ENVIRONMENT CANADA
INLAND WATERS

PROVINCE OF BRITISH COLUMBIA
MINISTRY OF ENVIRONMENT, LANDS AND PARKS
WATER MANAGEMENT DIVISION

FLOODPLAIN MAPPING PROGRAM
SALMON RIVER
SPA CREEK TO FALKLAND

DESIGN BRIEF

File: 2829

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DESIGN BRIEF

1.0 INTRODUCTION

This Design Brief and Floodplain Maps for a reach of the Salmon River were prepared under the Canada - British Columbia Floodplain Mapping Agreement by KPA Engineering Ltd. The floodplain delineation study, which was conducted from July to December 1991, encompassed a 45.4-km long reach of the Salmon River from Spa Creek to the Columbia-Shuswap Regional District boundary upstream of Falkland, a small community located between the cities of Vernon and Kamloops. A 2.0-km reach of Bolean Creek was also included in this study. This Design Brief presents a summary of the data, the methodologies used in the study and the subsequent findings.

The Ministry of Environment, Lands and Parks, Water Management Division contact persons in Victoria for this study were P. J. Woods, P. Eng., Head, Special Projects Section and R. W. Nichols, P. Eng., Senior Hydraulic Engineer. The Ministry of Environment, Lands and Parks contact person in the Regional Office in Kamloops was P. Doyle, P. Eng.

The floodplain delineation study contained the following components:

- a hydrology study to determine flood frequency characteristics of the Salmon River and Bolean Creek,
- development and calibration of a computer model to estimate flood profiles,
- determination of 200-Year Flood Levels
- delineation of the land occurring below the 200-Year Flood Levels as the 200-Year Floodplain.

River surveys were conducted by the Ministry of Environment, Lands and Parks, Surveys Section, in July 1981, and the resulting survey data was provided to KPA. The Ministry also provided topographic mapping derived from September 1984 aerial photography for use as a base for the Floodplain Maps.

The Floodplain Maps produced by this study at a scale of 1:5000, appear on nine sheets entitled "Floodplain Mapping, Salmon River, Spa Creek to Falkland" (Drawing Numbers 89-14-7 to 89-14-15). These maps are located in pockets in Appendix 4 of this Design Brief.

Printed output from the computer runs, a profile drawing (No. 2829-1) and four cross section drawings (Nos. 2829-2 to 2829-5) and other supporting documentation have been submitted to the Ministry of Environment, Lands and Parks under separate cover.

The methods and procedures used for the flood estimates, hydraulic analyses and preparation of the Floodplain Maps conformed to the standards and specifications set forth by the B. C. Ministry of Environment, Lands and Parks (1) and by Environment Canada (2).

2.0 SALMON RIVER DRAINAGE BASIN

2.1 Geography

The Salmon River drainage basin is located in south central British Columbia, lying to the west of a line between Vernon and Salmon Arm (Figure 1). The total drainage area of the river is 1510 km^2, ranging in elevation from 2038 m at the peak of Tahaetkun Mountain to 349 m at its mouth at Shuswap Lake.

The 115-km long Salmon River begins its course near the 1500 m elevation, collecting runoff from the gentle to moderately-sloped terrain of the Thompson Plateau as it flows toward the community of Westwold. In the area near Westwold, extending downstream to Falkland, the River occupies a broad valley. At Falkland the Salmon River joins one of its larger tributaries, Bolean Creek. From Falkland downstream to Silver Creek the valley is narrower. Below Silver Creek the valley broadens progressively to the mouth of the Salmon River.

There are no lakes along the course of the Salmon River, although several small lakes are located along some of its tributaries. The flows of the Salmon River are described as regulated in the Water Survey of Canada records. The extent of the regulation is small as there are no large storage reservoirs in the basin, and while this may affect low flows, the effect on large flood peaks is negligible.

2.2 Flood-Producing Events

Peak flows on the Salmon River and Bolean Creek occur during April, May or June, but most frequently during the month of May. This timing indicates that the flood events of these streams are snowmelt controlled. Rain-on-snow floods also occur but it would appear that the rain provides the lesser of the two influences during these events.

Precipitation is generally heavier in the northeastern part of the Salmon River basin. Westwold has a mean annual precipitation of 320 mm, Falkland precipitation averages 450 mm and Salmon Arm has a mean of 530 mm. Maximum precipitation occurs during the October to January period with a lesser peak centred in June.

2.3 Historic Floods

The two largest floods on the Salmon River in the past 70 years occurred in 1948 and in 1990. References to an earlier large flood in 1894 could not be confirmed by data or newspaper articles, although 1894 was the year in which a very large flood occurred on the Fraser River, to which the Salmon River is a tributary.

The 1948 flood is the largest on record for the Salmon River at the Falkland gauge, for which a daily peak flow of 49.0 m^3/s was recorded on the 28th of May. A newspaper account in "The Vernon News" reported that many farms in the Salmon Valley were severely "hit." Photographs of the flooding in 1948 are scarce, but one photograph filed with the Greater Vernon Museum and Archives of flooded farmland near Sweetsbridge appears as Photo 1 in Appendix 1. The Highway 97 bridge at XS-193 (Schweb's bridge) was rendered unsafe by the flood. The Armstrong Road bridge at XS-184 (Heywood Corner) was the site of a log jam. Several residents recounted how some of the neighbours used dynamite to destroy the bridge which released the jam.

In Falkland, Bolean Creek overflowed its banks and destroyed the Highway 97 Bridge over Bolean Creek. Flood waters passed through the western end of the community. "The Vernon News" of June 3, 1948 reported that:

> "With bulldozers and sandbags the creek was prevented from passing through the centre of the village. At several times a big stream went almost through the town."

The 1990 flood, which peaked at the Salmon River at Falkland gauge on June 15, with a daily flow of 41.1 m^3/s, was less severe than the 1948 event. In all but one comparison the 1948 flood levels were reported higher than 1990.

Several farm bridges along the Salmon River were moved or destroyed by the 1990 flood. Joe Abel, owner of the Falkland Ranch, upstream of the Highway 97 bridge at XS-296, reported 1500 acres of his hay fields and pasture under water.

In Falkland, Bolean Creek did not overflow its left bank, as it had in 1948. However, it did spill over the right bank and flowed through the Falkland Trailer Park adjacent to the Creek. Mobile homes were surrounded by water as a flood channel traversed a field next to the Park (Photos 3 and 4). Log jamming at a bend in Bolean Creek was reported as a cause of the overflow.

Erosion occurred at the left abutment of the Highway 97 bridge over Bolean Creek, undermining the fill under the road. A hole in the roadway developed at the abutment as a result (Photo 7).

Downstream of the highway bridge, a few properties suffered damage from flood waters. A large new gravel bar developed at the mouth of Bolean Creek (Photo 8), and new deposition was found just downstream of the Railway Bridge over Bolean Creek near XS-2 (Photo 6).

3.0 DATA USED FOR STUDY

3.1 Data Sources

Many different types of information were acquired for this study from a variety of sources. The main sources of data are listed below, and reports from which information was obtained are listed in the References Section.

Mapping

Maps used for this study are listed below:

- NTS 1:250,000 scale map sheet 82L
- B. C. Ministry of Environment, Lands and Parks 1:100,000 scale map sheet 82L/SW
- NTS 1:50,000 scale map sheets 82L/5, L/6, L/11, L/12
- B. C. Ministry of Crown Lands, Surveyor General Branch, 1:20,000 scale Land Management Map 82L.042
- B. C. Ministry of Environment, Lands and Parks, Surveys and Resource Mapping Branch, 1:5000 scale topographic base maps (nine sheets) 89-14-7 to 89-14-15
- B. C. Ministry of Environment, Lands and Parks, Surveys and Resource Mapping Branch, uncontrolled mosaics numbered 5467-4 to 5467-9 and 5467-13, approximate scale 1:10,000, showing location of cross sections, gauges and reference monuments on Salmon River and Bolean Creek.

Floodplain limits were delineated on the 1:5000 scale base maps. This mapping was found to agree closely with most of the cross section survey data. In a few heavily-forested areas minor discrepancies were discovered. In these areas the survey information governed over the topographic base maps for floodplain delineation purposes.

