THE CADMUS GROUP, INC.

Executive Park, Suite 100
1920 Highway 54
Durham, NC 27713
Telephone: (919) 544-6639 Telefax: (919) 544-9453

TRANSMITTAL

To: ✓Doug Tomchuk (EPA Region II)
Jerry Cura (Menzie-Cura)
Ron Sloan (NYSDEC)
Bruce Fidler (TAMS/NJ)

From: J. B. Butcher **Date:** June 25, 1993

Project: Hudson River PCBs **Pjn:** 4033-B01

Contents: Memorandum containing updated and revised Log Pearson III flood frequency analysis for the Fort Edward gage, including routing of earlier upstream flood peaks.

Flood Frequency Analysis, Fort Edward at Rogers Island Gage, Hudson River

In the Phase I report we provided a preliminary analysis of peak flood flows at the USGS gage Hudson River at Fort Edward at Rogers Island (#01327750). This represents the upstream end of the Thompson Island Pool; accurate determination of flood peaks here is important to analysis for the potential for scour of contaminated sediments contained in that area. The Phase I analyses were based on data through water year 1990. Complete 1991 data are now available as well (at the time of this analysis Fort Edward gage data had been incorporated into WATSTORE through June 1992 only, so water year 1992 was not complete.) More importantly, we determined that it was appropriate to revisit certain assumptions involved in the translation of peak flow estimates from the Hudson River at Hadley to Fort Edward. Finally, the Phase I estimates did not include confidence bounds; these are now included.

To obtain a statistical estimate of flood recurrence interval it is necessary to form the annual series of the flood peak values. This series is the set of annual maxima (largest flood event in each year of record). Flow records at Fort Edward commence in December 1976 (water year 1977); there are thus 15 years of record available. Empirical estimates of return frequency were presented in the Phase I report. However, due to the short period of record, these cannot provide a reasonable estimate of the probability of extreme events. Instead, these must be estimated using a statistical model. The method for accomplishing this recommended by the U.S. Water Resources Council (1967) is to use the log-Pearson Type III distribution to model the annual maxima series. Methods for implementing this analysis have been extensively developed by the USGS (1982). In essence, the method yields an expression for the flood Q_T (cfs) associated with any given recurrence interval, T (years), as

$$\log_{10} Q_T = \bar{X} + S \cdot K_T$$

in which $\bar{X}$ is the mean of the distribution of base-10 logarithms of flow, S is the standard deviation of the base-10 logarithms, and K_T is the "frequency factor" for recurrence interval T, given by

316891

$$K_T = \frac{2}{C_s}\left(\left[\left(U_T - \frac{C_s}{6}\right)\frac{C_s}{6} + 1\right]^3 - 1\right)$$

where U_T is the standard normal deviate corresponding to recurrence interval T and C_s is a stabilized estimate of skew, formed as a weighted average of the sample skew and generalized regional skew using the method of Wallis et al. (1974).

The first step in the current analysis was to apply USGS program J407 to the observed peak flows at the Hudson River at Fort Edward at Rogers Island gage. Estimated historical peak floods of 43,900 cfs (1900) and 89,100 cfs (1913) were reported. However, these were not included in the analysis because they occurred before the substantial upstream flood regulation was provided by the Great Sacandaga Lake reservoir. Based on the 1977-1991 peaks, the following estimates are obtained (Table 1):

Table 1: Log Pearson Type III Annual Flood Frequency, Fort Edward Gage, 1977-1991

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	30184.5	34780.5	27288.3
10	33481.1	39896.4	29925.6
25	37451.6	46512.4	32897.8
50	40297.6	51508.1	34936.8
100	43066.3	56548.7	36866.5
200	45788.3	61664.3	38721.1
500	49348.5	68580.9	41094.1

Unfortunately, the short period of record available at Fort Edward does not enable a very reliable prediction of large magnitude flows of most interest to us. We therefore, as in Phase I, attempted to

