# FLOOD HYDROGRAPH ESTIMATE FROM A UNIT HYDROGRAPH

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Flood hydrograph estimate from a unit hydrograph.

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Flood hydrograph estimate from a unit hydrograph.

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# SUMMARY

The Unit Hydrograph concept was used to simulate peak flows for two streamflow stations, Barlow Creek near Quesnel and Lillooet River near Pemberton. The unit hydrographs were derived from eleven rain-storm events for Barlow Creek and sixteen for Lillooet River. A duration time of twenty-four hours was considered acceptable as precipitation data for Quesnel Airport and Pemberton B.C.F.S. stations were recorded only on a daily basis. Two simulated peaks are presented for each station and when increased by the maximum suggested twenty percent are within three percent of the published values. It is recommended that the unit hydrograph be used, in locations where adequate precipitation data is available, to simulate the extreme peak flows at stations where the flood event has not been recorded.

## 1.0 Introduction

In the absence of stage record at times of peak flow, hydrograph estimates can be obtained through the use of the unit hydrograph and an adequate rainfall record for the basin.

A unit hydrograph can be derived from an average of several measured hydrographs reduced to a unit hydrograph basis where the runoff volume under the hydrograph is adjusted to one inch, or one centimetre. As the physical characteristics of basins remain relatively constant, the variations in the shape of hydrographs are caused by the variable characteristics of storms. Two basins are studied in this report: Barlow Creek (with a drainage of 69.9 square kilometres) and Lillooet River (with a drainage area of 2160 square kilometres). Rainfall records were obtained from two stations: Quesnel Airport and Pemberton B.C.F.S. The locations of these basins are shown in Figure 1.

### 1.1 Purpose of Report

The purpose of this report is to demonstrate that the unit hydrograph concept together with adequate precipitation record can be used to simulate a flood hydrograph for a single storm event.

## 2.0 Storm Characteristics

The storm characteristics are: rainfall duration, time-intensity pattern, areal distribution of rainfall, and amount of runoff. Their effects are discussed below.

## 2.1 Duration of Rain

A separate unit hydrograph is theoretically necessary for each possible duration of rain but the effect of small differences in duration is not significant and a suggested tolerance of $\pm$ 25 percent is ordinarily acceptable. A duration of twenty-four hours was used in this study as precipitation is not recorded for shorter periods. This duration was assumed acceptable for this study as both basins appear to have a slow response to precipitation.

## 2.2 Time-Intensity Pattern

To derive a separate unit graph for each possible rainfall-intensity pattern would require an infinite number of graphs. For practical purposes unit hydrographs can be based on the assumption of uniform intensity. For large basins or basins with slow response only changes in storm intensity lasting for hours will cause distinguishable effects on the hydrograph. The lag times (time between centroid of rainfall and hydrograph peak) for these basins are 12 and 18 hours for Barlow Creek and Lillooet River respectively.

## 2.3 Areal Distribution of Runoff

The areal pattern of runoff will cause variations in hydrograph shape. If a basin is small enough areal variation will not be great enough to cause major changes in hydrograph shape. Generally, unit hydrographs should not be applied to basins much over 5000 square kilometres. The drainage areas of the two basins used in the study are relatively small.

### 2.4 Amount of Runoff

It is assumed that in the unit graph concept, the ordinates of flow are proportional to the volume of runoff for all storms of a given duration. And it is also assumed that the time base of all hydrographs resulting from storms of a given duration is constant. Practically, the above assumptions are adequate for engineering purposes. Peak flows derived from the unit hydrograph concept are generally inceased from 10% to 20% to obtain the extreme flood peaks.

## 3.0 Determination of Excess Rainfall

There is a large variation in the rainfall-runoff relationship depending on the size of the storm being considered, as shown in Figures 2 and 3 for the Barlow Creek and Lillooet River basins. Such relations are typically curved, indicating an increasing percentage of runoff with increasing rainfall. Since only extreme peaks are being considered in this study, only those relationships yielding the highest ratios of rainfall to runoff were used to develop the correlation shown in Figures 2 and 3.

## 4.0 Derivation of Unit Hydrograph

The hydrograph of outflow from a basin is the sum of all elemental hydrographs from all subareas of the basin. Since the physical characteristics of the basin -- shape, size, slope, etc. -- are constant, the similarity in shape of hydrographs from storms of similar rainfall characteristics would be expected to be closely related. Many hydrographs from similar rainfall storms (similar to the extreme flood) were analyzed to obtain an average unit graph for each basin. The average unit hydrographs are listed in Tables 1 and 2, for Barlow Creek and Lillooet River respectively.

TABLE 1

UNIT HYDROGRAPH FOR BARLOW CREEK

| TIME IN HOURS | UNIT HYDROGRAPH IN $m^3/s$ |
|---|---|
| 0 | 0 |
| 24 | 10.0 |
| 48 | 5.38 |
| 72 | 2.97 |
| 96 | 1.70 |
| 120 | 0.76 |
| 144 | 0.42 |
| 168 | 0.28 |

TABLE 2

UNIT HYDROGRAPH FOR LILLOOET RIVER

| TIME IN HOURS | UNIT HYDROGRAPH IN $m^3/s$ |
|---|---|
| 0 | 0 |
| 24 | 109 |
| 48 | 258 |
| 72 | 130 |
| 96 | 71 |
| 120 | 45 |
| 144 | 33 |
| 168 | 24 |
| 192 | 20 |

## 5.0 Application of the Unit Hydrograph

Rainfall-runoff coefficients obtained from the developed relationships were applied to the recorded precipitation in order to obtain the excess rainfall. The hydrograph of direct runoff from each 24 hour period is obtained and the total hydrograph is the sum of all increments plus the estimated base flow. The hydrographs obtained from excess rainfall from the rainstorms of April 13, 1969 and October 7 to 13, 1984 are shown in Figures 4 and 5 with the unit graphs for Barlow Creek and Lillooet River respectively. All unit hydrograph simulated peak flows are increased by the maximum suggested 20 percent. This could mean that the measured precipitation data is underestimating the amount of rainfall actually contributing to runoff or that the duration of the high intensity periods is too long.

