate from non-fecal sources (Ishii and Sadowsky, 2008) adding a level of uncertainty when analyzing data. Waters contaminated with human feces are generally regarded as a greater risk to human health, as they are more likely to contain human-specific enteric pathogens (Scott *et al*., 2002). Measurement of total and fecal coliforms does not indicate the source of contamination, which can make the actual risk to human health uncertain; thus, it is not always clear where to direct management efforts.

The BC-approved water quality guidelines for microbiological indicators were developed in 1988 (Warrington, 2001) and include *E. coli*, enterococci, *Pseudomonas aeruginosa*, and fecal coliforms. The monitoring programs of the BC MOE have traditionally measured total coliforms, fecal coliforms, *E. coli* and enterococci, either alone or in combination, depending on the specific program. As small pieces of fecal matter in a sample can skew the overall results for a particular site, the 90th percentiles (for drinking water) and geometric means (for recreation) are generally used to determine if the water quality guideline is exceeded, as extreme values would have less effect on the data. The BC MOE drinking water guideline for raw waters receiving disinfection only is that the

90th percentile of at least five weekly samples collected in a 30-day period should not exceed 10 CFU/100 mL for either fecal coliforms or *E. coli* (Warrington, 2001).

To represent the worst case scenario, bacteriological samples were only collected during summer low flow and fall flush periods. *E. coli* concentrations were measured twelve times at the Meade Creek FSR site, and fourteen times at the other sites. *E. coli* concentrations were highest on average at the Highway 1 site, followed by the Banon Creek and Copper Canyon sites, and very low at both the Meade Creek FSR and Chipman Creek sites (Table 14). In those instances when at least five samples were collected within a 30-day period, a 90th percentile value was calculated, and these are summarized in Table 14. The requisite sampling frequency was met twice at all of the sites and only in 2011. Concentrations of *E. coli* measured during the winter months were consistently below the guideline levels for drinking water at all of the sites, but all of the sites (except the Meade Creek FSR site) had 90th percentiles exceeding the guideline during the summer months.

Table 14. Summary of results of *E. coli* analyses (CFU/100 mL) within the Chemainus watershed. Sites are listed upstream to downstream and tributaries in the order they enter the Chemainus River mainstem.

EMS ID	Site Name	No. Of Samples	Minimum	Maximum	2011 Summer 90th %ile	2011 Winter 90th %ile
E285670	Chemainus R. @ Meade Ck.	12	< 1	13	8.2	3.8
E283336	Chemainus R. @ Copper Canyon	14	< 1	170	111.6	8.6
E283509	Chemainus R. @ Provincial Park	14	< 1	78	50.4	6.8
E283570	Chemainus R. @ Grace Road	14	1	110	20	7.6
0120780	Chemainus R. @ Hwy 1	14	< 1	280	61	9.6
E285671	Chipman Ck. U/S from Chemainus R	14	1	19	12.6	1
E283338	Banon Ck. U/S from Chemainus R.	14	< 1	140	124	3.2

The source of the coliforms is unknown, but since higher levels are occurring at the Copper Canyon site (which is upstream from any residential or commercial development), the source of these coliforms may be due to a large extent to natural wildlife. Naturally elevated concentrations of coliforms are not uncommon in Vancouver Island watersheds: for example, in the untouched watershed of McKelvie Creek, an objective of 60 CFU/100 ml (90^{th} percentile for 5 samples in 30 days) was recommended to reflect natural variability within the watershed (Epps and Phippen, 2007). Regardless of their origin, these coliforms are of concern, as values were high during the summer months.

In the neighboring Cowichan and Koksilah rivers the provincial drinking water guideline for *E. coli* was exceeded at all sites and in nearly all sampling periods. Even the background site in the Cowichan River appeared to be affected by land and water uses occurring in Cowichan Lake upstream of the sampling location. Therefore, the objective recommended for *E. coli* in those watersheds was the same as the provincial drinking water guideline (Obee and Epps, 2011). Using the ecoregion approach, the Chemainus River at Meade Creek site, which was below the provincial drinking water guideline for *E. coli* for the sample period considered, may be considered background bacteriological levels for the Cowichan River.

In the Chemainus River, results for fecal coliforms and *E. coli* were not consistently similar (fecal coliform results in Appendix I). Studies have shown that *E. coli*, a component of the fecal coliforms group, is the main thermo-tolerant coliform species present in human and animal fecal samples (94%) (Tallon *et al*., 2005) and at contaminated bathing beaches (80%) (Davis *et al*., 2005). In those instances where fecal coliform concentrations were higher than those of *E. coli*, we can assume a high likelihood of contributions from non-fecal sources. Thus, the benefit of measuring both groups is limited. Given the uncertainty in linking thermotolerant (*i.e.*,fecal) coliforms to human sources of sewage, we recommend using *E. coli* as the microbiological indicator for the Chemainus River.

For the reasons given above, ***water quality objectives are recommended for* E. coli *in the Chemainus River watershed. It is* recommended *that the 90^{th} percentile of a minimum of 5 weekly samples collected within a 30-day period must not exceed 10 CFU/100 mL***

***for* E. coli.** Meeting these objectives will provide protection from most pathogens but not from parasites such as *Cryptosporidium* or *Giardia*. Sampling for these pathogens falls under the auspices of the water purveyor, in this case the District of North Cowichan and the Town of Ladysmith.

6.10 BIOLOGICAL MONITORING

Objectives development has traditionally focused on physical, chemical and bacteriological parameters. However, as aquatic life is typically the most sensitive use of a water body, the inclusion of biological data into the overall objective development program is crucial. In partnership with Canada's national biomonitoring program (Canadian Aquatic Biomonitoring Network (CABIN)), benthic macroinvertebrates have been collected from British Columbia streams for bioassessment purposes for many years. Using this information, biological objectives have been developed for Vancouver Island as outlined in Gaber (2013). The biological objective development process is summarized in the following paragraph:

Using a network of 102 minimally impacted (reference) streams on Vancouver Island and Gwaii Haanas National Park, ecologically-based numerical benchmarks were created by calculating the similarity of the benthic macroinvertebrate community of these sites to each other using the Bray-Curtis Coefficient (BCC). BCC is an ecological distance metric with values of 0 representing complete difference from the reference community and values of 100 representing a community identical to the reference community. By measuring the similarity of a test site to the 102 reference sites, its BCC score can be calculated, indicating its position relative to the ecological benchmarks. These ecological benchmarks were set as the 1^{st}, 10^{th}, and 20^{th} percentiles (a score of 15.2, 23.8, and 27.3, respectively) of the distribution of BCC scores for the 102 reference streams. The 20^{th} percentile score is recommended as the biological objective for Vancouver Island (*i.e.*, a stream must have a score of 27.3or greater to meet the objective), with values between the 20^{th} and the 10^{th} percentile score indicating further investigation required, and values between the 10^{th} and the 1^{st} percentile score indicating that activities adversely affecting stream conditions should cease. It is also recommended that, when a test sites BCC score does not meet the Vancouver Island biological objective, year over year scores should be increasing, indicating an improvement in the condition of that stream (Gaber, 2013). BCC scores for benthic invertebrate samples collected in the Chemainus River watershed in September 2010, and their interpretation regarding invertebrate community health, are summarized in Table 15 and Figure 7.