316892

extend the annual maxima series at Fort Edward by translating peaks downstream from the confluence of the Hudson River and Sacandaga River. Unfortunately, while gaging is available on both rivers just upstream of the confluence (Hudson River at Hadley, NY, #01318500; Sacandaga River at Stewart's Bridge near Hadley, NY, #01325000), USGS does not measure peak flows for the Hudson below the confluence with Sacandaga River, although daily average flows are reported as a "dummy" gage. Further, because the Sacandaga River flow is strongly controlled, peaks on the two rivers are unlikely to coincide. Therefore a method must be developed to estimate peak flow at Fort Edward from peak flow data for the Hudson River at Hadley and data for the Sacandaga River at Stewart's Bridge near Hadley. There are two issues here: (1) an estimate of the peaks below the Hudson-Sacandaga confluence must be formed, and (2) the peak estimate must be routed downstream to Fort Edward. In an early report (Malcolm Pirnie, 1975), it was estimated that the 100 year peak flow flood at Fort Edward was 41,400 cfs. However, this estimate was obtained using a *direct* translation of the 100 year flood at Hadley downstream, without proration for drainage area and further assuming that the flow in the Sacandaga would be zero during flooding in the Hudson. Examination of flow records in the Sacandaga shows that the zero flow assumption is not always valid. The method advocated by FEMA (1980 and 1984) for estimating flood recurrence at Fort Edward based on peaks at Hadley, was to assume that the Great Sacandaga Lake reservoir would contribute 8,000 cfs of flow to the Hudson River during extreme flood events. This is the discharge which results from the opening of one control valve, which may be done during major storms to prevent topping of the dam. At the time of the FEMA reports only a short period of record was available for the gage at Fort Edward. Thus, a Log Pearson III distribution was fit by FEMA to the period of record for the Hudson at Hadley and used to predict values at Fort Edward via:

$$Q_T(FE) = [Q_T(H) + 8000] \times \left(\frac{2817}{2719}\right)^{0.75} \qquad (FEMA)$$

where

$Q_T(FE)$ = flood (cfs) for a given recurrence interval T (years) at Fort Edward

$Q_T(H)$ = flood (cfs) for the corresponding recurrence interval at Hadley

The term (2,817/2,719) is the ratio of drainage areas (in square miles) between the Hudson just below the confluence with the Sacandaga River and the Hudson River at Fort Edward at Rogers Island. The

316893

exponent (here 0.75) is based on the USGS index-flood methodology which relates mean annual flood in a region to a fractional exponent of contributing drainage area. Given the assumption of a log-linear dependence of T year flood on mean annual flood, this means that the ratio of log peak floods at gages with differing drainage areas is equal to the ratio of the areas raised to this fractional power.

The FEMA approach of assuming a constant flood discharge from Great Sacandaga Lake is likely to overestimate the magnitude of floods (and is thus conservative for a flood insurance study). That is, examination of the record shows that on the days of peak flow in the Hudson at Hadley daily average flow in the Sacandaga at Stewart's Bridge was often near zero, and exceeded 8,000 cfs only twice between 1930 and 1976.

For the present study a modified approach was undertaken, which has been refined somewhat from Phase I. Prior to the period of record at Fort Edward, annual peaks were estimated from data from the Hudson River at Hadley gage and the Sacandaga River at Stewart's Bridge gage. Data from 1930 on only were used, as the Sacandaga River flow has been regulated by Conklingville dam since 27 March 1930. The starting point for our analysis was the set of reported peak flows in the Hudson River at Hadley (we started with the partial duration series, which contains all peaks above a specified reference level, as the maximum for Hudson plus Sacandaga did not necessarily occur with the largest magnitude peak in the Hudson alone). To these, we needed to add an estimate of the coincident peak in the Sacandaga. When peaks in the Hudson at Hadley and Sacandaga were reported on the same day, the two peak values were simply summed. However, when a peak in the Sacandaga did not coincide with a peak in the Hudson, we added the daily average flow in the Sacandaga to the peak in the Hudson at Hadley (this is probably not a bad assumption, as control in the Sacandaga tends to reduce fluctuations around the daily average). This gave us an artificial partial duration series of flood peaks for the Hudson below the confluence with the Sacandaga River, from which we selected an annual maxima series. Finally, we went back and checked this series against the sum of daily average flows in the Hudson at Hadley and Sacandaga at Stewart's Bridge. In seven instances (1932, 1951, 1955, 1959, 1969, 1971 and 1974) there was a value of the sum of daily averages which was greater than the synthetic peak, in which case the daily average maximum value was substituted into the annual maxima series. (These instances occurred during years in which the observed peaks in the Hudson were relatively small. The procedure necessarily underestimates some unmonitored flood peaks in the Hudson below Sacandaga, but is not thought to have a major impact on estimated recurrence frequency of extreme events.) The calculated annual maxima at

Hudson below Sacandaga and the measured annual maxima at the Fort Edward gage are displayed in Figure 1.

