HEC-SSP Examples

HEC-SSP Examples

Exported on 10/26/2023

Table of Contents

1 HEC-SSP Examples Introduction 7
1.1 Overview of Example Problems 7
1.2 Installing HEC-SSP Example Data 11
2 Bulletin 17B Examples 12
2.1 Example 1. Fitting the Log-Pearson Type III Distribution 12
2.2 Example 2. Analysis with High Outliers 19
2.3 Example 3. Testing and Adjusting for a Low Outlier 27
2.4 Example 4. Zero-Flood Years 35
2.5 Example 5. Confidence Limits and Low Threshold Discharge 42
2.6 Example 6. Use of Historic Data 49
3 Bulletin 17C Examples 57
3.1 Bulletin 17C | Expected Moments Algorithm Examples 57
3.2 Example 1. Systematic Record – Moose River at Victory, VT 58
3.3 Example 2. Analysis with Low Outliers – Orestimba Creek near Newman, CA 68
3.4 Example 3. Broken Record – Back Creek near Jones Springs, WV 78
3.5 Example 4. Historical Data – Arkansas River at Pueblo, CO 87
3.6 Example 5. Crest Stage Gage Censored Data – Bear Creek at Ottumwa, IA 97
3.7 Example 6. Historic Data and Low Outliers – Santa Cruz River at Lochiel, AZ 105
3.8 Example 7. User Overrides (Low Outliers and Confidence Limits) – Rapid Creek above Canyon Lake near Rapid City, SD 114
3.9 Example 8. [inf – inf] Perception Threshold – Pembina River at Neche, ND 126
3.10 Example 9. [0 – value] Perception Threshold – Clark Fork River below Cabinet Gorge Dam, ID 138
3.11 Example 10. Systematic and Historical Record with Regional Skew – Schuylkill River at Berne, PA 147

4 Bulletin 17 Variable Time Window Examples 157
4.1 Moving Window - Bushkill Creek 157
4.1.1 Input Data 157
4.1.2 Computing the Analysis 166
4.1.3 Variable Time Window Results 167
4.1.4 Report File 170
4.2 Expanding Window - Bushkill Creek 171
4.2.1 Input Data 171
4.2.2 Computing the Analysis 181
4.2.3 Expanding Time Window Results 183
4.2.4 Report File 186
5 General Frequency Analysis Examples 188
5.1 Example 7. Analyzing Stage Data 188
5.2 Example 8. Using User-Adjusted Statistics 194
5.3 Example 9. General Frequency – Graphical Analysis 204
5.4 Example 29. General Frequency, Fitting a Log Pearson Type III Distribution using the Expected Moments Algorithm 211
5.5 Example 30. General Frequency, Fitting an Analytical Distribution to a Precipitation Time Series 219
6 Volume Frequency Analysis Examples 227
6.1 Example 10. Volume Frequency Analysis, Maximum Flows 227
6.2 Example 11. Volume Frequency Analysis, Minimum Flows 237
6.3 Example 31. Volume Frequency, Fitting a Family of Log Pearson Type III Distributions to Volume-Duration Data using the Expected Moments Algorithm 248
7 Duration Analysis Examples 260
7.1 Example 12. Duration Analysis, BIN (STATS) Method 260
7.2 Example 13. Duration Analysis, Rank All Data Method 265
7.3 Example 14. Duration Analysis, Manual Entry 271
8 Coincident Frequency Analysis Examples 275

8.1 Example 15. Coincident Frequency Analysis, A and B can be Assumed Independent 275
8.2 Example 16. Coincident Frequency Analysis, A and B can not be Assumed Independent 283
9 Balanced Hydrograph Analysis Examples 292
9.1 Example 17. Balanced Hydrograph Analysis, Using an Historical Event Hydrograph 292
9.2 Example 18. Balanced Hydrograph Analysis, Using a Triangular-shaped Hydrograph 296
10 Distribution Fitting Analysis Examples 302
10.1 Example 20. Distribution Fitting, Analyzing Model Uncertainty Using a Time Series of Annual Maximum Streamflow 302
10.2 Example 21. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Annual Maxima Filtering 315
10.3 Example 22. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Peaks Over Threshold Filtering 329
10.4 Example 23. Distribution Fitting, Analyzing a Time Series of Daily Precipitation Accumulation Using Peaks Over Threshold Filtering 345
10.5 Example 24. Distribution Fitting, Analyzing a Time Series of Daily Average Snow Water Equivalent Using Annual Maxima Filtering 361
10.6 Example 25. Distribution Fitting, Analyzing a Time Series of Daily Average Flow to Estimate Flood Seasonality 375
10.7 Example 26. Distribution Fitting, Analyzing a Paired Data Record of Hydrologic Model Output 387
11 Curve Combination Analysis Examples 401
11.1 Example 19. Curve Combination Analysis, Combining Multiple Frequency Curves Using Graphical Techniques 401
12 Mixed Population Analysis Examples 406
12.1 Example 27. Mixed Population Analysis, Combining Two Frequency Curves using the Probability of Union Concept 406
12.2 Example 28. Mixed Population Analysis, Combining Three Frequency Curves using the Probability of Union Concept 410

13 Data Filtering Examples 416
13.1 Data Filtering, Extracting an Annual Maximum Series 416
13.2 Data Filtering, Extracting a Partial Duration Series 418
13.3 Data Filtering, Using Multiple Filters 421
13.4 Data Filtering, Starting Pool - Elevation Filtering 424
13.5 Data Filtering, Extracting an n-Day Duration Time Series 429
14 Correlation Analysis Examples 434
14.1 Coincident Events - West Branch Susquehanna River 434
14.1.1 Input Data 434
14.1.2 General Tab 450
14.1.3 Location Information Tab 451
14.1.3.1 Bower 451
14.1.3.2 Wharton 451
14.1.3.3 Cross Fork 452
14.1.3.4 Milesburg 453
14.1.4 Computing the Analysis 455
14.1.5 Results Tab 457
14.1.5.1 Log 459
14.1.5.2 Exceedance Probability 459
14.1.5.3 Standard Normal Deviate 460
14.1.6 Report File 464
14.2 Coincident in Time - Tar River 464
14.2.1 Input Data 465
14.2.2 Location Information Tab 466
14.2.2.1 Greenville 466
14.2.2.2 Pamlico Sound 467
14.2.3 Computing the Analysis 468
14.2.4 Results Tab 469
14.2.5 Report File 470

14.3 Paired Data 471
14.3.1 Input Data 471
14.3.2 General Tab 473
14.3.3 Location Information Tab 474
14.3.3.1 Arcade Revenue 474
14.3.3.2 CS Doctorates 475
14.3.3.3 Per Capita Cheese Consumption 476
14.3.3.4 CE Doctorates 477
14.3.4 Computing the Analysis 478
14.3.5 Results Tab 479
14.3.6 Report File 480
15 Record Extension Analysis Examples 482
15.1 Annual Peak Record Extension - MF Eel River 482
15.1.1 Input Data 482
15.1.2 General Tab 493
15.1.3 Data Tab 494
15.1.4 Computing the Analysis 496
15.1.5 Record Extension Tab 496
15.1.6 Report File 500
15.2 Daily Average Record Extension - Yellowstone River 501
15.2.1 Input Data 501
15.2.2 General Tab 503
15.2.3 Data Tab 504
15.2.4 Computing the Analysis 506
15.2.5 Results Tab 506
15.2.6 Report File 510

1 HEC-SSP Examples Introduction

Welcome to the U.S. Army Corps of Engineers, Hydrologic Engineering Center's (HEC) Statistical Software Package (HEC-SSP). HEC-SSP software allows users to perform statistical analyses of hydrologic data. The purpose of this guide is to illustrate the input and output results for 35 example problems. The example problems are provided to illustrate the use of specific options in HEC-SSP and to assist in verifying the correct execution of the HEC-SSP software. The HEC-SSP Examples guide provides a brief description of each example.

Out of the 35 example problems, the first six examples are the same examples described in the HEC-FFA[1] (Hydrologic Engineering Center's Flood Frequency Analysis) software user's manual. Furthermore, a comparison between the HEC-FFA and HEC-SSP results verifies that the HEC-SSP software produces the same results as HEC-FFA for these six data sets. The first six examples were analyzed in HEC-SSP with both Bulletin 17 and General Frequency Analysis; however, this guide displays only the results obtained using a Bulletin 17 Analysis. Full results for both analyses are included in the ***SSP_Examples.ssp*** study and show that the results are the same whether a Bulletin 17 or General Frequency Analysis was performed.

> Within the first six examples, the weighted skew option was selected and a regional skew value was entered from the generalized skew map of the United States provided within Bulletin 17B (Plate 1)[2].

1.1 Overview of Example Problems

Example Number	Example Problem Title	SSP_Examples.ssp	
		Analysis Name	**Data Record Name**

1 https://www.hec.usace.army.mil/publications/ComputerProgramDocumentation/CPD-13.pdf
2 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf

1 (see page 12)	Fitting the Log-Pearson Type III Distribution	FFA Test 1	Fishkill Creek-Beacon, NY
2 (see page 19)	Analysis with High Outliers	FFA Test 2	Floyd River-James IA
3	Testing and Adjusting for a Low Outlier	FFA Test 3	Back Creek-Jones Springs
4	Zero Flood Years	FFA Test 4	Orestimba Creek-Newman, CA
5	Confidence Limits and Low Threshold Discharge	FFA Test 5	Kaskaskia River-Vandalia, IL
6	Use of Historic Data	FFA Test 6	Ridley Creek-Moylan, PA
7	Analyzing Stage Data	Stage Analysis Test 7	Reservoir Stage
8	Using User-Adjusted Statistics	Local Runoff at Alb Test 8	Rio Grande at Alb Local Runoff
9	General Frequency - Graphical Analysis	Reg Flow Rio Grande Test 9	Rio Grande at Alb Reg Flow
10	Volume Frequency Analysis, Maximum Flows	Unreg Flow Rio Grande Test 10	Rio Grande at Alb Unreg Daily

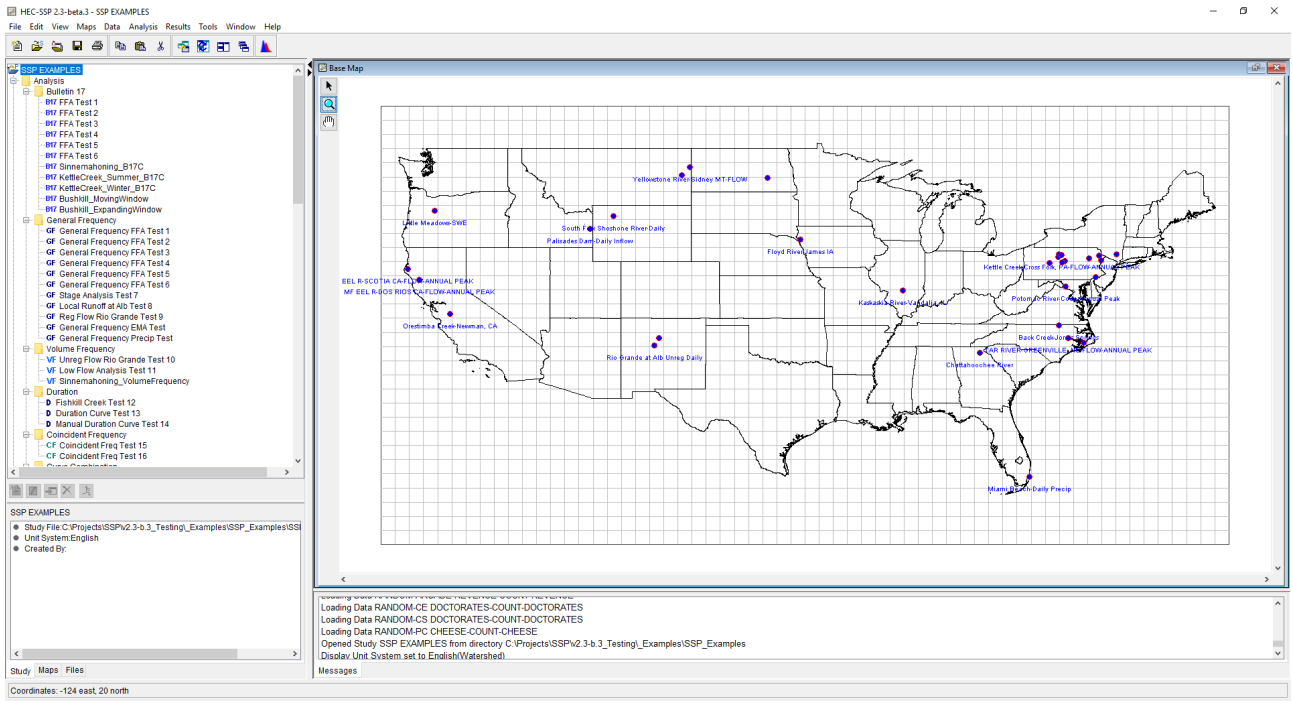
11	Volume Frequency Analysis, Minimum Flows	Low Flow Analysis Test 11	Chattahoochee River
12	Duration Analysis, Bin (STATS) Method	Fishkill Creek Test 12	Fishkill Creek-Daily Flow
13	Duration Analysis, Rank All Data Method	Duration Curve Test 13	Wondering River-Franklin
14	Duration Analysis, Manual Entry	Manual Duration Curve Test 14	Not Applicable
15	Coincident Frequency Analysis, A and B can be Assumed Independent	Coincident Freq Test 15	Not Applicable
16	Coincident Frequency Analysis, A and B cannot be Assumed Independent	Coincident Freq Test 16	Not Applicable
17	Balanced Hydrograph Analysis, Using an Historical Event Hydrograph	Balanced Hydrograph Test 17	Sinnemahoning Creek-Hourly
18	Balanced Hydrograph Analysis, Using a Triangular-shaped Hydrograph	Balanced Hydrograph Test 178	Sinnemahoning Creek-Triangular
19	Curve Combination Analysis, Combining Multiple Frequency Curves using Graphical Techniques	Curve Combination Test 19	Not Applicable
20	Distribution Fitting, Analyzing Model Uncertainty Using a Time Series of Annual Maximum Streamflow	Distribution Fitting Test 20	Potomac River-Flow-Annual Peak
21	Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Annual Maxima Filtering	Distribution Fitting Test 21	Sinnemahoning Creek-Daily
22	Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Peaks Over Threshold Filtering	Distribution Fitting Test 22	Sinnemahoning Creek-Daily

23	Distribution Fitting, Analyzing a Time Series of Daily Precipitation Accumulation Using Peaks Over Threshold Filtering	Distribution Fitting Test 23	Hawley 1 E PA-Daily-Precip-Inc
24	Distribution Fitting, Analyzing a Time Series of Daily Average Snow Water Equivalent Using Annual Maxima Filtering	Distribution Fitting Test 24	Little Meadows-SWE
25	Distribution Fitting, Analyzing a Time Series of Daily Average Flow to Estimate Flood Seasonality	Distribution Fitting Test 25	South Fork Shoshone River-Daily
26	Distribution Fitting, Analyzing a Paired Data Record of Hydrologic Model Output	Distribution Fitting Test 26	MCMC OUTPUT-TC
27	Mixed Population, Combining Two Frequency Curves using the Probability of Union Concept	Mixed Population Test 27	Kettle Creek-Summer-Flow-Annual Peak Kettle Creek-Winter-Flow-Annual Peak
28	Mixed Population, Combining Three Frequency Curves using the Probability of Union Concept	Mixed Population Test 28	Not Applicable
29	General Frequency, Fitting a Log Pearson Type III Distribution using the Expected Moments Algorithm	General Frequency EMA Test	South Fork Shoshone River-Flow-Annual Peak
30	General Frequency, Fitting an Analytical Distribution to a Precipitation Time Series	General Frequency Precip Test	Hawley 1E PA-3DAY-Precip-AMS
31	Volume Frequency, Fitting a Family of Log Pearson Type III Distributions to Volume-Duration Data using the Expected Moments Algorithm	Sinnemahoning_VolumeFrequency	Sinnemahoning Creek-Daily
32	Data Filtering, Extracting an Annual Maximum Series		Jamestown-Daily Max Temp
33	Data Filtering, Extracting a Partial Duration Series		Miami Beach-Daily Precip
34	Data Filtering, Using Multiple Filters		Palisades Dam-Daily Inflow

3 5	Data Filtering, Starting Pool/Elevation Filtering		Sayers Dam-Daily Elevation

1.2 Installing HEC-SSP Example Data

To install this study on your computer open the HEC-SSP software and select the **Help** | **Install Example Data** menu command. After the install is complete, open the ***SSP_Examples.ssp*** study and the HEC-SSP main window will appear as shown in Figure 1.



1 Figure 1. HEC-SSP Example Studies

> After opening the ***SSP_Examples.ssp*** study for the first time on your computer, you must compute each example before viewing tabular and graphical results.

The ***SSP_Examples.ssp*** study includes, nine Bulletin 17B analyses, eleven General Frequency analyses, three Volume Frequency analyses, three Duration analyses, two Coincidence Frequency analyses, one Curve Combination analysis, two Balanced Hydrograph analyses, seven Distribution Fitting analyses, and two Mixed Population analyses in this study. The following sections document each of the example data sets. HEC-SSP Bulletin 17C Examples[3] details ten additional examples which make use of the Expected Moments Algorithm and Bulletin 17C procedures.

3 https://www.hec.usace.army.mil/confluence/display/SSPDocs/HEC-SSP+Bulletin+17C+Examples

2 Bulletin 17B Examples

2.1 Example 1. Fitting the Log-Pearson Type III Distribution

In the ***SSP_Examples.ssp*** study, the input data for the Bulletin 17 analysis, ***FFA Test 1***, is the same as that for Example 1 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council (WRC) Bulletin 17B[4]. Example 1 illustrates the routine computation of a frequency curve by the Bulletin 17B methodology.

> ⚠ This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[5]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[6]). Bulletin 17C examples can be found here (see page 57).

The data for this example is from Fishkill Creek in Beacon, New York. The period of record used for this example is from 1945 to 1968. To view the data from HEC-SSP, right-click on the data record labeled "***Fishkill Creek-Beacon, NY***" in the study explorer and then select **Tabulate.** The data will appear as shown in Figure 1.

4 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
5 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
6 https://pubs.er.usgs.gov/publication/tm4B5

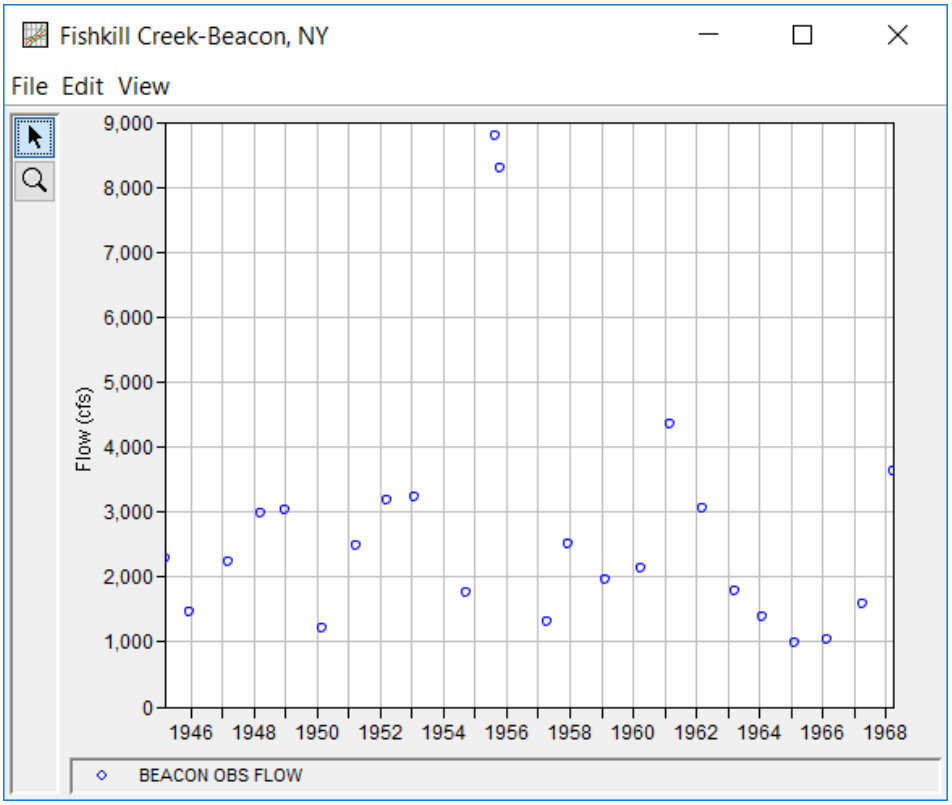
/FISHKILL C...

File Edit View

Ordinate	Date	Time	BEACON FLOW OBS
Units			cfs
Type			INST-VAL
1	05 Mar 1945	12:00	2,290
2	27 Dec 1945	12:00	1,470
3	14 Mar 1947	24:00	2,220
4	18 Mar 1948	24:00	2,970
5	01 Jan 1949	24:00	3,020
6	09 Mar 1950	12:00	1,210
7	01 Apr 1951	12:00	2,490
8	12 Mar 1952	12:00	3,170
9	25 Jan 1953	12:00	3,220
10	13 Sep 1954	12:00	1,760
11	20 Aug 1955	12:00	8,800
12	16 Oct 1955	12:00	8,280
13	10 Apr 1957	12:00	1,310
14	21 Dec 1957	12:00	2,500
15	11 Feb 1959	12:00	1,960
16	06 Apr 1960	12:00	2,140
17	26 Feb 1961	12:00	4,340
18	13 Mar 1962	12:00	3,060
19	28 Mar 1963	12:00	1,780
20	26 Jan 1964	12:00	1,380
21	09 Feb 1965	12:00	980
22	15 Feb 1966	12:00	1,040
23	30 Mar 1967	12:00	1,580
24	19 Mar 1968	12:00	3,630

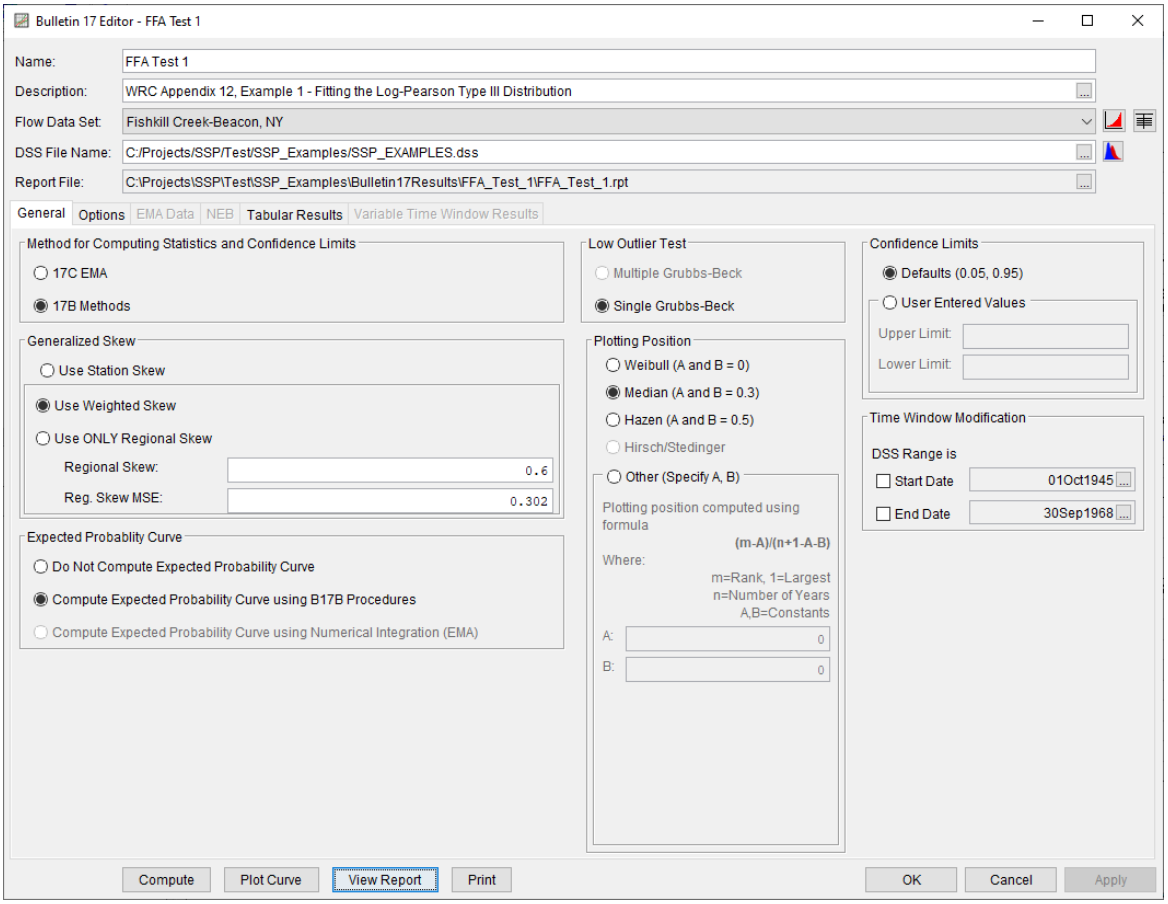
2 Figure 1. Tabulation of the Peak Flow Data for Fishkill Creek

To plot the data for this example, right-click on the data record again and then select **Plot**. A plot of the data will appear as shown in Figure 2.



3 Figure 2. Bulletin 17 Analysis Editor with FFA Test 1 Data Set

A Bulletin 17 and a General Frequency analysis have been developed for this example. To open the **Bulletin 17 Editor** analysis editor for Example 1, either double-click on the analysis labeled ***FFA Test 1*** from the Study Explorer, or from the **Analysis** menu select open, then select **FFA Test 1** from the list of available analyses. When **FFA Test 1** is selected, the Bulletin 17 analysis editor will appear as shown in Figure 3.



4 Figure 3. Bulletin 17 Analysis Editor with FFA Test 1 Data Set

Shown in Figure 3 are the general settings that were used to perform this frequency analysis. As shown, the **Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B, or develop a value from a regional analysis of nearby gages. In this example a value of 0.6 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.

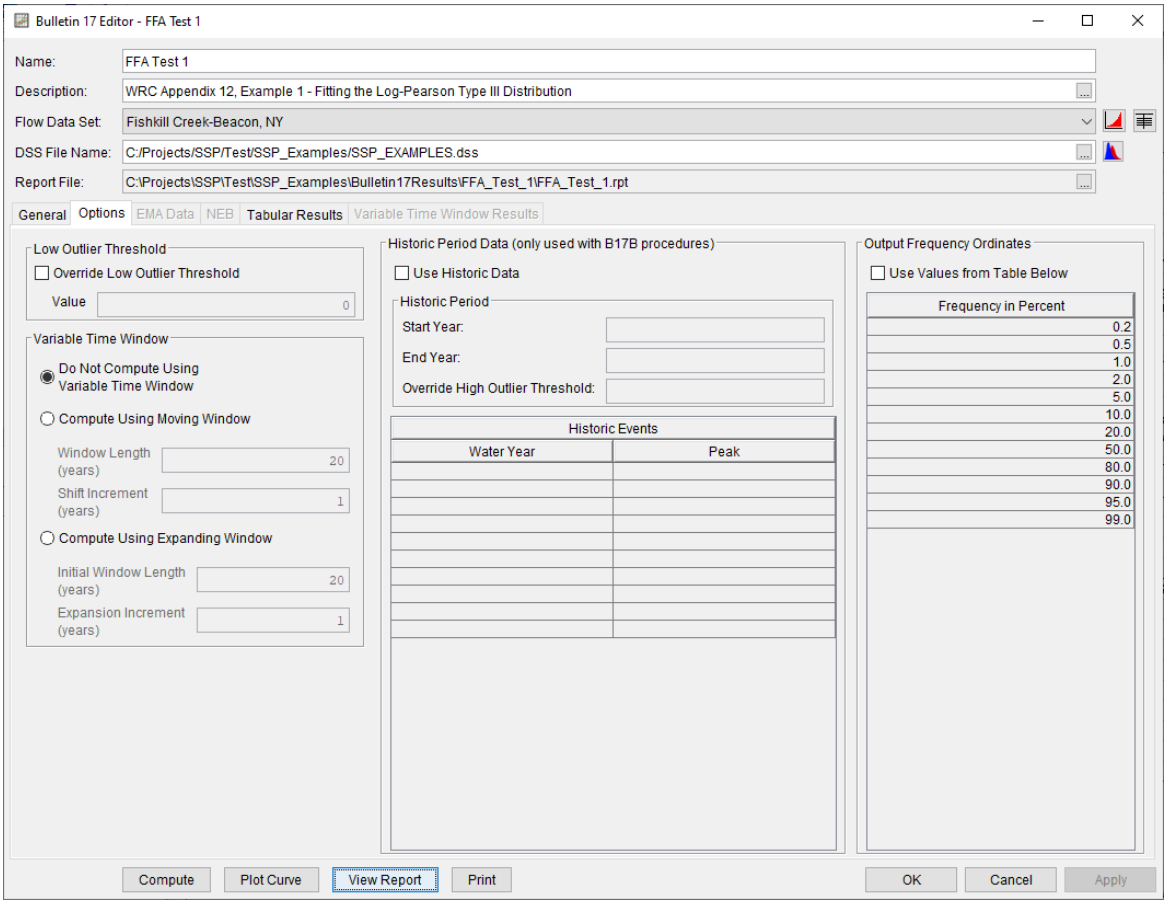


The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[7]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[8]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

7 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
8 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

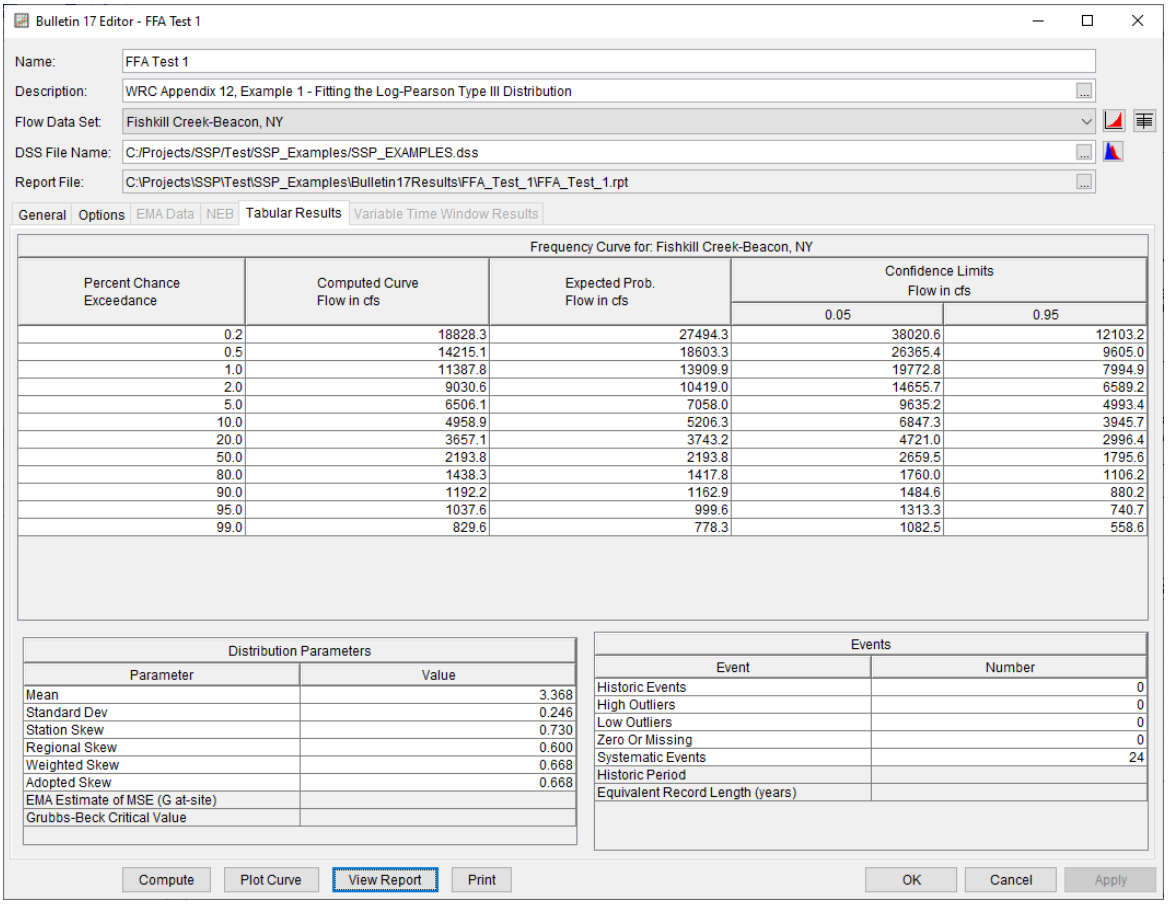
Also for this example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The **Median** plotting position method was selected, as well as the default **Confidence Limits**.

Shown in Figure 4 is the Bulletin 17 editor with the **Options Tab** selected. As shown in Figure 4, none of the available options for modifying the frequency analysis were selected for this example. These options include changing the **Low Outlier Threshold** and using **Historic Data**. Additionally, the option to override the default **Frequency Ordinates** was not selected.



5 Figure 4. Bulletin 17 Editor with Options Tab Selected for FFA Test 1

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 5.

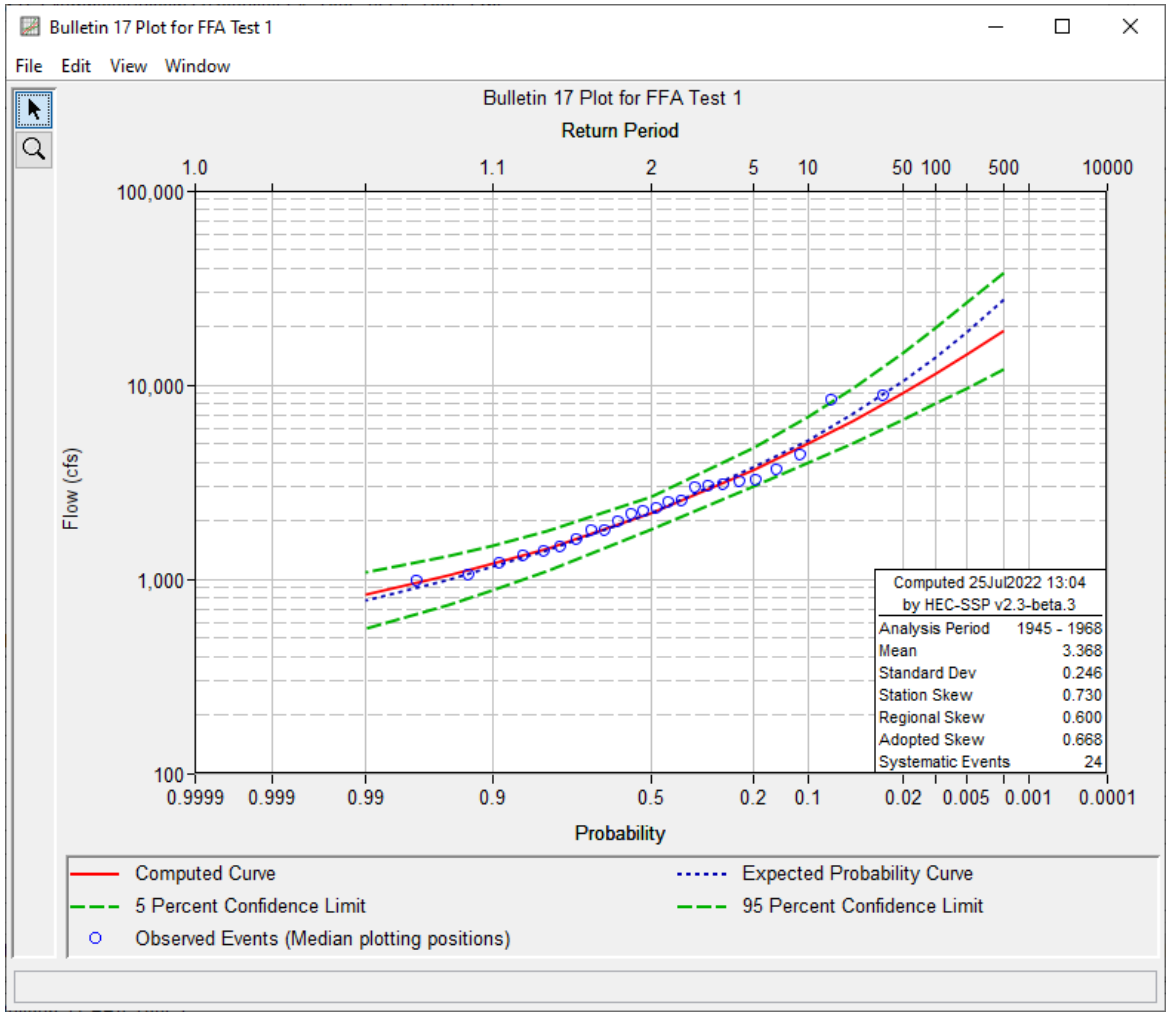


6 Figure 5. Bulletin 17 Analysis Window with Results Tab Shown for FFA Test 1

As shown in Figure 5, the Frequency Curve table contains the following results:

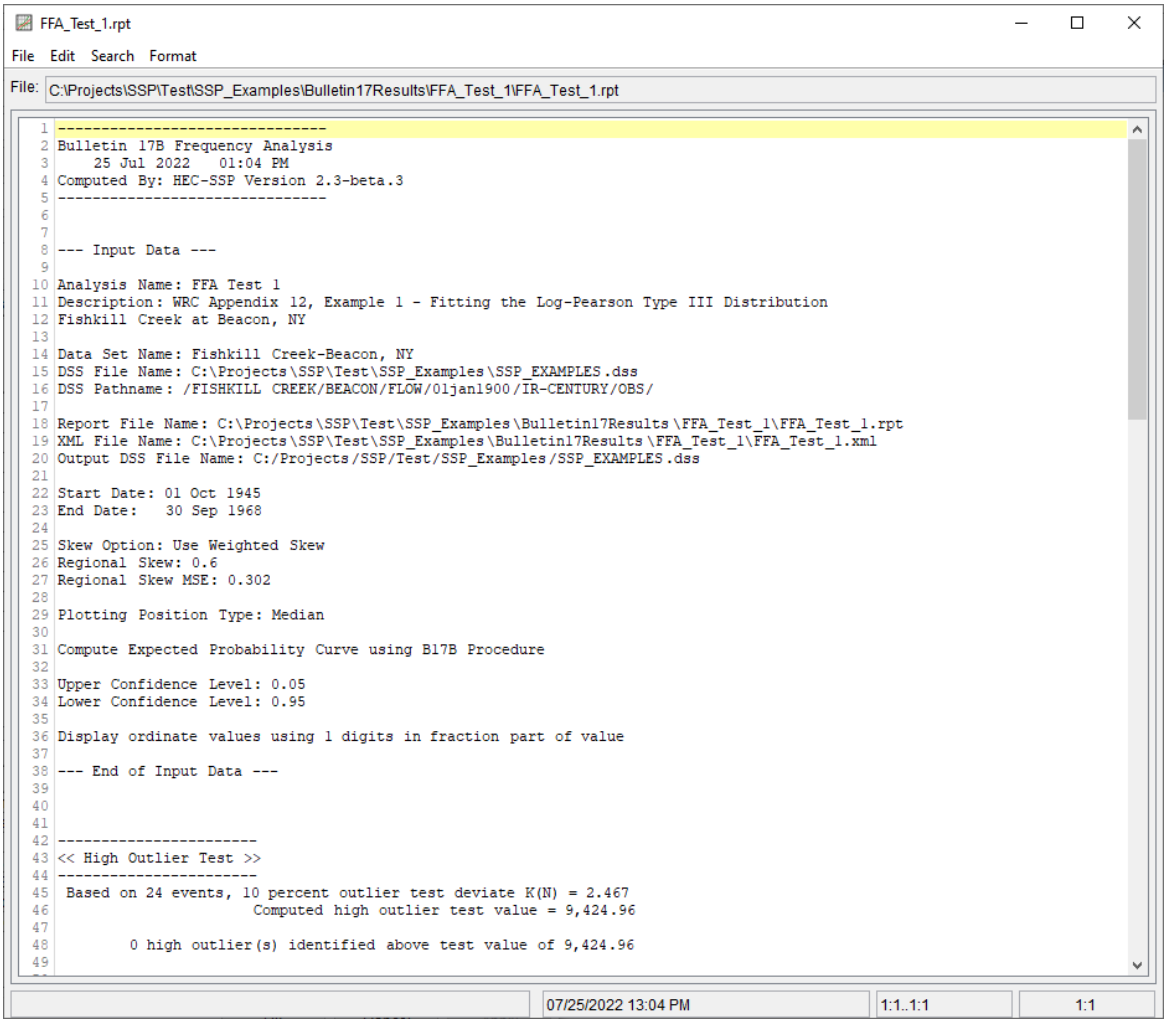
- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

On the bottom, left side of the results tab is a table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom, right side of the results tab is a Number of Events table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered). In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6.



7 Figure 6. Plotted Frequency Curves for FFA Test 1

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 7 is the report file for FFA Test 1. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis. The user should review the report file to understand how HEC-SSP performed the Bulletin 17 frequency curve calculations.



8 Figure 7. FFA Test 1 Report File

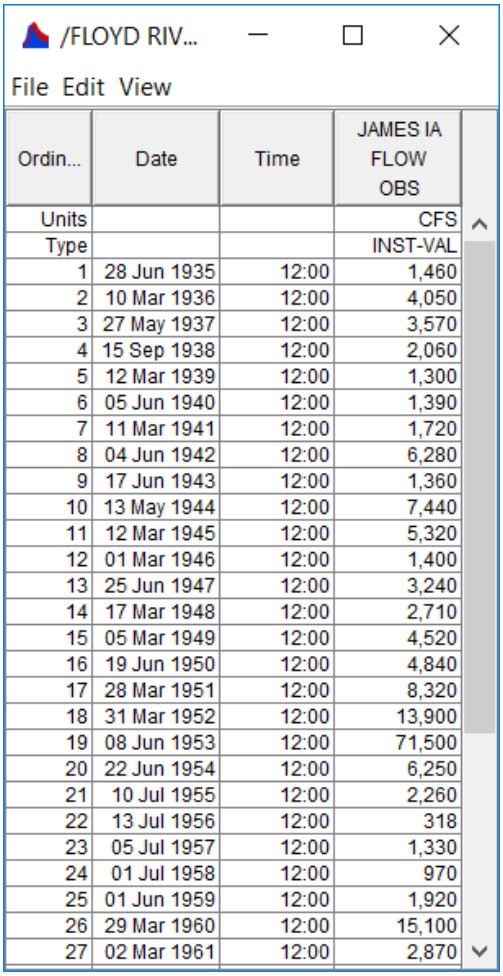
2.2 Example 2. Analysis with High Outliers

In the ***SSP_Examples.ssp*** study, the input data for the Bulletin 17 analysis, ***FFA Test 2***, is the same as that for Example 2 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council (WRC) Bulletin 17B[9]. ***FFA Test 2*** illustrates the application to data with a high outlier.

> ⚠ This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[10]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[11]). Bulletin 17C examples can be found here (see page 57).

9 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
10 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
11 https://pubs.er.usgs.gov/publication/tm4B5

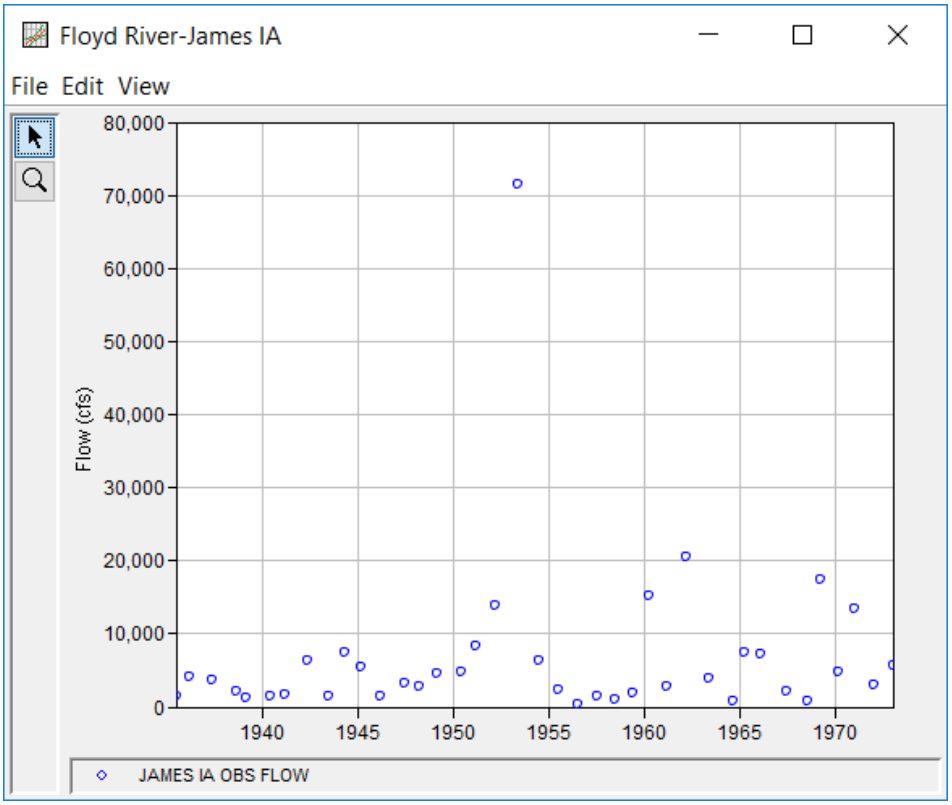
The data for this example is from Floyd River in James, Iowa. The period of record used is from 1935 to 1973. To view the data from HEC-SSP, right-click on the data record labeled "***Floyd River-James IA***" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure 1 (see page 20).



Ordin...	Date	Time	JAMES IA FLOW OBS
Units			CFS
Type			INST-VAL
1	28 Jun 1935	12:00	1,460
2	10 Mar 1936	12:00	4,050
3	27 May 1937	12:00	3,570
4	15 Sep 1938	12:00	2,060
5	12 Mar 1939	12:00	1,300
6	05 Jun 1940	12:00	1,390
7	11 Mar 1941	12:00	1,720
8	04 Jun 1942	12:00	6,280
9	17 Jun 1943	12:00	1,360
10	13 May 1944	12:00	7,440
11	12 Mar 1945	12:00	5,320
12	01 Mar 1946	12:00	1,400
13	25 Jun 1947	12:00	3,240
14	17 Mar 1948	12:00	2,710
15	05 Mar 1949	12:00	4,520
16	19 Jun 1950	12:00	4,840
17	28 Mar 1951	12:00	8,320
18	31 Mar 1952	12:00	13,900
19	08 Jun 1953	12:00	71,500
20	22 Jun 1954	12:00	6,250
21	10 Jul 1955	12:00	2,260
22	13 Jul 1956	12:00	318
23	05 Jul 1957	12:00	1,330
24	01 Jul 1958	12:00	970
25	01 Jun 1959	12:00	1,920
26	29 Mar 1960	12:00	15,100
27	02 Mar 1961	12:00	2,870

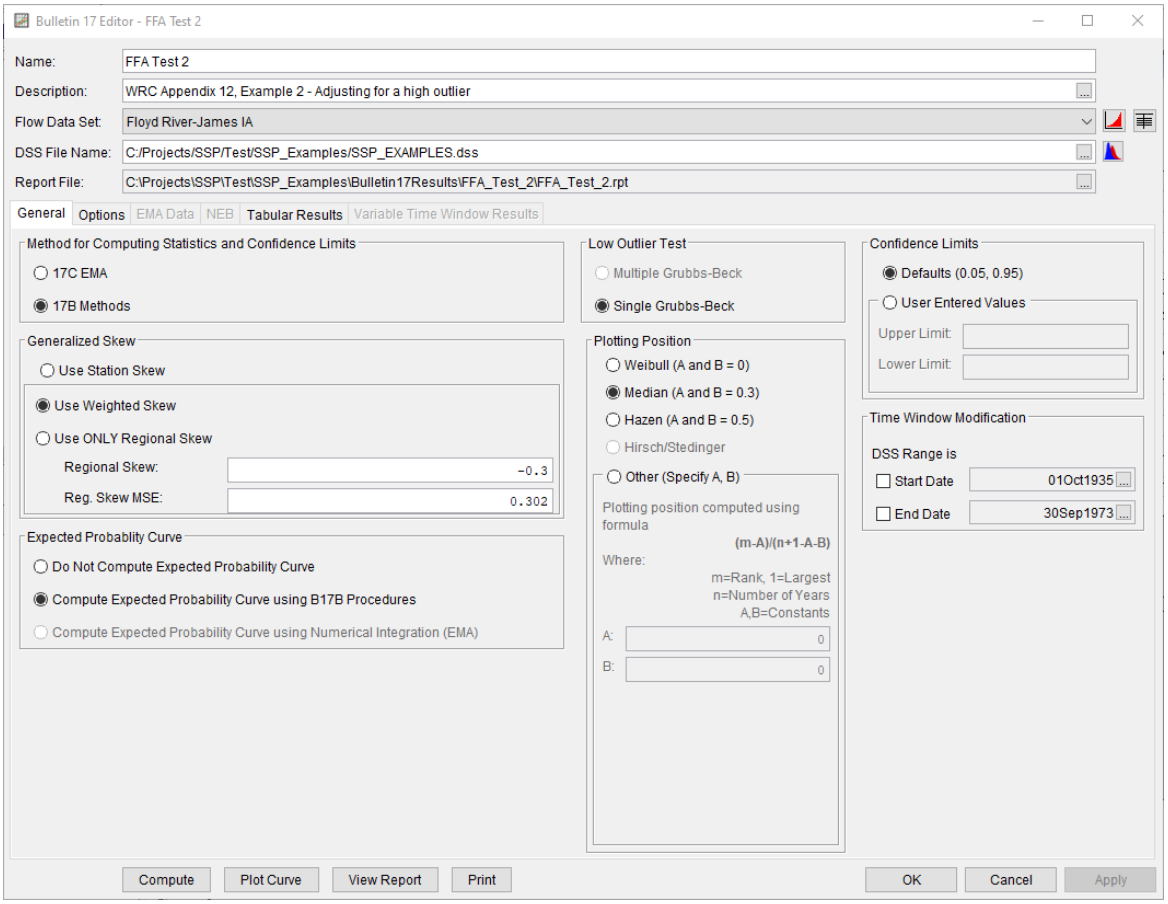
9 Figure 1. Tabulation of the Peak Flow Data for the Floyd River

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2 (see page 20).



10 Figure 2. Plot of Floyd River Data

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for ***FFA Test 2***, double-click on the analysis labeled ***FFA Test 2*** from the HEC-SSP main window, from the **Study Pane**. Alternatively, from the **Analysis** menu select **Open** and then select ***FFA Test 2*** from the list of available analyses in the **Open Analysis** dialog box. When ***FFA Test 2*** is opened, the **Bulletin 17 Editor** will appear as shown in Figure 3 (see page 21).



11 Figure 3. Bulletin 17 Analysis Editor with FFA Test 2 Data Set

Shown in Figure 3 (see page 21) are the general settings that were used to perform this frequency analysis. As shown, the **Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B (Plate 1)[12], or develop a value from a regional analysis of nearby gages. In this example a value of -0.3 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.



The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[13]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[14]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

12 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
13 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
14 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

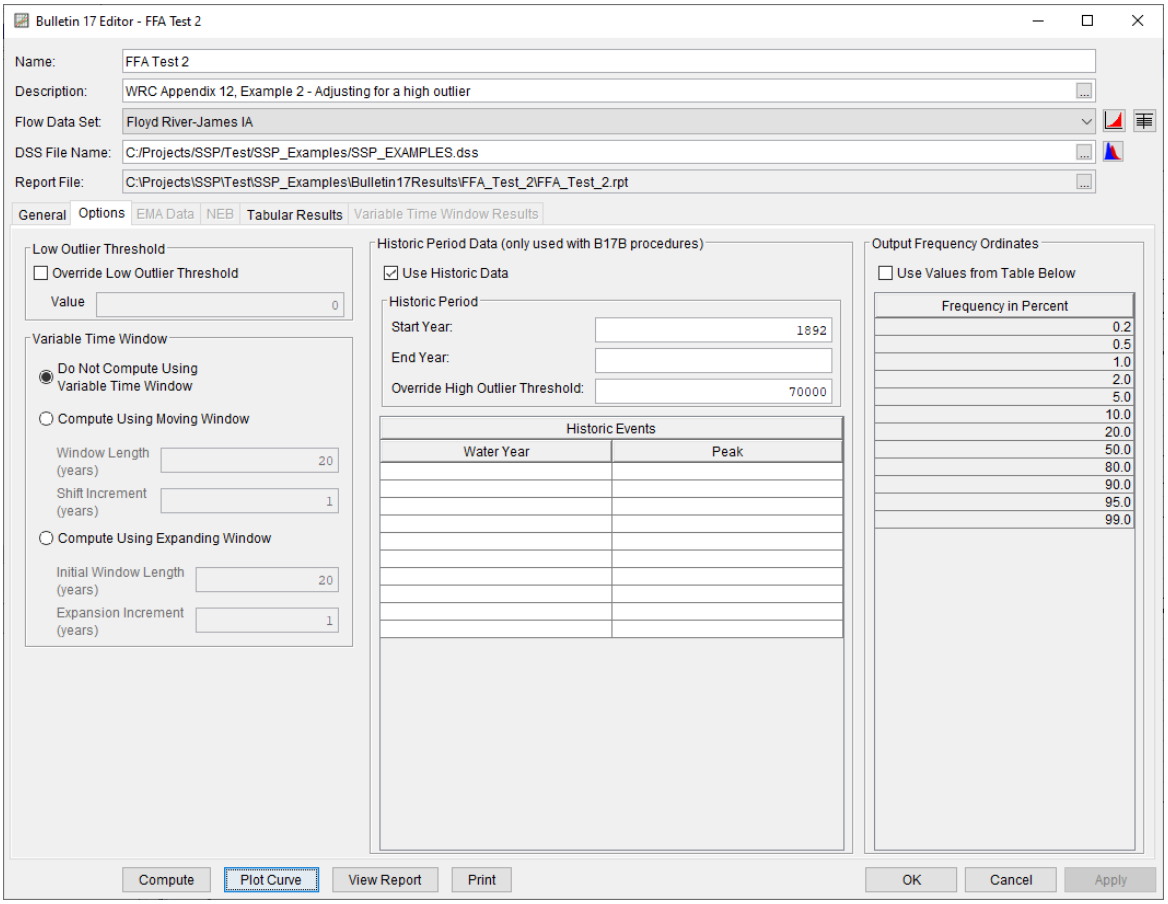
Also for this example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The **Median** plotting position method was selected, as well as the default **Confidence Limits**.

Shown in Figure 4 (see page 23) is the Bulletin 17 editor with the **Options** tab selected. As shown in Figure 4 (see page 23), the **Historic Period Data** option has been selected to reflect the fact that the 1953 flood peak of 71,500 cfs is known to be the largest flood since 1892. When the analysis was originally performed on this data set, the 1953 event was found to be a high outlier.

> The reader may replicate this result by un-checking the "***Use Historic Data***" box, hitting the **Compute** button, and reviewing the **Tabular Results** tab. High outliers should not be eliminated from an analysis, as they are valuable pieces of the flow record. However, when a high outlier is found in a data set, it suggests that the event might actually be the largest in a much longer period of record. The user should always try to locate and incorporate historic information to define a longer record and improve the quality of the frequency analysis.

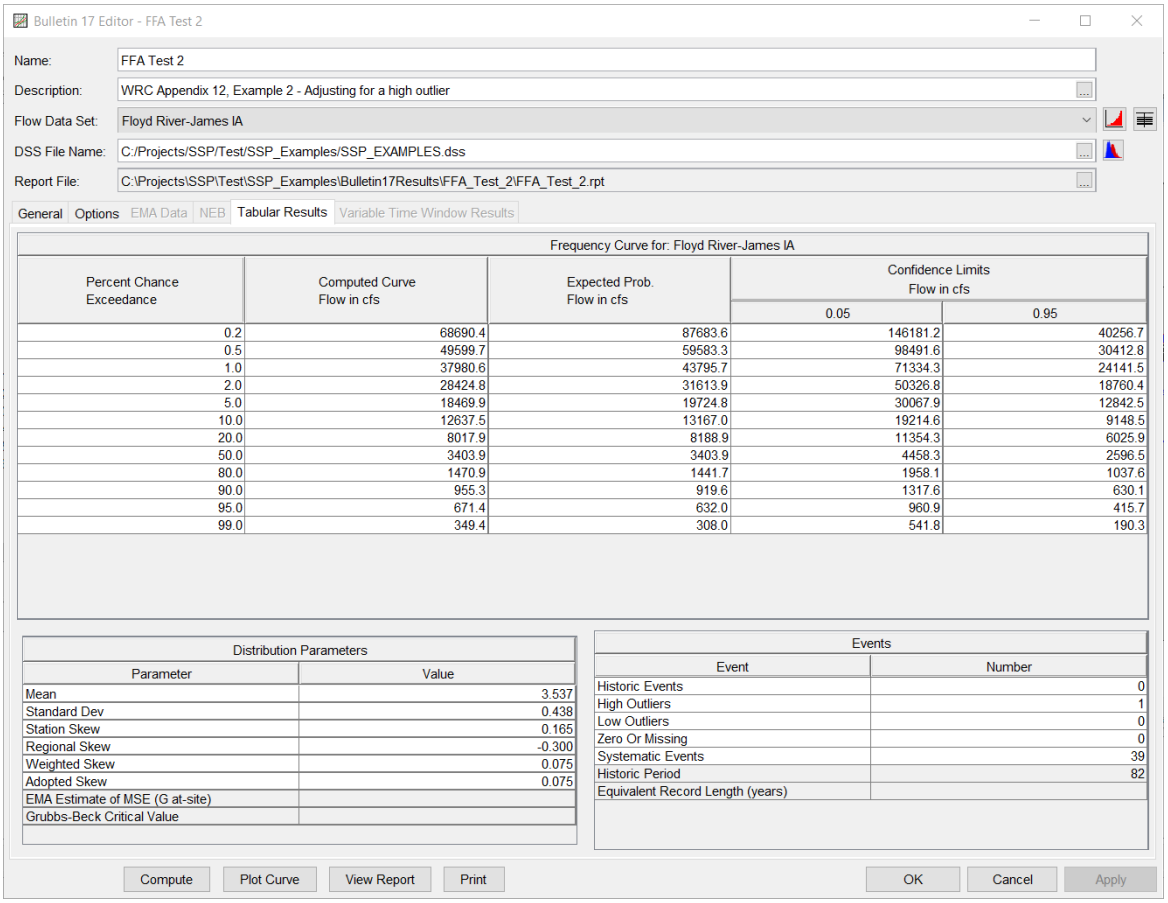
Since it was known that the 1953 event was the largest value since 1892, the year 1892 is entered as the **Start Year** for the historic period. Additionally, an **Override High Threshold Value** of 70,000 cfs was entered. By entering the High Threshold Value of 70,000 cfs, the 1953 flood of 71,500 cfs was removed from the systematic record and treated as a historic data value during the historic data adjustment calculations performed by HEC-SSP and outlined in Bulletin 17B, Appendix 6[15]. Since no **End Year** was entered for the historic period, the last year of the systematic data set will be used as the End Year. Other features on this tab include the **Low Outlier Threshold** and the option to override the default **Frequency Ordinates**, neither of which are selected in this example.

15 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf



12 Figure 4. Bulletin 17 Editor with Options Tab Selected for FFA Test 2

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 5 (see page 24).



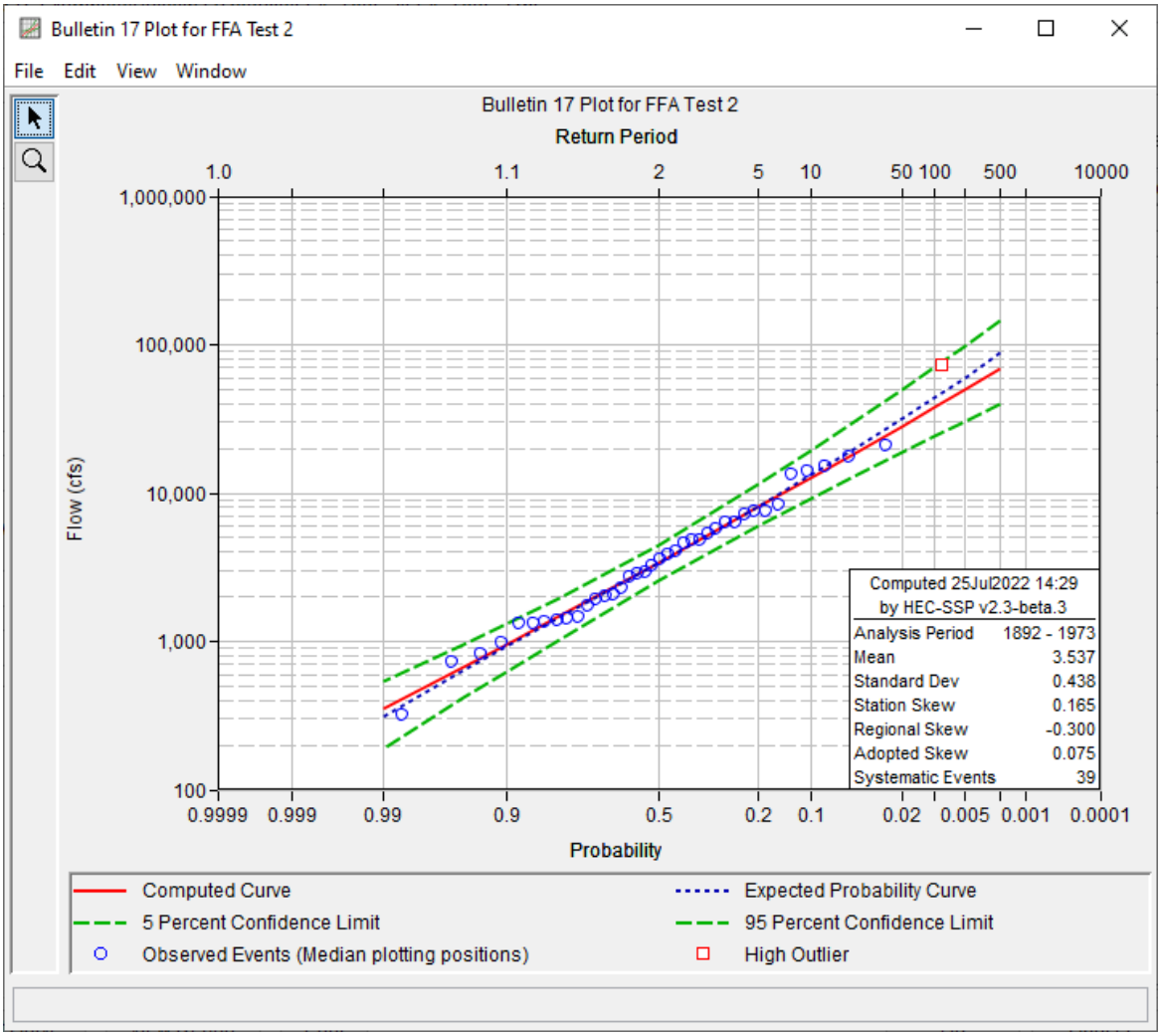
13 Figure 5. Bulletin 17 Editor with Results Tab Selected for FFA Test 2

As shown in Figure 5 (see page 24), the **Frequency Curve** table contains the following results:

- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

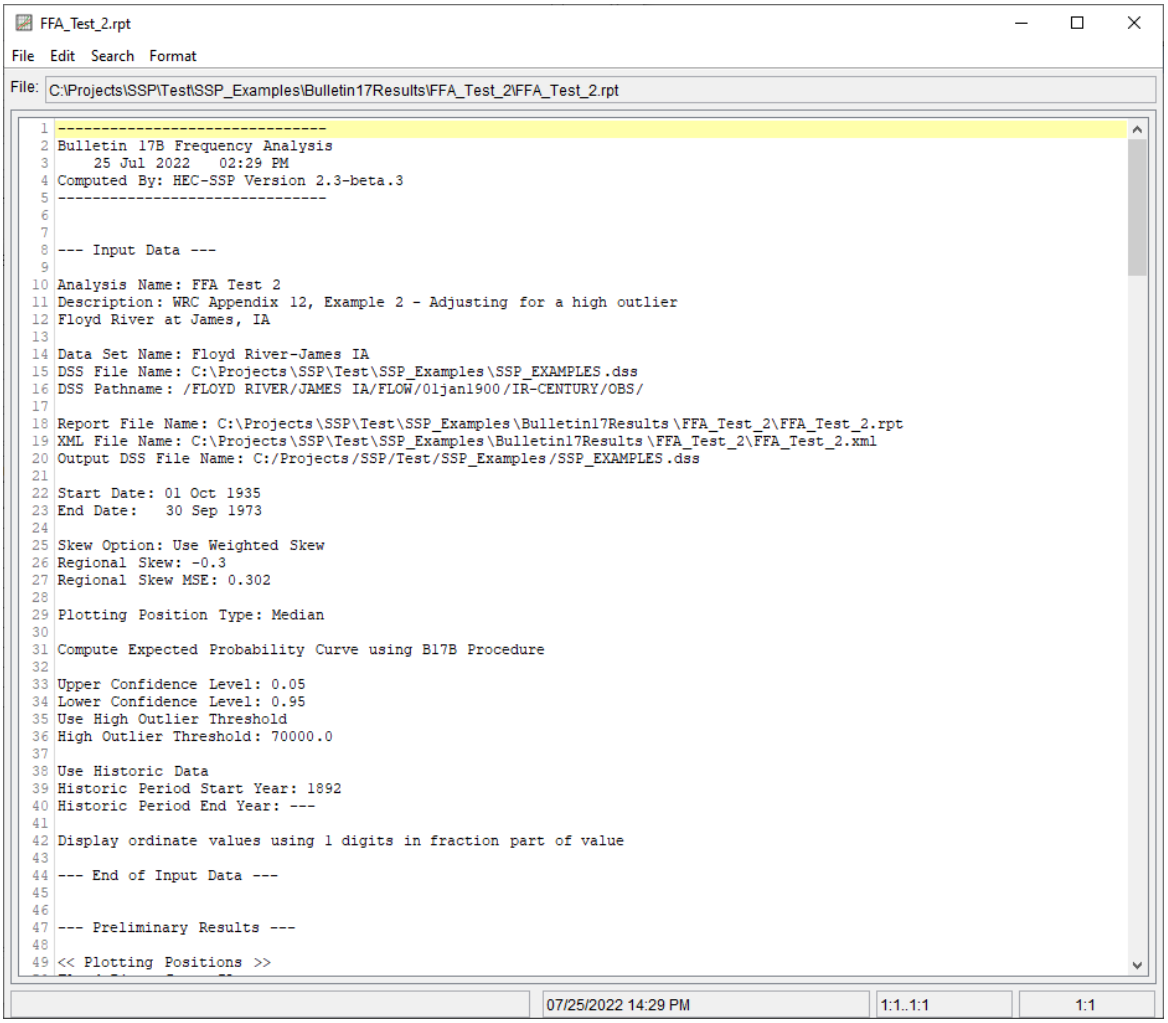
On the bottom left-hand side of the **Tabular Results** tab is the **Distribution Parameters** (statistics) table displaying the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side of the **Tabular Results** tab is the number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered).

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button (Figure 5 (see page 24)) at the bottom of the **Bulletin 17 Editor**. A plot of the results for this example is shown in Figure 6 (see page 25).



14 Figure 6. Plotted Frequency Curves for FFA Test 2

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the **Bulletin 17 Editor** (Figure 5 (see page 0)). The **View Report** button opens a text viewer window displaying the report file (e.g., ***FFA_Test_2.rpt***). Shown in Figure 7 (see page 26) is the report file for ***FFA Test 2***. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis. The user should review the report file to understand how HEC-SSP performed the frequency curve calculations.



15 Figure 7. FFA Test 2 Report File

2.3 Example 3. Testing and Adjusting for a Low Outlier

In the ***SSP_Examples.ssp*** study, the input data for the ***FFA Test 3*** Bulletin 17 analysis is the same as that for Example 3 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council (WRC) Bulletin 17B[16]. ***FFA Test 3*** illustrates the application to data with a low outlier.

16 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf



This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[17]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[18]). Bulletin 17C examples can be found here (see page 57).

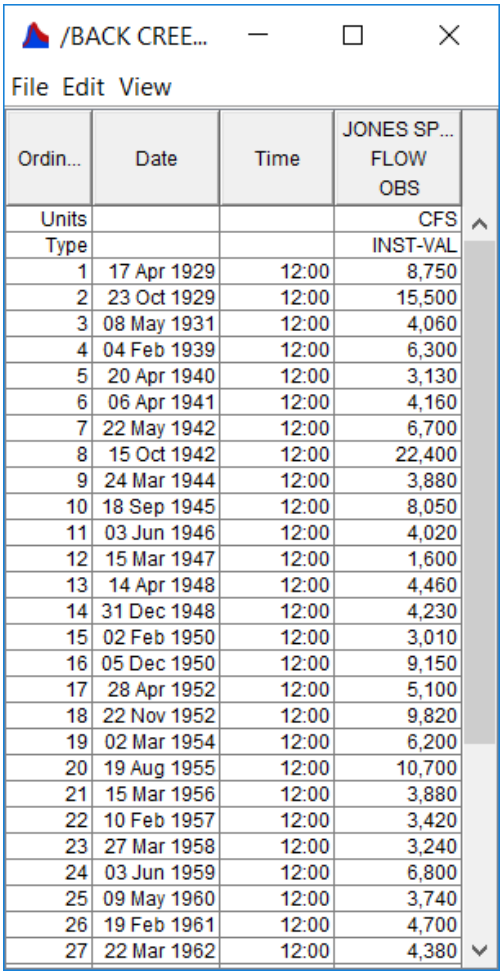


Note

HEC-SSP automatically screens for low outliers and, if low outliers are found, outputs the preliminary results in the report file in order to allow for comparison with the final results.

The data for this example is from Back Creek in Jones Springs, West Virginia. The period of record used for this example is from 1929 to 1973. To view the data in HEC-SSP, under the **Data** folder in the **Study Pane**, right-click on the data record labeled "***Back Creek-Jones Springs***" and click **Tabulate**. The data will appear as shown in Figure 1 (see page 28).

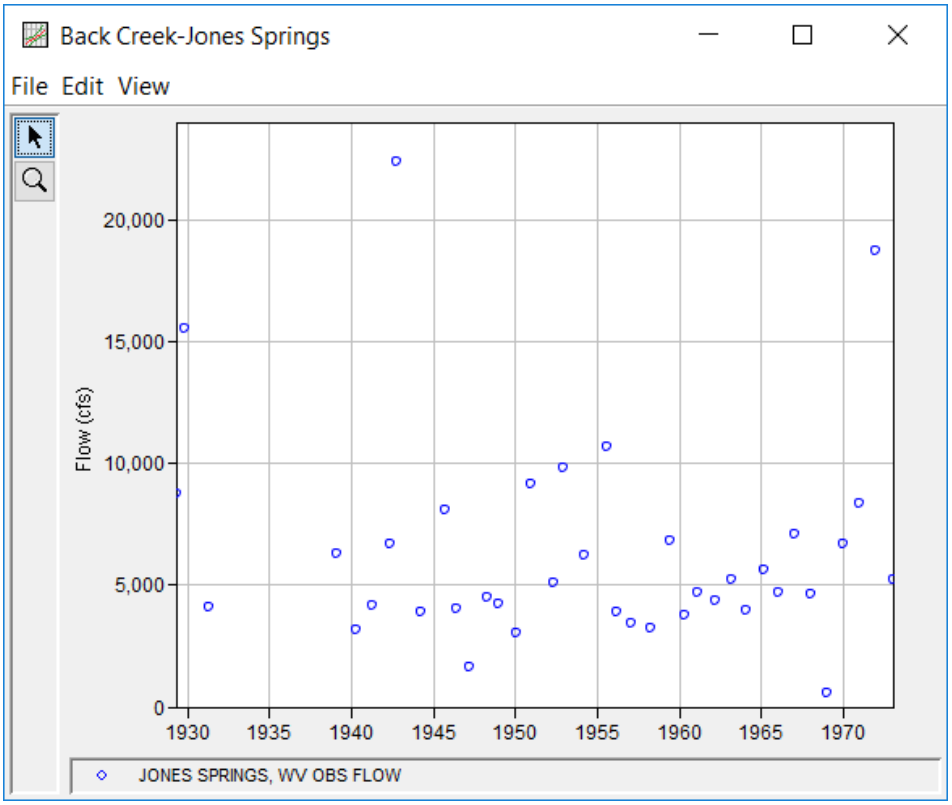
17 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
18 https://pubs.er.usgs.gov/publication/tm4B5



Ordin...	Date	Time	JONES SP... FLOW OBS
Units			CFS
Type			INST-VAL
1	17 Apr 1929	12:00	8,750
2	23 Oct 1929	12:00	15,500
3	08 May 1931	12:00	4,060
4	04 Feb 1939	12:00	6,300
5	20 Apr 1940	12:00	3,130
6	06 Apr 1941	12:00	4,160
7	22 May 1942	12:00	6,700
8	15 Oct 1942	12:00	22,400
9	24 Mar 1944	12:00	3,880
10	18 Sep 1945	12:00	8,050
11	03 Jun 1946	12:00	4,020
12	15 Mar 1947	12:00	1,600
13	14 Apr 1948	12:00	4,460
14	31 Dec 1948	12:00	4,230
15	02 Feb 1950	12:00	3,010
16	05 Dec 1950	12:00	9,150
17	28 Apr 1952	12:00	5,100
18	22 Nov 1952	12:00	9,820
19	02 Mar 1954	12:00	6,200
20	19 Aug 1955	12:00	10,700
21	15 Mar 1956	12:00	3,880
22	10 Feb 1957	12:00	3,420
23	27 Mar 1958	12:00	3,240
24	03 Jun 1959	12:00	6,800
25	09 May 1960	12:00	3,740
26	19 Feb 1961	12:00	4,700
27	22 Mar 1962	12:00	4,380

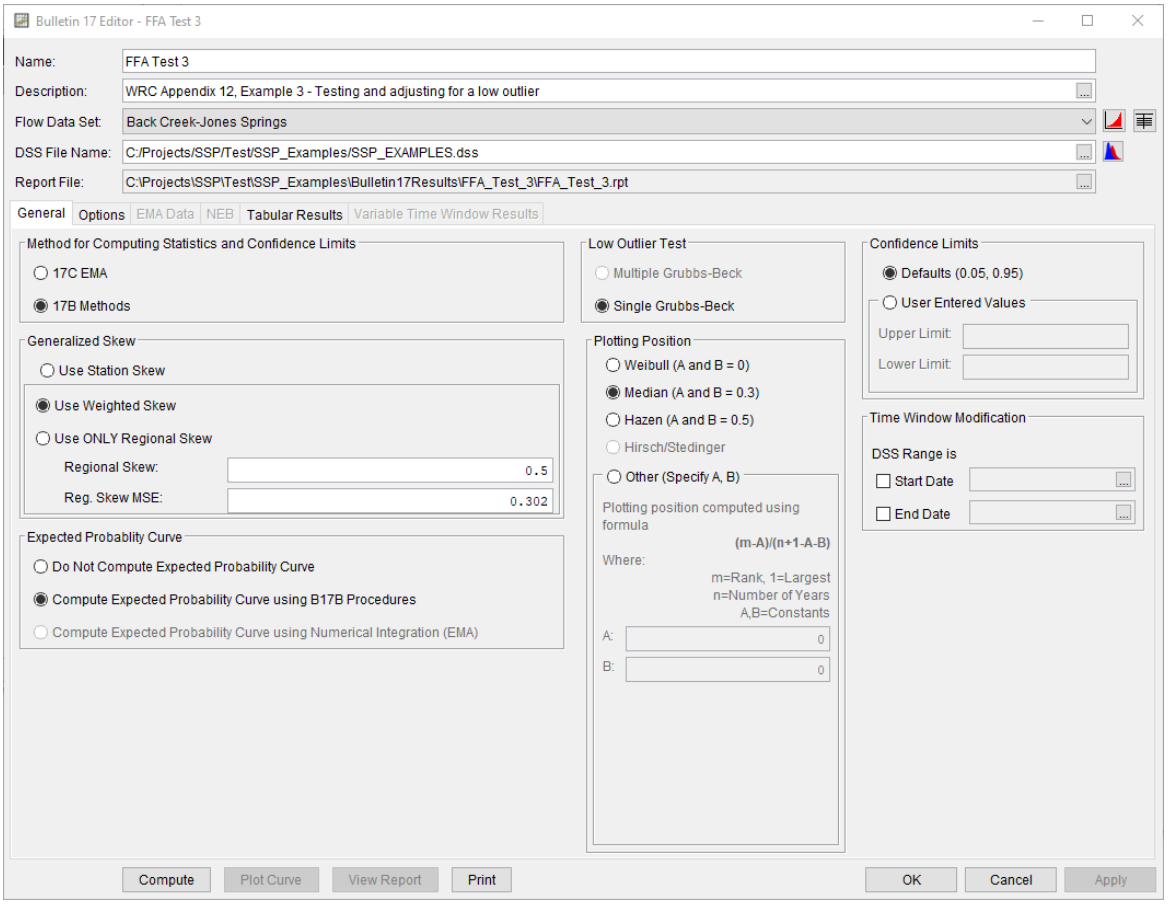
16 Figure 1. Tabulation of the Peak Flow Data for Back Creek

To plot the data for this example, right-click on the data record and click **Plot**. A plot of the data will appear as shown in Figure 2 (see page 29).



17 Figure 2. Plot of Back Creek Data

A Bulletin 17 and General Frequency analysis have been developed for this example and can be viewed in HEC-SSP; however, this example only displays the results of the Bulletin 17 analysis. To open the **Bulletin 17 Editor** for ***FFA Test 3***, from the **Study Pane** under the **Bulletin 17 Analysis** folder, double-click on the ***FFA Test 3*** analysis. Alternatively, from the **Analysis** menu select **Open** and then select ***FFA Test 3*** from the list of available analyses in the **Open Analysis** dialog box. When ***FFA Test 3*** is opened, the **Bulletin 17 Editor - *FFA Test 3*** will appear as shown in Figure 3 (see page 30).



18 Figure 3. Bulletin 17 Analysis Editor with FFA Test 3 Data Set

Figure 3 (see page 30) displays the settings entered in the **General** tab that were used to perform this frequency analysis. As shown, the **Generalized Skew** option was set to use **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B[19], or develop a value from a regional analysis of nearby gages. In this example, a value of 0.5 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.

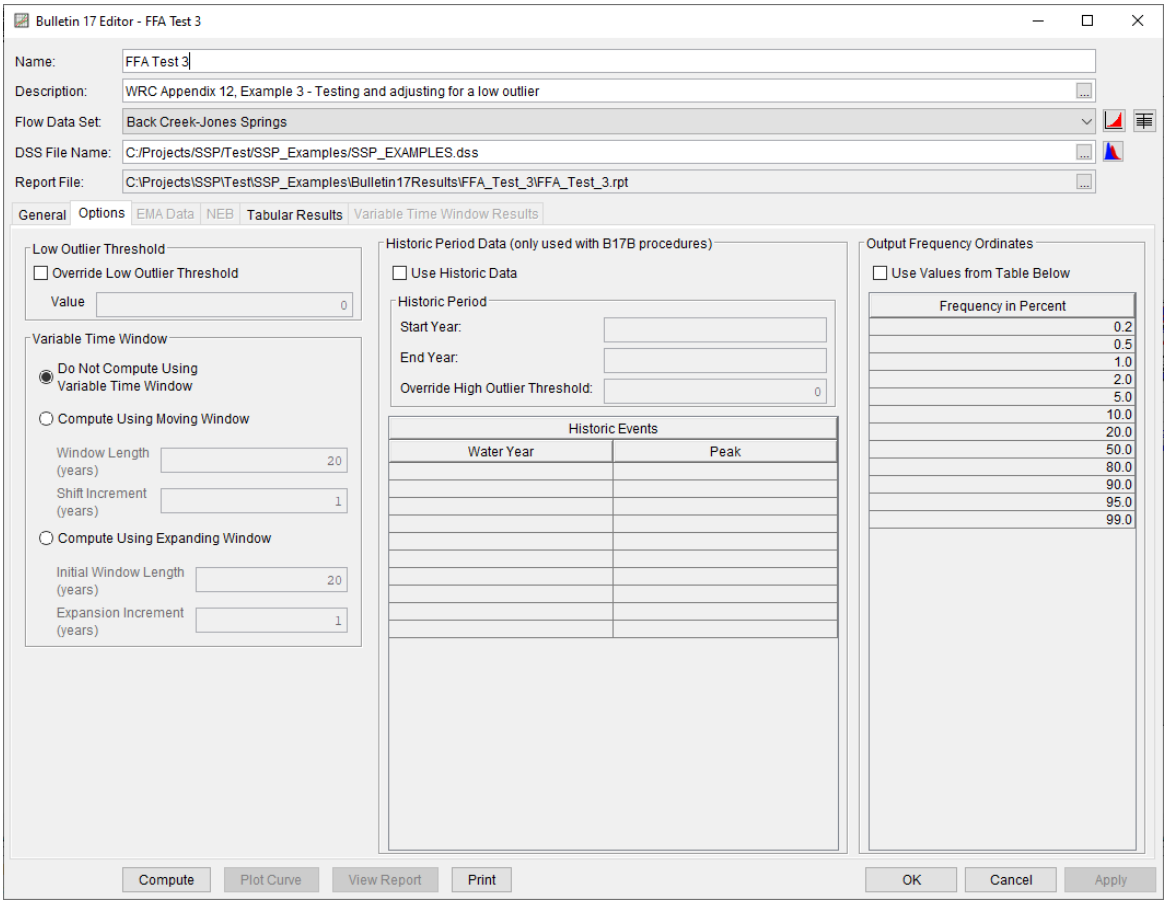


The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[20]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[21]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

19 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
20 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
21 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

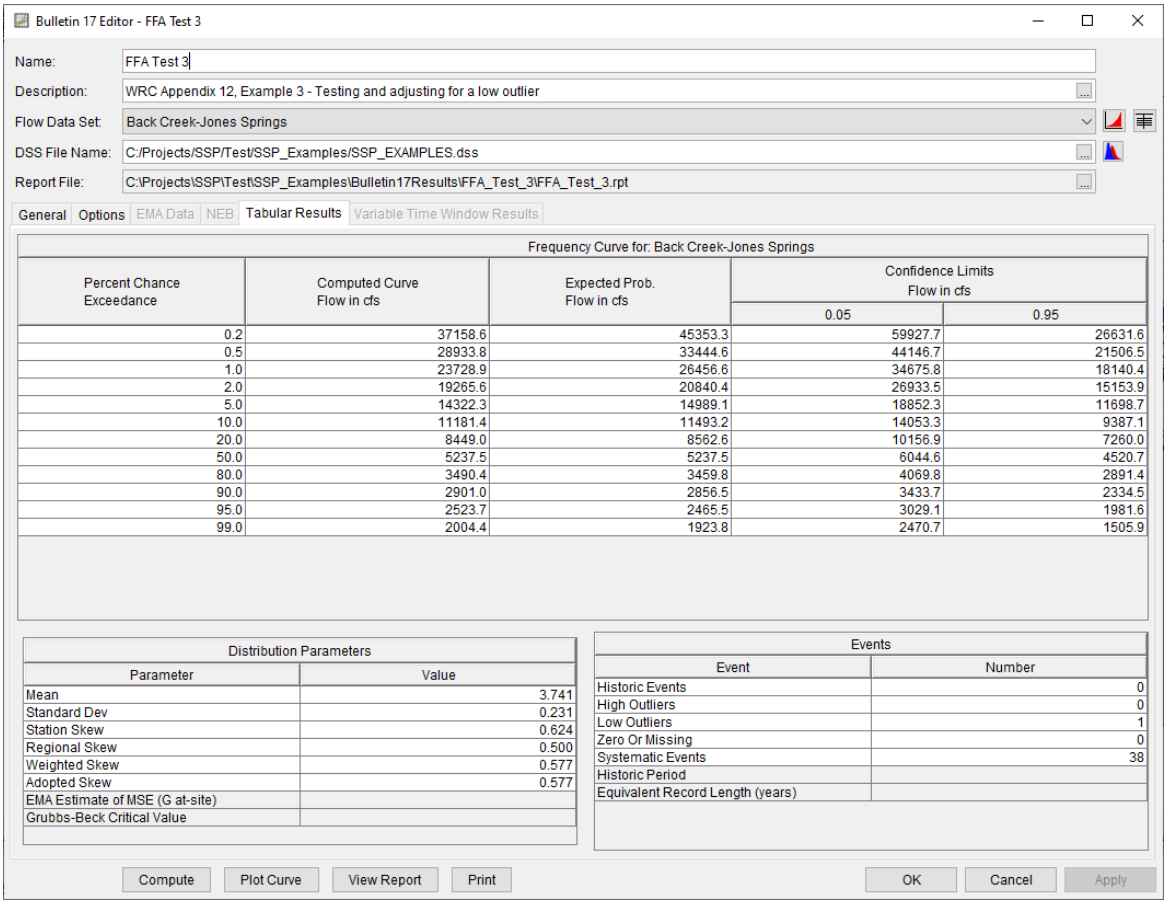
Also for this example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The **Median** plotting position method was selected, as well as the default **Confidence Limits**.