Table 15. Summary of Bray-Curtis Coefficient calculated for Chemainus River watershed monitoring sites for benthic invertebrate samples collected in 2010.

Site	Bray-Curtis Coefficient	Conclusion
Chemainus River @ Copper Canyon	18.39	Activities should cease
Chemainus River @ Provincial Park	34.35	Meets objective
Chemainus River @ Grace Rd	39.02	Meets objective
Chemainus River @ Hwy 1	38.64	Meets objective
Banon Ck @ Chemainus R.	29.68	Meets objective

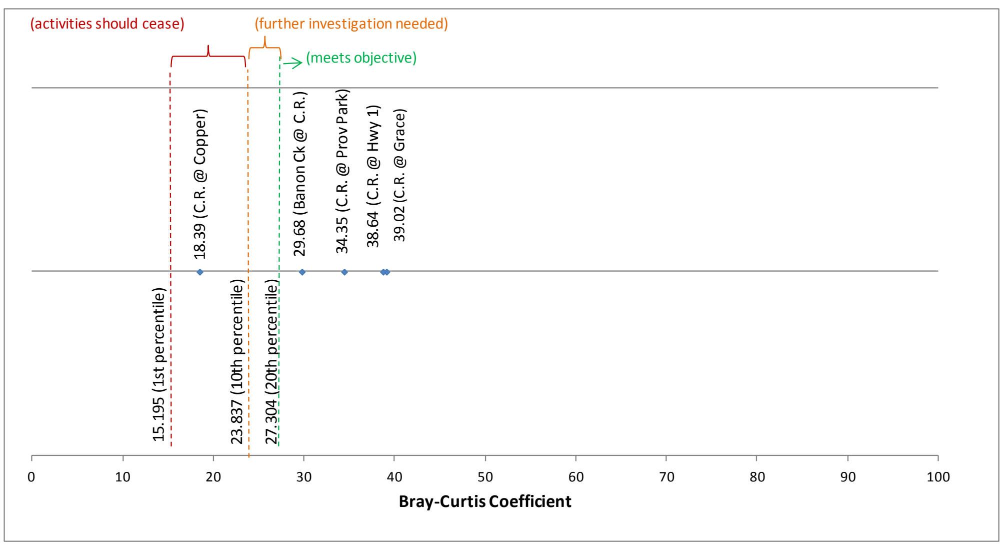

Figure 7. Summary of Bray-Curtis Coefficient calculated for five Chemainus River watershed monitoring sites for benthic invertebrate samples collected in 2010.

All BCC scores met the objective, with the exception of Chemainus River @ Copper Canyon results. This is surprising considering this location generally showed good water quality; however, this section of the river consisted of very large boulders that were very hard to sample, possibly underestimating organisms present at the site and potentially skewing the results negatively. This site was resampled at multiple stations along the reach in 2012 to re-assess BCC scores, but data were not yet available at the time of preparation of this report. As scores for most sites meet the Vancouver Island objective, and sampling challenges influenced results from the Copper Canyon site, no biological objective is proposed for the Chemainus River at this time. Benthic invertebrate sampling should continue at all Chemainus River sites to better understand what may be influencing the scores observed from the 2010 data.

7.0 MONITORING RECOMMENDATIONS

Attainment monitoring should occur at all six of the water quality monitoring sites. This will ensure water quality is protected throughout the watershed and help determine the source of exceedances, should they occur. If funding for future monitoring is restricted, consideration could be made to reduce or eliminate monitoring at the Chemainus River at Grace Rd and Chemainus River @ Provincial Park sites, in that order of priority.

In order to capture the periods where water quality concerns are most likely to occur (*i.e.*, freshet and summer low-flow) we recommend that a minimum of five weekly samples be collected within a 30-day period between August and September, as well as between October and November. Samples collected during the winter months should coincide with rain events whenever possible. In this way, the two critical periods (minimum dilution and maximum turbidity), will be monitored. Samples should be analyzed for general water chemistry (including pH, specific conductivity, TSS, turbidity, colour, DOC,TOC and total phosphorous), hardness, total and dissolved metals (low level analysis), as well as bacteriology (*E. coli*). Field measurements of temperature should also be taken. For determination of growing season phosphorous levels, monthly samples between May and September are recommended. Benthic invertebrate monitoring should also occur.

8.0 SUMMARY OF PROPOSED WATER QUALITY OBJECTIVES AND MONITORING SCHEDULE

In BC, water quality objectives are based mainly on approved or working water quality guidelines. These guidelines are established to prevent specified detrimental effects from occurring with respect to a designated water use. Designated water uses for the Chemainus River that are sensitive and should be protected are drinking water, irrigation, primary and secondary contact recreation, aquatic life and wildlife. The water quality objectives recommended here (Table 16) take into account background conditions, impacts from current land use and any known potential future impacts that may arise within the watershed. These objectives should be periodically reviewed and revised to reflect any future improvements or technological advancements in water quality assessment and analysis.

The recommended water quality monitoring program for the Chemainus River watershed is summarized in Table 17. It is recommended that future attainment monitoring occur once every 3-5 years based on staff and funding availability, and whether activities, such as forestry or development, are underway within the watershed.

Table 16. Summary of proposed water quality objectives for the Chemainus River watershed. All objectives apply throughout the watershed unless otherwise specified.