Air Photos

Selected stereo pairs from the September 1984 B. C. Government aerial photography, Roll No. BC84088, Photo Numbers 103-111, 122-126, 133-147, 154-162, 168-176, 183-186, 195-207, were used in the study. These photos provided stereo coverage of the rivers and floodplains up to cross section XS-319. The air photos from cross sections XS-320 to XS-329 were viewed at the Maps B. C. Air Photo Library.

Surveys

Survey data for a total of 198 cross sections, measurements for the 37 bridges in the study reach as they were in 1981, bridge photographs and channel photographs were provided by the B. C. Ministry of Environment, Lands and Parks (Project 81-FDC-3). The survey was found to be reliable and accurate for the purposes of this study. The general arrangement drawings for the new Salmon River Bridge providing access to the Spallumcheen Indian Band were provided by Watson Engineering Ltd. of Kamloops. Other bridges which had been modified or rebuilt since 1981, and all bridges at new locations, were measured by KPA during the 1991 site investigations (see Table 2, Section 3.2).

High-Water Marks

The most useful high-water marks obtained for this study were those read from gauges or related accurately to distinct physical features at recorded times and dates. A listing of the sources of high-water mark data appears in Table 1, below, and the actual high-water mark data is presented in Appendix 2.

Table 1

High-Water Mark Data Sources

Flood Event	No. of HWMs	Source of Data	Comments
1983	8	Don Johnson, Kamloops Regional Office, Water Management Branch, Ministry of Environment, Lands and Parks	marks fixed 1 week after peak
1990	5	Paul Doyle, Kamloops Regional Office, Water Management Branch, Ministry of Environment, Lands and Parks	photos provided, marks fixed right after peak
1990 1983	2	Water Survey of Canada	recorder gauge readings at WSC gauge 08LE020 Salmon River at Falkland.

Hydrologic Data

The flood data, comprising both daily and instantaneous peaks, was obtained from Water Survey of Canada (3, 4, 5, 6 & 7) for the Salmon River, Bolean Creek and several regional stations. Other valuable information was obtained from reports by the B. C. Ministry of Environment, Lands and Parks (8 & 9) and Crippen Consultants (10).

Anecdotal information pertaining to past floods was obtained from interviews with residents, and articles in "The Vernon Daily News" and "The Morning Star" newspapers.

3.2 Field Investigations

Two site investigations were conducted during the course of this study. The first field visit commenced on 12 August, 1991, and spanned three days. It included a thorough site reconnaissance with visits to every one of the 33 bridge sites identified in the initial study area by the 1981 survey. Meetings were conducted with local government personnel and local residents were interviewed.

A second site investigation which also spanned three days, commenced on 1 November, 1991. This visit included a reconnaissance of the area between cross section XS-308 and XS-329 (which was added to the study area after the initial site visit) and the four bridges there. A detailed field check of the preliminary mapping for the remainder of the study area was also conducted. Some additional interviews were held, and a search for flood photographs was made at the local museum and newspaper offices.

It was discovered that of the 37 bridges surveyed in 1981 in the enlarged study area, 9 were removed, 9 were rebuilt or upgraded in the same location, 2 were replaced at nearby locations and 3 new bridges were constructed at new locations. A summary of all bridges is presented in Table 2. All new, rebuilt and upgraded bridges were measured, and each of their deck elevations was related to a nearby point with a readily-identifiable elevation. Cross sections were also measured at all new bridge locations.

Several interviews were conducted by the Project Engineer during the field visits to collect information on high-water marks, recent changes along the stream courses and other information pertaining to past flooding. Each person interviewed, the cross section number near their residence (if applicable) and the date of each interview is listed below:

1. Paul Doyle, P. Eng., Ministry of Environment, Lands and Parks, Water Management, Kamloops, 12 August,
2. Claude McDonald, Watson Engineering Ltd., 12 August,
3. Mrs. Gordon, XS-278, 12 August,
4. Clara Fretz, XS-259/260, 12 August,
5. Mrs. Marshman, XS-14, 13 August,
6. Male resident (farmer), XS-246/247, 13 August,
7. Mike Kuziw, XS-221, 13 August,
8. Mr. Robbins, XS-212, 13 August,
9. John Bourgh, XS-14, 13 August,
10. Columbia-Shuswap Regional District Clerk, Salmon Arm, 14 August,
11. Male resident, XS-154/155, 14 August,
12. Mr. Needoba, XS-182/183, 14 August (resident since 1919),
13. Clayton Abel, Falkland Ranch, 2 November,
14. Vivian Buan, XS-9, 2 November,
15. Gordon & Leona Drozdowich, XS-9/10, 2 November,
16. Camille Noel, XS-5, 2 November,
17. Carl Schweb, XS-190, 2 November,
18. Male resident, XS-195, 2 November,
19. John Sharp, XS-176/177, 4 November,
20. Male resident, XS-164, 4 November,
21. Mr. McLellan, XS-159, 4 November.

Table 2 - Bridge Summary

Cross Section No.	Description
SALMON RIVER	
Bridges Same as in 1981	
154/155	Concrete farm bridge
193/194	Highway 97 bridge near Salmon Valley Road, high deck
226	Footbridge and irrigation pipe bridge, likely would be swept away in flood
231	Log bridge to support irrigation pipe, high deck
238/239	CN Railway bridge, very high deck
264/265	Farm bridge
270/271	Farm bridge, collapsing and soon to be replaced (new bridge completed Nov., 1991)
278	WSC metering bridge
280/281	Road bridge, skewed high deck
292	Unfinished farm bridge
294/295	CN Railway bridge, high skew
296/297	Highway 97 bridge, some skew
308	Farm bridge
317	CN Railway bridge
Bridges Upgraded or Rebuilt since 1981	
184/185	Armstrong Road bridge, same substructure, new deck
203/204	Farm bridge, same location but higher deck (Mr. Bourgh)
211/212	Farm bridge, same location but higher deck (Mr. Robbins)
217/218	Farm bridge, same location but higher deck (Mr. Robbins)
235/236	Cedar Hill Road (Sweet's Bridge), same substructure, new deck
246/247	Farm bridge replaced and raised by 0.6 m
253/254	Dear Road bridge, same substructure, deck strengthened by steel "I" beams
259/260	Driveway/farm bridge, higher deck (Mrs. Fretz)
284/285	Farm bridge, new deck added on top of old one.

Table 2 - Bridge Summary	
Cross Section No.	Description
SALMON RIVER - CONTINUED	
New Bridges	
120 m U/S of 147	Farm bridge
148 m U/S of 159	Farm bridge
30 m D/S of 164	Salmon Valley Road bridge, wood and steel
6 m U/S of 172	Road bridge to Spallumcheen Indian Band, concrete
70 m D/S of 225	Farm bridge
Bridges Removed since 1981	
149/150	Collapsed farm bridge
157/158	Small log footbridge
223/224	Farm bridge
229	Footbridge
299/300	Farm bridge
305/306	Farm bridge
311/312	Farm bridge
323/324	Farm bridge
326/327	Farm bridge
BOLEAN CREEK	
Bridges Same as in 1981	
2/3	CN Railway bridge
6/7	Highway 97 bridge
13/14	Driveway/farm bridge, some new concrete on left bank.

4.0 FLOOD FREQUENCY STUDIES

4.1 Methodology

A regional approach was used to estimate flood frequencies for the Salmon River. This method involves the estimation of flood frequencies for gauged streams which are hydrologically similar to the stream under study. These estimates are plotted as unit runoff values versus drainage area. A "design curve" is then fit to those points which best represent the conditions in the drainage basin in question.

A single-station analysis using the Salmon River gauge at Falkland might appear to be sufficient as WSC has recorded 46 daily peak flows at this gauge and it is located within the Study Area. A regional analysis, however, provides a more valid method of estimating floods for other locations on the Salmon River than prorating on a drainage area basis. It also provides an alternative method for estimating the flood frequency on Bolean Creek, which has peak flow records for only 12 years.

Single-station flood frequencies were analyzed with a computer program known as the Consolidated Flood Frequency Analysis Package (CFA), prepared by Environment Canada as a supplement to their Guide for procedures for floodplain delineation(2). The program provides routines which screen for data independence, trend, homogeneity and randomness. The program will perform tests for low and high outliers and permit incorporation of historic data. CFA uses the following four probability distributions:

- Generalized Extreme Value
- Three Parameter Log Normal
- Log Pearson Type III
- Wakeby.

