Contract Report 590

Managed Flood Storage Option for Selected Levees along the Lower Illinois River for Enhancing Flood Protection, Agriculture, Wetlands, and Recreation

First Report: Stage and Flood Frequencies and the Mississippi Backwater Effects

by
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Office of Surface Water Resources: Systems, Information, and GIS

Prepared for the
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Illinois State Water Survey
Hydrology Division
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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First Report: Stage and Flood Frequencies and the Mississippi Backwater Effects

INTRODUCTION

This report is the first of three reports that are planned for a three-year study being supported by the Office of Water Resources Management, Illinois Department of Natural Resources (previously Division of Water Resources, Illinois Department of Transportation). The study is entitled Managed Flood Storage Option for Selected Levees along the Lower Illinois River for Enhancing Flood Protection, Agriculture, Wetlands, and Recreation. The main goal is to examine the hydrologic and economic benefits of modifying some at-risk levees and drainage districts along the lower Illinois River to provide managed flood storage (as well as wetland and recreation functions), and to increase flood protection for other levees and districts. The study involves validation of UNET (one-dimensional unsteady flow through a full network of open channels) model (Barkau, 1993) application to the Illinois River, simulating flood profiles under various scenarios of tributary and main river flows, identifying levees at risk as possible candidates for modification to the flood storage option, determining a minimum set of such levees to obtain desirable protection against failure by high flood for other levees, and some investigation of the land use behind modified levees to maximize a mix of such uses as agriculture, recreation, wetlands, etc. The first step was to study the flood and stage frequencies applied to stations along the Illinois River and its major tributaries, as well as to understand the development of high floods in the Illinois River vis-a-vis the probability of high floods in the tributaries. This will be followed by model verification and validation, simulations, and other analyses as envisaged under the general objectives.

The Illinois River has been the focus of intensive study for more than 60 years, largely because of alterations caused by Lake Michigan inflows, wastewater effluents from the Chicago metropolitan area, and silting of backwater lakes and Peoria Lake, which significantly affected ecosystems, levee and drainage districts mostly below Peoria, and conversion of fast-flowing river to a navigable river with relatively flat pools (Figure 1). The levees and drainage districts removed about 200,000 acres of floodplain area. Flood levels kept on steadily rising with

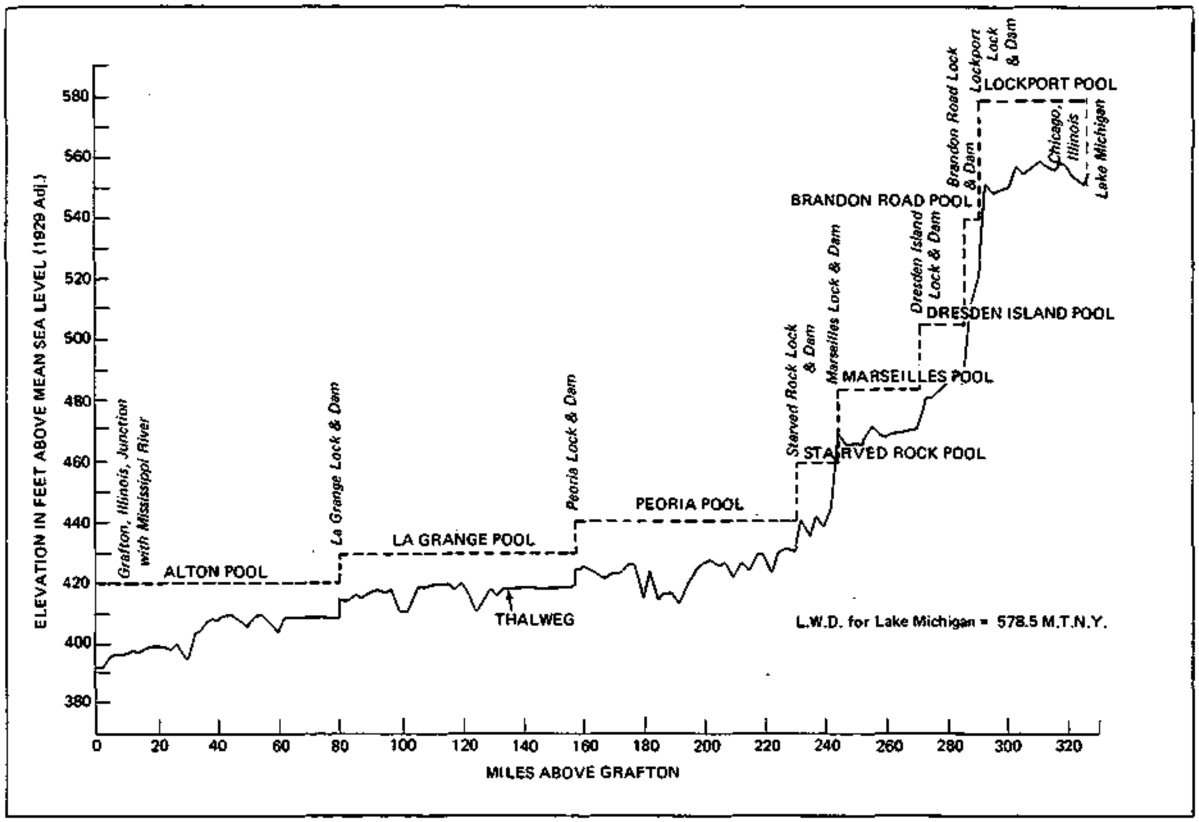


Figure 1. The Illinois River and navigation locks and dams

construction of new levees mostly completed in the 1920s. Table 1 lists the levee and drainage districts between Peoria and Grafton. Seven major locks and dams built in the 1930s as part of the Illinois Waterway provided enough surcharge storage in the pools to moderate the high flows and levels.

Flood magnitudes have considerably increased at Marseilles, Kingston Mines, and Meredosia since 1970. The top five floods (ranks 1 - 5) at these stations during the 1941-1993 period (after the completion of locks and dams on the Illinois River) occurred in Water Years 1983, 1957, 1970, 1981, and 1991 at Marseilles; 1983, 1943, 1985, 1982, and 1970 at Kingston Mines; and 1943, 1985, 1983, 1979, and 1974 at Meredosia. Thus, four out of the top five floods in the 1941-1993 period occurred during 1970-1993. Though one cannot surmise that this upward trend will continue, some notice of this trend needs to be incorporated in flood and stage frequency analyses. Some of the increase in flood peaks is attributed to a trend of increasing precipitation in the upper half of the Illinois River basin (Singh and Ramamurthy, 1990).

The Illinois River is a relatively large, managed river, and the applicability of particular probability distributions needs to be checked and validated. In the river reach below Peoria to Grafton, the LaGrange lock and dam creates LaGrange Pool, and the Alton lock and dam in the Mississippi River controls the Alton Pool in the Elinois River. The latter involves interaction With floods and stages in the Mississippi River. These pools do attenuate to some extent the flood flow in these reaches, but at high flow this effect decreases because of the limited extra storage provided by these pools. Under such conditions the annual floods and stages may be analyzed using usual frequency distributions.

The log-Pearson HI (LP3) distribution is being widely used, with some correction for skew value when the sample size is not very large. Use of regional skew to develop a weighted skew does cause problems when sample skew is a significantly positive value. Singh (1968, 1980b, 1983) and Singh and Nakashima (1981) have developed a versatile frequency analysis method that detects and modifies any outliers and inliers at significance levels of 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40 in various size samples and develops estimates of various recurrence interval floods using power-transformed normal distribution (PT), LP3, and mixed distribution (MD). An analysis of these flood estimates in terms of increase in peak values with increase in recurrence interval, consistency of results, and relative fitting of the distribution curves to the observed flood

Table 1. Levee and Drainage Districts along the Illinois River below Peoria Lake to Grafton, Illinois

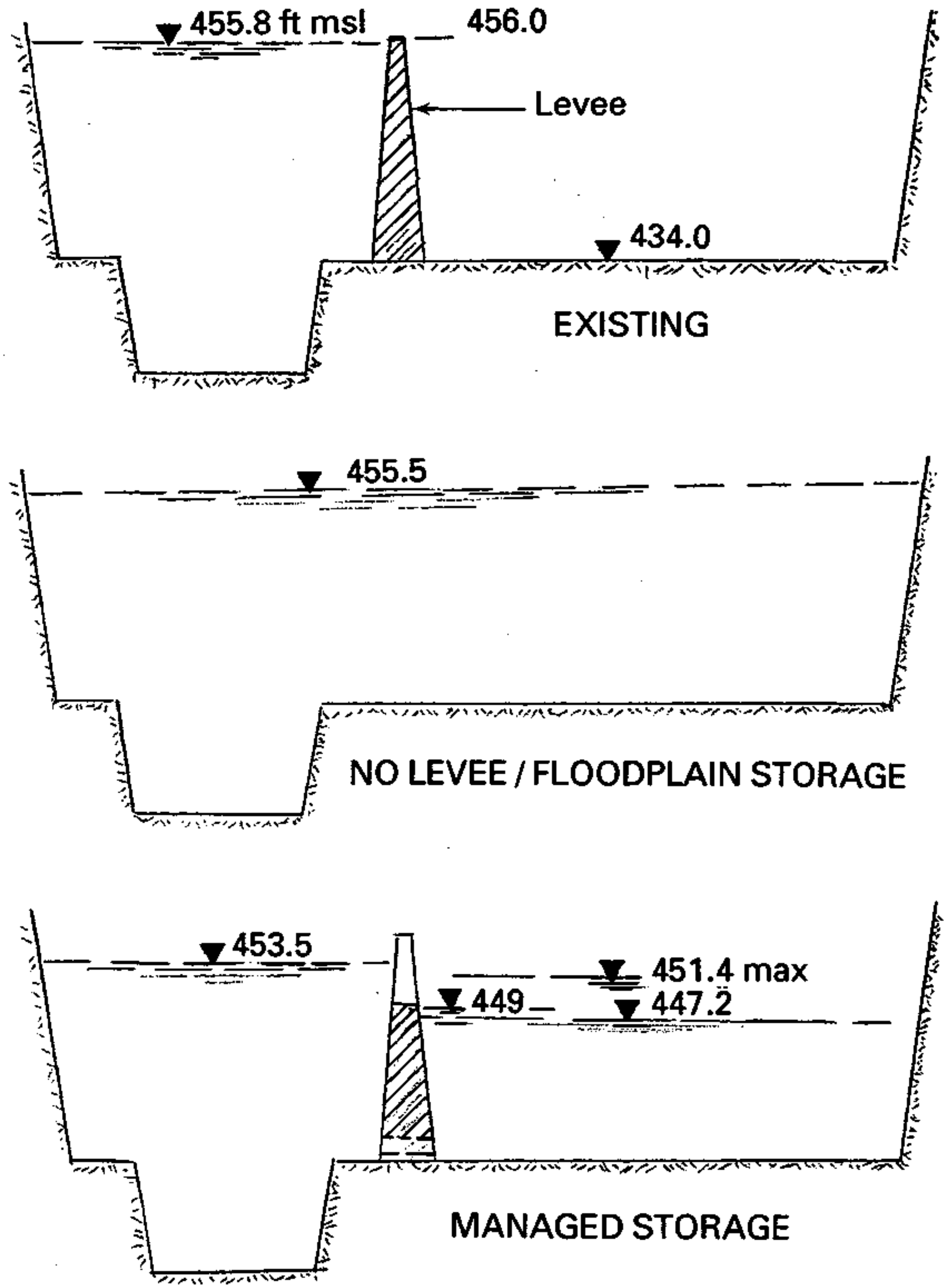
Levee and Drainage District	*Upstream river mile*	*Downstream river mile*
Pekin & Lamarsh	155.0	149.7
Spring Lake	147.2	134.2
Benner Special	146.0	138.0
East Liverpool	132.0	129.0
Liverpool	129.0	127.0
Thompson Lake	127.0	119.4
Lacey, Langellier, W. Matanzas & Kerton	119.4	111.8
Seahorn	111.8	107.0
Big Lake	107.0	102.0
Kelly Lake	102.0	97.0
Coal Creek	91.2	85.0
S. Beardstown & Valley	87.7	79.0
Crane Creek	85.1	83.8
Meredosia Lake & Willow Creek	79.0	72.7
Little Creek	78.3	75.1
McGee Creek	75.0	67.1
Valley City	66.2	62.5
Mauvaise Terre	65.8	63.4
Scott County	63.1	56.7
Big Swan	56.5	50.1
Hillview	50.0	43.2
Hartwell	43.1	38.2
Keach	38.0	32.8
Eldred & Spanky	32.4	23.8
Nutwood	23.6	15.1

data, can be carried out. Any trend of increasing flood peaks and stages can be examined by doing frequency analysis on split samples.

The Illinois River flood stage elevations in the Alton Pool (from Meredosia to Grafton) are governed by a mix of varying circumstances: 1) the backwater effects caused by the Mississippi River levels raise water stages in the Illinois River — the higher the Mississippi River level, the greater the distance upstream the backwater effect raises the water elevation in the Illinois River, 2) the greater the flood peak at Meredosia, the greater the distance downstream not experiencing Mississippi River backwater effects, 3) a combination of rather low flood at Meredosia and very high water stage at Grafton can push the backwater effects all the way up to Meredosia lock and dam, and 4) a combination of a very high flood at Meredosia and very low Mississippi River water elevation will restrict backwater effects in the Illinois to a small distance upstream of Grafton.

Managed Flood Storage Option

A preliminary study (Singh, 1991) indicates that an overall economic benefit may be achieved by conversion of some at-risk, selected levee districts to a managed flood storage function. The effects of a simple floodplain and managed storage on the peak stage and discharge of a 100-year flood at the Kingston Mines gage were estimated in a preliminary hydrologic analysis. The levee was considered to have crown elevation of 456.0 feet above mean sea level (feet-msl) or about the l00-year flood stage level of 455.8 feet-msl used in the preliminary study. This leaves a freeboard of only 0.2 feet instead of the usual 2 to 3 feet. A cut 500 feet long and 7 feet in depth was assumed to act as a broad-crested weir over which floodwaters would flow into the levee interior of 10,000 acres when Illinois River water elevations exceeded 449.0 feet-msl. Flow over this cut or fixed overflow section in the levee was simulated using a broad-crested weir flow equation and the volume of water that enters the area behind the levee (or levee interior) was subtracted from the flow in the river. Results suggest that a large amount of flood storage, such as that provided by inundating an entire levee district, can (reduce the peak stage at the levee by 2.3 feet (Figure 2) only if the flow into the levee interior is controlled or "managed" so that it occurs near the peak of the flood hydrograph. When the Illinois River is at peak stage of 453.5 feet-msl, water in the managed storage is at 447.2 feet-msl



100-Year Flood Stages

Figure 2. Schematics of flood storage option

and it rises to 451.4 feet-msl as the river level falls to that level. If an entire section of a levee is removed, then the inflow into the area, which had been protected by the levee, begins early during the flood, similar to the condition if there was no levee at all. Under this "no-levee" condition, much of the floodplain storage is filled early in the flood so it is not available to reduce the peak stage. Consequently, the reduction in the 100-year flood elevation is only 0.3 feet. Under the flood-storage option, the stored floodwater will begin flowing back into the river through bottom outlets after the river stage starts to recede. Unsteady modeling of the river flow is necessary to address flow dynamics and better estimation of the flood storage effect on river flow. The effect of managed flood storage would be to reduce the stage hydrograph only at high discharges, greatly lowering the peak stage (Figure 3) as well as the flood peak. The optimal flood stage at which the planned overflow occurs would have to be determined from various scenarios of at-risk levee conversions. The proposed research will analyze the effects of simple floodplain and managed flood storage by UNET model simulations of the flood stages resulting from varying flow conditions.

Additional benefits may be obtained by using the land behind storage-option levees for other functions (agriculture, wetlands, recreation, etc.). Although the primary function proposed for analysis is that of flood storage, it is likely that the levee overflow structures may be designed at a level where the flood overflow into the levee interior may occur with an average frequency of once every 10 to 20 years. Under these conditions, it will be feasible to use the lands for other functions for most years.

Acknowledgments

The study is jointly supported by the Office of Water Resource Management, Illinois Department of Natural Resources (previously Division of Water Resources, Illinois Department of Transportation) and the Illinois State Water Survey, Illinois Department of Natural Resources (previously Illinois State Water Survey, Illinois Department of Energy and Natural Resources). Gary Clark, Office of Water Resource Management, is serving in a liaison capacity during the entire course of this study. The U.S. Army Corps of Engineers District offices in St. Louis, Missouri, and Rock Island, Dlinois, provided some of the basic data used in this study. Computer runs for flood and stage frequency analyses were carried out by graduate research assistant

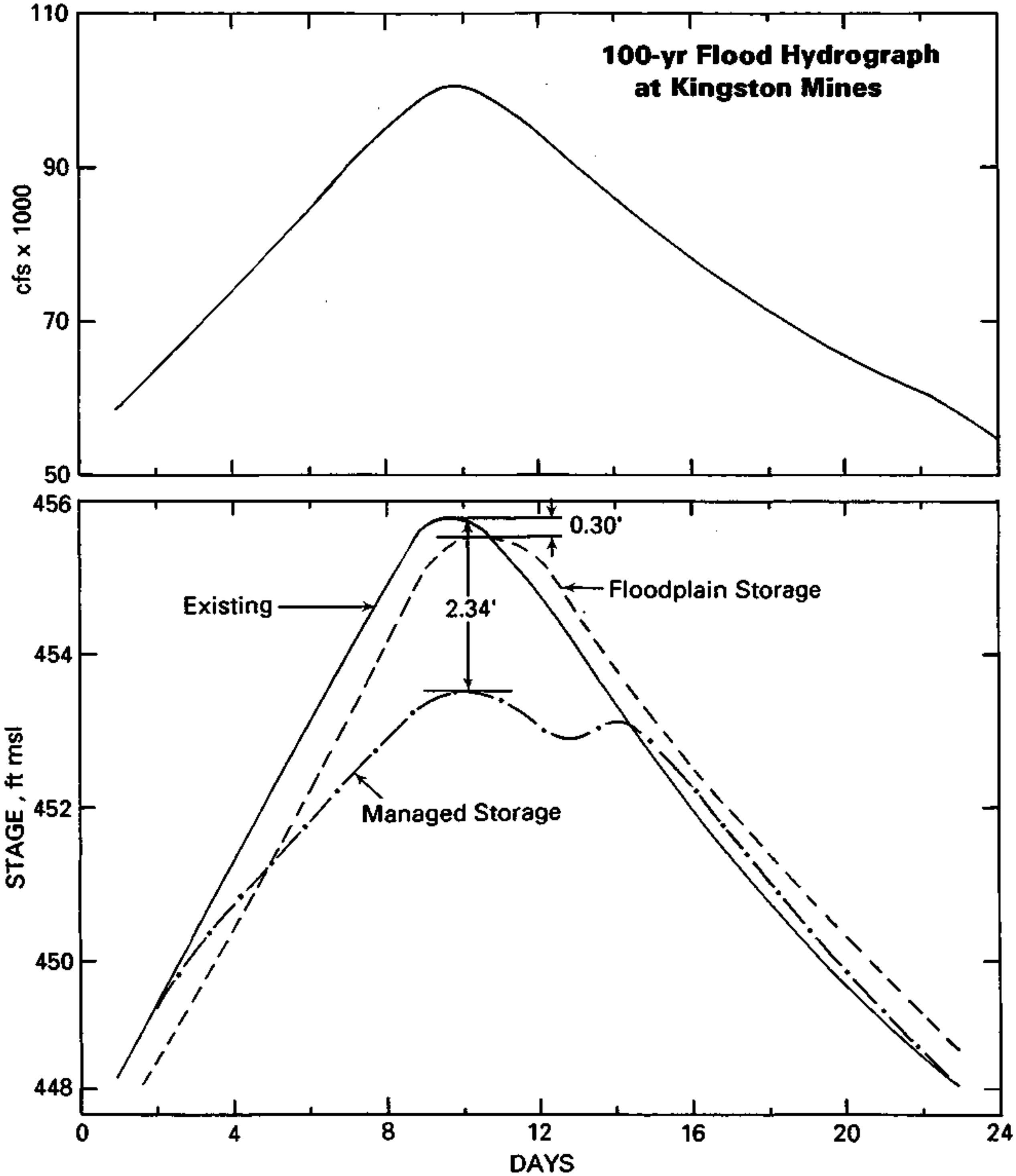


Figure 3. 100-year flood and stage hydrographs under different conditions

Zhaoyun Xing, who is studying for his Ph.D. in computer sciences at the University of Illinois. Kathleen Brown typed the manuscript, Linda Hascall assisted with the graphics, and Eva Kingston edited the report.

A GENERAL FREQUENCY PROGRAM

Many observed annual flood series exhibit reverse curvatures when plotted on lognormal probability paper. The most commonly used distributions in flood frequency analyses are the Pearson and log-Pearson, normal and lognormal, and Gumbel (extreme value) and log-Gumbel. None of these distributions, however, fits an observed flood series with reverse curvature. The occurrence of these curvatures may be attributed to seasonal variation in flood-producing storms, dominance of flow within the channel or floodplain, and variability in antecedent basin soil moisture and cover conditions. A mixed distribution model is required to analyze such flood series because of the mixed population of floods.

Existence of any significant outliers, inliers, or both in the flood series can lead to substantial bias in computed distribution parameters and high flood estimates. Such outliers and inliers need to be detected and modified. Only one detection and modification methodology currently exists (Singh, 1987).

This versatile flood frequency methodology uses a mixed distribution (MD) model to simulate the observed flood series, with objective detection and modification of any outliers and inliers at various significance levels. This methodology has been computerized and tested on hundreds of flood series from various parts of the world.

Rationale for Mixed Distributions

Moran (1959) calls the expression $a_1\ p_1(x) + \ldots + a_k\ p_k(x)$ a mixture of probability distributions $p_1(x), \ldots, p_k(x)$, if the $a_1 \ldots, a_k$ are non-negative and $a_1 + \ldots + a_k = 1$. Hald (1952) defines a population formed by two populations in a given proportion as a heterogeneous population. From careful analyses of the lognormal probability plots of observed annual flood series at many streamgaging stations in various parts of the world, Singh (1968) concludes that reverse curvatures in these plots are caused by the heterogeneity of the population of floods.

The magnitude of a flood peak depends largely on storm and basin characteristics. Storm characteristics of interest are the type of storm and intensity and duration of the storm. Rainfall may be caused by hurricanes, thunderstorms, and frontal or air-mass storms. High intensity and short duration storms usually cause much higher peak flow than low intensity and long duration storms with the same total precipitation. Basin characteristics mainly include relative dominance of flow within the channel or floodplain, the antecedent soil moisture condition, and the vegetal cover.

The effect of channel versus floodplain flow is explained as follows. Bankfull discharge in a river corresponds to about a 2-year or median flood. With an increase in flow, the water spreads over the floodplain. For low depths of inundation, the mean velocity of the composite flow section is much lower than at the bankfull discharge. The mean velocity slowly increases with increase in depth of flooding and may surpass the bankfull flow velocity. This addition of a new storage element can lead to flattening and subsequent rise of the flood probability curve at a different slope than for the floods within the channel. Conversion of storm rainfall or runoff is largely affected by the antecedent soil moisture condition and vegetal cover.

The magnitude of annual flood peaks depends on a number of factors that vary within a season and from season to season. The interaction between the distributions of these pertinent factors may produce a flood series resembling a conventional distribution shape or one exhibiting marked reverse curvature to be dealt with by the mixed-distribution concept. Mixed distributions have been considered in terms of rainfall and snowmelt floods (Waylen and Woo, 1982) and floods caused by hurricanes and other storms (Canterford and Pierrehumbert, 1977).

Mixed Distribution

The mixed distribution (MD) model (Singh, 1968; Singh and Sinclair, 1972; Singh, 1974) considers the observed annual maximum floods (or their logarithms) to belong to two populations with means μ_1, and μ_2, variances σ_1^2 and σ_2^2, and relative weights a and $1-a$:

$$p(x) = a\, p_1(x) + (1 - a)\, p_2(x)$$

$$p_1(x) = \frac{1}{\sigma_1\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left[-\frac{(x' - \mu_1)^2}{2\sigma_1^2}\right] dx'$$

$$p_2(x) = \frac{1}{\sigma_2\sqrt{2\pi}} \int_{-\infty}^{x} \exp\left[-\frac{(x' - \mu_2)^2}{2\sigma_2^2}\right] dx'$$

in which p is the probability of being equal to or less than x, and x = log Q where Q is the annual flood. The five parameters (μ_1, μ_2, σ_1, σ_2, and a) are linked to statistics: mean, standard deviation, and skew of observed annual flood series (Cohen, 1967). The MD model considers an observed flood series as essentially composed of two component distributions. Use of three or more component distributions increases the complexity of the problem and makes it intractable.

The values of the parameters can be obtained with a nonlinear programming algorithm (Singh and Nakashima, 1981). The nonlinear objective function is minimization of $\sum | \Delta Z |$ where AZ equals the difference between standard deviate corresponding to the observed probability equal to (m - 0.38)/(n + 0.24) and that fitted corresponding to p from the mixed-distribution equation; m is the ranked order for the flood series and n is the sample size. The following constraints apply.

$$1 = a_1 + a_2$$

$$\mu = a_1\mu_1 + a_2\mu_2$$

$$\sigma^2 = a_1\sigma_1^2 + a_2\sigma_2^2 + a_1 a_2 (\mu_2 - \mu_1)^2$$

$$g\sigma^3 = a_1 m_1 (3\sigma_1^2 + m_1^2) + a_2 m_2 (3\sigma_2^2 + m_2^2)$$

$$kt\sigma^4 = a_1 (3\sigma_1^4 + 6m_1^2 \sigma_1^2 + m_1^4) + a_2 (3\sigma_1^4 + 6m_2^2 \sigma_2^2 + m_2^4)$$

where $m_1 = \mu_1 - \mu$, $m_2 = \mu_2 - \mu$, $a_1 = a$, $a_2 = (1 - a)$, g = skewness, and kt = kurtosis.

Outlier/Inlier Detection and Modification

Barnett and Lewis (1978) define an outlier in a set of data as an observation or a subset of observations that appears to be inconsistent with the remainder of that set of data. When the values of the highest observed floods of an annual flood series are much higher or lower than expected, these values are designated as outliers and inliers, respectively. When the values of the lowest observed floods are much higher or lower than expected, these are designated as inliers and outliers, respectively. Analyses of storms causing outliers at the high end and of droughts causing outliers at the low end can provide a physical rationale for the presence of outliers and inliers.

A literature search showed availability of statistical tests for checking outliers at 0.01 and 0.05 levels, but no tests for inliers. Singh and Nakashima (1981) developed an objective methodology for successive detection and modification of any outliers and inliers at both ends of the flood spectrum at 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40 levels of significance, from experiments on millions of normally distributed numbers. The developed test statistic is termed a departure, which is given by

$$\Delta_i = Z_i - Z_{si}$$

where Z is the theoretical standard normal deviate and Z_s is the sample standardized deviate corresponding to the plotting position, *p*

$$p = \frac{m-\alpha}{n+1-2\alpha}$$

where *p* is the probability of nonexceedance, *m* is the rank order for the flood series ranked from low to high, and a = 0.38 (Blom, 1958). Figure 4 shows the values of the departures for the five highest and five lowest floods in an annual flood series at various probability levels. In this figure the five highest floods are ranked from high to low, and the five lowest floods are ranked from low to high (designated by 1,2,3,4, and 5, respectively). Table 2 provides test values of outlier and inlier departures determined at 23 probabilities for sample sizes 10, 15, 20, 25, 30, 40, 50, 60, 75 and 100. Usually the number of outliers and inliers at the high and low end of the flood spectrum increases with the sample size.

The observed annual flood series needs to be transformed to resemble a series distributed *as*$N(\mu, \sigma^2)$. This is achieved with the power transformation (Box and Cox, 1964):

$$y_i = (Q_i^{\lambda}-1)/\lambda;\ \lambda \neq 0$$

and

$$y_i = \log Q_i\ ;\ \lambda = 0$$

where Q is the annual flood, and λ is the transformation parameter. The λ, can be obtained with the maximum log-likelihood method (Singh, 1980a):

$$L_{\max}(\lambda) = -\frac{1}{2} n \log \sigma_y^{\,2}(\lambda) + \log J(\lambda;Q)$$

and

$$\log J(\lambda;Q) = (\lambda - 1)\sum_{i=1}^{n} \log Q_i$$

The skew of the *y* series is very close to zero but the kurtosis may be different than for a normal distribution. Singh and Nakashima (1981) provide adjustment values for various values of

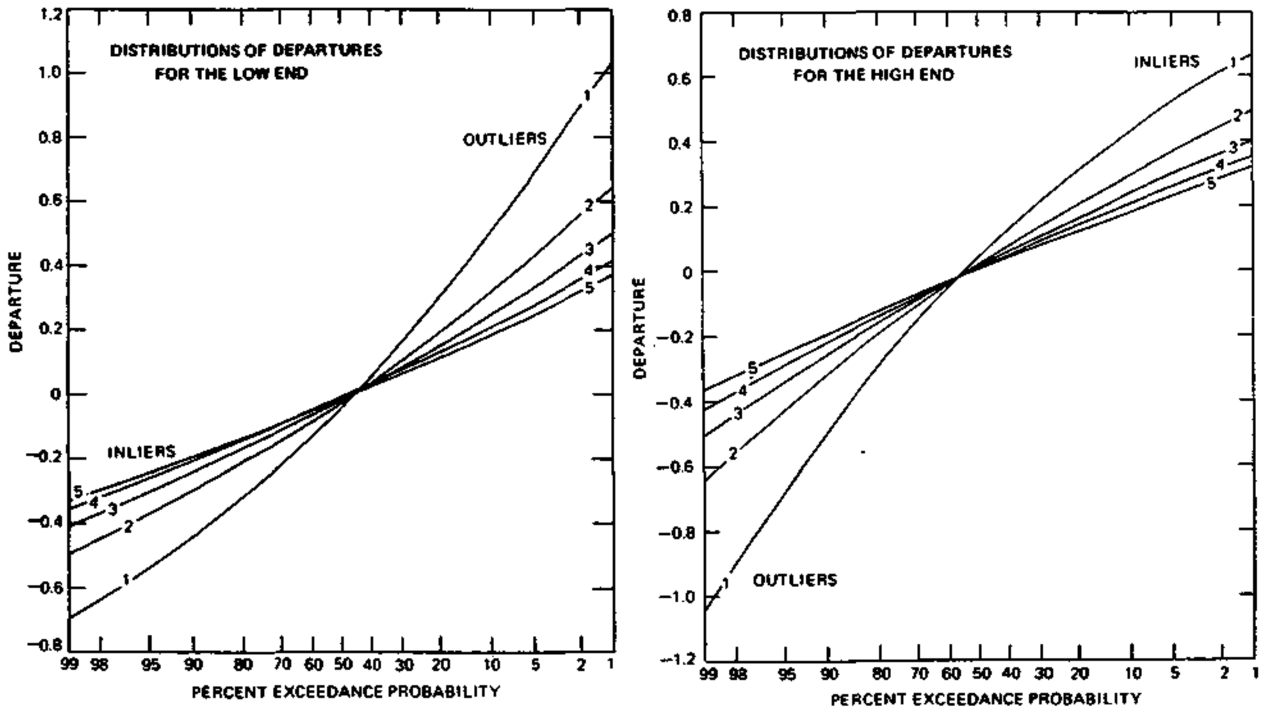


Figure 4. Distribution of departures for outliers and inliers

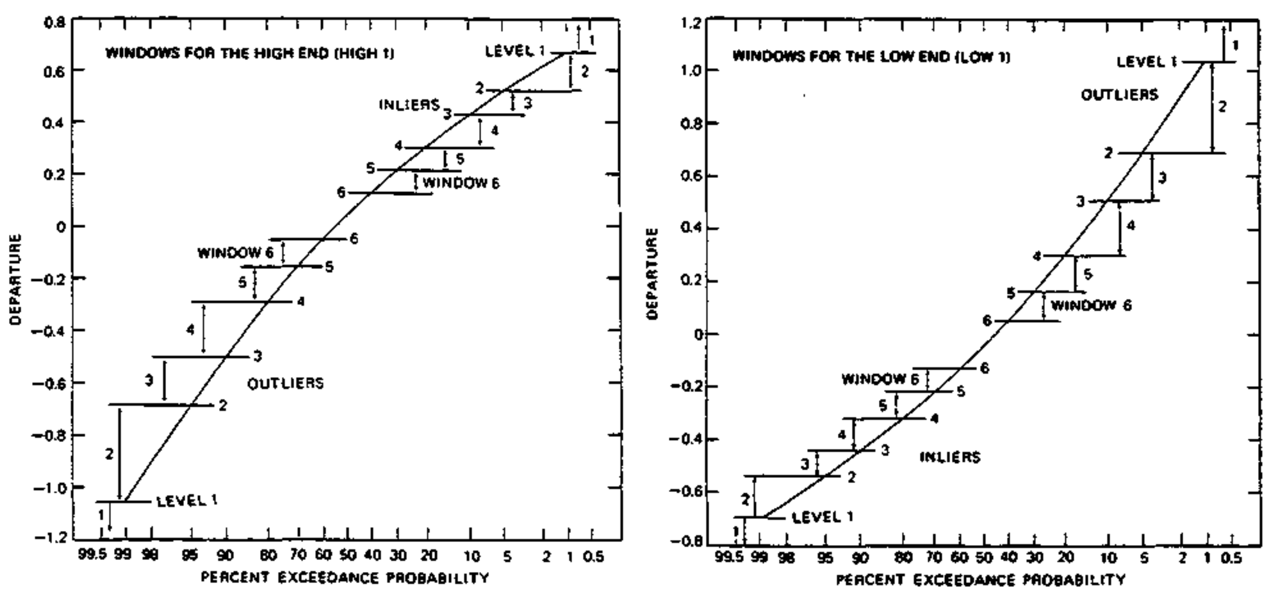


Figure 5. Successive testing for outliers/inliers and their modification

Table 2. Test Values of Outlier and Inlier Departures

			Test values of departures				
Window	p	*Outlier/ inlier*	*Low 1 15-100*	*Low 2 20-100*	*Low 3 25-100*	*Low 4 30-100*	*Low 5 40-100*
1	<0.01	Inlier	<-0.689	<-0.495	<-0.412	<-0.363	<-0.327
	>0.99	Outlier	>1.029	>0.643	>0.498	>0.418	>0.368
2	<0.05	Inlier	<-0.532	<-0.369	<-0.303	<-0.264	<-0.237
	>0.95	Outlier	>0.681	>0.421	>0.337	>0.285	>0.253
3	<0.10	Inlier	<-0.441	<-0.299	<-0.243	<-0.211	<-0.188
	>0.90	Outlier	>0.503	>0.321	>0.254	>0.217	>0.193
4	<0.20	Inlier	<-0.318	<-0.209	<-0.167	<-0.143	<-0.127
	>0.80	Outlier	>0.297	>0.197	>0.159	>0.137	>0.123
5	<0.30	Inlier	<-0.221	<-0.141	<-0.110	<-0.093	<-0.082
	>0.70	Outlier	>0.161	>0.112	>0.092	>0.081	>0.073
6	<0.40	Inlier	<-0.132	<-0.080	<-0.060	<-0.050	<-0.043
	>0.60	Outlier	>0.052	>0.043	>0.037	>0.034	>0.032
	p	*Outlier/ inlier*	*High 1 15-100*	*High 2 20-100*	*High 3 25-100*	*High 4 30-100*	*High 5 40-100*
1	<0.01	Inlier	<-1.054	<-0.654	<-0.511	<-0.429	<-0.377
	>0.99	Outlier	>0.679	>0.488	>0.407	>0.358	>0.323
2	<0.05	Inlier	<-0.683	<-0.433	<-0.341	<-0.290	<-0.256
	>0.95	Outlier	>0.529	>0.369	>0.300	>0.263	>0.235
3	<0.10	Inlier	<-0.500	<-0.322	<-0.258	<-0.220	<-0.195
	>0.90	Outlier	>0.438	>0.299	>0.241	>0.209	>0.186
4	<0.20	Inlier	<-0.295	<-0.197	<-0.161	<-0.139	<-0.124
	>0.80	Outlier	>0.317	>0.209	>0.166	>0.143	>0.126
5	<0.30	Inlier	<-0.159	<-0.112	<-0.094	<-0.082	<-0.074
	>0.70	Outlier	>0.221	>0.140	>0.110	>0.093	>0.082
6	<0.40	Inlier	<-0.051	<-0.043	<-0.039	<-0.035	<-0.032
	>0.60	Outlier	>0.132	>0.079	>0.060	>0.050	>0.043

Notes: 15-100,…, and 40-100 denote the range of sample size *n* in years, and p is the probability or significance level; windows 1,2,…, 6 refer to significance levels of 0.01, 0.05,…, 0.40 used for detection of outliers and inliers.

kurtosis for symmetric distributions. In the case of the asymmetrical y series, these adjustment factors do not yield the best results.

The detection and modification procedure begins from window 1 or significance or probability level 0.01, and any outliers/inliers detected are modified at that level (Figure 5). The resulting detransformed series is analyzed to test the departures, and the procedure is repeated, if necessary, to ensure that there are no outliers/inliers at the 0.01 significance level. By following the procedure sequentially from one level to the next, desired distribution statistics and floods are computed before moving to the next level. If no outliers/inliers are detected at a level, no modifications are done for that level. Windows 1, 2, 3, 4, 5, and 6 correspond to significance or probability levels (SL) of 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40, or their complements, respectively.

Kurtosis Correction

The power-transformed series, y, has a skew very close to zero but the kurtosis, *kt,* may not equal 3 as for a normal distribution. The kurtosis correction factors were developed following the procedure outlined by Box and Tiao (1973). Table 3 provides values of standard deviates with kurtosis correction. Parameter (3 is related to kurtosis, *kt,* by the expression:

$$kt = \frac{\Gamma[5(1+\beta)/2]\ \Gamma[(1+\beta)/2]}{\{\Gamma[3(1+\beta)/2]\}^2}$$

Distributions Used

Normal Distribution. The power-transformed series is considered a normal distribution, N(x,s^2), in which x is the mean and s is the standard deviation of y series. The estimate for a T-year flood is obtained from:

$$y_T = x + z_T s$$

where z_T is with β = 0 without kurtosis correction or with p corresponding to *kt* for the y series. The y_T is then transformed to Q_T with inverse transformation:

$$Q_T = (\lambda y_T + 1)^{1/\lambda}$$

Log-Pearson Type III Distribution or LP3. The power-transformed series is retransformed to the Q series after any detection and modification of outliers and inliers. The Q

Table 3. Values of Z_T for Various Values of β and T

β	*Values of Z_T for recurrence interval, T*					
	10	*25*	*50*	*100*	*500*	*1000*
-1.00	1.386	1.593	1.663	1.697	1.725	1.729
-0.95	1.384	1.592	1.665	1.708	1.762	1.777
-0.90	1.378	1.594	1.679	1.736	1.817	1.841
0.85	1.372	1.600	1.699	1.769	1.875	1.908
-0.80	1.366	1.608	1.721	1.803	1.935	1.977
-0.75	1.360	1.618	1.744	1.839	1.996	2.047
-0.70	1.355	1.629	1.768	1.875	2.056	2.117
-0.65	0.350	1.640	1.792	1.911	2.117	2.187
-0.60	1.345	1.651	1.815	1.946	2.178	2.257
-0.55	1.340	1.661	1.838	1.982	2.238	2.328
-0.50	1.335	1.672	1.861	2.016	2.298	2.398
-0.45	1.330	1.682	1.883	2.050	2.358	2.468
-0.40	1.326	1.691	1.904	2.083	2.418	2.538
-0.35	1.321	1.700	1.925	2.116	2.477	2.608
-0.30	1.315	1.709	1.945	2.148	2.535	2.677
-0.25	1.310	1.717	1.965	2.179	2.594	2.747
-0.20	1.305	1.725	1.984	2.210	2.651	2.816
-0.15	1.299	1.732	2.002	2.240	2.709	2.885
-0.10	1.293	1.739	2.020	2.269	2.766	2.954
-0.05	1.288	1.745	2.037	2.298	2.822	3.022
0.00	1.282	1.751	2.054	2.326	2.878	3.090
0.05	1.275	1.756	2.070	2.354	2.934	3.158
0.10	1.269	1.761	2.085	2.381	2.989	3.226
0.15	1.263	1.765	2.100	2.407	3.044	3.293
0.20	1.256	1.770	2.114	2.433	3.098	3.361
0.25	1.249	1.773	2.128	2.458	3.152	3.428
0.30	1.243	1.776	2.141	2.482	3.205	3.494
0.35	1.236	1.779	2.554	2.506	3.258	3.561
0.40	1.229	1.782	2.166	2.529	3.311	3.627
0.45	1.222	1.784	2.178	2.552	3.363	3.692
0.50	1.214	1.786	2.189	2.574	3.414	3.758
0.55	1.207	1.787	2.200	2.596	3.465	3.823
0.60	1.200	1.788	2.210	2.617	3.516	3.888
0.65	1.192	1.789	2.220	2.637	3.566	3.952

Table 3. Concluded

β	Values of Z_T for recurrence interval, *T*					
	10	*25*	*50*	*100*	*500*	*1000*
0.70	1.185	1.789	2.229	2.657	3.616	4.016
0.75	1.177	1.790	2.238	2.677	3.665	4.080
0.80	1.169	1.789	2.247	2.695	3.714	4.143
0.85	1.162	1.789	2.255	2.714	3.762	4.206
0.90	1.154	1.788	2.262	2.732	3.810	4.269
0.95	1.146	1.787	2.269	2.749	3.857	4.331
1.00	1.138	1.786	2.276	2.766	3.904	4.393

series is analyzed as an LP3 distribution (U.S. Water Resources Council, 1973) and the T-year flood estimate is obtained with the sample skew g_s as well as the weighted skew g_w. The weighted skew g_w is obtained from

$$g_W = g_s W + (1 - W) g_r$$

where w equals (n - 25)/75 and lies between 0 and 1, and g_r in the regional skew.

Mixed Distribution. The mixed distribution concept considers logarithms of annual floods to belong to two populations with means μ_1 and μ_2, variances σ_1^2 and σ_2^2, and relative weights a and 1 - a. Mixed distribution is a versatile distribution and can match most of the observed flood distribution shapes with proper values of a, μ_1, μ_2, σ_1, and σ_2. Kurtosis correction is valid only if the observed or power-transformed distribution is symmetrical. However, the mixed distribution allows for various combinations of skew, kurtosis, and asymmetries observed even after power transformation.

New Flood Frequency Methodology

Table 2 and Figures 4 and 5 clarify the concept of levels and windows. For the highest flood, the outlier H1 lies in window 1 if departure A < -1.054, in window 2 if -1.054 < A < -0.683, and so on for windows 3-6. If some outliers and/or inliers are detected in window 1, their departures are modified to respective values at level 1, and the procedure is followed sequentially from one window to the next. If no outliers and/or inliers are detected in a particular window, no modification is needed, and the program moves to the next window after developing and printing distribution statistics and flood estimates.

The Flow Chart

The detection and modification of outliers and inliers, as well as flood frequency analysis, follows the flow chart given in Figure 6. Some relevant explanations to clarify the methodology and the computer program are given below. The sequence numbers correspond to the numbers attached to various boxes in the flow chart.

