# CANADA / BRITISH COLUMBIA FLOODPLAIN MAPPING AGREEMENT

Ministry of Environment, Lands and Parks
Resources Inventory Branch

## A Design Brief
## on the
## Floodplain Mapping Project

## Village of Nakusp
## (Arrow Reservoir and Kuskanax Creek)

Water Inventory Section
Victoria, British Columbia
March, 1998
File:35100-30 / 300-7075

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## Preface

The purpose of this design brief is to present a description of the methodologies used and the results of the study undertaken to delineate the floodplain of Arrow Reservoir and Kuskanax Creek in the Village of Nakusp in British Columbia.

## 1. Introduction

This floodplain mapping was prepared by the Water Inventory Section of the B.C. Ministry of Environment, Lands and Parks, under the terms of the Canada/British Columbia agreement dated December, 1987 and entitled "An Agreement Respecting Floodplain Mapping in the Province of British Columbia" (Amended August 2, 1994).

The study area is within the boundaries of the Regional District of Central Kootenay and the Village of Nakusp. It is located approximately 150 km. north of Castlegar on Highway 6, in the Cassiar-Columbia Mountains, one of the six main physiographic areas of the Province (Appendix 1.1). Figure 1 shows the study area location. The location of floodplain mapping drawings 94-6, Sheets 1 to 2, are shown on Figure 2.

Kuskanax Creek is the largest tributary watercourse to Arrow Reservoir which flows through the Village of Nakusp. The creek flows about 30 kilometers in a westerly direction from the Slocan Mountains (peaks at the 2,400 meter elevation) through the Nakusp Hotsprings Provincial Park and the Village to Arrow Reservoir at an elevation of 440 meters. A Water Survey of Canada (WSC) hydrometric guage (08NE006) is located on Kuskanax Creek near the downstream end of the watershed area at Nakusp.

## 2. Background

Nakusp was established during the mining boom in the Slocan Valley at the turn of the century. The Nakusp Slocan Railway was completed in 1893. Ore from the Slocan Valley was loaded on steamers and shipped down the Columbia River to the smelter at Trail.

Timber land in the Nakusp area gave growth to a local industry and provided employment in logging and sawmilling. Several paddle steamers came into service on the lakes and Nakusp grew and prospered until the early 1950's, when the boats were retired and Nakusp ceased to be a distribution center for the area.

The Columbia River Treaty (CRT) was signed with the U.S. in 1964 to provide flood control and hydro-electric power generation. The Arrow Reservoir resulted from construction of the Keenleyside Dam (Figure 3) which was one of the CRT projects commenced in 1964 and completed in 1969. Concurrent with dam construction, road access improvements included a new improved road extending from Nakusp to Revelstoke. The improved road access as a result of dam construction increased

recreational activity from the south (Trail, Castlegar, Nelson) from the north (Revelstoke) and from the west (Vernon, etc.).

The population of Nakusp in 1986 was 1,410. Over the past few years the Village has once again become a thriving community with many amenities to attract tourism (Appendix 1.6).

Floodplain mapping of Arrow Reservoir (Columbia River) and tributaries has been issued in one other area as follows:

| Project Number | Project Name | Issue Date | Designation Date | No. of Drawings |
|---|---|---|---|---|
| A.1.22 | Columbia River at Revelstoke | November 1983 | December 1997* | 5 |

(*A design brief was prepared for projects designated after December 1987.)

## 3. Present Floodplain Mapping Study

The 1997/98 studies undertaken to delineate the floodplains for Arrow Reservoir and Kuskanax Creek in the Village of Nakusp utilized the following information:

- Floodplain Survey, Project #9414F037, September 1994, Hydrology Branch, Technical Surveys Section, BC Environment (Appendix 1.2).

- Topographic base mapping of the study area was produced in 1986 by the Mapping Section, Surveys and Resource Mapping Branch (Project 84-039) under the Provincial Large Scale Mapping Program.. This mapping is based on 1984 air photography and is 1:5000 scale with 1 meter contour intervals as indicated (Appendix 1.3).

- Hydrology study no. 427 of the Kuskanax Creek at Nakusp carried out by the Water Inventory Section, Resources Inventory Branch, March 1997, File No.76840-40 (Appendix 2).

- Background information on file related to flood levels adopted by BC Environment for administrative purposes related to the Flood Damage Reduction Program (Appendix 1.5).

## 4. Flood Magnitudes

Appendix 2 is a memorandum outlining the study undertaken to determine 20 and 200 year peak flow estimates for Kuskanax Creek.

Kuskanax Creek has no large lakes within its watershed. The months of May, June and July account for 72% of the annual flow. Annual peak flows occur from mid May to early June and are mainly the result of melting of the annual snowpack. The method used for determining peak flows was based on a frequency analysis of daily and instantaneous flows at the two long term hydrometric Water Survey of Canada (WSC) gauges on the creek. The log-Pearson type III distribution was selected which is consistent with regional analysis for this hydrologic zone.

A regional analysis of hydrologic zones for the Province entitled "Hydrologic Mapping and Data Sheet Compilation" has recently been carried out by the Water Inventory Section. Data sheets from this regional analysis for Kuskanax Creek are included in Appendix 2. The regional model was used to prorate the flows to the mouth of the creek at Arrow Reservoir. Results of the study are as follows:

| Location | Drainage Area ($km^2$) | Inst. Peak ($m^3s$) | Inst. Peak ($m^3s$) | Daily Peak ($m^3s$) | Daily Peak ($m^3s$) |
|---|---|---|---|---|---|
| | | 20-year | 200-year | 20-year | 200-year |
| Kuskanax Creek at mouth | 354 | 275 | 627 | 195 | 356 |

## 5. Hydraulic Analysis

### 5.1 General

Information sources listed in Appendix 1 and 2 were utilized in the HEC-2 water surface profile computer program version 6.4, developed by the Hydrologic Engineering Centre, US Army Corps of Engineers in Davis, California and currently administered by Haestad Methods, Inc. The profile calculations employ a standard step method and assume open flow channel conditions.

Appendix 3 is a summary of all the computer runs executed for this study.

In the cross section plot run, an assessment was made of the surveyed river sections which incorporated extensions obtained from the base contour topographic mapping. This run was also used to review other data such as flow

regime, loss coefficients, reach lengths, overbank information and relative Manning's "n" values.

Kuskanax Creek is typical of tributary streams to Arrow Reservoir having a gravel and boulder channel bed of steep profile which averages 1.7% in the study area. There is a natural rock canyon located near the mouth of the creek where Highway 23 bridges the watercourse (see Appendix 4 - Photos).

Manning's "n" values were selected using the color photographs included in the survey project, experience gained in other studies and a review of the information provided in "Roughness Characteristics of Natural Channels" (Appendix 1.4). The selected channel Manning's "n" varied from 0.040 to 0.055 in the study area.

## 5.2 Calculated Flood Levels

The water levels observed in the field (Appendix 1.2) and the flows recorded on September 15 to 20, 1994 (provided by WSC) were reviewed. The flows at the time of the field survey of about 3 to 4 $m^3$s were deemed to be too low to provide a calibration of the model applicable to flood conditions.

Using stage discharge data provided by WSC, a stage discharge curve was plotted for Kuskanax Creek at gauge 08NE006 (Figure 4) located at river cross section #5, just downstream of the CPR railway bridge in Nakusp. Data for the curve was matched and then extended to the estimated 1:20 and 1:200 year flows based on the HEC-2 river model calculations.

Estimated 1:20 and 1:200 year daily and instantaneous flow profiles were obtained (Appendix 3). Sensitivity to the assumed Arrow Reservoir level, flow (Q) and Manning's "n" values were undertaken as discussed in Section 5.3.

In accordance with standard Ministry practice, an allowance for hydraulic and hydrologic uncertainties (freeboard) was applied to the water surface elevations computed by the model for each cross section. An allowance of 0.3 meters and 0.6 meters was applied to the instantaneous and daily levels respectively, and the higher flood level selected. The Q200 instantaneous flood levels were found to dominate using this criteria, averaging 0.3 meters above the Q200 daily flood levels upstream of the rock canyon (bridge area) near the mouth of the creek.

Flood profile calculations for floodplain mapping purposes are based on open water conditions and do not account for potential problems related to ice or debris jam flooding. Site specific or general notes are placed on the mapping sheets when special flood hazards such as ice or debris jam flooding are known to exist. Bank erosion problems are known to occur in a study area as a result of high

channel velocities due to the steepness of the watercourse. The designated flood levels for Kuskanax Creek are listed in Table 1.

### 5.3 Sensitivity Studies

Sensitivity to flow (Q) studies were undertaken. The results indicate that a flood level increase of 0.1 meter occurs for each 10% increase in flow in the area upstream of the rock canyon (bridge) area. In the canyon area, an average level rise of 0.44 meter occurs with each 10 % increase in flow.

Sensitivity studies were also undertaken to determine the effect of increased Manning's "n" values on flood levels. A comparative computer model run using the Q 200 instantaneous flow and factors of 1.1 to 1.4 applied to the "n" values was undertaken (Appendix 3). Results indicated that a 20 % increase in "n" values will result in water level rise which is less than the 0.3 meter freeboard allowance.

An assessment was made of the effect of the assumed Arrow Reservoir flood level on flood levels at upstream creek cross sections. An interpolated cross section was added 150 meters from the downstream end of the study area to approximate creek conditions closer to the reservoir influence area. A starting reservoir level of 440.0 meters was increased to 443.5 meters with no measurable effect at the upstream sections due to the steep creek bed profile.