Next, the annual maxima series had to be translated downstream to the Fort Edward gage. We assumed, as in the FEMA studies, that a relationship should exist based on the ratio of drainage areas raised to a fractional power, *p*, but did not assume the value of *p a priori*. Instead, using the data from the years 1978-1990[1], we regressed the observed Ft. Edward annual maxima on the estimated maxima for the Hudson below confluence with the Sacandaga. No intercept was included in the model. This yielded an estimate of *p* as 0.815, which fits well with the "typical" value of 0.75.

For the calculation of the Log Pearson Type III flood distribution, we used the values

$$Ft.\ Edward = \left(\frac{2817}{2719}\right)^{0.815} \cdot (Hadley + Sacandaga)$$

for the period of water years 1930-1976, combined with annual maxima directly measured at Fort Edward for water years 1977 to 1991. The results are shown in Table 2, and displayed graphically, with 95% confidence limits, in Figure 2.

[1] 1977 was omitted as anomalous, as the peak upstream was significantly larger than the reported peak at Fort Edward and did not fit the pattern shown by later observations.

316895

Table 2: Log Pearson Type III Annual Flood Frequency, Fort Edward, 1930-1991

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	30126.0	33519.4	27571.8
10	34561.2	39218.7	31292.5
25	39882.6	46347.7	35590.9
50	43671.3	51581.3	38571.1
100	47330.0	56743.3	41399.3
200	50897.2	61868.9	44116.6
500	55514.0	68626.8	47582.8

Table 3 compares the estimates obtained by the different methods used here as well as those discussed in the Phase I Report.

Table 3. Comparison of Annual Flood Frequency Estimates at Fort Edward

Recurrence Interval (T)	1930-1991 Data (cfs)	1977-1991 Fort Edward Gage	Phase I Estimate (Table B.4-1)	FEMA (1984) Estimate
5	30126	30184	30090	--
10	34561	33481	34526	38800
25	39883	37452	39848	--
50	43671	40298	43636	48300
100	47330	43066	47293	52400
200	50897	45788	--	--
500	55514	49348	55471	62200

The current estimates from the 1930-1991 data are highly consistent with the estimates reported in Phase I. Both are somewhat higher than the estimate obtained from the 1977-1991 Fort Edward gage data alone, but within the large confidence bounds for those estimates (Table 1). Use of the 1977-1991 data alone is thought to result in a downward bias because of the relative paucity of large flood peaks observed during most of the 1980's. On the other hand, it appears clear that the FEMA estimates are too high. Similarly the estimates used by Zimmie (1985) in his assessment of erodibility in the Thompson Island Pool, which included a 100 year flood estimate in the Thompson Island Pool above Moses Kill of 63700 cfs, appear much too high. (As noted in the Phase I report, these estimates are apparently based on a misreading of the FEMA studies).

316897

In sum, we recommend use of the Log Pearson Type III annual flood frequency analysis based on the 1930-1991 data, and summarized in Table 2. Appendix 1 provides a listing of the Pearson Type III parameters, as well as a more detailed frequency tabulation.

316898

References

FEMA. 1980. Flood Insurance Study, Town of Fort Edward, New York. Federal Emergency Management Agency, Community #360885.

FEMA. 1984. Flood Insurance Study, Village of Fort Edward, New York. Federal Emergency Management Agency, Community #361536.

Malcolm Pirnie. 1975. Investigation of Conditions Associated with the Removal of Fort Edward Dam, Fort Edward, New York. Engineering Report to NYSDEC, Feb. 1975

U.S. Geological Survey. 1982. Guidelines for Determining Flood Flow Frequency. Water Resources Council Bull. 17A. Washington, DC

U.S. Water Resources Council. 1967. A Uniform Technique for Determining Flood Flow Frequencies. Water Resources Council Bull. 17. Washington, DC

Wallis, J.R., N. Matalas and J.R. Slack. 1974. Just a moment! *Water Resources Res.* 10(2): 211-219.

Zimmie, T.F. 1985. Assessment of Erodibility of Sediments in the Thompson Island Pool of the Hudson River. Report to NYSDEC, published as Appendix B of M.P. Brown *et al.*, 1988, Distribution of PCBs in the Thompson Island Pool of the Hudson River, Final Report of the Hudson River PCB Reclamation Demonstration Project Sediment Survey. EPA Grant C361167-01.

