NANAIMO RIVER

WATER MANAGEMENT PLAN

July 1993

THE NANAIMO RIVER WATER MANAGEMENT PLAN

This document was produced by Water Management, Vancouver Island Regional Headquarters, of the Ministry of Environment, Lands and Parks.

The Nanaimo River Water Management Plan was developed through the cooperative efforts of a Planning Team comprised of representatives from the Greater Nanaimo Water District, MacMillan Bloedel Ltd., Nanaimo Indian Band, Department of Fisheries and Oceans, and the Ministry of Environment, Lands and Parks. The contributions of these members are gratefully acknowledged.

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NANAIMO RIVER WATER MANAGEMENT PLAN
SUMMARY

The Nanaimo River Basin is located on the south east coast of Vancouver Island, British Columbia. The Nanaimo River Water Management Plan was initiated to ensure effective planning for the water resources of Nanaimo River and its tributaries. The overall purpose of this process is to sustain the water resources and identify management strategies for the long term benefit of all water uses within the watershed. The specific focus of the Plan was to identify strategies for management of the surface water resources in the watershed.

The Plan addresses water supply, water quality, fisheries and water use concerns that affect the water resources of the Nanaimo River. The Water Resource Management Model, was used to integrate various water resource requirements. The intent was to test this model as a means to assist in water management decision making for the Nanaimo River Basin; the model may be found useful for other watershed and for other potential water management conflict issues.

The planning process contributed as effective means to address water resource demands as it provided a forum for problems to be solved and decisions to be made. The process depended on the cooperation of multi-party planning team comprised of native, industrial, municipal, provincial and federal representatives. The Nanaimo River Water Management Plan is part of an ongoing process for water management in the Nanaimo River Basin.

At the present time, the primary water management issue in the Nanaimo River Basin is the enhancement of flows to meet fisheries requirements during September and October while continuing to maintain industrial and municipal water supply needs. Abundant water is available in the Nanaimo River during the winter and spring months. The Nanaimo River and its tributaries support major stocks of salmon and trout which have become highly prized as Native food and a commercial and recreational fishery resource. If the water supply is low, then the allocations for municipal and industrial use may compete with the need for enhanced river flows for fisheries.

The conclusions and recommendations detailed in Chapter 8 of the Plan pertain to the following topics:

- the supply and quality of the surface and groundwater resources,
- the salmon and recreational fisheries resources,
- various water resource uses such as municipal waterworks, industrial use, irrigation, domestic, wildlife and recreational activities, and
- reservoir operations including water management modelling, specific operations and storage.

Chapter 9, the implementation strategy, priorizes the recommended actions in Tables 9.1 - 9.3 and explicitly documents how the planning process will continue.

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CHAPTER 1 INTRODUCTION

1.1 Background

The Nanaimo River Basin is located on the south-east coast of Vancouver Island, British Columbia (Figure 1.1) and has water resources that support both consumptive and non-consumptive uses. Consumptive water uses include municipal, domestic, industrial and agricultural from surface and groundwater sources. Non-consumptive uses or "instream" water requirements include fisheries, wildlife and recreation.

Abundant water is available in the Nanaimo River during the winter and spring months, however, low flows do occur in most years during late summer and early autumn. During these times the limited water supply may lead to competition among water uses, such as between industrial, municipal and fisheries requirements.

The Nanaimo River and its tributaries support major stocks of salmon and trout which have become highly prized as Native food and a commercial and recreational fishery resource. In the past, all five species of Pacific salmon (chum, coho, chinook, pink and sockeye) have been observed in the river; however in recent years, the numbers of pink and sockeye have declined such that they are only occasionally found. In general, there has been a downward trend for the Pacific Salmon and other species observed in the Nanaimo River.

1.2 Water Management Issues and Concerns

Management of British Columbia's water resources must consider the growing population and development pressures that impact on water supply; balance the needs of water consumers with cultural, environmental, social and recreational demands; and must address flow levels in rivers to protect and maintain water quality to sustain fisheries, wildlife and river ecosystems (Ministry of Environment, Lands and Parks, 1991).

The City of Nanaimo, located adjacent to the Nanaimo River watershed, and other areas on the east coast of Vancouver Island are experiencing dramatic increases in population and development. These trends contribute to growing pressures on the water resources in the area and intensify the potential for competition between fisheries, industry and municipal water use.

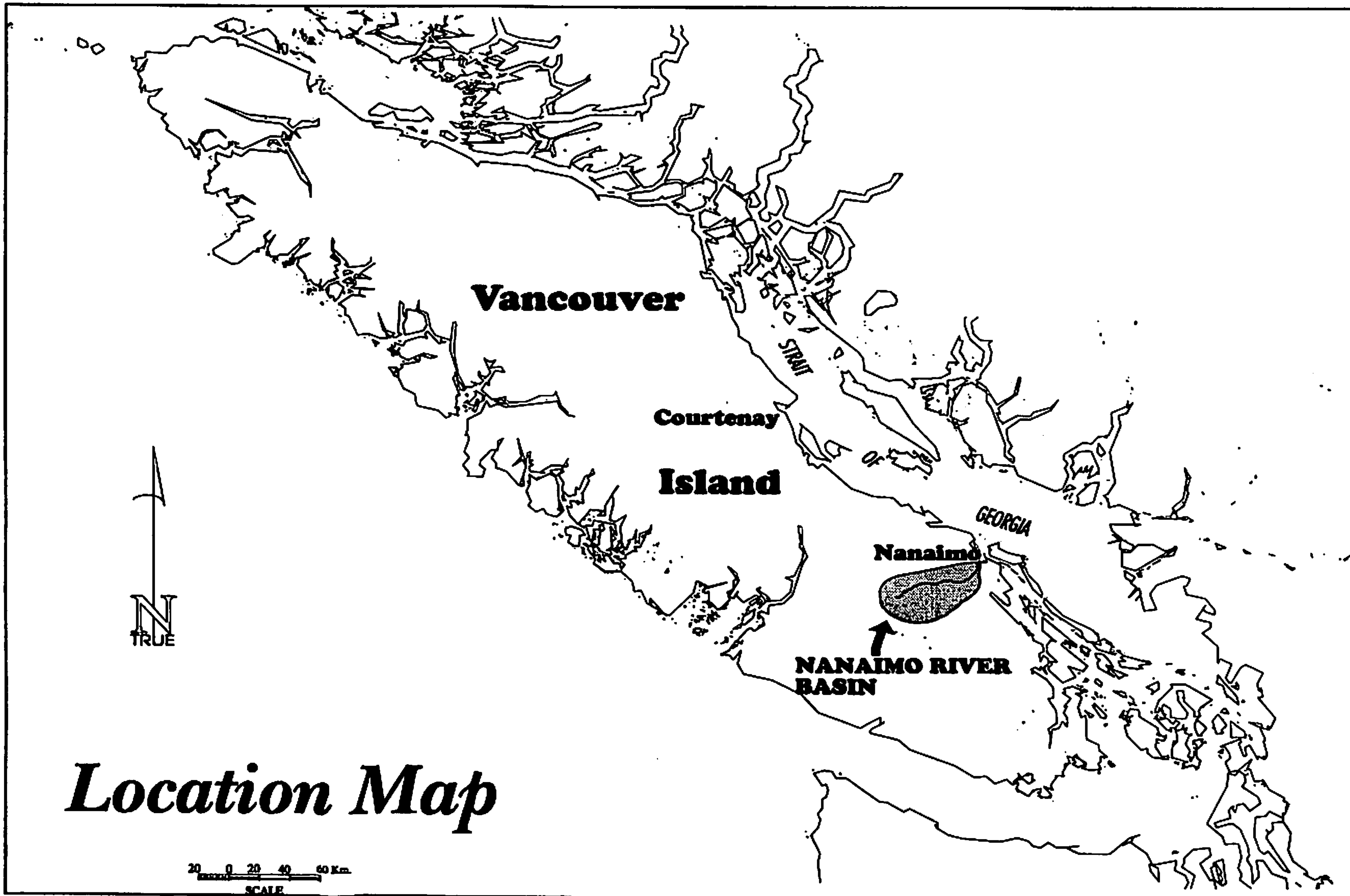


Figure 1.1 Location of Nanaimo River Basin

At the present time, the primary water management issue in the Nanaimo River Basin is the enhancement flows to meet fisheries requirements while maintaining industrial and municipal water supply needs with growing population pressures. The potential for these water uses to compete arises especially in late summer and early fall. If the water supply is low, then the allocations for municipal and industrial use compete with the need for enhanced river flows for fisheries.

From a fisheries resource perspective, there has been concern over the low flows in the Nanaimo River particularly during the months of September and October. The most critical reach of the river for salmon is the six mile section below the MacMillan Bloedel Ltd., Harmac pulpmill intakes. Migration within the reach downstream of the Harmac intakes is difficult if the residual flow is less than 1.4 m^3/sec. Migration through the falls area, above the intakes, is also difficult if the flow in the river is too low. Such flows delay autumn spawning of chinook salmon, forcing them to hold in the Nanaimo River estuary.

Other current water resource issues in the Nanaimo River Basin include groundwater management and water quality issues. Groundwater demand can affect river flows due to the inter-relationship between surface and ground water flows. Withdrawals from wells developed on the Nanaimo River floodplain and the adjacent Haslam Creek may affect flows in the river. Flows in Haslam Creek are affected by both industrial and irrigation withdrawls. The main lake in the area is Michael Lake, located at the head of Hokkenen Creek. Water supplies in the low lying creeks in this sub-basin may be affected by the local groundwater supply of the Cassidy Aquifer.

There is no regulation of groundwater use. For example in the Haslam Creek area there has been significant residential and commercial development that may result in an increase in unregulated groundwater withdrawls. There are water quality concerns related to the suitability of water for the various uses in the basin discussed further in Chapter Four, and other water quality issues focusing on temperature and fish disease concerns are detailed in Chapter Five.

1.3 Purpose and Objectives

Effective planning for the water resources of British Columbia must include provisions for preparing and implementing water management plans that address instream uses, contribute to the protection and enhancement of the water resources and provide a means for comparing management alternatives and resolving potential conflicts.

The Nanaimo River Water Management Planning process was initiated by the Ministry of Environment in June 1989. Although the overall purpose of this process is to sustain the water resources and identify management strategies for the optimal long term benefit of all water use interests within the Nanaimo River Basin, the current focus of the Nanaimo River Water Management Plan (NRWM Plan) is to identify strategies for management of the surface water resources in the watershed.

The planning process provides a forum for decisions to be made with the participation of the various water users, identifies how various water users needs will be met in conjunction with those of other water users, assesses existing allocations and current reservoir operations and then determines if there is need for alternate water management strategies. The process depends on the cooperation of multi-party planning team comprised of native, industrial, municipal, provincial and federal representatives (Appendix I, Planning Team Members). Although the intent of the plan will not change, it is proposed that specific components of the plan will be updated as more data and improved analysis becomes available. Thus, the NRWM Plan is the first stage of an ongoing process for water management in the Nanaimo River Basin.

More specifically the NRWM Plan goals are achieved through assessing the availability of water in the basin and providing adequate quantity and quality of water to meet the present and future consumptive water demands and instream requirements. As the importance of water quality and instream flows for fish, wildlife, recreation and aesthetics as well as for municipal, domestic, agricultural and industrial requirements is becoming increasingly apparent, the planning process will allow for an effective approach in sustaining the water resources and addressing competing demands. The NRWM Plan has the following objectives:

- description of the Nanaimo River Basin,
- description of the basin's population trends and land/ water uses within and adjacent to the basin,
- identification of the surface and groundwater resources within the basin,
- identification of the water quality issues,
- discussion of existing surface and instream water uses and consideration of future water demand issues,
- identification of fisheries water requirements,
- development of a framework to integrate water resource requirements,
- development of alternate water management strategies,
- recommendations outlining the short term water management strategies proposed for the Nanaimo River Basin.

The Water Resource Management Model (WRMM), has been incorporated into the plan as a planning tool designed to integrate various water resource requirements. This is the first time in British Columbia that this model has been used. The intent of the Regional Water Management office is to test this model as a tool to assist in water management decision-making for the Nanaimo River Basin. The scope of the NRWM Plan is area specific, focusing on the Nanaimo River Basin; however, the use of the model may be found useful for other basins and for other potential water management conflict issues.

1.4 The Study Area

The study area comprises the entire Nanaimo River Basin (Figure 1.2), however, field data collection and analysis concentrated on those reaches below the three reservoirs on the Nanaimo, the South Nanaimo River and Jump Creek systems and the tributaries affected by withdrawals for industrial or municipal use. Haslam Creek is a sub-basin included in the plan area, but it is not included in the model.

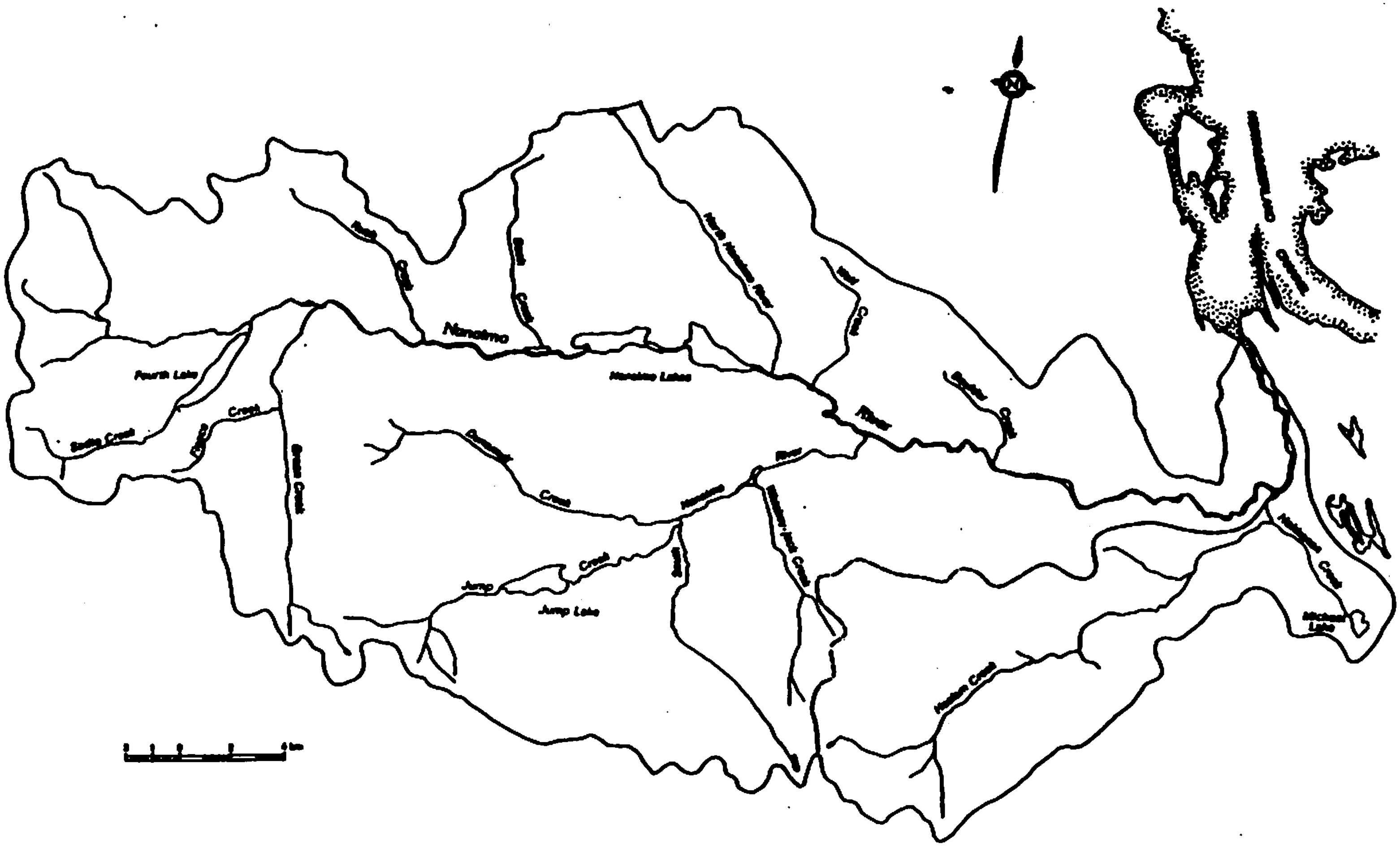


Figure 1.2 The Nanaimo River Water Basin and the Nanaimo River Water Management Plan Boundaries

CHAPTER 2 BASIN DESCRIPTION

2.1 Location and Size

The Nanaimo River flows easterly, from its origin at an altitude of 1524 metres at Mount Whymper, through the Second and First Nanaimo Lakes then turns in a northerly direction and flows for 56 km to its mouth at the south end of Nanaimo Harbour. The Nanaimo River drains an area of 813 square kilometres. The Haslam Creek sub-basin drains an area of 133 square kilometres (Figure 1.2).

There are several lakes and tributaries in the Nanaimo River Basin. As evident in Figure 1.2, the four main lakes in the study area are Fourth Lake, the Second and First Nanaimo Lakes and Jump Lake. The tributaries that the Nanaimo River drains from the north are Rush Creek, Dash Creek, North Nanaimo River, Wolf Creek and Boulder Creek; the tributaries flowing from the south include Sadie Creek, Fleece Creek, Green Creek, South Nanaimo River, Whiskey-jack Creek, Dunsmuir Creek, Jump Creek, Haslam Creek and Hokkanen Creek. The main Nanaimo River tributaries of interest for the NRWM Plan are the South Nanaimo River, Jump Creek, Sadie Creek and Haslam Creek (Figure 1.2). The Nanaimo River crosses the Island Highway at Cassidy, 10 km south of Nanaimo near the mouth.

2.2 Population

Population estimates for 1989 show Vancouver Island growing by 39 % over the next twenty-five years (Ministry of Finance and Corporate Relations, 1989). For this same time period, the east coast of Vancouver Island, from the City of Victoria to Nanaimo and north to Campbell River, has regional population increases estimated at exceeding 50 % (Barnett, 1991). More specifically, the Nanaimo Regional District estimates 47 % population increases over the next twenty-five years, making Nanaimo the fastest growing area on the Island and a major growth centre in Canada.

The main population areas served by and impacting the Nanaimo River Basin are the City of Nanaimo and the Electoral Areas of Cranberry Bright and Cedar (Figure 2.1). The City of Nanaimo does not fall within the boundaries of Nanaimo River Basin; however, its population has a major impact on the watershed. Nanaimo lies adjacent to the north-west section of the basin and has an estimated 1992 population of 62,000 people served by the Greater Nanaimo Water District Jump Creek reservoir. Nanaimo's population is forecasted to reach approximately 75,000 by the year 2000. This 2.3 % per year population growth will require increases in municipal water supply and place increasing pressures on the water resource (Hansen, 1992).

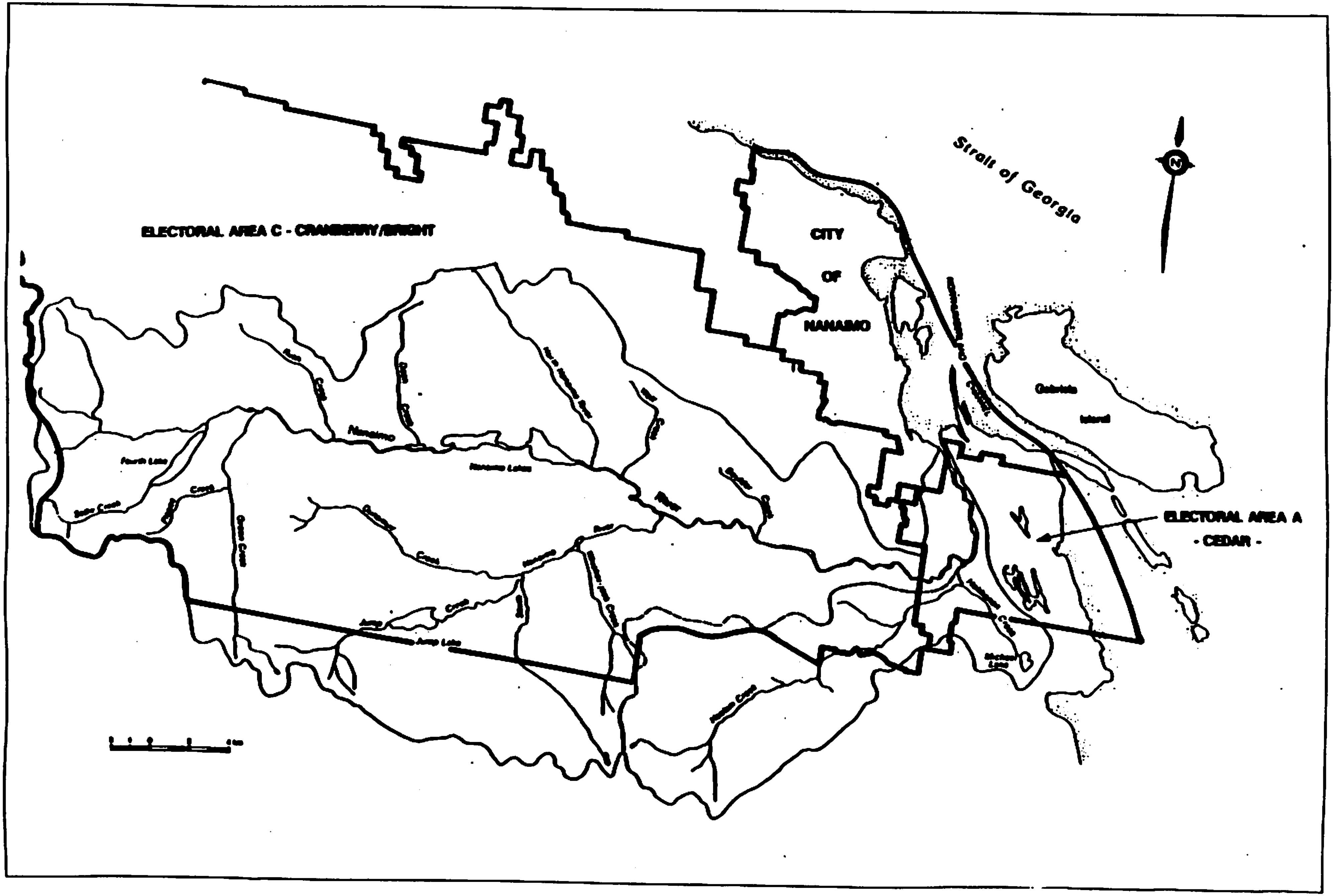


Figure 2.1 The Population Served by the Nanaimo River System

The Electoral Area of Cedar is characterized by the three residential communities of South Wellington, Cedar and Cassidy and has experienced tremendous population growth (4.3%) in the years from 1971-1976; however there has been only marginal growth since 1981 with estimated population of 4,536 (Regional District of Nanaimo, 1987). The Cranberry Bright Electoral Area includes the residential area of Extension and borders the South Wellington and Cassidy communities. There has been relatively little urbanization of this area due to limited services and the predominantly rural environment. There was no available population estimates or projections for this area (Regional District of Nanaimo, 1987).

2.3 Land Use in the Nanaimo River Basin

As the forest industry is the dominant activity and the major land use in the basin, it will be addressed as a separate issue. Other Nanaimo River Basin land uses will be discussed below as they occur within their respective land districts. Finally, projected land uses in the basin will then be addressed.

2.3.1 Forestry

Forestry operations occur throughout a major portion of the Nanaimo River Basin and fall under the jurisdiction of the Ministry of Forestry, Duncan and Port Alberni Forest Districts. In the Nanaimo River Basin the forest lands are mostly privately owned and operate as managed forest units (MFUs) or tree farm licences (TFLs). A MFU is an agreement between the owner of the forest company and the B.C. Assessment Authority and a TFL is an agreement between the owner and the Crown, where allowable annual cut (AAC) is approved by the province's Chief Forester (Woodgate, 1992). Both types of tenures require an approved five year working plan that specifies the rate of cut and management objectives (Lavis, 1992).

There is potential for forest harvesting to affect water quality, quantity and fisheries production. Forestry practices could limit input of organic debris for fish rearing habitats and could increase sediment loading. The volume of river run off is also a concern in the management of water, waste and fisheries (Ministry of Environment, Lands and Parks 1988). Therefore, if these resources are to be sustained, there must be cooperation between the stewards of these resources.

The forest industry has had operations in the Nanaimo area for many years through MacMillan Bloedel Ltd., Fletcher Challenge Ltd., Canadian Pacific Forest Products Ltd. and other smaller forestry operations (Figure 2.2). Fletcher Challenge is the largest land holder within the basin. Both the Mackay Lake area (MFU 68) and the Haslam Creek lands (MFU 65 and MFU 8) are presently inactive (Table 2.1). Old growth harvesting is currently taking place only at what is commonly referred to as the Nanaimo Lakes area. Approximately 40% of this area is designated as part of TFL 47 (MFU 8, also privately owned) with the forest cover being primarily 5 - 50 year old second growth. Therefore, harvesting is currently confined to the remaining 60 % of Nanaimo Lakes area (MFU 65) at an annual cut of approximately 100,000 cubic metres per year. The phasing in of second growth is tentatively scheduled to begin in the late 1990's (Mofenter, 1992).

MacMillan Bloedel Ltd. is the second major forest land owner within the basin. This forestry area is part of the Cowichan Woodlands Operation and is referred to as the Nanaimo River operation. All 65,000 hectares of the Cowichan Division of MacMillan Bloedel is within the MFU 19. First growth timber is harvested at a rate of approximately 190,000 cubic metres per year with an estimated completion of old growth harvesting by the year 2008 (Table 2.1). Second growth harvesting is planned to commence sometime in the years 2001 - 2002 (Lavis, 1992).

The third forest operation in the area, as mentioned earlier, is Canadian Pacific Forest Products Ltd. These holdings fall within the MFU 7, are relatively small and are scattered throughout the basin (Figure 2.2). The current harvest is minimal (under 10,000 cubic metres per year) and variable. The first growth timber is still being harvested and there are plans to commence second growth at sometime in the future.

2.3.2 Other Land Uses in the Nanaimo River Basin

The Nanaimo River Basin includes portions of the Dunsmuir, Cowichan Valley, Cranberry Bright and Cedar Land Districts (Figure 2.3). The Dunsmuir Land District is zoned agricultural-rural and is predominantly used for forestry and agricultural purposes. The majority of the Cowichan Valley Land District within the basin is zoned forestry 1, subdividable into fifty acre parcels. This area allows single family dwellings, agriculture, silviculture and gravel processing activities (Regional District of Nanaimo, 1987).

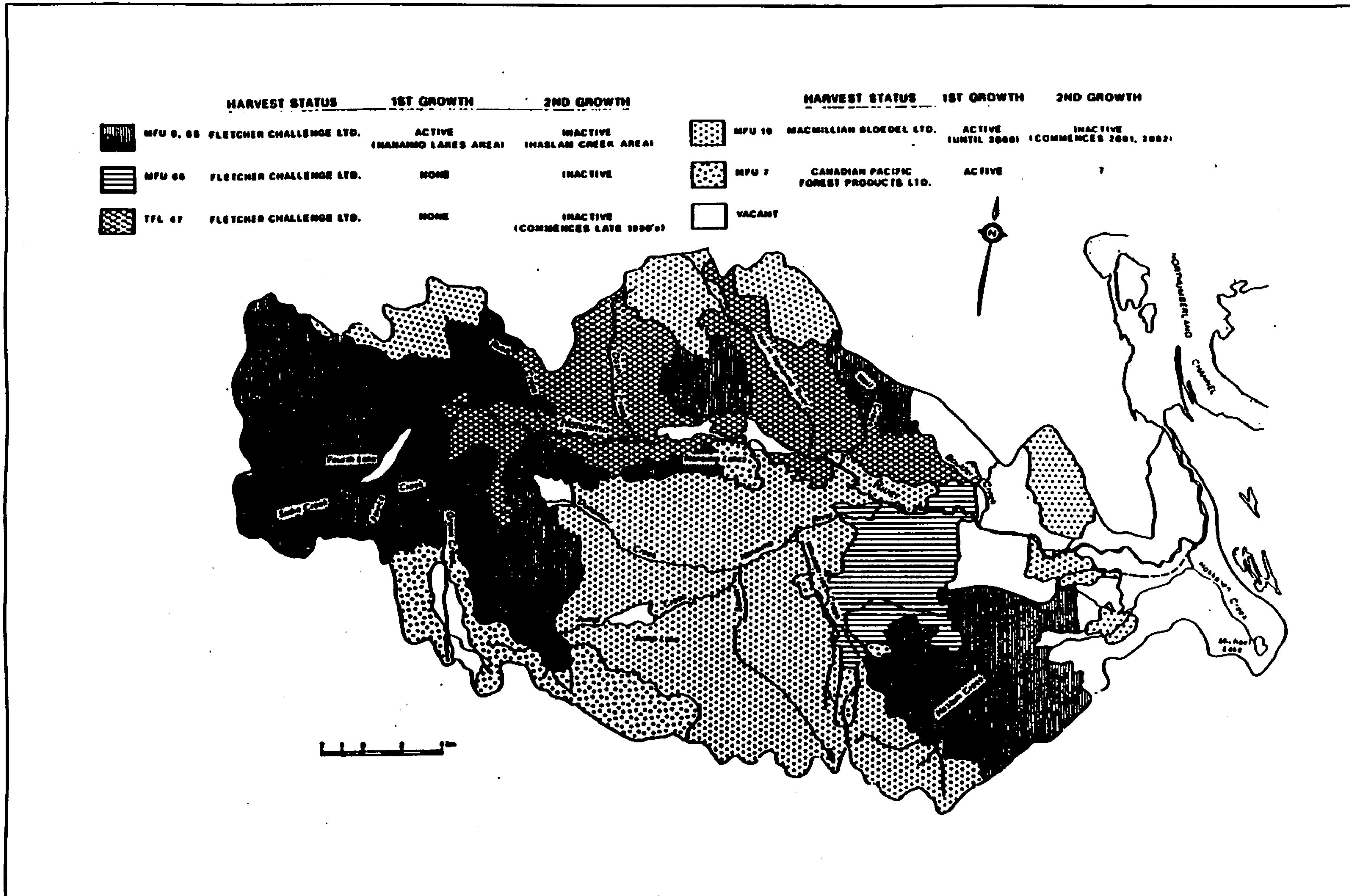


Figure 2.2 The Forestry Land Ownership in the Nanaimo River Basin

Table 2.1 Forest Harvest Status in the Nanaimo River Basin

Forest Company	Type of Operation	First Growth	Second Growth	Proposed Second Harvests
Fletcher Challenge Ltd.	MFU 8, 65 (Haslam Cr.) MFU 65 (Nanaimo L.) MFU 68 TFL 47	inactive active inactive inactive	inactive inactive inactive inactive	late 1990's
MacMillan Bloedel Ltd.	MFU 19	active until approx. 2008	inactive	2001 - 2002
Canadian Pacific Forest Products Ltd.	MFU 7	active	inactive	future

The Cranberry Bright Land District within the basin is predominantly rural in character with pockets of commercial, industrial and residential development. Agricultural Land Reserves (ALR) have an important bearing on land use patterns in this area. Approximately 10 % of this district is classified as ALR, a large proportion of these areas are undeveloped and agriculture is a primary and secondary source of income for a number of residents. At present approximately 65% of the Cranberry Bright Land District is classified as tree farm and other forest lands are used significantly for recreation (hiking, mountain biking, aesthetic use) and wildlife habitat. There are rural activities in the area such as hobby farming. Commercial development has been confined to the community of Extension with the exception of the strip of commercial and industrial development along the Island Highway (Regional District of Nanaimo, 1987).

The predominantly rural land use pattern in the adjoining district of Cedar includes activities such as hobby farming, agriculture, and silviculture. There is a transitional rural-residential land use pattern emerging that provides for the continued trend towards urbanization of the rural environment. Within this area forestry lands are classified as tree farm and forest reserves, management of mineral resources is confined to sand and gravel processing and parks are used for recreational purposes.

Commercial and industrial development in the area has been random and predominantly in the form of strip development along major roads. There is a proposal for a residential, tourist, commercial and marina development at Boat Harbour that involves a water lot and fifty hectares of land adjoining Hemer Park. There are utility and institutional services such as parks, firehalls, public utility stations, churches, halls and educational facilities (Regional District of Nanaimo, 1987).

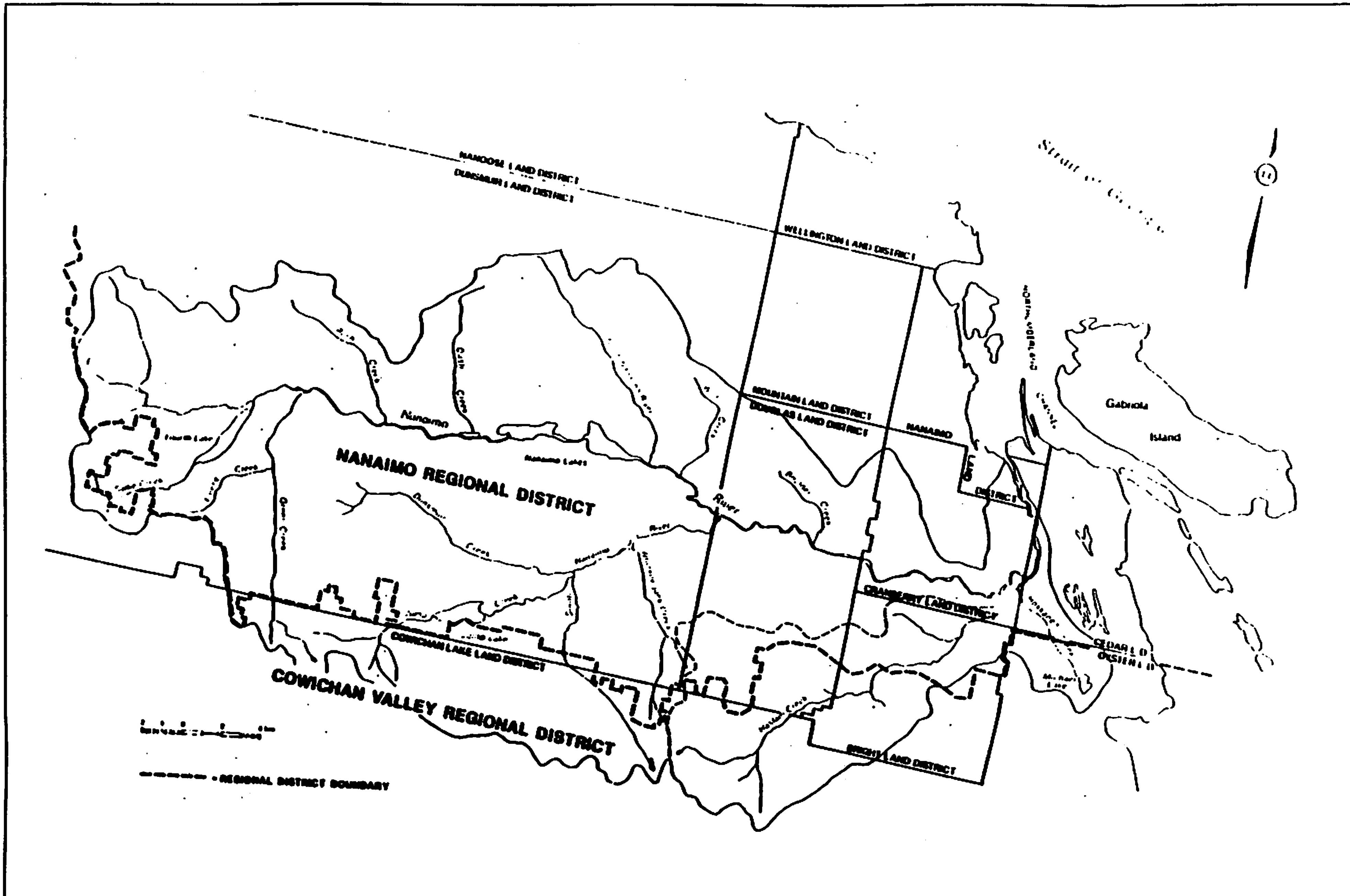


Figure 2.3 The Land Districts Within the Nanaimo River Basin

2.3.3 Projected Land Uses

Due to increasing populations and the tremendous growth in the areas surrounding the Nanaimo River Basin, the commercial and residential development issues are becoming important land use issues to consider. Within the basin, if present harvesting plans are followed, then second growth timber harvests will be phased in sometime in the next decade and this could result in different forestry management issues to consider. There is also proposals for exploration of natural gas and coal mining in Cedar and Cranberry Bright areas.

2.4 Basin Features

2.4.1 Geological Features

The study area falls into the physiographic region of British Columbia known as the Coast Mountains and Islands (Valentine et al, 1978). The topography is generally rolling with elevations ranging from sea level to 1700 meters above sea level. Bedrock is exposed over much of the Lowland area and according to Halstead (1961), consists mainly of Cretaceous Nanaimo Group shale, sandstone and conglomerate; whose weaker units have been eroded to form valleys, with the more resistant units resulting in cuesta-like ridges. Several transverse valleys cut these longitudinal valleys; though the largest of these, the Nanaimo River flows eastward from the upland, then flows north to Nanaimo Harbour, in which it is building a large delta (Zubel, 1991).

According to Halstead (1961 and 1967), the area has undergone glaciation. During the retreat and wastage of the last major ice, sea levels were considerably higher than present. Heavily loaded streams issuing from valley glaciers in Nanaimo River and Haslam Creek valleys deposited sand and gravel as deltas into a sea that was about 500 feet higher than present sea level. Marine and glacio-marine deposits were laid down in the seas that overlapped the lowland and left a veneer of marine gravel, sand or silty clay with fossil shells (Zubel, 1991).

During the period of lowering of sea level to the present, streams deposited gravel and sand and cut terraces in older deposits, and clays and silts were continually being deposited in the deeper waters. The deltaic sand and gravel deposits in the Nanaimo River valley are the source of the extensive aquifers in the basin (Zubel, 1991).

2.4.2 Vegetation

As described by Jones and Annas (1978) in the Soil Landscapes of British Columbia, the vegetation in the Nanaimo River Basin falls into three broad categories of the Krajina Biogeoclimatic Zone classification system: Coastal Douglas-fir (CDF) found to occur at elevations from sea level to 450 meters; Coastal Western Hemlock (CWH) ranges up to 1050 meters; Mountain Hemlock (MH) found at elevations from 900 to 1100 meters. Each of these zones is a geographic area having characteristic vegetation with associated animals, soils and climate.

The CDF zone is situated along the coastal region in the rain shadow of the Olympic Peninsula and Vancouver Island Mountains. Although other coniferous species are present, the zone is dominated by Douglas-fir, Western Red Cedar, Garry Oak, Arbutus and Pacific Madrone communities are also common. An understorey of salal and Oregon Grape dominates the shrub layer (Jones and Annas, 1978).

The CWH zone is the wettest and most productive forest zone in British Columbia. Western Hemlock, Douglas-fir, Pacific Silver Fir, Western Red Cedar and Sitka Spruce are the common tree species in this zone. An understorey of salal, mosses, lichens and ferns are common and their location varies with local topography and slope (Jones and Annas, 1978).

The MH zone is sub-alpine and occurs at high elevations along the Pacific Coast Mountains. At low elevations, the forests are dense and productive. Mountain Hemlock, Pacific Silver Fir and Yellow Cedar are the major tree species of the zone. The dominant shrubs are blueberries and False Azalea. In the upper elevations where the snowpack remains late into the spring, forests thin out into open parkland where trees are clumped and interspersed with sedge or mountain-heather communities. Forest regeneration is often slow due to the adverse climate (Jones and Annas, 1978).

2.4.3 Climate

The study area which lies in the rainshadow of the Vancouver Island Ranges and Olympic Mountains is characterized by a cool Mediterranean climate with dry, mild, sunny summers and mild moist winters. During the winter months, prevailing westerly winds carry weather systems over the western facing Vancouver Island slopes, where they drop their moisture (Schaefer, 1978). At this time of year, climate at the higher elevations is described as cold and snowy; climate at the lower elevations is described as moderate and rainy.

Based on the 1951- 1980 time period the mean annual temperatures of the southeastern lowlands of Vancouver Island area are just over 10 degrees C. and the average daily temperatures (average of the mean daily temperatures) for January and July are 2.6 and 18.0 degrees C. respectively (Schaefer, 1978). At four different climate stations located in the Nanaimo River basin, mean monthly temperatures were recorded (1978) and are detailed below in Table 2.2.

Table 2.2 Mean Monthly Temperatures Recorded 1978 for the Nanaimo River Basin Area (Ministry of Environment, 1978) Degrees Celsius

Location:	Elevation (metres)	January Mean Monthly Temperatures	July Mean Monthly Temperatures
Green Mountain	1174	- 1.0	16.0
Extension	451	0.0	17.0
Cassidy	201	2.0	18.0
Delta	5	2.0	17.0

The major portion of precipitation falls during the winter with the maxima usually occurring in December. The average annual precipitation varies from 76 centimetres at the mouth of the Nanaimo River to 152 centimetres at the headwaters. The large amount of precipitation during most of the year has, in the past, ensured that soils are constantly moist. During mid to late summer, the warming and drying of the soils normally results in summer moisture deficits estimating from less than 100 mm to 200 mm depending on the site (Schaefer, 1978).

Snow surveys from Green Mountain show that snow accumulates during the winter months and reaches its maximum in April when an average of 1390mm of water equivalent will be stored in the snowpack (Table 2.3). This water is released as the weather warms and the snowpack is usually depleted by the end of June.

Table 2.3 Green Mountain Snow Course Data, Mean Water Equivalent for Period of Record 1954 - 1985 (elevation 1400 m)

Date of Observation	Mean Snow Water Equivalent (mm)
January 1	443
February 1	843
March 1	1126
April 1	1480
May 1	1444
June 1	1188

2.4.4 Soils

According to Jungen and Lewis (1978), the Humo-Ferric Podzol soil landscape occurs predominantly within the Coastal Western Hemlock and Coastal Douglas-fir biogeoclimatic zones and in all low valleys away from the outer coast within the Nanaimo River Basin. This soil type has developed from glacial moraine derived from granodiorite bedrock. These soils are well to moderately well drained with dark reddish colours. Textures are predominantly coarse to medium. The soil temperature classes include mild mesic, cool boreal, and cold cryo-boreal while the soil moisture regime is dominantly humid.

The Dystric and Sombric Brunisol soil landscapes occupy a minor part of the basin and occur within the lowest elevations of the Coastal Douglas-fir biogeoclimatic zone. Of the two soil types, the Sombric occurs in the driest sites. It is usually found below elevations of 50 meters where effective moisture is lower than it is in the Dystric landscape. Both soils are moderately to slightly acidic and have low to moderate base saturations. Major parent materials include medium to coarse textured compact glacial till and fine textured marine. The soil temperature class is mild mesic and the moisture regime is semiarid (Jungen and Lewis, 1978).

CHAPTER 3 THE WATER RESOURCES

3.1 Surface Waters

The Nanaimo River at its mouth drains a watershed of 813 square kilometres. The flow of the river is measured by Water Survey of Canada at a site near Cassidy which has a drainage area of 665 square kilometres. The mean annual discharge (MAD) at this location for the years 1966 to 1988 is 39.3 cubic metres per second (m^3/sec). In terms of volume of water this is equal to 1,240 million cubic metres.

The distribution of this flow throughout the year is illustrated in Figure 3.1 which gives the mean monthly flows based upon the 1966 to 1988 period. Maximum flows are usually recorded in December. Low flows have historically occurred during the June to October period with most annual minimum daily discharges recorded during the latter part of August and early September. Most water use shortages occur during this period.

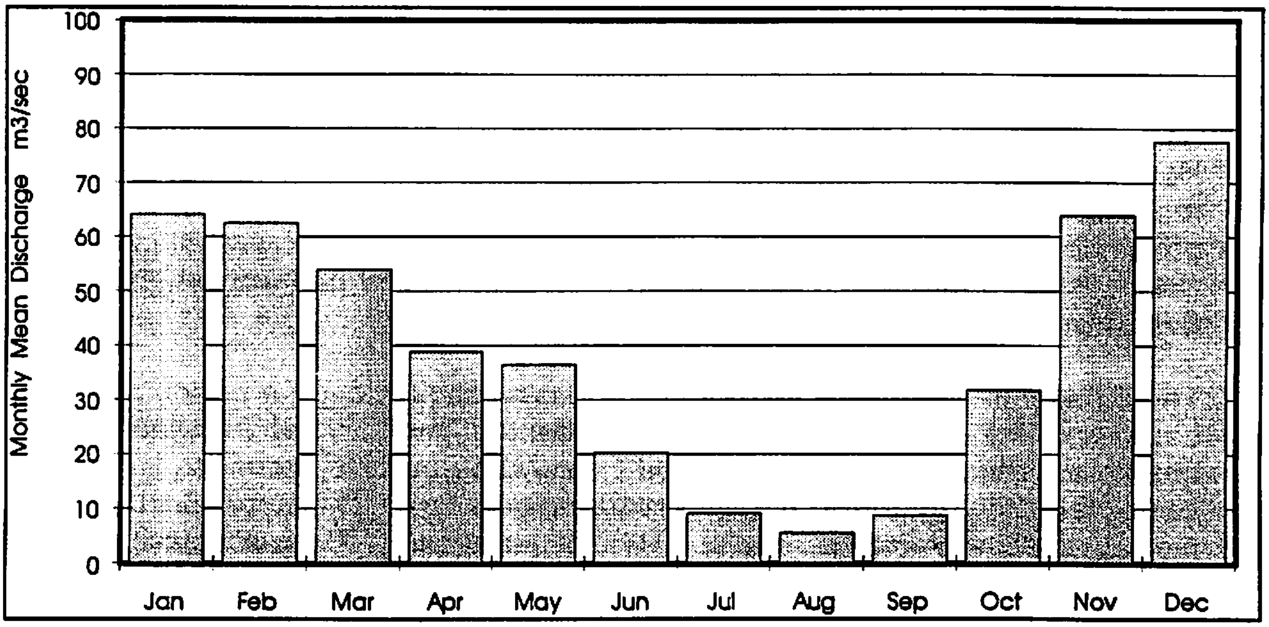


Figure 3.1 Mean Monthly Discharge, Nanaimo River near Cassidy (Water Survey of Canada Station Number 08HB034) 1966 to 1988

The natural flow regime is not represented at this site during this period because the site is situated downstream of storage and diversion works in the basin.

The Nanaimo Lakes are two significant natural lakes in the central portion of the basin. With surface areas of 200 and 180 hectares, they create a moderating effect on the flow of the river originating in the watershed upstream of the lakes. There are three man-made reservoirs in the basin. These are South Fork reservoir and Jump Lake reservoir, both owned and operated by the Greater Nanaimo Water District (GNWD), and Fourth Lake reservoir, owned and operated by MacMillan Bloedel Harmac Division (Harmac).

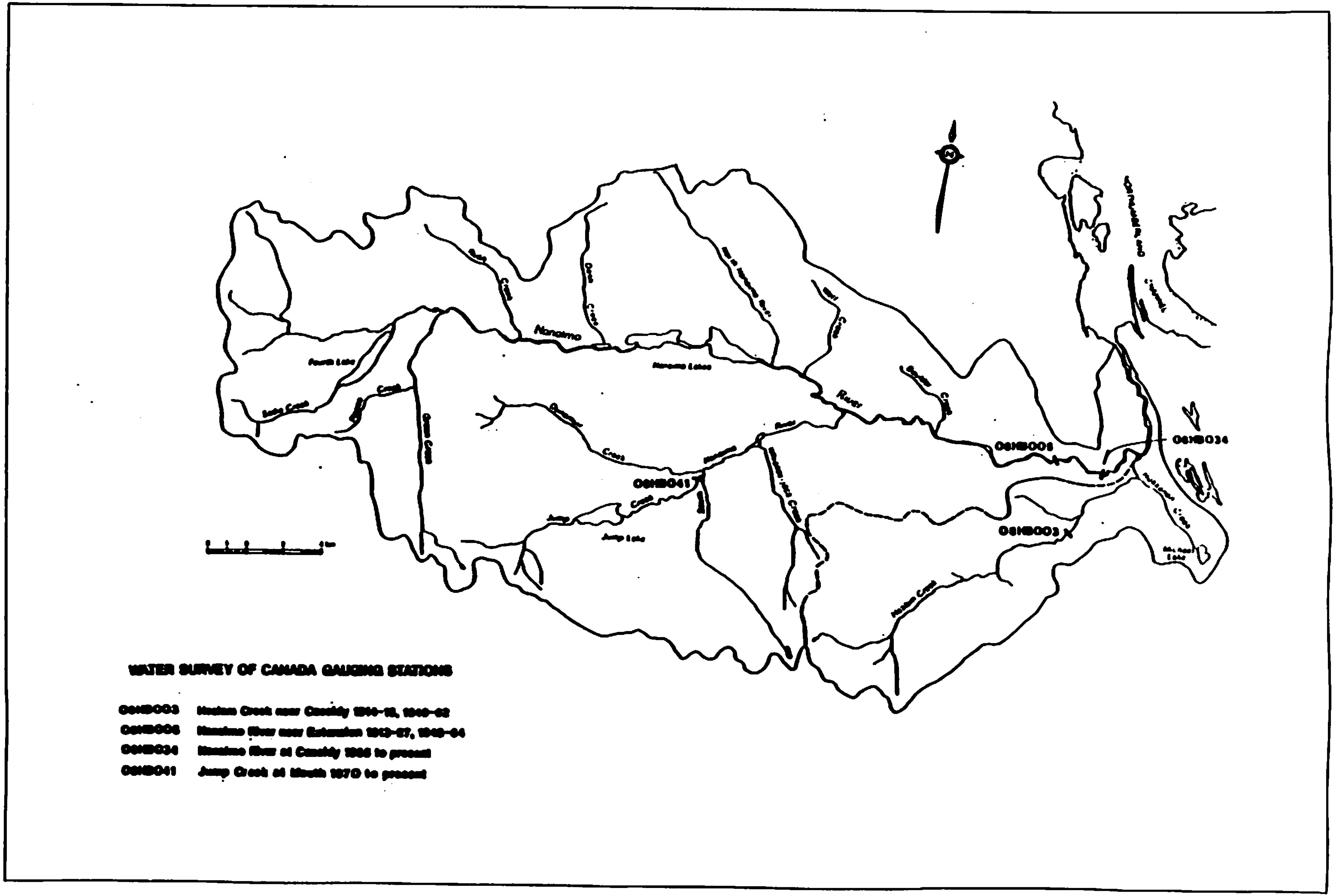
The GNWD diverts water at South Fork reservoir to provide the City of Nanaimo with its municipal water supply. The volume of water diverted in 1989 was 12 million cubic metres which is a rate of about 0.384 m^3/sec. Harmac controls the outflow from Fourth Lake reservoir to provide flow farther downstream which is then withdrawn from the river and pumped to Harmac. This diversion, which amounted to 76 million cubic metres (2.43 m^3/sec) in 1989, takes place at a site just downstream of the Island Highway. By regulating releases from their reservoirs, Harmac and the GNWD maintain a minimum residual flow of 1.38 m^3/sec in the lower Nanaimo River downstream of Harmac's water intake.

3.1.1 Streamflow Records

Within the Nanaimo River basin there are several sites where streamflow has been recorded. These sites are shown on Figure 3.2, and their period of record is given in Table 3.1.

Table 3.1 Hydrometric Stations in the Nanaimo River Basin

Hydrometric Station	Drainage Area km^2	Mean Annual Discharge m^3/sec	Years of Record	Notes
Nanaimo River near Cassidy 08HB034	684	39.3	1965-1988	flow regulated since 1963
Nanaimo River near Extension 08HB005	645	40.4	1913-1927 1948-1962	natural flow
Jump Creek at the Mouth 08HB041	62.2	4.80	1970-1988	flow regulated since 1974
Haslam Creek near Cassidy 08HB003	95.6	4.38	1914-1915 1949-1962	natural flow, 7 years complete data



Figu 3.2 naiı Riv Basi lydı etr. tat

In addition to the Nanaimo River near Cassidy (08HB034) which has been used above to provide a brief description of the river flows, there was another hydrometric station in operation on the Nanaimo River about 3 km upstream during the years 1913-27 and 1948-64. This station, Nanaimo River near Extension (08HB005), was recording natural flow up until 1963, and after that time the flows were subject to regulation by upstream storage. The mean annual discharge at this site during the period of record prior to regulation is 40.4 m^3/sec which is a volume of about 1,270 million cubic metres in the average year. The monthly distribution of this flow is shown in Figure 3.3. Both the mean annual discharge and the monthly mean flows are similar to those for station 08HB034. The most important difference between the two sets of data is seen in the month of August. The natural flow (Nanaimo River near Extension) for August has a mean value of 4.25 m^3/sec compared to the regulated flow (Nanaimo River near Cassidy) of 5.62 m^3/sec. The effect of the reservoirs has been to increase the August flow by about 30 percent. This effect applies to the river upstream of the Harmac diversion, and does not apply :o the river downstream of the diversion point.

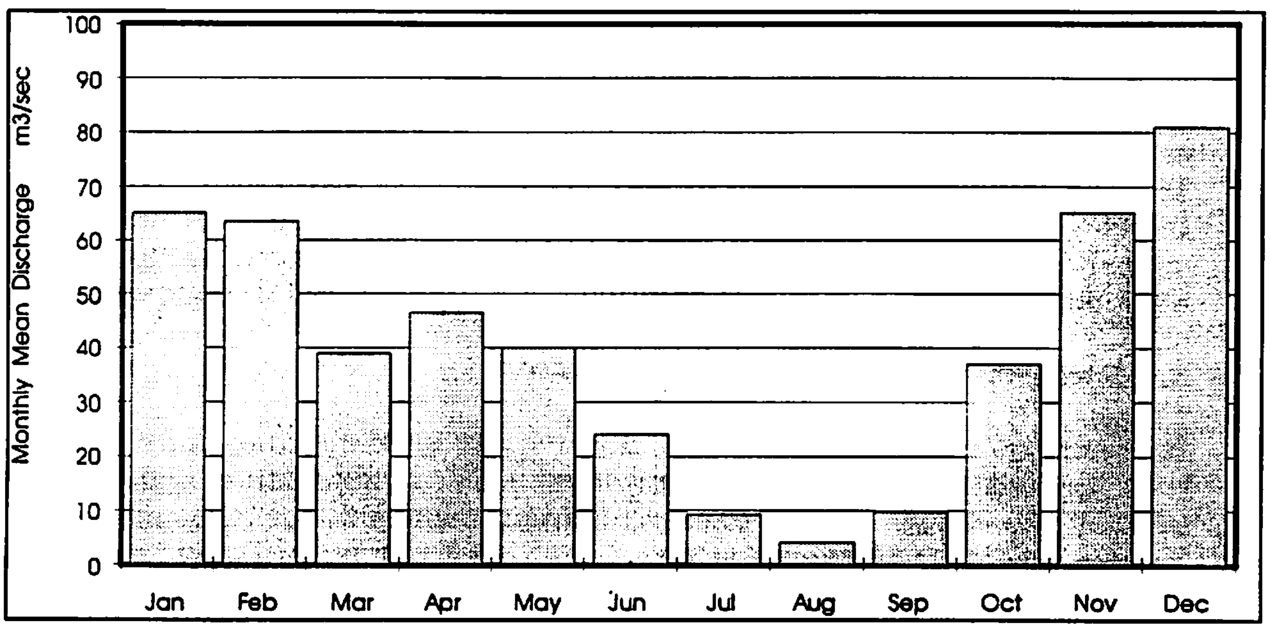


Figure 3.3 Monthly Mean Discharge, Nanaimo River near Extention (08HB005) during the Period 1913-27 and 1948-64

A hydrometric station, Jump Creek at the mouth (08HB041), has been in operation since 1970. From 1974 onward the flow recorded at this site has been subject to regulation by Jump Lake reservoir. In the period 1970-88, the mean annual discharge is 4.80 m^3/sec which is a volume of about 151 million cubic metres per year. The monthly mean flow is shown in Figure 3.4.

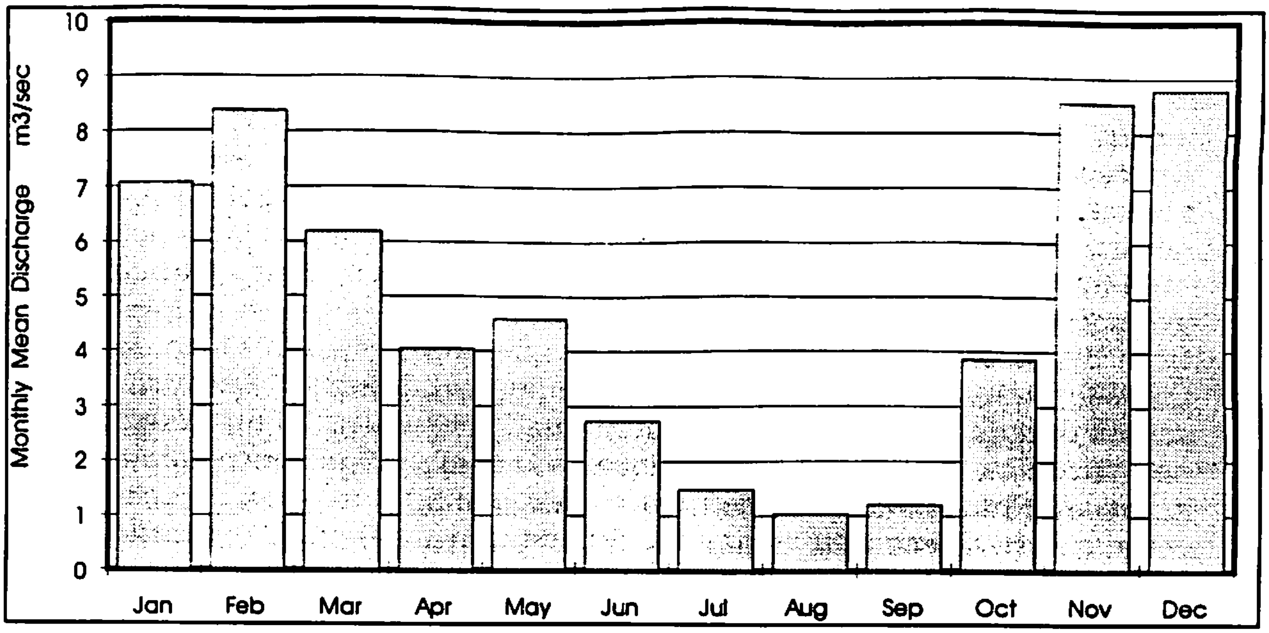


Figure 3.4 Monthly Mean Discharge, Jump Creek at the Mouth (08HB041) during the Period 1970-88

Haslam Creek also has some streamflow data. This was collected at a station called Haslam Creek near Cassidy (08HB003) which was in operation during 1914-15 and again in 1949-62. The records have significant gaps in them and therefore there are only seven years with complete records. For those seven years the mean annual discharge was 4.38 m^3/sec, an annual volume of 138 million cubic metres. Mean monthly flows are illustrated in Figure 3.5.

3.1.2 Reservoir and Lake Level Records

There are no significant records of water levels for the Nanaimo Lakes which could be used for this water management plan. Acquisition of water level data in the future would help in understanding the effect of the lakes on river flows. There are records of water levels on South Fork reservoir, Jump Lake reservoir, and Fourth Lake reservoir. These records are intermittent and missing data have been estimated by interpolation for the years 1980 to 1989.

The recorded water levels (or estimated when necessary) for the first day of each weekly period are presented in Appendix II. To illustrate the manner in which Jump Lake reservoir and Fourth Lake reservoir have been operated levels for 1989 and the mean levels for 1980 to 1989 are shown in Figures 3.6 and 3.7. South Fork reservoir is not operated as a storage reservoir and its levels remain relatively constant at the dam crest during the summer, and rise above the crest during the winter months as higher flows pass over the dam.

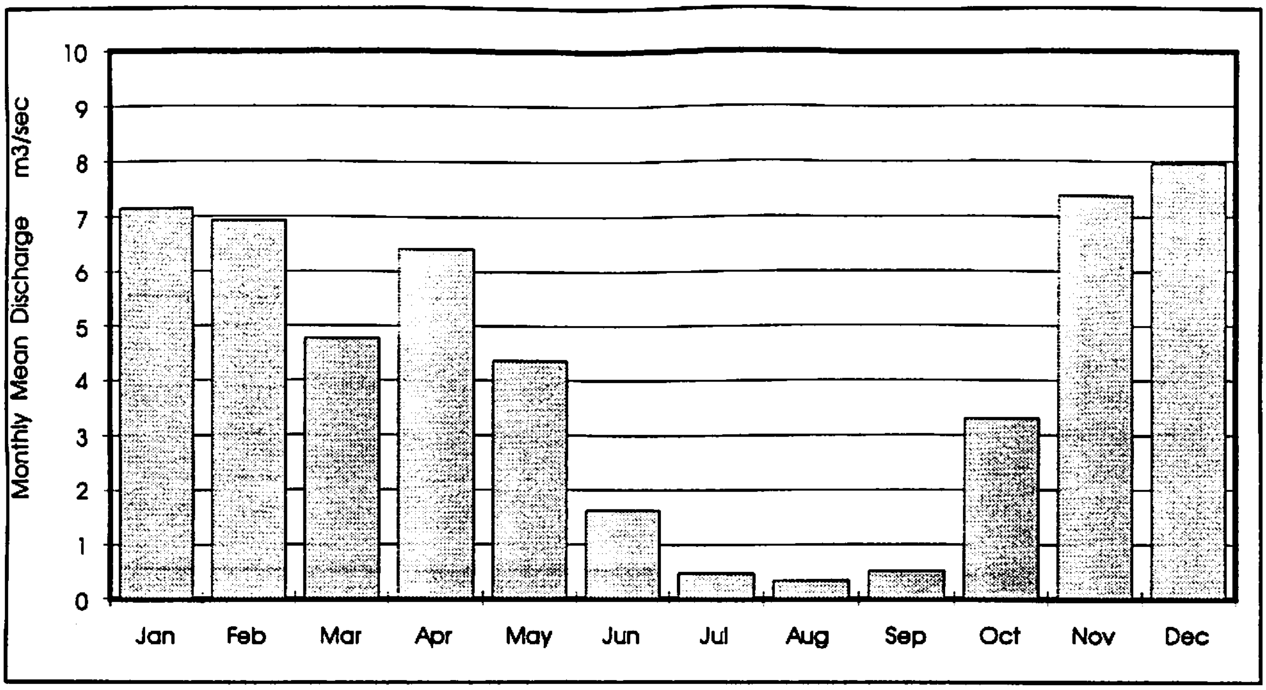


Figure 3.5 Monthly Mean Discharge, Haslam Creek near Cassidy (08HB003) during the Period 1914-15 and 1949-62

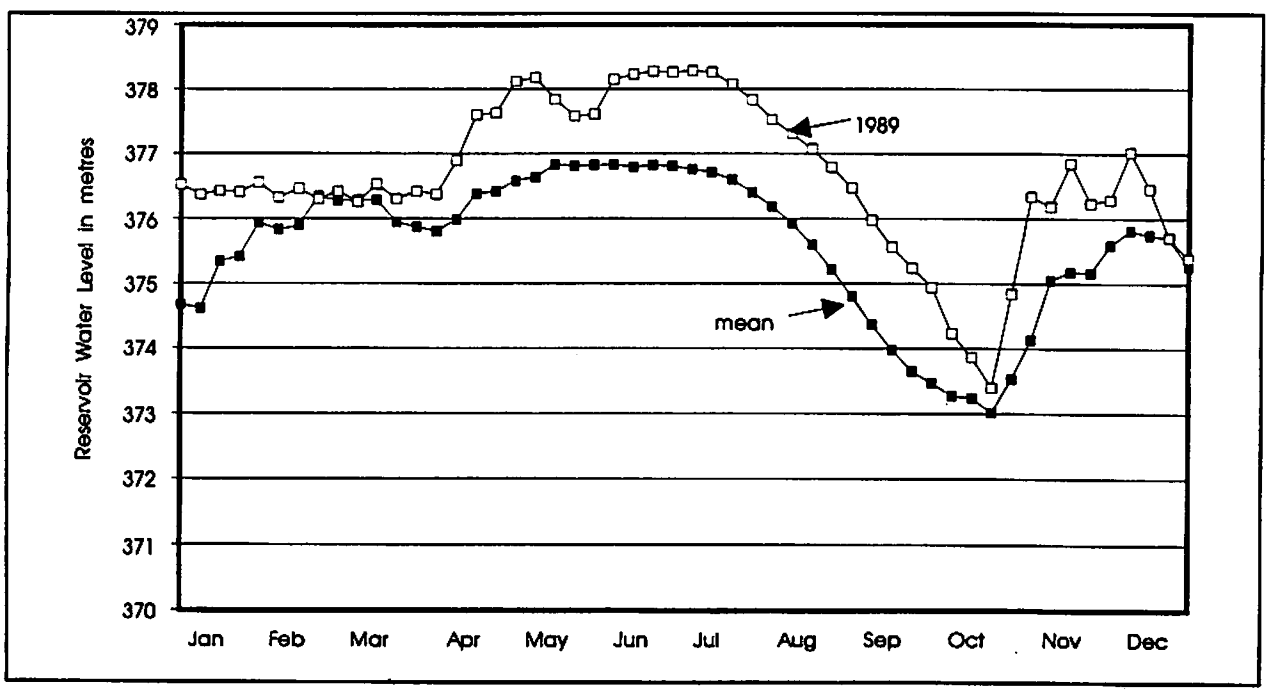


Figure 3.6 Jump Creek Reservoir Levels for 1989 and the Mean of the Levels from 1980 to 1989

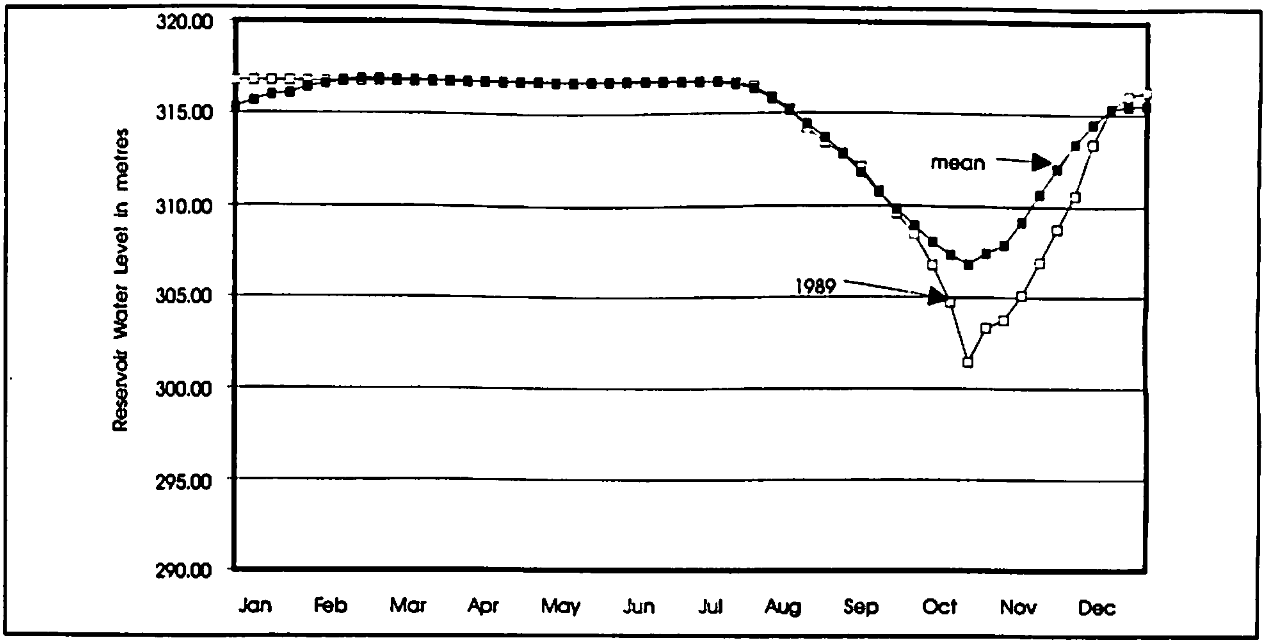


Figure 3.7 Fourth Lake Reservoir Levels for 1989 and the Mean of the Levels from 1980 to 1989

3.1.3 Effects of Storage and Diversion

Jump Lake reservoir has a live storage capacity of 17 million cubic metres at a site where the calculated natural flow (1980-89) is 146 million cubic metres per year on the average. It can therefore capture and hold about 12 percent of the average annual volume. The storage capacity of Jump Lake is primarily for the provision of regulated releases to South Fork for diversion to the GNWD and to maintain minimum flows for fish. The amount of water diverted to the GNWD varies from year to year and is increasing as the population increases. In 1989 the volume diverted was 12 million cubic metres. The reservoir is operated to release water in the summer when natural flows are low, and to store water in the winter when natural flows are high. This is shown in Figure 3.6.

Fourth Lake reservoir has a live storage capacity of 38 million cubic metres. At this location there are no records of streamflow, but estimates have been made based upon reservoir levels and releases. These estimates indicate that for the period 1980-89, the average annual volume of flow was 104 million cubic metres. The reservoir therefore has the potential to capture and hold about 37 percent of the average annual volume.

Releases are made from the reservoir to provide increased streamflow in the summer to compensate for withdrawals made downstream for use at Harmac, and to maintain minimum flows for fish. The volume of water withdrawn each year has been relatively constant during the period 1980-89, and in 1989 the withdrawal was 76 million cubic metres.

The principal effect of the reservoirs has been to increase summer flows in the Nanaimo River upstream of the Island Highway. However, downstream of the Harmac diversion, the summer flows are influenced by the amount being diverted. The minimum flow to be maintained downstream of the Harmac diversion is 1.38 m^3/sec.

In recent years reservoir releases have been increased in the fall to assist in the migration of spawning salmon.

3.1.4 Low Flows

The most critical time for meeting demands on the water resource is during periods of low flow. In the Nanaimo River basin this occurs in late summer and early fall. One criterion which indicates the impact of low flows on the fish resource is (Section 5.3.6) that fish habitat is good when flows are 30 percent of the mean annual discharge (MAD) and poor at 10 percent or less of MAD. For the Nanaimo River near Cassidy, the minimum recreational fish flow for April to July is recommended to be 7.8 m^3/sec which is 20% of MAD. During July to September a minimum flow of 5.85 m^3/sec, 15% of MAD is recommended, and in September a target minimum of 3.9 m^3/sec is suggested.

As a way of illustrating the natural low flow conditions in the Nanaimo River basin the historical streamflow records of Haslam Creek and the Nanaimo River near Extension have been examined. Table 3.2 is a listing of the mean monthly flows for July, August, and September for the period of record on Haslam Creek. The flows lower than 10% of MAD are shown in bold print and demonstrate that the natural flow regime is frequently lower than the desirable values. For example, 11 of the 14 months of August are less than 10% of MAD, and about one-third of them are less than 5% of MAD.

A similar review of the records for Nanaimo River near Extension shows that about half the months of August have mean flows less than 10% of MAD, and about one-fifth are less than 5% of MAD. These data are summarized in Table 3.3

Analyses of low flows are often based upon the average of the lowest 7 day period each year, rather than using the lowest one day flow which may present an uncertain picture of the low flow due to the difficulties in obtaining accurate measurements.

The 7 day low flow values for the Nanaimo River near Extension (natural flows) have been analyzed statistically. The mean 7 day low flow for the 32 years of record was 2.11 m^3/sec which is about 5% of MAD. On the average of once every five years, the 7 day low flow will drop to 1.29 sec or lower.

A similar analysis for Haslam Creek near Cassidy (Station No. 08HB003) produced a mean 7 day low flow of 0.208 m^3/sec which is also about 5% of MAD for the 16 years of flow records. T8he 7 day low flow will drop to 0.134 m^3/sec or lower once every five years on the average. Only 7 years of record are available for complete years, but 16 have sufficient data to derive the 7 day low flows for the longer period.

Table 3.2 Haslam Creek near Cassidy 08HB003, monthly mean discharge for July, August, and September

Year	Haslam Creek near Cassidy 08HB003 MAD=4.38 m^3/sec monthly mean discharge m^3/sec		
	July	August	September
1914	**0.273**	**0.099**	0.450
1915	**0.167**	---	---
1949	**0.344**	**0.251**	**0.268**
1950	0.507	**0.311**	**0.176**
1951	**0.184**	**0.136**	0.439
1952	**0.424**	**0.331**	0.333
1953	0.722	**0.374**	0.743
1954	1.15	**0.415**	0.972
1955	0.836	0.734	0.562
1956	0.769	**0.249**	0.482
1957	0.476	0.962	0.779
1958	**0.220**	**0.173**	0.506
1959	0.484	**0.193**	0.927
1960	0.505	0.492	**0.349**
1961	**0.188**	**0.130**	**0.319**
1962	**0.349**	---	---

*** Bold - mean monthly flow less than 10% of MAD**

Table 3.3 Summary of Incidence of Flows Less than 10% of MAD for Haslam Creek near Cassidy and the Nanaimo River near Extension

Months	Nanaimo River near Extension 08HB005 MAD=40.5 m^3/sec			Haslam Creek near Cassidy 08HB003 MAD=4.38 m^3/sec		
	Total Months of record	Number of months less than 10% MAD	Number of Months less than 5% MAD	Total Months of Record	Number of Months less than 10% MAD	Number of Months less than 5% MAD
July	28	7	2	16	8	3
August	29	15	6	14	11	5
September	29	11	6	14	5	1
October	28	3	3	13	1	0

The 7 day low flow periods for the Nanaimo River near Cassidy (regulated flows) have also been analyzed, and for the years 1965-85 the mean 7 day low flow was 4.12 m^3/sec which is about 10% of the MAD. This increase in the 7 day low flow over the natural condition has been one of the beneficial effects of the reservoirs on recreational fisheries upstream of the Harmac diversion.

The Lows Flows of 1987 in Perspective

The summer of 1987 was a period of low flows for long duration on many rivers on east Vancouver Island. Reference to Table 3.4, will illustrate that the calculated natural flows at Node 2 (Nanaimo River near Cassidy, station 08HB034) were low for a long period in 1987. The flows were below 10% of the mean annual discharge for a period of 16 weeks, and were below 5% of the mean annual discharge for 7 consecutive weeks and a total of 11 weeks.

Since 1987 is a year which would place a significant strain on a water supply system to meet demands, it is of interest to identify if this situation is a common occurrence or a rare occurrence. Because the recorded streamflow records of the Nanaimo River include the effects of reservoir operation, these records cannot be used to assess the natural low flow conditions in that watershed. Fortunately there are 40 years of natural flow records for the Chemainus River which is the watershed immediately south of the Nanaimo.

The results indicate that 1987 was a year of record low flows on the Chemainus River due to the length of time the low flows persisted. For example the low flows experienced over durations of 9 weeks, 13 weeks, and 17 weeks in 1987 were record lows for the forty years that the river has been gauged.

Statistically, the 9 week low flow in 1987 has a recurrence interval of about once in 50 years. Similarly the 13 week and 17 week low flows have recurrence intervals of 60 years and 80 years respectively.