Figure 4 (see page 32) displays the **Bulletin 17 Editor** with the **Options** tab selected. As shown in Figure 4 (see page 32), none of the available options for modifying the frequency curve were selected from the **Options** tab for this test example. These options include the **Low Outlier Threshold** and **Historic Period Data**. Additionally, the option to override the default **Frequency Ordinates** was not selected.



19 Figure 4. Bulletin 17 Editor with the Options Tab Selected for FFA Test 3

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button (from any tab) to perform the analysis. Once the computations have been completed a message window will open stating **Compute Complete**. Close this window and select the **Tabular Results** tab. The analysis results should resemble Figure 5 (see page 32).



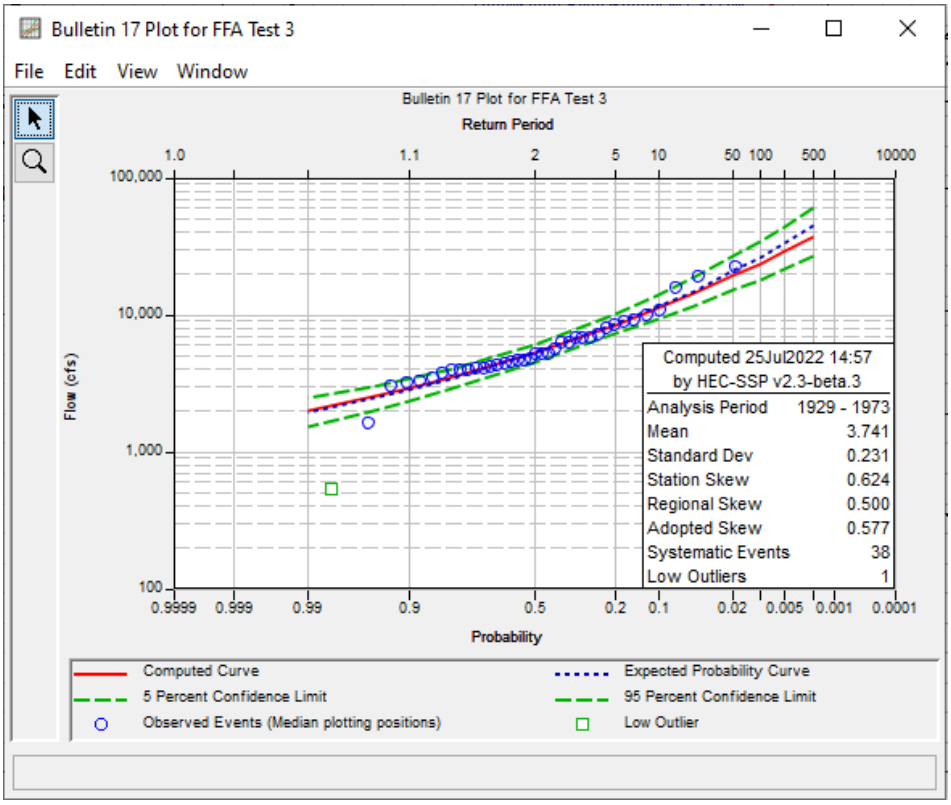
20 Figure 5. Bulletin 17 Editor with the Results Tab Selected for FFA Test 3

As shown in Figure 5 (see page 32), the **Frequency Curve** table contains the following results:

- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

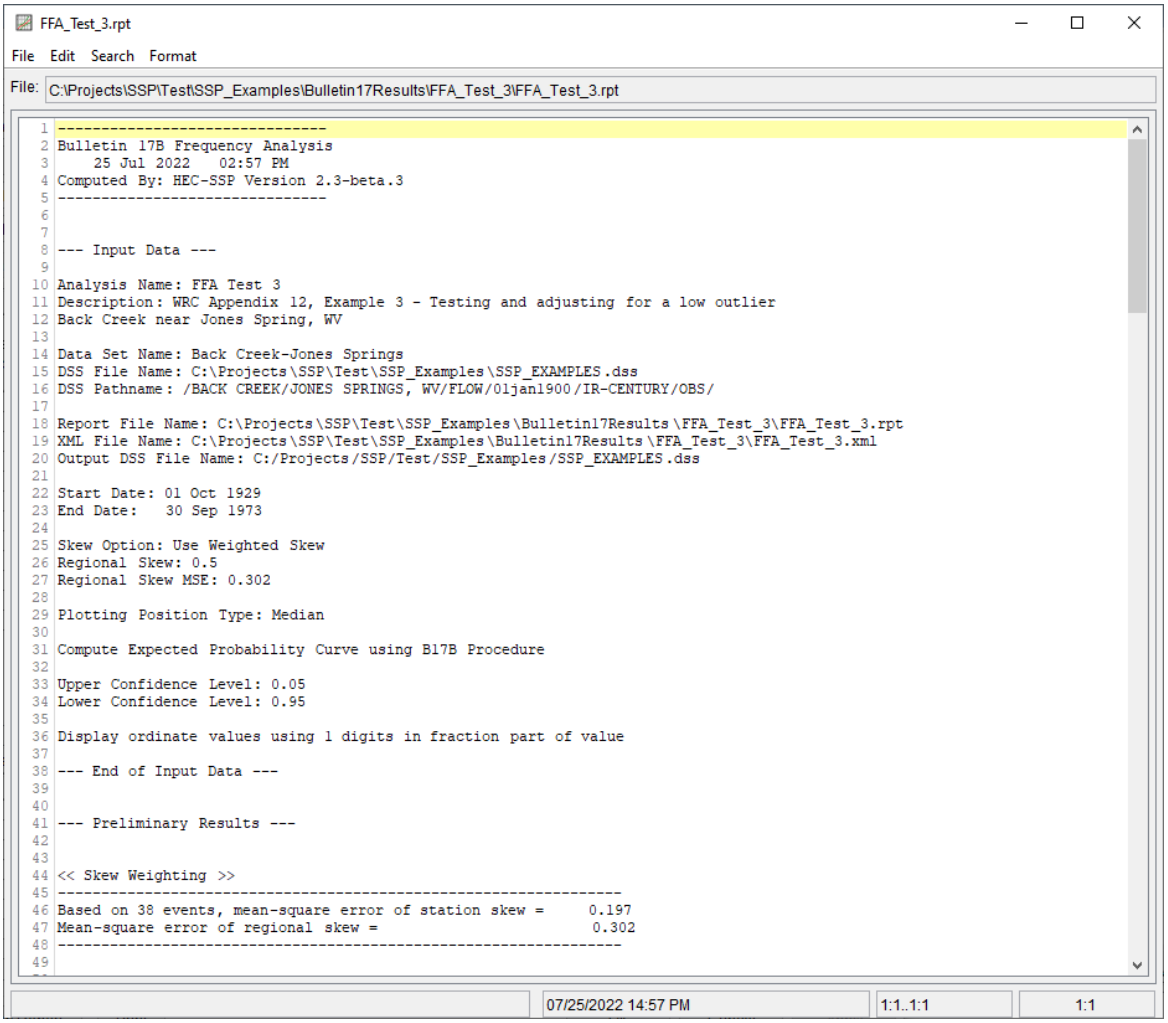
On the bottom left-hand side of the **Tabular Results** tab is the **Distribution Parameters** table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side of the **Tabular Results** tab is the number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered). In this analysis, the software detected one low outlier in the systematic record. As recommended in Bulletin 17B, if a low outlier is detected, then that data point will be removed and the Conditional Probability Adjustment will be used to recalculate the frequency curve and then the statistics without that point. Review the report file to see the original statistics, computed curves, the low outlier test, and recomputed curves.

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6 (see page 33).



21 Figure 6. Pot for FFA Test 3

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 7 (see page 34) is the report file for ***FFA Test 3***. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



22 Figure 7. Report File for FFA Test 3

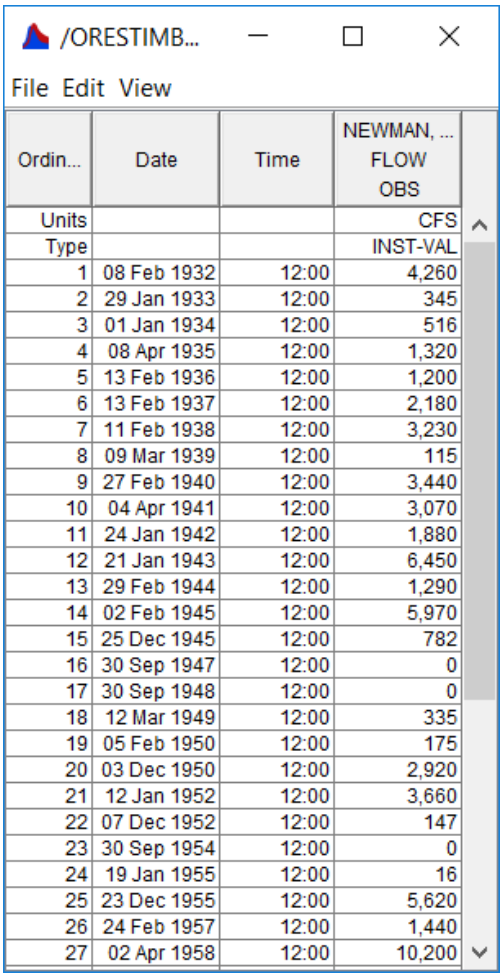
2.4 Example 4. Zero-Flood Years

In the ***SSP_Examples.ssp*** study, the input data for the ***FFA Test 4*** Bulletin 17 analysis is the same as that for Example 4 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council (WRC) Bulletin 17B[22]. ***FFA Test 4*** illustrates the application to data that includes several zero flow years.

> ⚠ This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[23]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[24]). Bulletin 17C examples can be found here (see page 57).

22 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
23 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
24 https://pubs.er.usgs.gov/publication/tm4B5

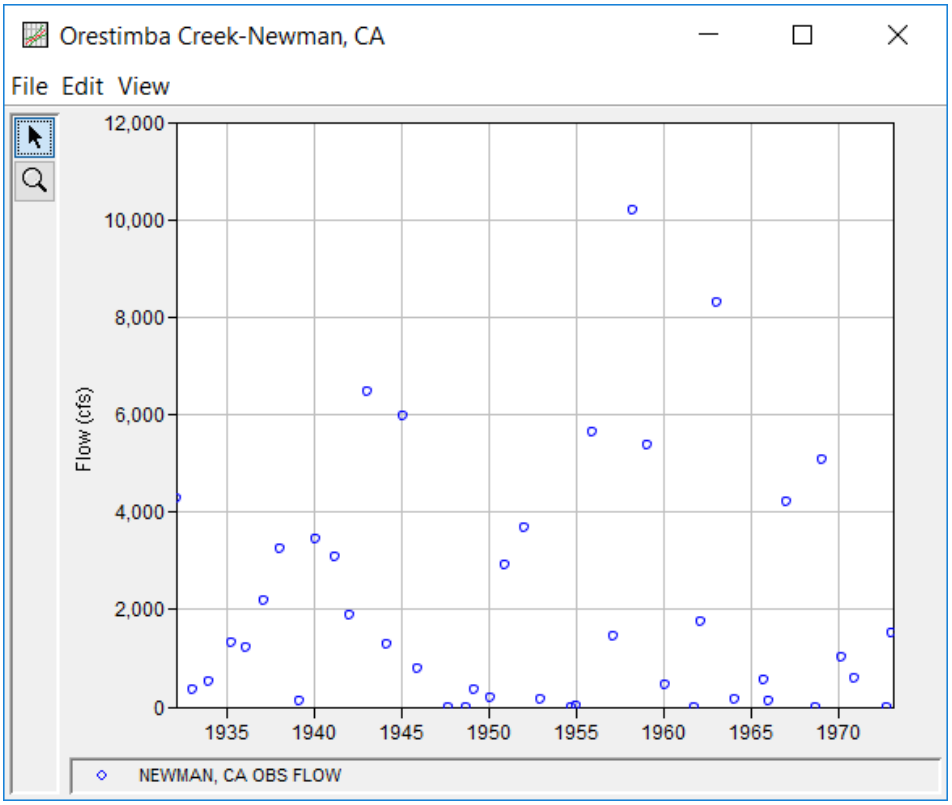
The data for this example is from Orestimba Creek in Newman, California. The period of record used for this example is from 1932 to 1973. To view the data in HEC-SSP, under the **Data** folder in the **Study Pane**, right-click on the data record labeled "***Orestimba Creek-Newman, CA***" and select **Tabulate**. The data will appear as shown in Figure 1 (see page 36).



Ordin...	Date	Time	NEWMAN, ... FLOW OBS
Units			CFS
Type			INST-VAL
1	08 Feb 1932	12:00	4,260
2	29 Jan 1933	12:00	345
3	01 Jan 1934	12:00	516
4	08 Apr 1935	12:00	1,320
5	13 Feb 1936	12:00	1,200
6	13 Feb 1937	12:00	2,180
7	11 Feb 1938	12:00	3,230
8	09 Mar 1939	12:00	115
9	27 Feb 1940	12:00	3,440
10	04 Apr 1941	12:00	3,070
11	24 Jan 1942	12:00	1,880
12	21 Jan 1943	12:00	6,450
13	29 Feb 1944	12:00	1,290
14	02 Feb 1945	12:00	5,970
15	25 Dec 1945	12:00	782
16	30 Sep 1947	12:00	0
17	30 Sep 1948	12:00	0
18	12 Mar 1949	12:00	335
19	05 Feb 1950	12:00	175
20	03 Dec 1950	12:00	2,920
21	12 Jan 1952	12:00	3,660
22	07 Dec 1952	12:00	147
23	30 Sep 1954	12:00	0
24	19 Jan 1955	12:00	16
25	23 Dec 1955	12:00	5,620
26	24 Feb 1957	12:00	1,440
27	02 Apr 1958	12:00	10,200

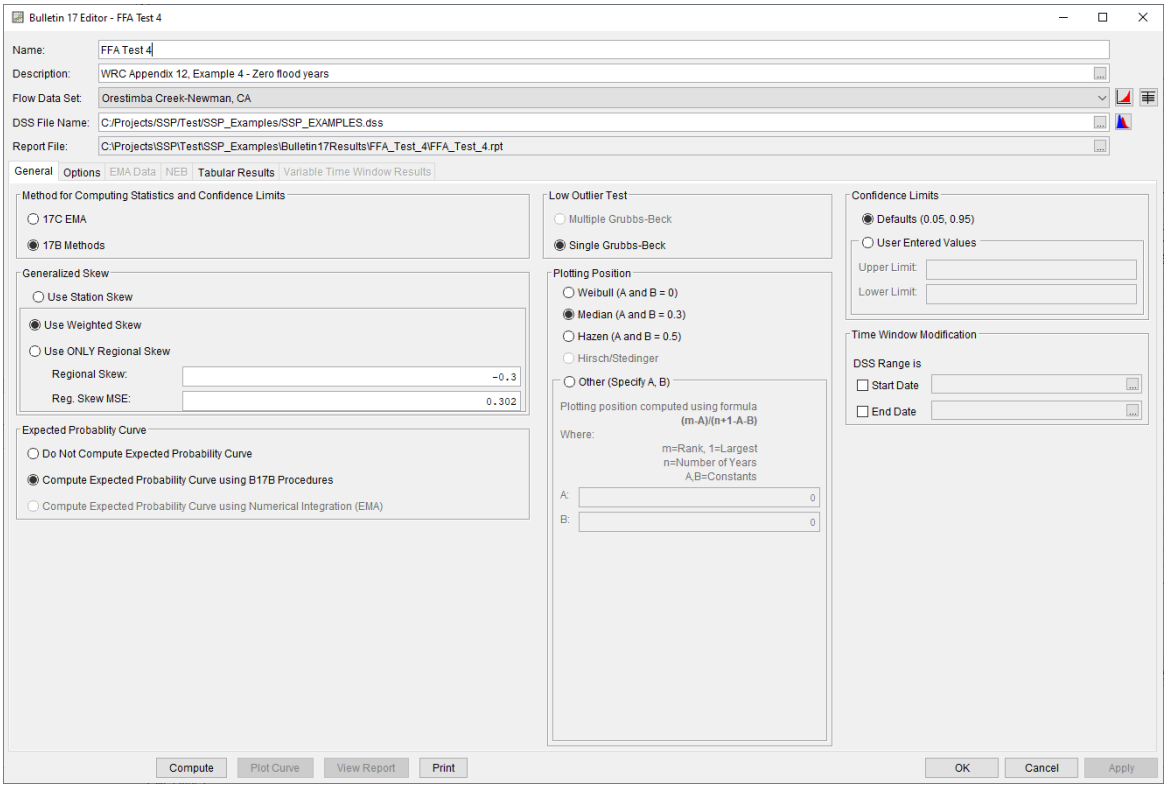
23 Figure 1. Tabulation of the Peak Flow Data for Orestimba Creek

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2 (see page 36). The years with peak flows measuring zero are visible.



24 Figure 2. Plot of Orestimba Creek Data

A Bulletin 17 and General Frequency analysis have been developed for this example and can be viewed in HEC-SSP; however, this example only displays the results of the Bulletin 17 analysis. To open the **Bulletin 17 Editor** for ***FFA Test 4***, from the **Study Pane** under the **Bulletin 17 Analysis** folder, double-click on the ***FFA Test 4*** analysis. Alternatively, from the **Analysis** menu select **Open** and then select ***FFA Test 4*** from the list of available analyses in the **Open Analysis** dialog box. When ***FFA Test 4*** is opened, the **Bulletin 17 Editor - *FFA Test 4*** will appear as shown in Figure 3 (see page 37).



25 Figure 3. Bulletin 17 Analysis Editor with FFA Test 4 Data Set

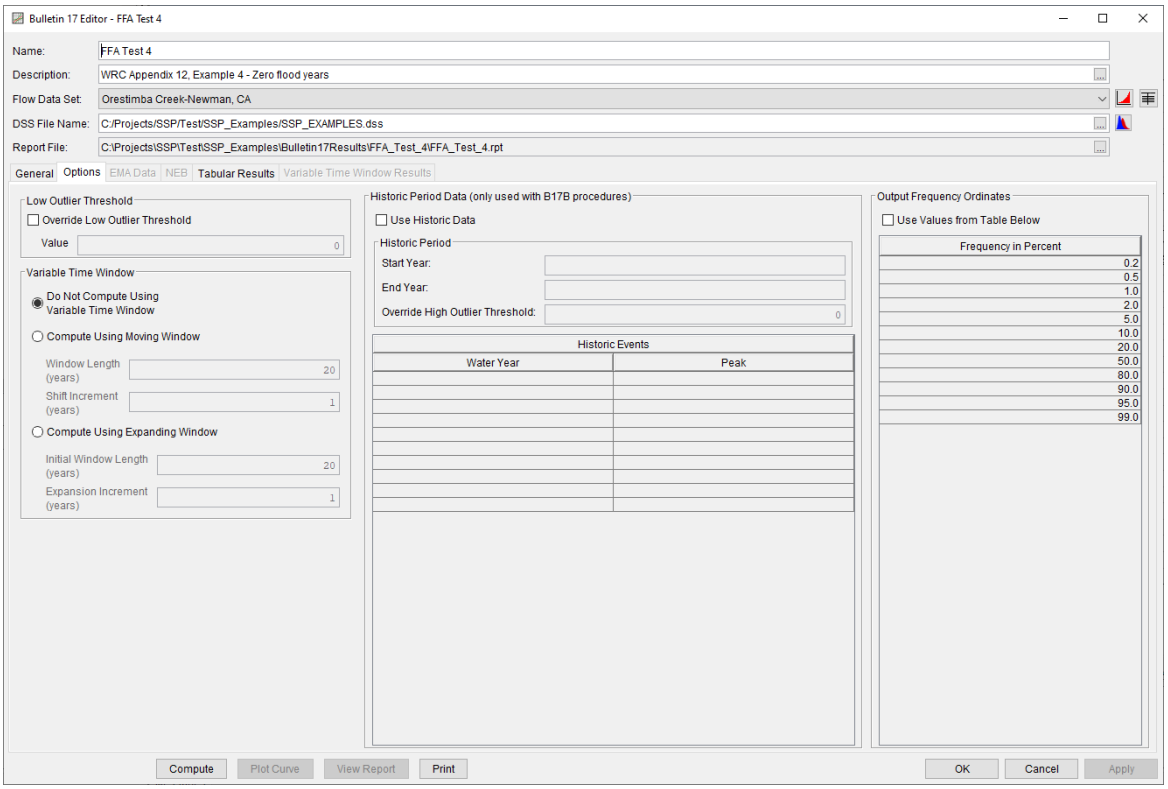
Figure 3 (see page 37) displays the settings entered in the **General** tab that were used to perform this frequency analysis. As shown, the **Generalized Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B[25], or develop a value from a regional analysis of nearby gages. In this example a value of -0.3 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.

> The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[26]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[27]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

Also for this example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The **Median** plotting position method was selected, as well as the default **Confidence Limits**.

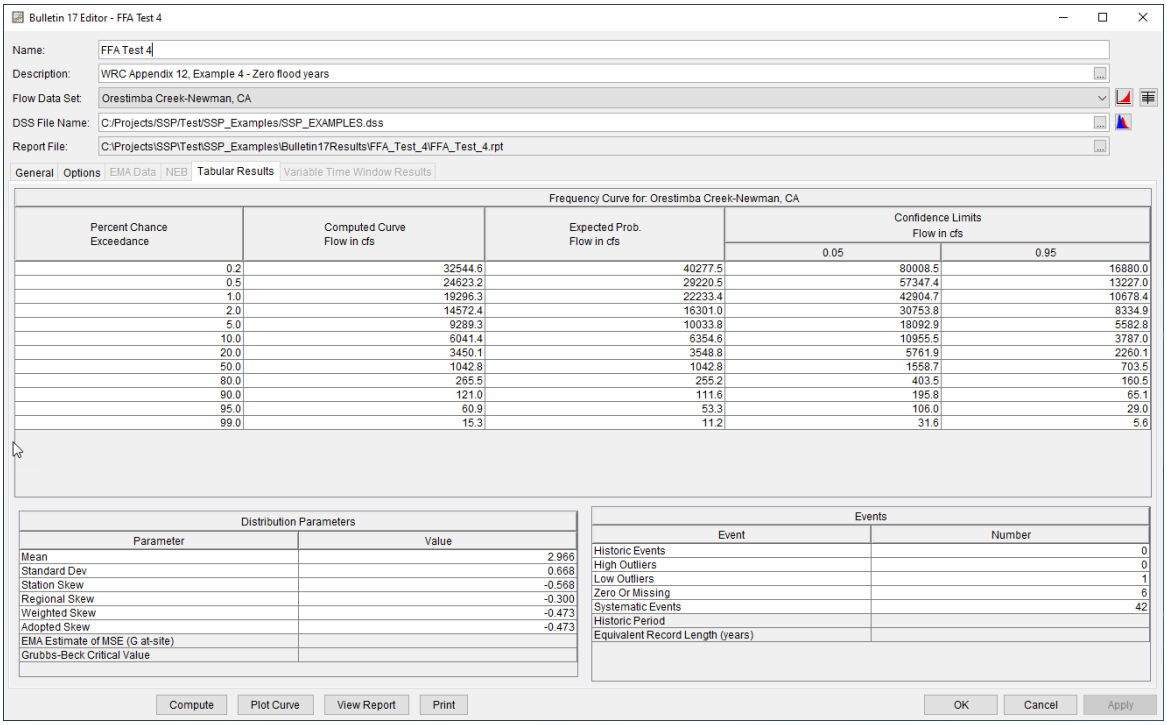
25 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
26 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
27 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

Shown in Figure 4 (see page 39) is the **Bulletin 17 Editor** with the **Options** tab selected. As shown in Figure 4 (see page 39), none of the available options for modifying the frequency curve were selected for this test example. These options include the **Low Outlier Threshold** and **Historic Period Data**. Additionally, the option to override the default **Frequency Ordinates** was not selected.



26 Figure 4. Bulletin 17 Editor with the Options Tab Selected for FFA Test 4

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button (from any tab) to perform the analysis. Once the computations have been completed a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 5 (see page 39).



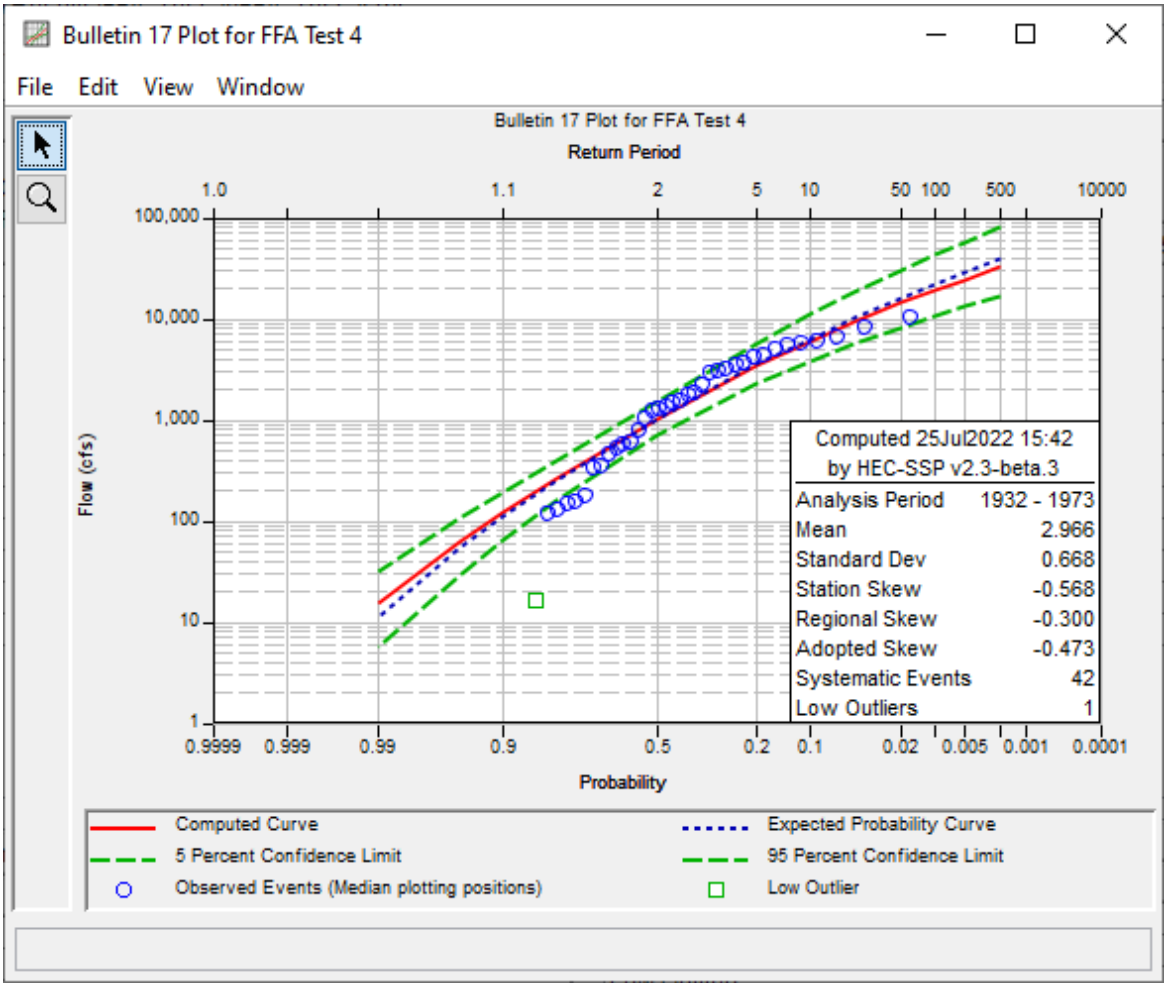
27 Figure 5. Bulletin 17 Editor with the Results Tab Selected for FFA Test 4

As shown in Figure 5 (see page 39), the **Frequency Curve** table contains the following results:

- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

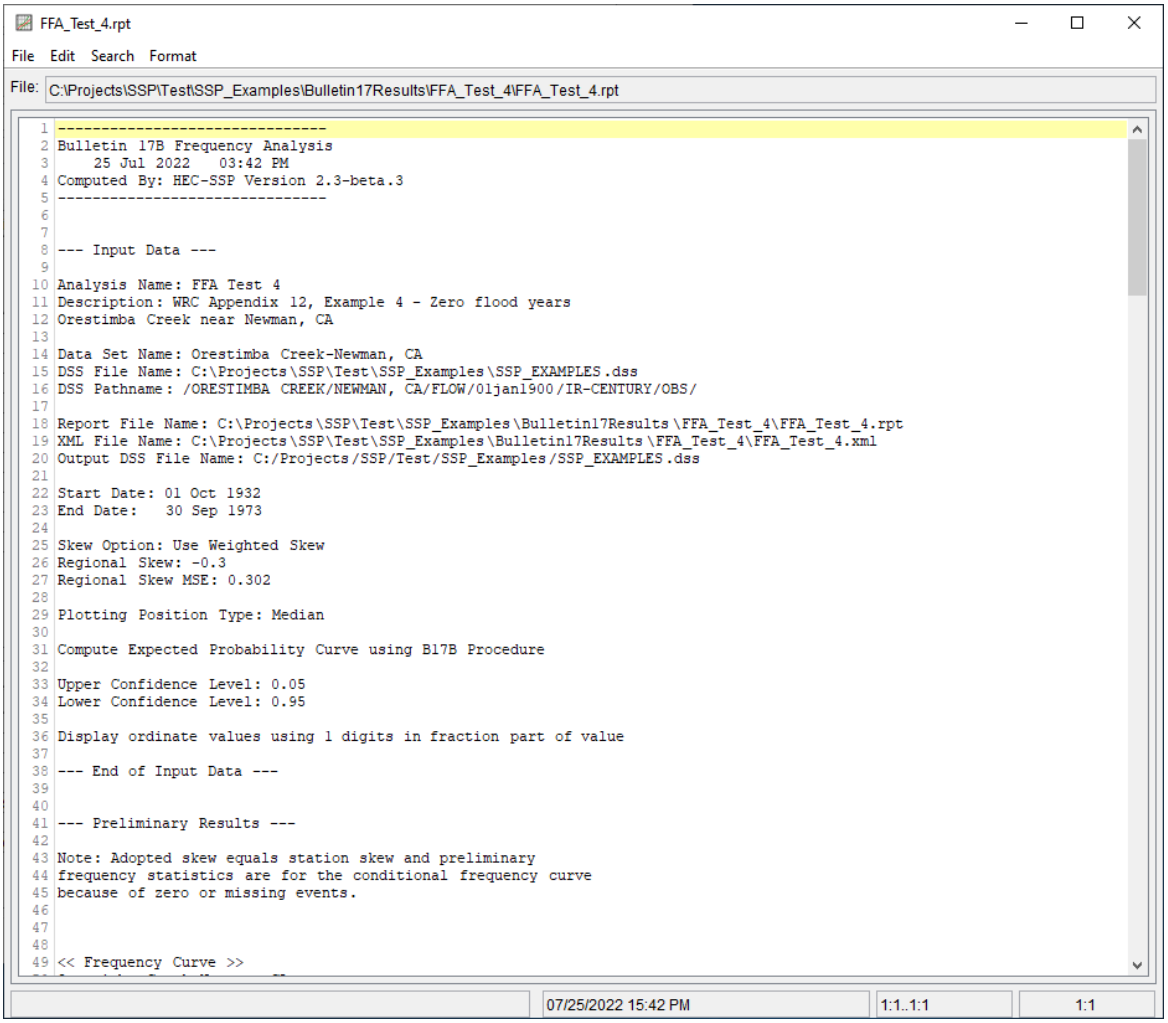
On the bottom left-hand side of the **Tabular Results** tab is the **Distribution Parameters** table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side of the **Tabular Results** tab is the number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered). As noted earlier, there were six zero values in this record, and also a low outlier. A zero value causes difficulty because the first step in fitting a Log Pearson III distribution is computing the base-10 log of each flow value, which is undefined for zero. Bulletin 17B recommends removing the zero values (and the low outlier) from the systematic record to compute a preliminary frequency curve, and then adjusting that curve with the Conditional Probability Adjustment. The final frequency curve and statistics are shown in the table, and the preliminary calculations can be reviewed in the report file.

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6 (see page 0).



28 Figure 6. Plot of FFA Test 4 Results

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the **Bulletin 17 Editor** (Figure 5 (see page 39)). The **View Report** button opens a text viewer window displaying the report file (e.g., ***FFA_Test_4.rpt***). Shown in Figure 7 (see page 0) is the report file for ***FFA Test 4***. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



29 Figure 7. Report File for FFA Test 4

2.5 Example 5. Confidence Limits and Low Threshold Discharge

In the ***SSP_Examples.ssp*** study, the ***FFA Test 5*** Bulletin 17 example analysis illustrates the use of user-entered confidence limits. Probabilities of 0.01 and 0.99 were entered for the computed confidence limit curves. This data set also includes two very low values, the higher of which is just above the default low outlier threshold. Therefore, this example also demonstrates the use of a user-entered low outlier threshold set to be higher than both values.

> ⚠ This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[28]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[29]). Bulletin 17C examples can be found here (see page 57).

The data used for the ***FFA Test 5*** example is from Kaskaskia River in Vandalia, Illinois. The period of record used for this example is from 1908 to 1970. To view the data in HEC-SSP, under the **Data** folder in the **Study Pane**, right-click on the data record labeled "***Kaskaskia River-Vandalia, IL***" and select **Tabulate**. The data will appear as shown in Figure 1 (see page 43).

/KASKASKI...

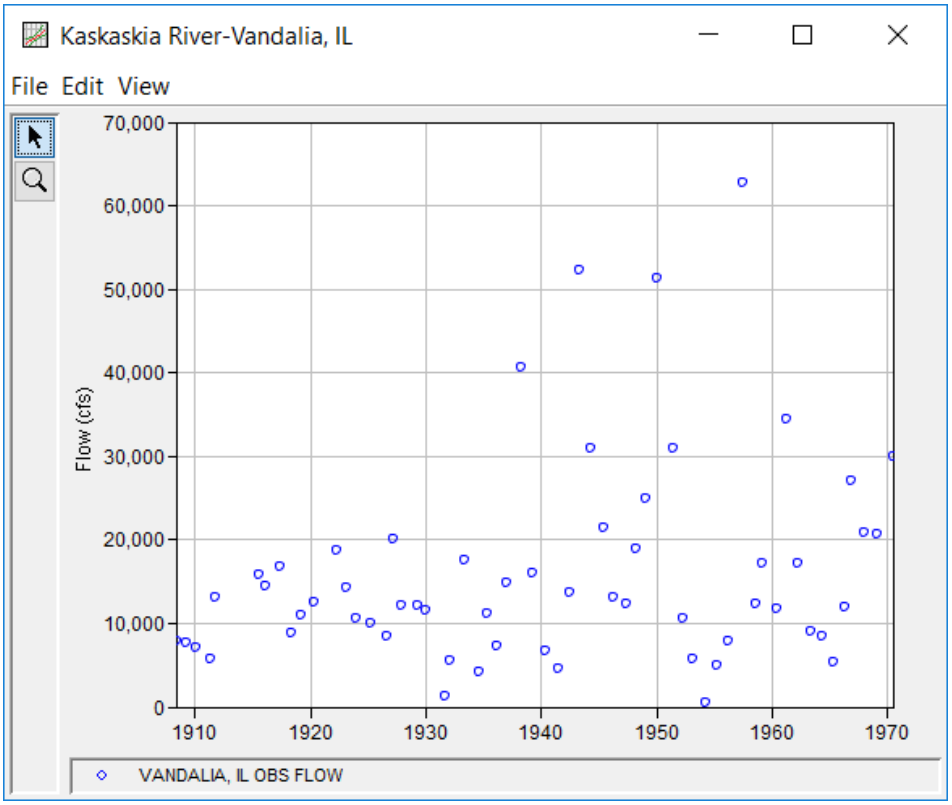
File Edit View

Ordin...	Date	Time	VANDALIA,... FLOW OBS
Units			CFS
Type			INST-VAL
1	06 May 1908	12:00	7,870
2	14 Apr 1909	12:00	7,670
3	01 Mar 1910	12:00	7,020
4	01 May 1911	12:00	5,670
5	04 Oct 1911	12:00	13,000
6	21 Jul 1915	12:00	15,800
7	31 Jan 1916	12:00	14,400
8	05 Jun 1917	12:00	16,800
9	11 May 1918	12:00	8,880
10	19 Mar 1919	12:00	11,000
11	19 May 1920	12:00	12,600
12	18 Apr 1922	12:00	18,800
13	17 Mar 1923	12:00	14,300
14	15 Dec 1923	12:00	10,500
15	16 Mar 1925	12:00	9,980
16	17 Sep 1926	12:00	8,460
17	20 Mar 1927	12:00	20,000
18	01 Dec 1927	12:00	12,200
19	14 May 1929	12:00	12,200
20	14 Jan 1930	12:00	11,500
21	18 Sep 1931	12:00	1,270
22	24 Jan 1932	12:00	5,550
23	15 May 1933	12:00	17,500
24	19 Aug 1934	12:00	4,250

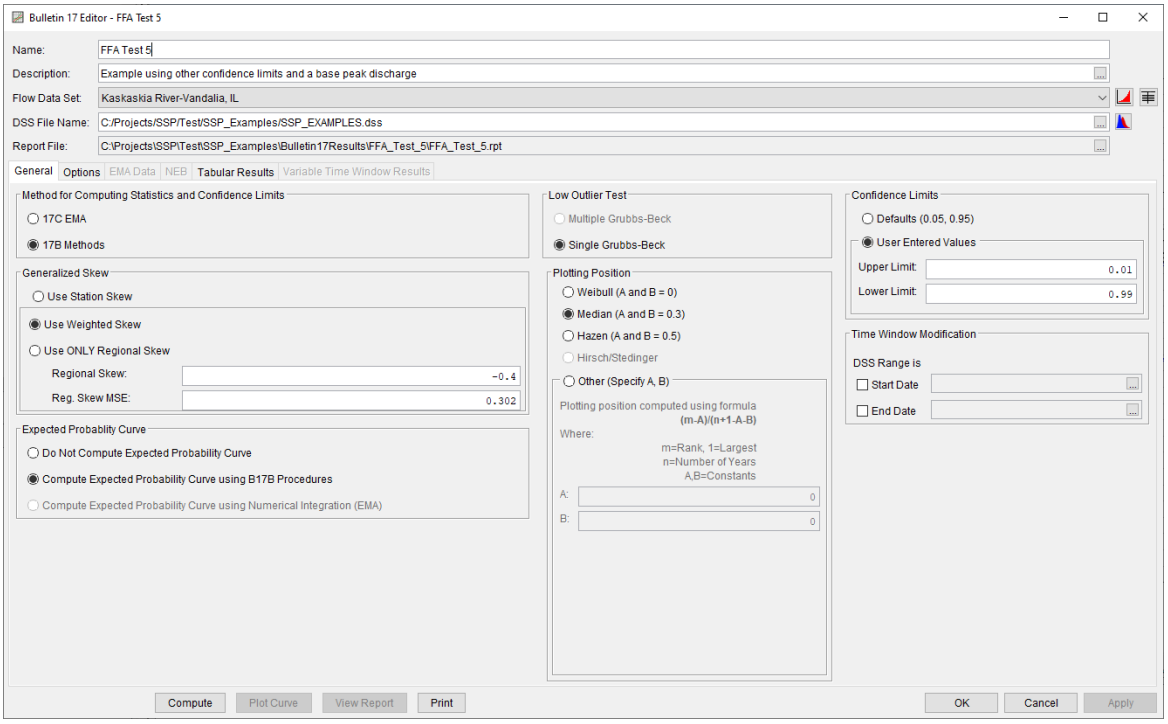
30 Figure 1. Tabulation of the Peak Flow Data for Kaskaskia River

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2 (see page 43).

28 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
29 https://pubs.er.usgs.gov/publication/tm4B5



A Bulletin 17 and General Frequency analysis have been developed for this example; however, this example only displays the results of the Bulletin 17 analysis. To open the **Bulletin 17 Editor** for ***FFA Test 5***, from the **Study Pane** under the **Bulletin 17 Analysis** folder, double-click on the ***FFA Test 5*** analysis. Alternatively, from the **Analysis** menu select **Open** and then select ***FFA Test 5*** from the list of available analyses in the **Open Analysis** dialog box. When ***FFA Test 5*** is opened, the **Bulletin 17 Editor - *FFA Test 5*** will appear as shown in Figure 3 (see page 44).



31 Figure 3. Bulletin 17 Analysis Editor for FFA Test 5

Shown in Figure 3 (see page 44) are the settings entered in the **General** tab that were used to perform this frequency analysis. As shown, the **Generalized Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B[30], or develop a value from a regional analysis of nearby gages. In this example a value of -0.4 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.

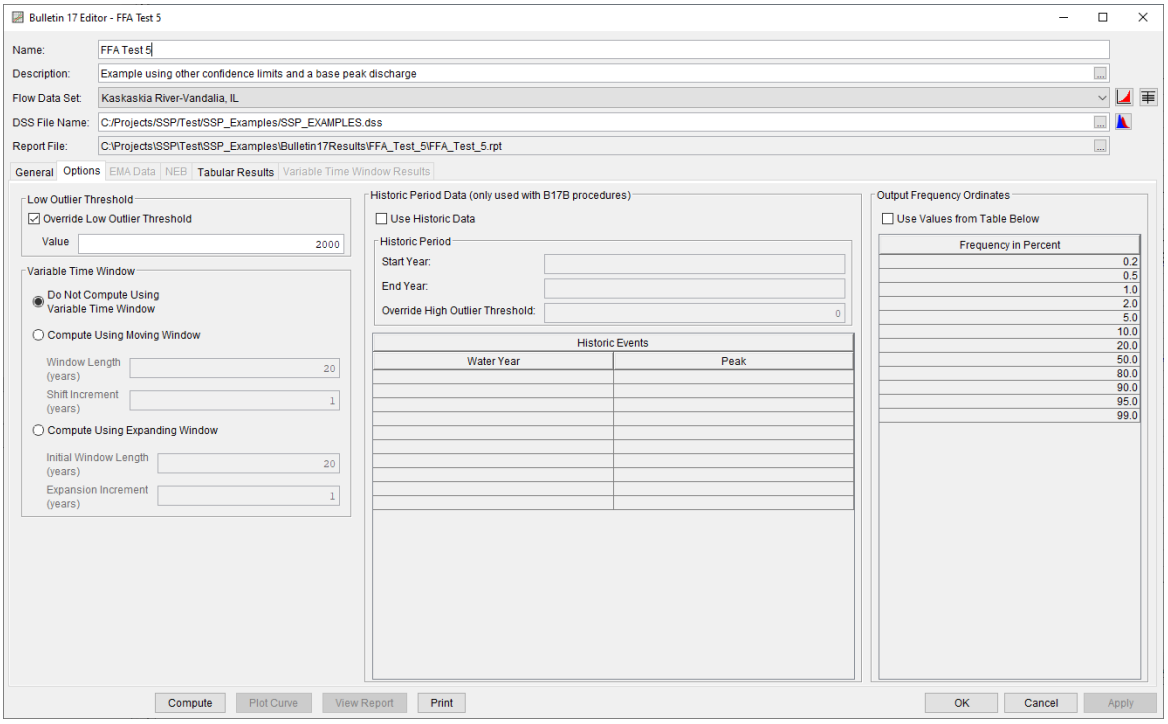
> The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[31]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[32]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

Also for the ***FFA Test 5*** example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The default method of **Median** plotting positions was selected. The default values for **Confidence Limits** were changed to 0.01 and 0.99.

Shown in Figure 4 (see page 46) is the **Bulletin 17 Editor** with the **Options** tab selected. As shown in Figure 4 (see page 46), a **Low Outlier Threshold** of 2000 cfs was entered. In the initial computation with this data (which the reader can reproduce by Computing without the "***Use Low Outlier Threshold***" box checked), the

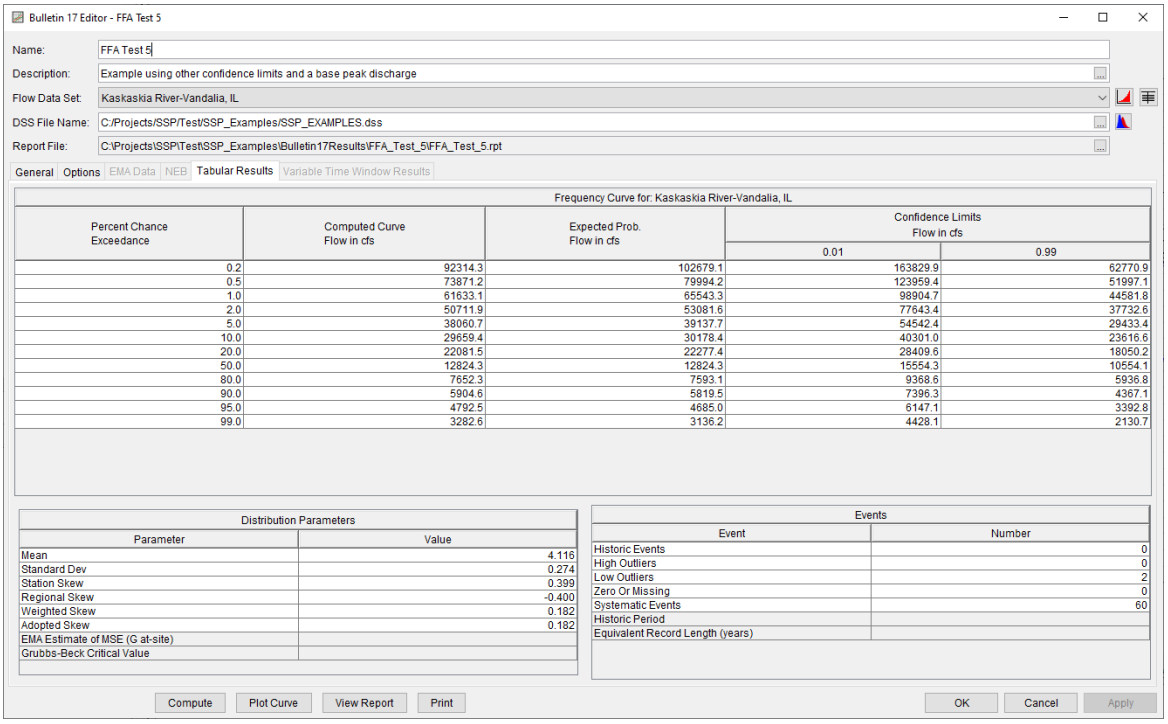
30 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
31 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
32 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

default low outlier threshold was 1,253 cfs, just below the second lowest value of 1,270 cfs. A look at the statistics and computed frequency curve from that run shows that the 1,270 cfs value is well below the computed curve and with a station skew of -0.21 the frequency curve does not fit the upper data well. By choosing to also censor the 1,270 cfs value with a threshold of 2000 cfs, the fit is improved. None of the other available options, such as **Historic Period Data** and the option to override the default **Frequency Ordinates** were selected for this test example.



32 Figure 4. Bulletin 17 Editor with the Options Tab Shown for FFA Test 5

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab from the analysis window. The analysis window should resemble Figure 5 (see page 46).



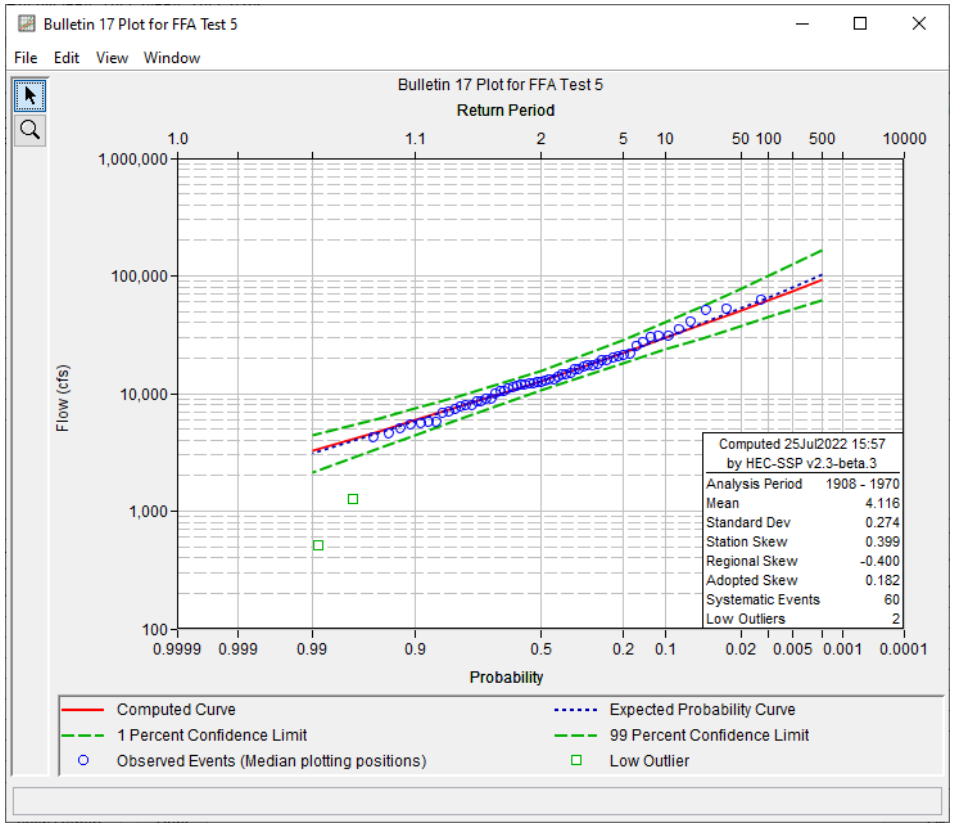
33 Figure 5. Bulletin 17 Editor with the Results Tab Selected for FFA Test 5

As shown in Figure 5 (see page 46), the **Frequency Curve** table contains the following results:

- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

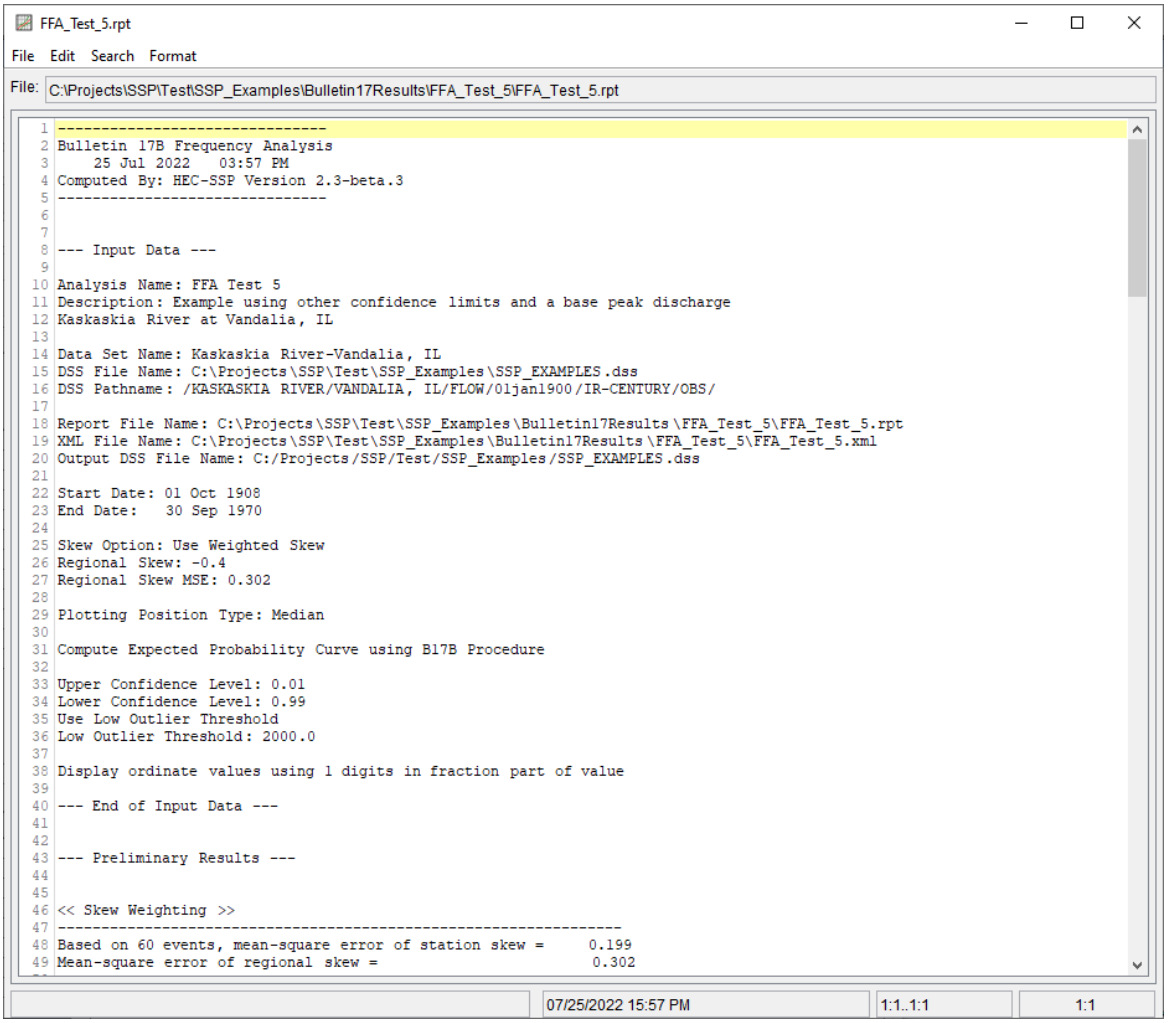
On the bottom left-hand side of the **Tabular Results** tab is the **Distribution Parameters** table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side of the **Tabular Results** tab is the number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (only if historic data was entered). With the user-defined low-outlier threshold of 2000 cfs, there are two low-outliers detected. The analysis report shows the program omitted these values and used the Conditional Probability Adjustment to recompute the resulting frequency curve and statistics. The report file (described below) includes the preliminary computation before removal of outliers and the default and user-defined outlier thresholds, as well as the final frequency curve and statistics.

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6 (see page 47).



34 Figure 6. Plot of the Frequency Curve Results for FFA Test 5

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the **Bulletin 17 Editor** (Figure 5 (see page 46)). The **View Report** button opens a text viewer window displaying the report file (e.g., ***FFA_Test_5.rpt***). Shown in Figure 7 (see page 48) is the report file for ***FFA Test 5***. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



35 Figure 7. Report File for FFA Test 5

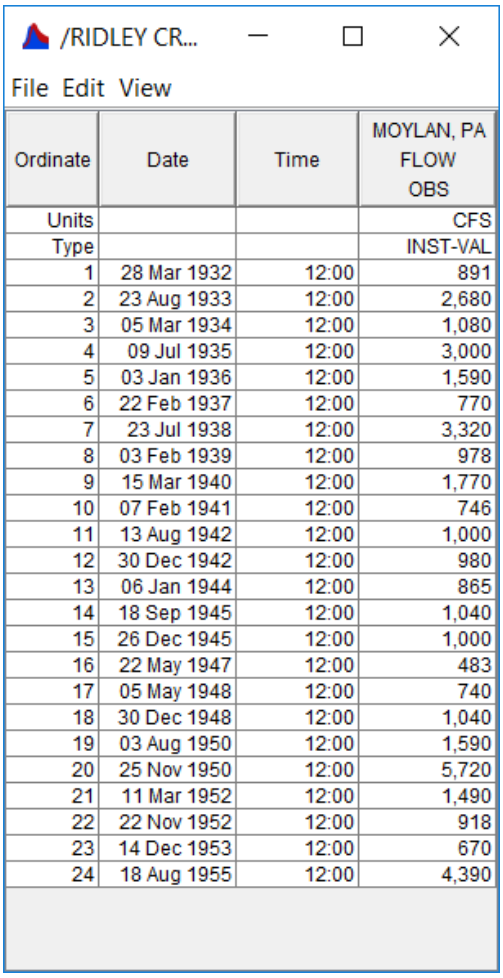
2.6 Example 6. Use of Historic Data

In the ***SSP_Examples.ssp*** study, the ***FFA Test 6*** Bulletin 17 example analysis demonstrates how to use historic information to improve a flow frequency analysis. A historic flood peak of 15,000 cfs which occurred in 1843 is included in the analysis. This value is the highest known value up to the present time (1974 for this example), even though the systematic record stopped in 1955.

> ⚠ This example uses Bulletin 17B procedures (Interagency Advisory Committee on Water Data, 1982[33]). Current Federal flood frequency guidance directs analysts to use Bulletin 17C procedures (England, et al., 2019[34]). Bulletin 17C examples can be found here (see page 57).

33 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
34 https://pubs.er.usgs.gov/publication/tm4B5

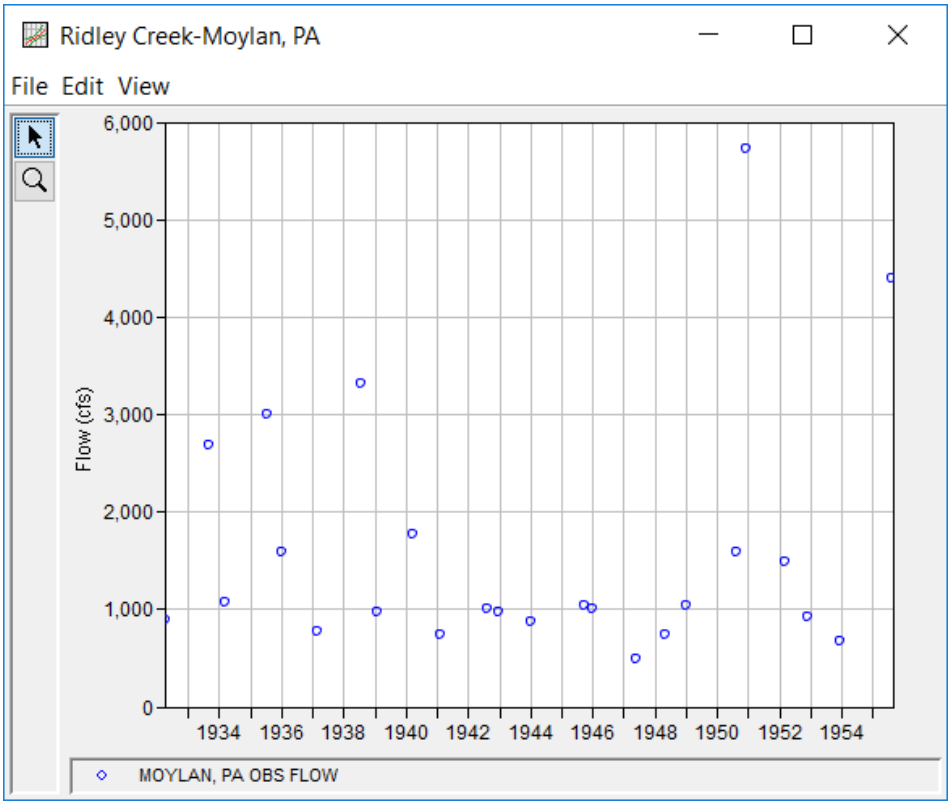
The data used for the ***FFA Test 6*** example is from Ridley Creek in Moylan, Pennsylvania. The period of record used for this example is from 1932 to 1955. To view the data in HEC-SSP, under the **Data** folder in the **Study Pane**, right-click on the data record labeled "**Ridley Creek-Moylan, PA**" and select **Tabulate**. The data will appear as shown in Figure 1 (see page 50).



Ordinate	Date	Time	MOYLAN, PA FLOW OBS
Units			CFS
Type			INST-VAL
1	28 Mar 1932	12:00	891
2	23 Aug 1933	12:00	2,680
3	05 Mar 1934	12:00	1,080
4	09 Jul 1935	12:00	3,000
5	03 Jan 1936	12:00	1,590
6	22 Feb 1937	12:00	770
7	23 Jul 1938	12:00	3,320
8	03 Feb 1939	12:00	978
9	15 Mar 1940	12:00	1,770
10	07 Feb 1941	12:00	746
11	13 Aug 1942	12:00	1,000
12	30 Dec 1942	12:00	980
13	06 Jan 1944	12:00	865
14	18 Sep 1945	12:00	1,040
15	26 Dec 1945	12:00	1,000
16	22 May 1947	12:00	483
17	05 May 1948	12:00	740
18	30 Dec 1948	12:00	1,040
19	03 Aug 1950	12:00	1,590
20	25 Nov 1950	12:00	5,720
21	11 Mar 1952	12:00	1,490
22	22 Nov 1952	12:00	918
23	14 Dec 1953	12:00	670
24	18 Aug 1955	12:00	4,390

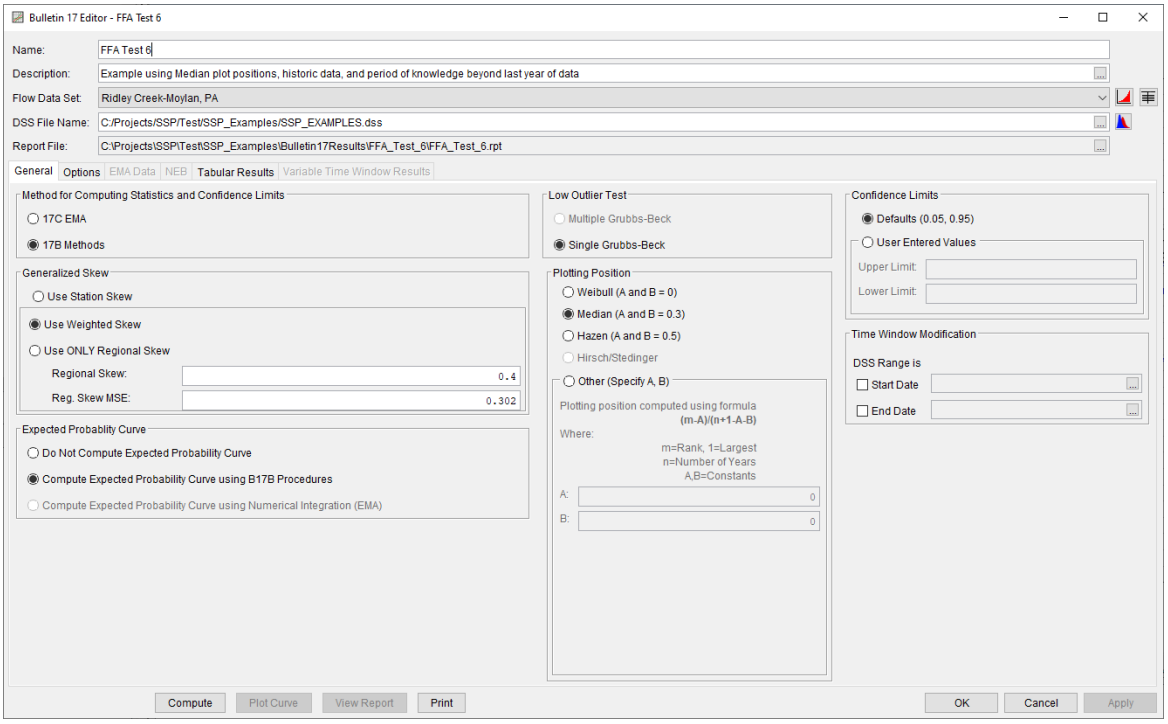
36 Figure 1. Tabulation of the Peak Flow Data for Ridley Creek

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2 (see page 0).



37 Figure 2. Plot of the Ridley Creek Data

A Bulletin 17 and General Frequency analysis have been developed for this example; however, this example only displays the results of the Bulletin 17 analysis. To open the **Bulletin 17 Editor** for ***FFA Test 6***, from the **Study Pane** under the **Bulletin 17 Analysis** folder, double-click on the ***FFA Test 6*** analysis. Alternatively, from the **Analysis** menu select **Open** and then select ***FFA Test 6*** from the list of available analyses in the **Open Analysis** dialog box. When ***FFA Test 6*** is opened, the **Bulletin 17 Editor - *FFA Test 6*** will appear as shown in Figure 3 (see page 0).



38 Figure 3. Bulletin 17 Analysis Editor for FFA Test 6

Shown in Figure 3 (see page 51) are the settings entered in the **General** tab that were used to perform this frequency analysis. As shown, the **Generalized Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. This selection requires the user to either look up a value from the generalized skew map of the United States, which is provided with Bulletin 17B[35], or develop a value from a regional analysis of nearby gages. In this example a value of 0.4 was taken from the generalized skew map of the U.S. from Bulletin 17B. Bulletin 17B suggests using a Regional Skew MSE of 0.302 whenever regional skew values are taken from the map.

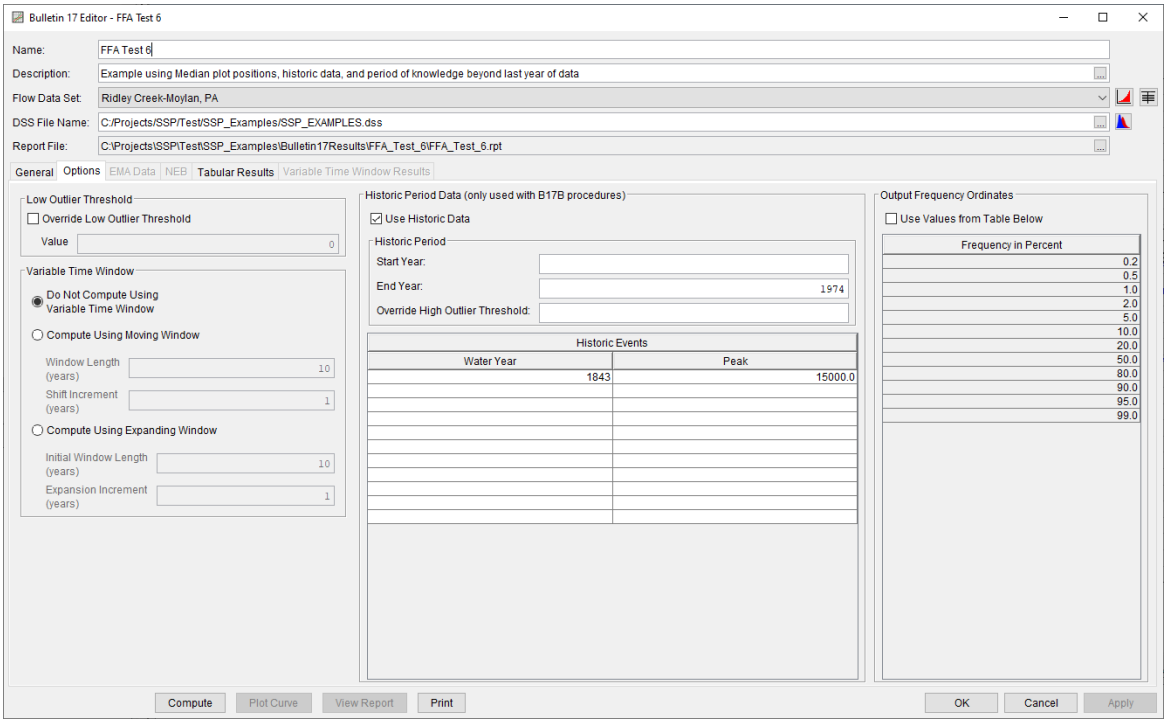
> ⚠ The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[36]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[37]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

Also for this example, the **Expected Probability Curve** option was selected to be computed in addition to the Log Pearson III computed curve. The **Median** plotting position method was selected, as well as the default **Confidence Limits**.

Shown in Figure 4 (see page 53) is the **Bulletin 17 Editor** with the **Options** tab selected. As shown in Figure 4 (see page 0), the **Historic Period Data** option has been selected to reflect a historical flood event of 15,000 cfs in 1843 and an analysis period from 1843 to 1974. Historic data is used to account for historic flood

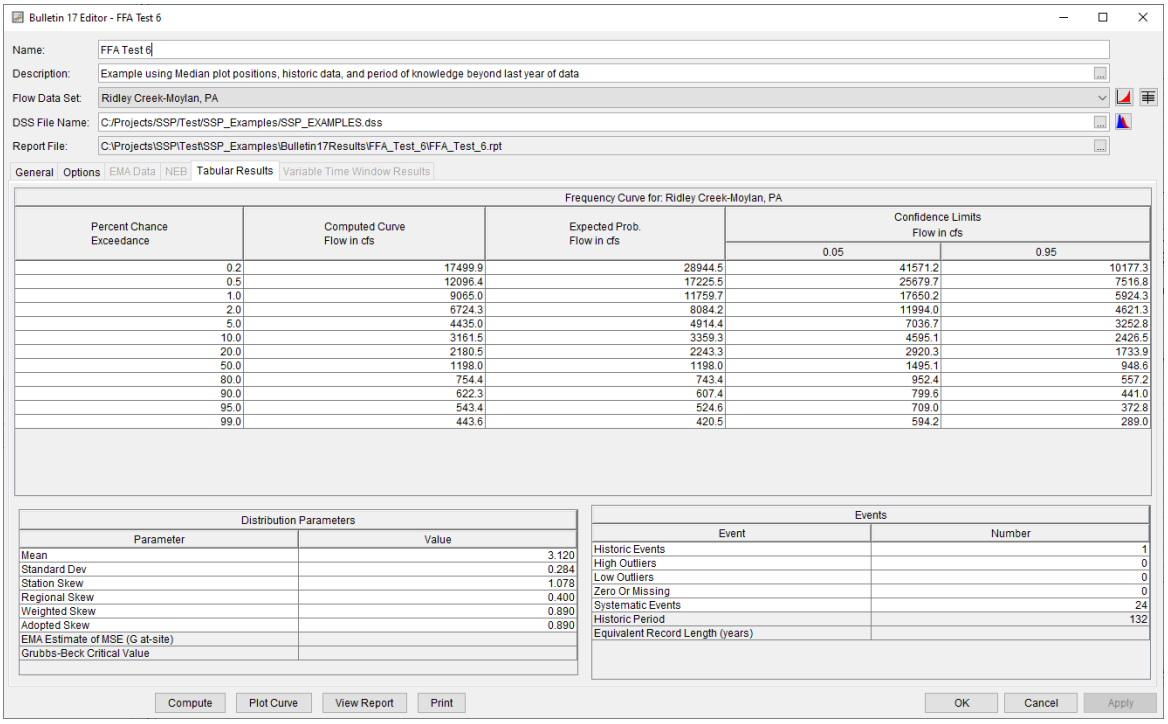
35 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf
36 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
37 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html

events large enough to be relevant to the analysis and not contained in the systematic data record. The additional information provided by historic data can improve the flood frequency analysis, especially when the data collection period for a given area is relatively short. Information for a **Historic Flood Peak** has been entered to account for a peak flow of 15,000 cfs in the 1843 water year. The Historic Period **Start Year** has been left blank. By default this value will be the earliest year found in the historic flood peak data or the systematic record. Therefore for this example, 1843 will automatically be used for the Start Year of the Historic Period. An **End Year** of 1974 has been entered. The systematic record for the gage ended in 1955, however when this analysis was performed in 1974, no other flood peaks of consequence had been observed between 1955 and 1974. Therefore, 1974 is set as the End Year for the historic period analysis. Other features on the **Options** tab include the **Low Outlier Threshold** and the option to override the default **Frequency Ordinates**. Neither option is selected in this example.



39 Figure 4. Bulletin 17 Analysis Editor with Options Tab Shown for FFA Test 6

Once all of the General and Optional settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab from the analysis window. The analysis window should resemble Figure 5 (see page 0).



40 Figure 5. Bulletin 17 Editor with the Results Tab Selected for FFA Test 6

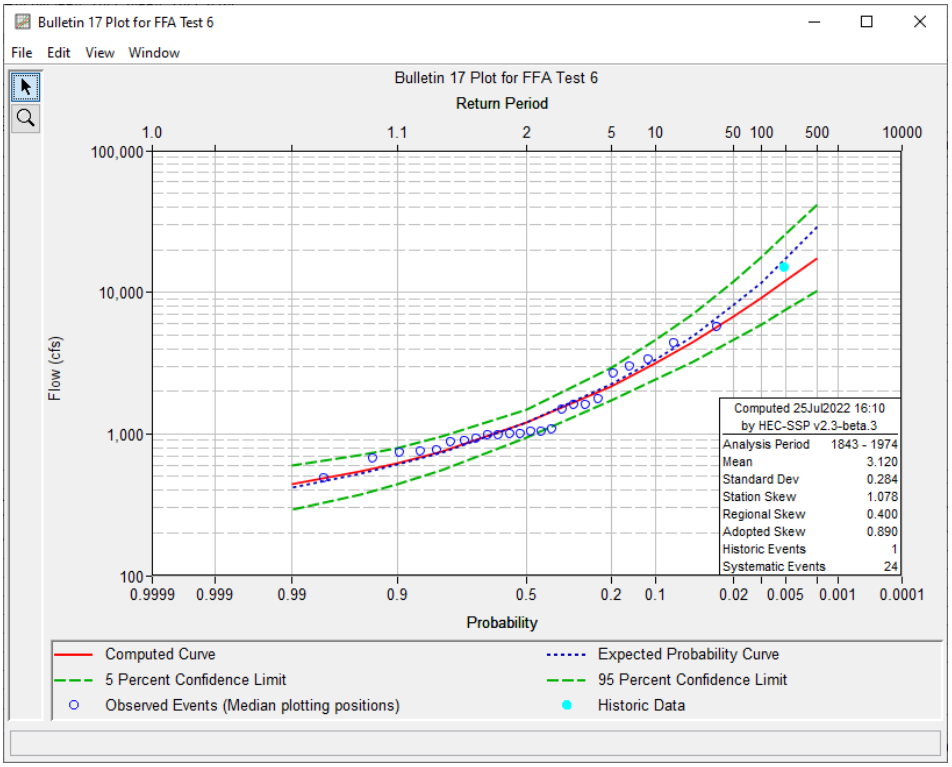
As shown in Figure 5 (see page 0), the **Frequency Curve** table contains the following results:

- Percent Chance Exceedance
- Computed Curve
- Expected Probability Curve
- Confidence Limits

On the bottom left-hand side of the **Tabular Results** tab is the **Distribution Parameters** table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side side of the **Tabular Results** tab is the number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered). The ***FFA Test 6*** example reports one historical flood event, and a historical period of 132 years, between 1843 and 1974. The reported statistics reflect the use of the historical data adjustment outlined in Bulletin 17B[38] Appendix 6. The report file (described below) shows the initial computation of the statistics and frequency curve before the historical data was used, and the resulting statistics and frequency curve after the historical data is taken into account.

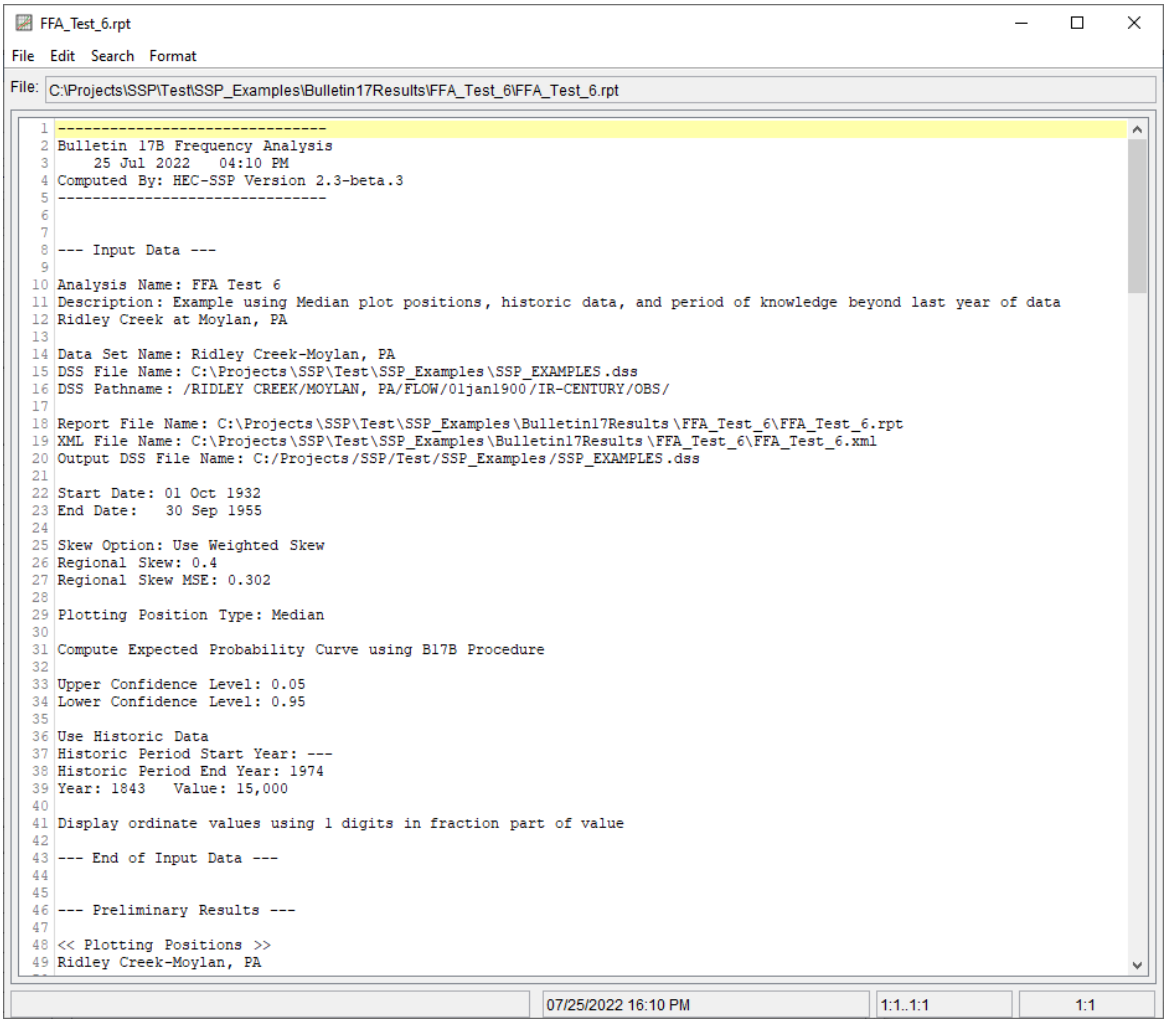
In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6 (see page 0).

38 https://water.usgs.gov/osw/bulletin17b/dl_flow.pdf



41 Figure 6. Plot of the Frequency Curve Results for FFA Test 6

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the **Bulletin 17 Editor** (Figure 5 (see page 53)). When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 7 (see page 0) is the report file for ***FFA Test 6***. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



42 Figure 7. Report File for FFA Test 6

3 Bulletin 17C Examples

3.1 Bulletin 17C | Expected Moments Algorithm Examples

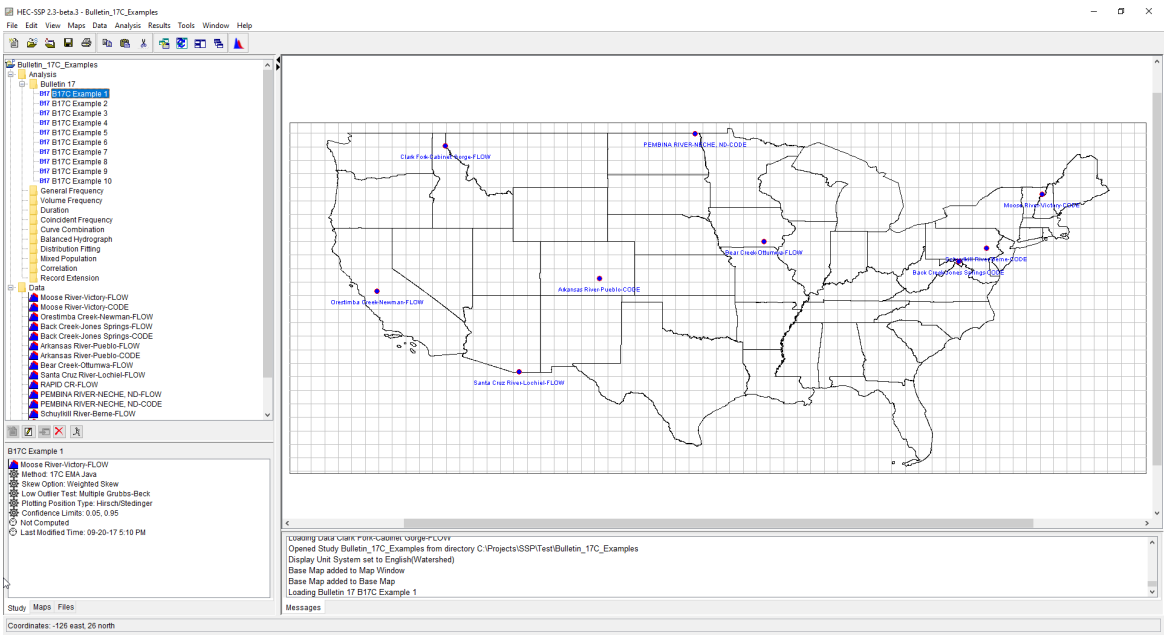
These examples use the Expected Moments Algorithm (EMA) to fit the Log Pearson Type III distribution to annual maximum flow data sets. The multiple inputs and outputs are provided to illustrate the use of selected options and to assist in verifying the correct execution of the program. The first six examples use the same data sets that are provided with the Bulletin 17C document (England, et al., 2018). As shown in the example data sets, the HEC-SSP software produces the same results as the USGS PeakFQ Software (Veilleux, Cohn, Flynn, Mason, & Hummel, 2013) for these six data sets. The last four examples make use of additional inputs and settings that are not demonstrated within the Bulletin 17C document.