4.2 Regional Streamflow Data

A total of 35 different streamflow gauges have operated at various intervals in or near the Salmon River catchment (see Table 3 for listing). Of these, 3 are currently recording: 08LE021 Salmon River near Salmon Arm, 08LE020 Salmon River at Falkland, and 08LE075 Salmon River above Salmon Lake. Of the total number of gauges, 23 have operated for less than 10 years, and 11 of these 23 have operated for less than 5 years. The gauge with the longest period of record is the 08LE020 Salmon River at Falkland Station with 46 years of peak flow data.

Two peak flow events (May 13 - 14, 1971 and May 30 - 31, 1972) have been identified as anomalously high by Crippen Consultants(10). It was found that the peak flows for Salmon River at Falkland (1040 km^2 drainage area) were higher than those of the next downstream gauge, 08LE021 Salmon River near Salmon Arm (1510 km^2 drainage area). A detailed study done by W. Obedkoff, Senior Hydraulic Engineer with the Ministry of Environment, Lands and Parks(8), concluded the 1971 and 1972 peak flows were incorrect as published.

Peak flows for the four Salmon River gauges and two other gauges located within the Salmon River catchment were plotted versus drainage area for the 1971 and 1972 maximum daily flows on a log-log graph. Three of the four Salmon River points fell on a straight line, but the Falkland point plotted well above the line. Estimated maximum daily flows as revised to fit these lines are shown below:

	Maximum Daily Flow (m^3/s)	
	1971	1972
WSC recorded flows	43.6	42.5
Estimated flows	30	34

Maximum daily flows were analyzed from the 12 gauges indicated in Table 3, with preliminary 1990 and 1991 flows added to the appropriate data sets. Maximum instantaneous flows were not analyzed since daily flows far outnumbered the instantaneous flows both by the number of stations and the number of recordings per station. All four probabilities were applied to each set of flood peak data. A plot of each flood frequency curve showing the individual data points was reviewed before a "best fit" probability distribution was chosen. The results were also compared to those produced by the Ministry of Environment, Lands and Parks, Water Management Division, with their computer program FREQAN and with flood frequencies produced by Crippen Consultants. The results from the CFA program were very similar to those produced by the FREQAN program.

TABLE 3
REGIONAL STREAMFLOW STATIONS

REGIONAL ANALYSIS	STATION NUMBER	DESCRIPTION	CATCHMENT AREA (km^2)	NUMBER OF YEARS RECORDED	SEASON OF RECORD	YEARS OF DAILY RECORD	YEARS OF INSTAN. RECORD
YES	08LE005	Chase Creek near Chase	279	12	Apr-Sep	1911-12	-
						15-23,63-68	-
-	08LE060	Spa Creek below Cowpersmith Diversion	13	4	Apr-Sep	1945-48	-
-	08LE042	Spa Creek above Cowpersmith Diversion	13	6	Apr-Sep	1923-28	-
						1931	-
YES	08LE067	Fowler Creek near Falkland	15.8	10	May-Sep	1955-64	-
YES	08LE096	Fowler Creek at 640m contour	15.8	8	all year	1974-80	-
						1986	-
-	08LE089	Salmon River above Fowler Creek	1070	9	all year	1974-80	-
						1985/86	-
-	08LE097	Salmon River near Glenemma	1170	3	all year	1974-76	-
YES	08LE065	Salmon River at Glenemma	1160	9	Apr-Sep	1951-53	-
					sporadic	1959-61	-
					all year	1974-76	-
-	08LE064	Salmon River near Falkland	1120	8	Apr-Sep	1951-53	-
					all year	1974-78	-
-	08LE023	Warren Creek near Salmon Arm	25.9	2	Apr-Aug	1911/12	-
YES	08LE020	Salmon River at Falkland	1040	48	Apr-Aug	1911/12	-
					Apr-Sep	1915-21	-
					Apr-Sep	1947-51	-
					all year	1952-61	-
					all year	1966-91	1974-91
YES	08LE001	Bolean Creek at Falkland	228	15	Apr-Sep	1911-21	-
						51, 62-64	-
YES	08LE094	Bolean Creek near the Mouth	224	12	all year	1974-85	-
-	08LE038	Blair Creek near Falkland (lower sta)	77.7	1	May-Sep	1921	-
YES	08LE008	Ingram Creek near the Mouth	63.2	11	Apr-Oct	1911-21	-
					Jun-Jul	1975	-
-	08LE059	Salmon River near Westworld	501	1	Aug-Sep	1946	-
YES	08LE019	Salmon River above Adelphi Creek	546	22	Apr-Dec	1911/12	-
						17-21,46/47	-
						64/65,67/68	-
						70-78	-
-	08LE095	Weyman Creek near the Mouth	95.6	4	Apr-Oct	1974-76	-
						1978	-
-	08LE063	Salmon River near Douglas Lake	237	3	May-Sep	1951-53	-
YES	08LE075	Salmon River above Salmon Lake	143	25	all year	1966-90	1966-90
YES	08LE021	Salmon River near Salmon Arm	1510	32	Apr-Sep	1911/12	-
					Apr-Sep	1961-73	-
					all year	1974-91	1974-91
YES	08LE072	Palmer Creek near Salmon Arm	18.1	12	May-Sep	1963	-
						1967-77	-
-	08LE093	Palmer Creek above Diversions	15.5	6	all year	1974-79	1975-79
YES	08LE044	Gordon Creek near Salmon Arm	18.9	14	Apr-Sep	1930/31	-
						1963	-
					all year	1965-75	-
-	08LE092	Gordon Creek above Diversions	17.9	6	all year	1974-79	1974-79
-	08LE088	Salmon River above Kernaghan Creek	1400	6	all year	1974-79	-
YES	08LE091	Kernaghan Creek above Diversions	8.3	8	all year	1974-80	1974-79
					Apr-Oct	1987	1987
-	08LE045	Grier Creek near Salmon Arm	13	1	Apr-Oct	1931	-
-	08LE090	Salmon River below Silver Creek	1210	4	all year	1974-77	-
YES	08LE043	Silver Creek near Salmon Arm	25.9	11	Apr-Sep	1923-28	-
						31, 45-48	-

The Three Parameter Log Normal distribution provided a good fit in most cases. The range of results from the four distributions was small compared to the range in unit peak flows over the region.

Two of the streams, Fowler Creek and Bolean Creek, each had a pair of gauges located very close to one another which collected flow data for different periods. For each stream, the data sets were combined to create a longer period of record.

With regard to the aforementioned anomalies of the Salmon River at Falkland station, flood frequencies were analyzed for the following three data sets:

- with the published 1971 and 1972 peaks
- without any 1971 and 1972 peaks
- with the revised 1971 and 1972 peaks.

As expected, the data set with the published data yielded the highest flood estimates. The latter two data sets provided values that were very similar to one another.

Maximum daily unit runoff values for the 20- and 200-year return periods were plotted against drainage areas using log-log scales. Separate curves were plotted for Salmon River and Bolean Creek, as there appeared to be a trend towards higher peaks in the Bolean and Chase Creek drainage areas. The point representing the Salmon River at Falkland station with the revised 1971 and 1972 flows was used as a fixing point for curve location as it has the longest period of record and is located within the study reach. The lines drawn were subjectively weighted by the period of record of each station.

4.3 Peaking Factors

Of the 14 gauges used in the regional analysis, only 6 recorded instantaneous flows. Their periods of record vary from 3 to 24 years. An examination of the relationship between the ratio of instantaneous to daily peaks, or peaking factor and flood magnitude showed that the peaking factor for higher floods is less than the mean peaking factor for the entire period of record. This contrasts with some other regions in British Columbia where larger peaking factors have been associated with larger floods. For this study the mean peaking factors for the entire period of record were assumed to be applicable to large floods.

In general the peaking factors were low, which is typical for snowmelt floods. The factors were plotted against drainage area, and the resulting pattern of points is presented in Figure 3. The plot shows the expected trend of a decrease in peaking factor with an increase in drainage area.

