Province of British Columbia
Ministry of Environment

# FLOODPLAIN MAPPING PROGRAM
# CAMPBELL & QUINSAM RIVERS

## DESIGN BRIEF

KLOHN LEONOFF
CONSULTING ENGINEERS

PB 5049 01

March 1989

**KLOHN LEONOFF**
CONSULTING ENGINEERS

Our File: PB 5049 0101
WP 53

May 19, 1989

British Columbia Ministry of Environment
Water Management Branch
3rd Floor, 737 Courtney Street
Victoria, British Columbia
V8V 1H5

Mr. P.J. Woods, P.Eng.
Head, Special Projects Section

Floodplain Mapping Program
Campbell and Quinsam Rivers

Dear Sir:

We are pleased to enclose the following in accordance with the study specifications for the Campbell and Quinsam Rivers Project:

- twelve coil-bound copies of the Design Brief;
- one original unbound copy of the Design Brief;
- two additional copies of the Study File;
- computer diskette containing the files used for the HEC-2 backwater calculations and the source code file for the reservoir routing program RESROUTE;
- reproducible mylars of the two floodplain maps;
- reproducible mylar of the Key Plan;
- a box of reports and information supplied by the Ministry of Environment on loan.

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We have enjoyed working with you on this project and thank you for the opportunity to provide engineering services for the Floodplain Mapping Program.

Yours very truly,

KLOHN LEONOFF LTD.

C. David Sellars, P.Eng.
Project Manager

CDS:ljb
Enclosures

# DESIGN BRIEF

| | |
|---|---|
| PROJECT: | FLOODPLAIN MAPPING PROGRAM |
| LOCATION: | CAMPBELL AND QUINSAM RIVERS, VANCOUVER ISLAND |
| CLIENT: | BRITISH COLUMBIA MINISTRY OF ENVIRONMENT |

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# 1. INTRODUCTION

## 1.1 PURPOSE AND SCOPE OF REPORT

In response to a request by the British Columbia Ministry of Environment, Klohn Leonoff Ltd. has carried out a floodplain mapping study for the lower Quinsam and Campbell Rivers. The purpose of the study is to delineate the limits of the 200-year floodplain.

The scope of this study includes:

- derivation of the discharge versus return period relationships for the Quinsam and Campbell Rivers;
- development of a backwater model, using HEC-2, for the Quinsam and Campbell Rivers using data from previous floods for calibration;
- selection of an appropriate tide level to be used for the backwater studies;
- selection of the appropriate Coastal Flood Level including freeboard; and
- delineation of the 200-year floodplain using topographic maps supplied by the British Columbia Ministry of Environment.

The floodplain maps are included in Appendix IV of this report. A study file has also been prepared containing the computer output for all the backwater simulations and is bound separately.

To ensure compliance with Ministry of Environment standards and procedures, discussions were held throughout the course of this study with Water Management Branch staff, Mr. Peter J. Woods, P.Eng. and Mr. Richard W. Nichols, P.Eng. Mr. Brendan Holden, P.Eng. also of the Water Management Branch, participated in the site visit and assisted in selection of an appropriate Coastal Flood Level. Contact was also made with James R. Card, P.Eng. of the Nanaimo office of the Ministry of Environment. Discussions were held with B.C. Hydro staff in the Engineering Division (P.A. Neudorf, P.Eng.) and Operations Division

(W.G. Joe, P.Eng. and B.H. Fast, P.Eng.) regarding operation of the Campbell River dams.

## 1.2 AREA DESCRIPTION

### 1.2.1 Geography and Climate

The following description of the geography and climate of the area is taken from a report by B.C. Hydro dated August 1983 entitled "Campbell River Probable Maximum Flood". The location of the study basin is shown on the key plan (Drawing A-1001).

"The Campbell River basin lies on the east side of the Vancouver Island mountains and drains to the north and east into the Strait of Georgia.

The basin above Strathcona Dam is very rugged with peaks rising to 2200 m and small areas of permanent snowpack exist. The reservoir formed by joining Upper Campbell and Buttle Lakes is about 50 km long and up to 5 km wide. The creeks feeding the reservoir tend to be short and steep. The Elk River sub-basin contains the longest watercourse which is 24 km long and falls about 760 m. The mean basin elevation is 950 m and the basin area is 1194 $km^2$.

Below Strathcona Dam the terrain is much less rugged with rolling heavily forested hills. The mean basin elevation is 250 m and the local basin area above Ladore Falls Dam is 243 $km^2$. The local basin area above John Hart Dam is 24 $km^2$.

The critical months of the year for heavy precipitation in the Campbell River basin are October through March. In this period frontal storms arriving from the southwest off the Pacific Ocean are associated with strong, moist winds that bring heavy precipitation for durations of a few hours to four days. Very often a series of cyclonic storms are carried in the flow of air separated by hours or days.

During these large winter storms the air temperature may be above freezing at all altitudes in the basin. Consequently, the accumulated snowpack may vary appreciably especially at low elevations. Typically a period of cooler weather in which the snowpack increases may be followed by a larger Pacific disturbance that raises temperatures and melts a portion of the snowpack."

The Quinsam River basin is located on the eastern side of the Campbell River basin and drains 280 $km^2$. The basin ranges from 1500 m elevation to 10 m with a mean basin elevation of 370 m. Due to its location it is subject to the same climatic influences as Campbell River.

### 1.2.2 B.C. Hydro Dams On The Campbell River

The following excerpt from the B.C. Hydro report dated December 1984, "Campbell River Inflow Forecasting and Operating Guidelines", describes the dams on the Campbell River. Maps showing the locations of the dams are contained in Operating Order No. 433, Appendix III.

"Three hydroelectric developments were built on the main stem of the Campbell River from 1946 to 1958 with a total nameplate generating capacity of 241.5 MW. Three diversions augment inflows to the system.

The Strathcona Development, constructed in 1957/58, is the furthest upstream and provides significant reservoir storage for the regulation of inflows. The reservoir storage between El. 220.0 (721.7 ft) and the maximum allowable reservoir level El. 224.64 (737.0 ft) is approximately 300 x $10^6$ $m^3$. Two units have a nameplate generating capacity of 67.5 MW and an average hydraulic capacity of about 180 $m^3/s$. Spill facilities include a Howell-Bunger valve with an average capacity of about 113 $m^3/s$ and a spillway with three vertical lift gates and a discharge capacity of 1220 $m^3/s$ at El. 224.64. A dam on the Heber River diverts a maximum flow of 8.5 $m^3/s$ into Upper Campbell Lake. A dike permanently diverts Crest Creek into Upper Campbell Lake.

Downstream of Strathcona is the Ladore Falls development which was constructed in 1949 with modifications from 1955 to 1957. The dam provides about 34 x $10^6$ $m^3$ of reservoir storage between the winter operating level El. 177.7 (583.0 ft) and the maximum allowable reservoir level El. 178.92 (587.0 ft). Two units have a nameplate generating capacity of 54 MW and an average hydraulic capacity of about 165 $m^3/s$. Spill facilities include a Howell-Bunger valve with an average capacity of about 96 $m^3/s$ and a spillway with three vertical lift gates and a discharge capacity of 1925 $m^3/s$ at El. 178.92. A dam on the Salmon River diverts a maximum flow of 42.5 $m^3/s$ into Lower Campbell Lake. Dams on the Quinsam River divert a maximum flow of 8.5 $m^3/s$ into Lower Campbell Lake.

Downstream of Ladore is the John Hart development which was constructed from 1946 to 1953. The dam provides only pondage for turbine operation and a source of potable water for Campbell River. Six units have a nameplate generating capacity of 120 MW and a hydraulic capacity of about 124 $m^3/s$. Spill facilities consist of a spillway with three vertical lift gates and a discharge capacity of 1895 $m^3/s$ at El. 140.73 (461.7 ft).

## 2. DATA USED FOR STUDY

### 2.1 DATA SOURCES

Sources of data used for this study were, B.C. Hydro reports and data, Ministry of Environment reports, Water Survey of Canada data and Fisheries and Oceans data. Data sources are referenced below with a brief explanation of their applicability.

a) "Operations Summary of the Campbell River Reservoirs and River Diversions", Operating Order No. 433, Operations

Control Department, B.C. Hydro, April 25, 1986. This document, contained in Appendix III, was used to develop a simulation model to route various floods through the Campbell River System. Included in this document were reservoir data and spillway and turbine rating curves. See Section 3.

b) Daily Power Records Data, Operations Control Department, B.C. Hydro, 1963-1987. This data was reviewed to obtain inflow volume data for Strathcona Reservoir. Historical reservoir operating practices were also analysed. See Sections 3 and 4, and Table 1.

c) B.C. Hydro, Interoffice Memo, to Mr. P.W. Bell, from R.H.D. Grace, February 24, 1987, File No. 502-1506.0. Subject: Downstream Flow Conditions at John Hart. Data contained in this memo was used for the January 13, 1987 calibration of HEC 2 backwater model. See Section 5.

d) Water Survey of Canada daily flow data for:

Station 08HD001 - Campbell River at Outlet of Campbell Lake;
Station 08HD003 - Campbell River near Campbell River;
Station 08HD005 - Quinsam River near Campbell River.

Data from the latter two stations were used to obtain specific return period flood flows and relationships between Strathcona inflow and Quinsam River flow. See Section 4.2. Data from the first station was used for comparison purposes with the results of this study. See Sub-Section 4.1.5.

e) River Survey, Project 87-FDC-1, British Columbia Ministry of the Environment. This river survey data included digital and non-digital cross-section data for the Quinsam and Campbell Rivers. Plots of sections, photos, and high water marks were also provided. These were used to set up and calibrate the HEC 2 backwater model. See Section 5.1.

f) "Coastal Environment and Coastal Construction, A Discussion Paper - Elevations and Setbacks for Flood and Erosion Prone Areas", B. Holden, British Columbia Ministry of Environment, 1987. This reference was used, in conjunction with a site visit with Mr. Holden, to determine the appropriate Coastal Flood Level. See Section 5.3.

g) "Transcript of the Hearing of Campbell River Flooding", British Columbia Department of Lands and Forests, Water Rights Branch, Water Investigations Branch, April 28, 1954. This transcript provided historical background and general information on hydrologic conditions resulting in flooding in the Campbell River area.

h) "Campbell River Probable Maximum Flood", B.C. Hydro, HGPD, Report No. H1626, August 1983. This report provided general hydrologic data and specific information used for routing inflows through the Campbell River System. See Section 4.1.

i) "Campbell River Inflow Forecasting and Operating Guidelines", B.C. Hydro, HGPD, Report No. H1436, December 1984. This report provided detailed information on the development of the existing operating order (Reference 2.1a).

j) Fisheries and Oceans, Tide Tables. These data were used in the analysis of the Coastal Flood Construction Level and backwater modelling. See Section 5.3.

k) "Loveland Bay Saddle Dam - Potential For Breaching To Reduce Flooding in Lower Campbell River - Overview Study", Draft, B.C. Hydro, HED, Report No. 2053, May 1988. This report along with discussions with B.C. Hydro Engineer, P.A. Neudorf, P.Eng., confirmed the applicability of the probability-tree analysis described in Section 4.1.

## 2.2 HISTORIC FLOODING

A site visit was made on January 31 to February 1, 1989 by Richard Rodman, P.Eng. of Klohn Leonoff Ltd. An assessment was made of the overbank flow areas along the Quinsam and Campbell Rivers. Areas of ineffective flow were identified along with treed, shrub covered and non-vegetated areas. Adjustments were made to the backwater model to account for conditions which were not evident from the topographic maps.

"Transcript of the Hearing of Campbell River Flooding", dated April 28, 1954, contained descriptions from local residents of flooding in the Campbell River area. Flooding in the area of Campbell River Lodge, on the south bank of Campbell River, occurred in 1908, February 1935, November 1939 and 1953. The maximum daily discharges measured at WSC Gauge No. 08HD001 for the February 1935 and November 1939 floods were 762 $m^3/s$ and 858 $m^3/s$. The maximum daily discharge measured at WSC Gauge No. 08HD003 for the November 1953 flood was 580 $m^3/s$. In December 1933 a small office on Tyee Spit was washed away by high tides and high winds. Long time local residents comment that winter flooding is to be expected in the area.

An attempt was made to obtain additional historic data on flooding. A few photographs were on file in the public museum depicting flooding on the banks of the Lower Campbell River. Most photographs were undated but several were from the 1935 flood. A private citizen, Ray Compton of 701 Thulin Street, Campbell River was contacted. He had three photographs of the 1935 flood including the Campbell River Lodge, Quinsam Hotel and the old highway bridge. Negatives were not available for photographic reproduction. The photographs demonstrated that high tide levels and high river discharges have resulted in the Campbell River overflowing its banks.

An article from the local newspaper, the Campbell River and Area Mirror, dated November 19, 1975 referred to flooding on the Campbell River. It states that "the Campbell River rose to a point where it was almost touching the Island Highway bridge". The flooding at the Quinsam River Fish Hatchery is also described (see Appendix I).

## 3. RESERVOIR OPERATION PROCEDURES

The Campbell River flood flows have been altered due to the construction of three dams; Strathcona (1957/58), Ladore Falls (1949) and John Hart (1946 to 1953). Strathcona Dam, the furthest upstream, is the only dam which has significant flood storage capabilities. The other two dams are essentially run-of-river plants with capability of several hours of storage only.

The B.C. Hydro Campbell River System, under normal conditions, is operated by the Operations Control Department at Burnaby Mountain in the Lower Mainland. During flood situations control is transferred to site personnel. Discussions were held with Norm Smith, Superintendent of the Campbell River System, regarding the operation of the Campbell River System.

He stated that prior to 1986 the normal maximum operating level of Strathcona Reservoir was 221 m. During flood events water level readings at Campbell River Lodge are used to determine how much water can be released. If tide levels are very high, releases are reduced until tide levels drop. If the critical maximum reservoir level, as defined in the Operating Order, is attained then releases must be made regardless of tide levels.

If sufficient water is available to fill the reservoir, the reservoir is kept as close as possible to the normal maximum level. The last two years have been low runoff years and therefore reservoir levels have been low.

Following the completion of a Probable Maximum Flood (PMF) study in 1983, new operating orders were introduced (see Reference 2.1a, Appendix III). The new operating order contains a logic diagram detailing how the dams are to be operated in the event of large inflows. PMF flood routings were carried out to determine at what reservoir level it would be necessary to fully open all spill facilities. This level is dependent on the volume of snow runoff expected and the volume of the flood already stored. If the reservoir was quite low prior to the beginning of the flood event, then much of the flood may be stored and the spill facilities need not be fully opened. If the reservoir is close to normal maximum and a major flood event occurs, the spill facilities would most likely need to be fully opened to prevent overtopping should this event be the PMF.

# 4. HYDROLOGY

## 4.1 CAMPBELL RIVER

### 4.1.1 General Methodology

Estimating a return period for outflows from the John Hart Dam involves a combination of simulation and probability analysis using a probability-tree method. Discussions with a B.C. Hydro Engineer involved in another study on the Campbell River confirmed the applicability of this method. (Reference (k) in Section 2.1).

### 4.1.2 Reservoir Levels

The probability associated with the initial reservoir level was estimated based on 18 of 25 years of recorded data. Two years were missing initial reservoir levels and five years were considered dry years with abnormally low levels. For each storm season, November through February, the maximum five-day volume storm and the associated initial reservoir level were selected (see Table 1). A percent duration analysis of the difference between the maximum normal operating level (221.59m) and the reservoir level prior to the storm was carried out (Drawing A-1002). The probability of the initial reservoir level being within a given range was obtained by computing the difference of the probabilities of the reservoir level being at the end points of the range.

## TABLE 1

**FIVE DAY STORM INFLOW VOLUMES AND ASSOCIATED RESERVOIR LEVEL PRIOR TO STORM EVENT* STRATHCONA RESERVOIR**

normal maximum operating level 221.59

| Storm Date | 5-Day Inflow Volume (millions $m^3$) | Initial Reservoir Level (m) |
|---|---|---|
| Feb 3 - 7, 1963 | 250.71 | 218.45 |
| Dec 22 - 26, 1963 | 219.22 | 218.85 |
| Oct 19 - 23, 1965 | 165.10 | 217.75 |
| Dec 15 - 19, 1966 | 207.58 | 220.00 |
| Jan 17 - 21, 1968 | 235.34 | 221.47 |
| Oct 26 - 30, 1968 | 199.00 | 221.53 |
| Jan 28 - Feb 1, 1971 | 158.14 | 215.80 |
| Nov 7 - 11, 1971 | 111.82 | 218.54 |
| Mar 15 - 19, 1972 | 177.74 | 214.94 |
| Jan 14 - 18, 1973 | 105.68 | 218.05 |
| Jan 14 - 18, 1974 | 144.02 | 219.30 |
| Dec 16 - 20, 1974 | 92.29 | 219.03 |
| Nov 2 - 6, 1975 | 257.81 | 219.61 |
| Dec 15 - 19, 1976 | 117.21 | 218.48 |
| Oct 22 - 26, 1977 | 134.37 | 217.11 |
| Nov 6 - 10, 1978 | 133.14 | 219.06 |
| Dec 17 - 21, 1979 | 171.23 | 220.10 |
| Dec 24 - 28, 1980 | 212.53 | 220.68 |
| Oct 30 - Nov 3, 1981 | 125.40 | 218.10 |
| Oct 22 - 26, 1982 | 257.60 | 218.85 |
| Jan 3 - 7, 1984 | 140.57 | - |
| Oct 7 - 11, 1984 | 192.67 | - |
| Feb 24 - 28, 1986 | 131.24 | 218.39 |
| Mar 4 - 8, 1987 | 175.65 | 219.17 |
| Nov 20 - 24, 1987 | 93.92 | 215.36 |

* Data from Reference 2.1b, Daily Power Records Data, Operations Control Department, B.C. Hydro.

### 4.1.3 Volume Frequency Analysis

A frequency analysis was carried out on the five-day storm volumes using the Environment Canada computer program, CFA88 (see Table 2). The probability of occurrence of a storm within a selected volume range was obtained by computing the difference of the probabilities of the volumes at the end points of the range.

TABLE 2

FIVE-DAY STORM INFLOW VOLUME FREQUENCY
ANALYSIS FOR UPPER CAMPBELL LAKE
LOG PEARSON TYPE III DISTRIBUTION

| Return Period (Years) | Exceedance Probability | Volume (millions $m^3$) |
|---|---|---|
| 1.003 | 0.997 | 54.5 |
| 1.05 | 0.952 | 90.4 |
| 1.25 | 0.800 | 125.0 |
| 2.0 | 0.500 | 166.0 |
| 5.0 | 0.200 | 210.0 |
| 10.0 | 0.100 | 234.0 |
| 20.0 | 0.050 | 254.0 |
| 50.0 | 0.020 | 275.0 |
| 100.0 | 0.010 | 289.0 |
| 200.0 | 0.005 | 301.0 |
| 500.0 | 0.002 | 316.0 |

### 4.1.4 Reservoir Operation Simulation

A computer program was written, using Quick Basic, to simulate the reservoir operation procedure. A program listing and sample output are contained in Appendix II. The program code is filed on the supplied diskette together with the HEC-2 data files. The program logic follows the logic diagram (Figure 4-3) contained in the operating order (Appendix III). Sufficient comments have been included in the program listing to allow identification of the path through the logic diagram. The last column of the resulting table indicates which step was implemented to obtain the outflow for that time step.

As can be seen on the sample output, diversion inflow from the Heber River is very small compared to storm inflows to Upper Campbell Lake. The diversion is turned off in the event of large inflows and a high reservoir level. The shape of the inflow hydrographs was based on a typical storm December 24 to 26, 1980. A six-hour time step was sufficient to simulate operation of the system.

B.C. Hydro monitors river levels on the Lower Campbell River and if possible reduces releases from the dams to prevent flooding. If the reservoir is below normal maximum, downstream flood protection measures are implemented. Figure 4-1 in the operating order (Appendix III) indicates flood levels given a tidal level and river flow. A mean tidal cycle was included in the routing program. The total downstream river discharge had to be estimated. Local inflows to Ladore and John Hart were estimated as 14% and 1.4% of the Strathcona inflow, respectively. These ratios were obtained from Reference 2.1h, "Campbell River Probable Maximum Flood".

The coincident Quinsam River flow ranged from 12% to 5% of the Strathcona inflow. These figures were obtained by comparison of peak flows on the Quinsam River with Strathcona inflows. The routings demonstrated that inflows downstream of Strathcona Dam only influence the maximum releases for events with combined return periods less than approximately eight years. For events greater than this the spillway gates must be fully opened to prevent overtopping should the event turn out to be a PMF.

### 4.1.5 Outflow Frequency

A probability-tree analysis was used to determine the outflow frequency relationship. A series of ranges of initial reservoir levels were selected with mid-points from 2.60 m to 0.07 m below normal maximum reservoir level. Up to nine storm volume ranges were selected. For each mid-range starting level, the mid-range storm volumes were routed through the Campbell River System, following the operating orders, to obtain the peak outflow for each combined event. The combined event probability is the product of the initial reservoir level range probability (Section 4.1.2) and the storm volume range probability (Section 4.1.3.). The peak outflows from each combined event were then ranked and a cumulative probability distribution developed from the combined event probabilities. Tables 3 and 4 demonstrate the probability-tree analysis for Strathcona peak outflows.

The resulting probability release relationship for Strathcona Dam, given in Table 4, is shown on Drawing A-1003. The John Hart release is calculated as Strathcona release plus local inflows, as described in Section 4.1.4 above. Events with return periods less than two years may be passed with power releases only. For events with return periods between two and eight years, power releases and controlled spilling are necessary. For events with return periods greater than eight years, all release facilities must be fully opened for periods of 12 hours or greater. Drawing A-1003 is generally in agreement with analyses carried out by B.C. Hydro in a separate concurrent study. It is apparent from this relationship that the B.C. Hydro dams provide flood control only for floods with a return period less than about 1 in 8 years.

The resulting 20-year and 200-year return period mean daily releases from John Hart are 1084 $m^3/s$ and 1340 $m^3/s$, respectively.

A Water Survey of Canada gauge, Campbell River at Outlet of Campbell Lake No. 08HD001, was in operation from 1910 to 1949. This gauge was located near the present location of Ladore Dam with a drainage area of 1400 $km^2$, compared to 1461 $km^2$ at John Hart dam (including Heber, Salmon and Quinsam Diversions). A frequency analysis was carried out using the Three Parameter Log Normal distribution on the unregulated annual maximum daily flows for this gauge as shown on Drawing A-1004. The 200-year return period flood estimate for the gauge of 1240 $m^3/s$ is similar to the value of 1340 $m^3/s$, obtained above, for releases from John Hart Dam. It should be noted that the analyses were for different periods of record and the John Hart releases include diversions from other drainage basins.

For comparison purposes, a Three Parameter Log Normal distribution was fitted to recorded Campbell River flows downstream of John Hart Dam, WSC Station No. 08HD003. This is shown on Drawing A-1005. The 200-year flood indicated by this relationship is 880 $m^3/s$, less than the 1340 $m^3/s$ determined above. This difference is because very few of the historic floods were large enough to result in full gate opening. This results in poor definition for the upper end of the frequency relationship.

## TABLE 3

## RESERVOIR ROUTING RESULTS FOR STRATHCONA DAM

| RUN NUMBER | DIFFERENCE BETWEEN NORMAL MAXIMUM AND INITIAL LEVEL. RANGE (m) | PROBABILITY OF BEING WITHIN RANGE | FLOOD VOLUME RANGE (millions $m^3$) | PROBABILITY OF BEING WITHIN RANGE | STRATHCONA MAXIMUM DAILY OUTFLOW ($m^3$/s) | COMBINED EVENT PROBABILITY |
|---|---|---|---|---|---|---|
| 1 | 2.2 - 3.0 | 0.37 | >316 | .002 | 400 | 0.00074 |
| 2 | 2.2 - 3.0 | 0.37 | 301 - 316 | .003 | 400 | 0.00111 |
| 3 | 2.2 - 3.0 | 0.37 | 289 - 301 | .005 | 400 | 0.00185 |
| 4 | 2.2 - 3.0 | 0.37 | 275 - 289 | .01 | 400 | 0.0037 |
| 5 | 2.2 - 3.0 | 0.37 | 254 - 275 | .03 | 400 | 0.0111 |
| 6 | 2.2 - 3.0 | 0.37 | 210 - 254 | .15 | 170 | 0.0555 |
| 7 | 2.2 - 3.0 | 0.37 | 166 - 210 | .30 | 170 | 0.111 |
| 8 | 2.2 - 3.0 | 0.37 | <166 | .50 | 170 | 0.185 |
| 9 | 1.5 - 2.2 | 0.23 | >316 | .002 | 400 | 0.00046 |
| 10 | 1.5 - 2.2 | 0.23 | 301 - 316 | .003 | 400 | 0.00069 |
| 11 | 1.5 - 2.2 | 0.23 | 289 - 301 | .005 | 400 | 0.00115 |
| 12 | 1.5 - 2.2 | 0.23 | 275 - 289 | .01 | 400 | 0.0023 |
| 13 | 1.5 - 2.2 | 0.23 | 254 - 275 | .03 | 400 | 0.0069 |
| 14 | 1.5 - 2.2 | 0.23 | 210 - 254 | .15 | 400 | 0.0345 |
| 15 | 1.5 - 2.2 | 0.23 | 166 - 210 | .30 | 170 | 0.069 |
| 16 | 1.5 - 2.2 | 0.23 | <166 | .50 | 170 | 0.115 |
| 17 | 0.7 - 1.5 | 0.15 | >301 | .005 | 400 | 0.00075 |
| 18 | 0.7 - 1.5 | 0.15 | 275 - 301 | .015 | 400 | 0.00225 |
| 19 | 0.7 - 1.5 | 0.15 | 254 - 275 | .03 | 400 | 0.0045 |
| 20 | 0.7 - 1.5 | 0.15 | 234 - 254 | .05 | 400 | 0.0075 |
| 21 | 0.7 - 1.5 | 0.15 | 210 - 234 | .10 | 400 | 0.015 |
| 22 | 0.7 - 1.5 | 0.15 | 166 - 210 | .30 | 400 | 0.045 |
| 23 | 0.7 - 1.5 | 0.15 | 125 - 166 | .30 | 400 | 0.045 |
| 24 | 0.7 - 1.5 | 0.15 | <125 | .20 | 170 | 0.03 |
| 25 | 0.3 - 0.7 | 0.10 | >289 | .01 | 1027 | 0.001 |
| 26 | 0.3 - 0.7 | 0.10 | 275 - 289 | .01 | 988 | 0.001 |
| 27 | 0.3 - 0.7 | 0.10 | 254 - 275 | .03 | 962 | 0.003 |
| 28 | 0.3 - 0.7 | 0.10 | 234 - 254 | .05 | 937 | 0.005 |
| 29 | 0.3 - 0.7 | 0.10 | 210 - 234 | .10 | 400 | 0.01 |
| 30 | 0.3 - 0.7 | 0.10 | 166 - 210 | .30 | 400 | 0.03 |
| 31 | 0.3 - 0.7 | 0.10 | 125 - 166 | .30 | 400 | 0.03 |
| 32 | 0.3 - 0.7 | 0.10 | <125 | .20 | 400 | 0.02 |