All of these test examples are provided with the software as a single HEC-SSP study labeled "Bulletin_17C_Examples." You can install this study on your computer by selecting the **Help** | **Install Example Data** menu option. After opening this study for the first time on your computer, you must compute each example before viewing tabular and graphical results.

A brief description of each example is provided. In most cases, the computed at-site station skew is used in lieu of a weighted skew to more clearly illustrate the effects of EMA and the other procedures outlined within Bulletin 17C. The example problems shown in this section are entitled:

1. Systematic Record – Moose River at Victory, VT
2. Analysis with Low Outliers – Orestimba Creek near Newman, CA
3. Broken Record – Back Creek near Jones Springs, WV
4. Historical and Data – Arkansas River at Pueblo, CO
5. Crest Stage Gage Censored Data – Bear Creek at Ottumwa, IA
6. Historic Data and Low Outliers – Santa Cruz River at Lochiel, AZ
7. User Overrides (Low Outliers and Confidence Limits) – Rapid Creek above Canyon Lake near Rapid City, SD
8. [inf – inf] Perception Threshold – Pembina River at Neche, ND
9. [0 – value] Perception Threshold – Clark Fork River below Cabinet Gorge Dam, ID
10. Systematic and Historical Record with Regional Skew – Schuylkill River at Berne, PA

When the "Bulletin_17C_Examples" study file is open, the screen will appear as shown in Figure 1. The following sections document each of the example data sets.



3.2 Example 1. Systematic Record – Moose River at Victory, VT

Example 1 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of systematic flood peaks. For this example, USGS gage 01134500 Moose River at Victory, Vermont is used. The Moose River is located in the northeastern part of the state and flows mostly from north to south through very hilly terrain. The Moose River basin is approximately 75 square miles of nearly all forest (England, et al., 2018). Historically, it was an important logging area and some logging still continues today. Attempts at farming in the basin have generally failed due to the presence of shallow rocky soil. There are a small number of villages in the basin, but overall it is sparsely populated with only a few miles of paved roadway. There is also a large bog approximately a third of a mile upstream from the gage. The bog is part of the 5,000 acre Victory Basin Wildlife management area. While there is no streamflow regulation in the basin, the bog attenuates peaks in the basin. The Moose River at Victory, VT stream gage has an annual peak record consisting of 68 peaks beginning in 1947 and ending in 2014, as shown in Figure 1 (see page 58). The annual peak flow record is tabulated within Table 1.

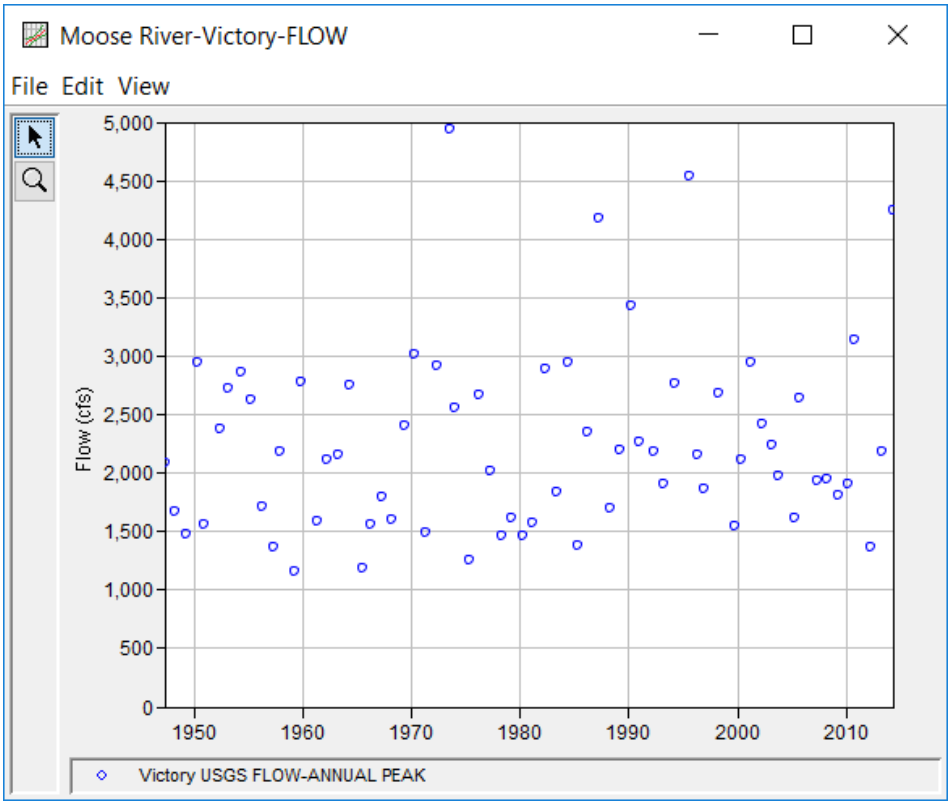


Table 1. Moose River at Victory, VT Annual Peak Flow Record.

Date	Flow (cfs)
13 Apr 1947	2080
28 Mar 1948	1670
28 Mar 1949	1480
21 Apr 1950	2940
05 Dec 1950	1560
02 Jun 1952	2380
27 Mar 1953	2720
23 Apr 1954	2860

Date	Flow (cfs)
15 Apr 1955	2620
30 Apr 1956	1710
22 Apr 1957	1370
21 Dec 1957	2180
04 Apr 1959	1160
29 Nov 1959	2780
24 Apr 1961	1580
08 Apr 1962	2110
22 Apr 1963	2160
15 Apr 1964	2750
14 Jun 1965	1190
26 Mar 1966	1560
03 Apr 1967	1800
24 Mar 1968	1600
29 Apr 1969	2400
25 Apr 1970	3010
04 May 1971	1490
05 May 1972	2920

Date	Flow (cfs)
01 Jul 1973	4940
22 Dec 1973	2550
20 Apr 1975	1250
02 Apr 1976	2670
31 Mar 1977	2020
10 May 1978	1460
26 Mar 1979	1620
10 Apr 1980	1460
21 Feb 1981	1570
18 Apr 1982	2890
04 May 1983	1840
31 May 1984	2950
17 Apr 1985	1380
31 Mar 1986	2350
31 Mar 1987	4180
06 Apr 1988	1700
06 Apr 1989	2200
18 Mar 1990	3430

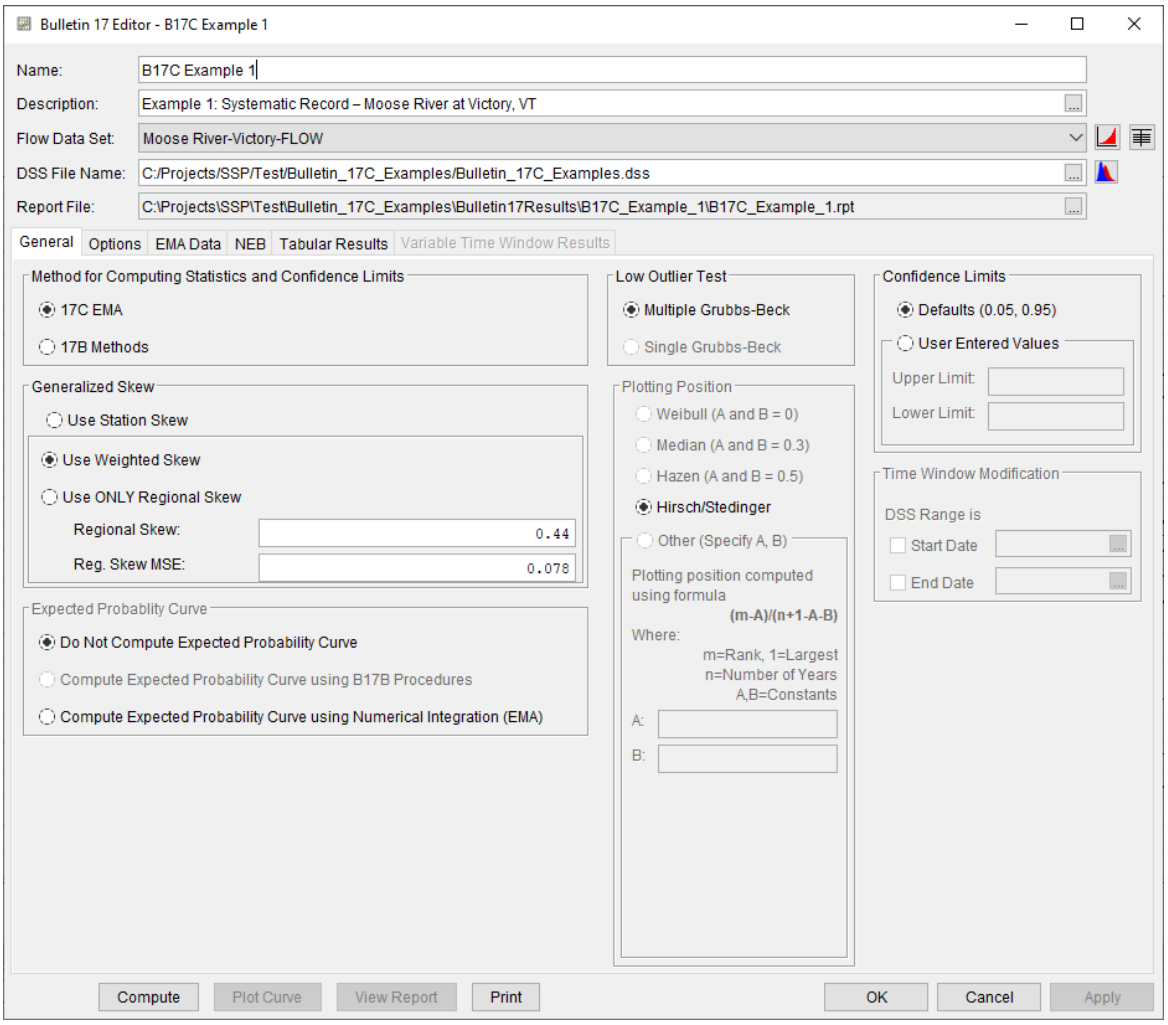
Date	Flow (cfs)
24 Dec 1990	2270
23 Apr 1992	2180
17 Apr 1993	1900
17 Apr 1994	2760
06 Aug 1995	4536
24 Apr 1996	2160
02 Dec 1996	1860
31 Mar 1998	2680
18 Sep 1999	1540
11 May 2000	2110
25 Apr 2001	2950
14 Apr 2002	2410
30 Mar 2003	2230
28 Oct 2003	1980
04 Apr 2005	1610
17 Oct 2005	2640
24 Apr 2007	1930
20 Apr 2008	1940

Date	Flow (cfs)
04 Apr 2009	1810
24 Mar 2010	1900
01 Oct 2010	3140
20 Mar 2012	1370
20 Apr 2013	2180
16 Apr 2014	4250

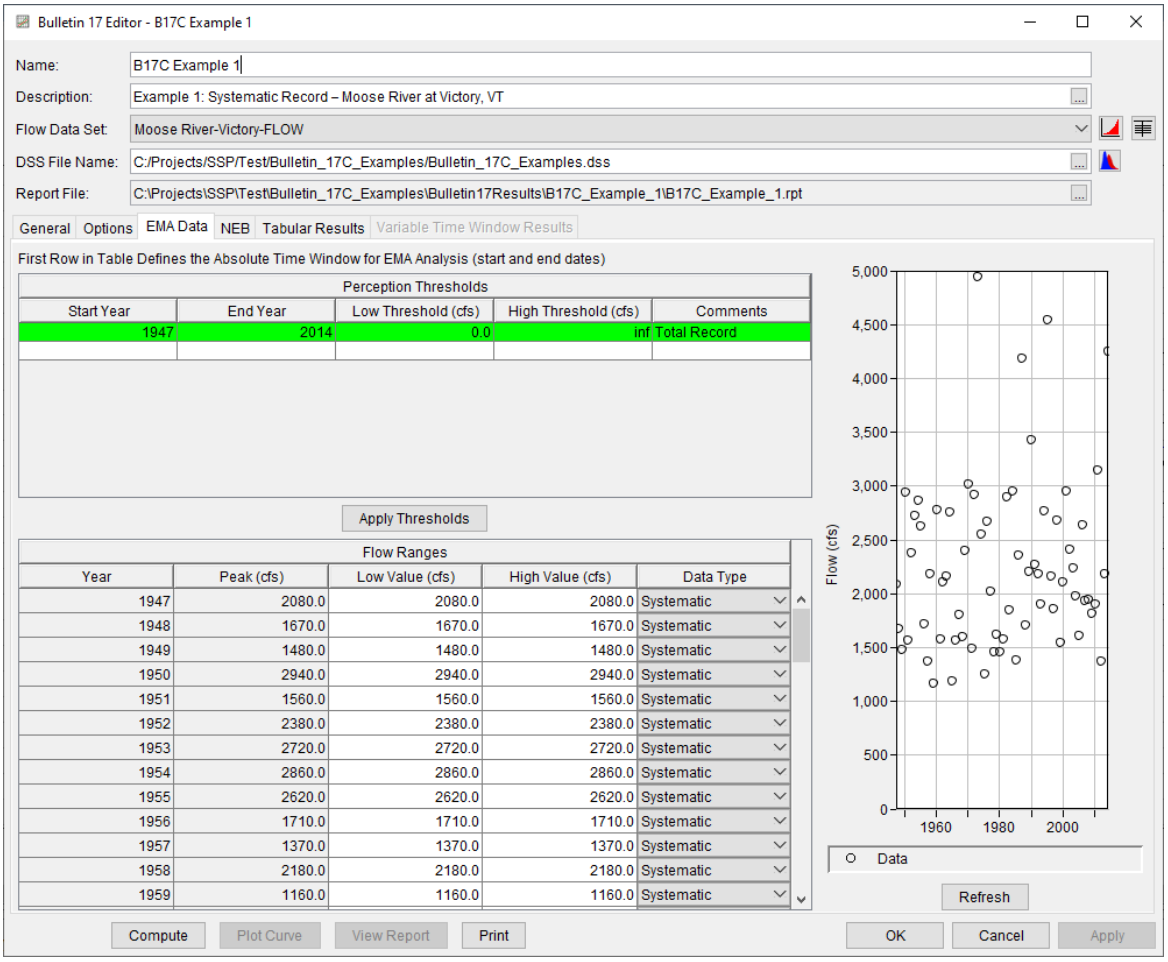
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 1**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 1**" from the list of available analyses. When "B17C Example 1" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 64). As shown, the **Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional Skew MSE. In this example, a regional skew coefficient of 0.44 was used along with a Regional Skew MSE of 0.078.

> The recommended procedure for estimating regional skew in Bulletin 17C is the Bayesian generalized least squares (B-GLS) method. Regional skew studies are available for many states t[39]hrough the Advisory Committee on Water Information, Subcommittee on Hydrology, Hydrologic Frequency Analysis Working Group website[40]. Regional skew values presented in these reports supersede the values from the Bulletin 17B generalized skew map.

39 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html
40 https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html



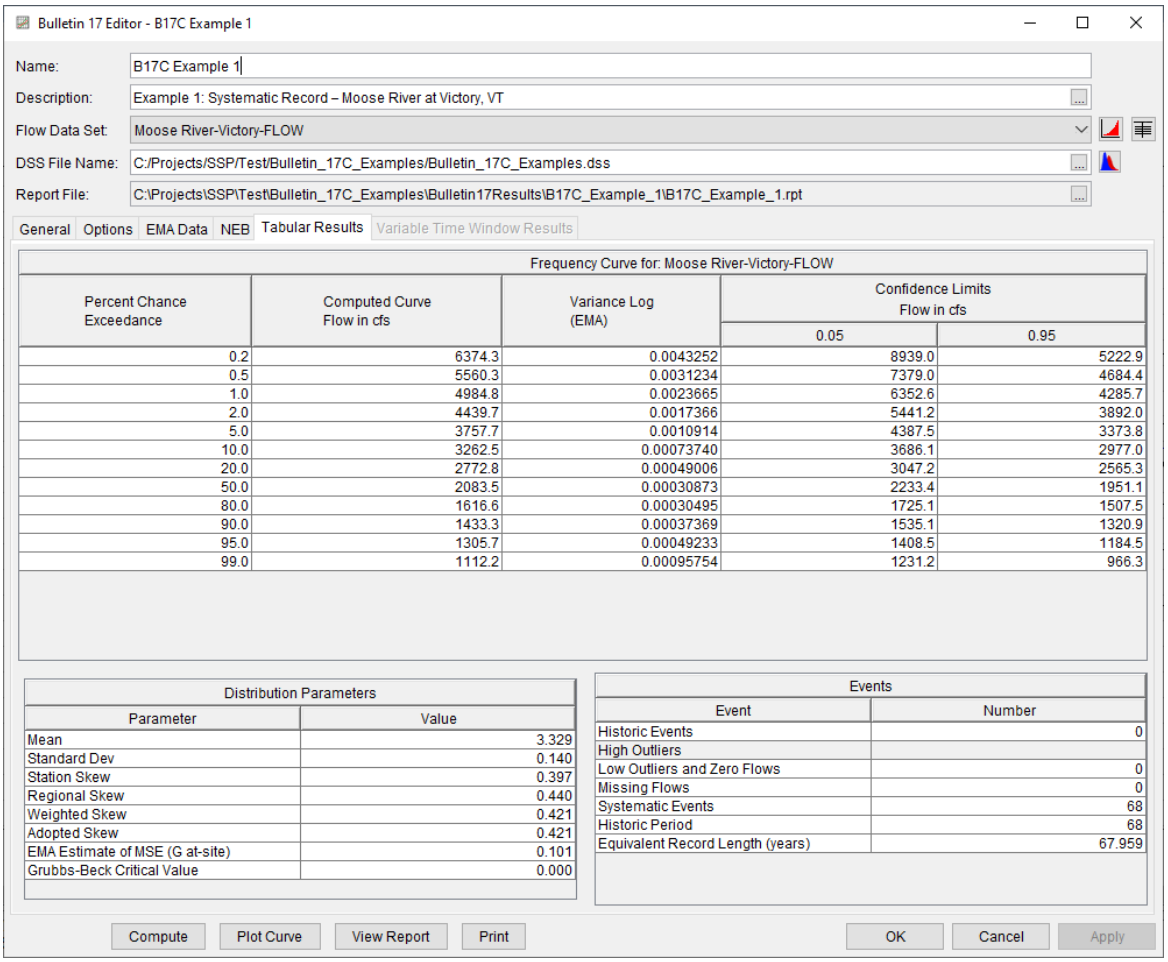
No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 63). Since this example uses an annual maximum series consisting entirely of systematic data with a complete record, a single zero – inf perception threshold is adequate. No modifications to the default flow ranges and data types are necessary.



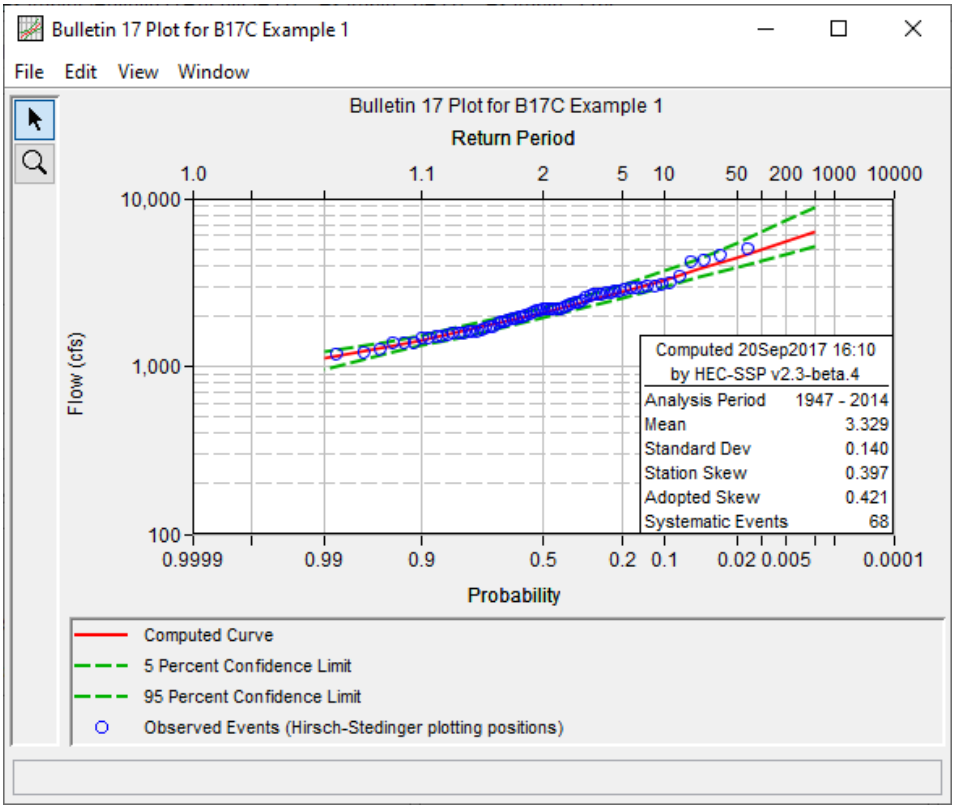
Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 66). As shown in Figure 4 (see page 66), the Frequency Curve table contains the following results:

- Percent Chance Exceedance
- Computed Curve (Log Pearson Type III results)
- Confidence Limits (5% and 95% chance exceedance)

On the bottom left side of the results tab is a table of Distribution Parameters for the observed station data (mean, standard deviation, and station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Additionally, the computed EMA Estimate of MSE (G at-site) and Grubbs-Beck Critical Value are shown within this table. On the bottom right side of the results tab is an Events table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers and zero flows found, number of missing flows, number of systematic events, the historic period in years, and the Equivalent Record Length in year.

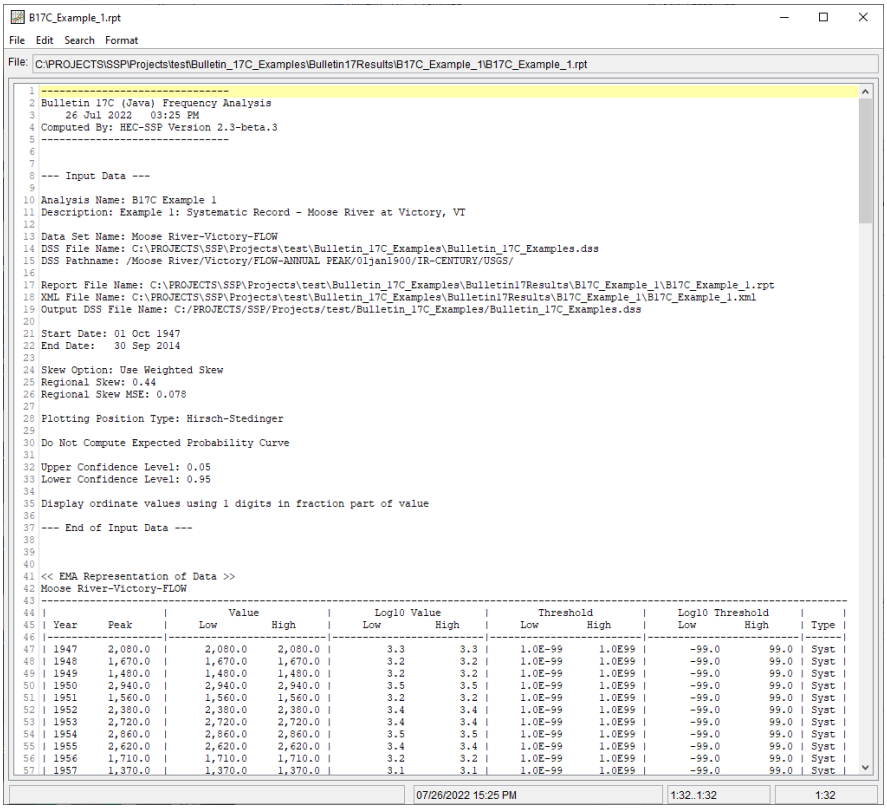


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA and Bulletin 17C procedures to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed Hirsch/Stedinger plotting positions are shown in Figure 5 (see page 66).



Because the annual peak flow record contains only systematic peaks with no historic information, no censored peaks, and no low outliers identified using the Multiple Grubbs-Beck Test, the fitted peak flow frequency curve using EMA and Bulletin 17C procedures is the same as that obtained using Bulletin 17B procedures. However, due to the appropriate consideration of the uncertainty in the skew coefficient within the Bulletin 17C procedures, the 5% and 95% confidence limits are different when compared against results obtained using Bulletin 17B procedures.

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected, a text viewer will open the file and display it on the screen. Shown in Figure 6 (see page 67) is the report file. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis. The user should review the report file to understand how the Bulletin 17C procedures were applied.



43 Figure 6. Report File for B17C Example 1.

3.3 Example 2. Analysis with Low Outliers – Orestimba Creek near Newman, CA

Example 2 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of systematic flood peaks when low outliers (a.k.a. Potentially Influential Low Flows, PILFs) are present. For this example, USGS gage 11274500 Orestimba Creek near Newman, CA is used. Orestimba Creek is a tributary to the San Joaquin River, whose 134 sq. mi. drainage area lies on the eastern slope of the Diablo Range section of the Coast Range Mountains of California. The drainage basin has an average basin elevation of approximately 1,550 feet with peak flows usually occurring in late winter. Orestimba Creek is one of the few tributaries in the area to maintain a definite stream channel from the foothills to the San Joaquin River (England, et al., 2018).

The Orestimba Creek near Newman, CA stream gage has an annual peak record consisting of 82 peaks beginning in 1932 and ending in water year 2013. Of the 82 annual peaks, there are 12 years for which the annual peak is 0 cfs, meaning the stream was dry for the entire year. The annual maximum series is plotted in Figure 1 (see page 68) and tabulated in Table 1.

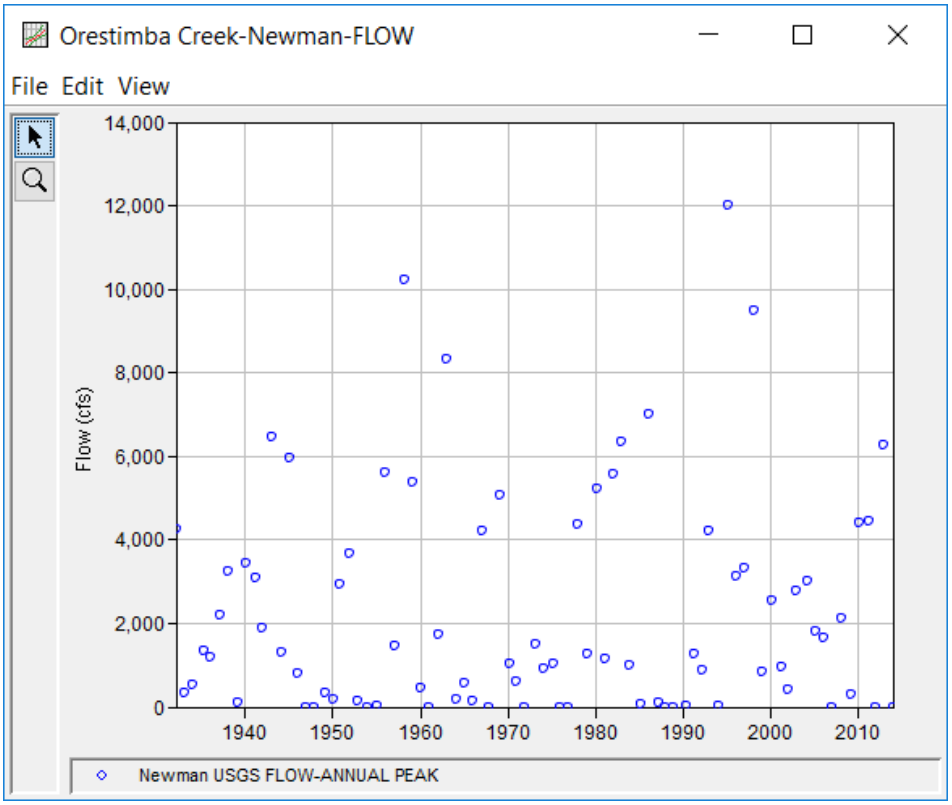


Table 1. Orestimba Creek near Newman, CA Annual Peak Flow Record.

Date	Flow (cfs)
08 Feb 1932	4260
29 Jan 1933	345
01 Jan 1934	516
08 Apr 1935	1320
13 Feb 1936	1200
13 Feb 1937	2180
11 Feb 1938	3230
09 Mar 1939	115

Date	Flow (cfs)
27 Feb 1940	3440
04 Apr 1941	3070
24 Jan 1942	1880
21 Jan 1943	6450
29 Feb 1944	1290
02 Feb 1945	5970
25 Dec 1945	782
30 Nov 1946	0
30 Nov 1947	0
12 Mar 1949	335
05 Feb 1950	175
03 Dec 1950	2920
12 Jan 1952	3660
07 Dec 1952	147
30 Nov 1953	0
19 Jan 1955	16
23 Dec 1955	5620
24 Feb 1957	1440

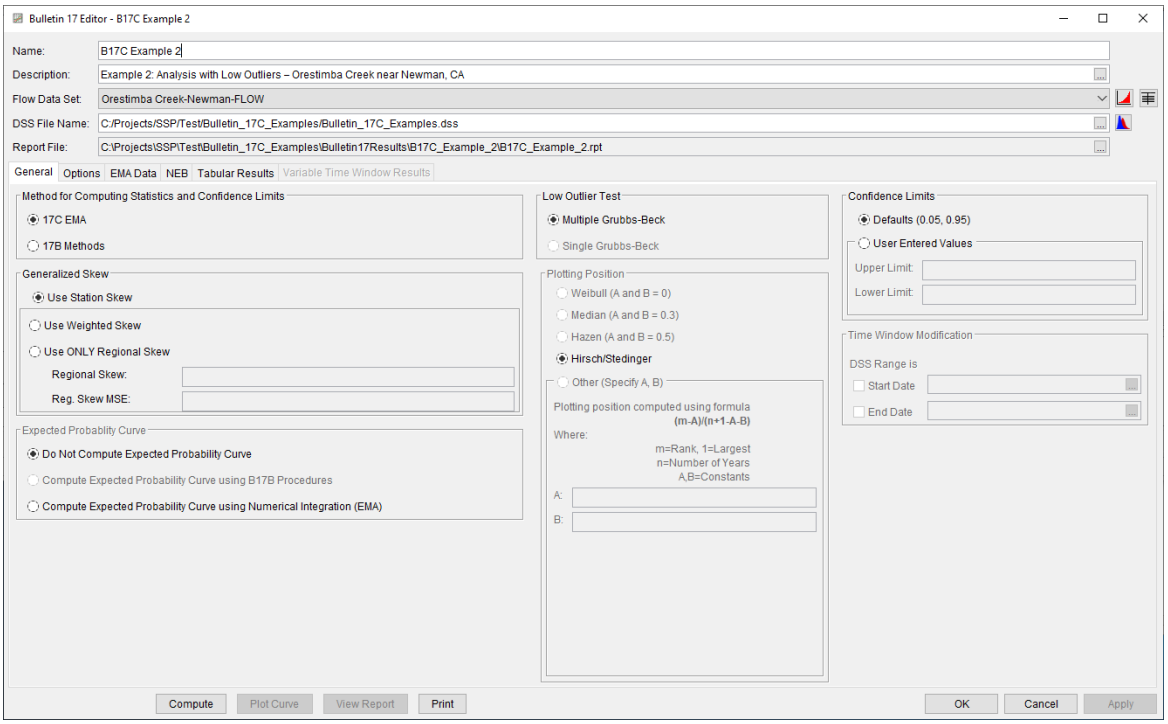
Date	Flow (cfs)
02 Apr 1958	10200
16 Feb 1959	5380
10 Feb 1960	448
30 Nov 1960	0
15 Feb 1962	1740
01 Feb 1963	8300
22 Jan 1964	156
06 Jan 1965	560
30 Dec 1965	128
24 Jan 1967	4200
30 Nov 1967	0
25 Jan 1969	5080
01 Mar 1970	1010
21 Dec 1970	584
30 Nov 1971	0
11 Feb 1973	1510
03 Mar 1974	922
08 Mar 1975	1010

Date	Flow (cfs)
30 Nov 1975	0
30 Nov 1976	0
17 Jan 1978	4360
21 Feb 1979	1270
16 Feb 1980	5210
29 Jan 1981	1130
05 Jan 1982	5550
24 Jan 1983	6360
25 Dec 1983	991
09 Feb 1985	50
19 Feb 1986	6990
06 Mar 1987	112
30 Nov 1987	0
30 Nov 1988	0
28 May 1990	4
24 Mar 1991	1260
15 Feb 1992	888
13 Jan 1993	4190

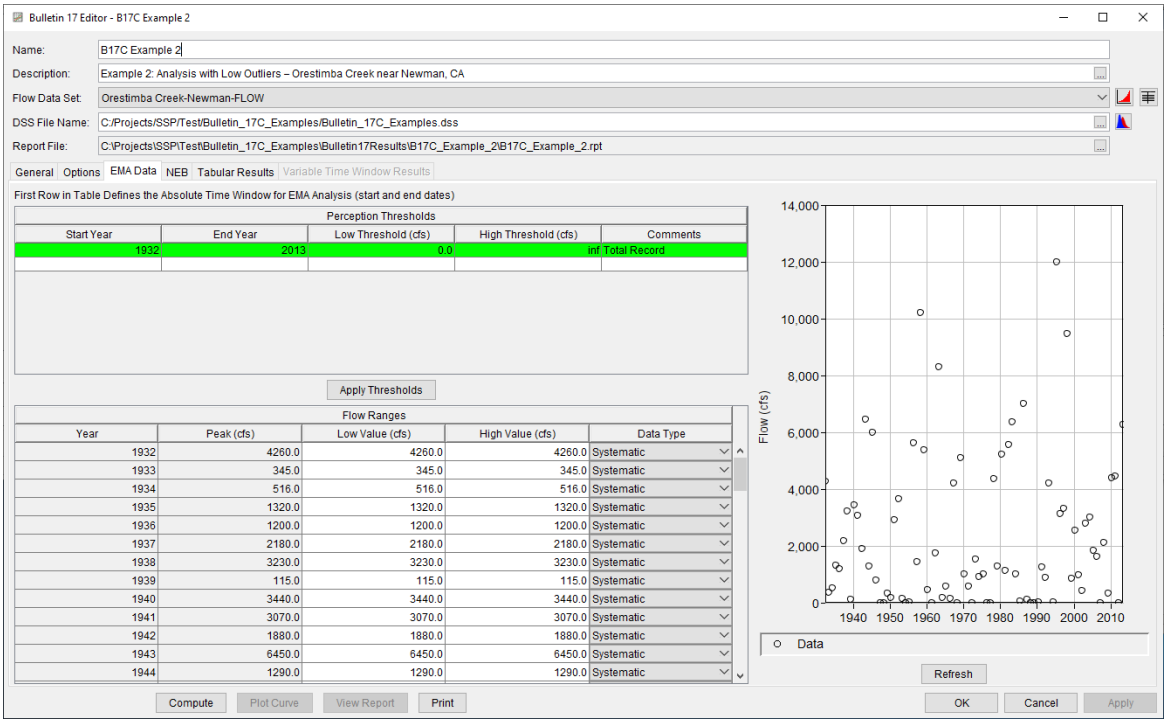
Date	Flow (cfs)
20 Feb 1994	12
10 Mar 1995	12000
19 Feb 1996	3130
23 Jan 1997	3320
03 Feb 1998	9470
09 Feb 1999	833
14 Feb 2000	2550
05 Mar 2001	958
03 Jan 2002	425
16 Dec 2002	2790
25 Feb 2004	2990
16 Feb 2005	1820
02 Jan 2006	1630
30 Nov 2006	0
25 Jan 2008	2110
17 Feb 2009	310
20 Jan 2010	4400
24 Mar 2011	4440

Date	Flow (cfs)
30 Nov 2011	0
24 Dec 2012	6250

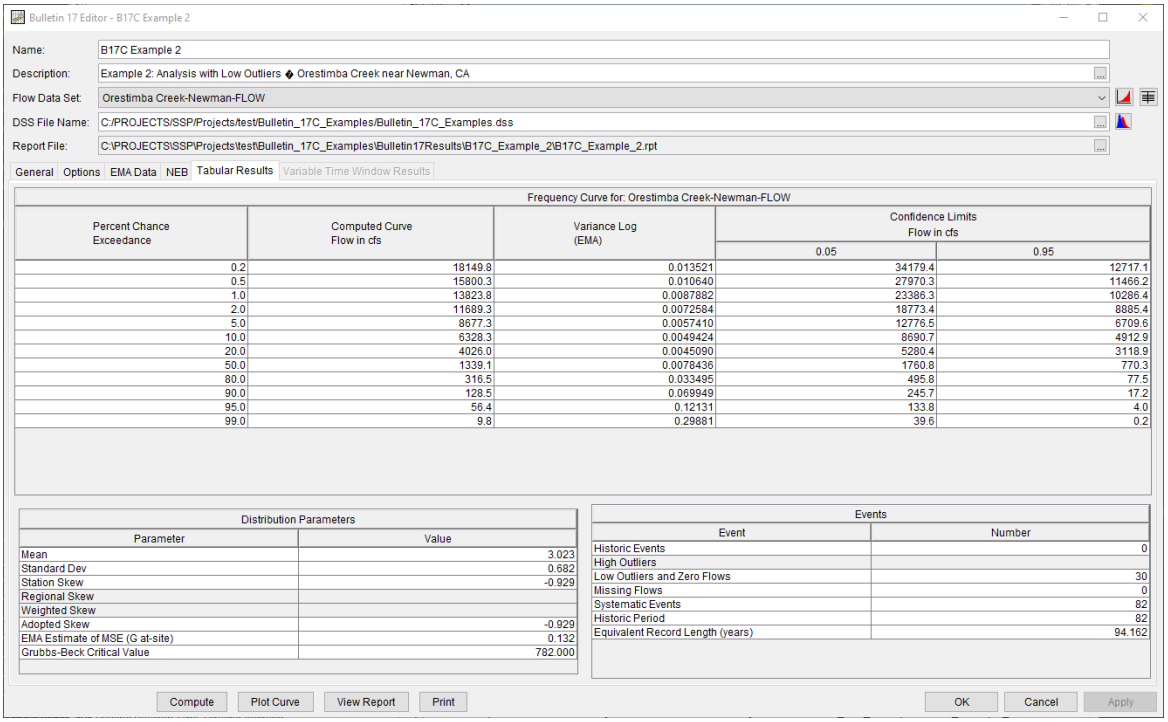
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 2**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 2**" from the list of available analyses. When "B17C Example 2" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 74). As shown, the **Skew** option was set to use the **Station Skew**.



No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 74). Since this example uses an annual maximum series consisting entirely of systematic data with a complete record, a single zero – inf perception threshold is adequate. No modifications to the default flow ranges and data types are necessary.

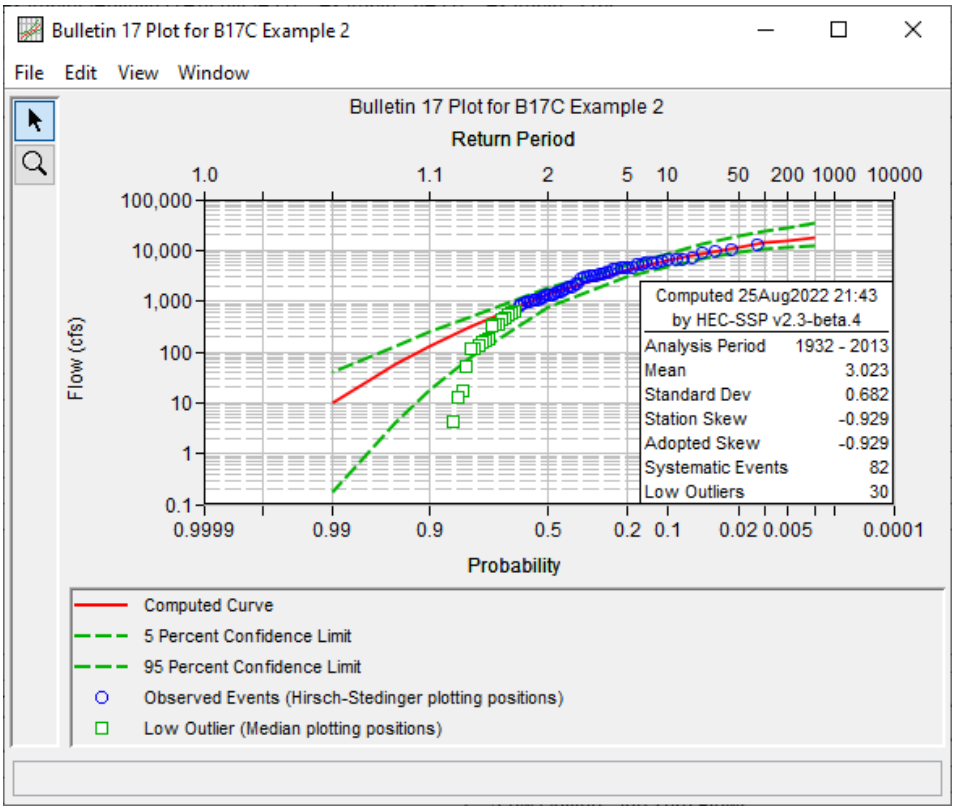


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 75).

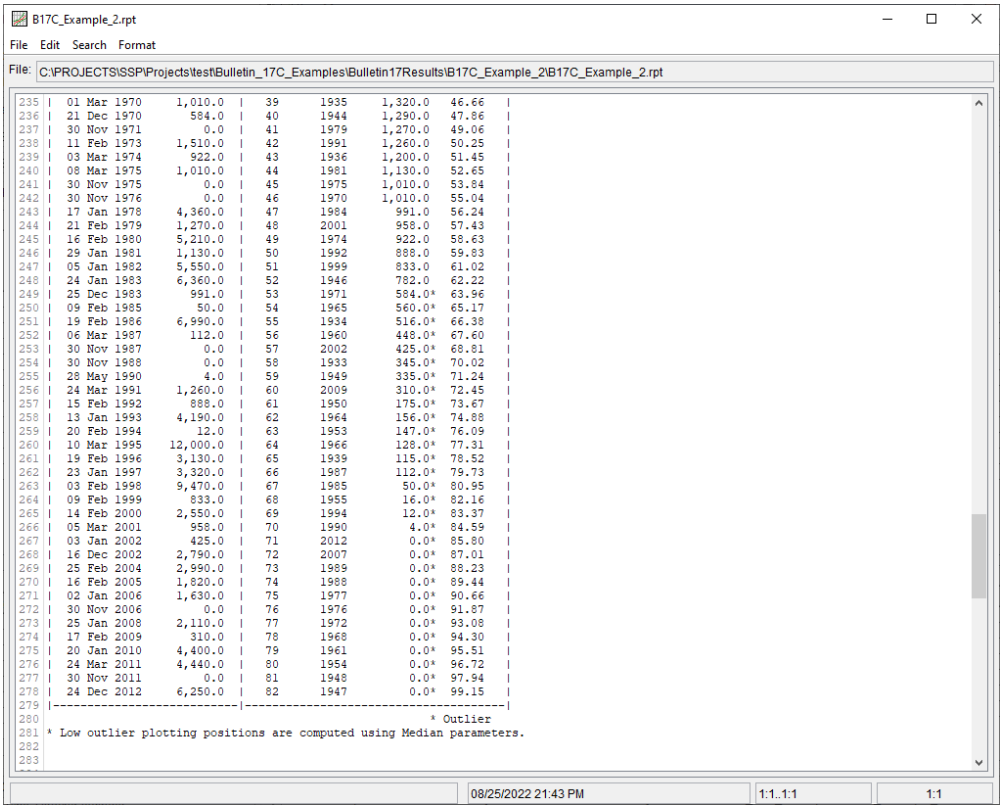


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed

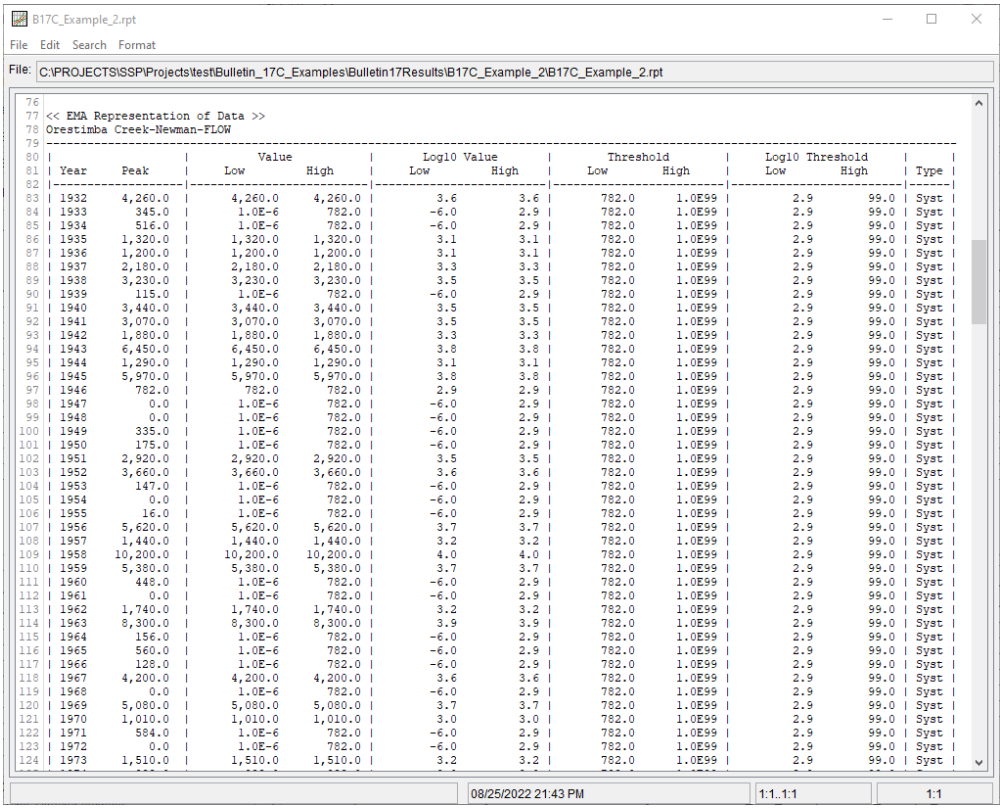
plotting positions are shown in Figure 5 (see page 76).



As shown in Figure 4 (see page 75), the Multiple Grubbs-Beck Test identified a low outlier threshold (critical value) of 782 cfs, which corresponds to the smallest peak that was retained. Thirty annual peak flows were thus identified and censored, as shown in Figure 6 (see page 76). These annual peak flows were then recoded to have a flow interval of zero – 782. The perception threshold for all systematic observations were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (i.e. 782 – inf), as shown in Figure 7 (see page 77).



44 Figure 6. Report File for B17C Example 2 showing censored low outliers and zero flows.



B17C_Example_2.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_2\B17C_Example_2.rpt

<< EMA Representation of Data >>
Orestimba Creek-Newman-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1932	4,260.0	4,260.0	4,260.0	3.6	3.6	782.0	1.0E99	2.9	99.0	Syst
1933	345.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1934	516.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1935	1,320.0	1,320.0	1,320.0	3.1	3.1	782.0	1.0E99	2.9	99.0	Syst
1936	1,200.0	1,200.0	1,200.0	3.1	3.1	782.0	1.0E99	2.9	99.0	Syst
1937	2,180.0	2,180.0	2,180.0	3.3	3.3	782.0	1.0E99	2.9	99.0	Syst
1938	3,230.0	3,230.0	3,230.0	3.5	3.5	782.0	1.0E99	2.9	99.0	Syst
1939	115.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1940	3,440.0	3,440.0	3,440.0	3.5	3.5	782.0	1.0E99	2.9	99.0	Syst
1941	3,070.0	3,070.0	3,070.0	3.5	3.5	782.0	1.0E99	2.9	99.0	Syst
1942	1,880.0	1,880.0	1,880.0	3.3	3.3	782.0	1.0E99	2.9	99.0	Syst
1943	6,450.0	6,450.0	6,450.0	3.8	3.8	782.0	1.0E99	2.9	99.0	Syst
1944	1,290.0	1,290.0	1,290.0	3.1	3.1	782.0	1.0E99	2.9	99.0	Syst
1945	5,970.0	5,970.0	5,970.0	3.8	3.8	782.0	1.0E99	2.9	99.0	Syst
1946	782.0	782.0	782.0	2.9	2.9	782.0	1.0E99	2.9	99.0	Syst
1947	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1948	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1949	335.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1950	175.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1951	2,920.0	2,920.0	2,920.0	3.5	3.5	782.0	1.0E99	2.9	99.0	Syst
1952	3,660.0	3,660.0	3,660.0	3.6	3.6	782.0	1.0E99	2.9	99.0	Syst
1953	147.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1954	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1955	16.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1956	5,620.0	5,620.0	5,620.0	3.7	3.7	782.0	1.0E99	2.9	99.0	Syst
1957	1,440.0	1,440.0	1,440.0	3.2	3.2	782.0	1.0E99	2.9	99.0	Syst
1958	10,200.0	10,200.0	10,200.0	4.0	4.0	782.0	1.0E99	2.9	99.0	Syst
1959	5,380.0	5,380.0	5,380.0	3.7	3.7	782.0	1.0E99	2.9	99.0	Syst
1960	448.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1961	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1962	1,740.0	1,740.0	1,740.0	3.2	3.2	782.0	1.0E99	2.9	99.0	Syst
1963	8,300.0	8,300.0	8,300.0	3.9	3.9	782.0	1.0E99	2.9	99.0	Syst
1964	156.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1965	560.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1966	128.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1967	4,200.0	4,200.0	4,200.0	3.6	3.6	782.0	1.0E99	2.9	99.0	Syst
1968	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1969	5,080.0	5,080.0	5,080.0	3.7	3.7	782.0	1.0E99	2.9	99.0	Syst
1970	1,010.0	1,010.0	1,010.0	3.0	3.0	782.0	1.0E99	2.9	99.0	Syst
1971	584.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1972	0.0	1.0E-6	782.0	-6.0	2.9	782.0	1.0E99	2.9	99.0	Syst
1973	1,510.0	1,510.0	1,510.0	3.2	3.2	782.0	1.0E99	2.9	99.0	Syst

08/25/2022 21:43 PM 1:1..1:1 1:1

45 Figure 7. Report File for B17C Example 2 showing recoded perception thresholds.

3.4 Example 3. Broken Record – Back Creek near Jones Springs, WV

Example 3 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of a broken record of systematic flood peaks. For this example, USGS gage 01614000 Back Creek near Jones Springs, West Virginia is used. Back Creek is a tributary to the Potomac River; the 235 square mile watershed lies within the Valley and Ridge province in West Virginia (England, et al., 2018). Gage 01614000 has an annual peak record consisting of 56 peaks beginning in 1929 and ending in 2012. There are three "broken record" periods where the gage was discontinued: 1932-1937, 1976-1991, and 1999-2003. Thus, there are 28 years of missing data at this gage during the period 1929-2012. There is a historic flood that occurred on March 17, 1936, during one of the periods when the gage was discontinued. This flood is noted in the USGS Annual Water Data Report for this gage, available in the peak-flow file, and there is historical information available for this large flood (Grover, 1937).

The Back Creek near Jones Springs, WV stream gage has an annual peak record consisting of 56 annual peaks. Of the 56 annual peaks, the October 1942 flood slightly exceeds the March 1936 historic flood peak. Based on the historical flood information in Grover (1937) for the 1936 flood, and the large regional floods and historical floods described by Wiley and Atkins (2010) in West Virginia for the period 1888-1996, information from the March 1936 flood can be used as a perception threshold to represent the 28 years of missing information. This assumes that if a flood equal to or larger than the March 1936 event occurred when the gage was not operational, it would have been noted and recorded in some way. The annual maximum series is plotted in Figure 1 (see page 78)and tabulated in Table 1.

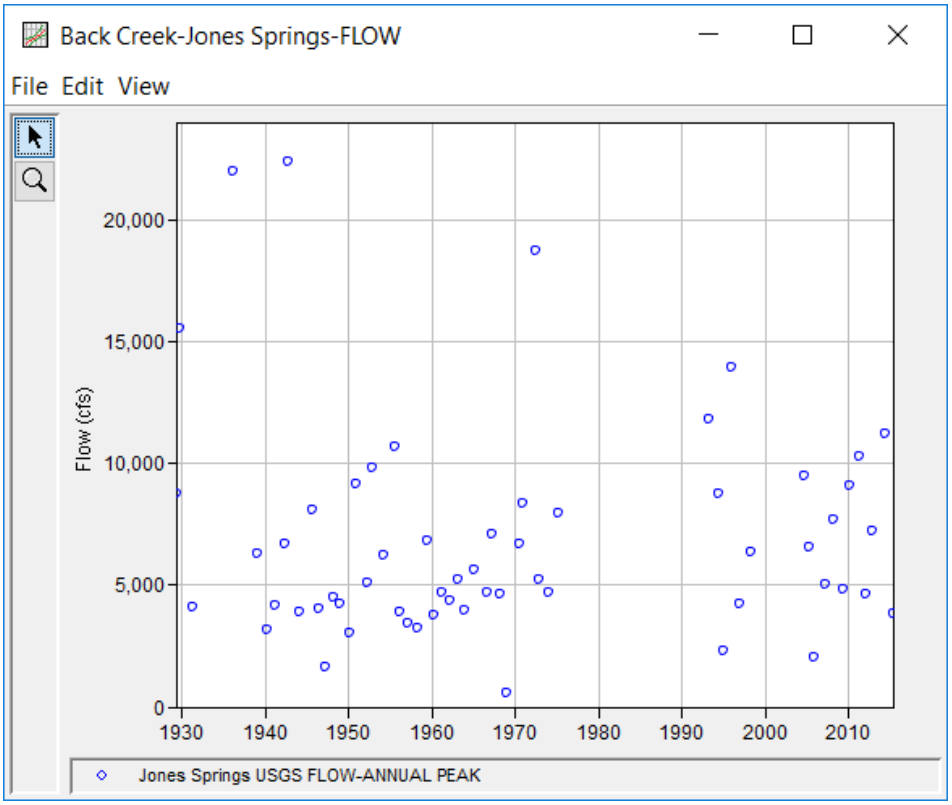


Table 1. Back Creek near Jones Springs, WV Annual Peak Flow Record.

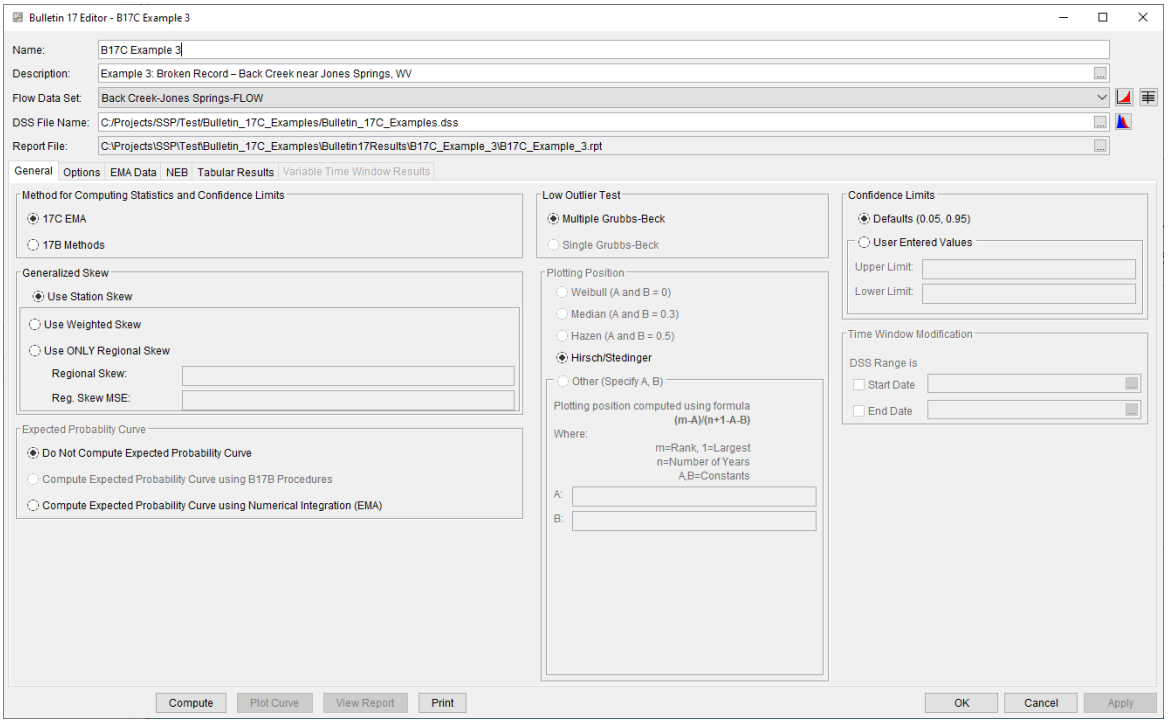
Date	Flow (cfs)
17 Apr 1929	8750
23 Oct 1929	15500
08 May 1931	4060
17 Mar 1936	22000
04 Feb 1939	6300
20 Apr 1940	3130
06 Apr 1941	4160
22 May 1942	6700

Date	Flow (cfs)
15 Oct 1942	22400
24 Mar 1944	3880
18 Sep 1945	8050
03 Jun 1946	4020
15 Mar 1947	1600
14 Apr 1948	4460
31 Dec 1948	4230
02 Feb 1950	3010
05 Dec 1950	9150
28 Apr 1952	5100
22 Nov 1952	9820
02 Mar 1954	6200
19 Aug 1955	10700
15 Mar 1956	3880
10 Feb 1957	3420
27 Mar 1958	3240
03 Jun 1959	6800
09 May 1960	3740

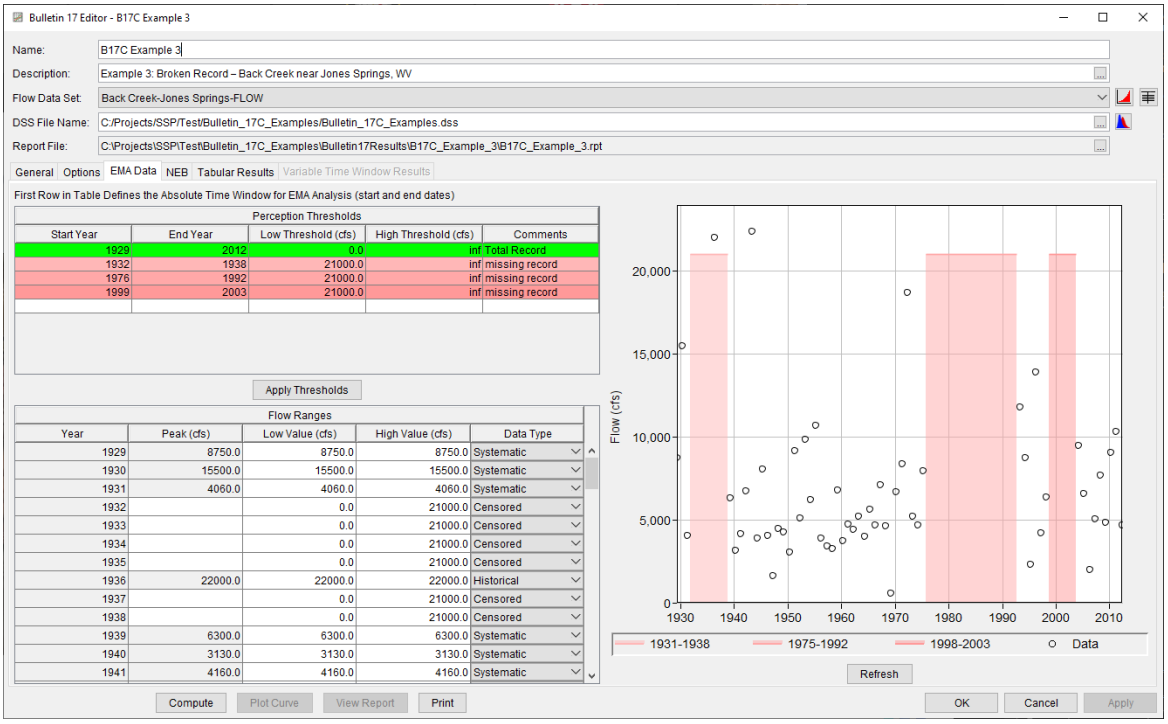
Date	Flow (cfs)
19 Feb 1961	4700
22 Mar 1962	4380
20 Mar 1963	5190
10 Jan 1964	3960
06 Mar 1965	5600
21 Sep 1966	4670
08 Mar 1967	7080
17 Mar 1968	4640
02 Feb 1969	536
10 Jul 1970	6680
13 Nov 1970	8360
22 Jun 1972	18700
09 Dec 1972	5210
27 Dec 1973	4680
20 Mar 1975	7940
05 Mar 1993	11800
08 May 1994	8730
16 Jan 1995	2300

Date	Flow (cfs)
19 Jan 1996	13900
09 Nov 1996	4190
21 Mar 1998	6370
29 Sep 2004	9460
29 Mar 2005	6560
30 Nov 2005	2000
16 Apr 2007	5040
21 Apr 2008	7670
05 May 2009	4830
14 Mar 2010	9070
17 Apr 2011	10300
01 Mar 2012	4650

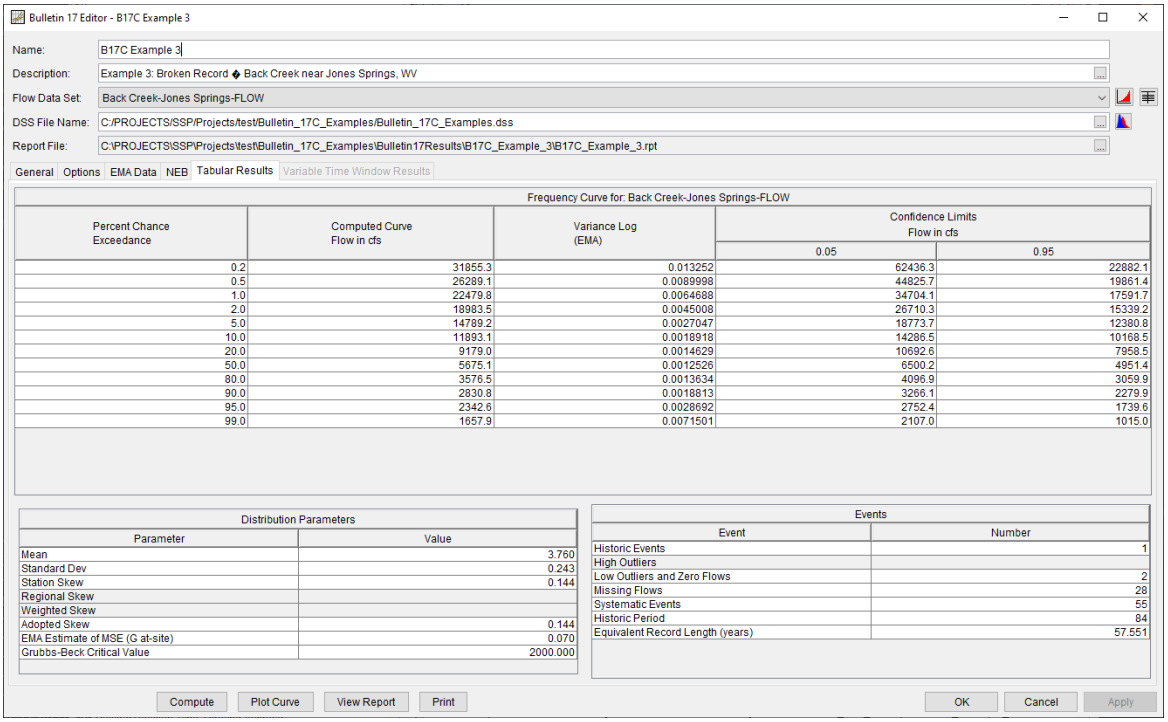
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 3**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 3**" from the list of available analyses. When "B17C Example 3" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 82). As shown, the **Skew** option was set to use the **Station Skew**.



No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 83). This example uses an annual maximum series consisting of both systematic data along with an historical event in March 1936. Also, the record is broken with multiple periods of missing with a complete record. Since 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data, a total of four perception thresholds are required. In this case, the March 1936 event can be used to inform the perception thresholds for the periods of missing annual peak flow data. The use of a perception threshold of 21000 – inf for these periods of missing data implies that had a flood event occurred with a peak flow greater than 21,000 cfs, someone would have measured and recorded it. Once all four perception thresholds have been entered as shown in Figure 3 (see page 83), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data. Finally, the March 1936 event should be set to the historical data type, as denoted by a USGS peak flow rate qualification code of "7", because it occurred during a period when the gage was discontinued.

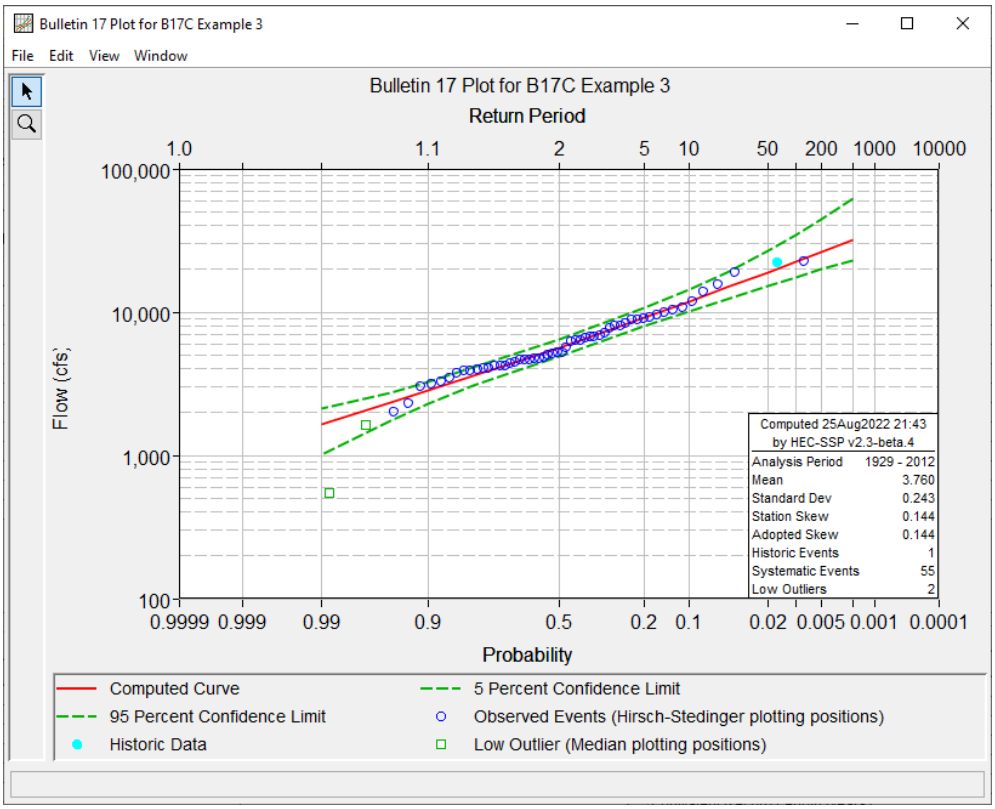


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 84).

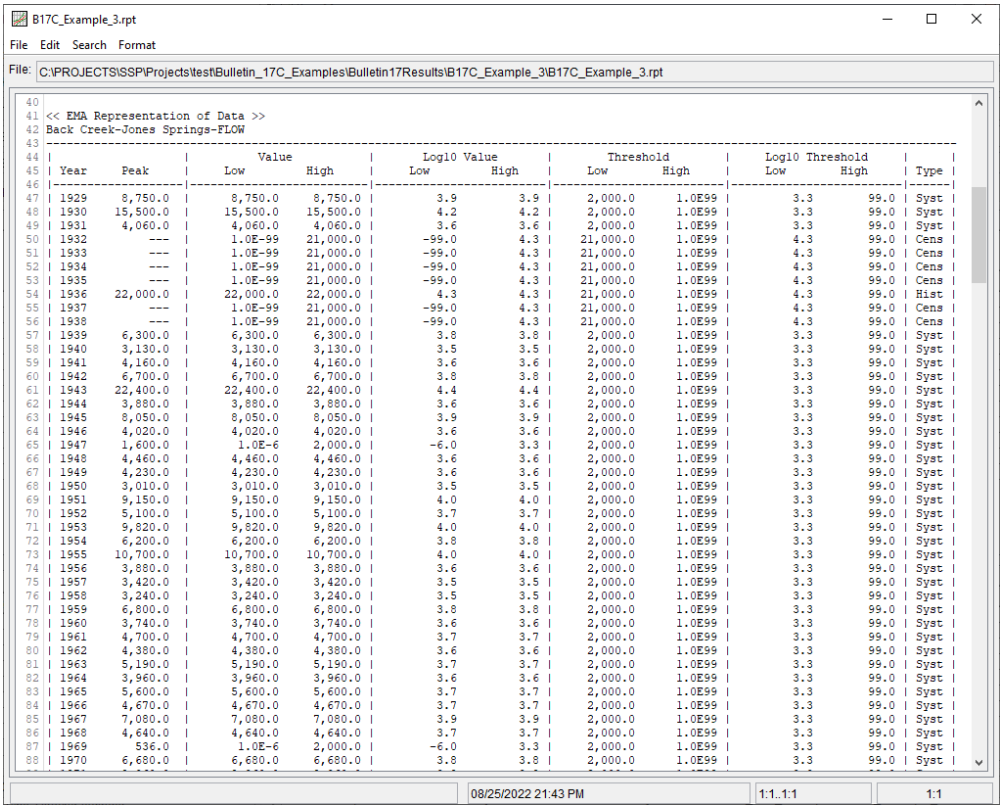


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed

plotting positions are shown in Figure 5 (see page 85).



As shown in Figure 4 (see page 84), the Multiple Grubbs-Beck Test identified a low outlier threshold (critical value) of 2000 cfs, which corresponds to the smallest peak that was retained. Two annual peak flows were identified and censored, as shown in Figure 6. (see page 85) These annual peak flows were then recoded to have a flow interval of zero – 2000. The perception threshold for all systematic observations were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (i.e. 2000 – inf), as shown in Figure 7 (see page 86).



B17C_Example_3.rpt

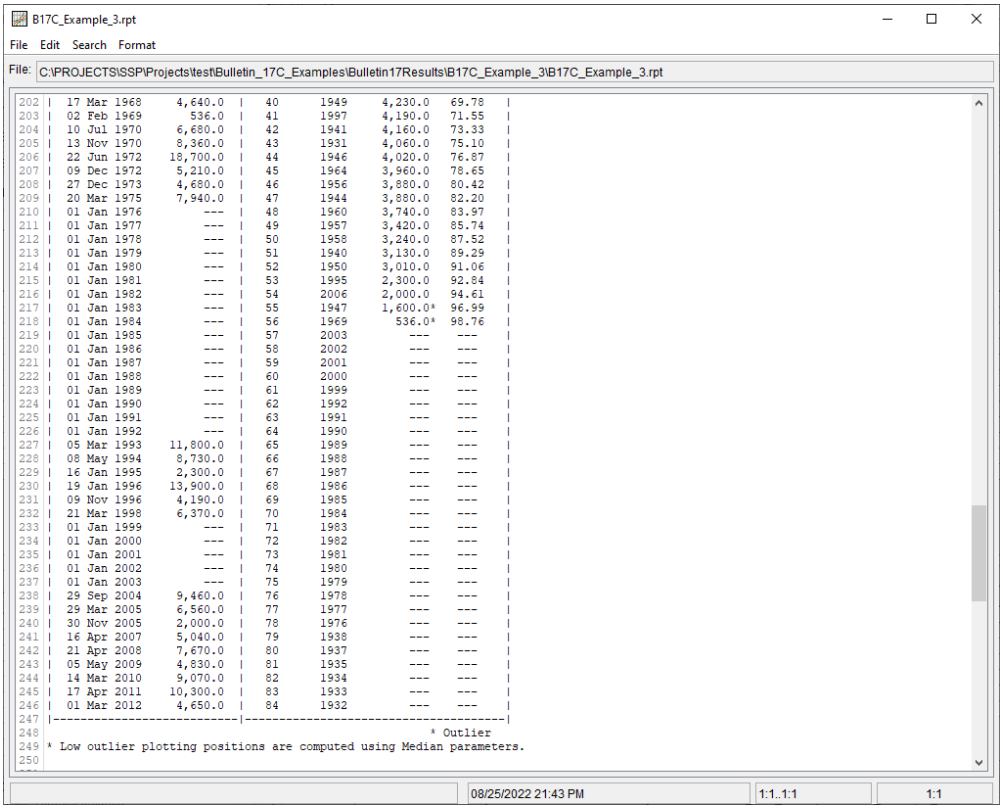
File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_3\B17C_Example_3.rpt

<< EMA Representation of Data >>
Back Creek-Jones Springs-FLOW

		Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1929	8,750.0	8,750.0	8,750.0	3.9	3.9	2,000.0	1.0E99	3.3	99.0	Syst
1930	15,500.0	15,500.0	15,500.0	4.2	4.2	2,000.0	1.0E99	3.3	99.0	Syst
1931	4,060.0	4,060.0	4,060.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1932	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1933	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1934	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1935	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1936	22,000.0	22,000.0	22,000.0	4.3	4.3	21,000.0	1.0E99	4.3	99.0	Hist
1937	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1938	---	1.0E-99	21,000.0	-99.0	4.3	21,000.0	1.0E99	4.3	99.0	Cens
1939	6,300.0	6,300.0	6,300.0	3.8	3.8	2,000.0	1.0E99	3.3	99.0	Syst
1940	3,130.0	3,130.0	3,130.0	3.5	3.5	2,000.0	1.0E99	3.3	99.0	Syst
1941	4,160.0	4,160.0	4,160.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1942	6,700.0	6,700.0	6,700.0	3.8	3.8	2,000.0	1.0E99	3.3	99.0	Syst
1943	22,400.0	22,400.0	22,400.0	4.4	4.4	2,000.0	1.0E99	3.3	99.0	Syst
1944	3,880.0	3,880.0	3,880.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1945	8,050.0	8,050.0	8,050.0	3.9	3.9	2,000.0	1.0E99	3.3	99.0	Syst
1946	4,020.0	4,020.0	4,020.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1947	1,600.0	1.0E-6	2,000.0	-6.0	3.3	2,000.0	1.0E99	3.3	99.0	Syst
1948	4,460.0	4,460.0	4,460.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1949	4,230.0	4,230.0	4,230.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1950	3,010.0	3,010.0	3,010.0	3.5	3.5	2,000.0	1.0E99	3.3	99.0	Syst
1951	9,150.0	9,150.0	9,150.0	4.0	4.0	2,000.0	1.0E99	3.3	99.0	Syst
1952	5,100.0	5,100.0	5,100.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1953	9,820.0	9,820.0	9,820.0	4.0	4.0	2,000.0	1.0E99	3.3	99.0	Syst
1954	6,200.0	6,200.0	6,200.0	3.8	3.8	2,000.0	1.0E99	3.3	99.0	Syst
1955	10,700.0	10,700.0	10,700.0	4.0	4.0	2,000.0	1.0E99	3.3	99.0	Syst
1956	3,880.0	3,880.0	3,880.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1957	3,420.0	3,420.0	3,420.0	3.5	3.5	2,000.0	1.0E99	3.3	99.0	Syst
1958	3,240.0	3,240.0	3,240.0	3.5	3.5	2,000.0	1.0E99	3.3	99.0	Syst
1959	6,800.0	6,800.0	6,800.0	3.8	3.8	2,000.0	1.0E99	3.3	99.0	Syst
1960	3,740.0	3,740.0	3,740.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1961	4,700.0	4,700.0	4,700.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1962	4,380.0	4,380.0	4,380.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1963	5,190.0	5,190.0	5,190.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1964	3,960.0	3,960.0	3,960.0	3.6	3.6	2,000.0	1.0E99	3.3	99.0	Syst
1965	5,600.0	5,600.0	5,600.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1966	4,670.0	4,670.0	4,670.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1967	7,080.0	7,080.0	7,080.0	3.9	3.9	2,000.0	1.0E99	3.3	99.0	Syst
1968	4,640.0	4,640.0	4,640.0	3.7	3.7	2,000.0	1.0E99	3.3	99.0	Syst
1969	536.0	1.0E-6	2,000.0	-6.0	3.3	2,000.0	1.0E99	3.3	99.0	Syst
1970	6,680.0	6,680.0	6,680.0	3.8	3.8	2,000.0	1.0E99	3.3	99.0	Syst

08/25/2022 21:43 PM 1:1..1:1 1:1



46 Figure 7. Report File for B17C Example 3 showing recoded perception thresholds.

3.5 Example 4. Historical Data – Arkansas River at Pueblo, CO

Example 4 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of systematic and historical flood events as well as paleoflood information. The largest historic floods are described as interval data, and multiple thresholds are needed to effectively extend the discontinued stream gaging record after the dam was built. A paleohydrologic bound of about 840 years (before water year 2004) was estimated at this site for inclusion in the flood frequency curve. No estimates of individual paleofloods were made at this site, due to the relatively wide channel geometry and the lack of apparent stratigraphic evidence of large paleofloods during a limited field study (England, et al., 2018).

When fitting the Log Pearson Type III distribution using either Bulletin 17B or Bulletin 17C procedures, an unregulated annual maximum series is required. However, peak flow rates downloaded from the USGS website do not always reflect unregulated conditions, as is the case with the Arkansas River near Pueblo, CO (07099500) gage. Pueblo Dam, which creates one of the largest reservoirs within Colorado, is immediately upstream of this gaging station. The dam was constructed between 1970 and 1975 and began impacting the annual maximum series due to flood control and water supply storage in water year 1974. As such, the annual maximum series downloaded from the USGS website was altered to reflect unregulated conditions for water year 1974 and 1975. The modified annual maximum series is plotted in Figure 1 (see page 87) and tabulated in Table 1.

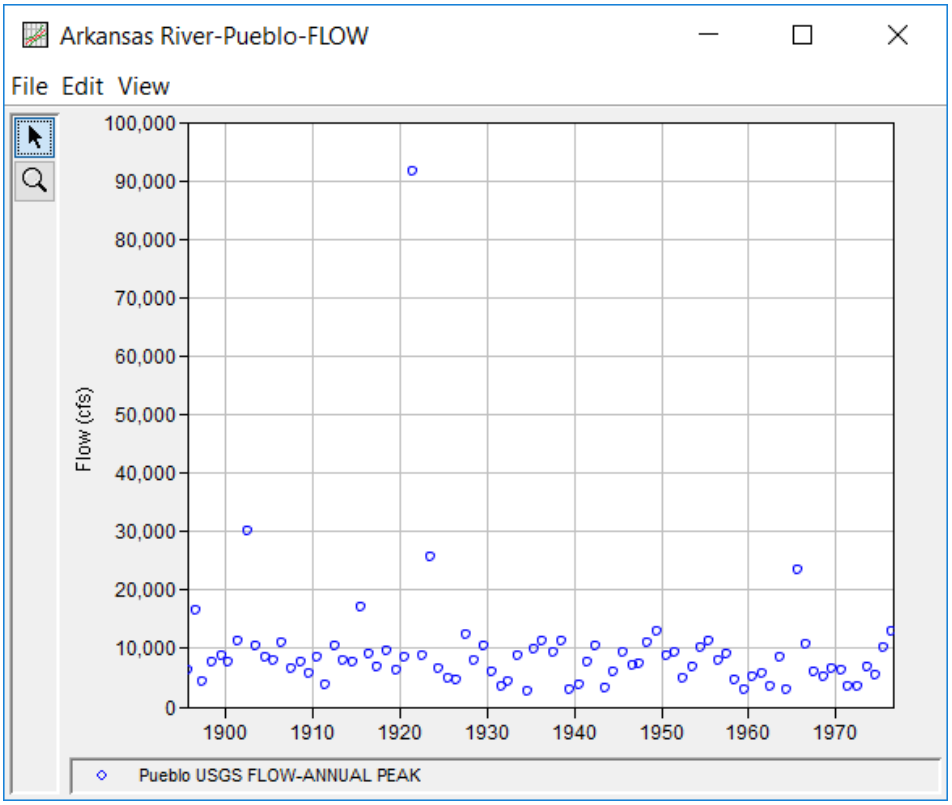


Table 1. Arkansas River near Pueblo, CO Annual Peak Flow Record (Modified).