## 6. Arrow Reservoir Flood Level

The Arrow Reservoir originally comprised two natural lakes, known as Upper Arrow and Lower Arrow respectively (Appendix 1.7). The reservoir behind Keenleyside Dam extends from the City of Revelstoke in the north (Figure 3) to almost as far south as the City of Castlegar.

Water surface and "safeline" elevations for the Arrow Reservoir are as follows:

| ELEVATION (Meters GSC) | COMMENTS |
|---|---|
| 414.5 | Pre-dam low water level |
| 420.0 | Minimum controlled water level |
| 430.0 | Pre-dam high water level |
| 440.0 | Normal full pool |
| 440.7 | Occasional surcharge level for routing of floods comparable to that which occurred in 1894 |
| 441.7 | Design flood level (for use in routing severe floods) |
| **443.5** | **BC Hydro "Safeline" based on slope stability analysis** |
| 444.7 | Keenleyside dam crest |

Erosion occurs around the perimeter of a new reservoir caused by wave action and sloughing. Wind created wave action results in the most erosion. Sloughing is caused by saturation of bank material. The composition of the banks of the reservoir makes a significant difference to the slope to which the banks will ultimately conform.

BC Hydro engaged a firm of consultants to study shoreline instability and determine a "safeline" around the reservoir. For the area lying south of the Akolkolex River confluence (located just north of Galena Bay), the safeline elevation for slope stability was determined to be 443.5 meters.

The policy of BC Environment when a large watercourse is controlled by a major dam is to determine the designated flood levels on a site specific basis. BC Environment used the BC Hydro "safeline" and selected the following building setback and elevation criteria for the Flood Damage Reduction Program in the late 1970's (Appendix 1.5) which are applicable to the Arrow Reservoir in the Nakusp area:

Flood Level - Arrow Reservoir 443.5 meters.
Setback - 30 meters from the 440.7 meter contour or below the "safeline".

These requirements have been used in subdivision approvals and in municipal zoning bylaws for lands around the Arrow Reservoir south of the Akolkolex River confluence.

## 7. Floodplain Mapping

The flood levels determined in the study were used to delineate the floodplain limits onto the existing contour mapping it the study area. The studies were based on the information noted in Section 3.

In accordance with the policy of the Ministry of Environment, Lands and Parks, the flood levels and floodplain limits shown on floodplain mapping sheets are based on a designated (1:200 year frequency) flood level plus an allowance for hydraulic and hydrologic uncertainties.

The mapping indicates the location of the floodplain limits, cross section and monument locations, and flood level isograms. Roads, rail lines and buildings are also identified. Particular attention should be paid to the "Notes" on the mapsheets with regard to ponding, ice and debris jamming and erosion.

## 7. Conclusions

1. This design brief presents an overview of the studies undertaken to produce the floodplain mapping sheets for the Arrow Reservoir and Kuskanax Creek in the Village of Nakusp. The floodplain limits outline the area which would be inundated by the designated flood.

2. The floodplain maps are administrative tools to provide information which will help to minimize future flood damages. They are not comprehensive floodplain management plans, nor do they provide solutions to site specific problems.

3. Flooding may occur outside 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.

## 8. Recommendations

1. It is recommended that the floodplains delineated on Drawing 94-6, Sheets 1 & 2 be designated under the terms of the Federal Provincial Floodplain Mapping Agreement.

2. The drawings may be used for administrative purposes related to the preparation of hazard map schedules for official plans; flood proofing requirements in zoning and building bylaws; and the identification of lands by Subdivision Approving Officers.

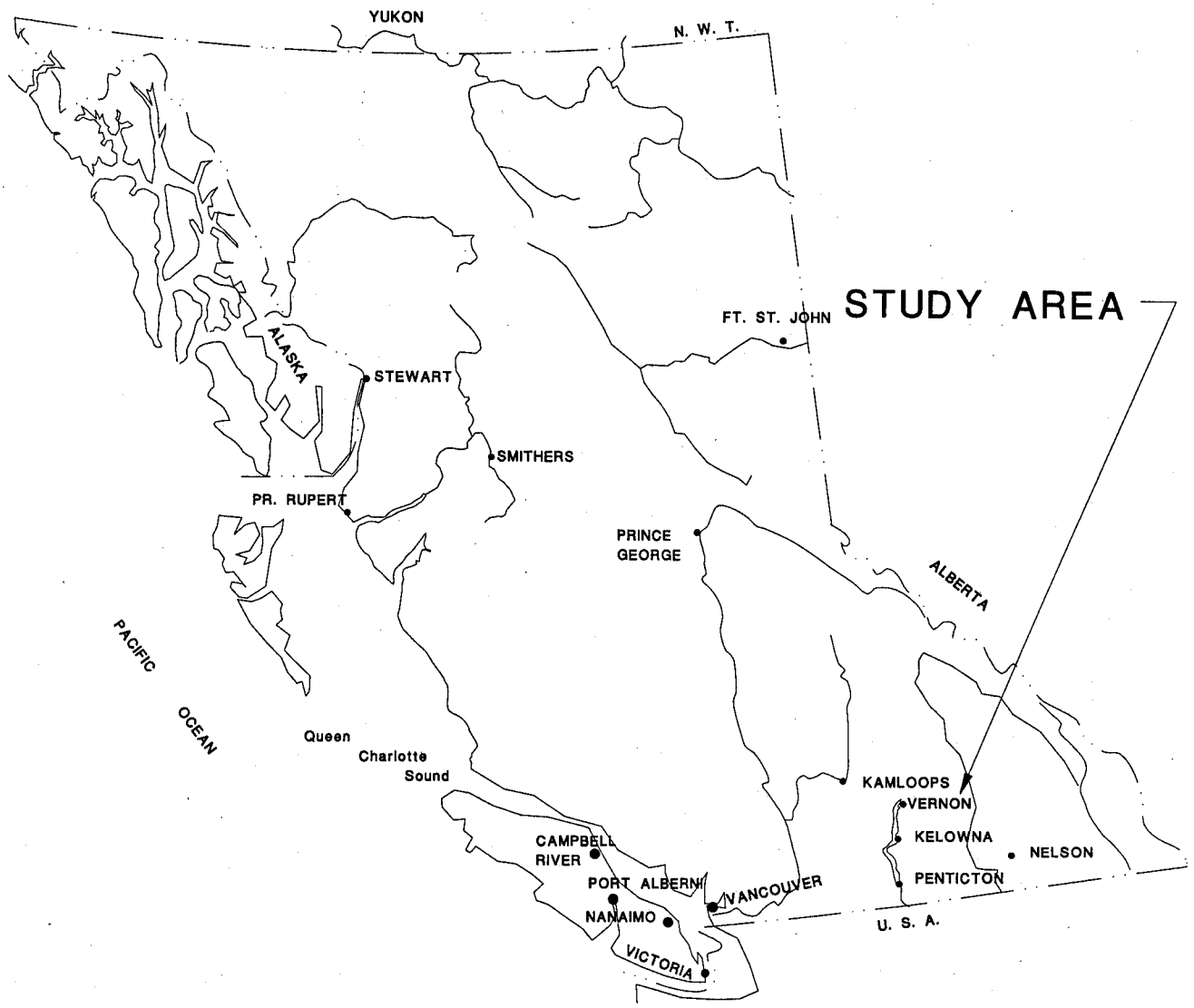
3. These floodplain maps should be reviewed to maintain the adequacy, accuracy and usefulness of the information when significant flood events, erosion, floodplain development or other changes occur within the study area.

B. Board

B.J.E. Board
Project Technician
Water Inventory Section

R.W. Nichols

R.W. Nichols, P.Eng.
Head
Floodplain Mapping Program




Province of British Columbia
Ministry of Environment, Lands and Parks
RESOURCES INVENTORY BRANCH
WATER INVENTORY SECTION