TABLE 3
(continued)

| RUN NUMBER | DIFFERENCE BETWEEN NORMAL MAXIMUM AND INITIAL LEVEL. RANGE (m) | PROBABILITY OF BEING WITHIN RANGE | FLOOD VOLUME RANGE (millions $m^3$) | PROBABILITY OF BEING WITHIN RANGE | STRATHCONA MAXIMUM DAILY OUTFLOW ($m^3/s$) | COMBINED EVENT PROBABILITY |
|---|---|---|---|---|---|---|
| 33 | 0.12 - 0.3 | 0.08 | >289 | .01 | 982 | 0.0008 |
| 34 | 0.12 - 0.3 | 0.08 | 254 - 289 | .04 | 974 | 0.0032 |
| 35 | 0.12 - 0.3 | 0.08 | 210 - 254 | .15 | 930 | 0.012 |
| 36 | 0.12 - 0.3 | 0.08 | 188 - 210 | .15 | 892 | 0.012 |
| 37 | 0.12 - 0.3 | 0.08 | 166 - 188 | .15 | 905 | 0.012 |
| 38 | 0.12 - 0.3 | 0.08 | 146 - 166 | .15 | 883 | 0.012 |
| 39 | 0.12 - 0.3 | 0.08 | 125 - 146 | .15 | 862 | 0.012 |
| 40 | 0.12 - 0.3 | 0.08 | 90 - 125 | .15 | 400 | 0.012 |
| 41 | 0.12 - 0.3 | 0.08 | <90 | .048 | 170 | 0.00384 |
| 42 | 0.12 - 0.02 | 0.05 | >289 | .01 | 1003 | 0.0005 |
| 43 | 0.12 - 0.02 | 0.05 | 254 - 289 | .04 | 959 | 0.002 |
| 44 | 0.12 - 0.02 | 0.05 | 210 - 254 | .15 | 916 | 0.0075 |
| 45 | 0.12 - 0.02 | 0.05 | 188 - 210 | .15 | 880 | 0.0075 |
| 46 | 0.12 - 0.02 | 0.05 | 166 - 188 | .15 | 891 | 0.0075 |
| 47 | 0.12 - 0.02 | 0.05 | 146 - 166 | .15 | 869 | 0.0075 |
| 48 | 0.12 - 0.02 | 0.05 | 125 - 146 | .15 | 854 | 0.0075 |
| 49 | 0.12 - 0.02 | 0.05 | 90 - 125 | .15 | 701 | 0.0075 |
| 50 | 0.12 - 0.02 | 0.05 | <90 | 0.048 | 170 | 0.0024 |

TABLE 4

CUMULATIVE PROBABILITY FOR STRATHCONA MAXIMUM DAILY OUTFLOWS

| RUN NUMBER | ORDERED STRATHCONA OUTFLOW ($m^3/s$) | COMBINED EVENT PROBABILITY | CUMULATIVE PROBABILITY | RETURN PERIOD (YRS) |
|---|---|---|---|---|
| 25 | 1027 | 0.001 | 0.001 | 1000.0 |
| 42 | 1003 | 0.0005 | 0.0015 | 666.7 |
| 26 | 988 | 0.001 | 0.0025 | 400.0 |
| 33 | 982 | 0.0008 | 0.0033 | 303.0 |
| 34 | 974 | 0.0032 | 0.0065 | 153.8 |
| 27 | 962 | 0.003 | 0.0095 | 105.3 |
| 43 | 959 | 0.002 | 0.0115 | 87.0 |
| 28 | 937 | 0.005 | 0.0165 | 60.6 |
| 35 | 930 | 0.012 | 0.0285 | 35.1 |
| 44 | 916 | 0.0075 | 0.036 | 27.8 |
| 37 | 905 | 0.012 | 0.048 | 20.8 |
| 36 | 892 | 0.012 | 0.06 | 16.7 |
| 46 | 891 | 0.0075 | 0.0675 | 14.8 |
| 38 | 883 | 0.012 | 0.0795 | 12.6 |
| 45 | 880 | 0.0075 | 0.087 | 11.5 |
| 47 | 869 | 0.0075 | 0.0945 | 10.6 |
| 39 | 862 | 0.012 | 0.1065 | 9.4 |
| 48 | 854 | 0.0075 | 0.114 | 8.8 |
| 49 | 701 | 0.0075 | 0.1215 | 8.2 |
| 29 | 400 | 0.01 | 0.1315 | 7.6 |
| 18 | 400 | 0.00225 | 0.13375 | 7.5 |
| 21 | 400 | 0.015 | 0.14875 | 6.7 |
| 17 | 400 | 0.00075 | 0.1495 | 6.7 |
| 23 | 400 | 0.045 | 0.1945 | 5.1 |
| 5 | 400 | 0.0111 | 0.2056 | 4.9 |
| 19 | 400 | 0.0045 | 0.2101 | 4.8 |
| 1 | 400 | 0.00074 | 0.21084 | 4.7 |
| 22 | 400 | 0.045 | 0.25584 | 3.9 |
| 20 | 400 | 0.0075 | 0.26334 | 3.8 |
| 11 | 400 | 0.00115 | 0.26449 | 3.8 |
| 30 | 400 | 0.03 | 0.29449 | 3.4 |
| 3 | 400 | 0.00185 | 0.29634 | 3.4 |
| 32 | 400 | 0.02 | 0.31634 | 3.2 |
| 12 | 400 | 0.0023 | 0.31864 | 3.1 |
| 14 | 400 | 0.0345 | 0.35314 | 2.8 |
| 40 | 400 | 0.012 | 0.36514 | 2.7 |
| 9 | 400 | 0.00046 | 0.3656 | 2.7 |

TABLE 4
(continued)

| RUN NUMBER | ORDERED STRATHCONA OUTFLOW ($m^3/s$) | COMBINED EVENT PROBABILITY | CUMULATIVE PROBABILITY | RETURN PERIOD (YRS) |
|---|---|---|---|---|
| 13 | 400 | 0.0069 | 0.3725 | 2.7 |
| 10 | 400 | 0.00069 | 0.37319 | 2.7 |
| 31 | 400 | 0.03 | 0.40319 | 2.5 |
| 4 | 400 | 0.0037 | 0.40689 | 2.5 |
| 2 | 400 | 0.00111 | 0.408 | 2.5 |
| 16 | 170 | 0.115 | 0.523 | 1.9 |
| 6 | 170 | 0.0555 | 0.5785 | 1.7 |
| 7 | 170 | 0.111 | 0.6895 | 1.5 |
| 15 | 170 | 0.069 | 0.7585 | 1.3 |
| 41 | 170 | 0.00384 | 0.76234 | 1.3 |
| 24 | 170 | 0.03 | 0.79234 | 1.3 |
| 8 | 170 | 0.185 | 0.97734 | 1.0 |
| 50 | 170 | 0.0024 | 0.97974 | 1.0 |

## 4.2 QUINSAM RIVER

The Quinsam River drainage basin is adjacent to the Upper Campbell River basin. Their respective drainage areas are 280 $km^2$ and 1194 $km^2$. The Quinsam basin is at an elevation ranging from 10 m to 1500 m while the Upper Campbell River basin ranges from 200 m to 2200 m.

From an analysis of the 25 peak annual storms on record, it was determined that peak inflows to Upper Campbell Lake occurred approximately one and one-half days prior to peak flows on the Quinsam River. Operational and flow records on the Lower Campbell River indicated that the associated peak downstream flows occurred approximately one to two days after the Upper Campbell Lake peak inflows. This was a result of river travel time and the effects of routing through three reservoirs. Thus it is reasonable to assume that during a large event on the Campbell River basin peak flows on the Campbell and Quinsam Rivers would be coincident.

The frequency analysis program, CFA88, was used to obtain the Generalized Extreme Value frequency distribution given in Table 5 and plotted on Drawing A-1006. This distribution resulted in the best fit of the data. The analysis was based on 31 years of maximum daily discharges as recorded by Water Survey of Canada at their station 08HD005, Quinsam River near Campbell River. All of these maximums occurred in the winter period when high inflows could be expected on the Campbell River. Records of instantaneous discharges indicated that the instantaneous discharge was less than 1.10% of the mean daily discharge.

TABLE 5

GENERALIZED EXTREME VALUE
FREQUENCY ANALYSIS OF MAXIMUM DAILY FLOWS -
QUINSAM RIVER NEAR CAMPBELL RIVER

| Return Period (Years) | Exceedance Probability | Flow ($m^3/s$) |
|---|---|---|
| 1.003 | 0.997 | 12.4 |
| 1.050 | 0.952 | 25.0 |
| 1.25 | 0.800 | 38.5 |
| 2.0 | 0.500 | 58.3 |
| 5.0 | 0.200 | 88.7 |
| 10.0 | 0.100 | 112.0 |
| 20.0 | 0.050 | 136.0 |
| 50.0 | 0.020 | 171.0 |
| 100.0 | 0.010 | 201.0 |
| 200.0 | 0.050 | 233.0 |
| 500.0 | 0.002 | 280.0 |

## 4.3 COMBINED FLOWS

For the purposes of floodplain mapping the 20 and 200 year maximum daily flows on the Quinsam River, 136 $m^3/s$ and 233 $m^3/s$ have been combined with the 20 and 200 year John Hart releases of 1084 $m^3/s$ and 1340 $m^3/s$, respectively.

# 5. HYDRAULIC ANALYSIS

## 5.1 BACKWATER MODEL CALIBRATION

The HEC-2 backwater model was used to estimate river levels. A detailed survey had been carried out by the Ministry of Environment which included 25 river cross-sections on the Campbell River and 16 river cross-sections on the Quinsam River. These cross-sections were provided to Klohn Leonoff in digital form along with maps showing their location and a series of photographs of the left and right banks of each cross-section and views looking upstream and downstream at each cross-section.

High water marks, recalled by local residents from a November 15, 1975 flood, were surveyed at three locations on the Campbell River and three locations on the Quinsam River. On the January 13, 1987, B.C. Hydro took water level measurements and flow discharge measurements at seven locations on the Campbell River (see Reference 2.1c). Figure A-1007 shows a typical rating curve developed by B.C. Hydro for cross section 13. The 20 and 200 year flood levels excluding freeboard are plotted on this figure.

The November 1975 flood had discharges of 565 $m^3/s$ on the Lower Campbell River and 138 $m^3/s$ on the Quinsam River, as recorded by Water Survey of Canada. This event had a return period in the range of two to eight years on the Campbell River and one in 20 years on the Quinsam River. The January 1987 flood had discharges of 486 $m^3/s$ on the Lower Campbell River and 49 $m^3/s$ on the Quinsam River. This event had a return period in the range of two to eight years on the Campbell River and one in two years on the Quinsam River. Associated tide levels for the two flood events were 0.5 m and 0.9 m, respectively, as taken from published tidal charts and Reference 2.1c.

Both these events were used for calibration purposes taking advantage of the range of flows and the different associated tide levels. A reasonable calibration was obtained for both floods as shown on Table 6. Calibration points are shown on Drawings B-1008 and B-1009.

TABLE 6

HEC-2 CALIBRATION RESULTS

| Distance U/S From Mouth of Campbell River (km) | Cross Section Number | November 15, 1975 Recorded Level (m) | November 15, 1975 Calibrated Level (m) | January 13, 1987 Recorded Level (m) | January 13, 1987 Calibrated Level (m) |
|---|---|---|---|---|---|
| 1.0 | 3 | - | - | 1.01 | 0.94 |
| 1.8 | 5 | - | - | 1.34 | 1.34 |
| 2.1 | 6 | 2.30 | 2.16 | 1.92 | 1.99 |
| 2.6 | 8 | - | - | 2.71 | 2.87 |
| 2.9 | 10 | 4.80 | 4.42 | - | - |
| 3.3 | 11 | 5.42 | 5.32 | 4.85 | 5.09 |
| 3.7 | 13 | - | - | 6.29 | 6.25 |
| 4.1 | 16 | - | - | 7.35 | 7.40 |
| Distance U/S From Mouth of Quinsam River (km) | | | | | |
| 1.1 | 8/9 | 14.51 | 14.20/14.59 | - | - |
| 1.3 | 10 | 14.54 | 15.16 | - | - |
| 1.4 | 11 | 15.77 | 15.41 | - | - |

Flood levels were well below bridge decks and therefore no special considerations were needed. The Island Highway bridge, crossing the Campbell River 2.6 km from the mouth, has no piers to restrict flows. The log bridge crossing the Campbell River 3.7 km upstream of the mouth has four piers which must be accounted for. The piers were modelled by adding points to the cross-section data to simulate piers. This reduces the flow area by the appropriate amount and also increases the wetted perimeter. It was felt that the detailed method of estimation of pier loss coefficients would introduce more error than accuracy. The selected method resulted in a good calibration for the January 13, 1987 data.

The same method was used for the two piers on the Highway 28 bridge, crossing the Quinsam River near the mouth.

For calibration, the main channel "n" values ranged from 0.035 to 0.065 and the overbank values ranged from 0.12 to 0.20 depending on conditions at each section. Each cross section was inspected during the site visit to confirm that the selected "n" values were reasonable.

## 5.2 SENSITIVITY ANALYSIS

The sensitivity of the backwater model investigated by varying the discharges, "n" values and tidal level. Table 7 contains the results of these runs. The 200-year Designated Flood Level run was used as the Base Case for the sensitivity analysis.

TABLE 7

SENSITIVITY ANALYSIS RESULTS
WATER SURFACE ELEVATION* (m)

| CROSS SECTION NUMBER | BASE CASE 200-YEAR RETURN PERIOD FLOOD | 20-YEAR RETURN PERIOD FLOOD | CASE 1 Q-10% | CASE 2 Q+10% | CASE 3 "n"-10% | CASE 4 "n"+10% | CASE 5 HHW Mean Tide | CASE 6 Extreme Tide on Record |
|---|---|---|---|---|---|---|---|---|
| CAMPBELL RIVER | | | | | | | | |
| 1 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.9 | 1.2 | 2.4 |
| 2 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 1.4 | 2.5 |
| 3 | 2.0 | 2.0 | 2.0 | 2.0 | 1.9 | 2.1 | 1.5 | 2.4 |
| 4 | 2.6 | 2.3 | 2.5 | 2.8 | 2.5 | 2.8 | 2.4 | 2.9 |
| 5 | 3.3 | 2.8 | 3.1 | 3.5 | 3.0 | 3.5 | 3.1 | 3.4 |
| 6 | 4.3 | 3.7 | 4.0 | 4.5 | 4.0 | 4.5 | 4.2 | 4.3 |
| 7 | 4.6 | 4.0 | 4.4 | 4.8 | 4.4 | 4.8 | 4.6 | 4.6 |
| 8 | 5.0 | 4.5 | 4.8 | 5.2 | 4.7 | 5.2 | 5.0 | 5.0 |
| 9 | 5.1 | 4.6 | 4.9 | 5.2 | 4.9 | 5.3 | 5.1 | 5.1 |
| 10 | 7.3 | 6.1 | 6.9 | 7.7 | 6.9 | 7.6 | 7.3 | 7.3 |
| 11 | 7.8 | 6.9 | 7.4 | 8.1 | 7.4 | 8.1 | 7.8 | 7.8 |
| 12 | 8.4 | 7.6 | 8.1 | 8.7 | 8.1 | 8.7 | 8.4 | 8.4 |
| 13 | 9.1 | 8.3 | 8.7 | 9.4 | 8.7 | 9.4 | 9.1 | 9.1 |
| 14 | 9.2 | 8.3 | 8.8 | 9.5 | 8.7 | 9.5 | 9.2 | 9.2 |
| 15 | 9.6 | 8.8 | 9.3 | 9.9 | 9.5 | 9.8 | 9.6 | 9.6 |
| 16 | 10.4 | 9.6 | 10.1 | 10.7 | 10.2 | 10.6 | 10.4 | 10.4 |
| 17 | 10.5 | 9.7 | 10.2 | 10.8 | 10.2 | 10.7 | 10.5 | 10.5 |
| 18 | 10.7 | 10.0 | 10.5 | 11.0 | 10.5 | 11.0 | 10.7 | 10.7 |
| 19 | 11.0 | 10.3 | 10.7 | 11.3 | 10.8 | 11.3 | 11.0 | 11.0 |
| 20 | 12.0 | 11.6 | 11.8 | 12.2 | 11.8 | 12.3 | 12.0 | 12.0 |
| 21 | 13.9 | 13.3 | 13.6 | 14.1 | 13.7 | 14.0 | 13.9 | 13.9 |
| 22 | 14.6 | 14.1 | 14.3 | 14.9 | 14.4 | 14.8 | 14.6 | 14.6 |
| 23 | 15.1 | 14.7 | 14.9 | 15.4 | 14.9 | 15.4 | 15.1 | 15.1 |

* Freeboard not included

TABLE 7
(continued)

| CROSS SECTION NUMBER | BASE CASE 200-YEAR RETURN PERIOD FLOOD | 20-YEAR RETURN PERIOD FLOOD | CASE 1 Q-10% | CASE 2 Q+10% | CASE 3 "n"-10% | CASE 4 "n"+10% | CASE 5 HHW Mean Tide | CASE 6 Extreme Tide on Record |
|---|---|---|---|---|---|---|---|---|
| Quinsam River | | | | | | | | |
| 1 | 10.5 | 9.7 | 10.2 | 10.8 | 10.2 | 10.7 | 10.5 | 10.5 |
| 2 | 10.5 | 9.8 | 10.2 | 10.8 | 10.2 | 10.7 | 10.5 | 10.5 |
| 2.5 | 10.6 | 9.8 | 10.3 | 10.9 | 10.3 | 10.8 | 10.6 | 10.6 |
| 3 | 11.0 | 10.1 | 10.8 | 11.3 | 10.8 | 11.3 | 11.0 | 11.0 |
| 4 | 11.8 | 11.0 | 11.7 | 12.0 | 11.6 | 12.0 | 11.8 | 11.8 |
| 5 | 12.7 | 12.0 | 12.6 | 12.9 | 12.5 | 12.9 | 12.7 | 12.7 |
| 6 | 13.7 | 13.0 | 13.6 | 13.9 | 13.7 | 13.8 | 13.7 | 13.7 |
| 7 | 14.4 | 13.7 | 14.3 | 14.6 | 14.3 | 14.5 | 14.4 | 14.4 |
| 8 | 14.9 | 14.2 | 14.7 | 15.0 | 14.7 | 15.0 | 14.9 | 14.9 |
| 9 | 15.2 | 14.6 | 15.1 | 15.4 | 15.1 | 15.4 | 15.2 | 15.2 |
| 10 | 15.7 | 15.1 | 15.6 | 15.8 | 15.6 | 15.7 | 15.7 | 15.7 |
| 11 | 16.0 | 15.4 | 15.9 | 16.1 | 16.0 | 16.0 | 16.0 | 16.0 |
| 12 | 17.2 | 16.6 | 17.1 | 17.3 | 17.1 | 17.3 | 17.2 | 17.2 |
| 13 | 17.5 | 16.9 | 17.4 | 17.7 | 17.4 | 17.7 | 17.5 | 17.5 |
| 14 | 18.8 | 18.3 | 18.7 | 18.9 | 18.7 | 18.9 | 18.8 | 18.8 |
| 15 | 19.5 | 18.8 | 19.3 | 19.7 | 19.5 | 19.5 | 19.5 | 19.5 |
| 16 | 20.0 | 19.2 | 19.8 | 20.2 | 20.0 | 20.1 | 20.0 | 20.0 |

* Freeboard not included

The discharge was varied ±10% of the base case. The resulting flows were:

| | CASE 1 $m^3/s$ | CASE 2 $m^3/s$ |
|---|---|---|
| Campbell River Above Quinsam River | 1206 | 1474 |
| Quinsam River | 210 | 256 |
| Campbell River Below Quinsam River | 1416 | 1730 |

The maximum variation in flood level was ±0.4 m on the Campbell River and ±0.3 m on the Quinsam River.

The estimated "n" values were varied ±10% of the base case values given in Section 5.1. Case 3 has low "n" values and Case 4 has high "n" values.

The maximum variation in flood level was ±0.4 m on the Campbell River and ±0.3 m on the Quinsam River.

The tidal level used for the Base Case was the Higher High Water Large Tide, 1.9 m GSC. Tidal sensitivity was tested using the Higher High Water Mean Tide, 1.2 m GSC, and the Extreme on Record, 2.4 m GSC, Cases 5 and 6, respectively. The variation in flood levels extended upstream for 2.1 km, cross section 6.

The maximum increase in water level from these sensitivity cases was 0.3 m. This was well within the 0.6 m of freeboard which was added to the base case water levels.

## 5.3 COASTAL FLOODING

Determination of the coastal natural boundary was made in conjunction
387-3668 with Brendan Holden of the British Columbia Ministry of Environment. Using an inclinometer, GSC benchmarks and recent topographic maps the elevation of the coastal natural boundary was estimated at three sites. The mean coastal boundary elevation was estimated to be 2.0 m.

This elevation integrates site specific factors such as exposure, fetch and wind direction. As recommended in Reference 2.1f, "Elevations and Setbacks for Flood and Erosion Prone Areas", the Coastal Flood Level including freeboard should be Coastal Natural Boundary elevation plus 1.5 m. Using this criterion the Coastal Flood Level including freeboard would be 3.5 m.

As a check on the above calculation, the following analysis was carried out. The two highest recorded tides at Campbell River are 2.43 m GSC (December 1967) and 2.24 m GSC (December 1982). The December 1982 extreme includes approximately 1.0 m due to storm surge. As explained in Reference 2.1f, there are physical limits to storm surge due to lack of fetch, confinement of surge due to bays and barometric low pressure zones due to storms. Based on discussions with Mr. B. Holden of the Ministry of Environment and the information presented above it is estimated that the maximum possible storm surge would be in the order of 1.2 m.

Wave runup is very limited in this area due to the short fetch and the direction of the prevailing winds. The winds are generally along shore in this area thus precluding wave runup. Any waves which develop, travel parallel to the shoreline and not perpendicular to it. Very little allowance is necessary for wave runup.

Tidal information is developed for use by navigators. Thus any rounding of values is done by truncation to err on the conservative side when calculating depths for navigation. An allowance of 0.3 m should be included to compensate for truncation in the published tidal levels.

A total of 1.5 m should be added to the Highest High Water Large Tide, 1.9 m to obtain a Coastal Flood Level including freeboard, i.e. 1.9 m + 1.5 m = 3.4 m. This compares well to the proposed value of 3.5 m derived above.

## 6. DESIGNATED FLOOD LEVEL

As outlined in the Terms of Reference freeboards of 0.6 m and 0.03 m should be used in association with the 20-year and 200-year return period mean daily and instantaneous discharges, respectively. Maximum instantaneous discharges on both the Campbell and Quinsam Rivers are less than 110% of the mean daily discharge. If the designated freeboard of 0.3 m is added to the sensitivity Case 2 (mean daily discharge plus 10%) the resulting flood level plus freeboard is less than that resulting from the mean daily discharge plus 0.6 m freeboard. Therefore the latter case governs. The freeboard of 0.6 m is reasonable considering the possible effects of wind waves and standing waves. Other factors which lend support to using a freeboard allowance are the unpredictability of "n" values in overbank residential areas and the unpredictability of debris dams.

The discharges, presented in Section 4.3, to be used in determining the Designated Flood Levels are:

| Return Period | 20 Years | 200 Years |
|---|---|---|
| Campbell River above Quinsam River ($m^3/s$) | 1084 | 1340 |
| Quinsam River ($m^3/s$) | 136 | 233 |
| Campbell River below Quinsam River ($m^3/s$) | 1220 | 1573 |

For both cases, the selected tidal level for backwater modelling was 1.9 m, Higher High Water Large Tide. The extent of the influence of this tidal level, as shown in the sensitivity analysis, Section 5.2, indicated that this level was appropriate.

While modelling these large discharges it was found that the bridge roadways on the Campbell River must be accounted for. The Island Highway bridge, located 2.6 km upstream of the mouth of the Campbell River, was modelled using the normal bridge method. Flood flows will impinge on the lower chord of the bridge deck but not overtop it.

Flood levels for the logging bridge, located on the Campbell River 3.7 km upstream from the mouth, rise above the road deck on one end of the bridge. Flows of this magnitude over this type of bridge would be expected to remove the bridge deck. Thus this section was modelled as if no bridge deck was present. The bridge piers were assumed to remain in the riverbed.

The Highway 28 bridge crosses the Quinsam River immediately upstream of the mouth. The flood levels on the Quinsam River did not reach the lower chord of the bridge deck. The surveyed cross-sections were extended using the 1:5000 scale maps supplied by the Ministry of Environment. At several locations the effective flow area was explicitly limited. Some sections were extended vertically from their end points by the HEC-2 program during the backwater computations. The areas outside of these limits were considered non-effective flow areas due to expansion or contraction of flows or significant obstructions to flow, as noted during the site visit.

In the immediate area of the mouth of the Campbell River the Designated Flood Level should correspond to the 3.5 m GSC, as discussed in Section 3.2.

The floodplain maps, Appendix IV, depict the Designated 200-year Return Period Flood Level including 0.6 m of freeboard. Table 7 demonstrates that the difference in flood levels between the 200-year and 20-year return period profiles is a maximum of 0.5 m near the mouth of the

Campbell River. This difference would not significantly affect the outline of the flooded area in this relatively flat area. Due to the steeper topography upstream of the Island Highway bridge, the difference in flooded area between the two events is even less. Only the 200-year return period event flood levels (including freeboard) have been shown on the maps.

## 7. CONCLUSIONS AND RECOMMENDATIONS

Historically the lower Campbell River area has been prone to winter flooding. Since the construction of the B.C. Hydro dams on the upper Campbell River, floods of low return period have been controlled to prevent significant flooding. The analysis carried out in this report, however, demonstrated that while low return period floods would continue to be controlled, the B.C. Hydro dams on the Campbell River do not significantly alter the 200-year flood discharge on the Campbell River.

A combination of high tide levels and high discharge was determined as part of this study to delineate the 200-year floodplain level including freeboard.

It is recommended that the floodplain area outlined on Maps 88-28-1 and 88-28-2 be designated the 200-year floodplain.

KLOHN LEONOFF LTD.

Richard F. Rodman, P.Eng.
Project Engineer

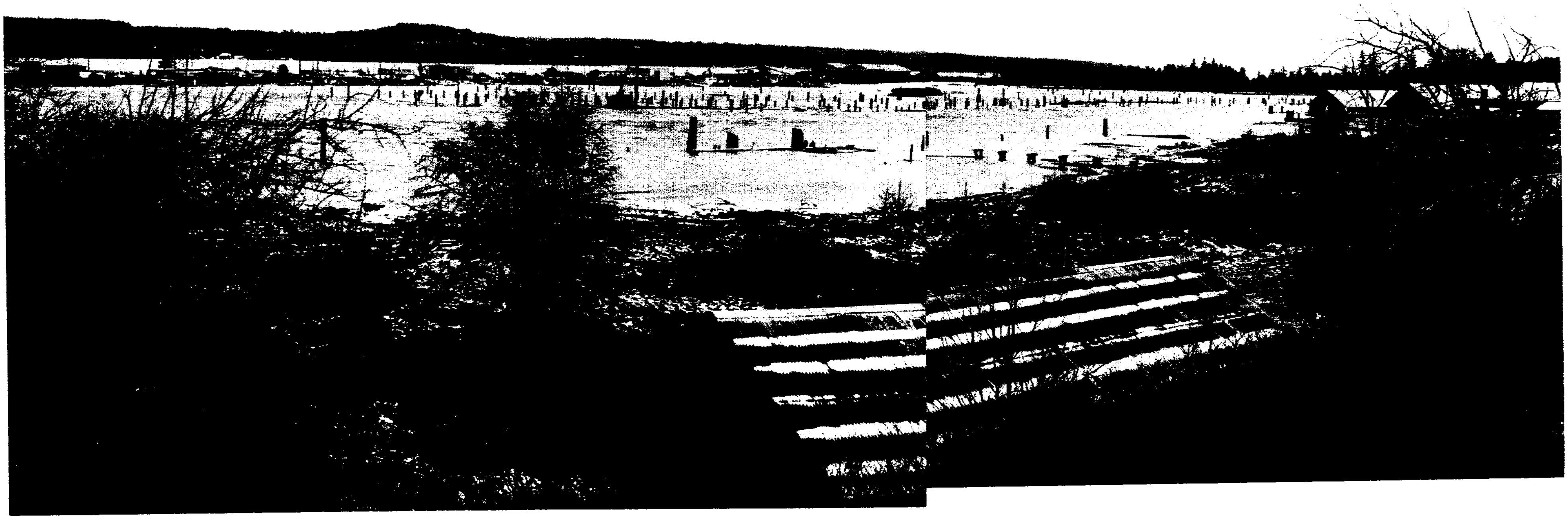
C. David Sellars, P.Eng.
Project Manager

RFR:CDS:tp/ljb

APPENDIX 1

## APPENDIX I

SITE VISIT PHOTOGRAPHS AND
NEWSPAPER ARTICLE



<u>Photo 1</u> Looking south from left bank of Campbell River at Tyee Spit. Tidal and river influence on natural boundary. Overbank ranges from elevation 1 m to 2 m.