All storms for which hydrographs have been simulated were investigated and are considered to be caused by rainstorms with very little if any contribution from snowmelt.

### 5.1 Barlow Creek and Basin

The comparison of the hydrograph produced from the unit graph and the observed hydrograph is shown in Figure 6 for Barlow Creek for the flood of April 13, 1969. Figure 7 shows the observed hydrograph and simulated peak for the flood of May 23, 1964.

### 5.2 Lillooet River Basin

The first day of antecedent precipitation has been included in the first 24 hours of rainfall for the Lillooet Basin. This assumption was made as there is the distinct possibility that this rainfall should be part of the first high intensity band of precipitation but was recorded in a different time period due to the 24 hour divisions.

Using the excess recorded rainfall beyond 72 hours has no effect on the peak but introduces some discrepancies into the falling limb of the simulated hydrograph. This may be due to the non-uniform areal distribution of rainfall after the peak rainfall has passed.

The comparison of the hydrograph produced from the unit graph and the observed hydrograph is shown in Figure 8 for the Lillooet River for the flood of October 8, 1984. Figure 9 shows the relationship between a partly observed and estimated hydrograph with one simulated from the unit graph with the excess rainfall for December 17, 1980.

## 6.0 Conclusion and Recommendations

The extreme peaks estimated by the unit graph method are within 3 percent of the observed or estimated values for Barlow Creek and Lillooet River respectively. The initial high intensity rainfall has the most effect on the peak flow, with base flow accounting for about 8 to 10 percent of the peak flow.

In analyzing streamflow hydrographs it is important to select related storms of approximately the same duration.

Barlow Creek basin has not been affected by any storms that have produced even one inch of runoff. The fact that Barlow Creek basin has lake storage contributed to its slow response and reduced peak.

The results of the study appear to be fairly accurate even though the smallest duration period was of 24 hours.

It is recommended that the unit hydrograph be used to simulate extreme peak flow events, where needed, in other basins with adequate precipitation data.

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Figures 1 to 9

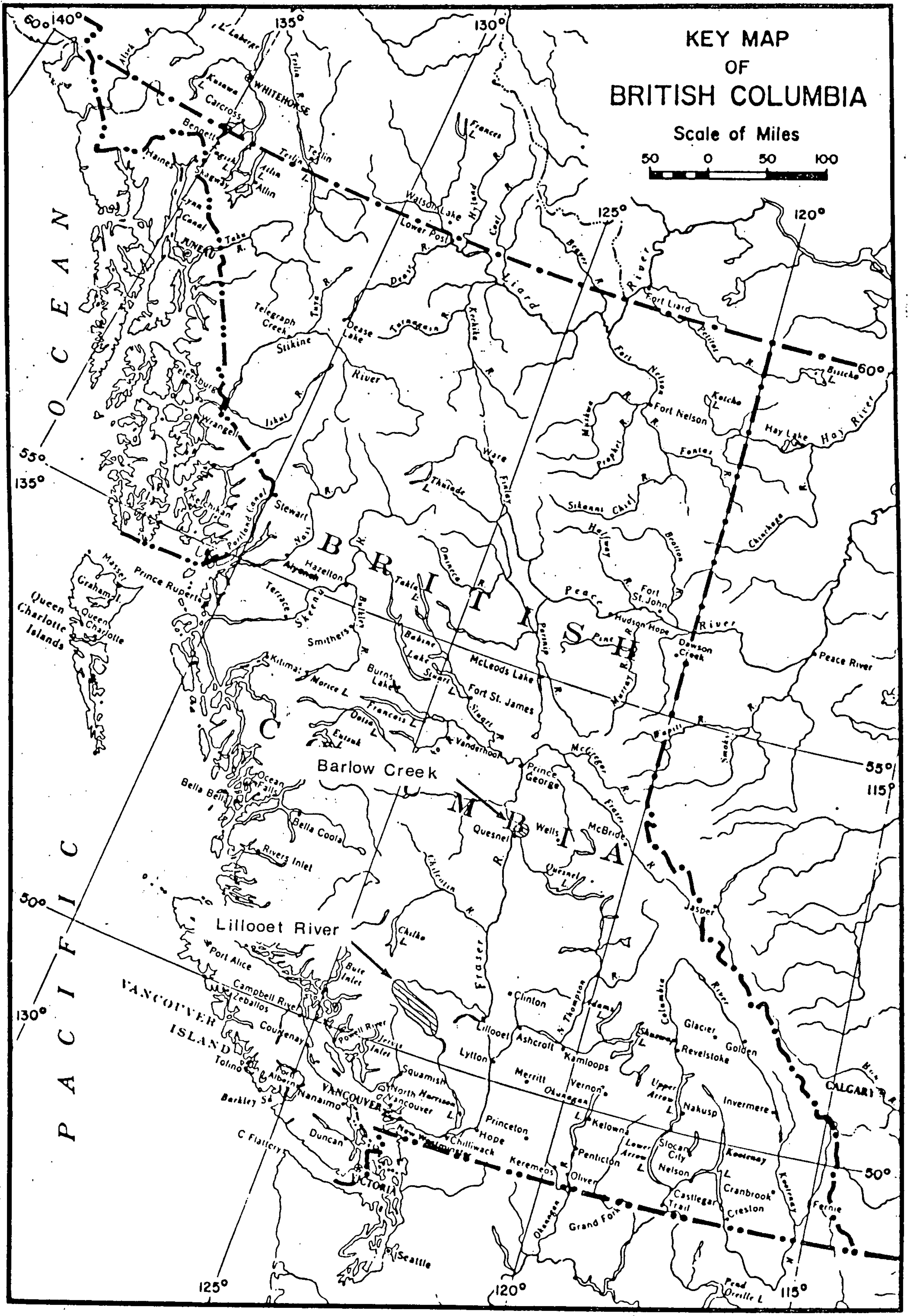


Figure 1 Key Map of British Columbia Showing Location of Barlow Creek and Lillooet River Basins

