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Cowichan-Koksilah Rivers Water Quality Assessment and Objectives

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WATER MANAGEMENT BRANCH
MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

COWICHAN-KOKSILAH RIVERS
WATER QUALITY ASSESSMENT AND OBJECTIVES

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SUMMARY

This report assesses the water quality of the Cowichan and Koksilah rivers located on the south-eastern side of Vancouver Island, and sets water quality objectives to protect their uses for drinking, irrigation, industrial consumption, water contact recreation, and aquatic life.

The Cowichan River, which originates at the outlet of Cowichan Lake, is the most important river on Vancouver Island for recreational fisheries (steelhead, cutthroat, rainbow, brown trout, and kokanee), and commercial fisheries (coho, chinook, and chum). The river is also important for water contact recreation such as kayaking, canoeing, etc., and as a source of water for domestic, irrigation, and industrial uses (B.C. Forest Products Crofton Pulp Mill). The Village of Lake Cowichan obtains its water supply from Cowichan Lake, while the City of Duncan obtains its water from wells adjacent to the Cowichan River downstream from the Island Highway.

The Koksilah River is also important for recreational and commercial fish species as well as recreational activities and domestic, irrigation, and industrial water supplies. However, since the river does not have a large lake within its watershed to provide water storage, summer stream flows are approximately 95 percent lower than flows in the Cowichan River. Consequently, the value of the above uses in the Koksilah River are reduced relative to the Cowichan River.

There are three permitted discharges on the Cowichan River. The sewage discharge from the Village of Lake Cowichan and the discharge of groundwater used in a Ministry of Environment fish hatchery have little or no impact on the water quality of the Cowichan River. The third permitted discharge is sewage from the Duncan/North Cowichan treatment plant. The effluent is not adequately diluted in the Cowichan River during the summer low flow period. High concentrations of nitrogen and phosphorus cause excessive periphyton growth for several kilometres downstream from the discharge.

Water quality objectives are set in the Cowichan River for a number of possible contaminants. These originate from a sawmill located at Youbou, a small abandoned base metal mine adjacent to Cowichan Lake, future base metal mining in the upper Cowichan watershed, public wharfs near the outlet of the lake, and the sewage discharges to the river.

Water quality objectives are set in the Koksilah River to protect water uses from two sources of contamination: potential bacterial contamination from dairy farms near Dougan Lake and contaminants from the Cowichan Valley Regional District incinerator/landfill, and gravel washing operations near Duncan.

Water quality objectives are set to protect the most sensitive water uses in both rivers. The objectives and a monitoring program for the Cowichan and Koksilah rivers are summarized in Tables 1 to 4.

INTRODUCTION

This study assesses the water quality of the Cowichan and Koksilah rivers which are located on south-eastern Vancouver Island (Figure 1). Three permitted discharges to the Cowichan River, a small abandoned base metal mine, public wharfs near the outlet of the lake, and an operational sawmill upstream from the Cowichan River are potential sources of contaminants to the Cowichan River. Nonpoint nutrient and bacteriological loading from farms, and runoff from gravel washing operations near Duncan are the potential sources of pollution in the Koksilah watershed.

This report discusses the water quality of the two rivers, interprets the impact of the nonpoint and point discharges, and develops water quality objectives to protect the major uses of the rivers.

A detailed Technical Appendix was prepared by the author, and forms the basis for the conclusions presented.

HYDROLOGY

The Cowichan River begins at the outlet of Cowichan Lake. Like most coastal streams with little snow pack, maximum stream flows occur in the winter while low flows occur in the late summer and early fall. The summer flow of the Cowichan River is controlled by a weir at the outlet of Cowichan Lake. The weir is operated by B.C. Forest Products in conjunction with a water storage licence for 62 000 dam^3 on Cowichan Lake. A rule curve specifies a minimum release of 7.08 m^3/s from June 1 to October 15. The 7-day average low flow with a return period of 2 years (1-in-2-year, 7-day average low flow) of the Cowichan River at the outlet of Cowichan Lake is 6.87 m^3/s, which is slightly lower than specified by the rule curve. The B.C. Forest Products pulp mill at Crofton withdraws water from the Cowichan River near Duncan, causing the lower Cowichan River to have a 1-in-2-year, 7-day average low flow of 5.25 m^3/s.

The Koksilah River has very low stream flows during the summer (0.3 m^3/s) principally because the river does not have a large headwater lake with water storage to augment summer low flows.

WATER USES

In 1986 the mainstem of the Cowichan River had the following licences: 15 domestic, 3 waterworks (14 230 m^3/d), 3 irrigation (4.6 dam^3/yr), and 1 industrial (BCFP:244 500 m^3/d). The Koksilah River has 11 domestic licences, 16 irrigation licences (565 dam^3/yr), and 4 industrial licences (5250 m^3/d). Two of the industrial licences are used for gravel washing, while the remaining two are for lawn watering and fish culture.

