MINISTRY OF ENVIRONMENT AND PARKS

COWICHAN-KOKSILAH WATER MANAGEMENT PLAN

Vancouver Island Region — Planning and Assessment Branch

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The objectives and major activities in this plan for the Cowichan-Koksilah were approved February, 1987 by the Ministry Executive and may proceed as Ministry and Regional priorities and funding allow.

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CHAPTER 1. INTRODUCTION

1.1 BACKGROUND AND PURPOSE

The water resources of eastern Vancouver Island support a number of instream and consumptive uses which vary in the degree of use with the time of year. Abundant water supplies are available during the winter and spring, particularly in some of the larger river systems, such as the Cowichan-Koksilah. However, water may become limiting for many purposes during the summer low-flow period, leading to conflicts among users. For example, demand for domestic, municipal, and irrigation water supplies peaks during the months of lowest natural stream flows. Also during the low-flow period, minimum instream flows are needed for waste dilution, fisheries and recreation. In addition to water quantity, appropriate levels of water quality are required to support various uses. Therefore, the management of water entails assessing and regulating for adequate supplies of water of adequate quality, particularly during the summer for a variety of users, and planning for the provision of future supplies as the demand for water increases over time. Since conflicts among water uses during the low-flow period are already apparent, it is accepted that these conflicts will intensify during the next decade as population and associated water uses increase.

In order to make sound resource decisions that will alleviate current or anticipated water use conflicts, a water manager must have ready access to up-to-date supply and use information, for all water uses. At present this is not the case, in that data are poorly organized or inaccessible for rapid problem-solving, are limited in most cases to allocating water for consumptive users only, and are usually not available for uses such as instream flows for fisheries, waste dilution or recreation. In addition to a lack of available data to consider in resolving supply/use imbalances, the water manager may not have an appropriate strategy to guide water management decisions.

For these reasons, the Cowichan-Koksilah Water Management Plan originated in a two-fold desire on the part of Vancouver Island regional water management staff to develop strategies to guide water management decisions in this watershed, and to improve the accessibility and organization of data fundamental to rational decision-making. A computer-based water management information system (described in Appendix 1.1) has been recently proposed to respond to the need for rapid retrieval of water management data. This plan represents the prototype application of portions of the information system, using the system as a tool for water management planning. It is intended to be the forerunner of other water management plans undertaken in areas of priority, should the information system be introduced Province-wide. Thus, the two purposes of the plan are:

1. To develop a strategy that will guide water management in the Cowichan-Koksilah watershed during a 5-year period, in the context of stated water management strategies and allocation criteria.

2. To provide a prototype application of the computer-based water management information system, to demonstrate its strengths and indicate where modifications can be made to overcome its weaknesses.

1.2 MINISTRY OF ENVIRONMENT MANDATE

The Ministry of Environment has a legislative mandate to manage water supply and use, water quality, fisheries, wildlife and air quality in the Province. Under the umbrella of the Environment Management Act, the Ministry is charged with developing policies for the management, protection and use of the environment, and for planning its use.

The Ministry of Environment has the responsibility for ensuring the environmental management of the water resource. The Water Act, administered by the Comptroller of Water Rights and the Regional Water Managers, Engineers and their staffs, is the basic legislation under which licences for the diversion and use of surface water are issued and regulated. The Comptroller of Water Rights or the Regional Water Manager can allow due regard for identified instream uses such as fisheries, recreation and waste management, and for flood protection. Short-term use of water and changes in and about a stream are also regulated under Section 7 of the Water Act. Currently, the Water Act has not been proclaimed to be applicable to groundwater. The Ministry is also responsible for reducing flood damage by controlling, or otherwise providing input to, floodplain development initiatives.

Under the Waste Management Act, the Ministry has a mandate to manage waste discharges such that the ambient quality of surface and ground waters is maintained at or above levels required for specific water uses. Recently, the Ministry initiated a program to establish ambient water quality objectives for various instream and diversion uses in specific locations. The Ministry is also recommending Provincial criteria for selected parameters, which may be applied in areas where ambient objectives have not yet been specified.

Fisheries management in the Cowichan-Koksilah watershed is a shared responsibility between the Provincial Ministry of Environment and the Federal Department of Fisheries and Oceans, under the Fisheries Act (Canada). The division of production and harvest management responsibilities between these two agencies in this watershed is along species lines: the Ministry of Environment is responsible for the management of anadromous and non-anadromous rainbow and cutthroat trout, brown trout, Dolly Varden char and kokanee salmon, while chinook, coho and chum salmon are managed by the Department of Fisheries and Oceans. Chinook and coho are considered freshwater sportsfish as well as commercial species. The distribution of these species within the Cowichan-Koksilah system overlaps and therefore both government agencies have key responsibilities in habitat management, including conserving, restoring and enhancing habitat, through negotiation with agencies and developers that may negatively impact that habitat. The Federal Fisheries Act is the primary legislation that both agencies utilize when dealing with habitat management problems.

1.3 PROGRAM GOALS AND OBJECTIVES

The goals and objectives of the three programs involved in this water management plan are outlined below, along with those of the Department of Fisheries and Oceans. It should be noted that the provincial goals and objectives are specific to that program and therefore may be potentially conflicting in circumstances where more than one progam may be involved.

1.3.1 WATER MANAGEMENT PROGRAM

The goal of the Water Management Program is to manage the water resources of the Province so that the greatest possible economic, social and recreational benefits can be realized by its residents, through reduced flooding and a supply of water which is plentiful and of good quality. Objectives to meet this goal include:

1. a high level of water resource quality for groundwater, fresh surface water and estuarine and coastal marine waters, achieved through processes including the establishment of resource quality objectives, and water quality monitoring;
2. assured protection of licensed private rights and instream use through allocation and regulation of the supply and use of surface water under the Water Act;
3. reduced potential for property damage and loss of life due to flooding and erosion, through processes including flood forecasting and response, regulation of floodplain development, and projects relating to protection from floods and erosion;
4. an assured adequate level of water service to the public through requiring appropriate technical works standards, and regulating water utilities;
5. an adequate information base on the supply capability of surface water and groundwater resources through the collection, storage and analyses of data;
6. a high level of public health engineering support for the Ministry of Health for supply and treatment of sources of water supply, etc.

7. a water management program which is managed cost effectively through, among other means, planning and program evaluation.

1.3.2 WASTE MANAGEMENT PROGRAM

The goal of the Waste Management Program is to protect the environment of British Columbia by controlling the impact of polluting substances. The relevant objective with respect to the water-based resources discussed in this plan is:

To preserve the quality of the water environment of the Province at or above acceptable levels by managing the discharge of pollutants.

1.3.3 FISHERIES MANAGEMENT PROGRAM

The Provincial Fisheries Management Program goal is to provide social and economic benefits through conservation and management of freshwater fisheries and habitats. Relevant objectives in attaining this goal are:

1. To maintain and enhance habitats which support natural and cultural populations of fish.
2. To provide abundant and diversified recreational opportunities while protecting desirable wild populations of fish.
3. To support and regulate commercial users of fish.

1.3.4 DEPARTMENT OF FISHERIES AND OCEANS

This Department's long-term policy goal is to manage, protect and enhance the fisheries and habitat resources of Canada's Pacific Region and to achieve their best use and full potential for Canadians. Resource and Environment goals supporting the policy goal are:

1. To conserve, manage and rehabilitate fish stocks and their habitats.
2. To optimize the efficiency of use of resources.
3. To ensure fair access to the fisheries resources by various groups.

1.4 ISSUES OF CONCERN RELATED TO WATER MANAGEMENT

The following issues were identified by regional staff as part of the development of the Terms of Reference (Cowichan-Koksilah Water Management Plan, Terms of Reference. October 1984).

The identification of these issues is important in that they more clearly define the scope of the water management plan, the collection of specific types of information, and the consideration of broader policy questions. Issue statements for the Cowichan-Koksilah plan area also provide a basis for subsequent assessment of the success of the plan, i.e. has the plan improved our ability to deal with those issues? Where no resolution to certain issues has been reached, the plan will outline activities to do so.

1.4.1 WATER MANAGEMENT

- Low stream flows during the April to October period lead to conflicts among consumptive users, as well as between consumptive uses and instream uses, particularly in the lower portions of tributaries.
- Potential exists for impact of groundwater use on surface water flows in the vicinity of Cowichan River.
- Areas and quantities of current groundwater use, and potential supplies, are poorly known.
- Increases in residential and agricultural development are expected during the next decade, with an accompanying increase in water demand.
- Winter flooding and erosion areas are adequately known in the lower reaches of both the Cowichan and Koksilah Rivers and in the vicinity of the Village of Lake Cowichan, but most other parts of the plan area have not been examined.
- Gravel removal from alluvial fans, mainly along the shores of Cowichan Lake, has resulted in some disturbance to tributary streams.

1.4.2 WASTE MANAGEMENT

- High levels of nutrients discharged in the effluent from the Village of Lake Cowichan and City of Duncan sewage treatment plants, in combination with high temperatures and low dilution flows during the summer, result in increased algal growth immediately downstream of the discharge points.
- Non-point source discharges (agricultural, industrial, domestic and municipal) may be occurring extensively, but information is lacking to identify the appropriate degree of concern.
- Steep valley wall logging causes debris flows, erosion and water siltation problems.

1.4.3 FISHERIES

Production Issues

- Low streamflows during the June to October period adversely affect available habitat for rearing, migrating and spawning fish which results in declining fish productivity. Other low streamflow effects include the limiting of fish migration movement from ocean waters to the Cowichan system, and increased poaching.
- Rearing production losses occur due to a variety of stresses including high water temperatures, reduced oxygen availability, increased predation and mortality caused by complete stream reach dewatering.
- Low streamflows combined with increased volumes of municipal sewage waste result in inadequate waste dilution and a lower ambient water quality which may not sustain an environment for fisheries productivity.
- Fish habitat damage and fish production losses can result from works in or about a stream, such as agricultural drainage, stream channelization, flood protection works, and gravel removal.

Harvest Issues

- Angler access difficulties may be caused by low streamflows in the Cowichan River or low lake levels on Cowichan Lake. Angler access may also be hindered by bank protection works and dyking. In addition, angler opportunities may be limited by reduced availability of those species particularly sensitive to stresses resulting from low streamflows.

1.5 SCOPE OF THE PLAN

The water management-related issues identified above (Section 1.4), in conjunction with Water Management Program goals and objectives given in Section 1.3, provide the extent or scope of this plan. Waste Management and Fisheries program objectives are taken into consideration in the plan only insofar as some of their interests implicitly require a particular quantity and quality of water in order to meet their program objectives.

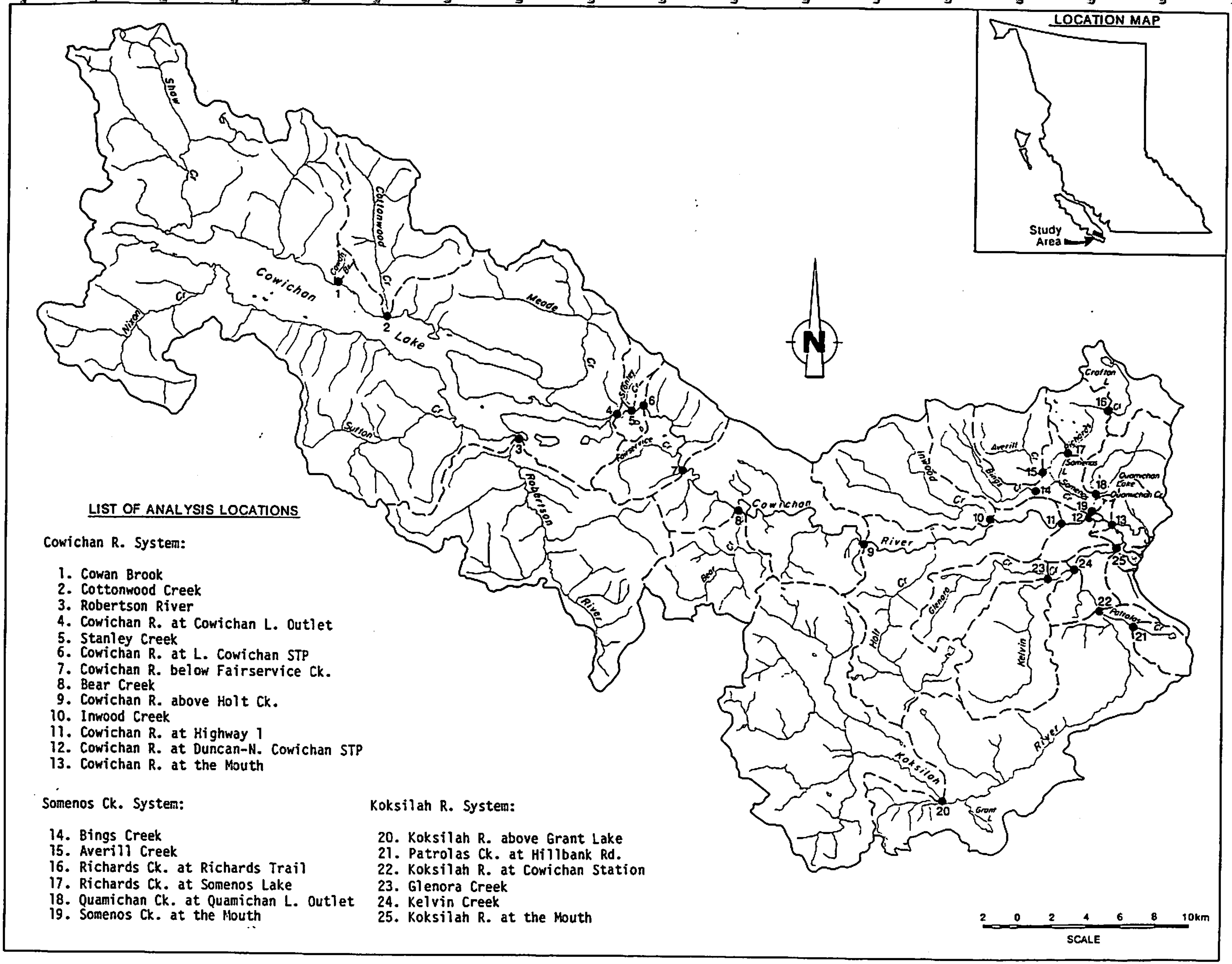
With respect to Water Management program objectives and identified issues, the allocation and regulation of the supply and use of surface water is extensively discussed in chapters 2 and 3.3 and conclusions drawn in Chapter 4. Although groundwater sections of the Water Act have not been proclaimed, and groundwater is therefore not licensed, considerable use of groundwater for both domestic consumption and irrigation occurs in the Cowichan-Koksilah area. Therefore, groundwater supply is discussed in Chapter 2, and its use and quality are presented in Chapter 3.4. Since the emphasis of this plan is on issues associated with the low-flow season, peak flows and issues related to high water are discussed briefly (Appendix 1.2). Also in Appendix 1.2 is a series of soils-based computer generated (CAPAMP) maps which has been produced to identify floodable soils in areas for which floodplain mapping is not yet available. A series of CAPAMP maps highlighting soil erosion was also prepared (Appendix 1.3). A discussion on the capability of the resource to meet future water supply needs forms a major part of the Chapter 4 analysis.

Water quality is the responsibility of two complementary programs, Waste Management, and Water Management. The Water Management Program is responsible for setting priority uses and establishing water quality objectives and criteria appropriate for these uses, and regulating water uses in a manner consistent with the objectives. The Waste Management Program is responsible, through regulating waste discharge, for ensuring that ambient objectives are maintained. The major mechanism of water quality regulation is permits, issued through regional operations under the authority of the Waste Management Act, which specify requirements for discharge quality. Therefore, with respect to Waste Management program objectives and identified issues, the primary interest relating to water management is the availability of water supplies for waste dilution at specific locations. Water for waste management purposes is discussed in Section 3.2.4.

Water management for fisheries is the focus of Section 3.2.1. The Cowichan and Koksilah systems are important for both anadromous (primarily a Federal responsibility) and resident (a Provincial responsibility) fish species. Therefore, with respect to the objectives of both provincial and federal fisheries programs and issues identified by fisheries managers, the major concern with respect to the Water Management program is the provision of water to maintain fisheries habitats and assist fisheries productivity. As a result, flows required for fisheries purposes are discussed in Section 3.2.1, and these flow requirements included in the Chapter 4 analysis.

1.5.1 SELECTION OF ANALYSIS LOCATIONS

Based upon the issues described above, and selection of priority analysis locations by Ministry of Environment staff of Water Management, Waste Management and Fisheries, and the Department of Fisheries and Oceans, a total of 25 water analysis locations (Fig. 1.1) was selected and approved by the Steering Committee. The locations were chosen where possible to coincide with water-related data sites (e.g. Water Survey of Canada gauges, FLAP (Flow Limitation Assessment Project) fisheries flow sites, Sewage Treatment Plants, etc.). Three of the sites were at the mouths of the major systems in the drainage (Cowichan River, Koksilah River and Somenos Creek) to permit an overall assessment for each of the systems. These analysis locations are expected to illustrate the range of management problems which occur in this watershed. Therefore, it should not be concluded that these are the only locations of interest to various water users, but merely a representative subset of a large number of locations. In the sections that follow, all analysis is keyed to these 25 locations.



LIST OF ANALYSIS LOCATIONS

Cowichan R. System:

1. Cowan Brook
2. Cottonwood Creek
3. Robertson River
4. Cowichan R. at Cowichan L. Outlet
5. Stanley Creek
6. Cowichan R. at L. Cowichan STP
7. Cowichan R. below Fairservice Ck.
8. Bear Creek
9. Cowichan R. above Holt Ck.
10. Inwood Creek
11. Cowichan R. at Highway 1
12. Cowichan R. at Duncan-N. Cowichan STP
13. Cowichan R. at the Mouth

Somenos Ck. System:

14. Bings Creek
15. Averill Creek
16. Richards Ck. at Richards Trail
17. Richards Ck. at Somenos Lake
18. Quamichan Ck. at Quamichan L. Outlet
19. Somenos Ck. at the Mouth

Koksilah R. System:

20. Koksilah R. above Grant Lake
21. Patrolas Ck. at Hillbank Rd.
22. Koksilah R. at Cowichan Station
23. Glenora Creek
24. Kelvin Creek
25. Koksilah R. at the Mouth

FIGURE 1.1 Water Analysis Locations and Sub-Basins.

1.6 DESCRIPTION OF THE STUDY AREA

1.6.1 BIOPHYSICAL

The Cowichan-Koksilah study area (Fig. 1.1) lies near the southeastern end of Vancouver Island, and covers an area of approximately 1241 km^2. The study area contains all drainage of the Cowichan and Koksilah Rivers, which discharge to Cowichan Bay near the community of Duncan. The Cowichan River originates in Cowichan Lake (and tributaries to the lake), and flows south-eastwards for approximately 47 km to Cowichan Estuary. At a mean annual discharge of about $53m^3/s$, the Cowichan River ranks fourth in size on Vancouver Island, after the Nimpkish, Campbell and Stamp Rivers. The Koksilah River originates south of the Cowichan Valley on the slopes of Waterloo Mountain, and after about 44 km empties into the Cowichan Estuary. With a mean annual discharge of about $10m^3/s$, the Koksilah is a much smaller river than the Cowichan. The watershed areas for the Cowichan and Koksilah Rivers are approximately 939 and 302 km^2, respectively.

The western section of the plan area lies in the Vancouver Island Ranges, with a number of peaks exceeding 1000 m in elevation in the area. The largest lake in the plan area is Cowichan Lake (surface elevation approximately 163 m), in the western section. The Cowichan River at the lake is regulated by a weir operated under a provisional rule curve last revised in 1974. The river has been described as consisting of three distinct gradient sections (Wester, 1967), the middle portion being the steepest (1:200), with the upper portion approximately 1:500, and the lower section flattening below Holt Creek, particularly beyond the Somenos Creek confluence, the approximate limit of tidal influence.

Numerous tributaries to the Cowichan system occur along the shores of Cowichan Lake. Robertson River, Sutton and Nixon Creeks are the largest drainages on the south side, and Shaw, Cottonwood and Meade Creeks the largest on the north. In the lower Cowichan Valley, a series of creeks drains the southern slopes of Mt. Prevost, including Inwood, Menzies, Bings and Averill. The latter three creeks, along with Richards and Quamichan Creeks, empty into the Cowichan River via Somenos Creek.

The gradient of the upper 38 km of the Koksilah River is moderate, with the lower 6 km having a very slight gradient, particularly after the river reaches the lower Cowichan Valley. Among the main tributaries to the Koksilah are Fellows Creek in the west, and Kelvin and Glenora Creeks which flow into the Koksilah approximately 4 km before the confluence of the Koksilah with the Cowichan. Grant Lake, in the southeastern Koksilah watershed, is the largest lake in the Koksilah drainage. The Koksilah is subject to flash floods, sedimentation problems, and low summer flows (Bell and Kallman, 1976).

During the winter, prevailing westerly winds carry weather systems over the west-facing slopes of Vancouver Island, where they drop their moisture (Schaefer, 1978). The major proportion of precipitation falls during the winter, maxima usually occurring in December. After passing the mountains, the drier air mass descends, is heated by compression, and clouds dissipate, resulting in a considerably drier climate on the east coast of Vancouver Island, with more hours of bright sunshine. The influence of the Olympic Mountains to the south also contributes to the rainshadow effect, so that the coastal lowlands of the lower Cowichan and Koksilah drainages experience a cool Mediterranean climate typified by dry, mild, sunny summers, and mild, moist winters. As soils in the lowlands are dry and warm, a mid- to late-summer moisture deficit is experienced, and soils in the area have been described as semi-arid (Lavkulich and Valentine, 1978).

From a hydrologic perspective, these climatic patterns mean that peak runoff generally occurs between December and February, as a result of heavy precipitation during the winter months. This differs from the pattern typical of most western Canadian rivers, which peak during the May-July period, as a result of snow-melt. Minimum discharge usually occurs during August to October in the Cowichan-Koksilah area.

Three biogeoclimatic zones are represented in the plan area. The majority of the Cowichan Valley downstream of Cowichan Lake, and most of the Koksilah drainage, is included in the Coastal Douglas Fir zone. Much of the characteristic vegetation of this area has disappeared, due to high settlement and agricultural value (Edgell, 1979). The dystric brunisol soils of this zone may experience soil water deficits as early as May. Of the area around Cowichan Lake, portions closest to the lake are in the Coastal Western Hemlock zone, whereas those at higher elevations are in the Subalpine Mountain Hemlock zone. These areas are dominated by hemlock, which is adapted to higher precipitation and mineral-poor soils, the soils in this zone being humo-ferric podzols (Lord and Valentine, 1978). Soil moisture deficits are lower, and occur later in the summer than closer to the east coast of Vancouver Island.

1.6.2 SOCIO-ECONOMIC

The forest industry has provided the economic base of the plan area for many decades (Ministry of Economic Development, 1978). Although this industry is expected to continue to be a major employer, the available timber supply in the area has declined and it appears unlikely that operations in the Cowichan Lake area will continue at the levels of the past 1-2 decades. This conclusion is supported by the recent closure of the sawmill at Honeymoon Bay. However, the sawmills at Youbou and Cowichan Bay, and the pulp mill at Crofton just outside the plan area, provide employment for residents of the area.

Agriculture has had a long history in the Cowichan region, an 1860 government survey recognizing "45,000 acres of superior agricultural lands waiting to be occupied" (Wells, 1860, cited in Bell and Kallman, 1976). The Fairbridge silt loams in the Duncan-Cowichan Bay area have since been rated the most desirable agricultural soils on Vancouver Island, being well-drained, gently sloping and having few or no stones (Bell and Kallman, 1976). The major component of present day agriculture in the Cowichan-Koksilah area (Fofonoff, pers. comm.) is dairying and the cultivation of crops related to the dairy industry (pasture, hay and other fodder crops).

The dairy industry is expected to increase at approximately the same rate as the Vancouver Island population, the major consumer of the products of the dairy industry. Most of the produce grown in the area is absorbed by the local market, and growth in this part of the industry will likely increase at the rate of the Cowichan area population. In general, there has recently been more expansion in agriculture in this area than in Greater Victoria, since agricultural land is still available, and especially in the North Cowichan area, there is a reasonable amount of arable land not yet being farmed. The major constraint to agricultural expansion is the availability of capital for land clearing and irrigation development.

The service and retail sector is centred in Duncan, which supplies the surrounding Cowichan Valley area and provides services to tourists travelling Highway 1 between Victoria and Nanaimo. Relatively inexpensive land in the area has also made it attractive for retirement, and for tourist development around Cowichan Lake.

The population of the plan area was nearly 30,000 in 1981 (Table 1.1), with the majority residing in Duncan and the district to the north of it (North Cowichan). Electoral Areas D and E of Cowichan Valley Regional District lie to the south of Duncan, including the Koksilah area. The Upper Cowichan Valley includes the Village of Lake Cowichan and communities around this lake. The plan area population is forecast to exceed 33,000 by 1991 and to reach nearly 37,000 by 2001, requiring among other water-related aspects, an increase in municipal water supply for the expected 23.6% population increase between 1981 and 2001.

TABLE 1.1
ACTUAL AND FORECAST POPULATION OF THE COWICHAN-KOKSILAH PLAN AREA

Area	1981*	1986**	1991**	1996**	2001**
Total	29,726	31,403	33,150	34,930	36,746
Duncan	4,225	4,463	4,711	4,964	5,222
North Cowichan	14,261	15,065	15,903	16,757	17,628
Electoral Area D	3,024	3,195	3,373	3,554	3,739
Electoral Area E	2,656	2,806	2,962	3,121	3,283
Upper Cowichan Valley (Electoral Areas F and I)	5,560	5,874	6,201	6,534	6,874
Percentage Increase		5.6	5.6	5.4	5.2

* Statistics Canada

** Economic and Social Analysis Unit, Ministry of Environment

<u>Note</u>: Forecasts for the 5 sub-areas assume the forecast growth rate of the total plan area also applies to each sub-area.

CHAPTER 2. SURFACE WATER AND GROUNDWATER SUPPLY

2.1 SURFACE WATER SUPPLY

2.1.1 INTRODUCTION

This chapter contains a discussion on surface water availability in the Cowichan-Koksilah River basin. As detailed below and in Appendix 2.1, water supply was estimated using several methods, and those estimates considered to be the most accurate representation of water supply are presented in this chapter, and used in the rest of the plan for comparisons to present and projected water use.

On eastern Vancouver Island, low annual flows have historically occurred during the June to October period, with most annual minimum daily discharges recorded during the last three weeks of August and the first two weeks of September (Environment Canada, 1983). Low flows are also traditionally recorded in southern Vancouver Island rivers several weeks earlier than those further north on the Island. Most water use shortages therefore occur during the June to October low flow period. This period coincides with irrigation water use, which usually peaks during the month of August. For these reasons, the June to October period was selected as the critical time for water supply analysis in the Cowichan- Koksilah River basin.

2.1.2 SUPPLY ESTIMATES

The minimum 7-day average flow (hereinafter referred to as 7-day low flow) was selected for water supply estimates for two main reasons. First, 7-day average low flows (usually at the 5-year recurrence interval) have been used by Vancouver Island Region for the past 5 to 10 years to estimate water supplies for allocation (water licensing) purposes. The 7-day average low flow is believed to be a reasonable estimate (as compared to daily low, average monthly, or average annual flows) of water supply to use in assessing water licence applications, and to mitigate and resolve conflicts between instream requirements and other water uses.

Second, 7-day average low flow statistics for Water Survey of Canada hydrometric stations in British Columbia with 5 years or more data up to 1971 (June - September 7-day averages) and up to 1972 (annual 7-day averages) have been published by the Federal Government and are readily available for use in estimating water supplies.

However, it should be noted that 7-day low flows cannot be statistically extrapolated with confidence for streams with 5 years or less of records. It is also difficult to estimate the spatial distribution of flows in ungauged watersheds since low flows are strongly influenced by surficial geological characteristics which cannot be readily incorporated into an estimation technique.

Monthly flows are a good indicator of the effects of regulation and storage. As a result, a monthly hydrograph (Figure 2.1) for the Cowichan River is presented. This hydrograph indicates that, although there are shortages during certain summer periods, water is available for storage.

In the sections that follow, 7-day low flows are estimated using the Water Survey of Canada data, regionalized flows based upon WSC gauge data, Water Allocation Section (Nanaimo) data including miscellaneous low flow measurements in the field, and Cowichan mainstem flows based upon gauge data at the Cowichan Lake weir.

2.1.2.1 Regionalized 7-Day Low Flow Estimates

In order to facilitate the estimation of 7-day low flows, the data records for 32 hydrometric stream gauge sites on Vancouver Island were chosen, the 7-day low flow extracted, and the flow "naturalized" by adjusting the flow to account for the licensed quantities upstream of the gauge location. Statistical frequency analysis was performed using the

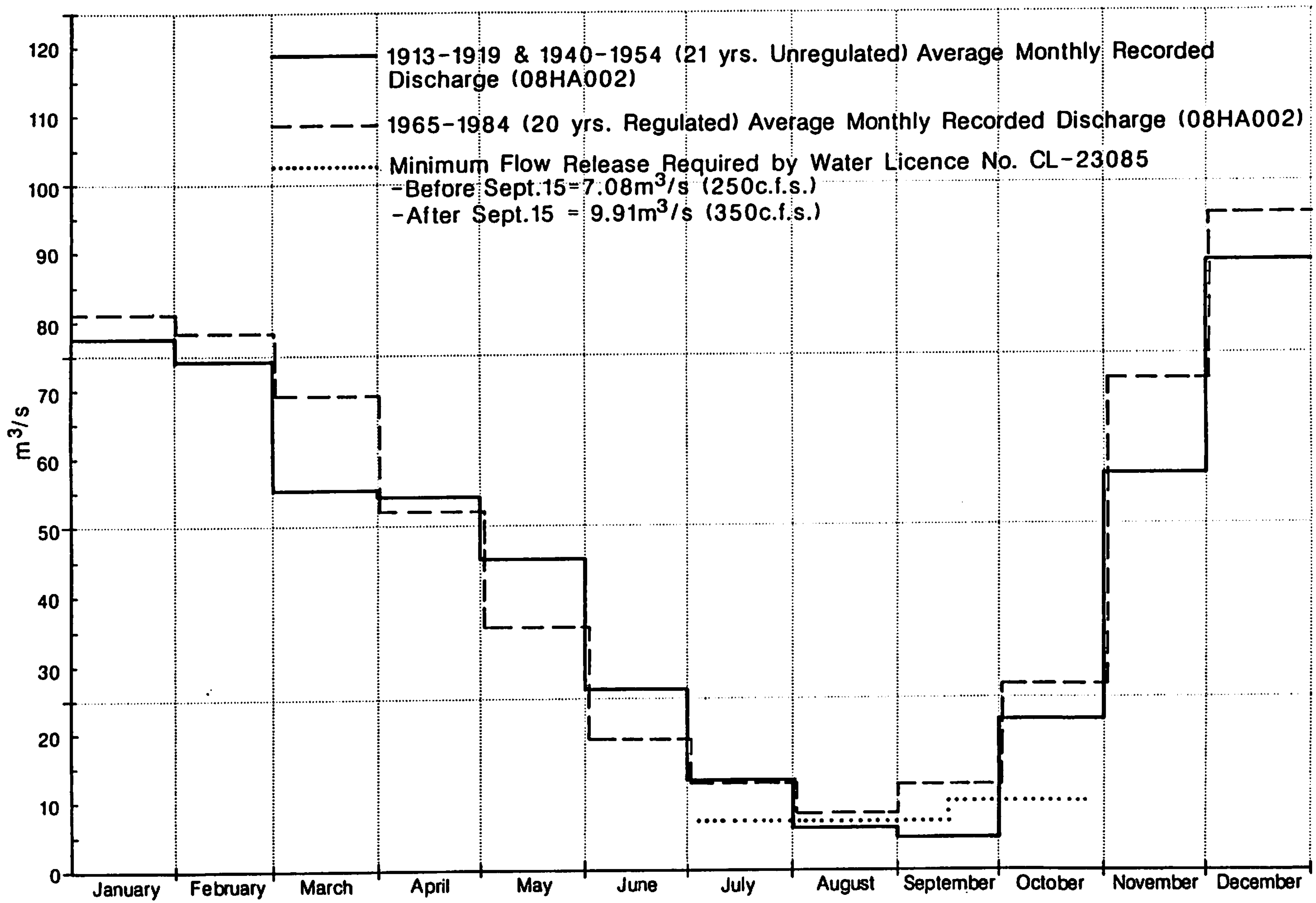


FIGURE 2.1 Cowichan River at Lake Cowichan - Effect of Storage and Flow Regulation on Discharge.

naturalized data to estimate the mean, 5, 10 and 20-year recurrence interval 7-day low flows, with the 95% confidence limits for each stream. The estimates for each recurrence interval were then compared to corresponding drainage areas of the stream gauges in order to establish a relationship between 7-day low flows and drainage area. Statistical regression analysis was used to calculate a regression line equation of 7-day low flow versus drainage area and the corresponding 95% confidence limits. (For a more detailed description of this analysis, see Appendix 2.1.)

For the Cowichan-Koksilah Plan, if a water analysis location of the Plan approximately corresponded with one of the hydrometric stream gauge sites, the statistical frequency analysis of the site data was considered to be the best estimate of the 7-day low flows for the mean, 5, 10 and 20-year recurrence intervals and 95% confidence level (e.g. Bings Creek, Averill Creek, Koksilah River, and Cowichan River). Where the analysis location for the Cowichan-Koksilah Plan does not correspond with one of the 32 hydrometric stream gauge sites, the drainage area above the analysis location was used in the regression equations to calculate the (regionalized) 7-day low flows and confidence levels. The results are presented in Appendix 2.1.

2.1.2.2 Water Allocation Section Flow Estimates

In order to assess how the regionalized 7-day low flow estimates compare with Water Allocation Section's existing supply analysis methods, water supply analysis was done for 13 of the 25 analysis locations using the Water Allocation Section's methodology. Water Allocation Section attempts to estimate the average 7-day low flow 5-year recurrence water supply, by using existing data within the watershed or adjoining watersheds. No adjustment is made for upstream use. Where sufficient data (5+ years) are available on the source (e.g. Bings Creek), the 7-day low flows are manually selected from the data, the plotting position is calculated, a plot is made of flow versus recurrence on log-normal or log-Gumbel paper, a straight line is estimated to fit the points plotted, and a 5-year recurrence 7-day low flow selected from the plotted line. Where insufficient data or miscellaneous flow data are available (e.g. Patrolas Creek), these data are compared with data from a similar period of time on the nearest comparable basin with a longer term record for which the 7-day low flow 5-year recurrence is known. The unknown 7-day low flow 5-year recurrence is calculated from the known 7-day low flow. Where no flow data are available (e.g. Bear Creek), a 5-year recurrence 7-day low flow unit yield is estimated from nearby hydrometric stream gauge stations and multiplied by the drainage area.

As the 1985 summer proceeded, it became apparent that it would be a significant low flow event. A program was initiated to measure and observe these low flows. Although all flows have not yet been analyzed, indications are that the 1985 low flows may represent between a 1 in 5 year (Chemainus River, September 6 to 10 7-day low flow) to a 1 in 40 year (Bings Creek, September 7 to 13 7-day low flow) low flow event. Preliminary 1985 low flow measurements are noted in the Water Allocation Section's table of estimates in Appendix 2.1. It should be noted that these represent residual flows, i.e. the water remaining following licensed extractions.

2.1.2.3 Cowichan River Flow Estimates

For the hydrometric station Cowichan River at Lake Cowichan 08HA002, the regulated flows during 1965 to 1983 were also analyzed and the results are presented in Appendix 2.1. These regulated flows (minimum 7-day average discharge from June 1 to September 30) represent the results of the operating procedure (see Appendix 3.6) being used from 1965 to 1983 to control the volume of water stored in Cowichan Lake and to control the releases from the lake. Since the regulation is an established fact, these low flows can be expected to occur in the future unless a significant change is made in the operating procedure.

2.1.2.4 Summary of Best Low Flow Estimates

Assessment of estimates derived through the various methods described above led to acceptance of those listed in Table 2.1 as being the "best" estimate available for each location. Some of the rationale for these choices is described in Section 2.1.3 (Conclusions) below.

TABLE 2.1
LOW FLOW SUPPLY ESTIMATES
(Minimum 7-Day Average Discharge for 5-Year Recurrence Interval)
AND METHOD OF DERIVATION

ANALYSIS LOCATION	SUPPLY ESTIMATE (m^3/s)	METHODOLOGY
1. Cowichan River System:		
Cowan Brook	0.003	Water Allocation Section
Cottonwood Creek	0.098	Water Allocation Section
Robertson River	0.257	Water Allocation Section
Cowichan R. at Cowichan L. Outlet	6.26	Storage Reg./WSC Gauge
Stanley Creek	0.001	Regionalization
Cowichan R. at L. Cowichan STP[4]	6.27	Storage Regulation
Cowichan R. below Fairservice Ck.	6.31	Storage Regulation
Bear Creek	0.016	Regionalization
Cowichan R. above Holt Creek	6.42	Storage Regulation
Inwood Creek	0.025	Regionalization
Cowichan R. at Highway 1	6.56	Storage Reg./WSC Gauge
Cowichan R. at Duncan-N. Cowichan STP[4]	6.57	Storage Regulation
Cowichan R. at the Mouth	6.68	Storage Regulation
2. Somenos Creek System:		
Bings Creek	0.021	WSC Gauge
Averill Creek	0.011	WSC Gauge
Richards Ck. at Richards Trail	0.006[1]	Storage Reg./Regional.
Richards Ck. at Somenos L.	0.012[1]	Storage Reg./Regional.
Quamichan Ck. at Quamichan L. Outlet	0[2]	Water Allocation Section
Somenos Ck. at the Mouth	0[3]	Water Allocation Section
3. Koksilah River System:		
Koksilah R. above Grant L. Outlet	0.090	Regionalization
Patrolas Ck. at Hillbank Rd.	0.034	Water Allocation Section
Koksilah R. at Cowichan Station	0.276	WSC Gauge
Glenora Creek	0.008	Regionalization
Kelvin Creek	0.046	Regionalization
Koksilah R. at the Mouth	0.435	Regionalization

1 Includes release of 0.003 m^3/s from Crofton Lake during low flow season.
2 Zero flow occurs for 2.5 to 3.5 months each year.
3 Zero flow known to occur, but frequency and duration not known.
4 Sewage Treatment Plant.

Refer to Appendix 2.1 for detail.

2.1.3 CONCLUSIONS ON SURFACE WATER SUPPLY

2.1.3.1 Cowichan River System

The regionalized method does not appear to adequately estimate the 7-day low flows for streams that flow into Cowichan Lake. Observation on August 30, 1985 indicated that there was little or no flow in most streams observed below 200 meters elevation (e.g. Robertson River, Sutton Creek, Nixon Creek, Wardroper Creek). However, even on the smaller creeks, significant flow was observed above 200 meters elevation. Of particular note were Cowan Brook and Croft Creek which exhibited dry creek channels at the road, but small water supply pipelines running up the creeks were supplying water to residents at Cowan Brook and a campground at Croft Creek. Estimated flow upstream near the intake on Cowan Brook was between 0.006-0.009 m^3/s. Indications are that all or most of the flow in the streams that flow into Cowichan Lake disappears underground into the gravel fans at their mouths during low flow periods. Therefore, the only reasonable estimate of water supply from these streams is from measurements or observations at the head of the fan, such as those taken at Cottonwood Creek. Water Allocation Section's water supply estimate, based on the unit yield of unregulated outflow at Lake Cowichan, may provide a reasonable preliminary estimate of water supply on these streams.

The water supply in the Cowichan River downstream of Cowichan Lake is based on the WSC gauge at Cowichan River at Cowichan Lake outlet. The average monthly supply hydrograph in Figure 2.1 demonstrates the effect that regulation at the lake has had on the supply in the river.

On streams tributary to the Cowichan River (Stanley Creek, Bear Creek and Inwood Creek), the regionalized method is the accepted estimate of the water supply (7-day low flow) as indicated by measured flows in 1985 on Stanley Creek.

2.1.3.2 Somenos Creek System

For Bings Creek and Averill Creek, the regionalized flow estimate (as it uses the naturalized WSC flow data on these sources) is accepted to be a reasonable estimate of the water supply in these streams. The Water Allocation Section's estimates have not been naturalized to account for the licensed requirement from the source.

Richards Creek low flows are to some extent regulated by storage on Crofton Lake, and depend upon the regulation of releases from the lake. Half of the flow at Richards Trail is assumed attributable to storage releases during the low flow season. It should be noted that in dry years, the flow in Richards Creek is fully attributable to storage releases from Crofton Lake.

Somenos Creek low flows are affected by natural storage in Somenos Lake. Due to backwater effects from the Cowichan River, there is no simple correlation between lake levels and streamflows. During the low flow season, a zero flow is known to occur, but its frequency and duration are not known.

Quamichan Creek low flows are affected by storage in Quamichan Lake. Records indicate that there is zero flow in Quamichan Creek for 2 1/2 to 3 1/2 months (August to mid-October) each year.

The 7-day low flow estimates do not adequately assess water supply in Somenos, Quamichan and Richards creeks due to natural and man-made regulation of lake levels. The supply may be more adequately assessed in terms of lake volumes, lake levels and average inflows to the lakes (i.e. average monthly hydrographs).

2.1.3.3 Koksilah River System

Patrolas Creek low flows do not appear to be adequately estimated by the regionalized method. Old miscellaneous flow records (1964 and 1965) indicate much larger low flows. Natural storage in Dougan Lake and swamps adjoining the creek may provide a larger low flow than indicated by this method. The Water Allocation Section estimate is accepted as a better preliminary estimate of water supply for Patrolas Creek.

For Glenora Creek, Kelvin Creek and the Koksilah River, the regionalized method is accepted as a reasonable estimate of the water supply (7-day low flow).

2.1.4 CONCLUSIONS

Due to the variety of methods used and given the limitations associated with these methods, the supply estimates should be used cautiously when drawing conclusions about available water supply as compared to current water use or projected water demand.

Further refinement of the regionalization techniques employed to derive supply estimates for ungauged stream sites, as well as expansion of the network of stream gauge stations and development of methods to account for storage regulation, would lead to better water supply estimates.

It is recommended that low flow estimation methods be further developed for computer-based assessment of surface water supplies.

2.2 GROUNDWATER SUPPLY

2.2.1 INTRODUCTION

This section, which evaluates groundwater supply within the Cowichan-Koksilah plan area, also addresses the interrelationship between groundwater and surface water, particularly in the lower Cowichan River area. For a more detailed assessment of the groundwater resource, refer to Appendix 2.2.

2.2.2 GROUNDWATER POTENTIAL ASSESSMENT

Based on available well record data, various hydrogeological reports and the surficial geology of the area, Figure 2.2 shows the general extent of the major groundwater aquifers and the relative degree of groundwater potential within the study area. The locations of wells with reported USgpm yields between 25 USgpm and 2,000 USgpm are plotted within these outlined areas.

The most productive aquifers are those outlined as areas underlain by confined and/or unconfined aquifers with known good groundwater potential. One of these areas of good groundwater potential lies southeast of Duncan. An analysis of water level data (between 1975 and 1982) from Provincial observation wells located southeast of Duncan along the Cowichan River indicates that production well pumping in the area has not caused any declining trends in local groundwater levels for the period of record. With the exception of very minor interference drawdown effects between wells, it appears that there is no "mining" of groundwater occurring in this area as a result of production well pumping. This suggests that the aquifer in the vicinity of the lower Cowichan River may be capable of supplying more groundwater to additional production wells. However, before additional production wells for Duncan's future municipal water supply or any other major use could be considered, a more detailed hydrogeologic investigation of the area immediately around the present production wells is recommended.

Near the mouth of the Cowichan River, there are some very productive large-diameter wells with reported yields between 1500 USgpm and 1865 USgpm. In the immediate area of these wells there are also several smaller diameter (6-inch) flowing artesian wells with estimated flows up to approximately 400 USgpm. It appears that this area is underlain by a significant confined groundwater reservoir, and that there is good potential for further groundwater development. A more detailed site-specific hydrogeologic assessment would be required to ascertain the extent of the groundwater potential in this area.

Figure 2.2 also outlines areas underlain by confined and/or unconfined aquifers with known moderate groundwater potential (i.e., limited potential for agricultural or municipal use). These areas were identified on the basis of available well record data (i.e., wells completed in sands and/or

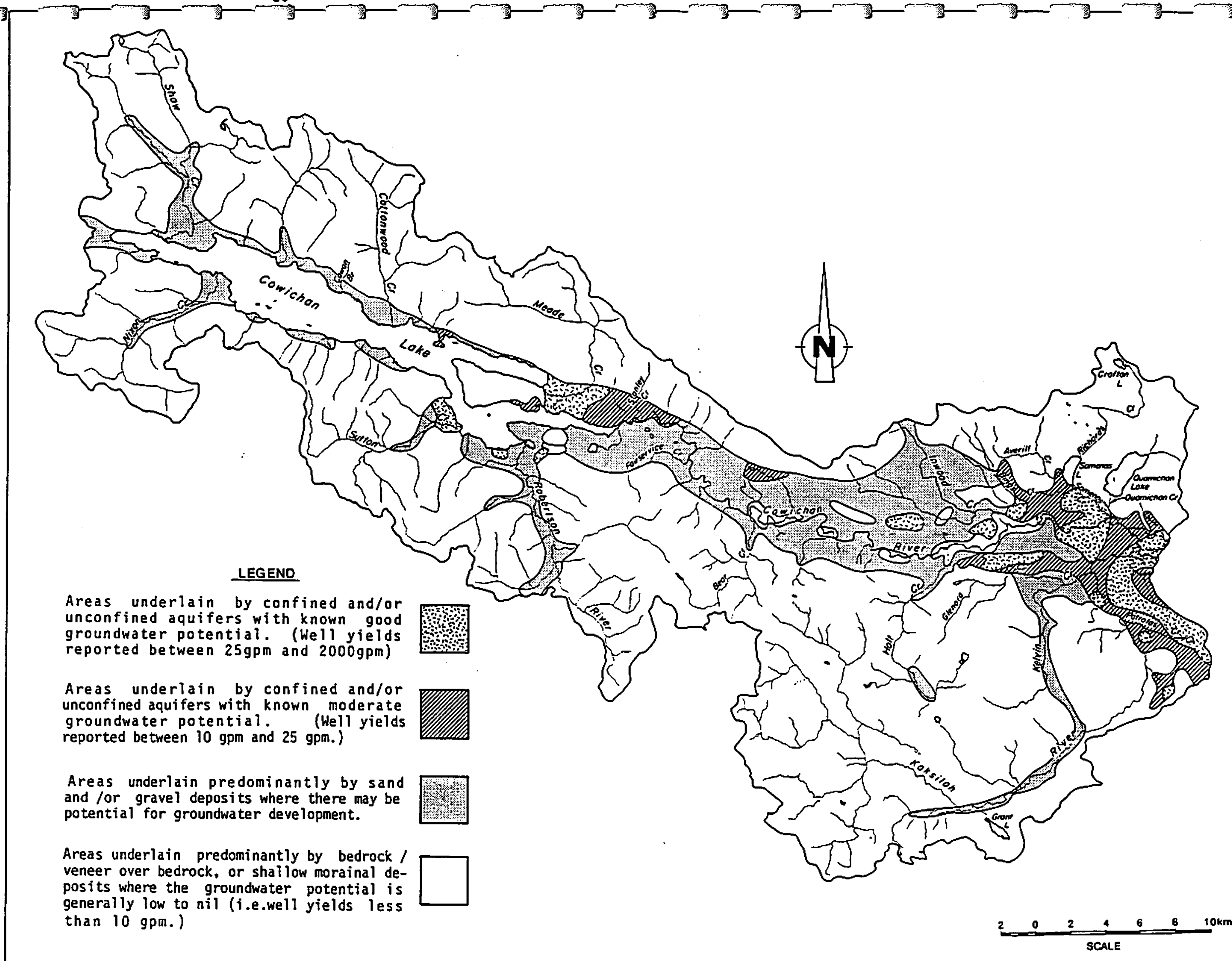


FIGURE 2.2 Groundwater Potenial.

gravels, having reported yields between 10 USgpm and 25 USgpm) and surficial geologic considerations. Well record analysis indicates that many wells within these outlined areas, although indicating yields of up to 25 USgpm, could have produced higher yields if the wells had penetrated the entire aquifer, and/or larger diameter wells were constructed and larger pumps installed, and/or better screen design was utilized. In other words, the groundwater potential for agricultural, domestic or municipal use could be greater than indicated (i.e., well yields in the order of hundreds of gallons per minute). The amount of further groundwater withdrawal that may be available from these aquifers is not fully known and may require detailed, costly studies to complete.

The third type of area in Figure 2.2 is underlain predominantly by sand and/or gravel deposits (as determined from surficial geology only), where there may be potential for groundwater development. Since there is little groundwater data available for these areas, it is difficult to ascertain the amount of groundwater that may be available. Further data by way of test wells, pumping tests, etc., would be required to assess the situation. Preliminary indications, however, are favourable for domestic supplies, and limited for agricultural or municipal supplies (i.e., well yields up to 50 USgpm).

The remaining map areas are underlain predominantly by bedrock or veneer over bedrock, or shallow morainal deposits in which the groundwater potential is generally low to nil. Wells completed within the bedrock areas have reported yields generally less than 10 USgpm. Some higher yielding wells (to about 50 USgpm) have also been reported, however, their sustained long-term yields have not been proven. Groundwater investigations for municipal or agricultural uses within these areas are not recommended. For domestic purposes, the groundwater potential may be adequate.

2.2.3 SURFACE WATER-GROUNDWATER INTER-RELATIONSHIP

Surface water-groundwater inter-relationships are difficult to assess. However, a study was conducted in 1975 to evaluate, among other objectives, the effects of major groundwater withdrawals on the flows in the Cowichan River (Foweraker, 1976). The study found: the presence of three distinct aquifers; a similarity in groundwater level and river level hydrograph curves for observation well and Cowichan River water level, suggesting that there is a good hydraulic continuity between the Cowichan River and the "middle aquifer"; and that groundwater withdrawals are expected to affect river flows to some extent, however, the exact relationship will not be known until production wells are utilized over a long term and the records analyzed.

To date, the effects on flows of the lower Cowichan River of major groundwater withdrawals by the City of Duncan's four production wells (estimated maximum withdrawal at 7,000 USgpm) and the District of North Cowichan's four production wells (estimated maximum withdrawal at 5,500 USgpm) have not been analyzed. In order to ascertain the present effects of groundwater withdrawals on the lower Cowichan River flows, a more detailed assessment of existing data is required to indicate the extent of surface water and groundwater inter-relationships.

Due to a lack of data elsewhere along the Cowichan and Koksilah Rivers, it is not known whether groundwater withdrawals from wells located along these rivers is affecting low flows. However, the amount of groundwater withdrawals from these wells is not as great as in the area southeast of Duncan (based on available data) and it is expected that surface water-groundwater conflicts will not be significant in the short term. If surface water supplies are fully allocated (i.e. licensed), however, in the short term, there may be potential for surface water-groundwater conflicts if aquifers, which are hydraulically connected to surface waters, are further developed.

2.2.4 CONCLUSIONS ON GROUNDWATER SUPPLY

Analysis of groundwater supply in the plan area indicates that there is potential for further development of the groundwater aquifers, with potential well yields of up to 2,000 USgpm.

The higher-yielding aquifers tend to be located at the mouths of major rivers or streams, while the lower-yielding aquifers tend to be located in areas of bedrock or shallow morainal deposits. Aquifers in the vicinity of the lower Cowichan River appear to have further potential for development. Preliminary hydrogeological studies indicate that there is direct hydraulic continuity between the Cowichan River and middle aquifer. However, further development of the aquifer may lead to problems in the management of surface water supplies in the lower Cowichan River.

CHAPTER 3. WATER USES

INTRODUCTION

In parallel with Chapter 2, which provided estimates of water supply at a number of analysis locations, the purpose of this chapter is to describe for the same locations, in terms of both quantity and quality, the current water uses in the Cowichan-Koksilah plan area and projected increases in water use over a 5-year period. The framework used to allocate and manage water is also discussed. In broad terms, the water uses described below are divided into two categories. Instream uses include fisheries (3.2.1), recreation (3.2.2), waterfowl (3.2.3), and waste dilution (3.2.4). Licensed water uses include estimates of actual water use (Section 3.3) and groundwater use (Section 3.4).

3.1 CURRENT WATER ALLOCATION AND MANAGEMENT PROCEDURES

In British Columbia, the Water Act is the principal instrument for allocating and regulating a public water resource among public users. The Appropriation Doctrine is the main aspect of the Water Act. Some of the more important elements of this appropriative water law include: the authorization of the use and diversion of surface water of a particular stream at a specified rate and/or volume at a designated location; the exercise of water rights only in the pursuit of some defined beneficial water purpose; the allocation takes precedence according to date of application; and most licences issued remain in effect unless abandoned by the licensee or cancelled for cause as defined in the Water Act.

The Water Act also allows for limited management of the water resources of the province. This can be achieved through: amendments to existing water licences under Section 11 (issue of final licences), Section 13 (transfer of licence), Section 15 (amending licence), Section 16 (transfer of licence), and Section 17 (apportionment of rights); suspension and cancellation of water licences for cause under Section 20; penalties for offences under Section 41; reservation of water for potential or future use under Section 44; inspection, regulation, determination and ordering of changes to water use (or misuse) and the repair of damage done to the water resource under Section 37.

The issuance (or not) of a water licence is based on a preliminary analysis or estimate of supply versus existing demands (water available) on the source. However, more credence is given to the resolution of administrative and legal concerns and problems. Water licence applications are received and processed, in many cases without full knowledge of existing or potential water resource use. Fisheries, waste dilution and other instream requirements and uses are considered when and where other government agencies or interest groups voice objections to the proposed use. This is particularly the case with those agencies with other legislative responsibility for the management of a resource that is dependent upon the water resource (i.e., Fisheries and Oceans Canada and the Fisheries Act). As populations have increased, increases have also occurred in water demand, instream requirements for recreation, and environmental awareness. In total, these have created more administrative and legal concerns and problems and a corresponding increase in time, effort and backlog in resolving water licence applications. The present water allocation procedure does not lend itself to addressing future supply and demand or other resource values not represented by special interest groups, other than through Section 44 of the Water Act.

3.2 INSTREAM WATER USES - WATER QUANTITY AND WATER QUALITY

This section describes the instream uses of water in the plan area, including fisheries (section 3.2.1), recreation (3.2.2), waterfowl (3.2.3) and waste management (3.2.4). As far as possible, an assessment is made for each instream use of the amount and quality of water required to support that use.

3.2.1 FISHERIES

3.2.1.1 Introduction

As outlined in Chapter 1, the four major fisheries issues related to water management are streamflow needs, water quality, angler access and habitat damage. It is important to address these issues because of the high commercial and sportfish value of this fishery.

The Cowichan River system, including the Koksilah River and tributaries, is considered one of the most valuable and productive salmon and trout streams on Vancouver Island. The major fish species present in the Cowichan-Koksilah system are coho, chinook and chum salmon; steelhead, rainbow and brown trout; resident and anadromous cutthroat trout; Dolly Varden char and kokanee. Until recently, this system consistently provided the greatest number of angler days and largest total catch of any Vancouver Island stream. Coho and chinook produced by this system provide an annual commercial and sportfish harvest of approximately 250,000 fish with an annual value of approximately $3.5 million (see Table 3.1). Present discounted values of the annual salmon catch (coho, chinook and chum) from the Cowichan-Koksilah River system, using a discount rate for social benefit/ cost purposes within the range of 5% to 10%, are estimated to be between $44 million and $87.8 million (B. Tutty, Department of Fisheries and Oceans, 1985).

