Canada - British Columbia
Floodplain Mapping Agreement

Floodplain Mapping - Kettle and Granby Rivers

DESIGN BRIEF

Granby River - The Flood of 1983

ACRES Acres International Limited

December 1991

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1 Introduction

This Design Brief and associated Floodplain Maps for the Kettle and Granby Rivers were prepared under the Canada-British Columbia Floodplain Mapping Agreement by Acres International Limited. The floodplain delineation study was conducted from August 1991 to January 1992, and encompassed a channel length of 52 km in the Kettle River basin located in the Kootenay region of British Columbia (see **Figure 1-1**). This Design Brief describes the data and analyses undertaken and summarizes the study findings.

Principal contacts within the Victoria offices of B.C. Environment, Lands and Parks, Water Management Division for the study were Mr. P.J. Woods, Head, Floodplain Delineation Section and Mr. R.W. Nichols, Senior Hydraulic Engineer. The Water Management Division contact in the Regional Office in Penticton was Mr. B.J. Symonds, Head, Engineering Section. Valuable assistance and guidance were provided to the study by these staff members, and their contributions are gratefully acknowledged.

The floodplain delineation study for the Kettle and Granby Rivers comprised the following principal tasks:

- completion of a hydrology study to assess flooding characteristics and estimate design flows for the study reaches;

- calibration of a computer backwater model (HEC-2) to estimate flood profiles, using cross-sectional data and topographic maps provided by B.C. Environment, Lands and Parks as input data;

- determination of 200- and 20-year flood levels for the study reaches, using the calibrated computer model;

- delineation of land areas with elevations lower than the 200-year flood levels plus freeboard as the "200-year floodplain", using topographic maps provided by B.C. Environment, Lands and Parks; and

- preparation of this Design Brief and associated Floodplain Maps.

2 Drainage Basin

2.1 Description of the Basin

The Kettle and Granby River basins lie within the Monashee (Columbia) mountains. The Kettle River is bounded on the west and east by the Beaverdell and Midway ranges, respectively, and by the Kettle River Range to the south. The Granby River is bounded on the west and east by the Midway and Christina ranges respectively (see **Figure 2-1**). The terrain is generally very rugged with the mountain peaks rising to over 2000 m and ground slopes as high as 50%. Significant mountain peaks in the basin are Almond (2320 m), Faith (2280 m), Roderick Dhu (1830 m), Big White (2320 m) and Mount Tanner (2420 m).

The catchment area at the downstream end of the study reach is 9840 km^2. The principal city in the study reach is Grand Forks. Smaller communities in the study reach are Cascade, Billings, Gilpin and Christina Lake. The study reach lies within the Kootenay Boundary Regional District.

2.2 Hydrological Characteristics

The Granby River flows from north to south and enters the Kettle River at the city of Grand Forks. The Kettle River flows generally north to south and turns northeast after it enters Washington State. Just prior to the confluence with the Granby, the Kettle River returns to British Columbia and turns east to parallel the border. After Christina Creek, the Kettle River turns south and flows back into Washington State. The study reach starts where the Kettle River returns to British Columbia and ends where it flows back into Washington State.

The Kettle River has two main tributaries in the study reach, the Granby River and Christina Creek. The drainage area of the study reach varies, as indicated in **Table 2–1**. All streams in the area have relatively steep grades and medium to large cobbles in the stream beds. Typically, the overbank areas are heavily forested.

The mean daily temperature ranges from -6.1°C. in January to 19.6°C. in July[1], with recorded temperature extremes of -38.9°C. and 42.2°C. Of the total annual precipitation of 860 mm, approximately two-thirds occurs as rain and one-third as snow.[2] The 100-year 24-hour maximum precipitation, as documented in the

[1] "Canadian Climatic Normals, Volume 2, Temperature, 1951-1980," Atmospheric Environment Service, Environment Canada, 1982.

[2] "Canadian Climatic Normals, Volume 3, Precipitation, 1951-1980," Atmospheric Environment Service, Environment Canada, 1982.

TABLE 2-1
DRAINAGE AREAS

Location		Drainage Area (km^2)
(a)	**Kettle River**	9840
	Upstream End of Study Reach (above Granby River)	6750
	Downstream of Granby River Confluence	8800
	At Cascade Falls (above Christina Creek)	8960
	Kettle River Near Laurier (Gauge 08NN012) (downstream end of study reach)	9840
(b)	**Granby River at the Mouth** (Gauge 08NN002)	2050
(c)	**Christina Creek**	520

Atmospheric Environment Service (AES) Rainfall Frequency Atlas for Canada[3], is 45 mm.

There are five flow gauging stations in the study basin with usable records (see **Table 2-2**). The mean annual runoff recorded at the long term station on the Kettle River near Laurier (WSC 08NN012) is 82.0 m^3/s. This is equivalent to a runoff depth of 263 mm, suggesting a runoff coefficient of 58%, which is normal for a heavily forested catchment. The annual flood peak occurs from late-April to mid-June. The annual runoff hydrograph is very much dominated by the spring freshet; on average, 76% of the annual flow is observed in April, May and June.

The snowmelt-dominated flow pattern observed for the Kettle River has also been observed from the flow record on Granby River and smaller basins like Hidden Creek to the east. This has important implications for the flood frequency analysis. It appears that throughout the basin the maximum annual flow is attributable to spring snowmelt supplemented by rainfall. No consideration needs to be given to rainfall-induced events at other times of the year.

While the annual flood peak is a snowmelt event, damaging floods usually require the occurrence of significant rainfall in addition to rapid snowmelt. These rains usually result from frontal systems moving in from the west coast which are subjected to significant orographic effects from the local topography. During the early summer, non-frontal "cold lows" occasionally pass through the area from the northwest, west or southwest, and sometimes produce significant amounts of rainfall before moving eastwards. Convective rainstorms typically occur in the summer months, but do not produce large floods, except on very small creeks.

2.3 Historical Floods

Over the years, the study area has been subjected to floods, some of which have caused significant damages. The following paragraphs describe the worst floods based on information obtained from newspaper files, discussions with long term residents of Grand Forks and, when available, Water Survey of Canada flow data.

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3 "Rainfall Frequency Atlas for Canada", Hogg, W.D. and D.A. Carr, Atmospheric Environment Service, Environment Canada, 1985.

TABLE 2-2
FLOW GAUGING STATIONS WITHIN THE STUDY BASIN WITH USABLE RECORDS

Item	Station				
	Kettle River Near Laurier	**Kettle River at Cascade**	**Kettle River at Carson**	**Kettle River Near Ferry**	**Granby River at Grand Forks**
Water Survey of Canada No.	08NN012	08NN006	08NN005	08NN013	08NN002
Drainage Area (km^2)	9840	8960	6730	5750	2050
Gauge Location LAT LONG	48-59-04N 118-12-55W	49-01-25N 118-12-30W	49-00-00N 118-29-45W	48-58-53N 118-45-55W	49-02-39N 118-26-19W
Period of Record[1]	1930-date	1916-34	1914-22	1929-date	1926-31 1966-date
Type of Flow	Natural	Natural	Natural	Natural	Natural
Rating Curve	Stable at medium and high flows	N/A	N/A	N/A	Stable at medium and high flows

1 "Historical Streamflow Summary to 1988, British Columbia", Inland Waters Directorate, Environment Canada, 1989.

May 1948

The flood of 1948 was widespread in southern British Columbia and is the flood of record for the Kettle River at Laurier. The recorded peak mean daily flow was 968 m^3/s, which corresponds to a return period of about 200 years (see Section 4). The flood appears to have been caused by high snowmelt runoff exacerbated by a series of heavy thunderstorms.

Flooding in the city of Grand Forks reached its peak on May 24, shortly after the failure of an abandoned dam on the Granby River. Prior to the dam failure, the city had attempted to dynamite a log jam formed behind the dam. However, their efforts were not sufficient, and, according to a report in the Nelson Daily News, ". . . the weight of water snapped a pier in the old dam and sent a five-foot wall of water roaring down the valley." Two elderly ladies were injured, ". . . when the sidewalk on which they were walking was swept away by the raging waters." **Photographs 1** and **2** provide an indication of the extent and severity of the flooding that took place. Low-lying areas were inundated to depths of as much as 8 ft. In all, more than 50 homes were isolated from the business section of Grand Forks, with scores of shoppers unable to return to their homes. A taxicab became stranded and its driver had to be rescued by boat. One young child drowned in Fourth of July Creek.

May 1956

Only eight years after the disastrous 1948 flood, the City of Grand Forks was subjected to another major flood. The flood of 1956 is the second largest flood of record, with a peak mean daily flow of 858 m^3/s as recorded at Laurier. The return period of this flood is about 30 years. The flood appears to have been caused by exceptionally warm weather occurring when the snowpack was fully ripened and the rivers already flowing high.

Flooding was extensive as is evident from **Photograph 3**. As in 1948, more than 50 homes were flooded. In addition, numerous farm buildings, two autocourts and thousands of hectares of farm land were under several feet of water. The Kettle River was reported to have risen from 12 to 18 ft above normal.

May 1983

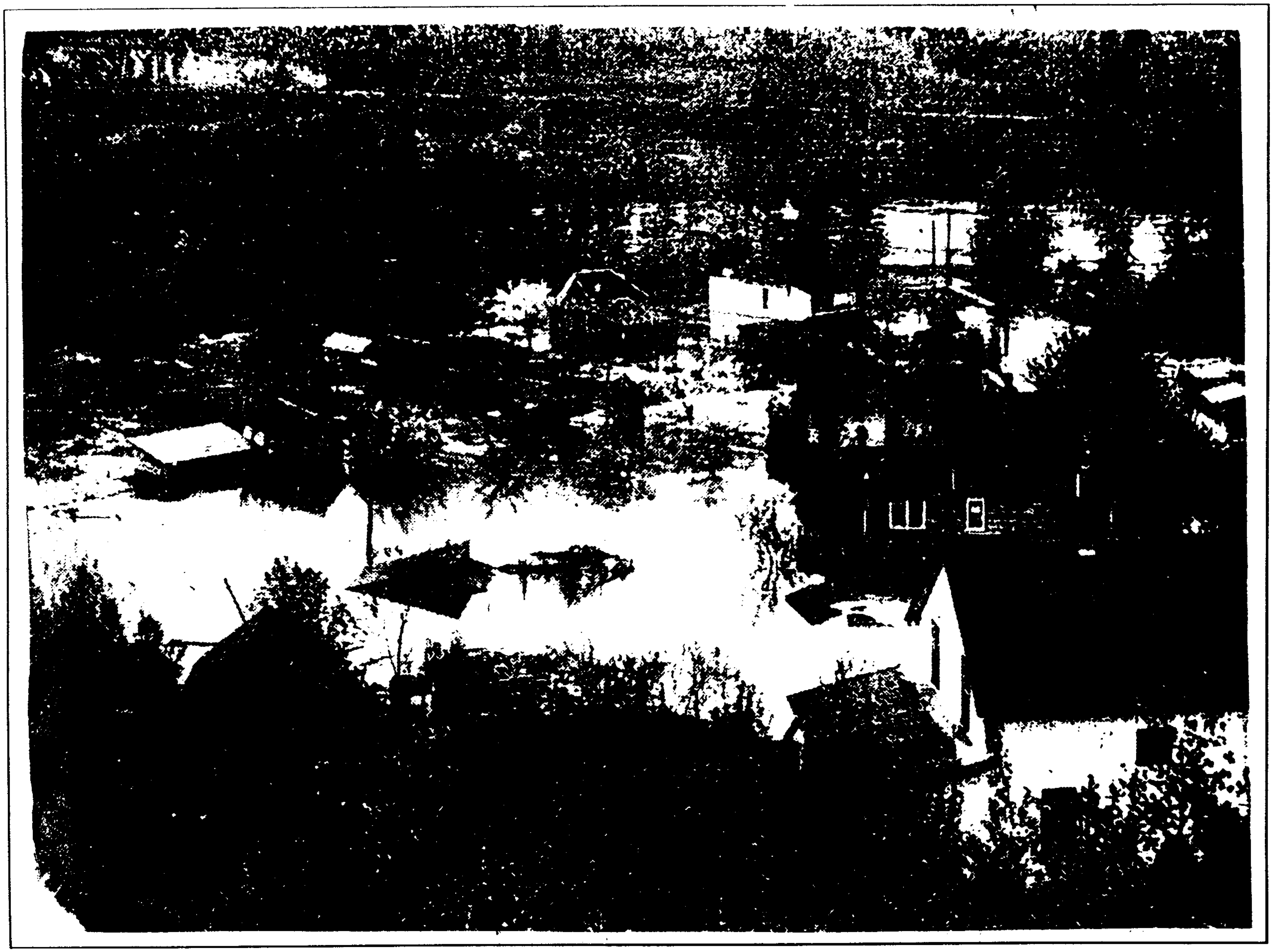
In late May 1983, flooding occurred on both the Kettle and Granby Rivers. The Kettle River peaked at a mean daily flow of 807 m^3/s, corresponding to a return period of just under 20 years. The Granby River peak flow was 329 m^3/s, which corresponds to a return period of just over 10 years.

Some houses adjacent to the Granby River were threatened by the flood as is evident from **Photograph 4**. Significant flooding occurred in the Grand Forks City Park (see **Photograph 5**). However, flooding of this park appears to be a fairly common occurrence.

May 1986

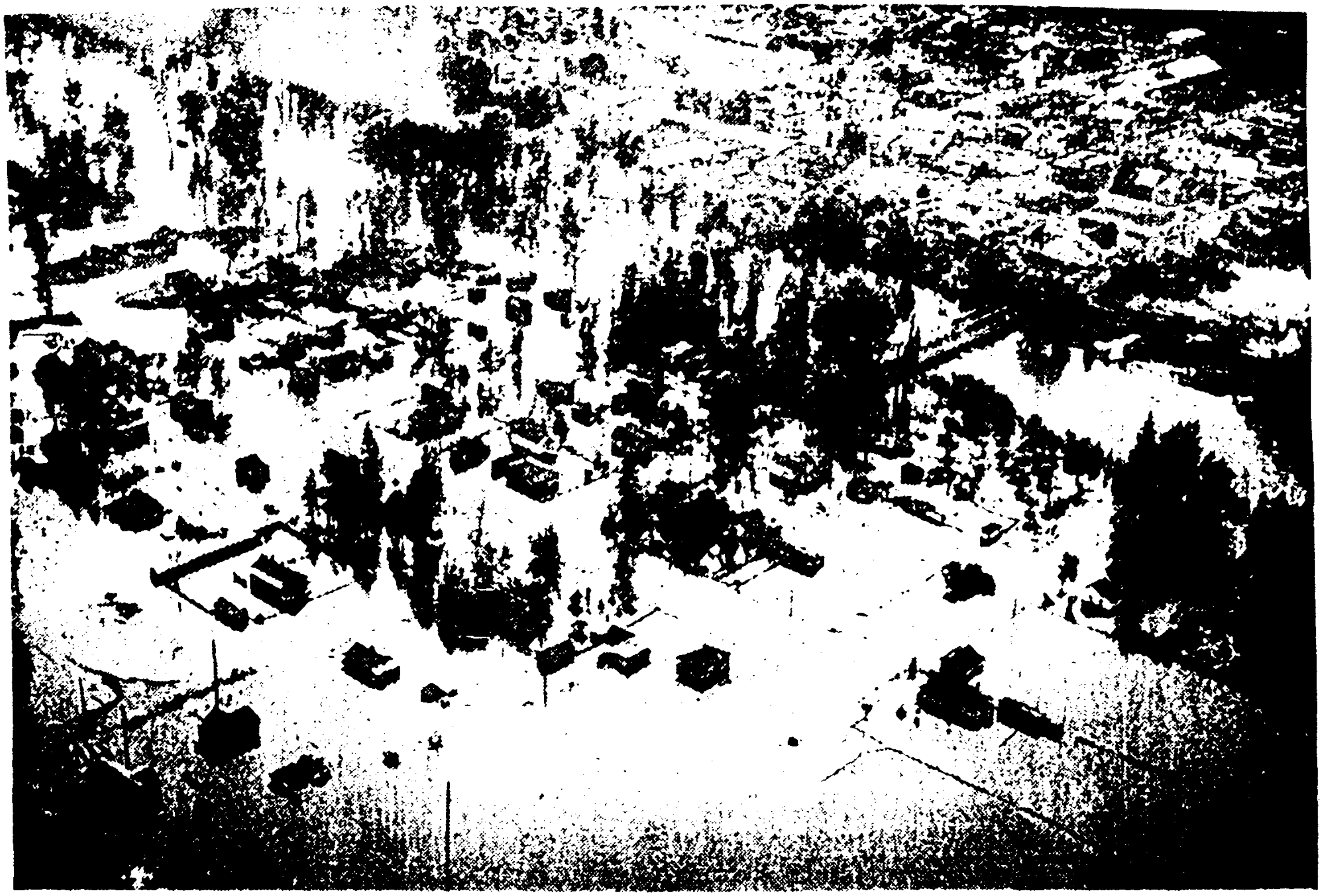
Once again, late May extreme snowmelt conditions produced flooding on the Kettle and Granby Rivers in 1986. The peak mean daily flow observed on the Kettle River was 725 m^3/s, while the observed peak on the Granby River was 309 m^3/s. Both of these peaks were somewhat greater than five-year return period floods.

The Grand Forks City Park area was flooded once again during this event. The Cooper Bridge (Cross Section #53, Sheet 5) was closed for some time, since the Highways Department suspected structural damage from log jams (see **Photograph 6**).



PHOTOGRAPH 1 View of some of the flooding in Grand Forks, taken from Observation Mountain (May 1948)

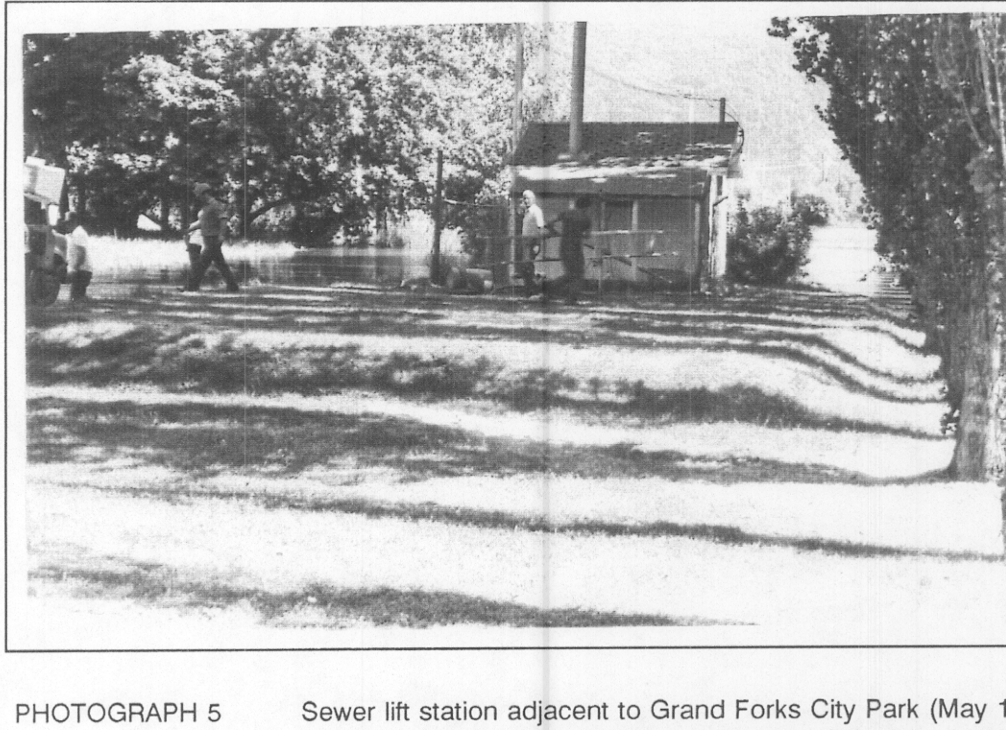
PHOTOGRAPH 2 Flooding in the downtown area of Grand Forks (May 1948)
(Corner of Central Avenue and Second Street)



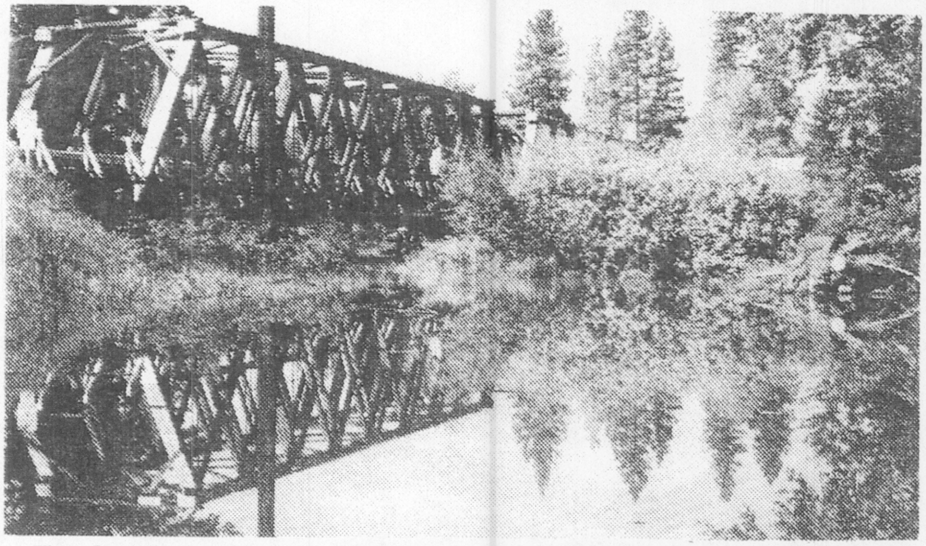
DAMAGE WHICH WILL RUN into thousands of dollars has been caused by flooding Granby and Kettle Rivers at Grand Forks where about 50 homes have been surrounded by water. This aerial photo of the scene of devastation, showing the Boundary city in the background, was taken for the Daily News from a plane by Art Stevens of Nelson.

PHOTOGRAPH 3 Aerial view of flooding in Grand Forks (May 1956)

PHOTOGRAPH 4 Residence on the Granby River (May 1983) (East side of Granby River between Cross-section #5 and #6, Sheet 7)

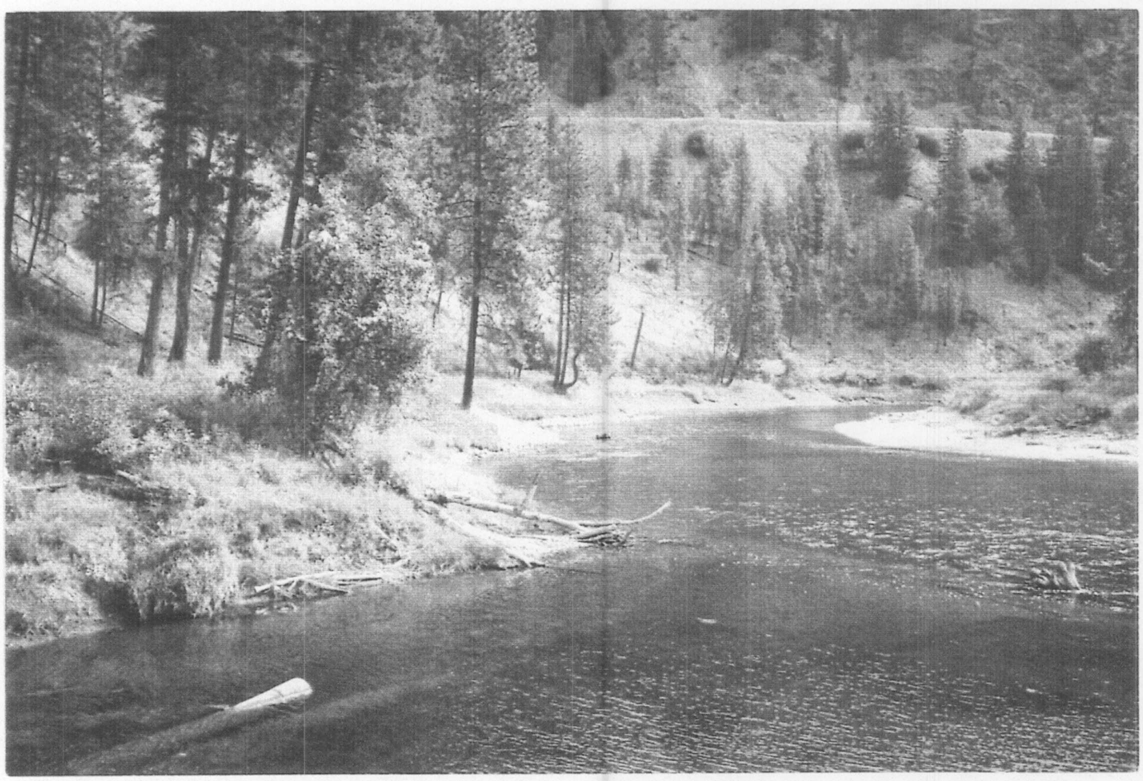


PHOTOGRAPH 5 Sewer lift station adjacent to Grand Forks City Park (May 1983) (Viewed south to the Kettle River, between Cross-sections #43 and #44, Sheet 7)

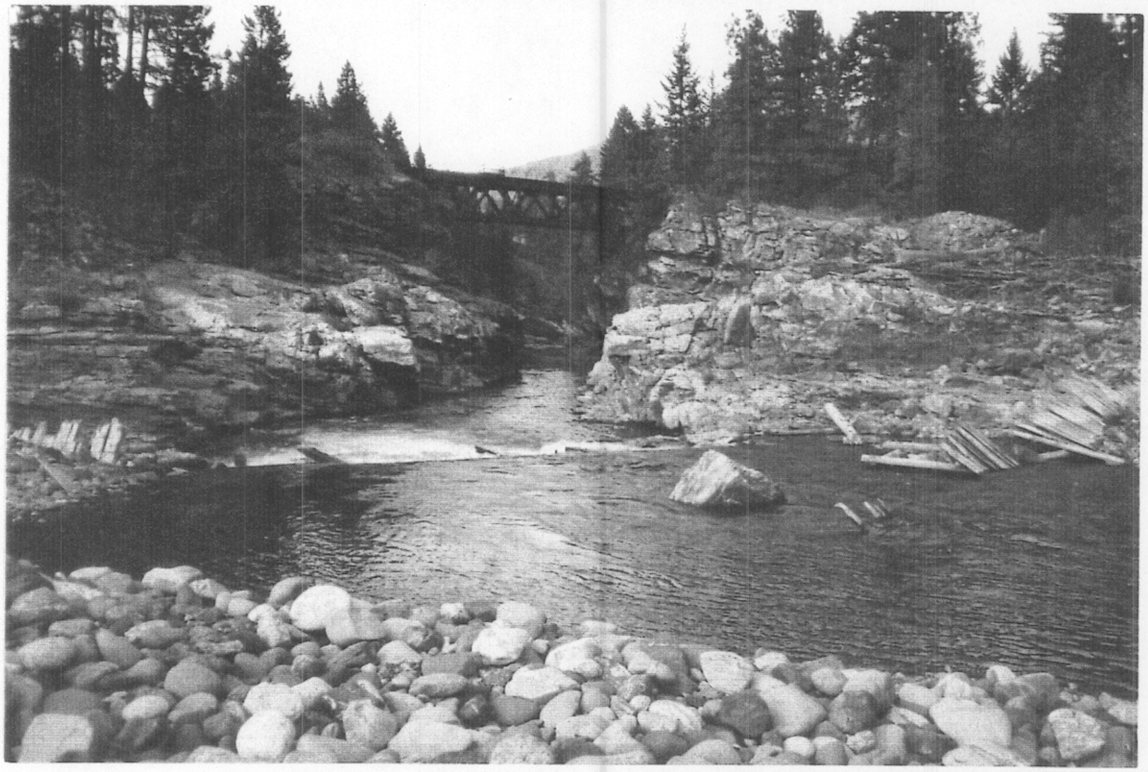


The Cooper Bridge was closed last week after the Highways Department suspected the pilings suffered structural damage when logs jammed during the recent high water in the Kettle River. Highways must wait until the water receeds before the extent of the damage, or the length of the closure can be determined.

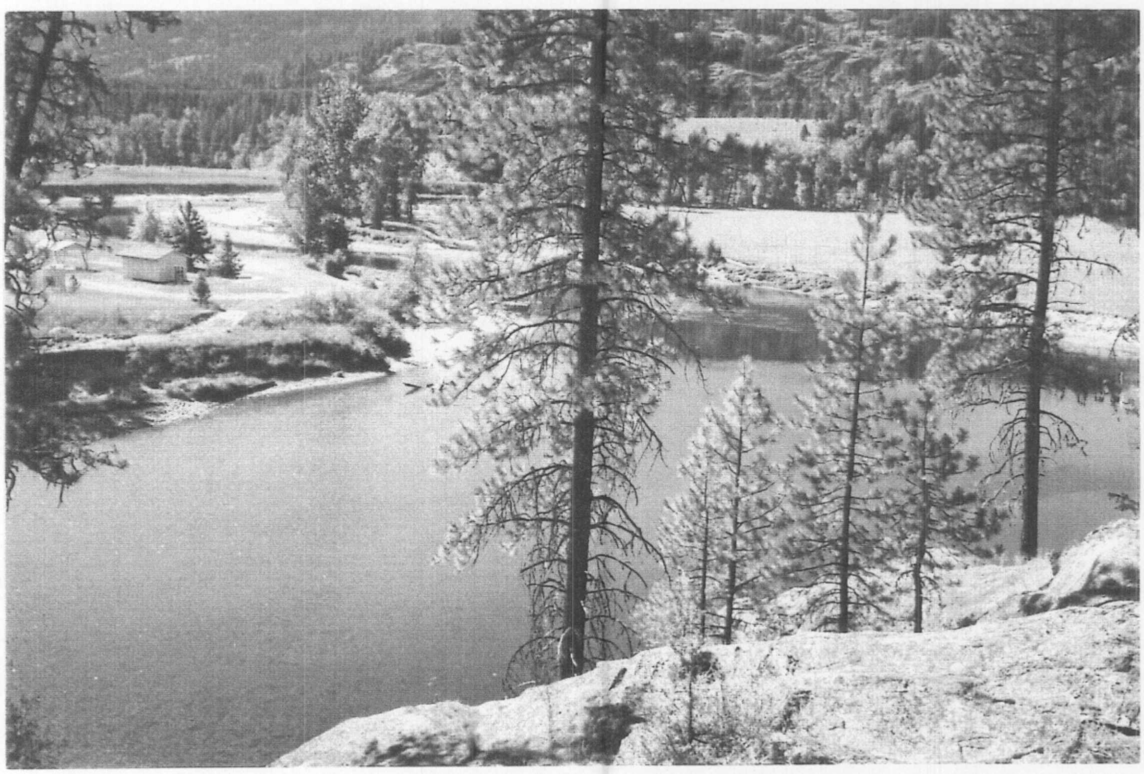
PHOTOGRAPH 6 Cooper Bridge damaged by log jamming during the flood (May 1986)
(Cross-section #53, Sheet 5)



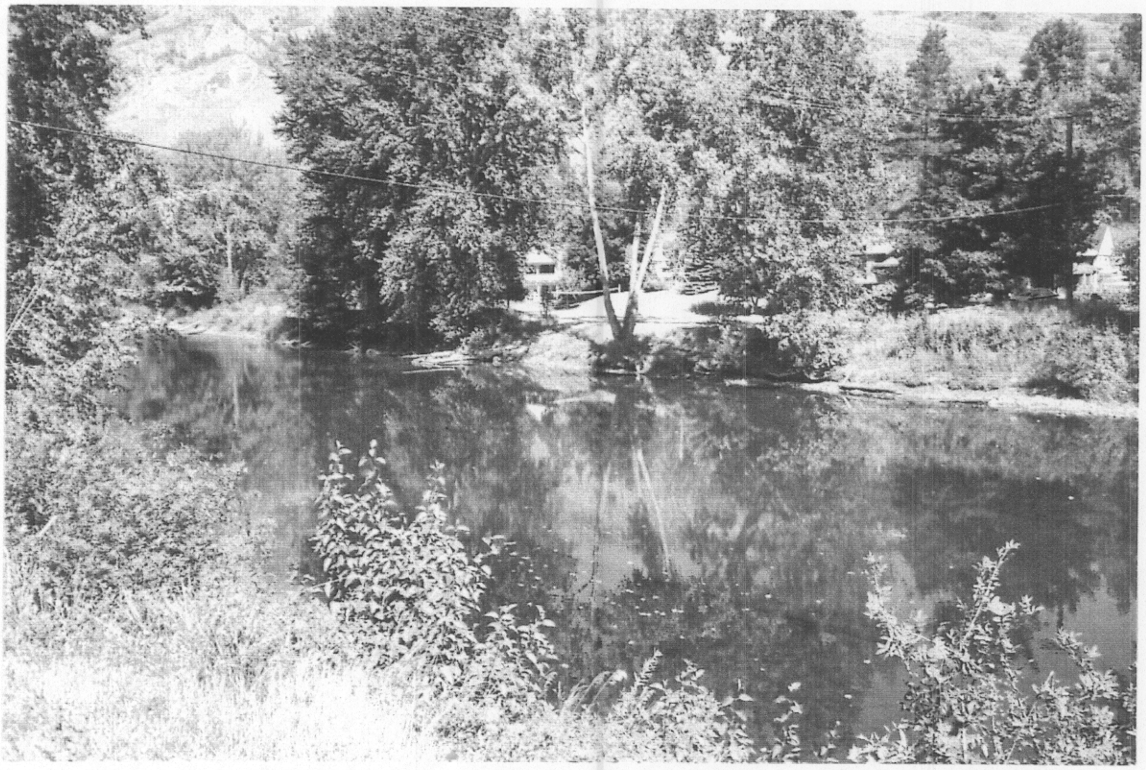
PHOTOGRAPH 7 Confluence of Christina Creek and Kettle River
(Viewed downstream towards Cross-section #13, Sheet 1)



PHOTOGRAPH 8 Kettle River at the site of the abandoned Cascade Dam (Viewed downstream; see Sheet 1)



PHOTOGRAPH 9 Upper reaches of the Granby River (Viewed upstream towards Cross-section #22, Sheet 9)



PHOTOGRAPH 10 Lower reaches of the Granby River
(Viewed upstream towards Cross-section #45, Sheet 7)

3 Data Used for the Study

3.1 Data Sources

3.1.1 The Study Basin

Flood frequency analysis requires at least ten years of data at a site before a meaningful analysis may be undertaken. Over the years, Water Survey of Canada has operated a number of gauging stations in the Kettle River basin. The five stations with usable records and the key characteristics of these stations are presented in Table 2-2.

3.1.2 The Study Region

In 1989, B.C. Environment undertook a regional flood frequency analysis for the Kootenay (Nelson) region.[1] In that study, no regional curves or regional equations were developed for estimating peak flows for ungauged basins, due to the diverse characteristics of the gauged basins and the influence of this diversity on flood characteristics. The plots of unit mean annual flood (mean annual flood divided by drainage area) versus drainage area presented in the B.C. Environment report showed significant scatter on a sub-region basis, with a general trend of increasing unit flood peaks with drainage area. Such a trend is not normally expected, as small basins typically generate higher unit flood peaks than do larger basins. This demonstrates that other factors (e.g. basin elevation, orientation, natural storage) exert a significant influence on the flood characteristics of Kootenay region watersheds.

3.2 Field Investigations

During the course of the study, two reconnaissance trips to the Grand Forks area were undertaken by the principal investigator. The dates of the trips were September 9 to 11 and November 26 to 28, 1991. On the first trip, a reconnaissance of the accessible study reaches was undertaken to estimate the hydraulic roughness of the overbank portions of the river and to make note of any features that would be relevant to the hydraulic analysis of floods. Some representative photographs were taken of the river along the study reaches (see **Photographs 7** to **10**). Discussions were held with Mr. Brian Symonds (Head, Engineering Section, Water Management Division) in Penticton; he provided background material on the study basin and past flooding problems. Discussions were also held with Mr. Brent Tipple of the Water Survey of Canada in Nelson, concerning flood records and rating curves for stations in the area. Newspaper archives in Nelson and Castlegar were examined for accounts of historical

[1] "Guide to Peak Flow Estimation for Ungauged Watersheds in the Kootenay (Nelson Region," Recksten, D.E. and Barr, L.J., B.C. Ministry of Environment, Water Management Branch, 1989

floods in the study area. Interviews were held with several long-term residents of the area concerning floods. The assistance of the following individuals is gratefully acknowledged:

Mr. Sam Dutoff	-	Proprietor, Esso Station
Mr. Leo Paulosky	-	B.C. Environment, Lands and Parks
Mr. John Churnoff	-	Resident
Mr. Barry Alcock	-	B.C. Environment, Lands and Parks
Mr. Art Hoefsloot	-	Surveyor
Mr. Ken McKinnon	-	Superintendent, City of Grand Forks

During the second field trip, uncertainties in the draft floodplain maps were reconciled. Further discussions were held with Mr. Symonds concerning flooding in the town of Grand Forks.

4 Flood Frequency Studies

The mountainous terrain of the Kettle region makes conventional regional hydrology analysis difficult, as demonstrated in the B.C. Environment regional hydrology study for the Kootenay (Nelson) region. Accordingly, the present study relied on the results of flood frequency analyses of the gauges in the study basin. This essentially complies with the recommended approach of the B.C. Environment regional study.

The study required water levels to be computed using the HEC-2 computer model for the following flow conditions:

- 200-year Instantaneous Flow
- 200-year Mean Daily Flow
- 20-year Instantaneous Flow
- 20-year Mean Daily Flow

It is evident from Figure 2-1 and Table 2-1 that the catchment area varies appreciably along the study reach. It was therefore necessary to derive the four desired flood flows at points along the study reach. The following sections of this report document the procedure used to estimate flood flows at four points in the study reach.

4.1 Flood Frequency Analysis and Results

Flood frequency analyses were undertaken at three locations:

- Kettle River near Laurier
- Kettle River at Cascade
- Granby River at Grand Forks

Analyses were undertaken where possible using both instantaneous and daily peak flow data. Supplementary analyses were undertaken for the two long-term stations excluding unusually low peak flows recorded in March 1931 on the Granby River and June 1930 on the Kettle River, as discussed below.

The Acres computer program used for the analysis, designated FDR, is based on Environment Canada's frequency analysis program "FDRPFFA". It incorporates slight modifications to the output format and the addition of graphics capabilities. The numerical results of FDR are identical to those of FDRPFFA. The program attempts to fit six different statistical distributions to the flood data:

- Gumbel (Extreme Value Type I)
- Pearson Type III

- Three-Parameter Lognormal
- Log Pearson Type III
- Two-Parameter Lognormal
- Normal Distribution

For this study only the first three distributions were considered as candidates for analysis as specified in the "Specifications for Engineering Studies, Floodplain Mapping Program". The computer program output was reviewed and the most appropriate distribution for the data was selected. For many flood frequency analyses conducted in Canada, the sample sizes under consideration are too small to make a confident choice of distribution. However, there is often enough evidence to reject some of the choices, and the differences among the remaining candidates are quite small on many occasions.

The detailed results of the flood frequency analyses for the present study are presented in **Appendix A**. The following discussion relates to the choice of distribution for each case.

(a) Kettle River near Laurier (Instantaneous)

Initial analyses using recorded flood peaks yielded reasonable results, but estimated flood peaks for most return periods were found to be slightly lower than those obtained from the daily flow series. Upon review, it was noted that the data point corresponding to 1948 (the flood of record) was missing, although there was a recorded daily flood peak. The instantaneous flood peak for this year was estimated at 1000 m^3/s, based on the ratio of instantaneous to daily flood peaks for the highest four floods for which both were available. The ratio used in this case was 1.034. This estimated value for 1948 was then added to the instantaneous flood peak series and the data set reanalysed. Of the three candidate distributions, only the Gumbel distribution did not provide a reasonable fit to the data, as indicated by the frequency plots and statistical indicators documented in Appendix A. The Pearson Type III and the Three Parameter Log Normal provided essentially identical results, whereas the Gumbel distribution yielded higher flood estimates.

(b) Kettle River near Laurier (Daily)

The results are very similar to those for the instantaneous flows. The rejection of an outlier (year 1930) was studied and this outlier was rejected for the analysis. The Gumbel distribution provided a poor fit and the other two distributions provided reasonable fits with identical results for the 200-year flood.

(c) Granby River at Grand Forks (Daily)

The flow record for Granby River is significantly shorter than that of the Kettle River, which accounted for poorer results in the analysis. There was no result for the Three Parameter Log Normal distribution and the other two provided poor fits. The rejection of an outlier (year 1931) resulted in a slightly better fit for the Pearson Type III distribution.

(d) Kettle River at Cascade (Daily)

The flow record for the Kettle River at Cascade was short but the frequency analysis yielded fairly good results. However, because of the short record and the small difference between the observed flows at Cascade and Laurier, it was decided that recorded flows at Laurier could adequately represent flows at Cascade. No reduction in design flows upstream of Christina Creek will be necessary for this reason.

The Pearson Type III distribution provided adequate fits for all the data sets, and was adopted for use in this study. Frequency plots based on the Pearson Type III distribution are shown in **Figures 4-1**, **4-2** and **4-3**. The calculated flows corresponding to various return periods are presented in **Table 4-1**.

4.2 Derivation of Design Flows

The values for the Kettle River at Laurier given in Table 4-1 indicated that instantaneous flood peaks are substantially equal to daily flood peaks, with differences attributable to minor factors. As discussed in Section 4.1(d), the Kettle River at Laurier flows can be used to represent conditions from Cascade to the confluence of the Granby River. That is, no flow reduction was required upstream of Christina Creek.

Comparison of daily flood values between Kettle River at Carson (WSC 08NN005) and Kettle River at Cascade (WSC 08NN006) indicated that flows at Carson were consistently about 58% of flows at Cascade. Therefore, it was decided to estimate design flows for the Kettle River from the town of Grand Forks to the upstream end of the study reach at Carson by multiplying design flows at Cascade by 0.60.

For the Granby River at Grand Forks, no instantaneous flood peak data were available. The instantaneous/daily flood peak ratio versus drainage area relationship for three nearby gauges was therefore investigated (see **Figure 4-4**). This investigation led to the decision to use a value of 1.17 for the instantaneous/daily flood peak ratio corresponding to the drainage area of 2050 km^2 for the Granby River at Grand Forks.