The Village of Lake Cowichan and the City of Duncan do not obtain their domestic water from the Cowichan River. The Village of Lake Cowichan has water intakes at the east end of Cowichan Lake, while the City of Duncan has wells located adjacent to the Cowichan River, approximately 1 km downstream from the highway bridge.

The fisheries resource of the Cowichan/Koksilah system has been estimated at 2 million dollars per year for sports fish (coho, chinook, steelhead, resident and anadromous trout), 2.5 million dollars per year in commercial fish (coho, chinook, and chum), and 650 thousand dollars per year in angler-day value (cost of sport fishing). The Cowichan River contributes the bulk of the sport and commercial value (approx. 80 to 90 percent).

Water-based recreation is well represented along the Cowichan and Koksilah rivers. There are five provincial parks and other regional, municipal, and community parks adjacent to the rivers. Kayaking and hiking trails are also important recreational uses of the watershed. Although no estimates of the recreational value are available, the Cowichan and Koksilah are considered to be recreationally important rivers.

WASTE DISCHARGES

There are three permitted direct discharges into the Cowichan River. The Village of Lake Cowichan is permitted (PE 247) to discharge 1728 m^3/d of treated (secondary) sewage that has been chlorinated and dechlorinated. The discharge is located about 3.5 km downstream from the outlet of Cowichan Lake.

The City of Duncan and the Municipality of North Cowichan jointly operate a similar sewage treatment facility near the City of Duncan. The permit (PE 1497) allows the direct discharge of 13 600 m^3/d of effluent 1.5 km downstream from the highway bridge near the mouth of the river. The maximum discharge to date has been 7850 m^3/d, which is 57 percent of the maximum permitted discharge.

The third permitted discharge into the Cowichan River is groundwater used for fish culture by a Ministry of Environment fish hatchery. The permit (PE 6603) allows for a maximum discharge of 5077 m^3/d. The location of the discharge is 1 km upstream from the Duncan/North Cowichan sewage discharge.

The dilution of these discharges by the Cowichan River is important in determining their impact on water quality. Based on the Pollution Control Objectives for Municipal Waste Discharges, the preferred dilution of the sewage effluent is greater than 200:1. The theoretical minimum dilution ratios for the sewage discharges were calculated using the 1-in-2-year, 7-day average low flow for the Cowichan River, and the average effluent discharges recorded in the low flow month (e.g., August or September). Using the above flow and discharge rates, the dilution ratios of the Village of Lake Cowichan and the Duncan/North Cowichan effluents are 330:1 and 68:1, respectively. Assuming the maximum permitted discharge of PE 1497 (13 000 m^3/d), the dilution ratio for the Duncan/North Cowichan effluent would be 33:1.

There are public wharfs, a small abandoned mine, and an operational sawmill upstream from the Cowichan River, which may impact the water quality of the river. Cowichan Copper (also known as Blue Grouse) was a base metal mine within the Cowichan Lake watershed. The mine site is not a source of metals to the system at this time. The public wharfs are a potential source of copper from anti-fouling paints. Microbiological contamination is possible from boats without septic holding tanks. The sawmill operated by B.C. Forest Products at Youbou may discharge anti-sapstaining compounds which are potentially toxic to fish. Water quality objectives are set at the outlet of Cowichan Lake to protect the water uses of the Cowichan River from the contaminants produced from these sources.

The Koksilah River does not have any permitted discharges; however, nonpoint nutrient and bacteriological contamination from dairy farms adjacent to Dougan Lake, and runoff from the Cowichan Valley Regional District incinerator/landfill, and gravel washing operations near Duncan, are potential sources of contaminants to the Koksilah River.

WATER QUALITY

The general water quality of the Cowichan River is typical of rivers on Vancouver Island. High precipitation in the watershed causes very soft water that is low in colour and nutrients. In the upper reaches of the Cowichan River the water is low in turbidity and suspended residues. The lower reaches of the Cowichan River can have elevated turbidity during high river flow due to the erosion of till deposits adjacent to the river. The Koksilah River is similar to the Cowichan River in general water quality; however, turbidity levels may be higher due to the absence of a large headwater lake to act as a sediment trap.

Coliform bacteria are frequently detected at the outlet of Cowichan Lake and in the Koksilah River at the highway. The source of the fecal coliform contamination has not been determined.

Metals data have been collected on the Cowichan and Koksilah rivers for several years. Total copper, lead, and to a lesser extent mercury and zinc are frequently detected in the Cowichan River near Riverbottom Road and the highway bridge, and in the Koksilah River at the highway. The concentrations of the above metals are generally low, with higher concentrations occurring during the winter months when stream flows are higher.

The impact of the permitted discharges on the water quality of the Cowichan River is variable. The impact of the discharge from the Ministry of Environment fish hatchery is minimal throughout the year because of the low concentrations of nitrogen and phosphorus in the effluent. The impact of the effluent from the Village of Lake Cowichan discharge is considered minor because of the high degree of dilution during the critical summer low flow period.

