

**PROVINCE OF BRITISH COLUMBIA**

**MINISTRY OF ENVIRONMENT**

**WATER MANAGEMENT BRANCH**

**PEMBERTON VALLEY FLOOD PROTECTION**

**1985 STUDY**

by

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**July 1985**

**File: P72-3**



## SYNOPSIS

This study, which was authorized following the record October 1984 flooding, examines the various levels of flood protection for the predominantly rural Pemberton Valley.

Sub-area unit costs for the recommended flood protection proposals, excluding the airport area, range from \$1355/ha to \$4455/ha for 1:50 protection and from \$1760/ha to \$6030/ha for 1:200 year protection.

1:200 year flood protection for the Village of Pemberton and the surrounding urbanized region, where there are very considerable benefits to be derived from increased flood protection, is expected to cost \$1.7 m.

The estimated overall cost for 1:50 year instantaneous flood protection works is \$10 m and for 1:200 year protection is \$13.7 m.



## TABLE OF CONTENTS

	<u>Page No.</u>
Title Page.....	i
Synopsis.....	ii
Table of Contents.....	iii
Location Plan.....	iv
List of Figures.....	v
List of Tables.....	vi
List of Appendices.....	vi
1.0 INTRODUCTION . . . . .	1
2.0 SCOPE OF REPORT. . . . .	2
3.0 HYDROLOGY. . . . .	3
3.1 October 1984 Storm . . . . .	3
3.2 Seismic Activity . . . . .	5
3.3 Effects of Timber Harvesting . . . . .	6
3.4 Flood Frequency - Discharge Estimates. . . . .	9
4.0 LILLOOET LAKE. . . . .	19
5.0 DESIGN FLOOD PROFILES. . . . .	22
6.0 PROTECTIVE WORKS . . . . .	23
6.1 General Considerations . . . . .	23
6.2 Dykes. . . . .	23
6.3 Roads as Flood Protection. . . . .	24
6.4 Erosion Protection . . . . .	24
6.5 Floodproofing as an Alternative to Area Dyking . . . . .	27
7.0 PROTECTION PROPOSALS BY AREAS. . . . .	29
7.1 Outdoor School Farm Area . . . . .	29
7.2 Salmon Slough to Ryan River. . . . .	30
7.3 Ryan River to Miller Creek . . . . .	37
7.4 Miller Creek to Pemberton (One Mile) Creek . . . . .	38
(Incl. Village of Pemberton and B.C. Railway Embankment)	
7.5 Pemberton Creek to Green River - Excluding Airport . . . . .	44
7.6 Airport Area . . . . .	45
7.7 North Arm Plug to Mount Currie I.R. #1 . . . . .	45
7.8 Mount Currie I.R. #1 to Lillooet Lake (Indian Lands). . . . .	47
8.0 COSTING. . . . .	49
9.0 SUMMARY. . . . .	71









## LIST OF TABLES

<u>Table No.</u>	<u>Page No.</u>	<u>Title</u>
1	4	Pemberton Valley Rainfall Analysis
2	8	Timber Harvesting Summary
3	11	Flood Magnitude and Return Period Prediction Data
4	21	Lillooet Lake Level Reduction Effects - 1:200 Instantaneous Flow
5	74	Overall Cost Summary
6	75	Unit Area Protection Costs

## LIST OF APPENDICES

- A Memorandum, Reksten to Coulson, Lillooet River near Pemberton - October 8, 1984, Flood Flow and Design Flows, June 26, 1985.
- B Memorandum, Wyman to Reksten, Lillooet River near Pemberton - Floodplain Mapping and Dyking Assessment, February 22, 1985.
- B1 Memorandum, Wyman to Reksten, Lillooet Lake Flood Frequency, March 6, 1985.
- C Memorandum, Reksten and Barr to Coulson, Lillooet River Basin Logging Activities, January 3, 1985.



LIST OF FIGURES

<u>Figure No.</u>	<u>Drawing No.</u>	<u>Title</u>	<u>Vol. No.</u>	<u>Page No.</u>
1	85-13	Location Plan.....	1	iv
2	85-13-18	Lillooet River Basin, Logging History 1938-83.....	1	7
3	85-13-28	Frequency-Discharge Curves, Lillooet River near Pemberton.....	1	12
4	85-13-29	Frequency-Discharge Curves, Ryan River at Mouth.....	1	13
5	85-13-30	Frequency-Discharge Curves, Miller Creek at Mouth.....	1	14
6	85-13-24	Frequency-Discharge Curves, Pemberton (1 Mile) Creek at Mouth.....	1	15
7	85-13-25	Frequency-Discharge Curves, Green River at Mouth.....	1	16
8	85-13-26	Frequency-Discharge Curves, Birkenhead River at Gauging Station 8MG008.....	1	17
9	85-13-27	Stage-Frequency Curves, Lillooet Lake.....	1	18
10	85-13-0	Lillooet Lake Details.....	1	20
11	85-13-15	Typical Dyke, Cross Section Details.....	1	25
12	85-13-17	Typical Raised Highway Fill Details.....	1	26
13	85-13-19	Typical Riprap, Protection Details.....	1	28
14	85-13-14	McKenzie Cut Protection.....	1	32
15	85-13-16	Typical Raised High Dyke Detail.....	1	35
16	85-13-6	Pemberton Valley Flood Protection, 1985 Study, XS-43 to XS-56.....	2	
17	85-13-7	Pemberton Valley Flood Protection, 1985 Study, XS-30 to XS-42.....	2	
18	85-13-8	Pemberton Valley Flood Protection, 1985 Study, XS-16 to XS-29.....	2	
19	85-13-9	Pemberton Valley Flood Protection, 1985 Study, XS-8 to XS-15.....	2	
20	85-13-10	Pemberton Valley Flood Protection, 1985 Study, XS-1 to XS-7.....	2	
21	85-13-11	Lillooet River Bed and Flood Profiles from Lake to XS-56.....	2	
22	85-13-12	Ryan River Flood Profiles from Lillooet River to XS-21.....	2	
23	85-13-13	Flood Profiles for Birkenhead River, Pemberton Creek, Miller Creek & Green River....	2	



## 1.0 INTRODUCTION

Following the flooding of historic proportions which took place throughout the Pemberton (Lillooet River) Valley on October 8th and 9th, 1984, the area residents represented by the Squamish-Lillooet Regional District, the Village of Pemberton and the Pemberton Valley Dyking District requested this comprehensive study of flood alleviation measures.

Extensive reclamation<sup>1</sup> and erosion control work was undertaken throughout the valley by the Prairie Farm Rehabilitation Administration (P.F.R.A.) during the period from 1946 to 1953, followed by rehabilitation and further improvement work, mainly bank protection, carried out with A.R.D.S.A. funding over a five year period starting in 1979. The latter project included both extensive bank protection and limited dyking works on the Mt. Currie Indian Band lands. All of the Lillooet River Dyking Improvements were intended to protect to the 1:50 year instantaneous flood level although this was not defined precisely.

Coincident with the A.R.D.S.A. program was a series of flood events, starting with what was then a near record one on Dec. 26, 1980, followed by a higher one on Oct. 31, 1981, severe ice damage during January 1984 and culminating with the October 1984 flood. Federal-Provincial funding was provided through the Provincial Emergency Program to repair damages caused to the protective works by these events and to restore river channels blocked with gravel and debris. Most of the gravel removed under this program was utilized, in conjunction with the A.R.D.S.A. Program, to further improve the flood protection system, particularly in the Ryan River area.

The Pemberton Valley Dyking District is the local authority responsible for dyke construction and maintenance throughout most of the

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<sup>1</sup> Cut off channels shortened the channel length by 5.5 km (3.4 miles)

valley with the exception of the Indian Lands, which, although mostly within the Dyking District's boundaries, have not been subject to taxation. Responsibility for maintenance of the A.R.D.S.A. improvements on Indian Lands rests with the Federal Department of Indian and Northern Affairs.

Earlier reports pertaining to Pemberton Valley flooding include those prepared by Doughty-Davies<sup>1</sup>, Wester<sup>2</sup> and Tempest<sup>3</sup>, all of the Provincial Ministry of the Environment or its forerunners.

## 2.0 SCOPE OF REPORT

This report concerns protection for development within the Pemberton Valley extending from Lillooet Lake upstream past the Forest Service Bridge to and including Lot 813.

Embodied in the report are:

1. Water surface profiles for the updated, dyke confined 1:200 and 1:50 year instantaneous flood projections for all (6) significant watercourses within the study area.
2. Water surface profiles for the dyke confined (except in the case of Lillooet River), October 1984 flood, for the above watercourses.
3. Cost estimates, by areas, for dyking to protect against the 1:200 and 1:50 year floods; including appropriate alternatives.

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<sup>1</sup> J.H. Doughty-Davies, Preliminary Report on Lillooet River Flood Control, B.C. Water Resources Service, Water Investigations Branch, (March 1972).

<sup>2</sup> J. Wester, Preliminary Report on Pemberton Valley Dyking District Drainage Proposals, B.C. Water Resources Service, Water Investigations Branch, (Aug. 1967)

<sup>3</sup> W. Tempest, Pemberton Valley Flood and Erosion Control, B.C. Ministry of Environment (Nov. 1977)

4. Examination of building elevation as an alternative to dyke construction.
5. Assessment of the potential flood relief achievable by the lowering of Lillooet Lake.
6. Consideration of the B.C. Railway embankment constriction.
7. Protection for the "McKenzie Cut" area.
8. Review of the options for drainage improvement in the Pemberton Village area.
9. Assessment of the extent and impact of timber harvesting in the area.
10. The relevance of seismic activity in relation to the October 1984 Meager Creek flood.

### 3. HYDROLOGY

#### 3.1 October 1984 Storm

##### 3.1.1 Observations

The Atmospheric Environmental Service<sup>1</sup>, determined that heaviest precipitation from a broad frontal system which moved onto the B.C. Coast on October 7th, 1984, was concentrated in the Squamish area and in Central Vancouver Island.

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<sup>1</sup> John Thomas, Pacific Region Technical Notes, 84-014, Canada, Atmospheric Environmental Service.