The steelhead fishery in this system provides over 8,500 angler days annually with an estimated value of about $220,000 (Department of Fisheries and Oceans, 1985). In addition, a unique brown trout fishery exists during the summer months on the Cowichan mainstem. Freshwater sportfish values on the Cowichan-Koksilah system have been estimated at over $650,000 (Reid, 1986). Cowichan Lake, supporting between 10,000 and 15,000 angler-days annually, is the most heavily fished large lake on Vancouver Island and is the Region's most important recreational fishing lake (Reid, pers. comm.).

TABLE 3.1
FISHERIES RESOURCES
COWICHAN-KOKSILAH RIVER SYSTEM

Species	Major Watercourse Habitats	Adult Escapement	Angler Days[1]	Angler Day Value (1982$)	Catch	Catch/ Angler Day	Sport Fish Harvest[2]	Commercial Harvest	Sport Fish Value[2] (1982$)	Commercial Value (1982$)
Coho[3]	Cowichan R.	37,470)	) 1,800	42,516	-		70,000	98,800	903,500	1,068,600
	Koksilah R.	6,150)			-		11,000	16,700	456,000	175,500
Chinook[3]	Cowichan R.	6,100)	) 1,500	34,430	-		13,000	20,600	425,700	640,200
	Koksilah R.	470)			-		1,000	1,600	40,000	49,500
Chum[3]	Cowichan R.	71,050	-		-			42,600		578,200
	Koksilah R.	4,400	-		-			2,600		36,400
Steelhead[4]	Cowichan R.	3,100	7,600	179,512	2,100	.28	900		210,000	
	Koksilah R.	1,300	900	21,258	200	.22	100		9,000	
Brown Trout[4]	Cowichan R. (Holt, Bear, Hatchery, Bings)	3,800	3,000	70,860	1,500	.5	300			
Searun Cutthroat[4]	Cowichan R. (Holt, Somenos, Bings)	1,900	500	11,810	250	.5	Minimal			
	Koksilah R. (Glenora, Kelvin)	1,800	100	2,362	50	.5	Minimal			
Resident Cutthroat, Rainbow, Kokanee[4]	Lake Cowichan		10,000-15,000	295,250						
TOTALS		137,540	27,900	$659,000	4,100		96,300	182,900	$2,044,200	$2,548,400

NOTE: Approximately 80% of angler-days are from resident anglers.

[1] Freshwater only
[2] Freshwater and saltwater
[3] Escapement estimates from Department of Fisheries and Oceans Spawning Escapement Records, averaged from 1973-1982.
[4] Escapement estimates provided by S. Hay, Provincial Fisheries Biologist, 1984

Cowichan Lake provides a stabilizing influence to the Cowichan River by moderating streamflows (particularly in upper reaches), silt loads, water temperature and nutrients. The Koksilah River, however, is subject to more extreme high and low flows as well as naturally-occurring high levels of sedimentation during the winter. As a result, fisheries resources in the Koksilah are more limited in variety and in numbers (see Apppendix 3.1).

3.2.1.2 Streamflow Needs for Fish

Relative to water management, the major issue concerning the fisheries resource is the provision and maintenance of adequate streamflows during the summer months for various portions of the life cycle (migration, spawning, incubation and rearing). Excessively low streamflow limits the wetted perimeter which reduces the habitable area. This eliminates important side channels causing fish to perish or stranding fish in isolated pools or shallow channels. The fish then become subject to a variety of stresses including high water temperatures, reduced oxygen, increased predation and poaching, etc. Low summer streamflows are directly related to declining fish productivity and survival.

An additional flow-related concern for anadromous fisheries management on the Cowichan mainstem concerns flow levels in the April to as late as mid-May period. During this time, salmon eggs that were spawned in areas of adequate late-fall flows have hatched. If water levels by April-May have declined, the alevins become trapped in the gravels which, although supplied with percolating subsurface flows, are not covered with enough water to permit them to reach the main river channel. A single 24-hour flushing flow released from Cowichan Lake during April-May could lead to considerably increased alevin survival, but may adversely affect recreational use of the fishery.

Fishery flow estimates (see Appendix 3.2) for eighteen analysis locations in the plan area are presented in Table 3.2. Three of the estimates

TABLE 3.2

ESTIMATED FISHERY FLOW REQUIREMENTS FOR THE COWICHAN-KOKSILAH RIVER WATERSHED

ANALYSIS LOCATION	BASIN AREA (km^2)	FISH FLOW REQUIREMENT[1] (m^3/s)	METHOD	HABITAT[2]
1. Cowichan River System:				
Cowan Brook	1.1	.01	Cross-section	L/L
Cottonwood Creek	39	.07	Cross-section	H/M
Robertson River	102	.17	Cross-section	H/H
Stanley Creek	4.8	.03	Cross-section	H/-
Cowichan R. below Fairservice Ck.	636	7.08	Regulated	H/-
Bear Creek	29	0.06	Cross-section	H/H
Cowichan R. above Holt Creek	717	7.08	Regulated	H/-
Inwood Creek	20	.04	Cross-section	
Cowichan R. at Highway 1	827	2.83	Regulated	H/-
2. Somenos Creek System:				
Bings Creek	15	.01	FLAP	H/H
Averill Creek	17	.01	FLAP	L/L
Richards Ck. at Richards Trail	11.3	.05	Toe-Width	H/H
Quamichan Ck. at Quamichan L. Outlet	17	.06	Toe-width	M/H (lake)
Somenos Creek at the Mouth	85.9	.06	Toe-width	M/-
3. Koksilah River System:				
Koksilah R. above Grant L. Outlet	117	.34	FLAP	H/H
Patrolas Ck. at Hillbank Rd.	8.4	.03	Cross-section	L/L
Koksilah R. at Cowichan Station	224	.42	Tutty (1985)	H/-
Glenora Creek	19	.03	Tutty (1985)	H/-
Kelvin Creek	56	.07	Tutty (1985)	H/H

[1] Flow required to provide habitat to sustain life phase of species in the area.

[2] Rating of accessible/inaccessible summer rearing capability for salmonids (see Appendix 3.1) H = high, M = moderate, L = low, - indicates none.

were derived using a late-summer habitat area vs. flow relationship (FLAP[1] data). Three used single cross-section vs. flow data (Tutty, 1984). The Cowichan River fisheries instream requirement is estimated to be the minimum flow release at Lake Cowichan (250 c.f.s. = 7.08 m^3/s), and the minimum flows which must be allowed to pass B.C. Forest Products' intake at Duncan (100 c.f.s. = 2.83 m^3/s), as specified in the water licences and "operation rule".

Those noted as "cross-section" were examined during the low-flow summer of 1985 in the field by the regional federal and provincial fisheries staff and the hydrologist from the regional Water Management staff. Fishery flow requirements were estimated after selecting a suitable portion of a stream, surveying the designated cross-section, and measuring the existing flow. An estimate was then made of the water level required above which the wetted perimeter would not be substantially increased, but below which the wetted perimeter and therefore fisheries habitat would be significantly reduced. This water level was then estimated as a percentage of the flow at the time of field inspection, and the fishery flow requirement was in turn estimated.

A subsequent joint meeting in October 1985, led to some modifications of estimates for fisheries requirements. However, it should be recognized that regardless of the method by which fisheries flows were estimated, each is appropriate for only one specific location on the stream, and upstream or downstream requirements may vary depending upon stream morphology at any other location on the same stream.

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[1] Flow Limitation Assessment Program.

In each case, an estimate of required fishery flow was also made with the Washington State technique of Swift III (1979)[1] which uses the toe width of the channel to estimate flows required to cover the channel bed.

The generalized relationship between streamflow and fisheries habitat is illustrated in Fig. 3.1. Flows specified are those required to sustain a population which is less than optimum and higher than extinction.

3.2.1.3 Water Quality for Fisheries

Inadequate streamflow can also affect water quality in the stream (see Section 3.2.4) because inadequate waste dilution occurs when streamflows fall below designated minimum levels. Water quality criteria for aquatic life are shown in Table 3.3; however, it should be noted that these are generalized provincial guidelines, and specific water quality objectives for the plan area may differ. Fish species may also be stressed by sub-lethal amounts of toxic substances, and these effects can be further aggravated by combined pollutants. In addition, habitat may suffer various types of degradation because of accelerated eutrophication, etc.

3.2.1.4 Angler Access

Angler access difficulties may be caused by low streamflows or low lake levels on Cowichan Lake. It may be difficult for anglers to reach fishing areas when streambeds or lake edges covered by aquatic plants are exposed. Also, angler opportunities may be limited by reduced availability of those species particularly sensitive to stresses resulting from low streamflows.

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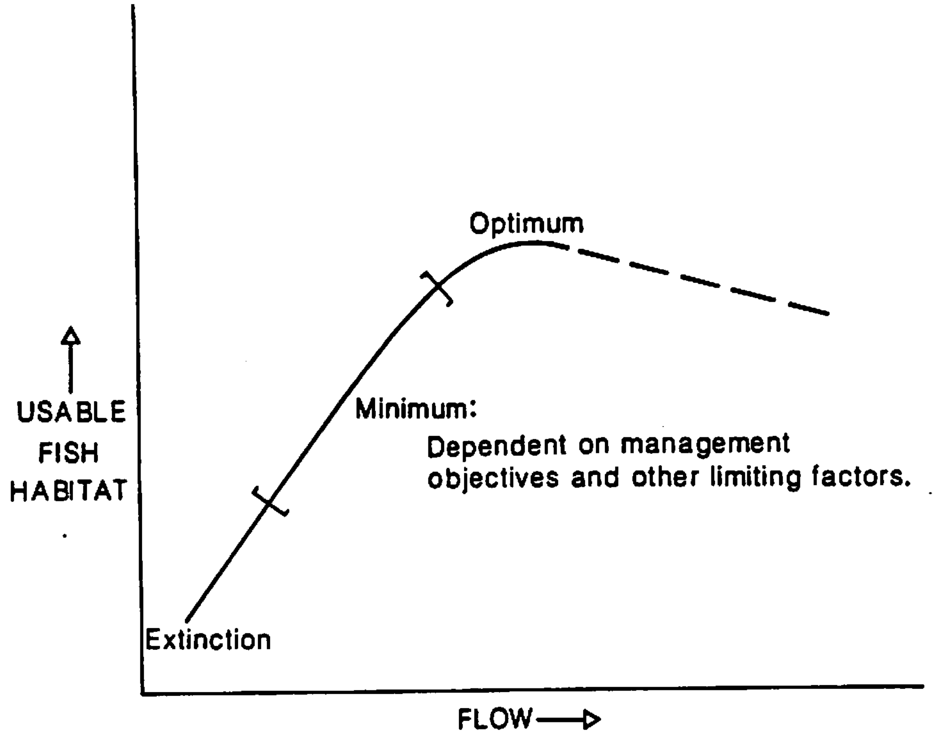
[1] Swift III, C. H. 1979. Preferred Stream Discharges for Salmon Spawning and Rearing in Washington. U.S. Dept. of Interior, Geol. Survey. Open-file report 77-422. 51 pp.

Note that these estimates seem to be best for single thread channels in sediment transport equilibrium which do not contain wide side-channel bars from high winter flows.



NOTE : The curve describes net productive habitat per area of stream channel.

FIGURE 3.1 **Relationship between Stream Flow and Usable Fish Habitat Used to Specify Required Minimum Flow.**

TABLE 3.3
WATER QUALITY FOR AQUATIC LIFE

PARAMETER	WATER QUALITY CRITERIA
Dissolved Oxygen	5.25 - 7.25 mg/l (minimum)
Nitrogen-phosphorus ratio (inorganic ammonia and nitrate compared to orthophosphorus/soluble reactive phosphorus)	15:1 phosphorus must be examined as the limiting factor <5:1 nitrogen must be examined as the limiting factor.
Total Suspended Solids	Maximum increase of 10 mg/l when background is < 100 mg/l 10% increase when background is > 100/mg/l
Turbidity	5 NTU increase when background < 50 NTU 10% increase when background is > 50 NTU
Temperature	See Appendix 3.1

Source: Working Criteria for Water Quality, Ministry of Environment, April, 1985, unpub.

3.2.1.5 Fisheries Habitat Damage

Potential damage to fish habitat resulting from activities taking place in or about a stream is regulated through approval mechanisms and through the water licensing and referral process under the provisions of the Water Act. Appendix 3.1 (Table 3) identifies high priority areas of concern for fish habitat protection.

3.2.2 WATER-BASED RECREATION

3.2.2.1 Introduction

Given the increasing demand for consumptive water withdrawals and the potential for conflict between instream (e.g. water-based recreation) and licensed (e.g. agriculture) water users, it becomes important to identify flows and water quality needed to maintain water-based recreation in the Cowichan-Koksilah plan area.

3.2.2.2 Water-Based Recreation in the Cowichan-Koksilah

Water-based recreation is well represented in the Cowichan-Koksilah plan area. There are five provincial parks (Class A and Class C) scattered along the Cowichan and Koksilah rivers, whitewater canoe/kayak routes can be found in selected portions of the major rivers, and hiking trails are situated adjacent to reaches of the Cowichan River. In addition to the parks managed by the Provincial Parks Branch and Forest Service, regional, municipal and community parks are found throughout the planning area (Figure 3.2). The area also includes some commercial (e.g. private campgrounds) and public (e.g. Cowichan Footpath - Cowichan Fish and Game Association) service developments adjacent to rivers and streams.

Although no figures on recreational use or demand are available for the Cowichan-Koksilah plan area, it is estimated that recreational use is very high (pers. comm. M. Turner, Parks and Outdoor Recreation Division). Some parts of the Cowichan River are used for angling throughout the year for a variety of fish species. Kayakers and whitewater canoeists use the Cowichan River to the greatest extent during high water periods from late winter until water levels drop in the early summer. Since regulation of the Cowichan River flow began with installation of the weir at Cowichan Lake in 1956, the length of season of flow sufficient for kayaking/canoeing has been extended. Later in the summer, parts of the Cowichan River are popular for swimming and for travelling downstream in inner tubes.

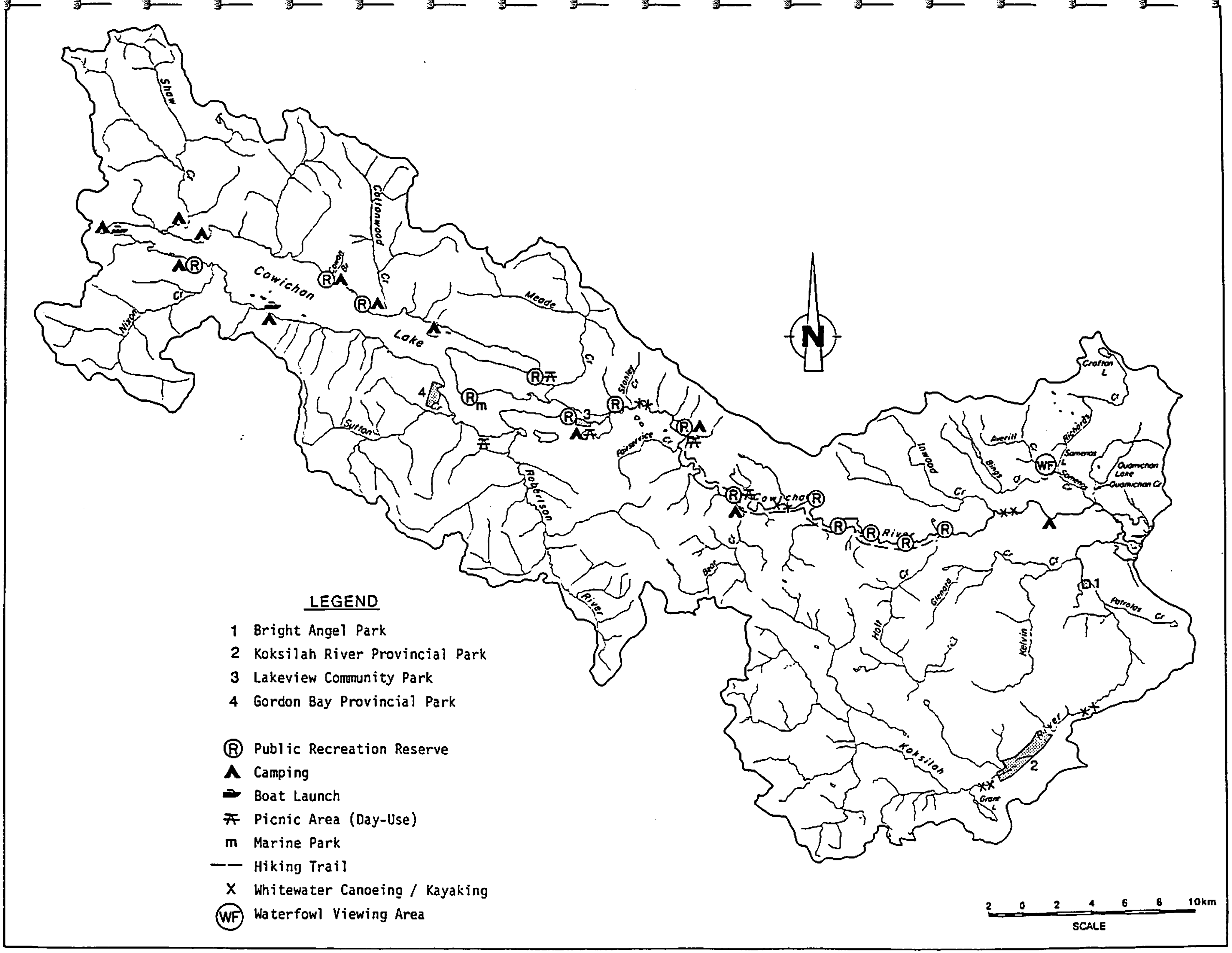


FIGURE 3.2 Recreational Areas.

The Outdoor Recreation Council (1977) rated the Koksilah and Cowichan rivers as provincially significant natural rivers that provide opportunities for kayaking, canoeing, hiking and fishing. The Cowichan River is one of the best known recreational fishing rivers on Vancouver Island due to the abundance and variety of desirable species (Outdoor Recreation Council 1977). Both the Cowichan and Koksilah rivers were rated as significant recreational trails that provided opportunities for hiking and horseback activities.

The importance of the Cowichan-Koksilah rivers was further emphasized by the Cowichan Estuary Task Force (1980) which described the lower end of the rivers as having very high ability to attract recreational use. The task force report also indicated that the rivers were of national significance for recreational activities.

Currently, in light of a recently prepared recreation corridor policy (Ministry of Lands, Parks and Housing, 1985), the Cowichan River has been categorized as a semi-primitive to roaded resource area. The purpose of such a category is to maintain the natural setting of the waterway environment for intermediate levels of recreational use. The more important objective of the Cowichan River Recreation Corridor is that the river should be free-flowing; however, minor alterations may be permitted provided that they do not detract from the natural qualities of the river environment. It has been indicated that the Cowichan River (adjacent Crown Lands only) has excellent park potential and may be considered as such by the Ministry of Lands, Parks and Housing within the next two years (pers. comm. M. Turner, Parks and Outdoor Recreation Division).

3.2.2.3 Minimum Instream Flows for Water-Based Recreation

Water-based recreation activities that are directly or indirectly related to instream flow requirements include: (1) instream recreation - fishing, swimming, wading, boating (canoes, kayaks), floating, waterfowl hunting/viewing; and (2) recreation adjacent to streams - camping, hiking, viewing, nature study, aesthetics. Maintaining participation in these activities is dependent upon certain instream flow requirements.

Flows (minimum desirable levels on rivers and lakes/reservoirs) for water-based recreation have not been identified for the Cowichan or Koksilah rivers, although techniques for determining instream flow needs for recreation have been developed elsewhere (Leopold 1969, Morris 1976) and may be applicable here.

In the absence of having specified flows for water-based recreation, it is assumed that flow requirements established for fisheries will also be suitable for some recreational purposes. It is recognized, however, that recreational areas may not coincide with fisheries areas.

3.2.2.4 Water Quality For Water-Based Recreation

Good water quality is one of the most important criteria associated with recreational use of a water resource (O'Riordan and Collins 1974, Parks 1973). Parameters of significance for water-based recreation include fecal coliforms (bacteria), phosphorus, colour, turbidity, pH, temperature, oil, scum and floating debris. Temporary ambient water quality criteria for each of these parameters are outlined in Working Criteria for Water Quality, Ministry of Environment, 1985. These will serve until they are revised or, each in turn, succeeded by permanent criteria following detailed study.

3.2.3 WATERFOWL

The most important waterfowl areas in the Cowichan-Koksilah basin are found adjacent to Somenos and Quamichan Lakes and in the drainage corridor downstream from these lakes to the Cowichan estuary (Canada Land Inventory, 1969). Somenos Lake, in particular, has prime migration, over-wintering and nesting areas used by Canada geese, swans, diving ducks and dabbling ducks. Other important migration and wintering areas are found in the lower Koksilah River, including Kelvin and Glenora Creeks, and Dougan Lake. Cowichan and Mesachie Lakes have severe limitations to waterfowl production due to various factors such as steep topography, reduced marsh edge, poor soil and water fertility and excessively deep or shallow water depths.

The most important time of year for waterfowl use is from September to mid-April when the heavy winter rainfall floods low-lying farmland in the vicinity of Somenos and Quamichan Lakes, providing extensive waterfowl habitat areas for migrating or wintering birds. To aid in the maintenance of winter water levels, Ducks Unlimited (Canada) have undertaken extensive enhancement of the waterfowl areas near Somenos and Quamichan Lakes and in particular, the area of the Nature Trust property near the Forest Museum. Since the summer period is much less critical for waterfowl use, reserving a minimum flow for waterfowl is not necessary. However, it should be recognized that the preservation of ponding areas and the maintenance of sufficient standing water in these areas during the winter months is very important to the waterfowl resources. Waterfowl are also not known to be substantially impacted by variations in water quality other than major oil slicks or other such unusual events.

3.2.4 WASTE MANAGEMENT

3.2.4.1 Introduction

Along with water quantity, ambient water quality should be one of the major considerations in any water management plan. Water quality has a direct impact on water use activities; a river or tributary may support either a wide or narrow range of activities depending upon the levels of ambient water quality. Since the Cowichan-Koksilah plan area supports a number of water-use activities which are affected by poor water quality conditions, such as fisheries, recreation and domestic use, the quality of water needed to maintain these activities will be very high.

In certain parts of the Cowichan-Koksilah area, inferior water quality conditions occur as a result of point and non-point source discharges. However, one of the major means of maintaining good water quality is through the provision of adequate flows for waste dilution. The purpose of this section is to identify flows which are necessary to maintain high ambient water quality in the plan area.

3.2.4.2 Effluent Permits in the Cowichan-Koksilah Plan Area

There are three Waste Management Permitted effluents that discharge directly into the Cowichan River (Figure 3.3, Table 3.4). Of these, the Village of Lake Cowichan Sewage Treatment Plant (STP), and the Duncan-North Cowichan STP have been identified as having the most prominent environmental impact on the Cowichan River (pers. comm. T. Oldham, Manager, Regional Waste Management, 1984) (Table 3.4). Both discharges contribute nitrogen and phosphorus which has resulted in enhanced filamentous green algal growth (chlorophyceae) to varying degrees, primarily during the summer months. For the Duncan-North Cowichan STP (PE 1497) it was observed that algal growth extended at least 1500 metres downstream of the discharge (memo from K. H. Austin to G. E. Oldham, Waste Management Branch, Oct. 7, 1985). Although the algal growth below the Duncan-North Cowichan STP is believed to be directly influenced by the effluent discharge from the STP, upstream nitrogen and phosphorus concentrations (from PE 247, PE 6603 and non-point sources) may be contributing to increased nutrient concentrations and enhanced algal growth. However, other environmental factors including light, temperature, water velocity and substrate also may have a significant influence on algal growth, in addition to the combined influence of nitrogen and phosphorous. Details of these permits and monitoring are given in Appendix 3.3.

There are no effluent permits discharging to water courses in the Koksilah watershed. However, there are discharges to land permitted under the Waste Management Act and the Health Act, as well as discharges from non-point sources such as agricultural operations and urban area runoff.

3.2.4.3 Ambient Water Quality of the Cowichan and Koksilah Rivers

Ambient monitoring sites are outlined in Figure 3.3. Due to the potential impact on water quality, ambient water quality monitoring is conducted in relation to discharges. (Data for a number of parameters have been collected for the period from 1972-1983. Ambient water quality data are contained in Appendix 3.4. For the purposes of this assessment, only 7 sites were found to have reasonable water quality monitoring data, which are listed in Appendix 3.5).

TABLE 3.4

PERMITS FOR DIRECT DISCHARGE INTO WATERS OF THE COWICHAN-KOKSILAH PLAN AREA

PERMIT NO.	NAME	TYPE OF DISCHARGE	TREATMENT REQUIRED	ENVIRONMENTAL IMPACT
PE 247	Village of Lake Cowichan	Sewage	lagoons (secondary treatment), chlorination, dechlorination	•detectable increase in Kjeldahl nitrogen and total phosphorus concentrations •enhanced filamentous green algal growth
PE 6603	Fisheries Branch, Ministry of Environment	Hatchery	direct discharge, no treatment	•limited sampling available; shows a very slight increase of ammonia and phosphorus and a small area of filamentous algal growth.
PE 1497	Duncan - North Cowichan Joint Utilities Board	Sewage	lagoons (secondary treatment), chlorination, dechlorination	•most prominent increase in nitrogen, phosphorus, coliform bacteria, oxygen demand, suspended solids •low summer flows are insufficient to ameliorate the effects of the effluent •enhanced filamentous green algal growth

Parameters showing reasonably consistent values, i.e. values tending not to vary over the period of monitoring, are given in Table 3.5. Comparison of these data with working water quality criteria suggests the following conclusions:

1. The Cowichan River has moderate sensitivity and the Koksilah River has low sensitivity to acidic inputs, as shown by alkalinity and calcium levels.

2. The Cowichan and Koksilah rivers have soft water, although in the Koksilah River water is somewhat harder, as shown by hardness levels.

3. Both rivers have moderate to high concentrations of total dissolved solids (as indicated by specific conductance) relative to Vancouver Island waters, but low relative to working criteria.

4. Both rivers are essentially neutral, having pH of 7.3.

For monitoring sites where parameter values were more variable, the following conclusions are suggested:

1. Both nitrogen and phosphorus levels increase from upstream to downstream in the Cowichan River, presumably the result of municipal effluent, septic tank discharges and other non-point sources from land. It should, however, be noted that both parameters increase naturally from upstream to downstream. The quantities of these nutrients are sufficient to have caused increased growth of green algae in various reaches of the Cowichan River, but in particular below the Duncan-North Cowichan STP. In the Koksilah River, significant increases of nutrients are also evident.

2. Fecal coliform levels in both the Cowichan and Koksilah Rivers exceed working criteria for shellfish located in Cowichan Bay, at the mouths of the rivers, and maximum values occasionally exceed

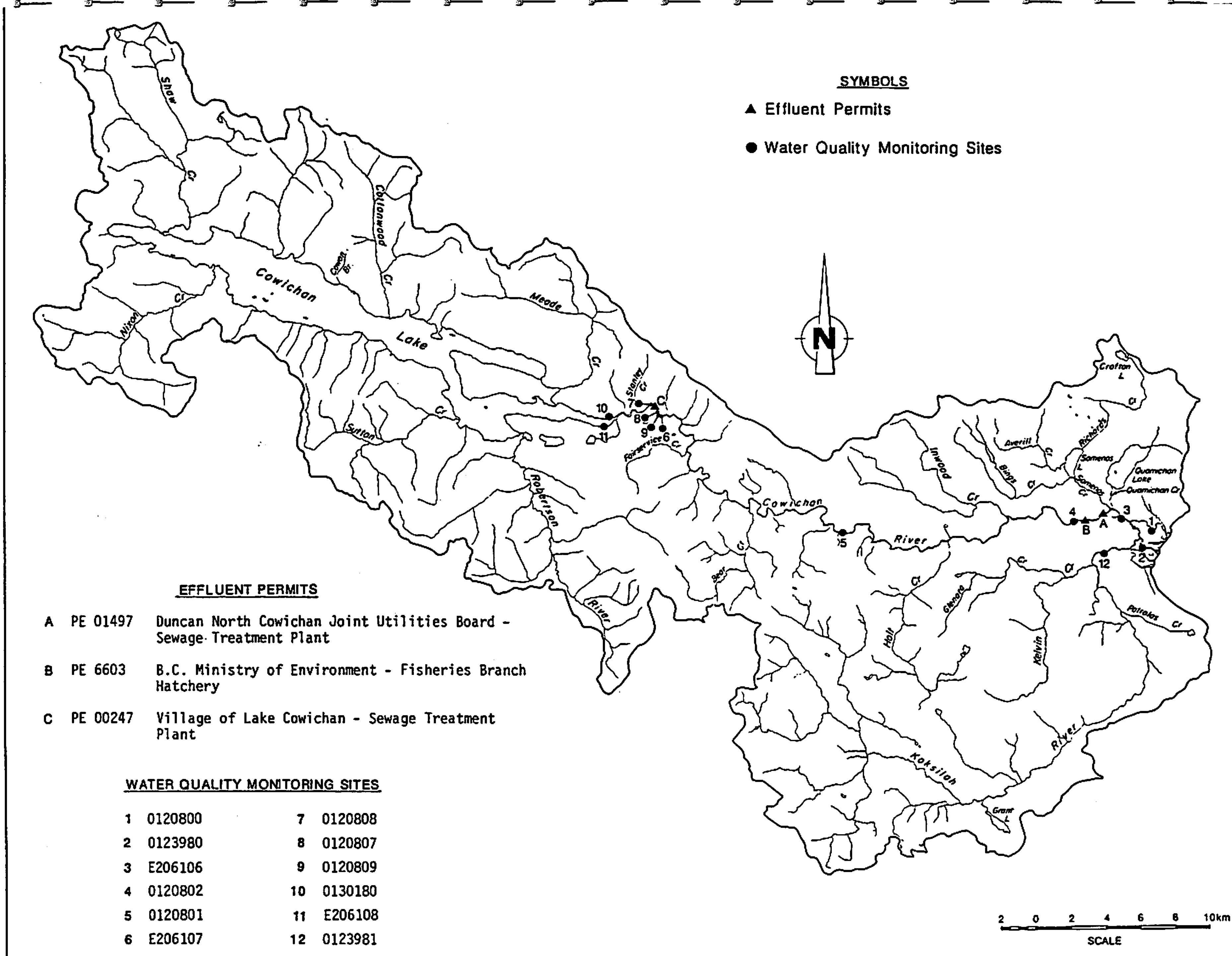


FIGURE 3.3 Effluent Permits and Water Quality Monitoring Sites.

bathing standards, although mean values are within the bathing criterion. It can be concluded these waters are usually safe for recreational use, but there is some health hazard to drinking untreated water. The high coliform levels, particularly in Cowichan Lake and the Koksilah River, are likely attributable to non-point domestic and/or agricultural sources.

3. The working criterion for copper is often exceeded in both the Cowichan and Koksilah watersheds. However, the values are only slightly greater than the criterion, presumably resulting from mined and natural ore bodies.

4. For other heavy metals, cadmium, lead and iron (possibly from ore bodies) have occasionally exceeded working criteria. Mercury and zinc have not exceeded the criteria.

3.2.4.4 Instream Flows Required for Effluent Permit Waste Dilution

For discharges to streams, rivers and estuaries, the dilution provided by the receiving water governs the degree of treatment which must be provided to the discharge; a lower dilution ratio dictates that a higher degree of treatment will be required. Dilution ratios are based on the lowest week's stream flow anticipated during the discharge period in an average year and the highest estimated hourly effluent discharge rate (both flows expressed in the same units).

The dilution ranges which govern municipal sewage effluent quality requirements are (i) ≥20:1 but <200:1, (ii) ≥200:1 but <2000:1, and (iii) ≥2000:1 (Ministry of Environment. Sept. 1975. Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia). If the receiving stream is used for recreation or domestic water extraction, discharge will be prohibited within the 20:1 to 200:1 dilution range, unless there is no feasible alternate solution. No discharge is normally allowed for dilution less than 20:1. Depending upon the parameter, the discharge should not cause any (or only negligible) increases in ambient levels of nutrients,

TABLE 3.5

AMBIENT WATER QUALITY FOR SELECTED PARAMETERS IN THE COWICHAN AND KOKSILAH RIVERS

PARAMETER	COWICHAN RIVER	KOKSILAH RIVER	WATER QUALITY (WORKING CRITERIA)[1]	USE
pH	7.3 ± .3	7.3 ± .3	5.0 - 9.0	Drinking Water-Raw State
specific conductance (μS/cm)	50 ± 4	106 ± 30	-	
alkalinity (mg/L)	19.0 ± 2	N/A	10-20 moderately sensitive to acid inputs >20 low sensitivity to acid inputs	Aquatic Life
hardness (mg/L)	21 ± 2	39 ± 2	80-100 desirable	Drinking Water
calcium (mg/L)	7	12.6	4-8 moderately sensitive to acidic inputs >8 low sensitivity to acidic inputs	Aquatic Life

[1] Pommen, L.W. 1985. Working Criteria for Water Quality. Ministry of Environment, Water Management Branch, Resource Quality Section.

coliforms, floatables and heavy metals in the receiving environment (Ministry of Environment. Sept. 1975. Pollution Control Objectives for Municipal Type Waste Discharges in British Columbia. Table 5.3. Receiving Water Quality Maintenance Objectives p. 28).

The dilution objective, based on the Pollution Control Objectives for Municipal Type Waste Discharge in British Columbia, for the Cowichan and Koksilah Rivers is $\geq$200:1 (pers. comm. T. Oldham, Manager, Regional Waste Management, 1985). That is, for parameters that are discharged into the receiving stream environment, the parameters should be sufficiently diluted at a ratio of 200:1. This dilution objective was set for BOD_5 and Suspended Solids, not for nitrogen or phosphorus, the parameters evidently resulting in algal growth in the Cowichan River.

1. Duncan-North Cowichan Sewage Treatment Plant

As the Duncan-North Cowichan STP (PE 1497) has been identified as contributing to increased algal growth on the Cowichan River, the following discussion illustrates the amount of flow required to maintain adequate dilution rates so as to minimize the environmental impact of the discharge (Table 3.6).

The effluent permit for the Duncan-North Cowichan treatment plant was based on an effluent dilution in the range of 20:1-200:1. Although the Cowichan River is used for domestic and recreational purposes, no feasible alternate solution for effluent was available at the time the permit was issued.

If the lowest flow on record under operation of the provisional rule curve for storage on Lake Cowichan is considered (3.11 m^3/s - Oct. 12, 1973) and maximum permitted discharge (.157 m^3/s) is taken into account, the dilution ratio for the permitted discharge would be 19.8:1. This is approximately equivalent to the low end of the dilution objective range (i.e. 20:1).

TABLE 3.6

INSTREAM FLOWS REQUIRED TO ACHIEVE VARIOUS DILUTION RATES FOR THE DUNCAN-NORTH COWICHAN SEWAGE TREATMENT PLANT

DISCHARGE CONDITIONS FOR DUNCAN-NORTH COWICHAN STP (PE1497)	INSTREAM FLOW REQUIRED m^3/s	DILUTION RATES
Permitted Discharge Conditions .157 m^3/s	3.11[1]	19.8:1
	3.52[3]	22.4:1
	31.4[4]	200:1
Observed Discharge Conditions .064 m^3/s[5]	6.57[2]	102.6:1
	3.52[3]	55:1
	12.8[4]	200:1

Note: a) The dilution objective for the Cowichan River is 200:1 (Regional Waste Management, 1985). Therefore, the flows required to achieve this objective are estimated to be 31.4 m^3/s assuming discharge at the permitted rate.

b) Monitoring data (Appendix 3.4) indicate that effluent from the Lake Cowichan STP is assimilated upstream of the Duncan-North Cowichan STP.

[1] Lowest recorded flow under operation of the Lake Cowichan storage - October 12, 1973

[2] Estimated 5-year 7-day average low flow prior to licensed extractions.

[3] Estimated water supply after licensed users are accounted for, i.e. available in-stream flow (Table 4.1).

[4] Flow required to maintain a dilution objective of 200:1.

[5] Mean discharge flow for August 1982, 1983, and 1984.

[6] Applies outside the Initial Dilution Zone - i.e. that zone around a waste discharge in a receiving water that is not subject to receiving water objectives. For point discharges in rivers and streams the zone may extend up to 300 feet downstream of the discharge point, but shall not exceed 25% of the width of the river or stream.

If 5-year recurrence interval 7-day average low flow estimates are considered (6.57 m^3/s) and observed discharge conditions (.064 m^3/s) are taken into account, the minimum dilution of effluent in recent summers has been 102.6:1, approximately mid-way in the 20:1-200:1 dilution range permitted.

However, to achieve a dilution of 200:1 on the Cowichan River, it is estimated that river flows of 31.4 m^3/s would be required to adequately dilute the permitted discharge from the Duncan-North Cowichan STP. Under recently observed effluent discharge conditions, only 12.8 m^3/s is required for 200:1 dilution.

The more important consideration, however, is that after water uses are accounted for on the Cowichan River, the remaining supply of flow available for dilution is estimated to be 3.52 m^3/s during the low flow period (Table 4.1). Given this available water supply and the permitted discharge from the Duncan-North Cowichan STP, the dilution is calculated to be 22.4:1. If recently observed effluent discharges are considered, the dilution is calculated to be 55:1. It should be noted that these rates of dilution will be achieved 80% of the time. There is a 20% risk that poorer dilution rates will occur.

A dilution of this magnitude is not adequate by current standards for either recreational or domestic use of the Cowichan, which currently does occur. Monitoring results indicate that this amount of dilution is not sufficient to prevent enhanced algal growth downstream of the outfall. It is recognized that factors other than flow may increase algal growth (e.g. water depth, temperature, light, substrate, etc.), however greater water flow will modify the effect of some of these factors.

The consequences of not providing adequate flows for waste dilution on the Cowichan River are paramount. The most serious implication is the potential for increased algal growth during the July to October period. The decomposition of algae in late fall could result in enhanced bacteria populations and reduced dissolved oxygen in the water and in the interstitial areas between the gravels. Further, increased algae growth is a nuisance to recreationists, including bathers and anglers. Lower flows would also result in slower water velocities and less flushing of the Cowichan River system. This may enhance the accumulation of decaying organic debris, reduced dissolved oxygen, and higher water temperature. It is possible that taste problems for direct extraction domestic water users would occur.

Other options[1] to control algal growth which do not involve greater flows for dilution include: (1) control of nutrient inputs, by chemical or other methods; (2) decreased volume of effluent discharged during low flow periods by seasonal drawdown or the provision of increased storage capacity; (3) land disposal of lagoon effluent during the summer months; and (4) marine disposal. Increased instream flow, in combination with one or more of these options, represents another alternative to improve dilution rates and decrease algal growth. An additional option would be upgrading of the sewage treatment plant to reduce suspended solids, which may indirectly also reduce phosphorus levels.

2. Lake Cowichan Sewage Treatment Plant

The Duncan-North Cowichan discharge, however, is not the only discharge to the Cowichan River. Instream flow required to achieve a 200:1 dilution ratio and the dilution available during low flows for the three waste management permits are outlined in Table 3.7. It is noted, for example, that after water uses are accounted for at the Village of Lake Cowichan STP, a dilution ratio of 329:1 is achieved.

Despite the relatively high dilution ratio at Lake Cowichan STP, algal growth still occurs, perhaps as a result of incomplete mixing. However, algal growth appears to be less extensive than at Duncan-North Cowichan STP (K. Austin, pers. comm., Waste Management). It appears that any flow sufficient to prevent an algal problem at the downstream Duncan-North Cowichan plant would also remove the existing problem at the Lake Cowichan plant. The assumption is that any increased flow would be provided through

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[1] Duncan and Associates Engineering, Ltd.

release of storage on Lake Cowichan or on upstream basins, and this flow would also increase the dilution available at the Village of Lake Cowichan outfall and provide the necessary dilution.

3. MOE Fish Hatchery

As noted earlier, the MOE fish hatchery located just downstream of the Highway 1 bridge has an insignificant effect on algal growth in the Cowichan River. This observation is substantiated by a calculation (Table 3.7) that dilution available at the hatchery is estimated to be 503:1 under permitted discharge amounts and low flow conditions.

3.2.4.5 Instream Flow Required to Maintain Ambient Water Quality in the Cowichan River

The preceding discussion concentrated on instream flow required to achieve stated dilution rates for direct discharge permits. While dilution of permitted discharges is a requirement under the Waste Management Act, dilution objectives may or may not achieve a desired level of ambient water quality. Therefore, it is necessary to consider instream flow required to maintain ambient water quality.

Derksen (1981) calculated that due to phosphorus inputs from the effluents, flows of 36 m^3/s in August 1980 and 78 m^3/s in September 1980 would have been needed to maintain total dissolved phosphorus at background levels below the Duncan-North Cowichan sewage discharge. Background total dissolved phosphorus levels for those months varied between 3 and 6 µg/L. While these levels may have an impact on algal growth, a variety of environmental factors may have a greater influence on algal growth than merely concentrations of nitrogen and phosphorus.

To achieve the provincial water quality criterion for fecal coliforms (200 Most Probable Number/100 mL for bathing, resampling performed when sample exceeds 400 coliforms/100 mL), it is estimated that (under conditions

TABLE 3.7

INSTREAM FLOW REQUIRED TO ACHIEVE 200:1 DILUTION AND DILUTION AVAILABLE DURING LOW FLOW ON THE COWICHAN RIVER

EFFLUENT DISCHARGE LOCATION (PERMITTED DISCHARGE) (m^3/s)	INSTREAM FLOW REQUIRED FOR 200:1 DILUTION (m^3/s)	7-DAY AVERAGE LOW FLOW IN RIVER (m^3/s)[1]	DILUTION AVAILABLE DURING LOW FLOW[1]
PE 247 - Village of Lake Cowichan STP (.019)	3.8	6.26	329:1
PE 6603 - MOE Fish Hatchery (.007)	1.4	3.52	502.9:1
PE 1497 - Duncan-North Cowichan STP (.157)	31.4	3.52	22.4:1

[1] Water available after licensed extractions have occurred (Table 4.1).

of the highest recorded fecal coliform level of 920 MPN during recorded flow of 8.84 m^3/s on October 6, 1982), instream flows of 40.7 m^3/s would have been required to reach the dilution criterion. Under conditions of recorded fecal coliform levels of 220 MPN and flow of 10.7 m^3/s, it is estimated that an instream flow of 11.8 m^3/s would have been required to achieve provincial criteria for fecal coliforms (bathing). This suggests that at the Cowichan River flow rate required for 200:1 dilution of recently observed Duncan treatment plant effluent discharge, the fecal coliform levels would approximate the provincial criterion for bathing.

It should be noted that coliform levels may not be directly attributable to point source discharges, (e.g. Lake Cowichan STP), but may be a result of non-point source discharges to Cowichan Lake and Cowichan River. Further, instream flows that are required to dilute the coliforms to an appropriate level must be of high quality, i.e. instream flow for dilution cannot be contaminated. These examples simply illustrate that a range of instream flows are required to maintain ambient water quality. The provision of instream flows for ambient water quality should be a function of point and non-point discharge conditions, and the most sensitive parameter for the most sensitive use.

3.3 LICENSED (SURFACE) WATER QUANTITY AND QUALITY

This section summarizes water use for the entire Cowichan-Koksilah watershed, the three main drainages, and each of the 25 analysis locations described in Chapter 2, and projects increased water requirements for the future.

3.3.1 SUMMARY OF LICENSED QUANTITIES

3.3.1.1 Cowichan-Koksilah Drainage and Major Systems

Table 3.8 illustrates the proportional licensed quantity by purpose among the three major systems in the Cowichan-Koksilah drainage (Fig. 3.4).

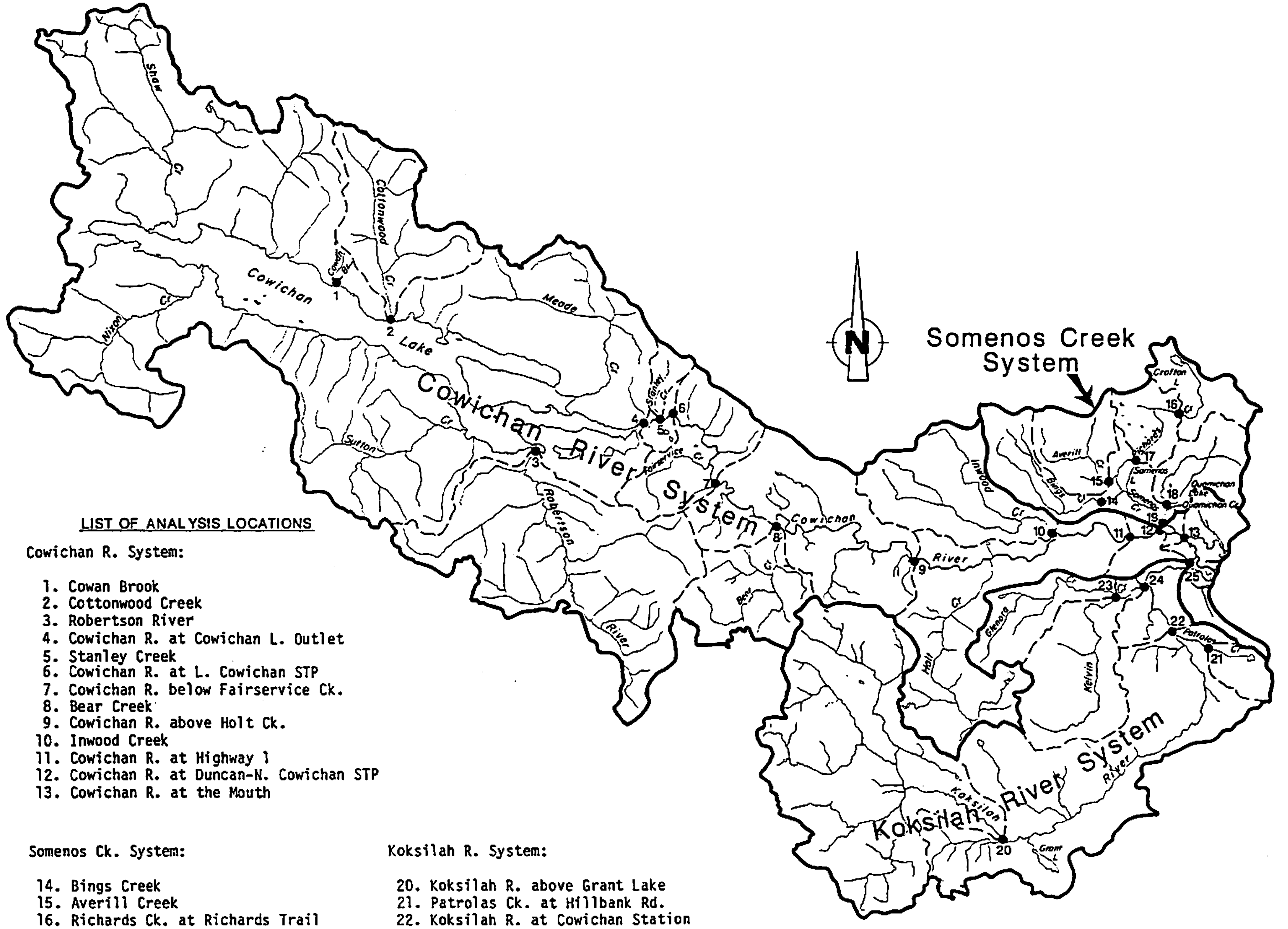
Highlights of this analysis are the dominant proportion of both industrial and waterworks licences in the Cowichan system, and the relatively large proportion of irrigation licences in the Koksilah. However, the Cowichan system supports 92% of the total quantity of water licensed, much of it due to one large licence as explained below.

TABLE 3.8

PERCENTAGE OF WATER QUANTITIES LICENSED BY PURPOSE WITHIN MAJOR SYSTEMS AND TOTAL PLAN AREA

SYSTEMS	DOMESTIC	IRRIGATION	INDUSTRIAL	WATERWORKS	TOTAL PLAN AREA
Cowichan	50	8	99	95	92
Somenos	33	39	0	5	3
Koksilah	17	53	1	0	5
Total	100	100	100	100	100

Summaries of licensed quantities according to purpose are given in Table 3.9. Licence totals for the whole Cowichan-Koksilah drainage show that the four main water purposes require flows of approximately 4.74 m^3/s. Of this total, 87% is for industrial purposes, 7% is for irrigation, 6% is for waterworks, and only 0.3% is for domestic purposes. Of the water required for industrial purposes, 87% is held by B.C. Forest Products in two licences, the largest for 2.83 m^3/s (100 cfs), or 68% of the water licensed in the entire plan area. This latter licence supplies industrial water to the pulp and paper mill in Crofton. The licence is supported by two storage licences on Cowichan Lake (totalling 49,700 acre-feet), with stored water released between mid-April and mid-October according to a provisional operating curve detailed in Appendix 3.6. The water intake for this licence is located close to Duncan, in the Cowichan River upstream of Highway 1 (see Table 3.9).



LIST OF ANALYSIS LOCATIONS

Cowichan R. System:

1. Cowan Brook
2. Cottonwood Creek
3. Robertson River
4. Cowichan R. at Cowichan L. Outlet
5. Stanley Creek
6. Cowichan R. at L. Cowichan STP
7. Cowichan R. below Fairservice Ck.
8. Bear Creek
9. Cowichan R. above Holt Ck.
10. Inwood Creek
11. Cowichan R. at Highway 1
12. Cowichan R. at Duncan-N. Cowichan STP
13. Cowichan R. at the Mouth

Somenos Ck. System:

14. Bings Creek
15. Averill Creek
16. Richards Ck. at Richards Trail
17. Richards Ck. at Somenos Lake
18. Quamichan Ck. at Quamichan L. Outlet
19. Somenos Ck. at the Mouth

Koksilah R. System:

20. Koksilah R. above Grant Lake
21. Patrolas Ck. at Hillbank Rd.
22. Koksilah R. at Cowichan Station
23. Glenora Creek
24. Kelvin Creek
25. Koksilah R. at the Mouth

FIGURE 3.4 Major Drainage Systems.

TABLE 3.9

SUMMARY OF LICENSED WATER QUANTITIES FOR SUB-BASINS AND PURPOSES

ANALYSIS LOCATION	DOMESTIC		IRRIGATION		INDUSTRIAL		WATERWORKS		TOTAL[2]		STORAGE		OTHER
									Sub-basin	Upstream			
	Gal/day	m^3/s	Ac.Ft.	m^3/s	Gal/day	m^3/s	Gal/day	m^3/s	m^3/s	m^3/s	Ac.Ft.	m^3/s	
1. Cowichan River System:													
Cowan Brook	10,750	0.001							0.001	0.001			
Cottonwood Creek									0	0			
Robertson River									0	0			
Cowichan R. at Cowichan L. Outlet	70,000	0.004	60.0	0.007	43.3 cfs 516,500	1.25	1,283,000	0.067	1.33	1.33	49,700.8	1.95	
Stanley Creek	1,500	*					200,000	0.011	0.011	0.01			
Cowichan R. at L. Cowichan STP	13,000	0.001	3.0	*	5,000	*			0.001	1.34			
Cowichan R. below Fairservice Ck.	7,700	*	2.0	*					*	1.34			LIM 1.0 AF $(<0.0005 m^3/s)$
Bear Creek									0	0			
Cowichan R. above Holt Creek	6,500	*	4.0	*					*	1.34			
Inwood Creek	5,000	*	65.0	0.008			200,000	0.011	0.019	1.36			
Cowichan R. at Highway 1	8,283	*	71.8	0.009	100 cfs 15,000	2.83	3,135,000	0.165	3.02	4.38	64.3	0.003	PWR 0.75 cfs $(0.021 m^3/s)$
Cowichan R. at Duncan-N. Cowichan STP									0	4.38			CON 0.5 cfs $(0.014 m^3/s)$
Cowichan R. at the Mouth									0	4.38			
Sub-Total[1]	122,733	0.006	205.8	0.024	143.3 cfs 536,500 gpd	4.09	4,818,000	0.253	4.37	4.38	49,765.1	1.953	
2. Somenos Creek System:													
Bings Creek	9,800	0.001	78.6	0.009					0.010	0.010			
Averill Creek	8,000	*	115.1	0.014					0.014	0.014	35.0	0.001	
Richards Ck. at Richards Trail	6,100	*					200,000	0.011	0.011	0.011	660	0.026	
Richards Ck. at Somenos L.	3,500	*	208	0.025					0.025	0.036	21.0	0.001	
Quamichan Ck. at Quamichan L. Outlet	33,880	0.002	379.3	0.045					0.047	0.047	12.0	*	
Somenos Ck. at the Mouth	6,000	*	248.3	0.030			50,000	0.003	0.033	0.139			CON 20.0 AF $(0.001 m^3/s)$
Sub-Total[1]	67,280	0.004	1,029.3	0.122	0	0	250,000	0.013	0.139	0.139	728.0	0.028	

TABLE 3.9 (Cont.)

SUMMARY OF LICENSED WATER QUANTITIES FOR SUB-BASINS AND PURPOSES

ANALYSIS LOCATION	DOMESTIC		IRRIGATION		INDUSTRIAL		WATERWORKS		TOTAL[2]		STORAGE		OTHER
									Sub-basin	Upstream			
	Gal/day	m^3/s	Ac. Ft.	m^3/s	Gal/day	m^3/s	Gal/day	m^3/s	m^3/s	m^3/s	Ac.Ft.	m^3/s	
3. Koksilah River System:													
Koksilah R. above Grant L. Outlet									0	0			
Patrolas Ck. at Hillbank Rd.	1,500	*	459	0.055					0.055	0.055			
Koksilah R. at Cowichan Station	23,250	0.001	309.8	0.037	6,000	*			0.038	0.093	18.0	0.001	PWR 0.25 cfs (0.007 m^3/s)
Glenora Creek	6,000	*	152	0.018					0.018	0.018			
Kelvin Creek	2,000	*	52.3	0.006					0.006	0.024			
Koksilah R. at the Mouth	5,500	*	449.3	0.053	2.0 cfs 3.5 AF 30,000	0.059			0.112	0.230			
Sub-Total[1]	38,250	0.002	1,422.4	0.169	2.0 cfs 3.5 AF 36,000gpd	0.059	0	0	0.230	0.230	18.0	0.001	
Grand Total[1]	228,263	0.012	2,657.5	0.316	145.3 cfs 3.5 AF 672,500 gpd	4.14	5,068,000	0.266	4.74	4.74	50,511.1	1.982	

[1] All totals and sub-totals are based upon licensed quantities which were then converted to flows.

[2] Total includes domestic, irrigation, industrial and waterworks licences; Sub-basin totals are within the sub-basin only, whereas Upstream totals include all licences above the analysis location. Gallons/day are Imperial gallons.

* <0.0005 m^3/s.

Note: Equivalent flows are expressed over a 120-day period for irrigation, and a 365-day period for other uses.

3.3.1.2 Estimated Actual Water Use and Storage

This section identifies only those analysis locations in which more than 100 acre-feet of storage has been developed and those where less than 100% of licensed quantity is estimated to be used. However, it should be noted that storage of less than 100 acre-feet is licensed in a number of streams. Therefore, estimated actual use can be considered 100% of licensed use except where indicated below. Estimates of actual water use were made on the basis of personal knowledge, telephone inquiries and some site inspections and evaluations.[1]

Cowichan River System

1. Cowichan River at Cowichan Lake Outlet
   Estimated total consumptive use above this analysis location is estimated at only 0.08 m^3/s. Most of this is for the Village of Lake Cowichan waterworks.

