PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT LANDS AND PARKS
VANCOUVER ISLAND REGION

QUENNELL-HOLDEN

WATER ALLOCATION PLAN

NOVEMBER 1991

written by:

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&
Evelyn Riechert

Regional Water Management
Vancouver Island Region
Nanaimo, B.C.

Approved: [signature]
Regional Water Manager
Vancouver Island Region

Date: 30 Sep 93

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WATER ALLOCATION PLAN: QUENNELL-HOLDEN 4-21-20

1.0 Introduction

The two primary program goals related to the Water Management Program's water allocation process is to ensure comprehensive planning for water use and to protect both licensed rights and instream uses of water. In order to achieve these goals the following policy and direction is required:

Regional Policy:

> **The region shall be subdivided into watershed areas and a water allocation plan shall be prepared for each watershed area.**
> **Water licence decisions will be made in accordance with approved plans.**

Water Allocation Plans are a means for identifying water demands and ensuring that water use is compatible with the goals of a sustainable environment. The plans are intended to replace or reduce most Water Licence Application Reports by pre-defining specific allocation directions and decisions.

The plans shall give directions regarding further water allocations by assessing the following:

- surface water resources available;
- in stream requirements for fisheries, water quality, recreation and other uses;
- existing and potential water demands.

In the development of Water Allocation Plans, referrals are made to other agencies for input and information (Federal & Provincial Fisheries, and the Water Management's Water Rights & Hydrology Sections in Victoria).

The Quennell-Holden Water Allocation Plan is the first plan completed for the Water Management Region 01 - Vancouver Island.

2.0 General Watershed Information

The Quennell-Holden Lake watershed area is located on the eastern coast of Vancouver Island, south of Nanaimo and north of Ladysmith Harbour. The Allocation area (Figure 1) is 5254 hectares and included the Chemainus Indian Reserve at the southerly end and the Harmac mill site at the north. Most of the land is rural and forested, with small farms and pockets of subdivisions (North Cedar, Boat Harbour and Yellowpoint).

It is a low lying area with the highest elevation at 93 m and the median elevation at 42 m. The main watershed covers 63 % of the Allocation Plan area or 3443 hectares and includes the two main lakes, Quennell and Holden. Several smaller watersheds are associated with Greenway, Priest and Long Lakes. There is no main river flowing through this Water Allocation Plan area, the streams within the watershed connect most of the major lakes together and they all appear to go dry during the normal low flow period, July to September..

The percentage of lakes within the watershed area is approximately 5 %, with the two largest lakes, Quennell and Holden having surface areas of approximately 120 ha and 38 ha respectively.

The number of water licences is broken down and categorized as follows:

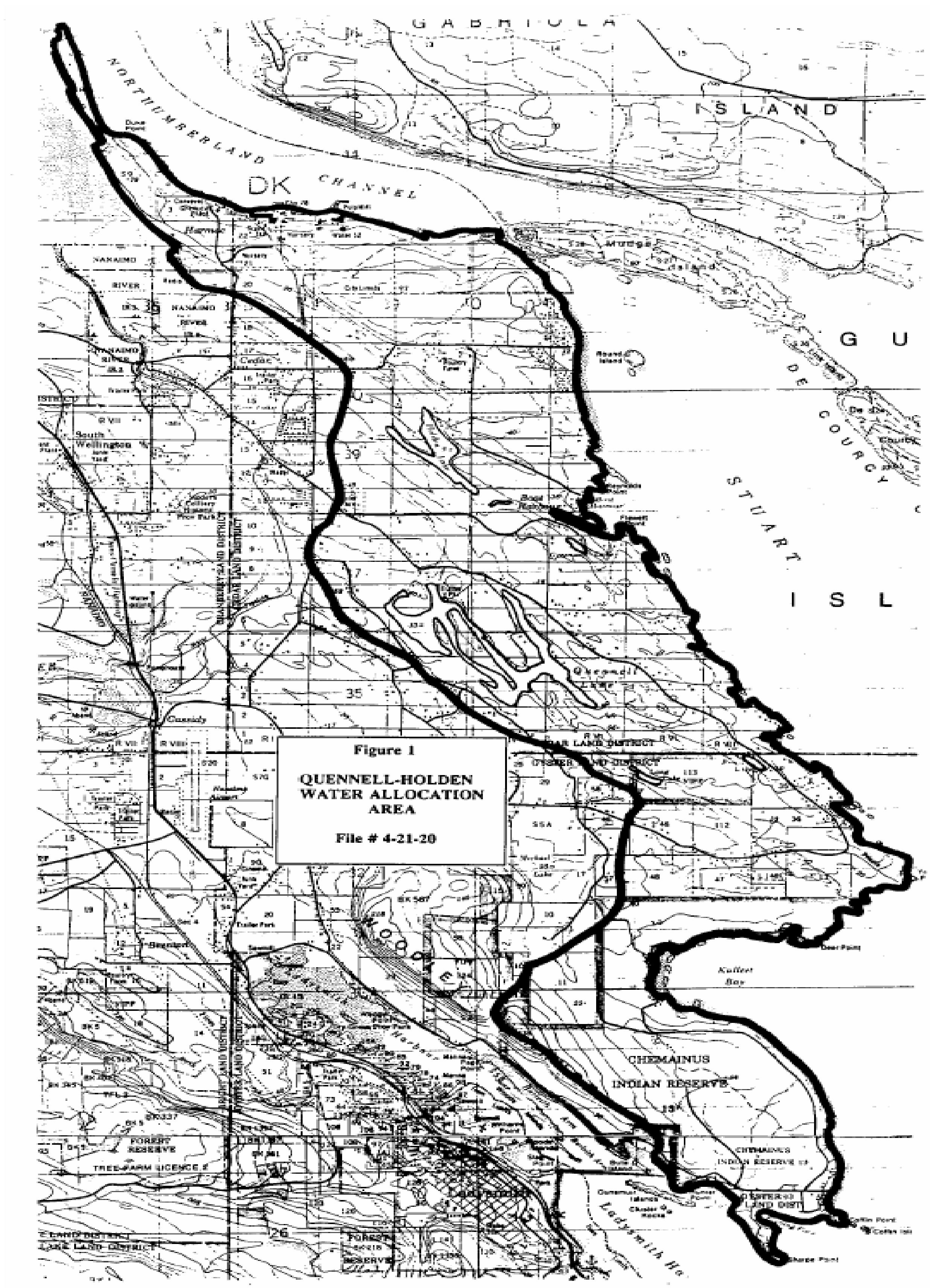
Irrigation	22 %
Domestic	71 %
Industrial	7 %

A review of the groundwater conditions in the Long Lake/ Priest Lake area was completed by Ministy Of Environment, Groundwater Section in 1986, Appendix (A). The majority of wells in the area are constructed in bedrock. There are variations in the wells, with some areas indicating poor quality (sulphur smell) and others with limited capacity, especially in the summer months.

The possibility exists that the Holden Creek valley contains an aquifer which may be quite productive.

Quennell Lake is used extensively for recreation- water skiing, canoeing and fishing.

A Water Quality study is planned on Quennell Lake by provincial water quality branch and the Federal Government. It is assummed this study will begin in 1992 and will investigate options to increase water quality in the lake.


GABRIOLA
ISLAND
NORTHUMBERLAND CHANNEL
DK
NANAIMO RIVER
NANAIMO RIVER
South Wellington
Cassidy
Mudge Island
DE COURCY
STUART ISL
Quennell Lake
Kulleet Bay
CHEMAINUS INDIAN RESERVE
FOREST RESERVE
TREE-FARM LICENCE
Ladysmith Ha
Figure 1
QUENNELL-HOLDEN WATER ALLOCATION AREA
File # 4-21-20

3.0 HydrologyHydrology

3.1 Hydrometric Data

There are no long term hydrometric stations within the Holden/Quennell watershed. The limited data and observations are as follows:

3.1.1 Quennell Lake water levels - WSC station #08HB055

As shown in Appendix (B1), water levels were recorded during the April-October period for the years 1976 to 1980 inclusive.

3.1.2 Observation of Quennell Lake outflow to Holden Creek

In 1978, Mrs. M. Haley reported that there is no flow from the Quennel Lake outlet to Holden Creek from the end of March to late December or early January. During a year of exceptionally heavy rainfall, the flow may commence in late November and continue until early April.

3.1.3 Holden Lake water levels - WSC station #08HB071

As shown in Appendix (B2), water levels were recorded during the April-October period for the years 1980 and 1983 to 1985 inclusive.

3.1.4 Holden Creek streamflow

Only one measurement was taken at an unknown location on Holden Creek. On May 21, 1980, the flow was 0.466 cfs.

3.1.5 Priest Lake water levels - WSC station #08HB066

Hydrometric Station #08HBB07 was established by the Hydrology Section, Victoria in June, 1980 and streamflow was measured from June, 1980 to September, 1982 inclusive. This data was collected and approved internally, but was not accepted by Water Survey of Canada for publication. Results are shown In Appendix (B2). The minimum discharge for 1980, '81, & '82 was 0.010 m3/s, 0.017 m3/s, & 0.016 m3/s respectively.

At the beginning of September, 1991, measurements were taken by the Regional office at the same location as the discontinued station mentioned above. The results are shown in Appendix (B3). The initial streamflow was 0.009 m3/s after an August of high precipitation. However, with a lack of rainfall over the next few months, the streamflow steadily decreased to zero. "No flow" conditions remained for the month of October.

3.1.6 Unnamed tributary to Holden Creek

While Holden Creek flow ceased at the beginning of October 1991, a small creek located 20 metres downstream of Stn. 08HBB07I continued to flow throughout October. The flow on October 10, 1991 was 0.0004 m3/s.

3.1.7 Priest Lake water levels - WSC station #08HB066

As shown in Appendix (B4), water levels were recorded for January - December, 1979.

3.1.8 Observations at Priest Lake outlet

Date	Reported by	Observations
11/21/68	W.D. Lasell	no outflow in summer
09/19/69	W.D. Lasell	no outflow in summer
11/30/70	W.D. Lasell	no flow at time of inspection
05/17/73	W.D. Lasell	seasonal flow only
11/19/73	D. Williams	no outflow at time of inspect
11/04/74	D. Williams	nil at inspection

3.1.9 Streamflow measurements on Priest Creek

As shown in Appendix (B5), gauge heights were recorded at a station identified as #08HB B05 on Priest Creek. Although a site description or stage discharge curve were not provided, the data sheet does show that flow ceases between April and November.

3.2 Streamflow Estimates

3.2.1 Low Flow Conditions

From the observations and measurements shown in Section 2.1, the streamflow ceases within the Quennell-Holden Water Allocation Plan area during the dry season. The streamflow during low flow conditions shall be considered zero for all creeks within this allocation plan.

3.2.2 Annual Volume Available

Due to the lack of long term measurements in this watershed, the annual volume of water available in the basin was calculated by two methods - by . regionalization of the flow characteristics from nearby gauged streams and by calculating runoff volume from annual precipitation.

3.2.2.1 Regionalization Method

Data on several nearby gauged basins were compiled and are shown in Table (1) (page 4). Three stations (Millstone R. & Bings Cr.) were monitored year round and two stations were only monitored for the summer months (French Cr. & Glenora Cr.).

By plotting a regional curve of the mean discharges versus drainage areas for nearby gauged basins, an adequate relationship was developed and shown in Figure (2). For the 34.43 km2 Quennell-Holden basin, the winter (October - March) mean flow was estimated at 1. 81m3 /sec and the summer (April - September) mean flow was estimated at 0.30 m3/sec. Annual mean discharge was then calculated at 1.06 m3/sec. Therefore, by regionalization, the annual volume available for the Quennell-Holden drainage area may be estimated at 33,500 dam3.

3.2.2.2 Precipitation Method

The nearest Precipitation station is located at Cassidy Airport, with 33 years of record. The annual precipitation (PPT) is 1103.6 mm.