TABLE 4-1
CALCULATED FLOOD PEAKS[1]

RETURN PERIOD (Years)	STATION		
	KETTLE RIVER NEAR LAURIER		GRANBY RIVER AT GRAND FORKS
	INST m^3/s	DAILY[2] m^3/s	DAILY[3] m^3/s
10	797	765	326
20	853	821	344
50	918	887	363
100	963	932	375
200	1006	974	385

1 Flood peaks for all return periods indicated were estimated using the Pearson Type III distribution.

2 The data point representing the 1930 daily flood peak was omitted from the daily flood peak analysis as an outlier.

3 The data point representing 1931 daily flood peak was omitted from daily flood peak analyses as an outlier.

The values derived for the design flows to be used in the floodplain mapping analysis are presented in **Table 4-2**. **Figures 4-5** and **4-6** show the rating curves for the Kettle River near Laurier and the Granby River at Grand Forks, respectively, together with the derived design flows and maximum recorded flows.

TABLE 4-2
DESIGN FLOWS FOR STUDY REACHES

Location	Q_{200}		Q_{20}	
	Inst.	Daily	Inst.	Daily
	m^3/s	m^3/s	m^3/s	m^3/s
(1) Kettle River Main Stem				
(i) Granby River to u/s end of study reach	604	584	512	493
(ii) Christina Creek to just d/s of Granby River	1006	974	853	821
(iii) Laurier gauge to just d/s of Christina Creek	1006	974	853	821
(2) Granby River	450	385	402	344

5 Hydraulic Analyses

5.1 River Backwater Modelling

In the floodplain mapping study for the Kettle and Granby Rivers, the hydraulic backwater analysis was undertaken using the most recent version of HEC-2[1]. The model was originally developed by the U.S. Army Corps of Engineers, and it has been widely used in North America and elsewhere. Starting with a known flow and water level, the model proceeds upstream (subcritical flow) or downstream (supercritical flow), calculating the unknown water levels using the Standard Step Method.

The use of the Standard Step Method assumes the following:

- flow is steady
- flow is gradually varied
- flow is one-dimensional
- river channels have small slopes, say less than 10%.

The model accounts for energy losses due to friction (Manning's "n"), flow contraction and expansion, and bridge losses of various types.

5.2 Data Requirements

The following types of data are required for a typical HEC-2 water surface profile study for a natural river under flood flow conditions:

- detailed river channel cross-sections, which are extended to include the floodplain area based on topographic base mapping data;

- estimates of the lengths of the flow paths between cross-sections (left overbank, right overbank and channel);

- estimates of Manning's "n" for the different parts of the cross-sections (often three values are sufficient: left overbank, right overbank and channel);

- when the flow width changes appreciably, values of expansion and contraction coefficient (the HEC-2 manual provides guidance on the choice of these coefficients);

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[1] "HEC-2 Water Surface Profiles, Users Manual", Hydrologic Engineering Centre, U.S. Army Corps of Engineers, Davis, California, 1982.

- detailed descriptions of bridges within the reach of interest; and

- the flow values to be modelled and the starting elevation for the most downstream cross-section (for a subcritical run).

A total of 108 detailed river cross-sections were provided by B.C. Environment, Lands and Parks in HEC-2 ready format. Of these, 81 were on the Kettle River and 27 on the Granby River. The locations of the cross-sections were shown on the provided topographic maps (1:5,000 scale, 1-m contour interval). The cross-sections essentially covered the "within-banks" portion of the river; they were extended manually to include the overbank portions using topographic information obtained from the maps. Lengths of the flow paths between cross-sections were estimated using the same maps. Data for a total of eight bridges, provided by B.C. Environment, Lands and Parks, were also input to the model.

5.3 Model Calibration

Prior to using HEC-2 to model the floods of interest, it is important to calibrate the model with at least one recorded flood event. A successful calibration adds confidence to the water surface profiles estimated for other flows. The calibration exercise assists in achieving several important objectives:

- elimination of errors in the basic data files;
- proper representation of flow through the bridges; and
- estimation of Manning's 'n' for the channel portion[2] of the cross-sections.

The Manning's "n" values for the overbank portions of the cross-sections were available from the field reconnaissance. The within-banks values were estimated as part of the calibration exercise. Expansion and contraction coefficients were estimated using guidance provided in the HEC-2 manual.

In June 1991, the Survey Branch of B.C. Environment, Lands and Parks, undertook a water level and high water mark survey for the study reach. The survey was carried out over a period of two days. Water levels and high water marks were observed for a total of 33 cross-sections. The survey notes indicated that the high water marks were not always well defined (the peak of the freshet had occurred about one month earlier) and they suggested that the recorded water levels would be more relevant for calibration purposes.

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2 Since calibration events rarely involve overbank flow, it is usually necessary to estimate "n" values for the overbank areas using general guidelines only.

After removing errors from the data files and ensuring that proper representation of the flow was occurring throughout the study reaches, and particularly through bridges, the HEC-2 model was calibrated for the observed water levels of June 1991 as recorded by the surveyors. The first step was to establish the channel values of Manning's "n" that provided the best possible match between observed and calculated water levels. The range in Manning's "n" was 0.030 to 0.050. On the Granby River, the values increased generally upstream, as would be expected. The mean absolute difference between observed and calculated water levels was 0.10 m for the Kettle River and 0.09 m for the Granby River.

Using the model parameters as determined above, and the 1991 freshet peak flows, the HEC-2 model was run and the calculated water levels compared to the recorded high water marks. The results for the Granby River were reasonable, with a mean absolute difference of 0.13 m. However, the results for the Kettle River indicated that the model significantly overestimated the water levels by an average of 0.8 m. To obtain a reasonable match between the calculated and observed water levels, Manning's "n" had to be reduced in some reaches to as low as 0.02 — much lower than would be expected given channel characteristics. Discussions were then held with USGS staff, who operate the Kettle River at Laurier gauge. They confirmed that the spring freshet peak flow occurred on 22 May 1991; however, there was a secondary peak at the end of May which was about 2 ft (0.6 m) lower than that of May 22. If this secondary peak produced the high water marks that were identified by the surveyors, this would account for much of the discrepancy. After discussion with B.C. Environment staff, it was agreed that the calibration obtained using the observed water levels was acceptable and would form the basis for the production runs.

Figures 5-1 and **5-2** show the observed and calculated water levels for the calibration data, illustrating the generally satisfactory agreement between them. If the "n" values had been adjusted downwards to yield closer agreement with the high water mark data, the calculated water levels in Figure 5-1 would fall consistently below the observed levels.

5.4 Production Runs

Once the HEC-2 model was satisfactorily calibrated for the study reaches, it was ready for calculation of the flood profiles of interest:

- 200-year instantaneous
- 200-year daily
- 20-year instantaneous
- 20-year daily

The required flows for each of the above runs are presented in Table 4-2. The starting water level at the downstream end of the study reach was obtained using the rating curve for the Kettle River at Laurier gauging station. Upstream of the Cascade rapids, the starting level was calculated using the slope-area method, and for the Granby River the starting level was the appropriate calculated Kettle River level at the confluence.

Several adjustments were made to the model prior to accepting the results as being truly representative of the hydraulic conditions that would actually occur. In areas where the floodplain is very wide and flat, the model indicated a significant portion of the flow occurring on the floodplain. In reality, the water would primarily be ponded in these areas, with little flow being conveyed. The cross-sections used in the model were adjusted to reflect this likelihood.

The results of the analyses indicated that none of the bridges would be overtopped in the 200-year flood. It should be noted that these calculations assumed that no debris would choke the openings under the bridges. The presence of sufficient material to cause a partial blockage would cause higher water levels in the areas immediately upstream of the affected bridges. The flow profile computed for the 200-year daily discharge case is presented in **Figure 5–2.**

5.5 Sensitivity Analysis

The sensitivity analysis is intended to determine the sensitivity of the computed water levels to changes in the two most important parameters that were estimated: the design discharge and the hydraulic roughness (Manning's "n").

5.5.1 Sensitivity to Discharge

The design flows adopted for the study were based on some single-site flood frequency analyses and a limited amount of regionalization of the results. Potential sources of error include:

- flow measurement at the gauges used to estimate the rating curves, leading in turn to errors in peak flow estimates;
- choice of frequency distribution;
- fitting of the frequency distribution to the data; and
- regionalization of the results.

The 200-year daily discharge flood profiles were re-run with changes in discharge at all points of -10%, +10% and +20%. **Table 5-1** shows the resulting mean change in water level. The data show that, for a 20% increase in discharge, the mean water level increase is within the 0.6 m freeboard allowance used in calculating flood levels for floodplain delineation purposes.

5.5.2 Sensitivity to Manning's "n"

The Manning's "n" values for the overbank portions of the cross-sections were based on observation and tables of "n" values for different types of vegetation. The channel values were derived in the calibration. Some uncertainty exists in these estimates.

The 200-year daily discharge flood profile was re-run with changes in Manning's "n" of -10%, +10% and +20%. **Table 5-1** shows the resulting mean change in water level. The results show that sensitivity to changes in Manning's "n" is comparable to sensitivity to changes in discharge.

5.6 Floodplain Mapping

The Terms of Reference for the present study called for the 200-year floodplain to be delineated as the maximum of:

(a) 200-year instantaneous water level plus 0.3 m freeboard
(b) 200-year daily water level plus 0.6 m freeboard

It was found that the 200-year daily level +0.6 m dominated over the entire study reach. The calculated 200-year and 20-year flood levels, including freeboard, are presented in **Appendix B**; the 200-year floodplain limits, including freeboard, are delineated on the mylar base maps of the study area.

The following points should be noted regarding the manner in which the floodplain was delineated:

(a) In areas where dykes exist, whether the dyke was estimated to be capable of containing the flow or not, the floodplain was delineated as if the dyke was not present. However, dykes were assumed to be capable of restricting conveyance of flows to the dyked channel. This is in accordance with Ministry policy (see Note 4 on the floodplain maps).

(b) Strictly defining floodplain limits on the basis of hydraulic calculations without considering topographic limitations can produce floodplain maps that are impractical to administer, based on B.C. Environment, Lands and Parks' experience in the Flood Damage Reduction Program. For example, a gentle rise in the middle of a floodplain could lead to the definition of a low-lying "island" in the floodplain that should, for practical purposes, be included in the floodplain. Similarly, a "backslope" area may be nominally excluded from the hydraulically defined floodplain, but it may be subject to flooding from a tributary that was not explicitly included in the hydraulic analysis. In keeping with B.C. Environment's practice, these considerations led to the definition of the floodplain limit in some areas based on engineering judgement, together with the results of the hydraulic analysis. In all areas, however, the water levels estimated from the hydraulic analyses are defined on the isograms shown on the maps.

(c) The hydraulic interaction between the Kettle River and Christina Lake is of interest. It had been reported by local observers that on occasion reverse flow occurs between the Kettle River and Christina Lake. This possibility is borne out by the hydraulic analyses. The occurrence of reverse flow will require a high stage in the Kettle River and will depend on the relative timing of the floods in the Kettle River and into Christina Lake. The floodplain limits for Christina Creek have been delineated on the maps by interpolating between the Christina Lake flood level[3] and that for the Kettle River.

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3 The designated flood level (including freeboard) for Christina Lake is 448.2 m. See "A Design Brief on the Floodplain Mapping Study, Christina Lake, An Overview of the Studies Undertaken to Produce Floodplain Mapping for Christina Lake", R.W. Nichols, Senior Hydraulic Engineer, Special Projects Section, November 1990. This report provides details regarding calculation of the Christina Lake flood levels.

TABLE 5-1
RESULTS OF SENSITIVITY ANALYSIS

ITEM	(a) Kettle River	(b) Granby River	(c) Combined
	Mean Increase in Water Level[1] (m)		
A. DISCHARGE			
-10%	-0.24	-0.15	-0.22
+10%	0.23	0.13	0.21
+20%	0.44	0.27	0.40
B. MANNING'S "n"			
-10%	-0.22	-0.14	-0.20
+10%	0.21	0.13	0.19
+20%	0.40	0.26	0.37

1 Compared to 200-year daily discharge run.

6 Recommendations

The maps (Drawings 90-34, Sheets 1 to 9) that were prepared together with this Design Brief depict the 200-year floodplain limits for the study reaches, based on technical standards established by B.C. Environment, Lands and Parks. It is recommended that these maps be designated under the terms of the joint Canada-British Columbia Floodplain Mapping Agreement.

Hydraulic calculations to define the floodplain limits have been undertaken in a careful and rigorous manner. However, some uncertainties do exist. For example, should bridge openings or narrow constrictions in the channel become clogged with debris, the water level immediately upstream of such blockages may surcharge to greater values than those indicated by the hydraulic analyses. The assumption of open channel flow conditions is in accordance with B.C. Environment, Lands and Parks practice.

The floodplain maps have been prepared based on the physical conditions as they existed in 1991. If any significant changes occur (e.g. construction of new bridges, filling in of floodplains to accommodate new development), the local authorities should report such changes to B.C. Environment, Lands and Parks, who are charged with the responsibility of monitoring the maps.

Figures

ACRES

FIG.1–1

B.C. ENVIRONMENT
FLOOD PLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
LOCATION MAP

ACRES

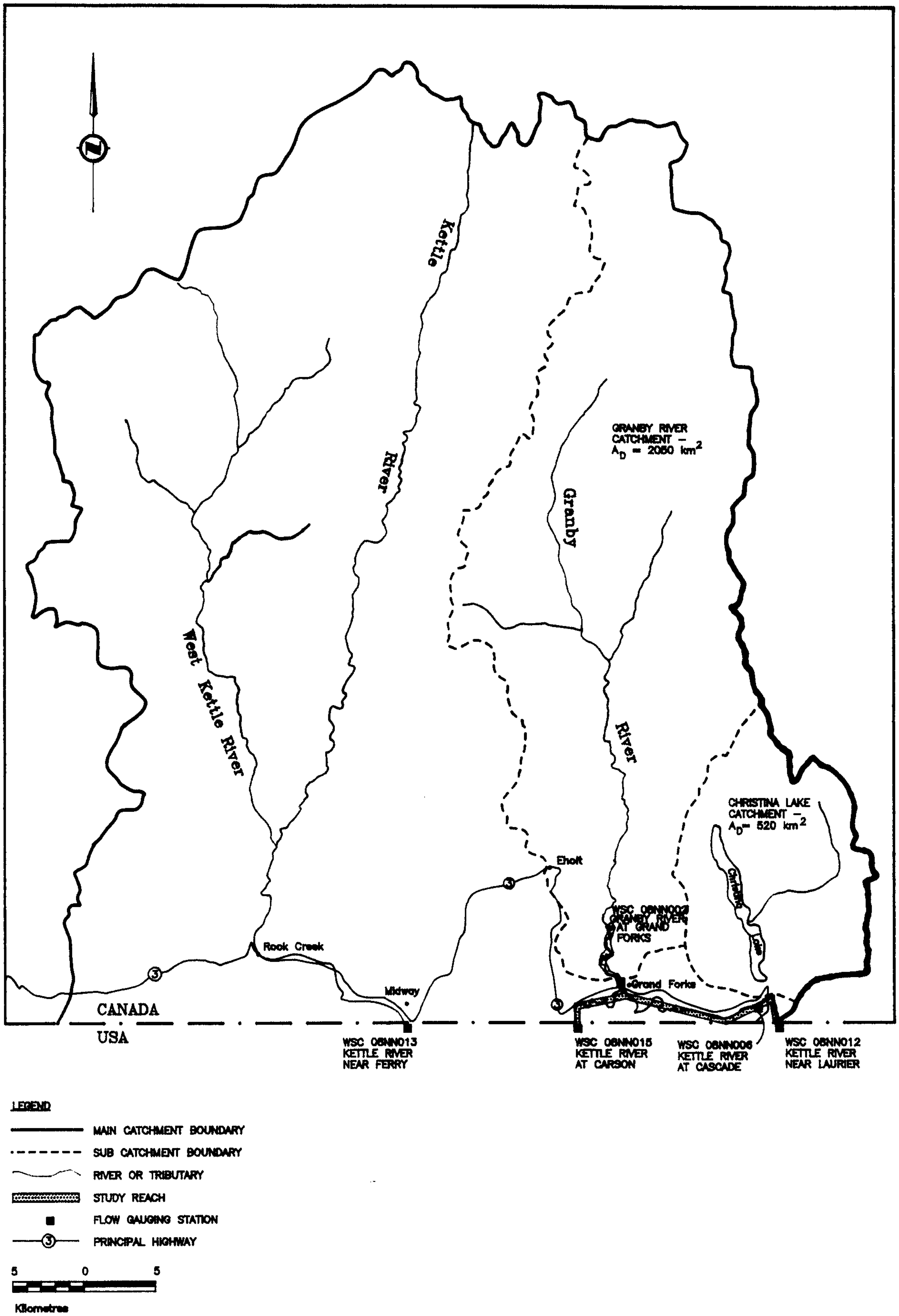


FIG. 2–1

B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM – KETTLE AND GRANBY RIVERS
STUDY AREA

ACRES

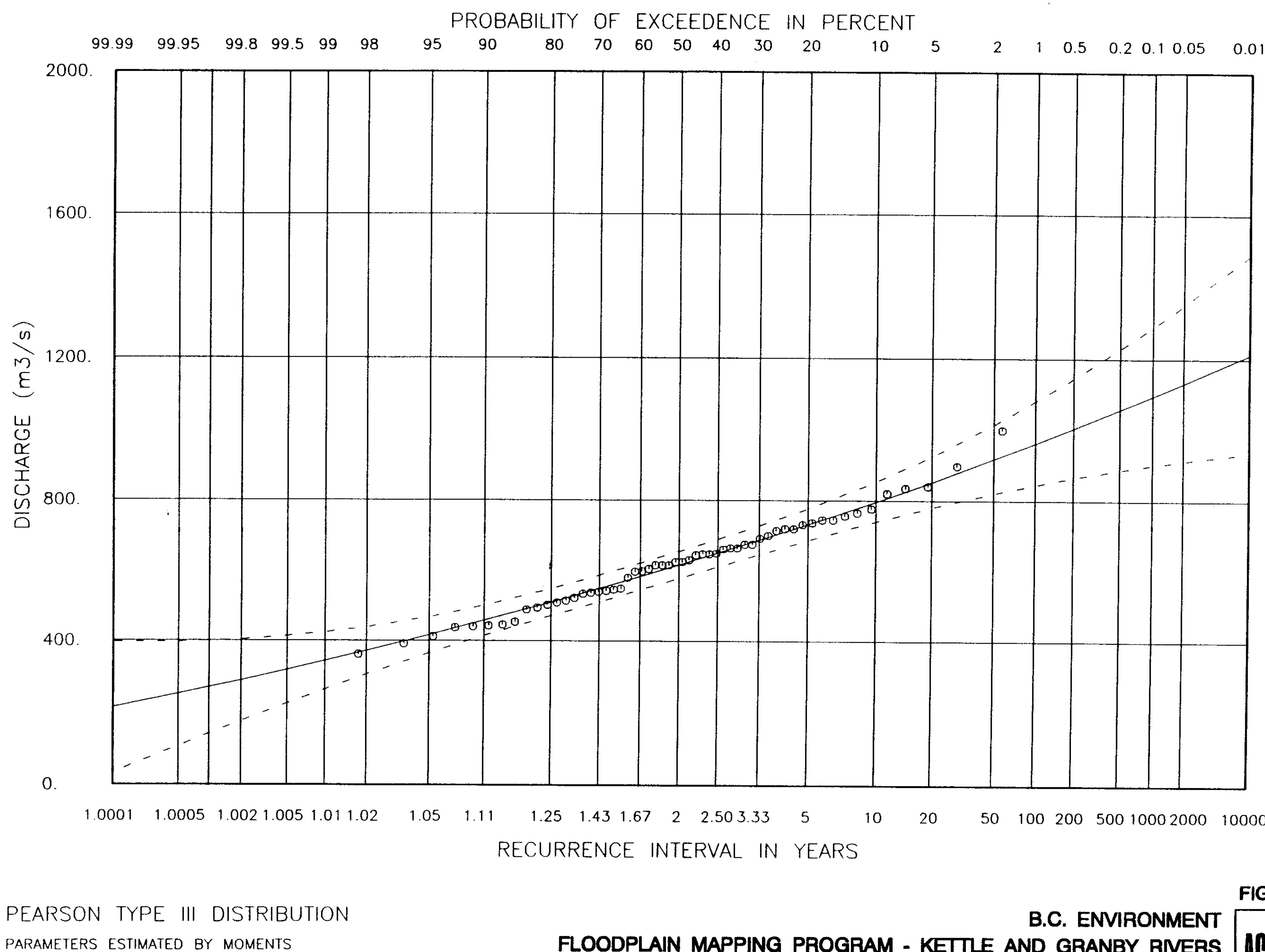


FIG 4-1

B.C. ENVIRONMENT

FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS

KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

ACRES

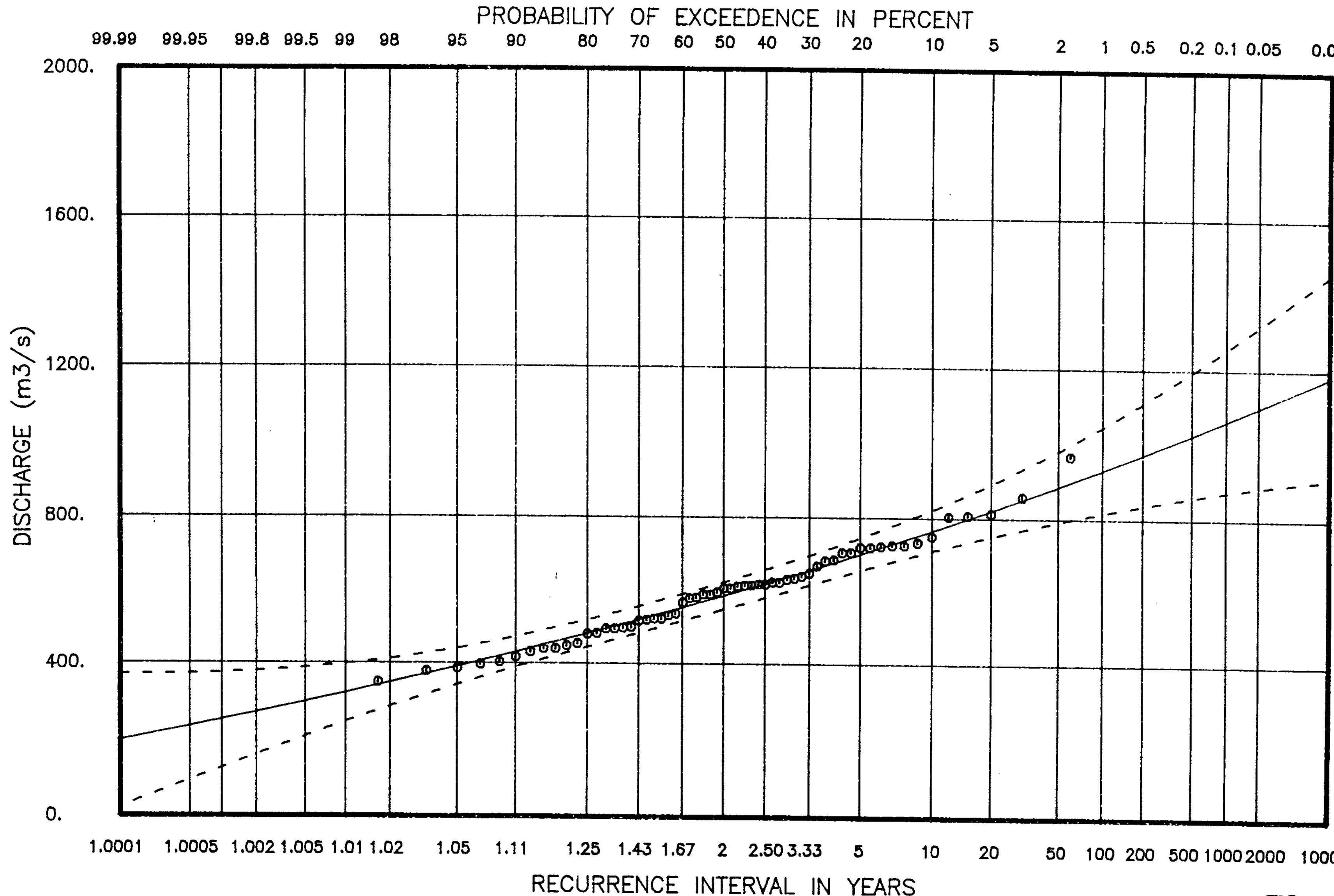


FIG 4-2

B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
FLOOD FREQUENCY DISTRIBUTION - STATION 08NN012 - DAILY PEAK FLOWS

ACRES

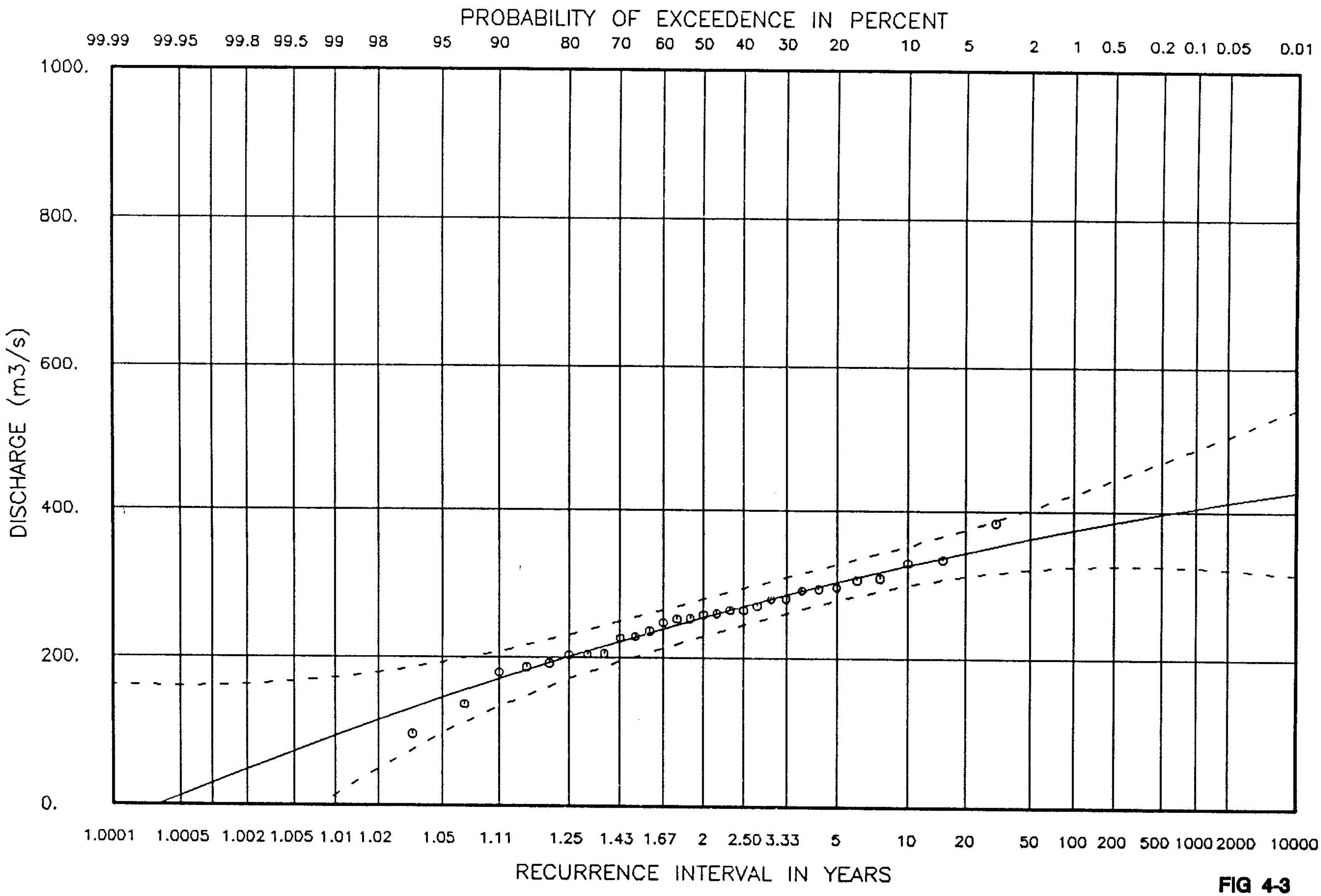
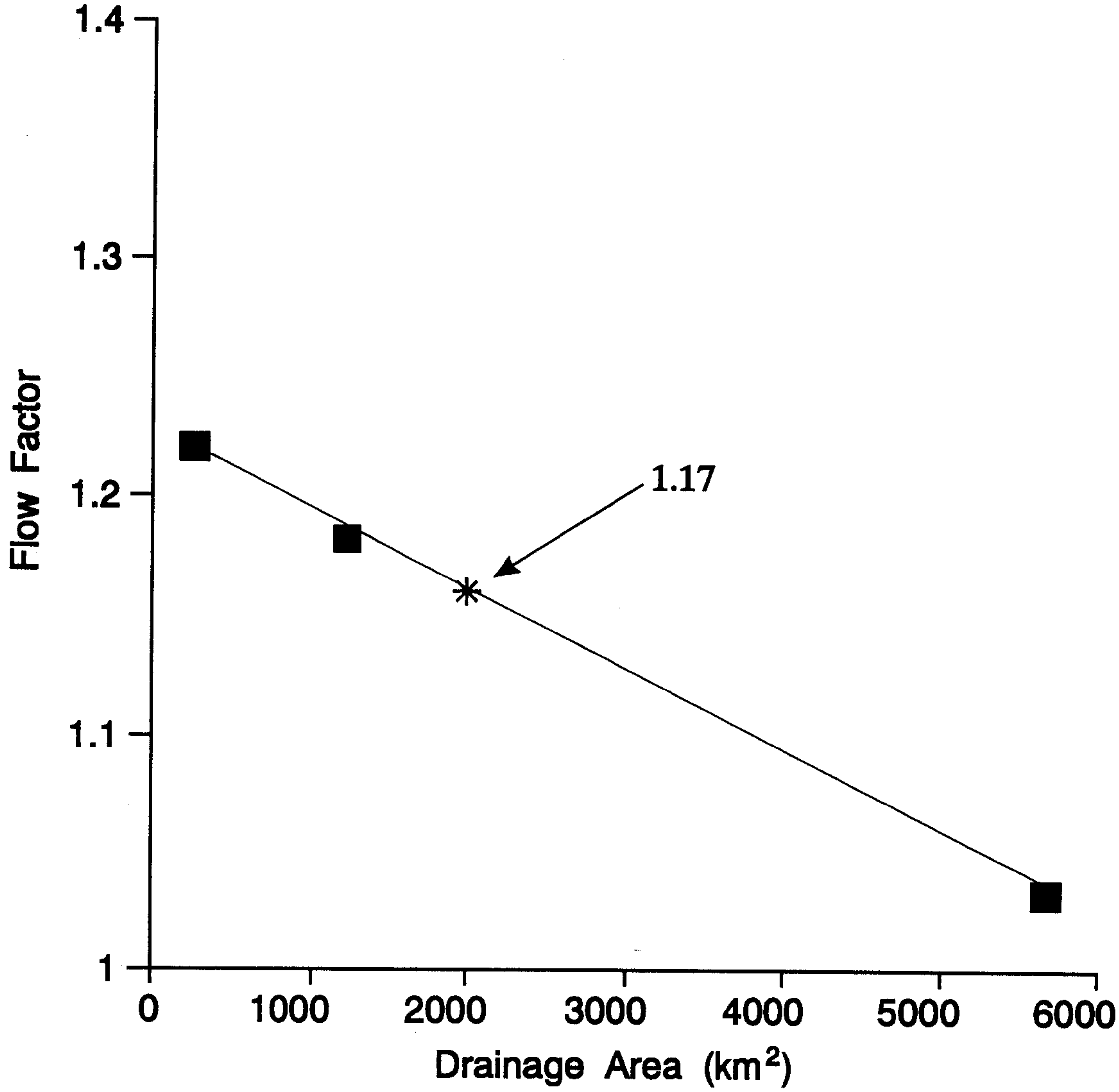


FIG 4-3

B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
FLOOD FREQUENCY DISTRIBUTION - STATION 08NN002 - DAILY PEAK FLOWS

ACRES



$$\text{Flow Factor} = \frac{\text{Instantaneous Peak}}{\text{Daily Peak Flow}}$$

FIG 4-4
B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
INSTANTANEOUS FLOOD PEAK RATIO VERSUS DRAINAGE AREA

ACRES

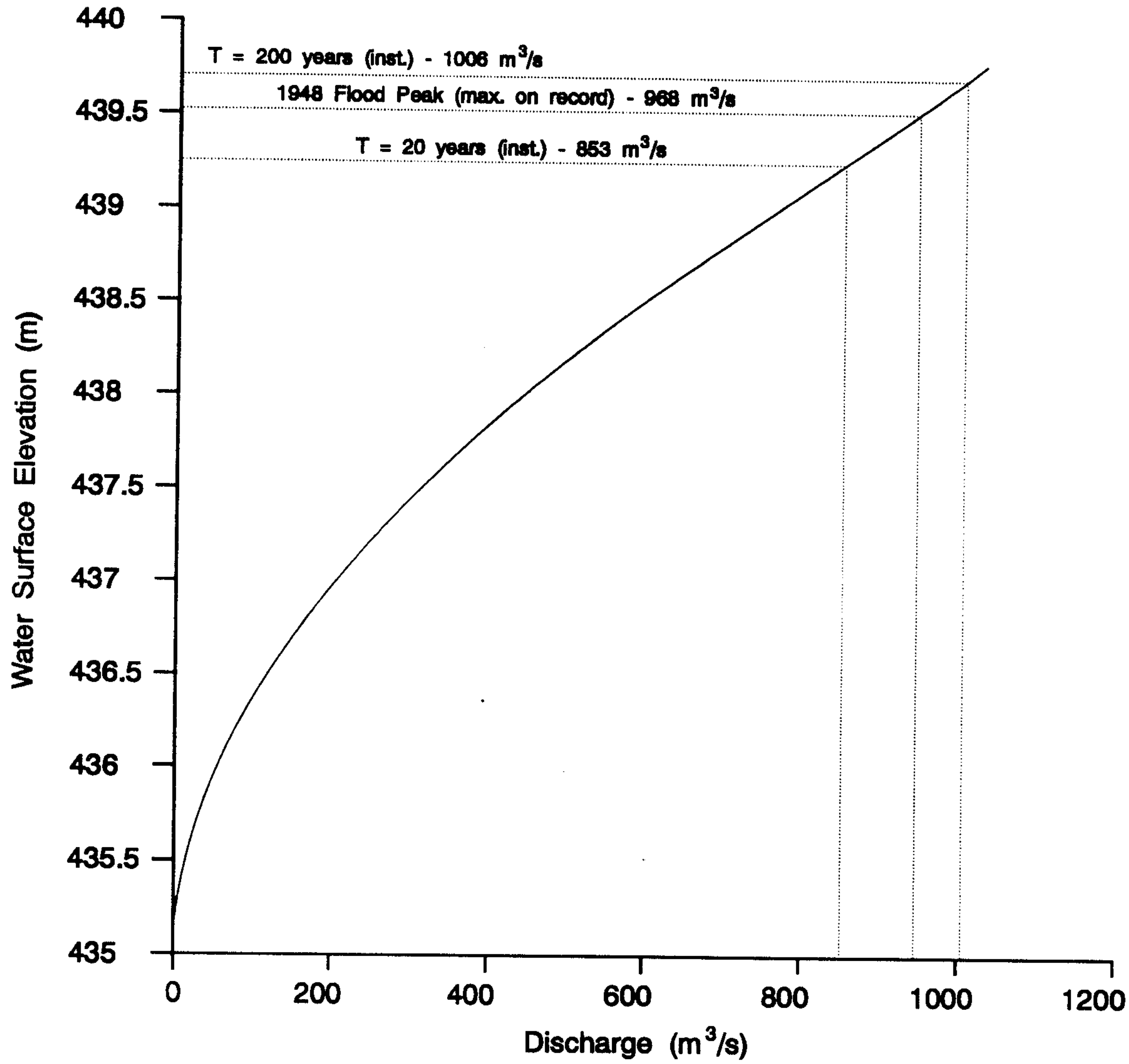


FIG 4-5

B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
RATING CURVE - STATION 08NN012

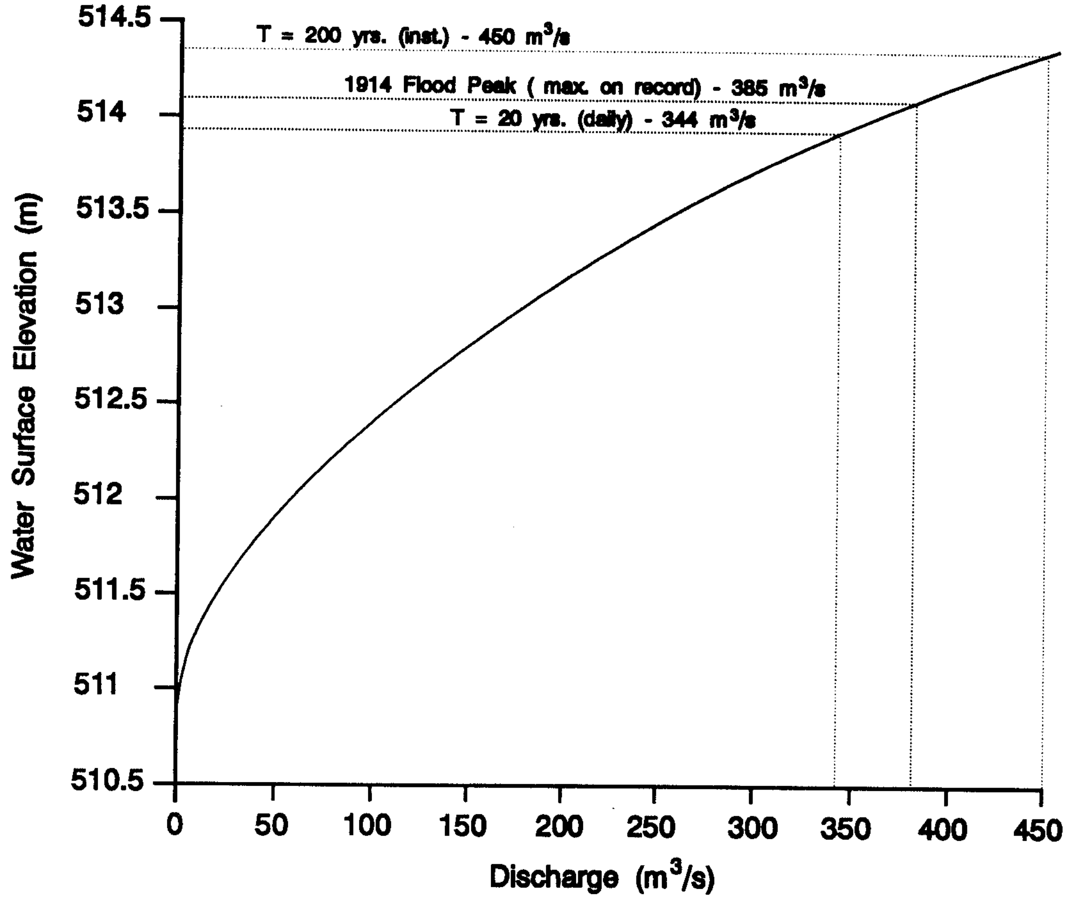


FIG 4-6

B.C. ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
RATING CURVE - STATION 08NN002