1 Feb. 1989

THE CAMPBELL RIVER AND AREA

# MIRROR

CAMPBELL RIVER EMERGENCY NUMBERS:

RCMP ........ 286-6221
FIRE ........ 287-3311
AMBULANCE ........ 287-3311
POISON CONTROL CENTER ... 287-7111
CRISIS LINE 287-7743 287-9144 287-9145

Issue 46 Vol. 5 PRESS RUN 7200 YOUR LOCALLY OWNED - INDEPENDENTLY OPERATED NEWSPAPER NEWSSTAND 15c Wed., Nov. 19, 1975

DESERTED AFTER FIGHTING losing battle against the Quinsam River is this jeep and Caterpillar left by Quinsam Fish hatchery workers Friday after struggling to clear a log jam pressing against the hatchery diversion fence. Although the water level has dropped this week following a 'cessation of torrential rain, the River left in its wake between $25,000 and $50,000 damage to the facility.

# Log jam, debris damages hatchery

*How you voted*

# The mixture as before

## Voters approve by-laws

Campbell River voters decided to stick with the aldermen they have and added a political veteran in the municipal elections Saturday by selecting incumbents Wallace Baikie and Peter Johnson and ex-alderman Ollie Penman to two-year terms on council.

The voters rejected Forde's stand against the recreation and drain sewer plebiscites, accepting the controversial by-laws by 74 and 55 per cent respectively.

Wallace Baikie led the aldermanic race, which saw a 30.66 percent election turnout, by drawing 1151 votes of a possible 5,508. Baikie is now starting his 11th year as alderman. Peter Johnson, first elected alderman in a by-election last November, ran a close second with 1136 votes, followed by Ollie Penman, with 1015. Penman previously served as alderman during 1970-74 before being defeated in the mayoralty contest last fall.

voting 'yes' and 40.57 rejecting the by-law, with a total of 67 spoiled ballots.

The controversial by-law became an issue of contention between Mayor Forde and five of the six aldermen on council last week when aldermen claimed Forde lacked leadership for not accepting the majority's approval of the project.

Also held Saturday were school board elections for three trustees for two-year terms and two positions for the Comox-Strathcona Regional Board.

School Board chairman Mike Henderson was re-elected to his position, leading the four candidates for the two Campbell River seats with 1596 votes. Taking the other position was local lawyer Ian Clague with 1062. The two remaining candidates, Frank Sullivan and Patrick Winters received 934 and 557 votes respectively.

SCHOOL TRUSTEES

In the Quadra Outlying

with Cortes Islanders turning out in greater numbers than Quadra residents.

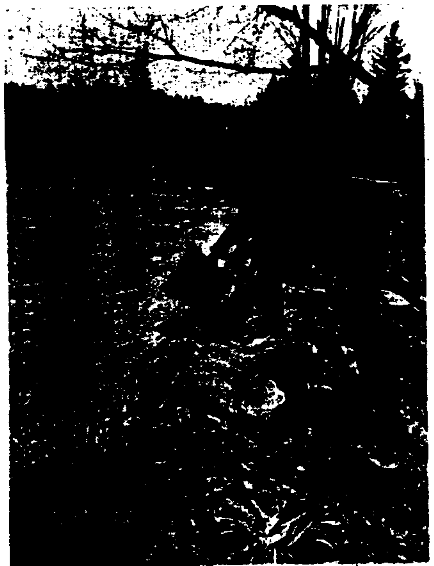
Freeman received 120 votes from cortes as opposed to Luoma's 27, nullifying the Quadra Island results of 68 for Luoma and 10 for Freeman. A travelling ballot box and a station at Stuart Island gave Freeman two votes and Luoma six.

REGIONAL BOARD

In Regional Board elections, the two incumbents for the Quinsam and Oyster Bay seats defeated their challengers, regaining the two-year positions on the board.

Norm Lysne (Quinsam) defeated contender Kevin Storrie 124-87 and Dick Trehearne overcame challenger Jack Torrance 119-98.

Oyster Bay-Black Creek residents approved a Fire District by-law calling for funds to be borrowed for the construction of a fire hall and the purchase of equipment near Black Creek by a vote of 220 to 70



FIGHTING A LOSING BATTLE, Ken Davidson throws another sandbag onto an S-bend on the Oyster River in an effort to prevent flooding of the Ken Scott residence last Thursday. Sandbagging proved futile however as the river ran over the dike later that afternoon. Fortunately damage to the residence was slight.

Between $25,000 - $50,000 worth of damage was done to the Quinsam Fish Hatchery diversion fence last week when the river swollen from torrential rainfalls and a high freezing level, brought down a mass of logs and debris, creating a major log jam.

Hatchery Superintendent Jim Van Tyne said the logs bent beams on the fence, which is used for diverting fish into the hatchery and for fish counts, despite week-long efforts to keep the area clear of debris with pike poles prior to the jam-up Wednesday night.

He said about a dozen hatchery workers struggled to clear the mess until 3:30 a.m. Thursday morning but gave up after the water level rose too high for the caterpillar and a skidder to operate. The water level was 12 to 14 feet above normal at that point, he said and "the situation was hopeless."

Ironically, the log jam did save the fence from further damage, as it acted to buffer the impact of additional logs rushing down the river and hitting it, he said.

Van Tyne said the design of the fence was based on even greater water volumes, but couldn't cope with the amount of debris brought down by the river.

He said the hatchery had figures to indicate that Thursday's level was theoretically reached every 35 years. The only way to deal with the problem would to have two Catepillars stationed on the banks at all times, a financially unfeasible plan, he said.

The workers tried again Friday to clear the log jam but were told by environment Canada officials in Vanocuver not to put themselves in jeopardy, said the superintendent.

"There wasn't anything we could do at that point anyway," he said.

Below the diversion fence the river had overflowed its bands and was threatening to flood the clarifier tanks and consequently back up the system, but Van Tyne said that was a lesser concern as the river would have to "flood the entire valley out" before it filled the tanks which are used to clean the water taken into the hatchery before it is returened to the river.

In an interview Tuesday afternoon, the superintendent said the water level had dropped substantially and that workers were now trying to clear the jam.

# Vandals admit responsibility

Five suspects have admitted responsibility for damage done Nov. 10 to the grass fields at Foreshore Park and three Campbell River schools, an RCMP spokesman said Tuesday.

But RCMP are awaiting instructions from the municipality and the school board before processing charges, he added.

The suspects, of adult age, were picked up Nov. 10 after RCMP were supplied descriptions of the individuals by a citizen who witnessed a vehicle driving on the Foreshore Park grass field in the early morning the day before.

The spokesman said that probably only the driver would be charged with wilful damage to public property. "The passengers didn't put a gun to the driver's head."

Municipal Administrator Lorne Anderson said city hall was waiting for the school district to hold its biweekly board meeting to discuss charges. "We want to co-ordinate any charges with the school board and proceed together on them."

The School Board held its meeting Tuesday night and their decision was not available before press time.

Anderson also said the citizen who reported the individuals is entitled to the $1,000 reward posted by the municipality providing the involved party is convicted.

# Premier to speak

Premier Dave Barrett is coming to Campbell River. The premier will speak to a public meeting in Campbell River Junior Secondary School 8:00 p.m. Nov. 27.

The meeting, will conclude a day of campaigning in the Comox valley.

Also present at the meeting will be Karen Sanford, New Democratic Party candidate in the Comox riding.

# Impaired driver gets jail term

Thomas Edward Nelson, Campbell River, pleaded guilty before Judge Anthony Sarich in provincial court Monday to a charge of impaired driving laid Oct. 18 and received a 30-day jail sentence after his counsel told the judge he couldn't afford to pay the fine.

COURT WAS TOLD

Court was told RCMP stopped Nelson in front of the Kerdan Hotel after observing him driving in an erratic fashion, narrowly avoiding colliding with a parked vehicle.

Crown Counsel Ian Clague said Nelson told RCMP he was driving the vehicle because the owner was impaired. RCMP found that Nelson had a blood-alcohol reading of .29.

Nelson also pleaded guilty to driving while under suspension and to a charge of breach of probation.

The Crown said Nelson was ordered to do 20 hours of community work Feb. 4 by Judge Roderick Haig-Brown and an additional 60 hours work on another occasion.

The local probation officer assigned him to janitorial work at a Campbell River church but Nelson failed to appear.

Nelson's lawyer, Don Young, said the probation officer later canceled the community work because of Nelson's poor health and the inclement weather.

Nelson, 50, suffers from alchohol problems, has no dependants or income, said his counsel.

"We think a fine would be unrealistic, your honor. There is little hope of Mr. Nelson paying the fine in the near future."

Young asked the judge to impose jail terms so that Nelson "could face all the problems at one time." Hopefully he can start fresh without problems."

Before sentencing Nelson to 30-days imprisonment on the impaired charge and a concurrent 30-day term for the breach of probation charge, Judge Sarich chastized Nelson for driving while so impaired.

"Driving that truck was extremely dangerous and foolish thing to do,

"I would suggest that driving is extremely dangerous any time you have had drink."

In other impaired driving cases, David Ernest Keen, 32, Campbell River, pleaded guilty to a charge laid Oct. 22, and received a $350 fine and a two-month licence suspension.

continued on page 5

A gap of 248 votes separated the three successful candidates and the two remaining candidates, political new-comers David (Scotty) MacLaren who received 767 votes and Wolfgang Rumpel with 578.

The voters gave strong support to by-law 690, which asked them whether or not a referendum on a $5.6 million recreation complex for Campbell River should be held by giving the question 74-36 percent approval. The response contradicts the stand taken by Regional Board Director Ken Forde, who voted against the idea of a referendum at a regional board meeting in Courtenay Sept. 30.

It is now expected that the results will be taken to the regional board in the spring of 1976 as evidence of public support for a referendum.

By-law 672, which asked the public to authorize the municipality to borrow $633,000 to proceed with Phase two of the five-year storm drain-sewer project received less dramatic support, with 55-46 percent

In the Quadra Outlying Islands school board seat, Cortes Islander Wilf Freeman upset incumbent Rosamund Luoma 132-101,

vote or 220 to 70.

The area is currently served by the Courtenay Fire Department.

## Out-of-town elections

Municipal elections were held simultaneously in 17 other Island Communities Saturday. The following as a brief rundown of election results in four north island towns. An X indicated incumbent. Accl: elected by acclamation.

SAYWARD

Mayor: Ron Smith, 72, X Ronald John Sprout, 53.

Council: (Two seats) Anita Joy Williams, John Duerksen accl).

Voter turnout, 73 percent.

GOLD RIVER

Three aldermen: Arthur Lampard, 202; William Mewhort, 151; Arthur Crape, 131; Brian Lawrence, 115; Alfred Mitchell 105; X Barbara Donovan 102; Robert Goldie 66.

School Board (one seat): X Lee A. Selzler (accl)

Voter turnout 46.3 percent.

PORT HARDY

Council (three seats): X Wayne Fox 191, Ray Phillips 185; X William Parker 154; Steve Benington 143; Peter Johnson 123.

Voter turnout 21 percent.

PORT MCNEIL

Council (two seats): John Ferrari, Heine Schilling (accl.) School Board (one seat): X Dale Chilton (accl.

(No figures available for voter turn-out.)

# Evacuees return to ravaged homes

The promise of good weather is good news for Port Alice, now mopping up after the floods and storm damage suffered by northern Vancouver Island last week.

The weather forecast looks good at least until Thursday, and it was a sunny Monday as work crews continued with the task of cleaning up the mess caused by Thursday's mud slide, repairing washed out roads and installing a Baily bridge over the Marble River to link Port Alice and outside points.

The 1,100 people who were evacuated from the stricken town have nearly all returned home, and the Rayonier pulp mill in the community is back in operation.

Residents are also returning to Kelsey Bay, where the Salmon River burst its banks last week, leaving 100 people to be airlifted to safety by helicopter. At least two houses and six mobile homes were destroyed.

At Port Hardy, residents and their guest refugees from Port Alice were not able to dry and thaw out until Friday, after 16½ hours without power.

The power outage, caused by two fallen transmission towers, left the 3,000 port Hardy residents and 1,000 evacuees without heat, light and cooking facilities, and almost without water as electric pumps came to a halt.

Sayward too was ravaged by floods, with rushing waters reaching into hundreds of homes.

Although there were no deaths or reported injuries, flood waters reached a depth of eight feet and hundreds of persons were evacuated.

More locally, the Oyster River went wild. Police and highways department work crews were called out to sandbag the banks and dump loads of rock. No homes were destroyed, but mobile homes were endangered.

The Campbell River rose to a point where it was almost touching the Island Highway bridge. On its bank could be seen four horses stranded in a flooded field. In a panic, the horses tried to jump a fence to drier land.

# APPENDIX II

# APPENDIX II

RESERVOIR ROUTING PROGRAM
- LISTING
- SAMPLE OUTPUT

# RESERVOIR ROUTING PROGRAM LISTING

```
DEFINT I-N
DECLARE SUB LinInterp (N, X, Y)
DECLARE SUB Storeroute (ResFixOut)
DIM TimeStep(40), QTide(40), QELTide(40), TideStep(40), Tide(40)
DIM ResInflow(40), VolEl(40), Vol(40), RatEl(40), Rating(40)
DIM Flag AS STRING
'
DATA 15
DATA 211.84,460.02
DATA 213.36,540.76
DATA 214.27,592.15
DATA 215.19,643.53
DATA 216.10,694.92
DATA 217.02,746.30
DATA 217.93,801.36
DATA 218.85,856.41
DATA 219.76,911.47
DATA 220.68,968.97
DATA 221.59,1027.70
DATA 222.50,1086.42
DATA 223.00,1118.68
DATA 224.00,1183.21
DATA 225.55,1283.23
DATA 13
DATA 201.2, 151.4
DATA 214.88,164.0
DATA 215.50,291.3
DATA 216.00,320.7
DATA 217.00,397.6
DATA 218.00,498.2
DATA 219.00,621.0
DATA 220.00,758.7
DATA 221.00,912.4
DATA 222.00,1073.9
DATA 223.00,1239.0
DATA 224.00,1407.4
DATA 225.00,1578.1
DATA 275.
DATA 20
DATA 1,0.36,1.2
DATA 2,0.36,0.19
DATA 3,0.36,0.85
DATA 4,0.47,-1.76
DATA 5,1.04,1.2
DATA 6,2.39,0.19
DATA 7,3.74,0.85
DATA 8,5.09,-1.76
DATA 9,6.44,1.2
DATA 10,6.59,0.19
DATA 11,5.31,0.85
DATA 12,4.03,-1.76
DATA 13,2.76,1.2
DATA 14,2.25,0.19
DATA 15,1.74,0.85
DATA 16,1.23,-1.76
DATA 17,0.72,1.2
DATA 18,0.60,0.19
DATA 19,0.48,0.85
DATA 20,0.36,-1.76
DATA 8.5
DATA 500.
DATA 220.57
DATA 220.5
DATA 170.0
DATA 1898.0
```

```
DATA .14
DATA .014
DATA .09
DATA 8
DATA -5.0,640.
DATA 0.3,640.
DATA 0.6,620.
DATA 0.9,580.
DATA 1.2,520.
DATA 1.5,390.
DATA 1.8,200.
DATA 2.1,0.0
DATA 6.0
DATA 20
DATA 0.01
DATA 3000000.0
DATA 400.0
DATA 170.0, 220.28, 170.0
'  Set up input and output files
'INPUT "What is the name of the data input file"; infile$
'OPEN infile$ FOR INPUT AS #2
INPUT "What is the name of the output file"; outfile$
OPEN outfile$ FOR OUTPUT AS #1
'
READ NV
PRINT #1, "Number of points on Volume Elevation Curve =", NV
PRINT #1, "Elevation (m)     Volume (millions m3)"
FOR I = 1 TO NV
        READ VolEl(I), Vol(I)
        PRINT #1, VolEl(I), Vol(I)
        Vol(I) = Vol(I) * 1000000#
NEXT I
'
READ NR
PRINT #1, "Number of points on Elevation Rating Curve =", NR
PRINT #1, "Elevation (m)     Discharge (m3/s)"
FOR I = 1 TO NR
        READ RatEl(I), Rating(I)
        PRINT #1, RatEl(I), Rating(I)
NEXT I
'
READ StormVol
PRINT #1, "Volume for inflow hydrograph (millions m3) ="; StormVol
'
READ NI
        NT = NI
PRINT #1, "Number of points on Inflow Hydrograph and Tide Data=", NI
PRINT #1, " Step   Normalized      Tide"
PRINT #1, "Number    Inflow       El.(m)"
FOR I = 1 TO NI
        READ TimeStep(I), ResInflow(I), Tide(I)
        PRINT #1, TimeStep(I), ResInflow(I), Tide(I)
        TideStep(I) = TimeStep(I)
NEXT I
'
READ DivInflow
PRINT #1, "Diversion inflow to Strathcona (m3/s) =", DivInflow
'
READ SnowLine
PRINT #1, "Snow Line elevation (m) =", SnowLine
'
READ CritRes42a
PRINT #1, "Critical Reservoir Elevation (Fig 4-2A) (m) =", CritRes42a
'
READ CritRes42c
```

```
PRINT #1, "Critical Reservoir Elevation (Fig 4-2C) (m) =", CritRes42c
'
READ QSCATurbines
PRINT #1, "Maximum Strathcona turbine flow (m3/s) =", QSCATurbines
'
READ OutflowLDRMax
PRINT #1, "Maximum Lador Outflow (m3/s) =", OutflowLDRMax
'
READ FactorLador
PRINT #1, "Local Lador inflow factor =", FactorLador
'
READ FactorJHT
PRINT #1, "Local JHT inflow factor =", FactorJHT
'
READ QuinFactor
PRINT #1, "Quinsam River flow factor =", QuinFactor
'
READ NQ
PRINT #1, "Number of points on D/S Flooding Data (Fig 4-1) =", NQ
PRINT #1, "Discharge (m3/s)   Tide Elevation (m)"
FOR I = 1 TO NQ
        READ QELTide(I), QTide(I)
        PRINT #1, QELTide(I), QTide(I)
NEXT I
'
READ DT
PRINT #1, "Time step for calculations (hrs) = ", DT
'
READ NumStep
PRINT #1, "Number of time steps for calculations = ", NumStep
'
READ DEL
PRINT #1, "Reservoir Elevation increment for routing iteration (m) =", DEL
'
READ Converge
PRINT #1, "Convergence criteria for routing ( m3) =", Converge
PRINT #1, "This value determines when reservoir volume satisfies the storage routing equation."
PRINT #1, "This value should be > (Slope of EL vs Volume curve) * (Res El increment)"
PRINT #1, "or convergence may not occur during reservoir storage routing."
'
READ RInflowCheck
PRINT #1, "Decision 1 trigger inflow for expected flood (m3/s) =", RInflowCheck
'
READ RInflow1, ResEl1, ResOut1
PRINT #1, "Initial conditions data:"
PRINT #1, "        Reserovoir inflow (m3) =", RInflow1
PRINT #1, "       Reservoir elevation (m) =", ResEl1
PRINT #1, "      Reservoir outflow (m3/s) =", ResOut1
'
PRINT #1, "Reservoir Routing Results using Strathcona Dam Local Operating Order"
PRINT #1,
PRINT #1, "Time  DivInflow TotInflow ResEL    Res    Down Stream Local Inflow  Total Flow   Tide Level"
PRINT #1, "                                 OutFlow   Lador    JHT   Quinsam  Local+Release                Flag"
PRINT #1, " Hrs   (m3/s)     (m3/s)   (m)    (m3/s)   (m3/s) (m3/s) (m3/s)      (m3/s)            (m)"
Fmt1$ = "####   ###.    ###,###.   ###.## #,###.   #,###. #,###. #,###.    ###,###.         ###.#      &"
PRINT #1, USING Fmt1$; 0!, DivInflow, RInflow1, ResEl1, ResOut1
'    End of data input and echo."
'  Begin following routing procedures.
'
X = ResEl1
CALL LinInterp(2, X, Y)
ResVol1 = Y
'
'  Convert Normalized Inflow Hydrograph to Inflow values (m3/s)
'
```

```
FOR I = 1 TO NI
        ResInflow(I) = ResInflow(I) * StormVol
NEXT I
'  Initialize data
ResInitialFloodEl = ResEl1
DTSeconds = DT * 3600!
'
'   Carry out routing for specified number of time steps
'      Begining of time step variables are ResEl1,ResOut1,RInflow1, etc.,
'     End of time step (IStep) are ResEl2, ResOut2, ResInflow(IStep), etc.,
'
FOR IStep = 1 TO NumStep
Flag = "Step ?"
'
'       Calculate local inflows DS of Upper Campbell Lake
'
QLadorLocal = FactorLador * ResInflow(IStep)
QJHTLocal = FactorJHT * ResInflow(IStep)
Quinsam = QuinFactor * ResInflow(IStep)
'
'       Decision 1 - Check forcast inflow
        IF (RInflow1 >= RInflowCheck OR ResInflow(IStep) >= RInflowCheck) THEN
'       Decision 1, YES
'               Decision 3 - Check if flood routing needed from Fig 4-2A
'                     based on snowline
                IF (ResEl1 >= CritRes42a) THEN
'               Decision 3, YES
'                       Decision 5 - Check if Recession has started
                        IF (ResInflow(IStep) < RInflow1) THEN
'                       Decision 5, YES
'                          Step 8 - Pass 1.5 times ResInflow (Subject to
'                          maximum discharge capacity) from Upper
'                          Campbell Lake or Previous 6 Hr Outflow,
'                          which ever is less.
                             Flag = "Step 8"
'                          Check if previous 6 hr outflow is less, use it
                             IF (ResOut1 <= 1.5 * ResInflow(IStep)) THEN
                             A = ResOut1
                             CALL Storeroute(A)
                             ELSE
                             A = 1.5 * ResInflow(IStep)
                             CALL Storeroute(A)
                             END IF
'                          If Capacity is exceeded, route with gates open
                             X = ResEl2
                             CALL LinInterp(1, X, Y)
                             FreeOut = Y
                             IF (FreeOut < ResOut2) THEN CALL Storeroute(0!)
'                Completed one routing step. Print out results and start next time step.
                        ELSE
'                       Decision 5, NO
                             Flag = "Step 5"
'                        Step 5-1 Recession not started in Upper Campbell, shut off diversions
                             IF (DivInflow > 0!) THEN
                             FOR II = IStep TO NI
                                     ResInflow(II) = ResInflow(II) - DivInflow
                             NEXT II
                             DivInflow = 0!
                             END IF
'                        Step 5-2 Pass Inflows up to max discharge capacity.
'                          Calculate reservoir level assuming passage of inflow.
                             A = ResInflow(IStep)
                             CALL Storeroute(A)
                             X = ResEl2
                             CALL LinInterp(1, X, Y)
```

```
                        FreeOut = Y
'                     Check if passage of infow > free outflow, then route with rating table.
                        IF (FreeOut < ResOut2) THEN CALL Storeroute(0!)
'                 Step 6 Pass inflows subject to maximum discharge cap from Lower Campbell lake.
                        A = OutflowLDRMax - QLadorLocal
                        IF (ResOut2 + QLadorLocal > OutflowLDRMax) THEN CALL Storeroute(A)
'    Decision 6 - Completed one routing step. Print out results and start next time step.
                  END IF
          ELSE
'    Decision 3, NO - Flood routing not needed from Fig 4-2A
'    Decision 4 - Check downstream flooding based on Fig 4-1.
'                 Select flood control if DS flooding caused by passing inflow +
'                 local flows.
'               Decision 4, NO  Therefore Step 3.
'                      Assume no flood control needed pass maximum turbine flow.
'                      Then check for DS flooding.
                   Flag = "Dec.4,Step 3"
                   A = QSCATurbines
                   CALL Storeroute(A)
                   X = ResE12
                   CALL LinInterp(1, X, Y)
                   FreeOut = Y
'                Check if free outflow < passage of infow , if so then route with rating table.
                   IF (FreeOut < ResOut2) THEN CALL Storeroute(0!)
                   DSTotFlow = ResOut2 + QLadorLocal + QJHTLocal + Quinsam
'                Check if flooding occurs with this discharge and tide level
                   X = Tide(IStep)
                   CALL LinInterp(3, X, Y)
                   AllowDSFlow = Y
                   IF (DSTotFlow > AllowDSFlow) THEN
                        Flag = "Dec.4,Step 4"
'                Decision 4, YES,  Flooding occurs therefore Step 4
'                Step 4 - The actual DS discharge is higher than the max allowable discharge.
'                Therefore flooding will occur if inflow is passed.
'                Therefore select DS flood control.
'                Step 4-1  Shut off diversions.
                        IF (DivInflow > 0!) THEN
                        FOR II = IStep TO NI
                             ResInflow(II) = ResInflow(II) - DivInflow
                        NEXT II
                        DivInflow = 0!
                        END IF
'                Step 4-2  Release 400 m3/s from Upper Campbell.
                        CALL Storeroute(400!)
'                 Check if free outflow < passage of 400, if so then route with rating table.
                        X = ResE12
                        CALL LinInterp(1, X, Y)
                        FreeOut = Y
                        IF (FreeOut < ResOut2) THEN CALL Storeroute(0!)
'                 Check allowable DS Q which will not cause flooding.
                      DSTotFlow = ResOut2 + QLadorLocal + QJHTLocal + Quinsam
'                 Check if flooding is occuring, if it is reduce outflow.
                        IF (DSTotFlow > AllowDSFlow) THEN
'                            Check if local flows > allowable DS flow.
                             IF (QLadorLocal + QJHTLocal + Quinsam > AllowDSFlow) THEN
'                                 Local flows > Allowable DS flow, therefore set SCA outflow at minimum.
                                  XResOut2 = .001
                                  Storeroute (XResOut2)
                             ELSE
'                                 Local flows < allowable flows therefore can release from SCA.
                                  XResOut2 = AllowDSFlow - QLadorLocal - QJHTLocal - Quinsam
                                  Storeroute (XResOut2)
                             END IF
                        END IF
                   END IF
```

```
            END IF
        ELSE
'       Decision 1  NO, Present and Previous inflow < 400. m3/s Therefore
'       Decision 2  Is Upper Campbell Lake level above the safe level Fig 4-2c?
            IF (ResEl1 > CritRes42c) THEN
'        Decision 2, YES
                        Flag = "Dec.2,Step 4"
'                   Step 4 -  Select DS flood control until initial flood level reached.
'                   Step 4-1  Shut off diversions
                    IF (DivInflow > 0!) THEN
                        FOR II = IStep TO NI
                            ResInflow(II) = ResInflow(II) - DivInflow
                        NEXT II
                        DivInflow = 0!
                    END IF
'                   Step 4-2  Release 400 m3/s from Upper Campbell and until initial
'                       level is reestablished.
                    IF (ResInitialFloodEl = 0!) THEN ResInitialFloodEl = ResEl1
                        CALL Storeroute(400!)
'                  Check if passage of infow > free outflow, if so then route with rating table.
                        X = ResEl2
                        CALL LinInterp(1, X, Y)
                        FreeOut = Y
                        IF (FreeOut < ResOut2) THEN CALL Storeroute(0!)
'                  Check alowable DS Q which will not cause flooding.
                        X = Tide(IStep)
                        CALL LinInterp(3, X, Y)
                        AllowDSFlow = Y
                        DSTotFlow = ResOut2 + QLadorLocal + QJHTLocal + Quinsam
'                  Check if flooding is occuring, if it is reduce outflow.
                        IF (DSTotFlow > AllowDSFlow) THEN
'                           Check if local flows > allowable DS flow.
                            IF (QLadorLocal + QJHTLocal + Quinsam > AllowDSFlow) THEN
'                               Local flows > Allowable DS flow, therefore set SCA outflow at minimum.
                                XResOut2 = .001
                                Storeroute (XResOut2)
                            ELSE
'                               Local flows < allowable flows therefore can release from SCA.
                                XResOut2 = AllowDSFlow - QLadorLocal - QJHTLocal - Quinsam
                                Storeroute (XResOut2)
                            END IF
                        END IF
            ELSE
'       Desision 2,  NO  Step 3. Normal operation.
'           Reservoir level below safe level Fig 42c therefore pass maximum turbine flow.
                Flag = "Dec.2,Step 3"
                X = QSCATurbines
                Storeroute (X)
'              Check alowable DS Q which will not cause flooding.
                        X = Tide(IStep)
                        CALL LinInterp(3, X, Y)
                        AllowDSFlow = Y
                        DSTotFlow = ResOut2 + QLadorLocal + QJHTLocal + Quinsam
'              Check if flooding is occuring, if it is reduce outflow.
                        IF (DSTotFlow > AllowDSFlow) THEN
'                           Check if local flows > allowable DS flow.
                            IF (QLadorLocal + QJHTLocal + Quinsam > AllowDSFlow) THEN
'                               Local flows > Allowable DS flow, therefore set SCA outflow at minimum.
                                XResOut2 = .001
                                Storeroute (XResOut2)
                            ELSE
'                               Local flows < allowable flows therefore can release from SCA.
                                XResOut2 = AllowDSFlow - QLadorLocal - QJHTLocal - Quinsam
                                Storeroute (XResOut2)
                            END IF
```

```
                                END IF

                        END IF
                END IF
'   Storage routing has completed. Check for downstream flooding.
        DSTotFlow = ResOut2 + QLadorLocal + QJHTLocal + Quinsam
        X = Tide(IStep)
        CALL LinInterp(3, X, Y)
        AllowDSFlow = Y
        IF (DSTotFlow > AllowDSFlow) THEN Flag = Flag + " DS Flooding"
'   Print out results and reset values for next time step.
PRINT #1, USING Fmt1$; DT * IStep, DivInflow, ResInflow(IStep), ResEl2, ResOut2, QLadorLocal, QJHTLocal, Quinsam, DSTotFlow, Tide(IStep), Flag
'
'       Reset values for next time step
'
RInflow1 = ResInflow(IStep)
ResEl1 = ResEl2
ResOut1 = ResOut2
ResVol1 = ResVol2
'
NEXT IStep
'
PRINT #1, "Program completed."
'
CLOSE #1
CLOSE #2
END

' Subroutine for Linear Interpolation
'     Must pass nt% Table number, 1=rating table,2=el Vol table, 3=Discharge tide table
'               x Known
'               y to be calculated
'      Arrays are passed in the SHARED Command
'
SUB LinInterp (NT%, Xknown, Ycalculated)
DEFINT I-N
DIM X(40), Y(40)
SHARED NR, RatEl(), Rating(), NV, VolEl(), Vol(), NQ, QELTide(), QTide(), Flag AS STRING
'     Select appropriate table, 1 for rating, 2 for volume, 3 for tide
IF (NT% = 1) THEN
        N = NR
        FOR I = 1 TO NR
                X(I) = RatEl(I)
                Y(I) = Rating(I)
        NEXT I
END IF
IF (NT% = 2) THEN
        N = NV
        FOR I = 1 TO NV
                X(I) = VolEl(I)
                Y(I) = Vol(I)
        NEXT I
END IF
IF (NT% = 3) THEN
        N = NQ
        FOR I = 1 TO NQ
                X(I) = QELTide(I)
                Y(I) = QTide(I)
        NEXT I
END IF
IF (NT% <> 1 AND NT% <> 2 AND NT% <> 3) THEN
        PRINT #1, "Table number not equal to 1,2 or 3, ie. NT%=", NT%
        PRINT #1, "Interpolation Failed"
        PRINT #1, "IStep = ", IStep
        PRINT #1, Flag
```

```
        STOP
END IF
'   Check if Xknown is within range of X() values
IF (Xknown < X(1)) THEN
        PRINT #1, "Interpolation Failed"
        PRINT #1, "IStep = ", IStep
        PRINT #1, Flag
        PRINT #1, "X value known =", Xknown, "less than table values."
        PRINT #1, " Xvalues              Yvalues"
        FOR I = 1 TO N
                PRINT #1, X(I), Y(I)
        NEXT I
        STOP
ELSE
        IF (Xknown > X(N)) THEN
                PRINT #1, "Interpolation Failed"
                PRINT #1, "IStep = ", IStep
                PRINT #1, Flag
                PRINT #1, "X value known =", Xknown, "greater than table values."
                PRINT #1, " Xvalues              Yvalues"
                FOR I = 1 TO N
                PRINT #1, X(I), Y(I)
                NEXT I
                STOP
        END IF
END IF
'   Locate Xknown in X() array.
FOR I = 1 TO N
        IF (Xknown = X(I)) THEN
                Ycalculated = Y(I)
                EXIT SUB
        END IF
        IF (Xknown < X(I)) THEN EXIT FOR
NEXT I
'
' Linear interpolation for YCalculated
'
Ycalculated = Y(I - 1) + (Y(I) - Y(I - 1)) / (X(I) - X(I - 1)) * (Xknown - X(I - 1))
'
END SUB

'
'   Subroutine for reservoir storage routing
'
SUB Storeroute (FixResOut)
DEFINT I-N
SHARED ResInflow(), IStep, DTSeconds, DEL, Converge, RInflow1, ResEl1, ResEl2, ResVol1, ResVol2, ResOut1, ResOut2, Flag AS STRING
'
' Inflow Vol -Outflow Vol = Change in Storage
'
' FIRST: Decide to increment or decrement reservoir elevation
'        Assume final res el = initial res el
'               ie., no change in volume
DEL = ABS(DEL)
ResEl2 = ResEl1
ICount = 0
'
' Set ResOut2 equal to previous outflow or specified value
'
IF (FixResOut > 0!) THEN
        ResOut2 = FixResOut
        ELSE
        X = ResEl2
        CALL LinInterp(1, X, Y)
        ResOut2 = Y
```

```
END IF
'
'  Change in Volume = Mean Inflow -Mean Outflow
'
        DV = (RInflow1 + ResInflow(IStep)) * DTSeconds / 2! - (ResOut1 + ResOut2) * DTSeconds / 2!
'
'                     Set direction of reservoir level adjustments to converge.
IF (ABS(DV) <= Converge) THEN
        ResVol2 = ResVol1
        EXIT SUB
END IF
IF (DV < -Converge) THEN DEL = -DEL
'  If outflow is not fixed, then route using discharge rating table
'
IF (FixResOut = 0!) THEN
        DO
'   Check for non convergence
                        ICount = ICount + 1
                        IF (ICount > 200) THEN
                                PRINT #1, "Storage routing did not converge in ", ICount, " iterations."
                                PRINT #1, "Check that convergence factor", Converge, " > slope of El vs Vol Curve"
                                PRINT #1, "times Res El increment ", DEL
                                PRINT #1, "Flag=", Flag
                                PRINT #1, "IStep=", IStep
                                PRINT #1, "ResEl1=", ResEl1
                                PRINT #1, "ResEl2=", ResEl2
                                STOP
                        END IF
'
                ResEl2 = ResEl2 + DEL
                X = ResEl2
                CALL LinInterp(2, X, Y)
                ResVol2 = Y
                CALL LinInterp(1, X, Y)
                ResOut2 = Y
                DV = (RInflow1 + ResInflow(IStep)) * DTSeconds / 2! - (ResOut1 + ResOut2) * DTSeconds / 2!
        LOOP UNTIL ABS(ResVol2 - ResVol1 - DV) <= Converge
        EXIT SUB
'
'   If outflow fixed routing using fixed reservoir outflow
'
ELSE
        ResOut2 = FixResOut
        DO
'   Check for non convergence
                        ICount = ICount + 1
                        IF (ICount > 200) THEN
                                PRINT #1, "Storage routing did not converge in ", ICount, " iterations."
                                PRINT #1, "Check that convergence factor", Converge, " > slope of El vs Vol Curve"
                                PRINT #1, "times Res El increment", DEL
                                PRINT #1, "Flag=", Flag
                                PRINT #1, "IStep=", IStep
                                PRINT #1, "ResEl1=", ResEl1
                                PRINT #1, "ResEl2=", ResEl2
                                STOP
                        END IF
'

                ResEl2 = ResEl2 + DEL
                X = ResEl2
                CALL LinInterp(2, X, Y)
                ResVol2 = Y
                DV = (RInflow1 + ResInflow(IStep)) * DTSeconds / 2! - (ResOut1 + ResOut2) * DTSeconds / 2!
        LOOP UNTIL ABS(ResVol2 - ResVol1 - DV) <= Converge
END IF
```

```
EXIT SUB
END SUB
```

