KLOHN-CRIPPEN

February 29, 1996

Ministry of Environment, Lands and Parks
Water Management Division
765 Broughton Street
Victoria, British Columbia, V8V 1X5

Mr. R.W. Nichols, P.Eng.,
Head, Floodplain Mapping Section, Hydrology Branch

Dear Mr. Nichols:

Floodplain Mapping Program, Duncan and Lardeau Rivers and Meadow Creek
Design Brief, Floodplain Maps and Study File

Please find enclosed 12 bound copies and one unbound copy of the Design Brief, one copy of the Study File and one set of prints and one set of reproducible mylar floodplain maps. Comments on the Draft Design Brief, from yourself and from Henry Mark, Manager of Operations Planning, at BC Hydro, have been incorporated.

It has been a pleasure working with the Ministry on this interesting study.

Yours truly,

KLOHN-CRIPPEN CONSULTANTS LTD.

Richard F. Rodman

Richard F. Rodman, P.Eng.
Manager, Hydrotechnical Engineering

Encls.

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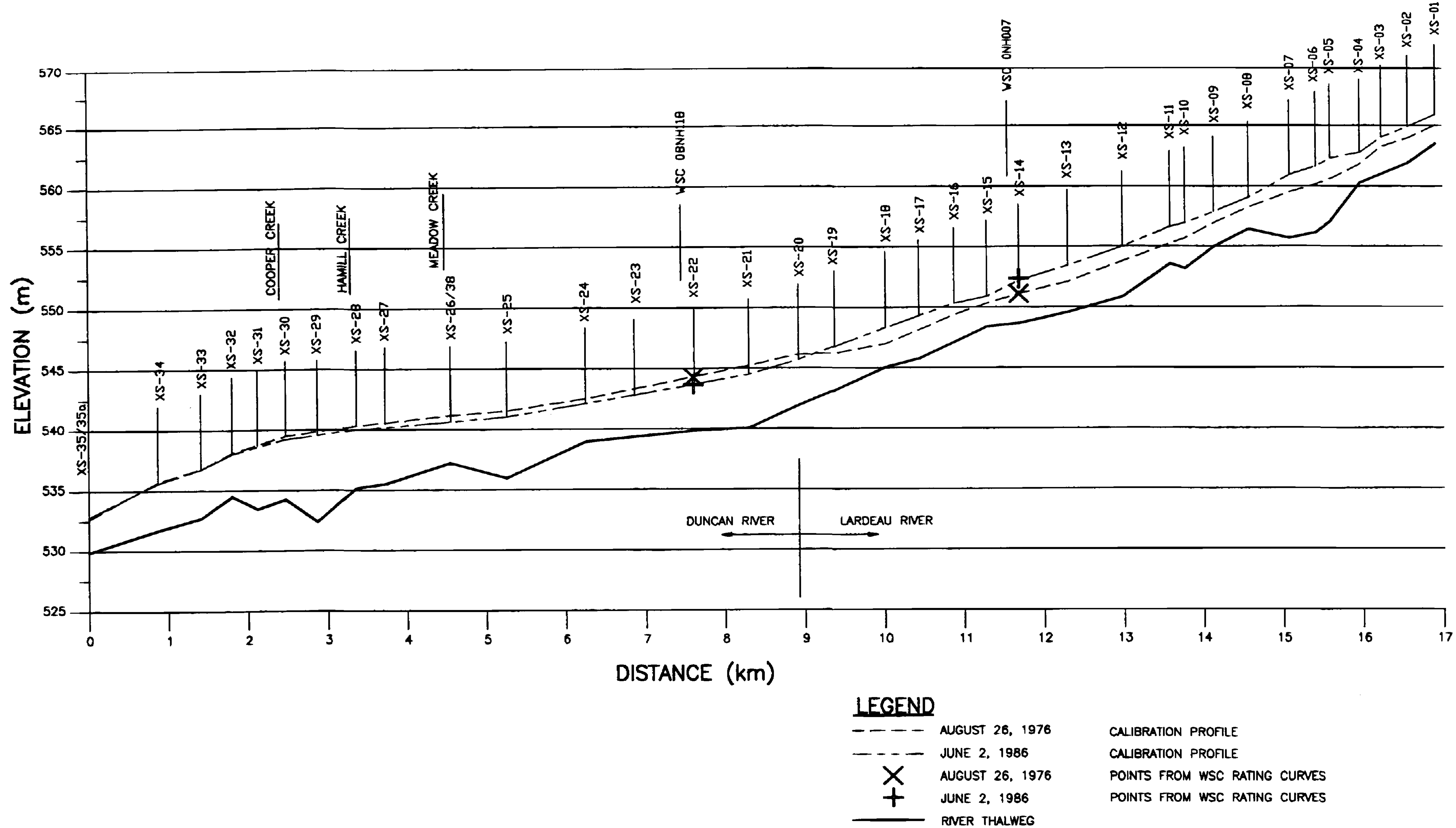

TO BE READ WITH KLOHN-CRIPPEN REPORT DATED FEB. 29, 1996

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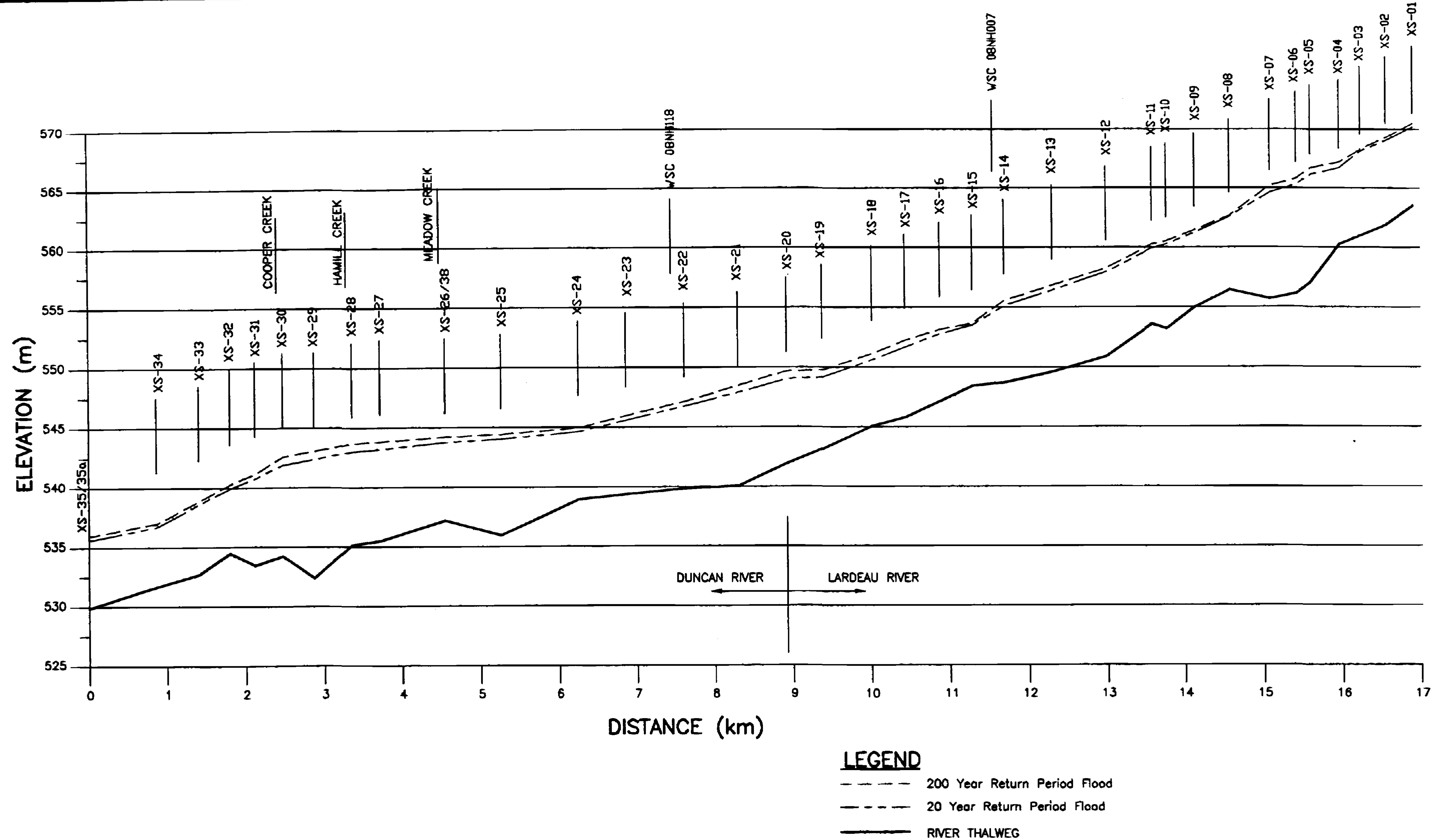
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

PROJECT
FLOODPLAIN MAPPING PROGRAM
DUNCAN AND LARDEAU RIVERS

TITLE
HEC-2 CALIBRATION PROFILES

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB.29, 1996	PW708701	B-1015	

Duncan/Lareau River Calibration



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PROJECT
FLOODPLAIN MAPPING PROGRAM
DUNCAN AND LARDEAU RIVERS

TITLE
DESIGN WATER LEVEL PROFILES

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB.29, 1996	PW708701	B-1016	

Duncan/Lareau River Calibration

Province of British Columbia

Ministry of Environment, Lands and Parks

FLOODPLAIN MAPPING DUNCAN AND LARDEAU RIVERS AND MEADOW CREEK

DESIGN BRIEF

PW 7087 01

FEBRUARY 1966

COVER PHOTO: FLOODING IN THE TOWN OF KASLO DUE TO HIGH KOOTENAY LAKE LEVELS AND KASLO RIVER FLOOD WATERS IN JUNE 1894. SOURCE: "GOLD CREEKS AND GHOST TOWNS" BY N.L. BARLEE, SEPTEMBER 1974.

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1. INTRODUCTION

1.1 Purpose and Scope of Study

This report contains details of a study conducted by Klohn-Crippen for the Duncan and Lardeau Rivers and Meadow Creek under the joint Federal/Provincial Floodplain Mapping Agreement. The purpose of this study is to delineate the limits of the 200-year floodplain and to display flood elevations on a topographic base map. This study was carried out in accordance with specifications outlined in the Ministry of Environment, Lands and Parks, Water Management Division, Invitation for Proposal for Engineering Services, received June 14, 1995, and our Proposal for Engineering Services dated July 4, 1995. Drawing A-1001 shows the study area location.

The scope of this study includes:

- review of available river survey data to confirm that it meets with the Ministry's requirements for floodplain mapping;
- determination of the 20-year and 200-year return period daily and instantaneous discharges for Duncan and Lardeau Rivers and Meadow Creek;
- set up and calibration of an HEC-2 backwater model for Duncan and Lardeau Rivers and Meadow Creek;
- determination of the 200-year return period Kootenay Lake level;
- delineation of the 200-year floodplain on topographic maps supplied by the BC Ministry of Environment; and
- documentation of the study in this comprehensive Design Brief.

The floodplain maps are included in Appendix IV of this report. A study file, which contains the HEC-2 output for all runs, is bound separately. To ensure compliance with study specifications and procedures, discussions were held throughout the study with Mr. Richard W. Nichols, P.Eng., Ministry of Environment, Lands and Parks, Water Management Division, Victoria. Others contacted included:

- Mr. Dwain Boyer and Mr. Ric Baker, of the BC Environment Kootenay Region Office in Nelson, were contacted for information related to the delivery of the flood damage reduction program including the identification of tributary alluvial fan hazard areas;
- Mr. Henry Mark and Mr. Kelvin Ketchum, of BC Hydro Operations Planning, reviewed this study and provided valuable information and analyses relevant to the operation of Duncan Dam; and
- Mr. Brent Tipple, from the Water Survey of Canada Sub-office in Nelson also supplied information for this study.

Other sources of information were the Kootenay Lake Archives (in Kaslo), the Nelson Museum, the Nelson Municipal Library and local long-term residents. Mr. Richard Rodman, of Klohn-Crippen, carried out site visits on August 15, 1995 and December 4, 1995 for the purpose of backwater model setup, collection of local information and verification of floodplain mapping.

2. STUDY AREA

The study area is located on the west side of the Rocky Mountains between the Purcell and Selkirk Mountain ranges, see Drawing A-1001 and A-1002. Lardeau River, a tributary of Duncan River, flows southward and joins Duncan River approximately 1 km downstream of BC Hydro's Duncan Dam. The Duncan River continues to flow south for approximately 9 km where it discharges into the north end of Kootenay Lake. Meadow Creek joins Duncan River approximately 5 km upstream of Kootenay Lake.

The elevations of the headwaters of Duncan and Lardeau Rivers range from El. 2400 m to El. 2700 m. Many glaciers and icefields are located in the Duncan River catchment while only a few are located in the Lardeau River catchment. The Meadow Creek catchment contains no glaciers and has a maximum elevation of approximately 2400 m. There are four snow course stations in the immediate project area. Data from these stations indicate that snowpacks, at an elevation of approximately 2000 m, attain snow water equivalent depths of 1200 mm by May 1. Recorded snowpack in the valley bottom reach maximum snow water equivalent depths of 100 mm and 200 mm in April. Recorded runoff flood events can occur from late May to mid-July and are generally a result of rapid snowmelt or rain-on-snow events. Low river flow usually takes place in the months of January through March when the basins are frozen.

The Lardeau River has a catchment of approximately 1620 km^2 and has one major lake, Trout Lake, located at about the midpoint of the catchment. This river is unregulated. The Duncan River, downstream of its confluence with Lardeau River, has a catchment area of approximately 4070 km^2. Additional local tributaries between the confluence with the Lardeau River and the mouth of Duncan River at Kootenay Lake consist of Hamill, Meadow and Cooper Creeks. Approximately 50% of the Duncan River catchment area is regulated by Duncan Dam. Meadow Creek has a catchment area of approximately 125 km^2 and has no glaciers in its catchment. Several small bridges and a small diversion dam are located along its length in the area of interest.

The two major rivers flowing into Kootenay Lake are Duncan River, from the north, and Kootenay River, from the south, see Drawing A-1003. As mentioned above, Duncan River is partially regulated by Duncan Dam. The Kootenay River inflow to Kootenay Lake is regulated by Libby Dam in the United States. The Kootenay Lake water level is regulated by the operation of West Kootenay Power's Corra Linn Dam and BC Hydro's Kootenay Canal Project, both of which are located approximately 15 m downstream of Nelson on the Kootenay River. The operation of all of the dams on the Duncan and Kootenay River systems are governed by the Columbia River Treaty (CRT) and the International Joint Commission (IJC).

3. DATA USED FOR STUDY

The following is a list of data sources used for this study along with explanations of their applicability.

BC Ministry of Environment, Lands and Parks, River Survey Project 9413F036, Duncan and Lardeau Rivers and Meadow Creek

These files provided:

- Summary of Field Survey.
- Request for Survey.
- Listing of Control and Traverse.
- Lardeau River - cross sections 1 to 20 - Downstream from Howser turnoff to Duncan River confluence.
- Duncan River - cross sections 19 to 38 - Upstream from Duncan River confluence to Meadow Creek.
- Meadow Creek - cross sections 1 to 11 - Upstream from Duncan River confluence to Meadow Creek Road.
- Floodplain Mapping sheets 95-7-1 through 95-7-5, showing locations of cross-sections and BC Control Survey bench marks.
- Surveyed cross-section data on diskette in HEC-2 GR card format.

BC Ministry of Environment, Lands and Parks, Correspondence and Background Information

- Note to file 340-2184, August 1995, "Flood Levels Adopted by BC Environment for Floodplain Management Purposes Downstream of Columbia River Treaty Dams. This provided the rational for the selection of the 200-year return period Kootenay Lake Level of 536.4 m (1760.0 ft).
- Letter from R.J. White, Head of Systems and Regulation Division, Water Planning and Management Branch, Inland Waters Directorate to Miss Pat

Sloan, Planning Officer, Water Investigations Branch, dated February 25, 1975. This letter provides a flood frequency curve for regulated peak elevation on Kootenay Lake at Queens Bay, based on work carried out by the Corps of Engineers on loan to BC Hydro and Power Authority.

- BC Ministry of Environment, Lands and Parks Drawing 85-47-1, File 0305030-6, "Flood Construction Levels, Kootenay Lake - West Arm, Open Water Conditions", Issued October 1985. This provided background information for the selected Kootenay Lake design level.

- Memo from D.C. Boyer, Head of Engineering to John Dyck, Regional Manager Water Management Branch, file 55.502007, dated March 12, 1987, "Lardeau River: Howser Road Turnoff Area". This memo describes possible river training works required to provide protection for the road and residents near the Howser Road turnoff. Locations of log jams and potential new channels were also described. This memo was attached to a letter to Mr. Dirks, M.L.A., from J.H. Dyck, Regional Water Manager, dated May 27, 1987.

- Letter from D.C. Boyer, Head of Engineering to Wayne Friesen, file 55.502010, dated August 24, 1984. This letter describes gravel bar removal, Cooper Creek Channel improvements and removal of Old Argenta Bridge. These are some of the issues related to floodplain management in the valley.

- Letter from J. Dyck, Engineer for the Kaslo Water District, to Sean Hennessey, Regional District of Central Kootenay, dated November 2, 1981, file 55.502006. This letter describes possible channel modifications and resulting consequences, including removal of log jams, on the Lardeau River upstream of the Howser Bridge.

- Letter from Mr B.E. Marr, Chief Engineer, Water Rights Branch Nelson, to Mr Roy Lake, President of Willet Farmers' Institute, Argenta, dated November 20, 1969, file 55.502011. This letter, and the attached memo, describe farming potential and drainage problems near the mouth of the Duncan River. The role of other agencies such as BC Hydro, Highways, and Federal Fisheries are discussed with respect Meadow Creek and Duncan River flood levels.

BC Hydro Duncan Dam Documentation

- "System Operating Order No. 441 - Duncan Dam Project", dated July 5, 1994, attached in Appendix III. This document described the normal filling procedures and the flood surcharge operation for Duncan Dam.

- "Duncan Dam Deficiency Investigations Flood Operating Procedures", Hydroelectric Division, Report No. H2057, dated April 1991. This report provided the technical backup for the present flood surcharge operation of Duncan Dam.

- "Duncan Dam Breach Inundation Study", Hydroelectric Generation Projects Division, Report No. H1831, dated August 1985. This report demonstrated the severity of a dam breach flood in the Duncan River Valley.

- "Duncan Dam Flood Frequency Analysis without System Operating Order No. 411", by Fax from Mr. Kelvin Ketchum to Mr. Richard Rodman, dated November 17, 1995.

Nelson Museum Archives

- The Nelson Miner, June 2, 1894, describes the lake level rise of 1 inch an hour and flooding on Kootenay Lake.

- Nelson Daily News, June 7, 1928, describes high water removing fish pens on the Lardeau River after flooding the area for 11 days.

- Nelson Daily News, May 23, 1924 describes the big flood of 1894. After a mild winter it drizzled throughout February and March. Soft snow remained on the hills until mid May. At the end of May temperatures reached 98 degrees Fahrenheit followed by a thunderstorm and cloud burst in the mountains. Flooding followed.

Kootenay Lake Archives, Kaslo

- "West Kootenay, Ghost Town Country", by N.L. Barlee, Canada West Publications, 1984. This publication describes the flood of 1894 and the tremendous damages which occurred in Kaslo due to a fire in February, high Kootenay Lake levels and Kaslo River Flooding in June. In addition on June 3, 1894 at about 4 pm a "stiff, hot wind, almost tropical in the opinion of old hands, began blowing in off the lake. It picked up velocity and soon reached gale or hurricane force. .... The waves on the lake, ten feet high, lashed the lakeshore relentlessly, destroying everything within their reach."

- "Gold Creek and Ghost Towns", by N.L. Barlee, September 1974. This publication contained a photograph of Kootenay Lake and Kaslo River flooding the town of Kaslo in June 1894.

Mr. Ernie Alexander, Local Historian and Resident of Cooper Creek since 1907

- Mr. Alexander said that floods used to occur in the river valley from the end of May to mid June. Now the rivers seemed to flood later in the year. Log jams have assisted in producing the meandering river. In 1935 the rail line was washed out due to rain-on-snow and a landslide. In 1938 Cooper Creek debris and sediment flow blocked the Duncan River for a short period. The upper Duncan River used to rise 9 feet in 9 hours. Hamill Creek originally flowed directly into Kootenay Lake. In the 1920s, it blocked with a debris flow and was redirected into its present location where it discharges into Duncan River.

"Kootenay Lake Chronicles" by Edward L. Affleck

- Volume 4 in a series entitled "The Kootenays in Retrospect", The Alexander Nicolls Press, Vancouver, B.C., 1978. This publication describes a snow and mud slide, in the 1920's, which changed the outlet of Hamill Creek from Kootenay Lake to its present position on Duncan River above Cooper Creek.

Environment Canada, Water Survey of Canada, HYDAT CD ROM (Version 4.93), Stream Flow and Water Level Data

The following stations were used:

STATION NAME	STATION NUMBER
Lardeau River at Gerrard	08NH066
Lardeau River at Marblehead	08NH007
Duncan River Below B.B. Creek	08NH119
Duncan River near Howser	08NH001
Duncan Reservoir at Duncan Dam	08NH127
Duncan River near Lardeau River	08NH118
Meadow Creek above John Creek	08NH124
John Creek near Meadow Creek	08NH125
Meadow Creek Diversion below John Creek	08NH128
Fry Creek below Carney Creek	08NH130
Carney Creek below Pambrun Creek	08NH131
Kootenay Lake at Queens Bay	08NH064

Mr. Brent Tipple, Environment Canada, Water Survey of Canada, Nelson Sub-office

Mr. Tipple supplied rating curves for the Duncan and Lardeau Rivers gauging sites. He also described several bank full events which were used for HEC-2 model calibration.

Environment Canada, Atmospheric Environment Service, Canadian Monthly Climate Data and 1961-1990 Normals, CD ROM 1993 Release

Duncan Lake Dam, Station 1142574, extreme hourly wind. This data was used to determine the 200-year return period wind which would result in lake level setup and waves at the north end of Kootenay Lake.

4. HISTORICAL FLOODING

A detailed listing of historic flood events was not found during the research portion of this study. Several accounts of the Kootenay Lake flood of 1894 were obtained. Some of these are contained in Appendix II. These extreme high water levels were due to rain-on-snow combined with a very rapid increase in temperature. This event has been estimated to be about a 200-year inflow flood event by Environment Canada (Environment Canada, 1975). Modelling of this event, by the US Army Corps of Engineers with the present Columbia River Treaty Flood Control dams, resulted in a maximum Kootenay Lake level of approximately El. 535.7 m (1757.5 ft) (Environment Canada, 1975).

Historical flooding in the Duncan and Lardeau River Valleys has been mentioned by Ernie Alexander, a resident of the valley since 1907. The floods he described appeared to be the result of rain-on-snow events. Some flooding and river redirection was attributed to accumulations of debris in the channels. In the 1920s, Hamill Creek was redirected from its original channel, discharging into Kootenay Lake, to its present channel, discharging into Duncan River.

BC Ministry of Environment files for these rivers contain documentation of debris accumulations and requests for debris removal. In addition bank protection works and training works were proposed for some areas along the Lardeau River. Mapping of the river valley, produced in 1947 and contained in Appendix II, indicates high water levels and log jam locations.

Mr. Brent Tipple, of the Water Survey of Canada sub-office in Nelson, was aware of two flood events which caused bank full discharge and some overtopping of the banks. These occurred on August 26, 1976 and June 2, 1986 and have been used for model calibration purposes.

It appears from anecdotal evidence that since the regulation of the Duncan River in 1967 by Duncan Dam, flooding in the Duncan River Valley has been reduced. The peak releases from Duncan Dam have been delayed so that they occur after the annual flood events on the Lardeau River.

5. FLOOD FREQUENCY ANALYSES

5.1 General

The streamflow regime in the study area is typical of the West Kootenays. Low river flows occur in the winter with the accumulation of snow at all elevations and high river flows in the spring and summer as a result of snowmelt and rain-on-snow events. The headwaters of the Duncan and Lardeau Rivers range in elevation from El. 2400 m to El. 2700 m. Many glaciers and ice fields are located in the Duncan River catchment while only a few are located in the Lardeau River catchment. Drawing A-1001 provides a location plan of the study area. Drawing A-1002 shows the river catchments and Water Survey of Canada gauging sites. Table 1 describes the relevant WSC stations in the study area.

The Duncan River has a catchment area of 4750 km^2, where it discharges into Kootenay Lake. The Lardeau River has a catchment of 1620 km^2, at the WSC gauge near Marblehead, upstream of its confluence with the Duncan River. Duncan Dam is located on the Duncan River just upstream of this confluence and has a catchment area of 2410 km^2. Between the confluence of the Duncan and Lardeau Rivers and Kootenay Lake the major local catchments are: Meadow Creek (125 km^2); Hamill Creek (309 km^2); and Cooper Creek (242 km^2). An additional local catchment of 44 km^2 is located between the mouth of the Lardeau River and Meadow Creek. Described below are flood frequency analyses carried out for the Lardeau River and Meadow Creek and the flood frequency analyses and reservoir routing simulations to obtain return period releases from Duncan Dam. In addition, an estimate of the unregulated flood frequency relationship for the Duncan River is described. Concurrent discharges, to be used for floodplain mapping purposes, for the Lardeau and Duncan Rivers and their local catchment areas are also derived.

Table 1 Relevant Water Survey of Canada Gauges

STATION NAME	STATION NUMBER	DATA TYPE	PERIOD OF RECORD	YEARS OF MAXIMUM INSTANTANEOUS DATA	YEARS OF MAXIMUM DAILY DATA	CATCHMENT AREA (km^2)
Lardeau River at Gerrard	08NH066	Flow	1934-1966	0	23	769
Lardeau River at Marblehead	08NH007	Flow	1917-present	30	51	1620
Duncan River Below B.B. Creek	08NH119	Flow	1962-present	31	31	1330
Duncan River near Howser	08NH001	Flow	1915-1967	0	39	2160
Duncan Reservoir at Duncan Dam	08NH127	Level	1967-present	26	27	2410
Duncan River near Lardeau River	08NH118	Flow	1963-present	31	31	4070
Meadow Creek above John Creek	08NH124	Flow	1967-1973	0	7	62.7
John Creek near Meadow Creek	08NH125	Flow	1967-1973	0	7	34.7
Meadow Creek Diversion below John Creek	08NH128	Flow	1968-1973	0	5	Regulated
Fry Creek below Carney Creek	08NH130	Flow	1973-present	20	21	461
Carney Creek below Pambrun Creek	08NH131	Flow	1973-present	20	21	118

All flood frequency analyses were carried out using the Environment Canada computer program, "Consolidated Flood Frequency Analyses (CFA)", (Environment Canada, 1992).

5.2 Lardeau River Analyses

The WSC stream gauging station, Lardeau River at Marblehead, has discontinuous instantaneous and maximum daily discharge data starting in 1917. As indicated in Table 1 there are 30 years of instantaneous and 51 years of maximum daily discharge data. All of the peak flood events occur from late May to early July. These are snowmelt or rain-on-snow events. WSC personnel who service this gauge indicated that the rating curve does shift from year to year due to movements of sediments and debris and therefore they carry out discharge measurements on a frequent basis. The water level gauge recorder has been located sufficiently upstream from the Duncan River to ensure that backwater from high flows on the Duncan River do not affect recorded water levels.

