US Army Corps
of Engineers

The Hydrologic
Engineering Center

GENERALIZED COMPUTER PROGRAM

723-X6-L7550

HECWRC.EXE (PC VERSION)

Flood Flow Frequency Analysis

Users Manual

February 1982

FLOOD FLOW FREQUENCY ANALYSIS

COMPUTER PROGRAM 723-X6-L7550

HECWRC.EXE (PC VERSION)

February 1982

PROGRAM USE

A:\ HECWRC.EXE
INPUT FILE? WRCEX1
OUPUT FILE? OUTEX1 /or Con/or Prn
PRINTER PLOTS? (Y/N) Y

This Must Be Capital Letter

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FLOOD FLOW FREQUENCY ANALYSIS

The Hydrologic Engineering Center

Computer Program 723-X6-L7550

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FLOOD FLOW FREQUENCY ANALYSIS

The Hydrologic Engineering Center
Computer Program 723-X6-L7550

1. PURPOSE

This users manual describes the 1 December 1981 version of the Flood Flow Frequency Analysis Program. The manual includes changes that have been made to the program to reflect techniques described in the revised, "Guidelines for Determining Flood Flow Frequency," Bulletin 17B, WRC, September 1981, hereafter referred to as the Guidelines.

2. ORIGIN OF PROGRAM

This program is a modification of the computer program FREQFLO written by Leo R. Beard and David Ford (Center for Research in Water Resources, the University of Texas at Austin) under contract to the Water Resources Council (WRC). The original program and documentation may be found in Appendix 13, Guidelines for Determining Flood Flow Frequencies, WRC, Bulletin 17, March 1976. The latest version of the Guidelines (Bulletin 17B) does not contain computer program documentation. The input and output formats of the original program have been restructured, a number of improvements and options have been added, and a few computational errors have been corrected.

3. COMPUTATION METHODS

The computation methods are basically as described in "Section V, Determination of Frequency Curve," in the Guidelines. A very brief description of how the computer program treats specific conditions follows, along with references to appropriate page or appendix numbers in the Guidelines:

- Graphical Analysis - The data are arrayed and the plotting positions may be computed by the Weibull, median or Hazen formulae (p. 26).
- The Distribution - The log-Pearson Type III distribution is used in the computation of frequency curve (pp. 9, 10).
- Skew Coefficient - The computed skew coefficient is weighted with the input generalized skew coefficient (pp. 10-15).
- Broken Record - A broken record is automatically analyzed as a continuous record (p. 15).

- Incomplete Record - Missing data at the low end is indicated by a negative number (-1) and the conditional probability adjustment is used to determine the frequency curve (p. 15 and Appendix 5).

- Zero Flood Years - Any flood events of zero are automatically deleted and the conditional probability adjustment is used to determine the frequency curve (p. 15 and Appendix 5).

- Outliers - Initially the program calculates the station skew coefficient for the systematic record which is presented under preliminary results in the output. The program then tests for high or low outliers in an order depending on the value of the station skew as discussed on pages 17-19 and shown on the flow chart on page 12-3 of the Guidelines. Basically if the skew is greater than 0.4, tests and adjustments for high outliers and historic peaks are made before testing for low outliers. If the station skew is less than -0.4, tests and adjustments are made for low outliers first. If the skew is between 0.4 and -0.4, tests for both high and low outliers are made based on systematic record statistics before any adjustments are made.

- Historic Events - Weighted plotting positions and statistics are computed incorporating any input historic events (p. 19 and Appendix 6).

- Confidence Limits - The .05 and .95 confidence limit curves are computed unless other limits are specified (p. 23 and Appendix 9).

- Expected Probability - The frequency curve ordinates are computed with and without the expected probability adjustment (pp. 24, 25 and Appendix 11).

4. GENERAL INPUT AND OUTPUT INFORMATION

The input is designed to be flexible as default values are provided for all decision variables. Any option or nonstandard item activated by the J1 or J2 card will remain in effect for all succeeding station data or until modified by another J1 or J2 card. The only cards actually required for a flood frequency analysis at a station are three or more annual flood peaks (QR cards) and the end-of-data (ED) card. Input data preparation is described in detail in Exhibit 2.

Example problems illustrating input preparation and output are shown in Exhibit 1. The program output has been arranged to enable the tables to be copied for report purposes. When special conditions are encountered in the analysis, such as historic data, high or low outliers, etc., the preliminary results based on the systematic data only are output before the final results.

Output options allow for printing summary tables for multistation applications (Figure 2a and b) or to suppress unwanted printout. There is also an option to punch statistical summary cards for each station analyzed

5. PROPOSED FUTURE DEVELOPMENT

Planned future capabilities include the ability to (1) read in statistics, either with or without flow data, and compute the frequency curve ordinates; (2) treat other durations of flow, such as 1-day, 3-day, etc.; and (3) adjust the statistics of short-record stations with those of long-record stations.

It is requested that any user of this program who finds a deficiency or would recommend desired additional capability notify the Hydrologic Engineering Center.

FLOW DIAGRAM FOR HISTORIC AND OUTLIER ADJUSTMENT

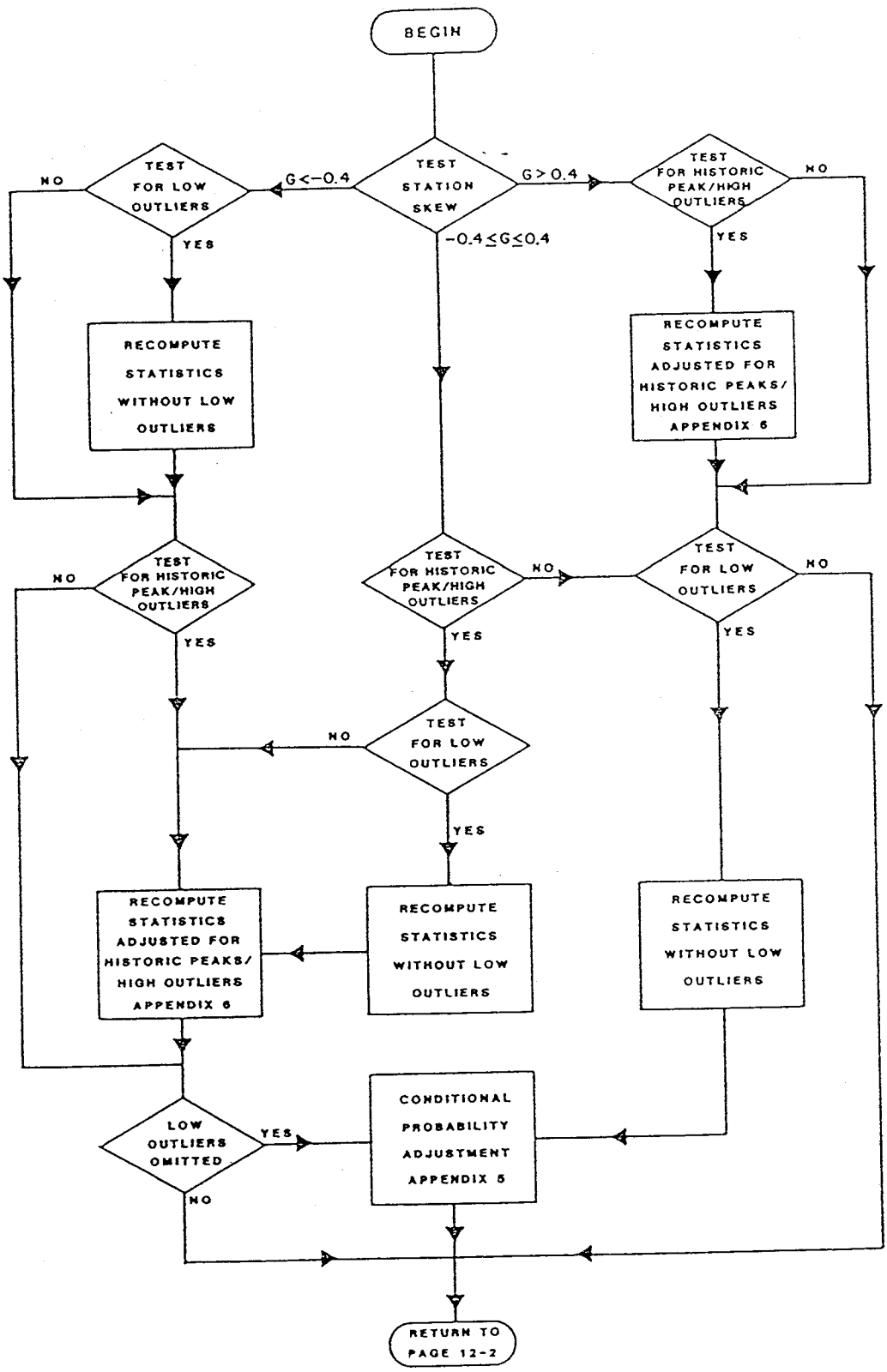

Figure 1. REVISED FLOW CHART FROM PAGE 12-3, BULLETIN 178

SUMMARY OF STATISTICS -- FINAL RESULTS

STATION NUMBER	STATION NAME AND LOCATION	AREA SQ MI	YEARS RECD	YEARS ANLZD	MEAN	STD DEV	COMP SKEW	GENL SKEW	ADOPT SKEW	HIST EVENT	OUTLIER HI	OUTLIER LO	ZERO/ MSNG	TOTAL PERIOD
01368000	WALLKILL RIVER NEAR UNIONVILLE NY	144.	38	38	3.255	.180	1.217	.40	.50	0	0	0	0	38
01370000	WALLKILL R AT PELLETS ISLAND MOUNTAIN NY	385.	49	49	3.617	.166	.698	.40	.50	0	0	0	0	49
01372500	WAPPINGER CREEK NEAR WAPPINGERS FALLS NY	181.	47	47	3.474	.303	.711	.40	.50	0	0	0	0	47
01373500	FISHKILL CREEK AT BEACON NY	186.	24	24	3.380	.258	.844	.40	.40	1	0	0	0	57
01377000	HACKENSACK RIVER AT RIVERVALE NJ	58.0	34	34	2.868	.192	-.067	.40	.30	0	0	0	0	34
01377475	HUSQUAPSINK BROOK NEAR WESTWOOD NJ	2.16	6	6	2.205	.393	2.357	.40	.40	0	0	0	0	6
01377490	HUSQUAPSINK BROOK AT WESTWOOD NJ	6.53	10	10	2.335	.099	.085	.40	.40	0	0	0	0	10
01377500	PASCACK BROOK AT WESTWOOD NJ	29.6	41	41	2.874	.249	.011	.40	.30	0	0	0	0	41
01378350	TENAKILL BROOK AT CRESSKILL NJ	3.01	11	11	2.235	.089	-.575	.40	.40	0	0	0	0	11
01378385	TENAKILL BROOK AT CLOSTER NJ	8.56	11	11	2.607	.150	.302	.40	.40	0	0	0	0	11
01378500	HACKENSACK RIVER AT NEW MILFORD NJ	113.	54	54	3.269	.185	.087	.40	.30	0	0	0	0	54
01378590	METZLER BROOK AT ENGLEWOOD NJ	1.54	11	11	2.261	.081	-.265	.40	.40	0	0	0	0	11
01378615	HOLE CREEK AT RIDGEFIELD NJ	1.18	6	6	2.443	.038	-.681	.40	.40	0	0	0	0	6
01378690	PASSAIC RIVER NEAR BERNARDSVILLE NJ	8.83	8	8	2.985	.327	.576	.30	.30	0	0	0	0	8
01379000	PASSAIC RIVER NEAR MILLINGTON NJ	55.4	57	57	2.899	.166	.300	.30	.30	0	0	0	0	57
01379500	PASSAIC RIVER NEAR CHATHAM NJ	100.	46	46	3.121	.183	.283	.30	.30	0	0	0	0	46
01380000	BEAVER BROOK AT OUTLET OF SPLITROCK RES NJ	5.50	21	21	1.809	.169	-.437	.30	.30	0	0	0	0	21
01380500	ROCKAWAY RIVER ABOVE RESERVOIR AT BOONTON NJ	116.	38	38	3.238	.181	-.088	.30	.20	0	0	0	0	38
01381000	ROCKAWAY RIVER BELOW RESERVOIR AT BOONTON NJ	119.	63	63	3.134	.252	.421	.30	.40	1	1	0	0	72
01381500	WHIPPANY RIVER AT MORRISTOWN NJ	29.4	54	54	2.910	.207	.036	.30	.20	0	0	0	0	54
01381900	PASSAIC RIVER AT PINE BROOK NJ	349.	9	9	3.453	.165	-.495	.30	.30	0	0	0	0	9
01382500	PEQUANNOCK RIVER AT MACOPIN INTAKE DAM NJ	63.7	40	40	2.831	.545	-1.307	.40	-.70	1	0	0	0	72
01383500	WANAQUE RIVER AT AWOSTING NJ	27.1	56	56	2.620	.255	.490	.40	.40	0	0	0	0	56
01384000	WANAQUE RIVER AT MONKS NJ	40.4	40	40	3.015	.274	.204	.40	.40	0	0	0	0	40
01384500	RINGWOOD CREEK NEAR WANAQUE NJ	19.1	40	40	2.679	.226	-.392	.40	.20	0	0	0	0	40
01385000	CUPSAW BROOK NEAR WANAQUE NJ	4.38	23	23	2.277	.292	.109	.40	.40	0	0	0	0	23
01385000	WEST BROOK NEAR WANAQUE NJ	11.8	40	40	2.734	.222	.090	.40	.30	0	0	0	0	40
01386500	BLUE MINE BROOK NEAR WANAQUE NJ	1.71	23	23	2.078	.266	-.033	.40	.40	0	0	0	0	23
01387000	WANAQUE RIVER AT WANAQUE NJ	90.4	60	60	2.790	.693	-.853	.40	-.20	0	0	0	0	60
01387500	RAMAPO RIVER NEAR MAHWAH NJ	118.	64	64	3.450	.259	.525	.40	.50	0	0	0	0	64
01388000	RAMAPO RIVER AT POMPTON LAKES NJ	160.	54	54	3.520	.267	.387	.40	.40	0	0	0	0	54
01388500	POMPTON RIVER AT POMPTON PLAINS NJ	355.	35	35	3.693	.300	.193	.40	.30	1	0	0	0	72
01389500	PASSAIC RIVER AT LITTLE FALLS NJ	762.	78	78	3.846	.182	.338	.40	.30	2	4	0	0	166
01389900	FLEISCHER BROOK AT MARKET ST,ELMWOOD PARK NJ	1.37	9	9	2.225	.083	-.352	.40	.40	0	0	0	0	9
01390450	SADDLE RIVER AT UPPER SADDLE RIVER NJ	10.9	9	9	3.009	.324	-.621	.40	.40	0	0	0	0	9
01390500	SADDLE RIVER AT RIDGEWOOD NJ	21.6	21	21	2.965	.240	.207	.40	.40	0	0	0	0	21
01390810	HOHOKUS BROOK AT ALLENDALE NJ	9.00	7	7	2.720	.157	.130	.40	.40	0	0	0	0	7
01390900	RAMSEY BROOK AT ALLENDALE NJ	2.55	1	1										
01391000	HOHOKUS BROOK AT HOHOKUS NJ	16.4	21	21	2.959	.239	.572	.40	.40	0	0	0	0	21
01391110	SADDLE RIVER AT PARAMUS NJ	45.0	7	7	3.143	.306	.469	.40	.40	0	0	0	0	7
01391485	SPROUT BROOK AT ROCHELLE PARK NJ	5.56	6	6	2.533	.246	.888	.40	.40	0	0	0	0	6
01391500	SADDLE RIVER AT LODI NJ	54.6	52	52	3.096	.231	.254	.40	.30	0	0	0	0	52
01392000	WEASEL BROOK AT CLIFTON NJ	4.45	38	38	2.575	.219	-.028	.40	.30	0	0	0	0	38
01392500	SECOND RIVER AT BELLEVILLE NJ	11.6	37	37	3.272	.158	.011	.30	.30	0	0	0	0	37
01393000	ELIZABETH RIVER AT IRVINGTON NJ	2.91	8	8	3.142	.052	1.413	.30	.30	0	0	1	0	8
01393450	ELIZABETH RIVER AT ORSINO LAKE, ELIZABETH NJ	16.9	3	3	3.487	.086	.916	.30	.30	0	0	0	0	3
01393500	ELIZABETH RIVER AT ELIZABETH NJ	20.2	51	51	3.157	.220	-.565	.30	.00	0	0	0	0	51
01393800	E FORK E BR RAHWAY R AT WEST ORANGE NJ	0.83	3	3	1.919	.018	-1.732	.30	.30	0	0	0	0	3
01394000	WEST BRANCH RAHWAY RIVER AT MILLBURN NJ	7.10	12	12	2.680	.294	.111	.30	.30	1	0	0	0	36
01394500	RAHWAY RIVER NEAR SPRINGFIELD NJ	25.5	38	38	3.056	.232	1.080	.30	.40	0	0	0	0	38