   Cowichan Lake has nearly 50,000 acre-feet of storage developed on it, to provide water for the pulp and paper mill at Crofton. Stored water is released according to a rule curve which specifies a water level on the falling stage at which control of the outflow commences. The rule curve (see Appendix 3.6) also requires the release of a minimum 250 cubic feet per second (7.08 m^3/s) until October 15, unless a lesser outflow is approved in writing by the Comptroller of Water Rights.

2. Stanley Creek
   Essentially all water licensed is for a waterworks licence requiring 0.011 m^3/s. No water is presently being used under this water licence.

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[1] Memo: G. Bryden, Water Management, Nanaimo, to G. Travers, Planning and Assessment Branch, Victoria, December 17, 1984.

3. Cowichan River at Highway 1
Just upstream of this analysis location are licences for 3.02 m^3/s, a large portion being due to the B.C. Forest Products licence for 2.83 m^3/s. Recorded monthly water use under this licence during the past 2 years ranged between 77% and 89%, averaging 84.1%, and at no time during this period exceeded the licensed quantity[1]. The licence is supported by storage on Cowichan Lake referred to previously. Also in this area is the intake for Duncan waterworks licences. Although these 4 licences total over 3 million gallons per day, very little use of them is made (e.g., only 188,000 gallons total during 1981), in favour of large groundwater wells north of the Cowichan River.

Somenos Creek System

1. Richards Creek at Richards Trail
A 200,000 gallon per day (0.011 m^3/s) waterworks licence diverts water from Crofton Lake to the community of Crofton, outside the Cowichan-Koksilah watershed. This licence is supported by storage of 660 acre-feet (0.026 m^3/s) on Crofton Lake, the headwaters of Richards Creek. During the summer season, 0.003 m^3/s is released from Crofton Lake into Richards Creek.

2. Richards Creek at Somenos Lake
Irrigation (0.025 m^3/s) constitutes virtually all of the licensing, however only 80% (0.020 m^3/s) of the licensed water quantity is estimated to be in actual use.

3. Somenos Creek at the Mouth
Over 90% of the 0.033 m^3/s licensed is for irrigation. However, more than half of the flow for irrigation licensed water quantity, along with a 0.003 m^3/s waterworks licensed water quantity, is estimated not to be in actual use. In total, only 0.011 m^3/s is estimated to be in actual use.

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[1] Source: B.C. Forest Products Ltd., June 1985.

Koksilah River System

1. Patrolas Creek at Hillbank Road
All of the 0.055 m^3/s licensed is for irrigation, with most of it (0.052 m^3/s) estimated to be in use.

2. Koksilah River at the Mouth
Licensing here is for industrial (0.059 m^3/s) and irrigation (0.053 m^3/s) purposes, totalling 0.112 m^3/s. A small amount of licensed water quantity for each purpose is not in use, with estimated actual use totalling 0.105 m^3/s.

3.3.1.3 Projected Water Requirements

1. Irrigation

Future irrigation requirements were estimated in three ways, with methods and detailed results given in Appendix 3.7.

a) CAPAMP Irrigation Analysis

This approach estimated the maximum biophysical water requirement of all Agricultural Capability class 1-5 soils currently in the Agricultural Land Reserve (Fig. 3.5), and mapped at a 1:20,000 scale, should these soils be irrigated. When compared to present amounts of water licensed for irrigation, these estimates indicate only 10% of the maximum water requirement is now licensed in the Cowichan-Koksilah drainage as a whole, with the Koksilah and Somenos systems at 14% and 12% respectively, and the Cowichan at only 2%. In addition to present surface licensed quantities, an unknown but possibly larger amount of groundwater is now used for irrigation (see Table 3.12). This analysis therefore indicates that at some future time, large increases in irrigation water over that currently licensed may be required should all of these soils be developed for agriculture. The source of this water may be either surface or groundwater.

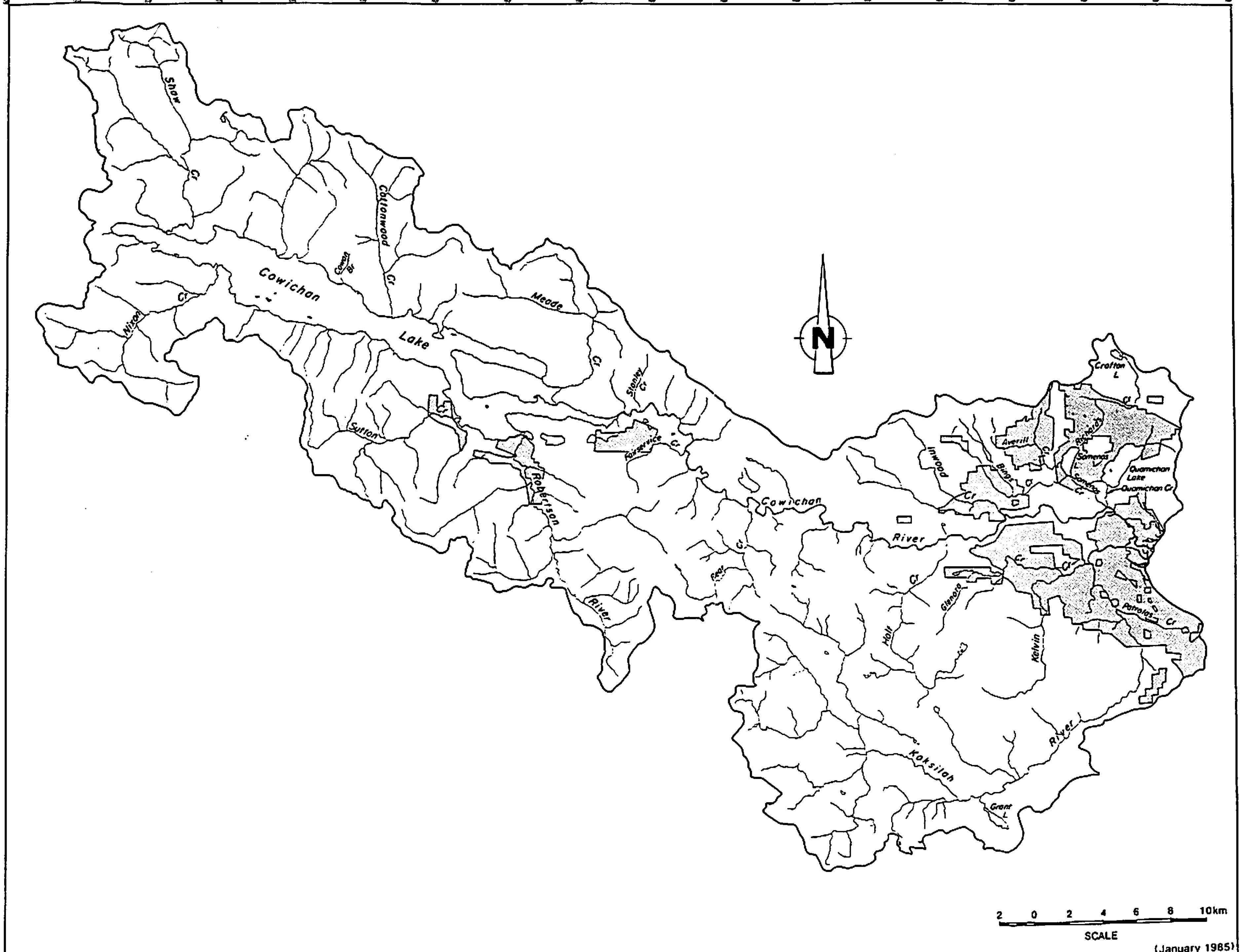

FIGURE 3.5 Agricultural Land Reserve.

b) CAPAMP Present Land Use Analysis

This analysis used 1981 air photographs to identify current utilization of high capability land (Agricultural Capability classes 1-3 inclusive), in the same ALR areas as above. Results in terms of area indicated higher proportions of Improved[1] land in the Somenos (77%) and Koksilah (73%) drainages than in the Cowichan (54%) drainage. Analysis locations with less than 60% improved agricultural land are the drainage area between Cowichan River at Holt Creek and Cowichan River at Highway 1 (8%), Kelvin Creek (42%), Inwood Creek (51%), Bings Creek (52%) and Richards Creek at Richards Trail (60%). In terms of ALR class 1-3 area yet to be developed for agriculture, the largest amount is in the Cowichan drainage (740 ha), with the Koksilah and Somenos drainages having 610 and 470 ha respectively. The conclusion from this analysis is that a reasonably large proportion of the best agricultural land is cleared and being used for agriculture purposes.

c) Ministry of Agriculture and Food (MAF) Projections

Whereas the above two analyses indicate where long-term irrigation increases will be required, the MAF estimates forecast expected increased irrigation within the next 5 years (Table 3.10), assuming sources of water are available. These estimates were based upon trends from Census Canada - Agricultural Data, knowledge of agricultural development activity in the area, and an assumption that nearly all increases will be associated with existing dairy farms (due to the relatively lower costs of providing irrigation to existing farms as compared to higher costs associated with clearing new lands). These estimates indicate that 60% of the increased irrigated area will be in the Somenos drainage, with 10% in the lower Koksilah subbasin, 10% below the furthest downstream Cowichan-Koksilah analysis locations, and 20% dispersed throughout the rest of the area. In total, they would represent approximately a 38% increase over the amount of water currently licensed for irrigation throughout the plan area. The source of this irrigation water may be either surface or groundwater, and given that a

[1] Improved includes Cultivated, Pasture and Rural classes.

large proportion of irrigation water is estimated to be currently supplied from groundwater sources (see Table 3.12), it is likely that the trend to groundwater use will continue, and that a large proportion of the 38% increase will be from groundwater. Costs involved in supplying irrigation water are also a factor.

TABLE 3.10

IRRIGATION WATER INCREASES ESTIMATED FOR THE PERIOD 1985-1989

ANALYSIS LOCATION	CURRENT WATER LICENSED		ESTIMATED INCREASES				PERCENTAGE WATER INCREASE[3]
			Area[1]		Water[2]		
	ha.m	ac.ft.	ha	acres	ha.m	ac.ft.	
Averill Creek	14.2	115.1	81	200	24.7	200	174
Richards Creek (lower)	25.7	208.0	121.5	300	37.0	300	144
Quamichan Creek	46.8	379.3	40.5	100	12.3	100	26
Cowichan River delta	0	0	40.5	100	12.3	100	-
Koksilah River near the mouth	55.4	449.3	40.5	100	12.3	100	22
Remainder of plan area	185.7	1505.8	81	200	24.7	200	13
TOTALS	327.8	2657.5	405	1000	123.3	1000	38

[1] Source: P. Fofonoff, Ministry of Agriculture and Food, Duncan.

[2] Assumes average water requirement of 1 acre-foot/acre.

[3] Assumes all additional irrigation water will be supplied by surface sources; current high use of groundwater for irrigation suggests groundwater may supply much of the increased requirement.

2. Waterworks

As indicated earlier in this chapter, the major waterworks licences in the plan area are: (1) the City of Duncan (4 licences on the Cowichan River issued between 1923 and 1967, totalling 3,325,000 gallons per day maximum daily allowable, and serving 9000 residents in 1983); (2) the Village of Lake Cowichan (3 licences on Cowichan Lake issued between 1955 and 1979, totalling 1,000,000 gallons per day maximum daily allowable, and serving 2500 residents in 1983). Details on these licences and the amount of use during the past several years are given in Appendix 3.8.

Under other waterworks licences, an additional 513,000 gallons per day are licensed from 9 sources, mostly from Cowichan Lake and its tributaries. However, of these additional waterworks licences, only 253,000 gallons per day (or 49%) of these additional licences are estimated to be actually used[1], and several of the unused licences will likely never be redeveloped or used (e.g. 200,000 gallons per day from Stanley Creek, and 50,000 gallons per day from Somenos Lake).

Analysis to estimate projected increases in waterworks requirements centred on the Duncan and Lake Cowichan areas, the main population concentrations in the plan area. In Chapter 1 (Section 1.6.2), forecast population increases from 1982-1986, and 1987-1991, average 5.6% and 5.6% for the plan area as a whole, declining to 5.4% and 5.2% increases during the subsequent two 5-year periods.

With respect to the City of Duncan, annual water use over the 4 years 1980-1983 inclusive averaged over 588 million gallons per year. This total represents 96.9% of the total licensed annual allowable (607 million gallons) under existing licences. Assuming a 5.6% population increase results in an equivalent increase in waterworks requirement, the present licensed maximum annual allowable diversion will not supply sufficient water for the increased population at the end of 1986. However, nearly all of the water supplied by the Duncan waterworks comes from four wells near the banks

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[1] G. Bryden, Water Management, Nanaimo.

of the Cowichan River which in total have a capacity of 7 million Imperial gallons per day. In 1981, only 188,000 gallons out of a total 542 million gallons were withdrawn from the Cowichan River, representing only 0.03% of the total. Several studies have indicated the Cowichan River has both quantity and quality shortcomings for use as a domestic supply in the low-flow season, and recommended groundwater be used to supply Duncan and the South End of the Municipality of North Cowichan (Sansom, 1970; Municipality of North Cowichan Water Supply Study, 1976; City of Duncan Water Distribution System Study, 1980). Water use trends from the river and wells indicate little use is being made of the four licences on the Cowichan River, and suggest this pattern is unlikely to change in the foreseeable future. This conclusion is supported by the City of Duncan study recommendation that a new well will be required to meet increased use by 1987, with a total increase by 2001 of 3 million gallons per day. Therefore, it can reasonably be concluded that there will be no increase in waterworks requirements for the Cowichan River intakes, although the degree of influence on Cowichan River surface waters of increased groundwater withdrawal is not known.

For the Village of Lake Cowichan, the licensed annual allowable of 197 million gallons was reported to have been exceeded in 1979, but not since, the 1980-1983 period averaging 166 million gallons per year. If a 5.6% growth rate is assumed for this community, the licensed annual allowable total should not be exceeded within a decade, based on 1980-83 average use, but will approximate the licensed total in 15 years (i.e. 1996). Although the number of connections to residences has generally increased for the past 8 years, the number of residents has shown a declining trend. However, water consumption has not declined during this period, and this may be the result of a slight trend to increased per capita water use (Appendix 3.8).

3. Industrial

At present, the major industrial water licences are related to forest industry activities, being held by B.C. Forest Products (100 cfs from the Cowichan River for the Crofton pulpmill, and 28.3 cfs for cooling water from

Cowichan Lake for the Youbou sawmill). An additional 15 cfs from Cowichan Lake is held by TAL Developments Ltd. for a sawmill, now closed, and 500,000 gpd by the same licencee on Ashburnham Creek (of which only 15,000 gpd is used). Together these licences represent a flow of over 4 m^3/s. However, only the Crofton mill licence can currently be considered consumptive and in full use. Therefore, the total consumptive industrial water use is approximately 2.8 m^3/s on the Cowichan mainstem.

Information supplied by the Crofton pulp mill indicates that recent expansions in mill capacity have been possible without increased water consumption, due to process improvements, and there are no indications of an increased water requirement in the near future. Nearly all licensed industrial water is for forest industry activities. The Ministry of Environment is not aware of any expansion plans in the forestry industry for the next five years. Therefore, it is concluded that there will be no immediate increase in this component of water use.

4. Domestic

By comparison with the above three classes of water use, domestic licences in total represent a flow requirement for the entire plan area of barely 0.01 m^3/s, or less than 0.3% of the licensed total. Although this amount represents a small proportion of total licensed quantities, domestic use peaks during the low-flow season. This is indicated by 1981 Duncan waterworks use figures showing August average use to be 2.7 times that during January. This low-flow season use, combined with a projected 5.6% increase in population between 1982 and 1986, indicates that some areas now obtaining barely adequate domestic supplies may experience shortages. However, for the whole plan area, any increase in domestic use will have little influence on total water requirements.

3.3.1.4 Water Quality Parameters of Concern for Licensed Purposes

For each licensed water use, a number of water quality parameters are of importance in assessing whether the ambient quality is sufficient to support a given use. For example, for domestic consumption (and waterworks purposes), the level of coliforms present is used as an indicator of the required degree of treatment by disinfection, filtration, etc. before the water is considered suitable for human consumption. Table 3.11 summarizes the major parameters for various uses which should be examined when undertaking an assessment of ambient water quality.

TABLE 3.11

IMPORTANT WATER QUALITY PARAMETERS FOR VARIOUS LICENSED PURPOSES

PURPOSE	WATER QUALITY PARAMETERS
Domestic and Waterworks	- Total and fecal coliforms, nitrate, phosphorus, metals, disease-carrying micro-organisms.
Industrial	- (no parameters identified)
Irrigation	- Dissolved solids (sodium, chloride, sulphate), metals (e.g. cadmium), disease-carrying micro-organisms.

Source: O. Hals, Water Management, Nanaimo.

3.4 GROUNDWATER USE AND QUALITY

3.4.1 GROUNDWATER USE

It is apparent from Figure 3.6 that present groundwater withdrawals for agricultural, municipal and industrial uses, are concentrated in the lower portion of the Cowichan-Koksilah drainage. A more detailed assessment of groundwater use and quality is in Appendix 2.2. On the southeast side of Duncan, there are presently 8 large diameter wells located along the north and south sides of the Cowichan River, supplying up to a total of approximately 12,000 USgpm of groundwater during maximum peak withdrawals. These wells supply the District of North Cowichan and City of Duncan with sufficient water to meet present municipal needs, and a Provincial fish hatchery.

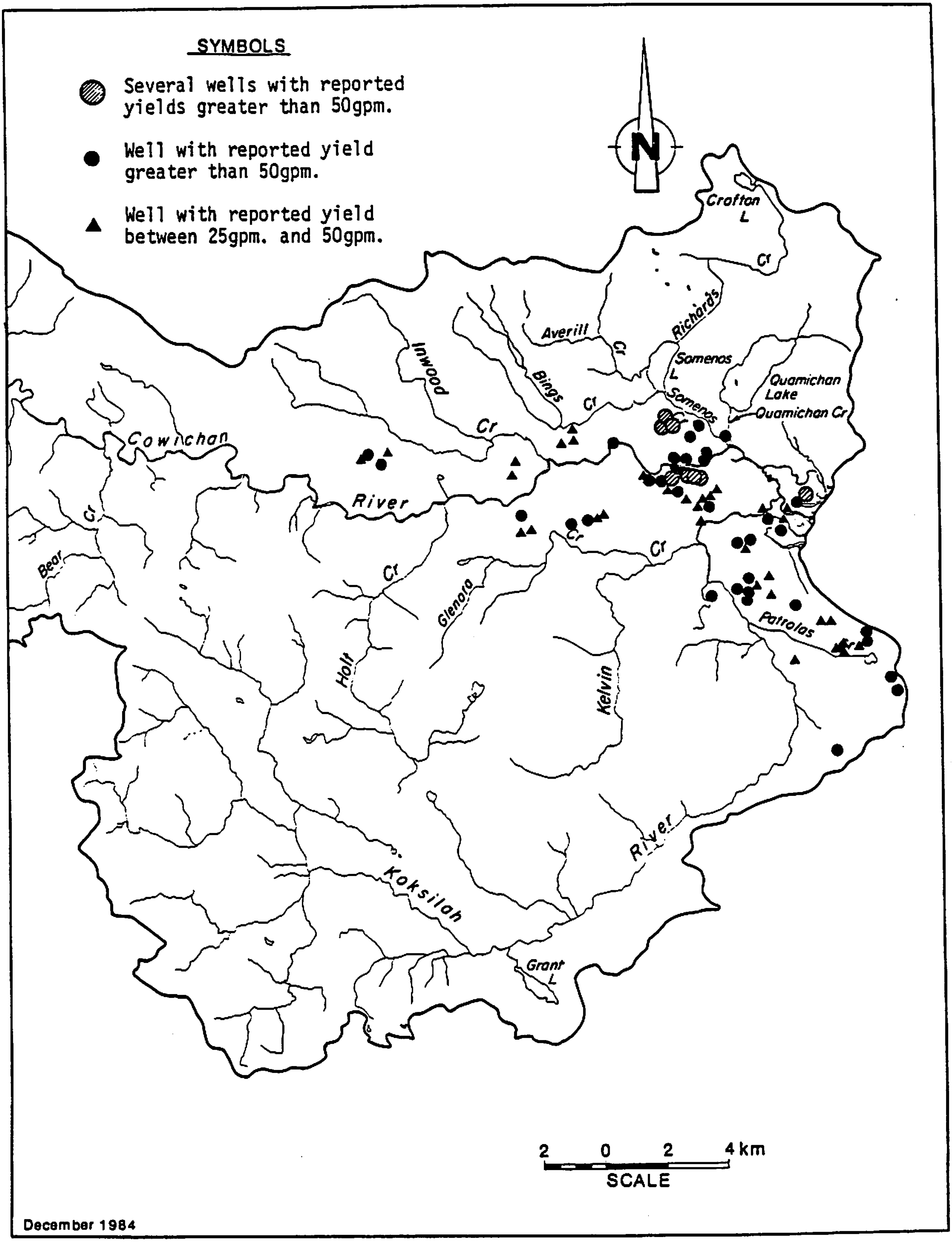

FIGURE 3.6 Major Production Wells in the Lower Cowichan-Koksilah Area.

Near the mouth of the Cowichan River, there are some very productive large-diameter wells owned by Doman Industries with reported yields between 1500 USgpm and 1865 USgpm. In the immediate area of these wells there are also several smaller diameter (6-inch) flowing artesian wells with estimated flows up to approximately 400 USgpm. However, it is not known to what extent groundwater is being utilized in this area and in other areas of the Cowichan-Koksilah River basin for industrial or other purposes. Groundwater withdrawals are not presently licensed or monitored. As a result, it is difficult to determine the degree of groundwater use or the nature of the use.

However, the use of groundwater for irrigation can be estimated by comparing known cultivated areas, and their assumed water requirements, to amounts of water licensed from surface sources for irrigation. Table 3.12 indicates that only 27% of water required for cultivated areas is estimated to be supplied from surface sources. Although these estimates are based upon several assumptions, it can be concluded that the majority (73%) of water used in the plan area for irrigation is supplied from groundwater.

The only other area in the Cowichan-Koksilah plan area which experiences large groundwater withdrawals is the eastern end of Cowichan Lake. These withdrawals are apparently for domestic use with reported yields between 25 USgpm and 50 USgpm.

During the past 25 years, the number of wells known to have been drilled in the plan area has quadrupled (Fig. 3.7), with the trend increasing in the past decade or so. The distribution of these wells within land districts is given in Appendix 3.9. During the past 5-year period (1980-1984), 313 known wells were drilled throughout the plan area, with the comparable number for 1975-1979 being 387 wells. In total, the number of known wells drilled from 1975-1984 represents an increase of almost 90% over the previous decade. If current trends continue, it is likely that 350-400 wells will be drilled throughout the plan area in the 5-year period 1985-1989.

TABLE 3.12

ESTIMATES OF CURRENT GROUNDWATER USE FOR IRRIGATION

LOCATION	CLASS 1-4 CULTIVATED[1] ha.	CLASS 1-4 CULTIVATED[1] ac.	WATER REQUIRED[2] (ac.ft.)	CURRENT IRRIGATION LICENSED AMOUNT (ac. ft.)	WATER REQUIRE-MENT NOT LICENSED (ac.ft.)[3]	% LICENSED[4]
Averill Creek	412.4	1019	1019	115.1	903.9	11.3
Bings Creek	151.8	375	375	78.6	296.4	21.0
Cowichan R. at Hwy. 1	86.7	214	214	71.8	142.2	33.6
Cowichan R. near mouth	89.0	220	220	0	220	0
Cowichan R. delta	442.9	1094	1094	0	1094	0
Cowichan R. at Duncan STP	117.1	289	289	0	286	0
Glenora Creek	207.6	513	513	152	361	29.6
Inwood Creek	177.7	439	439	65	374	14.8
Kelvin Creek	104.8	259	259	52.3	206.7	20.2
Koksilah R. at Cowichan Station	370.9	916	916	309.8	606.2	33.8
Koksilah R. at mouth	593.7	1466	1466	449.3	1017.7	30.6
Patrolas Creek	339.6	839	839	459	380	54.7
Quamichan Creek at Quamichan Lake	359.4	888	888	379.3	508.7	42.7
Richards Creek at Richards Trail	54.1	134	134	0	134	0
Richards Creek at Somenos L.	276.5	683	683	208	475	30.5
Somenos Creek at mouth	139.6	345	345	248.3	96.7	72.0
Totals			9693	2588.5	7102.5	26.7

[1] From Present Land Use analysis, assuming all land in Cultivated class is irrigated (see Appendix 3.7).

[2] Assumes water requirements of 1 ac.ft./ac.

[3] Column 3 minus Column 4.

[4] Column 4 divided by Column 3, expressed as a percentage.

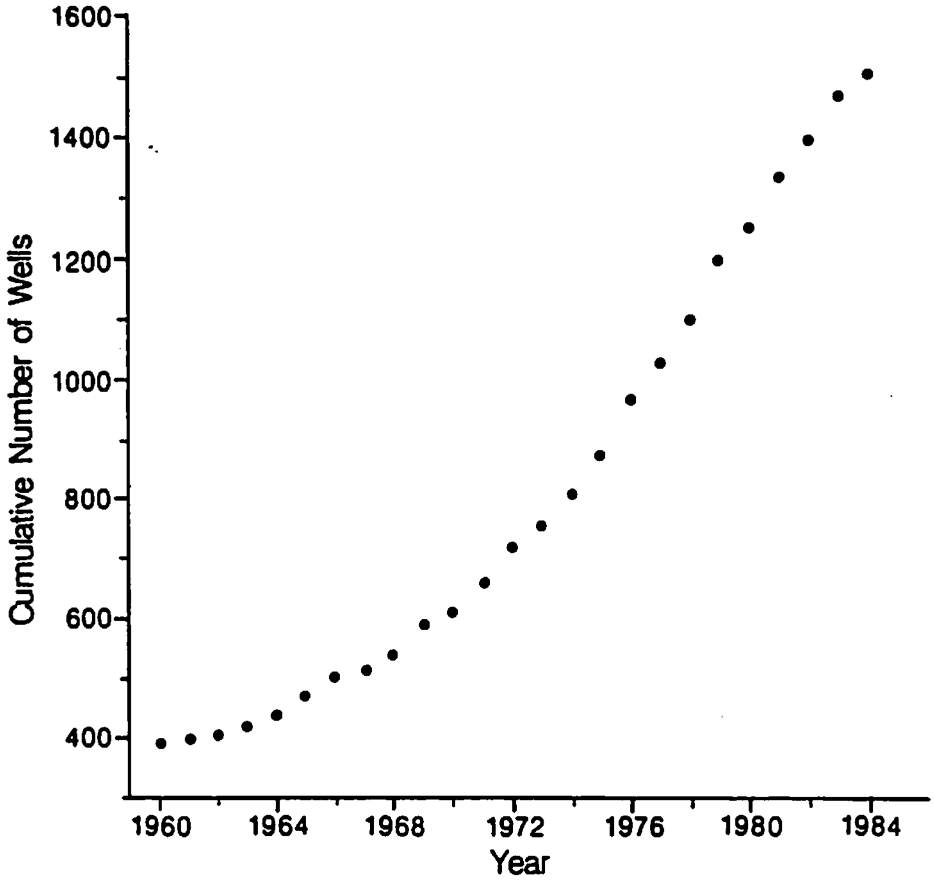

FIGURE 3.7 Cumulative Number of Wells Known to Have Been Drilled in the Cowichan - Koksilah Plan Area.

3.4.2 GROUNDWATER QUALITY

An analysis of the well type and depths indicates that the majority of wells with groundwater quality data (Table 1 in Appendix 2.2, Figure 3.8) are shallow (less than 200 ft. deep) and are completed in surficial (unconsolidated) deposits within shallow groundwater flow systems. There are five bedrock wells completed to depths of between 190 feet and 410 feet. These wells can also be considered completed within relatively shallow groundwater flow systems. The significance of a shallow groundwater flow system is that most natural waters will be relatively low in total dissolved solids (T.D.S.), low in specific conductance and be relatively soft to moderately soft in hardness. This appears to be the case for groundwaters within this study area.

Table 1 in Appendix 2.2 also indicates that for the parameters tested, most of the groundwaters within the study area have water quality within acceptable limits for drinking water based on the B.C. Drinking Water Quality Standards (Ministry of Health, 1982). The exceptions include the groundwater tested from wells no. 3, 11, 18, 19, 20 and 21 (which have pH values slightly above or below the recommended limits), and those from wells no. 13 and 14 (which have reported chloride levels which approach and exceed the recommended limit of 250 mg/L). Regarding the high chloride concentration and salt water content of these two latter wells (which are close to the fresh water-salt water interface), Kohut (1981) suggests that the source of the salt water content in the wells (particularly under pumping conditions) is from salt water located in a nearby distributary channel. The low chloride concentrations reported for groundwaters from nearby wells no. 8, 12, and 15 suggest that the above salt water intrusion problem is localized.

Additional groundwater quality information supplied by O. Hals (Water Supply - Health Engineering, Nanaimo) indicates that the parameters to exceed recommended levels most frequently are iron and manganese, with occasional high turbidity, nitrogen and phosphorus values.

At present, there are no other known contaminated groundwaters within the study area. There have been concerns that some wells operating near the City of Duncan's sewage treatment ponds, located east of Duncan and just north of the lower Cowichan River, may become contaminated by seepage of effluent from the treatment ponds. Further research and investigation of this site-specific area, including the possible construction of monitoring wells near the ponds, would be required to assess the potential for contamination. Further research would also be required to identify the source(s) and degree of any other potential groundwater contamination throughout the study area, and the vulnerability of producing aquifers to potential contamination.

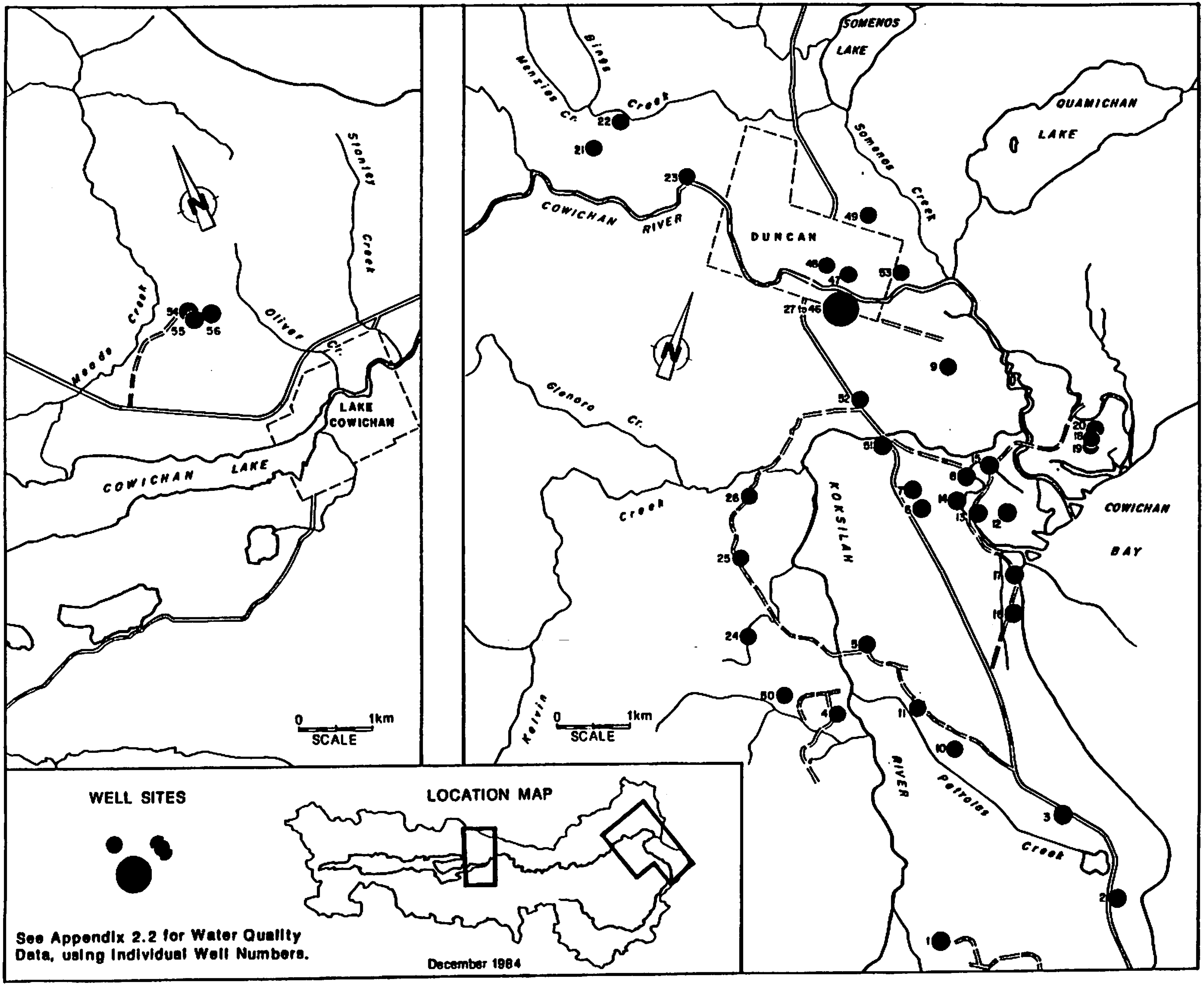

FIGURE 3.8 Location of Wells with Water Quality Data.

CHAPTER 4. ANALYSIS OF LOW-FLOW SEASON SUPPLY AND USE

INTRODUCTION

The purpose of this chapter is to integrate all information on water supply and use presented in previous sections of this report, and to indicate areas of existing or potential water shortages for various uses. It is emphasized that conclusions drawn at analysis locations strictly apply only at those locations, and the situation may well differ only a short distance upstream or downstream from the location. This is equally true for instream requirements that have been estimated. This chapter addresses current and future low-flow issues raised by Water Management, and the instream flow issues identified by Fisheries and Waste Management, detailed in Chapter 1. Conclusions on the other issues listed under Water Management in section 1.4.1 are presented in Chapter 5.

4.1 WATER SUPPLY FOR PRESENT LICENSED QUANTITIES

A summary of estimated 7-day low flow (5-year recurrence interval, from Table 2.1), total upstream present licensed quantities, and the surplus or shortage at each of the 25 analysis locations is given in Table 4.1. Examination of the surplus/shortage columns in Table 4.1 indicates five analysis locations at which the average 7-day low flow with 5-year return period is less than the quantity licensed. It is necessary to reiterate that water supplies given in Table 4.1 are estimates, and must be recognized as such. Conclusions drawn from Table 4.1 are based upon 7-day low flows with 5-year recurrences only, and use of confidence intervals in Appendix 2.1 may lead to differing conclusions.

Within each of the systems, the following locations are short of water for existing licences. On the Cowichan system, Stanley Creek has insufficient water supply for licensed quantities. In addition, Inwood Creek is nearing full allocation. Within the Somenos Creek system, Averill and lower

TABLE 4.1
SUMMARY OF WATER SUPPLY AND USE AT ANALYSIS LOCATIONS

ANALYSIS LOCATION	ESTIMATED SUPPLY[2] (m^3/s)	TOTAL UPSTREAM LICENSED[1] (m^3/s)	SURPLUS/ (SHORTAGE) FOR LICENCES (m^3/s)[3]	INSTREAM FLOW REQUIREMENTS (m^3/s) FOR FISHERIES[4]	WASTE DILUTION[5]
1. Cowichan River System:					
Cowan Brook	0.003	0.001	0.002	0.01	N/A
Cottonwood Creek	0.098	0	0.098	0.07	N/A
Robertson River	0.257	0	0.257	0.17	N/A
Cowichan R. at Cowichan L. Outlet	6.26	0.081	6.26[3]	7.08	N/A
* Stanley Creek	0.001	0.011	(0.010)	0.03	N/A
Cowichan R. at L. Cowichan STP	6.27	0.093	6.27	7.08	3.8
Cowichan R. below Fairservice Ck.	6.31	0.093	6.31	7.08	N/A
Bear Creek	0.016	0	0.016	0.06	N/A
Cowichan R. above Holt Creek	6.42	0.093	6.42	7.08	N/A
Inwood Creek	0.025	0.019	0.006	0.04	N/A
Cowichan R. at Highway 1	6.56	3.132	3.54	2.83	N/A
Cowichan R. at Duncan-N. Cowichan STP	6.57	3.132	3.55	2.83	31.4
Cowichan R. at the Mouth	6.68[6]	3.261[6]	3.66	2.83	N/A
2. Somenos Creek System:					
* Bings Creek	0.021	0.010	0.011	0.01	N/A
* Averill Creek	0.011	0.014	(0.003)	0.01	N/A
* Richards Ck. at Richards Trail	0.006[8]	0[7]	0.006	0.05	N/A
* Richards Ck. at Somenos L.	0.012	0.025	(0.013)	-	N/A
Somenos Ck. at the Mouth	0	0.129	-[10]	0.06	N/A
Quamichan Ck. at Quamichan L. Outlet	0	0.047	-[9]	0.06	N/A
3. Koksilah River System:					
* Koksilah R. above Grant L. Outlet	0.090	0	0.090	0.34	N/A
* Patrolas Ck. at Hillbank Rd.	0.034	0.055	(0.021)	0.03	N/A
* Koksilah R. at Cowichan Station	0.276	0.093	0.204	0.42	N/A
* Glenora Creek	0.008	0.018	(0.010)	0.03	N/A
* Kelvin Creek	0.046	0.024	0.032	0.07	N/A
* Koksilah R. at the Mouth	0.435	0.229	0.237	>0.42	N/A

[1] Total licensed quantity for Domestic, Irrigation, Industrial and Waterworks purposes.
[2] Minimum 7-day average low flow, 5-year return period, from Table 2.1.
[3] Surplus/(shortage) calculations take into account upstream residual flows following licensed extractions. Estimated supply for Cowichan R. at Cowichan L. outlet includes total upstream licensed use; downstream totals do not include licences upstream of the lake outlet.
[4] Methods for estimating minimum fisheries requirements are discussed in Section 3.3.
[5] Flow dilution of 200:1. N/A indicates no effluent permit exists in this sub-basin.
[6] Includes Somenos Creek drainage totals.
[7] All licences supported by storage on Crofton Lake.
[8] Includes release of 0.003 m^3/s from Crofton Lake during low flow season.
[9] All licensed requirements are withdrawn from Quamichan Lake.
[10] All licensed requirements are accommodated above the analysis location. However, there are periods of zero flow of unknown duration and frequency at the analysis location, but water is present due to the backup of the Cowichan River.
* Designated in Stream Register as fully recorded.

Richards Creeks have supply shortages for the 1 in 5 year low flow. Supply shortages in the Koksilah system are present in two tributaries, Patrolas Creek and Glenora Creek.

Of these analysis locations with identified shortages, Averill, Glenora, Richards and Stanley Creeks have already been designated as fully recorded streams, along with the Koksilah River and its tributaries.

4.2 WATER SUPPLY FOR INSTREAM USES

Minimum flow requirements for fisheries and waste dilution are given in Table 4.1. No flow is indicated for fisheries purposes at Richards Creek at Somenos Lake, since this location is not considered to be a low flow priority area for fish. Instream flow requirements estimated for fish were defined as the flow needed to produce the minimum amount of habitat required to sustain the life phase of species using that reach. The only analysis locations at which fisheries flow requirements are currently available are in the Cowichan system, Bings Creek, and at the mouth of Somenos Creek (see 4.4.1, item 6), using the minimum 7-day average low flow for the 5-year return period as the quantity criterion. At some locations, fisheries instream requirements are greater than natural low flows on streams with no water licensing. This indicates that fisheries production would increase if greater flows were available.

For waste dilution purposes, it was concluded that water flow is only one of several factors which are critical in the excessive production of algae downstream of the two sewage treatment plants on the Cowichan River. Insufficient river flow is available at the Duncan-North Cowichan STP to meet a 200:1 effluent dilution objective. The only other permitted effluent is for a fish hatchery, and it is assumed that dilution of effluent from this source will not become a problem at any river flow. It has not been possible to quantify minimum flows for recreation and waterfowl purposes, discussed in Sections 3.2.2 and 3.2.3.

4.3 WATER SUPPLY FOR PROJECTED LICENSED QUANTITIES

The current status of water supply is summarized in Table 4.2, along with projected water increases during 1985-1989. Irrigation projections, transformed into flows using the volumes estimated in Table 3.10, constitute the majority of expected increased demand. However, it is apparent that at 4 of the 13 analysis locations where irrigation increases are expected, there is already a water shortage for the 1 in 5-year return period. For the remaining 9 locations at which irrigation increases are projected, the increases represent only a small portion of the surplus water currently available, or naturally-stored water is available, with the exception of upper Richards Creek, where the increase is a third of the current surplus.

4.4 ANALYSIS LOCATION SUMMARIES

This section is intended to summarize information from all previous sections of the plan for each of the analysis locations, using water supply, all water uses, and projected increases, and drawing conclusions indicating whether management is required to resolve present or anticipated problems. Supply and licensed quantity calculations are summarized in Table 4.1, along with instream requirements, and irrigation projections are given in Table 4.2. In any case where the estimated supply is close to the amount licensed, confidence limits for the estimates should be consulted from Appendix 2.1, where applicable.

4.4.1 COWICHAN RIVER SYSTEM

1. Cowan Brook

Analysis based on recorded zero low flow at the hydrometric station at Cowichan Lake Road has indicated that licensed quantity exceeds the low flow (average 7-day, 5-year recurrence) supply. However, recent low flow observations indicate that there is significant flow upstream at the head of the fan but that this flow disappears into the fan gravels, leaving a dry

TABLE 4.2
WATER SUPPLY (m^3/s) FOR PROJECTED 1989 LICENSED QUANTITIES[1]

ANALYSIS LOCATION	CURRENT SURPLUS/(SHORTAGE) FOR LICENCES (m^3/s)	PROJECTED IRRIGATION INCREASES[2]
1. Cowichan River System:		
Cowan Brook	0.002	0
Cottonwood Creek	0.098	0
Robertson River	0.257	0
Cowichan R. at Cowichan L. Outlet	6.26	0
Stanley Creek	(0.010)	0
Cowichan R. at L. Cowichan STP	6.27	0
Cowichan R. below Fairservice Ck.	6.31	0
Bear Creek	0.016	0
Cowichan R. above Holt Creek	6.42	0
Inwood Creek	0.006	0
Cowichan R. at Highway 1	3.54	0.003
Cowichan R. at Duncan-N. Cowichan STP	3.55	0.001
Cowichan R. at the Mouth	3.66	0
2. Somenos Creek System:		
Bings Creek	0.011	0.001
Averill Creek	(0.003)	0.024
Richards Ck. at Richards Trail	0.006	0.002
Richards Ck. at Somenos L.	(0.013)	0.036
Somenos Ck. at the Mouth	-[3]	0.001
Quamichan Ck. at Quamichan L. Outlet	-[3]	0.012
3. Koksilah River System:		
Koksilah R. above Grant L. Outlet	0.090	0
Patrolas Ck. at Hillbank Rd.	(0.021)	0.007
Koksilah R. at Cowichan Station	0.204	0.004
Glenora Creek	(0.010)	0.003
Kelvin Creek	0.032	0.002
Koksilah R. at the Mouth	0.237	0.012

[1] Projected increases for waterworks, industrial and domestic purposes are discussed in section 3.1.3, and are concluded to be either nil or so small as to be of no consequence.
[2] From projections in Table 3.4; projection for "Remainder of Plan Area" has been pro-rated on the basis of the number of dairy farms present.
[3] Licensed requirements are fully accommodated mainly from natural storage, but periods of 0 flow occur annually downstream of the lakes.

streambed downstream. It is concluded that the low flow required to maintain the fisheries resource in this stream is not available either above or at the fan. Further observations of flow at the head of the fan (above the 200 meter contour) are required to determine if this source can supply water for further domestic purpose licences.

2. Cottonwood Creek

There are no present or projected water licences in this much larger sub-basin adjacent to Cowan Brook on the north side of Cowichan Lake. The estimated low flow is sufficient for the fisheries requirement at the head of the fan. Cottonwood Creek is valuable fisheries habitat, being well-shaded, having moderate gradient, and containing ideal rearing habitat. Any future water licence application in this sub-basin should be critically assessed for its potential effect on fisheries values.

3. Robertson River

This sub-basin near the southeast end of Cowichan Lake has an estimated 5-year low flow of 0.257 m^3/s at the head of the fan, although there is zero flow observed at Cowichan Lake Road, which runs through the fan. The flow estimated at the head of the fan is larger than the estimated fisheries requirement. No licences have yet been issued in this sub-basin, nor are any projected, so that low flows available for instream fisheries requirements are limited only by natural low flow supplies in the river.

4. Cowichan River at Cowichan Lake Outlet

Low flow releases from Cowichan Lake into the Cowichan River are regulated by a control structure, constructed around 1964 by B.C. Forest Products, to support their industrial withdrawal of 100 cfs (2.83 m^3/s) for a pulpmill in Crofton, from an intake in the Cowichan River downstream near Duncan. The structure controls an estimated 49,700 ac. ft. (61,290 dam^3) in the lake. In order to ensure that low flows are available for instream requirements (both waste dilution and fish flow requirements) and licensed quantities, BCFP is required to operate the control structure according to an "operation rule" (Appendix 3.6) and to ensure that a minimum of 100 cfs (2.83 m^3/s) is allowed to pass downstream of their intake near Duncan at all times.

The "operation rule" allows the company to commence regulation only when the lake level falls below 104.68 feet (local datum) following the winter high water season. BCFP must control the fluctuation of discharge within limits (outflow stage level fluctuation not to exceed 0.25 feet at any one time, nor 0.50 feet in 24 hours except when the outflow is less than 750 cfs when it shall not exceed 0.10 feet at any one time). The company is also required to maintain a minimum flow release of 250 cfs (7.08 m^3/s) prior to September 15, and 350 cfs (9.91 m^3/s) after September 15, the latter for upstream migration of fish.

Sewage treatment plant operators and fisheries agencies have requested increased low flows for specified periods to dilute wastes, to maintain fisheries habitat, and to aid fish migration. However, in some years, the company has not been able to maintain the existing required releases and has requested and received permission to reduce the required releases to 175 cfs to 200 cfs for a period to maintain storage supplies for later releases.

Figure 2.1 indicates that the required low flow releases have usually been achieved on an average monthly basis, and that regulation of storage has significantly increased the low flow supply in August, September and October. The 7-day low flow analysis, however, indicates that for shorter periods of time within the period of regulated flows, the required minimum release of 250 cfs (7.08 m^3/s) has not been achieved. A preliminary review of the streamflow records at Cowichan Lake indicates that perhaps an improvement in the "operation rule" or improved operations may afford a better maintenance of low flows. The "operation rule" has not been reviewed and revised since 1974. It is recommended that the "operation rule" and operation of the control structure be reviewed to determine if a revised "operation rule" or operation can provide a better distribution and control of low flows. Significant increases in low flow releases are not anticipated unless a larger volume of storage can be controlled (i.e. by lowering the natural outlet control or increasing the period and extent of high water around the lake). Preceding review of the rule curve, however, it is apparent that fisheries instream flow requirements should be re-assessed, using the methods employed elsewhere in the plan area.

The large supply of water within Cowichan Lake and its larger tributaries, compared with the relatively small licensed quantities, indicates that there is no overall water supply shortage or problem in this basin. Moreover, Cowichan Lake acts as a natural (albeit now regulated) storage reservoir that naturally mitigates low flow shortages that occur elsewhere in the plan area.

The only potential increased water requirement which might be expected is a slight increase in waterworks use by the Village of Lake Cowichan. Any such increase would have a negligible effect on downstream Cowichan River flows.

5. Stanley Creek

Stanley Creek enters the Cowichan River from the north, not far downstream of the Lake Cowichan dam. Estimates of the one year in five average 7-day low flow, instream fisheries requirements and licensed water quantities indicated that there is a low flow water shortage on this source. However, an unused waterworks licence for 200,000 gpd (0.011 m^3/s estimated equivalent flow) held by the Village of Lake Cowichan is subject to cancellation for non-use. When this waterworks licence is cancelled, the remaining few domestic water licences will be the only licensed requirements competing with fisheries instream flow requirements for low flows. The unused waterworks water licence should be cancelled . No future demand is forecast for this source.

A breached control structure on Stanley Creek, formerly used for the waterworks supply, could be repaired to provide a minor amount of regulation to increase low flows. The fisheries agencies should consider negotiating with the Village for the acquisition, repair and use of the structure to maintain flows for fisheries purposes.

6. Cowichan River at Lake Cowichan Sewage Treatment Plant

Licences above this location total 0.093 m^3/s, but only the 0.011 m^3/s licence on Stanley Creek would have any effect on the estimated low flow (6.27 m^3/s, 5-year recurrence interval), which greatly exceeds this amount. Minimum fisheries requirements of approximately 7.1 m^3/s are not available at the one year in five frequency. However, as recommended in (4) above, fisheries instream requirements should be re-assessed using appropriate methods. The stream channel slightly below the STP outfall is the site of algae growth due to an increase in nutrients. Although flow is only one of the factors influencing algal growth, dilution of maximum effluent flow of approximately 0.02 m^3/s is about 300:1, using the estimated 5-year low flow of 6.27 m^3/s (Table 4.1) following licensed extractions. The instream flow available for waste dilution exceeds the estimated instream requirement for this purpose.

No increases in licensed water requirements are projected.

7. Cowichan River below Fairservice Creek

Total licences to this location are only marginally greater than for the analysis location above. The estimated supply during the minimum 7-day average low flow is 6.31 m^3/s, but this is still less than the minimum fisheries requirement of 7.1 m^3/s. However, this requirement should be reviewed. No licensed increases are foreseen.

8. Bear Creek

This tributary enters the Cowichan River from the south, approximately two-thirds of the way up the Cowichan River from the estuary to the lake. None of the estimated 5-year low flow has been licensed nor are any licensed requirements projected. The estimated instream fisheries requirement is much greater than the estimated 7-day low flow. Bear Creek is another example of a stream in which natural low flow supplies are limiting for fisheries purposes.

9. Cowichan River above Holt Creek

This analysis location is approximately half-way down the Cowichan River from Cowichan Lake, with upstream water licences below Cowichan Lake still totalling only 0.012 m^3/s. The estimated low flow of 6.42 m^3/s indicates that there is less than enough water during the low flow period to satisfy fisheries requirements of 7.1 m^3/s. However, as with other Cowichan mainstem locations, the fisheries requirement should be re-assessed for its appropriateness.

10. Inwood Creek

Inwood Creek enters the Cowichan River from the north. The area has considerable agricultural potential. Present licensed quantities are only slightly less than the 5-year estimated low flow of 0.025 m^3/s.

Fisheries requirements for Inwood Creek are more than the estimated 5-year low flow. Inwood Creek contains significant fisheries habitats suitable for stocking, but a barrier near the mouth prevents these habitats from being utilized by anadromous fish. The possibility of stocking Inwood Creek is being investigated. If storage options exist in this sub-basin, greatly improved habitat for summer fish rearing would consolidate an effective stocking program.

Only about half of the agricultural class 1-3 land is now improved, indicating that agricultural potential is still present. However, it is not anticipated that any irrigation expansion will occur during the next 5 years. Headwater storage, if feasible, may provide a solution for future irrigation and fisheries flow requirements.

11. Cowichan River at Highway 1

Above this analysis location is the intake for BCFP's industrial licence (2.83 m^3/s), which is supported by storage on Cowichan Lake. Waterworks licences for Duncan are also located near this point, and although they total an equivalent flow of 0.165 m^3/s, almost no use is made of these licences, water being supplied instead from wells adjacent to the river. The total licensed flow upstream of this location but downstream of Cowichan Lake is 3.05 m^3/s, which is less than the 5-year estimated low flow of 6.56 m^3/s, controlled to a large extent by releases from Lake Cowichan storage.

The low flow water supply analysis indicates that the required residual flows past B.C. Forest Product's intake, for fisheries instream requirements and other uses, have been maintained or exceeded. As elsewhere on the Cowichan, the fisheries flow should also be re-examined at this location.

There are no projected increased licensed demands for waterworks or industrial purposes and the projected irrigation and domestic demands will not significantly affect the low flows. The city of Duncan and Municipal District of North Cowichan's future water demands will likely be obtained from groundwater well sources (similar to those already developed adjacent to the Cowichan River) and B.C. Forest Products increased production has been attained through improved water use, rather than increased water supplies. Therefore, there is no indicated shortage of water supply in the Cowichan River at Duncan for existing and projected demands and fisheries instream flow requirements.

12. Cowichan River at Duncan-North Cowichan Sewage Treatment Plant

Effluent from both the Duncan-North Cowichan Sewage Treatment Plant and the Ministry of Environment fish hatchery enter the river at this location. A 200:1 dilution objective for an STP effluent flow of 0.157 m^3/s requires a flow in the river of 31.4 m^3/s. This objective is not met during the low flow season.

The fisheries requirement is available at this location, but should be re-assessed using methods comparable to those employed elsewhere in the plan area.

13. Cowichan River at the Mouth

The estimated low flow supply at this location exceeds both licensing and fisheries requirements. The latter should be reviewed along with all other mainstem Cowichan locations. No additional requirements are anticipated in the near future.

4.4.2 SOMENOS CREEK SYSTEM

1. Bings Creek

Estimates of low flow water supply, instream fisheries requirements and licensed water demand indicate that the low flow water supply may be marginally adequate. There is considerable water available for storage and regulation of streamflow if suitable storage sites can be identified. A possible storage site has been identified on upper Bings Creek.

The present licensed quantity (0.010 m^3/s) is primarily for irrigation. Projected irrigation increases during the next 5 years are minimal (0.001 m^3/s), although the area has considerable longer-term agricultural potential.

This stream is estimated to be at the critical stage for the competing requirements of instream fisheries flows and irrigation demands. No further water should be allocated from this source (except domestic) unless off-stream storage or flow regulation is provided. Groundwater supply for irrigation may also be a possibility in part of the basin.

2. Averill Creek

Averill Creek experiences shortages for licences and fisheries requirements. If further irrigation water was available, it has been projected that an additional 81 hectares (200 acres) would be developed during the next 5 years (Table 3.4), requiring an amount of water nearly twice the present low-season supply. Groundwater potential is low to nil, other than near the mouth of the creek, where it is moderate. Storage appears to offer the best prospect to provide low flows to meet fisheries instream requirements and irrigation expansion. There is water available for storage and regulation if storage sites can be identified. No further water should be allocated from this source (except domestic), unless offstream storage or flow regulation is provided. Existing licensed demands should be assessed, storage sites identified and unused water licences cancelled.

3. Richards Creek at Richards Trail

Nearly all of the water licensed above this location (0.011 m^3/s) is for waterworks for Crofton. Storage is provided on Crofton Lake to support this waterworks licence. The estimated low flow supply is not sufficient to meet the minimum fisheries requirement.

During the next 5 years, an additional 0.002 m^3/s is projected to be required for irrigation. Since there is already insufficient water for fisheries purposes, increased low flows from Crofton Lake (either by better regulation of releases at the lake or by increased storage), or alternative storage and flow regulation sites, appears to offer the only additional water supply available for either irrigation or fisheries purposes. Groundwater potential in the area appears to be low to nil.

Since major fisheries habitat restoration of the stream for summer rearing has already occurred, additional storage regulation should be investigated in an attempt to meet both fisheries requirements, and a possible small increase in irrigation requirement. The prime fisheries habitat extends 100 m. below Richards Trail.