ACRES

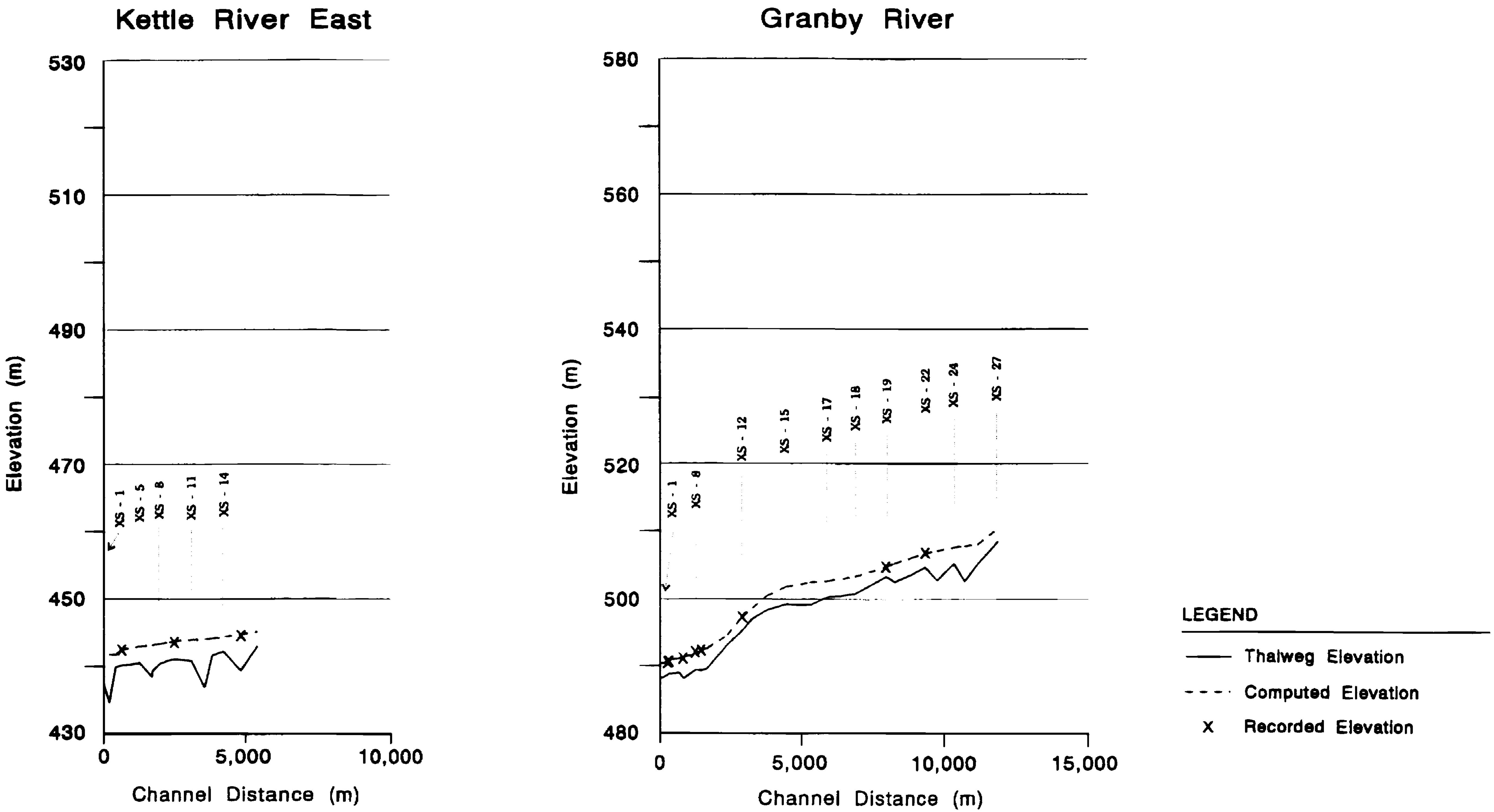


Fig. 5-1

BC ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
CALIBRATION PROFILE

ACRES

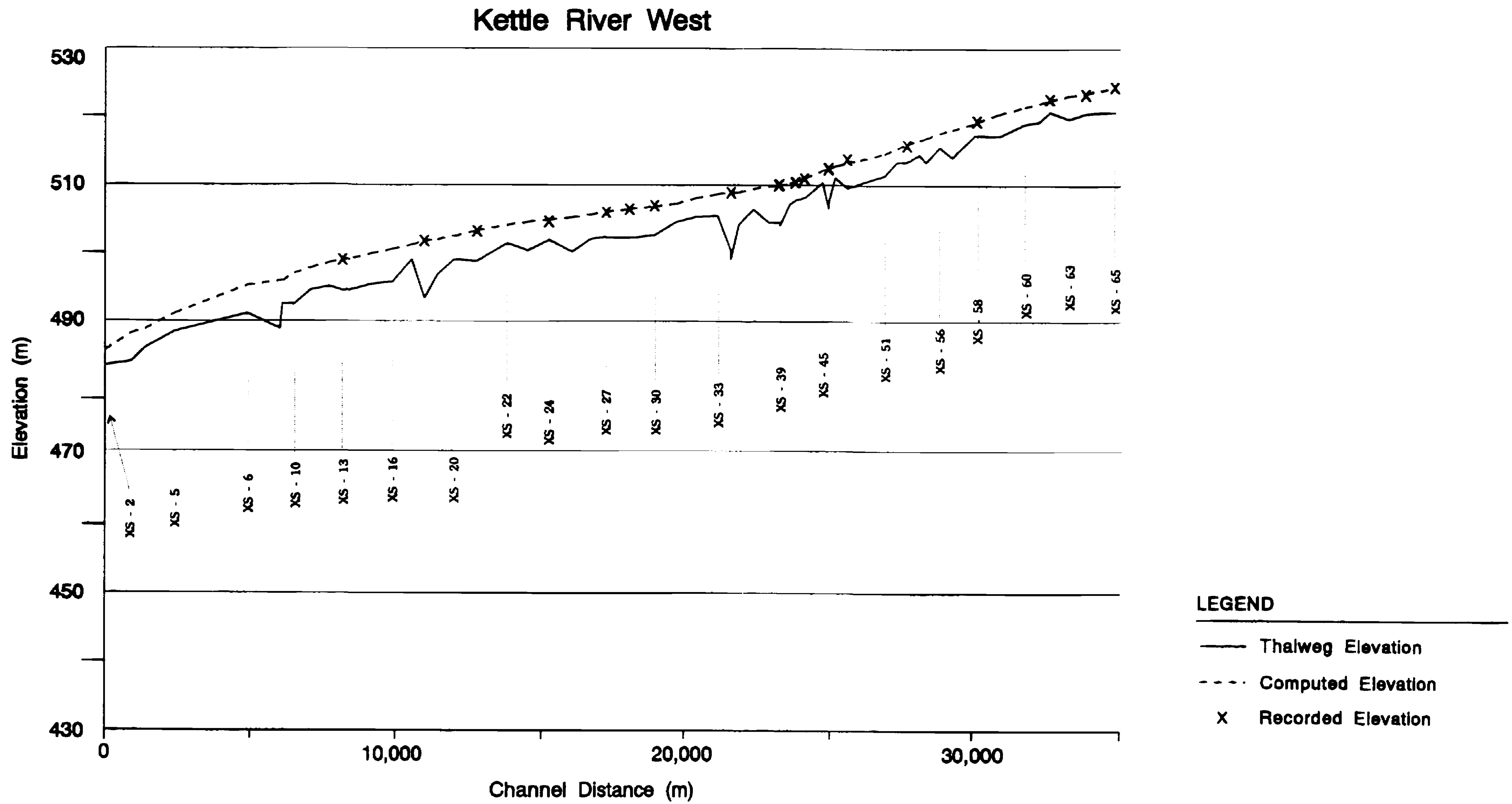


Fig. 5-2

BC ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
CALIBRATION PROFILE

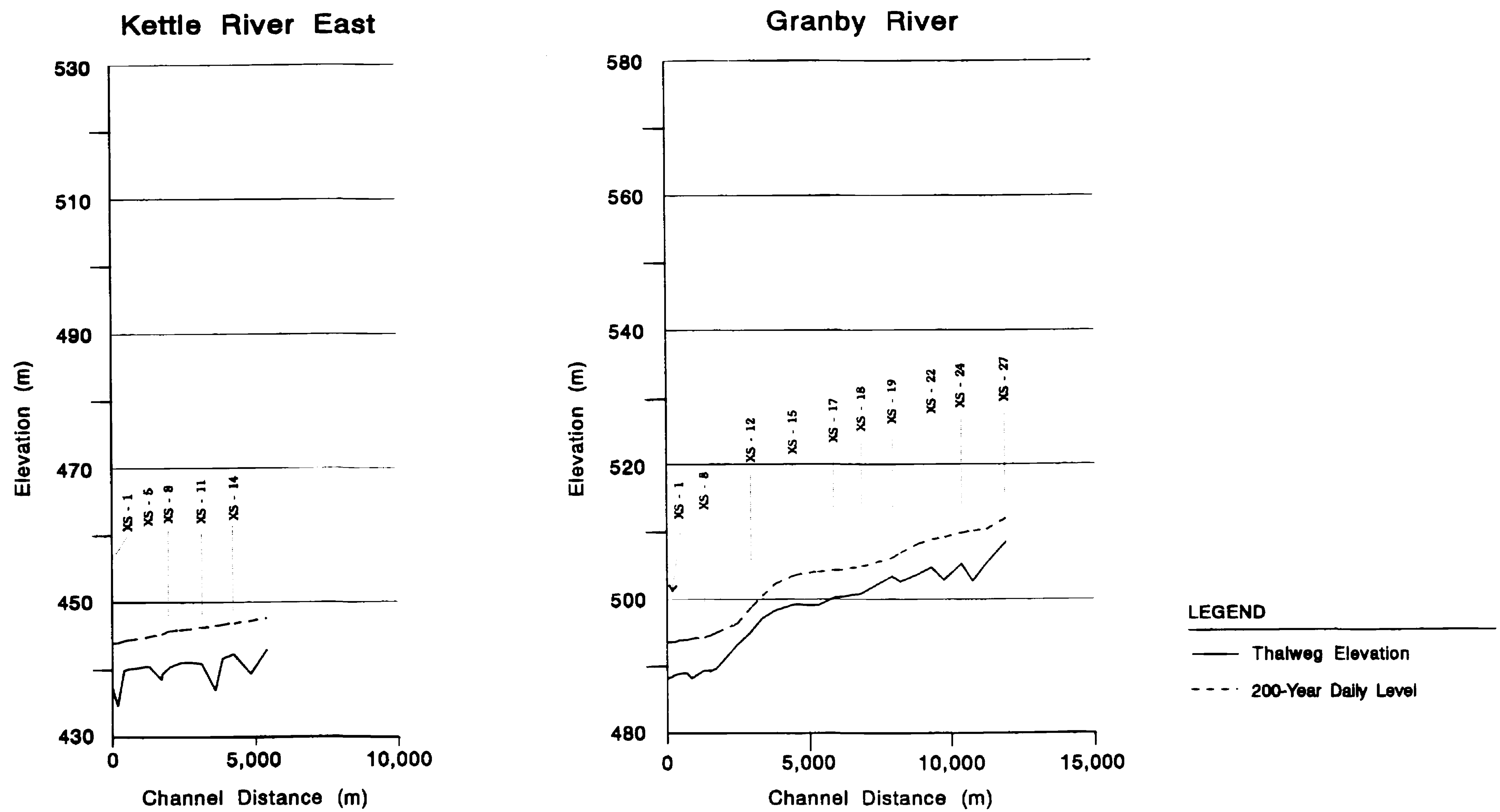


Fig. 5-3

BC ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
200-YEAR FLOOD PROFILE

ACRES

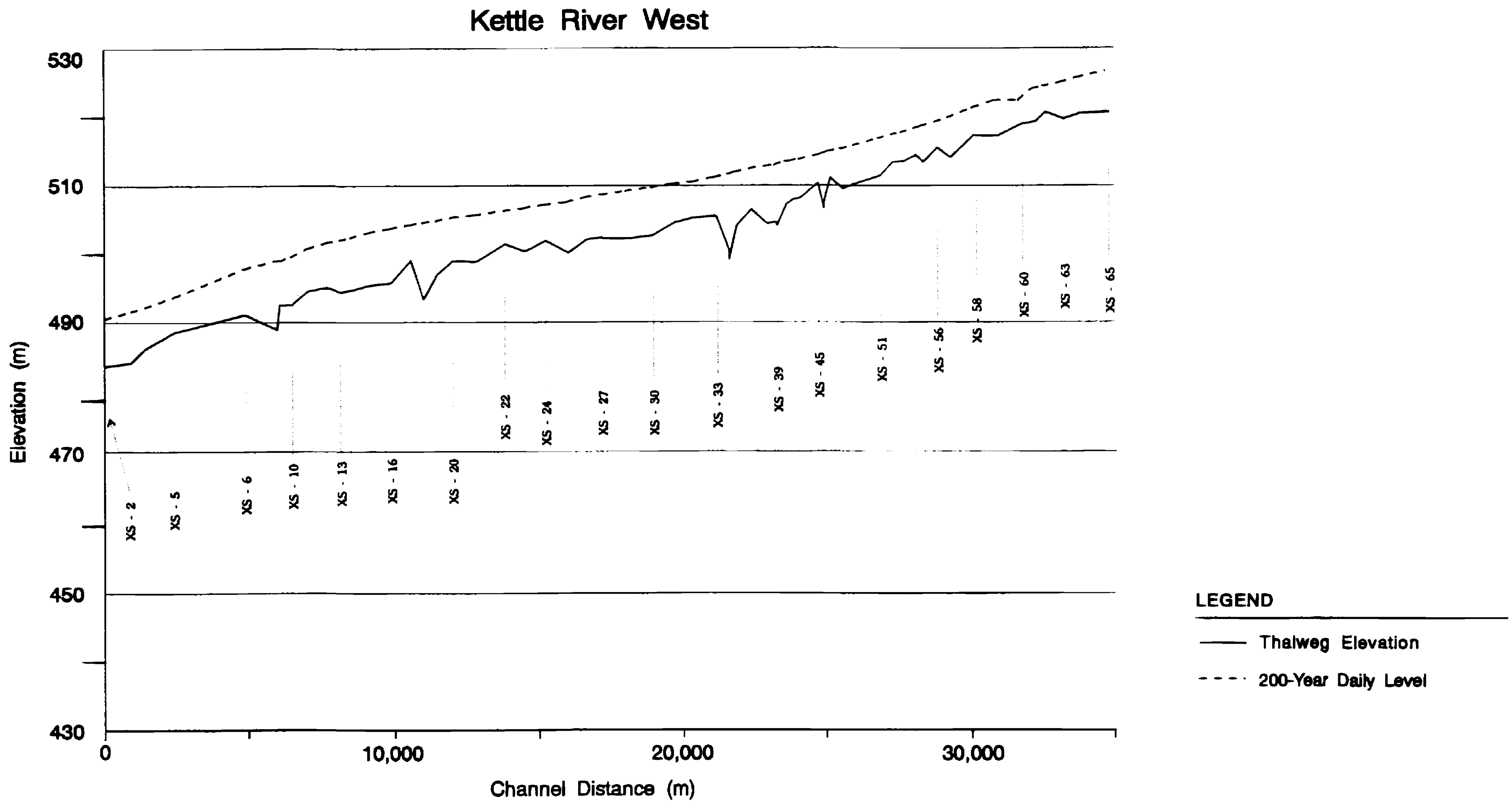
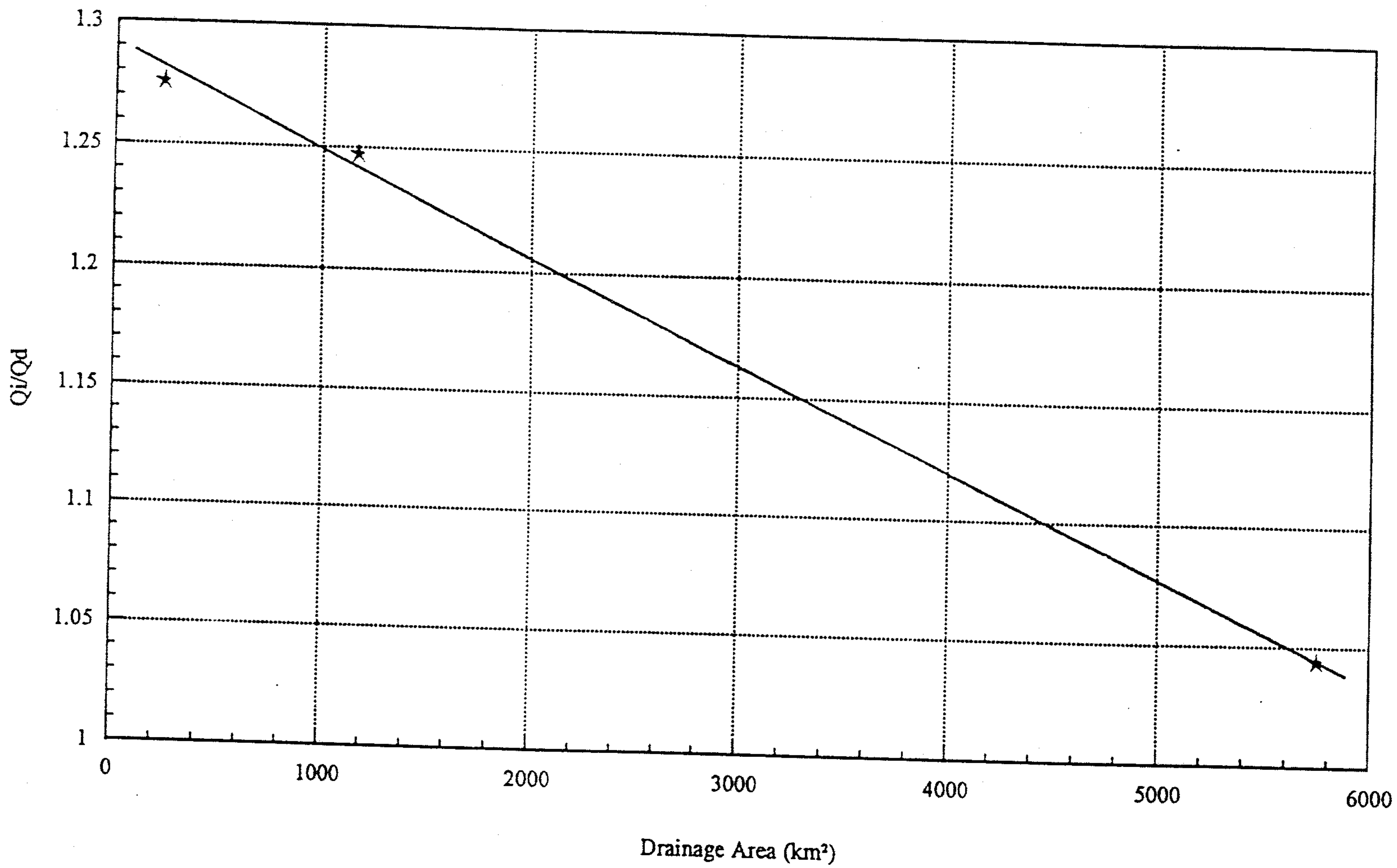


Fig. 5-4

BC ENVIRONMENT
FLOODPLAIN MAPPING PROGRAM - KETTLE AND GRANBY RIVERS
200-YEAR FLOOD PROFILE

Appendix A
Flood Frequency Analysis

ACRES



Kettle River Flood Study
Qi/Qd vs. Drainage Area for T=20

KETTLE RIVER NEAR LAURIER
(DAILY - FULL DATA SET)

ACRES

KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE FULL DATA SET

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1930	206.	968.	1	.016	61.000
1931	396.	858.	2	.033	30.500
1932	535.	813.	3	.049	20.333
1933	648.	807.	4	.066	15.250
1934	589.	804.	5	.082	12.200
1935	521.	750.	6	.098	10.167
1936	530.	733.	7	.115	8.714
1937	402.	725.	8	.131	7.625
1938	606.	725.	9	.148	6.778
1939	453.	722.	10	.164	6.100
1940	479.	719.	11	.180	5.545
1941	430.	719.	12	.197	5.083
1942	733.	705.	13	.213	4.692
1943	377.	705.	14	.230	4.357
1944	348.	685.	15	.246	4.067
1945	614.	682.	16	.262	3.813
1946	623.	668.	17	.279	3.588
1947	447.	648.	18	.295	3.389
1948	968.	640.	19	.311	3.211
1949	705.	634.	20	.328	3.050
1950	566.	631.	21	.344	2.905
1951	725.	623.	22	.361	2.773
1952	682.	623.	23	.377	2.652
1953	578.	617.	24	.393	2.542
1954	750.	617.	25	.410	2.440
1955	668.	614.	26	.426	2.346
1956	858.	614.	27	.443	2.259
1957	705.	612.	28	.459	2.179
1958	614.	606.	29	.475	2.103
1959	595.	606.	30	.492	2.033
1960	521.	595.	31	.508	1.968
1961	719.	589.	32	.525	1.906
1962	439.	589.	33	.541	1.848
1963	496.	580.	34	.557	1.794
1964	606.	578.	35	.574	1.743
1965	493.	566.	36	.590	1.694
1966	385.	535.	37	.607	1.649
1967	640.	530.	38	.623	1.605
1968	589.	521.	39	.639	1.564
1969	722.	521.	40	.656	1.525
1970	416.	518.	41	.672	1.488
1971	804.	515.	42	.689	1.452
1972	813.	498.	43	.705	1.419
1973	493.	496.	44	.721	1.386
1974	719.	493.	45	.738	1.356
1975	617.	493.	46	.754	1.326
1976	634.	481.	47	.770	1.298
1977	439.	479.	48	.787	1.271
1978	515.	453.	49	.803	1.245
1979	481.	447.	50	.820	1.220
1980	685.	439.	51	.836	1.196
1981	617.	439.	52	.852	1.173
1982	623.	430.	53	.869	1.151
1983	807.	416.	54	.885	1.130
1984	631.	402.	55	.902	1.109

KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1985	580.	396.	56	.918	1.089
1986	725.	385.	57	.934	1.070
1987	612.	377.	58	.951	1.052
1988	518.	348.	59	.967	1.034
1989	498.	206.	60	.984	1.017

STATISTICS OF DATA SERIES

SAMPLE SIZE = 60

MEAN =	586.5	MIN. =	206.0	MAX. =	968.0
S.D. =	139.6	C.S. =	.0526	C.K. =	3.4066

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	6.3433	MIN. =	5.3279	MAX. =	6.8752
S.D. =	.2600	C.S. =	-1.0143	C.K. =	5.6671

NORMAL DISTRIBUTION

MEAN = 586.467
S.D. = 139.629

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	301.842	226.509	151.176	16.546
1.050	409.502	353.461	297.419	7.888
1.250	511.137	468.976	426.815	4.473
2.000	622.697	586.465	550.233	3.074
5.000	746.118	703.957	661.797	2.980
10.000	814.331	765.432	716.533	3.178
20.000	871.768	816.185	760.602	3.388
50.000	937.185	873.290	809.396	3.640
100.000	981.112	911.353	841.593	3.808
200.000	1021.477	946.183	870.889	3.959
500.000	1070.556	988.389	906.222	4.136
1000.000	1105.068	1017.993	930.917	4.256
10000.000	1207.704	1105.764	1003.823	4.587

LOG NORMAL DISTRIBUTION

MEAN = 6.343
S.D. = .260

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	334.700	290.888	252.811	6.980
1.050	409.009	368.473	331.955	5.192
1.250	494.238	456.916	422.412	3.906
2.000	608.369	568.673	531.566	3.357
5.000	765.581	707.769	654.322	3.906
10.000	869.286	793.620	724.541	4.531
20.000	967.427	872.293	786.514	5.150
50.000	1092.769	970.174	861.333	5.920
100.000	1185.925	1041.442	914.561	6.464
200.000	1278.513	1111.236	965.845	6.976
500.000	1400.879	1202.106	1031.537	7.613
1000.000	1493.875	1270.242	1080.087	8.068
10000.000	1808.537	1495.811	1237.161	9.445

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = 3.673
BETA = 1445.470
GAMMA = -4722.135

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	342.166	233.414	124.663	5410.544
1.050	415.801	355.665	295.528	2991.866
1.250	510.422	468.635	426.847	2078.988
2.000	624.383	585.241	546.098	1947.386
5.000	746.554	703.584	660.614	2137.830
10.000	817.193	766.199	715.205	2537.024
20.000	881.121	818.255	755.388	3127.683
50.000	959.590	877.218	794.847	4098.076
100.000	1015.642	916.751	817.859	4919.973
200.000	1069.463	953.089	836.716	5789.727
500.000	1137.817	997.331	856.845	6989.345
1000.000	1187.767	1028.500	869.232	7923.749
10000.000	1345.371	1121.575	897.779	11134.127

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR PEARSON III

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.132
BETA = 3.888
GAMMA = 6.856

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	351.658	227.507	147.187	21.666
1.050	418.635	345.883	285.775	9.497
1.250	516.627	467.702	423.409	4.950
2.000	641.982	593.490	548.661	3.907
5.000	749.544	708.922	670.501	2.772
10.000	809.280	761.740	716.992	3.012
20.000	871.656	800.457	735.073	4.239
50.000	952.255	838.297	737.977	6.341
100.000	1009.642	860.057	732.635	7.978
200.000	1063.674	877.549	723.993	9.570
500.000	1130.085	895.716	709.953	11.563
1000.000	1176.671	906.551	698.440	12.975
10000.000	1310.055	930.212	660.502	17.035

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.079
BETA = 10.223
GAMMA = 7.154

MEAN = 6.343
S.D. = .253
C.S. = -.626

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	336.007	254.832	193.268	13.758
1.050	414.722	357.275	307.785	7.418
1.250	507.989	464.842	425.361	4.416
2.000	625.085	583.735	545.120	3.405
5.000	752.484	706.401	663.141	3.144
10.000	821.591	769.954	721.563	3.229
20.000	881.980	821.249	764.700	3.549
50.000	955.572	877.066	805.009	4.265
100.000	1008.380	912.859	826.386	4.951
200.000	1059.301	944.459	842.068	5.709
500.000	1124.124	981.107	856.286	6.770
1000.000	1171.479	1005.650	863.295	7.594
10000.000	1319.813	1072.269	871.154	10.334

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

A = -7377.252
M = 8.982
S = .018

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	370.996	233.380	146.810	23.061
1.050	421.209	355.665	300.320	8.415
1.250	512.328	468.642	428.680	4.434
2.000	625.717	585.241	547.384	3.327
5.000	747.903	703.577	661.878	3.040
10.000	818.894	766.193	716.883	3.309
20.000	883.586	818.253	757.750	3.822
50.000	963.748	877.226	798.473	4.680
100.000	1021.587	916.770	822.707	5.386
200.000	1077.616	953.122	843.010	6.108
500.000	1149.512	997.385	865.390	7.063
1000.000	1202.600	1028.571	879.726	7.777
10000.000	1373.353	1121.720	916.192	10.069

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = -8673.362
M = 9.133
S = .015

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	370.970	232.448	145.651	23.256
1.050	421.195	355.377	299.843	8.454-
1.250	512.485	468.706	428.666	4.443
2.000	625.894	585.430	547.582	3.325
5.000	747.883	703.648	662.030	3.033
10.000	818.627	766.103	716.949	3.299
20.000	883.017	817.978	757.730	3.806
50.000	962.716	876.687	798.346	4.657
100.000	1020.169	916.020	822.504	5.357
200.000	1075.783	952.156	842.735	6.073
500.000	1147.094	996.125	865.025	7.021
1000.000	1199.712	1027.085	879.298	7.729
10000.000	1368.750	1119.462	915.577	10.002

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

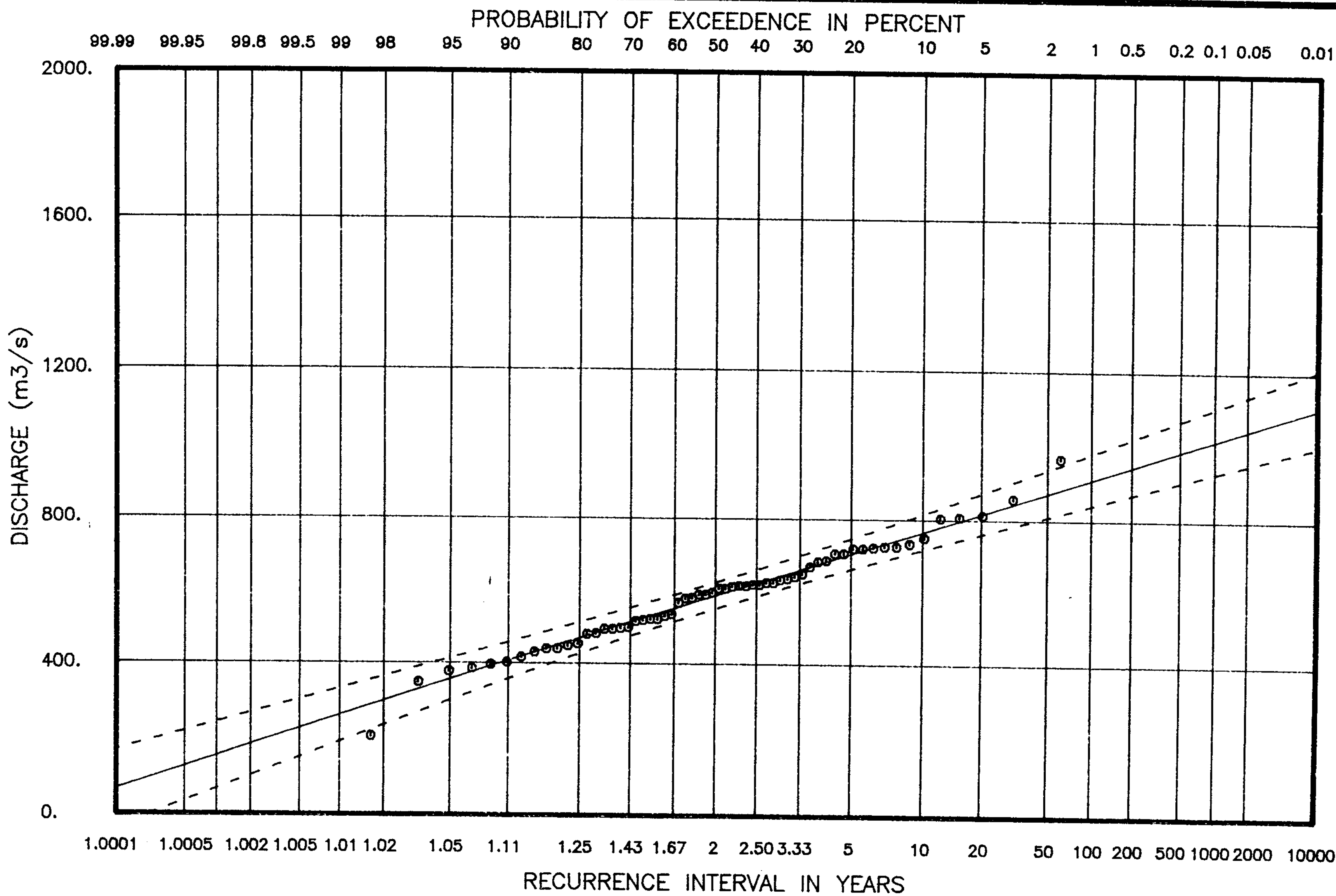
A = .009
U = 523.634

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	397.794	341.998	286.203	8.117
1.050	445.389	402.421	359.454	5.312
1.250	504.345	471.823	439.300	3.429
2.000	596.842	563.537	530.232	2.940
5.000	742.997	686.936	630.875	4.060
10.000	844.329	768.637	692.944	4.899
20.000	942.602	847.006	751.410	5.615
50.000	1070.519	948.447	826.376	6.403
100.000	1166.654	1024.463	882.273	6.905
200.000	1262.578	1100.202	937.826	7.343
500.000	1389.269	1200.125	1010.980	7.841
1000.000	1485.090	1275.644	1066.197	8.169
10000.000	1803.489	1526.381	1249.273	9.032

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .007
U = 517.461

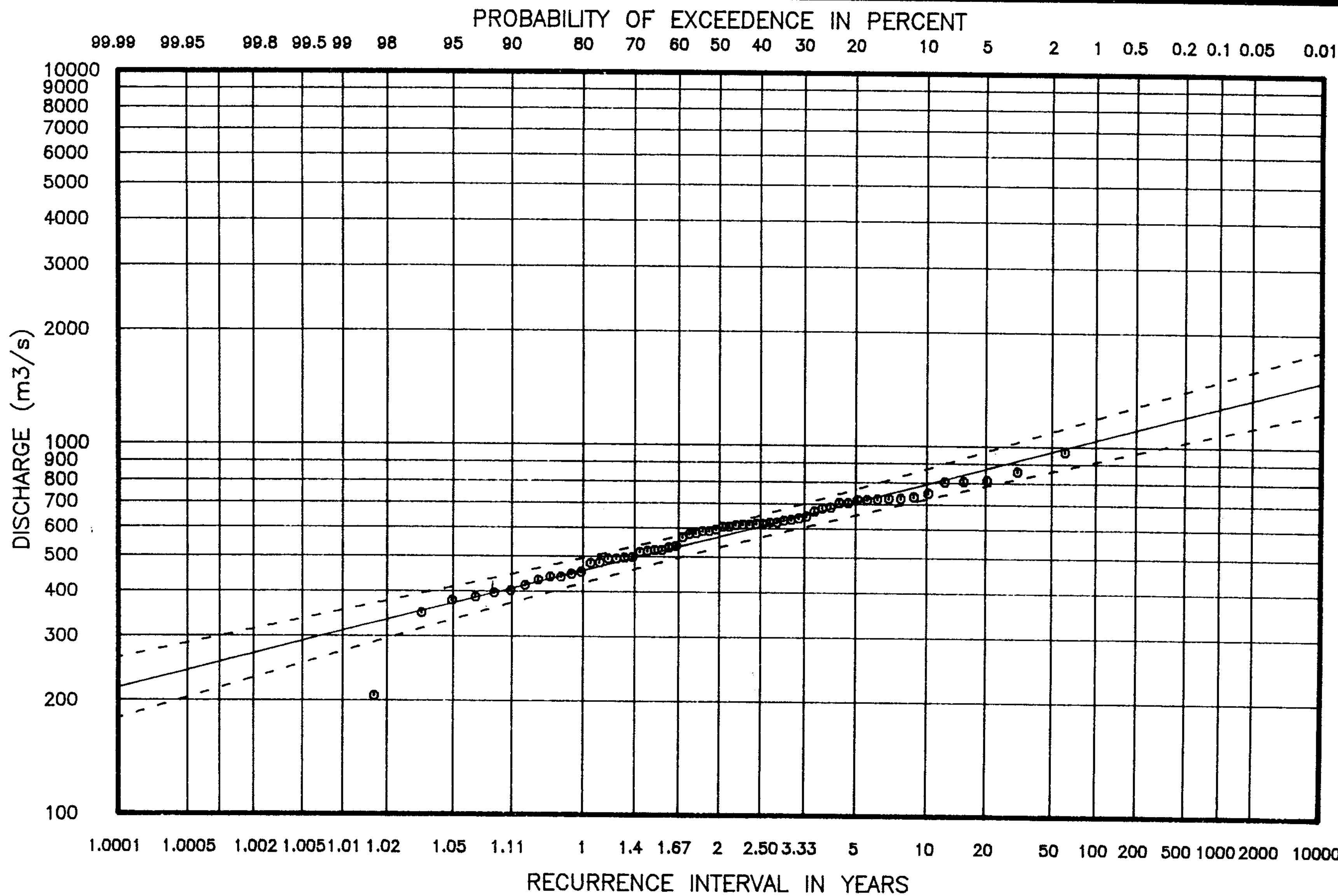
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	335.635	285.299	234.963	8.778
1.050	403.541	362.530	321.518	5.628
1.250	487.379	451.237	415.096	3.985
2.000	610.865	568.464	526.063	3.711
5.000	791.263	726.190	661.117	4.458
10.000	914.095	830.618	747.141	5.000
20.000	1032.915	930.788	828.661	5.459
50.000	1187.452	1060.448	933.443	5.958
100.000	1303.568	1157.610	1011.651	6.273
200.000	1419.424	1254.417	1089.410	6.544
500.000	1572.441	1382.136	1191.830	6.850
1000.000	1688.175	1478.662	1269.149	7.049
10000.000	2072.762	1799.149	1525.536	7.566



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

NORMAL DISTRIBUTION

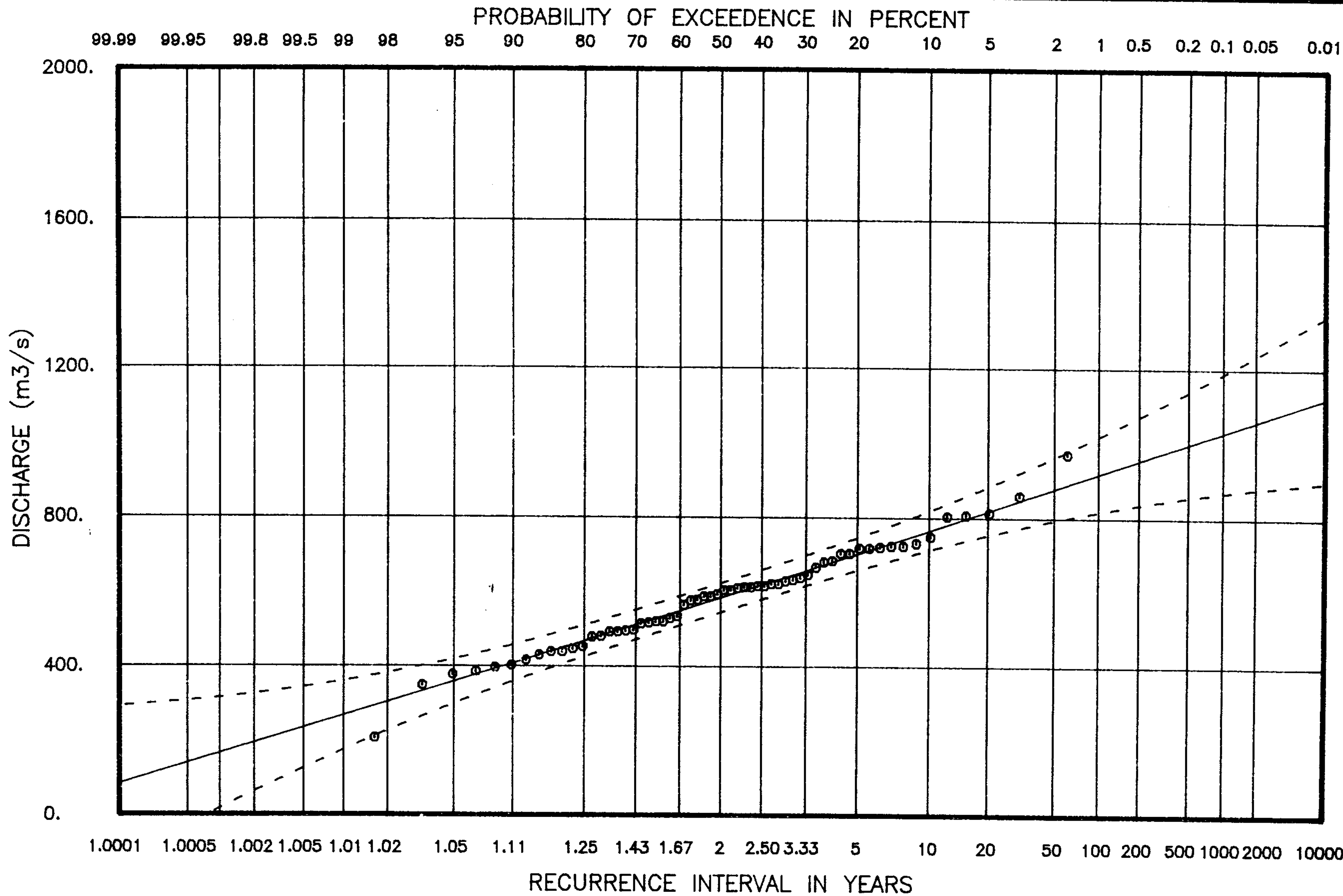
ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG NORMAL DISTRIBUTION