TO ACCOMPANY A DESIGN BRIEF ON THE
FLOODPLAIN MAPPING
VILLAGE OF NAKUSP
ARROW RESERVOIR AND
KUSKANAX CREEK

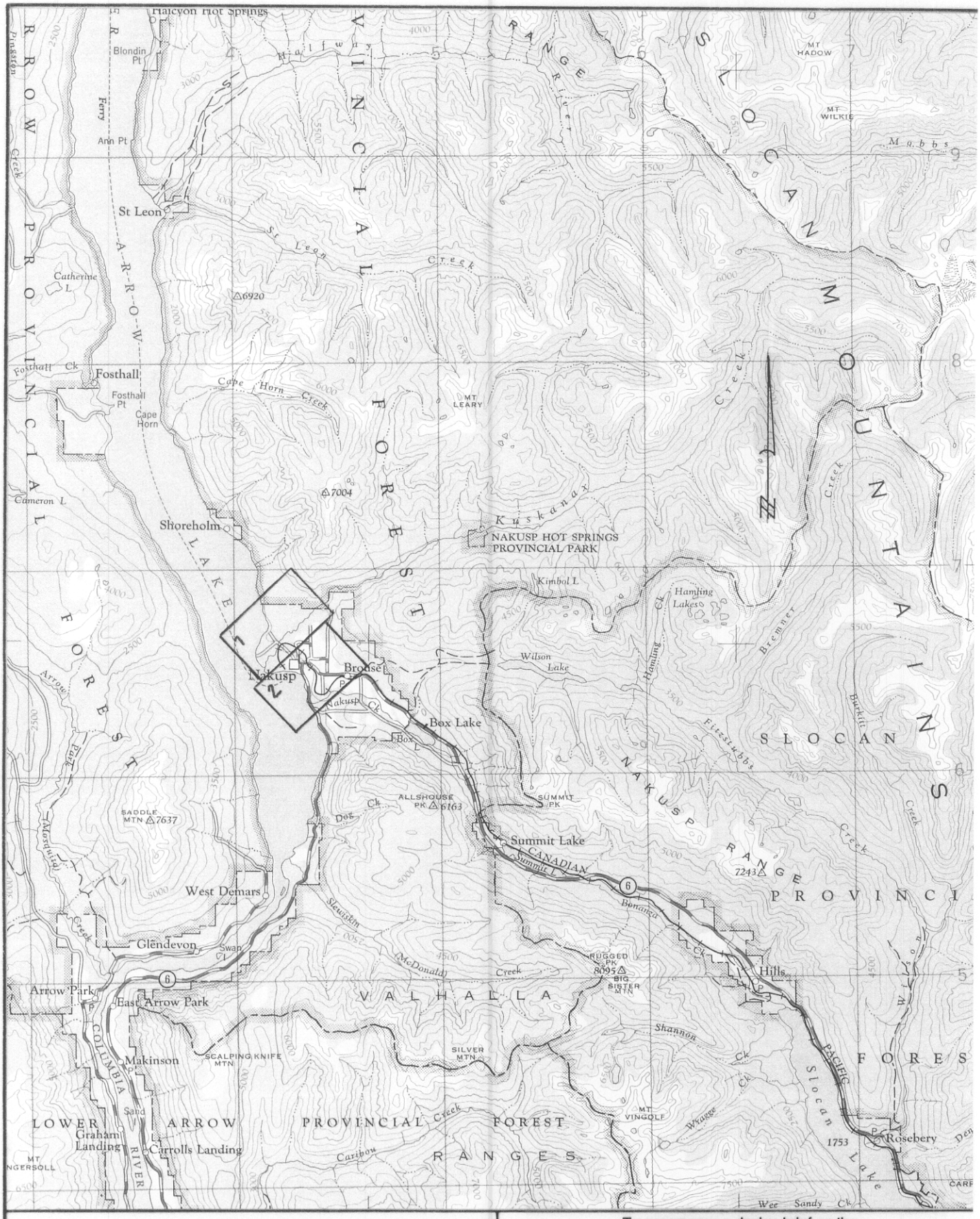
# STUDY AREA LOCATION

SCALE: VERT NOT TO SCALE
HOR

DATE
MARCH 1998

R.W. NICHOLS ENGINEER

FILE No. 35100-30/300-7075 DWG. No. FIGURE 1




**Province of British Columbia**

Ministry of Environment, Lands and Parks
Resources Inventory Branch
Water Inventory Section

To accompany a design brief on the
FLOOD PLAIN MAPPING
VILLAGE OF NAKUSP
ARROW RESERVOIR AND KUSKANAX CREEK
**KEY MAP**