4. Richards Creek at Somenos Lake

Licensed quantities exceed estimated supplies in this lower part of Richards Creek. However, the residual flow from upper Richards Creek somewhat alleviates this shortage. Indications are that actual low flow supplies closely approximate current actual licensed use. A minimum fisheries water requirement was not estimated for this location, since fisheries habitat in the vicinity is considered poor.

An additional 0.036 m^3/s is projected to be required within the next 5 years for irrigation. New storage and better regulation of existing storage appears to offer the best prospect for providing increased flows. Potential for locating large sources of groundwater in the lower Richards Creek drainage appears to be low to nil.

No further water should be allocated from this source unless offstream storage or flow regulation is provided to mitigate the demand on low flows. Existing licensed requirements should be assessed, storage sites and regulation potential identified and unused water licences cancelled.

5. Somenos Creek at the Mouth

Somenos Lake has an estimated volume of 4,200 dam^3 of which 366 dam^3 is required for existing licences. Additional extractions from the lake will reduce the water levels in the lake and may prolong the periods of zero flow in the outlet channel of Somenos Creek. Further data and information is required in order to assess the effects further withdrawals would have on the outflow from the lake.

Only a small increase in irrigation requirement is projected for the period to 1989. Groundwater potential is low to nil except southwest of Somenos Lake (where it is moderate) and along the creek downstream of Somenos Lake (where it is good). This indicates that large volumes of groundwater will not likely be available in much of the sub-basin.

The instream requirement for fisheries does not appear to be met, since periods of zero flow occur in Somenos Creek each year. However, the Cowichan River backs up into Somenos Creek, to the extent that adequate water is present for fish.

6. Quamichan Creek at Quamichan Lake Outlet

The total licensed quantity above this location is 0.047 m^3/s, nearly all of it for irrigation, and this is primarily supplied from Quamichan Lake. The lake has an estimated volume of 14,000 dam^3 of which 482 dam^3 is required for existing licences. An increased requirement of 125 dam^3 for irrigation is projected during the next 5 years. Groundwater potential in the area is low to nil. An initial evaluation indicates there is adequate water available in Quamichan Lake for existing and potential licensed requirements. However, additional extractions from the lake could prolong the period of zero flow already occurring each year in Quamichan Creek. The fisheries instream requirement is not being met and further analysis is required to determine the effect of further lake withdrawls on fisheries.

4.4.3 KOKSILAH RIVER SYSTEM

1. Koksilah River above Grant Lake Outlet

No licences have been issued above this location, so that all flow from the upper Koksilah drainage is available at the next analysis location downstream (Koksilah River at Cowichan Station). The 5-year estimated low flow is less than the estimated minimum fisheries requirement. No Agricultural Land Reserve is present in this sub-basin, and no water allocations are currently anticipated for irrigation or any other purpose.

2. Patrolas Creek at Hillbank Road

This tributary enters the Koksilah from the east, upstream of Cowichan Station, its source being Dougan Lake. Licensed quantities exceed the 5-year estimated low flow in this sub-basin. Most of the licensed quantity is for irrigation, and most of the class 1-3 land is already developed. An additional irrigation requirement of 0.007 m^3/s is projected in the next few years, should water be available. Groundwater potential in the sub-basin is rated moderate or good, indicating irrigation increases may be supplied from groundwater sources. Development of storage may also provide water for some irrigation requirements.

No further water should be allocated from this source unless offstream storage is provided to mitigate the demand on low flows. Existing licensed quantities should be assessed, storage sites identified and unused water licences cancelled.

Estimated fisheries flow requirements are not met.

3. Koksilah River at Cowichan Station

The 5-year estimated 7-day low flow is more than adequate for licensed use. About three-quarters of the most valuable agricultural land along the Koksilah River above this location is now improved. A forecast additional 0.004 m^3/s is indicated for irrigation increases in this area in the near future. Some of the lower part of this sub-basin (particularly east of the Koksilah) has moderate groundwater potential, and in general this area coincides with the agricultural land, where irrigation expansion can eventually be expected. The fisheries flow requirement is not available given current conditions.

4. Glenora Creek

Glenora Creek flows eastward to enter Kelvin Creek, which then joins the Koksilah River downstream of Cowichan Station. The estimated low flow is less than the existing licensed quantity. Groundwater potential in most of the agriculturally-suitable parts of the sub-basin (lower Glenora Creek upstream to Keating Lake) ranges from some potential through moderate to good potential. Since about one- quarter of the agricultural area is not yet developed, groundwater would appear to be the likely water source for future expansion. An additional requirement of 0.003 m^3/s is projected for this area in the next 5 years. Development of storage may also provide increased low flows provided suitable storage sites can be identified and developed. Storage development may additionally benefit fisheries flow requirements, which are greater than the mean year estimated low flow, and are therefore not being met. The Glenora-Kelvin system contains the most significant fisheries tributary habitat in the Koksilah River system, but large areas of Glenora Creek dewater each season, requiring fry salvage or unavoidable fry dessication or predation.

No further water should be allocated from this source unless storage is provided to mitigate the demand on low flows. Existing licensed demand should be assessed, storage sites identified and unused water licences cancelled.

5. Kelvin Creek

Present licensed quantities above this analysis location can be met according to the estimated low flow. However, less than half of the high capability agricultural land is now developed, so that increased demands for irrigation water can be expected. Groundwater potential in the ALR is generally moderate to some potential. The estimated fisheries requirement is greater than the supply estimate, indicating insufficient water is available for fisheries in this prime fisheries habitat.

No further water should be allocated from this source unless storage is provided to mitigate the demands on low flows. Existing licensed demand should be assessed, storage sites identified and unused water licences cancelled.

6. Koksilah River at the Mouth

Total licensing above this location is less than the low flow estimate. However, approximately one-quarter of the good agricultural land is not yet developed, so that increased requirements can be expected. An increase of approximately 0.012 m^3/s is projected for irrigation by 1989. Groundwater potential is moderate to good in most of the Agricultural Land Reserve, and the annual hydrograph indicates there is considerable water available for storage and regulation of flows if suitable storage sites can be identified and developed. The minimum fisheries requirement is not available once licensed quantities are withdrawn.

No further water should be allocated unless storage or flow regulation is provided to mitigate the demand on low flows.

4.4 SUMMARY

The preceding analysis indicates that the Cowichan River basin upstream of the outlet of Cowichan Lake has a sufficient supply of water for all existing licences and projected uses. The smaller tributaries may not have sufficient flow to meet fisheries requirements and flow is particularly limiting for fisheries in the alluvial fan areas of the tributaries. The mainstem of the Cowichan River downstream of Cowichan Lake has sufficient water supply for all existing licences and projected withdrawals. There is insufficient flow to meet fisheries requirements between the lake and the BCFP intake, but all Cowichan mainstem fisheries requirements should be re-assessed using methods comparable to those used in the rest of the plan area. Downstream of the intake, the flows meet fisheries requirements but there is insufficient flow to meet a 200:1 dilution objective at the discharge from the sewage treatment plant. In general, the larger tributaries to the Cowichan downstream of the lake have a sufficient water supply for existing licences but do not satisfy the required fisheries flows.

Within the Somenos basin, there is generally sufficient water to supply the existing licences with the exception of Averill Creek and Richards Creek which are over-committed. There is very little water available at low flow for future water uses. Fisheries requirements are generally not met with the exception of those areas where there is no fisheries flow required.

Within the Koksilah basin, there is low flow available to meet most of the existing licensed use. There is generally insufficient flow to meet fisheries requirements even without any licensed withdrawals. The Koksilah mainstem and all tributaries are presently noted as fully recorded in the stream register.

Storage and, in some cases, groundwater may be developed to mitigate increased licensed quantities and instream requirements during low flows. Potential storage sites and groundwater aquifers should be identified in these areas and development encouraged to mitigate low flow demand.

Flow regulation at Lake Cowichan has been able to maintain the required low flow releases on an average monthly basis However, low flow releases for shorter time intervals and less than average flow years have not been maintained in the Cowichan River. It is recommended that Cowichan mainstem fisheries seasonal instream requirements be assessed in the field, revised as appropriate, and if necessary the operation and the "operation rule" be reviewed to assess whether improvements can be attained.

CHAPTER 5. COWICHAN-KOKSILAH WATER MANAGEMENT PLAN CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 LOW-FLOW SEASON SUPPLY AND USE

1. Analysis locations at which there are indications of supply shortages for existing licences are:

   Cowichan system:
   - Stanley Creek

   Somenos system:
   - Averill Creek
   - Richards Creek at Somenos Lake

   Koksilah system:
   - Patrolas Creek at Hillbank Road
   - Glenora Creek

2. Analysis locations at which there are indications of supply shortages for instream fisheries purposes are listed below. Low instream flows for fisheries result in less than optimum fisheries survival and productivity.

   Cowichan system:
   - Cowan Brook
   - Cowichan River at Cowichan Lake Outlet
   - Stanley Creek
   - Cowichan River at Lake Cowichan Sewage Treatment Plant
   - Cowichan River below Fairservice Creek
   - Bear Creek
   - Cowichan River above Holt Creek
   - Inwood Creek

However, since a different method was used to estimate Cowichan River instream fisheries requirements, they should be reviewed, and revised if necessary. Therefore, the current apparent shortage in the upper Cowichan for this purpose may not be a real shortage.

Somenos system:
Bings Creek (fisheries requirement = surplus)
Averill Creek
Richards Creek at Richards Trail
Somenos Creek at the Mouth

Quamichan Creek at Quamichan Lake Outlet

Koksilah system:
Koksilah River above Grant Lake Outlet
Patrolas Creek at Hillbank Road
Koksilah River at Cowichan Station
Glenora Creek
Kelvin Creek
Koksilah River at the Mouth

In two cases (Bear Creek, Koksilah River above Grant Lake Outlet), fish habitat is limited during the low-flow period on streams with no water licences, indicating fish habitat in these areas is naturally limited.

3. With existing levels of treatment, instream flows required for dilution of sewage treatment plant effluents are not sufficient at the Duncan-North Cowichan Sewage Treatment Plant during the low flow period.

4. Estimates of water supply using only the 7-day low flow period are not entirely adequate to identify water shortages and to determine the full range of water management options for all water users, and may be supplemented by examining other temporal distributions of flow.

5. A variety of water supply estimate methods were used, since the regionalization methods alone did not appear to adequately assess water supplies. These methods should be further developed and tested.

6. The accuracy of small watershed water supply estimates is limited by a lack of adequate stream gauge records on small basins, resulting in very wide confidence limits and therefore only marginally useful supply estimates.

7. It may be possible to refine the regionalization methodology for determining supply estimates for ungauged sites to provide more accurate estimates, by including additional parameters such as climate, storage, topography and geology.

8. Water management decisions utilizing low flow calculations would be improved by direct computer access to all Water Survey of Canada flow data, and to analysis programs developed to interpret these data.

9. Fisheries instream flow requirements (quantities and temporal distribution) estimated in this plan for the Cowichan mainstem are not, at present, adequately defined to warrant changes to the operating rule curve for Cowichan Lake storage releases. However, subsequent to further studies to more precisely define seasonal fisheries requirements, a detailed evaluation of the operating rule curve should be carried out to meet refined fishery and other instream flow requirements identified in this plan.

10. Inventory of potential storage sites is incomplete (Appendix 5.1), upper Bings Creek being the only potential undeveloped site assessed.

11. Water quality analysis determined that nutrient and fecal coliform levels in both the Cowichan and Koksilah systems exceed working water quality criteria for sensitive uses. In addition, copper often exceeds the criterion in both systems, and other parameters occasionally exceed the criteria, based upon limited sampling.

12. Objectives and policies to integrate water quantity and water quality are inadequate. For example, the issuance of an effluent permit for a discharge to a stream does not carry with it a water licence which gives a commitment for the long-term required dilution flow. However, permits can be made subject to flow regulation by the permittee.

5.1.2 GROUNDWATER

1. The amount of groundwater use cannot be accurately estimated, but it is likely that groundwater provides the majority of irrigation water in the plan area.

2. Groundwater use has increased significantly during the past several decades, based on numbers of wells known to have been drilled, and is expected to continue to increase in the next 5-year period.

3. Considerable groundwater potential exists, and its location coincides reasonably well with arable soils areas.

4. In the lower Cowichan Valley, there appears to be direct hydraulic continuity between groundwater and surface water, and groundwater withdrawals may affect river flows to some (unknown) extent.

5. Groundwater quality is generally within drinking water quality objectives. There are site specific areas where groundwater quality problems such as high chlorides exist; however, further investigations are required to determine the magnitudes and extent of these problems.

5.1.3 FLOODING AND EROSION

1. Winter flooding and erosion areas in the lower Cowichan and Koksilah rivers are adequately identified on floodplain mapping, and a reasonable amount of dyking is in place. Areas of flooding in and around the Village of Lake Cowichan have also been identified.

2. Soils-based CAPAMP (Computer Assisted Planning and Assessment Map Production) mapping has been prepared for the plan area, to highlight areas with potential for flooding and/or erosion.

5.1.4 OTHER ISSUES

1. Issues relating to gravel removal and angler access have not been addressed in this plan.

5.2 RECOMMENDATIONS FOR ACTION

1. No further water (except for domestic purposes) should be allocated unless storage or flow regulation is provided on the following streams, all of which are already designated as fully-recorded in the Stream Register:
   Stanley Creek
   Bings Creek
   Averill Creek
   Richards Creek
   Koksilah River
   Patrolas Creek
   Glenora Creek
   Kelvin Creek

2. Before further water allocation is authorized, carry out the following data collection, regulation or analysis:

(a) Cowan Brook - determine low-flow supply at the head of the fan for possible allocation..
(b) Stanley Creek - cancel the unused waterworks licence to reduce potential conflict with instream fisheries low-flow requirements.
(c) Inwood Creek - assess headwaters for fisheries potential, and possible fisheries egress barrier at mouth of stream.
(d) Somenos Creek - assess potential effect on fisheries of further water allocation from Somenos Lake extending the period of zero outflow to Somenos Creek.

(e) Quamichan Creek - assess potential effect on fisheries of further water allocation from Quamichan Lake extending the period of zero outflow in Quamichan Creek.

For those analysis locations where water supply problems are identified in (1) and (2), carry out further analysis which may include a variety of temporal distributions to better define water supply, storage possibilities and management alternatives.

3. More precisely define quantitative and temporal instream fisheries requirements for various locations on the mainstem Cowichan River. Subsequently, if appropriate, review and modify if possible the provisional rule curve for Cowichan Lake, to provide a better temporal distribution of releases for fisheries and dilution flows using the existing storage range. Additional live storage on Cowichan Lake should also be further investigated.

4. Reassess instream flow requirements and consider protection of these requirements in the following additional sub-basins and their tributaries (with the exception of domestic licences where no feasible alternative for water supply is available):
   Cottonwood River
   Robertson River
   Bear Creek
   Inwood Creek

5. Measure streamflows during the low-flow season at selected locations, and attempt to refine techniques for estimating low flows to refine supply estimates and allow water surplus/shortage conclusions to be reached with greater confidence.

6. Improve the hydrometric network by establishing stream gauges on representative small basins.

7. Refined estimates of water requirements for fisheries purposes using appropriate methodologies should be made where both measured streamflow

and fisheries habitat area information is available, ensuring that measurements are compatible for estimating water supply.

8. A storage inventory at the reconnaissance level should be initiated to identify possible water storage sites in the headwaters of all streams having present or projected water shortages for either licensed or instream uses.

9. Further investigate those potential water storage sites previously identified (see Appendix 5.1), to augment the summer low flow for instream requirements, e.g. Bings Creek, Koksilah River, etc.

10. Evaluate whether real-time inflow forecasting to Cowichan Lake would improve the operation of the control works.

11. Review the operation of Crofton Lake storage, with the objective of increasing flows to Richards Creek within the existing storage range. Increasing the live storage of Crofton Lake should also be investigated.

12. Encourage the development of groundwater to satisfy existing and future irrigation requirements in the current or projected water-short basins.

13. Carry out the following priority groundwater studies:

    a) determine the extent of surface water and groundwater inter-relationships in the lower Cowichan Valley and specifically the effects of groundwater withdrawals for Duncan municipal water supplies on surface flows in the Cowichan River;
    b) assess through a questionnaire or survey, the degree of groundwater use in the area;
    c) undertake a groundwater quality sampling program to identify and analyze the potential for groundwater contamination, and the potential for salt water intrusion problems in the Cowichan Bay estuary area.

14. The list of streams having current or potential fish production ratings (Table 3, Appendix 3.1) should be considered when making decisions on water licence applications.

15. Investigate methods for reducing phosphorus and nitrogen releases to the Cowichan River from the Duncan-North Cowichan Sewage Treatment Plant, including, but not limited to, the following possibilities:

    a) reduce phosphorus inputs through chemical means.
    b) decrease effluent discharge during low-flow periods through storage.
    c) marine disposal of effluent.
    d) land disposal of effluent during the low-flow period.
    e) increase or modify low-flow season water supply in the river for greater dilution.
    f) provide better mixing of effluent with receiving water.

16. Use CAPAMP-identified potential flooding and erosion areas as indicators for further hazard identification in the field for future development assessment.

17. In conjunction with floodplain mapping, use CAPAMP-defined areas to recommend a policy of non-development in specific fan and other unstable areas subject to flooding and erosion.

18. Establish a water quality monitoring program and objectives for the Cowichan and Koksilah rivers.

5.3 LEGISLATIVE AND POLICY RECOMMENDATIONS

19. Consideration should be given to future amendments of the Water Act to recognize instream flow requirements including:
    i) fisheries
    ii) waste dilution
    iii) recreation

    and a method to allocate, protect or reserve specific flows for these uses should be incorporated.

20. The Water Act should be considered for amendment or policy developed to allow identification of water management areas where priority uses of water can be specified in a water management plan.

21. The section of the Water Act pertinent to groundwater should be amended and proclaimed to allow licensing of groundwater in specific areas where groundwater provides a major water supply, and where there may be impact upon surface supplies from the use of groundwater.

22. Policy or legislation should be developed to provide for the planning, allocation and management of water resources on a watershed basis.

5.4 RECOMMENDED PRIORITY ACTIVITIES

Table 5.1 contains all of the foregoing recommendations for action, subdivided by priority and category of action required.

TABLE 5.1
RECOMMENDED PRIORITY ACTIVITIES[1]

PRIORITY	ADMINISTRATIVE AND LICENSING	TECHNICAL AND INVENTORY STUDIES	LEGISLATION AND POLICY	CAPITAL WORKS
high	1, 2b, 12, 14	3, 5, 7, 8, 9, 18	19, 22	6
medium	17	2a, 4, 11, 13a, 13b, 15	20, 21	13c
low	16	2c, 2d, 2e, 10		

[1] Numbers in the body of the table refer to Recommendations in Sections 5.2 and 5.3.

CHAPTER 6

WATER MANAGEMENT INFORMATION SYSTEM CONCLUSIONS AND RECOMMENDATIONS

One of the main objectives of the Cowichan-Koksilah Water Management Plan was to demonstrate a prototype application of the information system, described in Appendix 1.1. This chapter draws conclusions on development of the system to date, and recommends steps which should be undertaken for its further development.

6.1 CONCLUSIONS

1. The pilot Water Licence module, the only module which was essentially operational by the end of the analysis phase of the Cowichan-Koksilah plan, provides rapid access and sorting capability to the following water licence information: georeferenced location, upstream-downstream distances, licence number, priority date, purpose, quantity, and quantity converted to common metric units. The program provides for summation of all licences upstream of any specified location.

2. A fully operational Water Information System module would be of considerable assistance to Regional Water Managers in accelerating licence application decisions and referrals.

3. Manual entry of water licence information was required for the Cowichan-Koksilah plan, but this time-consuming process could be greatly facilitated through computer software access and the use of existing computer data bases.

4. Modules for supply estimates, fisheries flows, and waste dilution flows have been conceptualized, but no development has yet taken place.

5. Other elements of a water management information system not yet incorporated into the structure include, for example, groundwater

information, storage opportunities, actual water use and temporal distribution of water use, other instream uses (e.g. recreation), and floodplain/erosion information.

6.2 RECOMMENDATIONS

1. The Water Management Program should support development of the Water Management Information System and initiate implementation.

2. Following approval of the system, development of the Water Licence module should be first priority for completion. This will require preparation of software to access the water billing system and the methods for digitizing points of diversion. This module should then be placed on-line for users.

3. Geographic areas for system implementation should then be priorized, so that the necessary geo-referencing can proceed.

4. Second priority after completion of the Water Licence module should be development of the Water Supply module.

5. Third priority should be development of the Fisheries Flow and Dilution Flow modules, which will mainly use information derived through the Fisheries and Waste Information Systems to indicate instream flow requirements.

6. Other elements of the information system identified in the conclusions (Section 6.1) could then be developed as priorities, budgets and information availability permit.

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APPENDIX 1.1

WATER MANAGEMENT INFORMATION SYSTEM
PILOT PROJECT

T. CHAMBERLIN
FISHERIES BRANCH
(April 1985)

APPENDIX 1.1

WATER MANAGEMENT INFORMATION SYSTEM PILOT PROJECT

1. INTRODUCTION

A pilot project to design and test water management information system techniques and applications was carried out in 1984-85 using information from the Cowichan River basin.

Information requirements for the system were defined by issues raised in a parallel water management plan, and vetted by a steering committee of representatives from the water, waste and fisheries programs, the Planning and Assessment Branch and the Canada Department of Fisheries and Oceans.

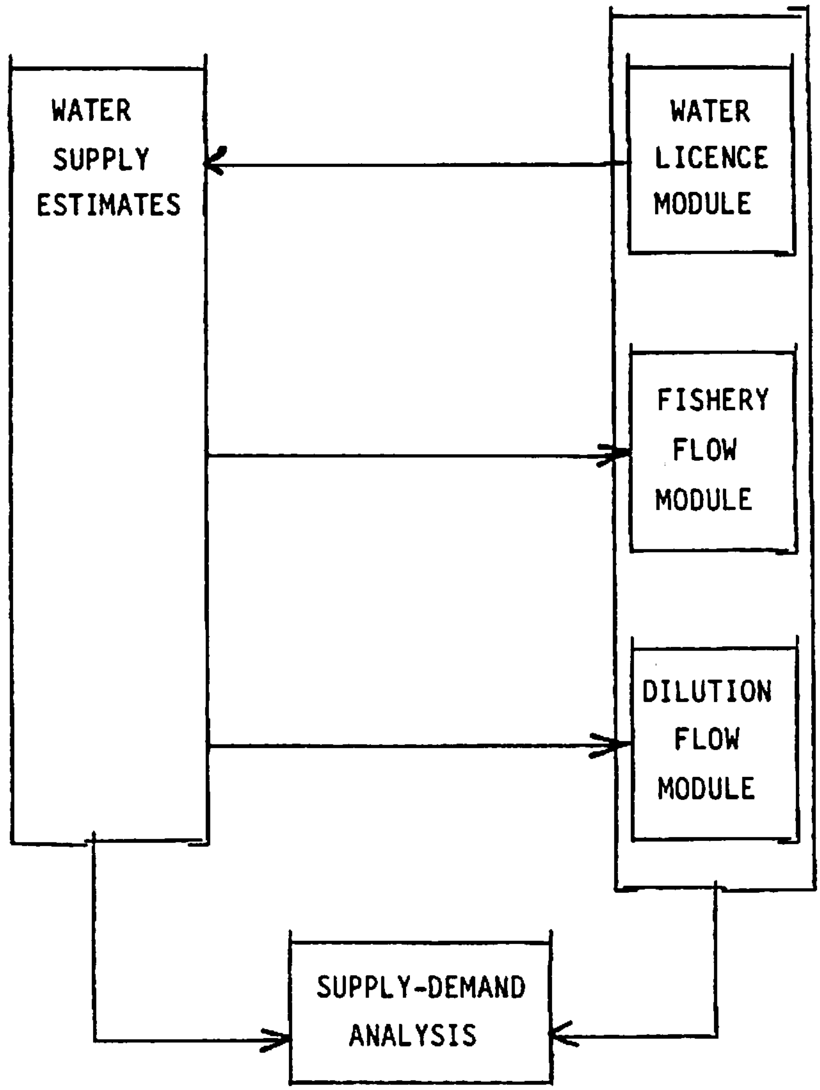
The pilot project emphasized frequently recurring information for which existing data base management techniques are available and for which large data sets exist. The information structure described in this report emphasizes the reorganization of existing data, and the addition of new data only as it becomes available.

For the purpose of this pilot project, high level report writing software (DATATRIEVE) and existing techniques from the Aquatic Biophysical Inventory System were used to demonstrate how water management information can be structured. A production application of the system will require an evaluation of the most appropriate software to meet regional and headquarters needs.

2. INFORMATION SYSTEM STRUCTURE

Water management options are evaluated by comparing water supply and water demand. The information (Fig. 1) which describes water demand has been divided into three modules: water licences, fishery flow requirements,

FIGURE 1
WATER MANAGEMENT INFORMATION SYSTEM
MODULE INTERACTIONS



and dilution flow requirements. A pilot data base for the water licence module has been designed and implemented to illustrate how the process can function. Other modules are described in this report, but are not yet functional.

The information system structure, as illustrated by the water licence module, is based on a data filing system which allows information about watersheds, tributaries, or sections of streams to be specifically addressed. This structure is created by using the provincial watershed coding system (Shera and Grant, 1980) to designate all tributary, subtributary, etc. relationships, and by digitizing the distance upstream from the mouth of all points of diversion, etc. within each stream. Algorithms (software) based on the watershed code and the distance upstream are then used to select the water licence information required for analysis.

2.1 WATER LICENCE MODULE

The water licence module permits the user to sort and sum licensed amounts of water by priority date, purpose and location within or between watersheds, above or below a specified location. It calculates an equivalent daily flow (cms) for each licensed use based on an assumed distribution through the year. This amount is used as input to the water supply module, and for comparison with other uses such as required fishery flows in a supply-demand analysis.

Although an operational water licence module has been developed for the Cowichan River pilot project, considerable additional design and development is required for efficient data entry and user-friendly output formats. In particular, techniques being developed for CAPAMP supported stream digitizing procedures (see Appendix A) should be utilized to create the required file structures.

Examples of the water licence module sorting process and output reports are included in Appendix B.

2.2 FISHERY FLOW MODULE

The fishery flow module has the objective of specifying flows required by fish populations so that they may be compared to available supply estimates. Several techniques for estimating required fishery flows are currently under evaluation in a parallel project (FLAP). For this pilot project, fishery flow estimates have been made for the 26 representative analysis locations. These estimates are subject to improvement as data and methodology permit.

Fishery flow estimates are subject to uncertainty in (a) biological requirements, and (b) hydrologic and hydraulic properties. In ungauged streams (the vast majority), biological requirements are subject to +/- 50-100% uncertainty while hydrologic and hydraulic properties may vary within two orders of magnitude (1,000 - 10,000%). Hence, fishery flow estimates must be used in full awareness of the assumed stream characteristics and available data.

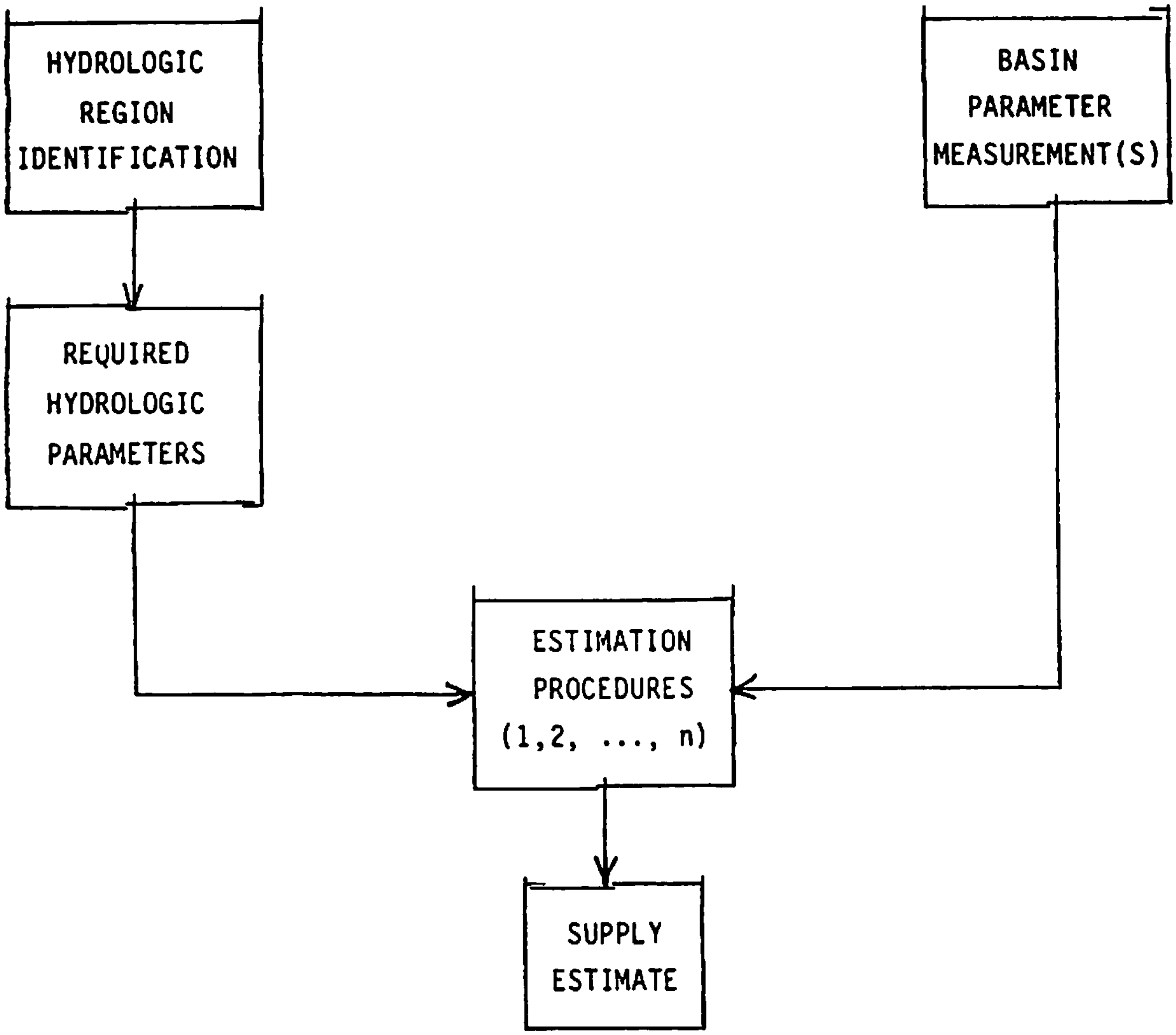
2.3 DILUTION FLOW MODULE

The dilution flow module has the objective of specifying flows required such that licensed (permitted) waste discharges result in specified water quality levels. It should enable changes in waste discharge, water use, or water quality objectives to be evaluated in the context of water management options. This module has not yet been developed, since it is dependent on output from all other modules in the information system.

2.4 WATER SUPPLY MODULE

The water supply module of the information system (Figure 2) has the objective of providing a best estimate of flow from a specific basin or sub-basin. Regionalized unit-area flow estimates for specific hydrologic parameters have been developed for the Cowichan River watershed using techniques described in Appendix 2.1 of the Cowichan-Koksilah Water Management

FIGURE 2
SUPPLY MODULE



Plan. Since the supply module is dependent on region and parameter specific estimate equations based on sub-basin area measurements, a generalized procedure is not included in this report.

Water supply estimate procedures must take into account the historical consumptive use of water. The water licence module, sorted by year, provides this use which is added to the recorded (WSC) flows to create a "naturalized" flow record. Frequency analysis of the "naturalized" flows provides the basic data for supply estimates. Software to computerize this process, when developed, will greatly reduce the time required to make supply estimates.

3. EXCLUDED INFORMATION REQUIREMENTS

Several important information requirements for water management have not been specified in the structure of an information system. Some are discussed in the Cowichan-Koksilah Water Management Plan, and are briefly listed here.

3.1 GROUNDWATER

The potential amount and quality of groundwater supplies can be estimated using standard techniques of well log and hydro-geologic analysis. Extraction and delivery costs will determine whether groundwater supplies are feasible.

3.2 WATER QUALITY

Water quality as it may be influenced by land use (agriculture, forestry, urbanization), soil and terrain interactions, or point source discharges has not been included here. Water quality data and mixing zones in a stream can be described using the data structure of the water licence module.

3.3 STORAGE

Storage opportunities and management options for moving water from one place to another are not discussed. Lee (1985), in a parallel study, has analyzed all existing storage options in the Vancouver Island Region. Her data is referenced by the provincial watershed code, and could be included in the supply analysis.

3.4 ACTUAL USE

The difference between actual and licensed use for most licences is not known. A conversion factor for actual use is included in the water licence module. When not known, it is assumed to be 1.

3.5 FUTURE USE

Future or potential use is evaluated through demographic or irrigation models which are run separately (e.g. on CAPAMP). The water management plan discusses these uses.

3.6 OTHER INSTREAM USES

Instream uses such as recreation, parks, transportation, etc. have not been addressed. Techniques are available for estimating these instream flow requirements.

3.7 OTHER WATER MANAGEMENT DATA

Information related to the use and management of floodplains, channel and bank stability, bed-material composition and other factors related to fish habitat (e.g. debris and cover) have not been included. It is important to note that most controversies between land or resource developments (especially forestry) and either water or fisheries are based on interpretations of these areas of information.

In particular, information about the soils, geology, vegetation and climate of a watershed may be vital for evaluating its potential for erosion, slope instability, or hydrologic change following forest harvesting or other land use. New techniques of using computerized analysis of these biophysical properties will enable better management of existing and future water supplies.

4. IMPLEMENTATION CONCERNS AND RECOMMENDATIONS

A global water management information system can not and should not be considered, and was not the objective of this pilot project. In addition to the excluded information areas (Section 3 above), design and development in the areas of software, data entry, training and policy would be required to implement the limited modules described above. Required development should be directed by the information needs analysis currently underway in the Water Management Program. The Cowichan-Koksilah Water Management Plan should provide valuable information for this process.

The following are preliminary suggestions for initiatives which would be required to establish the water licence module as a working tool in a regional (or headquarters) office. The time estimates are based on gut feeling and experience with the systematic mapping of water licence data sets during the Cowichan pilot project.

4.1 WATER LICENCE MAPPING

Prior to digitizing the location of water licence points of diversion, they must be plotted on a common map base. The 1:50 000 NTS base is sufficient for the purpose of within-stream ordering (although not for legal locations). I estimate that 1500 (+/- 500) licences per month can be so plotted.

4.2 WATER LICENCE DIGITIZING

The location (watershed code, distance upstream, UTM coordinate) of each point of diversion must be established. With appropriate enhancement of the stream digitizing software being developed by the Fisheries Program (see Appendix A), I estimate that the location of 4000 water licences per month could be digitized by one CAPAMP system operator.

Required software development for this task has not been specified, but is presumed to require from one to four weeks.

4.3 DATA ENTRY SOFTWARE

The specification and design of a system to (a) access information currently resident in the IBM and combine it with (b) information resulting from the digitizing process in (c) a water licence module with properties of the prototype of this pilot project is required, and is estimated to require from one to six weeks of software development.

4.4 SORTING AND OUTPUT SOFTWARE

The pilot water licence module is not sufficiently friendly. Improvement of sort/search algorithms and creation of necessary output formats would require from one to four weeks of software development.

Development of software identified in 4.2, 4.3 and 4.4 could proceed concurrently.

4.5 TRAINING AND POLICY

Prior to implmentation, Ministry and Water Management Branch policy would, of course, be required to support the use and maintenance of a water licence information system. The current functions of the Water Licensing Section, as well as activities in the water allocation process (in both regions and headquarters) would be affected.

APPENDIX A
CAPAMP SUPPORTED STREAM DIGITIZING - A SUMMARY

BACKGROUND:

A method of extracting elevation and distance information from 1:50 000 NTS maps for the calculation of stream gradients, and, hence, fishery production potentials, was developed in 1983 and 1984. The method with its map and tabular products (SHIP) was applied to pilot areas on Vancouver Island and evaluated in 1984. It was found useful but excessively labour intensive and a contract was let in late 1984 to develop and test software for computer assisted map digitizing processes to produce the same products.

This development was completed in early 1984 by DR Systems Ltd. (Nanaimo) and PAMAP (Victoria). Limited test production has been run on 10-20 map sheets on Vancouver Island. Production for the rest of British Columbia is anticipated for 1985-88 under the auspices of the coordinated Fed./Prov. Fisheries Habitat Inventory and Information Program.

PROCEDURE:

Maps of any scale are digitized using the INTERGRAPH software on graphics terminals and digitizing tables linked to the provincial VAX computer (collectively, the CAPAMP system). The lines (streams) and polygons (lakes) are stored on various levels in the system. Information about particular points (cells) on these lines is generated from the digitizing or elsewhere and used to create the required products.

Information currently generated during the digitizing process includes the following:

1. The watershed code number of the stream being digitized, which is used to organize and sort subsequent data. The computer generated number

replaces all existing watershed numbers below the third hierarchical level.

2. Distance upstream of all points along the stream line.
3. Location and elevation of all contour line crossings, and by interpolation, the elevation of any other point along the stream line.
4. Location of all stream, tributary and distributary mouths, and calculation of their elevations.
5. Inlet and outlet of all lakes, and their elevations.
6. The type of cell located along the stream line (e.g. tributary mouth, elevation point, end of stream, edge of map, etc.).
7. All locations are referenced by UTM coordinates which can be converted to latitude and longitude.

The procedure requires a map preparation phase, a digitizing phase, editing and the production of final products.

PRODUCTION:

The stream digitizing process permits a user to request any combination of the following maps and reports, for any combination of streams and/or their tributaries.

1. The basic stream drainage network map, with or without lakes, coastlines, cell locations or labels.
2. The dictionary report of watershed code numbers (old and new), watershed names (or aliases) and locations.
3. The tabular report listing, by stream, the total distance in each of up to five user defined gradient classes. This table can be rolled up to any specified hierarchical stream level.
4. A map showing the location of the stream classes defined in 3.
5. The tabular report listing all cell information.
6. A gradient profile (longitudinal) of the stream.

These products are produced, of course, only as required. They are stored as a data set on tape or disk until run on the provincial VAX computer. We are presently running only those reports required for steelhead trout production modelling.

FUTURE APPLICATIONS:

The software and procedures described above can be applied to any mapable information which is organized on a watershed or stream network basis. The system is scale-independent, so accuracy is only limited by the source map which is digitized. It is compatible with all other MOE computer mapping (e.g. soils, terrain, climate) as well as MOF forest cover maps, and the cadastral information of MLPH.

Immediate MOE applications for which the system seems suitable include SEAM site locations, water licence information management, floodplain covenant filing, fishery species distribution, migration barrier location, effluent permit locations, etc. Applications such as these are being identified in the various programs through the information needs analysis procedure.

Further information on any aspect of the CAPAMP stream digitizing procedure can be obtained from T. Chamberlin (387-4573).

WATER LICENSE
INFO SYSTEM

30-Jul-1985
Page 1

WATERSHED NUMBER	WATERSHED NAME	PRIORITY DATE	LICENSE NUMBER	QUANTITY	UNITS	PURPOSE	DISTANCE UPSTREAM	DISTANCE DOWNSTREAM	QUANTITY CMS	POD NO
924800060650000000000	BINGS C			0.00		PT	1.29	8.07	0.000000	
924800060650000000000	BINGS C	9-Mar-1951	F 14321	500.00	GD	DOM	4.75	4.65	0.000026	1
924800060650000000000	BINGS C	1-Aug-1951	F 15861	500.00	GD	DOM	0.79	8.62	0.000026	2
924800060650000000000	BINGS C	23-Aug-1951	F 16144	1.00	AF	IRR	0.76	8.65	1.000019	3
924800060650000000000	BINGS C	6-Feb-1953	F 15469	500.00	GD	DOM	4.30	5.10	0.000026	4
924800060650000000000	BINGS C	20-Feb-1953	F 15862	500.00	GD	DOM	4.83	4.57	0.000026	5
924800060650000000000	BINGS C	30-Jun-1954	F 17134	500.00	GD	DOM	4.42	4.98	0.000026	6
924800060650000000000	BINGS C	17-Sep-1957	F 18400	1000.00	GD	DOM	5.12	4.28	0.000053	8
924800060650000000000	BINGS C	1-Apr-1960	F 18401	30.00	AF	IRR	5.12	4.28	30.000570	8
924800060650000000000	BINGS C	2-Nov-1960	C 26358	1000.00	GD	DOM	5.73	3.68	0.000053	9
924800060650000000000	BINGS C	26-Apr-1966	F 19505	5.60	AF	IRR	5.12	4.28	5.600106	8
924800060650000000000	BINGS C	18-May-1967	C 32600	500.00	GD	DOM	4.46	4.94	0.000026	11
924800060650000000000	BINGS C	9-Aug-1967	C 32910	5.00	AF	IRR	4.53	4.88	5.000095	12
924800060650000000000	BINGS C	9-Aug-1967	C 32910	500.00	GD	DOM	4.57	4.83	0.000026	13
924800060650000000000	BINGS C	9-Oct-1970	C 36771	500.00	GD	DOM	4.50	4.91	0.000026	10

041.60111

APPENDIX B

1. WATER LICENCES SORTED BY PRIORITY DATE

WATER LICENSE
INFO SYSTEM

30-Jul-1985
Page 1

WATERSHED NUMBER	WATERSHED NAME	PRIORITY DATE	LICENSE NUMBER	QUANTITY	UNITS	PURPOSE	DISTANCE UPSTREAM	DISTANCE DOWNSTREAM	QUANTITY CMS	POD NO
924800060650000000000	BINGS C	9-Mar-1951	F 14321	500.00	GD	DOM	4.75	4.65	0.000026	1
924800060650000000000	BINGS C	9-Aug-1967	C 32910	500.00	GD	DOM	4.57	4.83	0.000026	13
924800060650000000000	BINGS C	18-May-1967	C 32600	500.00	GD	DOM	4.46	4.94	0.000026	11
924800060650000000000	BINGS C	20-Feb-1953	F 15862	500.00	GD	DOM	4.83	4.57	0.000026	5
924800060650000000000	BINGS C	17-Sep-1957	F 18400	1000.00	GD	DOM	5.12	4.28	0.000053	8
924800060650000000000	BINGS C	2-Nov-1960	C 26358	1000.00	GD	DOM	5.73	3.68	0.000053	9
924800060650000000000	BINGS C	30-Jun-1954	F 17134	500.00	GD	DOM	4.42	4.98	0.000026	6
924800060650000000000	BINGS C	9-Oct-1970	C 36771	500.00	GD	DOM	4.50	4.91	0.000026	10
924800060650000000000	BINGS C	6-Feb-1953	F 15469	500.00	GD	DOM	4.30	5.10	0.000026	4
924800060650000000000	BINGS C	1-Aug-1951	F 15861	500.00	GD	DOM	0.79	8.62	0.000026	2
924800060650000000000	BINGS C	9-Aug-1967	C 32910	5.00	AF	IRR	4.53	4.88	5.000095	12
924800060650000000000	BINGS C	23-Aug-1951	F 16144	1.00	AF	IRR	0.76	8.65	1.000019	3
924800060650000000000	BINGS C	1-Apr-1960	F 18401	30.00	AF	IRR	5.12	4.28	30.000570	8
924800060650000000000	BINGS C	26-Apr-1966	F 19505	5.60	AF	IRR	5.12	4.28	5.600106	8
924800060650000000000	BINGS C			0.00		PT	1.29	8.07	0.000000	

041.60111

APPENDIX B

2. WATER LICENCES SORTED BY PURPOSE

WATER LICENSE INFO SYSTEM

30-Jul-1985
Page 1

WATERSHED NUMBER	WATERSHED NAME	PRIORITY DATE	LICENSE NUMBER	QUANTITY	UNITS	PURPOSE	DISTANCE UPSTREAM	DISTANCE DOWNSTREAM	QUANTITY CMS	POD NO
924800060650000000000	BINGS C	1-Aug-1951	F 15861	500.00	GD	DOM	0.79	8.62	0.000026	2
924800060650000000000	BINGS C	6-Feb-1953	F 15469	500.00	GD	DOM	4.30	5.10	0.000026	4
924800060650000000000	BINGS C	30-Jun-1954	F 17134	500.00	GD	DOM	4.42	4.98	0.000026	6
924800060650000000000	BINGS C	18-May-1967	C 32600	500.00	GD	DOM	4.46	4.94	0.000026	11
924800060650000000000	BINGS C	9-Oct-1970	C 36771	500.00	GD	DOM	4.50	4.91	0.000026	10
924800060650000000000	BINGS C	9-Aug-1967	C 32910	500.00	GD	DOM	4.57	4.83	0.000026	13
924800060650000000000	BINGS C	9-Mar-1951	F 14321	500.00	GD	DOM	4.75	4.65	0.000026	1
924800060650000000000	BINGS C	20-Feb-1953	F 15862	500.00	GD	DOM	4.83	4.57	0.000026	5
924800060650000000000	BINGS C	17-Sep-1957	F 18400	1000.00	GD	DOM	5.12	4.28	0.000053	8
924800060650000000000	BINGS C	2-Nov-1960	C 26358	1000.00	GD	DOM	5.73	3.68	0.000053	9
924800060650000000000	BINGS C	23-Aug-1951	F 16144	1.00	AF	IRR	0.76	8.65	1.000019	3
924800060650000000000	BINGS C	9-Aug-1967	C 32910	5.00	AF	IRR	4.53	4.88	5.000095	12
924800060650000000000	BINGS C	26-Apr-1966	F 19505	5.60	AF	IRR	5.12	4.28	5.600106	8
924800060650000000000	BINGS C	1-Apr-1960	F 18401	30.00	AF	IRR	5.12	4.28	30.000570	8
924800060650000000000	BINGS C			0.00		PT	1.29	8.07	0.000000	
924800060650350000000	MENZIES C	16-Feb-1972	C 39819	500.00	GD	DOM	0.99	5.55	0.000026	7
924800060650350000000	MENZIES C	11-Jul-1954	F 18272	500.00	GD	DOM	1.57	4.97	0.000026	6
924800060650350000000	MENZIES C	15-Aug-1966	C 31702	1000.00	GD	DOM	1.69	4.85	0.000053	5
924800060650350000000	MENZIES C	5-Jul-1966	C 31700	500.00	GD	DOM	1.96	4.59	0.000026	3
924800060650350000000	MENZIES C	23-May-1953	F 16844	500.00	GD	DOM	2.07	4.48	0.000026	2
924800060650350000000	MENZIES C	3-Apr-1973	C 41666	600.00	GD	DOM	2.23	4.31	0.000032	1
924800060650350000000	MENZIES C	31-Aug-1965	C 30772	5.00	AF	IRR	0.24	6.30	5.000095	10
924800060650350000000	MENZIES C	15-Apr-1970	C 38953	10.00	AF	IRR	0.44	6.10	10.000190	9
924800060650350000000	MENZIES C	15-Apr-1970	C 38954	10.00	AF	IRR	0.71	5.83	10.000190	8
924800060650350000000	MENZIES C	14-Apr-1970	C 36628	8.00	AF	IRR	1.69	4.85	8.000152	5
924800060650350000000	MENZIES C	5-Jul-1966	C 31700	5.00	AF	IRR	1.87	4.67	5.000095	4
									079.60202	

APPENDIX B

3. WATER LICENCES SORTED BY WATERSHED CODE, PURPOSE AND DISTANCE UPSTREAM

APPENDIX 1.2

FLOODING

APPENDIX 1.2

FLOODING

1. INTRODUCTION

Flooding is an issue of major concern in selected portions of the Cowichan River area. However, the Cowichan-Koksilah Water Management Plan does not address this issue as it is not related to low flows, which is the major focus of the plan. For previous assessments, the reader is referred to reports by Wester (1967) and Brown (1984), and the Cowichan Estuary Task Force Report (1980), for summaries of flooding and dyking in the Cowichan-Koksilah estuary. As a result, information presented in this appendix is to acknowledge and briefly document work that has been prepared to date with respect to flooding. Two sources of information are presented, floodplain mapping based on reconnaissance and field surveys and floodable soils maps derived from computer-based data.

2. OVERFLOW FLOODING

Overflow includes inundation of lands from rivers and streams normally during freshet, and on a frequent to relatively infrequent basis.

Two types of overflow flooding maps are available for the plan area. As discussed below, they differ in scale, coverage and concept.

A series of 5 maps was published in 1981 by the Floodplain Planning and Surveys Section of Water Management Branch. These orthophoto maps are at a scale of 1:5000, and illustrate the 200-year floodplain limit (known as the Flood Construction Level, or FCL, since it includes a 0.6 m allowance for freeboard above the Design Flood Level, or DFL), assuming the absence of all dykes. The area covered by these maps includes the Koksilah River below its confluence with Glenora Creek, Cowichan River below the Allenby Road

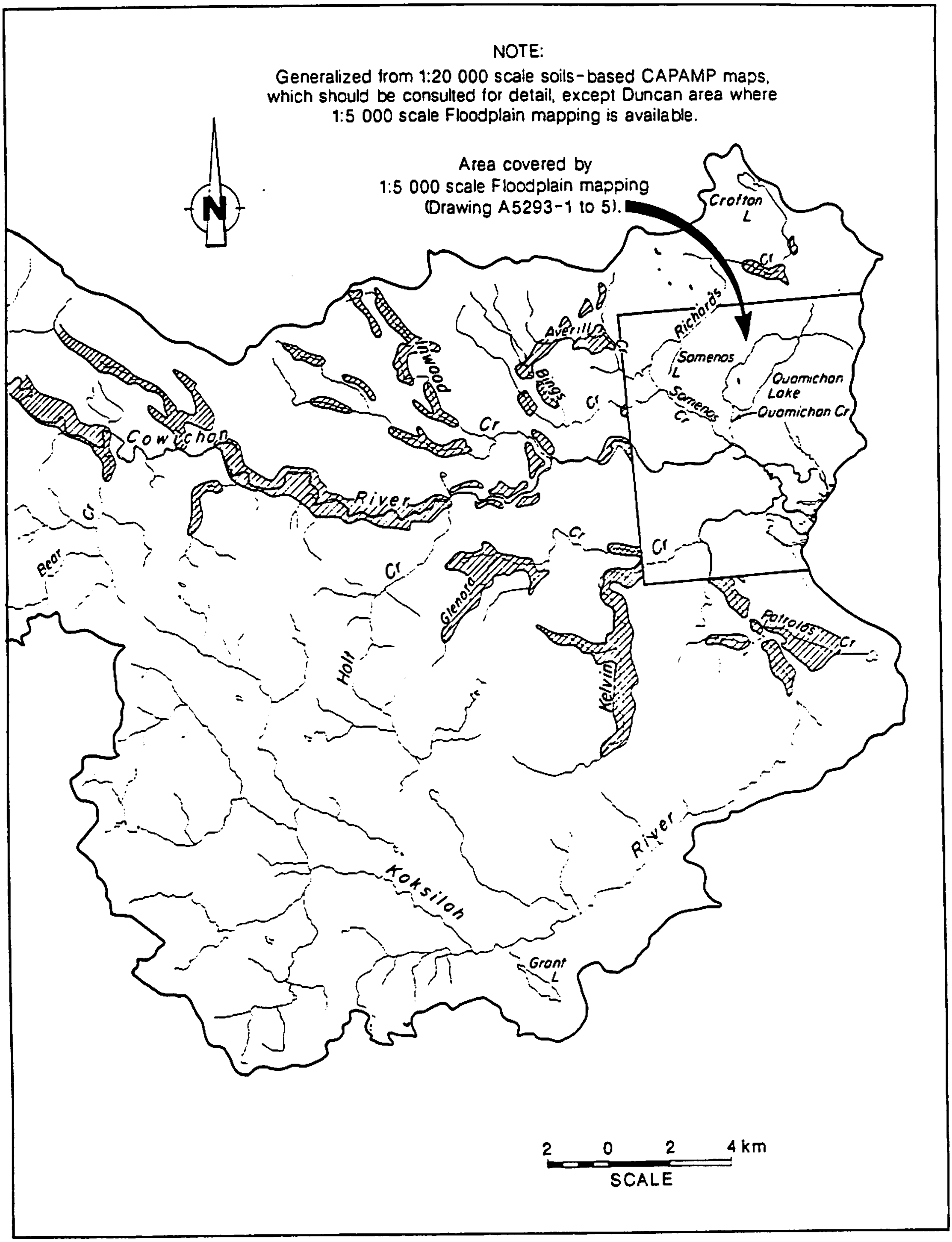


FIGURE 1 Floodplain Mapping and Areas Subject to Overflow Flooding. (see note)

("White") bridge, Somenos Creek and Lake and the lower portions of Richards Creek, and Quamichan Lake from its outlet to a short distance up MacIntyre Creek (Figure 1). A Zoning Bylaw for Electoral Areas D and E of the Cowichan Valley Regional District specifies minimum distances allowed from buildings to the natural boundaries of lakes and watercourses.

An additional series of maps was produced by Surveys and Resource Mapping Branch for this plan, using the CAPAMP (Computer Assisted Planning and Assessment Mapping Program) system. The Flood Drainage theme was based upon soils and agricultural capability mapping at 1:20,000. The soils selected for highlighting were generally poorly drained, but may include imperfectly to well-drained soils, and soils adjacent to estuaries or river margins, but could be of a wide range of textures. The soils included were mainly regosols, gleysols or gleyed soils. Two classes are represented: the first class includes lands subject to occasional, brief, commonly annual inundation to extended or very frequent overflow; the second class also includes lands subject to flooding, but not included in the first class due to less frequent inundation. The classes have been combined, for ease of presentation, and are shown on Figure 1, but the CAPAMP maps and tabular information should be consulted for greater detail and accuracy.

In areas of coverage by both types of maps, the more detailed Floodplain maps should be used in assessing areas subject to flooding. Where 1:5000 detail is not available, the 1:20,000 maps can provide a useful approximate guide to highlight those areas where development may not be advisable, or where there may be a need for flood protection for developments already in place.

3. HIGH WATER TABLE FLOODING

Other soils subject to the possibility of flooding, but not closely associated with rivers or streams, are also shown on the Flood Drainage CAPAMP maps. Areas of high water table flooding include soils often in depressions, or subject to seepage, and were mainly gleysols or gleyed soils, and occasionally regosols. Lands have been identified which are potentially improvable to high agricultural capability (i.e. classes 1 to 3), in contrast to those which are not improvable for agricultural purposes. In addition to agricultural applications, knowledge of the locations of high water table areas can be used in assessing the suitability for development.

Generalizations regarding this spatial distribution of high water table areas are difficult to make and a map illustrating high water table flooding has not been prepared for the plan _per se_. The CAPAMP maps should be consulted for areas of interest. However, although many of the high water table areas are not adjacent to watercourses, there are areas where inundation and high water table areas coincide. This is particularly the case in the Cowichan estuary - lower Cowichan River - Somenos Creek area, indicating that as well as freshet flooding at various frequencies, a naturally high water table may also limit activities. In other areas, such as the eastern end of Patrolas Creek, high water tables may be managed to result in productive agricultural land.