The discharge from the Duncan/North Cowichan sewage treatment facility has a detectable impact on the water quality of the Cowichan River. Fecal coliform concentrations remain low downstream from the discharge because of the adequate chlorination and dilution. However, the low dilution ratios in the summer can cause minor increases in turbidity and suspended residues and significant increases in ammonia-nitrogen and dissolved phosphorus. The high nutrient loading causes excessive periphyton growth for several kilometres downstream from the discharge. The excessive periphyton growth can interfere with spawning salmonids, increase intragravel biological oxygen demand, or decrease intragravel oxygen concentrations thereby affecting incubating fish eggs or the benthic community. High ammonia-nitrogen concentrations can cause an avoidance reaction or be toxic to fish.

WATER QUALITY OBJECTIVES

Water quality objectives are established to protect the most sensitive water uses of the Cowichan and Koksilah rivers and are summarized in Tables 1, 3 and 4.

The objectives are based on working criteria for water quality and on available data on ambient water quality, waste discharges, water uses, and limnological characteristics. Some objectives will be provisional until the water quality monitoring programs provide adequate data and the Ministry has established approved water quality criteria for the characteristics of concern.

Water quality objectives have no legal standing and are not directly enforced. The objectives should be considered as policy guidelines for resource managers to protect water uses in the specified water bodies. They will guide the evaluation of water quality, the issuing of permits, licences, and orders, and the management of the fisheries and the Province's land base. They will also provide a reference against which the state of water quality in a particular waterbody can be checked, and serve in making decisions on whether to initiate basin-wide water quality studies.

Depending on the circumstances, water quality objectives may already be met in a waterbody, or may describe water quality conditions which can be met in the future. To limit the scope of the work, objectives are only being prepared for waterbodies and for water quality characteristics which may be affected by anthropogenic activity, now and in the foreseeable future.

It is proposed that the following uses, not necessarily in order of importance, be adopted as the designated water uses to be protected in the rivers:

- domestic water supply
- industrial water supply
- aquatic life
- irrigation water supply
- primary-contact recreation

The water quality objectives outlined below are set to protect the most sensitive use. If the objectives are met for the most sensitive use, then all of the other uses of the rivers will be protected.

FECAL CONTAMINATION

COWICHAN RIVER

Bacteriological objectives are set for the Cowichan River based on the water use in a given reach. Above the Island Highway bridge the Cowichan River is used as a source of domestic water and primary contact recreation (fishing and kayaking). The most sensitive use for this section of the river is domestic water use. For any point in this reach, outside initial dilution zones of effluents, the following bacteriological objectives shall apply:

> the fecal coliform and Escherichia coli densities shall not exceed 10 cells/100 mL, and the Enterococci density shall not exceed 3 cells/100 mL in 90 percent of at least 5 weekly samples taken at any point within a 30-day period. The objective is based on the Ministry of Health guidelines for drinking water supplies (that require only chlorination or equivalent) and on the Ministry of Environment water quality criteria for microbiological indicators.

Within the Cowichan Band Indian Reserve there are no domestic water users; however, the Cowichan Band uses the river to catch fish. This use is considered equivalent to secondary-contact recreation. The bacteriological objectives for this reach of the Cowichan River (from the Island Highway bridge to the mouth) outside initial dilution zones are:

the Enterococci and Escherichia coli densities shall not exceed geometric means of 100 and 385 cells/100 mL, respectively, calculated from at least five weekly samples taken during a 30-day period. The objectives for this reach are based on the Ministry of Environment water quality criteria for bacteriological indicators.

KOKSILAH RIVER

The Koksilah River has several domestic water intakes. There is potential bacterial contamination from septic tanks and nonpoint loading from dairy farms adjacent to Dougan Lake and Patrolas Creek. Consequently, a fecal coliform objective based on the Ministry of Health guidelines for water supplies that require only chlorination (or equivalent) shall apply. The objectives for the Koksilah River are:

the fecal coliform and Escherichia coli densities shall not exceed 10 cells/100 mL, and the Enterococci density shall not exceed 3 cells/100 mL in 90 percent of at least five samples taken at any point within a 30-day period.

DISSOLVED OXYGEN

Adequate dissolved oxygen concentrations are essential to minimize the stress on the adult and juvenile salmon populations in the Cowichan and Koksilah rivers. The water quality objectives for dissolved oxygen apply to any point in the river systems excluding the initial dilution zones of effluents; however, monitoring (as outlined in Table 2) should be concentrated above and below the sewage discharges on the Cowichan River. The objectives are:

1) A minimum of 11.2 mg/L from October to May for the protection of "eyed" or hatched salmonid eggs,

2) A minimum of 8 mg/L during the remainder of the year for the protection of alevins and juvenile salmonids.

SUSPENDED RESIDUES

The suspended residue concentrations in the Cowichan and Koksilah rivers are generally low (average of 1.5 and 2.5 mg/L, respectively). The permitted sewage discharges into the Cowichan River would theoretically increase the suspended residue concentrations by 0.5 mg/L immediately outside the initial dilution zones during low flow.

The impact of the gravel washing operations adjacent to the Koksilah River near Duncan is not known, but they are potential sources of suspended residues to the Koksilah River.