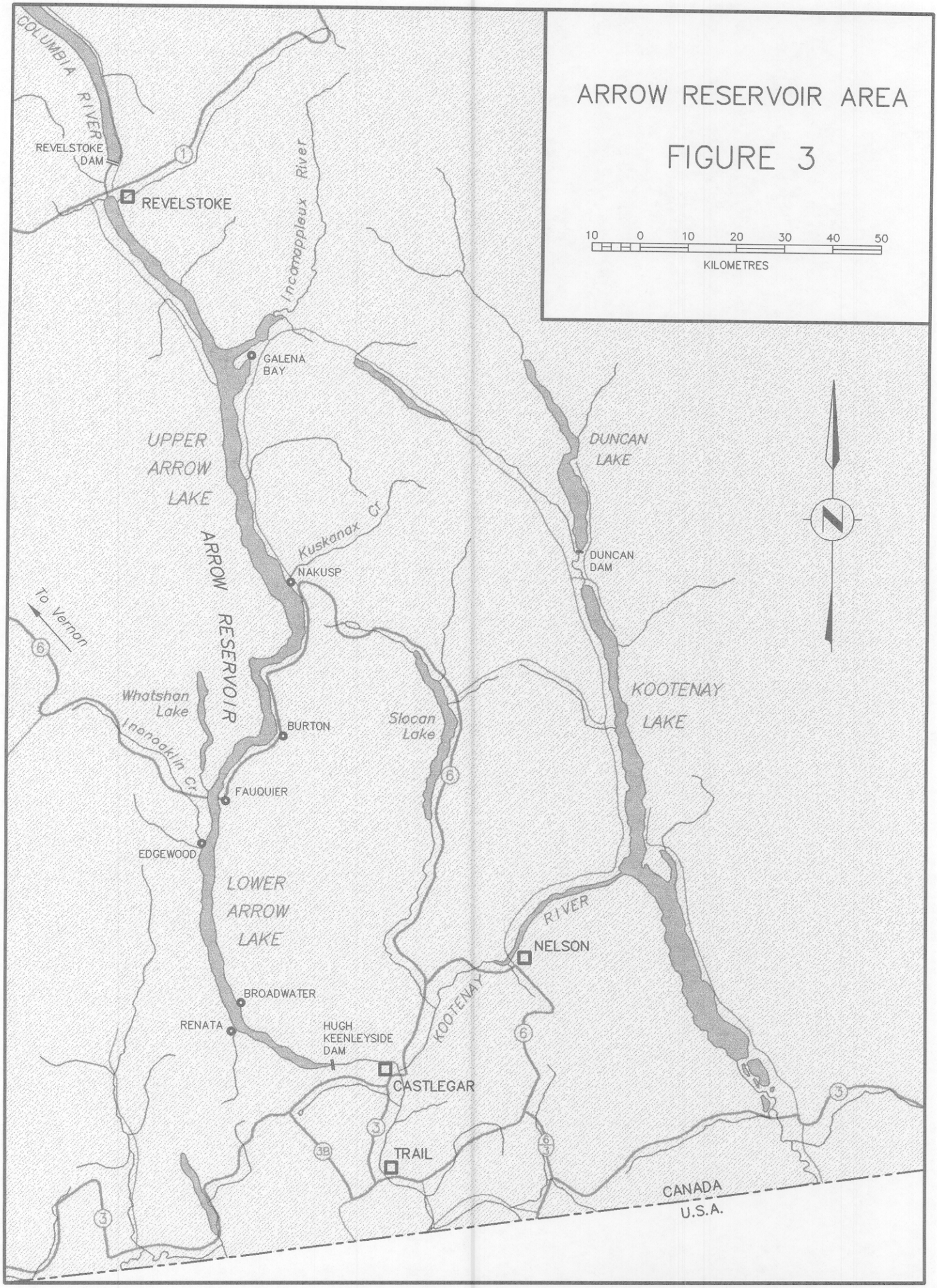
SCALE VERT
HOR 1:250 000

DATE
March 1998

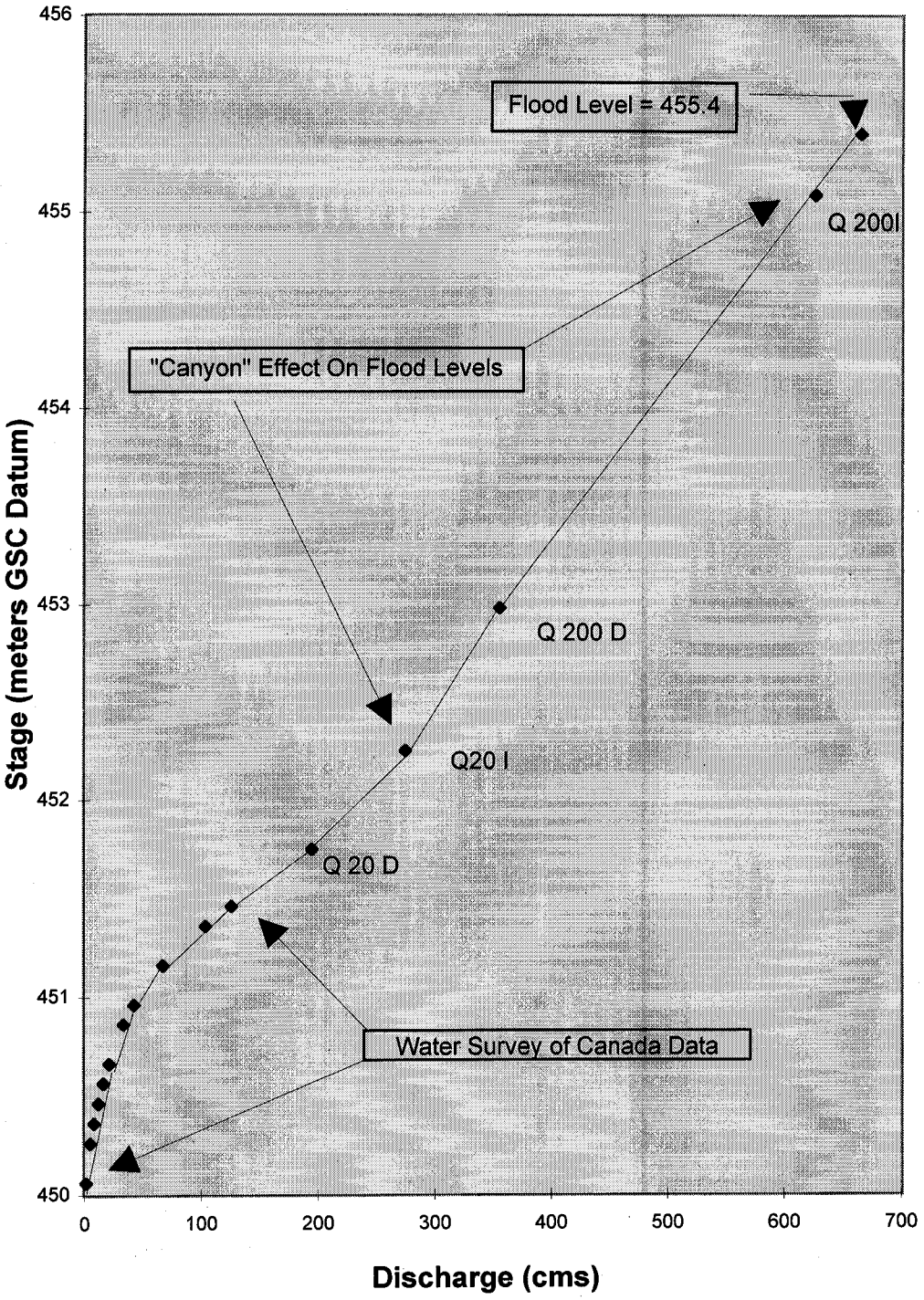
R.W.NICHOLS ENGINEER

FILE No 35100-30/300-7075 DWG No Figure 2

BCIL 7673-M E


ARROW RESERVOIR AREA
FIGURE 3
10 0 10 20 30 40 50
KILOMETRES
COLUMBIA RIVER
REVELSTOKE DAM
REVELSTOKE
Incomappleux River
GALENA BAY
UPPER ARROW LAKE
ARROW RESERVOIR
Kuskanax Cr
NAKUSP
DUNCAN LAKE
DUNCAN DAM
To Vernon
Whatshan Lake
Inonoaklin Cr
BURTON
Slocan Lake
KOOTENAY LAKE
FAUQUIER
EDGEWOOD
LOWER ARROW LAKE
KOOTENAY RIVER
NELSON
BROADWATER
RENATA
HUGH KEENLEYSIDE DAM
CASTLEGAR
TRAIL
CANADA
U.S.A.

# Figure 4
## Stage-Discharge Curve
## Kuskanax Creek at WSC Station 08NE006



# Table 1

## Designated Flood Levels
## Kuskanax Creek

| River XS # | Q 200 Selected Flood Level* (m) | Q 20 Selected Flood Level* (m) | Comments |
|---|---|---|---|
| 1.1 | **443.5** | - | Arrow Reservoir Flood Level |
| 1 | **444.8** | **443.9** | |
| 2 | **449.4** | **448.3** | |
| 3 | **451.3** | **450.2** | |
| 4 | **453.6** | **452.2** | |
| 5 | **455.4** | **452.4** | WSC Gauge Location Natural Rock Canyon (bridged ) Area |
| 6 | **456.1** | **452.6** | |
| 6A | **458.1** | **453.6** | |
| 7 | **460.5** | **456.4** | |
| 8 | **460.5** | **458.6** | |
| 9 | **464.1** | **463.3** | |
| 10 | **471.6** | **470.6** | |
| 11 | **474.8** | **474.0** | |
| 12 | **477.9** | **477.5** | |
| 13 | **482.4** | **481.8** | |
| 14 | **486.9** | **485.9** | |
| 15 | **492.7** | **492.1** | |
| 16 | **496.6** | **495.6** | |

*Based on Ministry Criteria of (Q D + 0.6) or (Q I + 0.3), whichever is the greater.

# APPENDIX 1

Detailed Information Sources

# APPENDIX 1

## Detailed Information Sources

| No. | Source | Contents |
|---|---|---|
| 1. | Atlas of British Columbia, U.B.C. Press W.R. 912.711 F231C.4. | General information on the people, environment and resource use. |
| 2. | Floodplain Survey, Project # 9414F037, Sept.15 - 20, 1994, Resource Inventory Branch, Technical Support Section, BC Environment. | Sixteen cross sections were surveyed on Kuskanax Creek commencing at Arrow Reservoir and extending 3.04 kilometers upstream. A water level profile was obtained along with data from WSC gauge 08NE006. |
| 3. | Topographic base mapping of the study area produced by the Lands Services Division, Surveys and Resource Mapping Branch, Topo/GIS Section, Project 84-039(T). | This mapping is based on 1984 air photography and is 1:5000 scale with 1 meter contour intervals or greater as indicated. |
| 4. | "Roughness Characteristics of Natural Channels" Geological Survey Water-Supply Paper 1849, by H. H. Barnes, Jr., US Department of the Interior, Geological Survey. | Photographs and descriptive data including Manning's "n" values for stream channels for which roughness coefficients have been determined. |
| 5. | BC Environment, Water Management Branch, Correspondence and background data on Arrow Reservoir flood levels. | File 0305030-8, Feb. 20, 1978;<br>File 0305030-6, Jan. 18, 1977. |
| 6. | Nakusp Visitor's Map, June 1994. | Information on sights, places, facilities and activities in Nakusp, British Columbia. |
| 7. | Arrow Reservoir Study Mitigation/Compensation Proposals, November 1980. | A report prepared by the Arrow Reservoir Committee, Chaired by H.M. Hunt of BC Environment Water Management Branch, established in 1975 to examine the question of regulation of the Arrow Reservoir. |

# APPENDIX 2

## Hydrology Report

Kuskanax Creek at Nakusp

Determination of 20 and 200 Year Peak Flows

Study No. 427
March 1997
file: 76840-40

SURFACE WATER SECTION REPORT

# KUSKANAX CREEK AT NAKUSP

## DETERMINATION OF 20 AND 200 YEAR PEAK FLOWS

At the request of the Floodplain Mapping Unit, a hydrology study was carried out to determine the 20-year and 200-year peak flows for Kuskanax Creek at the mouth.

Kuskanax Creek enters the Arrow Reservoir at the town of Nakusp. Its watershed is quite mountainous with a maximum elevation of 2400 m. Kuskanax Creek flows generally westerly and has no large lakes within its watershed. The months of May, June and July account for 72% of the normal annual flow. The annual peak flows occur from mid May to early July and are mainly the result of melting of the annual snowpack.

Hydrometric data are available from two long-term gauges on Kuskanax Creek. These gauges with their period of record of annual peak flows are:

| | | |
|---|---|---|
| Kuskanax Creek near Nakusp | 8NE006 | 1964 to 1996 |
| Kuskanax Creek at 1040 m Contour | 8NE117 | 1973 to 1996 |

### 1. Data Analysis

The method used for determining peak flows at the required location was based on a frequency analysis of the above two gauges and a regional model for prorating flows to the mouth. A regional analysis of hydrologic zones has been carried out by the Water Inventory Section. This analysis includes datasheets for hydrometric and precipitation stations and mapping of normal annual runoff and peak instantaneous flow for the complete Province. Datasheets from this regional analysis for Kuskanax Creek are included in this report.

### 2. Frequency Analysis of Peak Flows

Frequency analysis of daily and instantaneous peak flows was carried out for the two stations. The log-Pearson type III distribution was selected which is consistent with regional analysis for this hydrologic zone. The following table provides a summary of instantaneous and daily peak flow as taken from the frequency analysis.

| station | drainage area $km^2$ | inst peak flow $m^3/s$ 20-yr | 200-yr | daily peak flow $m^3/s$ 20-yr | 200-yr |
|---|---|---|---|---|---|
| 8NE006 | 337 | 264 | 603 | 188 | 343 |
| 8NE117 | 113 | 71.9 | 95.1 | - | - |

## 3. Regional Analysis

The regional analysis of instantaneous peak flows shows that peak flow increases with drainage area to the power of 0.785. This factor was used to prorate the instantaneous peak flow from the gauge (8NE006) to the mouth. The additional drainage area to the mouth was measured to be 16.9 $km^2$ which gives a factor of 1.039, that is, instantaneous peak flows are 3.9% higher at the mouth than at the gauge.

## 4. Peak Flow

The 20-yr and 200-yr instantaneous peak flows at the mouth were determined by increasing the peak flows from the frequency analysis for the gauge 8NE006. The ratios of instantaneous peak to daily peak as determined for the gauge were used without adjustment to give the ratios at the mouth. The results are in the following table.

| location | drainage area $km^2$ | inst peak $m^3/s$ 20-yr | 200-yr | daily peak $m^3/s$ 20-yr | 200-yr |
|---|---|---|---|---|---|
| Kuskanax Creek at mouth | 354 | 275 | 627 | 195 | 356 |

## 5. September 1994 Flows

The daily flows of September 16 to 20, 1994 were also requested. The observed flows at the gauge were increased in direct proportion to drainage area, that is by 5.0%. These flows are as follows:

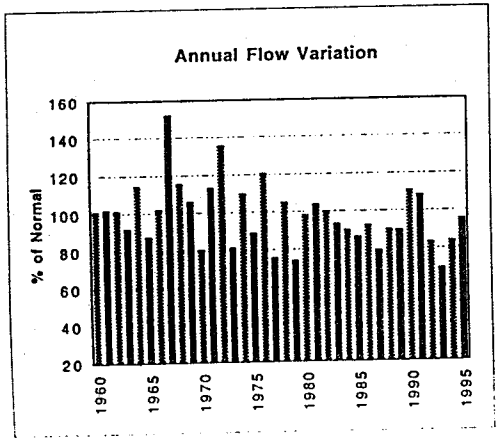
| date | daily flow $m^3/s$ at gauge 8NE006 | daily flow $m^3/s$ at mouth |
|---|---|---|
| Sept 16 | 3.32 | 3.49 |
| Sept 17 | 3.25 | 3.41 |
| Sept 18 | 3.16 | 3.32 |
| Sept 19 | 3.10 | 3.26 |
| Sept 20 | 2.97 | 3.12 |