4.4 Flood Flow Estimates

The drainage areas for Bolean Creek and Salmon River within the limits of the floodplain mapping study area range from 228 km^2 to 1299 km^2. Cumulative catchment areas were measured from 1:250,000 NTS maps at several locations. Using the curves in Figures 2 and 3, estimates of mean daily and instantaneous peak flows were estimated for use in the HEC-2 model, and appear in Table 4 below.

Table 4
Flood Flow Estimates

Location	Cumulative Drainage Area km^2	Estimated Peak Flows - m^3/s Daily 20-Yr.	Daily 200-Yr.	Instantaneous 20-Yr.	Instantaneous 200-Yr.
Bolean Creek at mouth	228	16	21	18	23
Salmon River at District Boundary	742	30	46	32	49
Salmon River upstream of Bolean Creek	812	31	48	33	51
Salmon River at Falkland	1040	35	54	37	57
Salmon River at Sweetsbridge	1109	38	59	40	62
Salmon River at Glenemma	1206	40	62	42	65
Salmon River at Spa Creek	1299	41	65	43	68

5.0 RIVER MORPHOLOGY

5.1 Bolean Creek

On the basis of information collected during the site investigations, interviews and interpretation from aerial photographs, some trends in river morphology which have had or will have an impact on flood levels, are apparent. One of the more significant trends is the deposition on the Bolean Creek fan and its effect on the Salmon River.

Long-term bed material deposition on alluvial fans is a well-known trend, yet because the flood events that cause major bed changes are relatively infrequent, complacent attitudes towards the hazards of developing on them are the norm. Part of the community of Falkland is situated on the Bolean Creek fan. On two occasions in the past 70 years, Bolean Creek has overflowed its banks and caused property damage in this area. In 1948 a flood channel directed itself towards the centre of the town, and in 1990 overflows occurred on the right bank. Neither flood resulted in a permanent avulsion of the main channel. Deposition of gravel, cobbles and boulders, which indicated an aggrading channel bed, was observed near the mouth of Bolean Creek following the 1990 flood.

The Bolean Creek fan has two distinct parts to it. The ground surface near the Creek is depressed relative to the rest of the fan, indicating that Bolean Creek has incised a floodplain into part of an older fan structure. This indication is supported by the observation that the toe of the older fan has been truncated by the Salmon River. The existence of such a structure can be explained by the following sequence of events:

1. Bolean Creek built a large fan at a time when the adjacent Salmon River reach was governed by a higher hydraulic control,

2. The hydraulic control was lowered such that the Salmon River incised a floodplain in its valley (this is supported by many other features along the Salmon River),

3. Bolean Creek responded to this change by degrading its profile near the mouth then began to widen its new floodplain, as it re-aggraded to its current configuration.

The limits of both the active part of the fan and the older fan are shown on Sheet 13 of the attached Floodplain Maps. The active part of the fan has been identified as subject to special flood hazard, as it would be reasonable to expect that an avulsion could occur within the active part of the fan during a future large flood, unless protective measures are undertaken, such as armoured dyking and/or channel enlargement with the necessary maintenance. The eastern part of the community is perched on the older fan. This part of Falkland is unlikely to be subject to flooding or avulsion from Bolean Creek, given the existing topography.

Human habitation on the fan has resulted in some topographic changes. The most significant of these, from a hydraulic perspective, are the built-up road embankments crossing the fan which act as barriers to down-valley conveyance of flood waters. Agencies which regulate the building or modification of such roads should be aware of the potential impact of their works on flood levels and flood limits.

The most significant road embankment across the fan is Highway 97. If the waterway opening under the highway bridge were to become blocked with debris during a major flood, the water would rise until the flow could pass over the embankment. Areas deemed, from field observations, to be subject to such inundation have been included within the limits of the active fan.

5.2 Salmon River

The transport and deposition of material by Bolean Creek has also determined the nature of the Salmon River near Falkland. Because of its steepness, Bolean Creek can carry larger bed material than the Salmon River can. Therefore, the Bolean fan has pushed the Salmon River to the far side of the valley and caused the Salmon River to aggrade at the confluence.

The Salmon River at Falkland gauge is located 170 m downstream of the mouth of Bolean Creek. A search for a trend in the rating curve shifts at the Falkland gauge revealed that from 1947 to June 1990 the water level for a constant discharge was very slowly rising by about 0.28 m in 44 years for a discharge of 5 m^3/s. The 1990 flood, however, caused a sudden upward shift of the rating curve by about

0.31 m at a flow of 5 m^3/s. This evidence supports statements by Mrs. Gordon, who lives near the gauge, that the 1990 flood levels were approximately as high as those in 1948. She also reported that a large gravel bar had been deposited during the 1990 flood, causing the bed of the river to rise.

The sharp change in the Salmon River's slope at the confluence, apparent in the profiles in Figure 4, is a result of Bolean Creek's sediment gradation and transport rate. The backwater effect of this extends upstream 2 km to cross section XS-289. In this reach the Salmon River has low banks and little velocity as it meanders through its broad floodplain which is readily inundated by minor floods.

Another low slope reach of the Salmon River occurs upstream of cross section XS-300. The main topographic feature which appears to control the profile here is an ancient alluvial fan of what is now a very small unnamed stream. There is also a narrowing of the valley walls downstream of the fan, which may coincide with an additional control by bedrock or large lag deposits. Unlike the control at the Bolean Creek confluence, this upstream control is not actively aggrading. However, the effect on the channel upstream is the same. The Falkland Ranch, which occupies the valley bottom from the upper control to the Regional District boundary, experiences overbank inundation much more frequently than areas between Falkland and Spa Creek.

There are several indications, such as the large ancient fans at very small stream valleys, and the remnants of gravel terraces, that suggest the Salmon River, and some of its tributaries, carried much greater discharges in earlier stages of their evolution. As a result, there are many valley-bottom areas which are not inundated by the more recent Salmon River's rare floods.

It was determined that certain reaches of the Salmon River have been straightened by some farmers decades ago. One particularly long reach of straightened channel exists between cross sections XS-177 and XS-180. Additional straightening took place between XS-189 and XS-191. The river appears to have responded to these changes by deepening its channel where it has been straightened, and for some distance upstream. Mr. Needoba, who lives just downstream of the Armstrong Road Bridge, reported that the river has incised its bed in the past 40 years, and that the overbank inundation of the 1948 flood was far greater than that of the 1990 flood. Downstream of the lower straightened reach, near cross section XS-176, local residents reported that the bed was aggrading and considerable bank erosion was occurring.

All of the above morphologic changes are occurring relatively slowly, and their effect on flood levels might approach the freeboard allowance of 0.6 m only after a long period of time. It would be prudent to monitor such changes, especially in the vicinity of Falkland, where considerable development has taken place. Monitoring could involve tracking the rating curve shifts at the Salmon River gauge, and observing and recording Bolean Creek deposition following large flood events.

6.0 HYDRAULIC ANALYSES

6.1 Model Development

The computer program known as HEC-2 was used to simulate 200-year flood profiles for the study reach. This program, written by the U. S. Army Corps of Engineers and widely used throughout North America for floodplain delineation studies, computes backwater profiles for steady state flow conditions using the Standard Step Method (12, 13).

The HEC-2 model was prepared for the study reach of the Salmon River in the following manner:

1. The cross section data from the river survey was provided in HEC-2 input format (GR data) by the B. C. Ministry of Environment, Lands and Parks.

2. Cross sections which appeared to have insufficient height to contain a large flood flow were extended using the contours on the 1:5000 scale topographic mapping.

3. Twenty-four of the 40 bridges listed in Table 2 were coded for the HEC-2 program. Nine bridges have been removed since 1981. The remaining 7 were not coded as bridges in the model as they were without piers and considered to be above the 200-year flood limit or were so small and poorly secured that they would be easily swept away in a flood. Additional cross sections were inserted at 9 bridge locations to achieve the recommended cross section spacing upstream and downstream from the bridges.

   Where bridges or piers were skewed to the direction of high-stage flows, care was taken to ensure the apparent widths of the bridge openings and apparent pier widths were represented in the model.

4. Thalweg and overbank distances were measured from the 1:5000 scale mapping and entered in the model.

5. Manning's "n" values for the river channels were estimated using photographic and tabular guides by Chow (14), taking into consideration roughness height (approximated from bed material sizes), river slope, vegetation, debris, sinuosity and cross section uniformity.