The extreme runoff experienced in both the Squamish and Pemberton areas was attributed to the duration and north-south orientation of the frontal system, rather than to its intensity which, as may be seen from the following rainfall analysis summary, Table 1, was not exceptionally great in the Pemberton Village area.

TABLE 1  
PEMBERTON VILLAGE RAINFALL<sup>1</sup> ANALYSIS

Duration	Precipitation	Return Period
1-day	68.4 mm	5 years
3-day	119.8 mm	20 years

Flow information from nearby gauged watersheds confirms the severity of this storm. The Squamish River peak instantaneous flow exceeded the previous record by some 15 percent, while the Elaho R. had its second highest peak flow and the Cheakamus River gauge near Brackendale recorded its third highest peak flow. In the small, glacier fed watersheds, Bridge River below the Bridge Glacier experienced a peak flow in the order of 200 m<sup>3</sup>/s, more than double the previous record flow (5 year period), Place Creek near Birken registered a peak flow 70 percent greater than the previous 16 year record, and at Sentinel Creek, above Garibaldi Lake, the gauging station which had been in place for 19 years was washed away!

Within the Lillooet River Basin the only active hydrometric station is #08MG005, on the Lillooet River near Pemberton, a station for which 64

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<sup>1</sup> B.C. Forest Service Precipitation Gauge, Pemberton Village



years of records dating back to 1914 are available. Unfortunately, during the 1984 flood, dyke overtopping and subsequent failure in the Miller Creek area caused a considerable flow, estimated<sup>1</sup> to have averaged 184 m<sup>3</sup>/s, to bypass this gauging station. Thus, the only reasonably accurate October 1984 flow data for the watershed are estimates for one location, derived from observed river flows adjusted to reflect bypassing overbank flow. The resulting provisional<sup>2</sup> estimated flows at this station, together with the previous recorded maximums, are:

Instantaneous Peak Flow	1310 m <sup>3</sup> /s	Previous Record	993 m <sup>3</sup> /s	Dec. 1980
Daily Peak Flow	1110 m <sup>3</sup> /s	Previous Record	900 m <sup>3</sup> /s	Oct. 1940

### 3.1.2 Analysis

The estimated maximum instantaneous and maximum daily flows at the Lillooet River gauging station, together with data from analysis<sup>3</sup> of flow records from previous major floods which had occurred while hydrometric stations were also in operation on the Green and Soo Rivers and on Rutherford Creek, were used to derive the probable flows at other locations throughout the drainage basin - see Table 3. Computer modelling techniques were then employed to reconcile these derived flows with flood profiles plotted from observed highwater marks<sup>4</sup>; appropriate adjustments were made where necessary.

### 3.2 Seismic Activity

The possibility that seismic activity might have triggered the sudden Meager Creek flood surge, which caused extensive damage on Oct. 9th,

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<sup>1</sup> R.W. Nichols, B.C. Ministry of Environment, Water Management Branch

<sup>2</sup> Beyond the range of the rating curve

<sup>3</sup> Appendix A

<sup>4</sup> Reference Water Management Branch Drawings No. 85-13-1 to 5 incl. not included in general distribution copies of report.

may be discounted since it has been established that the only recent preceding earth tremor of any significance, measuring 3.0 on the Richter Scale, occurred on September 22nd, and was centred in the Homathco Snowfield some 120 km to the northwest. A tremor of this magnitude would not be expected to cause ground or ice movement, even at its epicenter.

Examination of the Meager Creek watershed during the snow-free season would be necessary to determine the extent to which factors other than precipitation may have contributed to local problems in that area. The findings of such an investigation would, however, be inconsequential insofar as the study area is concerned since the steep Meager watershed constitutes only 13.5% of the Lillooet River drainage basin, as measured above the Ryan River confluence, and any sudden flow surges resulting from the collapse of channel blockages would have dissipated before reaching the study area.

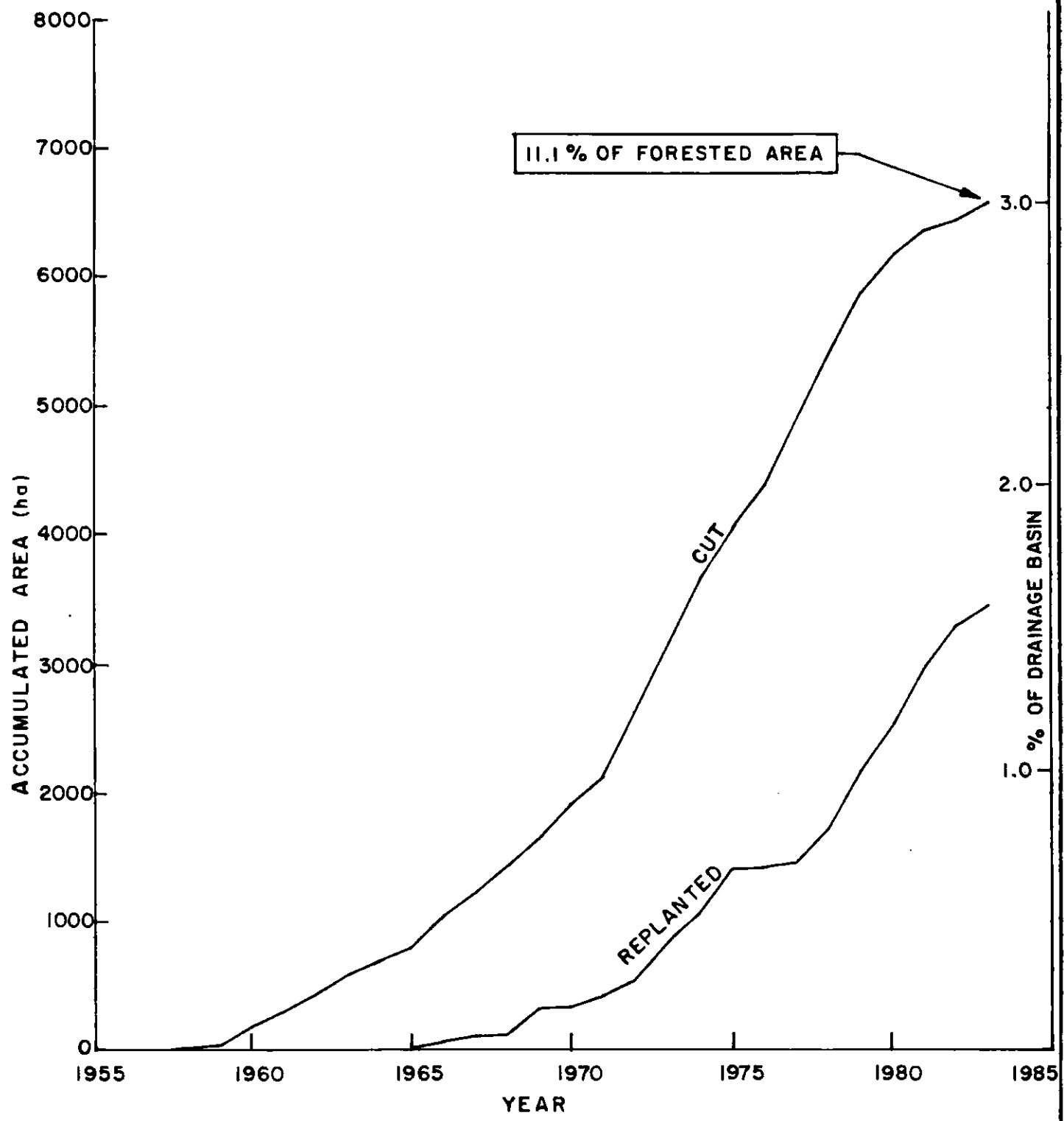
### 3.3 Effects of Timber Harvesting

An assessment of the extent of timber harvesting activity and its effect on peak flows was undertaken by the Surface Water Section<sup>1</sup>. A synopsis of this assessment, details of which are to be found in Appendix C, is as follows.

During the period since 1958, when logging in the Pemberton Valley was first recorded, the average cutting rate has been 262 hectares (ha) per annum, for a total cut of 6800 ha or 3.1 percent of the total watershed area - see Table 2; of this area approximately fifty percent has been replanted since 1965 - see Figure 2.

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<sup>1</sup> D.E. Reksten, Technical Memorandum, Ministry of Environment, Planning and Resource Management Division, Water Management Branch, (Jan. 1985)



Province of British Columbia  
 Ministry of Environment  
 WATER MANAGEMENT BRANCH

TO ACCOMPANY REPORT ON  
 PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 LILLOOET RIVER BASIN  
 LOGGING HISTORY 1938-83

D. E. REKSTEN / H. H. N - PORTER ENGINEER

SCALE: AS SHOWN

DATE  
 JUNE 1985

FILE No. P 72-3 DWG. No. 85-13-18

BCIL 7873-M.E.

FIGURE 2

In this watershed economically merchantable timber stands generally do not extend above the 1200 m elevation, consequently, to provide a more representative assessment of the stage to which harvesting has progressed the Timber Harvesting Summary provided in Table 2 includes "cut areas" as percentages of the "forested" watershed areas below the 1200 m elevation, for both the whole basin and for selected sub-basins.

TABLE 2  
TIMBER HARVESTING SUMMARY

Basin	Basin Area (km <sup>2</sup> )	Area Cut 1958-1983 (km <sup>2</sup> )	Cut Area as % of Basin	Forested Area (km <sup>2</sup> )	Cut Area as % of Forested Area
Lillooet River incl. tribs.	2160	68	3.1	610	11.1
<u>Sub-basins</u>					
Ryan River	419	17	4.1	82	20.8
Meager Creek	225	6	2.1	77	7.7
Pebble Creek	132	0.5	0.4	11	4.3
North Creek	82	2	2.4	14	14.0

From this tabulation, it is apparent that the extent of logging along the major watercourses has been comparatively small, ranging from 0.4 to 4.1 percent of watershed areas, and, consequently, will have had very little effect on the magnitudes of the recent flood events.

### 3.4 Flood Frequency - Discharge Estimates

#### 3.4.1 Peak Daily Flows

An analysis of the records from the seven hydrometric stations which have operated within the Lillooet River drainage basin was carried out by the Modelling Section<sup>1</sup>. In cases where the period of record was short, the resulting frequency estimates were adjusted to correspond with those for the longer established Lillooet River Station 08MG005.