Variable	Objective Value
pH	6.5 – 8.5 pH units
Turbidity	1 NTU max March - September 5 NTU max October – February 95% of samples ≤1 NTU at any intake
Temperature	Short term (< 5 years): 17^{o}C maximum average weekly anywhere in watershed Long term (5 – 10 years): 15^{o}C maximum instantaneous in lower Chemainus River and Bannon Creek
Total Suspended Solids (TSS)	26 mg/L max 6 mg/L average (based on a minimum of five weekly samples collected over a 30-day period)
Total Phosphorus	10 µg/L maximum 5 µg/L average (based on a minimum of monthly samples collected from May – Sept)
Escherichia coli	≤10 CFU/100 mL (90^{th} percentile) (based on a minimum 5 weekly samples collected over a 30-day period)
Total cadmium (provisional)	≤ 0.007 µg/L average
Total copper (provisional)	≤ 3.5 µg/L maximum, ≤ 2 µg/L average (minimum 5 weekly samples collected over a 30-day period)
Total zinc (provisional)	≤ 33 µg/L maximum, ≤ 7.5 µg/L average (minimum 5 weekly samples collected over a 30-day period)

Table 17. Proposed schedule for future water quality monitoring in the Chemainus River

Frequency and timing	Parameters to be measured
August – September (low-flow season): five weekly samples in a 30-day period	Temperature, TSS, turbidity, DOC, TOC, colour, total phosphorous, chlorophyll a, total and dissolved metals, hardness and *E. coli*
November – February (high-flow season): five weekly samples in a 30-day period	Temperature, TSS, turbidity, DOC,TOC, colour, total phosphorous chlorophyll a, total and dissolved metals, hardness and *E. coli*
Monthly from May-September	Total phosphorous
Once every five years in September	Benthic invertebrate sampling

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APPENDIX I. SUMMARY OF WATER QUALITY DATA

Table 18. Summary of general water chemistry for discrete water quality samples collected at Site E285670, Chemainus River at Meade Creek FSR 2011-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Ca-D (mg/L)	5.66	5.66	5.66		1
Carbon Total Organic (mg/L)	< 0.5	1.41	0.94	0.31	10
Ca-T (mg/L)	6.16	6.16	6.16		1
Diss Oxy (mg/L)	8.19	14.46	11.18	1.99	14
E. coli (CFU/100mL)	< 1	13	2.4	3.5	12
Hardness (Dissolved) (mg/L)	16.8	16.8	16.8		1
Hardness Total (T) (mg/L)	18	18	18		1
Mg-D (mg/L)	0.628	0.65	0.64	0.02	2
Mg-T (mg/L)	0.63	0.642	0.64	0.01	2
P--T (mg/L)	< 0.002	0.042	0.005	0.010	16
pH (pH units) -lab	7.25	7.72	7.42	0.14	10
Residue Non-filterable (mg/L)	< 1	1	1		16
Specific Conductance (µS/cm)	44.2	60	53.4	6.2	6
Temp (C)	3	16.3	9.1	5.0	14
Turbidity (NTU)	< 0.1	0.31	0.15	0.08	16
Ag-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ag-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Al-D (mg/L)	0.0101	0.0196	0.0149	0.0067	2
Al-T (mg/L)	0.0231	0.0285	0.0258	0.0038	2
As-D (mg/L)	0.00005	0.00008	0.00007	0.00002	2
As-T (mg/L)	0.00005	0.00007	0.00006	0.00001	2
Ba-D (mg/L)	0.0106	0.0107	0.0107	0.0001	2
Ba-T (mg/L)	0.0108	0.0111	0.0110	0.0002	2
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		2
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-T (mg/L)	< 0.000005	0.000007	0.000006	0.000001	2
Co-D (mg/L)	0.000011	0.000014	0.000013	0.000002	2
Co-T (mg/L)	0.000015	0.000021	0.000018	0.000004	2
Cr-D (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cr-T (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cu-D (mg/L)	0.00024	0.00046	0.00035	0.00016	2

	Minimum	Maximum	Average	Std Dev	No. of samples
Cu-T (mg/L)	0.0003	0.00047	0.00039	0.00012	2
Li-D (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Li-T (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Mn-D (mg/L)	0.00059	0.00073	0.00066	0.00010	2
Mn-T (mg/L)	0.00101	0.0012	0.00111	0.00013	2
Mo-D (mg/L)	0.00008	0.00012	0.00010	0.00003	2
Mo-T (mg/L)	0.00006	0.00008	0.00007	0.00001	2
Ni-D (mg/L)	< 0.00002	0.00005	0.00004	0.00002	2
Ni-T (mg/L)	0.00005	0.00006	0.00006	0.00001	2
Pb-D (mg/L)	0.000009	0.000014	0.000012	0.000004	2
Pb-T (mg/L)	< 0.000005	0.000012	0.000009	0.000005	2
Sb-D (mg/L)	< 0.00002	< 0.00002	< 0.00002		2
Sb-T (mg/L)	< 0.00002	< 0.00002	< 0.00002		2
Se-D (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Sn-D (mg/L)	< 0.00001	0.00005	0.00003	0.00003	2
Sn-T (mg/L)	< 0.00001	0.00007	0.00004	0.00004	2
Sr-D (mg/L)	0.0181	0.0198	0.0190	0.0012	2
Sr-T (mg/L)	0.0177	0.0204	0.0191	0.0019	2
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
U--D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
U--T (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
V--D (mg/L)	0.0003	0.0005	0.0004	0.0001	2
V--T (mg/L)	0.0004	0.0004	0.0004	0.0000	2
Zn-D (mg/L)	0.0006	0.0008	0.0007	0.0001	2
Zn-T (mg/L)	< 0.0001	0.0011	0.0006	0.0007	2