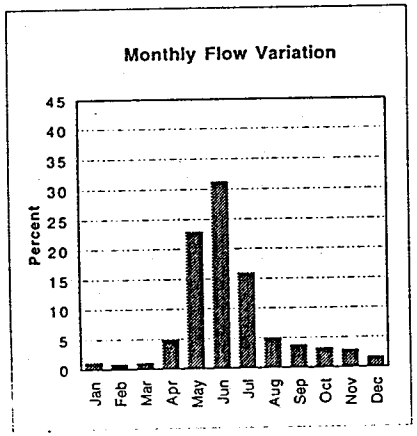
C.H. Coulson
Water Inventory Section

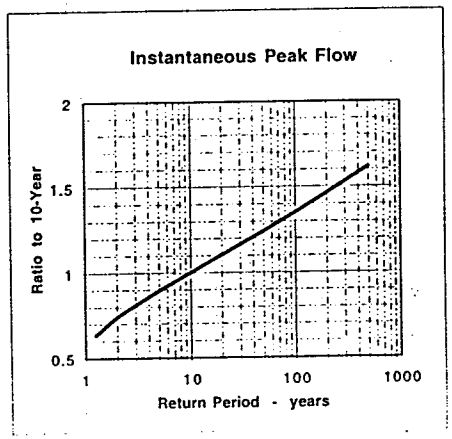
# KUSKANAX CREEK AT 1040 m CONTOUR 8NE117

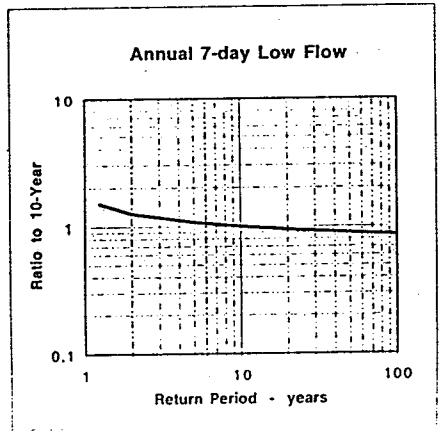
Monthly and Annual Flow in m3/s — d.a. = 113 km2 — median elevation = m

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean | Instantaneous Peak Flow date | Instantaneous Peak Flow m3/s | 7-Day Low Flow Jun-Sep | 7-Day Low Flow Annual | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | | | | | | | | | | | | | 5.79 | | | | | 1960 |
| 1961 | | | | | | | | | | | | | 5.84 | | | | | 1961 |
| 1962 | | | | | | | | | | | | | 5.82 | | | | | 1962 |
| 1963 | | | | | | | | | | | | | 5.27 | | | | | 1963 |
| 1964 | | | | | | | | | | | | | 6.58 | | | | | 1964 |
| 1965 | | | | | | | | | | | | | 5.02 | | | | | 1965 |
| 1966 | | | | | | | | | | | | | 5.86 | | | | | 1966 |
| 1967 | | | | | | | | | | | | | 8.72 | | | | | 1967 |
| 1968 | | | | | | | | | | | | | 6.62 | | | | | 1968 |
| 1969 | | | | | | | | | | | | | 6.08 | | | | | 1969 |
| 1970 | | | | | | | | | | | | | 4.60 | | | | | 1970 |
| 1971 | | | | | | | | | | | | | 6.48 | | | | | 1971 |
| 1972 | | | | | | | | | | | | | 7.78 | | | | | 1972 |
| 1973 | | | | | | | | | | | | 1.14 | 4.66 | | | | | 1973 |
| 1974 | 0.99 | 0.77 | 0.70 | 1.89 | 11.00 | 34.10 | 18.00 | 4.13 | 1.55 | 1.00 | 0.83 | 0.71 | 6.31 | Jun 16 | 63.4 | 1.140 | 0.670 | 1974 |
| 1975 | 0.51 | 0.48 | 0.51 | 0.81 | 11.00 | 22.20 | 10.70 | 4.08 | 3.15 | 2.64 | 3.04 | 1.99 | 5.11 | Jun 15 | 35.4 | 1.700 | 0.449 | 1975 |
| 1976 | 1.28 | 0.63 | 0.47 | 1.78 | 16.70 | 20.30 | 20.90 | 11.70 | 5.29 | 1.60 | 1.10 | 0.96 | 6.92 | Jun 30 | 42.5 | 2.410 | 0.439 | 1976 |
| 1977 | 0.64 | 0.55 | 0.51 | 4.35 | 13.40 | 17.80 | 5.09 | 2.73 | 2.94 | 1.62 | 1.38 | 0.98 | 4.34 | Jun 07 | 48.1 | 1.880 | 0.498 | 1977 |
| 1978 | 0.82 | 0.78 | 1.05 | 3.96 | 13.20 | 24.40 | 12.00 | 3.37 | 6.79 | 2.78 | 2.17 | 1.00 | 6.03 | Jun 05 | 46.4 | 2.510 | 0.720 | 1978 |
| 1979 | 0.72 | 0.63 | 0.66 | 1.46 | 14.40 | 19.10 | 7.23 | 1.62 | 1.39 | 1.19 | 1.05 | 1.49 | 4.26 | May 26 | 42.8 | 0.993 | 0.567 | 1979 |
| 1980 | 0.84 | 0.70 | 0.81 | 8.30 | 23.70 | 15.80 | 5.37 | 1.87 | 3.13 | 2.65 | 2.31 | 2.10 | 5.64 | May 21 | 45.9 | 1.450 | 0.617 | 1980 |
| 1981 | 1.83 | 1.05 | 0.95 | 2.79 | 18.60 | 16.80 | 15.70 | 3.97 | 2.27 | 3.51 | 2.49 | 1.15 | 5.96 | May 25 | 48.1 | 1.530 | 0.836 | 1981 |
| 1982 | 0.70 | 0.64 | 0.50 | 0.74 | 11.40 | 30.60 | 12.20 | 4.45 | 3.02 | 2.27 | 1.47 | 0.91 | 5.75 | Jun 15 | 49.7 | 2.070 | 0.465 | 1982 |
| 1983 | 0.73 | 0.60 | 0.73 | 2.98 | 16.00 | 18.60 | 13.10 | 2.86 | 2.83 | 1.52 | 3.07 | 1.06 | 5.36 | Jul 12 | 57.2 | 1.650 | 0.571 | 1983 |
| 1984 | 1.33 | 0.78 | 0.68 | 2.88 | 8.49 | 25.00 | 13.00 | 3.26 | 3.31 | 1.53 | 1.12 | 0.79 | 5.17 | Jun 29 | 79.1 | 1.830 | 0.645 | 1984 |
| 1985 | 0.58 | 0.52 | 0.49 | 3.02 | 19.50 | 18.90 | 5.49 | 1.68 | 2.69 | 3.81 | 1.89 | 0.76 | 4.96 | May 23 | 50.6 | 1.200 | 0.465 | 1985 |
| 1986 | 0.63 | 0.65 | 1.07 | 3.11 | 17.10 | 23.10 | 9.85 | 2.26 | 1.26 | 2.01 | 1.59 | 0.94 | 5.31 | May 28 | 73.2 | 0.983 | 0.584 | 1986 |
| 1987 | 0.72 | 0.62 | 0.94 | 4.77 | 21.40 | 15.60 | 5.00 | 1.76 | 1.00 | 0.75 | 0.91 | 0.73 | 4.54 | May 12 | 61.4 | 0.865 | 0.526 | 1987 |
| 1988 | 0.44 | 0.41 | 0.48 | 6.12 | 17.60 | 18.70 | 7.97 | 1.54 | 1.20 | 3.78 | 2.78 | 1.07 | 5.18 | May 13 | 44.1 | 0.817 | 0.385 | 1988 |
| 1989 | 0.78 | 0.63 | 0.56 | 3.08 | 14.30 | 22.60 | 7.38 | 3.24 | 2.32 | 1.68 | 3.81 | 1.37 | 5.15 | Jun 15 | 52.6 | 1.300 | 0.543 | 1989 |
| 1990 | 0.78 | 0.70 | 0.70 | 5.82 | 15.60 | 26.00 | 14.70 | 2.65 | 1.23 | 2.53 | 3.86 | 1.52 | 6.36 | Jun 24 | 49.7 | 0.849 | 0.626 | 1990 |
| 1991 | 0.87 | 0.80 | 0.70 | 2.88 | 16.70 | 24.90 | 19.30 | 4.78 | 1.36 | 0.79 | 0.66 | 0.50 | 6.22 | Jul 04 | 41.5 | 0.925 | 0.458 | 1991 |
| 1992 | 0.48 | 0.56 | 1.44 | 6.28 | 17.90 | 15.60 | 3.79 | 1.86 | 2.65 | 4.19 | 1.72 | 0.89 | 4.78 | May 26 | 41.1 | 1.120 | 0.440 | 1992 |
| 1993 | 0.59 | 0.46 | 0.49 | 1.74 | 21.40 | 11.10 | 5.95 | 2.02 | 0.92 | 1.10 | 0.95 | 0.73 | 3.99 | May 13 | 50.8 | 0.785 | 0.409 | 1993 |
| 1994 | 0.61 | 0.54 | 0.84 | 8.12 | 18.90 | 16.90 | 7.05 | 1.37 | 0.99 | 0.83 | 0.83 | 0.65 | 4.82 | May 26 | 35.2 | 0.734 | 0.516 | 1994 |
| 1995 | 0.63 | 0.56 | 0.66 | 1.77 | 17.00 | 20.40 | 5.84 | 5.24 | 1.67 | 5.90 | 3.56 | 2.47 | 5.50 | Jun 05 | 40.0 | 1.121 | 0.432 | 1995 |
| 1996 | | | | 4.09 | 11.80 | 25.40 | D | | | | | | | Jun 08 | 45.9 | | | 1996 |
| normal | 0.84 | 0.65 | 0.70 | 3.40 | 15.49 | 21.74 | 10.80 | 3.36 | 2.67 | 2.17 | 2.05 | 1.15 | 5.72 | average | 49.8 | 1.357 | 0.539 | average |
| mm | 20 | 14 | 16 | 78 | 367 | 499 | 256 | 80 | 61 | 51 | 47 | 27 | 1598 | 10-year | 65.1 | 0.793 | 0.418 | 10-year |