Table 3.4 Calculated Natural Flow at Nanaimo River near Cassidy 08HB034, 7 day averages in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
23	Jun 04-Jun 10	14.82	15.98	25.87	14.41	23.60	14.84	13.81	19.86	60.54	12.24
24	Jun 11-Jun 17	18.39	14.68	32.86	18.79	21.72	12.28	10.50	24.22	22.08	12.96
25	Jun 18-Jun 24	10.82	24.15	24.53	18.88	16.69	10.05	12.88	14.63	18.51	7.82
26	Jun 25-Jul 01	19.01	15.04	19.09	11.78	18.55	6.01	7.94	10.86	12.23	8.70
27	Jul 02-Jul 08	18.95	8.01	15.90	9.42	14.42	5.00	7.51	6.69	10.85	10.90
28	Jul 09-Jul 15	13.68	5.17	9.12	39.60	9.76	**1.89**	6.06	4.74	9.73	5.94
29	Jul 16-Jul 22	7.99	3.88	6.53	16.82	7.00	**1.75**	4.56	2.07	8.08	4.45
30	Jul 23-Jul 29	4.57	2.97	4.09	8.38	6.18	**1.20**	2.32	2.97	5.23	3.21
31	Jul 30-Aug 05	3.27	3.10	3.96	5.48	3.81	**0.44**	2.12	**1.55**	3.23	**1.93**
32	Aug 06-Aug 12	3.13	3.51	3.11	2.96	**0.94**	**1.04**	**1.11**	**1.71**	2.27	**1.93**
33	Aug 13-Aug 19	1.99	4.02	3.53	2.33	2.08	**1.39**	**0.88**	**1.52**	2.59	**1.72**
34	Aug 20-Aug 26	**1.93**	2.41	**1.78**	**1.72**	**1.60**	**0.50**	**0.77**	**1.00**	2.27	2.45
35	Aug 27-Sep 02	1.98	**0.08**	**1.34**	4.25	**0.71**	**1.37**	**0.17**	**0.08**	**1.74**	**1.94**
36	Sep 03-Sep 09	2.26	**0.43**	**1.17**	4.95	2.54	**0.15**	**0.00**	**0.20**	**0.68**	**0.09**
37	Sep 10-Sep 16	2.35	2.31	7.94	8.27	3.17	**1.93**	**1.75**	**0.00**	**0.79**	**0.55**
38	Sep 17-Sep 23	4.78	11.01	**0.00**	4.88	11.38	3.91	**0.10**	2.24	**1.74**	**0.53**
39	Sep 24-Sep 30	6.82	26.87	**1.43**	3.24	4.44	**1.36**	**1.34**	**0.39**	4.09	**1.22**
40	Oct 01-Oct 07	18.32	67.08	3.75	2.54	7.86	**1.35**	**1.62**	2.06	3.33	**0.58**
41	Oct 08-Oct 14	5.82	84.84	11.83	8.09	159.93	4.83	**1.50**	**0.51**	2.30	**1.07**
42	Oct 15-Oct 21	6.45	35.17	17.92	8.93	46.17	57.90	**1.49**	**1.69**	[illegible]	[illegible]
43	Oct 22-Oct 28	8.93	81.40	242.89	39.95	17.03	94.71	8.06	**0.72**	[illegible]	[illegible]
44	Oct 29-Nov 04	68.50	190.10	66.83	63.25	54.54	59.80	21.03	2.44	[illegible]	[illegible]
45	Nov 05-Nov 11	171.72	40.79	55.19	121.97	126.81	31.46	7.22	5.82	[illegible]	[illegible]

note: -unshaded values are less than 10% MAD
-bold values are less than 5% MAD

While this interpretation for the Chemainus River may not be directly applicable to the Nanaimo River, it does suggest that 1987 was an unusually long dry summer. The low flows in 1987 on the Englishman River were also the lowest and longest on record for the 14 years in which data are available.

Therefore the model results presented in Chapter 7 for 1987 should be kept in perspective since the supply of water in that year from mid July to late October may have a recurrence interval as great as once in 80 years.

3.1.5 Precipitation and Evaporation

Data for precipitation and evaporation were not available within the basin at sites that were representative of the entire watershed. Hence, precipitation at the climate station at Lake Cowichan Forestry District was selected, and a summary is found in Appendix II, Table 8. Evaporation data were selected from the only available site (Saanich) and are summarized in Appendix II, Table 9.

3.2 Groundwater

The following sections focus on the water well data, groundwater potential and unconsolidated deposits of the groundwater resources in the Nanaimo Basin area. Detailed in the Appendix III is the evaluation of groundwater resources within the Cassidy Aquifer and the associated maps depicting the extent of the bedrock exposure (Figure 1) and well locations (Figure 2).

3.2.1 Description of the Groundwater Resource

The Cassidy Aquifer, is designated as that portion of the major deposit of unconsolidated water-bearing materials which lies south of Haslam Creek and extends south easterly as far as the head of Ladysmith Harbour which lies outside the basin boundary. The Cassidy Aquifer occupies an area of 4.9 square kilometres and is part of a much larger alluvial aquifer system which extends north of Haslam Creek to South Wellington.

The upper aquifer is an important source of local water supplies. Individual dug and shallow drill wells are capable of yielding 1.3 to 3.1 L/sec.

The Harmac Division of MacMillan Bloedel Ltd. presently operates three infiltration galleries (Ranney collector wells) two of which are sited along the Nanaimo River and one beside Haslam Creek east of the Island Highway. These collector wells are recharged by Haslam Creek and the Nanaimo River. Harmac also operates three conventional drilled wells located north of Haslam Creek. These wells are all thought to be inter connected by permeable alluvial materials with the surface water withdrawals and are licensed together with the surface supplies.

The North Cedar Waterworks District developed five wells in the floodplain of the Nanaimo River to supply water for the community. These demands on the aquifer are expected to continue as developments are approved. Water withdrawals from these wells may affect flows in the Nanaimo River due to the interrelationship between surface and groundwater flows.

3.2.2 Water Well Data

The locations of approximately 1,500 water wells reported to have been constructed in the region which includes the Nanaimo River basin are detailed in Figure 2, Appendix III. This figure does not represent all wells constructed in the area, since there is no mandatory submission of well records and not all well records are valid. Figure 3.8 below presents the cumulative number of wells constructed in the area over the past 40 years.

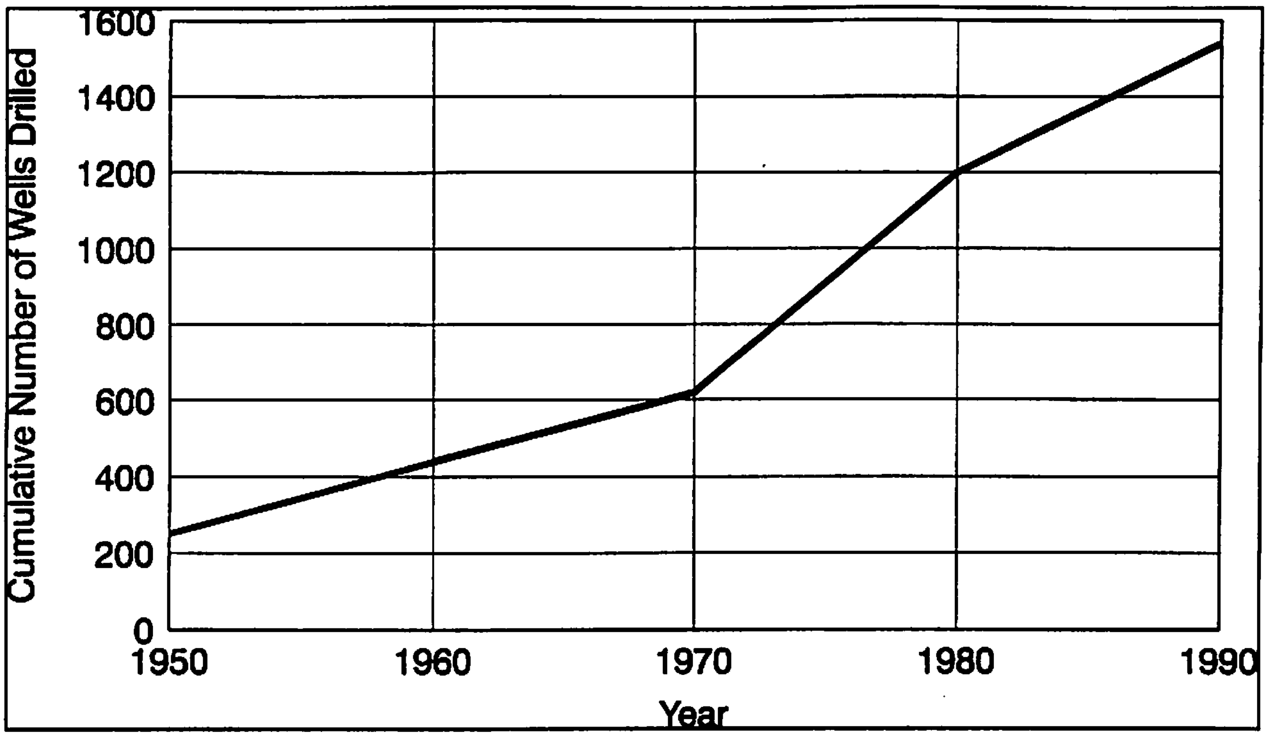


Figure 3.8 Cumulative Water Wells Constructed in Nanaimo River Basin Over Last 40 Years

3.2.3 Groundwater Potential

Bedrock

The extent of bedrock exposure (bare and shallow surficial veneer over bedrock) is shown in Figure 1, Appendix III. This map also shows that the majority of water wells (approximately 75%) constructed in the area are in bedrock. Wells constructed in bedrock generally obtain groundwater from water-filled fractures in the rock. Because fractures can be erratic in their extent, positions and concentrations, and the open volume only occupies about 1% of the rock mass, the amount of groundwater that is available for extraction can be limited. Additional groundwater can also be recovered from porous bedrock, such as some sandstones.

Approximately 87% of the wells constructed in bedrock have reported yields less than 0.6 L/s, but generally sufficient for domestic needs. Approximately 12.5% of the bedrock wells (about one hundred and forty wells) have reported yields between 0.6 L/s and 3 L/s. There are only 0.5% of the bedrock wells (six wells) that have reported yields between 3L/s and 6 L/s. These higher yields are not confirmed by long term pumping tests, but are based on drillers' short term tests. Longer term (up to seventy-two hours) constant rate pumping tests would be needed to assess the long term safe yields of these wells.

It is difficult to assess the potential for further development of water wells in bedrock, due to the lack of pumping test data and the uncertain nature of bedrock fractures. Additional wells in bedrock may be constructed, however, most yields are expected to be limited to meet only domestic needs. In areas where there are concentrations of wells, for example, South Wellington and east of Cassidy, construction of additional wells in bedrock may not be advisable due to potential pumping interference effects and the limited amount of groundwater in storage in the fractures of the bedrock to sustain additional groundwater withdrawals.

Unconsolidated Deposits

The general extent of the major unconsolidated confined and unconfined groundwater aquifers in the area, generally referred to as the Cassidy Aquifer is revealed in Figure 1, Appendix III. Also in this appendix, analysis of the hydrogeological cross-sections identifies the probable extent of a significant confined sand and gravel aquifer in the Cassidy area. The unconfined Cassidy Aquifer has been subdivided into 6 discrete areas, A to F,(Figure 2), and the complete evaluation of each of these aquifer areas is presented in Appendix III. The pertinent information regarding each of these areas is summarized in Table 3.5.

3.2.4 Groundwater Summary

The Nanaimo River Basin contains a significant and highly permeable sand and gravel aquifer, termed the Cassidy Aquifer, which provides groundwater for domestic, irrigation, community, fish hatchery and industrial uses. The extent of the Cassidy Aquifer has been identified and a quantitative assessment of the groundwater use and potential for further development has been addressed. There appears to be a significant groundwater/surface water inter-relationship and potential for further flow supply problems as these sources are developed.

3.3 Groundwater/Surface Water Inter-Relationship

Early investigations of the groundwater resources in the Cassidy area by Odynsky (1952) and Nasmith (1952), revealed that there is an inter-relationship between the permeable unconfined sand and gravel (Cassidy) aquifer and Nanaimo River and Haslam Creek. These surface waters along their courses, naturally draw from and lose water to the groundwater system due to the hydraulic continuity between these water courses and the Cassidy Aquifer.

Since the construction of a number of major production wells along the Nanaimo River and Haslam Creek during the past 40 years, the relationship between groundwater withdrawals and surface water flows and the potential for surface water/groundwater conflicts has not been fully assessed.

An assessment of the effects of major groundwater withdrawals and potential for additional withdrawals on stream flows will require among other considerations, a review and analysis of surface water use, groundwater inventory and extraction data, groundwater level measurements, streamflow measurements, water quality sampling (surface and groundwater), pumping tests and possibly test drilling and monitor well construction.

Table 3.5 Summary of Aquifer Areas

Unconf. Aquifer Area	Area sq. ft. X 10^6	Area acres	Estimated Average Aquifer Thickness ft.	Volume CU.FT. X 10^6	Assume Porosity, N = 0.25 Vol. GW in Storage CU.FT. X 10^6	GAL. X 10^6	Assuming specific Yield Factor = 0.88 Am't Extractable GW GAL.X10^6	Estimated Recharge From Precipitation * CU.FT. X 10^6	GAL. X 10^6
A	101	2323	20	2020	505	3777	3324	174	1299
B	29	667	10	290	73	546	480	50	373
C	29	667	10	290	73	546	180	50	373
D	68	1564	40	2720	680	5086	4476	117	875
E	21	483	25	525	131	980	862	36	270
F	44	1012	20	880	220	1646	1448	76	566
Total	325	7475	-	7055	1764	13194	11640	560	4081
Confined Aquifer									
Area	47	1079	40	1880	470	3516	3094		

NOTE: • Average annual precipitation (Nanaimo Airport) = 1104 mm. = 42.8 in.

- Based on a conservative Thornwaite water budget analysis, (Table 2) amount of moisture available for runoff + ground infiltration = 580 mm. = 22.8 in.
- Based on generally coarse nature of surficial materials, and assuming 90% infiltration (according to B. Turner), Estimated Amount of Annual Recharge = 522 mm. = 20.6 in.

CHAPTER 4 WATER QUALITY

4.1 Surface Water Quality

4.1.1 Introduction

Ambient water quality of the Nanaimo River Basin is assessed based on its suitability for various licensed demands and instream uses. Water uses and activities that affect the quality of the water within the watershed will provide the framework for this water quality assessment. The following sections outline the data available, discuss the quality of water necessary for the various water uses and analyzes trends of quality at one site.

4.1.2 Data Collection

Water Uses

A review of water licences revealed that water withdrawn from the Nanaimo River or its tributaries is used for the drinking water supply, industrial, irrigation and stock watering purposes. Even though water is not consumed, water for aquatic life, ecosystem protection and contact recreation is considered to be valuable. There are presently no permitted waste discharges in to the river.

The GNWD removes water at its South Fork reservoir and pipes it to the City of Nanaimo. This reservoir, situated near the bottom of the South Fork of the Nanaimo River watershed, is isolated and is partially protected by restricted access. MacMillan Bloedel Ltd. is the principal industrial user in the area; their intake down stream of site 0125180 (Figure 4.1). Salmon and trout are present throughout the watershed. For the purposes of this assessment, it is assumed that contact recreation occurs throughout the Nanaimo River watershed.

Watershed Activities

Activities in a watershed can affect the water quality. Knowledge of these activities and the impacts allows for a specific selection of parameters used for monitoring. Logging, the principle activity in the upper watershed (above the forks of North and South Nanaimo Rivers), and its associated erosion can lead to increased turbidity and suspended solids, especially during heavy rain events. This is particularly important in the South Fork where water is extracted for the community supply.

Mining exploration in the north fork is indicative of mineralization and inputs of metals into the water. In the past, there has been coal mining and placer mining below the forks, but little present activity. There are gravel pits which may contribute to turbidity and suspended solids.

In the lower river, below the highway, there are a number of farms and residences, which may be sources of nutrients (and possibly pesticides). Also water extraction in this lower area for irrigation, for residential use, or other reasons, may increase water quality concerns during low flow periods.

Water Quality Data

A historical data set consists of water quality samples collected from locations on the Nanaimo River between 1968 and 1984, at sites 0125180, 0125181, and 0130860 (Figure 4.1). The most complete data set was taken at site 0125180, Nanaimo River at the highway, where samples were as frequent as monthly. A fairly broad list of parameters were analyzed, including pH, specific conductance, basic ions and metals. This historical data set is useful for comparison to the recent data as well as part of the overall analysis. Summary statistics for the historical data set are provided in Appendix IV.

A more recent sampling program was carried out as part of this Water Management Plan. In 1990, the program consisted of monthly samples at four sites, from April to November, and analyzed for pH, temperature, dissolved oxygen, alkalinity, turbidity, suspended solids, nitrate-nitrite, ammonia nitrogen and ortho-phosphorus. Total and dissolved metals samples were also analyzed at two sites. "Objectives monitoring" were conducted twice for five consecutive weeks, once during a suspected run off period in May, and during a low flow period in August.

Bacteriological analysis and chlorophyll a were sampled for objectives at three sites during the low flow condition. The 1991 program was similar except that an additional site was added, metals analyses were done at all sites, and "objectives monitoring" was also conducted in November high flow. See Tables 4.1 and 4.2 for program summaries and Figure 4.1 for site locations. Also in Appendix IV is the monitoring schedule for both the 1990 and 1991 sampling programs. In the recent sampling programs, the list of parameters is much shorter than for the historical data set since the parameters selected were the ones most likely impacted by activities in the watershed.

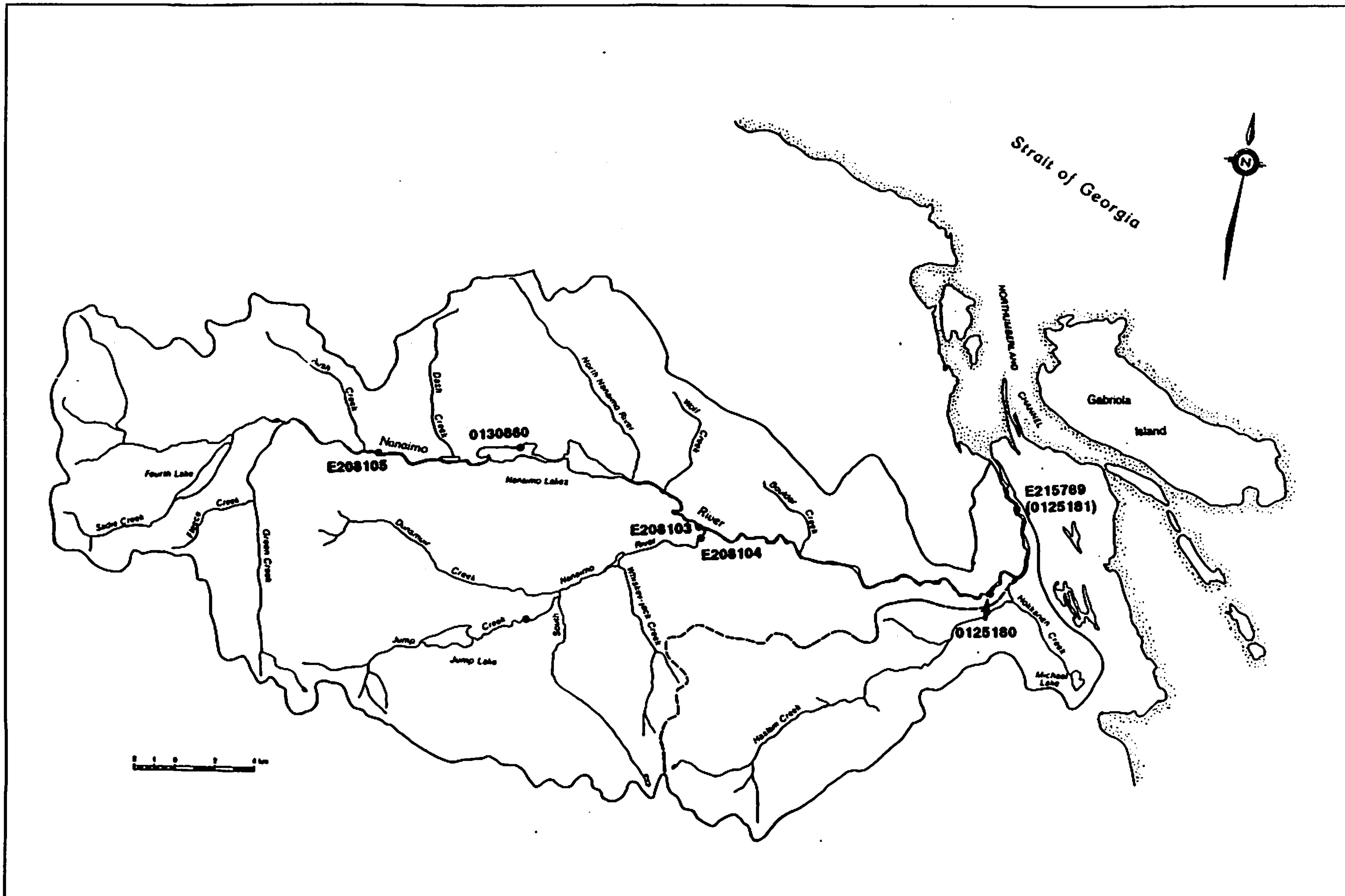


Figure 4.1 Surface Water Quality Sampling Locations in Nanaimo River Basin

In addition to the Ministry of Environment data, the Greater Nanaimo Water District does periodic checks of water quality at their South Fork reservoir, upstream of their intake to the Nanaimo water distribution system. Water was collected from a local water supply but is considered representative of water at the intake noted in Figure 4.1 as site "GNWD". The Greater Nanaimo Water District data is reported in Appendix IV.

4.1.3 Water Quality Assessment

The suitability of the Nanaimo River water for different uses was assessed by comparing available water quality data with criteria for water quality (Pommen, 1991).

Public Drinking Water Supply

The main parameters of concern for drinking water are coliforms, suspended solids, and heavy metals. Other parameters of interest in domestic water supplies, such as conductivity and hardness, do not have quality standards.

Domestic water for the City of Nanaimo is taken from the South Fork. Data is available for the reservoir from GNWD and from the MOELP 1990 and 1991 data sets (Appendix IV). There are very limited sources of coliforms in this watershed. The GNWD has had other extensive analyses of the water done including radioactivity and organic compounds.

The GNWD data shows that the water quality is far better than the water quality criteria for all parameters all the time with only a few exceptions. The principle exception was in a February 1990 sample where the nonfilterable solids (suspended solids) concentration was 6 mg/L, much greater than the provincial criteria of 1 mg/L. This was also confirmed with the turbidity measurement of 4 NTU (criteria is 1 NTU). The suspended solids criteria is at greatest risk of being exceeded because logging occurs in this watershed. Excursions are hard to catch because of the unpredictable rain events which can lead to substantial erosion. Two reservoirs, Jump Lake and the South Fork Reservoir provide some settling and suspended solids are generally not a problem. The second parameter which is outside the recommended criteria is pH which on one occasion was measured at 6.24 (compared to the recommended minimum of 6.5). However, this pH is not considered harmful and data shows the average value is much higher.

The conductivity has varied from 25 to 35 US/cm. The hardness has varied from 11 to 15. The heavy metals arsenic, cadmium, mercury and uranium were less than detectable. Aluminum, lead, and zinc were always much less than the criteria.

Site E208104, sampled by MOELP in 1990 and 1991, is the closest site to the GNWD intake. The presence of coliform bacteria confirms the need to chlorinate the drinking water (the criteria is that the presence of any bacteria requires chlorination). However, the bacteria levels are low and are below the criteria for contact recreation. The maximum value for suspended solids (2 mg/L) is greater than the criteria (1 mg/L). A review of the data shows a scarcity of analyses for the rainfall period from November to January, so no conclusions about the suitability of the water for drinking during that period can be made. With respect to heavy metals, the concentrations are always below the criteria levels; pH was always within the criteria, with a mean of 7.06. The mean alkalinity was 13.2.

Looking at downstream water quality, there was not much change. The water should be treated before drinking due the presence of bacteria in low numbers. More sampling should be done to determine whether suspended solids always meet criteria.

Industrial Use

MacMillan Bloedel Ltd. extracts water from both the Nanaimo River and from wells for use in the Harmac pulpmill. MOELP data for site 0125180, which is where Harmac extracts the water, shows that the suspended solids concentration never exceeds the Provincial industrial use criteria of 10 mg/L. However, even cleaner water is desirable and Harmac supplements this source with well water. Well water is much cleaner and is used preferentially in the bleach plant.

Irrigation/stock watering

None of the data shows impairment of water for irrigation or stock watering use. However, more suspended solids data would be desirable. Special mention is directed to microbiological indicators. Although the levels of fecal coliforms, E.coli, and Enterococci are lower than the criteria for general irrigation use or general livestock use, the water quality between the highway and the Cedar bridge (main area for these uses) has on occasion exceeded the most sensitive criteria.

The criteria for irrigation for crops to be eaten raw, 77/100 ml for E.coli and of 20/100 ml for Enterococci, was exceeded on one occasion. Also, the most stringent criteria for livestock, that is, for closely confirmed animals, battery, or feedlots, is the same as for drinking water, no bacteria. If the river is used for these latter purposes, further treatment may be needed.

Aquatic Life

As a broad generality, the Nanaimo and its tributaries meet all the criteria for protection of aquatic life. However, there have been the infrequent occasion when a criteria maximum has been exceeded slightly. One parameter of concern noted by fisheries agencies has been water temperature. This is substantiated by the data which shows that the criteria of 18 to 19 degrees C.(maximum weekly average) may have been exceeded at the River Camp, Highway and Cedar bridge sites (19.5 to 20.4) in July 1991. This is probably because these sites are downstream of major lakes and the river takes water off the warm surface layers.

The other group of parameters of concern are heavy metals. The average concentrations of all the heavy metals are less than the 30-day criteria for all the metals. However, on occasion, the criteria maximum is exceeded for copper, iron, lead and zinc. The copper criteria is for total copper. The criteria maximum is and 30-day average is 0.002 mg/L. The 30-day means meet the criteria, but instantaneous grabs have had concentrations up to 0.004 mg/L at all sites. This concentration is unlikely to pose a hazard to fish. However, on one occasion, a total concentration of 0.060 mg/L was observed; although this potentially shows a problem, the dissolved sample taken at the same time was analyzed at 0.001 mg/L. The total metals sample might have been contaminated; the zinc sample also showed a great difference between total and dissolved analyses.

The iron criteria is 0.3 mg/L maximum for a grab sample of total iron. This value has been rarely exceeded at the River Camp, highway, and Cedar bridge sampling sites with a maximum concentration of 0.62 mg/L found at the Cedar bridge. However, the excursion was found on only one occasion and was unlikely to adversely affect fish at such low concentration. The lead criteria is a maximum of 3 ug/L for total lead. This was exceeded at the highway in one sampling. At the same time the dissolved lead concentration was only 2 ug/L, and the 90th percentile for dissolved lead is only 1.5 ug/L. Lead is not likely to be a problem. The zinc criteria is 0.03 mg/L maximum for total zinc. This was exceeded on two occasions at the highway site and once at the Teepee bridge site. However, it has never been exceeded for dissolved zinc.

In summary, temperature is the main concern for survival of juvenile and adult salmonids for some periods in July. Heavy metals do exceed maximum criteria for copper, iron, lead, and zinc by a slight margin on an infrequent basis, but dissolved metals are always below the criteria value (for total metals). Metals do not impair the quality of water in the Nanaimo River.

Recreation

Microbiological criteria for contact recreation recognizes two levels of risk: primary and secondary contact. Primary contact criteria consider full submersion and risk of ingestion or intimate contact with eyes and nose. These criteria have been exceeded on a few occasions in the summer at the Teepee bridge, at the Highway bridge, and at the Cedar bridge, but not at the River Camp bridge. This suggests that the recreation occurring at these sites might be affecting the water quality for the purposes of recreation. The concentrations of bacteria have been much lower than secondary contact criteria throughout the watershed. The productivity of the Nanaimo River as measured by the concentration of total phosphorus or periphyton biomass (chlorophyl a) is moderately low and is about 10% of the recreation criteria.

4.1.4 Trend Assessment

The bulk of the historic data for the Nanaimo River is at site 0125180, at the Highway bridge. The recent data programs also collected samples at that site. There is quite a lot of data for the period 1968 to 1982, then relatively little data until 1990 and 1991. Consequently, there are two sets of data which can be analyzed for trends. The following data were chosen on the basis of similar parameters and similar methods of analysis. Since the frequency of sampling is different and variable, the geometric mean is used, instead of a simple arithmetic mean. The data is summarized in Table 4.1.

As can be seen from Table 4.1 there is essentially no change in the water quality for the parameters noted. It could be argued that the data shows a slight decrease in non-filterable residues (suspended solids) and turbidity, but a review of the data suggests that this is an result of sampling, with very few samples in 1990-91 during the rainy November to January period.

Table 4.1 Site 0125180 Trend Assessment 1968-82 to 1990-91 Ministry of Environment Data. (mg/L except pH)

	1968-1982			1990-1991		
	MIN	MAX	MEAN	MIN	MAX	MEAN
pH	6.8	8.2	7.14	6.8	7.8	7.16
ResNfilt	< 1	4	1.7	1	5	1.1
Turbidity	.2	11	1.21	.3	.9	.43
Alkalinity	8.3	29.1	12.2	11.9	19.1	14.7
NH3-N	.003	.1	.015	.005	.021	.007
NO2-NO3	< .001	6.1	.021	.02	.07	.03
Ca-D	3.4	12.9	4.87	4.14	7.99	5.3
Ca-T	4.1	5.5	4.76	4.18	8.25	5.4
Cu-T	< .001	.09	.003	.001	.004	.002
Fe-D	< .01	.3	.042	.02	.33	.04
Fe-T	.02	.6	.12	.04	.51	.08
Mg-D	.46	.85	.53	.47	.83	.58
Mg-T	.49	.85	.56	.48	.84	.60
Pb-D	< .001	< .05	.003	< .001	.002	.001
Pb-T	< .001	< .1	.002	< .001	.007	.0016
Zn-D	< .005	.22	.019	< .005	.011	.005
Zn-T	< .001	.1	.007	< .005	.18	.008

4.2 Groundwater Quality

4.2.1 Available Data

A review of well record data indicates that there is chemical analysis data of groundwater from only four water wells. Locations of the water quality test sites are shown in Figure 2, Appendix III and Table 4.2 below provides a summary of this groundwater quality data. A review of Water Quality Check Program indicates that there are analyses of groundwater quality for an additional 46 wells; however, the locations of these well sites are not provided since they have not been correlated with existing well record data. A summary of this data, followed by some statistical analyses of parameters is detailed in Appendix IV, Table 3. Further investigation and evaluation of this data is needed to match the location information with well record data from Groundwater Section's database files.

An analysis of the groundwater quality from the above-mentioned four wells indicates that the samples were obtained from relatively shallow depths (less than 61 m), within unconsolidated deposits and within a relatively shallow groundwater flow system. The significance of a shallow groundwater flow system is that most natural waters will be low in total dissolved solids (TDS), low in specific conductance and relatively soft to moderately soft in hardness. This appears to be the case for groundwaters within the Nanaimo River Basin area.

For the parameters tested, most of the groundwaters have chemical concentrations within acceptable water quality limits. A high iron content (11.1 mg/L dissolved) was noted at sample site number 3. This well (Observation Well 228) has not been used for production purposes for at least 40 years and the source of iron content in the water may be from corrosion of the well casing. Further analysis of the Water Quality Check Program reports is needed to evaluate and correlate sampling depths, aquifer types (ie. bedrock or unconsolidated), sampling dates, etc.

Table 4.2 Groundwater Sampling Sites and Quality Data.

Sample Site No.	1	2	3	4
BCGS Well no. (092G)	.001.2.3.2#25	.001.2.3.2#30	.001.2.3.4#16	.001.4.1.4#23
Type/Depth	UNC / 20'	UNC / 19'	UNC / 218'	UNC / 79'
Sample Date	76/07/22	76/08/16	84/09/26	90/11/21
pH	6.8	6.7	6.7	7.3
Temp. °C	-	13	-	-
Spec. Cond. µmho/cm	136	289	123	63.6
Alk. (phnl)	<0.5	<0.5	<0.5	-
Alk. (tot.)	29.9	106.0	55.6	17.5
Chloride (diss.)	20.7	19.4	5.5	3.8
Nitrogen (NO_2 + NO_3)	0.22	0.37	<0.02	<0.005
Nitrogen (KJel)	<0.01	0.23	0.37	-
Phosph. (diss.)	0.003	0.031	0.003	-
Calcium (diss.)	14.0	29.8	14.5	-
Iron (Tot.)	0.1	1.1	168	<0.03
Iron (diss.)	<0.1	0.6	11.1	<0.03
Magnesium (diss.)	3.3	7.9	4.34	1.26
Manganese (Tot.)	<0.02	0.2	0.43	0.01
Manganese (diss.)	<0.02	0.19	0.26	<0.005
Sodium (diss.)	5.5	14.3	4.3	3.18
T.D.S.	110	194	84	40
Hardness ($CaCO_3$)	48.5	107	54.3	22.3
Sulphate (diss.)	<5.0	11.9	1.3	4.1
Lead (diss.)	0.001	<0.001	<0.1	<0.001
Pot. (diss.)	0.5	2.2	0.4	0.13

4.2.2 Groundwater Quality Assessment

The upper zone of the Cassidy Aquifer is potentially susceptible to pollution because it occurs under shallow water table conditions and is comprised of highly permeable materials. In most areas the water table lies only 4.5 to 7.8 m below the ground surface. According to Kohut (1979), apart from individual, domestic and low density septic disposal systems, any large scale septic disposal schemes or sanitary landfill operations, whereby large quantities of untreated effluent or waste is disposed of in a small area, should not be permitted or approved without an adequate investigation and monitoring to assess the effects of any proposal on the groundwater regime. Particular precautions should be given to the designation of any petroleum storage facilities or highway salt storage areas, etc., in areas close to communities utilizing the upper aquifer for water supply.

Aquifer Contamination Potential

At present there are no known sites of contaminated groundwater within the basin area. However, the entire Cassidy Aquifer is potentially susceptible to contamination due to the fact that the aquifer occurs under shallow water table conditions (generally less than 7.8 m below ground, and is comprised of highly permeable sediments that are susceptible to rapid infiltration of potential contaminants into the groundwater system. Limited groundwater quality data has also been identified but water quality appears to be generally within drinking water quality guidelines. There are no apparent significant groundwater quality or contamination concerns.

CHAPTER 5 FISHERIES RESOURCE MANAGEMENT

5.1 Introduction

The Nanaimo River and its tributaries provide habitat for several salmonid species important for commercial, native and recreational purposes. The provincial Ministry of Environment Lands and Parks (MOELP) manage the freshwater fish resource through the Recreational Fisheries Branch and the federal Department of Fisheries and Oceans (DFO), are responsible for the anadromous salmon species which migrate into, reproduce and rear in the river. Anadromous steelhead and cutthroat trout are managed by the province since they are recreational rather than commercial species.

A decline in the Nanaimo River chinook stocks occurred during the 1980's and DFO has expressed a general concern about all the lower Georgia Strait chinook stocks. The sport, commercial, and native fishermen, tourism related industries, and the public also raised concern over these declines in these valuable chinook stocks. As a result, a *Lower Georgia Strait Chinook Rebuilding Program* was announced and initiated by the Department of Fisheries and Oceans in 1987. The rebuilding program embraces salmon enhancement, harvest restrictions, and habitat management as part of a long term strategy. As an immediate effort to halt the decline of chinook, significant catch restrictions were imposed beginning in 1988; a reduction from a 4 chinook limit per day to 2 chinook per day occurred and a further size restriction was introduced in 1989 by increasing the chinook retention size from 45 centimetres to 62 centimetres.

In local waters around Nanaimo, fin fish spot closures have been placed around Five Fingers and the Nanaimo River estuary each year to protect the mature chinook prior to their spawning migration into the river. Also, the Nanaimo River is closed to sport fishing for chinook salmon and coho from May 1 to October 20 each year, and only chinook (jacks) between 30 centimetres and 50 centimetres are allowed to be angled and retained after October 20.

Alternative native food fishing arrangements have also been made to further reduce the harvest pressure on chinook. However, despite all these efforts, the Nanaimo River chinook stocks are not responding as have other lower Georgia Strait chinook stocks such as the Cowichan River. Additional measures are required to reduce the fishing pressure on returning Nanaimo River chinook stocks. In 1992, a non-retention chinook fishery has been imposed from Dodd's Narrows north to Newcastle Island between July 15 to October 20.

Chinook rebuilding efforts are also being directed in the Nanaimo watershed through habitat and hatchery based strategies. The NRWM Plan will be a significant component of the habitat effort and an important insurance for the chinook resource. One goal of the plan is to provide enough water so that the chinook salmon can successfully migrate upstream. Chinook must spawn successfully each fall to perpetuate their cycle. If they do not spawn successfully, the wild run cannot rebuild and the stocks and the genetic heritage may be depleted, or even lost.

5.2 Salmon Management in the Nanaimo River

5.2.1 Background to Nanaimo River Chinook Flow Releases

In years when sufficient rainfall occurs, the Nanaimo River reservoirs contain more water than is required by the water licensees and some storage from both reservoirs can be released at critical salmon migration times through a coordinated water management plan. Small pulse flow(s) from the headwater reservoirs have been directed towards the biological requirements of the chinook salmon stocks. The Nanaimo River fall flows have been improved to assist salmon migration in the fall in 1989, 1990, and 1991.

The flow conditions that impair salmon migration are most acute in the lower reach of the Nanaimo River below the Island Highway downstream to tidewater as shown in the adjacent Figure 5.1. Chinook hold in the tidally influenced zone (Cedar Bridge area) awaiting suitable spawning migration flows. Minimum flows in this reach are regulated at 1.4 m^3/sec. However, during fall and winter, flood flows in 1990 exceeded 934^+ m^3/sec. This extreme fluctuation range is mainly due to natural factors. However, low flows and high water temperatures in the lower reach of the Nanaimo River are thought to limit fish migration. The South Nanaimo River watershed contains the Jump Creek reservoir which is managed by the Greater Nanaimo Water Board to supply domestic water for the Community of Nanaimo. The MacMillan Bloedel Ltd. (Harmac Pulp Mill) operation stores water in the Fourth Lake reservoir. During summer periods, this storage is released and subsequently withdrawn and pumped to the pulp mill from a location in the Nanaimo River immediately downstream of the Island Highway.

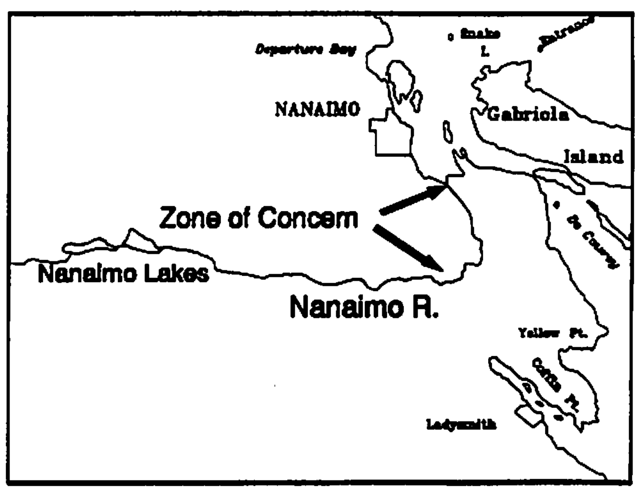


Figure 5.1 Zone of Low Flow Concern

The water withdrawals from large wells (not requiring a water licence) occur immediately adjacent the Harmac pumphouse and local vicinity. Also, the North Cedar Water District obtains water from their wells adjacent the lower Nanaimo River. More water withdrawals of this type can be expected in the Cedar area as populations grow and developments expand.

The natural variation in river flows, when coupled with the above water withdrawals in the lower Nanaimo River, have produced undesirable conditions especially during the chinook spawning migration periods in the late spring and again in the early fall of most years. A minimum flow of 1.1 m^3/sec. was stipulated on June 25, 1949 in the MacMillan Bloedel license since that was the lowest flow on record up to that time, Dept. of the Environment, (1973). At that time, discussions of flow dwelled on rearing requirements of juvenile fish. Now it appears that adequate chinook spawning migration flows and appropriate water conditions appear to have been underestimated. The minimum flow was raised from 1.1 to 1.4 m^3/sec as a condition of the water licence of the Greater Nanaimo Water District and their Jump Creek reservoir development on the South Nanaimo River.

The low flow conditions in the late spring through fall period are believed to have contributed to diminished productivity of the spring and fall chinook runs through delays in migration timing and spawning, and exposure to elevated temperatures causing direct fish kills, or indirectly through the acceleration of ich, a disease that results in premature chinook mortalities. In addition, the salmon, especially large chinook, are extremely vulnerable to illegal fishing and poaching activity when flows are at the minimum levels provided.

Until 1989, there was an informal arrangement between the DFO, the Nanaimo River hatchery staff and the staff of Harmac Pulp Mill to release water into the Nanaimo River. Requests were often made by the fisheries staff to release some water from the Fourth Lake dam to aid fall chinook migration. If storage was available, some surplus water was released. Such practices, although welcomed by DFO were outside of the water licence issued under the authority of the provincial *Water Act*.

A request was made by the Area Manager of the DFO to the Regional Water Manager in 1989 to examine the water management options to assist the rebuilding of the Nanaimo chinook stocks. As a result, the Nanaimo River Water Management Study was initiated and test flow releases were authorized for 1989 and 1990. A chinook counting fence was constructed in the fall of 1989 and in 1990 and chinook migration was measured by the Department to assess the response of chinook to the prescribed migration flow releases. The results of this assessment work are presented in Section 5.2.4.

5.2.2 Resource Description and Status

The Nanaimo watershed provides spawning and rearing habitat for four salmon species: chinook salmon- Oncorhynchus tshawytscha (Walbaum 1792), coho salmon- O. kisutch, chum salmon- O. keta and pink salmon - O. gorbuscha. The salmon life histories, their general distribution, and status of each species in the Nanaimo River are summarized below.

Chinook Salmon

There are at least four distinct chinook life history patterns known to exist within the Nanaimo River: the lower fall Chinook, upper fall, upper spring (ocean type stock) and the upper spring (stream type stock). The lower fall Chinook stock enter the intertidal reach as early as August and hold until rising water conditions in the fall stimulate a spawning migration to the lower mainstem river (below White Rapids Falls). Eggs are deposited in redds in clean gravel and eggs hatch and emerge as fry in the spring. The fry feed and rear in the fresh water approximately 90 days before migrating downstream to the sea. Once in salt water, juvenile chinook feed and migrate to the open Pacific Ocean and range as far as Alaska. Chinook are caught as 3, 4, or 5 year olds in sport, commercial, and native food fisheries. When the fish mature, they return to the Nanaimo estuary in late summer and hold until fall rains stimulate migration into the river to spawn. Shortly after the act of spawning, all salmon die. These lower fall stocks have declined over the years and are being harvested at an excessive rate of 80^{+}%. The Nanaimo River also has a significant hatchery enhancement effort directed at this stock.

The upper fall Chinook stock enter the intertidal reach as early as August and hold until rising water conditions stimulate a spawning migration. These fish have been observed ascending above White Rapids Falls into the upper river. Where this stock spawns is not known at this time. Eggs hatch from the gravel in the spring, and fry rear approximately 90 days and then migrate to sea. Mature adults return as 3, 4, or 5 year olds and are harvested in sport, commercial, and indian food fisheries. The status of this stock is unknown.

During periods of low flows which can occur as early as late April and extend until November in some years, White Rapids Falls is a partial or complete barrier to chinook migration. Passage over the falls was possible only if rainfall caused an increase in flows that afforded high water conditions allowing upstream passage. Continuous jumping tired, injured, and killed chinook due to stranding. They were also subject to increased poaching in this confined area.

The upper spring Chinook stock (ocean type/90 day fry rearing) enter the intertidal reaches as early as February and migrate over White Rapids Falls to the Nanaimo Lakes during the spring runoff period. The chinook hold in the lakes and deep river pools throughout the summer and then spawn in the Nanaimo River below or above the lakes during October. Eggs hatch from the gravel in the spring and fry feed and rear approximately 90 days (ocean type) and then migrate to the sea. Chinook are caught as 3, 4, or 5 year olds in the sport, commercial, and indian fisheries. These stocks are extremely depressed and are harvested at a rate of 80%+. These stocks are also being enhanced via the Nanaimo River hatchery.

The upper spring Chinook stock (stream type/1 year fry rearing) enter the intertidal reaches as early as February and migrate over White Rapids Falls to the Nanaimo Lakes during the spring runoff period. The chinook hold in the lakes and in some deep river pools throughout the summer and then spawn in the Nanaimo R. below or above the lakes during October. Eggs hatch from the gravel in the spring and fry rear for up to 1 year (similar to coho life history) and then migrate to the sea. Chinook adults are caught as 3, 4, or 5 year olds in the sport, commercial, and indian fisheries. These stocks are extremely depressed and are currently harvested at a rate of 80%.

Early in the water management study, it was determined that a low flow migration barrier existed at White Rapids Falls, a two stage falls located several kilometres upstream of the Island Highway. This physical barrier blocked the spring migration of chinook when low flows occur early in the year forcing the chinook to hold in the canyon below the falls. The barrier also effects the fall chinook run during extended periods of minimum fall flows forcing the chinook to spawn in the lower Nanaimo River. This barrier situation is believed to have commonly occurred in many years and a plan to improve passage was approved in late August, 1989. Remedial blasting was undertaken in September, 1989 by DFO to reduce the low flow velocity barrier and the height of the falls to improve chinook passage over the falls. Blasting of the by-pass channel at the upper section was also undertaken to increase the discharge through it when the Nanaimo River is at minimum flow. Further blasting or fishway passage work may be required if the chinook migration is still found to be impeded.

Coho Salmon

Coho salmon enter the intertidal reaches of the Nanaimo River beginning in late September extending through the fall and as late as the early winter period. Coho have the greatest distribution range in the Nanaimo watershed and typically spawn in the mainstem river and in most small tributary streams that are accessible to the sea. The eggs hatch from the gravel in the spring, and the fry rear for one year (sometimes two) before migrating to the sea as smolts. The adults mature in one or two years and are harvested by the sport, commercial, and indian fisheries. These stocks are currently harvested at a rate of approximately 75-80%. Some enhancement activity is directed towards coho production in the Nanaimo River hatchery via augmentation of fry into under utilized habitats below migration barriers, and through colonization of coho fry in some areas above migration barriers in the Nanaimo and Millstone Rivers. There are side channel development options in the lower river which may also have potential for development to improve coho production.

Chum Salmon

Chum salmon enter the intertidal reach of the Nanaimo River as early as September and spawn throughout the lower reaches of the river principally below the Island Highway downstream to the Cedar R. bridge area. Peak spawning occurs in early - mid October each year. Eggs hatch from the gravel in the spring, and fry immediately migrate to the sea. Chum are caught as 3 or 4 year olds and are harvested in commercial and indian food fisheries. These stocks are healthy and are harvested at a rate of approximately 44%. Minor activities are directed towards chum production at the Nanaimo River hatchery. There appears to be several side channel enhancement options below the Island Highway to increase chum production.

Pink Salmon

The pink salmon run utilized the lower reaches of the Nanaimo River and was historically large (50+ thousand) but due to deleterious factors such as coal mine waste run-off in the lower river, scouring of spawning beds, low water conditions, and large flow fluctuations, combined with high harvest exploitation rates in mixed stock fisheries, the pink stocks collapsed. The pink salmon run was thought to be extinct by DFO managers, however, a small remnant run of (200+) wild Nanaimo pink salmon was identified in 1989 by the Nanaimo River hatchery staff. This remnant run enters the intertidal reach of the Nanaimo River in late August and early September in both even and odd years. The pink salmon typically spawned in the lower 4 km. of the Nanaimo River and in off-channel, side channel, or in the lower reach of Haslam Creek.

Typically, the habitats pink utilize to spawn must contain small sized gravel and be protected from the effects of flood scour, or dewatering at low winter flows. There are very few pockets of this kind of habitat that remain in the Nanaimo River below the Island Highway. Pink eggs hatch from the gravel in the spring, and fry immediately migrate to the sea and then to the open Pacific. Mature adults return as 2 year olds (a 2 year cycle) and are harvested in mixed stock commercial fisheries and may contribute to a sports fishery. These stocks are thought to be harvested at 60%, however there is limited local directed fishery. Without a habitat development strategy directed at pink salmon, the run is threatened with extinction.

5.2.3 Salmonid Enhancement Program

In June of 1977, an ambitious project under the Salmonid Enhancement Program (SEP) was initiated in the Nanaimo watershed to assist the recovery of salmon populations in the local area. The project entailed stream monitoring, escapement estimates, the construction of chum incubation boxes plus some stream improvement work.

In 1979, the program was expanded to include the development, construction and operation of a hatchery on the Nanaimo River. The project encompasses four salmonid species and the entire Nanaimo River watershed including the estuary. The intent of the program is to enhance stocks in the Nanaimo watershed and to bring the natural runs of these salmonids to optimum production levels. Both natural and artificial means of enhancement are used.

In 1983, in conjunction with the Pacific Biological Station, a captive brood stock program was initiated. In this program, upper Nanaimo spring chinook salmon are incubated, reared, and then held in sea pens to grow and become mature adults. The rational behind this endeavour is to guarantee an egg supply for this depressed and valuable stock. The hatchery was expanded and a water system upgrade took place in 1987/88. SEP has spent an estimated $645,000 to build and upgrade the Nanaimo facility, which has an average operational cost of $230,000 a year.

Target escapements have been set by the DFO stock management biologist and fishery officers in consultation with the salmonid enhancement staff for the Nanaimo River The hatchery staff are working to rebuild the stocks to these recommended levels.

Chum

The target Nanaimo River chum escapement is 60,000. The fishery officer and management biologist look at the expectations for the Nanaimo system in the summer and if the expectations are greater than 45,000, no chum enhancement is scheduled for that fall. If the expected returns are uncertain, then returns are assessed in October. If favourable spawning numbers are present in the Nanaimo River then no enhancement is required. If the returns appear low, then enhancement of the stock is determined at that time and brood stock is collected. There has been no chum enhancement necessary for the years 1988, 1989, 1990.

Chinook

The target escapement of chinook for the Nanaimo River is 3,000 adults split 50/50 between wild and enhanced production. Rebuilding of the stock is expected to occur by 1997. The present egg targets for the enhanced production are 450,000 fall run chinook, 250,000 spring run chinook, and 300,000 captive brood stock. All chinook fry are released as smolts after rearing for 90-days.

Coho

The coho target escapement for the Nanaimo system is set at 7,000. The production goal of the enhancement facility is to rebuild the stock within 1 to 2 life cycles. The facility target is presently 250,000 spring fry releases into the system at a size of 2-3 grams, and 40,000 released at 20-25 gram smolts the following spring.

Pink

There is presently no escapement goal or management plan for the remnant pink salmon population in the Nanaimo River A careful rebuilding strategy is required to ensure that extinction of this species does not occur.

5.2.4 Nanaimo River Salmon Escapements

Table 5.1 summarizes the total return of chinook salmon to the Nanaimo River, 1975-1991. In years when escapement of spring chinook has been recorded, the estimated number of "Springs" are indicated in brackets; these numbers are included in the total number of Natural Spawners. Hatchery removals include spring and fall chinook removed for brood stock and any fish removed which died before spawning.

Table 5.1. Summary of the Total Return of Chinook Salmon to the Nanaimo River, 1975-1991

Year	Natural Spawners	Hatchery Removals	IFF Catch	Total Returns
1975	475		15	490
1976	880		50	930
1977	2380		60	2420
1978	2125		40	2165
1979**	2700 (900)	41	23	2764
1980**	2900 (1100)	82	200	3182
1981	210	15	100	325
1982	1090	62	21	1173
1983	1600	240	30	1870
1984	3000 (750)	178	50	3228
1985	650	264	185	1099
1986	700 (300)	258	190	1148
1987	400 (170)	357	50	807
1988	650 (225)	429	0	1079
1989	1150 (200)	402	0	1752*
1990	1275 (170)	122	0	1647*
1991	800 (200)	135	0	1135*

Naturally Spawning Escapement Target: 3450 (Spring run-type chinook should compose between 30-40% of this target.)

* Includes reported losses due to pre-spawn mortalities in river (200 in 1989, 250 in 1990, and 200 in 1991). These mortalities are additional to ones recorded in hatchery removals.

** Reference: Healey and Jordan (1981) escapement estimates re-calculated to exclude jack males (<50 cm.).

5.2.5 1989 and 1990 Nanaimo River Flow Release Results

In 1989, an experimental release flow of ~10 m^3/sec was tested. A counting fence was constructed in 1989 and in 1990 above the Nanaimo River bridge at Cedar. Mature chinook typically hold in the tidal portion of the Nanaimo River in the vicinity of the Cedar bridge during September. The release flows from the two reservoirs are staggered by approximately 24 hours (Jump Creek follows Fourth Lake) so that the effect is a single rise of water in the lower river is experienced by the holding salmon.

The following figures describe the results of the release flows in 1989 and 1990 compared with chinook migration past the chinook counting fence. The first pulse flow released in 1989 was approximately one third less than the target flow, and a subsequent second release was authorized which was further augmented by rainfall that caused the loss of the counting fence due to high water.

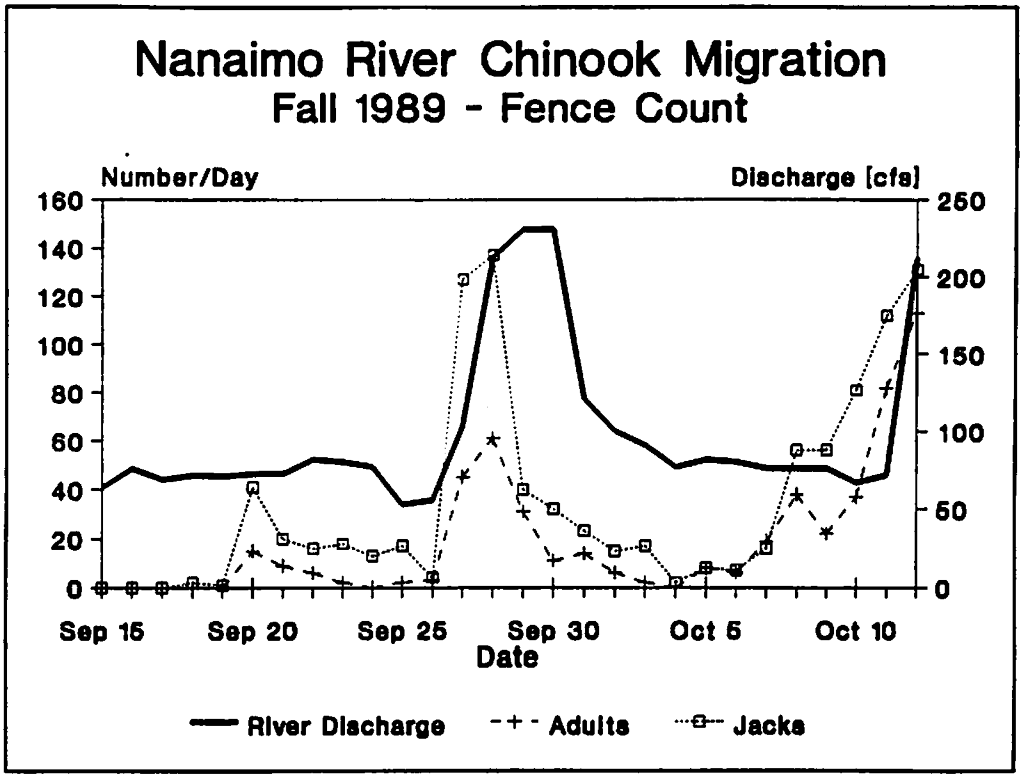


Figure 5.2 1989 Flow Release and Chinook Migration

In 1990, the target flow was released and was further augmented by precipitation to approximately double the target flow discharge. However, in 1990 the counting fence was not lost due to a superior fence design. When the river flows began to rise due to the pulse flow, an immediate migration of chinook salmon was measured and migration upstream was documented by river swims and assessments at White Rapids Falls. In 1989, salmon continued to move upstream from the estuary until the fence was lost. In 1990, when more water was released, the migration from the inter-tidal reach dropped off sharply indicating that the chinook population had moved into the Nanaimo River during the flow release.

5.2.6 Conclusions

The test release flows in the fall of 1989 and 1990 were successful to stimulate an immediate movement of chinook salmon from the lower estuarine reaches into the Nanaimo River. In addition, some silver bright chinook salmon were observed to successfully migrate with difficulty above the White Rapids falls to spawn in the Upper Nanaimo River. The upstream spawning areas utilized by this stock should be ascertained and the rebuilding potential assessed. In 1992, the Nanaimo River chinook escapement was comparable with the past three years.

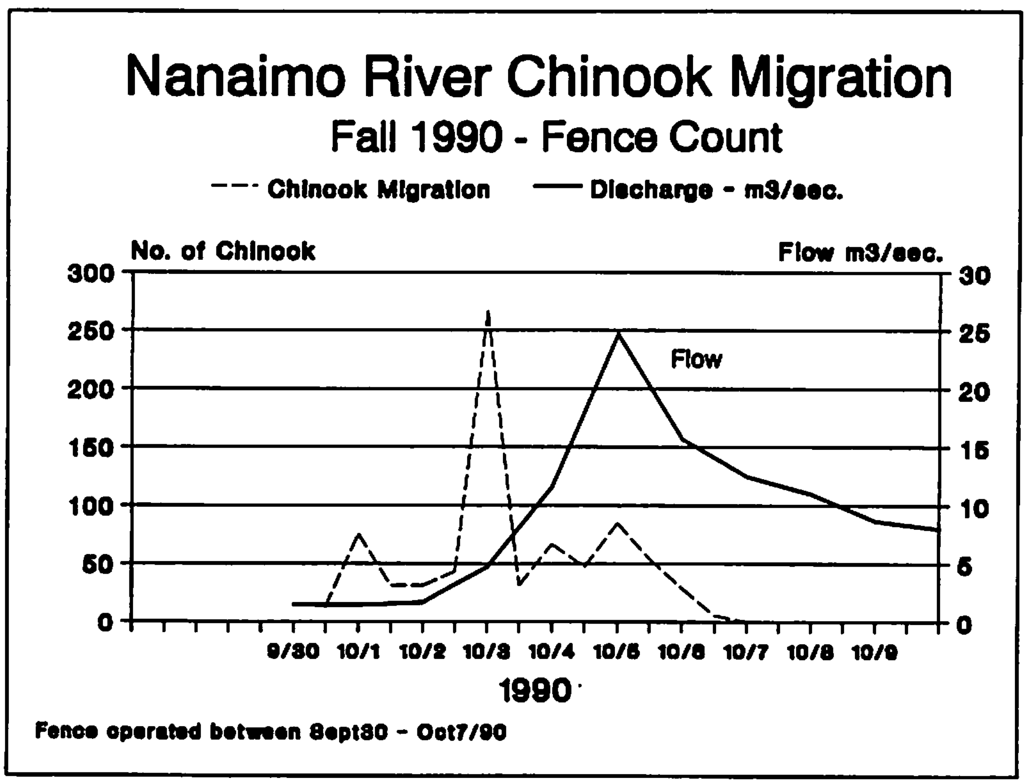


Figure 5.3 1990 Flow Release and Chinook Migration

The estimated total adult chinook spawners in the river was 1,000 (400 upper, 600 lower). An additional 367 chinook were collected for hatchery broodstock. The 1992 water release strategy worked well. However, the release timing should have been one week earlier than the October 2 start date because chinooks were holding in the Cedar bridge area for a considerable length of time (Brahniuk, 1992).

Nanaimo Watershed Fall Chinook Migration Flows
DFO Recommended Flow Releases

#1. Release flow target - 4 days @ 11.3 cms. (400 cfs.) measured at tidewater. If storage is available for one release, it should occur by mid October at the request of the Nanaimo Subdistrict Fishery Officer in consultation with hatchery and other DFO staff. The request will be made with at least 3 to 4 days advanced notice as part of an annual protocol.

#2. If storage is available for two releases, they would occur during late September or early October if water temperatures are below 20 degrees C.

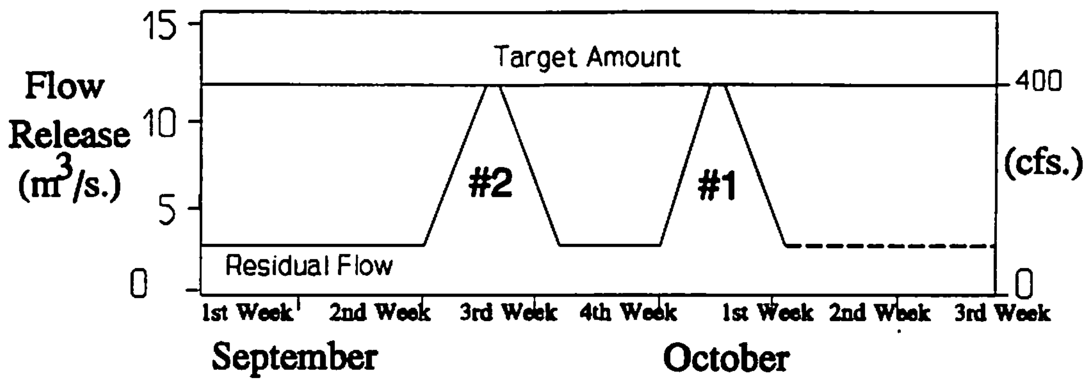


Figure 5.4 Recommended Nanaimo River Fall Release Flows

5.3 Recreational Fisheries Management

5.3.1 Introduction

Recreational fisheries in the Nanaimo River watershed occur in streams and lakes accounting for an estimated 23,120 angler days. These fisheries are conservatively estimated to have an economic value of $639,600 (Table 5.2).

Table 5.2 Estimated Angler Usage and Economic Values of Nanaimo River Sport Fisheries

RECREATIONAL FISHERY	ESTIMATED ANGLER DAYS	ESTIMATED ECONOMIC VALUE*
Stream fisheries:		
Steelhead	3,658 (2,345-4,413)	$109,740
Searun Cutthroat	350 (200-500)	$ 10,500
Resident Trout and Char	5,000	$150,000
Lake fisheries	14,112	$423,360
TOTAL	23,120	$693,600

* based on an average of $30 per angler per day (Fisheries Branch estimate, 1990)

The species of importance for recreational fisheries use are steelhead, resident rainbow, searun and resident cutthroat trout and Dolly Varden char. The life histories of the trout and char in the Nanaimo system are quite variable and differ in various respects between the anadromous, lake resident and stream resident forms of each species. A generalized summary of life histories of the sport fishes in the Nanaimo watershed is given in Table 5.3.

Table 5.3 Nanaimo Watershed Sport Fishes Life History Summary

SPECIES	RUN TIMING	SPAWNING PERIOD	FRY EMERGENCE	JUVENILE STREAM REARING	AGE AT FIRST SPAWNING	REPEAT SPAWNING	
						FEMALES	MALES
STEELHEAD	JAN-APR	APR-MAY	JUNE-JULY	2-3 YEARS	2.2-3.3	14%	<1%
RESIDENT RAINBOW LAKES STREAMS		MAR-MAY MAR-MAY	JULY JULY	1-2 YEARS 3-4 YEARS	3-4 YEARS 3-4 YEARS	YES YES	YES YES
SEARUN CUTTHROAT	SEPT-MAR	DEC-MAR	MAY-JUNE	2-3 YEARS	2.2-3.2	20%	5%
RESIDENT CUTTHROAT LAKES STREAMS		DEC-APR DEC-APR	JUNE-JULY JUNE-JULY	0-2 YEARS 3-4 YEARS	2-4 YEARS 2-4 YEARS	YES YES	YES YES
DOLLY VARDEN LAKES STREAMS		OCT-NOV OCT-NOV	APR-MAY APR-MAY	3-4 YEARS 3-6 YEARS	3-6 YEARS 3-6 YEARS	YES YES	YES YES

5.3.2 Stream Fisheries

Steelhead

The Nanaimo River ranks among the top six streams on Vancouver Island in terms of angler effort and among the top ten in terms of steelhead catch. In the five year period 1986-90 the mean annual effort was 3658 angler days and the mean annual catch was 1908 total steelhead. Of these, the mean wild catch was 1292 and the hatchery catch 616. A summary of Steelhead harvest analysis data for the Nanaimo River is illustrated in Figure 5.5. At a conservative estimate of $30 per angler day, the steelhead fishery on Nanaimo River over the past 5 years has an annual economic value of roughly $110,000.

The mainstem Nanaimo River is accessible to steelhead to just beyond Fourth Lake; however, while some steelhead do use these headwater regions, the greater proportion probably utilize those portions of the river below the fast water obstructions at White Rapids. The main tributaries utilized by steelhead include Haslam Creek, South Fork, North Fork and Green Creek as well as the smaller tributaries including Rush Creek (Figure 5.6).

Run timing and life history characteristics of Nanaimo River steelhead can be gleaned from Narver and Withler (1971). Their data are based on scale analysis of angler catches of steelhead taken between January 20 and April 13 in 1970. The fish capture dates in their sample concur with evidence relating to steelhead run timing. Steelhead enter the river in late winter (January through April), with the bulk of the run entering in February through March. Documented evidence of summer steelhead runs is lacking; however, at present it appears that no summer steelhead exists. Age at first spawning is variable but the majority spawn between ages four and five. Juvenile steelhead rear between two and three years in freshwater before smolting and migrating to the ocean. It is during this freshwater rearing phase of their life history that low summer flows limit the systems capacity to produce steelhead.

Steelhead enhancement projects have been carried out on Nanaimo River since 1980. Fry stocking was done above anadromous barriers from 1980 to 1985, using brood angled from Nanaimo River and incubated at the Community Economic Development Program (CEDP) hatchery near Cassidy. That program met with limited success although evaluation was cursory and inconclusive. In 1984 the program was changed to smolt introductions. Incubation operations were moved to Vancouver Island Hatchery in Duncan with parr reared in net pens at the Cobble Hill quarry. This program is still operating with an annual target release of 45,000 smolts producing a return of about 800-1,000 adipose clipped adults for the sport fishery.

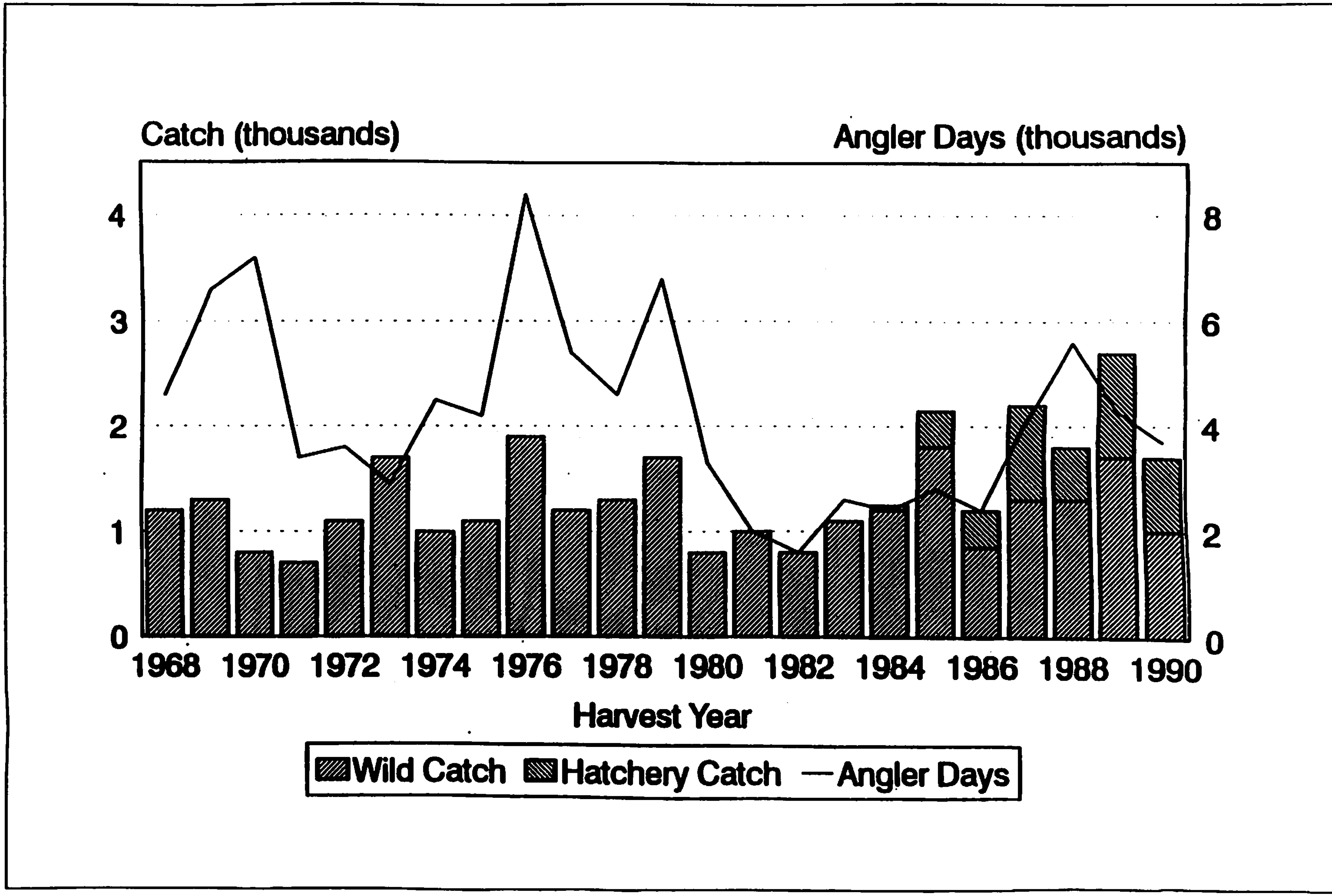


Figure [illegible].5 Summary of Steelhead Analysis Data for [illegible] River

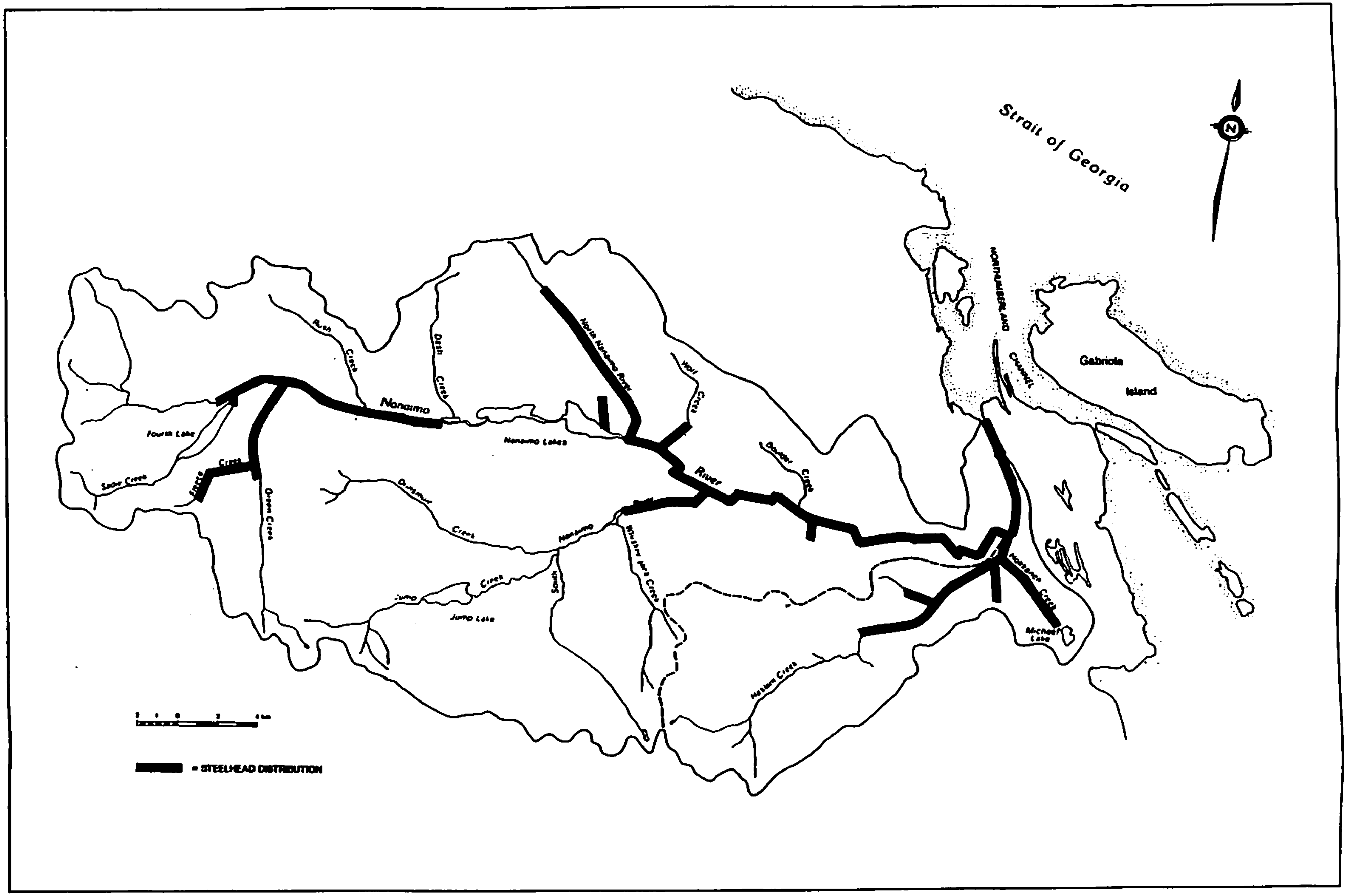


Figure 5.6 Steelhead Distribution in the Nanaimo River System

Table 5.4 Nanaimo River Steelhead Habitat Capability Estimates

MODEL	ESTIMATED SMOLT YIELD	MINIMUM AND MAXIMUM LIMITS	PROJECTED ADULT RUN SIZE
Mean Annual Discharge Model (Ptolemy, 1987)	17,518	(7,996-38,379)	-
Stream Wetted Area Model (Ptolemy, 1987)	10,817	(5,421-21,583)	-
Model A (Lirette et al. 1987)			
Mainstream			
Tributaries	19,669	-	-
	6,109	-	-
TOTAL	25,778	-	-
Model B (Lirette et al. 1987)			
Mainstream			
Tributaries	15,129	-	1,935
	2,645	-	794
TOTAL	17,774	-	2,729

Searun Cutthroat Trout

The Nanaimo River was once a very productive system for searun cutthroat trout, due to the large estuary and several productive small tributaries in the lower river. Reports from long time residents of the area indicated a healthy fishery existed in the river below the Haslam Creek confluence in the spring, and concentrated on the tidal portion of the river around the Chase river confluence at other times of the year. Today the sport fishery centred on cutthroat trout in the lower river is estimated to be 200 to 500 angler days, with an additional 500 angler days that are not targeting on cutthroat, but incidentally catch them in tidal waters of the river.

Wild searun cutthroat production occurs primarily in tributaries that flow directly to the estuary, including Holden Creek, Chase River, Hong Kong/Beck Creeks, and Wexford Creek. Over the past 20 years impacts on fish habitat have been significant, due to the rapid urbanization of the area west of the estuary and have reduced the capacity of these streams to produce wild cutthroat (and coho) smolts.

No searun cutthroat trout spawning or rearing takes place in the mainstem of the Nanaimo River, however, two tributaries below the Island highway (Thatcher Creek and lower Haslam Creek) both contain small numbers of fry and parr cutthroat.

Both systems have suffered extensive ditching due to agriculture, so habitat is limited. Morrison Creek, a tributary of Haslam Creek, drains the airport property, and was an important site for spawning and rearing. This area was lost to fish production when the airport expanded over 10 years ago. Thatcher Creek suffers from extreme low summer flows, causing cutthroat and coho to compete for the limited pool space in the summer months. Holden Creek, on the east side of the Nanaimo estuary, also contains both searun and resident cutthroat trout. Agricultural impacts to the stream have been extensive below Holden Lake with the loss of riparian vegetation and instream cover, due to ditching programs, reducing rearing habitat for salmonids.