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Table 19. Summary of general water chemistry for discrete water quality samples collected at Site E283336, Chemainus River at Copper Canyon, 2010-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Carbon Dissolved Organic (mg/L)	< 0.5	< 0.5	< 0.5		1
Carbon Total Organic (mg/L)	0.7	2.1	1.1	0.5	12
Ca-T (mg/L)	6.41	7.46	6.94	0.74	2
Chlorophyll a (mg/m2)	9.02	34	20.67	12.57	3
Color True (Col.unit)	< 5	< 5	< 5		1
Diss Oxy (mg/L)	8.82	14.88	11.96	2.09	16
E. coli (CFU/100mL)	< 1	170	16.64	44.63	14
Hardness Total (T) (mg/L)	19.1	22.5	20.8	2.4	2
Mg-D (mg/L)	0.689	0.751	0.720	0.044	2
Mg-T (mg/L)	0.658	0.933	0.777	0.141	3
N.Kjel:T (mg/L)	0.09	0.09	0.09		1
Nitrate (NO3) Dissolved (mg/L)	0.0567	0.0567	0.0567		1
Nitrate + Nitrite Diss. (mg/L)	0.0567	0.0567	0.0567		1
Nitrogen - Nitrite Diss. (mg/L)	< 0.002	< 0.002	< 0.002		1
Nitrogen Total (mg/L)	0.147	0.147	0.147		1
NO2+NO3 (mg/L)	0.057	0.057	0.057		1
Ortho-Phosphate Dissolved (mg/L)	0.0013	0.0013	0.0013		1
pH (pH units) -lab	7.18	7.87	7.46	0.22	13
P--T (mg/L)	< 0.002	0.008	0.003	0.002	19
Res:Tot (mg/L)	< 35	< 35	< 35		1
Residue Filterable 1.0u (mg/L)	34	34	34		1
Residue Non-filterable (mg/L)	< 1	10	1.52	2.06	19
Specific Conductance (µS/cm)	60.4	64.6	61.8	1.6	6
Temp (°C)	1.6	16.1	8.0	5.2	16
Turbidity (NTU)	0.1	0.76	0.22	0.17	19
Ag-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ag-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Al-D (mg/L)	0.0091	0.0188	0.0140	0.0069	2
Al-T (mg/L)	0.0103	0.0258	0.0158	0.0087	3
As-D (mg/L)	0.00004	0.00014	0.00009	0.00007	2
As-T (mg/L)	0.00004	0.000156	0.00011	0.00006	3
Ba-D (mg/L)	0.00972	0.0103	0.0100	0.0004	2
Ba-T (mg/L)	0.00967	0.0107	0.0103	0.0005	3
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		3
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		3

	Minimum	Maximum	Average	Std Dev	No. of samples
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Cd-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Co-D (mg/L)	0.00001	0.000018	0.000014	0.000006	2
Co-T (mg/L)	0.000015	0.0000183	0.000017	0.000002	3
Cr-D (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cr-T (mg/L)	< 0.0001	< 0.0001	< 0.0001		3
Cu-D (mg/L)	0.0003	0.00042	0.00036	0.00008	2
Cu-T (mg/L)	0.000336	0.00043	0.00037	0.00005	3
Li-D (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Li-T (mg/L)	< 0.0005	< 0.0005	< 0.0005		3
Mn-D (mg/L)	0.00082	0.00144	0.00113	0.00044	2
Mn-T (mg/L)	0.00104	0.00154	0.00126	0.00026	3
Mo-D (mg/L)	0.00008	0.00014	0.00011	0.00004	2
Mo-T (mg/L)	0.00009	0.000108	0.00010	0.00001	3
Ni-D (mg/L)	0.00004	0.0001	0.00007	0.00004	2
Ni-T (mg/L)	0.00004	0.00009	0.00006	0.00003	3
Pb-D (mg/L)	0.000006	0.000007	0.000007	0.000001	2
Pb-T (mg/L)	< 0.000005	0.000012	0.000008	0.000004	3
Sb-D (mg/L)	< 0.00002	0.00002	0.00002	0	2
Sb-T (mg/L)	< 0.00002	0.000026	0.000022	0.00	3
Se-D (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		3
Sn-D (mg/L)	< 0.00001	0.00007	0.00004	0.00004	2
Sn-T (mg/L)	< 0.00001	0.00007	0.00003	0.00003	3
Sr-D (mg/L)	0.0188	0.0229	0.0209	0.0029	2
Sr-T (mg/L)	0.0188	0.0251	0.0222	0.0032	3
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	< 0.000002	< 0.000002	< 0.000002		3
U--D (mg/L)	< 0.000002	0.000004	0.000003	0.000001	2
U--T (mg/L)	< 0.000002	0.000003	0.000003	0.000001	3
V--D (mg/L)	0.0003	0.0005	0.0004	0.0001	2
V--T (mg/L)	0.0003	0.00038	0.00033	0.00005	3
Zn-D (mg/L)	0.0004	0.0005	0.0005	0.0001	2
Zn-T (mg/L)	< 0.0001	0.0002	0.0001	0.0001	3

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Table 20. Summary of general water chemistry for discrete water quality samples collected at Site E283509, Chemainus River at Provincial Park, 2010-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Ammonia Dissolved (mg/L)	< 0.005	< 0.005	< 0.005		1
Ca-D (mg/L)	5.31	5.31	5.31		1
Carbon Total Organic (mg/L)	< 0.5	1.5	1.05	0.38	12
Ca-T (mg/L)	6.5	7.16	6.83	0.47	2
Chlorophyll a (mg/m2)	2.1	5.6	4.03	1.78	3
Color True (Col.unit)	< 5	< 5	< 5		1
Diss Oxy (mg/L)	8.32	14.9	11.7	2.35	16
E. coli (CFU/100mL)	< 1	78	9	20	14
Hardness (Dissolved) (mg/L)	16	16	16		1
Hardness Total (T) (mg/L)	19.6	21.6	20.6	1.4	2
Mg-D (mg/L)	0.67	0.768	0.72	0.07	2
Mg-T (mg/L)	0.684	0.9	0.80	0.11	3
N.Kjel:T (mg/L)	0.07	0.07	0.07		1
Nitrate (NO3) Dissolved (mg/L)	0.052	0.052	0.052		1
Nitrate + Nitrite Diss. (mg/L)	0.052	0.052	0.052		1
Nitrogen - Nitrite Diss. (mg/L)	< 0.002	< 0.002	< 0.002		1
Nitrogen Total (mg/L)	0.12	0.12	0.12		1
NO2+NO3 (mg/L)	0.05	0.05	0.05		1
Ortho-Phos Dis. (mg/L)	0.001	0.001	0.00		1
P--T (mg/L)	< 0.002	0.004	0.002	0.001	19
pH (pH units) -lab	7.24	7.6	7.39	0.10	13
Res:Tot (mg/L)	< 29	< 29	< 29		1
Residue Filterable 1.0u (mg/L)	28	28	28		1
Residue Non-filterable (mg/L)	< 1	3	1.2	0.5	19
Specific Conductance (µS/cm)	52	73.1	62.5	6.9	6
Temp (°C)	2	15.9	8.1	5.3	16
Turbidity (NTU)	0.1	1.02	0.28	0.20	19
Ag-D (mg/L)	< 0.000005	0.000011	0.000008	0.000004	2
Ag-T (mg/L)	< 0.000005	0.00002	0.000010	0.000009	3
Al-D (mg/L)	0.009	0.0207	0.015	0.008	2
Al-T (mg/L)	0.0135	0.175	0.072	0.089	3
As-D (mg/L)	0.00008	0.00016	0.00012	0.00006	2
As-T (mg/L)	0.00008	0.00022	0.00014	0.00007	3
Ba-D (mg/L)	0.00885	0.0106	0.00973	0.00124	2
Ba-T (mg/L)	0.00963	0.014	0.01141	0.00229	3
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		3