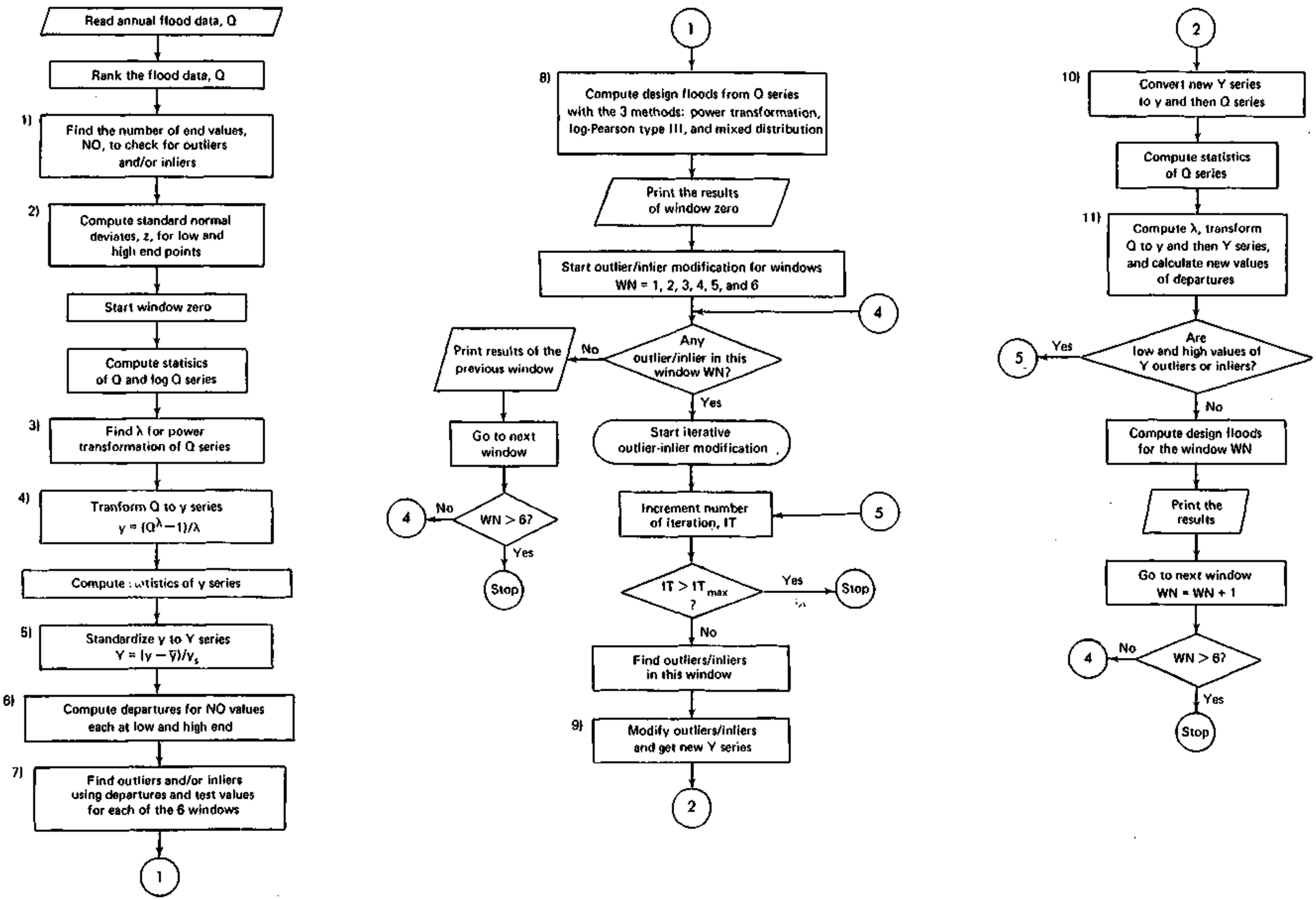


Figure 6. Flow chart for computer program

(1) Number of low as well as high floods, *NO*, that need to be checked to determine if they are outliers/inliers, can be provided as input information or computed from *NO* = [n/10] where *NO* = 5 for $n > 50$; n is the sample size of floods.

(2) Standard normal deviates from *NO* floods at both high and low end of the ranked flood series are obtained by converting p to z with a p-z subroutine, assuming a normal distribution:

$$p = \frac{m-\alpha}{n+1-2\alpha}; \; m = 1, 2, \ldots, n$$

The value of *a* is obtained from the previous information generated during the development of departure test statistics.

	a values for the 5 highest and lowest ranks				
n	*1*	*2*	*3*	*4*	*5*
10	0.425	0.474	0.492	0.506	0.511
15	0.414	0.464	0.485	0.498	0.506
20	0.408	0.455	0.478	0.491	0.501
25	0.406	0.448	0.472	0.486	0.496
30	0.404	0.443	0.467	0.481	0.491
40	0.403	0.440	0.459	0.473	0.482
50	0.403	0.440	0.454	0.467	0.475
60	0.403	0.440	0.451	0.462	0.469
75	0.403	0.440	0.450	0.458	0.463
100	0.403	0.440	0.450	0.456	0.460

(3) The parameter A, is computed.

(4) The given *Q* series is transformed to a *y* series.

(5) The *y* series is standardized to a *Y* series with:

$$Y_i = (y_i - \bar{y})/y_s$$

where y and y_s are the mean and standard deviation of the *y* series.

(6) The departures, Δ_m , for the *NO* values at the low end as well as at the high end are obtained from:

$$\Delta_m = z_m - Y_m$$

(7) Outliers and inliers, if any, are detected in each of the six windows according to the six levels, with departure values taken from Table 2.

(8) The floods corresponding to 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year recurrence intervals are computed with the three distribution methods described earlier, without any modification of outliers and/or inliers, i.e., with the window as 0.

(9-11) The detection of outliers and inliers is initiated from window 1. Any detected outlier and inliers are modified to correspond to the threshold level. The new *Y* series is transformed to a *y* series then to a *Q* series with the previous value of λ. A new λ is derived and the detection-modification process is repeated (usually two or three iterations) until no outliers and inliers are detected in the window under consideration. The final *Q* or *y* series is used in computing various T-year floods. The results are printed and the detection-modification process is applied to the next window.

Examples

The methodology for flood frequency analysis with objective detection and modification of outliers and inliers is applied to observed annual maximum floods for the Sangamon River near Oakford (drainage area 5,093 square miles) using the 1941-1993 record. Tables 4 and 5 provide the computer-printout results, which are explained briefly.

Table 4 starts with U.S. Geological Survey (USGS) gaging station number, river name and station location, and years of record, which determines the number of high or low floods considered for detection of any outliers and inliers. The five highest observed floods were 123,000, 68,700, 55,900, 45,800, and 44,700 cfs, respectively. The highest flood of 123,000 cfs is 1.79 times the next highest flood of 68,700 cfs and seems to be an outlier when the top five floods are considered. The five lowest observed floods were 3,800, 5,670, 5,960, 8,400, and 10,000 cfs, respectively.

The " level number" refers to windows 0 - 6; 0 corresponds to no consideration of any outliers/inliers, and windows 1-6 correspond to significance levels of 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40, respectively. The objective detection and modification of any outliers and inliers at various significance levels or windows is reflected in change of values of high and low floods. The major modification in this example is in the highest flood (H1) of 123,000 cfs.

The distribution statistics are given for PT (power transformed) normal distribution, LP3 (log-Pearson HI) distribution, and MD (mixed) distribution. For the PT, skew is very close to

Table 4. Flood Frequency Analysis for Sangamon River near Oakford,
Station Number 05583000, 1941-1993

Method		*Level No.* 0	1	2	3	4	5	6
		100-Year Flood in cfs						
Power Transform, PT								
With *kt* = 3.0		85346	85346	82548	77773	73171	68979	66722
With sample *kt*		98095	98095	92916	84457	76900	70643	66704
LP III								
Sample skew		81399	81399	78539	73997	69810	66110	65482
Weighted skew		80065	80065	78581	75904	73191	70595	68506
MD		102869	102869	97879	88707	77775	72098	68827
Type	*Rank*	*Observed and Modified Floods in cfs*						
Low	1*	3800	3800	3800	3800	3800	3824	4387
	2*	5670	5670	5670	5670	5670	5714	6331
	3*	5960	5960	5960	6239	6676	7045	7670
	4*	8400	8400	8400	8400	8400	8400	8737
	5*	10000	10000	10000	10000	10000	10000	9889
High	5*	44700	44700	44815	45607	46092	46092	46016
	4*	45800	45800	47513	48385	48866	48866	48721
	3*	55900	55900	55900	55900	55900	54856	52224
	2*	68700	68700	68700	68700	66068	60647	57298
	1*	123000	123000	112395	95194	81184	72095	66891
Method	*Statistics*	*Values of Statistics*						
PT	mean	21.053	21.053	25.717	37.177	56.491	89.013	93.108
	stddev	2.351	2.351	3.209	5.506	9.791	17.725	18.197
	skew	0.027	0.027	0.028	0.021	0.008	-0.003	-0.017
	kurtosis	4.379	4.379	4.179	3.819	3.492	3.238	2.999
	5th moment	2.393	2.393	1.984	1.176	0.504	0.128	-0.042
	lambda	0.133	0.133	0.165	0.221	0.281	0.343	0.349
LP3	mean	4.348	4.348	4.348	4.347	4.346	4.345	4.346
	stddev	0.271	0.271	0.270	0.266	0.261	0.257	0.247
	skew	-0.343	-0.343	-0.402	-0.489	-0.568	-0.638	-0.570
	kurtosis	4.279	4.279	4.153	3.982	3.878	3.827	3.481
	5th moment	-2.479	-2.479	-3.359	-4.606	-5.624	-6.389	-5.246
MD	weight'*a*'	0.510	0.510	0.522	0.519	0.407	0.219	0.204
	mul	4.302	4.302	4.293	4.276	4.231	4.089	4.048
	mu2	4.397	4.397	4.408	4.424	4.425	4.416	4.423
	sigmal	0.345	0.345	0.337	0.324	0.317	0.285	0.231
	sigma2	0.149	0.149	0.147	0.149	0.175	0.195	0.185
	Test Stat	2.674	2.674	2.532	2.604	2.585	2.319	2.179

Notes: Drainage area of the Sangamon River near Oakford is 5,093 square miles. An asterisk indicates high and low floods considered for outlier detection and modification.

Table 5. Flood Frequency Analysis for Sangamon River near Oakford, Station Number 5583000, 1941-1993

Method	*Level*	*2*	*10*	*25*	*50*	*100*	*500*	*1000*
		Flood in cfs for Recurrence Intervals (years)						
PT, *kt*=3.0	0	22870	48599	62908	73981	85346	113061	125621
PT, sample *kt*		22870	46599	64156	79922	98095	150959	179053
LP3, sample skew		23110	48378	61652	71553	81399	104170	113959
LP3, weighted skew		23195	48228	61141	70671	80065	101482	110563
MD		23292	44920	62777	81142	102869	165145	197497
PT, *kt*=3.0	1							
PT, sample *kt*								
LP3, sample skew				same as above				
LP3, weighted skew								
MD								
PT, *kt*=3.0	2	22976	48042	61629	72005	82548	107865	119179
PT, sample *kt*		22976	46371	62750	76959	92916	137393	160070
LP3, sample skew		23222	47863	60390	69560	78539	98796	107297
LP3, weighted skew		23219	47868	60407	69589	78581	98878	107401
MD		23479	44520	60964	77799	97879	155174	184754
PT, *kt*=3.0	3	23146	46954	59307	68543	77773	99406	108864
PT, sample *kt*		23146	45853	60136	71874	84457	117101	132736
LP3, sample skew		23376	46886	58229	66292	73997	90736	97507
LP3, weighted skew		23245	47126	58995	67580	75904	94407	102063
MD		23709	44060	57930	71736	88707	137921	163216
PT, kt=3.0	4	23298	45772	56940	65121	73171	91623	99531
PT, sample *kt*		23298	45138	57477	67042	76900	100858	111698
LP3, sample skew		23492	45849	56103	63190	69810	83683	89099
LP3, weighted skew		23248	46304	57504	65506	73191	90021	96886
MD		23584	44337	56151	66178	77775	113735	133606
PT, *kt*=3.0	5	23416	44577	54673	61932	68979	84813	91481
PT, sample *kt*		23416	44293	54936	62817	70643	88724	96526
LP3, sample skew		23558	44812	54114	60379	66110	77732	82125
LP3, weighted skew		23219	45452	56020	63488	70595	85946	92126
MD		23410	44142	55090	63495	72098	93320	103074
PT, *kt*=3.0	6	23418	43676	53242	60092	66722	81562	87790
PT, sample *kt*		23418	43686	53247	60093	66704	81537	87757
LP3, sample skew		23427	44046	53285	59611	65482	77681	82409
LP3, weighted skew		23195	44463	54554	61695	68506	83284	89266
MD		23556	43280	53399	61050	68827	87573	96032

Note: Drainage area of the Sangamon River near Oakford is 5,093 square miles.

zero (which is the purpose of power transformation) and kurtosis >3, indicating a sharper-peaked frequency distribution than a normal distribution. All odd central moments are zero for a normal distribution (Kite, 1977). In the present case, the fifth moment is generally positive, indicating that the transformed series is not symmetrical. The transformation parameter (λ) value increases with increase in window level. For the LP3, sample skew becomes progressively more negative with increase in window level.

Much higher kurtosis than 3.0 indicates a sharper peak frequency curve than for the normal distribution. For the MD, weight *a* remains close to 0.52 for windows 0 - 3 but drops off for windows 4 and 5. The test statistic shows goodness of fit given by $\sum|\Delta Z|$.

The 100-year flood peaks at various levels of significance or windows given for PT with *kt* = 3.0 (assuming power-transformed series as a normal distribution) and with sample *kt* (allowing for correction but considering power-transformed series as a symmetrical frequency distribution), for LP3 with sample skew as well as weighted skew assuming a regional skew of -0.4, and for MD. The 100-year flood values decrease as the level of detection or windows increases for all the three distributions used.

Table 5 contains values of 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year flood peaks derived with the three distributions at significance levels of 0.00, 0.01, 0.05, 0.10, 0.20,0.30, and 0.40, corresponding to windows 0, 1,2, 3, 4, 5, and 6, respectively. Because no outliers/inliers were detected in window 1, the flood peak values in window 1 remain the same as in window 0.

Figure 7 shows the fitted distribution curves with MD (and two-component normal distributions) and LP3 with sample skew as well as the observed peak floods for the 1941-1993 period for the Sangamon River near Oakford for window 3 or with outlier/inlier detection and modification carried to 0.10 significance level. The LP3 does not satisfactorily fit the high end of the flood spectrum.

The same methodology used for flood frequency was applied to stage frequency analysis. As an example, the frequency method applied to annual maximum stages observed in the Mississippi River at Grafton during 1941-1993 is considered here. Tables 6 and 7 provide the computer print-out results.

Table 6 starts with USGS gaging station number, name of the river and station location, and years of record. The five lowest stages (out of the 53 maximum annual stages) observed are

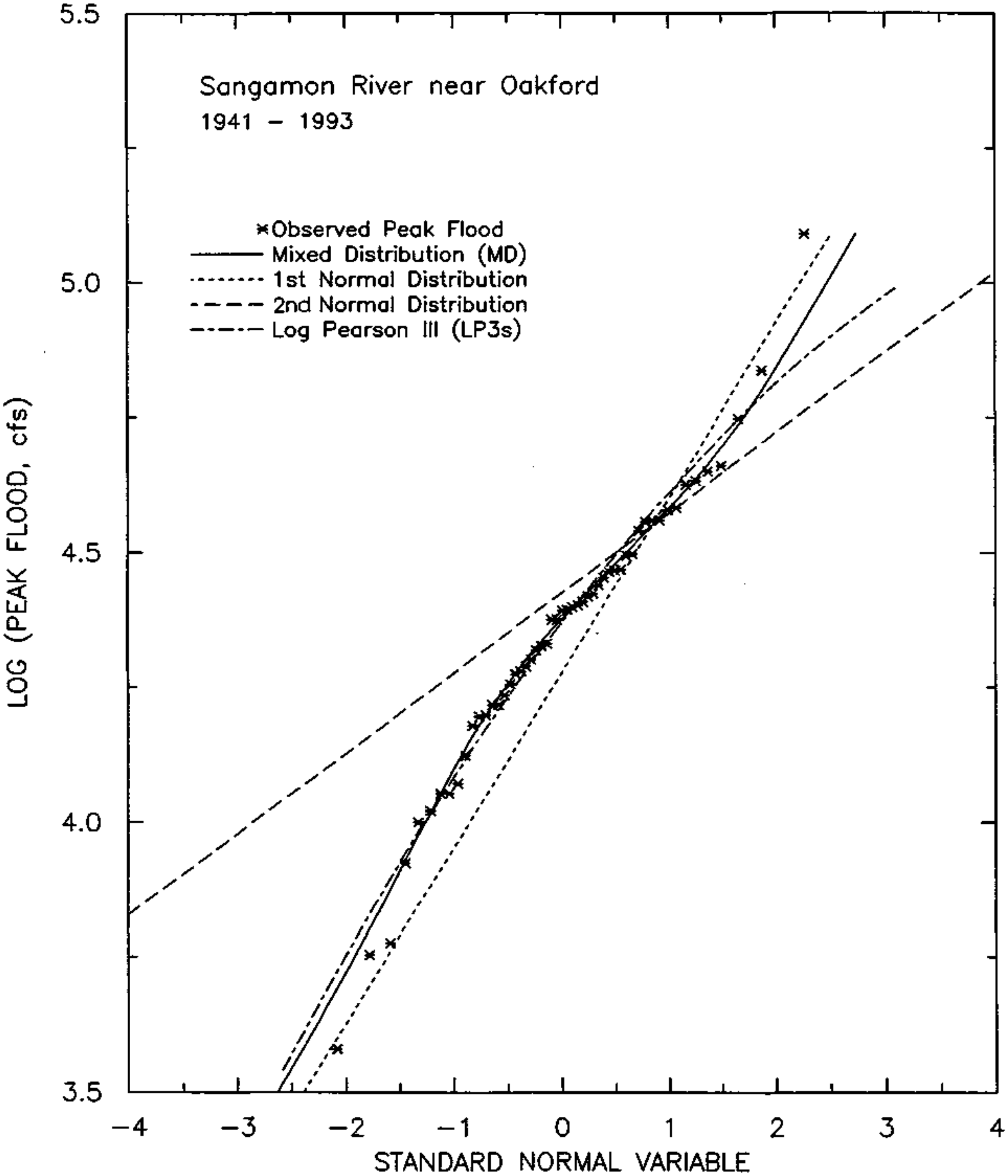


Figure 7. Sangamon River near Oakford, fitted flood probability curves

Table 6. Stage Frequency Analysis for Mississippi River at Grafton,
Station Number 05585500,1941-1993

Method		*Level* 0	1	2	3	4	5	6
		100-Year Stage in feet						
PT								
With *kt* = 3.0		53.42	53.47	52.78	52.16	51.52	51.11	51.01
With sample *kt*		46.62	46.72	47.02	47.36	47.89	48.39	49.07
LP3								
Sample skew		49.59	49.58	49.56	49.59	49.65	49.73	50.02
Weighted skew		46.72	46.73	46.75	46.82	46.96	47.14	47.47
MD		47.66	47.66	47.58	47.75	48.12	48.43	49.03
Type	*Rank*	*Observed and Modified Stages, in feet*						
Low	1*	27.63	27.42	26.90	26.51	25.93	25.33	24.72
	2*	27.69	27.69	27.52	27.20	26.73	26.25	25.76
	3*	28.09	28.09	27.98	27.69	27.27	26.86	26.43
	4*	28.09	28.09	28.09	28.09	27.71	27.33	26.95
	5*	28.09	28.09	28.09	28.09	28.08	27.74	27.39
High	5*	40.88	40.88	40.88	40.88	40.88	40.96	41.45
	4*	41.27	41.27	41.27	41.27	41.43	41.92	42.45
	3*	41.55	41.55	41.55	41.95	42.63	43.15	43.76
	2*	44.99	44.99	44.99	44.99	44.99	44.99	45.66
	1*	49.90	49.90	49.90	49.90	49.90	49.90	49.90
Method	*Statistics*	*Values of Statistics*						
PT	mean	0.526	0.526	0.571	0.631	0.742	0.885	1.054
	stddev	0.000	0.000	0.000	0.001	0.001	0.003	0.006
	skew	0.079	0.074	0.071	0.072	0.061	0.045	0.033
	kurtosis	1.964	1.971	2.031	2.102	2.221	2.345	2.482
	5th moment	0.810	0.774	0.743	0.717	0.601	0.435	0.265
	lambda	-1.899	-1.897	-1.746	-1.579	-1.335	-1.106	-0.909
LP3	mean	1.525	1.525	1.525	1.525	1.525	1.524	1.524
	stddev	0.063	0.063	0.064	0.064	0.065	0.067	0.068
	skew	0.507	0.502	0.483	0.460	0.418	0.367	0.326
	kurtosis	2.665	2.663	2.661	2.655	2.652	2.656	2.694
	5th moment	4.307	4.272	4.128	3.926	3.542	3.080	2.651
MD	weight'*a*'	0.345	0.345	0.345	0.275	0.265	0.264	0.204
	mul	1.465	1.465	1.464	1.459	1.461	1.462	1.458
	mu2	1.557	1.557	1.557	1.550	1.547	1.547	1.540
	sigmal	0.019	0.019	0.016	0.012	0.018	0.021	0.024
	sigma2	0.056	0.056	0.056	0.059	0.061	0.063	0.067
	Test Stat	5.166	5.041	4.588	3.167	3.090	3.164	2.563

Notes: Drainage area of the Mississippi River at Grafton is 171,300 square miles. An asterisk indicates high and low stages considered for outlier detection and modification.

Table 7. Stage Frequency Analysis for Mississippi River at Grafton, Station Number 05585500,1941-1993

Method	*Level*	*Stages in feet for Recurrence Intervals (years)* 2	10	25	50	100	500	1000
PT, *kt*=3.0	0	32.91	40.68	45.20	49.03	53.42	67.46	76.59
FT, sample *kt*		32.91	41.31	43.88	45.37	46.62	48.98	49.85
LP3, sample skew		33.12	40.65	44.28	46.95	49.59	55.75	58.45
LP3, weighted skew		33.58	40.36	43.12	44.99	46.72	50.41	51.89
MD, mixed dist		32.93	41.16	44.01	45.91	47.66	51.37	52.88
PT, *kt*=3.0	1	32.90	40.69	45.22	49.06	53.47	67.57	76.76
PT, sample *kt*		32.90	41.31	43.91	45.43	46.72	49.15	50.06
LP3, sample skew		33.12	40.65	44.28	46.95	49.58	55.73	58.42
LP3, weighted skew		33.58	40.36	43.12	44.99	46.73	50.42	51.90
MD, mixed dist		32.92	41.17	44.02	45.91	47.66	51.37	52.88
PT, *kt*=3.0	2	32.93	40.69	45.09	48.72	52.78	64.92	72.10
PT, sample *kt*		32.93	41.25	43.96	45.60	47.02	49.81	50.87
LP3, sample skew		33.12	40.66	44.29	46.94	49.56	55.66	58.32
LP3, weighted skew		33.57	40.38	43.14	45.01	46.75	50.43	51.91
MD, mixed dist		32.90	41.13	43.96	45.84	47.58	51.27	52.77
PT, *kt*=3.0	3	32.95	40.72	44.98	48.42	52.16	62.73	68.52
PT, sample *kt*		32.95	41.21	44.03	45.80	47.36	50.50	51.72
LP3, sample skew		33.12	40.70	44.33	46.97	49.59	55.65	58.29
LP3, weighted skew		33.56	40.42	43.20	45.07	46.82	50.51	51.99
MD, mixed dist		33.19	41.09	44.00	45.95	47.75	51.60	53.17
PT, *kt*=3.0	4	32.98	40.80	44.91	48.13	51.52	60.50	65.03
PT, sample *kt*		32.98	41.20	44.20	46.14	47.89	51.55	53.02
LP3, sample skew		33.11	40.78	44.41	47.05	49.65	55.65	58.25
LP3, weighted skew		33.54	40.50	43.31	45.20	46.96	50.67	52.16
MD, mixed dist		33.02	41.16	44.19	46.23	48.12	52.18	53.83
PT, *kt*=3.0	5	33.01	40.91	44.90	47.96	51.11	59.03	62.82
PT, sample *kt*		33.01	41.24	44.38	46.46	48.39	52.51	54.18
LP3, sample skew		33.11	40.88	44.52	47.15	49.73	55.65	58.20
LP3, weighted skew		33.52	40.60	43.45	45.36	47.14	50.88	52.37
MD, mixed dist		32.91	41.25	44.37	46.47	48.43	52.61	54.33
PT, *kt*=3.0	6	33.04	41.09	45.04	48.01	51.01	58.34	61.72
PT, sample *kt*		33.04	41.34	44.68	46.94	49.07	53.69	55.61
LP3, sample skew		33.12	41.07	44.76	47.42	50.02	55.96	58.52
LP3, weighted skew		33.52	40.78	43.70	45.66	47.47	51.29	52.81
MD, mixed dist		33.03	41.43	44.72	46.95	49.03	53.53	55.37

Note: Drainage area of Mississippi River at Grafton is 171,300 square miles.

27.63, 27.69, 28.09, 28.09, and 28.09 feet above the gage datum. The five highest stages are 49.90, 44.99, 41.55, 41.27, and 40.88 feet. The highest stage of 49.90 feet is 4.91 feet higher than the next highest stage, which in turn is 3.44 feet higher than the next highest stage. However, the differences between the third and fourth highest and between the fourth and fifth highest are only 0.28 and 0.39 feet, respectively.

The "level number" refers to windows 0-6, window 0 corresponds to no consideration of any outliers/inliers, and windows 1-6 correspond to significance levels of 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40, respectively. The objective detection and modification of any outliers/inliers at various significance levels is reflected in the changes in values of low and high stages.

Table 6 provides the distribution statistics for PT, LP3, and MD. For PT, the skew is close to zero and kurtosis is much lower than 3.0, indicating a flatter-peaked frequency distribution than a normal distribution. The fifth moment is positive, indicating that the transformed series is not symmetrical. The transformation parameter *X* algebraically increases from -1.899 to -0.909 with the increase in window level. For the LP3, the sample skew progressively decreases with increase in window level. Kurtosis values lie between 2.65 and 2.70, indicating flatter peaked frequency distribution than a normal distribution. For the MD, the weight *a* remains at 0.409 from window 0-5 and reduces slightly in window 6. Test statistics show a very good fit for windows 2 and 3.

The 100-year stage values at various levels of significance or windows are given for PT with *kt = 3.0* (assuming power-transformed series as a normal distribution) and with sample *kt* (allowing for correction but considering power-transformed series as a symmetrical frequency distribution), for LP3 with sample skew as well as weighted skew assuming a regional skew of -0.4, and for MD. The 100-year stage values generally decrease with PT *(kt* = 3.0) but generally increase with PT (sample *kt),* though significantly lower than the former. The 100-year stage values with LP3 and MD do not change significantly from window to window though values from LP3 (sample skew) are 2.87 to 2.55 feet higher than from LP3 (weighted skew) for windows 0-6 because the sample skew varies from 0.507 to 0.326 but the regional skew is -0.4.

Table 7 contains values of 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year stages derived with the three distributions at significance levels of 0.00, 0.01, 0.05, 0.10, 0.20, 0.30, and 0.40 corresponding to windows 0-6, respectively.

Figure 8 shows the fitted distribution curves with MD (and two component normal distributions), LP3 with sample skew, and observed annual peak stages for the 1941-1993 period for the Mississippi River at Grafton for window 3 or with outlier/inlier detection and modification carried to 0.10 significance level. The LP3 does not fit the observed peak stages satisfactorily.

General Frequency Method

The power transformation is a useful tool in detection and modification of any outliers and inliers. Various recurrence interval (T-year) floods and stages, however, cannot be estimated accurately because of the problem with kurtosis values significantly different from 3.0 for the normal distribution, and the asymmetrical frequency distribution as evidenced by fifth-order moments not being close to zero. This makes kurtosis correction based on symmetrical frequency distribution questionable.

The log-Pearson HI distribution with sample skew (when sample size is considerable, say, more than 40 or 50) should be useful for analyzing the Illinois River floods and stages. However, the generally used regional skew of -0.40, derived from natural stream flood records, may not apply to managed rivers such as the Illinois River.

The mixed distribution fits the observed flood peaks and stages very well for most of the gaging stations though at some stations the curves fitted by LP3 and MD are very close. For flood and stage frequency analyses, both LP3 and MD results may be considered and evaluated on their own merit.

The outlier/inlier detection and modification needs to be carried to an acceptable significance level. One or two decades ago, a level of 0.01 was used. It can be interpreted in the following words: if there are 100 sample of size *n* at one station, then one sample of these 100 samples will have a value as high or higher (or as low or lower) as the identified or perceived outlier. This is a very drastic limitation and can lead to practical detection of no or very few outliers/inliers. On the other hand, a significance level of 0.30 and 0.40 leads to another extreme.

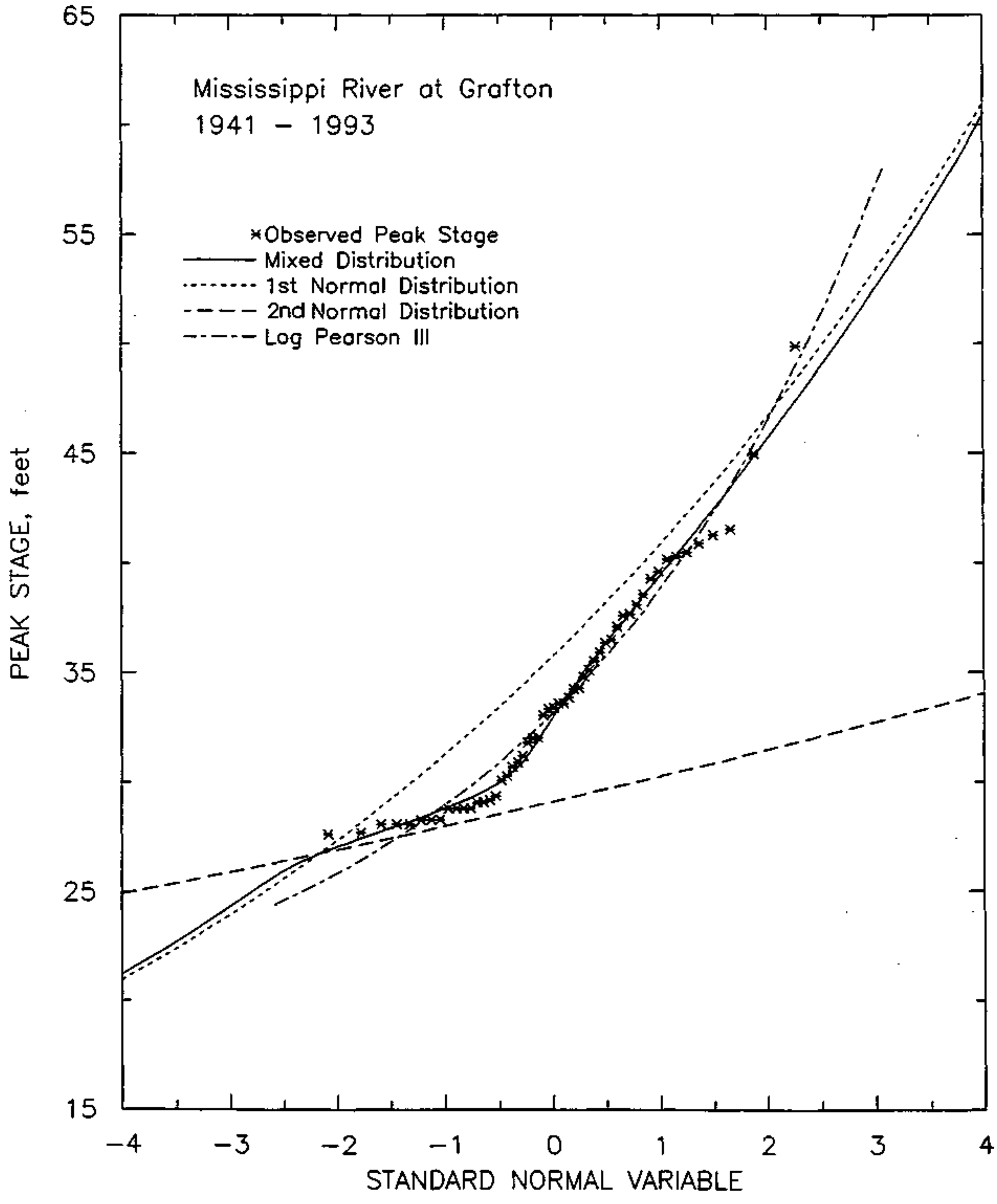


Figure 8. Mississippi River at Grafton, fitted stage probability curves

It seems that a satisfactorily acceptable level can be taken as 0.10 or window 3. Thus, the results presented hereafter from flood and stage analyses with the general frequency method are for outlier/inlier detection and modification carried to the 0.10 significance level or window 3.

WATER STAGES AND ELEVATIONS IN ALTON POOL, ILLINOIS RIVER

There are six stage stations in the Alton Pool (River mile or RM 80.2 from LaGrange Lock and Dam to RM 0.0 at the mouth of the Illinois River). Data for these stations together with their U.S. Army Corps of Engineers (USCOE) numbers are given below.

Location	*USCOE number*	*River mile*	*Average bed level, ft-msl*	*Continuous record*
Dlinois River at Meredosia	IM70	70.8	406.7	2/1884-12/1993
Illinois River at Valley City	IVC61	61.3	406.6	1/1884-12/1993
Illinois River at Florence	IF56	56.0	407.0	1/1942-12/1993
Dlinois River at Pearl	IP43	43.2	408.0	1/1942-12/1993
Dlinois River at Hardin	IH21	21.6	404.0	2/1932-12/1993
Mississippi River at Grafton	0218A	-0.2	391.9	9/1929-12/1993

The maximum water surface elevations and their date of occurrence in the available continuous record at each station from Meredosia to Grafton are: 446.69 feet above mean sea level (feet-msl) on 5/26/43, 444.93 feet-msl on 5/26/43, 443.60 feet-msl on 8/1/93, 442.75 feet-msl on 8/3-4/93, 442.30 feet-msl on 8/3/93, and 441.80 feet-msl on 8/1/93, respectively. It is obvious that the maximum water elevations at Meredosia and Valley City occurred during the highest flood at Meredosia, and those at Florence, Pearl, Hardin, and Grafton occurred during unprecedented Mississippi River floods and stages in July-August 1993.

The USCOE at St. Louis provided daily water elevations (WE) for the period of record at each station. These records give the annual maximum WE, number of days it persisted, and the magnitude and date of the record maximum WE. Figures 9 and 10 plot the historical annual maximum WE for Meredosia and Grafton.

Annual Maximum Water Elevations

After 1940, no new dams and levees were constructed along the Dlinois River downstream of Peoria. Concurrent data at four stations (Meredosia, Valley City, Hardin, and Grafton) cover calendar years 1941 - 1993, and data at two other stations (Florence and Pearl) cover 1942 - 1993. Table 8 provides the annual maximum water elevations for all six stations.

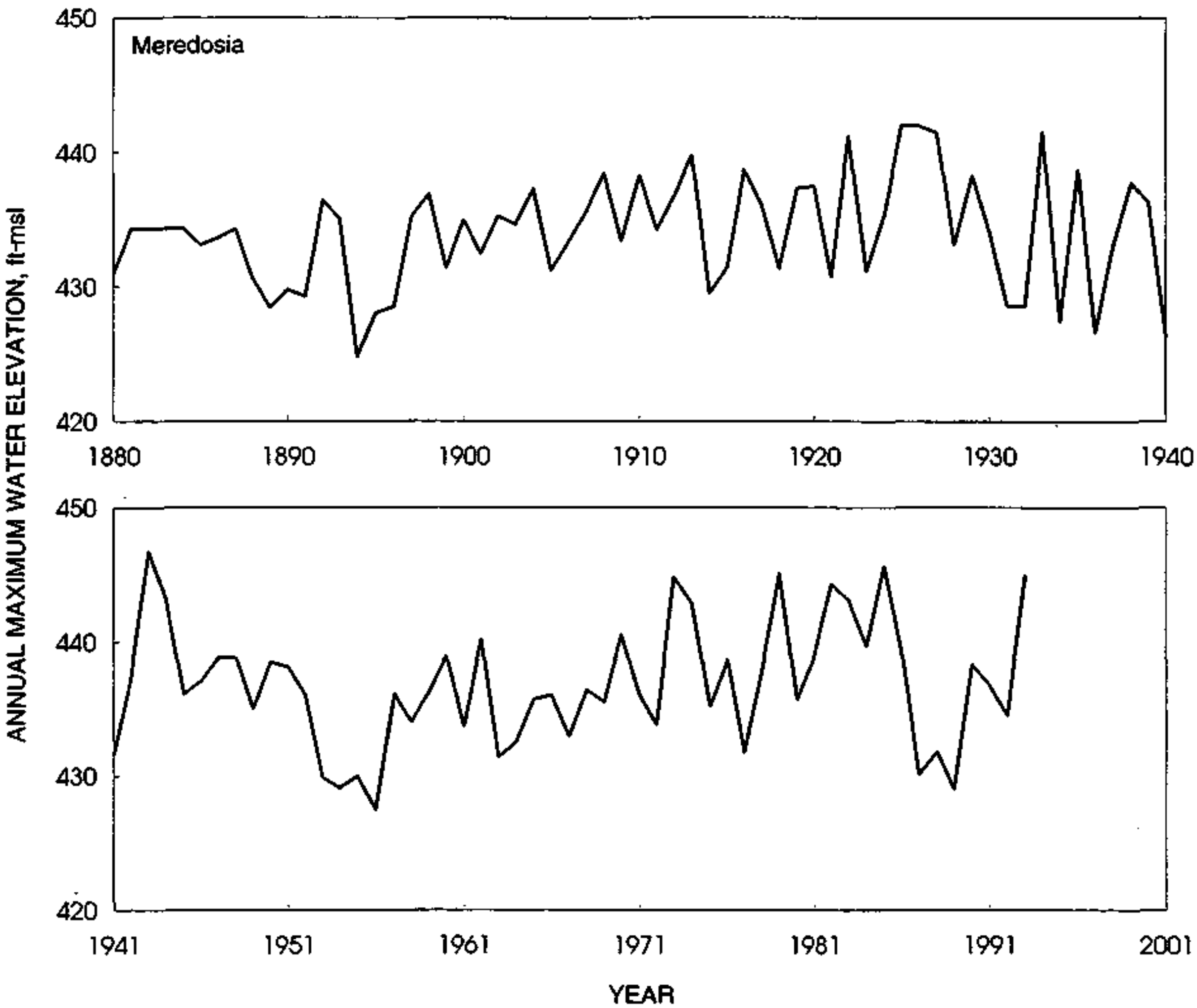


Figure 9. Annual maximum water elevations, Illinois River at Meredosia

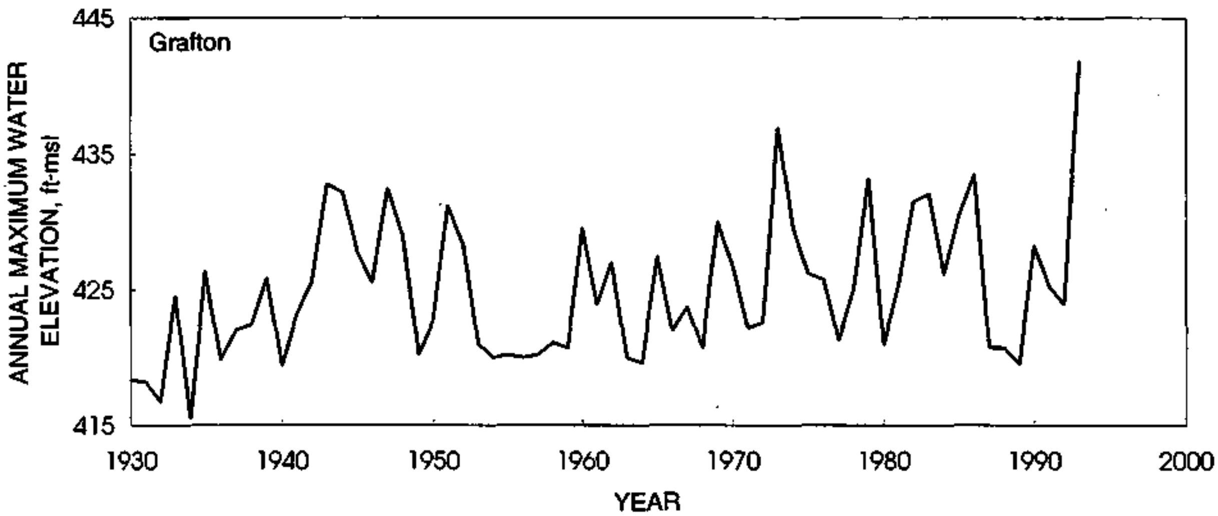


Figure 10. Annual maximum water elevations, Mississippi River at Grafton

Table 8. Annual Maximum Daily Water Elevations and Dates at Stage Stations in the Alton Pool, Illinois River (1941-1993)

Calendar	*Meredosia*		*Valley City*		*Florence*		*Pearl*		*Hardin*		*Grafton*	
year	*WE*	*Date*	WE	*Date*	*WE*	*Date*	WE	*Date*	*WE*	*Date*	*WE*	*Date*
1941	431.59(3)	11/11	430.00(3)	11/9					424.60(1)	11/9	423.09(1)	11/8
1942	437.40(1)	2/17	435.30(1)	2/17	433.70(2)	2/17	429.80(2)	2/17	426.10(1)	6/29	425.49(1)	6/29
									424.50(1)	2/18	419.49(1)	2/17
1943	446.69(1)	5/26	444.91(1)	5/26	442.80(1)	5/26	439.10(1)	5/26	434.70(2)	5/24	432.78(1)	5/24
1944	443.19(2)	5/1	441.54(1)	5/2	440.02(1)	5/3	437.00(1)	5/1	433.90(1)	5/1	432.19(2)	4/30
1945	436.09(2)	5/23	434.30(1)	5/24	433.00(1)	5/23	430.60(2)	6/21	429.20(1)	6/13	427.79(1)	6/13
							430.10(1)	5/23	427.40(2)	5/21	425.69(2)	5/20
1946	437.09(1)	1/15	435.21(1)	1/15	433.80(2)	1/14	431.00(1)	1/14	427.80(1)	1/14	425.49(1)	1/14
1947	438.79(1)	6/15	437.18(1)	6/15	436.20(1)	7/2	434.80(2)	7/2	433.40(2)	7/2	432.39(2)	7/2
	437.79(1)	7/2	436.85(1)	7/2	436.20(1)	6/15						
1948	438.79(1)	3/31	437.10(1)	3/29	435.90(1)	3/29	433.40(1)	3/28	430.80(2)	3/27	428.99(1)	3/27
1949	435.00(1)	2/27	432.90(1)	2/27	431.80(2)	2/7	429.30(4)	2/6	425.40(1)	2/2	420.19(1)	2/11
					431.60(3)	2/27			425.30(4)	2/3	419.89(1)	2/4
1950	438.50(2)	5/3	436.50(1)	5/4	434.90(2)	5/3	431.30(2)	5/4	426.60(2)	5/3	422.79(1)	6/24
											422.39 (3)	5/1
1951	438.09(2)	2/28	436.50(1)	7/24	435.50(1)	7/24	433.60(1)	7/24	431.80(1)	7/24	431.19(2)	7/20
	437.50(1)	7/23										
1952	436.00(2)	4/28	434.60(2)	4/29	433.60(2)	4/29	431.70(1)	4/30	429.80(2)	4/30	428.39(3)	4/30