Adult cutthroat trout in the lower reaches of the mainstem Nanaimo River are found primarily holding in pool tail-outs or shallow runs, feeding on salmon spawn in the fall and fry in the spring. All adult cutthroat trout found in the mainstem Nanaimo river are believed to have migrated to the area from one of the tributaries identified above. Snorkel surveys for chinook salmon in the month of September usually count between 50 to 100 cutthroat trout adults in the lower river. Educated guesses of the number of searun cutthroat trout adults in the lower Nanaimo river would range from 300 to 500 fish. A small hatchery program was initiated to enhance searun cutthroat trout in 1981.

The project was initially run with the help of Nanaimo River CEDP hatchery, with 600 fry planted in July 1982 into Holden creek. In March 1983, brood cutthroat were captured from Nanaimo river tributaries, and progeny reared at Vancouver Island Hatchery. Approximately 10,000 smolts were released into the lower river in the spring of 1984. No fish culture of sea run cutthroat has occurred since.

Resident Trout and Char

Resident cutthroat are found throughout the system, extending into the headwaters of mainstem and tributaries. Resident rainbow and Dolly Varden are present primarily above First Lake. The sport fishery for these species is found in two locations on the river: between First and Second Lake and upstream of Second lake for approximately 2 kilometres. Although there has been very little information collected on these fisheries, we conservatively estimate that 5000 angler days are targeted on resident trout and char in this area.

5.3.3 Lake Fisheries

Lake fisheries in the Nanaimo River watershed occur on at least twenty of the small lakes in the system. These fisheries accounted for an estimated 14,112 angler days and comprised 19.8% of the effort directed to lake fisheries in the Nanaimo/Cowichan Planning Unit (1989 Lakes Survey Questionnaire). At a conservative estimate of $30 per day, the economic value of the lake fisheries in the Nanaimo watershed is approximately $423,000.

The main target species in these fisheries are cutthroat and rainbow trout. Several of the lakes also contain Dolly Varden. The capacity of these lakes to produce fish is far exceeded by the fishery demand and therefore they depend heavily on a regular stocking program to meet angler needs. Summaries of lake size, species present, productive capacity, stocking information (for the 5 year period 1985-89) and angler effort and catch (from the 1989 Lakes Survey Questionnaire) for the lakes known to support recreational fisheries in the Nanaimo watershed are presented below (Table 5.5). The distribution of angler effort (days fishing on lakes) is illustrated in Figure 5.7.

Table 5.5 Summary of Small Lakes Fisheries in Nanaimo River Watershed

LAKE	SURFACE AREA (Ha)	SPECIES PRESENT[a]	ESTIMATED YEARLING CAPACITY[b]	STOCKING (1985-1989)				ANGLER DAYS (1989)	ANGLER CATCH (1989)	CPUE (1989)
				SPECIES	NUMBER	SIZE(g)	BROOD YEAR			
Barsby	2.0	CT	n.a.[c]	CT CT	1000 1018	26.4 39.5	87 88	31	99	3.2
Blind	4.0	CT,RT	207.5	CT RT RT RT RT RT	1000 2000 1000 1000 1000 1001	33.9 10.4 138.9 142.9 10.9 18.0	85 86 86 87 88 89	896	1378	1.5
Colliery #1	1.4	RT	n.a.	RT RT RT RT RT RT RT RT	1400 1500 1500 1500 432 1500 1500 1500	142.9 135.1 120.5 113.6 17.6 113.6 138.9 100.0	85 86 87 87 88 88 88 89	948[d]	1354[d]	1.4[d]
Colliery #2	1.4	RT	83.0	RT RT RT RT RT RT RT	1400 1500 1500 1500 1500 1500 1500	142.9 135.1 120.5 113.6 113.6 138.9 100.0	85 86 87 87 88 88 89			
Colliery #3	0.7	RT	76.1	RT RT RT RT RT	1500 1500 1150 1500 1500	142.9 135.1 120.5 109.9 113.6	85 86 87 87 88			
Crystal	7.0	CT	n.a.	CT CT CT CT	2000 1000 1000 1000	13.3 20.0 28.2 40.3	85 86 87 88	476	1000	2.1
Delphi	2.0		n.a.					0	0	0
First	196.0	RT, SH, CT, DV	1355.5	CT CT CT SH CT	2500 5000 4998 3206 5000	20.0 26.4 42.4 23.0 31.7	86 87 88 89 89	4023	5765	1.4

LAKE	SURFACE AREA (Ha)	SPECIES PRESENT[a]	ESTIMATED YEARLING CAPACITY[b]	STOCKING (1985-1989)				ANGLER DAYS (1989)	ANGLER CATCH (1989)	CPUE (1989)
				SPECIES	NUMBER	SIZE(g)	BROOD YEAR			
Fourth	200.0	CT, RT, DV	5187.0	CT	2000	13.3	85	614	1692	2.8
				RT	13628	3.9	87			
				RT	5000	10.9	88			
Harewood	7.6	CT	n.a.					169	344	2.0
Holden	37.6	CT	89210	CT	1011	39.8	87	758	984	1.3
				CT	2000	40.2	88			
				CT	2000	31.7	89			
McKay	2.6	CT	256.5	CT	2000	13.3	85	401	1128	2.8
				CT	1500	20.0	86			
				CT	1500	26.4	87			
				CT	1500	43.7	88			
Myles	3.1	CT	258.8					0	0	0
Quennell	119.8	CT, RT	119.8	RT	6000	21.7	85	4016	9887	2.5
				RT	6000	10.4	86			
				RT	20000	17.7	87			
				RT	10000	8.3	88			
				RT	10000	18.7	89			
				CT	12987	18.3	90			
Reinhart	6.9	CT, RT	599.9	CT	1000	18.4	85	38	108	2.8
Second	172.0	RT, SH, CT, DV	1189.6	SH	3285	11.3	87	877	1710	2.0
				SH	2514	9.3	88			
				SH	3193	23.0	89			
Stark	3.0		n.a.					0	0	0
Third	3.0	RT, CT, DV	171.2					38	76	2.0
Timberland	5.6	CT	360.4	CT	2000	13.3	85	758	1810	2.4
				CT	1000	33.9	85			
				CT	1500	20.0	86			
				CT	1500	26.4	87			
				CT	1500	40.3	88			
Williams	8.3	RT	n.a.	RT	2000	0.9	89	69	151	2.2

[a] SH = Steelhead
RT = Rainbow Trout
CT = Cutthroat Trout
DV = Dolly Varden

[b] Estimated number of yearling fish which the lake is innately capable of producing

[c] not available

[d] combined data for Colliery #1, #2, and #3

ESTIMATED DAYS SPENT SPORT FISHING IN LAKES OF THE NANAIMO RIVER WATERSHED
1989

LAKE NAME	CODE	LAKE DAYS
FIRST	1	3828
SECOND	2	835
FOURTH	3	584
HOLDEN	4	722
QUENNEL	5	3822
COLLERY DAM	6	948
BLIND	7	853
CRYSTAL & MCKAY	8	850
TIMBERLANDS	9	722
OTHERS	10	285
TOTAL DAYS		13500

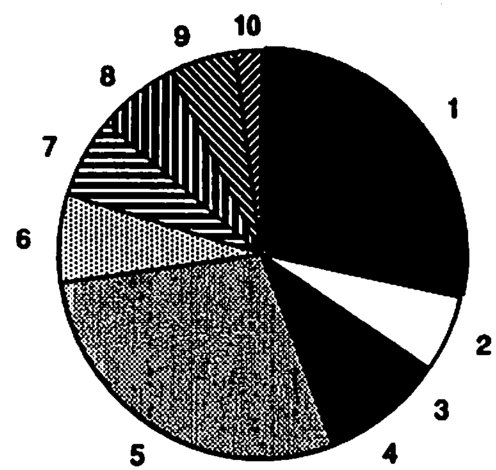


Figure 5.7 Distribution of Angler Efford Days on Lakes

5.3.4 Tennant Method Estimation of Flow Requirements

General guidelines for establishing flow criteria for fisheries and other environmental resources, following the Tennant method (Stalnaker and Arnette, 1976: Tennant 1976), are provided in Table 5.6. Mean monthly flows for the Nanaimo River at gauging station 08HB034 (Water Survey of Canada, 1988) are also provided. The average Nanaimo River flow over the April to September period and mean monthly flows in the Nanaimo River typically fall within the "poor" or "good" category (Table 5.6). According to Tennant (1976), flows between 10% MAD may not be adequate to sustain even short-term survival of aquatic life. At face value, the method clearly suggests that fisheries potential of the Nanaimo River drainage may be constrained by current base flow regimens.

However, tennant emphasizes the importance of evaluating the generalized criteria relative to observed/recorded conditions of any specific system. Development of stream-specific criteria necessitates monitoring, measurement, photodocumentation, and analysis of wetted width, water velocity, depth and other habitat related factors, over the discharge range of 10% MAD to 60% MAD. Within the terms of reference for the Nanaimo River investigation, results of such analyses have been provided in the following sections.

Table 5.6 Evaluation of Stream Flows for Fisheries and Other Environmental Resources (Tennant, 1976)

Management Value	April - September Base Flow Regimes (% MAD)
Excellent to Outstanding	60
Good	30
Poor or Minimum	10
Severe Degradation	less than 10

5.3.5 Instream Flow Requirements for Recreational Fisheries

As part of the NRWM Plan, the Ministry of Environment hired R.P. Griffiths and Associates to assess instream flow requirements for rearing fish. The study objective was to determine instream flow requirements for rearing and spawning trout species in the Nanaimo river. The specific tasks undertaken to meet the objective included employing the Tennant Method (Tennant 1976) for calculating instream flow requirements; measuring the wetted widths of the Nanaimo river at 80%, 40%, 20%, 10% and 5% of the Mean Annual Discharge

(MAD) (the MAD of the Nanaimo River is 39.3 m^3/sec.); relating changes in wetted width to discharges and evaluating it against changes in fish habitat.

During May - September, 1990 field data were collected at 26 stations (Griffiths, 1990). The stations were longitudenly stratified by habitat type. Habitat type was classified as described by Wightman and Ptolemy (1989). Substrates were classified according to deLeeuw (1981). Wetted width was collected at each station for each discreet flow and later converted to percent wetted width for comparison between discharges. Specific dates and flows examined are provided in Griffiths, 1990.

Habitat Type

There was a distinct change in hydraulic habitat characteristics at most stations over the range of observed discharges. Riffles and runs broadly dominated hydraulic types at the time of station selection 34.6% MAD and at 82.1% MAD however; conditions at 34.6% MAD were generally shallower, slower and less turbulent. Habitat continued to become shallower and slower with further reduction to 20.3% MAD but changes in habitat type were insignificant. The most wide spread and distinct changes were observed at 10.8% MAD. There was little change in habitat type with further reduction to 6.4% MAD.

Wetted Width

Channel width measurements at all stations relate to the main channel from rooted vegetation to rooted vegetation (Chamberlin 1980). Wetted width in the Nanaimo river decreased by an average of 29% over the range of observed discharges (Griffith, 1990). Widths receded relatively slow between flows of 82% MAD - 20% mad, then receded significantly to 10% MAD before slowing. The flow reduction with the single greatest effect on width was between 20% MAD and 10% MAD.

Usable Width

The estimated percentage of channel width useable for steelhead fry at all stations and discharges were estimated be Griffith, 1990. On average the estimated usability of channel width for fry increased with decreasing discharge, at least to 10.8% MAD. This is associated with corresponding decreases in depth and water velocity which benefit small fish. Results for parr were quite different than those for fry. Reduction in flow from 82% MAD to 35% MAD was beneficial to the wetted width for parr. Usability declined slightly as flows dropped from 35% MAD to 10% MAD then declined significantly as flows dropped to 6% MAD (Griffith, 1990).

In the case of parr usability is mainly related to water velocity and cover. At higher discharges maximum velocities were close to 1 m/sec. and with discharge reduction, the velocity decreases and usability increases. With discharge reduction below 20% MAD the cover becomes reduced as width and depth become diminished. Below 10% MAD shortage of cover, primarily depth, becomes acute and usability is reduced.

5.3.6 Recreational Fisheries Conclusions

As part of the Nanaimo River Water Management Plan, mainstem flow requirements for recreational fisheries (primarily winter steelhead, sea-run cutthroat and resident rainbow trout), were investigated from May-September, 1990 at 26 sites over a distance of 46km from the river's mouth to Fourth Lake. For purposes of the study, the river was divided into three sections: section 1 from the mouth to the Island Highway bridge; section 2 from the Island Highway bridge to South Fork confluence; and section 3 from South Fork to Fourth Lake, excluding the lengths of First and Second Lakes.

Measured wetted widths, supported by estimates of mean and maximum cross-sectional velocity, depth and habitat usability for trout fry and parr were collected at each site over a range of flows. These flows were 32.2, 13.6, 8.0, 4.2 and 2.5 m^3/s, corresponding to 80%, 40%, 20%, 10% and 5% of mean annual discharge (MAD), respectively.

There was a distinct change in hydraulic habitat characteristics at most measured stations over the ranges of observed discharges. Habitat became shallower and velocities slower as flows decreased to 20% MAD. The changes were significant between 20 - 10 % MAD. Widths receded relatively slow between 82% MAD - 20 % MAD, then receded significantly to 10 % MAD. The flow reduction with the single greatest effect on width was between 20 % MAD and 10 % MAD. The percentage of channel width for fry increased with decreasing discharge by at least 10 % MAD. This is associated with corresponding decreased in depth and velocity which benefit small fish. Reduction in flow for 82 % MAD to 35 % MAD was beneficial to the wetted width for parr. Useability declined slightly as flows dropped from 35 % MAD to 10 % MAD then declined significantly as flows dropped to 6 % MAD.

It is therefore recommended by the recreational fisheries for the purposes of the Water Resource Management Modelling (WRMM) framework utilized in the current Nanaimo River Water Management planning process that the following minimum flows be used. For the period of April to July, the minimum recreational fisheries flow requirement is 7.8 m^3/sec; for the period of July to September 5.85 m^3/sec.; and for September, 3.9 m^3/sec.

5.4 Native Fishery Management

The Nanaimo Indian Band has historically and is currently fishing the Nanaimo River for salmon, targeting mainly the chinook and chum salmon. This Indian Food Fishery, from the Cedar Bridge to the mouth of the river, takes priority over other user groups after conservation concerns are met and is required to assist in meeting the Nanaimo Bands food fish requirements. This fishery normally occurs form late September to early December. The salmon from this fishery are normally caught by gill net or spear.

In recent years, there have been serious chinook conservation concerns on the Nanaimo River stocks. The Indian Food Fishery targeting on chinook salmon has been delayed until approximately mid-October to provide further protection to the chinook stalks migrating upstream prior to this date. This Fishery, occurring after the middle of October, is targeting chum salmon stocks which are generally healthy. The extreme low water levels on the Nanaimo in recent years during September and October have delayed chinook migration upstream of the cedar bridge. This has resulted in chinook holding for long periods of time in the tidal portion of the Nanaimo River. With the current chinook restrictions in place, the low water pattern has a negative impact on the Nanaimo River Indian Food Fishery. Increased water flows through a water release program during late September and in early October move chinook salmon holding in the tidal portion upstream to the spawning grounds above the Cedar Bridge.

When Nanaimo river chinook stocks are rebuilt to escapement levels of 3,000, an Indian Food Fishery on chinook salmon in late September and early October would occur. Increased water flows during this time period would assist greatly in the conservation of these stocks by providing access to the upstream spawning grounds to ensure that adequate spawning requirements are achieved.

During consultation meetings with the Nanaimo Band in 1990 and 1991, it has been the bands position to support the water release program as it will benefit the Nanaimo River Salmon stocks (particularly chinook salmon) which will result in increased fishing opportunities to the Band.

5.5 Water Temperatures in the Nanaimo River and Ich.

Ich (ichthyophthirius) is a large fresh water ciliated protozoa with two stages in its life cycle: a non-parasitic (dormant) phase which resides in the bottom debris and multiplies through fission and an infectious phase in which it is free swimming and can attach to a fish and grow as a parasite to maturity. At 10 degrees C., the maturation period of the infectious stage is about thirty days. This time period is accelerated by approximately two and a half days for every 1 degree centigrade increase in temperature (ie. at 20 degrees C. maturation is less than five days). Therefore water temperatures directly affect the rate of reproduction of the parasite.

Over the past several years, both the fall run of Nanaimo River chinook in the river and in the Nanaimo River Hatchery have been infected in increasing numbers due to ich prior to spawning. The mortality is induced by high water temperatures (as high as 23+ degrees C.) that are experienced in the lower reaches of the Nanaimo River. Typically, a parasitized chinook is deprived of oxygen due to the suffocating effect of high infestation of ich upon the gill lamellae. Chinook are prone to infection due to stress and a weakened condition caused by maturation and crowding in pools, high temperatures, elevated body metabolism, and delayed spawning migration due to depressed river flows. Recently developed prophylactic saline bath treatments of 4% sodium chloride (salt) in hatchery holding troughs have been successful in controlling the ich organism once the chinook brood stock has been captured. However, it is not possible to treat the spawning population of chinook in the Nanaimo River.

Chinook mortality due to ich has been observed in the reach of the Nanaimo River below the Island Highway by DFO fishery officers and hatchery staff, however, the total impact of ich infestation on the chinook population is unknown and is difficult to assess. The increasing incidence of ich infestation over the past few years is a new development. Since elevated water temperature and low flow can be critical factors stressing and weakening spawning chinook, MacMillan Bloedel staff have measured daily water temperatures and residual river flows in the pool at their Nanaimo River Pump House adjacent the Island Highway. These temperatures are recorded by hand thermometer between 07:00 and 09:00 daily. It is probable that an additional 1 to as much as 3 degrees C. is recorded above those measured for the Cedar Bridge reach where the majority of pre-spawning chinook hold. Figures 5.8, 5.9, 5.10, and 5.11 present the 1990 and 1991 temperature and residual discharge data summaries. Historically, fish kills have been recorded in the lower Nanaimo River during the past twenty years and have been attributed to high summer water temperatures (Reid, 1992).

In summary, water temperatures above 20 degrees C. are stressful for all salmonids, but are of special concern for mature chinook salmon if they are concentrated in confined pools. Temperatures above 23 degrees C. are approaching lethal levels. Temperature reduction of the residual flows in the lower Nanaimo River would significantly reduce stress and diminish the affects of chinook mortality now caused by ich. A secondary benefit of lowered temperatures would be improved rearing conditions for juvenile salmonids especially in the reaches below the Pump House. It is recommended that a target temperatures of less than 20 degrees C. be the criteria for the lower Nanaimo River. The ideal rearing temperature is 18 degrees C. while improved egg survival occurs when spawning temperatures are less than 15 degrees C.

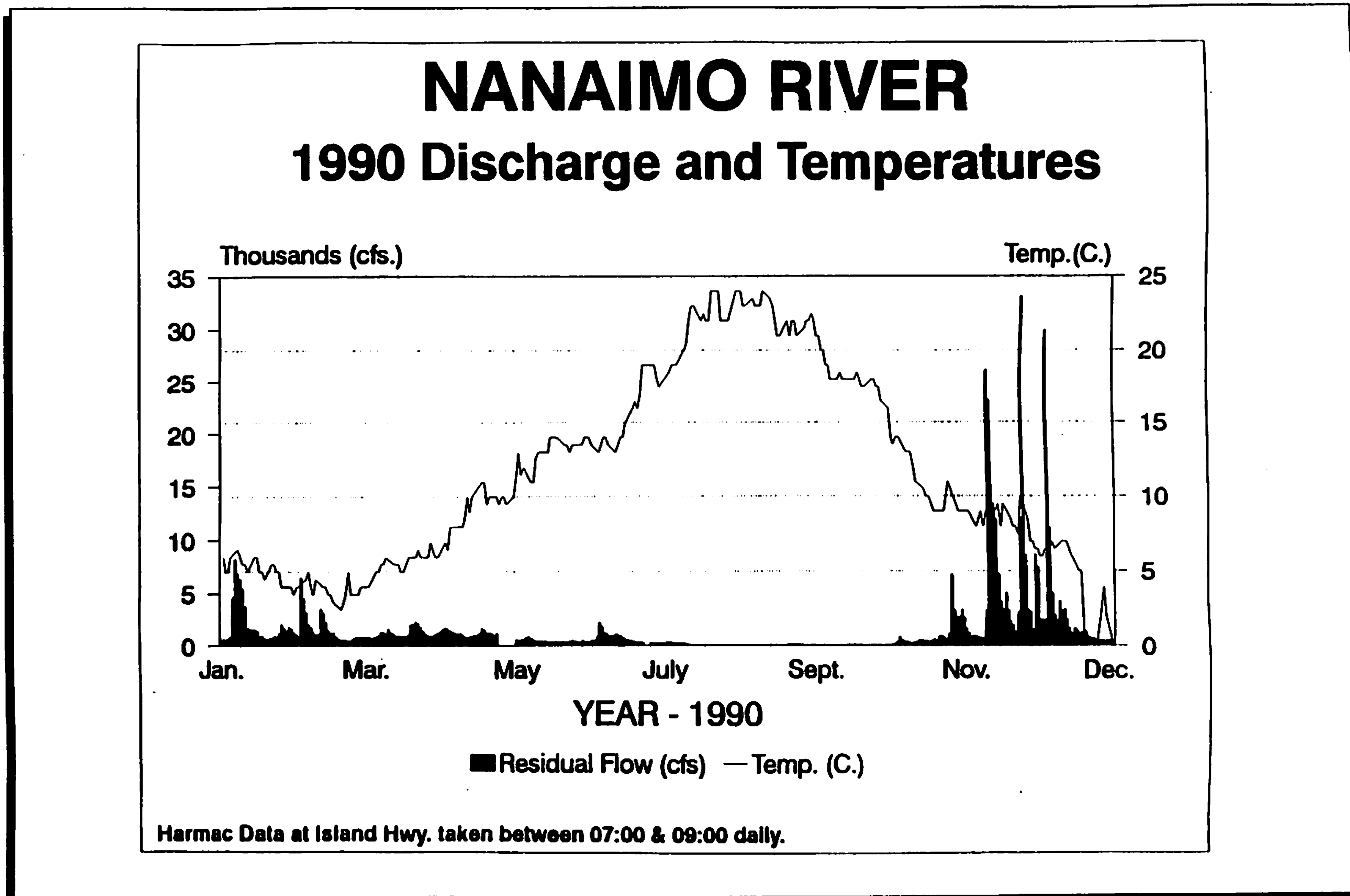


Figure 5.8 1990 Water Temperature and Residual Nanaimo River Discharge

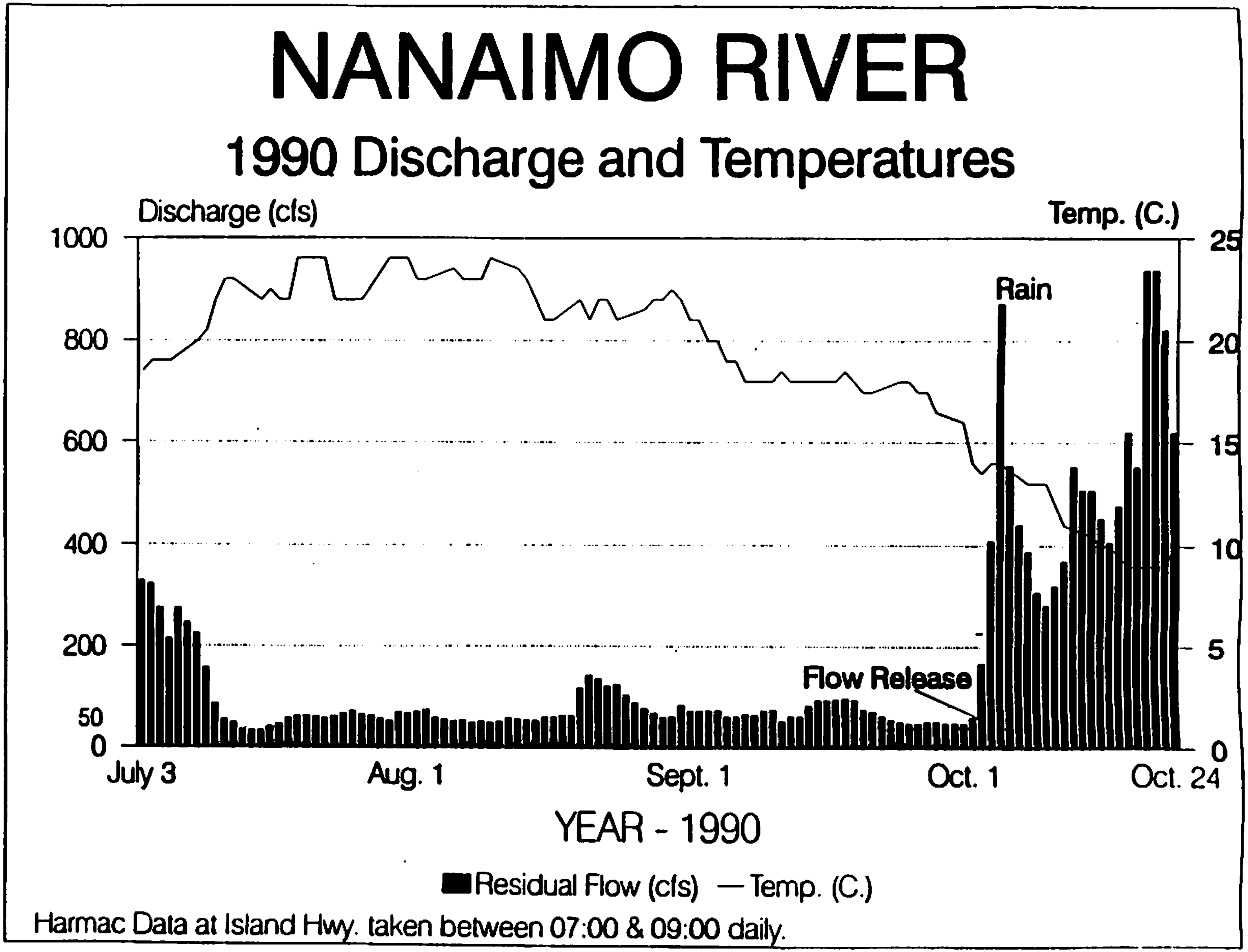


Figure 5.9 1990 Summer Water Temperatures and Residual Nanaimo River Discharge

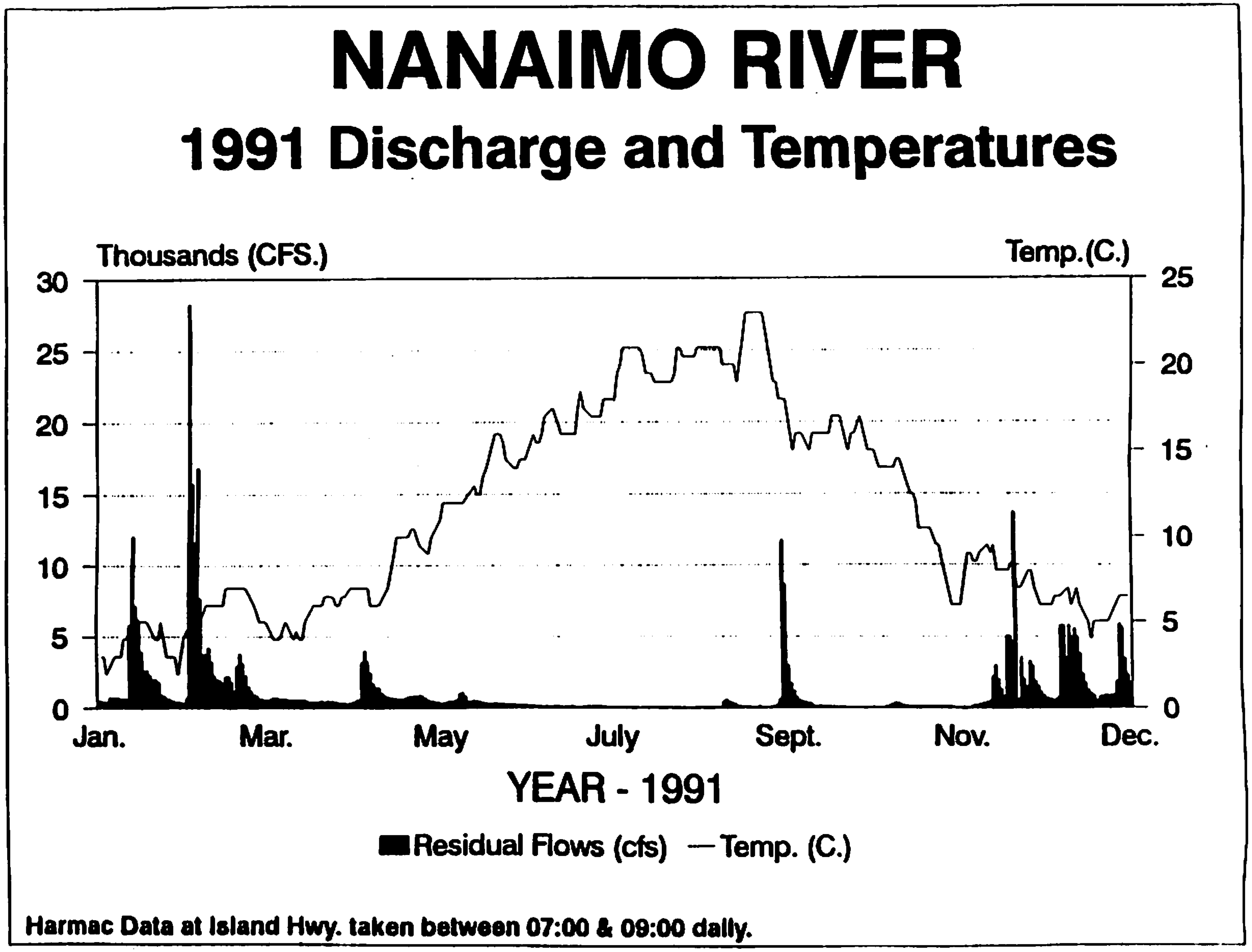


Figure 5.10 1991 Water Temperature and Residual Nanaimo River Discharge

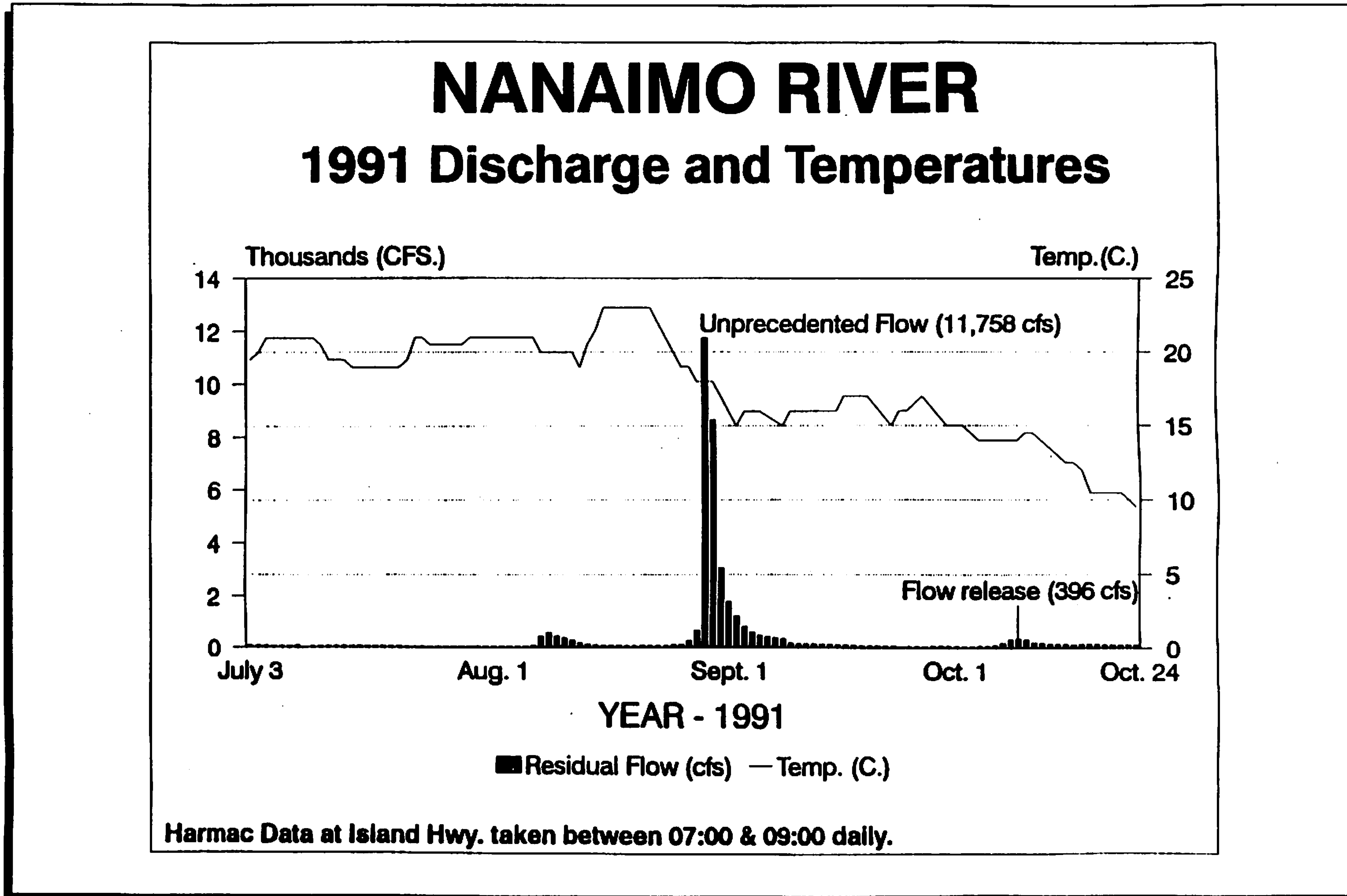


Figure 5.11 1991 Summer Water Temperatures and Residual Nanaimo River Discharge

CHAPTER 6 WATER RESOURCE USES

6.1 Introduction

Water resource use may be broadly categorized into three categories. The first category, those uses that are regulated under the *Water Act* by licence, approval, engineers order or other regulation. These include extractive demands such as municipal, industrial, agricultural and domestic demands and flow regulation works such as storage structures, fish hatchery and conservation works, land drainage and aesthetic improvement works and hydroelectric power developments. Natural uses such as fish, wildlife and recreational uses that have an instream flow requirement are also a water resource use category. The third broad category is groundwater uses that at present are unregulated and may, at some stage, have an affect on the natural uses and the regulated uses under the *Water Act*.

6.2 Water Management Procedures

In British Columbia, the *Water Act* is the principal instrument for allocating and regulating the crown water resource among users. 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 use of water for some defined beneficial purpose.
- The allocation takes precedence according to date of application.
- 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), 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 offenses 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.

6.3 Surface Water Licensed Uses

Figure 6.1 reveals the licensed storage and demand locations in the Nanaimo River Basin. Existing licensed quantities of surface waters in the Nanaimo River have been recorded (Table 6.1) based on the license locations and purposes (waterworks, domestic, industrial, irrigation, conservation and storage) and then summarized as total licensed demand by purpose in Table 6.2.

6.3.1 Municipal

The Greater Nanaimo Waterworks District's (GNWD's) demands are the only licensed municipal waterworks in the Nanaimo River watershed. Their licensed demand represents an average withdrawal of 2.0516 m^3/sec or 30.73% of the total extractive demands from the watershed. The total licensed storage on South Nanaimo River (3,157 dam^3) and Jump Creek (12,335 dam^3) is 15,492 dam^3. The GNWD has a further water licence application for 4,934 dam^3 for increased storage through the installation of gates on the spillway crest. These gates have been installed and the application should be issued. Therefore, the total licensed and application storage could supply 2.63 m^3/sec. for a three month period.

North Cedar Water Works District used to hold water licences on the Nanaimo River for water supplied from wells adjacent to the Nanaimo River upstream of Cedar Road and downstream of the Harmac intake. Water continues to be extracted from these wells, however, due to an appeal decision this water has been determined to be groundwater and therefore is not presently regulated by water licences.

6.3.2 Industrial

MacMillan Bloedel's Harmac industrial (pulp mill) licensed demand are from an intake and wells adjacent to the Nanaimo River and an intake (well) adjoining and associated with Haslam Creek. These intakes and wells are located approximately 40 km downstream of the Forth Lake dam on the Nanaimo River and between the Highway No. 1 bridge and the confluence of Haslam Creek with the Nanaimo River. During low flows Harmac pumps from the Nanaimo River into their intake pool adjoining Haslam creek. Their licensed demand represents an average withdrawal of 4.5306 m^3/sec or 67.87% of the total extractive demands from the watershed. Their total licensed storage volume could supply 5.5520 m^3/sec for a 3 month period.

The seven licences held by GNWD and Harmac represent 98.6% of the total watershed licensed extractive demands. Irrigation, domestic, other industrial and conservation account for only 1.4% of the licensed extractive demands. Other industrial uses are for watering stock and golf course irrigation. These other industrial water demands represent only 0.017% of the total licensed extractive demands from the watershed. Although they are not significant demands in comparison with the overall watershed supply and demand, they are on small tributary streams where local competition with instream fish flow requirements does occur.

6.3.3 Agriculture

Agriculture licensed demand for irrigation represents an average withdrawal of 0.0917 m^3/sec over a 90 day period or 1.374% of the total extractive demands from the watershed. Total licensed storage volume to support irrigation demands could supply 0.0235 m^3/sec for a 3 month period. Most of the irrigation demand (73%) is in the Haslam Creek drainage area. Irrigation from these low elevation drainages and small tributary streams competes with instream fish flow requirements.

6.3.4 Domestic

Domestic licensed demand represents an average withdrawal of 0.0009 m^3/sec or 0.014% of the total extractive demands from the watershed. Domestic demands do not significantly affect flows or compete with instream fish flow requirements.

6.3.5 Storage

There are three significant reservoirs in the Nanaimo River watershed: South Fork, Jump Creek and Fourth Lake reservoirs (Figure 6.1). The Greater Nanaimo Water District (GNWD) obtained authorization to construct a dam and store 3,034 dam^3 in the South Nanaimo River in 1954; with an additional 123 dam^3 authorized in 1955 giving a storage capacity of 3157 dam^3.

They also received authorization to construct a dam and store 12,335 dam^3 upstream in Jump Creek reservoir in 1973. These reservoirs support their licensed withdrawal of 177,300 m^3/day (39.0 million gallons/day) for waterworks supply, mainly to the City of Nanaimo. Gates were added to the existing spillway on the Jump Creek dam during 1986, thereby increasing the potential storage by 4,934 dam^3 to a total of 17,269 dam^3 and the spillway crest was raised 0.305 meters.

The Jump Creek reservoir has a total available drawdown of 14.91 meters between the full supply level (top of spillway gates elevation) of 378.84 meters (local datum) and the intake invert elevation of 363.93 meters (local datum). It is the practise of the GNWD to not increase the full supply level at the gates above 378.38 meters. The South Nanaimo River reservoir is downstream of the Jump Creek reservoir and has a total available drawdown of 15.0 meters. The GNWD is required to maintain 0.28 m^3/sec minimum residual flow passing their dam and intake in the South Nanaimo River, which is to be maintained past Harmac Mill's intake in the lower Nanaimo River.

MacMillan Bloedel Ltd. Harmac Division obtained authorization in 1957 to construct a dam on Fourth Lake (Sadie Creek) to store 43,155 dam^3 in support of their withdrawal of 3.54 m^3/sec for use by Harmac pulp mill. In the summer and early fall months, water is discharged from the reservoir to augment low flows in the Nanaimo River. The Fourth Lake reservoir has a total available drawdown of 31.4 meters between the full supply (spillway crest) elevation of 316.7 meters and 285.3 meters (GSC) and a usable storage available of approximately 38,600 dam^3. A flow of approximately 0.14 m^3/sec. is also released at all times from a low level outlet at the base of the main dam to Sadie Creek.

Harmac is required to maintain 1.10 m^3/sec (39.0 cfs) minimum residual flow past their intake in the lower Nanaimo River. The GNWD is required to maintain a 0.28 m^3/sec (10 cfs) minimum residual flow past their reservoir dam and intake in the South Nanaimo River. This 0.28 m^3/sec flow, in addition to Harmac's 1.10 m^3/sec flow, is to be maintained downstream past the Harmac mill intakes, for a total residual flow of 1.38 m^3/sec. Due to the relative locations and distances of these reservoirs to the Harmac Mill intakes, cutbacks in releases at South Nanaimo River by the GNWD affect the residual flow down stream of Harmac's intake in approximately 24 hours while make up releases by MacMillan Bloedel at Fourth Lake take approximately 72 hours to affect residual flow. This time lag factor affecting flows from the two reservoirs results in periods when the required residual flows in the lower Nanaimo River are less than specified by the license.

Storage in support of agricultural irrigation demands are primarily in dugouts in marshy areas or small dams at the outlet to ponds.

6.3.6 Conservation

There are two conservation water licences. One is for a fish fence at the outlet to a small private lake (Myles Lake). The other licence authorizes the construction and maintenance of fish spawning and rearing channels near the confluence Haslam Creek with the Nanaimo River. Neither of these licences affects flows of the Nanaimo River.

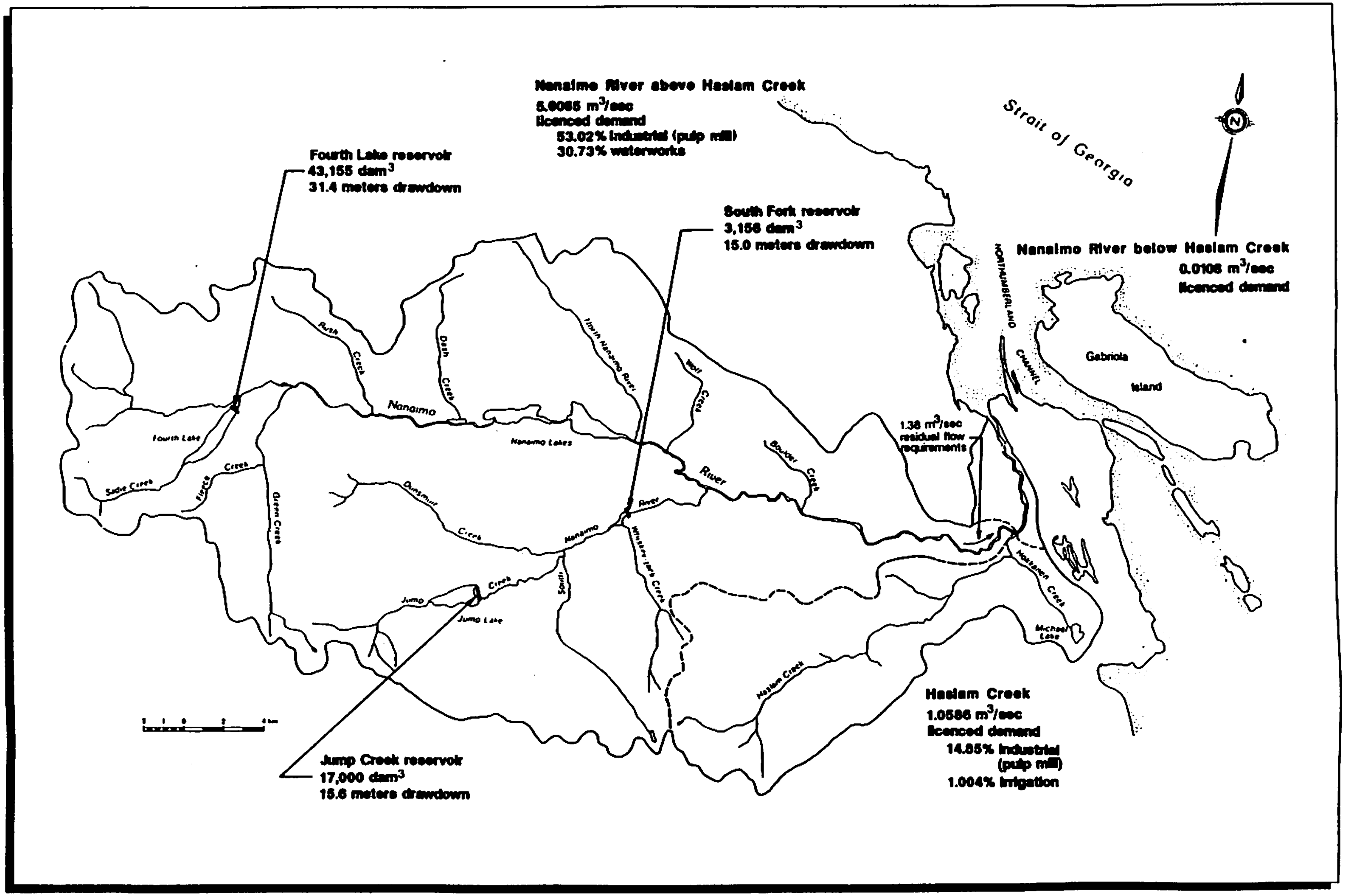


Figure 6.1 Water Licence Storage and Demand

Table 6.1 Existing Licensed Quantities Nanaimo River

Nanaimo River Above Haslam Creek Watershed

Licence Number	File Number	Priority Date	Source	Quantity/Units	Equivalent Flow m³/sec
Waterworks Purpose					
C007001	0242622	1908/05/08	South Nanaimo River	4.500 Mgpd	0.2367
C022272	0242622	1954/05/21	South Nanaimo River	9.500 Mgpd	0.4998
C041112	0316312	1973/01/25	South Nanaimo River	25.000 Mgpd	1.3151
			SUB-TOTAL	39.000 Mgpd	2.0516
Domestic Purpose					
C063206	0243078	1962/03/14	Stark Creek	750.000 gpd	
C063207	0370569	1962/03/14	Stark Creek	500.000 gpd	
C057506	0366815	1980/06/25	Lower Dohma Creek	1,250.000 gpd	
C057319	0367685	1980/12/12	Nanaimo River	500.000 gpd	
C063962	1000608	1986/05/26	Nanaimo River	500.000 gpd	
C065749	1000728	1987/05/28	Myles Lake	500.000 gpd	
C072631	1000856	1988/05/03	Nanaimo River	500.000 gpd	
C065841	1000865	1988/05/30	Nanaimo River	500.000 gpd	
			SUB-TOTAL	5,000.000 gpd	0.0003
Industrial (Pulpmill) Purpose					
F019385	0172183	1948/02/02	Nanaimo River	40.000 cfs	1.1327
F019387	0189088	1951/05/31	Nanaimo River	60.000 cfs	1.6989
F021212	0240189	1962/01/10	Nanaimo River	25.000 cfs	0.7079
			SUB-TOTAL	125.000 cfs	3.5395
Irrigation Purpose					
C070919	0172283	1948/02/12	Stark Creek	49.270 acft	0.0078
F044132	0242762	1962/02/28	Stark Creek	11.000 acft	0.0017
C063206	0243078	1962/03/14	Stark Creek	24.500 acft	0.0039
C063207	0370569	1962/03/14	Stark Creek	10.500 acft	0.0017
			SUB-TOTAL	95.270 acft	0.0151
Conservation Purpose					
C072636	1000771	1987/09/08	Myles Lake	fish fence	0.0000
Storage Purpose					
F048572	0187500	1951/01/26	Sadie Creek	35,000.000 acft	
C022273	0242622	1954/05/21	South Nanaimo River	2,460.000 acft	
C022587	0206860	1955/02/08	South Nanaimo River	100.000 acft	
Z100838	1000627	1986/07/11	Jump Creek	4,000.000 acft	
C041113	0316312	1973/01/25	Jump Creek	10,000.000 acft	
			SUB-TOTAL	51,560.000 acft	

Haslam Creek Watershed

Licence Number	File Number	Priority Date	Source	Quantity/Units	Eqivalent Flow m³/sec
Domestic Purpose					
F015929	0190198	1951/08/31	Patterson Creek	500.000 gpd	
C023852	0216532	1957/06/07	Hokkanen Creek	1,000.000	
C056812	0369852	1970/03/13	North Haslam Creek	333.000 gpd	
C056811	0369851	1970/03/13	North Haslam Creek	333.000 gpd	
C056810	0296149	1970/03/13	North Haslam Creek	333.000 gpd	
C039971	0305837	1971/08/10	Anderson Pond	500.000 gpd	
C039884	0309111	1971/10/05	Anderson Pond	500.000 gpd	
C041474	0310997	1972/10/17	Anderson Creek	500.000 gpd	
C060932	1000070	1982/09/13	Erdley Creek	500.000 gpd	
C060934	1000074	1982/09/28	Erdley Creek	500.000 gpd	
C060936	1000078	1982/10/04	Mathers Swamp	1,000.000 gpd	
C059654	1000118	1983/01/11	Moreland Creek	500.000 gpd	
C072655	1000963	1988/10/27	Michael Lake	500.000 gpd	
			SUB-TOTAL	6,999.000 gpd	0.0004
Industrial (Pulpmill) Purpose					
F019386	0173929	1948/06/04	Haslam Creek	35.000 cfs	**0.9911**
Industrial (Stock Watering) Purpose					
C070687	1000894	1951/08/31	Patterson Creek	500.000 gpd	
C070686	0190687	1951/08/31	Patterson Creek	500.000 gpd	
			SUB-TOTAL	1,000.000 gpd	0.0001
Conservation Purpose					
C058760	1000049	1982/08/09	Haslam Creek	0.000	0.0000
Irrigation Purpose					
C054220	0185491	1950/08/22	Pelter Creek	19.170 acft	0.0030
C054221	0346776	1950/08/22	Pelter Creek	0.830 acft	0.0001
F020569	0189958	1951/07/19	Michael Lake	30.000 acft	0.0048
F020876	0190198	1951/08/31	Patterson Creek	20.000 acft	0.0032
F017057	0190856	1951/09/10	Michael Lake	25.000 acft	0.0040
F020568	0189958	1952/09/09	Michael Lake	30.000 acft	0.0048
F039376	0215973	1957/05/07	Alfred Creek	23.000 acft	0.0037

Licence Number	File Number	Priority Date	Source	Quantity/Units	Eqivalent Flow m^3/sec
C023852	0216532	1957/06/07	Hokkanen Creek	60.000 acft	0.0095
F040859	0260582	1965/01/20	Michael Lake	23.000 acft	0.0037
C068241	1000880	1965/06/08	Sylvia Creek	0.870 acft	0.0001
C068240	0262858	1965/06/08	Sylvia Creek	19.130 acft	0.0030
C033663	0277881	1968/04/08	Michael Lake	25.000 acft	0.0040
F041012	0281322	1968/06/28	Michael Lake	25.000 acft	0.0040
C039971	0305837	1971/08/10	Anderson Pond	2.500 acft	0.0004
C039884	0309111	1971/10/05	Anderson Pond	7.500 acft	0.0012
C041474	0310997	1972/10/17	Anderson Creek	6.000 acft	0.0010
C060936	1000078	1982/10/04	Mathers Swamp	55.000 acft	0.0087
C059654	1000118	1983/01/11	Moreland Creek	0.800 acft	0.0001
C061399	1000401	1984/08/10	Sylvia Creek	46.000 acft	0.0073
C065746	1000735	1987/06/11	Patterson Creek	1.100 acft	0.0002
C065795	1000734	1987/06/11	Hilder Brook	1.000 acft	0.0002
			SUB-TOTAL	420.900 acft	0.0670
Storage Purpose					
C068240	0262858	1965/06/08	Sylvia Creek	19.130 acft	-0.0030
C068241	1000880	1965/06/08	Sylvia Creek	0.870 acft	-0.0001
C039972	0305837	1971/08/10	Anderson Pond	2.500 acft	-0.0004
C039840	0309111	1971/10/05	Anderson Pond	7.500 acft	-0.0012
C041475	0310997	1972/10/17	Anderson Creek	3.000 acft	-0.0005
C062114	0369641	1981/11/26	Anderson Creek	2.000 acft	-0.0003
C060933	1000070	1982/09/13	Erdley Creek	0.700 acft	-0.0001
C060935	1000074	1982/09/28	Erdley Creek	0.700 acft	-0.0001
C060937	1000078	1982/10/04	Mathers Swamp	56.300 acft	-0.0089
C059655	1000118	1983/01/11	Moreland Creek	1.100 acft	-0.0002
C061400	1000401	1984/08/10	Sylvia Creek	46.000 acft	-0.0073
C065795	1000734	1987/06/11	Hilder Brook	1.000 acft	-0.0002
C065746	1000735	1987/06/11	Patterson Creek	1.100 acft	-0.0002
			SUB-TOTAL	201.900 acft	-0.0225

Nanaimo River below Haslam Creek

Licence Number	File Number	Priority Date	Source	Quantity/Units	Equivalent Flow m^3/sec
Domestic Purpose					
F016151	0185868	1950/09/08	Thatcher Creek	500.000 gpd	
C034954	0285339	1969/04/01	Thatcher Creek	500.000 gpd	
F043953	0285398	1969/04/15	Thatcher Creek	500.000 gpd	
C055161	0342034	1977/09/12	Nanaimo River	1,000.000 gpd	
C057410	0365272	1979/03/13	Tara Swamp	500.000 gpd	
			SUB-TOTAL	3,000.000 gpd	0.0002
Industrial (Enterprise) Purpose					
C057410	0365272	1979/03/13	Tara Swamp	250.000 gpd	0.0000
Industrial (Golf Course Watering) Purpose					
C064082	1000497	1985/07/15	Tara Swamp	6.000 acft	0.0010
Irrigation Purpose					
C022149	0203451	1954/04/07	Nanaimo River	30.000 acft	0.0048
F042991	0285295	1969/03/17	Thatcher Creek	30.000 acft	0.0048
			SUB-TOTAL	60.000 acft	0.0096
Storage Purpose					
C064083	1000497	1985/07/15	Tara Swamp	6.000 acft	-0.0010

Mgpd	Million gallons per day
gpd	gallons per day
cfs	cubic feet per second
acft	acre feet
l/sec	litres per second
cms	cubic meters per second

*Estimated equivalent daily licensed consumptive demand during the low flow period.

<u>CONVERSIONS TO EQUIVALENT FLOW</u>

Waterworks	1.000 Mgpd	=1.8578 cfs	=0.0526 cms
Domestic	500 gpd	=0.0009 cfs	=0.026 l/sec
Industrial (Pulp Mill)	1.000 cfs		=0.0283 cms
Industrial (Stock Watering)	500 gpd	=0.0009 cfs	=0.026 l/sec
Industrial (Golf Course Watering)	1.0 acft	=0.0056 cfs	=0.00016 cms
Irrigation (per 90 days)	1.0 acft	=0.0056 cfs	=0.00016 cms
Conservation (non-consumptive)	0.000		=0.0000 cms
Storage (per 90 days)	1.0 acft	=-0.0056 cfs	=-0.00016 cms

(Storage is consider a negative demand during the low flow period)

Table 6.2 Nanaimo Watershed Total Licensed Demand By Purpose

PURPOSE AND % and No.	ABOVE HASLAM CREEK	HASLAM CREEK	BELOW HASLAM CREEK	TOTALS
WATERWORKS DEMAND **Number of licences** **% of Total Demand**	2.0516 cms 3 licences 30.73%			2.0516 cms 3 licences 30.73%
DOMESTIC DEMAND **Number of licences** **% of Total Demand**	0.0003 cms 8 licences 0.005%	0.0004 cms 13 licences 0.006%	0.0002 cms 5 licences 0.003%	0.0009 cms 26 licences 0.014%
INDUSTRIAL (PULP MILL) DEMAND **Number of licences** **% of Total Demand**	3.5395 cms 3 licences 53.02%	0.9911 cms 1 licence 14.85%		4.5306 cms 4 licences 67.87%
INDUSTRIAL (other) DEMAND **Number of licences** **% of Total Demand**		0.0001 cms 1 licence 0.002%	0.0010 cms 2 licences 0.015%	0.0011 cms 3 licences 0.017%
IRRIGATION (per 90 days) DEMAND **Number of licences** **% of Total Demand**	0.0151 cms 4 licences 0.226%	0.0670 cms 21 licences 1.004%	0.0096 cms 2 licences 0.144%	0.0917 cms 27 licences 1.374%
CONSERVATION DEMAND **Number of licences** **% of Total Demand**	0.0000 cms 1 licence 0.00%	0.0000 cms 1 licence 0.00%		0.0000 cms 2 licences 0.00%
TOTAL DEMAND **Number of licences** **% of Total Demand**	5.6065 cms 19 licences 83.98%	1.0586 cms 37 licences 15.86%	0.0108 cms 9 licences 0.16%	6.6759 cms 65 licences 100.00%

STORAGE **Number of licences**	69,546.17 dam3 5 licences	249.05 dams3 13 licences	7.40 dam3 1 licence	69,802.62 dams3 19 licences

6.4 Instream Water Requirements

6.4.1 Fisheries

Estimating the flow requirements for fish is a difficult task; while knowledge in this area is expanding at a fast rate, there are many gaps in available data and in the understanding of fish needs. The flow requirements requested by DFO for salmon management requirements are pulse flows intended to trigger fish migration and apply to the downstream reach of the Nanaimo River, below the Harmac intake. Two pulses of flow, of four days duration each, peaking at 11.3 m^3/s (400 cfs) are required; the volume of each pulse is 3,915 dam^3. Mature chinook typically hold in the tidal portion of the Nanaimo River in the vicinity of the Nanaimo River bridge during September.

In 1990 and 1991 the release flows from the two reservoirs were staggered by approximately 24 hours (Jump Creek follows Fourth Lake) so that the effect is a single rise of water at tide water was experienced by the holding salmon. As a result of the experimental flow releases, DFO recommends the flow release strategy be incorporated into the NRWM Plan if water is available for release during fall chinook migration periods when river water temperatures are below 20 C. (also refer to Section 5.5). It is further recommended that if future additional new storage is developed in the Nanaimo watershed, that water be reserved so that the recommended release flows can be made available in years of drought.

Recreational flow requirements have been determined for the period April 1 to October 31. These requirements are based on assessments by Recreational Fisheries, Ministry of Environment. Table 6.3 lists the recreational flow requirements that apply to the reach of the Nanaimo River upstream of the Harmac intake. These requirements are further considered in Chapter 7.

Table 6.3 Recreational Fish Flow Requirements (Lewis, 1992)

Period	**Minimum Recreational Flow Requirements**
April to June	7.8 m^3/sec (275 cfs)
July and Aug.	5.85 m^3/sec (207 cfs)
Sept. and Oct.	3.9 m^3/sec (138 cfs)

6.4.2 Wildlife Requirements

The Nanaimo River Basin supports an abundant and diverse wildlife resource.

The river, the adjacent riparian and valley bottom area, and the estuary play an important and often critical role in the seasonal life cycles of many wildlife species.

The two ungulate species in the area are black-tail deer and Roosevelk elk. Deer are abundant and utilize all parts of the basin, from valley-bottom to alpine, but depend heavily on south facing forested slopes in winter and valley flats for spring forage. The elk herd in this drainage, numbering about 250 animals is one of the few herds remaining on southern Vancouver Island. Again, this species uses all habitats, but is heavily dependent on the river and adjacent valley flats during winter and early spring.

The two major carnivores in this area, the wolf and cougar, occur in all habitats but tend to be closely associated with deer and elk, their main food source. Black bears, being more omnivorous, are more dependent on the valley flats in the spring, foraging on newly emergent vegetation. In other seasons, they are found in all habitats.

The smaller furbearers in the area are pine marten, found primarily in forested areas, and the river otter, mink and to a lesser extent, the racoon, occurring mostly in and around the river and estuary. The endangered Vancouver Island marmot are specific to alpine areas.

Upland game birds and waterfowl occur throughout the forest, with ptarmigan restricted to the alpine, blue grouse in both alpine and forested areas, and ruffed grouse usually in the riparian zones. Pheasant and California quail are found in the agricultural areas. Numerous waterfowl species utilize the estuary, lakes and marshes, and to a lesser extent the river.

The Nanaimo River Basin, like most areas of Eastern Vancouver Island, supports a tremendous abundance and diversity of insectivorous birds, small mammals, reptiles and amphibians. Most diversity and abundance is found in the remainder of old-growth forests and the mixed coniferous/ deciduous forests in the valley bottom riparian zones.

The Nanaimo River estuary has special significance. The Georgia Strait is a major migration stop-over and wintering area for water fowl, shore birds, and sea birds from all of western North America, including such threatened species as the Trumpeter swan. The Nanaimo Estuary has been designated as a critical wetland for migratory birds by both the provincial and federal governments. The estuary was recently purchased by The Nature Trust of British Columbia and the Ministry of Environment, Lands and Parks, and is protected and managed specifically for wildlife.

Appropriate water levels and flows are necessary to maintain critical wildlife habitats in the Nanaimo River Basin. In this study, criteria were not established for evaluating the impact of changing stream flows, and lake and reservoir conditions on wildlife. Because many species depend on the estuary, river, riparian zone and adjacent valley bottom, regulating flows in the system would significantly affect wildlife. If additional flow regulation is being considered, or if additional storage within existing facilities or new facilities are required to meet future water demands, the potential of flooding and/or water level reductions on wildlife habitats will have to be addressed (Davies, 1992).

6.4.3 Recreational Uses

The Nanaimo River Basin provides considerable recreational opportunities. The basin is located adjacent to a relatively large centre of population and the residents can easily access the basin and its opportunities. The recreational activities of this area are not limited only to the local residents around Nanaimo, but could potentially represent a provincial resource since, this area is a focal point for tourism.

The Nanaimo Lakes Division of Fletcher Challenge Canada owns part of the land in the upper basin and provides open access year round from Boulder Creek to their Dryland sort for public recreational activities. In excess of 50,000 user days are recorded annually. Fletcher Challenge maintains campgrounds with some facilities on First Lake and Shelton Lake. Wilderness campgrounds with limited facilities are also provided on Healy, Second and Fourth Lakes. The company also allows access to Green Mountain for public viewing of alpine meadows, elk and marmots. The area is popular for cross-country skiing. Hiking opportunities have been identified for Mount Moriarty and Mount Decosmos has been identified as having alpine skiing potential by the Ministry of Parks (Chin, 1991).

The waterfowl, game birds and mammals of the area are highly prized by hunters and naturalists. The Nanaimo area has a relatively high hunter density as is evidenced by the large and enthusiastic membership of the Nanaimo Fish and Game Club.

The Nanaimo estuary offers excellent accessible recreation opportunities for natural history groups and photographers. School groups, adult education classes and the Nanaimo District Naturalist Club conduct regular outings to the estuary to study and observe the abundant wildlife resources.

The Nanaimo River, as discussed in Chapter 5, is used for sport fishing and depends on adequate water supply in terms of appropriate instream flows and water levels as well as good water quality. Fishing activity begins at the end of

November and runs through to the end of March and occurs most commonly in the lower reaches of the Nanaimo River and in the more accessible Lakes. Activities in the river include swimming and canoeing.

The Nanaimo River has an active kayak club based out of the Malaspina College in Nanaimo that utilizes the river. The river is also used by novice and expert kyakers, depending on the season and the location within the river. The "top"section of the river is used for a novice to intermediate level of paddler (grade 1-2). From mile 16 to Old White Rapids, paddlers use the river as an expert run (grades 2-4). The character of the river then changes for eight or nine miles in the canyon where no paddling occurs. The fourth leg of the river, from Cassidy to the estuary is used as an excellent beginners area (Cohen, 1992).

Minimum water levels for most recreation activities have not been identified for the Nanaimo River. 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 most recreational purposes. It is recognized that recreational areas may not coincide with fisheries areas.

6.5 Groundwater Uses

The Cassidy aquifer area contains the most significant groundwater reservoirs in terms of aquifer potential and use. The Upper Aquifer is an important source of water supply for domestic, irrigation, community and industrial use. There are approximately 100 known domestic wells in the area. These wells are utilized for airport, irrigation, community and development (trailer parks, etc) use and are located in the south part of the aquifer area (Zubel, 1991).

The most significant groundwater wells in terms of use, are located in the northern part of the aquifer area, adjacent to the Nanaimo River and Haslam Creek. These major users are Harmac Pulp Mill (Production Wells "A", "C", "D", "E", and "F") for industrial purposes, Fisheries Canada Hatchery Well (formerly Harmac Prod. Well "B") for fisheries purposes and the Boat Harbour Development Production Well for community supplies (Zubel, 1991).

6.6 Future Water Resource Requirements

6.6.1 Future Water Demands

Municipal Demands

Population growth projections for the Nanaimo area suggests that the there will be a twenty-five percent rise in population by the year 2016 (Barnett, 1991) and as populations rise there will be increasing pressures on the water resources of the area.

More specifically, the GNWD has projected future water demands for the years 1995 through to 2015 that are based on population projections with an average annual growth rate of 2.32 %, maximum day demand of 1.44 m^3/day/person and an average water demand from June through to September of 0.894 m^3/day/person (Table 6.1).

Table 6.4 Nanaimo Water District - Water Study Update Water Demand Projections April 1992

Year	Population	Average Demand June- Sept. (m^3/day)	Maximum Day (m^3/day)
1995	62,412	55,823	89,873
2000	69,996	62,606	100,794
2005	78,501	70,213	113,041
2010	88,039	78,744	126,776
2015	98,737	88,313	142,181

It is anticipated that the GNWD reservoir at Jump Creek should be able to meet the population's water demands until 2010. Also the GNWD is duplicating its pipeline which will increase its ability to supply water from 86.4 million L/day (19 million gallons/day) to 227.3 - 286.4 million L/day (50-53 million gallons/day). It is expected that this process will be complete by the summer of 1993 (Hansen, 1992).

Industrial Demands

Harmac's current average water use is 245.5 million L/day (54 million gallons/day) with river water use requirements scheduled to decrease over time. In the 1992-1994 term, the water will be reduced to 80 % of current use. In the 1994 - 2000 term there will be substantive decease in water use within the plant to 67 % of current use or 163.7 million L/day (36 million gallons /day). It is anticipated that the same amount of water will be used from the wells as at present. In the long term there may be an addition of a new facility at Harmac. Overall, there will be substantially lower use of water by Harmac by December 31, 1993 (Duncanson, 1992).

6.6.2 Future Instream Requirements

The instream requirements for fisheries, wildlife and recreation have been detailed in this chapter and Chapter 5. In the future these water resource demands must be considered in the Nanaimo River watershed.

If new storage is developed or added in the watershed it is recommended by fisheries management that water be reserved, based on recommendations in Chapter 5, in order to provide flows in years of drought. In the future, if flow regulations and additional storage requirements are considered, then the affects of flooding and/or water restriction on wildlife habitats will have to be addressed. Finally, if any actions towards new or alternate storage facilities are initiated, then recreational interests must be considered.

CHAPTER 7 WATER MANAGEMENT MODELLING

7.1 The Need for Modelling

Flows in the Nanaimo River are naturally low in the late summer and early fall, returning to higher rates when fall rains replenish the basin, as illustrated in Figure 7.1. The period of low flow can result in poor habitat conditions for fish and, when it extends later into the fall than usual, it can delay fish migration up the river for spawning. It is important to note that these low flow cor. .itions are a natural phenomenon, not the result of the operation of Jump Creek and Fourth Lake reservoirs. These reservoirs have improved the flow regime in the late summer and have the potential to further improve the management of the river for fish.

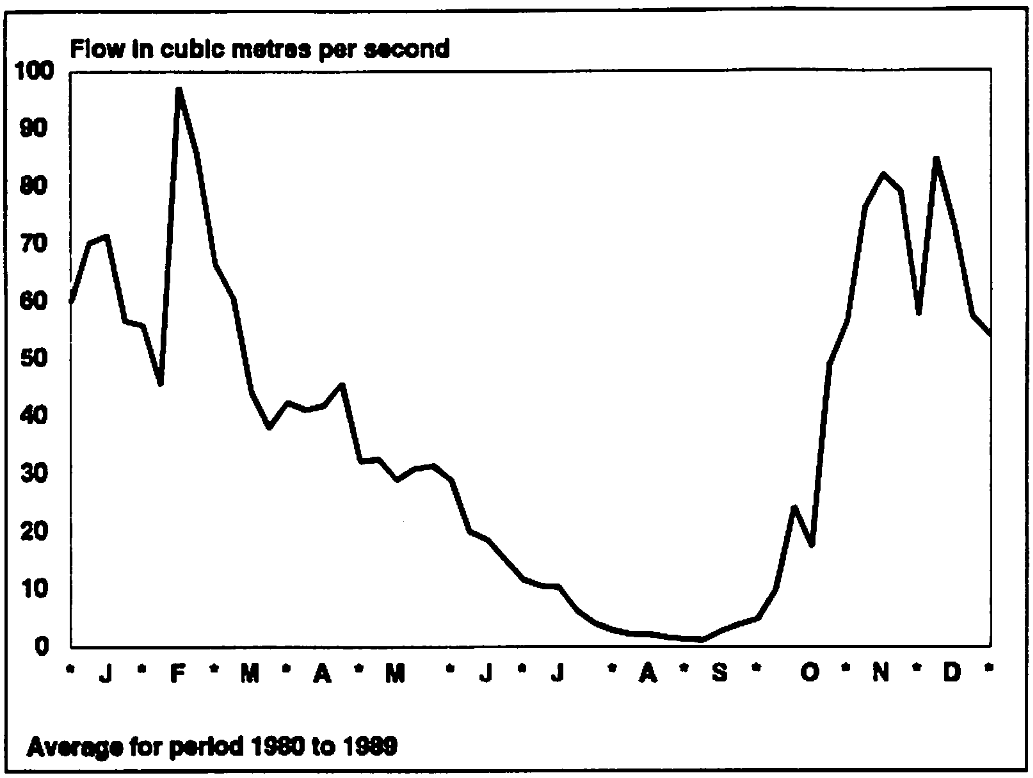


Figure 7.1 Average Natural Flow at the Mouth of the Nanaimo River

The three storage reservoirs in the basin, noted in Figure 7.2, as Jump Creek, Fourth Lake and South Forks control only 20% of the basin's natural runoff and have storage amounting to only 5% of the basin's natural runoff. More significantly, these reservoirs were designed for specific single purpose of providing water for consumptive use by the Greater Nanaimo Water District

(GNWD) and by the MacMillan Bloedel Pulp Mill, Harmac. Historically, both the GNWD and Harmac have made releases to improve conditions for fish at times when reservoir levels were sufficiently high.

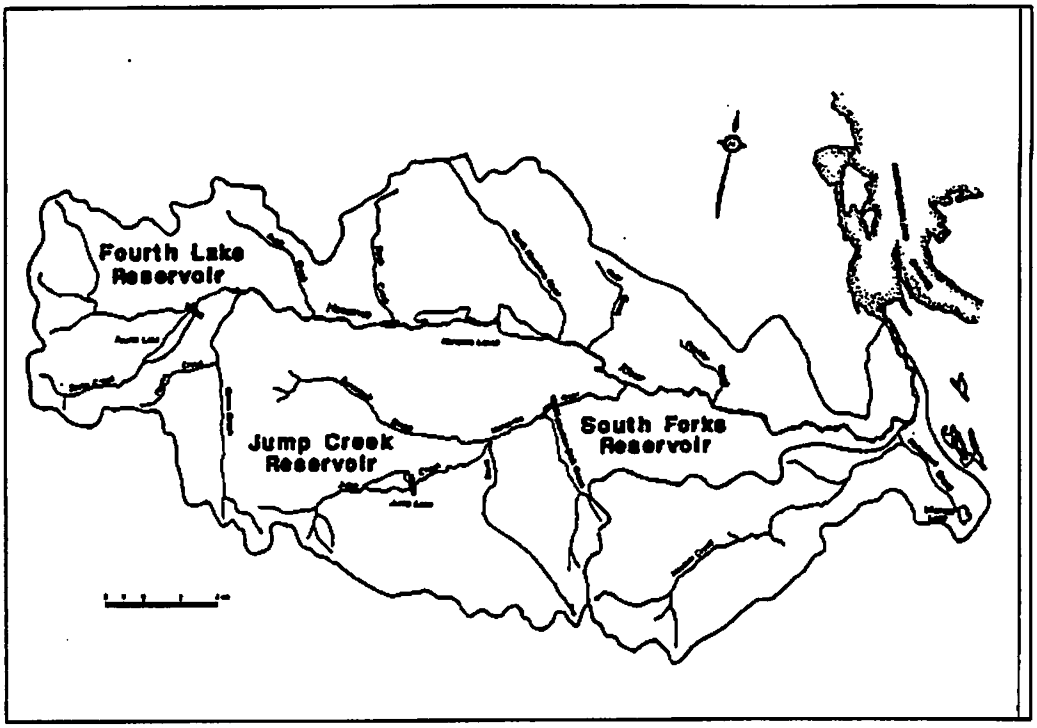


Figure 7.2 Nanaimo River Basin

Water management modelling allows for the assessment of the extent to which the existing storage facilities can be operated to both meet their primary objective of providing a secure water supply to the GNWD and Harmac, and to provide supplementary flows for fish. Future modelling work could include the evaluation of the effectiveness of adding additional storage in the basin.

A modelling process requires the review and description of many aspects of the basin, such as the determination of natural flows, the representation of operating policies, and description of the physical size and characteristics of dams and reservoirs, and the flow requirements of the City, Harmac, instream requirements and others. This process helps to structure a comprehensive approach to water management planning.

7.2 Modelling Introduction

The Water Resources Management Model (WRMM) is a computer program used to analyze water management problems involving the allocation of limited natural water supplies. This type of problem is becoming increasingly prevalent as both consumptive demands and awareness of instream flow requirements increase.

The WRMM can represent the natural flows, water demands and physical configuration of a basin. It is used to simulate a number of years for which natural flows have been computed, in various time steps. The Nanaimo River model, uses a 10 year simulation period, 1980 to 1989, with input data organized in one week time steps. The program allocates available flow in each week to demands in the watershed on the basis of user-specified priorities. When there is not enough water to meet all demands, the lowest priority demands suffer water deficits.

Water stored in a reservoir is treated as a "demand", and thus competes with other demands in the basin for water. This feature of the model allows control over the timing and magnitude of reservoir releases.

The model represents operational strategies for allocating water by recognizing both the individual uses of water and defined reductions in water available to each use as supply becomes limited. Different priorities are assigned to these reductions in demand in the form of penalty points. The model allows for the integration of these priorities which results in a sharing of any water deficits amongst the users. The complexity of the system of priorities is dependent upon the modeller; however, priorities are normally kept as simple as possible. In this regard, what must be kept in mind when developing a basin model is the relationship between model priorities and real-world operations.

The WRMM represents the physical components of a river basin, namely; dams, reservoirs, natural channels, diversions, withdrawals and instream uses. The physical capacity of each of these components, in terms of the flow and storage capacities of each and their hierarchical arrangement are defined within the model. Further information may be found in the WRMM manual - Water Resources Management Model Program Description (Alberta Environment, 1987).

7.3 Water Management in the Nanaimo River Basin

7.3.1 Natural Flows

General Hydrology

The mean annual natural runoff at the hydrometric station 08HB034 Nanaimo River, based on the period 1980 to 1989 is 1.18 million dam^3 (0.96 million ac-ft), with an average distribution as shown in Figure 7.1. Natural flow is the flow that would have occurred at a location on a river if man had not affected the flow regime by storing, withdrawing or diverting water. This flow is calculated by taking the recorded flows at the location of interest and adjusting them to account for such effects.

Natural flow is very important in water management modelling because it defines the total available supply of water, and its distribution in time and space. The model is used to analyze alternate allocations of the available natural flows amongst competing water demands. A discussion of the calculation of natural flows is given in Chapter 3, Section 3.1.

Hydrologic Context

Natural flows are currently available for the Nanaimo River Basin for the period 1980 to 1989. All conclusions drawn from the modelling are limited to the range of conditions that occurred in this ten year period. Return period estimates of the nearby Chemainus River indicate 1987, the extreme in the period of record, is approximately a one in eighty year low flow event for a four month period.

7.3.2 Demands

Greater Nanaimo Water District

Figure 7.3 shows the total annual demand for the GNWD from 1980 to 1989. Demand is growing and the highest total demand was recorded in 1987, 12,200 dam^3 (9,900 ac-ft). The average distribution of demand is illustrated in Figure 7.4. For modelling purposes, the 1987 demand volume was coupled with the average demand distribution. This was done to remove anomalies of demand that can occur in a given year.