Flood frequency analyses of instantaneous and maximum daily discharges for the relevant WSC stream gauging stations in the study area, indicated that the Generalized Extreme Value (GEV) probability distribution was the most applicable distribution. The other probability distributions which were compared to the GEV were: Three Parameter Lognormal; Log Pearson Type III; and Wakeby. The GEV distribution was selected since it provided the best fit to the data and did not result in the highest or lowest estimates of 20-year and 200-year return period events for the stations analyzed. Table 2 provides the results of the frequency analyses based on the GEV distribution. Drawings A-1004 and A-1005 show the maximum daily and instantaneous GEV

Table 2 - Return Period Discharge

LOCATION		Catchment Area	20-Year				200-Year			
			Maximum Daily Flow		Max. Instantaneous Flow		Maximum Daily Flow		Max. Instantaneous Flow	
Name	WSC Number	(km^2)	Q (m^3/s)	q($m^3/s/km^2$)	Q (m^3/s)	q($m^3/s/km^2$)	Q (m^3/s)	q($m^3/s/km^2$)	Q (m^3/s)	q($m^3/s/km^2$)
Lardeau River at Marblehead	08NH007	1,620	382	0.24	407	0.25	462	0.29	522	0.32
Lardeau River at Marblehead (July 15 - Sept. 15)	08NH007	1,620	265	0.16	---	---	338	0.21	---	---
Duncan River below B.B. Creek	08NH119	1,330	498	0.37	625	0.47	637	0.48	920	0.69
Duncan River near Howser	08NH001	2,160	579	0.27	---	---	683	0.32	---	---
Duncan River at Duncan Dam (Unregulated and extended period of record)	---	2,410	723	0.30	---	---	896	0.37	---	---
Fry Creek below Carney Creek	08NH130	461	180	0.39	229	0.50	222	0.48	339	0.74
Carney Creek below Pambrun Creek	08NH131	118	44	0.37	55	0.47	54	0.46	71	0.60
Meadow Creek [1]	---	125	47	0.37	58	0.47	57	0.46	75	0.60
Hamill Creek [2]	---	309	121	0.39	153	0.50	149	0.48	227	0.74
Cooper Creek [1]	---	242	89	0.37	113	0.47	111	0.46	146	0.60

Notes: 1. Pro-rated using unit runoff from Carney Creek.
2. Pro-rated using unit runoff from Fry Creek.

frequency plots. The estimated annual maximum discharges for the Lardeau River at Marblehead are:

- 20-year, 382 m^3/s (daily), 407 m^3/s (instantaneous); and
- 200-year, 462 m^3/s (daily), 522 m^3/s (instantaneous).

Section 5.5.1 describes the coincident discharges to be used for floodplain mapping of the Lardeau River.

Table 2 indicates the unit discharge for the return period discharges. The unit discharge for the Lardeau River at Marblehead is lower than Duncan River near Howser unit discharge values. This appears to be due to the attenuating effects of Trout Lake, which affects nearly 50% of the Lardeau River catchment area. In addition the Trout Lake catchment represents most of the high elevation fast runoff catchment area of the Lardeau River.

5.3 Meadow Creek Analyses

Meadow Creek has a catchment area of 125 km^2 and enters Duncan River just upstream of Kootenay Lake. The maximum elevation in the Meadow Creek catchment is approximately El. 2400 m. The three WSC gauges on Meadow Creek have insufficient data (7 to 5 years of maximum daily values) to carry out flood frequency analyses with any confidence. This data does indicate that peak discharges have occurred from late May to late June. Data from John Creek, a tributary to Meadow Creek, indicates peak discharges in this same period.

The only WSC gauge with a similar catchment area is Carney Creek below Pambrun Creek, 118 km^2, with maximum catchment elevation of approximately El. 2700 m. The timing of flood events on Carney Creek is from late May to early July, consistent with

Meadow Creek and the Lardeau River. Because of these similarities, the 20-year and 200-year unit discharges from Carney Creek, see Table 2 and Drawings A-1006 and A-1007, were used to estimate the following return period discharges for Meadow Creek: 20-year, 47 m^3/s (daily), 58 m^3/s (instantaneous) and 200-year, 57 m^3/s (daily), 75 m^3/s (instantaneous). In comparison, maximum recorded daily discharge on Meadow Creek, immediately downstream of John Creek, was 20.4 m^3/s on June 9, 1972. The catchment area at this point is approximately 97 km^2. This maximum discharge, recorded over a 7-year period of record, indicates that the Carney Creek data may somewhat overestimate discharges on Meadow Creek as would be expected due to the difference in catchment elevations. The peak discharge for 1972 on the Lardeau River had a return period of approximately 90 years and on the Duncan River approximately 20 years, based on estimated unregulated discharges. This indicates that the 1972 flood was well above normal.

As discussed in Section 7.2, Calculated River Flood Levels, the design flood levels in Meadow Creek, within the study area, are governed by the flood levels in the Duncan River and the elevation of Highway 31. Flood waters from Meadow Creek cannot drain into Duncan River due to high water levels and therefore pond and overtop Highway 31.

5.4 Duncan Dam Release Analyses

5.4.1 General

The Duncan River has been regulated since 1967, when the Duncan Storage Dam was completed. Estimation of the return period flood discharges on Duncan River are influenced by the operation of Duncan Dam. This dam is operated under the terms of the Columbia River Treaty and therefore its normal filling operation is governed by the Treaty. BC Hydro's System Operating Order (SOO) No. 4P-41 (see Appendix III) and Local Operating Orders No. 3P04-02B, 3P04-02D, 3P04-02F and 3P04-02G cover the operation of the Duncan Project. An Emergency Surcharge Operating Procedure (ESOP) is included in SOO 4P-41. During large runoff events with the reservoir level approaching full pool, the ESOP defines the minimum project discharge in order to preserve dam safety while minimizing the peak downstream discharge.

However, BC Hydro may choose to release more than the minimum specified by the ESOP if the dam is believed to be in any jeopardy. If, for example, the reservoir were full with the forecast calling for increasing inflows, BC Hydro may pass inflows to ensure that the reservoir level does not rise above the full pool level (BC Hydro, 1996). This scenario is referred to as "Duncan Dam Release without Emergency Surcharge Operating Procedure".

Klohn-Crippen developed a reservoir routing program which simulated the ESOP. Analyses of reservoir levels and inflow volumes were carried out. This preliminary analysis demonstrated that the releases from Duncan Dam with the ESOP were less than releases without the ESOP. Therefore, the results of the analysis of Duncan Dam Releases without ESOP are presented in Section 5.4.2.

For comparison purposes, an analysis of unregulated discharges on the Duncan River at Duncan Dam has also be carried out and is presented in Section 5.4.3.

5.4.2 Duncan Dam Release without Emergency Surcharge Operating Procedure

BC Hydro has stated that, for power optimization of the Kootenay River hydropower plants and sometimes due to operational constraints which may be imposed on BC Hydro as part of the Columbia River Treaty, Duncan Dam Reservoir will fill prior to the completion of the snowmelt recession limb in most years.

BC Hydro has indicated that, typically, the Kootenay River plants reach full discharge capacity and are on the point of spilling around May 1. At this time BC Hydro begins to release minimum flows, 3 m^3/s, from Duncan Dam and starts filling Duncan Reservoir. The date at which the Maximum Normal Level, El. 576.68 m, is reached depends on the size of the snowpack and therefore is quite variable. The reservoir typically fills prior to completion of the snowmelt recession limb.

BC Hydro has proposed the following scenario. It is likely that the Duncan Reservoir would be nearly empty on 1 May and would begin releasing minimum discharge, 3 m^3/s, on that date to begin refilling the reservoir. On balance, this typical operation minimizes the peak summer level for Kootenay Lake and produces the most energy benefits at the Kootenay River hydro projects through reduction of spill.

When the Maximum Normal Level is reached it is reasonable to assume that inflows would be released to prevent the reservoir from rising, for dam safety reasons, rather than following the Emergency Surcharge Operating Procedures contained in System Operating Order No. 4P-41. For this scenario, releases from Duncan Dam would equal inflows when the reservoir has reached Maximum Normal Level.

BC Hydro modelled this scenario using 67 years of daily inflow records. Depending on the water year, peak releases generally occurred from mid July to the end of August, see Table 3. Klohn-Crippen carried out a frequency analysis, using CFA, of the release discharges provided by BC Hydro from their modelling. This analysis resulted in a 20-year return period release of 470 m^3/s and 200-year return period release of 600 m^3/s, (see Drawing A-1008).

Table 3 Duncan Dam Releases Without Emergency Surcharge Operating Procedure

YEAR	DATE OF MAXIMUM RELEASE	DUNCAN DAM MAXIMUM RELEASE (m^3/s)	YEAR	DATE OF MAXIMUM RELEASE	DUNCAN DAM MAXIMUM RELEASE (m^3/s)
1915	18 Aug	262.9	1963	15 Aug	237.6
1916	22 Jul	323.4	1964	16 Jul	489.5
1917	27 Jul	265.1	1965	06 Aug	265.1
1918	20 Jul	386.1	1966	19 Jul	323.4
1919	04 Aug	281.6	1967	13 Jul	468.0
1934	30 Jul	265.1	1968	14 Jul	306.0
1935	25 Jul	326.7	1969	25 Jul	230.0
1936	23 Jul	255.2	1970	06 Aug	203.0
1937	03 Oct	212.3	1971	23 Jul	406.0
1938	21 Jul	242.0	1972	13 Jul	468.0
1939	24 Oct	321.2	1973	11 Aug	201.7
1940	31 Jul	223.3	1974	20 Jul	459.0
1941	17 Aug	155.1	1975	22 Aug	217.0
1942	21 Aug	185.9	1976	06 Sep	509.0
1943	14 Aug	170.5	1977	24 Aug	271.0
1944	13 Sep	116.6	1978	27 Jul	265.4
1945	20 Aug	118.8	1979	31 Aug	178.0
1946	14 Jul	339.9	1980	23 Jul	286.0
1947	16 Jul	358.6	1981	28 Jul	328.0
1948	25 Jul	232.1	1982	21 Jul	314.2
1949	22 Aug	113.3	1983	11 Aug	318.0
1950	28 Jul	292.6	1984	27 Aug	436.0
1951	18 Jul	416.9	1985	04 Aug	178.1
1952	02 Aug	210.1	1986	23 Jul	250.0
1953	21 Jul	326.7	1987	31 Jul	214.7
1954	18 Jul	470.8	1988	21 Jul	234.7
1955	21 Jul	430.1	1989	09 Aug	221.0
1956	15 Jul	370.7	1990	27 Jul	281.0
1957	17 Jul	249.7	1991	10 Aug	451.0
1958	05 Jul	273.9	1992	07 Aug	198.0
1959	25 Jul	435.6	1993	23 Aug	177.0
1960	24 Jul	282.7	1994	29 Jul	267.0
1961	17 Jul	289.3	1995	26 Jul	301.0
1962	28 Jul	288.2			

Note: Data provided by BC Hydro, Power Supply Operations, (BC Hydro, 1995a).

5.4.3 Duncan River Unregulated Analysis

Included on Drawing A-1008 is an unregulated annual daily peak discharge frequency analysis for Duncan River at Duncan Dam. This curve was developed by combining maximum daily discharges from BC Hydro daily inflow records (1982 to 1991, 1993 and 1994) and the WSC gauges Duncan River near Howser (1915 to 1919, 1934 to 1962) and Duncan River below B.B. Creek (1963 to 1981 and 1992). Values from the Howser gauge were factored up by the ratio of the catchment area of Duncan Dam to the gauge catchment area, 2410 km^2/2160 km^2 = 1.12. Values from the below B.B. Creek gauge were factored by 1.56, which was obtained from comparison of the 10 years of daily discharge data with the BC Hydro Duncan Dam daily inflows. As expected, this ratio is less than the ratio of catchment areas, 2410 km^2/1330 km^2 = 1.81, since the unit runoff would be expected to be less for a catchment of nearly twice the size. Comparison of the Duncan Dam release return period relationship and the unregulated annual peak discharge frequency analysis for Duncan River at Duncan Dam, shown on Drawing A-1008, indicates that the storage available in Duncan Reservoir reduces peak discharges from those which would have occurred without the dam:

	Daily Flood Discharge	
	20-year	**200-year**
Duncan River at Duncan Dam unregulated (natural) discharges	723 m^3/s	896 m^3/s
Duncan Dam Releases without ESOP	470 m^3/s	600 m^3/s

Downstream of the Lardeau River, the natural discharge from the Lardeau River and other local inflows, would be added to the Duncan River discharge at Duncan Dam to obtain the Duncan River discharge at the mouth. The column titled "Greater than Governing Design Discharge", contained in Table 10, presents these discharges.

5.5 Coincident Discharges

5.5.1 Lardeau River

Since the Duncan River has a major tributary within the study reach, the Lardeau River, it is necessary to determine the appropriate coincident discharges during flood events which occur at different times of the year. The analyses of the peak flood discharges on the Lardeau River indicated that they historically have occurred from late May to early July. This is the filling period for the Duncan Dam. At this time of year the reservoir level has historically been well below levels which would trigger spill releases. A minimum release of 3 m^3/s is specified in the System Operating Order during filling at low levels. Historically mean monthly releases from Duncan Dam, from late May to early July, average 60 m^3/s, using all of the records, or 80 m^3/s, if the months with minimum release of 3 m^3/s are removed from the record. The maximum monthly release from Duncan Dam in this period was 230 m^3/s. A release of 100 m^3/s has been selected as an appropriately conservative release from Duncan Dam to be used in coincidence with a flood on the Lardeau River, for the purposes of floodplain mapping. If there was serious flooding on the Lardeau and empty storage space at Duncan Dam, BC Hydro would likely reduce the Duncan discharge to 3 m^3/s, both for energy maximization and flood control reasons. Using a Duncan discharge of 100 m^3/s is likely conservative, but not unreasonable (BC Hydro, 1996).

Meadow, Hamill and Cooper Creeks join Duncan River below the Lardeau River. Review of the 5 to 7 years of overlapping data for Meadow Creek indicated that generally Meadow Creek peaks about 1 day before the Lardeau River. Comparison of Lardeau River floods with those on Carney Creek below Pambrun Creek and Fry Creek below Pambrun Creek indicated that several events on these creeks peaked about 1 day before the Lardeau River and some events peaked on the same day. For these reasons the 20-year and 200-year return period maximum daily discharge for these three creeks was added to the 20-year and 200-year instantaneous and daily discharges from the Lardeau River (see Table 4).

Similar to the Meadow Creek analysis, the maximum daily return period discharges for Cooper Creek were based on the unit runoff from Carney Creek below Pambrun Creek due to similarities in catchment areas. The maximum daily return period discharges for Hamill Creek were based on the unit runoff from Fry Creek below Pambrun Creek due to similarities in catchment area and basin exposure. Return period discharges and unit runoff for Fry Creek are presented in Table 2 and plots of the distributions on Drawings A-1009 and A-1010.

A summary of the local inflows and total flows coincident with a flood on the Lardeau River are presented in Table 4. The flows listed in Table 4 were used to determine governing flood levels discussed in Section 7.2, Tables 7 and 8.

5.5.2 Duncan River

As discussed in Section 5.4.1, BC Hydro is of the opinion that, should a major runoff event occur during the snowmelt period and with the reservoir at Maximum Normal Level (MNL), it is quite possible that a decision would be made to pass inflow to ensure that the reservoir is not surcharged. Although SOO Procedures are in place to permit short-term reservoir surcharge to reduce downstream flooding, these procedures are not mandatory and are used at the discretion of BC Hydro operating staff. If, for example, further rainfall is forecast with the reservoir at Maximum Normal Level, then BC Hydro would likely choose to release inflows to avoid jeopardizing dam safety. BC Hydro suggests that this scenario is sufficiently realistic and provides operational flexibility during high flow periods.

Table 4 Lardeau River Flood and Coincident Return Period Discharges

LOCATION	20-YEAR RETURN PERIOD DISCHARGE (m^3/s)				200-YEAR RETURN PERIOD DISCHARGE (m^3/s)			
	Daily		Instantaneous		Daily		Instantaneous	
	Local	Total	Local[1]	Total	Local	Total	Local[1]	Total
Lardeau at Marblehead	-	382	-	407	-	462	-	522
Duncan Dam Release	100	482	100	507	100	562	100	622
Meadow Creek[2] plus local catchment of 44 km^2	62	544	62	569	77	639	77	699
Hamill Creek[3]	121	665	121	690	149	788	149	848
Cooper Creek[2]	89	754	89	779	110	898	110	958
Total Discharge on Duncan River at Kootenay Lake		754		779		898		958

Notes:

1. Local instantaneous discharges are equal to daily discharges, as explained in Section 5.5.1.
2. Daily return period flow based on Carney Creek below Pambrun Creek unit runoff, see Table 2.
3. Daily return period flows based on Fry Creek below Carney Creek unit runoff, see Table 2.

Based on the information presented above, the flood release discharges without SOO, 470 m^3/s for 20-year and 600 m^3/s for 200-year, are recommended as the design discharges for floodplain mapping. They are presented in Table 5 along with the Lardeau and local inflows described below.

Table 5 Duncan Dam Flood Releases and Coincident Return Period Discharges

LOCATION	20-YEAR RETURN PERIOD DAILY DISCHARGE (m^3/s)		200-YEAR RETURN PERIOD DAILY DISCHARGE (m^3/s)	
	Local	Total	Local	Total
Lardeau at Marblehead (15 July - 15 September)	265	265	338	338
Duncan Dam	470	735	600	938
Meadow Creek[1] plus local catchment of 44 km^2	44	779	54	992
Hamill Creek[2]	84	863	104	1096
Cooper Creek[1]	63	926	78	1174
Total Discharge on Duncan River at Kootenay Lake		926		1174

Notes:

1. Daily return period flow based on 70% of Carney Creek below Pambrun Creek unit runoff, see Table 2.

2. Daily return period flow based on 70% of Fry Creek below Carney Creek until runoff, see Table 2.

For comparison, the Columbia River Treaty specifies a nominal maximum discharge for Duncan Dam of 570 m^3/s, although the Duncan Dam release facilities can release up to 1600 m^3/s at Maximum Normal Reservoir Level. The maximum release that has occurred, over nearly 30 years of operation, was 459 m^3/s on August 26, 1976. This is essentially the same as the estimate of 470 m^3/s for the 20-year return period release.

The Duncan Dam Beach Innundation Study estimates a maximum release of approximately 28,000 m^3 in the event of a breach of Duncan Dam (BC Hydro, 1985).

The reservoir routing results, described above, conclude that the peak releases from Duncan Dam are expected to occur as the reservoir is nearing or at MNL, that is generally between July 15 and September 15. Since the release from Duncan Dam is triggered by a large inflow flood it is likely that the Lardeau River will also be flooding. Due to the flood operating procedures for Duncan Dam, the maximum release can occur just before the peak reservoir inflow or up to about 12 hours after the peak reservoir inflow has occurred. For the purposes of deriving concurrent flows for floodplain mapping, it is reasonable to combine the return period daily discharge on the Lardeau River, which could occur between 15 July to 15 September, with the return period release from Duncan Dam.

Once a large release is initiated, the SOO requires that the lake level be monitored and, once levels start to drop, releases can be reduced. Therefore, the maximum release would be maintained for longer than instantaneous events. For these reasons, the maximum releases presented in Table 5 are considered daily values and there are no instantaneous values.

A flood frequency analysis was carried out for maximum daily discharges from 15 July to 15 September for the period of record on the Lardeau River at Marblehead. As shown in Table 2 and Drawing A-1011, the resulting return period daily discharges are 265 m^3/s for 20-year and 338 m^3/s for 200-year. These values are approximately 70% of the annual maximum values for the Lardeau River presented in Table 2, indicating that fairly high flows occur on the Lardeau River in this period.

Local inflows from Meadow Creek, Hamill Creek and Cooper Creek, coincident with return period releases from Duncan Dam, have been approximated as 70% of the annual daily return period discharges. Table 5 summarizes the discharges to be used coincident with return period releases from Duncan Dam. The flows listed in Table 5 were used to determine governing flood levels discussed in Section 7.2, Tables 7 and 8.

6. HYDRAULIC ANALYSES

6.1 General

All water surface profiles were estimated with the HEC-2 computer program. Input to this program includes cross-section geometry, reach lengths, discharges, ineffective flow areas and estimates of energy loss coefficients. Calibration of the computer model with known flows and corresponding river elevations is required to model river levels at various flows. Caution must be used when modelling beyond calibration events.

Cross-section geometry and reach lengths were obtained from detailed surveys which were carried out by the Ministry of Environment in September and October 1995. Locations of all cross sections are shown on the floodplain maps in Appendix IV. The cross-section data was provided to Klohn-Crippen along with topographic maps showing their locations and a set of photographs at each cross section showing the banks and views looking upstream and downstream. Extensions to the cross-sections were made, where required, based on the topographic maps. A site visit was made by Mr. Richard Rodman of Klohn-Crippen, on August 15, 1995, to assist in determining the correct modelling coefficients and cross-section configurations.

The following sections describe Kootenay Lake levels, the river profile model and model calibration.

6.2 Kootenay Lake Levels

For the purposes of HEC-2 backwater modelling of the Duncan River a mean high water Kootenay Lake level is recommended. There are no lake level gauges near the north end of Kootenay Lake, so the station Kootenay Lake at Queens Bay was used. The operation of Kootenay Lake is governed by the International Joint Commission (IJC) Order for Kootenay Lake. West Kootenay Power (WKP), as the holder of the IJC Order, is responsible for ensuring that a violation of the Order does not occur. Under terms of the Kootenay Canal Agreement, BC Hydro normally directs the discharges at the Corra Linn and Kootenay Canal projects, at the outlet of Kootenay Lake. However, WKP has the right to override BC Hydro's direction to ensure that the IJC Order conditions are met.

Inflows to Kootenay Lake are partially controlled by the upstream Duncan and Libby dams, both built under terms of the Columbia River Treaty. Operation of these two upstream dams, however, cannot force a violation of the Kootenay Lake IJC Order.

Typically, from April through mid-June, the maximum discharge from Kootenay Lake is maintained. During these months, the lake discharge is limited only by the discharge capability at Grohman Narrows, in the west arm of Kootenay Lake, upstream of Corra Linn. As the lake level nears its peak (typically in June) and begins receding, the Kootenay Lake discharge is typically reduced, while still observing the IJC Order.

BC Hydro reports that, between 1975 (when Libby began operation) and 1992, Duncan, Libby, and Kootenay Lake were operated in a fairly consistent manner. However, since 1993, summer releases from Libby Dam, have been augmented for US fisheries purposes. With low runoff conditions in 1993-94, the peak Kootenay Lake levels remained in the "normal" range. However, with average runoff in 1995, Kootenay Lake reached a peak level that was the third highest in the 22 years since construction of Libby Dam.

BC Hydro expects that these higher summer releases from Libby Dam, resulting in higher peak Kootenay Lake levels, will continue indefinitely. BC Hydro estimates that the peak Kootenay Lake level regime will be, on average, 0.6 m to 1.0 m higher with the Libby discharge regime that has been adopted for US fisheries concerns.

Klohn-Crippen carried out a flood frequency analysis of maximum annual instantaneous lake levels for the period 1972 to 1992, see Drawing A-1012. The mean of the instantaneous maximum lake levels is approximately El. 532.7 m. This level has been increased by 0.6 m, to El. 533.3 m, as an approximate estimate of the future average maximum Kootenay Lake level. This level is then used as the starting water level for all HEC-2 backwater analyses. As indicated in Section 7.3, the calculated water levels are not sensitive to the assumed starting water level at Kootenay Lake.

6.3 HEC-2 River Model Setup and Calibration

The cross sections provided by the Ministry of Environment were imported into the BOSS version of HEC-2. Back channel sections were connected to main channel sections to span the valley from side to side. Based on aerial photographs and survey data file, overbank locations were identified and marked as such. Two additional cross sections were created from 1:5000 topographic maps to represent the transition from Duncan River to Kootenay Lake. These cross sections were located 2.1 km and 2.5 km downstream of the furthest downstream surveyed cross section.

A surveyed river water surface profile was available for September and October 1994. The river was not in flood at that time and therefore this profile was not used for calibration. Mr. Brent Tipple, of Water Survey of Canada, Nelson Sub-office, identified August 26, 1976 and June 2, 1986 as dates on which bank full flow conditions occurred on the Duncan and Lardeau Rivers. Minor overtopping of the banks was experienced during these events. Table 6 provides the discharges used for these two calibration events. The discharges are based on the Duncan and Lardeau River gauges and Carney and Fry Creek gauges, used to estimate inflows from Meadow, Hamill and Cooper Creeks. Coincident Kootenay Lake levels, also shown in the Table 6, were obtained from the level gauge at Queens Bay. The profiles for the calibration events are shown on Drawing B-1015.

Table 6 Calibration Events

Location	August 26, 1976*	June 2, 1986
	Mainstream Discharge (m^3/s)	
Lardeau River	153	400
Duncan River downstream of Lardeau River	631	420
Duncan River downstream of Meadow Creek	649	476
Duncan River downstream of Hamill Creek	687	606
Duncan River at the Mouth	712	686
Kootenay Lake Level (m)	532.3	532.8

*Date of maximum release from Duncan Dam since dam construction, see Section 5.5.2.

7. FLOOD LEVELS

7.1 Kootenay Lake Flood Levels

The BC Ministry of Environment, Lands and Parks adopted the 200-year Kootenay Lake Flood Level as 536.4 m (1760.0 ft) in 1975 for administrative purposes under the flood damage reduction program. This level was based on routing of the estimated 200-year return period inflows through the Kootenay Lake system following the Columbia River Treaty Flood Operation and maximum lake level analyses provided by Environment Canada. The highest recorded level occurred in 1961 at 537.2 m (1762.4 ft). This level would reduce to 534.0 m (1752.0 ft) under the Columbia River Treaty Flood Operation Plan, as reported by Ministry of Environment, Lands and Parks. The largest flood of record, 1894, would produce a regulated level of 535.7 m (1757.5 ft). (Environment Canada, 1975).

Klohn-Crippen selected maximum instantaneous lake levels for the period 1972 to 1992 from the Water Survey of Canada Gauge Kootenay Lake at Queens Bay, as described in Section 6.2, and shown on Drawing A-1012. The resulting 200-year return period lake level was El. 534.8 m. As discussed in Section 6.2, summer releases from Libby Dam have been increased since 1992 for Fisheries purposes. This has resulted in an increase in the maximum annual Kootenay Lake level of approximately 0.6 m to 1.0 m, as estimated by BC Hydro Operations Planning, Power Supply Operations.

Since the mouth of the Duncan River is located at the north end of Kootenay Lake, Klohn-Crippen estimated the wind setup and wave generation expected due to winds blowing from the south. Eighteen years of extreme hourly winds were available from the AES station at Duncan Dam, Number 1142574. The maximum annual hourly winds from the southeast, south or southwest were selected and a frequency analysis carried out using CFA. The Three Parameter Lognormal distribution was selected and produced a

200-year return period wind speed of approximately 74 km/hr. For setup calculations the entire fetch, 103 km was reduced to an effective fetch of 12.4 km due to the narrow average width of 3.5 km. Assuming an average depth of 20 m resulted in a setup at the north end of Kootenay Lake of approximately 0.5 m. This value is an upper bound since a longer duration than hourly would most likely govern the setup.

Based on nomographs from the US Army Corps of Engineers, Shore Protection Manual a significant wave height of 1.2 m was estimated, with a required wind duration of 1.5 to 2 hours. Since hourly wind data was used the estimated significant wave height is also an upper bound.

Combining the various factors as follows results in an estimated Kootenay Lake level of El. 537.1 m. The Kootenay Lake level used for the HEC-2 simulations was El. 533.3 m.