ACRES

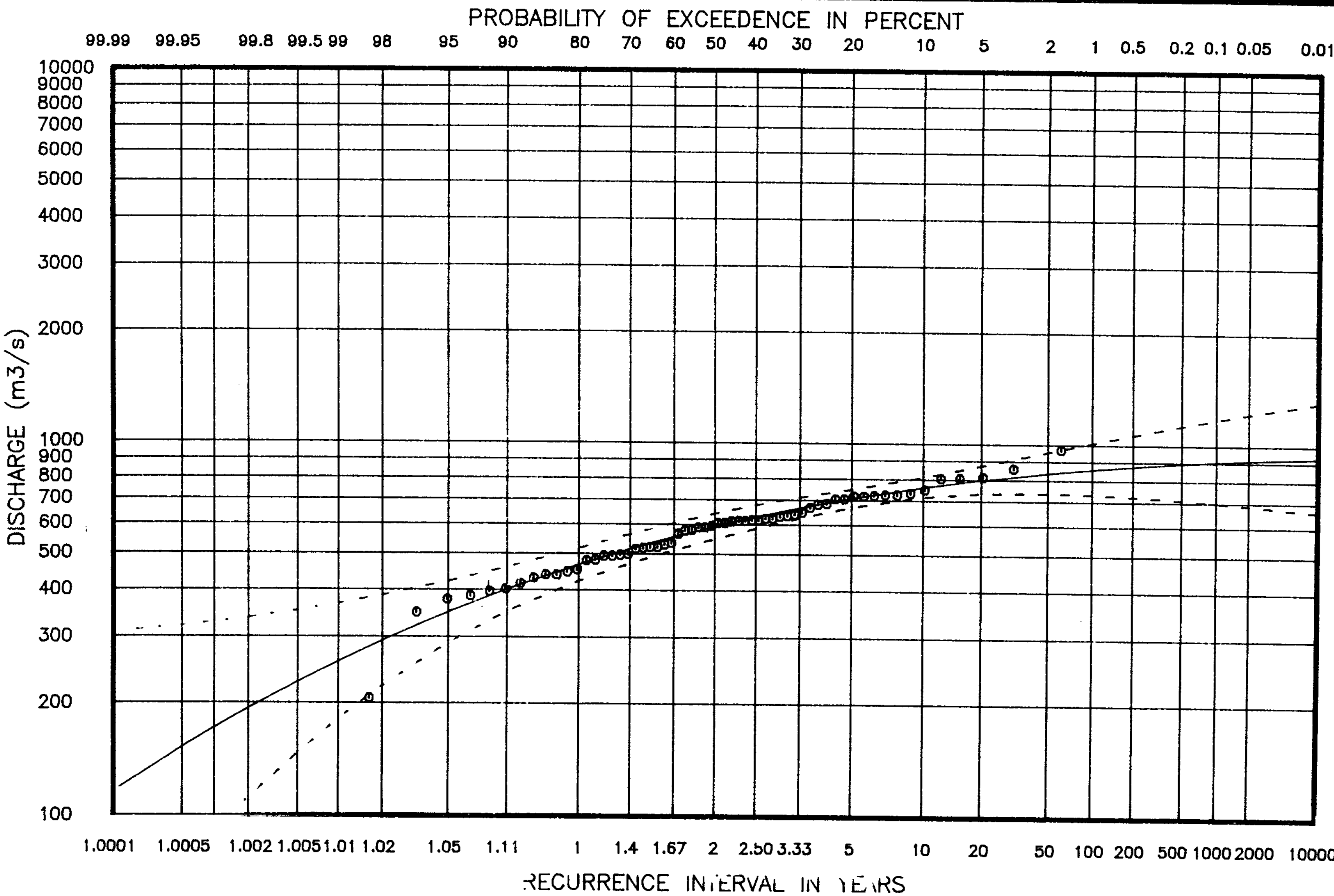


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

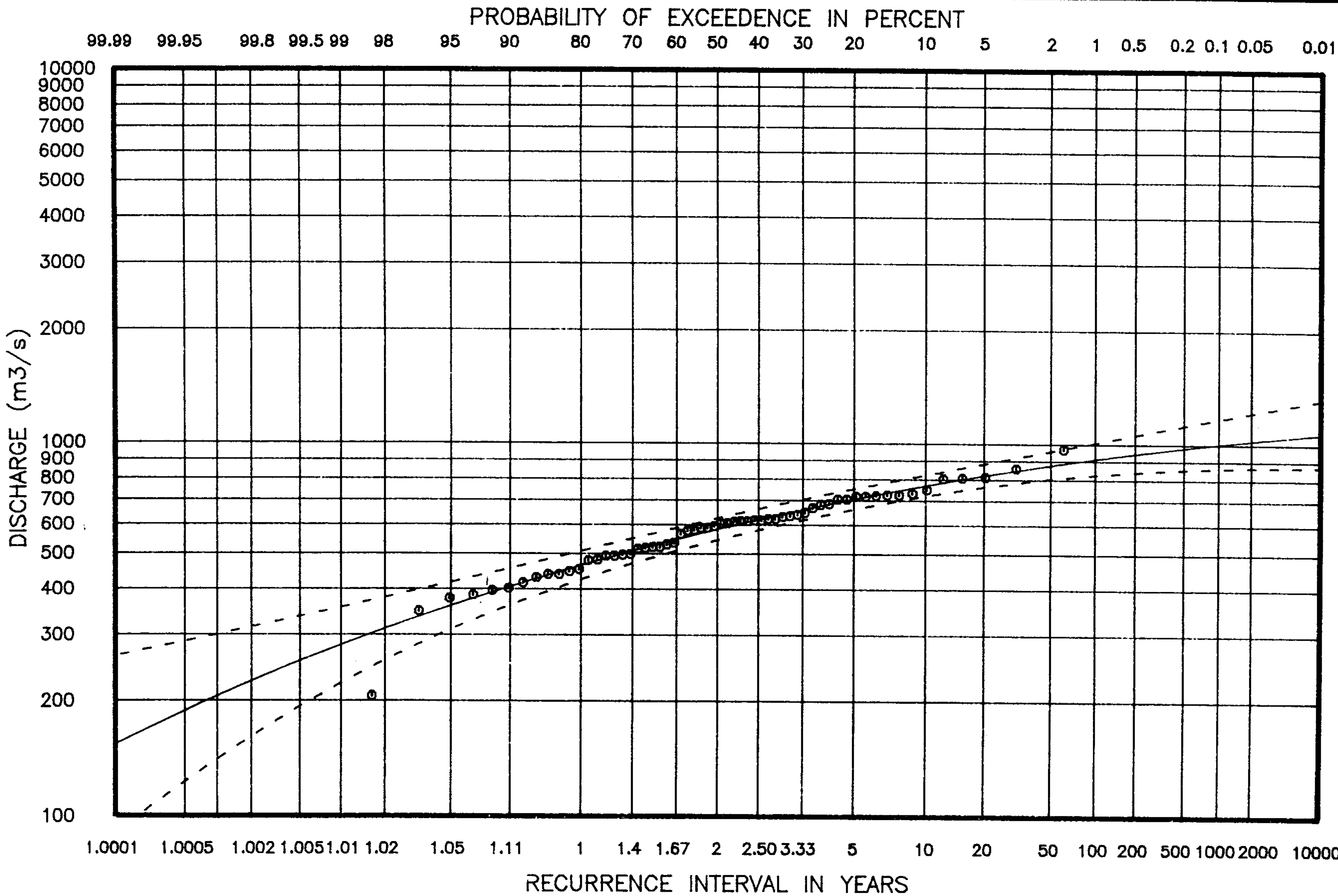


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

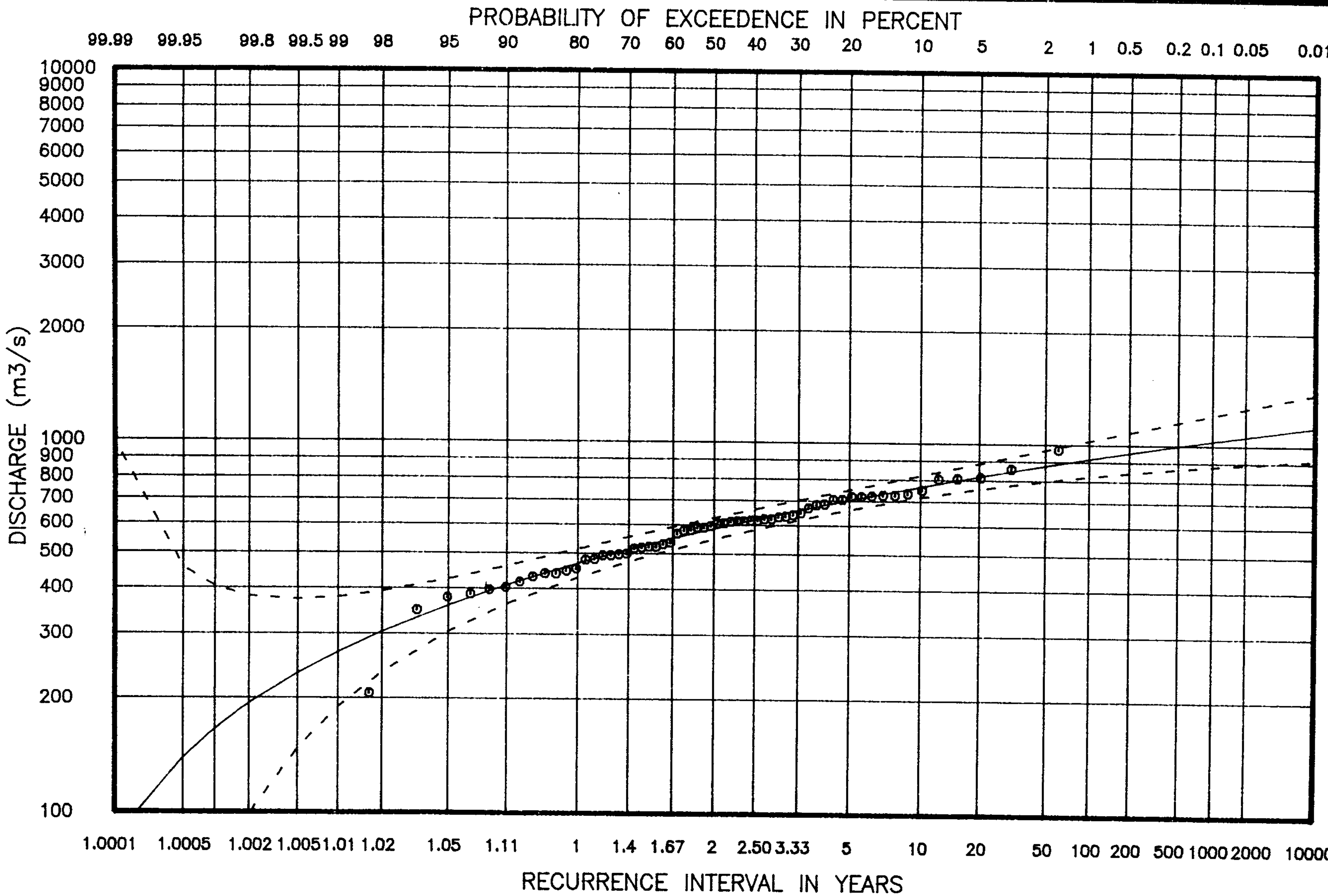


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

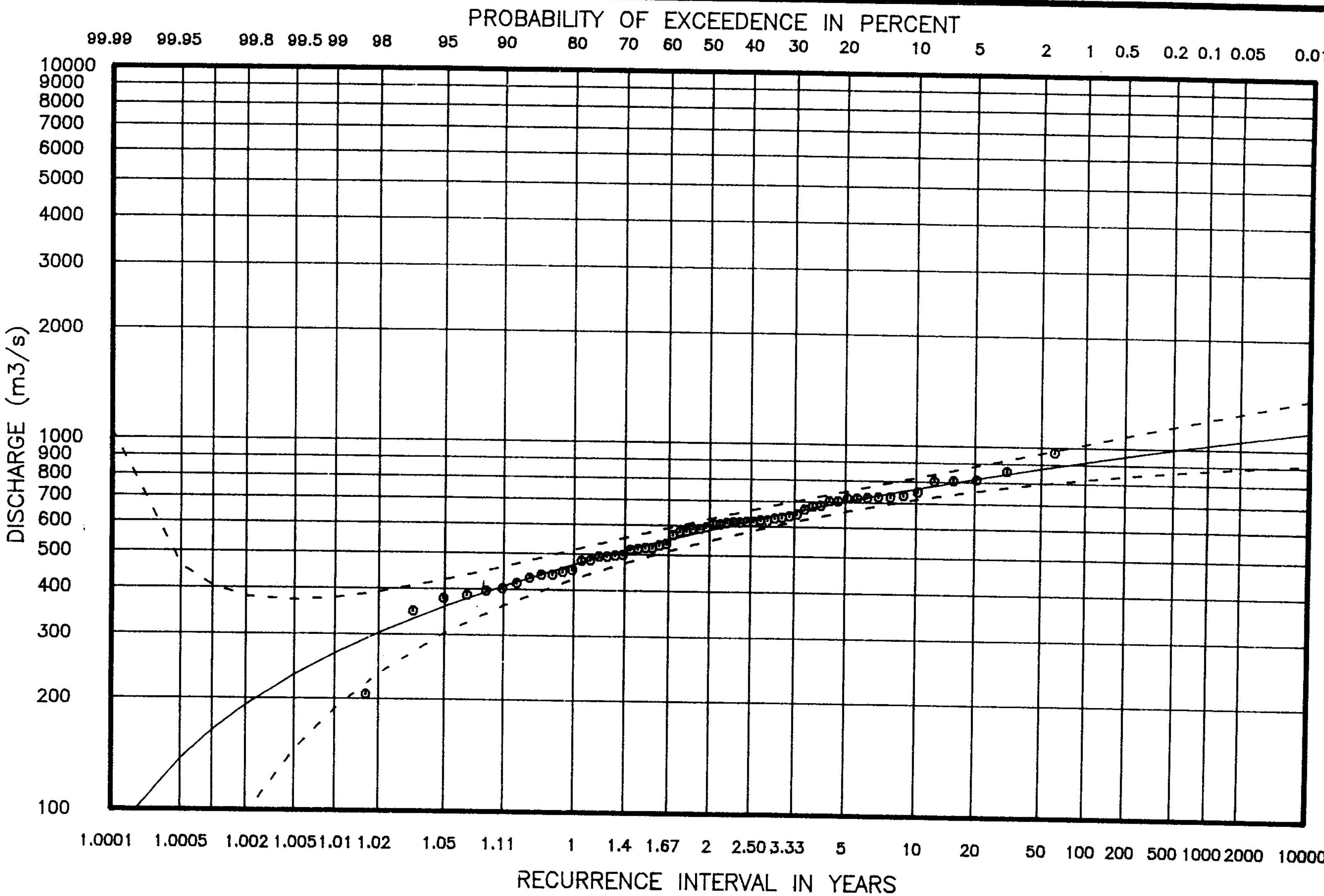


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

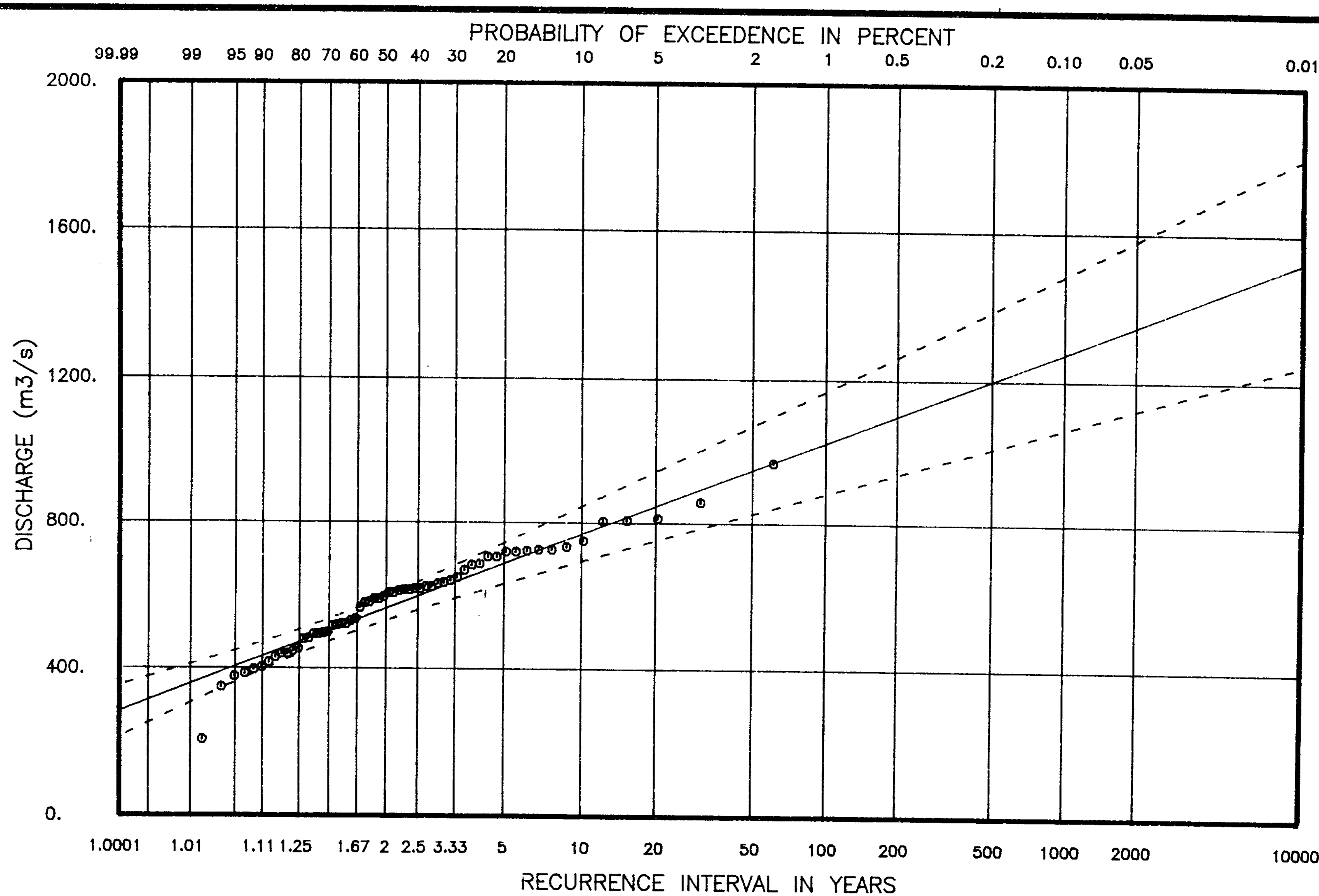


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

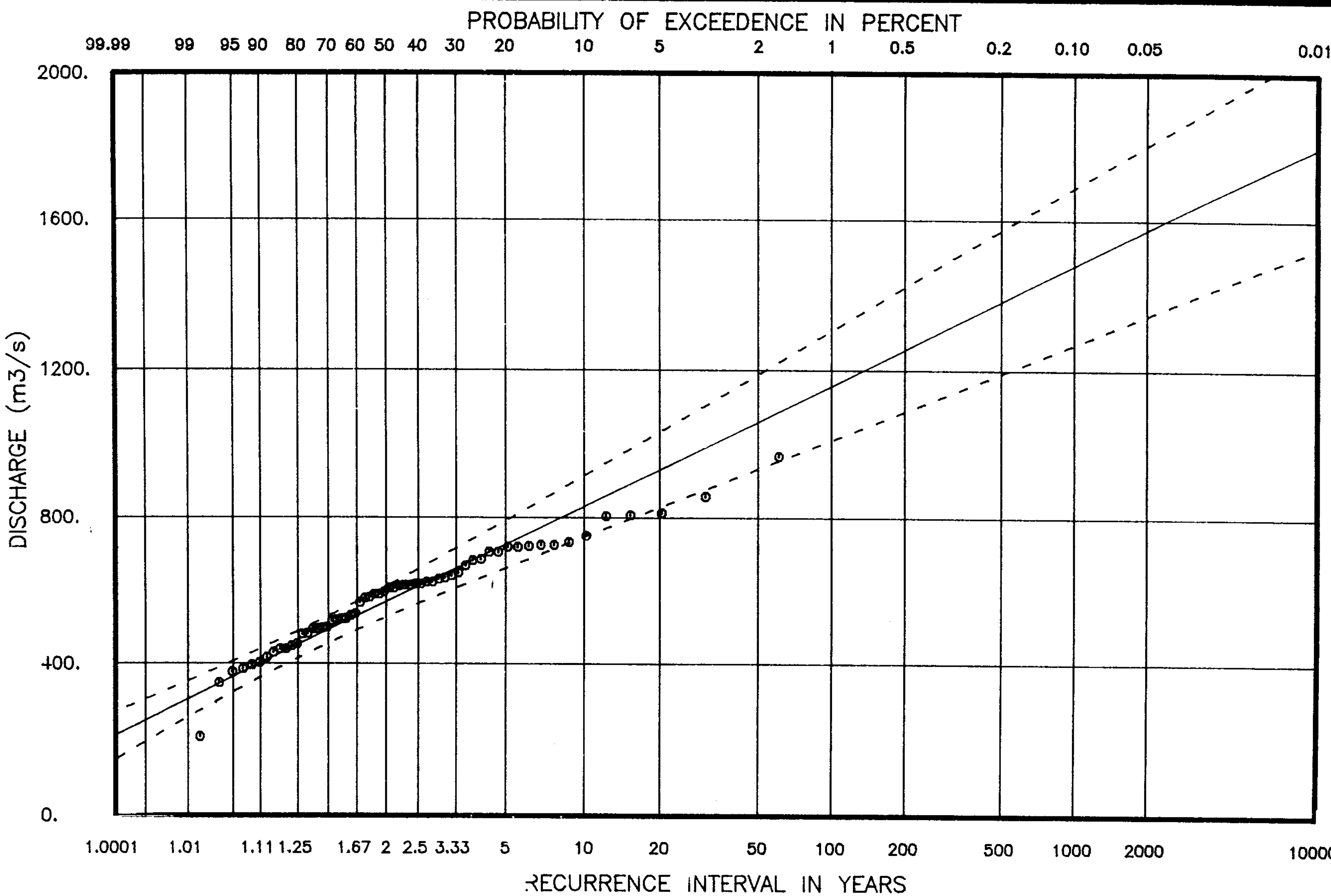


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

KETTLE RIVER NEAR LAURIER
(DAILY - 1930 REMOVED)

KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE 1930 REMOVED

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1931	396.	968.	1	.017	60.000
1932	535.	858.	2	.033	30.000
1933	648.	813.	3	.050	20.000
1934	589.	807.	4	.067	15.000
1935	521.	804.	5	.083	12.000
1936	530.	750.	6	.100	10.000
1937	402.	733.	7	.117	8.571
1938	606.	725.	8	.133	7.500
1939	453.	725.	9	.150	6.667
1940	479.	722.	10	.167	6.000
1941	430.	719.	11	.183	5.455
1942	733.	719.	12	.200	5.000
1943	377.	705.	13	.217	4.615
1944	348.	705.	14	.233	4.286
1945	614.	685.	15	.250	4.000
1946	623.	682.	16	.267	3.750
1947	447.	668.	17	.283	3.529
1948	968.	648.	18	.300	3.333
1949	705.	640.	19	.317	3.158
1950	566.	634.	20	.333	3.000
1951	725.	631.	21	.350	2.857
1952	682.	623.	22	.367	2.727
1953	578.	623.	23	.383	2.609
1954	750.	617.	24	.400	2.500
1955	668.	617.	25	.417	2.400
1956	858.	614.	26	.433	2.308
1957	705.	614.	27	.450	2.222
1958	614.	612.	28	.467	2.143
1959	595.	606.	29	.483	2.069
1960	521.	606.	30	.500	2.000
1961	719.	595.	31	.517	1.935
1962	439.	589.	32	.533	1.875
1963	496.	589.	33	.550	1.818
1964	606.	580.	34	.567	1.765
1965	493.	578.	35	.583	1.714
1966	385.	566.	36	.600	1.667
1967	640.	535.	37	.617	1.622
1968	589.	530.	38	.633	1.579
1969	722.	521.	39	.650	1.538
1970	416.	521.	40	.667	1.500
1971	804.	518.	41	.683	1.463
1972	813.	515.	42	.700	1.429
1973	493.	498.	43	.717	1.395
1974	719.	496.	44	.733	1.364
1975	617.	493.	45	.750	1.333
1976	634.	493.	46	.767	1.304
1977	439.	481.	47	.783	1.277
1978	515.	479.	48	.800	1.250
1979	481.	453.	49	.817	1.224
1980	685.	447.	50	.833	1.200
1981	617.	439.	51	.850	1.176
1982	623.	439.	52	.867	1.154
1983	807.	430.	53	.883	1.132
1984	631.	416.	54	.900	1.111
1985	580.	402.	55	.917	1.091

KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1986	725.	396.	56	.933	1.071
1987	612.	385.	57	.950	1.053
1988	518.	377.	58	.967	1.034
1989	498.	348.	59	.983	1.017

STATISTICS OF DATA SERIES

SAMPLE SIZE = 59

MEAN =	592.9	MIN. =	348.0	MAX. =	968.0
S.D. =	131.5	C.S. =	.3439	C.K. =	3.0289

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	6.3605	MIN. =	5.8522	MAX. =	6.8752
S.D. =	.2252	C.S. =	-.1912	C.K. =	2.6442

NORMAL DISTRIBUTION

MEAN = 592.915
S.D. = 131.508

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	325.444	253.894	182.344	14.020
1.050	426.689	373.461	320.234	7.091
1.250	522.302	482.258	442.214	4.131
2.000	627.327	592.914	558.501	2.888
5.000	743.616	703.572	663.529	2.832
10.000	807.915	761.472	715.028	3.034
20.000	862.064	809.273	756.481	3.245
50.000	923.743	863.057	802.370	3.498
100.000	965.162	898.905	832.648	3.667
200.000	1003.223	931.710	860.197	3.819
500.000	1049.502	971.461	893.419	3.997
1000.000	1082.046	999.343	916.640	4.117
10000.000	1178.831	1082.009	985.187	4.452

LOG NORMAL DISTRIBUTION

MEAN = 6.361
S.D. = .225

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	365.960	323.762	286.429	6.095
1.050	435.235	397.321	362.710	4.534
1.250	512.657	478.683	446.961	3.411
2.000	613.660	578.545	545.439	2.932
5.000	748.870	699.243	652.904	3.411
10.000	836.031	772.120	713.095	3.957
20.000	917.255	837.976	765.550	4.497
50.000	1019.430	918.815	828.131	5.170
100.000	1094.356	976.983	872.198	5.644
200.000	1168.054	1033.432	914.326	6.092
500.000	1264.381	1106.223	967.849	6.648
1000.000	1336.839	1160.318	1007.105	7.045
10000.000	1577.803	1336.754	1132.531	8.248

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = 22.610
BETA = 33.831
GAMMA = -171.990

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	385.808	296.061	206.314	4465.033
1.050	436.427	387.638	338.849	2427.333
1.250	517.186	480.705	444.224	1814.968
2.000	622.867	585.402	547.937	1863.929
5.000	744.577	700.739	656.902	2180.960
10.000	820.156	765.498	710.841	2719.284
20.000	891.244	821.315	751.387	3479.031
50.000	981.107	886.718	792.330	4695.941
100.000	1046.774	931.869	816.963	5716.690
200.000	1110.874	974.294	837.713	6795.059
500.000	1193.671	1027.142	860.612	8285.060
1000.000	1255.107	1065.163	875.219	9449.935
10000.000	1453.739	1182.598	911.458	13489.556

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR PEARSON III

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.022
BETA = 109.373
GAMMA = 8.716

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	383.161	310.878	252.231	10.401
1.050	438.994	392.430	350.804	5.579
1.250	515.865	479.849	446.347	3.601
2.000	621.097	582.708	546.692	3.174
5.000	747.796	700.470	656.140	3.253
10.000	827.364	768.242	713.345	3.689
20.000	904.705	827.443	756.779	4.441
50.000	1007.815	897.597	799.433	5.762
100.000	1087.425	946.450	823.751	6.908
200.000	1168.793	992.622	843.005	8.128
500.000	1279.452	1050.447	862.430	9.812
1000.000	1365.762	1092.228	873.476	11.119
10000.000	1670.856	1221.968	893.677	15.566

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.031
BETA = 53.646
GAMMA = 7.999

MEAN = 6.361
S.D. = .224
C.S. = -.273

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	379.465	306.832	248.102	10.570
1.050	439.229	391.494	348.946	5.724
1.250	517.612	481.047	447.065	3.645
2.000	622.314	584.452	548.892	3.123
5.000	745.716	699.946	656.985	3.151
10.000	820.838	764.948	712.864	3.508
20.000	892.142	820.839	755.235	4.144
50.000	985.242	885.990	796.737	5.283
100.000	1055.894	930.666	820.290	6.281
200.000	1127.137	972.369	838.852	7.348
500.000	1222.585	1023.883	857.476	8.824
1000.000	1295.957	1060.613	868.008	9.970
10000.000	1548.570	1172.065	887.100	13.859

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

A = -559.424
M = 7.043
S = .114

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	395.197	294.488	219.442	14.634
1.050	439.947	387.532	341.362	6.311
1.250	518.734	480.977	445.968	3.760
2.000	623.948	585.482	549.388	3.166
5.000	745.721	700.488	657.999	3.113
10.000	821.692	765.194	712.581	3.544
20.000	894.265	821.112	753.944	4.246
50.000	988.143	886.856	795.951	5.380
100.000	1058.414	932.406	821.400	6.306
200.000	1128.444	975.344	843.016	7.254
500.000	1221.083	1029.034	867.190	8.513
1000.000	1291.467	1067.810	882.886	9.461
10000.000	1529.095	1188.427	923.657	12.540

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = -277.200
M = 6.757
S = .151

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	390.442	305.777	239.471	12.160
1.050	439.269	391.573	349.056	5.718-
1.250	517.049	480.566	446.657	3.640
2.000	621.082	583.236	547.695	3.128
5.000	746.330	699.819	656.207	3.201
10.000	826.143	766.985	712.063	3.697
20.000	902.748	825.901	755.596	4.426
50.000	1002.325	896.175	801.268	5.569
100.000	1077.308	945.485	829.792	6.494
200.000	1152.452	992.421	854.612	7.438
500.000	1252.511	1051.716	883.112	8.693
1000.000	1329.024	1094.952	902.105	9.639
10000.000	1590.321	1231.585	953.770	12.718

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

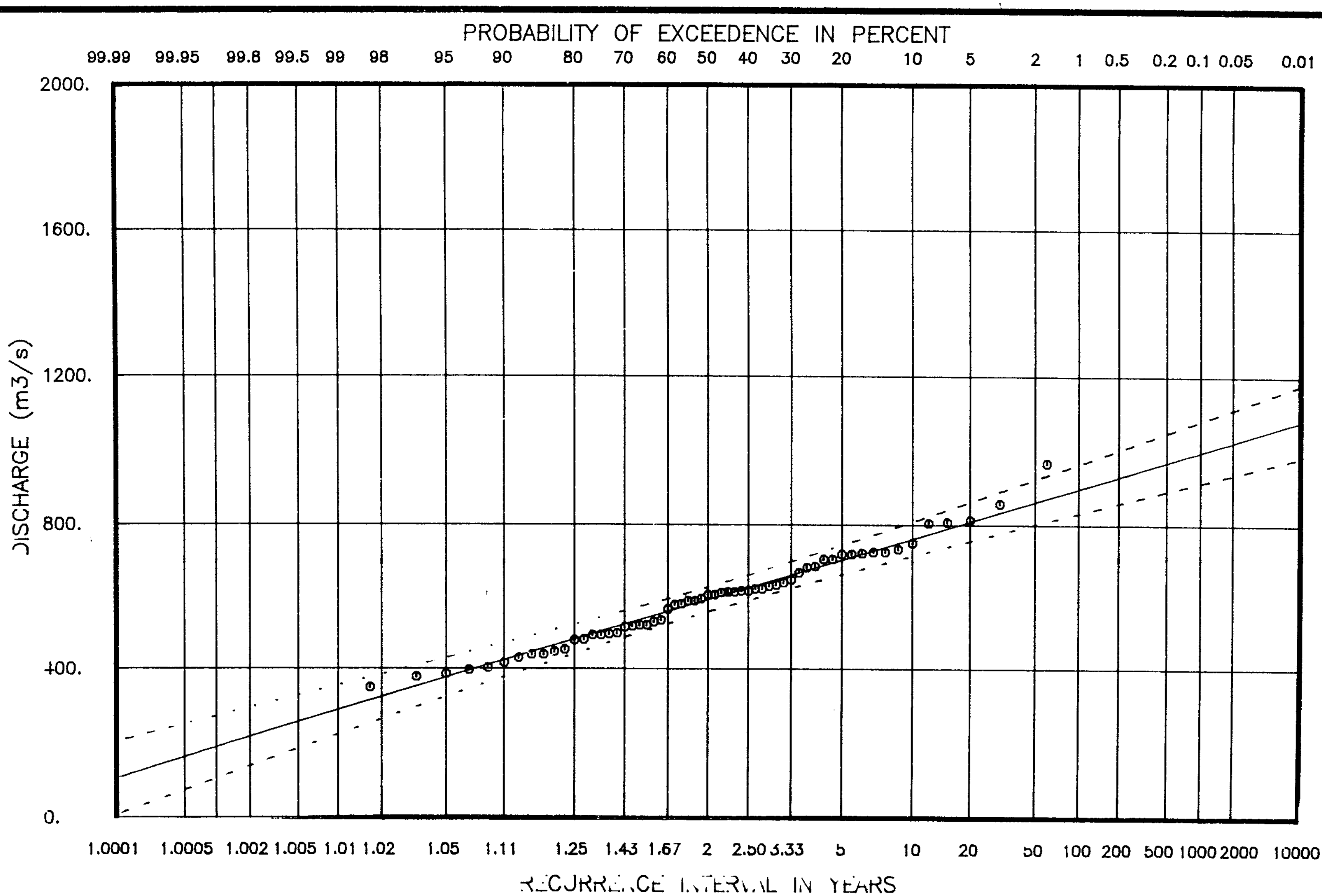
A = .010
U = 533.737

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	415.660	362.666	309.672	7.270
1.050	460.384	419.574	378.764	4.839
1.250	515.829	484.939	454.050	3.169
2.000	602.952	571.319	539.686	2.755
5.000	740.787	687.541	634.295	3.853
10.000	836.381	764.490	692.598	4.679
20.000	929.097	838.301	747.505	5.389
50.000	1049.784	933.842	817.901	6.177
100.000	1140.488	1005.437	870.387	6.683
200.000	1230.993	1076.771	922.548	7.126
500.000	1350.529	1170.882	991.235	7.633
1000.000	1440.938	1242.008	1043.079	7.969
10000.000	1741.355	1478.162	1214.969	8.858

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .009
U = 529.641

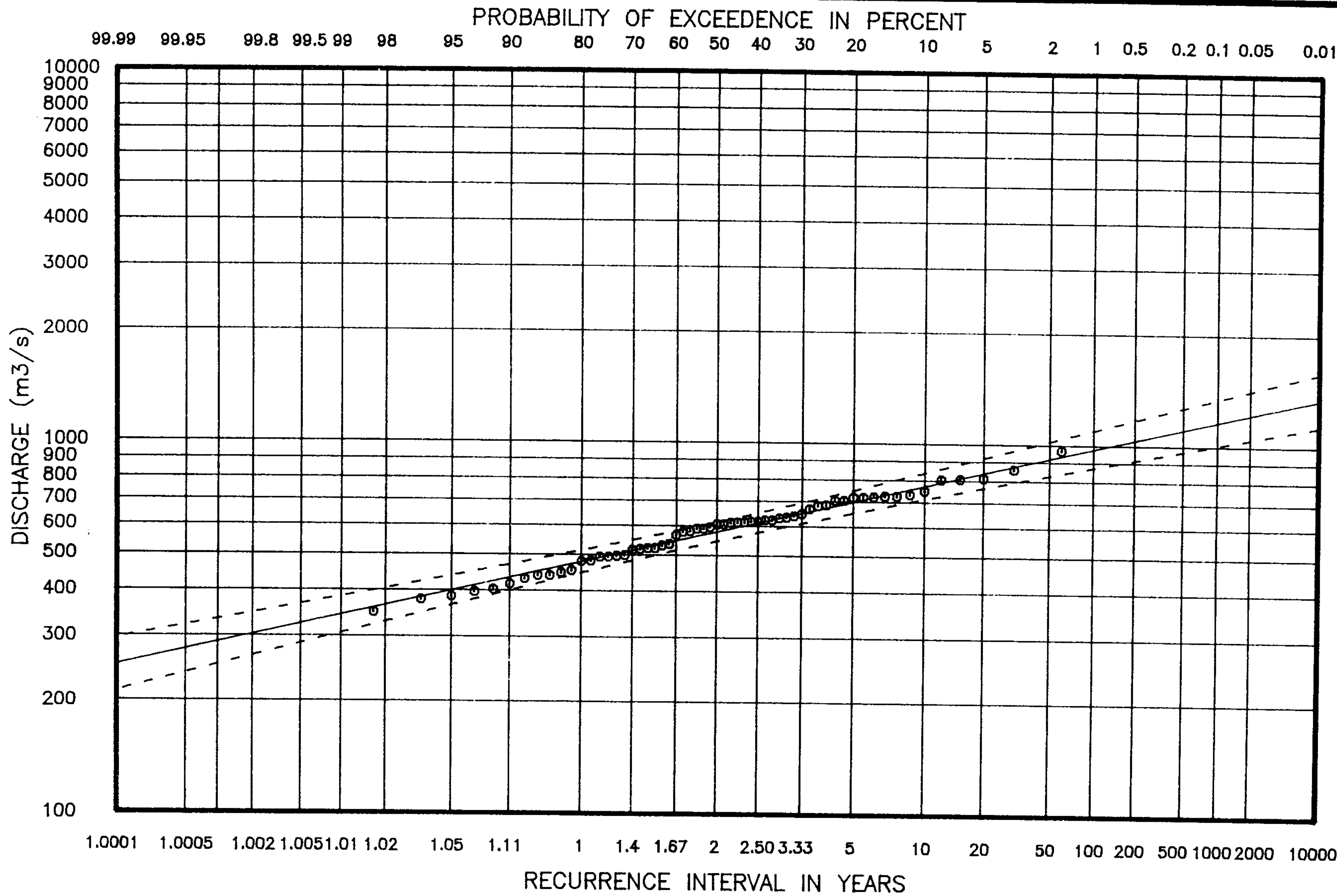
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	378.699	336.461	294.224	6.245
1.050	435.138	400.724	366.311	4.273
1.250	504.864	474.537	444.211	3.179
2.000	607.659	572.080	536.502	3.094
5.000	757.926	703.323	648.719	3.863
10.000	860.263	790.216	720.169	4.410
20.000	959.263	873.567	787.871	4.881
50.000	1088.027	981.456	874.884	5.402
100.000	1184.779	1062.303	939.827	5.736
200.000	1281.315	1142.855	1004.396	6.027
500.000	1408.817	1249.129	1089.441	6.360
1000.000	1505.253	1329.448	1153.643	6.579
10000.000	1825.714	1596.122	1366.530	7.156



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

NORMAL DISTRIBUTION

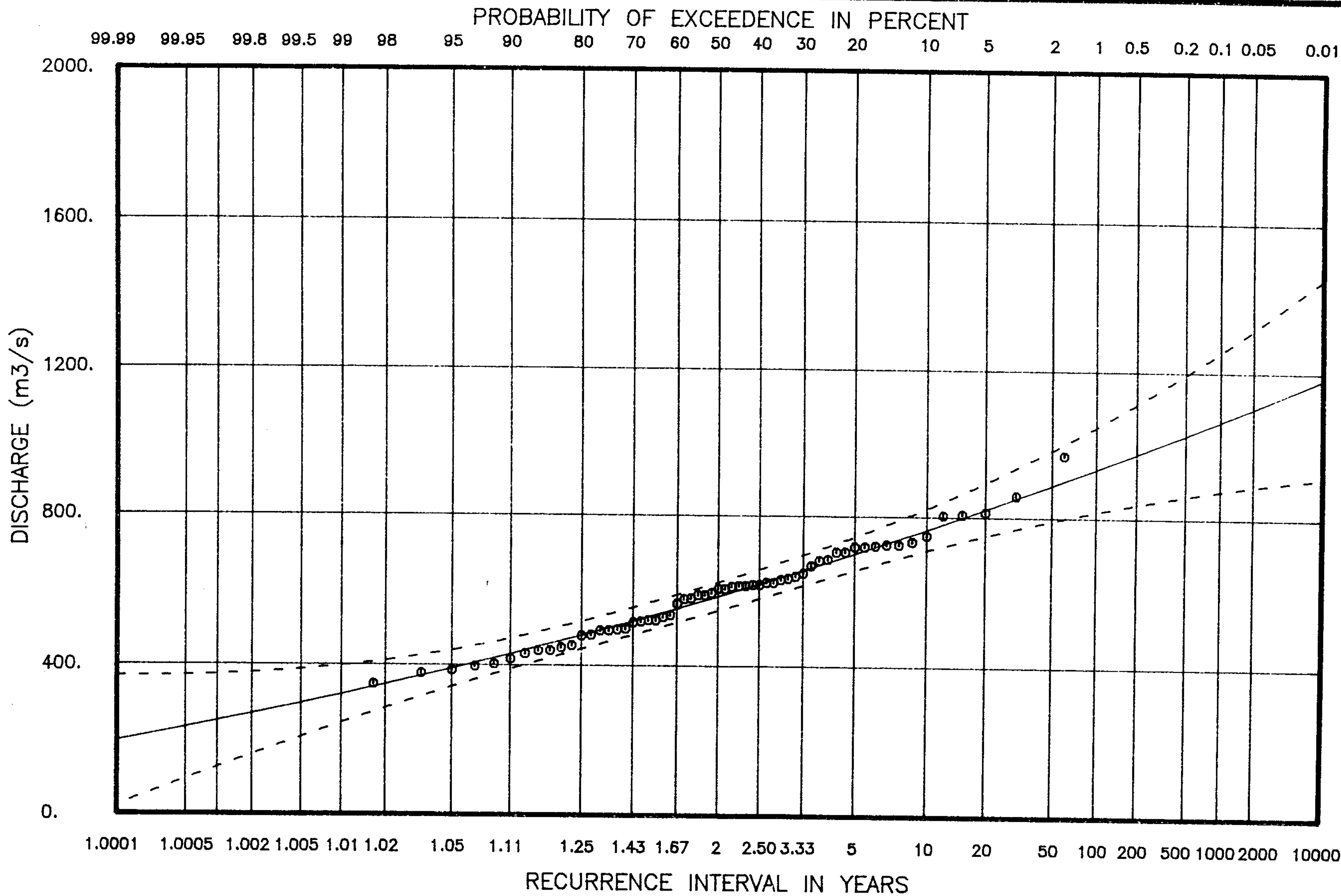
ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG NORMAL DISTRIBUTION