For other Lillooet River locations and for the smaller ungauged watersheds the return period estimates were derived, by the Surface Water Section<sup>2</sup>, from those for appropriate gauged locations using the 'regional envelope curve' published by the Water Survey of Canada<sup>3</sup>.

For the larger Ryan River watershed, the return period flows were determined from a plot of the return period estimates derived for the Green and Soo Rivers and for Rutherford Creek.

#### 3.4.2 Instantaneous Peak Flows

Return period estimates for instantaneous peaks for the Lillooet and Green River hydrometric stations (near Pemberton), and for the Lillooet Lake (stage) were determined, as for the daily peak flows,

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<sup>1</sup> R. Wyman, Technical Memorandum, Ministry of Environment, Modelling Section, Feb. 22, 1985. - See Appendix B

<sup>2</sup> D.E. Reksten, Technical Memorandum, Ministry of Environment, Surface Water Section, June 26, 1985. - See Appendix A.

<sup>3</sup> Canada, Inland Waters Directorate - Pacific and Yukon Region, Magnitude of Floods - British Columbia - Yukon Territory, (Vancouver:1982), Vol. 3

from analysis of records for these stations. Elsewhere along the Lillooet River the return period instantaneous flows were calculated from the return period daily flows, using modifications of the ratio of instantaneous to daily peak flows (I/D) as determined for the Lillooet River gauging station (08MG005).

For the other watersheds appropriate I/D factors<sup>1</sup> were used to obtain the return period instantaneous peak flows, the confidence limits for which are considerably wider than for the mainstem Lillooet River locations.

Figures 3 to 8 show the flood frequency-discharge relationships which were developed for representative locations in each watershed. Figure 9 shows the stage-frequency curves for Lillooet Lake.

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<sup>1</sup> See Appendix A, Table 2

TABLE 3  
FLOOD MAGNITUDE AND RETURN PERIOD PREDICTION DATA

EVENT	LILLOOET RIVER						RYAN R. At Mouth	MILLER CR. At Mouth	PEMBERTON CR. At Mouth	GREEN R. At Mouth	BIRKENHEAD R.	
	Above Wolverine Creek	Above Ryan River	Nr. Pemberton Gauge #8MG005	Above Green River	Lillooet L. #8MG020	At Gauge # 8MG008					At Mouth	
DRAINAGE AREA (km <sup>2</sup> )	1560	1660	2160	2218	3200	419	78	51	868	597	638	
October 1984 Flood												
- Daily flow	835	863	1110 <sup>1</sup>	1139	1513	330 <sup>2</sup>	124	25	350	149	160	
- Instantaneous flow	1002	1049	1310 <sup>1</sup>	1344	1755	430 <sup>2</sup>	174	(37)	(392)	(194)	(208)	
20 Year Return Period												
- Daily flow	593	622	746	765	990	256	100	46	382	267	278	
- Instantaneous flow	670	703	843	864	1130	333	140	69	416	347	361	
50 Year Return Period												
- Daily flow	655	690	840	860	1107	323	124	56	478	338	354	
- Instantaneous flow	753	792	966	990	1290	420	174	84	525	439	460	
200 year Return Period												
- Daily flow	796	830	992	1020	1312	432	170	79	660	536	565	
- Instantaneous flow	939	979	1170	1200	1570	562	240	118	740	697	734	

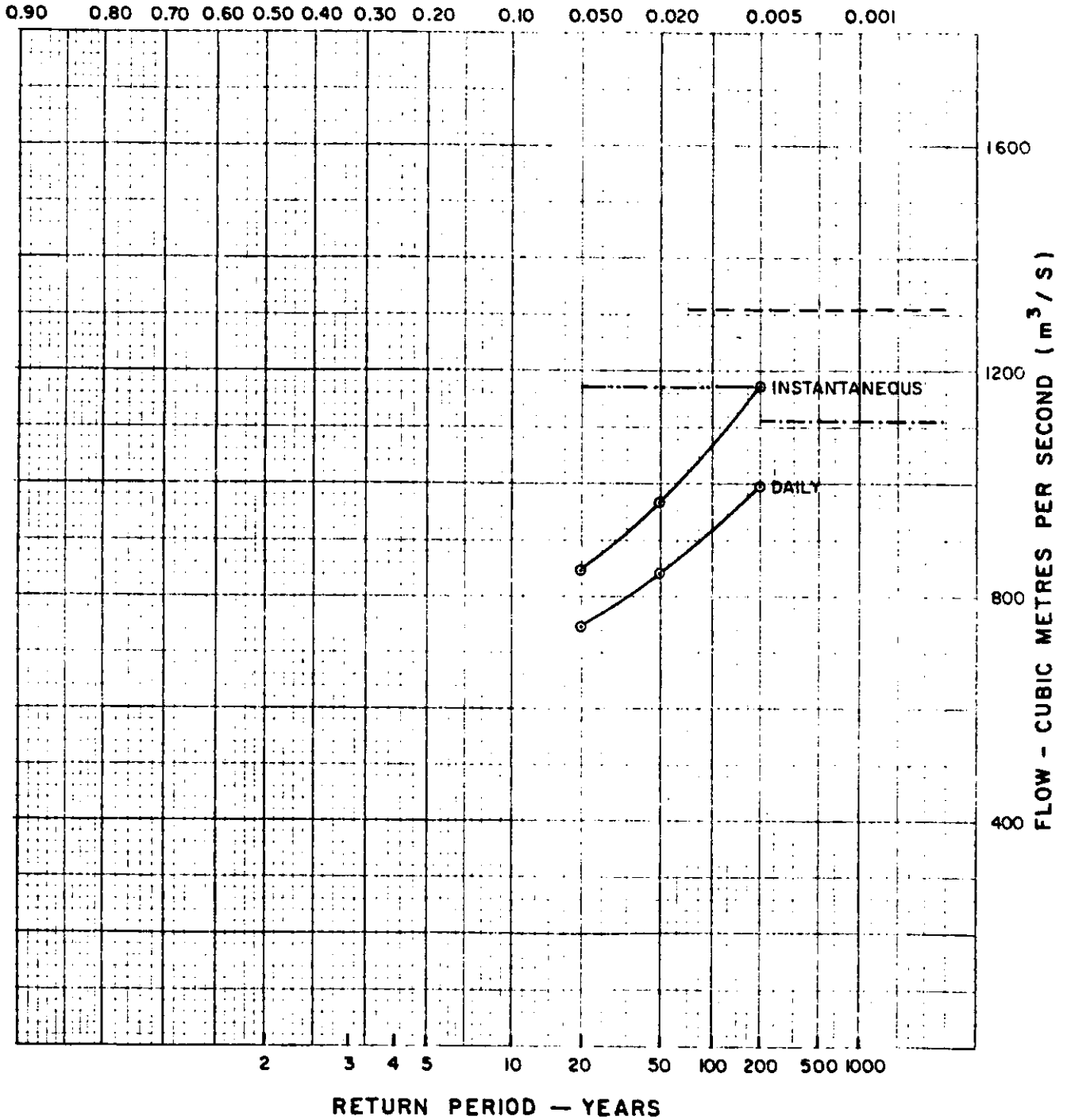
Footnotes:

- 1 Measured channel flow corrected for overbank loss
  - 2 Derived from flood profile analysis
- ( ) May be grossly in error due to lack of data





PROBABILITY OF OCCURRENCE



- · - · - · - PRELIMINARY OCT. 1984 INSTANTANEOUS PEAK FLOW AS RECORDED AT GAUGE
- - - - - PROBABLE OCT. 1984 INSTANTANEOUS PEAK FLOW
- · · · · · PROBABLE OCT. 1984 DAILY PEAK FLOW

HYDROMETRIC STATION No. 08MG005



Province of British Columbia  
 Ministry of Environment  
 WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 FREQUENCY - DISCHARGE CURVES  
 LILLOOET RIVER NR. PEMBERTON

SCALE: VERT. ....  
 HOR .....

DATE  
 JUNE 1985

*D. A. Nesbitt-Porter* ENGINEER

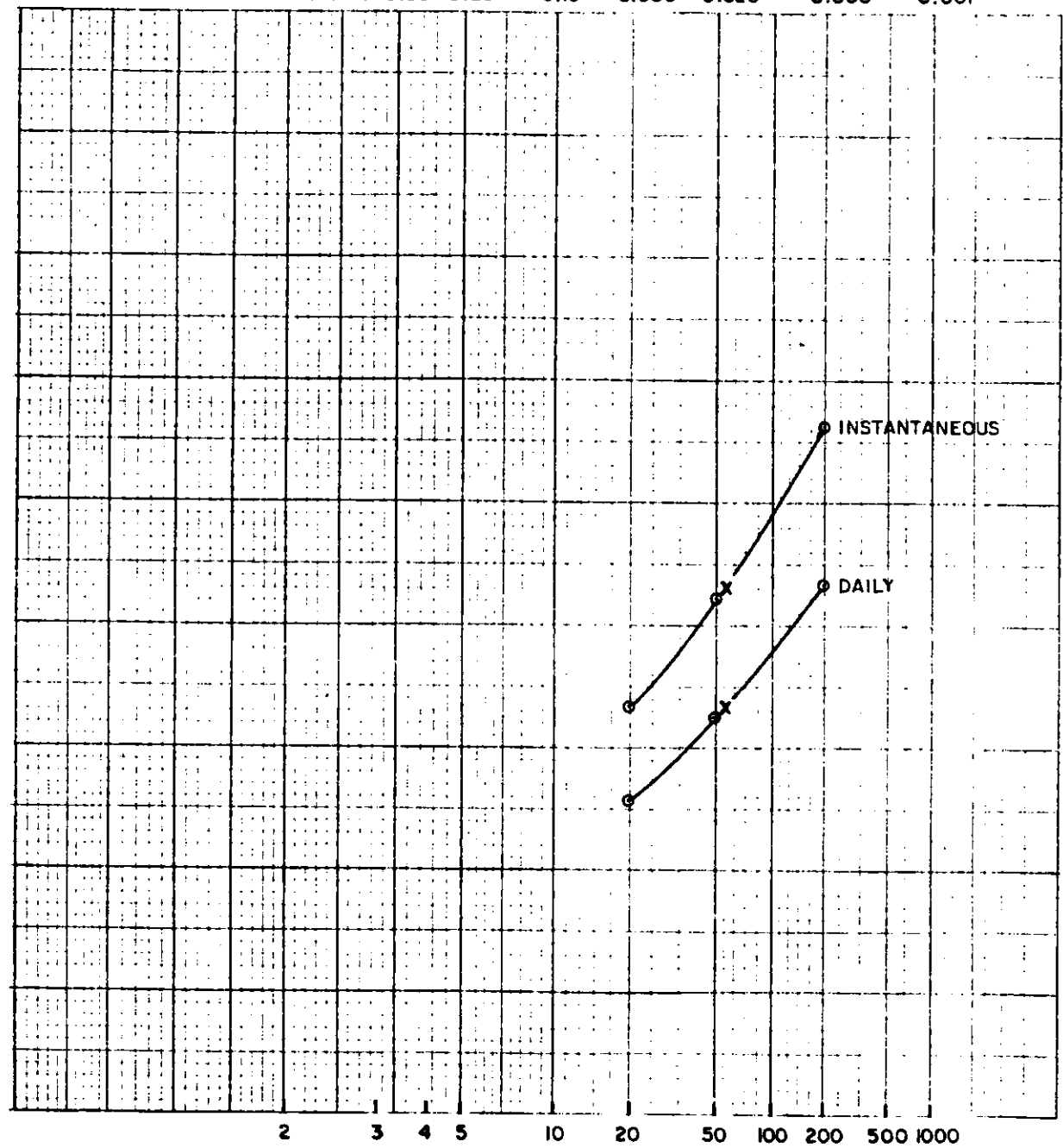
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BCNL 7873-ME