Future demands for the GNWD have been determined from Table 6.4 in Chapter 6, The Nanaimo Water District - Water Study Update Water Demand Projection April 1992. The June to September demand from the table was compared to that of 1987 and the resultant ratio of 1.96 was used to adjust the GNWD demand distribution to represent the demand for the year 2015.

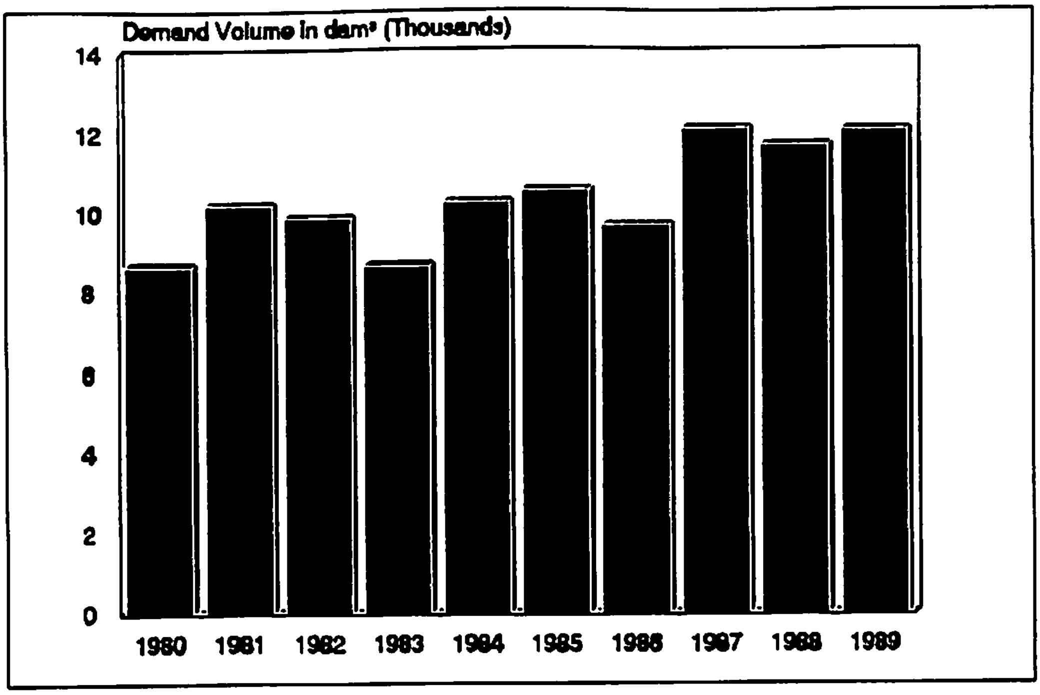


Figure 7.3 Greater Nanaimo Water District Annual Demands

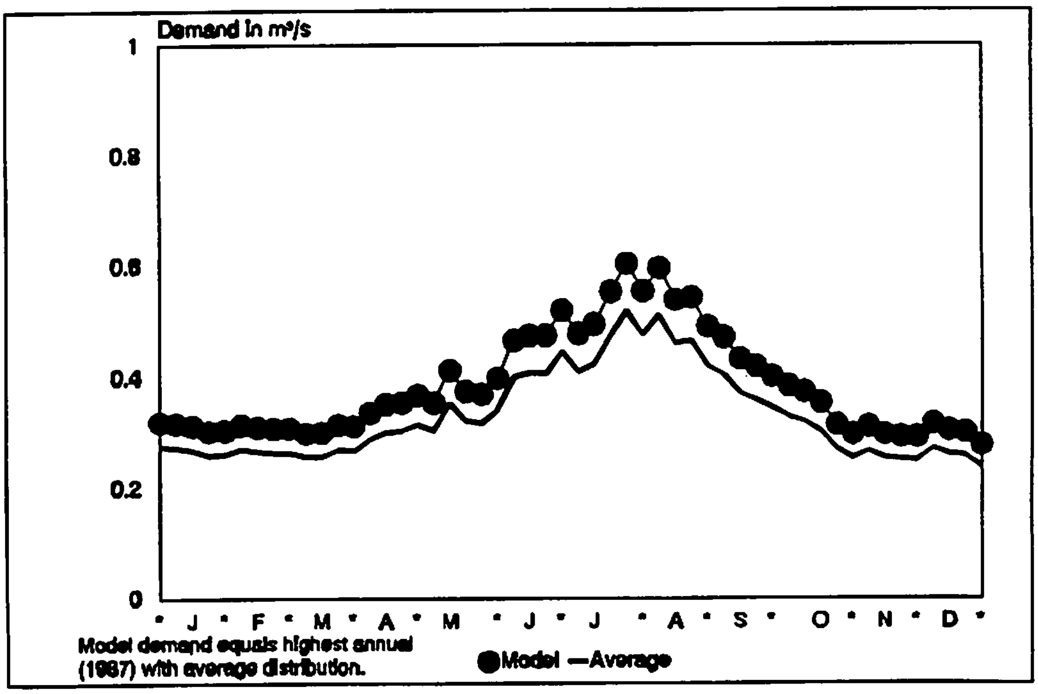


Figure 7.4 Greater Nanaimo Water District Demand Distribution

Harmac

Figure 7.5 shows the total annual demand from the river for Harmac during 1980 to 1989. Harmac's demand is relatively steady, with a maximum value of 62,600 dam^3 (50,800 ac-ft) occurring in 1987. During the simulation period, spot measurement of river use was made each morning by Harmac and as there was diurnal variation of use these were found to overestimate the water diverted from the river. Harmac has since installed an automatic recorder to determine river use. The river use demand figures in the model were determined by subtracting total well use from total mill use, both recorded on a 24 hour basis.

The average distribution of the Harmac river demand is shown in Figure 7.6. The 1987 annual volume was distributed according to the average distribution and used to represent their demand in the model. Harmac's demand for water in the model included river use but excluded well use as the hydrological effects of groundwater withdrawals on streamflow is unknown. The relationship between surface water and groundwater should be investigated in future studies.

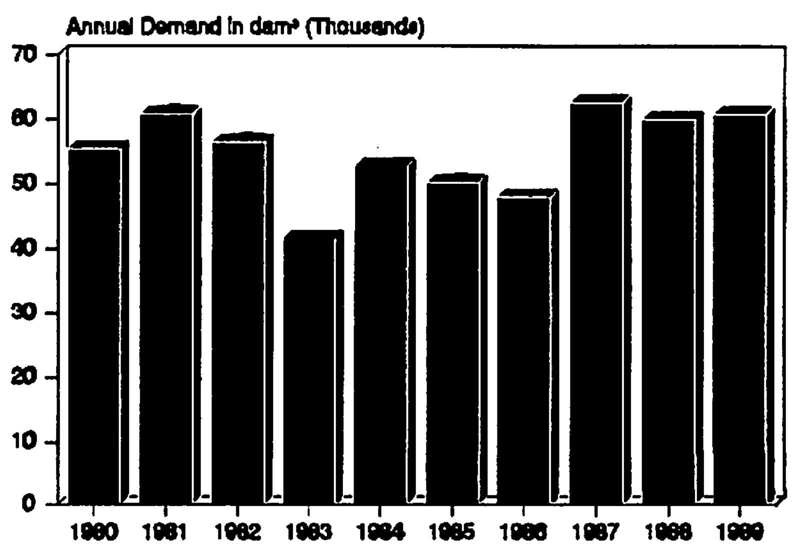


Figure 7.5 Harmac Annual Diversion From the Nanaimo River

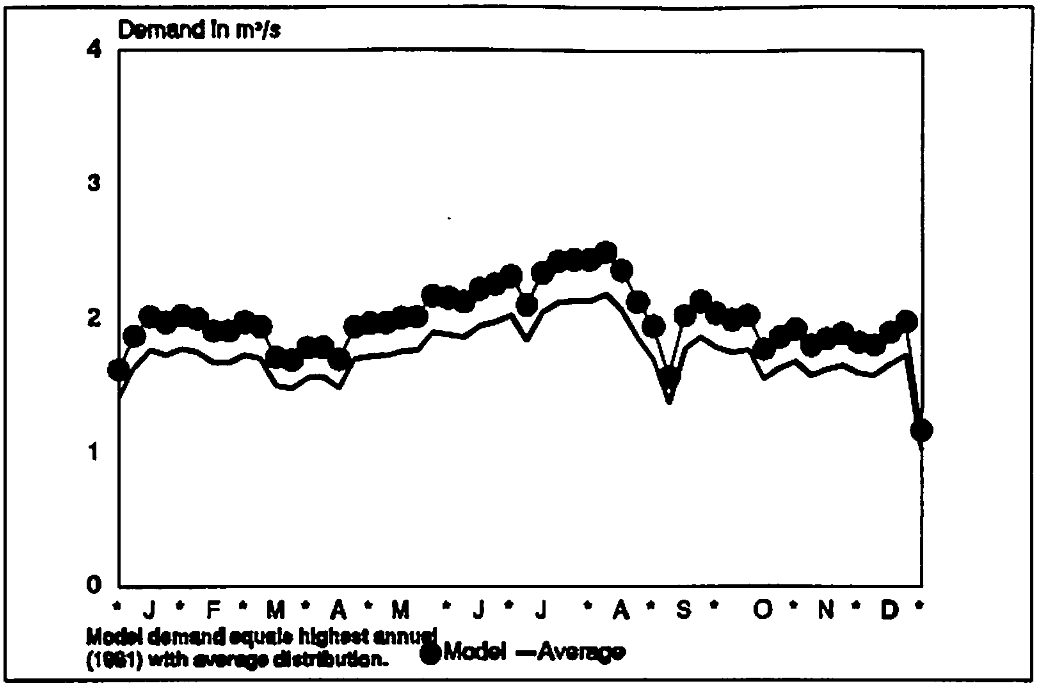


Figure 7.6 Harmac Present Annual Demand Distribution

Future river demands for Harmac will drop below present levels. From Chapter 6 section 6.6 it is indicated that their demands will decrease over time to 67% of present total use as their use of water becomes more efficient. Average mill use, during the 1980 to 1989 period was approximately 78,800 dams^3 (57 mgd). Present use is about 74,700 dams^3 (54 mgd), within 2 years this should drop to 50,000 dams^3 (36 mgd). Well use, estimated as 24,300 dams^3 (17.6 mgd) will not change but river use will drop from 54,800 dams^3 (39.6 mgd), during the 1980 to 1989 period, to 25,400 dams^3 (18.4 mgd) within 2 years.

Instream Flows- Flow Requirements for Fish

Estimating the flow requirements for fish is a difficult task; while knowledge in this area is expanding at a fast rate, there are many gaps in available data and in the understanding of natural systems. One of the uses of water management modelling is to evaluate the possibilities for meeting alternate flow requirements, based on assessment of natural flows and the potential for flow releases from storage.

In this study there were two separate sets of flow requirements for fish, recreation flows to maintain habitat during the summer and early fall and pulse flows to trigger the migration of Coho up the Nanaimo River during years when the return of higher flows to the river is late and fish are congregating at the mouth of the river.

Recreation Fishery Flow Requirements

Recreation fishery flow requirements with two separate reductions in the July to August period, noted as FULL, RED 1 and RED 2, were determined for the period April 1 to October 31. These requirements are based on discussions with Fisheries Biologists in the MOELP Nanaimo Regional Office(Reid, Wightman 1992). Table 7.1 lists the requirements and the total volume of water required to meet these demands, assuming no inflow or releases of water from the reservoirs. The recreation fisheries requirements are illustrated in Figure 7.7 which compares them to natural flows at Water Survey of Canada's hydrometric station 08HB034, Nanaimo River.

These flow requirements apply to the reach 23 (see Figure 7.14 for topology) of the Nanaimo River upstream of the Harmac intake. It should be recognized that much of the consumptive demand of the licencees and flow requirements for recreation fisheries purposes are met by natural inflows.

From late July until late September the recreation fishery flow requirements exceed the average natural flow as shown in Figure 7.7. However, the water discharged from Fourth Lake to meet the Harmac consumptive demands and the water released for minimum flow, both contribute to the recreation fish flows in stream channel 23. The licenced minimum flow of 1.38 m^3/s (49 cfs) required in channel 1 for fisheries plus the typical Harmac summer demand of about 2.1 m^3/s (74 cfs) means that flows in the reach above the Harmac intake very seldom drop below about 3.5 m^3/s (124 cfs).

Table 7.1 Recreational Flow Requirements for Fish

	Recreational Flow Requirement		
Period	Full (FULL)	First Reduction (RED 1)	Second Reduction (RED 2)
April to June	7.80 m^3/sec (275 cfs)	7.80 m^3/sec (275 cfs)	7.80 m^3/sec (275 cfs)
July to Aug	5.85 m^3/sec (207 cfs)	4.88 m^3/sec (172 cfs)	3.90 m^3/sec (138 cfs)
Sept to Oct	3.90 m^3/sec (138 cfs)	3.90 m^3/sec (138 cfs)	3.90 m^3/sec (138 cfs)
Total Volume ($dams^3$)	113,000	108,000	103,000

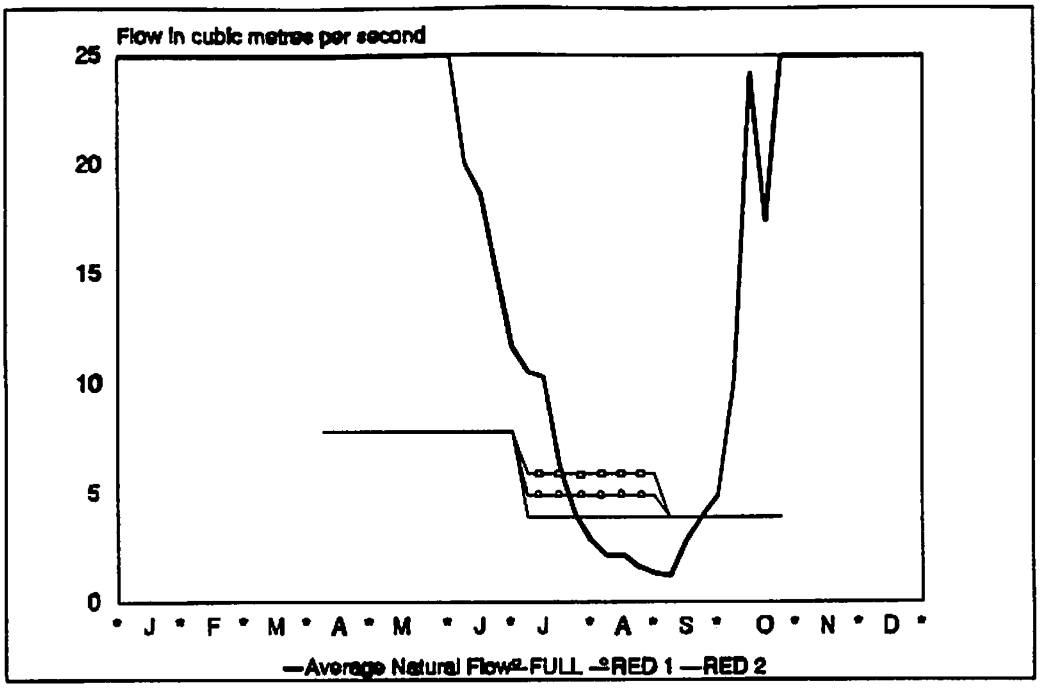


Figure 7.7 Recreational Flow Requirements - Upstream of the Harmac Intake

Pulse Flow Requirements

The flow requirements requested by the Department of Fisheries and Oceans are pulse flows intended to trigger fish migration and apply to channel 1, below the Harmac intake. They are illustrated in Figure 7.8 and described in detail in Chapter 5.

Two pulses of flow, four days duration each, which peak at 11.3 m^3/s (400 cfs) are required in channel 1. The volume of each pulse is 3,900 dam^3 (3,200 ac-ft). While there is a licensed requirement for a residual flow of 1.39 m^3/s (49.0 cfs) within this channel, any additional water required to meet the pulse flows would come from storage releases. The more important of the pulse flows would occur in early October, supplemented by a pulse in late September only if reservoirs were at sufficiently high levels and if the water temperature was conducive for fisheries purposes, section 5.5 of Chapter 5.

As the model did not allow for release of water from storage based upon water temperature, separate model runs were made with only one pulse in October and with the two pulses, in September and October, as illustrated in Fig. 7.8.

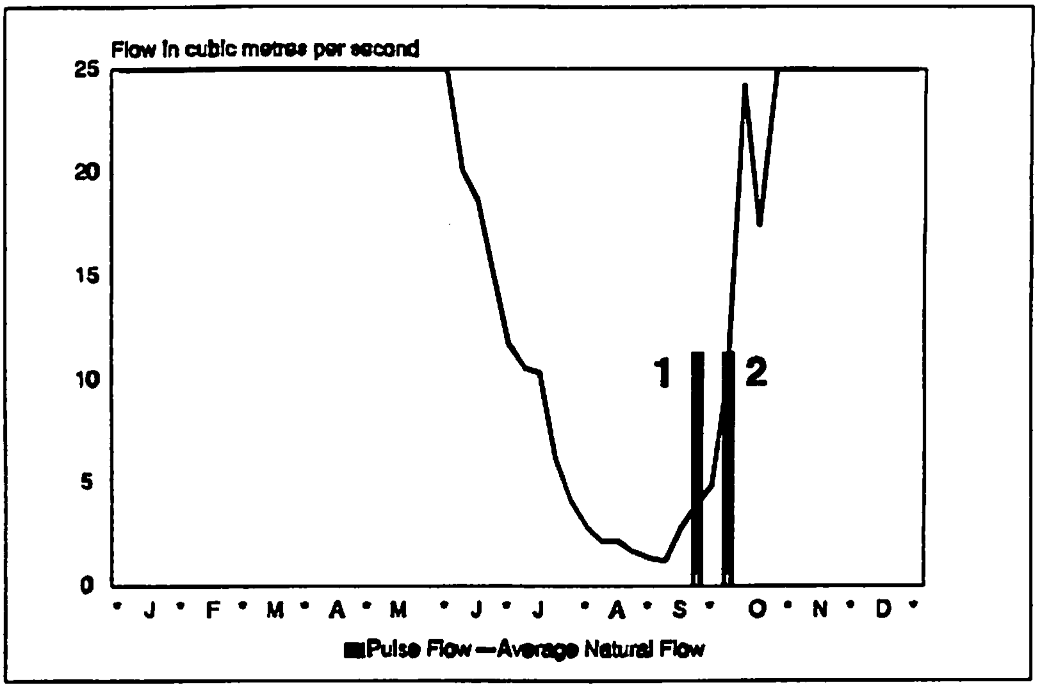


Figure 7.8 Pulse Flow Requirements - Downstream of the Harmac Intake

Minor Domestic and Irrigation Demands

There is a small licensed domestic demand of 76 dam^3 (62 ac-ft) per year and a licensed irrigation demand of 770 dam^3 (624 ac-ft) per year. Because these demands are small compared to other demands in the basin, the irrigation demand has been assigned the same priorities as Harmac and GNWD and the domestic demand has been treated as a mandatory withdrawal.

7.3.3 Supply/Demand Comparison

Annual Totals

The average June to October demands and gross reservoir storage are compared in Figure 7.9 to provide an impression of the **relative** magnitudes of supply and demand during the summer low flow period. Average natural June to October inflows to the two major points of diversion South Fork Reservoir for the GNWD and node 2 for Harmac are given in Figure 7.10.

GNWD's consumptive demand from South Forks reservoir is met by the natural inflow to this point on the river and storage releases from Jump Creek reservoir. The demand for water by Harmac is met by the natural inflow to node 2 together with releases from Fourth Lake. It should be noted that although inflow volumes exceed consumptive demands, as summer progresses inflows will decrease to a point where releases from storage are required to meet demands and maintain streamflows.

As discussed earlier, most of the annual demand for recreation fisheries is met by the natural inflow to node 2, the licenced residual flow in channel 1 together with the releases of water from Fourth Lake reservoir to meet Harmac's consumptive demands in reach 1.

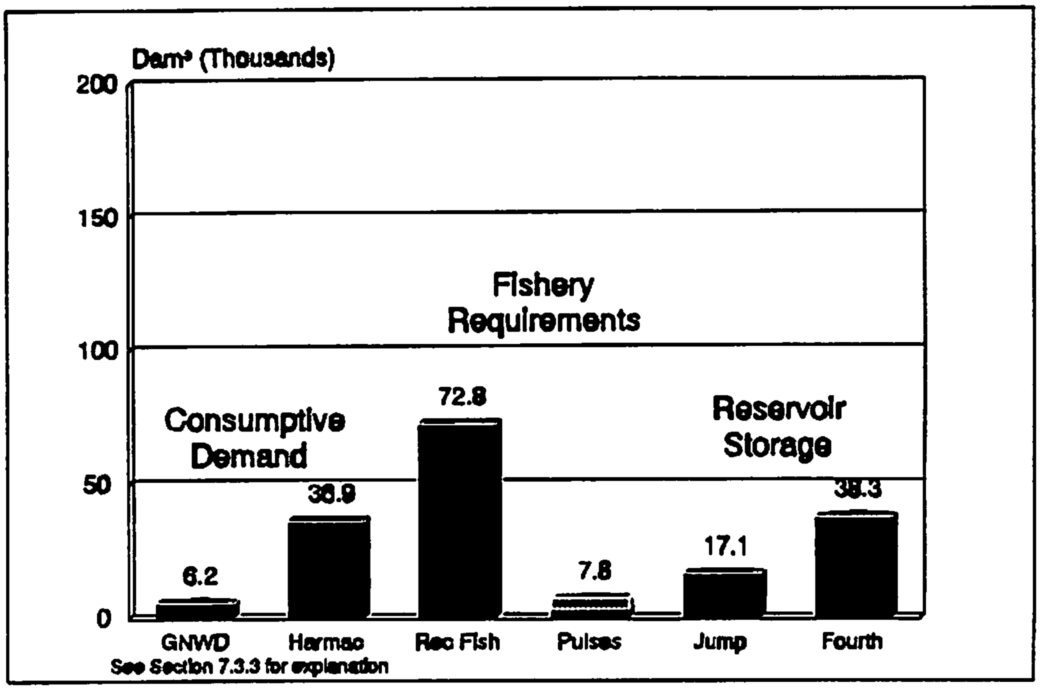


Figure 7.9 June to October Demands and Reservoir Volumes

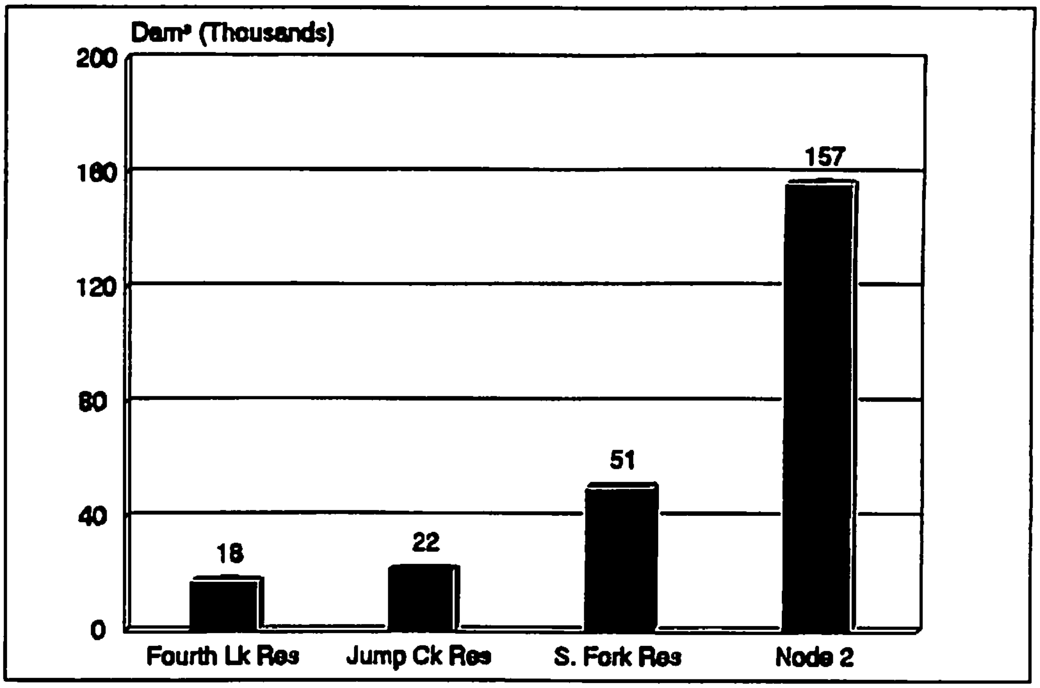


Figure 7.10 June to October Average Inflow

7.3.4 Summary of Reservoir Characteristics

The total storage of the Fourth Lake and Jump Creek reservoirs is 55,300 dam^3 (44,800 ac-ft), representing only 5% of the mean annual natural runoff of the Nanaimo River Basin. As noted earlier, the reservoirs were constructed as single purpose facilities.

Jump Creek Reservoir

Jump Creek Reservoir is operated primarily to provide a secure water supply for the GNWD. It is raised to an elevation of about 378.4 m (1241 ft) in the spring, flow conditions permitting, and maintained at about this level, with demands drawing the reservoir down over the summer and into the fall. Once inflows are sufficient, water levels are maintained at the spillway crest elevation of 376.4 m (1235 ft) over the winter.

There is no formal minimum flow requirement for the channel downstream of this reservoir. Minimum releases of about 1.1 m^3/s (39 cfs) were maintained from Jump Creek reservoir before 1986. Lower minimum releases have been used in subsequent years, about 0.6 to 0.9 m^3/s (20 to 30 cfs).

The storage-elevation curve for Jump Creek is illustrated as Figure 7.11. Gates above the spillway crest are used to raise the operating level to a maximum elevation of about 378.38 m (1241.4 ft) although the gates can extend the level to 378.56 m (1242.0 ft). It is operated at this lower level for safety reasons.

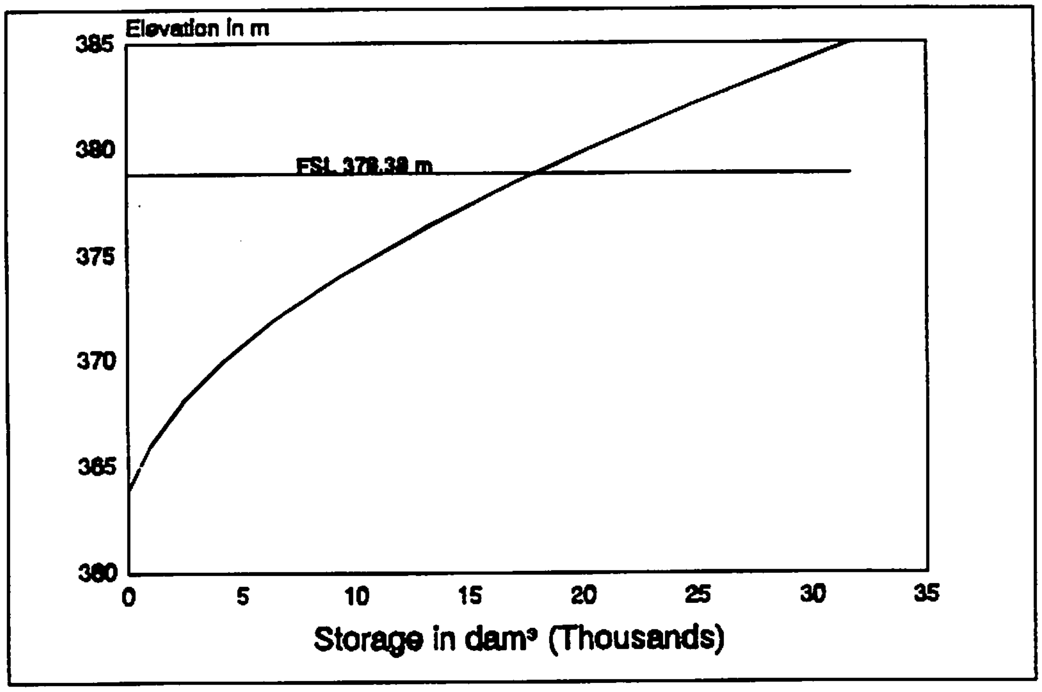


Figure 7.11 Jump Creek Reservoir Storage-Elevation Relationship

The spillway crest is at elevation 376.43 m (1235 ft). The total storage at the spillway crest is 13,200 dam^3 (10,700 ac-ft) and the storage at maximum summer operating level is about 17,100 dam^3 (13,800 ac-ft). Prior to 1986, the reservoir spillway and maximum operating level was at 376.1 m (1234 ft) and the full supply at that time was 13,000 dam^3 (10,500 ac-ft).

Low level discharges from Jump Creek reservoir are limited to 2.83 m3/s (100 cfs) because of structural problems related to the low level outlet. The lowest level on record occurred in 1986 in which the reservoir fell to an elevation of about 370.0 m (1214 ft), with 24% of its storage remaining, 4,200 dams^3(3,400 ac-ft).

South Fork Reservoir

South Fork reservoir is a small reservoir maintained at its full supply level except possibly under emergency conditions when it could be lowered to meet GNWD demands in a drought.

A minimum flow release from South Fork of $0.28 m^3/s$ (10 cfs) is maintained. Higher flows pass over the spillway of South Fork Reservoir at night as the GNWD demand drops.

Harmac is required to maintain a flow of 1.1 m^3/s (39 cfs) downstream at the Harmac intake, in addition to the 0.28 m^3/s (10 cfs) from South Fork for a total of 1.39 m^3/s When levels have been adequate, releases for pulse flows have been made from this reservoir.

Fourth Lake Reservoir

Fourth Lake usually stays at a full supply level (FSL) of 316.7 m (1039 ft) during the winter and spring. In mid-summer it begins to drop, as demands exceed inflow, rising again to FSL in the late fall. In 1987 Fourth Lake fell to 298.0 m (978 ft), with only 24% of its storage remaining, 9,200 $dams^3$ (7,500 ac-ft).

Figure 7.12 is an storage-elevation curve for Fourth Lake; Figure 7.13 is its elevation-discharge curve. The elevation-discharge curve only becomes a factor in this study when Fourth Lake reaches low levels.

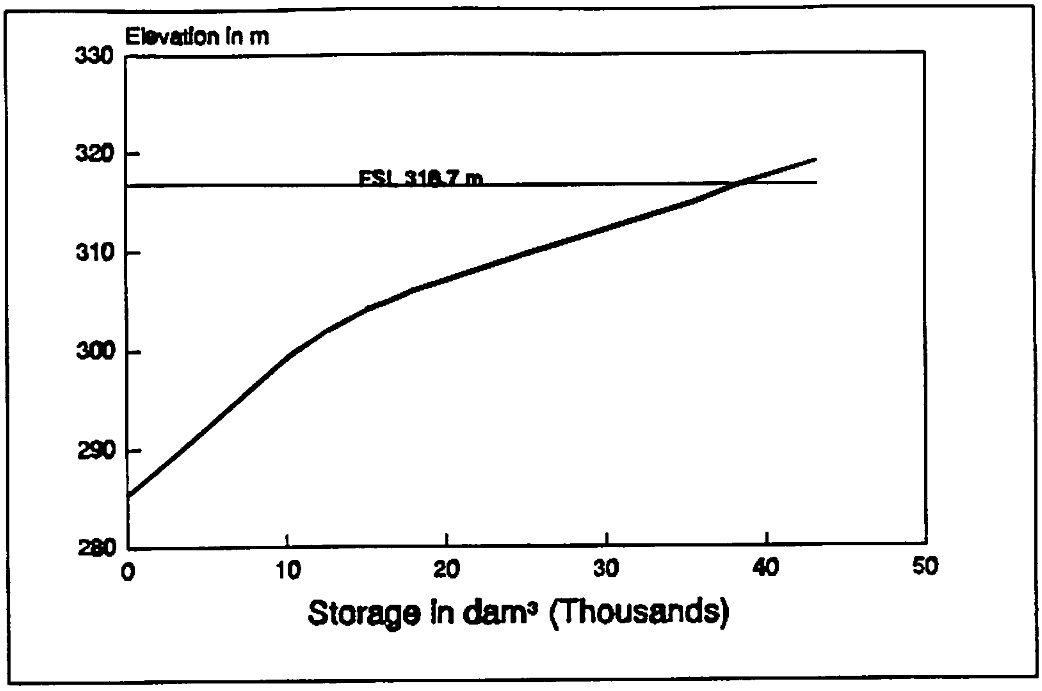


Figure 7.12 Fourth Lake Reservoir Storage-Elevation Relationship

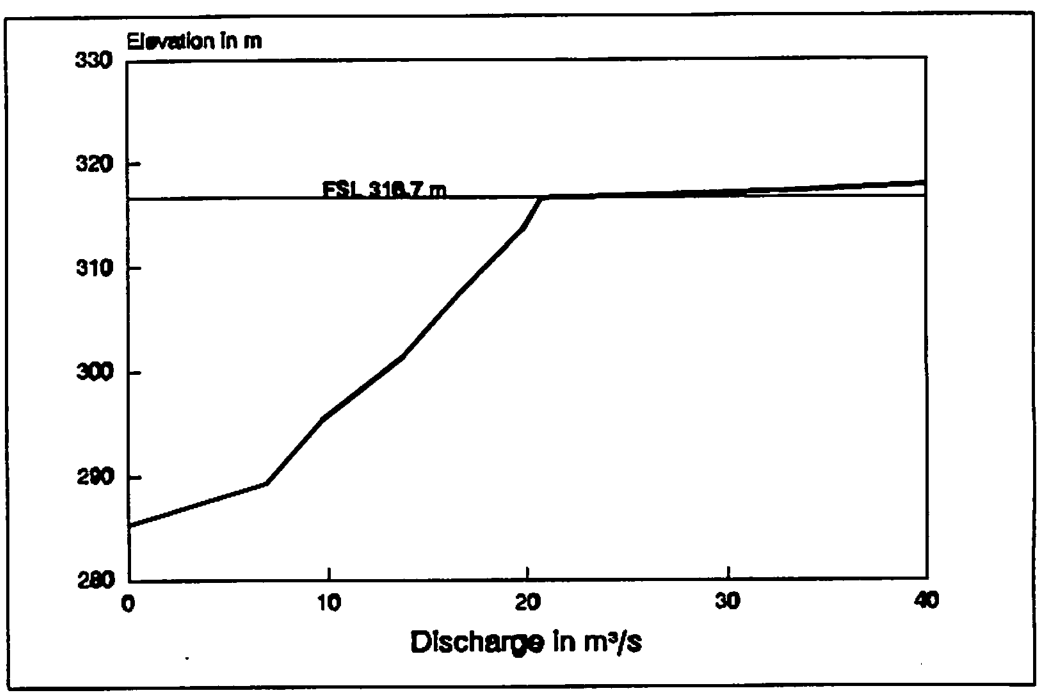


Figure 7.13 Fourth Lake Reservoir Elevation-Discharge Relationship

7.4 Application of the Water Resources Management Model

7.4.1 Modelling Objectives

In order to set effective modelling objectives it is necessary to have a clear understanding of the capabilities and limitations of the WRMM model. For the Nanaimo River Basin, the modelling objectives included:

- Assessment of alternative operating strategies for Jump Creek and Fourth Lake Reservoirs to determine if improved flow conditions for fish can be maintained given present and future water demands by licensees in the Nanaimo River.

and, if there is not adequate water to meet all requirements:

- Assess alternatives for the allocation of available water amongst the various demands; and,
- Determine the amount of storage required to meet the instream flow requirements.

The modelling results presented in this chapter address these three objectives.

7.4.2 Schematic Diagram

Figure 7.14, is a schematic diagram of the Nanaimo River Basin and consists of a set of links and nodes that define the physical layout (topology) of the basin. Table 7.2 lists the components of the Nanaimo River Basin schematic, their component numbers and component types. The component numbers were arbitrarily set. Pulse flow requirements are represented in channel 1 and recreation fishery flow requirements in channel 23.

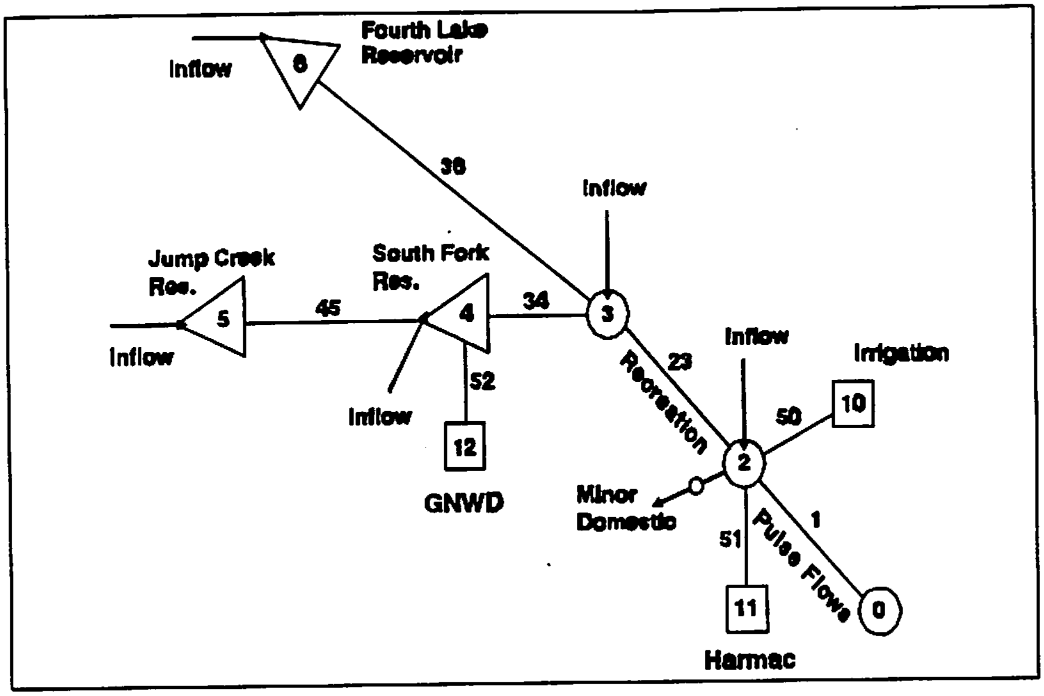


Figure 7.14 Schematic Diagram of the Nanaimo River

Table 7.2 Description of the Components of the WRMM Schematic

Components	Description
Channels	
1	Nanaimo River from the mouth to the Harmac Intake
23	Nanaimo River from the Harmac intake to the confluence with the South Fork
36	Nanaimo River from the confluence with the South Fork to Fourth Lake Reservoir
34	South Fork of Nanaimo River from the confluence with the main river to South Fork Reservoir
45	Jump Creek, from South Fork Reservoir to Jump Creek Reservoir
50, 51 & 52	Dummy channels to connect withdrawals; these represent the intake pipes
Reservoirs	
4	South Fork Reservoir

Components	Description
Channels	
5	Jump Creek Reservoir
6	Fourth Lake Reservoir
Major Licenced Consumptive Demands	
10	Irrigation
11	Harmac
12	Greater Nanaimo Water District (GNWD)
Minor Demands	
	Domestic demand at node 2
Nodes	
0, 2 & 3	Provide the points of connection of model links. (Note that reservoirs and major demands are also nodes)
Inflows	
2,3,4,5 & 6	Points at which natural flows enter the model

7.4.3 Relative Ranking of Demands

The first step in setting priorities is an initial ranking of all demands. In the case of the Nanaimo River Basin, this resulted in the following initial ranking of uses: licensed minimum flow for fish in channel 1, existing licensed uses ;NWD, Harmac, irrigation and minor domestic) and additional instream flows for fish in channels 1 and 23.

7.4.4 Scenario Development

The model describes the basin in terms of its physical configuration, natural flows, demands and priorities. A scenario is a unique combination of these factors. Once the purpose of the scenario has been defined, the parameters can then be set by examining all components of the model and making their physical and operational descriptions consistent with the scenario. The representation of operations is also achieved by means of the set of penalty points that establish the operating priorities for the model.

7.4.5 Model Calibration and Efficiency

Initial runs of the model were made using only the consumptive demand of present licensees and minimum instream flows of 1.38 m^3/sec (49.0 cfs) in channel 1. The results from these runs were compared to historical records of reservoir elevations for the same period in order to determine if the model could reasonably replicate these elevations.

The model allows for the optimum allocation water to the various demands; that is, to release exactly enough water from the reservoirs each week to meet all prescribed model demands, allowing for local natural inflows. This approach assumes that the dams are operated more precisely than would be the actual case. Consequently, the simulated reservoir levels were above those actually recorded. This type of run is of interest, however, because it identifies a theoretical upper limit to reservoir operational efficiency. Therefore it should be noted that even with ideal operations, there is a limit to what can be achieved in the real world with a given volume of storage.

The model was then changed to simulate reservoir operations with minimum constant withdrawals from each reservoir. This was done to more closely represent actual operations by preventing the model from reducing reservoir outflows to very low rates because of temporary increases in natural flows. The constant minimum rate used for Jump Creek Reservoir was 0.90 m3/s (32 cfs). Two rates were used for Fourth Lake: from the end of October to the third week of June, the minimum licence requirement - 1.1 m^3/s (39 cfs); and, from the third week of June to the end of October, the period of high demand for Harmac - 1.9 m^3/s (67 cfs). With these minimum withdrawal rates, the simulated reservoir levels and the recorded minima matched quite well, particularly when corrected for differences between the modelled average demand and the actual demands for the year in question, and for historical changes in Full Supply Level (FSL) at Jump Creek Reservoir.

A further refinement to the model was to allow both reservoirs, Jump Creek and Fourth Lake, to release water from storage to augment the required recreation fishery and pulse flows.

7.4.6 Reservoir Rule Curves

Reservoir storage is represented in the model as a demand that must compete for water with other demands. Reservoir penalties must be lower than the penalties for the lowest priority use that is allowed to draw water from the reservoir and higher than the penalties of uses that are not allowed to cause releases from the reservoir.

Reservoirs in the model have a number of zones that allow control over the extent to which different demands have access to reservoir storage. Lower priority demands such as the additional fisheries flow requirements can only draw water from the reservoirs when there is enough water in the reservoirs to meet licensed demand and licensed minimum instream flows.

In the WRMM, rule curves are used to represent the boundaries between reservoir zones. Rule curves introduce elements of operations into the modelling because they are based on the historical streamflow data used as input to the model. The rule curve for Fourth Lake, shown as Figure 7.15, is an example.

As the rule curve boundaries change during the year, the amount of water available to a given use can also change. The relative amount of water going to each use can thus be controlled by design of an appropriate rule curve. This approach is readily translated into real-world operating criteria for reservoirs.

Setting Reservoir Rule Curves

The main purpose of the rule curve for Fourth Lake and Jump Creek reservoirs is to assist the dam operators by indicating when releases can be made for recreation fishery or pulse flows. The rule is: water may be released for recreation fisheries or one of the two pulse flows **provided the reservoir elevation is above the rule curve**. Once started, a fish flow release must be terminated if the elevation falls below the rule curve.

Figures 7.15 and 7.16 illustrate rule curves for Fourth Lake and Jump Creek reservoirs, corresponding to the three scenarios; full recreation fishery flows (FULL), first reduction (RED 1) and second reduction (RED 2). The rule curves illustrate the boundary between the "A" and "B" zones for each reservoir. The "A" zone is the area below the FSL and above the rule curve.

The following procedure was used to establish the rule curves for the reservoirs under the three different scenarios. The first date on which recreation fishery releases might be required was noted to be about June 20. This was used as the date at which the rule curve begins to drop below FSL, allowing releases for recreation fishery requirements. Before June 20 recreation fishery flow requirements are met naturally.

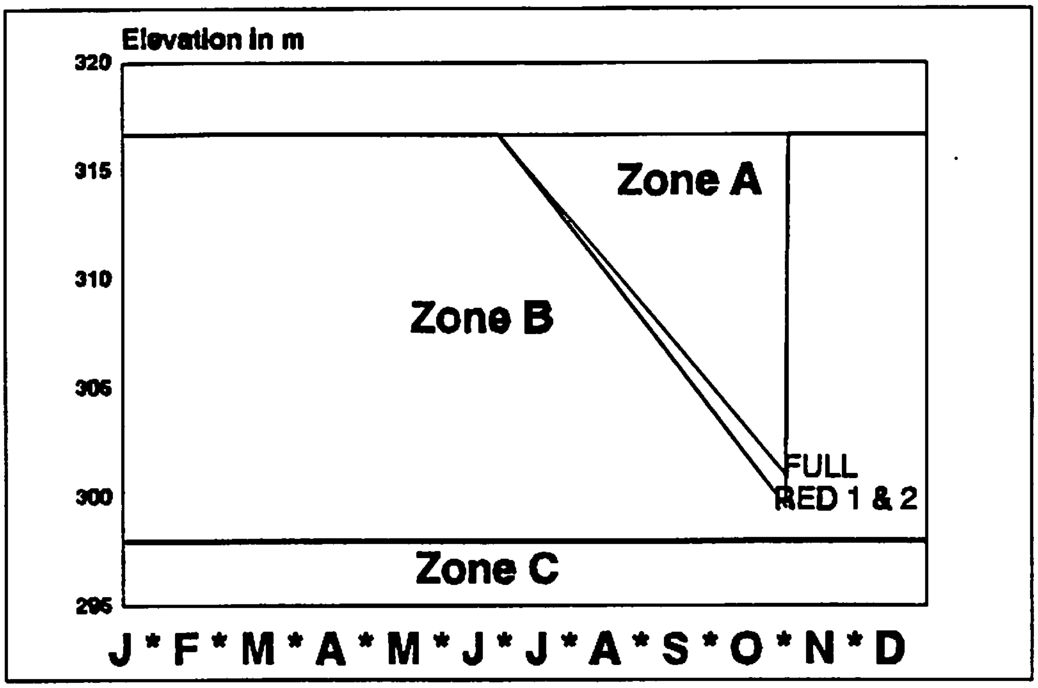


Figure 7.15 Rule Curves for Fourth Lake Reservoir - Present Consumptive Demand

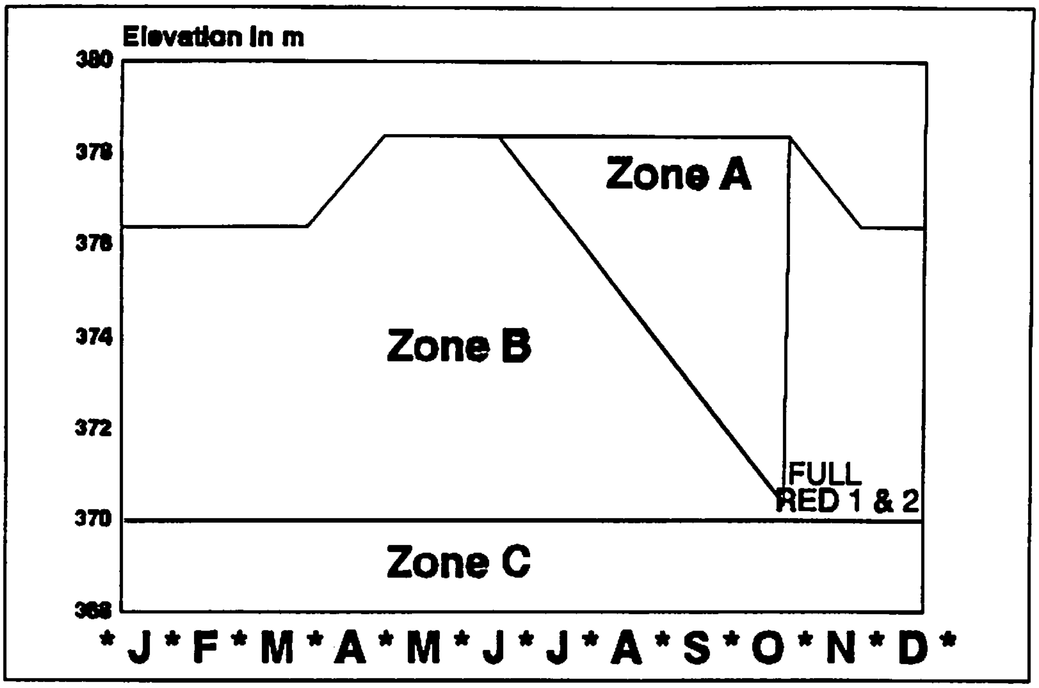


Figure 7.16 Rule Curves for Jump Creek Reservoir - Present Consumptive Demand

The last date on which recreation fishery flow releases would be required was set as October 30, although from September 1 onward the recreation fishery requirement of 3.90 m^3/s (138 cfs) is almost met as a consequence of the licenced minimum flow in channel 1 plus the water released from storage to meet the demand from Harmac. The end of the recreation fishery flow requirement period, October 31, was used as the point at which the recreation fishery rule curve line again joins the FSL elevation. The elevation of the lowest point on the rule curves was determined by trial runs to be the lowest elevation that could be attained without forcing Fourth Lake to fall below its low level for 1987, 298 m (978 ft) and Jump Creek to fall below its low level for 1986, 370 m (1213 ft).

7.4.7 Penalty Points

The strength of the WRMM is the flexibility it offers in the representation of different priorities for allocating limited water supplies. This allocation is achieved through the setting of priorities for water use based on a system of user-specified penalty points. When there is adequate water to meet all demands in the model, penalties are close to zero. When supplies are less than demands, the model uses the priority/penalty system to decide which uses to deficit and by how much.

The penalties reflect the relative value of water to each use and can be thought of as the cost of failing to deliver adequate water to all demands. The model minimizes the total cost of the shortage of water to the entire basin for each time step of the simulation. The use with the lowest penalty point values will be the first to experience a deficit.

Deficits are shared amongst uses; even a low priority use will usually receive at least a small fraction of its demand at the expense of a slight reduction in supply to a higher priority use. In other words, the low priority use might receive a 50% deficit while a higher priority use experiences a 10% deficit. This is a reasonable approach, since the seriousness of a deficit to a particular use increases with the size of the deficit.

This is accommodated in the WRMM by the assignment of demand zones to each use in the model. The zones are described as fractions of the ideal demand of each use. The 'A' zone is the first zone of "relaxation" and might represent a range of demand from, say, 80% to 100% of an ideal condition. Below this would be a 'B' zone, perhaps representing the range 50% to 80% and so on. The maximum number of lower relaxation zones is four and the minimum is one.

This approach allows individual zones to experience deficits in order of priority, so that deficits can be shared amongst any number of demands.

Penalty Zones

Model runs indicated that there was sufficient water to fully meet the GNWD and Harmac present consumptive demands and one zone was found to be adequate for each. The licensed minimum flows had the highest priority in the basin and required only one zone. These demands were given equal penalty points. In reaches where there are licensed minimum flow requirements and fish flow requirements (reaches 1, 23 and 34), two zones were required. In reaches 36 and 45 instream flow requirements were represented by single zones.

Jump Creek and Fourth Lake reservoirs have two operating zones, one in which releases can be made to consumptive demands, minimum instream flows and fish flow requirements, zone 'A', and a second zone from which only consumptive demands of the licencees and licensed minimum flows can draw upon, zone 'B'. In addition, both reservoirs have extreme high and low zones as required by the model for all reservoirs. The high zone, 'Z', is used to temporarily store runoff when inflows exceed outflow capacity and the low zone, 'C', is necessary to keep a reservoir from going completely dry.

South Fork Reservoir is not used as a storage facility and was given a single operating zone with a very high penalty. South Forks reservoir was maintained at FSL throughout the simulations.

Setting Penalties

Penalties for licensed demands were set at an arbitrary value of 25 in channels 1, 23, 34 and 36. Note that while this penalty value is arbitrary, the other penalties in the model were set in relation to this starting point in order to represent the basin priorities.

Consumptive demands for the GNWD, Harmac, domestic and irrigation use have been treated as having a lower priority than the minimum instream flows specified in their licences. They were thus assigned a value of 20 (20 < 25 is the only consideration necessary). The fish flow requirements were set to be lower than the consumptive demands and assigned a value of 5.

The 'A' zone for South Fork Reservoir was set to a high penalty, 500, to ensure that it always remained full. The high and low zones, necessary for all reservoirs were each assigned a penalty of 999.

Fourth Lake and Jump Creek reservoirs have two operating zones. The upper 'A' zones were assigned penalties of 1, so they are generally accessible to downstream consumptive and instream demands. Their lower 'B' zones were given penalties of 15, making them inaccessible to the fish flows, but accessible to the consumptive demands of the licencees, penalty of 20, and the licenced minimum flow in channel 1, penalty of 25. Note that during the pulse flows, the sum of the recreation fishery penalty and the pulse penalty must be less than the B zone of Fourth Lake and Jump Creek reservoirs; this condition (5 + 5 < 15) is met.

7.5 Modelling Results

7.5.1 Interpretation of Modelling Results

In reviewing the results of the scenario runs, several basic characteristics of the modelling must be kept in mind. The model is not intended to reflect historical patterns of reservoir operation or water demand. It operates the reservoirs according to the priorities set up for the model run; demands are as specified in the model, not actual historical demands. Actual historical values could be used for other modelling purposes, but are not helpful in terms of the purpose of the current scenarios.

The scenarios test the effectiveness of a possible set of operating priorities given a defined set of demands, in this case the highest demands recorded in the ten year period 1980 to 1989 were used in the model. The natural flow varies over time and it is the natural flow regime that makes each year unique and representative of historical conditions.

7.5.2 Scenario Evaluations

For all scenarios, the consumptive demand for the current licensees are always met and minimum reservoir levels are maintained above historical low values for the period of simulation. Any excess water is available to augment either recreation fishery flows required in channel 23 and the pulses flows in channel 1. It was noted during the model runs that natural inflows were high enough to meet the second pulse in October for the years 1980 and 1981 without releases from storage.

Present Maximum Consumptive Demand

In Table 7.3 the first scenario, FULL, with two pulses and a demand distribution of 20-15-10% MAD, pulse 1 is met six out of ten years, with an improvement in four years, pulse 2 is met six out of ten years and recreation fishery flows are met six out of ten years with improvements in the remaining years. Improvements in flows were noted in the Tables 7.3 and 7.6 if more than 50% of a pulse flow, 5.65 m^3/sec (200 cfs) was released in channel 1 or if flows in channel 23 were augmented by reservoir releases.

Table 7.3 Summary of Scenario Results - Present Consumptive Demand

	FULL			RED 1		RED 2	
	Pulse 1	Pulse 2	Rec. Fish (20-15-10% MAD)	Pulse 2	Rec. Fish (20-12.5-10% MAD)	Pulse 2	Rec. Fish (20-10-10% MAD)
1980	Y	Y	Y	Y	Y	Y	Y
1981	Y	Y	Y	Y	Y	Y	Y
1982	Y	Y	Y	Y	Y	Y	Y
1983	Y	Y	Y	Y	Y	Y	Y
1984	Y	Y	Y	Y	Y	Y	Y
1985	IMP		IMP	IMP	Y	Y	Y
1986			IMP	Y	Y	Y	Y
1987			IMP	Y	IMP	Y	Y
1988	Y	Y	Y	Y	Y	Y	Y
1989	IMP		IMP	Y	Y	Y	Y
	6/10	**6/10**	**6/10**	**9/10**	**9/10**	**10/10**	**10/10**

Note: IMP(improvement)
- pulse flow > 5.66 m^3/sec (200 cfs)
- augmented recreation fisheries flows

As the recreation fishery portion of the required fisheries flows was decreased in the RED 1 scenario, both the single pulse and the recreation fishery flows are met in nine out of ten years with an improvement in the remaining year. The fishery flow requirements of a single pulse flow and the recreation fish flow demand 20-10-10% MAD distributed from April to October in RED 2, are met in every year of the simulation.

As the fishery flow requirements increase in magnitude, the number of years the model can satisfy those demands decreases particularly during the relatively dry period of 1985 to 1989.

Tables 7.4 and 7.5 summarize the effects of the scenarios on minimum annual reservoir elevations in terms of remaining storage. The constraint imposed on each scenario was that the minimum reservoir elevations for any year should not fall below the lowest recorded for the ten year period of simulation. The tables indicate that the constraint was met and in the case of RED 1 and 2 reservoir levels were above the historical record. This constraint was selected in the absence of information that would assess the acceptability of reducing the reservoirs to lower elevations. The minimum reservoir level attained in each scenario is highlighted.

Table 7.4 Lowest Reservoir Levels for Fourth Lake Reservoir as a % of FSL Storage - Present Consumptive Demand

	Scenarios			
	FULL	**RED 1**	**RED 2**	**Recorded**
1980	42%	46%	51%	37%
1981	50%	64%	69%	69%
1982	39%	51%	56%	47%
1983	39%	48%	52%	56%
1984	60%	61%	63%	64%
1985	39%	34%	41%	33%
1986	32%	31%	39%	33%
1987	**24%**	**24%**	**28%**	**24%**
1988	37%	54%	57%	54%
1989	33%	34%	40%	31%

Table 7.5 Lowest Reservoir Levels for Jump Creek Reservoir as a % of FSL Storage - Present Consumptive Demand

	Scenarios			
	FULL	**RED 1**	**RED 2**	**Recorded**
1980	68%	78%	78%	47%
1981	71%	72%	75%	54%
1982	56%	69%	69%	53%
1983	63%	71%	73%	42%
1984	37%	60%	69%	50%
1985	37%	36%	43%	31%
1986	29%	34%	40%	**25%**
1987	**25%**	**25%**	**38%**	28%
1988	56%	60%	66%	49%
1989	33%	45%	51%	53%

Future Consumptive Demand

Future consumptive demands for the GNWD were estimated from Table 6.4 in Chapter 6, as discussed in section 7.3.2 while Harmac's future demands were based upon the proposed reduction in river use as discussed in section 7.3.2. The three model scenarios, FULL, RED 1 and RED 2, were rerun with the new GNWD demands.

The scenario FULL, Table 7.6, shows that pulse 1 and 2 are met six out of ten years, and recreation fishery flows are also met six times in the ten years of record with an improvement shown in each of the remaining years.

Table 7.6 Summary of Scenario Results - Future Consumptive Demand

	FULL			**RED 1**		**RED 2**	
	Pulse 1	Pulse 2	Rec. Fish (20-15-10% MAD)	Pulse 2	Rec. Fish (20-12.5-10% MAD)	Pulse 2	Rec. Fish (20-10-10% MAD)
1980	Y	Y	Y	Y	Y	Y	Y
1981	Y	Y	Y	Y	Y	Y	Y
1982	Y	Y	Y	Y	Y	Y	Y
1983	Y	Y	Y	Y	Y	Y	Y
1984	Y	Y	Y	Y	Y	Y	Y
1985			IMP		IMP	Y	Y
1986			IMP	IMP	IMP	Y	Y
1987			IMP	IMP	IMP	Y	Y
1988	Y	Y	Y	Y	Y	Y	Y
1989			IMP	Y	IMP	Y	Y
	6/10	**6/10**	**6/10**	**7/10**	**6/10**	**10/10**	**10/10**

Note: IMP(improvement)
- pulse flow > 5.66 m^3/sec (200 cfs)
- augmented recreation fisheries flows

With the decrease in the required recreation fishery flows for scenario RED 1, the number of times pulse 2 is met increases to seven with an improvement in two of the remaining three years and recreation fishery requirements are met in six out of ten years with improvements in the remaining four years. In the RED 2 scenario, pulse 2 and the recreation fishery flow are met in every year.

Minimum reservoir levels generally decreased through the simulation period as compared to the present demand scenario results, Table 7.3 to 7.6, and fishery flow requirements in channels 1 and 23 were met less often, Tables 7.4 and 7.5 to 7.7 and 7.8. The model allowed for additional releases of water from the reservoirs for fisheries purposes in order to compensate for the increased diversion of water out of the Jump Creek system by the GNWD. The releases for fisheries would only occur if the reservoirs were within Zone "A" of Figures 7.17 and 7.18. Flows in channel 1 were greater than those of the present consumptive demand scenario due primarily to the decreased rate of diversion by Harmac.

Table 7.7 Lowest Reservoir Levels for Fourth Lake Reservoir as a % of FSL Storage - Future Consumptive Demand

	Scenarios			
	FULL	**RED 1**	**RED 2**	**Recorded**
1980	37%	42%	48%	37%
1981	48%	58%	65%	69%
1982	35%	45%	52%	47%
1983	35%	46%	51%	56%
1984	55%	59%	63%	64%
1985	34%	34%	34%	33%
1986	29%	29%	31%	33%
1987	**24%**	**24%**	**24%**	**24%**
1988	31%	48%	55%	54%
1989	30%	31%	34%	31%

Table 7.8 Lowest Reservoir Levels for Jump Creek Reservoir as a % of FSL Storage - Future Consumptive Demand

	Scenarios FULL	RED 1	RED 2	Recorded
1980	55%	78%	78%	47%
1981	59%	70%	74%	54%
1982	52%	72%	72%	53%
1983	63%	69%	70%	42%
1984	35%	53%	57%	50%
1985	34%	34%	35%	31%
1986	27%	27%	33%	**25%**
1987	**25%**	25%	26%	28%
1988	52%	59%	59%	49%
1989	31%	31%	45%	53%

7.5.3 Supplementary Storage Requirements

The amount of storage required to fully meet each scenario is given in the following table:

Table 7.9 Supplemental Storage Requirements

Consumptive Demand	Supplementary Storage Requirements (Cubic Decameters) FULL	RED 1	RED 2
Present	11500	1530	0
Future	12300	5280	0

The maximum amount of storage required, to meet the FULL scenario with the future consumptive demand, would be about 72% of the volume of the Jump Creek reservoir, 17,000 dams^3 (14,000 ac-ft) at FSL. The minimum amount of storage remaining in the reservoirs for the various model runs was 14800 cubic decameters. Although the South Fork reservoir is always kept at full supply level, its live storage of 1310 cubic decameters was included in the latter total for comparison purposes.

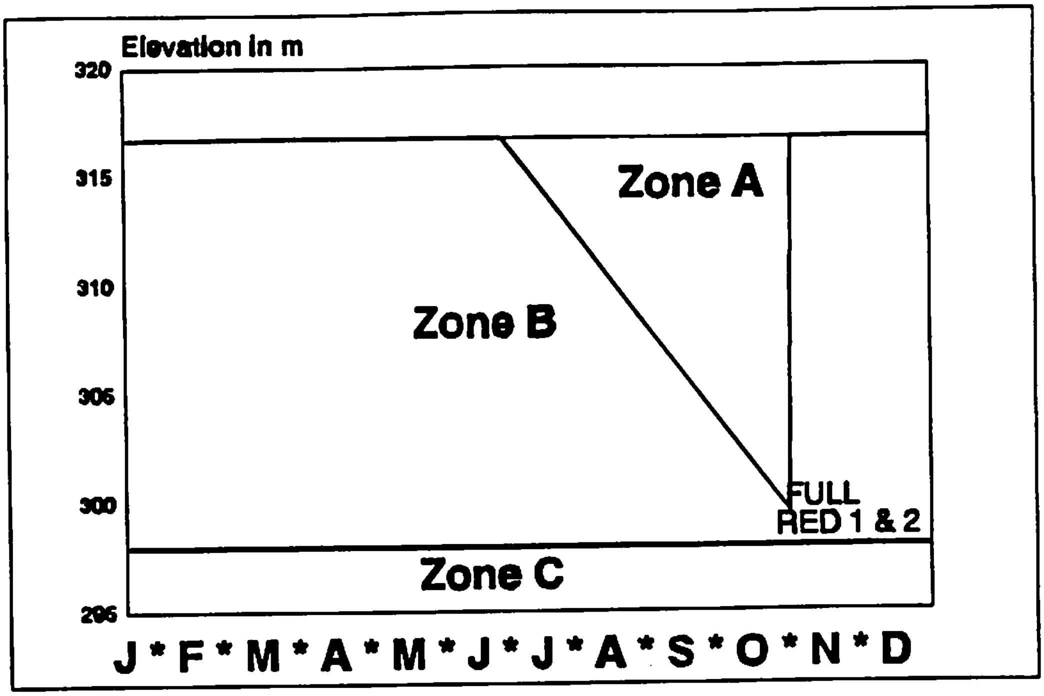


Figure 7.17 Rule Curves for Fourth Lake Reservoir - Future Consumptive Demand

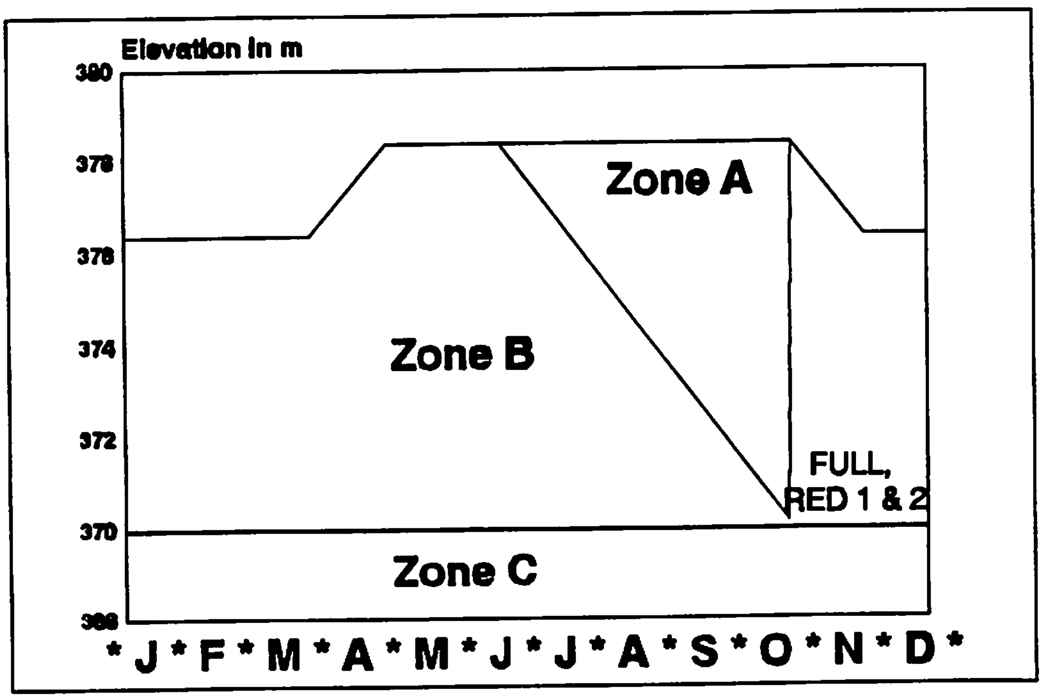


Figure 7.18 Rule Curves for Jump Creek Reservoir - Future Consumptive Demand

7.6 Discussion

Given the minimum reservoir levels, consumptive demands of the present licensees, and additional fishery flow requirements the best balance of water supply and demand is the RED 2 scenario for both the present and the future consumptive demand. Unless more storage is developed or additional storage be made available from the licencees, it is recommended that the reservoirs be operated to the RED 2 scenario.

The rule curves for RED 2, present consumptive demand, and RED 2 future consumptive demand are given as Figure 7.17 and 7.18, respectively. As discussed earlier in section 7.6.1, the rule for reservoir releases is that if the reservoir levels are above the rule curves then releases for fishery purposes can be made. Fishery requirements being 20-10-10% MAD during the period of April to October both with a single pulse flow in early October of 11.33 m3/sec (400 cfs). To meet these requirements, minimum flow figures for channel 23 at Water Survey of Canada's hydrometric station 08HB034 Nanaimo River are shown as Figures 7.19 and the target residual flows for channel 1 are given in Figure 7.20 as well as listed in the following table,

Table 7.10 Minimum Required Flows

Period	Channel 23	Channel 1
Apr 1 - Jun 30	7.80 m3/sec (275 cfs)	1.38 m3/sec (49 cfs)
Jul 1 - Aug 31	3.90 m3/sec (138 cfs)	1.38 m3/sec (49 cfs)
Sep 1 - Oct 4	3.90 m3/sec (138 cfs)	1.38 m3/sec (49 cfs)
Oct 5 - Oct 8	14.0 m3/sec (494 cfs)*	11.3 m3/sec (400 cfs)
Oct 9 - Oct 31	3.90 m3/sec (138 cfs)	1.38 m3/sec (49 cfs)

*The flow in channel 23 for Oct 5 to 8, includes the average diversion figure for Harmac.

An exception to the target flows in the two channels would be if the total of flow diverted from the Nanaimo River to meet Harmac's demand plus the residual flow of 1.4 m^3/sec (49 cfs) was greater than the demand distribution for recreation fish in channel 23. In this case the total of the diverted plus the residual flow should be used as the target. The operation of the reservoirs will have to be carefully coordinated between both Harmac and the GNWD.

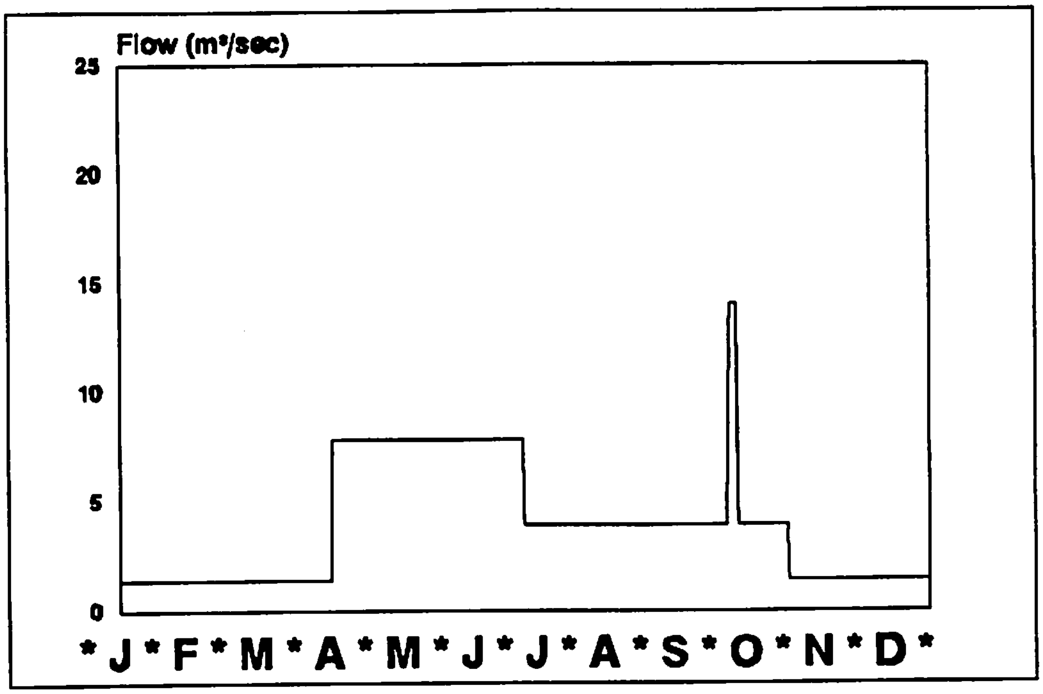


Figure 7.19 Minimum Flows Required in Channel 23

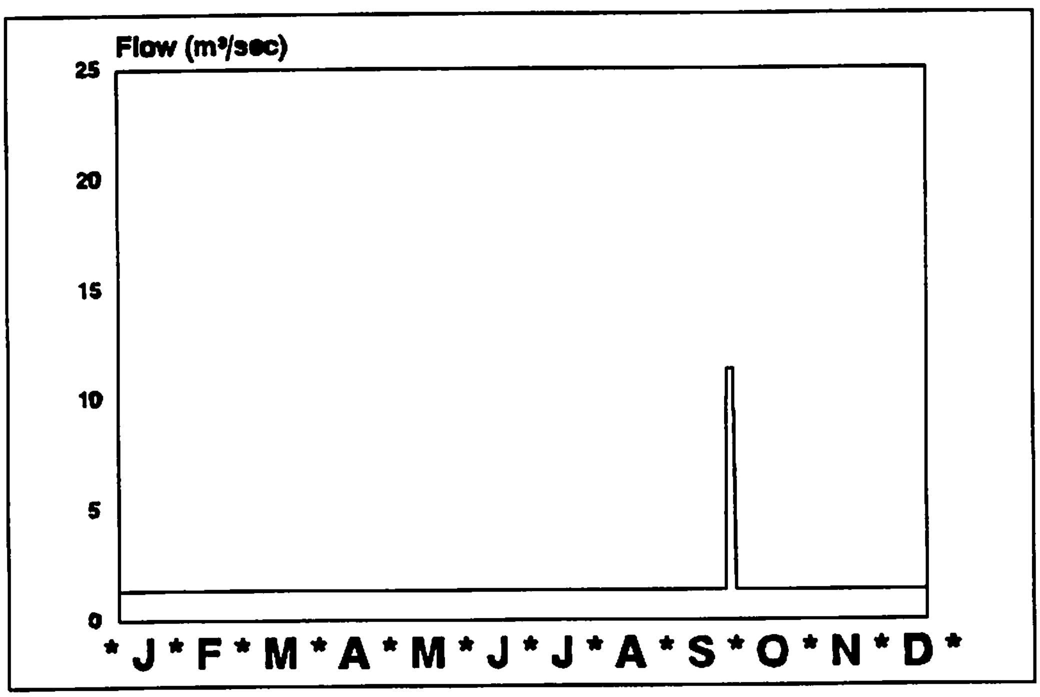


Figure 7.20 Minimum Flows Required in Channel 1

Additional scenarios may be run with the WRMM, however at this point it should be recognized that there is not enough storage to meet the full fisheries requirements. Furthermore as consumptive demands of the licences increase, less water will be available to satisfy the required fishery flows unless additional storage is developed.

The area which may require more work is the operation of the reservoirs. The model assumes that either of the two reservoirs may make releases to satisfy fishery flows after consumptive demands are met. The model performs this operation in an efficient manner releasing only enough water from storage to meet the demands, if the reservoirs are within Zone A. This results in a varied release from week to week depending upon natural inflow between nodes 2 and 3. An alternative to this would be to set a fixed storage release from one of the reservoirs and use the other reservoir to balance the flows in channels 1 and 23.

From an operational point-of-view it would be best to set a constant or slightly increasing release from Fourth Lake as it has been shown that there is a lag time, about 3 days, after water is released from Fourth Lake reservoir until it reaches channel 1. The lag time from Jump Creek is about one day.

Releases from Jump Creek could then be used to adjust the base flow releases in channels 23 and 1 by Fourth Lake reservoir. As with the model runs the majority of the water released for the October pulse flow would come from Fourth Lake. This proposal is a reversal of how the reservoirs are being currently operated and requires an operating agreement with both Harmac and the GNWD.

CHAPTER 8 CONCLUSIONS AND RECOMMENDATIONS

8.1 The Water Resources

Surface Waters

Due to limited information available on the surface water resources in the Nanaimo River watershed the existing data has been manipulated to describe the hydrology of the ten year period 1980 to 1989. These results are limited in accuracy due to the need to estimate extensive periods of missing data. Never-the-less these data have yielded enough information to draw conclusions on potential revisions to existing water management practices. Further refinement of reservoir operating procedures, particularly to manage low flows, will require a better knowledge of the hydrology of the basin.

In the lower reach of the Nanaimo River, between the Harmac intake and the estuary, there are few measurements of flow to verify that minimum flow requirements are being met and the interaction of groundwater aquifers with the Nanaimo River and Haslam Creek are unknown. Lack of information on these two conditions make it difficult to develop meaningful water management strategies for this area of the basin.

8.1(1) **It is recommended that water levels on Fourth Lake, Jump Lake, and Nanaimo Lakes (First and Second) be recorded as required for a period of five years to create a better understanding of how the lakes effect the flow regime of the river.**

8.1(2) **It is recommended that streamflow measuring stations be established for at least a five year period at the following sites:**
- **Nanaimo River above the tide water influence**
- **Haslam Creek near Cassidy 08HB003 (reactivate)**
- **Nanaimo River between First and Second Nanaimo Lakes**
- **Green Creek near the mouth**
- **North Nanaimo River near the mouth**

8.1(3) **It is recommended that temperature measurements on the Nanaimo River upstream at Harmac's intake be recorded.**

8.1(4) **It is recommended that a study be developed and implemented to determine the relationships between the groundwater of the Cassidy Aquifer and the streamflows in the Nanaimo River and Haslam Creek.**

8.1(5) It is recommended that meteorological data be established for a period of five years at higher elevations in the watershed.