200-year return period lake level	El. 534.8 m
Allowance for modified Libby Operation	0.6 m
Allowance for setup	0.5 m
Significant wave height	1.2 m
Resultant Kootenay Lake Level at the Duncan River Mouth	El. 537.1 m

This value is 0.7 m higher than the present designated Kootenay Lake 200-year flood level adopted in 1975. BC Hydro Operations Planning, Power Supply Operations intends to carry out a detailed return period study of the Kootenay Lake levels based on routing of historical inflows through the Kootenay Lake system accounting for the operation of the dams on the system, including the modified Libby Dam operation.

Klohn-Crippen recommends that the Kootenay Lake 200-year return period flood level remain unchanged at this time at El. 536.4 m until BC Hydro completes their study. Properties at or near the lake shore, that are exposed to a long fetch, may be subject to a special flood hazard related to wave action, as noted on Drawing 93-3-1. When BC Hydro completes their study a detailed wind wave analysis should also be carried out, with adjustments for wind duration, to re-evaluate the designated Kootenay Lake Flood Level at the mouth of the Duncan River.

7.2 Calculated River Flood Levels

The Duncan and Lardeau River flood levels are dependent on both regulated and natural flood flows. Based on the information presented in Tables 4 and 5 of Section 5.5, design discharges are as shown in Tables 7 and 8. The governing discharges and resulting water levels are shown in bold and italics in the tables.

The Duncan River 200-year return period release from Duncan Dam, without the ESOP and with coincident 200-year return period inflows for the period 15 July to 15 September, results in the maximum water levels. For the Lardeau River the maximum annual instantaneous discharge on the Lardeau River with an associated monthly release from Duncan Dam and estimated 200-year return period daily local inflows result in maximum water levels on the Lardeau River. The 20-year return period design discharges were similarly derived for both rivers.

Table 7 Design Discharges and Resulting Water Levels - 200-Year Return Period

Cross Section	Duncan River Flood[1]		Lardeau River Flood[2]	
	Discharge (m3/s)	Water Level (m)	Discharge (m3/s)	Water Level (m)
(Duncan River Mouth) XS-35/35a	***1174***	***534.9***[3,4]	958	534.6
XS-34	***1174***	***535.8***[3]	958	535.6
XS-33	***1174***	***537.5***	958	537.3
XS-32	***1174***	***538.7***	958	538.5[4]
XS-31	***1174***	***539.5***	958	539.2
XS-30	***1096***	***540.8***	848	540.3
XS-29	***1096***	***541.2***	848	540.6
XS-28	***992***	***541.8***	699	541.1
XS-27	***992***	***541.9***	699	541.2
XS-26/38	***938***	***542.2***	622	541.6
XS-25	***938***	***542.4***	622	541.9
XS-24	***938***	***542.9***	622	542.4
XS-23	***938***	***543.8***	622	543.3
XS-22	***938***	***544.8***	622	544.2
XS-21	***938***	***546.0***	622	545.2
(Lardeau River Mouth) XS-20	***338***	***547.1***	522	546.4
XS-19	***338***	***547.2***	522	547.0
XS-18	338	548.1	***522***	***548.8***[4]
XS-17	338	549.1	***522***	***549.8***

Notes:

1. See Table 5 for discharges.
2. See Table 4 for discharges.
3. Kootenay Lake Flood Level, El. 536.4 m, governs.
4. Bold and italic values govern. See Table 11 for levels used in Floodplain Delineation (including contingency allowances).

Table 7 Design Discharges and Resulting Water Levels - 200-Year Return Period (continued)

Cross Section (Lardeau River Upstream of Mouth)	Duncan River Flood[1]		Lardeau River Flood[2]	
	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)
XS-16	338	550.1	522	***550.6*** [4]
XS-15	338	550.8	522	***551.1***
XS-14	338	552.0	522	***552.8***
XS-13	338	553.2	522	***553.9***
XS-12	338	554.7	522	***555.2***
XS-11	338	556.3	522	***557.0***
XS-10	338	556.7	522	***557.2***
XS-9	338	557.8	522	***558.1***
XS-8	338	558.9	522	***559.1***
XS-7	338	560.6	522	***561.4***
XS-6	338	561.2	522	***561.9***
XS-5	338	561.9	522	***562.7***
XS-4	338	562.5	522	***563.2***
XS-3	338	563.9	522	***564.2***
XS-2	338	564.7	522	***565.1***
XS-1	338	565.7	522	***566.2***

Notes:

1. See Table 5 for discharges.
2. See Table 4 for discharges.
4. Bold and italic values govern. See Table 11 for levels used in Floodplain Delineation (including contingency allowances).

Table 8 Design Discharges and Resulting Water Levels - 20 year Return Period

Cross Section	Duncan River Flood[1]		Lardeau River Flood[2]	
	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)
(Duncan River Mouth)XS-35/35a	***926***	***534.5*** [3, 4]	779	534.3
XS-34	***926***	***535.5*** [3]	779	535.4
XS-33	***926***	***537.3***	779	537.1
XS-32	***926***	***538.4***	779	538.2
XS-31	***926***	***539.2***	779	538.9
XS-30	***926***	***540.2***	690	539.8
XS-29	***926***	***540.6***	690	540.1
XS-28	***863***	***541.2***	569	540.5
XS-27	***863***	***541.4***	569	540.7
XS-26/38	***735***	***541.8***	507	541.1
XS-25	***735***	***542.1***	507	541.4
XS-24	***735***	***542.6***	507	542.2
XS-23	***735***	***543.5***	507	543.0
XS-22	***735***	***544.5***	507	544.0
XS-21	***735***	***545.5***	507	544.8
(Lardeau River Mouth) XS-20	***265***	***546.5***	407	546.0
XS-19	***265***	***546.7***	407	546.7
XS-18	***265***	***547.7***	407	548.4
XS-17	265	548.7	***407***	***549.3*** [4]
XS-16	265	549.9	***407***	***550.3***

Notes:

1. See Table 5 for discharges.
2. See Table 4 for discharges.
3. Kootenay Lake Flood Level, El. 536.4 m, governs.
4. Bold and italic values govern. See Table 11 for levels used in Floodplain Delineation (including contingency allowances).

Table 8 Design Discharges and Resulting Water Levels - 20 year Return Period (continued)

Cross Section (Lardeau River Upstream of Mouth)	Duncan River Flood[1]		Lardeau River Flood[2]	
	Discharge (m^3/s)	Water Level (m)	Discharge (m^3/s)	Water Level (m)
XS-15	265	550.7	***407***	***551.0*** [4]
XS-14	265	551.7	***407***	***552.4***
XS-13	265	552.8	***407***	***553.6***
XS-12	265	554.4	***407***	***554.9***
XS-11	265	555.9	***407***	***556.7***
XS-10	265	556.3	***407***	***557.0***
XS-9	265	557.5	***407***	***557.9***
XS-8	265	558.7	***407***	***559.1***
XS-7	265	560.2	***407***	***560.9***
XS-6	265	560.8	***407***	***561.5***
XS-5	265	561.5	***407***	***562.3***
XS-4	265	562.2	***407***	***562.8***
XS-3	265	563.8	***407***	***564.0***
XS-2	265	564.5	***407***	***564.8***
XS-1	265	565.5	***407***	***565.9***

Notes:

1. See Table 5 for discharges.
2. See Table 4 for discharges.
4. Bold and italic values govern. See Table 11 for levels used in Floodplain Delineation (including contingency allowances).

7.3 Sensitivity Analyses

Sensitivity analyses were done to estimate the effect of modelling data assumptions on calculated design 200-year water levels presented in Section 7.2. Manning's "n", discharge and starting water level parameters were varied for the analyses and the results are shown in Table 9.

Table 9 HEC-2 Sensitivity Results

	Variation in Water Level from Design Levels (m)[1]					
	Mannings "n"		Discharge (m^3/s)		Kootenay Lake Water Level	
Cross-Section	Plus 10%	Minus 10%	Greater than Governing Design Discharge[2]	Less than Governing Design Discharge[3]	Plus 0.6 m	Minus 0.6 m
Kootenay Lake	0.0	0.0	0.0	0.0	0.6	-0.6
Transition to Kootenay Lake	0.0	0.0	0.0	0.0	0.6	-0.5
Duncan River Mouth XS-35/35a	0.4	-0.1	0.7	-0.4	0.0	0.1
XS-34	0.4	-0.1	0.6	-0.3	0.0	0.0
XS-33	0.1	-0.1	0.4	-0.3	0.0	0.0
XS-32	0.1	-0.1	0.5	-0.4	0.0	0.0
XS-31	0.2	-0.2	0.5	-0.4	0.0	0.0
XS-30	0.2	-0.2	1.2	-0.8	0.0	0.0
XS-29	0.2	-0.2	1.2	-0.8	0.0	0.0
XS-28	0.2	-0.2	1.3	-0.9	0.0	0.0
XS-27	0.2	-0.2	1.2	-0.9	0.0	0.0
XS-26/38	0.2	-0.2	1.1	-0.8	0.0	0.0
XS-25	0.2	-0.1	1.0	-0.7	0.0	0.0

Notes:

1. 200-year design water levels and flows are presented in Section 7.2, Table 7 (bold and italic values).
2. Based on unregulated (natural) Duncan River flows downstream of Duncan Dam and 200-year instantaneous flood plus 20% for the Lardeau River, see Table 10.
3. Approximately 40% of Duncan Dam design release plus 200-year daily fall flood downstream of Duncan Dam, and the 200-year instantaneous flood minus 20% for the Lardeau River, see Table 10.

Table 9 HEC-2 Sensitivity Results (continued)

	Variation in Water Level from Design Levels (m)[1]					
	Mannings "n"		Discharge (m^3/s)		Kootenay Lake Water Level	
Cross-Section	Plus 10%	Minus 10%	Greater than Governing Design Discharge[2]	Less than Governing Design Discharge[3]	Plus 0.6 m	Minus 0.6 m
XS-24	0.1	-0.1	0.7	-0.5	0.0	0.0
XS-23	0.1	-0.2	0.6	-0.5	0.0	0.0
XS-22	0.2	-0.2	0.5	-0.6	0.0	0.0
XS-21	0.3	-0.2	0.8	-0.8	0.0	0.0
Lardeau River Mouth XS-20	0.1	-0.2	0.7	-0.9	0.0	0.0
XS-19	0.2	-0.2	0.6	-0.5	0.0	0.0
XS-18	0.2	-0.2	0.4	-0.4	0.0	0.0
XS-17	0.1	-0.2	0.3	-0.5	0.0	0.0
XS-16	0.1	-0.1	0.2	-0.3	0.0	0.0
XS-15	0.1	-0.1	0.1	-0.1	0.0	0.0
XS-14	0.1	-0.1	0.3	-0.3	0.0	0.0
XS-13	0.1	-0.1	0.3	-0.3	0.0	0.0
XS-12	0.2	-0.2	0.3	-0.3	0.0	0.0
XS-11	0.1	-0.1	0.2	-0.3	0.0	0.0
XS-10	0.1	-0.1	0.2	-0.2	0.0	0.0

Notes:

1. 200-year design water levels and flows are presented in Section 7.2, Table 7 (bold and italic values).
2. Based on unregulated Duncan River flows downstream of Duncan Dam and 200-year instantaneous flood plus 20% for the Lardeau River, see Table 10.
3. Approximately 40% of Duncan Dam design release plus 200-year daily fall flood downstream of Duncan Dam, and the 200-year instantaneous flood minus 20% for the Lardeau River, see Table 10.

Table 9 HEC-2 Sensitivity Results (continued)

	Variation in Water Level from Design Levels (m)[1]					
	Mannings "n"		Discharge (m^3/s)		Kootenay Lake Water Level	
Cross-Section	Plus 10%	Minus 10%	Greater than Governing Design Discharge[2]	Less than Governing Design Discharge[3]	Plus 0.6 m	Minus 0.6 m
XS-9	0.1	-0.1	0.2	-0.2	0.0	0.0
XS-8	0.1	-0.1	0.2	-0.0	0.0	0.0
XS-7	0.1	-0.1	0.4	-0.5	0.0	0.0
XS-6	0.2	-0.2	0.3	-0.4	0.0	0.0
XS-5	0.1	-0.1	0.4	-0.4	0.0	0.0
XS-4	0.1	-0.1	0.3	-0.4	0.0	0.0
XS-3	0.1	-0.1	0.1	-0.1	0.0	0.0
XS-2	0.1	-0.1	0.2	-0.2	0.0	0.0
XS-1	0.1	-0.1	0.2	-0.3	0.0	0.0

Notes:

1. 200-year design water levels and flows are presented in Section 7.2, Table 7 (bold and italic values).
2. Based on unregulated Duncan River flows downstream of Duncan Dam and 200-year instantaneous flood plus 20% for the Lardeau River, see Table 10.
3. Approximately 40% of Duncan Dam design release plus 200-year daily fall flood downstream of Duncan Dam, and the 200-year instantaneous flood minus 20% for the Lardeau River, see Table 10.

Table 10 Discharges Used for Sensitivity Analyses

Location	Mainstream Discharge (m^3/s)		
	Greater than Governing Design Discharge	Less than Governing Design Discharge	Governing 200-Year Design Discharge (see Table 7)
Lardeau River	626	418	522
Duncan River downstream of Lardeau River	1358	638	938
Duncan River downstream of Meadow Creek	1435	692	992
Duncan River downstream of Hamill Creek	1584	796	1096
Duncan River at the Mouth	1694	874	1174

A plus or minus 10% variation in Mannings' "n" resulted in a maximum variation is calculated water level of plus 0.4 m and minus 0.2 m with a typical variation of plus or minus 0.2 m, see Table 9.

The variation in discharge used for the sensitivity analyses is presented in Table 10. Discharge was varied plus or minus 20% on the Lardeau River resulting in a maximum variation of plus 0.4 m and minus 0.5 m. In the Duncan River, the flow was varied from approximately 40% of the estimated 200-year daily flood to the estimated 200-daily unregulated Duncan River flow at Duncan Dam. The resulting variation in Duncan River estimated water levels was plus 1.3 m and minus 0.9 m, as shown in Table 9. The selection of an appropriate contingency allowance for the Lardeau and Duncan Rivers is discussed in Section 7.4.

The Kootenay Lake level used for the HEC-2 modelling, El. 533.3 m, was varied by 0.6 m. Effects on water levels in the Duncan River, see Table 9, were nil except for the first few cross sections which represented the transition to the Kootenay Lake.

7.4 Design River Flood Levels

The design river flood levels, including contingency allowances outlined below, are shown on Table 11. These levels were used to delineate the floodplain limits shown on the floodplain maps, Drawings 93-3-1 to 93-3-5. The profiles for the design water levels are shown on Drawing B-1016.

An appropriate contingency allowance, commonly known as "freeboard", must be added to the calculated water levels to obtain the flood construction levels. Due to the large amounts of floating debris which has been observed in the past and is expected to be mobilized during a large flood and also the presence of the Duncan Dam, with a spillway capable of releasing 1600 m^3/s at maximum normal operating level, the recommended contingency allowance for the Duncan River is 1.0 m.

Adding the 1.0 m allowance to the estimated 200-year water levels results in levels similar to or above the levels estimated for a Duncan River total discharge at the mouth of approximately 1500 m^3/s, the unregulated (natural) Duncan River 200-year discharge (see Table 9, Section 7.3, Sensitivity Analyses), except in the area of the Cooper and Hamill Creek Fans. Here the design water levels are below the unregulated (natural) Duncan River 200-year discharge case by approximately 0.2 m. Therefore, the 1.0 m contingency allowance accounts for operational flexibility in the Duncan Dam release facilities, future changes to operating procedures and hydrologic/hydraulic uncertainties.

For the Lardeau River the recommended contingency allowance is 0.6 m above the estimated instantaneous flood levels. This allowance accommodates hydrologic and hydraulic uncertainties, as presented in Section 7.3, Sensitivity Analyses, including the expected effects of floating debris. The Lardeau River Valley is very narrow with the river meandering from valley wall to valley wall. During a major event large amounts of debris will be mobilized, as has been observed in the past, which may form debris blockages in the main channel. Since the valley is narrow there is little overbank area for the flood waters to circumvent debris blockages. Increases in water levels may then be expected due to unpredictable occurrences of debris blockages in the main channel. For these reasons the contingency allowance of 0.6 m, above estimated instantaneous flood levels, is recommended for the Lardeau River.

Meadow Creek flood levels are governed by the flood levels in the Duncan River. Transposition of the Duncan River design flood levels into the Meadow Creek area inundates Meadow Creek. The backup of water from Meadow Creek would result in overtopping of Highway 31, which has a low section at approximately El. 543 m. This is consistent with the extended flood lines from Duncan River. Backwater calculations were not carried out for Meadow Creek since flood levels are governed by Duncan River levels. The design water levels for the Meadow Creek area are shown on the floodplain maps.

Table 11 Design Water Level Including Contingency Allowance [1]

Cross Section	20-Year Design Levels (m)	200-Year Design Levels (m)
(Duncan River Mouth) XS-35/35a	535.5 [2]	535.9 [2]
XS-34	536.5	536.8
XS-33	538.3	538.5
XS-32	539.4	539.7
XS-31	540.2	540.5
XS-30	541.2	541.8

Notes: 1. Contingency allowance, commonly known as "freeboard", of 1.0 m was used for the Duncan River and 0.6 m was used for the Lardeau River.
2. Kootenay Lake Level of El. 533.3 m was used for HEC-2 analysis but El. 536.4 m is the design Kootenay Lake flood level (see Section 7.1).

Cross Section	20-Year Design Levels (m)	200-Year Design Levels (m)
XS-29	541.6	542.2
XS-28	542.2	542.8
XS-27	542.4	542.9
XS-26/38	542.8	543.2
XS-25	543.1	543.4
XS-24	543.6	543.9
XS-23	544.5	544.8
XS-22	545.5	545.8
XS-21	546.5	547.0
(Lardeau River Mouth) XS-20	547.5	548.1
XS-19	547.7	548.2
XS-18	549.0	549.4
XS-17	549.9	550.4
XS-16	550.9	551.2
XS-15	551.6	551.7
XS-14	553.0	553.4
XS-13	554.2	554.5
XS-12	555.5	555.8
XS-11	557.3	557.6
XS-10	557.6	557.8
XS-9	558.5	558.7
XS-8	559.7	559.7
XS-7	561.5	562.0
XS-6	562.1	562.5

Notes: 1. Contingency allowance, commonly known as "freeboard", of 1.0 m was used for the Duncan River and 0.6 m was used for the Lardeau River.

Cross Section	20-Year Design Levels (m)	200-Year Design Levels (m)
XS-5	562.9	563.3
XS-4	563.4	563.8
XS-3	564.6	564.8
XS-2	565.4	565.7
XS-1	566.5	566.8

Notes:

1. Contingency allowance, commonly known as "freeboard", of 1.0 m was used for the Duncan River and 0.6 m was used for the Lardeau River.

8. ALLUVIAL FAN HAZARD

Prior to 1920, Hamill Creek discharged directly into Kootenay Lake (Afflect, 1978 and Alexander, 1995). A snow and mud slide in the 1920s forced Hamill Creek to discharge into Duncan River at its present location.

Alluvial fan hazards for the Duncan River Valley have been identified, on a preliminary basis, for Alexander Brook, Cooper Creek and Hamill Creek by the Ministry of Environment, Lands and Parks, Nelson Regional Office (MoELP, 1995). The alluvial fan hazard areas are described in the Regional District of Central Kootenay ByLaw No. 1000, 1993 and delineated on Schedule "E" of the bylaw. The alluvial fan hazard areas should be reviewed when topographic mapping of these areas is complete.

As noted on Drawing 93-3-2, the entire area of the tributary fans are subject to special flood hazards due to possible channel avulsion and erosion caused by channel accretion and/or debris jamming. The bylaws must be consulted to determine construction levels within the designated fan hazard areas. Where levels shown on the floodplain maps overlap with the fan hazard areas, both the requirements contained in the bylaws and the floodplain mapping levels must be satisfied.

9. CONCLUSIONS

1. This Design Brief presents an overview of the studies undertaken to produce the floodplain mapping sheets for the Duncan and Lardeau Rivers.

2. Duncan River flood releases are based on a Duncan Dam operating procedure suggested by BC Hydro, Power Supply Operations, which will provide operational flexibility during high flow periods.

3. The floodplain in the study area has a documented history of flooding and erosion problems dating back to the early 1900s.

4. The floodplain maps are administrative tools which depict minimum elevations for floodproofing. They are not comprehensive floodplain management plans and do not provide solutions to site specific problems.

5. Flooding may occur outside of the designated floodplain. Tributaries, ice jamming, channel obstructions and larger flood events may cause flooding which exceeds the flood levels shown on the drawings. These limitations are noted on the floodplain mapping sheets under floodplain data and under notes of caution on individual sheets.

10. RECOMMENDATIONS

1. The floodplain areas outlined on Drawings 93-3-1 to 93-3-5 for the Duncan and Lardeau Rivers are recommended for designation pursuant to the Canada-British Columbia Floodplain Mapping Agreement.

2. The designated 200-year return period Kootenay Lake Level should remain at its present level of El. 536.4 m (1760 ft). This level should be reviewed once BC Hydro Operations Planning, Power Supply Operations have completed their study on the expected Kootenay Lake flood levels.

3. Areas on the floodplain maps which are designated as alluvial fan hazard areas are subject to the requirements described in the Regional District of Central Kootenay ByLaw No. 1000. Where the floodplain mapping designated areas overlap the alluvial fan hazard areas both the requirements of the bylaw and the designated floodplain mapping levels must be satisfied. The bylaw provisions should be modified to include the floodplain information shown on Drawings 93-3-1 to 93-3-5.

4. The alluvial fan hazard areas should be reviewed when topographic mapping of these areas is complete.

5. Any future significant changes to the operation of the Kootenay Lake System dams must be reviewed to ensure that the designated floodplain areas and levels are not affected.

6. The floodplain maps should be reviewed to maintain the adequacy, accuracy and usefulness of the information when significant flood events, erosion, floodplain development or other changes occur within the study area.

7. A floodplain management plan should be developed for the valley to define the hazards, including alluvial fan hazards.

Yours truly,

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RFR:mn

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The Nelson Miner, June 2, 1894.

APPENDIX I

Photographs

Photo 1. Mouth of the Duncan River at Kootenay Lake. (August 15, 1995.)

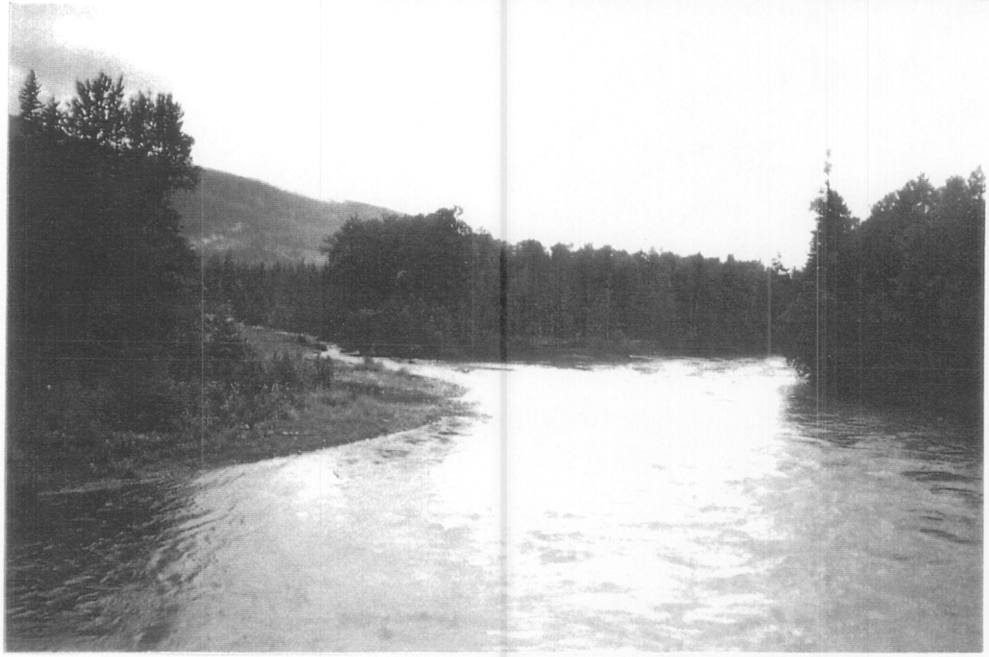


Photo 2. Looking upstream at the Cooper Creek Duncan River Confluence. (August 15, 1995.)

Photo 3. Floating debris on left bank of Duncan River near Cross Section 22. (August 15, 1995.)

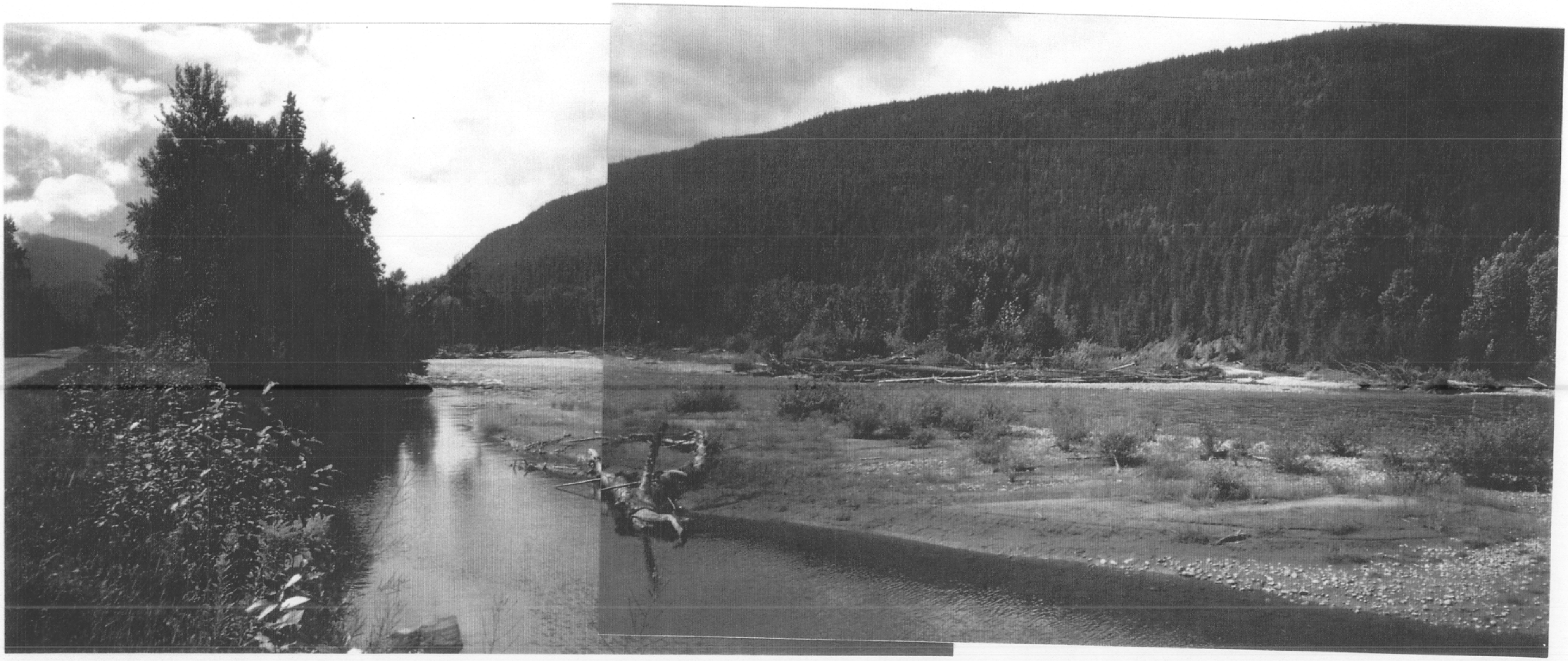


Photo 4. Debris on the Lardeau River near turnoff to Howser (looking from left bank). (August, 1995.)