	Minimum	Maximum	Average	Std Dev	No. of samples
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		3
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Cd-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Co-D (mg/L)	0.000015	0.000022	0.000019	0.000005	2
Co-T (mg/L)	0.000014	0.000189	0.000076	0.000098	3
Cr-D (mg/L)	< 0.0001	0.0002	0.0002	0.0001	2
Cr-T (mg/L)	< 0.0001	0.0002	0.0001	0.0001	3
Cu-D (mg/L)	0.00035	0.00046	0.00041	0.00008	2
Cu-T (mg/L)	0.00044	0.00108	0.00067	0.00035	3
Li-D (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Li-T (mg/L)	< 0.0005	< 0.0005	< 0.0005		3
Mn-D (mg/L)	0.00062	0.00113	0.0009	0.0004	2
Mn-T (mg/L)	0.00117	0.0108	0.0044	0.0055	3
Mo-D (mg/L)	0.0001	0.00012	0.00011	0.00001	2
Mo-T (mg/L)	0.00006	0.00011	0.00009	0.00003	3
Ni-D (mg/L)	0.00005	0.0001	0.00008	0.00004	2
Ni-T (mg/L)	0.00005	0.00027	0.00019	0.00012	3
Pb-D (mg/L)	0.000008	0.000011	0.000010	0.000002	2
Pb-T (mg/L)	< 0.000005	0.0001	0.000037	0.000054	3
Sb-D (mg/L)	< 0.00002	0.00002	0.00002	0	2
Sb-T (mg/L)	< 0.00002	0.00003	0.00002	0.00001	3
Se-D (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Se-T (mg/L)	< 0.00004	0.00007	0.00005	0.00002	3
Sn-D (mg/L)	< 0.00001	0.00002	0.00002	0.00001	2
Sn-T (mg/L)	< 0.00001	0.00004	0.00002	0.00002	3
Sr-D (mg/L)	0.0182	0.0229	0.02	0.00	2
Sr-T (mg/L)	0.0189	0.0253	0.02	0.00	3
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	0.000002	0.000004	0.000003	0.000001	3
U--D (mg/L)	< 0.000002	0.000003	0.000003	0.000001	2
U--T (mg/L)	< 0.000002	0.00001	0.000005	0.000004	3
V--D (mg/L)	0.0003	0.0003	0.0003	0.0000	2
V--T (mg/L)	< 0.0002	0.0008	0.0004	0.0003	3
Zn-D (mg/L)	0.0003	0.0007	0.0005	0.0003	2
Zn-T (mg/L)	< 0.0001	0.0015	0.0006	0.0008	3

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Table 21. Summary of general water chemistry for discrete water quality samples collected at Site E283570, Chemainus River at Grace Road, 2010-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Carbon Total Organic (mg/L)	0.6	1.9	1.18	0.42	13
Chlorophyll a (g/m2)	1.6	5.6	3.03	2.23	3
Color True (Col.unit)	< 5	< 5	< 5		1
Diss Oxy (mg/L)	7.99	14.85	11.67	2.36	16
E. coli (CFU/100mL)	1	110	12.9	29.0	14
Hardness (Dissolved) (mg/L)	17.4	17.4	17.4		1
Hardness Total (T) (mg/L)	22.4	23.1	22.75	0.49	2
N.Kjel:T (mg/L)	0.13	0.13	0.13		1
Nitrate (NO3) Dissolved (mg/L)	0.041	0.041	0.041		1
Nitrate + Nitrite Diss. (mg/L)	0.041	0.041	0.041		1
Nitrogen - Nitrite Diss. (mg/L)	< 0.002	< 0.002	< 0.002		1
Nitrogen Total (mg/L)	0.17	0.17	0.17		1
NO2+NO3 (mg/L)	0.04	0.04	0.04		1
Ortho-Phos Diss. (mg/L)	0.001	0.001	0.001		1
pH (pH units)	7.26	7.69	7.41	0.11	13
P--T (mg/L)	< 0.002	0.017	0.004	0.004	19
Res:Tot (mg/L)	31	31	31		1
Residue Filterable 1.0u (mg/L)	30	30	30		1
Residue Non-filterable (mg/L)	< 1	4.1	1.2	0.7	19
Specific Conductance (µS/cm)	56	74	66	6	6
Temp (°C)	3	17.6	9.1	5.9	16
Turbidity (NTU)	0.1	1.07	0.32	0.24	19
Ag-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ag-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Al-D (mg/L)	0.0124	0.0206	0.0165	0.0058	2
Al-T (mg/L)	0.0129	0.0274	0.0180	0.0081	3
As-D (mg/L)	0.00007	0.00024	0.00016	0.00012	2
As-T (mg/L)	0.00008	0.00019	0.00014	0.00006	3
Ba-D (mg/L)	0.0101	0.0155	0.0128	0.0038	2
Ba-T (mg/L)	0.0105	0.0157	0.0130	0.0026	3
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		3
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		3
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		3
Ca-T (mg/L)	5.74	7.83	7.00	1.11	3

	Minimum	Maximum	Average	Std Dev	No. of samples
Cd-D (mg/L)	0.000007	0.000014	0.000011	0.000005	2
Cd-T (mg/L)	< 0.000005	0.000008	0.000007	0.000002	3
Co-D (mg/L)	0.000013	0.00002	0.000017	0.000005	2
Co-T (mg/L)	0.000012	0.00002	0.000016	0.000004	3
Cr-D (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cr-T (mg/L)	< 0.0001	< 0.0001	< 0.0001		3
Cu-D (mg/L)	0.00045	0.00052	0.00049	0.00005	2
Cu-T (mg/L)	0.00051	0.0006	0.00055	0.00005	3
Li-D (mg/L)	0.0005	0.0005	0.00	0.00	2
Li-T (mg/L)	0.0005	0.0005	0.00	0.00	3
Mg-D (mg/L)	0.74	0.893	0.82	0.11	2
Mg-T (mg/L)	0.711	0.92	0.83	0.11	3
Mn-D (mg/L)	0.00077	0.00092	0.00085	0.00011	2
Mn-T (mg/L)	0.00091	0.00113	0.00099	0.00012	3
Mo-D (mg/L)	0.00007	0.00016	0.00012	0.00006	2
Mo-T (mg/L)	0.00007	0.00016	0.00012	0.00005	3
Ni-D (mg/L)	0.00005	0.00011	0.00008	0.00004	2
Ni-T (mg/L)	0.00003	0.00009	0.00007	0.00003	3
Pb-D (mg/L)	0.000008	0.000014	0.000011	0.000004	2
Pb-T (mg/L)	< 0.000005	0.00001	0.000008	0.000003	3
Sb-D (mg/L)	< 0.00002	0.00003	0.00003	0.00001	2
Sb-T (mg/L)	< 0.00002	0.00003	0.00002	0.00001	3
Se-D (mg/L)	< 0.00004	0.00006	0.00005	0.00001	2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		3
Sn-D (mg/L)	< 0.00001	0.00001	0.00001		2
Sn-T (mg/L)	< 0.00001	0.00005	0.00002	0.00002	3
Sr-D (mg/L)	0.0201	0.0267	0.0234	0.0047	2
Sr-T (mg/L)	0.0195	0.0276	0.0247	0.0045	3
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	< 0.000002	< 0.000002	< 0.000002		3
U--D (mg/L)	0.000003	0.000003	0.000003	0.00	2
U--T (mg/L)	< 0.000002	< 0.000002	< 0.000002		3
V--D (mg/L)	0.0004	0.0006	0.0005	0.0001	2
V--T (mg/L)	< 0.0002	0.0004	0.0003	0.0001	3
Zn-D (mg/L)	0.0012	0.0018	0.0015	0.0004	2
Zn-T (mg/L)	0.001	0.0019	0.0014	0.0005	3