ACRES

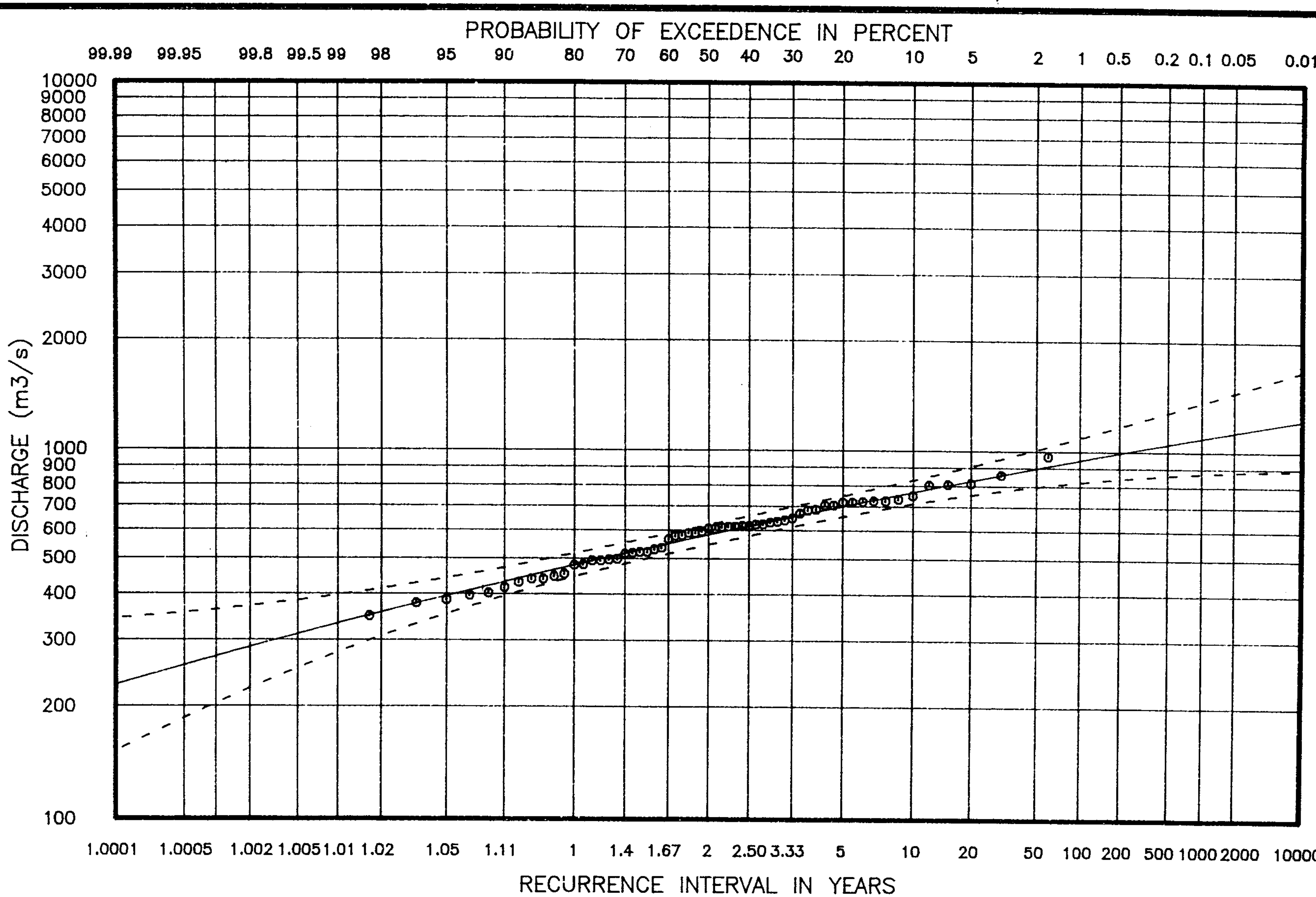


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

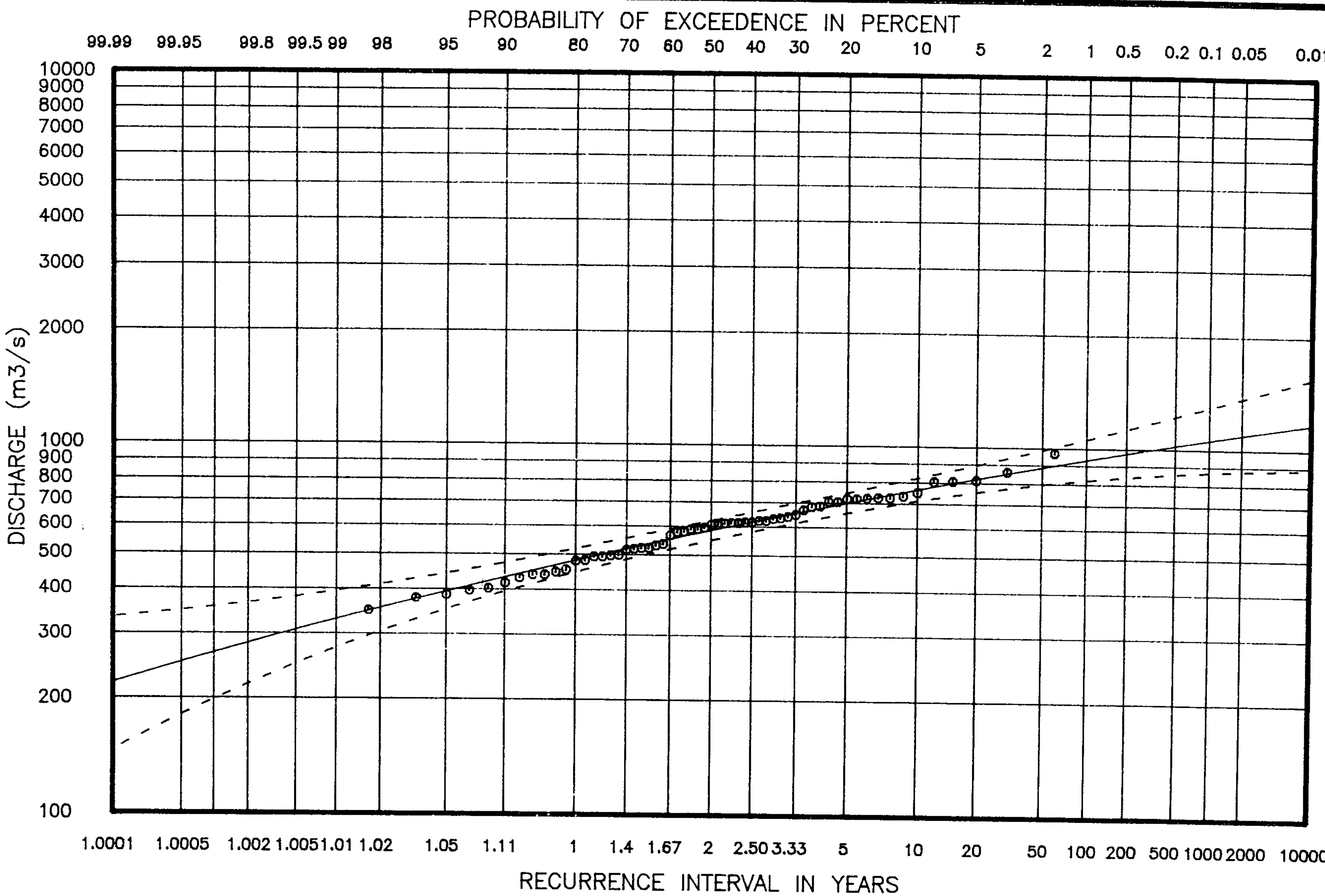


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

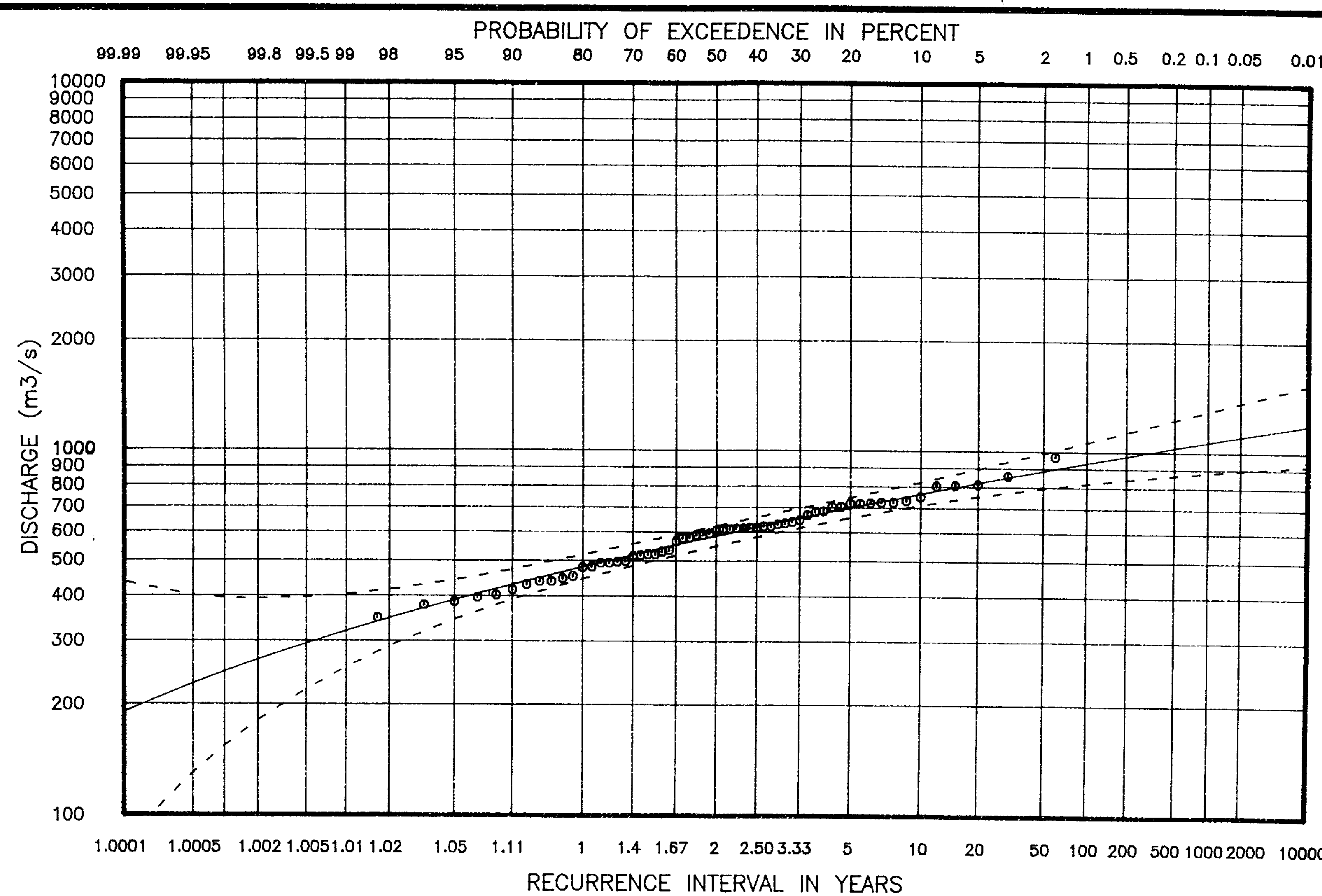
ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

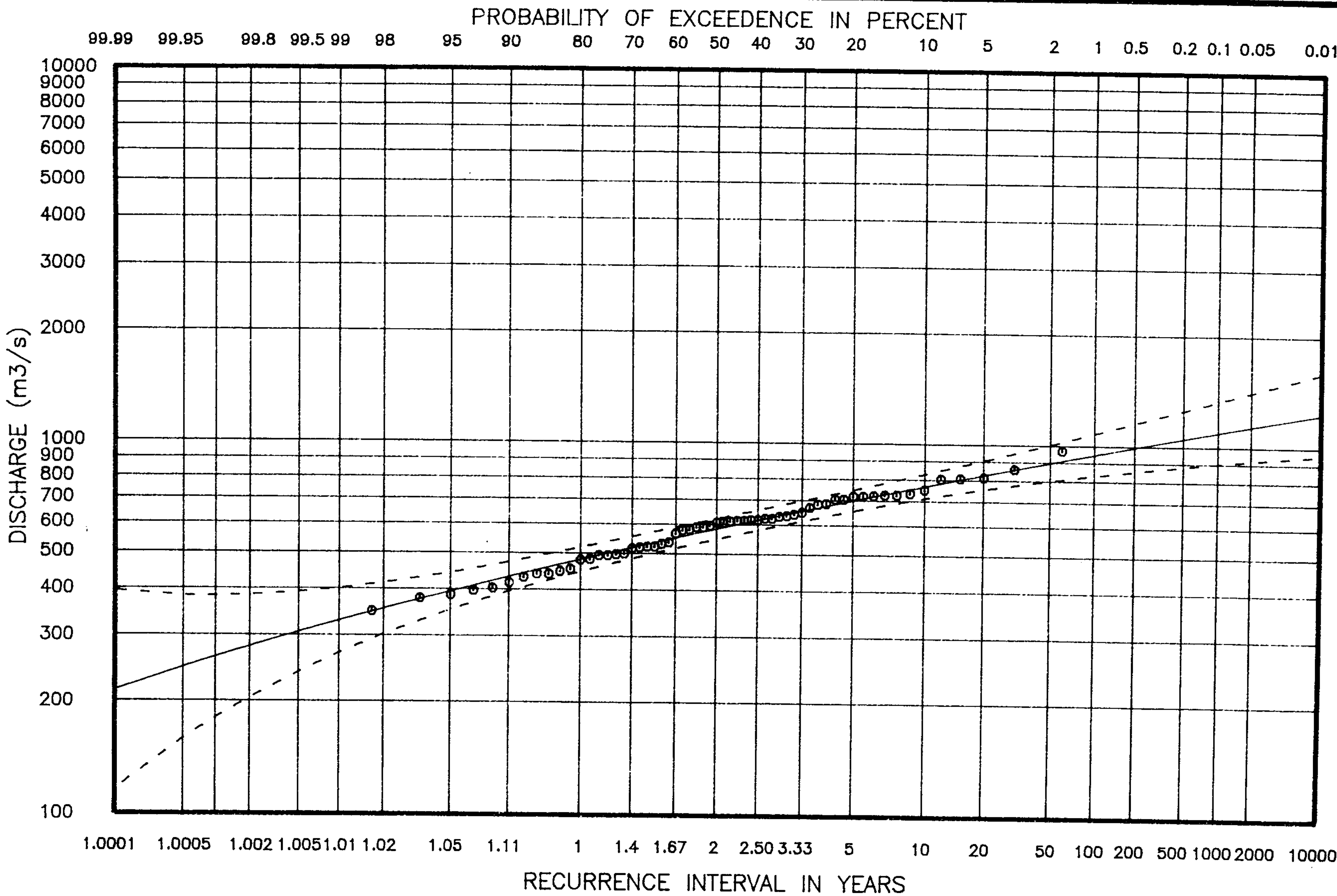


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

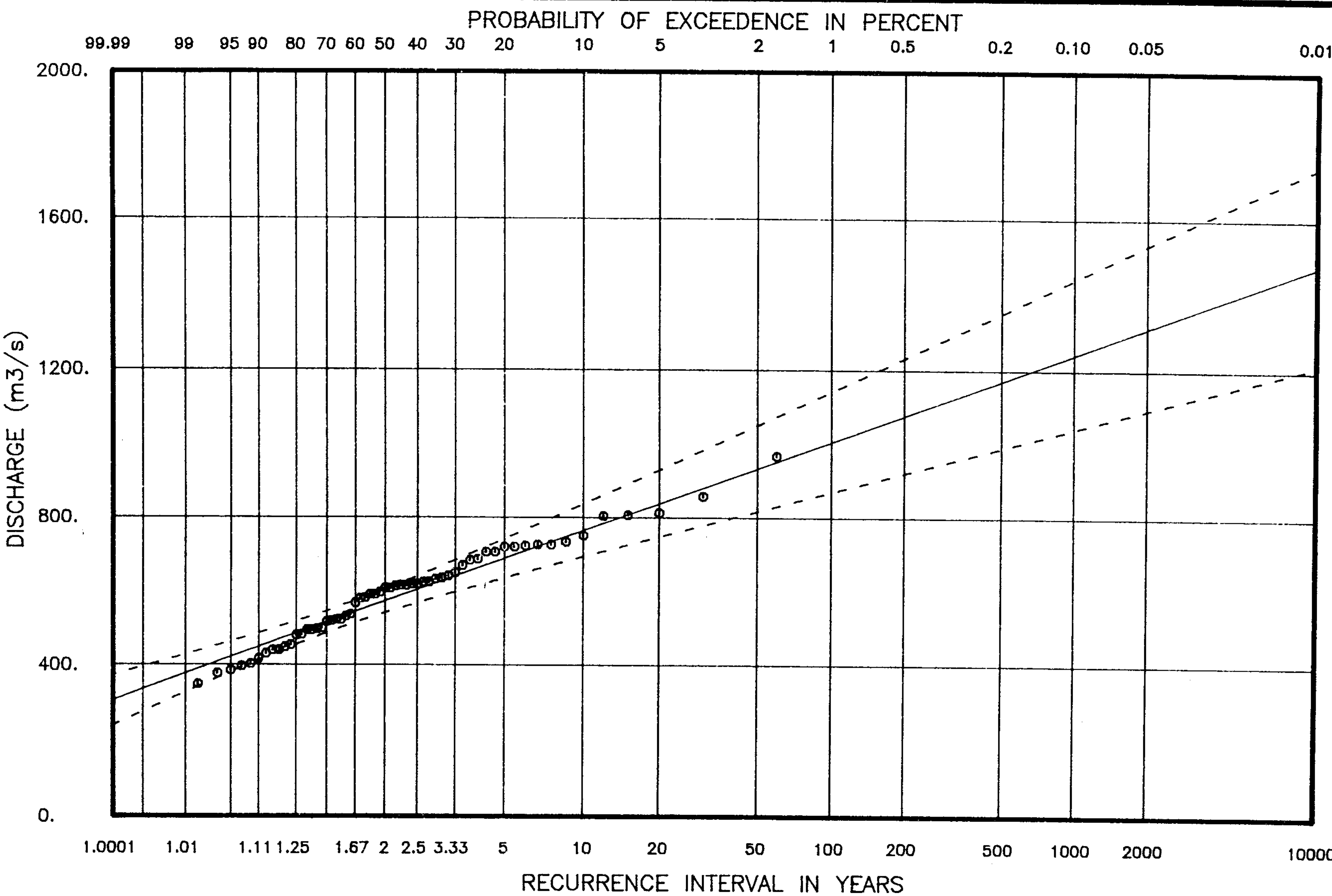


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

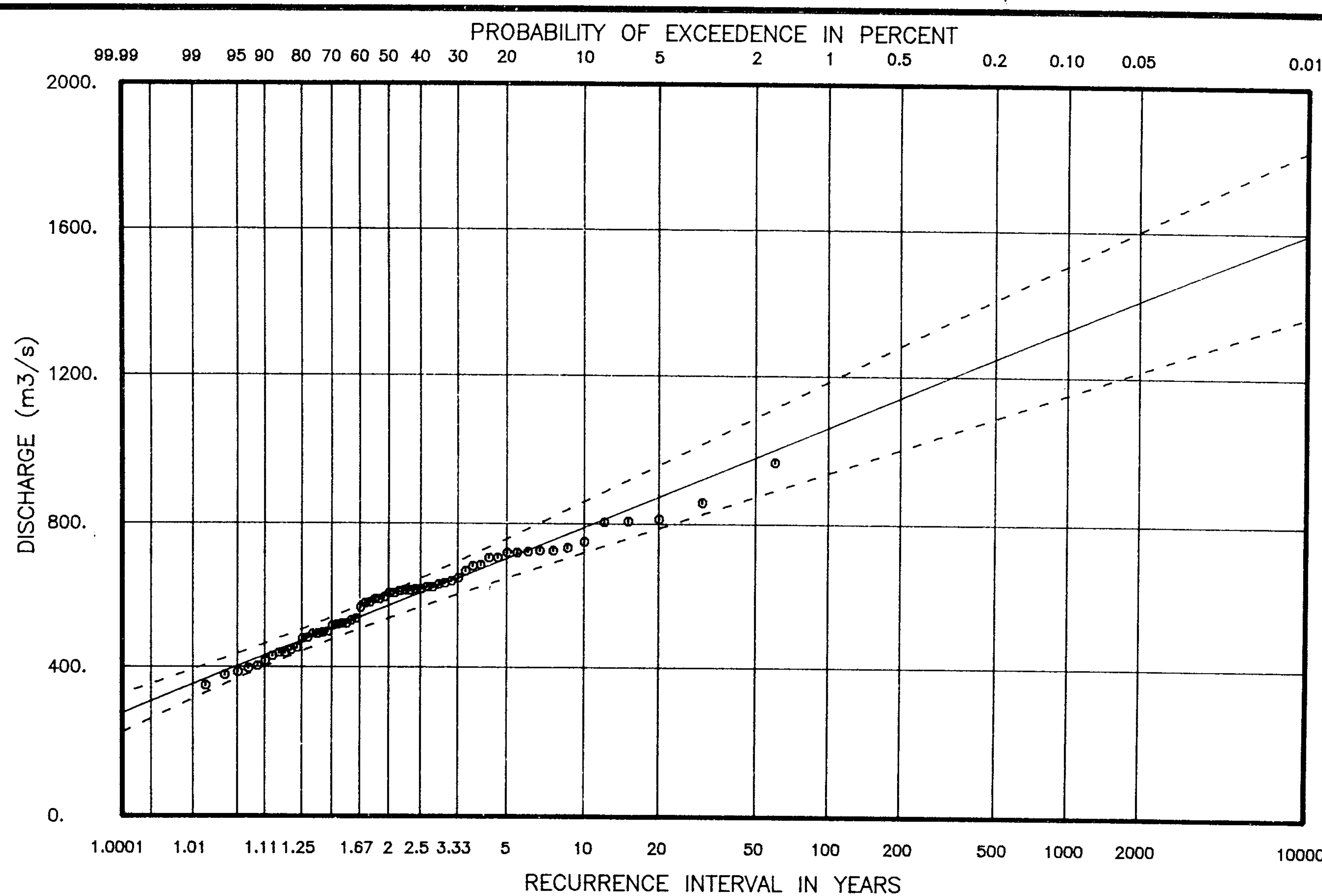


KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

KETTLE RIVER NEAR LAURIER
(INSTANTANEOUS - WITH ESTIMATED PEAK FOR 1948)

ACRES

KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1932	544.	1000.	1	.018	57.000
1933	674.	898.	2	.035	28.500
1934	597.	841.	3	.053	19.000
1935	547.	835.	4	.070	14.250
1936	538.	821.	5	.088	11.400
1937	436.	776.	6	.105	9.500
1938	614.	765.	7	.123	8.143
1940	487.	756.	8	.140	7.125
1941	445.	745.	9	.158	6.333
1942	776.	745.	10	.175	5.700
1943	391.	736.	11	.193	5.182
1944	362.	731.	12	.211	4.750
1945	614.	719.	13	.228	4.385
1946	623.	719.	14	.246	4.071
1948	1000.	714.	15	.263	3.800
1949	714.	699.	16	.281	3.563
1950	578.	691.	17	.298	3.353
1951	756.	674.	18	.316	3.167
1952	699.	674.	19	.333	3.000
1953	614.	663.	20	.351	2.850
1954	765.	663.	21	.368	2.714
1955	691.	660.	22	.386	2.591
1956	898.	648.	23	.404	2.478
1957	719.	646.	24	.421	2.375
1958	623.	646.	25	.439	2.280
1959	603.	643.	26	.456	2.192
1960	535.	629.	27	.474	2.111
1961	745.	623.	28	.491	2.036
1962	442.	623.	29	.509	1.966
1963	501.	614.	30	.526	1.900
1964	629.	614.	31	.544	1.839
1965	507.	614.	32	.561	1.781
1966	411.	603.	33	.579	1.727
1967	674.	597.	34	.596	1.676
1968	646.	595.	35	.614	1.629
1969	731.	578.	36	.632	1.583
1970	439.	547.	37	.649	1.541
1971	841.	544.	38	.667	1.500
1972	835.	541.	39	.684	1.462
1973	513.	538.	40	.702	1.425
1974	736.	535.	41	.719	1.390
1975	648.	532.	42	.737	1.357
1976	663.	521.	43	.754	1.326
1977	453.	513.	44	.772	1.295
1978	532.	507.	45	.789	1.267
1979	493.	501.	46	.807	1.239
1980	719.	493.	47	.825	1.213
1981	663.	487.	48	.842	1.188
1982	646.	453.	49	.860	1.163
1983	821.	445.	50	.877	1.140
1984	660.	442.	51	.895	1.118
1985	595.	439.	52	.912	1.096
1986	745.	436.	53	.930	1.075
1987	643.	411.	54	.947	1.056
1988	541.	391.	55	.965	1.036

KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1989	521.	362.	56	.982	1.018

STATISTICS OF DATA SERIES

SAMPLE SIZE = 56

MEAN =	622.1	MIN. =	362.0	MAX. =	1000.0
S.D. =	133.2	C.S. =	.3230	C.K. =	3.1509

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	6.4101	MIN. =	5.8916	MAX. =	6.9078
S.D. =	.2179	C.S. =	-.2394	C.K. =	2.8252

NORMAL DISTRIBUTION

MEAN = 622.071
S.D. = 133.162

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	353.152	278.787	204.421	13.271
1.050	455.179	399.858	344.536	6.883
1.250	551.642	510.023	468.404	4.060
2.000	657.837	622.070	586.303	2.861
5.000	775.739	734.120	692.501	2.821
10.000	841.018	792.748	744.477	3.029
20.000	896.018	841.150	786.281	3.245
50.000	958.684	895.610	832.536	3.504
100.000	1000.773	931.909	863.046	3.676
200.000	1039.454	965.127	890.800	3.831
500.000	1086.490	1005.378	924.266	4.014
1000.000	1119.567	1033.610	947.653	4.137
10000.000	1217.947	1117.316	1016.685	4.481

LOG NORMAL DISTRIBUTION

MEAN = 6.410
S.D. = .218

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	391.519	346.654	306.931	6.055
1.050	462.669	422.620	386.037	4.504
1.250	541.792	506.118	472.792	3.389
2.000	644.633	607.982	573.415	2.912
5.000	781.833	730.352	682.261	3.389
10.000	869.985	803.901	742.837	3.930
20.000	951.928	870.172	795.438	4.468
50.000	1054.738	951.292	857.991	5.136
100.000	1129.952	1009.518	901.921	5.607
200.000	1203.797	1065.918	943.832	6.052
500.000	1300.123	1138.500	996.968	6.604
1000.000	1372.445	1192.339	1035.867	6.999
10000.000	1612.204	1367.398	1159.764	8.194

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = 21.504
BETA = 38.345
GAMMA = -202.509

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	412.833	318.922	225.012	4672.165
1.050	464.545	413.302	362.060	2549.379
1.250	546.668	508.508	470.347	1898.539
2.000	653.825	614.923	576.020	1935.433
5.000	776.802	731.462	686.121	2255.749
10.000	852.971	796.625	740.279	2803.299
20.000	924.541	852.653	780.765	3576.538
50.000	1014.947	918.154	821.361	4815.577
100.000	1080.968	963.284	845.600	5854.937
200.000	1145.381	1005.630	865.879	6952.786
500.000	1228.532	1058.301	888.069	8469.233
1000.000	1290.197	1096.144	902.092	9654.351
10000.000	1489.379	1212.780	936.180	13761.165

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR PEARSON III

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.026
BETA = 69.778
GAMMA = 8.231

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	409.229	330.007	266.121	10.705
1.050	466.832	416.379	371.380	5.690
1.250	545.970	507.663	472.045	3.619
2.000	653.468	613.284	575.570	3.158
5.000	780.229	731.829	686.431	3.186
10.000	858.525	798.911	743.437	3.580
20.000	934.153	856.836	785.918	4.298
50.000	1034.449	924.676	826.552	5.581
100.000	1111.449	971.409	849.015	6.700
200.000	1189.732	1015.199	866.269	7.893
500.000	1295.521	1069.525	882.953	9.537
1000.000	1377.504	1108.425	891.907	10.813
10000.000	1663.837	1227.361	905.387	15.137

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.032
BETA = 46.698
GAMMA = 7.888

MEAN = 6.410
S.D. = .216
C.S. = -.293

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	405.802	327.988	265.096	10.591
1.050	467.140	416.309	371.008	5.731
1.250	547.332	508.784	472.951	3.633
2.000	653.861	614.414	577.346	3.096
5.000	778.133	731.002	686.726	3.108
10.000	853.085	795.995	742.725	3.446
20.000	923.884	851.524	784.831	4.058
50.000	1015.945	915.846	825.610	5.160
100.000	1085.548	959.702	848.445	6.130
200.000	1155.511	1000.455	866.207	7.169
500.000	1248.897	1050.553	883.709	8.604
1000.000	1320.424	1086.108	893.373	9.719
10000.000	1565.038	1193.156	909.641	13.498

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

A = -619.542
M = 7.118
S = .107

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	422.716	317.526	238.512	14.236
1.050	468.165	413.216	364.717	6.211
1.250	548.240	508.752	472.109	3.719
2.000	654.943	614.990	577.475	3.131
5.000	778.014	731.235	687.268	3.085
10.000	854.591	796.356	742.089	3.511
20.000	927.628	852.478	783.416	4.203
50.000	1021.964	918.288	825.131	5.322
100.000	1092.478	963.779	850.242	6.236
200.000	1162.667	1006.586	871.458	7.172
500.000	1255.392	1060.010	895.037	8.416
1000.000	1325.749	1098.527	910.248	9.354
10000.000	1562.751	1217.993	949.292	12.400

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = -427.006
M = 6.948
S = .127

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	417.537	323.774	251.067	12.653
1.050	467.325	415.454	369.341	5.853
1.250	547.346	508.569	472.540	3.656
2.000	653.277	613.838	576.780	3.098
5.000	778.420	730.955	686.385	3.130
10.000	857.040	797.395	741.902	3.589
20.000	931.943	855.111	784.612	4.281
50.000	1028.626	923.309	828.775	5.374
100.000	1100.959	970.768	855.972	6.261
200.000	1173.066	1015.657	879.371	7.168
500.000	1268.523	1071.988	905.903	8.375
1000.000	1341.112	1112.807	923.367	9.284
10000.000	1586.638	1240.479	969.843	12.245

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

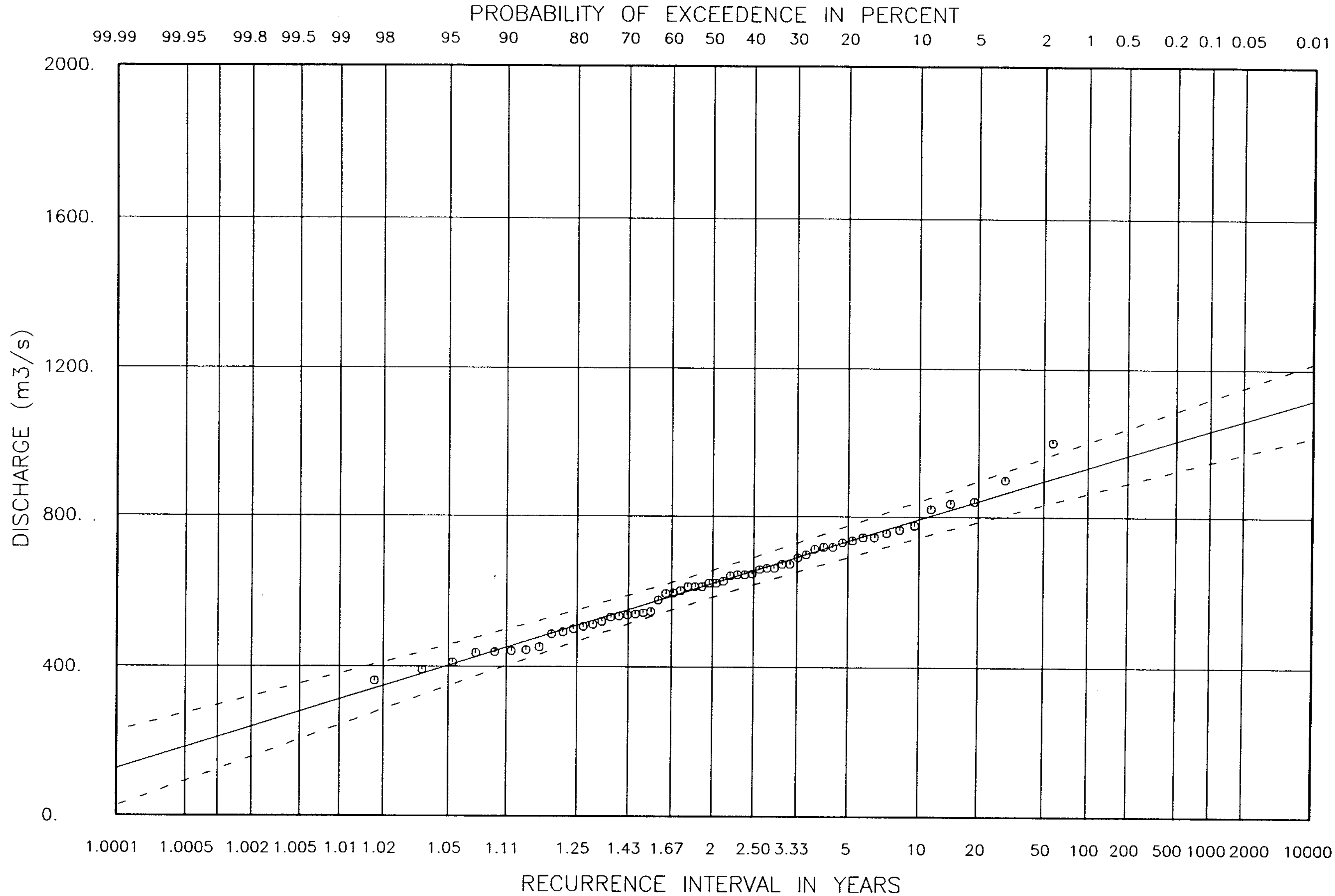
A = .010
U = 562.149

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	444.005	388.926	333.847	7.046
1.050	488.966	446.550	404.135	4.726
1.250	544.842	512.738	480.633	3.115
2.000	633.081	600.204	567.327	2.725
5.000	773.228	717.887	662.546	3.835
10.000	870.524	795.804	721.084	4.671
20.000	964.912	870.543	776.175	5.393
50.000	1087.790	967.286	846.783	6.198
100.000	1180.145	1039.781	899.417	6.716
200.000	1272.302	1112.012	951.721	7.171
500.000	1394.021	1207.306	1020.591	7.694
1000.000	1486.083	1279.327	1072.571	8.040
10000.000	1791.999	1518.451	1244.902	8.963

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .008
U = 557.836

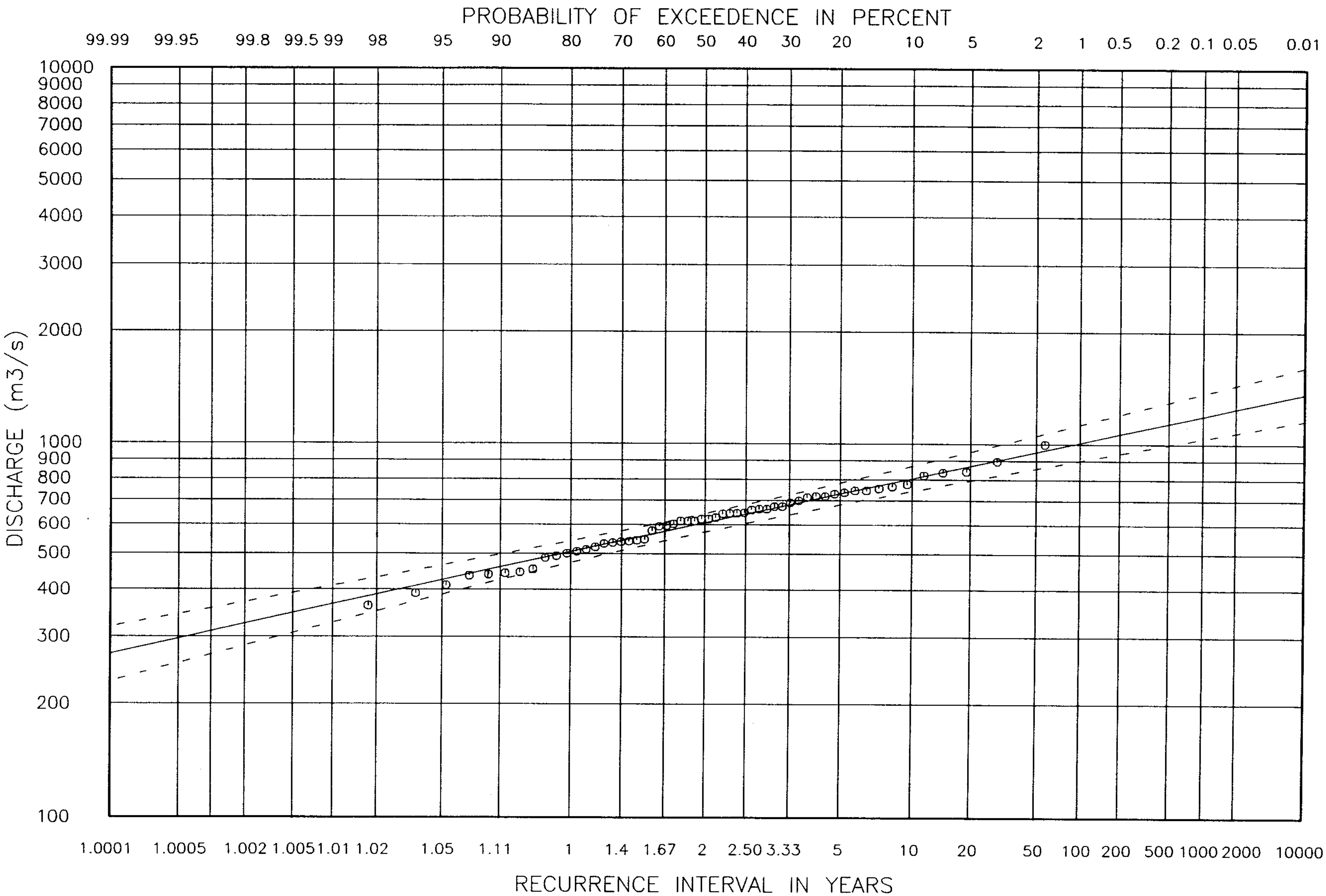
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	403.867	359.314	314.762	6.169
1.050	461.654	425.354	389.055	4.246
1.250	533.197	501.208	469.219	3.175
2.000	638.978	601.448	563.919	3.104
5.000	793.916	736.319	678.722	3.892
10.000	899.502	825.616	751.729	4.452
20.000	1001.664	911.271	820.877	4.935
50.000	1134.556	1022.142	909.729	5.472
100.000	1234.415	1105.225	976.036	5.815
200.000	1334.054	1188.005	1041.955	6.116
500.000	1465.658	1297.217	1128.776	6.460
1000.000	1565.199	1379.757	1194.315	6.687
10000.000	1895.982	1653.804	1411.626	7.285



KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

NORMAL DISTRIBUTION

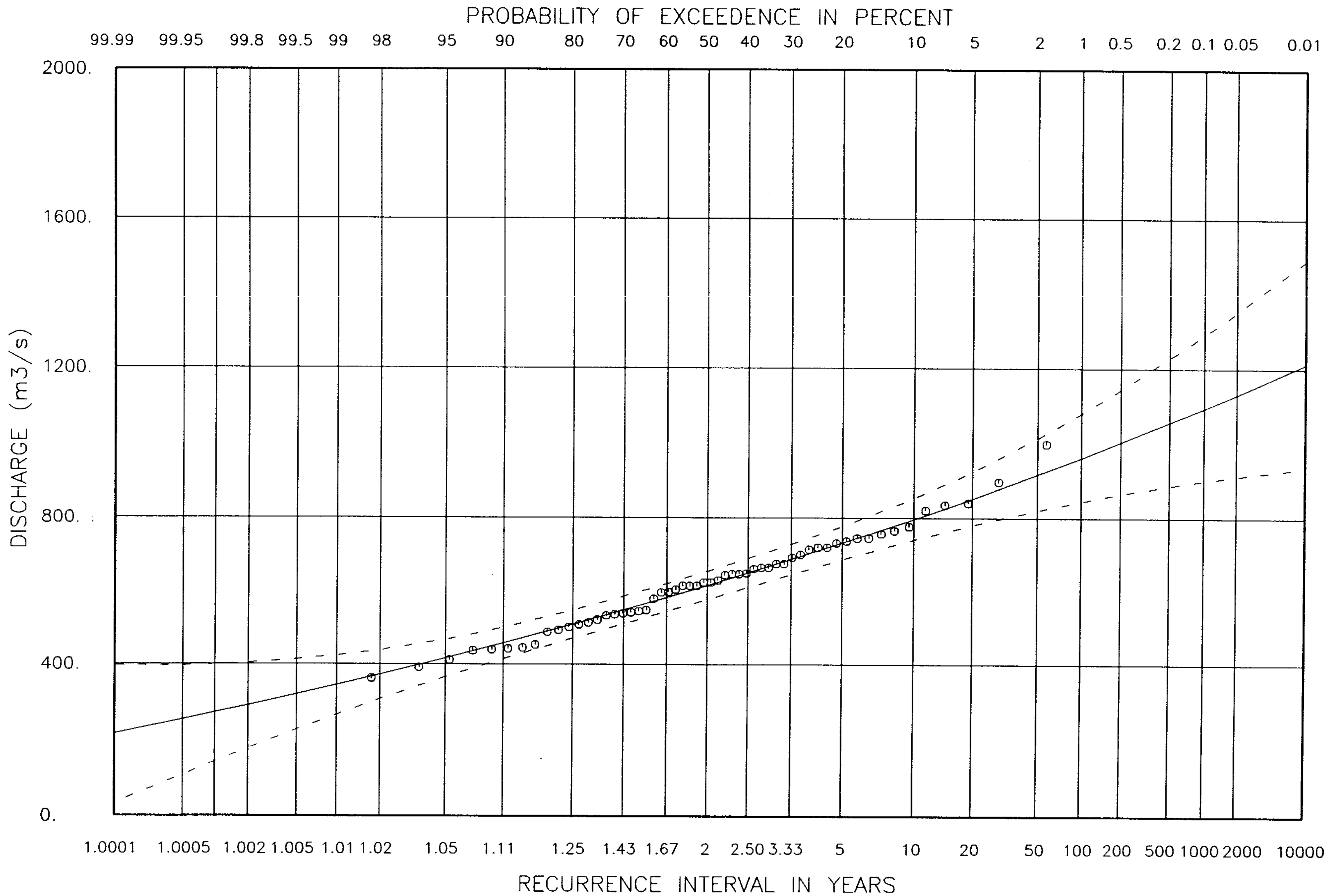
ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