Table 8. (Continued)

Calendar year	Meredosia WE	Meredosia Date	Valley City WE	Valley City Date	Florence WE	Florence Date	Pearl WE	Pearl Date	Hardin WE	Hardin Date	Grafton WE	Grafton Date
1953	429.90(2)	4/5	428.40(2)	4/5	427.50(1)	4/5	425.20(2)	4/5	422.50(1)	4/5	420.99(1)	4/5
1954	429.09(3)	4/24	427.50(4)	4/23	426.50(4)	4/23	424.00(5)	4/23	421.00(5)	4/23	419.99(2)	5/20
											419.59(1)	4/22
1955	430.00(1)	4/29	428.50(1)	4/29	427.40(2)	4/29	424.80(4)	4/28	422.10(1)	4/25	420.19(1)	4/25
1956	427.50(3)	6/1	426.10(3)	5/31	425.20(2)	5/31	423.20(1)	5/31	421.00(1)	5/31	419.99(1)	4/30
											419.39(1)	5/30
1957	436.10(2)	5/6	434.10(2)	5/6	432.70(2)	5/6	429.40(2)	5/7	424.80(3)	5/23	420.19(1)	6/15
									424.50(3)	5/6	419.89(1)	5/25
1958	434.00(2)	6/23	432.10(1)	6/23	430.80(2)	7/23	428.10(2)	7/23	424.50(1)	8/3	421.09(2)	7/23
					430.70(3)	6/23	427.70(2)	6/25	424.40(2)	7/23		
1959	436.20(1)	2/20	434.30(1)	2/20	432.70(1)	2/20	429.50(1)	2/21	424.80(2)	2/21	420.69(1)	4/9
											419.99(1)	2/21
1960	438.90(2)	4/8	437.20(2)	4/8	436.20(2)	4/10	434.00(1)	4/11	431.40(1)	4/10	429.49(1)	4/10
1961	433.70(1)	5/16	431.80(2)	5/15	430.60(2)	5/15	428.70(1)	5/11	426.30(1)	5/10	423.89(2)	5/10
1962	440.20(2)	3/29	438.30(2)	3/28	437.00(1)	3/29	433.80(2)	3/28	429.90(2)	3/26	426.99(1)	3/26
1963	431.40(1)	3/9	429.80(1)	3/9	428.80(1)	3/9	426.40(1)	3/6	422.80(2)	3/6	419.99(1)	3/7
1964	432.50(4)	4/28	430.70(3)	5/1	429.50(6)	4/27	426.90(5)	4/28	422.80(5)	4/28	419.59(2)	4/23
											419.29 (1)	4/28
1965	435.70(1)	4/19	434.30(2)	4/19	433.50(2)	4/19	431.60(1)	4/19	429.50(1)	4/19	427.39(1)	4/19

Table 8. (Continued)

Calendar year	*Meredosia*		*Valley City*		*Florence*		*Pearl*		*Hardin*		*Grafton*	
	WE	*Date*	*WE*	*Date*	*WE*	*Date*	*WE*	*Date*	*WE*	*Date*	*WE*	*Date*
1966	436.00(1)	5/25	434.00(2)	5/25	432.70(2)	5/25	429.90(2)	5/21	426.10(2)	5/20	421.99(2)	5/20
							429.90 (2)	5/25				
1967	432.90(2)	12/29	431.20(2)	12/29	430.00(1)	5/10	427.90(2)	4/19	425.50(1)	4/19	423.69(1)	4/19
					430.00(2)	12/28	427.50(4)	12/26	423.70(1)	12/24	419.59(1)	12/21
1968	436.40(1)	2/10	434.40(1)	2/12	433.00(3)	2/11	429.90(2)	2/11	426.40(1)	1/23	420.69(1)	1/24
							427.60(2)	1/23	425.00(2)	2/12	419.09(1)	2/12
1969	435.50(2)	2/10	434.30(2)	7/13	433.70(1)	7/13	432.70(2)	7/13	431.50(3)	7/12	429.99(3)	7/12
	435.00(2)	7/13										
1970	440.50(1)	5/22	438.50(1)	5/22	437.10(1)	5/22	433.80(1)	5/2	429.50(1)	5/2	426.69(1)	9/28
							433.80(2)	5/21	429.50(2)	5/18	426.39(1)	5/19
1971	436.05(1)	6/18	430.00(1)	3/2	429.30(1)	3/2	427.20(2)	3/3	424.50(1)	3/2	422.19(1)	3/4
1972	433.70(1)	5/1	431.90(2)	5/1	430.90(3)	4/30	428.40(2)	5/1	425.20(2)	5/5	422.59(1)	5/6
1973	444.70(1)	4/30	443.50(1)	4/30	442.40(1)	4/29	440.50(1)	4/29	438.20(1)	4/29	436.89(2)	4/28
1974	442.80(1)	6/30	440.80(1)	6/30	439.30(2)	6/30	436.10(1)	6/3	432.70(1)	6/3	429.56(1)	6/3
					438.90(1)	6/2					426.58(1)	6/30
1975	435.10(2)	5/9	433.80(3)	5/9	432.90(3)	5/10	431.00(1)	5/10	428.50(1)	5/12	426.19(1)	5/12
1976	438.60(4)	3/12	436.70(1)	3/12	435.50(1)	3/16	431.90(3)	3/13	427.00(2)	4/30	425.76(1)	4/30
							429.10(1)	5/2			419.18(1)	3/12

Table 8. (Continued)

Calendar year	*Meredosia* WE	*Meredosia* Date	*Valley City* WE	*Valley City* Date	*Florence* WE	*Florence* Date	*Pearl* WE	*Pearl* Date	*Hardin* WE	*Hardin* Date	*Grafton* WE	*Grafton* Date
1977	431.70(3)	5/7	431.00(1)	5/7	430.40(1)	5/7	428.50(1)	5/7	424.70(1)	5/8	421.28(1)	11/5
											419.66(1)	5/7
1978	437.80(1)	5/20	436.00(1)	4/15	434.90(1)	4/15	432.00(1)	4/16	428.25(1)	4/16	424.94(2)	5/16
	437.70(1)	4/15	436.00(2)	5/19	434.90(2)	5/19	431.80(3)	5/18	428.25(2)	5/16	424.70(1)	4/5
1979	445.10(3)	4/19	443.20(2)	4/19	441.90(1)	4/14	439.70(1)	4/14	436.50(1)	4/14	433.17(2)	4/14
	444.30(1)	4/14										
1980	435.70(3)	6/10	433.90(2)	6/11	432.90(2)	6/11	429.83(2)	6/12	425.00(4)	6/13	420.97(1)	6/19
1981	438.90(2)	5/23	436.90(2)	5/23	435.80(3)	5/22	433.08(1)	5/22	428.75(1)	5/21	425.29(1)	5/21
1982	444.30(1)	12/11	442.30(1)	12/12	441.00(1)	12/11	437.45(1)	12/11	433.75(2)	12/8	431.50(1)	12/8
1983	443.10(1)	4/14	441.40(1)	4/14	440.40(1)	4/14	437.55(1)	4/11	434.50(1)	4/10	432.05(1)	5/4
											432.04 (1)	4/10
1984	439.70(1)	3/30	437.80(2)	3/29	436.70(2)	3/29	433.40(2)	3/29	430.00(1)	4/24	426.14(1)	4/27
									428.50(4)	3/28	423.32(1)	3/29
1985	445.60(1)	3/10	443.60(1)	3/11	442.10(2)	3/10	438.55(1)	3/10	434.00(1)	3/9	430.47(1)	3/8
1986	439.30(1)	10/11	438.20(1)	10/11	437.70(1)	10/11	435.82(1)	10/10	434.50(2)	10/9	433.45(1)	10/9
1987	430.10(1)	12/31	428.70(2)	12/31	427.90(3)	12/31	425.40(1)	12/29	422.25(1)	12/29	420.72(1)	4/15
											419.69 (1)	12/29
1988	431.80(1)	4/14	430.60(1)	1/15	430.20(1)	1/13	429.05(1)	1/10	425.25(3)	1/9	420.71 (1)	1/15
											420.64 (1)	1/9

Table 8. (Concluded)

Calendar year	*Meredosia* WE	*Meredosia* Date	*Valley City* WE	*Valley City* Date	*Florence* WE	*Florence* Date	*Pearl* WE	*Pearl* Date	*Hardin* WE	*Hardin* Date	*Grafton* WE	*Grafton* Date
1989	429.00(1)	9/18	427.70(4)	9/16	427.00(3)	9/17	424.60(1)	9/17	421.15(1)	9/17	419.59(2)	3/21
											419.22(1)	9/16
1990	438.30(1)	6/26	436.90(2)	6/26	436.00(2)	6/26	433.55(1)	6/26	430.65(1)	6/26	428.24(1)	6/26
1991	436.80(2)	5/7	434.90(2)	5/6	434.30(1)	5/7	431.80(1)	5/7	428.30(1)	5/7	425.23(1)	5/8
1992	434.50(1)	11/29	433.30(1)	11/29	432.40(2)	11/28	429.70(2)	10/27	426.40(2)	11/27	423.91(1)	12/19
											423.87 (6)	11/26
1993	444.90(1)	7/28	444.10(1)	7/27	443.60(1)	8/1	442.75(2)	8/3	442.30(1)	8/3	441.80(1)	8/1

Notes: WE denotes maximum daily water elevation in a calendar year, in feet above mean sea level (ft-msl). A second line for a particular calender year indicates WE on a date closer to that for maximum WE at a preceding or succeeding stage station. The number in parentheses indicates the number of days that WE is maintained. For example 436.90 (2) 6/26 in the year 1990 for Valley City means that maximum daily stage of 436.90 ft-msl occurred for two days, beginning June 26, 1990.

The number in parentheses denotes the number of days the daily stage remained at the maximum level. The date denotes the first day of the period (if more than one day) with maximum elevation. A partial second line was added if the annual maxima did not occur near the same date at all stations.

Figure 11 indicates annual maximum water elevations observed at Meredosia and Grafton for the period 1941-1993 for the months of January through December. About 85% of observed maxima at Meredosia occurred from February to June, and about 79% occurred at Grafton from March to July. Of the highest ten values observed at Meredosia, eight occurred from March to June, the rank 4 value occurred in July 1993 because of exceptionally high backwater from the Mississippi River, and the rank 6 value occurred in December 1982. None of these ten values occurred during 1945 to 1969. At Grafton, seven of the ten highest WE values occurred from April to July, the highest observed WE so far occurred on August 1, 1993, and was 4.91 feet higher than the second highest on April 28, 1973, the rank 3 value occurred on October 9, 1986, and the rank 9 value occurred on December 8, 1982. None of these ten values occurred during 1952 to 1972.

	Meredosia		*Grafton*	
Rank	*WE,ft-msl*	*Date*	*WE,ft-msl*	*Date*
1	446.69	5/26/43	441.80	8/1/93
2	445.60	3/10/85	436.89	4/28/73
3	445.10	4/19/79	433.45	10/9/86
4	444.90	7/28/93	433.17	4/14/79
5	444.70	4/30/73	432.78	5/24/43
6	444.30	12/11/82	432.39	7/2/47
7	443.19	5/1/44	432.19	4/30/44
8	443.10	4/14/83	432.05	5/4/83
9	442.80	6/30/74	431.50	12/8/82
10	440.50	5/22/70	431.19	7/24/51

WE Rankings for Stations in Alton Pool. Table 9 provides the year and date of ranked annual maximum water elevations (in descending order of magnitude, rank 1 being the highest) and ranks of associated flood peaks at Meredosia. Also included are the ranks of maximum

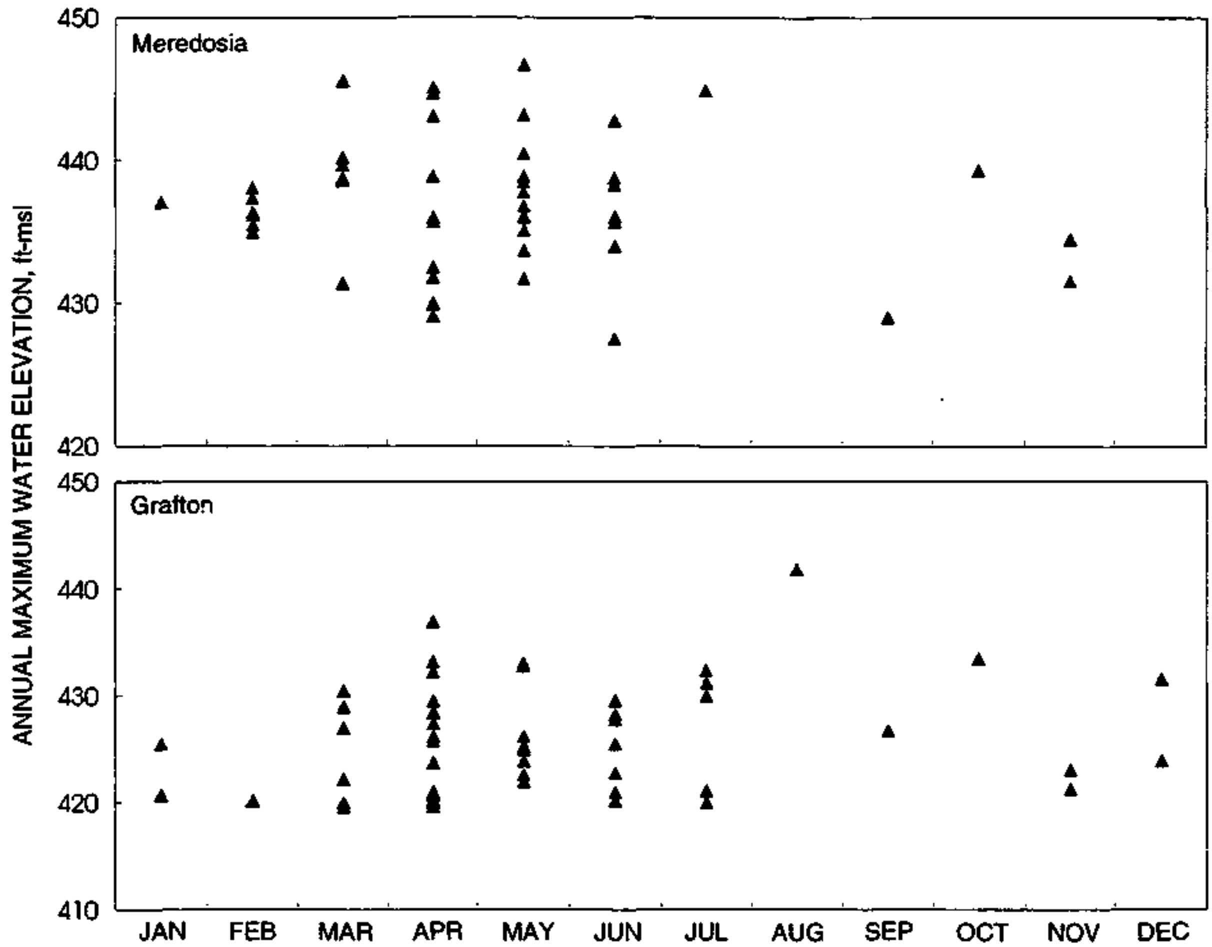


Figure 11. Annual maximum water elevations at Meredosia and Grafton, 1941-1993

Table 9. Ranked Annual Maximum Water Elevations and Floods at Meredosia and Related Water Elevation Ranks at Other Station in Alton Pool, Dlinois River

	Meredosia WE		*Meredosia Flood*		*WE Ranks at*					
	Rank	*Date*	*Rank*	*Date*	*Valley City*	*Florence*	*Pearl*	*Hardin*	*Grafton*	ΔWE
1943	1	5/26	123,000	1	1	2	4	4	5	13.91
1985	2	3/10	122,000	2	3	4	5	7	11	15.13
1979	3	4/19	111,000	4	5	5	3	3	4	11.93
1993	4	7/28	+80,000	13	2	1	1	1	1	3.10
1973	5	4/30	102,000	7	4	3	2	2	2	7.81
1982	6	12/11	112,000	3	6	6	7	9	9	12.80
1944	7	5/1	102,000	8	7	8	8	8	7	11.00
1983	8	4/14	94,000*	(11)	8	7	6	5	6	11.06
1974	9	6/30	110,000	5	9	9	9	11	(21)	16.22
1970	10	5/22	94,800	10	10	11	13	10	(22)	14.11
1962	11	3/29	91,900	11	11	12	14	17	20	13.21
1984	12	3/30	76,800	17	13	13	17	16	(33)	16.38
1986	13	10/11	69,600	24	12	10	10	6	3	5.85
1960	14	4/8	73,000	22	14	14	12	14	14	9.41
1981	15	5/23	75,500	18	17	18	19	23	27	13.61
1948	16	3/31	73,600	21	16	17	18	15	15	9.80
1947	17	6/15	68,300	25	15	15	11	10	6	5.40
1976	18	3/12	80,600	12	19	19	22	28	(52)	19.42
1950	19	5/3	77,200	15	20	21	26	27	(34)	16.11
1990	20	6/26	74,460	19	18	16	16	22	17	10.06

Notes: AWE = difference in water elevations at Meredosia and Grafton in feet.
* = average daily flow corresponding to maximum stage at Meredosia.
() = rank for the relevant flood and/or stage if annual maximum occurs in a different period than at Meredosia.
\+ = estimated flood peak at Meredosia.

water elevations occurring at Valley City, Florence, Pearl, Hardin, and Grafton for the year and related event at Meredosia. In 1983, mean daily flow (94,000 cfs) corresponding to maximum stage at Meredosia had a relative ranking of 11, though the peak discharge (104,000 cfs) on March 24 had a rank of 6. At Grafton, for 5 of the 20 years listed, the peak stage did not occur around that at Meredosia. Relative ranks for stages occurring around the Meredosia dates are given in parentheses. The differences between water elevations at Meredosia and Grafton, or AWE in feet (feet), are given in the last column of the table. The following inferences can be made.

1. When the rank number decreases from Meredosia to Grafton, the water elevation at Grafton considerably raises elevations upstream though the effect becomes attenuated with distance. This situation, when combined with relatively low flood peak at Meredosia but very high water elevation at Grafton, causes serious backwater effects from the Mississippi River, extending upstream to Meredosia. For example, in 1993 the Meredosia flood peak rank was 13 or about a 5-year flood, but the Grafton stage peak rank was 1 (higher by 4.91 feet over the rank 2 event) and caused the highest water elevations at Hardin, Pearl, and Florence, second highest at Valley City, and fourth highest at Meredosia. The AWE was only 3.1 feet, the minimum in the 53-year record, instead of 10 to 16 feet during moderate and low backwater effects. Similar, but less dire conditions occurred in 1947, 1986, and 1973. Had the maximum flood (123,000 cfs) occurred in 1993, water elevations at Meredosia and some stations downstream would have increased by about 3 feet or more, overtopping all six levees below Meredosia and probably some levees upstream.
2. When the rank number increases from Meredosia to Grafton, the backwater effects from the Mississippi River are moderate to low, depending on the relative increase in rank number. The maximum value of AWE in 20 years (Table 9) was 19.42 feet when the Grafton water elevation approached the lowest annual maximum.
3. Monthly distribution of maximum water elevations at Meredosia for the top 20 events is: 5 in March, 4 in April, 5 in May, 3 in June, and one each in July, October, and December. Two of the top six water elevations at Meredosia had very significant

backwater effects from the Mississippi River. The top three ranked floods occurred from March though May.

4. Ranks at Meredosia and Valley City are very similar, but this does not hold true for ranks at Florence, Pearl, Hardin, and Grafton where the Mississippi backwater effects vary in severity and upstream-reach length zone of influence.

Stage Frequency Analysis

The annual maximum stage series were derived from the annual maximum water elevation or WE series by subtracting the average bed level (ABL) from the water elevation at the stage station. These series at Meredosia, Valley City, Florence, Pearl, Hardin, and Grafton were run on the general frequency program. Table 10 provides the parameter values of fitted mixed distribution and log-Pearson III distribution with sample skew. The values of kurtosis for the corresponding power-transformed series are also included. These values are much lower than 3.0 for the normal distribution, indicating that the top portion of the frequency distribution curve for the power-transformed series (with practically zero skew) is flatter than for a normal distribution.

The following low (L) and high (H) stages were slightly modified in the third window (0.1 significance level) at each station.

		Modified	
Station	*HorL*	*from*	*to*
Meredosia	H5	38.00	37.74
Valley City	H5	36.60	36.20
Florence	H5	34.90	34.49
Pearl	None		
Hardin	None		
Grafton	H3	41.55	41.95
	L3	28.09	27.69
	L2	27.69	27.20
	L1	27.63	26.51

H5 indicates fifth highest value, L2 indicates second lowest value, and so on.

Table 10. Parameters for Fitted Mixed and Log-Pearson III Distributions

Parameter	*Meredosia*	*Valley City*	*Florence*	*Pearl*	*Hardin*	*Grafton*
	Stage station					
Mixed distribution						
a	0.872	0.925	0.415	0.831	0.913	0.409
μ_1	1.488	1.458	1.387	1.359	1.382	1.506
σ_1	0.059	0.066	0.066	0.086	0.083	0.051
μ_2	1.374	1.336	1.454	1.386	1.320	1.540
σ_2	0.039	0.034	0.066	0.063	0.005	0.068
Log-Pearson III distribution						
μ	1.474	1.449	1.426	1.364	1.377	1.525
σ	0.068	0.071	0.073	0.083	0.082	0.064
g	-0.159	-0.070	-0.112	-0.081	0.218	0.460
Power-transformed series						
Kurtosis	2.679	2.625	2.673	2.813	2.591	2.102

Notes: 1. Distribution parameters apply to log-transformed stages in the third window of outlier/inlier modification.

2. Modifications at Grafton included L1, L2, and L3 (from 27.63, 27.69, and 28.09 feet to 26.51, 27.20 and 27.69 feet, respectively), and H3 (from 41.55 to 41.95). Modifications at Florence, Valley City, and Meredosia included H5 (from 34.90, 36.60 and 38.00 feet to 34.49, 36.20 and 37.74 feet, respectively).
3. Power transformation modifies stage series to be close to normal, with skew very close to zero. A normal series has kurtosis equal to 3.0. A lesser kurtosis means the modified series are platykurtic or have flatter tops than the normal frequency distribution.

Figures 12-17 plot the fitted mixed distribution (and its two-component normal distributions), fitted log-Pearson HI distribution, and observed peak stages for the Meredosia, Valley City, Florence, Pearl, Hardin, and Grafton stations. Both distributions fit observed stages at Meredosia, Valley City, Florence, and Pearl equally well, but the fit with the mixed distribution is better than with the log-Pearson III distribution for the observed stages at Hardin and Grafton.

Table 11 provides various recurrence-interval or T-year maximum stages with both mixed and log-Pearson IE distribution at each of the stations. It also includes the two highest stages observed during the period 1941/1942 to 1993. Values of T-year stages up to 100-year recurrence interval from both the distributions at Meredosia, Valley City, Florence, and Pearl are very similar (differences within a range of -0.38 to 0.32). The range is a little higher for Hardin and Grafton in the case of T=50 and T=100 years. However, values from mixed and log-Pearson HI distributions for T=500 and 1,000 years are significantly different at Hardin and Grafton. Values from mixed distribution provide a better fit and seem to be more realistic and viable in terms of the historic data. Relevant T-year stage values were used to determine T-year water elevations at all six stations.

Table 12 provides the highest two stages, S_1 and S_2, and their date of occurrence at Grafton, Hardin, Pearl, Florence, Valley City, and Meredosia. The recurrence intervals T_1 and T_2 were fit to S_1 and S_2 using mixed distribution parameters and are also included in the table. The highest stages from Grafton to Meredosia are assigned recurrence intervals of 193, 126, 64, 33, 38, and 43 years in a record of 52 to 53 years. It is interesting to note that the fitted recurrence interval T is the highest at Grafton (193 years), followed by Hardin (136 years) and Pearl (64 years). The 1993 unprecedented high stage, 4.91 feet higher than the next highest stage at Grafton, greatly increased T at Hardin to 136 years and at Pearl to 64 years. The 1993 flood produced a stage at Grafton much higher than expected during a 53-year record. The backwater effect from the Mississippi River was so strong that it greatly increased T_1 at Hardin and moderately increased T_1 at Pearl, an effect that attenuates with distance upstream.

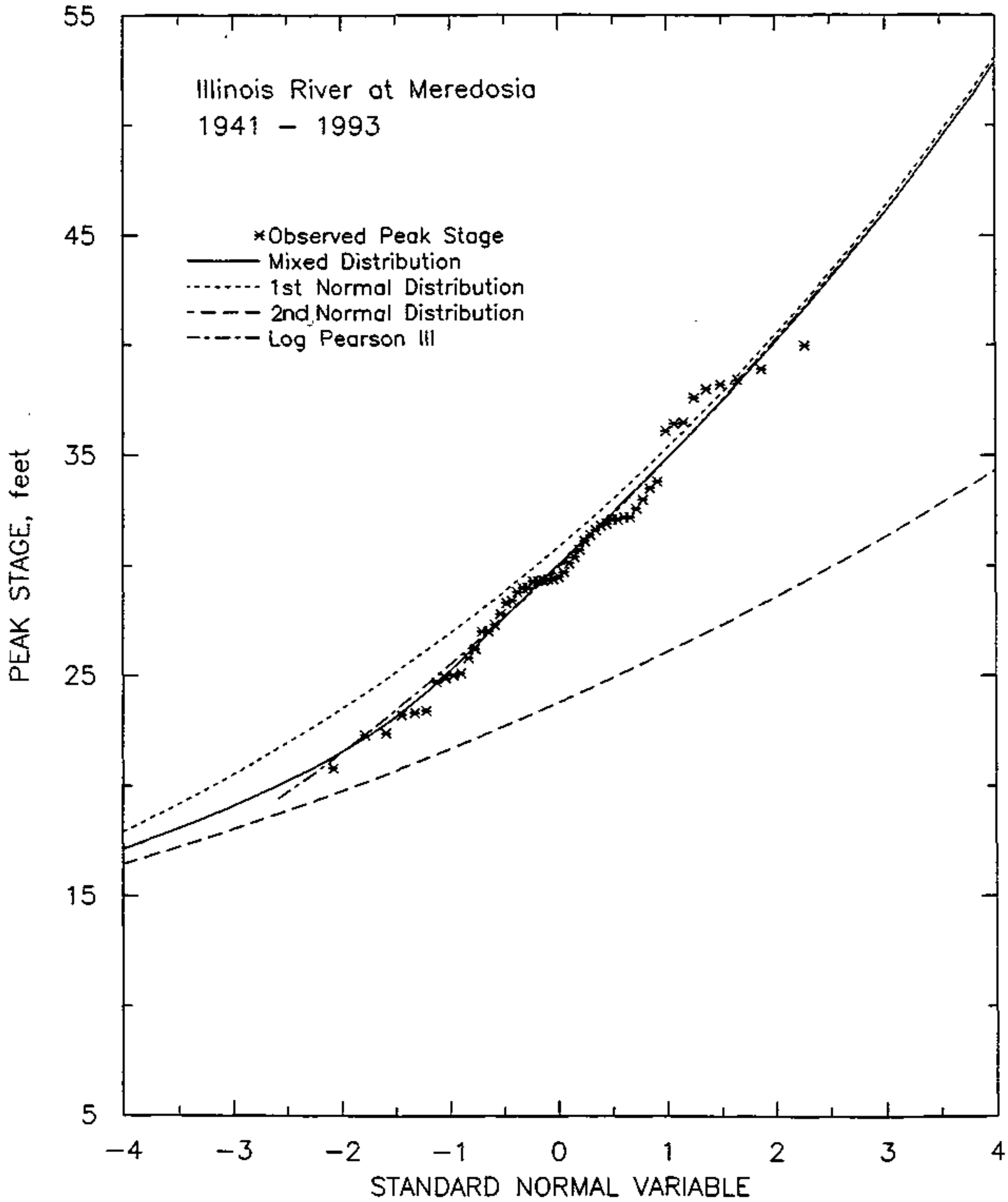


Figure 12. Fitted mixed and log-Pearson HI distributions to observed annual maximum stages, Illinois River at Meredosia, 1941-1993

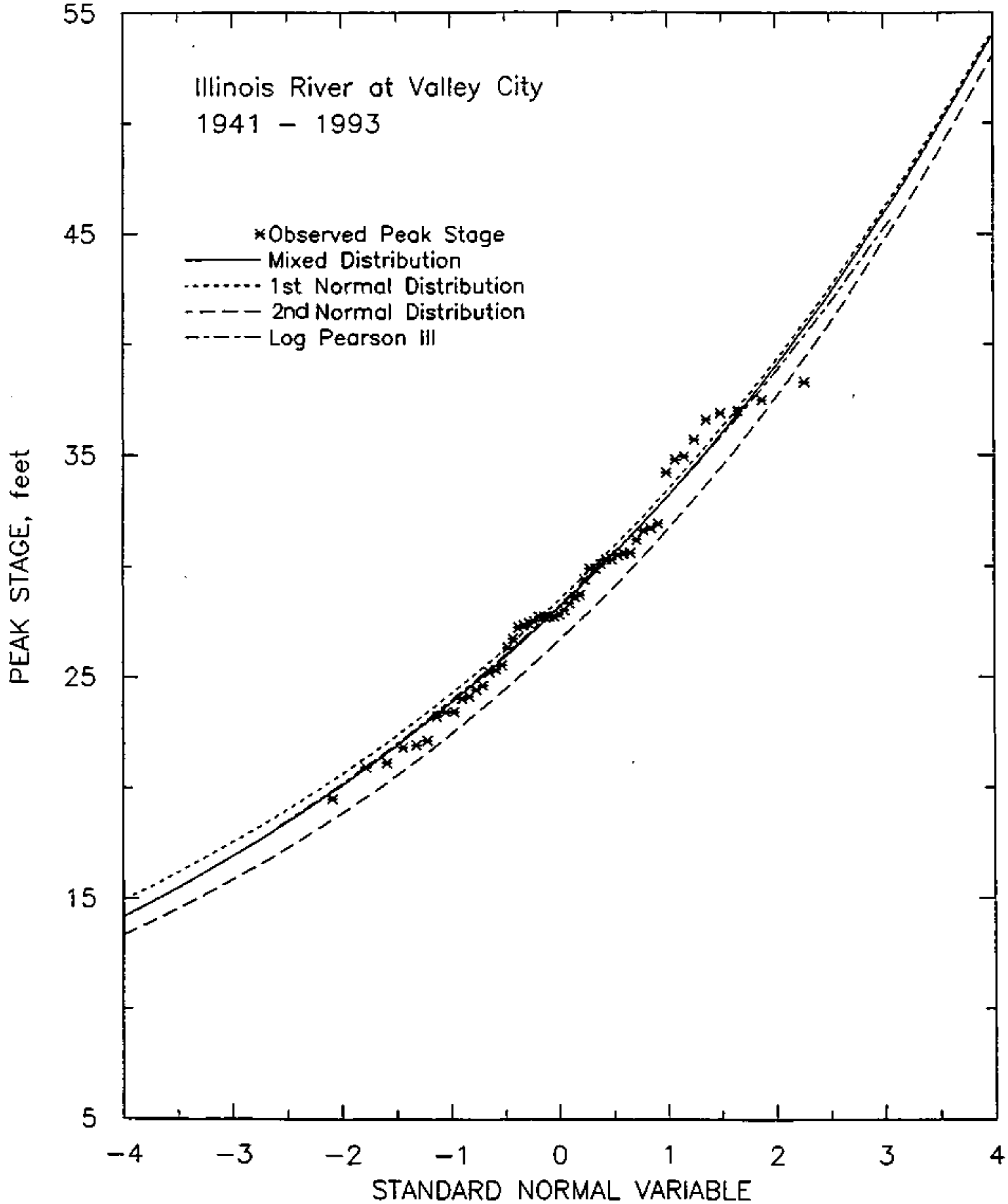


Figure 13. Fitted mixed and log-Pearson HI distributions to observed annual maximum stages, Illinois River at Valley City, 1941 -1993

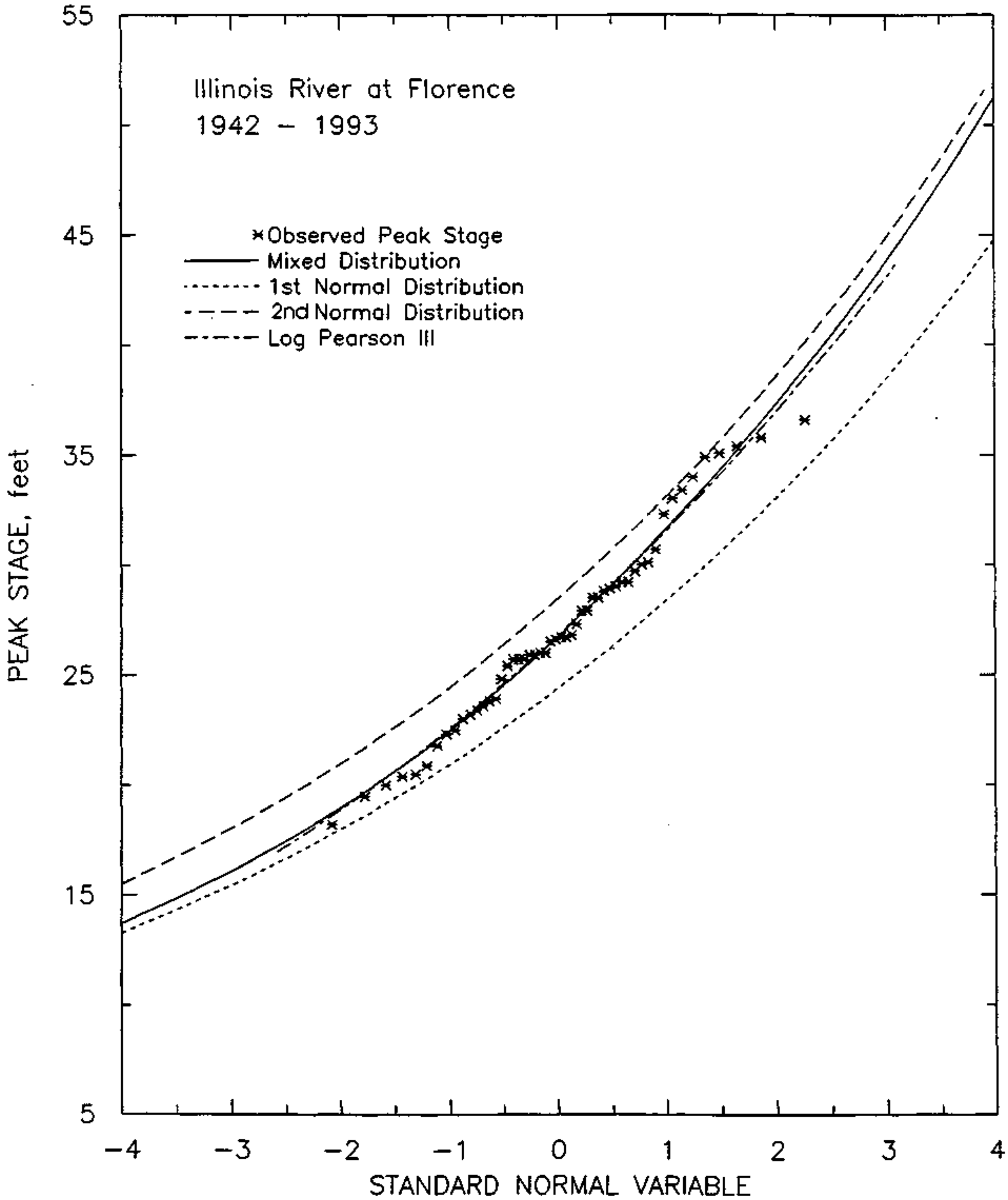


Figure 14. Fitted mixed and log-Pearson HI distributions to observed annual maximum stages, Illinois River at Florence, 1942-1993

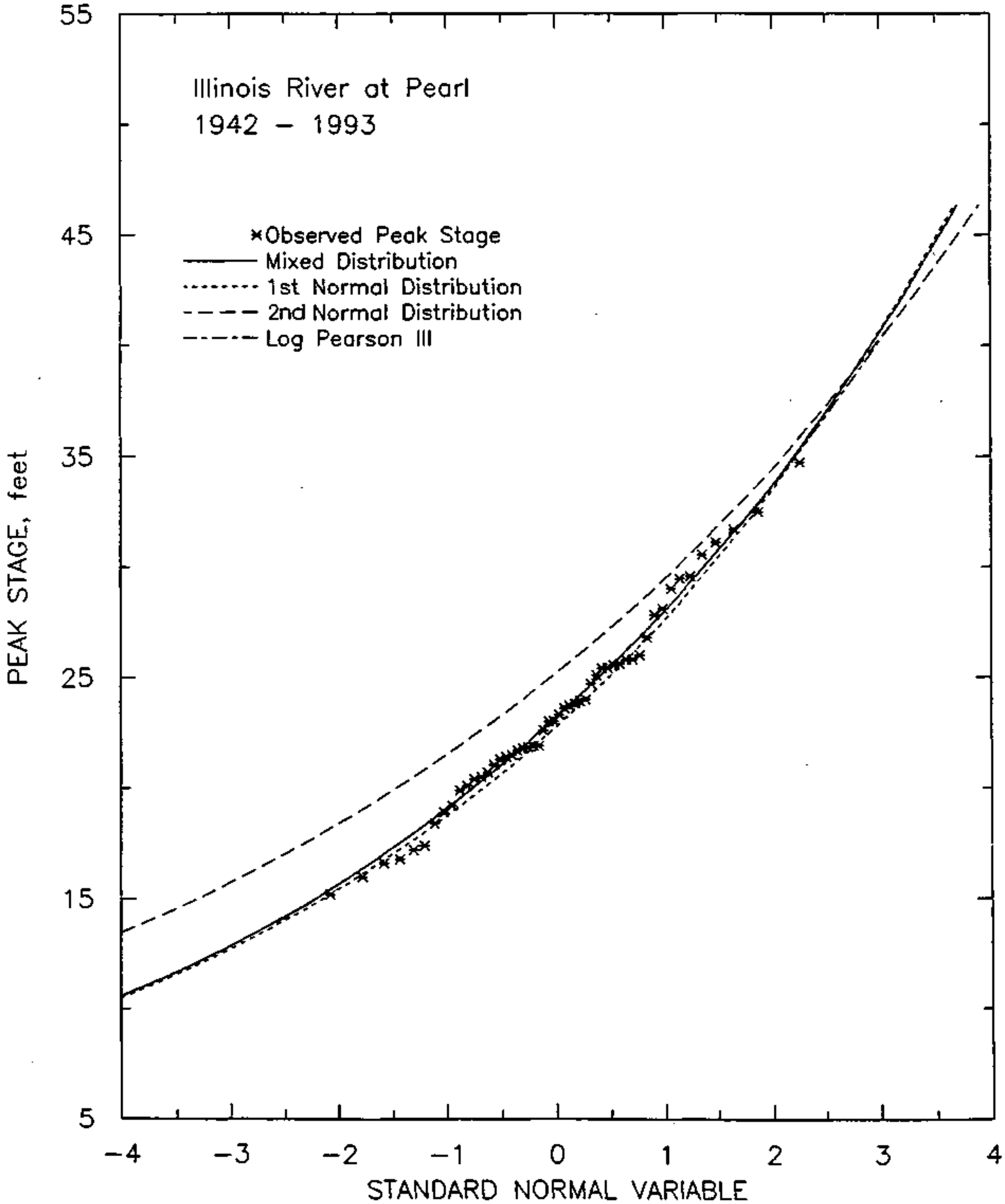


Figure 15. Fitted mixed and log-Pearson HI distributions to observed annual maximum stages, Illinois River at Pearl, 1942-1993

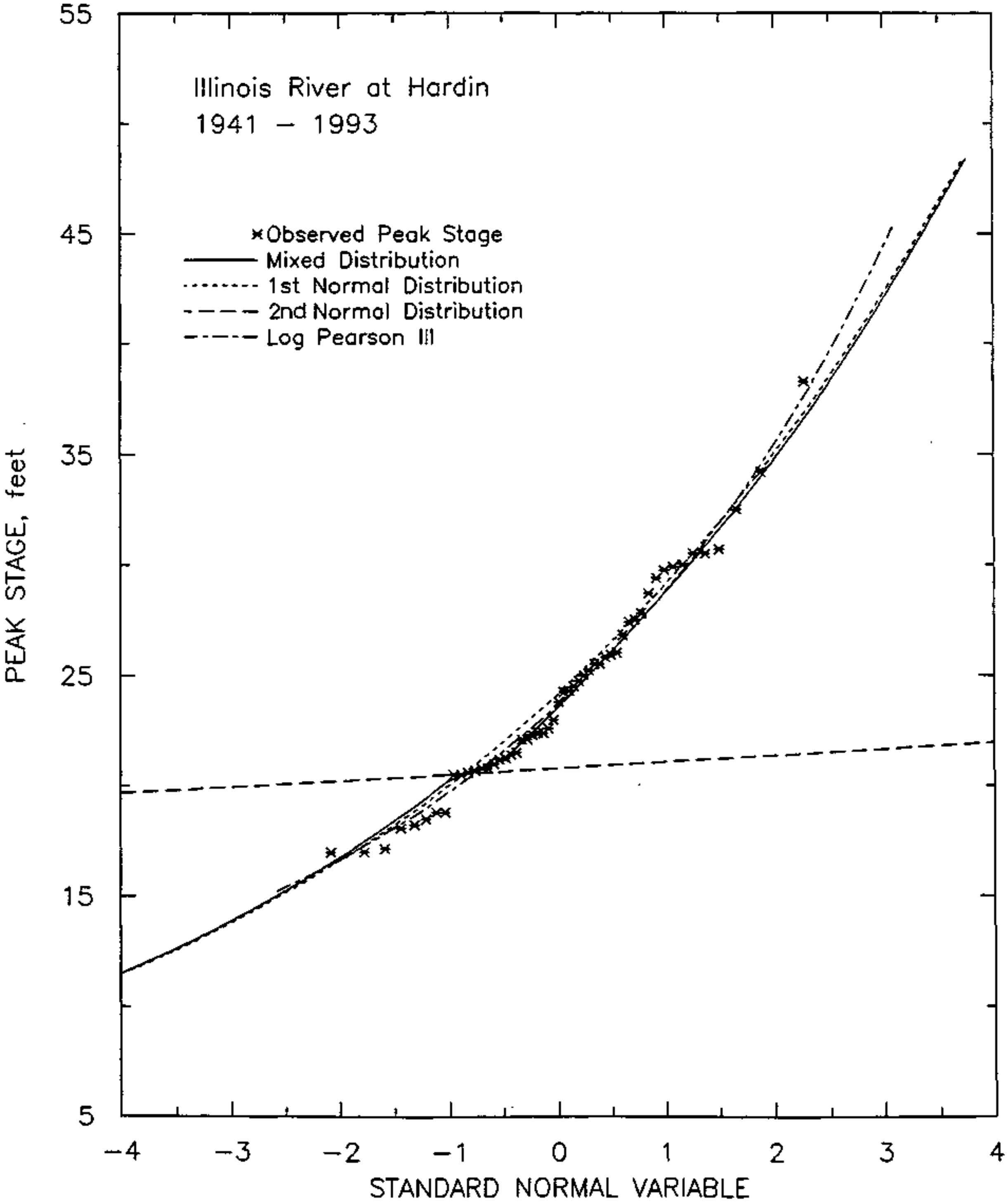


Figure 16. Fitted mixed and log-Pearson III distributions to observed annual maximum stages, Illinois River at Hardin, 1941-1993