The monthly PPT in mm is as follows:

JAN	177.5		JUL	22.6
FEB	117.1		AUG	32.7
MAR	108.4		SEPT	45.3
APR	57.5		OCT	101.2
MAY	38.4		NOV	161.4
JUN	39.7		DEC	201.8

QUENNELL LAKE\HOLDEN LAKE WATERSHED PLAN						
DATA AVAILABLE FROM NEARBY GAUGED BASINS WITH SIMILAR CHARACTERISTICS						
	Glenora Cr near Duncan 08HA056	Bings Creek @ mouth 08HA016	Quennell Holden Watershed	Millstone R @ Wellington 08HB027	Millstone R @ Nanaimo 08HB032	French Cr @ Coombs 08HB038
Distance from Quennell/Holden	35 km SSE	32 km SSE		18 km NW	18 km NW	57 km NW
Drainage Area (ha)	2080	1550	3443	4610	8620	5830
Median Elevation (m)	130	140	42	335	-	200
Mean Discharge (m^3/s)						
October-March	-	0.84	-	2.58	4.07	-
April-September	0.14	0.11	-	0.54	0.71	0.5
Annual	-	0.464	-	1.56	2.41	-
7-Day Avg Low Flow (m^3/s)						
Mean	0.015	0.017	-	0.017	0.123	0.001
5 year recurrence	0.012	0.011	-	0	0.018	0
Precipitation (mm)	Duncan Forestry		Nanaimo A			Parksville
October-March	832.9	832.9	867.4	867.4	867.4	722.2
April-September	209.4	209.4	236.2	236.2	236.2	241.7
Annual	1042.3	1042.3	1103.6	1103.6	1103.6	963.9

Table 1

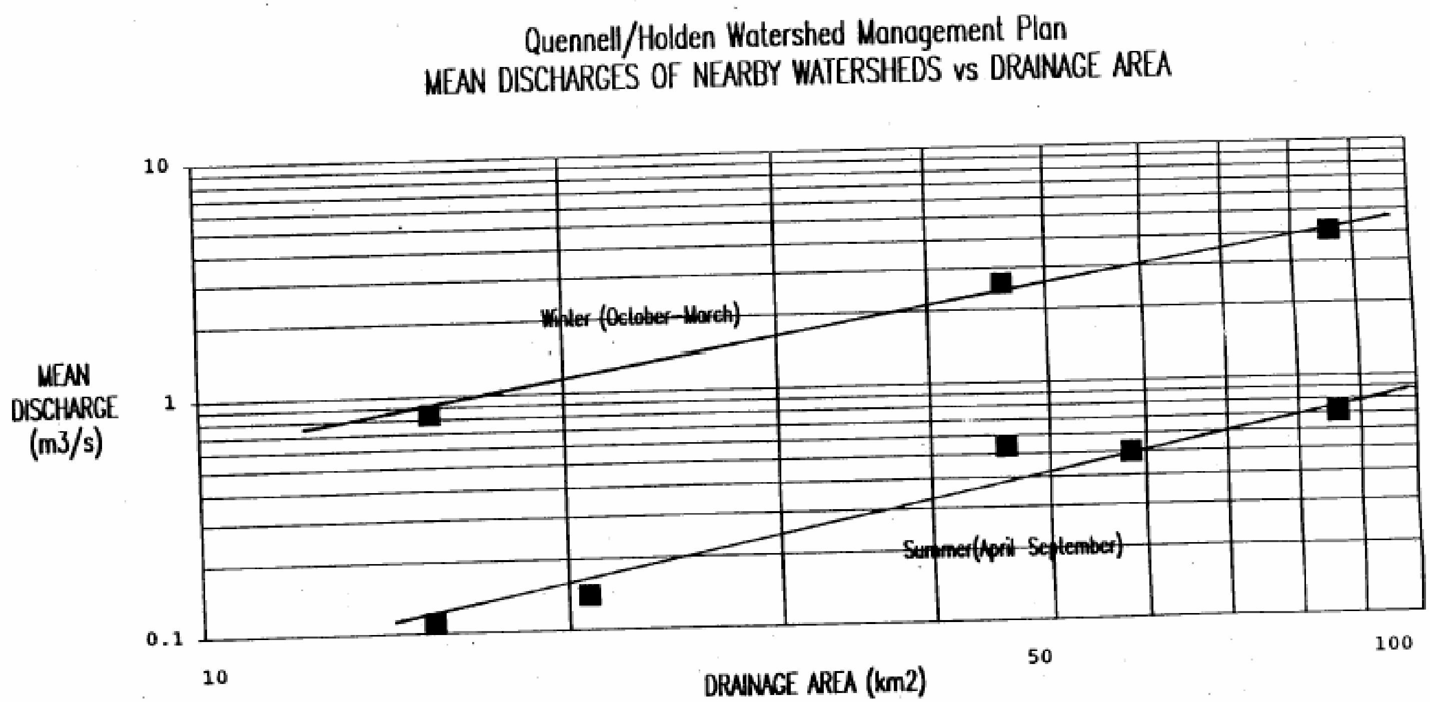

Quennell/Holden Watershed Management Plan
MEAN DISCHARGES OF NEARBY WATERSHEDS vs DRAINAGE AREA
10
1
0.1
MEAN
DISCHARGE
(m3/s)
Winter (October–March)
Summer(April September)
10
50
100
DRAINAGE AREA (km2)

Figure 2

The annual potential evapotranspiration as calculated by Air Management Branch, Ministry of Environment for the Nanaimo area is 526.2 mm with the open water evaporation at 745.0 mm. (refer to Appendix C).

Total potential annual yield for the watershed area is:

1103.6mm x 3443ha = 37,997 dam^3 or (30,791 acre feet)

Average Annual Yield minus the Potential Evapotranspiration and open water Evaporation is:

PPT	1103.6mm x 34.43km^2 =	37,997 dam^3
minus PE	526.2mm x 32.71km^2 =	17,212 dam^3
minus E	745.0mm x 1.72km^2 =	1,281 dam^3

	Total	19,504 dam^3 (15,812 acre feet)

Where: PPT = precipitation
PE = potential evapotranspiration
E = evaporation

The Monthly Potential Evapotranspiration rates indicate there is a deficit during the April to September period, therefore, there is no excess flow during that time. It is assumed then, that the yield available in the watershed area is only during surplus PPT periods - October to March.

By using different methods, regionalization and precipitation, two average annual volumes have been estimated - 34,000 dam^3 (section 2.2.1) and 19,504 dam^3 (section 2.2.2). Given the fact the watershed area used in the regionalization estimate had higher median elevations and the watershed is in a water deficit condition during the summer months, the conservative result of 19,504 dam^3 annual available volume will be used for the Quennell-Holden Lake watershed.

There fore, the unit yield for this Quennell-Holden Water Allocation Plan area is 5.66 dam^3 /ha (1192 acre feet/mi^2)

3.3 Lake Volumes Lakes Volumes

The following information has been collected from the Fisheries Branch, Ministry of Environment:

3.3.1 Quennell Lake

This is the largest lake within the Water Allocation Plan area, with a surface area of 119.8 ha and a volume of 4,159 dam^3. The mean depth is 3.5 metres and the maximum depth is 6.9 metres. There are no distinct inlets to the lake and there are two outlet channels on the north east arm of the lake which connects it to Holden Lake. The lake consists of several elongated arms and is generally fairly shallow and warm in the summer.

Volume minus open water evaporation[1] = 3975.0 dam^3 (3222.5 acre feet)

3.3.2 Holden Lake

This is the second largest lake, with a surface area of 37.6 ha. and a volume of 1,652.5 dam^3. The mean depth is 4.4 metres and the maximum depth is 6.5 metres. The lake is fairly shallow and warm in the summer. The outflow is Holden Creek, which is tributary to the ocean.

Volume minus Evaporation = 1513.9 dam^3 (1227.3 acre feet)

3.3.3 Greenway Lake

This is a small lake, with a surface area of 2.2 ha., and a volume of 72 dam^3. This lake's outflow goes in both directions during the winter months, to the north and to the south. The area surrounding the lake is quite flat.

Volume minus Evaporation = 63.8 dam^3 (51.7 acre feet)

3.3.4 Priest Lake

A small lake, with a surface area of 2.3 ha., and a volume of 109 dam^3. The inlet and the outlet are at the north end of the lake.

Volume minus Evaporation = 100.5 dam^3 (81.5 acre feet)

3.3.5 Florence Lake

Florence Lake is a "man-made" lake or reservoir on Priest Creek that was created by construction of an unauthorized and inadequate dam. Unsuccessful attempts were made to have the developer responsible for construction of the dam (Meadowlark Developments Ltd.) remove or improve the works. Landowners/users surrounding the lake have discussed the possibility of assuming responsibility for operation and maintenance. The issue was unresolved at time of this report.

Almost all the lakes within the Quennell-Holden Water Allocation Plan area have beaver activity at the outlets.

4.0 Instream Flow Requirements and Licensed Demand

4.1 Instream Values

Both Quennell Lake and Holden Lake are productive fish habitat. The problem with maintaining fish stock is the warm water temperatures during summer caused by the shallow depths. However, this shallow depth also provides for very good habitat. See the memo addressing this situation from Peter Law, Fisheries Biologist in Appendix (D). Fisheries recommendation is not to allow any further withdrawal on these two lakes.

As the streams within this watershed stop flowing during the summer months, there is no minimal instream flow requirement for fisheries.

Both Quennell Lake and Holden Lake have heavy recreational use.

The other lakes in the watershed should be maintained at close to the existing levels for aesthetic value and for the enjoyment of those living around the lakes.

4.2 Licensed Demand

Total licensed demand for the watershed is as follows:

Irrigation	289.45 acre feet
Storage	133.6 acre feet
Domestic	59,600 g.p.d. (80.16 acre feet p.a.)
Industrial	31,500 g.p.d. (42.37 acre feet p.a.)

TOTAL per annum (subtracting Storage) = 278.38 acre feet (343.38 dam^3).

4.2.1. Licenced Demand for Individual Lakes

QUENNELL LAKE			
Licenced purpose	Annual (acre feet)	6 mo. Apr. -Sept. acre feet)	90 day normal low flow (acre feet)
Irrigation	135.0	135.0	135.0
Domestic and Industrial (24, 850 gpd)	33.4	16.7	8.2
Total	168.4	151.7	143.2

HOLDEN LAKE			
Licenced purpose	Annual (acre feet)	6 mo. Apr. -Sept. (acre feet)	90 day normal low flow (acre feet)
Irrigation	4.7	4.7	4.7
Domestic and Industrial (5,500 gpd)	7.4	3.7	1.8
Total	12.1	8.4	6.5

PRIEST LAKE			
Licenced purpose	Annual (acre feet)	6 mo. Apr. -Sept. (acre feet)	90 day normal low flow (acre feet)
Irrigation	11.8	11.8	11.8
Domestic and Industrial (20,500 gpd)	27.6	13.8	6.8
Total	39.4	25.6	18.6

GREENWAY LAKE			
Licenced purpose	Annual (acre feet)	6 mo. Apr. -Sept. (acre feet)	90 day normal low flow (acre feet)
Irrigation	0.0	0.0	0.0
Domestic and Industrial (8,000 gpd)	10.8	5.4	2.7
Total	10.8	5.4	2.7

4.3 Projected Demand

A large residential development including a golf course is proposed for the Boat Harbour area. Preliminary plans indicate a connection to the North Cedar Waterworks district system. As recommended in the North Cedar Water Study, April 1985 by Chatwin Engineering Ltd. (Water Library # 8524), the waterworks district would use "wells" in the Nanaimo River flood plain or the Holden Creek aquifer to supply this additional demand.

5.0 Conclusions

Given the similar characteristics of the lakes and streams within the Quennell-Holden Water Allocation Plan area, conclusions are considered applicable to all sources. Some anomalies may occur with effuent streams being recharged by groundwater, however, these streams are infrequent exceptions.

The minimum streamflow during the summer months (April - September) :5hall be considered zero for all creeks.

Due to the sensitive nature of the fisheries habitat in Quennell and Holden Lakes and the small volumes in the other lakes, large water withdrawals not supported by further storage will have an adverse affect.

Watershed yield for the purpose of designing further water storage shall only be considered available during the 6 month October - March high flow period.

The annual unit yield for this area is 5.66 damJ/ha (1192 acre feet/mi2)

6. 0 Recommendations

6.1 Licencing

All streams are to be noted as fully recorded.

No further licencing for any purpose (for use during April - September) shall be recommended on any creek unless fully supported by storage.

Only domestic (household use) licences will be recommended on any of the lakes.