Date	Flow (cfs)
31 Jul 1895	6100
18 Aug 1896	16500
02 Jun 1897	4300
13 Jul 1898	7500
14 Aug 1899	8800
20 May 1900	7600
21 May 1901	11100
05 Aug 1902	30000

Date	Flow (cfs)
09 Jun 1903	10500
15 Aug 1904	8500
06 Aug 1905	8000
13 Jun 1906	11000
28 Jul 1907	6600
01 Aug 1908	7600
18 Aug 1909	5800
29 Jul 1910	8400
28 May 1911	3700
31 Jul 1912	10500
23 Jul 1913	7800
03 Aug 1914	7500
24 Jun 1915	17000
17 Jun 1916	8900
19 Jun 1917	6800
23 Jun 1918	9600
04 Sep 1919	6300
18 Jul 1920	8500

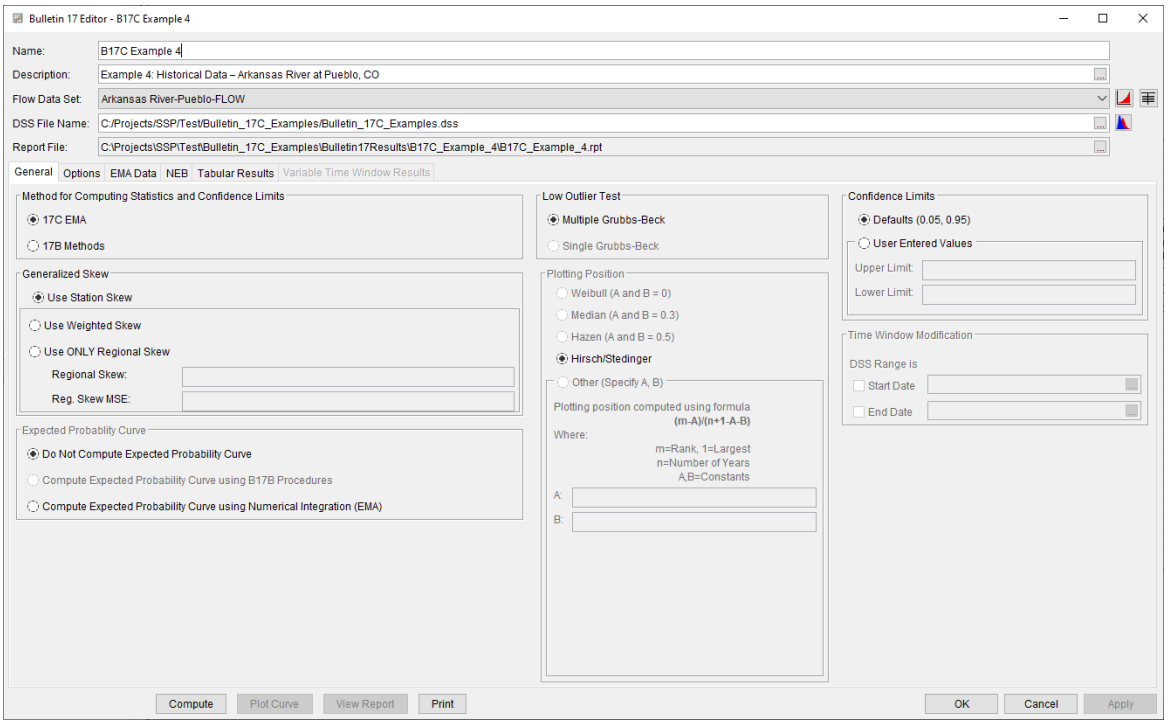
Date	Flow (cfs)
03 Jun 1921	91500
06 Aug 1922	8850
12 Jul 1923	25600
15 Jun 1924	6510
03 Jul 1925	4930
14 Jun 1926	4520
22 Jul 1927	12400
21 Jul 1928	7800
28 Jul 1929	10500
28 Aug 1930	6050
01 Sep 1931	3560
26 Jun 1932	4380
02 Aug 1933	8630
03 Aug 1934	2580
18 May 1935	9880
24 May 1936	11200
29 Aug 1937	9300
26 Aug 1938	11200

Date	Flow (cfs)
01 Jun 1939	2910
19 Aug 1940	3860
19 Jul 1941	7560
08 Jun 1942	10300
18 Aug 1943	3320
05 Jul 1944	5980
14 Aug 1945	9290
27 Aug 1946	7050
09 Jul 1947	7280
13 Jun 1948	10900
06 Jun 1949	12800
26 Jul 1950	8700
03 Aug 1951	9300
08 Jun 1952	4740
21 Jul 1953	6770
30 Jun 1954	10200
19 May 1955	11100
01 Aug 1956	8010

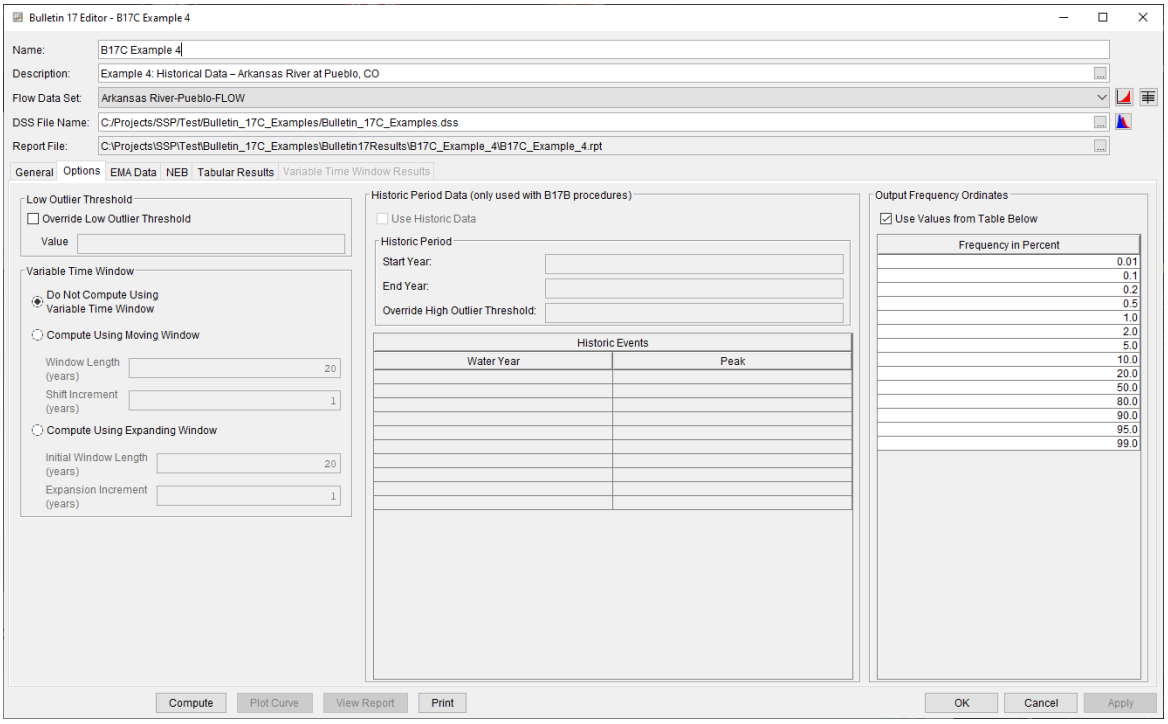
Date	Flow (cfs)
29 Jun 1957	9070
05 Jun 1958	4540
17 Jun 1959	2820
08 Jun 1960	5260
02 Aug 1961	5760
08 Jul 1962	3540
14 Aug 1963	8360
27 May 1964	2840
22 Aug 1965	23500
01 Aug 1966	10600
18 Jul 1967	5870
10 Aug 1968	5190
23 Aug 1969	6620
11 Aug 1970	6300
07 Jun 1971	3360
28 Jun 1972	3360
30 Jul 1973	6760
23 Jul 1974	5440

Date	Flow (cfs)
10 Jul 1975	10200
10 Jul 1976	12800

A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 4**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 4**" from the list of available analyses. When "B17C Example 4" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 93). As shown, the **Skew** option was set to use the **Station Skew**.



Commonly, within dam safety studies, estimates of flow or volume frequency are required at extremely small exceedance probabilities. As such, additional frequency ordinates (0.1- and 0.01-percent annual chance exceedance probabilities) were specified on the **Options** tab, as shown in Figure 3 (see page 93). It should be noted that estimating the frequency curve for these probabilities requires extrapolation far beyond the gaged data. However, the inclusion of paleoflood data makes this extrapolation more supportable.

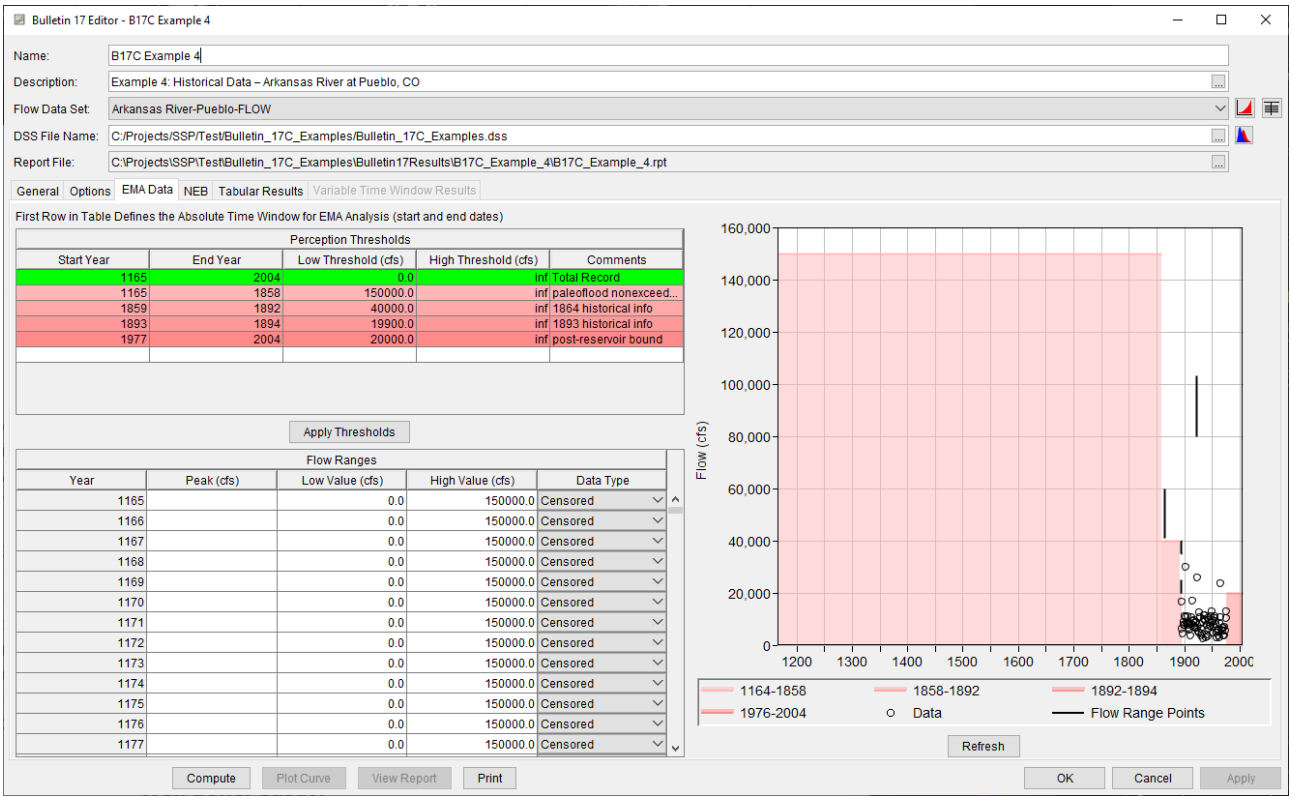


The **EMA Data** tab for this example is shown in Figure 4 (see page 95). This example uses an annual maximum series consisting of both systematic data along with historical events and paleoflood information. Multiple perception thresholds are needed to reasonably incorporate the various historical and paleoflood information.

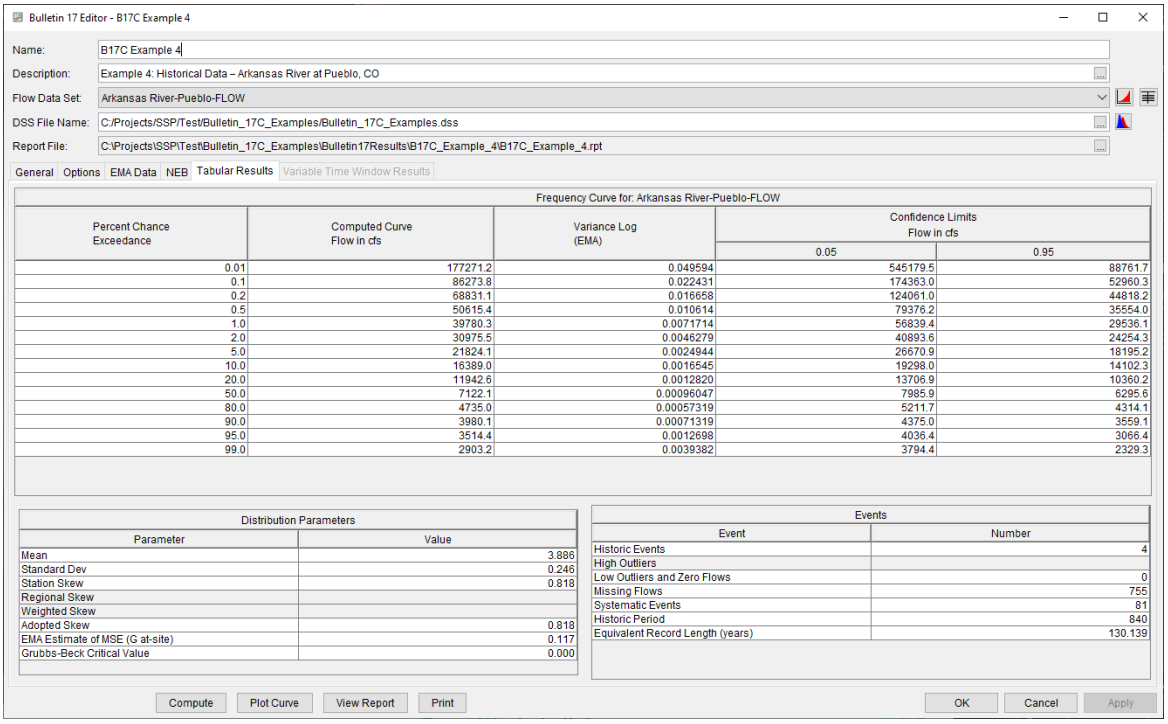
- The default "Total Record" perception threshold should be modified to reflect the additional paleoflood and post Pueblo Dam construction information. A start year of 1165 and end year of 2004 along with a perception threshold of zero – inf should be entered on the first line.
- The second perception threshold relates to the non-exceedance information obtained through the paleoflood analysis. A start and end year of 1165 and 1858 should be entered, respectively, along with a 150,000 – inf perception threshold. This implies that no floods exceeded a peak flow rate of 150,000 cfs from 1165 – 1858 even though there were no gages present.
- The third perception threshold represents a period of historical information from 1859 – 1892 where floods in excess of 40,000 cfs would have been recorded had they occurred. Additionally, an historical flow event that occurred in 1864 should be entered in the Flow Ranges table with a low and high flow value of 41,000 and 60,000 cfs, respectively, to denote uncertainty around the best-estimate of 50,500 cfs. The data type for this event should be set to Historical.
- The fourth perception threshold represents an additional period of historical information from 1893 – 1894. A perception threshold of 19,900 – inf should be entered for these two years. Two events that aren't part of the gage record occurred in 1893 and 1894. The 1893 event had a low and high flow value of 20,000 and 25,000, respectively, with a best-estimate of 22,500. The 1894 event had a low and high flow value of 35,000 and 40,000, respectively, with a best-estimate of 37,500. Both events should be entered in the Flow Ranges table and the data types should be set to Historical.
  The 1921 event should be entered as an historical event with uncertainty around the best estimate of 91,500 cfs. A low and high value of 80,000 and 103,000 should be used.
- The fifth and final perception threshold represents the period when the stream gage was discontinued after the construction of Pueblo Dam. It is known that floods in excess of 20,000 cfs

would have been recorded had they occurred. Therefore, a perception threshold of 20,000 – inf should be entered for these years.

Once all five perception thresholds have been entered as shown in Figure 4 (see page 95), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.



Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 5 (see page 95).



Bulletin 17 Editor - B17C Example 4

Name: B17C Example 4

Description: Example 4: Historical Data – Arkansas River at Pueblo, CO

Flow Data Set: Arkansas River-Pueblo-FLOW

DSS File Name: C:/Projects/SSP/Test/Bulletin_17C_Examples/Bulletin_17C_Examples.dss

Report File: C:\Projects\SSP\Test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_4\B17C_Example_4.rpt

General | Options | EMA Data | NEB | Tabular Results | Variable Time Window Results

Frequency Curve for: Arkansas River-Pueblo-FLOW

Percent Chance Exceedance	Computed Curve Flow in cfs	Variance Log (EMA)	Confidence Limits Flow in cfs	
			0.05	0.95
0.01	177271.2	0.049594	545179.5	88761.7
0.1	86273.8	0.022431	174363.0	52960.3
0.2	68831.1	0.016658	124061.0	44818.2
0.5	50615.4	0.010614	79376.2	35554.0
1.0	39780.3	0.0071714	56839.4	29536.1
2.0	30975.5	0.0046279	40893.6	24254.3
5.0	21824.1	0.0024944	26670.9	18195.2
10.0	16389.0	0.0016545	19298.0	14102.3
20.0	11942.6	0.0012820	13706.9	10360.2
50.0	7122.1	0.00096047	7985.9	6295.6
80.0	4735.0	0.00057319	5211.7	4314.1
90.0	3980.1	0.00071319	4375.0	3559.1
95.0	3514.4	0.0012698	4036.4	3066.4
99.0	2903.2	0.0039382	3794.4	2329.3

Distribution Parameters

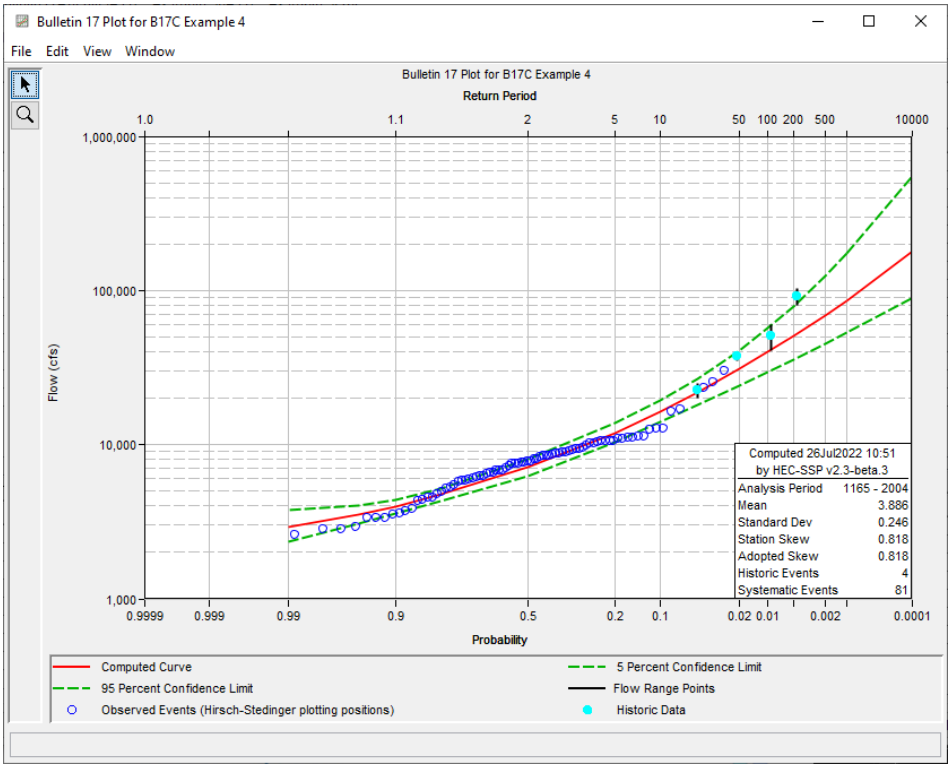
Parameter	Value
Mean	3.886
Standard Dev	0.246
Station Skew	0.818
Regional Skew	
Weighted Skew	
Adopted Skew	0.818
EMA Estimate of MSE (G at-site)	0.117
Grubbs-Beck Critical Value	0.000

Events

Event	Number
Historic Events	4
High Outliers	
Low Outliers and Zero Flows	0
Missing Flows	755
Systematic Events	81
Historic Period	840
Equivalent Record Length (years)	130.139

Compute | Plot Curve | View Report | Print | OK | Cancel | Apply

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed plotting positions are shown in Figure 6 (see page 95). As is shown, the Log Pearson Type III distribution is well fit to the majority of the data. However, the largest flood event (June 1921) is underfit by the EMA-computed Log Pearson Type III curve. This is likely due to the influence of the paleoflood information which lengthens the historical record from 85 years to 840 years. Consequently, the at-station skew coefficient is reduced which primarily affects the upper end of the computed curve. Had the paleoflood information not been included, a larger at-station skew coefficient would have been computed.



47 Figure 6. Plotted Frequency Curves for B17C Example 4.

3.6 Example 5. Crest Stage Gage Censored Data – Bear Creek at Ottumwa, IA

Example 5 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of censored data with variable perception thresholds due to the presence of a crest stage gage. A crest stage gage is a simple, reliable device used to obtain the elevation of the flood peak of a stream. Most commonly, a crest stage gage consists of a vertical metal pipe containing a wood or aluminum staff held in a fixed position with relation to a datum reference. At the bottom of the pipe is a perforated cap containing regranulated cork. When the water in the stream reaches and exceeds the height of the bottom cap (commonly referred to as the gage base), water is able to enter the pipe. As the water rises up the pipe, the cork floats on the water surface and as the water reaches its peak and starts to recede, the cork adheres to the staff thereby retaining the crest stage of the flood (England, et al., 2018). As a result, crest stage gages provide a censored record of peak flows, as no annual peak flow that results in a flood stage below the bottom cap of the pipe will be recorded.

For this example, USGS gage 05489490 Bear Creek at Ottumwa, IA is used. This gage is a crest stage gage and has a drainage area of 22.9 square miles. It is located in southeast Iowa in the Southern Iowa Drift Plain land-form region which is characterized by rolling hills and deeply carved stream channels (Prior, 1991). The stream banks and channel bed are comprised of sand, silt, and clay materials that are prone to shifting from hydrologic events. The Bear Creek at Ottumwa, IA stream gage has an annual peak record consisting of 50 annual peaks. The historical record for this gage spans from 1965 – 2014. The annual maximum series is plotted in Figure 1 (see page 97) and tabulated in Table 1.

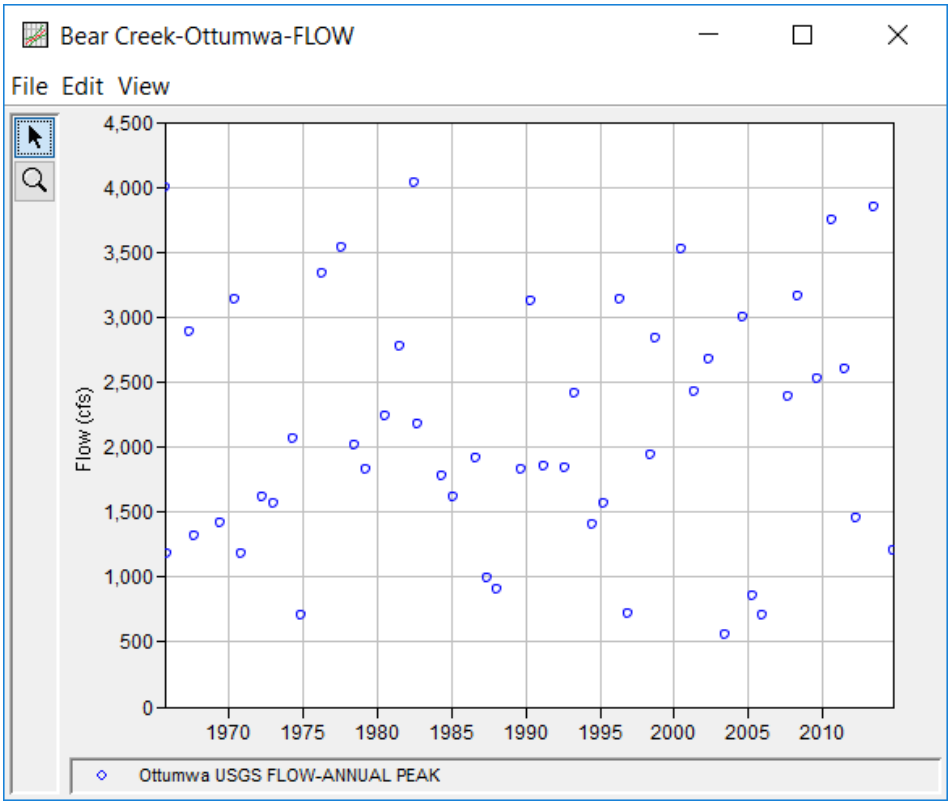


Table 1. Bear Creek at Ottumwa, IA Annual Peak Flow Record.

Date	Flow (cfs)
21 Sep 1965	4000
30 Nov 1965	1180
09 Jun 1967	2880
15 Oct 1967	1310
05 Jul 1969	1420
24 Jun 1970	3130
30 Nov 1970	1180
08 May 1972	1620

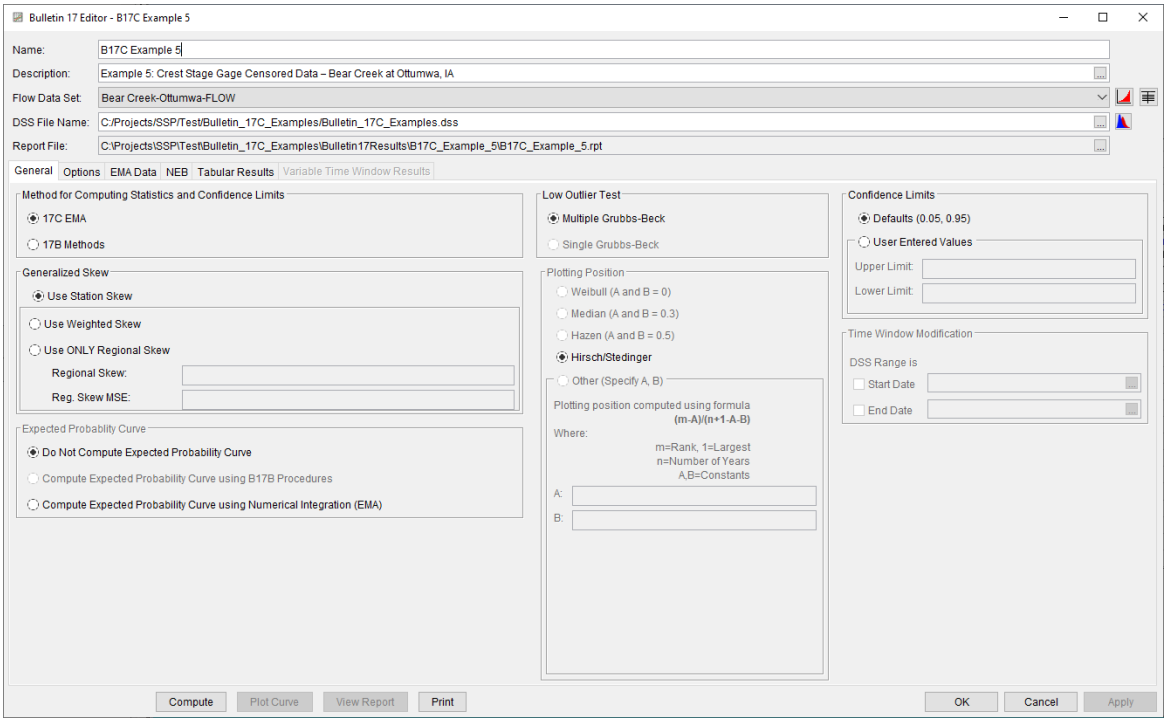
Date	Flow (cfs)
19 Jan 1973	1570
19 May 1974	2060
30 Nov 1974	705
24 Apr 1976	3340
07 Aug 1977	3530
21 Jul 1978	2010
29 Mar 1979	1830
17 Aug 1980	2240
04 Jul 1981	2770
03 Jul 1982	4030
08 Oct 1982	2180
08 Jun 1984	1780
04 Mar 1985	1610
19 Sep 1986	1910
31 May 1987	990
20 Feb 1988	899*
09 Sep 1989	1820
25 May 1990	3120

Date	Flow (cfs)
18 Apr 1991	1850
15 Sep 1992	1840
07 May 1993	2410
23 Jun 1994	1400
11 Apr 1995	1560
28 May 1996	3130
30 Nov 1996	714
18 Jun 1998	1940
05 Oct 1998	2840
23 Jun 2000	3520
15 May 2001	2430
11 May 2002	2670
26 Jun 2003	560
27 Aug 2004	3000
12 Apr 2005	859
30 Nov 2005	710
23 Aug 2007	2390
11 May 2008	3160

Date	Flow (cfs)
27 Aug 2009	2520
09 Aug 2010	3750
14 Jun 2011	2600
14 Apr 2012	1450
28 May 2013	3850
10 Sep 2014	1200

**gage height affected by backwater*

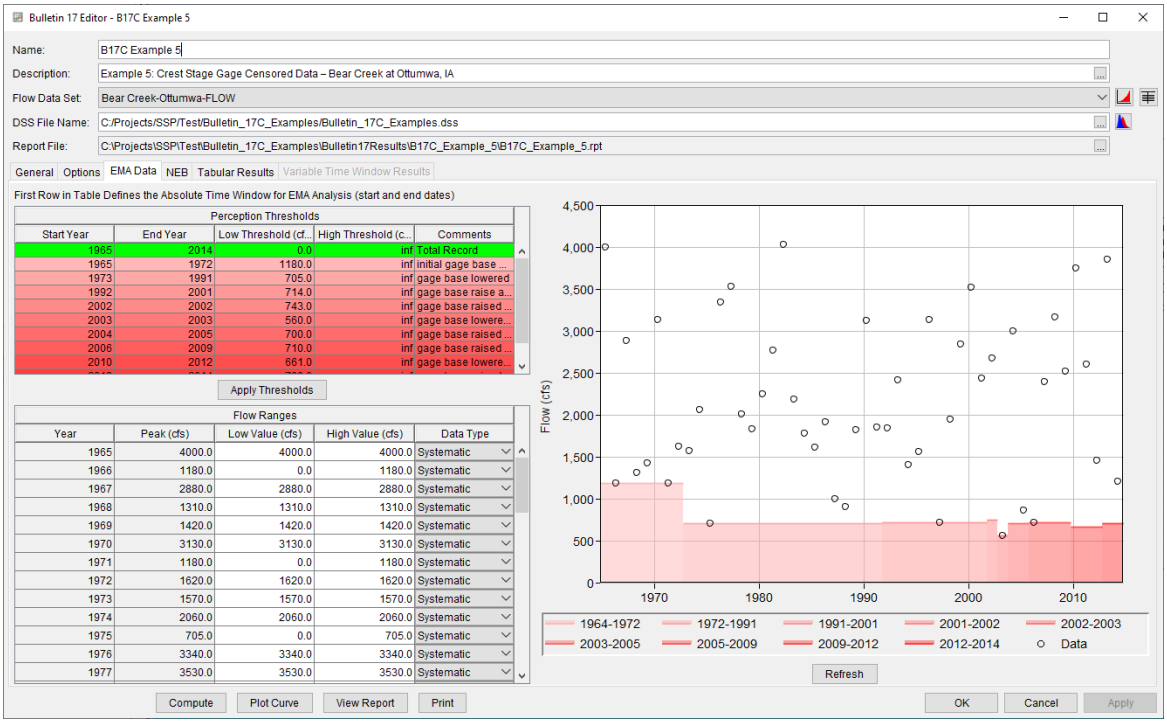
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 5**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 5**" from the list of available analyses. When "B17C Example 5" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 101). As shown, the **Skew** option was set to use the **Station Skew**.



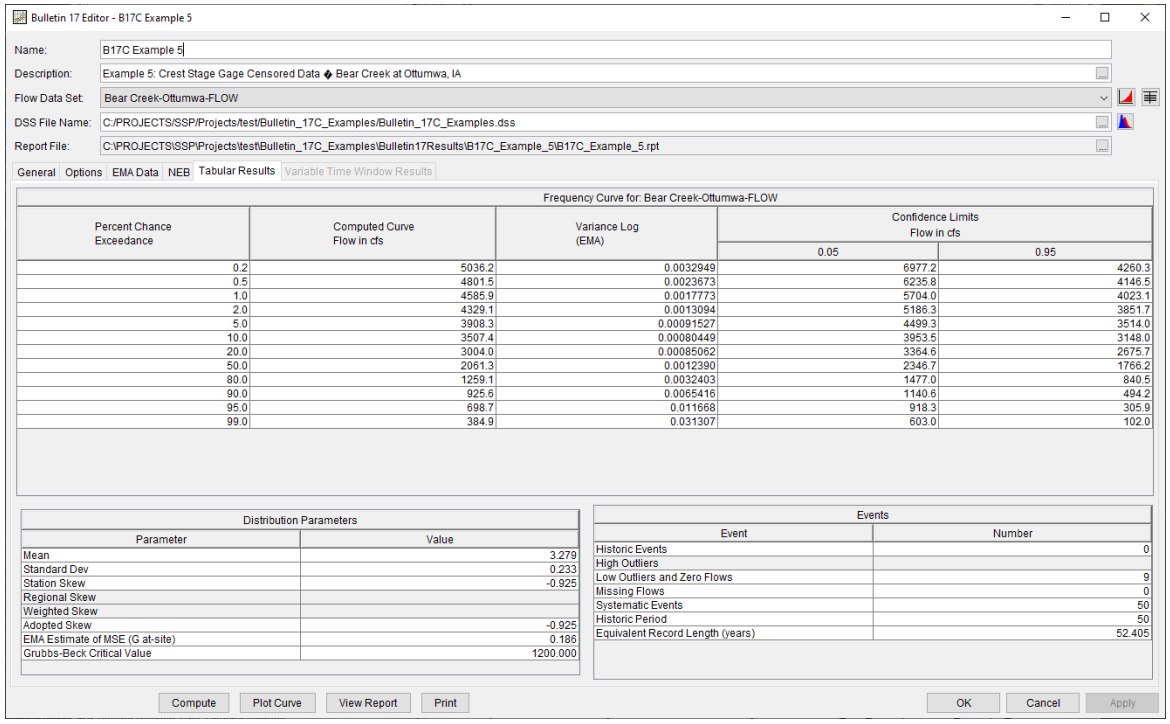
No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3. This example uses an annual maximum series consisting entirely of systematic data. However, physical changes to the actual gage base (i.e. minimum recordable flow rate) occurred in 1973, 1992, 2002, 2003, 2004, 2006, 2010, and 2013. To take the possibility of annual peak flows occurring below the gage base into account

within the EMA framework, perception thresholds are required for each change in the gage base, replacing the typical low value of zero for systematic observations with a low value equal to the gage base. For instance, the gage base was lowered from the initial setting of 1180 cfs to a gage base of 705 cfs in 1973. The next gage base change occurred in 1992. This requires a perception threshold of 705 – inf for water year 1973 through water year 1991. For information related to a specific crest stage gage, such as the gage base, consult your local USGS office. A total of nine different gage bases have been in effect for this gage. Including the first perception threshold (which sets the start and end year of the analysis), this requires a total of 10 perception thresholds. Once all perception thresholds have been entered as shown in Figure 3 (see page 102), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

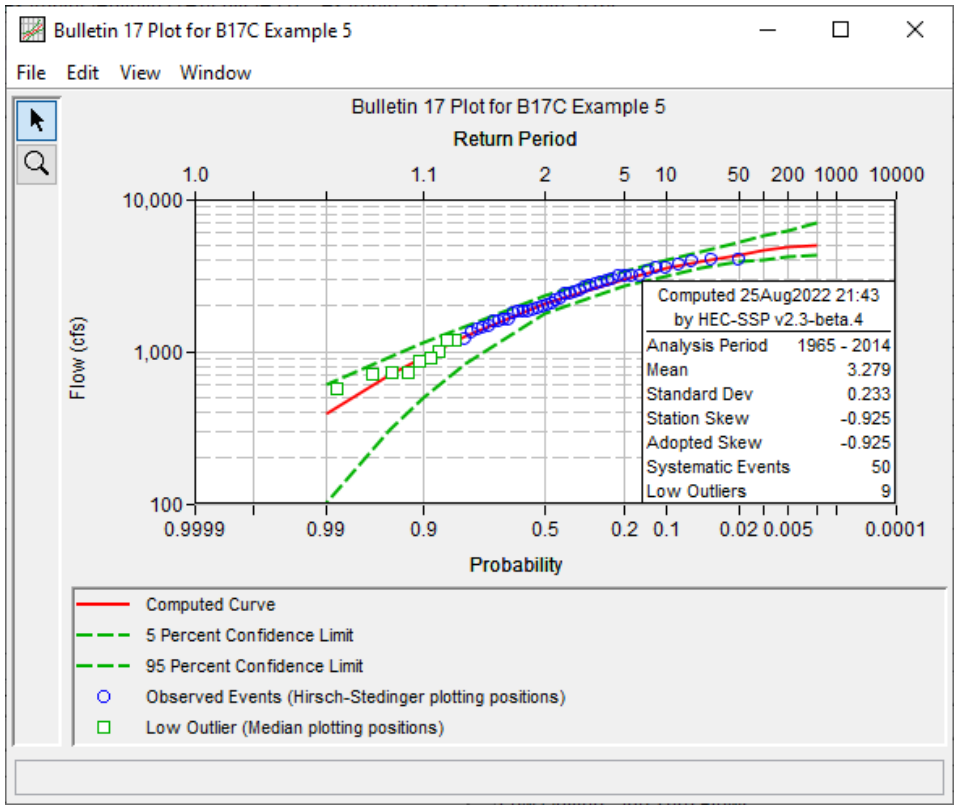
A peak flow rate below the gage base occurred in 1966, 1971, 1975, 1988, 1997, and 2006, as signified by the USGS qualification code of 4. This implies that the actual annual peak flow rate could have been between zero and whatever the gage base was at the time. This information requires a change to the flow range table. For each of these years, a low value of zero and high value of whatever the gage base was at the time should be entered. For instance, in water year 1966, the annual peak flow rate was below the gage base of 1180 cfs. Therefore, the flow range for that year should be entered as zero – 1180, as shown in Figure 3 (see page 102). The other five water years in which an annual peak flow was below the recordable limit should be entered in a similar fashion within the flow range table.



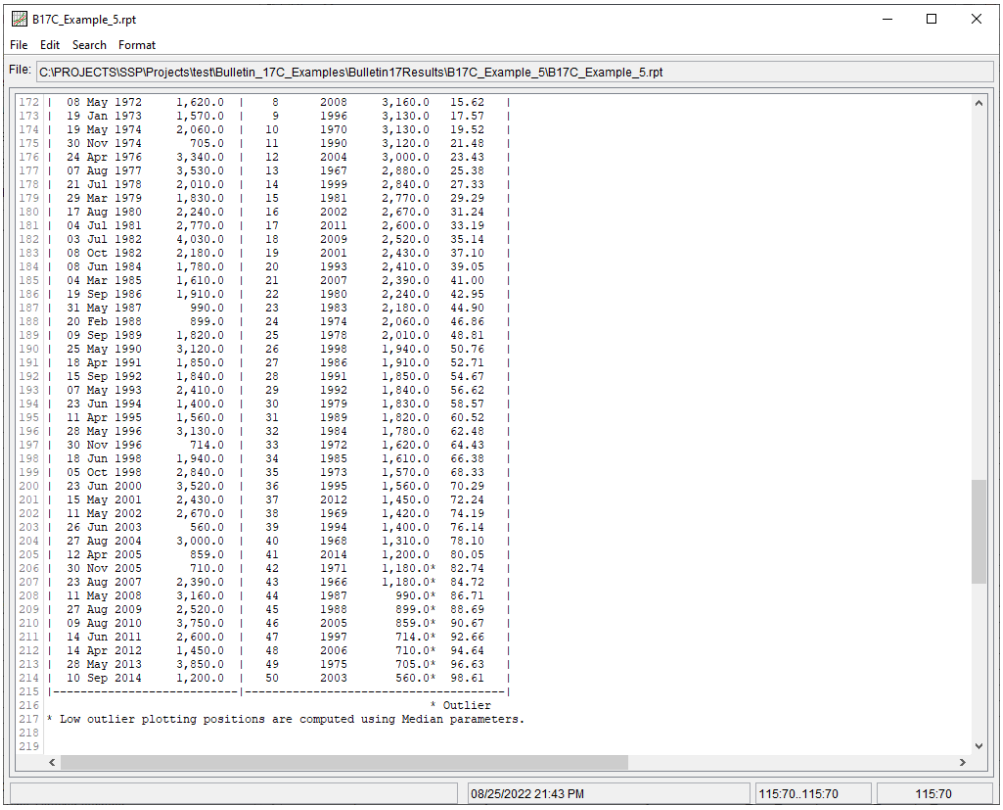
Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 102).



In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed plotting positions are shown in Figure 5 (see page 103).

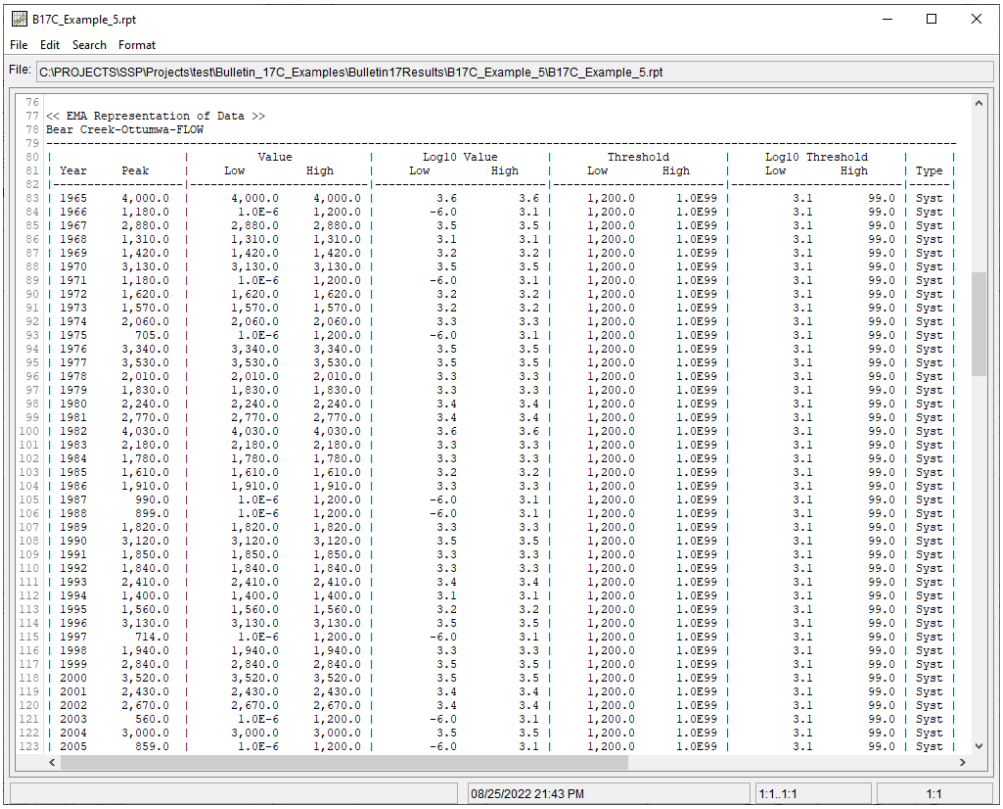


As shown in Figure 4 (see page 102), the Multiple Grubbs-Beck Test identified a low outlier threshold (critical value) of 1200 cfs, which corresponds to the smallest peak that was retained. Nine annual peak flows were identified and censored, as shown in Figure 6 (see page 104). These annual peak flows were then recoded to have a flow interval of zero – 1200. The perception threshold for all systematic observations were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (i.e. 1200 – inf), as shown in Figure 7 (see page 104).



172	08 May 1972	1,620.0	8	2008	3,160.0	15.62	
173	19 Jan 1973	1,570.0	9	1996	3,130.0	17.57	
174	19 May 1974	2,060.0	10	1970	3,130.0	19.52	
175	30 Nov 1974	705.0	11	1990	3,120.0	21.48	
176	24 Apr 1976	3,340.0	12	2004	3,000.0	23.43	
177	07 Aug 1977	3,530.0	13	1967	2,880.0	25.38	
178	21 Jul 1978	2,010.0	14	1999	2,840.0	27.33	
179	29 Mar 1979	1,830.0	15	1981	2,770.0	29.29	
180	17 Aug 1980	2,240.0	16	2002	2,670.0	31.24	
181	04 Jul 1981	2,770.0	17	2011	2,600.0	33.19	
182	03 Jul 1982	4,030.0	18	2009	2,520.0	35.14	
183	08 Oct 1982	2,180.0	19	2001	2,430.0	37.10	
184	08 Jun 1984	1,780.0	20	1993	2,410.0	39.05	
185	04 Mar 1985	1,610.0	21	2007	2,390.0	41.00	
186	19 Sep 1986	1,910.0	22	1980	2,240.0	42.95	
187	31 May 1987	990.0	23	1983	2,180.0	44.90	
188	20 Feb 1988	899.0	24	1974	2,060.0	46.86	
189	09 Sep 1989	1,820.0	25	1978	2,010.0	48.81	
190	25 May 1990	3,120.0	26	1998	1,940.0	50.76	
191	18 Apr 1991	1,850.0	27	1986	1,910.0	52.71	
192	15 Sep 1992	1,840.0	28	1991	1,850.0	54.67	
193	07 May 1993	2,410.0	29	1992	1,840.0	56.62	
194	23 Jun 1994	1,400.0	30	1979	1,830.0	58.57	
195	11 Apr 1995	1,560.0	31	1989	1,820.0	60.52	
196	28 May 1996	3,130.0	32	1984	1,780.0	62.48	
197	30 Nov 1996	714.0	33	1972	1,620.0	64.43	
198	18 Jun 1998	1,940.0	34	1985	1,610.0	66.38	
199	05 Oct 1998	2,840.0	35	1973	1,570.0	68.33	
200	23 Jun 2000	3,520.0	36	1995	1,560.0	70.29	
201	15 May 2001	2,430.0	37	2012	1,450.0	72.24	
202	11 May 2002	2,670.0	38	1969	1,420.0	74.19	
203	26 Jun 2003	560.0	39	1994	1,400.0	76.14	
204	27 Aug 2004	3,000.0	40	1968	1,310.0	78.10	
205	12 Apr 2005	859.0	41	2014	1,200.0	80.05	
206	30 Nov 2005	710.0	42	1971	1,180.0*	82.74	
207	23 Aug 2007	2,390.0	43	1966	1,180.0*	84.72	
208	11 May 2008	3,160.0	44	1987	990.0*	86.71	
209	27 Aug 2009	2,520.0	45	1988	899.0*	88.69	
210	09 Aug 2010	3,750.0	46	2005	859.0*	90.67	
211	14 Jun 2011	2,600.0	47	1997	714.0*	92.66	
212	14 Apr 2012	1,450.0	48	2006	710.0*	94.64	
213	28 May 2013	3,850.0	49	1975	705.0*	96.63	
214	10 Sep 2014	1,200.0	50	2003	560.0*	98.61	
215							
216						* Outlier	
217	* Low outlier plotting positions are computed using Median parameters.						
218							
219							

48 Figure 6. Report File for B17C Example 5 showing censored low outliers.Figure 7. Report File for B17C Example 5 showing recoded perception thresholds.



B17C_Example_5.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_5\B17C_Example_5.rpt

<< EMA Representation of Data >>

Bear Creek-Ottumwa-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1965	4,000.0	4,000.0	4,000.0	3.6	3.6	1,200.0	1.0E99	3.1	99.0	Syst
1966	1,180.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1967	2,880.0	2,880.0	2,880.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1968	1,310.0	1,310.0	1,310.0	3.1	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1969	1,420.0	1,420.0	1,420.0	3.2	3.2	1,200.0	1.0E99	3.1	99.0	Syst
1970	3,130.0	3,130.0	3,130.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1971	1,180.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1972	1,620.0	1,620.0	1,620.0	3.2	3.2	1,200.0	1.0E99	3.1	99.0	Syst
1973	1,570.0	1,570.0	1,570.0	3.2	3.2	1,200.0	1.0E99	3.1	99.0	Syst
1974	2,060.0	2,060.0	2,060.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1975	705.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1976	3,340.0	3,340.0	3,340.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1977	3,530.0	3,530.0	3,530.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1978	2,010.0	2,010.0	2,010.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1979	1,830.0	1,830.0	1,830.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1980	2,240.0	2,240.0	2,240.0	3.4	3.4	1,200.0	1.0E99	3.1	99.0	Syst
1981	2,770.0	2,770.0	2,770.0	3.4	3.4	1,200.0	1.0E99	3.1	99.0	Syst
1982	4,030.0	4,030.0	4,030.0	3.6	3.6	1,200.0	1.0E99	3.1	99.0	Syst
1983	2,180.0	2,180.0	2,180.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1984	1,780.0	1,780.0	1,780.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1985	1,610.0	1,610.0	1,610.0	3.2	3.2	1,200.0	1.0E99	3.1	99.0	Syst
1986	1,910.0	1,910.0	1,910.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1987	990.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1988	899.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1989	1,820.0	1,820.0	1,820.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1990	3,120.0	3,120.0	3,120.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1991	1,850.0	1,850.0	1,850.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1992	1,840.0	1,840.0	1,840.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1993	2,410.0	2,410.0	2,410.0	3.4	3.4	1,200.0	1.0E99	3.1	99.0	Syst
1994	1,400.0	1,400.0	1,400.0	3.1	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1995	1,560.0	1,560.0	1,560.0	3.2	3.2	1,200.0	1.0E99	3.1	99.0	Syst
1996	3,130.0	3,130.0	3,130.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
1997	714.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
1998	1,940.0	1,940.0	1,940.0	3.3	3.3	1,200.0	1.0E99	3.1	99.0	Syst
1999	2,840.0	2,840.0	2,840.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
2000	3,520.0	3,520.0	3,520.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
2001	2,430.0	2,430.0	2,430.0	3.4	3.4	1,200.0	1.0E99	3.1	99.0	Syst
2002	2,670.0	2,670.0	2,670.0	3.4	3.4	1,200.0	1.0E99	3.1	99.0	Syst
2003	560.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst
2004	3,000.0	3,000.0	3,000.0	3.5	3.5	1,200.0	1.0E99	3.1	99.0	Syst
2005	859.0	1.0E-6	1,200.0	-6.0	3.1	1,200.0	1.0E99	3.1	99.0	Syst

08/25/2022 21:43 PM 1:1..1:1 1:1

49 Figure 7. Report File for B17C Example 5 showing recoded perception thresholds.

3.7 Example 6. Historic Data and Low Outliers – Santa Cruz River at Lochiel, AZ

Example 6 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures with an annual maximum series comprised of systematic data and historical flood information that can be used to extend the historical period. For this example, USGS gage 09480000 Santa Cruz River near Lochiel, AZ is used. The stream gage in question has an approximate 82.2 sq. mi. contributing watershed with an annual peak record consisting of 65 peaks beginning in water year 1949 and ending in water year 2013. A large flood event occurred on October 9, 1977. This flood is noted in the USGS Annual Water Data Report for this gage and there is historical information available for this large flood indicating that this flood is the largest since 1927 (Aldridge & Eychaner, 1984). Of the 65 annual peaks, the August 15, 1984 flood is equal to the October 1977 historic flood peak. Based on information contained within Aldridge and Eychaner (1984) for the October 1977 flood, this event can be used as a perception threshold to represent the 22 years of missing information from 1927 to 1946. The annual maximum series is plotted in Figure 1 (see page 105) and tabulated in Table 1.

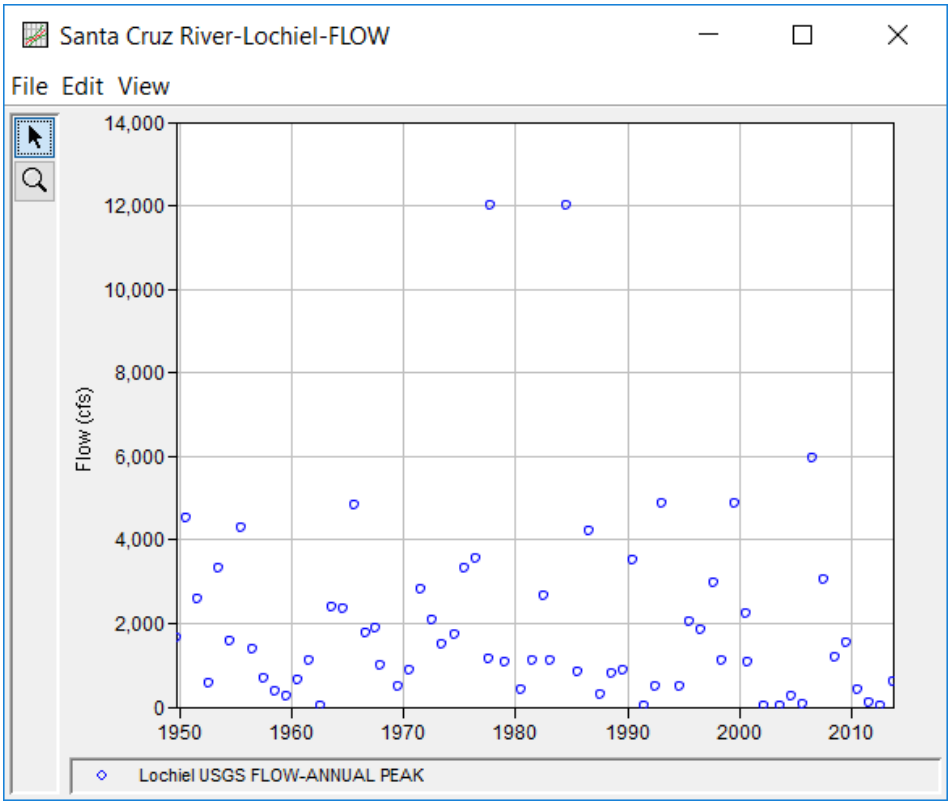


Table 1. Santa Cruz River at Lochiel, AZ Annual Peak Flow Record.

Date	Flow (cfs)
13 Sep 1949	1650
30 Jul 1950	4520
02 Aug 1951	2560
16 Aug 1952	550
14 Jul 1953	3320
22 Jul 1954	1570
06 Aug 1955	4300
17 Jul 1956	1360

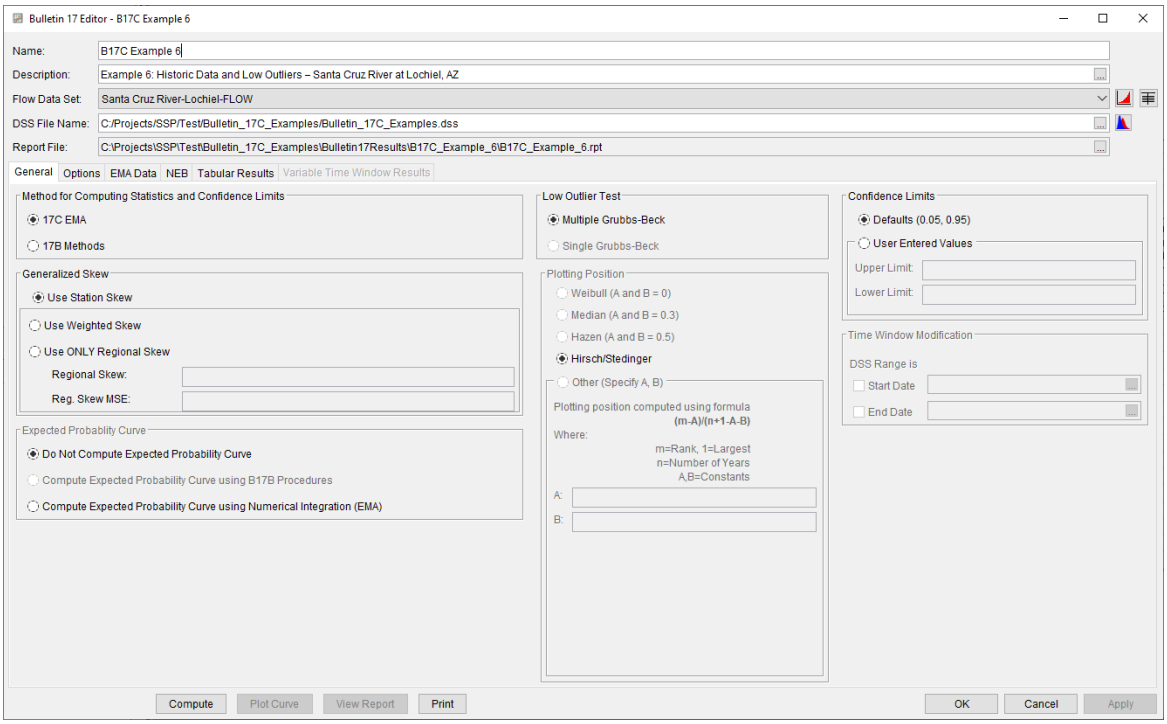
Date	Flow (cfs)
09 Aug 1957	688
07 Aug 1958	380
14 Aug 1959	243
30 Jul 1960	625
08 Aug 1961	1120
29 Jul 1962	8
25 Aug 1963	2390
09 Sep 1964	2330
12 Sep 1965	4810
18 Aug 1966	1780
03 Aug 1967	1870
20 Dec 1967	986
05 Aug 1969	484
03 Aug 1970	880
10 Aug 1971	2830
16 Jul 1972	2070
30 Jun 1973	1490
04 Aug 1974	1730

Date	Flow (cfs)
22 Jul 1975	3330
22 Jul 1976	3540
05 Sep 1977	1130
09 Oct 1977	12000
25 Jan 1979	1060
30 Jun 1980	406
15 Jul 1981	1110
11 Aug 1982	2640
04 Mar 1983	1120
15 Aug 1984	12000
19 Jul 1985	850
29 Aug 1986	4210
10 Aug 1987	291
23 Aug 1988	804
04 Aug 1989	871
17 Jul 1990	3510
26 Jul 1991	17
01 Aug 1992	483

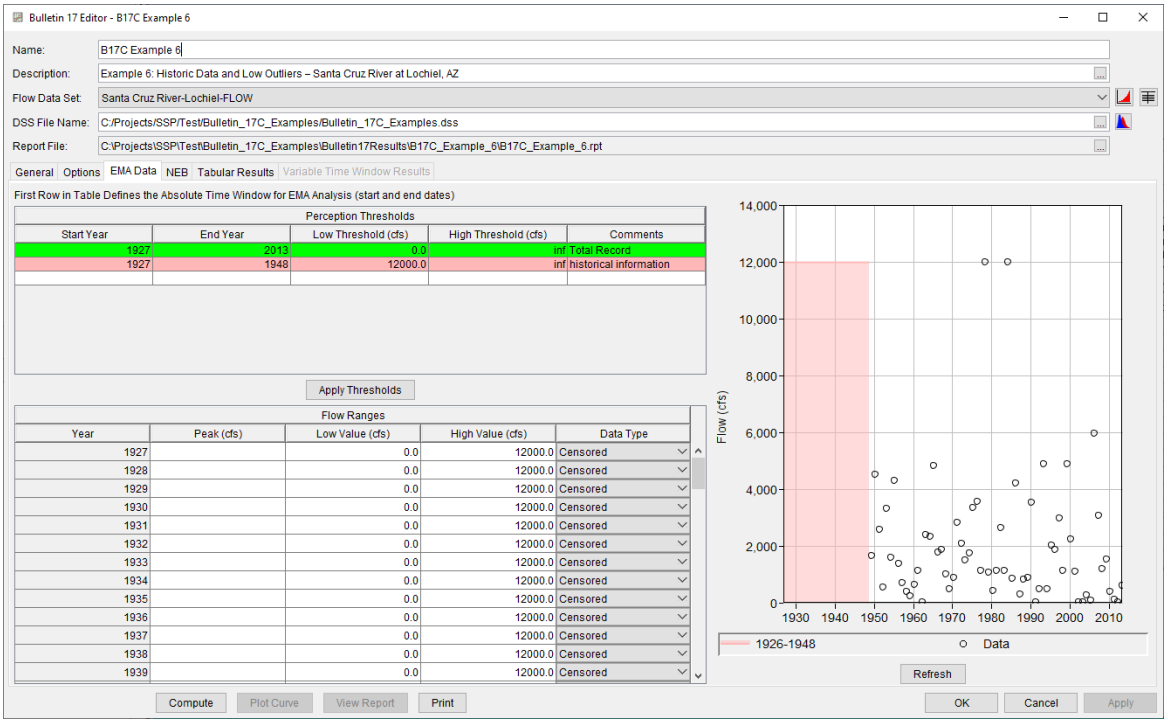
Date	Flow (cfs)
18 Jan 1993	4880
30 Aug 1994	478
12 Jul 1995	2020
10 Jul 1996	1860
11 Sep 1997	2970
07 Jul 1998	1110
28 Jul 1999	4870
06 Aug 2000	2240
22 Oct 2000	1080
04 Mar 2002	2
14 Aug 2003	22
05 Aug 2004	256
23 Aug 2005	73
08 Aug 2006	5940
19 Jul 2007	3060
23 Jul 2008	1180
01 Jul 2009	1530
31 Jul 2010	392

Date	Flow (cfs)
13 Aug 2011	95
28 Jul 2012	12
08 Sep 2013	612

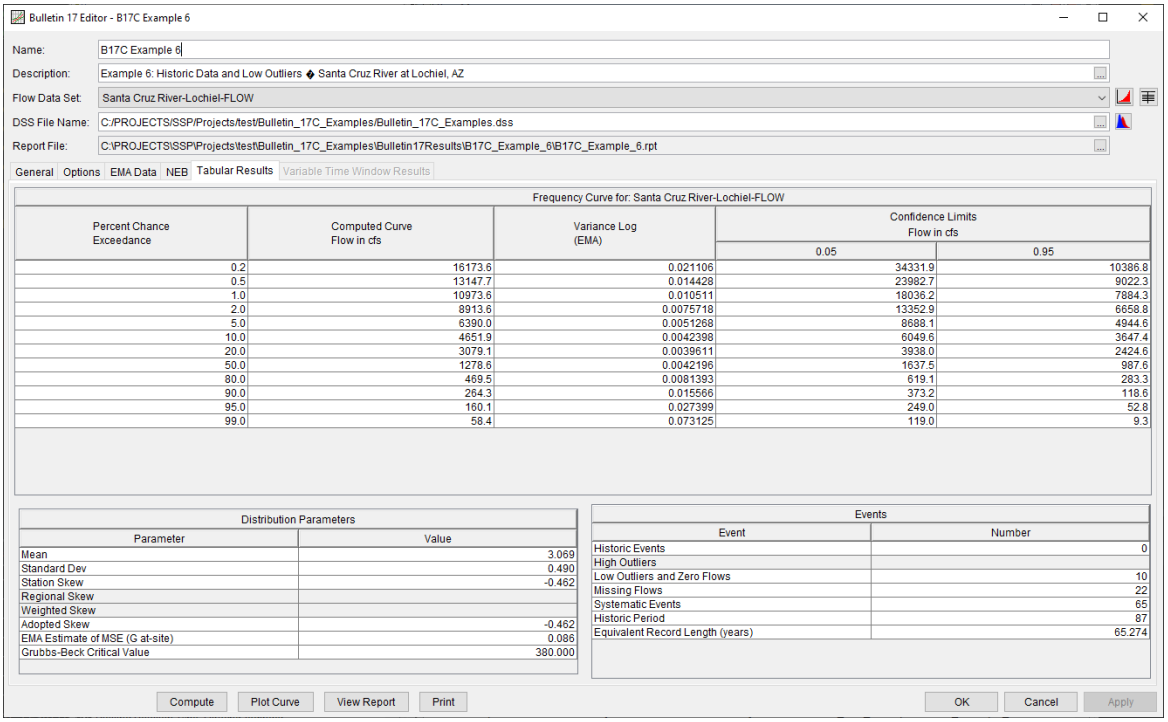
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 6**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 6**" from the list of available analyses. When "B17C Example 6" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 110). As shown, the **Skew** option was set to use the **Station Skew**.



No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 110). This example uses an annual maximum series consisting of systematic data along with historical information. As was previously mentioned, historical information indicates that the October 1977 flood event was the largest since at least 1927. This information can be used within EMA to extend the historical period through the use of a perception threshold. Specifically, the first perception threshold should be modified to start at water year 1927. Then, a second perception threshold of 12000 – inf should be added for the period of missing data spanning water years 1927 through 1948, as shown in Figure 3 (see page 110). Once both perception thresholds have been entered, click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data. No further changes to the flow range table are necessary.

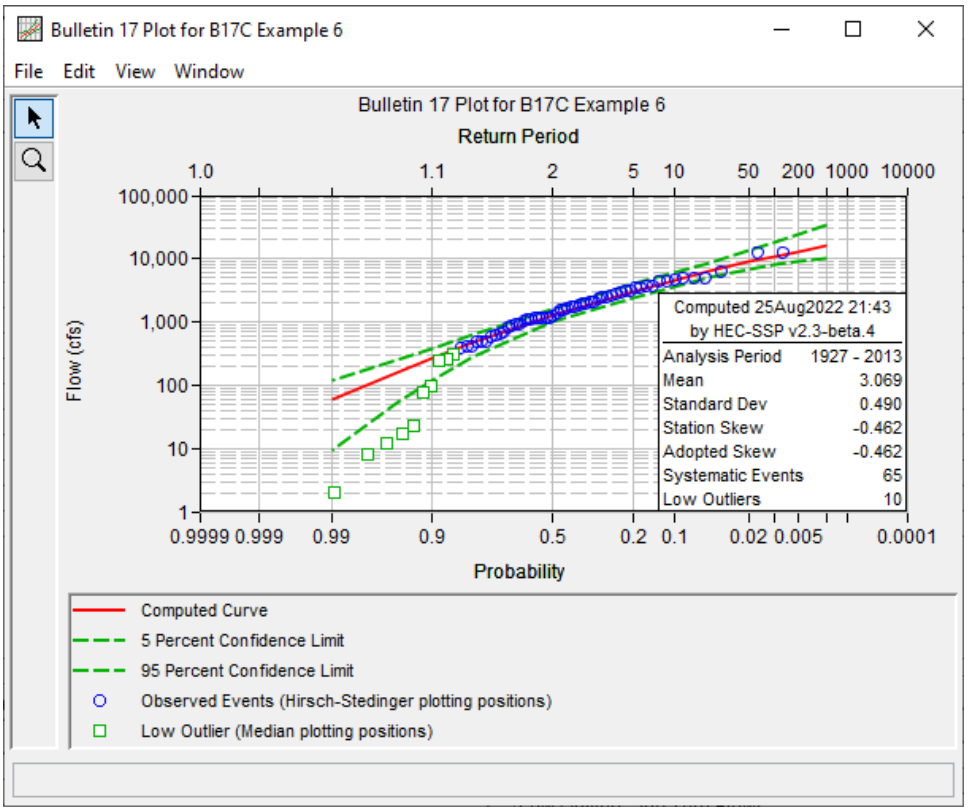


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 111).

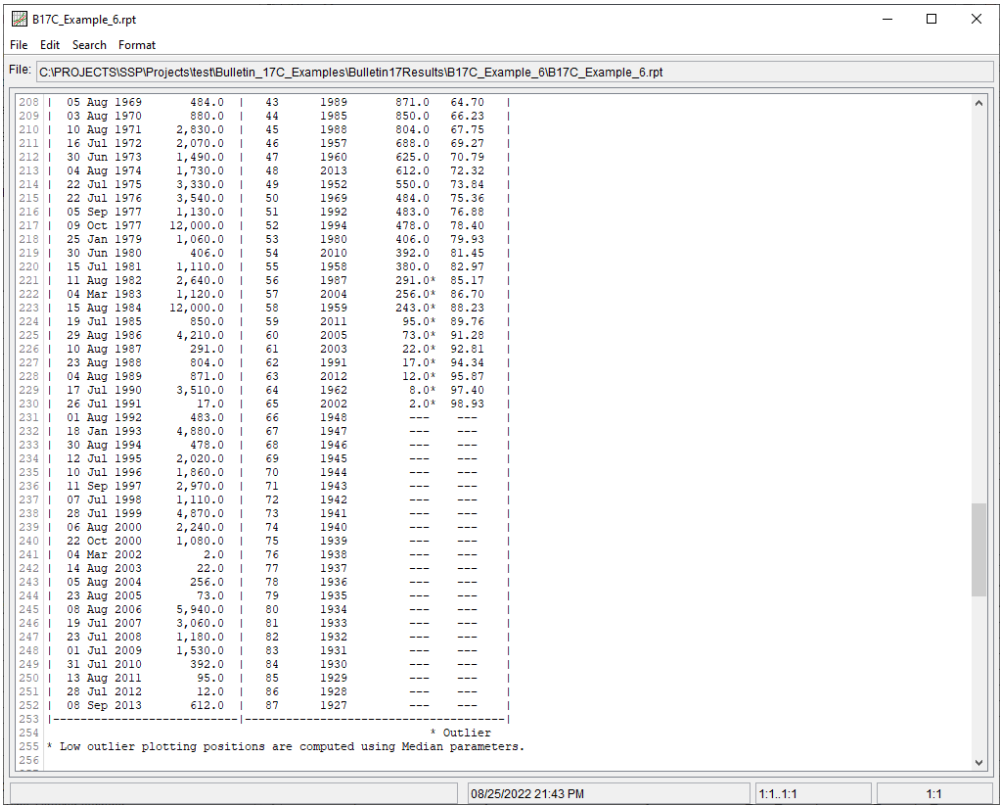


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed

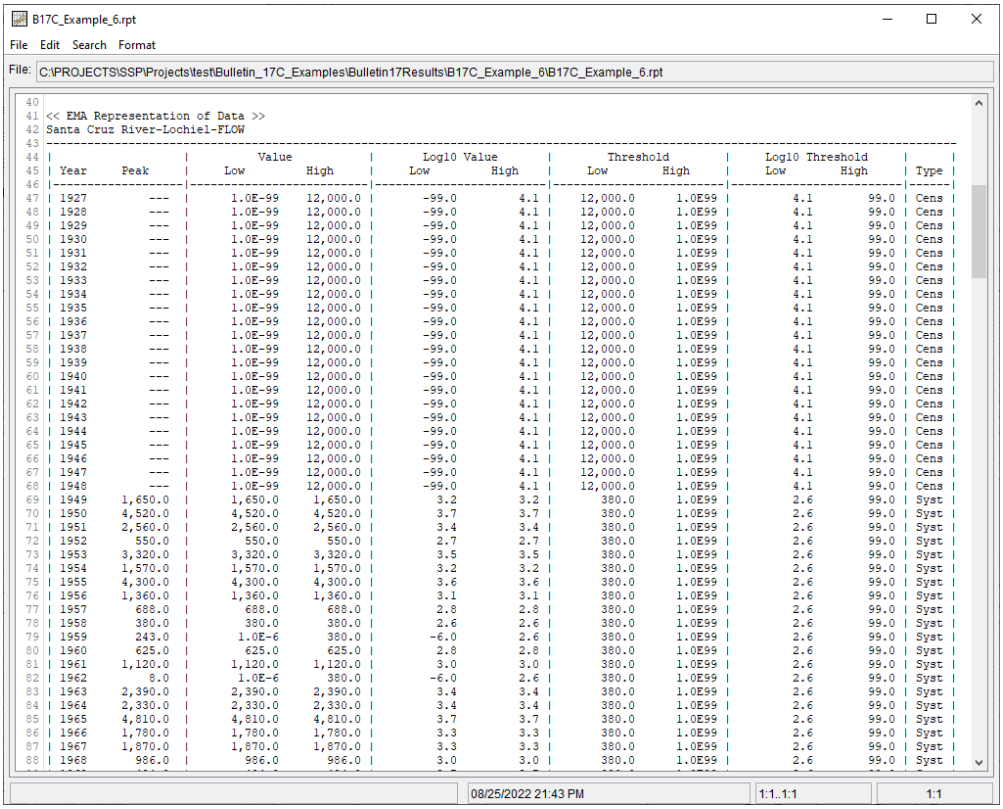
plotting positions are shown in Figure 5 (see page 112).



As shown in Figure 4 (see page 111), the Multiple Grubbs-Beck Test identified a low outlier threshold (critical value) of 380 cfs, which corresponds to the smallest peak that was retained. Ten annual peak flows were identified and censored, as shown in Figure 6 (see page 112). These annual peak flows were then recoded to have a flow interval of zero – 380. The perception threshold for all systematic observations were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (i.e. 380 – inf). The perception threshold for the years in which there is only historical nonexceedance data (i.e. 1927 – 1948) were left at 12,000 - inf, as shown in Figure 7 (see page 113).



50 Figure 6. Report File for B17C Example 6 showing censored low outliers.



B17C_Example_6.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_6\B17C_Example_6.rpt

<< EMA Representation of Data >>
Santa Cruz River-Lochiel-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1927	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1928	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1929	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1930	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1931	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1932	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1933	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1934	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1935	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1936	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1937	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1938	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1939	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1940	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1941	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1942	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1943	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1944	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1945	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1946	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1947	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1948	---	1.0E-99	12,000.0	-99.0	4.1	12,000.0	1.0E99	4.1	99.0	Cens
1949	1,650.0	1,650.0	1,650.0	3.2	3.2	380.0	1.0E99	2.6	99.0	Syst
1950	4,520.0	4,520.0	4,520.0	3.7	3.7	380.0	1.0E99	2.6	99.0	Syst
1951	2,560.0	2,560.0	2,560.0	3.4	3.4	380.0	1.0E99	2.6	99.0	Syst
1952	550.0	550.0	550.0	2.7	2.7	380.0	1.0E99	2.6	99.0	Syst
1953	3,320.0	3,320.0	3,320.0	3.5	3.5	380.0	1.0E99	2.6	99.0	Syst
1954	1,570.0	1,570.0	1,570.0	3.2	3.2	380.0	1.0E99	2.6	99.0	Syst
1955	4,300.0	4,300.0	4,300.0	3.6	3.6	380.0	1.0E99	2.6	99.0	Syst
1956	1,360.0	1,360.0	1,360.0	3.1	3.1	380.0	1.0E99	2.6	99.0	Syst
1957	688.0	688.0	688.0	2.8	2.8	380.0	1.0E99	2.6	99.0	Syst
1958	380.0	380.0	380.0	2.6	2.6	380.0	1.0E99	2.6	99.0	Syst
1959	243.0	1.0E-6	380.0	-6.0	2.6	380.0	1.0E99	2.6	99.0	Syst
1960	625.0	625.0	625.0	2.8	2.8	380.0	1.0E99	2.6	99.0	Syst
1961	1,120.0	1,120.0	1,120.0	3.0	3.0	380.0	1.0E99	2.6	99.0	Syst
1962	8.0	1.0E-6	380.0	-6.0	2.6	380.0	1.0E99	2.6	99.0	Syst
1963	2,390.0	2,390.0	2,390.0	3.4	3.4	380.0	1.0E99	2.6	99.0	Syst
1964	2,330.0	2,330.0	2,330.0	3.4	3.4	380.0	1.0E99	2.6	99.0	Syst
1965	4,810.0	4,810.0	4,810.0	3.7	3.7	380.0	1.0E99	2.6	99.0	Syst
1966	1,780.0	1,780.0	1,780.0	3.3	3.3	380.0	1.0E99	2.6	99.0	Syst
1967	1,870.0	1,870.0	1,870.0	3.3	3.3	380.0	1.0E99	2.6	99.0	Syst
1968	986.0	986.0	986.0	3.0	3.0	380.0	1.0E99	2.6	99.0	Syst

08/25/2022 21:43 PM 1:1..1:1 1:1

51 Figure 7. Report File for B17C Example 6 showing recoded perception thresholds.

3.8 Example 7. User Overrides (Low Outliers and Confidence Limits) – Rapid Creek above Canyon Lake near Rapid City, SD

Example 7 illustrates the computation of a peak flow frequency curve using EMA and Bulletin 17C procedures when a low outlier threshold and confidence limits are specified by the user. The data for this example comes from the USGS gage 06412500 Rapid Creek above Canyon Lake near Rapid City, South Dakota. Pactola Dam, which is located upstream of this stream gage, controls approximately 321 sq mi. As such, regulation effects were removed from the period of record. The annual maximum series for this example contains 90 peaks beginning in 1878 and ending in 2009. Information pertaining to 27 events not contained within the systematic record were sourced from a USGS report[41] (Harden, O'Connor, Driscoll, & Stamm, 2011). Within this record, the June 1972 flood is by far the largest observed event. In fact, the June 1972 flood event is nearly 2.5 times larger than the next largest historical flood event and approximately 12 times larger than the next largest systematic (i.e. gaged) flood event at this location (Schwarz, Hughes, Hansen, Petersen, & Kelly, 1975). The annual maximum series is plotted in Figure 1 (see page 114) and tabulated in Table 1.

41 https://pubs.usgs.gov/sir/2011/5131/

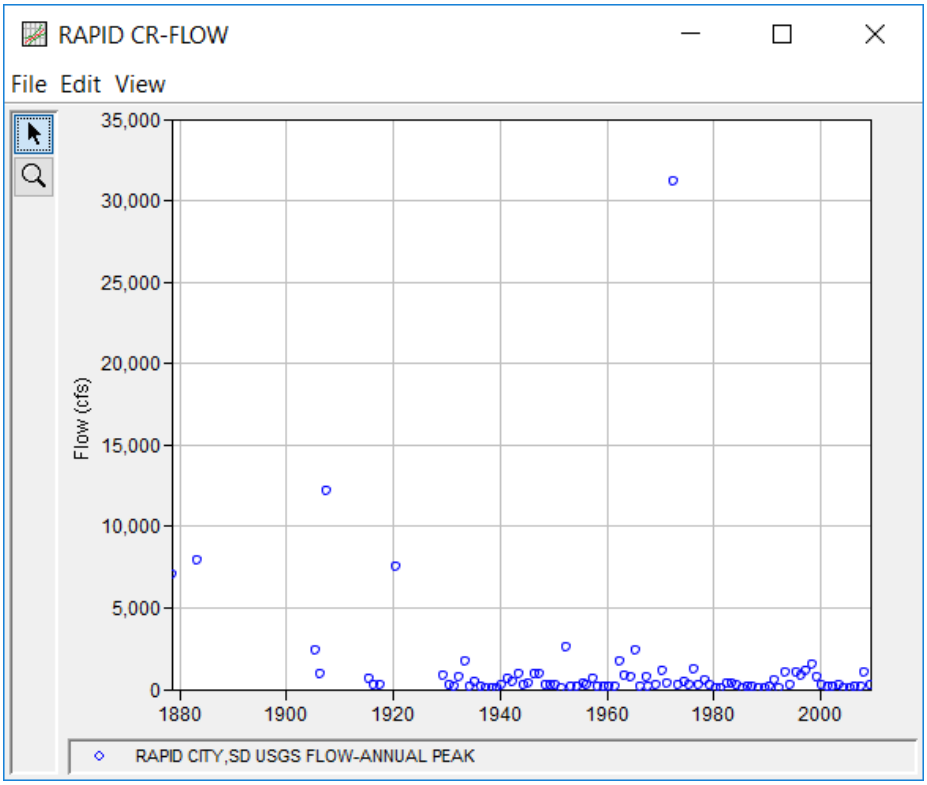


Table 1. Rapid Creek above Canyon Lake near Rapid City, SD Annual Peak Flow Record.