Groundwater

Groundwater use in the Nanaimo River Basin has increased significantly over the years. There appears to be direct hydraulic continuity between groundwater and surface water, and groundwater withdrawals appear to be affecting flows in the Nanaimo River. The effects of major groundwater withdrawals and potential for additional withdrawals on stream flows must be assessed. It is uncertain at this time how much additional groundwater development and extraction may occur in this area before existing production wells are significantly affected.

The Cassidy Aquifer area contains the most significant groundwater reservoirs in terms of aquifer potential and use. In the future the upper aquifer will continue to be an important source of water supply for domestic, irrigation, community and industrial use.

A groundwater management program must be established that concentrates on the ground/surface interaction, fisheries side channel issues, groundwater management areas restricting activities which could lead to aquifer degradation and to maintain the aquifer for water supply purposes.

8.1(6) It is recommended that further groundwater exploration and assessment be made in the region of the Cassidy Aquifer by: additional hydrogeological investigation and pumping tests to assess hydraulic aquifer properties (ie. Transmissivity, storage coefficient, well yields, etc.), and test drilling and geophysical surveys to assess aquifer thickness, extent and potential.

8.1(7) It is recommended that future water demands of municipal and industrial users and the effects of these uses on the aquifer be assessed in a Groundwater Management Program.

8.1(8) It is recommended that the Cassidy Aquifer be evaluated to address the growing number of groundwater concerns in terms of the land uses around it.

8.2 Water Quality

Surface Water Quality

The Greater Nanaimo Water District data show that water quality for all parameters in the basin is better than the water quality criteria for all parameters at all times with a few exceptions. In general, the Nanaimo River and its tributaries meet the criteria for protection of aquatic life; however, there has been the occasion when a parameter has been slightly greater than these criteria. Infrequently heavy metals exceed maximum criteria for copper, iron, lead, and zinc, but dissolved metals are always below the criteria value for total metals. Thus metals do not impair the quality of water in the Nanaimo River.

Water quality criteria for primary contact considers full submersion and risk of ingestion or intimate contact with eyes and nose. These criteria have been exceeded on a few occasions in the summer months. The concentrations of bacteria have been much lower than secondary contact criteria throughout the watershed. None of the data shows impairment of water for irrigation or stock watering use, however, more suspended solids data would be desirable. At stations farther downstream than the Greater Nanaimo Water District intakes, the water should be treated before drinking due the presence of bacteria in low numbers.

Adequate instream water quality levels must be maintained for municipal and fisheries interests. In the future, surface water quality issues may focus on logging, mining and access. Second growth timber harvesting is scheduled to start between the years 2000 and 2010. It is anticipated, however, that this type of logging will not create as large of an impact on water quality as first growth harvest since the construction of roads and ditches, the largest contributing factor to impact on water quality, will already be in place. There is also potential for mining sites to develop in the area. Even though there is a high degree of recreational demand for the areas around the Nanaimo Lakes, there is restricted access around the South Fork and Jump Creek reservoir areas which at present addresses the water quality concerns regarding access to the water supply.

8.2(1) It is recommended that the water quality monitoring program on the Nanaimo River give special consideration to suspended solids criterion.

Groundwater Quality

The regulation of groundwater quality is a management issue in the Nanaimo River watershed because the Cassidy Aquifer is potentially susceptible to contamination. The aquifer occurs under shallow water table conditions and is comprised of highly permeable sediments that are potentially susceptible to rapid infiltration. The interdependent relationship of surface and groundwater extraction in the river system is also a management concern. The contamination of the aquifer may become a water quality issue if development occurs in an uncontrolled manner.

For the parameters tested, most groundwater has chemical concentrations within acceptable water quality limits. Apart from individual, domestic and low density septic disposal systems, any large scale septic disposal schemes or sanitary landfill operations, where there is large quantities of untreated effluent or waste should not be permitted. Adequate investigation and monitoring is required to assess the effects of existing operations or proposals on the groundwater regime. Precaution should be given to the designation of any storage facilities or highway salt storage areas, in areas close to communities utilizing the upper aquifer for water supply.

8.2(2) **It is recommended that the Cassidy Aquifer be established as a Groundwater Management Area to restrict activities which could lead to aquifer degradation and to maintain the aquifer for water supply purposes.**

8.2(3) **It is recommended that further analysis of the Water Quality Check Program reports is needed to evaluate and correlate sampling depths, aquifer types (ie. bedrock or unconsolidated) and sampling dates.**

8.3 The Fisheries Resource

8.3.1 Salmon Fisheries Resource

The test release flows from the Jump Creek and Fourth Lake reservoirs in the fall of 1989 and 1990 were successful to stimulate an immediate movement of chinook salmon from the lower estuarine reaches into the Nanaimo River. In addition, some silver bright chinook salmon were observed to successfully migrate with difficulty above the White Rapids falls to spawn in the Upper Nanaimo River.

Results from the fall 1992 Nanaimo River reservoir release program confirmed the fisheries water release strategy with the chinook escapements comparable with the past three years, however, the release schedule should have been initiated one week earlier than the October 2, 1992 commencement date.

Water temperatures above 20 C. are stressful for all salmonids, but are of special concern for mature chinook salmon if they are concentrated in confined pools. Temperatures above 23 C. are approaching lethal levels. The ideal rearing temperature is 18 C. while improved egg survival occurs when spawning temperatures are less than 15 degrees C. Temperature reduction of the residual flows in the lower Nanaimo River would significantly reduce stress and diminish the effects of chinook mortality now caused by ich. A secondary benefit of lowered temperatures would be improved rearing conditions for juvenile salmonids especially in the reaches below the Pump House.

8.3.1(1) **It is recommended that the flow release strategy, as proposed in recommendation 8.5(1), be incorporated if water is available for release during fall chinook migration periods when river water temperatures are below 20 C.**

8.3.1(2) **It is recommended that investigations be conducted into means of reducing river water temperatures during periods of low flow. These investigations should be particularly directed towards remedial strategies that could lower water temperatures for holding chinook in the lower reach of the Nanaimo River downstream of the Pump House Pool.**

8.3.1(3) **It is recommended that the upstream spawning areas utilized by chinook should be ascertained and the rebuilding potential assessed.**

8.3.1(4) **It is recommended that a comprehensive fisheries production management plan for the Nanaimo River Basin be designed and implemented to coordinate strategies for all salmonid species, including but not limited to: flow enhancement on the main stem and tributaries, improved production by providing access to areas presently inaccessible to salmonids, and improvement of habitats to increase salmonid production.**

8.3.1(5) **It is recommended that any significant new storage development on the Nanaimo River or its tributaries be regulated to ensure the maintenance of instream flows for fisheries.**

8.3.2 Recreational Fisheries Resource

Nanaimo River salmon and trout both depend on fresh water for spawning however the species differ in the context to which they rear in freshwater after emerging from the gravel as fry. Pink and chum salmon, for example migrate to the sea immediately following emergence whereas steelhead trout may spend up to 4 years in the stream.

One of the important prerequisites to a productive salmonid stream is a relatively stable flow. Those salmonids that rear in a stream over more than one summer are found in discrete habitats and the carrying capacities of those habitats are affected by declining flows. Very low flows restrict the habitat available for trout rearing and consequently may limit the number of wild smolts the river can produce.

As a result of the mainstem flow requirement investigations for recreational fisheries in the Nanaimo River (Griffith, 1990), the following conclusions and recommendations were reached.

Wetted channel widths were significantly reduced when flows dropped from 13.6 m^3/s (34.6% MAD) to 4.2 m^3/s (10.8% MAD). However, the single greatest impact (ie. 12% reduction in mean wetted width) occurred when flows dropped from about 8 m^3/s (20.3% MAD) to 4.2 m^3/s. The width of riffle and glide habitats was more sensitive to flow reductions than that of pools. Usable riffle and glide habitat (as percent channel width) for trout fry was inversely related to reduced stream discharge, such that more fry habitat was created as flows dropped to 4.2 m^3/s (10.8% MAD).

Usable habitat for trout parr clearly increased when stream discharge dropped from 32.3 m^3/s (82.1% MAD) to 13.6 m^3/s (34.6% MAD). However, usable parr habitat decreased as flows dropped to 4.2 m^3/s (10.8% MAD), and dramatically with further reductions below 4.2 m^3/s. Thus, based on estimates of habitat usability, it appeared that a fisheries maintenance flow from 3.9 - 7.9 m^3/s (10 - 20% MAD) would be most beneficial to Nanaimo River steelhead and other trout species/stocks.

8.3.2(1) **It is recommended that a target of 5.9 m^3/s (15% MAD) for the 36km of sections from the Highway to Fourth Lake be used when water is available, as these areas are considered the most productive for these important species/stocks.**

Overall, Tennant's guidelines for required river flows were found to be excessive in this study, although Tennant's recommended minimum fisheries flow of 10% MAD (3.9 m^3/s) was well supported by these investigations.

For the 10km of section downstream of the Island Highway, decreases in discharge produced similar results to those observed upstream in terms of wetted stream width reductions. However, lower habitat complexity based on predominant small substrate and a lack of stable debris, resulted in much lower usable habitat for trout fry and parr.

8.3.2(2) **It is recommended that side channel enhancement be investigated as a means of increasing fish production in the 10 km reach downstream of the Island Highway.**

8.3.2(3) **It is recommended that given the fall pulse flows of approximately 11.3 m^3/s (29% MAD) required for adult chinook migration/ conservation, additional headwater storage should be investigated so that base rearing flows of 3.9 m^3/s (10% MAD) are not compromised during summer droughts.**

8.3.2(4) **It is recommended that a biophysical inventory be conducted to clearly address the relationship between juvenile standing stocks and habitat usability at specific flows since study has been done to identify the "bottlenecks" to steelhead/resident trout production in the Nanaimo River. This should indicate whether steelhead production is currently more limited by initial recruitment (ie. spawning), or by the availability of adequate habitat in the early life history stages.**

8.4 Water Resource Uses

Evaluations of the surface water flows in Section 3.1 and instream water requirements in Section 6.4 indicate that there is no flow available from the Nanaimo River, Haslam Creek or any tributaries, for additional extractive water uses for the three month period of July through September. However there is ample water available for the months of October through May for storage, when flows are above 60% MAD.

Licences held by Greater Nanaimo Water District and Harmac represent 98.6% of the total watershed licensed extractive demands and 99.6% of the total licensed storage in the watershed. Irrigation, domestic, conservation and other industrial (ie. stock watering and golf course watering) account for only 1.4% of the licensed extractive demand and 0.4% of the storage. The North Cedar Water Works District at one time held licences for their wells adjacent to the Nanaimo River. Thus the Greater Nanaimo Water District and Harmac water use and storage regulation will have the greatest impact on the low flows and instream fish flow requirements in the Nanaimo River watershed.

Future regulation of licensees, current licence use and any amendments should reflect the future projected demands. Licensing procedures are being revised and the pricing of water rights addressed in the legislative reviews and discussion papers currently under way for the Water Management Program.

8.4(1) **It is recommended that no further allocations for extractive demands issue (except domestic - see below) within the Nanaimo River watershed, including Haslam Creek or any tributaries, unless adequate supporting storage is to be provided. Appropriate notation is to be included in the Stream Register.**

8.4.1 Municipal Waterworks

In the Nanaimo River watershed 31% of the total licenced extractive demand and 32% of the total licenced storage is held by the Greater Nanaimo Water District. Regulation of water volumes and flows and coordination with Harmac's Fourth Lake water supply and flow releases is important for the maintenance of water supplies and instream fish flow requirements.

The Greater Nanaimo Water District's storage should be regulated in accordance with a provisional operation rule to supply at least 25% of the minimum flows required to maintain the instream fisheries resources in the Nanaimo River (see Appendix V).

The Greater Nanaimo Water District has estimated that its water reservoir supplies will be adequate until 2010 when the average daily demand will be 78,744 m^3/day and the maximum daily demand will be 126,776 m^3/day. The Greater Nanaimo Water District's water licences should be amended to reflect the water supply reservoirs ability to meet future demands.

The Greater Nanaimo Water District have applied for a water license and constructed gates on the spillway of Jump Creek Reservoir to increase storage. Although the spillway gates have been constructed and are being operated to store additional water, no authorization has been granted.

Low level discharges from Jump Creek Reservoir have been limited to 2.83 m^3/s (100 cfs) because of structural problems related to the low level outlet. Thus the flow release options to supply future demands and instream fish flows are limited. Furthermore the capability to dewater part of the reservoir for maintenance and repairs is limited.

The water quantities and quality in the South Fork of the Nanaimo River should be reserved and protected for community water supply.

8.4.1(1) **It is recommended that the Greater Nanaimo Water District continue to monitor, regulate and report the Jump Creek and South Fork reservoir levels and flow releases as directed by the Engineer under the Water Act and coordinate their operations with Harmac's operation of Fourth Lake reservoir.**

8.4.1(2) **It is recommended that the Greater Nanaimo Water District flow releases into the Nanaimo River be operated in accordance with a provisional operation rule.**

8.4.1(3) **It is recommended that the Greater Nanaimo Water District's water licence application (file 1000627) be granted for additional developed storage on Jump Creek reservoir. The license should note the full supply level (378.34 metres) and refer to the operation rule.**

8.4.1(4) **It is recommended that the Greater Nanaimo Water District review the design of the low level outlet to provide operational flexibility.**

8.4.1(5) **It is recommended that no other water use should be allowed in the South Fork of the Nanaimo River that may have an affect on the water quantity or quality for municipal waterworks uses.**

8.4.1(6) **It is recommended that the watershed land and resource uses in the South Fork of the Nanaimo River be managed to preserve the water quality by encouraging the land owners to follow the recommendations in the "Guidelines for Management of Crown Lands used as Community Water Supplies".**

8.4.2 Industrial Use

In the Nanaimo River watershed 67.9% of the total licenced extractive demand and 67.6% of the total licenced storage is held by the MacMillan Bloedel's, Harmac mill (Harmac). Regulation of water volumes and flows and coordination with Greater Nanaimo Water District's Jump Creek and South Fork supply and flow releases is important for the maintenance of water supplies and instream fish flow requirements.

Harmac's storage should be regulated in accordance with a provisional operation rule to supply approximately 75% of the minimum flows required to maintain the instream fisheries resources in the Nanaimo River (see Appendix V).

Harmac's present water demands are estimated to be 245 million L/day. Between 1993 - 1994 Harmac estimates that its water demands will be reduced to 164 million L/day due to improved equipment and efficiencies in the mill. Harmac's storage license on Fourth Lake authorizes 43,200 dam^3. Reports after the dam was completed indicates that only 38,600 dam^3 is available.

Other small industrial water demands are associated with agricultural and commercial pursuits such as livestock watering and golf course watering. These water demands are not significant in relation to the flows in the Nanaimo River but do impact the smaller tributaries. Adequate storage is required.

8.4.2(1) **It is recommended that Harmac continue to monitor, regulate and report the Fourth Lake reservoir levels and flows in the Nanaimo River as directed by the Engineer under the Water Act and coordinate their operations with Greater Nanaimo Water District's operation of Jump Creek and South Fork reservoir.**

8.4.2(2) **It is recommended that Harmac's flow releases into the Nanaimo River be operated in accordance with a provisional operation rule. The provisional operation rule should ensure that Harmac supplies approximately 75% of the supply required to maintain the fisheries resources from time to time.**

8.4.2(3) **It is recommended that Harmac's storage licence be revised to authorize the actual maximum storage volume.**

8.4.2(4) **It is recommended that Harmac review the operation of Haslam Creek Intake (Well "A") and the benefit of returning water to the surface.**

8.4.3 Irrigation

Irrigation represents approximately 1.4% of the total licenced extractive demand and less than 0.4% of the total licenced storage in the Nanaimo River watershed. However 73% of the irrigation demand is in the Haslam Creek drainage area. Thus most irrigation demands are competing directly with the instream fisheries requirements for the natural low summer flows in these relatively small creeks and shallow lakes. The mean monthly flow in August in Haslam Creek is below 10% MAD where significant reductions in the fisheries resources are indicated. Therefore no further irrigation demand should be considered without adequate storage (see recommendation 8.4.(1) above).

Soil, crop and climatic characteristics should be used to better define the irrigation water demands. Excessive rate of application of irrigation water that may affect reservoir drawdown, streamflow and return drainage water quality should be limited.

8.4.3(1) **It is recommended that soil, crop and climatic characteristics determine the irrigation requirements for new water license applications.**

8.4.3(2) **It is recommended that the maximum allowable rate of withdrawal for irrigation shall be limited to 47 litres per minute per hectare.**

8.4.4 Domestic

Domestic represents approximately 0.014% of the total licenced demand in the Nanaimo River watershed. Individual domestic demands have no significant impact on measurable flows in any stream.

8.4.4(1) **It is recommended that domestic purpose water demand shall be issued for 2275 lpd (500 gpd) per residence for a rural household. Supporting storage is not required but may be recommended.**

8.4.4(2) **It is recommended that domestic purpose water licenses not be issued within a community water supply area without leave from the community water supply agency.**

8.4.4(3) **It is recommended that domestic purpose water licences not be issued to support urban lot size subdivision development or provide proof of a potable water supply for subdivision.**

8.4.5 Approvals for Changes In and About a Stream

The Nanaimo River, Haslam Creek and most tributaries in the lower reaches of the watershed are accessible to fish. Rapid development in these lower reaches, including ditching for commercial, airport and agricultural developments have reduced streamside vegetation and instream spawning gravel and cover (see Section 5.3.2). To protect water quality and the instream fisheries resources changes in and about a stream should be regulated.

8.4.5(1) **It is recommended that changes in and about a stream be regulated by providing standard construction requirements until new Regulations under the Water Act are enacted.**

8.4.6 Wildlife Habitat and Recreational Activities

Appropriate water levels and flows are necessary to maintain critical wildlife habitats in the Nanaimo River Basin. In this study, criteria were not established for evaluating the impact of changing stream flows, and lake and reservoir conditions on wildlife. Because many species depend on the estuary, river, riparian zone and adjacent valley bottom, further regulating flows in the system would significantly affect wildlife.

Minimum water levels for most recreation activities have not been identified for the Nanaimo River. 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 that recreational areas may not coincide with fisheries areas.

8.4.6(1) **It is recommended that future Nanaimo River Water Management Plan processes encourage the participation of other stakeholders such as Native, wildlife and recreation representatives.**

8.5 Nanaimo River Reservoir Operations

Water Management Modelling

Given the minimum reservoir levels, consumptive demands of the present licensees, and additional fishery flow requirements the best balance of water supply and demand falls between the RED 1 (reduction 1) and RED 2 (reduction 2) scenario for the present consumptive demand and is RED 2 for the future consumptive demand, as detailed in Chapter 7. The rule curves for

RED 2, present consumptive demand, were given in Figure 7.16. If Harmac and Jump Creek reservoirs were operated at lower minimum storage levels, then the RED I scenario may be an option. With all of these scenarios, the operation of the reservoirs will have to be carefully coordinated with both Harmac and the Greater Nanaimo Water District.

8.5(1) **It is recommended that the reservoirs be operated to provide a <u>minimum</u> fishery requirements of 20-10-10% mean annual discharge (MAD), during the period of April to October and a single pulse flow in early October of 11.33 m^3/sec (400 cfs).**

8.5(2) **It is recommended that investigation of flow forecasting be undertaken to determine if forecasts could be made that would improve knowledge of the resource and hence improve reservoir operations.**

Additional scenarios may be run with the WRMM, however at this point it should be recognized that there is not enough storage to meet the full fisheries requirements. Furthermore as consumptive demands increase, less water will be available to satisfy the required fishery flows unless additional storage is developed.

Reservoir Operations

The area which may require more work is the operation of the reservoirs. The model assumes that either of the two reservoirs may make releases to satisfy fishery flows after consumptive demands are met. If the reservoirs are within Zone A, then the model performs this operation in an efficient manner releasing only enough water from storage to meet the demands.

Future water management processes need to explicitly coordinate operating guidelines for the Jump Creek and Fourth Lake reservoirs to overcome operational lags. There is a need for new operational rules to support the results of the WRMM framework to aid MacMillan Bloedel Ltd., and Greater Nanaimo Water District in operating their respective reservoirs.

8.5(3) **It is recommended that provisional operating rules based on present modelling assumptions be agreed upon by licensees. Suggested operation rules have been identified in Appendix V of this Plan, such that the current concepts and frameworks utilized in operating the reservoirs are integrated and developed into these operational plans.**

8.5(4) It is recommended that the integrated operating plans continue to be revised and updated as greater understanding of the Nanaimo River and the reservoir operations is developed.

Storage

Historical storage references have assessed the potential for other storage sites within the Nanaimo River watershed. The Greater Nanaimo Water District 1968 Water Report by Associated Engineering Services Ltd., cite two future storage locations above the South Fork reservoir. In the first storage site, located about 2.4 kilometres upstream from the existing South Fork dam, one dam could provide an effective storage volume of 328 million litres and another dam could provide 161 million litres. The second potential Greater Nanaimo Water District site is located on Jump Creek approximately 3.6 kilometres upstream from the confluence with the South Fork River. There is also potential for two dams at this site: one providing effective storage volume of 191 million litres and the other 631 million litres. Although the latter dam site provides more storage, more land is flooded.

A 1972 Fourth Lake Dam Study Report (MacMillan Bloedel Ltd, 1972) states that it is feasible to raise the Fourth Lake reservoir by 3.3 m adding a 6,362.39 dam^3 or 17 % of storage volume. At the present time, MacMillan Bloedel Ltd. does not see the necessity to add to their storage. They will have a significant reduction in water use by December 31, 1993. Even though the population and demand pressures on the City of Nanaimo will continue to rise, the Greater Nanaimo Water District estimates that the Jump creek reservoir will meet the City's water demands with the present system until the year 2010.

Temperature must also be considered when addressing the storage issue. If raising dam elevations is a possible strategy to increase storage, then the deep small surfaced dams that provide cooler temperatures than broad shallow reservoirs may help the temperature issues surrounding fisheries instream requirements.

8.5(5) It is recommended that a storage inventory be compiled including the previously identified sites and that Second and First Lakes be considered for additional storage in the watershed.

CHAPTER 9 IMPLEMENTATION STRATEGY

Implementation of the Nanaimo River Water Management Plan will require a continued commitment from the Regional Water Management Office and the Planning Team members. An implementation plan is a means to commit to the actions recommended in the plan through agreed upon strategies.

The strategies priorize the short and long term activities recommended by the Plan and explicitly document how the Nanaimo River Water Management Planning process will continue.

9.1 Priorization of Recommendations

The following is a summary of recommendations from Chapter 8. These recommendations are presented in Tables 9.1 - 9.3 to identify actions requiring immediate attention (these actions must be done and are not dependent on available resources) and actions required and recommended as resources become available. The tables also identify the agencies responsible and estimated resources and time frames.

9.2 Process Continuation

The Nanaimo River Water Management Planning process will continue through annual and biannual meetings and through Committees responsible for strategy follow up and reservoir operations.

Annual planning team meetings will be initiated by the Regional Water Management office. Biannual communications and/or meetings with the Greater Nanaimo Water District, Harmac, Habitat Management, Fish and Wildlife and the Regional Water Management will also occur.

The Implementation Committee (Table 9.4) will be responsible for following up on all recommendations addressed in the plan. Part of this responsibility will be to ensure a yearly report is compiled with the cooperation of Habitat Management, Fish and Wildlife, Harmac and Greater Nanaimo Water District through yearly assessment and operational summaries. These assessments will be submitted to the Regional Water Management manager as a record of release strategies/ outcomes and will contribute to the NRWM Plan five year update in 1998.

The Operational Committee (Table 9.4) will be responsible for the integrated operations of the reservoirs.

Table 9.1 Actions Requiring Immediate Attention

Recommendation	Lead Agency	Resource Estimate ($1,000)	When
8.5(3) Agreement of Provisional Operating Rules	RWM, MOELP	Meetings	July 1993 Sept. 1993
8.5(1) Operate to Reduction Scenario	RWM, MOELP	none	Oct.1993
8.3(1) Pulse Flow Release Strategy	HM, DFO	none	Oct. 1993
8.1(3) Temperature Measurements	Harmac, M&B	2	July 1993
8.3.1(2) Water Temp. Investigations	HM, DFO	5	July 1993
8.3.2(1) Targets Recreational Fish	RWM, MEOLP	none	July 1993
8.4(1) Fully Record Nanaimo River	RWM, MEOLP	none	Sept. 1993
8.4.1(1) GNWD Reservoir Levels	GNWD	existing	continuing
8.4.1(3) GNWD Water Application	RWM, MOELP	none	Sept. 1993
8.4.1(2) Operate GNWD Releases	GNWD	existing	July 1993
8.4.1(5) S. Fork Water	WM, MOELP	none	July 1993
8.4.1(6) Water Quality	RWM, MOELP	none	continuing
8.4.2(1) Fourth Lake Reservoir Levels and Flows	Harmac, M&B	none	continuing

Table 9.2 Actions Required as Resources Available

Recommendation	Lead Agency	Resource Estimate ($1,000)	When
8.5(4) Update Integrated Operating Plan	RWM, MOELP	Meeting	1994/95
8.1(4) Surface/ Groundwater Study	GW, MOELP	30	1994/95
8.1(6) Assessment of Cassidy Aquifer	GW, MOELP	50	1994/95
8.1(7) Groundwater Manag. Program	GW, MOELP	5	1994+
8.2(3) Water Quality Check Program	REP, MOELP	5	1993/94
8.2(1) water quality monitoring program	REP, MOELP	5/yr.	continuing
8.2(2) Groundwater Management Area	GW, MOELP	50	1995/96
8.5(2) Forecasting Inflow Contributions	RWM, MOELP	20	1994/95
8.1(2) Establish Hydrometric Stations	RWM, MOELP,	50	1994 +
8.1(5) Meteorological Observations	RWM,MOELP, GNWP	10	1994
8.3(4) Fisheries Production Man. Plan	HM, DFO	10	1994 +
8.1(1) Recording of Lake Water Levels	RWM MOELP, Harmac M&B and GNWD	2/yr	continuing
8.3.1(3) Assess Chinook Spawning Areas	HM, DFO	10	1994 +
8.3.2(2) Side Channel Enhancement	FW, MOELP	10	1994
8.3.2(4) Conduct Biophysical Inventory	FW, MOELP	10	1994
8.4.1(4) Evaluate Low Level Outlet	GNWD	10	1994
8.4.2(4) Review Harmac's Pump Practise	RWM, MOELP	none	1994
8.4.2(3) Revise Harmac's storage licence	RWM, MOELP	none	1994
8.4.3(2) Rate of Withdrawal for Irrigation	RWM, MOELP	none	July 1993
8.4.4(1) Issuance of Domestic Water	RWM, MOELP	none	July 1993
8.4.4(2) Issuance of Domestic Water within Community Supply Area	RWM, MOELP	none	July 1993
8.4.4(3) Domestic Water Licences	RWM, MOELP	none	July 1993
8.4.5(1) Changes in and about a Stream	RWM, MOELP	none	July 1993
8.4.3(1) Irrigation Requirements	RWM MOELP	none	July 1993

Table 9.3 Actions Recommended as Resources Available

Recommendation	Lead Agency	Resource Estimate ($1,000)	When
8.1(8) Evaluate Cassidy Aquifer	MOELP	50	1995 +
8.5(5) Update Storage Inventory	RWM, MOELP	50	1996
8.3.1.(5) Release Flows if New Storage	RWM, MOELP	none	1996 +
8.4.6(1) Stakeholder Participation	RWM, MOELP	5	1998
8.3.2(3) Headwater Storage Investigation	GNWD	to be determined	2000 +

Table 9.4 Committee Representatives

Agency	Operational Committee Representatives	Implementation Committee Representatives
MacMillan Bloedel Ltd., Harmac Division	John Zurbrigg	Murray Duncanson
Greater Nanaimo Water District	Wayne Hansen	Wayne Hansen
Habitat Management, Department of Fisheries and Oceans	Brian Tutty	Rick Higgins
Fish and Wildlife, Ministry of Environment, Lands and Parks	Craig Wightman	George Reid
Regional Water Management, Ministry of Environment, Lands and Parks	George Bryden	Bill Hollingshead

Table 9.5 Lead Agency Key for Tables 9.1 - 9.3

RWM, MOELP	Regional Water Management, Ministry of Environment, Lands and Parks
REP, MOELP	Regional Environmental Protection, Ministry of Environment, Lands and Parks
FW, MOELP	Fish and Wildlife, Ministry of Environment, Lands and Parks
GW, MOELP	Groundwater, Water Management Division, Ministry of Environment, Lands and Parks
HM, DFO	Habitat Management, Department of Fisheries and Oceans
Harmac, M&B	Harmac Division, MacMillan Bloedel Ltd.
GNWD	Greater Nanaimo Water District
RDN	Regional District of Nanaimo

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APPENDICES

NANAIMO RIVER
WATER MANAGEMENT PLAN

July 1993

APPENDICES

NANAIMO RIVER WATER MANAGEMENT PLAN

APPENDIX I

NANAIMO RIVER WATER MANAGEMENT PLANNING TEAM

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Murray Duncanson, MacMillan Bloedel Limited, Harmac Division
John Zurbrigg, MacMillan Bloedel Limited, Harmac Division
Bob Askin, Woodlands Services Division, MacMillan Bloedel Limited

Chief Bob Thomas, Nanaimo Indian Band Council
Chuck Poschenrieder, Nanaimo Indian Band Council

Rick Higgins, Habitat Management, Department of Fisheries and Oceans
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Bill Hollingshead, Regional Water Management, B.C. Environment
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APPENDIX II

CALCULATION OF NATURAL FLOWS

The method selected to evaluate the options for managing the water resource within the Nanaimo River basin is the Water Resources Management Model (WRMM) which is described in Chapter 7. The WRMM requires data that reflect natural flows as they would have occurred without the influence of storage reservoirs and diversion from the basin. The WRMM also requires that the data be organized into time steps of consistent length.
For this basin, and for this plan, a time step of 7 days was selected, rather than a longer duration, because of the need to identify low flow periods. Use of a time step shorter than 7 days was considered to be unrealistic due to the unavailability of a comprehensive network of streamflow gauging stations and other relevant data in the basin.

The WRMM requires that the configuration of the of the watershed be described as a system of nodes and channels. The configuration selected is shown in Figure 7.14. One notable feature is that the Nanaimo Lakes had to be designated as part of a channel since there were inadequate data to represent these lakes in the model in their actual physical state.

Node 6, Fourth Lake reservoir

Calculation of natural flows at Fourth Lake was based upon removing the effect of the reservoir by using the following water balance equation:

Inflow = Outflow +/- ıange in Storage

In this case, the inflow is unknown and the calculated value of the inflow will be assumed to be the natural flow as if the lake did not exist.

The outflow from Fourth Lake is based upon records of discharge through valves controlling the low level outlet, a constant discharge of 0.14 cubic metres per second (5 cubic feet per second) from a secondary low level outlet, and the flow over the spillway as calculated from the water levels in the Lake, Table 3. The calculated natural flows are given in Table 10.

Node 5, Jump Lake reservoir

Using the same water balance equation, the natural flow of Jump Creek was calculated. The outflow for the equation was the recorded flow at the hydrometric station 08HB041 Jump Creek at the Mouth, Table 2. The change in storage was calculated from the recorded water levels of Jump Lake, Table 4. The calculated natural flows are given in Table 11.

Node 4, South Fork reservoir

South Fork reservoir is not operated in a manner that makes full use of its live storage, and so it has had a relatively minor impact on the flows at that point. However, it is the point from which water is diverted from the river to the GNWD and therefore naturalization of the flow is necessary for use in the WRMM to evaluate options.

The water balance equation in the following form was used to calculate natural flows:

Inflow = Outflow + Diversion +/- change in storage

The outflow was calculated as the total of the flow over the dam (based upon water level records, Table 5), plus the releases through low level outlets. The diversion is based upon the recorded values provided by the GNWD, Table 6.

The change in storage, although relatively small, was calculated from the records of water level in the reservoir. In addition, the flow at this site has been affected by the storage of water in Jump Lake and hence the change in storage at Jump Lake also became a part of the calculation. The natural flows at this location are given in Table 12.

Node 2, Hydrometric Station 08HB034, Nanaimo River near Cassidy

At this location the recorded streamflow data for the period 1980 to 1989 includes all the man made influences that occurred upstream. Therefore to re-create the flows as they would have been without the influence of man requires the following calculation:

Nat flow = Rec flow + diversion +/- change in storage

The recorded flows are as given in Table 1, and the diversion by GNWD is given in Table 6.

The change in storage is occurring at Fourth Lake, Jump Lake, and South Fork. The change in storage for Fourth Lake was added to 08HB034 with a time adjustment to account for the time of travel from the Lake to the gauging station. Jump Lake and South Fork changes is storage were added directly without an adjustment for time of travel. The resulting calculated natural flow at this site is given in Table 13.

Natural Flow at Node 3

The WRMM requires streamflow data for all the nodes in the schematic configuration developed previously and shown in Figure 7.13, and the streamflow must represent natural flows without the effect of reservoir storage and diversions.

The natural flows for Nodes 2, 4, 5, and 6 have been calculated in the foregoing sections. Node 3, the confluence of the Nanaimo and the South Nanaimo Rivers, requires a calculation of the natural flow for input to the WRMM. The first step in determining the flow is to calculate the ungauged local inflow between Node 3 and Nodes 4 and 6 using the following relationship:

Qnode3 = area ratio(Qnode2 - Qnode4 -Qnode6)

where: area ratio =(665-201-28-91)/(665-201-28)=0.79

The resulting calculated natural local inflows at Node 3 are given in Table 14a.

The total flow at Node 3 is presented in Table 14b, and was calculated by adding the flows from Nodes 4 and 6 back into the local inflow values determined above (Table 14a).

The drainage areas related to the nodes of the model are given in Table 15.

Table 15 Drainage areas in square kilometres (not including Haslam Creek) upstream of each node and between nodes.

Node	Total Area Upstream	Net Area Between Next Upstream Nodes
1	680	15
2	665	91
3	574	345
4	201	151
5	50	
6	28	

Haslam Creek drainage area is 133 square kilometres at its confluence with the Nanaimo River.

Table 1

Nanaimo River near Cassidy

Station # 08HB034

recorded flows 7 day averages in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	85.91	41.24	18.67	43.60	190.80	10.36	14.64	106.13	9.16	72.33
2	JAN 08 - [illegible] 14	47.43	24.71	17.53	166.33	79.89	9.61	131.61	135.23	32.06	30.60
3	JAN 15 - [illegible] 21	59.51	59.40	35.66	59.69	23.49	24.84	232.10	38.84	90.77	79.29
4	JAN 22 - JAN 28	24.96	71.96	94.19	98.09	52.29	20.29	70.37	50.01	36.10	28.56
5	JAN 29 - FEB 04	81.13	24.11	63.70	41.49	37.66	11.93	69.69	114.24	48.74	61.41
6	FEB 05 - FEB 11	77.01	14.71	27.96	77.81	51.74	9.94	35.40	106.77	25.50	16.74
7	FEB 12 - FEB 18	32.79	171.56	157.44	276.00	76.84	28.80	14.96	98.61	84.57	11.23
8	FEB 19 - FEB 25	65.07	133.23	118.51	161.86	99.27	29.81	142.84	32.63	29.60	42.89
9	FEB 26 - MAR 04	192.21	32.51	80.34	48.69	54.13	29.01	107.24	67.57	23.83	28.14
10	MAR 05 - MAR 11	36.59	16.74	40.81	137.59	38.46	17.71	69.06	163.14	41.10	44.10
11	MAR 12 - MAR 18	36.16	13.44	25.31	111.90	43.29	14.00	40.53	69.84	25.34	68.17
12	MAR 19 - MAR 25	44.19	12.81	18.27	28.03	98.77	20.24	30.31	29.53	55.33	35.89
13	MAR 26 - APR 01	30.36	29.23	23.68	36.20	40.83	27.00	123.46	15.37	54.57	43.57
14	APR 02 - APR 08	25.34	43.60	20.87	38.70	20.17	60.79	22.44	19.97	80.93	70.37
15	APR 09 - APR 15	47.56	28.63	29.64	18.66	41.23	76.14	14.77	41.06	48.44	58.79
16	APR 16 - APR 22	91.71	43.91	32.11	16.34	54.61	33.06	17.11	51.31	53.69	59.40
17	APR 23 - APR 29	36.21	57.56	33.70	20.11	27.81	29.87	21.23	17.67	29.54	39.14
18	APR 30 - MAY 06	26.26	42.07	30.14	20.10	25.27	33.23	27.63	34.00	41.19	41.40
19	MAY 07 - MAY 13	22.00	24.20	39.70	17.70	33.17	23.67	29.16	30.70	30.03	30.34
20	MAY 14 - MAY 20	16.70	15.24	38.57	18.17	44.31	33.67	47.73	21.64	53.71	16.97
21	MAY 21 - MAY 27	16.86	15.76	40.91	21.91	66.81	30.21	61.30	12.10	32.06	12.17
22	MAY 28 - JUN 03	13.43	12.91	34.83	19.57	46.56	19.26	32.17	43.41	47.90	14.77
23	JUN 04 - JUN 10	13.59	15.06	24.47	13.43	23.17	14.31	13.63	19.09	50.10	14.03
24	JUN 11 - JUN 17	17.84	13.77	31.81	19.49	20.90	11.93	10.11	23.20	20.09	9.18
25	JUN 18 - JUN 24	10.54	23.01	23.94	13.43	16.20	9.57	12.34	13.53	17.54	7.39
26	JUN 25 - JUL 01	12.58	14.90	18.07	11.34	15.91	6.02	7.79	10.23	11.42	5.90
27	JUL 02 - JUL 08	17.81	7.90	15.43	8.91	14.00	4.45	7.41	6.33	10.24	10.27
28	JUL 09 - JUL 15	13.36	5.24	9.16	37.59	9.45	4.40	6.07	4.94	9.07	5.66
29	JUL 16 - JUL 22	8.18	3.82	6.58	16.53	7.02	4.23	5.00	5.35	7.37	5.13
30	JUL 23 - JUL 29	6.47	3.01	5.91	8.07	5.28	4.43	4.68	4.95	4.99	4.44
31	JUL 30 - AUG 05	7.04	3.32	6.40	5.51	5.32	4.67	4.77	4.62	4.78	4.89
32	AUG 06 - AUG 12	5.69	3.61	5.88	5.71	5.03	4.58	4.17	4.90	4.80	4.60
33	AUG 13 - AUG 19	5.85	4.20	4.64	5.15	5.24	4.26	4.67	4.94	5.46	5.02
34	AUG 20 - AUG 26	5.37	4.62	2.79	5.44	5.11	4.53	4.29	4.33	4.96	5.10
35	AUG 27 - SEP 02	5.51	5.34	3.23	8.08	5.07	3.82	5.65	4.76	3.07	4.80
36	SEP 03 - SEP 09	5.98	5.89	4.87	8.53	5.63	4.86	4.64	5.57	4.12	4.31
37	SEP 10 - SEP 16	5.84	5.89	7.84	9.04	5.56	5.87	4.67	5.41	5.40	4.57
38	SEP 17 - SEP 23	7.56	11.46	6.71	6.99	9.46	6.41	3.60	4.73	5.98	4.87
39	SEP 24 - SEP 30	8.34	20.39	6.68	5.72	5.15	4.98	5.62	4.09	8.87	6.71
40	OCT 01 - OCT 07	15.68	57.99	10.26	6.53	6.99	5.12	4.47	3.76	8.46	5.39
41	OCT 08 - OCT 14	8.28	50.96	11.97	9.26	135.27	6.75	6.62	5.00	6.25	8.96
42	OCT 15 - OCT 21	8.26	11.76	7.21	9.18	44.01	39.87	5.06	5.21	11.57	12.39
43	OCT 22 - OCT 28	8.62	26.50	212.71	28.77	16.13	67.63	7.15	4.73	10.86	72.44
44	OCT 29 - NOV 04	47.34	185.53	58.96	49.49	49.26	52.27	18.99	4.85	34.32	18.03
45	NOV 05 - NOV 11	148.63	37.01	49.40	105.06	121.83	29.24	6.80	6.36	128.26	68.29
46	NOV 12 - NOV 18	35.39	162.71	24.66	352.43	79.63	17.37	9.06	17.61	50.99	30.41
47	NOV 19 - NOV 25	92.31	126.84	22.10	92.91	65.60	14.46	157.69	46.14	85.30	34.17
48	NOV 26 - DEC 02	90.04	47.40	61.71	56.43	50.16	10.46	85.34	53.89	51.97	27.59
49	DEC 03 - DEC 09	38.57	170.41	118.11	24.54	53.27	49.37	31.99	139.10	54.43	137.51
50	DEC 10 - DEC 16	180.87	83.81	72.83	50.19	87.14	22.56	28.53	89.29	65.61	32.68
51	DEC 17 - DEC 23	73.66	102.89	145.50	24.46	43.66	14.56	110.90	19.87	30.39	14.54
52	DEC 24 - DEC 31	255.27	36.55	38.13	16.09	15.02	12.89	126.88	12.19	26.11	12.44

Table 2

Jump Creek at the Mouth

recorded flows 7 day averages

Station # 08HB041

in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	198[illegible]
1	JAN 01 - JAN 07	8.01	5.13	5.59	6.58	17.83	1.58	2.01	12.42	1.90	9.46
2	JAN 08 - JAN 14	4.80	4.43	5.36	18.27	8.70	1.42	4.33	14.73	3.13	3.54
3	JAN 15 - JAN 21	4.44	5.18	5.71	7.86	3.99	1.63	24.48	6.49	6.36	9.90
4	JAN 22 - JAN 28	2.43	6.86	8.41	12.01	4.59	1.63	7.24	7.81	4.41	3.5[illegible]
5	JAN 29 - FEB 04	8.60	3.13	7.32	6.81	4.75	1.52	7.42	13.94	4.08	8.1[illegible]
6	FEB 05 - FEB 11	6.48	2.63	5.95	9.27	5.96	1.49	3.95	12.76	3.86	1.8[illegible]
7	FEB 12 - FEB 18	2.85	20.57	15.98	28.10	9.13	2.52	1.73	11.83	10.73	1.10
8	FEB 19 - FEB 25	5.88	14.97	13.76	18.49	11.82	3.48	17.09	4.35	3.79	5.2[illegible]
9	FEB 26 - MAR 04	19.82	3.66	8.79	6.66	5.38	3.49	10.55	6.58	1.25	2.8[illegible]
10	MAR 05 - MAR 11	3.12	1.92	6.32	13.55	4.53	2.53	7.70	18.48	4.08	4.5[illegible]
11	MAR 12 - MAR 18	3.44	1.38	5.72	12.64	4.69	2.35	4.68	7.25	2.44	7.20
12	MAR 19 - MAR 25	3.75	1.92	5.29	4.23	12.35	2.53	3.16	2.59	5.74	3.6[illegible]
13	MAR 26 - APR 01	3.20	5.15	5.06	2.71	5.36	2.72	14.93	1.40	6.28	5.5[illegible]
14	APR 02 - APR 08	2.96	6.60	2.16	4.05	3.18	5.64	2.17	2.02	10.76	7.4[illegible]
15	APR 09 - APR 15	4.99	4.42	2.38	2.04	3.94	8.88	1.60	2.70	4.15	5.30
16	APR 16 - APR 22	8.13	7.45	2.51	1.80	6.92	3.62	2.02	5.48	7.34	7.7[illegible]
17	APR 23 - APR 29	4.01	10.83	2.22	2.57	3.53	3.82	2.53	1.63	3.89	3.[illegible]
18	APR 30 - MAY 06	3.08	7.08	2.21	2.63	3.32	4.06	3.00	3.78	5.77	5.[illegible]
19	MAY 07 - MAY 13	2.65	3.35	2.36	2.42	4.51	2.94	3.72	2.58	3.89	4.58
20	MAY 14 - MAY 20	1.98	2.13	4.27	2.37	6.03	4.26	5.71	2.38	7.56	3.0[illegible]
21	MAY 21 - MAY 27	2.13	2.39	5.92	2.77	9.10	3.78	7.40	1.17	4.07	1.[illegible]
22	MAY 28 - JUN 03	1.75	1.81	4.95	2.50	5.56	2.57	3.62	5.91	7.64	0.[illegible]
23	JUN 04 - JUN 10	1.87	2.27	3.49	1.71	3.04	1.92	1.63	2.29	8.33	1.36
24	JUN 11 - JUN 17	2.46	1.90	4.43	2.01	2.74	1.60	1.23	2.47	1.40	0.[illegible]
25	JUN 18 - JUN 24	1.44	3.72	3.45	1.57	2.13	1:37	1.46	1.52	2.01	0.[illegible]
26	JUN 25 - JUL 01	1.54	2.18	2.91	1.29	2.15	1.24	1.18	1.40	1.17	0.[illegible]
27	JUL 02 - JUL 08	2.36	1.21	2.52	1.01	1.88	0.96	1.15	1.07	1.31	1.33
28	JUL 09 - JUL 15	1.82	1.04	1.43	5.80	1.23	0.90	1.18	1.07	1.19	1.[illegible]
29	JUL 16 - JUL 22	1.24	1.01	1.33	2.17	1.11	0.74	1.17	1.34	0.90	1.[illegible]
30	JUL 23 - JUL 29	1.14	0.98	1.07	1.00	1.12	0.85	1.10	1.44	0.45	1.[illegible]
31	JUL 30 - AUG 05	1.20	0.95	0.88	0.86	1.18	0.89	0.97	1.50	0.60	0.99
32	AUG 06 - AUG 12	1.22	0.96	1.19	1.54	1.50	0.91	0.99	1.81	0.67	0.[illegible]
33	AUG 13 - AUG 19	1.33	0.94	1.19	1.01	1.51	0.89	1.21	1.83	1.03	0.[illegible]
34	AUG 20 - AUG 26	1.43	0.94	1.13	1.01	1.42	0.87	0.91	1.54	1.44	1.[illegible]
35	AUG 27 - SEP 02	1.43	0.95	1.20	1.53	1.31	0.89	1.91	1.24	0.97	1.49
36	SEP 03 - SEP 09	1.42	0.96	0.75	1.62	0.75	0.89	1.24	1.26	2.17	1.[illegible]
37	SEP 10 - SEP 16	1.40	0.97	0.61	1.36	0.76	0.90	1.35	1.22	2.27	0.[illegible]
38	SEP 17 - SEP 23	1.40	1.13	1.01	1.30	0.76	1.15	0.54	1.09	2.14	0.[illegible]
39	SEP 24 - SEP 30	1.39	1.38	1.05	1.30	0.79	1.24	0.69	1.02	2.19	1.98
40	OCT 01 - OCT 07	1.39	7.62	1.06	1.27	0.79	1.63	0.61	0.98	2.09	1[illegible]
41	OCT 08 - OCT 14	1.39	8.37	1.06	1.22	15.03	1.93	0.68	0.98	1.98	1.[illegible]
42	OCT 15 - OCT 21	1.36	2.25	1.08	1.22	6.19	3.69	0.72	0.96	2.09	1.[illegible]
43	OCT 22 - OCT 28	1.34	5.38	28.11	1.53	3.01	5.94	0.81	0.74	2.08	7.25
44	OCT 29 - NOV 04	2.30	23.40	9.87	2.49	8.21	8.03	1.91	0.65	2.80	3[illegible]
45	NOV 05 - NOV 11	21.17	6.43	8.11	13.60	16.10	5.25	1.46	0.57	14.56	11[illegible]
46	NOV 12 - NOV 18	4.80	19.40	6.28	39.21	9.45	4.83	1.19	0.71	6.50	7.[illegible]
47	NOV 19 - NOV 25	12.75	15.94	5.94	8.62	7.62	4.63	12.02	2.28	11.71	10.82
48	NOV 26 - DEC 02	11.57	6.56	6.93	5.63	5.34	4.28	11.47	5.59	6.16	[illegible]
49	DEC 03 - DEC 09	5.04	19.74	12.31	4.08	6.80	4.57	6.16	19.06	6.63	25[illegible]
50	DEC 10 - DEC 16	22.13	10.23	9.05	5.01	10.45	3.89	3.20	11.41	7.78	6.[illegible]
51	DEC 17 - DEC 23	8.53	10.95	15.06	4.18	4.94	3.49	11.29	5.41	3.39	3.80
52	DEC 24 - DEC 31	27.13	5.39	5.84	3.52	2.27	2.11	12.76	2.65	3.30	2[illegible]

Table 3

Fourth Lake reservoir

Lake levels in metres (assumed datum)

Period	Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	Jan-1		316.90	307.97	316.75	315.96	317.04	315.04	316.84	314.71	316.78
2	Jan-8		316.78	308.38	316.85	316.89	317.04	315.95	316.75	315.77	316.77
3	Jan-15		316.80	309.39	316.90	316.90	317.04	316.89	316.75	316.69	316.76
4	Jan-22	316.72	316.80	309.39	316.90	316.90	317.04	316.89	316.75	316.69	316.76
5	Jan-29	316.75	316.73	313.05	316.86	316.89	317.04	316.77	316.74	316.74	316.75
6	Feb-5	316.77	316.76	314.82	316.72	316.88	317.02	316.76	316.74	316.76	316.75
7	Feb-12	316.89	317.08	316.23	316.82	316.88	317.01	316.78	316.74	316.78	316.76
8	Feb-19	317.05	317.30	316.83	316.86	316.87	316.99	316.80	316.73	316.77	316.77
9	Feb-26	317.21	316.98	316.82	316.76	316.87	316.98	316.83	316.72	316.76	316.78
10	Mar-5	317.05	316.74	316.81	316.86	316.87	316.96	316.85	316.73	316.78	316.78
11	Mar-12	316.90	316.72	316.81	316.81	316.88	316.95	316.87	316.75	316.78	316.78
12	Mar-19	316.75	316.70	316.81	316.73	316.86	316.93	316.86	316.72	316.78	316.78
13	Mar-26	316.77	316.75	316.82	316.72	316.85	316.92	316.85	316.75	316.78	316.78
14	Apr-2	316.80	316.75	316.82	316.73	316.85	316.90	316.84	316.72	316.78	316.78
15	Apr-9	316.83	316.75	316.82	316.73	316.84	316.89	316.84	316.78	316.80	316.77
16	Apr-16	316.81	316.81	316.82	316.72	316.78	316.87	316.83	316.84	316.81	316.76
17	Apr-23	316.75	316.88	316.83	316.72	316.76	316.84	316.82	316.83	316.81	316.76
18	Apr-30	316.73	316.85	316.83	316.72	316.75	316.82	316.81	316.82	316.81	316.76
19	May-7	316.73	316.79	316.83	316.72	316.77	316.80	316.80	316.81	316.81	316.75
20	May-14	316.72	316.75	316.83	316.72	316.79	316.78	316.78	316.78	316.84	316.74
21	May-21	316.72	316.73	316.84	316.72	316.79	316.77	316.78	316.76	316.84	316.74
22	May-28	316.72	316.75	316.84	316.72	316.78	316.76	316.78	316.78	316.84	316.75
23	Jun-4	316.72	316.78	316.84	316.72	316.77	316.76	316.77	316.78	316.84	316.75
24	Jun-11	316.71	316.79	316.84	316.72	316.76	316.75	316.75	316.80	316.81	316.74
25	Jun-18	316.71	316.85	316.81	316.72	316.75	316.75	316.78	316.77	316.81	316.73
26	Jun-25	316.71	316.78	316.79	316.72	316.75	316.73	316.73	316.76	316.79	316.72
27	Jul-2	316.70	316.77	316.76	316.72	316.75	316.70	316.74	316.74	316.77	316.72
28	Jul-9	316.70	316.76	316.74	316.72	316.75	316.23	316.76	316.72	316.76	316.72
29	Jul-16	316.70	316.76	316.72	316.73	316.73	315.64	316.74	316.38	316.75	316.66
30	Jul-23	316.69	316.75	316.47	316.72	316.64	314.71	316.56	315.67	316.69	316.45
31	Jul-30	315.61	316.74	315.63	316.72	316.28	313.59	315.72	315.26	316.50	315.88
32	Aug-6	314.61	316.73	314.87	316.50	315.77	312.37	315.04	314.60	315.63	315.22
33	Aug-13	313.67	316.73	314.38	315.72	315.24	311.66	314.10	313.82	314.74	314.19
34	Aug-20	312.74	316.72	314.25	314.86	314.41	310.53	313.14	313.07	314.00	313.43
35	Aug-27	311.80	315.36	313.97	313.79	313.46	309.60	312.00	312.21	313.57	312.84
36	Sep-3	310.81	313.45	313.42	312.72	312.41	308.64	310.64	310.77	313.33	312.12
37	Sep-10	309.84	312.23	312.29	312.18	311.35	307.39	309.66	309.22	312.42	310.82
38	Sep-17	308.90	311.32	310.90	311.79	311.10	306.19	309.00	308.09	311.51	309.58
39	Sep-24	307.94	310.80	309.22	311.23	311.20	305.17	307.54	307.16	310.59	308.46
40	Oct-1	307.31	311.28	307.62	310.63	310.68	304.19	306.43	306.63	308.76	306.78
41	Oct-8	306.57	313.33	305.85	309.14	311.71	302.82	305.56	305.64	308.15	304.73
42	Oct-15	305.40	313.78	307.06	308.57	315.04	302.21	303.26	304.10	307.42	301.47
43	Oct-22	304.15	314.22	309.43	308.01	315.74	307.47	302.21	302.36	307.54	303.33
44	Oct-29	303.57	314.66	311.79	308.99	316.06	309.79	302.21	300.38	307.65	303.78
45	Nov-5	307.29	315.11	314.15	311.38	316.38	311.29	302.60	299.09	309.16	305.09
46	Nov-12	311.25	315.55	314.91	315.73	316.70	312.16	302.73	299.01	311.96	306.94
47	Nov-19	313.04	315.99	314.47	316.97	316.92	312.64	306.24	301.07	314.80	308.79
48	Nov-26	314.87	316.43	314.55	316.81	317.04	313.03	309.81	304.34	316.81	310.63
49	Dec-3	316.72	316.65	315.94	316.78	317.04	313.42	311.36	308.71	316.75	313.41
50	Dec-10	316.91	316.16	316.75	316.80	317.04	313.81	312.89	310.79	316.69	315.34
51	Dec-17	316.99	313.44	316.78	316.82	317.04	314.20	314.32	312.32	316.74	315.99
52	Dec-24	316.99	310.43	316.78	316.85	317.04	314.59	315.69	313.44	316.78	316.25

Table 4 — Jump Lake reservoir

Lake levels in metres (assumed datum)

Period	Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	Jan-1		376.35	374.55	374.96	374.47	375.49	370.79	376.21	372.69	376.52
2	Jan-8		375.73	372.62	375.41	376.56	375.13	371.86	375.64	372.21	376.37
3	Jan-15		374.99	371.55	376.42	376.09	375.25	375.77	376.22	375.36	376.43
4	Jan-22		376.34	372.47	376.15	375.29	375.87	376.38	374.68	375.18	376.41
5	Jan-29		376.28	374.90	376.39	376.30	376.13	376.15	375.02	375.74	376.56
6	Feb-5		375.74	375.13	375.22	376.06	376.02	376.35	375.93	375.67	376.3
7	Feb-12		375.63	373.79	376.31	376.58	375.96	375.98	376.62	375.76	376.4
8	Feb-19		376.24	376.71	376.82	376.75	376.26	375.87	375.93	376.21	376.3
9	Feb-26		376.40	375.97	376.45	376.16	376.34	376.99	375.75	375.97	376.4
10	Mar-5		376.25	376.22	375.44	376.13	376.16	376.12	377.24	376.73	376.2
11	Mar-12		376.17	375.21	376.68	376.16	375.84	376.43	376.51	377.04	376.5
12	Mar-19		376.21	373.84	375.98	376.29	375.50	376.05	376.26	377.10	376.3
13	Mar-26		376.29	372.10	375.36	376.39	375.46	376.71	376.19	377.93	376.4
14	Apr-2		376.45	370.79	376.01	376.35	376.12	376.25	376.16	377.71	376.3
15	Apr-9		376.40	371.22	376.34	376.24	376.45	376.20	376.43	377.71	376.8
16	Apr-16		376.33	372.16	376.25	376.58	376.47	376.17	377.65	378.26	377.6
17	Apr-23		376.63	372.92	376.31	376.24	376.26	376.30	377.42	378.05	377.6
18	Apr-30	376.24	376.54	373.84	376.33	376.28	376.39	376.28	377.56	378.29	378.1
19	May-7	376.24	376.38	374.70	376.29	376.31	376.36	376.29	377.70	377.93	378.1
20	May-14	376.21	376.26	376.07	376.33	376.44	376.30	376.58	377.95	378.32	377.8
21	May-21	376.21	376.25	376.40	376.34	376.44	376.40	376.47	377.89	378.10	377.5
22	May-28	376.18	376.28	376.38	376.36	376.48	376.33	376.46	377.99	378.17	377.
23	Jun-4	376.18	376.24	376.35	376.28	376.38	376.28	376.25	378.01	378.17	378.
24	Jun-11	376.26	376.28	376.40	376.36	376.29	376.22	376.14	377.91	377.86	378.
25	Jun-18	376.21	376.30	376.38	376.28	376.31	376.12	376.17	377.96	378.23	378.
26	Jun-25	376.18	376.34	376.25	376.25	376.25	376.04	376.14	378.06	378.28	378.
27	Jul-2	376.14	376.22	376.30	376.22	376.26	375.84	376.02	377.98	378.32	378.
28	Jul-9	376.24	376.10	376.22	376.23	376.20	375.71	375.89	377.91	378.34	378.
29	Jul-16	376.15	375.95	376.07	376.39	376.11	375.49	375.72	377.72	378.33	378.
30	Jul-23	375.95	375.77	375.97	376.23	376.00	375.29	375.41	377.29	378.33	377.
31	Jul-30	375.69	375.55	375.82	376.19	375.77	374.99	375.07	376.90	378.33	377.
32	Aug-6	375.49	375.28	375.87	376.07	375.44	374.68	374.75	376.38	378.21	377.
33	Aug-13	375.32	375.00	375.36	375.87	374.96	374.36	374.35	375.81	378.06	377.
34	Aug-20	374.89	374.71	375.08	375.36	374.42	374.03	373.89	375.21	377.83	376.
35	Aug-27	374.51	374.36	374.70	375.03	373.91	373.66	373.43	374.60	377.42	376.
36	Sep-3	374.20	374.19	374.29	374.69	373.28	373.33	372.47	374.10	377.13	375
37	Sep-10	373.83	373.90	374.19	374.29	373.20	373.02	371.81	373.57	376.42	375
38	Sep-17	373.50	373.53	374.14	374.06	373.15	372.78	371.36	373.06	375.67	375.
39	Sep-24	373.35	374.19	373.84	373.74	373.41	372.53	371.08	372.64	374.96	374.
40	Oct-1	373.23	375.82	373.43	373.29	373.20	371.97	370.79	372.20	374.54	374
41	Oct-8	373.35	376.75	373.53	372.76	374.97	371.06	370.46	371.76	373.91	373
42	Oct-15	373.28	376.25	373.23	372.36	376.52	370.64	370.00	371.27	373.23	373
43	Oct-22	373.21	376.05	374.29	372.47	376.01	374.60	369.60	370.80	373.43	374
44	Oct-29	372.92	376.62	376.73	373.52	375.65	376.20	370.10	370.42	372.89	37
45	Nov-5	376.06	376.30	376.28	376.27	376.36	376.29	370.61	370.27	375.96	37
46	Nov-12	376.45	376.52	375.67	376.68	376.61	375.56	370.18	370.90	376.42	37
47	Nov-19	376.19	376.50	374.55	376.78	376.28	374.56	372.41	371.96	376.17	37
48	Nov-26	376.38	376.28	372.92	376.32	376.33	373.16	376.58	375.21	376.45	37
49	Dec-3	376.30	376.38	376.20	375.96	375.85	371.46	376.00	376.62	376.40	37.
50	Dec-10	375.84	376.42	375.67	375.50	376.14	373.68	374.68	376.69	376.38	37
51	Dec-17	376.68	375.78	376.89	375.68	376.46	372.59	375.39	375.48	376.34	37
52	Dec-24	376.50	376.20	376.06	374.66	375.89	371.25	376.81	373.88	376.10	37

Table 5

South Fork reservoir

Reservoir levels in metres (assumed datum)

Period	Date	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	Jan-1		247.80	247.68	247.75	248.63	247.57	247.59	247.92	247.59	247.93
2	Jan-8		247.71	247.68	248.07	248.62	247.52	248.41	247.77	247.56	247.72
3	Jan-15		247.64	247.74	247.83	247.68	247.53	247.87	247.84	247.64	247.76
4	Jan-22		248.14	247.80	247.80	247.67	247.56	247.87	247.71	247.76	247.72
5	Jan-29		247.59	247.78	247.92	247.74	247.56	247.80	248.26	247.92	247.84
6	Feb-5		247.64	247.74	247.73	247.65	247.52	247.83	248.08	247.65	247.69
7	Feb-12		247.64	247.68	249.02	248.01	247.54	247.65	248.13	248.02	247.82
8	Feb-19		247.66	248.29	248.23	248.25	247.67	247.62	247.76	247.71	247.69
9	Feb-26		248.36	247.78	247.92	247.76	247.72	248.21	247.62	247.62	247.80
10	Mar-5		247.56	247.80	247.78	247.74	247.64	247.74	248.66	249.63	247.63
11	Mar-12		247.59	247.71	248.21	247.76	247.61	247.80	247.94	247.71	247.88
12	Mar-19		247.61	247.65	247.78	247.80	247.65	247.66	247.78	247.57	247.69
13	Mar-26		247.68	247.65	247.68	247.83	247.65	248.13	247.61	248.44	247.80
14	Apr-2		247.79	247.68	247.78	247.70	247.94	247.69	247.59	247.72	247.80
15	Apr-9		247.73	247.65	247.68	247.61	247.83	247.60	247.80	247.83	247.90
16	Apr-16		247.72	247.71	247.65	247.90	247.80	247.59	248.45	247.87	247.79
17	Apr-23		247.89	247.77	247.67	247.72	247.62	247.70	247.65	247.74	247.86
18	Apr-30	247.69	247.81	247.71	247.65	247.66	247.73	247.68	247.68	247.83	247.78
19	May-7	247.67	247.70	247.77	247.66	247.65	247.70	247.65	247.73	247.69	247.75
20	May-14	247.64	247.63	247.77	247.65	247.77	247.67	247.85	247.66	247.95	247.66
21	May-21	247.64	247.62	247.78	247.65	247.75	247.73	247.82	247.58	247.71	247.62
22	May-28	247.60	247.64	247.74	247.68	247.81	247.67	247.80	247.60	247.71	247.57
23	Jun-4	247.59	247.60	247.71	247.65	247.68	247.62	247.61	247.67	248.23	247.59
24	Jun-11	247.70	247.62	247.74	247.69	247.63	247.57	247.55	247.58	247.65	247.57
25	Jun-18	247.57	247.65	247.71	247.60	247.64	247.56	247.59	247.60	247.62	247.53
26	Jun-25	247.55	247.66	247.62	247.59	247.60	247.53	247.54	247.58	247.59	247.51
27	Jul-2	247.59	247.60	247.66	247.57	247.62	247.51	247.55	247.52	247.57	247.54
28	Jul-9	247.64	247.56	247.61	247.57	247.56	247.51	247.52	247.53	247.58	247.49
29	Jul-16	247.60	247.58	247.60	247.87	247.53	247.52	247.52	247.50	247.57	247.53
30	Jul-23	247.57	247.55	247.57	247.57	247.57	247.35	247.48	247.52	247.52	247.40
31	Jul-30	247.55	247.55	247.57	247.58	247.48	247.50	247.52	247.52	247.50	247.45
32	Aug-6	247.55	247.55	247.56	247.57	247.35	247.52	247.52	247.51	247.39	247.52
33	Aug-13	247.55	247.55	247.58	247.58	247.51	247.51	247.53	247.52	247.44	247.53
34	Aug-20	247.55	247.52	247.58	247.52	247.51	247.50	247.51	247.52	245.79	247.54
35	Aug-27	247.55	247.55	247.58	247.53	247.51	247.50	247.53	247.52	247.53	247.47
36	Sep-3	247.58	247.55	247.50	247.58	247.51	247.50	247.53	247.49	247.43	247.53
37	Sep-10	247.58	247.55	247.58	247.53	247.51	247.52	247.53	247.51	247.52	247.51
38	Sep-17	247.58	247.55	247.52	247.54	247.56	247.54	247.51	247.52	247.52	247.52
39	Sep-24	247.58	247.60	247.58	247.52	247.51	247.52	247.54	247.53	247.54	247.52
40	Oct-1	247.57	247.79	247.56	247.50	247.51	247.52	247.54	247.53	247.44	247.58
41	Oct-8	247.57	248.01	247.59	247.50	247.77	247.34	247.51	247.53	247.55	247.53
42	Oct-15	247.57	247.63	247.57	247.51	247.80	247.59	247.53	247.53	247.55	247.58
43	Oct-22	247.57	247.60	248.36	247.60	247.62	247.50	247.53	247.53	247.57	247.86
44	Oct-29	247.57	248.03	248.04	247.62	247.63	247.82	247.51	247.52	247.87	247.79
45	Nov-5	247.82	247.76	247.98	247.97	247.97	247.78	247.59	247.53	247.98	247.64
46	Nov-12	248.02	248.02	247.71	247.99	247.98	247.65	247.56	247.62	247.88	248.02
47	Nov-19	247.85	247.97	247.74	248.15	247.85	247.65	247.92	247.58	247.65	247.73
48	Nov-26	247.76	247.77	247.66	247.81	247.93	247.63	248.07	247.79	247.83	247.73
49	Dec-3	247.74	247.94	249.38	247.69	247.71	247.57	247.83	248.08	247.85	248.26
50	Dec-10	247.91	247.99	247.71	247.77	247.92	247.68	247.66	248.03	247.77	247.85
51	Dec-17	248.17	247.77	248.29	247.73	248.11	247.64	247.74	247.71	247.74	247.64
52	Dec-24	248.05	247.82	247.80	247.65	247.62	247.60	248.79	247.65	247.62	247.62

Table 6

Diversion from South Fork Reservoir to GNWD

recorded flows — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	0.246	0.222	0.311	0.199	0.266	0.271	0.321	0.347	0.281	0.293
2	JAN 08 - JAN 14	0.229	0.222	0.326	0.194	0.255	0.265	0.335	0.326	0.276	0.309
3	JAN 15 - JAN 21	0.217	0.219	0.327	0.201	0.243	0.288	0.275	0.346	0.274	0.306
4	JAN 22 - JAN 28	0.239	0.214	0.303	0.204	0.237	0.2[illegible]8	0.257	0.333	0.277	0.307
5	JAN 29 - FEB 04	0.235	0.219	0.313	0.208	0.302	0.229	0.277	0.281	0.278	0.284
6	FEB 05 - FEB 11	0.250	0.230	0.323	0.214	0.288	0.239	0.291	0.279	0.278	0.32
7	FEB 12 - FEB 18	0.246	0.216	0.308	0.186	0.290	0.268	0.277	0.282	0.276	0.32
8	FEB 19 - FEB 25	0.223	0.208	0.305	0.194	0.287	0.257	0.306	0.280	0.283	0.31
9	FEB 26 - MAR 04	0.208	0.221	0.310	0.199	0.293	0.253	0.284	0.291	0.270	0.32
10	MAR 05 - MAR 11	0.201	0.227	0.315	0.169	0.301	0.253	0.238	0.292	0.273	0.30
11	MAR 12 - MAR 18	0.203	0.234	0.320	0.193	0.259	0.269	0.222	0.311	0.274	0.30
12	MAR 19 - MAR 25	0.220	0.240	0.323	0.205	0.353	0.278	0.223	0.300	0.274	0.29
13	MAR 26 - APR 01	0.207	0.229	0.317	0.223	0.351	0.268	0.213	0.304	0.289	0.28
14	APR 02 - APR 08	0.348	0.230	0.309	0.204	0.414	0.273	0.241	0.301	0.288	0.28
15	APR 09 - APR 15	0.314	0.288	0.322	0.191	0.502	0.276	0.228	0.288	0.304	0.31
16	APR 16 - APR 22	0.342	0.313	0.334	0.254	0.390	0.293	0.204	0.294	0.334	0.29
17	APR 23 - APR 29	0.399	0.315	0.324	0.253	0.319	0.345	0.213	0.359	0.325	0.31
18	APR 30 - MAY 06	0.276	0.315	0.323	0.260	0.320	0.333	0.165	0.325	0.330	0.40
19	MAY 07 - MAY 13	0.265	0.340	0.333	0.258	0.535	0.353	0.260	0.425	0.376	0.40
20	MAY 14 - MAY 20	0.295	0.327	0.334	0.274	0.247	0.344	0.266	0.408	0.349	0.38
21	MAY 21 - MAY 27	0.277	0.330	0.313	0.247	0.221	0.392	0.270	0.507	0.352	0.27
22	MAY 28 - JUN 03	0.267	0.344	0.277	0.406	0.244	0.398	0.373	0.364	0.340	0.4
23	JUN 04 - JUN 10	0.303	0.340	0.398	0.398	0.249	0.414	0.377	0.504	0.340	0.6
24	JUN 11 - JUN 17	0.343	0.350	0.498	0.287	0.307	0.434	0.417	0.486	0.443	0.5
25	JUN 18 - JUN 24	0.262	0.361	0.549	0.271	0.351	0.584	0.278	0.489	0.479	0.4
26	JUN 25 - JUL 01	0.307	0.346	0.349	0.311	0.323	0.589	0.394	0.749	0.537	0.5
27	JUL 02 - JUL 08	0.375	0.376	0.284	0.293	0.342	0.651	0.368	0.477	0.448	0.5
28	JUL 09 - JUL 15	0.314	0.380	0.342	0.264	0.487	0.649	0.351	0.427	0.503	0.5
29	JUL 16 - JUL 22	0.405	0.440	0.297	0.318	0.563	0.639	0.352	0.623	0.621	0.4
30	JUL 23 - JUL 29	0.441	0.448	0.419	0.323	0.537	0.713	0.476	0.490	0.732	0.6
31	JUL 30 - AUG 05	0.449	0.436	0.331	0.262	0.559	0.524	0.487	0.556	0.686	0.4
32	AUG 06 - AUG 12	0.473	0.577	0.342	0.467	0.415	0.447	0.610	0.677	0.552	0.5
33	AUG 13 - AUG 19	0.350	0.519	0.316	0.416	0.431	0.604	0.573	0.496	0.532	0.3
34	AUG 20 - AUG 26	0.324	0.422	0.459	0.387	0.432	0.544	0.607	0.614	0.501	0.3
35	AUG 27 - SEP 02	0.266	0.392	0.340	0.325	0.378	0.469	0.488	0.577	0.529	0.4
36	SEP 03 - SEP 09	0.271	0.374	0.304	0.333	0.335	0.390	0.470	0.536	0.585	0.4
37	SEP 10 - SEP 16	0.332	0.393	0.279	0.343	0.310	0.344	0.266	0.417	0.516	0.5
38	SEP 17 - SEP 23	0.278	0.374	0.327	0.411	0.317	0.339	0.269	0.415	0.391	0.4
39	SEP 24 - SEP 30	0.259	0.345	0.348	0.423	0.278	0.350	0.254	0.386	0.324	0.4
40	OCT 01 - OCT 07	0.278	0.323	0.354	0.389	0.283	0.329	0.245	0.395	0.347	0.3
41	OCT 08 - OCT 14	0.250	0.327	0.344	0.375	0.246	0.367	0.259	0.385	0.327	0.3
42	OCT 15 - OCT 21	0.249	0.340	0.356	0.286	0.235	0.340	0.230	0.362	0.317	0.3
43	OCT 22 - OCT 28	0.232	0.349	0.323	0.251	0.260	0.137	0.227	0.296	0.308	0.3
44	OCT 29 - NOV 04	0.210	0.307	0.228	0.263	0.298	0.148	0.208	0.270	0.312	0.3
45	NOV 05 - NOV 11	0.290	0.384	0.218	0.291	0.256	0.142	0.236	0.271	0.307	0.3
46	NOV 12 - NOV 18	0.214	0.334	0.214	0.270	0.261	0.141	0.237	0.281	0.304	0.
47	NOV 19 - NOV 25	0.222	0.328	0.211	0.234	0.268	0.131	0.248	0.274	0.303	0.
48	NOV 26 - DEC 02	0.225	0.329	0.204	0.238	0.221	0.143	0.275	0.274	0.303	0.
49	DEC 03 - DEC 09	0.237	0.397	0.201	0.249	0.322	0.151	0.267	0.274	0.303	0.
50	DEC 10 - DEC 16	0.224	0.317	0.204	0.250	0.299	0.144	0.266	0.275	0.301	0.
51	DEC 17 - DEC 23	0.207	0.315	0.174	0.270	0.287	0.146	0.250	0.288	0.307	0.
52	DEC 24 - DEC 31	0.056	0.318	0.196	0.299	0.277	0.140	0.247	0.248	0.297	0