The suspended residue objective for the Cowichan and Koksilah rivers outside initial dilution zones is:

> not more than a 10 mg/L increase if background concentrations are less than 100 mg/L, or not more than a 10 percent increase if background concentrations are greater than 100 mg/L.

TURBIDITY

Turbidity is an important aesthetic characteristic for drinking water. For aquatic life, turbidity can limit light penetration and primary productivity. The turbidity objective is set due to possible impacts from the sewage discharges, the gravel washing operations, or any other anthropogenic disturbances.

The turbidity objective for any point outside an initial dilution zone of a permitted discharge is:

> if background turbidity levels are ≤50 NTU, the maximum increase should be ≤5 NTU; however, if background turbidity levels are >50 NTU, the maximum increase should be ≤10% of background.

AMMONIA-NITROGEN

The un-ionized fraction of ammonia is the most toxic form of nitrogen to aquatic life. The amount of un-ionized ammonia is calculated from the total ammonia concentration, temperature, and pH. The theoretical concentration of total ammonia outside the initial dilution zone of the Duncan-North Cowichan sewage discharge during the 1-in-2-year, 7-day average low flow can approach 0.600 mg/L. Although the pH and temperature of the Cowichan River during low flow vary from point to point and year to year, the theoretical total ammonia concentration is very close to the average 30-day criterion for the protection of aquatic life, as determined in Table 3. Because the toxicity of ammonia increases with increasing pH and temperature, the maximum and 30-day average ammonia objectives for the Cowichan River outside the Duncan/North Cowichan initial dilution zone will vary. Average and maximum ammonia objectives are outlined in Tables 3 and 4.

CHLOROPHYLL-*a*

Excessive periphyton growth can occur several kilometres downstream from a sewage treatment plant discharge because of the high concentrations of nitrogen and phosphorus in the effluent. High levels of periphyton can be aesthetically displeasing and can impair fish reproduction through the reduction of intragravel water flow and dissolved oxygen. Chlorophyll-*a* measurements are frequently used to measure periphyton biomass.

The Cowichan River downstream from the Duncan/North Cowichan sewage treatment discharge is used by the Cowichan Indian Band for salmon fishing. This activity is considered to require the same protection as secondary-contact recreation; consequently, a chlorophyll-*a* objective of 50 mg/m^2 for aesthetics is used for the Cowichan River downstream from the Village of Lake Cowichan and the Duncan/North Cowichan sewage discharges beyond the initial dilution zones.

TOTAL RESIDUAL CHLORINE

Chlorine is commonly used to disinfect effluents from sewage treatment plants. After such disinfection, a family of reactive chemicals called 'total residual chlorine' is produced. Since this 'total residual chlorine' is highly toxic to aquatic life even at concentrations below those measurable by present-day technology, these chemicals must be removed from effluents being discharged to particularly sensitive environments. Trout and salmon are recognized as being especially sensitive to 'total residual chlorine'. Removal of these chemicals is referred to as dechlorination, and is usually accomplished through reaction of the 'total residual chlorine' with a reducing agent such as sulphur dioxide. Dechlorination is required at both the Village of Lake Cowichan and the Duncan/North Cowichan sewage treatment plants because of the importance of the salmonid fishery within the Cowichan River.

A 'total residual chlorine' objective of 2 µg/L is set on the Cowichan River outside the initial dilution zones for the protection of aquatic life.

METALS

Detectable concentrations of total copper, total lead, and total zinc have been measured consistently since 1986 in the Cowichan River and near the mouth of the Koksilah River. Since the sources of the metals may be anthropogenic in nature (i.e., old mine site, gravel washing operations, landfill, etc.), the following objectives will apply outside initial dilution zones for the protection of aquatic life:

	30-day average*	maximum concentration
(a) dissolved copper	0.002 mg/L	0.004 mg/L
(b) dissolved lead	0.003 mg/L	0.008 mg/L
(c) dissolved zinc	0.030 mg/L	0.180 mg/L

* the 30-day average is calculated from a minimum of 5 weekly samples collected in 30 days.

If background metal concentrations upstream from known sources exceed the above objectives, then anthropogenic impacts should not be allowed to elevate the ambient metal concentrations outside initial dilution zones by more than 20 percent above background concentrations.

The objectives are expressed as the dissolved fraction to avoid confusion with metals associated with suspended residues which frequently increase down the length of the rivers.

COPPER-8-QUINOLINOLATE

In the past, chlorophenols have been used as an antistaining wood preservative by the BCFP sawmill at Youbou. Presently, the mill uses a new product: copper-8-quinolinolate (Cu-8). Because of the potential for this compound to enter Cowichan Lake and ultimately the Cowichan River, water quality objectives are required to protect the future fisheries resources of the Cowichan River. The water quality objective for Cu-8 at the headwaters of the Cowichan River is a maximum concentration of 0.0005 mg/L. The objective for Cu-8 must be regarded as provisional because of the limited data on environmental impact and toxicity.

MONITORING RECOMMENDATIONS

A summary of the recommended water quality monitoring is given in Table 2. Monitoring is required to determine whether water quality objectives are being achieved, and to provide ambient data to fill important data gaps.