   Channel roughness coefficients used for the Salmon River simulation ranged from 0.035 to 0.046. Generally, the steeper reaches contained larger bed material and were assigned higher roughness coefficient values. The low-slope reaches were typically more sinuous and vegetated with overhanging willows along much of their length.

   The highest coefficients, 0.050 to 0.065, were applied to the reaches of Bolean Creek where the bed was paved with large cobbles and boulders.

   Manning's "n" values for the overbank areas were estimated primarily on the basis of vegetation type. The values used ranged from 0.070 to 0.100.

   Overhanging branches, which were common along the banks of the Salmon River, were accounted for in the model by setting the channel limits on the cross sections such that the vegetated zones would be excluded from the channel and included in the overbanks, which had higher roughness coefficient values.

6. Hydraulic loss coefficients for expansion, contraction, pier shape, orifice flow and weir flow at bridges were generally selected in accordance with the recommendations outlined in the HEC-2 User's Manual (12).

7. The input data was completed by the addition of peak discharge data and necessary job control parameters. The upstream water level derived by Crippen Consultants (10) was used for the starting water level for the 200-year instantaneous flood event. For all other sensitivity and final runs, the starting water level was determined by the program using a starting slope for the energy grade line of 0.00306 at cross section XS-146.

6.2 Model Calibration

After the initial HEC-2 model of the Salmon River was developed it was calibrated using observed flow and high-water mark data from the following two historic flood events:

22 May, 1983
15 June, 1990.

Of these events, the 1983 flood had the greater number of observed high-water marks. The 1990 flood, however, was higher in magnitude. The peak flows of the Salmon River for each flood were prorated using WSC data and drainage area. The Bolean Creek flows were estimated using the slope of the regional flood frequency curve for the 1990 event.

The HEC-2 program was executed, then the resulting profiles were plotted with the observed high-water marks and a comparison was made. Channel roughness coefficients were adjusted, the bridge coding was altered and the model was run again. This was repeated until a reasonable fit was achieved for the majority of the high-water marks.

In most cases, the 1990 and 1983 profiles fell on or above the measured high-water marks. One high-water mark, taken in May 1983 at a farm bridge near cross section XS-260, was unreasonably high and was considered erroneous.

The profile also fell below the observed high-water mark at the Highway 97 bridge on Bolean Creek. It is possible that the recorded instances were affected by log jamming. Even with the 0.6 m of freeboard added, the simulated 200-year flood level fell below the recorded water levels. The relationship of Bolean Creek to the regional curve was re-evaluated and the flood estimates were revised upwards as shown in Figure 2. Channel roughnesses were also increased in an attempt to simulate the 1990 and 1948 flood events. With only one high-water mark in 1990 on the Highway 97 bridge and insufficient discharge information for Bolean Creek, further calibration of the model in the vicinity of Falkland was not possible.

6.3 Sensitivity Analyses

Sensitivity tests were conducted to estimate the impact of inaccurate data or modelling assumptions on the final results. The tests were used to indicate whether the standard freeboard quantities generally used by the B. C. Ministry of Environment, Lands and Parks were in a reasonable proportion to the effects of uncertainties in this study. The sensitivity analyses concentrated on two major parameters, flow and channel roughness.

The calibrated model using the 200-year peak instantaneous flow was established as the base simulation. The discharges in the model were all decreased by 10% and the program was executed. The discharges were then increased by 10% and 25% above the base simulation for two subsequent runs.

Similarly, three more simulations were made with Manning's "n" factored by -10%, +10% and +25%. The results of these six runs are summarized in Table 5 in terms of mean and maximum water level differences at cross sections between each test run and the base simulation.

Table 5 - Summary of Sensitivity Test Results

Sensitivity Test	Variation in Water Level from Base Simulation (m)			
	Salmon River		Bolean Creek	
	Mean	Maximum	Mean	Maximum
Roughness Coefficient Manning's "n"				
-10%	-0.058	-0.23	-0.066	-0.13
+10%	0.067	0.61	0.079	0.28
+25%	0.169	0.61	0.155	0.30
200-Year Instantaneous Peak flow				
-10%	-0.094	-0.65	-0.078	-0.11
+10%	0.119	0.70	0.096	0.36
+25%	0.246	0.84	0.189	0.50

The results show that the Salmon River is more sensitive to changes in flow than Bolean Creek, but less sensitive than Bolean Creek to changes in roughness.

A review of the detailed printed output from the sensitivity runs showed that water levels of the low-slope reaches were more sensitive to increases in both roughness and flow than in the steeper reaches. A greater sensitivity to changes in flow was noted at locations upstream of most bridges, especially those with the more constricted waterway openings.

6.4 River Flood Levels

Using the HEC-2 program, flood profiles were generated for the 200-year instantaneous and daily peak flows. A freeboard of 0.3 m was added to the peak instantaneous flood profiles, and a freeboard of 0.6 m was added to the daily flood profiles. At each cross section the higher combination of 200-year flood level plus freeboard was selected. This combination became the Flood Level (including freeboard) for that cross section, and a listing of these levels for all cross sections used in the modelling appears in Appendix 2.

Water levels corresponding to instantaneous and daily peak flows differed by a mean value of 0.046 m, and the governing condition was the 200-year daily peak water level plus 0.6 m freeboard at all cross sections. The magnitude of the water level changes indicated by the sensitivity analyses was generally less than the 0.6 m freeboard criterion, therefore this freeboard value appears to provide a reasonable margin of safety to account for uncertainties in the data and the computer model.

The Flood Levels (including freeboard) were used to delineate the floodplain by plotting them on the 1:5000 scale topographic mapping at each cross section. The contours were used to identify the floodplain limits between cross sections.

Isograms for the 200-year flood levels were located on the mapping and the corresponding 20-year flood level (including freeboard) for each isogram was calculated. Both flood levels were labelled at each isogram on the mapping.

7.0 RECOMMENDATIONS

On the basis of the findings of this study we recommend the following:

1. That the Floodplain Maps produced by this study, numbered 89-14-7 through 89-14-15, be designated under the terms of the Canada - British Columbia Floodplain Mapping Agreement.

2. That these Floodplain maps be reviewed and updated as required on the basis of significant future flood data or information relating to major physical changes to the floodplain.

3. That Water Survey of Canada review the published flood peak data for the Salmon River at Falkland gauge for the years 1971 and 1972 in view of the apparent anomalies identified in this study.

4. That the deposition of gravel in key stream channel reaches near Falkland be monitored following large future flood events. These key reaches include Bolean Creek from its mouth to cross section XS-10, and the Salmon River between cross sections XS-277 and XS-282.

5. That the feasibility of providing flood protection for Falkland from overflows from Bolean Creek be investigated.

6. That the B. C. Ministry of Transportation and Highways and the Regional District of Columbia-Shuswap be advised that elevation changes to Highway 97 and roads within the active part of the Bolean Creek fans may alter the area subject to flood hazard from that shown on Map No. 89-14-13.

This "Design Brief for the Floodplain Mapping Program for the Salmon River from Spa Creek to Falkland," is respectfully submitted by:

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12. U. S. Army Corps of Engineers, The Hydrologic Engineering Center, "HEC-2 Water Surface Profiles Users Manual," Davis, CA, September 1982.