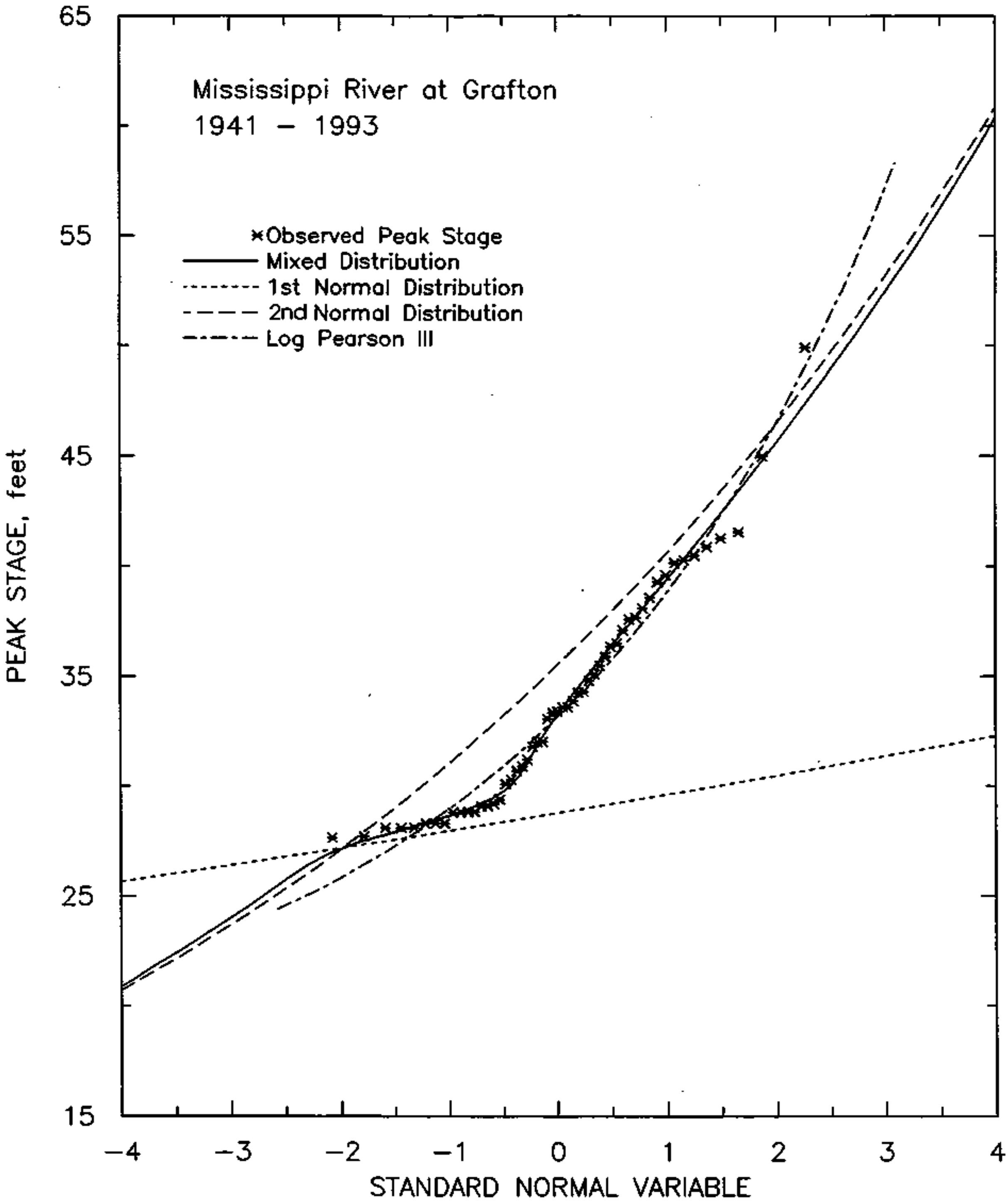


Figure 17. Fitted mixed and log-Pearson HI distributions to observed annual maximum stages, Mississippi River at Grafton, 1941-1993

Table 11. Various Recurrence - Interval Stages in Feet at Stage Recording Stations in Alton Pool, Illinois River

	Stages at recurrence interval,				*ft-msl*			*Two highest*
Distribution	*2-year*	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*	*stages recorded*
Mississippi River at Grafton (1941-1993)								
MD	33.33	40.62	43.91	46.19	48.34	52.96	54.83	49.90(1993)
LP3s	33.12	40.70	44.33	46.97	49.59	55.65	58.29	44.99(1973)
Illinois River At Hardin (1941-1993)								
MD	23.58	30.55	33.49	35.53	37.47	41.71	43.47	38.30(1993)
LP3s	23.66	30.48	33.64	35.91	38.12	43.18	45.36	34.20(1973)
Illinois River at Pearl (1942-1993)								
MD	23.18	29.44	32.15	34.07	35.91	40.01	41.72	34.75(1993)
LP3s	23.17	29.45	32.08	33.89	35.59	39.24	40.73	32.50(1973)
Illinois River at Florence (1942-1993)								
MD	26.73	33.19	35.85	37.66	39.35	42.97	44.44	36.60(1993)
LP3s	26.77	33.06	35.62	37.36	38.97	42.39	43.76	35.80(1943)
Illinois River at Valley City (1941-1993)								
MD	28.25	34.62	37.24	39.01	40.69	44.28	45.74	38.31 (1943)
LP3s	28.14	34.63	37.31	39.13	40.83	44.46	45.93	37.50(1993)
Illinois River at Meredosia (1941-1993)								
MD	30.02	36.22	38.68	40.34	41.89	45.19	46.53	39.99(1943)
LP3s	29.88	36.28	38.83	40.53	42.09	45.37	46.57	38.90(1985)

Notes: MD denotes values from stage frequency analysis with mixed distribution.
LP3s denotes values from stage frequency annalysis by Log-Pearson HI distribution with sample skew.

Table 12. Observed Maximum Stages, Dates and Fitted Recurrance Intervals for Stations in Alton Pool, Illinois River

Stage Station	RM	Av. bed level (ft-msl)	S_1 (ft)	S_2 (ft)	T_1 (yrs)	T_2 (yrs)	Continuous historical record used	1993 peak stage and rank
Mississippi River at Grafton	0.0	391.90	49.90 (8/1/93)	44.99 (4/28/73)	193	31	1941-1993	49.90: 1
Illinois River at Hardin	21.6	404.00	38.30 (8/3/93)	34.20 (4/29/73)	136	32	1941-1993	38.30: 1
Illinois River at Pearl	43.2	408.00	34.75 (8/1/93)	32.50 (4/29/73)	64	28	1942-1993	34.75: 1
Illinois River at Florence	56.0	407.00	36.60 (8/1/93)	35.80 (5/26/43)	33	25	1942-1993	36.60: 1
Illinois River at Valley City	61.3	406.60	38.31 (5/26/43)	37.50 (7/27/93)	38	28	1941-1993	37.50: 2
Illinois River at Meredosia	70.8	406.71	39.99 (5/26/43)	38.90 (3/10/85)	43	27	1941-1993	38.20: 4

Table 13. Various Recurrence - Interval River Water Elevations with MD at Stage Stations in Alton Pool, Dlinois River

Water surface elevations, ft-msl, at recurrance interval							
2-year	10-year	25-year	50-year	100-year	500-year	1000-year	Max. Observed elevation & year
Mississippi River at Grafton. RM = 0. and bed level = 391.9 ft-msl							
425.23	432.52	435.81	438.09	440.24	444.86	446.73	441.80(1993)
Illinois River at Hardin. RM = 21.6. and bed level = 404.0 ft-msl							
427.58	434.55	437.49	439.53	441.47	445.71	447.47	442.30(1993)
Illinois River at Pearl. RM = 43.19. and bed level = 408.0 ft-msl							
431.18	437.44	440.15	442.07	443.91	448.01	449.72	442.72(1993)
Illinois River at Florence. RM = 56.0. and bed level = 407.0 ft-msl							
433.73	440.19	442.85	444.66	446.35	449.97	451.44	443.60(1993)
Illinois River at Valley City. RM = 61.3. and bed level = 406.6 ft-msl							
434.85	441.22	443.84	445.61	447.29	450.88	452.34	444.91 (1943)
Illinois River at Meredosia. RM = 70.8 and bed level = 406.7 ft-msl							
436.72	442.92	445.38	447.08	448.59	451.89	453.23	446.69(1943)

T- Year River Water Elevations

Maximum water surface elevations for T equal to 2 to 1,000 years at each station were developed by adding corresponding stages to average river bed level. Table 13 provides this information and includes river mile and average bed elevation at each station, and maximum observed elevation and the year in which it occurred. Figure 18 provides the T-year elevations and the curve joining the points for a particular T defines the profile of the T-year flood elevations. The difference in water surface elevation from Meredosia to Grafton, or AWE, is given for each profile.

T, years	*2-year*	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1,000-year*
AWE, ft	11.49	10.40	9.57	8.99	8.35	7.03	6.50

Flood water profiles in Figure 18 apply if the same T-year stage or water elevation occurs around the same date at all stations. This is not always true because of the absence of a linear relationship between maximum water elevation at Grafton and maximum flood at Meredosia. The figure provides water profiles for the 1993 and 1943 flood events (1993 with maximum stage at Grafton and 1943 with maximum flood at Meredosia) for comparison with other T-year profiles. Maximum water surface elevations at four downstream stations (Florence, Pearl, Hardin, and Grafton) occurred in the beginning of August 1993 during the unprecedented Mississippi River flood and its backwaters upstream along the Illinois River. Maximum water elevations occurred at Valley City and Meredosia during the last week of May 1943.

Grafton Stages and Meredosia Flood Peaks

Water elevation or stage at Grafton and corresponding flood peak at Meredosia govern the flood profile in the Illinois River Alton Pool. Figure 19 provides Meredosia flood peak ranks versus Grafton maximum water elevation ranks, and curve A gives the worst historical joint probability of heavy flooding in the Alton Pool. Considering 100 years as the maximum design event, the interest lies in 25-,50-, and 100-year peak floods and stages for simulating the flood profiles using the UNET model (Barkau, 1993).

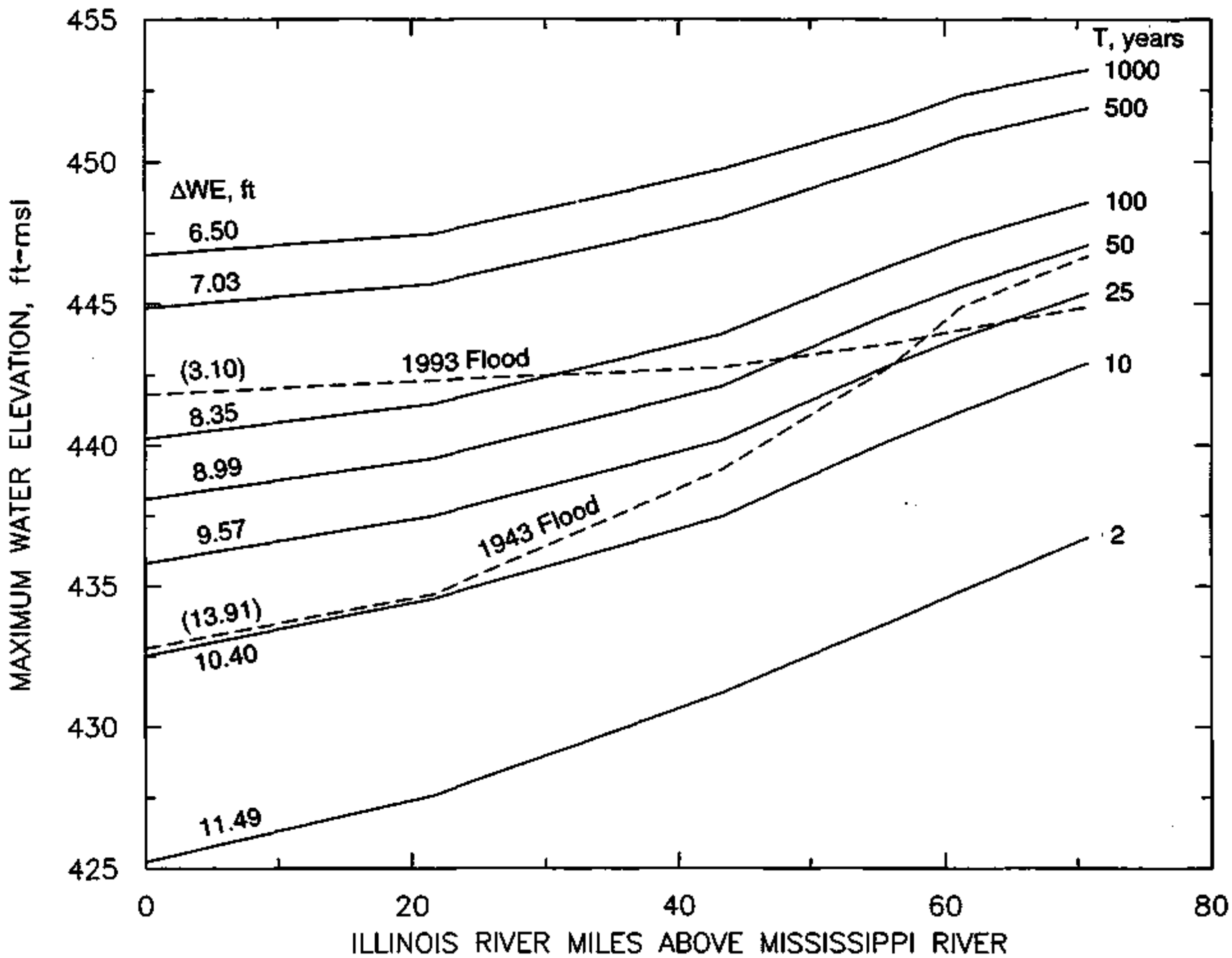


Figure 18. T-year maximum water elevation profiles for Illinois River from Meredosia to Grafton (T is average recurrence interval in years)

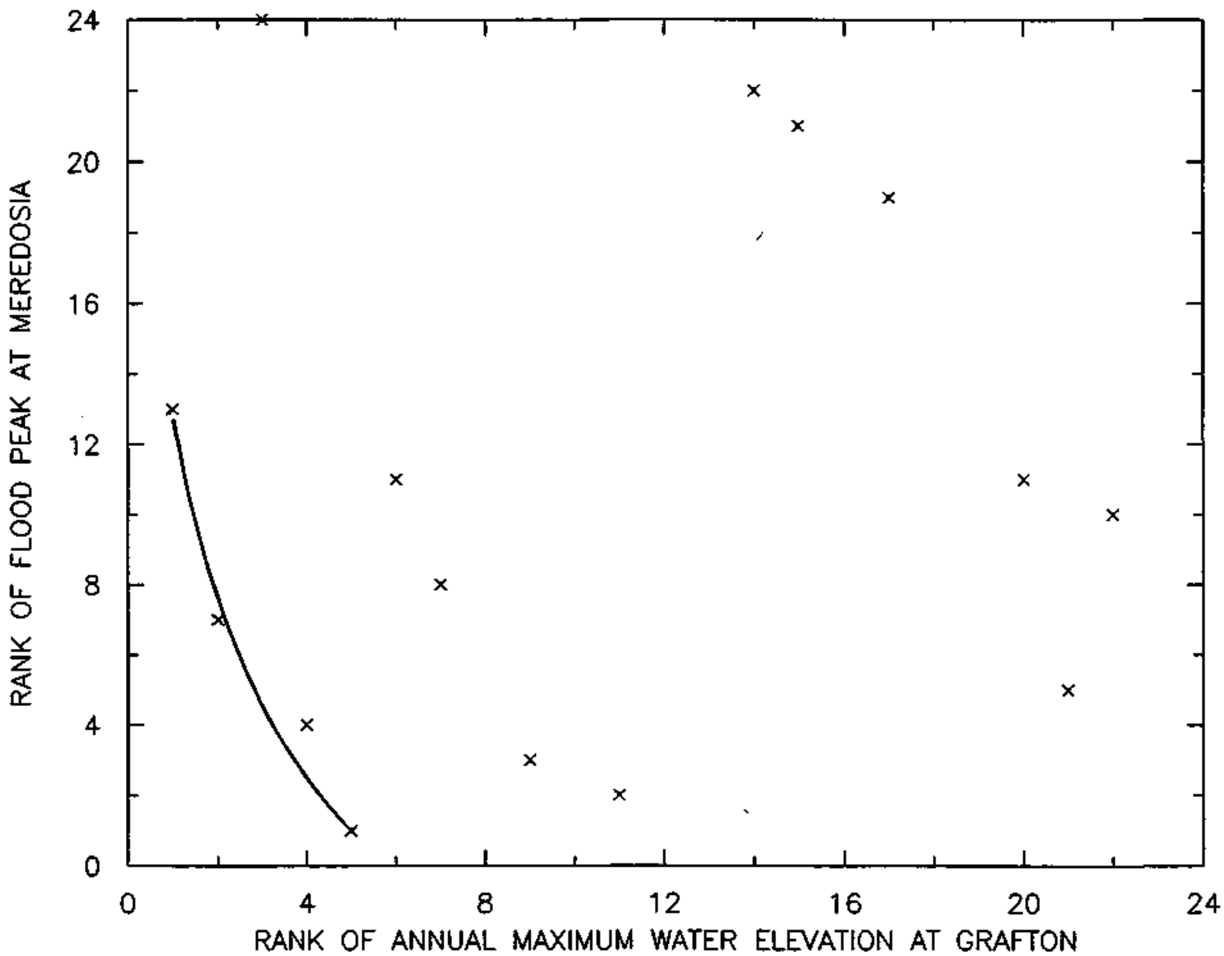


Figure 19. Meredosia flood peak ranks versus Grafton maximum water elevation ranks, using 1941-1993 data

Peak Flood at Meredosia		*Corresponding Maximum Water Elevation, Grafton*	
Rank	*T, years*	*Rank*	*T, years*
1	100	5.0	20
2	50	4.6	22
3	33	4.2	24
4	25	3.8	26

Thus, for maximum flood peaks at Meredosia corresponding to T of 100, 50, and 25 years, the design T for maximum elevations at Grafton may be taken as 25 years. The following combinations of Tf (recurrence interval for flood peaks at Meredosia) and T_w (associated recurrence interval for maximum flood elevations at Grafton) provide various scenarios.

(T_f, T_w): (100, 25), (100, 50), and (100, 10)

(T_f, T_w): (50, 25), (50,50), and (50, 10)

(T_f, T_w): (25,25), (25, 50), and (25, 10)

For maximum water elevations at Grafton, the following joint probabilities of T_w, Tf may be considered.

(T_w, T_f): (100, 10), (100, 25), (100, 50)

(T_w, T_f): (50, 25), (50, 10)

Various combinations may be simulated to analyze chances of levee damage and failure, and to consider suitable, efficient, and effective measures to enhance safety of structures and to minimize loss of life and property in case of a levee break. These combinations include:

(T_f, T_w): (100, 50), (100, 25), (100, 10)

(T_f, T_w): (50,100), (50, 50), (50, 25), (50, 10)

(T_f, T_w): (25,100), (25, 50), (25, 25), (25, 10)

(T_f, T_w): (10, 50), (10, 100)

These simulated flood profiles also need to be validated for the 1993 and 1943 flood events.

Highest Observed Water Surface Profiles, Alton Pool, Illinois River

Figure 20 provides the observed water surface profiles (joining maximum water elevations at six stage stations in the Alton Pool) for the eight highest water elevations at Meredosia in 1943, 1985, 1979, 1993, 1973, 1982, 1944, and 1983. Each profile also includes the Meredosia rank and associated flood peak rank as well as the Grafton rank. The difference in maximum water elevations (AWE) at Meredosia and Grafton are also given for each event. These eight profiles cover Grafton WE ranks of 5, 11,4, 1, 2, 9, 7, and 8, respectively. Grafton WE ranks of 3 and 6 are not included. Thus, two more profiles with the missing ranks at Grafton are also included. The information presented in Figure 20 is given in a tabular form below.

	WE Rank			
Year	*Meredosia*	*Grafton*	*Meredosia Qp Rank*	*AWE, ft*
1943	1	5	1	13.91
1985	2	11	2	15.13
1979	3	4	4	11.93
1993	4	1	13	3.10
1973	5	2	7	7.81
1982	6	9	3	12.80
1944	7	7	8	11.00
1983	8	8	11	11.06
1986	13	3	24	5.85
1947	17	6	25	5.40

Note: Qp denotes the flood peak at Meredosia.

The lower the AWE, the more pronounced are the Mississippi River backwater effects. In 1993, maximum backwater effects were felt up to Meredosia from June to September during unprecedented high water levels and floods in the Mississippi River. A minimal backwater effect was felt in the 1985 event (out of the ten listed) when the rank of Grafton WE was 11.

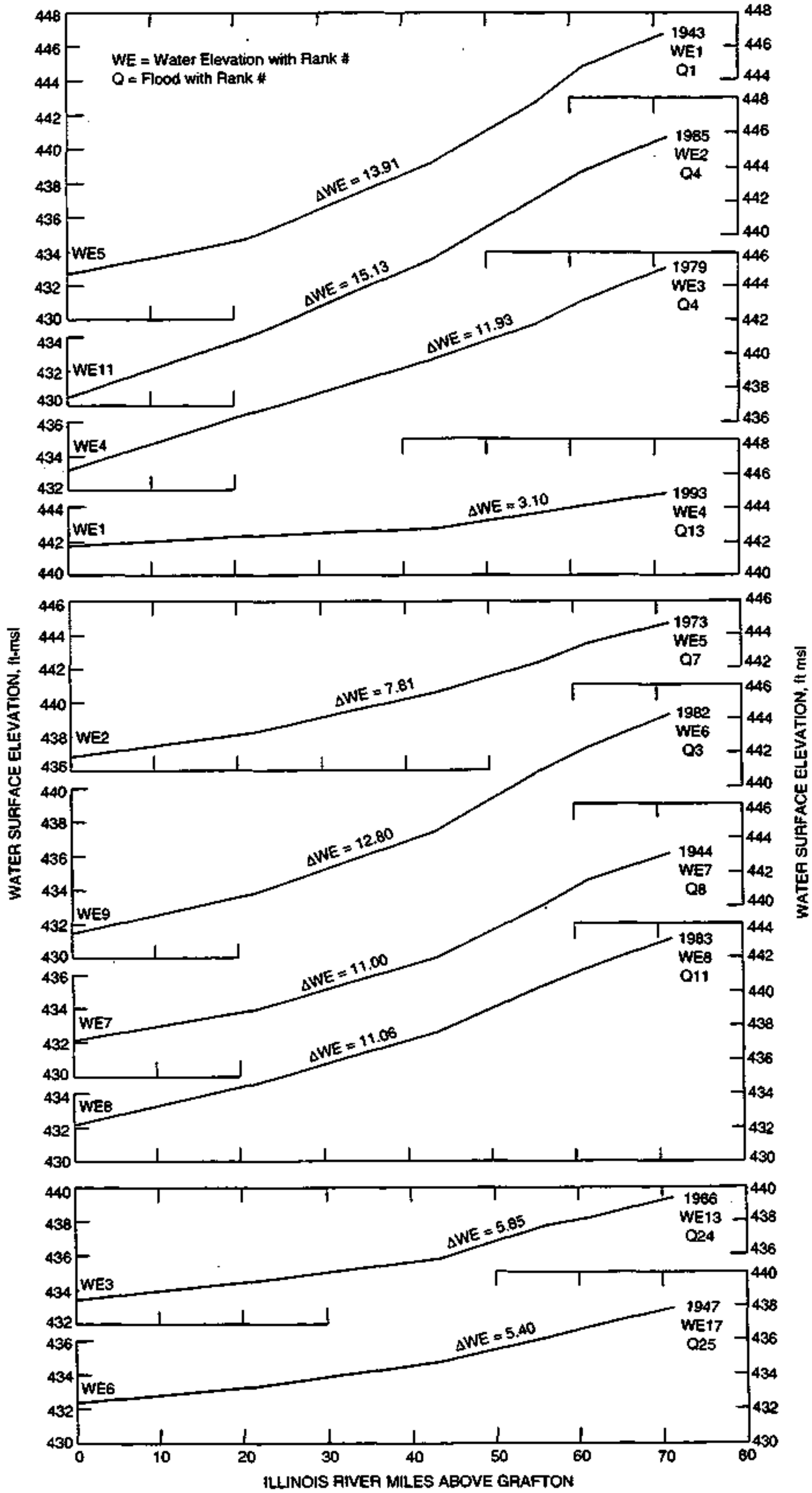


Figure 20. Highest observed water surface profiles, Meredosia to Grafton, 1941-1993 (WE3 is WE with rank 3, Q3 is flood peak with rank 3, etc.)

Observed Stage Hydrographs for 1943 and 1993 Events

The 1943 event was marked by the historical maximum flood (123,000 cfs), on May 26-28 and stage or water elevation WE, though the corresponding WE at Grafton ranked fifth in the 1941-1993 record. The dates of maximum WE and their ranks from Meredosia to Grafton are as follows.

Location	*Max WE, ft-msl*	*Rank*	*Date*
Illinois River at Meredosia	446.69	1	5/26/43
Illinois River at Valley City	444.91	1	5/26/43
Illinois River at Florence	442.80	2	5/26/43
Illinois River at Pearl	439.10	4	5/26/43
Illinois River at Hardin	434.70	4	5/24/43
Mississippi River at Grafton	432.78	5	5/24/43

Note: Maximum WE at Hardin lasted two days (May 24 and 25).

Figure 21 provides daily water elevations at the six stations from May 17 to May 31, 1943 which were used to draw WE hydrographs. The daily flows at Meredosia are also plotted and connected to yield the flood hydrograph. The figure shows that:

1. The water elevation at Grafton reached its maximum value on May 24 and started declining thereafter, at a steep rate from May 26 to May 31. The effect of this decline was an increase in water surface slope and a reduction in water surface elevations at Hardin and Pearl.
2. The flood discharge remained about 123,000 cfs at Meredosia from May 26 to May 28. The corresponding daily water elevations at Meredosia were 446.69, 446.59, and 446.40 feet-msl, respectively. The steep decline of 0.4, 0.5, and 0.5 feet per day occurred during the next three days.
3. Because of limited backwater effects from the Mississippi River, the water elevation values at Valley City, Florence, Pearl, Hardin, and Grafton show a steadily increasing rate of decline over time.
4. The difference in maximum water elevation at Meredosia and Grafton, 13.91 feet, substantiates that Mississippi backwater effects were not considerable. The rank of

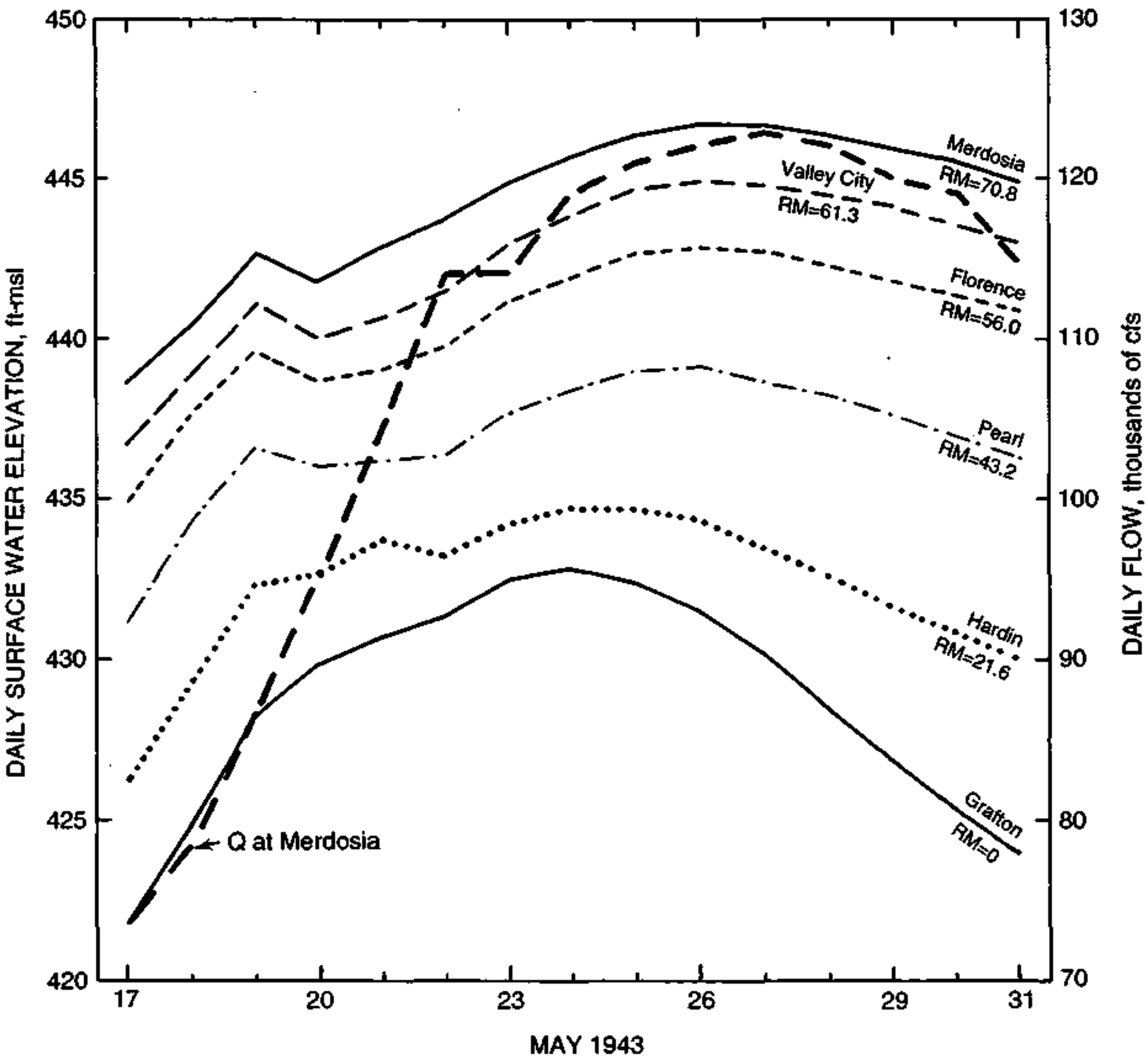


Figure 21. Water elevation versus time curves at Meredosia, Valley City, Florence, Pearl, Hardin, and Grafton during May 17-31, 1943

maximum WE was 5 at Grafton and 1 at Meredosia. The ranks in Alton Pool steadily dropped from 1 at Meredosia/Valley City to 5 at Grafton.

The 1993 event, on the other hand, presents a classic example of the tremendous backwater effects from the Mississippi River. Unprecedented floods in the Mississippi River in July and August caused maximum water elevations of record at Grafton, Hardin, Pearl, and Florence. The dates of maximum water elevations and their ranks from Meredosia to Grafton are given below.

Location	*Max WE, ft msl*	*Rank*	*Date*
Illinois River at Meredosia	444.91	4	7/28/93
Illinois River at Valley City	444.10	2	7/27/93
Illinois River at Florence	443.60	1	8/1/93
Illinois River at Pearl	442.75	1	8/3/93
Illinois River at Hardin	442.30	1	8/3/93
Mississippi River at Grafton	441.80	1	8/1/93

Note: Maximum water elevation at Pearl lasted two days (August 3 and 4).

Figure 22 provides daily water elevations at the six stations from July 25 to August 8, 1993, which were used to draw WE hydrographs. The daily flows at Valley City (Meredosia was dropped as a discharge station in October 1989) are also plotted and connected to yield the daily flood hydrograph. The observed peak on August 1 was 92,000 cfs as a result of levee breaks, and the flow was accelerated because of a drop in water elevation at the breaks and consequent steepening of the water surface slope. Without the levee break the flood peak would have been about 82,000 cfs at Valley City and about 80,000 cfs at Meredosia. This peak flow will have a rank of 13 among the annual maximum floods at Meredosia from 1941-1993. The stage at Valley City was affected by the Mississippi backwaters from June to September 1993. Figure 22 shows that:

1. The water elevation graphs are much flatter than those for the 1943 event (Figure 21), a result of exceptionally high and prolonged WEs at Grafton, which experienced a rank of 2 (436.89 feet-msl), in 1973 that was 4.92 feet lower than that in 1993.

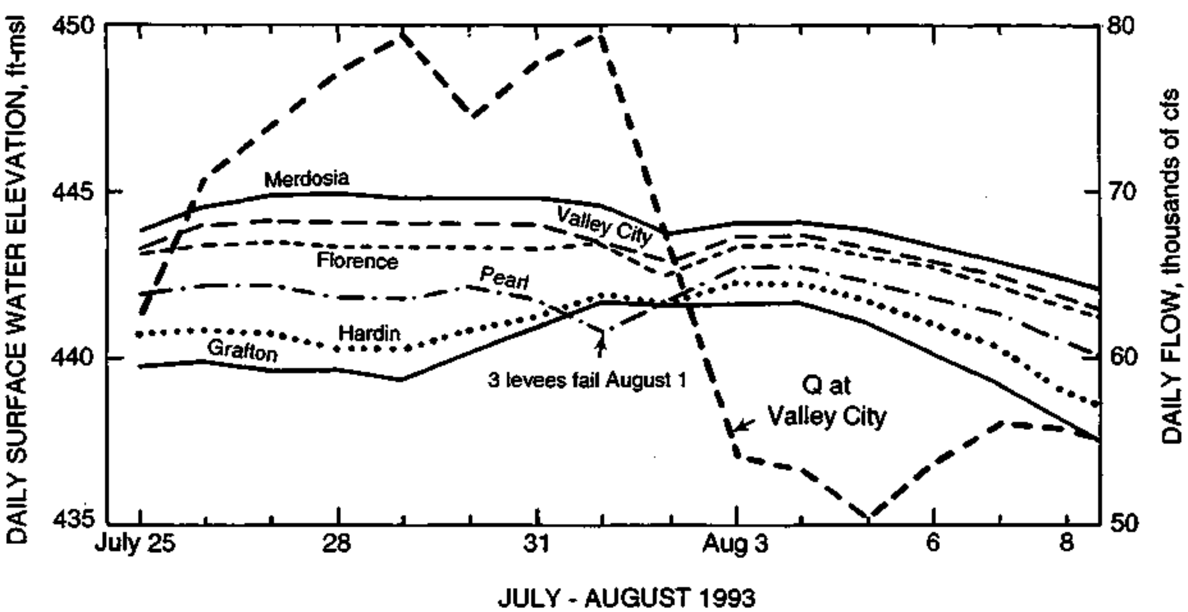


Figure 22. Water elevation versus time curves at Meredosia, Valley City, Florence, Pearl, Hardin, and Grafton during July 25 to August 8, 1993

2. The WE hydrographs show a dip on August 1 at Pearl, and on August 2 at Florence, Valley City, and Meredosia. These dips were caused by failure of the Eldred, Hartwell, and Hillview levees (approximately from RM 24 to RM 50) on August 1 after overtopping due to backwaters from the Mississippi River. Waters pouring into areas protected by these levees lowered the WE at Pearl on August 1, and the effect reached upper stations the next day.
3. The difference in maximum water elevations at Meredosia and Grafton is only 3.10 feet, the lowest amount in the 53-year record. The rank of maximum water elevation at Grafton was 1, which was maintained by backwaters up to Florence, and then it dropped to 3 at Valley City, and 4 at Meredosia. This is the reverse of what happened in 1943.

FLOOD FREQUENCY ANALYSES FOR MAJOR TRIBUTARIES

. Five major tributaries discharge into the Illinois River downstream of Peoria: Mackinaw River near Green Valley, Spoon River at Seville, Sangamon River near Oakford, La Moine River at Ripley, and Macoupin Creek near Kane. For each of these tributaries, Table 14 provides the U.S. Geological Survey (USGS) gaging station number, period for which the continuous historical flood record is available, size of drainage area (DA), station location and distance upstream of mouth or confluence with the Illinois River, drainage area at the mouth, and Illinois River mile (RM) at the confluence.

The general frequency program was used to develop distribution parameter values (mixed and log-Pearson HI distributions) for the entire record as well as split samples to examine the trends, if any, in various frequency floods for each of the five tributaries. The results are given for the parameter values (Table 15) and for 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year flood peaks fitted with mixed distribution as well as log-Pearson HI (LP3) distribution (Table 16). Any outliers/inliers detected at the upper and lower end of the flood spectrum are modified at the 0.1 significance level (Table 17).

Most of the modifications are minor except for the highest flood of 123,000 cubic feet per second (cfs) that occurred in the Sangamon River near Oakford on May 20, 1943. The second and third highest floods were 68,700 cfs on December 12, 1982 and 55,900 cfs on April 15, 1979, respectively. Corresponding flood peaks at Meredosia were 123,000, 112,000, and 111,000 cfs with ranks of 1, 3, and 4, respectively. The second highest flood (122,000 cfs at Meredosia) occurred on March 10, 1985; a corresponding flood peak (78,800 cfs at Kingston Mines at RM 144.4) occurred on March 6, 1985. Flood peaks in the Spoon, Sangamon, and La Moine Rivers (between Kingston Mines and Meredosia) at their respective gaging stations were 29,200 cfs on March 6, 26,500 cfs on February 25, and 28,000 cfs on March 7, 1985.