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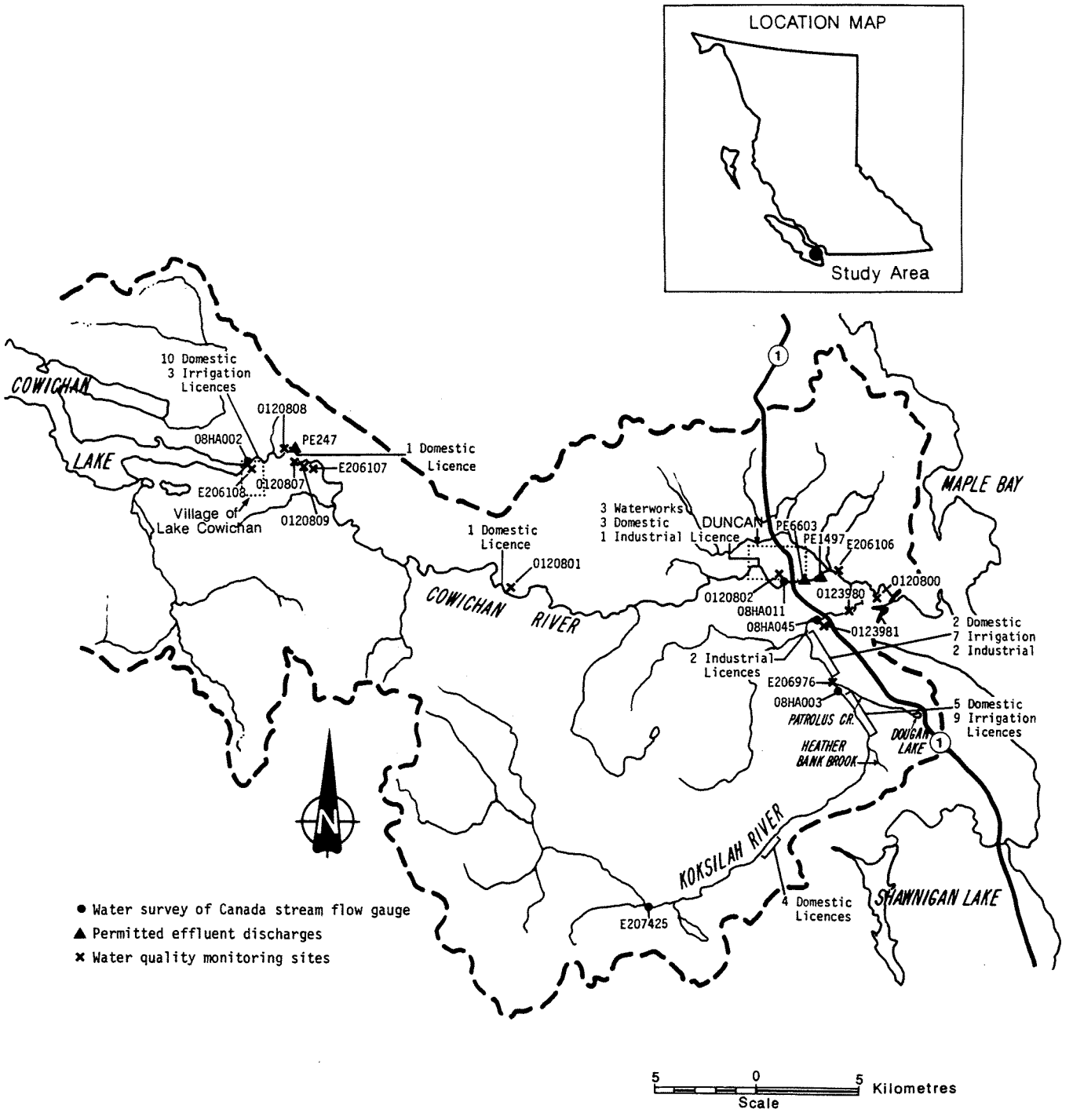

Figure 1: The Cowichan/Koksilah Study Area.