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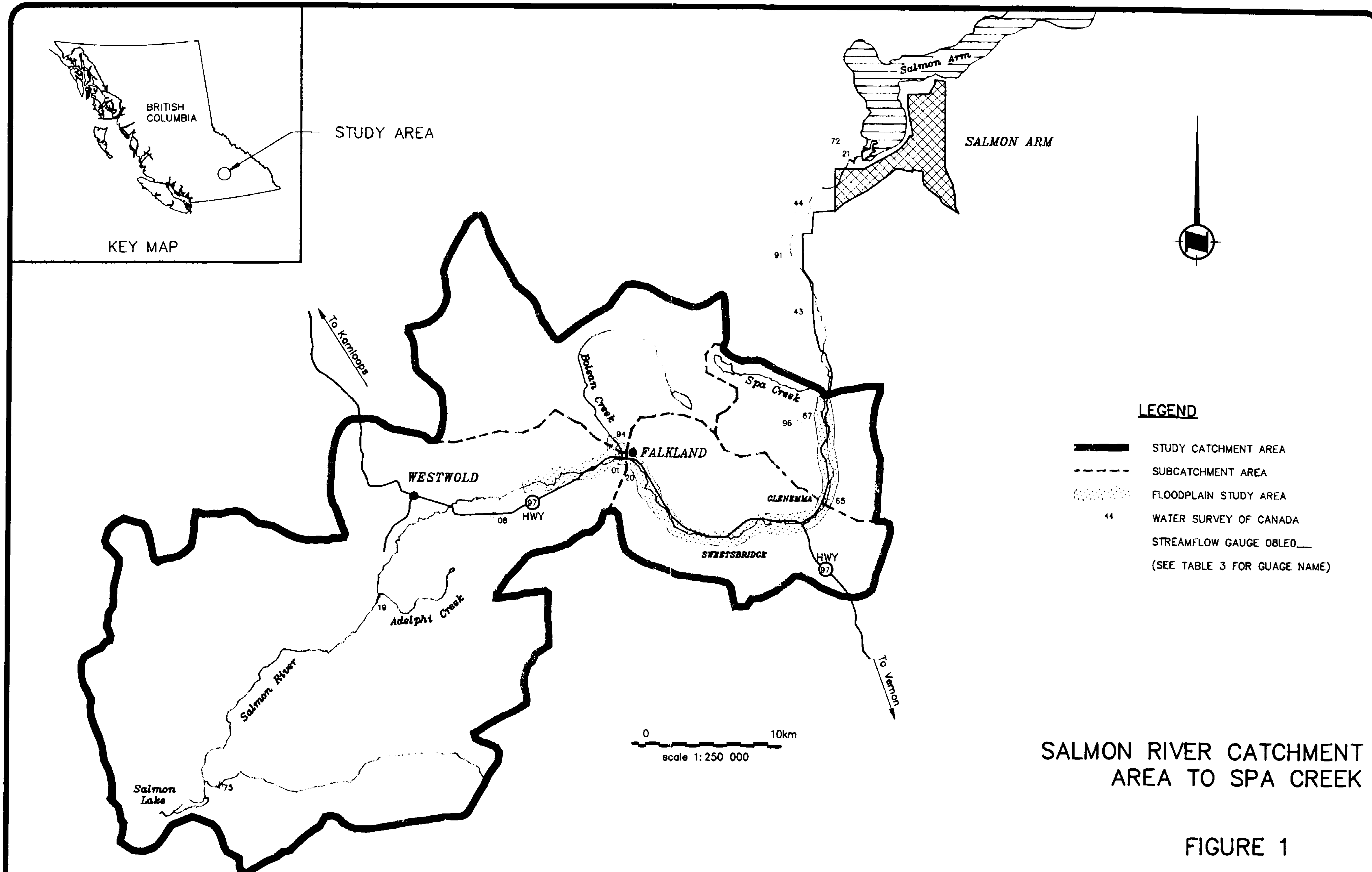
FIGURES



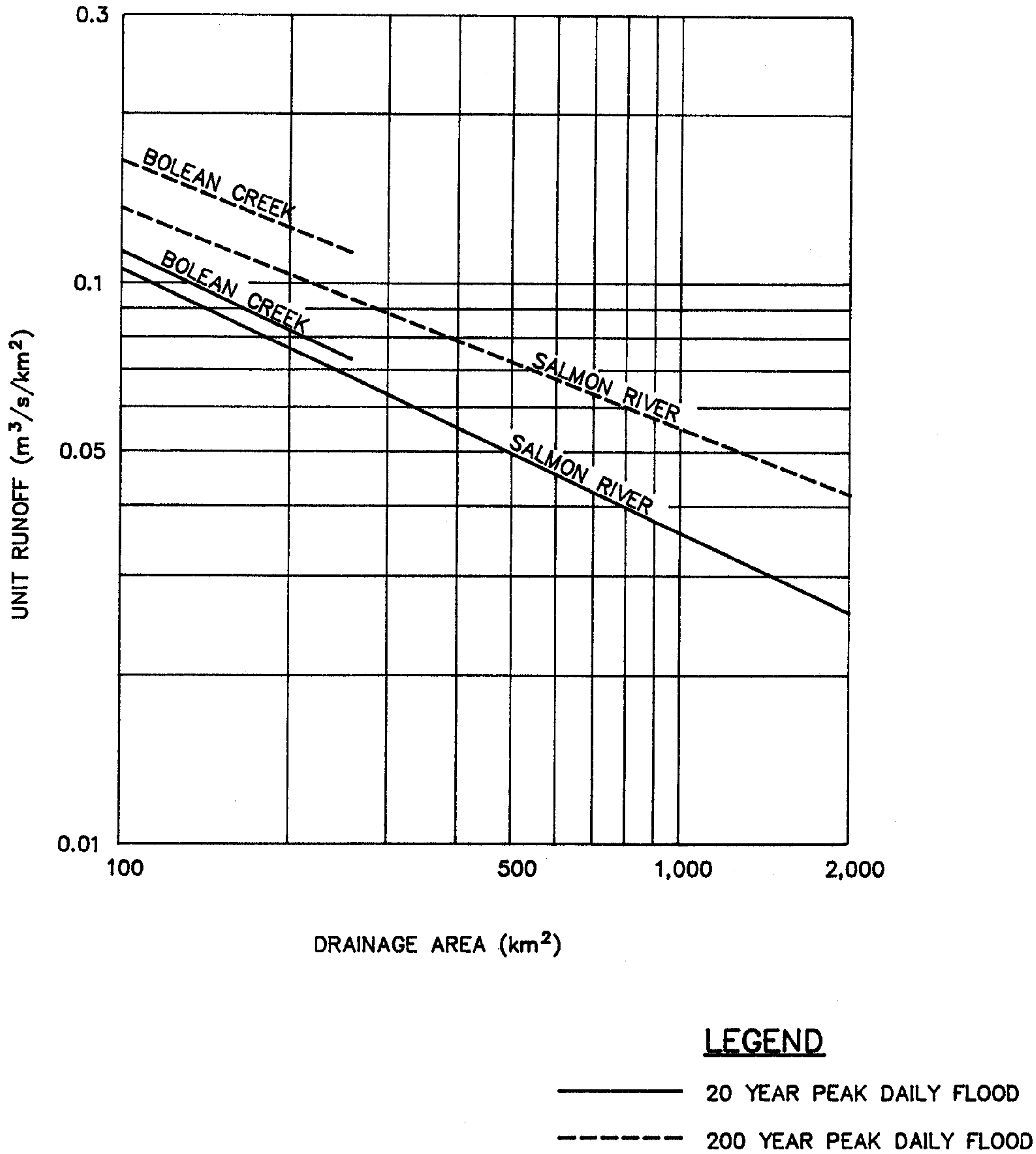
SALMON RIVER CATCHMENT AREA TO SPA CREEK

FIGURE 1

KPA ENGINEERING LTD.