FIGURE 3

PROBABILITY OF OCCURRENCE

0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.050 0.020 0.005 0.001



X PROBABLE OCT. 1984 FLOW



Province of British Columbia  
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PEMBERTON VALLEY FLOOD PROTECTION  
1985 STUDY  
FREQUENCY - DISCHARGE CURVES  
RYAN RIVER AT MOUTH

SCALE: VERT.....  
HOR.....

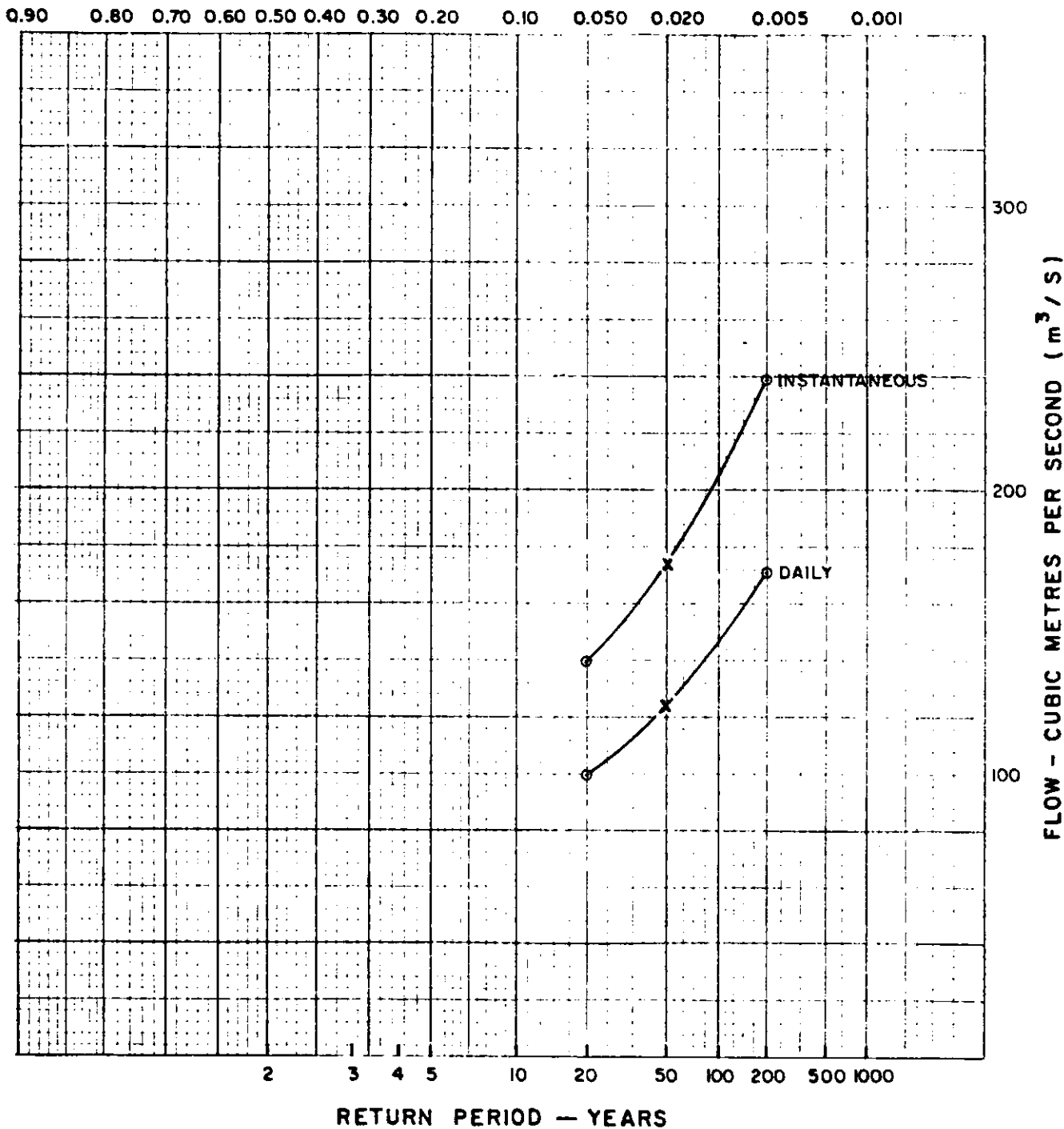
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JUNE 1985

*A. H. Nesbitt - Porter* ENGINEER  
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BCL 7873-ME

FIGURE 4

PROBABILITY OF OCCURRENCE



X PROBABLE OCT. 1984 FLOW



Province of British Columbia  
 Ministry of Environment  
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PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 FREQUENCY - DISCHARGE CURVES  
 MILLER CREEK AT MOUTH

SCALE: VERT. \_\_\_\_\_  
 HOR \_\_\_\_\_

DATE  
 JUNE 1985

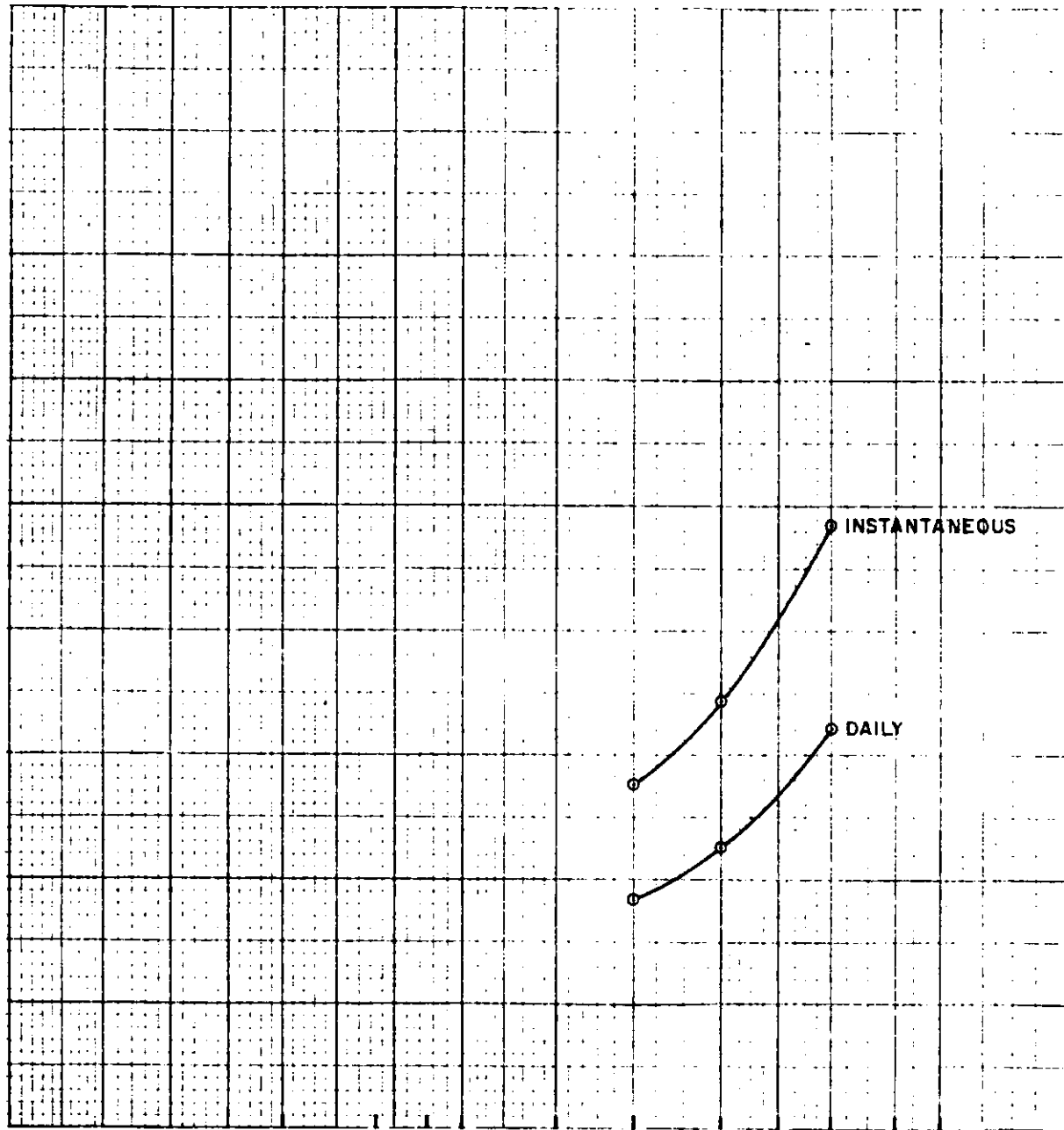
*W. G. Nesbitt-Parker* ENGINEER  
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BCIL 7673-ME

FIGURE 5

PROBABILITY OF OCCURRENCE

0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.050 0.020 0.005 0.001



RETURN PERIOD - YEARS

FLOW - CUBIC METRES PER SECOND (m<sup>3</sup>/s)



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PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 FREQUENCY - DISCHARGE CURVES  
 PEMBERTON (1 MILE) CR. AT MOUTH

SCALE: VERT.....  
 HOR .....