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Table 22. Summary of general water chemistry for discrete water quality samples collected at Site 0120780, Chemainus River at Highway 1, 1986-2012.

	Minimum	Maximum	Average	Std Dev	No. of samples
Alkalinity pH 4.5/4.2 (mg/L)	9.7	16.1	12.5	2.9	4
Alkalinity Total 4.5 (mg/L)	9.9	28.6	16.4	5.3	12
Ammonia Dissolved (mg/L)	< 0.005	0.01	0.006	0.002	16
Bromide Dissolved (mg/L)	< 0.05	< 0.05	< 0.05	0	4
Carbon Dissolved Organic (mg/L)	< 0.5	< 0.5	< 0.5		1
Carbon Total Inorganic (mg/L)	2.8	3.9	3.3	0.6	3
Carbon Total Organic (mg/L)	0.5	2.2	1.4	0.5	16
Chlorophyll A (g/m2)	6.25	84.7	35.1	43.2	3
Chloride:D (mg/L)	1.1	6.6	2.2	1.8	8
Color True (Col.unit)	< 5	10	6.67	2.89	3
Diss Oxy (mg/L)	6.79	14.62	11.3	2.7	16
*E Coli (*CFU/100mL)	< 1	280	32.1	75.0	14
Fluoride D (mg/L)	0.01	0.01	0.01	0	2
Fluoride T (mg/L)	0.01	0.01	0.01	0	2
Hardness (Dissolved) (mg/L)	10.1	17.4	14.7	2.9	9
Hardness Total (Extr) (mg/L)	10.4	10.4	10.4		1
Hardness Total (T) (mg/L)	10.4	26.6	17.9	6.10	6
Nitrate (NO3) Dissolved (mg/L)	0.0081	0.185	0.0878	0.0684	5
Nitrate + Nitrite Diss. (mg/L)	0.0081	0.19	0.0750	0.0509	32
Nitrogen - Nitrite Diss. (mg/L)	< 0.002	< 0.005	< 0.005		6
Nitrogen Total (mg/L)	0.1	0.28	0.16	0.07	5
NO2+NO3 (mg/L)	0.008	0.008	0.008		1
Ortho-Phos Dissolved (mg/L)	< 0.001	0.003	0.002	0.001	12
pH (pH units) -lab	6.4	7.83	7.26	0.33	49
Phos Tot. Dissolved (mg/L)	0.003	0.006	0.004	0.001	11
P--T (mg/L)	0.002	0.056	0.007	0.009	50
Res:Tot (mg/L)	20	41	31	15	2
Residue Filterable 1.0u (mg/L)	10	40	28	11	5
Residue Non-filterable (mg/L)	1	49	3	8	38
Silica:D (mg/L)	4.6	5.4	5.00	0.57	2
Specific Conductance (µS/cm)	26	85.9	47.5	16.5	36
Sulfat:D (mg/L)	1.5	4.8	2.5	0.8	38
Sulfur Dissolved (mg/L)	0.87	0.88	0.88	0.01	2
Sulfur Total (mg/L)	0.56	0.87	0.73	0.16	3
Temp (°C)	3.2	20	10.0	6.6	16
Turbidity (NTU)	0.14	5.04	0.56	1.01	23

	Minimum	Maximum	Average	Std Dev	No. of samples
Ag-D (mg/L)	< 0.000005	< 0.00002	< 0.000015	0.000008	6
Ag-T (mg/L)	< 0.000005	< 0.00002	< 0.000014	0.000008	7
Al-D (mg/L)	0.0094	0.088	0.035	0.029	6
Al-T (mg/L)	0.012	0.144	0.044	0.050	6
As-D (mg/L)	< 0.0001	0.00021	0.00012	0.00004	6
As-T (mg/L)	< 0.0001	0.000249	0.00014	0.00007	7
Ba-D (mg/L)	0.0055	0.0181	0.0089	0.0031	16
Ba-T (mg/L)	0.007	0.0178	0.0101	0.0032	15
B--D (mg/L)	< 0.005	0.018	0.010	0.004	12
B--T (mg/L)	0.007	0.009	0.008	0.001	4
Be-D (mg/L)	< 0.000002	0.000011	0.000006	0.000005	6
Be-T (mg/L)	0.000002	0.000019	0.000008	0.000006	7
Bi-D (mg/L)	0.000005	0.00008	0.000025	0.000028	6
Bi-T (mg/L)	0.000005	0.00002	0.000014	0.000008	7
Ca-D (mg/L)	3.3	9.85	5.55	1.71	37
Ca-E (mg/L)	3.3	3.3	3.3		1
Ca-T (mg/L)	3.3	10.4	5.9	1.8	40
Cd-D (mg/L)	0.000008	0.00006	0.00002	0.00002	6
Cd-T (mg/L)	0.000009	0.00006	0.00003	0.00002	7
Co-D (mg/L)	< 0.000005	0.000057	0.000028	0.000019	6
Co-T (mg/L)	0.000018	0.00017	0.000055	0.000054	7
Cr-D (mg/L)	< 0.0001	0.0002	0.0002	0.0001	6
Cr-T (mg/L)	0.0001	0.006	0.0009	0.0021	8
C--T (mg/L)	5	5.4	5.20	0.20	3
Cu-D (mg/L)	0.00055	0.0033	0.0012	0.0011	6
Cu-T (mg/L)	0.0006	0.008	0.0023	0.0027	8
Fe-D (mg/L)	< 0.01	0.55	0.07	0.10	36
Fe-T (mg/L)	< 0.02	3.21	0.23	0.53	38
Hg-D (mg/L)	< 0.00005	< 0.00005	< 0.00005		1
Hg-T (mg/L)	< 0.00005	< 0.00005	< 0.00005		1
K--D (mg/L)	0.1	0.2	0.2	0.1	5
K--E (mg/L)	0.2	0.2	0.2		1
K--T (mg/L)	0.1	0.3	0.2	0.1	4
Li-D (mg/L)	0.0< 0005	0.00009	0.00007	0.00002	4
Li-T (mg/L)	0.00006	0.00016	0.00010	0.00005	4
Mg-D (mg/L)	0.42	1.12	0.69	0.18	40
Mg-E (mg/L)	0.5	0.5	0.50		1
Mg-T (mg/L)	0.43776	1.57	0.74	0.22	42
Mn-D (mg/L)	0.000417	0.003	0.00138	0.00089	6
Mn-T (mg/L)	0.001059	0.0062	0.00237	0.00193	6
Mo-D (mg/L)	0.00003	0.00075	0.00020	0.00027	6