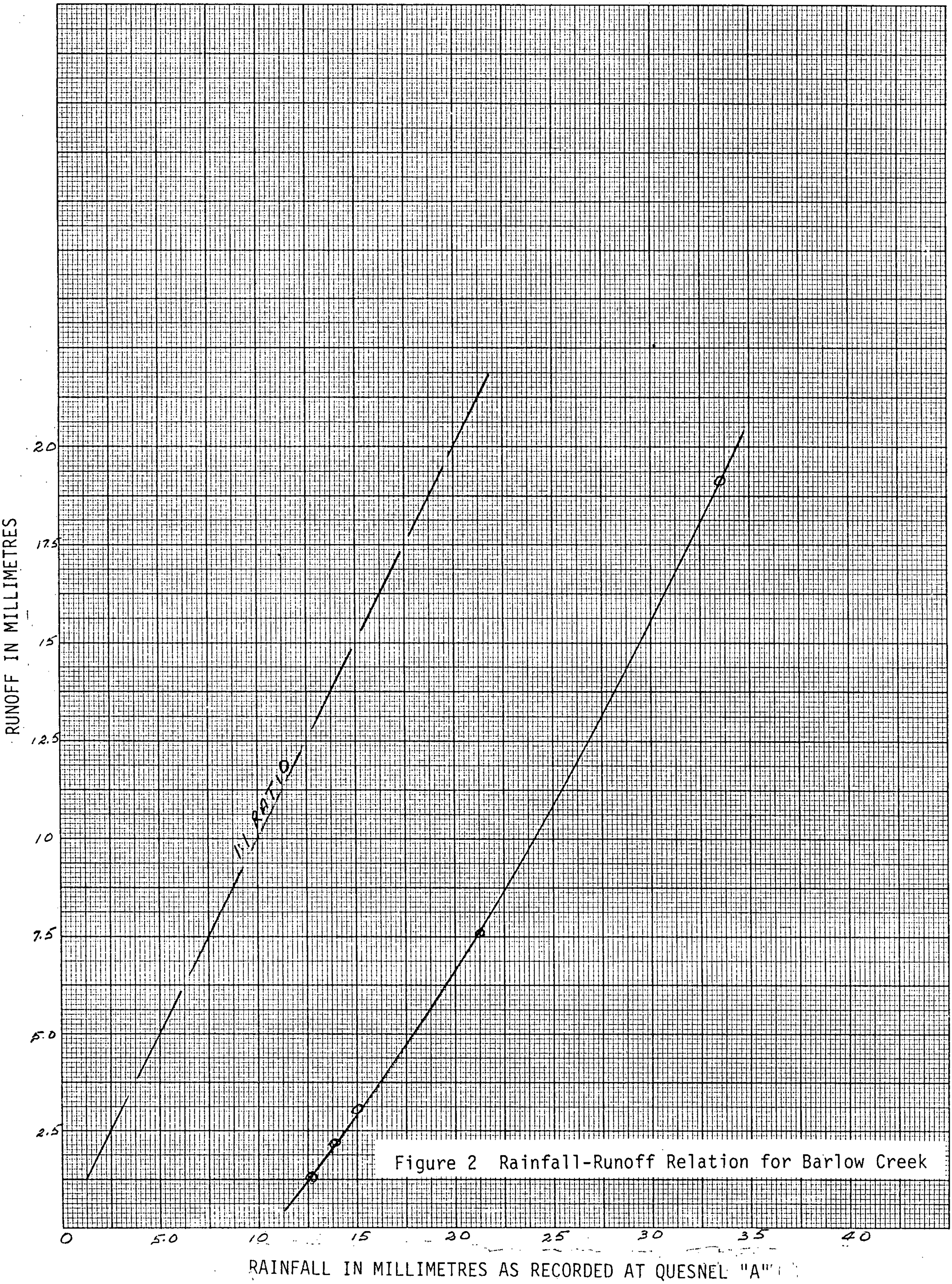


Figure 2 Rainfall-Runoff Relation for Barlow Creek

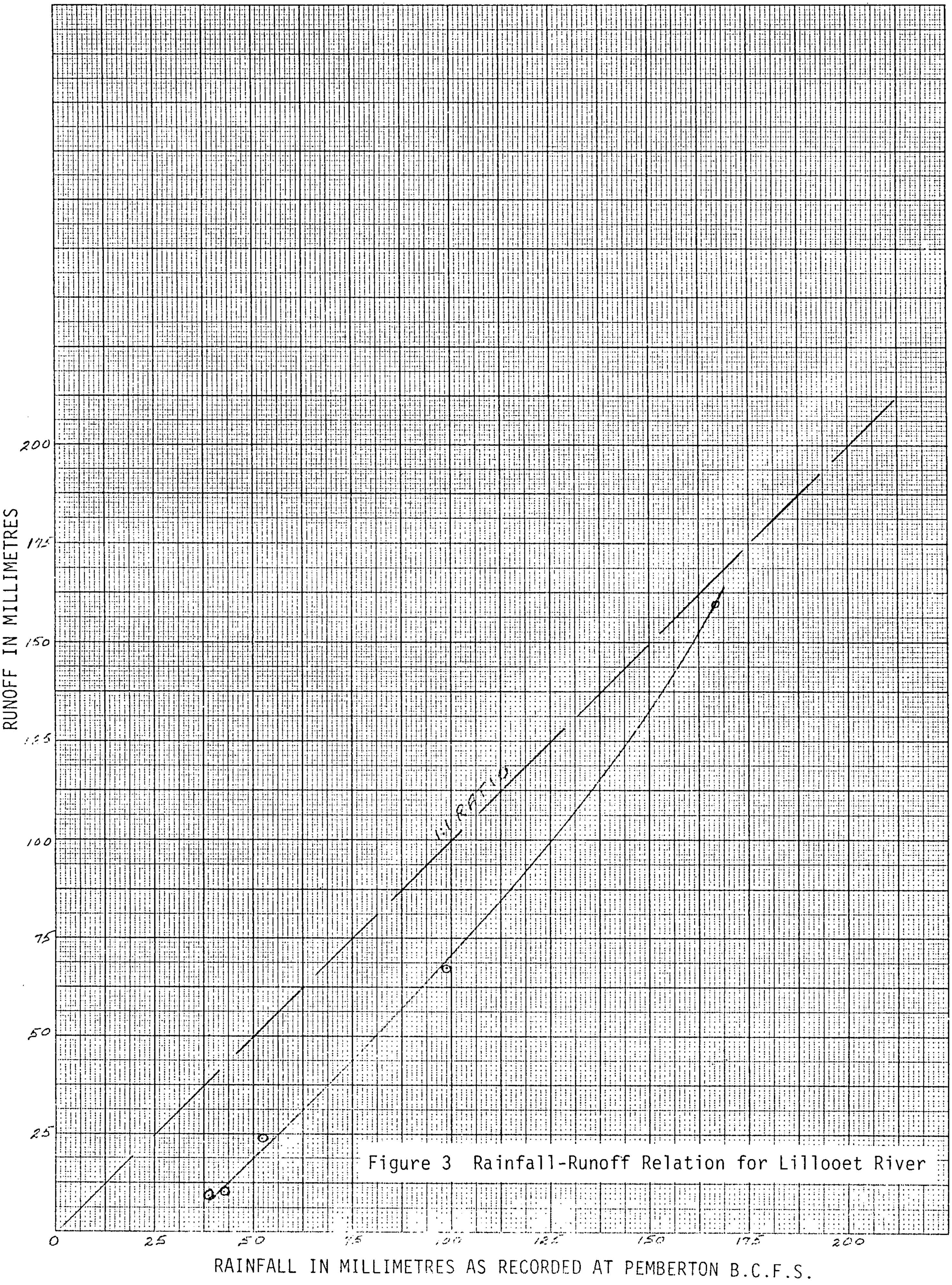


Figure 3 Rainfall-Runoff Relation for Lillooet River

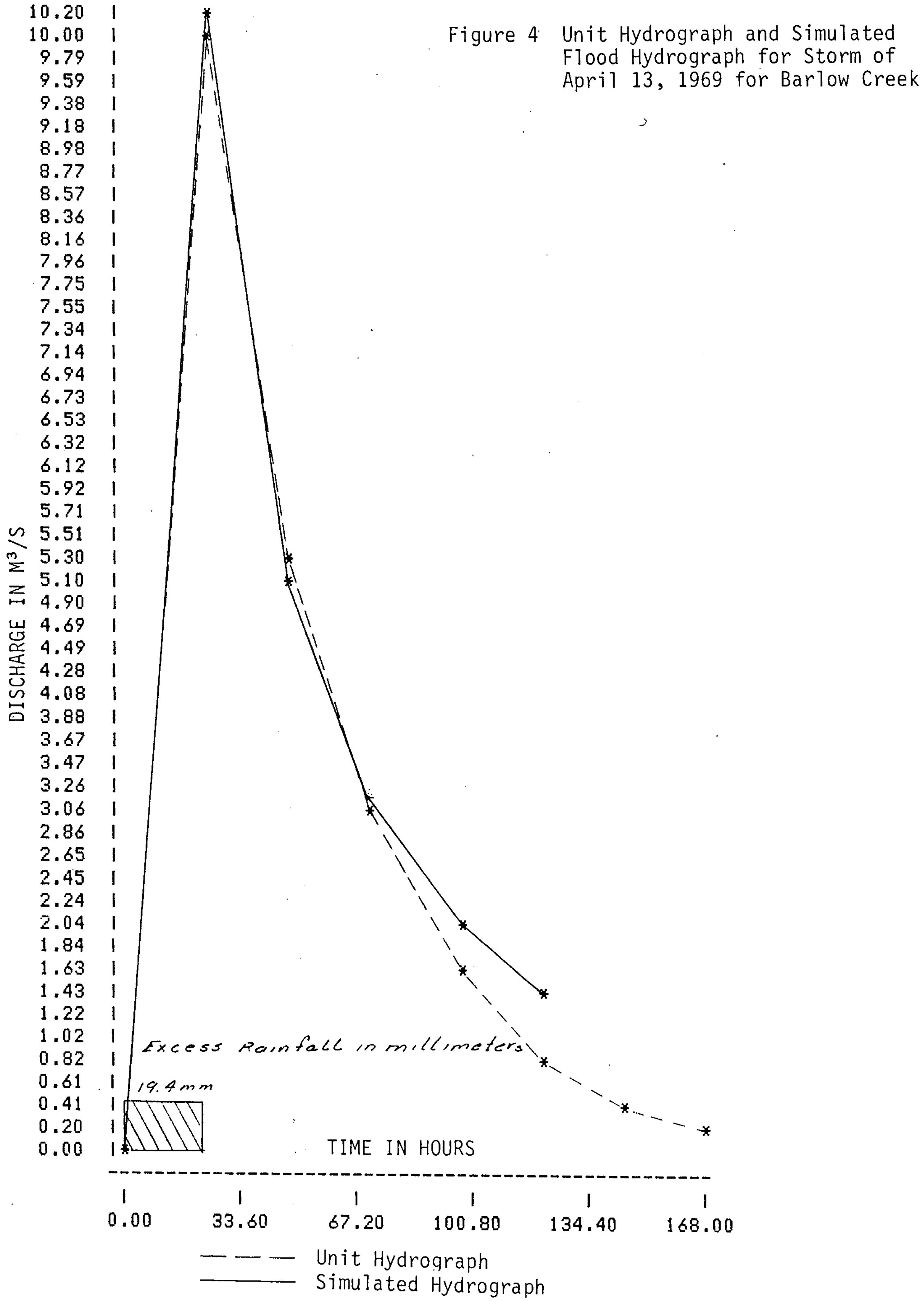
Figure 4 Unit Hydrograph and Simulated Flood Hydrograph for Storm of April 13, 1969 for Barlow Creek
DISCHARGE IN M³/S
10.20
10.00
9.79
9.59
9.38
9.18
8.98
8.77
8.57
8.36
8.16
7.96
7.75
7.55
7.34
7.14
6.94
6.73
6.53
6.32
6.12
5.92
5.71
5.51
5.30
5.10
4.90
4.69
4.49
4.28
4.08
3.88
3.67
3.47
3.26
3.06
2.86
2.65
2.45
2.24
2.04
1.84
1.63
1.43
1.22
1.02
0.82
0.61
0.41
0.20
0.00
Excess Rainfall in millimeters
19.4mm
TIME IN HOURS
0.00
33.60
67.20
100.80
134.40
168.00
Unit Hydrograph
Simulated Hydrograph