316899

Appendix 1. Detailed Results of Log Pearson Type III Flood Frequency Analysis for Fort Edward, 1930-1991

Parameters

$\bar{X}$	4.3578
S	0.1429
C_s	-0.146 (regional skew = 0.345; sample skew = -0.3148)

Detailed Recurrence Interval Table

Recurrence Interval (T)	T Year Flood	Upper 95% Conf. Limit	Lower 95% Conf. Limit
5	29847.39	34022.46	26856.46
10	34561.20	39218.71	31292.48
20	38625.99	44639.32	34588.97
25	40685.65	49153.36	35485.91
30	40894.71	47733.89	36392.76
40	42468.16	49906.38	37630.90
50	43671.27	51581.26	38571.12
60	44644.34	52944.28	39327.72
70	45460.75	54093.47	39959.97
80	46163.63	55086.88	40502.50
90	46780.51	55961.73	40977.33
100	47329.98	56743.33	41399.26
150	49425.95	59744.33	43000.31
200	50897.20	61868.88	44116.61
250	52030.50	63515.20	44972.49
300	52951.87	64859.78	45665.84
350	53727.89	65996.44	46248.14
400	54398.05	66981.06	46749.81
450	54987.68	67849.66	47190.30
500	55513.98	68626.78	47582.78

316900

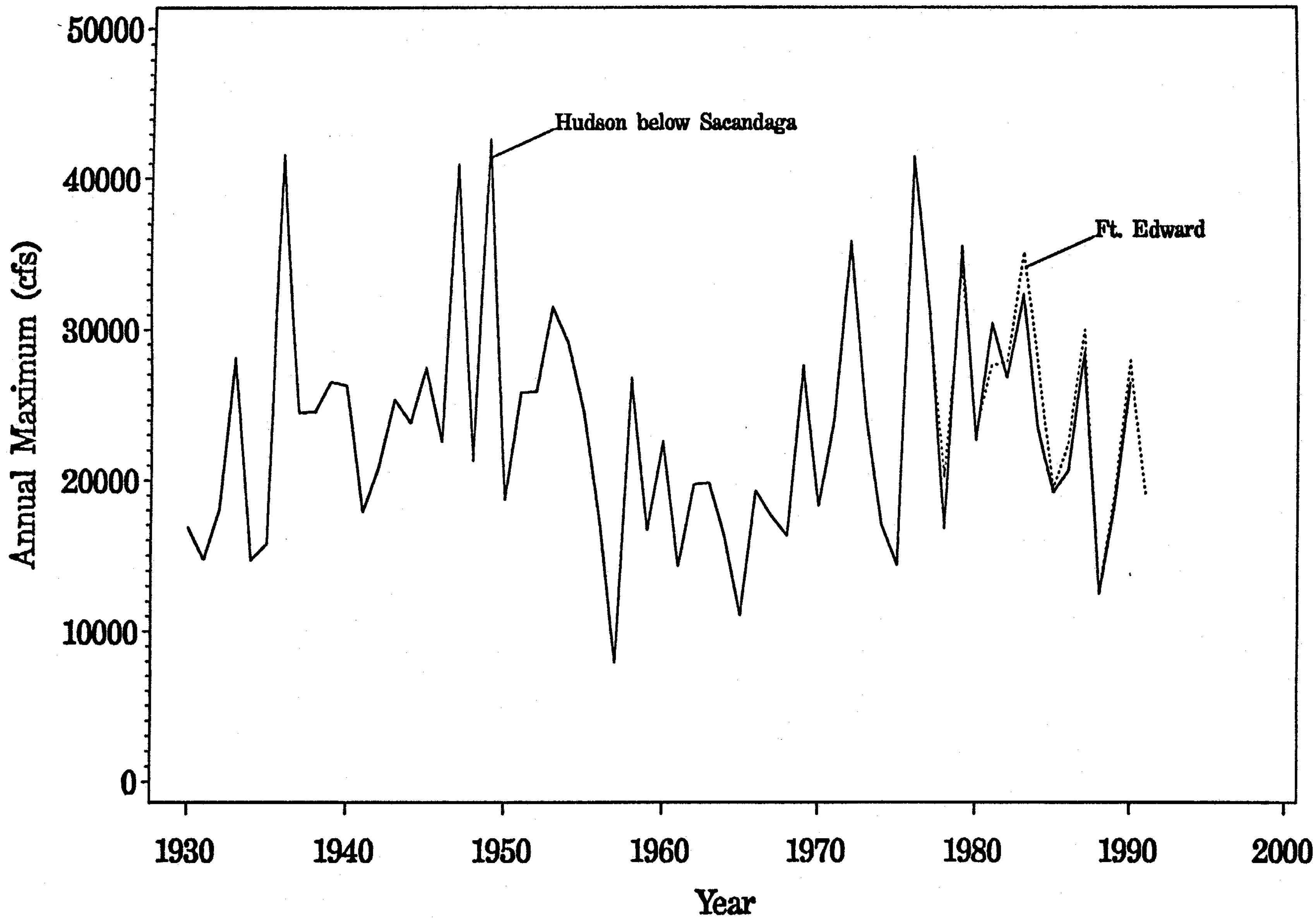

Figure 1. Annual Maxima
Hudson River below Sacandaga and Hudson River at Fort Edward