	Minimum	Maximum	Average	Std Dev	No. of samples
Mo-T (mg/L)	0.00004	0.00017	0.00011	0.00005	7
N.Kjel:T (mg/L)	< 0.01	0.21	0.06	0.04	26
Na-D (mg/L)	1.1	2	1.5	0.3	10
Na-E (mg/L)	1.1	1.1	1.1		1
Na-T (mg/L)	1.2	1.6	1.4	0.2	4
Ni-D (mg/L)	0.00005	0.00035	0.00022	0.00013	6
Ni-T (mg/L)	0.000072	0.00083	0.00030	0.00027	7
Pb-D (mg/L)	< 0.00001	0.00028	0.00006	0.00011	6
Pb-T (mg/L)	< 0.00001	0.00036	0.00009	0.00013	7
Sb-D (mg/L)	0.000005	0.000149	0.000040	0.000055	6
Sb-T (mg/L)	0.000005	0.000039	0.000021	0.000013	7
Se-D (mg/L)	< 0.00004	0.00005	0.00005	0.00001	2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		3
Si-D (mg/L)	1.86	2.74	2.36	0.27	12
Si-E (mg/L)	2.27	2.27	2.27		1
Si-T (mg/L)	2.09	2.86	2.54	0.22	12
Sn-D (mg/L)	< 0.00001	0.00014	0.00004	0.00005	6
Sn-T (mg/L)	< 0.00001	0.00012	0.00003	0.00004	7
Sr-D (mg/L)	0.013	0.036	0.020	0.006	16
Sr-T (mg/L)	0.014	0.036	0.021	0.007	15
Te-D (mg/L)	< 0.02	< 0.02	< 0.02		8
Te-T (mg/L)	< 0.02	< 0.02	< 0.02		8
Ti-D (mg/L)	< 0.002	< 0.003	< 0.003		12
Ti-T (mg/L)	0.002	0.027	0.01	0.01	12
Tl-D (mg/L)	< 0.000002	0.00001	0.000004	0.000003	6
Tl-T (mg/L)	< 0.000002	0.000009	0.000004	0.000003	7
U--D (mg/L)	< 0.000002	0.00001	0.000005	0.000003	6
U--T (mg/L)	< 0.000002	0.00001	0.000005	0.000003	7
V--D (mg/L)	0.00012	0.0005	0.00027	0.00013	6
V--T (mg/L)	0.0002	0.00081	0.00042	0.00022	7
Zn-D (mg/L)	0.0007	0.013	0.0062	0.0030	40
Zn-T (mg/L)	0.0009	0.017	0.0072	0.0038	32
Zr-D (mg/L)	< 0.003	< 0.003	< 0.003	0.00	8
Zr-T (mg/L)	< 0.003	< 0.003	< 0.003	0.00	8

Table 23. Summary of general water chemistry for discrete water quality samples collected at Site E285671, Chipman Creek U/S from Chemainus River, 2011-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Ca-D (mg/L)	5.12	5.12	5.12		1
Carbon Total Organic (mg/L)	0.5	1.79	1.18	0.40	12
Ca-T (mg/L)	6.78	6.78	6.78		1
Diss Oxy (mg/L)	9.26	15.4	11.93	1.81	16
E. coli (CFU/100mL)	1	19	2	5	14
Hardness Total (Extr) (mg/L)	15.7	15.7	15.7		1
Hardness Total (T) (mg/L)	21	21	21		1
Mg-D (mg/L)	0.69	0.869	0.78	0.13	2
Mg-T (mg/L)	0.68	0.88	0.78	0.14	2
P--T (mg/L)	< 0.002	0.017	0.004	0.004	18
pH (pH units) -lab	7.26	7.66	7.43	0.14	12
Residue Non-filterable (mg/L)	< 1	1.6	1.03	0.14	18
Specific Conductance (µS/cm)	46.3	65.8	58.72	7.39	5
Temp (°C)	1.7	13.3	7.18	4.29	16
Turbidity (NTU)	0.1	0.78	0.20	0.17	18
Ag-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ag-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Al-D (mg/L)	0.009	0.022	0.016	0.009	2
Al-T (mg/L)	0.0098	0.0265	0.0182	0.0118	2
As-D (mg/L)	0.00005	0.00007	0.00006	0.00001	2
As-T (mg/L)	0.00003	0.00005	0.00004	0.00001	2
Ba-D (mg/L)	0.00819	0.00929	0.00874	0.00078	2
Ba-T (mg/L)	0.00835	0.00937	0.00886	0.00072	2
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		2
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-D (mg/L)	< 0.000005	0.000006	0.000006	0.000001	2
Cd-T (mg/L)	< 0.000005	0.000005	0.000005	0.000000	2
Co-D (mg/L)	0.000009	0.000021	0.000015	0.000008	2
Co-T (mg/L)	0.000012	0.000018	0.000015	0.000004	2
Cr-D (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cr-T (mg/L)	< 0.0001	< 0.0001	< 0.0001		2
Cu-D (mg/L)	0.0003	0.00047	0.00039	0.00012	2
Cu-T (mg/L)	0.00027	0.00045	0.00036	0.00013	2