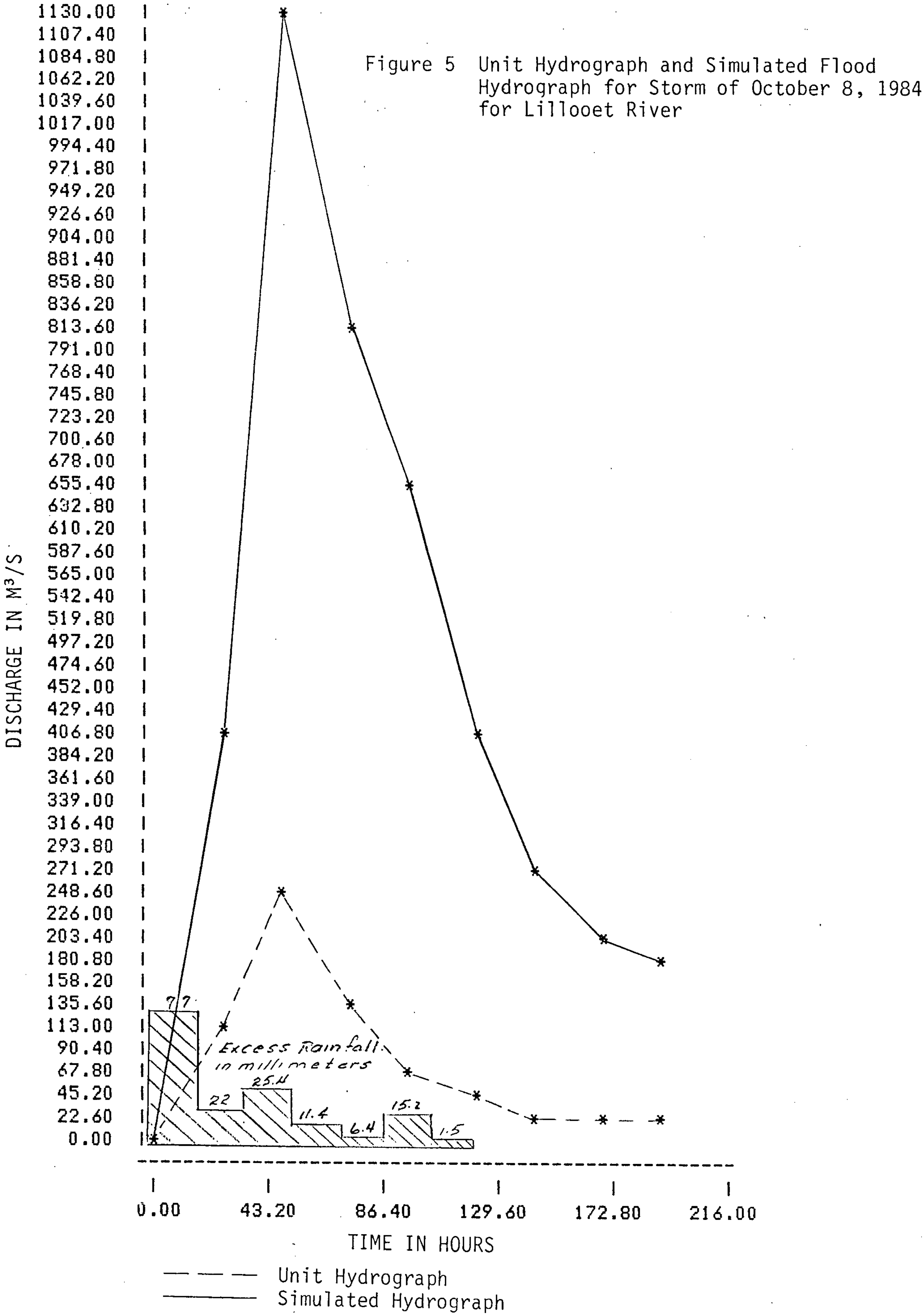
Figure 5 Unit Hydrograph and Simulated Flood Hydrograph for Storm of October 8, 1984 for Lillooet River
DISCHARGE IN M³/S
1130.00
1107.40
1084.80
1062.20
1039.60
1017.00
994.40
971.80
949.20
926.60
904.00
881.40
858.80
836.20
813.60
791.00
768.40
745.80
723.20
700.60
678.00
655.40
632.80
610.20
587.60
565.00
542.40
519.80
497.20
474.60
452.00
429.40
406.80
384.20
361.60
339.00
316.40
293.80
271.20
248.60
226.00
203.40
180.80
158.20
135.60
113.00
90.40
67.80
45.20
22.60
0.00
77
Excess Rainfall in millimeters
22
25.4
11.4
6.4
15.2
1.5
0.00
43.20
86.40
129.60
172.80
216.00
TIME IN HOURS
Unit Hydrograph
Simulated Hydrograph