Any applications for an increase in storage on any of the lakes, or proposal for changes to the existing storage, must address the concerns of the other users including fisheries & recreation) and of the surrounding property owners. The onus will be placed on the applicant to reach a mutually agreeable position with concerned parties.

Florence Lake: no further water licences shall be allowed until the responsibility for operation and maintenance of the dam is resolved.

If an applicant claims that the source is an anomaly to the conclu" ions presented in this Water Allocation Plan, the onus wil be placed on the applicant to prove that unrecorded water is available.

6.2 Technical and Inventory

Gauges on Quennell Lake and Holden Lake should be established to help determine the annual acceptable lake levels for all users in the future. Gauges are also required to assist in water quality and fisheries studies.

Low flow measurements in the Holden Creek basin should be continued as this area is a potential source of water for proposed developments.

This Water Allocation Plan should be re-evaluated in 10 years, or when there is any major development within the plan area.

Water Rights maps should be updated to indicate the area of the watershed boundary for any future applications.

The Point of Interest (POI) database should be updated to note all sources within the plan area as being fully recorded according conditions provided in this Quennell-Holden Water Allocation Plan.

APPENDIX (A)

Province of British Columbia

Ministry of Environment
WATER MANAGEMENT BRANCH

MEMORANDUM

To: Dr. J.C. Foweraker, Head
Groundwater Section
Water Management Branch

Date: March 18, 1986
Our File: 92 G4

Re: Woodlot Licence 003

As requested by Mr. B. Hollingshead, Regional Water Manager, a review has been undertaken of available information on groundwater conditions in the vicinity of the lands associated with the above. Comments have been requested on the potential impact of logging on groundwater quantity and quality on adjoining areas. The areas in which logging is proposed are shown in Figure 1 and include Crown lot 113 (Area A), Crown lots 50, 111, 115 and 124 (Area B), and private lots 11 and 100. Available well records on file with the Groundwater Section, existing geologic reports and air photographs were examined for the preparation of this report. Areas downslope of the proposed logging activities, which may be potentially impacted are shown in Figure 1. The downslope areas were delineated on the basis of topographic and surface water drainage considerations.

GEOLOGY

Area A

Available geologic mapping (Muller and Jeletzky, 1970) indicates this area is underlain by sandstone and conglomerate of the Upper Cretaceous, De Courcey Formation. These rocks dip gently towards the northwest and form a series of alternating northwest to southeast trending bedrock ridges and linear depressions. Priest Lake, Long Lake and a number of smaller ponds and swamps occur within these depressions.

.../2

Northeast-southwest trending lineaments probably reflecting fracture planes in the bedrock and northwest-southeast striking lineaments probably reflecting bedding planes (Figure 2) are evident on air photographs covering the area. Areas downslope are also underlain by the same rock types. According to available surficial geology mapping (Halstead, 1963) a varied stony, loamy and clayey marine veneer commonly less than 1.5 metres in thickness mantles the bedrock. Alluvial deposits of gravel, sand, silt, clay and peat are also found within the Long Lake and Priest Lake depressions.

Area B and Private Lots 11, 100

These lands are underlain for the most part by sandstone and conglomerate of the De Courcy Formation (Muller and Jeletzky, 1970). Shale, siltstone and sandstone of the Cedar District Formation and the Northumberland Formation have also been mapped along the western slope of the Woodley Range facing Ladysmith Harbour and in Lot 11 respectively. These strata strike northwest to southeast and dip gently towards the northeast. The number of northeast-southwest striking lineaments probably reflecting fracture planes in the bedrock are evident on air photographs covering the area. One major lineament through lot 111 has been mapped by Muller and Jeletzky (1970) as a fault (Figure 3). Halstead (1963) shows the higher elevations (above 90 metres) of the Woodley Range locally covered by thin (less than 1.5 metres thick) deposits of marine veneer comprised of gravel and sand overlying bedrock. The eastern flank of the Woodley Range between the 90 and 60 metre elevations is however mantled by marine gravels and sand overlying ground moraine deposits of till with lenses of gravel, sand and silt. Below the 60 metre elevation contour clayey marine deposits up to 15 metres in thickness overlie bedrock. Further eastward and downslope of the proposed logging area a varied stony, loamy and clayey marine veneer less than 1.5 metres in thickness mantles the bedrock.

GROUNDWATER CONDITIONS

Available well record data on file indicates that the majority of domestic wells in the region are constructed in bedrock. Fracture zones and lithologic contacts constitute the major water-producing zones in the bedrock. Widespread fracturing in the bedrock appears to be more important than individual major fault zones in governing the regional availability and movement of groundwater. Some faults may act as relative barriers to groundwater flow and can be associated with poor quality (saline) groundwaters. Locally shallow dug wells, completed in low lying areas within the unconsolidated deposits may also yield domestic supplies. Wells and springs reported to occur downslope of the proposed logging areas are shown in Figure 1 and listed in Tables 1 and 2. Coordinate locations for these sites are from water well location maps on file with the Groundwater Section. Table 1 indicates, there are forty-nine reported domestic wells situated downslope of Area A (DL113). Reported well depths range from 3 to 122 m. Twelve wells are reported east of Area B (well depths ranging from 6.7 to 145 m) and a further 26 wells (well depths ranging from 9 to 138 m) are reported along the southwesterly facing slope of the Woodley Range along Ladysmith Harbour (Figure 1). The majority of reported well yields are generally low (<.3 L/s) although a few individual wells may yield 0.6 to 2 L/s. The current status of these wells is presently unknown; some may not be in use due to poor water quality or limited capacity. Others for which records are not on file may also exist. A field inventory would be required to confirm the status of these water sources.

Groundwater supplies for many residents, particularly in the area north of Yellow Point and along the north shore of Ladysmith Harbour may be marginal due to limited well capacities, variations in water quality and significant well density. Water conservation measures in these areas may be required for some residences during the late summer months.

Regionally areas of groundwater recharge and discharge have been recognized in terrains underlain by the Nanaimo Group. Generally upland areas act as groundwater recharge areas where infiltration of precipitation and surface water sources occurs. In these areas groundwater levels may lie several metres below the ground surface. Water levels in topographically low lying areas are generally closer to ground surface or under flowing artesian conditions indicative of groundwater discharge conditions. These latter areas are generally localized at the toe of slopes, within valleys and along coastal shorelines.

Based on available water level data and topographic considerations the proposed logging areas appear situated for the most part in groundwater recharge areas. Areas below the 40 metre contour elevation appear to lie within groundwater discharge areas.

Available groundwater quality analyses in the vicinity of Woodlot licence 003 are listed in Table 3. From the limited data available and known water quality variations elsewhere in wells completed in the Nanaimo Group it is expected that groundwater quality would vary locally both areally and with depth. Coastal wells along Ladysmith Harbour and Stuart Channel may be subject to sea water intrusion resulting in elevated concentrations of sodium and chloride. Locally high iron concentrations and sulphurous smelling groundwaters may be a problem at certain times of the year (late summer months).

POTENTIAL EFFECTS OF PROPOSED LOGGING ACTIVITIES

The effects of logging on groundwater quantity and quality are difficult to quantify. Removal of a large portion of timber from a watershed often leads to increased annual runoff due to the reduction in evapotranspiration. Effects on groundwater regimes however are little understood. An increase in annual runoff might imply reduced groundwater recharge but it is generally found that there is an increased component of subsurface discharge (groundwater inflow) to streams which would suggest increased groundwater recharge. Available long-term (10 year) water level data from bedrock observation wells in fractured bedrock aquifers in the southern coastal region of British Columbia (Kohut et al, 1984) indicate groundwater levels respond cyclically on a seasonal basis to climatic variations. Groundwater recharge (infiltration of precipitation to the groundwater regime) occurs as water levels rise in response to fall and winter precipitation. Thereafter waterlevels decline during the dry summer months.

Due to the relatively thin soil cover in Areas A and B (including the associated private lands) and the limited storage capacity of the bedrock, extensive removal of forest cover and soil disturbance (road, skid trails, etc.) in upland areas may have a noticeable effect on groundwater recharge. Where forest cover and undisturbed soil conditions are present this likely contributes to sustaining the period during which groundwater recharge occurs during the winter months. With forest cover removal and soil disturbance, water levels in the bedrock might be expected to rise more rapidly in response to fall-winter precipitation. With reduced moisture retention capacity of the materials overlying the bedrock, this may then be followed by a relatively early recession of water levels during the dry summer months. The net effect could be greater seasonal extremes with higher water levels during the winter months but possibly lower water levels occurring somewhat earlier during the summer season. Low water levels during the late summer months can be accompanied by a deterioration in water quality during these periods. Where well supplies are already marginal the situation could be aggravated.

The magnitude of any effects of logging on the groundwater regime, however, on an annual basis, will depend upon the relative location and area logged, methods of logging and climatic variations. According to the Management and Working plan, (Barker, 1985), it is indicated that approximately 8 percent of the total area of 398 hectares may be clearcut with clearcut opening sizes normally limited to 7 ha. Based on the proposed annual cut of 1350 m^3 this would be equivalent to approximately 6 hectares to be logged each year.

In consideration of the limitations on clear cutting, designated areas for clear cutting and magnitude of the annual cut, it would appear unlikely that these logging activities during the five year term of the plan would have a major impact upon the groundwater regime and existing wells, providing natural drainage features are not appreciably altered. Suitable undisturbed buffer areas adjacent to surface water bodies and along the southwesterly facing slope of the Woodley Range along Ladysmith Harbour should be considered.

SUMMARY AND CONCLUSIONS

Groundwater from bedrock wells and shallow dug wells are an important source of water supply for residents situated downslope of the proposed logging areas. Well density is significant particularly along the northern shore of Ladysmith Harbour and north of Yellow Point. Available supplies in these areas may be marginal due to limited well capacities, variations in water quality and well density. Water conservation measures may be required during the late summer months. The proposed logging areas are situated for the most part within groundwater recharge areas which supply bedrock aquifers downslope. The proposed methods of logging and limited annual cut however, would probably not have a major impact upon the groundwater regime and existing wells providing natural drainage courses are not altered. Undisturbed buffer zones adjacent to surface water bodies and along the southwest facing slope of the Woodley Range along Ladysmith Harbour are recommended.