Table 7

Diversion from Nanaimo River to Harmac

recorded flows — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	2.21	2.58	3.05	1.86	0.00	1.71	1.74	2.43	2.59	2.50
2	JAN 08 - JAN 14	2.21	2.32	2.50	2.01	2.08	2.69	2.40	2.31	2.69	2.72
3	JAN 15 - JAN 21	2.21	2.69	2.58	2.22	2.38	2.43	2.44	2.53	2.55	0.00
4	JAN 22 - JAN 28	2.29	2.73	2.38	2.18	2.32	2.39	2.57	2.58	2.52	0.00
5	JAN 29 - FEB 04	2.29	2.82	2.44	2.13		2.32	2.51	2.65	2.55	0.00
6	FEB 05 - FEB 11	2.29	2.75	2.36	2.05		2.44	2.52	2.54	2.54	0.00
7	FEB 12 - FEB 18	2.21	2.72	2.32	2.05		2.47	2.56	2.55	2.58	2.58
8	FEB 19 - FEB 25	2.21	2.40	2.13	1.99		2.69	2.74	2.44	2.69	2.58
9	FEB 26 - MAR 04	2.21	2.50	2.24	2.00		2.80	2.47	2.52	2.74	2.47
10	MAR 05 - MAR 11	2.29	2.65	2.31	1.91		2.37	2.46	2.49	2.83	2.59
11	MAR 12 - MAR 18	2.29	2.66	1.92	2.09		0.54	1.88	2.65	2.61	2.64
12	MAR 19 - MAR 25	2.29	2.71	1.94	2.22		0.59	1.03	2.58	2.62	2.64
13	MAR 26 - APR 01	2.21	2.68	2.01	2.32		2.37	0.62	2.57	2.65	2.61
14	APR 02 - APR 08	2.21	2.20	2.63	2.19		1.91	2.60	0.00	2.67	0.00
15	APR 09 - APR 15	2.21	2.28	2.17	1.96	0.00	1.20	2.52	0.00	2.54	2.65
16	APR 16 - APR 22	2.29	2.89	2.93	1.97	2.39	2.47	2.41	0.00	2.60	2.50
17	APR 23 - APR 29	2.29	2.40	2.94	2.10	2.24	2.62	2.55	0.00	2.65	2.68
18	APR 30 - MAY 06	2.29	2.81	2.87	2.12	2.01	2.81	2.26	2.52	2.61	2.73
19	MAY 07 - MAY 13	2.21	2.50	2.86	2.12	2.44	2.74	2.38	2.50	2.71	2.68
20	MAY 14 - MAY 20	2.21	2.54	2.63	2.08	2.68	2.77	2.46	2.82	2.12	2.79
21	MAY 21 - MAY 27	2.21	2.80	2.65	2.13	2.78	2.87	2.38	2.86	2.75	2.56
22	MAY 28 - JUN 03	2.29	2.98	2.59	2.08	2.87	2.83	2.63	2.31	2.80	2.69
23	JUN 04 - JUN 10	2.29	2.90	2.09	2.39	2.48	2.97	2.62	2.75	2.75	2.83
24	JUN 11 - JUN 17	2.29	2.79	2.65	2.75	2.73	2.90	2.59	2.64	2.73	2.83
25	JUN 18 - JUN 24	2.21	2.90	2.73	2.80	2.95	2.95	2.66	2.76	2.75	2.83
26	JUN 25 - JUL 01	2.21		2.46	2.78	2.83	2.60	2.60	3.04	2.85	2.78
27	JUL 02 - JUL 08	2.21			2.79	1.98	2.29	2.54	2.81	2.94	2.85
28	JUL 09 - JUL 15	2.29			2.98	3.05	2.92	2.39	2.88	3.02	2.84
29	JUL 16 - JUL 22	2.29		3.01	2.82	3.07	2.97	2.60	2.93	3.09	2.86
30	JUL 23 - JUL 29	2.29		2.90	2.73	3.01	2.86	2.85	2.82	3.09	2.87
31	JUL 30 - AUG 05	2.21		3.05	2.70	3.06	2.88	2.82	2.73	3.09	3.06
32	AUG 06 - AUG 12	2.21		2.92	2.77	3.11	2.98	2.88	2.98	3.13	2.99
33	AUG 13 - AUG 19	2.21			2.84	3.00	2.91	2.83	2.93	2.44	3.05
34	AUG 20 - AUG 26	2.29			2.82	3.02	2.94	2.86	2.73	1.18	2.73
35	AUG 27 - SEP 02	2.29			2.90	2.96	1.00	2.36	2.84	0.63	2.83
36	SEP 03 - SEP 09	2.29	2.07			2.85	2.01	1.65	2.57	0.57	2.91
37	SEP 10 - SEP 16	2.21	2.73	2.44		3.01	2.82	1.64	3.09	1.82	2.89
38	SEP 17 - SEP 23	2.21	2.58	2.77		2.79	2.78	2.38	2.90	2.63	2.60
39	SEP 24 - SEP 30	2.21	1.87	2.73		2.78	2.72	2.62	1.95	2.83	2.84
40	OCT 01 - OCT 07	2.29	2.19	2.67		2.48	2.77	2.71	0.92	2.65	2.83
41	OCT 08 - OCT 14	2.29	2.61	2.62		2.14	2.49	2.50	2.79	2.72	2.87
42	OCT 15 - OCT 21	2.29	2.82			2.16	2.53	2.46	2.72	2.78	0.77
43	OCT 22 - OCT 28	2.21	2.31			2.45	1.94	2.40	2.83	2.72	2.38
44	OCT 29 - NOV 04	2.21	2.62			2.51	2.63	2.25	2.86	2.50	2.67
45	NOV 05 - NOV 11	2.21	2.95			2.41	2.15	1.96	2.81	2.61	2.86
46	NOV 12 - NOV 18	2.29	3.01			2.54	2.64	1.78	2.89	2.44	2.89
47	NOV 19 - NOV 25	2.29	2.56	2.39	1.91	2.64	2.63	1.71	2.67	2.56	2.89
48	NOV 26 - DEC 02	2.29	1.85	2.65	2.07	2.70	2.38	1.44	2.61	2.48	2.89
49	DEC 03 - DEC 09	2.21	2.22	2.15	2.15	2.65	2.39	1.64	2.53	2.33	2.74
50	DEC 10 - DEC 16	2.21	2.82	2.17	2.33	2.66	2.31	2.15	2.46	2.51	2.81
51	DEC 17 - DEC 23	2.21	3.11	2.00	2.42	2.68	2.27	2.68	2.17	2.56	2.80
52	DEC 24 - DEC 31	2.29	2.30		1.87		1.06	1.25	1.62	1.27	1.60

Table 8

Precipitation at Cowichan Lake Forestry station

7 day totals in mm

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	29	3	31	149	163	10	84	100	28	55
2	JAN 08 - JAN 14	127	25	12	96	16	8	83	76	185	75
3	JAN 15 - JAN 21	2	116	55	31	31	12	179	12	46	97
4	JAN 22 - JAN 28	0	26	131	103	45	1	80	166	98	13
5	JAN 29 - FEB 04	142	1	26	2	0	8	72	95	30	36
6	FEB 05 - FEB 11	28	5	34	245	123	112	3	46	74	0
7	FEB 12 - FEB 18	37	270	224	158	41	27	42	53	20	40
8	FEB 19 - FEB 25	76	29	124	173	86	10	205	6	1	72
9	FEB 26 - MAR 04	137	6	79	16	73	17	8	171	92	37
10	MAR 05 - MAR 11	17	11	12	166	11	1	80	56	12	104
11	MAR 12 - MAR 18	101	13	13	81	71	1	15	43	59	33
12	MAR 19 - MAR 25	21	38	10	13	79	104	103	5	112	29
13	MAR 26 - APR 01	21	62	42	143	10	46	55	0	88	108
14	APR 02 - APR 08	41	56	15	24	48	5	4	56	61	67
15	APR 09 - APR 15	55	78	104	12	89	30	22	86	3	[illegible]
16	APR 16 - APR 22	58	33	20	0	11	38	12	9	0	24
17	APR 23 - APR 29	7	49	22	28	15	54	49	3	68	0
18	APR 30 - MAY 06	8	39	17	13	31	31	28	38	4	[illegible]
19	MAY 07 - MAY 13	6	5	7	37	51	20	58	37	46	[illegible]
20	MAY 14 - MAY 20	20	12	1	17	88	0	33	0	16	12
21	MAY 21 - MAY 27	17	32	2	0	48	6	59	7	50	25
22	MAY 28 - JUN 03	11	8	3	1	2	9	0	67	45	[illegible]
23	JUN 04 - JUN 10	37	39	5	33	14	14	0	0	5	[illegible]
24	JUN 11 - JUN 17	6	20	0	34	0	12	30	18	1	24
25	JUN 18 - JUN 24	5	35	0	30	4	15	11	19	4	14
26	JUN 25 - JUL 01	28	3	46	21	15	1	14	0	25	3
27	JUL 02 - JUL 08	35	0	0	5	4	0	6	14	2	[illegible]
28	JUL 09 - JUL 15	7	8	83	70	0	0	12	0	11	7
29	JUL 16 - JUL 22	11	0	0	4	0	0	1	0	0	[illegible]
30	JUL 23 - JUL 29	0	1	4	8	13	0	0	12	0	[illegible]
31	JUL 30 - AUG 05	0	0	6	2	0	2	0	0	0	[illegible]
32	AUG 06 - AUG 12	0	0	14	0	7	15	0	6	10	0
33	AUG 13 - AUG 19	4	0	0	0	2	0	0	4	9	20
34	AUG 20 - AUG 26	0	28	0	0	0	0	0	0	0	2
35	AUG 27 - SEP 02	20	32	10	58	10	7	1	4	0	[illegible]
36	SEP 03 - SEP 09	22	2	28	25	23	8	0	0	1	0
37	SEP 10 - SEP 16	0	0	15	60	25	48	29	55	92	[illegible]
38	SEP 17 - SEP 23	15	39	2	8	5	0	28	0	64	[illegible]
39	SEP 24 - SEP 30	40	34	5	3	0	1	34	0	0	1
40	OCT 01 - OCT 07	0	65	29	3	32	0	0	4	26	8
41	OCT 08 - OCT 14	29	20	3	3	281	52	0	0	100	65
42	OCT 15 - OCT 21	6	0	90	61	1	143	0	0	34	10
43	OCT 22 - OCT 28	1	101	201	21	40	87	93	3	136	13
44	OCT 29 - NOV 04	162	136	65	136	160	73	81	51	195	39
45	NOV 05 - NOV 11	148	90	53	189	74	28	13	123	165	[illegible]
46	NOV 12 - NOV 18	33	95	48	329	54	28	132	79	232	[illegible]
47	NOV 19 - NOV 25	121	134	11	113	91	21	194	179	82	[illegible]
48	NOV 26 - DEC 02	133	84	206	33	102	45	108	257	50	102
49	DEC 03 - DEC 09	20	214	11	70	65	73	3	201	61	15
50	DEC 10 - DEC 16	133	45	242	65	103	4	144	67	34	[illegible]
51	DEC 17 - DEC 23	76	90	142	1	18	0	208	27	32	[illegible]
52	DEC 24 - DEC 31	221	16	33	32	21	27	128	19	76	28

Table 9

Evaporation at Saanichton CDA

7 day totals in mm (includes some estimates)

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	4	4	4	4	4	4	4	4	4	4
2	JAN 08 - JAN 14	4	4	4	4	4	4	4	4	4	4
3	JAN 15 - JAN 21	4	4	4	4	4	4	4	4	4	4
4	JAN 22 - JAN 28	4	4	4	4	4	4	4	4	4	4
5	JAN 29 - FEB 04	4	4	4	4	4	4	4	4	4	4
6	FEB 05 - FEB 11	4	4	4	4	4	4	4	4	4	4
7	FEB 12 - FEB 18	4	4	4	4	4	4	4	4	4	4
8	FEB 19 - FEB 25	4	4	4	4	4	4	4	4	4	4
9	FEB 26 - MAR 04	4	4	4	4	4	4	4	4	4	4
10	MAR 05 - MAR 11	4	4	4	4	4	4	4	4	4	4
11	MAR 12 - MAR 18	5	5	5	5	5	5	5	5	5	5
12	MAR 19 - MAR 25	10	10	10	10	10	10	10	10	10	10
13	MAR 26 - APR 01	10	10	10	10	10	10	10	10	10	10
14	APR 02 - APR 08	14	10	11	11	12	9	11	11	12	10
15	APR 09 - APR 15	12	12	15	13	10	11	12	12	14	11
16	APR 16 - APR 22	11	15	20	13	16	16	13	13	14	11
17	APR 23 - APR 29	19	12	20	16	19	12	15	15	17	14
18	APR 30 - MAY 06	22	14	17	17	15	16	15	17	17	17
19	MAY 07 - MAY 13	20	16	20	18	20	19	16	19	18	20
20	MAY 14 - MAY 20	16	15	19	20	14	28	17	21	19	22
21	MAY 21 - MAY 27	13	20	26	28	16	19	17	20	19	22
22	MAY 28 - JUN 03	16	25	29	26	24	24	21	24	23	25
23	JUN 04 - JUN 10	11	14	22	23	14	23	20	23	23	23
24	JUN 11 - JUN 17	22	20	30	19	27	22	20	23	22	22
25	JUN 18 - JUN 24	21	16	34	21	23	34	23	28	25	25
26	JUN 25 - JUL 01	13	25	20	21	20	28	21	24	23	23
27	JUL 02 - JUL 08	18	28	18	25	21	31	23	24	27	19
28	JUL 09 - JUL 15	20	22	24	15	27	34	22	23	26	19
29	JUL 16 - JUL 22	19	22	21	21	32	34	25	28	29	21
30	JUL 23 - JUL 29	28	26	30	23	32	35	26	27	30	22
31	JUL 30 - AUG 05	22	26	18	27	30	22	27	28	29	19
32	AUG 06 - AUG 12	27	36	17	24	23	23	30	28	29	18
33	AUG 13 - AUG 19	18	29	22	27	22	31	26	24	25	16
34	AUG 20 - AUG 26	19	22	24	23	25	23	24	22	23	14
35	AUG 27 - SEP 02	13	17	16	13	22	21	20	19	20	13
36	SEP 03 - SEP 09	13	18	16	14	15	18	17	18	17	16
37	SEP 10 - SEP 16	20	23	21	17	19	21	24	26	24	22
38	SEP 17 - SEP 23	5	6	7	10	7	6	8	9	8	8
39	SEP 24 - SEP 30	9	13	12	16	20	17	16	18	17	15
40	OCT 01 - OCT 07	7	3	6	4	5	5	5	7	4	4
41	OCT 08 - OCT 14	10	11	12	8	9	11	8	11	6	6
42	OCT 15 - OCT 21	5	4	6	4	6	7	5	7	4	4
43	OCT 22 - OCT 28	8	5	3	5	4	15	5	6	3	4
44	OCT 29 - NOV 04	5	6	5	4	7	10	5	6	4	4
45	NOV 05 - NOV 11	5	1	4	3	5	5	3	3	3	3
46	NOV 12 - NOV 18	2	6	3	6	2	4	4	4	4	4
47	NOV 19 - NOV 25	2	4	4	8	4	3	3	3	3	3
48	NOV 26 - DEC 02	5	4	3	3	5	3	3	3	3	3
49	DEC 03 - DEC 09	3	3	3	3	3	3	3	3	3	3
50	DEC 10 - DEC 16	7	7	6	7	7	7	7	7	7	7
51	DEC 17 - DEC 23	3	3	3	3	3	3	3	3	3	3
52	DEC 24 - DEC 31	1	2	2	2	1	2	2	2	1	2

Table 10

Natural Flow at Node 6

Fourth Lake reservoir

Calculated natural flow — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	5.17	3.87	1.47	2.83	9.92	16.68	3.07	3.01	3.57	2.12
2	JAN 08 - JAN 14	5.49	2.58	3.41	8.09	7.88	16.68	4.42	1.34	3.10	1.91
3	JAN 15 - JAN 21	5.51	3.12	6.02	7.27	7.69	16.68	5.39	1.34	0.37	1.71
4	JAN 22 - JAN 28	5.26	1.36	6.02	9.41	7.44	16.68	2.81	1.30	0.83	1.51
5	JAN 29 - FEB 04	1.70	0.80	5.83	1.79	7.20	16.18	1.86	1.19	1.50	1.40
6	FEB 05 - FEB 11	4.03	9.58	4.70	1.33	6.96	15.14	2.11	1.08	2.19	1.6
7	FEB 12 - FEB 18	12.01	26.56	4.70	8.03	6.71	14.12	2.91	0.98	2.13	1.84
8	FEB 19 - FEB 25	23.08	25.36	4.23	2.07	6.48	13.12	3.80	0.77	1.92	2.10
9	FEB 26 - MAR 04	24.02	4.94	3.68	3.63	6.24	12.15	4.77	0.71	2.09	2.3
10	MAR 05 - MAR 11	12.88	0.81	3.61	6.25	6.01	11.21	5.82	1.09	2.35	2.3
11	MAR 12 - MAR 18	4.34	0.41	3.71	1.64	5.78	10.29	6.17	0.95	2.35	2.35
12	MAR 19 - MAR 25	1.79	0.77	3.80	0.66	5.56	9.40	5.75	0.97	2.35	2.35
13	MAR 26 - APR 01	2.72	1.34	3.90	0.73	5.33	8.54	5.34	0.89	2.37	2.3
14	APR 02 - APR 08	3.79	1.34	4.00	0.87	5.12	7.70	4.94	1.53	2.77	2.3
15	APR 09 - APR 15	4.35	2.30	4.10	0.75	3.98	6.77	4.55	3.84	3.32	1.94
16	APR 16 - APR 22	2.31	5.27	4.20	0.60	1.99	5.65	4.18	4.61	3.53	1.82
17	APR 23 - APR 29	0.94	6.55	4.31	0.57	1.58	4.61	3.81	4.19	3.53	1.8
18	APR 30 - MAY 06	0.82	3.89	4.41	0.57	1.62	3.64	3.38	3.79	3.55	1.7
19	MAY 07 - MAY 13	0.75	1.77	4.51	0.57	2.38	2.75	2.79	3.08	4.28	1.12
20	MAY 14 - MAY 20	0.67	1.09	4.62	0.57	2.78	2.22	2.37	1.83	4.88	1.09
21	MAY 21 - MAY 27	0.60	1.17	4.72	0.57	2.46	1.98	2.35	1.98	4.88	1.2
22	MAY 28 - JUN 03	0.55	1.86	4.83	0.57	2.14	1.75	2.30	2.35	4.87	1.3
23	JUN 04 - JUN 10	0.50	2.37	4.87	0.57	1.83	1.53	1.64	2.78	4.11	1.19
24	JUN 11 - JUN 17	0.46	3.89	4.17	0.57	1.54	1.36	1.91	2.69	3.53	1.02
25	JUN 18 - JUN 24	0.40	4.10	3.14	0.57	1.35	1.10	1.55	1.90	3.10	0.8
26	JUN 25 - JUL 01	0.33	2.21	2.21	0.57	1.34	0.46	1.09	1.47	2.47	0.6
27	JUL 02 - JUL 08	0.29	1.95	1.40	0.62	1.34	0.53	1.33	0.84	1.97	0.61
28	JUL 09 - JUL 15	0.29	1.71	0.74	0.79	1.04	0.63	1.29	0.30	1.64	0.87
29	JUL 16 - JUL 22	0.42	1.48	0.68	0.83	0.81	0.21	0.68	0.01	1.48	0.
30	JUL 23 - JUL 29	0.11	1.26	0.13	0.60	0.53	-0.10	0.35	0.51	1.52	0.
31	JUL 30 - AUG 05	-0.02	1.05	0.41	0.48	0.58	-0.66	0.12	0.71	-0.01	0.24
32	AUG 06 - AUG 12	-0.13	-0.86	0.88	0.38	0.58	1.00	0.19	0.02	0.54	-0.58
33	AUG 13 - AUG 19	-0.06	0.68	-0.30	0.45	0.28	0.07	0.11	0.26	0.19	0.
34	AUG 20 - AUG 26	-0.28	-2.09	-0.10	0.62	-0.17	0.51	-0.02	0.57	0.21	0.
35	AUG 27 - SEP 02	-0.34	-3.24	0.08	0.62	0.08	-0.16	-1.06	-0.41	0.66	-0.22
36	SEP 03 - SEP 09	-0.50	-0.69	1.59	1.52	0.31	-0.18	0.08	-0.73	0.09	-1.42
37	SEP 10 - SEP 16	-0.11	1.16	-0.37	0.63	2.08	0.46	0.18	-0.52	0.63	-0.
38	SEP 17 - SEP 23	1.04	1.98	0.13	-0.54	1.92	0.38	-0.82	0.01	0.63	-0.
39	SEP 24 - SEP 30	2.05	3.96	-0.03	-0.65	0.74	1.26	0.07	0.15	-1.51	1.75
40	OCT 01 - OCT 07	1.74	7.08	1.79	-0.57	7.98	-0.10	1.09	0.58	1.10	-2.08
41	OCT 08 - OCT 14	0.54	1.57	6.89	1.84	13.06	1.41	0.98	0.28	0.76	1.
42	OCT 15 - OCT 21	1.10	1.57	10.22	1.84	4.66	12.96	1.13	-0.20	2.84	7.
43	OCT 22 - OCT 28	1.87	1.57	10.57	4.30	3.44	7.43	2.83	-0.48	2.84	8.53
44	OCT 29 - NOV 04	12.08	1.57	10.57	7.82	3.44	4.96	1.72	0.90	7.27	2.82
45	NOV 05 - NOV 11	12.63	1.57	5.34	14.16	3.44	2.94	0.98	2.15	9.49	5.
46	NOV 12 - NOV 18	5.90	1.57	1.42	28.73	4.16	1.70	9.49	3.20	9.28	5
47	NOV 19 - NOV 25	6.04	1.57	2.33	7.62	15.09	1.40	11.86	6.61	7.71	6.08
48	NOV 26 - DEC 02	6.09	4.47	4.60	2.24	16.68	1.40	5.10	6.14	2.28	9.08
49	DEC 03 - DEC 09	4.05	7.07	3.12	2.82	16.68	1.40	5.10	12.78	0.50	6.
50	DEC 10 - DEC 16	12.35	-0.13	1.86	3.73	16.68	1.40	4.72	5.06	0.62	2
51	DEC 17 - DEC 23	13.55	-1.05	2.66	4.72	16.68	1.40	4.57	3.75	1.47	0.97
52	DEC 24 - DEC 31	12.62	-1.41	1.93	2.94	16.68	1.59	5.33	4.22	3.51	1.00

Table 11

Natural Flow at Node 5 — Jump Lake reservoir

Calculated natural flow — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	6.69	3.26	0.77	7.70	23.50	0.69	3.84	10.77	0.70	8.99
2	JAN 08 - JAN 14	8.98	2.59	3.08	21.14	7.20	1.70	13.95	16.42	10.99	3.73
3	JAN 15 - JAN 21	8.11	8.84	7.62	7.02	1.86	3.18	26.33	2.39	5.91	9.84
4	JAN 22 - JAN 28	7.64	6.67	14.49	12.76	7.38	2.46	6.52	8.66	5.81	4.00
5	JAN 29 - FEB 04	5.98	1.52	7.89	3.56	4.02	1.18	8.06	16.22	3.89	7.45
6	FEB 05 - FEB 11	5.56	2.34	2.60	12.28	7.58	1.21	2.66	14.95	4.10	2.31
7	FEB 12 - FEB 18	12.54	22.34	23.81	29.68	9.66	3.55	1.50	9.64	12.08	0.58
8	FEB 19 - FEB 25	10.11	15.49	11.38	17.35	9.96	3.71	20.60	3.89	2.96	5.66
9	FEB 26 - MAR 04	5.54	3.17	9.66	3.75	5.31	2.94	7.85	11.19	3.71	2.30
10	MAR 05 - MAR 11	7.09	1.67	3.55	17.18	4.62	1.52	8.66	16.20	5.03	5.41
11	MAR 12 - MAR 18	4.43	1.52	2.30	10.36	5.09	1.51	3.49	6.47	2.64	6.47
12	MAR 19 - MAR 25	4.54	2.17	0.96	2.69	12.67	2.43	5.23	2.35	8.33	4.04
13	MAR 26 - APR 01	5.38	5.66	2.75	4.44	5.22	4.54	13.50	1.31	5.62	5.33
14	APR 02 - APR 08	5.40	6.45	2.90	5.08	2.83	6.67	2.01	2.86	10.75	9.05
15	APR 09 - APR 15	5.04	4.19	4.09	1.75	5.00	8.93	1.52	6.54	5.86	7.52
16	APR 16 - APR 22	5.03	8.39	4.41	1.99	5.86	2.98	2.42	4.74	6.70	7.81
17	APR 23 - APR 29	4.44	10.55	4.51	2.65	3.63	4.22	2.45	2.07	4.63	5.30
18	APR 30 - MAY 06	3.06	6.57	4.38	2.49	3.42	3.98	3.00	4.22	4.63	6.04
19	MAY 07 - MAY 13	2.54	3.00	5.92	2.56	4.93	2.74	4.67	3.38	5.12	3.50
20	MAY 14 - MAY 20	2.01	2.09	5.30	2.37	6.02	4.57	5.36	2.20	6.89	2.20
21	MAY 21 - MAY 27	2.02	2.47	5.84	2.84	9.22	3.56	7.36	1.46	4.27	1.91
22	MAY 28 - JUN 03	1.76	1.69	4.87	2.26	5.24	2.39	2.99	5.97	7.64	2.24
23	JUN 04 - JUN 10	2.11	2.38	3.64	1.95	2.77	1.76	1.29	1.99	7.38	1.60
24	JUN 11 - JUN 17	2.32	1.98	4.35	1.75	2.79	1.28	1.33	2.59	2.55	1.03
25	JUN 18 - JUN 24	1.34	3.84	3.06	1.49	1.95	1.11	1.35	1.85	2.17	0.86
26	JUN 25 - JUL 01	1.41	1.80	3.06	1.21	2.18	0.63	0.83	1.15	1.28	0.91
27	JUL 02 - JUL 08	2.67	0.83	2.29	1.03	1.68	0.63	0.73	0.88	1.38	1.25
28	JUL 09 - JUL 15	1.56	0.50	0.95	6.30	0.94	0.34	0.71	0.46	1.17	0.44
29	JUL 16 - JUL 22	0.54	0.56	0.94	1.67	0.67	0.24	0.41	0.01	0.88	0.33
30	JUL 23 - JUL 29	0.47	0.44	0.69	0.87	0.55	0.12	0.24	0.21	0.47	0.14
31	JUL 30 - AUG 05	0.72	0.27	0.48	0.48	0.35	0.10	0.17	-0.13	0.22	0.29
32	AUG 06 - AUG 12	0.79	0.26	0.43	0.38	0.31	0.11	-0.03	0.05	0.24	0.12
33	AUG 13 - AUG 19	0.26	0.22	0.49	0.25	0.17	0.07	0.07	0.34	0.26	0.08
34	AUG 20 - AUG 26	0.47	0.06	0.18	0.18	0.15	-0.05	-0.23	0.02	0.15	0.08
35	AUG 27 - SEP 02	0.67	0.54	0.19	0.67	-0.28	0.07	-0.50	0.00	0.07	-0.15
36	SEP 03 - SEP 09	0.49	0.23	0.50	0.61	0.56	0.13	-0.23	-0.07	-0.07	0.21
37	SEP 10 - SEP 16	0.58	0.05	0.48	0.79	0.64	0.28	0.58	-0.08	0.04	0.12
38	SEP 17 - SEP 23	1.02	2.78	0.25	0.50	1.40	0.54	0.06	0.07	0.39	0.16
39	SEP 24 - SEP 30	1.09	5.43	0.04	0.17	0.27	-0.10	0.20	-0.07	1.12	0.20
40	OCT 01 - OCT 07	1.68	10.50	1.32	-0.04	5.20	0.06	0.04	0.07	0.53	0.10
41	OCT 08 - OCT 14	1.23	6.82	0.32	0.20	19.33	1.21	-0.12	0.15	0.25	0.79
42	OCT 15 - OCT 21	1.19	1.62	3.74	1.51	4.59	12.48	0.02	0.15	2.60	4.94
43	OCT 22 - OCT 28	0.61	7.17	32.76	4.13	2.01	10.16	1.68	0.09	0.72	11.28
44	OCT 29 - NOV 04	10.26	22.41	8.44	9.62	10.31	8.31	2.78	0.39	10.43	2.58
45	NOV 05 - NOV 11	22.40	7.11	6.32	14.90	16.87	3.16	0.70	1.65	16.11	13.96
46	NOV 12 - NOV 18	3.97	19.35	3.49	39.53	8.42	2.30	5.32	2.54	5.73	5.93
47	NOV 19 - NOV 25	13.35	15.22	1.88	7.16	7.78	1.14	22.87	10.33	12.58	10.77
48	NOV 26 - DEC 02	11.33	6.88	15.33	4.43	3.85	0.49	9.55	9.61	5.98	11.36
49	DEC 03 - DEC 09	3.61	19.86	10.76	2.94	7.70	9.69	2.87	19.28	6.59	23.54
50	DEC 10 - DEC 16	24.75	8.29	12.75	5.47	11.46	1.16	4.98	7.85	7.62	4.60
51	DEC 17 - DEC 23	7.97	12.22	12.46	1.63	3.14	0.74	15.44	1.41	2.63	2.98
52	DEC 24 - DEC 31	26.65	1.06	2.99	3.05	1.28	1.32	10.89	-0.31	4.63	1.88

Table 12

Natural Flow at Node 4

South Fork reservoir

Calculated natural flow — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	19.18	8.50	4.40	17.88	77.50	1.39	13.40	20.70	2.24	26.5[illegible]
2	JAN 08 - JAN 14	26.67	7.45	6.00	51.25	65.70	2.05	47.57	39.32	10.95	9.[illegible]
3	JAN 15 - JAN 21	16.88	30.92	14.33	18.86	4.03	4.10	39.27	8.66	11.42	20.[illegible]
4	JAN 22 - JAN 28	19.55	20.79	27.68	35.65	18.55	3.52	21.22	27.04	12.84	8.67
5	JAN 29 - FEB 04	14.64	2.98	16.39	10.83	7.75	1.67	21.56	38.42	13.74	18.[illegible]
6	FEB 05 - FEB 11	18.63	5.82	6.03	59.50	20.59	1.57	10.11	47.73	9.35	6.[illegible]
7	FEB 12 - FEB 18	25.03	8.54	33.38	77.90	24.56	8.50	5.25	25.67	26.27	15.[illegible]
8	FEB 19 - FEB 25	35.49	68.55	30.22	51.14	45.93	7.95	86.13	9.99	7.40	12.1[illegible]
9	FEB 26 - MAR 04	21.62	20.88	34.85	13.98	15.71	9.16	26.44	36.80	25.55	11.[illegible]
10	MAR 05 - MAR 11	28.92	2.93	10.42	60.34	11.80	4.31	28.47	46.74	83.80	11.[illegible]
11	MAR 12 - MAR 18	13.91	4.15	5.51	42.91	13.68	4.37	10.81	21.06	6.97	15.[illegible]
12	MAR 19 - MAR 25	15.51	6.99	2.46	9.39	28.89	6.63	14.36	8.82	49.96	12.1[illegible]
13	MAR 26 - APR 01	17.37	11.28	5.74	16.02	13.18	13.92	45.76	4.01	30.90	15[illegible]
14	APR 02 - APR 08	13.83	14.76	7.08	11.71	6.28	25.97	5.53	7.12	17.11	28.[illegible]
15	APR 09 - APR 15	15.41	11.75	13.56	6.65	13.93	26.09	3.95	25.41	16.78	20.[illegible]
16	APR 16 - APR 22	22.83	14.74	11.51	6.91	15.58	9.42	8.24	99.33	15.68	24.0[illegible]
17	APR 23 - APR 29	11.21	21.40	14.31	8.07	8.77	8.49	8.10	6.18	10.56	15[illegible]
18	APR 30 - MAY 06	9.21	13.34	13.46	6.60	8.42	12.03	9.52	11.71	11.41	13[illegible]
19	MAY 07 - MAY 13	6.74	7.32	16.42	7.34	11.49	7.37	7.78	9.41	12.83	8.[illegible]
20	MAY 14 - MAY 20	5.29	5.28	16.14	6.75	11.99	10.51	15.94	6.35	17.39	5.3[illegible]
21	MAY 21 - MAY 27	4.47	7.45	14.63	7.09	14.98	10.30	19.48	3.86	9.52	[illegible]
22	MAY 28 - JUN 03	4.45	4.56	12.75	8.75	13.19	5.77	9.37	8.26	13.83	[illegible]
23	JUN 04 - JUN 10	6.20	5.26	10.12	6.15	7.18	4.29	3.31	5.56	23.27	[illegible]
24	JUN 11 - JUN 17	6.69	4.61	11.29	5.74	7.09	3.17	3.01	5.26	6.84	[illegible]
25	JUN 18 - JUN 24	2.44	8.33	9.03	3.11	4.30	2.50	3.06	4.70	5.40	[illegible]
26	JUN 25 - JUL 01	2.69	4.71	6.54	2.66	4.41	1.17	1.67	2.70	3.41	[illegible]
27	JUL 02 - JUL 08	7.17	2.44	5.97	2.00	3.01	1.17	1.68	1.78	3.48	[illegible]
28	JUL 09 - JUL 15	4.46	1.56	3.19	9.82	1.41	0.77	1.72	1.27	3.09	[illegible]
29	JUL 16 - JUL 22	2.31	1.55	2.35	3.19	1.07	0.43	0.80	0.49	1.99	[illegible]
30	JUL 23 - JUL 29	1.56	1.22	2.04	1.98	1.32	0.31	0.25	0.60	1.11	[illegible]
31	JUL 30 - AUG 05	1.46	1.06	1.87	1.30	-0.03	0.22	0.14	0.13	0.56	[illegible]
32	AUG 06 - AUG 12	1.43	1.19	1.30	1.50	-0.28	0.13	0.19	0.21	0.51	[illegible]
33	AUG 13 - AUG 19	0.71	0.83	1.34	0.73	-0.52	0.09	0.17	0.63	0.61	[illegible]
34	AUG 20 - AUG 26	0.82	0.42	1.23	0.19	-0.53	-0.08	-0.04	0.35	0.47	[illegible]
35	AUG 27 - SEP 02	1.10	1.42	0.59	0.88	-0.84	-0.05	-0.40	0.20	0.25	[illegible]
36	SEP 03 - SEP 09	1.05	1.15	0.43	0.87	0.56	0.07	0.04	0.22	-0.28	[illegible]
37	SEP 10 - SEP 16	1.23	0.98	1.61	0.84	1.47	0.48	1.00	0.33	-0.22	[illegible]
38	SEP 17 - SEP 23	1.62	8.63	0.98	0.72	3.06	0.99	0.16	0.31	0.39	[illegible]
39	SEP 24 - SEP 30	2.54	15.39	1.90	0.52	0.99	0.08	0.24	0.13	1.46	[illegible]
40	OCT 01 - OCT 07	3.62	23.32	3.61	0.22	7.08	0.25	0.22	0.39	0.56	[illegible]
41	OCT 08 - OCT 14	2.76	16.85	3.84	0.49	33.19	2.70	-0.18	0.35	0.78	[illegible]
42	OCT 15 - OCT 21	3.08	4.51	18.39	2.48	9.00	18.82	0.14	0.35	3.35	[illegible]
43	OCT 22 - OCT 28	2.52	16.46	73.18	7.52	4.42	23.00	3.38	0.21	32.59	[illegible]
44	OCT 29 - NOV 04	14.17	26.18	23.73	24.81	10.99	20.41	4.61	0.80	22.49	9.[illegible]
45	NOV 05 - NOV 11	50.86	15.37	17.72	26.19	33.90	8.47	1.69	2.45	28.03	[illegible]
46	NOV 12 - NOV 18	16.20	61.67	6.79	108.93	27.44	4.07	7.91	6.50	14.20	[illegible]
47	NOV 19 - NOV 25	48.75	30.13	4.85	22.04	30.29	3.11	56.31	35.20	33.55	[illegible]
48	NOV 26 - DEC 02	19.29	15.78	41.82	13.93	12.37	0.04	31.37	20.06	16.55	14[illegible]
49	DEC 03 - DEC 09	8.47	27.51	69.47	7.46	20.62	12.06	3.71	43.35	19.67	[illegible]
50	DEC 10 - DEC 16	52.72	20.94	25.86	15.16	48.36	4.90	9.12	18.58	13.78	
51	DEC 17 - DEC 23	33.38	20.62	31.95	6.72	11.71	2.67	82.48	5.06	7.60	[illegible]
52	DEC 24 - DEC 31	30.52	12.50	9.93	7.46	3.17	3.20	106.73	2.09	14.25	[illegible]

Table 13

Natural Flow at Node 2

Calculated natural flow

7 day averages

Nanaimo River near Cassidy stn # 08HB034

in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	56.93	38.87	12.53	45.10	197.02	9.72	19.19	105.83	12.20	71.93
2	JAN 08 - JAN 14	72.79	23.10	16.90	169.74	78.41	10.16	144.96	137.14	43.65	31.09
3	JAN 15 - JAN 21	72.86	63.51	43.79	58.86	21.59	26.69	235.06	35.05	91.68	79.50
4	JAN 22 - JAN 28	60.26	71.60	106.44	99.36	55.31	21.35	69.72	51.36	37.90	29.33
5	JAN 29 - FEB 04	52.97	22.67	70.45	37.60	37.19	11.78	70.52	116.74	48.83	60.91
6	FEB 05 - FEB 11	41.96	15.38	29.84	81.43	53.74	9.86	34.38	109.25	26.21	17.56
7	FEB 12 - FEB 18	104.35	174.58	169.66	278.32	77.72	30.08	15.06	96.58	86.09	11.02
8	FEB 19 - FEB 25	87.75	133.67	116.24	160.04	97.54	30.27	146.91	32.38	29.00	43.65
9	FEB 26 - MAR 04	52.70	30.97	81.49	46.24	54.33	28.65	104.75	72.77	27.19	27.91
10	MAR 05 - MAR 11	63.42	16.51	38.33	141.72	38.84	16.91	70.34	160.98	41.77	45.35
11	MAR 12 - MAR 18	44.98	13.77	22.20	109.25	43.95	13.39	39.53	69.30	25.77	67.69
12	MAR 19 - MAR 25	36.82	13.37	14.27	26.57	99.44	20.38	32.72	29.55	58.45	36.61
13	MAR 26 - APR 01	43.94	30.08	21.69	38.22	40.99	29.13	122.08	15.57	53.98	43.70
14	APR 02 - APR 08	42.78	43.65	21.92	39.93	20.20	62.01	22.47	21.26	81.27	72.30
15	APR 09 - APR 15	41.17	28.79	31.70	18.53	42.86	76.40	14.89	45.59	50.51	61.24
16	APR 16 - APR 22	40.49	45.46	34.37	16.77	53.66	32.58	17.72	50.67	53.36	59.82
17	APR 23 - APR 29	31.61	57.63	36.29	20.44	28.18	30.58	21.33	18.45	30.63	40.97
18	APR 30 - MAY 06	26.50	41.65	32.64	20.23	25.71	33.40	27.75	34.75	40.34	41.99
19	MAY 07 - MAY 13	22.14	23.98	43.60	18.09	34.24	23.75	30.38	31.84	31.78	29.58
20	MAY 14 - MAY 20	17.01	15.47	39.95	18.45	44.57	34.31	47.59	21.73	53.35	16.53
21	MAY 21 - MAY 27	16.99	16.18	41.14	22.25	67.15	30.35	61.53	12.94	32.61	12.54
22	MAY 28 - JUN 03	13.69	13.20	35.03	19.73	46.41	19.44	31.85	43.89	48.40	16.93
23	JUN 04 - JUN 10	14.15	15.56	25.04	14.08	23.11	14.53	13.57	19.31	49.25	14.93
24	JUN 11 - JUN 17	17.99	14.35	32.17	19.48	21.24	12.02	10.67	23.77	21.64	9.81
25	JUN 18 - JUN 24	10.69	23.48	23.99	13.62	16.35	9.86	12.44	14.31	18.13	7.77
26	JUN 25 - JUL 01	12.76	14.71	18.50	11.57	16.27	5.88	7.79	10.66	12.01	6.54
27	JUL 02 - JUL 08	18.51	7.86	15.40	9.24	14.13	3.91	7.37	6.54	10.71	10.68
28	JUL 09 - JUL 15	13.40	5.06	8.94	38.41	9.61	2.82	5.97	4.66	9.52	5.56
29	JUL 16 - JUL 22	7.88	3.79	6.35	16.32	6.86	1.71	4.50	2.05	7.93	4.39
30	JUL 23 - JUL 29	4.48	2.90	3.97	8.23	4.72	1.18	2.28	2.91	5.17	3.18
31	JUL 30 - AUG 05	3.15	3.06	3.20	5.40	3.44	0.43	2.09	1.41	3.19	1.87
32	AUG 06 - AUG 12	2.99	3.47	3.71	2.88	2.58	1.02	1.09	1.66	2.23	1.90
33	AUG 13 - AUG 19	1.95	3.98	3.44	2.29	2.05	1.37	0.86	1.47	2.54	1.69
34	AUG 20 - AUG 26	1.85	2.39	1.75	1.69	1.56	0.44	0.54	1.00	2.23	2.42
35	AUG 27 - SEP 02	1.85	-0.80	1.31	4.13	0.43	1.35	-0.33	0.07	1.72	1.77
36	SEP 03 - SEP 09	2.17	0.38	1.08	4.83	2.44	0.11	-0.23	0.12	0.59	0.04
37	SEP 10 - SEP 16	2.24	2.29	7.28	8.13	3.06	1.87	1.66	-0.23	0.75	0.53
38	SEP 17 - SEP 23	4.61	10.56	-1.39	4.78	11.13	3.80	0.09	2.20	1.68	0.51
39	SEP 24 - SEP 30	5.42	25.74	1.41	3.19	4.38	1.24	1.31	0.30	3.90	1.18
40	OCT 01 - OCT 07	15.09	65.33	3.53	2.48	6.80	1.35	1.61	2.04	3.22	0.56
41	OCT 08 - OCT 14	5.30	53.62	11.76	5.03	156.50	4.63	1.37	0.50	2.22	0.91
42	OCT 15 - OCT 21	5.24	12.87	17.31	7.97	45.34	55.02	1.48	1.67	12.25	15.14
43	OCT 22 - OCT 28	6.21	30.19	227.18	31.80	16.67	82.96	7.81	0.71	10.21	79.15
44	OCT 29 - NOV 04	56.78	186.18	65.34	62.13	52.78	58.25	20.56	2.37	43.65	19.82
45	NOV 05 - NOV 11	167.85	39.57	54.06	119.40	123.89	30.91	7.10	5.53	138.71	75.30
46	NOV 12 - NOV 18	40.47	164.41	20.67	364.43	79.31	16.84	16.07	22.82	59.58	33.90
47	NOV 19 - NOV 25	98.92	127.82	16.81	89.91	67.08	12.35	183.96	57.55	95.67	40.60
48	NOV 26 - DEC 02	95.97	49.52	74.46	55.08	48.83	8.06	87.48	63.37	53.24	37.79
49	DEC 03 - DEC 09	38.34	170.65	120.72	23.75	54.56	55.93	33.86	152.11	54.47	144.11
50	DEC 10 - DEC 16	184.32	76.11	77.01	50.98	88.51	21.22	35.40	94.74	65.78	34.48
51	DEC 17 - DEC 23	73.27	94.79	143.01	22.22	42.00	13.20	120.06	19.76	29.99	15.00
52	DEC 24 - DEC 31	254.79	22.82	35.38	16.08	14.27	13.49	129.36	13.07	28.06	12.68

Table 14a

Natural Local Inflow at Node 3 (excludes flow from Nodes 4 & 6)

Calculated natural flow — 7 day averages — in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	25.74	20.93	5.26	19.26	86.58	-6.60	2.15	64.87	5.05	34.1
2	JAN 08 - JAN 14	32.10	10.33	5.92	87.22	3.82	-6.77	73.44	76.22	23.39	15.3
3	JAN 15 - JAN 21	39.87	23.28	18.51	25.86	7.79	4.67	150.42	19.79	63.12	45.
4	JAN 22 - JAN 28	28.00	39.07	57.46	42.89	23.16	0.91	36.09	18.19	19.13	15.1
5	JAN 29 - FEB 04	26.97	14.92	38.10	19.74	17.57	-4.79	37.21	60.93	26.54	32.4
6	FEB 05 - FEB 11	14.51	-0.02	15.10	16.27	20.69	-5.41	17.51	47.75	11.58	7.
7	FEB 12 - FEB 18	56.69	110.19	103.95	151.99	36.69	5.90	5.45	55.24	45.57	-4.
8	FEB 19 - FEB 25	36.03	31.41	64.61	84.39	35.66	7.27	45.01	17.08	15.56	23.2
9	FEB 26 - MAR 04	20.99	4.07	33.94	22.62	25.58	5.79	58.10	27.86	-0.36	11.8
10	MAR 05 - MAR 11	23.79	10.10	19.20	59.36	16.61	1.09	28.48	89.39	-35.06	24.
11	MAR 12 - MAR 18	21.59	7.27	10.26	51.11	19.34	-1.00	17.82	37.37	13.00	39.
12	MAR 19 - MAR 25	14.06	4.44	6.33	13.05	51.34	3.44	9.96	15.61	4.85	17.5
13	MAR 26 - APR 01	18.28	13.80	9.52	16.96	17.76	5.27	56.06	8.43	16.36	20
14	APR 02 - APR 08	20.18	21.76	8.56	21.60	6.95	22.39	9.48	9.96	48.50	32
15	APR 09 - APR 15	17.58	11.65	11.09	8.79	19.72	34.40	5.04	12.91	24.03	30.
16	APR 16 - APR 22	11.15	20.10	14.74	7.31	28.51	13.83	4.19	-42.08	26.98	26.
17	APR 23 - APR 29	13.40	23.45	13.97	9.32	14.08	13.81	7.44	6.38	13.06	19
18	APR 30 - MAY 06	13.01	19.29	11.67	10.32	12.37	14.01	11.73	15.21	20.06	20
19	MAY 07 - MAY 13	11.58	11.76	17.91	8.04	16.09	10.77	15.65	15.29	11.59	15.
20	MAY 14 - MAY 20	8.73	7.19	15.16	8.80	23.54	17.05	23.13	10.71	24.55	7.
21	MAY 21 - MAY 27	9.42	5.97	17.21	11.52	39.27	14.27	31.37	5.61	14.38	5
22	MAY 28 - JUN 03	6.88	5.36	13.78	8.23	24.56	9.41	15.95	26.30	23.46	7
23	JUN 04 - JUN 10	5.89	6.27	7.94	5.81	11.14	6.89	6.81	8.66	17.28	[illegible]
24	JUN 11 - JUN 17	8.57	4.62	13.20	10.41	9.95	5.92	4.54	12.50	8.91	[illegible]
25	JUN 18 - JUN 24	6.20	8.73	9.34	7.85	8.45	4.94	6.18	6.09	7.81	[illegible]
26	JUN 25 - JUL 01	7.70	6.16	7.70	6.59	8.31	3.37	3.97	5.13	4.84	[illegible]
27	JUL 02 - JUL 08	8.73	2.74	6.34	5.24	7.72	1.74	3.45	3.11	4.16	[illegible]
28	JUL 09 - JUL 15	6.83	1.42	3.96	21.97	5.66	1.12	2.34	2.44	3.79	[illegible]
29	JUL 16 - JUL 22	4.07	0.61	2.62	9.71	3.93	0.85	2.40	1.23	3.52	[illegible]
30	JUL 23 - JUL 29	2.23	0.33	1.42	4.47	2.26	0.76	1.33	1.42	2.01	[illegible]
31	JUL 30 - AUG 05	1.35	0.74	0.73	2.86	2.28	0.68	1.45	0.45	2.09	[illegible]
32	AUG 06 - AUG 12	1.34	1.12	1.21	0.79	1.80	-0.09	0.56	1.13	0.93	[illegible]
33	AUG 13 - AUG 19	1.02	1.95	1.90	0.88	1.82	0.95	0.46	0.46	1.37	[illegible]
34	AUG 20 - AUG 26	1.03	3.21	0.49	0.70	1.79	0.01	0.47	0.06	1.22	[illegible]
35	AUG 27 - SEP 02	0.86	0.80	0.50	2.08	0.94	1.23	0.89	0.23	0.64	[illegible]
36	SEP 03 - SEP 09	1.28	-0.07	-0.73	1.93	1.24	0.18	-0.28	0.50	0.61	[illegible]
37	SEP 10 - SEP 16	0.88	0.11	4.76	5.26	-0.38	0.74	0.38	-0.03	0.27	[illegible]
38	SEP 17 - SEP 23	1.54	-0.03	-1.97	3.64	4.86	1.92	0.59	1.48	0.53	[illegible]
39	SEP 24 - SEP 30	0.66	5.06	-0.37	2.62	2.10	-0.06	0.79	0.01	3.11	[illegible]
40	OCT 01 - OCT 07	7.68	27.61	-1.48	2.24	-8.51	0.96	0.24	0.85	1.23	[illegible]
41	OCT 08 - OCT 14	1.58	27.82	0.82	2.14	87.10	0.41	0.45	-0.06	0.54	[illegible]
42	OCT 15 - OCT 21	0.83	5.37	-8.93	2.89	25.03	18.37	0.17	1.20	4.79	[illegible]
43	OCT 22 - OCT 28	1.44	9.62	113.31	15.78	6.96	41.49	1.26	0.77	-19.92	[illegible]
44	OCT 29 - NOV 04	24.13	125.17	24.51	23.31	30.30	25.97	11.24	0.53	10.97	[illegible]
45	NOV 05 - NOV 11	82.45	17.88	24.49	62.45	68.37	15.40	3.51	0.74	79.94	[illegible]
46	NOV 12 - NOV 18	14.51	79.92	9.85	179.14	37.68	8.74	-1.06	10.37	28.52	[illegible]
47	NOV 19 - NOV 25	34.86	75.94	7.61	47.60	17.14	6.20	91.47	12.43	42.98	[illegible]
48	NOV 26 - DEC 02	55.77	23.12	22.15	30.74	15.62	5.22	40.30	29.37	27.18	[illegible]
49	DEC 03 - DEC 09	20.39	107.50	38.02	10.64	13.63	33.54	19.79	75.83	27.10	[illegible]
50	DEC 10 - DEC 16	94.21	43.69	38.94	25.34	18.54	11.79	17.03	56.17	40.59	[illegible]
51	DEC 17 - DEC 23	20.80	59.42	85.64	8.52	10.75	7.22	26.07	8.65	16.53	[illegible]
52	DEC 24 - DEC 31	167.20	9.27	18.58	4.47	-4.41	6.88	13.67	5.34	8.14	[illegible]

Table 14b

Natural Flow at Node 3

Calculated natural flow | 7 day averages | in cubic metres per second

Period	Dates	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
1	JAN 01 - JAN 07	50.09	33.30	11.13	39.98	174.00	11.48	18.62	88.58	10 86	62.85
2	JAN 08 - JAN 14	64.26	20.36	15.33	146.55	77.40	11.96	125.44	116.88	37 43	27.02
3	JAN 15 - JAN 21	62.26	57.32	38.87	51.99	19.52	25.45	195.08	29.79	74.90	67.43
4	JAN 22 - JAN 28	52.82	61.22	91.17	87.96	49.16	21.11	60.12	46.53	32.81	25.31
5	JAN 29 - FEB 04	45.80	18.70	60.32	32.35	32.52	13.05	60.63	100.54	41.77	52.28
6	FEB 05 - FEB 11	38.10	15.38	25.82	77.11	48.24	11.30	29.73	96.56	23.13	15.66
7	FEB 12 - FEB 18	89.28	145.29	142.03	237.91	67.97	28.52	13.61	81.89	73.98	12.29
8	FEB 19 - FEB 25	78.17	125.32	99.07	137.61	88.06	28.34	134.94	27.84	24.87	37.48
9	FEB 26 - MAR 04	47.12	29.89	72.47	40.23	47.53	27.11	89.31	65.37	27 28	24.89
10	MAR 05 - MAR 11	57.09	13.83	33.23	125.94	34.43	16.62	62.77	137.22	51 09	38.72
11	MAR 12 - MAR 18	39.24	11.83	19.47	95.66	38.80	13.66	34.79	59.37	22.32	57.27
12	MAR 19 - MAR 25	33.08	12.19	12.59	23.10	85.79	19.46	30.07	25.40	57 16	31.96
13	MAR 26 - APR 01	39.08	26.41	19.16	33.71	36.27	27.73	107.17	13.33	49 63	38.28
14	APR 02 - APR 08	37.41	37.87	19.65	34.18	18.35	56.06	19.95	18.61	68 38	63.68
15	APR 09 - APR 15	36.50	25.69	28.75	16.19	37.62	67.28	13.55	42.16	44 13	53.11
16	APR 16 - APR 22	37.53	40.11	30.45	14.82	46.08	28.91	16.61	61.86	46 19	52.70
17	APR 23 - APR 29	28.05	51.39	32.58	17.96	24.43	26.91	19.35	16.75	27 16	35.90
18	APR 30 - MAY 06	23.04	36.53	29.54	17.49	22.42	29.68	24.63	30.70	35 01	38.4
19	MAY 07 - MAY 13	19.07	20.85	38.84	15.95	29.96	20.88	28.22	27.78	28 70	25.3
20	MAY 14 - MAY 20	14.69	13.56	35.92	16.11	38.31	29.78	41.44	18.89	46 82	14.4
21	MAY 21 - MAY 27	14.49	14.60	36.57	19.18	56.71	26.55	53.19	11.45	28.79	11.0
22	MAY 28 - JUN 03	11.87	11.78	31.36	17.54	39.89	16.93	27.61	36.90	42 16	14.8
23	JUN 04 - JUN 10	12.59	13.90	22.93	12.53	20.15	12.70	11.78	17.01	44 66	12.9
24	JUN 11 - JUN 17	15.71	13.12	28.66	16.71	18.59	10.45	9.46	20.45	19 27	8.5
25	JUN 18 - JUN 24	9.04	21.16	21.51	11.53	14.10	8.54	10.80	12.69	16 11	6.7
26	JUN 25 - JUL 01	10.71	13.08	16.45	9.82	14.06	4.99	6.73	9.30	10 72	5.7
27	JUL 02 - JUL 08	16.19	7.13	13.71	7.85	12.07	3.45	6.46	5.71	9 61	9.0
28	JUL 09 - JUL 15	11.58	4.69	7.89	32.57	8.10	2.52	5.35	4.01	8 52	4.8
29	JUL 16 - JUL 22	6.80	3.63	5.65	13.74	5.82	1.48	3.86	1.73	6 99	3.8
30	JUL 23 - JUL 29	3.89	2.81	3.59	7.04	4.12	0.97	1.93	2.53	4 64	2.6
31	JUL 30 - AUG 05	2.79	2.86	3.01	4.64	2.83	0.24	1.71	1.29	2 63	1.7
32	AUG 06 - AUG 12	2.64	3.17	3.39	2.67	2.10	1.04	0.94	1.36	1 98	1.5
33	AUG 13 - AUG 19	1.68	3.46	2.94	2.06	1.56	1.12	0.74	1.35	2 17	1.5
34	AUG 20 - AUG 26	1.57	1.54	1.62	1.51	1.08	0.44	0.41	0.98	1 91	2.1
35	AUG 27 - SEP 02	1.62	-1.02	1.17	3.58	0.18	1.02	-0.57	0.01	1 55	1.4
36	SEP 03 - SEP 09	1.83	0.40	1.28	4.32	2.11	0.07	-0.16	-0.01	0 42	-0.1
37	SEP 10 - SEP 16	2.00	2.26	5.99	6.73	3.16	1.67	1.56	-0.22	0 68	0.4
38	SEP 17 - SEP 23	4.20	10.56	-0.87	3.82	9.84	3.29	-0.06	1.80	1 54	0.4
39	SEP 24 - SEP 30	5.25	24.40	1.51	2.50	3.82	1.26	1.10	0.29	3 07	1.5
40	OCT 01 - OCT 07	13.04	57.99	3.92	1.89	8.53	1.10	1.55	1.82	2 89	0.1
41	OCT 08 - OCT 14	4.88	46.23	11.54	4.46	133.35	4.52	1.25	0.52	2 08	1.3
42	OCT 15 - OCT 21	5.02	11.45	19.68	7.20	38.69	50.14	1.43	1.35	10 97	14.
43	OCT 22 - OCT 28	5.83	27.64	197.06	27.60	14.82	71.92	7.48	0.50	15 51	70.
44	OCT 29 - NOV 04	50.36	152.91	58.82	55.94	44.73	51.34	17.57	2.23	40 73	18.1
45	NOV 05 - NOV 11	145.94	34.81	47.55	102.80	105.71	26.81	6.16	5.34	117 46	67.
46	NOV 12 - NOV 18	36.61	143.16	18.06	316.81	69.29	14.51	16.35	20.07	52 00	30.
47	NOV 19 - NOV 25	89.65	107.63	14.79	77.26	62.52	10.70	159.64	54.24	84 24	36.
48	NOV 26 - DEC 02	81.15	43.38	68.57	46.91	44.68	6.66	76.77	55.56	46 02	34.
49	DEC 03 - DEC 09	32.92	142.08	110.62	20.92	50.93	47.01	28.60	131.95	47 27	125.
50	DEC 10 - DEC 16	159.28	64.50	66.66	44.23	83.58	18.06	30.87	79.81	54 99	29.
51	DEC 17 - DEC 23	67.74	78.99	120.24	19.96	39.14	11.28	113.12	17.46	25 60	13.
52	DEC 24 - DEC 31	210.34	20.36	30.44	14.89	15.44	11.66	125.73	11.65	25 89	11.

APPENDIX III

GROUNDWATER EVALUATION

The Nanaimo River Basin Surficial Geology Groundwater Resource Evaluation (August, 1991) is revealed in the attached blueprint Figure 1. The Nanaimo River Basin Groundwater Resource Evaluation (August, 1991) aquifers boundaries and well locations are revealed in the attached blueprint Figure 2.

Extent of the Cassidy Aquifer

In delineating the areal extent of the unconfined aquifer, the first consideration was the location of permeable sand and/or gravel deposits as outlined by Halstead (1961). The present extent of the Cassidy Aquifer was subsequently modified by analyzing additional geological information from water well drillers' lithological logs as contained in numerous water well records and from interpretation of the hydrogeological cross-sections that are presented in Figures 3 - 9.

Aquifer Area "A"

There is very limited groundwater information by way of water well records, etc. regarding this aquifer area. The area is underlain by permeable fluvial and glaciofluvial sand and gravel deposits. The limited well record data indicates that the thickness of the unconfined aquifer is about 6 m.(20 ft.).

Groundwater levels range from about 70 m. (240 ft) elevation in the northwest part of the aquifer to about 35 m (120 ft.) elevation in the southeast part of the aquifer. Figure 2 also shows that the predominant direction of groundwater flow is in an eastern direction; from the Upland area towards the Nanaimo (Cassidy) airport area.

An evaluation of well record data and interpretation of cross-section (Figure 3), suggests that part of a confined (or semi-confined) aquifer underlies the southeastern section of Aquifer area "A".

As indicated in Table 3.5 chapter 3, the amount of groundwater in storage is estimated at about 3.8×10^9 gallons, of which about 3.3×10^9 gallons may be available for extraction. The unconfined and confined aquifers receive an estimated 1.3×10^9 gallons of recharge each year from precipitation. This is equivalent to continuous pumping at about 2,500 gpm. According to Nasmith (1952), Aquifer Area "A" receives significant additional recharge from influent seepage from the Nanaimo River and Haslam Creek.

Extraction of groundwater in excess of the annual recharge from precipitation may induce additional seepage of Nanaimo River and Haslam Creek flows into the aquifer, thereby reducing surface flows to some extent. The degree of surface water / groundwater inter-relationship and potential conflict with licensed use needs to be further evaluated.

As previously indicated, there are at present very few reported records of wells for this area. Extraction of groundwater is likely limited to meet domestic needs. There is potential for further groundwater development of this aquifer area.

Aquifer Area "B"

This aquifer area, although lying outside and adjacent to the Nanaimo River basin, is part of the main Cassidy Aquifer. According to Halstead (1961), this area is underlain by terraced fluvial and glacio-fluvial sand and gravel deposits.

The main source of recharge to this aquifer area is predominantly from precipitation. The annual amount of recharge is estimated at 0.4×10^9 gallons. The predominant direction of groundwater flow is towards the southeast, with eventual discharge into Ladysmith Harbour. Assessment of well record data indicates that flowing artesian conditions exist in the area, substantiating groundwater discharge into Ladysmith Harbour.

A review of 35 water well records indicates that most of the wells are constructed in unconsolidated sediments; are shallow, less than 18 m (60 ft) deep; have reported yields up to 1.3 L/s (20 gpm), and that the estimated average thickness of this aquifer is about 3 m (10 ft.). Further investig[illegible]on by way of test drilling and geophysical testing would be needed to determi[illegible] the aquifer thickness and depth of the unconsolidated deposits in this area. The estimated amount of groundwater use is less than 0.01×10^9 gallons per year, based on an assumed average domestic and gardening need of 1000 gallons per day. As noted in Table 3.5 chapter 3, the estimated amount of groundwater in storage is 0.55×10^9 gallons, of which about 0.48×10^9 gallons can be extracted. This suggests that there is further potential for groundwater development from this unconsolidated aquifer.

Aquifer Area "C"

There is very little groundwater information available for this aquifer area. This area was delineated as a potential aquifer based primarily on the distribution of terraced sand and gravel fluvial deposits as outlined by Halstead (1961). Of the three reported wells constructed within this area, one is a shallow flowing well beside Haslam Creek, of unknown yield. The other two wells are constructed in unconsolidated materials and are 10 m (32 ft.)

and 14.5 m (48 ft) deep, and have reported yields of 1 L/s (15 gpm) and 0.2 L/s (3 gpm), ie. sufficient for domestic needs.

Table 3.5 chapter 3, shows that the amount of recharge from precipitation is estimated at about 0.4 X 10^9 gallons per year. This is equivalent to continuous pumping at about 48 L/s (760 gpm). There is also good potential for additional recharge to this aquifer area from seepage from the Nanaimo River, which flows across this area. Stream flow measurements would be needed to quantify the amount of recharge. Based on an estimated aquifer thickness of 3 m (10 ft.), the amount of groundwater in storage that can be effectively extracted is estimated at 0.5 X 10^9 gallons. Further hydrogeological site investigation, test drilling and possibly geophysical investigations would be needed to further define the groundwater potential of this under-developed aquifer.

Aquifer Area "D"

This aquifer area contains the most significant groundwater reservoirs in terms of aquifer potential and use. It is underlain by two major water-bearing sand and gravel deposits, arbitrarily designated as the Upper and Lower (Cassidy) Aquifers, as shown in Figures 3, 4, 8. The extent of these aquifers has been defined on the basis of distribution of sand and gravel deposits and evaluation of water well record data.

According to Kohut (1979), the Upper Aquifer, occurs under water table conditions, ranges in thickness from 6 m (20 ft.) to 26 m (85 ft.), and is comprised mainly of terraced fluvial sand and gravel (Halstead, 1961). Based on an evaluation of well record data and cross-sectional views, the Upper Aquifer overlies a massive deposit of blue clay (possibly glacial till) which ranges from 6 m (20 ft.) to 30m (100 ft.) in thickness. This clay unit overlies the Lower Aquifer which occurs under confined conditions and is comprised mainly of compacted sand interbedded with cemented gravel and/or yellow clay.

Kohut (1979) analyzed groundwater level data from well records and determined that shallow groundwater in the Upper Aquifer generally moves from west to east through the main area of the aquifer. A local groundwater mound (divide) occurs north of the airport, as shown in Figure 1. This divide coincides closely to the south boundary of the Nanaimo River basin area. From this area, groundwater moves northward towards Haslam Creek and Nanaimo River, and southward towards Ladysmith Harbour.

Recharge to the Upper Aquifer comes from precipitation and influent seepage from Haslam Creek and Nanaimo River in the upper reaches of these water courses. The amount of precipitation recharging the Upper Aquifer is estimated at 0.9 X 10^9 gallons per year. This is equivalent to about 107 L/s

(1700 gpm) of continuous pumping. As indicated in Table 3.5 chapter 3, the amount of groundwater in storage in the Upper Aquifer is estimated at 5.1 X 10^9 gallons, assuming an average aquifer thickness of 7.6 m (25 ft.). Assuming a specific yield of 0.88, the estimated amount of extractable groundwater is 4.5 X 10^9 gallons.

The Upper Aquifer is an important source of water supply for domestic, irrigation, community and industrial use. There are approximately 100 known domestic wells in the area. Based on an average conservative withdrawal rate of 0.2 L/s (3 gpm), the total amount of groundwater use from these wells is about 19 L/s (300 gpm). Well record data indicates that there are about 9 water wells completed in the Upper Aquifer that have potential well yields of between 3.2 L/s (50 gpm) and 6.3 L/s (100 gpm). These wells are utilized for airport, irrigation, community and development (trailer parks, etc) use and are located in the south part of the aquifer area. Total withdrawals from these wells is estimated at about 32 L/s (500 gpm).

The most significant (major) groundwater wells in terms of use, are located in the northern part of the aquifer area, adjacent to the Nanaimo River and Haslam Creek. These major users, capable of extracting more than 63 L/s (1000 gpm) include:

- Harmac Pulp Mill Production Well "A" : 202 L/s (3200 gpm)
- Harmac Pulp Mill Production Well "C" : 101 L/s (1600 gpm)
- Harmac Pulp Mill Production Well "D" : 215 L/s (3400 gpm)
- Harmac Pulp Mill Production Well "E" : 76 L/s (1200 gpm)
- Harmac Pulp Mill Production Well "F" : 76 L/s (1200 gpm)
- Fisheries Canada Hatchery Well (formerly Harmac Prod. Well "B") : 63 L/s (1000 gpm)
- Boat Harbour Development Prod. Well : 76 L/s (1200 gpm)

The above figures represent the actual production capacities of each well, with the exception of the Boat Harbour Development well, which has not yet been put in production.

Based on limited pumping test data, it appears that the transmissivity of the Upper Aquifer is about 7 X 10^{-2} m^2/s (Foweraker, et al, 1985). To obtain more information regarding the hydraulic properties of the Upper Aquifer it is recommended that pumping test of selected production wells be performed.

A provincial observation well (No. 228), completed to a depth of 66.5 m (218 ft.) is located in the south part of Aquifer area D (Figure 2), in the vicinity of the majority of domestic, irrigation and development wells. Historic hydrograph data for this observation well since 1978 is shown in Figure 9, and indicates that this well reflects seasonal fluctuations of water levels with an annual cycle in response to precipitation. Based on the trend of the seasonal low water levels for the period of record, it is evident that there is a natural equilibrium between aquifer withdrawals and recharge. This implies that the aquifer in the vicinity of this observation well is not being depleted and that there is potential for further development.

There are no observation wells at present in the area of the major production wells in the north part of the aquifer area. Based on information from Harmac Pulp Mill, Fisheries Canada and E. Livingston (for Boat Harbour Development), the total amount of withdrawal from these major wells is estimated at about 732 L/s (11,600 gpm), or 6.1 X 10^9 gallons per year. At this time there are no reported indications that this amount of withdrawal has caused any significant local "mining" or depletion of the aquifer.

Personal communications with Harmac Pulp Mill technical staff indicate that the well performance in their production wells has decreased. Further investigation is required to assess the apparent decrease in well performance to determine whether it is a well hydraulic problem (ie. encrustation or bridging of screens, etc.) or an aquifer depletion concern. An observation well in the vicinity of the major production wells is recommended to evaluate water level trends in response to major groundwater withdrawals.

Assuming that the storage capacity of the Upper Aquifer has not been diminished, the amount of precipitation recharging the aquifer (estimated at 0.9 X 10^9 gallons) is not sufficient to maintain withdrawal rates from the major production wells. Additional recharge to the highly permeable unconfined sand and gravel Upper Aquifer, of at least 5.8 X 10^9 gallons per year, is most likely being provided from naturally influent and induced streamflow see pages from Haslam Creek and Nanaimo River to maintain the above major withdrawals. This amount of recharge is equivalent to a flow of about 25 cfs. Historical streamflow data to 1986 for the Nanaimo River at Cassidy (upstream of the major production wells) indicates that in Sept.,1973, a minimum daily discharge of 1.22 m^3/s (43 cfs), was reported.

It is evident from the above analysis that groundwater extraction from the major wells along the Nanaimo River and Haslam Creek, near its confluence with the Nanaimo River, may have a significant influence on low flow conditions of the Nanaimo River, downstream of the major wells. Further evaluation by way of streamflow measurements is needed to assess the actual amount of streamflow loss to the aquifer and production wells. It is uncertain at this time how much additional groundwater development and extraction may occur in this area before existing production wells are significantly affected.

In order to mitigate the above concerns, it is recommended that an evaluation be considered of the potential for artificially recharging the aquifer in the vicinity of the major production wells, as well as the potential for recycling industrial water.

An outline of the probable extent of the Lower Aquifer is shown in Figure 1. The Lower Aquifer is comprised mainly of interbedded sand with cemented gravel and/or yellow clay, and directly overlies the bedrock. The maximum known thickness of the unconsolidated deposits overlying bedrock in the Cassidy area is 66 m (218 ft.), occurring in Observation Well 228, located southwest of the airport. Based on depth to bedrock contours (after Kohut, 1979), and cross-sectional views (Figures 3, 4 and 5) there is evidence of a major bedrock trough trending north to south along the western side of the airport. It is within this bedrock low that the Lower Aquifer occurs.

Assuming an average aquifer thickness of 40 ft. (12 m), the amount of groundwater in storage in the Lower Aquifer is estimated at 3.5 X 10^6 gallons. The source(s) of recharge to this confined aquifer is not known but may in part come from leakage from the overlying aquifer and in part from the surrounding bedrock. The Lower Aquifer has not been developed to date; consequently, its yield potential is not definitely known. According to Kohut (1979), it should be capable of providing several hundred gallons per minute (up to 20 L/s) to individual wells.

Aquifer Area "E"

Aquifer area "E" occupies an area of approximately 21 X 10^6 sq. ft. or about 483 acres. There are approximately 21 wells constructed in the shallow sand and/or gravel deposits to depths of less than 13m (50 ft.).

Based on limited lithological and water level data from well records, it appears that the unconfined aquifer may have an average thickness of 7.6 m (25 ft.). Assuming a porosity of 0.25 for sands and gravels, and a specific yield of 0.88, the amount of extractable groundwater from storage is estimated at 1 X 10^9 gallons. Recharge to the unconfined aquifer is predominantly from rainfall and is estimated at 0.3 X 10^9 gallons per year.

Water level data from well records indicates that the unconfined aquifer has a relatively shallow groundwater table, and groundwater flow is from the airport area towards Ladysmith Harbour. At least two significant springs (one recorded flowing at 0.6 L/s (10 gpm) to 1.2 L/s (20 gpm) in August 1976), indicative of groundwater discharge from the unconfined aquifer occur at the head of Ladysmith Harbour. Kohut (1979) indicated that additional groundwater discharge may also occur below sea level within Ladysmith Harbour.

The amount of groundwater flow into Ladysmith Harbour was estimated by Kohut (1979) to be in the range of 1 L/s (16 gpm) to 10 L/s (160 gpm), assuming an aquifer permeability of 10^{-2} cm/sec to 10^{-3} cm/sec, an hydraulic gradient of 0.015, and an estimated saturated aquifer thickness of 7.6 m (25 ft.), and an aquifer width of 1067 m (3500 ft.).

Estimated potential well yields range from 2 gpm (0.1 L/s) to as high as 75 gpm (4.7 L/s). Well use appears to be predominantly domestic and minor irrigation/development. There is good potential for additional well development for domestic and minor irrigation/development purposes.

Kohut (1979) suggests that although there is very little stratigraphic data for the region between the airport and Ladysmith Harbour, it is probable that the bedrock low, mentioned previously, may also extend to Ladysmith Harbour. Within this bedrock low, there is a possibility that the Lower Aquifer of aquifer area "D" may extend towards Ladysmith harbour.

There is no data available on the hydraulic gradient and direction of flow in the Lower Aquifer, although it would be expected to be from the airport area towards Ladysmith Harbour. North of Ladysmith Harbour significant artesian flows may be expected from wells drilled into the Lower Aquifer. Further groundwater exploration by way of test drilling and geophysical testing would be needed to investigate these possibilities.

Aquifer Area "F"

Aquifer area "F", occupying an area of approximately 44 X 10^6 sq. ft. or about 1012 acres, has been delineated as the area from the confluence of the Nanaimo River and Haslam Creek to the Nanaimo delta. This narrow elongated floodplain aquifer, bounded on each side by predominantly shale and sandstone bedrock, is underlain mainly by fluvial sand and gravel with some minor silt and clay (Halstead, 1961). The actual thickness of the unconsolidated sediments is not known from available well record data; however, cross-sections 6 and 7 (Figure 8) indicate that the average thickness may be in the order of 15 m (50 ft.). Further evaluation by way of geophysical testing and/or test drilling within the floodplain and deltaic deposits will be needed to confirm this.

Based on available well record data and an assumed average aquifer thickness of 6 m (20 ft.), the volume of groundwater in storage that can be extracted is estimated at about 1.4 X 10^9 gallons. Recharge to this aquifer from precipitation is estimated at 0.6 X 10^9 gallons per year. The amount of additional recharge from the Nanaimo River is not known but may be more significant than precipitation. Further evaluation of streamflow data is needed to assess the amount of influent seepage.

There are about 19 shallow wells constructed in this aquifer area. Well depths are typically less than 12 m (40 ft.) deep. The yields from the majority of the wells are generally sufficient for domestic use and one well in the delta was reportedly rated at 6.3 L/s (100 gpm). There are five major production wells constructed for the North Cedar Water Works District, whose potential yields vary between 12.6 m (200 gpm) and 32.2 L/s (510 gpm). According to G. U. Proctor (1989), the present production from three of its five wells is just over 30 L/s (480 gpm). The other two production wells were taken out of service due to iron bacteria problems.

Based on the volume of extractable groundwater in this area and the amount of recharge, this aquifer has a significant capacity for additional development of higher capacity production wells. To determine the quantitative capacity of this aquifer more detailed hydrogeological investigations and assessments are needed including, test drilling, pumping tests, geophysical surveys and streamflow measurements.

APPENDIX IV

WATER QUALITY

HISTORICAL DATA - Appendix A

Equis Data for site # 0125180 from 1968 to 1982 is filed in Environmental Protection files, Regional Ministry of Environment, Nanaimo, File # 77900 - 40/NAN.

1990 - 1991 DATA - Appendix B

SEAM data from January 1990 to December 1992 for sites #ed 0125180, E208103, E208104, E208105, E215781.

GNWD DATA - Appendix C

Greater Nanaimo Water District water quality files for South Fork Dam collected in Nanaimo 1989-1991.

Available water quality data for the watershed was assembled and a summary of this data was reported by Yonge (1989). From this study (largely at one site up to 1984) it became evident that more recent data from a number of representative sites would be desirable to examine the Nanaimo River Basin.

A monitoring program was subsequently developed to augment existing data. This program was set up compatible with Provincial procedures for setting water quality objectives, although it is not the purpose of this report to recommend objectives for this basin. A 1990 sampling program was implemented on a short time frame and small budget. A follow up monitoring program in 1991 attempted to fill in data for periods and locations not previously sampled.

The 1990 and 1991 monitoring programs sampled a short priority list of parameters instead of the long non-specific list used in the historic database. Tables 1 and 2 show the 1990 and 1991 Programs monitoring schedules.