APPENDIX 1.3

SURFACE SOIL EROSION POTENTIAL

APPENDIX 1.3

SURFACE SOIL EROSION POTENTIAL

1. INTRODUCTION

The potential for surface soil erosion has not generally been addressed in water management plans to date due to the difficulty of accessing such information. The recently developed CAPAMP (Computer Assisted Planning and Assessment Mapping Program) process, however, enables resource managers to access data on surface soil erosion potential (one of a number of themes generated by CAPAMP) in a rapid and efficient manner once basic soil data have been entered into the system. Data on surface soil erosion potential is primarily derived from basic soils mapping and consideration of a number of relevant factors. Information is presented in both tabular and map form. This information can be applied in a number of ways, such as determining the relationship between different types of land use and the levels of suspended solids, the identification of land areas that may require more stringent management practices to curb soil loss, or simply to illustrate the extent of the different classes of soil erosion, such as the relationship of very severe classes to slight or negligible classes.

The purposes of this section are to briefly outline the methodology and factors considered in deriving surface soil erosion potential, to discuss the distribution of Class 4 (severe) and Class 5 (very severe) surface soil erosion potential, and to consider possible application of surface soil erosion information in the Cowichan-Koksilah plan area.

2. METHODOLOGY AND FACTORS CONSIDERED IN SURFACE SOIL EROSION POTENTIAL

Surface soil erosion potential estimates were based upon basic soils mapping (1:20,000), as well as, an evaluation of physical factors, such as rainfall erosivity, soil erodibility, and slope steepness. Classes of potential soil loss are expressed in tonnes/ha/yr (Table 1), and each soil polygon is given an erosion class rating which is represented in both map and table form. (It should be noted that basic soils mapping does not cover all of the plan area, and, as a result, surface soil erosion potential is restricted to areas that have some soils information, generally the agriculturally usable eastern half of the plan area.)

TABLE 1

SURFACE SOIL EROSION POTENTIAL

CLASS SYMBOL	VALUE	AMOUNT OF SOIL LOST
1	Negligible	(<6 tonnes/ha/yr)
2	Slight	(6-11 tonnes/ha/yr)
3	Moderate	(11-22 tonnes/ha/yr)
4	Severe	(22-33 tonnes/ha/yr)
5	Very Severe	(>33 tonnes/ha/yr)

3. SURFACE SOIL EROSION POTENTIAL IN THE COWICHAN-KOKSILAH PLAN AREA

An overview of the distribution of Class 4 (severe, 22-33 tonnes/ha/yr) and Class 5 (very severe, >33 tonnes/ha/yr) polygons reveals that most of the plan areas north of Somenos and Quamichan Lakes, and in particular north of Richards Creek, have high potential for soil erosion. Other areas of high potential soil loss include south of Currie and Glenora creeks, east of Kelvin Creek, portions adjacent to the Koksilah River, areas south of Patrolas Creek, and an extensive area north of the Cowichan River in the vicinity of Currie Creek (Figure 1).

It should be noted that while potential surface soil erosion areas cover a significant proportion of the plan area, actual soil loss or erosion will be directly related to the type of land use (e.g. farmed or forested lands) and the method of operation (e.g. harvesting methods, exposure of bare soil, etc.). The delineation of high potential surface soil erosion areas is intended to identify those portions of the plan area that may be more susceptible to soil loss. Various techniques for erosion control are currently under investigation in the Fraser Valley, and the application of techniques eventually determined to be effective will also be appropriate for the Cowichan-Koksilah area. Therefore, areas identified on these maps as having high soil loss potential should not be written off, as future management techniques will minimize these losses.

4. APPLICATION OF SURFACE SOIL EROSION INFORMATION

The information on soil loss potential generated by the CAPAMP process could be used by the Ministry of Environment to suggest areas where ambient monitoring for suspended solids should be undertaken, should land use in erosion-sensitive areas be potentially degrading ambient water quality. In cooperation with other Ministries such as Forests, or Agriculture and Food, more appropriate land use operations could be suggested to land users, where soil erosion problems occur or might potentially occur. At present, the Ministry of Agriculture and Foods has indicated that most cultivated lands in this area are used for perennial crops, with little likelihood of exposed soil and therefore currently exhibit a low potential for soil erosion. Similarly, most of the plan area was logged many years ago, and although second growth may be logged to some extent in this century, present logging is restricted to small, isolated pockets of timber, with limited soil erosion possibilities.

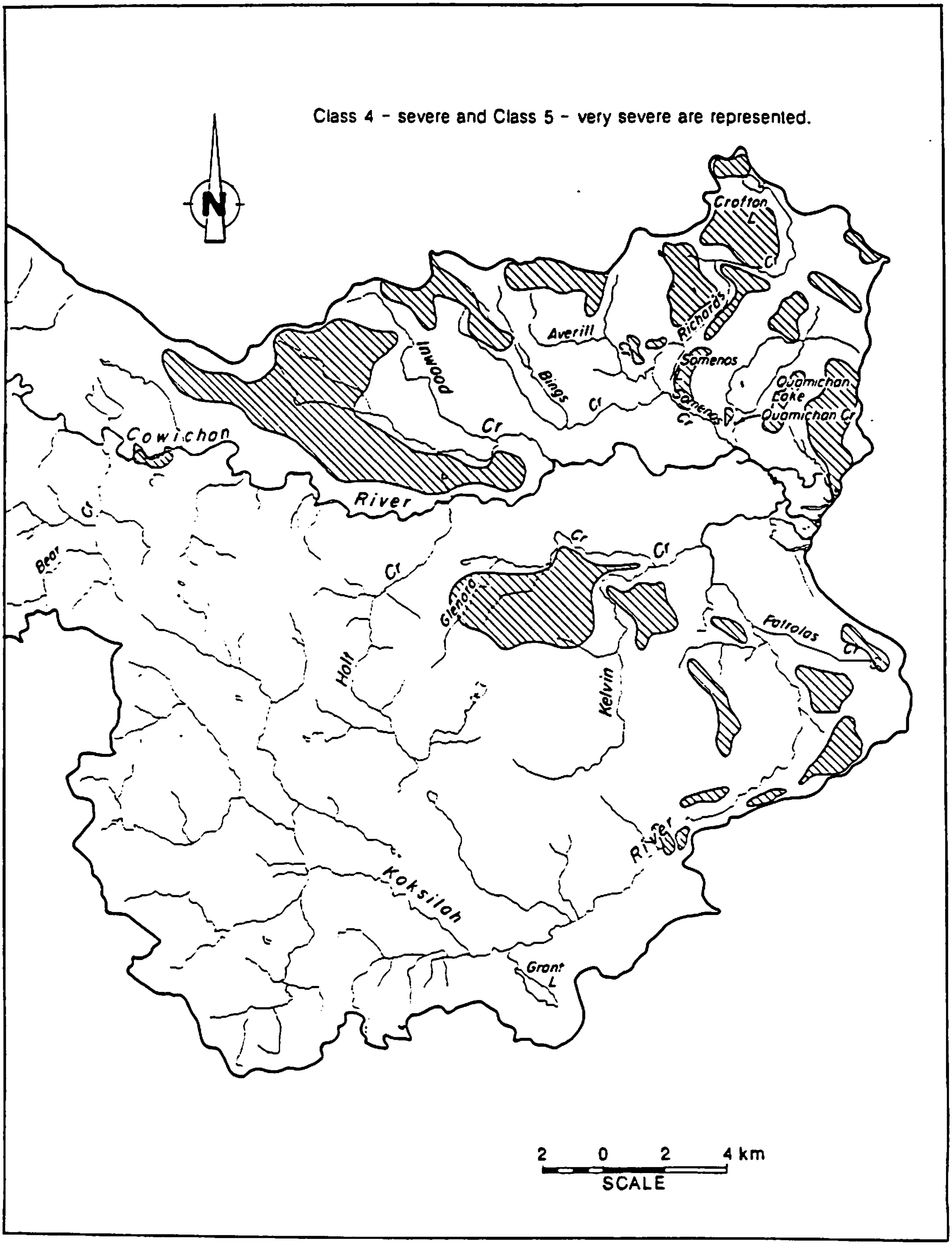


FIGURE 1 Potential Soil Erosion Areas.

APPENDIX 2.1

METHODOLOGY USED TO DERIVE SURFACE WATER SUPPLY ESTIMATES

APPENDIX 2.1

METHODOLOGY USED TO DERIVE SURFACE WATER SUPPLY ESTIMATES

INTRODUCTION

This appendix describes the methodology used to derive supply estimates in the Cowichan-Koksilah River basin. In the first section, flow estimates for Water Survey of Canada (WSC) hydrometric gauges in the plan area are presented. Low flow data extraction and naturalization techniques are described and low flow frequency estimates based on WSC recorded data are provided. The second section outlines the regionalization methodology used to estimate water supply for ungauged stream-sites in the study area, and the third section draws conclusions and recommendations on the regionalized results. The fourth section presents supply estimates for some of the analysis locations as estimated using Water Allocation Section's (Nanaimo) methods. The fifth section includes supply estimates for the Cowichan main-stem below Cowichan Lake, based on WSC gauge records during the period of regulation.

1. SUPPLY ESTIMATES - WSC STATIONS

1.1 WSC HYDROMETRIC DATA

The fourteen active and discontinued WSC hydrometric stations in the Cowichan-Koksilah River basin are listed in Table 1, and their locations are shown in Figure 1. Only those WSC gauges where there was no significant storage and a period of record which was longer than five years were used in the analysis (08HA003 Koksilah River at Cowichan Station; 08HA015 Averill Creek near Duncan; 08HA016 Bings Creek near the mouth). If storage began during the period of record, only those WSC stations with 5 or more years of pre-storage discharge measurements were used (08HA002 Cowichan River at Lake Cowichan prior to 1956). The problems created by storage regulation will be discussed in a later section.

TABLE 1
COWICHAN-KOKSILAH WATER MANAGEMENT PLAN
WATER SURVEY OF CANADA STATIONS

STATION NUMBER	STATION NAME	DRAINAGE AREA (km^2)	PERIOD OF RECORD	LENGTH OF RECORD (Years)	*REGULATED (Years)	STATUS OF STATION
08HA002	Cowichan R. at L. Cowichan	596	1913-84	52	**1956	Active
08HA011	Cowichan R. nr. Duncan	826	1960-84	25	**1956	Active
08HA036	Cowan Br. nr. Youbou	0.73	1975-79	5	†REG	Discontinued
08HA014	Somenos Cr. nr. Duncan	63.7	1961-63	3	†REG	Discontinued
08HA008	Bings Cr. nr. Duncan	14.8	1952-55	4	NAT	Discontinued
08HA016	Bings Cr. nr. the Mouth	15.5	1961-84	24	NAT	Active
08HA043	Bings Cr. at Drinkwater Rd.	2.99	1980-82	3	NAT	Discontinued
08HA042	Bings Cr. (West Branch) nr. Duncan	2.25	1980-82	3	NAT	Discontinued
08HA015	Averill Cr. nr. Duncan	17.1	1961-84	8	†REG	Active
08HA021	Quamichan Cr. at Outlet of Quamichan L.	-	1954-71	1	NAT	Discontinued
08HA003	Koksilah R. at Cowichan Station	223	1914-84	35	NAT	Active
08HA045	Koksilah R. below Kelvin Cr.	282	1981-82	2	NAT	Discontinued
08HA019	Patrolas Cr. nr. Cowichan Station	-	1964	1	NAT	Discontinued
08HA056	Glenora Cr. nr. Duncan	-	1983	1	NAT	Discontinued

* If year is provided by the WSC, it is listed; otherwise only the WSC classification of NAT (natural flow) or REG (regulated flow) is provided.

** WSC states that regulation began in 1965. Storage licences actually indicate that regulation occurred in 1956.

† Water Management Branch staff (Nanaimo) indicate that these streams are actually unregulated.

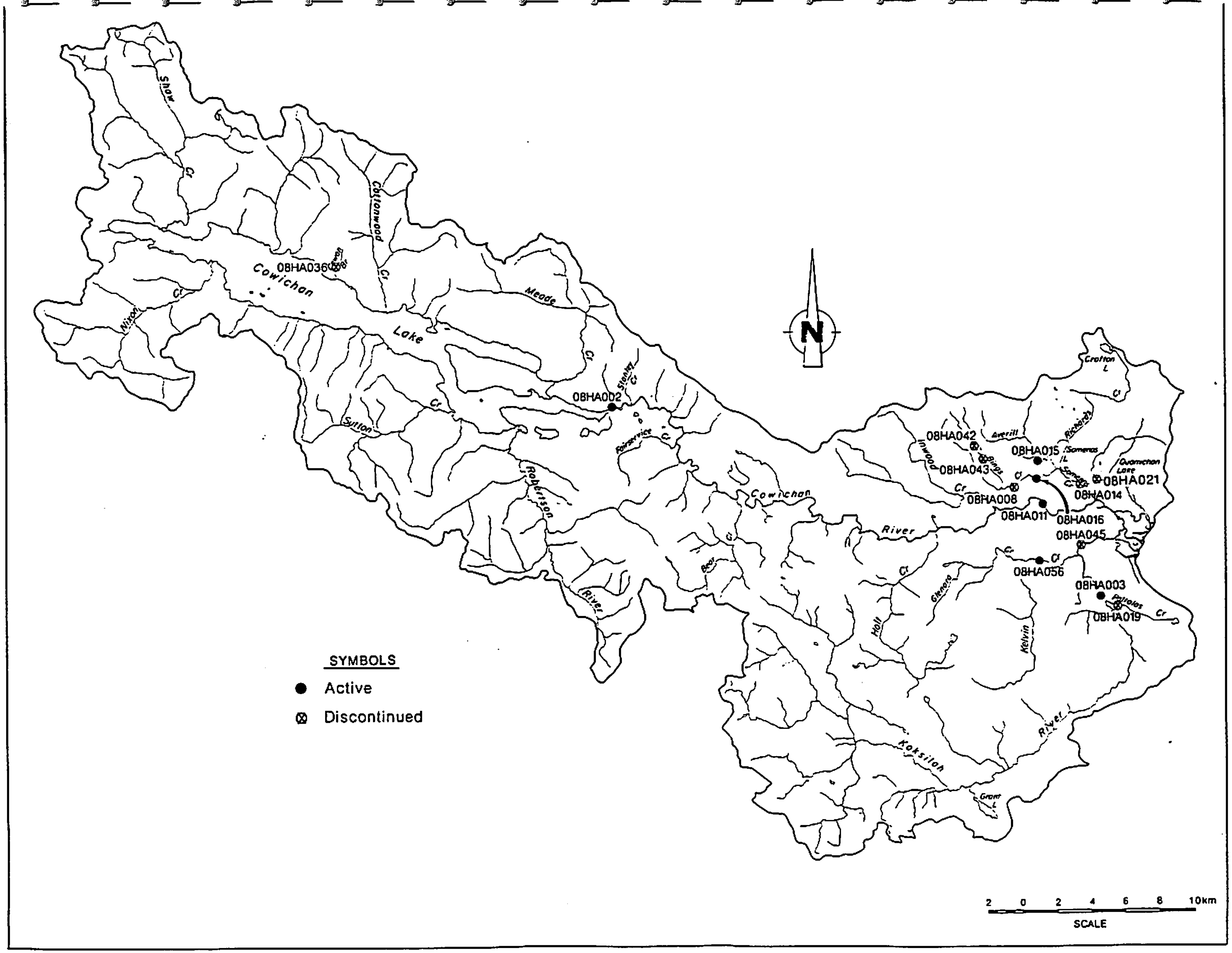


FIGURE 1 Status and Location of Water Survey of Canada Hydrometric Stations.

On eastern Vancouver Island, low flows have historically occurred during the June to September period, with most annual minimum daily discharges recorded during the last three weeks of August and the first two weeks of September. Low flows are also traditionally recorded in southern Vancouver Island rivers several weeks earlier than those further north on the Island. Most water use shortages occur during the June to September low flow period. This period includes irrigation water use, which usually peaks during the month of August. Therefore, the June to September period was selected as the critical time for water supply analysis in the Cowichan-Koksilah River basin.

Until recently, it has been necessary to manually extract June-September minimum 7-day average daily discharges from WSC microfiches. However, it is now possible to obtain 7-day average low flows (or any other critical duration) by computer using a low flow extraction program which has been developed by L. Barr. This program can be accessed through Surface Water Section, Water Management Branch, in Victoria.

1.2 NATURALIZATION OF WSC DATA

As a step in determining if there is a water supply surplus or deficit in a stream, it is necessary to adjust or "naturalize" the hydrometric gauge data to account for total consumptive withdrawals. Statistical analysis and regionalization techniques can then be applied to the naturalized data. The Water Survey of Canada gauge data for the four hydrometric stations in the Cowichan-Koksilah River basin were naturalized using the following method. All licences above each WSC station were identified and plotted on 1:50,000 scale maps. Licences were then chronologically listed by priority date over the period of record by type (e.g. domestic, irrigation). Using assumptions described below, the water licences were converted to a daily flow (m^3/s) and the WSC gauge data were adjusted accordingly by year. The first assumption was that unless otherwise specified, licences expressed as a flow (m^3/s or cfs) were assumed to be used uniformly throughout the year. This assumption applied to all domestic, industrial and waterworks licences.

Licences for irrigation were converted to flow rates based on estimates of the period of irrigation use. Water Management Branch staff indicated that irrigation withdrawals can be expected to occur throughout the June-September period.[1] Therefore, the second naturalization assumption was that water allocated for irrigation was used over a 120-day irrigation period. Irrigation licence totals were therefore divided by 120, and converted to a flow rate.

Two other assumptions were used throughout the flow estimation procedure. The first was that all licences are fully used, i.e. actual use is identical to licensed quantity. G. Bryden and A. Dambergs estimated actual water use for the larger licences in the study area, but most of these were located downstream of the four WSC gauges and did not significantly alter the discharge data. The estimated actual water use data were used to adjust the recorded data for WSC station 08HA011 Cowichan River near Duncan.

The second assumption is that all use is consumptive, i.e. there are no return flows. Return flows may be substantial in some cases. By not including return flows in the naturalization procedure, the result is that discharge estimates from WSC gauge data are low.

1.3 WATER SUPPLY ESTIMATES

Frequency analysis was performed using the naturalized, published hydrometric data based on June-September minimum 7-day average discharge data. Frequency estimates and the corresponding 95% confidence limits were selected for the mean, 5, 10 and 20-year recurrence intervals and are presented in Table 2.[2]

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[1] Meeting in Nanaimo with G. Bryden and J. Card, October 10, 1984.

[2] Frequency analysis estimates were selected from the Pearson Type III and the Log-Pearson Type III probability distributions. Probability distribution selection was based on the Kolmogorov-Smirnov statistic (best-fit), standard error of estimate and the width of the 95% confidence limits. Frequency estimates were made using the following criteria of record length.

Record Length (yrs)	Recurrence Interval
5 to 8	5, 10
≥ 9	20

TABLE 2

08HA002 - COWICHAN RIVER AT LAKE COWICHAN

JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)

Drainage Area (km^2)	Period of Record	Record Length (yrs)	*Licences (as flow)	95% Confidence	Mean Annual	5 Year	10 Year	20 Year
596	+1913-56	24	**0.0	Upper	3.81	2.05	1.53	1.20
				Estimate	3.09	1.62	1.14	0.823
				Lower	2.37	1.28	0.848	0.562

08HA003 - KOKSILAH RIVER AT COWICHAN STATION

JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)

Drainage Area (km^2)	Period of Record	Record Length (yrs)	*Licences (as flow)	95% Confidence	Mean Annual	5 Year	10 Year	20 Year
223	1914-83	32	0.092	Upper	0.418	0.306	0.256	0.222
				Estimate	0.376	0.276	0.222	0.181
				Lower	0.334	0.249	0.192	0.147

* Licences as flow include domestic, irrigation, industrial and waterworks licences to 1983

**Above WSC gauge 08HA002 licences (as a flow) total 1.34 m^3/s. However, due to the large size of Cowichan Lake (surface area = 62.7 km^2) it was assumed that the licenced withdrawals had no significant effect on the discharges recorded at WSC station 08HA002. This decision was made during a meeting on March 29, 1985 with G. Bryden and J. Card, Water Management Branch, Nanaimo.

\+ Pre-storage period only.

TABLE 2 (cont.)

08HA015 - AVERILL CREEK NEAR DUNCAN

JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)

Drainage Area (km^2)	Period of Record	Record Length (yrs)	*Licences (as flow)	95% Confidence	Mean Annual	5 Year	10 Year	20 Year
17.1	1961-83	7	0.013	Upper	0.015	0.013	0.012	
				Estimate	0.013	0.011	0.010	
				Lower	0.011	0.009	0.008	

08HA016 - BINGS CREEK NEAR THE MOUTH

JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)

Drainage Area (km^2)	Period of Record	Record Length (yrs)	*Licences (as flow)	95% Confidence	Mean Annual	5 Year	10 Year	20 Year
15.5	1961-83	22	0.010	Upper	0.029	0.023	0.021	0.020
				Estimate	0.026	0.021	0.018	0.017
				Lower	0.023	0.018	0.016	0.014

Discharge measurements at WSC station 08HA011 Cowichan River near Duncan began in 1960, four years after storage regulation started on Cowichan Lake. Based on the assumption that only those WSC stations with 5 or more years of pre-storage discharge data could be used, frequency analysis was not performed for this station. However, using mean monthly discharge data and the frequency analysis estimates calculated for WSC gauge 08HA002 Cowichan River at Lake Cowichan, supply estimates were made for WSC station 08HA011 and are presented in Table 3 with a description of the methodology.

TABLE 3
08HA011 - COWICHAN RIVER NEAR DUNCAN
JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)**

Drainage Area (km^2)	Period of Record	Record Length (yrs)	*Licences (as flow)	Mean Annual	5 Year	10 Year	20 Year
826	1960-82	25	3.04	4.76	3.33	2.87	2.56

* Licences as Flow include domestic, irrigation, industrial and waterworks licences to 1982.

** The following discussion will outline the method used to calculate discharge estimates for WSC station 08HA011. Using the procedure outlined in section 2.2, August and September mean monthly discharge data for WSC stations 08HA002 Cowichan River at Lake Cowichan and 08HA011 were naturalized for the period of record 1960-82. As earlier noted in Table 1, it was assumed that because of the large size of Cowichan Lake, licenced withdrawals had no significant effect on the discharges recorded at WSC station 08HA002. Therefore, only the mean monthly data from WSC station 08HA011 was actually naturalized (using the licenced quantities between the two gauge sites).

Regression analysis was conducted on the naturalized August-September mean monthly discharge data (WSC station 08HA002 and 08HA011). The frequency analysis estimates for WSC gauge 08HA002 (Table 4) were then entered into the resulting regression equation ($y = 1.76 + 0.97x$; where 'x' = Frequency analysis estimate from WSC station 08HA002 and 'y' = the discharge estimate for WSC station 08HA011) and discharge estimates were calculated for WSC gauge station 08HA011 (see above Table 3)

2. SUPPLY ESTIMATES - UNGAUGED STREAMS

2.1 HYDROMETRIC REGIONALIZATION METHODS

The purpose of hydrometric regionalization is to group and analyze existing WSC gauge data so that flow estimates can be made at ungauged stream sites. On the southern half of Vancouver Island, thirty-two WSC hydrometric stations were selected for use in the regionalization procedure. These gauges and the corresponding period of record are listed in Table 4.

Leith (1978, p.2) suggests that for statistical reasons, a sample size of at least 30 gauges is necessary when using regression analysis to regionalize discharges. To ensure that the sample size was large enough, WSC stations which are located in the Port Alberni and Campbell River regions were included. These include WSC stations located on the Stamp, Puntledge, Campbell, Sproat, Ash and Oyster Rivers (Table 4). Several of these stations have been regulated during some of the period of record, resulting in higher than natural flows during the low-flow season.

June-September minimum 7-day average low flows were obtained using the Surface Water Section's low flow extraction program. The flow data were then manually naturalized using the procedure outlined in Section 2.2.2. Frequency analysis was used to calculate discharge estimates and the corresponding 95% confidence limits for the mean, 5, 10 and 20-year recurrence intervals. The discharge estimates and confidence limits are presented in Table 4.

The frequency analysis results were used to plot low flow regression type relationships (log-log) between discharges (m^3/s) and drainage areas

TABLE 4
HYDROMETRIC STATION LOW FLOW FREQUENCY DATA
COWICHAN-KOKSILAH WATER MANAGEMENT PLAN

HYDROMETRIC STATION		DRAINAGE AREA (km^2)	PERIOD OF RECORD	LENGTH OF RECORD (yrs)	FREQUENCY DISTRIBUTION *	JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)											
						MEAN-YEAR			5-YEAR			10-YEAR			20-YEAR		
						Estimate	95% Confidence		Estimate	95% Confidence		Estimate	95% Confidence		Estimate	95% Confidence	
Number	Name						Low	High		Low	High		Low	High		Low	High
8HA-1	Chemainus R. nr. Westholme	355	1914-83	33	2	0.697	0.582	0.817	0.439	0.374	0.515	0.372	0.311	0.446	0.326	0.266	0.399
8HA-2	Cowichan R. at Lk. Cowichan	596	1913-56	24	2	3.09	2.37	3.81	1.62	1.28	2.05	1.14	08485	1.53	0.823	0.562	1.20
8HA-3	Koksilah R. at Cowichan Station	223	1914-83	32	2	0.376	0.334	0.418	0.276	0.249	0.306	0.222	0.192	0.256	0.181	0.147	0.222
8HA-15	Averill Cr. nr. Duncan	17.1	1961-83	7	2	0.013	0.011	0.015	0.011	0.009	0.013	0.010	0.008	0.012	0.009	0.007	0.012
8HA-16	Bings Cr. nr. the Mouth	15.5	1961-83	22	2	0.026	0.023	0.029	0.021	0.018	0.023	0.018	0.016	0.021	0.017	0.014	0.020
8HB-1	Qualicum R. nr. Bowser	148	1913-64	18	2	0.858	0.690	1.03	0.614	0.523	0.720	0.548	0.458	0.655	0.502	0.411	0.612
8HB-2	Englishman R. nr. Parksville	324	1915-83	10	2	0.691	0.474	0.908	0.446	0.327	0.610	0.356	0.246	0.515	0.292	0.187	0.454
8HB-4	Little Qualicum R. at Outlet Cameron Lk.	135	1913-83	33	1	1.08	0.943	1.22	0.757	0.630	0.884	0.635	0.493	0.777	0.543	0.385	0.701
8HB-5	Nanaimo R. nr. Extension	645	1913-63	29	1	2.40	2.01	2.79	1.56	1.24	1.88	1.34	0.981	1.70	1.20	0.802	1.60
8HB-7	Puntledge R. nr. Cumberland	453	1914-52	39	2	10.0	9.36	10.6	8.39	7.83	8.98	7.64	7.06	8.27	7.05	6.43	7.73
8HB-8	Sproat R. nr. Alberni	347	1913-55	34	2	7.12	5.90	8.34	3.95	3.26	4.79	2.96	3.71	2.35	2.28	1.73	3.00
8HB-9	Stamp R. nr. Great Central	456	1913-22	9	1	10.9	8.19	13.6	8.26	5.83	10.7	6.48	3.57	9.39	4.87	1.27	8.47
8HB-10	Stamp R. nr. Alberni	899	1914-58	35	2	12.4	10.5	14.3	7.76	6.68	9.02	5.97	7.18	4.97	4.71	3.73	5.93

TABLE 4 (Cont.)

HYDROMETRIC STATION		DRAIN-AGE AREA (km^2)	PERIOD OF RECORD	LENGTH OF RECORD (yrs)	FRE-QUENCY DISTRI-BUTION *	JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)											
						MEAN-YEAR			5-YEAR			10-YEAR			20-YEAR		
						Esti-mate	95% Confidence		Esti-mate	95% Confidence		Esti-mate	95% Confidence		Esti-mate	95% Confidence	
Number	Name						Low	High		Low	High		Low	High		Low	High
8HB-11	Tsolum R. nr. Courtenay	258	1914-64	5	2	0.130	0.011	0.249	0.068	0.035	0.134	0.057	0.027	0.121	0.049	0.021	0.115
8HB-16	Ash R. nr. Great Central L.	293	1957-66	10	2	2.56	2.02	3.10	1.97	1.61	2.41	1.78	1.42	2.23	1.63	1.27	2.11
8HB-18	Qualicum R. at Outlet Horne L.	111	1958-62	5	1	0.188	0.145	0.231	0.054	0.0	0.226	0.011	0.0	0.204	0.001	0.0	0.194
8HB-22	Nile Cr. nr. Bowser	15.0	1959-83	25	1	0.169	0.153	0.185	0.140	0.125	0.154	0.120	0.103	0.137	0.102	0.080	0.124
8HB-23	Ash R. below Moran Cr.	378	1960-83	24	1	3.41	3.33	3.49	3.24	3.17	3.31	3.20	3.12	3.27	3.16	3.08	3.25
8HB-24	Tsable R. nr. Fanny Bay	113	1960-83	23	2	0.403	0.326	0.480	0.267	0.225	0.317	0.232	0.191	0.281	0.207	0.167	0.257
8HB-25	Browns R. nr. Courtenay	86.0	1960-70	7	1	0.165	0.085	0.245	0.105	0.031	0.180	0.057	0.0	0.156	0.012	0.0	0.148
8HB-27	Millstone R. nr. Wellington	46.1	1961-74	9	2	0.022	0.008	0.036	0.008	0.004	0.017	0.005	0.002	0.013	0.004	0.001	0.011
8HB-29	Little Qualicum R. nr. Qualicum Beach	237	1961-83	23	1	1.38	1.18	1.58	1.01	0.843	1.17	0.909	0.725	1.09	0.846	0.644	1.05
8HB-41	Jump Cr. at the Mouth	62.2	1971-75	5	2	0.311	0.10	0.522	0.194	0.111	0.338	0.165	0.089	0.309	0.146	0.073	0.293
8HB-44	Trent R. nr. Royston	72.0	1971-76	6	2	0.021	0.0	0.059	0.003	0.0	0.015	0.001	0.0	0.011	0.001	0.0	0.008
8HD-1	Campbell R. at Outlet Campbell Lk.	1400	1910-46	35	2	21.5	18.8	24.2	14.9	13.0	17.1	12.5	10.7	14.7	10.8	8.96	13.0
8HD-11	Oyster R. below Woodhus Cr.	298	1974-83	9	2	2.09	1.43	2.75	1.42	1.03	1.96	1.21	0.839	1.75	1.07	0.703	1.62

TABLE 4 (Cont.)

HYDROMETRIC STATION		DRAIN-AGE AREA (km²)	PERIOD OF RECORD	LENGTH OF RECORD (yrs)	FRE-QUENCY DISTRI-BUTION *	JUNE-SEPTEMBER MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m³/s)											
						MEAN-YEAR			5-YEAR			10-YEAR			20-YEAR		
						Esti-mate	95% Confidence		Esti-mate	95% Confidence		Esti-mate	95% Confidence		Esti-mate	95% Confidence	
Number	Name						Low	High		Low	High		Low	High		Low	High
8HD-12	Springer Cr. nr. Sayward	12.2	1976-80	5	2	0.062	0.002	0.122	0.028	0.011	0.070	0.022	0.008	0.060	0.017	0.006	0.055
8HA-10	San Juan R. nr. Port Renfrew	580	1960-82	23	2	2.19	1.80	2.58	1.49	1.28	1.74	1.32	1.11	1.57	1.20	0.994	1.45
8HA-33	Shawnigan Cr. nr. Mill Bay	91.9	1974-83	10	2	0.046	0.019	0.073	0.023	0.016	0.033	0.020	0.014	0.030	0.019	0.012	0.029
8HA-34	Craigflower Cr. below Burnside Rd.	13.5	1975-81	5	1	0.004	0.002	0.006	0.003	0.001	0.005	0.002	0.0	0.004	0.001	0.002	0.004
8HB-3	Haslam Cr. nr. Cassidy	95.6	1914-61	14	1	0.208	0.156	0.260	0.134	0.080	0.188	0.099	0.038	0.161	0.071	0.002	0.140
8HB-12	Nahmint R. nr. Port Alberni	140	1925-30	6	2	1.73	0.663	2.80	1.09	0.738	1.60	0.991	0.639	1.54	0.937	0.580	1.51
8HB-38	French Cr. nr. Coombs	58.3	1929-84	5	2	0.005	0.001	0.011	0.002	0.0	0.006	0.001	0.0	0.005	0.001	0.0	0.004

* 1. Pearson Type III - Method of Moments.
2. Log-Pearson Type III - Method of Moments.

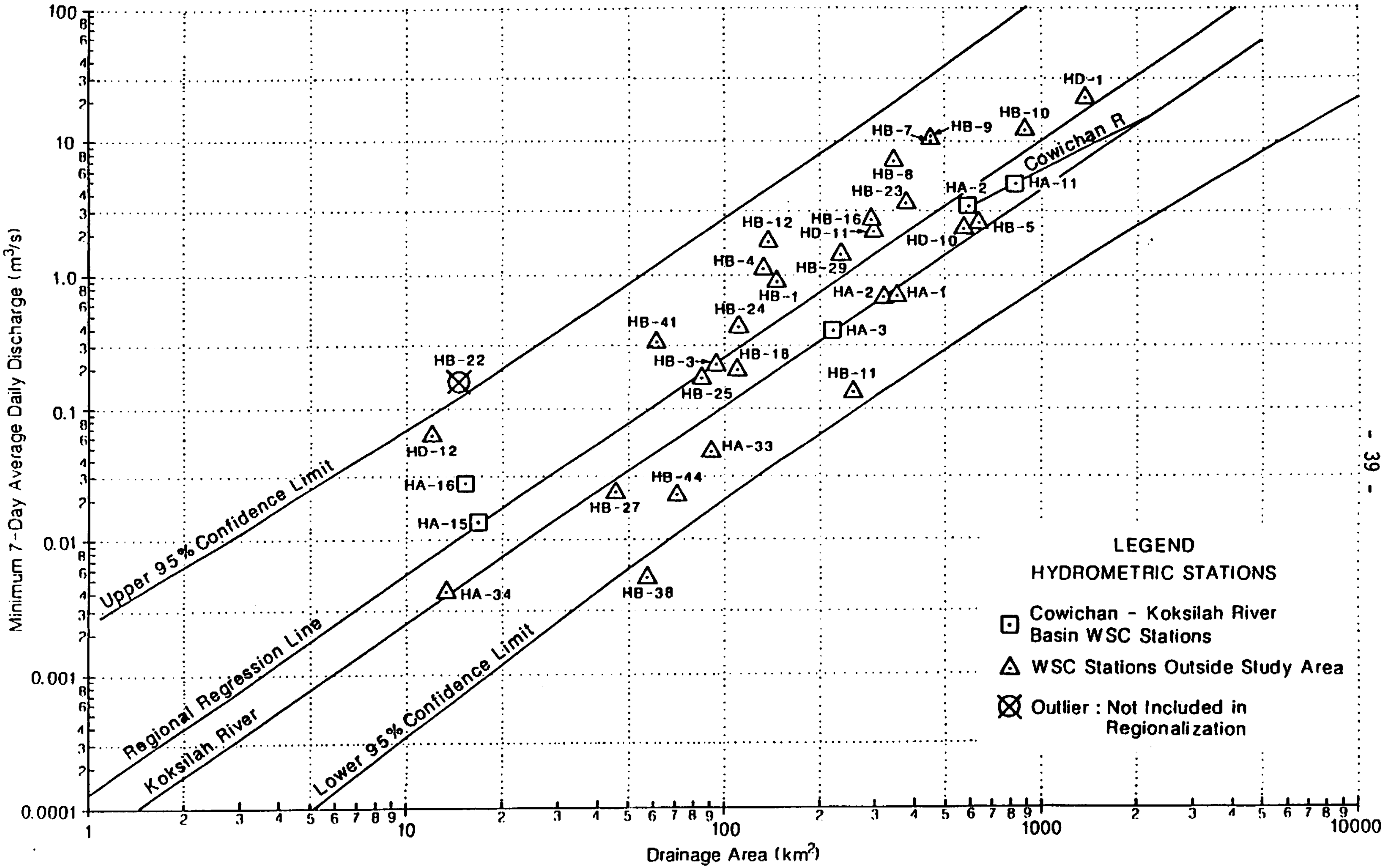

FIGURE 2 Regional Mean-Year June-September 7-Day Average Low Flow for Southern Vancouver Island.

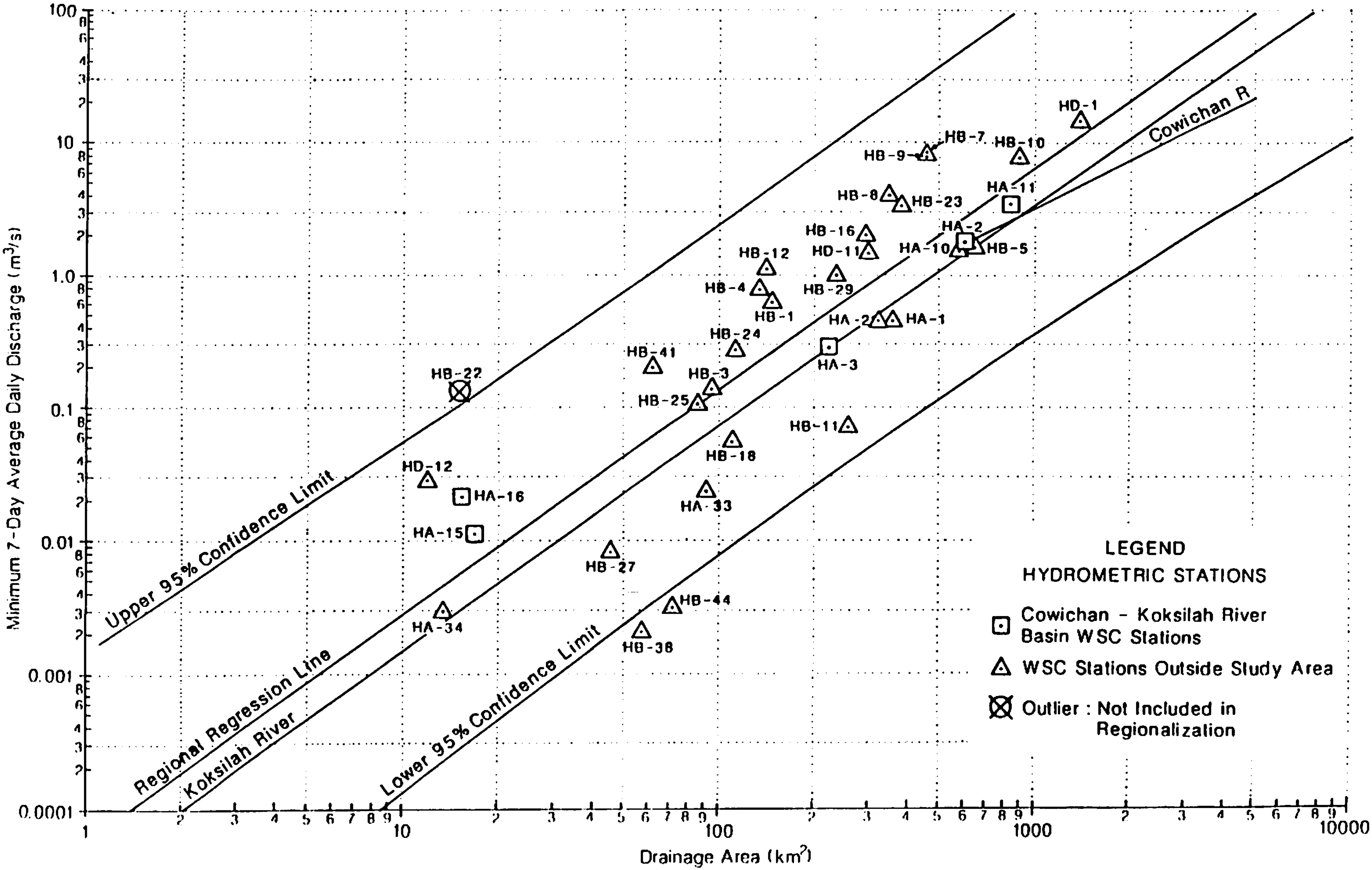

FIGURE 3 Regional 5-Year June-September 7-Day Average Low Flow for Southern Vancouver Island.

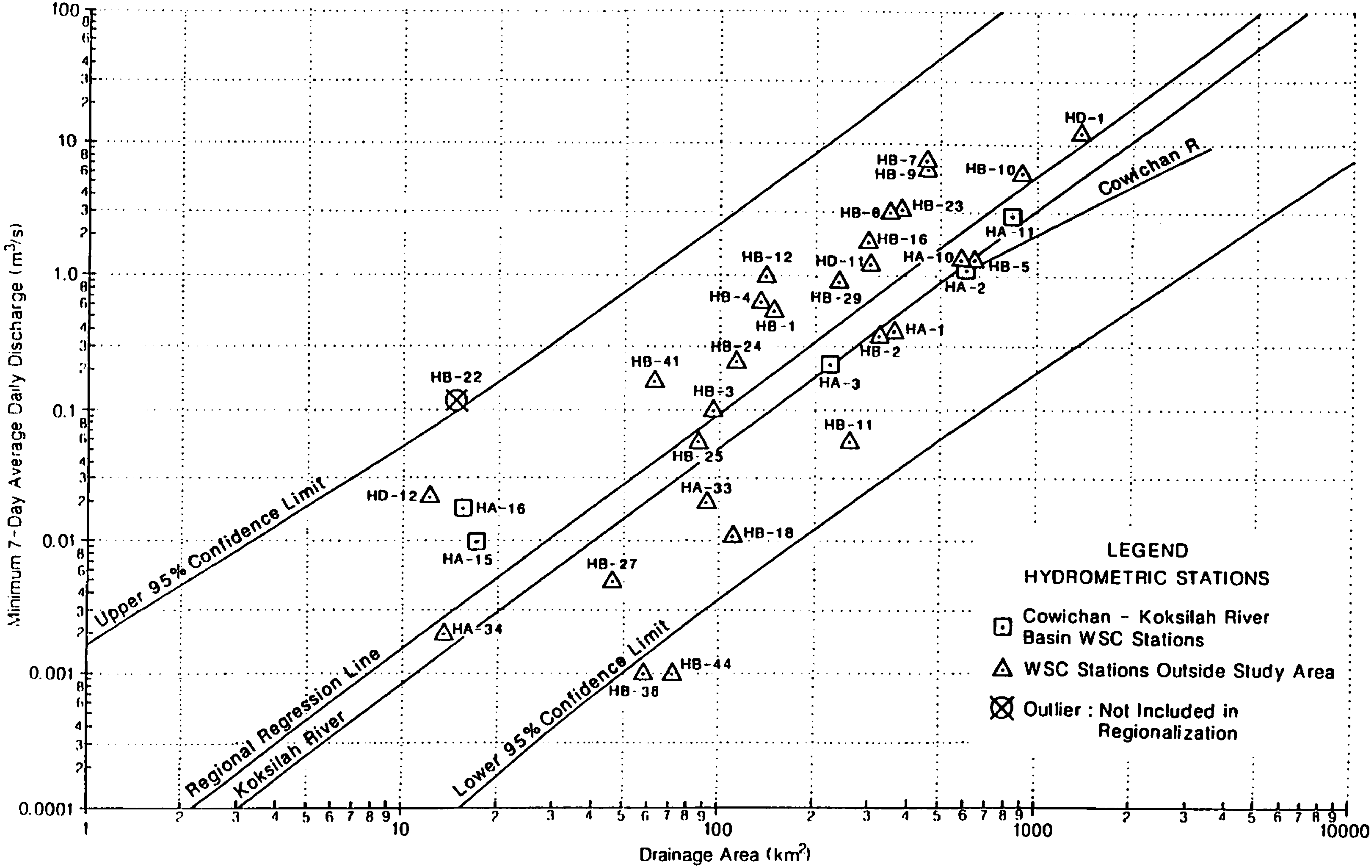

FIGURE 4 Regional 10-Year June-September 7-Day Average Low Flow for Southern Vancouver Island.

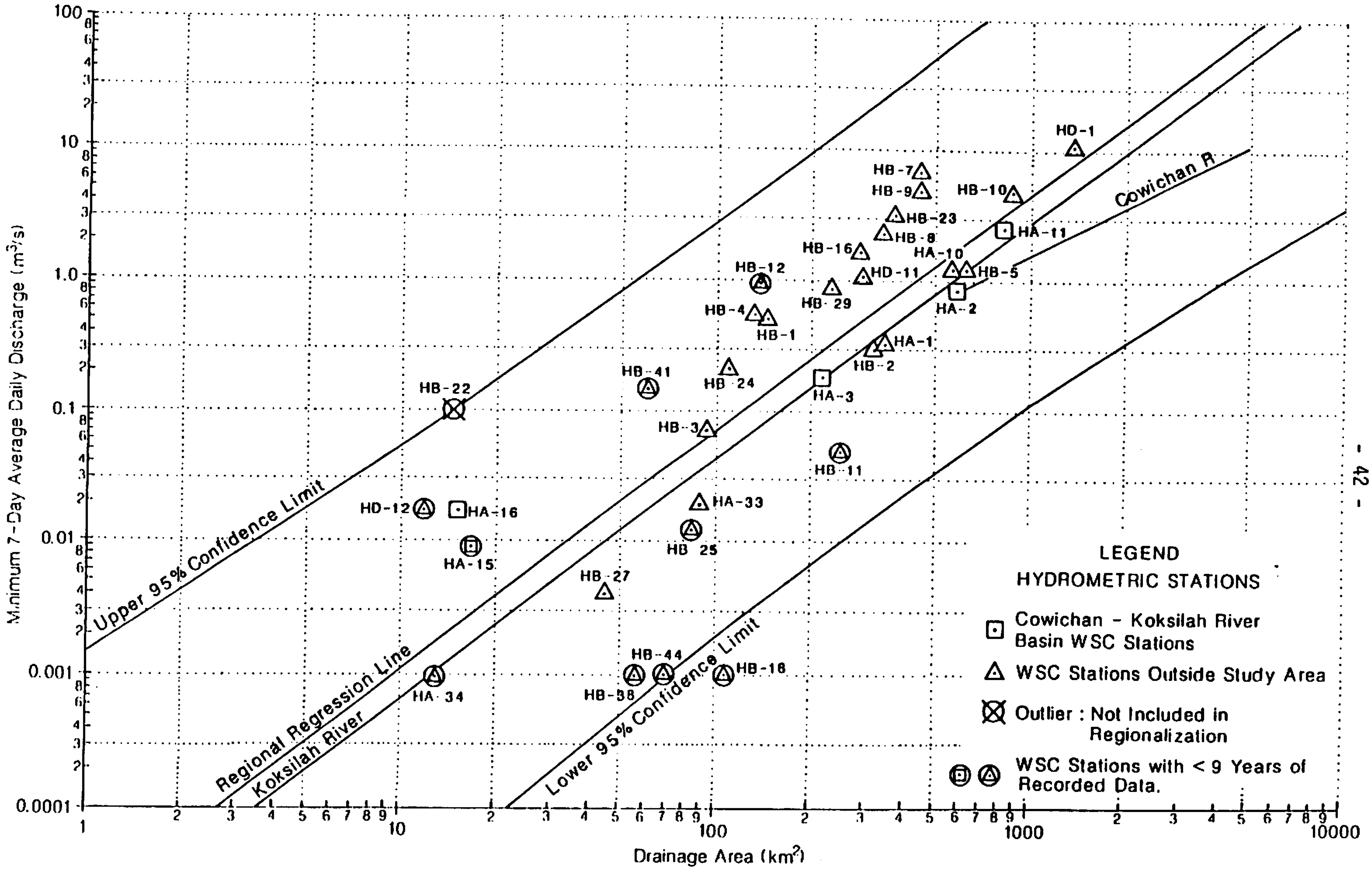

FIGURE 5 Regional 20-Year June-September 7-Day Average Low Flow for Southern Vancouver Island.

(km^2) for the mean, 5, 10 and 20-year recurrence intervals. Regression equations were calculated and confidence limits around the regression line were established (Figures 2 - 5).

Despite having adequate recorded discharge data, WSC station 08HB022 Nile Creek near Bowser was removed from the analysis. High discharges were observed in this stream even during periods when low flows were observed and measured in adjacent streams of similar drainage area and apparent morphometric characteristics. Therefore, Nile Creek is an outlier with respect to the other WSC stations and was removed from the sample.

WSC station 08HA036, Cowan Brook near Youbou, which is located on the north side of Lake Cowichan, was also not used in the regionalization. The period of record was too short and incomplete to allow for any calculation of reliable frequency analysis estimates.

2.2 WATER SUPPLY ESTIMATES

Seven-day low flows (Table 5) were estimated at 26 locations (Fig. 1.1, see Chapter 1) to appraise various water quality, water management and fisheries concerns in the Cowichan-Koksilah River basin. The procedure used to provide flow estimates at ungauged stations was as follows:

1. Drainage boundaries and areas were determined.
2. The drainage areas were then converted to a logarithmic value and used in the regression equations (Table 6) to obtain water supply estimates. Alternatively, the curves in Figures 2-5 could be used for quick reference, but the equations would provide more significant figures.
3. Where a requested water supply analysis location was not significantly removed from a WSC station, the frequency analysis estimates calculated from that WSC station data were used.
4. For requested locations on the Koksilah mainstem, estimates were made from a line parallel to the regional regression line through point (plot) HA-3 (Figures 2-5). This line was not mathematically

TABLE 5 LOW FLOW ESTIMATES
MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)
COWICHAN-KOKSILAH WATER MANAGEMENT PLAN

STREAM SITE	DRAINAGE AREA (km^2)	LOW FLOW RECURRENCE INTERVAL (YEARS)											
		MEAN-YEAR ESTIMATE	95% CONFIDENCE LEVEL		5-YEAR ESTIMATE	95% CONFIDENCE LEVEL		10-YEAR ESTIMATE	95% CONFIDENCE LEVEL		*20-YEAR ESTIMATE	95% CONFIDENCE LEVEL	
			Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Richards Cr. at Somenos L.	24.9	0.022	0.002	0.269	0.012	0.001	0.229	0.008	0.0	0.231	0.006	0.0	0.250
Richards Cr. at Richards Trail	11.3	0.006	0.0	0.079	0.003	0.0	0.065	0.002	0.0	0.065	0.001	0.0	0.048
Quamichan Cr. at Quamichan L. Outlet	17.0	0.012	0.001	1.50	0.006	0.0	0.021	0.004	0.0	0.122	0.003	0.0	0.132
Stanley Cr. at the Mouth	4.84	0.001	0.0	0.015	0.001	0.0	0.024	-	-	-	-	-	-
Inwood Cr. at the Mouth	38.3	0.046	0.004	0.541	0.025	0.001	0.466	0.017	0.001	0.468	0.012	0.0	0.478
Patrolas Cr. at Hillbank Rd.	8.36	0.004	0.0	0.055	0.002	0.0	0.045	0.001	0.0	0.034	0.001	0.0	0.050
Cowan Br. at the Mouth	1.15	-	-	-	-	-	-	-	-	-	-	-	-
Kelvin Cr. near the Mouth (FLAP)	55.1	0.083	0.007	0.957	0.046	0.003	0.830	0.033	0.001	0.891	0.024	0.001	1.08
Glenora Cr. near the Mouth (FLAP)	19.2	0.014	0.001	0.175	0.008	0.0	0.158	0.005	0.0	0.050	0.004	0.0	0.173
Bings Cr. near the Mouth 08HA016	15.5	0.026	0.023	0.029	0.021	0.018	0.023	0.018	0.016	0.021	0.017	0.014	0.020
Averill Cr. near Duncan 08HA015	17.1	0.013	0.011	0.015	0.011	0.009	0.013	0.010	0.008	0.012	0.009	0.007	0.012
Cowichan R. near Duncan 08HA011	826	4.76	-	-	3.33	-	-	2.87	-	-	2.56	-	-
Koksilah R. above Grant L. Outlet (FLAP)	117	0.136	-	-	0.090	-	-	0.065	-	-	0.058	-	-
Koksilah R. at Cowichan Station 08HA003	223	0.376	0.334	0.418	0.276	0.249	0.306	0.222	0.192	0.256	0.181	0.147	0.222

TABLE 5 LOW FLOW ESTIMATES
MINIMUM 7-DAY AVERAGE DAILY DISCHARGE (m^3/s)
COWICHAN-KOKSILAH WATER MANAGEMENT PLAN (Cont.)

STREAM SITE	DRAINAGE AREA (km^2)	LOW FLOW RECURRENCE INTERVAL (YEARS)											
		MEAN-YEAR ESTIMATE	95% CONFIDENCE LEVEL		5-YEAR ESTIMATE	95% CONFIDENCE LEVEL		10-YEAR ESTIMATE	95% CONFIDENCE LEVEL		*20-YEAR ESTIMATE	95% CONFIDENCE LEVEL	
			Lower	Upper		Lower	Upper		Lower	Upper		Lower	Upper
Cowichan R. below Fairservice Cr.	636	3.37	-	-	1.77	-	-	1.24	-	-	0.897	-	-
Cowichan R. above Holt Cr.	717	3.95	-	-	2.07	-	-	1.46	-	-	1.05	-	-
Cowichan R. at Highway 1	827	4.77	-	-	2.50	-	-	1.76	-	-	1.27	-	-
Robertson R. at the Mouth	102	0.231	0.020	2.61	0.133	0.008	2.33	0.099	0.004	2.59	0.073	0.002	2.72
Cottonwood Cr. at the Mouth	39.2	0.047	0.004	1.81	0.026	0.001	2.07	0.018	0.001	0.499	0.013	0.0	0.516
Bear Cr. at the Mouth	29.1	0.029	0.002	0.348	0.016	0.001	0.305	0.011	0.0	0.313	0.007	0.0	0.287
Cowichan R. at Lk. Cowichan 08HA002	596	3.09	2.37	3.81	1.62	1.28	2.05	1.14	0.848	1.53	0.823	0.562	1.20
Village of Lake Cowichan STP (PE247)	605	3.15	-	-	1.65	-	-	1.16	-	-	0.839	-	-
Duncan-North Cowichan STP (PE1497)	835	4.83	-	-	2.53	-	-	1.78	-	-	1.28	-	-
Koksilah R. at the Mouth	293	0.624	-	-	0.435	-	-	0.328	-	-	0.309	-	-
Somenos Cr. at the Mouth	85.9	0.174	0.015	1.97	0.099	0.006	1.76	0.073	0.003	1.92	0.054	0.001	2.02
Cowichan R. near the Mouth	922	5.51	-	-	2.88	-	-	2.03	-	-	1.46	-	-

* See Appendix 2.1 for the limitations associated with the 20-year estimates.

TABLE 6: REGRESSION EQUATIONS

1. Regional Regression Equations:

mean-year	$y = -3.97 + 1.66x$
5 - year	$y = -4.31 + 1.71x$
10 - year	$y = -4.56 + 1.77x$
20 - year	$y = -4.79 + 1.82x$

2. Cowichan River Regression Equations:

mean-year	$y = -3.18 + 1.32x$
5 - year	$y = -3.47 + 1.32x$
10 - year	$y = -3.62 + 1.32x$
20 - year	$y = -3.75 + 1.32x$

3. Koksilah River Regression Equations:

mean-year	$y = -4.30 + 1.66x$
5 - year	$y = -4.58 + 1.71x$
10 - year	$y = -4.85 + 1.77x$
20 - year	$y = -5.00 + 1.82x$

where:

'x' is the log of the drainage area (km^2).
'y' is the log of the estimated June to September 7-day average discharge (m^3/s).

derived, but it was anticipated that more representative discharge estimates could be made for analysis locations on the Koksilah River by using a method which was based on the analysis of the Koksilah WSC gauged data. Estimates were then made by using the appropriate equation (Table 6) or directly from the curves using the calculated drainage areas.