316901

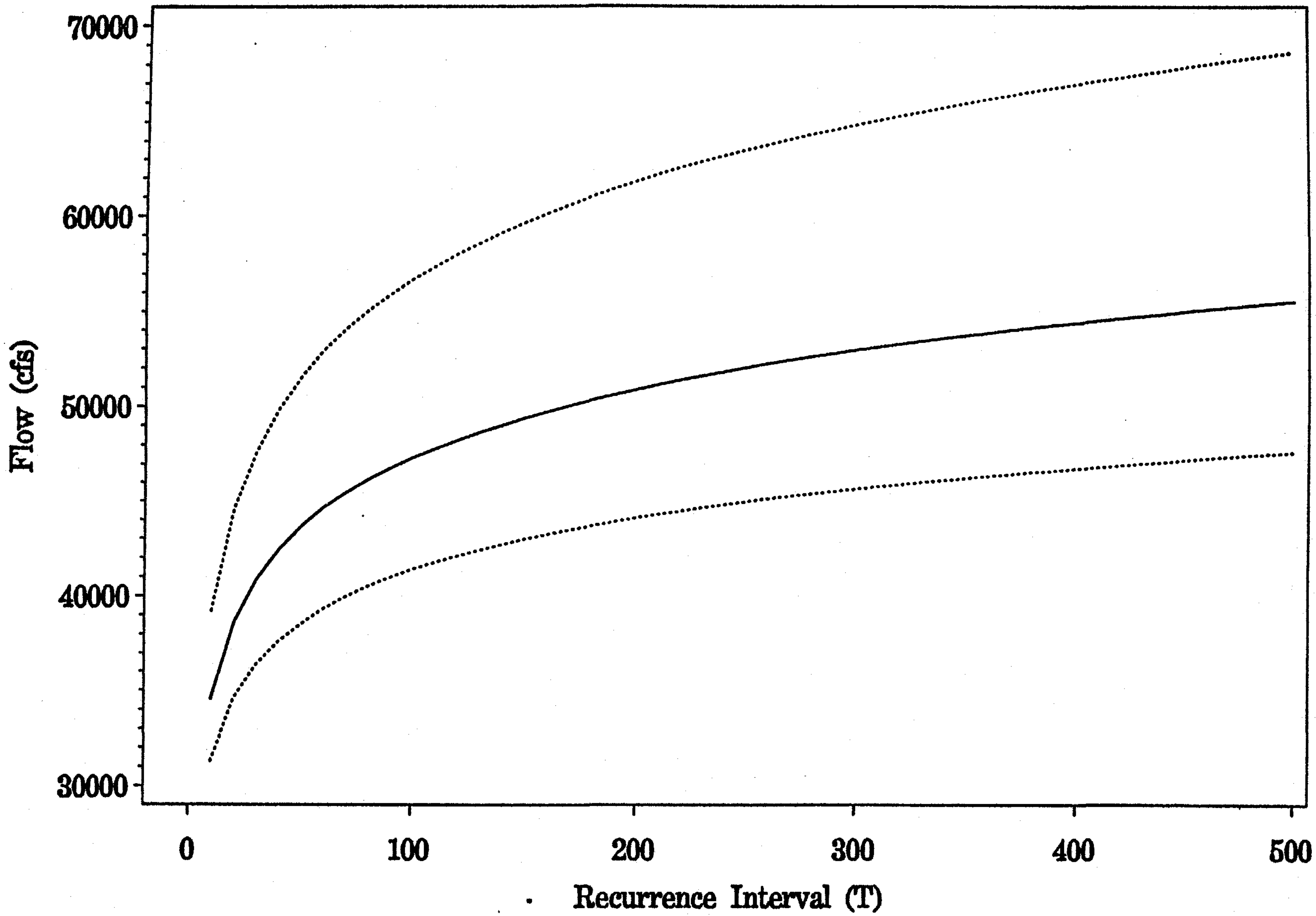

Figure 2. Log Pearson Type III Annual Flood Distribution
Hudson River at Ft. Edward at Rogers Island 1930–1991
(1930–1976 maxima calculated from Hudson River at Hadley and Sacandaga River at Stewart's Bridge)

316902