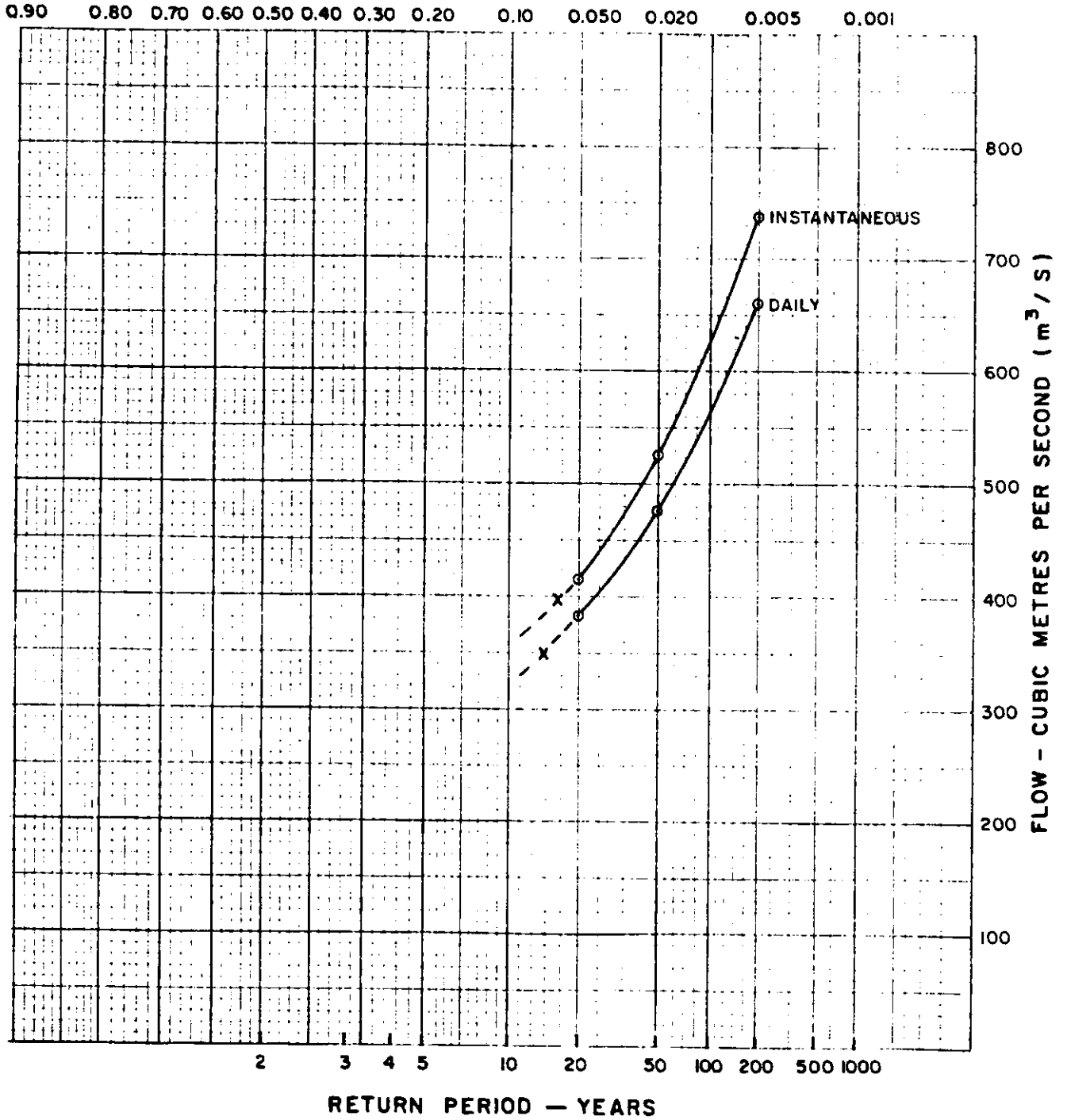
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*A. A. Nesbitt-Porter* ENGINEER  
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BCIL 7673-M-E

FIGURE 6

PROBABILITY OF OCCURRENCE



X PROBABLE OCT. 1984 FLOW



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PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 FREQUENCY - DISCHARGE CURVES  
 GREEN RIVER AT MOUTH

*W.A. Nesbitt-Porter* ENGINEER

SCALE: VERT.....  
 HOR.....

DATE  
 JUNE 1985

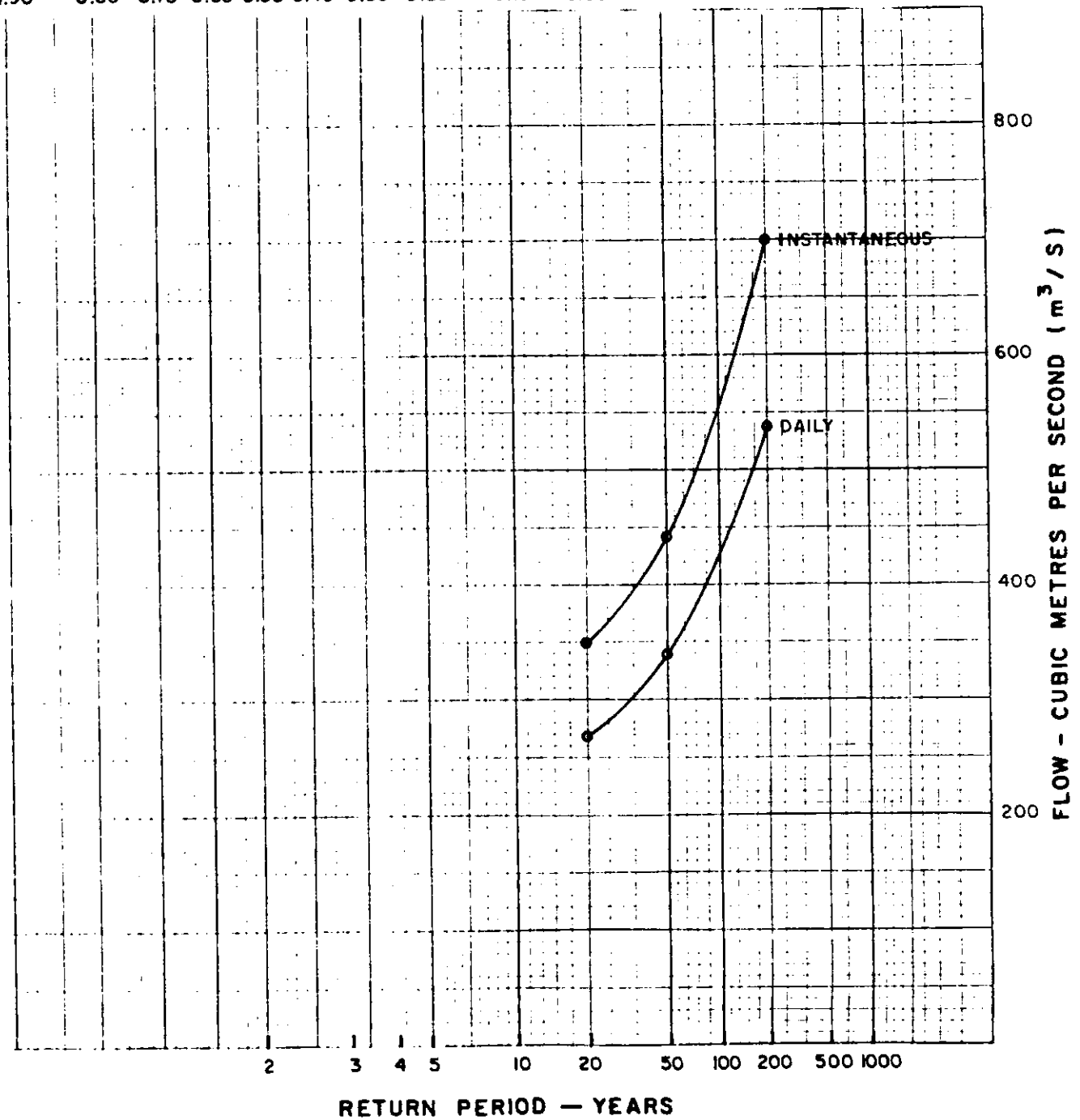
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FIGURE 7

PROBABILITY OF OCCURRENCE

0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.050 0.020 0.005 0.001



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PEMBERTON VALLEY FLOOD PROTECTION  
 1985 STUDY  
 FREQUENCY - DISCHARGE CURVES  
 BIRKENHEAD RIVER AT GAUGING STN. 8MGO08

SCALE: VERT.....  
 HOR.....