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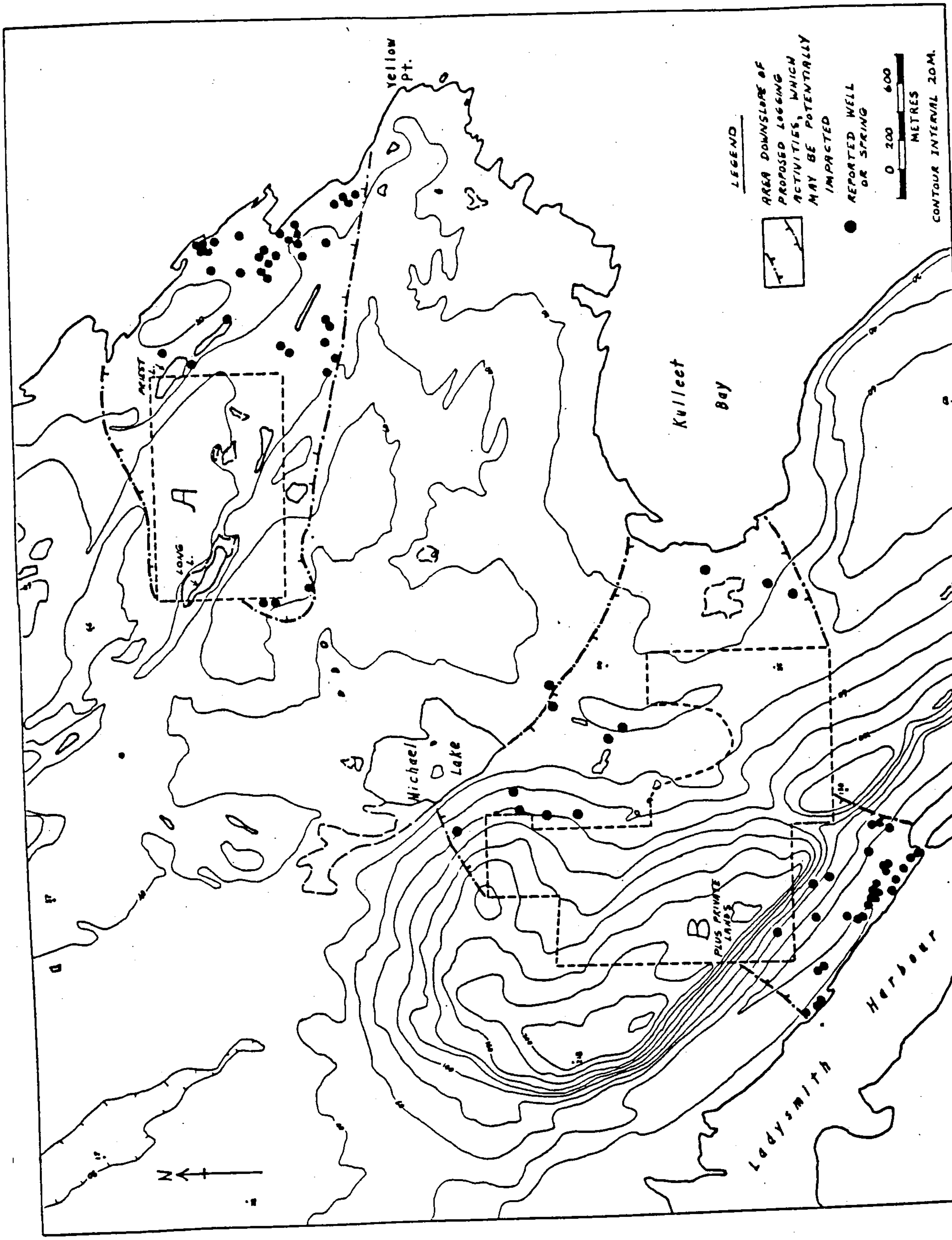
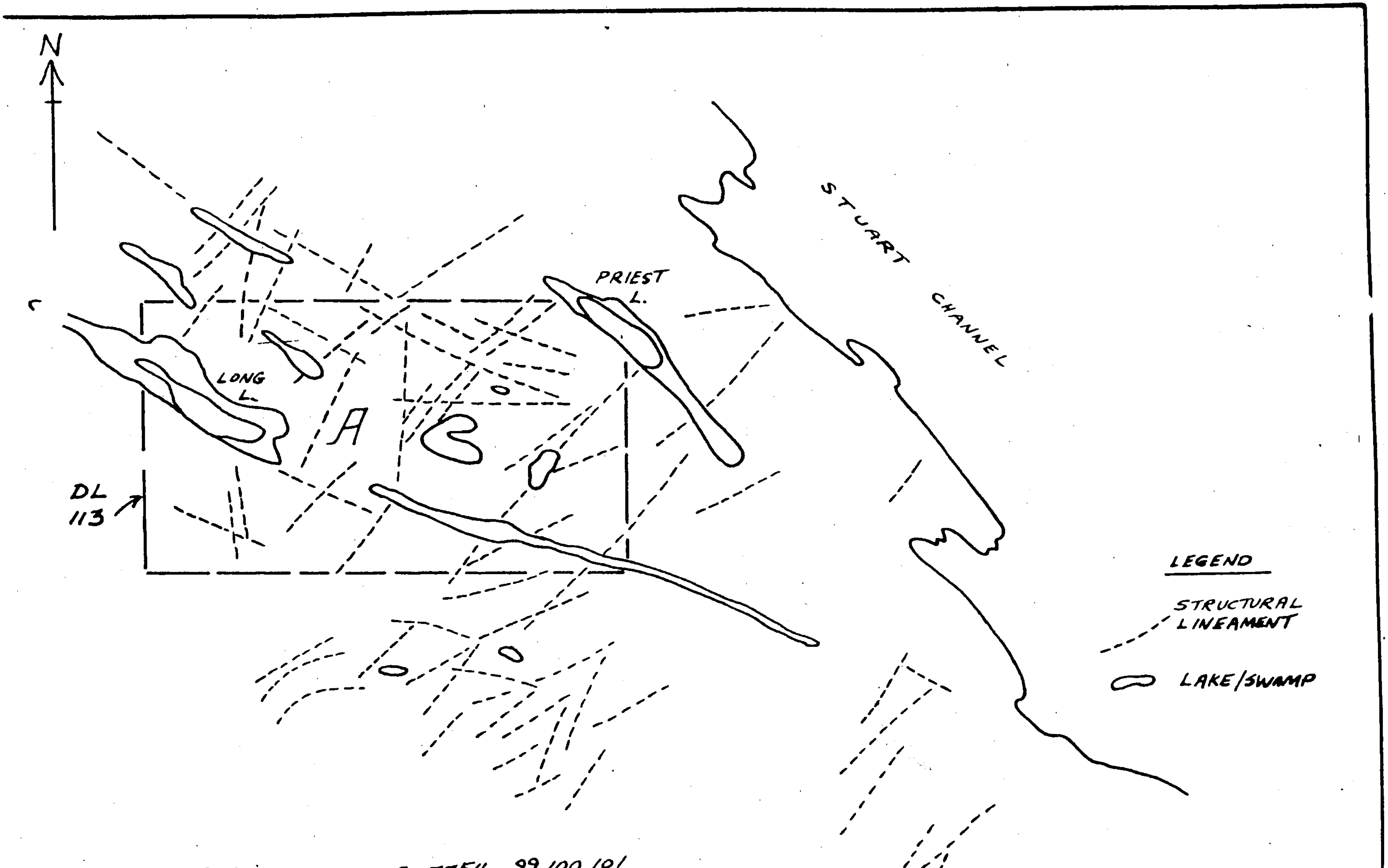
AK:bc



LEGEND
AREA DOWNSLOPE OF PROPOSED LOGGING ACTIVITIES, WHICH MAY BE POTENTIALLY IMPACTED
REPORTED WELL OR SPRING
0 200 600
METRES
CONTOUR INTERVAL 20M.
Yellow Pt.
Kulleet Bay
Michael Lake
Ladysmith Harbour
A
LONG L.
B
PLUS PRIVATE LANDS
N

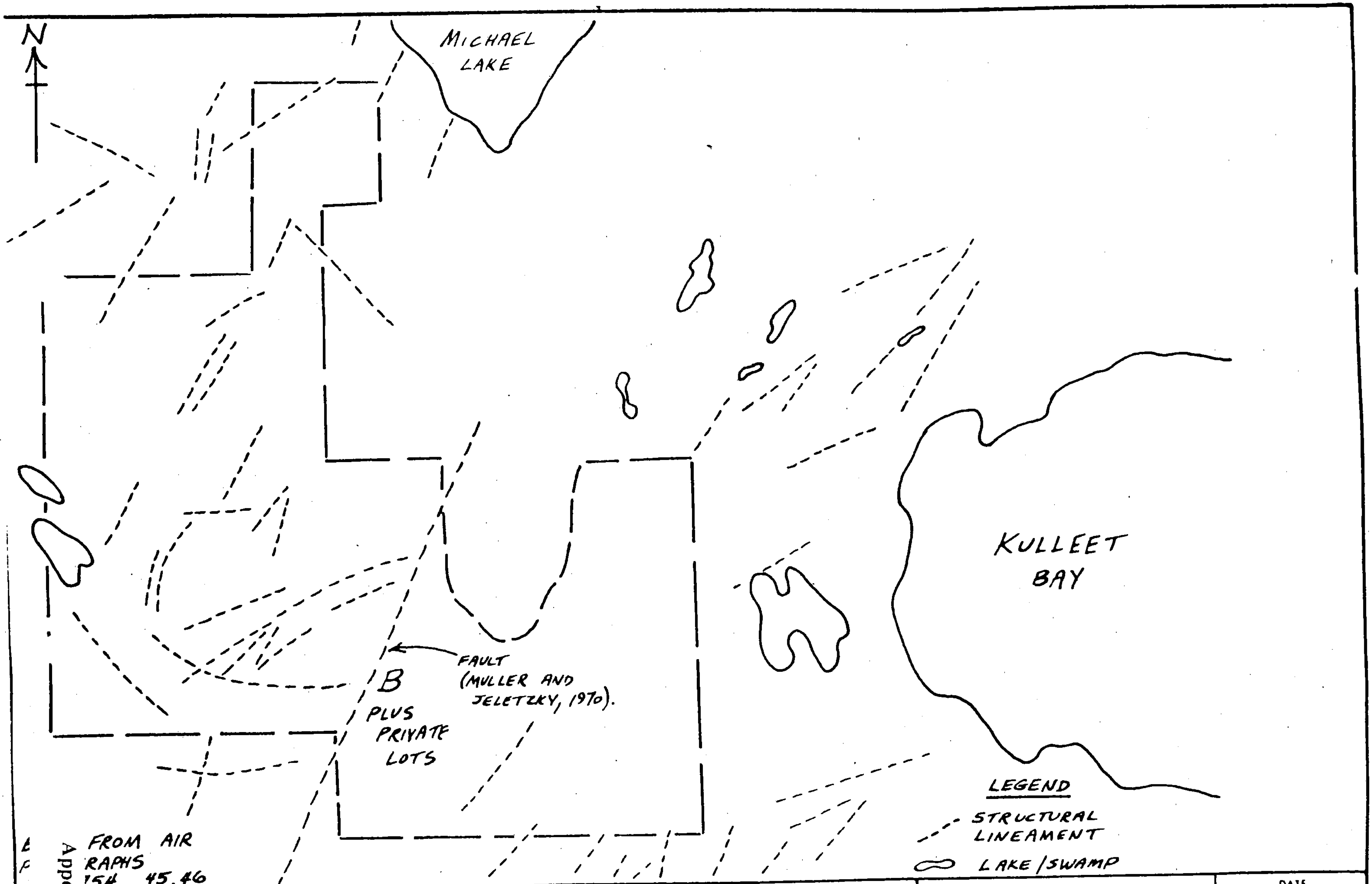
FIGURE 1.



BASE FROM AIR PHOTOGRAPHS BC 7754 99, 100, 101, 184, 185

Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON WOODLOT LICENCE 003	SCALE: VERT. — HOR. 1 cM ≈ 160 M.	DATE MARCH 1986
			APK ENGINEER
		FILE No 92 G 4	DWG No FIG. 2.

Appendix A9



Province of British Columbia Ministry of Environment WATER MANAGEMENT BRANCH	TO ACCOMPANY REPORT ON WOODLOT LICENCE 003	SCALE: VERT. — HOR. 1CM ≈ 160M DATE MARCH 1986 APK ENGINEER FILE No 92G4 DWG No FIG. 3.