DATE DECEMBER 1991

FILE NO. 2829



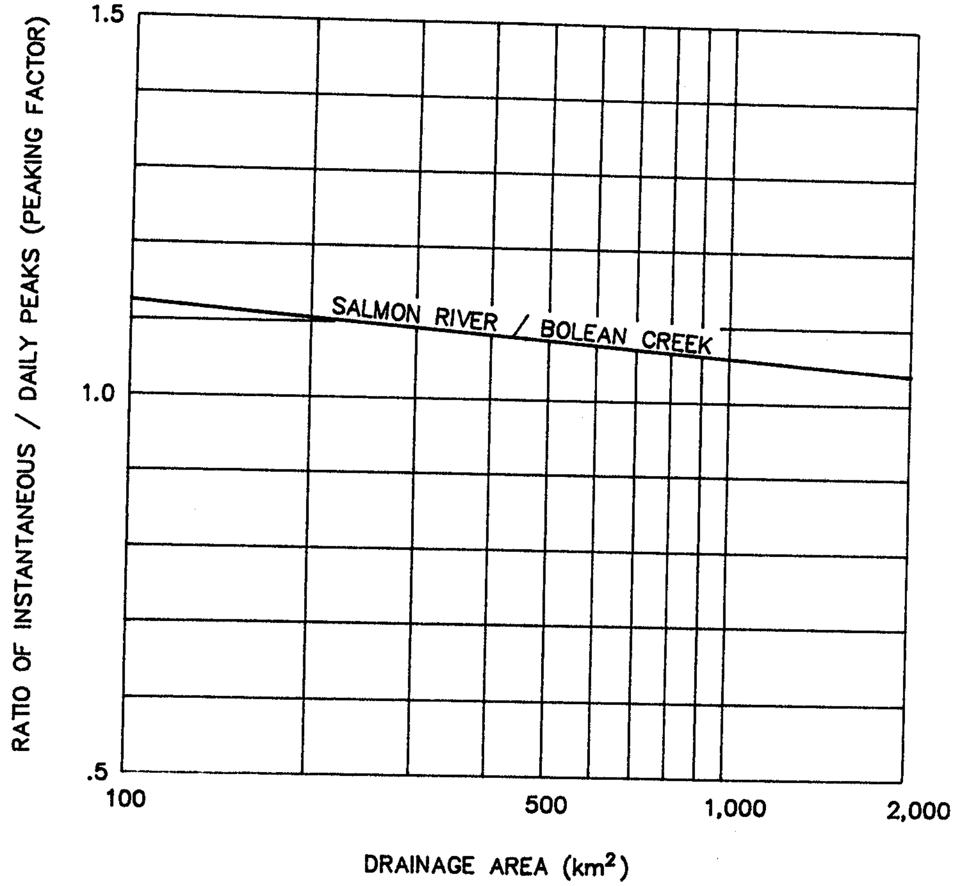
RELATION OF PEAK UNIT RUNOFF TO DRAINAGE AREA

FIGURE 2

KPA ENGINEERING LTD.

DATE DECEMBER 1991

FILE NO. 2829



RELATION OF PEAKING FACTOR TO DRAINAGE AREA

FIGURE 3

DATE DECEMBER 1991

FILE NO. 2829

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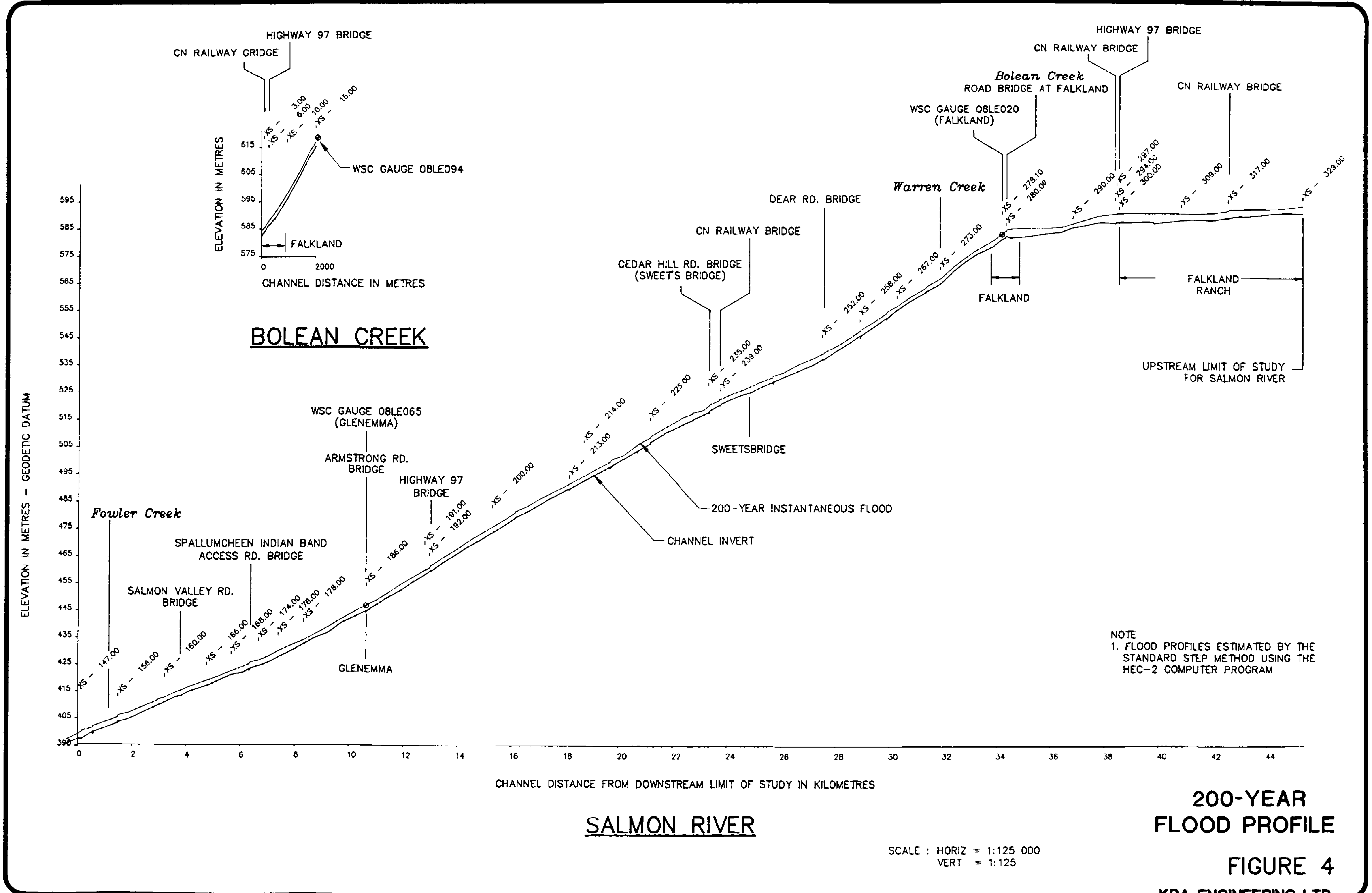

200-YEAR FLOOD PROFILE

FIGURE 4

FILE 829 NOV 1991

APPENDICES

APPENDIX 1

HISTORICAL FLOOD PHOTOGRAPHS

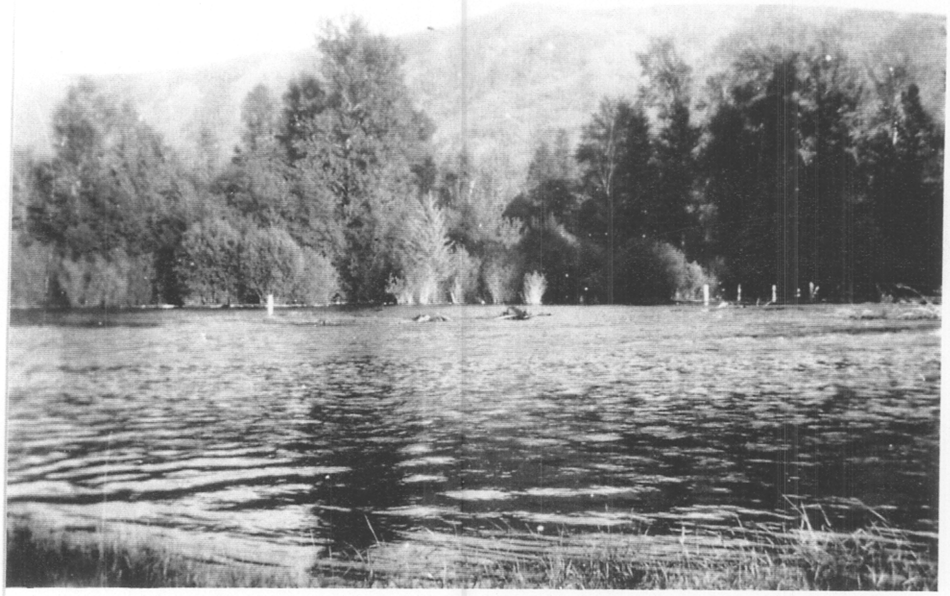

Photo 1 Sweetsbridge Farm during the May 1948 flood somewhere between XS-240 and XS-245. (Photo courtesy of Greater Vernon Museum & Archives).

Photo 2 Attempts to save a driveway bridge during the June 1990 flood. Looking toward the left abutment along the upstream side of the bridge at cross section XS-260.

Photo 3 Bolean Creek floodwaters surrounding a house in the Falkland Trailer Park, June 1990.