RESERVOIR ROUTING PROGRAM
SAMPLE OUTPUT

Number of points on Volume Elevation Curve = 15

| Elevation (m) | Volume (millions m3) |
|---|---|
| 211.84 | 460.02 |
| 213.36 | 540.76 |
| 214.27 | 592.15 |
| 215.19 | 643.53 |
| 216.1 | 694.92 |
| 217.02 | 746.3 |
| 217.93 | 801.36 |
| 218.85 | 856.41 |
| 219.76 | 911.47 |
| 220.68 | 968.97 |
| 221.59 | 1027.7 |
| 222.5 | 1086.42 |
| 223 | 1118.68 |
| 224 | 1183.21 |
| 225.55 | 1283.23 |

Number of points on Elevation Rating Curve = 13

| Elevation (m) | Discharge (m3/s) |
|---|---|
| 201.2 | 151.4 |
| 214.88 | 164 |
| 215.5 | 291.3 |
| 216 | 320.7 |
| 217 | 397.6 |
| 218 | 498.2 |
| 219 | 621 |
| 220 | 758.7 |
| 221 | 912.4 |
| 222 | 1073.9 |
| 223 | 1239 |
| 224 | 1407.4 |
| 225 | 1578.1 |

Volume for inflow hydrograph (millions m3) = 275

Number of points on Inflow Hydrograph and Tide Data= 20

| Step Number | Normalized Inflow | Tide El.(m) |
|---|---|---|
| 1 | .36 | 1.2 |
| 2 | .36 | .19 |
| 3 | .36 | .85 |
| 4 | .47 | -1.76 |
| 5 | 1.04 | 1.2 |
| 6 | 2.39 | .19 |
| 7 | 3.74 | .85 |
| 8 | 5.09 | -1.76 |
| 9 | 6.44 | 1.2 |
| 10 | 6.59 | .19 |
| 11 | 5.31 | .85 |
| 12 | 4.03 | -1.76 |
| 13 | 2.76 | 1.2 |
| 14 | 2.25 | .19 |
| 15 | 1.74 | .85 |
| 16 | 1.23 | -1.76 |
| 17 | .72 | 1.2 |
| 18 | .6 | .19 |
| 19 | .48 | .85 |
| 20 | .36 | -1.76 |

Diversion inflow to Strathcona (m3/s) = 8.5
Snow Line elevation (m) = 500
Critical Reservoir Elevation (Fig 4-2A) (m) = 220.57
Critical Reservoir Elevation (Fig 4-2C) (m) = 220.5
Maximum Strathcona turbine flow (m3/s) = 170
Maximum Lador Outflow (m3/s) = 1898
Local Lador inflow factor = .14
Local JHT inflow factor = .014
Quinsam River flow factor = .09

Number of points on D/S Flooding Data (Fig 4-1) = 8

| Discharge (m3/s) | Tide Elevation (m) |
|---|---|
| -5 | 640 |
| .3 | 640 |
| .6 | 620 |
| .9 | 580 |
| 1.2 | 520 |
| 1.5 | 390 |
| 1.8 | 200 |
| 2.1 | 0 |

Time step for calculations (hrs) = 6
Number of time steps for calculations = 20
Reservoir Elevation increment for routing iteration (m) = .01
Convergence criteria for routing ( m3) = 3000000
This value determines when reservoir volume satisfies the storage routing equation.
This value should be > (Slope of EL vs Volume curve) * (Res El increment)
or convergence may not occur during reservoir storage routing.
Decision 1 trigger inflow for expected flood (m3/s) = 400
Initial conditions data:
Reserovoir inflow (m3) = 170
Reservoir elevation (m) = 220.28
Reservoir outflow (m3/s) = 170
Reservoir Routing Results using Strathcona Dam Local Operating Order

| Time | DivInflow | TotInflow | ResEL | Res OutFlow | Down Stream Local Inflow Lador | JHT | Quinsam | Total Flow Local+Release | Tide Level | Flag |
|---|---|---|---|---|---|---|---|---|---|---|
| Hrs | (m3/s) | (m3/s) | (m) | (m3/s) | (m3/s) | (m3/s) | (m3/s) | (m3/s) | (m) | |
| 0 | 9. | 170. | 220.28 | 170. | | | | | | |
| 6 | 9. | 99. | 220.28 | 170. | 14. | 1. | 9. | 194. | 1.2 | Dec.2,Step 3 |
| 12 | 9. | 99. | 220.28 | 170. | 14. | 1. | 9. | 194. | 0.2 | Dec.2,Step 3 |
| 18 | 9. | 99. | 220.28 | 170. | 14. | 1. | 9. | 194. | 0.9 | Dec.2,Step 3 |
| 24 | 9. | 129. | 220.28 | 170. | 18. | 2. | 12. | 202. | -1.8 | Dec.2,Step 3 |
| 30 | 9. | 286. | 220.28 | 170. | 40. | 4. | 26. | 240. | 1.2 | Dec.2,Step 3 |
| 36 | 9. | 657. | 220.34 | 170. | 92. | 9. | 59. | 330. | 0.2 | Dec.4,Step 3 |
| 42 | 9. | 1,029. | 220.53 | 170. | 144. | 14. | 93. | 421. | 0.9 | Dec.4,Step 3 |
| 48 | 9. | 1,400. | 220.84 | 170. | 196. | 20. | 126. | 512. | -1.8 | Dec.4,Step 3 |
| 54 | 0. | 1,763. | 221.14 | 935. | 248. | 25. | 159. | 1,367. | 1.2 | Step 5 DS Flooding |
| 60 | 0. | 1,804. | 221.38 | 974. | 253. | 25. | 162. | 1,414. | 0.2 | Step 5 DS Flooding |
| 66 | 0. | 1,452. | 221.56 | 974. | 203. | 20. | 131. | 1,328. | 0.9 | Step 8 DS Flooding |
| 72 | 0. | 1,100. | 221.62 | 974. | 154. | 15. | 99. | 1,242. | -1.8 | Step 8 DS Flooding |
| 78 | 0. | 751. | 221.62 | 974. | 105. | 11. | 68. | 1,157. | 1.2 | Step 8 DS Flooding |
| 84 | 0. | 610. | 221.57 | 915. | 85. | 9. | 55. | 1,064. | 0.2 | Step 8 DS Flooding |
| 90 | 0. | 470. | 221.52 | 705. | 66. | 7. | 42. | 820. | 0.9 | Step 8 DS Flooding |
| 96 | 0. | 330. | 221.49 | 495. | 46. | 5. | 30. | 575. | -1.8 | Step 8 |
| 102 | 0. | 190. | 221.47 | 400. | 27. | 3. | 17. | 446. | 1.2 | Dec.2,Step 4 |
| 108 | 0. | 157. | 221.44 | 400. | 22. | 2. | 14. | 438. | 0.2 | Dec.2,Step 4 |
| 114 | 0. | 124. | 221.39 | 400. | 17. | 2. | 11. | 430. | 0.9 | Dec.2,Step 4 |
| 120 | 0. | 91. | 221.33 | 400. | 13. | 1. | 8. | 422. | -1.8 | Dec.2,Step 4 |

Program completed.

APPENDIX III

APPENDIX III

OPERATING ORDER NO. 433,
APRIL 25, 1986 OPERATIONS
SUMMARY OF THE CAMPBELL RIVER
RESERVOIRS AND RIVER DIVERSIONS

ELECTRICAL OPERATIONS

SYSTEM OPERATIONS AND MAINTENANCE DIVISION

OPERATIONS CONTROL DEPARTMENT

25 April 1986


# OPERATING ORDER NO. 433

(NEW ORDER)

(Supersedes O.O. No. 412, Sections 3 to 6)

## OPERATIONS SUMMARY OF THE CAMPBELL RIVER RESERVOIRS AND RIVER DIVERSIONS

DIRECTORY

6.0 DATA COLLECTION PLATFORMS (DCP)

6.1 Elk River DCP
6.2 Wolf River DCP
6.3 Strathcona Dam DCP
6.4 Upper Campbell Lake DCP
6.5 Salmon River DCP
6.6 Quinsam River DCP

7.0 HYDRAULIC DATA

7.1 Strathcona
7.2 Ladore
7.3 John Hart
7.4 Heber Diversion
7.5 Salmon Diversion
7.6 Quinsam Diversion
7.7 Quinsam Storage Dam

8.0 ATTACHMENTS

1. Plan of Campbell River System
2. Plan of Heber Diversion
3. Plan of Salmon Diversion
4. Plan of Quinsam Diversion
5. Operating Procedures During High Inflow Periods (excerpts from HGP Report #H1436, Section 4)
6. Regression Equations for Inflow Forecasting (excerpts from HGP Report #H1436, Section 3)
7. Statistics for the Regression Correlation (excerpts from HGP Report #H1436, Section 2)
8. Graph of Minimum Maintenance Releases

## 1.0 GENERAL

The Production Superintendent of the North Vancouver Island Area or his delegate is directly responsible for prescribing and carrying out spilling operations for the Campbell River System for flood flow releases. The Operations Planning and the Hydrology sections at SCC will assist where appropriate. The general policy for such operations is covered in O.O. No. 410. Additional information may be found in Report #H1436 - "Campbell River - Inflow Forecasting and Operating Guidelines" and in the Emergency Preparedness Plan for Strathcona, Ladore and John Hart dams.

### 1.1 Description of Projects (See Attachment 1)

The Campbell River System consists of a chain of three reservoirs: Upper Campbell Lake, Lower Campbell Lake and John Hart Lake which feed, respectively, the Strathcona, Ladore and John Hart Generating Stations. Three diversions augment the inflows to the two upstream reservoirs. The Heber River Diversion diverts flows into Upper Campbell Lake; the Salmon and the Quinsam Diversions augment inflows into Lower Campbell Lake. These diversions add 414 square km of drainage to the original 1,461 square km of drainage controlled by the reservoir system.

## 2.0 WATER LICENCE REQUIREMENTS

### 2.1 Upper Campbell

2.1.1 Normal maximum reservoir storage elevation to be 727' (221.59 m).

2.1.2 Maximum licensed storage in Upper Campbell Lake is 1,160,000 acre-feet (584,837 cfsd).

2.1.3 Reservoir to be at or near maximum on 1 July.

2.1.4 Observe a 3' per month maximum draw down rate in July, August and September. At the end of this 3 month period the total draw down below the 1 July reservoir elevation should not exceed 9'. Consent from the Comptroller of Water Rights must be obtained prior to drafting Upper Campbell elevation below 716' (218.24 m) before the end of September. This consent should be obtained as early as possible.

### 2.2 Lower Campbell

Maximum licensed storage in Lower Campbell is 251,000 acre-feet (126,547 cfsd).

2.3 <u>Heber Diversion</u> (See Attachment 2)

2.3.1 A flow of 20 cfs (0.57 $M^3/S$) is to be maintained at Heber Falls in Heber Creek below point of diversion (unless total available supply is less).

2.3.2 The above 20 cfs (0.57 $M^3/S$) reference flow is supplanted by a corresponding reference flow of 22 cfs (0.62 $M^3/S$) minimum at the downstream B. C. Forest Products Ltd. bridge gauge. This gauge is approximately 6 km downstream of the dam. A gauge reading of 2.05' (0.62 m) is necessary to provide 22 cfs (0.62 $M^3/S$).

2.4 <u>Salmon Diversion</u> (See Attachment 3)

2.4.1 At the Water Survey of Canada Gauge 8HD7, which is about 10 km downstream of the Salmon Diversion Dam and 3 km above the confluence of the Salmon and Memekay Rivers fisheries flow is to be as follows:

Aug 20 to Nov 15 - 100 cfs (2.8 $M^3/S$) minimum
Nov 16 to Aug 19 - 83 cfs (2.4 $M^3/S$) minimum.

2.4.2 The minimum fisheries flow water release is 5 cfs (0.15 $M^3/S$) at all times.

<u>NOTE</u>: The fisheries flow at the diversion dam when added to the Paterson Creek flow must meet the required flow at the 8HD7 gauge.

2.5 <u>Quinsam Diversion</u> (See Attachment 4)

2.5.1 The rate of diversion under this licence may be restricted by the Water Comptroller at any time in order to provide for fisheries maintenance.

2.5.2 Required flows:

| | |
|---|---|
| Feb 1 to May 31 and Sep 1 to Nov 15 | 60 cfs (1.7 $M^3/S$) immediately below Lower Quinsam Lake |
| All year round | 10 cfs (0.3 $M^3/S$) minimum in Quinsam River immediately above Middle Quinsam Lake. This flow is normally read on the Argonaut Bridge gauge. |

2.5.3 Water Level

In Wokas Lake/Upper Quinsam Lake a minimum of 2' (0.6 m) of storage is to be maintained above elevation 1186.5' (361.65 m) for use in maintaining flows required in 2.5.2 above, if natural inflow is less than required outflow.

## 3.0 FLOOD RELEASES

Operation during floods is the responsibility of the North Vancouver Island Production Superintendent or his delegate.

The following normal maximum operating elevations, plant operations and flood routing are guidelines only. Alternate operations mutually accepted by the field staff and System Control Centre may be necessary to conform with the prevailing circumstances during the flood storms. In case of conditions which may cause severe flooding, the procedures in the Emergency Preparedness plans may be applicable.

### 3.1 Upper Campbell

3.1.1 The normal maximum operating elevations for Upper Campbell are:

| | |
|---|---|
| Oct 1 - Feb 28 | 721.8' to 725.6' (220 m to 221.16 m) |
| Mar 1 - Sep 30 | 727.0' (221.6 m) |

The winter maximum operating elevation is dependent on the snowline elevation. Refer to attachment 5, sheet 8 for details.

3.1.2 The design maximum flood level for Upper Campbell Reservoir is 737.0' (224.64 m).

3.1.3 During periods of high inflow, the Strathcona Generating Units should be put on full load before the elevation encroaches on the normal maximum operating elevation. This action is taken to generate some energy from the inflow which may otherwise have to be spilled when the elevation does exceed the normal maximum operating elevation.

3.1.4 Flood damage upstream of the Strathcona Dam has been observed at several campsites when lake level is 730' (222.5 m) or higher.

3.1.5 Refer to Attachments 5, 6 and 7 for excerpts from Report #H1436 detailing the flood routing procedures for the October to February period.

3.2 Lower Campbell

3.2.1 The normal maximum operating elevations for Lower Campbell for minimizing downstream flooding are:

| | |
|---|---|
| Dec 15 to Feb 15 | 583.0' (177.70 m) |
| Mar 1 | 583.5' (177.85 m) |
| Mar 15 | 584.0' (178.00 m) |
| Apr 1 | 584.5' (178.16 m) |
| Apr 15 to Oct 15 | 585.0' (178.30 m) |
| Nov 1 | 584.5' (178.16 m) |
| Nov 15 | 584.0' (178.00 m) |
| Dec 1 | 583.5' (177.85 m) |

Linear interpolation should be used to obtain the normal maximum operating elevations for dates not included in the above.

3.2.2 The elevation of Lower Campbell shall not, under any circumstances, be allowed to exceed 587.0' (178.92 m) under controlled operations. Only during extreme flood conditions should Lower Campbell be allowed to rise up to elevation 587.0' (178.92 m). Such high elevations should be for short durations and the rise should be carefully controlled. When the Lower Campbell Lake rises to 587.0' (178.92 m) the Loveland and Big Slide Saddle Dams should be kept under surveillance. The Civil Inspection Section from the System Operations and Maintenance Division should be notified in order that inspections for seepage or settlement can be made.

3.2.3 The Ladore Generating Units should be operated at full load in advance of operating the Strathcona Units at full load since the Ladore Units at full load may, under moderate inflow conditions, be sufficient to control water levels.

3.3 John Hart

3.3.1 The normal operating range for the John Hart Headpond is between 456' (138.99 m) and 458' (139.60 m). However, under abnormal conditions a maximum forebay elevation with spill gates closed of 459' (139.90 m) is tolerable. As of October 1985, due to dam safety considerations, the forebay level is being operated between 455.5' and 456.5' (138.8 m to 139.1 m).

3.3.2 John Hart forebay may be used for minor re-regulation (hourly) with maximum elevation not to exceed 460.75' (140.43 m).

3.3.3 Flood damages downstream of John Hart Dam may involve various low lying areas. Listed below are two of the more sensitive areas. Maximum safe discharge at John Hart is dependent on the prevailing wind and tides but is considered to be nominally 16,000 cfs (453 $M^3/S$) average. During extremely high tides, even full turbine discharge alone may cause flooding.

3.3.3.1 Egan's Property - located downstream of the confluence of the Quinsam River and 580 m upstream of the Highway Bridge. Stage of Campbell River there should not exceed 16' (4.88 m) geodetic which corresponds to 20,000 cfs (560 $M^3/S$). This flow is the combined Quinsam River flow, John Hart turbines and spillway releases. The stage there is not influenced by the tide.

3.3.3.2 Campbell River Lodge - located 518 m downstream of the Highway Bridge. Stage of Campbell River there should not exceed 6.9' (2.1 m) geodetic. The gauge height there is determined by the combined Quinsam River flow, John Hart turbine and spillway and is influenced by the tide. Refer to Sheet 7 of Attachment 5 for an estimate of the stage given the flow and the tide.

## 3.4 Heber Diversion

This diversion provides a maximum of 300 cfs (8.5 $M^3/S$) of additional inflow into Crest Lake which then flows into Upper Campbell. There is no flood control requirement for the diversion dam, however, for habitat protection in the Elk River Valley, the diversion is to be turned off whenever the inflow from the Elk River into Upper Campbell Lake is greater than 1540 cfs (43.6 $M^3/S$) and has an upward trend. This corresponds to a total inflow into Upper Campbell Lake of approximately 15,000 cfs (425 $M^3/S$) average over a 4 to 6 hour period. The diversion should also be turned off when there is danger of flooding at Campbellton due to high spills at the Strathcona Dam.

3.5 Salmon Diversion

This diversion provides a maximum of 1500 cfs (43 $M^3/S$) of additional inflow into Lower Campbell. There is no flood control requirement for the diversion dam, however, the diversion should be turned off when there is danger of flooding at Campbellton due to high spills at the Ladore Dam and John Hart Dam.

3.6 Quinsam Diversion

This diversion provides a maximum of 300 cfs (8.5 $M^3/S$) of additional inflow into Lower Campbell. There is no flood control requirement for the diversion dam. As the Quinsam River flows naturally back into the Campbell River above Campbellton, turning it off to assist in flood control at Campbellton is not considered effective, however there may be some benefit due to the time delay to charge up the Quinsam River System.

## 4.0 SPILLWAY OPERATION

Spillway tests were conducted in connection with the dam safety review in 1982.

4.1 Strathcona Dam

4.1.1 Sluice gates - revised elevation vs discharge curves were derived from the test results. The revised curves show a lower discharge capacity than the superseded curves. There is no restriction on the use of any or all of the sluice gates.

4.1.2 Low level outlet - operation of the L.L.O. was tested and there is no restriction on the use of the L.L.O.

4.2 Ladore Dam

4.2.1 Sluice gates - revised elevation vs discharge curves were derived from the test results. The revised curves show a higher discharge capacity than the superseded curves. There is no restriction on the use of any or all of the sluice gates.

4.2.2 Low level outlet - operation of the L.L.O. was not tested during the 1982 tests. It is not required for passing the PMF and is considered out of service.

4.3 John Hart Dam

4.3.1 Sluice gates - revised elevation vs discharge curves were derived from the test results. The revised curves show a higher discharge capacity than the superseded curves. There is no restriction on the use of any or all of the sluice gates.

4.4 Debris Booms

Debris loads against all booms should be noted prior to any major flood, and checked regularly during floods.

5.0 FISHERIES REQUIREMENTS

5.1 John Hart

5.1.1 As a result of their inspections the fisheries have suggested a minimum of 1000 cfs (28.3 $M^3/S$) or 29 MW at John Hart Generating Station. Reference: Planning Division recommendations 2 December, 1963.