5. Water supply estimates for the Cowichan River mainstem were made using a different method than that used for the Koksilah River analysis locations. It was anticipated that by using the two Cowichan River WSC stations, that is, the frequency analysis estimates for WSC station 08HA002 Cowichan River at Lake Cowichan (Table 2) and the discharge estimates calculated for WSC station 08HA011 Cowichan River near Duncan (Table 3), more representative supply estimates could be provided for analysis locations on the Cowichan River. The procedure involved running a line between the two Cowichan River WSC station plots in Figures 2 - 5. However, it was found that for analysis locations with drainage areas larger than 900 km^2 the supply estimates at the 20-year recurrence interval were larger than those calculated for the 5-year recurrence interval. This was caused by the changing slope of the Cowichan River estimation lines which increased with the recurrence interval. Therefore, the slope of the mean-year recurrence interval Cowichan River estimation line (Figure 2) was transferred to the 5, 10 and 20-year graphs (Figures 3 - 5) and positioned through WSC station 08HA002 (plot HA-2). This method of estimation appears to provide more consistent water supply estimates. Regression equations were calculated for each Cowichan River supply estimation line (Table 6).

For estimates from the regionalized curve, the confidence limits were calculated at the 95% confidence level, and are listed with the water supply estimates in Table 5. No confidence limits were calculated for the water supply points on the Cowichan and Koksilah rivers (except WSC stations) because of the method of estimation (lines through WSC plots). The confidence limits associated with these estimates should be within those calculated for the regional regression lines (Figures 2 - 5). However, it is important to appreciate that the water supply estimates calculated from the above method have wide confidence limits and this should be considered when making comparisons with total consumptive withdrawals.

To calculate a 7-day low flow estimate, the drainage area above the point of interest is required, and a choice of the appropriate equation is made, based upon the location of the desired estimate and the desired return interval.

By following the above procedures, flow estimates can be made for other streamsites in and around the study area. Some caution, however, should be observed when using the regionalized curve and the parallel Koksilah curve to make estimates from the 20-year regression equation ($y = -4.79 + 1.82x$). Nine stations used in the 20-year regression analysis have only 5 to 8 years of record. Twenty-year supply estimates could be somewhat inaccurate though to what degree is difficult to determine. It is anticipated that the 95% confidence limits associated with the 20-year regression line would be wide enough to allow for the difference (Figure 4).

3. CONCLUSIONS AND RECOMMENDATIONS

The regionalization procedure developed in this appendix was designed to enable a Water Manager to make 7-day average discharge estimates on ungauged streams on southeastern Vancouver Island, specifically in the Cowichan-Koksilah River basins. This regionalized method should represent an improvement of water supply estimates and provide a more consistent methodology. However, further refinement of the regionalization techniques, improved coverage of WSC gauge stations and development of methods to account for storage regulation would lead to better water supply estimates.

The regionalization results indicate that the effectiveness of the hydrometric network could be improved. It is clear from Figures 2 - 5 that there are significant gaps in the representation of WSC gauges with drainage areas less than 80 km^2. Of the 8 WSC stations in this range, 7 have only 5 to 9 years of non-storage discharge data. It is for streams of this size (<80 km^2), however, where most water supply estimates are required for fisheries and other instream uses. It is accordingly recommended that Surface Water Section, Water Management Branch review the hydrometric network on southern Vancouver Island with the objective of increasing the number of WSC gauge stations with areas of less than 80 km^2.

Refinement of regionalization techniques is an on-going process. With the existing method, flow estimates are made on the basis of drainage area size above a fixed location in the river basin. Further research into the effects which other basin morphometric characteristics, such as surficial stratigraphy and precipitation, have on recorded discharges could help identify stream categories and explain why streams of similar size have different discharges. It may then be possible to provide better estimates for ungauged streams.

During the preliminary analysis of this study, attempts were made to develop other methods of low flow estimation. Unit area discharges were calculated for each of the WSC stations used in the regionalization procedure for East Vancouver Island and plotted on small scale maps. Isolines connecting unit area discharges of equal value were then roughed in. Based on this initial analysis, approximate water supply estimates were made for small ungauged basins. Further refinement and development of this technique would lead to better defined patterns and perhaps an effective method of water supply estimation.

4. WATER ALLOCATION SECTION ESTIMATES

Supply estimates were also prepared by Water Allocation Section (Nanaimo) to provide a comparison to results produced by the regionalization method described in sections 1-3 of this appendix. The method involves using existing data within a watershed or adjoining watersheds, and results in a 5-year recurrence 7-day residual (i.e. following licensed extractions) low flow estimate, as detailed in section 2.1.2.2 of this plan. Some of these estimates took into account flows measured during the 1985 low flow event.

Estimates derived through this procedure are presented in Table 7, along with 1985 measured flows.

TABLE 7
MINIMUM 7-DAY AVERAGE DAILY DISCHARGE FOR 5-YEAR RECURRENCE INTERVAL, AS PREPARED BY WATER ALLOCATION SECTION, NANAIMO

SOURCE	SUPPLY ESTIMATE (m^3/s)	1985 MEASURED FLOWS
Cowan Br.	0.003	0.0 flow at road but 0.006-0.008 m^3/s upstream on Aug. 30, 1985
Cottonwood Cr.	0.098	0.160 - Aug. 30, 0.147 - Sept. 10, 0.159 - Sept. 12
Robertson R.	0.257	0.0 flow at road Aug. 30, Sept. 10, pools upstream - water flows into gravel
Stanley Cr.	0.012	0.001 m^3/s Aug. 30, Sept. 10 & Sept. 12
Bear Cr.	0.048	
Inwood Cr.	0.031	0.0 flow Sept. 9
Bings Cr.	0.012	0.009 m^3/s Aug. 28 & 0.008 m^3/s avg. Sept. 7-13 - 7 days
Averill Cr.	0.003	0.002 m^3/s avg. - Sept. 4-10, 7 days
Richards Cr.	0.005	
Somenos Cr.	N/A	
Quamichan Cr.	N/A	
Patrolas Cr.	0.034	
Glenora Cr.	0.016	0.021 m^3/s - Sept. 1-7 - 7 days avg.
Kelvin Cr.	0.044	0.030 m^3/s - Sept. 9 & 0.034 m^3/s Sept. 12
Koksilah R.	0.374	0.185 m^3/s - Sept. 1-7 - 7 days avg.

N/A - Supply not estimated due to influence of natural lake storage.

Water Allocation Section also prepared average monthly flow hydrographs to illustrate temporal distribution of supply. Figures 6-9 demonstrate monthly variation in flow at four WSC hydrometric gauge locations, and a fifth, Cowichan River at Lake Cowichan, is presented in Chapter 2 (Fig. 2.1).

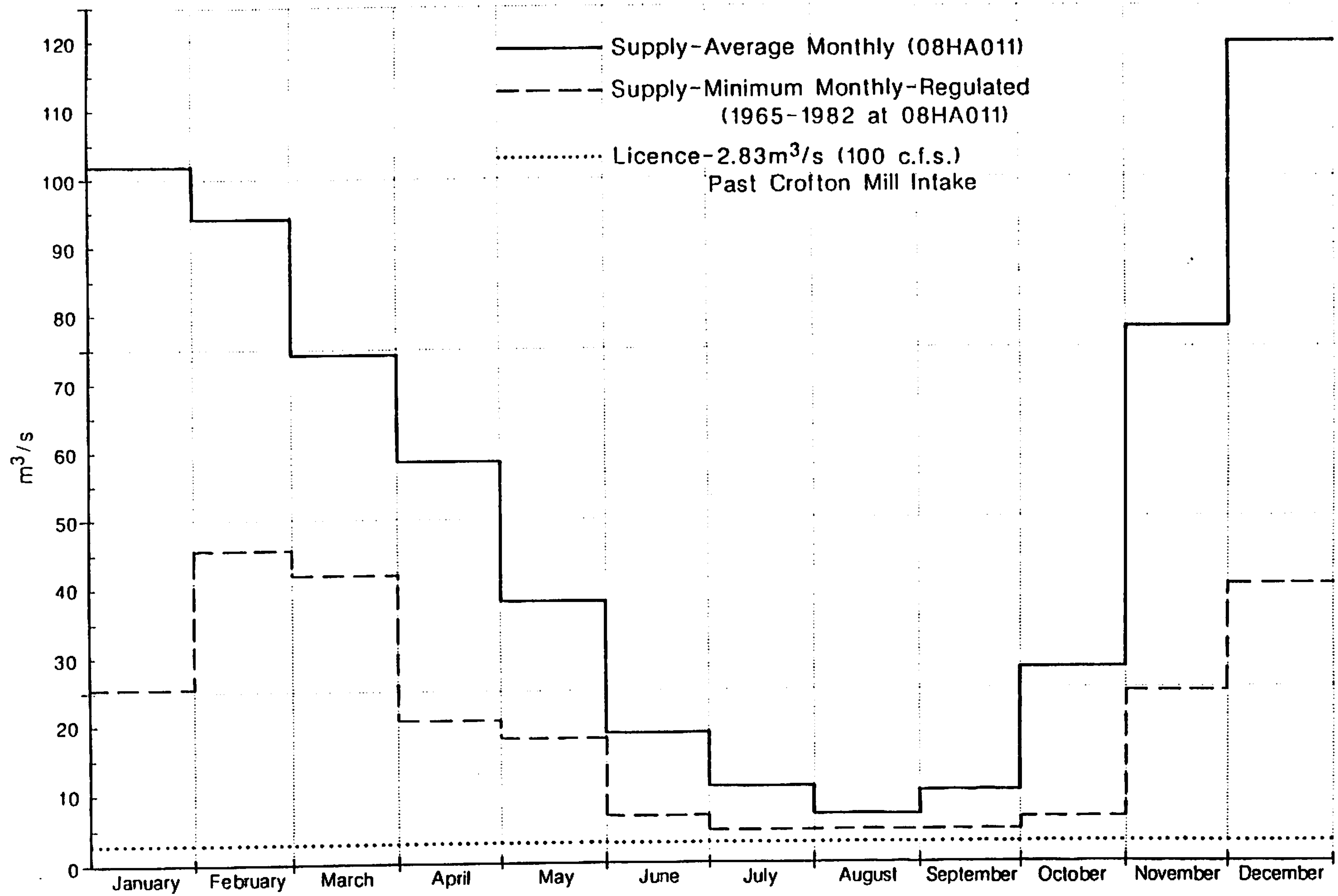

FIGURE 6 Cowichan River at Duncan - Average Monthly Recorded Discharge and Major Licenced Withdrawal.

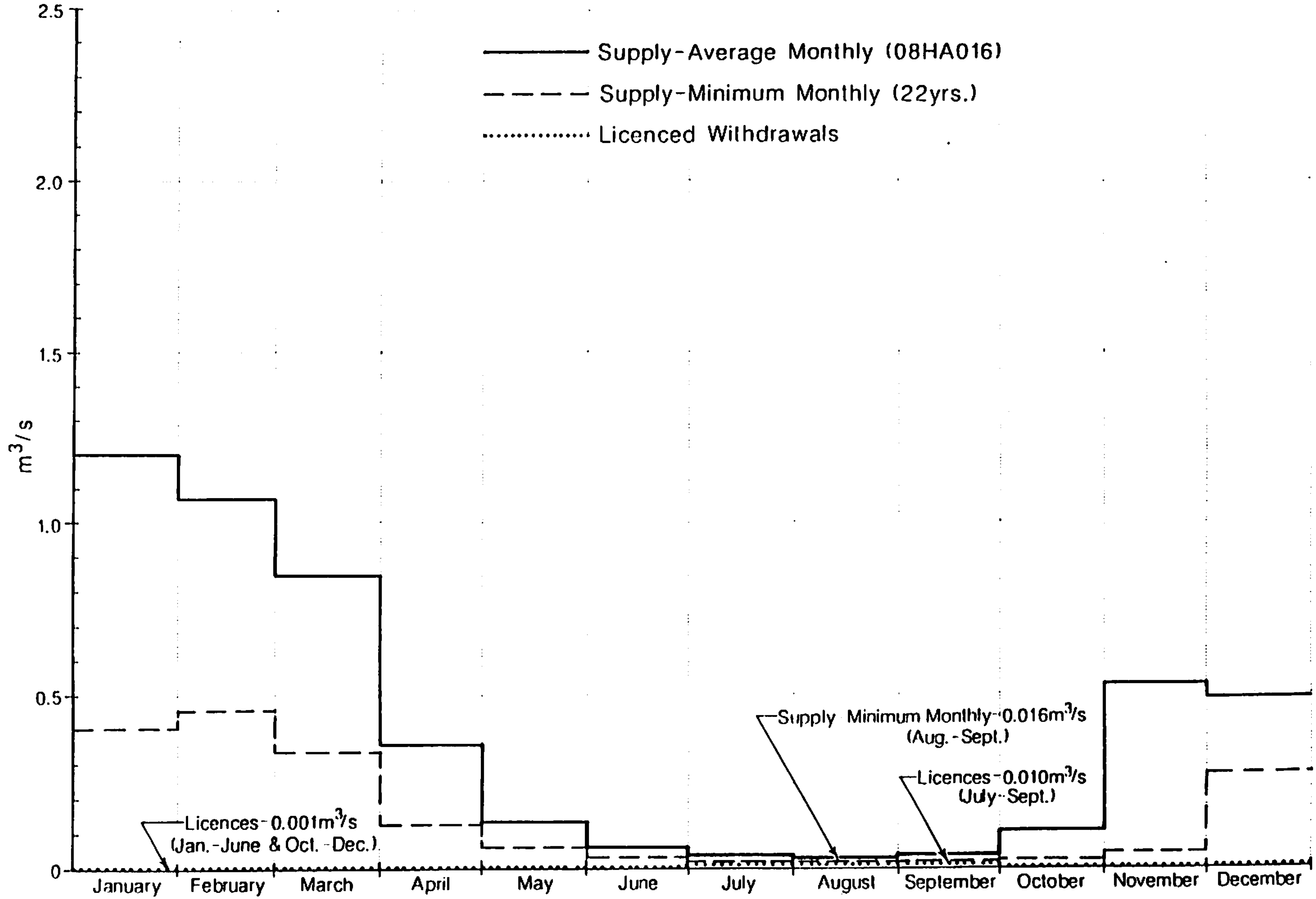

FIGURE 7 Bings Creek – Average Monthly Recorded Discharge and Licenced Withdrawals.

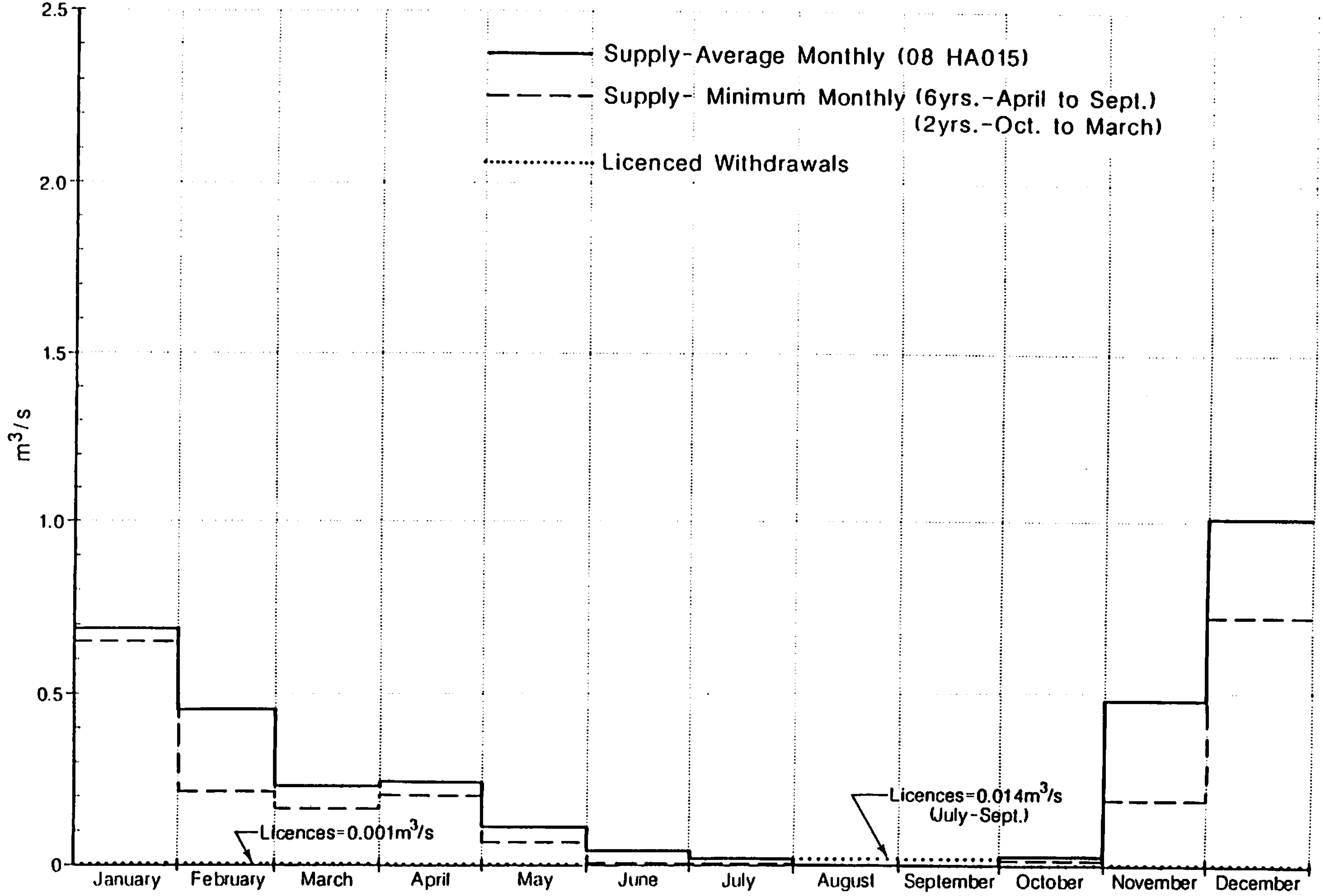

FIGURE 8 Averill Creek - Average Monthly Recorded Discharge and Licenced Withdrawals.

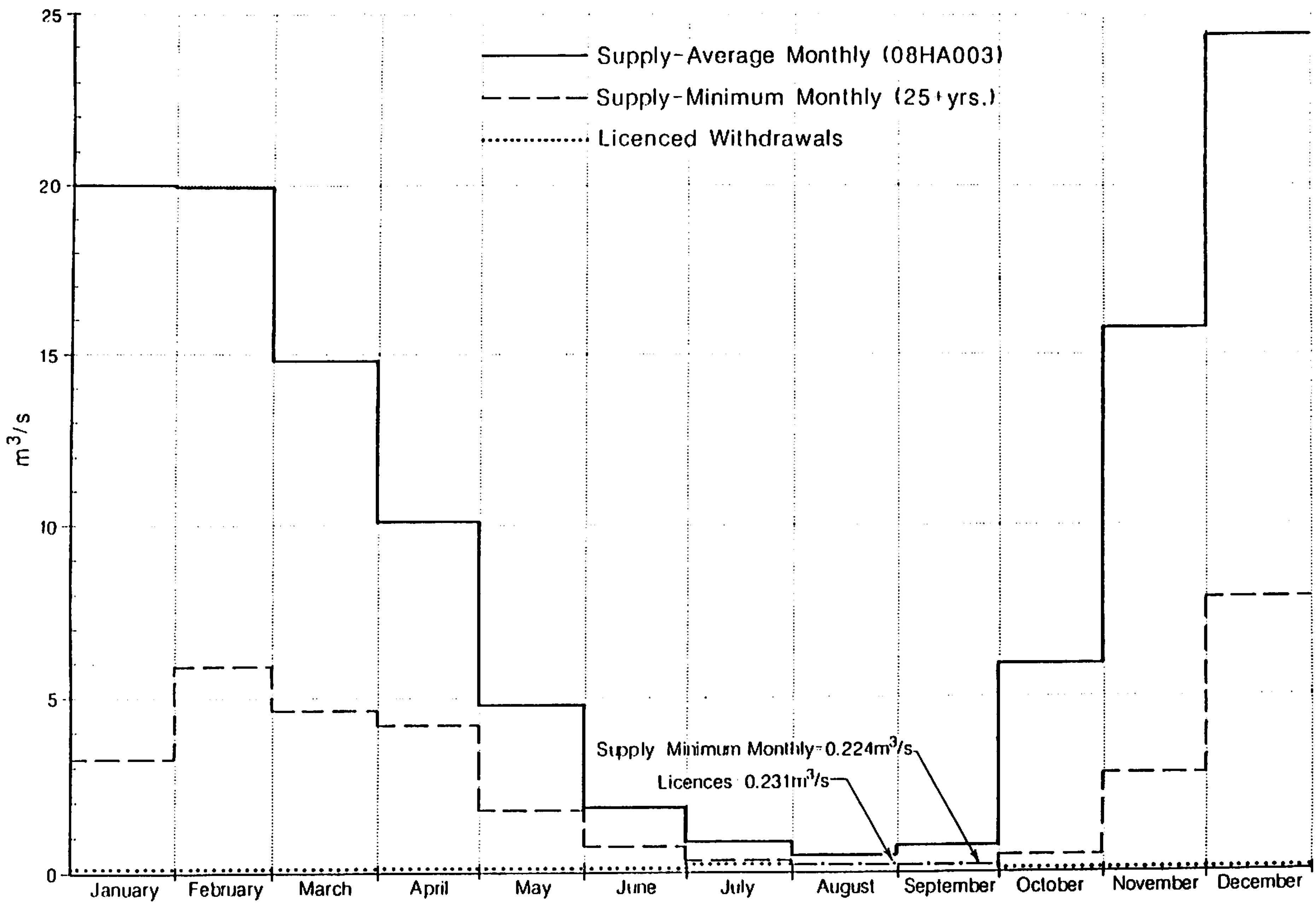

FIGURE 9 Koksilah River at Cowichan Station - Average Monthly Recorded Discharge and Licenced Withdrawals.

5. COWICHAN RIVER MAIN STEM WATER SUPPLY (Regulated Flow)

INTRODUCTION

Prior sections of this appendix have derived values of the 7 day low flows for natural conditions on the main stem of the Cowichan River. Given that the outflow from Cowichan Lake has been artificially controlled since the early 1960's, and that some form of control will continue, the following analyses are presented to illustrate the low flows which have occurred in the river during a period of regulation.

The period selected for analysis is 1965 to 1983 inclusive. The objective is to determine the minimum 7 day mean daily discharge with 5 year recurrence interval which could be expected at seven locations on the Cowichan River from the lake outlet to the mouth.

ANALYSES

Streamflow data are available for the Cowichan River at Lake Cowichan (Station No. 08HA002) from which annual minimum 7 day mean daily discharges have been extracted. These are listed in Table 8.

The discharges for the Cowichan River at Lake Cowichan are accepted as the regulated outflow from the lake and represent the supply (7 day low flow) in the river immediately downstream of the lake. The discharges at Duncan, however, incorporate the impact of all withdrawals from the river between the two hydrometric stations. Thus, while the 7 day low at the upstream station is an average of 6.96 m^3/sec, the average is 5.34 m^3/sec at the station near Duncan. The 7 day low flow is therefore affected by withdrawals which average at least 1.62 m^3/sec and possibly more when the local runoff between the two stations is considered. Because of the effect of the withdrawals, the local runoff cannot be estimated by simple subtraction of the flows at the two stations. The data in Table 8 were analyzed to determine the probability of the 7 day low flow values. Based upon a Pearson III probability distribution using a method of moments calculation, the 7 day low flows were determined for selected return periods and are presented in Table 9 for both hydrometric stations.

The method selected to estimate the runoff downstream of the station at Lake Cowichan is based upon the runoff being a function of watershed discharge area. In this case, the runoff is the annual minimum 7 day mean daily discharge for selected recurrence intervals as presented for 33 hydrometric stations in Table 4. Four hydrometric stations were selected from that table and the pertinent information is given in Table 10. These stations have been selected because their watersheds are adjacent to or within the Cowichan River basin and hence some hydrologic similarities should exist between them and the portion of the Cowichan basin for which runoff estimates are required.

Using the data from Table 10 in regression analyses resulted in good correlations between watershed area and 7 day low flows for those four hydrometric stations. The following equations were adopted:

(a) 5 year return period $Q_7 = 0.00148\ A^{0.976}$
coefficient of correlation $r = 0.999$

(b) 10 year return period $Q_7 = 0.00125\ A^{0.967}$
coefficient of correlation $r = 0.999$

(c) 20 year return period $Q_7 = 0.00121\ A^{0.936}$
coefficient of correlation $r = 0.994$

(d) mean 7 day low flow $Q_7 = 0.00157\ A^{1.04}$
coefficient of correlation $r = 0.998$

where

Q_7 = annual minimum 7 day mean daily discharge in m^3/sec
A = watershed area in km^2

The results of the analyses are illustrated graphically in Figure 10.

To estimate the 7 day low flows on the Cowichan River downstream of the lake, the following method was adopted. Starting with the 7 day low flow at the hydrometric station Cowichan River at Lake Cowichan, the 7 day low flow at the next downstream point of interest was calculated using the foregoing equations where A is the watershed area between the two sites, and the two low flows were then added to produce the 7 day low flow at the point of interest. For each point of interest, the area was always calculated back to the hydrometric station in order to retain the exponential relationship of the equations which estimate flow. The results are presented in Table 11.

While there is no direct method to verify the accuracy of these results, there is one check which can be made. The foregoing analyses have produced two sets of 7 day low flows for the hydrometric station Cowichan River near Duncan 08HA011. The first was a straight forward probability analysis of recorded flows as listed in Table 9, and the second is the estimated flow given in Table 11 which has eliminated the upstream withdrawals which were inherent in the data of Table 9. In Table 12, those two sets of data are compared and their differences calculated. On the average, it is seen that the upstream withdrawals could have been 2.14 m^3/sec and this is consistent with the major licensed withdrawal of 2.8 m^3/sec (100 cfs) by B.C.F.P. for the Crofton mill.

DISCUSSION

The results of the analyses as presented in Table 11 fulfill the objective of this section and their accuracy is deemed to be adequate for this initial planning study.

There could be further investigation into the correctness of applying a probability analysis to regulated streamflow records in which some of the natural randomness has been removed. Nevertheless, the use of the results within the context of this planning study can be accepted as an initial assessment of the water supply where the criterion is the annual minimum 7 day mean daily discharge with a 5 year recurrence interval.

TABLE 8. **Annual (June - Sept.) minimum 7 day mean daily discharge (m^3/sec) as recorded at hydrometric stations Cowichan River at Lake Cowichan 08HA002 and Cowichan River near Duncan 08HA011 from 1965 to 1983 inclusive.**

YEAR	COWICHAN RIVER	
	At Lake Cowichan 08HA002	Near Duncan 08HA011
1965	6.03	4.66
1966	7.06	6.31
1967	6.05	4.32
1968	7.61	5.26
1969	7.43	5.07
1970	5.89	4.64
1971	8.04	6.72
1972	7.37	6.14
1973	7.10	4.58
1974	8.71(max)	6.77
1975	7.10	6.92(max)
1976	7.59	5.41
1977	7.24	4.98
1978	6.70	4.78
1979	5.56(min)	3.94(min)
1980	5.86	4.90
1981	6.25	4.93
1982	7.44	5.38
1983	7.27	5.86
Mean	6.96	5.34
Median	7.10	5.07
Maximum	8.71	6.92
Minimum	5.56	3.94

TABLE 9. Results of probability analyses (Pearson III, method of moments) for annual minimum 7 day mean daily discharge at hydrometric stations Cowichan River at Lake Cowichan 08HA002 and Cowichan River near Duncan 08HA011.

RECURRENCE INTERVALS (YEARS)	ANNUAL MINIMUM 7 DAY MEAN DAILY DISCHARGE (m^3/sec)	
	Cowichan River At Lake Cowichan	Cowichan River Near Duncan
2 (mean)	6.96	5.27
5	6.26	4.60
10	5.90	4.29
20	5.59	4.04

TABLE 10. **Annual minimum 7 day mean daily discharges at selected hydrometric stations. Discharges in m^3/sec have been "naturalized" and are from Table 4.**

Hydrometric Station	Watershed Area (km^2)	Minimum 7 day mean daily discharge (m^3/sec)			
		Mean	5 year Recurrence	10 year Recurrence	20 year Recurrence
Chemainus River 08HA001	355	0.697	0.439	0.372	0.326
Koksilah River 08HA003	209	0.376	0.276	0.222	0.181
Bings Creek 08HA016	15.5	0.026	0.021	0.018	0.017
Haslam Creek 08HB003	95.6	0.208	0.134	0.099	0.071

TABLE 11. Calculated annual minimum 7 day mean daily discharge at selected points of interest on the Cowichan River for selected return periods.

Location on the Cowichan River	Watershed Area, Gross and Intermediate (km^2)	Average Minimum 7-Day Daily Discharge m^3/sec			
		Mean	5 year recurrence	10 year recurrence	20 year recurrence
at Lake Cowichan (station 08HA002)	596	6.96	6.26	5.90	5.59
at Village of Lake Cowichan STP (PE 247)	605 (9)	6.98	6.27	5.91	5.60
below Fairservice Creek	636 (40)	7.03	6.31	5.94	5.63
above Holt Creek	717 (121)	7.19	6.42	6.03	5.70
near Duncan (Station 08HA011)	826 (230)	7.41	6.56	6.14	5.79
at Highway 1	827 (231)	7.41	6.56	6.14	5.79
at Duncan/North Cowichan STP (PE 1497)	835 (239)	7.43	6.57	6.15	5.79
near the mouth	922 (326)	7.60	6.68	6.24	5.86

TABLE 12. Recorded and calculated annual minimum 7 day mean daily discharge at hydrometric station Cowichan River near Duncan 08HA011.

RECURRENCE INTERVALS (YEARS)	ANNUAL MINIMUM 7 DAY MEAN DAILY DISCHARGE (m^3/sec)		
	Recorded 1965-83	Calculated (No Withdrawals)	Difference
2 (mean)	5.27	7.41	2.14
5	4.60	6.56	1.96
10	4.29	6.14	1.85
20	4.04	5.79	1.75

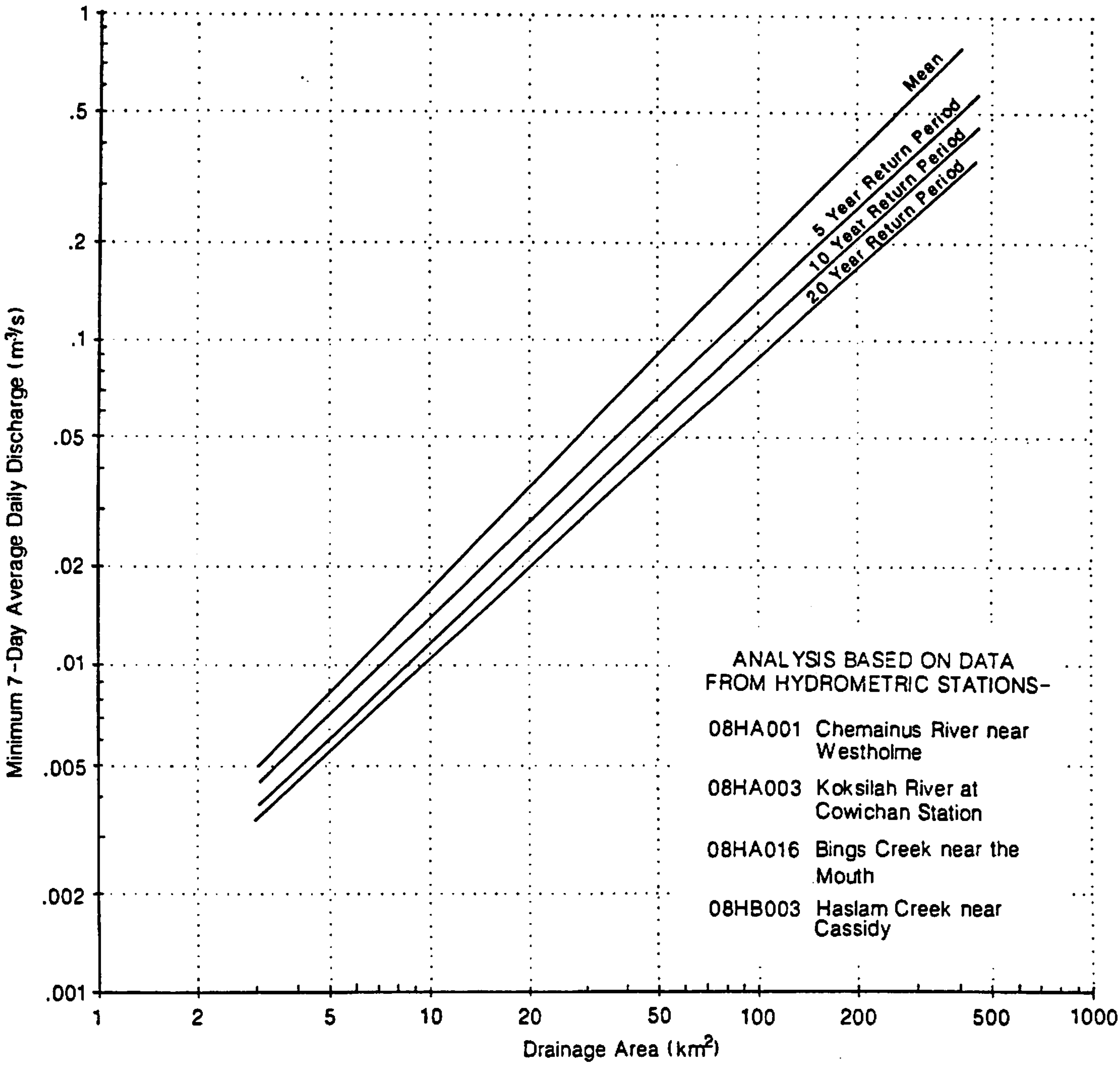

FIGURE 10 Drainage Area versus 7-Day Low Flow for 4 Hydrometric Stations and Selected Return Periods.

APPENDIX 2.2

GROUNDWATER RESOURCE EVALUATION

(M. Zubel, Groundwater Section, Water Management Branch)

APPENDIX 2.2

COWICHAN-KOKSILAH WATER MANAGEMENT PLAN GROUNDWATER RESOURCE EVALUATION

By M. Zubel, Groundwater Section

1. INTRODUCTION

The following report is an office evaluation of the groundwater resource within the Cowichan and Koksilah watersheds. It is based upon a review and analysis of available groundwater reports on file, water well record data, geologic reports and maps. This report also addresses the following concerns (terms of reference) as requested by Planning and Assessment Branch:

1. Update well information, and extend information around Cowichan Lake and along the Koksilah River where it exists, using the map and report prepared by K. Ronneseth in 1982, but only within the confines of the study area;

2. Assess available water quality information in the study area;

3. Discuss interrelationship between groundwater and the lower Cowichan River, or in other areas where there may be potential for such conflict;

4. Provide quantitative assessment where possible with respect to large potential groundwater sources, such as might be used for agriculture, domestic or municipal uses;

5. Discuss potential for expanding Duncan's municipal water supply in the future.

2. GEOLOGY

Much of the study area is underlain by bedrock at surface, or veneer deposits over bedrock (see Figure 1). According to Muller and Jeletzky (1970), the bedrock areas consist predominantly of volcanic, intrusive and sedimentary rocks of Upper Cretaceous to Permian and older ages. Halstead (1966) indicates that during the Pleistocene Epoch, as a result of glaciation and deglaciation, the Cowichan valley was filled with a moderately thick succession of unconsolidated sediments. These glacial sediments consist of till, clay, silty clay, sand and gravel, deposited in continental and marine environments directly by ice or from its meltwaters. Presently, the maximum thickness of the unconsolidated surficial deposits in the valley is not exactly known; however, a well located at the mouth of the Cowichan River was drilled to a depth of 200 feet without encountering bedrock. Flanked by bedrock uplands, the main valley occupied by permeable water-bearing valley fill deposits is considered the most important source of groundwater.

3. HYDROGEOLOGIC DATA

In the Groundwater Section files, there are over 3,000 records of well data for the study area and various hydrogeological reports. One of these reports deals with the groundwater potential for agricultural capabilities for the eastern part of the study area (Ronneseth, 1982). Additional well information since the Ronneseth report was reviewed, and pertinent data was utilized to update and modify the groundwater capability map for that area. In addition, all available well information for the rest of the study area was reviewed to extend the information on groundwater for the rest of the study area. Figure 1 is the resulting map which shows the areas where groundwater is presently available and being utilized, and where potential groundwater may exist.

4. GROUNDWATER POTENTIAL ASSESSMENT

Based on available well record data and the surficial geology of the area, Figure 1 shows the general extent of the major groundwater aquifers and the relative degree of groundwater potential within the study area. As shown in Figure 1, the most productive aquifers (presently being used for agricultural, municipal and industrial uses) are those outlined as areas underlain by confined and/or unconfined aquifers with known good groundwater potential. The location of wells with reported yields between 25 USgpm and 2,000 USgpm are plotted within these outlined areas.

On the southeast side of Duncan, there are presently 8 large diameter wells located along the north and south sides of the Cowichan River (which appears to be the main source of recharge to these wells), supplying up to a total of approximately 12,000 USgpm of groundwater during maximum peak withdrawals. These wells supply the District of North Cowichan and City of Duncan sufficient water to meet present municipal needs, and a Provincial fish hatchery. An analysis of water level data (between 1975 and 1982) from Provincial observation wells located in the vicinity of these production wells, indicates that production well pumping has not caused any declining trends in local groundwater levels for the period of record. With the exception of very minor interference drawdown effects between wells, it appears that there is no "mining" of groundwater occurring in this area as a result of production well pumping. This suggests that the aquifer in the vicinity of the lower Cowichan River may be capable of supplying more groundwater to additional production wells. However, before additional production wells for Duncan's future municipal water supply or any other major use, could be considered, a more detailed hydrogeologic investigation of the area immediately around the present production wells is recommended. The objective of this study would be to more fully assess the effects of present withdrawals upon the aquifer, potential pumping interference effects on existing wells by additional well(s), and more importantly, the present and future effects of major groundwater withdrawals upon low flows of the Cowichan River which may lead to conflicts with other water users (such as fisheries). This hydrogeologic investigation could involve an assessment of the actual extent and characteristics (i.e., aquifer transmissivities, storativity, etc.) of the aquifer(s), the amount of recharge and groundwater flow, hydrologic and meteorologic data, the actual amount of groundwater withdrawals, and could involve field inventories, well drilling, pumping tests, possible geophysical testing, and water level monitoring (both surface and groundwater).

Near the mouth of the Cowichan River, there are some very productive large-diameter wells owned by Doman Industries with reported yields between 1500 USgpm and 1865 USgpm. In the immediate area of these wells there are also several smaller diameter (6-inch) flowing artesian wells with estimated flows up to approximately 400 USgpm. It is not known to what extent ground water is being utilized in this area for industrial or other purposes. However, it appears that this area is underlain by a significant confined groundwater reservoir, and that there is good potential for further ground water development. A more detailed site specific hydrogeologic assessment would be required to ascertain the extent of the groundwater potential in this area.

Figure 1 also outlines areas underlain by confined and/or unconfined aquifers with known moderate groundwater potential; (i.e., limited potential for agricultural or municipal use). These areas were identified on the basis of available well record data, i.e., wells completed in sands and/or gravels, having reported yields betweeen 10 USgpm and 25 USgpm, and surficial geologic considerations. Well record analysis indicates that many wells within these outlined areas, although indicating yields of up to 25 USgpm, could have produced higher yields if the wells had penetrated the entire aquifer, and/or larger diameter wells were constructed and larger pumps installed, and/or better screen design was utilized. In other words, the groundwater potential for agricultural, domestic or municipal use could be greater than indicated, (i.e., well yields in the order of hundreds of gallons per minute). The amount of further groundwater withdrawal that may be available from these aquifers is not fully known and may require detailed, costly studies to complete.

The third type of area in Figure 1 is underlain predominantly by sand and/or gravel deposits (as determined from surficial geology only), where there may be potential for groundwater development. Since there is little to no groundwater data available for these areas, it is difficult to ascertain the amount of groundwater that may be available. Further data by way of test wells, pumping tests, etc., would be required to assess the situation. Preliminary indications, however, are favourable for domestic supplies, and for only limited agricultural or municipal supplies (i.e., well yields up to 50 USgpm).

The remaining parts of the map area are underlain predominantly by bedrock/veneer over bedrock or shallow morainal deposits in which the groundwater potential is generally low to nil. Wells completed within the bedrock areas have reported yields generally less than 10 USgpm. Some higher yielding wells to about 50 USgpm have also been reported, however, their sustained long-term yields have not been proven. Groundwater investigations for municipal or agricultural uses within these areas are not recommended. For domestic purposes, the groundwater potential may be adequate.

5. GROUNDWATER-SURFACE WATER INTER-RELATIONSHIP

In 1975, the Groundwater Section was involved in a research project regarding the groundwater potential of the lower Cowichan River aquifers, south to south-east of Duncan. One of the objectives of the project was to evaluate the effects of major groundwater withdrawals on the flows in the Cowichan River. According to Foweraker (1976), the project was able to identify:

1) The presence of three distinct aquifers.

2) A similarity in groundwater level and river level hydrograph curves for observation well and Cowichan River water level, suggesting that there is a good hydraulic continuity between the Cowichan River and the "middle aquifer."

3) That groundwater withdrawals are expected to affect river flows to <u>some extent</u>, however, the exact relationship will not be known until production wells are utilized over a long term and the records analyzed.

To date, the effects of major groundwater withdrawals by the City of Duncan's four production wells (estimated maximum withdrawal at 7,000 USgpm) and the District of North Cowichan's four production wells (estimated maximum withdrawals at 5,500 USgpm), on flows of the lower Cowichan River have not been analyzed. In order to ascertain the present effects of groundwater withdrawals on the lower Cowichan River flows, a more detailed assessment of existing data is required. This would include determining the the amount of groundwater withdrawals in the area, the extent of surface water allocation (i.e., licenses), and additional river and groundwater level data from sources both upstream and downstream of the production well fields.

Due to a lack of data elsewhere along the Cowichan and Koksilah Rivers, it is not known whether groundwater withdrawals from wells located along these rivers is affecting low flows. The amount of groundwater withdrawals from these wells is not as great as in the area south-east of Duncan. Therefore, surface water-groundwater conflicts are not expected to be significant. However, if surface water supplies are fully allocated (i.e., licensed), there may be potential for surface water-groundwater conflicts if aquifers, hydraulically connected to surface waters, are further developed. Collection of groundwater and river level data, groundwater use, and other relevant data regarding the groundwater resource would be required to determine the relationship between surface waters and any underlying aquifers, and to assess the potential for and extent of surface water-groundwater conflicts in these areas.

6. GROUNDWATER QUALITY ASSESSMENT

Figure 2 shows the locations of wells within the Cowichan-Koksilah plan area for which there is groundwater chemistry data. Table 1 provides a summary of the available groundwater quality data, and the following comments are an assessment of this data.

An analysis of the well type and depths indicates that the majority of wells with groundwater quality data are shallow (less than 200 ft. deep) and are completed in surficial (unconsolidated) deposits within shallow ground water flow systems. There are five bedrock wells completed to depths of between 190 feet and 410 feet. These wells can also be considered completed within relatively shallow groundwater flow systems. The significance of a shallow groundwater flow system is that most natural waters will be relatively low in total dissolved solids (T.D.S.), low in specific conductance and be relatively soft to moderately soft in hardness. This appears to be the case for groundwaters within this study area (see Table 1). Table 1 also indicates that for the parameters tested, most of the groundwaters within the study area have chemical concentrations within acceptable limits for drinking water quality based on the B.C. Drinking Water Quality Standards (1982). The exceptions include the groundwater tested from wells no. 3, 11, 18, 19, 20 and 21 (which have pH values slightly above or below the recommended limits), and those from wells no. 13 and 14 (which have reported Chloride levels over and almost above the recommended limit of 250 mg/L). Regarding the high Chloride concentration and salt water content of these two latter wells, (which are close to the fresh water-salt water interface). Kohut (1981) suggests that the source of the salt water content in the wells (particularly under pumping conditions) is from salt water located in a nearby distributary channel. The low chloride concentrations reported for groundwaters from nearby well no.'s 8, 12, and 15 suggest that the above salt water intrusion problem is localized.

At present, there are no other known contaminated groundwaters within the study area. There have been concerns that some wells operating near the City of Duncan's sewage treatment ponds, located east of Duncan and just north of the lower Cowichan River, may become contaminated by seepage of effluent from the treatment ponds. Further research and investigation of this site specific area, including the possible construction of monitoring wells near the ponds would be required to assess the potential for contamination. Further research would also be required to identify the source(s) and degree of any other potential groundwater contamination throughout the study area; and the vulnerability of producing aquifers to potential contamination.

7. CONCLUSIONS AND RECOMMENDATIONS

Available data have been reviewed and compiled, and a map prepared showing the groundwater resource potential in the study area. Figure 1 shows the locations of existing known aquifers capable of providing groundwater supplies to agricultural, municipal, industrial and domestic uses. A quantitative assessment of large potential groundwater sources was done utilizing this map.

The amount and extent of potential surface water-groundwater conflicts is not fully known within the study area. Further investigations and analysis of data are required to better assess the potential problem(s).

Analysis of water quality data indicates that for the parameters tested, most groundwaters within the study area are within drinking water quality objectives, and that there are no apparent significant groundwater concerns. Further research is required to identify and analyze the potential for groundwater contamination by man-made activities and the potential for salt water intrusion problems in the Cowichan Bay estuary area.

M. Zubel
Senior Geological Engineer
Groundwater Section

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TABLE 1
COWICHAN/KOKSILAH WATER MANAGEMENT PLAN
GROUNDWATER QUALITY DATA

Well # (Fig.2)	Well Type* & Depth (ft.)	Sample Date	pH	Temp (°C)	T.D.S	Conductivity (mho/cm)	Total Hardness	Alkalinity (HCO_3/CO_3)	Cl	SO_4	NO_2/NO_3	Fe (Diss.)	Fe (Total)	Ca	Mg
1	B-250	02/76	8.0	16	-	300	136	136	15.0	-	-	-	0.4	-	-
2	S- 96	09/78	8.5	15	-	180	85	85	7.6	-	-	-	0.8	-	-
3	S- 27	03/72	6.0	-	-	-	5	-	>5.0	-	-	-	3.0	-	-
4	B-410	06/74	7.5	17	-	435	119	204	15.0	-	-	-	0.4	-	-
5	S- 78	07/78	8.5	14	-	500	102	238	30.0	-	-	-	5.0	-	-
6	S-103	12/65	7.5	14	-	245	120	-	c 22.7	-	-	-	1.0	-	-
7	S- 74	05/73	7.5	14	-	245	120	-	c 15.2	-	-	-	1.0	-	-
8	S- 14	12/80	-	10	-	200	-	-	c 37.9	-	-	-	-	-	-
9	S- 15	05/75	-	16	-	78	-	-	-	-	-	-	1.0	-	-
10	S- 82	06/82	7.6	13	-	195	85	85	7.6	-	-	-	1.6	-	-
11	B-300	11/79	10.0	13	-	1000	290	299	143.0	-	-	-	0.5	-	-
12	S-160	02/76	7.9	15	-	-	86	-	45.0	-	-	-	L0.5	-	-
13	S- 10	12/80	-	15	-	1130	-	-	c393.9	-	-	-	-	-	-
14	S- 15	12/80	-	20	-	800	-	-	c242.4	-	-	-	-	-	-
15	S- 20	05/75	6.5	-	-	-	34	-	15.2	-	-	-	1.2	-	-
16	S-158	06/82	8.5	14	-	275	119	136	7.6	-	-	-	1.3	-	-
17	S- 42	06/82	8.0	20	-	300	119	136	7.6	-	-	-	1.8	-	-
18	S-200	10/75	9.2	12	-	510	45	-	105.0	L5.0	L0.02	-	10.4	5.9	7.4
19	S-160	12/75	9.0	14	210	385	39	-	71.6	L5.0	L0.02	-	0.2	4.2	6.9
20	S-146	03/78	9.1	-	-	-	40	80	75.0	L5.0	2.90	-	0.1	10.0	30.0
21	S- 26	05/75	5.7	16	-	-	20	25	10.0	L5.0	3.00	0.04	-	15.0	35.0
22	S- 36	05/71	6.0	18	-	440	102	-	c 75.8	-	-	-	1.0	-	-
23	S- 47	11/61	7.3	-	40	-	29	25	1.2	8.0	-	-	0.1	9.8	1.0
24	B-210	07/82	7.3	14	-	610	51	238	75.0	-	-	-	2.3	-	-
25	S- 36	07/82	7.8	15	-	400	153	119	22.0	-	-	-	2.0	-	-
26	S- 93	12/74	6.7	18	-	-	40	50	7.5	L5.0	-	-	0.3	30.0	10.0
27	S- 63	08/68	7.1	-	63	-	32	36	6.5	L5.0	-	0.04	L0.1	9.0	1.5
28	S- 79	10/68	7.0	-	-	-	45	46	-	-	6.50	0.06	-	-	-
29	S- 70	11/68	6.9	-	-	-	-	38	-	-	2.50	0.04	L0.1	7.5	5.4
30	S- 82	09/68	7.1	-	61	-	41	44	1.5	-	-	0.02	L0.1	8.5	2.6
31	S- 80	05/75	7.4	9	40	-	33	-	L0.5	L5.0	-	0.04	L0.1	7.7	3.3
32	S- 31	09/75	6.7	18	-	60	24	25	1.8	L5.0	0.09	-	0.1	8.5	0.8
33	S- 20	09/75	6.7	15	-	60	25	25	1.7	L5.0	0.13	-	0.1	8.5	0.8
34	S- 39	09/75	6.7	15	-	62	25	26	1.8	L5.0	0.07	-	0.2	8.8	0.8
35	S- 14	09/75	6.8	19	-	61	25	25	1.7	L5.0	0.09	-	0.3	8.8	0.8
36	S- 35	09/75	6.8	17	-	50	20	20	1.6	L5.0	0.05	-	L0.1	7.0	0.6
37	S- 36	09/75	6.8	18	-	55	22	23	1.6	L5.0	0.09	-	0.2	7.8	0.7
38	S-152	12/75	6.9	11	-	66	29	29	1.8	L5.0	0.09	-	0.1	9.7	1.1
39	S-104	02/84	-	-	-	-	-	-	-	-	-	0.10	0.4	7.6	1.0
40	S- 65	03/76	7.3	-	36	-	25	-	1.5	22.6	-	0.04	L0.1	6.0	1.2
41	S- 73	02/77	7.3	-	44	-	23	31	2.5	L5.0	L0.10	0.04	-	7.3	1.3
42	S- 49	03/77	6.0	-	50	-	26	28	3.0	L5.0	L0.10	0.04	-	7.9	1.6
43	S- 75	04/77	7.1	-	59	-	27	37	6.0	L5.0	L0.10	-	L0.1	9.4	0.9
44	S- 80	06/78	7.4	-	42	49	22	26	L0.5	L5.0	L0.10	0.02	0.5	7.6	1.5
45	S- 70	06/78	7.0	-	48	57	24	29	L0.5	6.8	L0.10	0.02	L0.1	8.3	0.8
46	S- 76	04/82	7.0	-	53	57	25	32	2.5	L5.0	0.15	0.02	L0.1	8.8	0.8
47	S- 49	08/63	7.0	-	45	-	32	29	1.9	L5.0	L0.10	-	L0.1	9.5	1.1
48	S- 53	10/69	6.8	-	74	-	37	36	5.2	6.3	-	0.03	L0.1	9.8	3.1
49	S- 70	07/68	6.9	-	-	-	44	49	-	-	L0.10	0.06	0.1	-	-
50	B-190	07/82	8.0	16	-	395	85	187	15.0	-	-	-	0.6	-	-
51	S- 30	06/75	7.5	14	-	270	120	-	c15.2	-	-	-	2.5	-	-
52	S- 21	02/66	6.0	19	-	115	70	-	c22.7	-	-	-	1.0	-	-
53	S- 80	01/70	7.4	-	86	-	48	62	6.7	13.0	-	0.07	-	8.8	6.3
54	S-130	04/71	-	-	-	-	-	-	-	-	-	0.10	2.1	-	-
55	S- 91	10/70	8.1	-	170	-	88	103	2.0	18.2	-	0.10	0.8	24.2	6.6
56	S- 79	04/71	7.7	-	123	-	56	74	1.0	7.2	0.88	0.10	2.1	20.6	1.0

Well Type* B - Bedrock
S - Surficial

Note: Units in mg/less otherwise noted
L - less than
c - denotes calculated value

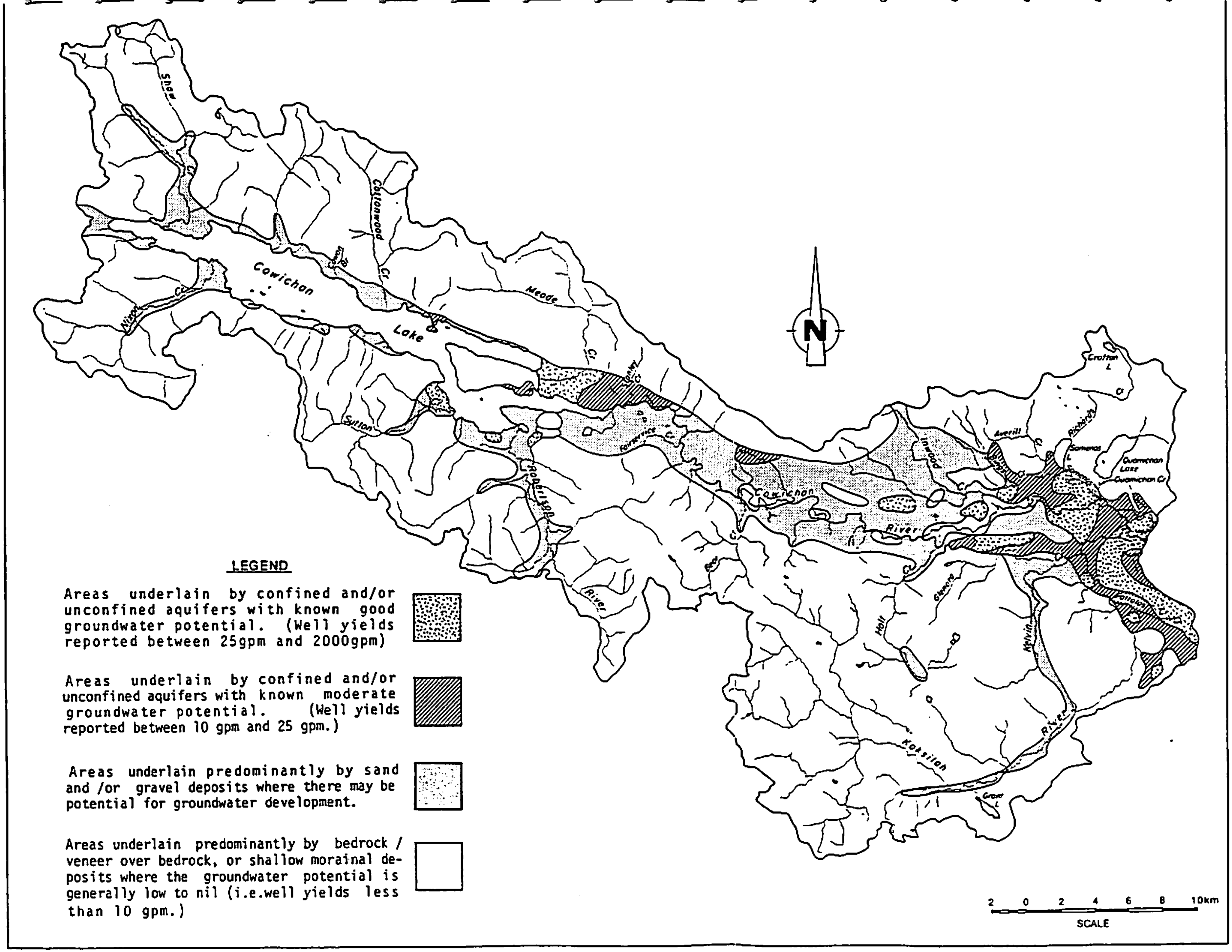

FIGURE 1 Groundwater Potenial.