Photo 5. Looking upstream along Meadow Creek including outlet under Highway 31. (December 4, 1995.)

APPENDIX II

Historical Accounts of Flooding

"West Kootenay Ghost Town Country"

by N.L. Barlee, 1984

Canada West Publications

West Kootenay [illegible]
by N.L. Barlee 1984
Canada West Publications

[illegible]
[illegible] in fact, exist. The reasons for their confidence [illegible]
[illegible]
closely for so many years. A perusal of the information and the clues
available lead to some interesting conclusions. These are the clues:

John Cecchini - Was a section foreman for the C.P.R. on the Columbia and Western between Appledale and Slocan City. He worked for the railway from 1912 until 1940. Cecchini had a good reputation in the area, and was highly regarded for his common sense and veracity. Cecchini's original account is accepted without reservation by all sources. Until John Cecchini's death in Nelson in 1960, his version of the incident of 1924 never varied. Considering Cecchini's steady character it must be assumed that the original details are accurate.

Hanson - Also vaguely referred to as Olafson by one source. Evidently Hanson did not record his mine, a not uncommon practise in those days. His statements about the type of quartz and the 'free gold' ring true because this is the only region on the entire Slocan Slope where gold and not silver predominated. Mines like the Chapleau, Crusader, Black Prince, Golden Wedge, Gold Reef and a number of others were all rich gold producers, with many of these properties carrying bluish-white quartz. Lemon Creek also carried placer gold, the only major stream in the Slocan where placer gold is found. Geologically everything fits.

The South Fork - Unfortunately, Hanson, the Scandinavian miner, did not specify which of the five 'south forks' his mine was on. The 1926 map of the area shows the 1st, 2nd, 3rd and 4th forks as well as 'South Fork Creek,' which was also known as Monument Creek. Most of those who know the story believe that Hanson meant Monument Creek because it was the stream that was called the 'South Fork' then. It is, however, a most difficult creek to prospect, varying in elevation from 4,000 feet on the lower section to 6,000 feet on the upper reaches. Hanson probably meant Monument Creek which was then generally called South Fork Creek.

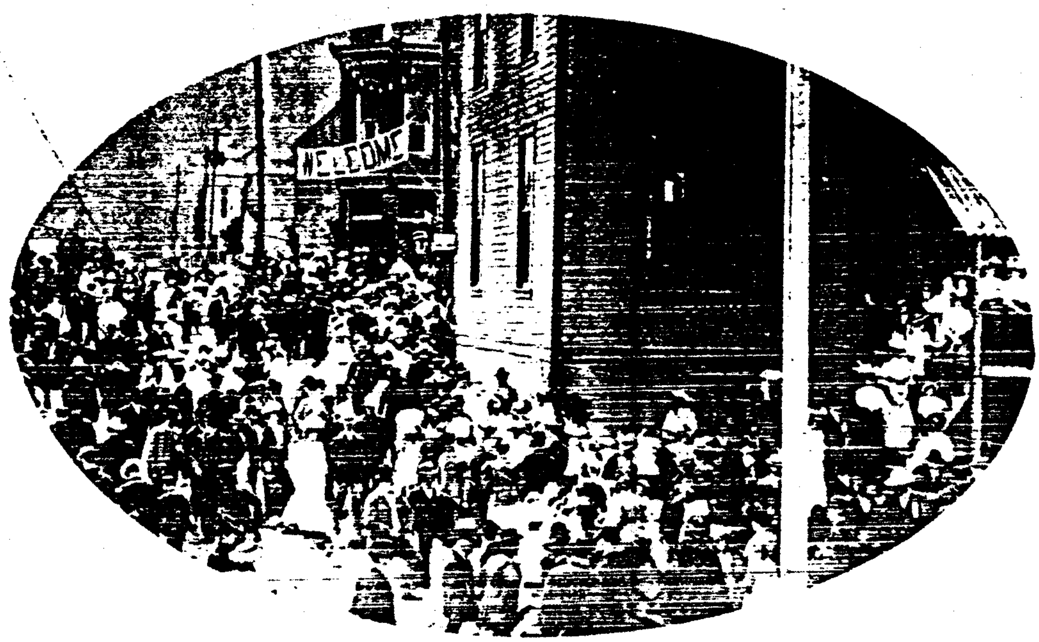
Hanson's Mine and Camp - The Scandinavian mentioned to Cacchini that there was a 'tunnel' and a 'camp' at his mine. Both of these important indicators may be extremely hard to locate after a lapse of fifty-nine years. The tunnel may well be caved or otherwise hidden by underbrush or deadfalls and the original camp may have been razed by forest fire and simply may not exist physically any longer. The abandoned tunnel is the key to the lost mine; when it's found, so is Cecchini's Mine.

KASLO'S FLOOD TREASURES

In 1894 Kaslo, that historic little city on the upper reaches of Kootenay Lake, was visited by two catastrophes. On the twenty-fifth of February a disastrous fire swept most of Front Street, the city's main street. By the next morning much of the street was a smoking ruins. A few months later, after the mining town had barely recovered from this setback, an unusually late spring resulted in Kootenay Lake rising to unprecedented heights. By early June the water had risen twenty-eight feet above the low water mark. In the lower part of town nearly every business and house was inundated, some of them under ten feet of water. The sternwheelers, unable to land at unstable wharves, simply steamed up Front Street and landed far up that street. A walk through Kaslo was replaced by a "row through Kaslo" as the inhabitants, unaccustomed to such sights, took to their boats and rowed aimlessly among the stores and along the flooded streets.

On June 3rd, the weather which had been unrelentingly hot, became oppressively so. Kootenay Lake turned unusually calm and remained that way until about 4 in the afternoon when it suddenly changed. A stiff, hot wind, almost tropical in the opinion of old hands, began blowing in off the lake. It picked up quickly in velocity and soon reached gale or hurricane force. Soon everything not anchored down was airborne; signs, lumber, small trees, barrels, and even light stoves. The air turned a brownish-black and small rocks carried along at dangerous speeds struck the sides of buildings like rifle bullets. Several dogs that had failed to take cover during the storm, vanished without a trace. The waves on the lake, ten feet high, lashed the lakeshore relentlessly, destroying everything within their reach.

Barely an hour later the storm subsided but Kaslo was a shambles.

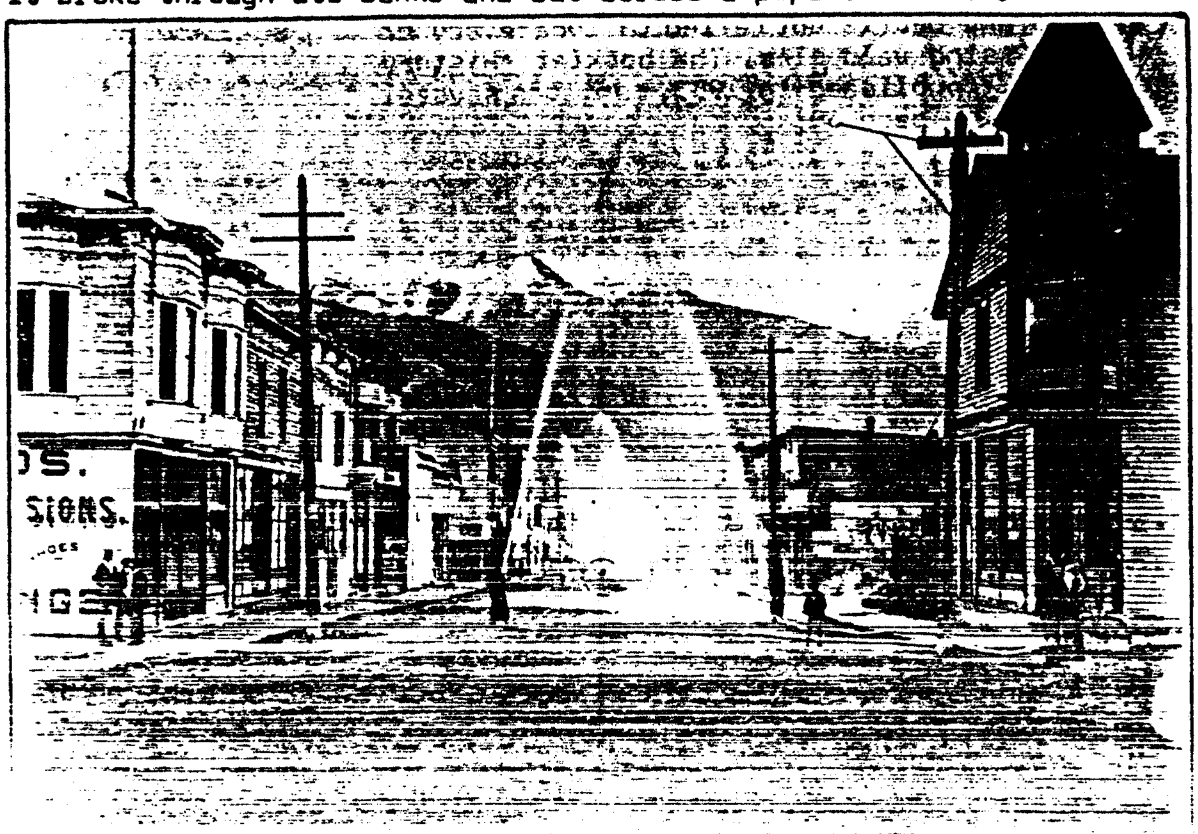


Kaslo was crowded, especially on holidays. [illegible]

More than sixty houses had been demolished or swept away, including all of the houses below Third Street. The business section was equally hard hit; Byer's big hardware store was gone, as was the jail, the Chinese wash houses, The Bay View Hotel and several other two storey buildings along Front Street.

Surprisingly, only one life was lost. The townspeople, shocked by the onslaught, recovered and began cleaning up. Just as they started a rain began. Within a few minutes, accompanied by a violent and vivid electrical storm, it turned into a deluge. The work continued amid the flashes of lightning and the roll of thunder until nightfall, when the exhausted workers finally went home.

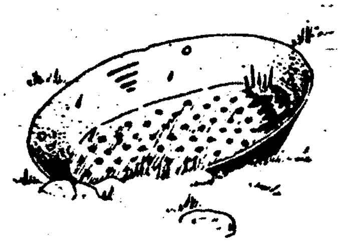
But the ordeal wasn't finished, the heat wave had caused the Kaslo River to rise dangerously and the bridge across the river on Third St. was threatened as the water coming down from the high country buffeted it continually. Early the following morning several trees carried down by the current, lodged against the bridge. In quick order other debris rapidly piling up behind the tree created a jam. With the water of the river flowing over the decking of the structure, the bridge was doomed. When another tree struck it, the bridge broke in two and with a roar, bridge, debris and trees were carried down the river and out into the lake. Farther upriver, another jam had blocked the natural channel and it broke through its banks and cut across a populated flat.



Soon dozens of homes were being [illegible] by the runaway river. Mayor Kane's house, John Keen's residence and J. F. Green's home were just a few of the many fine residences lost to the river. Homes on the south side of the river were completely abandoned as families headed for refuge on higher ground. For five days and nights the wild river remained on the rampage, destroying or flooding everything in its way. The buildings on the upper end of D Avenue, including Kapp's Bottling Works, were demolished.

On June 9th, the flood waters finally began to recede, but Kaslo was devastated. The fire had wrought havoc along Front Street but the later storm, high water and rampaging river had virtually demolished much of the remainder of the city. Third Street had vanished, large sections of D Avenue laid waste and much of the rest of the city had been severely damaged. In all, nearly 100 houses and businesses had been destroyed. It was estimated that nearly half of Kaslo was gone.

Once again the citizens began to rebuild. Lumber was salvaged to be used in construction, the river was relocated and its banks shored up and a general and slow cleaning up process began. Because of the disasters many families had lost valuable possessions. Gold and silver jewellery, sterling silver cutlery, coins and other valuables were all lost to the water and mud. Some people spent days searching through the mud and debris but failed to locate any of their missing valuables. The booklet "History of Kaslo," published in 1953, mentions several instances on page 38:



> "Many people spent days digging for their possessions in the sand and gravel in the flooded district. By digging almost anywhere, a variety of objects (were) found. One man found a diamond ring while helping to shovel sand from a house, ... children enjoyed themselves .... digging up anything from spoons to cooking utensils."

Ninety years have passed since those disasters struck old Kaslo, but from time to time items of value and rarity still turn up in the most unexpected places. Hundreds of coins, including a few fine gold pieces, have been unearthed or simply picked up in the original areas that were flooded in 1894. Many of the coins, because of their dates, rarity and condition, have an extremely high numismatic value. Other items of value, especially gold and silver jewellery, have also been found, often in the most unlikely places and occasionally occurring in caches of two or more pieces within a few feet of each other.

Today Kaslo has recovered from those calamities of the past, and there are few signs of that flood of long ago. The [illegible] river [illegible] channel south of the original one and the [illegible] [illegible]

Newspaper Articles

Should this line tell us, Nelson will be

D

...realization that
...kind of trap.
...ated scornfully.
...? The idea is ab-
...implies trust. Do
...ever trust you?"
...after a moment
..."Since you have
in here tonight, you
...what I intend to
...mind after the
...u made before
...have reached the
...e. I think I must
...and it as long
...—," but before
...er sentence, he

... Perhaps it would
... to know some-
... ly don't suspect.
...self didn't realize
... is why I couldn't
...son I woke you
...morning, Gloria.

...interrupted here
...hand. "Wait, you
...n't you see that
...ance to ridicule
... myself in your
...n't true. I'd never
...is true. I swear it.
...yself until to-
... met you, it ir-
... that you dis-
... believed I couldn't
...inking about it. I
... you out of my
... ou avoided me
... asking you to
... 'Stranger Souls,'
...hen we played the
... you in my arms,
... ou. I was deter-
you. I wanted to
...anted to make you
... had treated me,
... ou because you
... of everything
...now that now." His
...d, he was pleading
... ds awoke no re-
... an who stood
... edulously. Her
a bitter little smile
and then she was
... suffering of the
... evealed in what

...love me. If you had
... you have forced
... me? If you had
... t you have been
...me, to give me time
...ything? You knew
... step I had taken
... married. If you
... was your chance
...tead you forced me
...ou, you humbled me
... iends, you ex-
... ur friends, and
... u made love to
... I know why you

... de about you,"
... y, "because I
... from you when

THIRTY YEARS AGO TODAY WAS FLOOD RAMPAGE

Nelson Depot Was Island; Trains Dare Not Cross the Bridges

KASLO CITIZENS FLED WATERFRONT

At Balfour Steamer Delivered Mails Through Window of the Store

(From The Nelson Miner of June 2, 1894.)

Thursday, May 31: The sun is still shining and 85 degrees in the shade were registered today. The lake has risen nearly two feet since yesterday, and even if the weather suddenly changes, a rise of several more feet may be looked for. If the warm weather continues, it is difficult to see where the flood will stop. The C. P. R. train which went out last night plowed its way through two feet of water just outside the station, and got down to Robson all right, although the curved trestle on this side of the Kootenay bridge was considered risky, but after crossing it was seen to be so bad that the train did not attempt to return. The passenger were brought back this morning on a hand car. Among them was Mr. Goepel.

Trestles Afloat

The approaches to the Slocan bridge are not in a safe condition to admit of the passage of a train. At the C.P.R. depot the station is an island. There are two feet of water on the rails in front of the station. The water is up to the floor of the freight shed and will soon be in it. The floor of the depot itself is today a foot out of water. The first two trestles on the line are afloat and probably many others, and altogether it looks as if it would be some time before the whistle of the incoming train is heard again.

On the lake front all the lower houses are more or less submerged. At the brewery the water fills the ground floor to the depth of six or seven feet and bottles and casks galore are floating about. J. MacDonald's cottages and R. E. Lemon's house have four feet of water in them. At Buchanan's lumber yard the water is up to the eaves of the shed, and all the lumber is afloat, but it appears to be well boomed in.

An Inch An Hour

Both the wharves, of course, are entirely under water and all the boat houses that are usually secured to the city wharf are moored alongside the collection of little shacks that cluster on the knoll near the foot of the wharf. John Doray's little cabin stands with its feet in the water and his promising looking garden is fast being swallowed up by the all devouring flood. And the lake is steadily rising at the rate of about an inch an hour.

Meanwhile from all around comes news of disaster. At Kaslo the warehouses are flooded, and the denizens of houses in the lower part of the town have had to flee before five feet of water.

At Balfour the Nelson steams right up to the store and delivers her mails thrugh the windows.

Steamer Ran to Little Dalles

Along the line of the Spokane and Northern the floods are out, and passengers are transferred by steamer between Waneta and Little Dalles. ... be entirely cut off from the outside world.

Friday, June 1. At noon today the water had risen 10 inches since 8 o'clock last night and is still rising. The water has reached the floor of the C.P.R. depot and the platform looks as if an earthquake had been playing under it. It has assumed the appearance an ordinary sidewalk presents when a man has tanked up a little too much.

Staff Left Station

The staff have had to clear out and are now in the Lemon block. They will probably have a little leisure time now.

By the latest reports the trestle on this side of the Kootenay bridge has gone out.

EAST KOOTENAY MEN ARE JAILED

Three in Local Jail for Theft, Doing Bodily Harm and Liquor Act Charges

Three new boarders were received in the past few days at the Nelson jail. Provincial Constable Donohue of Kimberley has brought to this city Archie McLellan of Kimberley who was sentenced there to six months in the Nelson jail for theft.

David Leveque of Cranbrook will serve eight months for occasioning actual bodily harm at Cranbrook. F. J. McMillan of Crow's Nest was brought to the city by Provincial Constable Smith of Crow's Nest. McMillan answered to two charges, the first for using insulting language, and the second under the Liquor act. He was fined $20 on the first charge and $25 on the second or in default one month on each charge.

LISTER, AND AIDE PLAN A BUSY WEEK

Creston Candidate Will Campaign in Salmon Valley, West Arm

Lieut. Col. Fred Lister, Conservative candidate for the Creston riding, accompanied by Major E. Mallandaine, will speak at Salmo on Monday evening and at Fruitvale on Tuesday evening.

They will spend Wednesday visiting Waneta and the Pend d'Oreille, and will visit Robson and Syringa creek on Thursday.

On Friday there will be a meeting at South Slocan, and on Saturday at Willow Point.

Procter, Harrop and Longbeach will be visited later in the following week.

VANCOUVER WHEAT

VANCOUVER, May 30.—Merchants' exchange wheat prices, for No. 1 northern, for prompt delivery from prairie points:

Bid, $1.08; asked, $1.09⅝.

Poverty brings us strange bedfellows and riches bring us queer nightmares.

... love crawls out through the skylight.

MAY 31 1924

D

R
n ny.

int purple shadows be- She was suddenly very s too proud to show s gripping her heart; m eton would begin to n ns on her. She felt ld scream aloud if he r.

glance in his derection, he turned and came the small table he a small amount of glasses, added cracked er, and proffered her a took her head in refusal wn at her mockingly. rink a toast to our aid lightly. to sit there in silence, ittle shrug of his shoul- ed his glass and sat it e. She watched him cigaret and drew a of relief as he sat r. But with a sud- t he flung the cigaret place and came toward

ds gripped the arms ough to hold to them as her eyes sought dimly realized that his s strange. His face was ed somehow older. With singing in her ears ay. ooping to her, draw- him. Her first instinct gle, but pride conquered nd she lay limp against ips hard on hers left passive, although he s he kissed her. He single word. released her, so abruptly gered. He put out his her, but she drew back , and her voice was hen she spoke. expected something

circumstances, I should atural procedure," he re- not quite steady. before this afternoon, I married you be- you. You knew that; e bargain." ' it never occurred to you be considerate," she hate you, I despise amed any man could e."

forgotten that you're to in the movies," he said ought to compensate attentions to you." ng himself another ld hear the clink of ss and the swish of the had a sudden mad desire room, to be alone, and ng him a look she ward the door, d, she had a feeling ry to stop her, but could not hurry. And in the hall; for the time aped from him, she

"P ying the Game."

IRKE BREAKS N ARM IN FALL

. Clarke, mother-in-law McLeah, Edgewood ave- t in the Kootenay ospital, where she terday afternoon, at lock, suffering from a Dr. L. E. Borden at-

RECALLS HIGH WATER THIRTY SUMMERS AGO

John Bell Tells of Big Flood of Eighteen Hundred Ninety-four

TWENTY-NINE FEET ABOVE LOW WATER

Flats Were Flooded; Bogus-town Was Bush and Inundated

"Just 30 years ago was the year of the big flood," said John Bell, old-timer of Nelson, recently, "and that year, 1894, the water in the lake rose 29 feet above low water."

"After an open and mild winter," he continued, "it drizzled almost continually all February and March. We had a great deal of light rain at the lake level and a great deal of soft snow in the hills until about the middle of April, with very little frost at night. About April 18 or 19 there was almost 4 feet of soft snow, full of water, up at the Silver King. I was up there at the time, and measured it.

"This sort of weather continued until May 16, when all at once it grew very hot, and about May 25 it reached 98 degrees, after which the heat gradually decreased."

Thunder and Wind

The weather was still very warm on May 27, Mr. Bell said, when there broke one of the worst thunder and wind storms he has ever seen. "It was a regular cyclone or cloudburst in the mountains," he said.

"The lake began to rise rapidly, as all the soft snow in the mountains melted, and for a couple of days it rose at the rate of 1 inch an hour, then more slowly after that until June 3 it stood 29 feet above low water."

J. Fred Hume and Harold Selous rowed across the lake and marked the height of the water on the rocky face of the cliff across the lake from town, Mr. Bell said, and recently he checked their record with the present gauge of the Nelson Launch club and found that the measurements used were the same.

Water in Freight Yards

He stated that the old Canadian Pacific railway freight shed on the flats at the east end of the yards, now used as a workshop, had water lapping three-quarters of the way up its doors.

"The water came right up into the draw between the old Grand Central hotel, across the street from the court house, and the point where the Chinese mission now stands, and a boat could be rowed up to that point," he said.

"The steamer Nelson, Capt. D. C. McMorris, could not land at the wharf, which was then just below W. O. Miller's house, because it was under water. He had to tie up to the bank.

"A baggageman had a house of one and one-half of a story just immediately north of Mr. Miller's, immediately below the track, and the water picked it up and turned it end for end. It carried away the

DEFERS VISIT HERE FOR TIME

Premier Oliver Will Address Nelson Voters at a Later Date

Premier Oliver has deferred his visit to Nelson until a later date in the campaign, and will not be heard in Nelson on Tuesday next, as anticipated, according to word received by Kenneth Campbell, M.P.P., yesterday.

In place of speaking here Tuesday, he will on that evening address an audience in Rossland. His itinerary as planned at present is: Crawford Bay on Monday afternoon, at 1:30 o'clock; Kaslo, Monday evening; Rossland, Tuesday evening.

FIRE SITUATION MUCH IMPROVED

Birchbank Fire Practically Out; Winlaw Flames Now Controlled

After some weeks the district is again practically free from forest fires, according to District Forester F. A. MacDonald. He reports the Birchbank fire practically out. A small crew of men is being kept on the job as a precautionary measure.

At Winlaw the fire is now confined to a small area, and a number of the men have been taken off. It is hoped, should the weather remain favorable, that the fire will be totally out by tomorrow. No new fires have been reported since Sunday.

EDWARD PARKER DIES AT FAIRVIEW

He Leaves a Widow, Two Sons and Three Daughters; One Brother

The death occurred last evening of Edward Augustus Parker, Chatham street, Fairview, aged 64 years, who leaves his wife, Katherine Hamilton Parker; three daughters, Edna of Spokane, Mary of Seattle, and Vera of Vancouver; and two sons, Frank and Melville of Nelson.

He is also survived by a brother, Charles Parker, of Cranbrook, B.C.

The deceased was born in Waterloo, Que., 64 years ago, and has been a resident of Nelson for the last five years. The funeral will be held tomorrow.