WELL LOCATION CO-ORDINATES	DATE COMPLETED	DEPTH (feet)	AQUIFER TYPE	MAJOR PRODUCING ZONE (feet)	NON-PUMPING WATER LEVEL BELOW GROUND (feet)	REPORTED YIELD gpm.
X5, Y9 #1	1954	204	sandstone	170	--	>0.5
2	1961	80	sandstone/shale	40, 72	--	2+
3	1959	125	bedrock	--	--	1.3
9	1952	--	--	--	--	--
5	1967	100	sandstone	54	6	0.5
6	1968	85	sandstone	--	8	15
7	1973	200	sandstone/shale	123,167,195	33	2.3
8	1973	400	shale-granite	--	20	1.5
9	1979	84	shaley sandstone	75	47	1
X5, Y8 #1	1957	80	sandstone	--	9	2.4
3	1957	54	sandstone	52	30	8
4	1962	83	sandstone	--	15	10+
5	1962	20	sandstone	--	2	--
6	1962	24	gravel	--	surface	--
7	1962	68	shale	33,54,67.5	8	9.6
8	1955	53	sandstone	10,45	17	5.5
10	1962	5	bedrock	--	--	--
12	1950	116	sandstone/shale	--	--	2
13	1965	105	sandstone	100	5	2
14	1965	156	sandstone	40,62,80,120,154	14	10
16	1971	100	sandstone	98	25	5
17	1971	216	shale	100,155,197	92	0.3
18	1969	174	sandstone	--	26	6
20	1972	90	shaley sandstone	47,57,83	20	12
21	1972	311	sandstone	113-116,155-157 174-177,199-203	39	2
28	1973	130	shaley sandstone	--	55	1.5
31	1976	140	shaley sandstone	83,129	28	5
32	1977	230	sandstone	165	45	15
38	1979	392	shaley sandstone	385	78	1
41	1978	84	sandstone	21,80	20	2
42	1981	142	sandstone	98,131	35	3.5
43	1975	228	sandstone	226,228	54	30
44	1975	400	shaley sandstone	319,356,396	56	4
45	1981	162	shaley sandstone	94	70	1.25
46	1975	240	--	236	--	9
47	1979	310	shaley sandstone	300	61	7
48	--	260	sandstone	--	55	8
X4, Y8 #4	--	10	sandstone	--	0	--
17	1973	110	shaley sandstone	58,80,103	48	4
52	1982	265	sandstone	--	93	6
R7Sec.1#2	1966	105	sandstone	76,92	2	8
4	1967	119	sandstone	45	12	25
5	1970	122	sandstone/shale	--	--	8
6	1970	94	sandstone/shale	--	53	1
7	1969	97	shaley sandstone	36,64	15	2.5
8	1974	135	shaley sandstone	74	22	0.5
9	1974	110	shaley sandstone	76	45	1
13	1977	166	shaley sandstone	120,158	87	0.5
14	1978	292	shaley sandstone	172	5	0.25

TABLE 3

AVAILABLE GROUNDWATER QUALITY ANALYSES, IN VICINITY OF WOODLOT LICENCE 003

WELL COORDINATES	DATE SAMPLED	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	SO_4^{2-}	Cl^{-}	ALKALINITY TOTAL	HARDNESS	SPECIFIC CONDUCTANCE μmhos/cm	pH	FLUORIDE	IRON	COMMENTS
X2, Y6, #22	Aug. 76	294	97	1050	3.6	204	2180	158	1130	6900	7.6	--	0.2	--
X3, Y8, #19	Mar. 82	--	--	258	--	--	--	--	--	1310	8.8	0.99	--	--
X4, Y7, #1	--	--	--	--	--	--	--	--	68	--	--	--	--	Sulphurous
X4, Y8, #7	--	--	--	--	--	--	--	--	34	--	6.0	--	0.6	--
X5, Y8, #37	--	--	--	64.5	--	--	--	--	--	312	7.4	0.68	--	--

Concentrations reported in mg/L except for pH (relative units).

WELLS/SPRINGS DOWNSLOPE OF PROPOSED LOGGING AREA B INCLUDING PRIVATE LANDS

WELL LOCATION	DATE COMPLETED	DEPTH (feet)	AQUIFER TYPE	MAJOR PRODUCING ZONE (feet)	NON-PUMPING WATER LEVEL BELOW GROUND (feet)	REPORTED YIELD gpm.
X2, Y6 #1	1957	60	sandstone	18	17	0.4
3	--	--	--	--	0	--
4	1956	30	sandstone	25-30	6	10
6	1955	46	sandstone/shale	42	15	10
10	1965	256	shaley sandstone	168	--	.2
11	1966	90	shale	55	35	2
12	1966	70	shale	37,60	22	3
15	1968	80	sandstone	--	15	2
16	1971	75	shaley sandstone	26,69	12.5	2
17	1972	60	shaley sandstone	15,26,31,46	14	2.5
20	1973	200	shaley sandstone	--	15	.25
21	1973	80	shaley sandstone	--	15	10
22	1975	114	shaley sandstone	59,84,108	43	.75
23	--	138	shaley sandstone	79	48	0.5
25	1976	120	shaley sandstone	39,52	9	1
26	1978	64	shaley sandstone	51	24	30
27	1977	65	shale	--	20	20
30	1975	130	shaley sandstone	126	16	.5
31	1975	140	shaley sandstone	--	26	.3
33	1978	190	shaley sandstone	21	--	.05
34	1978	105	sandstone	35	20	.5
35	1979	453	shaley sandstone	300	--	--
36	1980	62	shaley sandstone	46	31	3.5
X3, Y6,#1	1973	40	shaley sandstone	35,38	3	5
2	1977	63	shale	30,34	17	3
5	1974	60	shaley sandstone	40	10	4
X4, Y6,#3	1979	475	sandstone	455	259	5
4	1975	125	clay/stoney sand	101	0	10
X4, Y7,#1	--	--	--	--	+1	1
X3, Y7,#1	1962	--	till	--	2	--
2	--	22	--	--	--	--
3	1968	110	sandstone	100	22	4.5
4	1973	140	sandstone	--	6	3.5
6	--	210	sandstone/shale	199-202	28	10
7	1978	290	shaley sandstone	280	10	15
8	1982	385	shaley sandstone	358	32	7
9	1982	363	shaley sandstone	363	35	30
X3, Y8,#33	1980	200	sandstone	--	--	--

Appendix A13

APPENDIX (B)

WATER SUPPLY & INVESTIGATION DIVISION - WATER RESOURCES SERVICE

HYDROMETRIC STATION DESCRIPTION

STATION NUMBER: 8HBP07 **STATION NAME:** Holden Creek on Cedar-Harmac

DRAINAGE BASIN: Alberni District **SYSTEM:** Vancouver Island

LATITUDE: 49 - 06' - 50" N **LONGITUDE:** f123 - 50' - 09" W

MAP: 92G/4 **SCALE:** 1:50,000

ESTABLISHED BY: GMC and HNB **DATE:** June 12/1980

DESCRIPTION: 2 meter staff gauge on right bank of Holden Creek directly behind J.L. Knighton residence which is first property on left hand side of Rugg Road and about 300m from intersection with Holden Corso Road.

From south: take Yellow Pt. turn off from Island Hwy. just north of Ladysmith; then left on Harmac Rd., left on Yellow Pt. Rd., right on McMillan Rd., right on Holden-Corso Rd., and right on Rugg Rd.

BENCH MARK - 1 #3931 on downstream face of 2' Alder about 3' from left bank and about 50' u/s of foot bridge.

BENCH MARK - 2 # 3932 on streamside face of 18" Cedar on left bank and about 25' u/s of bridge.

Bench Mark - 3 # 3933 on u/s face of 2' Cedar on u/s side of bridge, leftbank.

GAUGE ZERO IS 1.756m **' BELOW B.M. - 1;** **GAUGE ZERO IS** 1.676m **' BELOW B.M. - 2.**

GEODETIC ZERO OF GAUGE: ______ '. Gauge zero is 1.651m below B.M. 3.

READER: Jack l. Knighton
RR#2 Rugg Rd.
Site H1 Nanaimo, B.C. V9R5K2

PHONE: 722-2872

RATE: ______

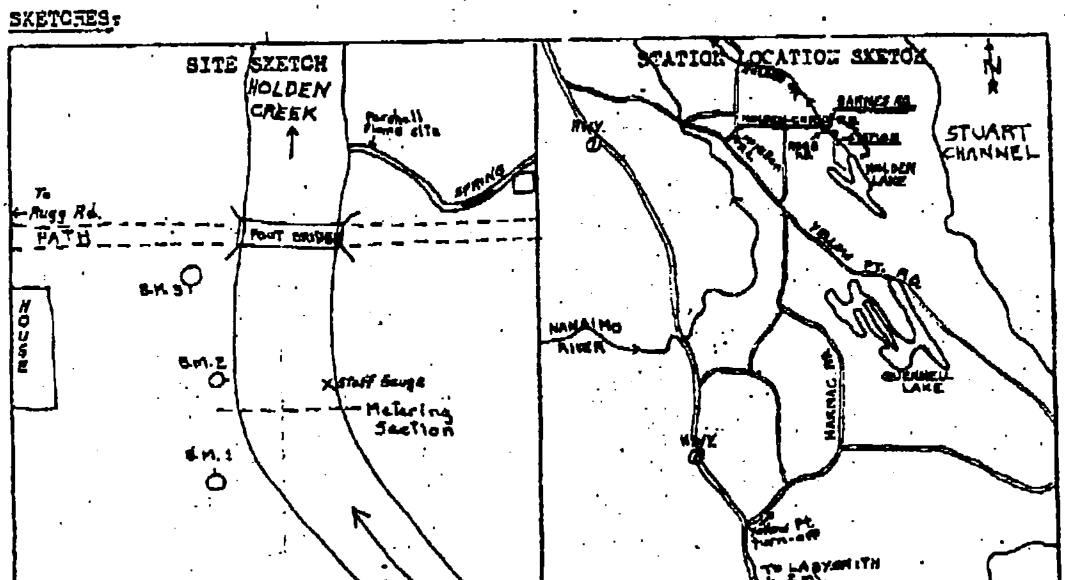
READING FREQUENCY: Twice weekly

GENERAL: Levels.

	B.M.1	B.M.2	B.M.3
Mar 27/81	1.757M	1.675M	1.656M
June 16/82	1.758M	1.675M	1.649M

REVISIONS:

SKETCHES:



Appendix B2(a)

27 MARCH 1984

MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH
SURFACE WATER SECTION

STATION NAME HOLDEN CREEK BELOW HOLDEN LAKE — STATION NO 08HB07

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR THE YEAR 1980

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1							0.050	0.014	0.018E	0.020E	0.041	0.454
2							0.049	0.013E	0.018	0.020	0.042E	0.455E
3							0.050E	0.012E	0.018	0.020E	0.042	0.456E
4							0.051	0.010	0.018E	0.020E	0.042E	0.457E
5							0.051E	0.010E	0.018	0.020	0.041E	0.457
6							0.051	0.011E	0.018E	0.020E	0.041	0.459E
7							0.050E	0.011	0.018E	0.020	0.037E	0.461
8							0.048	0.011E	0.018	0.019E	0.032E	0.475E
							0.046E	0.012E	0.018E	0.018	0.028	0.490E
							0.044	0.012	0.019	0.018E	0.026E	0.504
							0.043E	0.012E	0.018E	0.018E	0.024	0.512
						0.062	0.042E	0.012	0.018	0.018	0.025E	0.614
						0.059	0.041	0.012E	0.018E	0.018E	0.026	0.698E
						0.050	0.039E	0.012	0.018E	0.018	0.026E	0.783
						0.054E	0.037E	0.013E	0.018E	0.018E	0.027E	0.636E
						0.059	0.034	0.013E	0.019	0.018E	0.027E	0.488
						0.061E	0.022	0.014	0.019E	0.018	0.028	0.532E
						0.063	0.013	0.014	0.019E	0.018E	0.028E	0.575E
						0.069E	0.013E	0.014E	0.020	0.019E	0.028E	0.618E
						0.075	0.014E	0.014	0.020E	0.019	0.022	0.662
						0.067E	0.014	0.015E	0.020	0.019E	0.028E	0.675E
						0.060E	0.014E	0.016E	0.021E	0.020E	0.028	0.688
						0.052	0.014	0.018	0.021	0.020	0.028E	0.751E
						0.060E	0.014	0.018E	0.021E	0.020E	0.028	0.814
						0.067	0.014E	0.018	0.020	0.020E	0.028E	1.07 E
						0.062E	0.014E	0.018E	0.020E	0.020	0.028	1.32 E
						0.057	0.014	0.017	0.020E	0.020E	0.261	1.57
						0.055E	0.014E	0.018E	0.020	0.020	0.238E	1.41 E
						0.054E	0.014E	0.018	0.020E	0.021E	0.215	1.26 E
						0.052E	0.014	0.018E	0.020E	0.022	0.304E	1.10
							0.014E	0.018E		0.032E		1.11 E
TOTAL							0.942	0.438	0.569	0.611	1 855	22.554
MEAN							0.030	0.014	0.019	0.020	0.062	0.728
DAM3							81.4	37.8	49.2	52.8	160	1950
MAX							0.051	0.018	0.021	0.032	0.304	1.57
MIN							0.013	0.010	0.018	0.018	0.022	0.454

MAXIMUM DAILY DISCHARGE 1.57 CMS ON 27 DECEMBER NOT VALID
MINIMUM DAILY DISCHARGE 0.010 CMS ON 4 AUGUST VALID

FOR THE PERIOD JULY TO DECEMBER
MEAN DISCHARGE 0.147 CMS
TOTAL DISCHARGE 2230 DAM3

LOCATION LAT 49 06 50 N
LOCATION LONG 123 50 09 W

TYPE OF GAUGE MANUAL

E-ESTIMATED.