The normal operating minimum is 1200 cfs (34 $M^3/S$). (Discharges less than 1000 cfs (28.3 $M^3/S$) would also create problems for the Crown Forest Mill pumphouse intake.)

5.1.2 The normal plant operating minimum is 52 MW or 1800 cfs (51 $M^3/S$). The reduction from 52 MW to 29 MW should be done gradually over a 80 minute period to avoid stranding juvenile fish in isolated pools. The subsequent increase back from 29 MW to 52 MW should also be done gradually over a 80 minute period to avoid flushing juvenile fish downstream.

5.2 Heber Diversion

5.2.1 Fisheries requirements are as stipulated by the Water Licence (refer to Section 2.0).

5.2.2 Operating guidelines to meet fisheries requirements are:

5.2.2.1 Following Decrease in Runoff

At the point that Crest Lake water level falls, under full diversion supply, to approximately 1087' (331.32 m), open the fishwater spillgate to 0.8' (24 cm) setting. Maintain this setting until runoff supply again increases.

5.2.2.2 Following Increase in Runoff

When Crest Lake water level reaches approximately 1086.5' (321.17 m), close the fishwater spillgate. Do not reopen until a reduction in runoff again necessitates reopening of the bypass to maintain the minimum 22 cfs (0.63 $M^3/S$) flow at the B. C. Forest Products Ltd. Bridge.

5.2.2.3 General

5.2.2.3.1 Some degree of judgement will be required to determine the frequency of adjustment of fish water releases due to the large uncontrolled runoff area between the dam and the gauging site.

5.2.2.3.2 The proposed setting of spillgate setting of 0.8' (24 cm) will waste only a minor amount of water. Experience will determine this wastage and the possible justification for more frequent regulation.

5.2.2.3.3 Normally, these operating guidelines will apply only during the mid-summer dry spell period.

## 6.0 DATA COLLECTION PLATFORMS (DCPs)

Information from DCPs are received at the System Control Centre hourly or half-hourly. The information may be utilized to provide advance indication of increasing and decreasing inflows to the basins. The accuracy of the forecast inflow for the basins may also be improved through the use of the DCP information. Field personnel access the DCP information from a terminal in the JHT Control Room.

### 6.1 Elk River DCP (ELK)

Located on Elk River approximately one-half way between Crest Lake and Upper Campbell Lake. It provides real time information on the air temperature, precipitation, river stage and corresponding river flow.

### 6.2 Wolf River DCP (WOL)

Located on the Upper Wolf River. It provides real time information on the air temperature, precipitation and snow water equivalent.

6.3 Strathcona Dam DCP (SCA)

Located near the logging bridge on Upper Campbell Lake. It provides real time information on the air temperature and precipitation.

6.4 Upper Campbell Lake DCP (UCL)

Located at Strathcona Dam. It provides real time Upper Campbell Lake elevations.

6.5 Salmon River DCP (WSC No. 8HD15) (SAM)

Located above the Salmon River Diversion Dam. It provides real time information on the air temperature, precipitation, river stage and corresponding river flow.

6.6 Quinsam River DCP (WSC #8HD5) (QSM)

Located above confluence with Campbell River. It provides real time information on the air temperature, precipitation, river stage and corresponding river flow.

## 7.0 HYDRAULIC DATA

### 7.1 Strathcona

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 740.00 | 225.55 | Dam crest (2,680 m long). |
| 737.00 | 224.64 | Maximum allowable elevation permitted by the structures. |
| 729.07 | 222.22 | Top of flash boards on closed spill gates. |
| 728.00 | 221.90 | Maximum surcharged level. |
| 727.00 | 221.60 | Normal maximum operating elevation (1 March - 30 September). |
| 725.92 | 221.13 | Top of three 30' w x 21' h vertical closed sluice gates. |
| 721.80 | 220.00 | Maximum initial elevation for 1 October - 1 March to route the PMF without exceeding 224.64 m. |
| 704.90 | 214.85 | Sill elevation of spillway gates. |
| 702.00 | 214.00 | Upper Campbell separates into two lakes. |
| 700.00 | 213.36 | Insufficient head to remote start G1/G2. |

| | | |
|---|---|---|
| 655.00 | 199.64 | Bottom of live storage. |
| 630.00 | 192.02 | Sill elevation of 22' diameter common intake for HBV, G1 and G2. |
| 580.00 | 176.78 | Centre line of 8' diameter Howell Bunger valve. |

7.2 Ladore

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 589.00 | 179.53 | Dam crest (500 m long). |
| 587.00 | 178.92 | Maximum elevation under the PMF. |
| 585.00 | 178.31 | Top of flash boards on spill gates. Normal maximum operating elevation (summer). |
| 584.50 | 178.16 | Top of three 30' w x 30.5' h vertical sluice gates. |
| 583.00 | 177.70 | Normal maximum operating elevation (winter). |
| 572.00 | 174.35 | SCA tailwater weir separates SCA tailwater from Lower Campbell. |
| 554.00 | 168.86 | Sill elevation of three spillway gates. |
| 535.00 | 163.07 | Bottom of live storage. |
| 509.00 | 155.14 | Centre line of 8' diamater Howell Bunger valve. |
| 494.00 | 150.57 | Centre line of 20' diameter common intake for HCV, G1 and G2. |

7.3 John Hart

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 465.00 | 141.73 | Dam crest (1,040 m long). |
| 459.50 | 140.40 | Top of three 30' w x 30.5' h vertical sluice gates. Normal maximum operating elevation. |
| 459.00 | 139.90 | Maximum elevation under the PMF. |
| 456.50 | 139.14 | Temporary maximum operating elevation since Oct/85 due to dam safety. |

| | | |
|---|---|---|
| 455.00 | 138.68 | Maximum draw down without derating unit capacity. |
| 455.00 | 138.68 | Minimum elevation for operation of District of Campbell River pump station. |
| 438.00 | 133.50 | Centre line of three 12' diameter intakes. |
| 429.00 | 130.76 | Sill elevation of three spillway gates. |

7.4 Heber Diversion

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 1165.00 | 355.09 | Dam crest (630 m long). |
| 1164.00 | 354.79 | Maximum elevation permitted under the PMF. |
| 1160.00 | 353.57 | Normal maximum operating elevation. |
| 1155.00 | 352.04 | Elevation of 150 m long free crest weir. |
| 1145.00 | 349.00 | Centre line of 6' diameter diversion intake. |
| 1142.00 | 348.08 | Centre line of 4' diameter sluice intake for fish water compensation. |

7.5 Salmon Diversion

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 749.00 | 228.30 | Dam crest (190 m long). |
| 747.70 | 227.90 | Maximum elevation permitted under the PMF. |
| 735.50 | 224.20 | Elevation of 225 m free crest weir. |
| 734.00 | 223.72 | Normal maximum operating elevation. |
| 725.80 | 221.22 | Sill elevation of 22' w x 13' h diversion canal intake radial gates. |
| 719.00 | 219.15 | Sill elevation of 10.5' w x 8.5' h sluice gate for fish water compensation. |

7.6 Quinsam Diversion

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 1015.00 | 309.37 | Dam crest (510 m long). |
| 1011.50 | 308.31 | Maximum elevation permitted under the PMF. |
| 1006.00 | 306.63 | Normal maximum operating elevation. |
| 1005.00 | 306.32 | Elevation of 225 m long free crest weir. |
| 999.00 | 304.50 | Sill elevation of 5' w x 9.75' h diversion canal intake. |
| 974.50 | 297.03 | Centre line of 3' diameter sluice intake for fish water compensation. |

7.7 Quinsam Storage Dam

| Elevation (Feet) | Elevation (Metres) | Comments |
|---|---|---|
| 1,208.00 | 368.20 | Dam Crest (225 m long). |
| 1,204.00 | 366.98 | Maximum elevation permitted under the PMF. |
| 1,198.00 | 365.15 | Normal maximum operating elevation. |
| 1,196.00 | 364.54 | Elevation of 160 m long free crest weir. |
| 1,182.50 | 360.43 | Sill elevation of 8' w x 12' h sluice gate. |

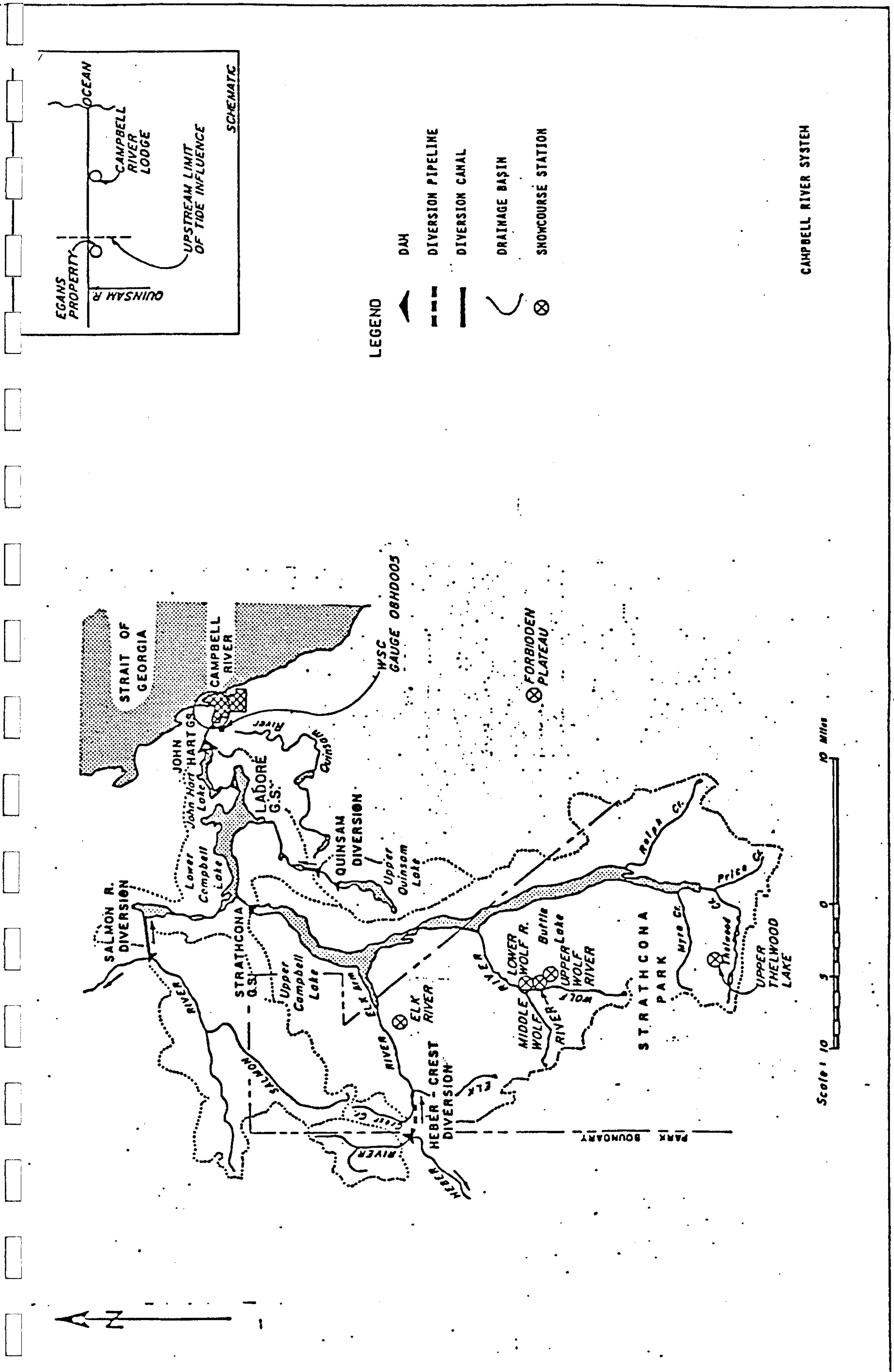
8.0 ATTACHMENTS

1. Plan of Campbell River System
2. Plan of Heber Diversion
3. Plan of Salmon Diversion
4. Plan of Quinsam Diversion

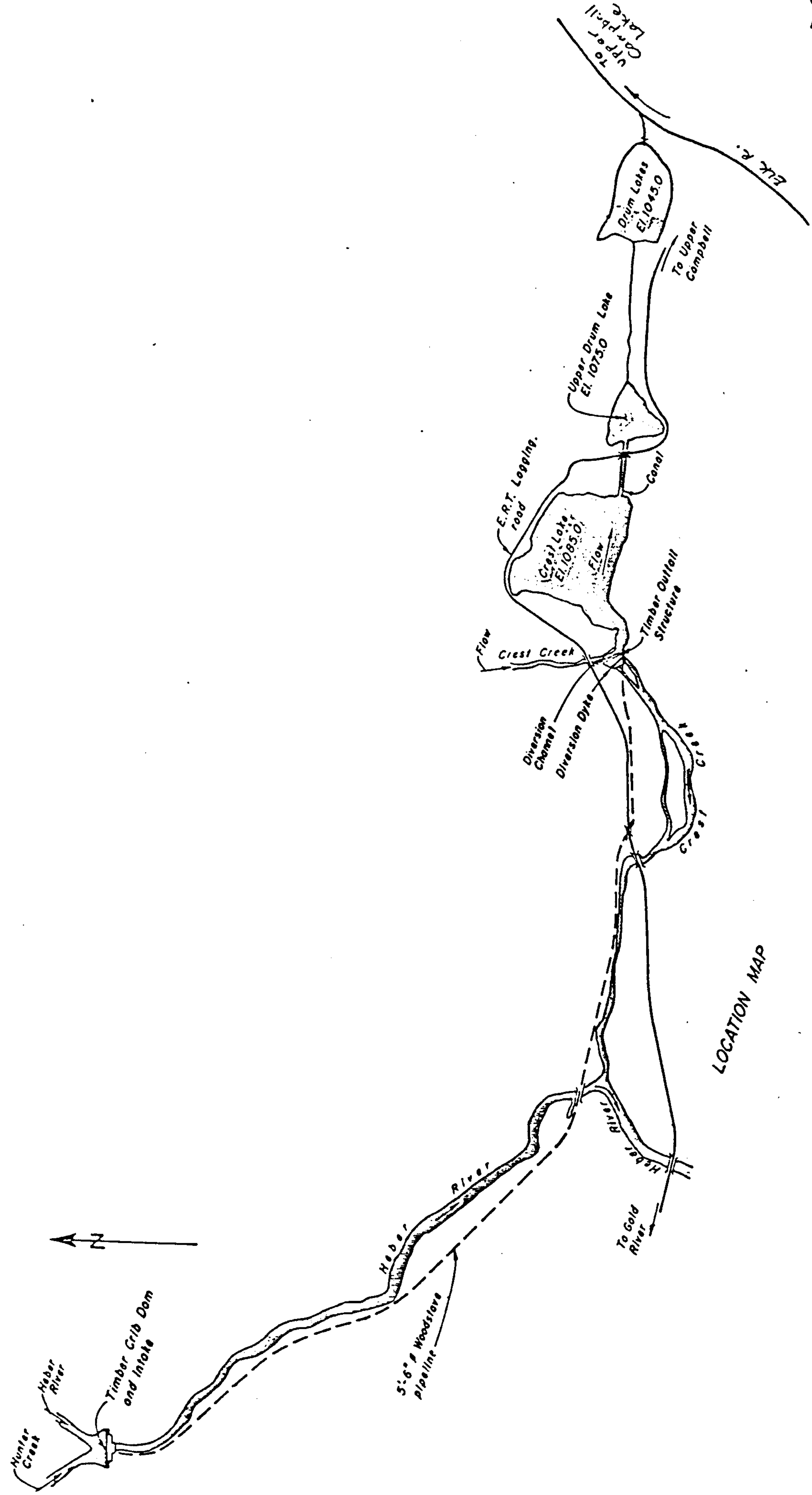
5. Operating Procedures During High Inflow Periods (excerpts from HGP Report #H1436, Section 4)
6. Regression Equations for Inflow Forecasting (excerpts from HGP Report #H1436, Section 3)
7. Statistics for the Regression Correlation (excepts from HGP Report #H1436, Section 2)
8. Graph of Minimum Maintenance Releases

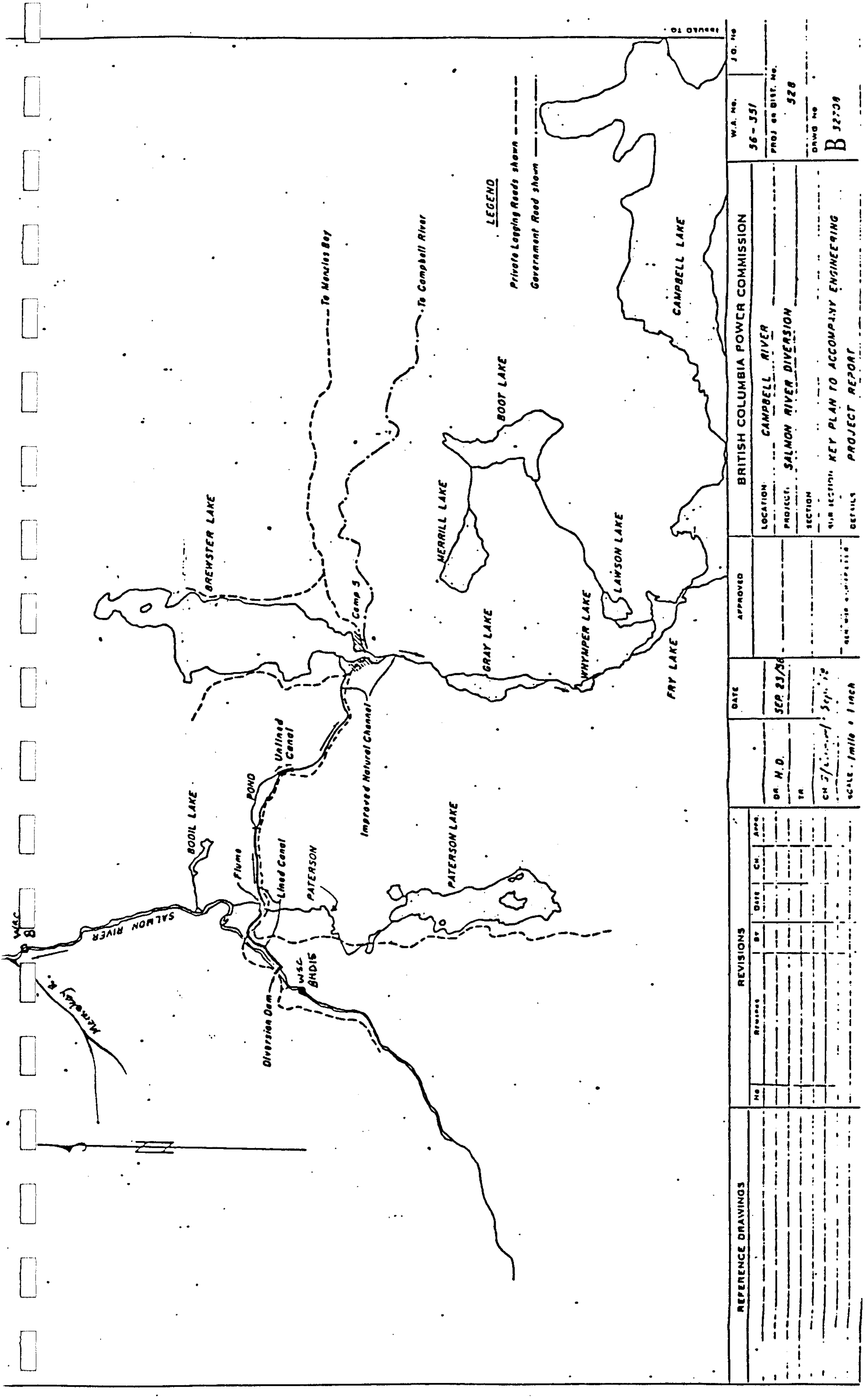
W. N. TIVY, MANAGER
OPERATIONS CONTROL DEPARTMENT

QR63

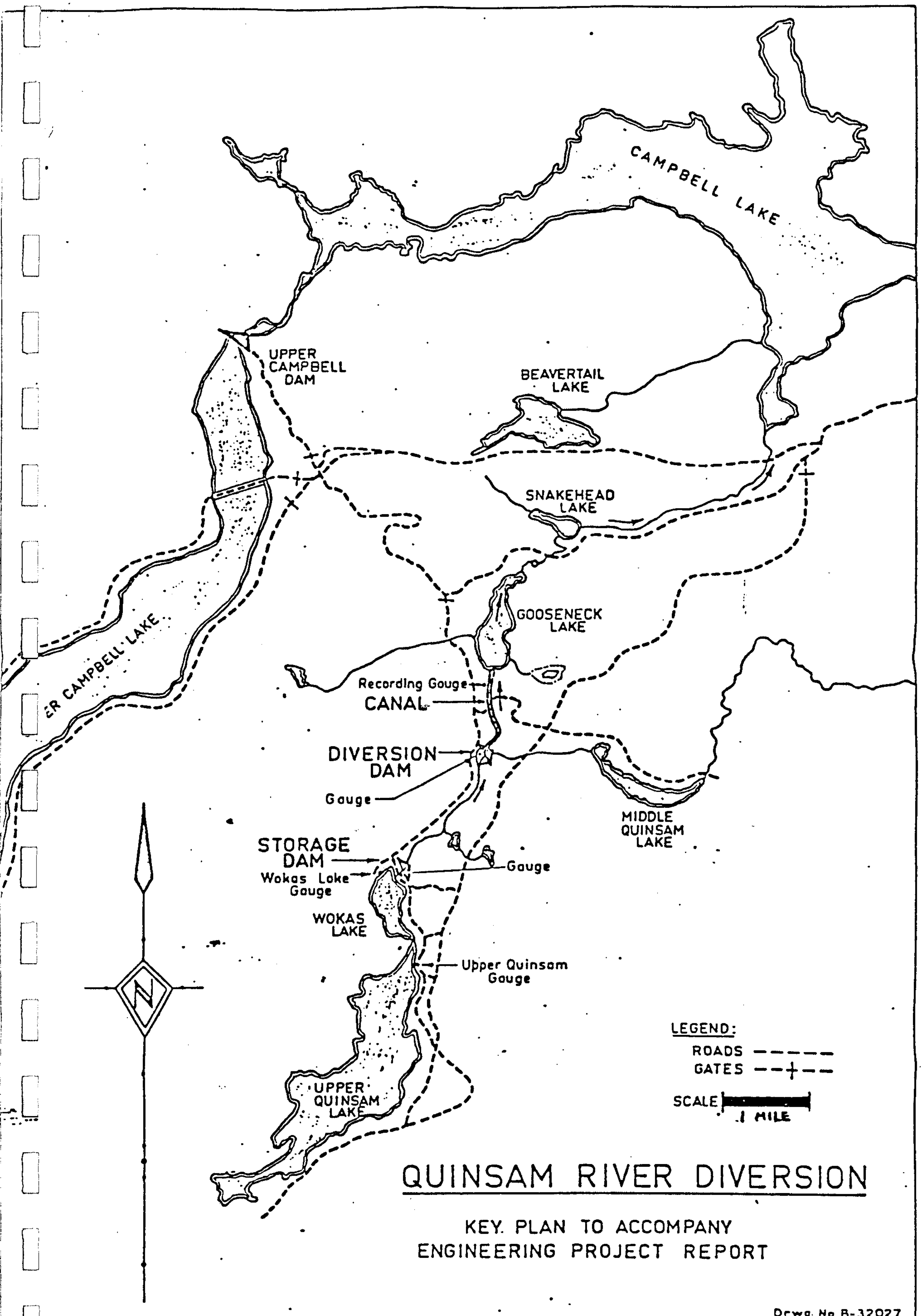

CAMPBELL RIVER SYSTEM
LEGEND
DAM
DIVERSION PIPELINE
DIVERSION CANAL
DRAINAGE BASIN
SNOWCOURSE STATION
SCHEMATIC
OCEAN
CAMPBELL RIVER LODGE
UPSTREAM LIMIT OF TIDE INFLUENCE
EGANS PROPERTY
QUINSAM R.
STRAIT OF GEORGIA
CAMPBELL RIVER
JOHN HART G.S.
John Hart Lake
LADORE G.S.
Quinsam River
WSC GAUGE
FORBIDDEN PLATEAU
QUINSAM DIVERSION
Upper Quinsam Lake
Lower Campbell Lake
SALMON R. DIVERSION
STRATHCONA G.S.
Upper Campbell Lake
Elk Arm
ELK RIVER
LOWER WOLF R.
Buttle Lake
UPPER WOLF RIVER
MIDDLE WOLF RIVER
WOLF RIVER
Ralph Cr.
Price Cr.
Myra Cr.
Thelwood Cr.
UPPER THELWOOD LAKE
STRATHCONA PARK
HEBER - CREST DIVERSION
PARK BOUNDARY
SALMON RIVER
HEBER RIVER
Scale 0 5 10 Miles
N

# HEBER DIVERSION




WAC 8
Memekay R.
SALMON RIVER
BOOIL LAKE
Flume
POND
Diversion Dam
Lined Canal
Unlined Canal
WSC 8HD15
PATERSON
BREWSTER LAKE
Improved Natural Channel
Camp 5
To Menzies Bay
To Campbell River
PATERSON LAKE
MERRILL LAKE
GRAY LAKE
BOOT LAKE
LEGEND
Private Logging Roads shown
Government Road shown
WHYMPER LAKE
LAWSON LAKE
FRY LAKE
CAMPBELL LAKE
ISSUED TO
REFERENCE DRAWINGS
REVISIONS
DATE
APPROVED
BRITISH COLUMBIA POWER COMMISSION
LOCATION CAMPBELL RIVER
PROJECT SALMON RIVER DIVERSION
SECTION
SUB SECTION KEY PLAN TO ACCOMPANY ENGINEERING
DETAILS PROJECT REPORT
DR. H.D.
SEP. 23/56
TR.
SCALE. 1 mile = 1 inch
W.A. No. 56-351
J.O. No.
PROJ or DIST. No. 528
DRWG No B 32709

O.O. No. 433
Attachment 4




| Des. N.C.A. | Date | Approvals | | Date | BRITISH COLUMBIA POWER COMMISSION | W.A.No. 56-355 | Cross Index |
|---|---|---|---|---|---|---|---|
| Dr. G.E.C. | Apr./58 | Submitted | | | Campbell River | | |
| Ch: | | Recommend. | | | Quinsam River Diversion | Proj. or Dist. No. 530 | |
| Des. Ch: | | | | | Key Plan To Accompany | | |
| Scale: | | Appr. | | Aug 1958 | Engineering Project Report | Drwg. No. B.32027 | |

## 4.3 REVISED OPERATING PROCEDURES

The operating procedures presented in this section have been designed to guide operation personnel during high flow periods. Key factors in the procedure are:

1. The collection of real-time data from the Elk River hydrometeorological station.

2. The prediction of inflows to Upper Campbell Lake by regression equations using real-time data.

3. Calculating system outflows based on the potential overtopping of Strathcona Dam and on optional flood routing downstream of John Hart Dam.

4. Monitoring of downstream conditions.

The following steps should be taken to ensure dam safety in an extreme flood and to provide optional flood control downstream of John Hart Dam. Fig. 4-3 is a logic diagram of the steps outlined below. The effective period for these procedures will be roughly October through February when the flood potential is highest.

Step 1: Read/obtain data on:

1. Upper Campbell level.

2. Lower Campbell level.

3. Elk River level, discharge, precipitation and temperature.

4. Tide height for Campbell River.

5. River stage at the Campbell River Lodge.

6. Upper Campbell basin snowline.

7. Inflows to Upper Campbell Lake.

8. Quinsam River flow from gauge 08HD005.

9. Weather data from Campbell River and Comox Airports including storm warnings.

Step 2: Use the Elk River hydrometeorological data to forecast the inflow to Upper Campbell Lake for the next 12 hours and for the next 24 hours using the regression equations from Section 3.4. If the Elk River DCP data is unavailable use the less preferred Strathcona DCP data, as explained in Section 2.3.