DATE  
 JUNE 1985

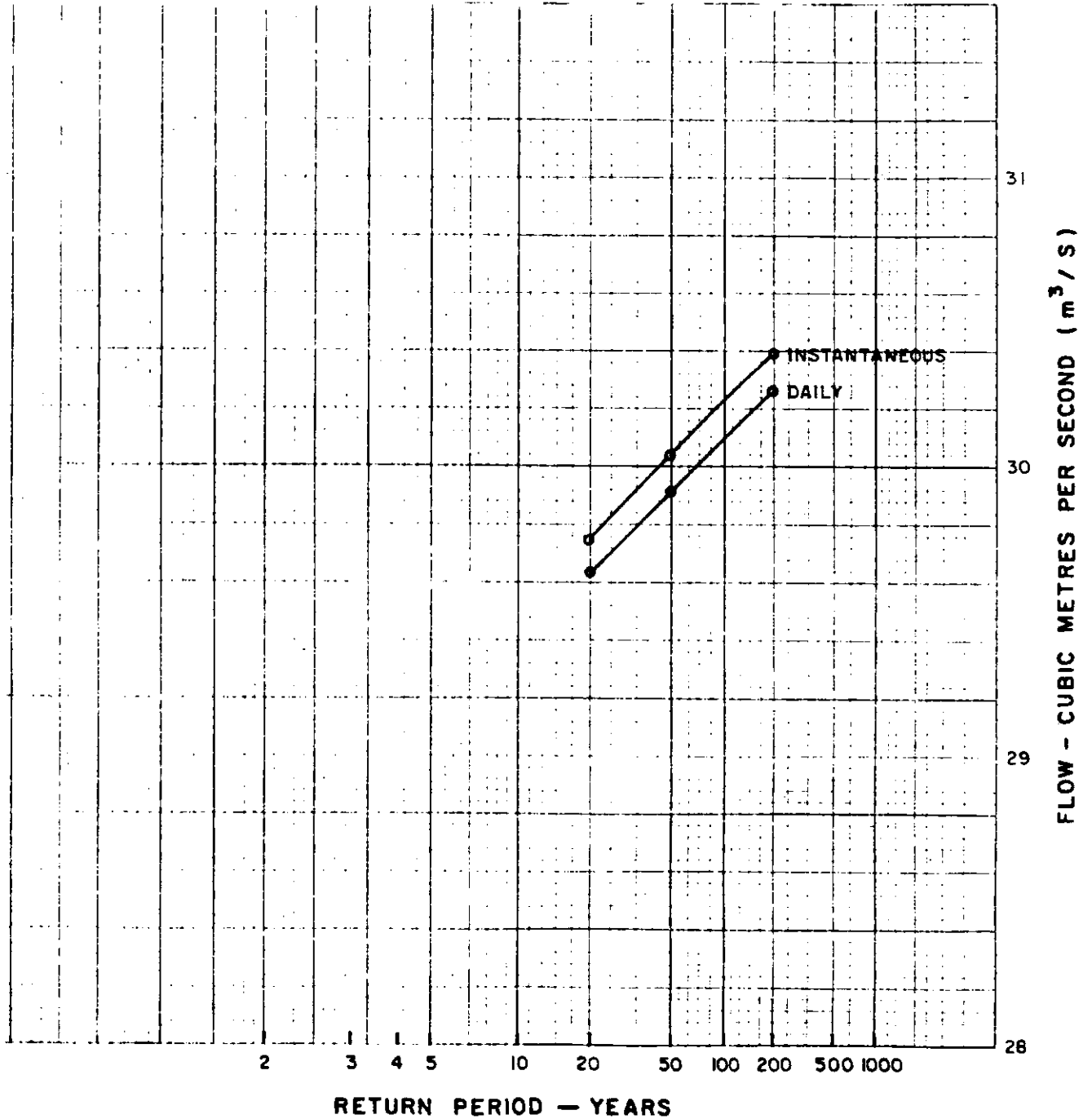
*A. M. Nesbitt-Parker* ENGINEER  
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BCIL 7873-ME

FIGURE 8

PROBABILITY OF OCCURRENCE

0.90 0.80 0.70 0.60 0.50 0.40 0.30 0.20 0.10 0.050 0.020 0.005 0.001



HYDROMETRIC STATION No. 08MG020



Province of British Columbia  
Ministry of Environment  
WATER MANAGEMENT BRANCH

PEMBERTON VALLEY FLOOD PROTECTION  
1985 STUDY  
STAGE - FREQUENCY CURVES  
LILLOOET LAKE

SCALE: VERT.....

HOR.....

DATE

JUNE 1985

*W. H. Marshall-Rutter*

ENGINEER

FILE No. P 72 - 3

DWG No. 85-13-27

BCIL 7873-ME

FIGURE 9

#### 4.0 LILLOOET LAKE

The water level in Lillooet Lake is controlled by narrows, some 24 km (15 miles) downstream from the head of the lake - see Figure. 10. During the period of P.F.R.A. activity in the valley, from 1946-53, extensive dredging of the narrows was carried out, resulting in a general lowering of the Lillooet Lake water levels and consequent changes along the downstream reach of the Lillooet River.

Following the 1984 flood, during which the lake reached a record level of 199.36 m (654.1 ft.), there was renewed local interest in the possibility that further excavation of the narrows would result in significant flood relief, at a reasonable cost.

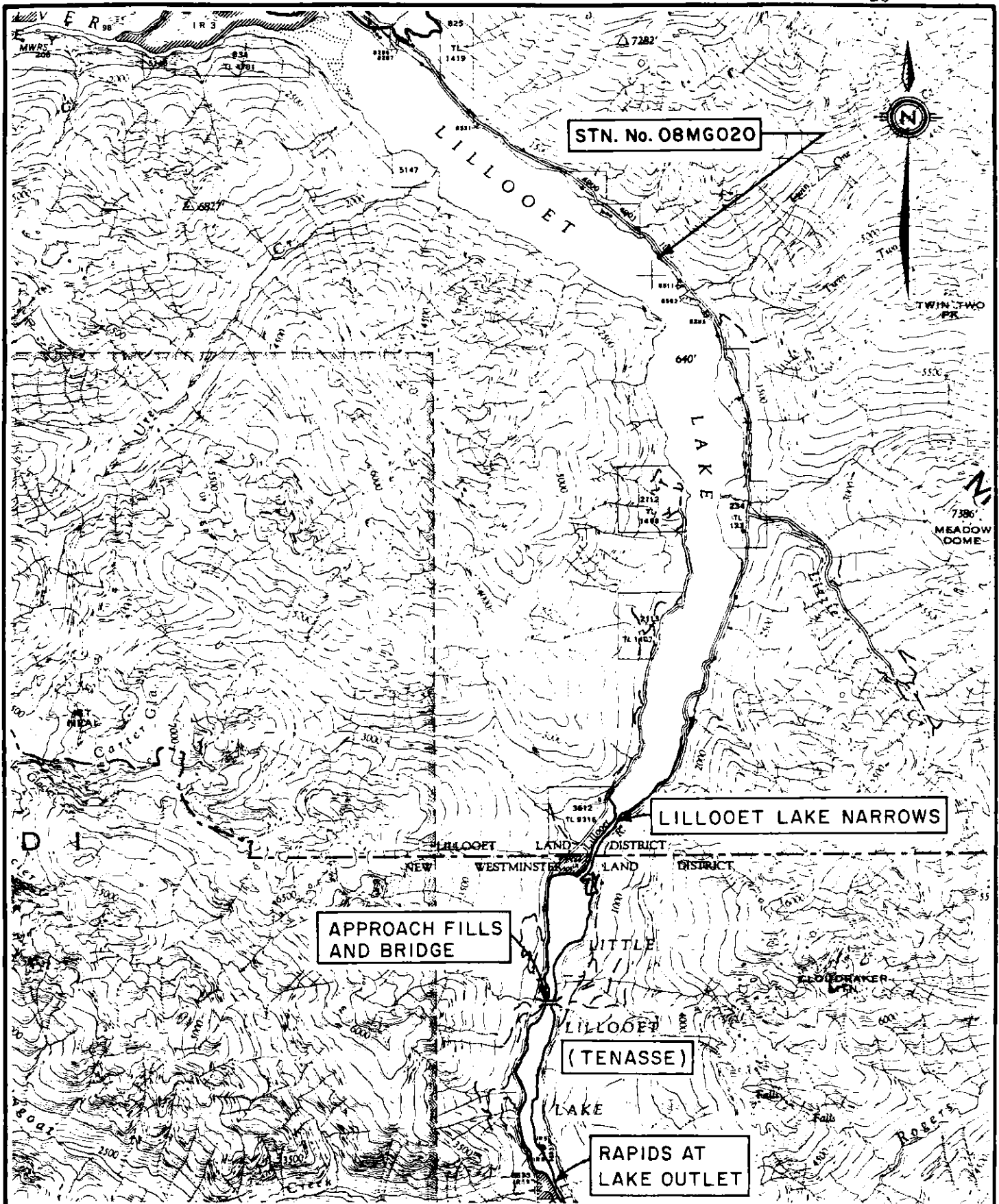
To test the validity of this contention, 1:200 year instantaneous flow design flood profiles were calculated from Lillooet Lake upstream, assuming (a) that the lake level had been lowered by 1.3 m (4.0 feet) without any allowance for consequent bed scouring and (b) that the lake level had been lowered by 3.0 m (10.0 feet) and that 3.0 m of scour had resulted at cross section 0 (XS-0), reducing to zero scour at cross section 10 (XS-10). The flood profile elevation reductions which would result from these changes are shown in Table 4, from which it may be seen that the expected flood relief becomes insignificant (less than 0.3 m or 1.0 feet) by XS-4 and XS-11 (Green River confluence) respectively.

Extrapolation of updated cost estimates from the 1972 Doughty-Davies Report<sup>1</sup> indicates that a probable minimum expenditure in excess of \$4 million, as determined in Section 8.2 would be required just to widen and deepen the narrows, undetermined further expenditures would be required for modifications to the Forestry Bridge crossing of the Little Lillooet (Tenasse) Lake Narrows, for excavation of those Narrows and for improvements to the outlet of Little Lillooet (Tenasse) Lake.

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<sup>1</sup> J.H. Doughty-Davies, Preliminary Report on Lillooet River Flood Control, B.C. Water Resources Service, Water Investigations Branch, (March 1972, Design #1, p. 9





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TO ACCOMPANY REPORT ON  
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 1985 STUDY  
**LILLOOET LAKE DETAILS**

SCALE: 1:125 000  
 MAP NO. 92 J/SE

DATE  
 JULY 1985

*H. A. Nichol* ENGINEER  
 FILE No. P72-3 DWG No. 85-13-0

BCIL 7873-M.E.

FIGURE 10

In addition to the direct cost of such a project, which is prohibitively high in comparison to the meager benefits to be derived, a reduction in the level of Lillooet Lake would cause increased velocities in both the Lillooet and Birkenhead Rivers, resulting in further bank erosion, bed scour and consequent undercutting of the toe of existing riprap protection.