Date	Flow (cfs)
1878	7060
1883	7900
1905	2350
1906	922
1907	12200
1915	654
1916	217
1917	287

Date	Flow (cfs)
1920	7540
1929	870
1930	213
1931	170
1932	747
1933	1690
1934	128
1935	479
1936	110
1937	92
1938	94
1939	68
1940	268
1941	592
1942	448
1943	882
1944	254
1945	359

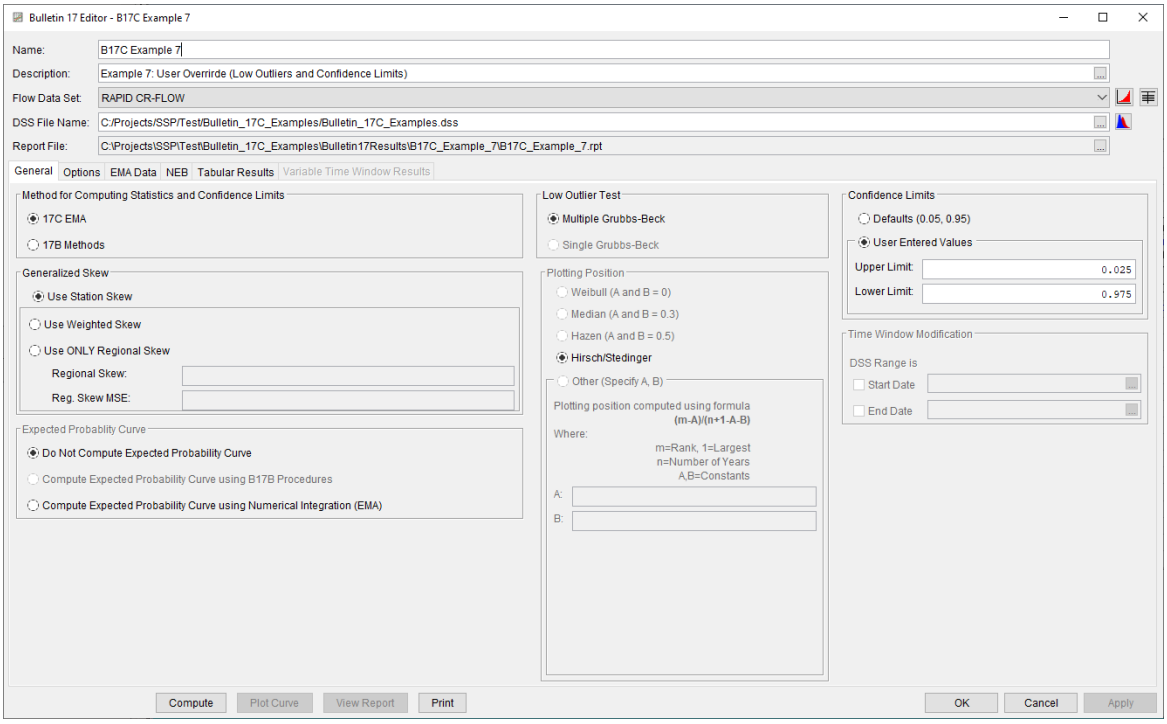
Date	Flow (cfs)
1946	943
23 Jun 1947	950
22 Jun 1948	245
15 Aug 1949	290
15 Apr 1950	209
15 Jun 1951	77
23 May 1952	2600
16 Jun 1953	152
12 Aug 1954	140
29 Jul 1955	326
29 May 1956	203
14 Jul 1957	595
30 May 1958	131
30 Jun 1959	169
16 Jul 1960	135
01 Jul 1961	111
13 Jul 1962	1700
06 Jun 1963	827

Date	Flow (cfs)
11 Jun 1964	735
19 May 1965	2380
22 Mar 1966	174
15 Jun 1967	726
04 Oct 1967	123
20 May 1969	246
14 Jun 1970	1150
26 Apr 1971	353
09 Jun 1972	31200
09 May 1973	196
22 Aug 1974	476
07 Jun 1975	253
15 Jun 1976	1220
08 May 1977	216
21 May 1978	498
17 Jun 1979	200
16 Jul 1980	87
13 Jul 1981	96

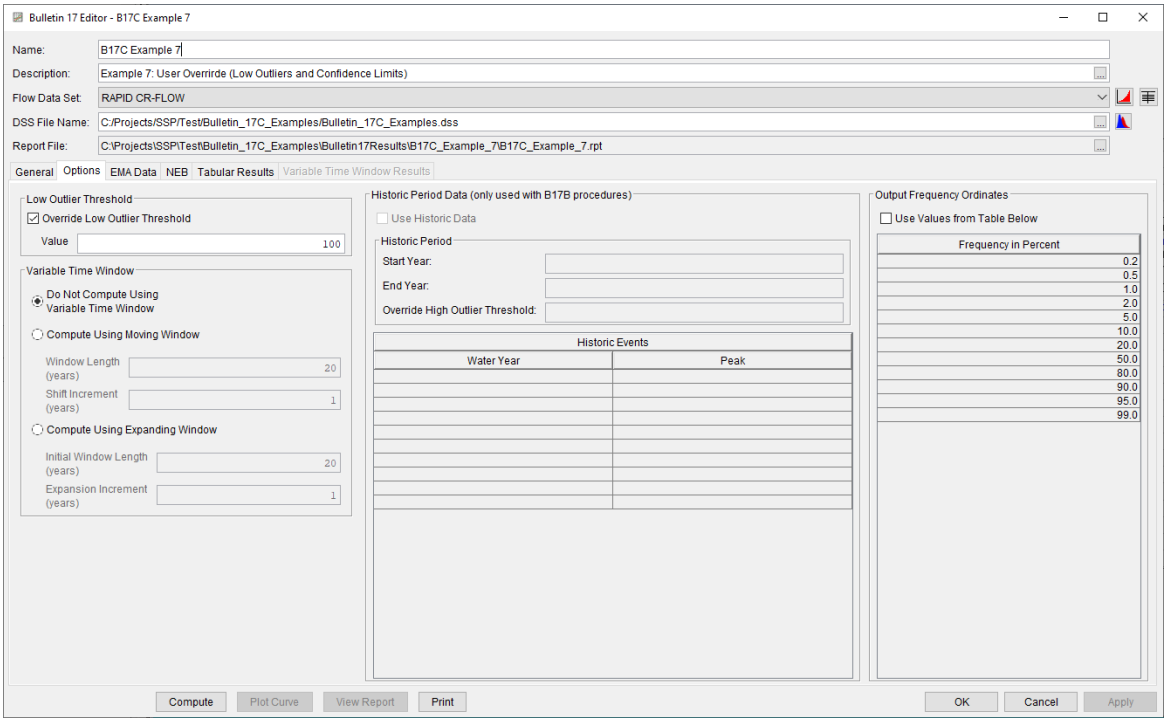
Date	Flow (cfs)
22 Jul 1982	384
11 May 1983	303
15 Jun 1984	229
15 Jul 1985	87
04 Jun 1986	142
29 May 1987	115
03 Aug 1988	80
12 Jul 1989	64
07 Jul 1990	108
11 May 1991	487
21 May 1992	64
20 Jun 1993	1000
29 Apr 1994	227
09 Jun 1995	1020
01 Jun 1996	823
02 Jun 1997	1090
24 Jun 1998	1490
16 Jun 1999	698

Date	Flow (cfs)
20 May 2000	264
15 Jul 2001	131
06 Jul 2002	159
21 Jun 2003	243
01 Jul 2004	67
10 Jul 2005	61
07 Aug 2006	104
17 Aug 2007	177
24 May 2008	1000
26 Apr 2009	277

A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 7**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 7**" from the list of available analyses. When "B17C Example 7" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 120). As shown, the **Skew** option was set to use the **Station Skew** and the default confidence limits were modified to **0.025** and **0.975** to produce a 95% confidence interval.

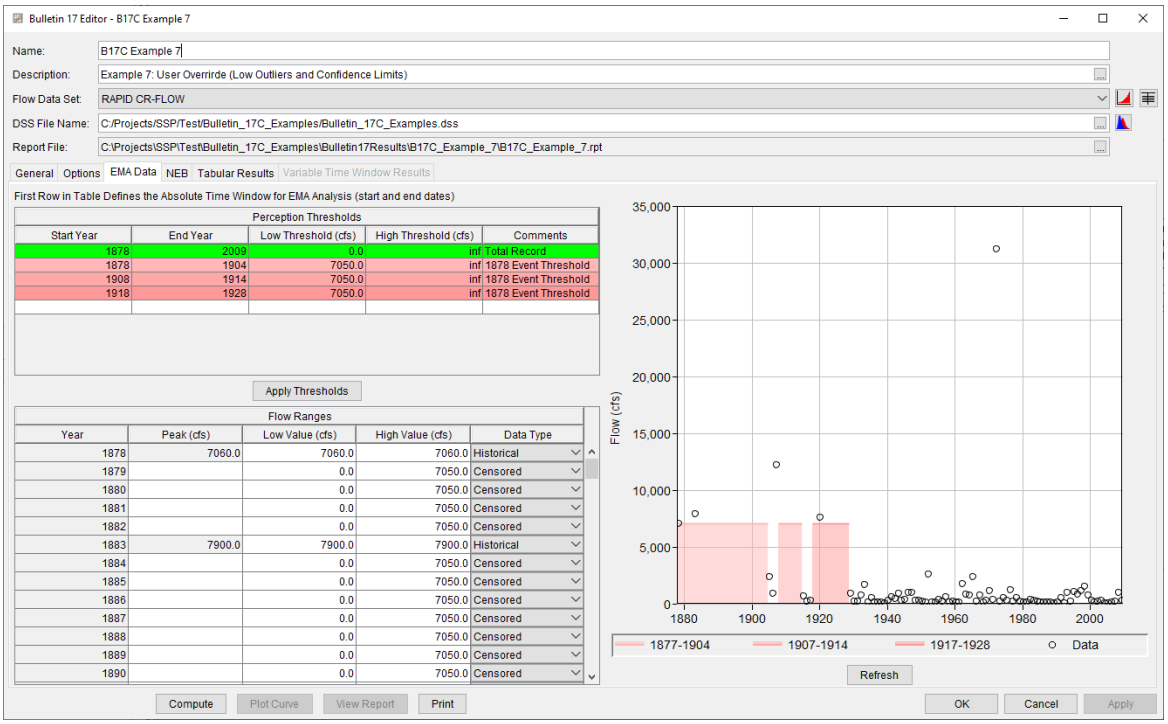


A low outlier threshold of **100** cfs was specified on the **Options** tab, as shown in Figure 3 (see page 120). This low outlier threshold was selected to censor more information than the default Grubbs-Beck critical value. When using this option, careful attention should be paid to the selection of the specified low outlier threshold as the resultant parameter estimation can be heavily impacted.

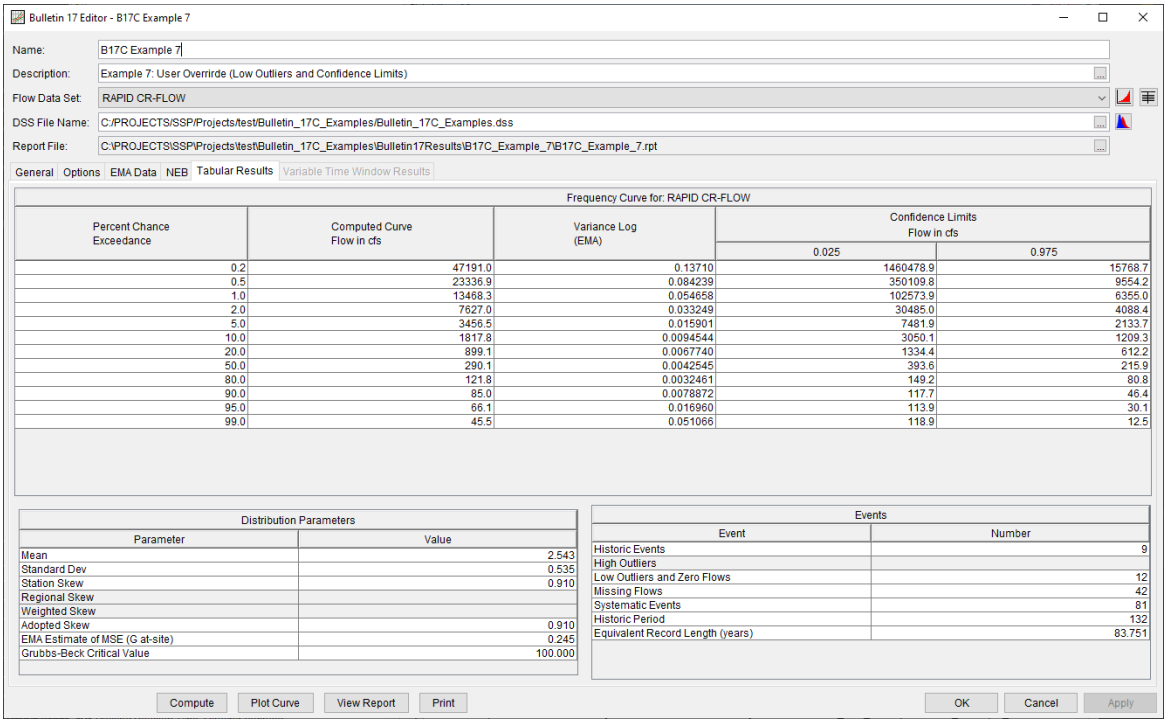


The **EMA Data** tab for this example is shown in Figure 4 (see page 122). This example uses an annual maximum series consisting of systematic and historical data with several missing periods. The missing periods span 1879 – 1882, 1884 – 1904, 1908 – 1914, 1918 – 1919, and 1921 – 1928. Since 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data, a total of four perception thresholds are required.

In this example, the June 1878 event can be used to inform the perception threshold for the missing periods of annual peak flow data. The use of a perception threshold of 7050 – inf for this period implies that had a flood event occurred with a peak flow greater than 7050 cfs, someone would have measured and recorded it. This value was chosen because historical events of this magnitude were in fact recorded. Once all four perception thresholds have been entered as shown in Figure 4 (see page 121), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

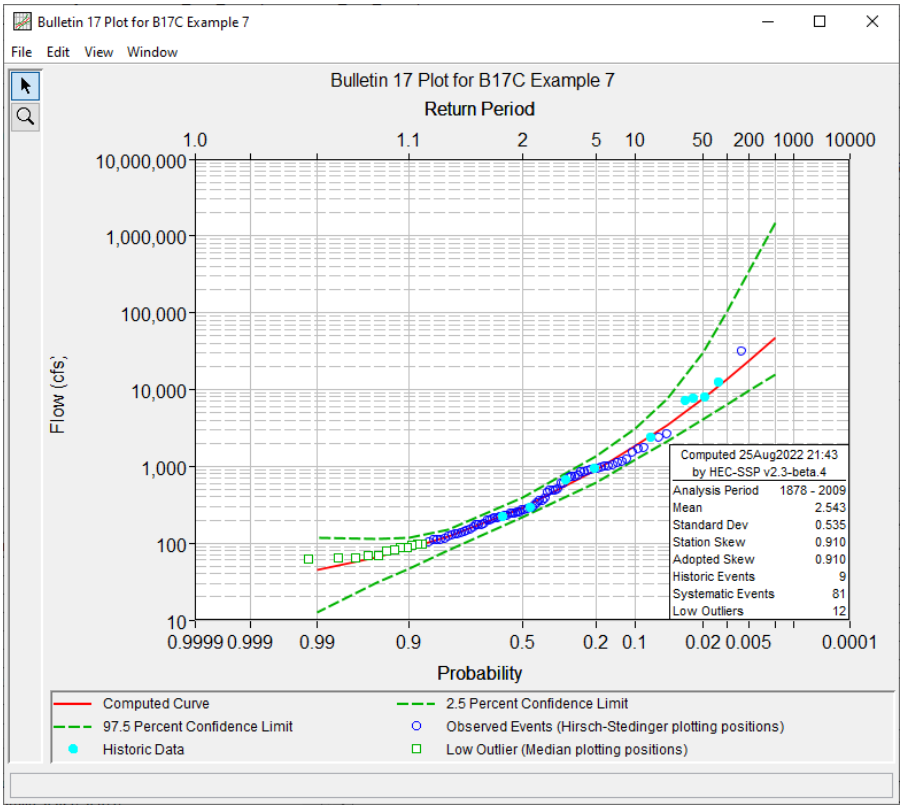


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 5 (see page 122).

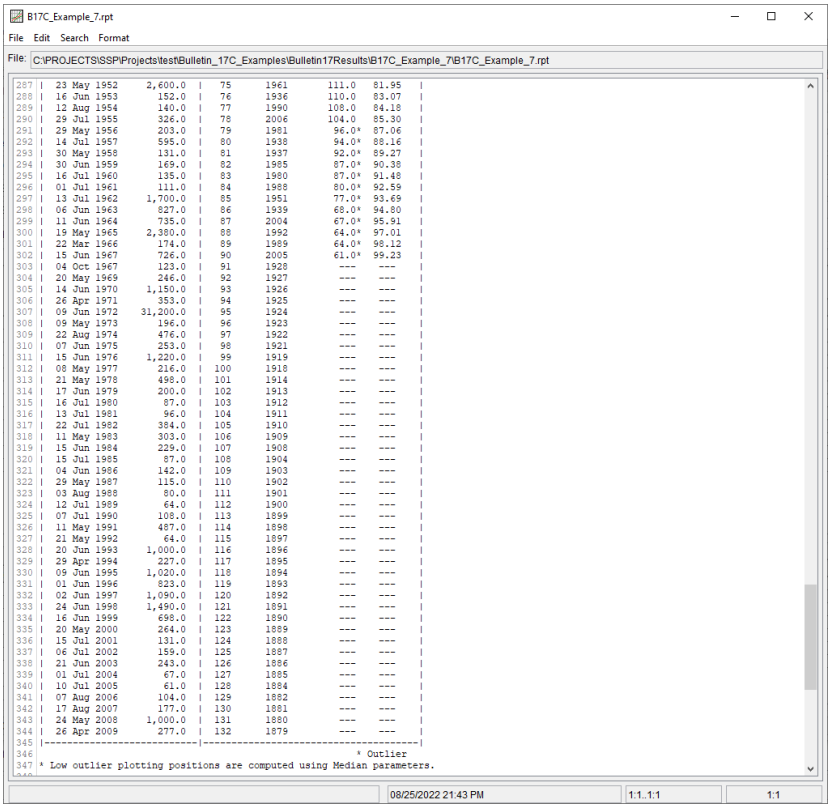


52 Figure 5. Bulletin 17 Analysis Tabular Results Tab for B17C Example 7.

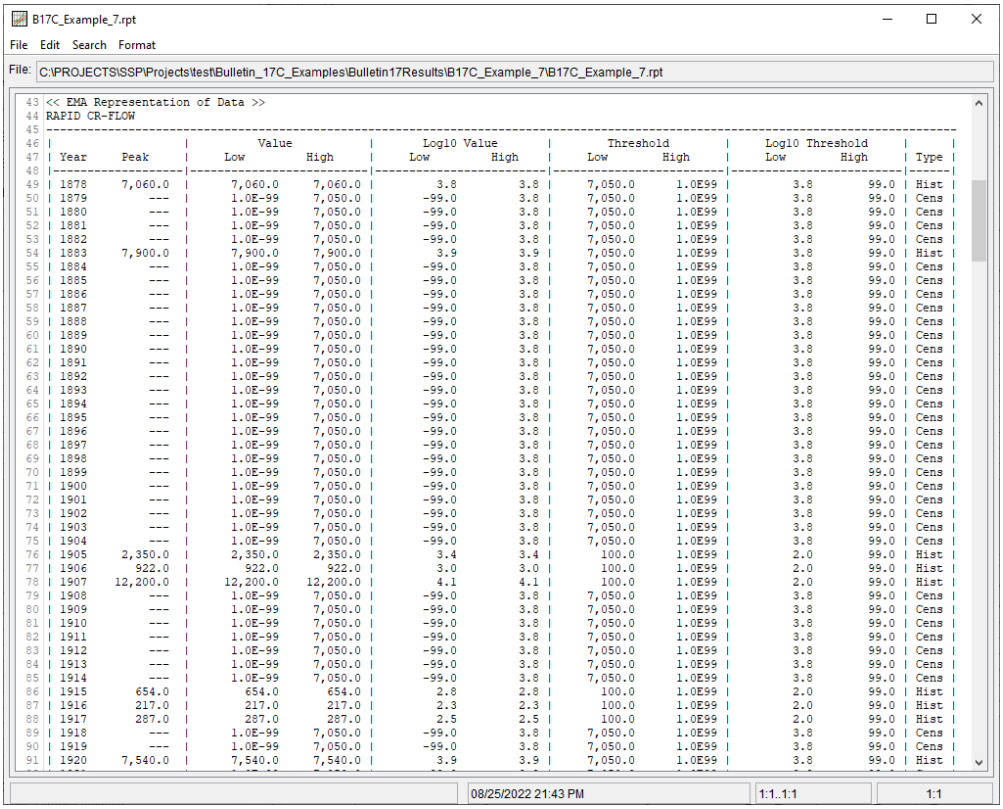
In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 2.5% and 97.5% confidence limits, and the computed plotting positions are shown in Figure 6 (see page 123).



As shown in Figure 7 (see page 123), twelve values less than the defined low outlier threshold of 100 cfs were identified. These annual peak flows were then recoded to have a flow interval of zero – 100. The perception threshold for all systematic observations were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (i.e. 100 – inf), as shown in Figure 8 (see page 125).



53 Figure 7. Report File for B17C Example 7 showing censored low outliers.



B17C_Example_7.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_7\B17C_Example_7.rpt

<< EMA Representation of Data >>
RAPID CR-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1878	7,060.0	7,060.0	7,060.0	3.8	3.8	7,050.0	1.0E99	3.8	99.0	Hist
1879	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1880	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1881	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1882	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1883	7,900.0	7,900.0	7,900.0	3.9	3.9	7,050.0	1.0E99	3.8	99.0	Hist
1884	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1885	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1886	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1887	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1888	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1889	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1890	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1891	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1892	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1893	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1894	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1895	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1896	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1897	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1898	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1899	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1900	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1901	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1902	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1903	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1904	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1905	2,350.0	2,350.0	2,350.0	3.4	3.4	100.0	1.0E99	2.0	99.0	Hist
1906	922.0	922.0	922.0	3.0	3.0	100.0	1.0E99	2.0	99.0	Hist
1907	12,200.0	12,200.0	12,200.0	4.1	4.1	100.0	1.0E99	2.0	99.0	Hist
1908	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1909	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1910	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1911	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1912	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1913	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1914	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1915	654.0	654.0	654.0	2.8	2.8	100.0	1.0E99	2.0	99.0	Hist
1916	217.0	217.0	217.0	2.3	2.3	100.0	1.0E99	2.0	99.0	Hist
1917	287.0	287.0	287.0	2.5	2.5	100.0	1.0E99	2.0	99.0	Hist
1918	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1919	---	1.0E-99	7,050.0	-99.0	3.8	7,050.0	1.0E99	3.8	99.0	Cens
1920	7,540.0	7,540.0	7,540.0	3.9	3.9	7,050.0	1.0E99	3.8	99.0	Hist

08/25/2022 21:43 PM 1:1..1:1 1:1

54 Figure 8. Report File for B17C Example 7 showing recoded perception thresholds.

3.9 Example 8. [inf – inf] Perception Threshold – Pembina River at Neche, ND

Example 8 demonstrates how an [inf – inf] perception threshold can be used to compute a peak flow frequency curve using EMA and Bulletin 17C procedures. The use of an [inf – inf] perception threshold for missing years implies that no knowledge is available for those missing years. This produces a result that is equivalent to the elimination of the missing years from the analysis. The data for this example comes from the USGS gage 05100000 Pembina River at Neche, North Dakota. The annual maximum series for this example contains 109 peaks beginning in 1904 and ending in 2016. Two periods of missing data exist within this record, 1909 and 1916-1918. The annual maximum series is plotted in Figure 1 (see page 127) and tabulated in Table 1.

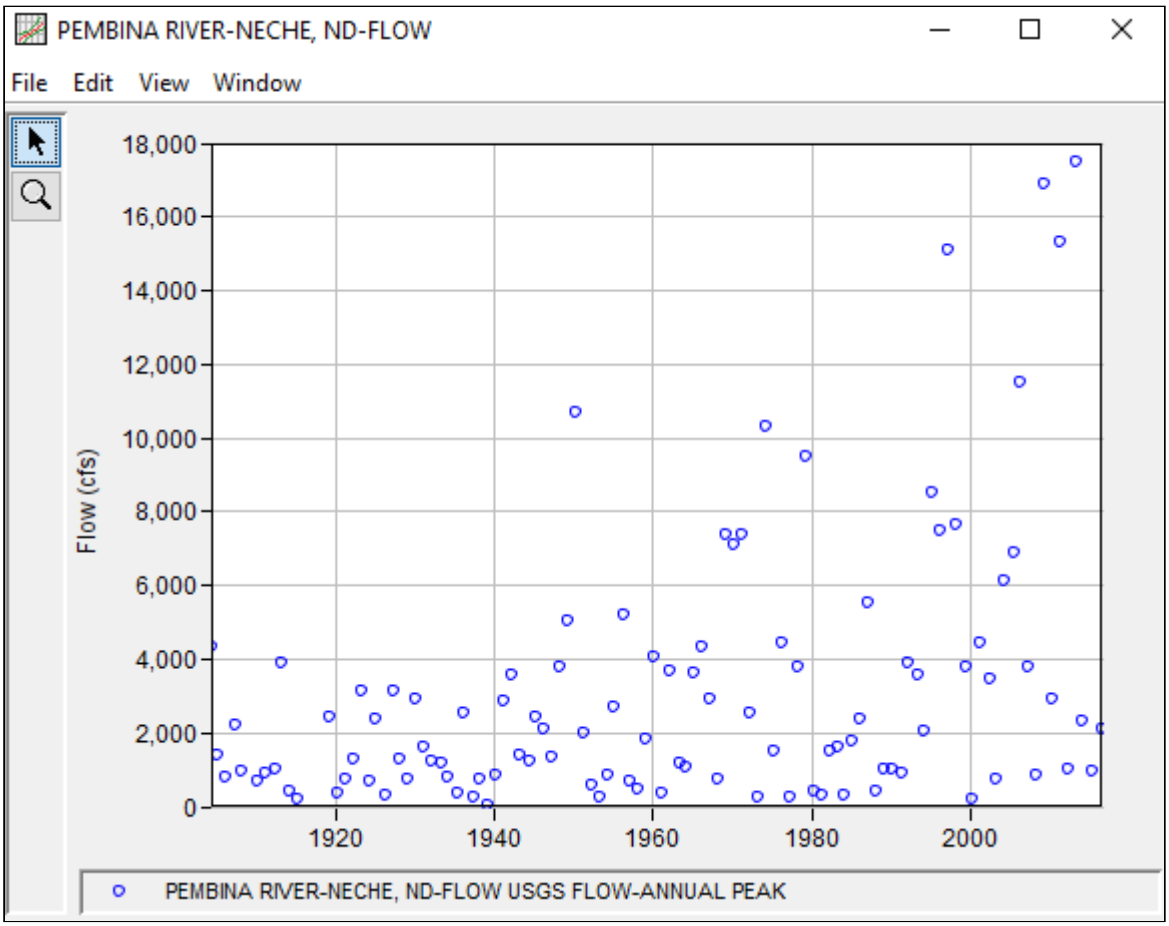


Table 1. Pembina River at Neche, ND Annual Peak Flow Record.

Date	Flow (cfs)
02 May 1904	4300
05 Apr 1905	1372
04 Apr 1906	800
14 May 1907	2190
10 Apr 1908	927
15 Mar 1910	685

Date	Flow (cfs)
23 Mar 1911	900
29 Jul 1912	1000
07 Apr 1913	3870
18 Apr 1914	388
07 Apr 1915	180
15 Apr 1919	2430
19 Apr 1920	361
13 Apr 1921	733
07 Apr 1922	1300
20 Apr 1923	3120
20 Apr 1924	674
28 Mar 1925	2350
06 Jul 1926	318
12 May 1927	3110
25 Mar 1928	1270
21 Mar 1929	750
08 Apr 1930	2900
09 Apr 1931	1580

Date	Flow (cfs)
09 Apr 1932	1240
26 May 1933	1180
09 Apr 1934	780
18 Jun 1935	364
15 Apr 1936	2530
08 Jun 1937	237
20 Mar 1938	730
04 Apr 1939	52
20 Apr 1940	816
14 Apr 1941	2830
07 Apr 1942	3550
27 Mar 1943	1400
06 Aug 1944	1200
29 Mar 1945	2440
24 Mar 1946	2070
11 Apr 1947	1320
21 Apr 1948	3770
22 Apr 1949	5010

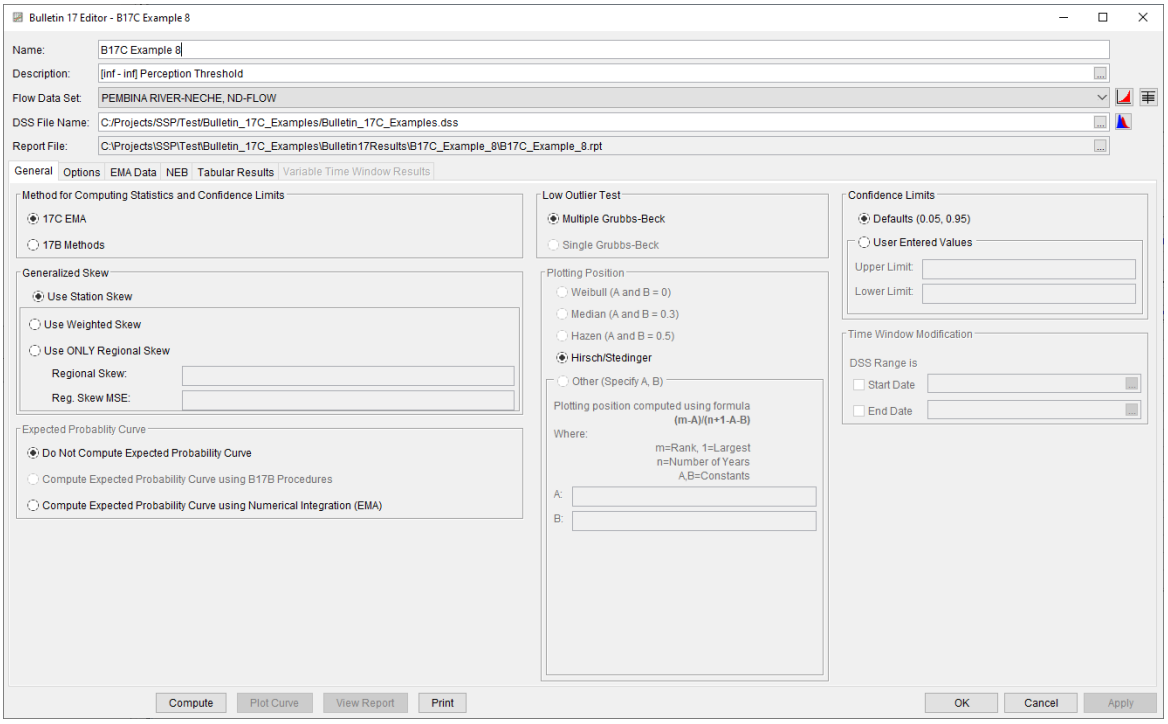
Date	Flow (cfs)
20 Apr 1950	10700
07 Apr 1951	2000
03 Apr 1952	550
10 Jun 1953	250
07 Jul 1954	846
05 Apr 1955	2700
27 Apr 1956	5200
27 Mar 1957	661
07 Apr 1958	442
05 Apr 1959	1800
14 Apr 1960	4040
03 Apr 1961	372
21 Apr 1962	3650
28 Jul 1963	1150
17 Apr 1964	1080
13 Apr 1965	3600
03 Apr 1966	4300
23 Apr 1967	2900

Date	Flow (cfs)
28 Mar 1968	734
21 Apr 1969	7360
27 Apr 1970	7070
12 Apr 1971	7350
16 Apr 1972	2550
27 Mar 1973	224
28 Apr 1974	10300
18 May 1975	1500
19 Apr 1976	4430
21 May 1977	261
11 Apr 1978	3800
20 Apr 1979	9500
07 Apr 1980	435
01 Apr 1981	285
08 Jun 1982	1520
09 Apr 1983	1630
07 Apr 1984	312
20 Mar 1985	1750

Date	Flow (cfs)
24 Mar 1986	2390
07 Apr 1987	5510
06 Apr 1988	420
17 Apr 1989	1000
03 Apr 1990	1000
16 Jun 1991	888
01 Apr 1992	3900
30 Jul 1993	3580
02 Apr 1994	2040
23 Apr 1995	8500
18 Apr 1996	7500
27 Apr 1997	15100
16 Apr 1998	7620
02 Jun 1999	3790
22 Mar 2000	208
22 Apr 2001	4420
12 Jun 2002	3440
20 May 2003	712

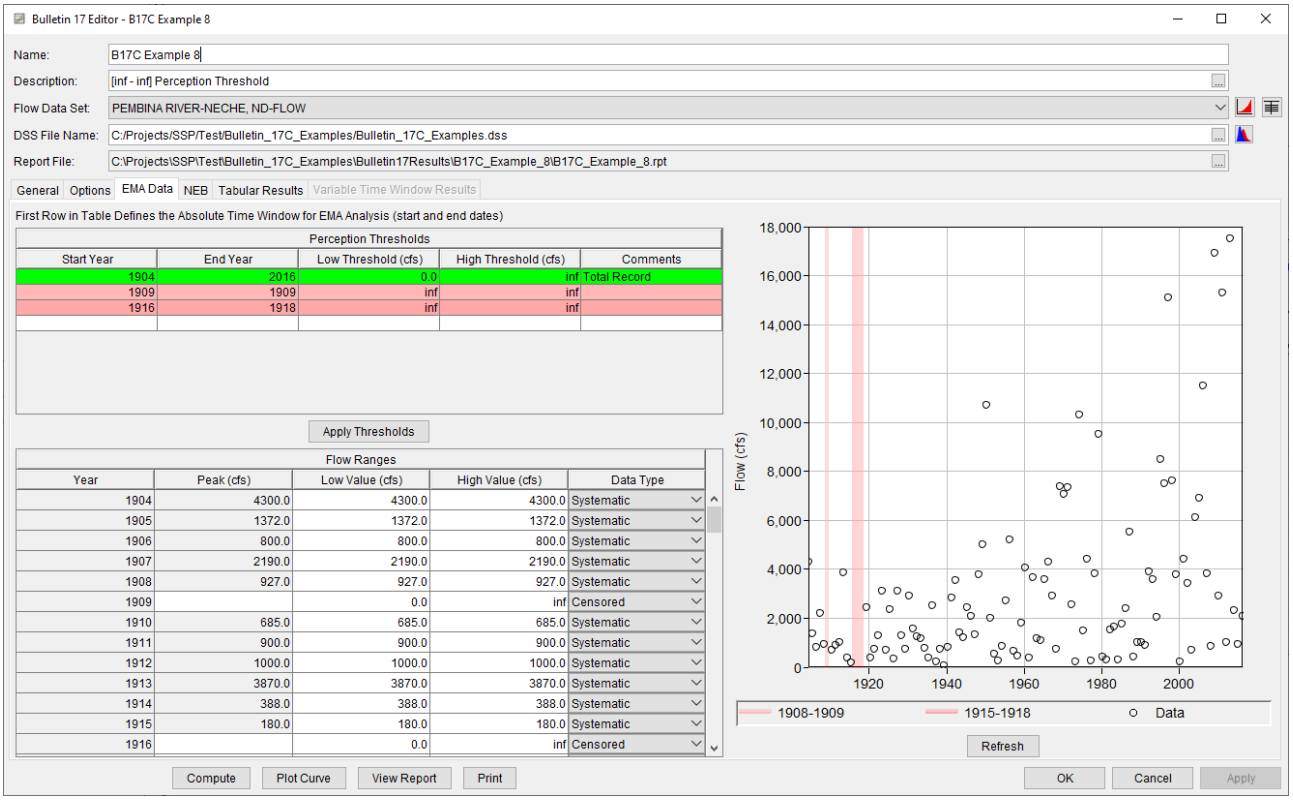
Date	Flow (cfs)
01 Apr 2004	6120
02 Jul 2005	6890
17 Apr 2006	11500
30 Mar 2007	3800
13 Apr 2008	847
20 Apr 2009	16900
04 Apr 2010	2900
19 Apr 2011	15300
05 Jul 2012	991
21 May 2013	17500
13 Apr 2014	2300
19 May 2015	927
20 Jul 2016	2090

A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 8**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 8**" from the list of available analyses. When "B17C Example 8" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 133). As shown, the **Skew** option was set to use the **Station Skew**.

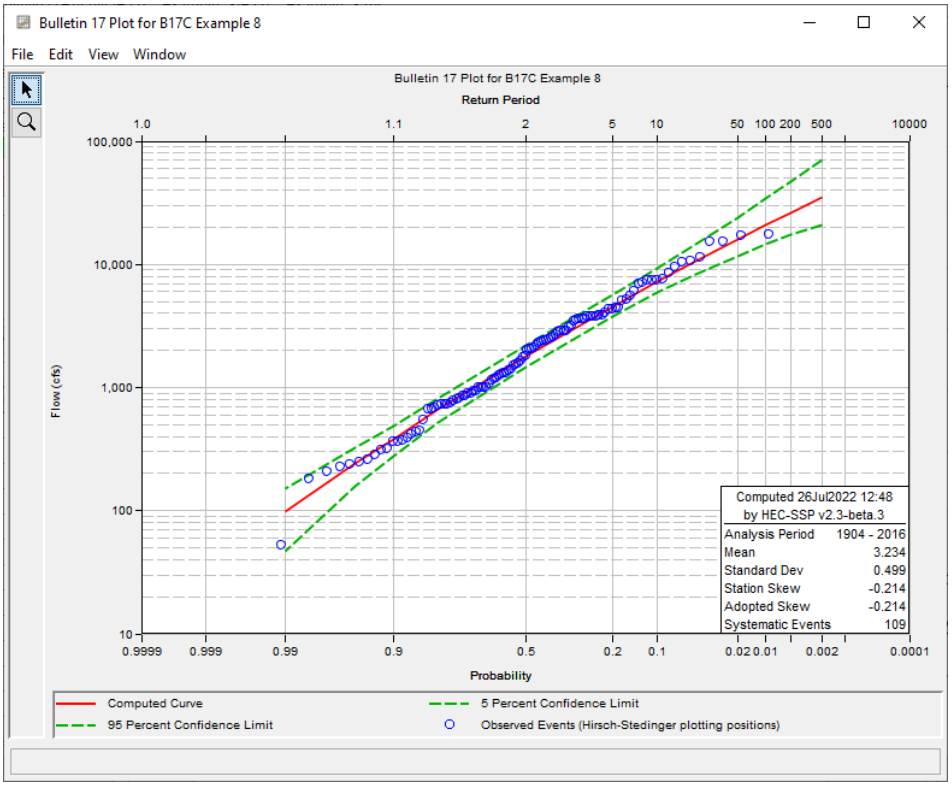


No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 134). This example uses an annual maximum series consisting of systematic data with two missing periods. The missing periods include 1909 and 1916 – 1918. Since 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data, a total of three perception thresholds are required. An inf – inf perception threshold is used to convey zero additional knowledge about the missing periods because the complementary flow range for such a perception threshold is zero – inf. Using the aforementioned perception thresholds and flow ranges is equivalent to removing the missing periods of record from the computations. Once all three perception thresholds have been entered as shown in Figure 3 (see page 134), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

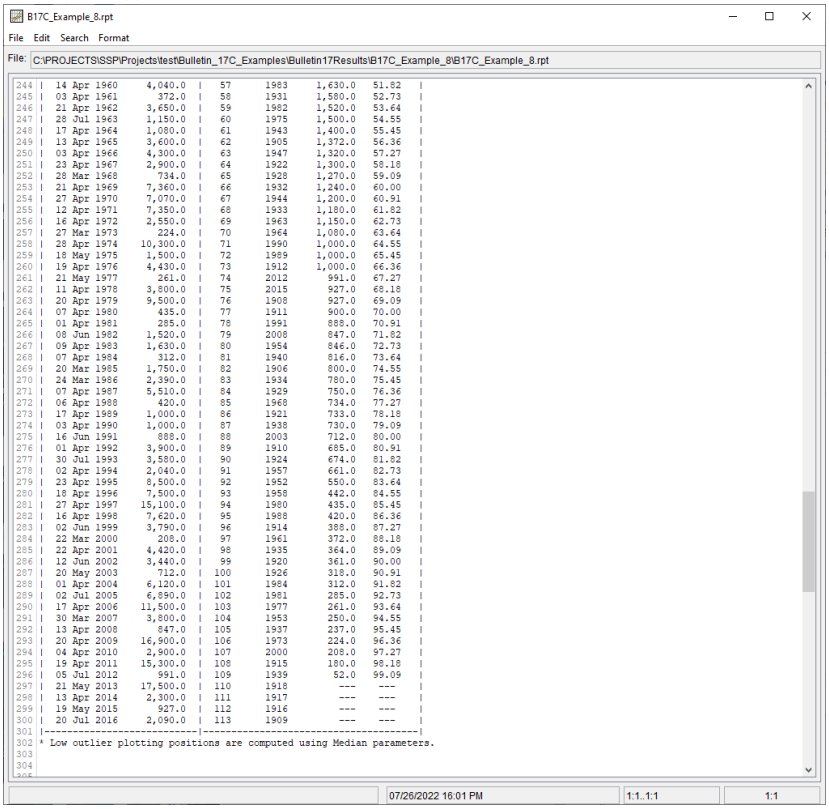
Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 134).



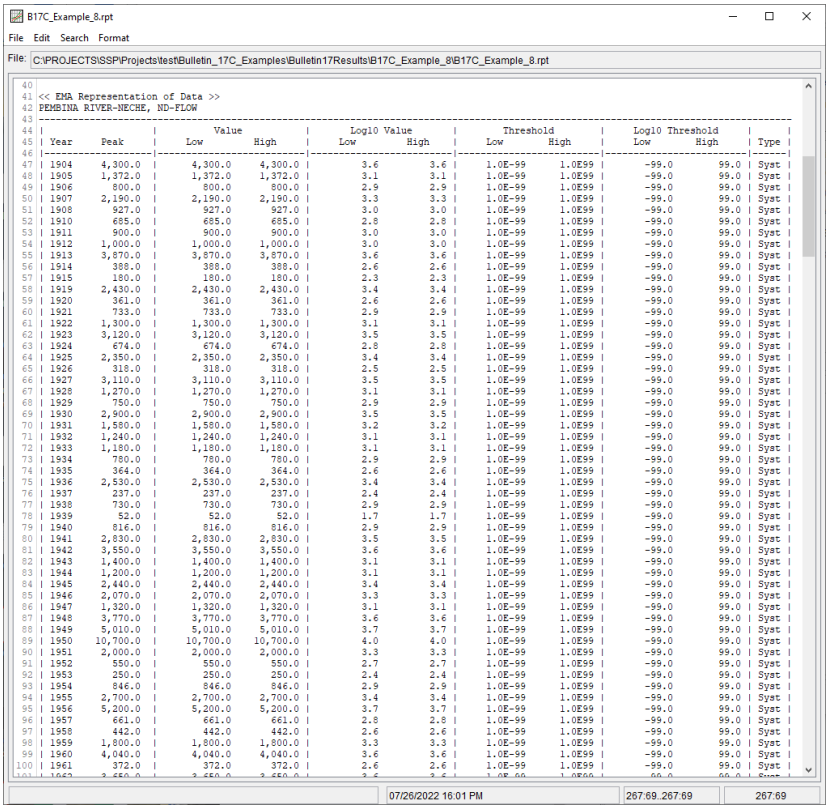
In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed plotting positions are shown in Figure 5 (see page 135).



As shown in Figure 6 (see page 136), four years were demarcated using an inf – inf perception threshold (and zero – inf flow range). These annual peak flows were then removed from the EMA computations, as shown in Figure 7 (see page 137).



55 Figure 6. Report File for B17C Example 8 showing missing periods.



B17C_Example_8.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_8\B17C_Example_8.rpt

```
<< EMA Representation of Data >>
PEMBINA RIVER-NECHE, ND-FLOW
```

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1904	4,300.0	4,300.0	4,300.0	3.6	3.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1905	1,372.0	1,372.0	1,372.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1906	800.0	800.0	800.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1907	2,190.0	2,190.0	2,190.0	3.3	3.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1908	927.0	927.0	927.0	3.0	3.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1910	685.0	685.0	685.0	2.8	2.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1911	900.0	900.0	900.0	3.0	3.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1912	1,000.0	1,000.0	1,000.0	3.0	3.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1913	3,870.0	3,870.0	3,870.0	3.6	3.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1914	388.0	388.0	388.0	2.6	2.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1915	180.0	180.0	180.0	2.3	2.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1919	2,430.0	2,430.0	2,430.0	3.4	3.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1920	361.0	361.0	361.0	2.6	2.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1921	733.0	733.0	733.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1922	1,300.0	1,300.0	1,300.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1923	3,120.0	3,120.0	3,120.0	3.5	3.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1924	674.0	674.0	674.0	2.8	2.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1925	2,350.0	2,350.0	2,350.0	3.4	3.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1926	318.0	318.0	318.0	2.5	2.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1927	3,110.0	3,110.0	3,110.0	3.5	3.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1928	1,270.0	1,270.0	1,270.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1929	750.0	750.0	750.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1930	2,900.0	2,900.0	2,900.0	3.5	3.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1931	1,580.0	1,580.0	1,580.0	3.2	3.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1932	1,240.0	1,240.0	1,240.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1933	1,180.0	1,180.0	1,180.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1934	780.0	780.0	780.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1935	364.0	364.0	364.0	2.6	2.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1936	2,530.0	2,530.0	2,530.0	3.4	3.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1937	237.0	237.0	237.0	2.4	2.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1938	730.0	730.0	730.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1939	52.0	52.0	52.0	1.7	1.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1940	816.0	816.0	816.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1941	2,830.0	2,830.0	2,830.0	3.5	3.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1942	3,550.0	3,550.0	3,550.0	3.6	3.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1943	1,400.0	1,400.0	1,400.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1944	1,200.0	1,200.0	1,200.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1945	2,440.0	2,440.0	2,440.0	3.4	3.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1946	2,070.0	2,070.0	2,070.0	3.3	3.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1947	1,320.0	1,320.0	1,320.0	3.1	3.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1948	3,770.0	3,770.0	3,770.0	3.6	3.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1949	5,010.0	5,010.0	5,010.0	3.7	3.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1950	10,700.0	10,700.0	10,700.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1951	2,000.0	2,000.0	2,000.0	3.3	3.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1952	550.0	550.0	550.0	2.7	2.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1953	250.0	250.0	250.0	2.4	2.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1954	846.0	846.0	846.0	2.9	2.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1955	2,700.0	2,700.0	2,700.0	3.4	3.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1956	5,200.0	5,200.0	5,200.0	3.7	3.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1957	661.0	661.0	661.0	2.8	2.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1958	442.0	442.0	442.0	2.6	2.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1959	1,800.0	1,800.0	1,800.0	3.3	3.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1960	4,040.0	4,040.0	4,040.0	3.6	3.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1961	372.0	372.0	372.0	2.6	2.6	1.0E-99	1.0E99	-99.0	99.0	Syst

07/26/2022 16:01 PM 267:69..267:69 267:69

56 Figure 7. Report File for B17C Example 8 showing missing periods removed from EMA computations.

3.10 Example 9. [0 – value] Perception Threshold – Clark Fork River below Cabinet Gorge Dam, ID

Example 9 exhibits how a [0 – value] perception threshold can be used to compute a peak flow frequency curve using EMA and Bulletin 17C procedures. When using a [0 – value] perception threshold, the corresponding flow range spans [value – inf]. For instance, when using a [0 – 5000 cfs] perception threshold, the corresponding flow range would be [5000 cfs – inf]. This implies that the flow for the specified missing years must have exceeded 5000 cfs. The data for this example comes from the USGS gage 12391950 Clark Fork River below Cabinet Gorge Dam, ID. The annual maximum series consists of unregulated daily average flows. The period of record used for this example contains 77 peaks beginning in 1929 and ending in 2008. Two periods of missing data also exist within this record, 1940-1941 and 1944. The annual maximum series is plotted in Figure 1 (see page 139) and tabulated in Table 1.

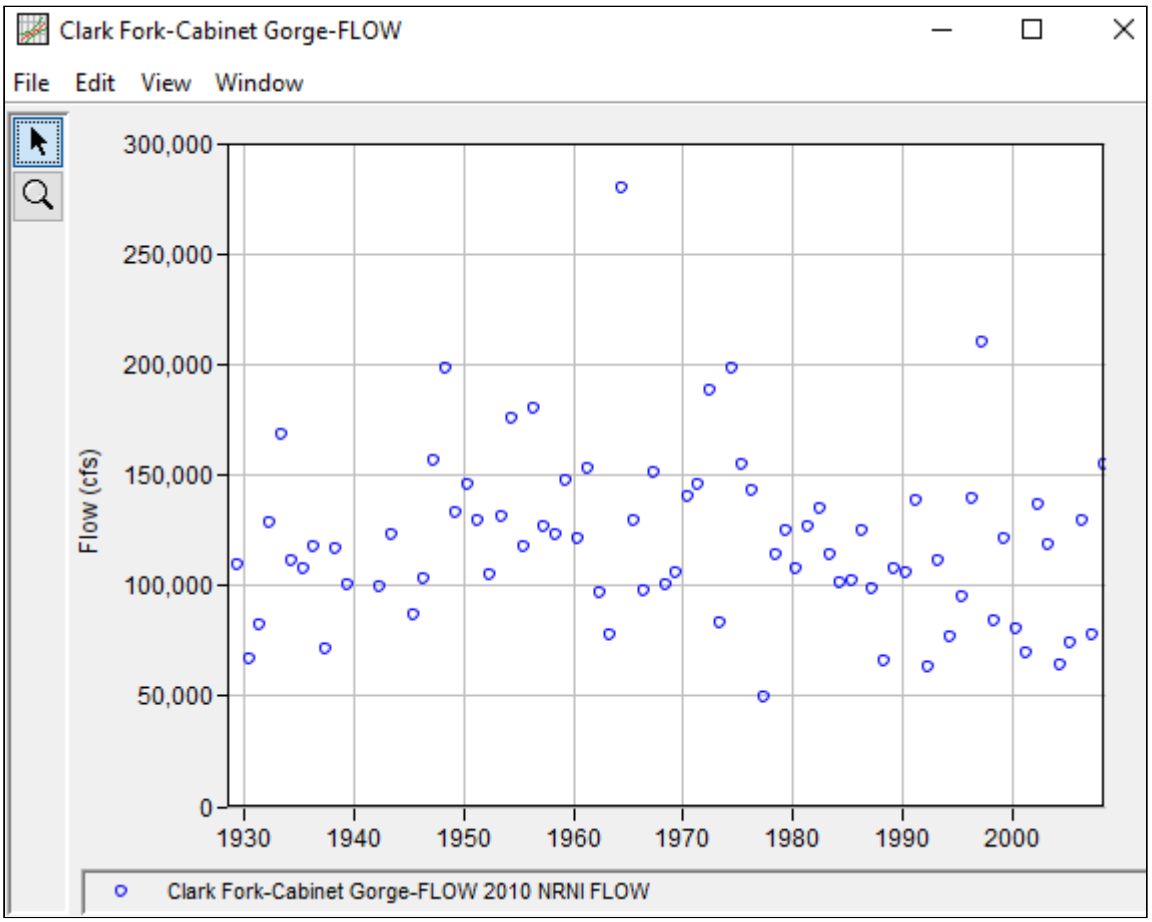


Table 1. Clark Fork River below Cabinet Gorge Dam, ID Annual Peak Flow Record.

Date	Flow (cfs)
25 May 1929	109495
01 Jun 1930	66383
17 May 1931	81758
23 May 1932	128563
17 Jun 1933	167893
26 Apr 1934	110603

Date	Flow (cfs)
24 May 1935	107358
16 May 1936	117050
29 May 1937	71113
28 May 1938	116598
05 May 1939	100232
28 May 1942	99448
20 Jun 1943	122767
03 Jun 1945	86562
30 May 1946	102445
10 May 1947	156245
24 May 1948	198024
17 May 1949	132621
23 Jun 1950	145329
13 May 1951	129430
29 Apr 1952	104365
14 Jun 1953	131126
21 May 1954	175076
15 Jun 1955	117428

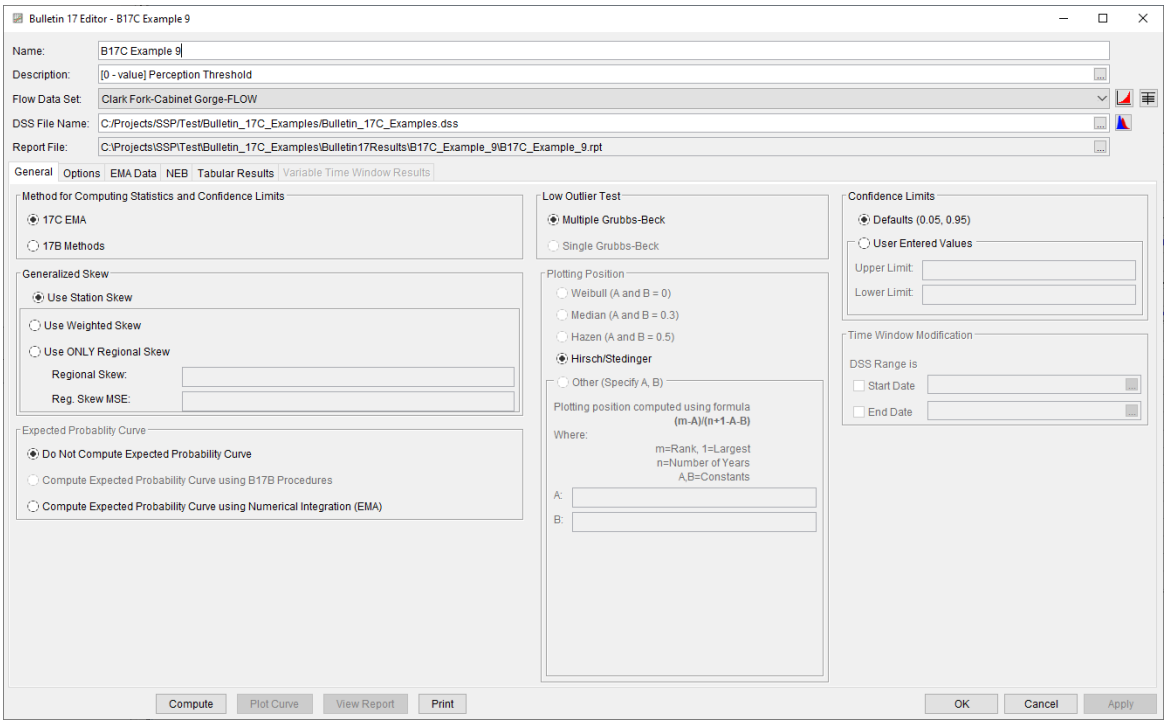
Date	Flow (cfs)
23 May 1956	179458
07 May 1957	126620
26 May 1958	123080
07 Jun 1959	146887
05 Jun 1960	121354
28 May 1961	152917
30 May 1962	96903
01 Jun 1963	77746
10 Jun 1964	279802
20 Jun 1965	128903
02 Jun 1966	97380
24 May 1967	150874
05 Jun 1968	99891
15 May 1969	105457
07 Jun 1970	139836
14 May 1971	145726
03 Jun 1972	188257
20 May 1973	83173

Date	Flow (cfs)
18 Jun 1974	197601
21 Jun 1975	154409
12 May 1976	142478
04 May 1977	49246
09 Jun 1978	113623
27 May 1979	124395
27 May 1980	107620
26 May 1981	126384
17 Jun 1982	134238
31 May 1983	113659
01 Jun 1984	101039
26 May 1985	101664
01 Jun 1986	124274
02 May 1987	98245
15 May 1988	65824
12 May 1989	106999
01 Jun 1990	105787
20 May 1991	138662

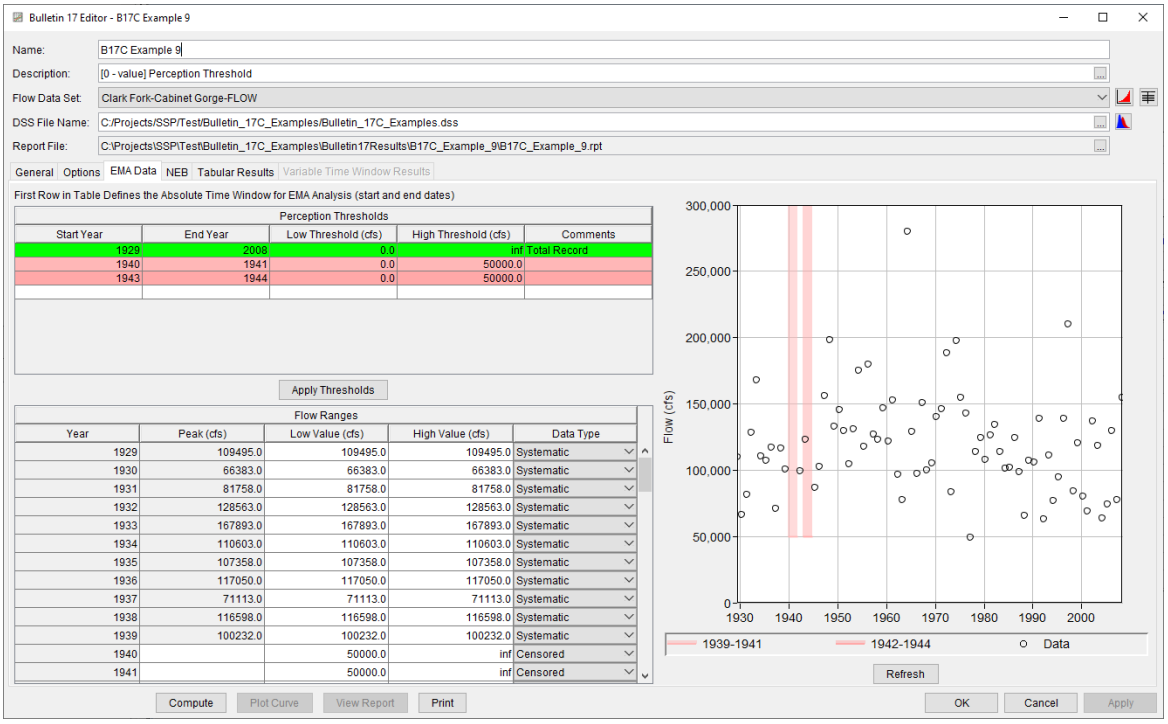
Date	Flow (cfs)
02 May 1992	63063
16 May 1993	110858
13 May 1994	76657
09 Jun 1995	94839
10 Jun 1996	139015
18 May 1997	209671
29 May 1998	83841
27 May 1999	120556
25 May 2000	80067
28 May 2001	68919
02 Jun 2002	136674
01 Jun 2003	118023
08 Jun 2004	63594
07 Jun 2005	73941
21 May 2006	129591
14 May 2007	77787
21 May 2008	154560

A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 9**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 9**" from the list of available analyses. When

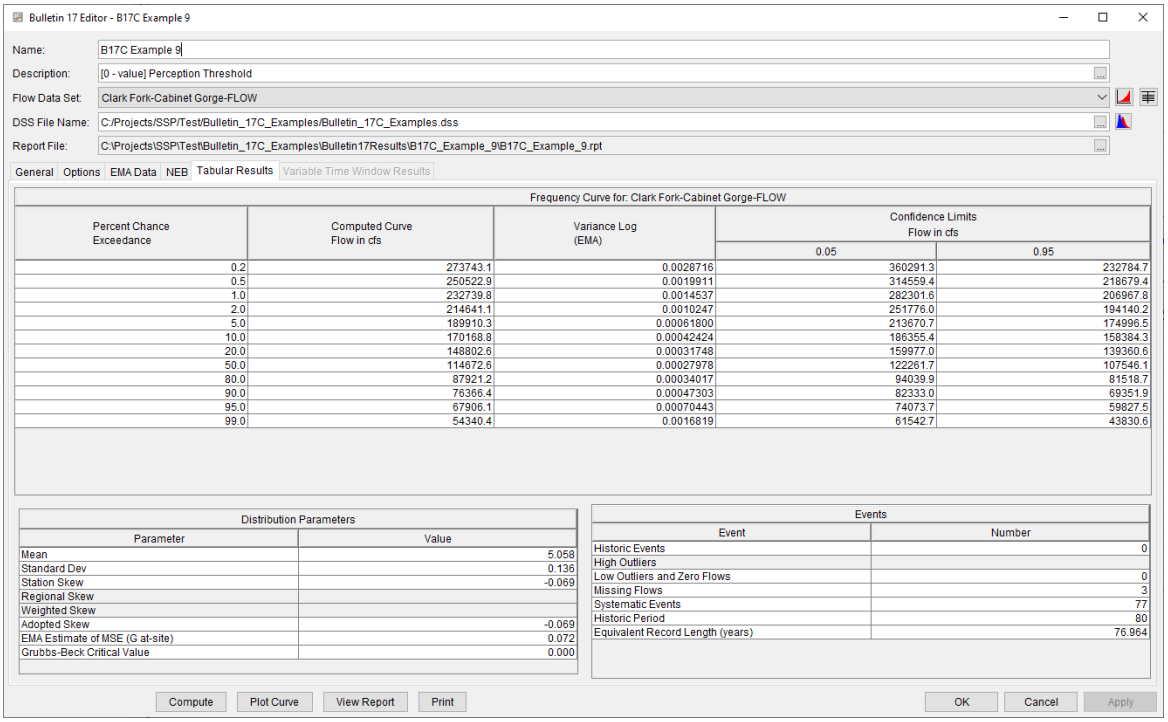
"B17C Example 9" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 144). As shown, the **Skew** option was set to use the **Station Skew**.



No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 144). This example uses an annual maximum series consisting of systematic data with two missing periods. The missing periods include 1940 – 1941 and 1944. Since 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data, a total of three perception thresholds are required. In this example, both missing periods make use of a perception threshold of 0 – 50000. This perception threshold implies that had a flow **less than** 50000 cfs occurred, someone would have measured and recorded it. The complementary flow range for this perception threshold is 50000 – inf. Once all three perception thresholds have been entered as shown in Figure 3 (see page 144), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

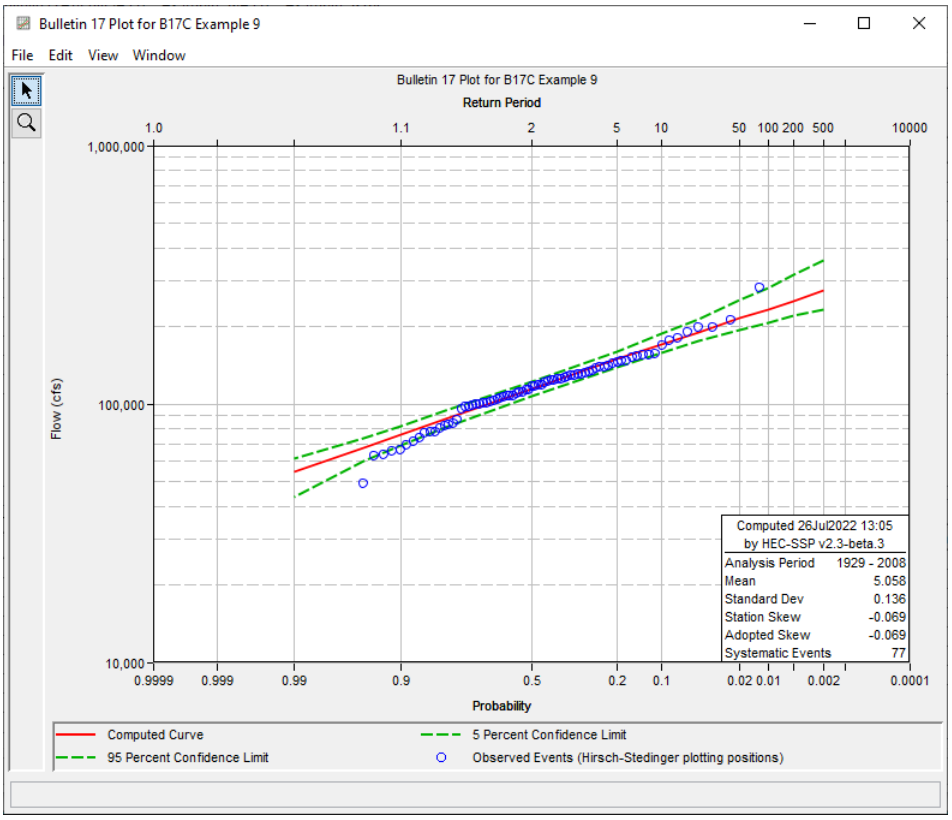


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 145).

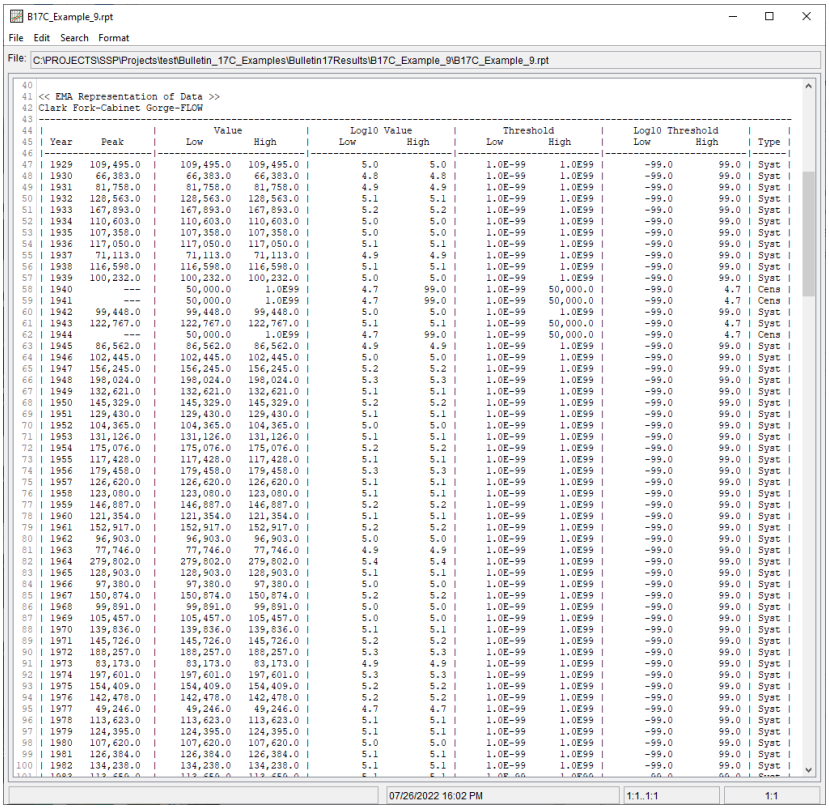


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed

plotting positions are shown in Figure 5 (see page 146).



As shown in Figure 6 (see page 146), the perception thresholds for the missing years were encoded as 0 – 50000 while the flow ranges were set to 50000 – inf. This causes the EMA-computed standard deviation and skew absolute value to decrease (compared to the use of inf – inf perception thresholds).



B17C_Example_9.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_9\B17C_Example_9.rpt

<< EMA Representation of Data >>
Clark Fork-Cabinet Gorge-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1929	109,495.0	109,495.0	109,495.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1930	66,383.0	66,383.0	66,383.0	4.8	4.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1931	81,758.0	81,758.0	81,758.0	4.9	4.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1932	128,563.0	128,563.0	128,563.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1933	167,893.0	167,893.0	167,893.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1934	110,603.0	110,603.0	110,603.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1935	107,358.0	107,358.0	107,358.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1936	117,050.0	117,050.0	117,050.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1937	71,113.0	71,113.0	71,113.0	4.9	4.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1938	116,598.0	116,598.0	116,598.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1939	100,232.0	100,232.0	100,232.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1940	---	50,000.0	1.0E99	4.7	99.0	1.0E-99	50,000.0	-99.0	4.7	Cens
1941	---	50,000.0	1.0E99	4.7	99.0	1.0E-99	50,000.0	-99.0	4.7	Cens
1942	99,448.0	99,448.0	99,448.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1943	122,767.0	122,767.0	122,767.0	5.1	5.1	1.0E-99	50,000.0	-99.0	4.7	Syst
1944	---	50,000.0	1.0E99	4.7	99.0	1.0E-99	50,000.0	-99.0	4.7	Cens
1945	86,562.0	86,562.0	86,562.0	4.9	4.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1946	102,445.0	102,445.0	102,445.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1947	156,245.0	156,245.0	156,245.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1948	198,024.0	198,024.0	198,024.0	5.3	5.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1949	132,621.0	132,621.0	132,621.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1950	145,329.0	145,329.0	145,329.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1951	129,430.0	129,430.0	129,430.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1952	104,365.0	104,365.0	104,365.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1953	131,126.0	131,126.0	131,126.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1954	175,076.0	175,076.0	175,076.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1955	117,428.0	117,428.0	117,428.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1956	179,458.0	179,458.0	179,458.0	5.3	5.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1957	126,620.0	126,620.0	126,620.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1958	123,080.0	123,080.0	123,080.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1959	146,887.0	146,887.0	146,887.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1960	121,354.0	121,354.0	121,354.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1961	152,917.0	152,917.0	152,917.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1962	96,903.0	96,903.0	96,903.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1963	77,746.0	77,746.0	77,746.0	4.9	4.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1964	279,802.0	279,802.0	279,802.0	5.4	5.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1965	128,903.0	128,903.0	128,903.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1966	97,380.0	97,380.0	97,380.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1967	150,874.0	150,874.0	150,874.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1968	99,891.0	99,891.0	99,891.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1969	105,457.0	105,457.0	105,457.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1970	139,836.0	139,836.0	139,836.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1971	145,726.0	145,726.0	145,726.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1972	188,257.0	188,257.0	188,257.0	5.3	5.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1973	83,173.0	83,173.0	83,173.0	4.9	4.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1974	197,601.0	197,601.0	197,601.0	5.3	5.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1975	154,409.0	154,409.0	154,409.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1976	142,478.0	142,478.0	142,478.0	5.2	5.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1977	49,246.0	49,246.0	49,246.0	4.7	4.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1978	113,623.0	113,623.0	113,623.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1979	124,395.0	124,395.0	124,395.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1980	107,620.0	107,620.0	107,620.0	5.0	5.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1981	126,384.0	126,384.0	126,384.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1982	134,238.0	134,238.0	134,238.0	5.1	5.1	1.0E-99	1.0E99	-99.0	99.0	Syst

07/26/2022 16:02 PM 1:1..1:1 1:1

57 Figure 6. Report File for B17C Example 9 showing EMA Representation of Data.

3.11 Example 10. Systematic and Historical Record with Regional Skew – Schuylkill River at Berne, PA

Example 10 exhibits the use of a regional skew coefficient and MSE with systematic and historical data. The regional skew and MSE were estimated for this location in conjunction with several other large subbasins within the Delaware River watershed (Goldman & Konieczki, 2009).

> Examples of additional regional skew studies can be found through online searches, from the U.S. Army Corps of Engineers, and USGS, amongst others. Several regional skew studies have been compiled and made available at the following location: https://acwi.gov/hydrology/Frequency/b17c/supplementary-materials/reports.html.

The data for this example comes from the USGS gage 01470500 Schuylkill River at Berne, PA. The period of record used for this example contains 70 peaks beginning in 1942 and ending in 2016. A single period of missing data exists within this record. Also, a historic flood event occurred outside the period of gaging record in April 1942. The annual maximum series is plotted in Figure 1 (see page 147) and tabulated in Table 1.

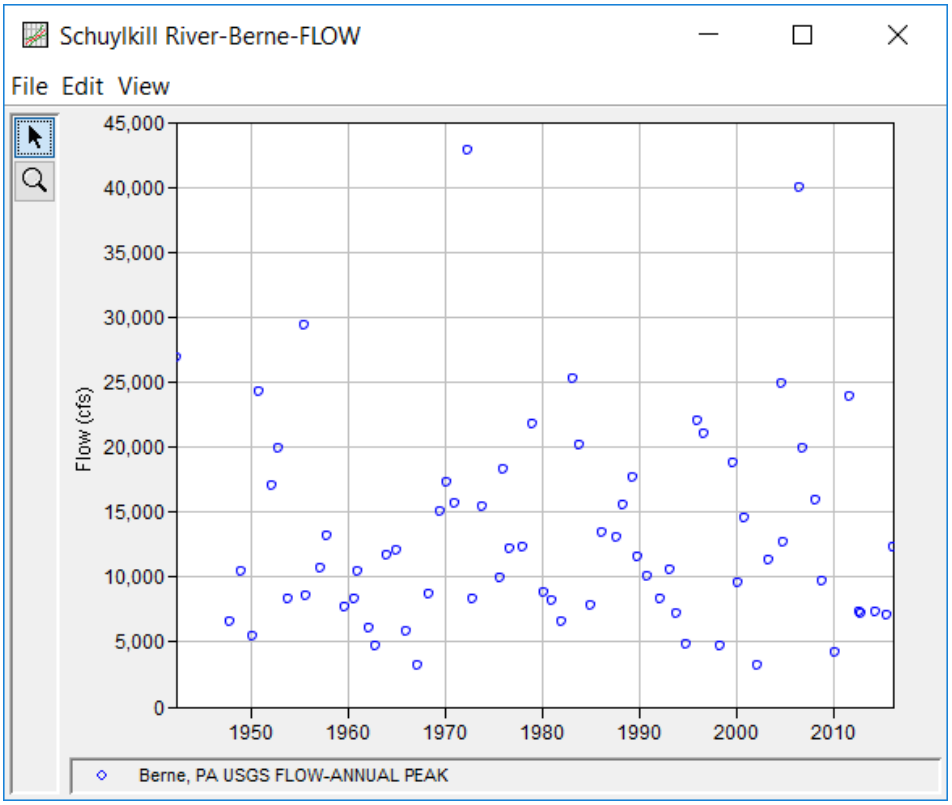


Table 1. Schuylkill River at Berne, PA Annual Peak Flow Record.

Date	Flow (cfs)
30 Apr 1942	26900
08 Nov 1947	6500
30 Dec 1948	10400
23 Mar 1950	5430
04 Dec 1950	24200
11 Mar 1952	17000
22 Nov 1952	19900
07 Dec 1953	8290

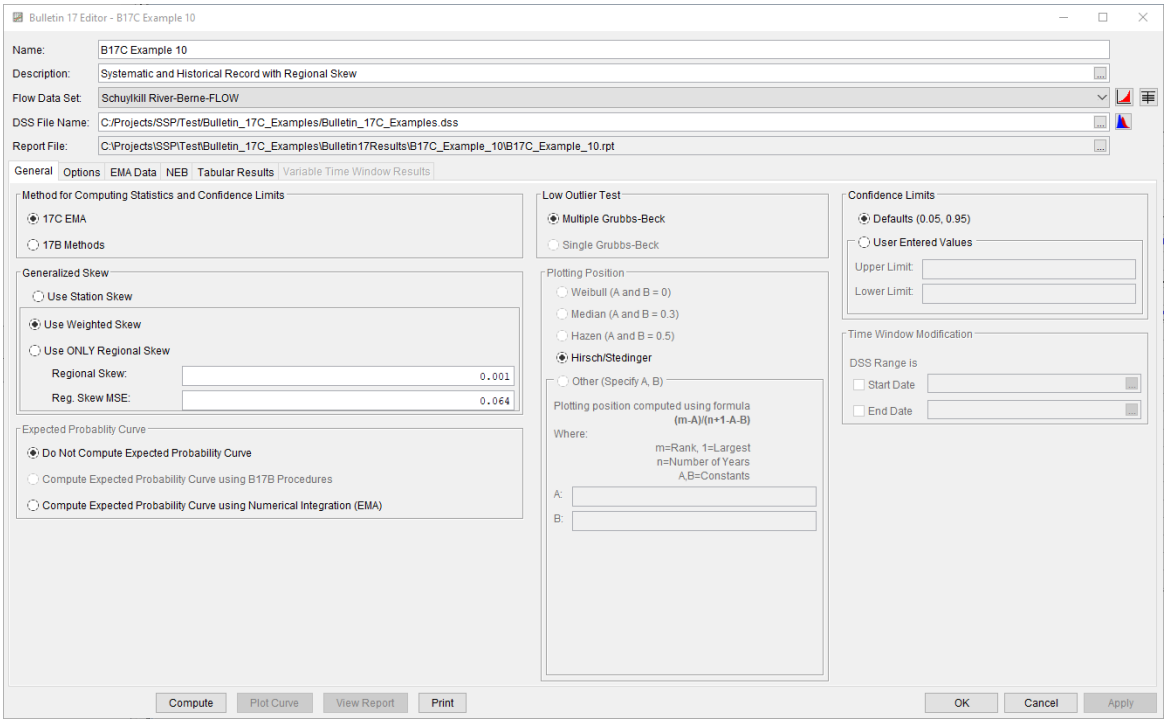
Date	Flow (cfs)
19 Aug 1955	29400
15 Oct 1955	8580
06 Apr 1957	10700
21 Dec 1957	13100
03 Sep 1959	7710
20 Sep 1960	8290
26 Feb 1961	10400
12 Mar 1962	6010
10 Nov 1962	4720
25 Jan 1964	11700
08 Feb 1965	12000
14 Feb 1966	5850
06 Mar 1967	3220
31 May 1968	8640
02 Aug 1969	15000
02 Apr 1970	17300
13 Feb 1971	15600
22 Jun 1972	42800

Date	Flow (cfs)
08 Nov 1972	8290
21 Dec 1973	15400
26 Sep 1975	9920
26 Jan 1976	18300
09 Oct 1976	12100
26 Jan 1978	12300
25 Jan 1979	21700
21 Mar 1980	8780
11 Feb 1981	8110
03 Feb 1982	6600
16 Apr 1983	25300
14 Dec 1983	20100
12 Feb 1985	7850
15 Mar 1986	13400
13 Sep 1987	13000
19 May 1988	15500
06 May 1989	17600
16 Nov 1989	11500

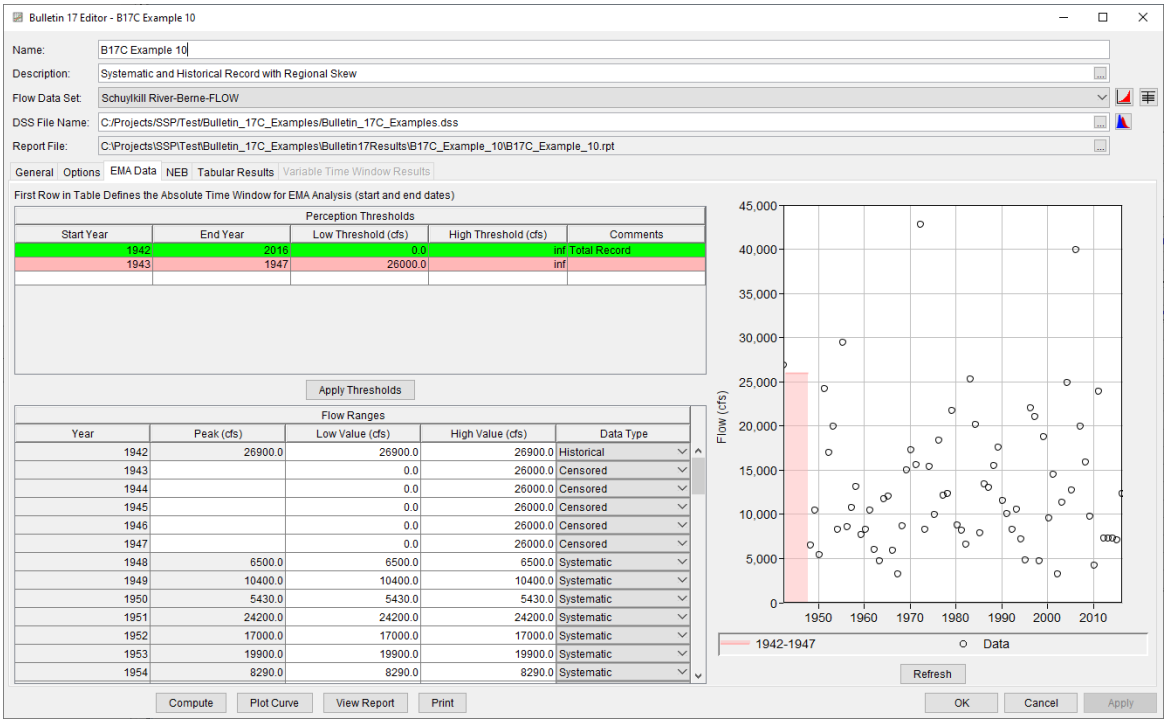
Date	Flow (cfs)
04 Dec 1990	10000
27 Mar 1992	8280
11 Apr 1993	10500
05 Dec 1993	7210
28 Nov 1994	4820
19 Jan 1996	22000
19 Oct 1996	21000
12 May 1998	4720
16 Sep 1999	18700
22 Mar 2000	9530
17 Dec 2000	14500
15 Apr 2002	3230
21 Jun 2003	11300
18 Sep 2004	24900
28 Nov 2004	12700
28 Jun 2006	39900
17 Nov 2006	19900
05 Mar 2008	15900

Date	Flow (cfs)
12 Dec 2008	9720
14 Mar 2010	4210
08 Sep 2011	23900
18 Sep 2012	7240
21 Dec 2012	7220
16 May 2014	7240
01 Jul 2015	7040
25 Feb 2016	12300

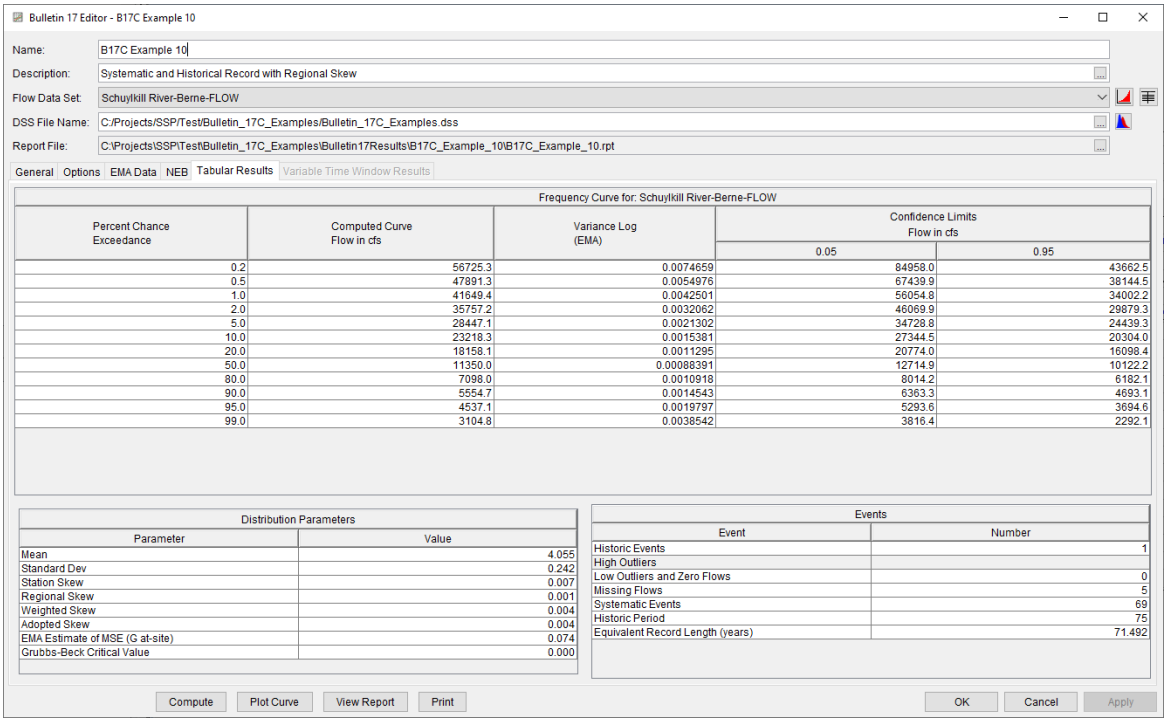
A Bulletin 17 Analysis using EMA and Bulletin 17C procedures has been developed for this example. To open the analysis, either double-click on the analysis labeled "**B17C Example 10**" from the Study Explorer or from the **Analysis** menu select open, then select "**B17C Example 10**" from the list of available analyses. When "B17C Example 10" is selected, the Bulletin 17 analysis editor will appear as shown in Figure 2 (see page 152) As shown, the **Skew** option was set to use the **Weighted Skew**. To use the weighted skew option, the user must enter a value for the Regional Skew and the Regional MSE. In this example, a regional skew of 0.001 was used along with a Regional Skew MSE of 0.064.



No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure 3 (see page 153). This example uses an annual maximum series consisting of both systematic data and an historical event in April 1942. Also, the record is broken with a period of missing data spanning 1943 – 1947. Since 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data, two perception thresholds are required. In this case, the peak discharge estimate associated with the April 1942 event can be used to inform the perception threshold for the period of missing annual peak flow data. The use of a perception threshold of 26000 – inf for this period of missing data implies that had a flood event occurred with a peak flow greater than 26,000 cfs, someone would have measured and recorded it. Since the April 1942 event was not directly measured, the perception threshold should span 1942 – 1947. Once the perception thresholds have been entered as shown in Figure 3 (see page 153), click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data. Finally, the April 1942 event should be set to the historical data type, as denoted by a USGS peak flow rate qualification code of "7".