Figure 2a. Example Output - Summary of Station Statistics

SUMMARY OF FREQUENCY CURVE ORDINATES

STATION NUMBER	STATION NAME AND LOCATION	AREA SQ MI	YEARS ANLZD	TOTAL PERIOD	PERCENT CHANCE EXCEEDANCE 50.	10.	2.	1.	.5	.2
01368000	WALLKILL RIVER NEAR UNIONVILLE NY	144.	38	38	1740	3110	4680	5470	6330	7620
01370000	WALLKILL R AT PELLETS ISLAND MOUNTAIN NY	385.	49	49	4010	6850	9990	11500	13200	15600
01372500	WAPPINGER CREEK NEAR WAPPINGERS FALLS NY	181.	47	47	2810	7490	14900	19400	24800	33900
01373500	FISHKILL CREEK AT BEACON NY	186.	24	67	2300	5240	9190	11300	13800	17700
01377000	HACKENSACK RIVER AT RIVERVALE NJ	58.0	34	34	723	1320	1960	2270	2610	3090
01377075	HUSQUAPSINK BROOK NEAR WESTWOOD NJ	2.16	6	6	151	528	1240	1710	2310	3370
01377490	HUSQUAPSINK BROOK AT WESTWOOD NJ	6.53	10	10	213	292	362	392	423	465
01377500	PASCACK BROOK AT WESTWOOD NJ	29.6	41	41	728	1590	2660	3220	3840	4800
01378350	TENAKILL BROOK AT CHESSKILL NJ	3.01	11	11	170	225	274	294	315	343
01378385	TENAKILL BROOK AT CLOSTER NJ	8.56	11	11	395	637	883	998	1120	1290
01378500	HACKENSACK RIVER AT NEW MILFORD NJ	113.	54	54	1820	3250	4770	5500	6290	7420
01378590	METZLER BROOK AT ENGLEWOOD NJ	1.54	11	11	180	233	279	298	317	345
01378615	ADLE CREEK AT RIDGEFIELD NJ	1.18	6	6	276	312	339	350	360	374
01378690	PASSAIC RIVER NEAR BERNARDSVILLE NJ	8.83	8	8	930	2590	5110	6570	8310	11100
01379000	PASSAIC RIVER NEAR MILLINGTON NJ	55.4	57	57	777	1310	1840	2090	2360	2730
01379500	PASSAIC RIVER NEAR CHATHAM NJ	100.	46	46	1290	2290	3360	3860	4410	5190
01380000	BEAVER BROOK AT OUTLET OF SPLITROCK RES NJ	5.50	21	21	63	107	152	173	196	227
01380500	ROCKAWAY RIVER ABOVE RESERVOIR AT BOONTON NJ	116.	38	38	1710	2970	4250	4840	5470	6350
01381000	ROCKAWAY RIVER BELOW RESERVOIR AT BOONTON NJ	119.	63	72	1310	2920	5050	6200	7520	9580
01381500	WHIPPANY RIVER AT MORRISTOWN NJ	29.4	54	54	799	1510	2280	2640	3040	3600
01381900	PASSAIC RIVER AT PINE BROOK NJ	349.	9	9	2780	4670	6570	7460	8400	9730
01382500	PEQUANNOCK RIVER AT MACOPIN INTAKE DAM NJ	63.7	40	72	784	2990	5460	6540	7600	8960
01383500	WANAQUE RIVER AT AMSTING NJ	27.1	56	56	401	902	1570	1930	2350	3000
01384000	WANAQUE RIVER AT POMPTON PLAINS NJ	40.4	40	40	992	2370	4300	5380	6640	8630
01384500	RINGWOOD CREEK NEAR WANAQUE NJ	19.1	40	40	469	938	1470	1720	2010	2420
01385000	CUPSAW BROOK NEAR WANAQUE NJ	4.38	23	23	181	458	864	1100	1370	1810
01386000	WEST BROOK NEAR WANAQUE NJ	11.8	40	40	529	1060	1680	1990	2330	2840
01386500	BLUE MINE BROOK NEAR WANAQUE NJ	1.71	23	23	115	268	479	595	730	942
01387000	WANAQUE RIVER AT WANAQUE NJ	90.4	60	60	651	4600	13800	20000	27900	41600
01387500	RAMAPO RIVER NEAR MAHWAH NJ	118.	64	64	2680	6210	11200	14000	17300	22600
01388000	RAMAPO RIVER AT POMPTON LAKES NJ	160.	54	54	3180	7450	13300	16600	20300	26300
01388500	POMPTON RIVER AT POMPTON PLAINS NJ	355.	35	72	4770	12200	22800	28700	35600	46500
01389500	PASSAIC RIVER AT LITTLE FALLS NJ	762.	78	166	6870	12100	17700	20300	23200	27300
01389900	FLEISCHER BROOK AT MARKET ST,ELMWOOD PARK NJ	1.37	9	9	166	215	258	276	294	318
01390450	SADDLE RIVER AT UPPER SADDLE RIVER NJ	10.9	9	9	971	2720	5500	7160	9180	12500
01390500	SADDLE RIVER AT RIDGEWOOD NJ	21.6	21	21	890	1910	3230	3930	4720	5950
01390810	HOHOKUS BROOK AT ALLENDALE NJ	9.00	7	7	513	845	1190	1350	1520	1770
01390900	RAMSEY BROOK AT ALLENDALE NJ	2.55	1							
01391000	HOHOKUS BROOK AT HOHOKUS NJ	16.4	21	21	877	1880	3160	3840	4610	5800
01391110	SADDLE RIVER AT PARAMUS NJ	45.0	7	7	1330	3510	6830	8770	11100	14900
01391425	SPROUT BROOK AT ROCHELLE PARK NJ	5.56	6	6	329	719	1230	1500	1810	2300
01391500	SADDLE RIVER AT LODI NJ	54.6	52	52	1220	2500	4040	4820	5690	6990
01392000	PASEL BROOK AT CLIFTON NJ	4.45	38	38	366	727	1150	1360	1590	1930
01392500	SECOND RIVER AT BELLEVILLE NJ	11.6	37	37	1840	3010	4180	4720	5280	6080
01393000	ELIZABETH RIVER AT IRVINGTON NJ	2.91	8	8	1350	1610	1790	1860	1940	2030
01393050	ELIZABETH RIVER AT ORSINO LAKE, ELIZABETH NJ	16.9	3	3	3040	3970	4740	5060	5380	5810
01393500	ELIZABETH RIVER AT ELIZABETH NJ	20.2	51	51	1440	2750	4060	4670	5290	6170
01393800	E FORK E BR RAHWAY R AT WEST ORANGE NJ	0.83	3	3	82	87	91	92	93	95
01394000	WEST BRANCH RAHWAY RIVER AT MILLBURN NJ	7.10	12	36	463	1160	2130	2670	3300	4290
01394500	RAHWAY RIVER NEAR SPRINGFIELD NJ	25.5	38	38	1100	2300	3810	4600	5500	6860

Figure 35. Example Output - Summary of Exceedence Discharges

EXHIBIT 1

EXAMPLE INPUT AND OUTPUT

Computer Program 723-X6-L7550

Flood Flow Frequency Analysis

The input and output for six test examples are provided to illustrate the use of selected options and to assist in verifying the correct execution of the program. A brief description of each test example is provided. In all cases a generalized skew value was assumed.

a. Test 1 - Fitting the Log-Pearson Type III Distribution

The input data for Test 1 are the same as that for Example 1 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council Bulletin 17B, September 1981. Test 1 illustrates the routine computation of a frequency curve.

b. Test 2 - Adjusting for High Outliers

The input data for Test 2 are the same as that for Example 2 in Appendix 12 of the WRC Guidelines. Test 2 illustrates the application to data with a high outlier. Note that preliminary results are output to enable comparison of the systematic data results with the results adjusted for a high outlier.

c. Test 3 - Testing and Adjusting for a Low Outlier

The input data for Test 3 are the same as that for Example 3 in Appendix 12 of the WRC Guidelines. Test 3 illustrates the application to data with a low outlier. Note that the program outputs the test value in the input flow units and automatically screens for low outliers. If low outliers are found, the program outputs the preliminary results to allow comparison with the final results.

d. Test 4 - Zero Flood Years

The input data for Test 4 are the same as that for Example 4 in Appendix 12 of the WRC Guidelines. Test 4 illustrates the application to data that includes several zero flood events.

e. Test 5 - Use of IPRØUT, CLIMIT and BASEPK

This test illustrates the use of three variables which modify the standard mode of computation and output. On the J1 card, the value for IPRØUT is 33 which is the sum of 1 (to suppress the printout of the input data for preliminary results) and 32 (to suppress the frequency plot based on the expected probability adjustment). The variable CLIMIT on the J2 card sets the confidence limit probability. In this case, .01 specifies the .01 and .99 confidence limit curves. This data set includes two very low values, and the second lowest value just missed being classified as a low outlier. As both of these values were below 2,000 cfs, this amount was input for the variable BASEPK and the program identified any values below 2,000 cfs as low outliers.

f. Test 6 - Use of IPPC, IFMT, OR Cards and IYRL

This test illustrates the use of variables which modify the standard mode of operation and provide for the incorporation of historic flood peaks. On the J1 card, the value of IPPC is 2 to compute the median plotting positions rather than the Weibull. The IPROUT value of 21 is the sum of 1 (to suppress input data listing for preliminary results), 4 (to suppress the plot of preliminary results), and 16 (to suppress the plot based on the computed values, i.e., without the expected probability adjustment, from the final results). IFMT is 2 as the input data are punched in the format of four 8-column fields for day, month, year and flow. Note that the value for CLIMIT is .01 for this test as it was for Test 5 because it was not reset by a J2 card and the tests were run sequentially.

A historic flood peak of 15,000 cfs which occurred in 1843 is input on the OH card. This value is the highest known value up to the present time, even though the systematic record stopped in 1955. Therefore, the year 1974 is input for IYRL on the SI card.

LISTING OF TEST DATA (INPUT)

```
TT TEST NO. 1 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT WRC APPENDIX 12, EXAMPLE 1 - FITTING THE LOG-PEARSON TYPE III DIST
TT FISHKILL CREEK AT BEACON, NY
ID 01-3735  FISHKILL CREEK AT BEACON, NEW YORK  DA=190 SQ MI          1945-68
GS  3735                .6
QR  373503051945      2290
QR  373512271945      1470
QR  373503151947      2220
QR  373503181948      2970
QR  373501011949      3020
QR  373503091950      1210
QR  373504011951      2490
QR  373503121952      3170
QR  373501251953      3220
QR  373509131954      1760
QR  373508201955      8800
QR  373510161955      8280
QR  373504101957      1310
QR  373512211957      2500
QR  373502111959      1960
QR  373504061960      2140
QR  373502261961      4340
QR  373503131962      3060
QR  373503281963      1780
QR  373501261964      1380
QR  373502091965       980
QR  3735    1966      1040
QR  3735    1967      1580
QR  3735    1968      3630
ED
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```
TT TEST NO. 2 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT WRC APPENDIX 12, EXAMPLE 2 - ADJUSTING FOR A HIGH OUTLIER
TT FLOYD RIVER AT JAMES, IA
ID 06-6005  FLOYD RIVER AT JAMES, IOWA          DA=882 SQ MI          1935-73
GS  6005              -0.3
SI  1892                 1
QR  600506281935      1460
QR  600503101936      4050
QR  600505271937      3570
QR  600509151938      2060
QR  600503121939      1300
QR  600506051940      1390
QR  600503111941      1720
QR  600506041942      6280
QR  600506171943      1360
QR  600505131944      7440
QR  600503121945      5320
QR  600503011946      1400
QR  600506251947      3240
QR  600503171948      2710
QR  600503051949      4520
QR  600506191950      4840
QR  600503281951      8320
QR  600503311952     13900
QR  600506081953     71500
QR  600506221954      6250
QR  600507101955      2260
QR  600507131956       318
QR  600507051957      1330
QR  600506311958       970
QR  600506011959      1920
QR  600503291960     15100
QR  600503021961      2870
QR  600503291962     20600
QR  600506021963      3810
QR  600509091964       726
QR  600504021965      7500
QR  600502101966      7170
QR  600506191967      2000
QR  600507211968       829
QR  600504051969     17300
QR  600503041970      4740
QR  6005     1971    13400
QR  6005     1972     2940
QR  6005     1973     5660
ED
```

```
TT TEST NO. 3 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT WRC APPENDIX 12, EXAMPLE 3 - TESTING AND ADJUSTING FOR A LOW OUTLIER
TT BACK CREEK NEAR JONES SPRINGS, WV
ID 01-6140 BACK CR  NEAR JONES SPRINGS, WEST VA    DA=243 SQ MI    1929-31,39-73
GS016140                0.5
QR  614004171929     8750
QR  614010231929    15500
QR  614005081931     4060
QR  614002041939     6300
QR  614004201940     3130
QR  614004061941     4160
QR  614005221942     6700
QR  614010151942    22400
QR  614003241944     3880
QR  614009181945     8050
QR  614006031946     4020
QR  614003151947     1600
QR  614004141948     4460
QR  614012311948     4230
QR  614002021950     3010
QR  614012051950     9150
QR  614004281952     5100
QR  614011221952     9820
QR  614003021954     6200
QR  614008191955    10700
QR  614003151956     3880
QR  614002101957     3420
QR  614003271958     3240
QR  614006031959     6800
QR  614005091960     3740
QR  614002191961     4700
QR  614003221962     4380
QR  614003201963     5190
QR  614001101964     3960
QR  614003061965     5600
QR  6140     1966    4670
QR  6140     1967    7080
QR  6140     1968    4640
QR  6140     1969     536
QR  6140     1970    6680
QR  6140     1971    8360
QR  6140     1972   18700
QR  6140     1973    5210
ED
```

Station Year

```
TT TEST NO. 4 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT WRC APPENDIX 12, EXAMPLE 4 - ZERO FLOOD YEARS
TT ORESTIMBA CREEK NEAR NEWMAN, CA
ID 11-2745  ORESTIMBA CREEK NEAR NEWMAN, CA     DA=134 SQ MI                1932-73
GS112745                -0.3
QR  274502081932     4260
QR  274501291933      345
QR  274501011934      516
QR  274504081935     1320
QR  274502131936     1200
QR  274502131937     2180
QR  274502111938     3230
QR  274503091939      115
QR  274502271940     3440
QR  274504041941     3070
QR  274501241942     1880
QR  274501211943     6450
QR  274502291944     1290
QR  274502021945     5970
QR  274512251945      782
QR  2745     1947       0
QR  2745     1948       0
QR  274503121949      335
QR  274502051950      175
QR  274512031950     2920
QR  274501121952     3660
QR  274512071952      147
QR  2745     1954       0
QR  274501191955       16
QR  274512231955     5620
QR  274502241957     1440
QR  274504021958    10200
QR  274502161959     5380
QR  274502101960      448
QR  2745     1961       0
QR  274502151962     1740
QR  274502011963     8300
QR  274501221964      156
QR  2745     1966      560
QR  274512301965      128
QR  274501241967     4200
QR  2745     1968       0
QR  274501251969     5080
QR  274503011970     1010
QR  274512211970      584
QR  2745     1972       0
QR  274502111973     1510
ED
```

```
TT TEST NO. 5 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT EXAMPLE USE OF PRINTOUT SUPPRESSION (IPROUT), OTHER CONFIDENCE LIMITS
TT (CLIMIT), AND A BASE PEAK DISCHARGE (BASEPK)
J1     2              33
J2                   .01
ID  05-5925  KASKASKIA RIVER AT VANDALIA,ILL    DA=1980 SQ MI            1908-70
GS  5925             -.4
SI                          2000
QR  592505061908     7870
QR  592504141909     7670
QR  592503011910     7020
QR  592505011911     5670
QR  592510041911    13000
QR  592507211915    15800
QR  592501311916    14400
QR  592506051917    16800
QR  592505111918     8880
QR  592503191919    11000
QR  592505191920    12600
QR  592504181922    18800
QR  592503171923    14300
    1      2.      3      4
```

(Continued on following page)

QR	592512151923	10500
QR	592503161925	9980
QR	592509171926	8460
QR	592503201927	20000
QR	592512011927	12200
QR	592505141929	12200
QR	592501141930	11500
QR	592509181931	1270
QR	592501241932	5550
QR	592505151933	17500
QR	592508191934	4250
QR	592505161935	11200
QR	592503261936	7290
QR	592501151937	14900
QR	592503311938	40700
QR	592503141939	16000
QR	592505031940	6760
QR	592506121941	4560
QR	592507121942	13600
QR	592505181943	52200
QR	592504241944	31000
QR	592506101945	21500
QR	592505041946	13000
QR	592506101947	12300
QR	592503281948	19000
QR	592502161949	25000
QR	592501041950	51300
QR	592506291951	31000
QR	592504151952	10500
QR	592503051953	5680
QR	592504191954	505
QR	592504251955	5000
QR	592502271956	7840
QR	592506291957	62700
QR	592508041958	12400
QR	592502121959	17200
QR	592506301960	11800
QR	592504101961	34400
QR	592503251962	17100
QR	592505221963	9000
QR	592505041964	8500
QR	592505041965	5350
QR	592505191966	11900
QR	592512101966	27000
QR	592512231967	20800
QR	592501311969	20700
QR	592506161970	30000
ED		

```
TT TEST NO. 6 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT EXAMPLE USE OF MEDIAN PLOT POSITIONS(IPPC),WRC FORMAT(IFMT), HISTORIC
TT DATA(QR CARD), AND PERIOD OF KNOWLEDGE BEYOND LAST YEAR OF DATA(IYRL)
J1      2                21        2
ID 01-4765 RIDLEY CREEK AT MOYLAN, PA            DA=31.9 SQ MI          1932-55
GS  4765                 .4
SI           1974
QH      5       8    1843   15000
       28       3    1932     891
       23       8    1933    2680
        5       3    1934    1080
        9       7    1935    3000
        3       1    1936    1590
       22       2    1937     770
       23       7    1938    3320
        3       2    1939     978
       15       3    1940    1770
        7       2    1941     746
       13       8    1942    1000
       30      12    1942     980
        6       1    1944     865
       18       9    1945    1040
       26      12    1945    1000
       22       5    1947     483
        5       5    1948     740
       30      12    1948    1040
        3       8    1950    1590
       25      11    1951    5720
       11       3    1952    1490
       22      11    1952     918
       14      12    1953     670
       18       8    1955    4390
ED
```

Day Month Year Flow

OUTPUT FROM TEST DATA

```
*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************


**TITLE CARD(S)**
TT   TEST NO. 1 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT   WRC APPENDIX 12, EXAMPLE 1 - FITTING THE LOG-PEARSON TYPE III DIST
TT   FISHKILL CREEK AT BEACON, NY

**STATION IDENTIFICATION**
ID   01-3735  FISHKILL CREEK AT BEACON, NEW YORK  DA=190 SQ MI            1945-68

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   3735  -0.        .60

**SYSTEMATIC EVENTS**
     24 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
```

FINAL RESULTS
-PLOTTING POSITIONS- 01-3735 FISHKILL CREEK AT BEACON, NEW YORK

.....EVENTS ANALYZED.....				...ORDERED EVENTS...			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
3	5	1945	2290.	1	1955	8800.	.0400
12	27	1945	1470.	2	1956	8280.	.0800
3	15	1947	2220.	3	1961	4340.	.1200
3	18	1948	2970.	4	1968	3630.	.1600
1	1	1949	3020.	5	1953	3220.	.2000
3	9	1950	1210.	6	1952	3170.	.2400
4	1	1951	2490.	7	1962	3060.	.2800
3	12	1952	3170.	8	1949	3020.	.3200
1	25	1953	3220.	9	1948	2970.	.3600
9	13	1954	1760.	10	1958	2500.	.4000
8	20	1955	8800.	11	1951	2490.	.4400
10	16	1955	8280.	12	1945	2290.	.4800
4	10	1957	1310.	13	1947	2220.	.5200
12	21	1957	2500.	14	1960	2140.	.5600
2	11	1959	1960.	15	1959	1960.	.6000
4	6	1960	2140.	16	1963	1780.	.6400
2	26	1961	4340.	17	1954	1760.	.6800
3	13	1962	3060.	18	1967	1580.	.7200
3	28	1963	1780.	19	1946	1470.	.7600
1	26	1964	1380.	20	1964	1380.	.8000
2	9	1965	980.	21	1957	1310.	.8400
-0	-0	1966	1040.	22	1950	1210.	.8800
-0	-0	1967	1580.	23	1966	1040.	.9200
-0	-0	1968	3630.	24	1965	980.	.9600

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 578.7

HIGH OUTLIER TEST

BASED ON 24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 9425.