TABLE 4

## LILLOOET LAKE LEVEL REDUCTION EFFECTS - 1:200 INSTANTANEOUS FLOW

XS# <sup>1</sup>	1.3 m Drop No Scour	3.0 m Drop		Distance from Lake (km)
	W.L. Reduction (m)	Assumed Scour (m)	W.L. Reduction (m)	
0	1.2	3.0	3.0	0
1	1.0	2.7	3.1	1.5
2	0.6	2.4	3.0	2.4
3	0.4	2.1	2.7	3.1
4	0.2	1.8	2.4	3.8
5	0.1	1.5	2.1	4.7
6		1.2	1.8	5.5
7		0.9	1.4	6.3
8		0.6	1.1	7.1
9		0.3	0.9	7.9
10			0.5	8.7
11			0.3	9.4
12			0.1	10.1

The hydraulic efficiency of the Little Lillooet (Tenasse) Narrows road crossing, a four-span bridge with extensive approach embankments, was

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<sup>1</sup> Cross Section Number (XS#)

examined on October 10th, 1984 when the lake was almost at its recorded maximum peak instantaneous stage of 199.36 m<sup>1</sup>. At that time the head loss across the structure was observed to be 0.55 m (1.8 feet). The stage-frequency curve for Lillooet Lake - see Figure 9, being very flat throughout the 20-200 year return period range, indicates that this relatively small head loss probably remains fairly constant for all peak flows.

## 5.0 DESIGN FLOOD PROFILES

The peak instantaneous flood frequency-discharge predictions shown in Table 3 were utilized in conjunction with the HEC-11 computer program to simulate, dyke confined, flood flow conditions along all of the significant watercourses within the study area. The resulting flood profiles for the anticipated 1:50 year and 1:200 year floods are shown on the river profile Figures 16-20 inclusive, in addition to which confined Oct. 1984 flow<sup>2</sup> profiles are shown for all watercourses except the Lilloet River, for which the unconfined (1984 conditions) observed profile is shown, and for Miller Creek where it is assumed to be coincident with the 1:50 year profile.

The accuracy of these flood profiles is affected by the lack of up-to-date cross section survey data, none of which is more recent than 1978, this deficiency has, however, been partially overcome by manipulation of the Mannings "n" roughness coefficient during computer modelling<sup>2</sup>.

The simultaneous occurrence of equal return period floods is assumed at each river or lake confluence for the purpose of determining the

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<sup>1</sup> 14 years of record only, 1971 to 1984.

<sup>2</sup> Ref. Section 3.1.2.

downstream starting conditions for each flood profile. While this coincidence of events is quite improbable, the conservative errors so induced are insignificant since, in the case of low-gradient tributaries the height of any necessary dyking would otherwise be determined by design flood conditions in the mainstem channel, and where steeper gradient tributaries are concerned the induced error diminishes rapidly as one moves upstream. In the case of Lillooet Lake, the stage (surface elevation) is not frequency sensitive, as may be seen from Figure 9, and hence the consequences of minor errors in the basic assumption are unimportant.

It should be noted that in the derivation of the mainstem Lillooet River design flows<sup>1</sup> the simultaneous occurrence of equal-magnitude flow events is not assumed.

## **6.0 PROTECTIVE WORKS**

### **6.1 General Considerations**

For each significant floodplain area protective measures have been considered for both the 1:50 year ( $Q_{50}$ ) and the 1:200 year ( $Q_{200}$ ) instantaneous flows. In each case, to provide sufficient freeboard, the design dyke crest profile was set a minimum of 0.6 m (2.0 feet) above the theoretical flood profile. In areas where a paved roadway is relied upon for protection, the minimum freeboard allowance is reduced to 0.3 m (1.0 feet) because of the scour resistance of the pavement.

### **6.2 Dykes**

It has been assumed that all new dyking would be of granular fill construction, however, impervious clays or other locally available

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<sup>1</sup> Ref. Section 3.4

material would be incorporated where practical or necessary.

Typically, dykes would be built as detailed in Figure 11, having a 4.0 m (13 feet) minimum crest width and 2:1 side slopes, protected where necessary with broken rock riprap.

Where the integrity of an existing dyke is in anyway suspect its reconstruction or relocation has been assumed.

A minimum setback of 30 m (100 feet) from the top of the riverbank is generally maintained and an average clearing width of 25 m (80 feet) is assumed, to provide room for a separate truck return road.

### **6.3 Roads as Flood Protection**

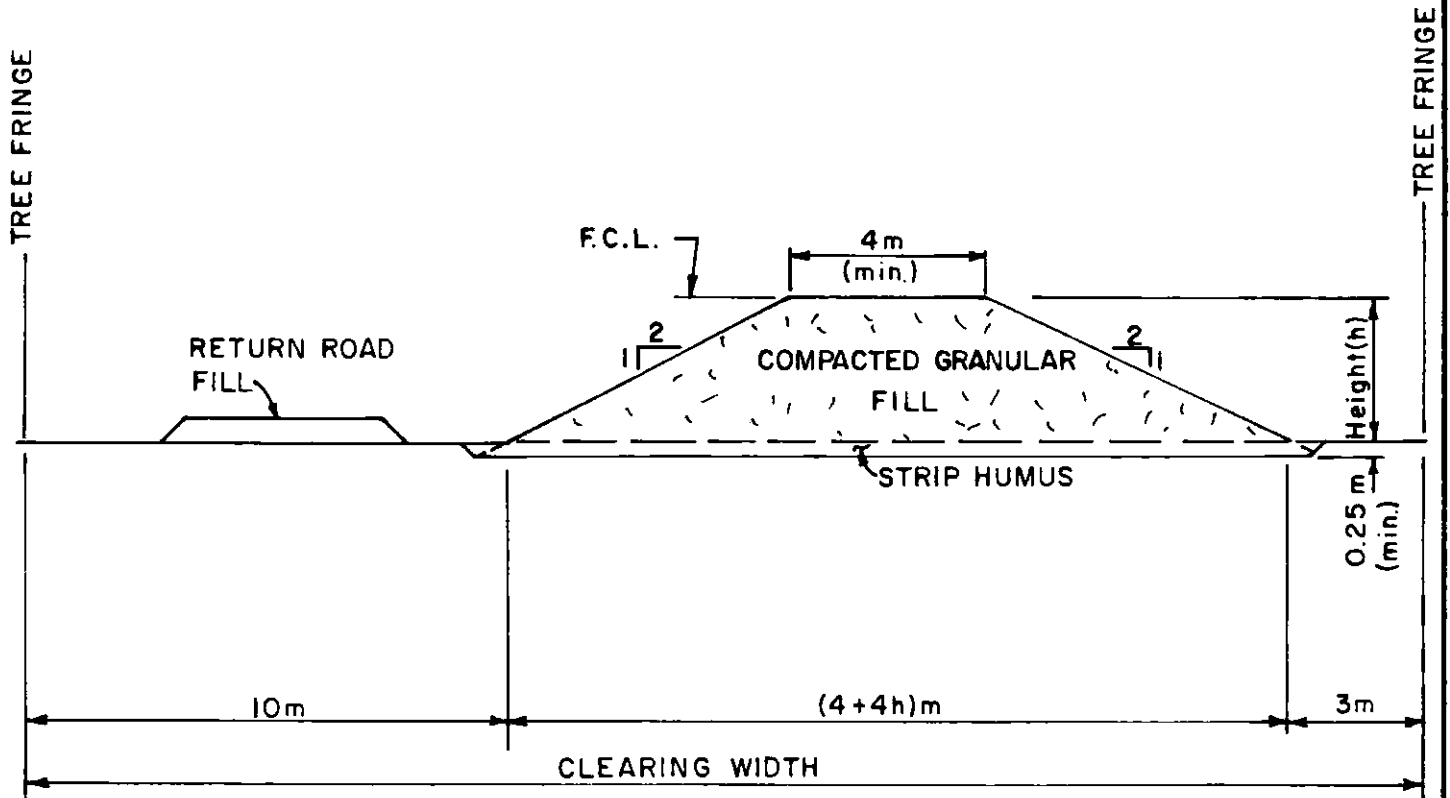
Where it is proposed to raise public roadways, to provide the required protection, cross section geometry as shown on Figure 12 has been assumed for costing purposes.

### **6.4 Erosion Protection**

#### **6.4.1 Natural Banks**

Under the 1979-1984 A.R.D.S.A. Program, bank protection was provided for most of the serious erosion areas, with the exception of the Ryan River and the McKenzie cut between XS-26 and XS-31, along the Lillooet River. Some hitherto stable areas now require protection.

Where such erosion threatens existing or proposed dykes, through loss of the adjacent overbank area, broken rock riprap protection is proposed. Typical bank protection details are shown on Figure 13.



**NOTE:**

FLOOD CONSTRUCTION LEVEL ( F.C.L. )  
 = DESIGN FLOOD ELEVATION + 0.6 m



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 TYPICAL DYKE  
 CROSS SECTION DETAILS

SCALE: NOT TO SCALE

DATE

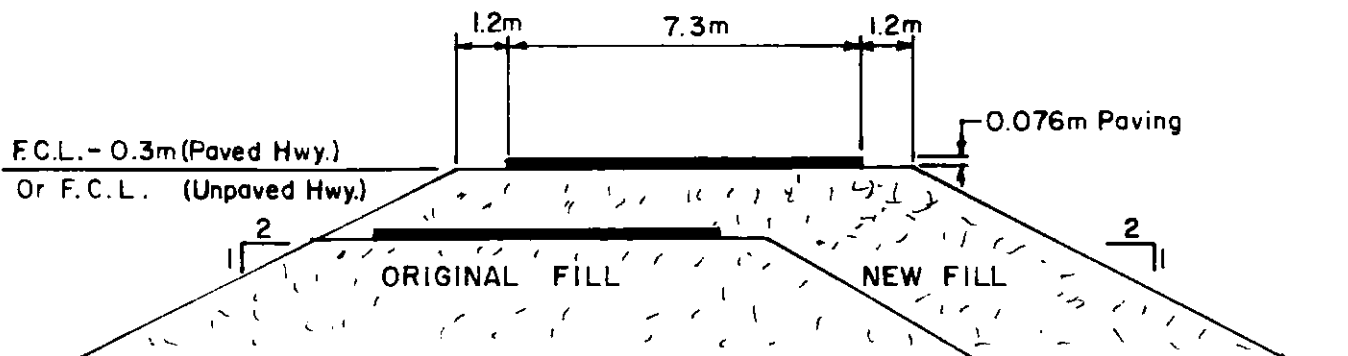
JUNE 1985

*W. A. Nesbitt Partner* ENGINEER

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DWG No. 85-13-15

FIGURE 11



SURFACING QUANTITIES

BLACK TOP ≈ 1400 tonnes/km

PRIMER ≈ 1100 litre/km

NOTE:

FLOOD CONSTRUCTION LEVEL ( F.C.L.)  
= DESIGN FLOOD ELEVATION + 0.6 m



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FILL DETAIL

SCALE:

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DATE

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*H. H. Nesbitt Kauter*

ENGINEER

FILE No P 72-3

DWG No. 85-13-17

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FIGURE 12

#### 6.4.2 Exposed dykes

Where dykes are considered to be vulnerable to erosion riprap protection is required, as shown on Figure 13.