Table 1. 1990 Ministry of Environment Monitoring Schedule

Site	Location	Frequency	Date	Parameter
0125180	at highway	5 times weekly in 30 days	low flow	MF fecal E. coli Enterococci
E208103	at MB bridge	5 times weekly in 30 days	low flow high flow	turbidity suspended solids
E208104	at TP bridge	monthly and 4 times in the fall	April-November	pH temperature Dis. oxygen alkalinity NH3-N NO2-NO3-N ortho-phosphate
E208105	South Fork	5 times weekly in 30 days at 2 sites	low flow high flow	total metals dissolved metals D-Al T-Cu LL D-Cu LL T-Cd SLL D-Cd SLL T-Pb LL D-Pb LL T-Zn LL hardness
E215789	@ Cedar bridge	once at 3 sites	low flow	Chlorophyl a 6x

Table 2. 1991 Ministry of Environment Monitoring Schedule

Site	Location	Frequency	Date	Parameter
0125180	at highway	5 times weekly in 30 days	August	MF fecal
E208103	at MB bridge	5 times weekly in 30 days	April August	turbidity suspended solids
E208104	at TP bridge	monthly	January to November	pH temperature dis. oxygen alkalinity NH3-N NO2/NO3-N orthophosphate
E208105	South Fork	5 times weekly in 30 days monthly (3)	April August January February March	total metals dissolved metals plus Cu Com T-Cu LL D-Cu LL T-Cd SLL D-Cd SLL T-Pb LL D-Pb LL T-Zn LL D-Zn LL hardness

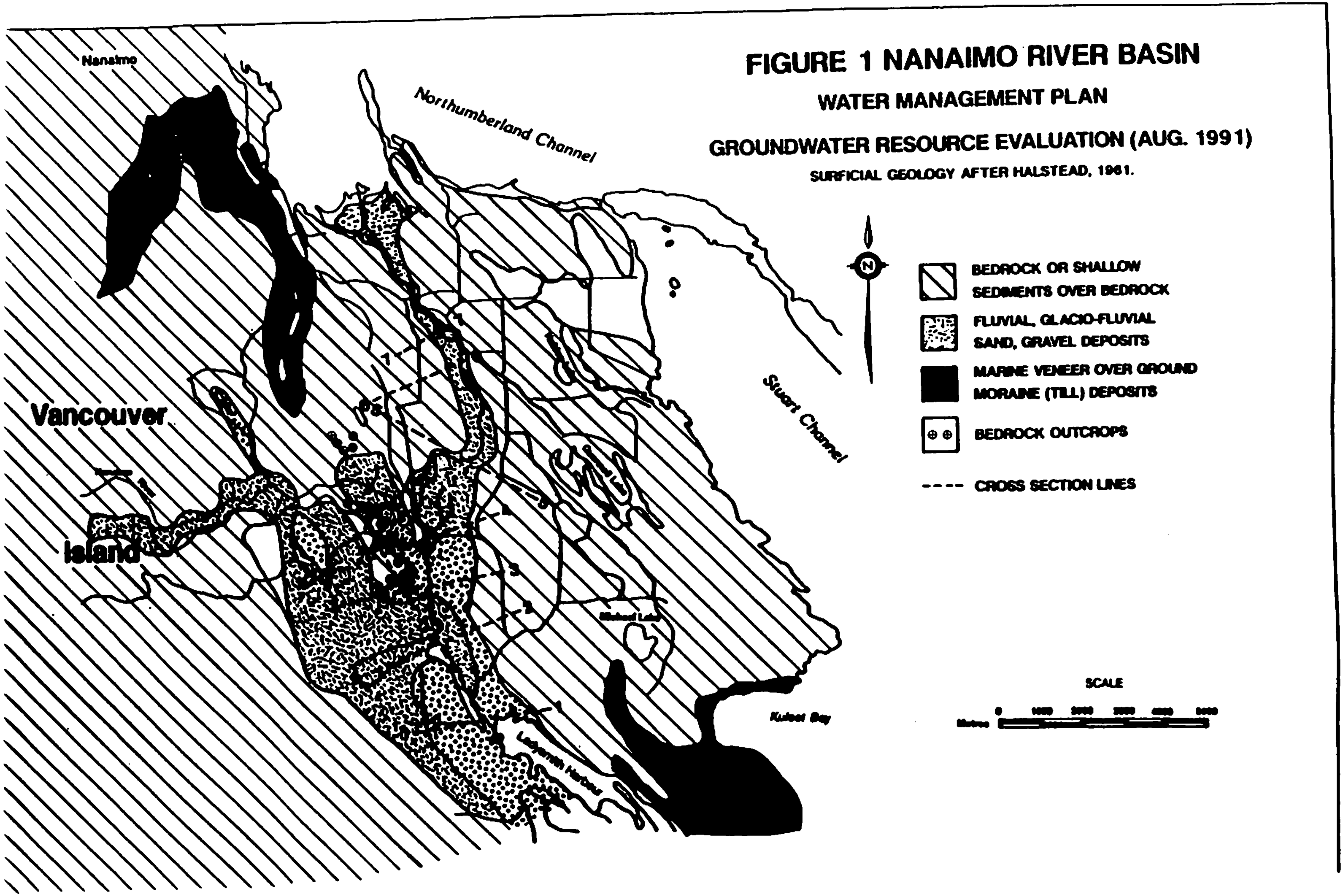

FIGURE 1 NANAIMO RIVER BASIN

WATER MANAGEMENT PLAN

GROUNDWATER RESOURCE EVALUATION (AUG. 1991)

SURFICIAL GEOLOGY AFTER HALSTEAD, 1961.

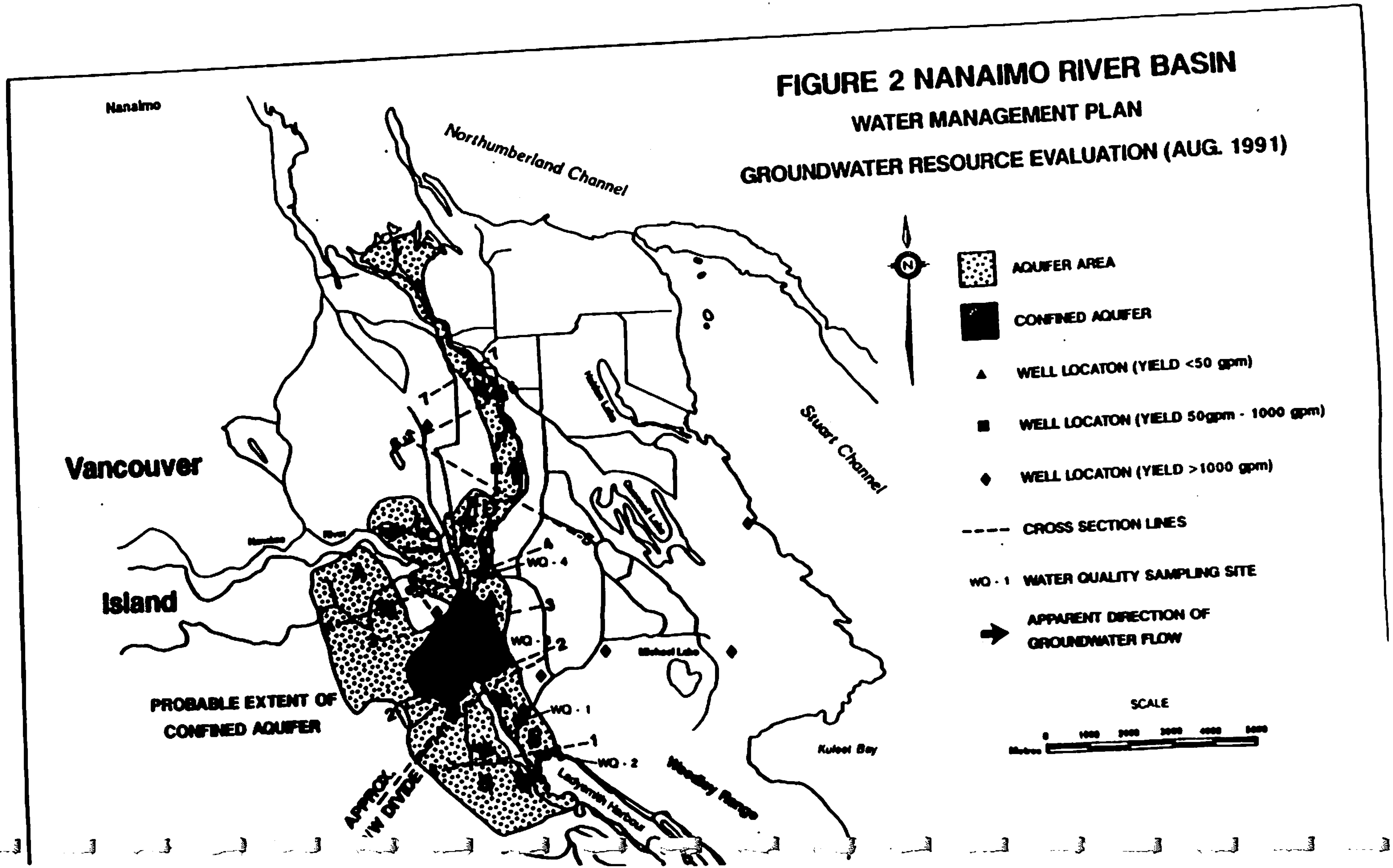

FIGURE 2 NANAIMO RIVER BASIN
WATER MANAGEMENT PLAN
GROUNDWATER RESOURCE EVALUATION (AUG. 1991)

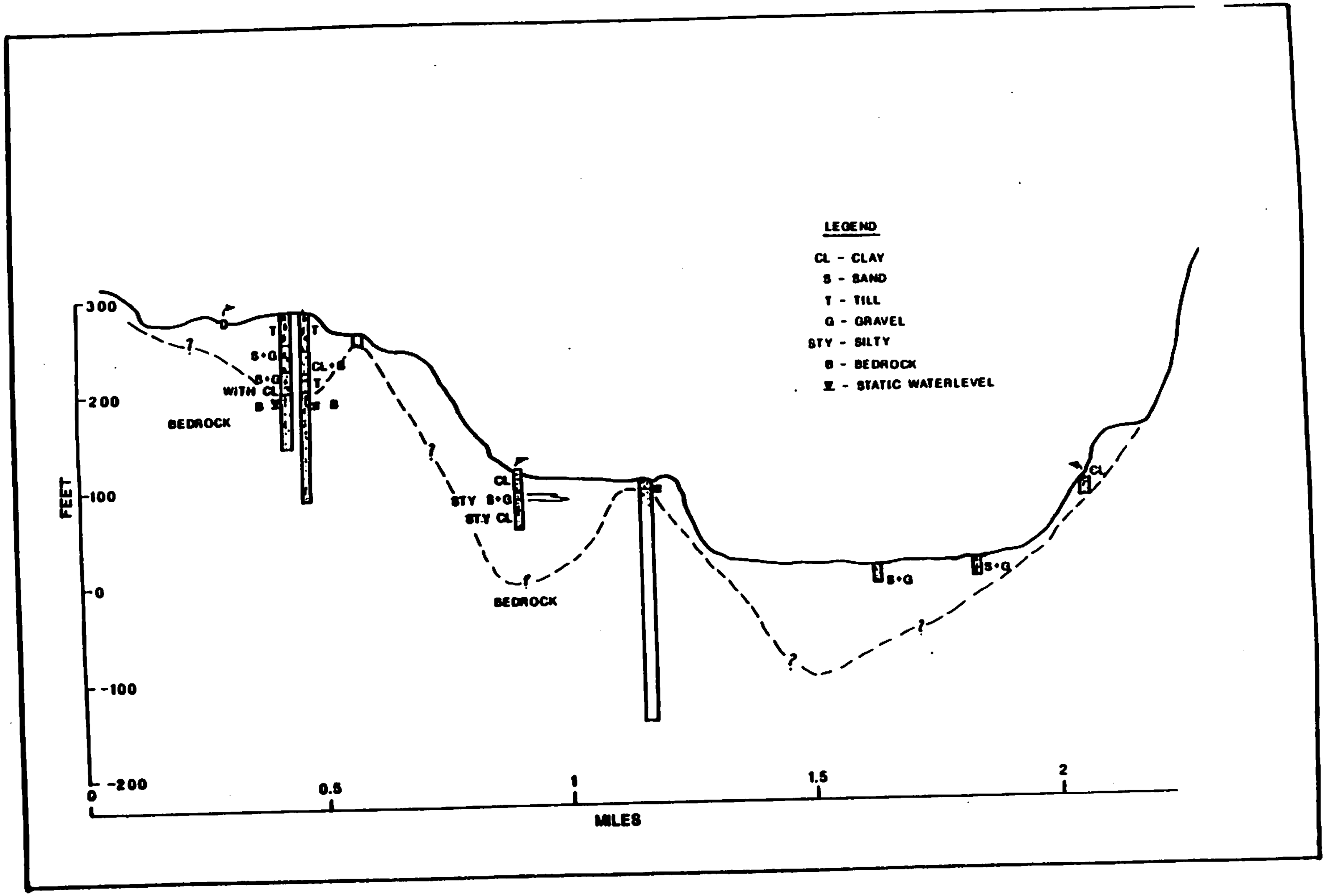

Figure 3. Groundwater Resource Evaluation Cross Section 1

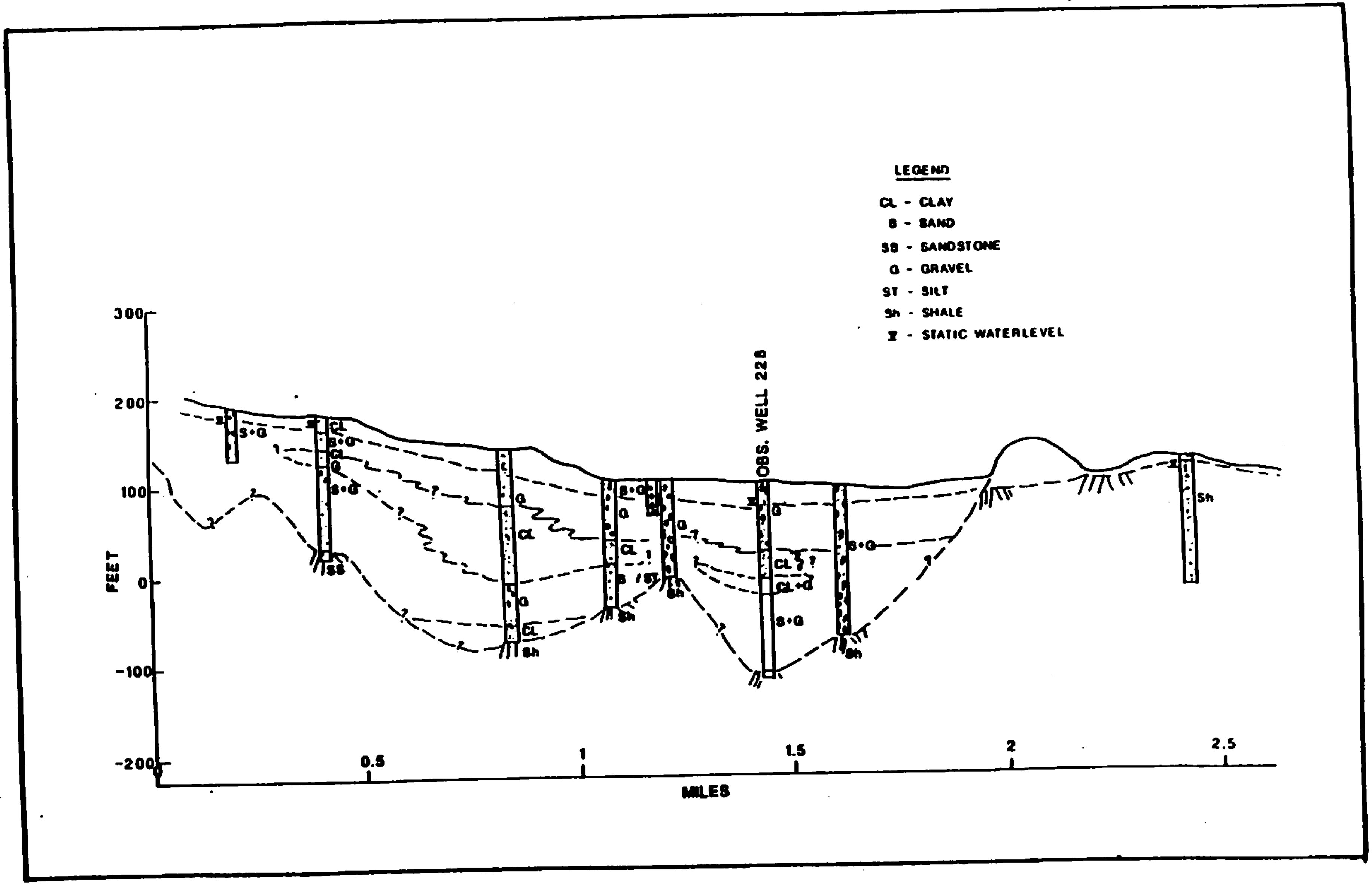

Figure 4. Groundwater Resource Evaluation Cross Section 2

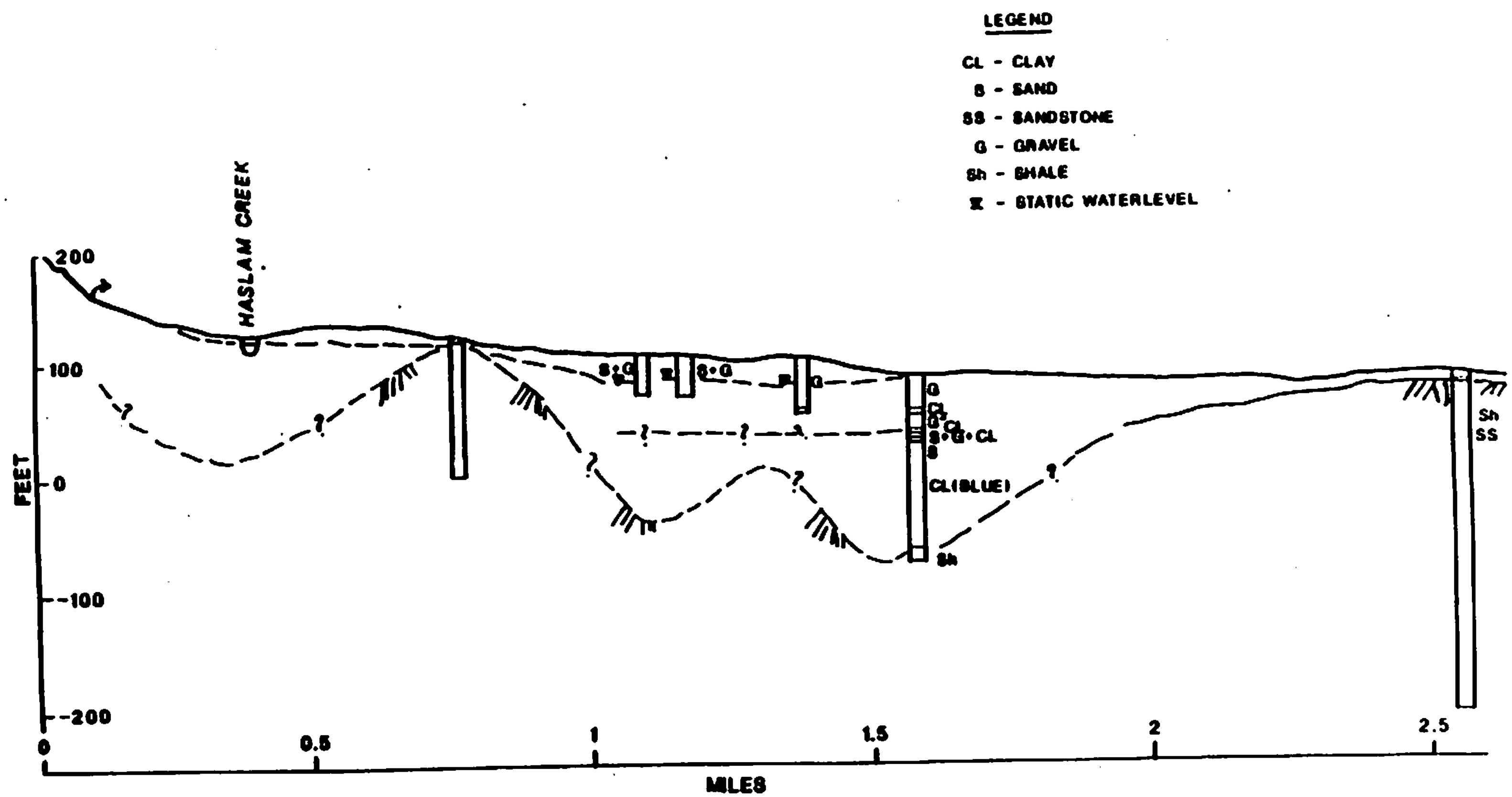

Figure 5. Groundwater Resource Evaluation Cross Section 3

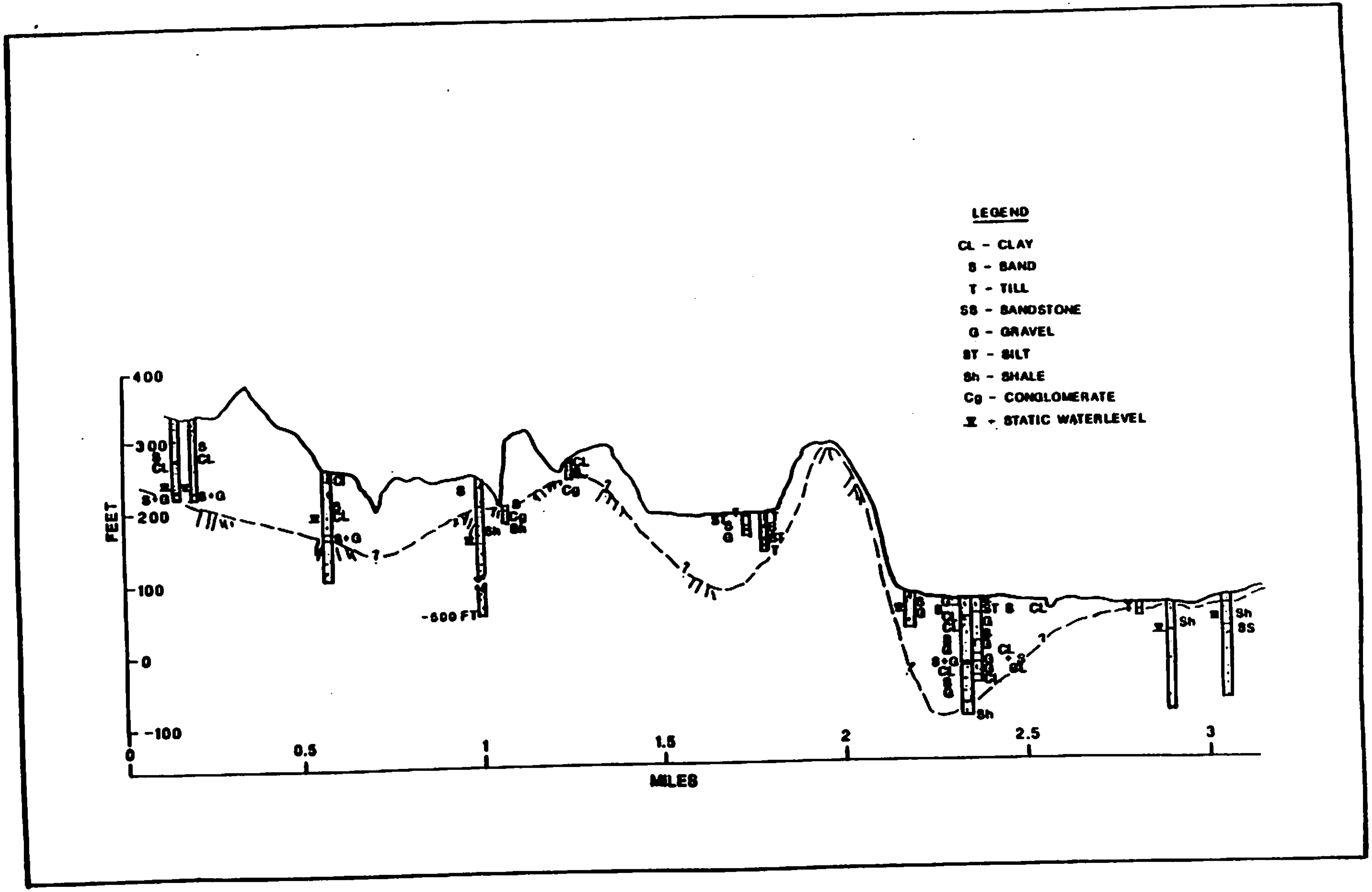

Figure 6. Groundwater Resource Evaluation Cross Section 4

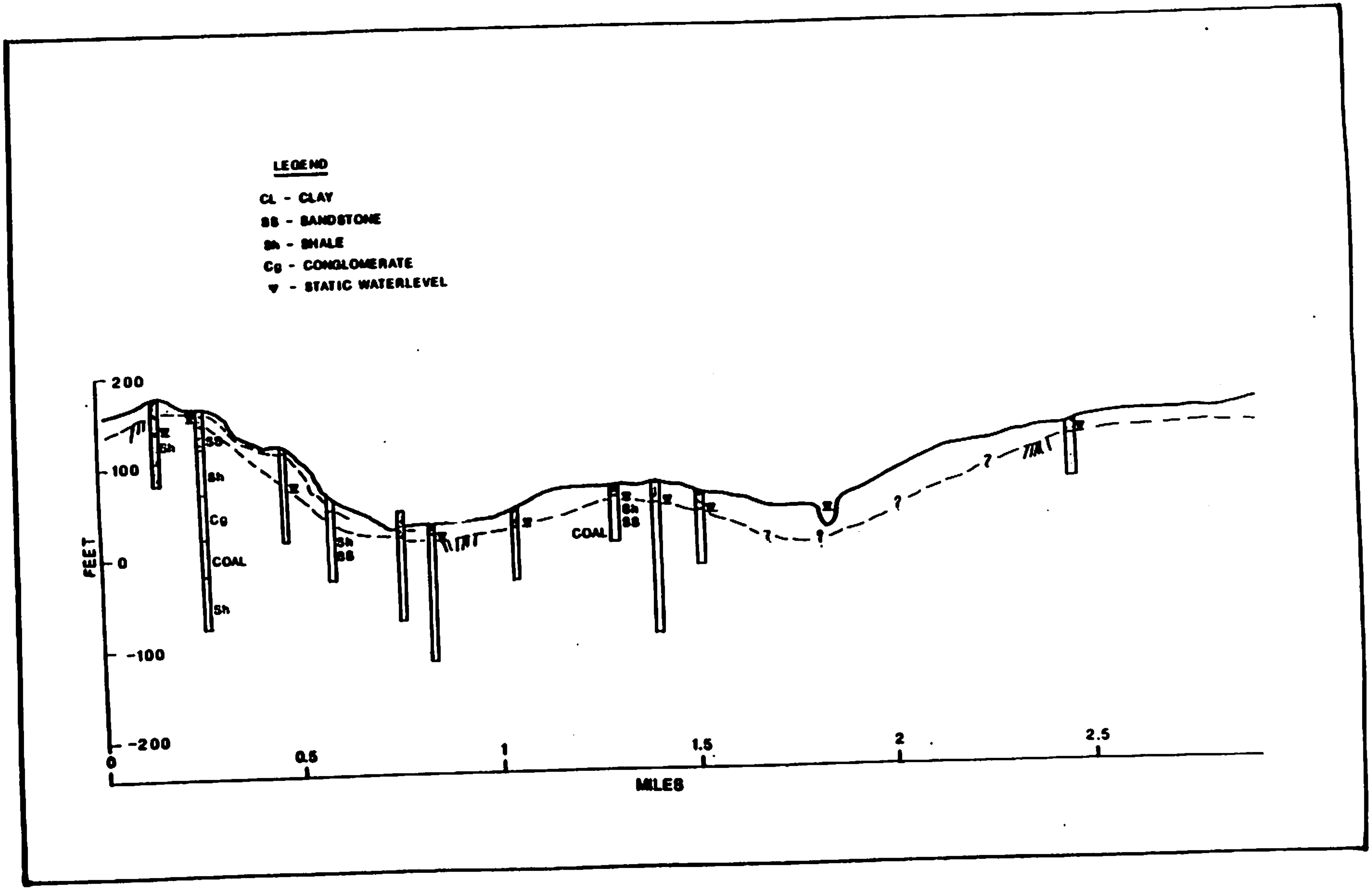

Figure 7. Groundwater Resource Evaluation Cross Section 5

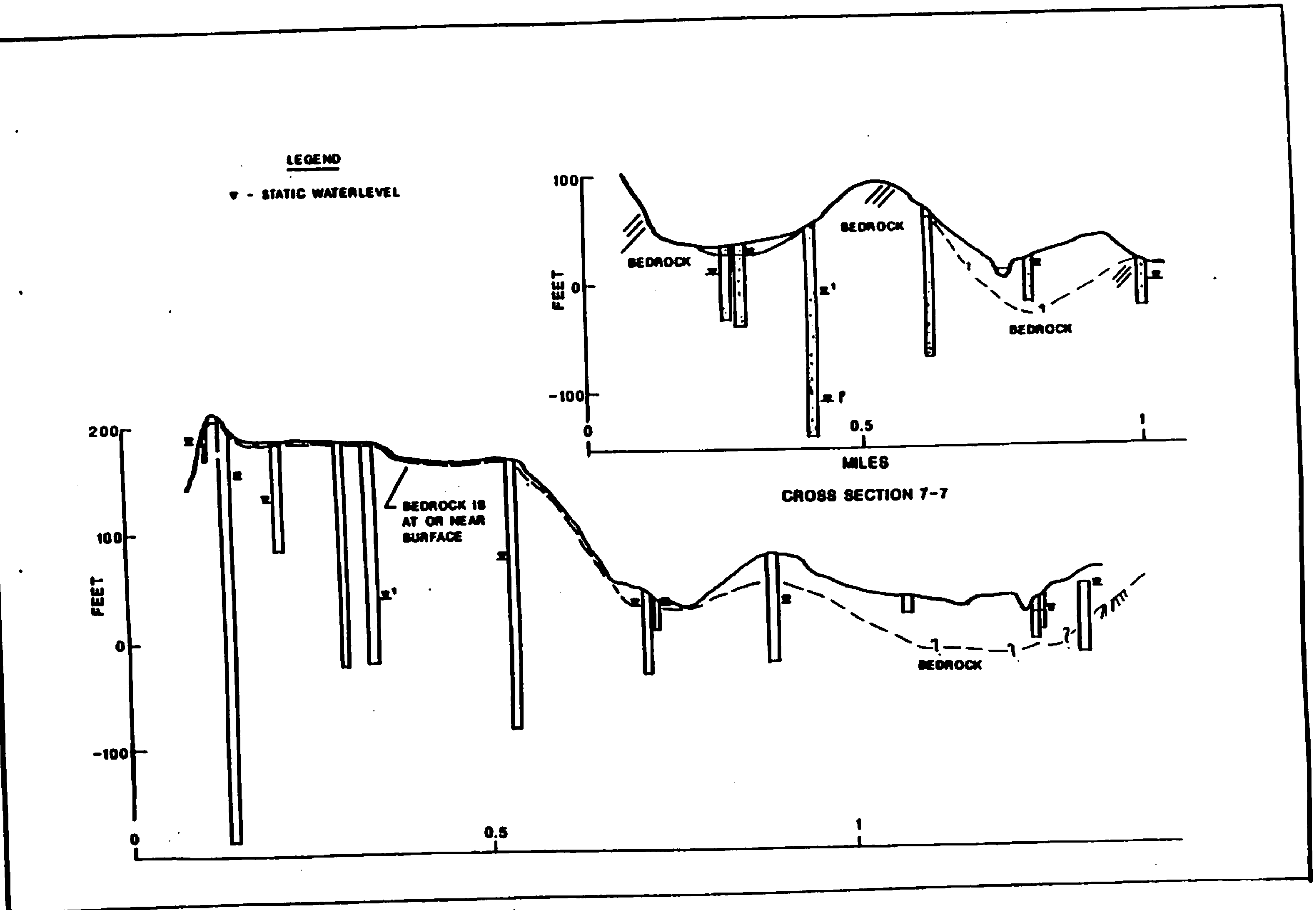

Figure 8. Groundwater Resource Evaluation Cross Section 6 and 7

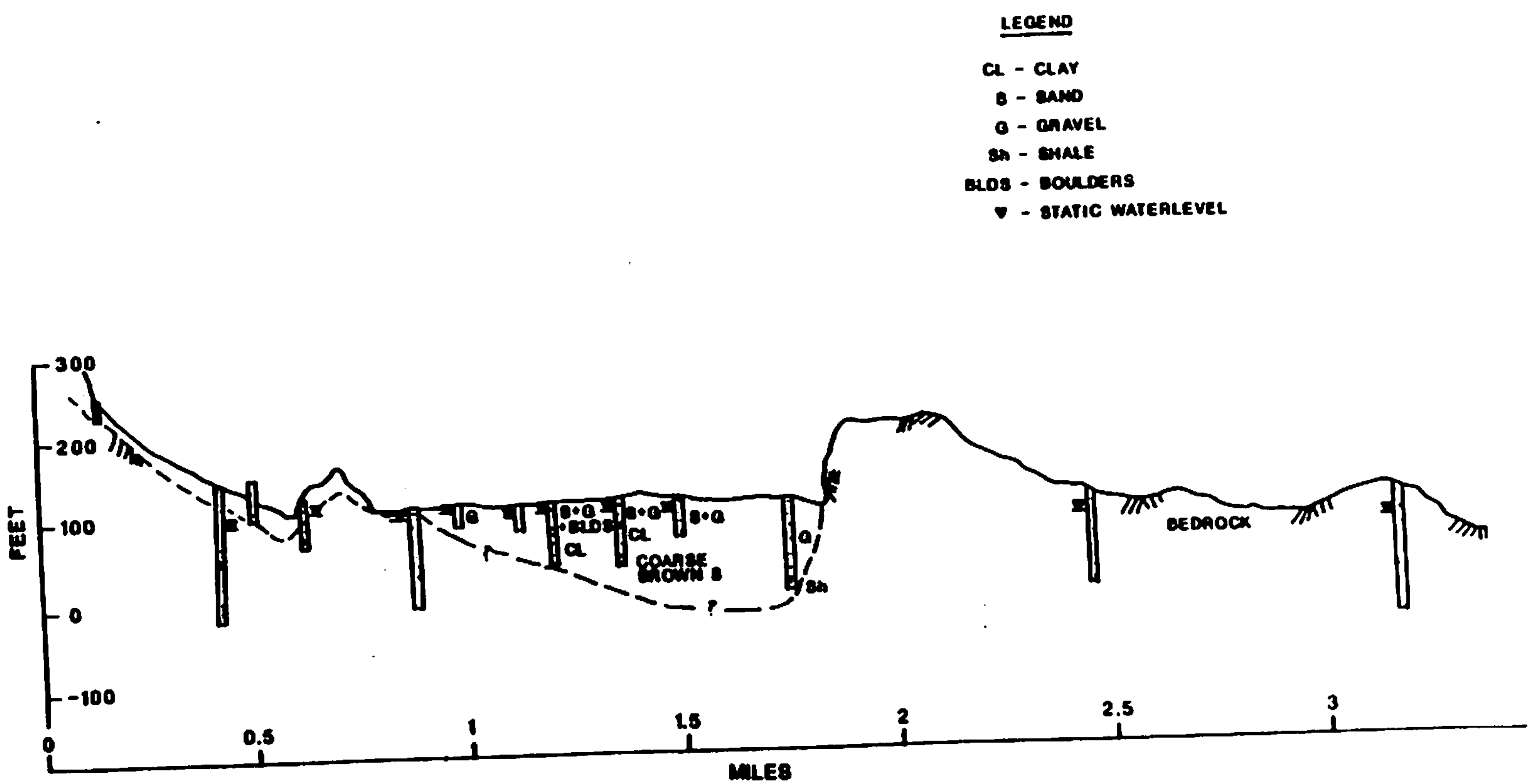

Figure 9. Groundwater Resource Evaluation Cross Section 8

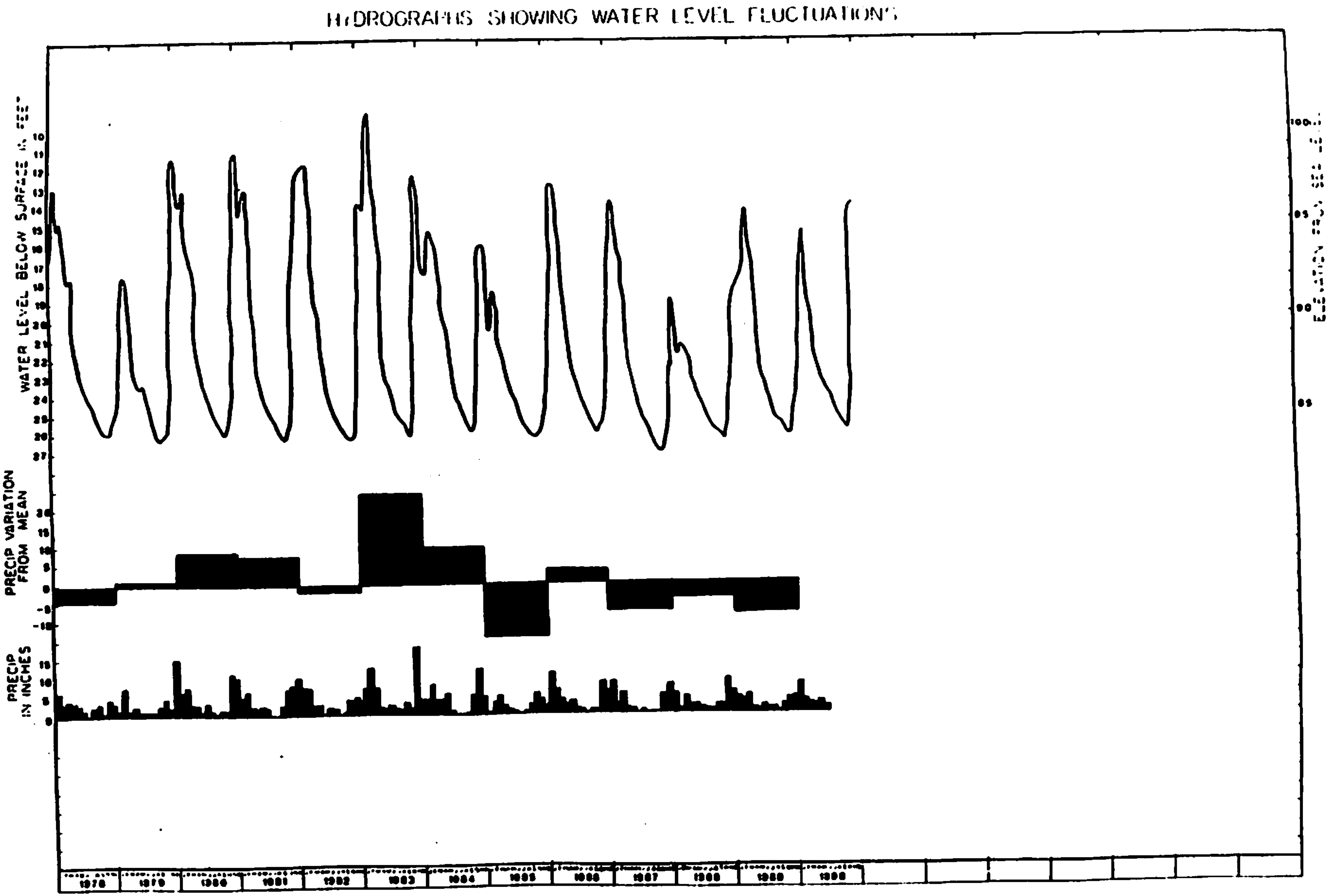

Figure 10. Groundwater Hydrographs of Water Level Fluctuations

Table 3 Water Quality Check Program Chemistry Analysis

Parameter:	NTS A	NTS B	NTS C	Last Name	First Name and Middle Init	Phone No.	Address #1	Address #2	City	Postal Code
units:										
	92	G	4	Raffle	Robert	754-4189	2045 Plecas Rd. Sl SW RR#4		Nanaimo	V9R-5X9
	92	G	4	Stead	Doug		RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Baun	Judy	753-5954	620 Chestnut St.		Nanaimo	V9S-2L2
	92	G	4	Tonn	Walter K. & Agnes A.	754-6802	1261 Scotchtown Rd. Site Z RR#4 Nanaimo		Nanaimo	V9R-5X9
	92	G	4	Pittman	David		Site V2 RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Couchman	Angela	753-0757	Site SW RR#4 NanaimoB.C.		Nanaimo	V9R-5X9
	92	G	4	Thatcher	F.	754-9527	Site R RR #4 Thatcher Rd. Nanaimo		Nanaimo	V9R-5X3
	92	G	4	Thatcher	F.	754-9527	Site R RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Stupich	Stan		P.O. Box 105 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Lapi	Christy		P.O. Box 29 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Leed	Larry W.		P.O. Box 1686 Ladysmith B.C.		Ladysmith	V0R-2E0
	92	G	4	Paton	Steve	245-8111	Box 74 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Gardner	Mary		RR#1 Hinn Rd. Ladysmith		Ladysmith	V0R-2E0
	92	G	4	Greene	Sharon		Box 47 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Sundstrom	V.A.		P.O. BOX 1737 Ladysmith B.C.		Ladysmith	V0R-2E0
	92	G	4	Rudd	Murray	883-9224	P.O. Box 94 Garden Bay, B.C.	Springhill Rd. Parksville	Garden Bay	V0N-1S0
	92	G	4	Scurfield		722-2520	P.O. Box 1162		Nanaimo	V9R-6E7
	92	G	4	Askin	Susan	754-7987	724 O'Brien Place Drive Nanaimo		Nanaimo	V9R-6B1
	92	G	4	Sanford	W.J.	722-2283	Box 128 Cedar P.O. Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Bertram	Cindy	722-2747	Box 333 1751 Akenhead Rd.		Cedar	V0R-1J0
	92	G	4	Luttman	Richard	722-2118	1940 Harmac Rd. Box 300 Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Wilson	Linda	722-2898	1339 Ivor Rd. C-12 Site 1 RR#2		Nanaimo	V9R-5K2
	92	G	4	Clemens	Brian	641-1420	2948 Nelson Rd. RR#2 Site J2 C.5		Nanaimo	V9R-5K2
	92	G	4	Brachat	Daryl		5714 Caddell Dr. S. Delta B.C.	Brachat Cabin	Cedar	V4E-1B5
	92	G	4	Butler	Ron		P.O. BOX 39		Cedar	V0R-1J0
	92	G	4	Reynolds	Peter J.		RR#3 Decourcey		Ladysmith	V0R-2E0
	92	G	4	Swain	Douglas		Site K2 RR#2		Nanaimo	V9R-5K2
	92	G	4	Cameron	Colin		Box 15 Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Wilson	Linda	722-2898	1339 Ivor rd. C-12 Site I RR#2		Nanaimo	V9R-5K2
	92	G	4	Voysey	Omer W.	722-3669	RB 60 RR#4		Nanaimo	V9R-5X9
	92	G	4	Morgan	Owen	722-2791	P.O. Box 238 Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Morgan	Christine G.	722-2681	P.O. Box 274		Cedar	V0R-1J0
	92	G	4	Cliffe	Robert G.	722-2625	Site G C-18 RR#2		Nanaimo	V9R-5K2
	92	G	4	Klimes	Greg	722-2627	RR#2 Site G		Nanaimo	V9R5K2
	92	G	4	Kasas	Ted	722-2033	RR#2 Site I Aquarian Place		Nanaimo	V9R-5K2
	92	G	4	Woodward	V.H.		Tinsu Rd. RR #3		Ladysmith	V0R-2E0
	92	G	4	Giovando	Larry B.		RR#4 Site Q2		Nanaimo	V9R-5X9
	92	G	4	MacNaughton	Donna	753-0497	General Delivery Cedar P.O.		Nanaimo	V0R-1J0
	92	G	4	Littleton	David	753-2852	RR#1 Site X-3		Nanaimo	V9R-5K1
	92	G	4	Tudor	Vera		Site L Shasta Rd. RR#2		Nanaimo	V9R-5K2
	92	G	4	Beaudry	Victor		Site H2 RR#2		Nanaimo	V9R-5K2
	92	G	4	Preston	Mark		Box 95 Cedar P.O., Cedar B.C.		Cedar, Sout	V0R-1J0
	92	G	4	McGregor	Robin	754-1291	Site J2 RR#2		Nanaimo	V9R-5K2
	92	G	4	McGregor	Robin	754-1291	Site J2 RR#2		Nanaimo	V9R-2K5
	92	G	4	Lewis	Ted	245-2641	RR#4 Quennell R.D. RB64		Nanaimo	V9R-5X9
	92	G	4	Klimes	Gregory J.	722-2627	Site G C-37 RR#2		Nanaimo	V9R-5K2

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units:										
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	92	G	4	Stead	Doug		RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Baum	Judy	753-5954	620 Chestnut St.		Nanaimo	V9S-2L2
	92	G	4	Tonn	Walter K. & Agnes A.	754-5802	1261 Scotchtown Rd. Site Z RR#4 Nanaimo		Nanaimo	V9R-5X9
	92	G	4	Pittman	David		Site V2 RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Couchman	Angela	753-0757	Site SW RR#4 NanaimoB.C.		Nanaimo	V9R-5X9
	92	G	4	Thatcher	F.	754-9527	Site R RR #4 Thatcher Rd. Nanaimo		Nanaimo	V9R-5X3
	92	G	4	Thatcher	F.	754-9527	Site R RR#4 Nanaimo B.C.		Nanaimo	V9R-5X9
	92	G	4	Stupich	Stan		P.O. Box 105 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Lapi	Christy		P.O. Box 29 Cassidy,B.C.		Cassidy	V0R-1H0
	92	G	4	Leed	Larry W.		P.O. Box 1866 Ladysmith B.C.		Ladysmith	V0R-2E0
	92	G	4	Paton	Steve	245-8111	Box 74 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Gardner	Mary		RR#1 Hinn Rd. Ladysmith		Ladysmith	V0R-2E0
	92	G	4	Greene	Sharon		Box 47 Cassidy B.C.		Cassidy	V0R-1H0
	92	G	4	Sundstrom	V.A.		P.O. BOX 1737 Ladysmith B.C.		Ladysmith	V0R-2E0
	92	G	4	Rudd	Murray	883-9224	P.O. Box 94 Garden Bay, B.C.	Springhill Rd. Parksville	Garden Bay	V0N-1S0
	92	G	4	Scurfield		722-2520	P.O. Box 1162		Nanaimo	V9R-6E7
	92	G	4	Askin	Susan	754-7987	724 O'Brien Place Drive Nanaimo		Nanaimo	V9R-6B1
	92	G	4	Sanford	W.J.	722-2283	Box 128 Cedar P.O. Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Bertram	Cindy	722-2747	Box 333 1751 Akenhead Rd.		Cedar	V0R-1J0
	92	G	4	Luffman	Richard	722-2118	1940 Harmac Rd. Box 300 Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Wilson	Linda	722-2898	1339 Ivor Rd. C-12 Site 1 RR#2		Nanaimo	V9R-5K2
	92	G	4	Clemens	Brian	841-1420	2948 Nelson Rd. RR#2 Site J2 C.5		Nanaimo	V9R-5K2
	92	G	4	Brachat	Daryl		5714 Caddell Dr. S. Delta B.C.	Brachat Cabin	Cedar	V4E-1B5
	92	G	4	Butler	Ron		P.O. BOX 39		Cedar	V0R-1J0
	92	G	4	Reynolds	Peter J.		RR#3 Decourcey		Ladysmith	V0R-2E0
	92	G	4	Swain	Douglas		Site K2 RR#2		Nanaimo	V9R-5K2
	92	G	4	Cameron	Colin		Box 15 Cedar,B.C.		Cedar	V0R-1J0
	92	G	4	Wilson	Linda	722-2898	1339 Ivor rd. C-12 Site I RR#2		Nanaimo	V9R-5K2
	92	G	4	Voysey	Omer W.	722-3869	RB 50 RR#4		Nanaimo	V9R-5X9
	92	G	4	Morgan	Owen	722-2791	P.O. Box 236 Cedar B.C.		Cedar	V0R-1J0
	92	G	4	Morgan	Christine G.	722-2681	P.O. Box 274		Cedar	V0R-1J0
	92	G	4	Cliffe	Robert G.	722-2626	Site G C-18 RR#2		Nanaimo	V9R-5K2
	92	G	4	Klimes	Greg	722-2627	RR#2 Site G		Nanaimo	V9R5K2
	92	G	4	Kasse	Ted	722-2033	RR#2 Site I Aquarian Place		Nanaimo	V9R-5K2
	92	G	4	Woodward	V.H.		Tiesu Rd. RR #3		Ladysmith	V0R-2E0
	92	G	4	Giovando	Larry B.		RR#4 Site Q2		Nanaimo	V9R-5X9
	92	G	4	MacNaughton	Donna	753-0497	General Delivery Cedar P.O.		Nanaimo	V0R-1J0
	92	G	4	Littleton	David	753-2852	RR#1 Site X-3		Nanaimo	V9R-5K1
	92	G	4	Tudor	Vera		Site L Shasta Rd. RR#2		Nanaimo	V9R-5K2
	92	G	4	Beaudry	Victor		Site H2 RR#2		Nanaimo	V9R-5K2
	92	G	4	Preston	Mark		Box 98 Cedar P.O., Cedar B.C.		Cedar, Sout	V0R-1J0
	92	G	4	McGregor	Robin	754-1291	Site J2 RR#2		Nanaimo	V9R-5K2
	92	G	4	McGregor	Robin	754-1291	Site J2 RR#2		Nanaimo	V9R-2K5
	92	G	4	Lewis	Ted	245-2641	RR#4 Quennell R.D. RB64		Nanaimo	V9R-5X9
	92	G	4	Klimes	Gregory J.	722-2627	Site G C-37 RR#2		Nanaimo	V9R-5K2

Parameter:	Description of Sampling Site	Location of Sampling Site	Corner	Size	Sector	T.P.	R	LD
units:								
	Lot 2 Sec 12 Range 5 Plan 32838 Cranberry Dist	Well tap at head			12		5	19
	South Wellington 100 ft. drilled well							
	River Terrace Rd. Lot 20 Plan 28345 Sec 5&6 Range 5 Cranberry	Lot 20 River Terrace Rd. untreated Tap water			5&6		5	19
	Lot 1 Sec 11 Range 6 Plan 1700 Cranberry Dist	Tap water from Tonn's well			11		6	19
	200 ft well Cranberry Bright Van. Isl.							
	End of Minto Rd. South Wellington							
	Cedar Bank Farms . Tap from residential house well	Sec 9 Range 7 Cranberry Dist			9		7	19
	Cedar Bank Farms Sec 9 Range 7 Cranberry Dist				9		7	19
	Dug well cement casing gravel pit.							
	Last House Cassidy							
	Lead Tap water Cassidy 24 ft. well							
	Nanaimo Airport							
	Gardner dug well Cassidy area							
	Home Cassidy well							
	Drilled well Cassidy area							
	Judge's Farm Cassidy B.C. (Springhill Rd. Parksville ?)	Judge's Farm Cassidy,B.C. (Springhill Rd. Parksville ?)						
	Remainder of Fract. sec.5 Range 6 Cedar Ld.				5		6	7
	Lot 16 Plan 9877 Sec 7 Range 6 LD 7	2596 Pylades Drive Cedar B.C.			7		6	7
	Tap water from Sanford well Cedar B.C.							
	Lot 2 Plan 2189 Sec 3 LD 32	Well is downhill from septic field.			3			33
	Lot 1 Sec 17 Range 8 Plan 40229 Cranberry Dist	Tap Water from Luffman well			17		8	19
	Lot 2 Sec 19 Range 4 Plan 35760 Cedar Dist	Cedar Dist			19		4	7
	Lot A Section 17 Range 4 Plan 37964 Cedar Dist	Well on our property.			17		4	7
	Tap Water	Brachat Cabin						7
	Water Domestic	Cedar B.C.			9		1	7
	Reynolds 150 ft. Well Cedar Dist.	Lot C						
	Swain Tap water Cedar							
	Domestic Well	Cedar	0					
	Lot 2 Sec.19 RGE.4 PLAN 35760 CEDAR DIST	Cedar Dist			19		4	7
	South 10 chains & west 10 chains of Sec.10 RGE.2 Cedar L.D.	Dug well			10		2	7
	Lot 1 Plan 18581 Sec.1 Range 7 Cedar land Dist.				1		7	7
	Tap water from Morgan's well , Cedar	E1/2 Lot 2 Sec. 8 Rge.2 Cedar Dist. Plan 8303	E1/2		8		2	7
	Tap water from well at 1813 Rugg Rd. Cedar B.C.	Sec.2 Range 14 except parcel B and west 60 chains			2		14	
	Lot 1 Stevens Rd. Sec.13&14 Range 4 Plan 29878 Cedar Dist	Tap Well.Water taken during low flow conition.Quite gassy,no smell			13		4	7
	Lot 3 sect.17 Range4 Cedar dist. Plan 39123				17		4	7
		Ladysmith						
	120 ft. well 300 ft. from lake with peat bottom.	Cedar area						
	MacNaughton Domestic Well	85 Morden Rd. Water doesn't meet Can. Drinking Water Standards . See coliform amount.						
	Siding on property	Nanaimo River Rd.						
	Cedar	Well in Cedar						
	Well uncertain depth Cedar Nanaimo area							
	Lot A Sec.17 Plan 37964 Cedar	Water is chlorinated after the holding tank by a carbon filter.			17		4	
	Tap water from McGregor well in Cedar B.C.	Cedar B.C.						
	Tap water Lewis's well-Cedar,B.C.							
	Lot #1 Ravenhill Rd. Sections 13 & 14 Range #4 Plan # 29878 Cedar Land District							

Parameter:	Lot	Plan	Date of Sample	Water Sample Source	Depth	Depth	Water Treated? (Y/N/?)	Treatment Type	pH	Res Filterable-0.45u	Turbidity	Alkaline Total 4.5
units:			yy-mm-dd		Metres	Feet			pH units	mg/L	NTU	mg/L
	2	32838	87-07-27	Tap well	101	330	Y	Bleach	8.3		76.0	268.0
			81-03-09	Tap water	30	100			7.4	278	30.0	208.0
	20	26345	86-05-26	Tap water	4	12	N		6.9	142	8.3	70.1
	1	1700	85-08-28	Tap water	6	20	N		6.9	142	0.5	101.0
			85-02-26	Tap well	61	200			8.3	682	1.0	240.0
			86-02-16	Tap Well	26	86	Y	Softener	7.4	982	2.8	366.0
			85-07-16	House well	37	122	N		8.0	666	0.2	179.0
			85-07-16	Dug well	4	12			6.8	140	4.7	81.4
			88-10-11	Dug well	0	0			6.4		0.1	28.3
			82-08-03	Tap water	0	0			6.6	88	0.2	46.5
			84-02-13	Tap water	7	24			6.5	53	0.6	26.2
			87-09-09	Well	8	25	N		6.5		15.0	39.7
			82-08-23	Well	5	18			6.9	116	0.3	72.0
			82-06-22	Tap water	0	0			6.5	80	0.2	34.0
			81-08-11	Tap water	10	33			8.0	678	38.0	359.0
			88-12-30	Well	24	80	N		7.9	114	1.9	84.2
			89-01-23	Tap water	0	0	N		8.5		1.0	220.0
	16	9877	88-08-29	Well	35	115	N		9.0		3.5	220.0
			88-09-13	Tap water	21	70	N		8.0		0/1	196.0
	2	2189	88-10-03	Well	0	0	N		6.9		1.3	35.0
	1	40229	88-06-13	Well	3	10	Y	Household Bleach	8.0		4.8	204.0
	2	35760	88-04-11	Tap	73	240	N		6.9		3.0	132.0
	A	37984	88-05-15	Tap Water	64	210	Y	Charcoal filter	9.1		0.7	188.0
			82-01-03	Tap Water	0	0			7.0	562	3.6	124.0
			83-04-30	Well	0	0			7.7	178	100.0	120.0
	C		84-07-19	Well	46	150			8.1	1940	3.5	181.0
			85-01-14	Tap Well	0	0			8.7	194	3.4	140.0
			83-03-01	Well	0	?			8.8	136	3.5	98.0
	2	35760	87-12-23	Tap Well	73	240	UNK		7.2		2.0	252.0
			87-10-19	Dug well	6	20	No		6.8		0.4	43.8
	1	18561	87-03-10	Well	34	112	No		8.2	400	0.5	222.0
	2	8303	87-03-30	Tap Well	17	55	Unk		7.4	264	0.1	186.0
			88-08-06	Tap water	122	400	No		7.7	4090	0.6	81.9
	1	29876	88-08-11	Tap Well	91	300	No		6.4	1490	2.0	82.7
	3	33123	87-02-23	Well	37	122	No		7.5	246	0.4	170.0
			83-03-22	Tap Well	51	168			7.7	280	18.0	185.0
			82-12-06	Well	37	120			7.8	164	8.5	103.0
			82-10-08	Domestic Well	49	160			6.9	248	0.7	158.0
			87-05-16	Spring	0	0	No		6.5	58	0.2	19.8
			82-03-15	Well	29	95			7.3	302	0.4	170.0
			82-02-26	Well	0	?			5.7	166	0.5	24.5
			82-01-26	Well	49	160			8.3	1130	2.9	335.0
	8	37964	88-04-21	Well	64	210	Yes	Chlorinated	9.3	372	1.1	205.0
			88-11-17	Tap Well	64	210	Yes	Resin Filter	7.3	324	1.0	41.9
			88-01-28	Tap-Well	20	67	Yes	Filter (not charc	7.1	228	0.5	172.0
			[illegible]	Well	[illegible]	300	[illegible]		[illegible]	170	1.0	49.7

Parameter:	Hardness Total	Specific Conductance	Co	Colifo	Coliform - Total	Flo	Flourid	Flouride Dissolved	P	Boron	Boron	Bar	Barium	Barium	Calcium	Ch	Chrom	Chromium	Co	Copper
units:	mg/L	uS/cm	LD	DV	MPN	LD	DV	mg/L	LD	DV	mg/L	LD	DV	mg/L	mg/L	LD	DV	mg/L	LD	DV
	30.8	585	<	2.20	0.0			0.44			0.31			0.05	8.07	<	0.03	0.02		
	130.0	490	<	2.20	0.0	<	0.10	0.05			0.00			0.00	42.50			0.00		
	74.5	231			9.2	<	0.10	0.05			0.01	<	0.01	0.01	25.40	<	0.01	0.01	<	0.01
	85.9	225	>	16.00	0.0	<	0.10	0.06			0.02	<	0.01	0.01	23.30	<	0.01	0.01		
	14.8	1210	<	2.20	0.0			1.28			0.88	<	0.01	0.01	5.35	<	0.01	0.01	<	0.01
	61.5	1510	<	2.00	0.0			0.10			0.30	<	0.01	0.01	17.50	<	0.01	0.01		
	44.4	1210	<	2.20	0.0			0.16			0.24			0.39	14.30	<	0.01	0.01	<	0.01
	73.7	226			2.2	<	0.10	0.05	<	0.01	0.01			0.02	21.70	<	0.01	0.01	<	0.01
	56.8	203			55.0	<	0.10	0.05	<	0.01	0.01	<	0.01	0.01	15.70	<	0.01	0.01		
	43.4	116	<	2.20	0.0	<	0.10	0.05	<	0.01	0.01	<	0.01	0.01	13.90	<	0.01	0.01		
	26.5	77	<	2.20	0.0	<	0.10	0.05	<	0.01	0.01	<	0.01	0.01	7.87	<	0.01	0.01		
	42.3	129	<	2.20	0.0	<	0.10	0.05			0.05	<	0.01	0.01	12.40	<	0.01	0.01		
	60.8	187			0.0	<	0.10	0.05			0.03	<	0.01	0.01	18.40	<	0.01	0.01		
	33.8	112	<	2.20	0.0	<	0.10	0.05	<	0.01	0.01	<	0.01	0.01	10.10	<	0.01	0.01		
	138.0	1200	<	2.20	0.0			0.23			0.00			0.00	42.90			0.00		
	71.6	176	<	2.00	0.0	<	0.10	0.05	<	0.01	0.01	<	0.01	0.01	15.60	<	0.01	0.01		
	10.8	590	<	2.00	0.0			0.80			0.25			0.01	2.88	<	0.01	0.01		
	5.3	640	<	2.00	0.0			1.89			0.55	<	0.01	0.01	1.81	<	0.01	0.01	<	0.01
	218.0	1060	<	2.00	0.0			0.46			0.80			0.15	63.80	<	0.01	0.01		
	39.3	134			6.0	<	0.10	0.05	<	0.01	0.01			0/01	11.80	<	0.01	0.01		
	35.7	610			30.0			0.54			0.85			0.02	11.00	<	0.01	0.01		
	32.6	410			2.0			0.27			0.48			0.15	10.50	<	0.01	0.01		
	1.5	620	<	2.00	0.0			3.15			0.96	<	0.01	0.01	0.51	<	0.01	0.01		
	60.6	1060	<	2.20	0.0			0.53	••		0.00			0.00	19.50			0.00		
	58.2	276	>	16.00	0.0			0.17			0.07			0.07	15.20	<	0.01	0.01	<	0.01
	140.0	3680	<	2.20	0.0			4.30			0.73			0.03	46.00			0.04		
	8.8	340	<	2.20	0.0			1.28			0.23			0.01	3.02	<	0.01		<	0.01
	6.3	200			2.2			0.32			0.10			0.01	1.93	<	0.01	0.01		
	23.3	630	>	16.00	0.0			0.78			1.01			0.12	8.30	<	0.01	0.01		
	67.7	220	<	2.20	0.0			0.10			0.18			0.12	17.90			0.01		
	11.7	702	<	2.00	0.0			0.44			0.21	<	0.01	0.01	3.75	<	0.01	0.01	<	0.01
	42.6	450	>	16.00	0.0			0.19			0.17			0.07	13.20	<	0.01	0.01	<	0.01
	185.0	7190	<	2.00	0.0			0.96			1.06			3.38	64.70	<	0.01	0.01		
	227.0	2340	<	2.00	0.0			1.74			0.90			0.18	80.10	<	0.01	0.01		
	92.6	420	<	2.00	0.0			0.29			0.10			0.20	29.20	<	0.01	0.01		
	13.5	450	<	2.20	0.0			1.12			0.34			0.01	4.03	<	0.01	0.01	<	0.01
	5.7	250			2.2			0.22			0.10	<	0.01	0.01	1.60	<	0.01	0.01		
	126.0	403	>	16.00	0.0			0.10			0.07			0.05	41.70	<	0.01	0.01		
	21.9	70	<	2.00	0.0	<	0.10	0.06			0.02	<	0.01	0.01	6.65	<	0.03	0.02		
	80.1	503			2.2			0.55			0.22			0.14	29.30	<	0.01	0.01		
	73.4	250			2.2	<	0.10	0.06	<	0.01	0.01			0.06	18.80	<	0.01	0.01		
	76.2	1680			2.2			1.48			0.00			0.00	28.20			0.00		
	3.2	668	<	2.00	0.0			3.50			1.12			0.03	1.19	<	0.01	0.01	<	0.01
	<0.1	612	<	2.00	0.0	<	0.10	0.06			0.66	<	0.01	0.01	<.02	<	0.01	0.01	<	0.01
	132.0	384	<	2.00	0.0	<	0.10	0.06			0.06			0.28	43.20	<	0.01	0.01		
	58.1	280	>	16.00	16.0	<	0.10	0.06			0.02			0.03	16.60	<	0.01	0.01		

Parameter:	Copper	Iron	Iron	Iron	Magnesium	Mag	Manga	Manganese	Zinc	zinc	zinc	Nitr	Nitro	Nitrogen NO3+NO2 Dis	Nitr	Nitrog	Nitrogen NO3 Diss(N)	Nitr	Nitrog
units:	mg/L	LD	DV	mg/L	mg/L	LD	DV	mg/L	LD	DV	mg/L	LD	DV	mg/L	LD	DV	mg/L	LD	DV
	0.03			4.44	2.59			0.09			0.02	<	0.02	0.01	<	0.02		<	0.005
	0.00			1.30	5.90			0.00			0.00			0.00	<	0.02	0.01	<	0.005
	0.01			0.50	2.69			0.14			0.02			0.83			0.83	<	0.005
	0.04			0.08	6.74			0.03			0.19			0.28			0.25		
	0.01			0.06	0.29			0.01	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.02			0.09	4.33			0.01	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.01			0.02	2.12			0.02	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.01			1.38	4.74			0.07			0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.05	<	0.01	0.01	4.02	<	0.01	0.01			0.03			8.60			8.60	<	0.005
	0.05			0.03	2.11	<	0.01	0.01			0.01			0.00			1.05	<	0.005
	0.13			0.10	1.41	<	0.01	0.01			0.01			0.00			0.04	<	0.005
	0.02			3.50	2.78			0.14			0.41			0.61			0.61	<	0.005
	0.23			0.08	3.62			0.02			0.02			0.00			1.47	<	0.005
	0.06			0.10	2.03	<	0.01	0.01			0.01			0.00			0.52	<	0.005
	0.00			4.50	7.50			0.00			0.00			0.00	<	0.02	0.01	<	0.005
	0.03			1.19	7.93			0.04			0.01			0.24			0.24	<	0.005
	0.04			0.04	0.87	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.01			0.28	0.31	<	0.01	0.01			0.01	<	0.01	0.01	<	0.02	0.01	<	0.005
	0.05	<	0.01	0.01	14.30			0.06			0.06			0.08			0.05		
	0.12			0.18	2.38			0.02			0.13			0.10			0.10	<	0.005
	[illegible]			0.74	2.00			0.31	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	[illegible]			0.43	1.58			0.07			0.02	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.02			0.06	0.05	<	0.01	0.01	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.00			0.60	2.90			0.00			0.00			0.00	<	0.02	0.01	<	0.005
	0.01			18.20	4.43			0.62	<	0.01	0.01			0.00	<	0.02	0.01	<	0.005
	0.09			0.41	6.16			0.09			0.32			0.00	<	0.02	0.01	<	0.005
	0.01			0.22	0.30			0.01	<	0.01	0.01			0.00	<	0.02	0.01	<	0.005
	0.11			0.54	0.37	<	0.01	0.01	<	0.01	0.01			0.00	<	0.02	0.01	<	0.005
	0.39			0.21	0.62			0.02			0.03			1.28			1.28	<	0.005
	0.19			0.06	5.58	<	0.01	0.01			0.04	••		1.24			1.24	<	0.005
	0.01			0.06	0.57			0.02	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.01			0.04	2.39			0.28			0.05			0.11			0.11	<	0.005
	0.02			0.12	5.73			2.18			1.95	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.03			0.31	8.67			0.15			0.14			0.53			0.49		
	0.12			0.08	4.78			0.06			0.03			0.10			0.10	<	0.005
	0.01			0.99	0.83			0.03			0.02			0.00			0.02	<	0.005
	0.18			0.60	0.41			0.01			0.05			0.00			0.20	<	0.005
	0.02			0.27	5.43			0.07			0.01			0.00			0.05		
	0.07	<	0.03	0.02	1.28	<	0.01	0.01			0.08			0.78			0.78	<	0.005
	0.05			0.07	6.29			0.02			0.05			0.00			1.20		
	0.57			0.21	6.42			0.01			0.04			0.00			1.98	<	0.005
	0.00			0.50	1.40			0.00			0.00			0.00			0.00	<	0.020
	0.01			0.09	0.08	<	0.01	0.01	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.01			0.09	0.01	<	0.01	0.01	<	0.01	0.01	<	0.02	0.01	<	0.02	0.01	<	0.005
	0.09			0.12	5.89			0.83	<	0.01	0.01			0.03			0.03	<	0.005
	[illegible]			[illegible]	[illegible]			[illegible]			[illegible]			[illegible]			4.24		

Parameter:	Nitrogen NO2 Diss (N)	Well Number	Lab Form Number
units:	mg/L		
	0.003		1003370
	0.003		103554W
	0.003		1002203
	0.007		1001256
	0.003		1000658
	0.003		1001783
	0.003		1001272
	0.003		1001271
	0.003		1001134
	0.003		209856W
	0.003		316184W
	0.003		87010546
	0.003		210647W
	0.003		207356W
	0.003		108587W
	0.003		88014873
	0.003		88015573
	0.003		88008297
	0.015		88009259
	0.003		88009811
	0.003		88003668
	0.003		88000404
	0.003		88002667
	0.003		200019W
	0.003		304259W
	0.003		405171W
	0.003		413659W
	0.003		302150W
	0.003		300143
	0.003		300140
	0.003		1002901
	0.003		1002923
	0.003		1002496
	0.043		1002511
	0.003		1002894
	0.003		302796W
	0.003		216810W
	0.006		213767W
	0.003		1003368
	0.024		2022684W
	0.003		201784W
	0.010		200771W
	0.003		1002206
	0.003		1003703
	0.003		1001721
	0.014		1001746

Appendix IV - B

SEAM DATA - 1990 - 1992

S E A M
MINISTRY OF ENVIRONMENT AND PARKS
HISTORICAL STATISTICS REPORT
Sorted by Site Number

SEAM Historical Statistics File

Site : 0125180 - NANAIMO R. AT HIGHWAY #1
Region : 01 - VANCOUVER ISLAND
Est. Ag. : 10 - VANCOUVER ISLAND, NANAIMO

Site Type : 21 RIVER,STREAM OR CREEK
No. Days Visited : 69
First Date Visited : 84/03/29
Most Recent Date Visited : 92/12/02

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No Obs. (Used)
FW	0002 Color True	Col.unit	5.000	5.000	5.000	**************	89/11/21	1	[illegible]
FW	0004 pH	pH units	8.000	6.800	7.217	0.3094	92/11/09	36	36
FW	0008 Residue Nonfilt.	mg/L	5.000	1.000	1.733	1.4376	92/12/02	27	1[illegible]
FW	0011 Specific Conductance	uS/cm	56.000	35.000	43.333	**************	92/03/10	3	
FW	0013 Temperature	C	20.000	6.600	10.220	4.8839	91/12/10	10	1[illegible]
FW	0014 Oxygen Dissolved	mg/L	9.600	7.900	8.987	**************	91/07/29	3	3
FW	0015 Turbidity	NTU	4.600	0.300	0.884	0.8143	92/12/02	28	28
FW	0102 Alkalinity Total 4.5	mg/L	19.700	11.900	15.732	2.3850	92/11/09	25	2[illegible]
FW	0113 Nitrogen Kjel.Tot(N)	mg/L	0.070	0.070	0.070	**************	89/08/29	1	
FW	0147 E Coli	CFU/cL	118.000	10.000	53.000	**************	90/08/29	3	[illegible]
FW	0148 Enterococcus	CFU/cL	33.000	8.000	17.000	**************	90/08/29	3	3
FW	0450 Coliform - Fecal	CFU/cL	106.000	1.000	17.091	30.8479	92/08/24	11	1[illegible]
FW	1104 Chloride Dissolved	mg/L	2.600	2.600	2.600	**************	89/11/21	1	
FW	1107 Hardness Dissolved	mg/L	13.100	12.400	12.750	**************	90/04/24	2	
FW	1108 Nitrogen Amm.Diss(N)	mg/L	0.021	0.005	0.010	0.0055	92/11/09	30	11
FW	1109 Nitrogen NO3+NO2 Dis	mg/L	0.070	0.020	0.034	0.0114	92/11/09	33	22
FW	1118 Phosphorus Ort.Dis-P	mg/L	*************	*************	*************	**************	92/11/09	31	
FW	1120 Silica Reactive Diss	mg/L	4.300	4.300	4.300	**************	89/11/21	1	
FW	1121 Sulfate Dissolved	mg/L	1.600	1.400	1.500	**************	89/11/21	2	[illegible]
FW	Ag-D Silver Dissolved	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Ag-T Silver	mg/L	*************	*************	*************	**************	92/12/02	9	[illegible]
FW	Ag-T Silver	None	*************	*************	*************	**************	92/02/06	1	
FW	Al-D Aluminum Dissolved	mg/L	0.130	0.030	0.088	0.0314	92/12/02	35	1
FW	Al-T Aluminum	mg/L	0.260	0.020	0.090	0.0772	92/12/02	34	21
FW	Al-T Aluminum	None	0.330	0.330	0.330	**************	92/02/06	1	1
FW	As-D Arsenic Dissolved	None	*************	*************	*************	**************	92/02/06	1	
FW	As-D Arsenic Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	
FW	As-T Arsenic	None	*************	*************	*************	**************	92/02/06	1	[illegible]
FW	As-T Arsenic	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	B--D Boron Dissolved	mg/L	0.020	0.010	0.011	0.0029	92/12/02	35	1[illegible]
FW	B--D Boron Dissolved	None	*************	*************	*************	**************	92/02/06	1	
FW	B--T Boron	mg/L	0.090	0.010	0.055	0.0232	92/12/02	9	
FW	B--T Boron	None	0.050	0.050	0.050	**************	92/02/06	1	1
FW	Ba-D Barium Dissolved	mg/L	0.010	0.000	0.005	0.0050	92/12/02	35	11
FW	Ba-D Barium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	
FW	Ba-T Barium	mg/L	0.020	0.000	0.007	0.0062	92/12/02	34	1
FW	Ba-T Barium	None	0.010	0.010	0.010	**************	92/02/06	1	[illegible]
FW	Be-D Beryllium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Be-D Beryllium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	[illegible]
FW	Be-T Beryllium	None	*************	*************	*************	**************	92/02/06	1	
FW	Be-T Beryllium	mg/L	*************	*************	*************	**************	92/12/02	9	
FW	Bi-D Bismuth Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Bi-D Bismuth Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-T Bismuth	None	*************	*************	*************	**************	92/02/06	1	

S E A M
MINISTRY OF ENVIRONMENT AND PARKS
HISTORICAL STATISTICS REPORT
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SEAM Historical Statistics File

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	Bi-T Bismuth	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Ca-D Calcium Dissolved	None	3.480	3.480	3.480	**************	92/02/06	1	1
FW	Ca-D Calcium Dissolved	mg/L	7.990	4.140	5.501	1.0818	92/12/02	35	35
FW	Ca-T Calcium	None	3.510	3.510	3.510	**************	92/02/06	1	1
FW	Ca-T Calcium	mg/L	8.250	4.180	5.635	1.1381	92/12/02	35	35
FW	Cd-D Cadmium Dissolved	mg/L	0.010	0.000	0.005	**************	92/12/02	8	2
FW	Cd-T Cadmium	None	0.000	0.000	0.000	**************	92/11/16	1	1
FW	Cd-T Cadmium	mg/L	0.002	0.000	0.001	**************	92/12/02	7	2
FW	Co-D Cobalt Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-D Cobalt Dissolved	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	Co-T Cobalt	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	Co-T Cobalt	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-D Chromium Dissolved	mg/L	0.000	0.000	0.000	**************	92/12/02	35	1
FW	Cr-D Chromium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-T Chromium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-T Chromium	mg/L	0.040	0.000	0.020	**************	92/12/02	35	2
FW	Cu-D Copper Dissolved	mg/L	0.004	0.000	0.001	0.0011	92/12/02	35	25
FW	Cu-T Copper	mg/L	0.004	0.000	0.002	0.0012	92/12/02	38	28
FW	Fe-D Iron Dissolved	None	0.050	0.050	0.050	**************	92/02/06	1	1
FW	Fe-D Iron Dissolved	mg/L	0.330	0.020	0.055	0.0510	92/12/02	35	35
FW	Fe-T Iron	None	0.230	0.230	0.230	**************	92/02/06	1	1
FW	Fe-T Iron	mg/L	0.510	0.040	0.098	0.0838	92/12/02	35	35
FW	K--D Potassium Dissolved	mg/L	0.600	0.600	0.600	**************	92/08/24	4	1
FW	K--D Potassium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	K--T Potassium	mg/L	*************	*************	*************	**************	92/08/24	4	0
FW	K--T Potassium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mg-D Magnesium Dissolved	None	0.460	0.460	0.460	**************	92/02/06	1	1
FW	Mg-D Magnesium Dissolved	mg/L	0.830	0.470	0.583	0.0852	92/12/02	35	35
FW	Mg-T Magnesium	None	0.470	0.470	0.470	**************	92/02/06	1	1
FW	Mg-T Magnesium	mg/L	0.840	0.480	0.602	0.0884	92/12/02	35	35
FW	Mn-D Manganese Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Mn-D Manganese Dissolved	mg/L	0.030	0.000	0.008	0.0089	92/12/02	35	10
FW	Mn-T Manganese	mg/L	0.040	0.000	0.011	0.0111	92/12/02	35	14
FW	Mn-T Manganese	None	0.010	0.010	0.010	**************	92/02/06	1	1
FW	Mo-D Molybdenum Dissolved	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	Mo-D Molybdenum Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-T Molybdenum	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-T Molybdenum	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	Na-D Sodium Dissolved	mg/L	4.240	2.380	3.410	0.7875	92/08/24	4	4
FW	Na-D Sodium Dissolved	None	1.470	1.470	1.470	**************	92/02/06	1	1
FW	Na-T Sodium	None	1.520	1.520	1.520	**************	92/02/06	1	1
FW	Na-T Sodium	mg/L	4.370	2.370	3.582	0.8581	92/08/24	4	4
FW	Ni-D Nickel Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-D Nickel Dissolved	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	Ni-T Nickel	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-T Nickel	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	P--D Phosphorus Tot. Diss	mg/L	*************	*************	*************	**************	92/08/24	8	0
FW	P--D Phosphorus Tot. Diss	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	mg/L	0.007	0.003	0.005	**************	92/08/24	6	2