Procter Salmon Is Caught by Dr. Prentice

A salmon weighing 14½ lbs. was

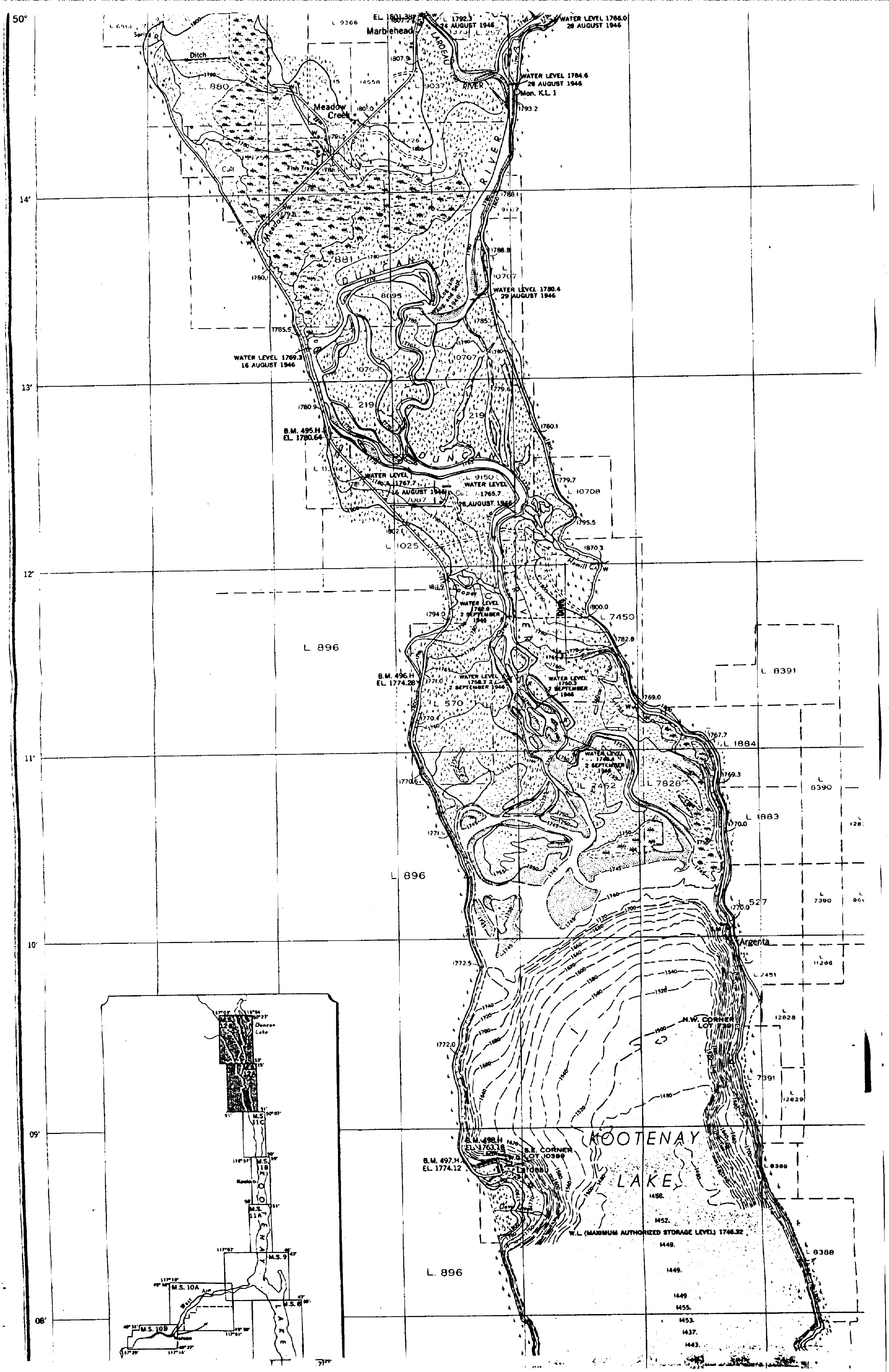
WORKER INJURED AT BONNINGTON FALLS

Descending Skip Connects With Man's Head; In Local Hospital

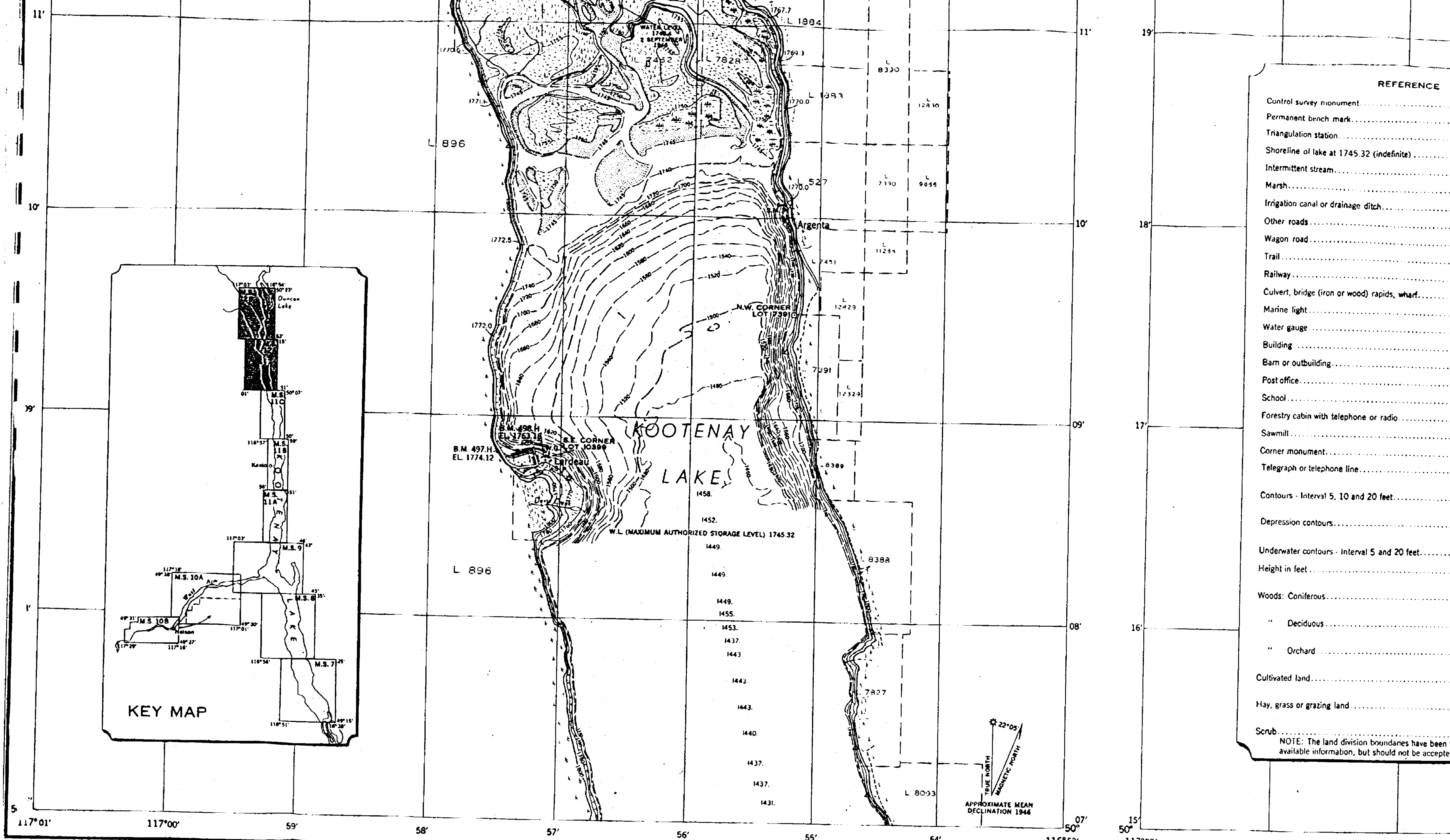
C. H. Bailey, a workman at the Bonnington construction work, was injured Wednesday night when unhooking a skip used in raising rock from the great hole being excavated there. Dr. L. E. Borden was summoned and went immediately to the scene of the accident.

Bailey rested easy until yesterday afternon, when a freight train was flagged, and he was brought to the city, and removed to the hospital in the ambulance. The skip on coming down hit Bailey on the head.

Duncan and Lardeau Rivers
1947 Mapping



50°
14'
13'
12'
11'
10'
09'
08'
Marblehead
LARDEAU RIVER
Meadow Creek
DUNCAN RIVER
Ditch
Fish Trap
WATER LEVEL 1766.0 28 AUGUST 1946
WATER LEVEL 1784.6 28 AUGUST 1946
Mon. K.L. 1
WATER LEVEL 1780.4 29 AUGUST 1946
WATER LEVEL 1769.3 16 AUGUST 1946
B.M. 495.H EL. 1780.64
WATER LEVEL 1767.7 16 AUGUST 1946
WATER LEVEL 1765.7 28 AUGUST 1946
WATER LEVEL 1762.0 2 SEPTEMBER 1946
B.M. 496.H EL. 1774.28
WATER LEVEL 1758.2 2 SEPTEMBER 1946
WATER LEVEL 1760.3 2 SEPTEMBER 1946
WATER LEVEL 1758.4 2 SEPTEMBER 1946
L. 896
L. 570
L. 7450
L. 7828
L. 8391
L. 1884
L. 1883
L. 527
Argenta
N.W. CORNER LOT 7391
B.M. 498.H EL. 1763.16
B.M. 497.H EL. 1774.12
S.E. CORNER LOT 10399
Lardeau
KOOTENAY LAKE
W.L. (MAXIMUM AUTHORIZED STORAGE LEVEL) 1748.32
M.S. 12B
M.S. 12A
M.S. 11C
M.S. 11B
M.S. 11A
M.S. 9
M.S. 10A
M.S. 10B
M.S. 8
Duncan Lake
Kaslo
Nelson



Datum is Mean Sea Level (1928 Adjustment) Geodetic Service of Canada.

NEW VALUES FOR BENCH MARKS 1947 INTERNATIONAL JOINT ADJUSTMENT

Bench Marks Nos.

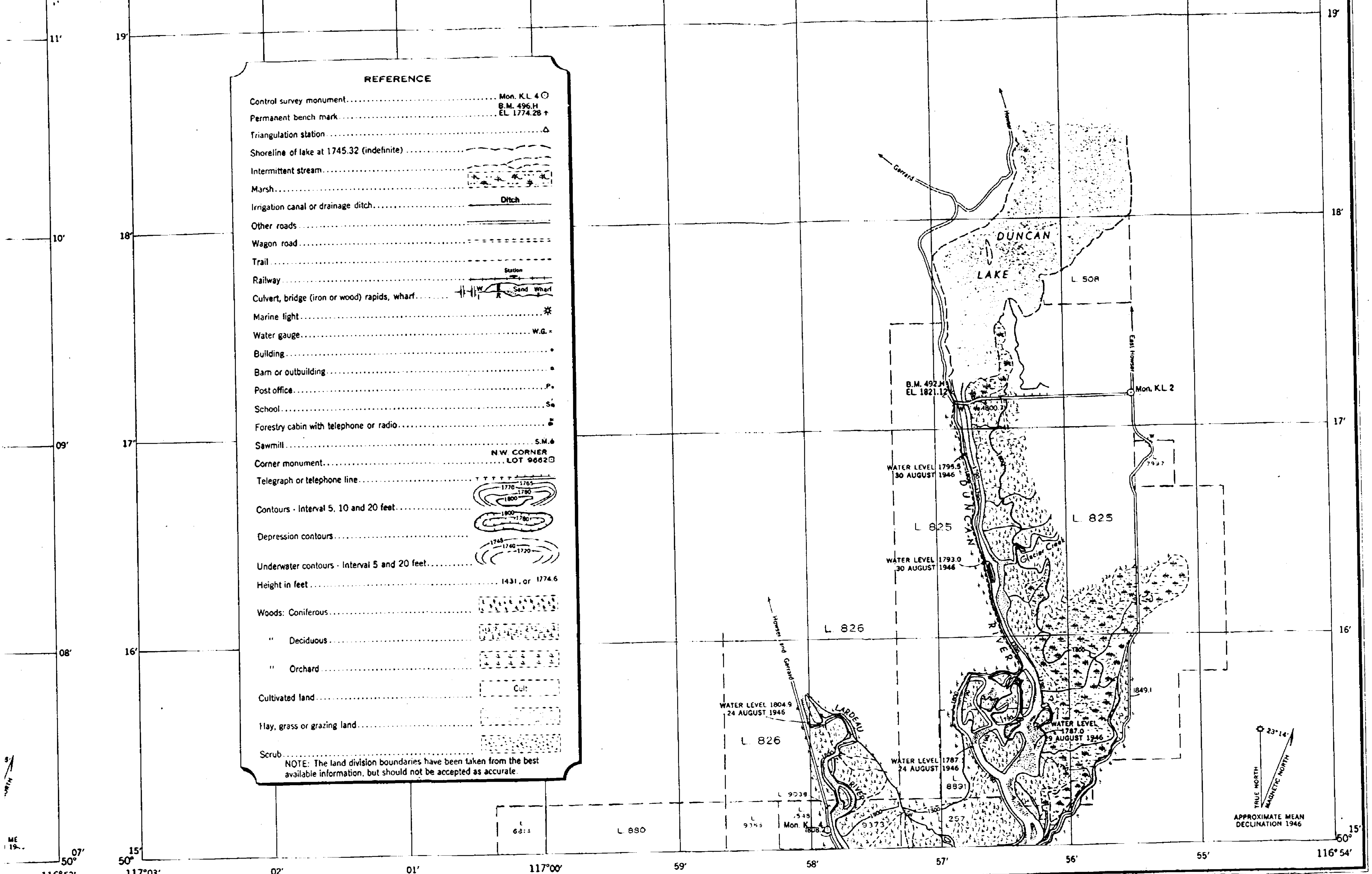
492 H 1821.12 496 H 1774.30

COLUMBIA RIVER BASIN

KOOTENAY RIVER - KOOTENAY LAKE AREA

BRITISH COLUMBIA

SCALE 1:31680 OR 1 INCH TO ½ MILE



[COLU]MBIA RIVER BASIN

[DUNCAN RIVER]- KOOTENAY LAKE AREA

BRITISH COLUMBIA

SCALE 1:31680 OR 1 INCH TO ½ MILE

Transverse Mercator Projection
North American 1927 Datum

Compiled, drawn and printed at the office of the Surveyor General, Ottawa, 1947, from surveys by the Legal Surveys and Map Service in 1946, and from aerial photographs by the Royal Canadian Air Force, in connection with the investigation of the water resources of the Columbia River Basin, by the International Joint Commission under the Reference of March 9, 1944.

Underwater elevations from bathymetric survey by the Department of Public Works.

APPENDIX III

Duncan Dam Project

System Operating Order No. 4P-41, May 26, 1995

SYSTEM OPERATING ORDER 4P-41

(Major Rewrite and Supersedes S.O.O. 441 dated 20 October 1994)

DUNCAN DAM PROJECT

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1.0 PURPOSE OF SYSTEM OPERATING ORDER

The purpose of this Operating Order is to summarize the operating requirements for the Duncan Dam Project (DCD) and to define the operating responsibilities for Power Supply Operations, Transmission and Distribution Operations and Power Facilities in accordance with System Operating Order 4P-10.

2.0 GENERAL OPERATING RESPONSIBILITIES

The **Manager of Power Supply Operations** is responsible for the planning, forecasting, coordination, directing, dispatching and recording of the operation of DCD, the reservoir storage content, water releases, pre-spills for flood routing purposes and for coordination of planned maintenance outages.

The **Manager of Power Facilities** is responsible for the detailed operation of the DCD equipment and facilities to meet the operational requirements prescribed by Power Supply Operations and for implementing spillway releases for dam safety purposes. The Manager of Power Facilities is also responsible for maintenance of the equipment and facilities.

3.0 AUTHORITIES FOR POWER PRODUCTION

There are no hydro-electric power generating facilities at the Duncan Dam Project, however the operation of Duncan Dam will impact the generating projects on the Kootenay River.

4.0 AUTHORITIES FOR FLOOD ROUTING

Transmission and Distribution Operations normally has the operating responsibility for directing flood flow releases for Duncan Dam. The operating responsibility can be transferred from Transmission and Distribution Operations to the Kootenay Generation Manager or his/her delegate.

The Kootenay Generation Manager is responsible for liaising with and providing flood inflow routing information to the local public, local municipal governments, local fishery agencies and local residential, industrial, and commercial entities.

The Kootenay Generation Manager shall implement the flood control procedures for the Duncan Dam Project to route floods with consideration for local site conditions and with appropriate assistance from Power Supply Operations. Under emergency conditions where flooding upstream or downstream of a project is imminent, the Kootenay Generation Manager shall take necessary action to address the emergency.

5.0 DESCRIPTION OF DUNCAN PROJECT

Duncan Dam is one of three dams constructed in Canada under the terms of the Columbia River Treaty. The Duncan reservoir provides storage for increasing hydroelectric generation in the Columbia River Basin and for flood control. Construction commenced in 1965 and the Project was commissioned in 1967. A Dam Caretaker is on site seven days a week during regular working hours.

The Duncan Project is located immediately upstream of the confluence of the Duncan and Lardeau rivers, about 8 km upstream of Kootenay Lake and 42 km north of Kaslo, B.C. The Project consists of a zoned earthfill dam, a surface spillway in the left abutment, and two low level outlets in the right abutment for normal operational releases. There are no generation facilities at the Duncan Dam Project.

The reservoir has a surface area of 71.5 km^2 at the maximum normal level of 576.68m and a live storage of $1.73^{*} 10^9 m^3$. The basin drainage area is 2410 km^2.

6.0 WATER LICENCES RIGHTS AND OBLIGATIONS

B.C. Hydro is authorized by Conditional Water Licence No. 27067 to store a maximum of 1.4 million acre-feet of water in the Duncan reservoir. The maximum pool elevation is not to exceed 1892 feet.

7.0 WATER RELEASES FOR COLUMBIA RIVER TREATY

Power Supply Operations is responsible for the scheduling of Duncan releases under the Columbia River Treaty. The releases are set through agreement with the U.S. Entity taking into consideration dam safety, flood control, power generation, dam safety and agreements between the Entities that may be in place from time to time.

7.1 Assured Operating Plan (AOP)

The Columbia River treaty requires that an Assured Operating Plan (AOP) be prepared and agreed to each year by the Entities for the operation of Columbia River Treaty storage (of which 1.4 MAF is at Duncan) for the sixth succeeding year of operation. The AOP provides information for planning the power systems in B.C., and the U.S. Pacific Northwest. For the Duncan Dam Project, the AOP outlines operating rule curves that define the draft and refill rights and obligations for the Project, and provides a default position from which the Detailed Operating Plan is constructed. Power Supply Operations is responsible for the AOP.

7.2 Detailed Operating Plan (DOP)

The Columbia River Treaty also requires that a Detailed Operating Plan be prepared and agreed to each year by the Entities for the Operation of Columbia River storage in the following year. Operating Rule Curves established in the appropriate AOP (i.e.: for application in the following year), may be updated/altered by mutual agreement of the two Entities. If no agreement is reached, then the rules agreed to in the AOP are the default rules. Power Supply Operations is responsible for the DOP.

7.3 Actual Operations

The U.S. Entity makes its official request for Duncan Project releases each Friday for the following week (starting at 0800 hr Saturday). Duncan Dam actual releases may be increased (or decreased) at B.C. Hydro's option (e.g.: to optimize the Kootenay River System generation) provided:

1) Kootenay Lake release > Duncan release
2) Treaty flood control provisions are maintained
3) Hydraulic discharge capabilities meet Treaty requirements.
4) Arrow actual releases are increased (or decreased) correspondingly.

8.0 FLOOD CONTROL

Regulation of Duncan Reservoir for flood control purposes in Canada and the U.S. is governed by the Columbia River Treaty.

All flood inflows up to the Probable Maximum Flood (PMF) can be safely routed by following the procedures described in B.C. Hydro Report No. H2057 'Duncan Dam Deficiency Investigations, Flood Operating Procedures' (April 1991). A copy of the logic and simulation results is contained in Attachment 22.6 of SOO 4P-41A.

9.0 DUNCAN RESERVOIR OPERATING REQUIREMENTS

Duncan reservoir is operated under the terms of the Columbia River Treaty.

10.0 DUNCAN POWERHOUSE OPERATION

There are no hydro-electric power generating facilities at the Duncan Project.

11.0 DUNCAN DISCHARGE FACILITIES OPERATION

Discharge facilities at Duncan Dam consist of two 6.1 m diameter pressure tunnels approximately 309 m long controlled at the downstream ends by radial gates 5.87 m wide by 4.8 m high and a gated spillway consisting of two 8.1 m wide by 12.2 m high vertical lift gates on an overflow agee section.

Operation of the Outlet Works and the Spillway shall be in accordance with L.O.O.'s 304-510B, 304-510F, and 304-510G. The low level outlet works are the preferred means of discharging water from the Duncan Project. The spillway is only to be used to control the surcharge storage during local flood conditions when the reservoir is full.

Except under emergency conditions, the total discharges from the low level outlets is not to exceed 300 m^3/s (10.6 kcfs). This may be increased to 566 m^3/s (20 kcfs) if the spillway capacity is not adequate to discharge project requirements. The minimum allowable discharge from Duncan Dam is 3.0 m^3/s (0.1 kcfs) average over 24 hours. During June, July and August, this may be compressed into 6 hours to provide a 12 m^3/s (0.4 kcfs) flow for fish transport. The maximum rate of change of outflow is 120 m^3/s (4.2 kcfs) per day.

When the reservoir is filling and the level reaches elevation 575.8 m, the Low Level Operating Gates (LLOG) shall be opened to discharge the lesser of:

(a) 300 m^3/s
(b) A percentage of the calculated inflow as follows:

Reservoir Elevation	% of Inflow to be Discharged
575.8 m	25
576.1 m	50
576.4 m	75
576.7 m	100

This procedure may be modified under the direction of the SCC System Power Dispatcher on the generation desk.

12.0 FISHERIES INTERESTS

There are no known formal agreements, restrictions, or obligations for specific fisheries operations at the Duncan Project. As yet, there are no identified concerns on issues such as spawning, incubation, rearing, habitat protection, gas supersaturation, high water temperatures, freezing conditions, discharge rates of change, water levels and water depths.

There is an understanding that BC Hydro will assist in the migrations of bull trout as outlined in section 12.1.

12.1 Duncan Fish Run Procedures

Around late May or early June each year bull trout migrate from Kootenay Lake up the Duncan River to the base of Duncan Dam. At this time the project outflows are normally between 3.0 and 30 m^3/s (100 and 1000 cfs). Dam operations are then modified to allow fish to pass up one of the discharge tunnels much the same way a boat is allowed to pass through a navigation lock. Details are as follows:

- Periodically, after sufficient fish are spotted congregating in the flip bucket, the LLOG is closed.
- The upstream maintenance gate is then closed to cut off inflow into the tunnel and isolate it from the reservoir.
- The LLOG gate is then opened to allow fish to go into the tunnel. A seine is used to corral the fish into the tunnel.
- Once the fish are in the tunnel the LLOG gate is then closed and the upstream maintenance gate is opened slightly to prime the tunnel.
- Once the tunnel is filled, normally within 15 minutes, the upstream maintenance gate is fully opened to allow the fish to migrate into the Duncan Reservoir.
- The trout are not expected to spawn until sometime in the fall at which time they return to Kootenay Lake.

A fish weir was constructed at the toe of the outlet of LLOG #2 in June 1994. This makes LLOG #2 the preferred gate for fish transfers in low-tailwater years. The weir has removable stoplogs and helps fish enter the flip bucket by staggering the jump from the tailwater.

In a normal year, this operation is repeated 10 to 12 times, transferring hundreds of fish into Duncan Reservoir. This operation does not affect normal storage operation at the project.

13.0 RECREATIONAL INTERESTS

Duncan reservoir is used for recreation, but there are no formal agreements for operating the project in a specific manner for recreation.

14.0 RESIDENTIAL, COMMERCIAL, AND INDUSTRIAL INTERESTS

The community of Howser uses the Duncan reservoir as a source of drinking water. The intake is located about 2 km south of the Howser boat launch at elevation 546.7m (1793.6 ft.). The Howser water users should be informed by the Dam Caretaker when the reservoir is projected to fall below elevation 548.6m (1799.8 ft.). Power Supply Operations has the responsibility of informing the Kootenay Generation Manager or his/her delegate when it is projected that the water level will fall below 548.6m (1799.8 ft.).

There are no known formal agreements, restrictions, or obligations for residential, commercial or industrial purposes in the operation of the Duncan Project.

15.0 LAND USE IMPACT AND SHORELINE EROSION CONTROL

There are no known restrictions with regards to land use impact and shoreline erosion control in the operation of Duncan reservoir. The Kootenay Generation Manager or his/her delegate shall notify Power Supply Operations of newly observed impacts on the environment and jointly develop contingency plans. Action may include:

(a) notification to other departments within B.C. Hydro,
(b) notification to the public and government agencies,
(c) public consultation,
(d) salvage and rescue operations.

16.0 TRANSFER OF OPERATING RESPONSIBILITY

The Transmission and Distribution Operations System Power Dispatcher at SCC on the generation desk normally has the Operating Responsibility for Duncan Dam and directs the operation of the discharge facilities. The Operating Responsibility can be transferred from the SCC System Power Dispatcher to the Kootenay Generation Manager or his/her delegate for flood routing purposes and special need conditions.

The procedure for transfer of Operating Responsibility is as follows:

The Kootenay Generation Manager or his/her delegate contacts the East Kootenay Control (EKC) Dispatcher to request transfer of the Operating Responsibility.

The East Kootenay Control (EKC) Dispatcher contacts the SCC System Power Dispatcher on the Generation desk and requests transfer of the Operating Responsibility.

The Operating Responsibility is transferred from (to) the SCC System Power Dispatcher on the Generation desk to (from) the Kootenay Generation Manager or his/her delegate via the East Kootenay Control (EKC) Dispatcher. Transfers of responsibility will be recorded in Control Centre logs.

When the reservoir is full, inflows can be passed in accordance with the guidelines presented in Attachments 22.6 and 22.7 of SOO 4P-41A.

17.0 AVAILABILITY OF EQUIPMENT AND FACILITIES

The Kootenay Generation Manager or his/her delegate shall notify Power Supply Operations of planned equipment and facility outages or unusual conditions which may affect the operation of the Duncan Project or the integrated system.

Power Supply Operations shall coordinate the maintenance outages for all equipment and facilities essential to the operation of the Duncan Project and the integrated system.

18.0 MAINTENANCE OF OPERATING ORDERS

Power Supply Operations shall review this System Operating Order at least once every 4 years to ensure all information and operating requirements are current and comply with recommendations contained in Emergency Preparedness Programs, Operation, Maintenance and Surveillance Manuals, Dam Deficiency Investigations, Comprehensive Inspections and Reviews, Spillway Discharge Test Reports, Flood Flow Regulation Reports, environmental obligations, Water Licence obligations and other accepted reports.

Power Supply Operations shall ensure that the information contained in the System Operating Orders and the Local Operating Orders are consistent and current. Power Supply Operations shall reissue this Order prior to 01 June 1999.

19.0 HYDROLOGICAL AND METEOROLOGICAL DATA

A data collection platform (DCP) is installed at the Duncan Dam in a shed beside the low level maintenance gate shaft #2. Information from the DCP is transmitted to the System Control Center via satellite. The data measured by the DCP includes water level, precipitation and temperature. The data is collected hourly and transmitted every 3 hours.

Data from the Duncan Dam DCP, plus data from the DCPs “Duncan River at BB Creek" (stream flow and met. data), “East Creek" (snowplow and met. data), and “Kootenay Lake at Queens Bay" (lake level and met. data) is transmitted electronically to the dam each morning at 0600 hrs.

Headwater readings are obtained manually by reading the Stevens Recorder or the backup tape gauge located in low level maintenance gate shaft #2. If both these devices fail, the staff gauges in the forebay must be used. Tailwater readings are obtained from the staff gauge located in the outfall ditch on the east side of the dam.

A climate station (#1142574) is located in Meadow Creek beside Hydro House #1. The associated high level wind anemometer is located on the crest of the dam; the low level anemometer is part of the climate station.

Duncan Dam has two snow courses (2D07 and 2D07A). They are located approximately 1 km down the forestry access road which spurs off the viewpoint road. Lists of meteorological stations are available in Attachments 22.3, 22.4 and 22.5 of SOO 4P-41A.

20.0 PROJECT DATA

Elevation		
Feet	Meters	Comments
1907	581.25	Dam Crest
1900	579.13	Top of impervious core
1897	578.21	Maximum surcharge
1892	576.68	Normal maximum operating elevation
1853	564.80	Spillway sill elevation
1794.2	546.87	Minimum operating level
1791.0	545.90	Tailwater at minimum release

21.0 REFERENCE DOCUMENTS

"Duncan Dam Operation, Maintenance and Surveillance Manual", January 1994.

"Duncan Dam, Deficiency Investigations", June 1993, Report No. H2029.

"Duncan Dam, Deficiency Investigations, Flood Operating Procedures", April 1991, Report No. H2057.

"Columbia River Treaty Flood Control Operating Plan", October 1972.

"Detailed Operating Plan for Columbia River Treaty Storage", September 1993.

West Kootenay Production Area Local Operating Orders:

LOO 304-510	Duncan Dam General
LOO 304-510B	Duncan Dam Water Release Procedures
LOO 304-510F	Duncan Dam Low Level Gate Operation
LOO 304-510G	Duncan Dam Spillway Gate Operation
LOO 304-510H	Duncan Dam Low Level Maintenance Gate Operation

22.0 ATTACHMENTS

S.O.O. 4P-41A contains the text of these attachments.