-SKEW WEIGHTING -

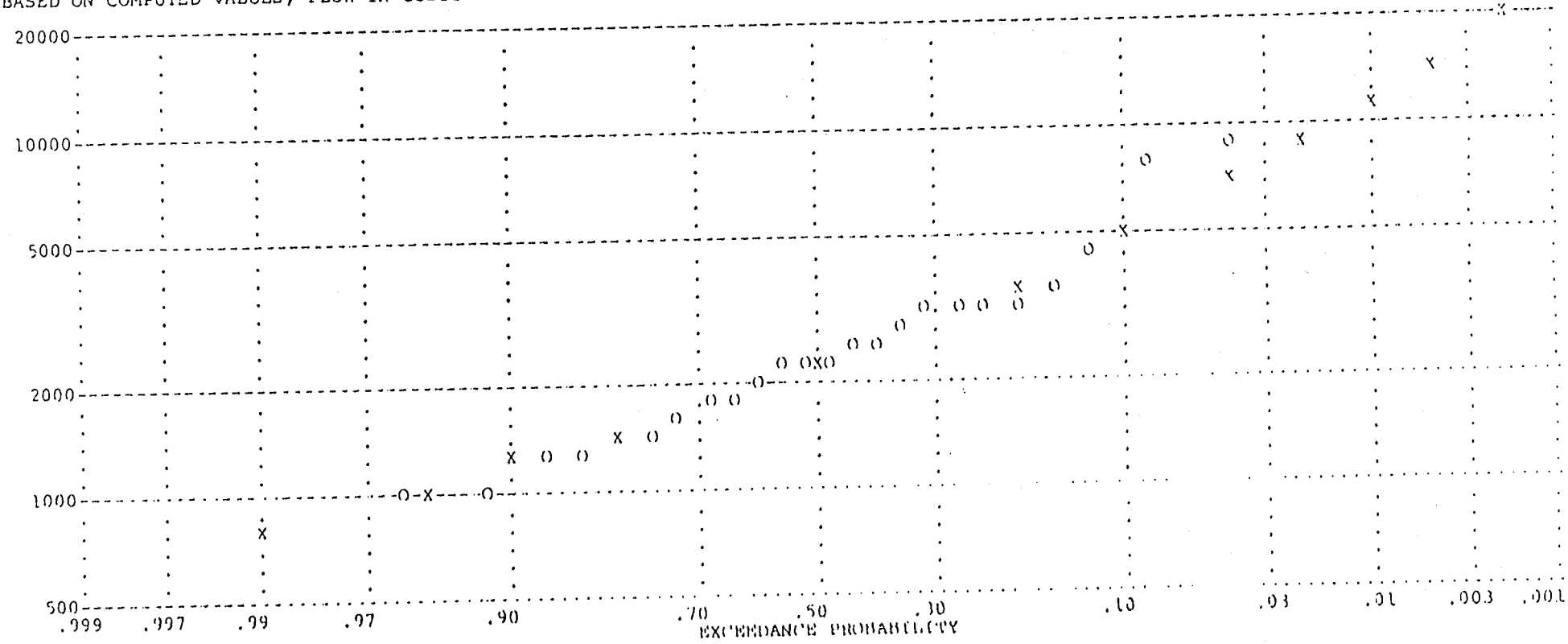
BASED ON 24 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.277
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 01-3735 FISHKILL CREEK AT BEACON, NEW YORK

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.05 LIMIT	CONFIDENCE LIMITS 0.95 LIMIT
19200.	28300.	0.002	39100.	12300.
14500.	19000.	0.005	26900.	9740.
11500.	14100.	0.010	20100.	8080.
9110.	10500.	0.020	14800.	6640.
7100.	7820.	0.040	10800.	5380.
4960.	5210.	0.100	6850.	3950.
3650.	3740.	0.200	4710.	2990.
2190.	2190.	0.500	2650.	1790.
1440.	1420.	0.800	1760.	1110.
1200.	1170.	0.900	1490.	884.
1040.	1010.	0.950	1320.	746.
841.	791.	0.990	1100.	568.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.3684	HISTORIC EVENTS	0
STANDARD DEVIATION	0.2456	HIGH OUTLIERS	0
COMPUTED SKEW	0.7300	LOW OUTLIERS	0
GENERALIZED SKEW	0.6000	ZERO OR MISSING	0
ADOPTED SKEW	0.7000	SYSTEMATIC EVENTS	24

FINAL RESULTS
-FREQUENCY PLOT - 01-3735 FISHKILL CREEK AT BEACON, NEW YORK DA=190 SQ MI 1945-68
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

EXHIBIT 1
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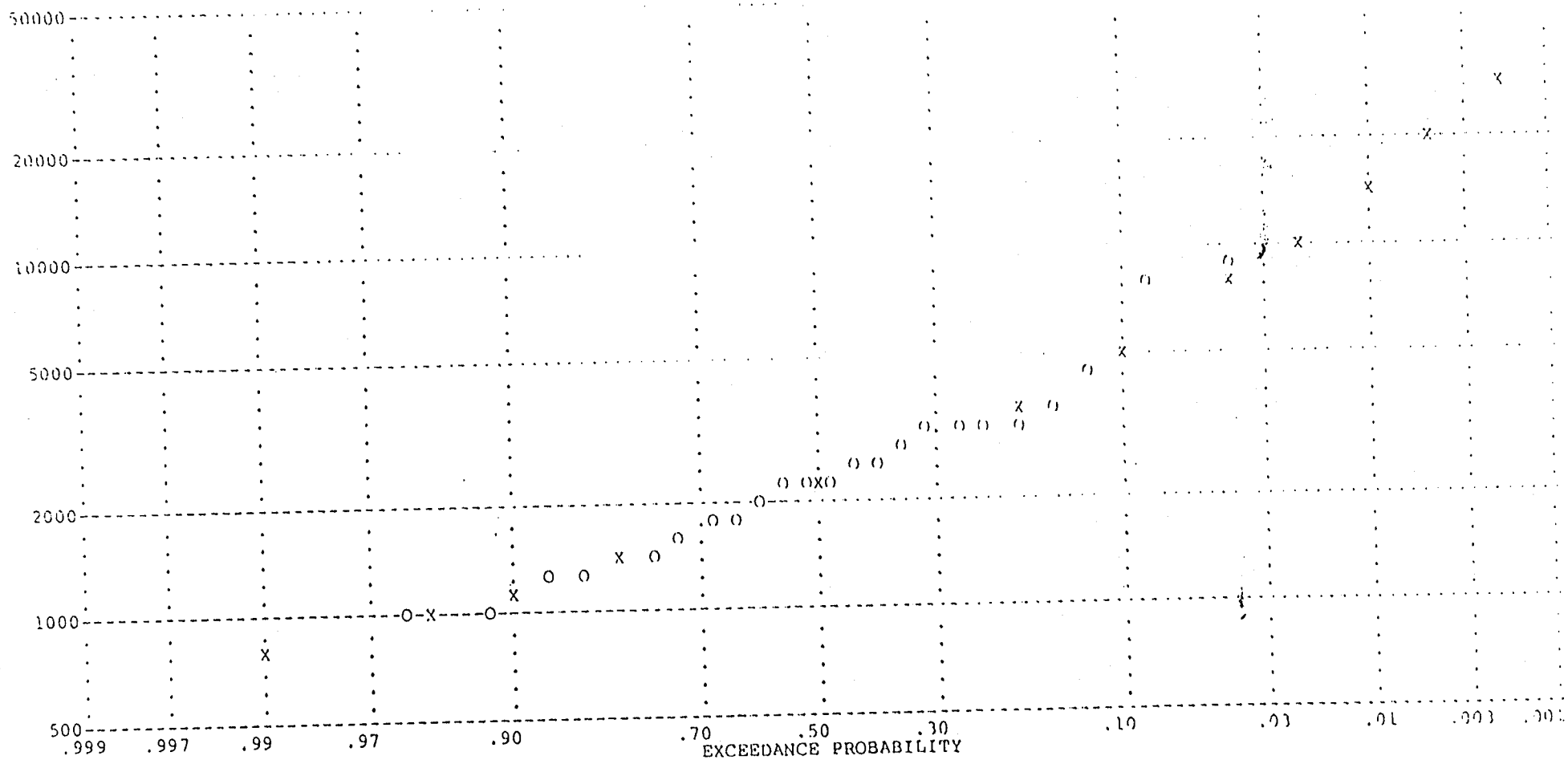
FINAL RESULTS
-FREQUENCY PLOT - 01-3235 FISHKILL CREEK AT BEACON, NEW YORK DA-190 SQ MI 1945-69
BASED ON EXPECTED PROBABILITY ADJUSTMENT, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

EXHIBIT 1
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*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************


**TITLE CARD(S)**
TT   TEST NO. 2 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT   WRC APPENDIX 12, EXAMPLE 2 - ADJUSTING FOR A HIGH OUTLIER
TT   FLOYD RIVER AT JAMES, IA

**STATION IDENTIFICATION**
ID   06-6005  FLOYD RIVER AT JAMES, IOWA          DA=882 SQ MI          1935-73

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   6005  -0.       -.30

**SPECIAL STATION INFORMATION**
    IYRA    IYRL   NOUTL  BASEPK
SI  1892      -0      1     -0.

**SYSTEMATIC EVENTS**
     39 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
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PRELIMINARY RESULTS
-PLOTTING POSITIONS- 06-6005 FLOYD RIVER AT JAMES, IOWA

.....EVENTS ANALYZED.....				.....ORDERED EVENTS.....			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
6	28	1935	1460.	1	1953	71500.	.0250
3	10	1936	4050.	2	1962	20600.	.0500
5	27	1937	3570.	3	1969	17300.	.0750
9	15	1938	2060.	4	1960	15100.	.1000
3	12	1939	1300.	5	1952	13900.	.1250
6	5	1940	1390.	6	1971	13400.	.1500
3	11	1941	1720.	7	1951	8320.	.1750
6	4	1942	6280.	8	1965	7500.	.2000
6	17	1943	1360.	9	1944	7440.	.2250
5	13	1944	7440.	10	1966	7170.	.2500
3	12	1945	5320.	11	1942	6280.	.2750
3	1	1946	1400.	12	1954	6250.	.3000
6	25	1947	3240.	13	1973	5660.	.3250
3	17	1948	2710.	14	1945	5320.	.3500
3	5	1949	4520.	15	1950	4840.	.3750
6	19	1950	4840.	16	1970	4740.	.4000
3	28	1951	8320.	17	1949	4520.	.4250
3	31	1952	13900.	18	1936	4050.	.4500
6	8	1953	71500.	19	1963	3810.	.4750
6	22	1954	6250.	20	1937	3570.	.5000
7	10	1955	2260.	21	1947	3240.	.5250
7	13	1956	318.	22	1972	2940.	.5500
7	5	1957	1330.	23	1961	2870.	.5750
6	31	1958	970.	24	1948	2710.	.6000
6	1	1959	1920.	25	1955	2260.	.6250
3	29	1960	15100.	26	1938	2060.	.6500
3	2	1961	2870.	27	1967	2000.	.6750
3	29	1962	20600.	28	1959	1920.	.7000
6	2	1963	3810.	29	1941	1720.	.7250
9	9	1964	726.	30	1935	1460.	.7500
4	2	1965	7500.	31	1946	1400.	.7750
2	10	1966	7170.	32	1940	1390.	.8000
6	19	1967	2000.	33	1943	1360.	.8250
7	21	1968	829.	34	1957	1330.	.8500
4	5	1969	17300.	35	1939	1300.	.8750
3	4	1970	4740.	36	1958	970.	.9000
-0	-0	1971	13400.	37	1968	829.	.9250
-0	-0	1972	2940.	38	1964	726.	.9500
-0	-0	1973	5660.	39	1956	318.	.9750

-SKEW WEIGHTING -

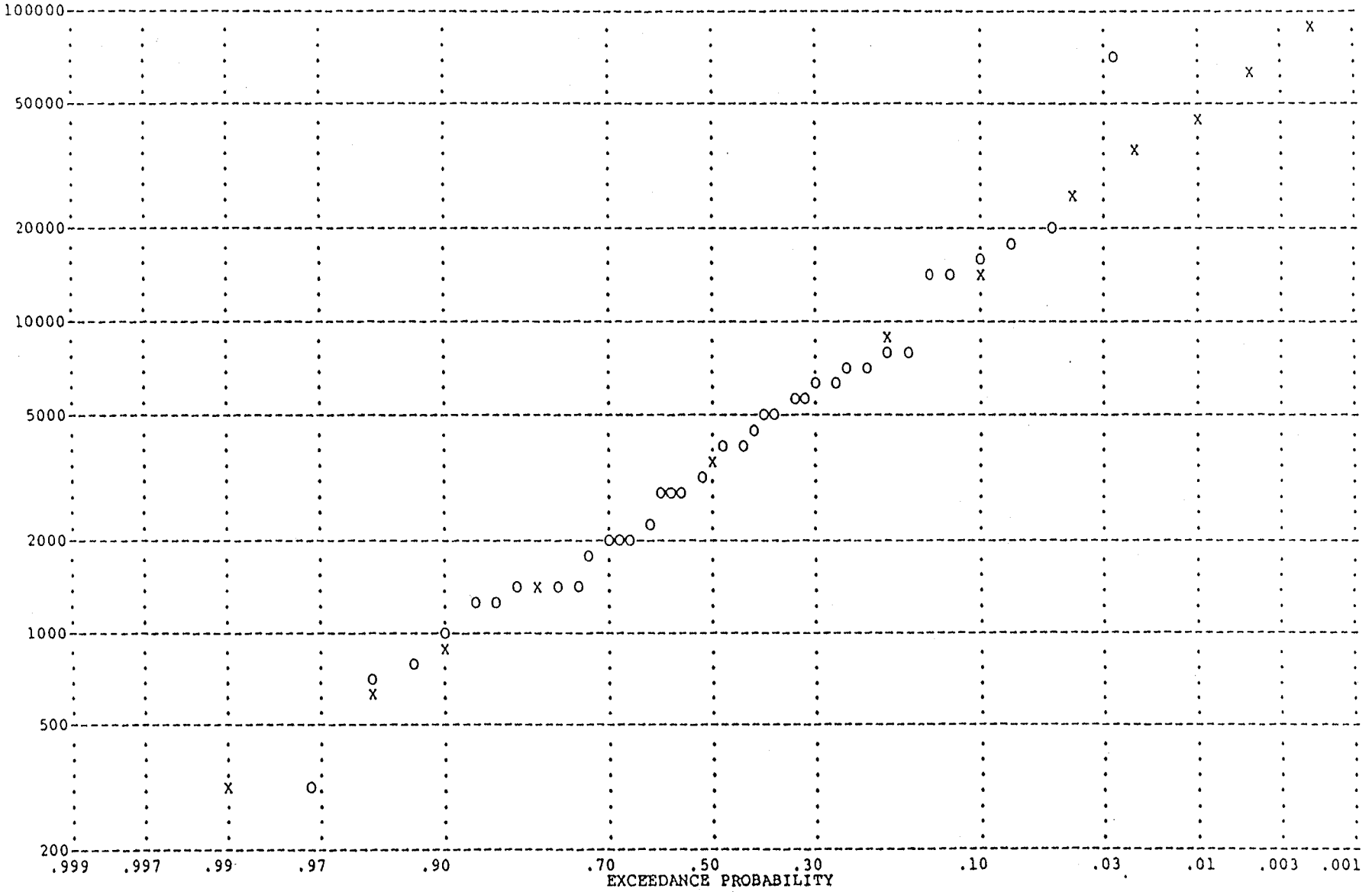
BASED ON 39 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = .158
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = .302

PRELIMINARY RESULTS
-FREQUENCY CURVE- 06-6005 FLOYD RIVER AT JAMES, IOWA

FLOW, CFS COMPUTED	FLOW, CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS .05 LIMIT	CONFIDENCE LIMITS .95 LIMIT
88700.	116000.	.002	199000.	50100.
62300.	76000.	.005	130000.	37000.
46700.	54500.	.010	91500.	28800.
34100.	38300.	.020	62800.	21900.
24200.	26200.	.040	41600.	16200.
14300.	14900.	.100	22300.	10100.
8780.	8980.	.200	12700.	6490.
3530.	3530.	.500	4700.	2650.
1450.	1420.	.800	1970.	1000.
924.	888.	.900	1300.	595.
639.	600.	.950	933.	385.
323.	284.	.990	514.	170.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.5553	HISTORIC EVENTS	0
STANDARD DEVIATION	.4642	HIGH OUTLIERS	0
COMPUTED SKEW	.3566	LOW OUTLIERS	0
GENERALIZED SKEW	-.3000	ZERO OR MISSING	0
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	39

PRELIMINARY RESULTS
-FREQUENCY PLOT - 06-6005 FLOYD RIVER AT JAMES, IOWA DA=882 SQ MI 1935-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

FINAL RESULTS
-PLOTTING POSITIONS- 06-6005 FLOYD RIVER AT JAMES, IOWA

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
6	28	1935	1460.	1	1953	71500.	.0120
3	10	1936	4050.	2	1962	20600.	.0309
5	27	1937	3570.	3	1969	17300.	.0566
9	15	1938	2060.	4	1960	15100.	.0823
3	12	1939	1300.	5	1952	13900.	.1080
6	5	1940	1390.	6	1971	13400.	.1336
3	11	1941	1720.	7	1951	8320.	.1593
6	4	1942	6280.	8	1965	7500.	.1850
6	17	1943	1360.	9	1944	7440.	.2107
5	13	1944	7440.	10	1966	7170.	.2364
3	12	1945	5320.	11	1942	6280.	.2620
3	1	1946	1400.	12	1954	6250.	.2877
6	25	1947	3240.	13	1973	5660.	.3134
3	17	1948	2710.	14	1945	5320.	.3391
3	5	1949	4520.	15	1950	4840.	.3648
6	19	1950	4840.	16	1970	4740.	.3905
3	28	1951	8320.	17	1949	4520.	.4161
3	31	1952	13900.	18	1936	4050.	.4418
6	8	1953	71500.	19	1963	3810.	.4675
6	22	1954	6250.	20	1937	3570.	.4932
7	10	1955	2260.	21	1947	3240.	.5189
7	13	1956	318.	22	1972	2940.	.5445
7	5	1957	1330.	23	1961	2870.	.5702
6	31	1958	970.	24	1948	2710.	.5959
6	1	1959	1920.	25	1955	2260.	.6216
3	29	1960	15100.	26	1938	2060.	.6473
3	2	1961	2870.	27	1967	2000.	.6730
3	29	1962	20600.	28	1959	1920.	.6986
6	2	1963	3810.	29	1941	1720.	.7243
9	9	1964	726.	30	1935	1460.	.7500
4	2	1965	7500.	31	1946	1400.	.7757
2	10	1966	7170.	32	1940	1390.	.8014
6	19	1967	2000.	33	1943	1360.	.8270
7	21	1968	829.	34	1957	1330.	.8527
4	5	1969	17300.	35	1939	1300.	.8784
3	4	1970	4740.	36	1958	970.	.9041
-0	-0	1971	13400.	37	1968	829.	.9298
-0	-0	1972	2940.	38	1964	726.	.9555
-0	-0	1973	5660.	39	1956	318.	.9811

NOTE- PLOTTING POSITIONS BASED ON-HISTORIC PERIOD (H) = 82
NUMBER OF HISTORIC EVENTS PLUS HIGH OUTLIERS(Z) = 1
WEIGHTING FACTOR FOR SYSTEMATIC EVENTS (W) = 2.1316

EXHIBIT I
18

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 39 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.671

0 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 206.8

HIGH OUTLIER TEST

BASED ON 39 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.671

1 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 62395.
OR INPUT BASE OF 71500.

NOTE - COLLECTION OF HISTORICAL INFORMATION AND COMPARISONS WITH SIMILAR DATA SETS SHOULD BE EXPLORED IF NOT INCORPORATED IN THIS ANALYSIS.

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 1 HIGH OUTLIER(S)
AND 0 HISTORIC EVENT(S)

-SKEW WEIGHTING -

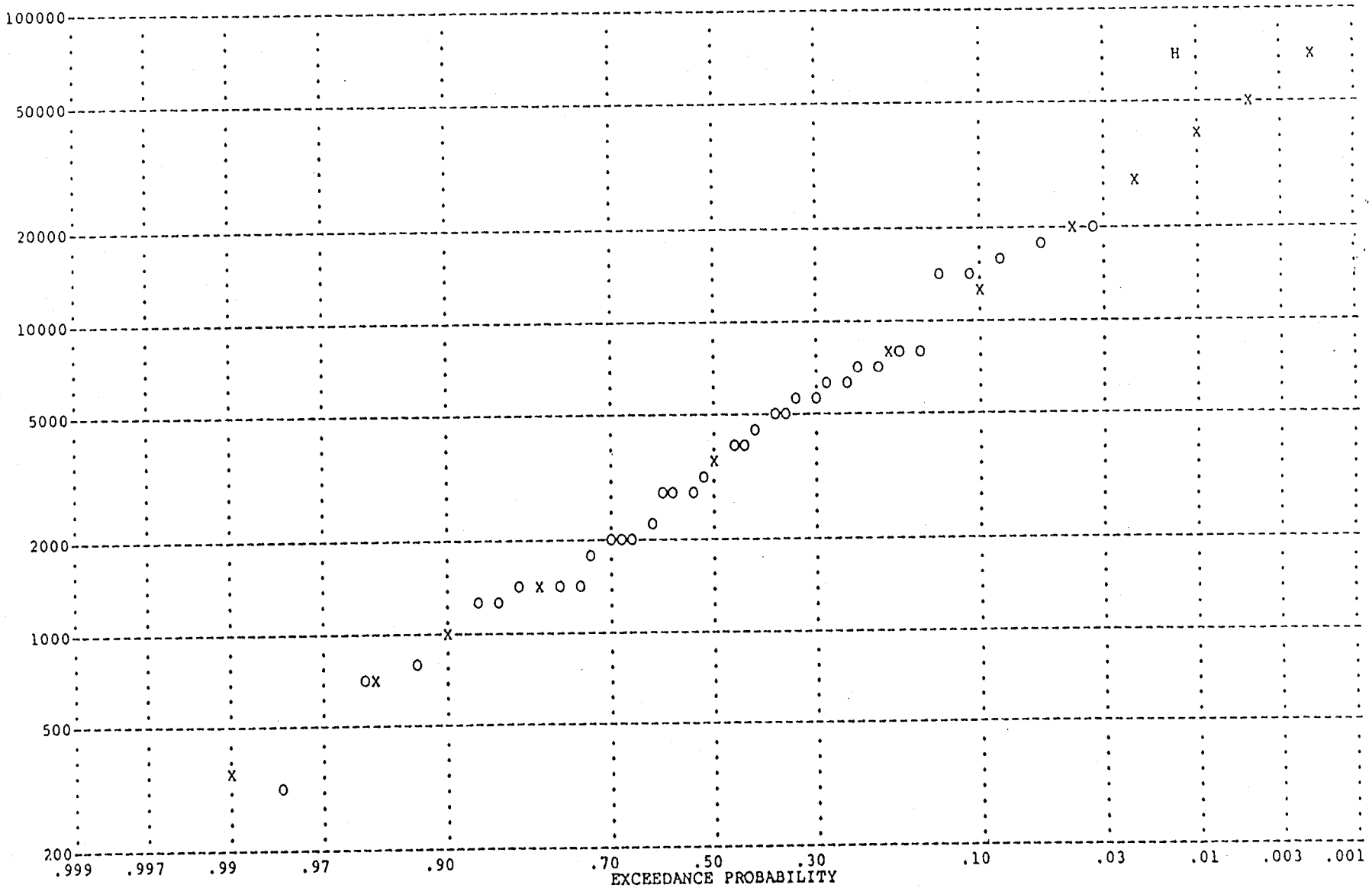
BASED ON 82 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.073
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 06-6005 FLOYD RIVER AT JAMES, IOWA

FLOW, CFS COMPUTED	EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS .05 LIMIT	.95 LIMIT
70900.	91000.	.002	152000.	41300.
50800.	61300.	.005	101000.	31000.
38700.	44700.	.010	73000.	24500.
28800.	32100.	.020	51200.	19000.
20800.	22500.	.040	34700.	14300.
12700.	13200.	.100	19300.	9170.
8010.	8180.	.200	11300.	6020.
3390.	3390.	.500	4440.	2590.
1470.	1440.	.800	1960.	1040.
958.	923.	.900	1320.	632.
676.	637.	.950	967.	419.
356.	315.	.990	551.	195.