Design T-Year Floods

Figures 23-27 show fitted mixed distribution (together with two-component normal distributions) and log-Pearson III with sample skew (LP3s) distribution to the observed annual floods for the period 1941-1993 for the five USGS gaging stations. Distributions for the

Table 14. Relevant Data for Major Tributaries to Illinois River below Peoria, Illinois

Tributary	*USGS station no.*	*Period of record*	*DA, sq mi*	*Upstream of mouth, mi*	*DA at mouth, sq mi*	*IL River mile*
Mackinaw River near Green Valley	05568000	1922-1993	1089	13.7	1136	147.7
Spoon River at Seville	05570000	1919-1993	1636	38.7	1855	120.4
Sangamon River near Oakford	05583000	1931-1993	5093	25.7	5419	88.9
La Moine River at Ripley	05585000	1921-1993	1293	12.3	1350	83.5
Macoupin Creek near Kane	05587000	1941-1993	868	16.1	961	23.2

Table 15. Fitted Mixed Distribution (MD) and Log-Pearson III (LP3s) Distribution Parameters

River and		*MD parameters*					*LP3s parameters*		
station	*Period*	*a*	μ_1	σ_1	μ_2	σ_2	μ	*a*	*g*
Mackinaw River near Green Valley									
	1922-1993	0.283	3.704	0.120	4.023	0.307	3.932	0.304	0.450
	1922-1951	0.545	3.640	0.145	4.213	0.183	3.901	0.329	0.265
	1941-1993	0.285	3.776	0.105	4.048	0.315	3.970	0.299	0.486
	1973-1993	0.101	3.909	0.525	4.119	0.303	4.097	0.338	-0.289
Spoon River at Seville									
	1919-1993	0.445	3.907	0.176	4.232	0.168	4.088	0.236	-0.122
	1941-1993	0.308	3.954	0.195	4.192	0,179	4.119	0.214	-0.206
	1973-1993	0.272	3.968	0.272	4.225	0.199	4.155	0.249	-0.444
Sangamon River near Oakford									
	1931-1993	0.548	4.194	0.333	4.463	0.142	4.315	0.296	-0.675
	1941-1993	0.519	4.276	0.324	4.424	0.149	4.347	0.266	-0.489
	1973-1993	0.532	4.449	0.230	4.386	0.148	4.419	0.198	0.188
La Moine River at Ripley									
	1921-1993	0.286	3.736	0.285	4.0.37	0.209	3.951	0.270	-0.474
	1941-1993	0.499	3.869	0.261	4.140	0.167	4.005	0.258	-0.480
	1973-1993	0.169	3.651	0.334	4.167	0.182	4.079	0.290	-1.224
Macoupin Creek near Kane									
	1941-1993	0.549	3.778	0.369	4.165	0.170	3.952	0.354	-0.666
	1973-1993	0.124	3.550	0.149	4.094	0.194	4.027	0.261	-0.589

Notes: MD = mixed distribution (μ_1 and σ_1 are mean and standard deviation of one component distribution, μ_2 and σ_2 of second component distribution, a is weight of first component distribution and 1-*a* of second component), LP3s = Log-Pearson Type III distribution with sample skew (μ, σ, and *g* denote mean, standard deviation, and skew)

Table 16. Flood Frequency Analysis for Major Tributaries to Illinois River below Peoria, Illinois

Record	*Observed Qmax*	*Method*	*Floods at various recurrence intervals, cfs* 2-year	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*
Mackinaw River near Green Valley, 1075 sq mi									
1922-1993	51,000	MD	7,700	22,674	32,484	40,788	49,953	74,928	87,992
		LP3s	8,122	21,571	32,274	42,433	54,770	94,303	117,327
		LP3w	8,428	21,195	30,093	37.882	46,714	71,923	85,121
1922-1951	31,000	MD	6,729	22,630	28,882	33,511	38,151	49,223	54,191
		LP3s	7,696	21,412	32,039	41,911	53,664	89,970	110,383
		LP3w	8,322	20,320	27,203	32,531	37,968	50,995	56,762
1941-1993	51,000	MD	8,228	24,482	35,428	44,734	55,091	83,797	98,537
		LP3s	8,834	23,191	34,655	45,566	58,854	101,657	126,716
		LP3w	9,412	22,432	30,629	37,388	44,678	63,853	73,155
1973-1993	51,000	MD	12,757	32,515	46,120	58,233	72,554	119,907	150,941
		LP3s	12,985	33,048	45,165	54,813	64,888	89,916	101,378
		LP3w	13,184	32,628	43,642	52,079	60,609	80,716	89,471
			10,300	**27,600**	**39,600**	**50,000**	**62,000**	**97,800**	**118,500**
Spoon River at Seville. 1636 sq mi									
1919-1993	37,300	MD	12,518	24,398	30,069	34,246	38,417	48,264	52,620
		LP3s	12,371	24,340	30,906	35,972	41,166	53,830	59,574
		LP3w	12,475	24,190	30,352	34,993	39,657	50,672	55,516

Table 16. Continued

Record	Observed Qmax	Method	2-year	10-year	25-year	50-year	100-year	500-year	1000-year
			Floods at various recurrence intervals, cfs						
1941-1993	36,400	MD	13,429	24,330	29,913	34,119	38,270	48,546	53,104
		LP3s	13,370	24,426	30,046	34,217	38,364	48,017	52,211
		LP3w	13,504	24,233	29,390	33,099	36,692	44,718	48,068
1973-1993	36,400	MD	14,911	28,500	35,772	41,375	47,158	61,475	68,120
		LP3s	14,911	28,822	35,509	40,276	44,849	54,861	58,949
		LP3w	14,846	28,935	35,869	40,878	45,738	56,567	61,065
			14,000	**26,100**	**32,300**	**37,800**	**41,000**	**51,800**	**56,000**
Sangamon River near Oakford, 5093 sq mi									
1931-1993	123,000	MD	23,402	43,319	54,631	65,235	78,745	121,921	144,680
		LP3s	22,294	46,445	57,412	64,868	71,719	85,645	90,903
		LP3w	21,959	47,156	59,550	68,384	76,824	95,089	102,430
1941-1993	123,000	MD	23,709	44,060	57,930	71,736	88,707	137,921	163,216
		LP3s	23,376	46,886	58,229	66,292	73,997	90,736	97,507
		LP3w	23,245	47,126	58,995	67,580	75,904	94,407	102,063
1973-1993	68,700	MD	25,848	47,037	60,837	72,286	84,498	115,524	130,104
		LP3s	25,889	47,514	60,057	70,114	80,778	108,329	121,561
		LP3w	27,133	45,948	54,329	60,124	65,569	71,167	81,794
			24,500	**46,300**	**59,000**	**72,000**	**87,500**	**138,000**	**163,000**

Table 16. Concluded

Record	Observed Qmax	Method	2-year	10-year	25-year	50-year	100-year	500-year	1000-year
			Floods at various recurrence intervals, cfs						
La Moine River at Ripley, 1293 sq mi									
1921-1993	28,000	MD	9,411	18,826	23,940	27,913	32,029	42,278	47,049
		LP3s	9,385	19,104	23,864	27,274	30,552	37,737	40,669
		LP3w	9,359	19,151	24,017	27,532	30,934	38,475	41,586
1941-1993	28,000	MD	10,817	20,414	25,169	28,775	32,471	41,748	46,189
		LP3s	10,599	20,831	25,725	29,194	32,504	39,685	42,857
		LP3w	10,547	20,924	26,020	29,689	33,236	41,086	44,324
1973-1993	28,000	MD	13,404	24,173	29,697	33,881	38,142	48,516	53,263
		LP3s	13,706	24,685	28,046	29,859	31,231	33,289	33,852
		LP3w	12,488	27,401	35,422	41,461	47,502	61,581	67,699
			12,000	**23,000**	**26,800**	**31,000**	**35,000**	**45,000**	**49,000**
Macoupin Creek near Kane. 868 sq mi									
1941-1993	40,000	MD	10,519	22,106	28,196	33,326	39,341	59,392	71,296
		LP3s	9,804	23,597	30,441	35,262	39,800	49,324	53,020
		LP3w	9,588	24,124	32,113	38,096	44,025	57,530	63,211
1973-1993	27,800	MD	11,482	21,292	26,427	30,348	34,355	44,108	48,541
		LP3s	11,283	21,882	26,680	29,972	33,027	39,369	41,821
		LP3w	11,062	22,287	27,943	32,071	36,107	4,5201	49,016
			10,800	**22,800**	**29,300**	**34,600**	**39,600**	**59,400**	**71,300**

Notes: Suitable T-year flood values are given in bold; MD denotes mixed distribution; LP3s denotes log-Pearson III distribution with sample skew; and LP3w denotes Log-Pearson III distribution with weighted skew

Table 17. Record Periods, Outlier/Inlier Modifications, and Maximum Flood Peaks

Period	Outliers/Inliers				Maximum flood peak, cfs
Mackinaw River near Green Valley					
1922-1993			none		51,000
1922-1951			none		31,000
1941-1993	L1	1,830	→	1,940	51,000
	L3	4,400	→	3,757	
	L4	4,520	→	4,039	
	L5	4,620	→	4,292	
1973-1993	H2	46,700	→	46,106	51,000
Spoon River at Seville					
1919-1993			none		37,300
1941-1993			none		36,400
1973-1993			none		36,400
Sangamon River near Oakford					
1931-1993	H1	123,000	→	93,289	123,000
	H4	45,800	→	49,441	
	H5	44,700	→	46,807	
	L5	5,900	→	6,056	
1941-1993	H1	123,000	→	95,194	123,000
	H4	45,800	→	48,385	
	H5	44,700	→	45,607	
	L3	5,940	→	6,239	
1973-1993	L2	11,800	→	12,101	68,700
La Moine River at Ripley					
1921-1993	L4	3,490	→	3,467	28,000
	L5	3,770	→	3,747	
1941-1993			none		28,000
1973-1993			none		28,000
Macoupin Creek near Kane					
1941-1993	L3	2,640	→	2,268	40,000
1973-1993	H2	26,700	→	26,384	27,800

Notes: H1 denotes the highest observed flood, H2 the second highest flood, and so on.
L1 denotes the lowest obeserved flood, L2 the second lowest flood, and so on.

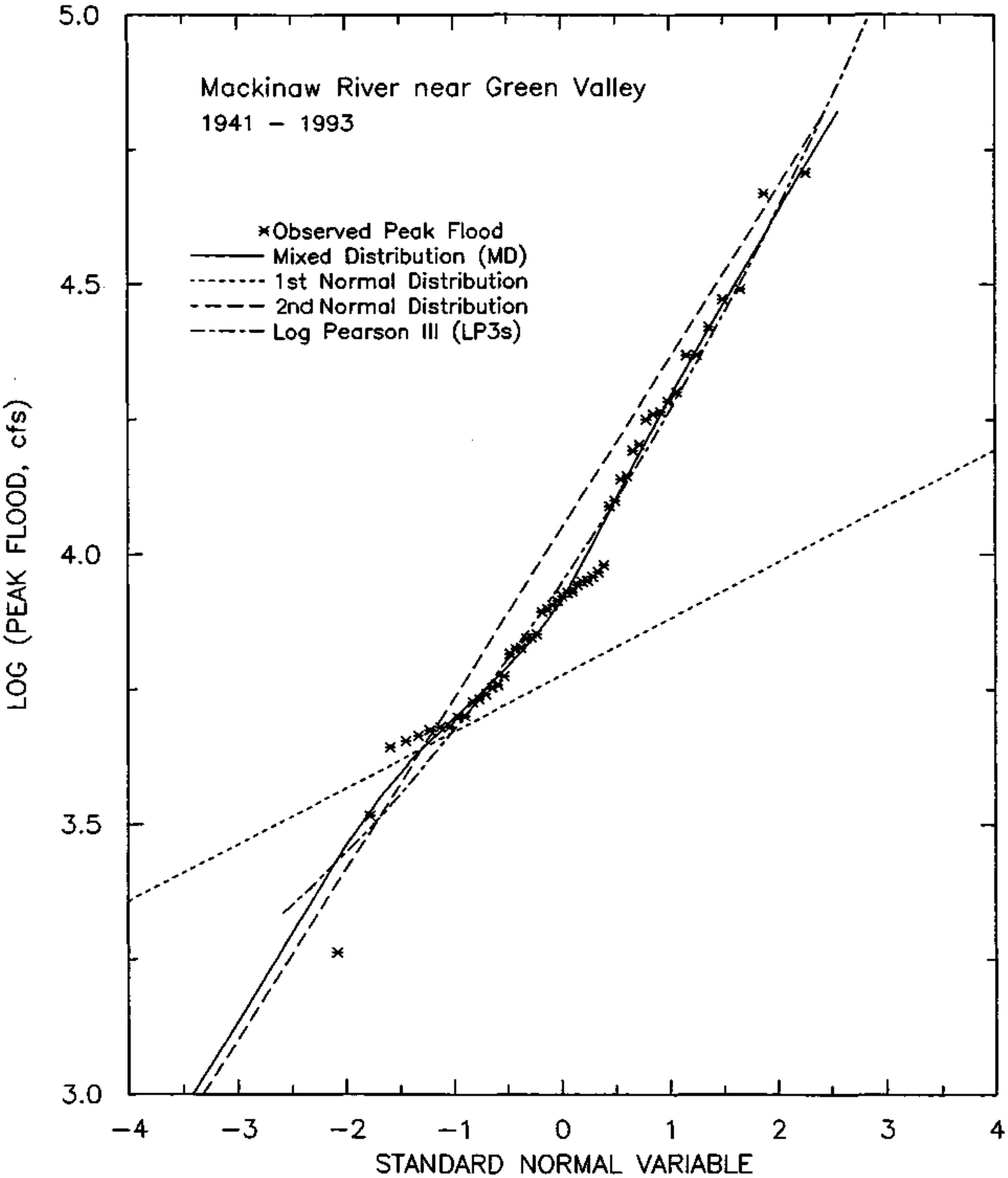


Figure 23. Fitted MD and LP3s distributions to observed annual maximum floods: Mackinaw River near Green Valley, 1941-1993

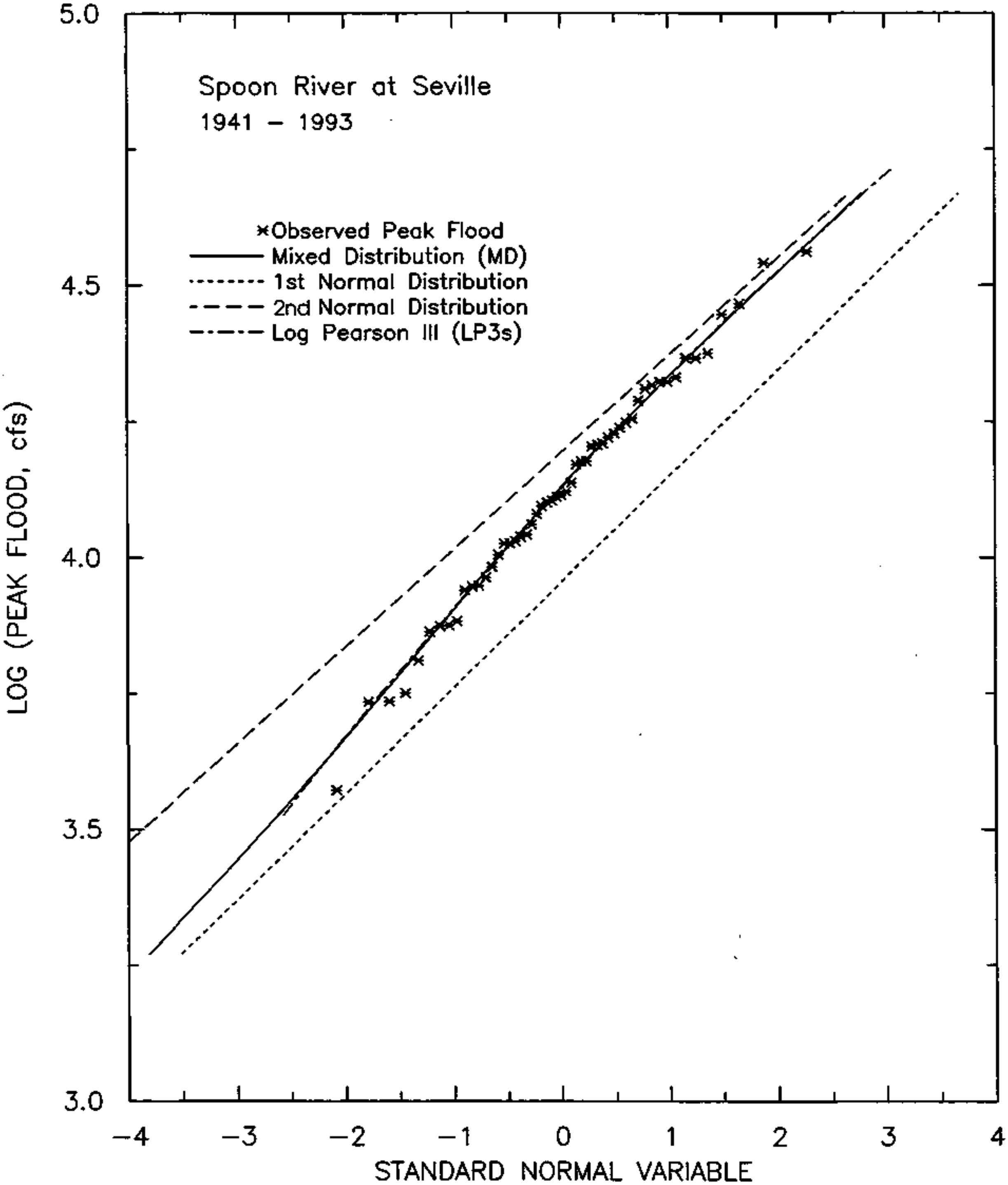


Figure 24. Fitted MD and LP3s distributions to observed annual maximum floods: Spoon River at Seville, 1941-1993

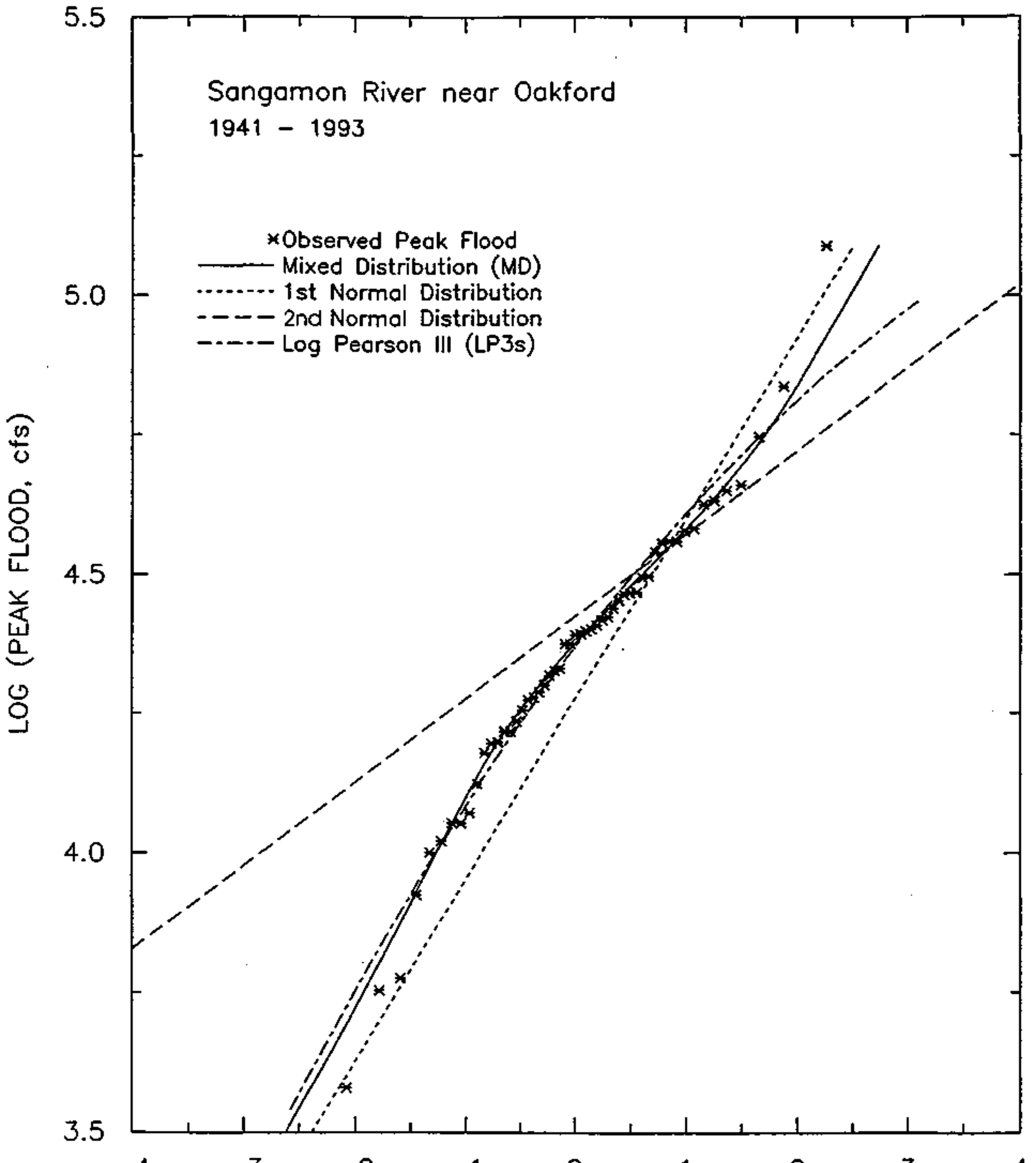


Figure 25. Fitted MD and LP3s distributions to observed annual maximum floods: Sangamon River near Oakford, 1941-1993

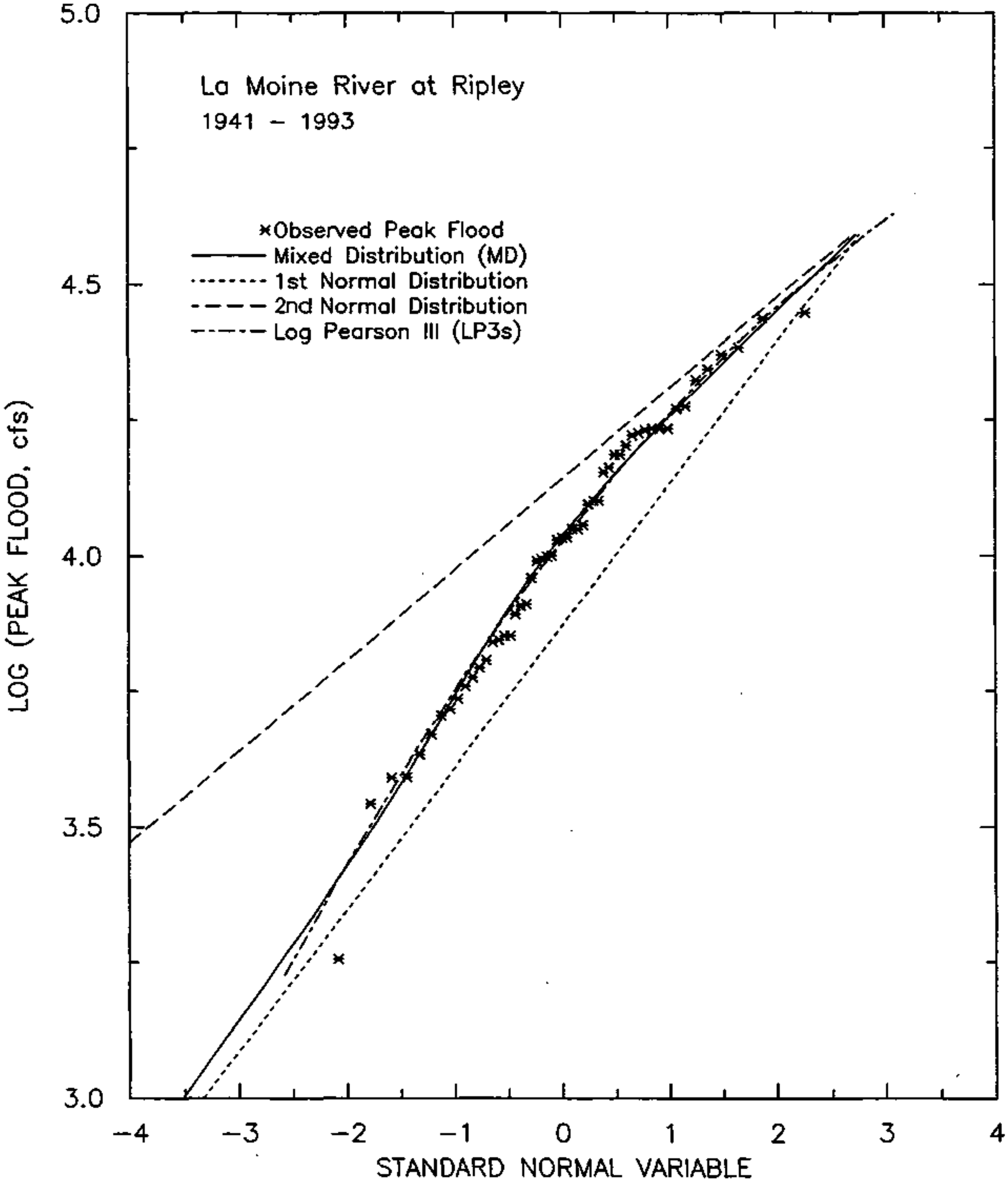


Figure 26. Fitted MD and LP3s distributions to observed annual maximum floods: La Moine River at Ripley, 1941-1993

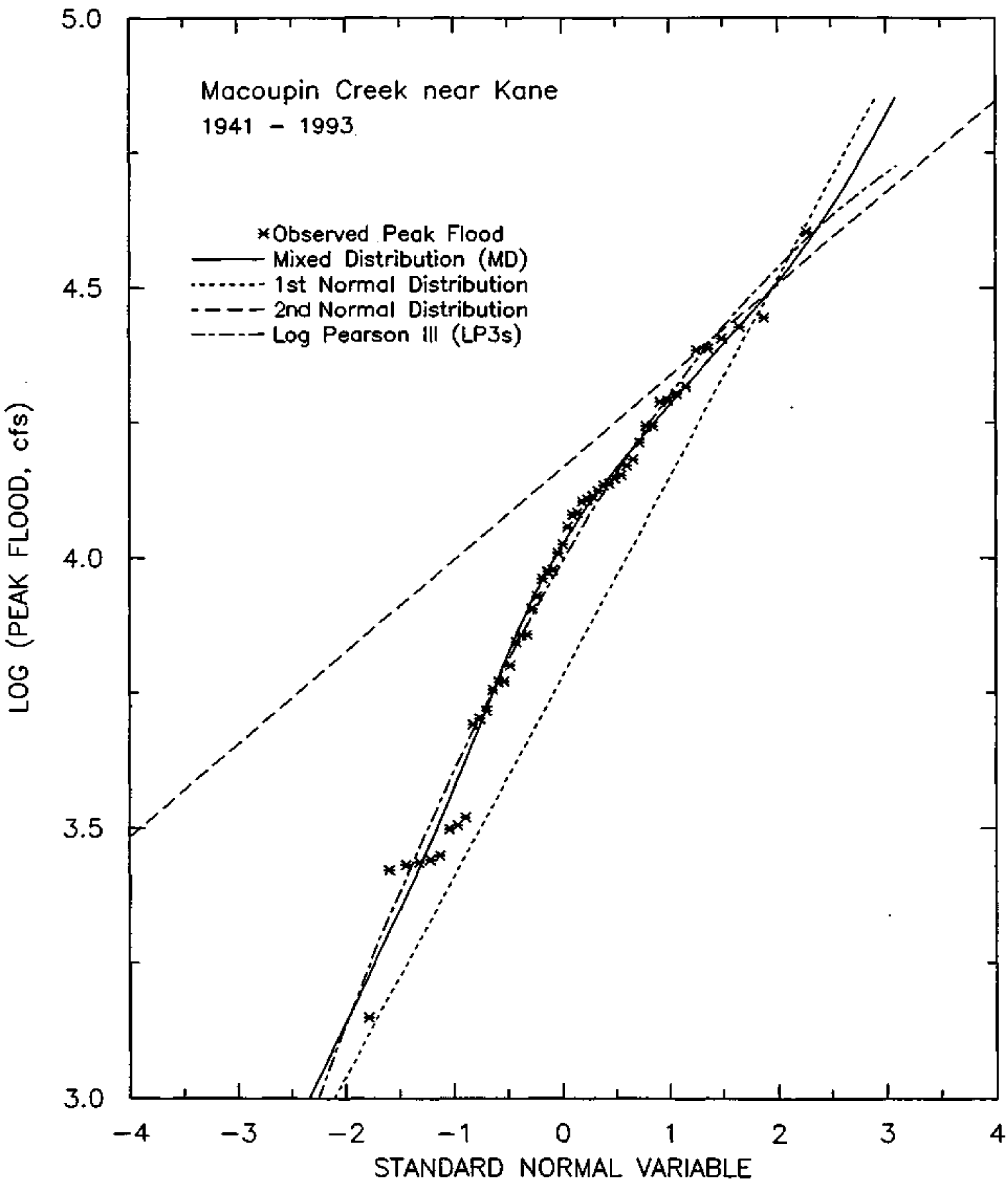


Figure 27. Fitted MD and LP3s distributions to observed annual maximum floods: Macoupin Creek near Kane, 1941-1993

Mackinaw River near Green Valley, for the 1922-1951 record (Figure 28) clearly demonstrate the versatility of mixed distribution to fit various shapes of flood frequency curves.

Table 16 provides values of 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year floods with mixed distribution (MD), log-Pearson HI with sample skew (LP3s) and log-Pearson HI with weighted skew (LP3w), for different record lengths at each station. Suitable estimates for design floods (shown in bold figures in the table) were made for various recurrence intervals (T).

Mackinaw River near Green Valley. The period of record covers 1922 to 1993. Table 16 provides various T-year floods derived using four periods (1922-1993, 1922-1951, 1941-1993, and 1973-1993). The five highest (H) and lowest (L) floods during these periods are given below.

		Observed H and L floods (cfs)				
Period	*H/L*	*1*	*2*	*3*	*4*	*5*
1922-1993	H	51,000	46,700	31,000	29,700	26,400
	L	1,830	2,420	3,050	3,280	3,370
1922-1951	H	31,00	26,400	24,300	19,700	19,300
	L	2,420	3,050	3,280	3,370	3,450
1941-1993	H	51,000	46,700	31,000	29,700	26,400
	L	1,830	3,280	4,400	4,520	4,620
1973-1993	H	51,000	46,700	29,700	23,400	23,400
	L	1,830	4,730	6,540	6,970	7,830

There is a significant trend of increase in values of both high and low floods over time. Estimating a representative design flood requires consideration of both trend and suitable underlying distribution.

Figure 29 plots the values of flood peaks for each of the seven recurrence intervals (2 to 1,000 years) with mixed, LP3s, and LP3w distributions at the middle of each of the four periods listed above. Curves for 2-, 10-, 25-, and 50-year recurrence intervals show an increasing trend over time, and the trend becomes more pronounced as T increases. It is considered that the period (1954 to 1993) adequately represents dry, average, and wet years. It also includes the recent 20-year period of higher precipitation and increased flows and flood peaks. Thus, suitable values from these curves for the year 1973 are adopted as design flood peaks (bold type in Table 16).

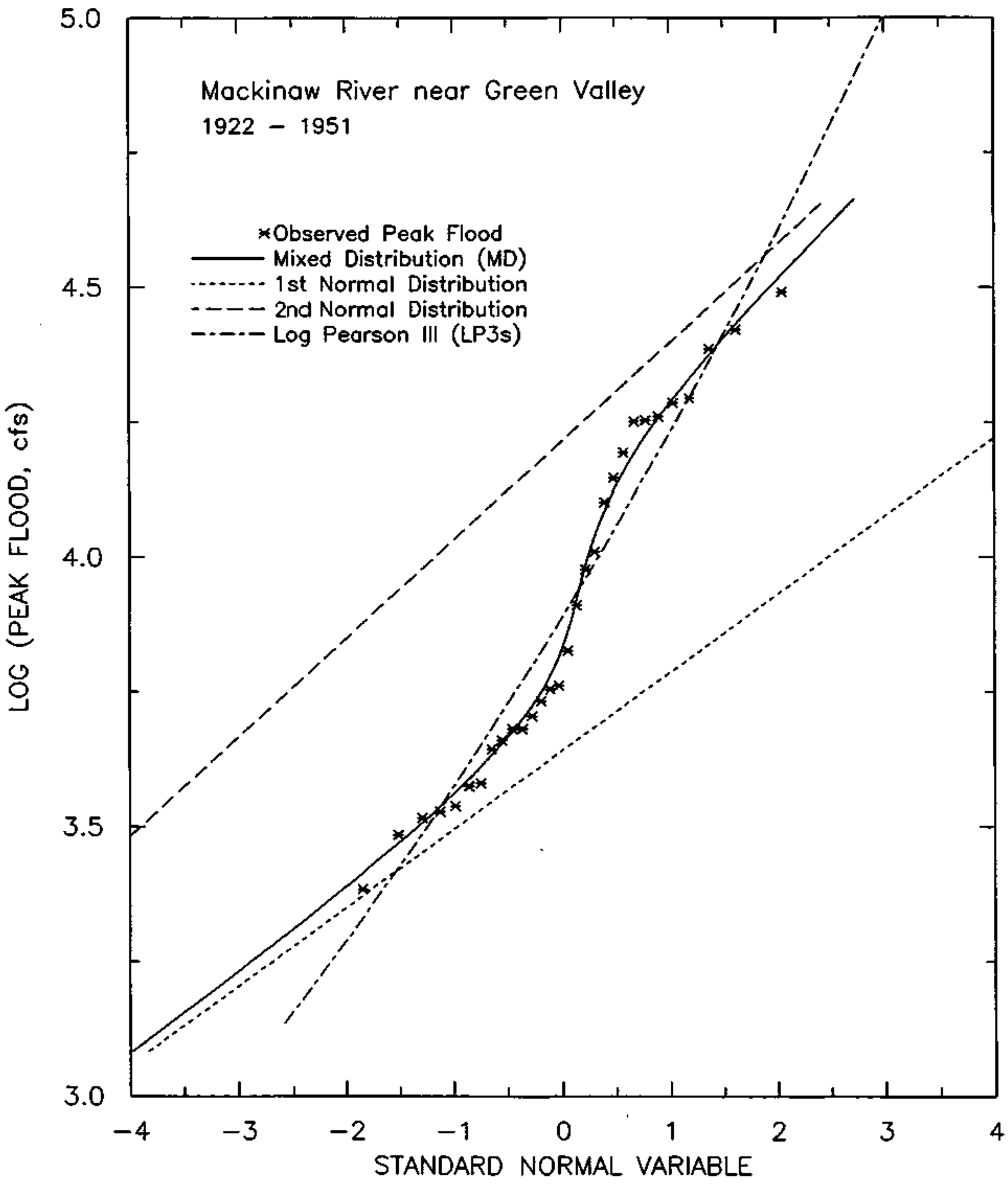


Figure 28. Fitted MD and LP3s distributions to observed annual maximum floods: Mackinaw River near Green Valley, 1922-1951

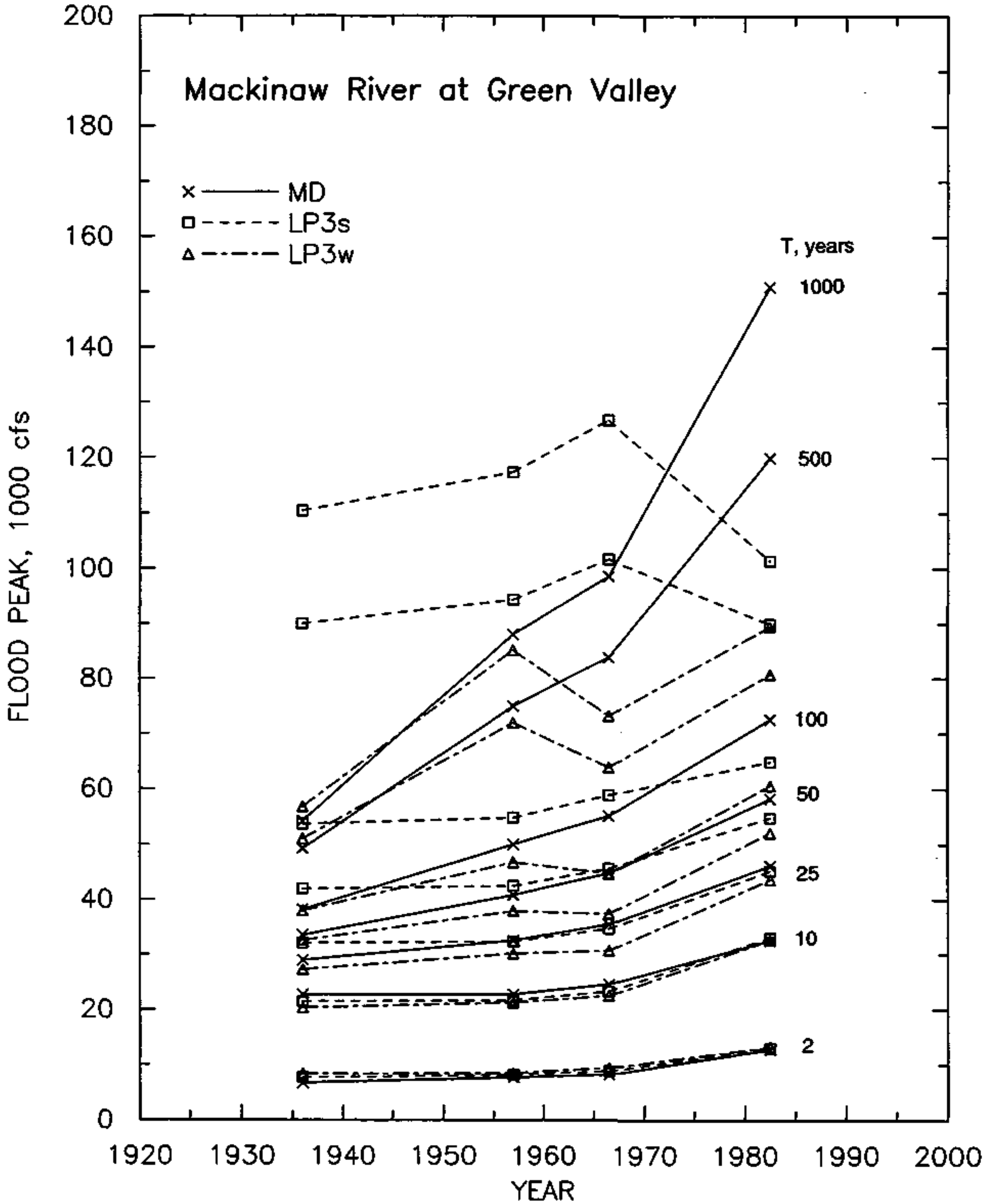


Figure 29. 2- to 1000-year flood peaks for various periods: Mackinaw River

Figure 28 shows that for the period 1922-1951, the floods from LP3s for T>10 years will vary greatly but gradually exceed those from mixed distribution as T increases. Significantly high positive skews for the periods 1922-1993, 1922-1951, and 1941-1993 cause 100-, 500-, and 1,000-year flood peaks with LP3s to be progressively much higher than with MD. The LP3w values are lower than the MD values. However, the use of regional skew of -0.4 for the Mackinaw River basin is open to question, more so when the 72-year record (1922-1993) yields a sample skew of 0.450. The observed maximum flood of 51,000 cfs may be assigned a recurrence interval of 50 to 75 years.

Suitable design flood estimates for various recurrence intervals have been derived considering the representative recent 40-year period (1954-1993), a trend of increasing flood peak with years, and relative goodness of fit of MD, LP3s, and LP3w curves with the observed floods.

Spoon River at Seville. The sample skew for the periods 1919-1993, 1941-1993, and 1973-1993 is negative with values of -0.122, -0.206, and -0.444, decreasing with decrease in length of period of record. Five highest (H) and lowest (L) floods occurring in these periods are given below. There is no significant trend of increase in values of both high and low floods from one period to the other.

		Observed H and L floods (cfs)				
Period	*H/L*	*1*	*2*	*3*	*4*	*5*
1919-1993	H	37,300	36,400	34,700	29,200	27,900
	L	3,560	3,730	4,530	4,710	5,420
1941-1993	H	36,400	34,700	29,200	27,900	23,700
	L	3,730	5,420	5,430	5,630	6,470
1973-1993	H	36,400	34,700	29,200	21,400	21,000
	L	3,730	6,470	7,470	7,630	8,840

Figure 30 plots values of flood peaks for each of the seven recurrence intervals with MD, LP3s, and LP3w for the three periods listed above. These values are plotted at the middle of the relevant period. The curves show an increase in flood peaks in the 1973-1993 period and the increase intensifies as T increases. Table 16 provides the best estimates of design floods for 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year recurrence interval (in bold type) by considering 1954-1993 as the period representative of dry, average and wet years as well as of recent 20 years of increasing flows and flood peaks. In developing these estimates, consideration was given to the

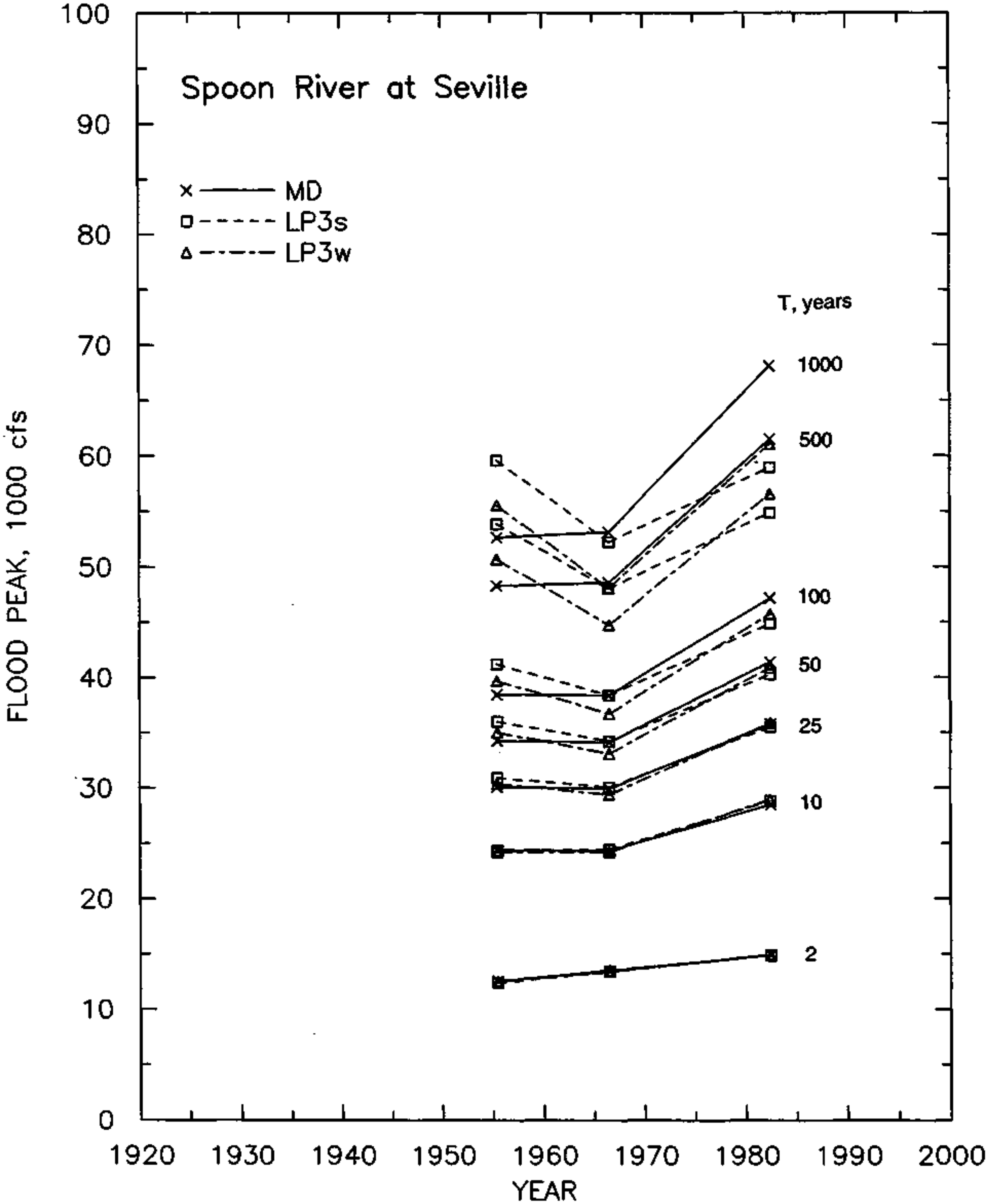


Figure 30. 2- to 1000-year flood peaks for various periods: Spoon River at Seville

representative recent 40-year period, the trend of increasing floods in the last 20 years, and the relative goodness of fit of MD, LP3s, and LP3w.

Sangamon River near Oakford. The annual flood peak record of 1931-1993 was analyzed for three periods: 1931-1993, 1941-1993, and 1973-1993, and MD provided the best fit for the observed floods in these periods. Values of flood peaks for 2-, 10-, and 25-year recurrence intervals are in the same general range with these distributions, but for T exceeding 25 years and going to 1,000 years, the flood peaks obtained with mixed distributuion become progressively higher than with LP3s and LP3w for the first two periods, and with LP3w for the third period (positive sample skew in the third period makes MD values not much higher than LP3s values).

The five highest (H) and lowest (L) floods occurring in the three periods are given below.

		Observed H and L floods (cfs)				
Period	*H/L*	*1*	*2*	*3*	*4*	*5*
1931-1993	H	123,000	68,700	55,900	45,800	44,700
	L	3,480	3,800	4,630	5,670	5,960
1941-1993	H	123,000	68,700	55,900	45,800	44,700
	L	3,800	5,670	5,940	8,400	10,000
1973-1993	H	68,700	55,900	45,800	42,900	36,000
	L	11,300	11,800	15,800	18,000	18,800

Three of the five lowest floods that occurred in 1931-1993 also occurred in 1941-1993 but none of them occurred during 1973-1993. The highest flood (123,000 cfs) occurred on May 20, 1943. The second highest flood (68,700 cfs) occurred December 12, 1982. The tremendous difference between the highest and the next highest flood shows that 1943 flood is an outlier and was detected as such by the general frequency program.

Figure 31 plot values of flood peaks for each of the seven recurrence intervals with MD, LP3s, and LP3w for the three periods listed above. Table 16 (bold type) provides the best estimates of design floods for 2-, 10-, 25-, 50-, 100-, 500-, and 1000-year recurrence intervals. The highest flood (123,000 cfs) has an estimated average recurrence interval of about once in 300 years.

La Moine River at Ripley. The record of three periods was considered: 1921-1993, 1941-1993, and 1973-1993. The five highest (H) and lowest (L) floods in these periods are given in the following table.