Decision 1: Is either the present or forecast inflow to Upper Campbell Lake greater than 400 $m^3/s$?

Decision 2: If inflows to Upper Campbell Lake are less than 400 $m^3/s$ then check if the Upper Campbell Lake level is above the safe level as indicated in Fig. 4-2C. For example, if the Upper Campbell basin snowline is at El. 220 then an initial reservoir of 220.0 m or lower is required on Upper Campbell Lake to pass the PMF.

Step 3: If Upper Campbell Lake is at or below the safe level then continue normal operation. Return to Step 1 each day.

Decision 3: If inflows to Upper Campbell Lake are greater than 400 $m^3/s$ then check on Fig. 4-2A if flood routing must be carried out to ensure the safety of Strathcona Dam. If optional downstream flood control (Decision 4) has not been initiated then enter Fig. 4-2A with the present level of Upper Campbell Lake, otherwise use the level of Upper Campbell Lake when downstream flood control was initiated. For example, if downstream flood control was initiated when Upper Campbell Lake was at El. 219.6 then flood routing to ensure the safety of Strathcona Dam is not required until Upper Campbell Lake rises to 220.5 m. The initial reservoir level would be 219.6 m, the level of Strathcona when downstream flood control was initiated.

Decision 4: If flood routing is not required to maintain dam safety, optional downstream flood control may be selected.

Optional downstream flood control once started cannot be discontinued until either:

1. Flood routing is started (as per Fig. 4-2A).

2. Strathcona levels are below the safe levels indicated by Fig. 4-2C.

<u>Step 4</u>: If downstream flood control is selected then perform the following:

1. Shut off diversions.

2. Release 400 $m^3/s$ (daily averages) from Upper Campbell Lake and record the reservoir level when releases were initiated. The river stage at the Campbell River Lodge may be limited to 2.10 m by controlling outflows from John Hart Dam. Estimate the John Hart outflow by deducting the Quinsam River flow from the estimated bankful capacity using Fig. 4-1 given a stage of 2.10 m. The tide height should be the maximum height anticipated in the next 3 hours.

3. After 3 hours go to Step 1.

<u>Decision 5</u>: If flood routing must be carried out (Decision 3) check if the inflows to Upper Campbell Lake are in recession.

<u>Step 5</u>: If the inflows are not in recession then do the following:

1. Shut off the diversion if they are still open.

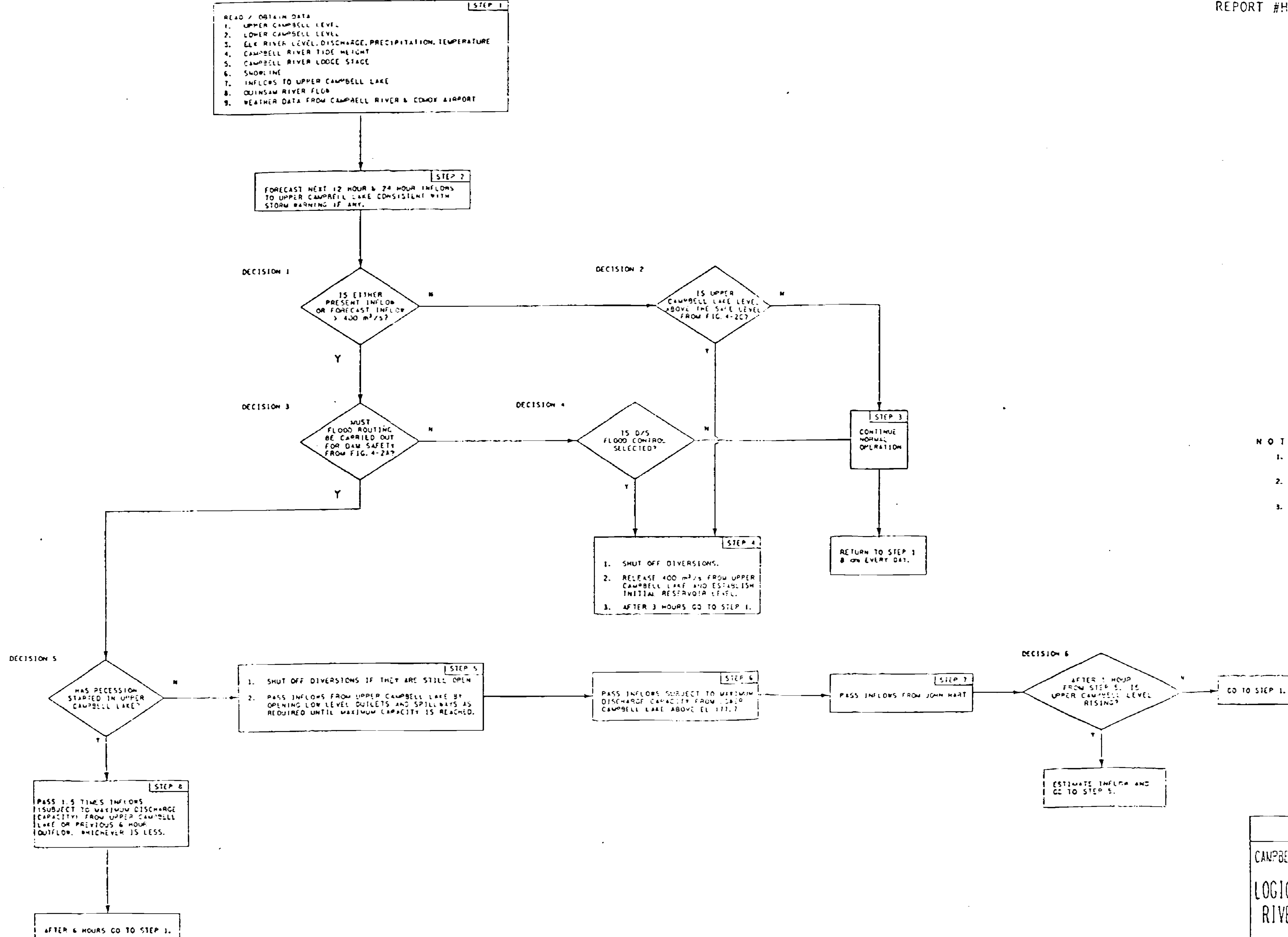
2. Pass inflows to Upper Campbell Lake by opening the spillway gates and low level outlet until maximum capacity is reached.

<u>Step 6</u>: Pass inflows to Lower Campbell Lake subject to the maximum discharge capacity of the spillway above El. 177.7.

<u>Step 7</u>: Pass inflows to John Hart Lake.

Decision 6: Check if Upper Campbell Lake is rising 1 hour after performing Step 5. If it is rising, estimate the inflow and go to Step 5. If it is not rising, go to Step 1.

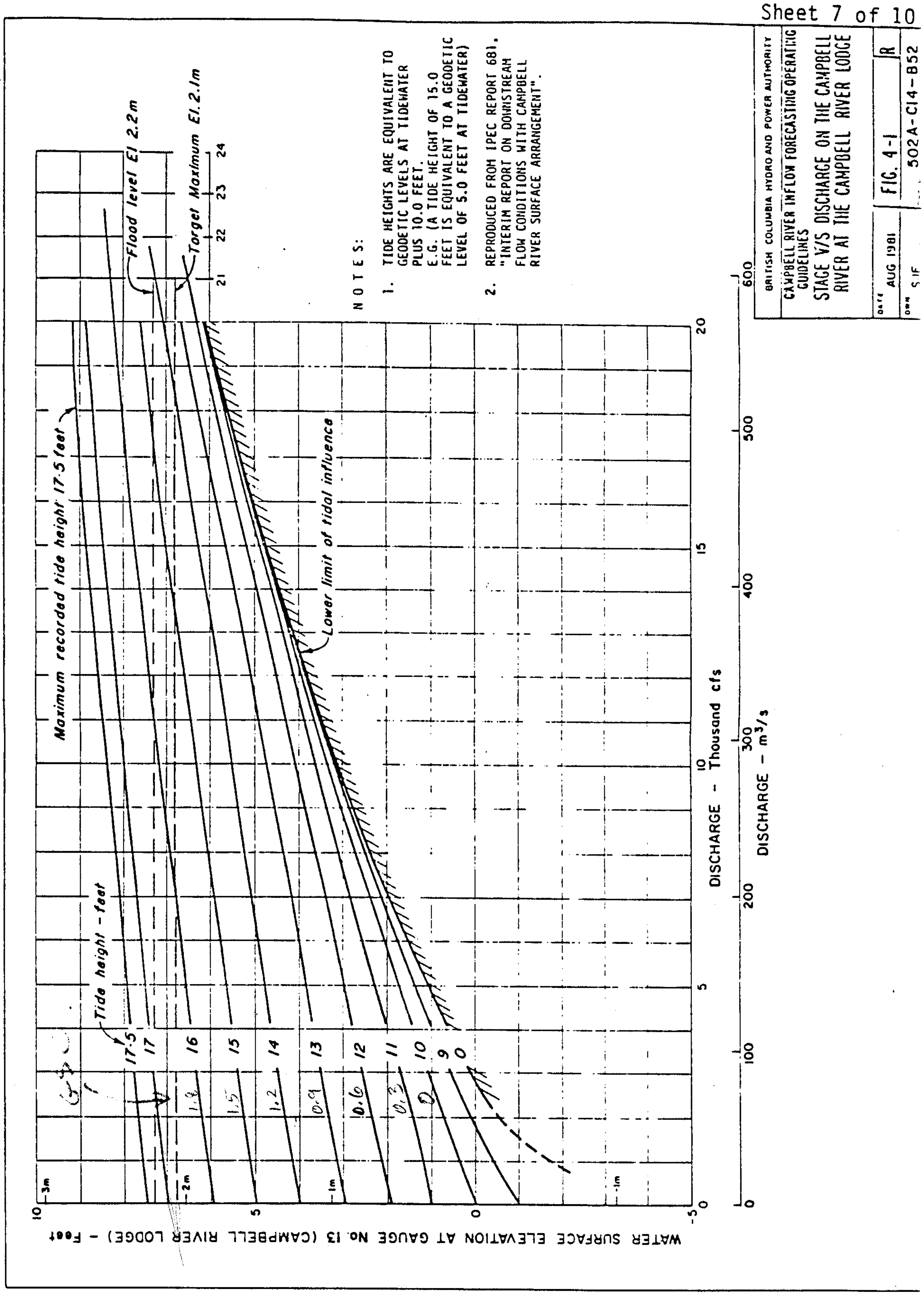
Step 8: If the inflows to Upper Campbell Lake are in recession (Decision 5) then pass 1.5 times inflows or the previous 6-hour outflow whichever is less (subject to the maximum discharge capacity). After 6 hours go to Step 1.




NOTES:

1. THIS FLOW CHART SHOULD BE USED ALONG WITH FIGURES 4-2A AND 4-2C.
2. THE FLOW CHART APPLIES TO THE PERIOD OCTOBER TO FEBRUARY, I.E. FLOOD SEASON.
3. ONCE THE FLOOD CONTROL OPTION IS SELECTED, IT MUST BE CONTINUED UNTIL THE UPPER CAMPBELL LEVEL IS AT OR BELOW THE SAFE LEVEL ON FIG. 4-2C.

| |
|---|
| BRITISH COLUMBIA HYDRO AND POWER AUTHORITY |
| CAMPBELL RIVER INFLOW FORECASTING & OPERATING GUIDELIN |
| LOGIC DIAGRAM FOR THE REVISED CAMPBELL RIVER SYSTEM OPERATING PROCEDURES |
| DATE MAY 1985 — FIG. 4-3 |
| DWN. MWB — DWG. No. 502A-C14-051 |


Maximum recorded tide height 17.5 feet
Flood level El 2.2 m
Target Maximum El. 2.1 m
Lower limit of tidal influence
Tide height - feet
17.5
17
16
15
14
13
12
11
10
9
0
NOTES:
1. TIDE HEIGHTS ARE EQUIVALENT TO GEODETIC LEVELS AT TIDEWATER PLUS 10.0 FEET. E.G. (A TIDE HEIGHT OF 15.0 FEET IS EQUIVALENT TO A GEODETIC LEVEL OF 5.0 FEET AT TIDEWATER)
2. REPRODUCED FROM IPEC REPORT 681, "INTERIM REPORT ON DOWNSTREAM FLOW CONDITIONS WITH CAMPBELL RIVER SURFACE ARRANGEMENT".
DISCHARGE - Thousand cfs
DISCHARGE - m³/s
WATER SURFACE ELEVATION AT GAUGE No. 13 (CAMPBELL RIVER LODGE) - Feet
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
CAMPBELL RIVER INFLOW FORECASTING OPERATING GUIDELINES
STAGE V/S DISCHARGE ON THE CAMPBELL RIVER AT THE CAMPBELL RIVER LODGE
AUG 1981
FIG. 4-1
R
502A-C14-B52

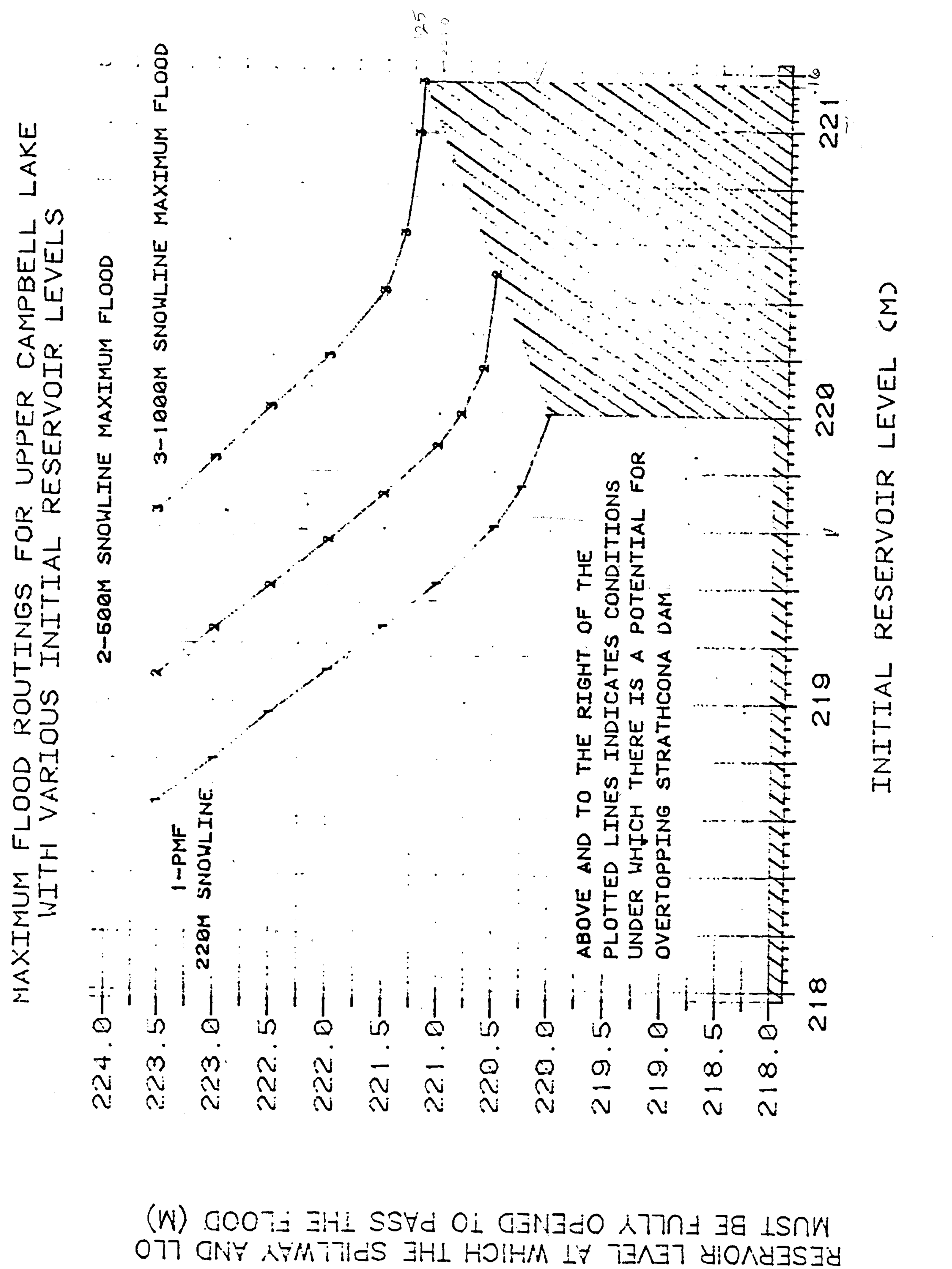

MAXIMUM FLOOD ROUTINGS FOR UPPER CAMPBELL LAKE
WITH VARIOUS INITIAL RESERVOIR LEVELS
1-PMF
220M SNOWLINE
2-500M SNOWLINE MAXIMUM FLOOD
3-1000M SNOWLINE MAXIMUM FLOOD
ABOVE AND TO THE RIGHT OF THE
PLOTTED LINES INDICATES CONDITIONS
UNDER WHICH THERE IS A POTENTIAL FOR
OVERTOPPING STRATHCONA DAM
224.0
223.5
223.0
222.5
222.0
221.5
221.0
220.5
220.0
219.5
219.0
218.5
218.0
218
219
220
221
INITIAL RESERVOIR LEVEL (M)
RESERVOIR LEVEL AT WHICH THE SPILLWAY AND LLO
MUST BE FULLY OPENED TO PASS THE FLOOD (M)

FIGURE 4-2 A

SNOW WATER EQUIVALENTS FOR MAXIMUM FLOOD SIMULATIONS

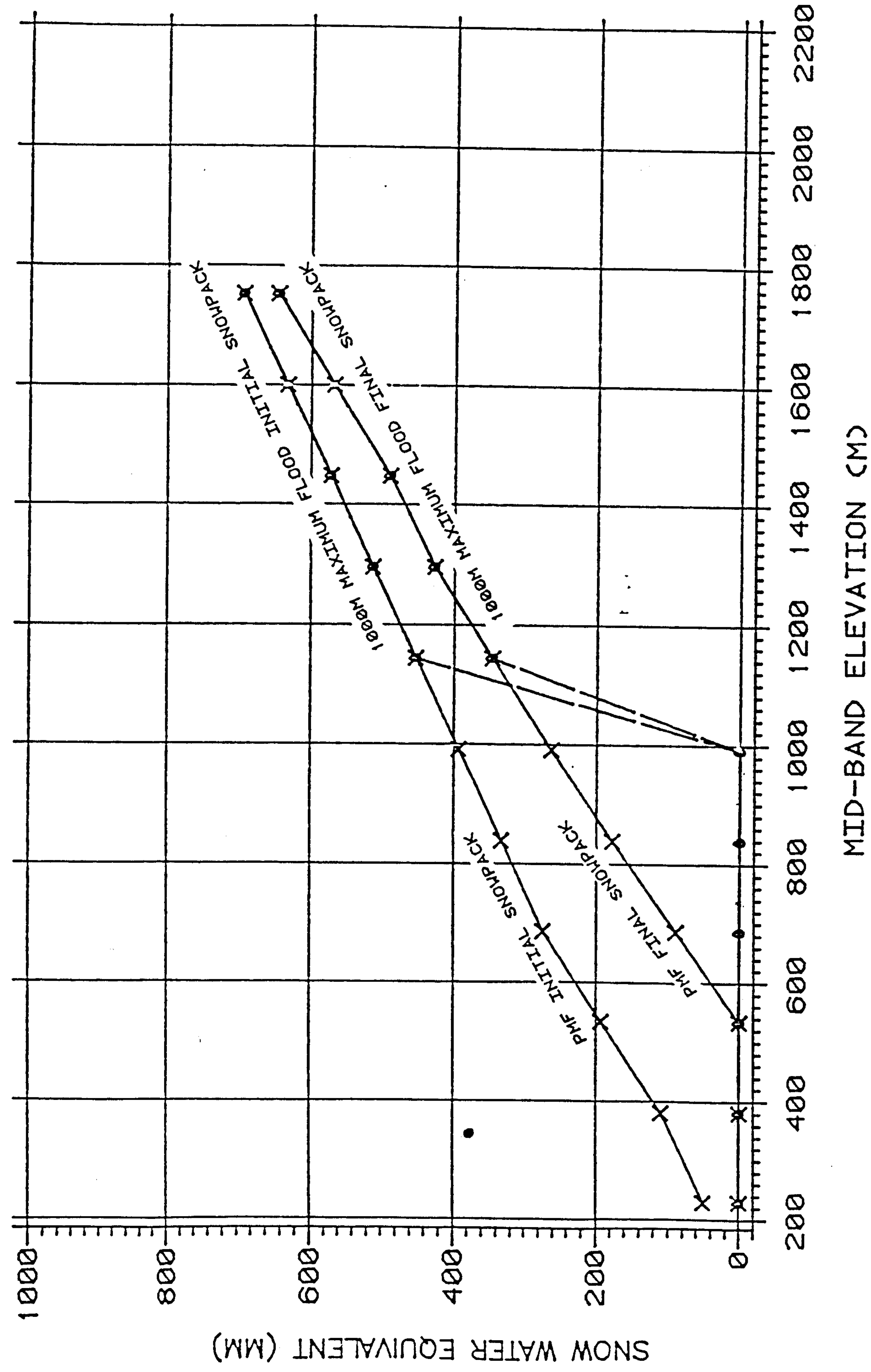



FIGURE 4-2B

MAXIMUM UPPER CAMPBELL LAKE LEVEL FOR VARIOUS SNOWLINES

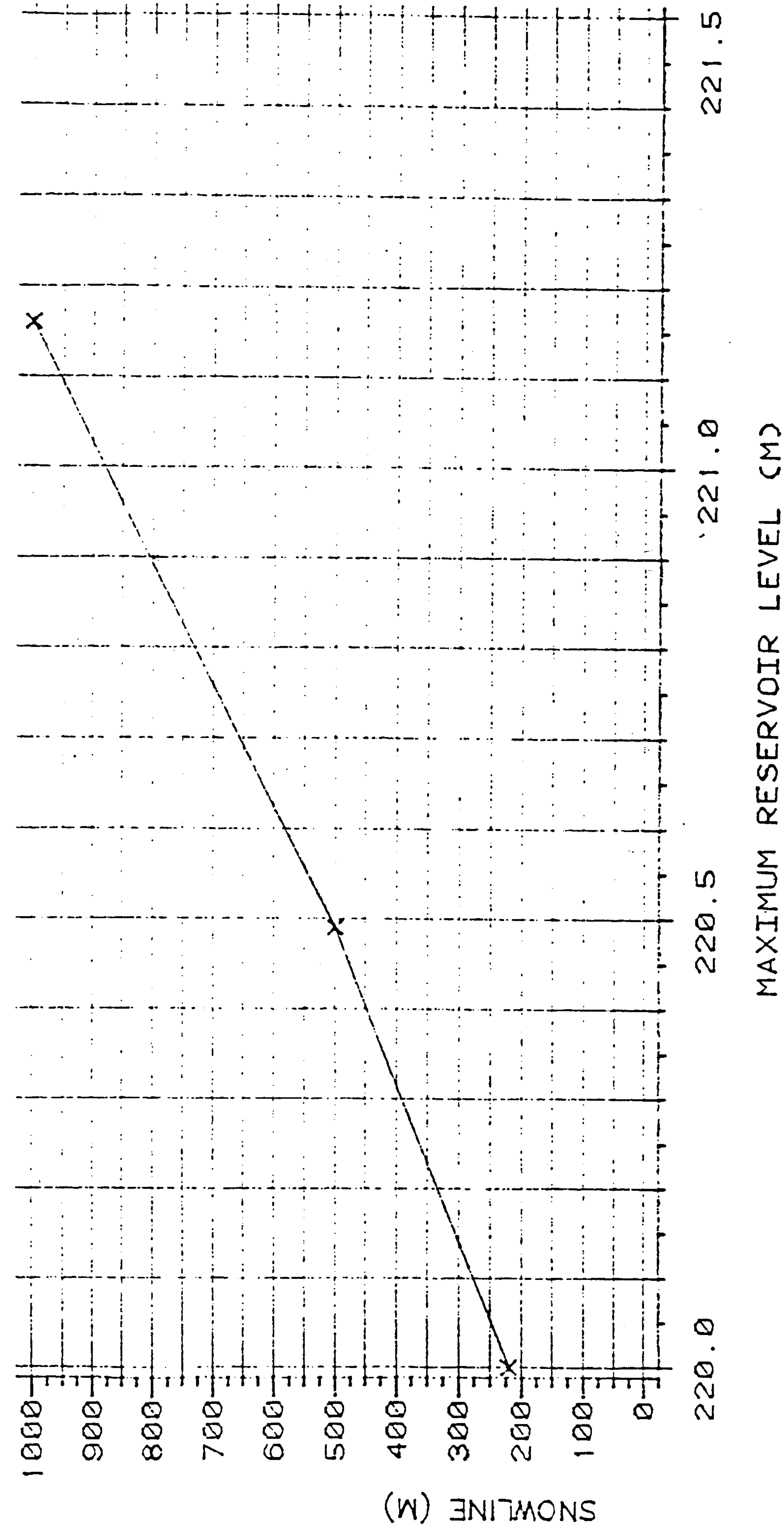



FIGURE 4-2 C

## 3.4 THE REGRESSION EQUATIONS

Reconstitution of inflows to Upper Campbell Lake were attempted for 6, 12 and 24 hours in a predictive mode. The analysis was based on average conditions at 1200 and 2400 hours each day which were compiled from hourly records at the Elk River station for the winters of 1980/81, 1981/82 and 1982/83. The record includes 13 significant high inflow periods of which the inflows of 9 December to 11 December 1980 were the largest.

For several reasons the regression input data were limited to periods when high flows occurred in the Elk River. The most important restriction was the inability of the Elk River DCP to measure low flows prior to October 1983. In addition the Heber River diversion may contribute an unknown flow up to 8.5 $m^3/s$ to flow at the gauge. Since the diversion is closed during high inflow periods there is no need to adjust the recorded Elk River flows during these periods. By limiting the regression data to high inflow periods the resulting regression equation should be heavily weighted towards the average meteorologic conditions producing high inflows.

The results for the 6-hour predictions were statistically significant, but not acceptable for use as an operational tool. This was largely due to the relatively large fluctuations in the recorded inflows to Upper Campbell Lake in a 6-hour period. The inflows are calculated from water levels that can vary significantly due to wind set-up and wave action.

The correlation for the 12-hour prediction was the best of the three. This is a result of the prediction period of 12 hours being close to the basin response time. In such a case, the effects of the recorded parameters should be perceptible by the end of the forecast period. The relative magnitude of error introduced by the measurement of inflows from reservoir water levels should also be less since a larger volume of water flows into the reservoir in 12 hours.

The derived 12-hour inflow prediction equation is as follows:

INFLOW = 80 + 6.6 x FLOW6 + 15 x PREC6 + 5.3 x TEMP6

where:

INFLOW = the average inflow into Upper Campbell Lake for the next 12 hours in $m^3/s$. The independent variables are as defined in Section 3.3.

Relevant statistics are given in Table 3-1.

The correlation for the 24-hour inflow prediction was not as good as for the 12-hour prediction because of the quick basin response time. The changing meteorological conditions in a 24-hour period can affect the inflows in the same period. This means that the recorded data available at the forecast time may not reflect basin conditions for the next full 24 hours. However, the correlation is acceptable if the regressed equation is used as an indication of daily trends.

The derived 24-hour inflow prediction equation is as follows:

INFLOW = 90 + 5.4 x FLOW6 + 11 x PREC6 + 6.2 x TEMP6

where:

INFLOW = the average inflow into Upper Campbell Lake for the next 24 hours in $m^3/s$. The independent variables are as defined in Section 3.3.

Relevant statistics are given in Table 3-2.

The derived regression equations are dependent on a single DCP station at Elk River, which leaves the inflow forecast dependent on the continual operation of the DCP. If the Elk River DCP is inoperative during a storm, the 6-hourly values of Elk River flow, Elk River air temperature and Elk River precipitation can be approximated in the prediction equations as follows:

Elk River flow = 0.07 x inflow to Strathcona as calculated by Power Records

Elk River air temperature = air temperature at Strathcona DCP

Elk River precipitation = Precipitation recorded at Strathcona DCP

The inflow forecasts provided by those approximations would, however, be less reliable than those obtained by using the Elk River DCP data and, therefore, these forecasts should be used with caution. As more data become available during the next 3 to 5 years at Elk River and Strathcona DCP's the above approximations could be refined.