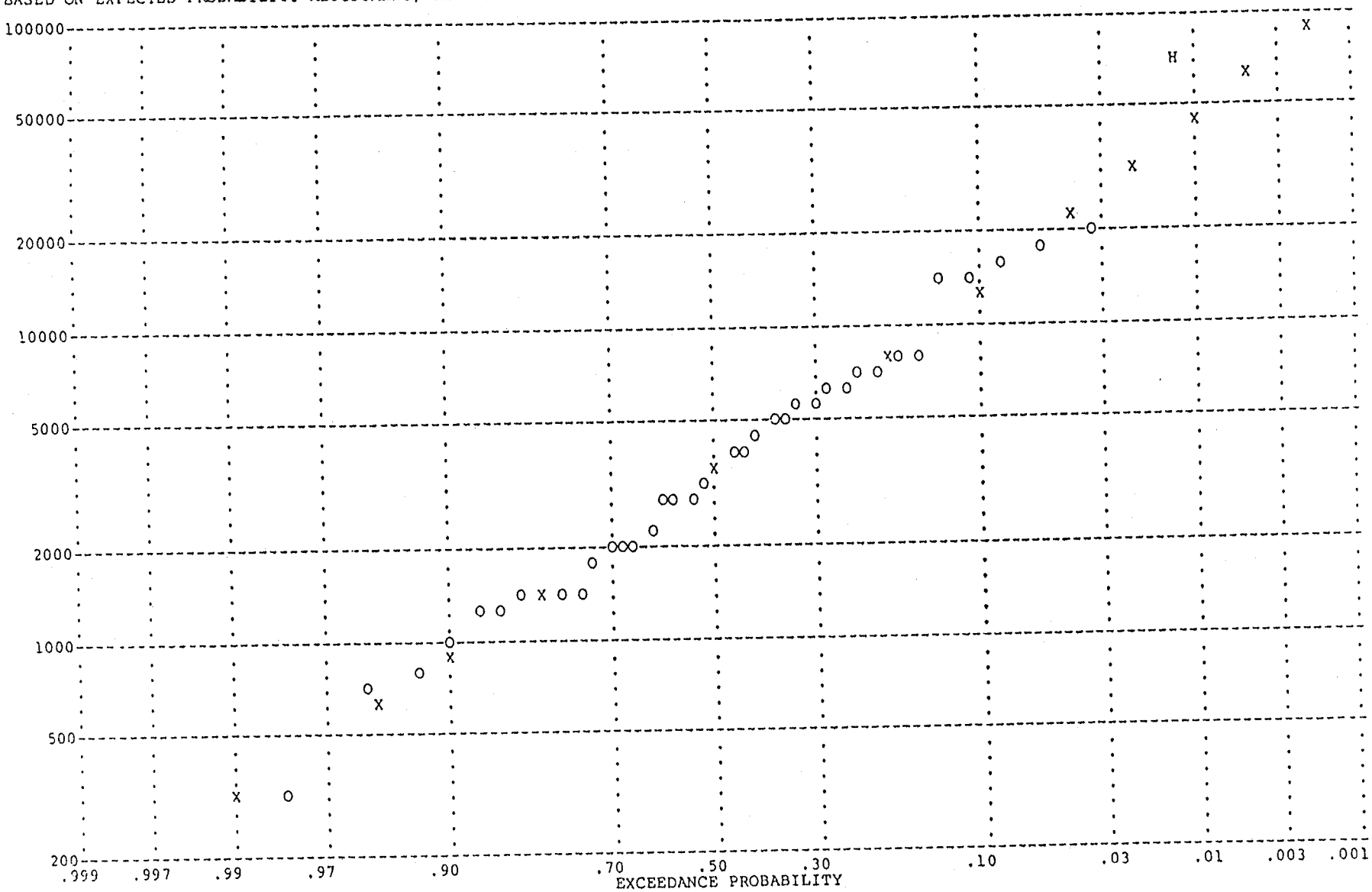
FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.5374	HISTORIC EVENTS	0
STANDARD DEVIATION	.4377	HIGH OUTLIERS	1
COMPUTED SKEW	.1654	LOW OUTLIERS	0
GENERALIZED SKEW	-.3000	ZERO OR MISSING	0
ADOPTED SKEW	.1000	SYSTEMATIC EVENTS	39
		HISTORIC PERIOD	82

FINAL RESULTS
-FREQUENCY PLOT - 06-6005 FLOYD RIVER AT JAMES, IOWA DA=882 SQ MI 1935-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

FINAL RESULTS
-FREQUENCY PLOT - 06-6005 FLOYD RIVER AT JAMES, IOWA DA=882 SQ MI 1935-73
BASED ON EXPECTED PROBABILITY ADJUSTMENT, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

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*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************


**TITLE CARD(S)**
TT   TEST NO. 3 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT   WRC APPENDIX 12, EXAMPLE 3 - TESTING AND ADJUSTING FOR A LOW OUTLIER
TT   BACK CREEK NEAR JONES SPRINGS, WV

*STATION IDENTIFICATION**
ID   01-6140 BACK CR  NEAR JONES SPRINGS, WEST VA    DA=243 SQ MI    1929-31,39-73

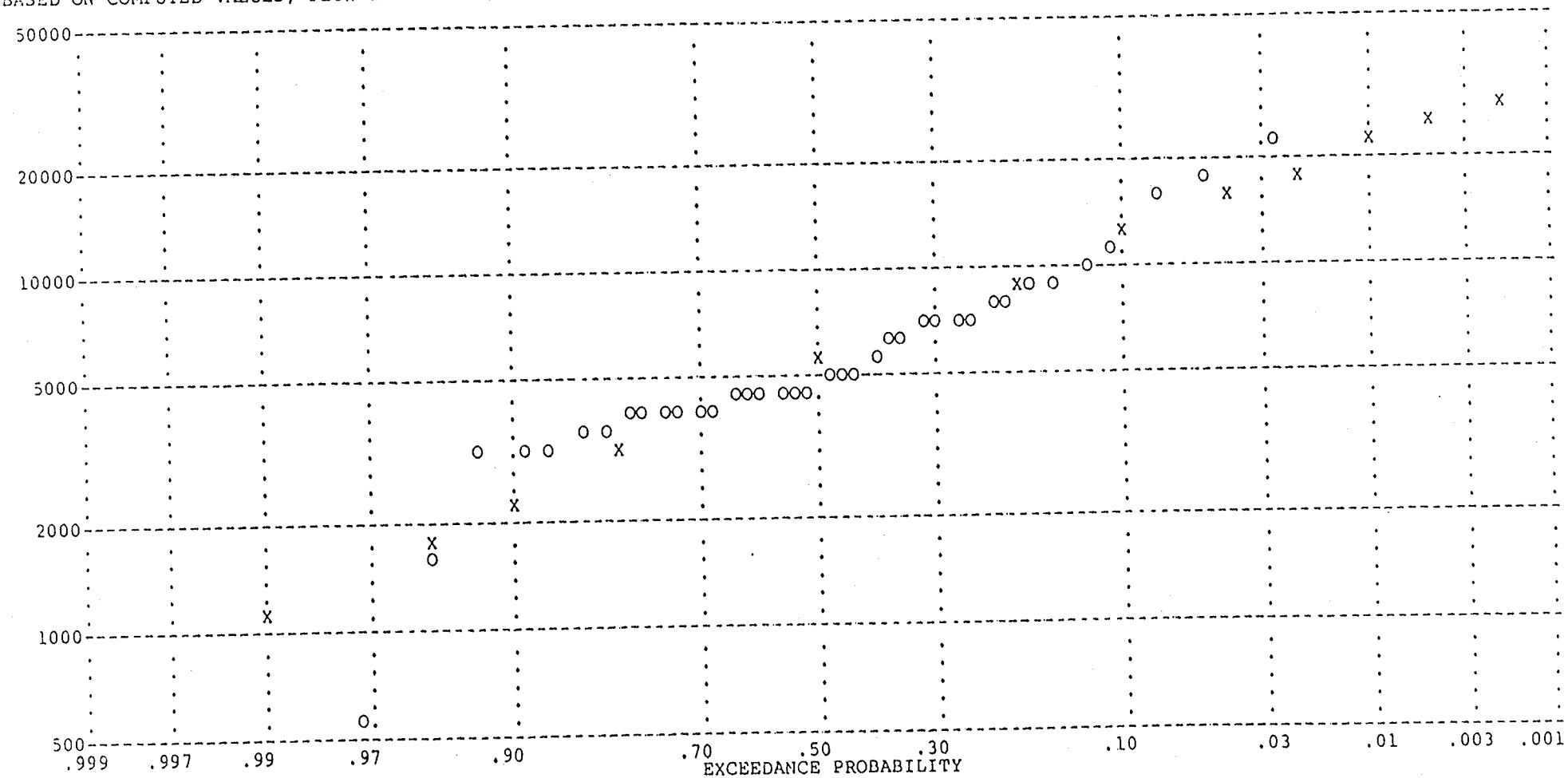
*GENERALIZED SKEW**
     ISTN    GGMSE    SKEW
GS 016140    0.000    0.50