# KUSKANAX CREEK NEAR NAKUSP 8NE006

location: 50°16'39", 117°44'53"

Monthly and Annual Flow in m3/s — d.a. = 337 km2 — median elevation = m

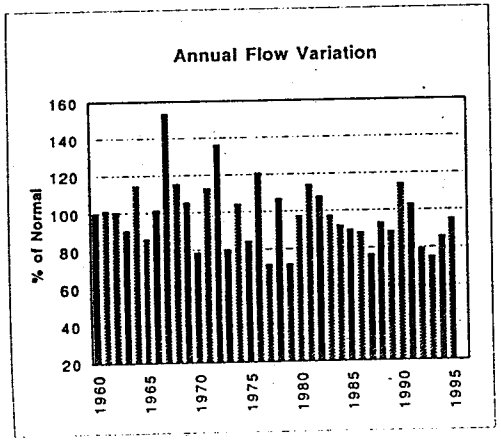
| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Mean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1960 | | | | | | | | | | | | | 14.5 |
| 1961 | | | | | | | | | | | | | 14.6 |
| 1962 | | | | | | | | | | | | | 14.5 |
| 1963 | | | | | | | | | | | | 3.8 | 13.1 |
| 1964 | 2.9 | 2.2 | 2.2 | 4.1 | 25.7 | 65.9 | 41.2 | 15.4 | 11.8 | 14.9 | 7.8 | 4.1 | 16.5 |
| 1965 | 2.8 | 2.5 | 2.6 | 7.6 | 30.0 | 47.5 | 20.2 | 9.0 | 6.5 | 7.0 | 8.4 | 4.7 | 12.4 |
| 1966 | 3.6 | 3.1 | 3.7 | 10.0 | 43.6 | 60.4 | 25.2 | 6.7 | 4.1 | 5.8 | 5.0 | 4.1 | 14.6 |
| 1967 | 2.9 | 2.6 | 2.0 | 4.2 | 37.9 | 145.0 | 39.5 | 8.0 | 4.1 | 8.2 | 8.4 | 3.5 | 22.1 |
| 1968 | 3.6 | 3.9 | 5.2 | 4.7 | 35.4 | 67.6 | 36.1 | 10.6 | 12.8 | 8.6 | 6.8 | 4.5 | 16.7 |
| 1969 | 2.9 | 2.4 | 3.0 | 12.7 | 50.2 | 59.4 | 17.2 | 5.5 | 5.7 | 9.8 | 8.8 | 4.7 | 15.2 |
| 1970 | 3.2 | 2.7 | 2.6 | 3.7 | 33.5 | 56.6 | 10.9 | 4.8 | 5.5 | 5.5 | 4.0 | 2.7 | 11.3 |
| 1971 | 3.1 | 5.2 | 2.8 | 7.4 | 51.4 | 62.9 | 33.2 | 8.9 | 4.9 | 6.8 | 4.8 | 3.4 | 16.3 |
| 1972 | 3.0 | 3.0 | 5.6 | 6.9 | 58.8 | 77.8 | 46.1 | 12.4 | 6.2 | 7.7 | 4.8 | 3.5 | 19.7 |
| 1973 | 3.0 | 2.4 | 3.0 | 5.2 | 36.8 | 42.3 | 17.8 | 6.1 | 3.9 | 6.9 | 6.6 | 3.5 | 11.5 |
| 1974 | 2.9 | 2.9 | 2.9 | 9.3 | 31.5 | 67.8 | 40.2 | 8.6 | 5.5 | 3.5 | 2.9 | 2.4 | 15.1 |
| 1975 | 2.1 | 1.9 | 1.8 | 2.4 | 26.0 | 48.9 | 23.4 | 9.9 | 9.0 | 6.4 | 7.6 | 6.7 | 12.2 |
| 1976 | 3.9 | 2.8 | 2.7 | 7.6 | 39.4 | 51.5 | 49.9 | 23.9 | 13.4 | 5.9 | 4.2 | 3.3 | 17.4 |
| 1977 | 2.4 | 2.6 | 2.5 | 10.9 | 29.9 | 40.4 | 10.9 | 6.7 | 7.1 | 4.2 | 3.8 | 2.9 | 10.4 |
| 1978 | 2.4 | 2.1 | 4.4 | 10.6 | 31.3 | 63.7 | 27.6 | 8.2 | 15.9 | 8.1 | 6.2 | 4.2 | 15.4 |
| 1979 | 3.2 | 3.1 | 3.6 | 5.8 | 34.1 | 41.0 | 14.6 | 4.9 | 4.0 | 3.4 | 2.9 | 3.8 | 10.4 |
| 1980 | 2.4 | 2.3 | 2.8 | 20.8 | 57.9 | 38.2 | 12.5 | 5.5 | 7.5 | 7.0 | 6.4 | 5.5 | 14.1 |
| 1981 | 5.6 | 3.9 | 4.2 | 8.7 | 47.6 | 46.7 | 41.1 | 11.1 | 6.1 | 9.4 | 7.8 | 4.2 | 16.5 |
| 1982 | 2.5 | 2.4 | 2.0 | 3.5 | 32.1 | 75.2 | 30.8 | 13.0 | 9.2 | 7.4 | 5.3 | 3.1 | 15.6 |
| 1983 | 2.5 | 2.3 | 3.4 | 9.6 | 39.4 | 47.8 | 31.9 | 8.5 | 6.9 | 4.4 | 7.9 | 3.6 | 14.1 |
| 1984 | 4.1 | 2.9 | 2.9 | 9.0 | 20.0 | 58.6 | 33.7 | 9.7 | 9.4 | 4.4 | 3.1 | 2.3 | 13.3 |
| 1985 | 2.0 | 1.8 | 1.8 | 10.0 | 45.8 | 46.8 | 14.3 | 4.7 | 7.0 | 10.2 | 7.6 | 3.1 | 13.0 |
| 1986 | 2.4 | 2.2 | 3.8 | 10.4 | 37.1 | 50.0 | 21.9 | 7.0 | 4.1 | 5.8 | 5.2 | 2.8 | 12.8 |
| 1987 | 2.2 | 2.0 | 3.3 | 13.1 | 47.0 | 36.5 | 12.9 | 5.0 | 3.0 | 2.2 | 2.4 | 2.2 | 11.0 |
| 1988 | 1.8 | 1.7 | 2.0 | 17.4 | 42.0 | 45.4 | 21.0 | 5.7 | 3.8 | 9.2 | 8.1 | 3.5 | 13.5 |
| 1989 | 2.6 | 2.0 | 1.8 | 8.6 | 34.2 | 49.6 | 16.5 | 8.0 | 7.3 | 5.3 | 12.1 | 5.8 | 12.8 |
| 1990 | 3.2 | 2.6 | 2.6 | 16.7 | 36.6 | 60.5 | 36.8 | 8.6 | 4.3 | 6.9 | 12.7 | 5.7 | 16.5 |
| 1991 | 3.2 | 3.5 | 2.8 | 9.9 | 40.9 | 54.8 | 40.8 | 10.6 | 4.4 | 2.8 | 2.4 | 2.2 | 14.9 |
| 1992 | 2.1 | 2.4 | 5.2 | 15.1 | 39.5 | 34.5 | 9.8 | 5.3 | 5.9 | 9.3 | 5.4 | 3.1 | 11.5 |
| 1993 | 2.3 | 1.8 | 1.9 | 7.5 | 53.5 | 27.3 | 15.7 | 7.3 | 3.5 | 3.5 | 2.9 | 2.3 | 10.9 |
| 1994 | 2.2 | 1.8 | 3.0 | 21.7 | 45.3 | 41.3 | 17.3 | 5.2 | 3.3 | 2.7 | 2.4 | 2.2 | 12.4 |
| 1995 | 1.7 | 2.0 | 2.4 | 6.6 | 38.1 | 46.4 | 14.0 | 12.3 | 5.4 | 14.5 | 12.0 | 9.3 | 13.8 |
| 1996 | | | 3.4 | 13.2 | 29.4 | 58.1 | 47.0 | 14.4 | 7.5 | 7.9 | 7.0 | 4.4 | |
| normal | 2.9 | 2.6 | 3.0 | 8.9 | 38.3 | 57.6 | 26.9 | 8.7 | 7.0 | 6.8 | 6.4 | 3.8 | 14.4 |
| mm | 23 | 19 | 24 | 69 | 305 | 443 | 214 | 70 | 54 | 54 | 49 | 31 | 1350 |