SEAM Historical Statistics File

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	Pb-D Lead Dissolved	mg/L	0.002	0.001	0.001	0.0005	92/12/02	37	[illegible]
FW	Pb-T Lead	mg/L	0.007	0.001	0.002	0.0014	92/12/02	38	[illegible]
FW	S--D Sulfur Dissolved	mg/L	0.530	0.040	0.365	0.2207	92/08/24	4	[illegible]
FW	S--D Sulfur Dissolved	None	0.470	0.470	0.470	**************	92/02/08	1	1
FW	S--T Sulfur Total	None	0.400	0.400	0.400	**************	92/02/08	1	1
FW	S--T Sulfur Total	mg/L	0.600	0.400	0.500	0.0816	92/08/24	4	[illegible]
FW	Sb-D Antimony Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Sb-D Antimony Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Sb-T Antimony	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Sb-T Antimony	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Se-D Selenium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Se-D Selenium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	[illegible]
FW	Se-T Selenium	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Se-T Selenium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Si-D Silicon Dissolved	mg/L	2.240	1.700	1.980	0.2186	92/12/02	8	[illegible]
FW	Si-D Silicon Dissolved	None	1.900	1.900	1.900	**************	92/02/08	1	[illegible]
FW	Si-T Silicon	mg/L	2.400	1.700	2.072	0.2195	92/12/02	9	9
FW	Si-T Silicon	None	2.300	2.300	2.300	**************	92/02/08	1	1
FW	Sn-D Tin Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Sn-D Tin Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	[illegible]
FW	Sn-T Tin	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Sn-T Tin	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Sr-D Strontium Dissolved	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Sr-D Strontium Dissolved	mg/L	0.023	0.000	0.003	0.0081	92/12/02	8	[illegible]
FW	Sr-T Strontium	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW	Sr-T Strontium	mg/L	0.022	0.000	0.002	0.0073	92/12/02	9	9
FW	Te-D Tellerium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Te-D Tellerium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	[illegible]
FW	Te-T Tellurium	mg/L	0.000	0.000	0.000	**************	92/12/02	9	[illegible]
FW	Te-T Tellurium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Ti-D Titanium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Ti-D Titanium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ti-T Titanium	mg/L	*************	*************	*************	**************	92/12/02	9	[illegible]
FW	Ti-T Titanium	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW	Tl-D Thallium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Tl-D Thallium Dissolved	mg/L	0.008	0.000	0.003	**************	92/12/02	8	3
FW	Tl-T Thallium	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW	Tl-T Thallium	mg/L	0.000	0.000	0.000	**************	92/12/02	9	[illegible]
FW	V--D Vanadium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	V--D Vanadium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	35	0
FW	V--T Vanadium	mg/L	0.010	0.000	0.005	**************	92/12/02	35	2
FW	V--T Vanadium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Zn-D Zinc Dissolved	mg/L	0.011	0.000	0.005	0.0040	92/12/02	35	[illegible]
FW	Zn-T Zinc	mg/L	0.180	0.000	0.023	0.0522	92/12/02	38	19
FW	Zr-D Zirconium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Zr-D Zirconium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Zr-T Zirconium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW	Zr-T Zirconium	mg/L	*************	*************	*************	**************	92/12/02	9	[illegible]

SEAM Historical Statistics File

TOTAL NUMBER OF PARAMETERS FOR SITE 0125180 : 142

Site : E208103 - NANAIMO RIVER AT RIVER CAMP BRIDGE

Region : 01 - VANCOUVER ISLAND
Est. Ag. : 10 - VANCOUVER ISLAND, NANAIMO

Site Type : 21 RIVER,STREAM OR CREEK
No. Days Visited : 53
First Date Visited : 90/04/19
Most Recent Date Visited : 92/12/02

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	0004 pH	pH units	7.800	6.800	7.147	0.2856	92/11/09	36	36
FW	0008 Residue Nonfilt.	mg/L	10.000	1.000	2.214	2.7508	92/12/02	26	14
FW	0011 Specific Conductance	uS/cm	31.000	31.000	31.000	**************	92/03/10	1	1
FW	0013 Temperature	C	20.400	6.000	9.700	4.8878	91/12/10	11	11
FW	0014 Oxygen Dissolved	mg/L	10.600	9.700	10.075	0.4113	91/11/14	4	4
FW	0015 Turbidity	NTU	5.600	0.200	0.786	0.9578	92/12/02	29	29
FW	0102 Alkalinity Total 4.5	mg/L	19.600	11.800	15.412	1.7303	92/11/09	26	26
FW	0147 E Coli	CFU/cL	2.000	1.000	1.500	0.5774	90/08/29	4	4
FW	0148 Enterococcus	CFU/cL	15.000	1.000	8.667	**************	90/08/29	4	3
FW	0450 Coliform - Fecal	CFU/cL	48.000	1.000	7.600	14.6075	92/08/24	14	10
FW	1108 Nitrogen Amm.Diss(N)	mg/L	0.042	0.005	0.011	0.0099	92/11/09	28	14
FW	1109 Nitrogen NO3+NO2 Dis	mg/L	0.060	0.020	0.035	0.0151	92/11/09	32	14
FW	1118 Phosphorus Ort.Dis-P	mg/L	*************	*************	*************	**************	92/11/09	32	0
FW	Ag-D Silver Dissolved	mg/L	*************	*************	*************	**************	92/03/10	2	0
FW	Ag-T Silver	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Ag-T Silver	None	*************	*************	*************	**************	92/02/06	1	0
FW	Al-D Aluminum Dissolved	mg/L	0.140	0.030	0.063	0.0309	92/03/10	20	13
FW	Al-T Aluminum	None	0.360	0.360	0.360	**************	92/02/06	1	1
FW	Al-T Aluminum	mg/L	0.530	0.050	0.126	0.1348	92/03/10	19	14
FW	As-D Arsenic Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	As-D Arsenic Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	As-T Arsenic	None	*************	*************	*************	**************	92/02/06	1	0
FW	As-T Arsenic	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	B--D Boron Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	B--D Boron Dissolved	mg/L	0.010	0.010	0.010	0.0000	92/03/10	19	9
FW	B--T Boron	mg/L	0.070	0.070	0.070	**************	92/03/10	1	1
FW	B--T Boron	None	0.090	0.090	0.090	**************	92/02/06	1	1
FW	Ba-D Barium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Ba-D Barium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	19	1
FW	Ba-T Barium	None	0.010	0.010	0.010	**************	92/02/06	1	1
FW	Ba-T Barium	mg/L	0.000	0.000	0.000	**************	92/03/10	19	1
FW	Be-D Beryllium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Be-D Beryllium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Be-T Beryllium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Be-T Beryllium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-D Bismuth Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Bi-D Bismuth Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-T Bismuth	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Bi-T Bismuth	None	*************	*************	*************	**************	92/02/06	1	0

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Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	Ca-D Calcium Dissolved	None	3.220	3.220	3.220	**************	92/02/06	1	1
FW	Ca-D Calcium Dissolved	mg/L	6.130	4.240	5.083	0.5808	92/03/10	19	9
FW	Ca-T Calcium	None	3.290	3.290	3.290	**************	92/02/06	1	1
FW	Ca-T Calcium	mg/L	6.150	4.260	5.120	0.6100	92/03/10	19	19
FW	Cd-D Cadmium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Cd-T Cadmium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Co-D Cobalt Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-D Cobalt Dissolved	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Co-T Cobalt	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-T Cobalt	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Cr-D Chromium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-D Chromium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Cr-T Chromium	mg/L	0.000	0.000	0.000	**************	92/03/10	19	1
FW	Cr-T Chromium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cu-D Copper Dissolved	mg/L	0.006	0.000	0.002	0.0015	92/03/10	19	12
FW	Cu-T Copper	mg/L	0.004	0.000	0.002	0.0010	92/03/10	20	15
FW	Fe-D Iron Dissolved	None	0.050	0.050	0.050	**************	92/02/06	1	1
FW	Fe-D Iron Dissolved	mg/L	0.120	0.030	0.058	0.0251	92/03/10	19	19
FW	Fe-T Iron	None	0.300	0.300	0.300	**************	92/02/06	1	1
FW	Fe-T Iron	mg/L	0.590	0.060	0.134	0.1251	92/03/10	19	9
FW	K--D Potassium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	K--D Potassium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	K--T Potassium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	K--T Potassium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mg-D Magnesium Dissolved	None	0.410	0.410	0.410	**************	92/02/06	1	1
FW	Mg-D Magnesium Dissolved	mg/L	0.570	0.480	0.520	0.0269	92/03/10	19	19
FW	Mg-T Magnesium	None	0.490	0.490	0.490	**************	92/02/06	1	1
FW	Mg-T Magnesium	mg/L	0.610	0.480	0.537	0.0333	92/03/10	19	19
FW	Mn-D Manganese Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Mn-D Manganese Dissolved	mg/L	0.050	0.010	0.018	0.0140	92/03/10	19	10
FW	Mn-T Manganese	None	0.010	0.010	0.010	**************	92/02/06	1	1
FW	Mn-T Manganese	mg/L	0.060	0.010	0.018	0.0129	92/03/10	19	17
FW	Mo-D Molybdenum Dissolved	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Mo-D Molybdenum Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-T Molybdenum	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Mo-T Molybdenum	None	*************	*************	*************	**************	92/02/06	1	0
FW	Na-D Sodium Dissolved	None	0.960	0.960	0.960	**************	92/02/06	1	1
FW	Na-D Sodium Dissolved	mg/L	1.310	1.310	1.310	**************	92/03/10	1	1
FW	Na-T Sodium	None	1.090	1.090	1.090	**************	92/02/06	1	1
FW	Na-T Sodium	mg/L	1.420	1.420	1.420	**************	92/03/10	1	1
FW	Ni-D Nickel Dissolved	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	Ni-D Nickel Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-T Nickel	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-T Nickel	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	P--D Phosphorus Tot. Diss	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	P--D Phosphorus Tot. Diss	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Pb-D Lead Dissolved	mg/L	0.001	0.001	0.001	**************	92/03/10	20	2
FW	Pb-T Lead	mg/L	0.004	0.001	0.002	0.0013	92/03/10	20	6

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Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	S--D Sulfur Dissolved	None	0.290	0.290	0.290	**************	92/02/08	1	1
FW	S--D Sulfur Dissolved	mg/L	0.320	0.320	0.320	**************	92/03/10	1	1
FW	S--T Sulfur Total	mg/L	0.300	0.300	0.300	**************	92/03/10	1	1
FW	S--T Sulfur Total	None	0.300	0.300	0.300	**************	92/02/08	1	1
FW	Sb-D Antimony Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Sb-D Antimony Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sb-T Antimony	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sb-T Antimony	None	*************	*************	*************	**************	92/02/08	1	0
FW	Se-D Selenium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Se-D Selenium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Se-T Selenium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Se-T Selenium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Si-D Silicon Dissolved	None	1.700	1.700	1.700	**************	92/02/08	1	1
FW	Si-D Silicon Dissolved	mg/L	1.800	1.800	1.800	**************	92/03/10	1	1
FW	Si-T Silicon	mg/L	2.100	2.100	2.100	**************	92/03/10	1	1
FW	Si-T Silicon	None	2.300	2.300	2.300	**************	92/02/08	1	1
FW	Sn-D Tin Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Sn-D Tin Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sn-T Tin	None	*************	*************	*************	**************	92/02/08	1	0
FW	Sn-T Tin	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sr-D Strontium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Sr-D Strontium Dissolved	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Sr-T Strontium	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Sr-T Strontium	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Te-D Tellerium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Te-D Tellerium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Te-T Tellurium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Te-T Tellurium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ti-D Titanium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ti-D Titanium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Ti-T Titanium	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Ti-T Titanium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Tl-D Thallium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Tl-D Thallium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Tl-T Thallium	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Tl-T Thallium	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	V--D Vanadium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	V--D Vanadium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	V--T Vanadium	mg/L	*************	*************	*************	**************	92/03/10	19	0
FW	V--T Vanadium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Zn-D Zinc Dissolved	mg/L	*************	*************	*************	**************	92/03/10	20	0
FW	Zn-T Zinc	mg/L	0.010	0.008	0.008	0.0020	92/03/10	20	5
FW	Zr-D Zirconium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Zr-D Zirconium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Zr-T Zirconium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Zr-T Zirconium	None	*************	*************	*************	**************	92/02/08	1	0

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TOTAL NUMBER OF PARAMETERS FOR SITE E208103 : 135

Site : E208104 - NANAIMO RIVER SOUTH FORK

Region : 01 - VANCOUVER ISLAND
Est. Ag. : 10 - VANCOUVER ISLAND, NANAIMO

Site Type : 21 RIVER,STREAM OR CREEK
No. Days Visited : 50
First Date Visited : 90/04/19
Most Recent Date Visited : 92/12/02

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	0004 pH	pH units	8.000	6.700	7.124	0.2829	92/11/09	34	[illegible]
FW	0008 Residue Nonfilt.	mg/L	2.000	1.000	1.308	0.4804	92/12/02	25	13
FW	0011 Specific Conductance	uS/cm	30.000	26.000	28.000	**************	92/03/10	2	[illegible]
FW	0013 Temperature	C	17.000	5.000	8.370	3.8381	91/12/10	10	
FW	0014 Oxygen Dissolved	mg/L	13.000	10.000	11.450	1.6763	91/11/14	4	
FW	0015 Turbidity	NTU	1.100	0.200	0.481	0.2288	92/12/02	27	27
FW	0102 Alkalinity Total 4.5	mg/L	17.900	9.700	13.987	2.6915	92/11/09	24	24
FW	0113 Nitrogen Kjel.Tot(N)	mg/L	0.100	0.100	0.100	**************	90/05/09	1	[illegible]
FW	0147 E Coli	CFU/cL	38.000	8.000	25.250	12.6853	90/08/29	4	[illegible]
FW	0148 Enterococcus	CFU/cL	89.000	4.000	35.750	36.8806	90/08/29	4	[illegible]
FW	0450 Coliform - Fecal	CFU/cL	62.000	1.000	12.636	19.1169	92/08/24	14	11
FW	1108 Nitrogen Amm.Diss(N)	mg/L	0.021	0.005	0.008	0.0051	92/11/09	27	[illegible]
FW	1109 Nitrogen NO3+NO2 Dis	mg/L	0.060	0.020	0.035	0.0144	92/11/09	30	[illegible]
FW	1118 Phosphorus Ort.Dis-P	mg/L	*************	*************	*************	**************	92/11/09	30	[illegible]
FW	Ag-D Silver Dissolved	mg/L	*************	*************	*************	**************	92/03/10	2	0
FW	Ag-T Silver	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Ag-T Silver	None	*************	*************	*************	**************	92/02/06	1	[illegible]
FW	Al-D Aluminum Dissolved	mg/L	0.050	0.020	0.047	0.0095	92/03/10	17	[illegible]
FW	Al-T Aluminum	mg/L	0.390	0.050	0.104	0.0860	92/03/10	16	[illegible]
FW	Al-T Aluminum	None	0.090	0.090	0.090	**************	92/02/06	1	1
FW	As-D Arsenic Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	As-D Arsenic Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW	As-T Arsenic	None	*************	*************	*************	**************	92/02/06	1	[illegible]
FW	As-T Arsenic	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	B--D Boron Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	B--D Boron Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	[illegible]
FW	B--T Boron	mg/L	0.050	0.050	0.050	**************	92/03/10	1	1
FW	B--T Boron	None	0.090	0.090	0.090	**************	92/02/06	1	1
FW	Ba-D Barium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Ba-D Barium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	16	1
FW	Ba-T Barium	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Ba-T Barium	mg/L	0.000	0.000	0.000	**************	92/03/10	16	1
FW	Be-D Beryllium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Be-D Beryllium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Be-T Beryllium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Be-T Beryllium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-D Bismuth Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Bi-D Bismuth Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-T Bismuth	mg/L	*************	*************	*************	**************	92/03/10	1	0

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Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	Bi-T Bismuth	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ca-D Calcium Dissolved	None	2.570	2.570	2.570	**************	92/02/08	1	1
FW	Ca-D Calcium Dissolved	mg/L	6.340	2.990	4.634	1.1588	92/03/10	16	16
FW	Ca-T Calcium	mg/L	6.200	2.990	4.686	1.1266	92/03/10	16	16
FW	Ca-T Calcium	None	2.610	2.610	2.610	**************	92/02/08	1	1
FW	Cd-D Cadmium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Cd-D Cadmium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Cd-T Cadmium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Cd-T Cadmium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Co-D Cobalt Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Co-D Cobalt Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Co-T Cobalt	None	*************	*************	*************	**************	92/02/08	1	0
FW	Co-T Cobalt	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Cr-D Chromium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Cr-D Chromium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Cr-T Chromium	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Cr-T Chromium	None	*************	*************	*************	**************	92/02/08	1	0
FW	Cu-D Copper Dissolved	mg/L	0.002	0.001	0.001	0.0003	92/03/10	17	11
FW	Cu-T Copper	mg/L	0.060	0.000	0.008	0.0156	92/03/10	17	14
FW	Fe-D Iron Dissolved	mg/L	0.210	0.010	0.069	0.0897	92/03/10	16	16
FW	Fe-D Iron Dissolved	None	0.030	0.030	0.030	**************	92/02/08	1	1
FW	Fe-T Iron	mg/L	0.310	0.020	0.126	0.1035	92/03/10	16	16
FW	Fe-T Iron	None	0.040	0.040	0.040	**************	92/02/08	1	1
FW	K--D Potassium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	K--D Potassium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	K--T Potassium	None	*************	*************	*************	**************	92/02/08	1	0
FW	K--T Potassium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Mg-D Magnesium Dissolved	mg/L	0.620	0.360	0.461	0.0843	92/03/10	16	16
FW	Mg-D Magnesium Dissolved	None	0.330	0.330	0.330	**************	92/02/08	1	1
FW	Mg-T Magnesium	None	0.340	0.340	0.340	**************	92/02/08	1	1
FW	Mg-T Magnesium	mg/L	0.620	0.370	0.474	0.0844	92/03/10	16	16
FW	Mn-D Manganese Dissolved	mg/L	0.010	0.000	0.005	**************	92/03/10	16	2
FW	Mn-D Manganese Dissolved	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Mn-T Manganese	mg/L	0.020	0.000	0.010	**************	92/03/10	16	2
FW	Mn-T Manganese	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW	Mo-D Molybdenum Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Mo-D Molybdenum Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Mo-T Molybdenum	None	*************	*************	*************	**************	92/02/08	1	0
FW	Mo-T Molybdenum	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Na-D Sodium Dissolved	mg/L	1.260	1.260	1.260	**************	92/03/10	1	1
FW	Na-D Sodium Dissolved	None	0.910	0.910	0.910	**************	92/02/08	1	1
FW	Na-T Sodium	mg/L	1.260	1.260	1.260	**************	92/03/10	1	1
FW	Na-T Sodium	None	0.970	0.970	0.970	**************	92/02/08	1	1
FW	Ni-D Nickel Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	Ni-D Nickel Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ni-T Nickel	None	*************	*************	*************	**************	92/02/08	1	0
FW	Ni-T Nickel	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW	P--D Phosphorus Tot. Diss	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	P--D Phosphorus Tot. Diss	None	*************	*************	*************	**************	92/02/08	1	0
FW	P--T Phosphorus Total	None	*************	*************	*************	**************	92/02/08	1	0

SEAM Historical Statistics File

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Ct (Us
FW P--T	Phosphorus Total	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Pb-D	Lead Dissolved	mg/L	0.002	0.001	0.002	**************	92/03/10	17	[illegible]
FW Pb-T	Lead	mg/L	0.004	0.001	0.002	0.0012	92/03/10	17	[illegible]
FW S--D	Sulfur Dissolved	mg/L	0.320	0.320	0.320	**************	92/03/10	1	[illegible]
FW S--D	Sulfur Dissolved	None	0.280	0.280	0.280	**************	92/02/08	1	1
FW S--T	Sulfur Total	mg/L	0.300	0.300	0.300	**************	92/03/10	1	[illegible]
FW S--T	Sulfur Total	None	0.300	0.300	0.300	**************	92/02/08	1	[illegible]
FW Sb-D	Antimony Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Sb-D	Antimony Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Sb-T	Antimony	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Sb-T	Antimony	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Se-D	Selenium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Se-D	Selenium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Se-T	Selenium	None	*************	*************	*************	**************	92/02/08	1	0
FW Se-T	Selenium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Si-D	Silicon Dissolved	mg/L	2.000	2.000	2.000	**************	92/03/10	1	[illegible]
FW Si-D	Silicon Dissolved	None	1.800	1.800	1.800	**************	92/02/08	1	[illegible]
FW Si-T	Silicon	None	2.000	2.000	2.000	**************	92/02/08	1	1
FW Si-T	Silicon	mg/L	2.300	2.300	2.300	**************	92/03/10	1	1
FW Sn-D	Tin Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Sn-D	Tin Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Sn-T	Tin	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Sn-T	Tin	None	*************	*************	*************	**************	92/02/08	1	0
FW Sr-D	Strontium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW Sr-D	Strontium Dissolved	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW Sr-T	Strontium	mg/L	0.000	0.000	0.000	**************	92/03/10	1	[illegible]
FW Sr-T	Strontium	None	0.000	0.000	0.000	**************	92/02/08	1	1
FW Te-D	Tellerium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Te-D	Tellerium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Te-T	Tellurium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Te-T	Tellurium	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Ti-D	Titanium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW Ti-D	Titanium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Ti-T	Titanium	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Ti-T	Titanium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Tl-D	Thallium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW Tl-D	Thallium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW Tl-T	Thallium	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW Tl-T	Thallium	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW V--D	Vanadium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	16	[illegible]
FW V--D	Vanadium Dissolved	None	*************	*************	*************	**************	92/02/08	1	0
FW V--T	Vanadium	mg/L	*************	*************	*************	**************	92/03/10	16	0
FW V--T	Vanadium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Zn-D	Zinc Dissolved	None	0.000	0.000	0.000	**************	92/02/08	1	[illegible]
FW Zn-D	Zinc Dissolved	mg/L	0.005	0.005	0.005	**************	92/03/10	16	1
FW Zn-T	Zinc	mg/L	0.030	0.000	0.010	0.0116	92/03/10	17	5
FW Zr-D	Zirconium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	[illegible]
FW Zr-D	Zirconium Dissolved	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Zr-T	Zirconium	None	*************	*************	*************	**************	92/02/08	1	[illegible]
FW Zr-T	Zirconium	mg/L	*************	*************	*************	**************	92/03/10	1	0

SEAM Historical Statistics File

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
PT 0143	Chlorophyll A	ug/cm2	6.520	3.890	5.446	1.0982	90/09/27	5	5
PT 0460	Biomass	mg	120.000	77.000	96.333	**************	90/09/27	3	3
PT 0462	Biomass Ash- Free Wt	mg	86.000	53.000	67.667	**************	90/09/27	3	3

TOTAL NUMBER OF PARAMETERS FOR SITE E208104 : 142

Site : E208105 - NANAIMO RIVER AT TEEPEE BRIDGE

Region : 01 - VANCOUVER ISLAND
Est. Ag. : 10 - VANCOUVER ISLAND, NANAIMO

Site Type : 21 RIVER,STREAM OR CREEK
No. Days Visited : 47
First Date Visited : 90/04/19
Most Recent Date Visited : 92/12/02

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW 0004	pH	pH units	7.800	6.800	7.179	0.2728	92/11/09	34	34
FW 0008	Residue Nonfilt.	mg/L	2.000	1.000	1.375	0.5175	92/12/02	23	8
FW 0011	Specific Conductance	uS/cm	35.000	35.000	35.000	**************	92/03/10	1	1
FW 0013	Temperature	C	16.900	4.300	9.133	4.6877	91/12/10	9	9
FW 0014	Oxygen Dissolved	mg/L	10.000	9.100	9.633	**************	91/07/29	3	3
FW 0015	Turbidity	NTU	1.200	0.100	0.342	0.2436	92/12/02	26	26
FW 0102	Alkalinity Total 4.5	mg/L	24.500	10.600	16.284	3.4454	92/11/09	25	25
FW 0147	E Coli	CFU/cL	9.000	1.000	5.000	**************	90/08/29	3	2
FW 0148	Enterococcus	CFU/cL	104.000	17.000	54.667	**************	90/08/29	3	3
FW 0450	Coliform - Fecal	CFU/cL	16.000	1.000	4.667	5.0249	92/08/24	10	9
FW 1108	Nitrogen Amm.Diss(N)	mg/L	0.010	0.005	0.007	0.0019	92/11/09	28	9
FW 1109	Nitrogen NO3+NO2 Dis	mg/L	0.060	0.020	0.032	0.0116	92/11/09	31	20
FW 1118	Phosphorus Ort.Dis-P	mg/L	*************	*************	*************	**************	92/11/09	31	0
FW Ag-D	Silver Dissolved	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW Ag-T	Silver	None	*************	*************	*************	**************	92/02/06	1	0
FW Ag-T	Silver	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW Al-D	Aluminum Dissolved	mg/L	0.050	0.020	0.043	0.0123	92/12/02	30	12
FW Al-T	Aluminum	mg/L	0.210	0.030	0.079	0.0502	92/12/02	31	18
FW Al-T	Aluminum	None	0.080	0.080	0.080	**************	92/02/06	1	1
FW As-D	Arsenic Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW As-D	Arsenic Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW As-T	Arsenic	None	*************	*************	*************	**************	92/02/06	1	0
FW As-T	Arsenic	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW B--D	Boron Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW B--D	Boron Dissolved	mg/L	0.012	0.010	0.010	0.0007	92/12/02	29	9
FW B--T	Boron	mg/L	0.100	0.010	0.056	0.0329	92/12/02	9	9
FW B--T	Boron	None	0.050	0.050	0.050	**************	92/02/06	1	1
FW Ba-D	Barium Dissolved	mg/L	0.010	0.000	0.005	0.0050	92/12/02	29	11
FW Ba-D	Barium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW Ba-T	Barium	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW Ba-T	Barium	mg/L	0.010	0.000	0.007	0.0045	92/12/02	31	12
FW Be-D	Beryllium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW Be-D	Beryllium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW Be-T	Beryllium	None	*************	*************	*************	**************	92/02/06	1	0
FW Be-T	Beryllium	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW Bi-D	Bismuth Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0

SEAM Historical Statistics File

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Us..)
FW	Bi-D Bismuth Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-T Bismuth	None	*************	*************	*************	**************	92/02/06	1	0
FW	Bi-T Bismuth	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Ca-D Calcium Dissolved	mg/L	11.300	3.440	5.644	1.8872	92/12/02	29	29
FW	Ca-D Calcium Dissolved	None	4.480	4.480	4.480	**************	92/02/06	1	1
FW	Ca-T Calcium	mg/L	11.700	3.530	5.663	1.8719	92/12/02	31	1
FW	Ca-T Calcium	None	4.510	4.510	4.510	**************	92/02/06	1	1
FW	Cd-D Cadmium Dissolved	mg/L	0.010	0.001	0.007	**************	92/12/02	7	3
FW	Cd-T Cadmium	None	0.000	0.000	0.000	**************	92/11/16	1	1
FW	Cd-T Cadmium	mg/L	0.000	0.000	0.000	**************	92/12/02	6	1
FW	Co-D Cobalt Dissolved	mg/L	*************	*************	*************	**************	92/12/02	29	0
FW	Co-D Cobalt Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-T Cobalt	mg/L	0.000	0.000	0.000	**************	92/12/02	31	2
FW	Co-T Cobalt	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-D Chromium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-D Chromium Dissolved	mg/L	0.000	0.000	0.000	**************	92/12/02	29	2
FW	Cr-T Chromium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-T Chromium	mg/L	0.000	0.000	0.000	**************	92/12/02	31	2
FW	Cu-D Copper Dissolved	mg/L	0.007	0.000	0.001	0.0017	92/12/02	30	22
FW	Cu-T Copper	mg/L	0.005	0.000	0.002	0.0013	92/12/02	32	3
FW	Fe-D Iron Dissolved	None	0.020	0.020	0.020	**************	92/02/06	1	1
FW	Fe-D Iron Dissolved	mg/L	0.150	0.010	0.032	0.0307	92/12/02	29	27
FW	Fe-T Iron	None	0.030	0.030	0.030	**************	92/02/06	1	1
FW	Fe-T Iron	mg/L	0.200	0.010	0.061	0.0443	92/12/02	31	0
FW	K--D Potassium Dissolved	mg/L	0.400	0.400	0.400	**************	92/08/24	4	1
FW	K--D Potassium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	K--T Potassium	None	*************	*************	*************	**************	92/02/06	1	0
FW	K--T Potassium	mg/L	0.800	0.800	0.800	**************	92/08/24	4	1
FW	Mg-D Magnesium Dissolved	None	0.380	0.380	0.380	**************	92/02/06	1	1
FW	Mg-D Magnesium Dissolved	mg/L	0.840	0.340	0.473	0.1272	92/12/02	29	9
FW	Mg-T Magnesium	mg/L	0.850	0.360	0.495	0.1373	92/12/02	31	31
FW	Mg-T Magnesium	None	0.390	0.390	0.390	**************	92/02/06	1	1
FW	Mn-D Manganese Dissolved	mg/L	0.000	0.000	0.000	0.0000	92/12/02	29	5
FW	Mn-D Manganese Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mn-T Manganese	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mn-T Manganese	mg/L	0.010	0.000	0.007	0.0047	92/12/02	31	8
FW	Mo-D Molybdenum Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-D Molybdenum Dissolved	mg/L	*************	*************	*************	**************	92/12/02	29	0
FW	Mo-T Molybdenum	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-T Molybdenum	mg/L	*************	*************	*************	**************	92/12/02	31	0
FW	Na-D Sodium Dissolved	None	0.920	0.920	0.920	**************	92/02/06	1	1
FW	Na-D Sodium Dissolved	mg/L	1.260	1.120	1.187	**************	92/08/24	3	3
FW	Na-T Sodium	None	0.980	0.980	0.980	**************	92/02/06	1	1
FW	Na-T Sodium	mg/L	1.380	1.130	1.245	0.1047	92/08/24	4	4
FW	Ni-D Nickel Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-D Nickel Dissolved	mg/L	*************	*************	*************	**************	92/12/02	29	0
FW	Ni-T Nickel	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-T Nickel	mg/L	0.010	0.010	0.010	**************	92/12/02	31	1
FW	P--D Phosphorus Tot. Diss	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--D Phosphorus Tot. Diss	mg/L	*************	*************	*************	**************	92/08/24	4	0

SEAM Historical Statistics F -

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	P--T Phosphorus Total	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	mg/L	*************	*************	*************	**************	92/08/24	4	0
FW	Pb-D Lead Dissolved	mg/L	0.001	0.001	0.001	**************	92/12/02	30	3
FW	Pb-T Lead	mg/L	0.002	0.001	0.001	0.0003	92/12/02	32	11
FW	S--D Sulfur Dissolved	mg/L	0.400	0.280	0.365	0.0574	92/08/24	4	4
FW	S--D Sulfur Dissolved	None	0.360	0.360	0.360	**************	92/02/06	1	1
FW	S--T Sulfur Total	None	0.300	0.300	0.300	**************	92/02/06	1	1
FW	S--T Sulfur Total	mg/L	0.400	0.300	0.375	0.0500	92/08/24	4	4
FW	Sb-D Antimony Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Sb-D Antimony Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sb-T Antimony	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sb-T Antimony	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Se-D Selenium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Se-D Selenium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Se-T Selenium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Se-T Selenium	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Si-D Silicon Dissolved	None	1.400	1.400	1.400	**************	92/02/06	1	1
FW	Si-D Silicon Dissolved	mg/L	2.100	1.000	1.617	0.4631	92/12/02	8	8
FW	Si-T Silicon	None	2.700	2.700	2.700	**************	92/02/06	1	1
FW	Si-T Silicon	mg/L	2.300	1.100	1.789	0.3919	92/12/02	9	9
FW	Sn-D Tin Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sn-D Tin Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Sn-T Tin	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Sn-T Tin	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sr-D Strontium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Sr-D Strontium Dissolved	mg/L	0.024	0.000	0.003	0.0085	92/12/02	8	8
FW	Sr-T Strontium	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Sr-T Strontium	mg/L	0.025	0.000	0.003	0.0083	92/12/02	9	9
FW	Te-D Tellerium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Te-D Tellerium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Te-T Tellurium	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Te-T Tellurium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ti-D Titanium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ti-D Titanium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Ti-T Titanium	mg/L	0.000	0.000	0.000	**************	92/12/02	9	3
FW	Ti-T Titanium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Tl-D Thallium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Tl-D Thallium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Tl-T Thallium	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Tl-T Thallium	mg/L	0.000	0.000	0.000	**************	92/12/02	9	3
FW	V--D Vanadium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	V--D Vanadium Dissolved	mg/L	0.000	0.000	0.000	**************	92/12/02	29	1
FW	V--T Vanadium	None	*************	*************	*************	**************	92/02/06	1	0
FW	V--T Vanadium	mg/L	0.010	0.010	0.010	**************	92/12/02	31	2
FW	Zn-D Zinc Dissolved	mg/L	0.010	0.000	0.004	0.0035	92/12/02	30	13
FW	Zn-T Zinc	mg/L	0.040	0.000	0.007	0.0086	92/12/02	32	22
FW	Zr-D Zirconium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Zr-D Zirconium Dissolved	mg/L	*************	*************	*************	**************	92/12/02	8	0
FW	Zr-T Zirconium	mg/L	*************	*************	*************	**************	92/12/02	9	0
FW	Zr-T Zirconium	None	*************	*************	*************	**************	92/02/06	1	0

SEAM Historical Statistics F[illegible]

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
PT 0143	Chlorophyll A	[illegible]	1.060	0.610	0.900	0.2036	90/09/27	5	5
PT 0460	Biomass	[illegible]	82.000	30.000	60.667	**************	90/09/27	3	
PT 0462	Biomass Ash- Free Wt	[illegible]	58.000	21.000	43.333	**************	90/09/27	3	

TOTAL NUMBER OF PARAMETERS FOR SITE E208105 : 139

Site : E215789 - NANAIMO RIVER AT CEDAR RD BRIDGE

Region : 01 VANCOUVER ISLAND
Est. Ag. : 10 - VANCOUVER ISLAND, NANAIMO

Site Type : 21 RIVER,STREAM OR CREEK
No. Days Visited : 44
First Date Visited : 91/04/16
Most Recent Date Visited : 92/12/02

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW 0004	pH	pH units	7.800	6.800	7.158	0.3120	92/11/09	24	
FW 0008	Residue Nonfilt.	mg/L	6.000	1.000	1.778	1.8415	92/12/02	17	
FW 0011	Specific Conductance	uS/cm	41.000	41.000	41.000	**************	92/03/10	1	
FW 0013	Temperature	C	19.500	6.800	9.400	4.9887	91/12/10	8	8
FW 0015	Turbidity	NTU	4.600	0.300	0.800	1.0583	92/12/02	17	17
FW 0102	Alkalinity Total 4.5	mg/L	21.100	14.600	17.736	2.0379	92/11/09	14	
FW 0450	Coliform - Fecal	CFU/dL	109.000	1.000	27.444	34.2804	92/08/24	10	
FW 1107	Hardness Dissolved	mg/L	15.700	15.700	15.700	**************	91/04/29	1	1
FW 1108	Nitrogen Amm.Diss(N)	mg/L	0.159	0.005	0.034	0.0554	92/11/09	19	7
FW 1109	Nitrogen NO3+NO2 Dis	mg/L	0.060	0.020	0.038	0.0140	92/11/09	20	
FW 1118	Phosphorus Ort.Dis-P	mg/L	0.021	0.003	0.011	**************	92/11/09	20	
FW Ag-D	Silver Dissolved	mg/L	*************	*************	*************	**************	92/03/10	2	
FW Ag-T	Silver	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Ag-T	Silver	None	*************	*************	*************	**************	92/02/06	1	0
FW Al-D	Aluminum Dissolved	mg/L	0.100	0.030	0.054	0.0200	92/03/10	16	
FW Al-T	Aluminum	None	0.360	0.360	0.360	**************	92/02/06	1	
FW Al-T	Aluminum	mg/L	0.640	0.050	0.139	0.1680	92/03/10	15	14
FW As-D	Arsenic Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW As-D	Arsenic Dissolved	None	*************	*************	*************	**************	92/02/06	1	
FW As-T	Arsenic	None	*************	*************	*************	**************	92/02/06	1	
FW As-T	Arsenic	mg/L	*************	*************	*************	**************	92/03/10	1	
FW B--D	Boron Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW B--D	Boron Dissolved	mg/L	0.010	0.010	0.010	0.0000	92/03/10	15	10
FW B--T	Boron	mg/L	0.070	0.070	0.070	**************	92/03/10	1	
FW B--T	Boron	None	0.100	0.100	0.100	**************	92/02/06	1	
FW Ba-D	Barium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	15	
FW Ba-D	Barium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW Ba-T	Barium	None	0.010	0.010	0.010	**************	92/02/06	1	
FW Ba-T	Barium	mg/L	0.010	0.010	0.010	**************	92/03/10	15	
FW Be-D	Beryllium Dissolved	None	*************	*************	*************	**************	92/02/06	1	
FW Be-D	Beryllium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Be-T	Beryllium	None	*************	*************	*************	**************	92/02/06	1	0
FW Be-T	Beryllium	mg/L	*************	*************	*************	**************	92/03/10	1	
FW Bi-D	Bismuth Dissolved	None	*************	*************	*************	**************	92/02/06	1	
FW Bi-D	Bismuth Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW Bi-T	Bismuth	mg/L	*************	*************	*************	**************	92/03/10	1	0

SEAM Historical Statistics Fi

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)
FW	Bi-T Bismuth	[illegible]	*************	*************	*************	**************	92/02/06	1	0
FW	Ca-D Calcium Dissolved	[illegible]	7.640	4.120	5.561	1.1062	92/03/10	15	15
FW	Ca-D Calcium Dissolved	[illegible]	3.700	3.700	3.700	**************	92/02/06	1	1
FW	Ca-T Calcium	[illegible]	3.800	3.800	3.800	**************	92/02/06	1	1
FW	Ca-T Calcium	[illegible]	7.650	4.330	5.625	1.0788	92/03/10	15	15
FW	Cd-D Cadmium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cd-D Cadmium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Cd-T Cadmium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cd-T Cadmium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Co-D Cobalt Dissolved	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Co-D Cobalt Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-T Cobalt	None	*************	*************	*************	**************	92/02/06	1	0
FW	Co-T Cobalt	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Cr-D Chromium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Cr-D Chromium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cr-T Chromium	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Cr-T Chromium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Cu-D Copper Dissolved	mg/L	0.001	0.000	0.001	0.0003	92/03/10	15	10
FW	Cu-T Copper	mg/L	0.004	0.000	0.001	0.0011	92/03/10	16	13
FW	Fe-D Iron Dissolved	None	0.060	0.060	0.060	**************	92/02/06	1	1
FW	Fe-D Iron Dissolved	[illegible]	0.090	0.020	0.046	0.0235	92/03/10	15	15
FW	Fe-T Iron	None	0.300	0.300	0.300	**************	92/02/06	1	1
FW	Fe-T Iron	mg/L	0.620	0.040	0.138	0.1447	92/03/10	15	15
FW	K--D Potassium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	K--D Potassium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	K--T Potassium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	K--T Potassium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mg-D Magnesium Dissolved	mg/L	1.790	0.520	0.723	0.3073	92/03/10	15	15
FW	Mg-D Magnesium Dissolved	None	0.570	0.570	0.570	**************	92/02/06	1	1
FW	Mg-T Magnesium	None	0.640	0.640	0.640	**************	92/02/06	1	1
FW	Mg-T Magnesium	mg/L	1.790	0.550	0.751	0.2880	92/03/10	15	15
FW	Mn-D Manganese Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Mn-D Manganese Dissolved	mg/L	0.020	0.000	0.010	**************	92/03/10	15	3
FW	Mn-T Manganese	None	0.010	0.010	0.010	**************	92/02/06	1	1
FW	Mn-T Manganese	mg/L	0.040	0.000	0.016	0.0152	92/03/10	15	5
FW	Mo-D Molybdenum Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-D Molybdenum Dissolved	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Mo-T Molybdenum	None	*************	*************	*************	**************	92/02/06	1	0
FW	Mo-T Molybdenum	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Na-D Sodium Dissolved	mg/L	2.670	2.670	2.670	**************	92/03/10	1	1
FW	Na-D Sodium Dissolved	None	1.790	1.790	1.780	**************	92/02/06	1	1
FW	Na-T Sodium	None	1.900	1.900	1.900	**************	92/02/06	1	1
FW	Na-T Sodium	mg/L	2.530	2.530	2.530	**************	92/03/10	1	1
FW	Ni-D Nickel Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-D Nickel Dissolved	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Ni-T Nickel	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ni-T Nickel	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	P--D Phosphorus Tot. Diss	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	P--D Phosphorus Tot. Diss	None	*************	*************	*************	**************	92/02/06	1	0
FW	P--T Phosphorus Total	mg/L	*************	*************	*************	**************	92/03/10	1	0

SEAM Historical Statistics F· ·

Sm St	Parameter	Unit	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	Of (Us
FW	P--T Phosphorus Total	None	*************	*************	*************	**************	92/02/06	1	0
FW	Pb-D Lead Dissolved	mg/L	*************	*************	*************	**************	92/03/10	18	0
FW	Pb-T Lead	mg/L	0.004	0.001	0.002	0.0013	92/03/10	18	9
FW	S--D Sulfur Dissolved	None	0.580	0.580	0.580	**************	92/02/06	1	1
FW	S--D Sulfur Dissolved	mg/L	0.660	0.660	0.660	**************	92/03/10	1	1
FW	S--T Sulfur Total	mg/L	0.600	0.600	0.600	**************	92/03/10	1	1
FW	S--T Sulfur Total	None	0.600	0.600	0.600	**************	92/02/06	1	1
FW	Sb-D Antimony Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sb-D Antimony Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sb-T Antimony	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sb-T Antimony	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Se-D Selenium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Se-D Selenium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Se-T Selenium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Se-T Selenium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Si-D Silicon Dissolved	None	2.100	2.100	2.100	**************	92/02/06	1	1
FW	Si-D Silicon Dissolved	mg/L	2.200	2.200	2.200	**************	92/03/10	1	1
FW	Si-T Silicon	mg/L	2.600	2.600	2.600	**************	92/03/10	1	1
FW	Si-T Silicon	None	2.800	2.800	2.800	**************	92/02/06	1	1
FW	Sn-D Tin Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sn-D Tin Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sn-T Tin	None	*************	*************	*************	**************	92/02/06	1	0
FW	Sn-T Tin	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Sr-D Strontium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Sr-D Strontium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Sr-T Strontium	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Sr-T Strontium	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Te-D Tellerium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Te-D Tellerium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Te-T Tellurium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Te-T Tellurium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Ti-D Titanium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Ti-D Titanium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Ti-T Titanium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Ti-T Titanium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Tl-D Thallium Dissolved	None	0.000	0.000	0.000	**************	92/02/06	1	1
FW	Tl-D Thallium Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	1	1
FW	Tl-T Thallium	None	*************	*************	*************	**************	92/02/06	1	0
FW	Tl-T Thallium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	V--D Vanadium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	V--D Vanadium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	V--T Vanadium	None	*************	*************	*************	**************	92/02/06	1	0
FW	V--T Vanadium	mg/L	*************	*************	*************	**************	92/03/10	15	0
FW	Zn-D Zinc Dissolved	mg/L	0.000	0.000	0.000	**************	92/03/10	18	1
FW	Zn-T Zinc	mg/L	0.020	0.005	0.012	0.0053	92/03/10	18	6
FW	Zr-D Zirconium Dissolved	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Zr-D Zirconium Dissolved	None	*************	*************	*************	**************	92/02/06	1	0
FW	Zr-T Zirconium	mg/L	*************	*************	*************	**************	92/03/10	1	0
FW	Zr-T Zirconium	None	*************	*************	*************	**************	92/02/06	1	0

SEAM Historical Statistics F[illegible]

Sm St	Parameter	[illegible]it	Maximum Observation	Minimum Observation	Mean	Standard Deviation	Most Recent Date	No. Obs. (Tot)	No. Obs. (Used)

TOTAL NUMBER OF PARAMETERS FOR [illegible] E215789 : 135

Appendix IV - C

GREATER NANAIMO WATER DISTRICT (GNWD) DATA

1989 - 1991

TABLE 1

ANALYTICAL RESULTS
GENERAL WATER QUALITY
APRIL 14, 1989 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
pH	7.67	-	6.5-8.5
Odour	None Detectable*	-	Inoffensive
Colour	<5 APHA Units (TCU)	-	<15 TCU
Turbidity	0.40 NTU	1 NTU	< 5 NTU
Dissolved Solids	33.0 mg/L	-	<500 mg/L
Sulfate	1 mg/L	500 mg/L	<150 mg/L
Nitrate	0.018 mg N/L	10 mg/L	-
Nitrite	<0.002 mg N/L	1 mg/L	-
Chloride	1.32 mg/L	-	<250 mg/L
Flouride	0.078 mg/L	1.5 mg/L	-
Sulfide	<0.5 mg/L**	-	<0.05 mg/L
Cyanide	<0.001 mg/L	0.2 mg/L	-

< Is less than.
* As determined by six experienced taste and odour panelists.
** Less than 0.05 based on odour.

TABLE 2

ANALYTICAL RESULTS
METALS
APRIL 14, 1989 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Arsenic	<0.001 mg/L	0.05 mg/L	-
Barium	<0.005 mg/L	1.0 mg/L	-
Boron	<0.05 mg/L	5.0 mg/L	-
Cadmium	<0.0002 mg/L	0.005 mg/L	-
Chromium	<0.001 mg/L	0.05 mg/L	-
Iron	0.056 mg/L	-	<0.3 mg/L
Manganese	0.0026 mg/L	-	<0.05 mg/L
Mercury	0.00005 mg/L	0.001 mg/L	-
Lead	0.014 mg/L	0.05 mg/L	-
Selenium	<0.001 mg/L	0.01 mg/L	-
Silver	<0.0001 mg/L	-	-
Sodium	1.1 mg/L	-	-
Uranium	<0.0002 mg/L	0.1 mg/L	-
Zinc	<0.0005 mg/L	-	<5.0 mg/L

TABLE 3

ANALYTICAL RESULTS
ORGANIC COMPOUNDS
APRIL 14, 1989 SAMPLE
GREATER NANAIMO WATER DISTRICT

GROUP 1	AROMATIC HYDROCARBONS NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Benzene	<0.05 mg/L	0.005 mg/L	-
Toluene	<0.01 mg/L	-	<0.024 mg/L
Xylenes	<0.05 mg/L	-	<0.3 mg/L

GROUP 2	HALOGENATED PARAFFINS, OLEFINS AND AROMATICS NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Bromoform	<0.001 mg/L	-	-
Chloroform	<0.001 mg/L	0.35 mg/L	-
Bromodichloromethane	<0.001 mg/L	-	-
Chlorodibromomethane	<0.001 mg/L	-	-

GROUP 3	PHENOLIC COMPOUNDS NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Pentachlorophenol	<0.001 mg/L	0.06 mg/L	<0.03 mg/L
2,3,4,6-Tetrachlorophenol	<0.001 mg/L	0.1 mg/L	<0.001 mg/L
2,4,6-Trichlorophenol	<0.002 mg/L	0.005 mg/L	<0.002 mg/L
2,4-Dichlorophenol	<0.05 mg/L	0.9 mg/L	-

TABLE 3 CONT'D

ANALYTICAL RESULTS
ORGANIC COMPOUNDS
APRIL 14, 1989 SAMPLE
GREATER NANAIMO WATER DISTRICT

GROUP 4	PESTICIDES AND PCB's NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Aldrin	<0.0001 mg/L	0.0007 mg/L	-
Dieldrin	<0.0001 mg/L	0.0007 mg/L	-
Heptachlor	<0.0002 mg/L	0.003 mg/L	-
Heptachlor Epoxide	<0.0002 mg/L	0.003 mg/L	-
Methoxychlor	<0.0005 mg/L	0.9 mg/L	-
Alpha-Chlordane	<0.00005 mg/L	-	-
Gamma-Chlordane	<0.00005 mg/L	-	-
Endrin	<0.0001 mg/L	-	-
Lindane	<0.00005 mg/L	0.004 mg/L	-
Toxaphene	<0.001 mg/L	-	-
Diazinon	<0.0005 mg/L	0.02 mg/L	-
Parathion	<0.0005 mg/L	0.05 mg/L	-
Methyl Parathion	<0.0005 mg/L	0.007 mg/L	-
Alpha Hexachloro benzene	<0.001 mg/L	-	-
Beta Hexachloro benzene	<0.001 mg/L	-	-
Captan	<0.001 mg/L	-	-
Metolachlor	<0.001 mg/L	-	-
Malathion	<0.001 mg/L	0.19 mg/L	-
PCB's	<0.0005 mg/L	-	-

TABLE 3 CONT'D

ANALYTICAL RESULTS
ORGANIC COMPOUNDS
APRIL 14, 1989 SAMPLE
GREATER NANAIMO WATER DISTRICT

GROUP 5	HERBICIDES NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
2,4,5-TP	<0.001 mg/L	-	-
2,4-D	<0.001 mg/L	-	-
Dicamba	<0.001 mg/L	0.12 mg/L	-
Picloram	<0.001 mg/L	-	-
p,p'-DDD	<0.0001 mg/L	-	-
p,p'-DDT	<0.0001 mg/L	-	-
p,p'-DDE	<0.0001 mg/L	-	-
Glyphosate	<0.005 mg/L	0.28 mg/L	-

GROUP 6	MISCELLANEOUS ORGANICS NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Trifluralin	<0.0005 mg/L	-	-
Triallate	<0.001 mg/L	0.23 mg/L	-
Diclofop-methyl	<0.009 mg/L	0.009 mg/L	-
Benzo α Pyrene	<0.00005 mg/L	0.00001 mg/L	-

CPRT LABORATORIES INC.

Consumer Products Research & Testing

6-22 Gurdwara Road, Nepean, Ontario K2E 8A2
Mailing Address: P.O. Box 5224, Ottawa, Ontario K2C 3H5
Tel: (613) 226-5342
Fax: (613) 226- 4

19 October 1990

Sample #: 000747

Client: Wayne Hansen
455 Wallace St.
Nanaimo, B.C.
V9R 5J6

Report #: 000140

Attention: same as above

Date Completed: Oct. 10, 1990

Date Sample Rec'd: Sept. 21, 1990

CERTIFICATE OF ANALYSIS

Sample Description: city water

RESULTS:

" The drinking water quality testing program is made available by CPRT Laboratories Inc. as a service to the Canadian public. CPRT Laboratories Inc. is confident that the independent laboratory to which the water analysis is assigned meets the highest US and Canadian standards for work of this type, but CPRT Laboratories Inc. cannot and therefore does not represent or warrant that the test data are accurate. Subscribers relying solely upon such data do so at their own risk, and CPRT Laboratories Inc. will not be liable to any subscriber who is damaged or injured thereby."

NOTE:
- * Indicates that Maximum Acceptable Concentration Levels (MACL) have been exceeded, or in the case of pH are either too high or too low.
- nd Indicates that none of this substance has been detected at or above the detection level.
- mg/L Milligram per litre is equivalent to parts per million (ppm

ANALYSIS PERFORMED	MACL (mg/L)	Health or Aesthetic Concern	Level Detected (mg/L)
INORGANIC CHEMICALS - METALS			
Arsenic	0.05	H	nd
Barium	1.0	H	nd
Cadmium	0.005	H	nd
Chromium	0.05	H	nd
Copper	1.0	A	0.047
Iron	0.3	A	0.090
Lead	0.05	H	0.003
Manganese	0.05	A	0.015
Mercury	0.001	H	nd
Nickel	0.15	H	nd
Selenium	0.01	H	nd
Silver	0.05	H	nd
Sodium	20	H + A	2.5
Zinc	5	A	0.021

INORGANIC CHEMICALS - OTHER, AND PHYSICAL FACTORS

Total Alkalinity (CaCO3)	-	A	20
Chloride	250	A	nd
Fluoride	1.5	H + A	nd
Nitrate /Nitrite	10	H	nd
Sulphate	500	H + A	nd
Hardness (as CaCO3)	80-100	A	20
pH (Standard Units)	6.5-8.5	A	7.7
Total Dissolved Solids	500	A	30
Turbidity (NTU)	5	H + A	0.4

ORGANIC CHEMICALS - TRIHALOMETHANES

Bromoform	-	H	nd
Bromodichloromethane	-	H	nd
Chloroform	-	H	nd
Dibromochloromethane	-	H	nd
Total THMs (sum of four above)	0.35	H	nd

ORGANIC CHEMICALS - VOLATILES

Benzene	0.005	H	nd
Vinyl chloride	0.002	H	nd
Carbon Tetrachloride	0.005	H	nd
1,2-Dichlorethane	0.005	H	nd
Trichloroethylene	0.005	H	nd
1,4-Dichlorobenzene	0.075	H	nd
1,1-Dichloroethylene	0.007	H	nd
1,1,1-Trichloroethane	0.20	H	nd
Acrolein	-	H	nd
Acrylonitrile	-	H	nd
Bromobenzene	0.010	H	nd
Bromomethane	0.005	H	nd
Chlorobenzene	0.6	H	nd
Chloroethane	0.003	H	nd
Chloroethylvinyl ether	-	H	nd
Chloromethane	0.01	H	nd
1,1-Chlorotoluene	0.005	H	nd
1,3-Chlorotoluene	0.005	H	nd
Dibromochloropropane	0.025	H	nd
Dibromomethane	0.005	H	nd
1,2-Dichlorobenzene	0.62	H	nd
1,3-Dichlorobenzene	0.62	H	nd
Dichlorodifluoromethane	-	H	nd
1,1-Dichloroethane	0.002	H	nd
Trans-1,2-Dichloroethylene	0.07	H	nd
Cis-1,2-Dichloroethylene	0.07	H	nd
Dichloromethane	0.05	H	nd
1,2-Dichloropropane	0.005	H	nd
Trans-1,3-Dichloropropene	0.005	H	nd
Cis-1,3-Dichloropropene	0.00[illegible]	H	nd
2,2-Dichloropropane	0.005	H	nd
1,1-Dichloropropane	-	H	nd
1,3-Dichloropropane	-	H	nd
Ethylbenzene	0.68	H + A	nd
Ethylenedibromide (EDB)	0.02	H	nd
Styrene	0.14	H	nd
1,1,1,2-Tetrachloroethane	0.005	H	nd

ORGANIC CHEMICALS - VOLATILES (continued)

1,1,2,2-Tetrachloroethane	0.005	H	nd
Tetrachloroethylene	0.005	H	nd
Trichlorobenzene(s)	-	H	nd
1,1,2-Trichloroethane	0.2	H	nd
Trichlorofluoromethane	-	H	nd
1,2,3-Trichloropropane	0.005	H	nd
Toluene	2.0	H + A	nd
Xylene	0.3	H + A	nd

ORGANIC CHEMICALS - PESTICIDES, HERBICIDES AND PCBs

Alachlor	-	H	nd
Atrazine	0.06	H	nd
Chlordane	0.02	H	nd
Dalapon	-	H	nd
Dicamba	-	H	nd
Dieldrin	0.0007	H	nd
Dinoseb	-	H	nd
Endrin	0.0002	H	nd
Heptachlor	0.003	H	nd
Heptachlor Epoxide	-	H	nd
Hexachlorobenzene	0.02	H	nd
Hexachloropentadiene	-	H	nd
Lindane	0.004	H	nd
Methoxychlor	0.9	H	nd
PCBs	0.008	H	nd
Picloram	-	H	nd
Silvex 2,4,5-TP	0.01	H	nd
Simazine	0.01	H	nd
Toxaphene	0.005	H + A	nd
2,4-D	0.1	H	nd

RECOMMENDATION:

For parameters above MACL please find enclosed herewith a copy of information sheet(s) suggesting possible methods of water treatment.

J. Matshela Molepo Ph.D

Encl.

TABLE 1

GENERAL WATER QUALITY
JUNE 28, 1991 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Conductivity (umho/cm)	35	-	-
pH	6.24	-	6.5-8.5
Odour	Non Detectable*	-	Inoffensive
Colour (TCU)	<5 APHA Units	-	<15
Turbidity (NTU)	0.30	5	<1
Hardness (mg $CaCO_3$/L)	14.4	-	-
Sulfate (mg/L)	<1.0	500	<150
Nitrate (mg N/L)	<0.005	10	-
Nitrite (mg N/L)	<0.002	1	-
Chloride (mg/L)	4	-	<250
Fluoride (mg/L)	<1	1.5	-
Sulfide (mg/L)	<0.5	-	<0.05
Cyanide (mg/L)	<0.001	<0.2	-
Total Solids (mg/L)	40.0	-	-
Suspended Solids (mg/L)	<1.0	-	-
Dissolved Solids (mg/L)	40.0	500	-

< Is less than
* As determined by five experienced taste and odour panelists
** Less than 0.05 based on odour

TABLE 2

METALS AND ELEMENTS
JUNE 28, 1991 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Aluminum (mg/L)	0.012	-	-
Antimony (mg/L)	<0.0002	0.0002	-
Arsenic (mg/L)	<0.001	0.05	-
Barium (mg/L)	0.007	1.0	-
Boron (mg/L)	0.003	5.0	-
Bromine (mg/L)	0.0018	-	-
Cadmium (mg/L)	<0.0001	0.005	-
Calcium (mg/L)	5.3	-	-
Chromium (mg/L)	0.001	0.05	-
Copper (mg/L)	<0.0003	-	1.0
Iodine (mg/L)	0.0013	-	-
Iron (mg/L)	0.15	-	0.3
Lead (mg/L)	<0.0001	0.05	-
Magnesium (mg/L)	0.052	-	-
Manganese (mg/L)	0.020	-	0.05
Mercury (mg/L)	<0.001	0.001	-
Phosphorus (mg/L)	0.042	-	-
Potassium (mg/L)	0.240	-	-
Selenium (mg/L)	<0.001	0.01	-
Silicon (mg/L)	2.1	-	-
Silver (mg/L)	<0.0002	0.05	-
Sodium (mg/L)	1.9	-	-
Strontium (mg/L)	0.017	-	-
Titanium (mg/L)	0.0016	-	-
Uranium (mg/L)	<0.00005	0.02	-
Zinc	<0.0005	-	5.0

TABLE 3

RADIOACTIVITY
JUNE 28, 1991 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Gross Alpha (Bq/L)	<0.03	0.1	-
Gross Beta (Bq/L)	<0.09	1.0	-

TABLE 4

ORGANIC COMPOUNDS
JUNE 28, 1991 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Benzene (mg/L)	<0.0005	0.005	-
Bromodichloromethane (mg/L)	<0.0008	-	-
Bromoform (mg/L)	<0.0008	-	-
Bromomethane (mg/L)	<0.0002	-	-
Carbon Tetrachloride (mg/L)	<0.0008	-	-
Chlorobenzene (mg/L)	<0.0005	0.08	0.03
Chloroethane (mg/L)	<0.002	-	-
2-Chloroethylvinyl Ether (mg/L)	<0.001	-	-
Chloroform (mg/L)	<0.0008	-	-
Chloromethane (mg/L)	<0.002	-	-
Bis (2 Chloroethyl) Ether (mg/L)	<0.002	-	-
Dibromochloromethane (mg/L)	<0.0008	-	-
1,2 Dichlorobenzene (mg/L)	<0.002	0.02	0.003
1,3 Dichlorobenzene (mg/L)	<0.002	-	-
1,4 Dichlorobenzene (mg/L)	<0.002	0.005	-
Dichlorodifluoromethane (mg/L)	<0.0005	-	-
1,1 Dichloroethane (mg/L)	<0.0008	-	-
1,2 Dichloroethane (mg/L)	<0.0005	-	-
1,1 Dichloroethylene (mg/L)	<0.0005	-	-
Trans-1,2 Dichloroethylene (mg/L)	<0.0005	-	-
1,2 Dichloropropene (mg/L)	<0.0008	-	-
Cis-1,3 Dichloropropene (mg/L)	<0.0005	-	-
Trans-1,3 Dichloropropene (mg/L)	<0.0005	-	-
Ethylbenzene (mg/L)	<0.0005	-	-
Methylene Chloride (mg/L)	<0.004	-	-
Methyl Ethyl Ketone (mg/L)	<0.001	-	-
Methyl Isobutyl Ketone (mg/L)	<0.001	-	-
1,1,2,2 Tetrachloroethane (mg/L)	<0.0008	-	-
Tetrachloroethane (PCE) (mg/L)	<0.0008	-	-
Toluene (mg/L)	<0.0015	-	0.024
1,1,1 Trichloroethane (mg/L)	<0.0005	-	-
1,1,2 Trichloroethane (mg/L)	<0.0005	-	-
Trichloroethylene (TCE) (mg/L)	<0.0005	-	-
Trichlorofluoromethane (mg/L)	<0.0005	-	-
Vinyl Chloride (mg/L)	<0.0005	-	-
Xylenes (mg/L)	<0.0005	-	0.03
Styrene (mg/L)	<0.0005	-	-
Total Trihalo Methane (mg/L)	<0.0013	0.35	0.005
Phenol (mg/L)	<0.001	0.002	0.002

TABLE 5

PESTICIDES
JUNE 28, 1991 SAMPLE
GREATER NANAIMO WATER DISTRICT

	NANAIMO WATER	GUIDELINES FOR CANADIAN DRINKING WATER QUALITY MAC	AO
Endrin (mg/L)	<0[illegible]06	-	-
Lindane (mg/L)	<0[illegible]04	0.004	-
Methoxyclor (mg/L)	<0[illegible].8	0.9	-
Toxaphene (mg/L)	<0.0024	-	-
2,4-D (mg/L)	<0.0001	-	-
2,4,5-T (mg/L)	<0.0001	-	-
2,4,5-TP (Silvex) (mg/L)	<0.0001	-	-

APPENDIX V

PROVISIONAL OPERATION GUIDELINES

PROVISIONAL OPERATION GUIDELINES

JUMP CREEK AND SOUTH FORK RESERVOIRS

1. The Jump Creek reservoir full supply level of 378.34 metres (1241 feet) should be maintained until June 30 each year.

2. At least 0.3 m^3/sec (10 cfs) is to be maintained below the South Fork Dam at all times.

3. When the Jump Creek reservoir water level is in Zone A, 25% of the flow required to maintain at least the following flows at Water Survey Canada (WSC) station 08HB034 is to be released from Jump Creek and South Fork reservoirs.. Coordination with Harmac is required to determine natural flow and portion of make up water to be released.

Period	Minimum Flow Required at WSC Station 08HB034	25% GNWD*	75% Harmac*
Fish Habitat Maintenance Flows			
Jul 1 - Oct 31	3.90 m^3/sec (138 cfs)	1.0 m^3/sec (35 cfs)	2.9 m^3/sec (103 cfs)
Chinook Migration Pulse Flow			
Oct 5 - Oct 8	14.0 m^3/sec (494 cfs)*	3.5 m^3/sec (124 cfs)	10.5 m^3/sec (370 cfs)

*Note - Natural uncontrolled watershed flow would proportionally reduce required flow releases at each reservoir.

4. When reservoir water levels are in Zone B, flow releases shall be limited to the maintenance of the flow below South Fork Dam in clause 2 above.

5. Jump Creek Spillway gates are to be opened (lowered into spillway) before October 30 and remain opened until March 20.

6. Records of Jump Creek and South Fork water levels and the flow release below South Fork reservoir are to be kept and submitted monthly to the Engineer under the Water Act.

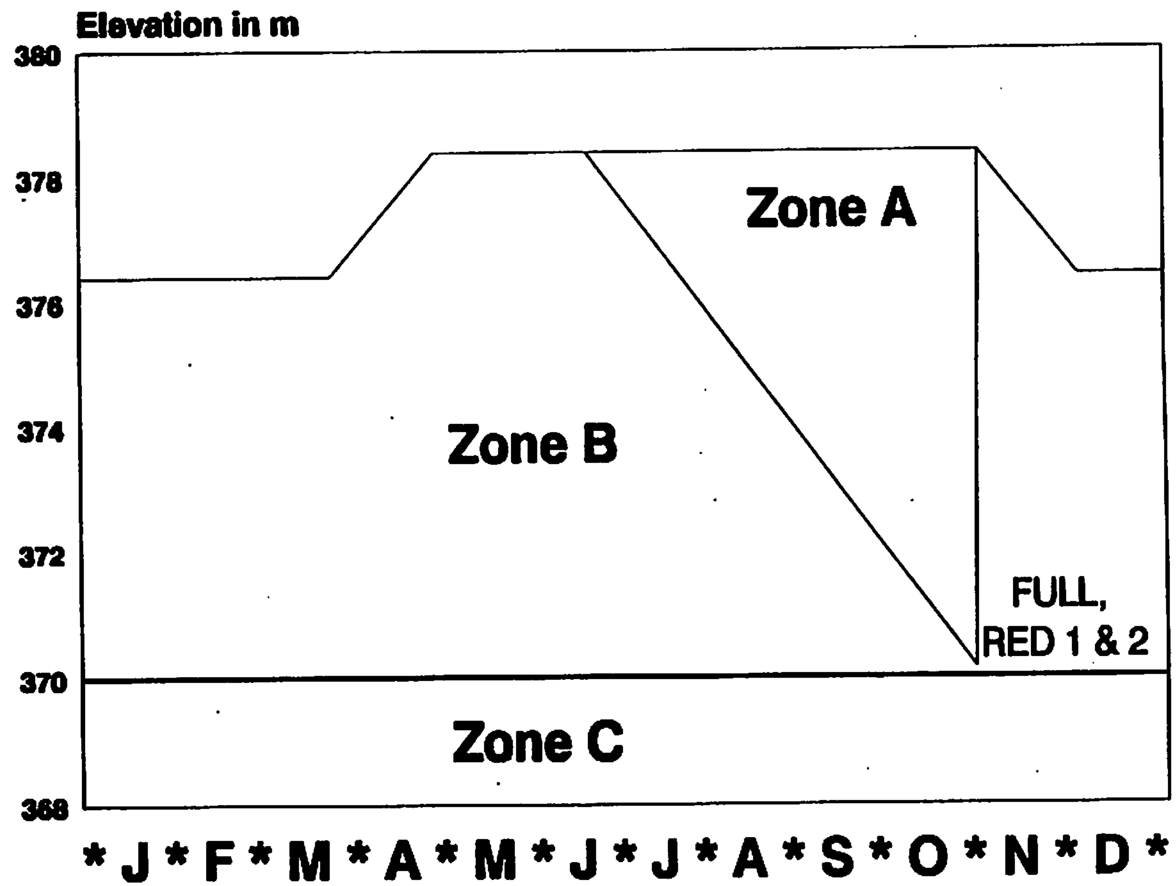

Figure 1 - JUMP CREEK RESERVOIR OPERATIONAL ZONES

PROVISIONAL OPERATION GUIDELINES

FOURTH LAKE RESERVOIR

1. The Fourth Lake reservoir full supply level of 316.7 metres (1039 feet) should be maintained until June 30 each year.

2. At least 1.4 m^3/sec (49 cfs) residual flow is to be maintained below the Harmac intake at the Vancouver Island Highway bridge at all times.

3. When the Fourth Lake reservoir water level is in Zone A, 75% of the flow required to maintain at least the following flows at Water Survey Canada (WSC) station 08HB034 is to be released from Fourth Lake reservoir. Coordination with GNWD is required to determine natural flow and portion of make up water to be released.

Period	Minimum Flow Required at WSC Station 08HB034	25% GNWD*	75% Harmac*
Fish Habitat Maintenance Flows			
Jul 1 - Oct 31	3.90 m^3/sec (138 cfs)	1.0 m^3/sec (35 cfs)	2.9 m^3/sec (103 cfs)
Chinook Migration Pulse Flow			
Oct 5 - Oct 8	14.0 m^3/sec (494 cfs)*	3.5 m^3/sec (124 cfs)	10.5 m^3/sec (370 cfs)

*Note - Natural uncontrolled watershed flow would proportionally reduce required flow releases at each reservoir.

4. When reservoir water levels are in Zone B, flow releases shall be limited to the maintenance of the residual flow in clause 2 above.

5. Records of Fourth Lake reservoir water levels and the flow release, flow at WSC Station 08HB034, Harmac diversion quantity and residual flow past the diversion are to be kept and submitted monthly to the Engineer under the Water Act.

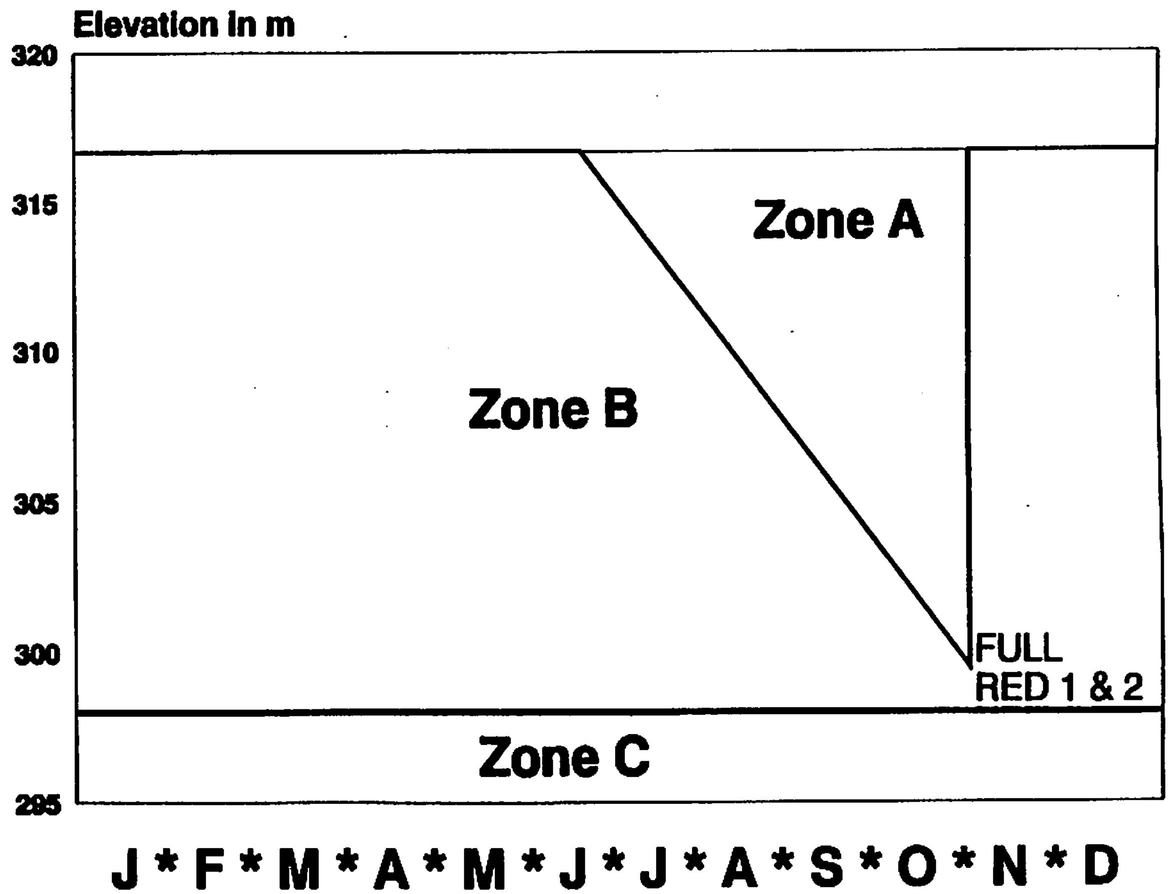

Figure 2-Fourth Lake Operational Zones

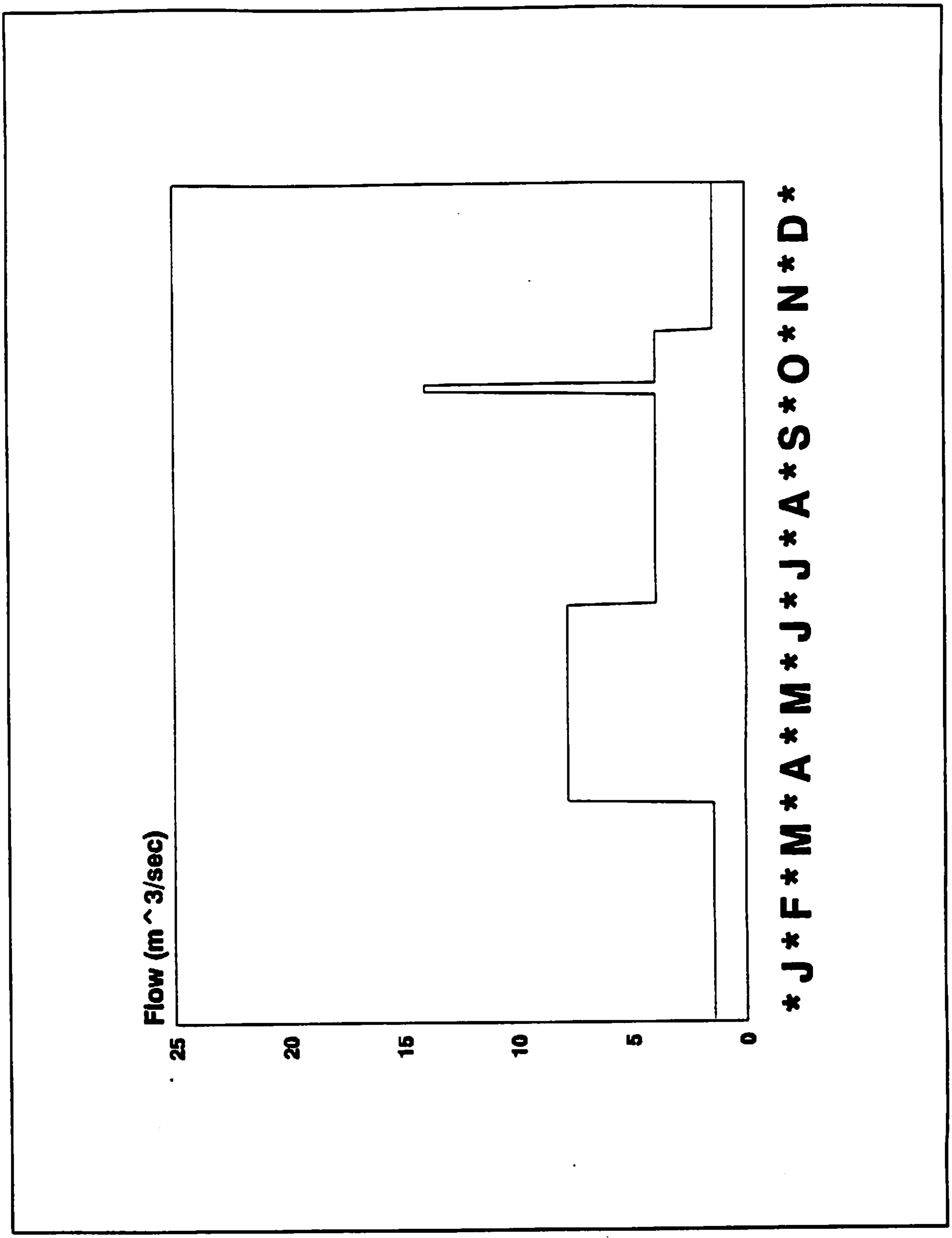

Figure 3 - Nanaimo River Target Flows

RULE CURVE ZONES

The **RULE CURVE ZONES** provide a means to indicate to the operators of the dams when releases can be safely made for fish habitat maintenance and Chinook Salmon migration pulse flows without affecting future licenced demands. The **RULE** is: water is available for a zone provided that the reservoir water level is above the rule curve and in that zone.

ZONE A Sufficient water supply is available in storage to satisfy all the projected demands and the fisheries instream flow reqirements (ie. 3.90 m^3/sec (138 cfs) fish habitat maintenance flow and 14.0 m^3/sec (494 cfs) Chinook migration pulse flow). When the reservoir water level is in ZONE A there is excess water in storage beyond the water required to satisfy the GNWD's projected demand to the year 2015 and Harmac's reduced river use demands.

ZONE B Sufficient water supply is available in storage to satisfy the GNWD's projected demand to the year 2015, Harmac's reduced river use demands and the maintenance of minimum fish flow releases (licence requirements of 10 cfs in the South Fork and 49 cfs residual below the Harmac pumphouse).

ZONE C Reserved water supply to ensure against any unforseen circumstances. Ensures that the reservoir never goes dry.

The South Fork reservoir is to be maintained at full supply level as a further reserve and emergency supply for the GNWD municipal water supply.