APPROVAL FIN R

Appendix B2(

22 SEPTEMBER 1983

MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH
SURFACE WATER SECTION

STATION NAME — HOLDEN CREEK BELOW HOLDEN LAKE — STATION NO - 08HB807

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR THE YEAR 1981

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	1.12	0.674	0.602	0.165E	0.104	0.109	0.054E	0.028	0.022	0.046E	0.079	0.324	1
2	1.09 E	0.643E	0.560E	0.202	0.104E	0.107E	0.052E	0.026E	0.022E	0.046	0.091E	0.318E	2
3	1.05 E	0.611E	0.519	0.214E	0.104E	0.104E	0.051E	0.024E	0.022E	0.045E	0.102E	0.313E	3
4	1.02	0.580	0.500E	0.226	0.104	0.102E	0.049	0.021E	0.022	0.045E	0.114	0.308E	4
5	0.909E	0.534E	0.480E	0.218E	0.106E	0.100	0.049E	0.019	0.021E	0.044	0.124E	0.302	5
6	0.797E	0.489E	0.461	0.210E	0.107E	0.100E	0.048	0.018E	0.021E	0.044E	0.133	0.380	6
7	0.686	0.443	0.443E	0.202	0.109	0.100	0.048E	0.018	0.020	0.044	0.143E	0.416E	7
8	0.616E	0.419E	0.425E	0.194E	0.111E	0.099E	0.047E	0.018E	0.020E	0.044E	0.154E	0.452E	8
9	0.547	0.396E	0.407	0.187E	0.112E	0.099E	0.047	0.018E	0.020E	0.044E	0.164E	0.488	9
10	0.519	0.372	0.384E	0.179	0.114	0.098	0.047E	0.018	0.020	0.044	0.174	0.599E	10
11	0.494E	0.372E	0.362E	0.160E	0.119E	0.097E	0.046E	0.018E	0.021E	0.042E	0.188E	0.710	11
12	0.470	0.372	0.339	0.142	0.124	0.096	0.046	0.017	0.022	0.041	0.202	0.903E	12
13	0.434E	0.403E	0.319E	0.142E	0.125E	0.096E	0.045E	0.017E	0.023E	0.041E	0.208E	1.10 E	13
14	0.398	0.435E	0.300E	0.142E	0.127E	0.096E	0.044E	0.018E	0.023E	0.041E	0.214E	1.29	14
15	0.384E	0.466	0.280	0.142	0.128	0.096	0.043	0.018	0.024	0.040	0.220	1.19 E	15
16	0.369E	0.933E	0.273E	0.208E	0.126E	0.092E	0.040E	0.019E	0.024E	0.040	0.226	1.08 E	16
17	0.355	1.41	0.266	0.273	0.124	0.088	0.038	0.020	0.024	0.040E	0.228E	0.980	17
18	0.424E	1.39 E	0.216E	0.283E	0.128E	0.084E	0.037E	0.020E	0.024E	0.041E	0.231E	1.08 E	18
19	0.492	1.38 E	0.167	0.292E	0.133	0.079	0.035E	0.020	0.024E	0.040	0.233	1.19 E	19
20	0.632E	1.38	0.162E	0.302	0.124E	0.073E	0.034	0.021E	0.024	0.041E	0.261E	1.29	20
21	0.773E	1.23	0.156	0.274E	0.114	0.067	0.032	0.022	0.026E	0.041E	0.288E	1.26 E	21
22	0.913	1.12 E	0.132E	0.246	0.116E	0.062E	0.031E	0.022E	0.028	0.041	0.316	1.22	22
23	0.959E	1.02 E	0.107E	0.237E	0.119E	0.058E	0.031E	0.023E	0.029E	0.043E	0.326E	1.19 E	23
24	1.00 E	0.910	0.083	0.229E	0.122E	0.054E	0.030	0.023	0.031E	0.045E	0.337E	1.17 E	24
25	1.05	0.901E	0.089E	0.220	0.124	0.049	0.028E	0.023E	0.032	0.047	0.347	1.13	25
26	0.976E	0.891E	0.096E	0.152E	0.119E	0.049E	0.026	0.024E	0.033E	0.055E	0.368E	1.14 E	26
27	0.901E	0.882	0.102	0.083	0.114	0.049	0.025E	0.024	0.035E	0.063	0.380	1.13	27
28	0.827	0.749	0.108E	0.093E	0.112E	0.051E	0.024	0.023E	0.036	0.067E	0.375E	1.12 E	28
29	0.788E		0.115E	0.104E	0.109E	0.054E	0.023E	0.023E	0.042E	0.071E	0.369E	1.10 E	29
30	0.749		0.122E	0.114	0.106E	0.056	0.023E	0.022	0.047	0.075E	0.364	1.09 E	30
31	0.712E		0.128		0.104		0.022	0.022E		0.079		1.08	31
TOTAL	22.454	21.405	8.703	5.835	3.592	2.464	1.195	0.647	0.782	1.480	6.959	27.343	
MEAN	0.724	0.764	0.281	0.194	0.116	0.082	0.039	0.021	0.026	0.048	0.232	0.882	
DAM3	1940	1850	752	504	310	213	103	55.9	67.6	128	601	2360	
MAX	1.12	1.41	0.602	0.302	0.133	0.109	0.054	0.028	0.047	0.079	0.380	1.29	
MIN	0.355	0.372	0.083	0.083	0.104	0.049	0.022	0.017	0.020	0.040	0.079	0.302	

MAXIMUM DAILY DISCHARGE 1.41 CMS ON 17 FEBRUARY
MINIMUM DAILY DISCHARGE 0.017 CMS ON 13 AUGUST

LOCATION LAT 49 06 50 N
LOCATION LONG 123 50 09 W

E-ESTIMATED

FOR THE PERIOD JANUARY TO DECEMBER
MEAN DISCHARGE 0.282 CMS

TYPE OF GAUGE: MANUAL

APPROVAL FIN. REP.

Appendix B2(c)

22 SEPTEMBER 1983

MINISTRY OF ENVIRONMENT
WATER MANAGEMENT BRANCH
SURFACE WATER SECTION

STATION-NAME HOLDEN-CREEK BELOW HOLDEN LAKE — STATION NO 08HB807

DAILY DISCHARGE IN CUBIC METRES PER SECOND FOR THE YEAR 1982

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1				0.226	0.119	0.026	0.104	0.035E	0.016				1
2				0.224	0.119	0.026	0.083	0.034	0.016E				2
3				0.233	0.114	0.026	0.056	0.033E	0.016				3
4				0.233	0.096	0.026	0.044	0.032	0.016E				4
5				0.233	0.093	0.305	0.030	0.031E	0.016				5
6				0.233	0.092	0.508	0.026	0.030	0.021E				6
7				0.214	0.088	0.302	0.024	0.027E	0.026				7
8				0.192	0.079	0.150	0.022	0.024	0.026E				8
9				0.174	0.075	0.098	0.019	0.021E	0.026				9
10				0.168	0.071	0.077	0.018	0.018	0.026E				10
11				0.157	0.067	0.069	0.019	0.018E	0.026				11
12				0.147	0.067	0.050	0.018	0.019	0.026E				12
13				0.142	0.063	0.036	0.018	0.020E	0.026				13
14				0.138	0.059	0.032	0.018	0.022	0.026E				14
15				0.124	0.056	0.124	0.020	0.024E	0.026				15
16				0.114	0.067	0.147	0.022	0.026	0.026E				16
17				0.109	0.047	0.176	0.071	0.027E	0.026				17
18				0.096	0.044	0.154	0.063	0.028	0.025E				18
19				0.088	0.041	0.112	0.059	0.030E	0.024				19
20				0.124	0.040	0.073	0.056	0.032	0.024E				20
21				0.124	0.039	0.050	0.050	0.033E	0.024				21
22				0.114	0.036	0.034	0.050	0.034	0.022E				22
23				0.104	0.036	0.094	0.047	0.033E	0.020				23
24				0.109	0.034	0.124	0.044	0.032	0.020E				24
25				0.114	0.032	0.104	0.044	0.032E	0.020				25
26				0.119	0.032	0.104	0.044	0.032	0.020E				26
27				0.124	0.030	0.104	0.044	0.027E	0.019				27
28				0.114	0.030	0.104	0.041	0.022	0.019E				28
29				0.119	0.029E	0.098	0.039	0.019E	0.019				29
30				0.114	0.029E	0.079	0.036	0.016	0.019E				30
31					0.028		0.036	0.016E					31
TOTAL				4.524	1.852	3.412	1.265	0.827	0.662				
MEAN				0.151	0.060	0.114	0.041	0.027	0.022				
DAM3				391	160	295	109	71.5	57.2				
MAX				0.233	0.119	0.508	0.104	0.035	0.026				
MIN				0.088	0.028	0.026	0.018	0.016	0.016				

MAXIMUM DAILY DISCHARGE 0.508 CMS ON 6 JUNE
MINIMUM DAILY DISCHARGE 0.016 CMS ON 30 AUGUST

FOR THE PERIOD APRIL TO SEPTEMBER
MEAN DISCHARGE 0.069 CMS

LOCATION LAT 49 06 50 N
LOCATION LONG 123 50 09 W

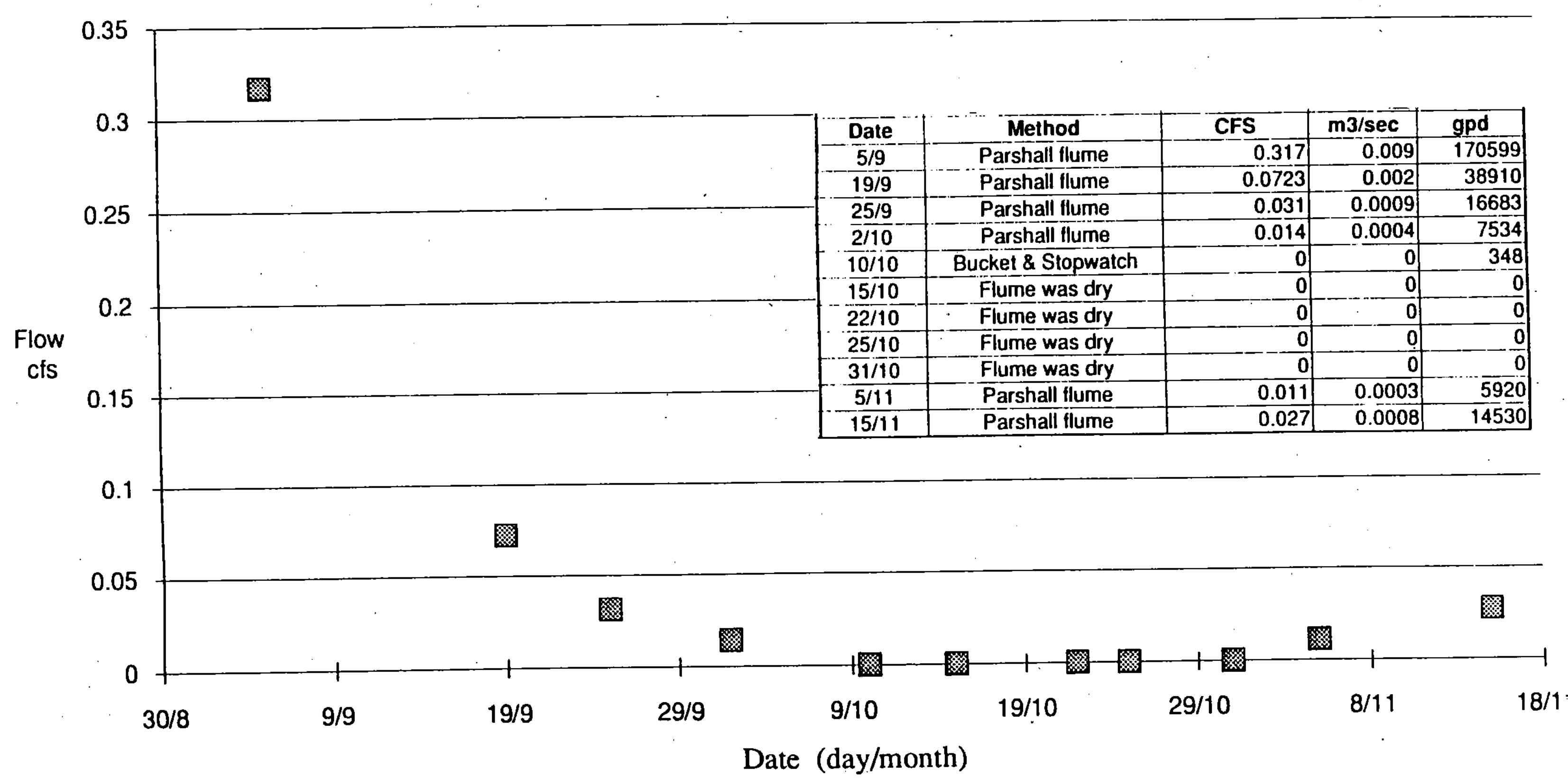
TYPE OF GAUGE: MANUAL

E-ESTIMATED

APPROVAL FIN. REP.