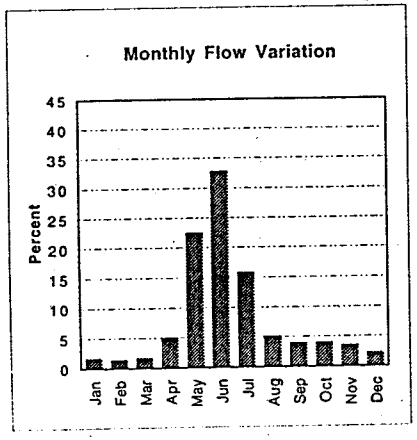
Instantaneous Peak Flow / Daily Peak I

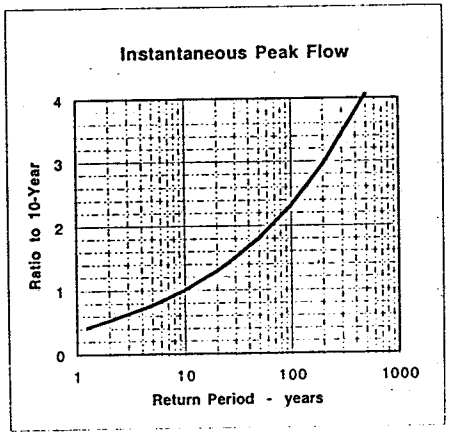
| Year | date | m3/s | m3/s |
|---|---|---|---|
| 1960 | | | |
| 1961 | | | |
| 1962 | | | |
| 1963 | | | |
| 1964 | Jul 09 | 111.6 | 93.7 |
| 1965 | Jun 11 | 87.5 | 76.2 |
| 1966 | Jun 01 | 108.5 | 96.3 |
| 1967 | Jun 22 | 401.4 | 263.0 |
| 1968 | Jun 02 | 279.3 | 183.0 |
| 1969 | Jun 04 | 148.0 | 122.0 |
| 1970 | Jun 03 | 160.0 | 128.0 |
| 1971 | Jun 23 | 163.0 | 134.0 |
| 1972 | Jun 01 | 348.0 | 228.0 |
| 1973 | May 17 | 109.4 | 97.1 |
| 1974 | Jun 16 | 105.0 | 102.0 |
| 1975 | Jun 05 | 80.2 | 71.9 |
| 1976 | Jun 30 | 160.0 | 127.0 |
| 1977 | Jun 07 | 107.0 | 83.3 |
| 1978 | Jun 05 | 143.0 | 106.0 |
| 1979 | May 27 | 79.5 | 64.6 |
| 1980 | May 21 | 94.3 | 83.0 |
| 1981 | May 25 | 111.0 | 93.2 |
| 1982 | Jun 14 | 117.0 | 109.0 |
| 1983 | Jul 12 | 106.0 | 103.0 |
| 1984 | Jun 29 | 135.0 | 112.0 |
| 1985 | May 23 | 110.0 | 97.6 |
| 1986 | May 30 | 125.0 | 109.0 |
| 1987 | May 12 | 93.5 | 81.4 |
| 1988 | May 13 | 85.8 | 75.0 |
| 1989 | Jun 15 | 87.6 | 76.6 |
| 1990 | Jun 24 | 95.6 | 84.1 |
| 1991 | Jul 03 | 95.1 | 82.8 |
| 1992 | May 26 | 76.9 | 68.9 |
| 1993 | May 13 | 156.2 | 124.0 |
| 1994 | May 12 | 75.9 | 72.9 |
| 1995 | May 31 | 83.8 | 74.0 |
| 1996 | Jun 08 | 107.0 | 93.8 |
| average | | 132 | 107 |
| 10-year | | 204 | 155 |

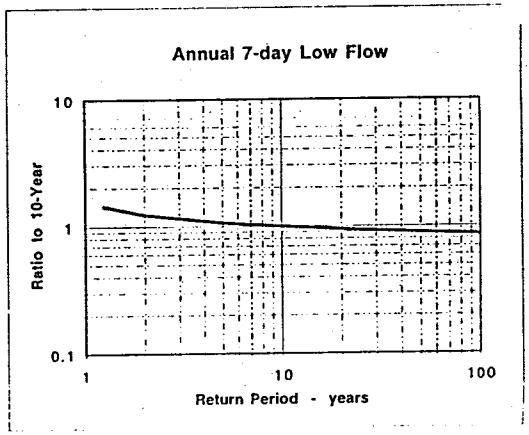
7-Day Low Flow

| Jun-Sep | Annual | Year |
|---|---|---|
| | | 1960 |
| | | 1961 |
| | | 1962 |
| | | 1963 |
| 8.48 | 1.87 | 1964 |
| 6.07 | 2.28 | 1965 |
| 3.88 | 2.54 | 1966 |
| 3.35 | 1.72 | 1967 |
| 7.83 | 2.54 | 1968 |
| 4.08 | 2.26 | 1969 |
| 3.33 | 2.32 | 1970 |
| 3.95 | 2.15 | 1971 |
| 5.34 | 2.71 | 1972 |
| 3.22 | 2.23 | 1973 |
| 4.31 | 1.88 | 1974 |
| 5.51 | 1.45 | 19 |
| 8.01 | 2.46 | 197 |
| 4.53 | 2.19 | 1977 |
| 6.52 | 1.86 | 1978 |
| 3.23 | 2.36 | 1979 |
| 4.50 | 2.03 | 1980 |
| 4.72 | 3.24 | 1981 |
| 7.29 | 1.90 | 1982 |
| 5.36 | 1.98 | 1983 |
| 5.72 | 2.18 | 1984 |
| 3.16 | 1.79 | 1985 |
| 3.19 | 1.93 | 1986 |
| 2.60 | 1.89 | 1987 |
| 2.75 | 1.54 | 1988 |
| 4.85 | 1.73 | 1989 |
| 3.19 | 2.19 | 1990 |
| 3.35 | 2.07 | 1991 |
| 3.57 | 1.98 | 1992 |
| 2.87 | 1.54 | 1993 |
| 2.63 | 1.71 | 1994 |
| 3.76 | 1.53 | 1995 |
| | | 1996 |
| 4.54 | 2.06 | average |
| 2.81 | 1.65 | 10-year |



# APPENDIX 3

## HEC-2 Computer Run Summaries

Kuskanax Creek at Nakusp

# Kuskanax Creek

## Hec-2 Run Summary

| Run # | Comments |
|---|---|
| 1. | Cross section plot run. |
| 2. | Work file to review input data. |
| 3. | Calibration to match WSC data for Q = 67.4 cms. |
| 4. | Calibration to match WSC data for Q = 126.0 cms. |
| 5. | Q200 Daily: Q = 366 cms. |
| 6 | Multiple Q - 200 D & I, 20 D & I<br>*Flood levels selected (including freeboard)* |
| 7. | Sensitivity to Manning's "n" - Q200 I,<br>*Flood level rise for an "n" increase of 20% is less than the freeboard allowance at all except one section.* |
| 8. | Sensitivity to "Q"<br>*For each 10% Q increase, a flood level rise of;*<br>• *0.1 meter occurs in the area upstream of the rock canyon,*<br>• *0.44 meter occurs in the rock canyon area.* |
| 9. | Sensitivity of Creek flood levels to Arrow Reservoir Level<br>*Creek flood levels are insensitive to reservoir levels due to the steep creek profile.* |