# TABLE 3-2

## THE 24-HOUR INFLOW PREDICTION EQUATION AND STATISTICS

INFLOW = 90 + 5.4 x FLOW6 + 11 x PREC6 + 6.2 TEMP6

where:

INFLOW = inflow to Upper Campbell Lake for the next 24 hours in $m^3/s$.

FLOW6 = average discharge of the Elk River for the previous 6 hours in $m^3/s$.

PREC6 = measured precipitation at Elk River for the previous 6 hours in mm.

TEMP6 = average temperature at Elk River for the previous 6 hours in degrees Celcius.

$R^2$ = 0.65 Total F value = 70.1
R = 0.81 Prob. > F = 0.0001

| Independent Variable | Coefficient | Partial F Value | Prob. > F |
|---|---|---|---|
| FLOW6 | 5.4 | 8.9 | 0.0001 |
| PREC6 | 11.0 | 8.1 | 0.0001 |
| TEMP6 | 6.2 | 2.0 | 0.0496 |

# TABLE 3-1

## THE 12-HOUR INFLOW PREDICTION EQUATION AND STATISTICS

INFLOW = 80 + 6.6 x FLOW6 + 15 x PREC6 + 5.3 x TEMP6

where:

INFLOW = inflow to Upper Campbell Lake for the next 12 hours in $m^3/s$.

FLOW6 = average discharge of the Elk River for the previous 6 hours in $m^3/s$.

PREC6 = measured precipitation at Elk River for the previous 6 hours in mm.

TEMP6 = average temperature at Elk River for the previous 6 hours in degrees Celcius.

$R^2$ = 0.75 Total F value = 111.6
R = 0.86 Prob. > F = 0.0001

| Independent Variable | Coefficient | Partial F Value | Prob. > F |
|---|---|---|---|
| FLOW6 | 6.6 | 10.7 | 0.0001 |
| PREC6 | 15.0 | 11.0 | 0.0001 |
| TEMP6 | 5.3 | 1.7 | 0.0952 |

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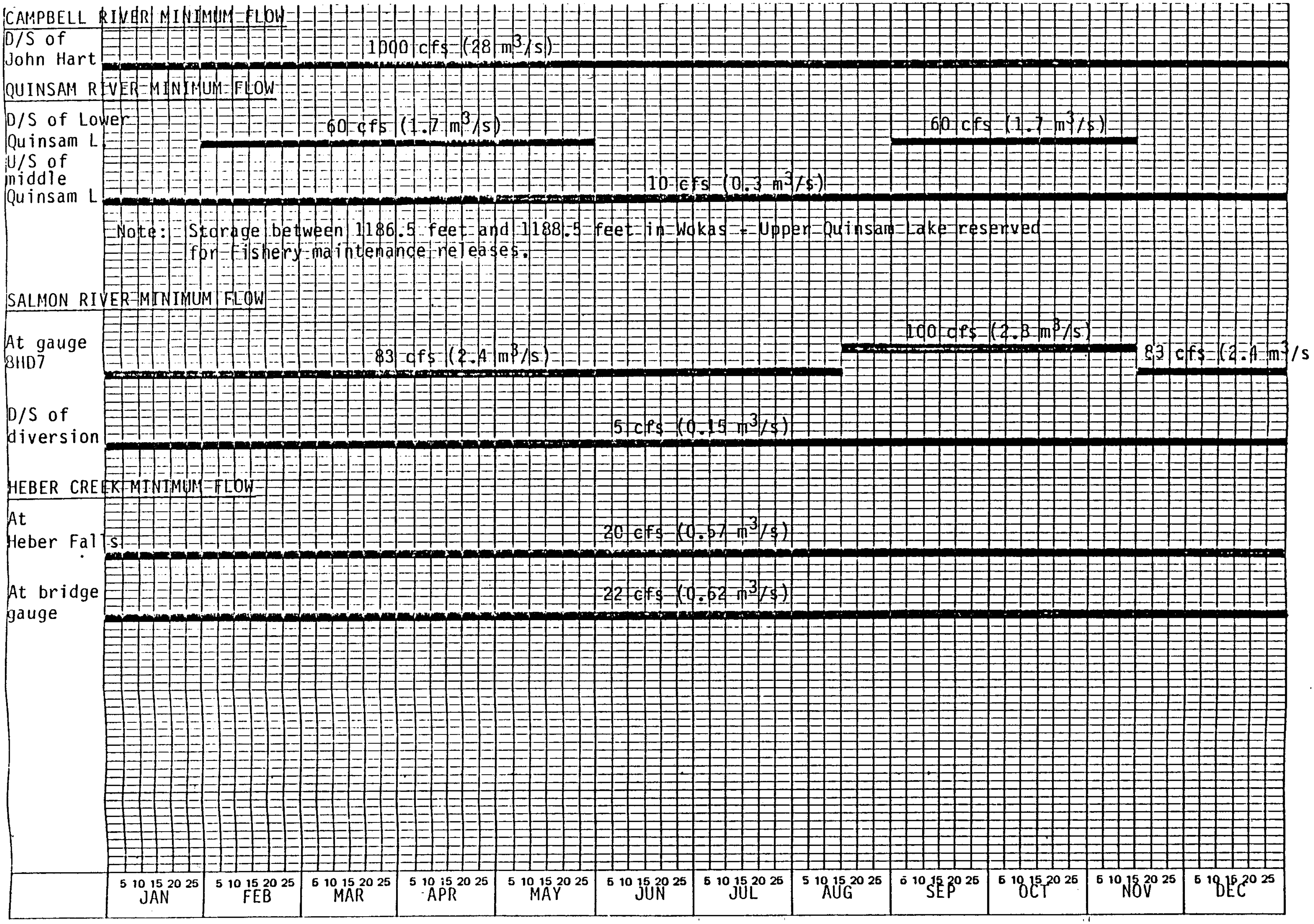
BRITISH COLUMBIA HYDRO AND POWER AUTHORITY
OPERATIONS CONTROL DEPARTMENT

O.O. No. 43?
Attachment No. 8

# CAMPBELL RIVER MINIMUM MAINTENANCE FLOWS



# APPENDIX IV

# APPENDIX IV

FLOODPLAIN MAPS



KLOHN LEONOFF LTD.
CONSULTING ENGINEERS


## NOTES

**Produced by:** KLOHN LEONOFF LTD
10180 Shellbridge Way
Richmond, B.C. V6X 2W7

**Survey:** River survey done by Surveys Section, Water Management Branch, Project 87FDC-1, dated June 1987.
a) Horizontal control based on provincial network.
b) Elevations are in metres and are referred to Geodetic Survey of Canada datum. ( ◉ indicates Survey Monument).

**Mapping:** Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 85-035.
a) Contour interval 1 metre and greater; spot elevatons shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted.
b) Grid origin referred to U.T.M. Projection Zone 10.

## FLOODPLAIN DATA

1. The floodplain areas as depicted on this map have been designated pursuant to the Canada/British Columbia Floodplain Mapping Agreement (1988) by the Minister of the Environment for Canada and the Minister of Environment for British Columbia.

   Flooding may still occur outside of the designated floodplain areas. The Ministers do not assume any liability by reason of the designation or failure to designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
3. The flood levels were computed using a standard step method modelling technique, assuming open water flow conditions.
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not delineated for side streams and tributaries.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment.
9. MAPS AVAILABLE FROM THE MINISTRY OF CROWN LANDS, SURVEYS AND RESOURCE MAPPING BRANCH, MAPS B.C. MAP AND AIR PHOTO SALES, VICTORIA, B.C.

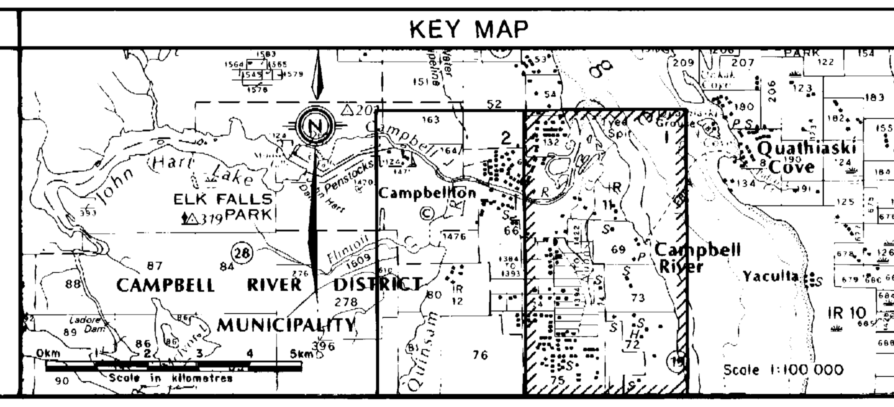
## LEGEND

DESIGNATED FLOODPLAIN LIMIT

FLOOD LEVEL
(Freeboard included)
200 Year Frequency
20 Year Frequency

(METRES G.S.C. DATUM)

## KEY MAP




## REVISIONS

| No. | DESCRIPTION | DATE |
|---|---|---|

ISSUE OF MAPPING
DATE

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTÉRIEURES
BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT
CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

DRAWN F.C.
CHECKED R.F.R.
RIVER SURVEY M.P.
DESIGNED B.B.

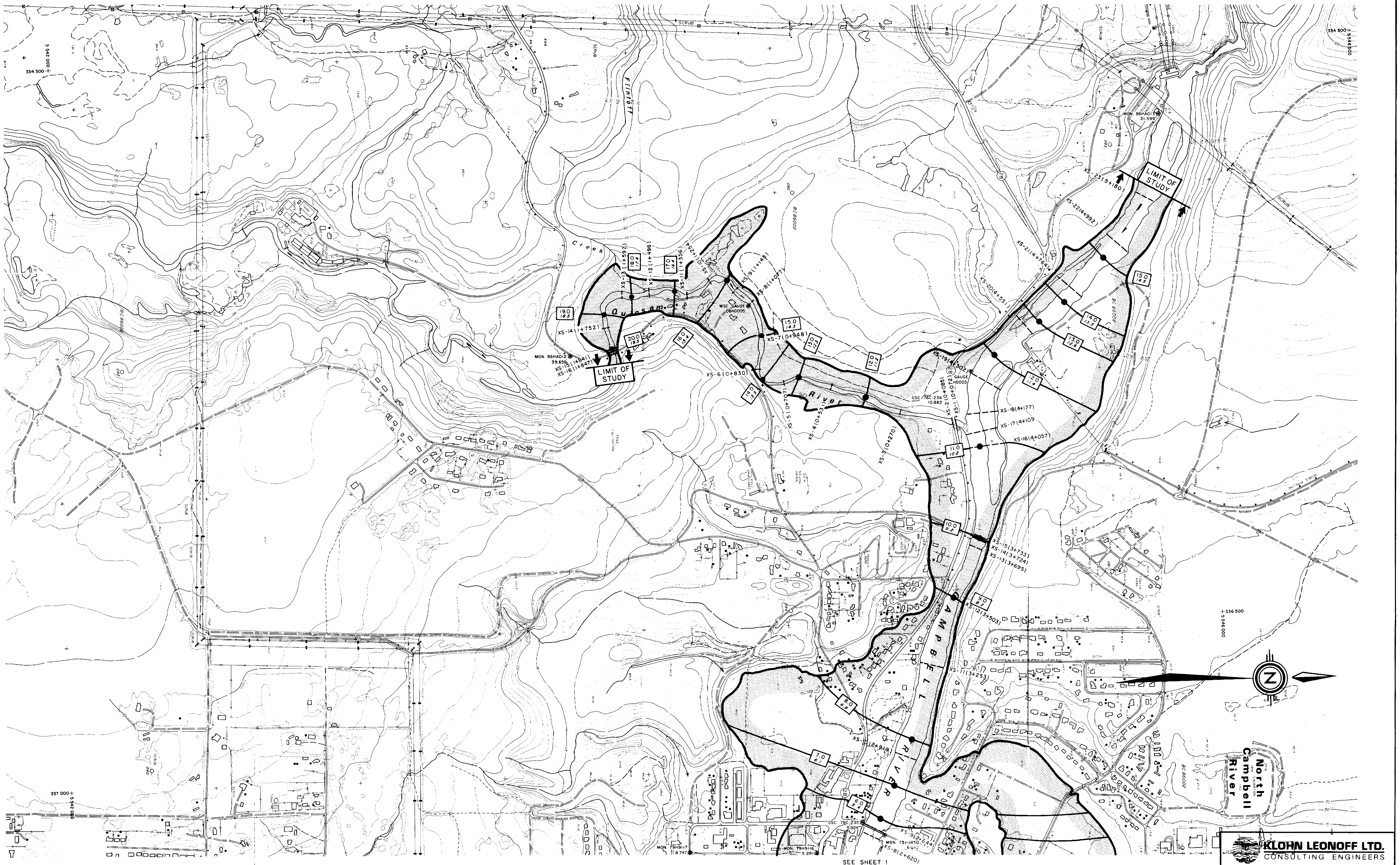
# FLOODPLAIN MAPPING
# CAMPBELL & QUINSAM RIVERS

100m 0 100 200 300 400 500m
Scale in metres

ENGINEER
RECOMMENDED
APPROVED

FILE No. 92-2590-S.1
N.T.S.MAP No. 92K/3
SCALE 1:5 000
NEGATIVE No.
DRAWING No. 88-28-1
REV.
SHEET 1 of 2

DDfImg




## NOTES

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10180 Shellbridge Way
Richmond, B.C. V6X 2W7

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a) Horizontal control based on provincial network.
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**Mapping:** Base mapping done by Map Production Division, Surveys and Resource Mapping Branch, Project 85-035.
a) Contour interval 1 metre and greater; spot elevatons shown to 0.1 metres, with accuracy to ± 0.3 metres, except where noted.
b) Grid origin referred to U.T.M. Projection Zone 10 .

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   Flooding may still occur outside of the designated floodplain areas. The Ministers do not assume any liability by reason of the designation or failure to designate areas on this map.
2. The Designated Flood has a statistical frequency of occurrence of once every 200 years.
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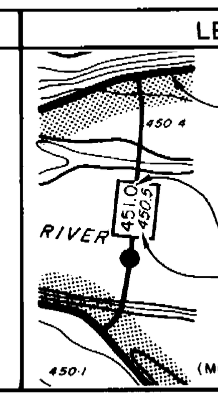
4. The floodplain limits assume the absence of all dykes.
5. The floodplain limits and flood levels include an allowance for freeboard.
6. The floodplain limits are not established on the ground by legal survey.
7. The floodplain limits are not delineated for side streams and tributaries.
8. The required setback of buildings from the natural boundaries of lakes and watercourses to allow for the passage of floodwaters and possible bank erosion is not shown. This information is available either through local municipalities or the Ministry of Environment.
9. MAPS AVAILABLE FROM THE MINISTRY OF CROWN LANDS, SURVEYS AND RESOURCE MAPPING BRANCH, MAPS B.C. MAP AND AIR PHOTO SALES, VICTORIA, B.C.

## LEGEND

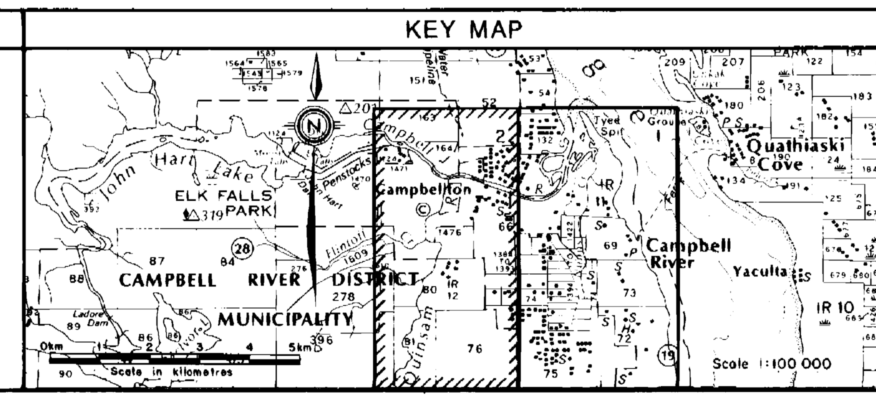



DESIGNATED FLOODPLAIN LIMIT

FLOOD LEVEL
(Freeboard included)
200 Year Frequency
20 Year Frequency

(METRES G.S.C. DATUM)

## KEY MAP




## REVISIONS

| No. | DESCRIPTION | DATE |
|---|---|---|
| | | |

ISSUE OF MAPPING
DATE

DRAWN F.C.
CHECKED R.F.R.
RIVER SURVEY M.P.
DESIGNED B.B.
ENGINEER
RECOMMENDED
APPROVED

ENVIRONMENT CANADA INLAND WATERS / ENVIRONNEMENT CANADA EAUX INTÉRIEURES
BRITISH COLUMBIA MINISTRY OF ENVIRONMENT / COLOMBIE-BRITANNIQUE MINISTÈRE DE L'ENVIRONNEMENT
CANADA BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT / L'ACCORD CANADA COLOMBIE-BRITANNIQUE SUR LA CARTOGRAPHIE DES PLAINES D'INONDATION

# FLOODPLAIN MAPPING
# CAMPBELL & QUINSAM RIVERS

100m 0 100 200 300 400 500m
Scale in metres

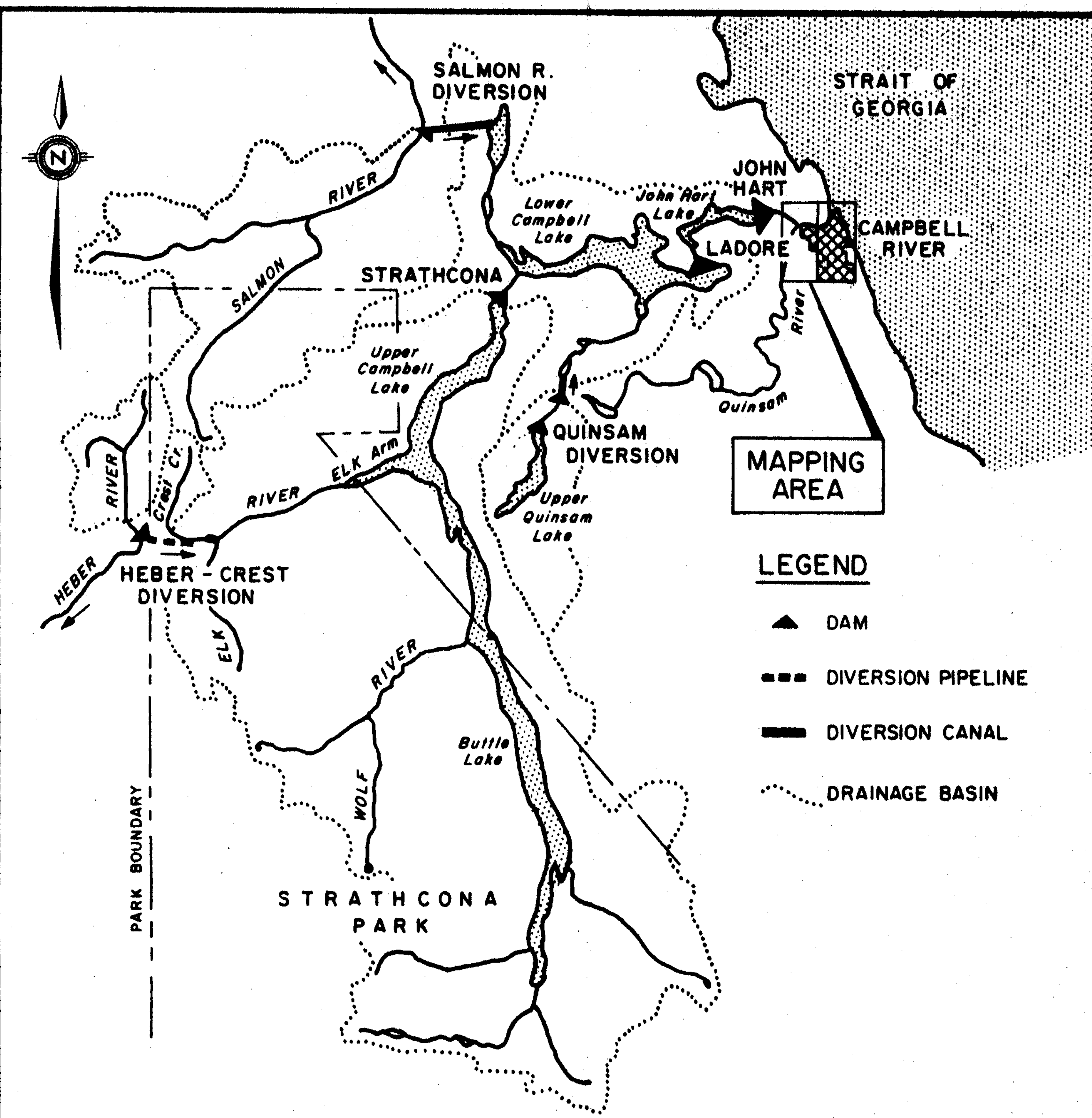
KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

FILE No. 92-2590-S.1
N.T.S.MAP No. 92K/3
SCALE 1:5 000
NEGATIVE No.
DRAWING No. 88-28-2
REV.
SHEET 2 of 2

DDflmg

DRAWINGS

# DRAWINGS

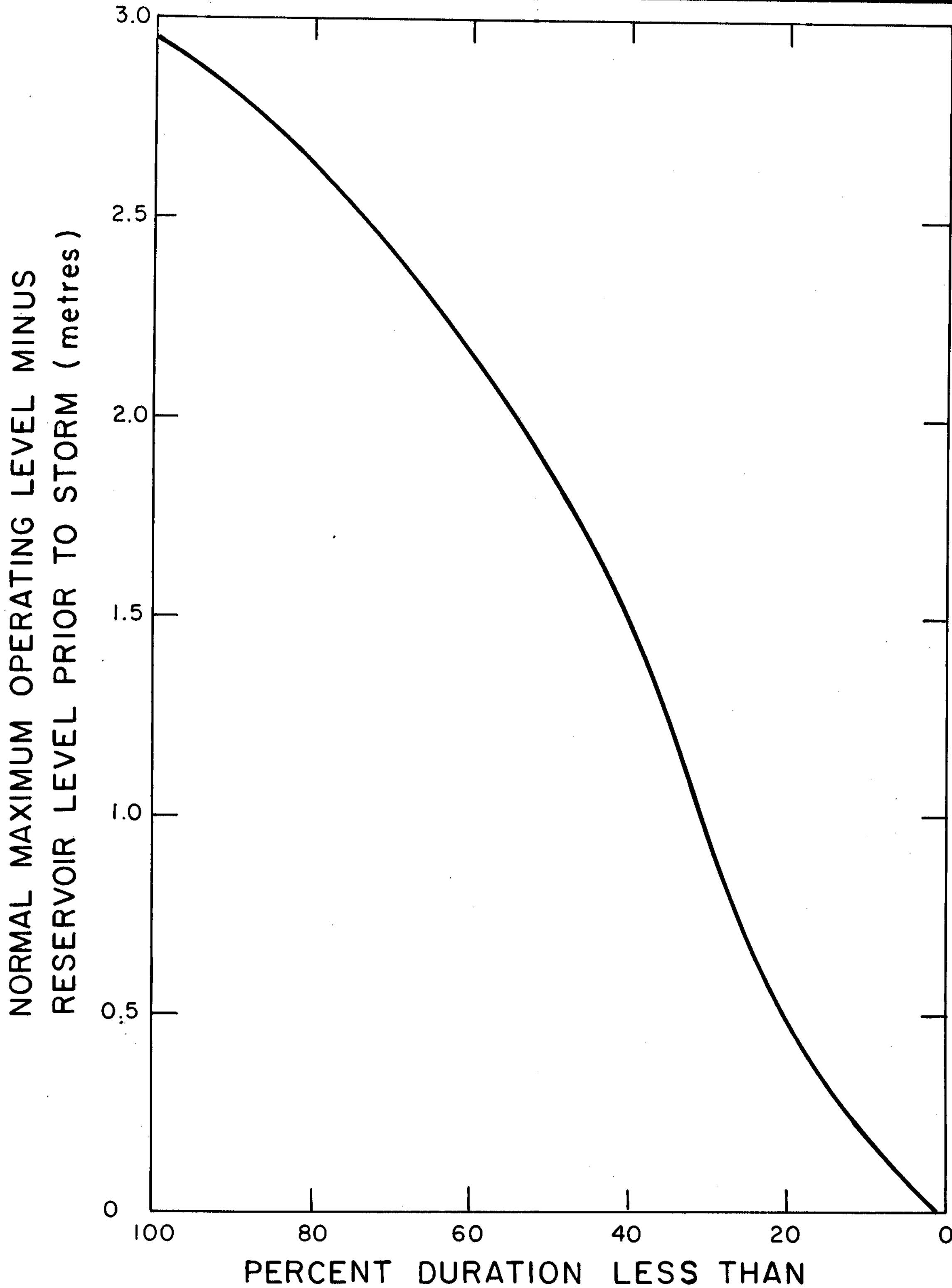



AS A MUTUAL PROTECTION TO OUR CLIENT, THE PUBLIC AND OURSELVES, ALL REPORTS AND DRAWINGS ARE SUBMITTED FOR THE CONFIDENTIAL INFORMATION OF OUR CLIENT FOR A SPECIFIC PROJECT AND AUTHORIZATION FOR USE AND/OR PUBLICATION OF DATA, STATEMENTS, CONCLUSIONS OR ABSTRACTS FROM OR REGARDING OUR REPORTS AND DRAWINGS IS RESERVED PENDING OUR WRITTEN APPROVAL

0 5 10 miles
SCALE

**KLOHN LEONOFF LTD.**
CONSULTING ENGINEERS

| | |
|---|---|
| PROJECT | FLOODPLAIN MAPPING PROGRAM<br>CAMPBELL AND QUINSAM RIVERS |
| TITLE | KEY PLAN |
| CLIENT: | B.C. MINISTRY OF ENVIRONMENT |
| DATE OF ISSUE | MAY 19, 1989 |
| APPROVED | KEK |
| PROJECT No. | PB 5049 01 |
| DWG. No. | A-1001 |
| REV. | |