22.1 Location Map and Area Plan
22.2 Project Data Table
22.3 Streamflow and Water Level Stations.
22.4 Meteorological Stations
22.5 Snowcourse Stations
22.6 Logic Diagram of Reservoir Routing Operating Procedure
22.7 Reservoir Routing Operating Diagram

Paul T.B. Adams, P.Eng.
Manager,
Power Supply Operations

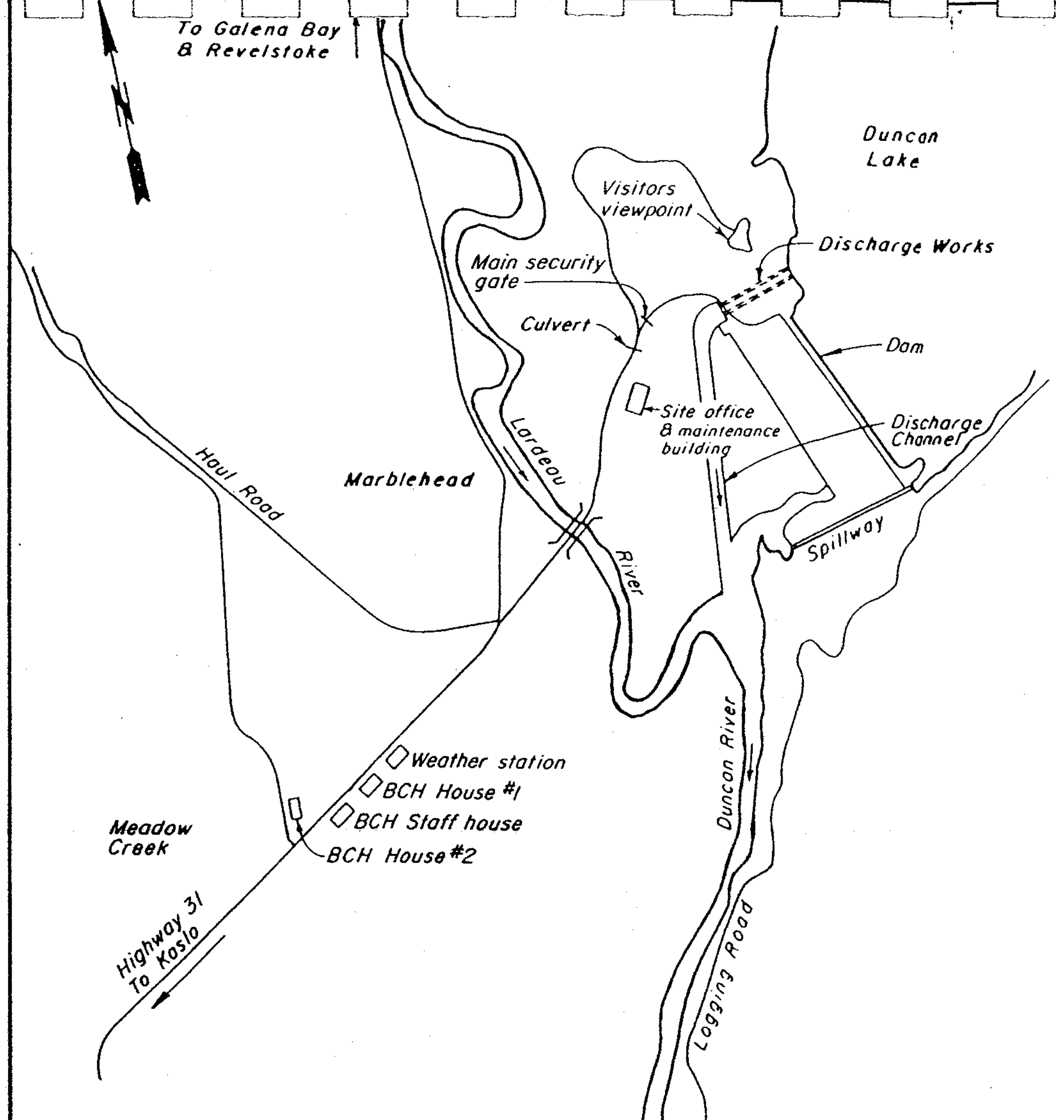
SYSTEM OPERATING ORDER 4P-41A
(Attachments to S.O.O. 4P-41)

DUNCAN DAM PROJECT
(New Order)

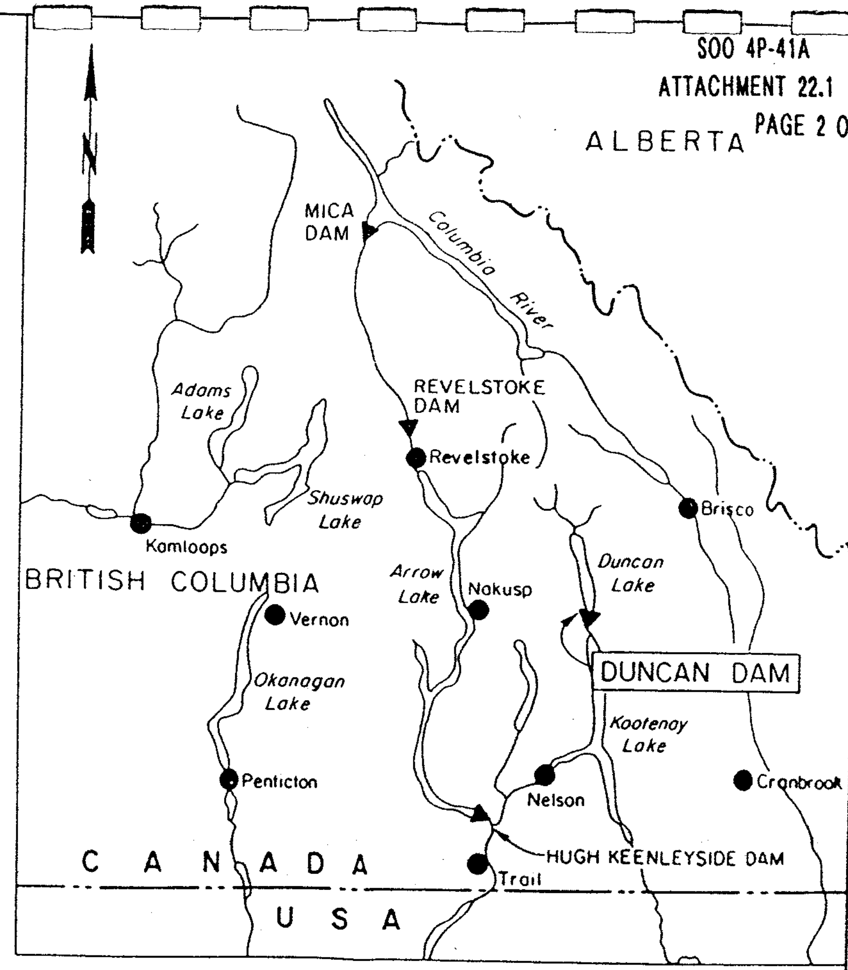
TABLE OF CONTENTS

	Title	Page
22.1	Location Map and Area Plan	2
22.2	Project Data Table	3
22.3	Streamflow and Water Level Stations	4
22.4	Meteorological Stations	5
22.5	Snowcourse Stations	6
22.6	Logic Diagram of Reservoir Routing Operating Procedure	7
22.7	Reservoir Routing Operating Diagram	8

Paul T.B. Adams, P.Eng.
Manager,
Power Supply Operations



Area Plan
N.T.S.



Location Map

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	
DUNCAN DAM	
LOCATION MAP & AREA PLAN	
DATE JUL 1990	
DWN	DWG. No. 210-C14-B127

PROJECT DATA

1. GENERAL

Project Name	Duncan Dam	
Location	On the Duncan River, about 8 km from the north end of Kootenay Lake.	
Geographical Coordinates	Latitude Longitude	50° 15' 10"N 116° 54' 34"W
Water Licence	No. 0236916 and amendments	
Operational Date	April 1967	

2. DAM

Name of Dam	Duncan	
Use	Storage	
Type	Zoned earthfill embankment, with an upstream impervious blanket and slurry trench cut-off.	
Foundation Materials	Earth and rock	
Crest Length	792m	2600 ft.
Elevation of Top of Dam	581.25m	1907 ft.
Elevation of Top of Impervious Core	579.13m	1900 ft.
Top Width	9.1m	30 ft.
Normal Freeboard	4.6m	15 ft.
Surcharge of Riprap Above Dam Crest	0.9m	3 ft.
Volume	$4.9 \times 10^6 m^3$	6.4×10^6 cu yd.

3. RESERVOIR

Name	Duncan Lake	
Area at Maximum Operating Level	71.5 km^2	27.6 sq. mi.
Drainage Area	2410 km^2	930 sq. mi.
Total Storage		
(El. 546.87 to 576.68)	$1.73 \times 10^9 m^3$	1.40×10^6 ac ft.
(El. 576.69 to 578.21)	$109.6 \times 10^6 m^3$	88.9×10^3 ac ft.

Live Storage	$1.73 \times 10^9 m^3$	1.4×10^6 ac ft.
Maximum Flood Level	578.21m	1897 ft.
Maximum Operating Level	576.68m	1892 ft.
Minimum Operating Level	546.87m	1794.2 ft.

4. DIVERSION TUNNELS

Present Status	Used for discharge works.	
Number	2	
Diameter (Concrete Lined)	6.10m	20 ft.
Length	332.84m	1092 ft.
Flow Regime	Free surface	
Design Flow (for Diversion)	685 m^3/s	24,200 cfs

5. SPILLWAY

Location	Left abutment	
Type	Gated (2 vertical lift sluice gates), low ogee crest, concrete lined chute, plunge pool.	
Construction Materials	Concrete and rock.	
Design Flood	Probable Maximum Flood	
Vertical Lift Gates:		
Location	On overflow ogee section	
Number	2 fixed roller gates.	
Size (w x h)	8.69m x 12.19m	28.5 ft. x 40 ft.
Capacity of Gated Section		
@ El. 578.21m	1430 m^3/s	50,400 cfs
@ El. 576.68	1190 m^3/s	42,000 cfs
Energy Dissipation	Plunge pool	

6. DISCHARGE

Purpose	To make normal (non flood) releases from the reservoir.
Location	In rock through right abutment.
Number	2 tunnel 6.10 m (20 ft.) in diameter and 332.84 m (1092 ft.) long.
Lining	Unreinforced concrete.
Capacity @ El. 576.68m	525 m^3/s (18,500 cfs) each tunnel.
Operating Gates	Radial 5.87 m wide x 4.80 m high (19.25 ft. x 15.75 ft.) at downstream end of tunnel with electrically operated hydraulic hoists.
Maximum Water Velocity in Tunnel	9.1 m/s 30 ft./s
Flow Regime	Pressure

STREAMFLOW AND WATER LEVEL STATIONS

Station Name	Station Number	Agency Responsible	Drainage Area (km^2)	Period of Record
STREAMFLOW:				
Duncan River below B.B. Creek[2]	08NH119	WSC[1]	1330	1962-present (DCP: 1984-present)
Duncan River near Howser	08NH001	WSC	2160	1915-19, 34-67
Duncan River below Duncan Dam	08NH126	WSC/BCH	2440	1967-present
Duncan River below Lardeau River	08NH118	WSC	4070	1963-present
WATER LEVEL:				
Duncan Lake at Howser	08NH110	WSC		1915-19, 34-67
Duncan Reservoir at Duncan Dam[2]	08NH127	WSC/BCH		1967-present (DCP: 1984-present)

1 Water Survey of Canada.
2 Data Collection Platforms (DCPs) have been installed at these stations.
3 Station Numbers refer to Atmospheric Environment Service (AES) station numbers.
4 Data Type Codes: T = temperature, P = precipitation, I = precipitation intensity, W = wind, E= evaporation, S = sunshine.
5 B.C. Ministry of Environment.
6 Numbers refer to B.C. Ministry of Environment.
7 Snowcourse measured by Duncan Dam Dam Caretaker.
8 Snow Pillow and DCP also installed.
9 Wind anemometer located on crest of Duncan Dam.

STREAMFLOW AND WATER LEVEL STATIONS

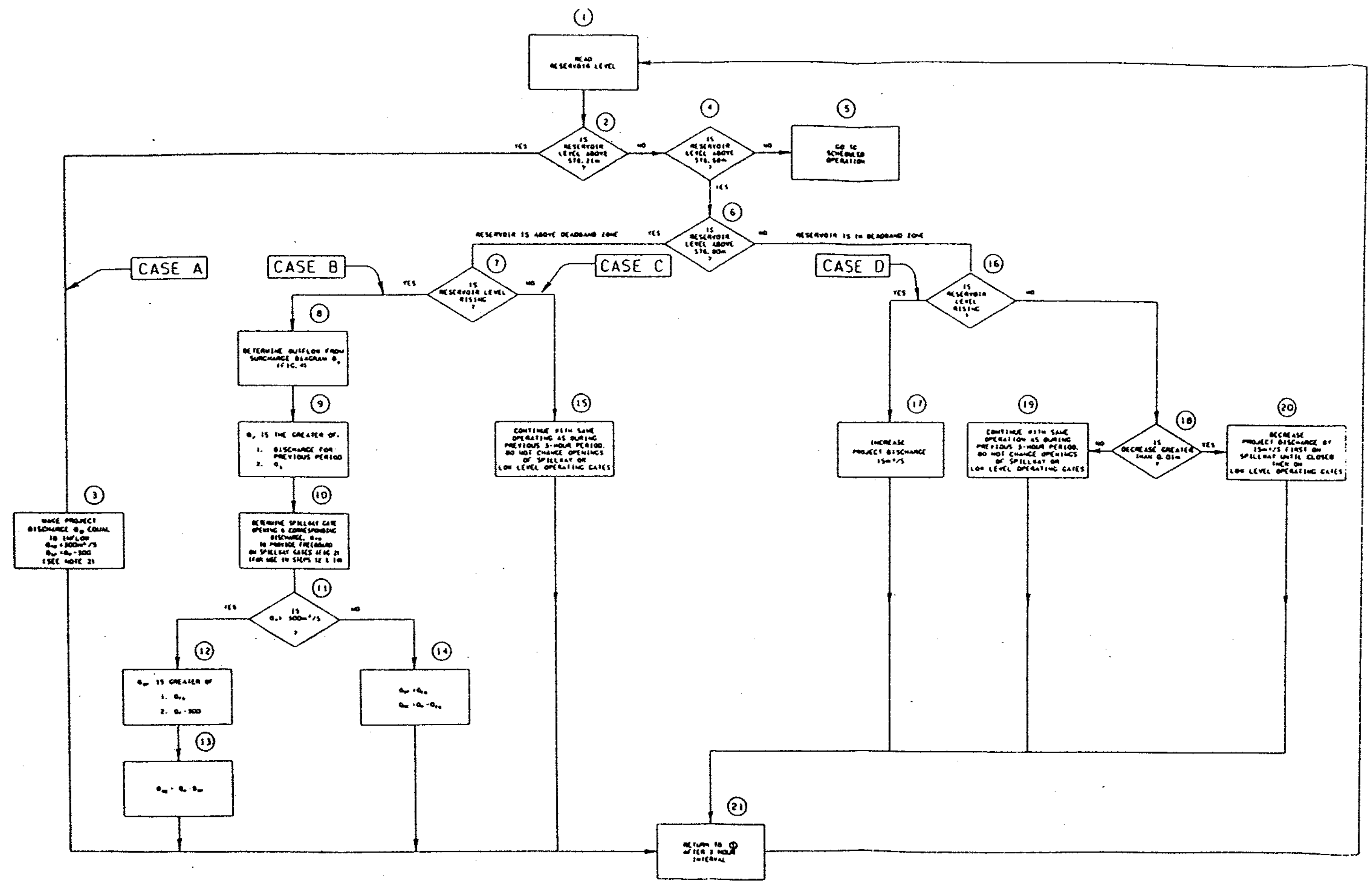
Station Name	Station[3] Number	Agency Responsible	Station Elevation (m)	Period of Record	Type[4] of Data
Brisco	1171020	AES	823	1924-present	P
Bugaboo Ck. Lodge	1171105	AES	1494	1972-present	T,P
Duncan Lake Dam[2,9]	1142574	AES/BCH	549	1963-present (DCP: 1984-present)	T,P,I,W,E
Duncan River at B.B. Creek		WSC	590	1984-present	T,P
East Creek[2]		MOE[5]	2030	1984-present	T,P
Glacier NP Mt. Fidelity	117CA90	AES	1875	1969-present	T,P
Glacier NP Rogers Pass	1173191	AES	1323	1892-present	T,P
Golden	1173210	AES	787	1902-present	T,P,I
Kaslo	1143900	AES	588	1894-present	T,P
Revelstoke	1176751	AES	443	1898-present	T,P,I,W,S

1 Water Survey of Canada.
2 Data Collection Platforms (DCPs) have been installed at these stations.
3 Station Numbers refer to Atmospheric Environment Service (AES) station numbers.
4 Data Type Codes: T = temperature, P = precipitation, I = precipitation intensity, W = wind, E= evaporation, S = sunshine.
5 B.C. Ministry of Environment.
6 Numbers refer to B.C. Ministry of Environment.
7 Snowcourse measured by Duncan Dam Dam Caretaker.
8 Snow Pillow and DCP also installed.
9 Wind anemometer located on crest of Duncan Dam.

STREAMFLOW AND WATER LEVEL STATIONS

Station Name	Number[6]	Elevation	Years of Record
Bugaboo Creek	2A26	1510	11
Duncan Lake[7,10]	2D07	650	19
East Creek[8]	2D08	2030	18
Ferguson	2D02	880	45
Fidelity Mountain	2A17	1870	22
Glacier	2A02	1250	47
Mount Abbot	2A14	1980	26
Mount Templeman	2D09	1860	18
Vermont Creek	2A19	1520	19

1 Water Survey of Canada.
2 Data Collection Platforms (DCPs) have been installed at these stations.
3 Station Numbers refer to Atmospheric Environment Service (AES) station numbers.
4 Data Type Codes: T = temperature, P = precipitation, I = precipitation intensity, W = wind, E= evaporation, S = sunshine.
5 B.C. Ministry of Environment.
6 Numbers refer to B.C. Ministry of Environment.
7 Snowcourse measured by Duncan Dam Dam Caretaker.
8 Snow Pillow and DCP also installed.
9 Wind anemometer located on crest of Duncan Dam.
10 Station 2D07A will eventually replace 2D07. They are at the same location.



EXAMPLE:

RESERVOIR LEVEL ABOVE EL. 576.80m AND RISING

(1) RESERVOIR LEVEL = EL.577.0m

(2) RESERVOIR LEVEL BELOW 576.21m

(4) RESERVOIR LEVEL ABOVE 576.60m

(6) RESERVOIR LEVEL ABOVE 576.80m

(7) 577.0 > 576.90 : RESERVOIR IS RISING, CASE B

(8) OUTFLOW, Q_c FROM SURCHARGE DIAGRAM

a. PREVIOUS 3 HR. OUTFLOW 120 m³/s

b. INFLOW = (577.0-576.90)*6689+120 = 789 m³/s

c. Q_c = 190 m³/s

(9) Q_c IS GREATER THAN THE PREVIOUS 3 HR. OUTFLOW OF 120 m³/s PROJECT DISCHARGE Q_p = 190 m³/s

(10) Q_{FB} = 43m³/s (FIG. 2)

(11) Q_p < 300m³/s

(14) Q_{SW} = 43m³/s
Q_{LL} = 190 - 43 = 147m³/s

(21) RETURN TO (1) AFTER 3 HOURS

NOTES:

1. Q_{SW} = SPILLWAY DISCHARGE

Q_{LL} = LOW LEVEL OPERATING GATE DISCHARGE

Q_c = REQUIRED DISCHARGE FROM SURCHARGE DIAGRAM

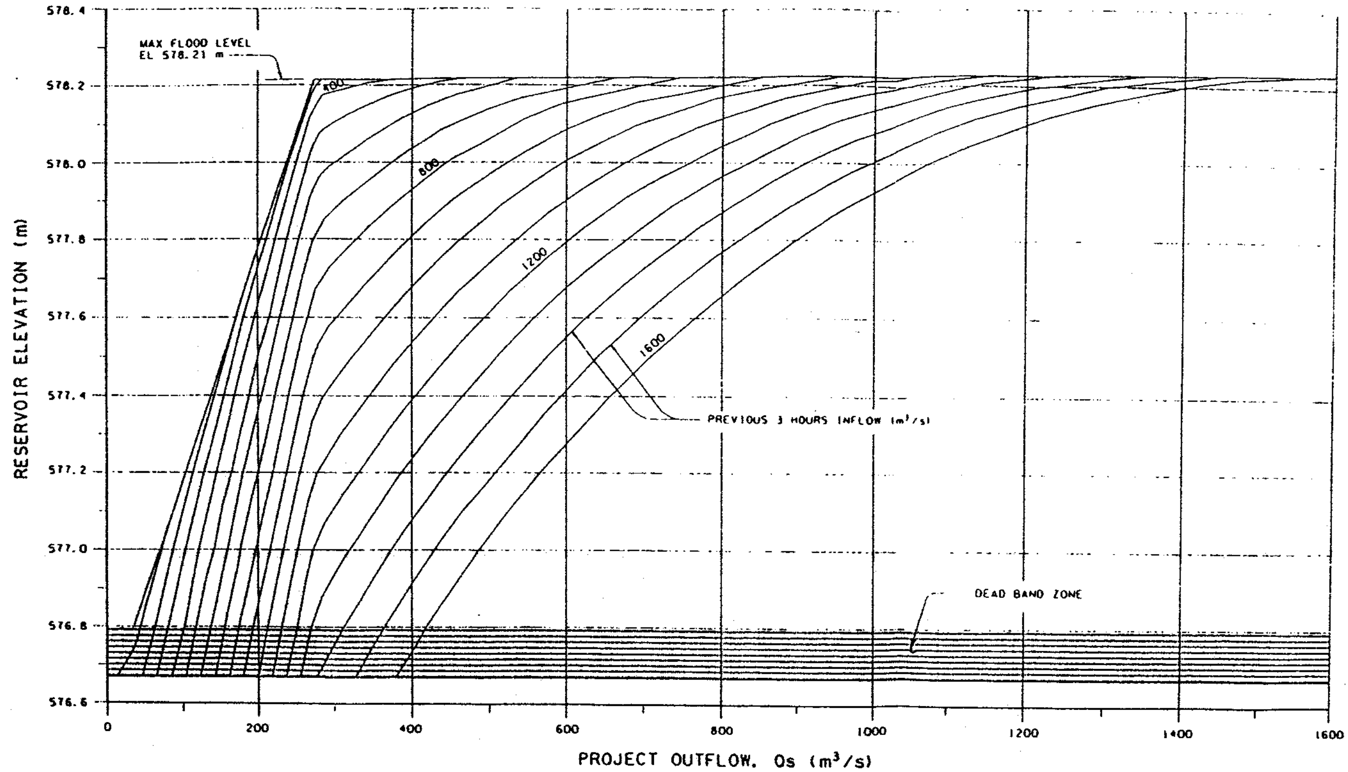
Q_p = PROJECT DISCHARGE

Q_{FB} = REQUIRED DISCHARGE TO PROVIDE FREEBOARD ON SPILLWAY GATES

2. FOR CASE A, IF SPILLWAY GATES ARE FULLY OPEN LOW LEVEL OPERATING GATES MAY BE USED UP TO 600m³/s TO INCREASE PROJECT DISCHARGE.

3. ADAPTED FROM DWG 210-C14-C165.

BRITISH COLUMBIA HYDRO AND POWER AUTHORITY	
DUNCAN DAM	
LOGIC DIAGRAM OF RESERVOIR ROUTING OPERATING PROCEDURE	
DATE NOV 1993	
DWN /S.E	DWG. No. 210-C14-C476 R



CALCULATION OF PREVIOUS 3 HOURS INFLOWS

INFLOW = (E2 − E1) × 6689 + OUTFLOW

WHERE : INFLOW : PREVIOUS 3 HOURS INFLOW IN m^3/s

E2 : RESERVOIR ELEVATION NOW m

E1 : RESERVOIR ELEVATION 3 HOURS PREVIOUS m

6689 : A CONSTANT

$= 836.13\ (m^3/s) \cdot DAYS \cdot \frac{1}{3\ HRS} \cdot \frac{24\ HRS}{DAY}$

OUTFLOW : SUM OF SPILLWAY AND LOW LEVEL OPERATING GATE DISCHARGE, m^3/s

* IF THE ROUTING INTERVAL IS NOT 3 HOURS RECALCULATE THE CONSTANT USING THE ABOVE EQUATION

NOTES:

1. ADAPTED FROM DWG 210-C-14-C166.

BChydro	
DUNCAN DAM	
RESERVOIR ROUTING OPERATING DIAGRAM	
DATE JAN 1994	
DRN S.K	DWG No. 210-C14-C477 R

MANUAL No. 210/02

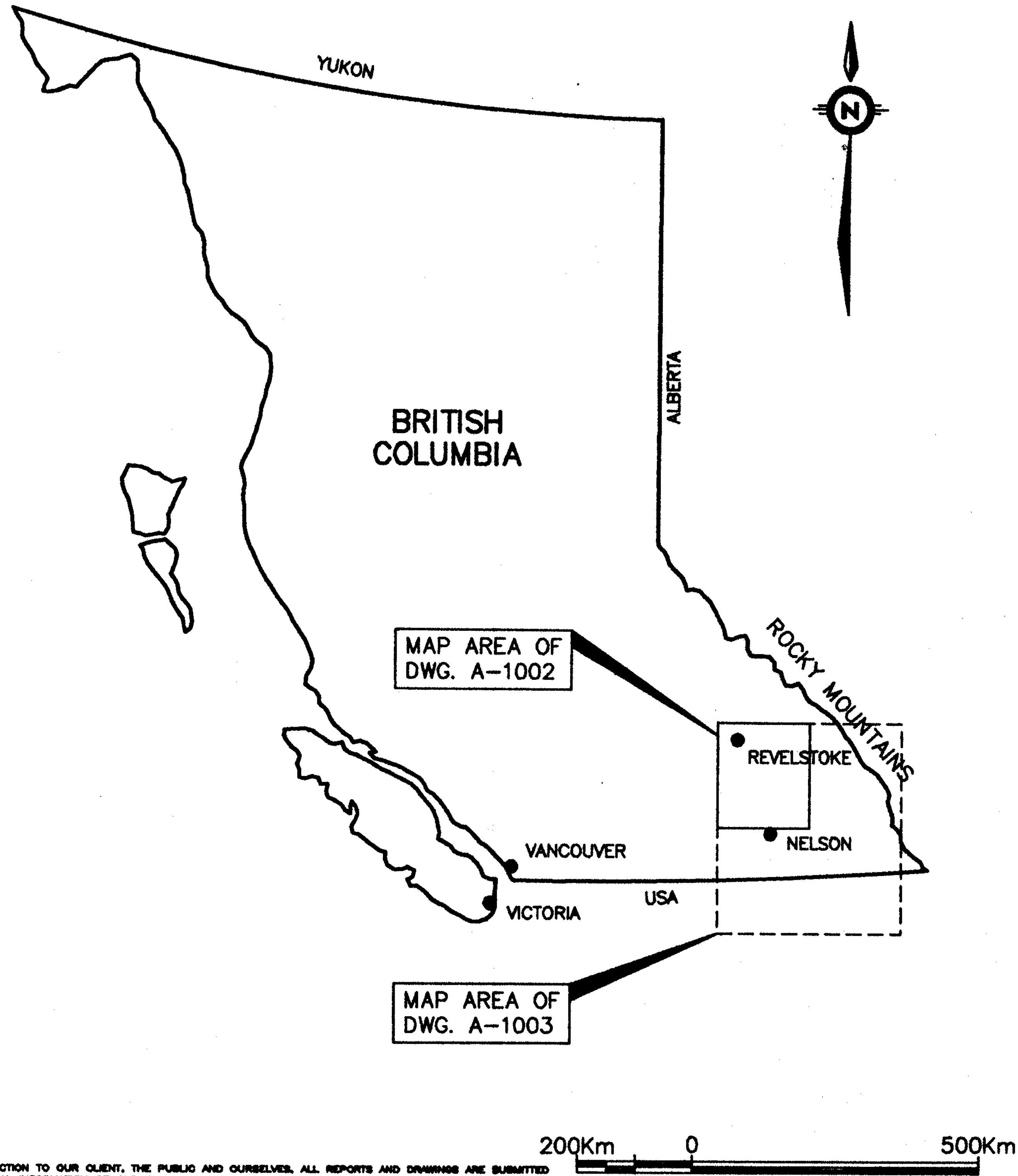
USER: S. C/04, FEB1994

APPENDIX IV

Floodplain Maps

DRAWINGS

A-1001	Location of Study Area
A-1002	Study Area
A-1003	Kootenay Lake System
A-1004	Flood Frequency Plot of Lardeau at Marblehead, Maximum Daily Discharge
A-1005	Flood Frequency Plot of Lardeau At Marblehead, Maximum Instantaneous Discharge
A-1006	Flood Frequency Plot of Carney Creek below Pambrun Creek, Maximum Daily Discharge
A-1007	Flood Frequency Plot of Carney Creek below Pambrun Creek, Maximum Instantaneous Discharge
A-1008	Duncan River Daily Discharges at Duncan Dam
A-1009	Flood Frequency Plot of Fry Creek below Carney Creek, Maximum Daily Discharge
A-1010	Flood Frequency Plot of Fry Creek below Carney Creek, Maximum Instantaneous Discharge
A-1011	Flood Frequency Plot of Lardeau at Marblehead, July 15 - September 15, Maximum Daily Discharge
A-1012	Flood Frequency Plot of Kootenay Lake at Queens Bay, Maximum Instantaneous Level (1972 to 1992)
A-1013	Stage - Discharge Curve, Duncan River - WSC 08NH118
A-1014	Stage - Discharge Curve, Lardeau River - WSC 08NH007
B-1015	HEC-2 Calibration Profiles
B-1016	Design Water Level Profiles