LOG NORMAL DISTRIBUTION

ACRES

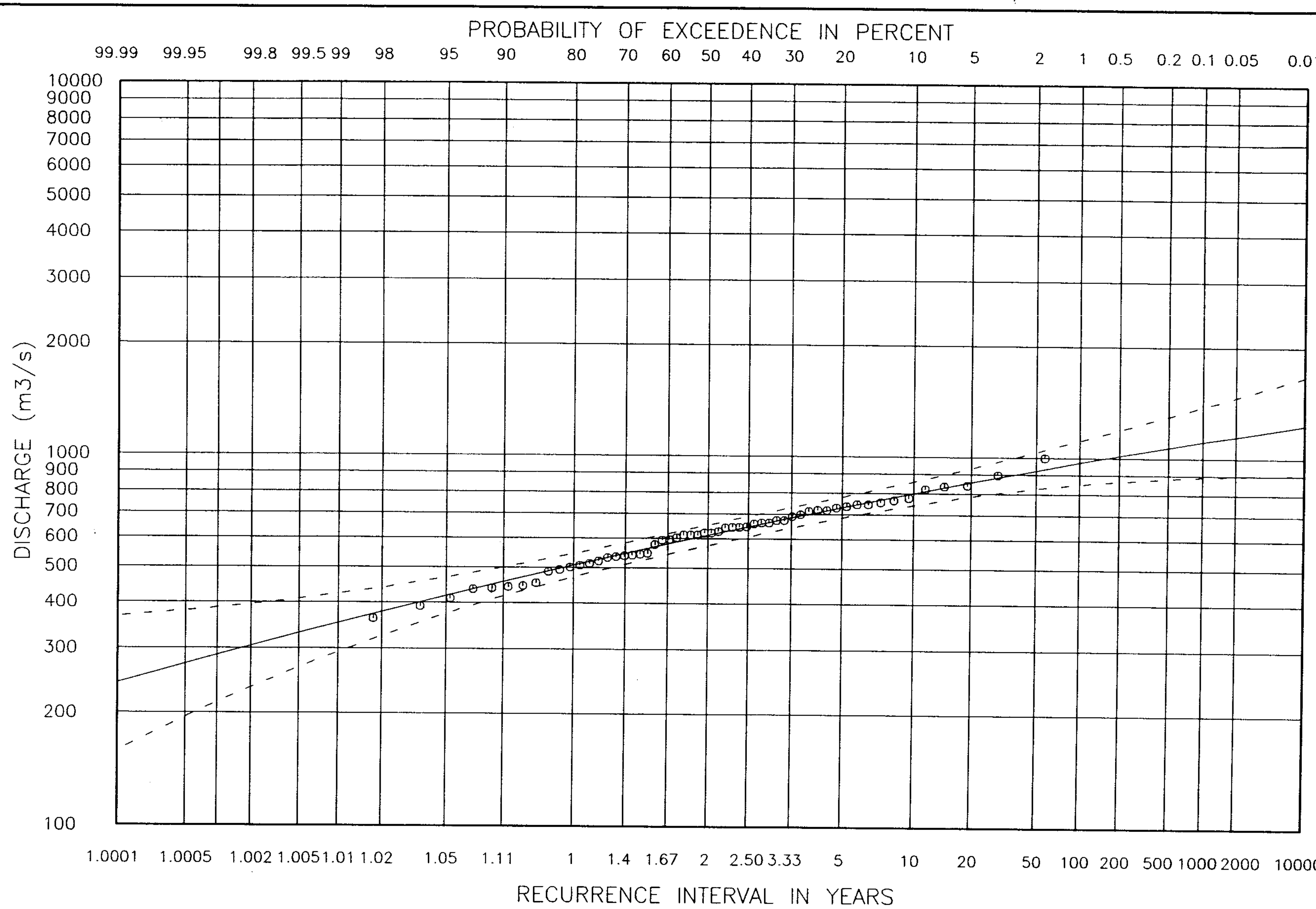


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

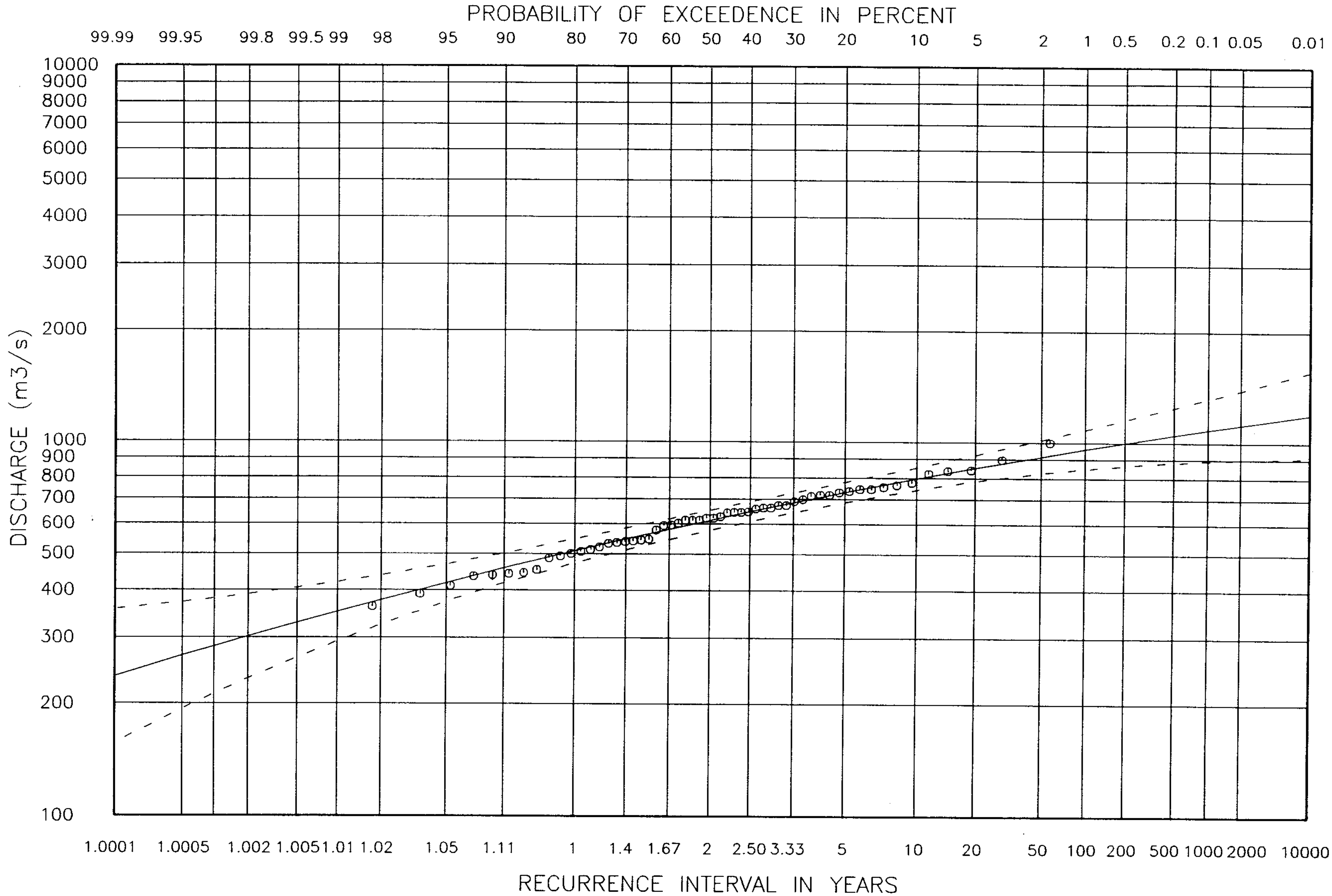


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

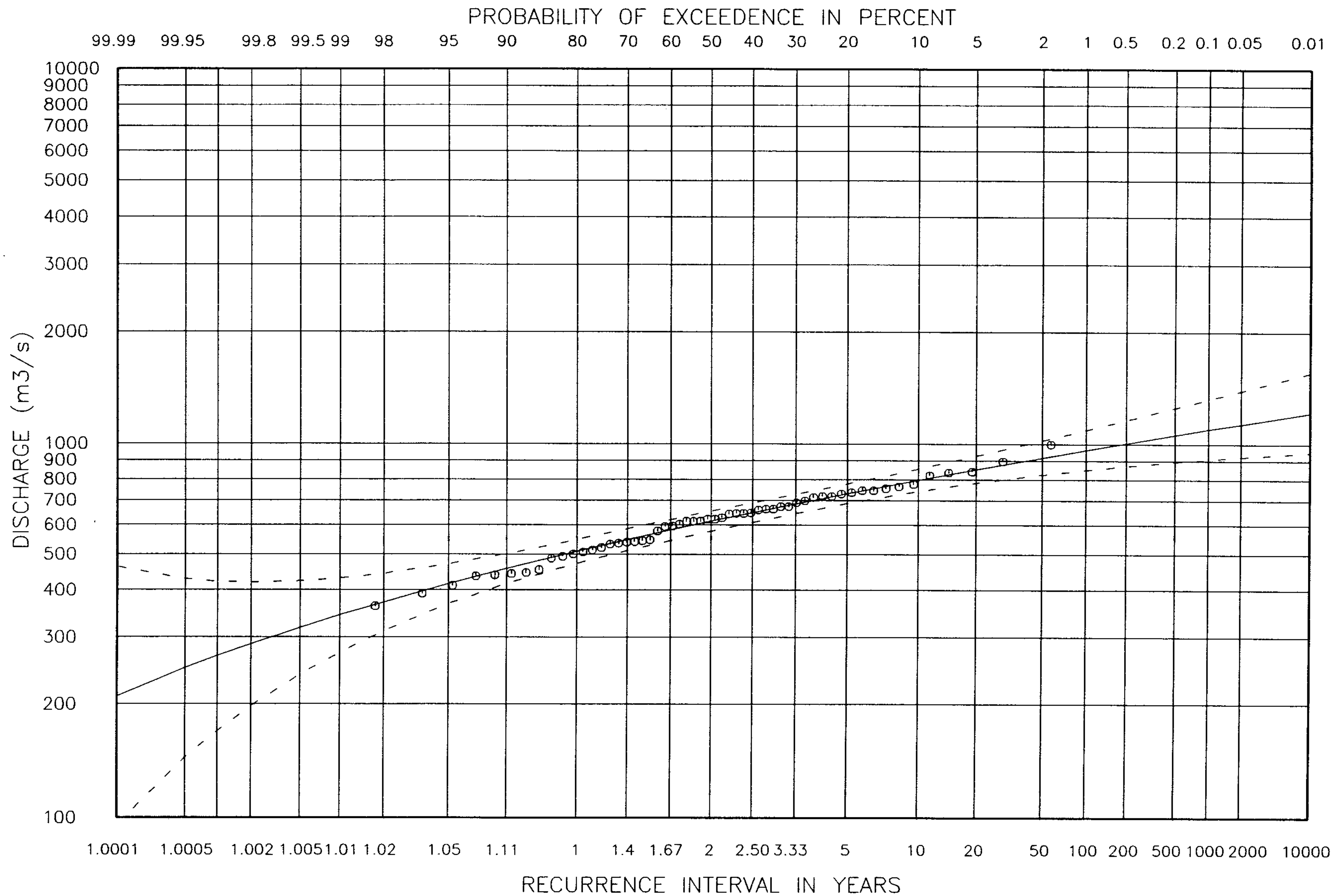


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

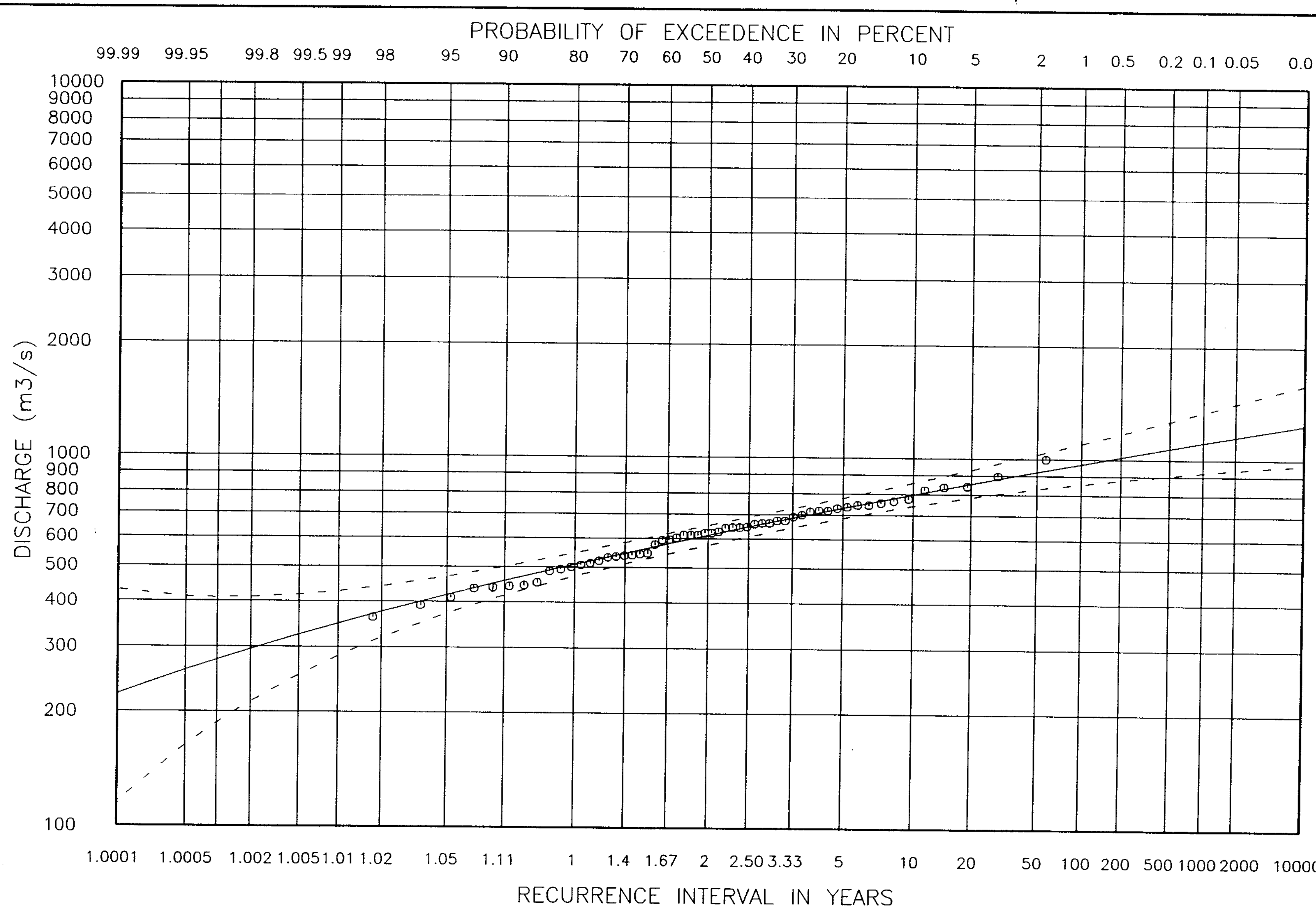


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

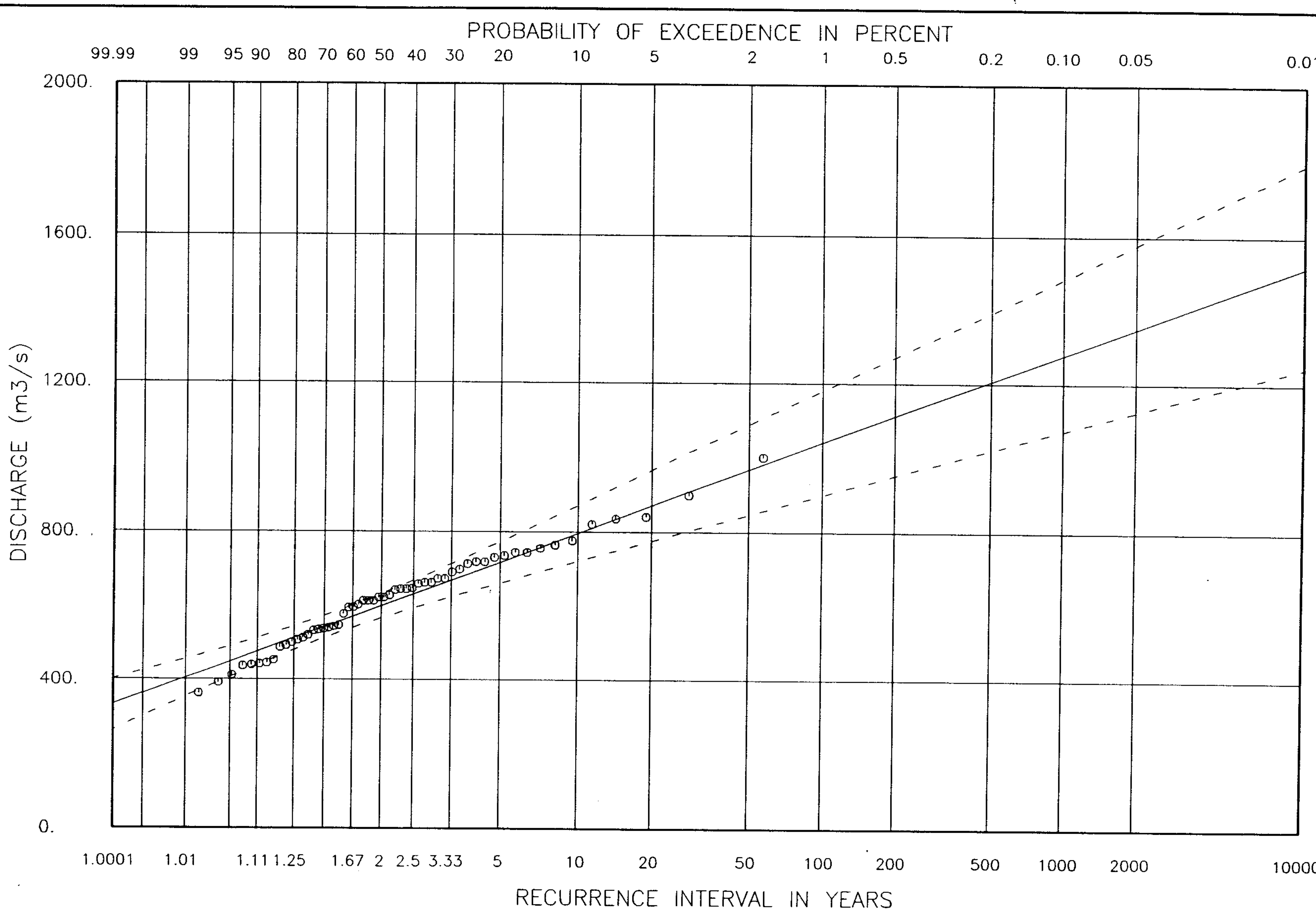


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

THREE PARAMETER LOGNORMAL DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

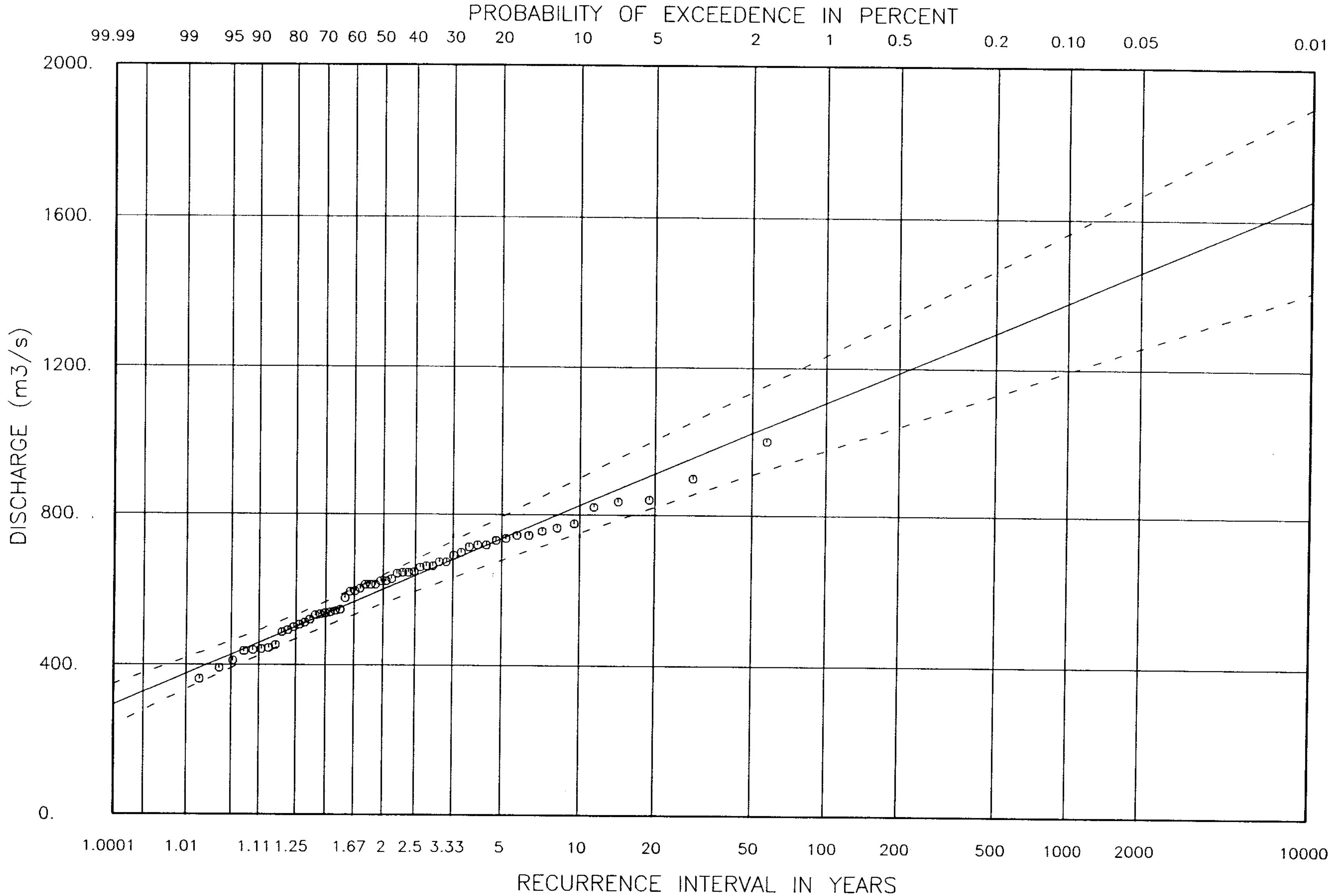


KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



KETTLE RIVER NEAR LAURIER MAXIMUM INSTANTANEOUS DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

GRANBY RIVER AT GRAND FORKS
(DAILY - FULL DATA SET)

ACRES

GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE *FULL DATA SET*

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1914	385.	385.	1	.032	31.000
1915	271.	334.	2	.065	15.500
1927	206.	329.	3	.097	10.333
1928	292.	309.	4	.129	7.750
1929	137.	306.	5	.161	6.200
1930	97.	296.	6	.194	5.167
1931	29.	294.	7	.226	4.429
1967	265.	292.	8	.258	3.875
1968	294.	281.	9	.290	3.444
1969	259.	280.	10	.323	3.100
1970	180.	271.	11	.355	2.818
1971	334.	265.	12	.387	2.583
1972	306.	265.	13	.419	2.385
1973	227.	261.	14	.452	2.214
1974	281.	259.	15	.484	2.067
1975	253.	254.	16	.516	1.938
1976	248.	253.	17	.548	1.824
1977	187.	248.	18	.581	1.722
1978	205.	237.	19	.613	1.632
1979	193.	229.	20	.645	1.550
1980	296.	227.	21	.677	1.476
1981	265.	206.	22	.710	1.409
1982	254.	205.	23	.742	1.348
1983	329.	204.	24	.774	1.292
1984	261.	193.	25	.806	1.240
1985	237.	187.	26	.839	1.192
1986	309.	180.	27	.871	1.148
1987	280.	137.	28	.903	1.107
1988	229.	97.	29	.935	1.069
1989	204.	29.	30	.968	1.033

STATISTICS OF DATA SERIES

SAMPLE SIZE = 30

MEAN =	243.7	MIN. =	28.6	MAX. =	385.0
S.D. =	72.0	C.S. =	-.9778	C.K. =	4.9507

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	5.4212	MIN. =	3.3534	MAX. =	5.9532
S.D. =	.4775	C.S. =	-3.1174	C.K. =	14.5282

NORMAL DISTRIBUTION

MEAN = 243.747
S.D. = 72.005

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	114.018	58.121	2.225	47.028
1.050	165.171	123.589	82.006	16.453
1.250	214.441	183.158	151.875	8.352
2.000	270.630	243.746	216.862	5.393
5.000	335.618	304.335	273.052	5.026
10.000	372.319	336.037	299.754	5.280
20.000	403.451	362.209	320.968	5.568
50.000	439.067	391.658	344.249	5.919
100.000	463.047	411.286	359.525	6.154
200.000	485.115	429.248	373.380	6.364
500.000	511.980	451.013	390.045	6.610
1000.000	530.888	466.279	401.670	6.776

LOG NORMAL DISTRIBUTION

MEAN = 5.421
S.D. = .477

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	95.673	66.040	45.585	18.126
1.050	134.310	101.942	77.374	13.484
1.250	186.213	151.326	122.976	10.144
2.000	270.292	226.155	189.226	8.718
5.000	415.910	337.990	274.669	10.144
10.000	530.518	417.067	327.878	11.766
20.000	652.169	496.116	377.404	13.374
50.000	825.912	603.108	440.408	15.374
100.000	968.271	686.949	487.363	16.785
200.000	1120.866	773.846	534.263	18.117
500.000	1339.444	894.000	596.693	19.770
1000.000	1518.378	989.246	644.509	20.951

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -35.202
BETA = 4.184
GAMMA = 391.031

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	161.719	-7.557	-176.833	8277.565
1.050	181.486	106.541	31.596	3664.785
1.250	228.615	189.292	149.968	1922.904
2.000	286.291	255.171	224.051	1521.761
5.000	327.437	304.877	282.317	1103.176
10.000	349.446	325.203	300.959	1185.499
20.000	372.908	339.348	305.787	1641.082
50.000	402.574	352.658	302.741	2440.899
100.000	422.933	360.120	297.307	3071.542
200.000	441.496	366.040	290.584	3689.783
500.000	463.547	372.135	280.722	4470.040
1000.000	478.554	375.758	272.962	5026.700

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR PEARSON III

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.744
BETA = .412
GAMMA = 5.728

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	378.473	20.337	1.093	142.967
1.050	194.075	88.204	40.087	38.562
1.250	349.489	188.744	101.933	30.126
2.000	346.329	272.700	214.724	11.688
5.000	429.225	304.867	216.539	16.729
10.000	503.002	307.197	187.613	24.113
20.000	489.175	307.404	193.177	22.717
50.000	382.657	310.853	252.522	10.162
100.000	392.935	317.733	256.924	10.388
200.000	642.582	329.174	168.625	32.709
500.000	1512.355	352.484	82.153	71.218
1000.000	3293.110	377.391	43.249	105.932

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.257
BETA = 2.214
GAMMA = 5.989

MEAN = 5.421
S.D. = .382
C.S. = -1.344

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	106.956	52.744	26.010	34.571
1.050	158.014	106.905	72.327	19.107
1.250	214.240	172.676	139.175	10.547
2.000	279.063	245.310	215.639	6.304
5.000	341.701	310.633	282.390	4.661
10.000	367.547	338.307	311.393	4.054
20.000	383.757	356.991	332.093	3.535
50.000	396.620	373.375	351.493	2.953
100.000	402.624	381.668	361.803	2.614
200.000	406.897	387.556	369.135	2.381
500.000	411.186	392.742	375.127	2.244
1000.000	413.867	395.271	377.510	2.248

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

NO MOMENT SOLUTION FOR THREE PARAMETER LOGNORMAL

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR THREE PARAMETER LOGNORMAL

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

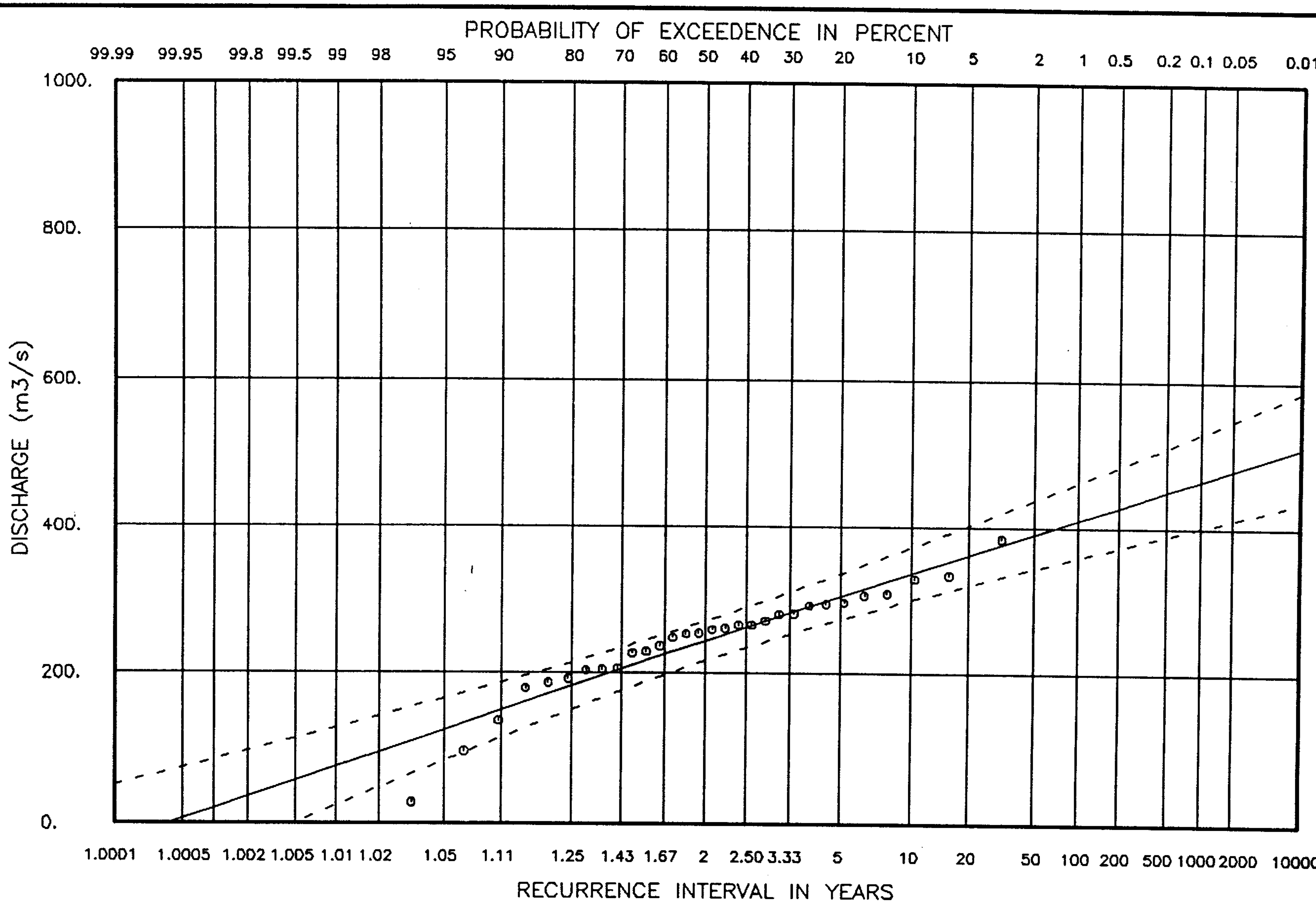
A = .018
U = 211.345

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	159.078	117.678	76.278	17.203
1.050	180.718	148.837	116.955	10.475
1.250	208.758	184.626	160.495	6.391
2.000	256.634	231.922	207.210	5.210
5.000	337.154	295.557	253.960	6.882
10.000	393.852	337.689	281.526	8.133
20.000	449.035	378.103	307.172	9.174
50.000	520.991	430.415	339.839	10.290
100.000	575.120	469.616	364.112	10.986
200.000	629.154	508.673	388.192	11.582
500.000	700.545	560.202	419.858	12.251
1000.000	754.553	599.146	443.739	12.684

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .012
U = 205.425

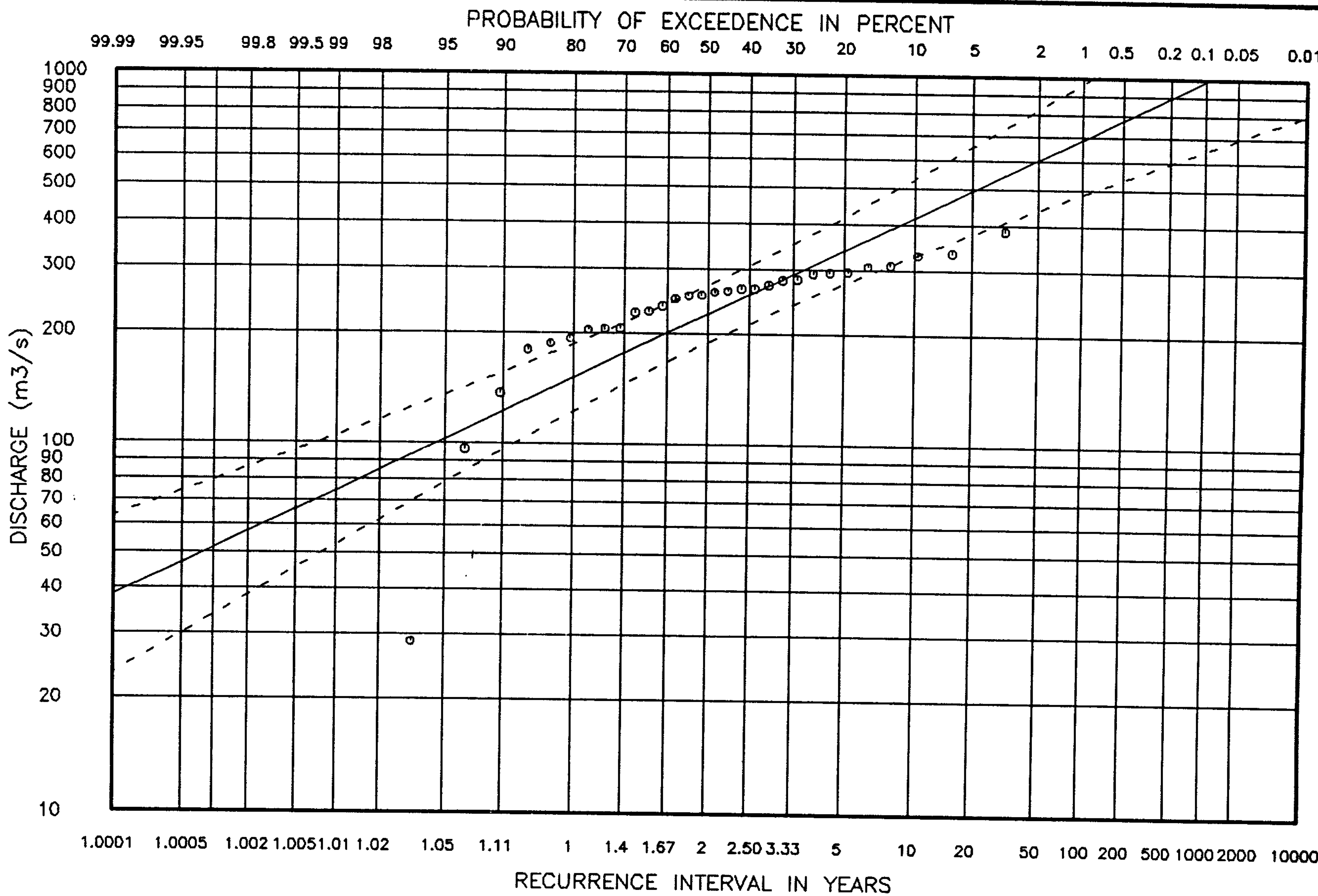
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	107.095	62.511	17.928	34.876
1.050	146.377	110.053	73.728	16.140
1.250	196.670	164.659	132.649	9.506
2.000	274.377	236.822	199.267	7.754
5.000	391.551	333.914	276.278	8.441
10.000	472.135	398.198	324.260	9.080
20.000	550.316	459.860	369.405	9.619
50.000	652.167	539.676	427.186	10.193
100.000	728.765	599.487	470.209	10.545
200.000	805.229	659.079	512.929	10.843
500.000	906.257	737.700	569.143	11.173
1000.000	982.690	797.120	611.550	11.384