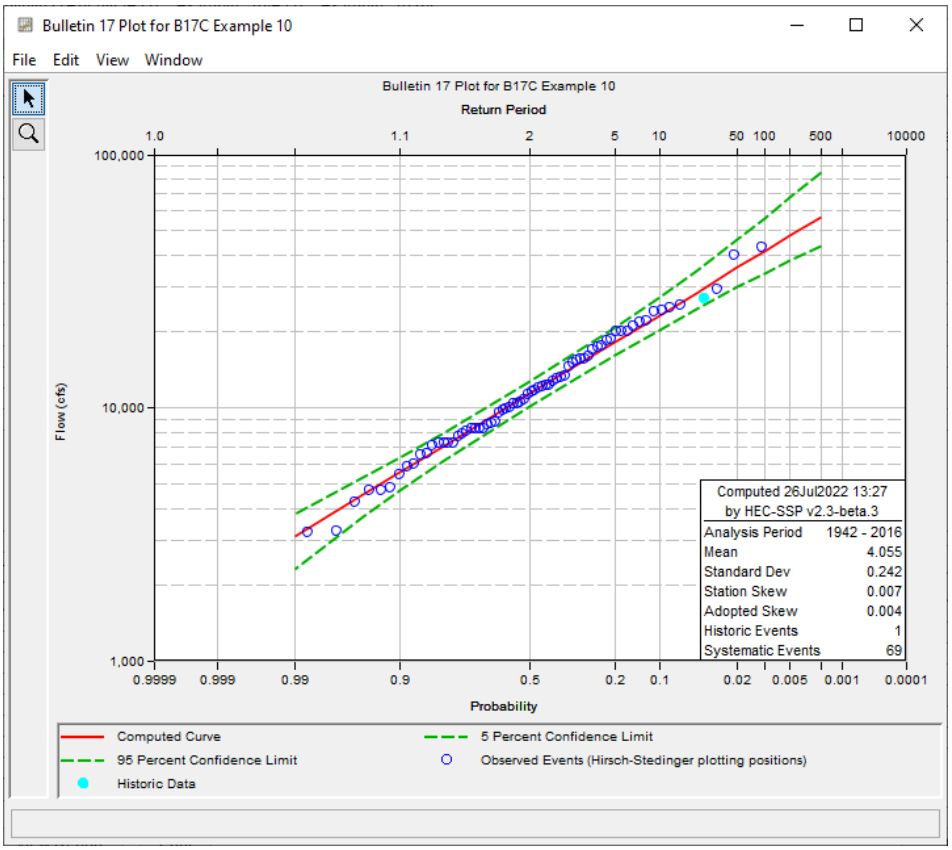


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab. The analysis window should resemble Figure 4 (see page 154).

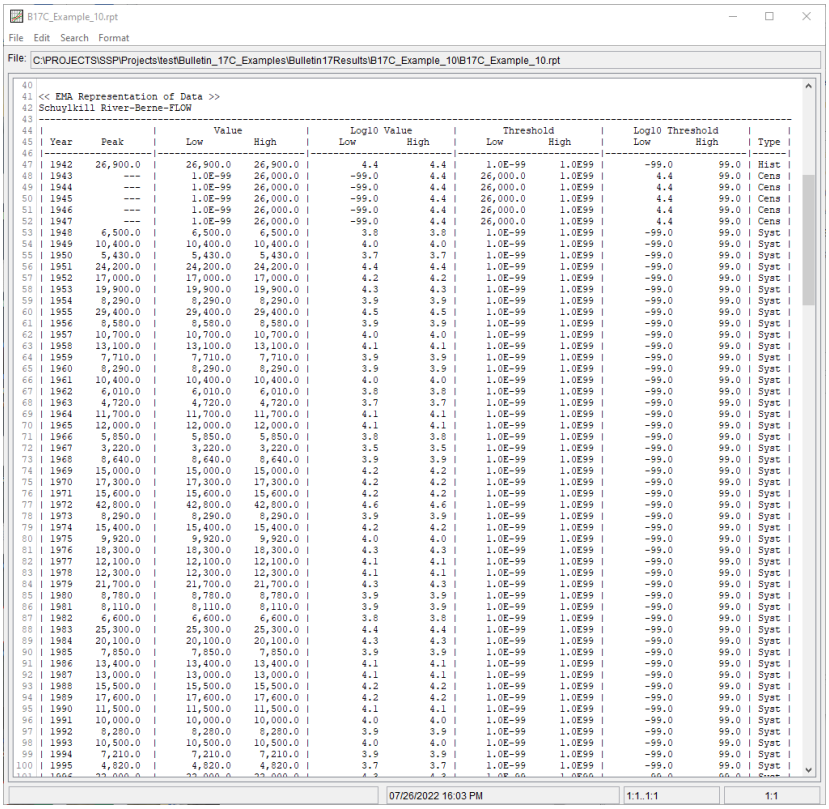


In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window. The Log Pearson Type III distribution fit using EMA to the input annual maximum flow data set, the 5% and 95% confidence limits, and the computed

plotting positions are shown in Figure 5 (see page 155).



As shown in Figure 6 (see page 155), the 1942 – 1947 period used a perception threshold of 26000 – inf. Since the 1943 – 1947 period was missing, the complementary flow range of 0 – 26000 cfs was assigned and used within the computations.



B17C_Example_10.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_10\B17C_Example_10.rpt

<< EMA Representation of Data >>
Schuylkill River-Berne-FLOW

	Value		Log10 Value		Threshold		Log10 Threshold		
Year	Peak	Low	High	Low	High	Low	High	Low	High	Type
1942	26,900.0	26,900.0	26,900.0	4.4	4.4	1.0E-99	1.0E99	-99.0	99.0	Hist
1943	---	1.0E-99	26,000.0	-99.0	4.4	26,000.0	1.0E99	4.4	99.0	Cens
1944	---	1.0E-99	26,000.0	-99.0	4.4	26,000.0	1.0E99	4.4	99.0	Cens
1945	---	1.0E-99	26,000.0	-99.0	4.4	26,000.0	1.0E99	4.4	99.0	Cens
1946	---	1.0E-99	26,000.0	-99.0	4.4	26,000.0	1.0E99	4.4	99.0	Cens
1947	---	1.0E-99	26,000.0	-99.0	4.4	26,000.0	1.0E99	4.4	99.0	Cens
1948	6,500.0	6,500.0	6,500.0	3.8	3.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1949	10,400.0	10,400.0	10,400.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1950	5,430.0	5,430.0	5,430.0	3.7	3.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1951	24,200.0	24,200.0	24,200.0	4.4	4.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1952	17,000.0	17,000.0	17,000.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1953	19,900.0	19,900.0	19,900.0	4.3	4.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1954	8,290.0	8,290.0	8,290.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1955	29,400.0	29,400.0	29,400.0	4.5	4.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1956	8,580.0	8,580.0	8,580.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1957	10,700.0	10,700.0	10,700.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1958	13,100.0	13,100.0	13,100.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1959	7,710.0	7,710.0	7,710.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1960	8,290.0	8,290.0	8,290.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1961	10,400.0	10,400.0	10,400.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1962	6,010.0	6,010.0	6,010.0	3.8	3.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1963	4,720.0	4,720.0	4,720.0	3.7	3.7	1.0E-99	1.0E99	-99.0	99.0	Syst
1964	11,700.0	11,700.0	11,700.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1965	12,000.0	12,000.0	12,000.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1966	5,850.0	5,850.0	5,850.0	3.8	3.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1967	3,220.0	3,220.0	3,220.0	3.5	3.5	1.0E-99	1.0E99	-99.0	99.0	Syst
1968	8,640.0	8,640.0	8,640.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1969	15,000.0	15,000.0	15,000.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1970	17,300.0	17,300.0	17,300.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1971	15,600.0	15,600.0	15,600.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1972	42,800.0	42,800.0	42,800.0	4.6	4.6	1.0E-99	1.0E99	-99.0	99.0	Syst
1973	8,290.0	8,290.0	8,290.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1974	15,400.0	15,400.0	15,400.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1975	9,920.0	9,920.0	9,920.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1976	18,300.0	18,300.0	18,300.0	4.3	4.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1977	12,100.0	12,100.0	12,100.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1978	12,300.0	12,300.0	12,300.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1979	21,700.0	21,700.0	21,700.0	4.3	4.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1980	8,780.0	8,780.0	8,780.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1981	8,110.0	8,110.0	8,110.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1982	6,600.0	6,600.0	6,600.0	3.8	3.8	1.0E-99	1.0E99	-99.0	99.0	Syst
1983	25,300.0	25,300.0	25,300.0	4.4	4.4	1.0E-99	1.0E99	-99.0	99.0	Syst
1984	20,100.0	20,100.0	20,100.0	4.3	4.3	1.0E-99	1.0E99	-99.0	99.0	Syst
1985	7,850.0	7,850.0	7,850.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1986	13,400.0	13,400.0	13,400.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1987	13,000.0	13,000.0	13,000.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1988	15,500.0	15,500.0	15,500.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1989	17,600.0	17,600.0	17,600.0	4.2	4.2	1.0E-99	1.0E99	-99.0	99.0	Syst
1990	11,500.0	11,500.0	11,500.0	4.1	4.1	1.0E-99	1.0E99	-99.0	99.0	Syst
1991	10,000.0	10,000.0	10,000.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1992	8,280.0	8,280.0	8,280.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1993	10,500.0	10,500.0	10,500.0	4.0	4.0	1.0E-99	1.0E99	-99.0	99.0	Syst
1994	7,210.0	7,210.0	7,210.0	3.9	3.9	1.0E-99	1.0E99	-99.0	99.0	Syst
1995	4,820.0	4,820.0	4,820.0	3.7	3.7	1.0E-99	1.0E99	-99.0	99.0	Syst

07/26/2022 16:03 PM 1:1..1:1 1:1

58 Figure 6 Report File for B17C Example 10 showing EMA Representation of Data.

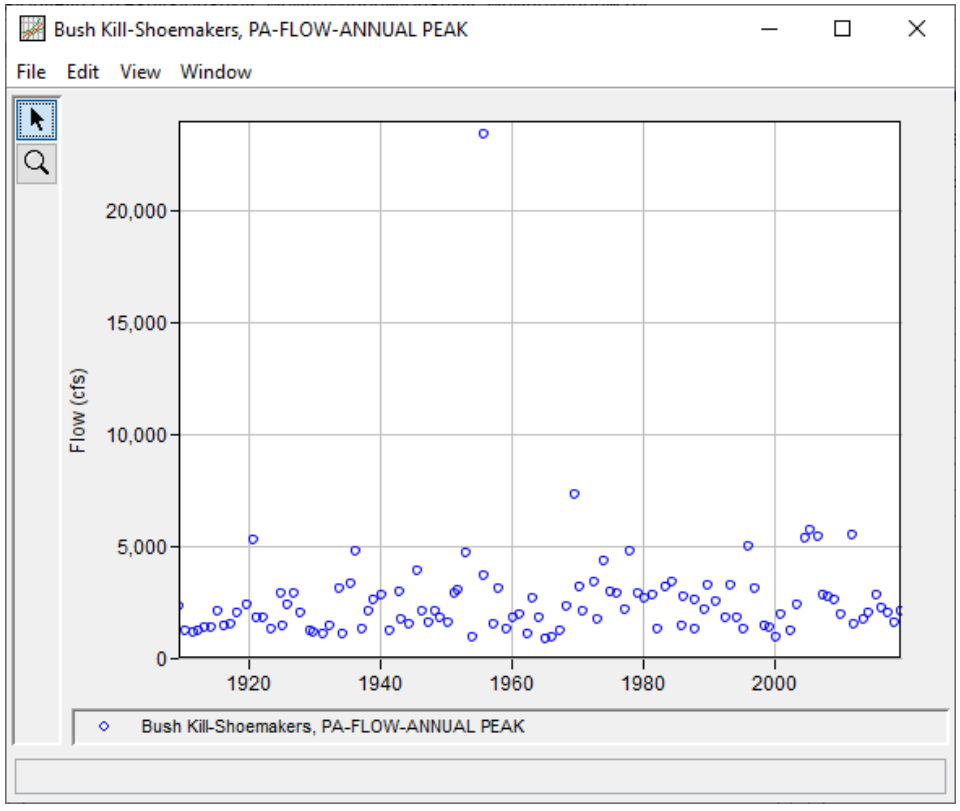
4 Bulletin 17 Variable Time Window Examples

4.1 Moving Window - Bushkill Creek

In the ***SSP_Examples.ssp*** study, the Bulletin 17 analysis **Bushkill_MovingWindow** illustrates how to utilize the *Moving Window* computational option. In this example, a 20 year time window that increments by 5 years is used to explore how individual flood peaks impact a flow-frequency curve as well as the parameters of the Log Pearson Type III Distribution.

4.1.1 Input Data

The Bushkill Creek at Shoemakers, PA[42] stream gage has an annual peak record consisting of 111 peaks beginning in 1909 and ending in 2019, as shown in Figure 1. The annual peak flow record is tabulated within Table 1.



59 Figure 1. Bushkill Creek Annual Peak Flow Record

42 https://waterdata.usgs.gov/nwis/uv?site_no=01439500

Table 1. Bushkill Creek at Shoemakers, PA Annual Peak Flow Record

Date	Flow (cfs)
20 Feb 1909	2270
07 Mar 1910	1190
14 Jun 1911	1120
15 Mar 1912	1190
28 Mar 1913	1350
29 Mar 1914	1350
24 Feb 1915	2070
02 Apr 1916	1430
27 Mar 1917	1510
26 Feb 1918	1970
22 Jul 1919	2380
24 Jul 1920	5250
10 Mar 1921	1780
08 Mar 1922	1780
24 Mar 1923	1270
30 Sep 1924	2830
12 Feb 1925	1430

Date	Flow (cfs)
16 Nov 1925	2380
16 Nov 1926	2830
19 Oct 1927	1970
15 Mar 1929	1190
18 Nov 1929	1150
29 Mar 1931	1080
01 Apr 1932	1430
16 Sep 1933	3070
12 Apr 1934	1040
10 Jul 1935	3330
18 Mar 1936	4770
06 Apr 1937	1240
25 Jan 1938	2070
06 Dec 1938	2540
31 Mar 1940	2790
06 Apr 1941	1220
28 Sep 1942	2920
30 Dec 1942	1710

Date	Flow (cfs)
25 Apr 1944	1500
19 Jul 1945	3900
28 May 1946	2080
06 Apr 1947	1580
21 Mar 1948	2080
31 Dec 1948	1780
29 Mar 1950	1540
31 Mar 1951	2860
08 Nov 1951	2980
11 Dec 1952	4680
07 Dec 1953	928
19 Aug 1955	23400
16 Oct 1955	3680
06 Apr 1957	1460
21 Dec 1957	3050
06 Mar 1959	1260
05 Apr 1960	1800
26 Feb 1961	1890

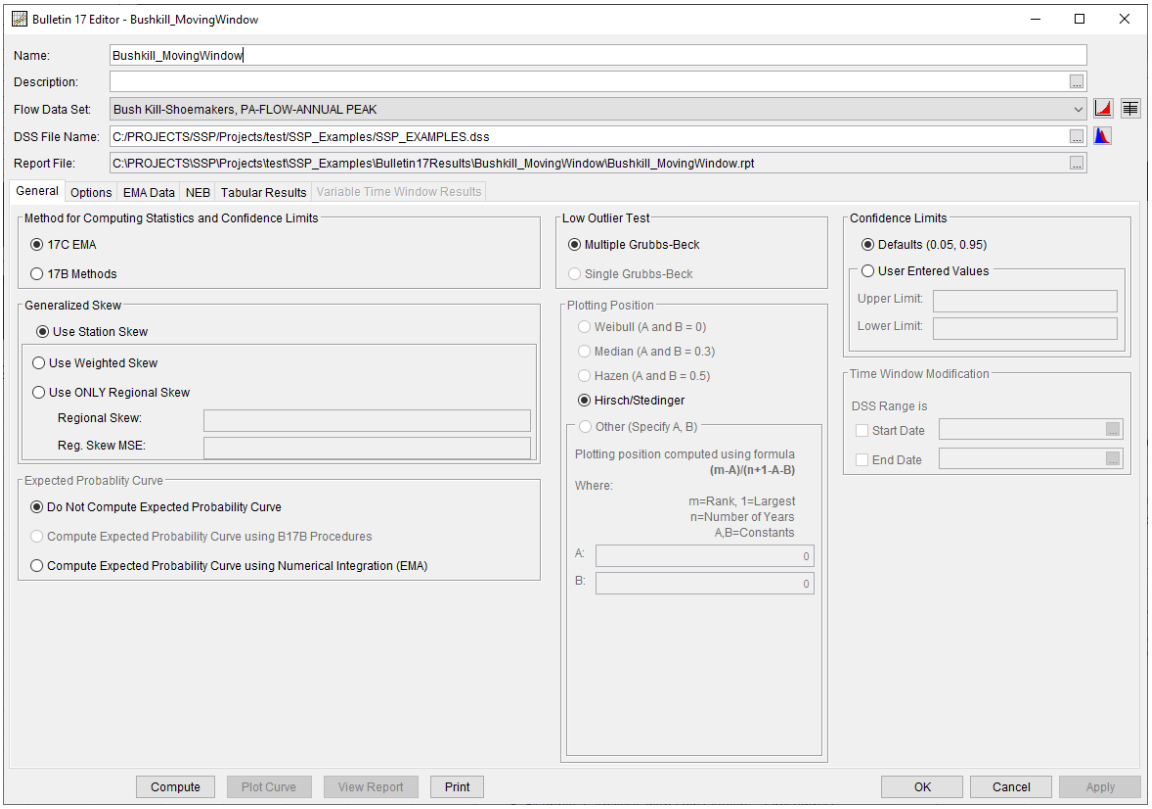
Date	Flow (cfs)
08 Apr 1962	1060
27 Mar 1963	2680
10 Mar 1964	1800
09 Feb 1965	804
06 Mar 1966	880
15 Mar 1967	1200
30 May 1968	2290
28 Jul 1969	7300
02 Apr 1970	3130
23 Oct 1970	2070
23 Jun 1972	3360
03 Feb 1973	1730
21 Dec 1973	4280
08 Dec 1974	2910
28 Jan 1976	2830
25 Feb 1977	2120
09 Jan 1978	4720
25 Jan 1979	2830

Date	Flow (cfs)
22 Mar 1980	2670
12 May 1981	2770
04 Feb 1982	1300
16 Apr 1983	3160
05 Apr 1984	3340
27 Sep 1985	1420
15 Mar 1986	2730
13 Sep 1987	2580
30 Nov 1987	1260
06 May 1989	2120
20 Oct 1989	3260
04 Dec 1990	2470
31 May 1992	1780
01 Apr 1993	3210
28 Mar 1994	1750
08 Mar 1995	1280
27 Jan 1996	4990
02 Dec 1996	3060

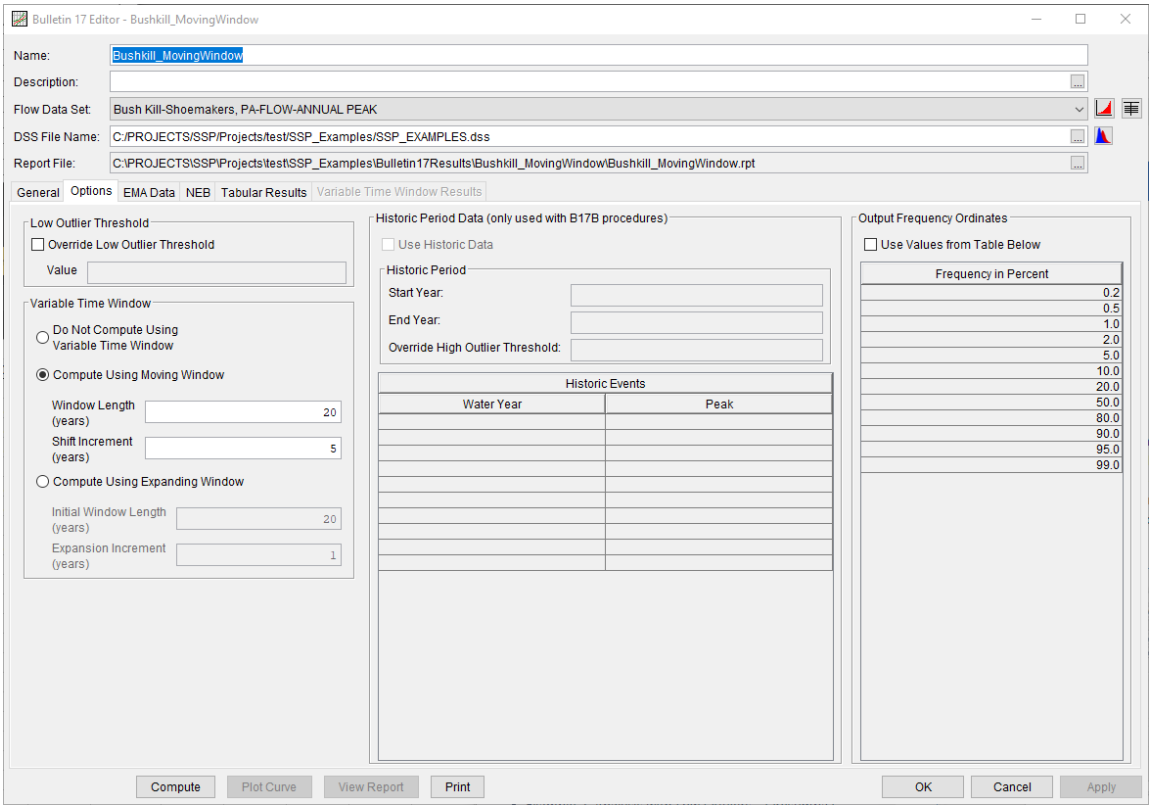
Date	Flow (cfs)
12 May 1998	1450
24 Jan 1999	1360
28 Feb 2000	895
17 Dec 2000	1930
29 May 2002	1210
22 Jun 2003	2340
18 Sep 2004	5330
03 Apr 2005	5670
28 Jun 2006	5380
16 Apr 2007	2790
09 Mar 2008	2750
12 Dec 2008	2590
25 Jan 2010	1940
28 Aug 2011	5480
08 Dec 2011	1480
11 Jun 2013	1740
01 May 2014	2030
01 Jul 2015	2790

Date	Flow (cfs)
25 Feb 2016	2220
07 Apr 2017	1970
25 Feb 2018	1550
24 Jan 2019	2070

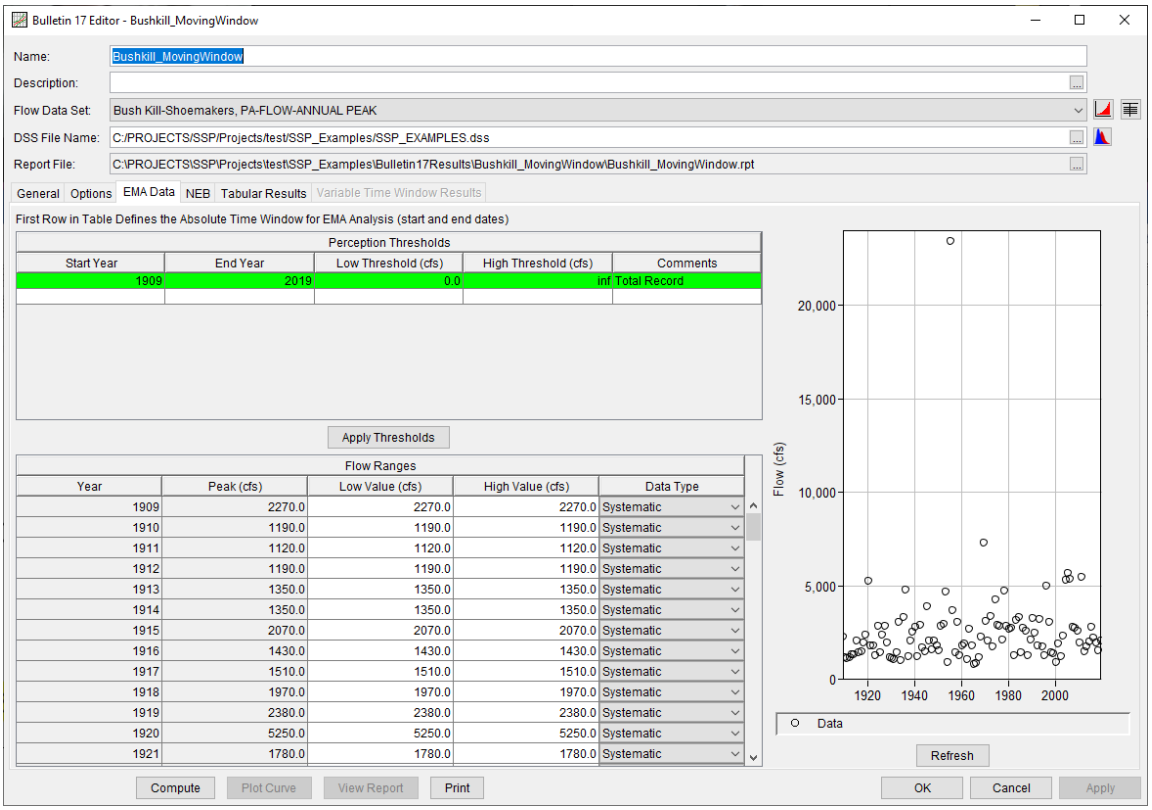
A Bulletin 17 Analysis using Bulletin 17C procedures and the *Variable Time Window | Moving Window* compute option has been developed for this example. To open the analysis, either double-click on the analysis labeled **Bushkill_MovingWindow** from the Study Explorer or from the **Analysis** menu select open, then select **Bushkill_MovingWindow** from the list of available analyses. When **Bushkill_MovingWindow** is selected, the Bulletin 17 analysis editor **General** tab will appear as shown in Figure 2. As shown, the *17C EMA* computational option was selected along with all the subsequent default options.



On the **Options** tab, the *Compute Using Moving Window* option was selected within the *Variable Time Window* panel. A *Window Length* of **20** years and a *Shift Increment* of **5** years was entered, as shown in Figure 3.



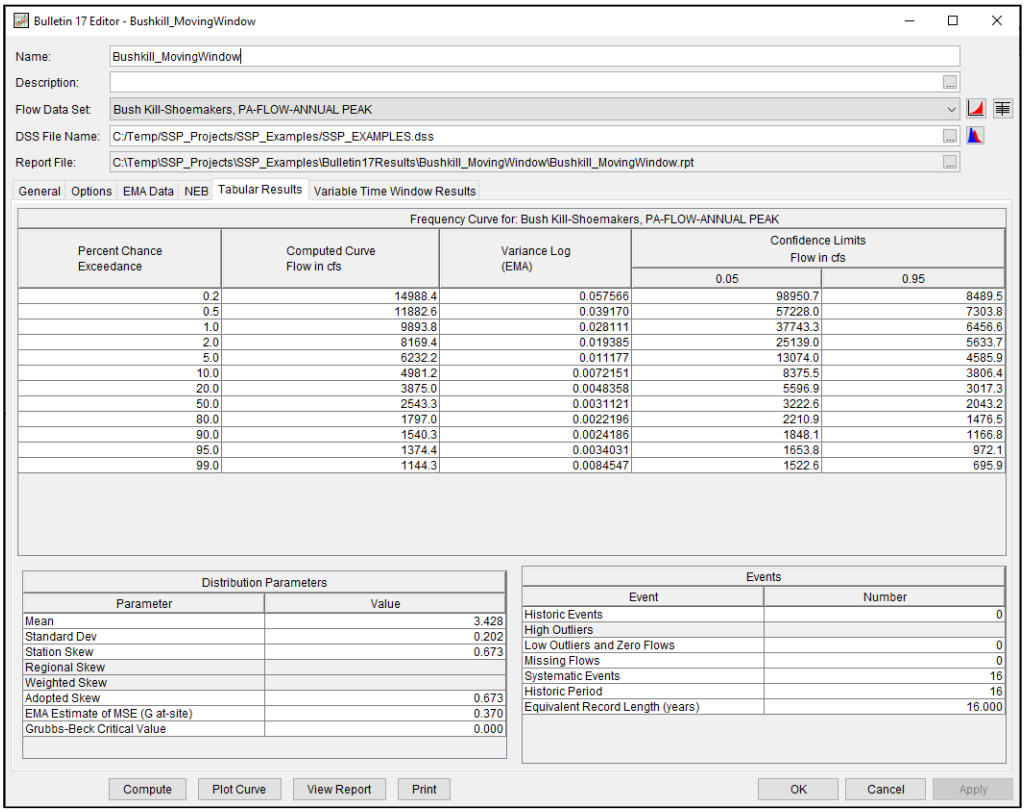
The **EMA Data** tab for this example is shown in Figure 4. Since this example uses an annual maximum series consisting entirely of systematic data with a complete record, a single zero – inf perception threshold is adequate. No modifications to the default flow ranges and data types are necessary.



4.1.2 Computing the Analysis

Once all of the **General**, **Options**, and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. A *Compute Warnings* message will be shown noting that the user specified time window length and shift do not evenly divide the compute time window. This message is simply notifying the user that the final compute time window will be shifted by less than 5 years. Once the computations have been completed, a message window will open stating **Compute Complete**.

Close these windows and then select the **Tabular Results** tab. The analysis window should resemble Figure 5.



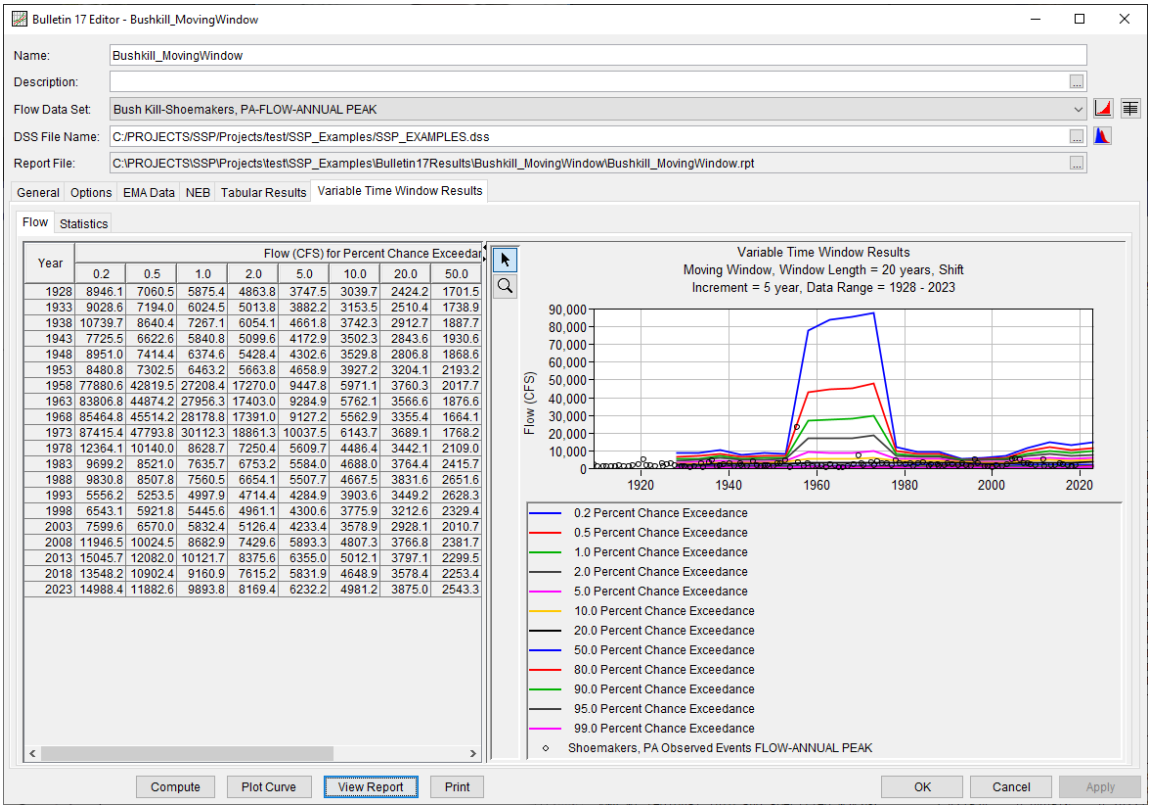
60 Figure 5. Bulletin 17 Analysis Tabular Results Tab for Bushkill_MovingWindow

> When using the Variable Time Window compute option, the **Tabular Results** tab will only contain the results from the final time window computation. In this example, the final time window spans water years 2004 - 2019, which is 16 total years.

In addition to the tabular results, a graphical plot of the computed frequency curves for the final time window can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window.

4.1.3 Variable Time Window Results

Upon clicking the **Variable Time Window Results** tab, two sub-tabs become available: **Flow** and **Statistics**. The **Flow** sub-tab contains the evolution of quantile information for each time window and each of the frequency ordinates specified within the **Options** tab | *Output Frequency Ordinates* table, as shown within Figure 6.



61 Figure 6. Quantile information for each time window in the moving window analysis

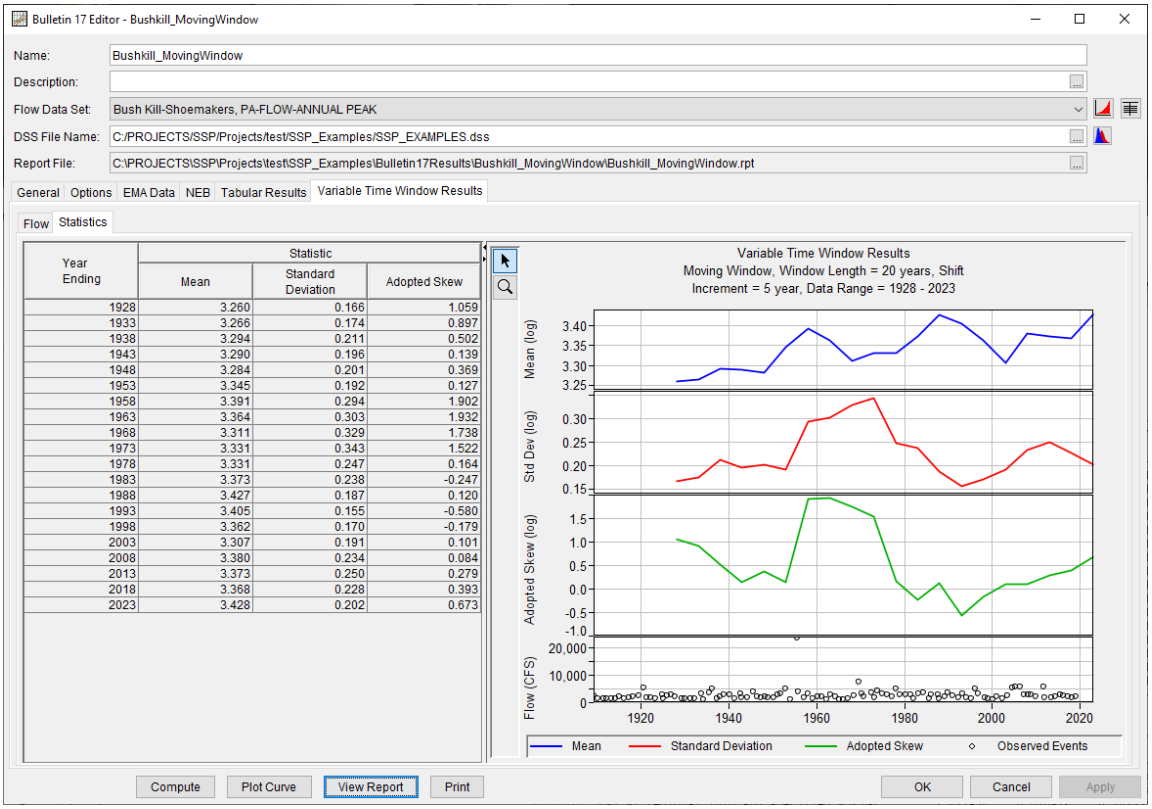
Within this example, 20 time windows were derived from the input data, as shown in Table 2. Notice that the last time window contains fewer than 20 years.

Table 2. Time Windows for Bushkill_MovingWindow Bulletin 17 Analysis

Begin Year	End Year	Number of Years
1909	1928	20
1914	1933	20
1919	1938	20
1924	1943	20
1929	1948	20
1934	1953	20

Begin Year	End Year	Number of Years
1939	1958	20
1944	1963	20
1949	1968	20
1954	1973	20
1959	1978	20
1964	1983	20
1969	1988	20
1974	1993	20
1979	1998	20
1984	2003	20
1989	2008	20
1994	2013	20
1999	2018	20
2004	2019	16

The **Statistics** sub-tab contains the evolution of Log Pearson Type III parameters for each time window, as shown within Figure 7.

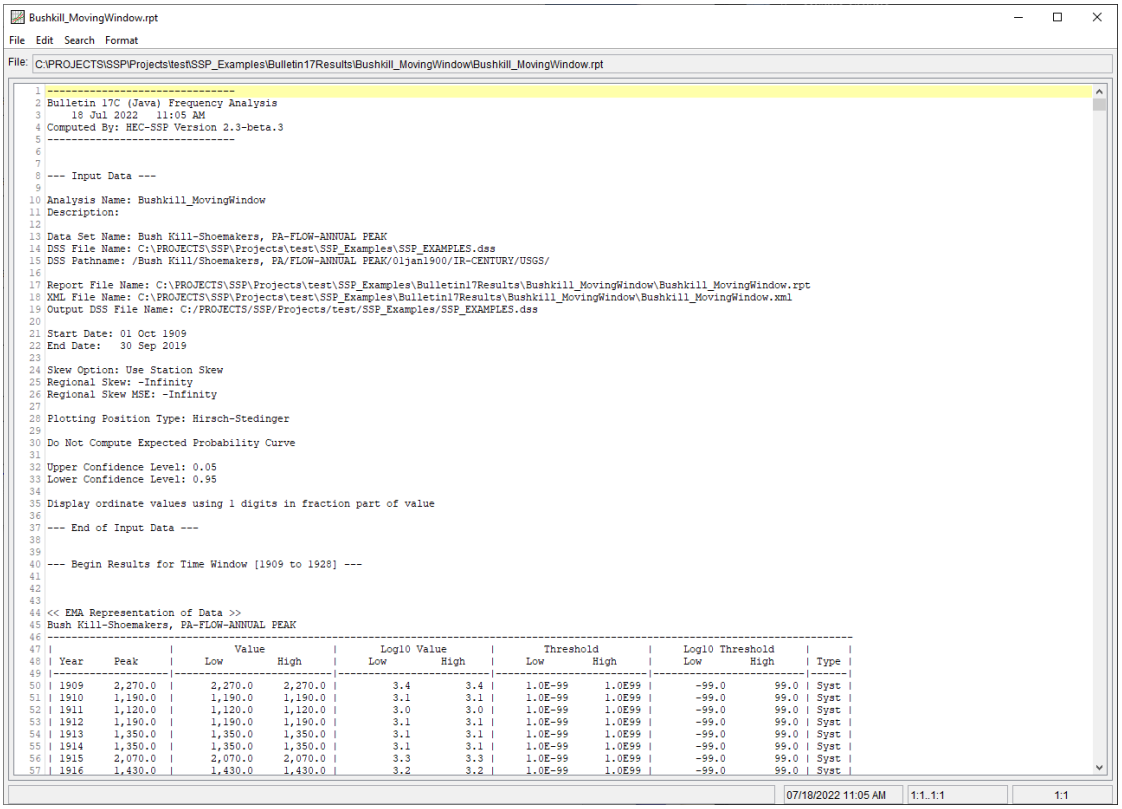


62 Figure 7. Log Person III parameters for each 20 year window in the moving window analysis

> Notice the extreme event in 1955. The peak flow rate for the 1955 event was 23,400 cfs; whereas, the next largest flood was 7,300 cfs in 1969. The inclusion (or exclusion) of this flood event causes dramatic changes to the computed quantiles (e.g. 1/100 annual exceedance probability flow rate) as well LPIII parameters (e.g. skew).

4.1.4 Report File

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected, a text viewer will open the file and display it on the screen. Shown in Figure 8 is the report file. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results for each of the time windows. Additionally, a final summarization of all the time windows is included. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis. The user should review the report file to understand how the Bulletin 17C procedures were applied for each time window.



63 Figure 8. Report File for Bushkill_MovingWindow

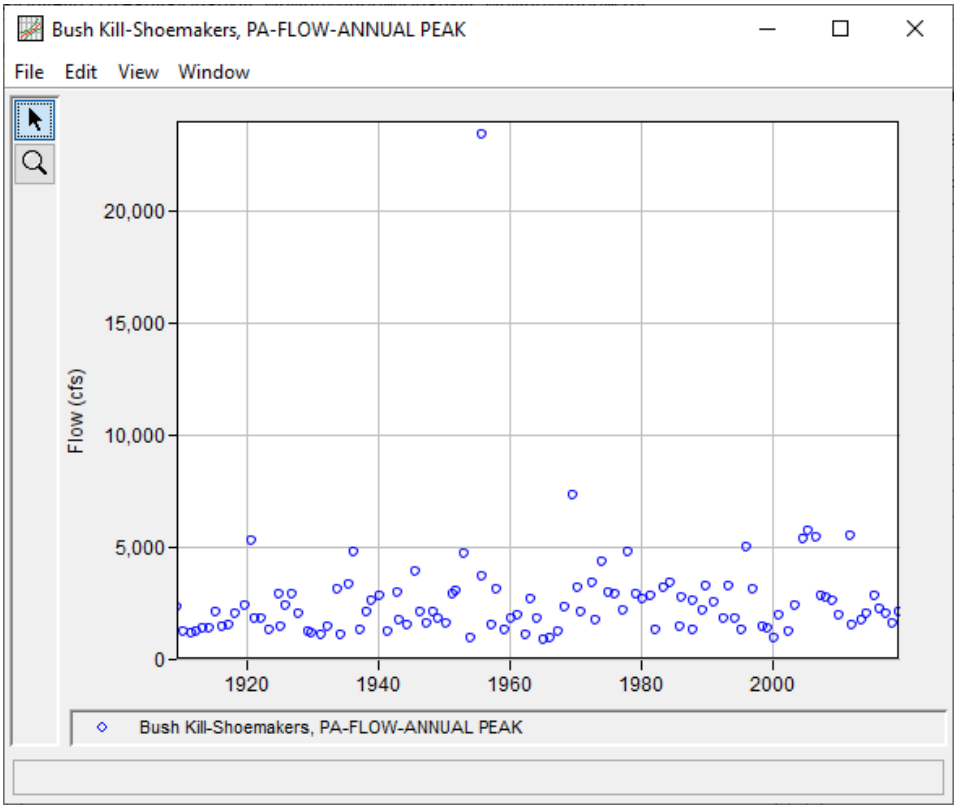
4.2 Expanding Window - Bushkill Creek

In the ***SSP_Examples.ssp*** study, the Bulletin 17 analysis **Bushkill_ExpandingWindow** illustrates how to utilize the *Expanding Window* computational option. In this example, an initial period of 20 years is incrementally expanded by 5 years to explore how individual flood peaks impact a flow-frequency curve as well as the parameters of the Log Pearson Type III Distribution.

4.2.1 Input Data

The Bushkill Creek at Shoemakers, PA[43] stream gage has an annual peak record consisting of 111 peaks beginning in 1909 and ending in 2019, as shown in Figure 1. The annual peak flow record is tabulated within Table 1.

43 https://waterdata.usgs.gov/nwis/uv?site_no=01439500



64 Figure 1. Bushkill Creek Annual Peak Flow Record

Table 1. Bushkill Creek at Shoemakers, PA Annual Peak Flow Record

Date	Flow (cfs)
20 Feb 1909	2270
07 Mar 1910	1190
14 Jun 1911	1120
15 Mar 1912	1190
28 Mar 1913	1350
29 Mar 1914	1350
24 Feb 1915	2070

Date	Flow (cfs)
02 Apr 1916	1430
27 Mar 1917	1510
26 Feb 1918	1970
22 Jul 1919	2380
24 Jul 1920	5250
10 Mar 1921	1780
08 Mar 1922	1780
24 Mar 1923	1270
30 Sep 1924	2830
12 Feb 1925	1430
16 Nov 1925	2380
16 Nov 1926	2830
19 Oct 1927	1970
15 Mar 1929	1190
18 Nov 1929	1150
29 Mar 1931	1080
01 Apr 1932	1430
16 Sep 1933	3070

Date	Flow (cfs)
12 Apr 1934	1040
10 Jul 1935	3330
18 Mar 1936	4770
06 Apr 1937	1240
25 Jan 1938	2070
06 Dec 1938	2540
31 Mar 1940	2790
06 Apr 1941	1220
28 Sep 1942	2920
30 Dec 1942	1710
25 Apr 1944	1500
19 Jul 1945	3900
28 May 1946	2080
06 Apr 1947	1580
21 Mar 1948	2080
31 Dec 1948	1780
29 Mar 1950	1540
31 Mar 1951	2860

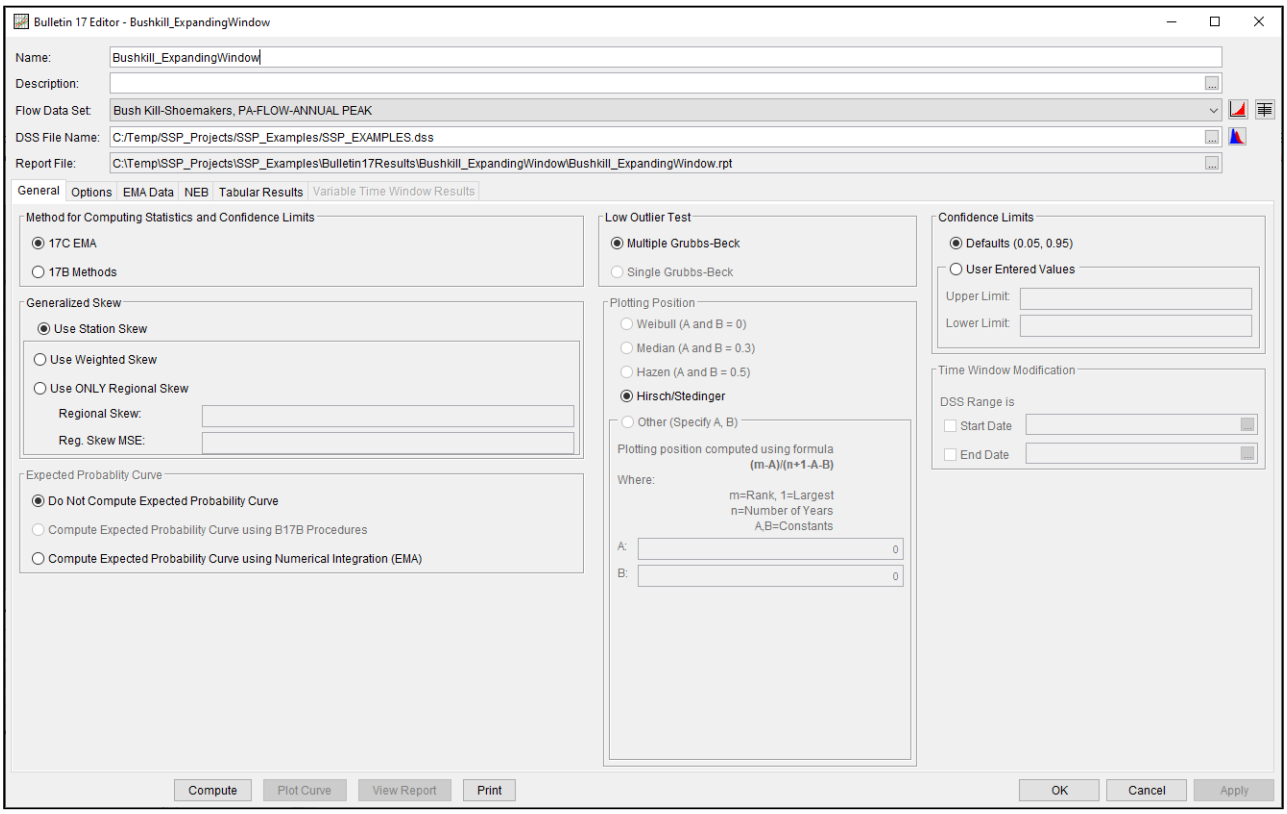
Date	Flow (cfs)
08 Nov 1951	2980
11 Dec 1952	4680
07 Dec 1953	928
19 Aug 1955	23400
16 Oct 1955	3680
06 Apr 1957	1460
21 Dec 1957	3050
06 Mar 1959	1260
05 Apr 1960	1800
26 Feb 1961	1890
08 Apr 1962	1060
27 Mar 1963	2680
10 Mar 1964	1800
09 Feb 1965	804
06 Mar 1966	880
15 Mar 1967	1200
30 May 1968	2290
28 Jul 1969	7300

Date	Flow (cfs)
02 Apr 1970	3130
23 Oct 1970	2070
23 Jun 1972	3360
03 Feb 1973	1730
21 Dec 1973	4280
08 Dec 1974	2910
28 Jan 1976	2830
25 Feb 1977	2120
09 Jan 1978	4720
25 Jan 1979	2830
22 Mar 1980	2670
12 May 1981	2770
04 Feb 1982	1300
16 Apr 1983	3160
05 Apr 1984	3340
27 Sep 1985	1420
15 Mar 1986	2730
13 Sep 1987	2580

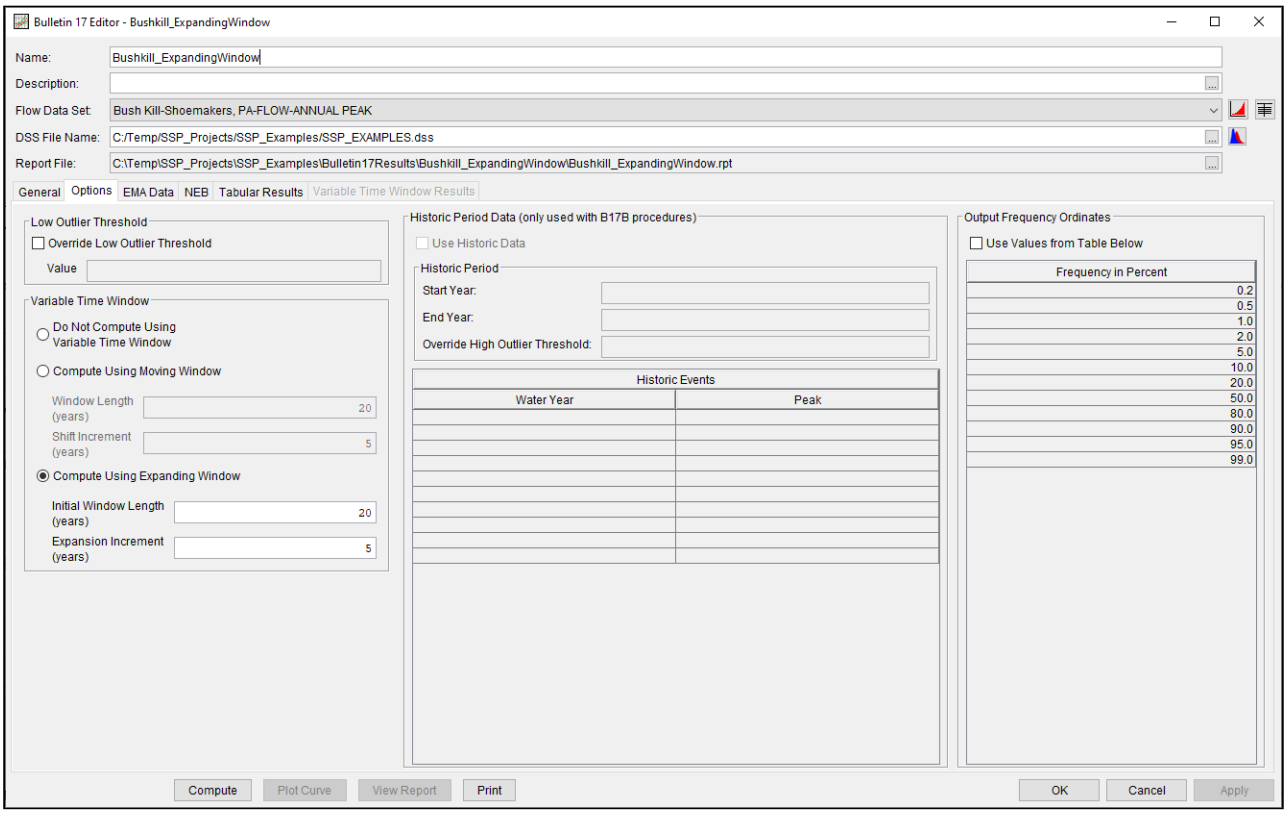
Date	Flow (cfs)
30 Nov 1987	1260
06 May 1989	2120
20 Oct 1989	3260
04 Dec 1990	2470
31 May 1992	1780
01 Apr 1993	3210
28 Mar 1994	1750
08 Mar 1995	1280
27 Jan 1996	4990
02 Dec 1996	3060
12 May 1998	1450
24 Jan 1999	1360
28 Feb 2000	895
17 Dec 2000	1930
29 May 2002	1210
22 Jun 2003	2340
18 Sep 2004	5330
03 Apr 2005	5670

Date	Flow (cfs)
28 Jun 2006	5380
16 Apr 2007	2790
09 Mar 2008	2750
12 Dec 2008	2590
25 Jan 2010	1940
28 Aug 2011	5480
08 Dec 2011	1480
11 Jun 2013	1740
01 May 2014	2030
01 Jul 2015	2790
25 Feb 2016	2220
07 Apr 2017	1970
25 Feb 2018	1550
24 Jan 2019	2070

A Bulletin 17 Analysis using Bulletin 17C procedures and the *Variable Time Window | Expanding Window* compute option has been developed for this example. To open the analysis, either double-click on the analysis labeled **Bushkill_ExpandingWindow** from the Study Explorer or from the **Analysis** menu select open, then select **Bushkill_ExpandingWindow** from the list of available analyses. When **Bushkill_ExpandingWindow** is selected, the Bulletin 17 analysis editor **General** tab will appear as shown in Figure 2. As shown, the *17C EMA* computational option was selected along with all the subsequent default options.

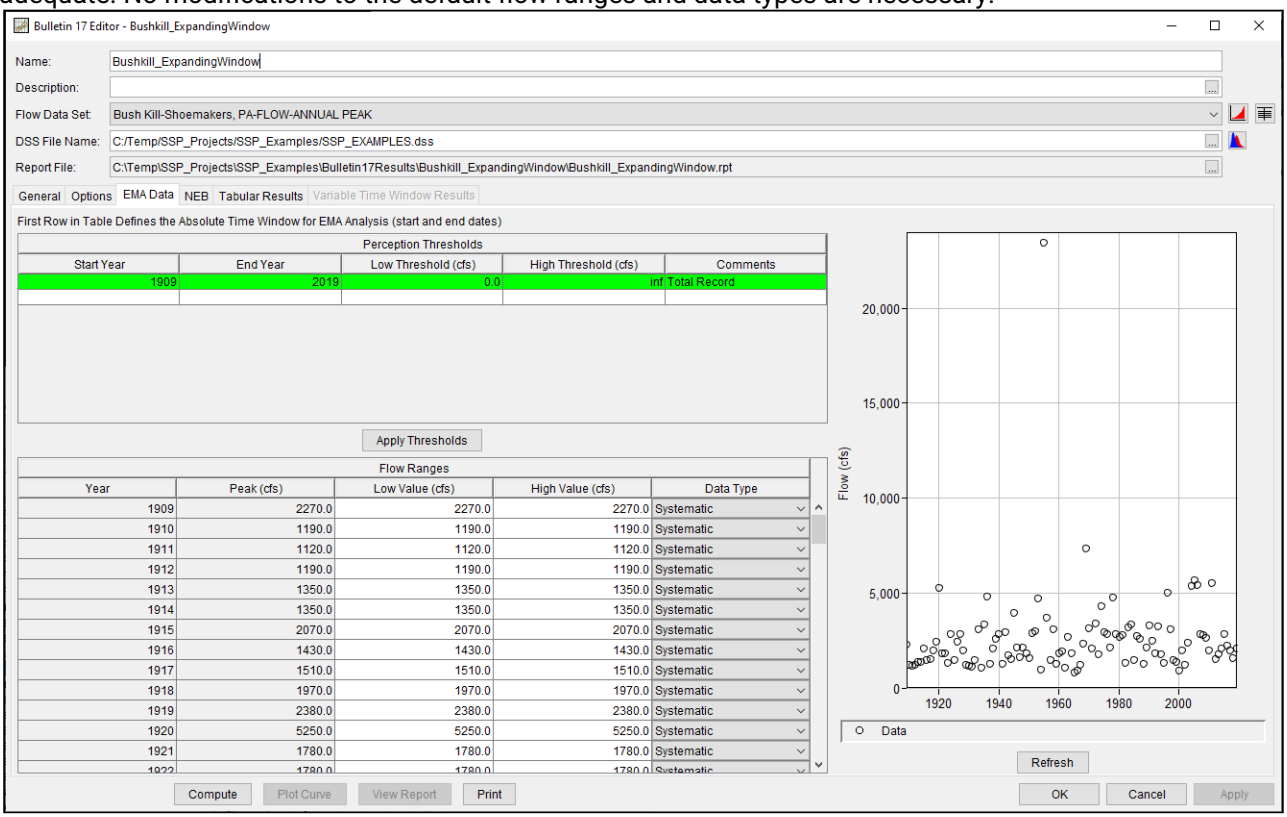


On the **Options** tab, the *Compute Using Expanding Window* option was selected within the *Variable Time Window* panel. An *Initial Window Length* of **20** years and an *Expansion Increment* of **5** years was entered, as shown in Figure 3.



The **EMA Data** tab for this example is shown in Figure 4. Since this example uses an annual maximum series consisting entirely of systematic data with a complete record, a single zero – inf perception threshold is

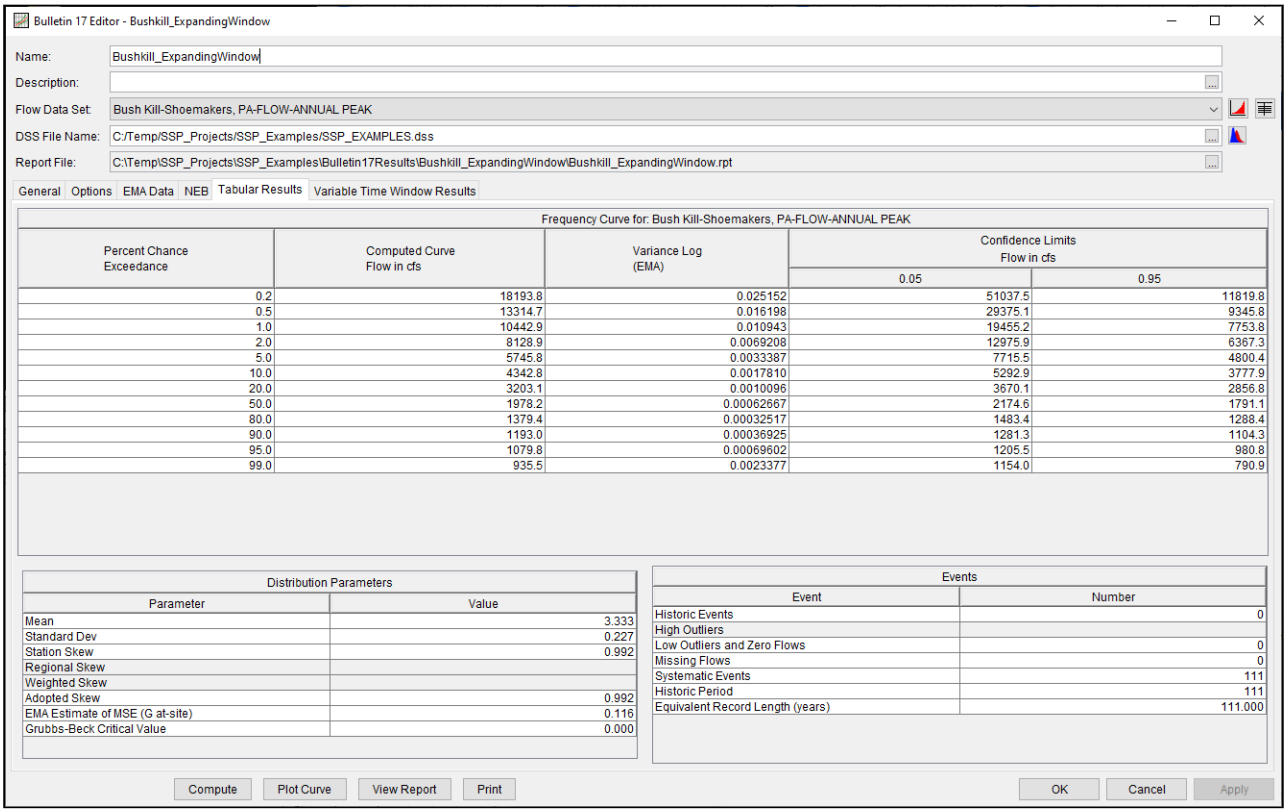
adequate. No modifications to the default flow ranges and data types are necessary.



4.2.2 Computing the Analysis

Once all of the **General**, **Options**, and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. A *Compute Warnings* message will be shown noting that the final expansion increment was less than 5 years. Once the computations have been completed, a message window will open stating **Compute Complete**.

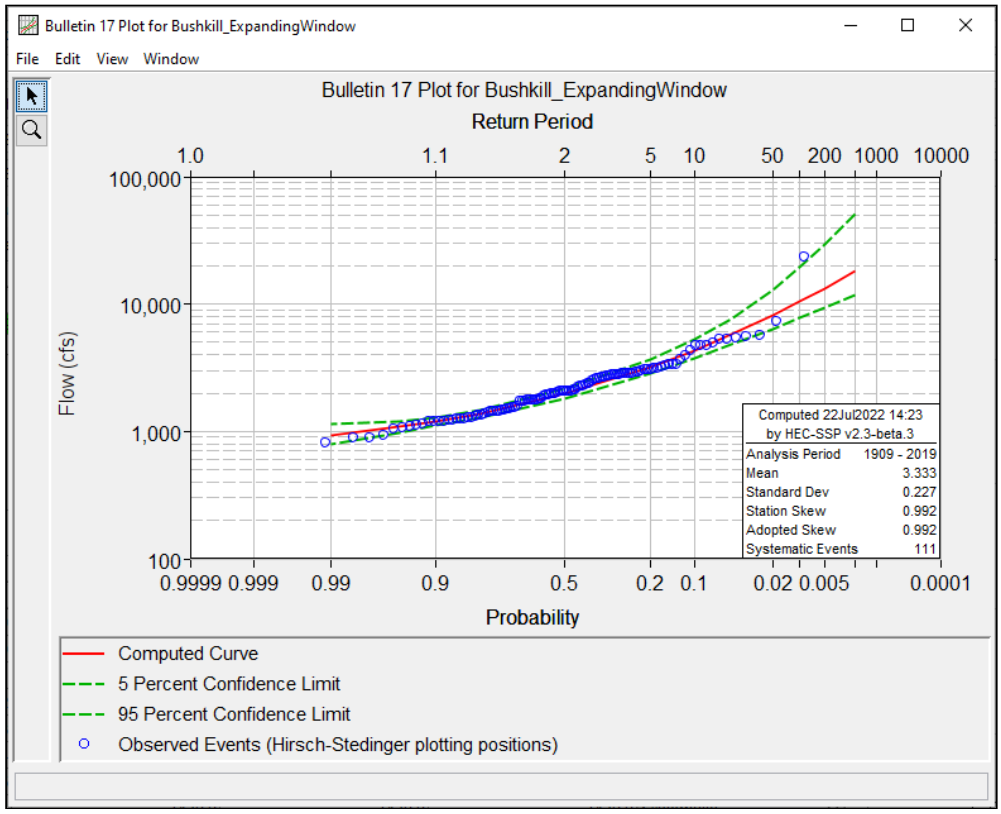
Close these windows and then select the **Tabular Results** tab. The analysis window should resemble Figure 5.



65 Figure 5. Bulletin 17 Analysis Tabular Results Tab for Bushkill_ExpandingWindow

When using the Expanding Time Window compute option, the **Tabular Results** tab will only contain the results from the final time window computation. In this example, the final time window spans water years 1909 - 2019, which is 111 total years.

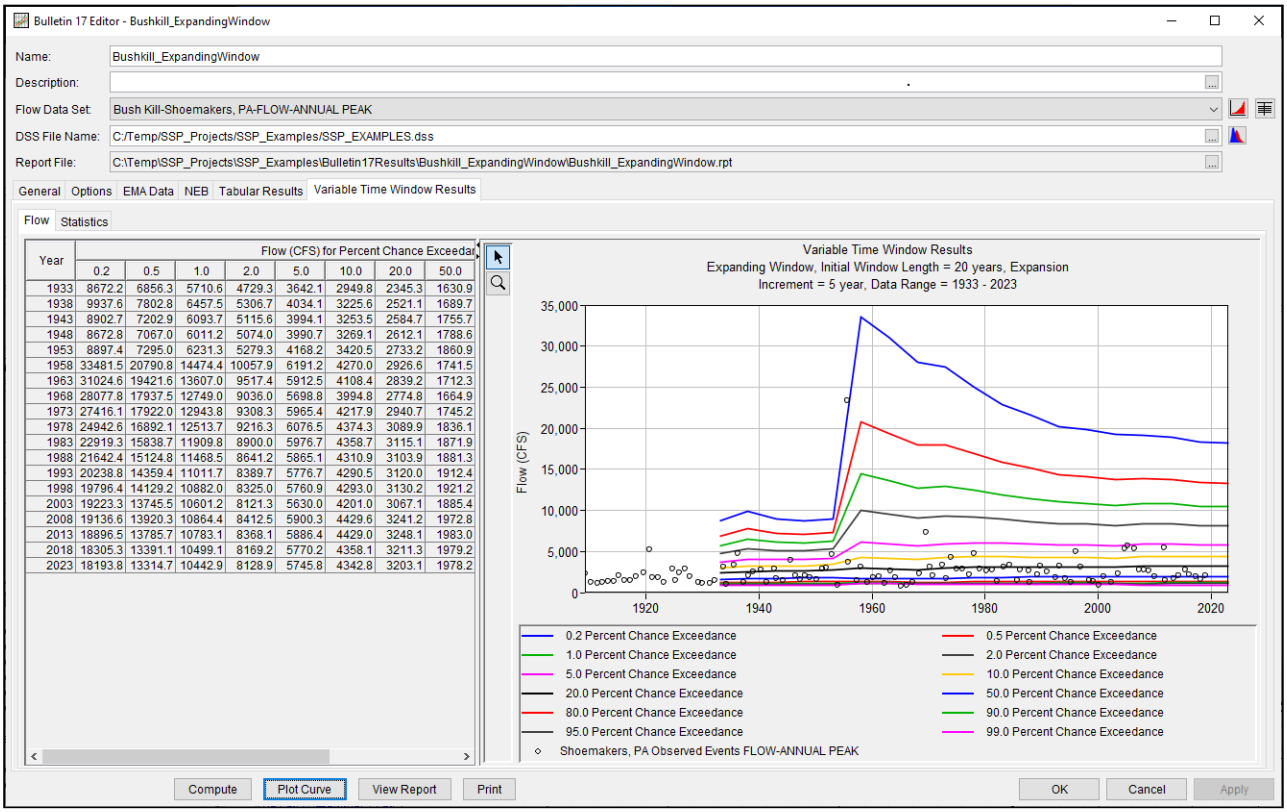
In addition to the tabular results, a graphical plot of the computed frequency curves for the final time window can be obtained by pressing the **Plot Curve** button at the bottom of the analysis window.



66 Computed frequency curve

4.2.3 Expanding Time Window Results

Upon clicking the **Variable Time Window Results** tab, two sub-tabs become available: **Flow** and **Statistics**. The **Flow** sub-tab contains the evolution of quantile information for each time window and each of the frequency ordinates specified within the **Options** tab | *Output Frequency Ordinates* table, as shown within Figure 6.



67 Figure 7. Quantile information for each time window in the expanding window analysis

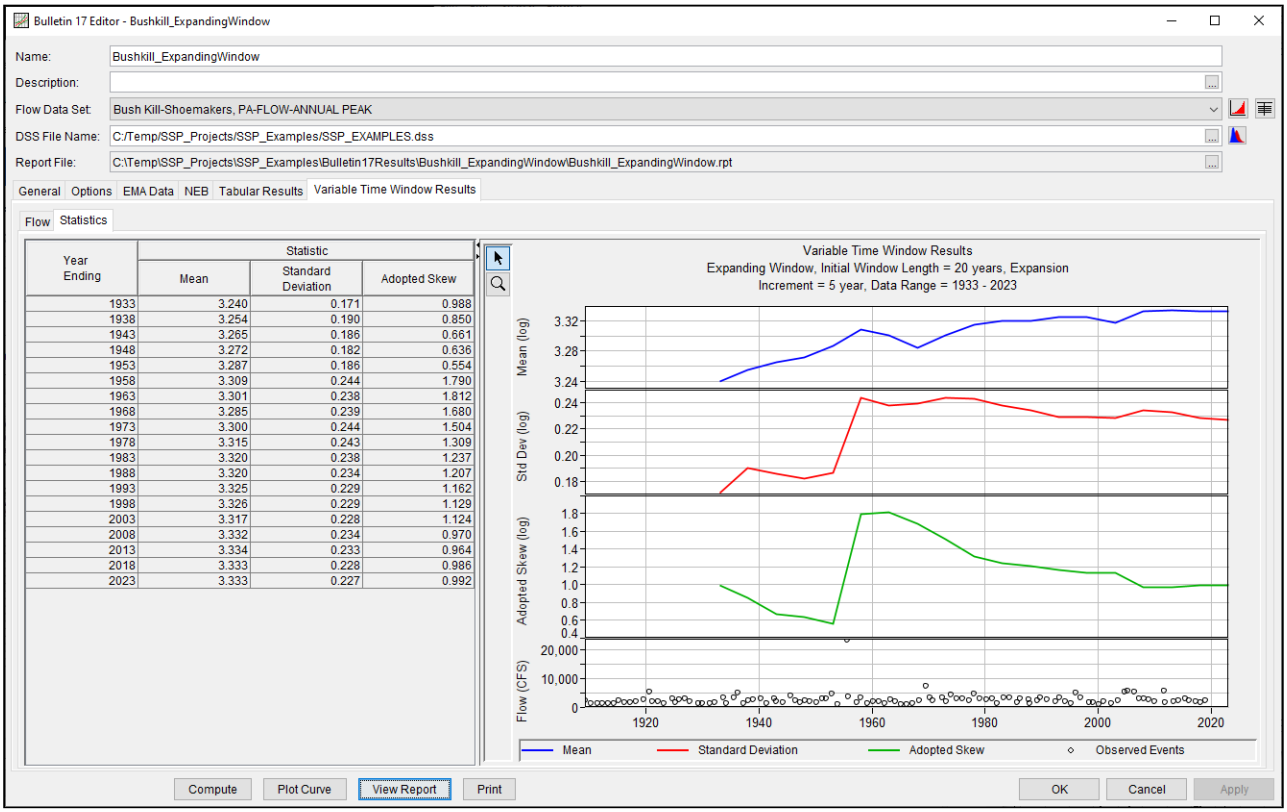
Within this example, 19 time windows were derived from the input data, as shown in Table 2.

Table 2. Time Windows for Bushkill_ExpandingWindow Bulletin 17 Analysis

Begin Year	End Year	Number of Years
1909	1933	25
1909	1938	30
1909	1943	35
1909	1948	40
1909	1953	45
1909	1958	50

Begin Year	End Year	Number of Years
1909	1963	55
1909	1968	60
1909	1973	65
1909	1978	70
1909	1983	75
1909	1988	80
1909	1993	85
1909	1998	90
1909	2003	95
1909	2008	100
1909	2013	105
1909	2018	110
1909	2019	111

The **Statistics** sub-tab contains the evolution of Log Pearson Type III parameters for each time window, as shown within Figure 7.



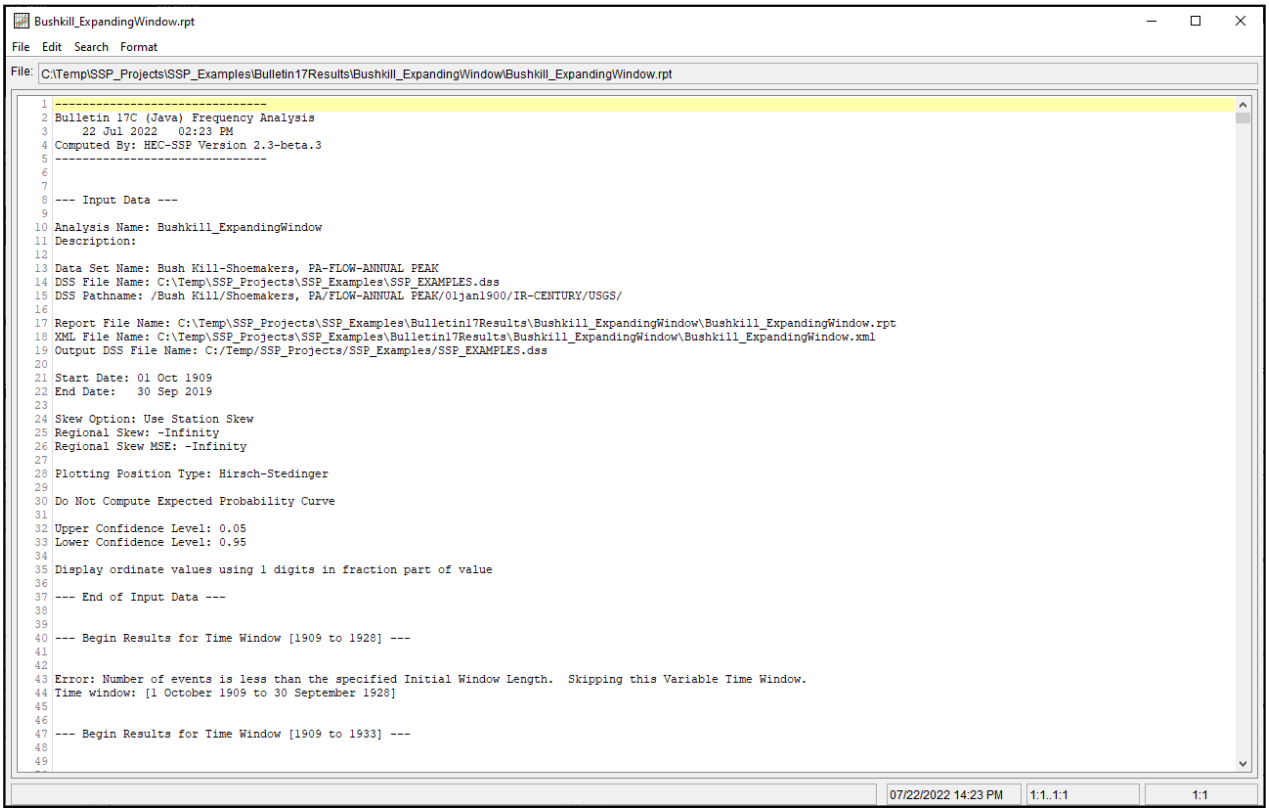
Year Ending	Statistic		
	Mean	Standard Deviation	Adopted Skew
1933	3.240	0.171	0.988
1938	3.254	0.190	0.850
1943	3.265	0.186	0.661
1948	3.272	0.182	0.636
1953	3.287	0.186	0.554
1958	3.309	0.244	1.790
1963	3.301	0.238	1.812
1968	3.285	0.239	1.680
1973	3.300	0.244	1.504
1978	3.315	0.243	1.309
1983	3.320	0.238	1.237
1988	3.320	0.234	1.207
1993	3.325	0.229	1.162
1998	3.326	0.229	1.129
2003	3.317	0.228	1.124
2008	3.332	0.234	0.970
2013	3.334	0.233	0.964
2018	3.333	0.228	0.986
2023	3.333	0.227	0.992

68 Figure 7. Log Person III parameters for each 20 year window in the expanding window analysis

Notice the extreme event in 1955. The peak flow rate for the 1955 event was 23,400 cfs; whereas, the next largest flood was 7,300 cfs in 1969. The inclusion (or exclusion) of this flood event causes dramatic changes to the computed quantiles (e.g. 1/100 annual exceedance probability flow rate) as well LPIII parameters (e.g. skew).

4.2.4 Report File

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected, a text viewer will open the file and display it on the screen. Shown in Figure 8 is the report file. The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results for each of the time windows. Additionally, a final summarization of all the time windows is included. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis. The user should review the report file to understand how the Bulletin 17C procedures were applied for each time window.

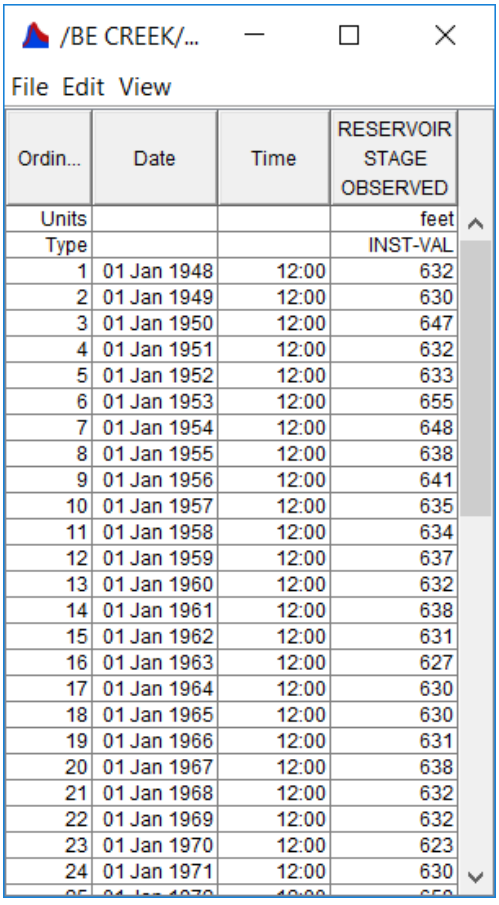


69 Figure 8. Report File for Bushkill_ExpandingWindow

5 General Frequency Analysis Examples

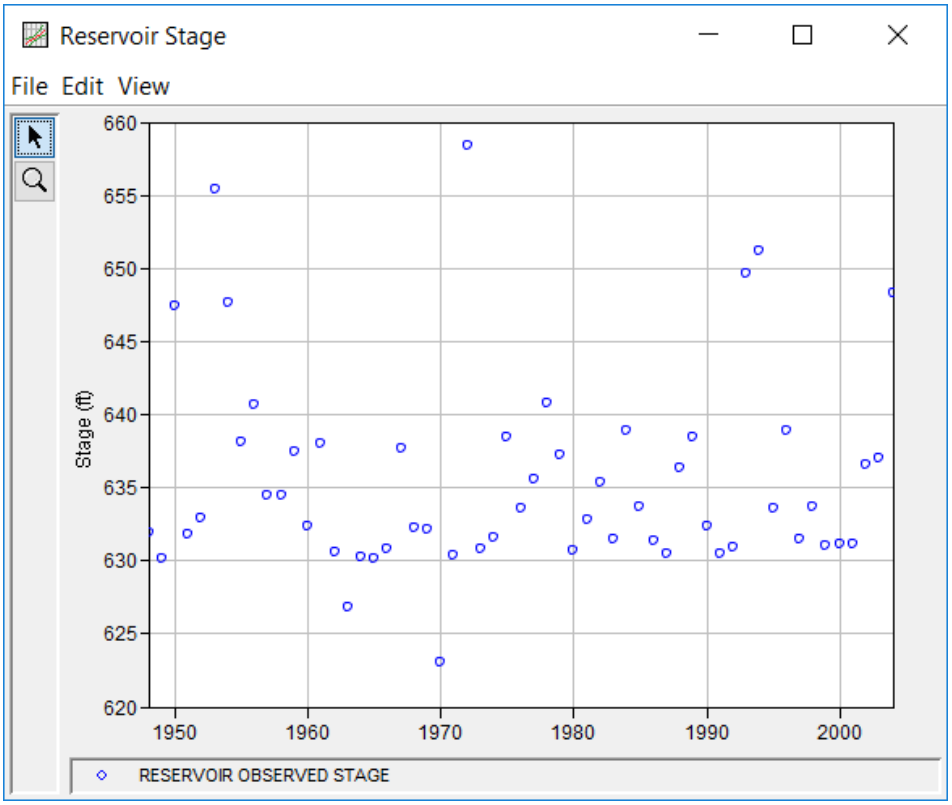
5.1 Example 7. Analyzing Stage Data

In the ***SSP_Examples.ssp*** study, the ***Stage Analysis Test 7*** example demonstrates how to use the General Frequency analysis to analyze stage data. The data used for this example is annual maximum stage data for a reservoir. The period of record used for this example is from 1948 to 2004. To view the data, right-click on the data record labeled "***Reservoir Stage***" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure 1.

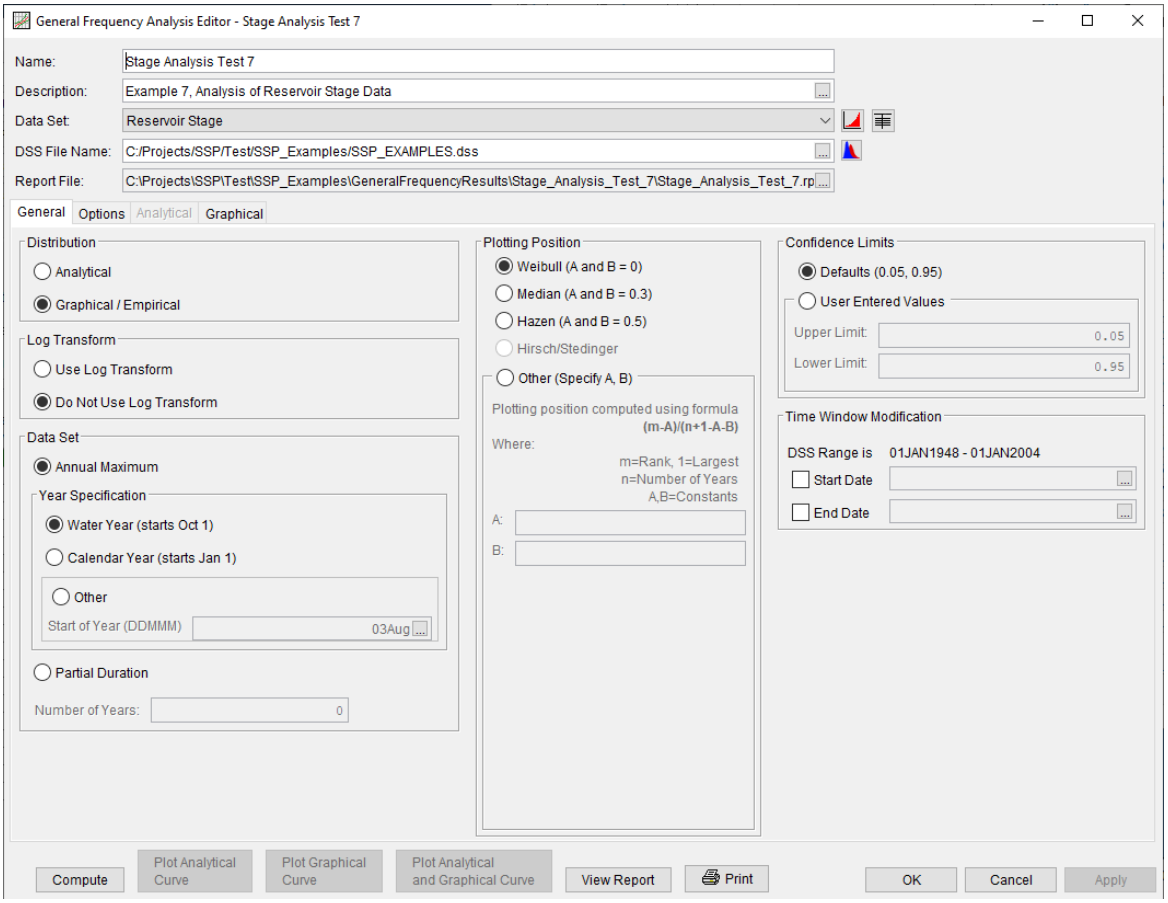


Ordin...	Date	Time	RESERVOIR STAGE OBSERVED
Units			feet
Type			INST-VAL
1	01 Jan 1948	12:00	632
2	01 Jan 1949	12:00	630
3	01 Jan 1950	12:00	647
4	01 Jan 1951	12:00	632
5	01 Jan 1952	12:00	633
6	01 Jan 1953	12:00	655
7	01 Jan 1954	12:00	648
8	01 Jan 1955	12:00	638
9	01 Jan 1956	12:00	641
10	01 Jan 1957	12:00	635
11	01 Jan 1958	12:00	634
12	01 Jan 1959	12:00	637
13	01 Jan 1960	12:00	632
14	01 Jan 1961	12:00	638
15	01 Jan 1962	12:00	631
16	01 Jan 1963	12:00	627
17	01 Jan 1964	12:00	630
18	01 Jan 1965	12:00	630
19	01 Jan 1966	12:00	631
20	01 Jan 1967	12:00	638
21	01 Jan 1968	12:00	632
22	01 Jan 1969	12:00	632
23	01 Jan 1970	12:00	623
24	01 Jan 1971	12:00	630

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2.