KLOHN-CRIPPEN

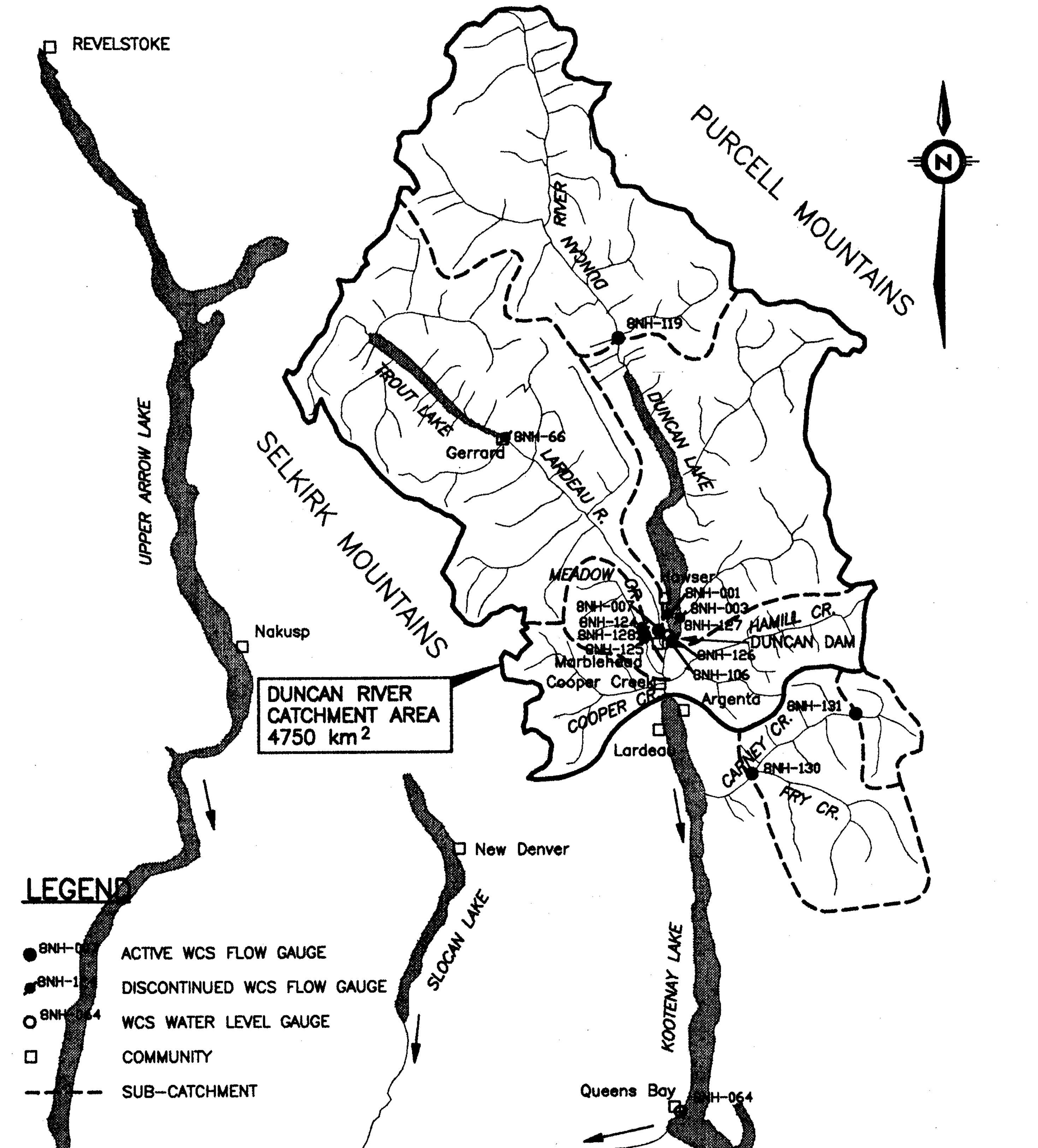
PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS

TITLE: LOCATION OF STUDY AREA

CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB.29, 1996	PW7087 01	A-1001	

APPROVED: K.Z. R[illegible]



SCALE 1:7,500,000

KLOHN-CRIPPEN

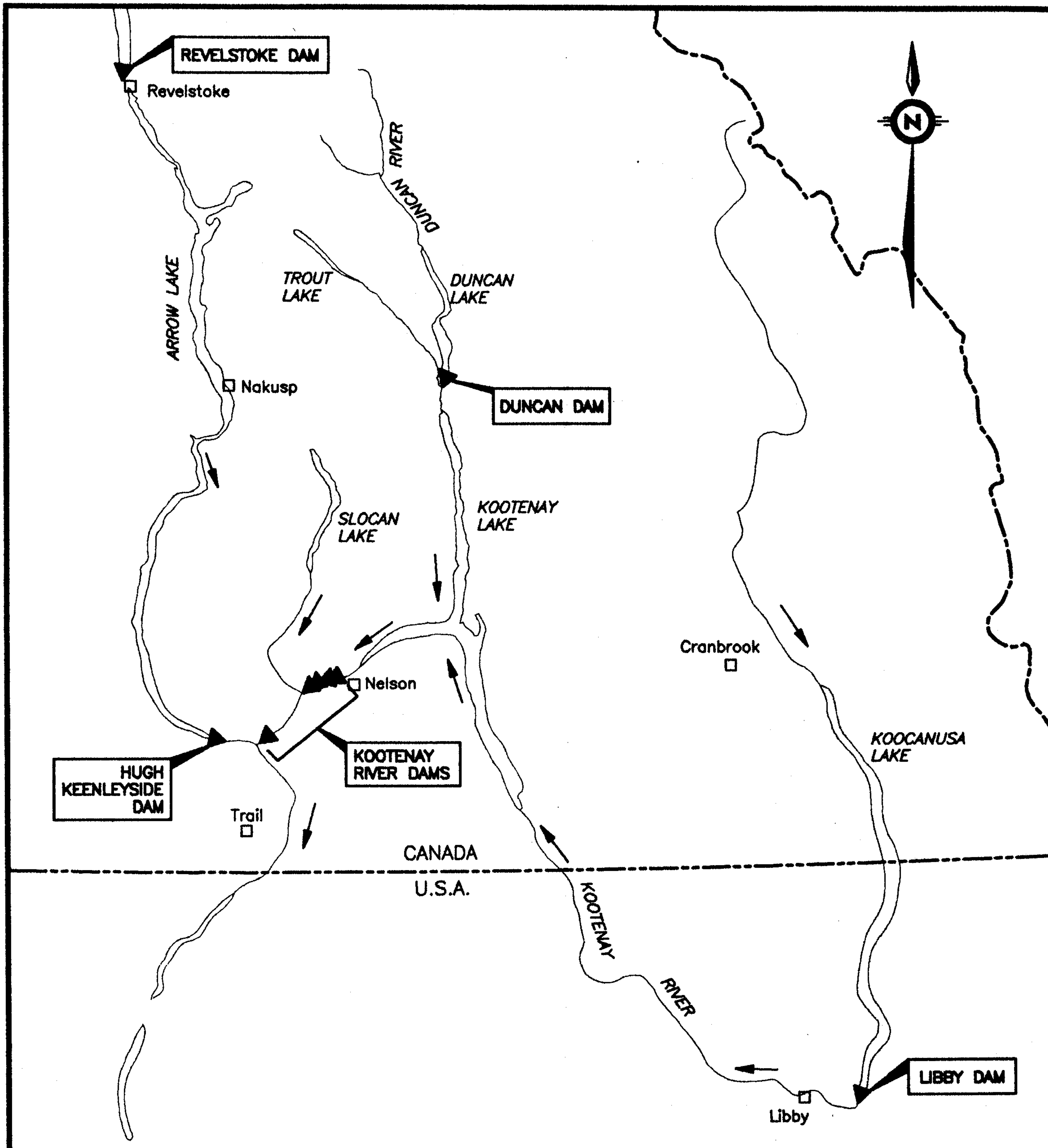
PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS

TITLE: STUDY AREA

CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB.29, 1996	PW7087 01	A-1002	

APPROVED: [signature]



SCALE 1:1,500,000

KLOHN-CRIPPEN

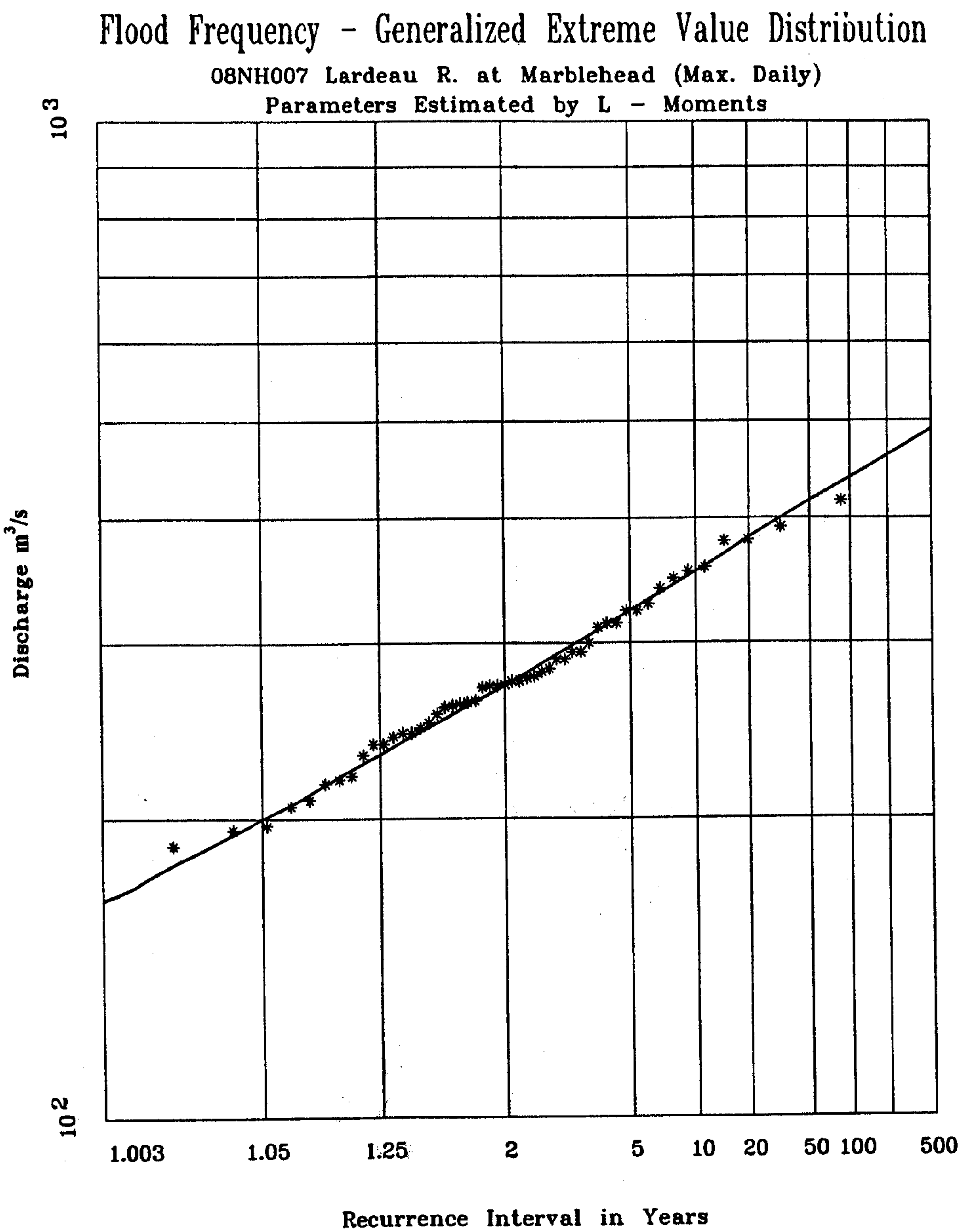
PROJECT: FLOODPLAIN MAPPING PROGRAM
DUNCAN AND LARDEAU RIVERS

TITLE: KOOTENAY LAKE SYSTEM

CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS

DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
FEB.29, 1996	PW7087 01	A–1003	

APPROVED: R.J. R[illegible]

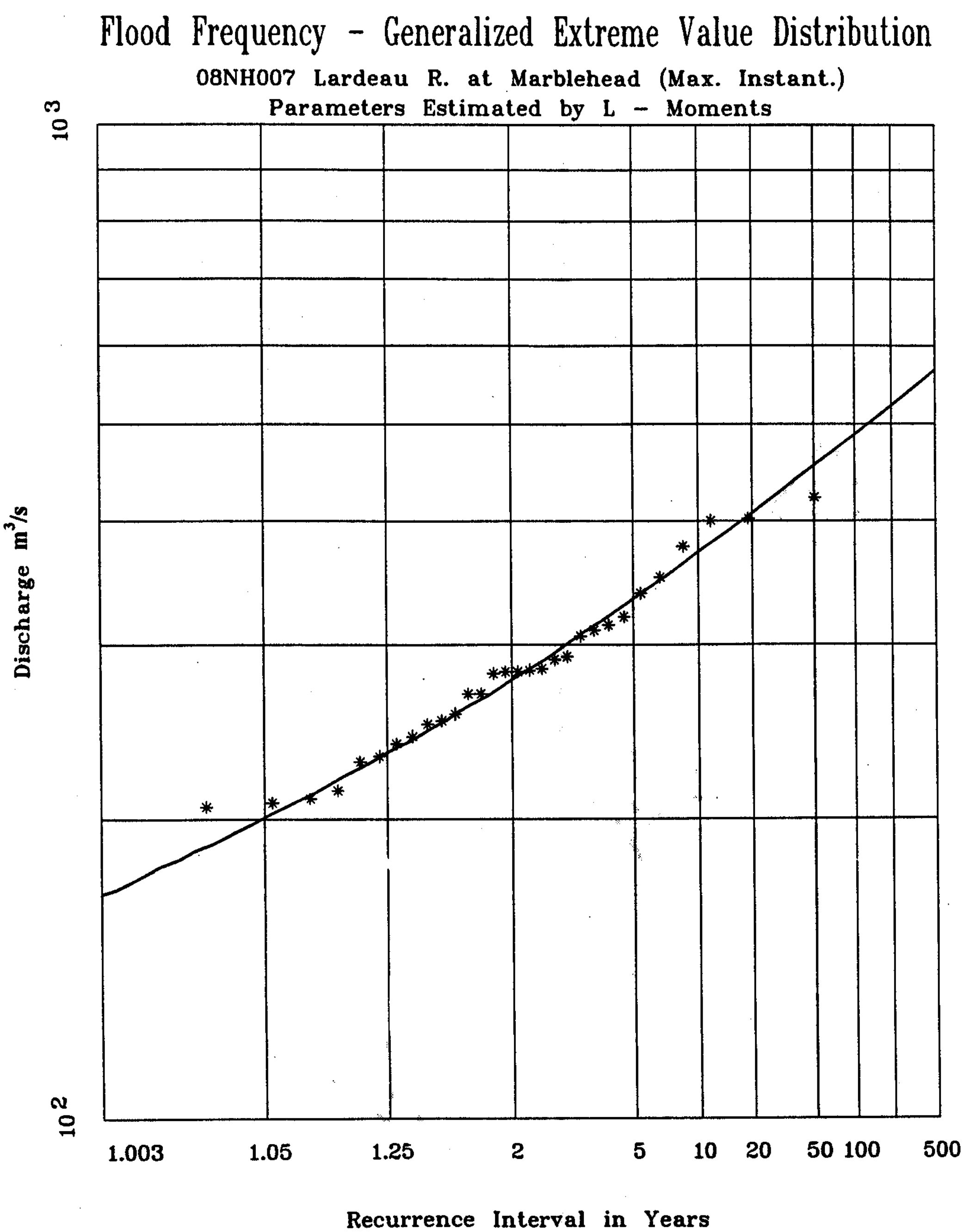


KLOHN-CRIPPEN

PROJECT	FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS
TITLE	Flood Frequency Plot of Lardeau at Marblehead Maximum Daily Discharge

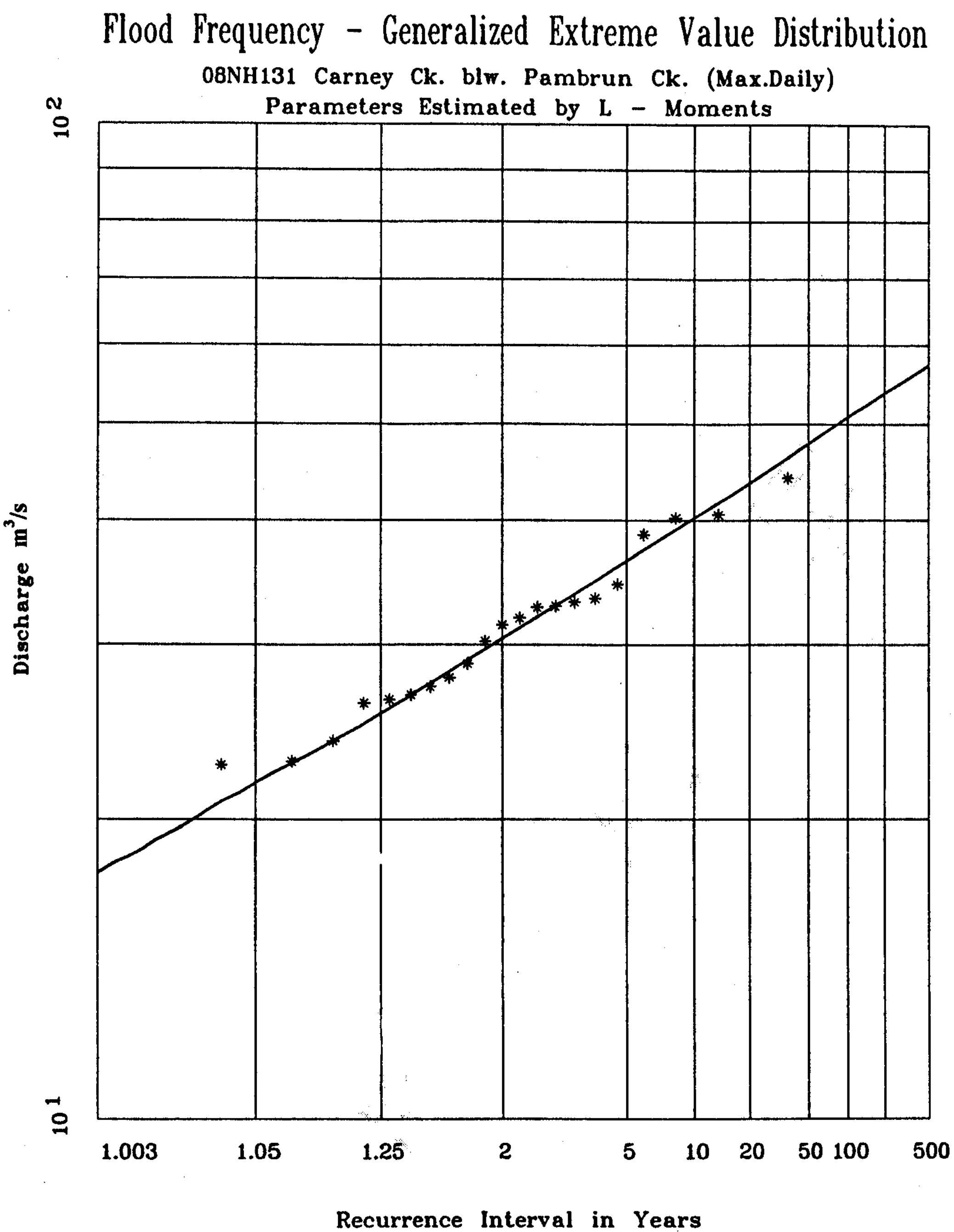
CLIENT:	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	Feb. 29, 1996	PW7087 01	A-1004	
	APPROVED R. J. Rodman			

FIGSHTS.XLS



KLOHN-CRIPPEN	PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
	TITLE: Flood Frequency Plot of Lardeau at Marblehead Maximum Instantaneous Discharge			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE: Feb. 29, 1996 APPROVED: B.J. Rod...	PROJECT No.: PW7087 01	DWG. No.: A-1005	REV.

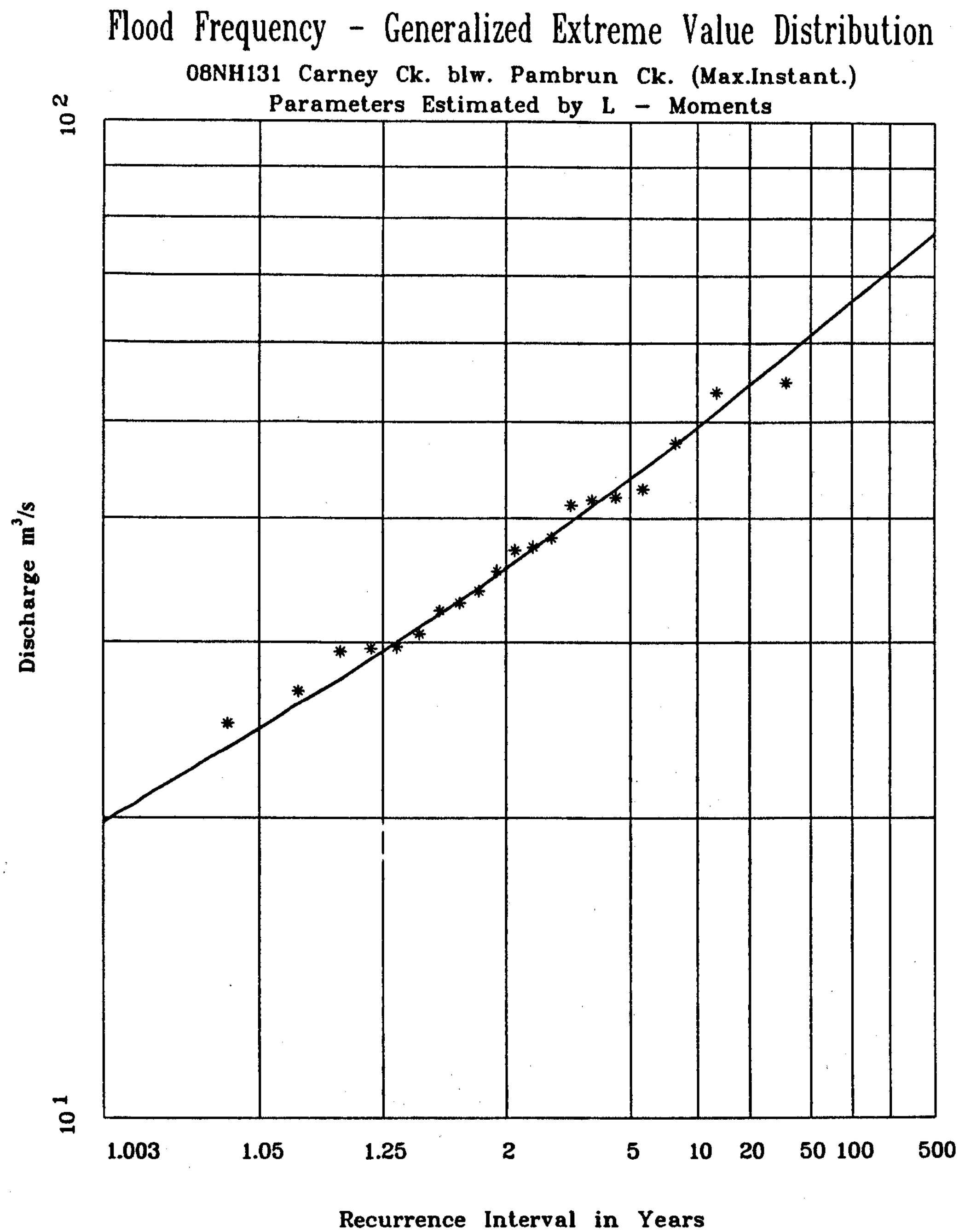
FIGSHTS.XLS



KLOHN-CRIPPEN

PROJECT	FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
TITLE	Flood Frequency Plot of Carney Creek below Pambrun Creek Maximum Daily Discharge			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE Feb. 29, 1996 APPROVED R.J. Rod	PROJECT No. PW7087 01	DWG. No. A-1006	REV.