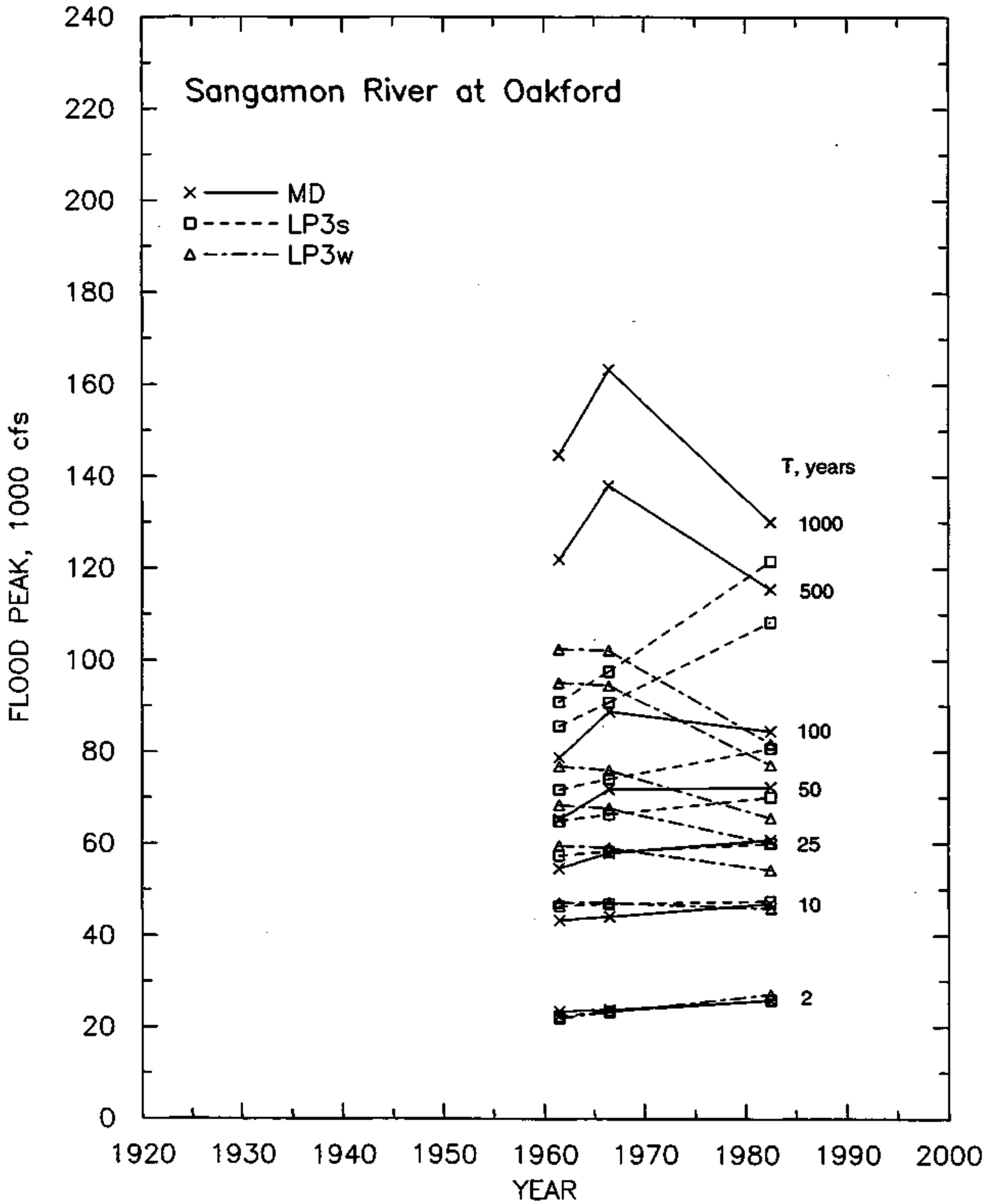


Figure 31. 2- to 1000-year flood peaks for various periods: Sangamon River near Oakford

Period	H/L	Observed H and L floods (cfs) 1	2	3	4	5
1921-1993	H	28,000	27,300	24,100	23,400	22,000
	L	1,280	1,800	3,140	3,490	3,700
1941-1993 •	H	28,000	27,300	24,100	23,400	22,000
	L	1,800	3,490	3,890	3,900	4,290
1973-1993	H	28,000	27,300	23,400	22,000	21,000
	L	1,800	4,290	5,430	7,110	8,120

The five highest floods are the same in both 1921-1993 and 1941-1993 periods. Thus, the period 1921-1940 did not contribute any of these floods. Only the third highest flood (24,1000 cfs) did not occur in the 1973-1993 period. The lowest floods also increased greatly in this period. Sample skews for the first two periods (-0.474 and -0.480) are not much different from the assumed regional skew (-0.4). However, a rapid increase in lowest flood values, without a corresponding increase in highest values in 1973-1993 period, makes the fitted LP3s curve flatten out at the upper end, so much so that the 25-year flood peak (28,046 cfs) is slightly less than 1000-year flood peak (33,852 cfs). However, floods peaks with LP3w for the period 1971-1993 are much higher than LP3s and higher than with MD. Design values (Table 16) generally follow those developed from mixed distribution. Figure 32 plots values of flood peaks for each of the seven recurrence intervals with MD, LP3s, and LP3w for the three periods listed above. There is a trend of increase in flood peaks. Table 16 (bold type) provides the suitable design flood estimates for the 40-year repesentative period.

Macoupin Creek near Kane. The annual flood record covers the period 1941-1993. The frequency program was applied to two data sets: 1941-1993 and 1973-1993. The five highest (H) and lowest (L) floods in these periods are given below.

Period	H/L	Observed H and L floods (cfs) 1	2	3	4	5
1941-1993	H	40,000	27,800	26,700	25,400	24,300
	L	906	1,410	2,640	2,700	2,730
1973-1993	H	27,800	26,700	19,400	17,500	15,200
	L	3,150	3,310	4,910	5,030	7,180

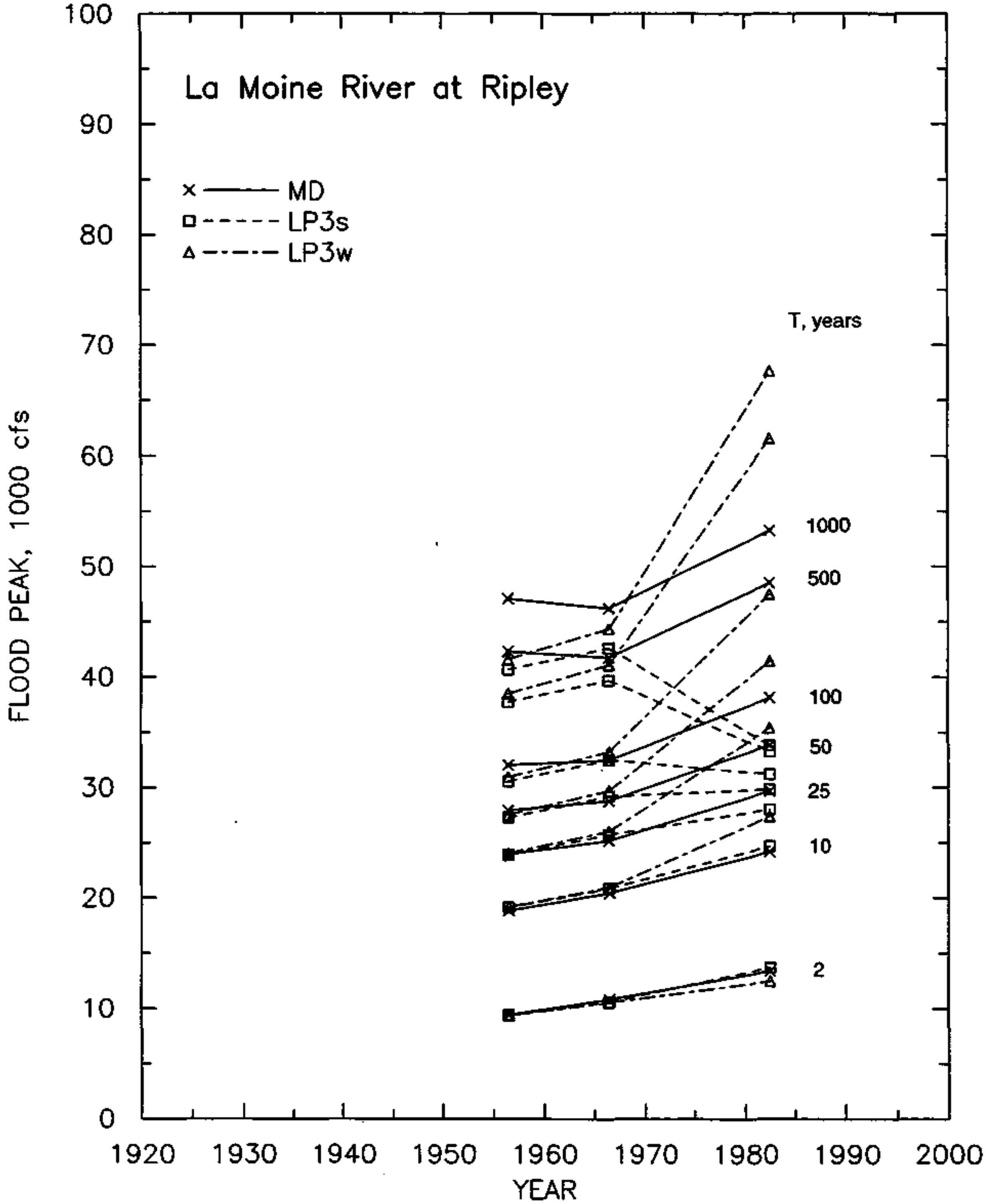


Figure 32. 2- to 1000-year flood peaks for various periods: La Moine River at Ripley

Only the second and third highest floods in 1941-1993 period occur as the first and second highest floods in the 1973-1993 period. Moreover, the lowest flood peaks in the 1973-1993 period are about double or more than those in the 1941-1993 period. Accordingly, the standard deviation, σ, is greatly reduced from 0.359 for the longer period to 0.261 for 1973-1993 period, which significantly reduces flood peaks with LP3s. These peaks increase slightly with LP3w, the weighted skew being less negative than the sample skew.

Figure 33 plots values of flood peaks for each of the seven recurrence intervals with MD, LP3s, and LP3w for the two periods listed above. Table 16 (bold type) provides the best estimates of design flood for 2-, 10-, 25-, 50-, 100-, 500-, and 1,000-year recurrence intervals.

Peak Flood Versus T Curves

Figure 34 plots design peak floods at recurrence intervals of 2 to 1,000 years for the five tributaries. Flood peak vs. T curves for the Spoon and La Moine Rivers and Macoupin Creek show a progressive gradual increase in flood peak as T increases. However, such curves for the Sangamon and Mackinaw Rivers show a substantial, progressive increase with increase in recurrence interval. All curves are well defined.

Floods in the Illinois River below Peoria to Grafton are largely governed by outflows from Peoria Lake and flood flows from the Mackinaw, Spoon, Sangamon, and La Moine Rivers, and Macoupin Creek, which add considerably to the flood volumes and flood peaks. Concurrent tributary flood peaks and Illinois River flow below Peoria will primarily determine the flood hydrographs from Peoria to Grafton.

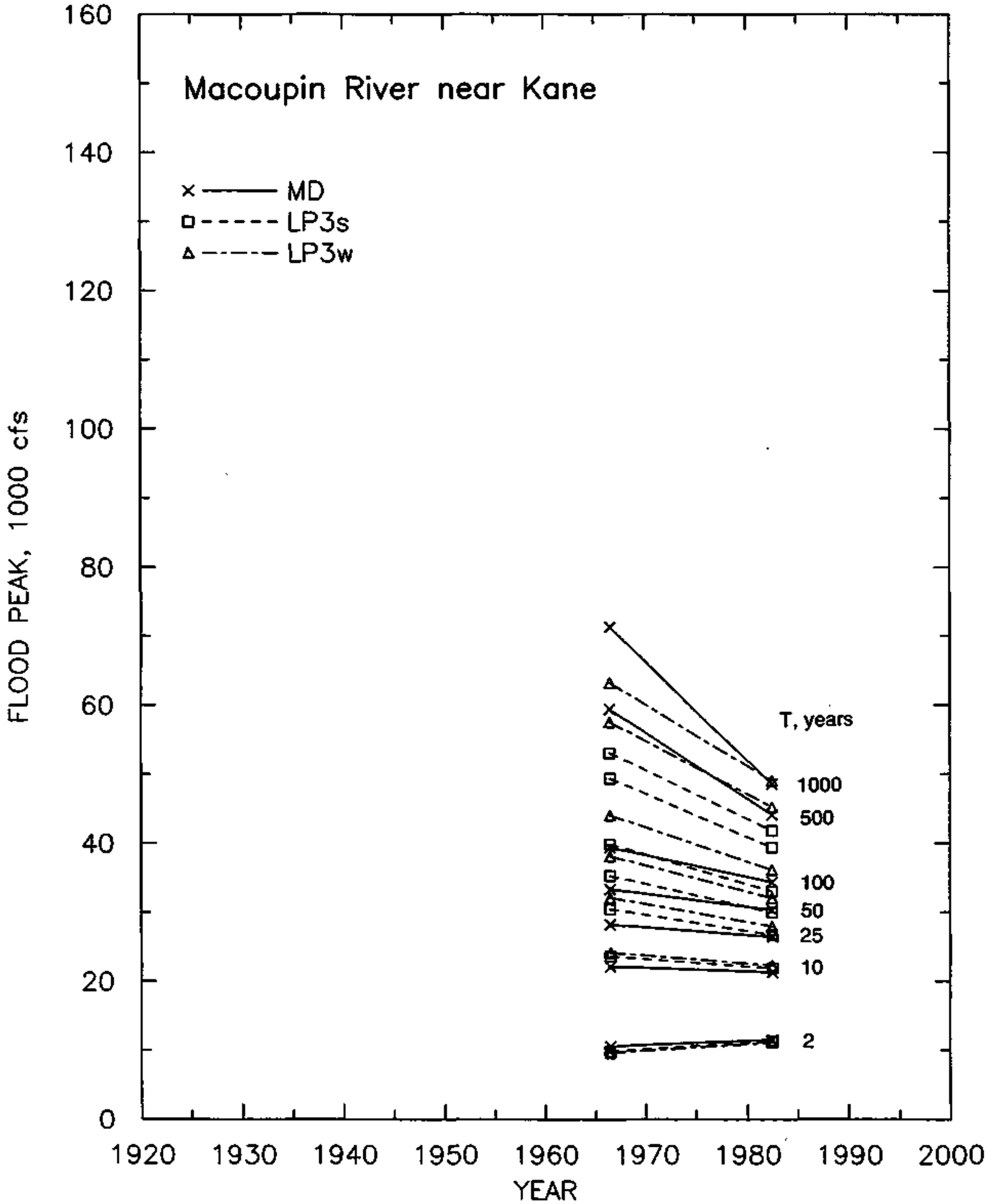


Figure 33. 2- to 1000-year flood peaks for various periods: Macoupin Creek near Kane

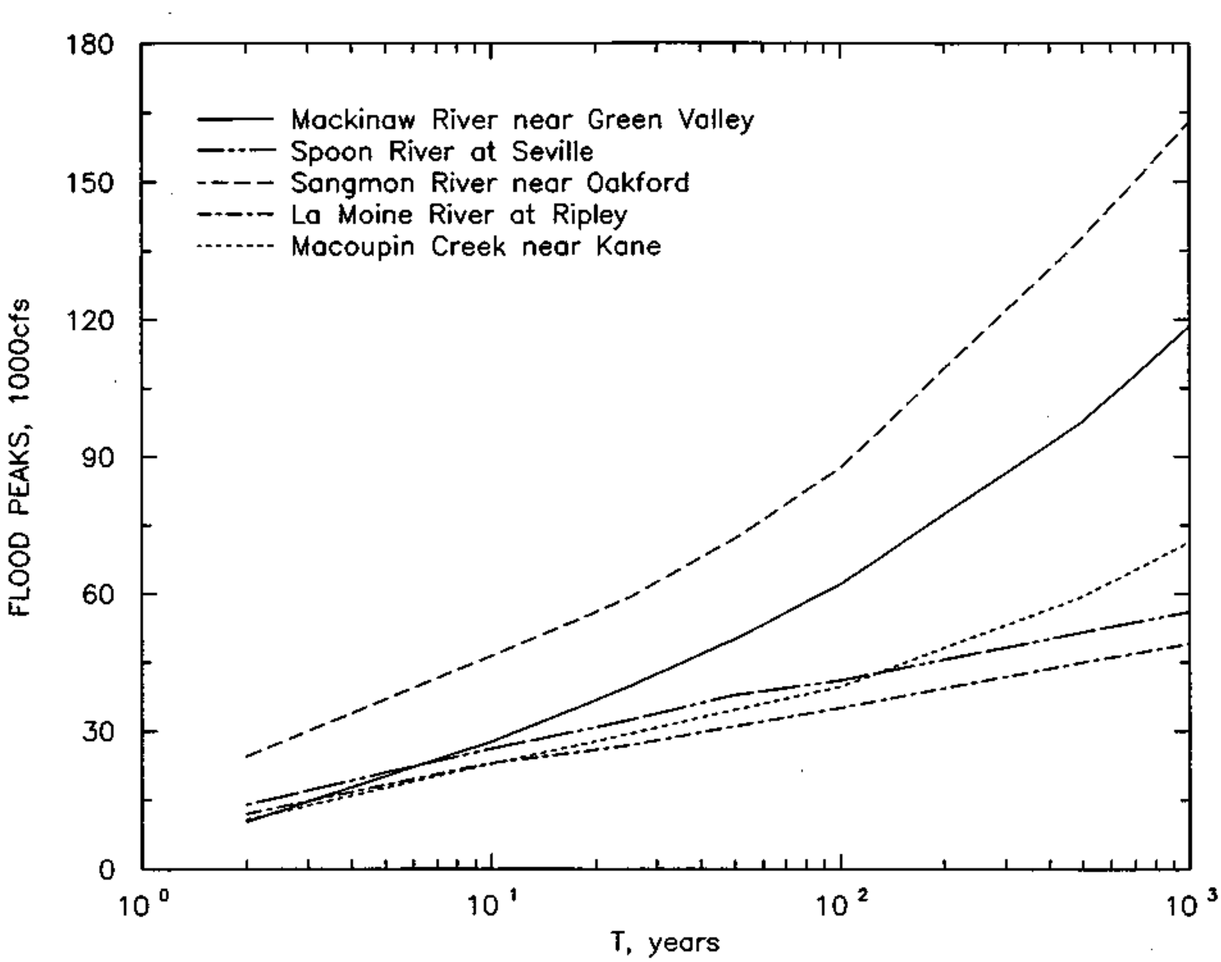


Figure 34. Flood peak versus T curves for Mackinaw, Spoon, Sangamon, and La Moine Rivers, and Macoupin Creek

FLOODS AND STAGES: ILLINOIS RIVER BELOW MARSEILLES

In the river reach from Marseilles to Grafton, there are three long-term U.S. Geological Survey (USGS) gaging stations where the daily flow, stage, and annual peak flow data are available: Marseilles, Kingston Mines, and Meredosia.

Location	*Record (years)*	*Drainage area (sq mi)*	*River mile (mi)*
Illinois River at Marseilles	1920-1993	8,259	246.5
Illinois River at Kingston Mines	1941-1993	15,818	144.4
Illinois River at Meredosia*	1939-1993	26,028	71.3
Illinois River at Valley City**	1985-1993	26,742	61.4

Notes:

*stage data for 1939-1993, and flow data for 1939-1989.
**stage data for 1985-1993, and flow data for 1990-1993

The general frequency program was used to develop distribution parameter values (mixed and log-Pearson III distributions) for the entire record as well as split samples to examine any time trends in various frequency floods and stages at Marseilles, Kingston Mines, and Meredosia.

Flood Frequency and Design Floods

Annual peak flood data are available at Marseilles, Kingston Mines, and Meredosia for the 1941-1993 period of record, after adjusting annual peaks at Valley City (1990-1993) to corresponding values at Meredosia. Table 18 provides 16 top ranked flood peaks at each station and the date of occurrence.

Flood flows passing through Peoria Lake, on the way to Kingston Mines, are modified primarily by increased lake storage and also by flood flows in the Mackinaw River entering the Illinois River at mile 147.7 or 3.3 miles upstream of the gage at Kingston Mines. In order to investigate the correlation between peak flows at Kingston Mines and at Meredosia, it is necessary to consider the top five floods at Meredosia and ranks for corresponding floods at Kingston Mines.

Table 18. Ranked Peak Floods at Marseilles, Kingston Mines, and Meredosia (1941-1993)

	Illinois River at Marseilles		*Illinois River at Kingston Mines*		*Illinois River at Meredosia*	
Rank	*Date*	*Peak, cfs*	*Date*	*Peak, cfs*	*Date*	*Peak, cfs*
1	12/4/82	94,100	12/7/82	88,800	5/26/43	123,000
2	7/14/57	93,900	5/23/43	83,100	3/10/85	122,000
3	5/15/70	92,500	3/6/85	78,800	12/12/82	112,000
4	6/14/81	88,500	3/22/82	77,200	4/19/79	111,000
5	11/29/90	85,800	5/18/70	75,400	6/29/74	110,000
6	2/24/85	84,800	3/21/79	72,300	3/24/82	104,000
7	4/26/50	83,300	5/25/74	71,900	5/2/73	102,000
8	3/14/82	75,800	4/28/50	71,400	4/29/44	102,000
9	2/7/42	74,400	12/3/90	70,800	11/27/85	96,800
10	5/21/43	73,800	3/15/90	69,100	5/22/70	94,800
11	4/6/47	72,000	11/12/85	67,100	3/29/62	91,100
12	3/20/79	71,100	3/9/76	66,300	8/1/93	89,630
13	11/20/85	68,300	4/26/44	64,200	3/37/76	80,600
14	3/6/76	66,900	4/25/73	63,300	2/28/51	77,800
15	5/13/66	66,500	3/25/62	62,100	5/2/50	77,200
16	1/5/93	66,000	2/17/84	60,000	6/7/80	76,900

Rank, Meredosia flood	1	**2**	3	4	5
Rank, corresponding flood at Kingston Mines	2	**3**	1	6	7

Over a relatively very long record, corresponding flood peaks at Meredosia and Kingston Mines will generally have similar recurrence interval (T) values, for T > 20 years.

Flood Frequency Analyses. The general frequency program was used to develop mixed (MD) and log-Pearson HI (LP3) distribution parameters for the entire record, as well as split samples to examine any time trends in floods at the three stations. Table 19 provides the results, which show the change in parameter values when different record lengths are used to fit frequency distributions to observed data.

Table 20 presents the flood peaks derived with the fitted parameters for recurrence intervals of 2, 10, 25, 50, 100, 500, and 1,000 years for various record lengths at each of the three stations for mixed distribution (MD), log-Pearson III with sample skew (LP3s) distribution, and log-Pearson III with weighted skew (LP3w) distribution. The outlier/inlier detection and modification resulted only in minor changes to one flood each in 1904-1993, 1941-1993, and 1941-1980 records for the Illinois River at Marseilles, and Table 21 gives relevant information.

Design floods. Figures 35-37 show flood frequency curves fitted using mixed distribution or MD (together with two component normal distributions) and log-Pearson III with sample skew (LP3s) distribution to the observed annual floods for the period 1969-1993 at Marseilles, Kingston Mines, and Meredosia. The mixed distribution yields an S-shaped curve fitting the observed flood peaks very well compared to a rather poor fit with LP3s distribution, at least for Marseilles and Kingston Mines. However, if 1941-1993 data are used, the fitted MD curves have a reduced severity of reversed curvature but still fit the data somewhat better than with LP3s distribution (Figures 38-40).

Design floods for T = 2, 10, 25, 50, 100, 500, and 1,000 years at Marseilles, Kingston Mines, and Meredosia were determined using the same procedure used for major tributaries (see previous chapter). This procedure allows consideration of any time trends and estimation of design values as indicated for the 1954-1993 period. Design T-year flood peaks are given in bold in Table 20.

Table 19. Fitted Mixed Distribution (MD) and Log-Pearson III (LP3s) Distribution Parameters for Peak Floods

	MD parameters					*LP3s parameters*		
Period	*a*	μ_1	σ_1	μ_2	σ_2	μ	σ	*g*
<u>Illinois River at Marseilles</u>								
1904-1993	0.759	4.584	0.166	4.826	0.090	4.643	0.183	-0.211
1904-1940	0.640	4.479	0.139	4.694	0.115	4.556	0.166	-0.059
1941-1993	0.526	4.613	0.167	4.803	0.110	4.703	0.171	-0.446
1941-1980	0.071	4.340	0.100	4.710	0.134	4.684	0.163	-0.532
1969-1993	0.357	4.551	0.100	4.843	0.093	4.739	0.170	-0.394
1981-1993	0.318	4.534	0.123	4.867	0.095	4.761	0.187	-0.641
<u>Illinois River at Kingston Mines</u>								
1941-1993	0.702	4.611	0.147	4.817	0.064	4.672	0.159	-0.381
1941-1980	0.850	4.622	0.153	4.787	0.025	4.647	0.153	-0.310
1969-1993	0.367	4.550	0.104	4.824	0.070	4.724	0.157	-0.623
1981-1993	0.376	4.627	0.181	4.826	0.075	4.752	0.158	-1.070
<u>Illinois River at Meredosia</u>								
1921-1993	0.315	4.615	0.187	4.856	0.122	4.780	0.184	-0.692
1921-1940	0.527	4.602	0.236	4.809	0.110	4.700	0.214	-0.677
1941-1993*	0.140	4.542	0.086	4.855	0.125	4.811	0.162	-0.413
1941-1980	0.299	4.671	0.157	4.851	0.121	4.797	0.156	-0.428
1969-1993	0.216	4.634	0.100	4.923	0.102	4.861	0.157	-0.599
1981-1993	0.485	4.738	0.185	4.962	0.089	4.853	0.182	-0.742

Notes: MD = mixed distribution (μ_1 and σ_1 are mean and standard deviation of one component distribution; μ_2 and σ_2 of second distribution; and a is weight of first component distribution and 1-*a* of second component distribution)
LP3s = log-Pearson Type III distribution with sample skew (μ, σ, and g denote mean, standard deviation, and skew)
* = fifth window parameters (see general frequency program)

Table 20. Flood Frequency Analysis for Illinois River at Marseilles, Kingston Mines, and Meredosia

Record	*Observed Qntax*	*Method*	*Floods at various recurrence intervals, cfs* 2-year	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*
Illinois River at Marseilles									
1904-1993	94,100	MD	44,544	75,177	86,315	93,919	101,253	118,375	126,249
		LP3s	44,581	74,684	89,147	99,616	109,837	133,014	142,854
		LP3w	44,660	74,581	88,799	99,031	108,971	131,357	140,762
1904-1940	77,000	MD	36,102	59,153	69,010	75,860	82,407	96,967	103,082
		LP3s	36,131	58,647	69,811	78,061	86,262	105,420	113,799
		LP3w	36,796	57,841	67,090	73,489	79,516	92,455	97,669
1941-1993	94,100	MD	52,704	81,009	93,029	101,539	109,833	128,872	137,227
		LP3s	51,950	81,746	94,350	102,876	110,759	127,182	133,606
		LP3w	51,851	81,886	94,765	103,543	111,710	128,888	135,673
1941-1980	93,900	MD	49,783	75,244	87,198	95,879	104,392	123,992	132,446
		LP3s	49,910	76,041	86,504	93,383	99,601	112,112	116,843
		LP3w	49,584	76,503	87,838	95,504	102,592	117,381	123,177
1969-1993	94,100	MD	59,447	86,520	96,784	103,840	110,504	125,128	131,189
		LP3s	56,187	88,625	102,648	112,252	121,224	140,221	147,773
		LP3w	56,208	88,597	102,561	112,111	121,020	139,848	147,318
1981-1993	94,100	MD	64,512	92,830	103,945	111,630	118,922	134,966	141,619
		LP3s	60,430	96,566	110,788	119,985	128,169	144,192	150,070
		LP3w	59,245	98,376	116,068	128,440	140,179	165,612	175,939
			55,000	**84,200**	**96,000**	**105,000**	**113,000**	**131,000**	**137,000**

Table 20. Continued

Record	Observed Qmax	Method	*Floods at various recurrence intervals, cfs* 2-year	10-year	25-year	50-year	100-year	500-year	1000-year
<u>Illinois River at Kingston Mines</u>									
1941-1993	88,800	MD	48,862	73,025	80,617	85,925	91,268	105,454	112,726
		LP3s	48,126	73,910	84,927	92,445	99,450	114,245	120,117
		LP3w	48,162	73,864	84,787	92,217	99,124	113,654	119,398
1941-1980	83,100	MD	45,312	65,851	75,470	84,205	92,892	113,263	122,245
		LP3s	45,123	68,600	78,834	85,903	92,561	106,868	112,645
		LP3w	45,312	68,358	78,091	84,700	90,837	103,736	108,834
1969-1993	88,800	MD	58,849	78,498	85,487	90,168	94,539	103,881	107,667
		LP3s	54,922	81,483	91,548	97,977	103,653	114,670	118,687
		LP3w	54,200	82,510	94,452	102,546	110,050	125,773	131,965
1981-1993	88,800	MD	61,554	81,772	90,219	96,550	103,306	123,929	135,570
		LP3s	60,167	84,705	91,885	95,839	98,922	103,839	105,293
		LP3w	57,460	88,906	102,857	112,575	121,785	141,765	149,904
			52,200	**76,500**	**85,000**	**91,800**	**98,200**	**113,000**	**117,500**
<u>Illinois River at Meredosia</u>									
1921-1993	123,000	MD	63,998	97,815	112,800	123,509	133,974	157,894	168,260
		LP3s	63,284	99,501	113,289	122,048	129,730	144,433	149,706
		LP3w	62,826	100,241	115,302	125,178	134,069	151,804	158,438

Table 20. Concluded

Record	*Observed Qmax*	*Method*	*Floods at various recurrence intervals, cfs*						
			2-year	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*
1921-1940	105,000	MD	54,616	86,240	101,372	113,829	128,088	170,959	192,840
		LP3s	52,925	89,849	104,676	114,296	122,862	135,594	145,704
		LP3w	51,674	91,926	110,776	124,132	136,918	164,926	176,397
1941-1993	123,000	MD	67,546	100,900	116,003	126,834	137,384	161,378	171,668
		LP3s	66,442	102,411	117,628	127,946	137,511	157,539	165,419
		LP3w	66,409	102,457	117,764	128,163	137,820	158,091	166,086
1941-1980	123,000	MD	64,542	96,591	110,999	121,276	131,294	153,960	163,642
		LP3s	64,264	97,374	111,150	120,419	128,962	146,697	153,619
		LP3w	64,178	97,492	111,495	120,970	129,742	148,083	155,292
1969-1993	122,000	MD	77,206	109,420	122,983	132,468	141,529	161,675	170,109
		LP3s	75,201	111,883	125,952	134,998	143,030	158,753	164,536
		LP3w	74,319	113,126	129,495	140,590	150,875	172,425	180,912
1981-1993	122,000	MD	78,182	110,037	127,051	137,159	147,371	174,128	188,093
		LP3s	75,090	116,781	132,185	141,812	150,141	165,753	171,233
		LP3w	73,069	119,893	141,037	155,829	169,877	200,367	212,755
			71,000	**105,000**	**120,600**	**130,000**	**139,500**	**161,000**	**169,000**

Note: Numbers in bold type represent design T-year flood peaks.

Table 21. Record Periods, Outlier/Inlier Modifications, and Maximum Flood Peaks

Period		*Outlier/Inliers*			*Maximum Flood Peak, cfs*
Illinois River at Marseilles					
1904-1993	H1	94,100	→	98,097	94,100
1904-1940			none		77,000
1941-1993	H1	94,100	→	96,018	94,100
1941-1980	L2	19,300	→	19,568	93,900
1969-1993			none		94,100
1981-1993			none		94,100
Illinois River at Kingston Mines					
1941-1993			none		88,800
1941-1980			none		83,100
1969-1993			none		88,800
1981-1993			none		88,800
Illinois River at Meredosia					
1921-1993			none		123,000
1921-1940			none		105,000
1941-1993			none		123,000
1941-1980			none		123,000
1969-1993			none		122,000
1981-1993			none		122,000

Note: H1 is the highest flood and L2 is the second lowest flood during the record considered.

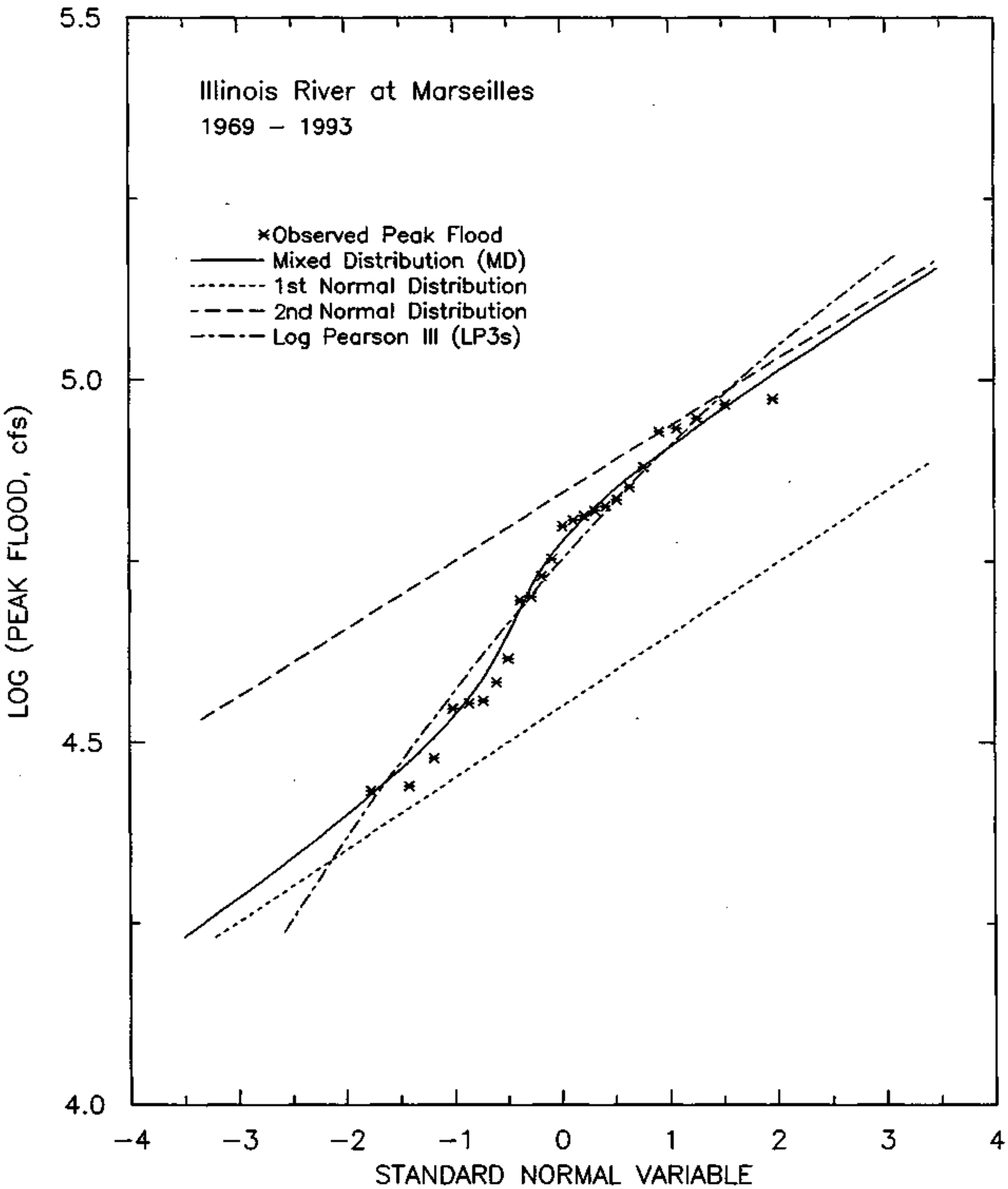


Figure 35. Fitted MD and LP3s distribution to annual maximum floods, Illinois River at Marseilles, 1969-1993

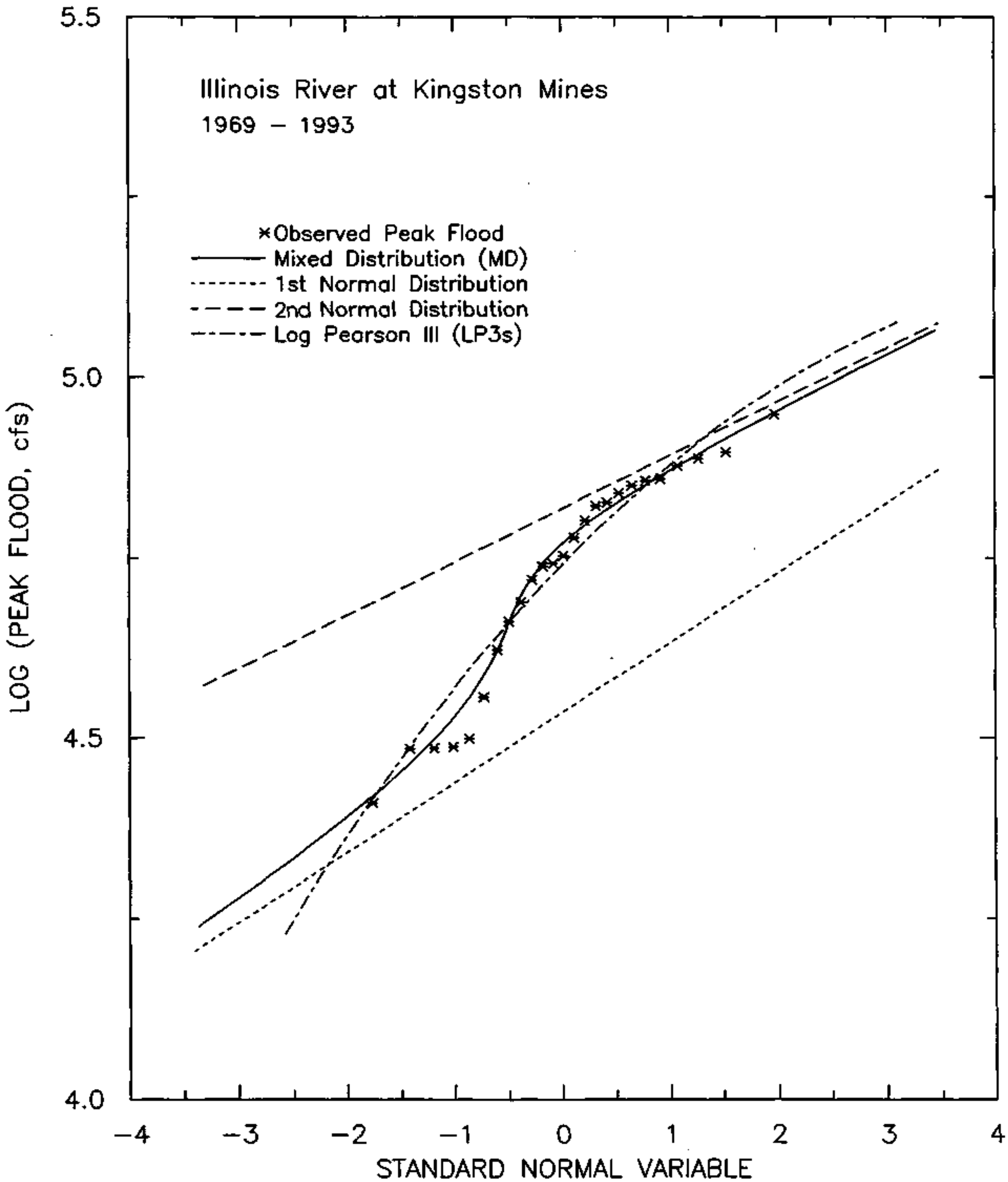


Figure 36. Fitted MD and LP3s distribution to annual maximum floods, Dlinois River at Kingston Mines, 1969-1993

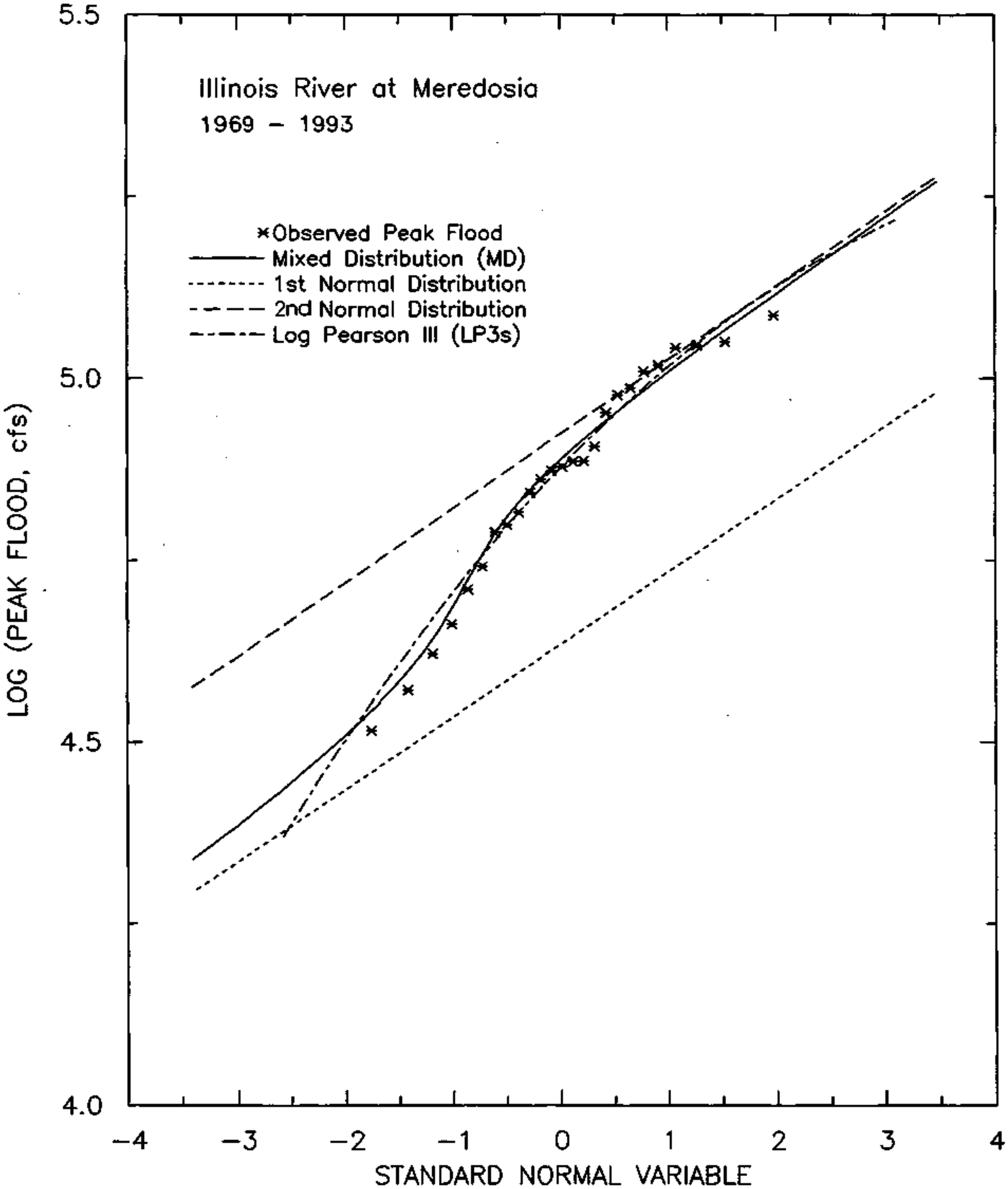


Figure 37. Fitted MD and LP3s distribution to annual maximum floods, Illinois River at Meredosia, 1969-1993