Table 1
WATER QUALITY OBJECTIVES FOR THE COWICHAN AND KOKSILAH RIVERS

Water Bodies	Cowichan River		Koksilah River
	Lake to Highway	Highway to Mouth	
Designated Water Uses	Drinking, aquatic life, irrigation, industrial, primary-contact recreation	Aquatic life, secondary-contact recreation	Drinking, aquatic life, irrigation, industrial, primary-contact recreation
Fecal Coliforms[1]	<10/100 mL 90th percentile	not applicable	<10/100 mL 90th percentile
Escherichia coli[1]	<10/100 mL 90th percentile	<385/100 mL geometric mean	<10/100 mL 90th percentile
Enterococci[1]	<3/100 mL 90th percentile	<100/100 mL geometric mean	<3/100 mL 90th percentile
Turbidity[2]	≦ 5 NTU increase: background ≦50 NTU ≦ 10 % increase: background >50 NTU		
Suspended Residues[2]	≦ 10 mg/L increase: background ≦100 mg/L ≦ 10 % increase: background >100 mg/L		
Ammonia Nitrogen[3]	see Tables 3 and 4		not applicable
Chlorophyll-a[4]	50 mg/m² maximum		not applicable
Total Chlorine Residual[5]	0.002 mg/L maximum		not applicable
Dissolved Oxygen	11.2 mg/L minimum Oct-May 8.0 mg/L minimum June-Sept		
Copper, Dissolved[3] [2]	2 µg/L average, 4 µg/L maximum or 20 % increase over background, whichever is greater		
Lead, Dissolved[3] [2]	3 µg/L average, 8 µg/L maximum or 20 % increase over background, whichever is greater		
Zinc, Dissolved[3] [2]	30 µg/L average, 180 µg/L maximum or 20 % increase over background, whichever is greater		
Copper-8-Quinolinolate[6]	0.5 µg/L maximum		not applicable

Note: the objectives apply to discrete samples from all parts of the water-body except from initial dilution zones of effluents. These excluded dilution zones are defined as extending up to 100 m downstream from the discharge point and no more than 50 percent across the width of the stream, from the surface to the bottom.

[1] the geometric mean and 90th percentile are calculated from at least 5 weekly samples taken in a period of 30 days. All bacteriological objectives apply on a year-round basis.

[2] the increase (NTU, mg/L or %) is over levels measured at a site upstream from a discharge or a series of discharges and as close to them as possible, and applies to downstream levels.

[3] average of at least 5 weekly samples taken in a period of 30 days during low river flow

[4] based on the average from 5 to 10 individual samples collected on the same day outside the initial dilution zones. Natural substrates are to be used and, if the periphyton distribution is clumped, the percent cover of the community sampled must be noted.

[5] since the objective is below the minimum detectable concentration, it may be necessary to estimate the receiving water concentration using effluent loading and streamflow.

[6] provisional objective, to be finalized when additional analysis by the Ministry of Environment has been completed.

Table 2
MONITORING SCHEDULE FOR THE COWICHAN AND KOKSILAH RIVERS

SITES	FREQUENCY AND TIME	CHARACTERISTICS TO BE MEASURED
Cowichan River E206108 0120808 E206107 0120801 0120802 E206106 Koksilah River E207425 E206976 0123981	5 weekly samples over 30 days during low flow (e.g. August) and high flow (e.g. January)	fecal coliform, (membrane filtration method) Escherichia coli, and Enterococci
Cowichan River 0120808 E206107 0120802 E206106	same frequency as fecal coliform during low flow	dissolved oxygen, temperature
Cowichan River 0120808 E206107 0120802 E206106 Koksilah River E206976 0123981	same frequency as fecal coliform	suspended residues, turbidity
Cowichan River E206106 E206107	5 weekly samples collected over 30 days during low flow	ammonia-nitrogen, field pH, and temperature
Cowichan River E206106 E206107	5 to 10 individual samples collected on the same day during low flow	chlorophyll-a, phaeophytin, biomass, and taxonomy-1 sample
Duncan/North Cowichan sewage treatment facilities following dechlorination	5 weekly samples (min) over 30 days during low flow plus monthly samples	total residual chlorine, discharge volume and stream flow

Table 2 (continued)

Cowichan Lake near outlet 0130180 Cowichan River E206108 Koksilah River 0123981	5 weekly samples over 30 days during low and high river flow	dissolved copper, dissolved lead, dissolved zinc
Cowichan River E206108	5 weekly samples over 30 days during high river flow	Copper-8-quinolinolate

TABLE 3

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.6	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.7	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
6.8	2.08	2.05	2.02	1.99	1.96	1.94	1.92	1.90	1.88	1.86	1.84
6.9	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.0	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.1	2.08	2.05	2.02	1.99	1.97	1.94	1.92	1.90	1.88	1.86	1.84
7.2	2.08	2.05	2.02	1.99	1.96	1.95	1.92	1.90	1.88	1.86	1.85
7.3	2.08	2.05	2.02	1.99	1.97	1.95	1.92	1.90	1.88	1.86	1.85
7.4	2.08	2.05	2.02	2.00	1.97	1.95	1.92	1.90	1.88	1.87	1.85
7.5	2.08	2.05	2.02	2.00	1.97	1.95	1.93	1.91	1.88	1.87	1.85
7.6	2.09	2.05	2.03	2.00	1.97	1.95	1.93	1.91	1.89	1.87	1.85
7.7	2.09	2.05	2.03	2.00	1.98	1.95	1.93	1.91	1.89	1.87	1.86
7.8	1.78	1.75	1.73	1.71	1.69	1.67	1.65	1.63	1.62	1.60	1.59
7.9	1.50	1.48	1.46	1.44	1.43	1.41	1.39	1.38	1.36	1.35	1.34
8.0	1.26	1.24	1.23	1.21	1.20	1.18	1.17	1.16	1.15	1.14	1.13
8.1	1.00	0.989	0.976	0.963	0.952	0.942	0.932	0.922	0.914	0.906	0.899
8.2	0.799	0.788	0.777	0.768	0.759	0.751	0.743	0.736	0.730	0.724	0.718
8.3	0.636	0.628	0.620	0.613	0.606	0.599	0.594	0.588	0.583	0.579	0.575
8.4	0.508	0.501	0.495	0.489	0.484	0.479	0.475	0.471	0.467	0.464	0.461
8.5	0.405	0.400	0.396	0.381	0.387	0.384	0.380	0.377	0.375	0.372	0.370
8.6	0.324	0.320	0.317	0.313	0.310	0.308	0.305	0.303	0.301	0.300	0.298
8.7	0.260	0.257	0.254	0.251	0.249	0.247	0.246	0.244	0.243	0.242	0.241
8.8	0.208	0.206	0.204	0.202	0.201	0.200	0.198	0.197	0.197	0.196	0.196
8.9	0.168	0.166	0.165	0.163	0.162	0.161	0.161	0.160	0.160	0.160	0.160
9.0	0.135	0.134	0.133	0.132	0.132	0.131	0.131	0.131	0.131	0.131	0.131