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

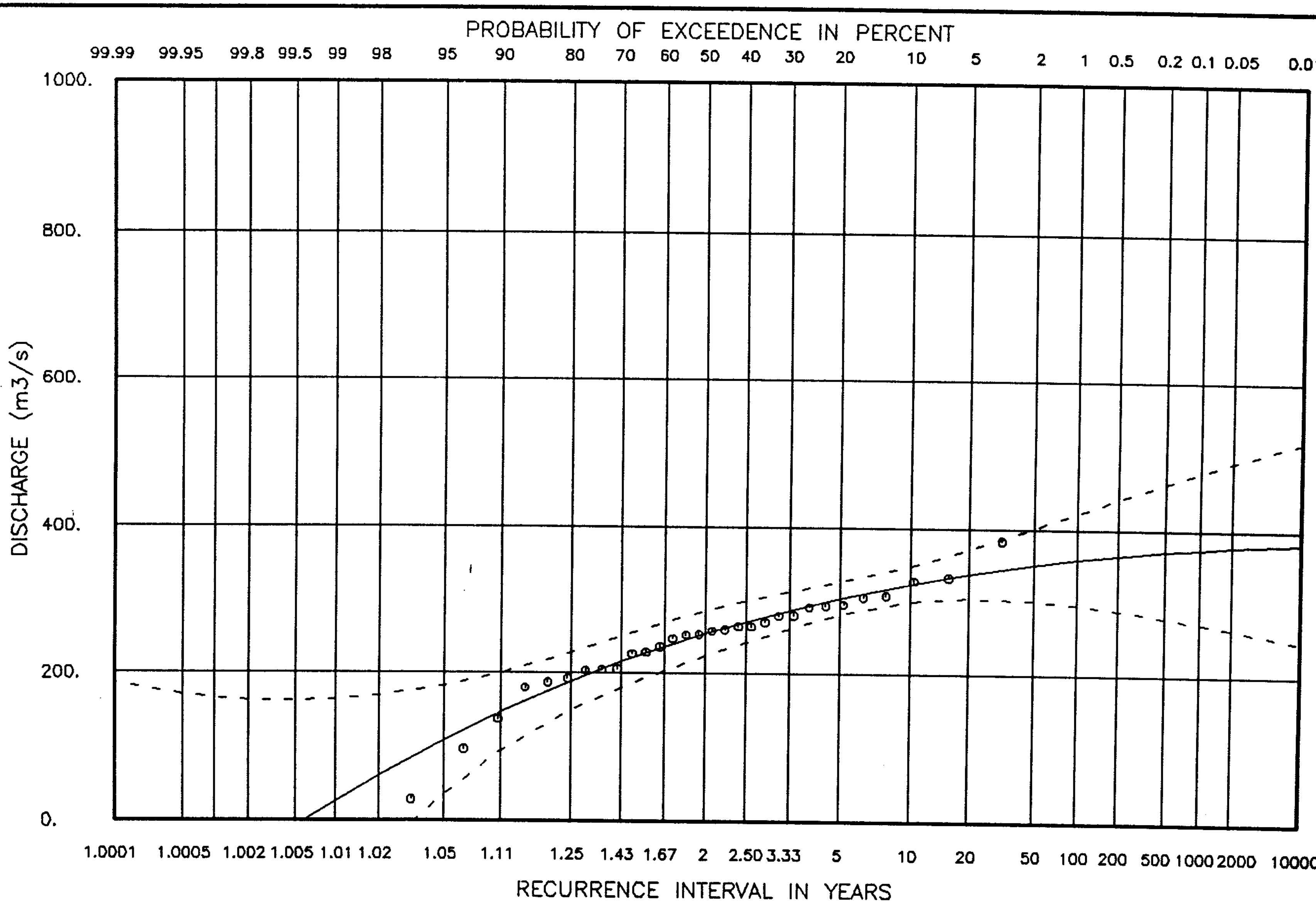
NORMAL DISTRIBUTION

ACRES



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG NORMAL DISTRIBUTION

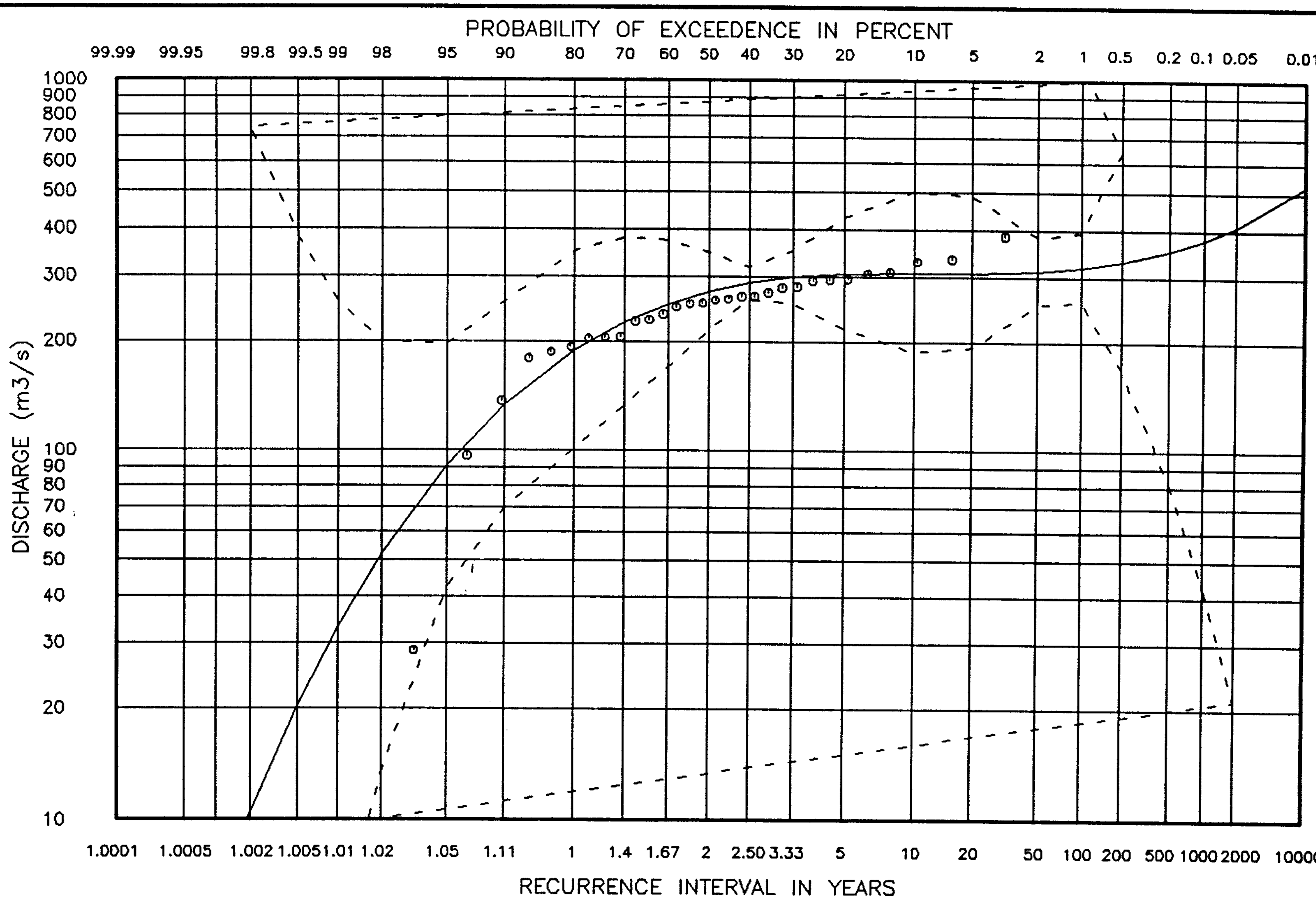


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

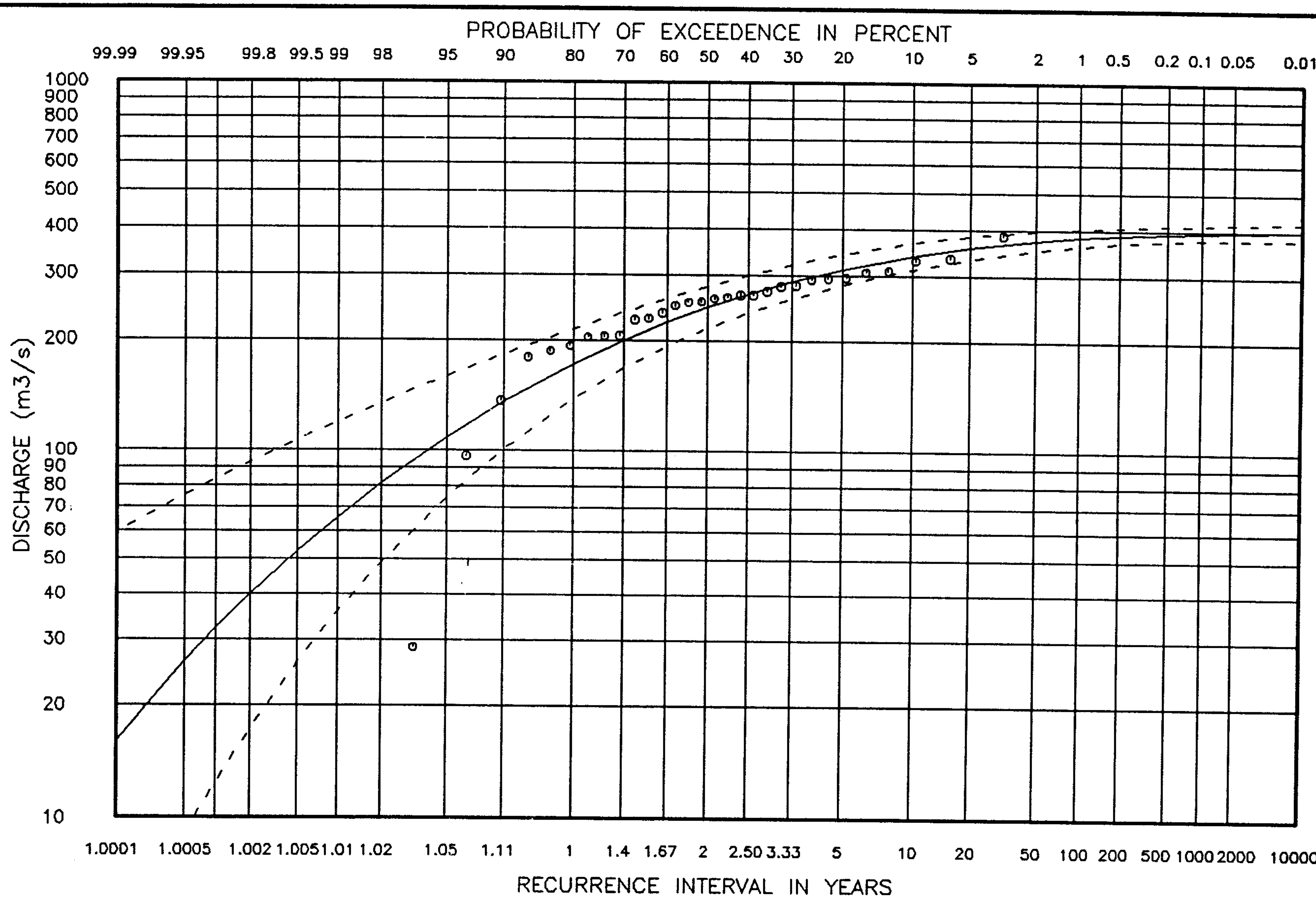


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

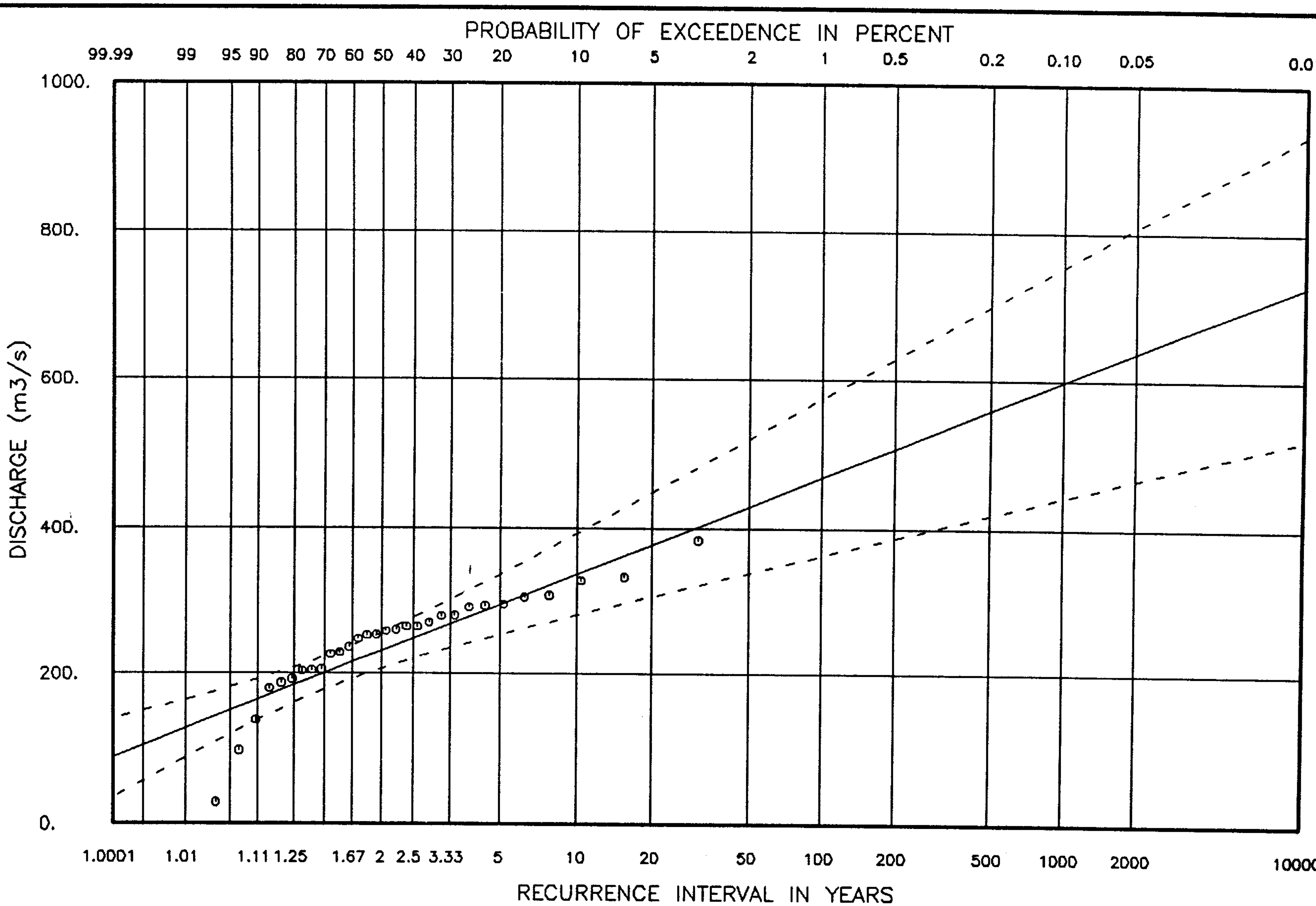


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

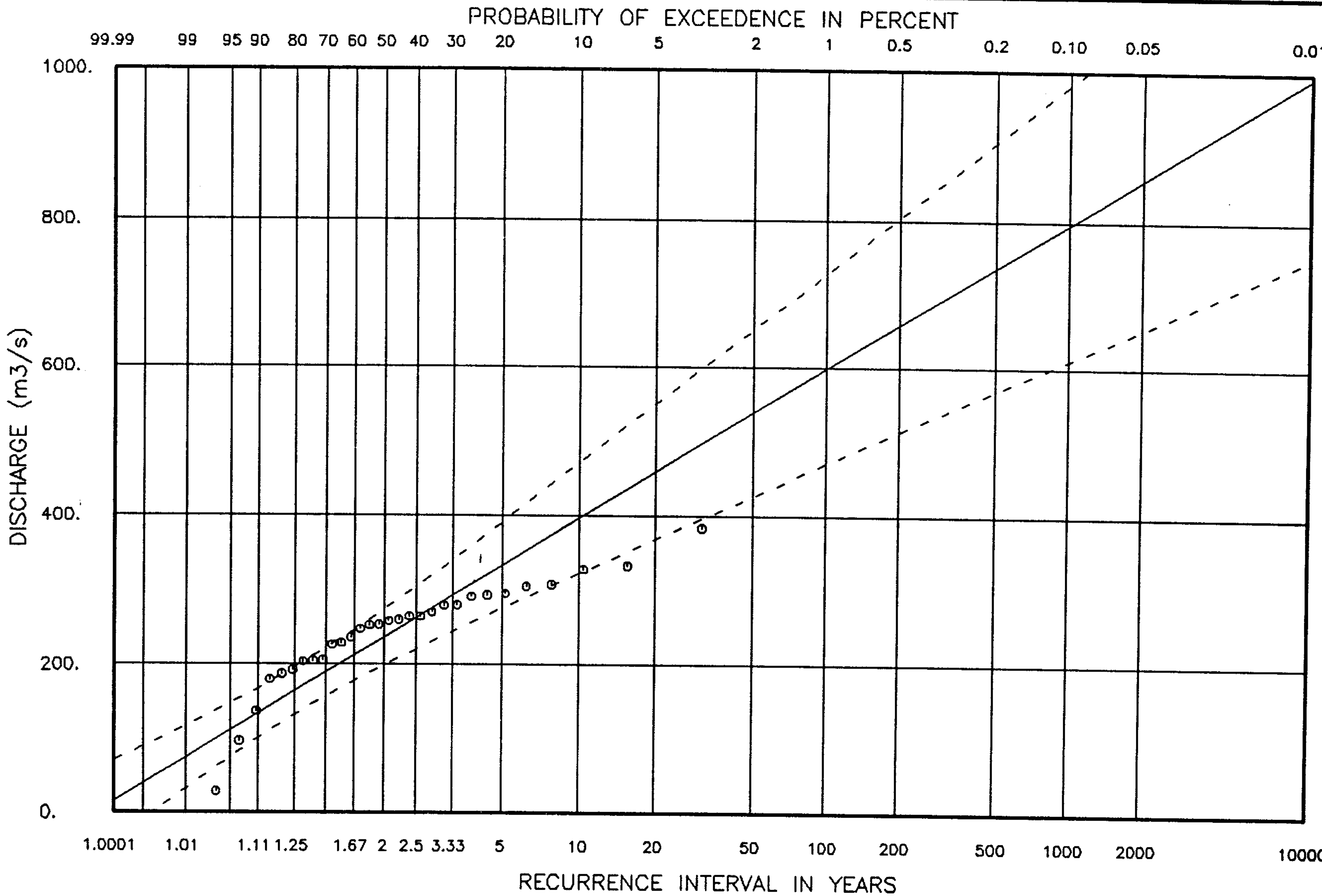


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

GRANBY RIVER AT GRAND FORKS
(DAILY - 1931 REMOVED)

ACRES

GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE 1931 REMOVED

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1914	385.	385.	1	.033	30.000
1915	271.	334.	2	.067	15.000
1927	206.	329.	3	.100	10.000
1928	292.	309.	4	.133	7.500
1929	137.	306.	5	.167	6.000
1930	97.	296.	6	.200	5.000
1967	265.	294.	7	.233	4.286
1968	294.	292.	8	.267	3.750
1969	259.	281.	9	.300	3.333
1970	180.	280.	10	.333	3.000
1971	334.	271.	11	.367	2.727
1972	306.	265.	12	.400	2.500
1973	227.	265.	13	.433	2.308
1974	281.	261.	14	.467	2.143
1975	253.	259.	15	.500	2.000
1976	248.	254.	16	.533	1.875
1977	187.	253.	17	.567	1.765
1978	205.	248.	18	.600	1.667
1979	193.	237.	19	.633	1.579
1980	296.	229.	20	.667	1.500
1981	265.	227.	21	.700	1.429
1982	254.	206.	22	.733	1.364
1983	329.	205.	23	.767	1.304
1984	261.	204.	24	.800	1.250
1985	237.	193.	25	.833	1.200
1986	309.	187.	26	.867	1.154
1987	280.	180.	27	.900	1.111
1988	229.	137.	28	.933	1.071
1989	204.	97.	29	.967	1.034

STATISTICS OF DATA SERIES

SAMPLE SIZE = 29

MEAN =	251.2	MIN. =	96.8	MAX. =	385.0
S.D. =	60.5	C.S. =	-.3836	C.K. =	3.8331

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	5.4925	MIN. =	4.5726	MAX. =	5.9532
S.D. =	.2796	C.S. =	-1.4451	C.K. =	6.1977

NORMAL DISTRIBUTION

MEAN = 251.166
S.D. = 60.496

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	143.045	95.211	47.376	24.532
1.050	185.799	150.214	114.628	11.567
1.250	227.033	200.262	173.491	6.527
2.000	274.171	251.165	228.158	4.473
5.000	328.840	302.069	275.298	4.327
10.000	359.754	328.704	297.654	4.612
20.000	385.987	350.693	315.399	4.914
50.000	416.006	375.434	334.863	5.277
100.000	436.221	391.925	347.630	5.519
200.000	454.826	407.016	359.206	5.736
500.000	477.476	425.302	373.128	5.990
1000.000	493.419	438.128	382.837	6.162

LOG NORMAL DISTRIBUTION

MEAN = 5.493
S.D. = .280

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	147.353	118.127	94.697	10.795
1.050	179.545	152.317	129.218	8.030
1.250	217.239	191.957	169.617	6.041
2.000	270.118	242.870	218.372	5.192
5.000	347.763	307.290	271.528	6.041
10.000	401.173	347.544	301.084	7.007
20.000	452.883	384.720	326.817	7.965
50.000	520.283	431.326	357.578	9.156
100.000	571.235	465.485	379.312	9.996
200.000	622.527	499.109	400.158	10.789
500.000	691.228	543.123	426.752	11.774
1000.000	744.083	576.292	446.338	12.477

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -11.602
BETA = 27.189
GAMMA = 566.610

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	167.510	73.326	-20.858	4598.835
1.050	192.339	143.780	95.221	2371.048
1.250	231.330	201.752	172.175	1444.213
2.000	280.113	255.016	229.920	1225.423
5.000	326.916	302.828	278.739	1176.195
10.000	352.132	325.769	299.407	1287.226
20.000	375.217	343.675	312.133	1540.136
50.000	404.097	362.735	321.373	2019.625
100.000	424.848	374.815	324.783	2443.001
200.000	444.710	385.443	326.176	2893.895
500.000	469.723	397.786	325.850	3512.518
1000.000	487.800	406.101	324.402	3989.212

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR PEARSON III

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.202
BETA = 1.915
GAMMA = 5.879

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	200.509	81.636	33.238	43.876
1.050	198.383	139.807	98.527	17.087
1.250	238.255	200.166	168.166	8.506
2.000	295.790	258.795	226.427	6.524
5.000	328.761	305.854	284.543	3.527
10.000	360.756	324.149	291.257	5.224
20.000	399.004	335.825	282.649	8.417
50.000	446.621	345.457	267.208	12.541
100.000	478.777	350.019	255.888	15.295
200.000	507.196	353.056	245.760	17.689
500.000	538.742	355.503	234.588	20.298
1000.000	557.937	356.559	227.865	21.863

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.117
BETA = 5.121
GAMMA = 6.089

MEAN = 5.493
S.D. = .264
C.S. = -.884

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	156.002	98.968	62.785	22.220
1.050	188.949	147.636	115.356	12.047
1.250	228.605	198.374	172.141	6.926
2.000	278.941	252.278	228.163	4.906
5.000	331.554	304.024	278.780	4.233
10.000	357.524	328.840	302.458	4.084
20.000	378.692	347.704	319.251	4.169
50.000	403.366	366.907	333.743	4.626
100.000	420.690	378.424	340.403	5.170
200.000	437.158	388.027	344.418	5.821
500.000	457.714	398.450	346.860	6.771
1000.000	472.371	404.968	347.183	7.517

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

NO MOMENT SOLUTION FOR THREE PARAMETER LOGNORMAL

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR THREE PARAMETER LOGNORMAL

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

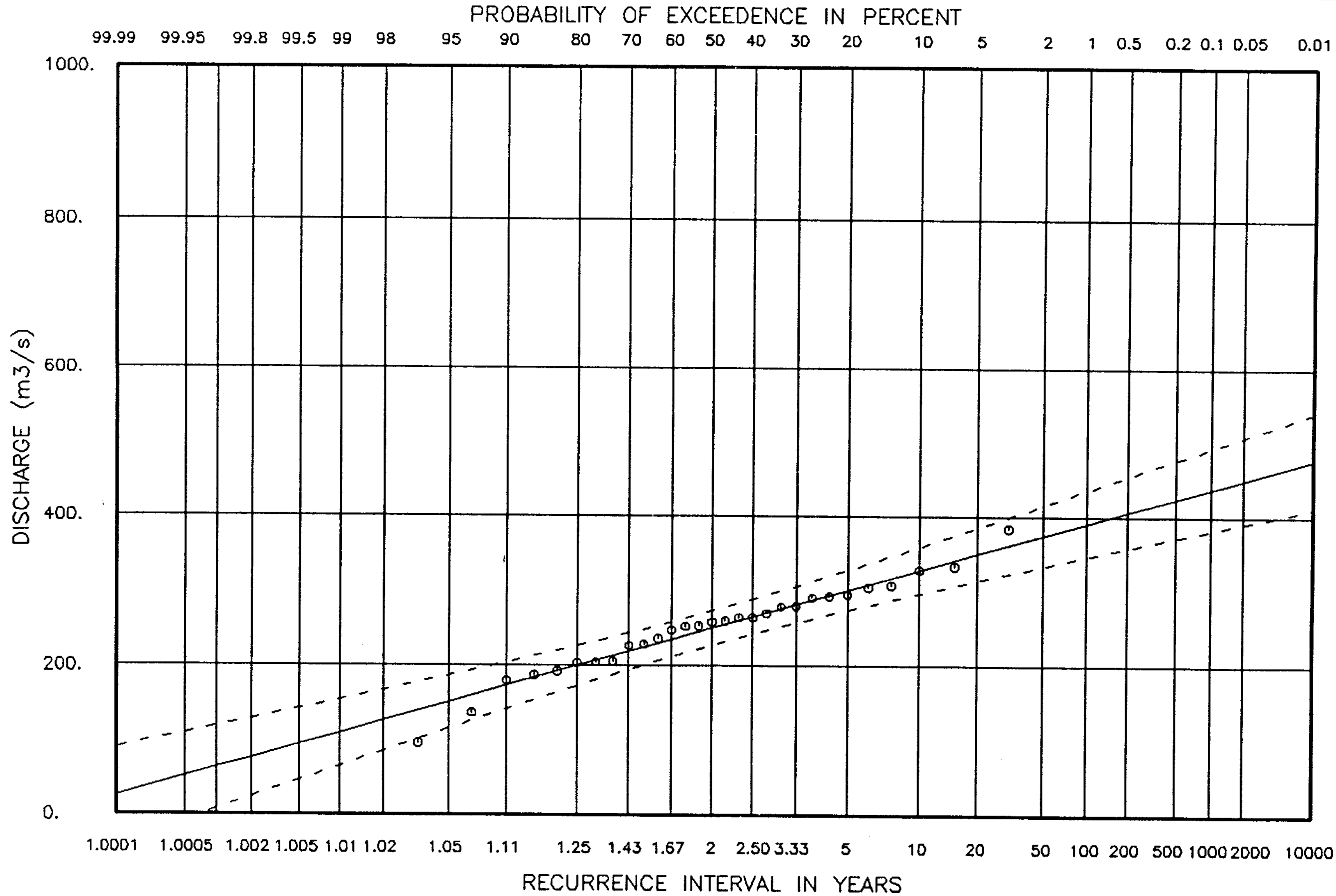
A = .021
U = 223.943

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	180.676	145.247	109.818	11.910
1.050	198.709	171.426	144.143	7.771
1.250	222.146	201.495	180.844	5.004
2.000	262.379	241.231	220.083	4.281
5.000	330.292	294.695	259.097	5.898
10.000	378.155	330.092	282.029	7.110
20.000	424.748	364.047	303.345	8.142
50.000	485.510	407.997	330.484	9.277
100.000	531.219	440.932	350.644	9.998
200.000	576.851	473.746	370.641	10.627
500.000	637.141	517.038	396.936	11.342
1000.000	682.752	549.758	416.764	11.812

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .016
U = 220.374

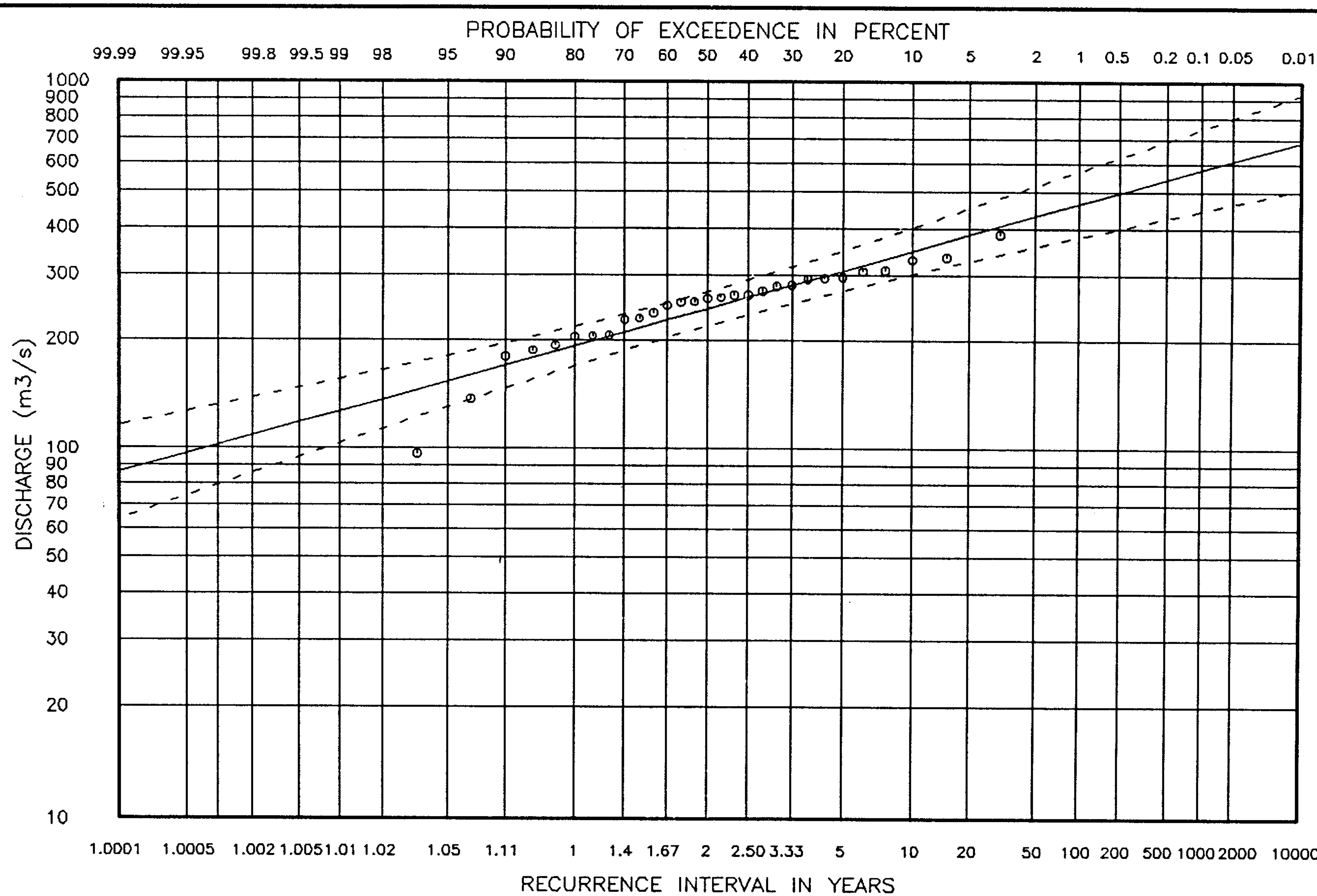
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	147.172	113.078	78.983	14.722
1.050	176.549	148.771	120.992	9.117
1.250	214.248	189.768	165.288	6.299
2.000	272.665	243.946	215.226	5.748
5.000	360.917	316.841	272.764	6.793
10.000	421.646	365.103	308.561	7.562
20.000	480.572	411.398	342.224	8.210
50.000	557.347	471.322	385.297	8.912
100.000	615.089	516.226	417.363	9.351
200.000	672.732	560.967	449.201	9.728
500.000	748.894	619.993	491.093	10.152
1000.000	806.515	664.604	522.694	10.426



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

NORMAL DISTRIBUTION

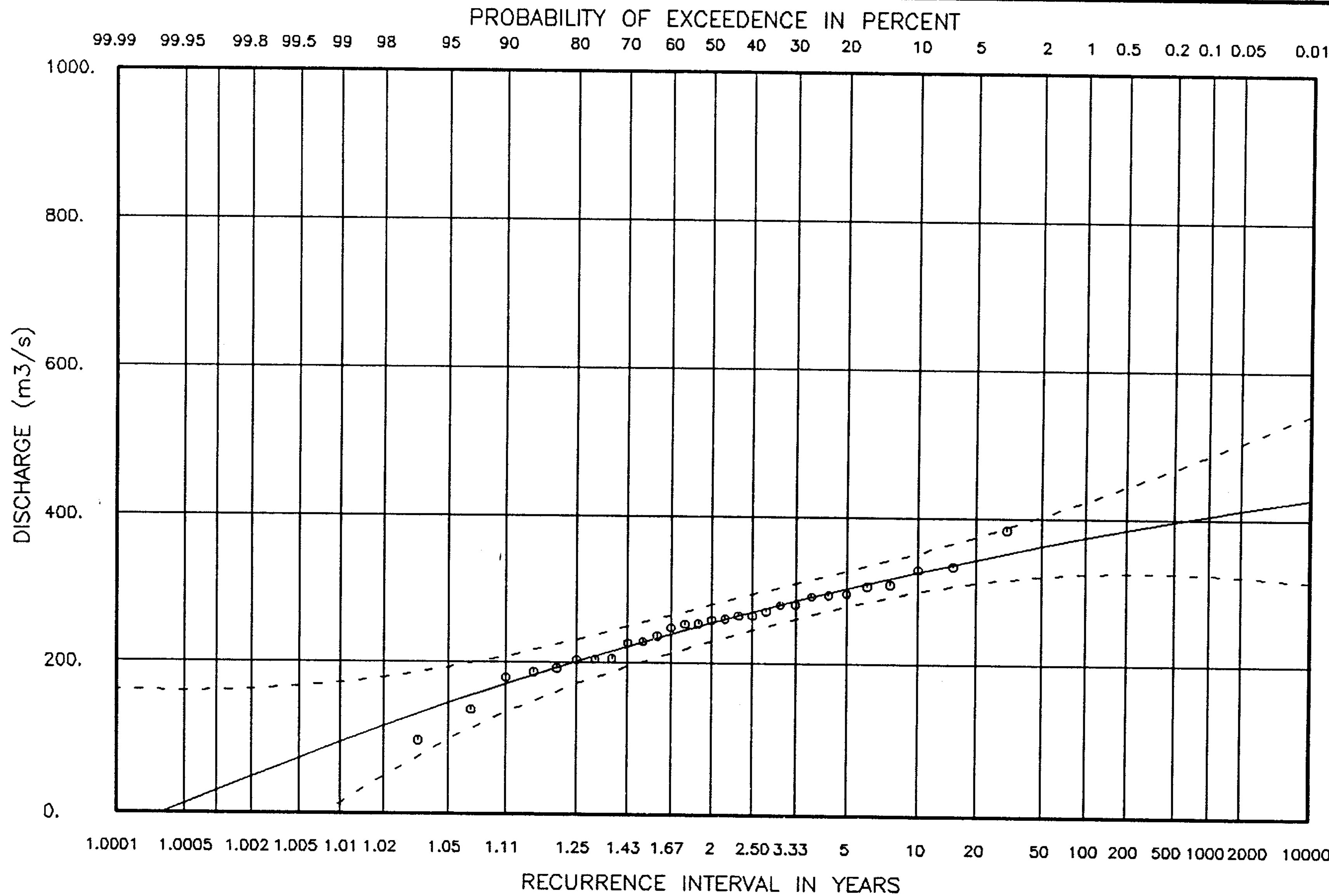
ACRES



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG NORMAL DISTRIBUTION

ACRES

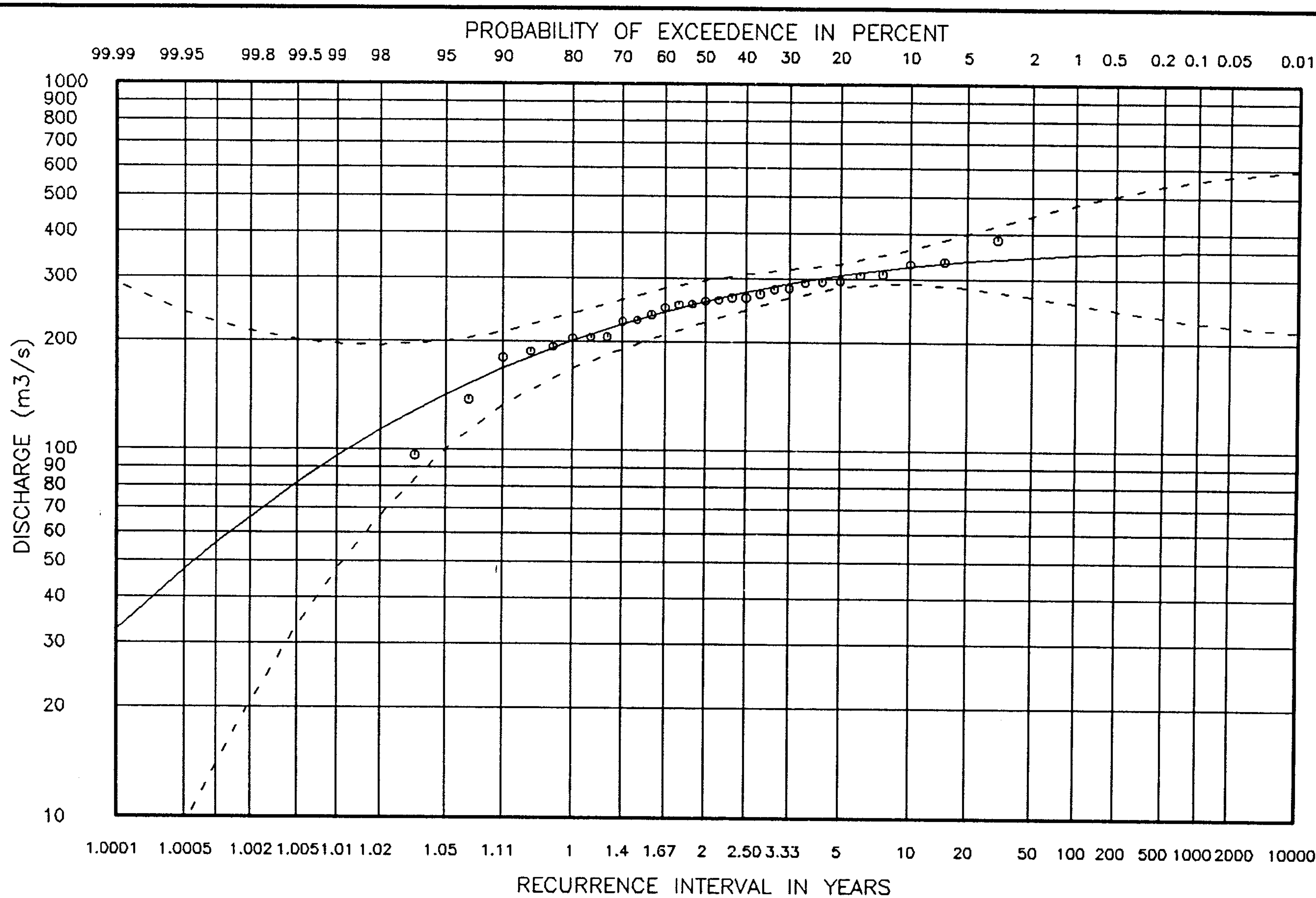


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

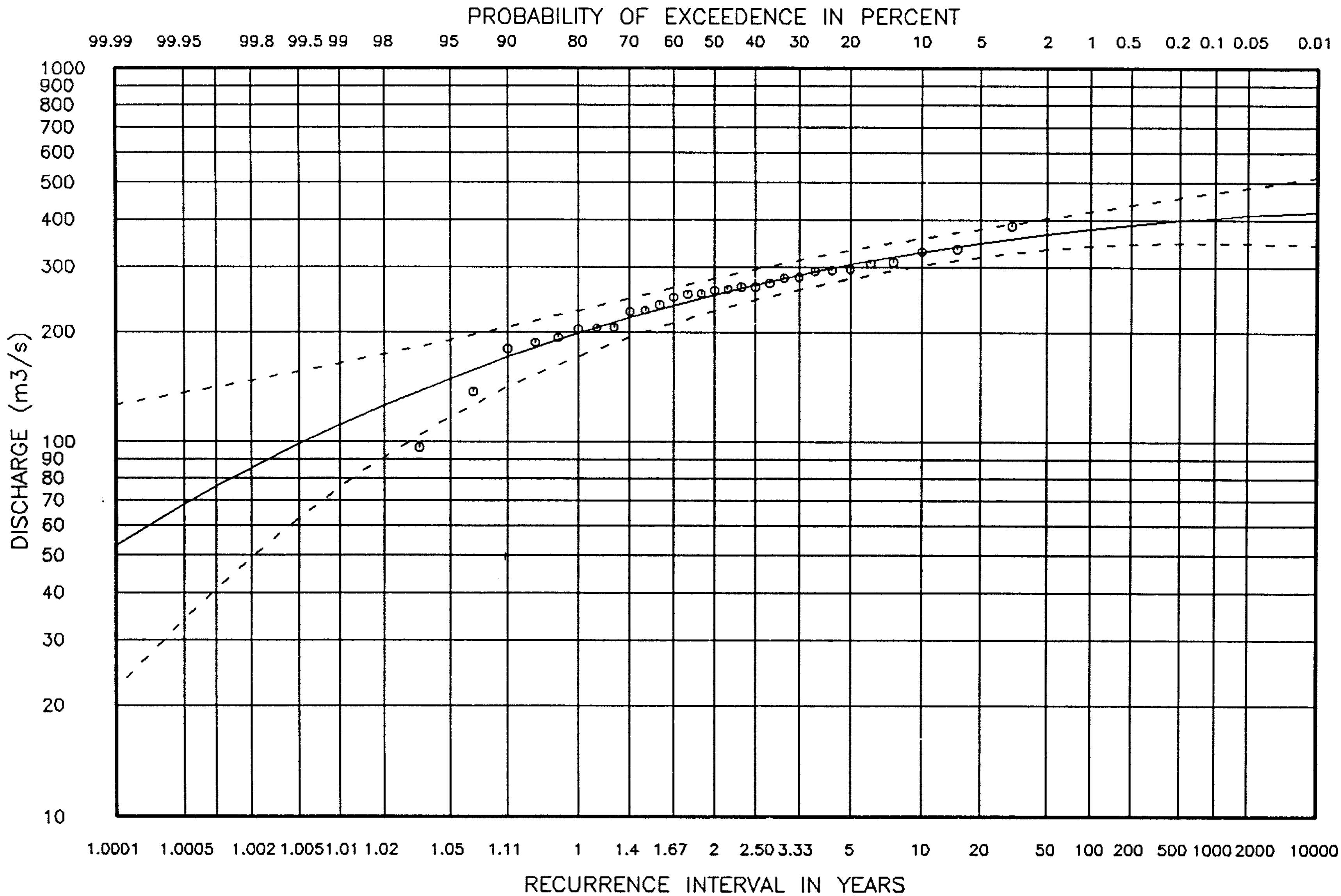


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

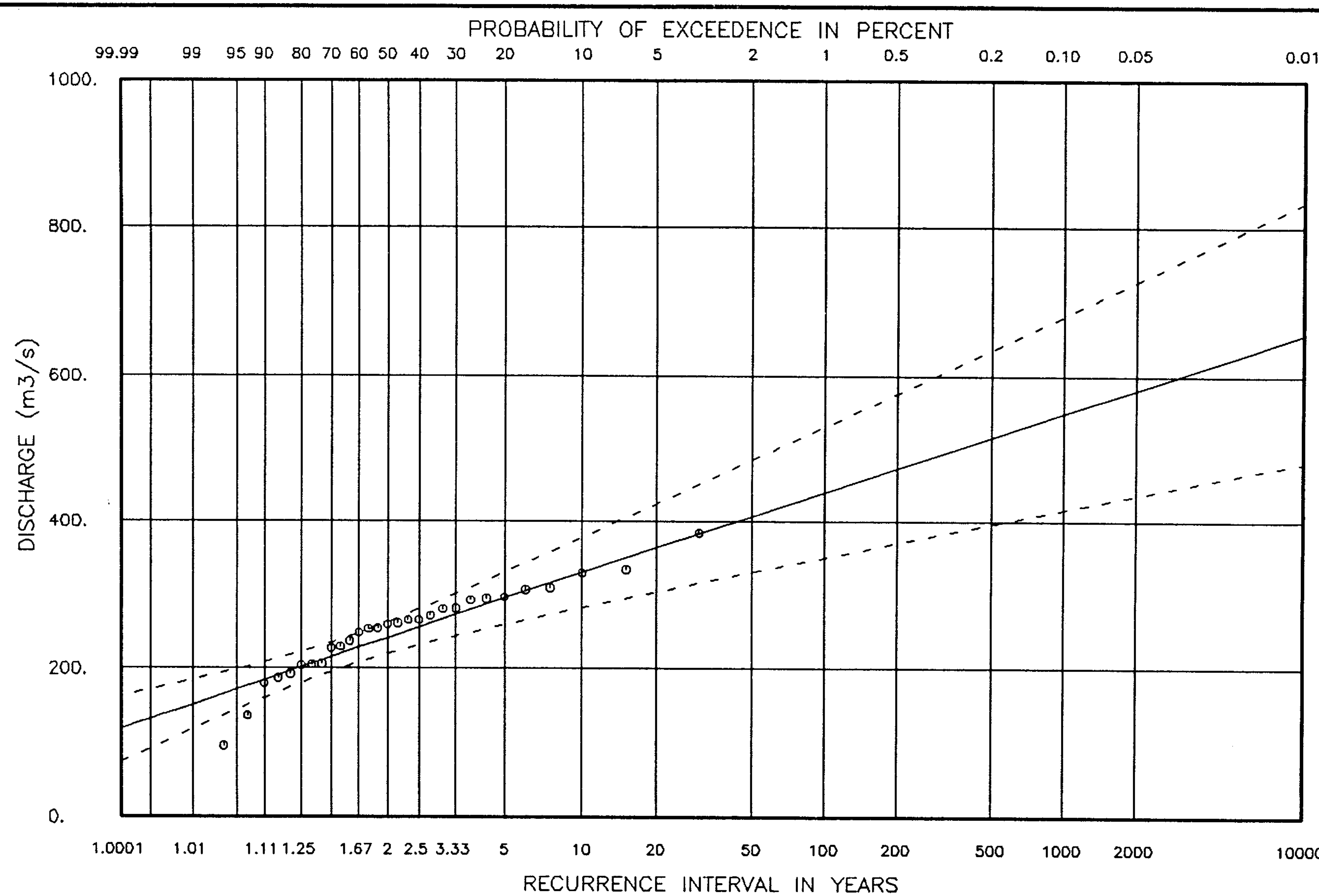


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

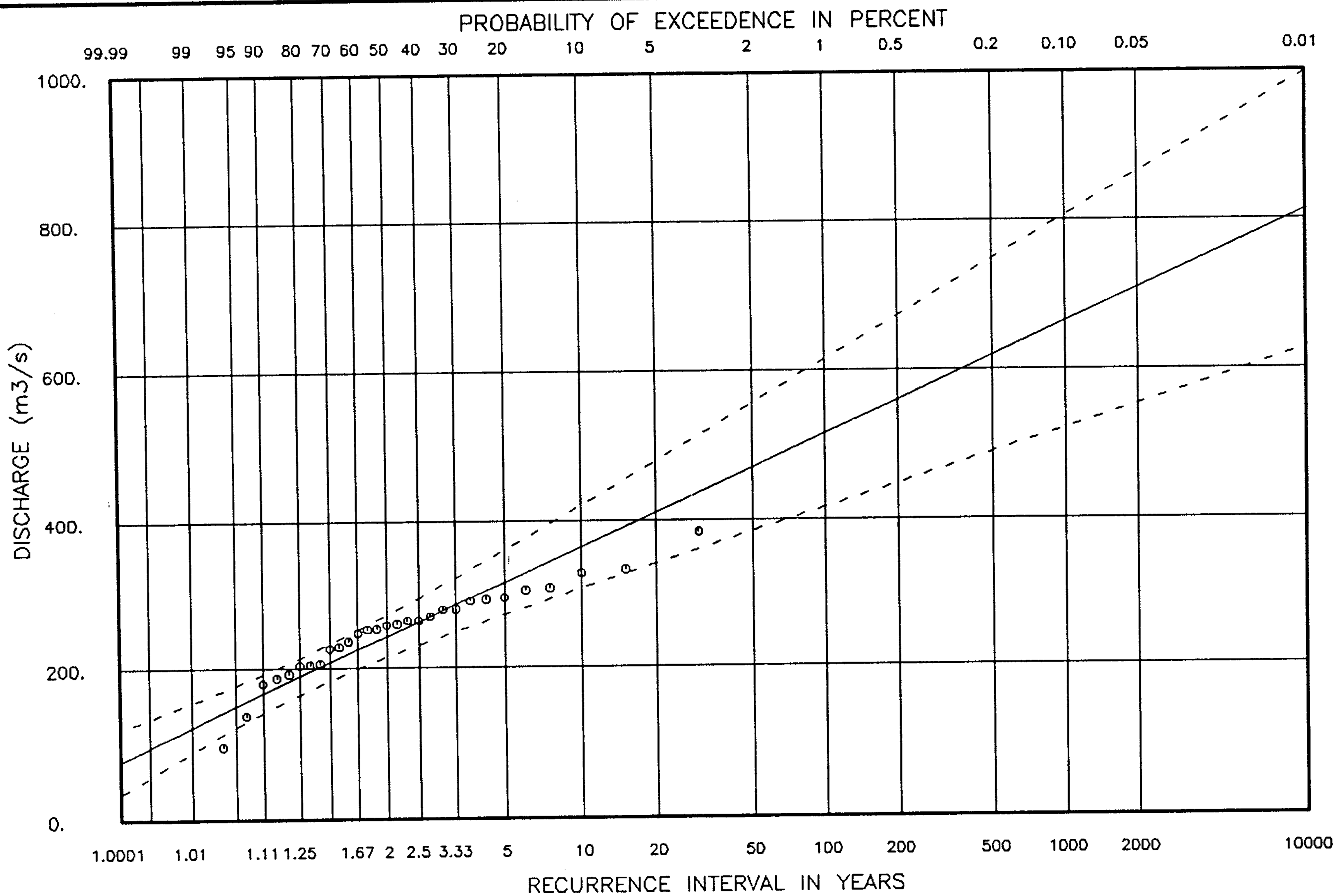


GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



GRANBY RIVER AT GRAND FORKS MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