*SYSTEMATIC EVENTS**
     38 EVENTS TO BE ANALYZED

*END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


-SKEW WEIGHTING -
-----------------------------------------------------------------
BASED ON  38 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =  0.197
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =  0.302
-----------------------------------------------------------------
```

PRELIMINARY RESULTS
-FREQUENCY PLOT - 01-6140 BACK CR NEAR JONES SPRINGS, WEST VA DA=243 SQ MI 1929-31,39-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

EXHIBIT 1
25 of 44

FINAL RESULTS
-PLOTTING POSITIONS- 01-6140 BACK CR NEAR JONES SPRINGS, WEST VA

EVENTS ANALYZED				ORDERED EVENTS			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
4	17	1929	8750.	1	1943	22400.	.0256
10	23	1929	15500.	2	1972	18700.	.0513
5	8	1931	4060.	3	1930	15500.	.0769
2	4	1939	6300.	4	1955	10700.	.1026
4	20	1940	3130.	5	1953	9820.	.1282
4	6	1941	4160.	6	1951	9150.	.1538
5	22	1942	6700.	7	1929	8750.	.1795
10	15	1942	22400.	8	1971	8360.	.2051
3	24	1944	3880.	9	1945	8050.	.2308
9	18	1945	8050.	10	1967	7080.	.2564
6	3	1946	4020.	11	1959	6800.	.2821
3	15	1947	1600.	12	1942	6700.	.3077
4	14	1948	4460.	13	1970	6680.	.3333
12	31	1948	4230.	14	1939	6300.	.3590
2	2	1950	3010.	15	1954	6200.	.3846
12	5	1950	9150.	16	1965	5600.	.4103
4	28	1952	5100.	17	1973	5210.	.4359
11	22	1952	9820.	18	1963	5190.	.4615
3	2	1954	6200.	19	1952	5100.	.4872
8	19	1955	10700.	20	1961	4700.	.5128
3	15	1956	3880.	21	1966	4670.	.5385
2	10	1957	3420.	22	1968	4640.	.5641
3	27	1958	3240.	23	1948	4460.	.5897
6	3	1959	6800.	24	1962	4380.	.6154
5	9	1960	3740.	25	1949	4230.	.6410
2	19	1961	4700.	26	1941	4160.	.6667
3	22	1962	4380.	27	1931	4060.	.6923
3	20	1963	5190.	28	1946	4020.	.7179
1	10	1964	3960.	29	1964	3960.	.7436
3	6	1965	5600.	30	1956	3880.	.7692
-0	-0	1966	4670.	31	1944	3880.	.7949
-0	-0	1967	7080.	32	1960	3740.	.8205
-0	-0	1968	4640.	33	1957	3420.	.8462
-0	-0	1969	536.	34	1958	3240.	.8718
-0	-0	1970	6680.	35	1940	3130.	.8974
-0	-0	1971	8360.	36	1950	3010.	.9231
-0	-0	1972	18700.	37	1947	1600.	.9487
-0	-0	1973	5210.	38	1969	536.	.9744

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 38 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.661

1 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 945.8

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 1 LOW OUTLIER(S)

HIGH OUTLIER TEST

BASED ON 37 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.650

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 22760.

-SKEW WEIGHTING -

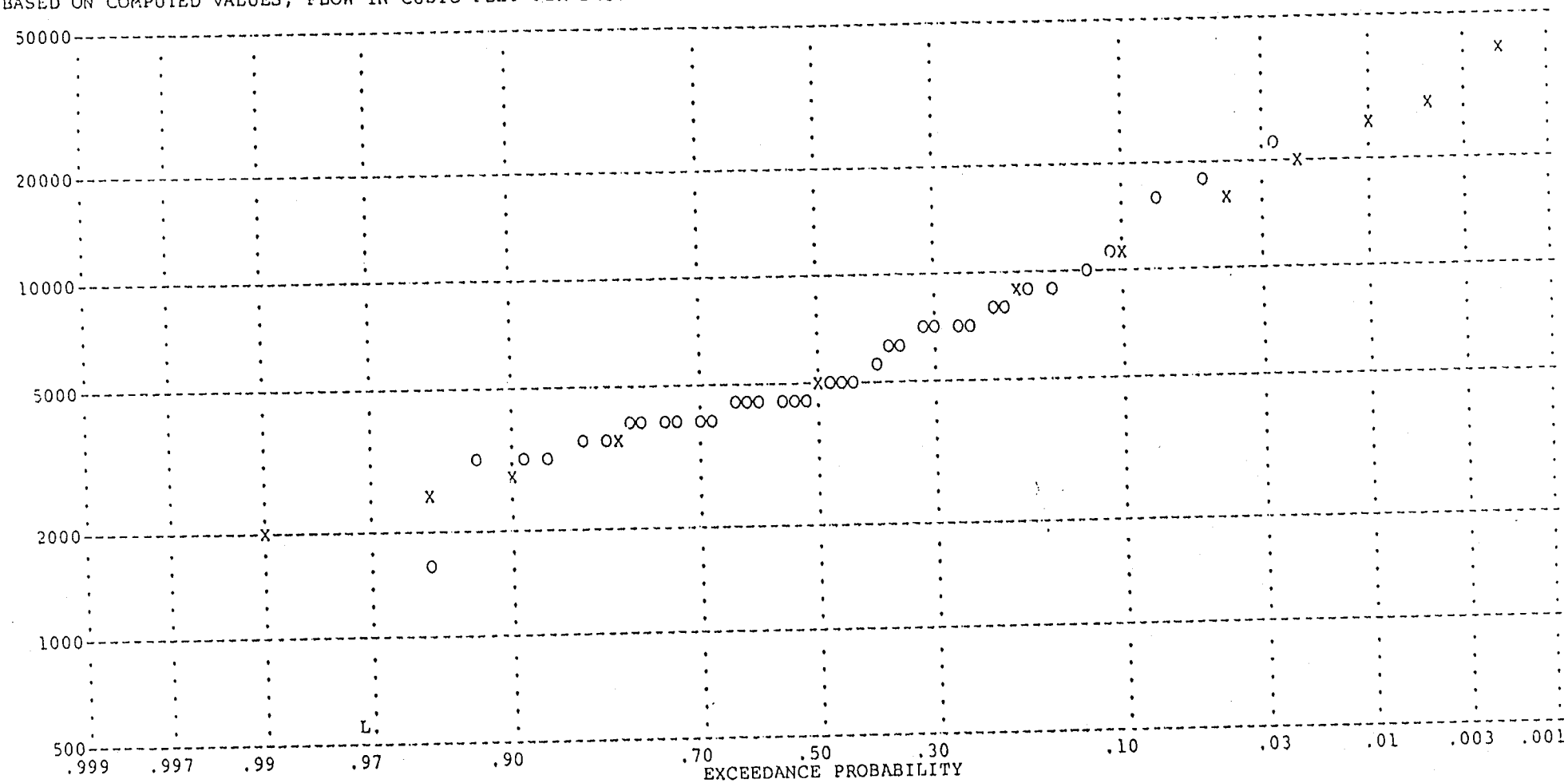
BASED ON 38 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.186
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 01-6140 BACK CR NEAR JONES SPRINGS, WEST VA

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.05 LIMIT	CONFIDENCE LIMITS 0.95 LIMIT
37700.	46200.	0.002	61000.	27000.
29300.	33900.	0.005	44800.	21700.
23900.	26700.	0.010	35000.	18300.
19400.	21000.	0.020	27100.	15200.
15500.	16300.	0.040	20700.	12500.
11200.	11500.	0.100	14100.	9390.
8440.	8550.	0.200	10100.	7250.
5230.	5230.	0.500	6030.	4510.
3490.	3460.	0.800	4070.	2890.
2910.	2860.	0.900	3440.	2340.
2530.	2480.	0.950	3040.	1990.
2020.	1940.	0.990	2490.	1520.

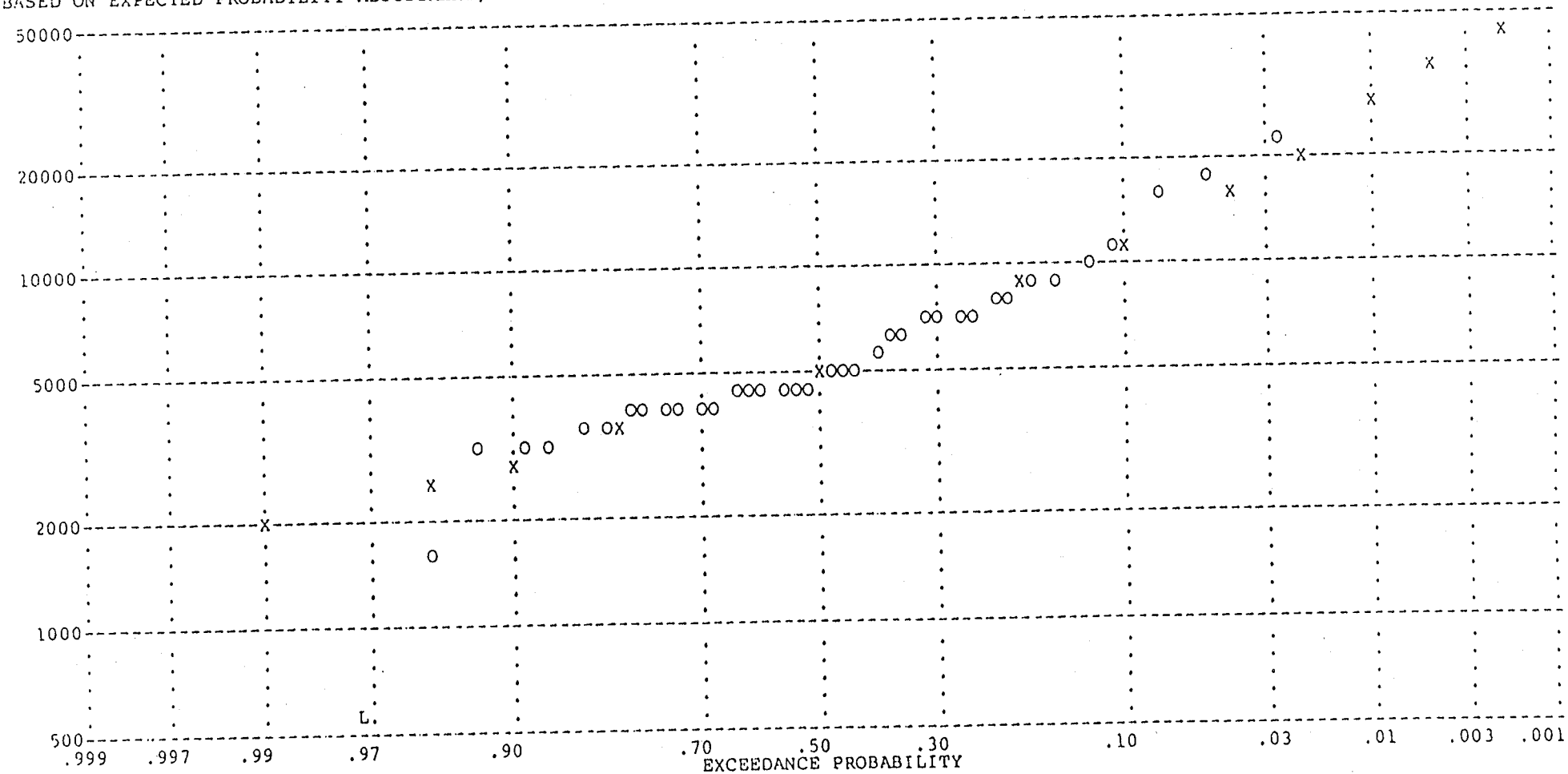
FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.7413	HISTORIC EVENTS	0
STANDARD DEVIATION	0.2315	HIGH OUTLIERS	0
COMPUTED SKEW	0.6238	LOW OUTLIERS	1
GENERALIZED SKEW	0.5000	ZERO OR MISSING	0
ADOPTED SKEW	0.6000	SYSTEMATIC EVENTS	38

FINAL RESULTS
-FREQUENCY PLOT - 01-6140 BACK CR NEAR JONES SPRINGS, WEST VA DA=243 SQ MI 1929-31,39-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

FINAL RESULTS
-FREQUENCY PLOT - 01-6140 BACK CR NEAR JONES SPRINGS, WEST VA DA=243 SQ MI 1929-31,39-73
BASED ON EXPECTED PROBABILITY ADJUSTMENT, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

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*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************
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TITLE CARD(S)
TT TEST NO. 4 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT WRC APPENDIX 12, EXAMPLE 4 - ZERO FLOOD YEARS
TT ORESTIMBA CREEK NEAR NEWMAN, CA

STATION IDENTIFICATION
ID 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA DA=134 SQ MI 1932-73

GENERALIZED SKEW

	ISTN	GGMSE	SKEW
GS	112745	0.000	-0.30

SYSTEMATIC EVENTS
42 EVENTS TO BE ANALYZED

END OF INPUT DATA
ED ++
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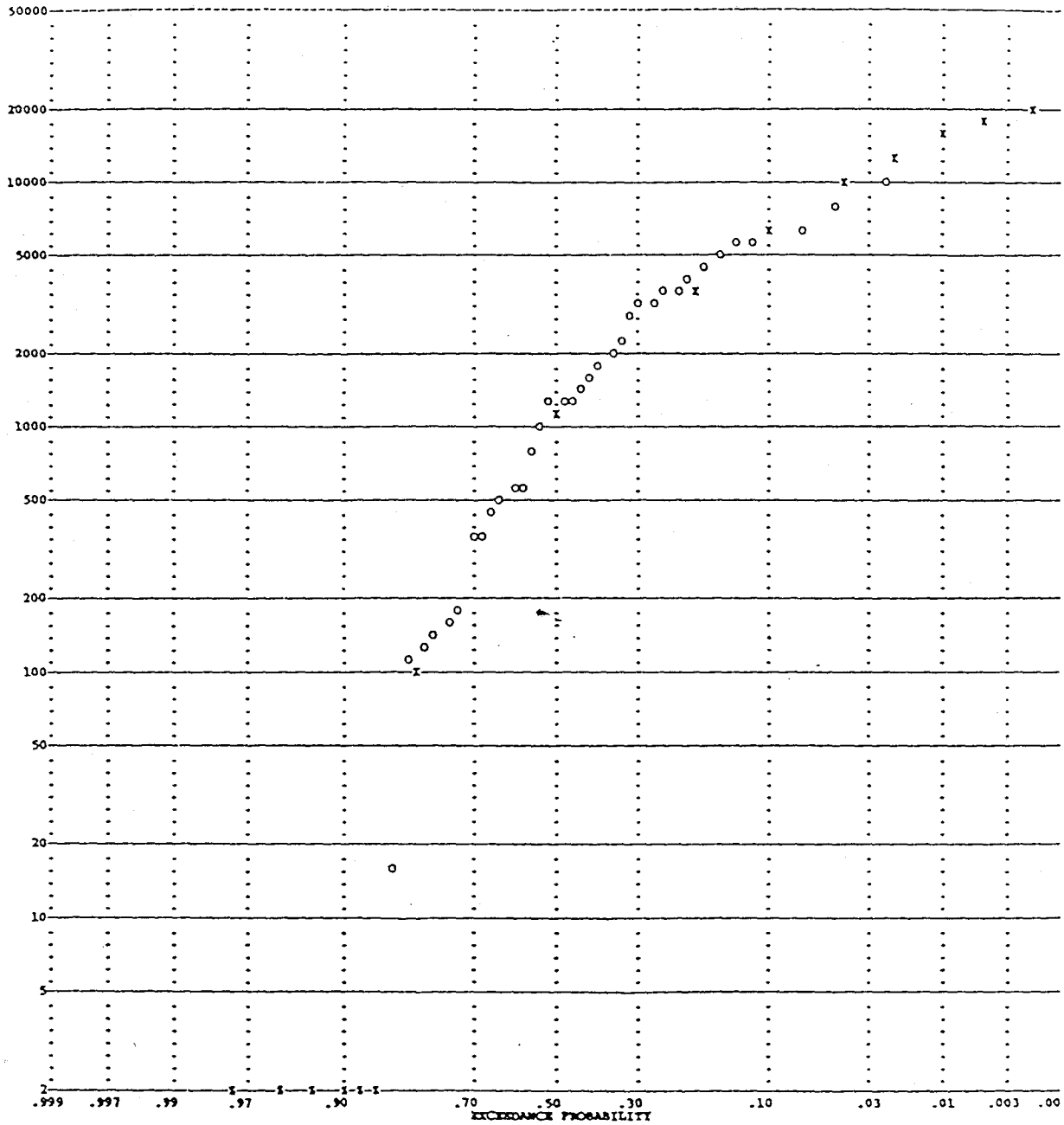
NOTE - ADOPTED SKEW EQUALS COMPUTED SKEW AND PRELIMINARY FREQUENCY STATISTICS ARE FOR THE CONDITIONAL FREQUENCY CURVE BECAUSE OF ZERO OR MISSING EVENTS.

PRELIMINARY RESULTS
-FREQUENCY CURVE- 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.05 LIMIT	CONFIDENCE LIMITS 0.95 LIMIT
19868.	21800.	0.002	42000.	11400.
16898.	18300.	0.005	34600.	9880.
14498.	15600.	0.010	28900.	8620.
12025.	12800.	0.020	23200.	7300.
9475.	9950.	0.040	17500.	5890.
6101.	6310.	0.100	10500.	3950.
3735.	3800.	0.200	6020.	2500.
1077.	1077.	0.500	1570.	732.
104.	94.	0.800	175.	53.
0.	0.	0.900	0.	0.
0.	0.	0.950	0.	0.
0.	0.	0.990	0.	0.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.0786	HISTORIC EVENTS	0
STANDARD DEVIATION	0.6443	HIGH OUTLIERS	0
COMPUTED SKEW	-0.8360	LOW OUTLIERS	0
GENERALIZED SKEW	-0.3000	ZERO OR MISSING	6
ADOPTED SKEW	-0.8360	SYSTEMATIC EVENTS	42

PRELIMINARY RESULTS
-FREQUENCY PLOT - 11-2745 [illegible] CREEK NEAR [illegible], CA DA-134 SQ MI 1932-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O-OBSERVED EVENT, H-HIGH OUTLIER OR HISTORIC EVENT, L-LOW OUTLIER, Z-ZERO OR MISSING X-COMPUTED CURVE

FINAL RESULTS
-PLOTTING POSITIONS- 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA

.....EVENTS ANALYZED.....				.....ORDERED EVENTS.....			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
2	8	1932	4260.	1	1958	10200.	.0233
1	29	1933	345.	2	1963	8300.	.0465
1	1	1934	516.	3	1943	6450.	.0698
4	8	1935	1320.	4	1945	5970.	.0930
2	13	1936	1200.	5	1956	5620.	.1163
2	13	1937	2180.	6	1959	5380.	.1395
2	11	1938	3230.	7	1969	5080.	.1628
3	9	1939	115.	8	1932	4260.	.1860
2	27	1940	3440.	9	1967	4200.	.2093
4	4	1941	3070.	10	1952	3660.	.2326
1	24	1942	1880.	11	1940	3440.	.2558
1	21	1943	6450.	12	1938	3230.	.2791
2	29	1944	1290.	13	1941	3070.	.3023
2	2	1945	5970.	14	1951	2920.	.3256
12	25	1945	782.	15	1937	2180.	.3488
-0	-0	1947	0.	16	1942	1880.	.3721
-0	-0	1948	0.	17	1962	1740.	.3953
3	12	1949	335.	18	1973	1510.	.4186
2	5	1950	175.	19	1957	1440.	.4419
12	3	1950	2920.	20	1935	1320.	.4651
1	12	1952	3660.	21	1944	1290.	.4884
12	7	1952	147.	22	1936	1200.	.5116
-0	-0	1954	0.	23	1970	1010.	.5349
1	19	1955	16.	24	1946	782.	.5581
12	23	1955	5620.	25	1971	584.	.5814
2	24	1957	1440.	26	1966	560.	.6047
4	2	1958	10200.	27	1934	516.	.6279
2	16	1959	5380.	28	1960	448.	.6512
2	10	1960	448.	29	1933	345.	.6744
-0	-0	1961	0.	30	1949	335.	.6977
2	15	1962	1740.	31	1950	175.	.7209
2	1	1963	8300.	32	1964	156.	.7442
1	22	1964	156.	33	1953	147.	.7674
-0	-0	1966	560.	34	1966	128.	.7907
12	30	1965	128.	35	1939	115.	.8140
1	24	1967	4200.	36	1955	16.	.8372
-0	-0	1968	0.	37	1968	0.	.8605
1	25	1969	5080.	38	1948	0.	.8837
3	1	1970	1010.	39	1954	0.	.9070
12	21	1970	584.	40	1947	0.	.9302
-0	-0	1972	0.	41	1972	0.	.9535
2	11	1973	1510.	42	1961	0.	.9767

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 36 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.639

1 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 23.9
BASED ON THE STATISTICS AFTER 6 ZERO OR MISSING EVENTS DELETED

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 1 LOW OUTLIER(S)
AND/OR 6 ZERO OR MISSING EVENT(S)

HIGH OUTLIER TEST

BASED ON 35 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.628

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 41786.

-SKEW WEIGHTING -

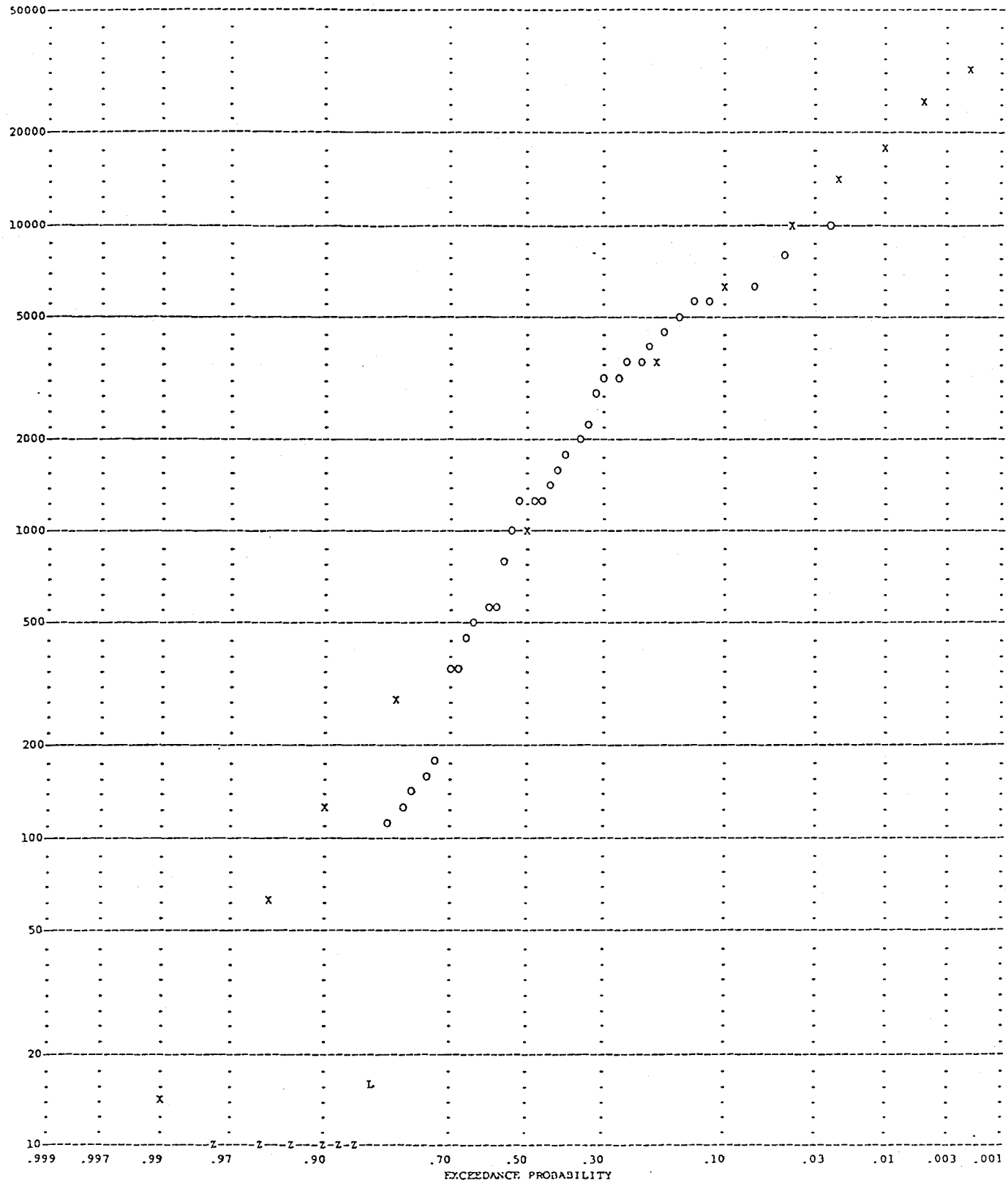
BASED ON 42 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.167
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA

FLOW, CFS COMPUTED	FLOW, CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.05 LIMIT	CONFIDENCE LIMITS 0.95 LIMIT
31000.	36900.	0.002	75500.	16200.
23700.	27200.	0.005	54800.	12800.
18700.	21000.	0.010	41300.	10400.
14200.	15600.	0.020	29900.	8160.
10300.	11100.	0.040	20400.	6130.
6000.	6260.	0.100	10900.	3770.
3450.	3540.	0.200	5770.	2260.
1050.	1050.	0.500	1570.	708.
266.	258.	0.800	405.	161.
121.	113.	0.900	195.	65.
60.	54.	0.950	105.	29.
15.	11.	0.990	31.	5.

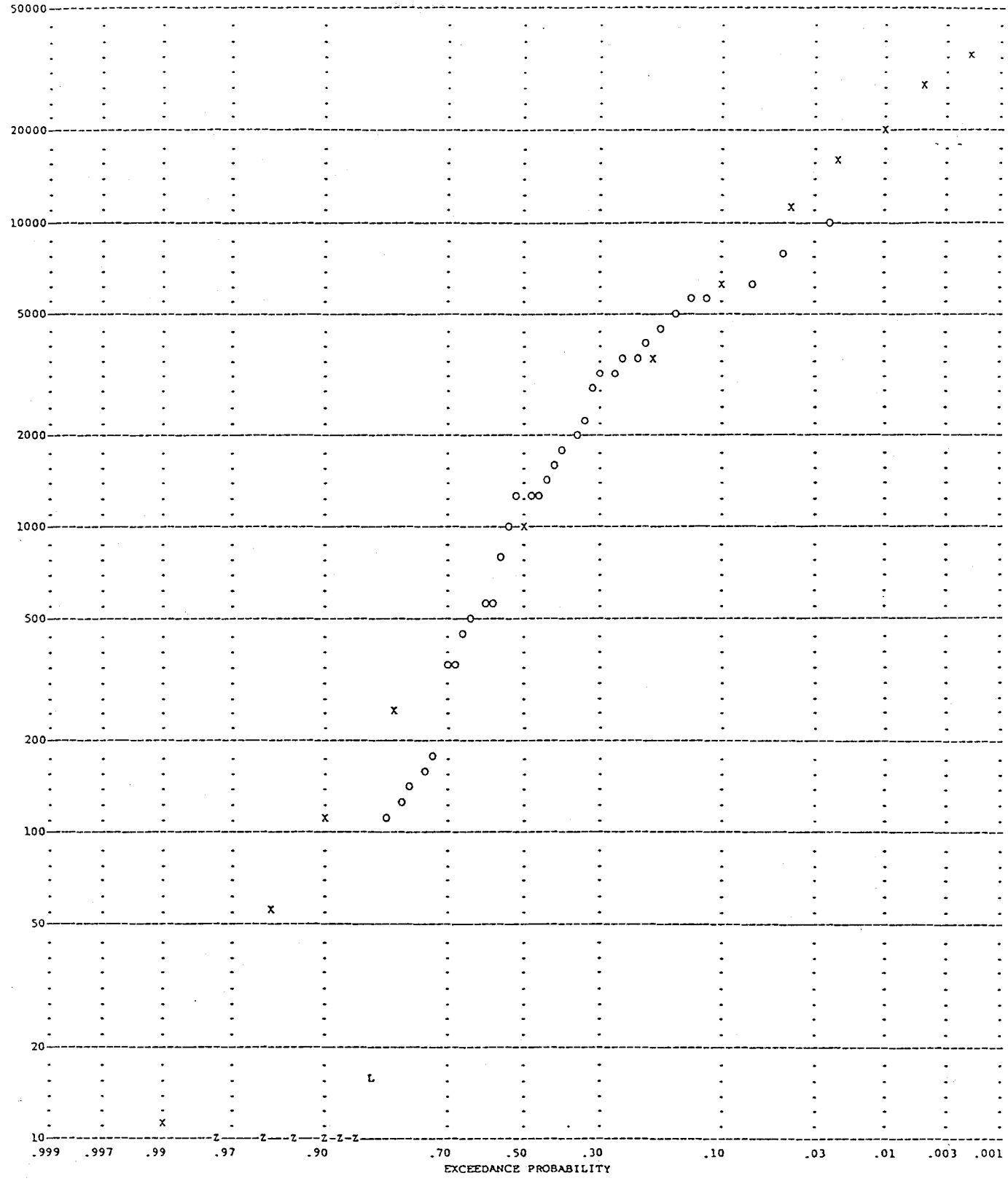
FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	2.9657	HISTORIC EVENTS	0
STANDARD DEVIATION	0.6682	HIGH OUTLIERS	0
COMPUTED SKEW	-0.5682	LOW OUTLIERS	1
GENERALIZED SKEW	-0.3000	ZERO OR MISSING	6
ADOPTED SKEW	-0.5000	SYSTEMATIC EVENTS	42

FINAL RESULTS
-FREQUENCY PLOT - 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA DA-134 SQ MI 1932-73
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O-OBSERVED EVENT, H-HIGH OUTLIER OR HISTORIC EVENT, L-LOW OUTLIER, Z-ZERO OR MISSING X-COMPUTED CURVE

FINAL RESULTS
-FREQUENCY PLOT - 11-2745 ORESTIMBA CREEK NEAR NEWMAN, CA DA=134 SQ MI 1932-73
BASED ON EXPECTED PROBABILITY ADJUSTMENT, FLOW IN CUBIC FEET PER SECOND



LEGEND - O-OBSERVED EVENT, H-HIGH OUTLIER OR HISTORIC EVENT, L-LOW OUTLIER, Z-ZERO OR MISSING X-COMPUTED CURVE

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*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************

**TITLE CARD(S)**
TT   TEST NO. 5 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT   EXAMPLE USE OF PRINTOUT SUPPRESSION (IPROUT), OTHER CONFIDENCE LIMITS
TT   (CLIMIT), AND A BASE PEAK DISCHARGE (BASEPK)

**JOB CARD(S)**
     IPPC   ISKFX  IPROUT    IPMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1    -0      -0     33      -0      -0      -0      -0      -0      -0

       A       B   CLIMIT
J2 -0.     -0.       .01

**STATION IDENTIFICATION**
ID    05-5925  KASKASKIA RIVER AT VANDALIA,ILL    DA=1980 SQ MI            1908-70

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   5925  -0.      -.40

**SPECIAL STATION INFORMATION**
    IYRA    IYRL   NOUTL  BASEPK
SI    -0      -0      -0   2000.

**SYSTEMATIC EVENTS**
     60 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

-SKEW WEIGHTING -
-----------------------------------------------------------------------
BASED ON  60 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =    .199
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =    .302
-----------------------------------------------------------------------

 PRELIMINARY RESULTS
-FREQUENCY CURVE-  05-5925  KASKASKIA RIVER AT VANDALIA,ILL
*****************************************************************
*........FLOW,CFS........*              *...CONFIDENCE LIMITS...*
*                        *              *                       *
*          EXPECTED      * EXCEEDANCE   *                       *
*  COMPUTED PROBABILITY  * PROBABILITY  *  .01 LIMIT  .99 LIMIT *
*------------------------*--------------*-----------------------*
*   58300.     60600.     *    .002      *   96600.     40900.  *
*   53300.     55100.     *    .005      *   86500.     37900.  *
*   49100.     50500.     *    .010      *   78100.     35200.  *
*   44300.     45400.     *    .020      *   69000.     32200.  *
*   39100.     39800.     *    .040      *   59100.     28800.  *
*   31100.     31500.     *    .100      *   45000.     23600.  *
*   24300.     24500.     *    .200      *   33600.     18800.  *
*   13600.     13600.     *    .500      *   17500.     10700.  *
*    6530.      6450.     *    .800      *    8420.      4770.  *
*    4180.      4060.     *    .900      *    5600.      2810.  *
*    2790.      2660.     *    .950      *    3930.      1720.  *
*    1200.      1070.     *    .990      *    1910.       603.  *
*+++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++*
*   FREQUENCY CURVE STATISTICS   *     STATISTICS BASED ON       *
*--------------------------------*-------------------------------*
*  MEAN LOGARITHM          4.0869 *  HISTORIC EVENTS          0 *
*  STANDARD DEVIATION       .3486 *  HIGH OUTLIERS        0     *
*  COMPUTED SKEW          -1.0942 *  LOW OUTLIERS         0     *
*  GENERALIZED SKEW        -.4000 *  ZERO OR MISSING      0     *
*  ADOPTED SKEW            -.8000 *  SYSTEMATIC EVENTS       60 *
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EXHIBIT 1
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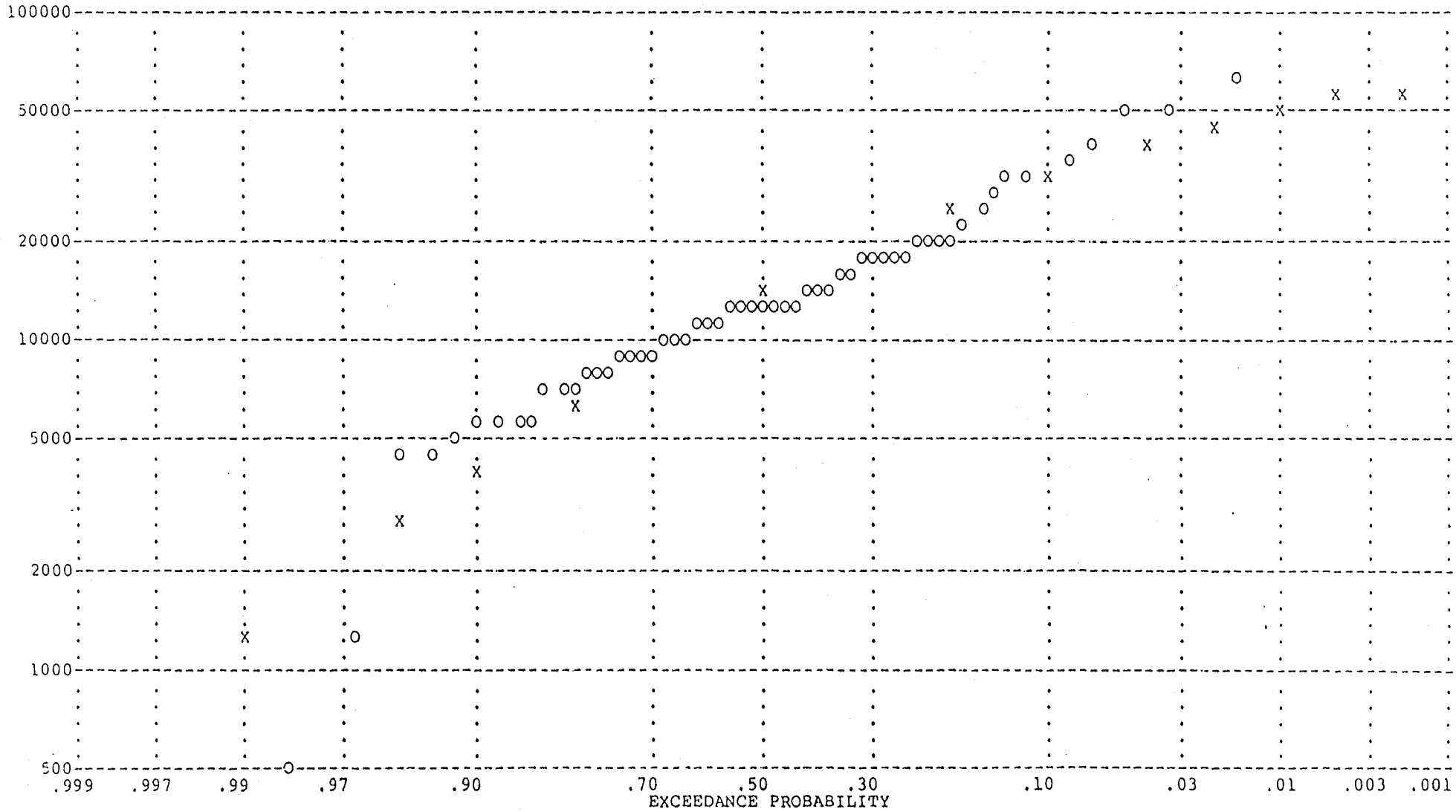
PRELIMINARY RESULTS
-FREQUENCY PLOT - 05-5925 KASKASKIA RIVER AT VANDALIA,ILL DA=1980 SQ MI 1908-70
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

FINAL RESULTS
-PLOTTING POSITIONS- 05-5925 KASKASKIA RIVER AT VANDALIA,ILL

.....EVENTS ANALYZED.....				...ORDERED EVENTS...			
MON	DAY	YEAR	FLOW,CFS	RANK	WATER YEAR	FLOW,CFS	WEIBULL PLOT POS
5	6	1908	7870.	1	1957	62700.	.0164
4	14	1909	7670.	2	1943	52200.	.0328
3	1	1910	7020.	3	1950	51300.	.0492
5	1	1911	5670.	4	1938	40700.	.0656
10	4	1911	13000.	5	1961	34400.	.0820
7	21	1915	15800.	6	1944	31000.	.0984
1	31	1916	14400.	7	1951	31000.	.1148
6	5	1917	16800.	8	1970	30000.	.1311
5	11	1918	8880.	9	1967	27000.	.1475
3	19	1919	11000.	10	1949	25000.	.1639
5	19	1920	12600.	11	1945	21500.	.1803
4	18	1922	18800.	12	1968	20800.	.1967
3	17	1923	14300.	13	1969	20700.	.2131
12	15	1923	10500.	14	1927	20000.	.2295
3	16	1925	9980.	15	1948	19000.	.2459
9	17	1926	8460.	16	1922	18800.	.2623
3	20	1927	20000.	17	1933	17500.	.2787
12	1	1927	12200.	18	1959	17200.	.2951
5	14	1929	12200.	19	1962	17100.	.3115
1	14	1930	11500.	20	1917	16800.	.3279
9	18	1931	1270.	21	1939	16000.	.3443
1	24	1932	5550.	22	1915	15800.	.3607
5	15	1933	17500.	23	1937	14900.	.3770
8	19	1934	4250.	24	1916	14400.	.3934
5	16	1935	11200.	25	1923	14300.	.4098
3	26	1936	7290.	26	1942	13600.	.4262
1	15	1937	14900.	27	1946	13000.	.4426
3	31	1938	40700.	28	1912	13000.	.4590
3	14	1939	16000.	29	1920	12600.	.4754
5	3	1940	6760.	30	1958	12400.	.4918
6	12	1941	4560.	31	1947	12300.	.5082
7	12	1942	13600.	32	1928	12200.	.5246
5	18	1943	52200.	33	1929	12200.	.5410
4	24	1944	31000.	34	1966	11900.	.5574
6	10	1945	21500.	35	1960	11800.	.5738
5	4	1946	13000.	36	1930	11500.	.5902
6	10	1947	12300.	37	1935	11200.	.6066
3	28	1948	19000.	38	1919	11000.	.6230
2	16	1949	25000.	39	1952	10500.	.6393
1	4	1950	51300.	40	1924	10500.	.6557
6	29	1951	31000.	41	1925	9980.	.6721
4	15	1952	10500.	42	1963	9000.	.6885
3	5	1953	5680.	43	1918	8880.	.7049
4	19	1954	505.	44	1964	8500.	.7213
4	25	1955	5000.	45	1926	8460.	.7377
2	27	1956	7840.	46	1908	7870.	.7541
6	29	1957	62700.	47	1956	7840.	.7705
8	4	1958	12400.	48	1909	7670.	.7869
2	12	1959	17200.	49	1936	7290.	.8033
6	30	1960	11800.	50	1910	7020.	.8197
4	10	1961	34400.	51	1940	6760.	.8361
3	25	1962	17100.	52	1953	5680.	.8525
5	22	1963	9000.	53	1911	5670.	.8689
5	4	1964	8500.	54	1932	5550.	.8852
5	4	1965	5350.	55	1965	5350.	.9016
5	19	1966	11900.	56	1955	5000.	.9180
12	10	1966	27000.	57	1941	4560.	.9344
12	23	1967	20800.	58	1934	4250.	.9508
1	31	1969	20700.	59	1931	1270.	.9672
6	16	1970	30000.	60	1954	505.	.9836

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 60 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.837

2 LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 1253.2
OR INPUT BASE OF 2000.0

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 2 LOW OUTLIER(S)

HIGH OUTLIER TEST

BASED ON 58 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.824

0 HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 78238.

-SKEW WEIGHTING -

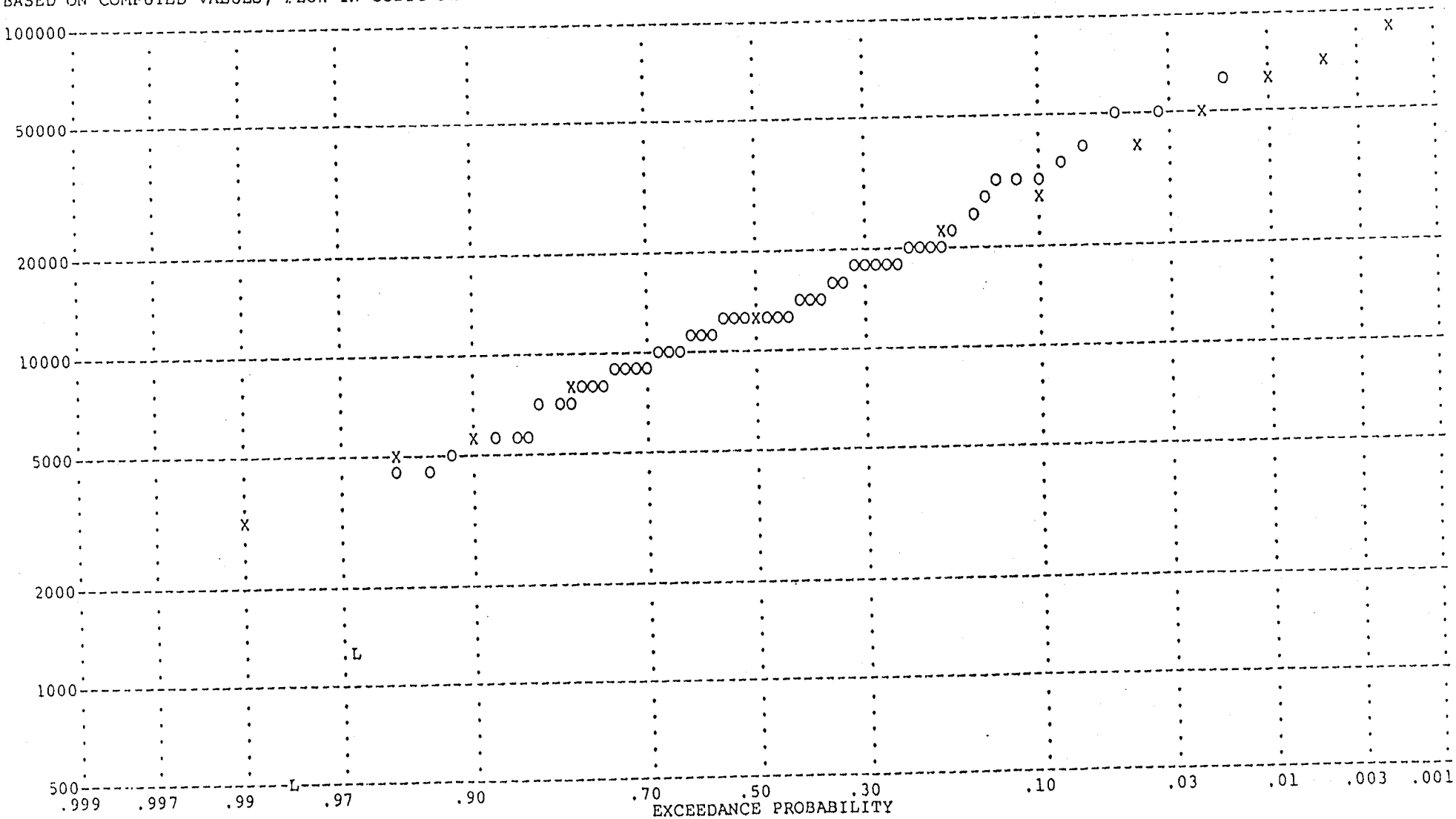
BASED ON 60 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.113
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 05-5925 KASKASKIA RIVER AT VANDALIA,ILL

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.01 LIMIT	CONFIDENCE LIMITS 0.99 LIMIT
93600.	104000.	0.002	167000.	63500.
74600.	80900.	0.005	126000.	52500.
62100.	66100.	0.010	99900.	44900.
51000.	53400.	0.020	78200.	37900.
41100.	42500.	0.040	60000.	31500.
29700.	30200.	0.100	40400.	23600.
22100.	22300.	0.200	28400.	18000.
12800.	12800.	0.500	15500.	10500.
7650.	7590.	0.800	9360.	5930.
5910.	5830.	0.900	7410.	4370.
4810.	4700.	0.950	6170.	3410.
3310.	3160.	0.990	4460.	2150.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	4.1163	HISTORIC EVENTS	0
STANDARD DEVIATION	0.2738	HIGH OUTLIERS	0
COMPUTED SKEW	0.3993	LOW OUTLIERS	2
GENERALIZED SKEW	-0.4000	ZERO OR MISSING	0
ADOPTED SKEW	0.2000	SYSTEMATIC EVENTS	60

FINAL RESULTS
-FREQUENCY PLOT - 05-5925 KASKASKIA RIVER AT VANDALIA,ILL DA=1980 SQ MI 1908-70
BASED ON COMPUTED VALUES, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

EXHIBIT 1
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*********************************
* FLOOD FLOW FREQUENCY ANALYSIS *
* VERSION DATE  --  FEB 9, 1982 *
* AFTER BULLETIN 17B, SEPT 1981 *
*********************************


**TITLE CARD(S)**
TT   TEST NO. 6 FLOOD FLOW FREQUENCY ANALYSIS PROGRAM
TT   EXAMPLE USE OF MEDIAN PLOT POSITIONS(IPPC),WRC FORMAT(IFMT), HISTORIC
TT   DATA(QR CARD), AND PERIOD OF KNOWLEDGE BEYOND LAST YEAR OF DATA(IYRL)

**JOB CARD(S)**
     IPPC   ISKFX  IPROUT    IFMT    IWYR   IUNIT   ISMRY   IPNCH    IREG
J1     2      -0      21       2      -0      -0      -0      -0      -0

**STATION IDENTIFICATION**
ID   01-4765 RIDLEY CREEK AT MOYLAN, PA            DA=31.9 SQ MI           1932-55

**GENERALIZED SKEW**
     ISTN   GGMSE    SKEW
GS   4765  -0.        .40

**SPECIAL STATION INFORMATION**
    IYRA    IYRL   NOUTL  BASEPK
SI    -0    1974     -0     -0.

**HISTORIC EVENTS**
QH   5   8  1843    15000.

**SYSTEMATIC EVENTS**
     24 EVENTS TO BE ANALYZED

**END OF INPUT DATA**
ED ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++
++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++++


-SKEW WEIGHTING -
-----------------------------------------------------------------
BASED ON  24 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW =    .315
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW =    .302
-----------------------------------------------------------------
```