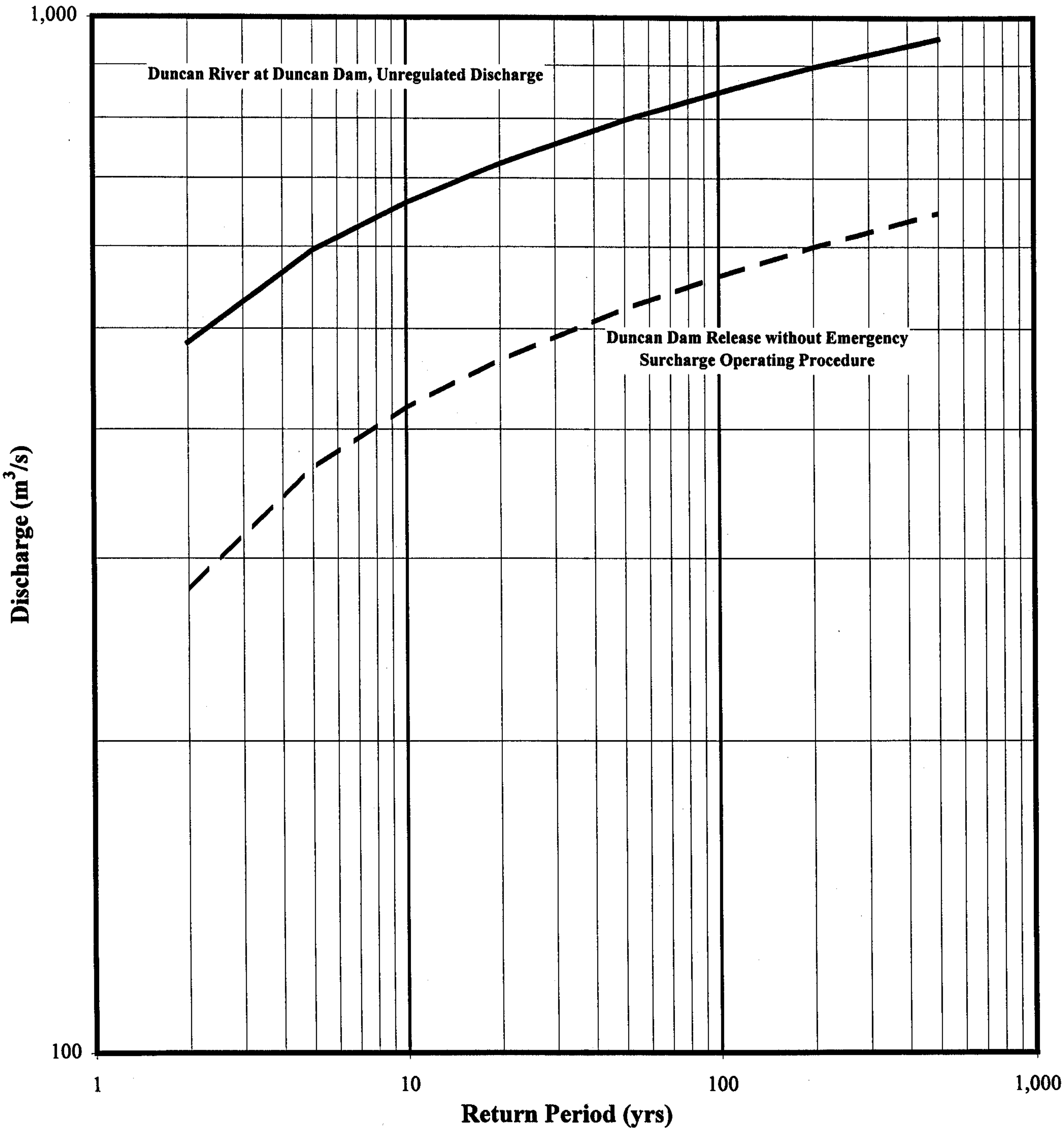
FIGSHTS.XLS



KLOHN-CRIPPEN	PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS
	TITLE: Flood Frequency Plot of Carney Creek below Pambrun Creek Maximum Instantaneous Discharge

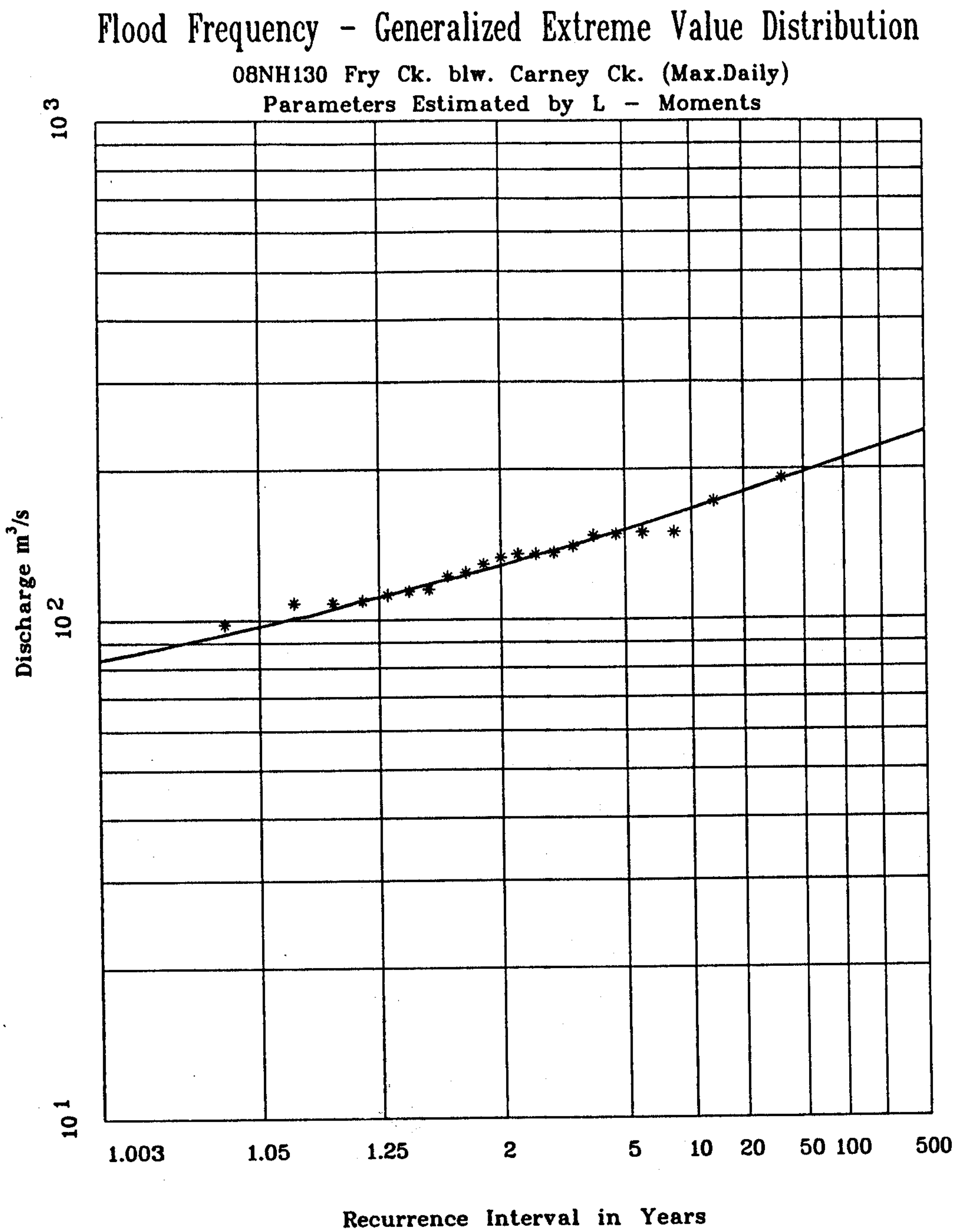
CLIENT:	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	Feb. 29, 1996 APPROVED R.J. Rodman	PW7087 01	A-1007	

FIGSHTS.XLS



KLOHN-CRIPPEN	PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
	TITLE: Duncan River Daily Discharges at Duncan Dam			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE: Feb. 29, 96 APPROVED: R.F. Rodman	PROJECT No.: PW7087 01	DWG. No.: A-1008	REV.

FIGSHTS.XLS



KLOHN-CRIPPEN

PROJECT	FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS
TITLE	Flood Frequency Plot of Fry Creek below Carney Creek Maximum Daily Discharge

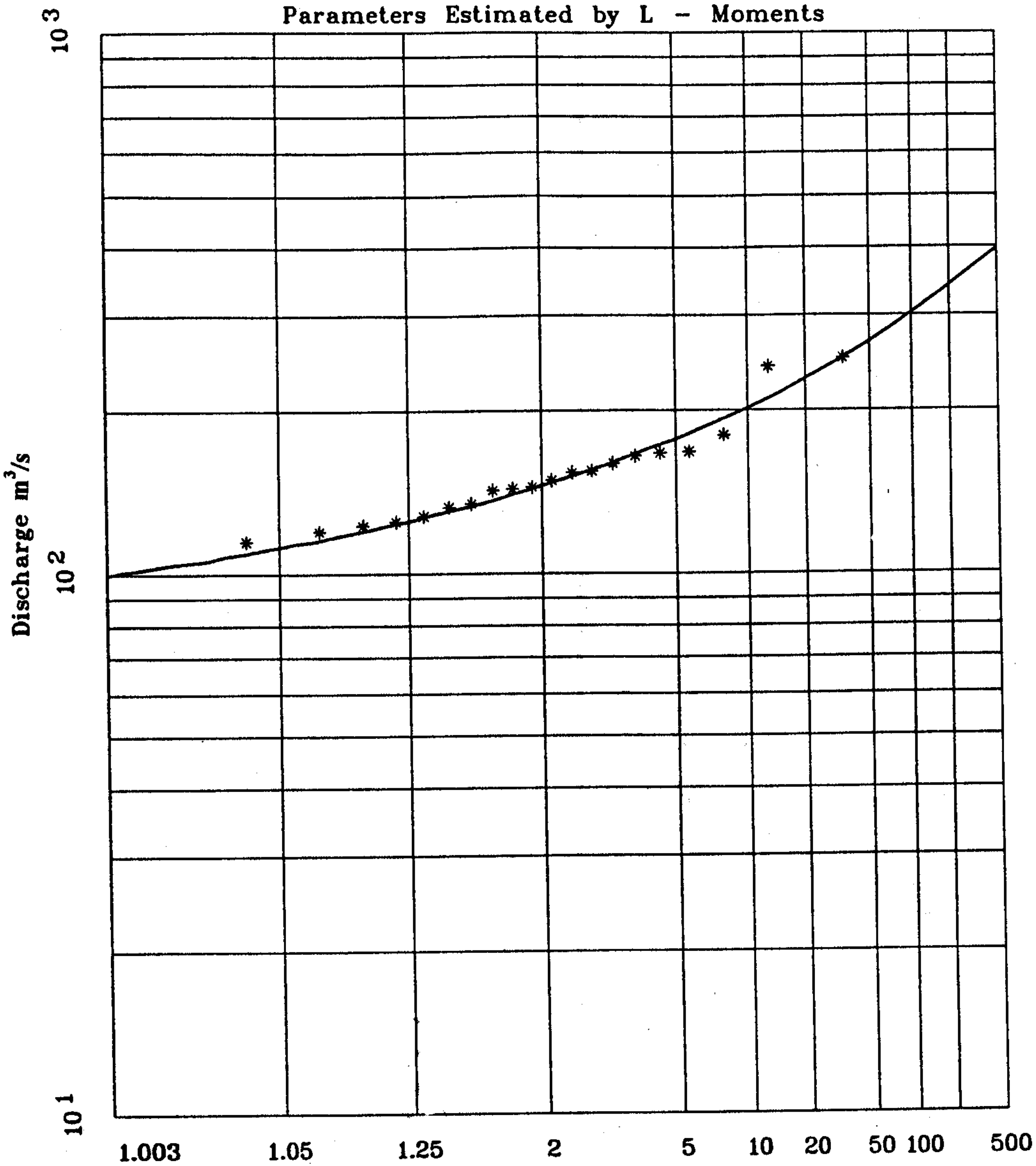
CLIENT:	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	Feb. 29, 1996 APPROVED R.F. Rodman	PW7087 01	A-1009	

FIGSHTS.XLS

Flood Frequency - Generalized Extreme Value Distribution

08NH130 Fry Ck. blw Carney Ck. (Max.Instant.)

Parameters Estimated by L - Moments



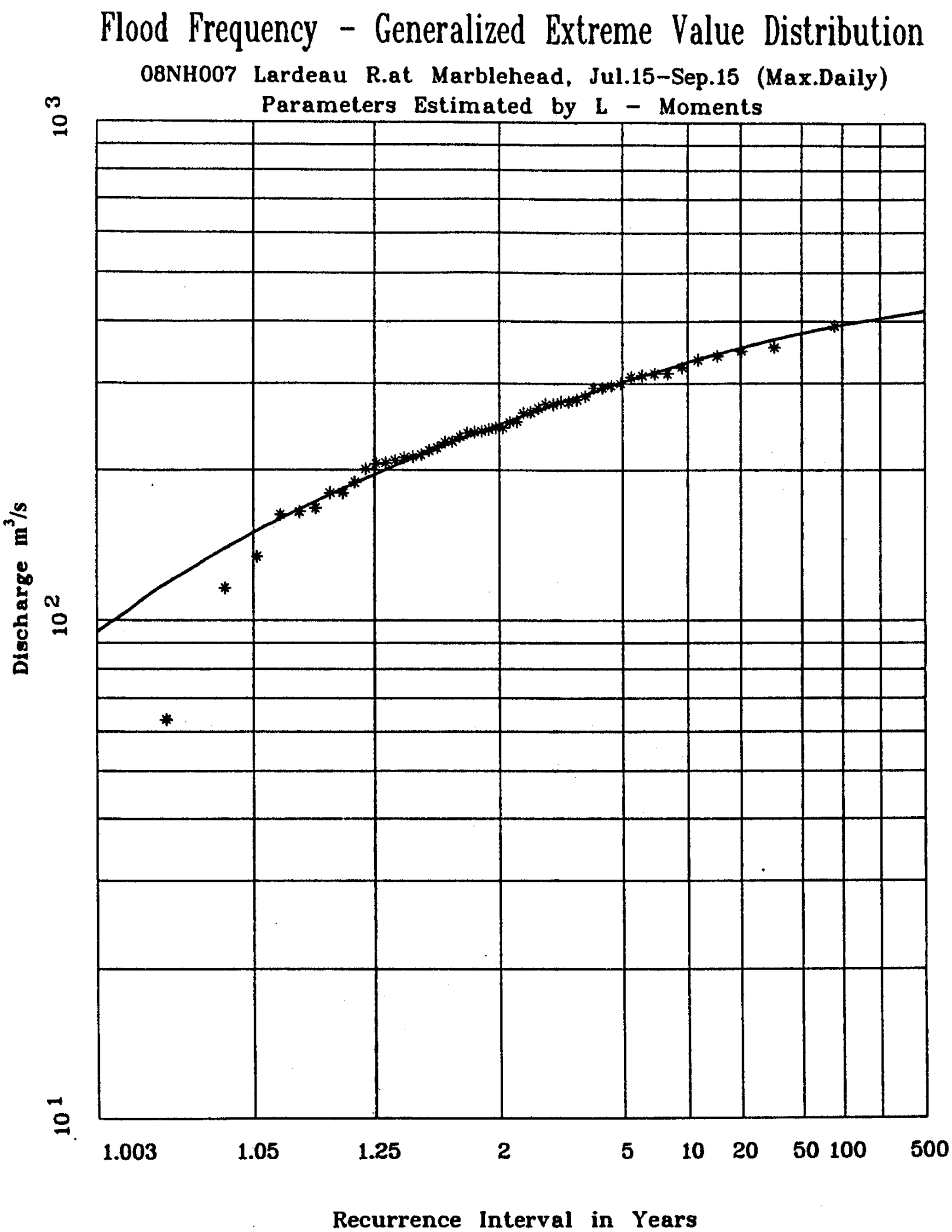
KLOHN-CRIPPEN

PROJECT: FLOODPLAIN MAPPING PROGRAM
DUNCAN AND LARDEAU RIVERS

TITLE: Flood Frequency Plot of Fry Creek below Carney Creek
Maximum Instantaneous Discharge

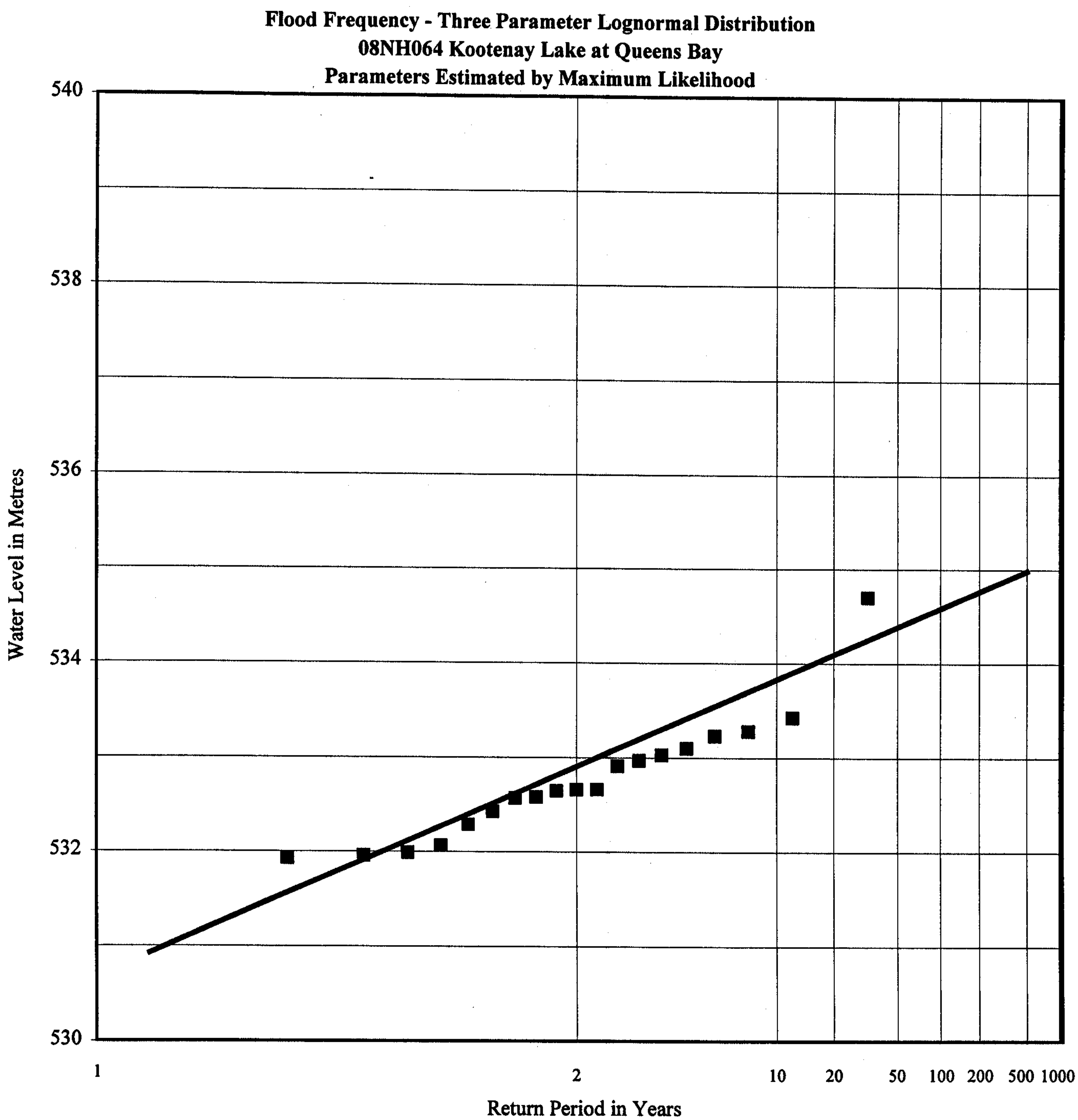
CLIENT:	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	Feb. 29, 1996 APPROVED R.J. Rod[illegible]	PW7087 01	A-1010	

FIGSHTS.XLS



KLOHN-CRIPPEN	PROJECT FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
	TITLE Flood Frequency Plot of Lardeau at Marblehead July 15 - September 15, Maximum Daily Discharge			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE Feb. 29, 1996 APPROVED R.F. Rodman	PROJECT No. PW7087 01	DWG. No. A-1011	REV.

FIGSHTS.XLS



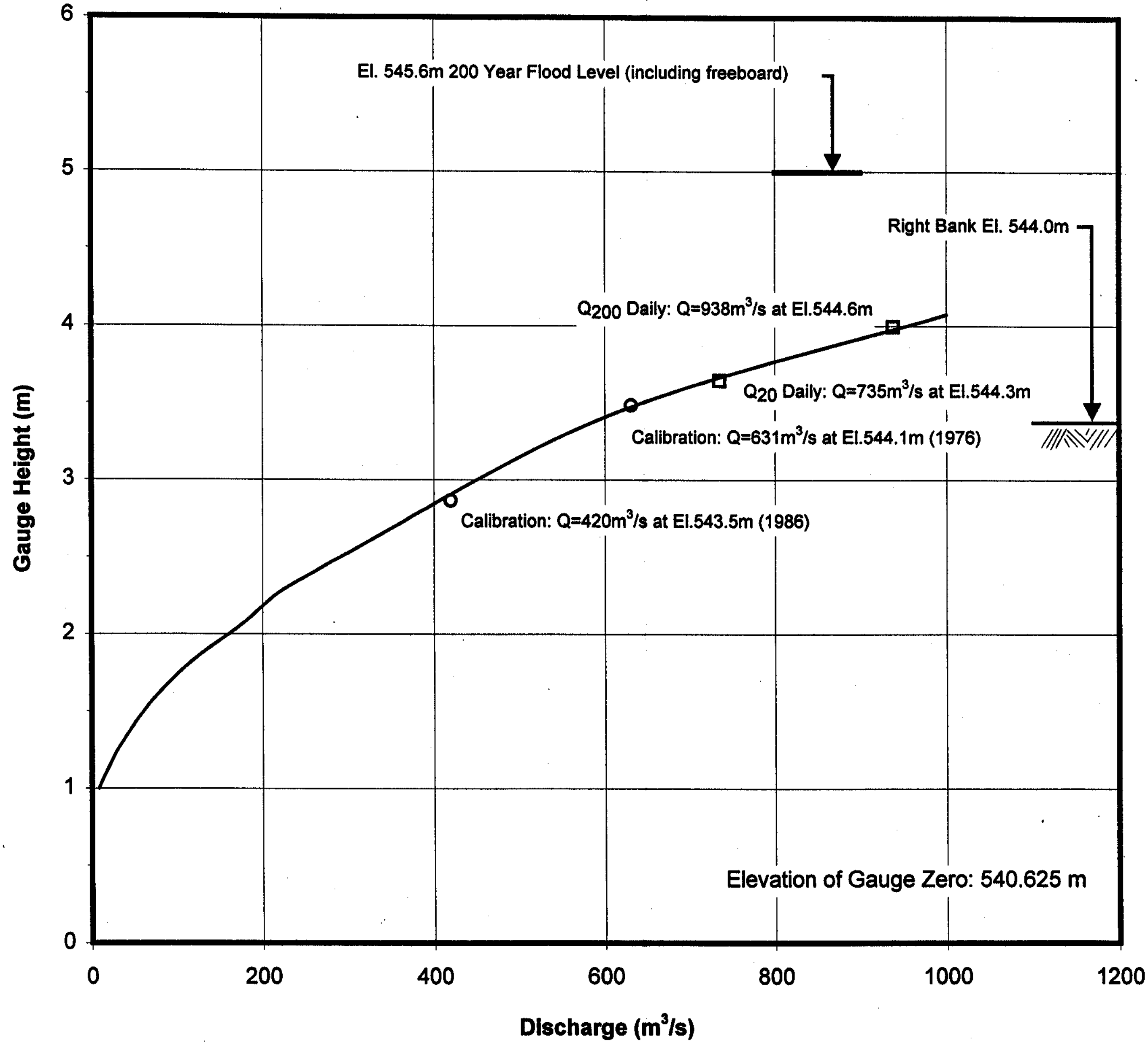
KLOHN-CRIPPEN

PROJECT	FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS
TITLE	Flood Frequency Plot of Kootenay Lake at Queens Bay Maximum Instantaneous Level (1972 to 1992)

CLIENT:	DATE OF ISSUE	PROJECT No.	DWG. No.	REV.
BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	Feb. 29, 1996	PW7087 01	A-1012	
	APPROVED R. I. Rod[illegible]			

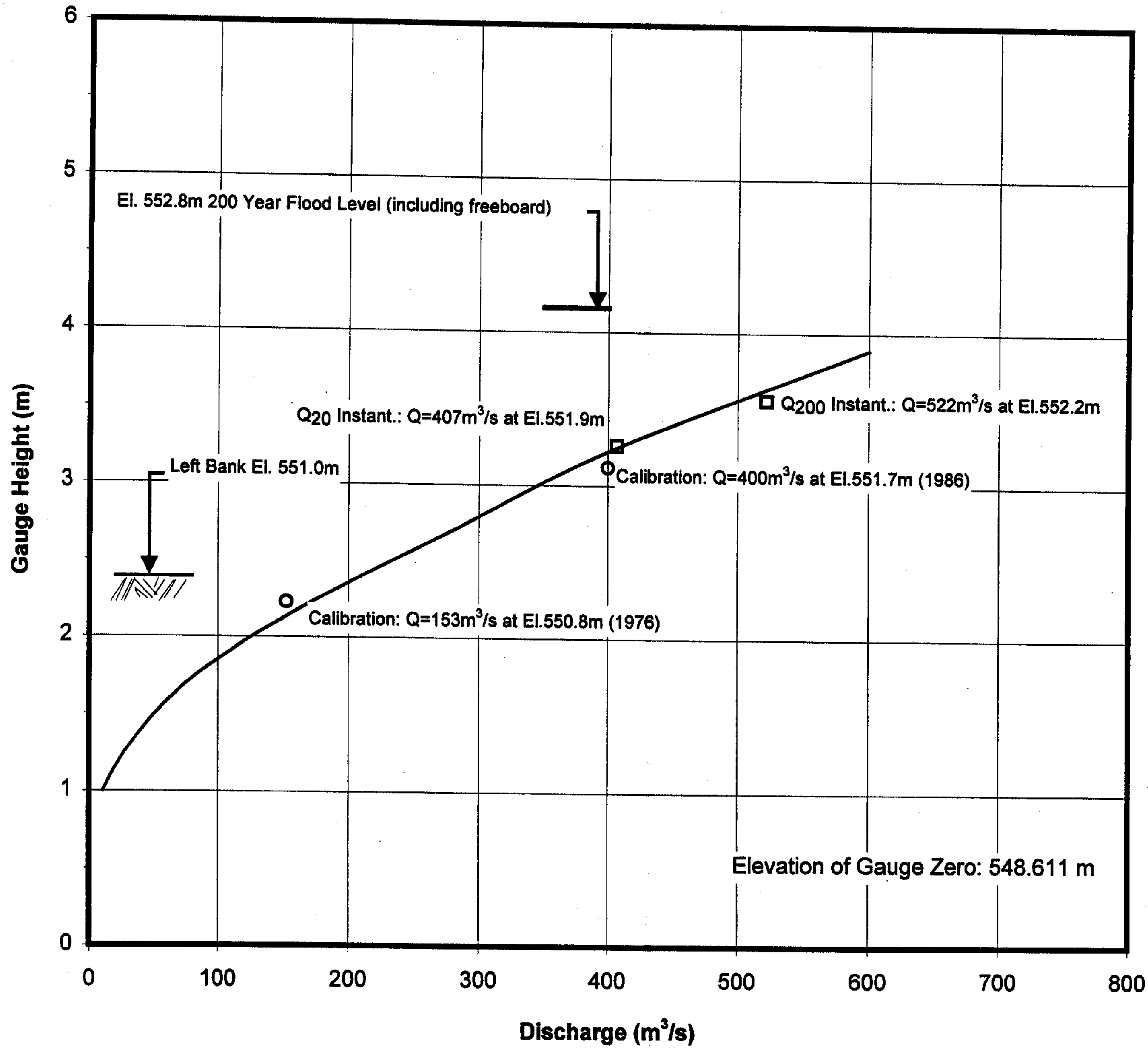
FIGSHTS.XLS

STAGE-DISCHARGE CURVE
Duncan River below Lardeau River
WSC Station No. 08NH118
Located Downstream of XS-22



KLOHN-CRIPPEN	PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
	TITLE: Stage-Discharge Curve Duncan River - WSC No. 08NH118			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE: Feb. 29, 1996 APPROVED: R.J. Rod...	PROJECT No.: PW7087 01	DWG. No.: A-1013	REV.

STAGE-DISCHARGE CURVE
Lardeau River at Marblehead
WSC Station No. 08NH007
Located Upstream of XS-15



KLOHN-CRIPPEN	PROJECT: FLOODPLAIN MAPPING PROGRAM DUNCAN AND LARDEAU RIVERS			
	TITLE: Stage-Discharge Curve Lardeau River - WSC No. 08NH007			
CLIENT: BC MINISTRY OF ENVIRONMENT, LANDS AND PARKS	DATE OF ISSUE: Feb. 29, 1996 APPROVED: R.F. Rodman	PROJECT No.: PW7087 01	DWG. No.: A-1014	REV.

RATING.XLS