KETTLE RIVER AT CASCADE
(DAILY)

ACRES

KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

YEAR	DATA	ORDERED	RANK	PROBABILITY	RETURN PERIOD
1916	430.	830.	1	.053	19.000
1917	595.	716.	2	.105	9.500
1918	453.	694.	3	.158	6.333
1919	694.	682.	4	.211	4.750
1920	365.	637.	5	.263	3.800
1921	830.	595.	6	.316	3.167
1923	464.	586.	7	.368	2.714
1924	535.	583.	8	.421	2.375
1925	583.	535.	9	.474	2.111
1926	456.	493.	10	.526	1.900
1927	682.	464.	11	.579	1.727
1928	716.	456.	12	.632	1.583
1929	314.	453.	13	.684	1.462
1930	210.	430.	14	.737	1.357
1931	362.	365.	15	.789	1.267
1932	493.	362.	16	.842	1.188
1933	637.	314.	17	.895	1.118
1934	586.	210.	18	.947	1.056

STATISTICS OF DATA SERIES

SAMPLE SIZE = 18

MEAN =	522.5	MIN. =	210.0	MAX. =	830.0
S.D. =	158.5	C.S. =	-.0247	C.K. =	2.9642

STATISTICS OF OF LOGS OF DATA SERIES

MEAN =	6.2090	MIN. =	5.3471	MAX. =	6.7214
S.D. =	.3387	C.S. =	-.8893	C.K. =	4.1681

NORMAL DISTRIBUTION

MEAN = 522.500
S.D. = 158.460

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	277.850	113.997	-49.856	68.120
1.050	379.963	258.070	136.177	22.385
1.250	480.866	389.164	297.462	11.168
2.000	601.305	522.498	443.691	7.148
5.000	747.538	655.836	564.134	6.627
10.000	831.959	725.602	619.244	6.947
20.000	904.094	783.199	662.304	7.316
50.000	986.980	848.006	709.032	7.767
100.000	1042.933	891.202	739.471	8.069
200.000	1094.498	930.730	766.961	8.339
500.000	1157.346	978.627	799.909	8.655
1000.000	1201.617	1012.223	822.829	8.868
10000.000	1333.558	1111.832	890.106	9.451

LOG NORMAL DISTRIBUTION

MEAN = 6.209
S.D. = .339

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	294.730	207.641	146.286	16.599
1.050	366.623	282.528	217.722	12.349
1.250	454.875	373.905	307.348	9.290
2.000	588.437	497.211	420.127	7.984
5.000	804.365	661.185	543.491	9.290
10.000	963.441	767.519	611.439	10.775
20.000	1124.063	868.079	670.390	12.248
50.000	1341.951	997.061	740.809	14.079
100.000	1512.445	1093.508	790.613	15.371
200.000	1688.691	1189.919	838.464	16.591
500.000	1931.495	1318.204	899.646	18.105
1000.000	2123.209	1416.352	944.821	19.187
10000.000	2814.998	1752.433	1090.949	22.462

PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -1.957
BETA = 6553.076
GAMMA = 13350.003

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	358.975	110.312	-138.351	11784.956
1.050	393.542	256.910	120.278	6475.441
1.250	482.143	389.359	296.574	4397.375
2.000	608.275	523.151	438.026	4034.355
5.000	747.599	656.022	564.446	4340.116
10.000	832.326	725.177	618.028	5078.142
20.000	913.039	782.081	651.122	6206.556
50.000	1016.600	845.902	675.204	8089.964
100.000	1092.889	888.320	683.752	9695.202
200.000	1167.531	927.053	686.575	11397.059
500.000	1263.899	973.879	683.860	13744.993
1000.000	1335.235	1006.654	678.072	15572.591
10000.000	1564.222	1103.485	642.749	21835.864

PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -307.204
BETA = 1.001
GAMMA = 830.017

MEAN = 522.500
S.D. = 307.361
C.S. = -1.999

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	4.526	-812.110	-1628.746	38703.119
1.050	363.525	-97.764	-559.052	21862.035
1.250	582.741	338.324	93.907	11583.756
2.000	721.371	613.953	506.534	5090.922
5.000	795.293	760.675	726.058	1640.639
10.000	815.061	799.697	784.333	728.164
20.000	824.378	817.837	811.296	309.997
50.000	829.477	827.383	825.288	99.265
100.000	830.542	829.564	828.586	46.342
200.000	830.247	830.009	829.770	11.323
500.000	830.756	830.123	829.490	29.998
1000.000	832.265	830.873	829.481	65.982
10000.000	850.716	843.211	835.705	355.703

LOG PEARSON TYPE III DISTRIBUTION BY MOMENTS

ALPHA = -.151
BETA = 5.058
GAMMA = 6.971

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	425.058	156.656	57.736	47.307
1.050	412.322	262.221	166.763	21.451
1.250	488.336	383.467	301.118	11.457
2.000	633.149	522.238	430.755	9.127
5.000	768.371	663.461	572.875	6.957
10.000	856.577	733.602	628.282	7.345
20.000	968.409	787.860	640.972	9.779
50.000	1140.992	843.868	624.118	14.297
100.000	1282.470	877.806	600.828	17.968
200.000	1430.502	906.291	574.178	21.631
500.000	1634.012	937.378	537.742	26.337
1000.000	1792.617	956.901	510.795	29.750
10000.000	2336.451	1003.820	431.276	40.039

LOG PEARSON TYPE III DISTRIBUTION BY MAXIMUM LIKELIHOOD

ALPHA = -.170
BETA = 3.878
GAMMA = 6.869

MEAN = 6.209
S.D. = .335
C.S. = -1.016

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	333.001	152.663	69.988	36.963
1.050	400.673	261.992	171.311	20.134
1.250	491.788	386.530	303.800	11.414
2.000	618.336	525.378	446.395	7.721
5.000	756.252	660.518	576.904	6.415
10.000	822.288	724.543	638.417	5.998
20.000	873.931	772.282	682.457	5.860
50.000	932.678	819.568	720.175	6.127
100.000	974.024	847.029	736.592	6.621
200.000	1013.759	869.240	745.324	7.289
500.000	1063.847	892.432	748.637	8.327
1000.000	1099.672	906.322	746.968	9.165
10000.000	1204.132	936.787	728.799	11.898

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MOMENTS

NO MOMENT SOLUTION FOR THREE PARAMETER LOGNORMAL

THREE PARAMETER LOG NORMAL DISTRIBUTION BY MAXIMUM LIKELIHOOD

NO MAXIMUM LIKELIHOOD SOLUTION FOR THREE PARAMETER LOGNORMAL

GUMBEL TYPE I DISTRIBUTION BY MOMENTS

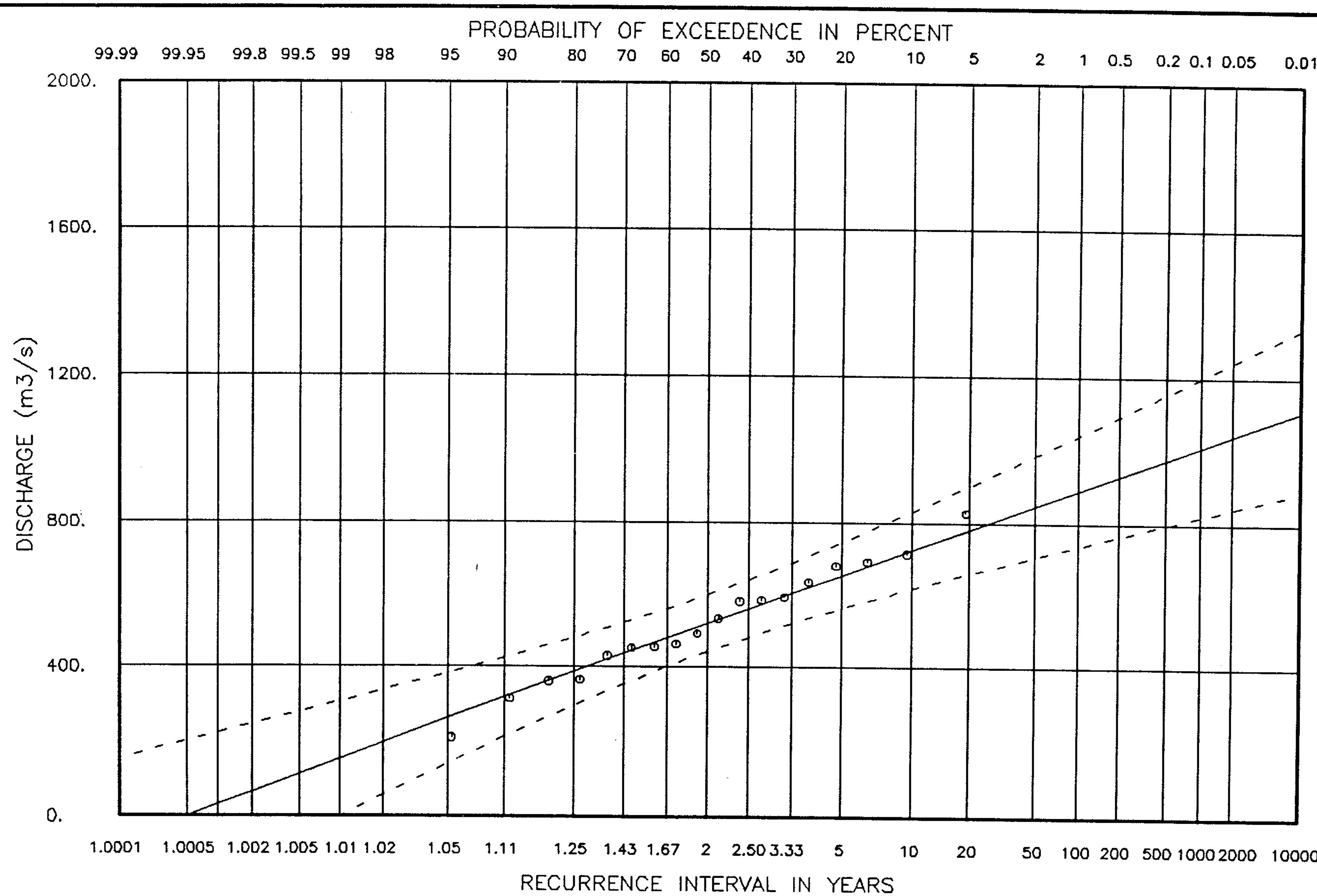
A = .008
U = 451.193

RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	366.420	245.062	123.703	23.470
1.050	407.090	313.633	220.177	14.122
1.250	463.133	392.395	321.657	8.544
2.000	568.918	496.478	424.038	6.915
5.000	758.455	636.519	514.583	9.079
10.000	893.873	729.238	564.604	10.700
20.000	1026.104	818.177	610.250	12.044
50.000	1198.811	933.299	667.787	13.483
100.000	1328.839	1019.567	710.295	14.376
200.000	1458.696	1105.520	752.344	15.141
500.000	1630.318	1218.919	807.519	15.996
1000.000	1760.180	1304.623	849.065	16.549
10000.000	2191.900	1589.175	986.451	17.975

GUMBEL TYPE I DISTRIBUTION BY MAXIMUM LIKELIHOOD

A = .007
U = 445.410

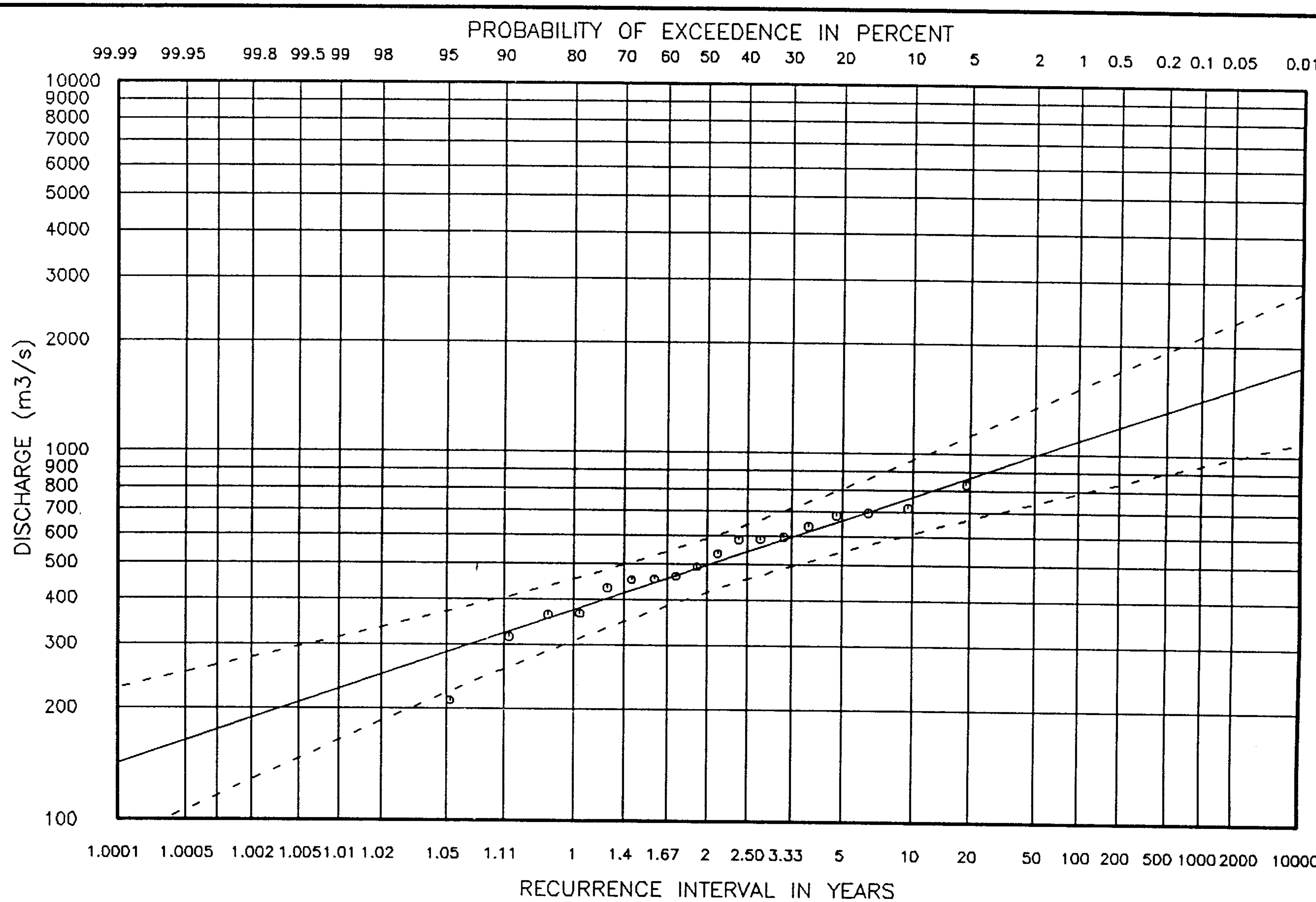
RETURN PERIOD	UPPER CONFIDENCE LIMIT	FLOOD ESTIMATE	LOWER CONFIDENCE LIMIT	STANDARD ERROR PERCENT
1.005	301.064	198.436	95.809	24.511
1.050	364.211	280.595	196.978	14.123
1.250	448.648	374.962	301.275	9.314
2.000	586.117	499.668	413.219	8.200
5.000	800.132	667.457	534.782	9.421
10.000	948.746	778.548	608.349	10.361
20.000	1093.331	885.109	676.887	11.149
50.000	1281.985	1023.041	764.097	11.996
100.000	1423.990	1126.402	828.813	12.521
200.000	1565.811	1229.386	892.960	12.969
500.000	1753.258	1365.253	977.248	13.469
1000.000	1895.105	1467.938	1040.771	13.791
10000.000	2366.730	1808.872	1251.015	14.616



KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

NORMAL DISTRIBUTION

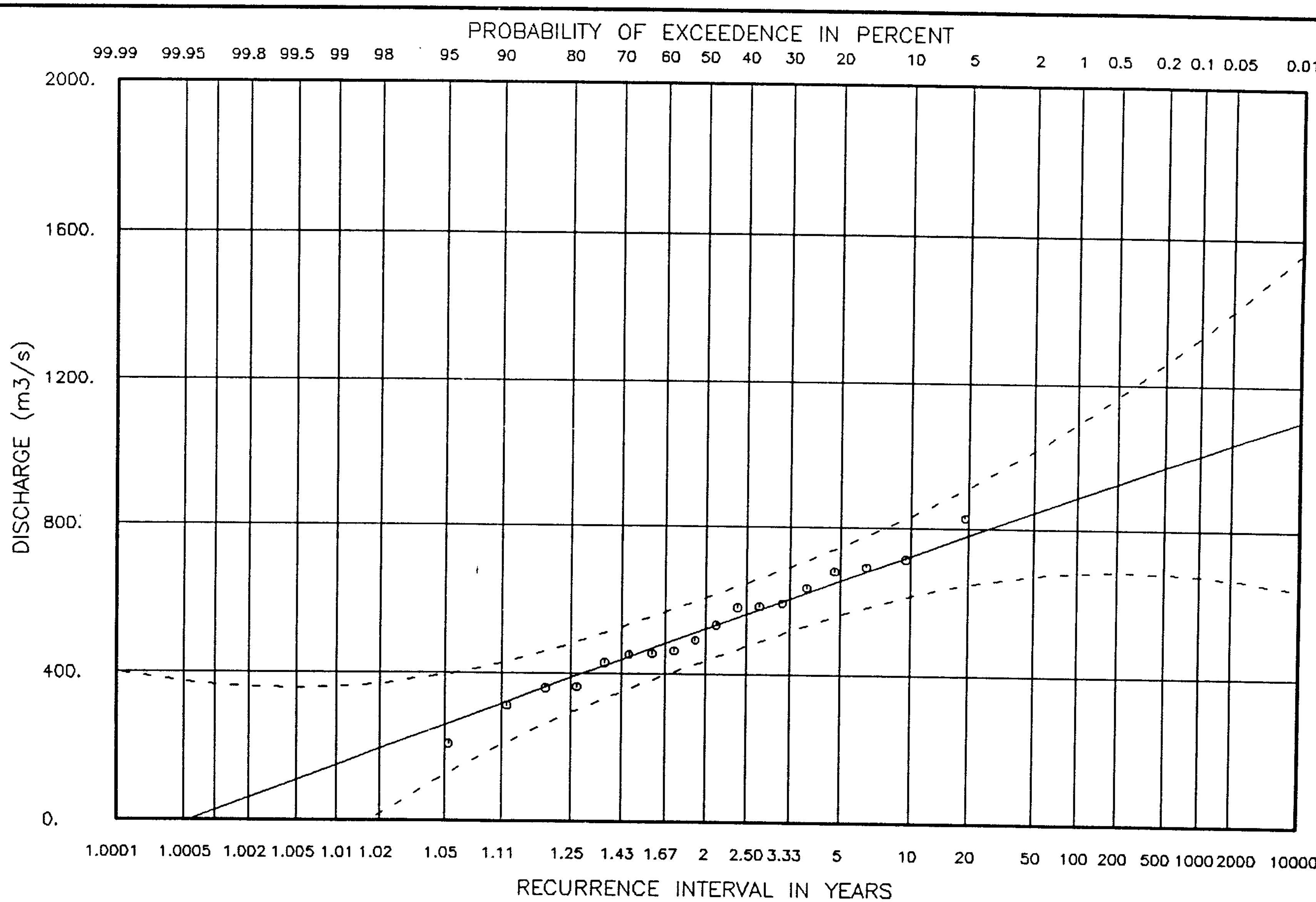
ACRES



KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

LOG NORMAL DISTRIBUTION

ACRES

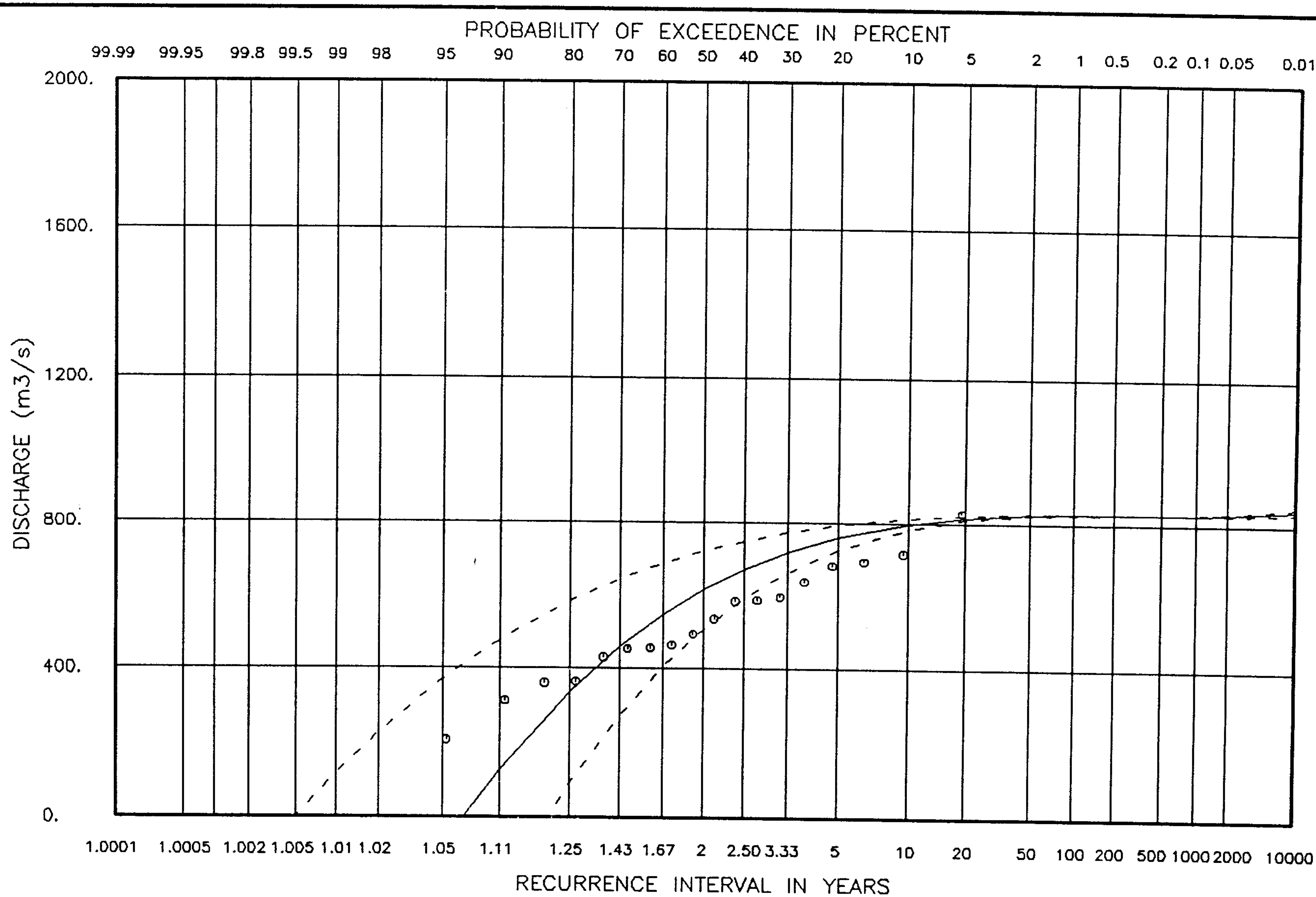


KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

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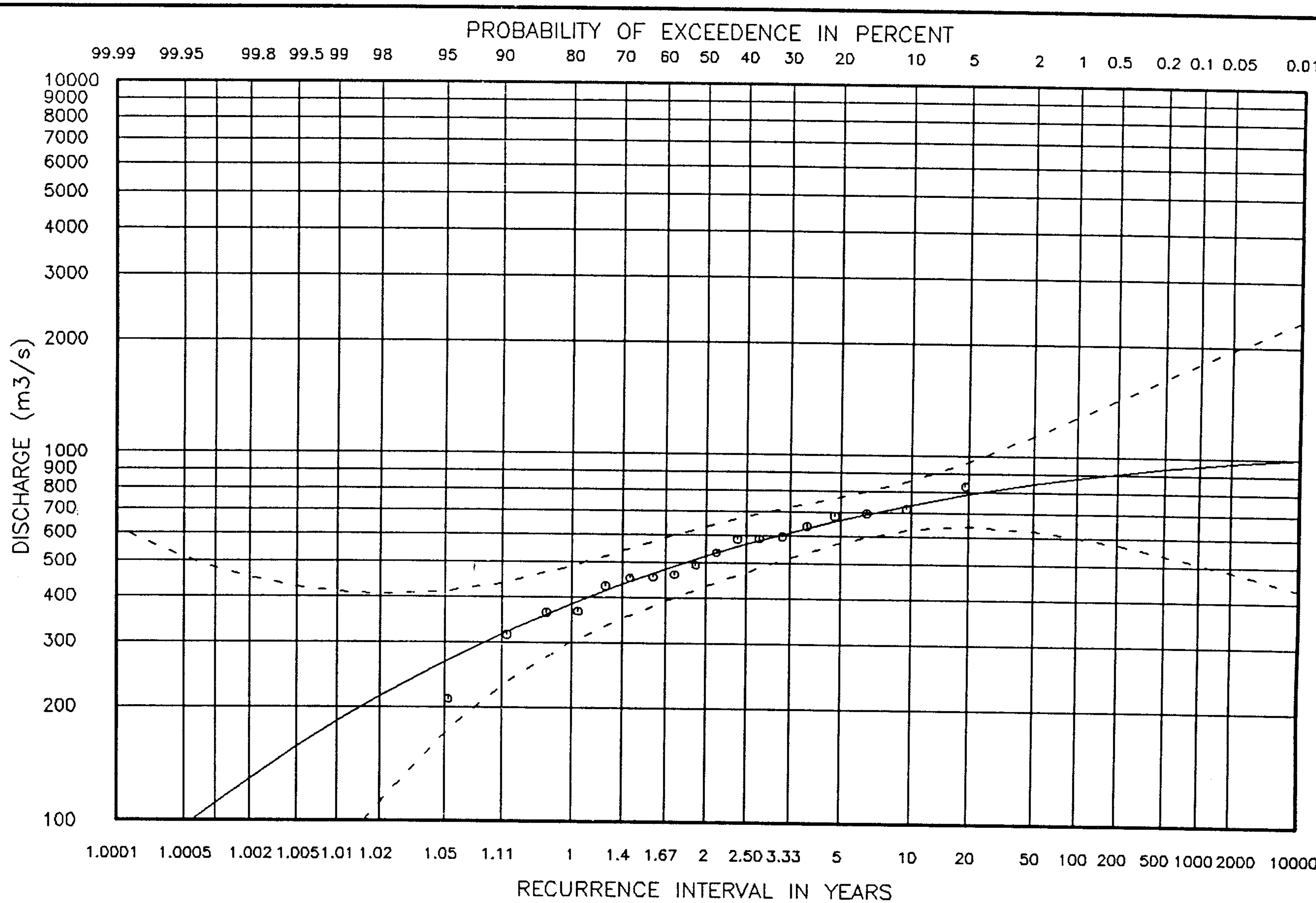
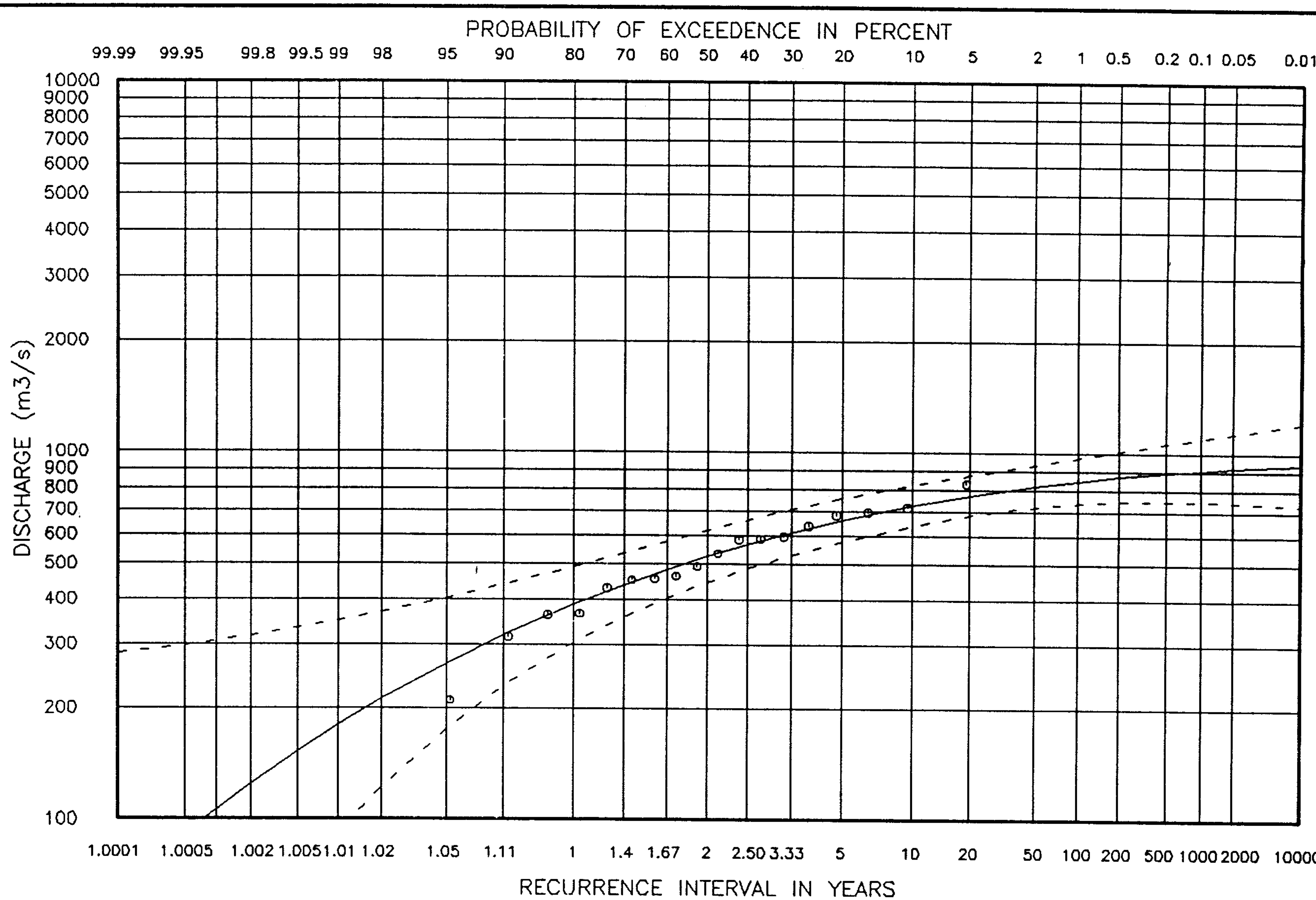


KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES

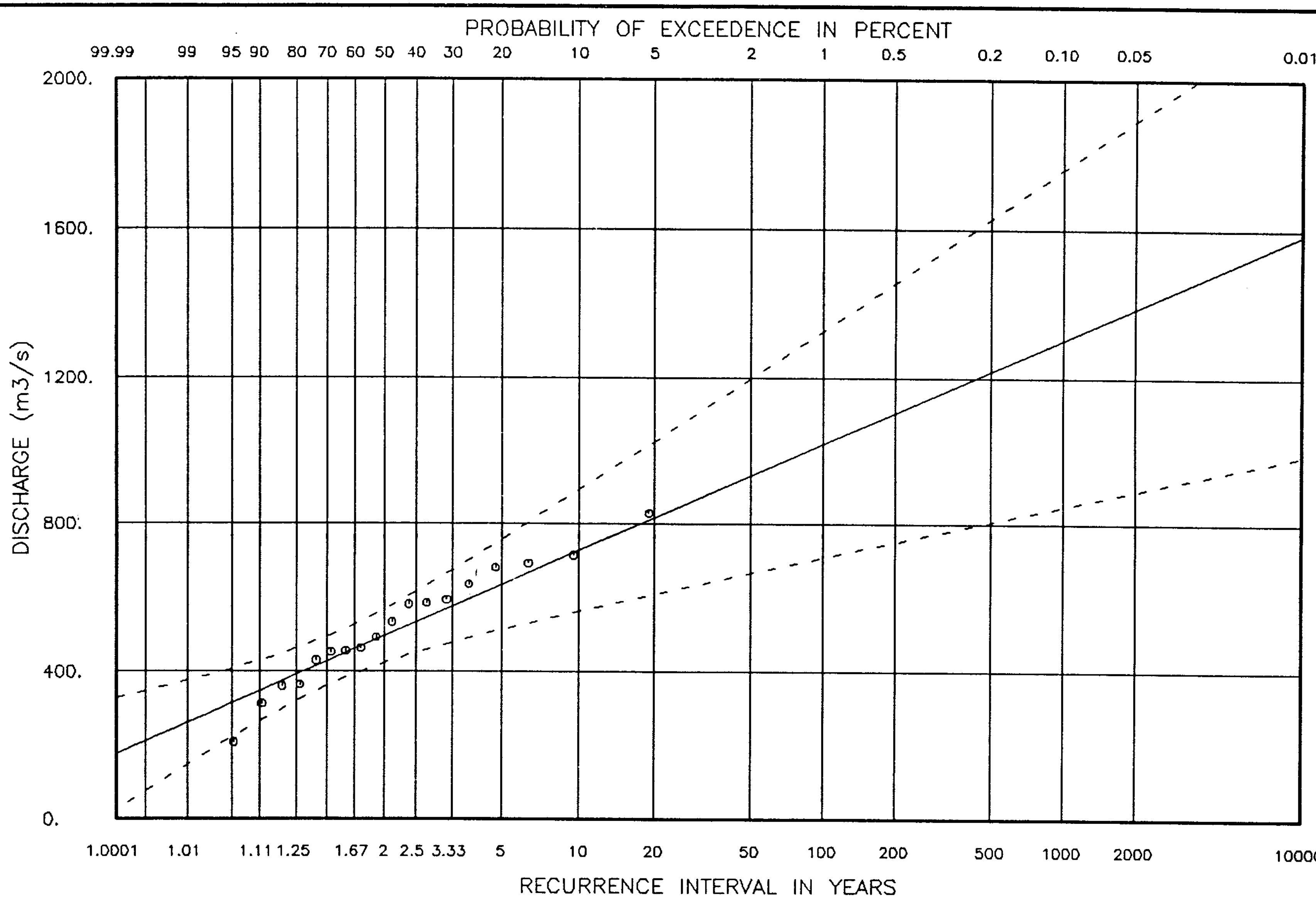


KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

LOG PEARSON TYPE III DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

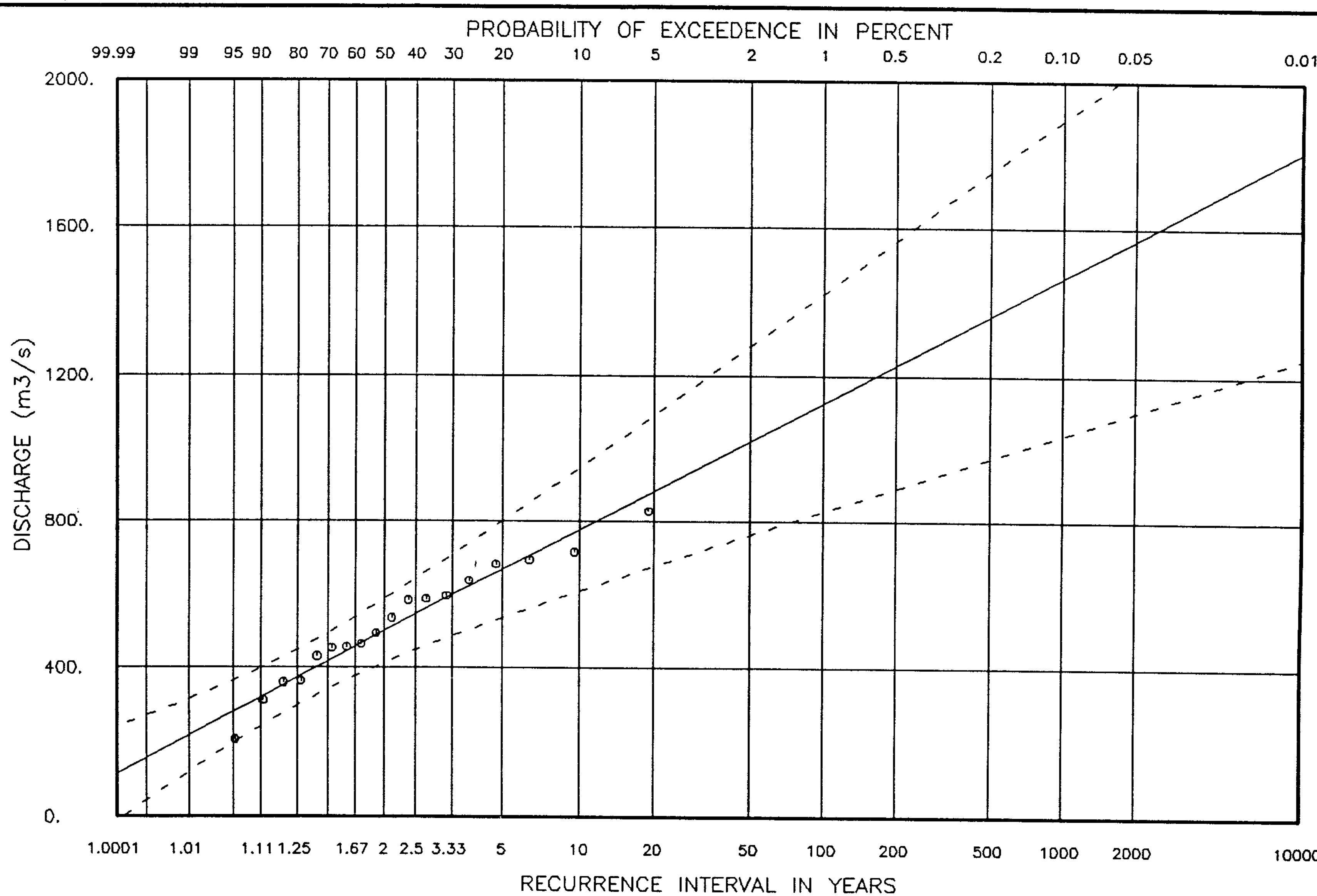


KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MOMENTS

ACRES



KETTLE RIVER AT CASCADE MAXIMUM DAILY DISCHARGE

GUMBEL TYPE I DISTRIBUTION

PARAMETERS ESTIMATED BY MAXIMUM LIKELIHOOD

ACRES

Appendix B
Calculated Flood Levels
(including freeboard)

ACRES

KETTLE RIVER - EAST

SEC NO	20-YR (m)	200-YR (m)
1	444.1	444.5
2	444.3	444.6
3	444.5	444.9
4	444.7	445.1
5	445.2	445.6
6	445.5	445.9
7	445.6	445.9
8	446.0	446.4
9	446.1	446.5
10	446.1	446.5
11	446.5	446.9
12	446.7	447.1
13	446.9	447.3
14	447.1	447.5
15	447.5	447.9
16	447.9	448.2

KETTLE RIVER - WEST

SEC NO	20-YR m	200-YR m
2	490.5	491.0
3	491.6	492.1
4	492.2	492.8
5	493.9	494.3
7	498.1	498.5
8	499.2	499.7
9	499.1	499.6
10	499.7	500.2
11	500.9	501.4
12	501.7	502.2
13	502.1	502.7
14	502.5	503.1
15	503.2	503.8
16	503.9	504.4
17	504.5	504.9
18	504.8	505.2
19	505.1	505.6
20	505.6	506.0
21	506.1	506.4
22	506.7	507.1
23	507.1	507.3
24	507.5	507.8
25	507.9	508.2
26	508.5	508.9
27	508.9	509.3
28	508.9	509.3
29	509.5	509.9
30	510.0	510.4
31	510.5	510.9
32	510.8	511.2
33	511.6	511.9
34	511.9	512.2
35	512.0	512.3
36	512.2	512.6
37	512.7	513.1
38	513.0	513.5
39	513.2	513.7
40	513.2	513.7
41	513.7	514.2
42	513.8	514.3
43	513.8	514.3
44	514.0	514.5
45	514.7	515.1
46	514.9	515.3
47	515.0	515.4
48	515.3	515.7
49	515.7	516.1
50	516.2	516.5
51	517.2	517.5
52	517.8	518.1
53	518.2	518.4
54	518.8	519.1
55	519.1	519.4
56	519.7	520.0
57	520.3	520.6
67	521.7	522.0
58	521.7	522.1
59	521.7	522.1
60	522.7	523.1
61	523.8	524.1
62	524.5	524.8
63	524.9	525.2
64	525.4	525.7
65	526.1	526.5
66	527.0	527.4

GRANBY RIVER

SEC NO	20-YR m	200-YR m
1	513.7	514.2
2	513.8	514.3
3	513.8	514.3
4	513.9	514.3
5	514.0	514.5
6	514.1	514.6
7	514.3	514.7
8	514.6	515.0
9	514.9	515.2
10	515.3	515.6
11	516.7	516.9
12	519.4	519.6
13	520.8	521.0
14	522.7	522.9
15	524.0	524.2
16	524.6	524.7
17	524.9	525.0
18	525.4	525.5
19	526.6	526.8
20	527.4	527.5
21	528.7	528.9
22	529.4	529.6
23	529.7	529.9
24	530.4	530.6
25	530.7	530.9
26	530.9	531.2
27	532.5	532.7