Appendix B2(d

Holden Creek Streamflow - 1991



Date	Method	CFS	m3/sec	gpd
5/9	Parshall flume	0.317	0.009	170599
19/9	Parshall flume	0.0723	0.002	38910
25/9	Parshall flume	0.031	0.0009	16683
2/10	Parshall flume	0.014	0.0004	7534
10/10	Bucket & Stopwatch	0	0	348
15/10	Flume was dry	0	0	0
22/10	Flume was dry	0	0	0
25/10	Flume was dry	0	0	0
31/10	Flume was dry	0	0	0
5/11	Parshall flume	0.011	0.0003	5920
15/11	Parshall flume	0.027	0.0008	14530

PRIEST LAKE NEAR LADYSMITH - STATION NO. 08HB066

DAILY WATER LEVEL IN METRES FOR 1979

DAY	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	DAY
1	1.387	1.280	1.219	1.280	1.128	1.158	1.067	0.945	0.853	0.823	0.975	---	1
2	---	---	---	---	---	---	---	---	---	---	---	1.286	2
3	---	---	---	---	---	---	---	---	---	---	0.991	---	3
4	---	---	---	---	---	---	---	---	---	---	---	---	4
5	---	---	---	---	---	---	---	---	---	---	---	---	5
6	---	---	---	---	---	---	---	---	---	---	---	---	6
7	---	---	---	---	---	---	---	---	---	---	1.000	---	7
8	1.387	1.311	1.311	1.341	1.189	1.128	1.067	0.914	0.853	0.823	---	---	8
9	---	1.341	---	---	---	---	---	---	---	---	---	1.341	9
10	---	---	---	---	---	---	---	---	---	---	---	---	10
11	---	---	---	---	---	---	---	---	---	---	---	---	11
12	---	---	---	---	---	---	---	---	---	---	1.006	---	12
13	---	---	---	---	---	---	---	---	---	---	---	---	13
14	---	---	---	---	---	---	---	---	---	---	---	---	14
15	1.396	1.189	1.341	1.295	1.222	1.097	1.036	0.884	0.853	0.823	---	1.494	15
16	---	---	---	---	---	---	---	---	---	---	---	1.402	16
17	---	---	---	---	---	---	---	---	---	---	---	---	17
18	---	---	---	---	---	---	---	---	---	---	1.012	---	18
19	---	---	---	---	---	---	---	0.884	---	---	---	---	19
20	---	---	---	---	---	---	---	---	---	---	---	---	20
21	---	---	---	---	---	---	---	---	---	---	---	---	21
22	1.420	1.250	1.219	1.128	1.219	1.097	1.006	0.853	0.823	0.853	---	---	22
23	---	---	---	---	---	---	---	---	---	---	---	---	23
24	---	---	---	---	---	---	---	---	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	1.055	---	25
26	---	---	---	---	---	---	---	---	---	---	---	1.341	26
27	---	---	---	---	---	---	---	---	---	0.945	---	---	27
28	---	1.189	---	---	---	---	---	---	---	0.975	---	---	28
29	1.280		1.280	1.128	1.219	1.067	0.975	0.823	0.823	---	---	---	29
30	1.280		---	---	---	---	---	---	---	---	1.128	---	30
31	---		---		---		---	---		0.975		1.219	31
MEAN	---	---	---	---	---	---	---	---	---	---	---	---	MEAN
MAX	---	---	---	---	---	---	---	---	---	---	---	---	MAX
MIN	---	---	---	---	---	---	---	---	---	---	---	---	MIN

TYPE OF GAUGE - MANUAL
LOCATION - LAT 49 03 18 N
LONG 123 46 16 W
DATA CONTRIBUTED BY -
BRITISH COLUMBIA MINISTRY OF ENVIRONMENT

REGULATED

WATER LEVELS ARE REFERRED TO ASSUMED DATUM

DAILY DISCHARGES

BRITISH COLUMBIA WATER RESOURCES SERVICE
WATE' 'VESTIGATIONS BRANCH

Station Name *Priest Creek* Ion No. *08HB 805*

Daily Gauge Heights in Feet and Daily Discharges in Cubic Feet per Second for the Year 19*79*

Drainage Area square miles Type of Gauge Manual ☐ Recording ☐

Day	January Gauge Height	January Discharge	February Gauge Height	February Discharge	March Gauge Height	March Discharge	April Gauge Height	April Discharge	May Gauge Height	May Discharge	June Gauge Height	June Discharge
1	1.60		1.60		2.00		1.50	0.0	1.50	0.0	1.50	0.0
2	1.60		1.62		1.90		1.50		1.50			
3	1.60		1.64		1.90		1.50		1.50			
4	1.60		1.64		2.00		1.50		1.50			
5	1.60		1.70		2.00		1.50		1.50			
6	1.60		1.70		2.10		1.50		1.50			
7	1.60		1.70		2.00		1.50		1.50			
8	1.60		1.90		1.90		1.55		1.50			
9	1.60		2.00		1.90		1.55		1.50			
10	1.60		2.00		1.90		1.50	0.0	1.50			
11	1.60		1.90		1.80		1.50	0.0	1.50			
12	1.60		1.90		1.60		1.60		1.50			
13	1.60				1.70		1.70		1.50			
14	1.60		1.90		1.70		1.80		1.50			
15	1.60		2.00		1.70		1.80		1.50			
16	1.60		2.00		1.70		1.60		1.50			
17	1.60		2.10		1.70		1.50	0.0	1.50			
18	1.60		2.10		1.70		1.50		1.50			
19	1.60		2.20		1.70		1.50		1.50			
20	1.50		2.00		1.70		1.50		1.50			
21	1.76		2.00		1.70		1.50		1.50			
22	1.70		1.90		1.60		1.50		1.50			
23	1.70		1.90		1.60		1.50		1.50			
24	1.70		2.20		1.60		1.50		1.50			
25	1.70		2.40		1.60		1.50		1.50			
26	1.70		2.40		1.60		1.50		1.50			
27			2.40		1.50	0.0	1.50		1.50			
28			2.10		1.50		1.50		1.50			
29	1.90				1.50		1.50		1.50			
30	1.60				1.50		1.50		1.50			
31	1.60				1.50				1.50			
total												
mean												
ac-ft												
max												
min												

Day	July Gauge Height	July Discharge	August Gauge Height	August Discharge	September Gauge Height	September Discharge	October Gauge Height	October Discharge	November Gauge Height	November Discharge	December Gauge Height	December Discharge
1	1.50	0.0	1.50	0.0		0.0		0.0	1.60	0.0	2.70	
2												
3									1.60			
4												
5											2.90	
6												
7											3.60	
8									1.60			
9												
10											2.90	
11												
12												
13												
14												
15									1.60		2.70	
16											3.60	
17									1.60			
18												
19											2.20	
20												
21							1.50				1.10	
22												
23												
24												
25									1.60			
26												
27												
28							1.50					
29												
30									1.80			
31												
total												
mean												
ac-ft												
max												
min												

For the Year or For the Period (*Jan* to *Dec*)

Maximum instantaneous / daily discharge, cfs at G.H. ft at on

Minimum instantaneous / daily discharge, cfs at G.H. ft at on

Mean discharge, cfs Total discharge, ac-ft

Computed from Table No. dated from to

Total discharge cfs-days

Accuracy

Maximum instantaneous / daily gauge height, ft at on

Minimum instantaneous / daily gauge height, ft at on

	January to		to		to December		Summary
	Gauge Height	Discharge	Gauge Height	Discharge	Gauge Height	Discharge	
Computed by / Date							
Checked by / Date							

Approved by

Appendix B5

APPENDIX (C)

BRITISH COLUMBIA MONTHLY POTENTIAL EVAPOTRANSPIRATION AND OPEN WATER EVAPORATION ESTIMATES CALCULATED FROM THE PRIESTLEY AND TAYLOR MODEL

R.L. Davis, P.Ag.
Air Management Branch
Ministry of Environment

Monthly estimates of potential evapotransipiration and open water evaporation at 28 locations in BC are presented in this report. These estimates were caluclated using the Priestley and Taylor (1972) formula,

$$LE = 1.26 \left(\frac{S}{S+\gamma}\right) (Q^*-G) \quad (1)$$

where:

LE = evaporation flux (MJ m^{-2} mo^{-1})

Q^*= net radiation flux (MJ m^{-2} mo^{-1})

G = heat flux into either the soil or water body (MJ m^{-2} mo^{-1})

γ = psycnrometric constant (0.66 mb $^{o}C^{-1}$)

S = slope of the saturation vapour pressure versus temperature curve at mean air temperature (mb $^{o}C^{-1}$).

The Priestley and Taylor approach has been widely applied with considerable accuracy to estimate both potential evapotranspiration from green vegetation (Davies and Allen, 1973; Rouse et al., 1977; Bailey, 1977; Davis, 1978) and evaporation from shallow open water bodies (Stewart and Rouse, 1976).

Use of this model is limited in BC by the lack of radiation data. However, radiation can be estimated from temperature and sunshine data.

The assumption is often made with small error that G = 0 on a monthly basis.

The value of S can be estimated using the empirical technique described by Dilley (1968).

$$S = \{25029/(T + 237.3)^2\} \{\exp(17.269T/(T + 237.3))\} \quad (2)$$

where:

T = mean air temperature (^{o}C).

Net radiation, Q^*, can be estimated using the Linacre (1968) equation,

$$Q^* = (1-r)\, K\downarrow - 2.988(.2 + .8\, n/N)(100-T) \quad (3)$$

where:

$K\downarrow$ = solar radiation flux (MJ m^{-2} mo^{-1})
r = the albedo (reflectivity of the surface)
n = hours of bright sunshine
N = maximum possible hours of bright sunshine (available from meteorological tables).

When longterm normals of solar radiation are not available, it is necessary to estimate normal $K\downarrow$ from an Angstrom regression equation as follows:

$$K\downarrow = Q_o\,(.21 - .565\ n/N) \qquad (4)$$

where:

Q_o = solar radiation flux at the top of the earth's surface (MJ m^{-2} mo^{-1}) (available from meteorological tables).

Equation 4 was developed using solar radiation and hours of sunshine data from several British Columbia climate stations.

Evapotranspiration is calculated using r = 0.25 and evaporation is calculated using r = 0.07 in equation 3. Evaporation flux in MJ m^{-2} mo^{-1} is converted to mm mo^{-1} using the following conversion

$$1\ \text{MJ}\ m^{-2}\ mo^{-1} = 0.423\ \text{mm}\ mo^{-1}.$$

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Rouse, W.R., P.F. Mills, and R.B. Stewart, 1977: Evaporation in high latitudes. Water Resources Research, 13:909-914.

Stewart, R.B. and W.R. Rouse, 1976: A simple method for determining the evaporation from shallow lakes and ponds. Water Resources Research, 12:623-628.

Note variations in Precip.