PRELIMINARY RESULTS
-FREQUENCY CURVE- 01-4765 RIDLEY CREEK AT MOYLAN, PA

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS .01 LIMIT	CONFIDENCE LIMITS .99 LIMIT
13600.	21000.	.002	49100.	7070.
9890.	13400.	.005	30400.	5530.
7680.	9640.	.010	20900.	4550.
5910.	6950.	.020	14100.	3700.
4480.	4980.	.040	9410.	2960.
3000.	3170.	.100	5300.	2130.
2130.	2190.	.200	3310.	1570.
1200.	1200.	.500	1640.	865.
754.	742.	.800	1030.	479.
613.	597.	.900	855.	361.
527.	506.	.950	750.	291.
414.	387.	.990	614.	206.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.1120	HISTORIC EVENTS	0
STANDARD DEVIATION	.2740	HIGH OUTLIERS	0
COMPUTED SKEW	.9416	LOW OUTLIERS	0
GENERALIZED SKEW	.4000	ZERO OR MISSING	0
ADOPTED SKEW	.7000	SYSTEMATIC EVENTS	24

FINAL RESULTS
-PLOTTING POSITIONS- 01-4765 RIDLEY CREEK AT MOYLAN, PA

EVENTS ANALYZED MON	DAY	YEAR	FLOW,CFS	ORDERED EVENTS RANK	WATER YEAR	FLOW,CFS	MEDIAN PLOT POS
3	28	1932	891.	1	1843	15000.	.0053
8	23	1933	2680.	2	1952	5720.	.0297
3	5	1934	1080.	3	1955	4390.	.0709
7	9	1935	3000.	4	1938	3320.	.1121
1	3	1936	1590.	5	1935	3000.	.1534
2	22	1937	770.	6	1933	2680.	.1946
7	23	1938	3320.	7	1940	1770.	.2358
2	3	1939	978.	8	1936	1590.	.2770
3	15	1940	1770.	9	1950	1590.	.3183
2	7	1941	746.	10	1952	1490.	.3595
8	13	1942	1000.	11	1934	1080.	.4007
12	30	1942	980.	12	1949	1040.	.4419
1	6	1944	865.	13	1945	1040.	.4832
9	18	1945	1040.	14	1946	1000.	.5244
12	26	1945	1000.	15	1942	1000.	.5656
5	22	1947	483.	16	1943	980.	.6068
5	5	1948	740.	17	1939	978.	.6481
12	30	1948	1040.	18	1953	918.	.6893
8	3	1950	1590.	19	1932	891.	.7305
11	25	1951	5720.	20	1944	865.	.7717
3	11	1952	1490.	21	1937	770.	.8130
11	22	1952	918.	22	1941	746.	.8542
12	14	1953	670.	23	1948	740.	.8954
8	18	1955	4390.	24	1954	670.	.9367
8	5	1843	15000.	25	1947	483.	.9779

NOTE- PLOTTING POSITIONS BASED ON-HISTORIC PERIOD (H) = 132
NUMBER OF HISTORIC EVENTS PLUS HIGH OUTLIERS(Z) = 1
WEIGHTING FACTOR FOR SYSTEMATIC EVENTS (W) = 5.4583

-OUTLIER TESTS -

LOW OUTLIER TEST

BASED ON 132 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 3.109

LOW OUTLIER(S) IDENTIFIED BELOW TEST VALUE OF 172.9

HIGH OUTLIER TEST

BASED ON 24 EVENTS, 10 PERCENT OUTLIER TEST VALUE K(N) = 2.467

HIGH OUTLIER(S) IDENTIFIED ABOVE TEST VALUE OF 6136.