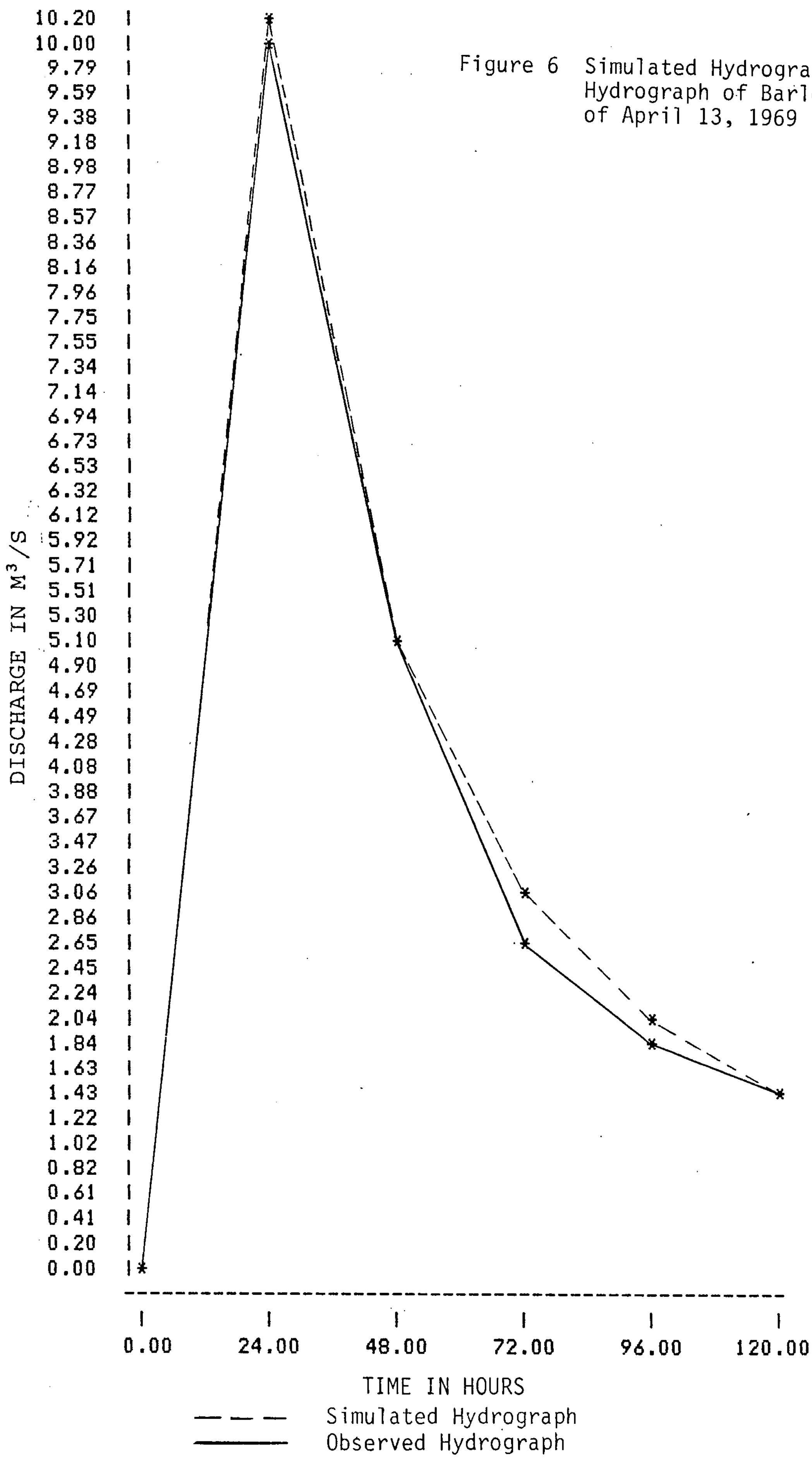


Figure 6 Simulated Hydrograph and Observed Hydrograph of Barlow Creek for Storm of April 13, 1969