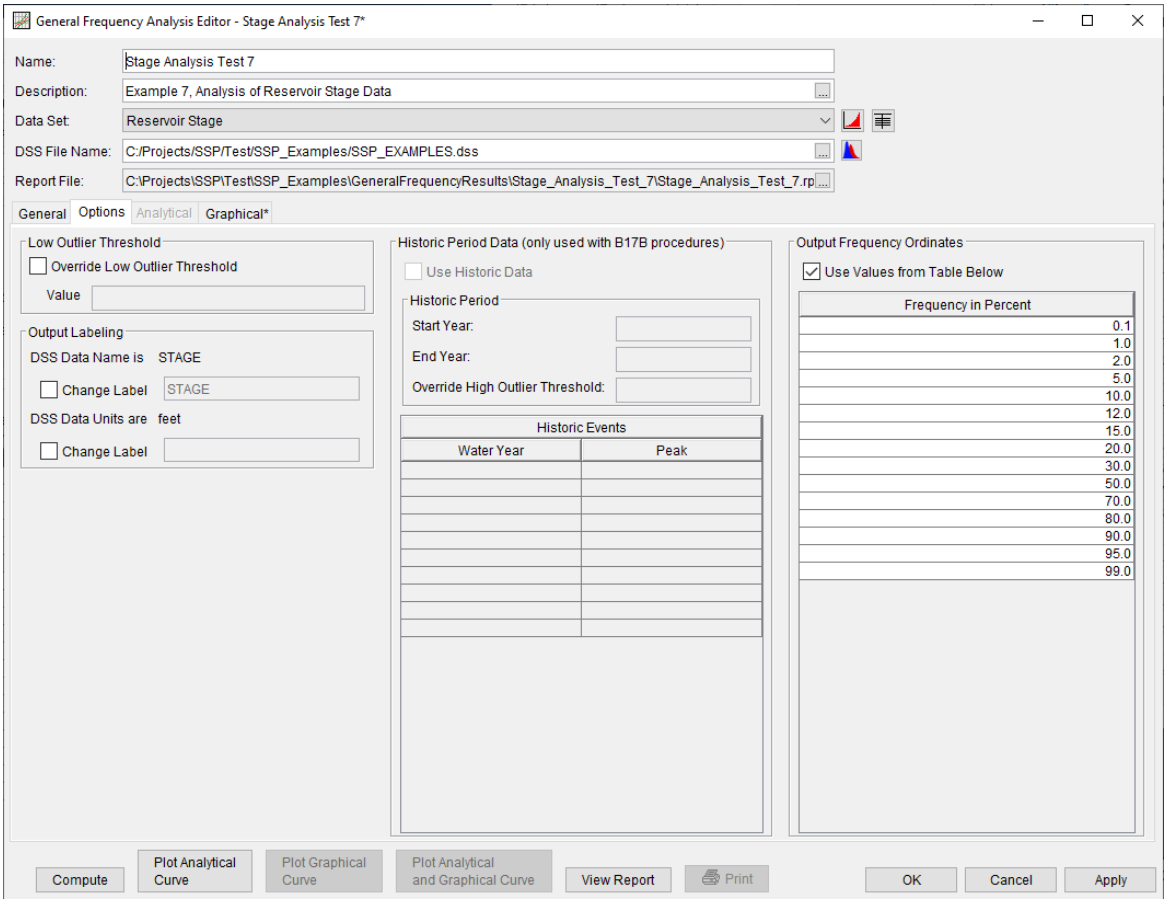


A General Frequency analysis has been developed for this example. To open the **General Frequency Analysis Editor** for this example, either double-click on the analysis labeled ***Stage Analysis Test 7*** from the study explorer; alternatively, from the **Analysis** menu select open, then select ***Stage Analysis Test 7*** from the list of available analyses. When Test 7 is opened, the **General Frequency Analysis Editor** will appear as shown in Figure 3. For this analysis, the **Graphical / Empirical**, **Do Not Use Log Transform**, and **Annual Maximum** options were selected. Also, the **Weibull** plotting position method was selected, the default **Confidence Limits** were selected, and no modification was made to the time window.

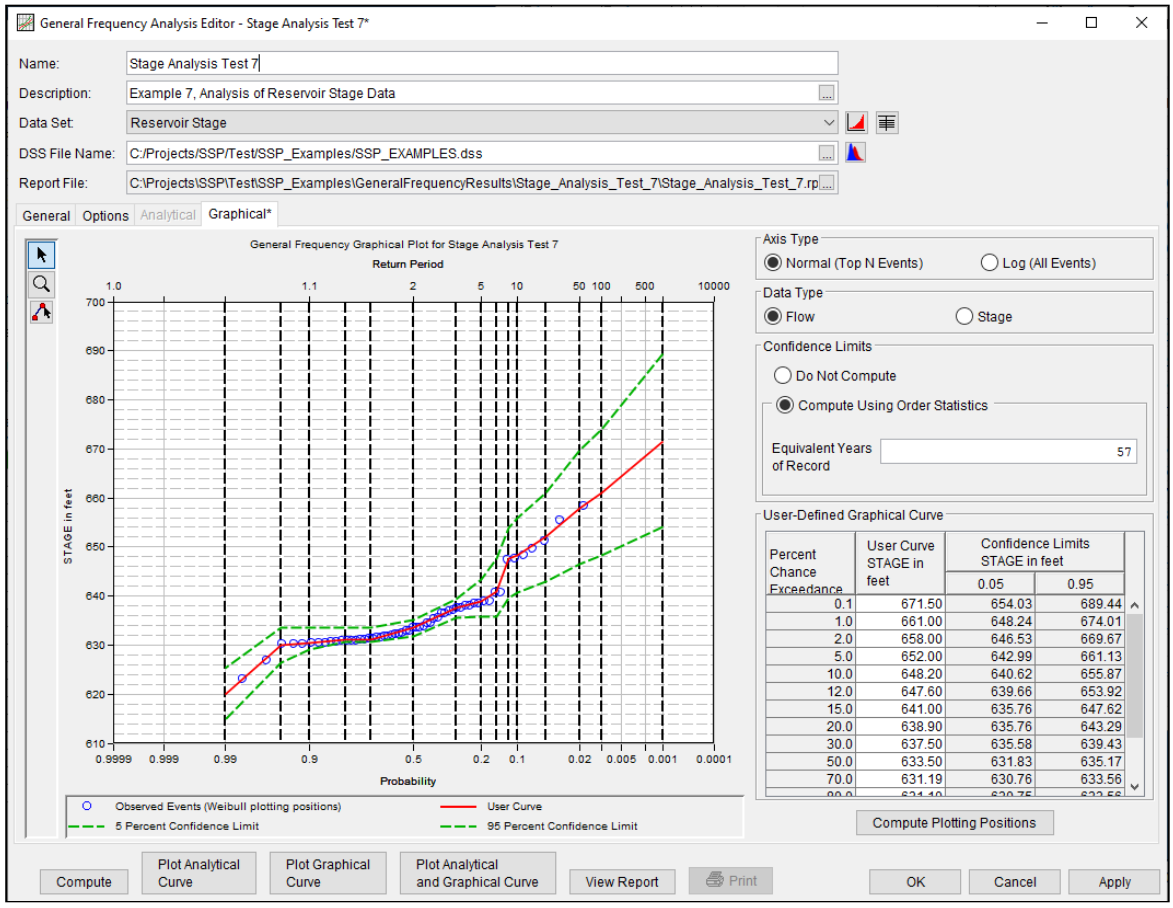


70 Figure 3. General Frequency Analysis Editor for Stage Analysis Test 7

Shown in Figure 4 is the General Frequency analysis editor with the **Options** tab selected. Features on this tab include the **Low Outlier Threshold**, adding **Historic Date** to the analysis, an option to override the default **Frequency Ordinates**, and **Output Labeling**. The 0.1 percent frequency ordinate was added to the **User Specified Frequency Ordinates** table.

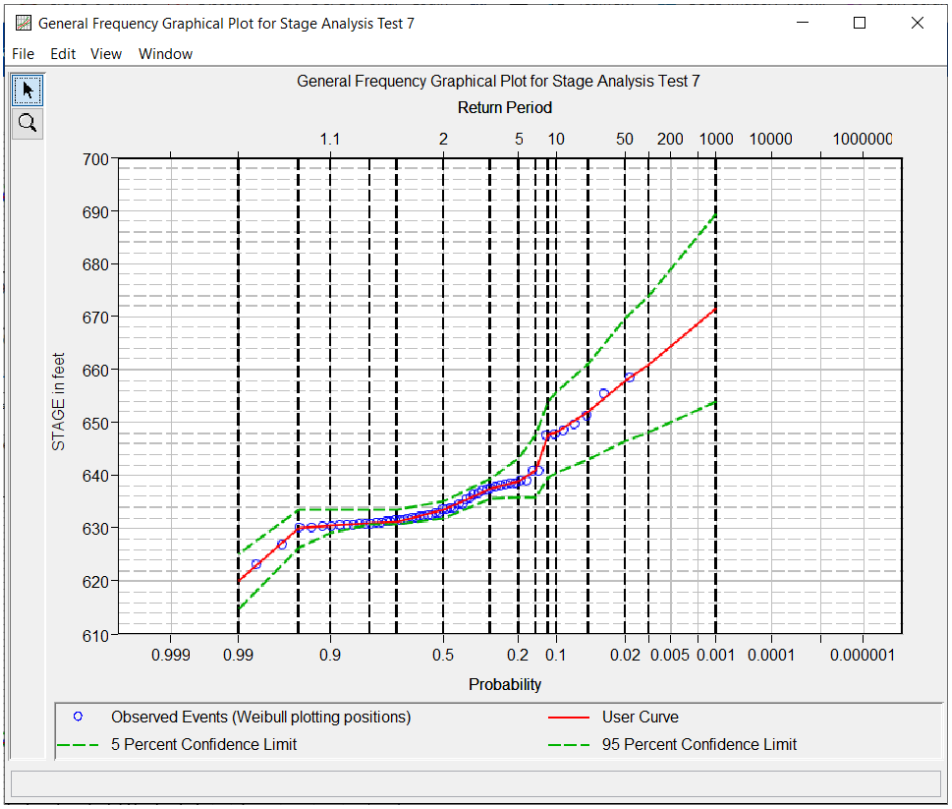


In this example, a graphical analysis was performed on the peak stage data. Shown in Figure 5 is the **Graphical** tab. The frequency curve was entered manually into the **User-Defined Graphical Curve** table. When the **Compute** button is pressed, the program plots the graphical frequency curve along with the annual maximum peak stage values.



71 Figure 5. General Frequency Graphical Tab Shown for Stage Analysis Test 7

In addition to the table and plot available on the Graphical tab, a plot of the graphical frequency curves can be obtained by pressing the **Plot Graphical Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6.

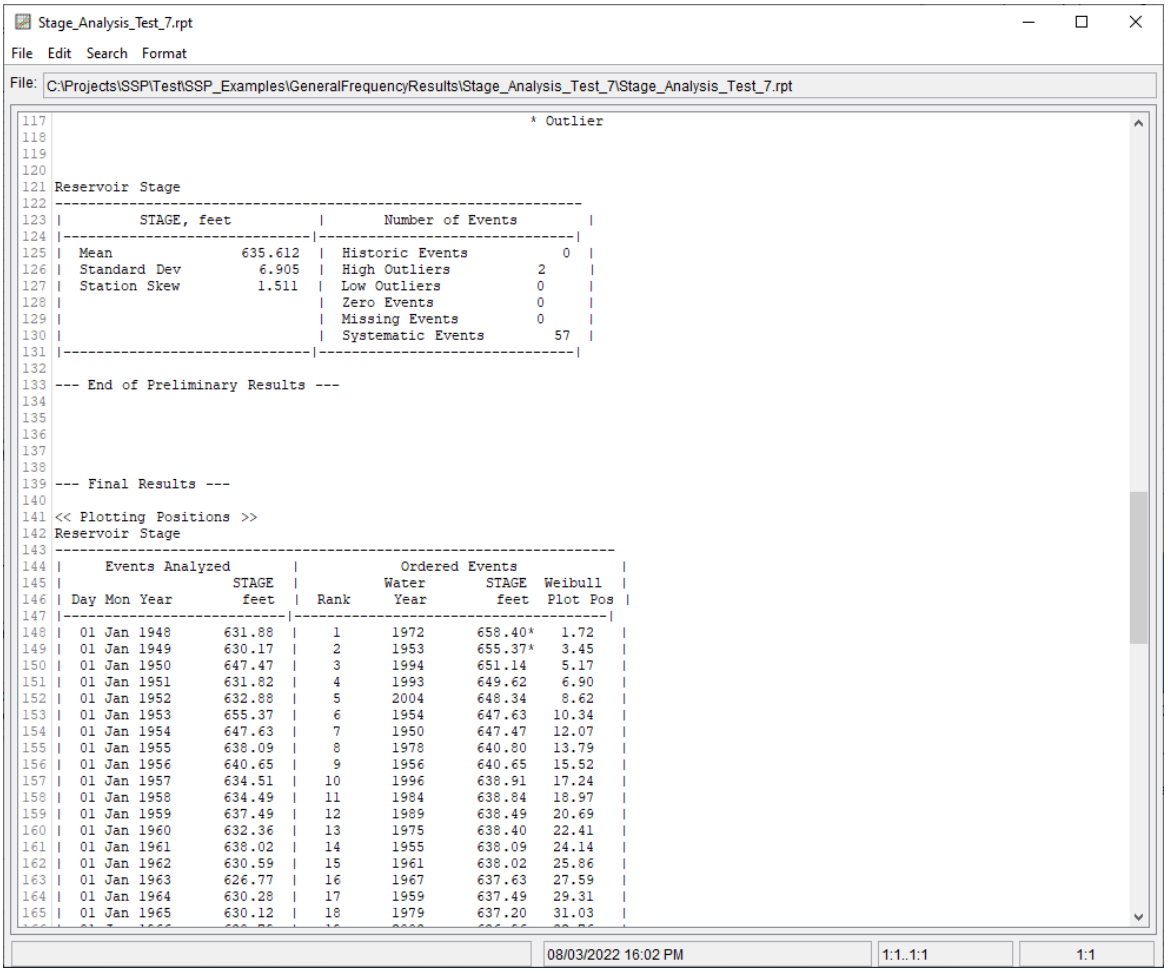


72 Figure 6. Plot of the Frequency Curve Results for Stage Analysis Test 7

Graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 7 is the report file for ***Stage Analysis Test 7***.

The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, the final computed frequency curve results, and the user-defined graphical frequency curve. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



Stage_Analysis_Test_7.rpt

File Edit Search Format

File: C:\Projects\SSP\Test\SSP_Examples\GeneralFrequencyResults\Stage_Analysis_Test_7\Stage_Analysis_Test_7.rpt

```
                                                  * Outlier



Reservoir Stage
-----------------------------------------------------------------
|         STAGE, feet           |       Number of Events        |
|-------------------------------|-------------------------------|
|  Mean               635.612   |  Historic Events           0  |
|  Standard Dev         6.905   |  High Outliers             2  |
|  Station Skew         1.511   |  Low Outliers              0  |
|                               |  Zero Events               0  |
|                               |  Missing Events            0  |
|                               |  Systematic Events        57  |
|-------------------------------|-------------------------------|

--- End of Preliminary Results ---




--- Final Results ---

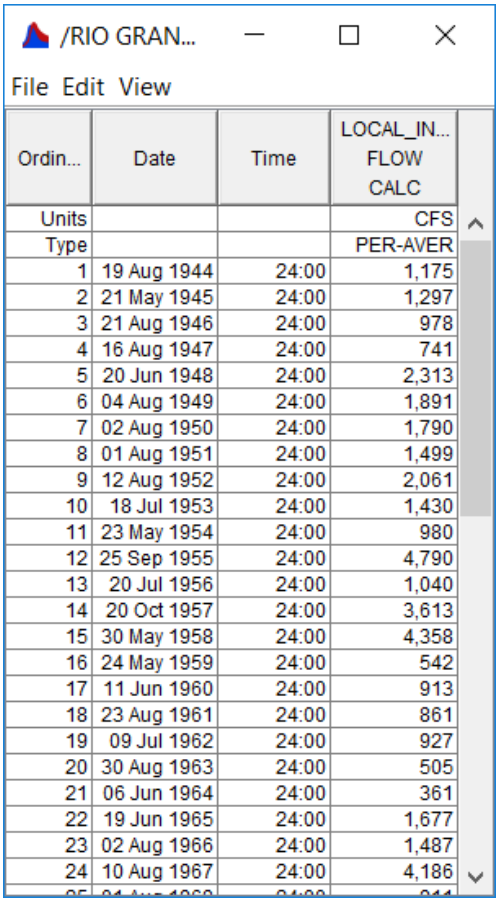
<< Plotting Positions >>
Reservoir Stage
-------------------------------------------------------------------------
|     Events Analyzed         |            Ordered Events               |
|                        STAGE  |          Water       STAGE  Weibull   |
| Day Mon Year            feet  |  Rank     Year        feet  Plot Pos  |
|-----------------------------|-----------------------------------------|
|  01 Jan 1948       631.88   |     1      1972       658.40*   1.72    |
|  01 Jan 1949       630.17   |     2      1953       655.37*   3.45    |
|  01 Jan 1950       647.47   |     3      1994       651.14    5.17    |
|  01 Jan 1951       631.82   |     4      1993       649.62    6.90    |
|  01 Jan 1952       632.88   |     5      2004       648.34    8.62    |
|  01 Jan 1953       655.37   |     6      1954       647.63   10.34    |
|  01 Jan 1954       647.63   |     7      1950       647.47   12.07    |
|  01 Jan 1955       638.09   |     8      1978       640.80   13.79    |
|  01 Jan 1956       640.65   |     9      1956       640.65   15.52    |
|  01 Jan 1957       634.51   |    10      1996       638.91   17.24    |
|  01 Jan 1958       634.49   |    11      1984       638.84   18.97    |
|  01 Jan 1959       637.49   |    12      1989       638.49   20.69    |
|  01 Jan 1960       632.36   |    13      1975       638.40   22.41    |
|  01 Jan 1961       638.02   |    14      1955       638.09   24.14    |
|  01 Jan 1962       630.59   |    15      1961       638.02   25.86    |
|  01 Jan 1963       626.77   |    16      1967       637.63   27.59    |
|  01 Jan 1964       630.28   |    17      1959       637.49   29.31    |
|  01 Jan 1965       630.12   |    18      1979       637.20   31.03    |
```

08/03/2022 16:02 PM 1:1..1:1 1:1

73 Figure 7. Report File for Stage Analysis Test 7

5.2 Example 8. Using User-Adjusted Statistics

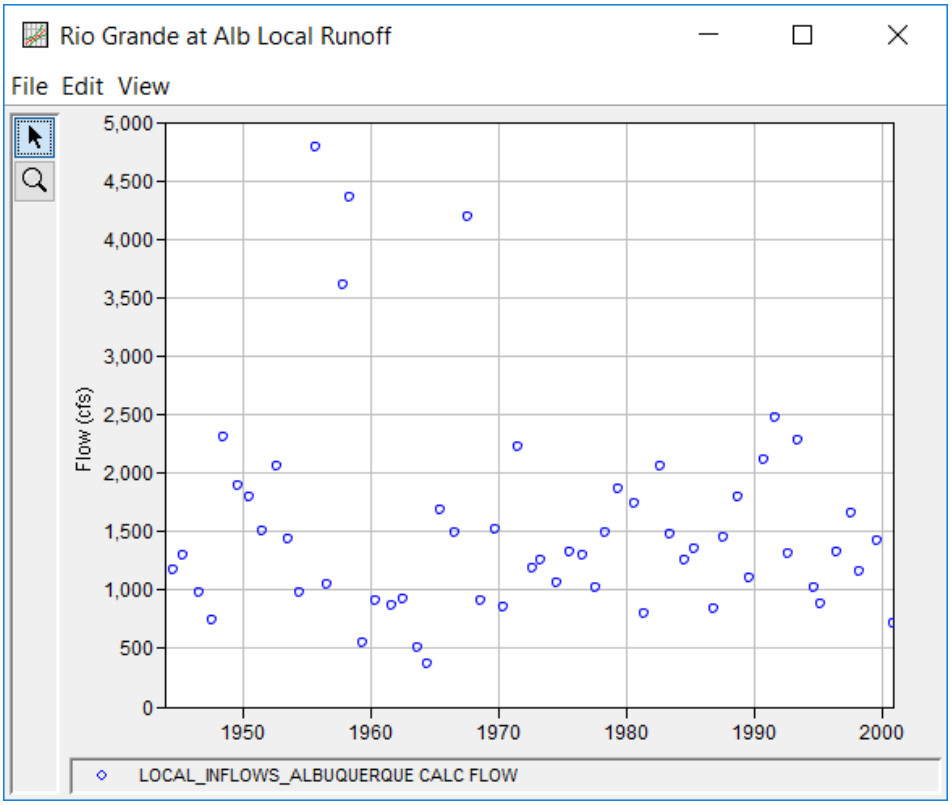
In the ***SSP_Examples.ssp*** study, the ***Local Runoff at Alb Test 8*** example demonstrates how to use the General Frequency analysis and enter user-adjusted statistics. The data for this example is from an analysis that computed local runoff for the Rio Grande at Albuquerque. The data includes unregulated daily average flows generated by rainfall-runoff from areas downstream of upstream reservoirs. The period of record used for this example is from 1944 to 2000. To view the data, right-click on the data record labeled "***Rio Grande at Alb Local Runoff***" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure 1.



Ordin...	Date	Time	LOCAL_IN... FLOW CALC
Units			CFS
Type			PER-AVER
1	19 Aug 1944	24:00	1,175
2	21 May 1945	24:00	1,297
3	21 Aug 1946	24:00	978
4	16 Aug 1947	24:00	741
5	20 Jun 1948	24:00	2,313
6	04 Aug 1949	24:00	1,891
7	02 Aug 1950	24:00	1,790
8	01 Aug 1951	24:00	1,499
9	12 Aug 1952	24:00	2,061
10	18 Jul 1953	24:00	1,430
11	23 May 1954	24:00	980
12	25 Sep 1955	24:00	4,790
13	20 Jul 1956	24:00	1,040
14	20 Oct 1957	24:00	3,613
15	30 May 1958	24:00	4,358
16	24 May 1959	24:00	542
17	11 Jun 1960	24:00	913
18	23 Aug 1961	24:00	861
19	09 Jul 1962	24:00	927
20	30 Aug 1963	24:00	505
21	06 Jun 1964	24:00	361
22	19 Jun 1965	24:00	1,677
23	02 Aug 1966	24:00	1,487
24	10 Aug 1967	24:00	4,186

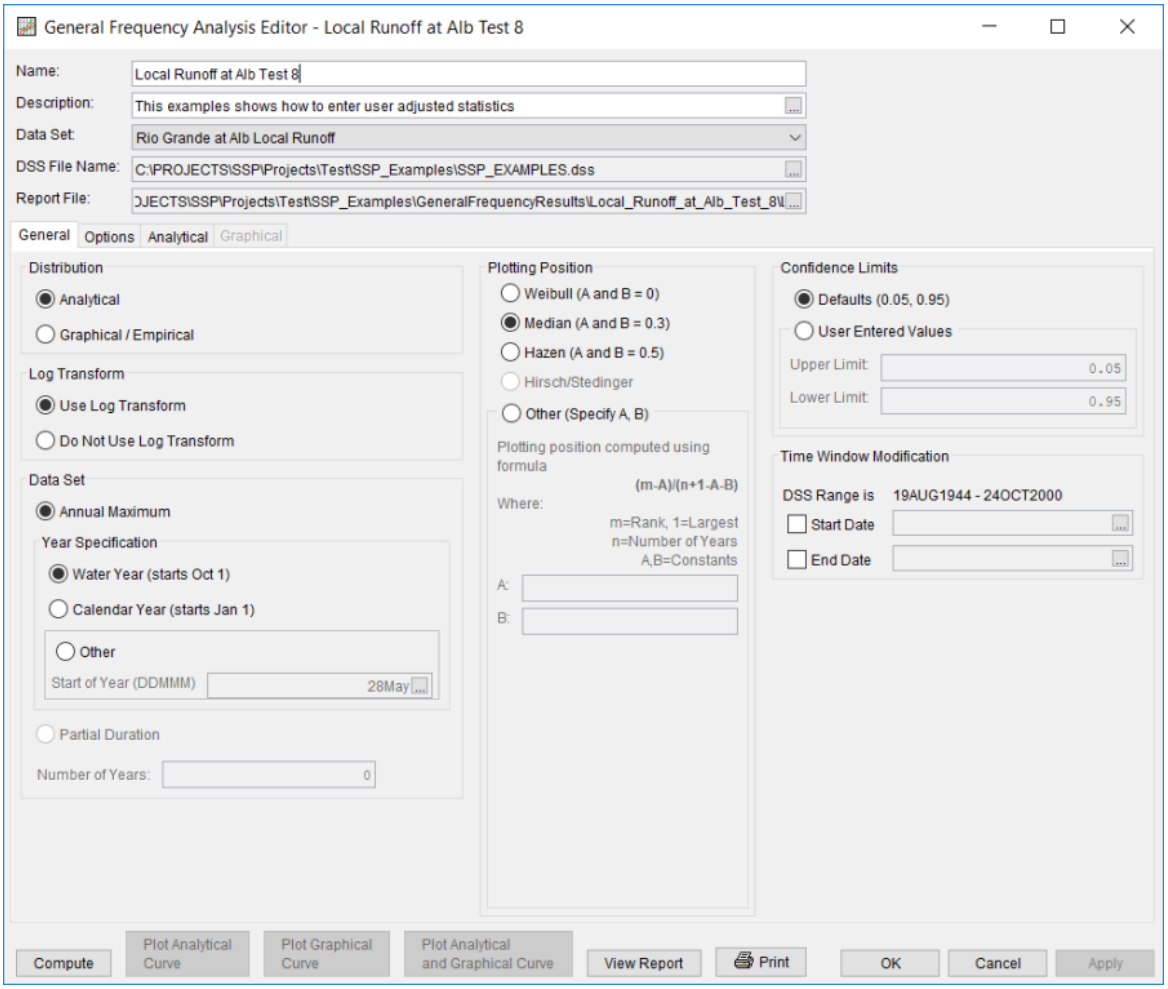
74 Figure 1. Tabulation of the Peak Flow Data for Example 8

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2.



75 Figure 2. Plot of Data for Example 8

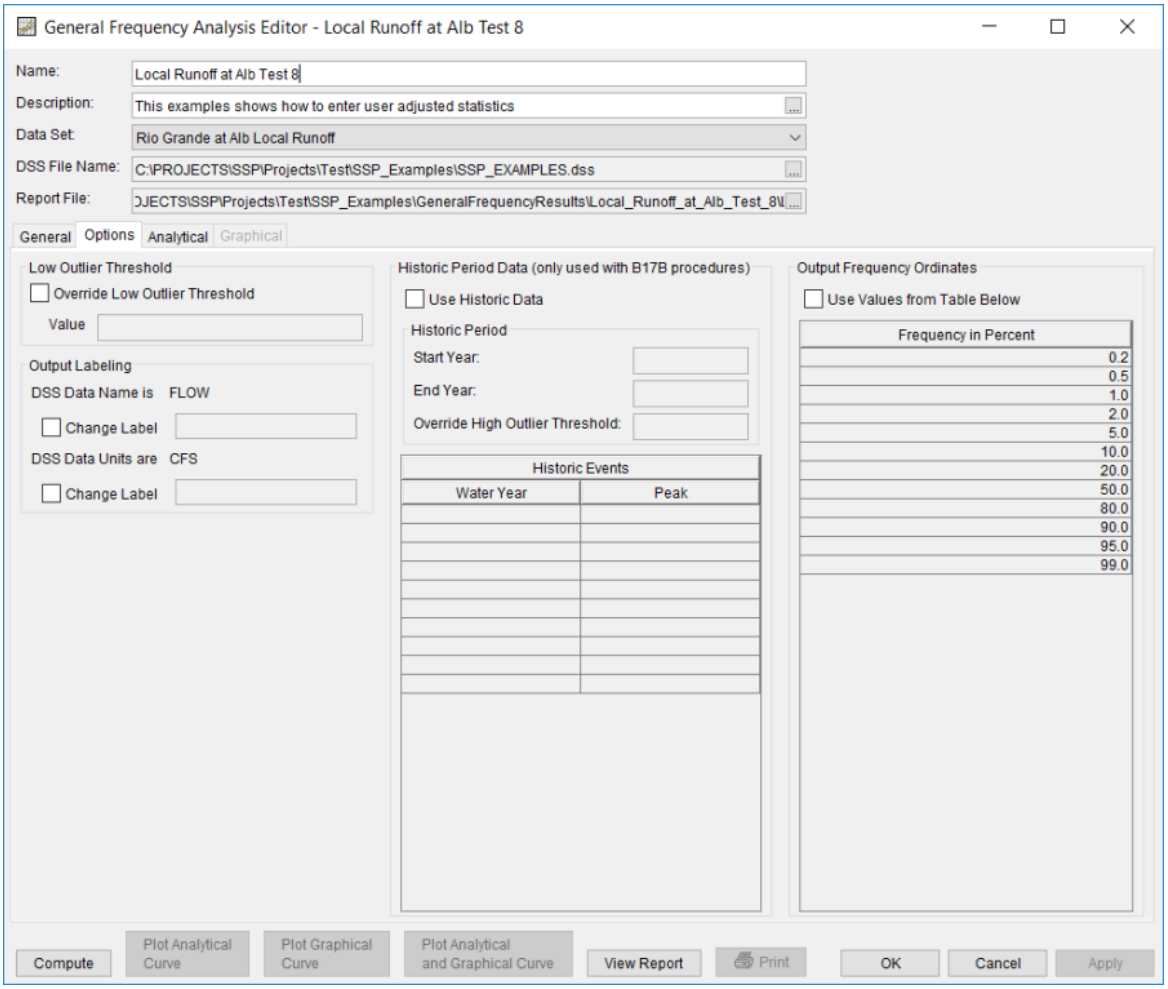
A General Frequency analysis has been developed for this example. To open the **General Frequency Analysis Editor** for this example, either double-click on the analysis labeled ***Local Runoff at Alb Test 8*** from the study explorer, or from the **Analysis** menu select open, then select ***Local Runoff at Alb Test 8*** from the list of available analyses. When Test 8 is opened, the **General Frequency Analysis Editor** will appear as shown in Figure 3.



76 Figure 3. General Frequency Analysis Editor for Local Runoff at Alb Test 8

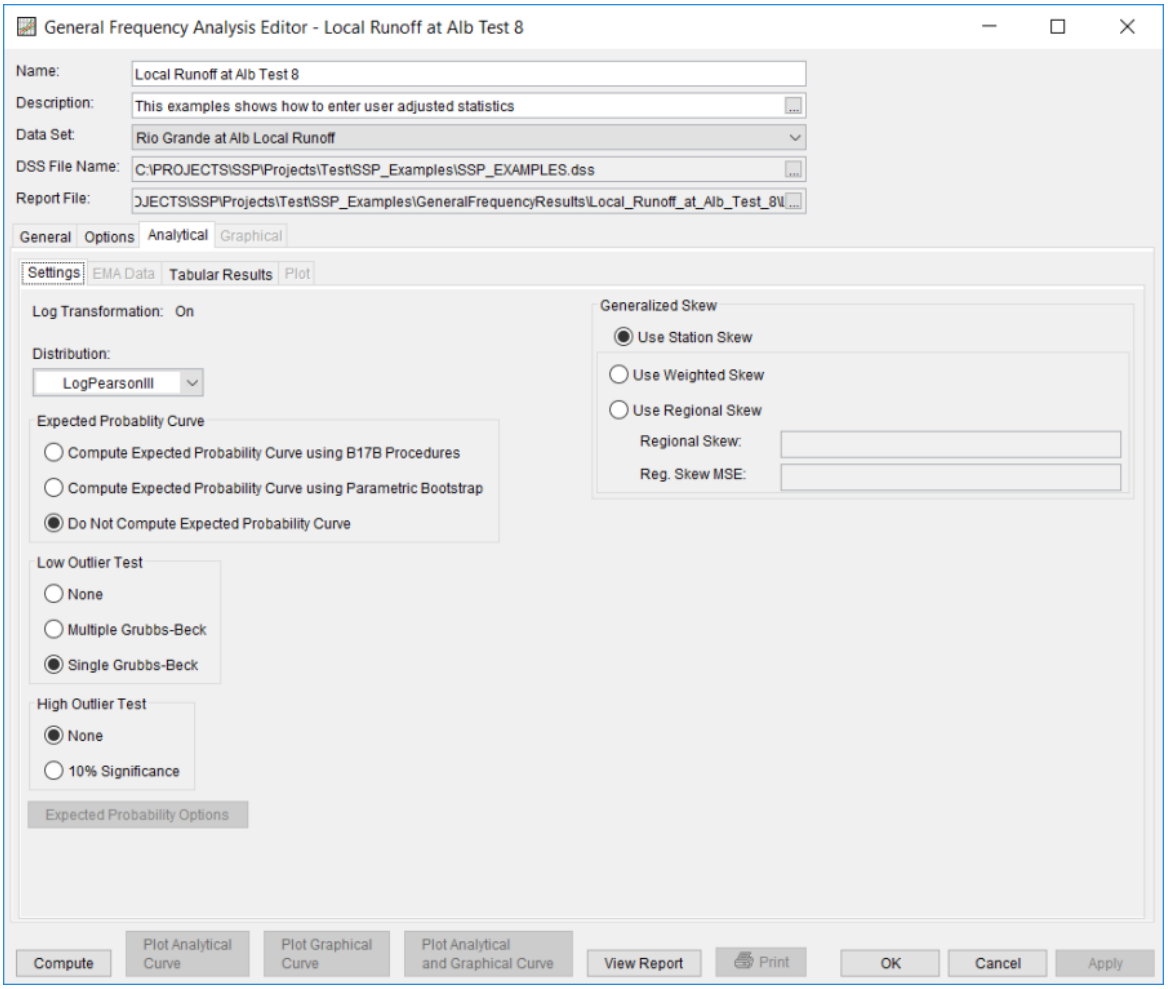
Shown in Figure 3 are the general settings that were used to perform this frequency analysis. For this analysis, the **Analytical**, **Use Log Transform**, and **Annual Maximum** options were selected. Also, the **Median** plotting position method was selected, the default **Confidence Limits** were selected, and no modification was made to the **Time Window**.

Shown in Figure 4 is the **General Frequency Analysis Editor** with the **Options** tab selected. Features on this tab include the **Low Outlier Threshold**, an option to use **Historic Data**, an option to override the default **Frequency Ordinates**, and **Output Labeling**. All defaults settings were selected for this example.



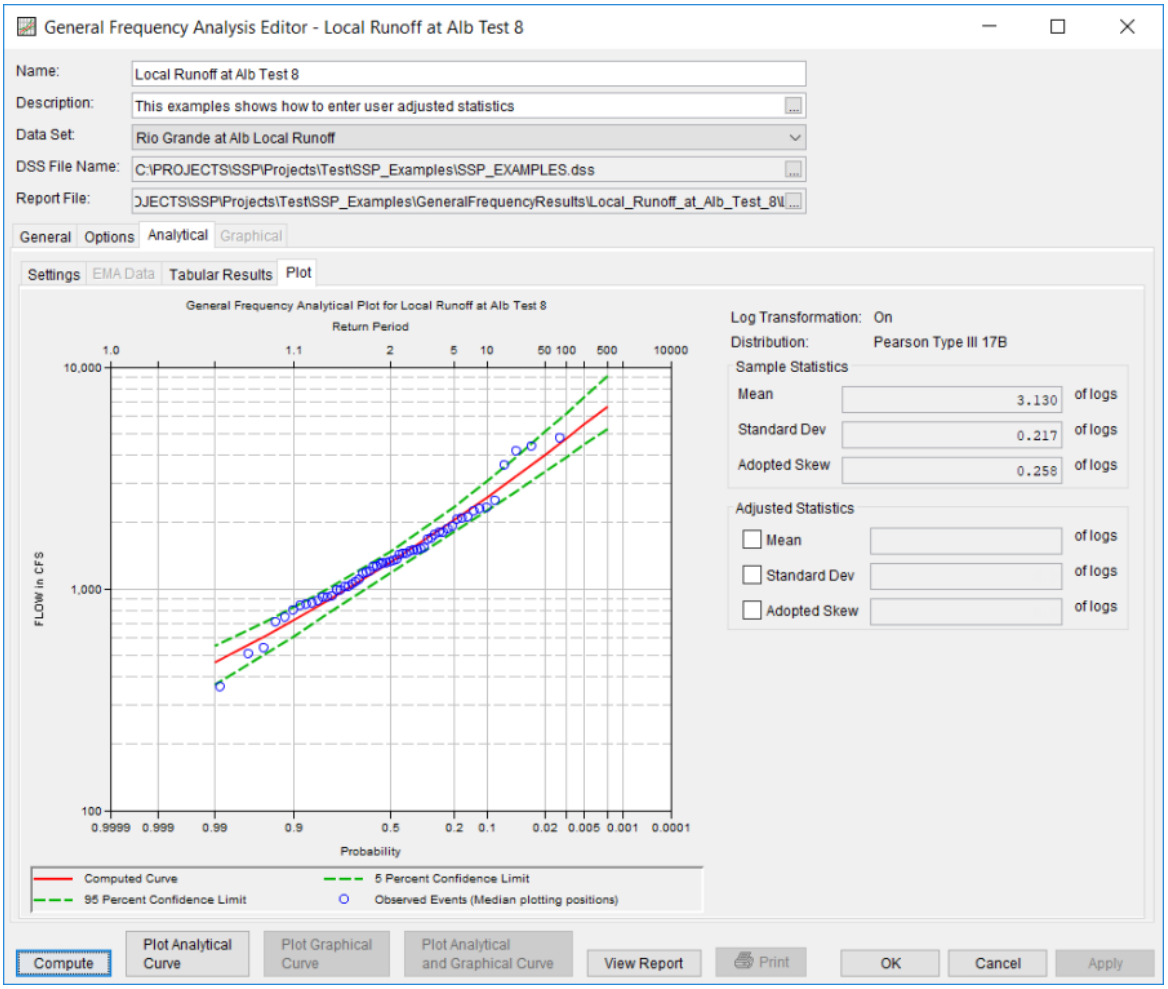
77 Figure 4. General Frequency Analysis Editor with Options Tab Shown for Local Runoff at Alb Test 8

In this example, an analytical analysis was performed. Shown in Figure 5 is the **Settings** tab for the analytical analysis. As shown, the distribution and fitting method combination which was selected for this example is **LogPearsonIII | Product Moments**. The **Do Not Compute Excepted Probability**, **Single Grubbs-Beck**, and no high outlier test options were selected. Also, the **Skew** option was set to **Use Station Skew**.



78 Figure 5. General Frequency Analysis Editor with Settings Tab Shown for Local Runoff at Alb Test 8

Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Analytical Compute Complete**. Close this window and then select the **Plot** tab within the analytical analysis. The analytical plot window should resemble Figure 6.

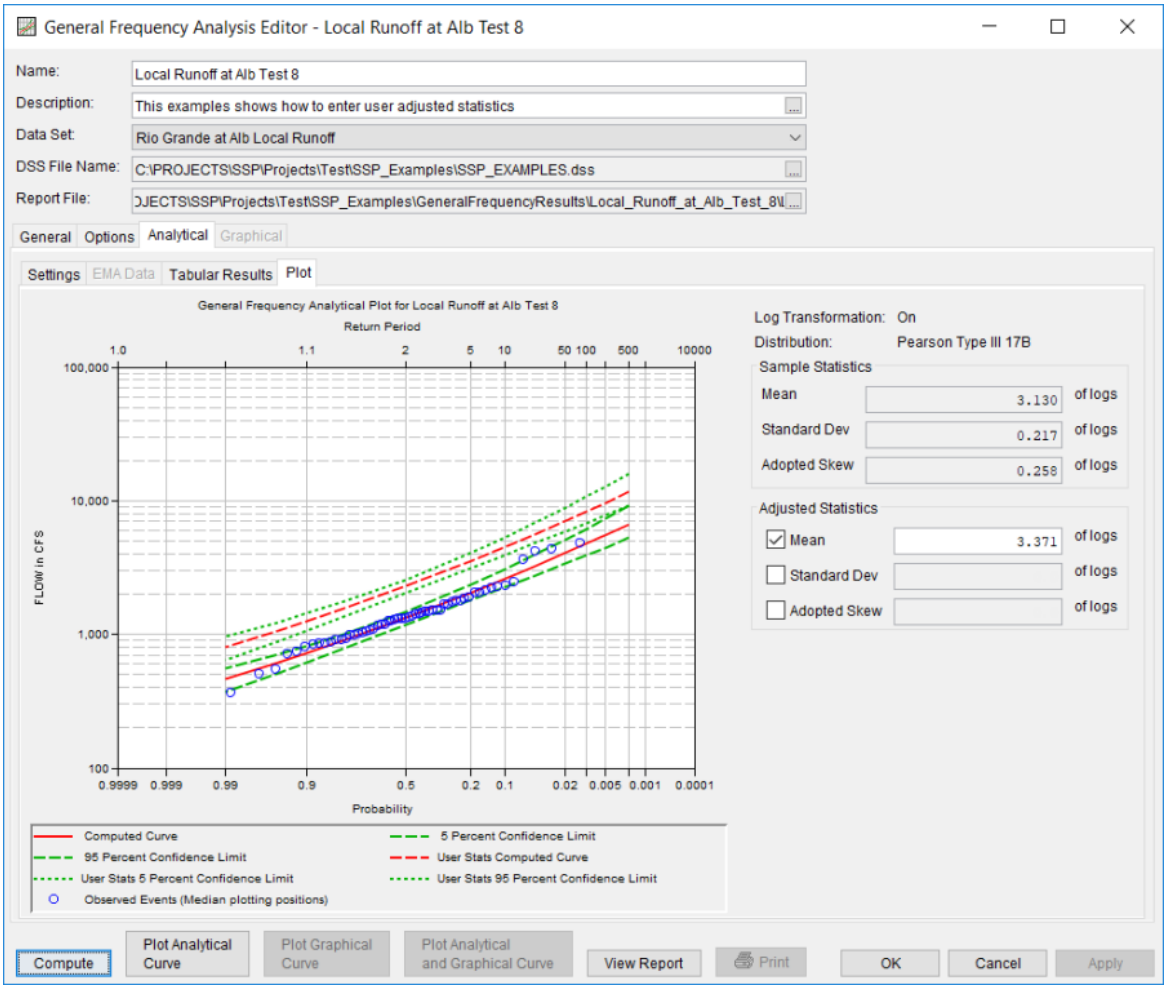


79 Figure 6. The Plot Tab for Local Runoff at Alb Test 8

As shown in Figure 6, the **Plot** tab contains a graph of the systematic data, the computed frequency curve, and the confidence limits. The right side of the plot tab contains a table of **Sample Statistics** and **Adjusted Statistics**. The user has the option to enter one or more adjusted statistics within in the Adjusted Statistics table. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to compute a frequency curve using the user statistics.

As mentioned at the beginning of this example, the annual peak flows were based on daily averaged flows. In order to compute an instantaneous peak flow frequency curve, a relationship between daily averaged flows and the corresponding instantaneous peak flows was developed. This was done by plotting daily averaged flow and the corresponding instantaneous peak flow for selected flood events. Using this relationship, a Mean of 3.371 was computed and entered in the User Statistics table and the analytical analysis was recomputed.

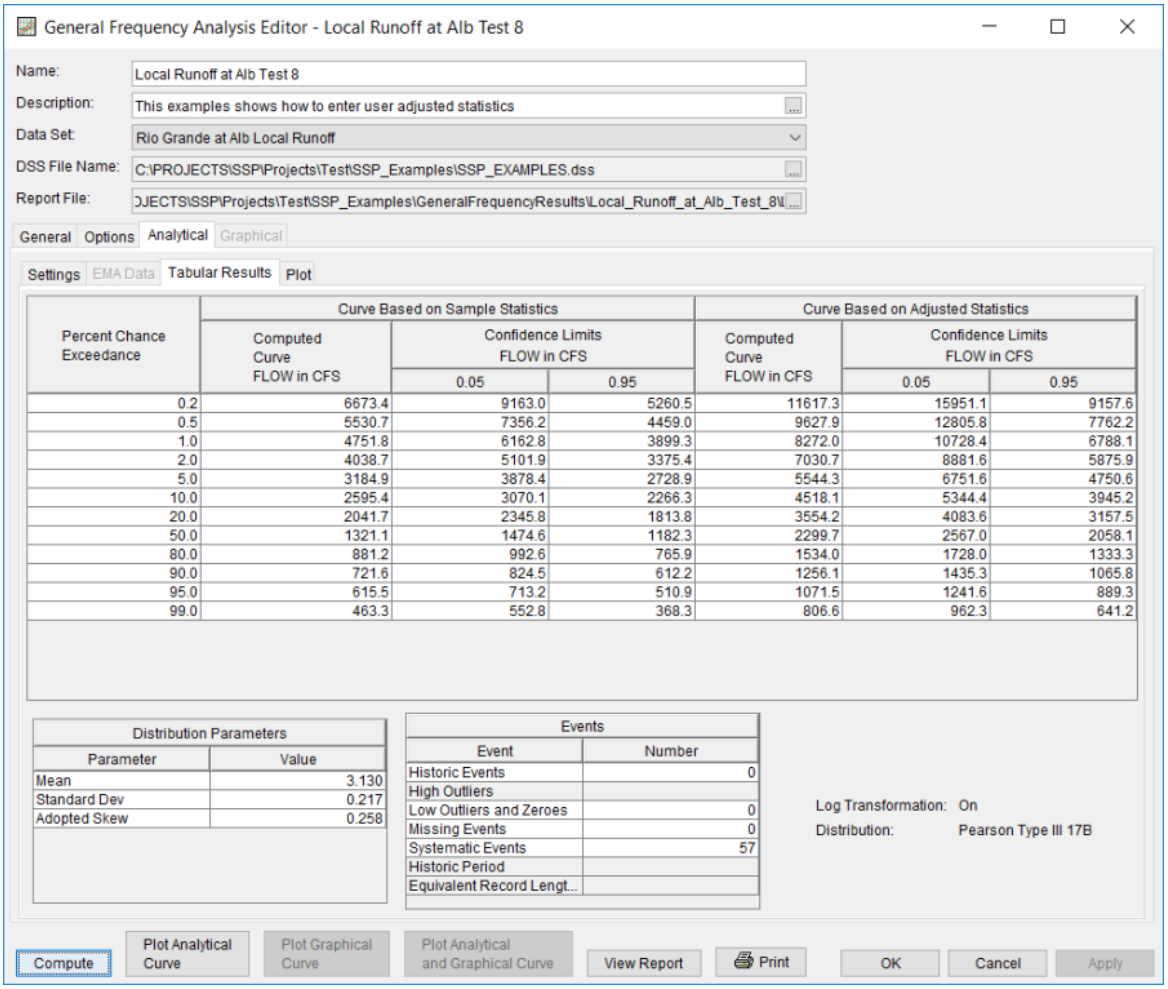
Figure 7 shows that the frequency curve computed from the user-adjusted statistics is added to the graph. This figure also shows that the user does not have to enter values for all statistics in order for the program to compute a user-adjusted frequency curve. The program will use statistics computed from the systematic and historic data if the statistics are not defined in the User Statistics table. In this example, the program used the computed statistics for standard deviation, adopted skew, equivalent years of record and the user-defined mean of 3.371 when computing the user-adjusted frequency curve.



80 Figure 7. Plot Tab with User Adjusted Statistics and Frequency Curves for Local Runoff at Alb Test 8

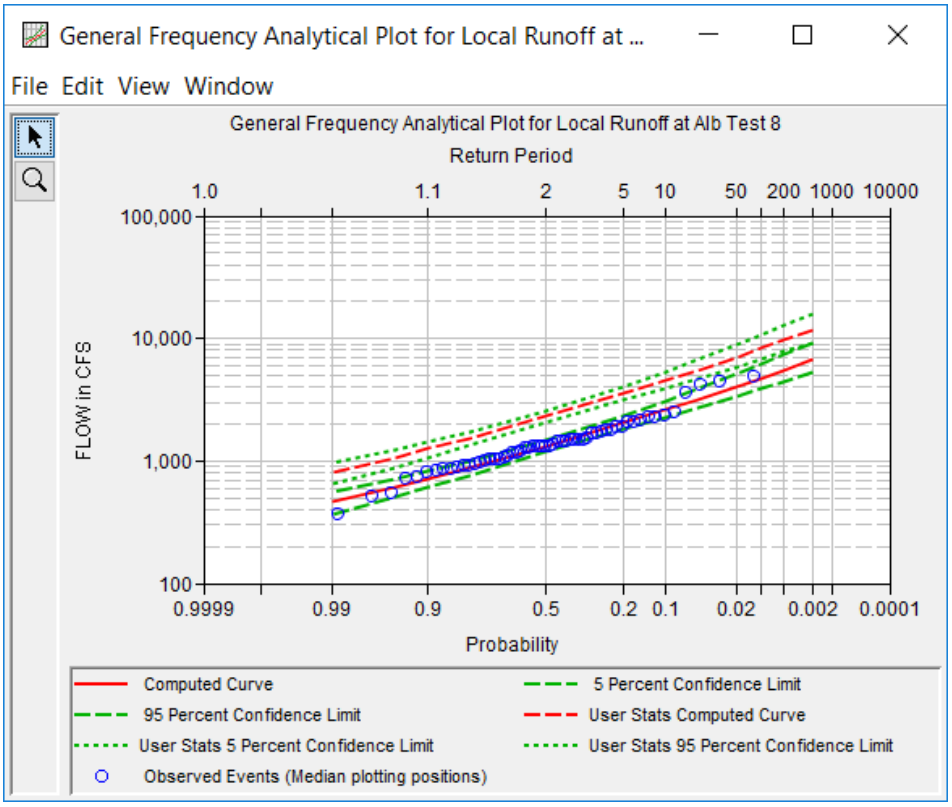
Select the **Tabular Results** tab to see information for both the computed and user-adjusted frequency curves. As shown in Figure 8, the Frequency Curve table contains the percent chance exceedance, computed curves (Log-Pearson III results), and the Confidence Limits (5% and 95% chance exceedance curves) for both the computed and user-adjusted statistics.

On the bottom left-hand side of the results tab is a **Distribution Parameters** table of Statistics for the observed station data (mean, standard deviation, station skew) and regional adjustment (regional skew, weighted skew, and adopted skew). Also on the bottom right-hand side of the results tab is a table of Number of **Events** table showing the number of historic events used in the analysis, number of high outliers found, number of low outliers, number of zero or missing data years, number of systematic events in the gage record, and the historic record length (if historic data was entered).



81 Figure 8. General Frequency Editor with Results Tab Selected for Local Runoff at Alb Test 8

In addition to the tabular results, a graphical plot of the computed frequency curves can be obtained by pressing the **Plot Analytical Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 9.

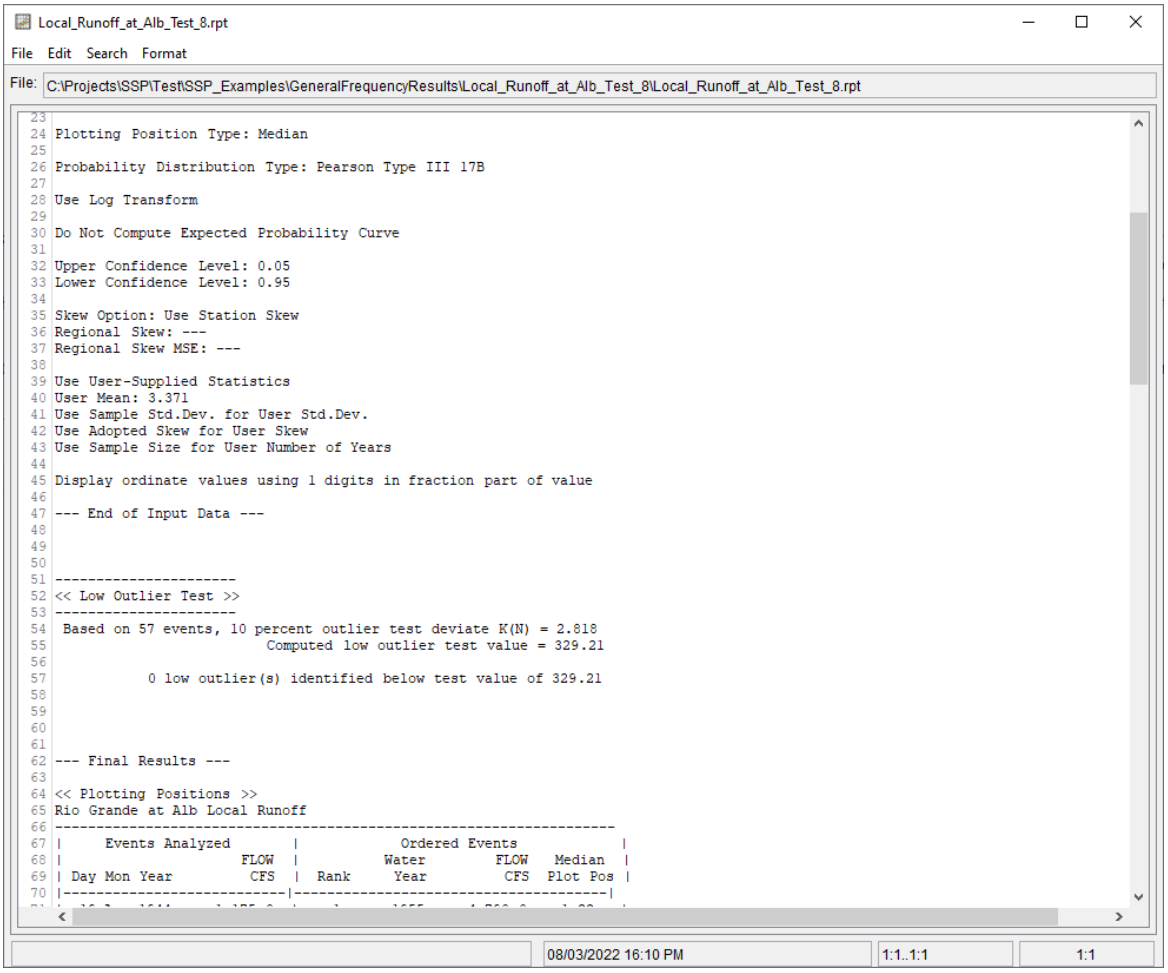


82 Figure 9. Plot of the Frequency Curve Results for Local Runoff at Alb Test 8

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

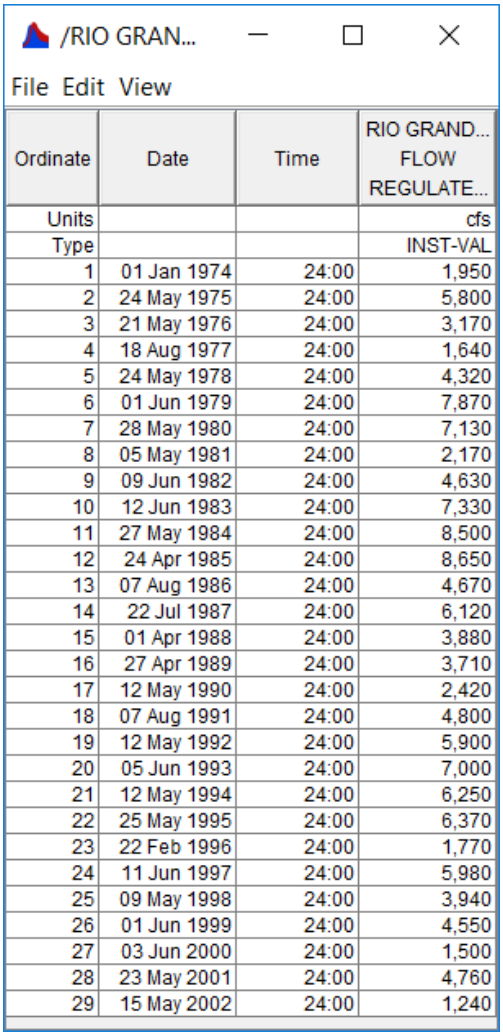
In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 10 is the report file for ***Local Runoff at Alb Test 8***.

The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



5.3 Example 9. General Frequency – Graphical Analysis

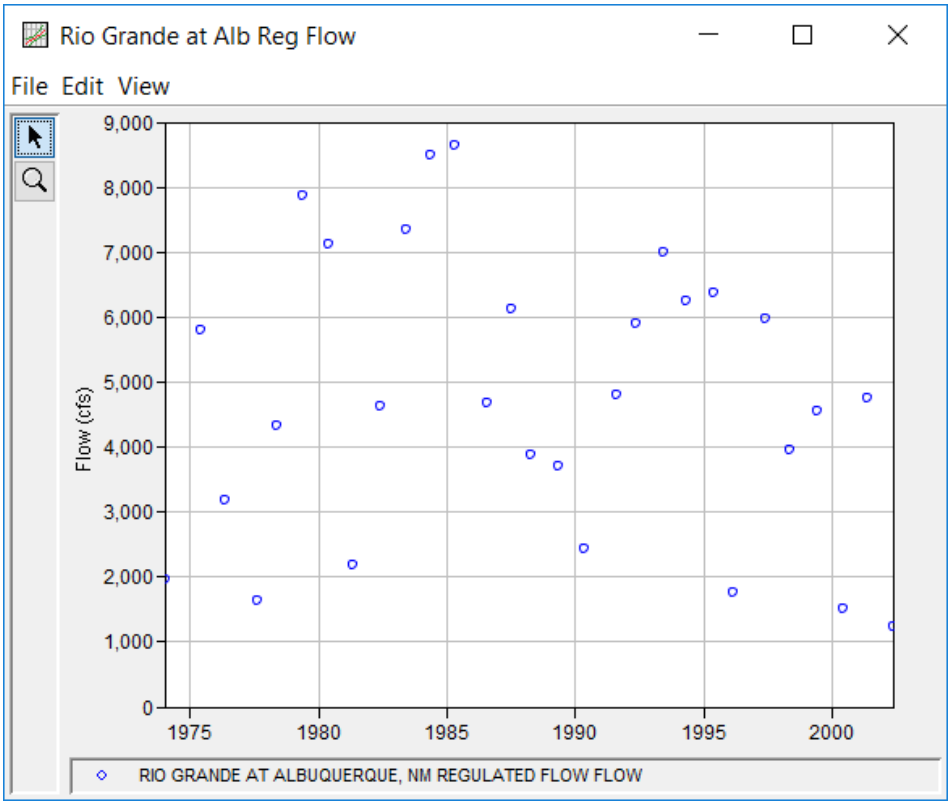
In the ***SSP_Examples.ssp*** study, the ***Reg Flow Rio Grande Test 9*** example demonstrates how to create a Graphical Analysis within a General Frequency analysis. The data for this example is from an analysis that computed regulated flow for the Rio Grande at Albuquerque. The data includes regulated daily average flows from upstream reservoirs routed downstream to Albuquerque. The period of record used for this example is from 1974 to 2002. To view the data, right-click on the data record labeled "***Rio Grande at Alb Reg Flow***" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure 1.



Ordinate	Date	Time	RIO GRAND... FLOW REGULATE...
Units			cfs
Type			INST-VAL
1	01 Jan 1974	24:00	1,950
2	24 May 1975	24:00	5,800
3	21 May 1976	24:00	3,170
4	18 Aug 1977	24:00	1,640
5	24 May 1978	24:00	4,320
6	01 Jun 1979	24:00	7,870
7	28 May 1980	24:00	7,130
8	05 May 1981	24:00	2,170
9	09 Jun 1982	24:00	4,630
10	12 Jun 1983	24:00	7,330
11	27 May 1984	24:00	8,500
12	24 Apr 1985	24:00	8,650
13	07 Aug 1986	24:00	4,670
14	22 Jul 1987	24:00	6,120
15	01 Apr 1988	24:00	3,880
16	27 Apr 1989	24:00	3,710
17	12 May 1990	24:00	2,420
18	07 Aug 1991	24:00	4,800
19	12 May 1992	24:00	5,900
20	05 Jun 1993	24:00	7,000
21	12 May 1994	24:00	6,250
22	25 May 1995	24:00	6,370
23	22 Feb 1996	24:00	1,770
24	11 Jun 1997	24:00	5,980
25	09 May 1998	24:00	3,940
26	01 Jun 1999	24:00	4,550
27	03 Jun 2000	24:00	1,500
28	23 May 2001	24:00	4,760
29	15 May 2002	24:00	1,240

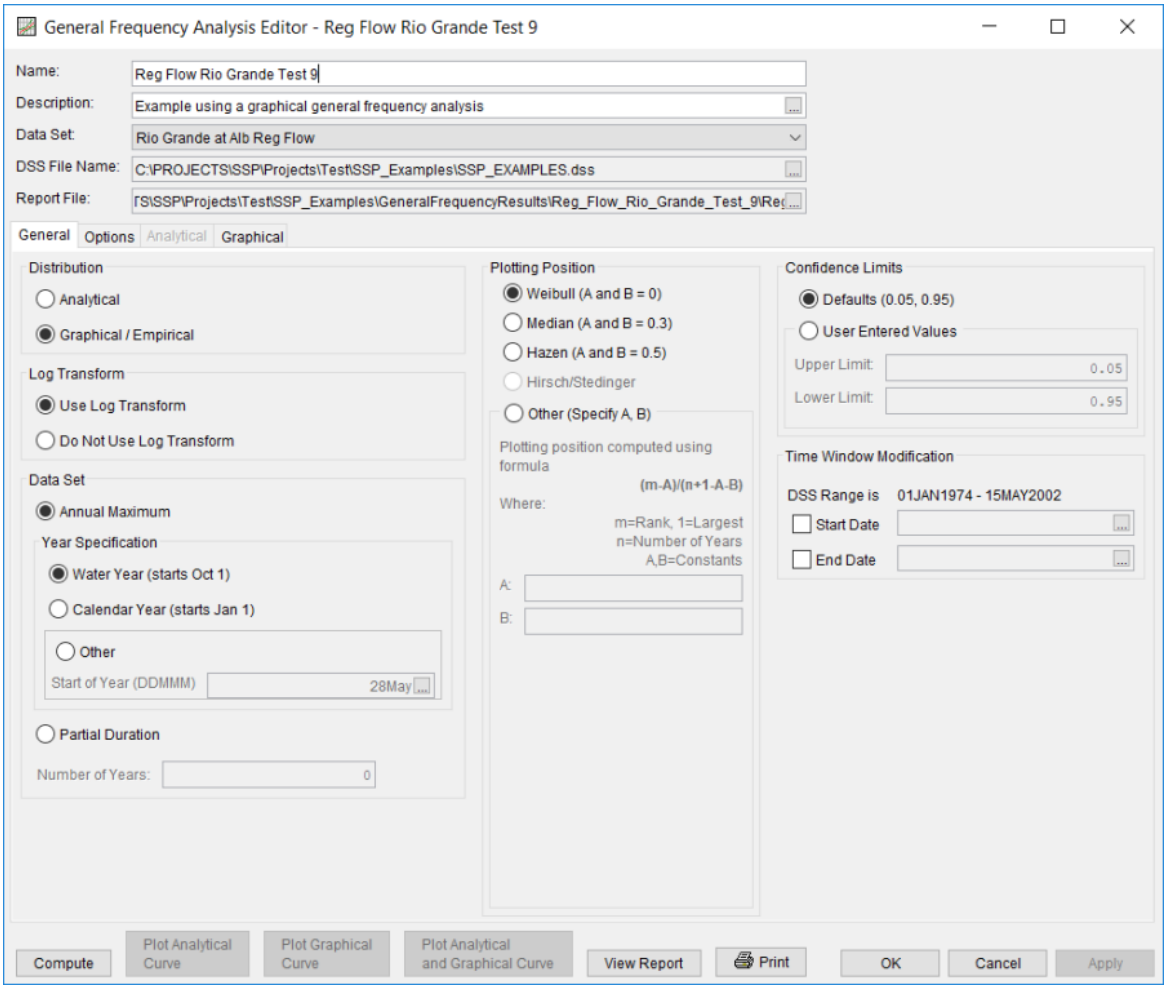
83 Figure 1. Tabulation of the Peak Flow Data for Example 9

To plot the data for this example, right-click on the data record and then select **Plot**. A plot of the data will appear as shown in Figure 2.



84 Figure 2. Plot of Data for Example 9

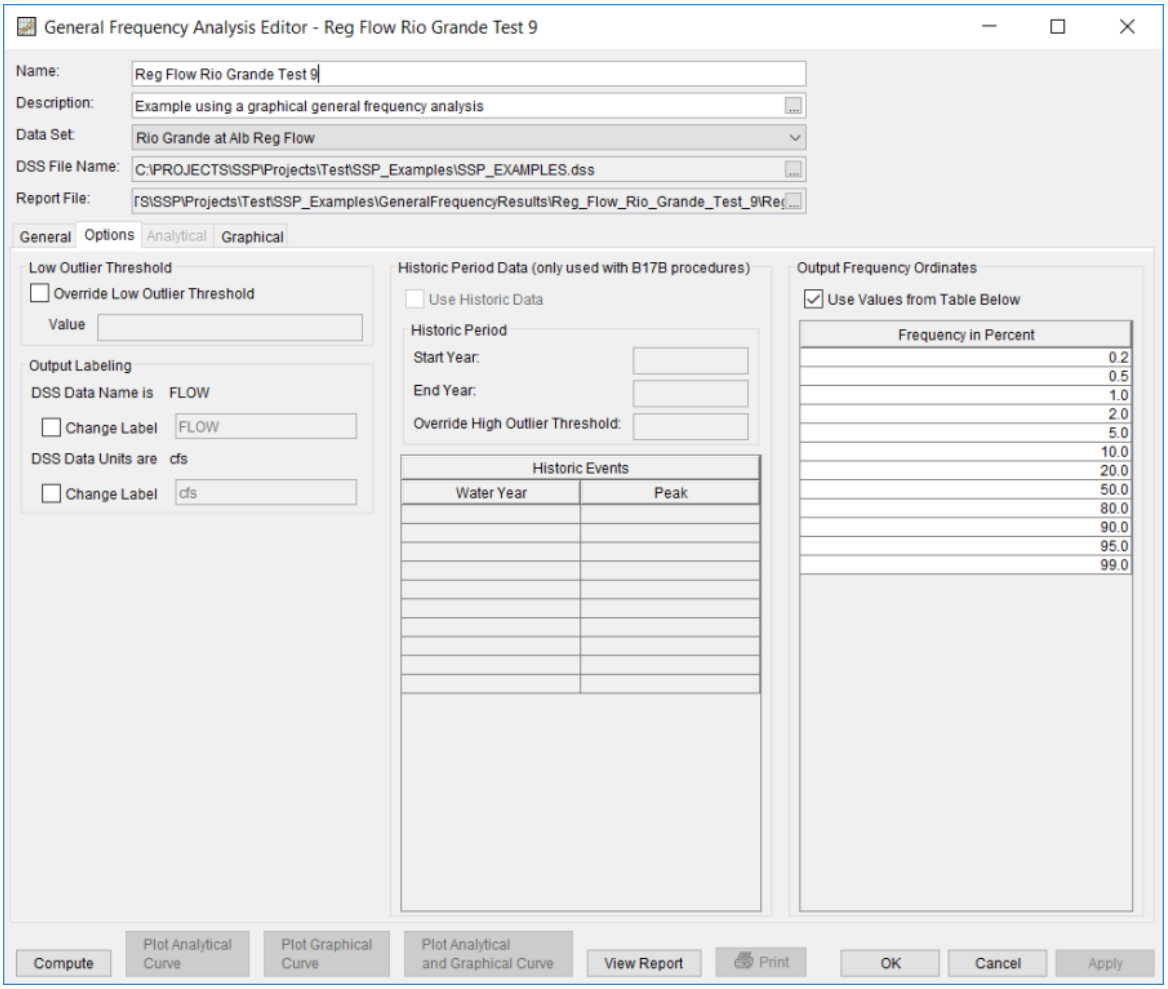
A General Frequency analysis has been developed for this example. To open the **General Frequency Analysis Editor** for this example, either double-click on the analysis labeled ***Reg Flow Rio Grande Test 9*** from the study explorer, or from the **Analysis** menu select open, then select ***Reg Flow Rio Grande Test 9*** from the list of available analyses. When Test 9 is opened, the **General Frequency Analysis Editor** will appear as shown in Figure 3.



85 Figure 3. General Frequency Analysis Editor for Reg Flow Rio Grande Test 9

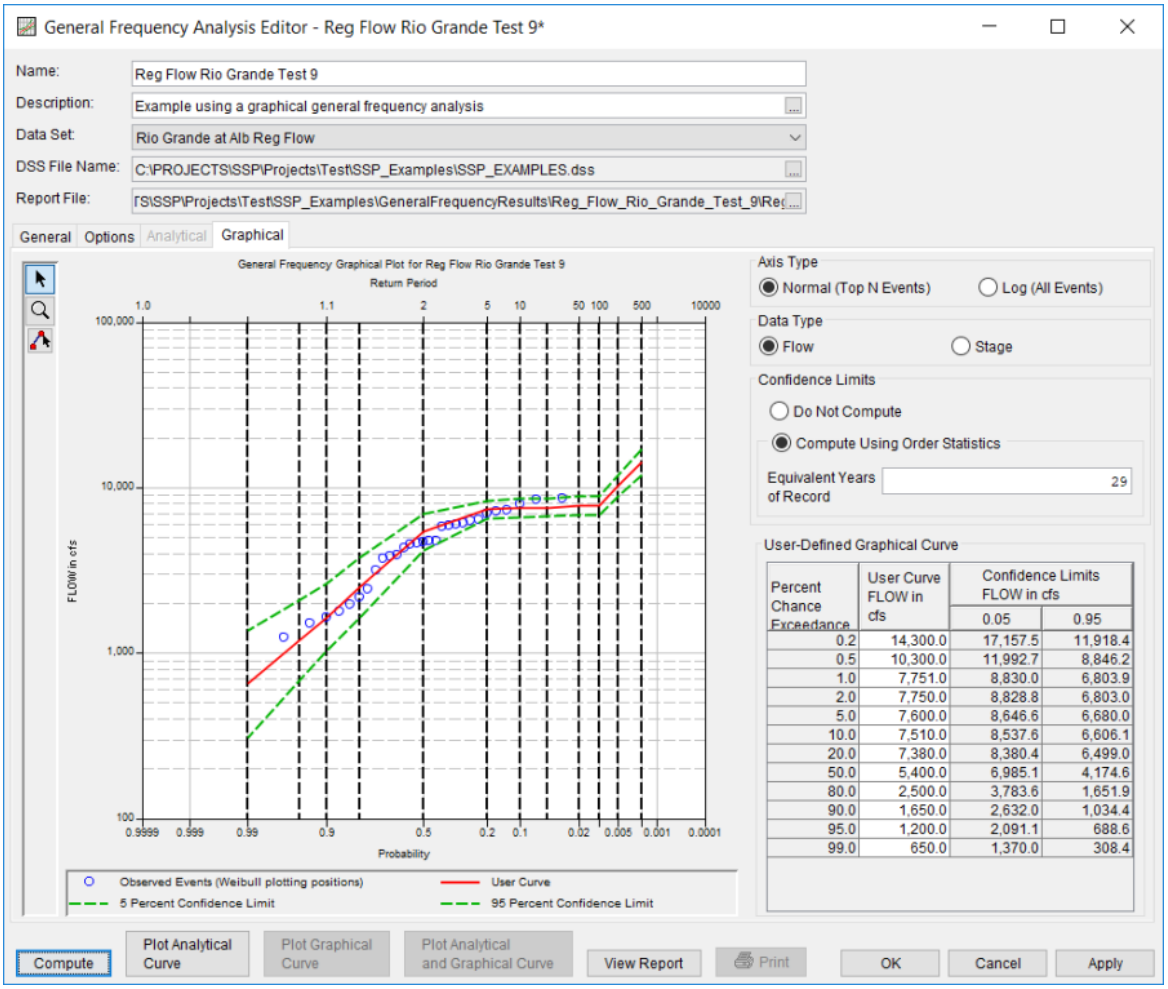
Shown in Figure 3 are the general settings that were used to perform this frequency analysis. For this analysis, the **Graphical / Empirical**, **Use Log Transform**, and **Annual Maximum** options were selected. Also, the **Weibull** plotting position method was selected, the default **Confidence Limits** were selected, and no modification was made to the **Time Window**.

Shown in Figure 4 is the General Frequency analysis editor with the **Options** tab selected. Features on this tab include the **Low Outlier Threshold**, an option to use **Historic Data**, an option to override the default **Frequency Ordinates**, and **Output Labeling**. All defaults settings were selected for this example.



86 Figure 4. General Frequency Analysis Editor with Options Tab Shown for Reg Flow Rio Grande Test 9

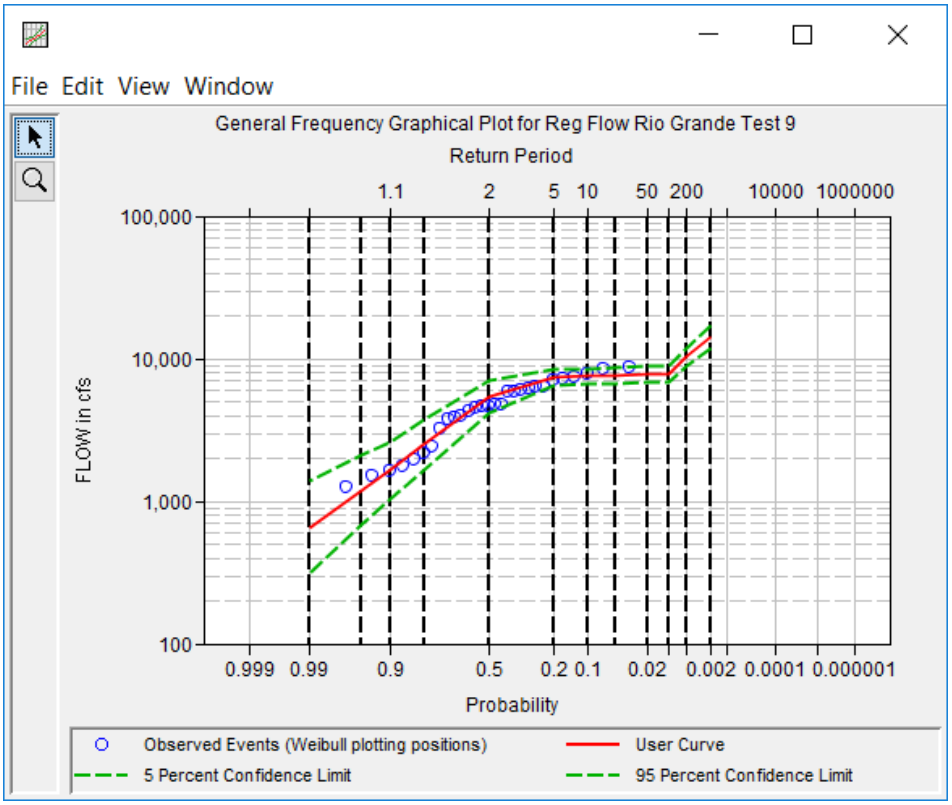
In this example, a graphical analysis was performed. Shown in Figure 5 is the **Graphical** tab. As shown, a graph containing the systematic data and graphical curve is on the left side and a table containing the user-entered frequency curve is on the right side of the window. The frequency curve was entered manually into the **User-Defined Graphical Curve** table. When the **Compute** button is pressed, the program plots the graphical frequency curve along with the annual maximum flow values. For this example, a reservoir model was used to route synthetic hydrographs through the reservoir network upstream of Albuquerque using current operating criteria. This was done for the 0.2, 0.5, 1.0, 2.0, 10, 20, and 50 percent events. Output from the model was input into the Frequency Ordinates table. For the more frequent events (10 year and below), the graphical curve was fit to the data visually. This example shows how a reservoir network can influence the frequency curve. Notice how the frequency curve is flat for the 20 through the 1 percent chance events. The reservoir network is able to control flooding in this range. This example also shows that as flood events become larger, the reservoir network has less influence on controlling downstream flooding.



Percent Chance Exceedance	User Curve FLOW in cfs	Confidence Limits FLOW in cfs	
		0.05	0.95
0.2	14,300.0	17,157.5	11,918.4
0.5	10,300.0	11,992.7	8,846.2
1.0	7,751.0	8,830.0	6,803.9
2.0	7,750.0	8,828.8	6,803.0
5.0	7,600.0	8,646.6	6,680.0
10.0	7,510.0	8,537.6	6,606.1
20.0	7,380.0	8,380.4	6,499.0
50.0	5,400.0	6,985.1	4,174.6
80.0	2,500.0	3,783.6	1,651.9
90.0	1,650.0	2,632.0	1,034.4
95.0	1,200.0	2,091.1	688.6
99.0	650.0	1,370.0	308.4

87 Figure 5. Graphical Tab Shown for Reg Flow Rio Grande Test 9

A graphical plot of the graphical frequency curve can be obtained by pressing the **Plot Graphical Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6.

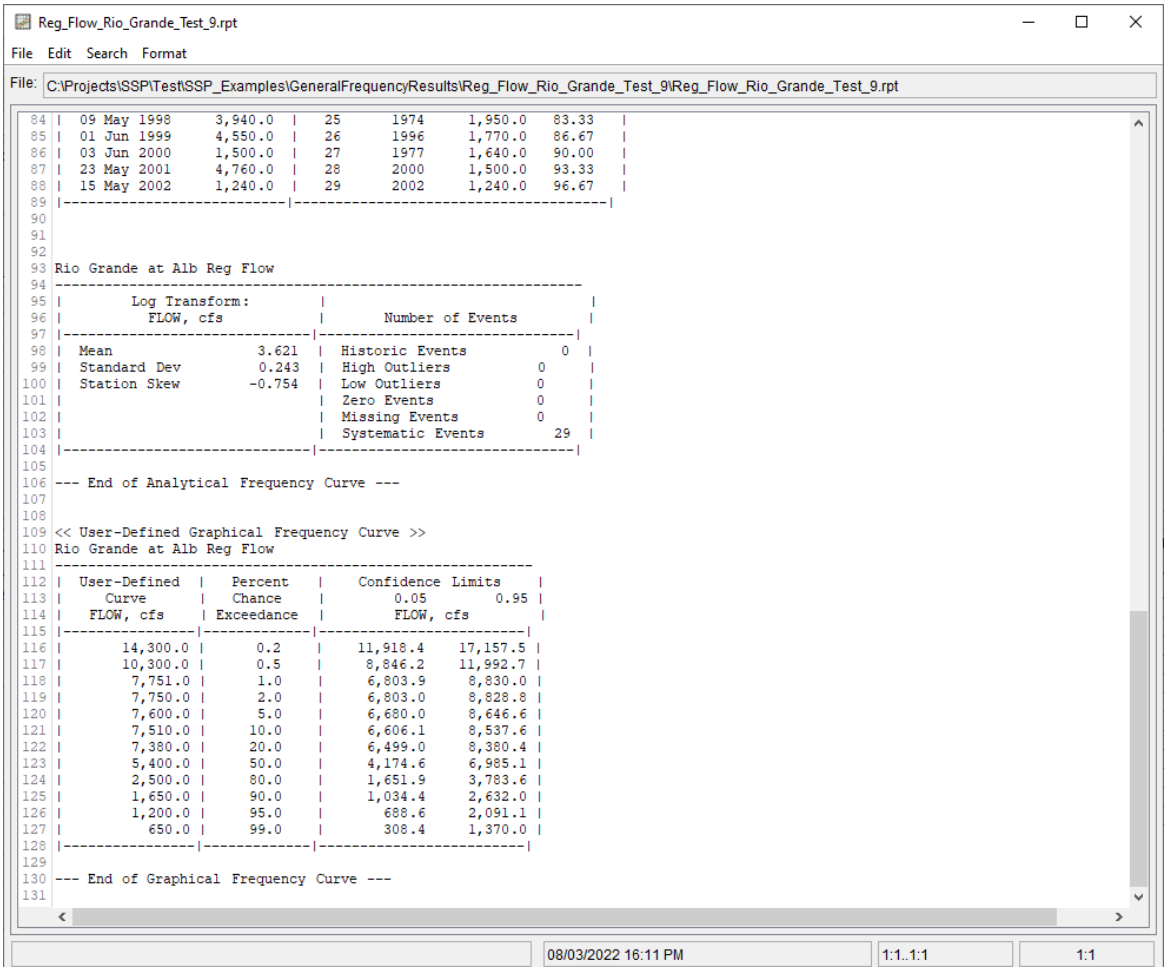


88 Figure 6. Plot of the Frequency Curve Results for Reg Flow Rio Grande Test 9

The graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 7 is the report file for ***Reg Flow Rio Grande Test 9***.