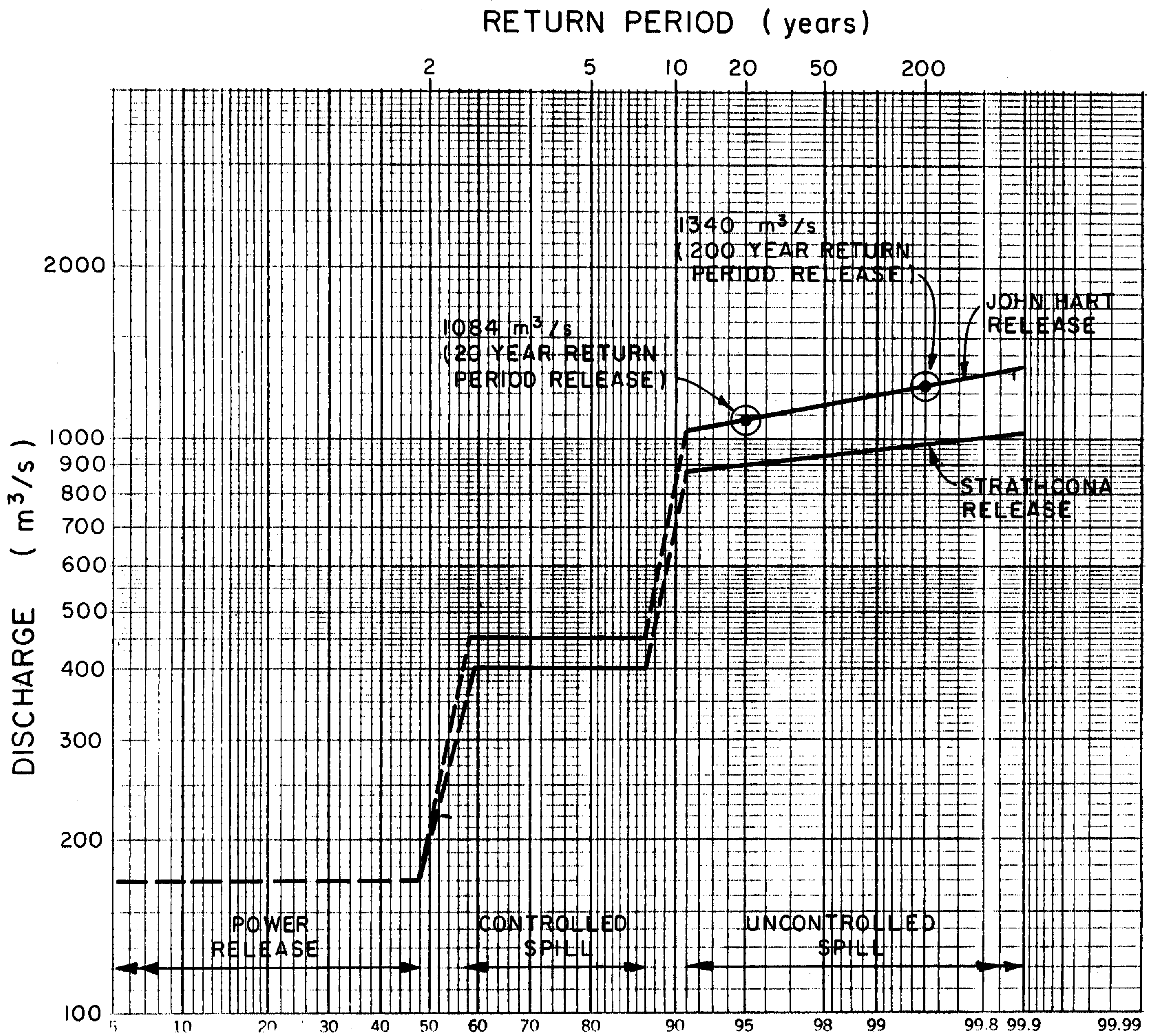





SCALE

| | |
|---|---|
| **KLOHN LEONOFF LTD.** CONSULTING ENGINEERS | PROJECT: FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS<br>TITLE: FREQUENCY OF INITIAL RESERVOIR LEVELS |

| CLIENT: | DATE OF ISSUE / APPROVED | PROJECT No. | DWG. No. | REV. |
|---|---|---|---|---|
| B. C. MINISTRY OF ENVIRONMENT | MAY 19, 1989 | PB 5049 01 | A-1002 | |






SCALE

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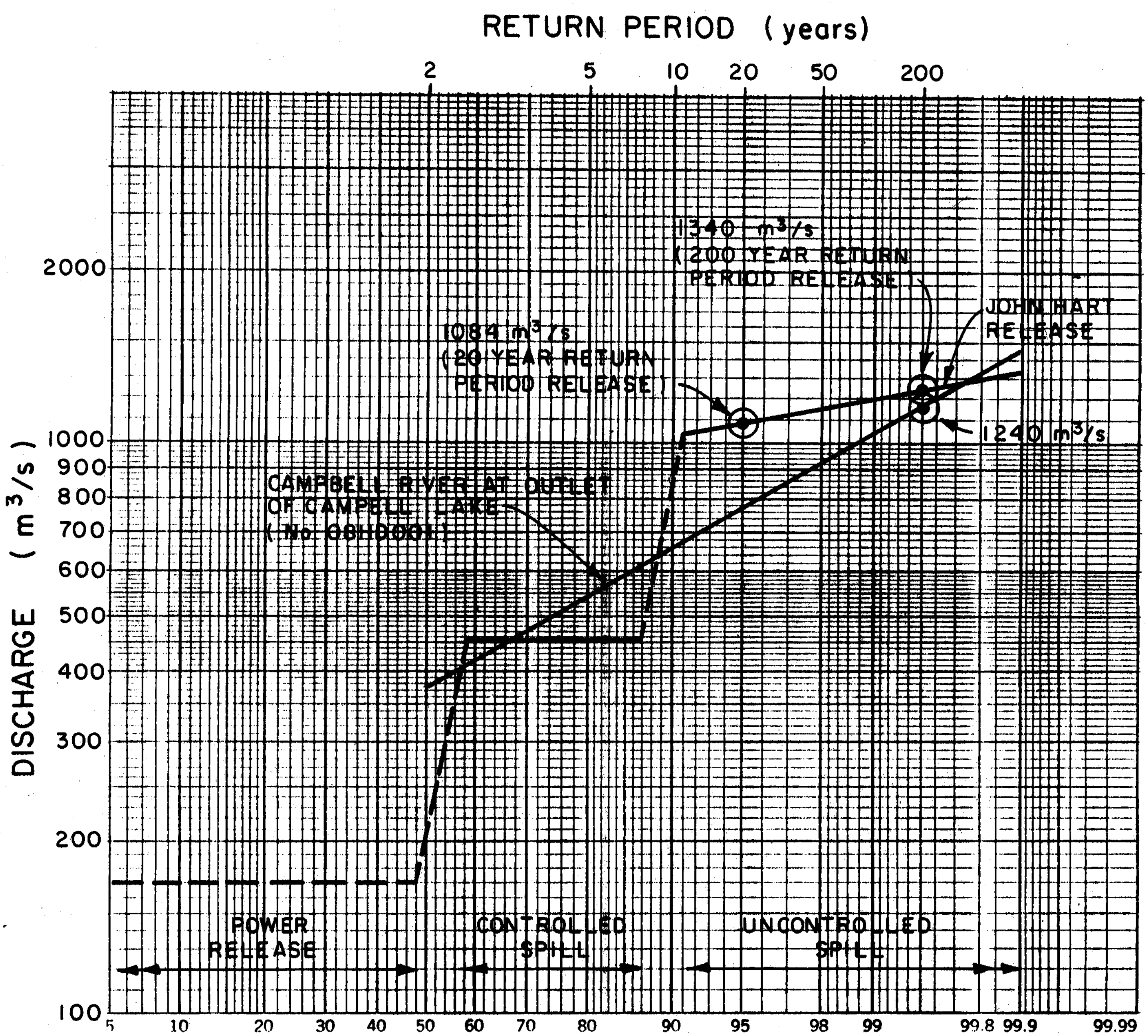
PROJECT: FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS

TITLE: RETURN PERIOD VS STRATHCONA RELEASE AND JOHN HART RELEASE

CLIENT: B.C. MINISTRY OF ENVIRONMENT

| DATE OF ISSUE | PROJECT No. | DWG. No. | REV. |
|---|---|---|---|
| MAY 19, 1989 | PB 5049 01 | A-1003 | |

APPROVED



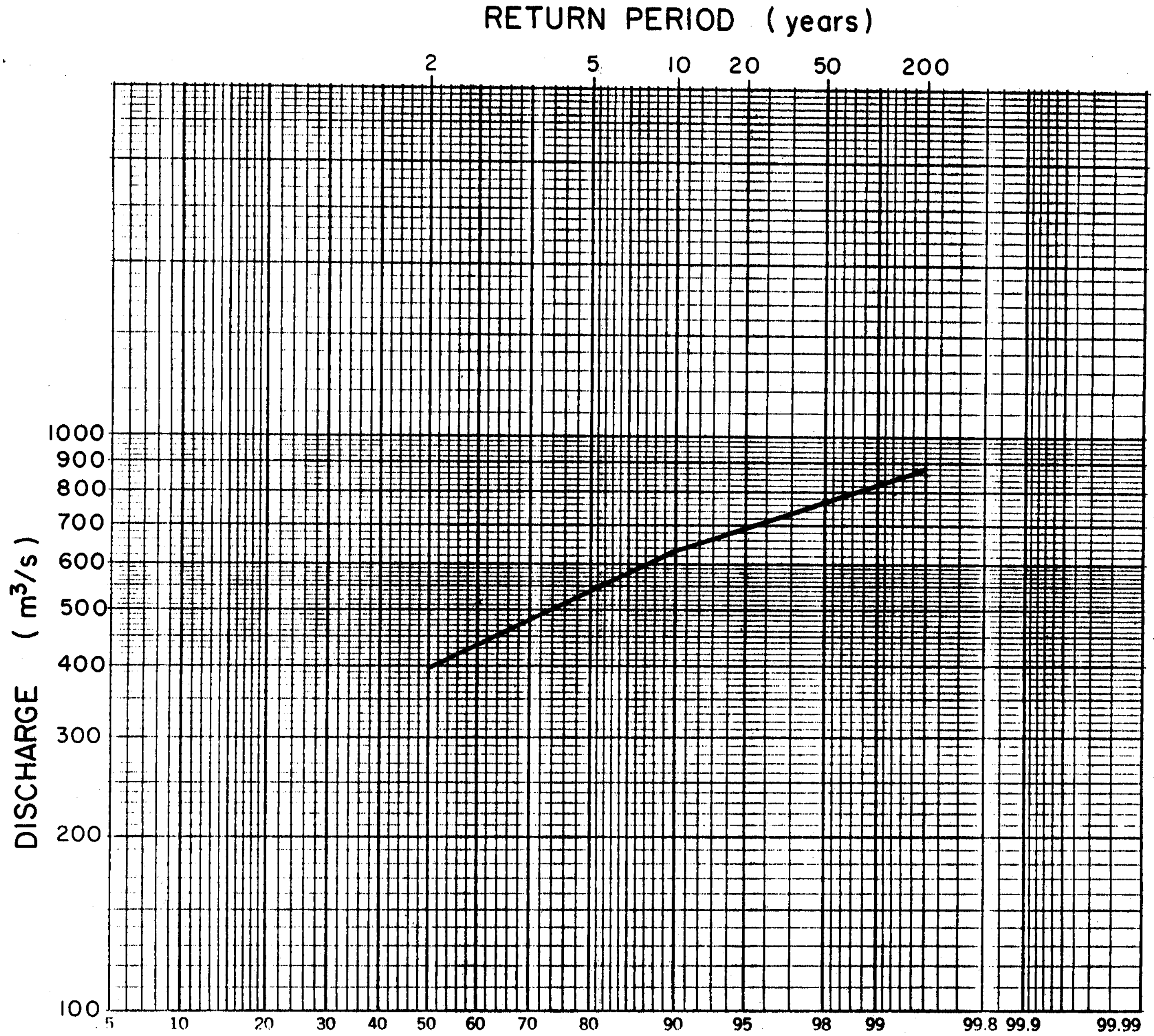

NOTES : - GAUGE No. 08HD001 HAS UNREGULATED DATA FROM 1910 TO 1946.
- THREE PARAMETER LOG NORMAL DISTRIBUTION.



SCALE

**KLOHN LEONOFF LTD.**
CONSULTING ENGINEERS

| | |
|---|---|
| PROJECT | FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS |
| TITLE | RETURN PERIOD VS JOHN HART RELEASE AND CAMPBELL R. AT OUTLET OF CAMPBELL LAKE |
| CLIENT: | B.C. MINISTRY OF ENVIRONMENT |
| DATE OF ISSUE | MAY 19, 1989 |
| APPROVED | K7K |
| PROJECT No. | PB 5049 01 |
| DWG. No. | A-1004 |
| REV. | |




NOTES :
- REGULATED DISCHARGES WERE USED TO DEVELOP THIS DISTRIBUTION FOR COMPARISON PURPOSES ONLY.
- THREE PARAMETER LOG NORMAL DISTRIBUTION.
- WSC STATION No. 08HD003.



SCALE

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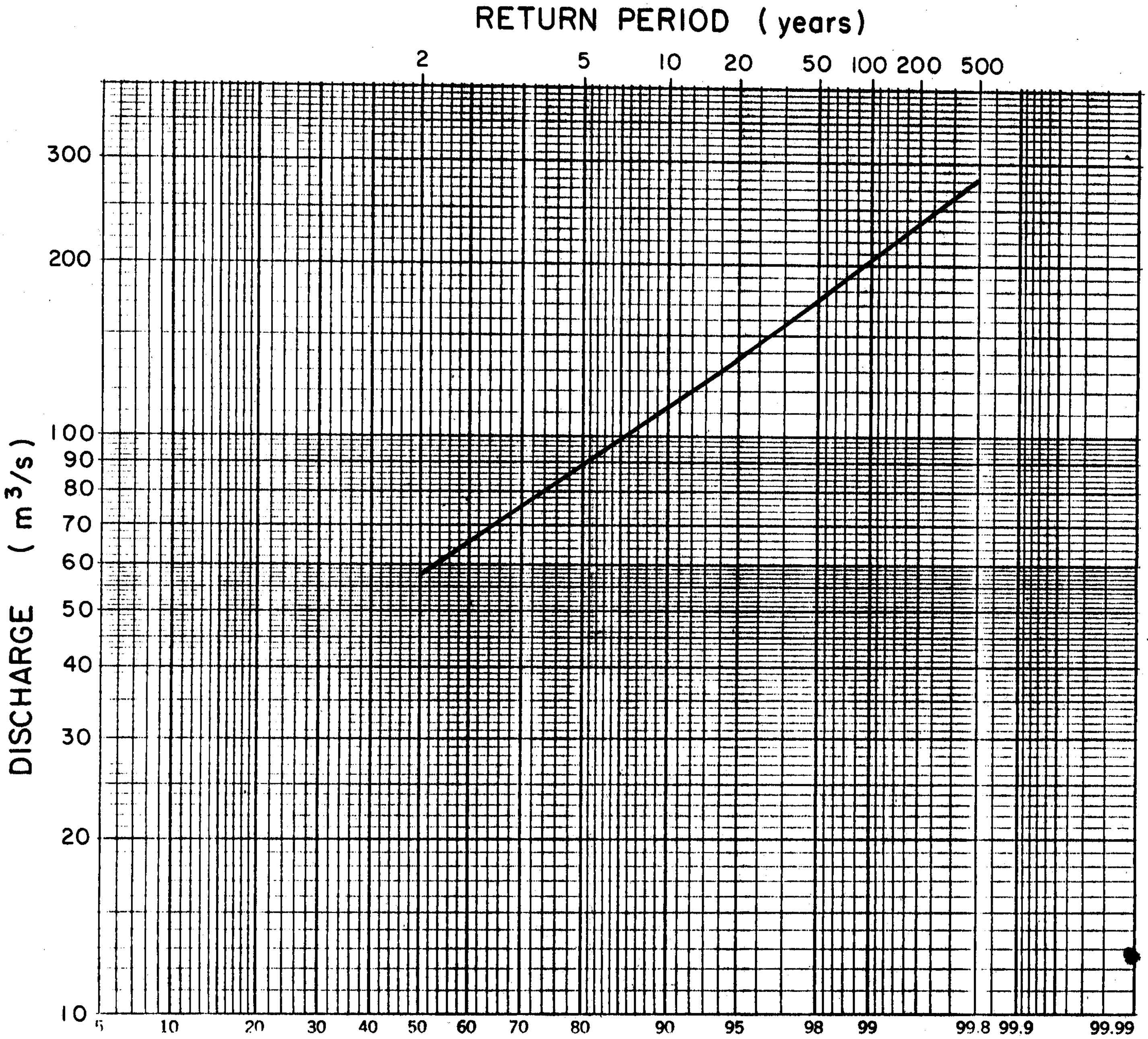
PROJECT: FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS

TITLE: RETURN PERIOD VS MAXIMUM ANNUAL DISCHARGE CAMPBELL RIVER ABOVE QUINSAM RIVER

| CLIENT: | DATE OF ISSUE | PROJECT No. | DWG. No. | REV. |
|---|---|---|---|---|
| B.C. MINISTRY OF ENVIRONMENT | MAY 19, 1989 | PB 5049 01 | A-1005 | |
| | APPROVED | | | |




NOTES : – GENERALIZED EXTREME VALUE DISTRIBUTION.
– WSC STATION No. 08HD005.



SCALE

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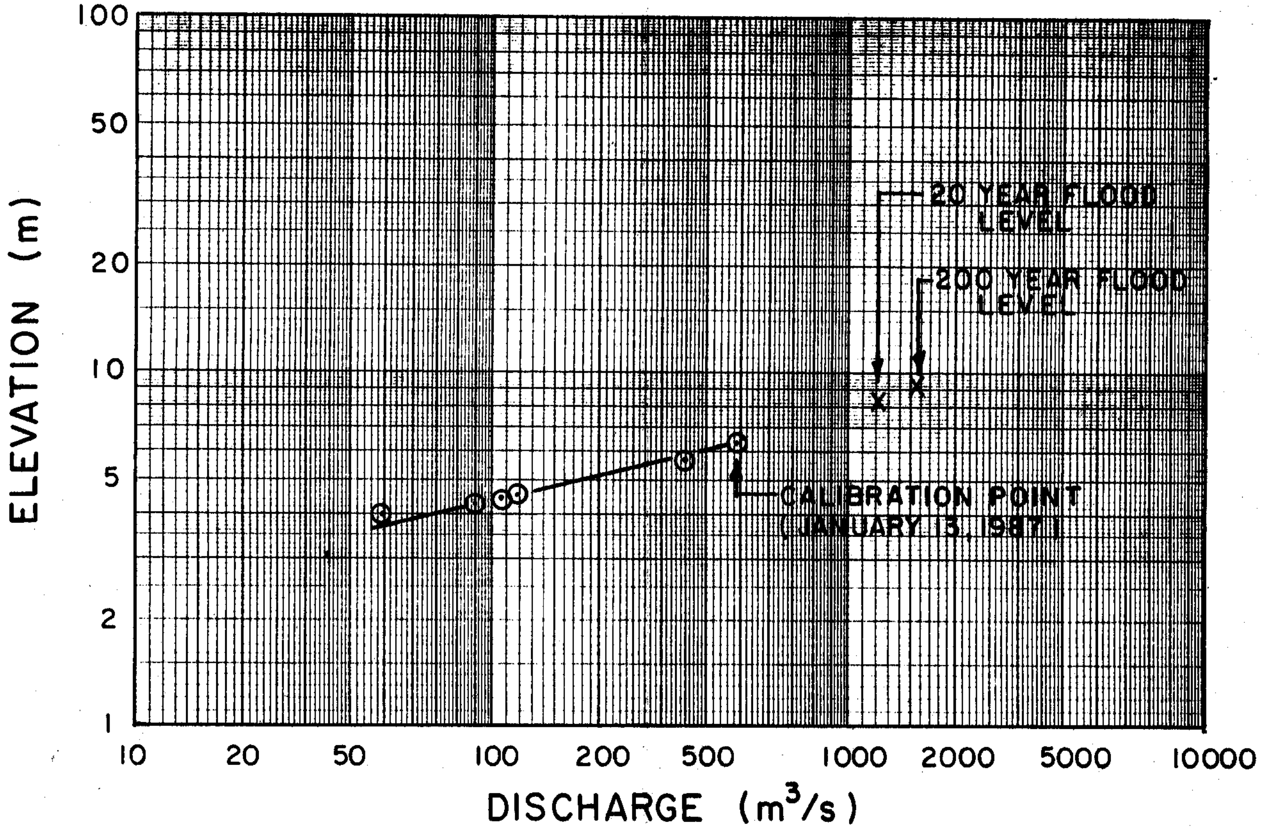
PROJECT: FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS

TITLE: RETURN PERIOD VS MAXIMUM ANNUAL DISCHARGE QUINSAM RIVER NEAR CAMPBELL RIVER

| CLIENT: | DATE OF ISSUE | PROJECT No. | DWG. No. | REV. |
|---|---|---|---|---|
| B. C. MINISTRY OF ENVIRONMENT | MAY 19, 1989 | PB 5049 01 | A-1006 | |
| | APPROVED: R.E.R. | | | |

760




## LEGEND

⊙ RECORDED POINTS ( DATA SUPPLIED BY B.C. HYDRO )

X CALCULATED POINTS



SCALE

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CONSULTING ENGINEERS

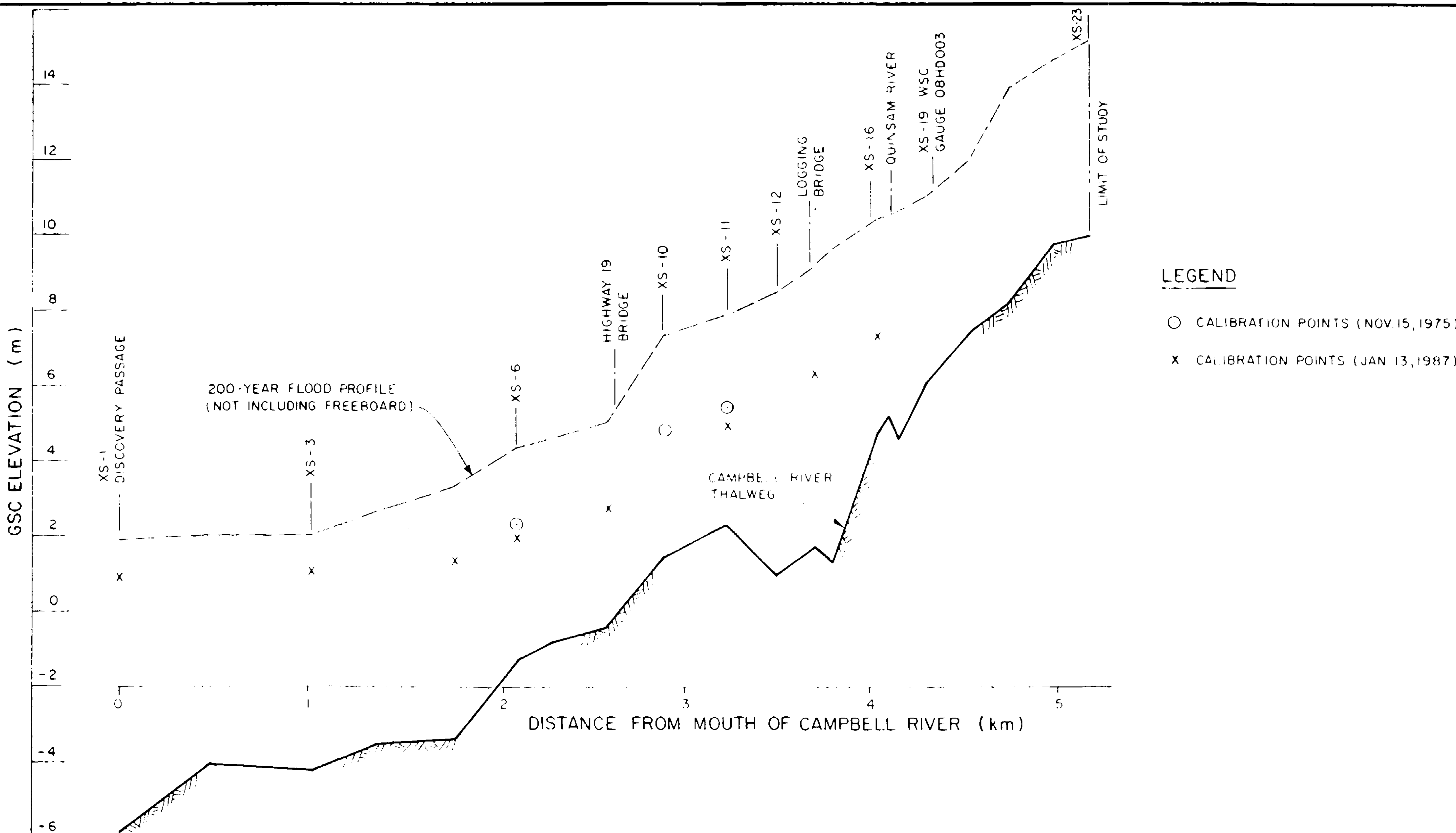
PROJECT: FLOODPLAIN MAPPING PROGRAM CAMPBELL AND QUINSAM RIVERS

TITLE: RATING CURVE FOR CROSS SECTION 13

CLIENT: B.C. MINISTRY OF ENVIRONMENT

| DATE OF ISSUE | PROJECT No. | DWG. No. | REV. |
|---|---|---|---|
| MAY 19, 1989 | PB 5049 01 | A-1007 | |

APPROVED: R.J.R.




MAY 19, 1989

SCALE AS SHOWN

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CONSULTING ENGINEERS

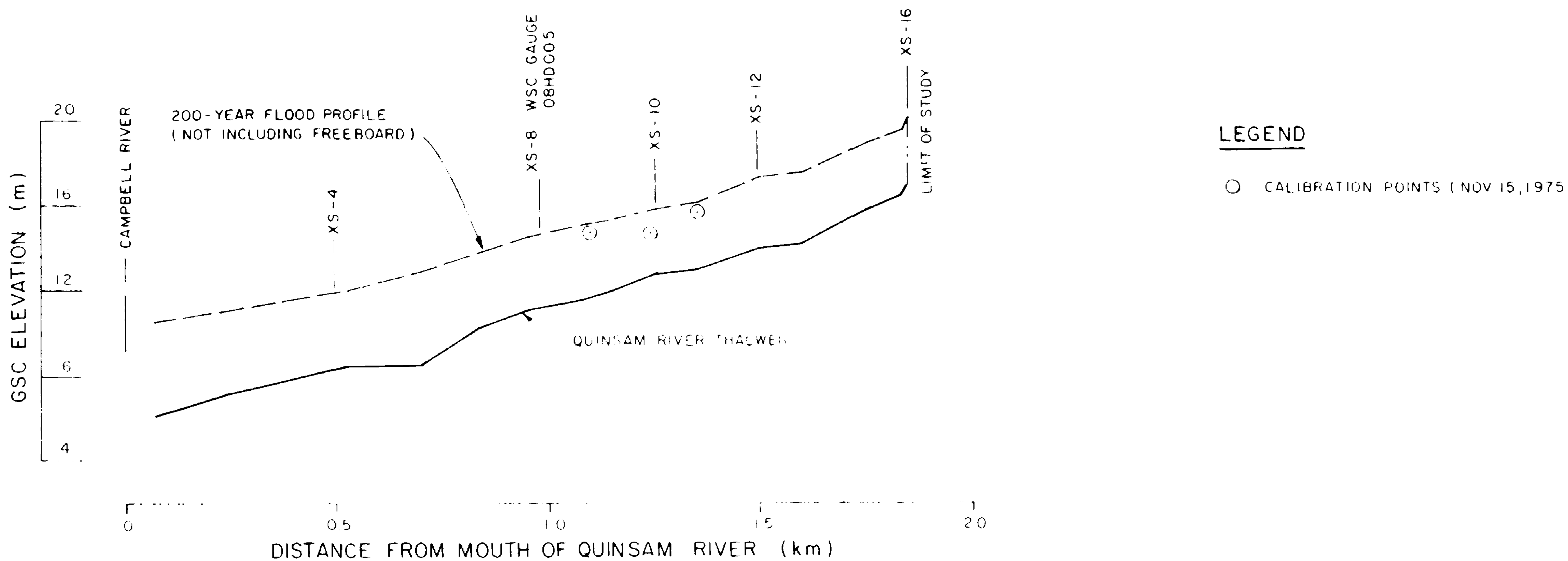
PROJECT: FLOODPLAIN MAPPING PROGRAM
CAMPBELL AND QUINSAM RIVERS

TITLE: PLOT OF FLOOD PROFILE AND
CALIBRATION POINTS - CAMPBELL RIVER

CLIENT: B.C. MINISTRY OF ENVIRONMENT

| DATE OF ISSUE | PROJECT No | DWG No | REV |
|---|---|---|---|
| MAY 19, 1989 | PB 5049 01 | B-1008 | |

APPROVED




MAY 19, 1989

SCALE AS SHOWN

KLOHN LEONOFF LTD.
CONSULTING ENGINEERS

PROJECT: FLOODPLAIN MAPPING PROGRAM
CAMPBELL AND QUINSAM RIVERS

TITLE: PLOT OF FLOOD PROFILE AND CALIBRATION POINTS - QUINSAM RIVER

CLIENT: B.C. MINISTRY OF ENVIRONMENT

| DATE OF ISSUE | PROJECT No | DWG No | REV |
|---|---|---|---|
| MAY 19, 1989 | PB 5049 01 | B-1009 | |