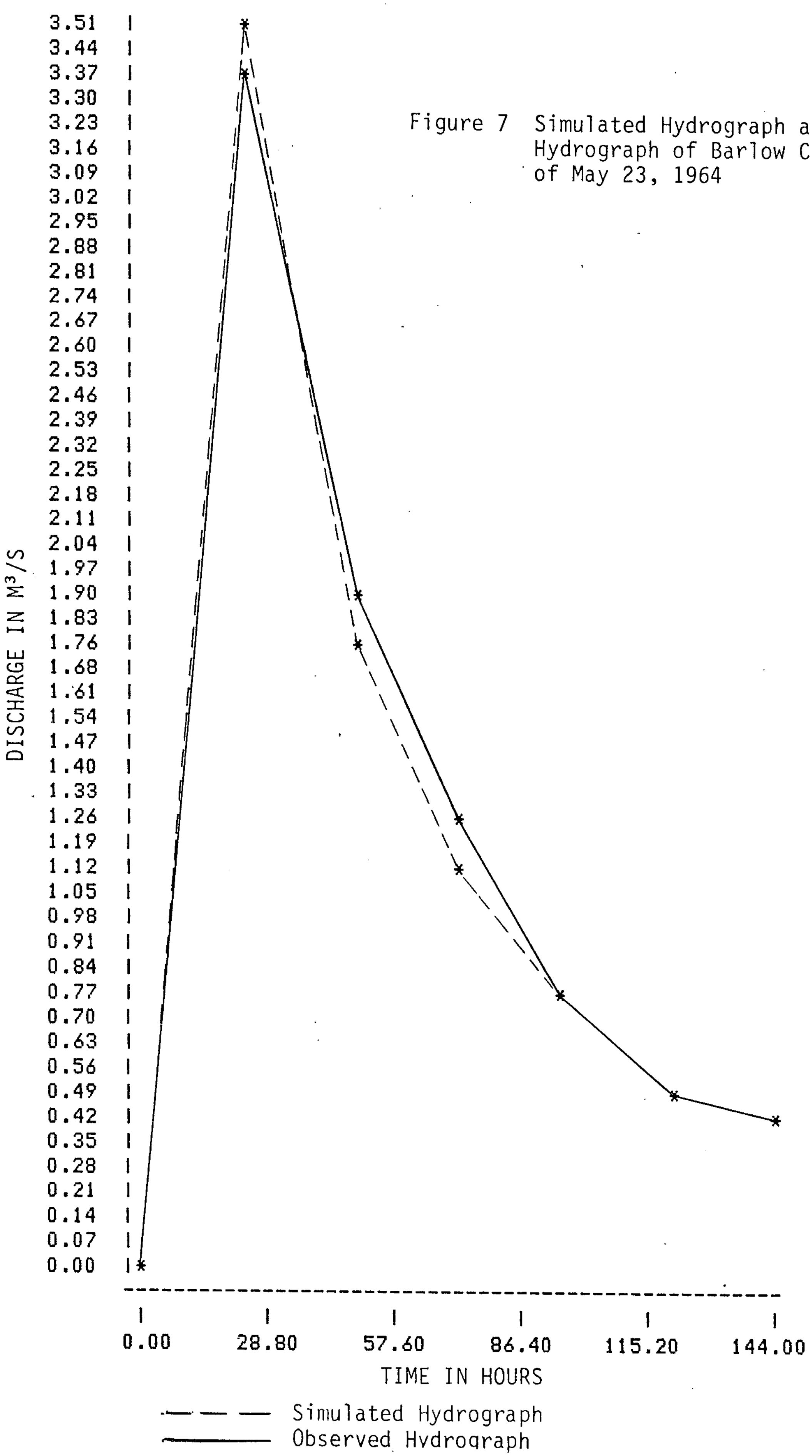


Figure 7 Simulated Hydrograph and Observed Hydrograph of Barlow Creek for Storm of May 23, 1964