Photo 4 A mobile home in the Falkland Trailer Park, June 1990.

Photo 5 A flood channel of Bolean Creek in the fields to the West of the Falkland Trailer Park, June 1990.

Photo 6 Deposition of gravel, cobbles and boulders which occurred during the June 1990 flood near the Railway Bridge over Bolean Creek.

Photo 7 A hole in the pavement at the left abutment of the Highway 97 bridge over Bolean Creek caused by undermining by flood flows, June 1990.

Photo 8 Looking upstream toward gravel deposited during the June 1990 flood at the Salmon-Bolean confluence. Note the placid surface of the Salmon River whose profile is controlled here by the continually aggrading mouth of Bolean Creek.

APPENDIX 2

HIGH-WATER MARK DATA

Appendix 2

High-Water Mark Data

Location		High-Water Mark Elevation (in m-Geodetic)	
Cross Section	Description	On or Near 25 May, 1983	On or Near 15 June, 1990
Salmon River			
163	Salmon Valley Road Bridge	414.62	415.38
171	Spallumcheen Band Road Bridge	424.77	--
185	Armstrong Road Bridge	446.07	446.70
194	Highway 97 Bridge	460.95	461.06
236	Cedar Hill Road Bridge	519.44	--
260	Driveway Bridge (Mrs. Fretz)	553.43*	--
278	WSC Gauge 08LE020	582.57	583.00
281	Bridge at Falkland	583.88	--
293	Highway 97 Bridge	589.67	590.01
Bolean Creek			
7	Highway 97 Bridge	--	587.95

* This elevation appears to be erroneous, therefore was not used for calibration purposes.

APPENDIX 3

FLOOD LEVELS INCLUDING FREEBOARD

Flood Levels Including Freeboard

Cross Section Number	Flood Level (m)	Cross Section Number	Flood Level (m)	Cross Section Number	Flood Level (m)
Salmon River		Salmon River		Salmon River	
XS - 146.0	397.91	XS - 180.0	439.67	XS - 218.0	500.38
XS - 147.0	399.86	XS - 181.0	442.69	XS - 219.0	501.04
XS - 147.4	400.55	XS - 182.0	445.54	XS - 220.0	502.50
XS - 147.6	400.98	XS - 183.0	447.26	XS - 221.0	506.17
XS - 148.0	402.16	XS - 184.0	447.48	XS - 222.0	506.24
XS - 149.0	402.05	XS - 185.0	447.51	XS - 223.0	506.34
XS - 150.0	402.52	XS - 186.0	447.69	XS - 224.0	506.64
XS - 151.0	402.74	XS - 187.0	449.57	XS - 225.0	508.95
XS - 152.0	405.26	XS - 188.0	452.00	XS - 226.0	509.28
XS - 153.0	406.08	XS - 189.0	455.34	XS - 227.0	509.74
XS - 154.0	406.16	XS - 190.0	458.13	XS - 228.0	513.19
XS - 155.0	406.26	XS - 191.0	460.52	XS - 229.0	516.65
XS - 156.0	406.93	XS - 192.0	461.56	XS - 230.0	517.83
XS - 157.0	407.99	XS - 193.0	462.03	XS - 231.1	518.13
XS - 158.0	410.00	XS - 194.0	462.34	XS - 231.2	518.19
XS - 159.0	411.76	XS - 195.0	462.44	XS - 232.0	518.25
XS - 159.2	412.41	XS - 196.0	465.28	XS - 233.0	519.06
XS - 159.3	412.36	XS - 197.0	468.04	XS - 234.0	520.54
XS - 159.4	412.93	XS - 198.0	470.98	XS - 235.0	520.83
XS - 160.0	413.63	XS - 199.0	473.46	XS - 236.0	520.91
XS - 161.0	415.69	XS - 200.0	476.36	XS - 237.0	521.22
XS - 163.0	416.08	XS - 201.0	479.13	XS - 238.0	522.76
XS - 164.0	416.10	XS - 202.0	481.48	XS - 238.5	523.15
XS - 165.0	417.58	XS - 203.0	481.60	XS - 239.0	523.19
XS - 166.0	419.87	XS - 204.0	481.63	XS - 240.0	523.36
XS - 167.0	421.30	XS - 205.0	482.14	XS - 241.0	524.80
XS - 168.0	423.35	XS - 206.0	483.84	XS - 242.0	526.41
XS - 169.0	424.99	XS - 207.0	486.79	XS - 243.0	527.66
XS - 170.0	426.02	XS - 208.0	488.32	XS - 244.0	529.34
XS - 171.0	426.06	XS - 209.0	490.11	XS - 245.0	531.02
XS - 172.0	426.17	XS - 210.0	491.79	XS - 246.0	531.00
XS - 173.0	426.69	XS - 211.0	492.14	XS - 247.0	531.74
XS - 174.0	427.38	XS - 212.0	492.25	XS - 248.0	531.78
XS - 175.0	428.57	XS - 213.0	492.30	XS - 249.0	532.91
XS - 176.0	430.83	XS - 214.0	494.91	XS - 250.0	535.75
XS - 177.0	433.29	XS - 215.0	498.00	XS - 251.0	538.11
XS - 178.0	434.96	XS - 216.0	500.16	XS - 252.0	539.91
XS - 179.0	437.22	XS - 217.0	500.23	XS - 253.0	539.93

Flood Levels Including Freeboard (cont'd)

Salmon River

Cross Section Number	Flood Level (m)
XS - 254.0	539.98
XS - 255.0	540.35
XS - 256.0	542.93
XS - 257.0	545.17
XS - 258.0	548.02
XS - 259.0	548.19
XS - 260.0	548.22
XS - 261.0	548.57
XS - 262.0	551.36
XS - 263.0	554.44
XS - 264.0	554.50
XS - 265.0	554.53
XS - 266.0	555.15
XS - 267.0	557.20
XS - 268.0	560.83
XS - 269.0	563.80
XS - 270.0	563.99
XS - 271.0	564.11
XS - 272.0	564.52
XS - 273.0	567.37
XS - 274.0	572.09
XS - 275.0	575.17
XS - 276.0	577.99
XS - 277.0	581.08
XS - 278.0	583.81
XS - 278.1	583.84
XS - 279.0	584.52
XS - 280.0	584.77
XS - 281.0	584.93
XS - 282.0	585.44
XS - 283.0	585.59
XS - 284.0	585.61
XS - 285.0	585.59
XS - 286.0	585.78
XS - 287.0	585.88
XS - 288.0	585.91
XS - 289.0	586.27
XS - 290.0	587.53

Salmon River

Cross Section Number	Flood Level (m)
XS - 291.0	588.72
XS - 292.1	590.26
XS - 292.2	590.24
XS - 292.3	590.24
XS - 292.4	590.45
XS - 293.0	590.62
XS - 294.0	591.18
XS - 295.0	591.17
XS - 296.0	591.24
XS - 296.5	591.25
XS - 297.0	591.28
XS - 298.0	591.35
XS - 299.0	591.35
XS - 300.0	591.36
XS - 301.0	591.37
XS - 302.0	591.39
XS - 303.0	591.39
XS - 304.0	591.39
XS - 305.0	591.39
XS - 306.0	591.39
XS - 307.0	591.39
XS - 308.0	591.39
XS - 308.5	591.39
XS - 309.0	591.40
XS - 310.0	591.43
XS - 314.0	591.75
XS - 315.0	592.44
XS - 316.0	592.49
XS - 317.0	592.66
XS - 318.0	593.02
XS - 319.0	593.19
XS - 320.0	593.23
XS - 321.0	593.24
XS - 322.0	593.25
XS - 328.0	593.71
XS - 329.0	594.44
XS - 281.0	584.93

Bolean Creek

Cross Section Number	Flood Level (m)
XS - 1.0	585.43
XS - 2.0	585.72
XS - 3.0	585.79
XS - 4.0	585.95
XS - 5.0	587.88
XS - 6.0	588.41
XS - 7.0	588.74
XS - 8.0	588.95
XS - 9.0	591.15
XS - 10.0	598.28
XS - 11.0	608.02
XS - 12.0	614.47
XS - 13.0	614.85
XS - 14.0	615.05
XS - 15.0	617.33

APPENDIX 4

FLOODPLAIN MAPS