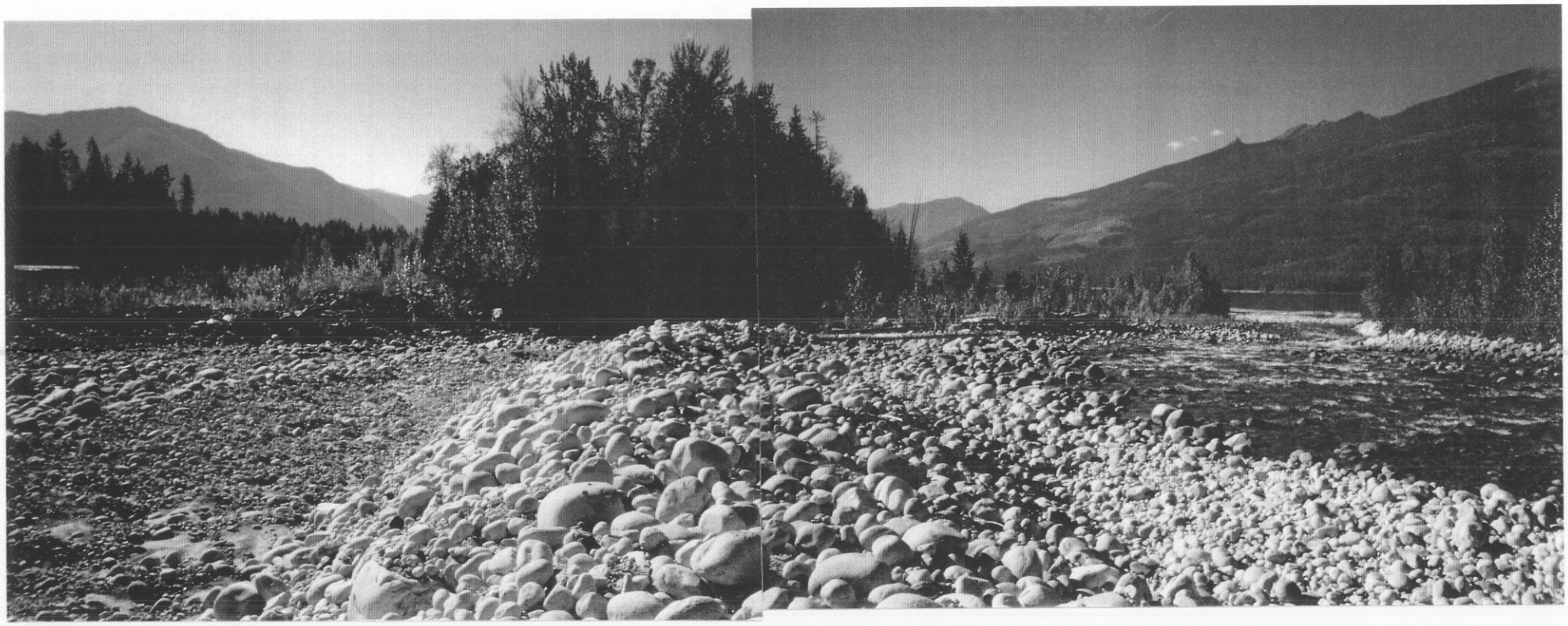
# APPENDIX 4

## PHOTOS

# KUSKANAX CREEK AT NAKUSP

## CROSS SECTION 1

## VIEW DOWNSTREAM



9414F037

SEPTEMBER, 1994

# KUSKANAX CREEK AT NAKUSP

## CROSS SECTION 11

## VIEW UPSTREAM FROM RIGHT BANK

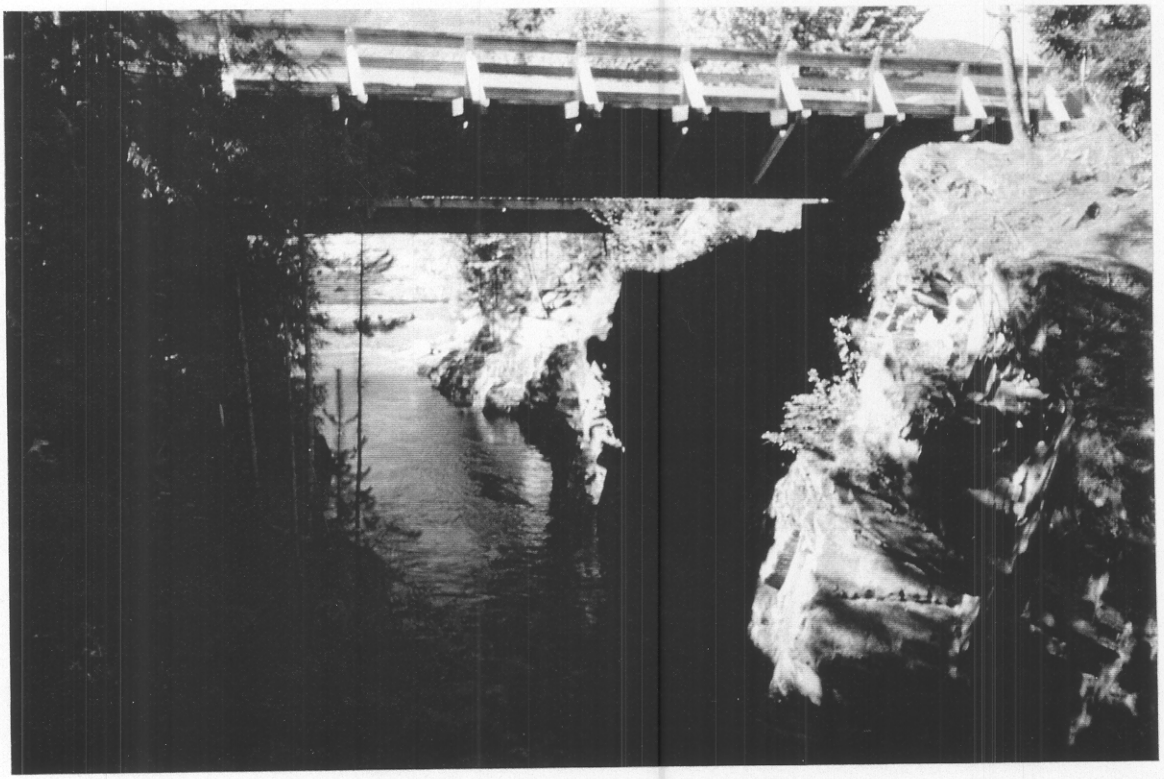
9414F037

SEPTEMBER, 1994

# KUSKANAX CREEK

## UPSTREAM AT HWY. 23 BRIDGE

VIEW DOWNSTREAM



VIEW DOWNSTREAM

9414F037

SEPT,1994

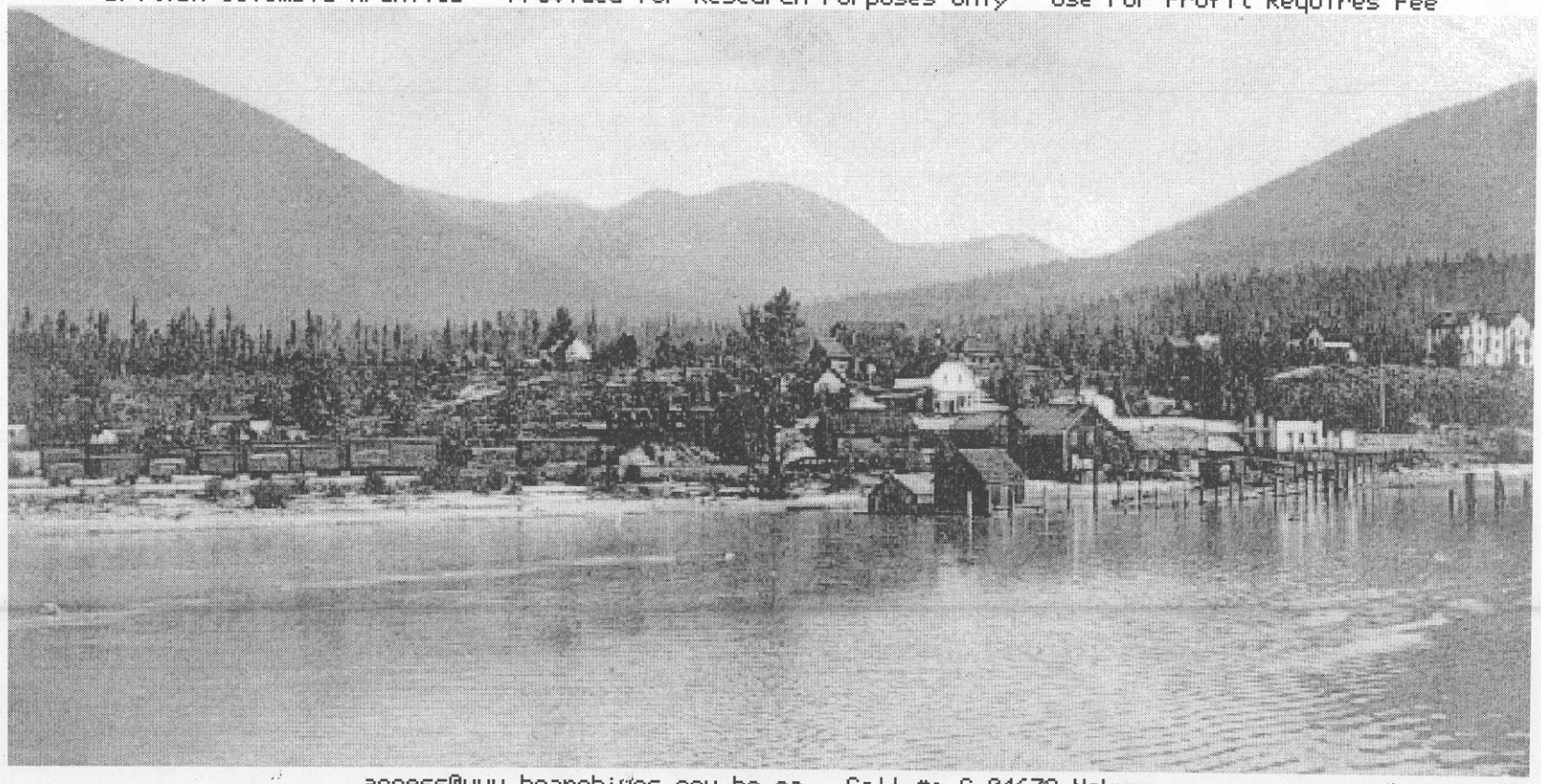


THE ARROW RESERVOIR AND NAKUSP IN 1968.

THE MOUTH OF KUSKANAX CREEK IS ON THE OUTER END OF THE POINT OF LAND.



KUSKANAX CREEK CAN BE SEEN IN THIS PHOTO (191..) FLOWING FROM THE BOTTOM CENTRE TO THE RIGHT.





ENTIRE LOWER AREA IS NOW BELOW ARROW RESERVOIR FLOOD LEVEL.

WHITE BUILDING AT LOWER RIGHT OF THIS 1897 PHOTO IS THE OLD C.P.R. STATION.



AREA AROUND BUILDING IN LEFT FOREGROUND IS NOW PART OF ARROW RESERVOIR. (PHOTO ca. 1892)
LELAND HOTEL STILL EXISTS, 1998.



THIS 1905 PHOTO SHOWS THE ORIGINAL LAKE LEVEL BELOW THE OLD C.P.R. STATION.



THE HIGHEST STRUCTURE IN THIS PHOTO (ca. 1897) WOULD PROBABLY BE THE ONLY ONE ABOVE PRESENT WATER LEVEL.

OLD C.P.R. STATION IS IN LEFT FOREGROUND.




1913 PHOTO OF THE OLD C.P.R. STATION. PRESENT RESERVOIR LEVEL IS NEAR THE TOE OF THE SLOPE IN THE BACKGROUND.



LOOKING DOWNSTEAM ON KUSKANAX CREEK AT THE CANYON (192..).


LOOKING UPSTREAM ON KUSKANAX CREEK FROM THE CANYON (191..).