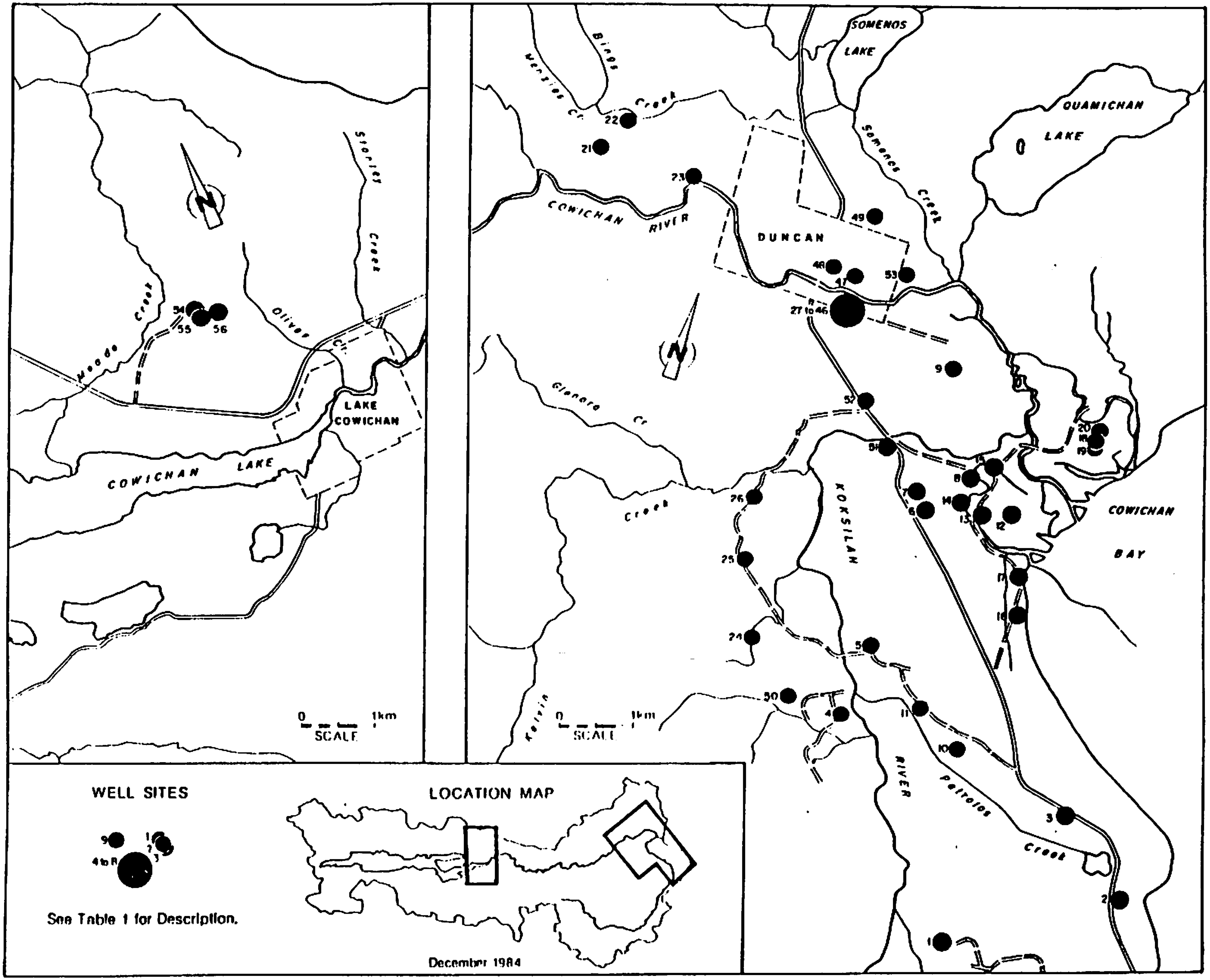

FIGURE 2 Location of Wells with Water Quality Data.

APPENDIX 3.1

FISHERIES RESOURCES

APPENDIX 3.1

FISHERIES RESOURCES

1. SPECIES PRESENT

Chum, coho and chinook salmon are present in large numbers in the Cowichan River and in addition, this river provides a summer fishery for brown trout that is unique in British Columbia. Other species commonly found in the system are rainbow trout, anadromous and resident cutthroat trout and Dolly Varden char. The Koksilah River has important chum, coho and chinook salmon populations, with steelhead and searun cutthroat trout also present. Cowichan Lake provides important rearing habitat for kokanee salmon and lake trout.

Steelhead and coho salmon utilize the entire river system for spawning including the tributaries to Cowichan Lake. On the Koksilah River, most coho spawn downstream of Marble Falls, however, steelhead and cutthroat move upstream of the falls to spawn. Chinook salmon spawn in the Cowichan River mainstem upstream of Skutz Falls and in the lower reaches of the Koksilah River. Chum salmon spawn in the lower mainstems of both the Cowichan and Koksilah Rivers, particularly in the side channels of these mainstems.

The small tributaries to Cowichan Lake provide important spawning and rearing areas for lake species as well as coho salmon, steelhead and cutthroat trout. Tributaries to the Cowichan River mainstem are nursery streams for steelhead, cutthroat and brown trout and coho salmon. The side channels of the Cowichan River mainstem provide very important chum spawning areas as well as rearing areas for all species. Tributaries to the Koksilah River are also important nursery streams for the salmon, steelhead and searun cutthroat present in this system.

2. FISH SUPPLY, EFFORT AND CATCH

Fisheries supply, effort and catch information is presented in Table 3.1 in Chapter 3. Chum and coho salmon are present in the greatest numbers, with chum primarily concentrated in the lower reaches of the mainstem of the river system and coho utilizing the entire system. Trends in fish supply in the watershed are available for some species. Historical records of chinook escapements indicate that runs were consistently higher in the late 1930's to mid-1940's period. However, records over the past decade do not seem to indicate consistent declines or increases in chinook, coho or chum escapements. Steelhead catch trends in the Cowichan River system have remained relatively constant or increased over the last ten years, but the number of steelhead kept has declined due to management regulations. In this system, approximately 44% of the steelhead caught are kept. In the Koksilah River system both catch and kill declined steadily from 1976 to 1982 but have increased slightly since then. Approximately 72% of the steelhead caught in the Koksilah system are kept.

Harvest of certain species is regulated in order to protect wild stocks. Wild steelhead trout are managed on a catch and release basis but hatchery steelhead, which are differentially marked, may be kept by the angler. Cutthroat and brown trout are primarily managed with a catch and release regulation but there is a seasonal opening. When this opening is in effect, minimum size limits are employed to prevent overharvesting of these stocks.

Most tributary streams in this system have little fishing activity. The nursery streams on the south side of the Cowichan River between the Village of Lake Cowichan and Bear Creek are closed to fishing by regulation. Other Cowichan River tributaries are subject to area closures for parts of the year. These streams are reserved for spawning and rearing steelhead, salmon, brown trout and searun cutthroat.

3. FISH CULTURE AND STOCKING

Fish culture facilities are found at four locations in the Cowichan-Koksilah watershed:

1. Ministry of Environment Hatchery located one kilometer downstream of the highway bridge on the south side of the Cowichan River. Water source is groundwater, incubation capacity is 500,000 eggs.
2. Cowichan Indian Band Community Development Hatchery located about two kilometers downstream of the highway bridge on the south side of the Cowichan River. Water source is groundwater, incubation capacity is 500,000 eggs.
3. Ministry of Environment Net Pen Rearing Facility in Lake Cowichan at the B.C. Forestry Research Station. Rearing capacity is 60,000 fish.
4. A small public involvement hatchery on Grant Lake outlet creek which flows into the Koksilah River.

Coho have occasionally been stocked in some tributaries of the Cowichan-Koksilah system. Brown trout are stocked in tributaries to the Cowichan mainstem and steelhead are stocked in the Cowichan River mainstem downstream of Duncan where they are able to migrate to the ocean easily (see Table 1). There is no fish stocking program for Cowichan Lake.

4. FISH LIFE HISTORY PHASES

The year-round life history phases for fish species in the Cowichan-Koksilah system are presented in Table 2 and Figure 1. This information, when combined with the knowledge of the species present within the streams or stream reaches, is intended to provide an understanding of the particular fish reproduction or growth phase that may be affected by maximum streamflow events (high or low flow) or by disturbances within or about the stream. Spawning, incubation, rearing and migration phases will vary in their sensitivity to streamflow changes or instream disturbances and, therefore, this information can be used to refine estimates of minimum flow requirements for

TABLE 1
STOCKING PROGRAM
(1975-1985)

STEELHEAD

Brood Year	Smolts Released	Estimated Adult Return (Year)	Estimated Legal Total Catch (Kill)
1980	9,367	450 (1983/1984)	135 (45)
1981	3,274	92 (1984/1985)	223 (87)
1982	45,701	1,778 (1985/1986)	700 (300)
1983	[43,058]	[1,500](1986/1987)	- - -
[1984]	[50,000]	[2,000](1987/1988)	- - -

Note: All releases were into the lower Cowichan River in the vicinity of Duncan.

[ ] estimated

Source: "Steelhead Harvest Analysis" Reports, Nanaimo

BROWN TROUT

Release Site	Number
Hatchery Creek	3,000
Oliver Creek	1,000
Skutz Creek 1	500
Skutz Creek 2	500
Holt Creek	2,500
Bear Creek	2,500
Dale Creek	500
Bings Creek	600

Source: Provincial Fisheries Biologist, Nanaimo

TABLE 2

FISHERIES LIFE HISTORY PHASES

SPECIES LIFE HISTORY PHASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Steelhead (winter)												
Spawning (& upstream migration)	X	X	X	X	X						X	X
Incubation	X	X	X	X	X	X	X					X
Rearing (1-3 years in stream)	X	X	X	X	X	X	X	X	X	X	X	X
Migration (downstream)					X	X						
Searun Cutthroat												
Spawning (& upstream migration)	X	X	X	X	X					X	X	X
Incubation	X	X	X	X	X	X						X
Rearing	X	X	X	X	X	X	X	X	X	X	X	X
Migration (downstream)					X	X						
Resident Cutthroat												
Spawning	X	X	X	X	X	X				X	X	X
Incubation	X	X	X	X	X	X	X	X		X	X	X
Rearing				X	X	X	X	X	X			
Overwintering	X	X	X	X						X	X	X
Lake-Stream migration				X	X	X						
Resident Rainbow												
Spawning	X	X	X	X	X							
Incubation		X	X	X	X	X	X					
Rearing				X	X	X	X	X	X			
Overwintering	X	X	X							X	X	X
Lake-Stream migration				X	X	X						

TABLE 2
FISHERIES LIFE HISTORY PHASES

SPECIES LIFE HISTORY PHASE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown Trout												
Spawning									—	—	—	—
Incubation	—	—	—						—	—	—	—
Rearing	—	—	—	—	—	—	—	—	—	—	—	—
Kokanee												
Spawning									—	—	—	
Incubation	—	—	—						—	—	—	—
Rearing	—	—	—	—	—	—	—	—	—	—	—	—
Chinook												
Spawning (& upstream migration)									—	—	—	
Incubation	—	—	—	—								—
Rearing				—	—	—	—					
Migration (downstream)				—	—	—	—					
Coho												
Spawning (& upstream migration)										—	—	—
Incubation	—	—	—	—	—							—
Rearing (1 year in stream)	—	—	—	—	—	—	—	—	—	—	—	—
Migration (downstream)					—	—						
Chum												
Spawning (& upstream migration)											—	—
Incubation	—	—	—	—	—							—
Rearing				—	—	—						
Migration (downstream)				—	—	—						

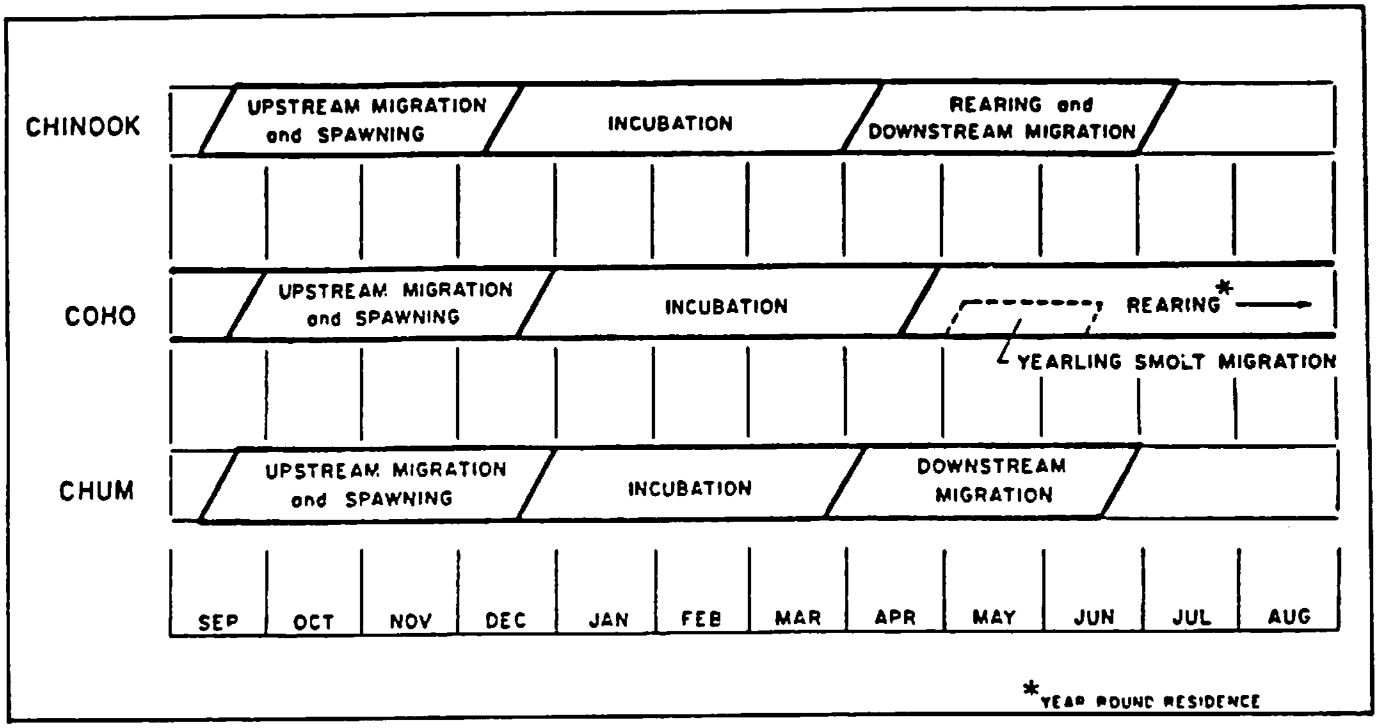

FIGURE 1 Freshwater Life Cycles for the Cowichan-Koksilah River Salmon.

fish or to specify times of year when particular instream activities that may disturb fish may or may not take place.

Spawning periods for fish species in the Cowichan-Koksilah system occur at various times throughout the year. Chinook, coho and chum migrate upstream to spawn from September to December, and egg incubation extends through to April or May. Chinook and chum fry generally proceed immediately to the ocean, although some chinook fry remain in the stream for several months to rear. Coho fry generally migrate as yearlings. Streamflows must be sufficient for the spawning fish to migrate upstream successfully and find suitable habitat in tributary streams or mainstem side channels. Fry migration downstream will also be affected by water availability in the system.

Adult steelhead and searun cutthroat begin moving upstream in the fall to spawn, with spawning occurring through to the spring when the adults migrate back downstream to the ocean. Downstream migration of steelhead and cutthroat smolts occurs from mid-April to mid-June. Brown trout begin spawning in September which may coincide with the autumn low streamflow period. This species is considered very sensitive to streamflow fluctuations because the adult fish remain in the streams during the summer months. Since adult fish require relatively more water in a stream for survival, the presence of brown trout will affect the minimum streamflow requirements.

Resident cutthroat and rainbow trout are also affected by water availability in streams as these species migrate to the streams from Lake Cowichan in order to spawn. The migration out of the lake begins in mid-April with the fish returning to the lake during June.

For species such as coho, steelhead and cutthroat, insufficient streamflow during the summer rearing period in the tributaries to Cowichan Lake and the side channels of the Cowichan River often forces rearing fish to move to Cowichan Lake where they tend to suffer high mortality. Other species do not normally rear in streams, instead migrating to lakes (e.g.

rainbow trout) or to the ocean (eg. steelhead, chinook and chum) for rearing. These species require adequate streamflow to complete their migration through the system.

5. SUMMER REARING HABITAT CAPABILITY FOR SALMONIDS

Table 3 includes a list of streams or portions rated for summer rearing capability for salmonids. The list was prepared jointly be G. Reid and B. Tutty, and reflects both freshwater and anadromous fishery values.

6. TEMPERATURE LIMITS ON THE DEVELOPMENT STAGES OF PACIFIC SALMON

Temperature limits for four development stages (optimum, migration, spawning and hatching) of five Pacific salmon species (chinook, coho, chum, pink and steelhead) are illustrated in Figure 2. This information, combined with that given in Table 2 and Figure 1 on the seasonality of Cowichan-Koksilah salmonid life stages, demonstrates the inter-related importance of temperature and flow rates on the productive capacity of these species.

TABLE 3

Cowichan Subbasin Classification of Accessible/Inaccessible Summer Rearing Capability for Salmonids

Stream Code	Name	Accessible Habitat Classification	Inaccessible Habitat Classification
92-4800	Cowichan Mainstem	High	-
92-4800	Bible Camp Sidechannel	High	-
92-4800	Bonsall's Slough	High	-
92-4800	Dale's Creek	High	-
92-4800	Flangut Alley Sidechannel	High	-
92-4800	Fishladder Creek	High	-
92-4800	Major Jimmy's Slough	High	-
92-4800	Rotary park Creek	High	-
92-4800	Trailer Park Ponds	High	-
92-4800-020	Koksilah River Mainstem	High	-
92-4800-020-050	Kelvin Creek	High	High
92-4800-020-050-130	Glenora Creek	High	-
92-4800-020-425	Wild Deer Creek	High	High
92-4800-020-500	Grant Lake Creek	High	High
92-4800-020-670	South Koksilah (Mainstem only)	High	High
92-4800-020-700	Fellows Creek	High	High
92-4800-055	Quamichan Creek	Moderate	High (Lake)
92-4800-060	Somenos Creek	Moderate	-
92-4800-060-650	Bings Creek	High	High
92-4800-060-800	Averill Creek	Low	Low
92-4800-060-900	Richards Creek	High	High
92-4800-125-250	Currie Creek	Low	Low
92-4800-190	Holt Creek	High	High
92-4800-390	Skutz Creek	High	High
92-4800-400	Bear Creek	High	High
92-4800-470	Fairservice Creek	High	Low
92-4800-495	Kwasin Creek	High	High
92-4800-500	Stanley Creek	High	-
92-4800-510	Hatchery Creek	High	-
92-4800-515	Oliver (Beadnell) Creek	High	-
92-4800-520	Beaver Creek	High	-
92-4800-580	Mesachie Creek	Low	High (Lake)
92-4800-585	Robertson Creek	High	High
92-4800-600	Ashburnham Creek	Moderate	Moderate
92-4800-605	Sutton Creek	High	Moderate
92-4800-605-130	Millar Creek	High	
92-4800-650	Meade Creek	High	Moderate
92-4800-725	Coonskin Creek	High	Moderate
92-4800-735	Youbou Creek	Low	-
92-4800-750	Cottonwood Creek	High	Moderate
92-4800-750-250	Widow Creek (Mainstem)	High	-
92-4800-820	Croft Creek	Low	-
92-4800-850	Wardroper Creek	Low	-
92-4800-875	McKay Creek	High	Moderate
92-4800-900	Nixon Creek	High	Moderate
92-4800-900-625	Raymond Creek	High	-
92-4800-950	Shaw Creek	High	High
92-4800-960	Little Shaw Creek	Moderate	High
92-4800	Lakehead Creek	High	-

*Classification - High salmonid rearing capability
- Moderate salmonid rearing capability
- Low salmonid rearing capability

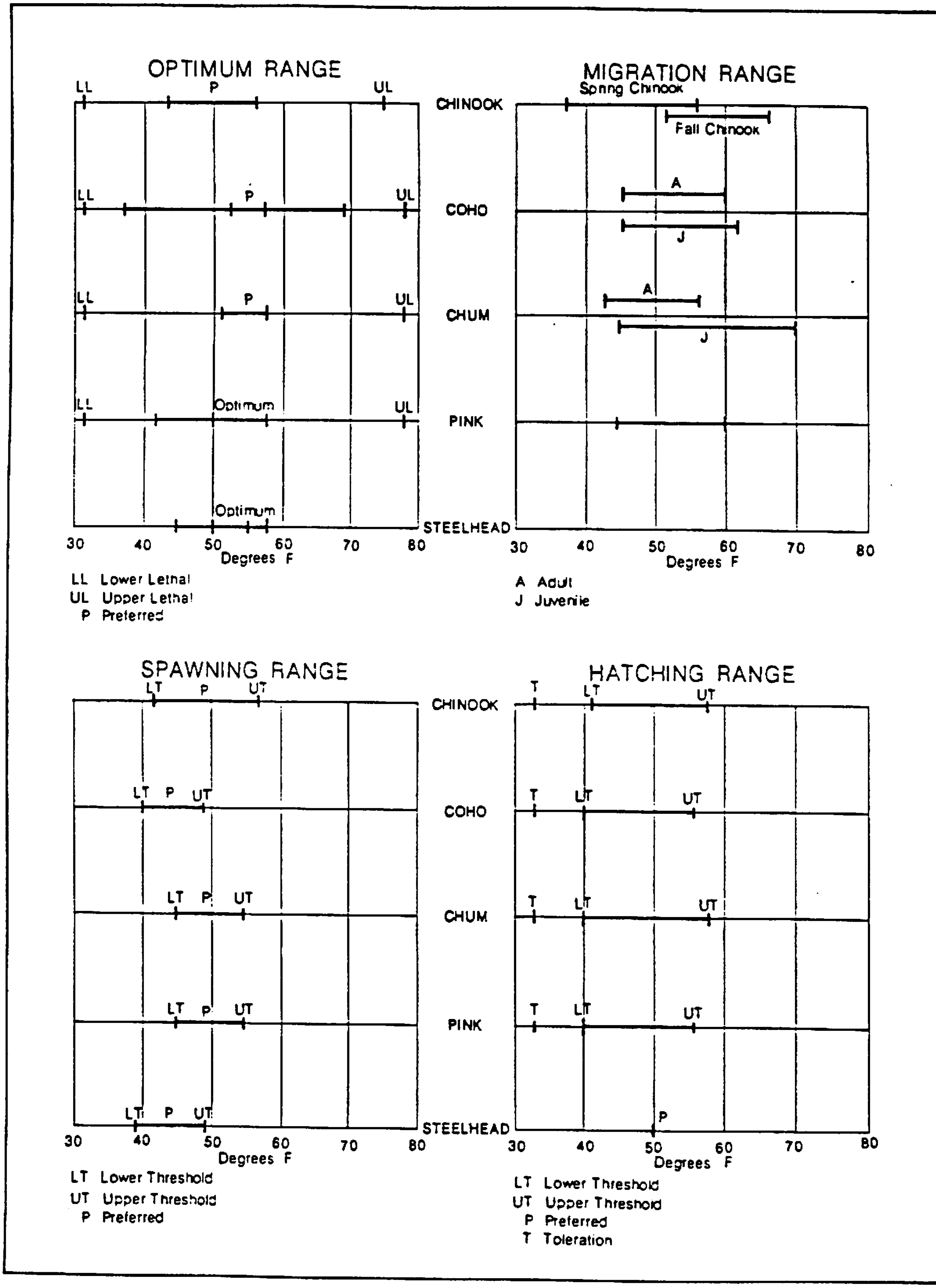

FIGURE 2 Temperature Limits on the Developement Stages of the Pacific Salmon. (from M.C. Bell, 1983)

APPENDIX 3.2

FISHERY FLOW ESTIMATES

APPENDIX 3.2

FISHERY FLOW ESTIMATES

Estimating fishery flow requirements for a particular stream reach requires information of three major types: the management objectives for the reach; the habitat requirements of fish species using the reach; and the physical (hydrologic/hydraulic) properties of the reach. The most appropriate estimation technique will then be a function of the availability of these types of information and the degree of accuracy required in the water management framework.

For example, in streams where natural flows are very much greater than total demand, an approximate fishery flow estimation technique is appropriate. On the other hand, regulated streams with high demand for available water may require detailed hydraulic simulations.

Flows required by fish may often be greater than natural flows. Many streams on the east coast of Vancouver Island are naturally flow limiting, causing severe reductions in natural survival in some years. When such streams are integral to fishery management objectives, water management techniques to enhance flows should be considered.

APPENDIX 3.3

WASTE MANAGEMENT AND WATER QUALITY

APPENDIX 3.3

WASTE MANAGEMENT AND WATER QUALITY

EFFLUENT PERMITS

The Village of Lake Cowichan has a permit (PE 247) to discharge a daily maximum of 1635 m^3 of secondary-treated (lagoon) effluent to the Cowichan River below Cowichan Lake.

The second permit (PE 6603) is issued to the Fisheries Branch's hatchery near Duncan. This permit allows 5077 m^3 of effluent to be discharged daily to the Cowichan River at a point upstream of the Duncan-North Cowichan sewage treatment plant.

The third permit (PE 1497) is issued to the Duncan-North Cowichan Utilities Board to discharge effluent (secondary-treated - lagoon) from the sewage treatment plant. This permit allows 13 600 m^3 of effluent per day to be discharged into the Cowichan River near its confluence with Somenos Creek.

1. VILLAGE OF LAKE COWICHAN SEWAGE TREATMENT PLANT

The discharge from the Village of Lake Cowichan sewage treatment plant enters the Cowichan River about 3 1/2 km downstream of the weir at Cowichan Lake. The outlet is at the deepest point in the river so that dilution is as rapid as possible (Figure 3.7).

Analysis of monitoring data shows that the permit is generally in compliance (Table 1). Permittee data shows occasional high fecal coliform levels.

TABLE 1
COMPARISON OF PERMIT CONDITIONS WITH EFFLUENT MONITORING DATA

PERMIT	PARAMETER	PERMIT REQUIREMENT	ACTUAL LEVELS Max.	Min.	Mean	No. of Values	YEARS OF DATA ANALYZED	COMPLIANCE
PE 247 Village of Lake Cowichan Sewage Treatment Plant	BOD_5 mg/L	45	96	6	26.5 (19.8)[1]	77	Daily: Jan. 1983	3/24 O/C[2]
	TSS mg/L	60	60	5	24.8 (28.4)	77	to Dec. 1984	0/24 O/C
	Residual chlorine mg/L	.05	.34	0	.08	180	Monthly: 1979-84	300/480 O/C
	Flow GPD	360,000 (1636 m^3/day or 0.02 m^3/s)	1,075,333	22,000	430,600	676		
	Total nitrogen mg/L							(18.2)
	Total phosphorus mg/L				5.51mg/L (3.2)	78		
	Total coliform/100 ml		630,000[3]	1,100	37,986	49		
	Fecal coliform/100 ml		80,000[3]	10	1,624 (778)	77		
PE 6603 Fish and Wildlife Branch Hatchery	BOD_5 mg/L	10	No effluent data available.					
	TSS mg/L	5						
	NH_3-N mg/L	0.17						
	NO_3-N mg/L	0.06						
	PO_4-P mg/L	0.07						
	Flow m^3/d	5077 (.059 m^3/s)						
PE 1497 Duncan Sewage Treatment Plant	BOD_5 mg/L	30	63	5	19.8 (16.7)	14	June 1982 to Aug. 1984	
	TSS mg/L	40	29	1.5	13.5 (14.5)	14		
	Residual chlorine mg/L	0.02	-	-	-	-		
	Flow US gal/day	3,593,130 (13,600 m^3/day) (0.157 m^3/s)	6336T	1277T	2585T	824		
	Total nitrogen mg/L		22	1.52	12.90 (15.9)	14		
	Total phosphorus mg/L		15.6	.89	4.22 (3.4)	14		
	Fecal coliform		27	<2	7.68 (13.2)	14		

[1] ( ) - Brackets indicate monitoring by Waste Management Branch, all other data is permittee monitoring information.
[2] O/C - Out of compliance.
[3] Prior to disinfection.

Environmental impact from the effluent appears to be a detectable (but small) increase in Kjeldahl nitrogen and total phosphorus concentrations. It appears that the effluent is well diluted. Minimum dilution is 537:1, and dilution is usually at about 700:1. Phosphorus is usually the limiting factor above the discharge. This is more evident in historical data with a mean N:P ratio of 13:1. The N:P ratio of effluent is N limiting and the river is usually N limiting below the outfall. Since there is an increase in P from the discharge, some green algal problems resulting from the discharge have been noted, particularly in slow reaches with good sun exposure. Water quality above and below the permit is presented in Table 2. (Note that this table is typical or representative of the ambient water quality near Lake Cowichan STP.)

TABLE 2

COMPARISON OF TOTAL NITROGEN AND TOTAL PHOSPHORUS LEVELS ABOVE AND BELOW LAKE COWICHAN SEWAGE TREATMENT PLANT

Date	Site	Flow m^3/day	Dilution	Total N (mg/L)	Total P (mg/L)	N:P
May 2/84	above	N/A	N/A	.14	.009	15.5:1
	effluent			17.36	3.16	5.5:1
	below			.09	.009	10:1
Sept. 26/83	above	1,002,240		0.11	.008	13.7:1
	effluent	1,429	700:1	18.84	3.62	5.2:1
	below	1,003,669		0.07	0.01	7:1
Oct. 6/82	above	941,760		.04	.006	6.7:1
	effluent	1,370	687:1	22	3.66	6:1
	below	943,130		.05	0.013	3.8:1

2. FISHERIES BRANCH HATCHERY

The discharge from the hatchery enters the Cowichan River about 1 km below the Island Highway at Duncan, on the right (south) bank (Figure 3.7).

Permit requirements are outlined in Table 1. The permit levels are expected levels based on monitoring of other provincial hatcheries, and the well-known and relatively constant variables within hatcheries. The calculated minimum dilution is 248:1, based on minimum river flows known for July, and coincidental maximum hatchery flows.

There are no monitoring data available to date, but it is anticipated that outside the Initial Dilution Zone there will be no detectable increase in any parameter over background levels.

3. DUNCAN-NORTH COWICHAN SEWAGE TREATMENT PLANT

This discharge enters the Cowichan River about 1.5 km downstream of the Island Highway. The outfall is near the left (north) bank (Figure 3.7).

The permit was originally issued in 1972, then upgraded in 1978. Discharge at the present site started August 13, 1980. Permit specifications are outlined in Table 1.

Analysis of monitoring data shows that the permit is generally in compliance for BOD_5, TSS, and residual chlorine. Fecal coliforms are occasionally high, varying in the receiving water from non-detectable up to 540 MPN/100 ml. The input of phosphorus to the river is significant and algae blooms downstream of the discharge are well documented (Derksen 1981). There is concern that the introduction of excess nutrients during the summer low flow period promotes the extensive growth of river bottom algal mats, smothering or otherwise altering benthic fish food communities, and at times contributing to dissolved oxygen deficiencies resulting from the decay of excess organic matter (Department of Fisheries and Oceans, 1985).

Calculated minimum dilution is approximately 29:1. Historical effluent data (May '82 to April '83) show mean total N is 14.2 mg/L (standard deviation = 5.7) and mean total P is 4.3 (standard deviation = 3.8). The mean N:P ratio is 4.8:1 showing that the effluent is typically N limiting (although data show it is occasionally low on P).

Historical upstream data for total N and total P show the river is P limited (total N and total P are the only consistent parameters available). However, due to high inputs of P and relatively low inputs of N, downstream data usually indicate N limitation (Derksen, 1981). This is shown in Table 3 of recent data (except upstream data is N limiting). (Note that this table is typical or representative of ambient water quality data near the Duncan STP.)

TABLE 3

COMPARISON OF TOTAL NITROGEN AND TOTAL PHOSPHORUS LEVELS ABOVE AND BELOW DUNCAN SEWAGE TREATMENT PLANT

Date	Site	Flow m^3/day	Dilution	Total N (mg/L)	Total P (mg/L)	N:P
Sept. 26/83	upstream	846,720		0.05	0.01	5:1
	effluent	6,763	125:1	17.93	4.02	4.5:1
	downstream	853,483		0.20	0.051	3.9:1
Oct. 6/83	upstream	763,776		0.03	.008	3.7:0
	effluent	6,717	114:1	22.00	4.74	4.6:1
	downstream	770,493		0.19	.049	3.9:1

The Environmental Protection Service conducted an intensive monitoring program associated with the new outfall before and following start-up Aug. 13, 1980 (Derksen, 1981). Their conclusion was that while there was no deterioration in water quality due to fecal coliforms, nutrient input was resulting in an algae bloom that was potentially harmful to chum salmon spawning areas, as well as coho and chinook rearing areas.

A follow-up inspection in 1983 indicated less growth of algae, which was attributed to increased flow. The maximum chlorophyll a concentration measured (one site only) was 376 mg/m^2, well above the 100 mg/m^2 (Nordin, 1985) recommended for protection of fisheries in streams. Derksen (1981) indicated a mean river flow of 5.2 m^3/s and a mean effluent discharge of 0.062 m^3/s for a dilution of 84:1. Calculations indicated that to achieve background levels of total phosphorus, river flows during August 1980 would need to have been 36 m^3/s, about 7 times greater than the mean-year estimated low flow (see Chapter 5 for further discussion).

APPENDIX 3.4

OVERVIEW OF COWICHAN RIVER WATER QUALITY DATA

OVERVIEW OF COWICHAN RIVER WATER QUALITY DATA

SITE	PARAMETER	UNITS	#DATA PTS	YEARS	MEAN	MAX.	90TH PRCNTL	COMMENTS
120800	pH		30	72-83	7.3	7.6	7.6	MIN= 6.5
	RES TOT	MG/L	37	71-83	1003.5	13690	2133.6	MIN= 36 GEOMN=96
	RESNF T	MG/L	32	71-83	7.8	42	20.2	
	SPF COND	US/CM	22	73-83	574.14	7380	1398.2	PCT50= 69
	TURBIDITY	NTU	29	71-83	2.02	13	4.1	
	ALK TOT	MG/L	4	74-76	24.8	26.8	26.7	
	CHLORIDE	MG/L	3	76-80	63.3	185		PCT50=3.3
	HARDNESS	MG/L	25	71-81	35.2	167	75	PCT50=23
	AMMONIA	MG/L	14	75-83	.03	.08	.06	
	NITRATE	MG/L	23	71-83	.04	.07	.065	TOTAL
	NIT KJEL	MG/L	19	74-83	.145	.32	.3	
	NIT TOT	MG/L	19	74-83	.18	.36	.34	
	COD	MG/L	27	71-83	9.8	16	12.4	
	PHENOL	MG/L	9	79-83	.002	.003	.002	
	PHOS ORT	MG/L	20	74-83	.01	.03	.02	
	PHOS TOT	MG/L	38	71-83	.026	.065	.0397	
	SILICA	MG/L	14	75-83	3.2	4.2		
	SULPHATE	MG/L	28	71-83	8.67	66.4	26.18	
	TAN&LIG	MG/L	13	71-76	.2	.3	.26	
	ARSENIC	MG/L	4	82-83	L			
	CADMIUM	MG/L	17	73-83	.00289	.0032	L.01	EQUIS MAX NOT CORRECT
	CALCIUM	MG/L	17	73-81	9.07	17.6	12.8	DISSOLVED
	COPPER	MG/L	29	71-83	.0046	.01	.01	TOTAL
	IRON	MG/L	28	71-86	.27	1.1	.47	TOTAL
	LEAD	MG/L	27	72-83	.017	.019		TOTAL PCT50=.001
	MAGNESIUM	MG/L	12	76-83	2.25	11.2	8.89	TOTAL
	MERCURY	MG/L	24	71-83	.00005	.00013	.000075	TOTAL
	ZINC	MG/L	28	71-83	.007	.018	.0113	TOTAL
	ALUMINUM	MG/L	4	82-83	.077	.17	.15	TOTAL
	COL.FECL	MPN	33	71-83	182	920	541	TOTAL
	COL. TOT	MPN	30	71-83	943	G2400	2330	
120801	pH		11	73-77	7.47	7.7	7.68	MIN=7.3
	RES TOT	MG/L	15	71-77	38.2	76	64	
	RESNF T	MG/L	11	71-77	6.56	20	20	
	SPF COND	US/CM	11	73-77	50.36	56	56	MIN=46
	TURBIDITY	NTU	15	71-77	1.9	12	6.48	
	ALK TOT	MG/L	3	75-76	21.7	23		MIN=20
	HARDNESS	MG/L	15	71-77	22	28	25.6	MIN=18.9
	AMMONIA	MG/L	4	75-77	.0095	.011		
	NITRATE	MG/L	12	71-75	.0425	.09	.087	DISSOLVED
	NIT KJEL	MG/L	6	75-77	.17	.31	.28	TOTAL
	NIT TOT	MG/L	6	75-77	.188	.35	.29	

SITE	PARAMETER	UNITS	DATA PTS	YEARS	MEAN	MAX.	90TH PRCNTL	COMMENTS
120801	PHOS ORT	MG/L	9	73-77	.003	.003		
	PHOS TOT	MG/L	15	71-77	.0097	.032	.0224	
	SILICA	MG/L	3	75-76	2.6	2.9		
	SULPHATE	MG/L	14	71-77	4.57	L5		
	CADMIUM	MG/L	5	72-77	.0004	L.0005		TOTAL
	CALCIUM	MG/L	10	72-77	7.17	8	7.99	
	COPPER	MG/L	14	71-77	.003	.01	.01	TOTAL
	IRON	MG/L	14	71-77	.26	1.3	.88	TOTAL
	LEAD	MG/L	15	71-77	.0027	.008	.0074	TOTAL
	MAGNESIUM	MG/L	8	73-77	.67	.83		DISSOLVED
	MERCURY	MG/L	14	71-77	.000053	.00014	.0001	TOTAL
	ZINC	MG/L	15	71-77	.0063	.019	.013	TOTAL
	COL FECL	MPN	12	71-77	40	240	207	
	COL TOT	MPN	11	71-77	148	348	326	
120802	pH		71	68-83	7.45	8.2	7.7	MIN=7
	RES TOT	MG/L	27	73-83	43.6	130	71.6	
	RESNF T	MG/L	35	69-83	8.86	96	29.2	
	SPF COND	US/CM	63	68	52.14	64.3	59	MIN=30
	TURBIDITY	NTU	54	68-83	2.7	37	6.8	
	ALK TOT	MG/L	41	68-76	19.51	23.5	22.08	
	CHLORIDE	MG/L	42	68-81	1.7	2.5	2.07	MIN=.3
	HARDNESS	MG/L	50	68-83	21.6	27.4	24.28	DISSOLVED
	AMMONIA	MG/L	29	68-83	.026	.1	.019	
	NIT TOT	MG/L	14	76-83	.0307	.07	.06	
	NIT KJEL	MG/L	29	73-83	.109	.28	.24	
	NIT TOT	MG/L	26	74-83	.1076	.28	.262	
	COD	MG/L	19	74-83	9.3	11.7	10	
	PHENOL	MG/L	10	78-83	.00245	.007	.0066	
	PHOS ORT	MG/L	26	68-83	.0028	.004	.003	DISSOLVED
	PHOS TOT	MG/L	43	68-83	.0149	.115	.0348	
	SILICA	MG/L	51	68-83	3.05	4.4	4.16	
	SULPHATE	MG/L	53	68-83	3.096	5.7	5	DISSOLVED
	CADMIUM	MG/L	20	73-83	.0025	.0007	.01	TOTAL
	CALCIUM	MG/L	51	68-81	7.5	8.9	8.48	DISSOLVED
	CHROMIUM	MG/L	6	75-83	.0083	L		
	COPPER	MG/L	31	68-83	.004	.008	.01	TOTAL
	IRON	MG/L	24	73-83	.1896	.71	.55	TOTAL
	LEAD	MG/L	33	68-83	.0157	.034	.1	TOTAL
	MAGNESIUM	MG/L	12	78-83	.73	1.19	1.09	TOTAL
	MANGANESE	MG/L	23	68-83	.0117	.02	.02	TOTAL
	MERCURY	MG/L	21	73-83	.000053	.0001	.000058	TOTAL
	NICKEL	MG/L	16	73-83	.01775	L.01		TOTAL
	POTASSIUM	MG/L	36	68-83	.258	.8	.43	TOTAL
	SODIUM	MG/L	39	68-76	1.387	1.9	1.6	DISSOLVED
	ZINC	MG/L	30	68-83	.0083	.05	.0154	TOTAL
	ALUMINUM	MG/L	4	81-83	.145	.35	.31	TOTAL
	COBALT	MG/L	8	73-83	.0505	L.01		TOTAL
	COL FECL	MPN	29	73-83	33	350	49	
	COL TOT	MPN	24	73-83	102	350	240	

SITE	PARAMETER	UNITS	DATA PTS	YEARS	MEAN	MAX.	90TH PRCNTL	COMMENTS
120808	pH		9	76-82	7.4	7.7	7.55	MIN=7.1
	SPF COND	US/CM	9	76-83	49.9	52	51.2	MIN=46
	NITRATE T	MG/L	6	76-83	.03	.05	.0425	
	NIT KJEL	MG/L	6	77-83	.083	.12		
	NIT TOT	MG/L	6	78-83	.105	.15	.1275	
	PHOS TOT	MG/L	7	76-83	.0068	.009	.009	
	COL FECL	MPN	7	76-83	48.8	170	110	
	COL TOT	MPN	6	76-83	138	350	215	
120809	pH		8	76-83	7.4	7.7	7.6	MIN=7.0
	SPF COND	US/CM	8	76-83	50.25	52	52	MIN=47
	NITRATE T	MG/L	6	76-83	.028	.05	.035	
	NIT KJEL	MG/L	5	78-83	.156	.28	.21	
	NIT TOT	MG/L	5	78-83	.184	.28		
	PHOS TOT	MG/L	6	76-83	.0867	.017	.011	
	COL FECL	MPN	6	76-83	60	240	.112	
	COL TOT	MPN	5	76-83	645	G2400	237	
130180	pH		25	71-83	7.29	7.6	7.6	MIN=6.9
	RES TOT	MG/L	30	71-83	32.9	44	37.8	
	RESNF T	MG/L	20	73-83	.68	3	2.9	
	SPF COND	US/CM	25	73-83	48.68	52	52	MIN=44
	TURBIDITY	NTU	30	71-83	.66	3	1.1	
	ALK TOT	MG/L	4	74-76	19.4	20.5		
	CHLORIDE	MG/L	4	76-823	1.6	1.7		
	HARDNESS	MG/L	25	71-83	16.8	21	20.4	DISSOLVED
	AMMONIA	MG/L	17	72-83	.0058	.012	.0104	
	NITRATE T	MG/L	14	76-83	.035	.07	.065	
	NIT KJEL	MG/L	21	74-83	.090	.16	.15	
	NIT TOT	MG/L	21	74-83	.119	.21	.204	
	COD	MG/L	22	72-83	10.12	11.7	10.7	
	PHENOL	MG/L	9	78-83	.0021	.003	.002	
	PHOS ORT	MG/L	23	73-83	.003	.003		
	PHOS TOT	MG/L	27	72-83	.0059	.014	.008	
	SILICA	MG/L	15	75-83	2.36	3.2	3.14	
	SULPHATE	MG/L	24	72-83	4.6	L5		
	TAN&LIG	MG/L	14	72-75	.257	.3	.3	
	CADMIUM	MG/L	18	73-83	.0035	L.01		TOTAL
	CALCIUM	MG/L	18	73-83	6.9	7.7	7.52	DISSOLVED
	COPPER	MG/L	30	71-83	.0076	.12	.01	TOTAL
	IRON	MG/L	26	71-83	.086	.4	.13	TOTAL
	LEAD	MG/L	29	72-83	.015	.004	.1	TOTAL
	MAGNESIUM	MG/L	12	76-83	.55	.65	.64	TOTAL
	MERCURY	MG/L	22	72-83	.00005	.00007	.000057	TOTAL
	NICKEL	MG/L	13	74-83	.022	L.05		TOTAL
	ZINC	MG/L	29	71-83	.006	.012	.01	TOTAL
	ALUMINUM	MG/L	4	82-83	.027	.05		
	COL FECL	MPN	10	71-83	3.8	17	16	
	COL TOT	MPN	18	71-83	23	109	82	

SITE	PARAMETER	UNITS	DATA PTS	YEARS	MEAN	MAX.	90TH PRCNTL	COMMENTS
123980	DATA SHOWS CONTAMINATION WITH TIDEWATER WHICH NULLIFIES STATISTICAL ANALYSIS							
123981	pH		23	73-83	7.34	7.7	7.66	MIN=7.
	RES TOT	MG/L	28	71-83	68.286	101	92	
	RESNF T	MG/L	22	71-83	3.3	10	7.7	
	SPF COND	US/MC	22	71-832	106.32	164	148	MIN=53
	TURBIDITY	NTU	27	71-83	1.9	16	4.06	
	HARDNESS	MG/L	25	71-83	39.59	58.8	57.54	DISSOLVED
	AMMONIA	MG/L	15	75-83	.1667	.117	.06	
	NITRATE T	MG/L	14	76-83	.068	.14	.125	
	NIT KJEL	MG/L	18	74-83	.123	.51	.222	
	NIT TOT	MG/L	18	74-86	.194	.655	.326	
	COD	MG/L	26	71-83	11.5	28.3	17.49	
	PHENOL	MG/L	8	78-83	.002	.003		
	PHOS ORT	MG/L	21	74-83	.005	.031	.0066	
	PHOS TOT	MG/L	29	71-83	.015	.066	.022	
	SILICA	MG/L	13	75-83	.722	8.8	8.64	
	SULPHATE	MG/L	27	71-83	6.08	10.4	5.89	
	TAN&LIG	MG/L	14	71-76	.2357	.4	.35	
	CADMIUM	MG/L	15	72-83	.00237	L.01		TOTAL
	CALCIUM	MG/L	18	72-83	12.667	18.7	18.07	DISSOLVED
	COPPER	MG/L	28	71-83	.0035	.007	.0047	TOTAL
	IRON	MG/L	28	71-83	.302	1.7	.58	TOTAL
	LEAD	MG/L	31	71-83	.01316	.025		TOTAL
	MAGNESIUM	MG/L	11	75-83	.0187	2.93	2.86	TOTAL
	MERCURY	MG/L	28	71-83	.00005	.00007	.00006	TOTAL
	NICKEL	MG/L	11	74-83	.0209	L.05		TOTAL
	ZINC	MG/L	26	71-83	.075	.03	.0154	TOTAL
	COL FECL	MPN	25	71-83	128	1600	307	
	COL TOT	MPN	23	71-83	386	G1609	1328	
127230	pH		7	73	6.7	6.9		
	NITRATE	MG/L	8	73	.21	.37	.35	DISSOLVED
	NITRITE	MG/L	8	73	.0065	.011		DISSOLVED
	PHOS TOT	MG/L	8	73	.105	.167		
	COL FECL	MPN	6	73	60	110	53	
	COL TOT	MPN	3	73	4133	5400		
126420	pH		7	73	7.6	7.8		MIN=7.4
	NITRATE	MG/L	8	73	.2225	.52		DISSOLVED
	NITRITE	MG/L	8	73	.005	.005		DISSOLVED
	PHOS TOT	MG/L	8	73	.0609	.093		
	COL FECL	MPN	6	73	108	280		
	COL TOT	MPN	3	73	230	260		

APPENDIX 3.5

AMBIENT WATER QUALITY SITES USED IN ASSESSMENT

APPENDIX 3.5

AMBIENT WATER QUALITY SITES USED IN ASSESSMENT

The sites for which there is reasonable data are listed in descending order from the top of the system:

0130180	Cowichan Lake near the weir
0120808	Cowichan River above PE-247
0120809	Cowichan River below PE-247
0120801	Cowichan River off Riverbotton Road
0120802	Cowichan River at Highway 1 (and above PE-1497)
0120800	Cowichan River near tidewater (and below PE-1497)
0123981	Koksilah River at Highway 1

APPENDIX 3.6

COWICHAN LAKE STORAGE

APPENDIX 3.6

COWICHAN LAKE STORAGE

British Columbia Forest Products Limited is authorized by C.L.'s 23085 and 29542, to store water in and to regulate the outflow of Cowichan Lake.

The licensed quantity is 49,700 acre feet (6.13×10^7 m^3) which is controlled over a live storage range of about 1 meter (full supply level is 104.68 feet and the zero storage level is 101.50 feet; elevations refer to an assumed local datum; 104.68 feet is 532.72 feet G.S.C. datum).

The control structure consists of the following items, listed in order from left bank to right bank.

1) boat lock structure - allows boat passage between the lake and the river.
2) overflow weir - allows passage of winter flood flows, at water levels above 104.68 feet.
3) an island, separating the weir from the control structure.
4) four control gates - allows control of outflow, and thus lake level.
5) fishway - allows free passage of fish between the lake and river.

Normally operation of the control structure commences around mid April and continues to mid October, at which time the gates and boat lock are left in an open position to allow free passage of water.

The following provisional operating rules have been used since 1974:

1. The control of outflow through the dam may commence when the lake level reaches 104.68 feet on the lake gauge, corresponding to elevation 532.72 feet Geological Survey of Canada datum, on its falling stage, following the winter high water season in each year.

2. After control commences the licensee shall maintain a minimum outflow from the lake of 250 cubic feet per second except when release of a lesser outflow is approved in writing by the Comptroller of Water Rights. The storage in the lake shall be regulated so that its level does not exceed the following gauge readings on the dates specified except when higher levels occur under unregulated conditions:

June 30	104.4 feet
August 5	103.5 feet
September 15	102.5 feet
October 15	101.5 feet

3. After October 15 the gates of the dam shall be fully opened until commencement of the next following operating season.

4. Regulation of storage releases must be controlled so that fluctuations in river level as indicated on Water Survey of Canada Gauge No. 8H A2 located at the highway bridge at Cowichan Lake Village are not greater than 0.25 foot during any adjustment or in excess of 0.50 foot in any 24 hour period, except when outflow from the lake is less than 750 cubic feet per second the licensee, so far as is practicable, shall control further reductions in flow so that lowering of the water level at the said gauge does not exceed 0.10 foot at any one time.

The provisional rule curve is shown attached. Also shown is the 1983 water level data as an example operating year. The lake discharges for this same period of record are also attached to demonstrate typical operations.

1983 OPERATION

DATE	WATER LEVEL (ft.)		FLOW		COMMENTS
	LAKE	RIVER	c.f.s.	m^3/s	
15 April	104.46	101.23	1880	53.2	Control commences
20 April	104.20	100.64	660	18.7	Lake level below f.s.l.
30 April	104.30	100.61	610	17.3	
10 May	104.30	100.61	610	17.3	
20 May	104.18	100.52	485	13.7	
30 May	104.27	100.32	265	7.50	
10 June	104.39	100.32	265	7.50	
20 June	104.62	100.33	275	7.79	
30 June	104.59	100.52	485	13.7	
10 July	104.15	100.55	540	15.3	10-14 lake level rising
14 July	105.14	101.18	1780	50.4	sharply maximum lake level
20 July	104.57	101.07	1520	43.0	
30 July	103.77	100.68	725	20.5	
10 August	103.39	100.30	250	7.08	
20 August	103.17	100.30	250	7.08	
30 August	102.98	100.30	250	7.08	
10 September	102.77	100.48	430	12.2	
20 September	102.40	100.54	510	14.4	
30 September	101.97	100.40	345	9.77	
10 October	101.68	100.36	305	8.64	
15 October	101.51	100.32	265	7.50	
23 October	101.86	100.46	405	11.5	Control ends.

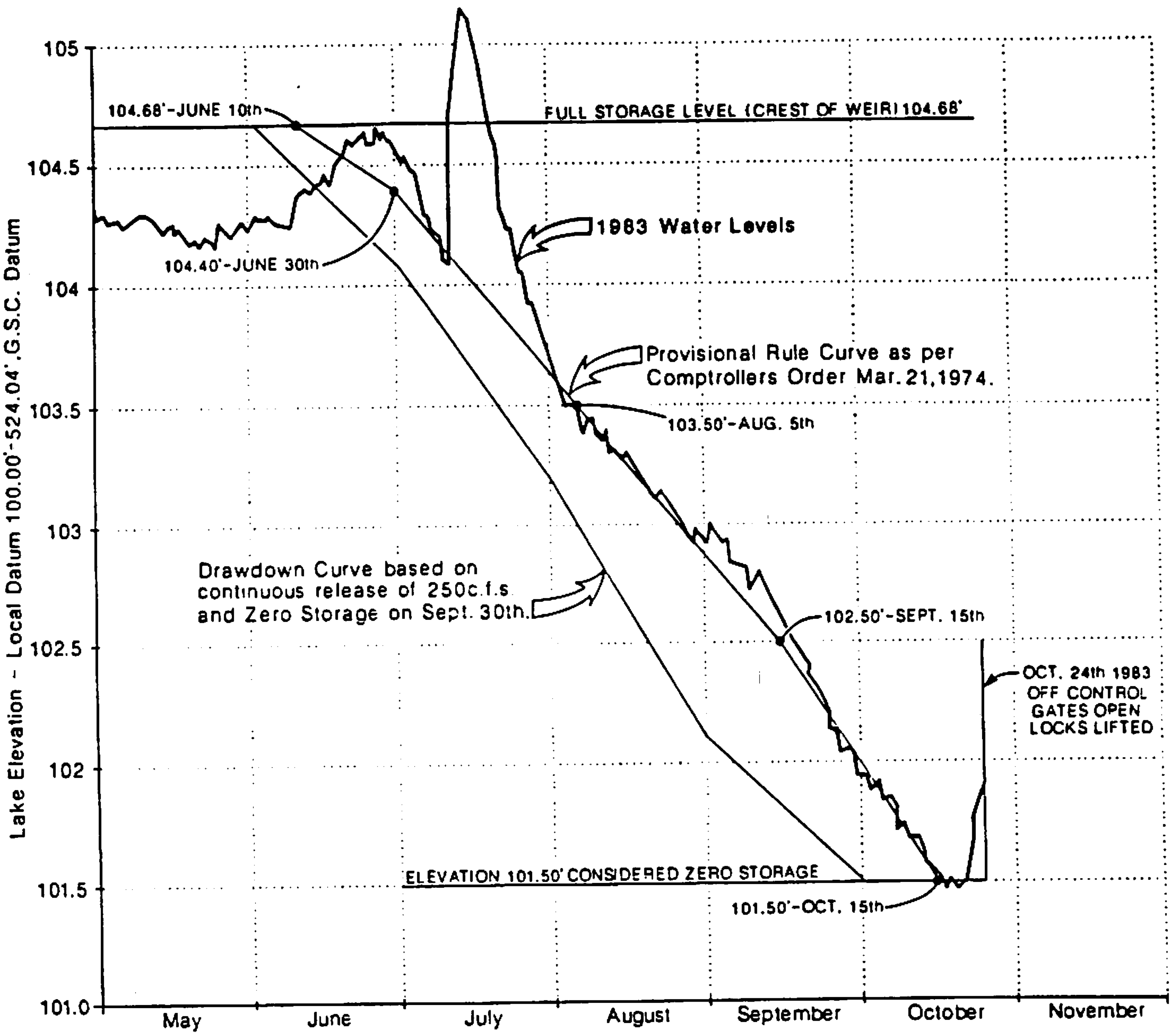

FIGURE 1 Cowichan Lake Storage Provisional Rule Curve and 1983 Water Levels.