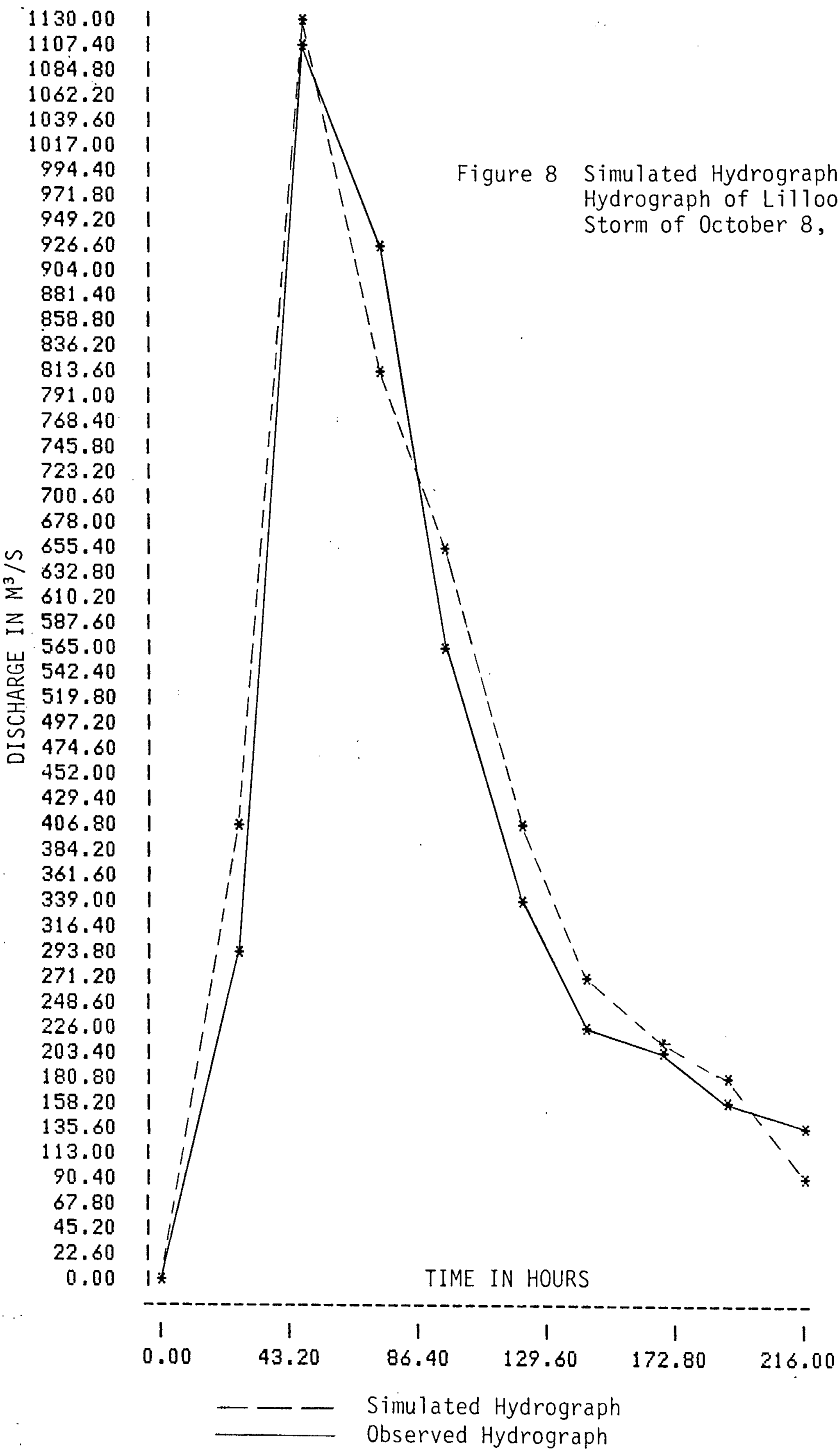


Figure 8 Simulated Hydrograph and Observed Hydrograph of Lillooet River for Storm of October 8, 1984

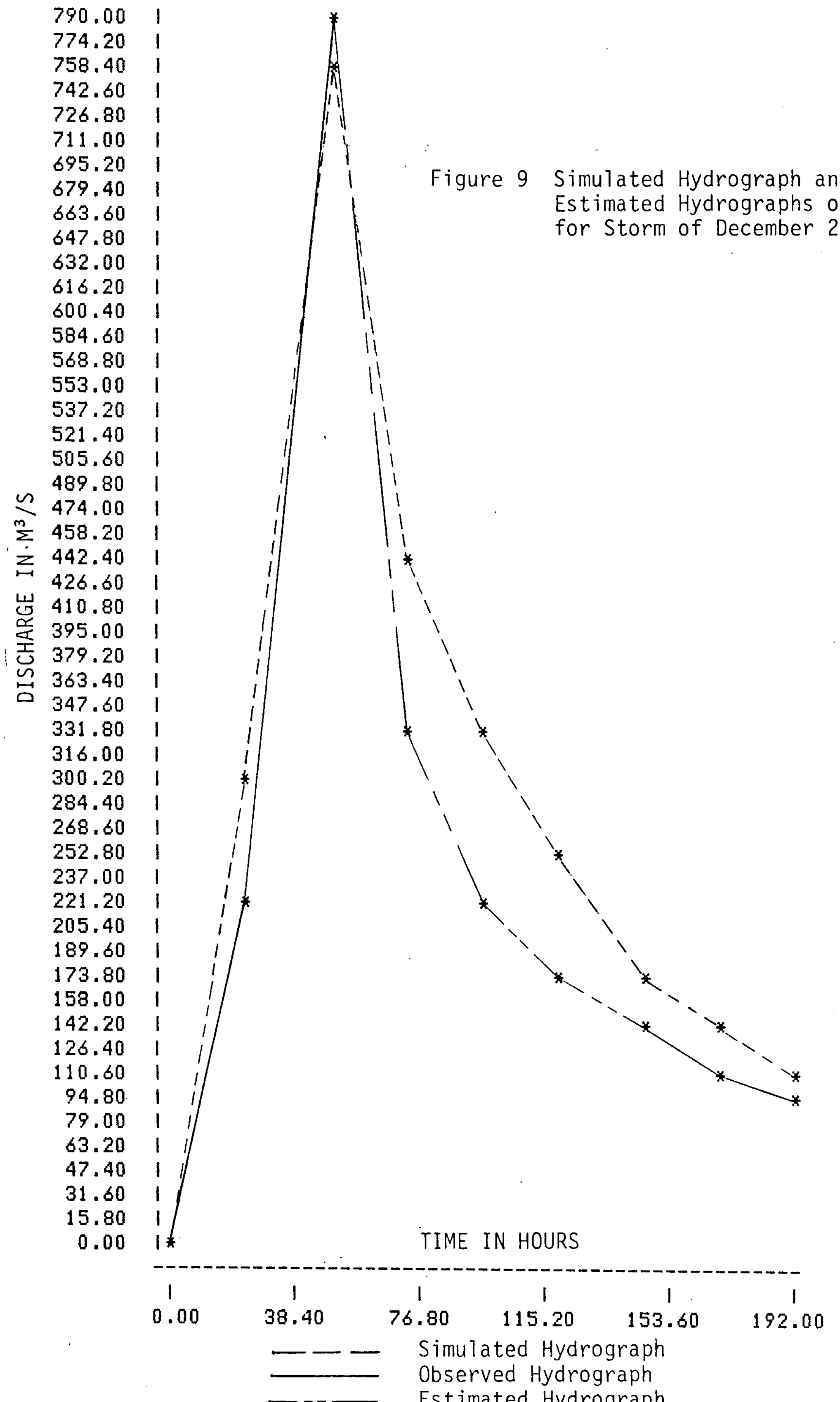


Figure 9 Simulated Hydrograph and Observed and Estimated Hydrographs of Lillooet River for Storm of December 27, 1980