#### 6.5 Floodproofing as an Alternative to Area Dyking

Some of the means by which isolated existing buildings can be protected from flood damage include:

- i construction of a surrounding ring-dyke,
- ii raising them above the Flood Construction Level (F.C.L.) on gravel pads,
- iii elevation of the building by the addition of concrete or masonry foundation walls

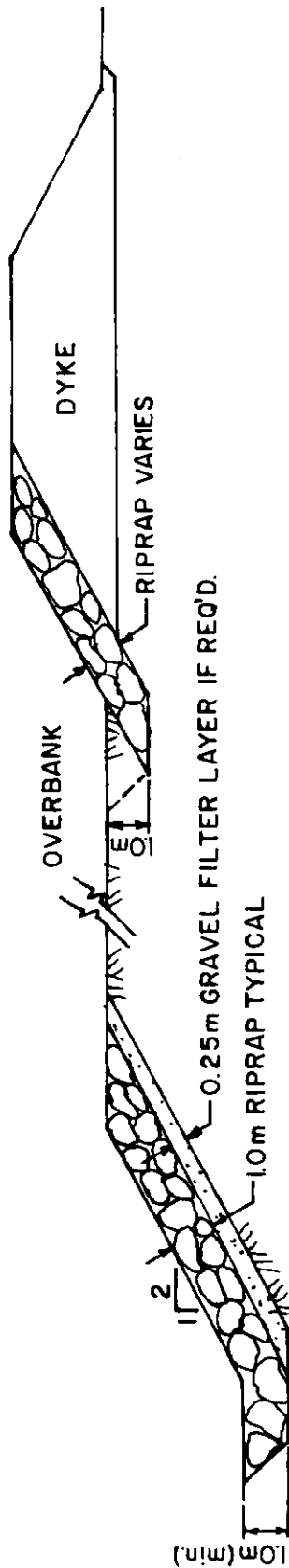
Mobile homes are readily suited to the raised gravel berm solution, which can be undertaken economically, whereas, for permanent homes having brick or stonework chimneys, patios, carports or other appurtenances, the cost can readily approach the total value, particularly in the case of older houses.

Some of the disadvantages of floodproofing, as compared to comprehensive dyking, are that ring-dykes are aesthetically unattractive and may necessitate the provision of pumping systems to control the internal water levels; contamination of water wells frequently results as a consequence of flooded septic disposal fields or broken sewer pipes and both access and egress along flooded roads may be hazardous or even impossible.

Based on experiences elsewhere, it is estimated that to raise an average 1200 ft<sup>2</sup> house would cost \$45,000, while a mobile home would cost an estimated \$15,000.

Because of the multiplicity of designs, sizes, ages and construction materials involved, estimates are not provided for barns or other farm buildings.





SCALE:	NOT TO SCALE	DATE:	JUNE 1985
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		DWG No.	85-13-19

TO ACCOMPANY REPORT ON  
**PEMBERTON VALLEY FLOOD PROTECTION**  
 1985 STUDY  
**TYPICAL RIPRAP**  
 PROTECTION DETAILS

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FIGURE 13

## **7.0 PROTECTION PROPOSALS - BY AREAS**

The natural drainage system divides the study area into six logically independent zones. For examination of the flood protection requirements, these areas have been treated individually. A further subdivision of the two downstream areas segregates the Indian Band lands and the airport area, to facilitate possible separate funding consideration from appropriate sources.

### **7.1 Outdoor School Farm Area**

#### **Background**

This low area extending from XS-52 to XS-56, on the left bank of the Lillooet River, is partially dyked where a privately undertaken cutoff channel was constructed subsequent to the downstream P.F.R.A. Project. The area, which includes an ox-bow lake used for recreational and instructional purposes by the Outdoor Farm School, is also vulnerable to flooding from upstream overbank flow.

Surface runoff from the adjacent mountainside causes drainage problems.

#### **Proposed Works**

To provide 1:50 year flood protection for this area, dyking as shown on Figure 16 and averaging 2.0 m (6.5 feet) in height is required, together with drainage outlet culverts and additional bank protection. Improvements to the internal drainage interceptor ditching are also anticipated.

For 1:200 year protection similar works but with a dyke averaging 2.5 m (8.2 feet) in height are proposed.

The estimated costs of the protective works, details of which are provided in Section 8, Area 1, are:

1:50 year - \$411,000  
1:200 year - \$529,000

## 7.2 Salmon Slough to Ryan River Confluence

### 7.2.1 Lillooet River Dyking

#### Background

During the October 1984 flood the upstream portion of this largely undyked area, which extends from XS-54 to XS-26, suffered considerable depositional damage as a result of silt and sand laden overbank flow emanating in the vicinity of XS-28, above the Forest Service Bridge.

This bridge, locally considered to have been the cause of the problem, is located at the upstream end of a long, naturally constricted, reach of the river. Pending completion of a current survey project it will not be possible to determine the extent to which this bridge is responsible for the considerable increase in the flood profile gradient which is evident in this vicinity.

Similar breakout and silt deposition problems were encountered downstream of XS-28, along the McKenzie Cut, where the continuing lateral development of this artificially created reach resulted in breaching of an old, privately constructed silt berm which had, until 1984, afforded a measure of protection for the downstream reach, locally known as Dr. Dill's farm.

Successive surveys and flood level observations show that this 4.36 km long reach of the river, which started in 1947 as a small pilot channel, has been degraded<sup>1</sup> and widened to the extent that it no longer constitutes the significant flow constriction noted in the Tempest report<sup>2</sup>. This being so, it is probable that its banks, which are mainly comprised of peat and consolidated muskeg with an overlying layer of silt, may now be considered to be relatively stable.

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<sup>1</sup> See Figure 21

<sup>2</sup> W. Tempest, Pemberton Valley Dyking District, Flood & Erosion Control, B.C. Ministry of Environment, 1977

Along the right bank of the Lillooet River, down to the Ryan River confluence, intermittent portions of low dyking, road fills and high ground provide varying degrees of protection for the area.

### **Proposed Works**

For both the 1:50 and 1:200 year situations the most comprehensive protection would be provided by dyking across low areas, along an alignment close to the riverbank, as shown on Figures 16-18 inclusive. The proposed dyke would start at high ground upstream of XS-53, cross the upper reaches of Salmon Slough, where a floodbox is required for flow control and probably for fish passage, tie into the Forest Service Bridge approach fill, continue downstream enclosing most of the developed lands and incorporating existing dyking and road fills where practical. The average heights of dyking, where required, are respectively 0.85 m (2.8 feet) and 1.1 m (3.6 feet) for the 1:50 and 1:200 year events.

At the downstream end, from XS-27 to XS-32, the old partially eroded berm along the McKenzie Cut would be replaced by a new dyke set back from the top of the bank by a minimum distance of 10.0 m (33 feet) if the riverbank is adequately protected with riprap, or 30.0 m (100 feet) if the bank remains unprotected.

As a less permanent alternative to dyking and riprapping of the right bank, which averages between five and six metres (18 feet) in height, it could be shaped, as shown on Figure 14, to a three-to-one slope and the spoil material used to raise a twenty metre (65 feet) wide strip of the adjacent ground by some 1.8 m (6 feet), to the 1:200 design dyke height, thus eliminating the necessity for dyking. Erosion of the sloped bank, which could be retarded by planting with suitable vegetation such as willows, should be very gradual, although from time-to-time riprapping of localized areas would be required. A strip

along the riverside of this raised berm would have to be sown to grass but could be used for hay production, or grazing if fenced to prevent animal disturbance of the sloped bank; the remainder could be cultivated.

Provision for riprapping of <sup>400</sup>~~4,000~~ m of the left bank between XS-48 and XS-49 is included as Area 2L in the Overall Cost Summary - Table 5.

The estimated costs for the two levels of protection, details of which are provided in Section 8, Area 2.1, are:

1:50 year - \$1,819,000  
1:200 year - \$2,332,000

Estimates could be reduced by the following amounts if the indicated alternative routes or options were adopted:

	1:50	1:200
Alternative route 2A - highway alignment	- \$285,000	\$ 383,000
Alternative route 2B - setback alignment <sup>1</sup>	- \$ 95,000	\$ 61,000
McKenzie Cut - berm option 2C	- \$838,000	\$1,103,000

## 7.2.2 Ryan River Dyking - Left Bank

### Background

Within the study area, starting at XS-R21 below the old logging bridge, this river which carries a considerable gravel bedload parallels the Lillooet River for about 14.2 km (8.8 miles). Immediately upstream from the bridge a very steep right bank tributary gulley introduces sufficient large sized rock to maintain a steep control section. The consequent high localized velocities and downstream bedload deposition resulted in extensive overtopping of the dyke and flow diversion during the October 1984 flood. Throughout the remainder of the dyked reach, terminating at the Erickson Road/highway intersection

<sup>1</sup> All excluded houses are believed to be above 1:200 year flood level.