APPENDIX 3.7

PROJECTED IRRIGATION WATER REQUIREMENTS

APPENDIX 3.7

PROJECTED IRRIGATION WATER REQUIREMENTS

Irrigation currently represents a large proportion of licensed use in the area, and as is emphasized below, relatively large areas of high agricultural capability land are not yet being irrigated. It is therefore important to estimate how much additional water may be required for irrigation, both in the near-term and distant future, so that regional Ministry staff are able to plan water management to meet this requirement.

Future irrigation requirements were estimated in three ways, two of them being more useful for long-term rather than short-term planning. First, the Computer Assisted Planning and Assessment Mapping Program (CAPAMP) developed by Surveys and Resource Mapping Branch was used to estimate the maximum biophysical water requirement. This analysis assumed total agricultural utilization of all suitable soils currently within the Agricultural Land Reserve (ALR, see Figure 3.5), of Agricultural Capability classes 1-5 inclusive. Potential constraints imposed by costs, market availability, proximity to water, technology of water delivery, etc. were not considered in this analysis. This level of maximum theoretical water requirement was then compared to present licensed irrigation quantities to yield an indication of the amount which might eventually be required, assuming factors such as the amount of ALR area remain constant into the future.

The second method also utilized the CAPAMP system, but rather than yielding estimates of the volume of water which might eventually be required, it concentrated on Present Land Use (1981) of potential agricultural areas, and indicated where areas not yet developed for agriculture remain. By implication, these will also be the locations of future irrigation needs.

The third method of estimating irrigation requirements concentrated on the near-term, and relied on estimates of increased irrigation water use by P. Fofonoff, District Agriculturist (Duncan), of the Ministry of Agriculture and Food. These estimates were made for both the amount of increased water use expected, and the sub-basin where the use is expected to occur. These estimates were based mainly on the assumption that most increases will occur on dairy farms where a reasonable level of irrigation is already occurring, and represent the intuition of the MAF official for the area. These estimates also made use of results from the CAPAMP analysis of Present Land Use in the various agricultural capability classes and sub-basins (see Appendix PLU).

1. CAPAMP IRRIGATION ANALYSIS

Methods

This approach was based on all 1:20,000 soils mapping available in the plan area. Since this mapping is concentrated in the Lower Cowichan and Koksilah valleys and the Somenos drainage, the tables summarizing this information below include only those 15 sub-basins (of the total of 25) in which both soils mapping and ALR occur.

Under this analysis, irrigation requirement (IR) refers to the amount of water needed for the optimal production of a given crop. It is a function of soil (available water storage capacity, drainage, irrigability, etc.), crop (depth of root zone, crop cover or consumptive use factor, etc.), and climatic conditions (precipitation, evapotranspiration, etc.).

Irrigation water requirements for soil polygons were based upon 1:20,000 soil and agricultural capability maps, long-term climate information, and the results from a three-year soil moisture and evapotranspiration program. The methodology used is similar to that of Coligado et al. (1968) and Wallis et al. (1985). The IR was computed for 15 water storage capacities (10 mm, 20 mm, 30 mm, 40 mm, 50 mm, 60 mm, 70 mm, 80 mm, 90 mm, 100 mm, 110 mm, 120 mm, 130 mm, 140 mm, and 150 mm) and three risk levels (10%, 20% and 50%). A risk level of 20%, for instance, means that in 20 out of 100 years the irrigation requirement associated with a polygon (as shown on the irrigation maps) will be exceeded. Since a soil polygon is comprised of up to three soils, the average water storage capacity for the polygon was considered equal to $(a_1S_1 + a_2S_2 + a_3S_3)/(a_1 + a_2 + a_3)$, where a is area of the soil, S is the available water storage capacity, and subscripts 1, 2 and 3 refer to the number of soils. Only the irrigable soils were considered in these calculations. The irrigability or the agricultural capability of a soil polygon was determined from the agricultural capability maps.

Several assumptions were made in the calculations of irrigation water requirement for a crop. These were:

i) The growing period from April 30 to September 30 was considered critical for irrigation purposes.
ii) Soils were assumed to be at field capacity at the beginning of the growing season. Also, lateral run on and run off from soils were considered negligible.
iii) Soils with agricultural capability CLI class 5 or better, and slope gentler than 30%, were considered irrigable.
iv) Various pasture and hay species including alfalfa constitute major crops in the plan area. An average root zone depth of 1 m and consumptive use factor of 1.0 were assumed.
v) The availability coefficient was considered to be 0.5. This means that irrigation must be applied when 50% of the available water storage capacity is exhausted.
vi) For a soil polygon with water storage capacity other than those used for IR calculations, the irrigation requirement was interpolated or extrapolated. A linear relationship between IR and two adjacent storage capacities was assumed.
vii) In poorly drained soils with water table level 1.7 m deep or less during the growing season, the computed irrigation requirement was adjusted to account for capillary rise. A rise of 0.30 m in water table reduced IR by 45 mm.

A map series covering all or portions of seven 1:20,000 irrigation maps at the 10%, 20% and 50% risk levels was produced, including all of the plan area where detailed soils data exist. The irrigable soil polygons are shown on the resultant maps, each identified by a polygon number and irrigation water requirement in hectare-meters.

It should be noted that the irrigation maps and tables yield only the irrigation requirement of the crops grown in the area and do not consider losses associated with water application techniques. To obtain the amount of water that must be applied to the crop, the irrigation water requirement as calculated above must be increased by dividing by a water application efficiency factor. In the case of sprinkler irrigation, an application efficiency factor of 0.72 was deemed appropriate. In addition, 20% further must be added to the irrigation requirement thus calculated, to maintain the plant root zone free of salt buildup (termed the salt leaching factor).

The maximum potential irrigation requirement for each sub-basin was determined by summing requirements for all polygons (or pro-rated portions of them) on the various map sheets, providing the polygons (or portions) were located within the ALR.

Results

Table 1 summarizes maximum potential irrigation requirements at three risk levels for each sub-basin, given the assumption that all class 1-5 soils in the ALR are irrigated. Present Licensed and Estimated Present Actual Irrigation are also summarized in the table, and in all sub-basins these are considerably below the 20% risk maximum water requirement, the risk frequency which is used for water management.

TABLE 1
LICENSED, ESTIMATED ACTUAL AND MAXIMUM POTENTIAL IRRIGATION (ha.m)
ON AGRICULTURAL LAND RESERVE AREAS

Sub-basin	Present Licensed Irrigation	Estimated Present Actual Irrigation	Maximum Potential[1] Irrigation Requirement			Present Licensed as % of Potential (20% Risk)
			10% Risk	20% Risk	50% Risk	
1) Cowichan R. drainage						
Inwood Creek	8.0	8.0	183.5	173.4	152.2	4.6
Cowichan R. at Hwy 1	8.9	8.9	259.3	244.3	213.6	3.6
Cowichan R. at Duncan-N. Cowichan STP	0	0	78.7	73.8	63.0	0
Cowichan R. near the mouth	0	0	48.3	44.4	36.0	0
Cowichan R. delta	0	0	294.3	276.4	231.9	0
Sub-total	16.9	16.9	864.1	812.3	696.7	2.1
2) Somenos Ck. drainage						
Bings Creek	9.7	9.7	162.4	157.1	145.8	6.2
Averill Creek	14.2	14.2	285.4	269.1	233.7	5.3
Richards Ck. at Richards Trail	0	0	54.7	51.3	45.4	0
Richards Ck. at Somenos L.	25.7	20.0	251.1	240.1	210.6	10.7
Quamichan Ck. at Quamichan L.	46.8	46.8	247.3	232.2	205.4	20.2
Somenos Ck.	30.6	10.9	115.6	107.4	91.8	28.5
Sub-total	127.0	101.6	1116.5	1057.2	932.7	12.0
3) Koksilah R. drainage						
Patrolas Ck. at Hillbank Rd.	56.6	53.5	202.5	189.9	159.9	29.8
Koksilah R. at Cowichan Station	38.2	38.2	326.7	308.1	274.2	12.4
Glenora Creek	18.7	18.7	239.8	225.3	199.7	8.3
Kelvin Creek	6.5	6.5	165.2	155.8	135.7	4.2
Koksilah R. near the mouth	55.4	49.8	428.4	404.0	350.7	13.7
Sub-total	175.4	166.7	1362.6	1283.1	1120.2	13.7
Grand Total	319.3	285.2	3343.2	3152.6	2749.6	10.1

[1] Risk indicated is the proportion of years this water requirement will be exceeded.

When the three major drainages are examined separately, it is evident that there is very little licensed irrigation use in the Cowichan drainage, particularly on the lower mainstem. Further, the proportion of the maximum potential requirement which is now licensed is very small, averaging only 2% throughout the Cowichan drainage. In total, there is a large amount of potential irrigable land in the drainage which is yet to be licensed for irrigation.

In the Somenos Creek drainage, a much larger volume of water is currently licensed for irrigation, 80% of which is now estimated to be in use for irrigation. With the exception of the Somenos Creek and Quamichan Creek sub-basins, however, less than 20% of the maximum potential irrigation requirement is now licensed, the drainage in total averaging only 12% of maximum. The largest potential irrigation expansion appears to exist in the Averill Creek and lower Richards Creek sub-basins.

Of the three major drainages, the Koksilah area is the site of the largest amount of water licensed for irrigation to date, 95% of the licensed total having been developed. Patrolas Creek sub-basin, with nearly 30% of the maximum potential now licensed, has reached the highest level of irrigation development in the entire plan area, but potentially requires three times the present licensed amount. Although nearly 14% of the maximum potential water requirement in the Koksilah drainage is now licensed, a great deal of licensed irrigation potential remains to be developed.

In summary, the CAPAMP analysis of maximum potential irrigation requirement, based solely upon the amount of agricultural capability class 1-5 soils in the ALR, indicates extensive demand for licensed irrigation water can be expected throughout the plan area in the future. This conclusion is supported by Table 1 which shows only 10% of the maximum requirement at the 20% risk level is currently licensed.

2. CAPAMP PRESENT LAND USE ANALYSIS

Methods

Another approach to estimating where increased licensed irrigation may occur is to examine current utilization of land having high agricultural capability. A series of 1981 aerial photographs was used to assign present land use classes to the basic soil polygons for which potential irrigation requirements were calculated above. The classes of land use assigned were Cultivated (obvious signs of cropping), Pasture (grazing; unused for farming for approximately 5 years), Rural (primarily small semi-forested holdings) and Forested. Each polygon was assigned either a use class which occurred throughout the whole polygon (i.e., 100% that class of use), or a dominant (70%) or sub-dominant (30%) use. The proportion in the latter categories was assumed to be 70:30, although this ratio may have varied between approximately 60:40 and 80:20 in any given polygon. The information was entered into the CAPAMP system, and maps and tables produced which indicated categories of use, and their proportions. This information was further analyzed by the computer to produce a total area of use by category for each sub-basin. Since soils mapping, as explained under the Irrigation Analysis section, did not cover the entire plan area, totals were obtained for the same 15 sub-basins as above. However, the tabular information could be generated by area within Agricultural Capability classes, permitting an assessment of 1981 agricultural activity in each Agricultural Capability class, in each sub-basin.

Results

Results summarized by present land use and agricultural capability classes are presented at the end of this Appendix as Table 4. In every sub-basin, either Cultivated or Forested was the dominant land use, with the other of those two classes being the next most prevalent. Only in Averill Creek and Somenos Creek sub-basins was Rural an important class in terms of area of use, with Pasture the least prevalent in all but three sub-basins.

In order to better assess usage of high agricultural capability areas, totals in classes 1-3 inclusive were tabulated for both total area and area (and percentage) currently being used for agricultural purposes (Table 2). The latter category was termed Improved, and included Cultivated, Pasture and Rural classes. A comparison of Improved area to total class 1-3 area indicated which sub-basins were currently being the most exploited for agriculture. The assumption is that areas of high agricultural capability that are not now heavily used for agriculture may form the centers of future agricultural activity. Conversely, those areas now highly developed for agriculture have only limited expansion potential remaining. Since the Present Land Use analysis of Improved land does not include agricultural capability classes 4 and 5, which were included in the CAPAMP Irrigation analysis, this approach may yield a useful indication of the locations of present and most likely future agricultural activity, and therefore indicate where irrigation water will be required.

The Cowichan drainage (Table 2) as a whole has a lower proportion of improved class 1-3 land than the other two drainages, with little more than half of the land classed as improved. However, the average for the Cowichan drainage is greatly influenced by the largest sub-basin (upstream of Highway 1), which exhibits a very low proportion of improved land. Since this sub-basin includes the mainstem beyond Holt Creek, and the Holt Creek drainage, this result is not surprising. Particularly in the lower Cowichan drainage, two-thirds or more of the high capability land is now improved, suggesting that large increases in licensed irrigation will not be required in the future.

In the Somenos Creek drainage, upper Richards Creek and Bings Creek appear to be the areas where the greatest proportional increases in agriculture, and therefore irrigation water, can be expected in the future. However, in terms of total area, these are among the smallest sub-basins in the Somenos drainage. In the three largest sub-basins (Averill, lower Richards and Quamichan Creeks), approximately 80% or more of the high capability land is already improved, and major increases in water demand for these areas are not likely. The same appears to be true of Somenos Creek.

TABLE 2
PRESENT LAND USE OF HIGHLY-RATED AGRICULTURAL CAPABILITY PORTIONS OF AGRICULTURAL LAND RESERVE

Sub-basin	Total ALR Area (ha)	ALR Area (ha) in Agricultural Capability Classes 1-3	Amount of Improved* ALR Area in Agricultural Capability Classes 1-3 ha	%
1) Cowichan R. drainage				
Inwood Creek	406.8	292.6	150.2	51.3
Cowichan R. at Hwy 1	587.8	386.8	29.8	7.7
Cowichan R. at Duncan-N. Cowichan STP	191.0	179.5	118.8	66.2
Cowichan R. near the mouth	142.3	141.4	103.1	72.9
Cowichan R. delta	767.1	626.6	482.5	77.0
Sub-total	2095.0	1626.9	884.4	54.4
2) Somenos Ck. drainage				
Bings Creek	372.6	305.0	159.2	52.2
Averill Creek	725.9	596.3	502.3	84.2
Richards Ck. at Richards Trail	138.4	89.7	53.6	59.8
Richards Ck. at Somenos L.	593.3	297.4	236.3	79.5
Quamichan Ck. at Quamichan L.	585.8	464.8	389.6	83.8
Somenos Ck.	284.4	263.2	206.5	78.5
Sub-total	2700.4	2016.4	1547.5	76.7
3) Koksilah R. drainage				
Patrolas Ck. at Hillbank Rd.	476.6	403.8	338.8	83.9
Koksilah R. at Cowichan Station	716.5	517.6	377.2	72.9
Glenora Creek	549.9	262.6	191.3	72.8
Kelvin Creek	399.2	226.8	96.2	42.4
Koksilah R. near the mouth	1005.0	852.1	647.8	76.0
Sub-total	3147.2	2262.9	1651.3	73.0
Grand Total	7942.6	5906.2	4083.2	69.1

* Improved includes Cultivated, Pasture and Rural classes.

In the Koksilah drainage, the highest proportion of improved land is in the Patrolas Creek sub-basin, with all other sub-basins except Kelvin Creek (the smallest) now 70% or more improved. In total, the Koksilah drainage has the largest amount of ALR area, class 1-3 area, and improved area, with the Somenos drainage somewhat smaller in all categories, and the Cowichan drainage the smallest. In terms of class 1-3 area yet to be improved, however, the Cowichan drainage has the most available (743 ha), the Koksilah is next (612 ha), and the Somenos drainage has the least (468 ha). It can be concluded that long-term increased irrigation requirements follow the same order. However, as indicated below, forecasts for near-term irrigation increases may not follow conclusions based on present land use, when availability of capital and other factors are included.

3. MINISTRY OF AGRICULTURE AND FOOD PROJECTIONS

Methods and Results

In order to obtain a projection of increased irrigation requirements during the next 5 years, the District Agriculturist in Duncan was asked to estimate amount of area and approximate locations of expected increased activity. Based upon trends from Census Canada - Agricultural Data, and knowledge of agricultural development activity in this area, an estimated 1000 additional acres (405 hectares) could possibly be developed under irrigation during the next 5 years.[1] Under the assumption that nearly all increases in irrigation will be associated with existing dairy farms, and using the present land use analysis as a further guide, the following areas in each sub-basin were estimated to be those most likely to experience increased irrigation during the next 5 years (Table 3).

4. SUMMARY

For long-range water management planning, it is evident from the CAPAMP Irrigation analysis that greatly increased quantities of water will be

[1] Memo: P. Fofonoff (Ministry of Agriculture and Food, Duncan) to B. Turner. January 11, 1985.

TABLE 3

IRRIGATION INCREASES EXPECTED 1985-1989

SUB-BASIN	INCREASES EXPECTED Area[1] ha	Area[1] acres	Water[2] ha.m	Water[2] ac.ft.	CURRENT WATER LICENSED ha.m	CURRENT WATER LICENSED ac.ft.	PERCENTAGE WATER INCREASE
Averill Creek	81	200	24.7	200	14.2	115.1	174
Richards Creek (lower)	121.5	300	37.0	300	25.7	208.0	144
Quamichan Creek	40.5	100	12.3	100	46.8	379.3	26
Cowichan River delta	40.5	100	12.3	100	0	0	-
Koksilah River near the mouth	40.5	100	12.3	100	55.4	449.3	22
Remainder of plan area	81	200	24.7	200	185.7	1505.8	13
TOTALS	405	1000	123.3	1000	327.8	2657.5	38

[1] Source: P. Fofonoff, Ministry of Agriculture and Food, Duncan.

[2] Assumes average water requirement of 1 acre-foot/acre.

required if all agricultural capability class 1-5 land in the ALR is developed for agriculture. The CAPAMP Present Land Use analysis, concentrating on class 1-3 soils only, suggests that approximately 70% of the higher capability land is already improved, mainly for cultivation. From the long-range perspective, however, it appears that significant increases in irrigation water will be required in future. For the immediate future (1985-93), the Ministry of Agriculture and Food estimate of an approximate increase of 400 ha in irrigation area represents less than a 7% increase in the amount of improved area existing in the plan area in 1981. However, in specific sub-basins these increases are large, and several of the areas where irrigation is expected are areas where no further surface water remains to be allocated.

TABLE 4
PRESENT LAND USE (HECTARES)[1] IN AGRICULTURAL CAPABILITY CLASSES

AVERILL CREEK

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	20.1	271.3	109.0	12.0	25.9	438.3
Forested	1.1	57.5	35.4	8.7	68.9	171.6
Pasture	0	1.2	0.9	2.0	2.9	7.0
Rural	0	87.0	12.8	5.3	3.9	109.0
Total	21.2	417.0	158.1	28.0	101.6	725.9[3]

BINGS CREEK

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7[4]	Total
Cultivated	7.4	102.4	37.2	4.8	1.9	153.7
Forested	0	100.6	45.2	42.8	17.5	206.1
Pasture	0	0	0.9	0	0	0.9
Rural	0	7.5	3.8	0	0.5	11.8
Total	7.4	210.5	87.1	47.6	19.9	372.5[3]

[1] 1 hectare = 2.47 acres
[2] From 1981 air photos
[3] Total ALR in the sub-basin
[4] No class 6 or 7 in this sub-basin

COWICHAN RIVER AT HIGHWAY 1

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5[4]	Total
Cultivated	0	23.5	2.4	60.8	20.7	107.4
Forested	5.4	247.6	104.0	17.3	86.3	460.6
Pasture	0	0	0	0	0.5	0.5
Rural	0	3.9	0	15.3	0	19.2
Total	5.4	275.0	106.4	93.4	107.5	587.7[3]

COWICHAN RIVER NEAR THE MOUTH

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5[4]	Total
Cultivated	31.5	44.4	13.1	0	0	89.0
Forested	8.5	5.9	23.9	0	0.8	39.1
Pasture	0	0	0	0	0	0
Rural	0	14.1	0	0	0	14.1
Total	40.0	64.4	37.0	0	0.8	142.2[3]

[1] 1 hectare = 2.47 acres

[2] From 1981 air photos

[3] Total ALR in the sub-basin

[4] No class 6 or 7 in this sub-basin

COWICHAN RIVER DELTA

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	109.6	207.1	126.2	0	27.7	470.6
Forested	1.9	84.8	57.4	17.7	58.1	219.9
Pasture	0	0	16.5	0	0	16.5
Rural	12.4	5.3	5.4	3.4	33.6	60.1
Total	123.9	297.2	205.5	21.1	119.4	767.1[3]

COWICHAN RIVER AT DUNCAN - NORTH COWICHAN SEWAGE TREATMENT PLANT

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5[4]	Total
Cultivated	66.7	25.9	24.5	0	1.7	118.8
Forested	1.8	47.4	11.5	2.2	7.4	70.3
Pasture	0.8	0	0.5	0	0	1.3
Rural	0.2	0.2	0	0	0.1	0.5
Total	69.5	73.5	36.5	2.2	9.2	190.9[3]

[1] 1 hectare = 2.47 acres

[2] From 1981 air photos

[3] Total ALR in the sub-basin

[4] No class 6 or 7 in this sub-basin

GLENORA CREEK

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	24.6	76.2	68.4	38.4	23.9	231.5
Forested	0	21.5	49.8	103.9	96.1	271.3
Pasture	0	1.2	3.3	5.0	7.0	16.5
Rural	0	15.4	2.2	7.7	5.0	30.3
Total	24.6	114.3	123.7	155.0	132.0	549.6[3]

INWOOD CREEK

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5[4]	Total
Cultivated	5.2	88.6	52.9	31.0	14.9	192.6
Forested	5.2	102.8	34.4	26.6	35.6	204.6
Pasture	0	0.3	0	0.5	0.7	1.5
Rural	0	1.4	1.8	0	4.8	8.0
Total	10.4	193.1	89.1	58.1	56.0	406.7[3]

[1] 1 hectare = 2.47 acres
[2] From 1981 air photos
[3] Total ALR in the sub-basin
[4] No class 6 or 7 in this sub-basin

KELVIN CREEK

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	1.5	61.7	33.0	8.6	7.7	112.5
Forested	0.6	64.8	65.2	41.3	114.8	286.7
Pasture	0	0	0	0	0	0
Rural	0	0	0	0	0	0
Total	2.1	126.5	98.2	49.9	122.5	399.2[3]

KOKSILAH RIVER AT COWICHAN STATION

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	14.4	231.1	113.8	11.6	44.4	415.3
Forested	0.4	87.8	52.2	32.0	94.5	266.9
Pasture	0	0	1.3	0	0	1.3
Rural	0.1	16.0	0.5	0	16.3	32.9
Total	14.9	334.9	167.8	43.6	155.2	716.4[3]

[1] 1 hectare = 2.47 acres
[2] From 1981 air photos
[3] Total ALR in the sub-basin

KOKSILAH RIVER AT THE MOUTH

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	131.7	374.5	87.5	0	40.8	634.5
Forested	11.0	137.2	56.1	23.7	84.2	312.2
Pasture	0	2.1	2.1	0	0	4.2
Rural	22.6	10.2	17.1	2.2	1.9	54.0
Total	165.3	524.0	162.8	25.9	126.9	1004.9[3]

PATROLAS CREEK AT HILLBANK ROAD

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	36.4	88.0	199.3	15.9	7.9	347.5
Forested	3.0	37.7	24.3	34.8	28.1	127.9
Pasture	0	7.9	0	1.5	3.5	12.9
Rural	0	7.2	0	0	7.2	14.4
Total	39.4	140.8	223.6	52.2	46.7	502.7[3]

[1] 1 hectare = 2.47 acres

[2] From 1981 air photos

[3] Total ALR in the sub-basin

QUAMICHAN CREEK AT QUAMICHAN LAKE OUTLET

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	1.4	280.4	60.2	17.4	20.7	380.1
Forested	0	44.6	30.6	5.7	64.9	145.8
Pasture	0	0	0.3	0	5.7	6.0
Rural	0	32.5	14.8	2.7	3.8	53.8
Total	1.5	357.5	105.9	25.8	95.1	585.7[3]

RICHARDS CREEK AT RICHARDS TRAIL

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	2.0	34.0	17.6	0.5	3.8	57.9
Forested	0	13.2	22.9	10.4	28.3	74.8
Pasture	0	0	0	0	3.0	3.0
Rural	0	0	0	1.9	0.8	2.7
Total	2.0	47.2	40.5	12.8	35.9	138.4[3]

[1] 1 hectare = 2.47 acres

[2] From 1981 air photos

[3] Total ALR in the sub-basin

RICHARDS CREEK AT SOMENOS LAKE

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5-7	Total
Cultivated	0	119.6	113.3	43.6	34.6	311.1
Forested	0	13.3	47.8	64.0	123.7	248.8
Pasture	0	0	0.9	13.3	8.5	22.7
Rural	0	1.5	1.0	1.1	7.1	10.7
Total	0	134.4	163.0	122.0	173.9	593.3[3]

SOMENOS CREEK AT THE MOUTH

Present Land Use[2]	Agricultural Capability Class 1	2	3	4	5[4]	Total
Cultivated	0	70.6	68.3	0.7	0	139.6
Forested	0	26.4	30.3	3.6	8.2	68.5
Pasture	0	0	6.7	0	3.5	10.2
Rural	0	39.6	21.3	3.3	1.9	66.1
Total	0	136.6	126.6	7.6	13.6	284.4[3]

[1] 1 hectare = 2.47 acres
[2] From 1981 air photos
[3] Total ALR in the sub-basin
[4] No class 6 or 7 in this sub-basin

APPENDIX 3.8

WATERWORKS LICENSED QUANTITIES AND USE

APPENDIX 3.8

WATERWORKS LICENSED QUANTITIES AND USE
1. VILLAGE OF LAKE COWICHAN
COMMUNITY WATER SUPPLY

Year	Reported Water Use							Licensed Water Quantities			
	Number of Residents	Number of Connections	Annual Water Use[1]	Average Daily Water Use[2]	Maximum Daily Water Use[2]	Ratio Max/Avg	Daily Per Capita Use[2]	Annual Allowable[1]	Maximum Daily Allowable[2]	Licence Number	Source of Supply
1955								(54,750,000)[3]	300,000	CL58227	Cowichan Lk.
1964								(54,750,000)[3]	300,000	CL58228	Cowichan Lk.
1979								87,600,000 / (197,100,000)[3]	400,000 / 1,000,000	CL58342	Cowichan Lk.
1976	3000	752	136,013,000	372,638	697,000	1.9	124				
1977	2850	765	140,468,000	384,843	822,000	2.1	135				
1978	2900	773	191,327,000	524,184	989,000	1.9	181				
1979	2925	779	208,350,000	570,822	1,000,000	1.8	195				
1980	2369	911	174,035,000	476,808	988,000	2.1	201				
1981	2600	895	144,934,615	397,081	3,205,000?	8.1?	153				
1982	2508	965	185,054,810	507,999	-		202				
1983	2508	965	161,941,750	443,676	-		177				

[1] Imperial gallons

[2] Imperial gallons per day

[3] Estimated annual allowable using maximum/average = 2.0

2. CITY OF DUNCAN
COMMUNITY WATER SUPPLY

	Reported Water Use							Licensed Water Quantities			
Year	Number of Residents	Number of Connections	Annual Water Use[1]	Average Daily Water Use[2]	Maximum Daily Water Use[2]	Ratio Max/Avg	Daily Per Capita Use[2]	Annual Allowable[1]	Maximum Daily Allowable[2]	Licence Number	Source of Supply
1923									270,000	FL9364	Cowichan R.
1955									1,980,000	CL22757	Cowichan R.
1962									1,000,000	CL28077	Cowichan R.
1967									75,000	CL33092	Cowichan R.
								(606,813,000)[3]	3,325,000		
1976	6900	3070	12,145,843?	33,276?			-				
1977	7000	3100	22,112,000?	60,581?	4,672,000	77.1?	-				
1978	7000	3500	2,938,000?	8,049?			-				
1979	7100	3550	9,671,000?	26,496?	1,899,000		-				
1980	7100	4087	653,920,000	1,791,562	454,000?	0.3?	252				
1981	9000	3087	541,608,837	1,483,860	4,816,100	3.2	165				
1982	9000	2991	594,100,700	1,627,673			181				
1983	9000	3120	563,383,900	1,543,518	3,760,900	2.4	172				

[1] Imperial gallons

[2] Imperial gallons per day

[3] Estimated annual allowable using maximum/average = 2.0

APPENDIX 3.9

NUMBER OF WELLS DRILLED ANNUALLY
WITHIN THE COWICHAN-KOKSILAH PLAN AREA

APPENDIX 3.9

NUMBER OF WELLS DRILLED ANNUALLY WITHIN THE COWICHAN-KOKSILAH PLAN AREA

YEAR WELL DRILLED	LAND DISTRICT									TOTAL	CUMULATIVE TOTAL
	HELMCKEN	SHAWNIGAN	COWICHAN	QUAMICHAN	SAHTLAM	COMIAKEN	SOMENOS	SEYMOUR	COWICHAN LAKE		
1984	-	7	7	10	4	2	4	-	4	38	1513
83	3	9	18	20	7	2	-	-	13	72	1475
82	1	6	17	8	8	8	-	-	13	61	1403
81	3	10	16	28	15	9	5	-	5	91	1342
1980	1	11	12	14	2	3	8	-	-	51	1251
79	1	10	18	37	22	5	7	-	2	102	1200
78	1	6	10	26	6	6	6	2	5	68	1098
77	-	8	4	36	4	-	6	-	7	65	1030
76	1	11	8	37	8	4	14	-	8	91	965
75	2	1	8	24	8	7	3	-	8	61	874
74	-	5	8	29	5	-	5	-	-	52	813
73	1	5	3	17	7	1	4	-	2	40	761
72	-	3	8	30	6	2	4	-	4	57	721
71	1	4	9	21	4	1	6	-	6	52	664
1970	-	-	4	9	2	2	3	-	2	22	612
69	1	1	4	25	2	2	3	-	9	47	590
68	-	2	3	12	1	1	2	-	7	28	543
67	-	1	1	6	-	-	4	-	1	13	515
66	-	-	4	13	-	1	9	-	-	27	502
65	-	3	4	7	2	2	12	-	1	31	475
64	-	-	2	5	1	3	5	-	-	16	444
63	-	-	3	7	1	-	3	-	-	14	428
62	-	-	1	6	-	-	3	-	1	11	414
61	-	-	1	9	-	1	6	-	-	17	403
1960	-	-	1	-	1	2	5	-	-	9	386
Pre-1960	-	17	34	55	40	54	149	1	27	377	

APPENDIX 4.1

SUMMARY OF WATER-SHORT STREAMS

APPENDIX 4.1
SUMMARY OF WATER-SHORT STREAMS IN THE COWICHAN-KOKSILAH PLAN AREA[1]

STREAM	TRIBUTARY TO	STATUS
Averill Ck.	Somenos L.	Fully recorded except domestic (1951)
Bings Ck.	Somenos L.	Fully recorded except small domestic unless fully supported by storage
Claeys Ck.	Inwood Ck.	Possible water shortage (1969)
Daly Ck.	Cowichan Lk.	Fully recorded (1950)
Denham Br.	Cowichan Lk.	Possible water shortage (1980)
Glenora Ck.	Kelvin Ck.	Fully recorded except small domestic unless storage provided (1984)
Greendale Br.	Cowichan R.	Fully recorded (1980)
Heather Bank Br.	Koksilah R.	Fully recorded for all purposes except small domestic unless fully supported by storage (1984)
Koksilah R.	Cowichan Bay	Koksilah R. and tributaries fully recorded except domestic (1980)
Menzies Ck.	Bings Ck.	Water for small domestic use (1972)
Norie Ck.	Koksilah R.	Norie Ck. and tributaries fully recorded for all purposes unless supported by storage (1980)
Pepper Br.	Cowichan L.	Fully recorded for all purposes (1982)
Railway Br.	Cowichan L.	Possible water shortage (1973)
Raphael Ck.	Averill Ck.	Fully recorded except domestic (1951)
Richards Ck.	Somenos Lk.	Fully recorded except domestic or storage provided (1980)
Shaw Ck.	Cowichan Lk.	Possible water shortage (1971)
Stanley Ck.	Cowichan R.	Fully recorded except domestic (1979)
Stephen Ditch	Patrolas Ck.	Fully recorded (1975)
Swan Ck.	Cowichan R.	Possible water shortage (1979)
Tzouhalem Ck.	-	Fully recorded (1978)
Williars Spr.	Koksilah R.	Fully recorded (1978)
Weeks Ck.	Koksilah R.	Fully recorded except domestic (1977)

[1] Extracted from Stream Register, April 19, 1985.

APPENDIX 5.1

POTENTIAL WATER STORAGE SITES

APPENDIX 5.1
POTENTIAL STORAGE SITES
(extracted from compilation by Anne Lee, for Water Management, Nanaimo, 1985).

NAME OF STREAM	CATCHMENT AREA	VOLUME OF STORAGE	EXISTING STORAGE	PURPOSE OF POTENTIAL STORAGE	SOURCE OF INFORMATION
Bings Creek	0.49 mi^2 (reservoir basin)	870 AF (132 m high dam)	0	irrigation	Hydrologic study of proposed reservoir by W. Obedkoff, Surface Water Section, July 28, 1978. Heyland, S. D. 1979. Corporation of District of North Cowichan Irrigation Study. MOE, Victoria.
Cowichan River - Marie Canyon	--	217 x $10^6 m^3$	0	hydroelectric power (10-20 MW)	B.C. Hydro and Power Authority. 1985. Small Hydro Studies (I. McIntosh).
Holt Creek	--	--	0	hydroelectric power	White, A. V. 1919. Water Power of British Columbia. Commission of Conservation, Ottawa.
Koksilah River - headwaters area	--	--	0	fisheries/waterfowl	Tutty, B. D. 1984. The Koksilah River. Low Streamflows and Salmon Production. Unpublished. Department of Fisheries and Oceans. Ducks Unlimited, pers. comm.
Koksilah River - Grant Lake	--	(300 ft. high dam to store 50 ft. water)	0	irrigation?	Kidd, G. J. A. 1953. Preliminary Survey of Irrigation and Domestic Water Supply Possibilities for the Duncan Area. Water Rights Branch, Victoria.
Cowichan River - Cowichan Lake	--	--	49,500 AF	Water supply for Municipality of North Cowichan (South End)	Mould, S. B. 1976. Municipality of North Cowichan Water Supply Study. MOE.
- Cowichan Lake	Surface area = 24 mi^2	Each 1 ft. of storage = 15,360 AF	--	Water supply for Cowichan-Duncan area; irrigation use by Cowichan Agricultural Society	Kidd, G. J. A. 1953.
- Cowichan Lake	--	--	--	Hydroelectric power for city of Duncan	White, A. V. 1919.
- Cowichan Lake - Nitinat River	--	3 ft. presently authorized, 5.5 ft. storage available.	--	Protect floodplains in Duncan and around Cowichan Lake from floodwaters, using storage and partial diversion to Nitinat River.	Wester, J. 1967. Report on Cowichan-Koksilah River Preliminary Flood Control Proposals. MOE.

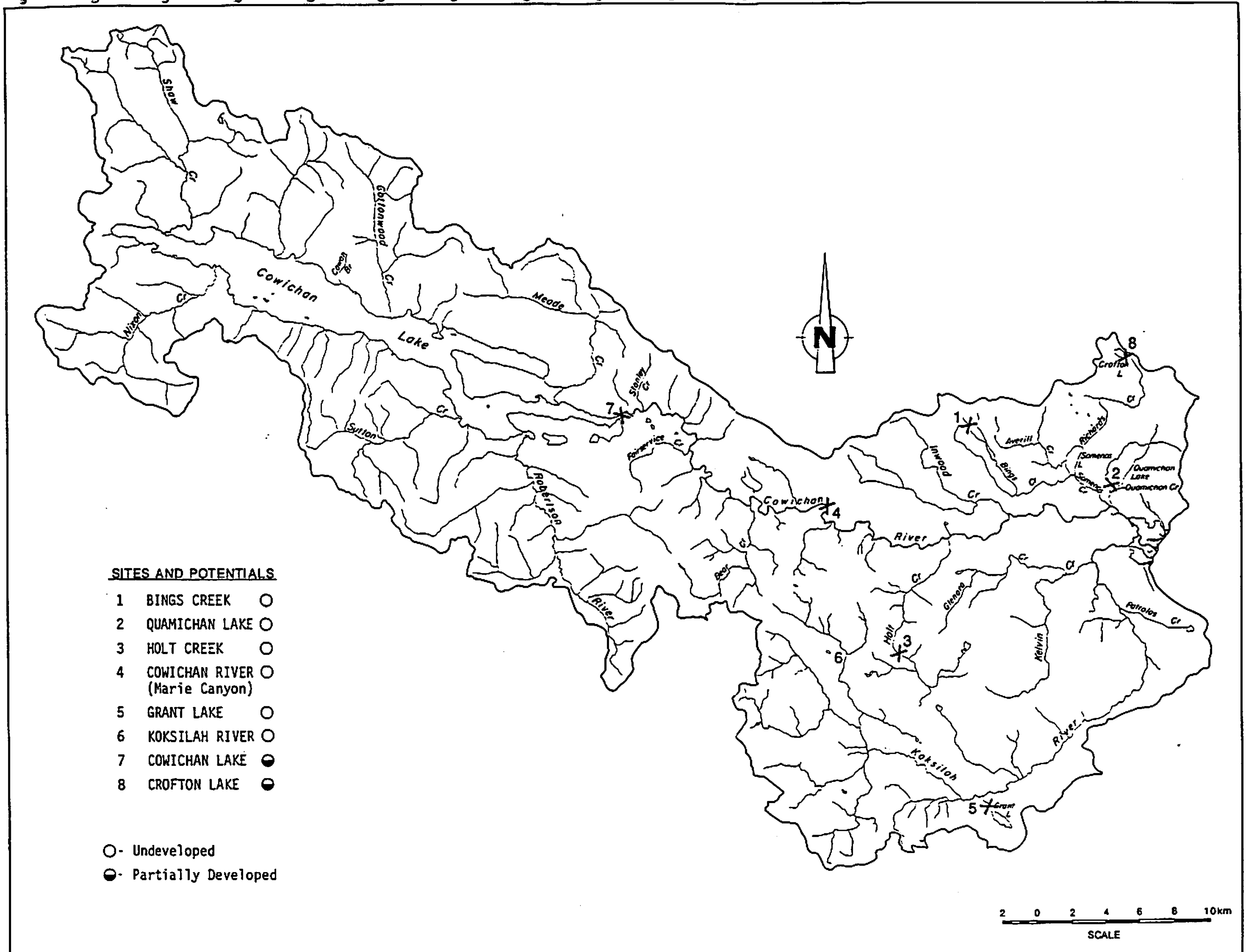

FIGURE 1 Potential and Existing Water Storage Sites.

MINISTRY OF ENVIRONMENT AND PARKS

COWICHAN-KOKSILAH WATER MANAGEMENT PLAN

EXECUTIVE SUMMARY

Vancouver Island Region

Planning and Assessment Branch

September, 1986

The objectives and major activities in this plan for the Cowichan-Koksilah are adopted and may proceed as Ministry and Regional priorities and funding allow.

B. E. Marr
Deputy Minister
Ministry of Environment and Parks

Feb 6, 1987.
Date

INTRODUCTION

The Cowichan-Koksilah plan area, located on the southeast coast of Vancouver Island (Figure 1), supports a number of instream and offstream water users. The area contains a significant recreational river, important salmon and trout resources, and an established agricultural community. Abundant water supplies are generally available throughout most of the year in the rivers and larger tributaries to accommodate these uses. However, during the summer low flow period, water supplies become limiting, leading to water use conflicts such as inadequate dilution flows, declining fisheries productivity and restrictions to licensed water users. It is expected that these conflicts will intensify during the next decade as population and associated water demands increase.

The purpose of this plan is to develop a water management strategy that will address low flow water issues in the Cowichan-Koksilah watershed. In addition, the plan area was selected as a pilot to test a prototype water management information system.

MANAGEMENT OBJECTIVES

Surface water supplies in the Cowichan-Koksilah plan area during the 5-year term of this plan should be managed, as possible, to:

1. Provide adequate water supplies for licensed users.

2. Ensure adequate low flows to meet the instream uses, including fisheries, recreation and dilution flows for water quality.

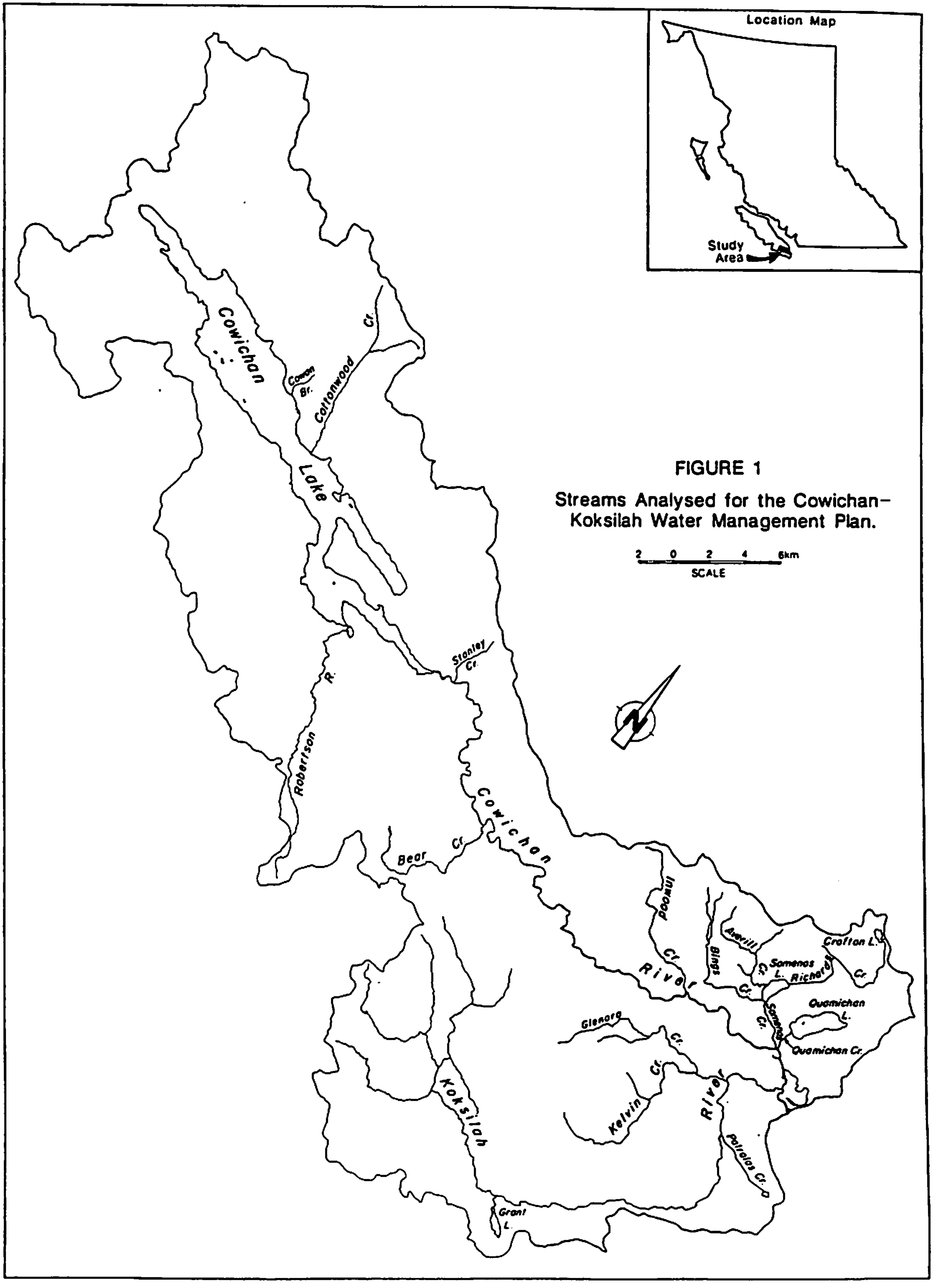

FIGURE 1

Streams Analysed for the Cowichan-Koksilah Water Management Plan.

THE PHYSICAL SETTING

The plan area (1241 km^2) includes the entire watersheds of the Cowichan and Koksilah rivers, which discharge to Cowichan Bay near the community of Duncan. Low flows in the area generally occur during the June to October period, with most annual minimum daily discharges recorded during the last three weeks of August and first two weeks of September.

Population in the area is estimated to be around 31,400 and is expected to grow to 36,750 by the year 2001. While Duncan serves as the major retail service center, much of the economy in the area is resource based.

Agriculture has had a long history in the Cowichan region, with an emphasis on dairying and the cultivation of crops related to the dairy industry. Irrigation use constitutes approximately 7% of total licensed water, with the greatest withdrawals for irrigation occurring in the Somenos and Koksilah watersheds. There is still considerable land available for expansion in these areas, but development will be dependent on markets and capital costs for clearing. As a result, it is expected that existing major agriculture operations will expand only marginally, and any increase in irrigation requirements is expected to be small.

In addition to irrigation, other licensed water users in the plan area include: (1) domestic licences (0.3% of total licensed water) primarily located in the Cowichan and Somenos watersheds, (2) waterworks licences (6% of total licensed water) which are concentrated in the Cowichan watershed, and (3) an industrial licence (87% of total licensed water) held by B.C. Forest Products to supply water from the Cowichan River to the pulp and paper mill in Crofton.

Considerable fisheries production occurs throughout the larger rivers and tributaries, and includes major species such as coho, chinook, chum, steelhead and a unique brown trout fishery.

Until recently, the Cowichan-Koksilah system consistently provided the greatest number of angler days and largest total catch of any Vancouver Island watershed. Angler demand has increased in the last few years, while production has remained relatively constant. The provision and maintenance of adequate streamflows during the summer months is an essential prerequisite to continued or expanded fisheries production. Fisheries flow requirements estimated for a number of areas in this plan are intended to enable fisheries agencies to meet production targets.

Water-based recreation is well-represented in the plan area and includes a number of provincial parks, recreational reserves, day-use areas, and hiking trails adjacent to the Cowichan River. The Cowichan and Koksilah rivers are used for a variety of activities including whitewater canoeing, kayaking and swimming. Instream flows to support these activities have not been quantified. The Cowichan River, however, is being considered for designation as a Recreational Corridor, with the intent of maintaining the waterway environment for recreational use.

As the Cowichan-Koksilah supports a variety of users, high standards of water quality are necessary. One method of improving water quality is through the provision of adequate flows for the dilution of waste from effluent permits and non-point source discharges. Flows for adequate dilution at selected locations in the plan area have been determined and are based on Waste Management dilution objectives.

Groundwater is extensively used, with the number of wells known to have been drilled in the plan area during the past 25 years having quadrupled, with the trend increasing in the past decade or so. There is considerable potential for further groundwater extraction along the valley bottoms of the Cowichan River, and to a lesser extent in other parts of the plan area. In those areas where there is a shortage of surface water, groundwater may be utilized, particularly for irrigation.

SUMMARY OF ANALYSES

Generalized conclusions are presented below for each major system. Conclusions are based upon estimated 7-day low flow water supplies (5-year return period), present and projected licensed withdrawals, and estimated instream requirements for fisheries and waste dilution purposes.

1. Cowichan River

Three tributaries to Cowichan Lake were examined (Cowan Brook, Cottonwood Creek and Robertson River), and adequate low flow supplies are available for the very small amount licensed in these streams. However, gravel fans, which intercept surface flows, are common at the mouths of tributaries to Cowichan Lake, and streams may become subsurface in these areas. The result is that surface flows may be inadequate for either fisheries or licensed purposes in the fan areas, although sufficient water may be present above the fans during the low flow season.

Below the storage dam on Cowichan Lake, which was constructed in the 1960s to support a B.C. Forest Products licensed industrial withdrawal downstream near Duncan, 7-day low flow is greater than 6 m^3/s for the 5-year return period. The industrial licence requires that nearly 3 m^3/s be allowed to pass downstream of the industrial intake, located not far upstream of the Highway 1 bridge. Other licensed withdrawals above this point are minimal.

Instream requirements for Cowichan River fisheries were based upon the storage and industrial licence requirements, rather than on fisheries habitat requirements. It was concluded that the flow required is not available in all reaches of the Cowichan. Instream flow is also required for dilution of the effluent from two sewage treatment plants discharging to the Cowichan River. Adequate dilution is available for the Village of Lake Cowichan plant, not far downstream of the storage dam. However, there is inadequate dilution during low flows for effluent from the Duncan-North

Cowichan sewage treatment plant, located downstream of the industrial intake mentioned previously. The Cowichan River is also used for recreational instream purposes during much of the year (kayaking, canoeing, boating, tubing and swimming), but a required flow was not estimated for these purposes.

Below the storage dam, three tributaries (Stanley, Bear and Inwood Creeks) were examined. Stanley Creek is currently over-licensed, but the proposed cancellation of an unused waterworks licence would resolve this apparent shortage. There are no water licences on Bear Creek, but natural low flows are inadequate for fisheries purposes. Inwood Creek is nearing full allocation, but contains unutilized agricultural potential and significant fisheries habitat, presently inaccessible to fish.

2. Somenos Creek

Bings Creek currently has surplus water available for licensing, and marginally adequate flows are available for fisheries purposes. Agricultural potential remains in the area, but its development may be dependent on construction of water storage or exploitation of possible groundwater potential.

Averill Creek flows into Somenos Lake, as does Bings Creek. There are already shortages for both licensed and fisheries requirements, and irrigation increases during the next five years have been projected, if storage or groundwater is developed.

Richards Creek originates with storage releases from Crofton Lake, and flows into the north end of Somenos Lake. The lower valley has been developed for agriculture, but summer low season flows are insufficient for current licences. Fisheries requirements in upper Richards Creek are not currently being met. Groundwater potential throughout the valley appears to be low, suggesting that projected irrigation increases will have to rely upon improved Crofton Lake releases or alternative storage sites.

Somenos Creek drains Somenos Lake into the Cowichan River. Licensed requirements are supplied from Somenos Lake, but any additional licensing from the lake may prolong the zero flow period in Somenos Creek.

Quamichan Creek drains Quamichan Lake, and enters Somenos Creek at its confluence with the Cowichan. Licensed and projected requirements can be supplied from Quamichan Lake, but any future licensing may prolong the period of zero flow in Quamichan Creek. Fisheries requirements in the creek are not currently being met.

3. Koksilah River

There are no water licences on the upper Koksilah, but natural low flows are less than estimated fisheries requirements based upon habitat availability. Low flows are therefore limiting for potential fisheries production. This indicates that an increased low flow would provide more fisheries habitat, and hence production. Below the confluence with Patrolas Creek, adequate surface flows are available in the Koksilah for the predominantly agriculture-related licences, but instream flows are insufficient for fisheries purposes. Moderate groundwater potential apparently exists for irrigation expansion. In the vicinity of the mouth of the Koksilah, enough water is available for licensed requirements, but agricultural expansion can be expected. Groundwater potential is moderate to good, and considerable water is available for storage and flow regulation if suitable storage sites are developed. On the lower Koksilah, fisheries requirements are not available during the low flow season.

Patrolas Creek enters the Koksilah above Cowichan Station, originating in Dougan Lake and flowing through a valley highly developed for agriculture. Licensed requirements are not available from surface flows, nor are fisheries instream requirements. Groundwater development appears to be a potential source for projected irrigation increases.

Glenora Creek joins Kelvin Creek, which then flows into the Koksilah below Cowichan Station. Existing licensed and fisheries flow requirements on Glenora Creek are not available during the low flow season. Groundwater potential appears to be present to meet projected irrigation increases. Location and development of suitable storage sites may also provide additional water, and could be of benefit to fisheries interests. The Glenora-Kelvin system contains the most significant fisheries tributary habitat in the Koksilah system. Kelvin Creek itself has enough low-flow season water to meet licensed requirements, but a considerable area of high capability agricultural land is yet to be developed. The fisheries requirement is not available in Kelvin Creek, and no additional water should be licensed without provision for storage.

The Koksilah mainstem and all tributaries are presently noted as fully recorded in the Stream Register.

PRIORITY MANAGEMENT ACTIVITIES

A total of 23 management activities are recommended. Those of high priority are outlined below, followed by brief statements of medium and low priority items.

1. Administrative and Licensing

(a) no further water should be allocated (except for domestic purposes) unless storage and flow regulation is provided on the following streams, all of which are already designated as fully recorded in the Stream Register: Stanley, Bings, Averill, Richards, Patrolas, Glenora and Kelvin Creeks; Koksilah River;
(b) cancel the unused waterworks licence on Stanley Creek;
(c) encourage groundwater development to satisfy existing and future irrigation requirements in the current and projected water-short areas;
(d) the list of streams (see Plan appendix 3.1, Table 3) having current or potential fish production ratings should be considered when making decisions on future water licence applications.

2. Technical and Inventory Studies

(a) determine fisheries instream requirements for the Cowichan mainstem utilizing a method based on habitat availability as employed elsewhere in the plan area. Should this analysis indicate instream shortages for fisheries purposes, review the provisional rule curve for Cowichan Lake storage releases, and investigate the possibility of additional live storage;
(b) measure streamflows during the low-flow season at selected locations, and attempt to refine techniques for low flow supply estimates;
(c) where both measured streamflows and fisheries habitat area information are available, attempt to refine fisheries instream flow requirements;
(d) investigate those potential water storage sites previously identified, to augment the low flow;
(e) an inventory of storage potential at the reconnaissance level should be initiated for all streams having present or projected water shortages;
(f) establish water quality objectives and a monitoring program for the Cowichan and Koksilah rivers.

3. Capital Works

(a) improve the hydrometric network by establishing stream gauges on representative small basins.

4. Legislation and Policy

(a) Consideration should be given to future amendments of the Water Act to recognize instream flow requirements including fisheries, waste dilution and recreation, and a method to allocate, protect or reserve specific flows for these uses should be incorporated;
(b) policy or legislation should be developed to provide for the planning, allocation and management of water resources on a watershed basis.

Medium priority management activities include:

- further assessment of low flow supplies and requirements on Cowan Brook, Cottonwood, Bear and Inwood Creeks and Robertson River;
- review modifications to Crofton Lake storage releases;
- specific groundwater studies to better define supplies, use and quality;
- assessment of possibilities for reducing phosphorus and nitrogen levels in effluent from the Duncan-North Cowichan sewage treatment plant;
- in conjunction with existing floodplain mapping, use new mapping indicating potential flood and erosion areas;
- change the Water Act to:
  - enable groundwater licensing in specified areas;
  - identify water management areas where priority uses of water can be specified in a water management plan.

Other lower priority activities are also recommended in the plan. Implementation of these activities is subject to Regional and Program priorities and resources.

Recommendations on the water management information system are also presented in the plan, and are summarized below:

(a) The Water Management Program should continue to develop the Water Management Information System and initiate implementation.

(b) The Water Licence module should be first priority for completion, including geo-referencing of priority areas, then development of the Water Supply, Fisheries Flow and Dilution Flow modules, and eventually other elements (e.g. groundwater, storage, actual water use, other instream uses, and floodplain/erosion information).