	Minimum	Maximum	Average	Std Dev	No. of samples
Li-D (mg/L)	< 0.0005	0.0005	0.0005	0	2
Li-T (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Mn-D (mg/L)	0.00087	0.00095	0.00091	0.00006	2
Mn-T (mg/L)	0.001	0.00101	0.00101	0.00001	2
Mo-D (mg/L)	0.00007	0.00014	0.00011	0.00005	2
Mo-T (mg/L)	0.00007	0.00012	0.00010	0.00004	2
Ni-D (mg/L)	0.00005	0.00014	0.00010	0.00006	2
Ni-T (mg/L)	0.00003	0.00009	0.00006	0.00004	2
Pb-D (mg/L)	0.000006	0.000015	0.000011	0.000006	2
Pb-T (mg/L)	< 0.000005	0.00001	0.000008	0.000004	2
Sb-D (mg/L)	< 0.00002	0.00002	0.00002	0	2
Sb-T (mg/L)	< 0.00002	< 0.00002	< 0.00002	0	2
Se-D (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Sn-D (mg/L)	< 0.00002	0.00003	0.00003	0.00001	2
Sn-T (mg/L)	< 0.00001	0.0001	0.00006	0.00006	2
Sr-D (mg/L)	0.017	0.0234	0.0202	0.0045	2
Sr-T (mg/L)	0.0173	0.0238	0.0206	0.0046	2
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
U--D (mg/L)	< 0.000002	0.000002	0.000002	0	2
U--T (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
V--D (mg/L)	0.0004	0.0005	0.0005	0.0001	2
V--T (mg/L)	0.0003	0.0004	0.0004	0.0001	2
Zn-D (mg/L)	0.0005	0.0008	0.0007	0.0002	2
Zn-T (mg/L)	0.0001	0.0002	0.0002	0.0001	2

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Table 24. Summary of general water chemistry for discrete water quality samples collected at Site E283338, Banon Creek U/S from Chemainus River, 2011-12.

	Minimum	Maximum	Average	Std Dev	No. of samples
Carbon Total Organic (mg/L)	1.6	3.4	2.5	0.6	12
Diss Oxy (mg/L)	8.46	15.05	11.96	2.35	15
E. coli (CFU/100mL)	< 1	140	19.8	43.3	14
Hardness (Dissolved) (mg/L)	10.4	10.4	10.4		1
Hardness Total (T) (mg/L)	14.4	14.4	14.4		1
pH (pH units) -lab	7.06	8.66	7.40	0.42	12
P--T (mg/L)	< 0.002	0.051	0.01	0.01	18
Residue Non-filterable (mg/L)	< 1	1	1		18
Specific Conductance (µS/cm)	37.1	56.4	46.2	7.0	5
Temp (°C)	2.9	18.5	8.2	5.5	16
Turbidity (NTU)	0.1	1.1	0.4	0.3	17
Ag-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ag-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Al-D (mg/L)	0.0345	0.072	0.0533	0.0265	2
Al-T (mg/L)	0.0419	0.0794	0.0607	0.0265	2
As-D (mg/L)	0.00005	0.00008	0.00007	0.00002	2
As-T (mg/L)	0.00003	0.00006	0.00005	0.00002	2
Ba-D (mg/L)	0.00552	0.00771	0.00662	0.00155	2
Ba-T (mg/L)	0.00536	0.0079	0.00663	0.00180	2
B--D (mg/L)	< 0.05	< 0.05	< 0.05		2
B--T (mg/L)	< 0.05	< 0.05	< 0.05		2
Be-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Be-T (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Bi-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Bi-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Ca-D (mg/L)	3.34	3.34	3.34		1
Ca-T (mg/L)	4.87	4.87	4.87		1
Cd-D (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Cd-T (mg/L)	< 0.000005	< 0.000005	< 0.000005		2
Co-D (mg/L)	0.000022	0.000034	0.000028	0.000008	2
Co-T (mg/L)	0.000035	0.000051	0.000043	0.000011	2
Cr-D (mg/L)	< 0.0001	0.0001	0.00		2
Cr-T (mg/L)	< 0.0001	0.0001	0.00		2
Cu-D (mg/L)	0.00047	0.00053	0.00050	0.00004	2
Cu-T (mg/L)	0.00051	0.00054	0.00053	0.00002	2
Li-D (mg/L)	< 0.0005	< 0.0005	< 0.0005		2
Li-T (mg/L)	< 0.0005	< 0.0005	< 0.0005		2

	Minimum	Maximum	Average	Std Dev	No. of samples
Mg-D (mg/L)	0.49	0.564	0.527	0.052	2
Mg-T (mg/L)	0.491	0.56	0.526	0.049	2
Mn-D (mg/L)	0.00259	0.00323	0.00291	0.00045	2
Mn-T (mg/L)	0.00347	0.00637	0.00492	0.00205	2
Mo-D (mg/L)	< 0.00005	0.00006	0.00006	0.00001	2
Mo-T (mg/L)	< 0.00005	< 0.00005	< 0.00005		2
Ni-D (mg/L)	0.0001	0.0001	0.0001	0.0000	2
Ni-T (mg/L)	0.00008	0.00013	0.00011	0.00004	2
Pb-D (mg/L)	0.000019	0.000025	0.000022	0.000004	2
Pb-T (mg/L)	0.000015	0.000023	0.000019	0.000006	2
Sb-D (mg/L)	< 0.00002	< 0.00002	< 0.00002		2
Sb-T (mg/L)	< 0.00002	< 0.00002	< 0.00002		2
Se-D (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Se-T (mg/L)	< 0.00004	< 0.00004	< 0.00004		2
Sn-D (mg/L)	< 0.00001	< 0.00001	< 0.00001		2
Sn-T (mg/L)	< 0.00001	0.00009	0.00005	0.00006	2
Sr-D (mg/L)	0.0123	0.0166	0.0145	0.0030	2
Sr-T (mg/L)	0.0125	0.0169	0.0147	0.0031	2
Tl-D (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
Tl-T (mg/L)	< 0.000002	< 0.000002	< 0.000002		2
U--D (mg/L)	0.000003	0.000007	0.000005	0.000003	2
U--T (mg/L)	0.000007	0.00001	0.000009	0.000002	2
V--D (mg/L)	0.0005	0.0007	0.0006	0.0001	2
V--T (mg/L)	0.0005	0.0006	0.0006	0.0001	2
Zn-D (mg/L)	0.0004	0.0006	0.0005	0.0001	2
Zn-T (mg/L)	0.0001	0.0003	0.0002	0.0001	2