Monthly Precipitation, Potential Evapotranspiration and Open Water Evaporation (mm)

PPT = Precipitation, PE = Potential Evapotranspiration, E = Open Water Evaporation, NA = Not Available

Location	Elevation(m)	Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Agassiz	15	PPT	214.6	170.9	145.3	115.6	80.0	76.2	47.8	59.9	105.4	193.0	203.7	235.2	1647.6
		PE	-	0.6	21.7	41.4	77.6	85.9	106.9	82.9	44.2	13.9	-	-	478.1
		E	-	7.1	33.8	62.6	105.3	115.4	143.9	113.7	56.4	24.8	1.6	-	664.6
Alberni	9	PPT	294.1	226.1	170.9	101.9	38.6	35.8	26.4	40.4	60.2	222.3	313.4	312.2	1842.3
		PE	-	0.9	20.5	45.3	78.3	95.9	117.7	88.0	54.1	12.9	-	-	513.6
		E	-	6.6	32.3	64.5	119.4	129.4	158.7	120.9	80.3	22.9	2.1	-	737.1
Campbell River	105	PPT	227.1	165.6	143.3	76.5	48.5	51.1	39.1	51.6	68.1	166.4	231.1	270.3	1538.7
		PE	-	-	20.5	46.0	89.3	95.5	120.7	87.1	42.2	11.3	-	-	512.6
		E	-	4.8	31.8	64.7	121.5	127.0	160.0	117.1	60.7	20.8	-	-	708.4
Castlegar	493	PPT	31.0	30.5	45.5	38.4	45.0	62.0	32.3	34.5	36.8	61.0	57.4	45.7	520.1
		PE	-	-	20.5	47.1	94.1	108.2	140.1	108.5	48.2	12.2	-	-	578.8
		E	-	4.4	33.3	67.1	128.3	145.9	189.0	149.1	71.2	22.9	0.3	-	811.5
Cowichan Bay	104	PPT	157.5	106.7	82.0	52.3	36.8	33.5	21.6	25.7	39.4	97.8	144.5	163.6	961.4
		PE	-	0.2	22.8	48.7	87.7	98.0	120.7	92.1	47.8	13.7	-	-	531.7
		E	-	7.1	36.1	69.5	119.7	132.4	163.1	126.9	70.7	25.3	1.3	-	752.1
Cowichan Lake	177	PPT	341.4	252.5	206.5	132.1	53.1	50.3	31.8	40.6	81.5	245.9	314.2	371.6	2121.5
		PE	-	0.6	19.6	42.1	76.1	84.6	106.1	81.4	43.8	12.9	-	-	467.2
		E	-	6.5	30.8	59.9	103.7	113.9	142.9	111.8	64.3	23.4	1.6	-	658.8
Cresent Valley	610	PPT	104.6	77.0	60.5	40.9	54.9	64.8	36.3	41.1	49.5	67.6	84.8	104.4	786.4
		PE	-	-	18.4	46.3	84.4	96.2	125.1	93.1	44.9	11.4	-	-	519.8
		E	-	4.2	30.0	66.4	115.2	129.9	168.8	128.3	67.0	22.1	-	-	731.9
Estevan Point	6	PPT	385.3	318.0	292.1	232.7	120.4	97.0	87.6	89.9	171.7	375.9	421.4	435.9	3027.9
		PE	-	0.4	23.3	46.8	79.9	90.4	98.5	73.7	42.9	13.9	-	-	469.8
		E	-	7.7	37.0	66.8	109.4	122.5	140.2	110.5	63.5	25.6	1.4	-	684.6
Fort St. John	693	PPT	33.3	27.9	27.2	23.4	33.0	61.7	62.7	53.6	32.5	29.7	32.0	32.8	449.8
		PE	-	-	6.2	36.3	83.2	99.9	109.7	79.6	29.0	-	-	-	443.9
		E	-	-	14.1	54.4	114.8	135.6	148.7	111.4	46.1	8.5	-	-	633.6

Location	Elevation(m)	Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annu.
Germansen Landing	747	PPT	55.9	34.8	29.2	37.1	28.4	50.3	47.5	48.0	34.8	45.5	53.1	60.5	525.1
		PE	-	-	6.9	32.7	73.0	96.5	97.0	68.4	24.1	0.4	-	-	399.0
		E	-	-	14.8	49.0	101.0	131.4	131.7	95.8	38.1	6.9	-	-	568.7
Haney	345	PPT	28.7	15.5	8.1	12.4	19.1	36.3	25.9	26.9	20.3	18.5	20.6	28.2	260.5
		PE	-	-	19.5	52.7	96.6	112.0	133.7	100.8	46.3	9.9	-	-	571.5
		E	-	1.7	32.5	75.7	131.6	150.9	179.8	138.7	69.2	21.1	-	-	801.2
Kitimat	128	PPT	336.0	268.2	189.7	141.0	74.7	58.2	52.8	81.3	194.8	352.8	301.8	325.6	2376.7
		PE	-	-	13.7	38.6	75.0	88.0	95.2	68.6	31.1	5.0	-	-	415.2
		E	-	-	24.3	56.3	102.9	118.9	128.5	94.7	47.1	12.2	-	-	584.9
McLeod Lake		PPT	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		PE	-	-	8.2	34.2	71.0	93.9	97.3	69.1	26.1	1.9	-	-	401.7
		E	-	-	15.8	28.1	50.6	127.5	131.8	96.3	40.8	9.2	-	-	500.1
Nanaimo	32	PPT	161.8	110.7	101.3	63.5	37.3	39.4	23.1	25.7	43.9	106.4	153.9	180.6	1047.6
		PE	-	-	22.0	48.1	87.5	98.0	118.7	91.4	47.1	13.4	-	-	526.2
		E	-	6.7	35.1	68.7	119.6	132.4	160.4	126.0	69.8	25.3	1.0	-	745.0
Oliver	304	PPT	35.6	19.6	19.8	20.8	28.2	31.8	23.4	25.7	16.0	20.6	27.7	35.8	305.0
		PE	-	-	23.9	57.1	100.3	118.4	144.2	108.9	53.7	14.3	-	-	620.8
		E	-	5.4	38.4	81.3	136.3	159.2	193.4	149.0	78.9	26.8	0.3	-	869.0
Prince George	676	PPT	59.2	42.9	31.5	29.5	42.2	58.2	57.9	73.4	55.9	61.0	54.9	54.1	620.7
		PE	-	-	10.7	38.5	80.2	96.5	104.8	76.3	30.6	3.5	-	-	441.1
		E	-	-	20.2	56.7	110.4	131.0	142.2	160.4	47.6	11.8	-	-	626.3
Prince Rupert	34	PPT	214.1	208.8	180.3	183.9	122.7	107.2	120.9	147.1	241.8	359.2	269.2	259.3	2414.5
		PE	-	-	13.3	34.0	62.3	65.7	68.0	55.0	27.6	5.6	-	-	331.5
		E	-	0.2	22.6	49.2	85.3	88.5	91.5	75.9	41.6	12.8	-	-	467.6
Saanichton	61	PPT	144.5	98.3	64.5	43.4	29.7	28.7	18.5	26.2	36.8	87.1	123.2	145.5	864.4
		PE	-	-	23.8	50.6	91.1	103.0	122.6	93.2	48.8	14.2	-	-	547.3
		E	-	7.3	37.8	72.3	124.6	139.4	165.9	122.2	72.3	26.4	0.9	-	769.1
Salmon Arm	506	PPT	61.5	39.4	29.5	29.7	37.8	48.3	38.1	43.2	38.1	48.5	52.1	64.5	530.7
		PE	-	-	17.0	45.7	86.9	100.0	123.3	92.6	41.8	9.0	-	-	516.3
		E	-	2.5	28.2	65.5	118.5	134.7	166.0	127.5	62.2	18.2	-	-	723.3
Sandspit	8	PPT	155.4	111.0	101.9	80.8	45.7	47.2	48.3	48.0	86.4	184.7	184.9	166.6	1260.9
		PE	-	-	16.1	39.9	72.6	78.9	85.9	66.2	23.6	7.1	-	-	400.3

Location	Elevation(m)	Parameter	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Smithers	524	PPT	48.3	27.9	22.4	20.6	35.1	44.2	48.0	41.7	39.1	55.4	54.1	55.6	492.4
		PE	-	-	9.7	34.9	70.4	83.8	90.3	69.0	28.4	2.5	-	-	389.0
		E	-	-	18.5	51.4	96.8	113.7	122.4	96.2	44.5	9.6	-	-	553.1
Summerland	454	PPT	30.5	17.8	14.7	21.8	26.4	34.8	26.4	24.9	19.3	21.6	25.7	32.3	296.1
		PE	-	-	22.2	53.6	95.2	111.3	137.2	104.9	51.5	13.6	-	-	589.5
		E	-	4.9	35.9	76.6	129.7	150.0	184.5	144.0	76.1	25.9	0.3	-	827.9
Trail	579	PPT	83.3	56.1	52.6	38.9	53.9	62.0	28.7	33.3	31.0	61.0	77.7	85.9	664.1
		PE	-	-	20.8	47.0	88.1	109.9	135.1	101.2	48.7	12.6	-	-	563.4
		E	-	4.8	33.5	66.7	119.8	148.2	181.8	139.0	71.9	23.5	1.0	-	790.2
Vancouver	5	PPT	147.3	116.6	93.7	61.0	47.5	45.2	29.7	37.1	61.2	122.2	141.2	165.4	1068.1
		PE	-	-	23.3	52.1	93.0	103.8	123.4	93.1	47.5	14.1	-	-	550.3
		E	-	7.2	37.0	74.3	127.0	140.4	166.7	157.2	110.2	26.1	0.9	-	847.0
Vernon	360	PPT	43.9	26.7	18.5	20.3	29.7	37.8	29.7	30.0	34.0	31.5	32.3	52.3	386.7
		PE	-	-	19.8	51.0	92.5	107.1	131.9	101.1	47.4	11.2	-	-	
		E	-	3.5	32.7	73.0	126.2	144.3	177.5	139.1	70.6	22.3	-	-	789.2
Victoria	69	PPT	106.9	75.7	49.0	34.3	21.3	21.3	12.4	19.6	33.0	73.9	94.7	14[illegible].8	656.9
		PE	-	1.3	27.2	56.4	97.9	108.7	126.8	96.8	51.9	17.1	-	-	584.1
		E	-	9.6	42.8	80.5	133.8	147.3	171.9	133.9	76.6	30.9	2.7	-	830.0
Williams Lake	674	PPT	34.5	25.1	27.7	16.0	23.4	61.0	44.2	44.7	33.5	30.0	25.7	35.8	401.6
		PE	-	-	14.1	43.2	84.3	108.6	115.8	87.7	37.7	6.3	-	-	497.7
		E	-	-	25.3	63.3	116.0	147.7	157.0	122.0	57.7	16.3	-	-	~~705.3~~ 633.5

APPENDIX (D)

Province of British Columbia
Ministry of Environment

MEMORANDUM

2569 Kenworth Road, Nanaimo, British Columbia V9T 4P7 — Telephone: (604) 758-3951

To: B. Cook/E. Riechert
Water Management

Date: May 28, 1991

File: Quennel Lake
N/C PU

Re: Volume of Water Required to Maintain Fish Habitat - Quennel Lake and Holden Lake

Recently you approached me about the water volume of the above lakes that would be necessary to maintain viable fisheries habitat. The objective of your assessment is to define the available water quantities that could be licensed from these lakes in the future. I have reviewed the fisheries files for both of these sites and recommend that any new application for water withdrawal in the summer months be rejected due to the problem of water quantity and quality.

Quennel Lake

Upon reviewing the bathymetry of the lake, we find that 90% of the lake volume is less than 6 meters in depth. This is a very important factor in fisheries productivity, as fish primarily feed in the limnetic zone of a lake. This 6m zone represents the depth in the lake in which light can penetrate. In the case of Quennel Lake, the mean depth of 3.5m is unique for a typical lake on Vancouver Island, and makes it more productive for fish growth. There are problems, however, with this shallow nature to the lake, especially in the summer months. Fish will go to the deepest part of the lake to maintain coql water contact. Water temperatures can warm considerably (23 degrees) and interact with the phosphorus input of fertilizers and septic runoff, and this creates significant algae blooms. On occasion, this causes a massive fish kill when the algae dies in the late summer months (September, 1990).

In 1988, the Fisheries Branch were toying with the idea of increasing the flushing rate of this lake by introducing water from the Harmac Pulp Mill water line. Costs were exorbitant, so the idea was terminated.

Concerning the licensing of water from the lake, it is thought that this would reduce summer rearing.

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Holden Lake

Holden Lake's bathymetry reveals a lake that is essentially 100% littoral, and is considered to be totally accessible to fish. In the summer months, the situation described above is magnified with high water temperatures and algae blooms. Fish kills were occurring on this lake with regularity in the early 1980's, until a local farm stopped operation (and fertilizing). Water withdrawals from this lake in the summer months would reduce fish production in this lake.

P. D. Law
Fisheries Biologist

PDL/gb
WATER-MA.MEM