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.6	1.82	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.7	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.41	1.31	1.22
6.8	1.83	1.81	1.80	1.78	1.77	1.64	1.52	1.42	1.32	1.22
6.9	1.82	1.81	1.80	1.78	1.77	1.64	1.53	1.42	1.32	1.22
7.0	1.83	1.81	1.80	1.79	1.77	1.64	1.53	1.42	1.32	1.22
7.1	1.83	1.81	1.80	1.79	1.77	1.65	1.53	1.42	1.32	1.23
7.2	1.83	1.81	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.3	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.4	1.83	1.82	1.80	1.79	1.78	1.65	1.53	1.42	1.32	1.23
7.5	1.83	1.82	1.81	1.80	1.78	1.66	1.54	1.43	1.33	1.23
7.6	1.84	1.82	1.81	1.80	1.79	1.66	1.54	1.43	1.33	1.24
7.7	1.84	1.83	1.81	1.80	1.79	1.66	1.54	1.44	1.34	1.24
7.8	1.57	1.56	1.55	1.54	1.53	1.42	1.32	1.23	1.14	1.07
7.9	1.33	1.32	1.31	1.31	1.30	1.21	1.12	1.04	0.970	0.904
8.0	1.12	1.11	1.10	1.10	1.09	1.02	0.944	0.878	0.818	0.762
8.1	0.893	0.887	0.882	0.878	0.874	0.812	0.756	0.704	0.655	0.611
8.2	0.714	0.709	0.706	0.703	0.700	0.651	0.606	0.565	0.527	0.491
8.3	0.571	0.568	0.566	0.564	0.562	0.523	0.487	0.455	0.424	0.396
8.4	0.458	0.456	0.455	0.453	0.452	0.421	0.393	0.367	0.343	0.321
8.5	0.369	0.367	0.366	0.366	0.365	0.341	0.318	0.298	0.278	0.261
8.6	0.297	0.297	0.296	0.296	0.296	0.277	0.259	0.242	0.227	0.213
8.7	0.241	0.240	0.240	0.241	0.241	0.226	0.212	0.198	0.186	0.175
8.8	0.196	0.196	0.196	0.197	0.198	0.185	0.174	0.164	0.154	0.145
8.9	0.160	0.161	0.161	0.162	0.163	0.153	0.144	0.136	0.128	0.121
9.0	0.132	0.132	0.133	0.134	0.135	0.128	0.121	0.114	0.108	0.102

- the average of the measured values must be less than the average of the corresponding individual values in this Table.
- each measured value is compared to the corresponding individual values in this Table. No more than one in five of the measured values can be greater than one-and-a-half times the corresponding criteria values in this Table.

TABLE 4

MAXIMUM CONCENTRATION OF TOTAL AMMONIA NITROGEN FOR PROTECTION OF AQUATIC LIFE
(mg/L-N)