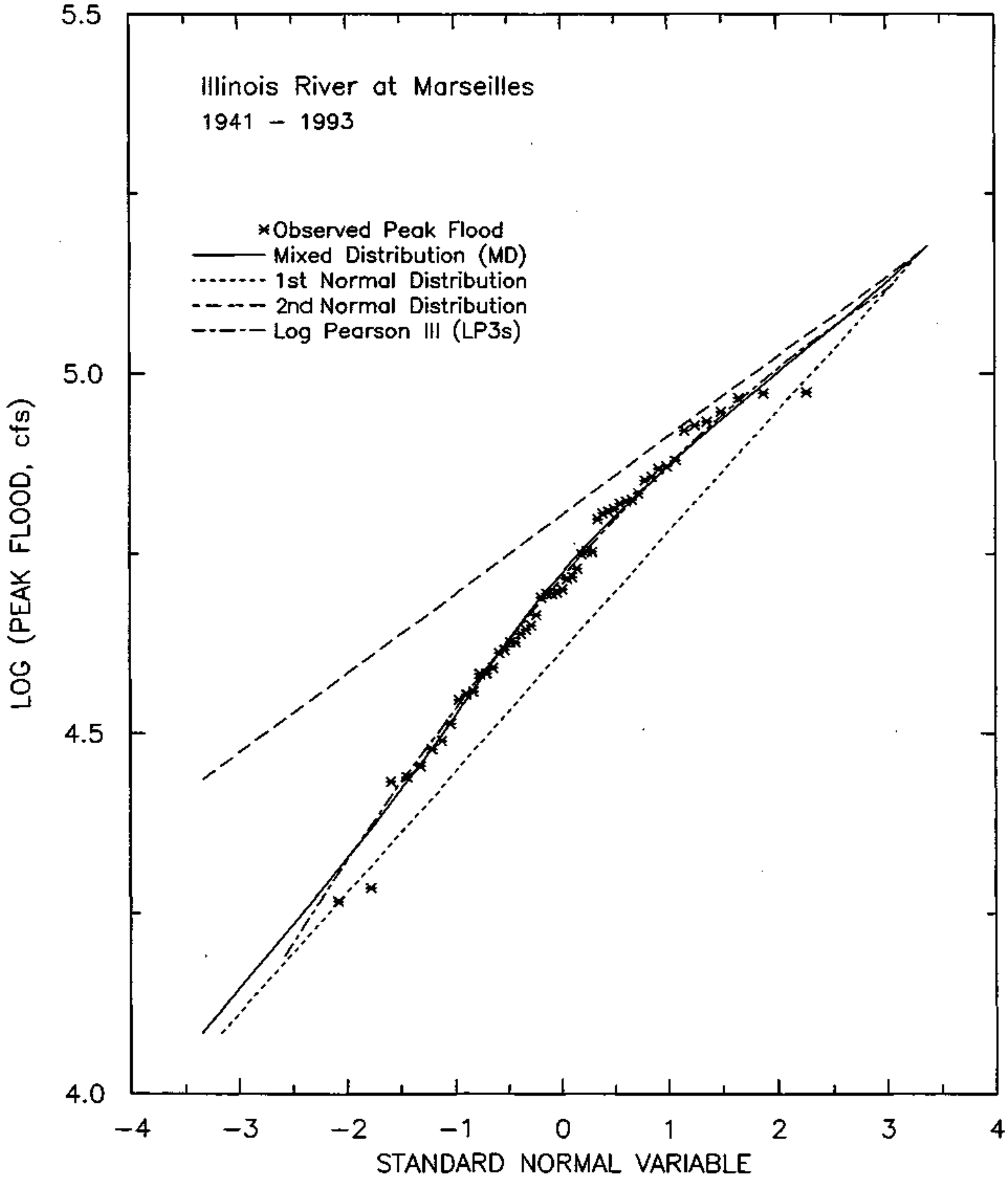


Figure 38. Fitted MD and LP3s distribution to annual maximum floods,
Illinois River at Marseilles, 1941-1993

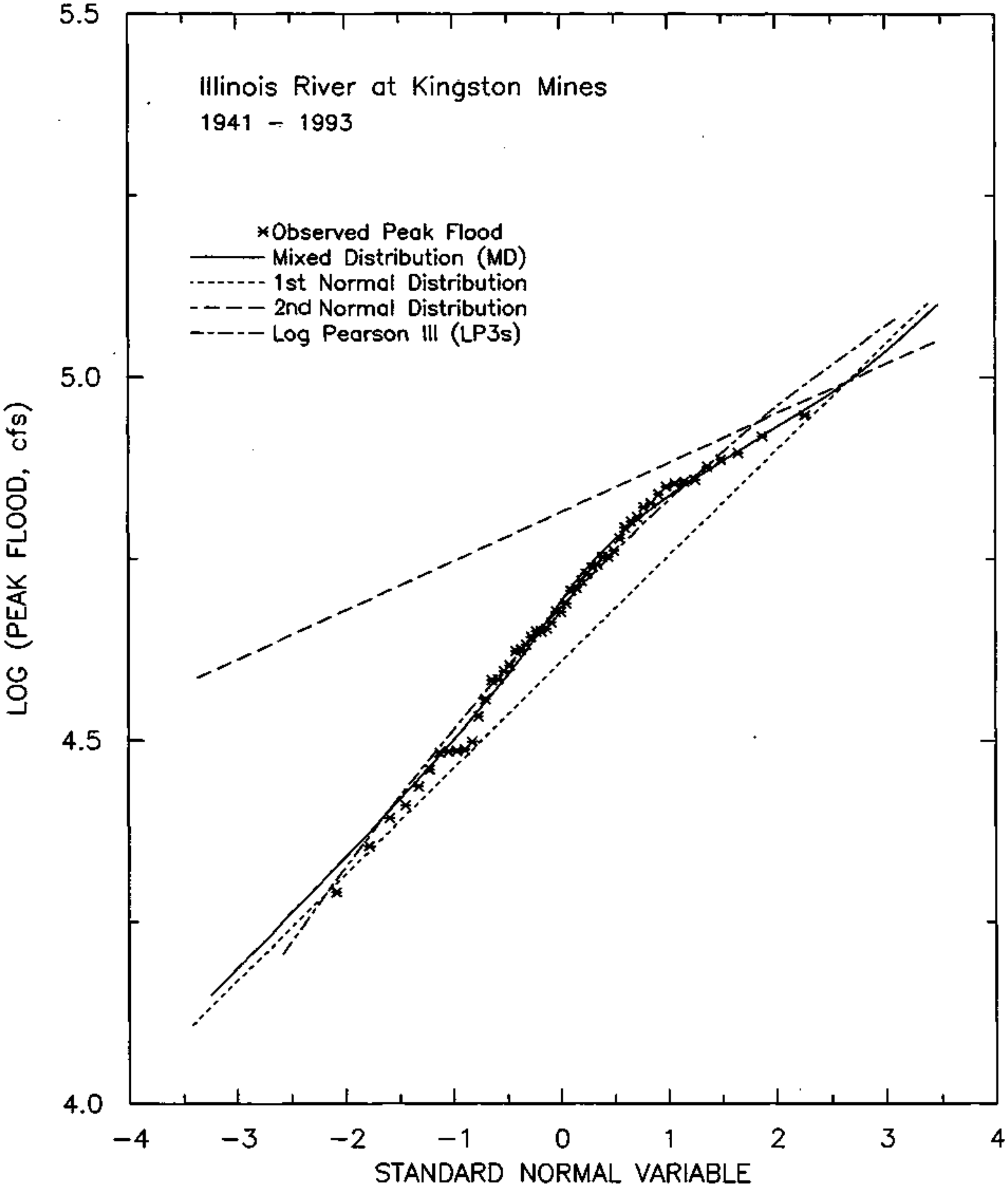


Figure 39 . Fitted MD and LP3s distribution to annual maximum floods, Illinois River at Kingston Mines, 1941-1993

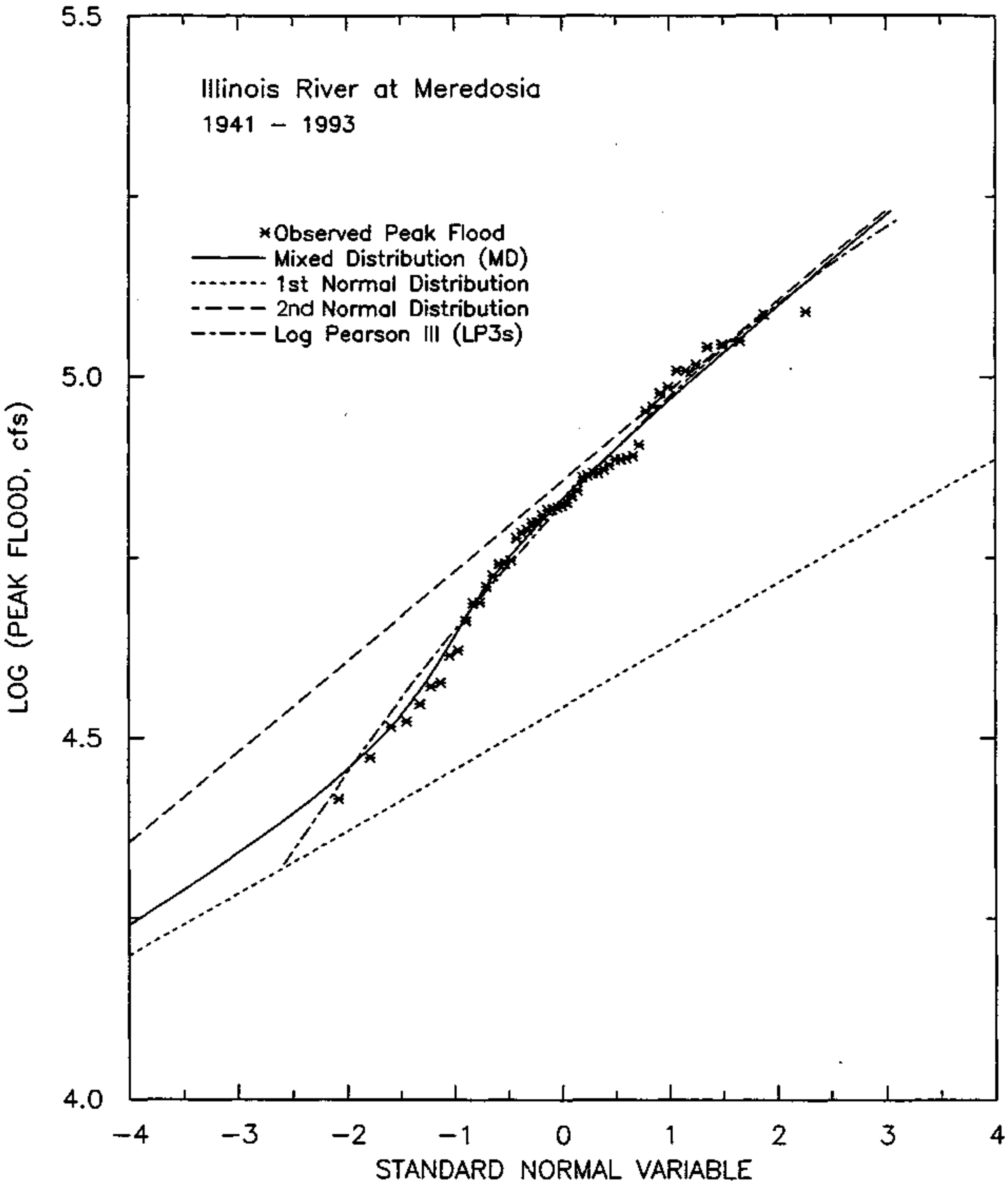


Figure 40. Fitted MD and LP3s distribution to annual maximum floods, Illinois River at Meredosia, 1941-1993

Figure 41 plots design peak floods at recurrence intervals of 2 to 1,000 years at Marseilles, Kingston Mines, and Meredosia. Similar T-year peak floods at Kingston Mines are significantly lower than at Marseilles, largely due to Peoria Lake flood surcharge storage capacity that lowers the flood peak but increases the number of days with high flows.

Stage Frequency and Design Stages

Annual peak stage data are available at Marseilles, Kingston Mines, and Meredosia for the 1941-1993 period. To investigate any time trends, the data were analyzed for the entire period and subperiods: 1941-1993,1941-1980, 1969-1993, and 1981-1993. The datum of the USGS gage at Marseilles is 462.91 ft-msl (feet above mean sea level), 428.00 ft-msl at Kingston Mines and 418.00 ft-msl at Meredosia.

The general frequency program was used to develop mixed and log-Pearson HI distribution parameters for the entire record as well as for subperiods. Table 22 shows the change in parameter values when different record lengths are used to fit stage frequency distributions to the observed data.

Table 23 gives the stage peaks derived with the fitted parameters for recurrence intervals of 2, 10, 25, 50, 100, 500, and 1,000 years for various record lengths at each station for mixed distribution and log-Pearson III distribution with sample skew (LP3s) and weighted skew (LP3w). The outlier/inlier detection and modification resulted in the following minor adjustments.

Station	*Record*	*Outliers/inliers*		*Maximum stage, feet*
Meredosia	1941-1993	H5	26.75 → 26.70	28.61
Meredosia	1941-1980	H3	26.75 → 26.66	28.61
Meredosia	1969-1993	H1	27.62 → 28.12	27.62
Kingston Mines	1941-1993	H5	24.28 → 24.03	26.02

Note: H1 denotes the highest stage, H2 the second highest stage, and so on for a particular record; no outliers/inliers detected in the Marseilles stage records

Design T-year stages are given in bold in Table 23. Corresponding water surface elevations above mean sea level (feet-msl) are also given. Figures 42 and 43 plot design peak stages and water elevations at recurrence intervals of 2 to 1,000 years at Marseilles, Kingston

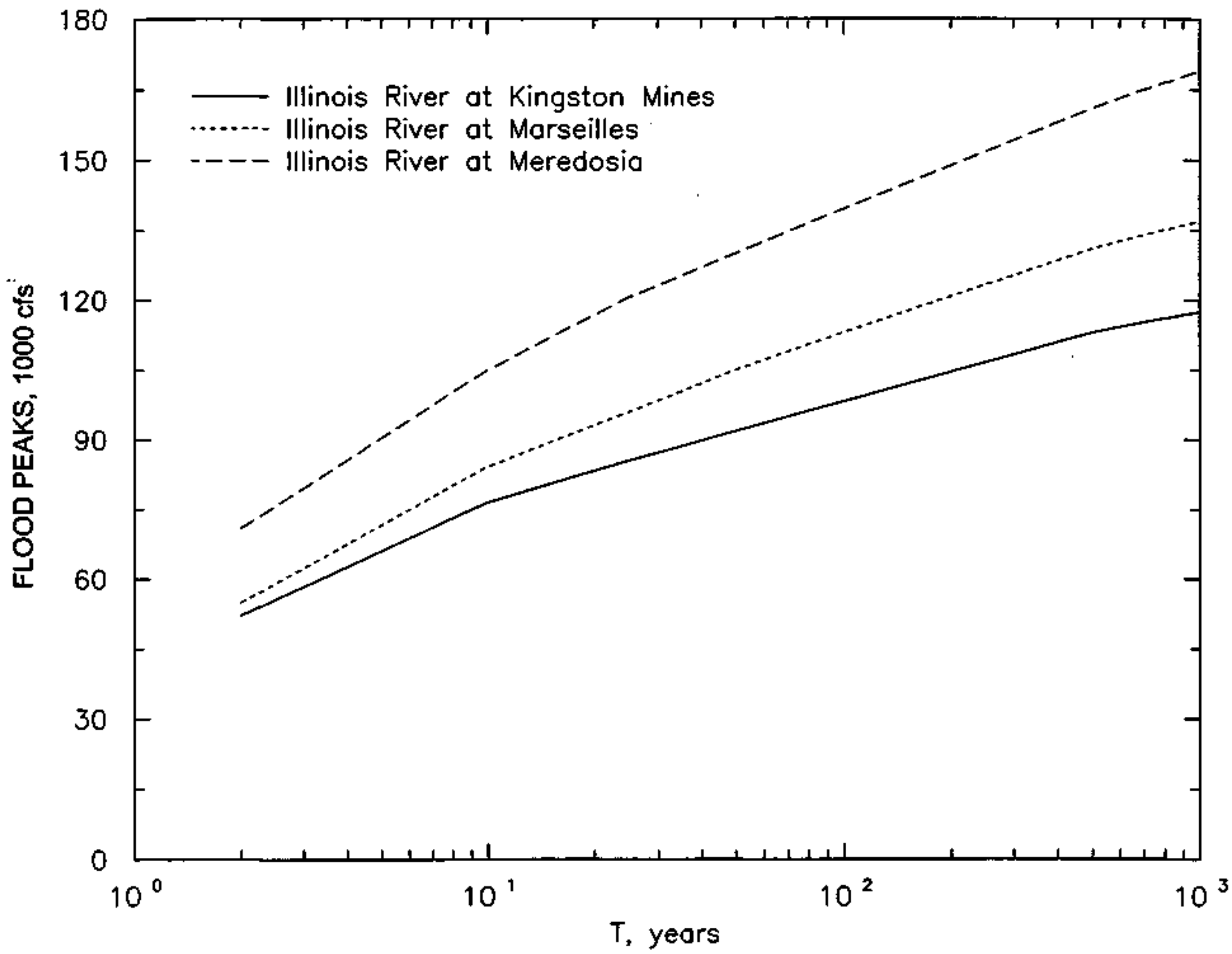


Figure 41. T-year flood peaks for Illinois River at Marseilles, Kingston Mines, and Meredosia

Table 22. Fitted Mixed Distribution (MD) and Log-Pearson HI Distribution (LP3s) Parameters for Peak Stages

	MD parameters					*LP3s parameters*		
Period	*a*	μ_1	σ_1	μ_2	σ_2	μ	*a*	*g*
Dlinois River at Meredosia								
1941-1993	0.131	1.041	0.072	1.292	0.089	1.259	0.122	-0.606
1941-1980	0.255	1.112	0.105	1.292	0.079	1.246	0.116	-0.657
1969-1993	0.250	1.175	0.111	1.337	0.084	1.296	0.115	-0.593
1981-1993	0.181	1.069	0.083	1.350	0.078	1.299	0.134	-0.916
Dlinois River at Kingston Mines								
1941-1993	0.859	1.258	0.080	1.189	0.122	1.248	0.090	-0.353
1941-1980	0.913	1.240	0.079	1.180	0.145	1.235	0.088	-0.341
1969-1993	0.908	1.294	0.072	1.107	0.005	1.277	0.088	-0.299
1981-1993	0.829	1.318	0.061	1.147	0.058	1.288	0.088	-0.613
Illinois River at Marseilles								
1941-1993	0.449	0.918	0.128	1.084	0.078	1.009	0.132	-0.604
1941-1980	0.288	0.869	0.128	1.045	0.082	0.994	0.126	-0.753
1969-1993	0.313	0.874	0.078	1.109	0.072	1.036	0.132	-0.520
1981-1993	0.596	0.981	0.141	1.167	0.038	1.056	0.146	-0.741

Notes:

MD = mixed distribution (μ_1 and σ_1 are mean and standard deviation of one component distribution; μ_2 and σ_2 of second component distribution; and *a* is weight of first component distribution and 1-*a* of second component distribution)

LP3s = Log-Pearson Type IE distribution with sample skew (μ, σ, and *g* denote mean, standard deviation, and skew)

Table 23. Stage Frequency Analysis for Illinois River at Marseilles, Kingston Mines, and Meredosia

Record	*Observed max. stage*	*Method*	*Stages at various recurrence intervals, feet* 2-year	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*
Illinois River at Marseilles									
1941-1993	16.78	MD	10.73	14.52	15.99	17.00	17.95	20.07	20.97
		LP3s	10.53	14.72	16.27	17.25	18.11	19.76	20.36
		LP3w	10.46	14.82	16.52	17.63	18.64	20.66	21.43
1941-1980	15.20	MD	10.31	13.68	15.05	16.00	16.89	18.86	19.67
		LP3s	10.23	13.86	15.09	15.83	16.46	17.61	18.00
		LP3w	10.09	14.05	15.58	16.59	17.49	19.30	19.99
1969-1993	16.78	MD	11.64	15.31	16.68	17.60	18.47	20.32	21.08
		LP3s	11.14	15.68	17.41	18.53	19.54	21.53	22.27
		LP3w	11.07	15.76	17.66	18.92	20.08	22.46	23.39
1981-1993	16.78	MD	12.73	16.04	17.12	18.08	19.43	23.51	25.31
		LP3s	11.85	16.90	18.67	19.73	20.68	22.39	22.98
		LP3w	11.60	17.26	19.66	21.30	22.82	26.06	27.34
		Design stages, ft	**11.13**	**14.96**	**16.40**	**17.52**	**18.25**	**20.14**	**20.95**
		Design water elevation, ft-msl	**474.04**	**477.87**	**479.31**	**480.43**	**481.16**	**483.05**	**483.86**
Illinois River at Kingston Mines									
1941-1993	26.02	MD	17.83	22.84	25.00	26.52	28.00	31.38	32.88
		LP3s	17.92	22.90	24.81	26.06	27.19	29.49	30.38
		LP3w	17.94	22.88	24.75	25.97	27.07	29.28	30.12

Table 23. Continued

Record	Observed max. stage	Method	Stages at various recurrence intervals, feet 2-year	10-year	25-year	50-year	100-year	500-year	1000-year
1941-1980	26.02	MD	17.27	22.01	24.11	25.62	27.15	31.09	33.18
		LP3s	17.38	22.10	23.92	25.11	26.19	28.38	29.22
		LP3w	17.41	22.07	23.83	24.97	26.00	28.06	28.84
1969-1993	25.55	MD	19.26	24.13	26.14	27.52	28.82	31.63	32.79
		LP3s	19.10	24.31	26.35	27.69	28.91	31.43	32.41
		LP3w	19.17	24.24	26.15	27.38	28.48	30.69	31.52
1981-1993	25.55	MD	20.04	24.53	26.29	27.48	28.59	30.96	31.92
		LP3s	19.84	24.78	26.47	27.50	28.40	30.08	30.68
		LP3w	19.67	24.97	26.98	28.30	29.48	31.88	32.79
		Design stages, ft	**18.50**	**23.40**	**25.50**	**26.90**	**28.05**	**31.10**	**32.50**
		Design water elevation, ft msl	**446.50**	**451.40**	**453.50**	**454.90**	**456.05**	**459.10**	**460.50**
Illinois River at Meredosia									
1941-1993	28.61	MD	18.84	25.08	27.71	29.55	31.28	35.11	36.70
		LP3s	18.68	25.42	27.85	29.38	30.72	33.29	34.21
		LP3w	18.57	25.56	28.25	29.99	31.56	34.70	35.88
1941-1980	28.61	MD	18.31	24.00	26.29	27.86	29.34	32.51	33.85
		LP3s	18.15	24.25	26.39	27.71	28.85	30.98	31.74
		LP3w	17.98	24.47	26.96	28.59	30.05	33.00	34.11

Table 23. Concluded

Record	*Observed max. stage*	*Method*	*Stages at various recurrence intervals, feet*						
			2-year	*10-year*	*25-year*	*50-year*	*100-year*	*500-year*	*1000-year*
1969-1993	27.62	MD	20.37	26.96	29.68	31.55	33.32	37.17	38.77
		LP3s	20.31	27.17	29.64	31.19	32.55	35.15	36.09
		LP3w	20.14	27.39	30.23	32.11	33.81	37.28	38 61
1981-1993	27.62	MD	21.27	27.57	30.12	31.86	33.50	37.07	38.54
		LP3s	20.85	28.31	30.64	31.98	33.07	34.93	35.52
		LP3w	20.23	29.19	32.95	35.51	37.90	42.94	44.95
		Design stages, ft	**19.50**	**25.82**	**28.38**	**30.08**	**31.55**	**34.76**	**36.05**
		Design water elevation, ft msl	**437.50**	**443.82**	**446.38**	**448.08**	**449.55**	**452.76**	**454.05**

Note: Numbers in bold type represent design T-year stages.

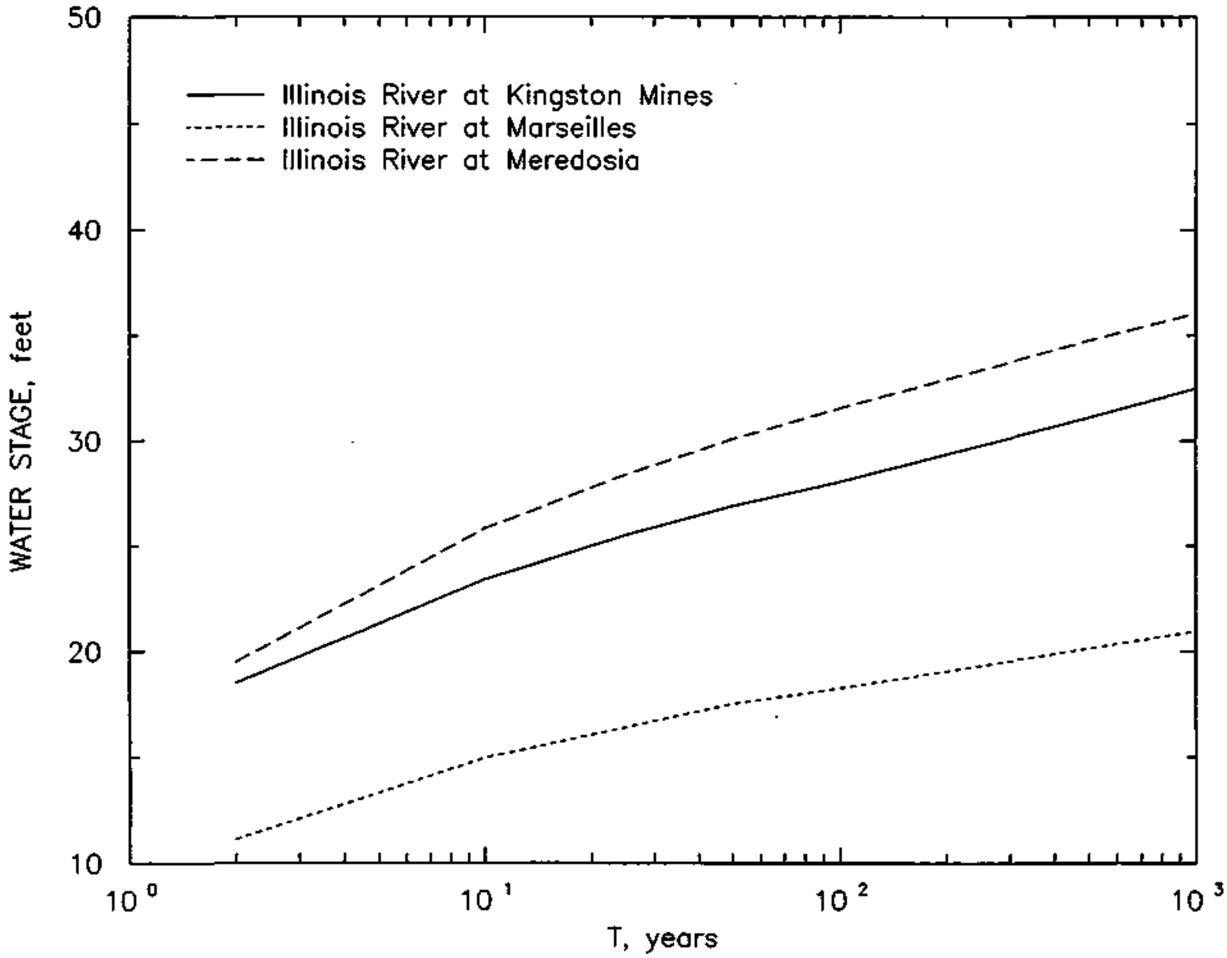


Figure 42. T-year stages for Illinois River at Marseilles, Kingston Mines, and Meredosia

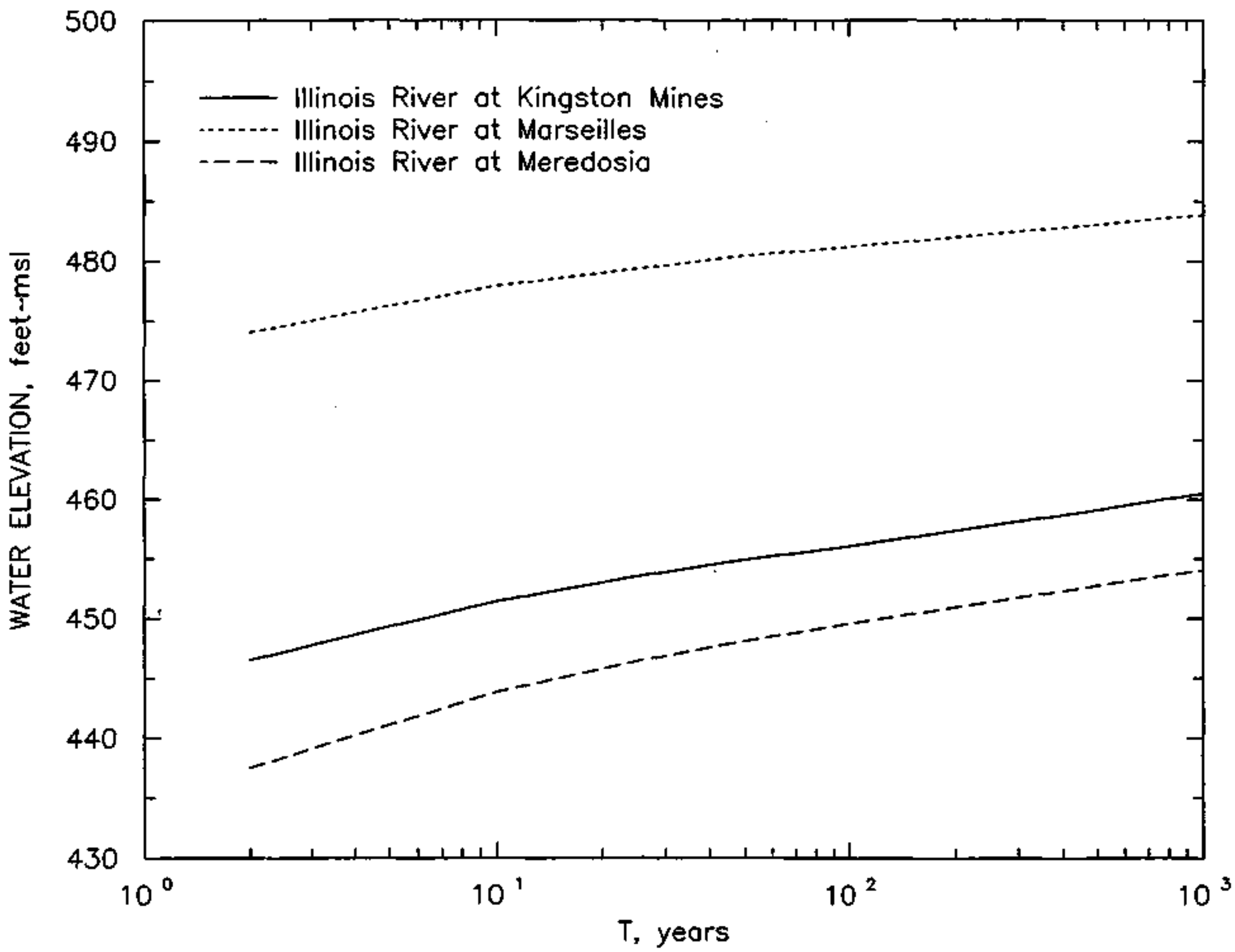


Figure 43. T-year water elevations for Illinois River at Marseilles, Kingston Mines, and Meredosia

Mines, and Meredosia. Design elevations at Meredosia are 0.78 to 1.00 feet higher than those derived in the chapter on "Water Stages and Elevations in Alton Pool, Illinois River," for the 1941-1993 record because of the consideration of time trends in increasing stages.

Concurrency of Tributary and Illinois River Flood Peaks

Table 24 provides the USGS streamgaging stations starting from the Illinois River at Marseilles downstream to Grafton and stations (nearest to Illinois River) on major tributaries entering the river in this reach. It includes information on USGS station number, length of historical record of daily flows, drainage area in square miles, tributary station distance upstream of confluence with the Illinois River, drainage area of tributaries at their mouth, and Dlinois River miles for stations along the river (Marseilles, Kingston Mines, and Meredosia) and at the confluence of tributaries with the river. Only annual peak flow data are available for the period 1957-1988 for the Mackinaw River near Green Valley. Consequently, daily flow hydrographs for this period cannot be developed.

Table 25 provides annual flood peaks and dates of occurrence for 1941-1993 record ten highest peak flood events (ranked 1 to 10 in descending order of magnitude) for the Illinois River at Meredosia. Flood ranks, magnitudes, and dates of occurrence at other stations in corresponding years are also included. To consider concurrency of tributary and Illinois River flood peaks, the lag time in days between stations, and the effect of Peoria Lake, flood data and available daily flow data were analyzed and evaluated in terms of two reaches: Marseilles to Kingston Mines and Kingston Mines to Meredosia.

In the Marseilles to Kingston Mine reach, the Fox River at Dayton is 5.3 miles upstream of the Illinois River, and the confluence is only 6.9 miles below the Marseilles gage. For all practical purposes, the lag between these flows is negligible. The Vermilion River near Lenore is 17.2 miles upstream of confluence and 20.2 miles downstream of the Marseilles gage. Travel times to the confluence will not be significantly different. Peoria Lake stretches from about mile 182 to 162 (starting 64.5 miles downstream of the Marseilles gage), about 44 miles below the confluence of the Vermilion and Illinois Rivers. This may introduce a lag of one or two days during flood conditions. Travel through Peoria Lake includes both translation and attenuation of the flood peak. However, when the crest of the

Table 24. Relevant Data for the Illinois River and Major Tributaries below Marseilles

Tributary	*USGS station no.*	*Historical record*	*Drainage area (sq mi)*	*Upstream of mouth (mi)*	*Drainage area at mouth (sq mi)*	*River mile*
Illinois River at Marseilles	05543500	1920-1993	8259			246.5
Fox River at Dayton	05552500	1916-1993	2642	5.3	2658	239.6
Vermilion River						
near Leonore	05555300	1972-1993	1251	17.2	1331	226.3
at Lowell	05555000	1932-1971	1278	10.5	1331	226.3
Mackinaw River near Green Valley	05568000	1922-1956 1957-1988* 1989-1993	1073	17.3	1136	147.7
Illinois River at Kingston Mines	05568500	1940-1993	15818			144.4
Spoon River at Seville	05570000	1919-1993	1636	38.7	1855	120.4
Sangamon River near Oakford	05583000	1931-1993	5093	25.7	5419	88.9
LaMoine River at Ripley	05585000	1921-1993	1293	12.3	1350	83.5
Illinois River						
at Meredosia	05585500	1939-1989	26028			71.3
at Valley City	05586100	1990-1993	26742			61.4
Macoupin Creek near Kane	05587000	1941-1993	868	16.1	961	23.2

Note: An asterisk denotes data for annual maximum peak flow only.

Table 25. Peak Floods in the Illinois River and Major Tributaries below Marseilles

///. River

Ill. River Kingston Peoria Ill . River

	Macoupin	*Meredosia*	*La Moine*	*Sangamon*	*Spoon*	*Mines*	*Mackinaw*	*Lake*	*Vermilion*	*Fox*	*Marseilles*
Rank	1	1	18	1	28	2	11		10	38	10
Q_p	40,000	123,000	14,500	123,000	12,900	83,100	18,200		21,400	10,600	73,800
Date	5/18/43	5/26/43	5/21/43	5/20/43	5/20/43	5/23/43	5/19/43		5/21/43	5/21/43	5/21/43
Rank	10	2	1	21	3	3	10		18	4	6
Q_p	19,400	122,000	28,800	26,500	29,200	78,800	18,400		18,500	28,400	84,800
Date	2/24/85	3/10/85	3/7/85	2/25/85	3/6/85	3/6/85	2/25/85		2/25/85	3/5/85	2/24/85
Rank	3	3	6	2	9	1	1		2	6	1
Q_p	26,700	112,000	21,000	68,700	21,000	88,800	51,000		31,800	26,000	94,100
Date	12/4/82	12/12/82	12/5/82	12/5/82	4/4/83	12/7/82	12/6/82		12/4/82	12/3/82	12/4/82
Rank	2	4	34	3	30	6	6		12	2	12
Q_p	27,800	111,000	8,120	55,900	12,600	72,300	23,600		21,200	29,800	71,100
Date	4/12/79	4/19/79	4/12/79	4/15/79	3/31/79	3/24/79	3/5/79		3/5/79	3/20/79	3/20/79
Rank	22	5	29	6	1	7	30		19	5	19
Q_p	12,800	110,000	10,000	42,900	36,400	71,900	7,910		17,400	26,800	64,000
Date	1/21/74	6/29/74	6/2/74	6/25/74	6/24/74	5/25/74	6/5/74		6/23/74	5/17/74	5/22/74
Rank	31	6	28	29	17	4	8		8	25	8
Q_p	9,140	104,000	10,700	23,700	16,900	77,200	20,000		23,000	14,800	75,800
Date	2/21/82	3/24/82	3/16/82	3/20/82	7/21/82	3/22/82	3/12/82		4/13/82	3/13/82	3/14/82
Rank	20	7	22	4	21	14	4		21	11	17
Q_p	13,300	102,000	12,400	45,800	16,000	63,300	29,700		16,500	18,300	64,900
Date	4/23/73	5/2/73	4/22/73	4/25/73	4/24/73	4/25/73	4/21/73		12/31/72	4/23/73	1/1/73

Table 25. Concluded

	Macoupin	*Ill. River Meredosia*	*La Moine*	*Sangamon*	*Spoon*	*Ill. River Kingston Mines*	*Mackinaw*	*Peoria Lake*	*Vermilion*	*Fox*	*Ill. River Marseilles*
Rank	4	8	9	5	18	13	5		9	13	23
Q_p	25,400	102,000	17,100	44,700	16,600	64,200	26,400		22,300	18,000	56,100
Date	4/24/44	4/29/44	4/25/44	4/26/44	3/17/44	4/26/44	4/24/44		4/24/44	3/5/44	4/24/44
Rank	24	9	5	19	23	11	9		15	12	13
Q_P	12,100	96,800	22,000	28,400	15,000	67,100	19,200		20,200	18,100	68,300
Date	12/12/85	11/27/85	11/19/85	11/25/85	11/20/85	11/12/85	11/21/85		11/19/85	11/10/85	11/20/85
Rank	8	10	3	7	5	5	33		4	15	3
Q_P	20,100	94,800	24,100	42,300	23,700	75,400	7,000		24,800	17,000	92,500
Date	10/14/69	5/22/70	9/27/70	5/3/70	5/17/70	5/18/70	9/22/70		5/15/70	6/3/70	5/15/70

Note: Q_p denotes the peak flood in cubic feet per second (cfs) inflow flood hydrograph covers many days, attenuation of the flood peak is mostly attributable to lake surcharge storage and the translation time causing lag between inflow and outflow flood peaks may be a day or two depending on the flood magnitude. The Mackinaw River near Green Valley is 17.3 miles upstream of the Illinois River confluence, which is about 14 miles below Peoria Lake and 3.3 miles upstream of the Kingston Mines gage. It may take a day or less for floods in Mackinaw River near Green Valley to travel to the confluence. Travel time from Marseilles to Kingston Mines, a distance of 81 miles excluding Peoria Lake, may be two to three days during high flood conditions plus a lag of one to two days caused by Peoria Lake. Thus, the total travel time or lag from Marseilles to Kingston Mines may be three to five days during major floods.

In the Kingston Mines to Meredosia reach, the first confluence is with the Spoon River at river mile 120.4, or 24 miles downstream of Kingston Mines. During flood flows, it may take 12 to 24 hours to travel this distance. The Spoon River at Seville is 38.7 miles upstream of the Illinois River, and it may take a day or more for the flood to travel from Seville to the Illinois River. The next confluence is with the Sangamon River at river mile 88.9, a distance of 31.5 miles that may entail lags of about one day during flood conditions. The Sangamon River at Oakford is 25.7 miles upstream of its mouth, and the flood may take about a day to reach the confluence. The LaMoine River meets the Illinois River atriver mile 83.5, only 5.4 miles below the confluence of the Illinois and Sangamon Rivers. The LaMoine River at Ripley is only 12.3 miles upstream of its mouth at the Illinois River. The Meredosia station is at river mile 71.3. Lag time from Kingston Mines to Meredosia may range from two to four days during high flood episodes. When the two reaches are combined, flood flows from Marseilles may take five to nine days to reach Meredosia.

Concurrency and the other effects are discussed below for the top five floods at Meredosia. Table 26 provides daily flow peak or $\overline{Q}_p$ values at the gaging stations along the Illinois River and major tributaries entering the river between Marseilles and Meredosia. The $\overline{Q}_p$ denotes the maximum daily peak flow. The lag or the number of days $\overline{Q}_p$ occurs at a station upstream before $\overline{Q}_p$ occurs at Meredosia are also included together with the dates on which $\overline{Q}_p$ occurred. Values of $t_1(t_2)$ and $t_3(t_4)$ for the daily flow hydrograph at each station are also shown.