STATISTICS AND FREQUENCY CURVE ADJUSTED FOR 0 HIGH OUTLIER(S)
AND 1 HISTORIC EVENT(S)

-SKEW WEIGHTING -

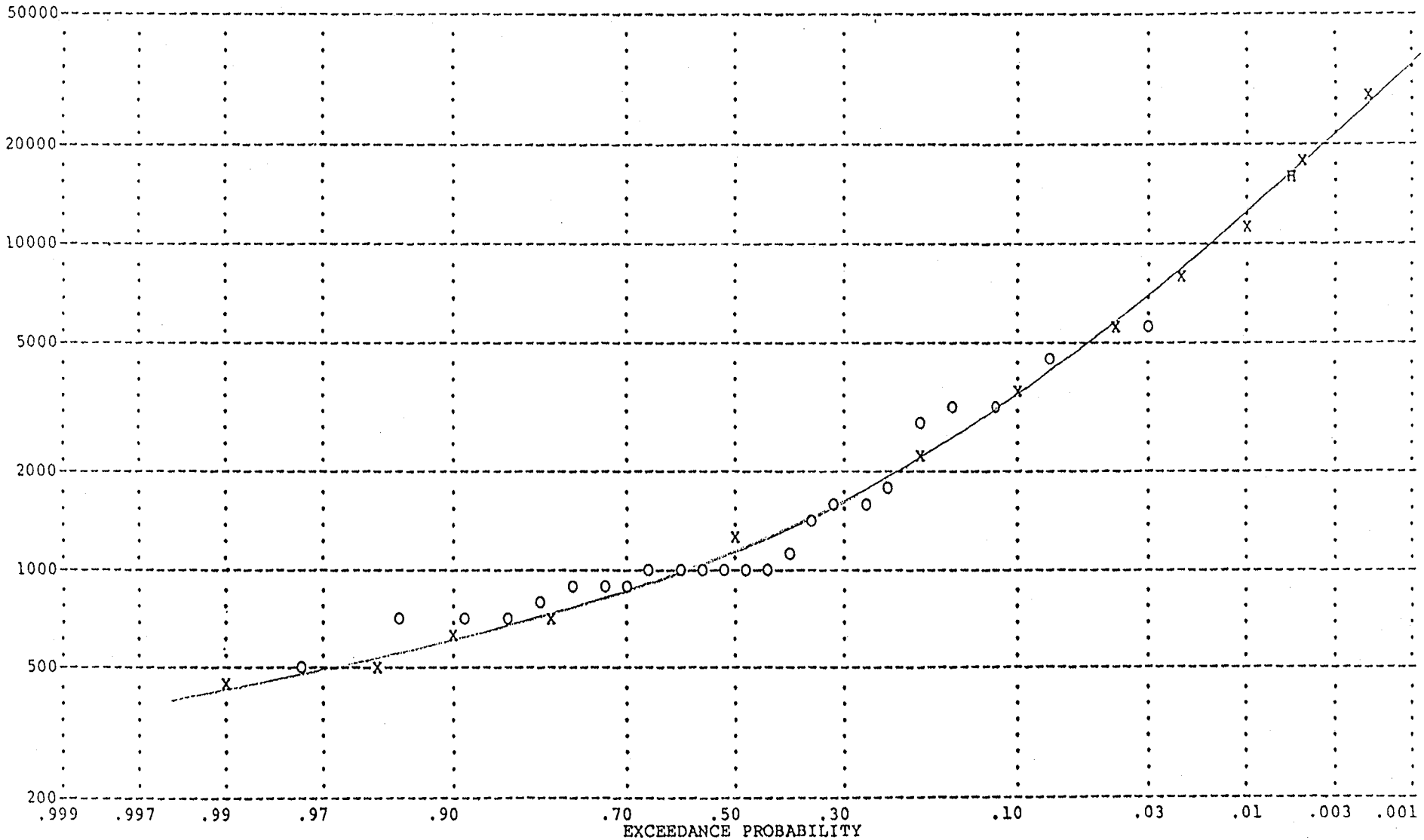
BASED ON 132 EVENTS, MEAN-SQUARE ERROR OF STATION SKEW = 0.116
DEFAULT OR INPUT MEAN-SQUARE ERROR OF GENERALIZED SKEW = 0.302

FINAL RESULTS
-FREQUENCY CURVE- 01-4765 RIDLEY CREEK AT MOYLAN, PA

FLOW,CFS COMPUTED	FLOW,CFS EXPECTED PROBABILITY	EXCEEDANCE PROBABILITY	CONFIDENCE LIMITS 0.01 LIMIT	CONFIDENCE LIMITS 0.99 LIMIT
17600.	29300.	0.002	72000.	8630.
12200.	17400.	0.005	41300.	6490.
9100.	11800.	0.010	26800.	5190.
6740.	8110.	0.020	17100.	4100.
4930.	5570.	0.040	10800.	3190.
3160.	3360.	0.100	5710.	2210.
2180.	2240.	0.200	3420.	1590.
1200.	1200.	0.500	1650.	847.
754.	744.	0.800	1040.	472.
623.	608.	0.900	876.	363.
545.	526.	0.950	780.	301.
446.	423.	0.990	659.	226.

FREQUENCY CURVE STATISTICS		STATISTICS BASED ON	
MEAN LOGARITHM	3.1200	HISTORIC EVENTS	1
STANDARD DEVIATION	0.2838	HIGH OUTLIERS	0
COMPUTED SKEW	1.0783	LOW OUTLIERS	0
GENERALIZED SKEW	0.4000	ZERO OR MISSING	0
ADOPTED SKEW	0.9000	SYSTEMATIC EVENTS	24
		HISTORIC PERIOD	132

FINAL RESULTS
-FREQUENCY PLOT - 01-4765 RIDLEY CREEK AT MOYLAN, PA DA=31.9 SQ MI 1932-55
BASED ON EXPECTED PROBABILITY ADJUSTMENT, FLOW IN CUBIC FEET PER SECOND



LEGEND - O=OBSERVED EVENT, H=HIGH OUTLIER OR HISTORIC EVENT, L=LOW OUTLIER, Z=ZERO OR MISSING X=COMPUTED CURVE

EXHIBIT 1
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EXHIBIT 2

INPUT DESCRIPTION

Flood Flow Frequency Analysis

Computer Program 723-X6-L7550

This exhibit contains a detailed description of each variable on each input card. Many of the cards shown can be omitted if certain options are not required. The Summary of Input Cards at the end of this exhibit shows the sequential arrangement of cards and the location of variables on the cards.

The location of variables for each input card is shown by field number. The cards are normally divided into ten fields of eight columns each except field 1. Variables occurring in field 1 may only occupy card columns 3-8 since card columns 1 and 2 are reserved for the required identification characters. The different values a variable may assume and the conditions for each are described for each variable. Some variables are used simply to indicate whether or not a program option is to be used. The values for these variables are integer values and must be right justified (punched on the far right side of the field) without any decimal points. Other variables are assigned numbers which express the variable's magnitude. For these, either a "+" or a "±" sign where the value may also be negative, is shown in the description under "value" and the numerical value of the variable is entered as input. Where the variable value is to be zero, the variable may be left blank, since a blank field is read as zero and any number without a sign is considered positive. Unless noted otherwise, variable names beginning with the letters I, J, K, L, M or N represent integer variables and a decimal point must not appear in the field. All others are floating point variables and may either have a decimal point or be right justified. The location of variables on cards is sometimes referred to by an abbreviated designation, for example, J1.4 means the fourth field of the J1 card.

Those cards that are flagged with two asterisks are required cards and must be supplied for each job. Several jobs may be processed at the same time by stacking the respective data decks.

TT
J1

A. TITLE CARDS

*TT Card - Title Card

Field	Variable	Value	Description
1-10	--	Alpha	Alphanumeric information to identify the run. As many TT cards may be supplied as necessary to input the desired descriptive information.

B. JOB CARDS

*J1 Card - First Job Card

Job card which specifies program options. If omitted, default values in parentheses will be assigned. When this card is provided, the specified input options will be maintained for all succeeding stations until another J1 card is encountered.

Field	Variable	Value	Description
1	IPPC		Plotting positions in the program are computed by the general formula (m-A)/N+1-A-B) where: m = order number N = number of years A,B = constants The standard constants may be specified below. If other constants are desired, they may be specified on the J2 card.
		0 or 1	Weibull plotting positions will be used for output and plotting (A and B equal 0.).
		2	Median plotting positions will be used for output and plotting (A and B equal .3).
		3	Hazen plotting positions will be used for output and plotting (A and B equal .5).
		4	Plotting positions constants (A and B) will be read in on J2 card.

*Optional card

*J1 Card - First Job Card (continued)

Field	Variable	Value	Description
2	ISKFX (1)	0 or 1	Adopted skew coefficient will be the weighted value computed in accordance with the WRC Guidelines and rounded to the nearest tenth.
		2	Adopted skew coefficient will be the weighted value computed as above, except it is not rounded.
		3	Adopted skew coefficient will be set equal to the input generalized skew coefficient which is read in on the GS card, i.e., no weighting with the station skew coefficient.
3	IPROUT (1)	+	The sum of the following output codes which suppress selected portions of the normal output. For example, a value of 63 would suppress all output except the printout of the frequency curve ordinates and corresponding statistics of the final results.
		Codes	
		0	No output suppressed.
		1	Suppress the printout of input data, arrayed data, and plotting positions of the preliminary results.
		2	Suppress the printout of the frequency curve ordinates and corresponding statistics of the preliminary results.
		4	Suppress the plot of the preliminary results.
		8	Suppress the printout of input data, arrayed data, and plotting positions of the final results.
		16	Suppress the plot based on computed flows from the final results.
		32	Suppress the plot based on the expected probability adjustment of the flows from the final results.
		64	Suppress the printout of the frequency curve ordinates and corresponding statistics of the final results. A value of 127 for IPROUT will suppress all station output except for the summary of results.

*Optional card

J1

*J1 Card - First Job Card (continued)

Field	Variable	Value	Description
4	IFMT (1)	0 or 1	Flow data is in the format specified for QH or QR cards.
		2	Data is in the format of four 2-column fields for day, month, year and flow (note order of day and month).
		3	Format of data is specified by FT card for month, day, year and flow (note order of month and day).
		4	Format of data is specified by FT card for day, month, year and flow (note order of day and month).
5	IWYR (10)	0	Annual series data selected from the standard water year (October-September), IWYR will be set to 10.
		+	The order number of the first month in the water year, e.g., 1 for calendar year beginning in January, etc.
6	IUNIT (1)	0 or 1	Label for plot will be "CUBIC FEET PER SECOND."
		2	Label for plot will be "CUBIC METERS PER SECOND."
		3	Label for plot will be input on FU card.
7	ISMRY (0)	0	No summary will be printed.
		1	A summary of the final results will be printed for all of the stations in the run.
		2	A summary of the preliminary results will be printed.
		3	A summary of both the preliminary and the final results will be printed.

*Optional card

*J1 Card - First Job Card (continued)

Field	Variable	Value	Description
8	IPNCH (0)	0	No station statistics will be punched.
		1	Station statistics will be punched for final results.
		2	Station statistics will be punched for the preliminary results.
		3	Station statistics will be punched for the preliminary and final results.

The punched data format is shown below:

Item	Card Columns
SS - punched on each card	1- 2
USGS part number	9-10
Station identification number	11-16
Station mean	17-24
Station standard deviation	25-32
Station computed skew coefficient	33-40
Station generalized skew coefficient	41-48
Station adopted skew coefficient	49-56
Number of historic events	57-60
Number of high outliers	61-64
Number of low outliers	65-68
Number of zero or missing flows	69-72
Number of events in systematic record	73-76
Historic period	77-80

9	IREG (0)		This field is only needed when the input flow data is in WATSTORE format. Otherwise the field should be left blank.
		0	Delete all events with a known or unknown effect of regulation or diversion. All flow cards with a "1", "2", "5", or "6" in column 33 are deleted.
		1	Delete all events with a known effect of regulation or diversion. All flow cards with a "2" or a "6" in column 33 are deleted.
		2	Include all flow data, regardless of the code in column 33 of the flow card.

*Optional card

J2
FT
FU

*J2 Card - Second Job Card

Job card which specifies nonstandard plotting position constants and criteria for confidence limits.

Field	Variable	Value	Description
1	A	+	Plotting position constants A and B. Default values are those specified by IPPC (J1.1). IPPC must equal 4 to activate these input constants.
2	B	+	
3	CLIMIT (.05)	+	Confidence limit probability for either side. Default value of zero computes the .05 and the complimentary .95 confidence limits. The approximating equations become less accurate for small sample sizes as smaller values are specified, e.g., the .01 limit values are less accurate than .05 limit values for 10 years of data.

*FT Card - Flow Format

Provide this card if IFMT (J1.4) is 3 or 4.

Field	Variable	Value	Description
1-10	IFRMT	Alpha	Format of data on cards. If IFMT is 3, the format specification must have fields for data in the following order: month, day, year, and flow, e.g., "(8X, 2I2, I4, F8.0)" is the standard program format. The parentheses must be included in the format specification. If IFMT is 4, the format specification must have fields for data in the following order: day, month, year, and flow, e.g., "(3I8, F8.0)" is the format of input data for the program in the WRC Guidelines. The parentheses must be included in the format specification.

*FU Card - Flow Units Label

Provide this card if IUNIT (J1.6) equals 3.

Field	Variable	Value	Description
1-10	IUNT	Alpha	Alphanumeric label of input units for printer plot of frequency curve.

*Optional card

C. STATION DATA CARDS

*ID Card - Station Identification and Information

Field	Variable	Value	Description
1-10	ISTA	Alpha	Alphanumeric information such as station number, location, drainage area, period of record, etc. Although columns 2-8 may be used for station identification, only columns 3 through 48 are printed as a heading for each table. If this card is not provided, the brief station identification on the GS card (GS.1) will be used. If a GS card is not provided, the array is filled with blanks.

*GS Card - Generalized Skew

This card is used to specify the generalized (regional) skew coefficient which will be weighted with the station skew coefficient in accordance with the WRC Guidelines. If this card is not provided, the computed station skew coefficient, rounded to the nearest tenth if ISKFX(J1.2) is equal to 0 or 1, will be used in computing the frequency curve.

Field	Variable	Value	Description
1	ISTN	Alpha	Brief alphanumeric identification of station, e.g., could be USGS station number, to assist in identifying card. If a ID card is not provided, the information in this field will be used to label the output.
2	GGMSE (0.302)	+	Mean squared error (MSE) of the generalized skew if Plate I, Bulletin 17b is not used. If left blank, a value of 0.302 will be used to correspond with Plate I.
3	SKEW	±	Generalized skew coefficient.

*Optional card

SI

*SI Card - Special Station Information

This card is used to input a historic period other than that represented by the flow data cards, to specify the number of high outliers in the systematic record, and to input a base peak discharge.

Field	Variable	Value	Description
1	IYRA	+	The earliest year for defining a period during which the largest recorded events (see NOUTL, SI.3) or historic events (see QH cards) are known to be a maximum. If left blank, IYRA will be the first year found on either QH or QR cards.
2	IYRL	+	The last year of the period for which the historic information applies. If left blank, IYRL will be the last year found on either QH or QR cards.
3	NOULT (0)	+	Number of flood peaks in the systematic record (QR cards) that are considered to be the high outliers in the historic period IYRA to IYRL.
4	BASEPK	+	Magnitude of base flood peak. Any recorded event less than or equal to this value will be treated as a low outlier. Note that the program automatically applies the WRC procedures to identify and adjust for low outliers.

*Optional card

*QH Card - Historic Flood Peak

This card is used to input historic flood peaks that are to be weighted with the systematic record (QR cards). Care must be exercised in selecting historic peaks as those peaks in the systematic record that exceed the smallest historic peak will be treated as high outliers. Any peaks in the systematic record that are larger than the smallest input historic peak are automatically weighted along with the historic peaks. A nonstandard format and order of month and day may be used, see J1.4.

Field	Variable	Value	Description
1	ISTN	Alpha	Brief alphanumeric identification of station e.g., could be USGS station number, to assist in identifying data.
2	IMO,IDAY IYR	+	The month number (columns 9 and 10), the day (columns 11 and 12) and the year (columns 13-16) of the flood flow peak. The month and/or day may be left blank. The year must be the calendar year of the event if the month is indicated; otherwise, the year must be the water year. (See J1.5 for establishing water year.)
3	QH	+	Historic annual flood peak. The program is dimensioned for up to 50 historic peaks.

*Optional card

QR
ED

**QR Card - Systematic (Recorded) Flood Peak

This card is used to input recorded flood peaks. A period of years may be absent (broken record). The QR is not required in the first two columns. Two blanks or a G blank (Regional Frequency Computation program flow card) is treated as a QR card. A nonstandard format and order of month and day may be used, see IFMT (J1.4).

Field	Variable	Value	Description
1	ISTN	Alpha	Brief alphanumeric identification of station, e.g., could be USGS station number, to assist in identifying data.
2	IM,IDY, IY	+	The month number (columns 9 and 10), the day (columns 11 and 12) and the year (columns 13-16) of the flood flow peak. The month and/or day may be left blank. The year must be the calendar year of the event if the month is indicated; otherwise, the year must be the water year. (See J1.5 for establishing water year.)
3	Q	+	Recorded annual flood peak. If flow was too low to record, enter -1, and the data will be analyzed by the incomplete record procedure. The number of QH cards plus QR cards is dimensioned for up to 130 values.