pH	Temp. 0.0	1.0	2.0	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0
6.5	27.7	28.3	27.9	27.5	27.2	26.8	26.5	26.2	26.0	25.7	25.5
6.6	27.9	27.5	27.2	26.8	26.4	26.1	25.8	25.5	25.2	25.0	24.7
6.7	26.9	26.5	26.2	25.9	25.5	25.2	24.9	24.6	24.4	24.1	23.9
6.8	25.8	25.5	25.1	24.8	24.5	24.2	23.9	23.6	23.4	23.1	22.9
6.9	24.6	24.2	23.9	23.6	23.3	23.0	22.7	22.5	22.2	22.0	21.8
7.0	23.2	22.8	22.5	22.2	21.9	21.6	21.4	21.1	20.9	20.7	20.5
7.1	21.6	21.3	20.9	20.7	20.4	20.2	19.9	19.7	19.5	19.3	19.1
7.2	19.9	19.6	19.3	19.0	18.8	18.6	18.3	18.1	17.9	17.8	17.6
7.3	18.1	17.8	17.5	17.3	17.1	16.9	16.7	16.5	16.3	16.2	16.0
7.4	16.2	16.0	15.7	15.5	15.3	15.2	15.0	14.8	14.7	14.5	14.4
7.5	14.4	14.1	14.0	13.8	13.6	13.4	13.3	13.1	13.0	12.9	12.7
7.6	12.6	12.4	12.2	12.0	11.9	11.7	11.6	11.5	11.4	11.3	11.2
7.7	10.8	10.7	10.5	10.4	10.3	10.1	10.0	9.92	9.83	9.73	9.65
7.8	9.26	9.12	8.98	8.88	8.77	8.67	8.57	8.48	8.40	8.32	8.25
7.9	7.82	7.71	7.60	7.51	7.42	7.33	7.25	7.17	7.10	7.04	6.98
8.0	6.55	6.46	6.37	6.29	6.22	6.14	6.08	6.02	5.96	5.91	5.86
8.1	5.21	5.14	5.07	5.01	4.95	4.90	4.84	4.80	4.75	4.71	4.67
8.2	4.15	4.09	4.04	3.99	3.95	3.90	3.86	3.83	3.80	3.76	3.74
8.3	3.31	3.27	3.22	3.19	3.15	3.12	3.09	3.06	3.03	3.01	2.99
8.4	2.64	2.61	2.57	2.54	2.52	2.49	2.47	2.45	2.43	2.41	2.40
8.5	2.11	2.08	2.06	2.03	2.01	1.99	1.98	1.96	1.95	1.94	1.93
8.6	1.69	1.67	1.65	1.63	1.61	1.60	1.59	1.58	1.57	1.56	1.55
8.7	1.35	1.33	1.32	1.31	1.30	1.29	1.28	1.27	1.26	1.26	1.25
8.8	1.08	1.07	1.06	1.05	1.04	1.04	1.03	1.03	1.02	1.02	1.02
8.9	0.871	0.863	0.856	0.849	0.844	0.839	0.836	0.833	0.832	0.831	0.831
9.0	0.703	0.697	0.692	0.688	0.685	0.682	0.681	0.681	0.680	0.681	0.682

	11.0	12.0	13.0	14.0	15.0	16.0	17.0	18.0	19.0	20.0
6.5	25.2	25.0	24.8	24.6	24.5	24.3	24.2	24.0	23.9	23.8
6.6	24.5	24.3	24.1	23.9	23.8	24.6	23.5	23.3	23.3	23.2
6.7	23.7	23.5	23.3	23.1	23.0	22.8	22.7	22.6	22.5	22.4
6.8	22.7	22.5	22.3	22.2	22.0	21.9	21.8	21.7	21.6	21.5
6.9	21.6	21.4	21.3	21.1	21.0	20.8	20.7	20.6	20.5	20.4
7.0	20.3	20.2	20.0	19.9	19.7	19.6	19.5	19.4	19.3	19.2
7.1	18.9	18.8	18.7	18.5	18.4	18.3	18.2	18.1	18.0	17.9
7.2	17.4	17.3	17.2	17.1	16.9	16.8	16.8	16.7	16.6	16.5
7.3	15.9	15.7	15.6	15.5	15.4	15.3	15.2	15.2	15.1	15.1
7.4	14.2	14.1	14.0	13.9	13.9	13.8	13.7	13.6	13.6	13.5
7.5	12.6	12.5	12.4	12.4	12.3	12.2	12.2	12.1	12.1	12.0
7.6	11.1	11.0	10.9	10.8	10.8	10.7	10.7	10.6	10.6	10.5
7.7	9.57	9.50	9.43	9.37	9.31	9.26	9.22	9.81	9.15	9.12
7.8	8.18	8.12	8.07	8.02	7.97	7.93	7.90	7.87	7.84	7.82
7.9	6.92	6.88	6.83	6.79	6.75	6.72	6.69	6.67	6.65	6.64
8.0	5.81	5.78	5.74	5.71	5.68	5.66	5.64	5.62	5.61	5.60
8.1	4.64	4.61	4.59	4.56	4.54	4.53	4.51	4.50	4.49	4.49
8.2	3.71	3.69	3.67	3.65	3.64	3.63	3.62	3.61	3.61	3.61
8.3	2.97	2.96	2.94	2.93	2.92	2.92	2.91	2.91	2.91	2.91
8.4	2.38	2.37	2.36	2.36	2.35	2.35	2.35	2.35	2.35	2.36
8.5	1.92	1.91	1.91	1.90	1.90	1.90	1.90	1.90	1.91	1.92
8.6	1.55	1.54	1.54	1.54	1.54	1.54	1.55	1.55	1.56	1.57
8.7	1.25	1.25	1.25	1.25	1.25	1.26	1.26	1.27	1.28	1.29
8.8	1.02	1.02	1.02	1.02	1.03	1.03	1.04	1.05	1.06	1.07
8.9	0.832	0.834	0.838	0.842	0.847	0.853	0.861	0.870	0.880	0.891
9.0	0.684	0.688	0.692	0.698	0.704	0.711	0.720	0.729	0.740	0.752