Table 26. Relevant Information for Top Five Floods: Marseilles to Meredosia

Meredosia rank	*Item*	*Meredosia*	*LaMoine*	*Sangamon*	*Spoon*	*Kingston Mines*	*Peoria Lake*	*Vermilion*	*Fox*	*Marseilles*
1	$\overline{Q}_p$	123,000	14,200	120,000	10,600	82,200		19,900	9,960	70,700
	Date	5/27/43	5/21/43	5/20/43	5/20/43	5/23/43		5/21/43	5/21/43	5/21/43
	Lag		6	7	7	4		6	6	6
	$t_1(t_2)$	11(6)	2(1)	1(1)	2(2)	3(2)		1(1)	1(1)	2(1)
	$t_3(t_4)$	15(7)	5(4)	2(1)	2(2)	10(5)		1(1)	1(1)	3(2)
2	$\overline{Q}_p$	120,000	26,800	25,900	27,800	77,800		13,000*	24,000	70,300*
	Date	3/10/85	3/7/85	2/25/85	3/6/85	3/6/85		3/5/85	3/5/85	3/5/85
	Lag		3	13	4	4		5	5	5
	$t_1(t_2)$	10(3,4,6)	1(1)	6(1)	1(1)	4(2)		1(1)	2(2)	1(1)
	$t_3(t_4)$	16(6,7,9)	2(2)	11(2)	2(1)	8(3)		1(1)	2(2)	2(1)
	$\overline{Q}_p$							17,000		77,000
	Date							2/25/85		2/24/85
	Lag							13		14
	$t_1 (t_2)$							1(1)		2(1)
	$t_3 (t_4)$							1(1)		2(1)
3	$\overline{Q}_p$	112,000	19,000	63,200	19,100	86,700		30,000	22,800	87,800
	Date	12/12/82	12/6/82	12/5/82	12/5/82	12/7/82		12/4/82	12/3/82	12/4/82
	Lag		6	7	7	5		8	9	8
	$t_1(t_2)$	5(4)+2	1(1)	2(1)	1(1)	4(2)		1(1)	1(1)	2(1)
	$t_3(t_4)$	12(4)	2(1)	2(1)	2(2)	6(2)		2(1)	2(1)	3(1)
4	$\overline{Q}_p$	109,000	7,460	54,200	10,300*	65,500*		16,400	17,000*	62,700*
	Date	4/19/79	4/12/79	4/15/79	4/8/79	4/15/79		4/13/79	4/12/79	4/13/79
	Lag		7	4	6	4		6	7	6
	$t_1(t_2)$	6(2)	5(1)	2(1)	2(1)	3(2)		2(2)	1(1)	1(1)

Table 26. Concluded

Meredosia rank	*Item*	*Meredosia*	*LaMoine*	*Sangamon*	*Spoon*	*Kingston Mines*	*Peoria Lake*	*Vermilion*	*Fox*	*Marseilles*
	$t_3(t_4)$	10(3)	5(1)	4(2)	3(2)	7(3)		2(2)	2(1)	1(1)
	$\bar{Q}_p$				12,100	72,200			28,900	68,500
	Date				3/31/79	3/24/79			3/20/79	3/20/79
	Lag				19	26			27	30
	$t_1(t_2)$				2(1)	15(5)			2(1)	1(1)
	$t_3(t_4)$				3(1)	21(7)			2(1)	2(1)
5	$\bar{Q}_p$	110,000	6,230*	42,800	32,700	69,800*		16,200	10,400*	34,600*
	Date	6/29/74	6/26/74	6/25/74	6/24/74	6/24/74		6/23/74	6/23/74	6/23/74
	Lag		3	4	5	5		6	6	6
	$t_1(t_2)$	6(3)	2(2)	1(1)	2(1)	3(2)		1(1)	1(1)	2(1)
	$t_3(t_4)$	10(5)	3(2)	3(2)	2(1)	4(2)		1(1)	2(2)	2(1)
	$\bar{Q}_p$		9,860			71,900			21,600	57,800
	Date		6/2/74			5/25/74			5/17/74	5/23/74
	Lag		27			35			43	37
	$t_1(t_2)$		2(2)			7(5)			2(1)	2(2)
	$t_3(t_4)$		4(3)			10(6)			2(1)	2(2)

Notes: * = relevant daily flow peak from a nearby hydrograph

$\bar{Q}_p$ = daily flow peak, in cfs, in a water year October to September

t_1 = number of days daily flow > 0.9 $\bar{Q}_p$

t_2 = number of day with $\bar{Q}_p$ in t_1 period

t_3 = number of days with daily flow > 0.8 $\bar{Q}_p$

t_4 = number of day with $\bar{Q}_p$ in t_3 period

Lag = date of $\bar{Q}_p$ at Meredosia - date of $\bar{Q}_p$ at station under consideration

t_1 = number of days daily flow > 0.9 $\overline{Q}_p$

t_2 = number of day in the t_1 period when $\overline{Q}_p$ occurs. There can be more than one value of t_2 if more than 1 day have the same $\overline{Q}_p$

t_3 = number of days daily flow > 0.8 $\overline{Q}_p$

t_4 = number of day in the t_3 period when $\overline{Q}_p$ occurs. There can be more than one value of t_4 if more than one day has the same $\overline{Q}_p$

When $\overline{Q}_p$ at a tributary station, Kingston Mines or Marseilles, occurred much earlier or much later than at Meredosia, another relevant value from a somewhat lower flood rise was used. This occurred during multiple peak hydrographs.

1. *Flood of May 1943.* Daily flow peak or $\overline{Q}_p$ (123,000 cfs) at Meredosia occurred on May 27, 1943. Such flows occurred at Kingston Mines (82,200 cfs) and at the Sangamon River at Oakford (120,000 cfs) on May 23 and May 20, respectively, or four days and seven days prior to the peak flow at Meredosia. The confluence of the Sangamon and Illinois Rivers is 55.5 miles downstream of Kingston Mines and only 17.6 miles upstream of Meredosia. Allowing for a day or less of travel time from Oakford to the confluence, if the peak flow had occurred May 23 or 24 at Oakford (so that flood peaks in the Illinois River and the Sangamon River are practically concurrent), the peak at Meredosia would have probably been 150,000 cfs or more, but the crest segment of the flood hydrograph would have been about two-thirds the width. Nonconcurrent peak flow contributions, particularly from the Kingston gage and the Sangamon River (and to a lesser extent from the Spoon and LaMoine Rivers) results in an attenuated and wider crest of the flood hydrograph at Meredosia. Hydrographs at various stations are shown in Figure 44, for which day 1 starts on May 11, 1943.

From Marseilles to Kingston Mines, daily flow peaks occurred at Marseilles, in the Fox and Vermilion Rivers, and at Kingston Mines on May 21, May 21, May 21, and May 23, respectively. The double-peak hydrograph at Marseilles, combined with those from the Fox and Vermilion Rivers, was modified by Peoria Lake. A daily flow peak of 16,300 cfs occurred on May 19 in the Mackinaw River near Green Valley, and it caused a minor peak

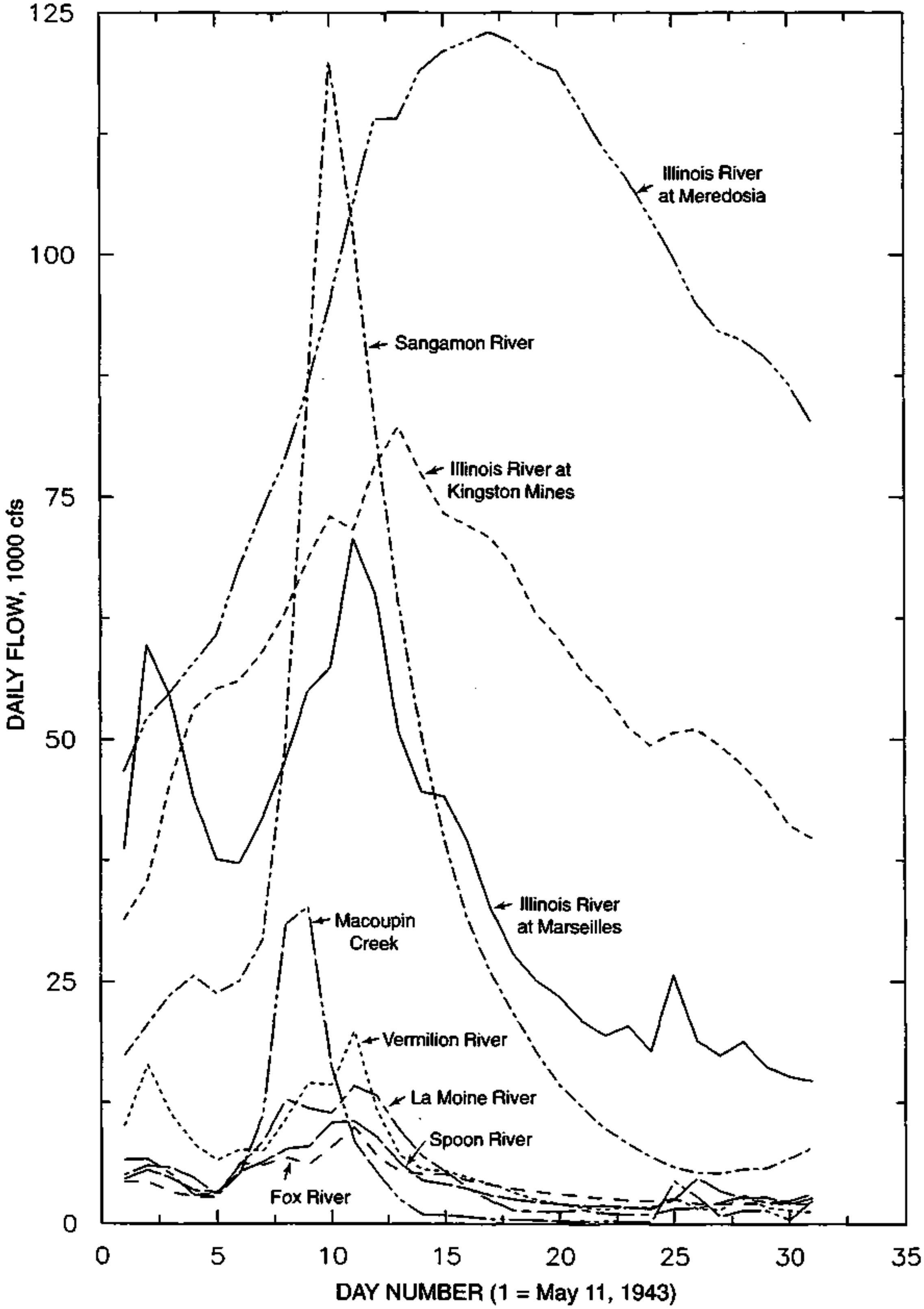


Figure 44. Flood hydrographs at Illinois River and tributary gaging stations, May 1943 flood

(73,000 cfs) in the daily flow hydrograph at Kingston Mines on May 20 followed by a $\bar{Q}_p$ of 82,200 cfs on May 23.

2. *Flood of March 1985.* The $\bar{Q}_p$ of 120,000 cfs at Meredosia occurred on March 10, 1985, and that at Kingston Mines (77,800 cfs) occurred on March 6, or four days earlier than at Meredosia. This time difference or lag is the same as for the May 1943 flood. The Spoon, Sangamon, and LaMoine River daily flow peaks have ranks of 3, 21, and 1, respectively, in the 1941-1993 record. The daily flow at Oakford exceeded 21,060 cfs from February 24 to March 6, with one peak of 25,900 cfs on February 25 and another of 23,400 cfs on March 5. Thus the flood peaks at Kingston Mines and in the Spoon, Sangamon, and LaMoine Rivers are rather in phase timewise, and produced a second high $\bar{Q}_p$ at Meredosia. A very flat crest segment of the Sangamon River flow hydrograph significantly increased the width of the crest segment at Meredosia.

From Marseilles to Kingston Mines, values of concurrent $\bar{Q}_p$ (or close in value to actual $\bar{Q}_p$) occurred March 5 at Marseilles and March 6 at Kingston Mines. The hydrograph at Kingston Mines (Figure 45) was significantly affected by the distinctly double-peak hydrograph at Marseilles, though the time difference between the two peaks of Marseilles hydrograph was significantly reduced by the flood flow passing through Peoria Lake on the way to Kingston Mines.

3. *Flood of December 1982.* The $\bar{Q}_p$ of 112,000 cfs at Meredosia occurred on December 12, 1982, and that at Kingston Mines (86,700 cfs) occurred on December 7, i.e., five days earlier than at Meredosia. Flood peaks on the Spoon, Sangamon, and LaMoine Rivers have ranks of 9, 2, and 6, respectively, in the 1941-1993 record, and corresponding $\bar{Q}_p$ values occurred on December 5, 5, and 6, all a day or two earlier than at Kingston Mines. Allowing for travel time for these tributary flows and flow at Kingston Mines, the daily flow hydrograph at Meredosia shows a double peak. The fir $\bar{Q}_p$ of 112,000 cfs occurred on December 12, followed by another $\bar{Q}_p$ of 104,000 cfs on December 17 and 18, 1995. Had the tributary flows occurred a few days earlier or that at Kingston Mines a few days later (Figure 46), the flood hydrograph at Meredosia would have been a single peak hydrograph with significantly higher $\bar{Q}_p$.

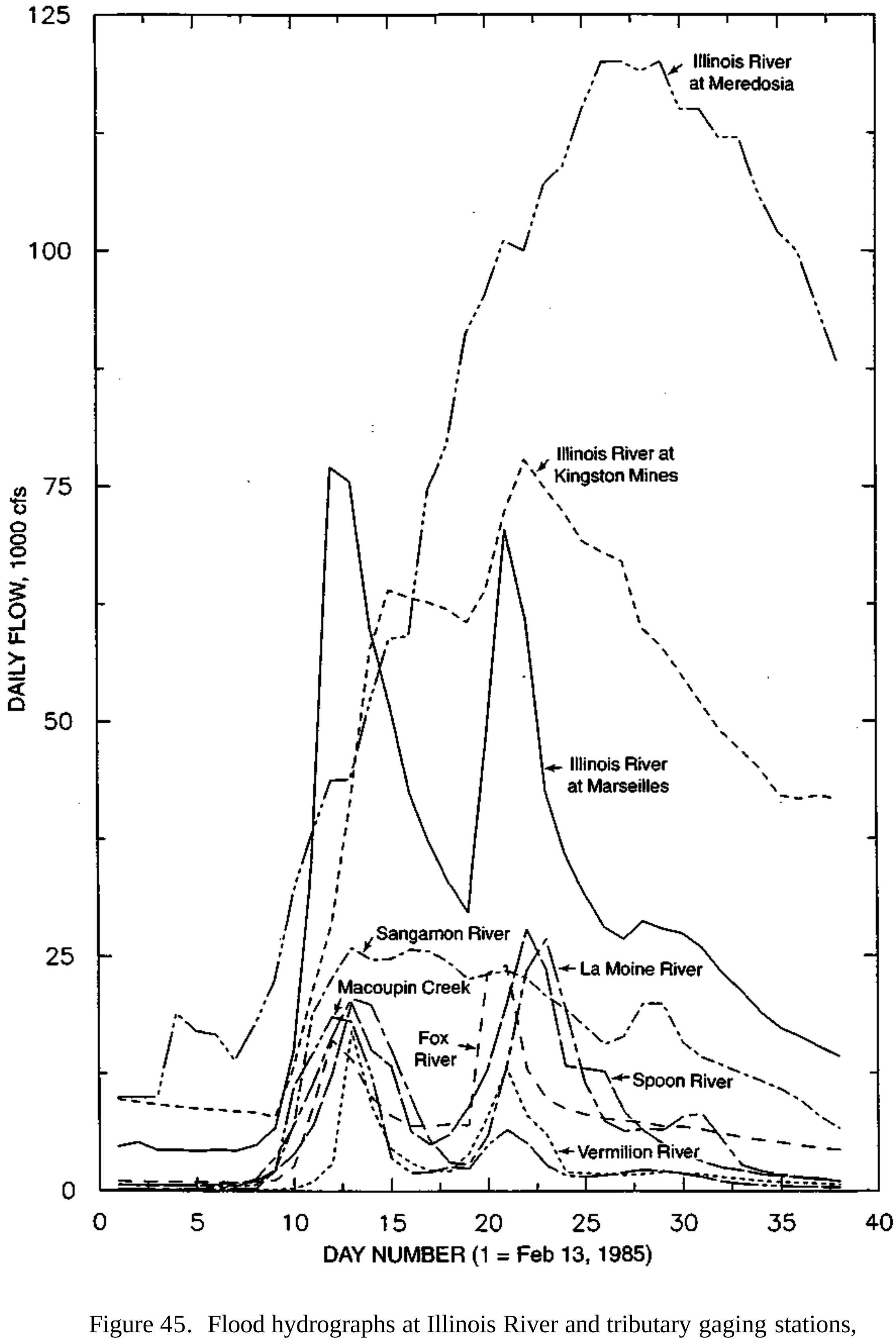


Figure 45. Flood hydrographs at Illinois River and tributary gaging stations, March 1985 flood

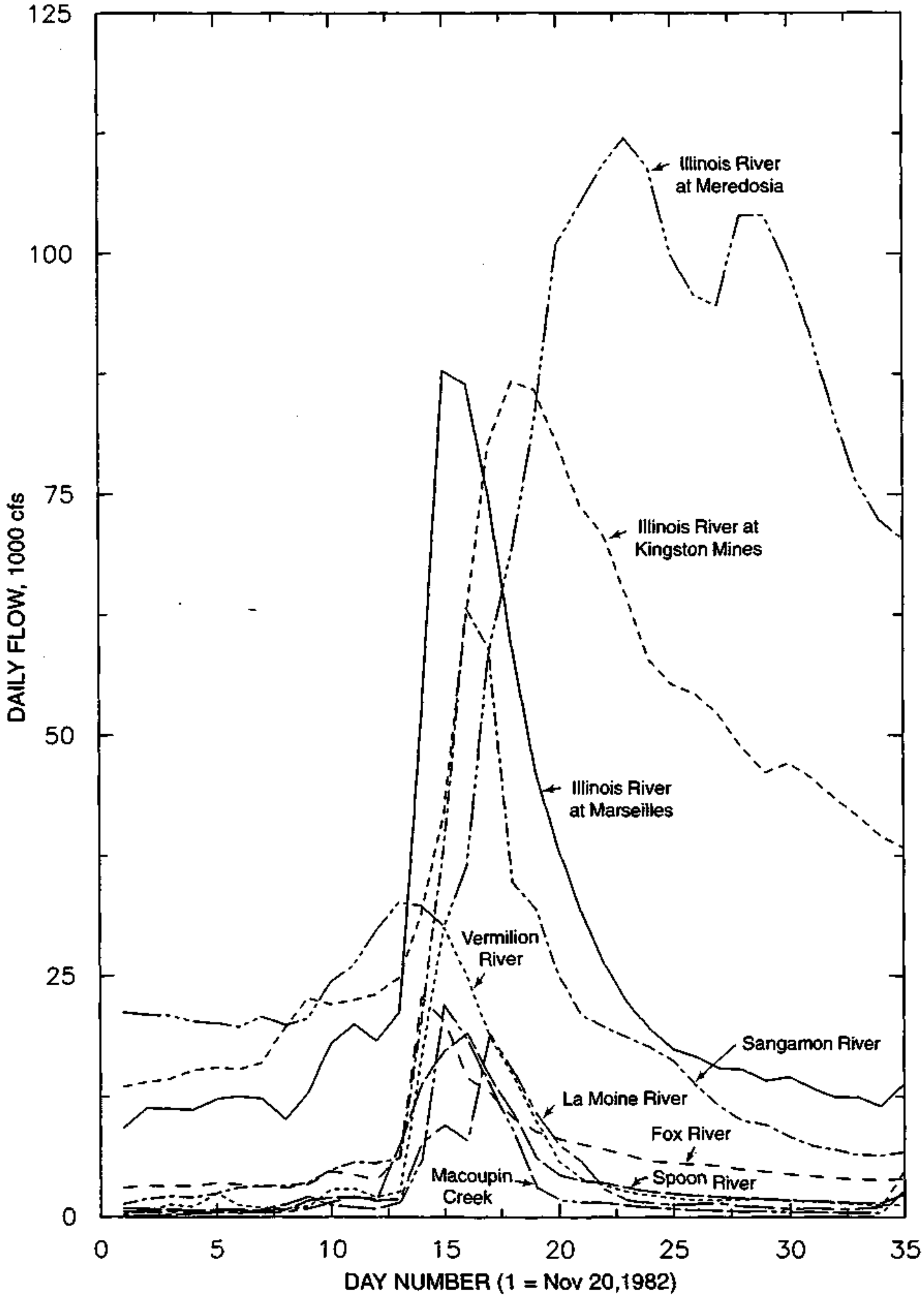


Figure 46. Flood hydrographs at Illinois River and tributary gaging stations, Dec. 1982 flood

From Marseilles to Kingston Mines, a $\overline{Q}_p$ of 87,800 cfs occurred at Marseilles on December 4, and a $\overline{Q}_p$ of 86,700 cfs occurred at Kingston Mines on December 7. $\overline{Q}_p$ values of 22,800 and 30,000 cfs were observed in the Fox and Vermilion Rivers on December 3 and 4, respectively. $\overline{Q}_p$ values at Marseilles and Kingston Mines are the highest in the available record and have a lag of three days. The daily flow hydrographs at Marseilles and Kingston Mines are single-peaked and well defined as shown in Figure 46. The moderating influence of Peoria Lake flood surcharge storage is evident in that $\overline{Q}_p$ values for Marseilles, Dayton, and Leonore (87,800, 22,800, and 30,000 cfs) are merged and attenuated greatly to form a single-peaked, well-defined outflow hydrograph, which is joined by a 51,000 cfs flood peak in the Mackinaw River near Green Valley on December 6, resulting in a $\overline{Q}_p$ of 88,800 cfs at Kingston Mines on December 7.

4. *Flood of April 1979.* Relevant daily flow peak values are used for the Spoon River, Fox River, and Illinois River at Kingston Mines and Marseilles. These flow values are somewhat lower than corresponding $\overline{Q}_p$ values, but they provided expected lag times. A $\overline{Q}_p$ of 109,000 cfs at Meredosia occurred on April 19, 1979. Figure 47 shows multiple-peak hydrographs at practically all gaging stations covered. Local daily flow peaks of 101,000 cfs occurred at Meredosia on March 24-25 and April 2-4. A relevant daily flow peak of 65,500 cfs occurred on April 15 at Kingston Mines though the $\overline{Q}_p$ of 72,200 cfs was observed on March 24. Relevant daily flow peaks of 7460, 54,200, and 10,300 cfs occurred on April 12, 15, and 13, respectively, in the LaMoine, Sangamon, and Spoon Rivers. Flows at Kingston Mines and in the Sangamon River are rather in phase timewise and result in a sharp hydrograph peak at Meredosia.

The relevant daily flow peak of 62,700 cfs occurred at Marseilles on April 13 in the Marseilles to Kingston Mines reach. Corresponding flow values of 17,000 and 16,400 cfs occurred in the Fox and Vermilion Rivers on April 12 and 13. These flows are rather in phase in travel along the Illinois River, resulting in a daily flow peak of 65,500 cfs on April 15 at Kingston Mines. Peoria Lake surcharge storage delayed the peak by only a day because of the high lake level from preceding high flows.

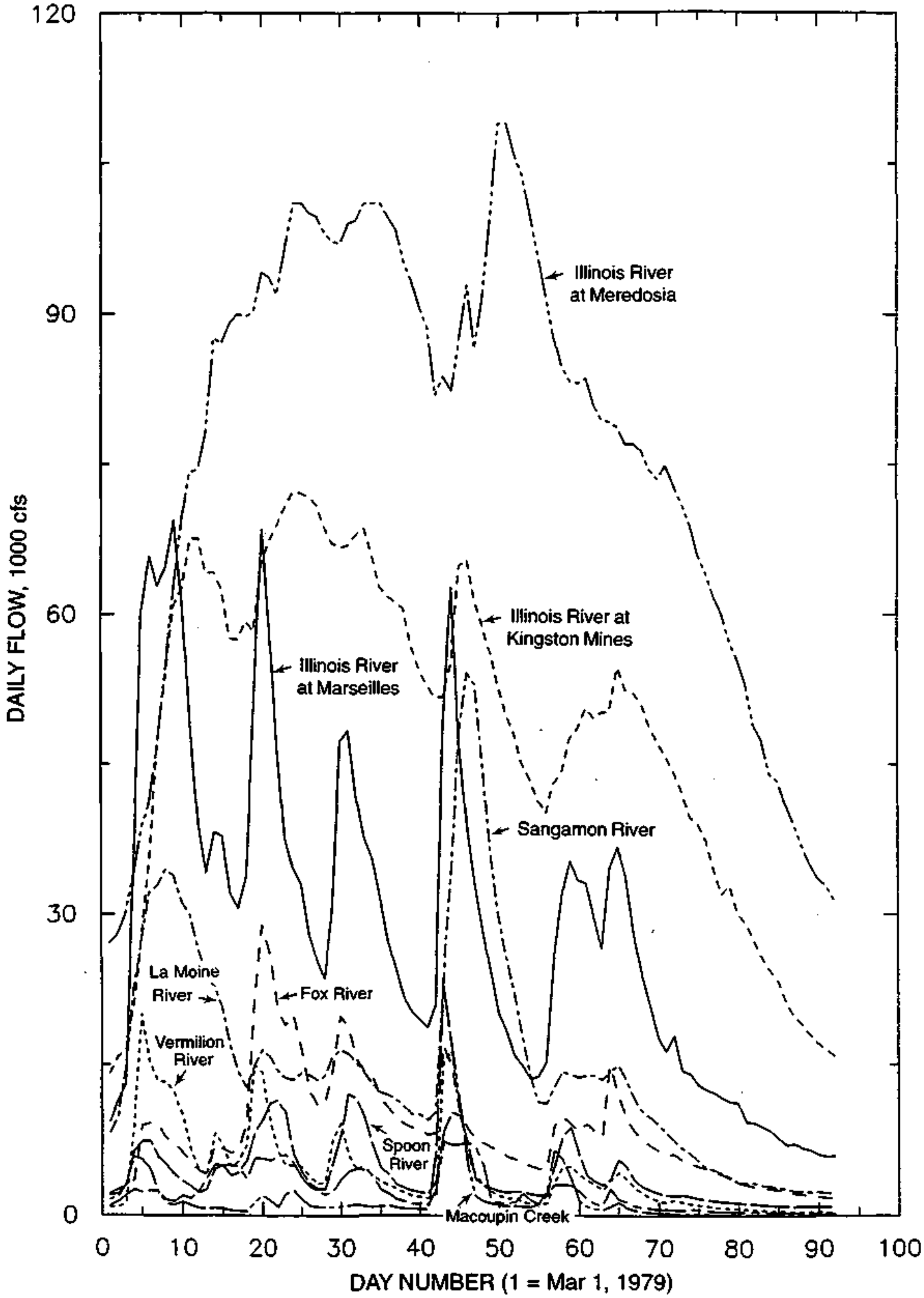


Figure 47. Flood hydrographs at Illinois River and tributary gaging station: April 1979 flood

5. *Flood of June 1974.* The $\overline{Q}_p$ of 110,000 cfs at Meredosia occurred on June 29. The relevant daily flow peak of 69,800 cfs occurred on June 24 at Kingston Mines and values of $\overline{Q}_p$ of 32,700 and 42,800 on June 24 and June 25 in the Spoon and Sangamon Rivers. The relevant daily flow peak of 6,230 cfs in the La Moine River occurred on June 26 ($\overline{Q}_p$ of 9,860 occurred on June 2). All these flow peaks appear to be in good phase timewise and resulted in $\overline{Q}_p$ of 110,000 cfs at Meredosia (Figure 48).

From Marseilles to Kingston Mines, the relevant $\overline{Q}_p$ values and their dates of occurrence follow: 34,600 cfs on June 23 at Marseilles, 10,400 cfs on June 23 for the Fox River, 16,200 cfs on June 23 for the Vermilion River near Leonore, and 69,800 cfs on June 24 at Kingston Mines. Figure 48 shows multiple peak hydrographs, but the peak segments are distinct and separate.

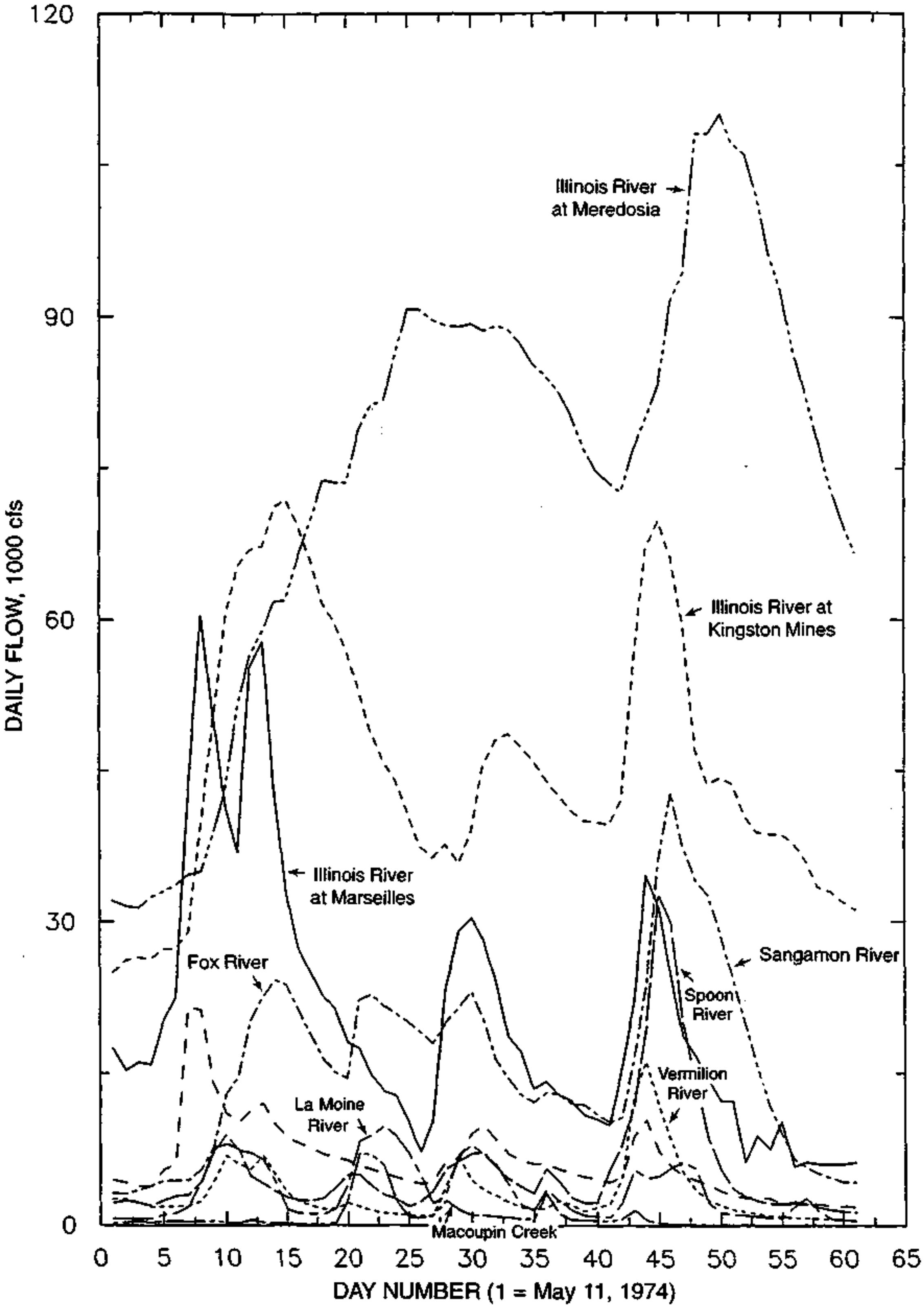


Figure 48. Flood hydrographs at Illinois River and tributary gaging stations, June 1974 flood

COMPARISONS AND CONCLUSIONS

The design floods and stages developed for the Dlinois River and major tributaries below Peoria Lake are compared with similar information available from some reports and accessory maps prepared by the Rock Island and St. Louis Districts of the U.S. Army Corps of Engineers (USCOE). Broad conclusions and suggestions are made from the overall information developed in this report.

T-Year Water Elevations in Alton Pool, Illinois River

There are six stage stations in the Alton Pool (river mile or RM 80.2 from LaGrange Lock and Dam to RM 0.0 at the mouth of the Illinois River). Pertinent data for these stations are given below.

Location	*RM*	*Continuous record*
niinois River at Meredosia	70.8	2/1884-12/1993
Illinois River at Valley City	61.3	1/1884-12/1993
Illinois River at Florence	56.0	1/1942-12/1993
Illinois River at Pearl	43.2	1/1942-12/1993
niinois River at Hardin	21.6	2/1932-12/1993
Mississippi River at Grafton	-0.2	9/1929-12/1993

After 1940, no new dams and levees were constructed along the Illinois River. Concurrent data at four stations (Meredosia, Valley City, Hardin, and Grafton) cover calendar years 1941-1993. Data at other two stations (Florence and Pearl) cover 1942-1993. Values derived for 10-, 25-, 50-, 100-, and 500-year water elevations at the six stations, using the general frequency program, are given in Table 27. Values of two maximum observed elevations at the gaging stations and their fitted recurrence interval (using mixed distribution) in years are also included. Values of 10- to 500-year water elevations were read from Plate A-38, Water Surface Profiles, Mouth to Mile 80.0, report from the USCOE, St. Louis District, 1981. Due to the absence of water elevation data for the exceptionally high floods and stages in July or August 1993 in the Mississippi River in the 1981 study, the USCOE water

Table 27. Comparison of T-year Water Elevations in this Study and from USCOE Report for Alton Pool

Illinois River at	*River mile*	*Source*	*Record used*	*Design WE, feet-msl, for T equal to* 10	25	50	100	500	*Obsd two max WE (feet-msl)*	*Year*	*Fitted T, years*
Meredosia	70.8	Table 13	1941-1993	442.92	445.38	447.08	448.59	451.89	446.69	1943	43
		USCOE		442.50	444.95	446.00	446.80	448.25	445.60	1985	27
		A		0.42	0.43	1.08	1.79	3.64			
Valley City	61.3	Table 13	1941-1993	441.22	443.84	445.61	447.29	450.88	444.91	1943	38
		USCOE		440.65	443.10	444.50	445.50	447.00	444.10	1993	28
		A		0.57	0.74	1.11	1.79	3.88			
Florence	56.0	Table 13	1942-1993	440.19	442.85	444.66	446.35	449.97	443.60	1993	33
		USCOE		439.50	441.95	443.35	444.50	446.20	442.80	1943	25
		A		0.69	0.90	1.31	1.85	3.77			
Pearl	43.2	Table 13	1942-1993	437.44	440.15	442.07	443.91	448.01	442.72	1993	64
		USCOE		437.10	439.60	441.25	442.60	444.50	440.47	1973	28
		A		0.34	0.55	0.82	1.31	3.51			
Hardin	21.6	Table 13	1941-1993	434.55	437.49	439.53	441.47	445.71	442.30	1993	136
		USCOE		434.30	436.50	438.15	440.20	443.90	438.20	1973	32
		A		0.25	0.99	1.38	1.27	1.81			
Mississippi at Grafton	-0.2	Table 13	1941-1993	432.52	435.81	438.09	440.24	444.86	441.80	1993	193
		USCOE		432.40	435.30	437.50	439.85	443.70	436.89	1973	31
		A		0.12	0.51	0.59	0.39	1.16			

Notes: Table 13 is in this report. USCOE refers to Rock Island District, Plate A-38, Water Surface Profiles, May 1981, fitted T-year values to two maximum observed stages are with the mixed distribution, and A in feet denotes WE from Table 13 minus WE from USCOE.

elevations are lower than those derived in this study. The differences, A values (water elevation from Table 13 minus water elevation from USCOE) are included in Table 27. These A values become significantly and progressively higher with increase in T for stage gaging stations at Meredosia, Valley City, Florence, and Pearl.

T-Year Flood Peaks in Major Tributaries

There are five major tributaries to the Illinois River downstream of Peoria Lock and Dam.

Tributary	*RM at mouth*	*Gaging station u/s of mouth (mi)*	*Continuous record (water years)*
Mackinaw River near Green Valley	147.7	13.7	1922-1993
Spoon River at Seville	120.4	38.7	1919-1993
Sangamon River near Oakford	88.9	25.7	1931-1993
La Moine River at Ripley	83.5	12.3	1921-1993
Macoupin Greek near Kane	23.2	16.1	1941-1993

The 10-, 25-, 50-, 100-, and 500-year design floods developed in this study for these tributaries, using the general frequency method and consideration of any increasing trend in flood peaks, are given in Table 28. Corresponding flood peaks (USCOE, 1992), available for four stations excluding Macoupin Creek near Kane, are also given in Table 28. The major differences in T-year flood peaks are mostly in Mackinaw River near Green Valley for T = 10 to 100-years.

T-Year Flood Peaks at Illinois River Gaging Stations

There are three gaging stations on the Illinois River used for flood frequency analyses in this report.

The 10-, 25-, 50-, 100-, and 500-year design floods developed in this study at these gaging stations, using the general frequency method and consideration of any increasing trend in flood peaks, are given in Table 29. Corresponding flood peaks (USCOE, 1992) are also given in the table. The T-year flood peaks at Kingston Mines and Meredosia are not much

Table 28. Comparison of T-year Floods in Major Tributaries to the Illinois River

		T-year flood peaks				
River and Station	*Source*	*10*	*25*	*50*	*100*	*500*
Mackinaw River	Table 16	27,600	39,600	50,000	62,000	97,800
	USCOE*	21,100	31,300	40,800	52,200	88,200
	USCOE†	21,500	32,500	43,100	56,300	101,000
Spoon River	Table 16	26,100	32,300	37,800	41,000	51,800
	USCOE*	23,600	29,800	34,500	39,400	51,100
	USCOE†	23,900	30,300	35,400	40,700	54,100
Sangamon River	Table 16	46,300	59,000	72,000	87,500	138,000
	USCOE*	49,700	64,500	75,500	86,500	112,000
	USCOEf	50,300	65,800	77,700	89,700	118,000
LaMoine River	Table 16	23,000	26,800	31,000	35,000	45,000
	USCOE*	17,500	22,400	26,200	30,300	40,500
	USCOEf	17,700	22,900	27,100	31,600	43,400
Macoupin Creek	Table 16	22,800	29,300	34,600	39,600	59,400

Notes: Table 16 is in this report. USCOE refers to Rock Island District, Illinois River Water Surface Profiles, 1992 report. * denotes computed flow and t denotes modified flow used in modeling.

different. However, the values at Marseilles as derived in this study are significantly higher than those of USCOE, mostly because the latter used flood data before 1941 with greater proportion of low flood peaks.

Illinois River/station	*River mile (mi)*	*Drainage area (sq mi)*	*Continuous record (water years)*
Illinois River at Marseilles	246.5	8,259	1920-1993
Illinois River at Kingston Mines	144.4	15,818	1941-1993
niiinois River at Meredosia	7.1.3	26,028	1939-1993*

Note: * denotes flow data at Valley City gaged adjusted to that at Meredosia for years 1990-1993

T-Year Water Elevations at Marseilles, Kingston Mines, and Meredosia

According to the U.S. Army Corps of Engineers (USCOE), Rock Island District, no stage or water elevation frequency analyses were conducted with the observed maximum annual stages or water elevations at these three stations. The unsteady flow model profiles yield the approximate relevant T-year water elevations and the same are given in Table 30.

The 10-, 25-, 50-, 100-, and 500-year design water elevations, developed in this study using the general frequency method and consideration of any increasing trend in water elevations, are taken from in Table 23 of this report and given in Table 30. These values at Meredosia are somewhat higher than the corresponding values in Table 13 and Table 27 because the latter were developed from 1941-1993 data, without consideration of any increasing trend.

Difference in water elevations (Table 23 values minus those from USCOE water surface profiles), or A feet, are also given in Table 30. At Marseilles, the USCOE values are 2.67 (for T = 10) to 1.35 (T = 500) feet lower than corresponding values developed in this study. USCOE values are significantly lower, probably due to using data including years 1920-1940 which had a higher proportion of lower water elevations. At Kingston Mines, values of A are rather low, starting with 0.10 feet (T = 10) to 0.70 feet (T = 500). At Meredosia, the corresponding range is -0.18 to 1.16.

Table 29. Comparison of T-year Floods at Marseilles, Kingston Mines, and Meredosia

		T-year flood peaks				
Illinois River station	*Source*	*10*	*25*	*50*	*100*	*500*
at Marseilles	Table 20	84,200	96,000	105,000	113,000	131,000
	USCOE	73,600	87,400	97,300	107,000	128,000
at Kingston Mines	Table 20	76,500	85,000	91,800	98200	113,000
	USCOE	74,000	85,600	93,600	101000	118,000
at Meredosia	Table 20	105,000	120,600	130,000	139,500	161,000
	USCOE	100,000	117,000	129,000	140,000	164,000

Notes: Table 20 is in this report. USCOE refers to Rock Island District, Illinois River Water Surface Profiles, 1992 report.

Table 30. Comparison of T-year Water Elevations
at Marseilles, Kingston Mines, and Meredosia

		T-year water elevations, feet-msl and Δ feet				
Illinois River station	*Source*	*10*	*25*	*50*	*100*	*500*
at Marseilles	Table 23	477.87	479.31	480.43	481.16	483.05
	USCOE	475.2	476.7	478.5	479.5	481.7
	Δ, feet	2.67	2.61	1.93	1.66	1.35
at Kingston Mines	Table 23	451.40	453.50	454.6	455.8	459.10
	USCOE	451.3	453.2	454.6	455.8	458.4
	Δ, feet	0.10	0.30	0.30	0.25	0.70
at Meredosia	Table 23	443.82	446.38	448.08	449.55	452.76
	USCOE	444.0	446.5	447.9	449.1	451.6
	Δ, feet	-0.18	-0.12	0.29	0.45	1.16

Notes: Table 23 is in this report. USCOE refers to Rock Island District, Illinois River Water Surface Profiles, 1992 report. A in feet = difference between Table 23 and USCOE values.

Conclusions

The general frequency program is very versatile for fitting probability distributions to observed maximum floods and stages, which indicate fitting curves to be straight lines or with curvatures of various shapes when plotted on lognormal probability paper. It also provides an objective way of detecting outliers/inliers at both the low and high end of the flood spectrum and their modification at various significance levels as desired.

The annual maximum water elevations at six stations in the Alton Pool of the Dlinois River are largely governed by the relative severity of the Mississippi backwaters and the magnitude of flood peak and volume at Meredosia. During the 1941-1993 period, the highest water elevations were recorded in 1993 at Grafton, Hardin, Pearl, and Florence, but at Florence the rank was 2 and at Meredosia, the rank was 4 (the flood at Meredosia was only a 4- or 5-year flood). However, the highest water elevations were recorded at Valley City and Meredosia in 1943 when the flood peak at Meredosia was the highest observed. Flood water surface profiles in the Alton Pool depend on the joint probability of high Mississippi backwaters and high Meredosia flood peaks.

Flood frequency analyses of the annual floods observed in five major tributaries (Mackinaw River, Spoon River, Sangamon River, La Moine River, and Macoupin Creek) show that there is 1) a significant trend of increase in values of both high and low flood over time in Mackinaw River and La Moine River, 2) no significant trend for the Spoon River and Sangamon River, and 3) a slight decreasing trend in value of high floods and a significant increasing trend in value of low floods in the Macoupin Creek.

For the Illinois River at Marseilles, Kingston Mines, and Marseilles, the trend of increase in high floods is significant at all three stations. A similar trend is exhibited by the observed high stages. Consideration of these trends has been incorporated in developing design T-year floods, stages, and water elevations.

Ten highest floods and their daily flow hydrographs observed at Meredosia (1941-1993 period) were analyzed in terms of floods and hydrographs associated with that observed at Meredosia for Illinois River at Marseilles and Kingston Mines and major tributaries: Fox River, Vermilion River, Mackinaw River, Spoon River, Sangamon River, La Moine River, and Macoupin Creek. For the Illinois River from Kingston Mines to Meredosia and the major tributaries in this reach and Mackinaw River, the relevant flood ranks (1 is the highest) are given below.

Month	*Year*	*Meredosia*	*La Moine*	*Sangamon*	*Spoon*	*Kingston Mines*	*Mackinaw*
May	1943	1	18	1	28	2	11
Feb-Mar	1985	2	1	21	3	3	10
Dec	1982	3	6	2	9	1	11
April	1979	4	34	3	30	6	6
June	1974	5	29	6	1	7	30
March	1982	6	28	29	17	4	8

There seems to be better correlation between flood ranks at Meredosia and Kingston Mines. The relative efficiency drops to 2/3 for Sangamon, to 1/3 for La Moine and Spoon, and to 1/6 for Mackinaw River. While working for the U.S. Army Corps of Engineers, Robert Barkau used the December 1982 flood to verify the UNET model results and to develop T-year flood profiles by using flow adjustment factors (considering the 1982 flood as a 25-year flood) for river reaches from Lockport to Marseilles, Marseilles to Kingston Mines, and Kingston Mines to Meredosia. The use of adjustment factors implies relative tributary flood contributions for various recurrence intervals to be proportionate to those for the December 1982 flood. This assumption neglects higher flood stages occurring in portions of reaches depending on variability in the tributary flood. A new scheme needs to be developed for better simulation of flood profiles under varying flood contributions from the tributaries.

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