**ED Card - End of Data Card

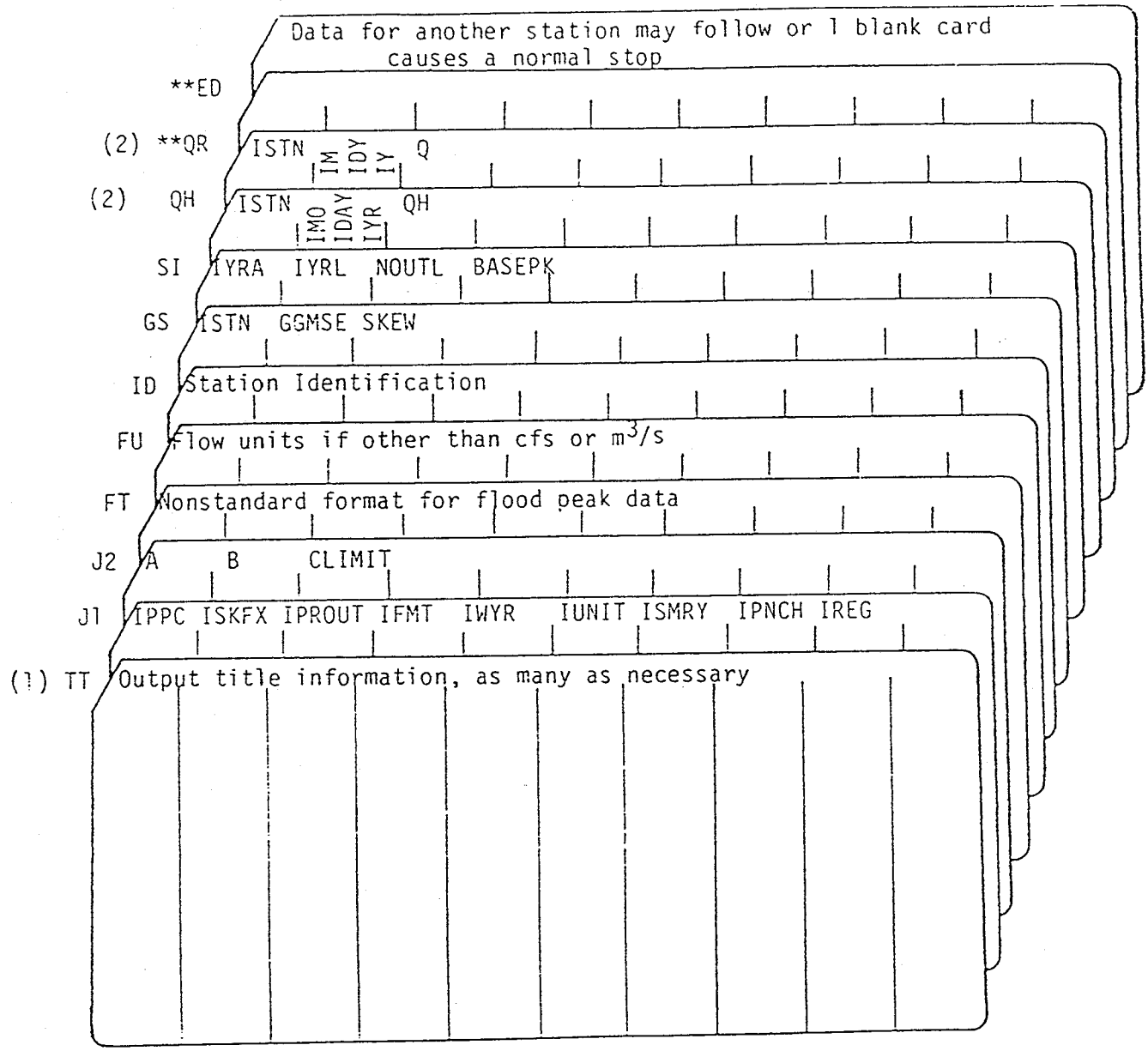
The program reads flow data until it encounters a card that does not have a "20", "21", "QR", "G", and a blank, or two blanks in the first two columns, or has a completely blank card or an ED in the first two columns. When any of these conditions occur, a new station is assumed unless there is no more data (end of file) in which case normal termination occurs.

**Required card

SUMMARY OF INPUT CARDS

Flood Flow Frequency Analysis

Computer Program 723-X6-L7550



** Required cards, cards without two asterisks are optional.

(1) The card codes, e.g., TT, J1, J2, etc., are required in columns 1 and 2, except for the QR card. For the QR card, two blanks or G blank are also acceptable.

(2) Standard program format for flood peaks. Nonstandard formats possible, see IFMT (J1.4).

GPO 587-010/28055

THIRD SCIENTIFIC ASSEMBLY

BALTIMORE, MARYLAND

May 10-19, 1989

INTERNATIONAL ASSOCIATION FOR HYDROLOGIC SCIENCES

SESSION (W2) PC METHODS
FOR FLOOD FREQUENCY ANALYSIS
AND FLOOD FORECASTING

FLOOD FLOW FREQUENCY
PC APPLICATION OF BULLETIN 17B

by

Vernon K. Hagen

- Many individuals distrust methods that allow for personal judgment and prefer a mathematical fitting of curves (Dalrymple).

- In dealing with atmospheric phenomena, the characteristics of the "true" probability curve are unknown and must be estimated from the sample probability curve. The estimate of the probability from a sample will almost always be in error. The problem, therefore, is to find a method which will reduce this error of estimate. (Friedman & James).

- Despite whatever theoretical advantages the gamma method may have, there is still some question regarding the practical advantages it has over older methods such as the Hazen-skew and the Pearson Type III. (Cruff & Rantz).

- Powell developed a probability paper in 1943 for the Gumbel method which had arithmetic scales for data but subsequent users often learned that logarithmic scales were necessary to reduce curvature in frequency lines and account for a type of skewness not anticipated by Gumbel. (Potter).

- Flows cannot be negative and therefore cannot conform to the normal distribution, their logarithms are more nearly normally distributed than are flows expressed in natural numbers. (Beard).

- One of the important uses of the theoretical curve is to extend a limited number of observations so as to cover a longer period of time. (Foster).

4. Interagency Hydrology Committee

The evolution of Bulletin 17B began with H. A. Foster's publication, "Theoretical Frequency Curves" in 1924. His early description of the Pearson Type III method involved probability distribution of peak discharges. It used natural data to compute mean, standard deviation, and skew coefficient, which were used to define distribution of the data. Later publications provided descriptions of other worthy techniques for flood flow frequency analyses. Each method has its proponents, who lauded the advantages of their favorite. Thus, the many Federal agencies involved in water resources development had different guidance regarding flood flow frequency analyses. In August 1966, a task force on Federal Flood Control Policy issued a report[1] entitled, "A Unified National Program for Managing Flood Losses." This report was critical of agencies using different procedures for processing flood information. It concluded that the problem regarding different techniques for reporting flood frequencies should be resolved. Solution of the problem was assigned to the newly formed Water Resources Council, which directed its Hydrology Committee to take the necessary action.

The Hydrology Committee was well prepared for the task. It had been studying the problem by assigning members to a Work Group on Flow Frequency Methods. This body of technical experts, headed by Manuel A. Bensen of the U.S. Geological Survey had issued a report in April 1966. It was entitled, "Bulletin 13, Methods of Flow Frequency Analysis." Six analytical methods and procedures for applying them to the data were summarized in Bulletin 13. Although the document discussed the various methods pro and con, it did not recommend any one method as being preferable to the others. Responding to its mandate, the work group issued "Bulletin 15, A Uniform Technique for Determining Flood Flow Frequencies" in December 1967. The previously described six analytical methods were considered for selection as a base method. Graphical solutions were not viewed as acceptable because of personal bias involved in shaping the curves. Among the analytical methods tested and reviewed, the log-Pearson Type III method was chosen to serve as the base method for Federal agencies. Since the choice of a base method could not be made solely on a statistical basis, a choice on administrative grounds was justified; provided, there were compelling reasons. The work group concluded that it had adequate reasons for the choice. A paper[2], "Uniform Flood-Frequency Estimating Methods for Federal Agencies," by Manuel A. Benson, October 1968, described the deliberations of the work group as they selected the base method.

While Bulletin 15 recommended the log-Pearson Type III as the base method, it also stipulated that there should be provisions for using

other methods where adequate justification exists. The selection of a base method helped to reduce the differences in flood frequencies issued by various agencies. However, the procedures for applying the method were not developed in sufficient detail to prevent different views on its application. In an effort to gain better uniformity, the work group continued to study the problem. Agreement did not come quickly because of the parochial interests of various agencies and difficulty involved in changing long-standing procedures. Also, the work of one agency did not usually overlap work of another agency and differences were not always readily apparent. With the passage of the National Flood Insurance Act of 1968 and its implementation, pressure began to build within the Water Resources Council for more uniform flood frequency data among agencies.

The National Flood Insurance Program required flood probability relationships throughout the country at flood-prone communities. Thus, differences in flood frequency relationships caused a major deterrent to efficient completion of flood insurance studies. Representatives of the Federal Insurance Administration continued to press the Hydrology Committee for publication of more detailed procedures for applying the base method. In response to this encouragement, the Hydrology Committee published "Bulletin 17, Guidelines for Determining Flood Flow Frequency" in March 1976. The latest version of this document is Bulletin 17B[3] and is dated March 1982. It was issued by the Hydrology Subcommittee of the Interagency Advisory Committee on Water Data and contained a report[4]

prepared by Leo R. Beard on candidate procedures and tests of the procedures. After the demise of the Water Resources Council, the Interagency Hydrology Committee needed a new sponsor. The Advisory Committee became the logical choice.

A computer program for processing the base method was written by Leo R. Beard and David Ford (Center for Research in Water Resources, the University of Texas at Austin) under contract to the Water Resources Council. The original program and documentation may be found in Appendix 13 of Bulletin 17 (March 1976). However, Bulletin 17B refers the user to the Hydrologic Engineering Center, U.S. Army Corps of Engineers (HEC) or the U.S. Geological Survey for computer programs on the base method. This paper discusses the program manual[5] published by HEC and entitled, "Flood Flow Frequency Analysis Users Manual." The program contains restructured input and output formats as well as the addition of improvements and options. Initially written for main frame computers, the software has been adapted for use by personal computers. The program is installed on a 5-1/4 inch, double-sided, double density floppy disk capable of holding approximately 360K bytes. The disk contains the executable program (HECWRC.EXE) and example input data. Copies of the disk and information relating to the program are available from private vendors as HEC is no longer providing and supporting its PC programs for the general public.

5. Capabilities of HECWRC.EXE

Examples of the flood flow frequency analyses are provided in Appendix 12 of Bulletin 17B. The computer input and output for six examples are found in Exhibit 1 of the Users Manual for Flood Flow Frequency Analysis. Information on the following items may be obtained from the examples:

- Fitting the log-Pearson Type III Distribution
- Computation of Confidence Limits
- Testing and Adjusting for High Outliers
- Testing and Adjusting for Low Outliers
- Adjusting for Zero Flood Years
- Adjusting for Historic Peaks
- Conditional Probability Adjustment
- Expected Probability

6. Data sources in federal government

The best source of information on flood peaks in the United States is the U.S. Geological Survey. This information may be obtained by: personal contact with Headquarters and field offices of the USGS, published documents, written requests, or by the WATSTORE computer-based retrieval system. The latter method requires membership in the organization and a computer modem communication device. Requests for data

are accommodated by the batch mode process. Most of the water data collected by other Federal agencies are also available from WATSTORE. This system is fully active, however, new flood peaks may not be included in the files as there are processing delays. Other Federal agencies may have flood peak data which are not in the WATSTORE system. This may be due to the lack of resources to prepare the data in proper format to be received by WATSTORE or the data may not have been obtained in accordance with USGS procedures.

7. Other organizations with peak flow data

Many state organizations obtain data on peak flood discharges as do independent entities such as: irrigation districts, dam owners, power companies, and communities. These data may have been made available through WATSTORE but generally they require individual efforts to locate sources and to verify values obtained. Cooperative stream gaging programs exist between the USGS and other Federal agencies as well as between the USGS and state agencies. These cooperative agreements generally involve USGS collection, processing, and dissemination of data with the other cooperatives paying part of the costs.

8. Indirect methods of measuring peak flow

Indirect measurements make use of the energy equation for computing discharge. The specifics differ for different types of flow, such as

open-channel flow, flow over dams, and flow through culverts. However, all the methods involve the following general factors:

- Physical characteristics of the channel: dimensions and conformation of the channel within the reach used, and boundary conditions.

- Water-surface elevations at time of peak stage to define the upper limit of the cross-sectional areas and the difference in elevation between two significant points.

- Hydraulic factors based on physical characteristics such as water-surface elevations and discharge, roughness coefficients and discharge coefficients.

- A comprehensive document[6] on the measurement of peak discharge by indirect methods was published by the World Meteorological Organization in 1968. Information is provided on the techniques available to estimate the maximum flow associated with a specific flood event by using data on high-water surfaces. High-water marks established during or immediately after a flood are the most reliable. There is usually much evidence following a flood which can be used to reconstruct a water-surface profile. Trained investigators should be used in this endeavor as some indicators may be misleading. An example of this problem is high-water marks

on the upstream face of a building. High velocities may have caused the water to pile up and exceed the level of free flowing water.

9. Accuracy of data

Several factors tend to reduce the accuracy of peak discharge values used in flood flow frequency analysis. Few of the peak discharges listed in publications were actually measured by direct use of current meters. There are several reasons for the inability to make direct measurement of peak flows. The primary reason being the inability to have the proper resources in the right location at the exact timing of peak flows. Other factors involve inability to cross the stream with measuring equipment at the desired location, debris being transported by the high flows such as trees and ice, peak flow is not sustained for a long enough period to complete measurement, moveable bed and banks during measurement, and other reasons.

Under normal conditions of stream flow measurement with good equipment and experienced personnel, the accuracy of stream discharge measurements is expected to range between two and five percent. Therefore, it is highly unlikely that the accuracy of obtaining peak discharges would be less than five percent. In the case of indirect measurements of discharge, errors of 15 to 20 percent are not uncommon. A realization of the accuracy of peak flow data is important in the analysis of flood

flow probabilities. It follows that the results of flood flow probability analysis has limited accuracy and that large expenditures to improve the accuracy may not be warranted. Decisions based on flood probabilities must be tempered with the knowledge that results are subject to change.

10. Non-homogeneous and mixed populations of data

Changing conditions and alternative sources of floods will have significant impact on flood probability analysis. Development within the watershed contributing flow to the location of interest can significantly alter the runoff associated with similar storms. The development could consist of water resource projects which: store water for later release (reservoirs), divert water to another stream (irrigation channels), accelerate velocity (channel improvement), or other types of projects. Urban development of smaller watersheds can increase the discharge of the 1% chance flood two-fold. Thus, probability studies must include a thorough analysis of peak flood events to be sure the data are consistent. In some cases, this may involve adjustment to account for development. Types of mixed populations can include annual flood peak discharges obtained from short-duration, high-intensity rainfall for some years with other peak flows originating from long-duration snowmelt runoff. This type of mixed population is common in the northwestern part of the United States. In the northeastern part of the United States, mixed populations of hurricane-induced storms causing

peak flows some years and other years with peak flows from general rain storms and much less discharge. Information is provided in Bulletin 17B on methods to process these data with the most reliable results.

11. Historical events

The systematic record of annual peak flow events can often be supplemented by searching for historical information on floods. Newspapers are a valuable source of historical information. Although tedious, a search of the local newspaper accounts can provide data that will improve the frequency analysis for many stream gaging stations. Information on lack of flood events is important to the study as well as finding notable floods and estimates of their peak flow. As indicated previously, the longer the period of record (sample of data), the more likely it will represent the true population (infinite length of data). The computer program developed for Bulletin 17B contains procedures for including historical information. An acceptable method for extending periods of annual peak discharges is to use a calibrated and verified runoff model with recorded rainfall amounts from historical storms. This procedure involves considerable effort but may be worthwhile if there is a lengthy record of rainfall and a short record of annual peak discharges.

12. Limitations of probability relationships

Although the statistical processes presented in Bulletin 17B can be extrapolated to extremely rare events, the uncertainty of results increases with each increment of increase in the length of the tail (upper portion of curve). The output from the computer program extends to the 500-year flood. Many statistical experts caution against extending curves beyond 100- to 200-year floods because of the lack of supporting information. Few records (including historical records) are longer than 100 years. However, the National Flood Insurance Program has adopted the 500-year flood as an advisory rare flood event to inform communities of flood potential. The computer model was designed to accommodate this need, not because of any stated level of accuracy. Risk assessment analysts promote the concept of extending probability relationships to rare events, such as 10^{-6}. Without such estimates, the traditional risk assessment cannot be performed. However, the log-Pearson Type III method is not considered an appropriate procedure to estimate such rare probabilities. References 7 and 8 discuss in some detail the problems and potential for estimating probabilities of extreme floods. However, a specific procedure is not recommended for conducting an actual study at any particular location.

13. Technical content of Bulletin 17B

The composition of Bulletin 17B is based on providing advice on consistent and effective techniques for computing a frequency curve from gaged data. It also provides additional advice on how to logically improve the frequency relationship developed strictly from gaged events. Minor information is provided on frequency curves for ungaged locations. Although the Hydrology Subcommittee has made significant studies on ways to provide consistent frequency results for ungaged locations, the Subcommittee has not yet published recommended procedures. Because of the large variability in answers and the great uncertainties in the various procedures, publication of recommended frequency methods for ungaged locations by the Hydrology Subcommittee does not appear likely in the near future. Subjects addressed in Bulletin 17B are as follows:

- Procedures for computing the statistical parameters (mean, standard deviation, and skew) for the log-Pearson Type III distribution.

- Due to the large variability of skew values, means for obtaining more consistent results are provided.

- The reliability of frequency computations is an important factor in many water resource decisions; therefore, confidence limits can be computed from gage record length in years or an equivalent

length of record and log-Pearson Type III statistical parameters by procedures described in Bulletin 17B.

- Some annual peak flow gaging records contain unusually high and/or low values which are not consistent with the trend of the other data. These events are called outliers and receive special treatment.

- Whenever stream gaging stations are placed in well populated locations, there is usually historical information regarding flood peaks available from newspapers or other sources that predates the recorded record by many years. This valuable information is processed to improve the frequency estimates at the gage.

- Annual peak flood events at a gaging station can result from different sources such as snowmelt runoff and rainfall runoff. Procedures for computing individual frequency curves and statistical combination to obtain one representative frequency curve are discussed.

- Another method to address the reliability of frequency curves is called expected probability. This procedure adjusts the frequency curve to statistically account for the length of record being less than infinite. It attempts to define the frequency curve that would result if the period of record was significantly longer.

The adjustments are greater for short records and tend toward minor amounts for long periods of record.

- Some records of annual peak flows have several events that are significantly lower than the trend of the majority of events. They could be zero events, low outliers, or events below the gage recording level. The conditional probability adjustment deletes these events below a truncation discharge value (no more than 25 percent of the total number of events should be deleted) and adjusts the frequency curve to account for their omission.

- A technique is provided to improve a short period record frequency curve by comparing it with a frequency curve of a similar watershed with a significantly longer period of record. A weighted average of the two estimates will generally be more accurate than the estimate of the shorter record by itself.

- Plotting positions for individual peak flood events are important to obtain a graphical view of how well the computed frequency curve reflects the data trends. A specific formula for computing plotting positions is not recommended in Bulletin 17B. However, the subject computer program permits a choice of three formulas. The general formulas are the same but the values of the constants vary. There is minor difference in plotting positions except for the top few values.

- Risk is defined in Bulletin 17B as the probability that one or more events will exceed a given flood magnitude within a specified period of years. Figure 10-1 of the Bulletin provides a handy reference for these determinations; given the annual exceedence frequency in percent and the period of time in years. This concept is very important to loan officials who desire to know the probability of a house being flooded during the term of a potential mortgage. Also, the probability of a levee design flood being exceeded during its estimated physical life can be an important decision-making consideration when selecting its design flood. For example: a levee designed for the 1% chance annual flood would have a 40% chance of having its design flood exceeded during a 50-year period.

14. <u>Conclusions regarding Bulletin 17B</u>

- The guidelines for flood flow frequency analysis apply to stream gage records of annual peak flow with a period of homogeneous record 10 years or longer.

- Although the guidelines provide for improved consistency in flood flow frequency estimates, there is still need for professional judgment in many aspects. It is important that these judgments be made by experienced individuals who are knowledgeable about the subject and the impacts of their decisions.