The report file contains a listing of the input data, preliminary results, outlier and historical data tests, and additional calculations needed. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.

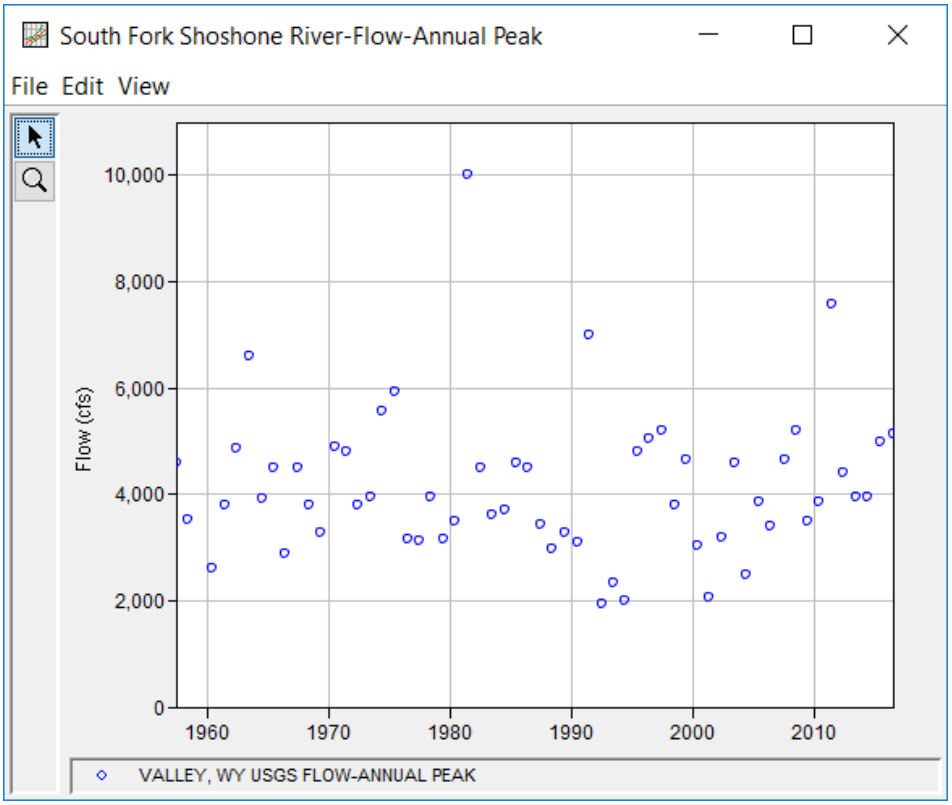


89 Figure 7. Report File for Reg Flow Rio Grande Test 9

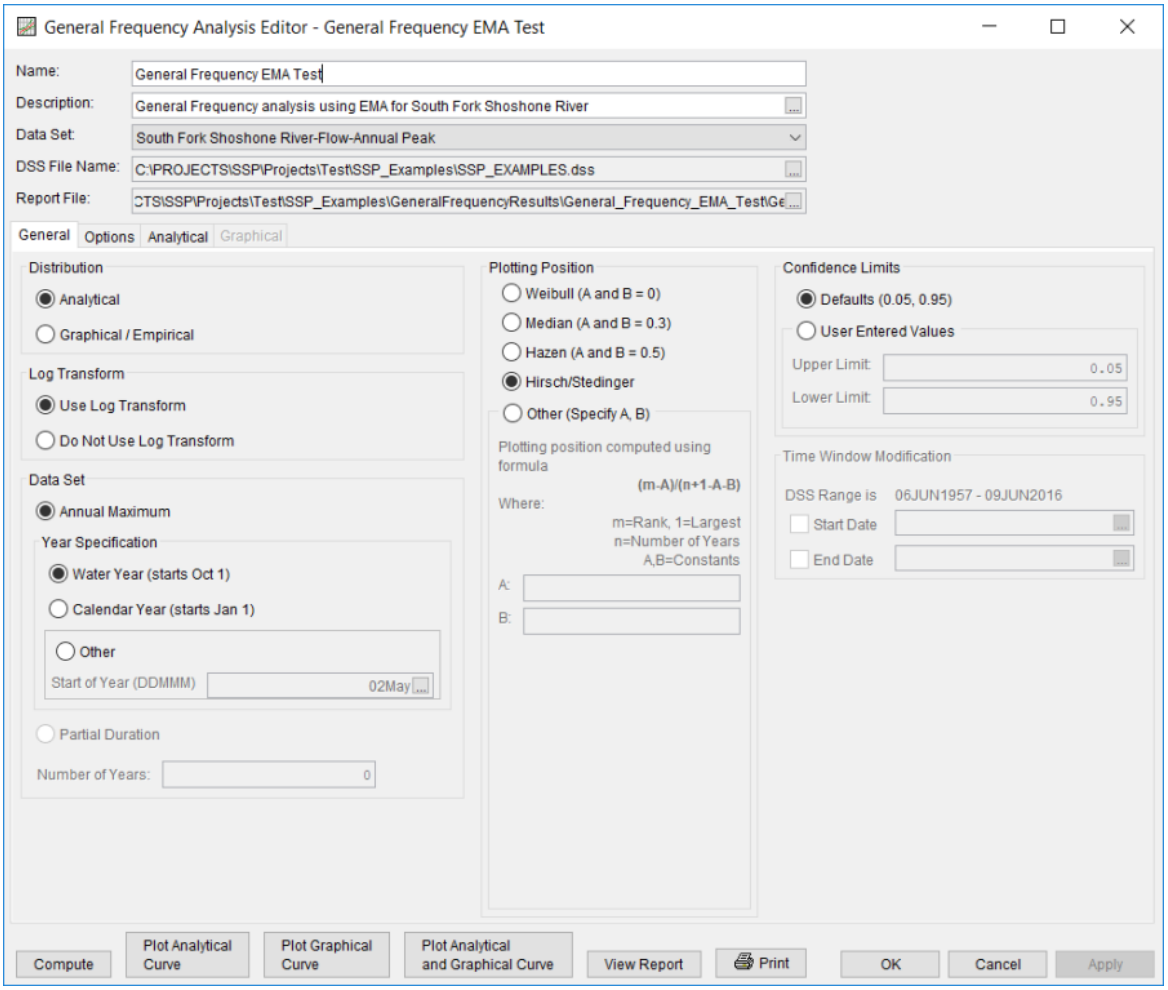
5.4 Example 29. General Frequency, Fitting a Log Pearson Type III Distribution using the Expected Moments Algorithm

This example demonstrates how to use the Expected Moments Algorithm (EMA) to fit the Log Pearson Type III distribution to an annual maximum series of streamflow within the General Frequency analysis. The data for this example consists of an instantaneous peak annual maximum series of streamflow for a location along the South Fork Shoshone River River near Valley, WY[44]. This stream gage is operated by the USGS (gage ID: 06280300). The period of record used for this example is from 1957 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**South Fork Shoshone River-Flow-Annual Peak**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 211).

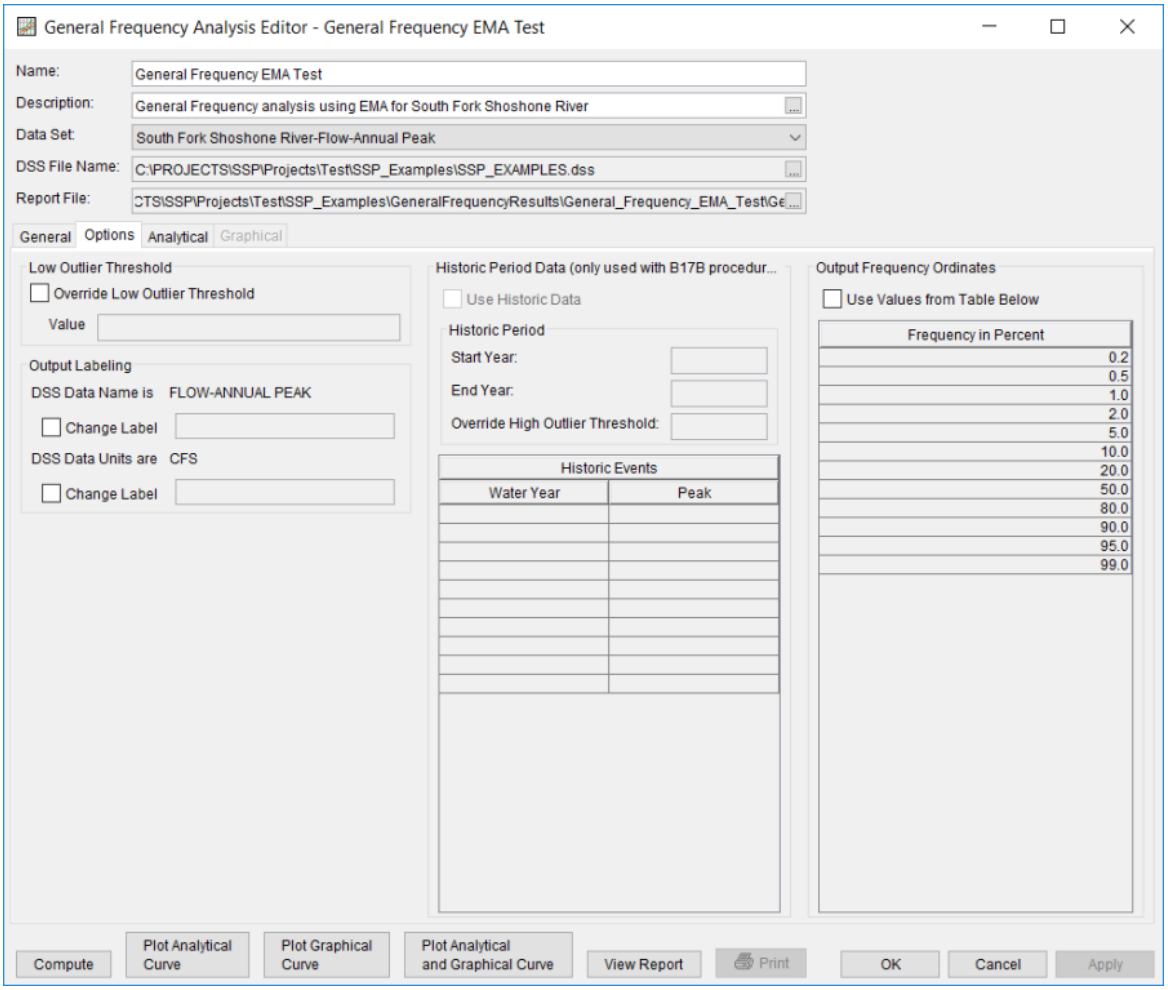
44 https://waterdata.usgs.gov/wy/nwis/uv/?site_no=06280300



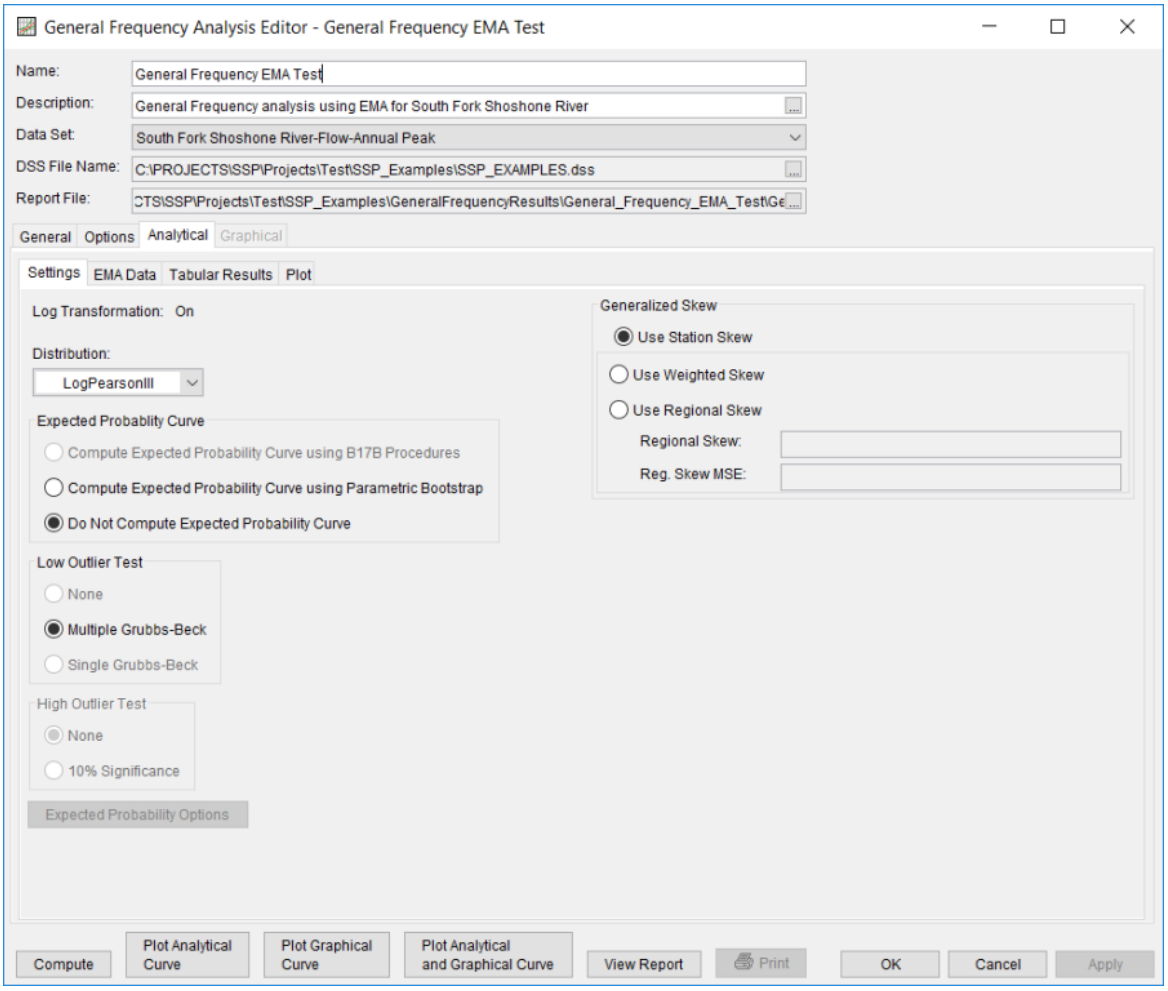
A General Frequency analysis has been developed for this example. To open the General Frequency analysis editor for this example, either double-click on the analysis labeled **General Frequency EMA Test** from the study explorer, or from the **Analysis** menu, select open, then select **General Frequency EMA Test** from the list of available analyses. When this analysis is opened, the General Frequency editor will appear as shown in Figure 2 (see page 211). Shown in Figure 2 (see page 0) are the general settings that were used to perform this frequency analysis. As shown, the **Analytical**, **Use Log Transform**, and **Annual Maximum** options were selected. Also, the **Hirsch/Stedinger** option was selected within the **Plotting Position** panel (which is only available once the **LogPearsonIII | EMA** distribution and fitting method combination is selected on the **Analytical | Settings** tab). Finally, the default confidence limits options were left unchanged.



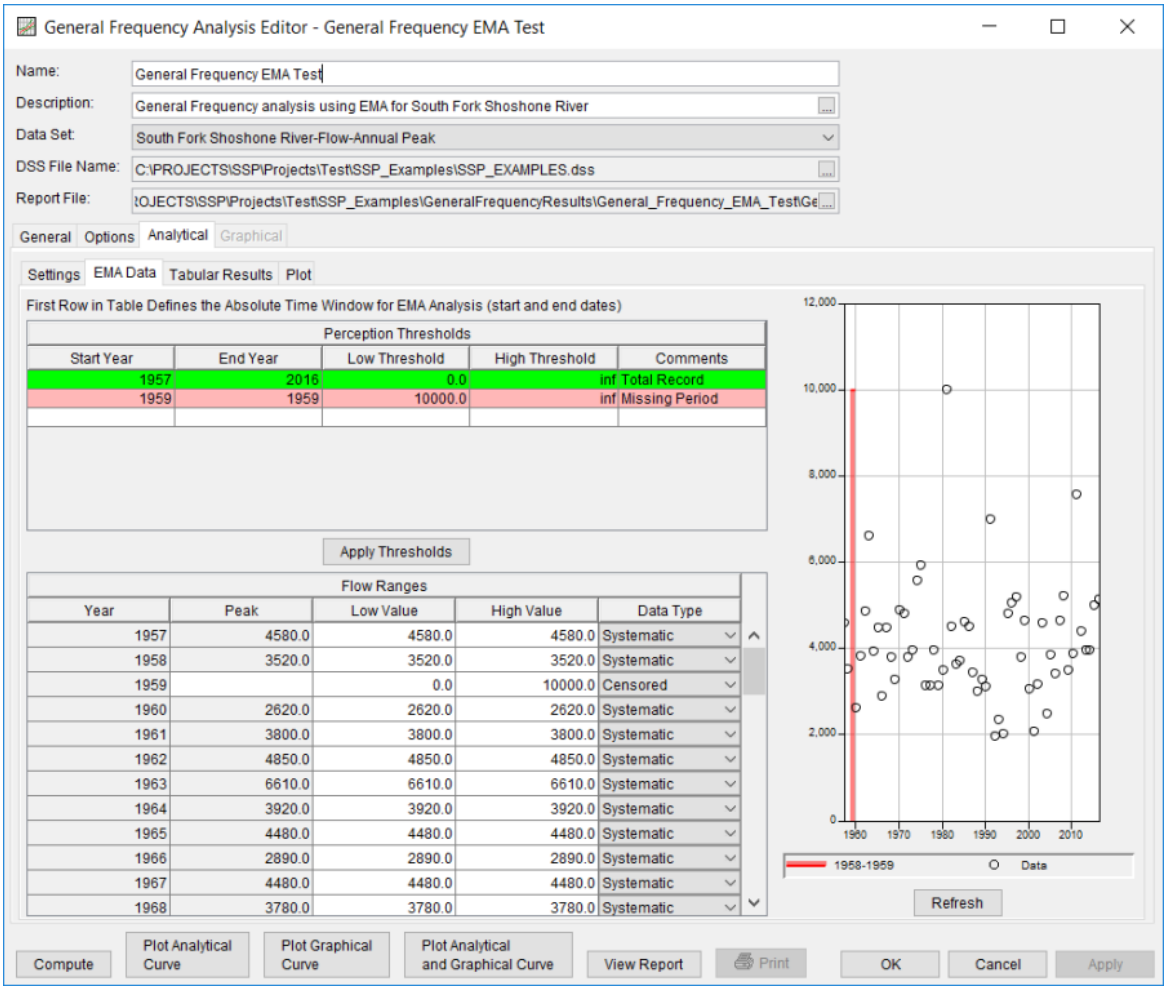
Shown in Figure 3 (see page 212) is the General Frequency analysis editor with the **Options Tab** selected. Features on this tab include the **Low Outlier Threshold**, an option to use **Historic Data**, an option to override the default **Frequency Ordinates**, and **Output Labeling**. All default settings were selected for this example.



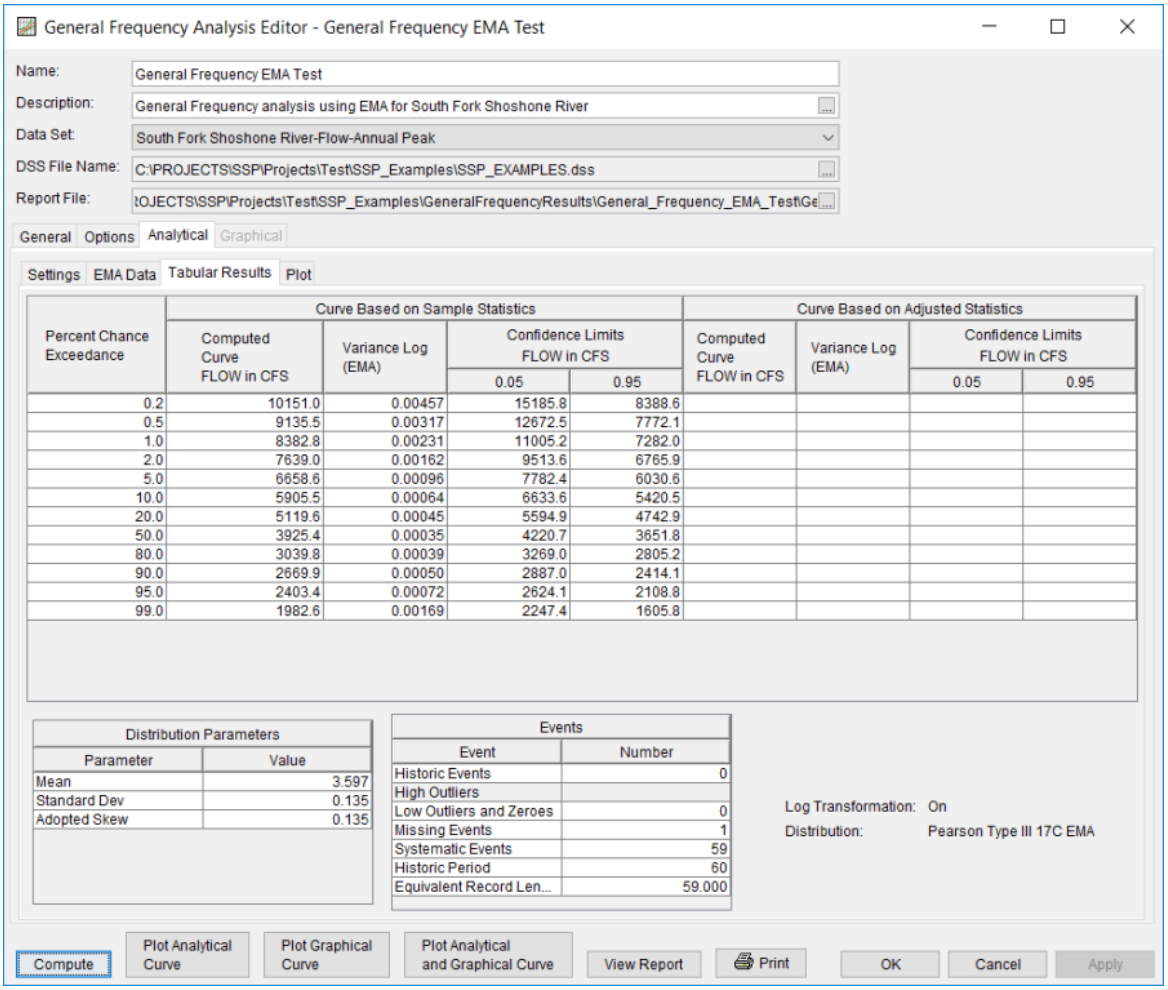
In this example, an analytical analysis was performed. Shown in Figure 4 (see page 211) is the **Settings** tab for the analytical analysis. As shown, the distribution and fitting method combination which was selected for this example is **LogPearsonIII | EMA**. The **Do Not Compute Excepted Probability**, **Multiple Grubbs-Beck**, and no high outlier test options were selected. Also, the **Skew** option was set to **Use Station Skew**.



The **Analytical | EMA Data** tab for this example is shown in Figure 5 (see page 211). Data required for the EMA computations is entered here. Specifically, flow ranges, perception thresholds, and data types are entered here. The data for this record contains a missing period spanning a single water year (1959). 17C EMA requires a **non** zero – inf perception threshold for all periods of missing data. In this case, the largest observed event (which occurred in 1981) was used to inform the perception threshold for water year 1959. The use of a perception threshold of 10000 – inf implies that had a flood event occurred with a peak flow greater than 10,000 cfs, someone would have measured and recorded it. Once the perception threshold has been entered, click the **Apply Thresholds** button to assign a complementary flow range for the period of missing data. No modifications to the default flow ranges and data types are necessary.

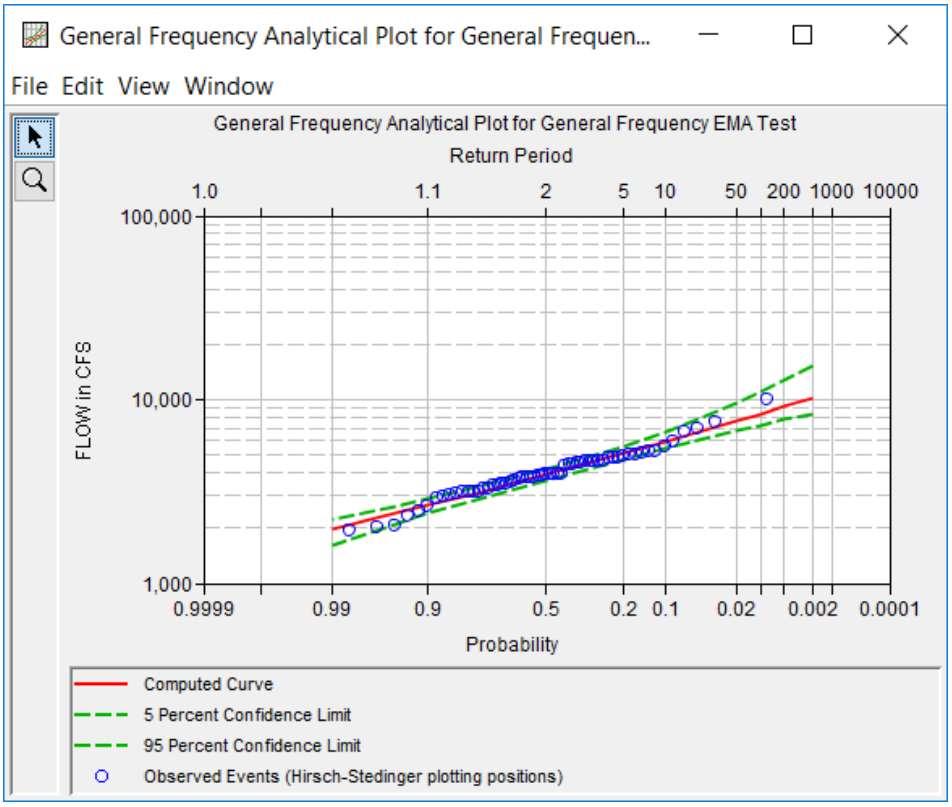


Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Analytical Compute Complete**. Close this window and then select the **Analytical | Tabular Results** tab. This window should resemble Figure 6 (see page 211). Within this tab is a tabular listing of the computed frequency curve and confidence limits that were specified as part of the analysis. Tables containing Distribution Parameters in addition to Events is shown along the bottom of the window. Finally, the lower right hand panel displays the selected distribution and whether or not the log transform was selected.

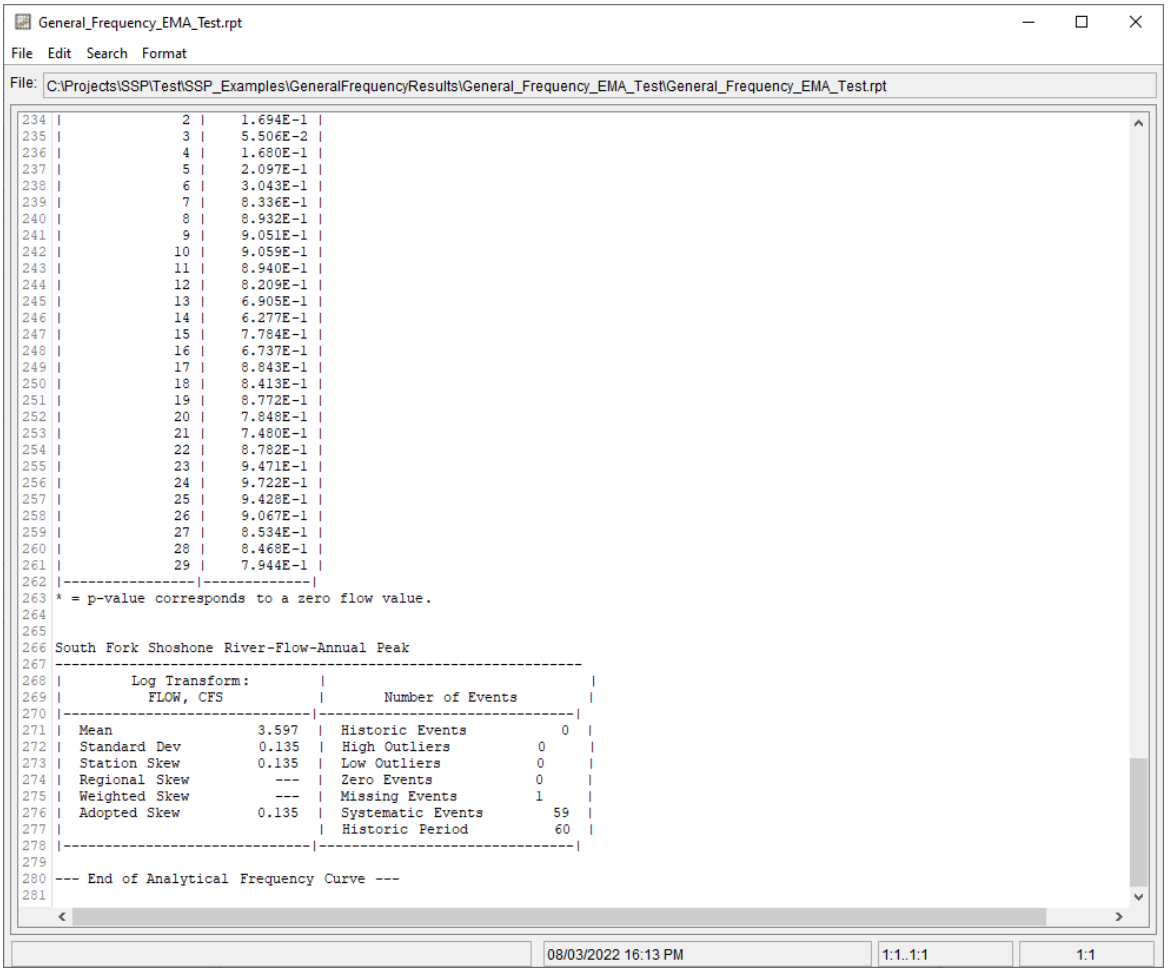


In addition to the tabular results, the **Analytical | Plot** tab contains a graph of the input data and the computed frequency curves, as specified within the analysis. The right side of the plot tab contains a table of **Sample Statistics** and **Adjusted Statistics**. The user has the option to enter one or more adjusted statistics within in the Adjusted Statistics table. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to compute a frequency curve using the user statistics.

A graphical plot of the input and computed results can be obtained by pressing the **Plot Analytical Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 7 (see page 0).

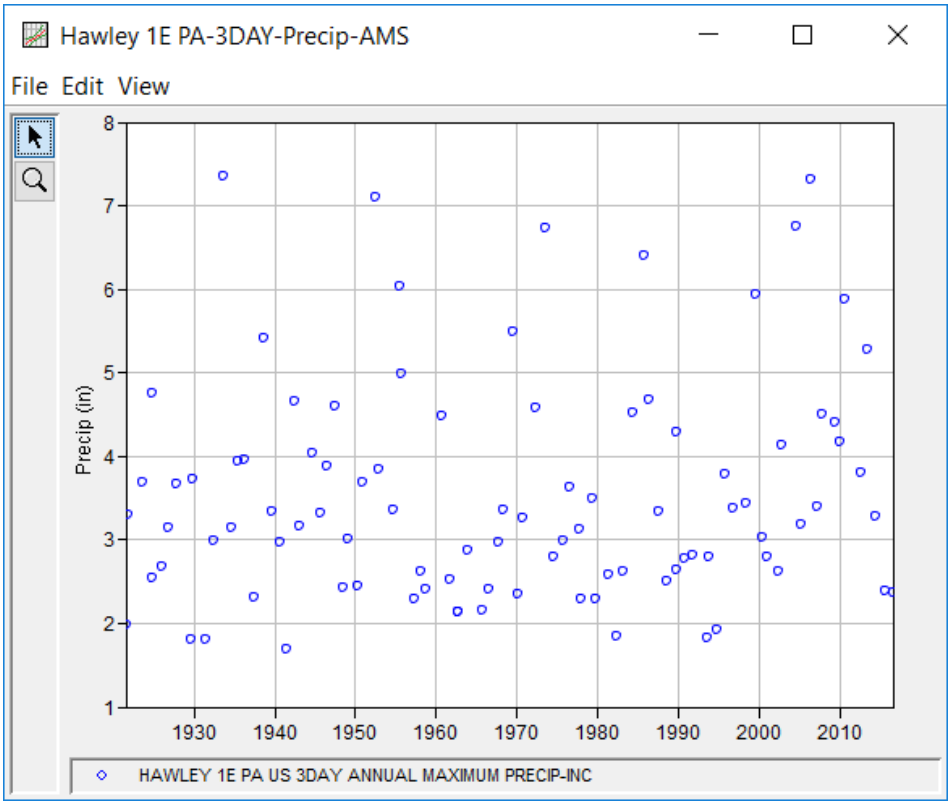


In addition to the tabular and graphical results, there is a report file that shows the input data, summary statistics, and the computed results. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 8 (see page 217).

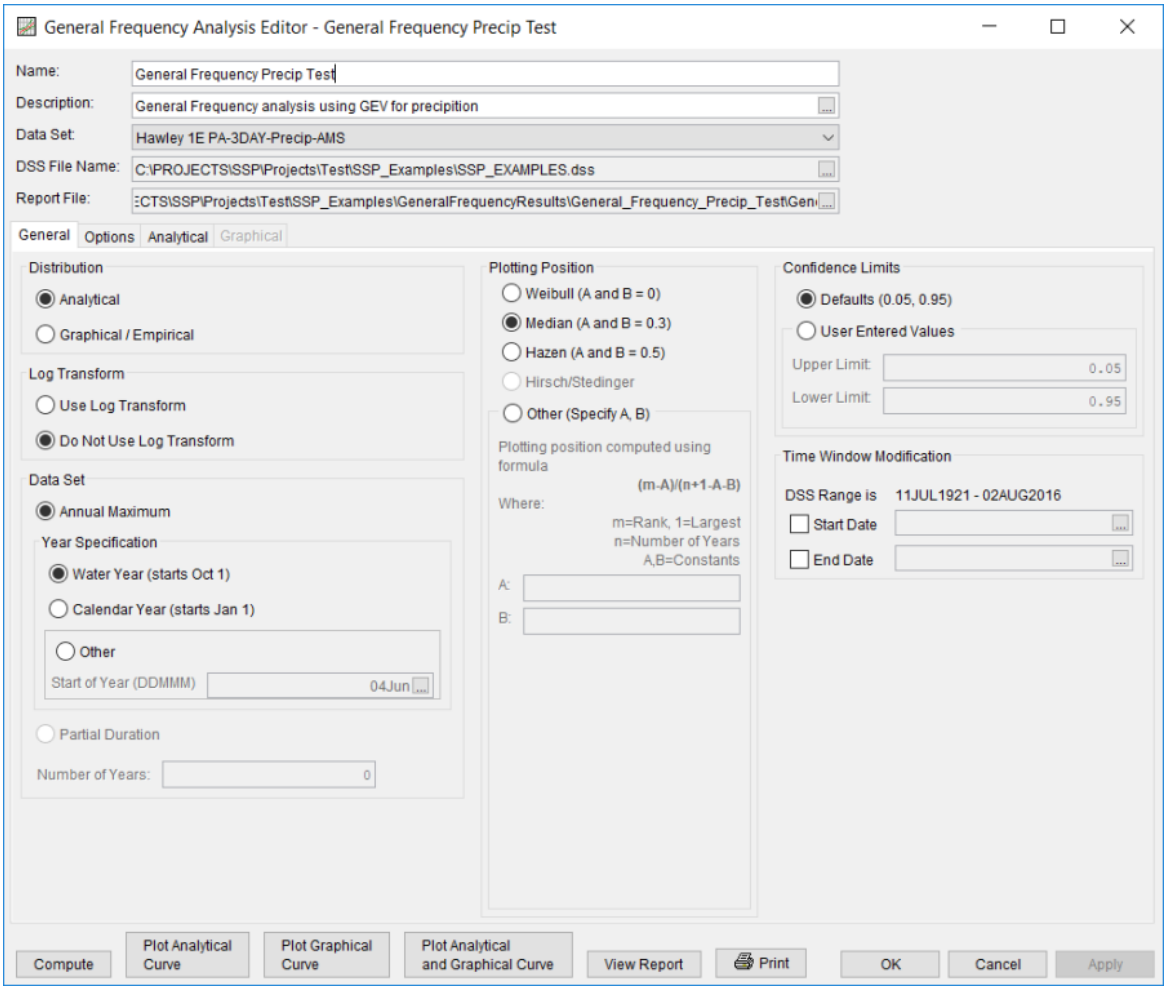


5.5 Example 30. General Frequency, Fitting an Analytical Distribution to a Precipitation Time Series

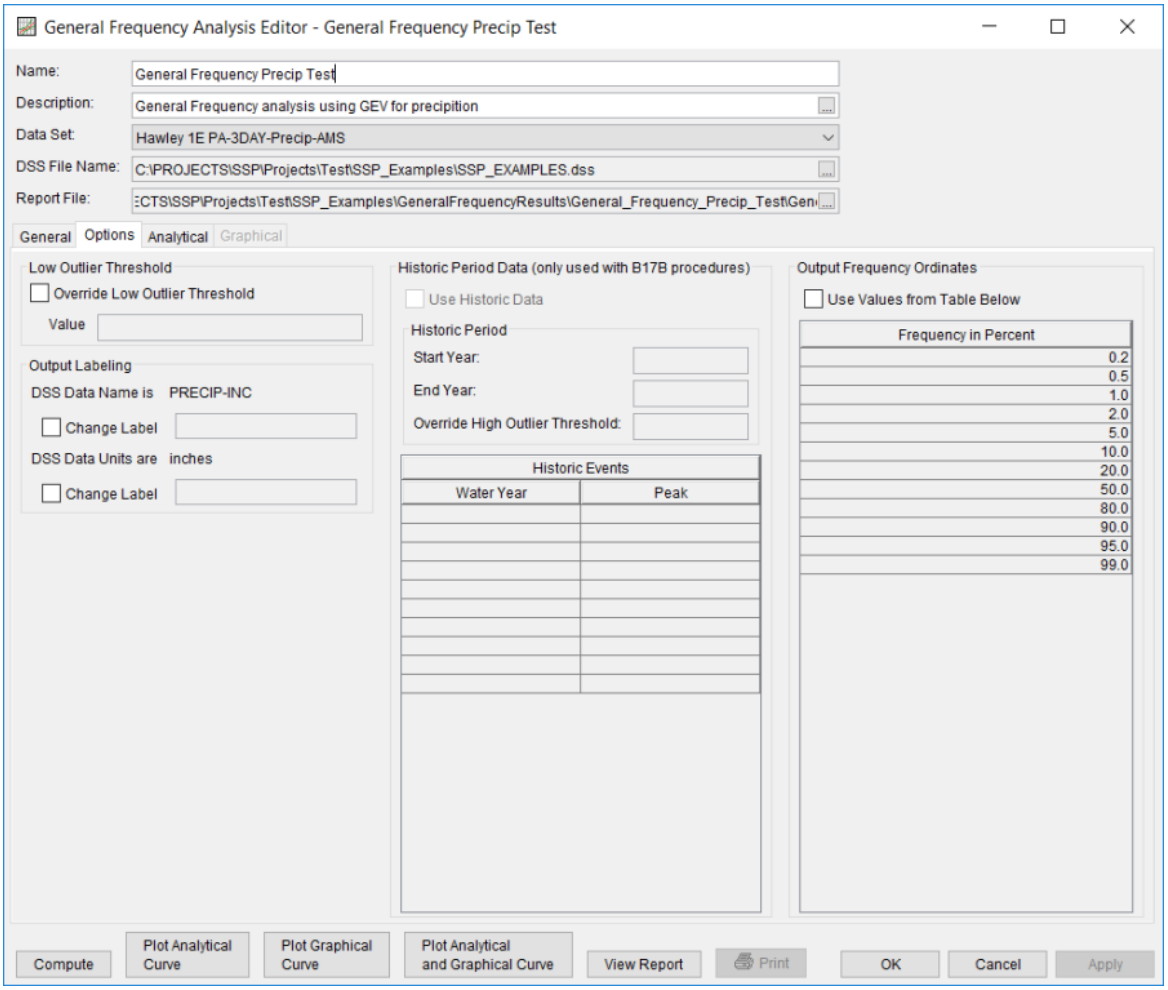
This example demonstrates how to fit an analytical distribution to an annual maximum series of precipitation depths within the General Frequency analysis. The data for this example consists of an annual maximum series of 3-day duration precipitation depths for a precipitation gage located near Hawley, Pennsylvania. This precipitation gage is operated by the NWS. Daily precipitation data was downloaded from the NWS website ("https://www.ncdc.noaa.gov/") as a .csv file, ingested to the study using an HEC-DSSVue plugin, accumulated to a 3-day duration, and an annual maximum series was extracted using tools contained within HEC-SSP. The period of record used for this example is from 1921 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Hawley 1E PA-3DAY-Precip-AMS**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 219).



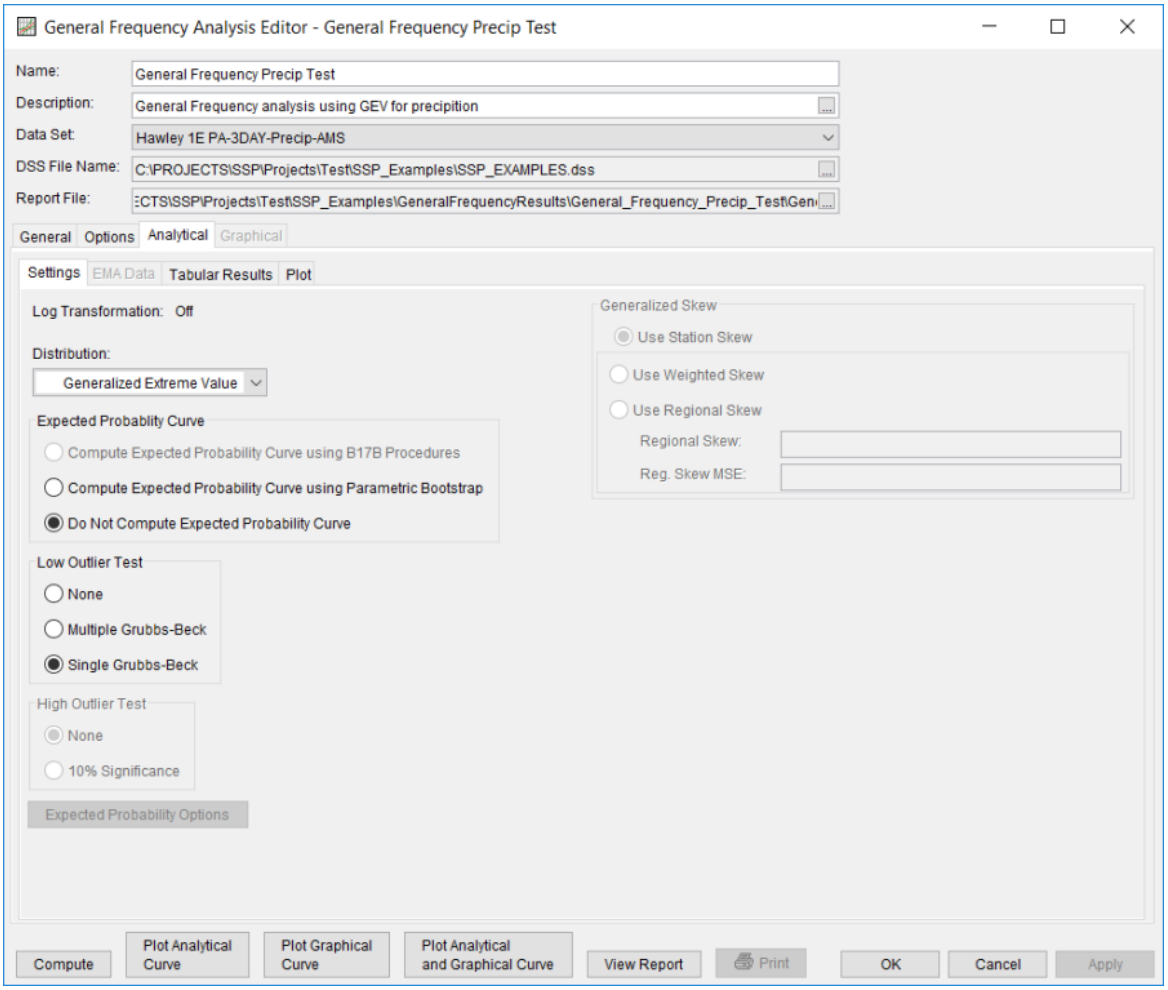
A General Frequency analysis has been developed for this example. To open the General Frequency analysis editor for this example, either double-click on the analysis labeled **General Frequency Precip Test** from the study explorer, or from the **Analysis** menu, select open, then select **General Frequency Precip Test** from the list of available analyses. When this analysis is opened, the General Frequency editor will appear as shown in Figure 2 (see page 219). Shown in Figure 2 (see page 219) are the general settings that were used to perform this frequency analysis. As shown, the **Analytical**, **Do Not Use Log Transform**, and **Annual Maximum** options were selected. Also, the **Median** option was selected within the **Plotting Position** panel. Finally, the default confidence limits options were left unchanged.



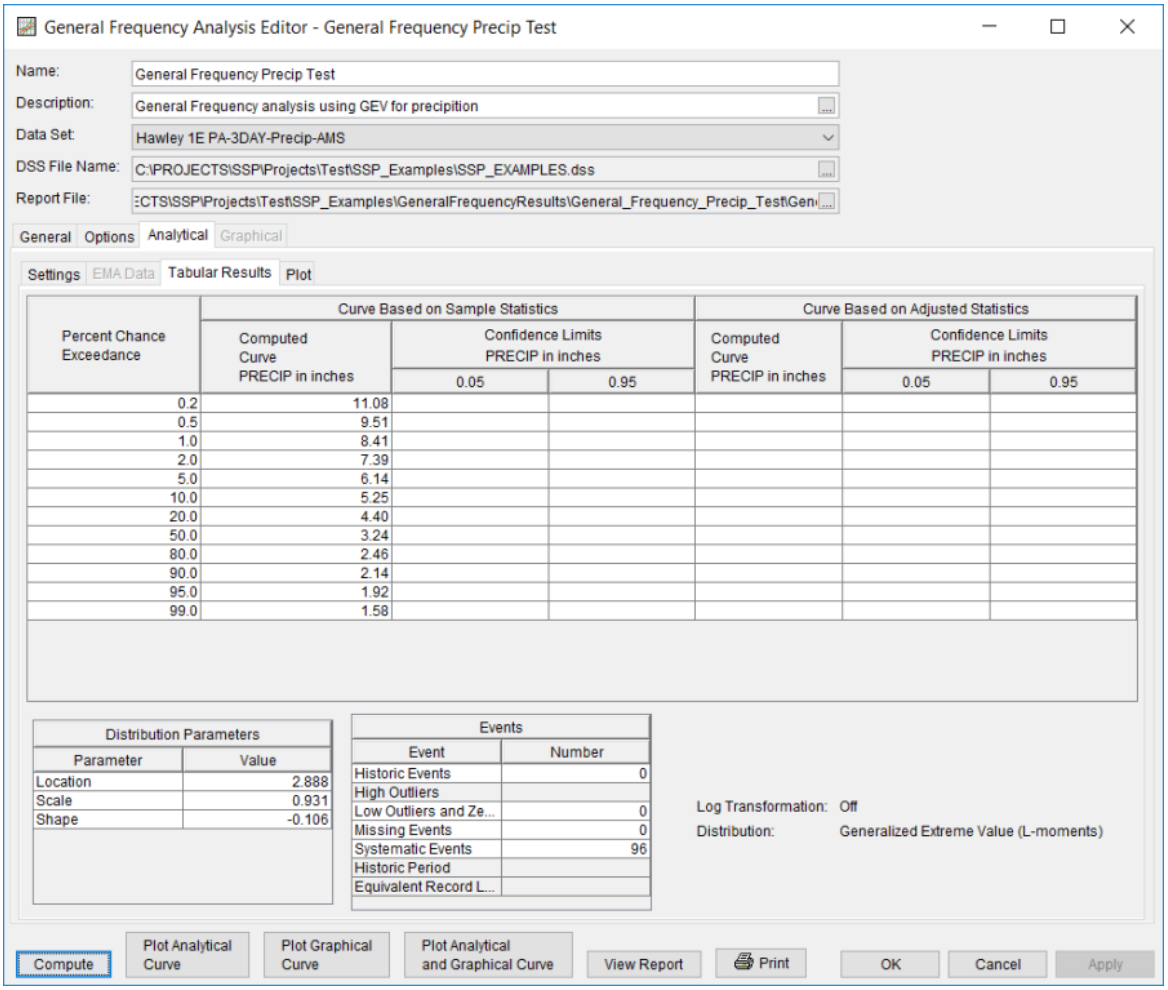
Shown in Figure 3 (see page 220)is the General Frequency analysis editor with the **Options Tab** selected. Features on this tab include the **Low Outlier Threshold**, an option to use **Historic Data**, an option to override the default **Frequency Ordinates**, and **Output Labeling**. All defaults settings were selected for this example.



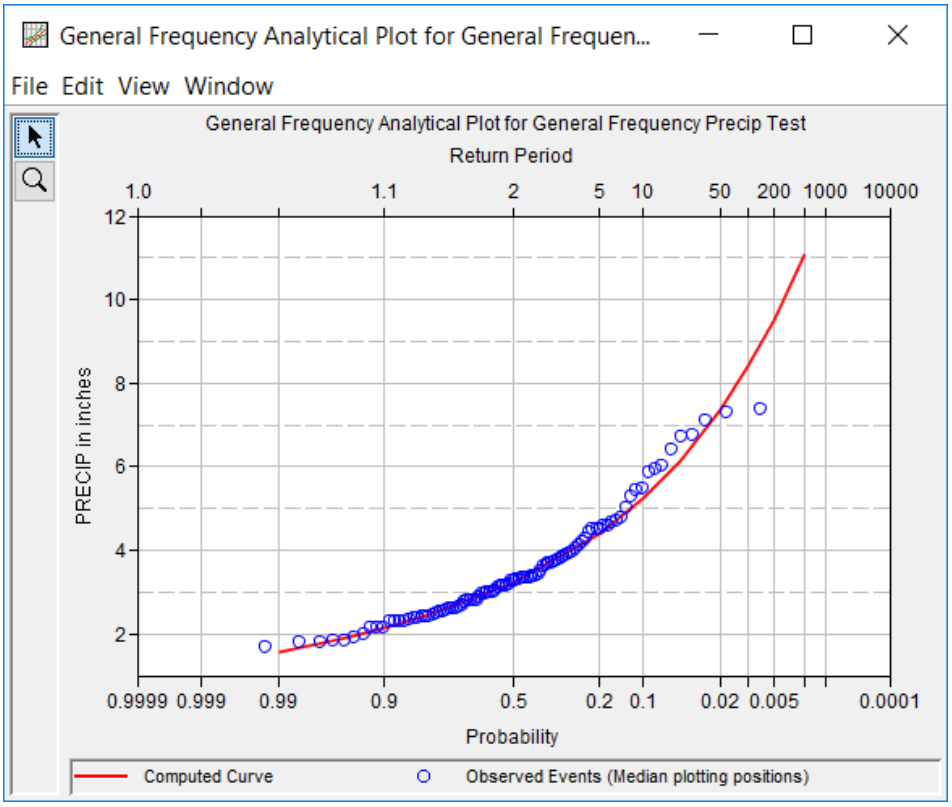
In this example, an analytical analysis was performed. Shown in Figure 4 (see page 221) is the **Settings** tab for the analytical analysis. As shown, the distribution and fitting method combination which was selected for this example is **Generalized Extreme Value | L-Moments**. The **Do Not Compute Excepted Probability** and **Single Grubbs-Beck** options were selected.



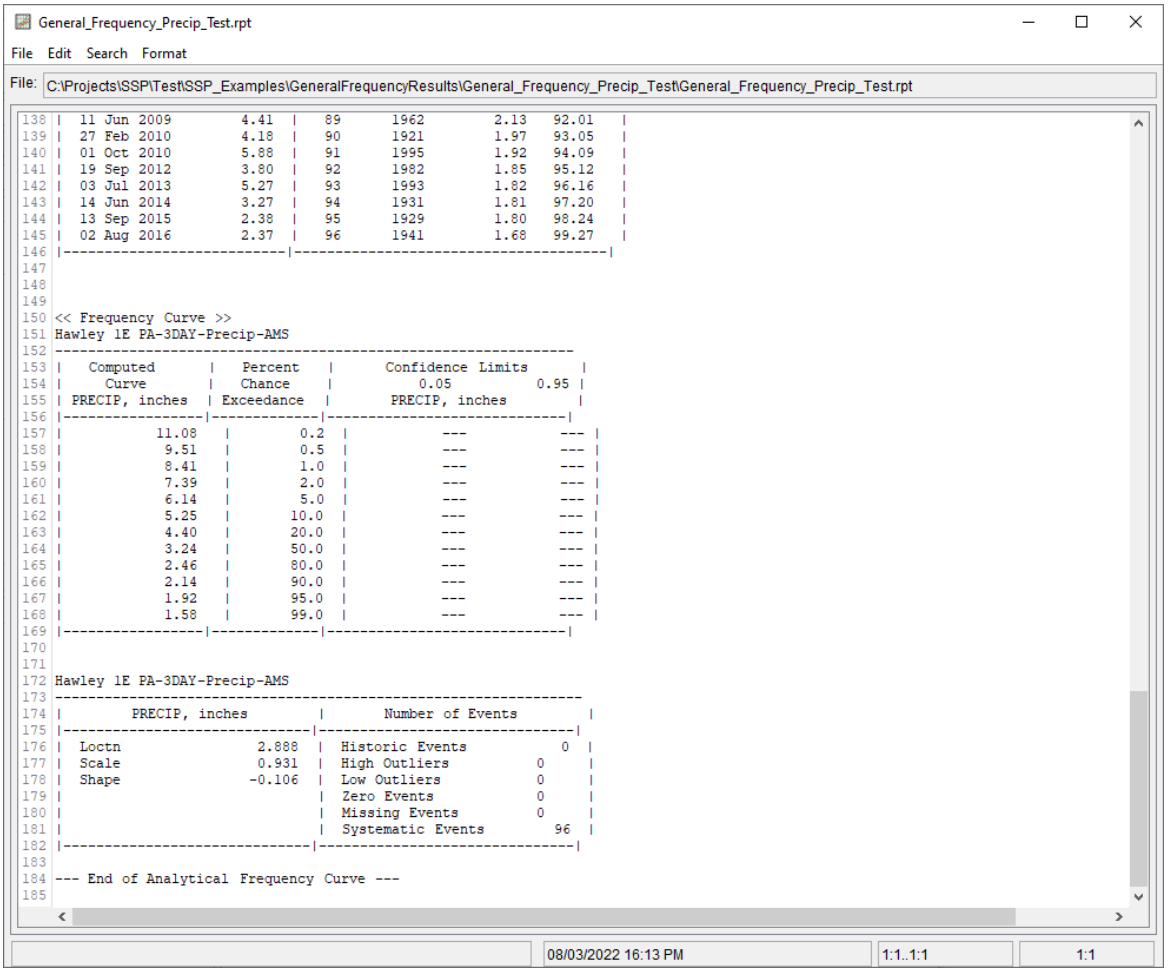
Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Analytical Compute Complete**. Close this window and then select the **Analytical | Tabular Results** tab. This window should resemble Figure 5 (see page 222). Within this tab is a tabular listing of the computed results that were specified as part of the analysis. Also, a table of Distribution Parameters is shown along the bottom of the window. Also on the bottom is an Events table showing values pertinent to the number of different types of events used within the analysis. Finally, the lower right hand panel displays the selected distribution and whether or not the log transform was selected.



In addition to the tabular results, the **Analytical | Plot** tab contains a graph of the input data and the computed frequency curves, as specified within the analysis. The right side of the plot tab contains a table of **Sample Statistics** and **Adjusted Statistics**. The user has the option to enter one or more adjusted statistics within in the Adjusted Statistics table. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to compute a frequency curve using the user statistics.
A graphical plot of the input and computed results can be obtained by pressing the **Plot Analytical Curve** button at the bottom of the analysis window. A plot of the results for this example is shown in Figure 6 (see page 223).



In addition to the tabular and graphical results, there is a report file that shows the input data, summary statistics, and the computed results. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 7 (see page 224).

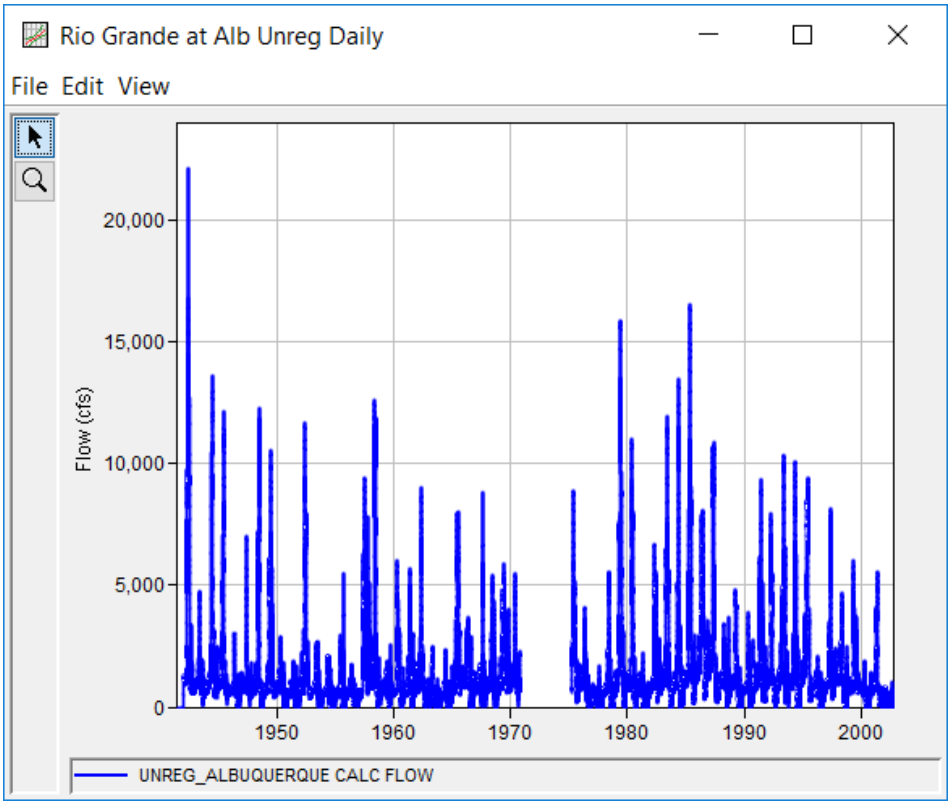


90 Figure 7. General Frequency Precip Test Report File.

6 Volume Frequency Analysis Examples

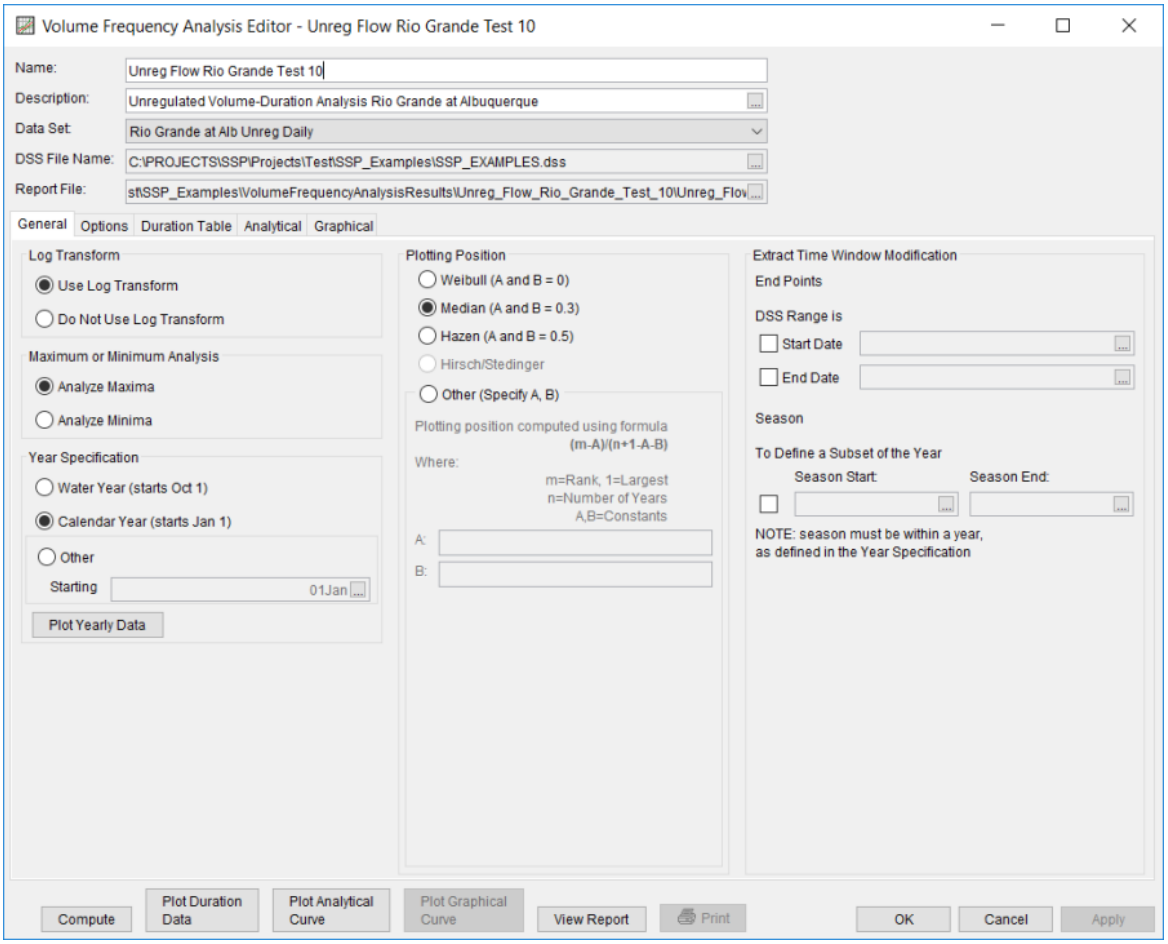
6.1 Example 10. Volume Frequency Analysis, Maximum Flows

In the ***SSP_Examples.ssp*** study, the ***Unreg Flow Rio Grande Test 10*** example demonstrates how to perform a Volume Frequency analysis for maximum flows. The data for this example was derived from an analysis where a time-series of daily average unregulated flows were computed for the Rio Grande at Albuquerque. The period of record for this example is from 1941 to 2002. To view the data, right-click on the data record labeled "***Rio Grande at Alb Unreg Daily***" in the study explorer and then select **Plot**. The data will appear as shown in Figure 1.



91 Figure 1. Plot of Daily Average Flow for Example 10

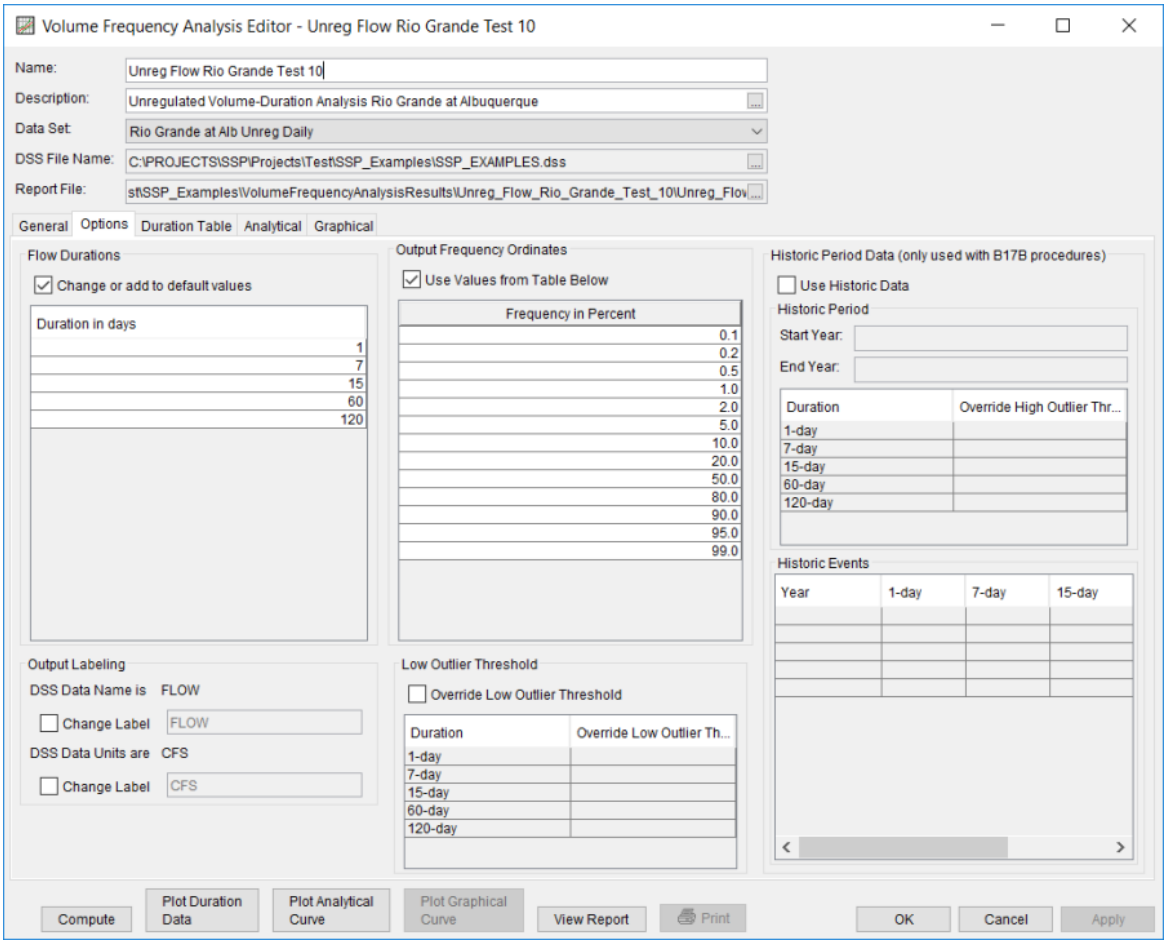
A Volume Frequency analysis has been developed for this example. To open the **Volume Frequency Analysis Editor** for this example, either double-click on the analysis labeled ***Unreg Flow Rio Grande Test 10*** from the study explorer, or from the **Analysis** menu select open, then select ***Unreg Flow Rio Grande Test 10*** from the list of available analyses. When Test 10 is opened, the **Volume Frequency Analysis Editor** will appear as shown in Figure 2.



92 Figure 2. Volume Frequency Analysis Editor for Unreg Flow Rio Grande Test 10

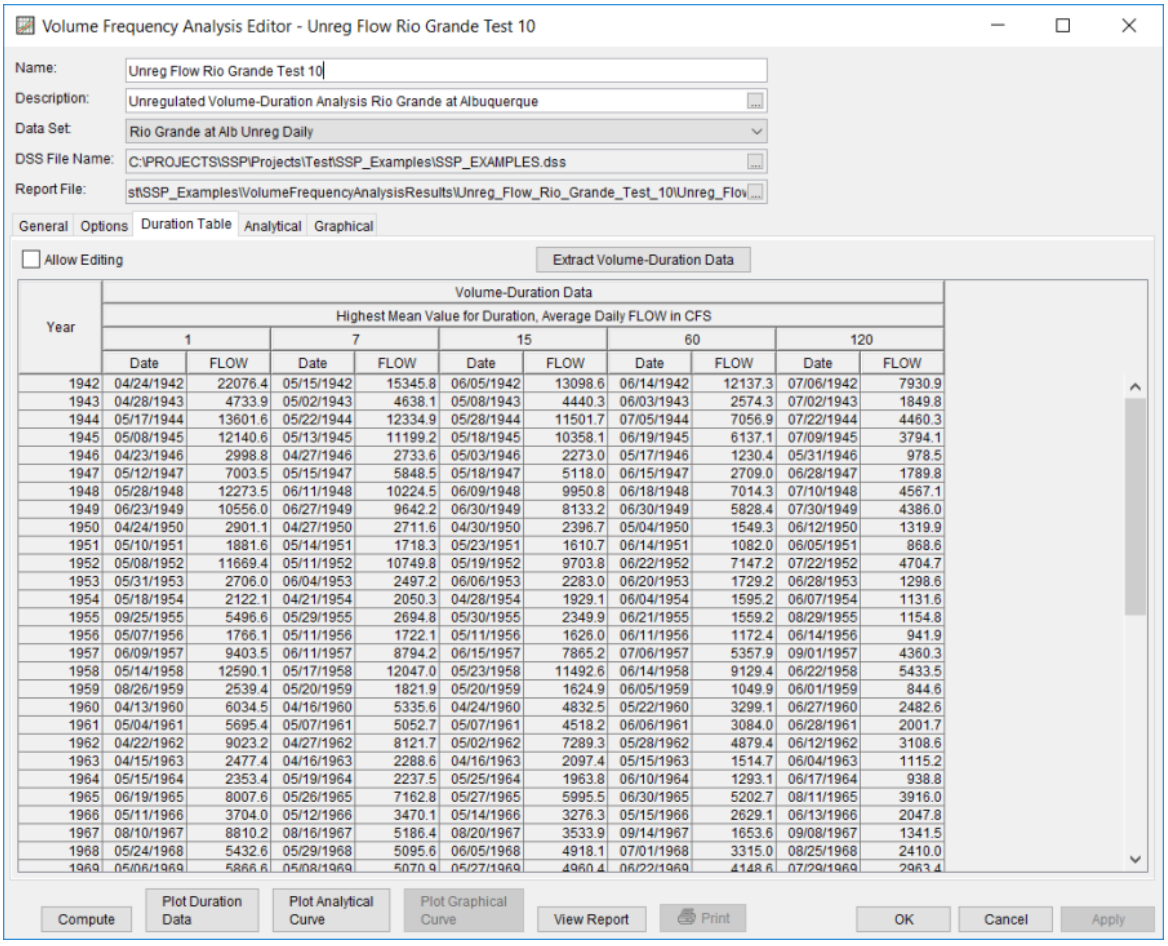
Shown in Figure 2 are the general settings that were used to perform this frequency analysis. For this analysis, the **Use Log Transform** option was selected, the **Weibull** plotting position method was selected, **Analyze Maxima** was selected, the **Calendar Year** option was selected, and no modification was made to the **Time Window**.

Shown in Figure 3 is the **Volume Frequency Analysis Editor** with the **Options** tab selected. Features on this tab include an option to override the default **Flow Duration** values, an option to override the default **Frequency Ordinates**, and **Output Labeling**. Both the flow-duration and frequency ordinate tables were modified.



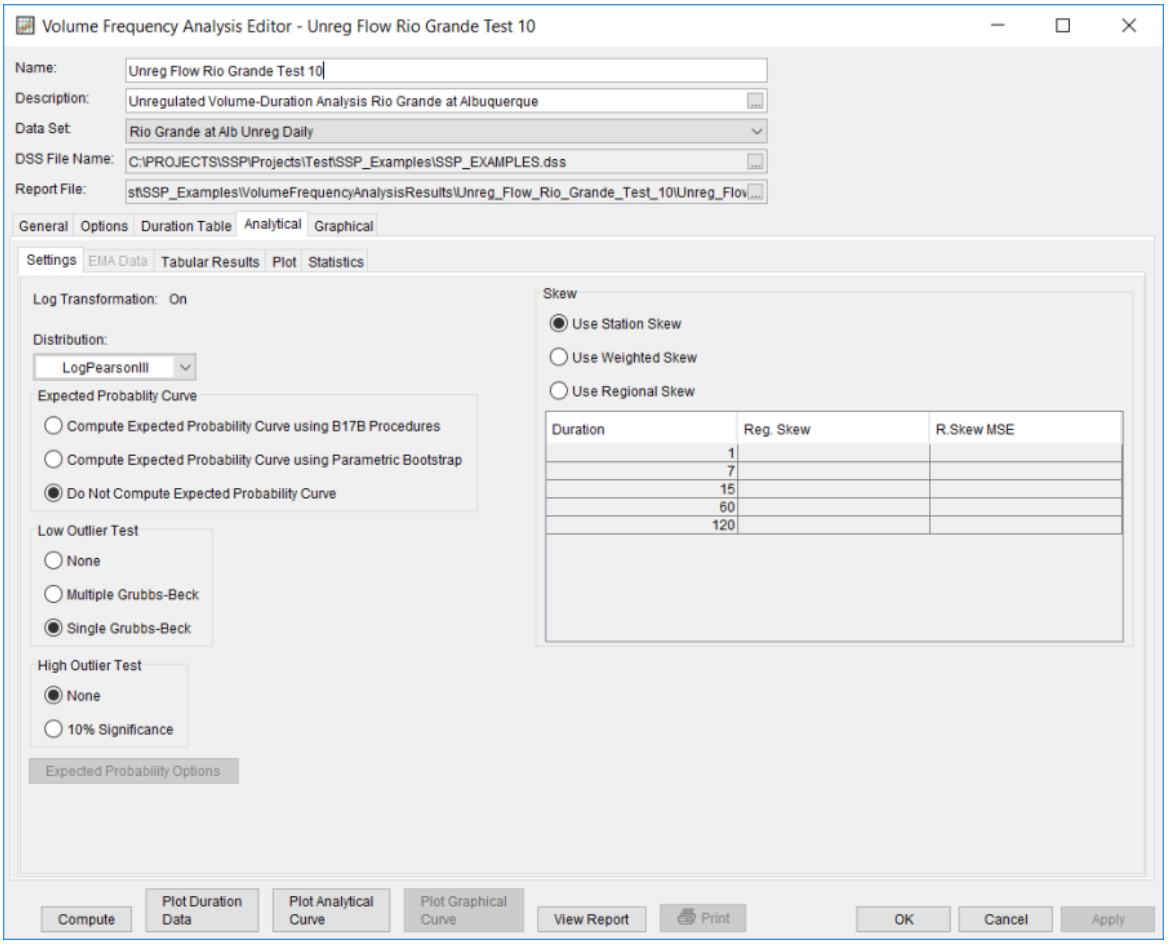
93 Figure 3. Options tab Shown for Unreg Flow Rio Grande Test 10

Once all of the General and Optional settings are set or selected, the user can extract the volume-duration data from the time-series of daily flows. Select the **Duration Data** tab and press the **Extract Volume-Duration Data** button at the bottom of the table. The table should then fill with the flow-duration values, as shown in Figure 4.



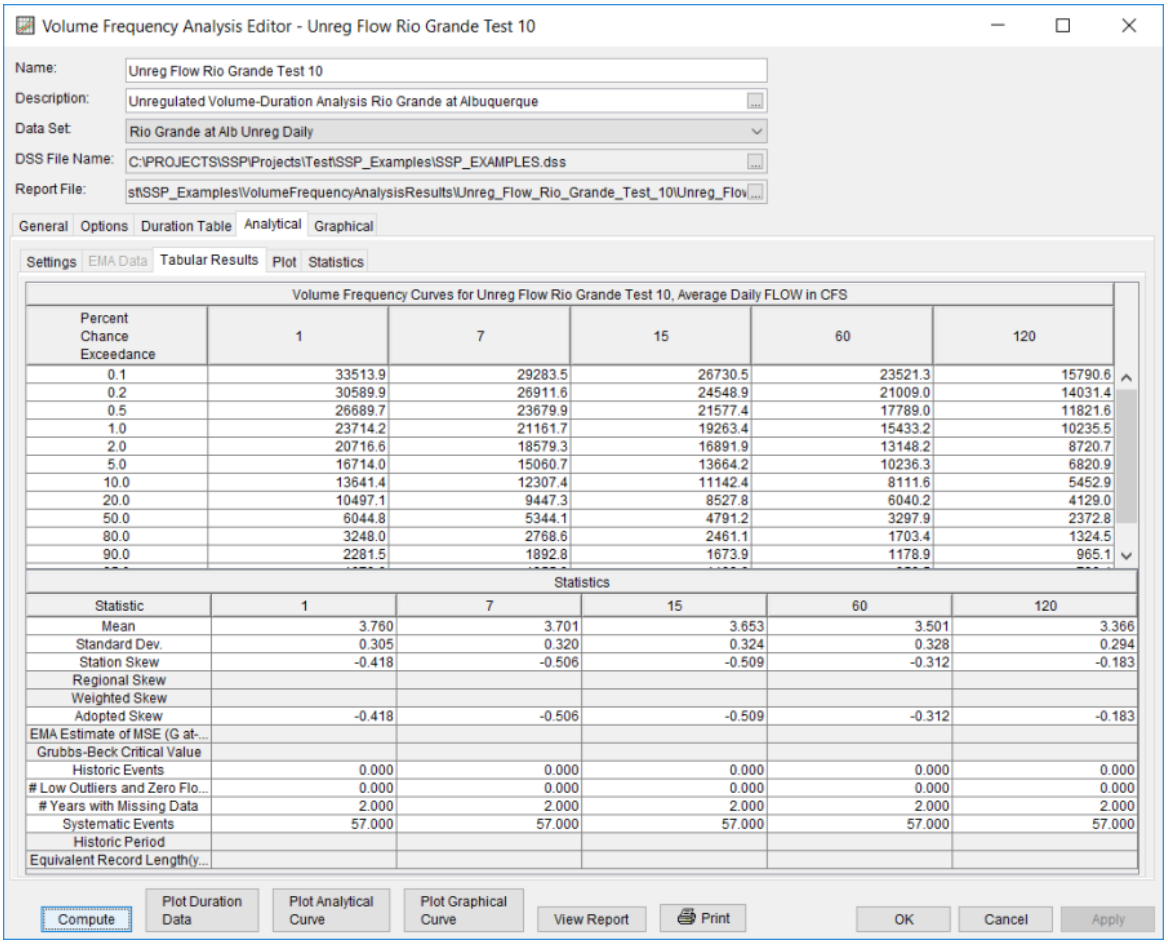
94 Figure 4. Volume-Duration Data Table for Unreg Flow Rio Grande Test 10

Once the data has been extracted, the user must choose to perform an Analytical or Graphical analysis. In this example, an analytical analysis was performed. Shown in Figure 5 is the **Settings** tab for the analytical analysis. As shown, the distribution and fitting method combination which was selected for this example is **LogPearsonIII | Product Moments**. The **Do Not Compute Excepted Probability**, **Single Grubbs-Beck**, no high outlier test, and **Use Station Skew** options were selected.



95 Figure 5. Settings tab Shown for Unreg Flow Rio Grande Test 10

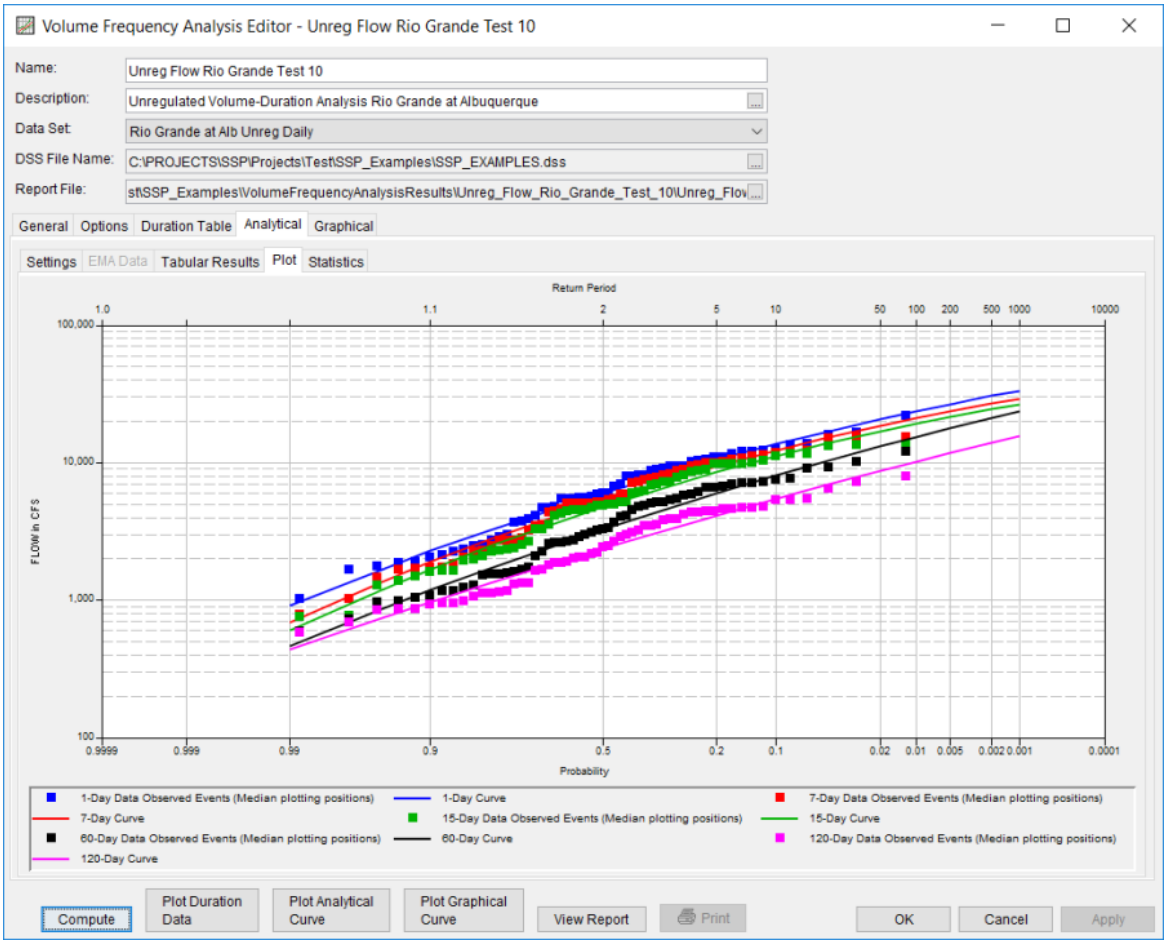
Press the **Compute** button to perform the analysis. A message window will open stating that a few of the annual maxima occurred near the beginning of the year. The message suggests that the user change the year/season specification to better capture independent events. You want to minimize the possibility that the same flood event is used for consecutive years. Press the OK button to finish the compute. Once the computations have been completed, a message window will open stating **Compute Complete**. Close this window and then select the **Tabular Results** tab within the analytical analysis. The results table should resemble Figure 6. The top portion of the results table contains the percent chance exceedance for all durations (the report contains confidence limits). The bottom portion of the results table contains the statistics for all duration.



96 Figure 6. Tabular Results tab for Unreg Flow Rio Grande Test 10

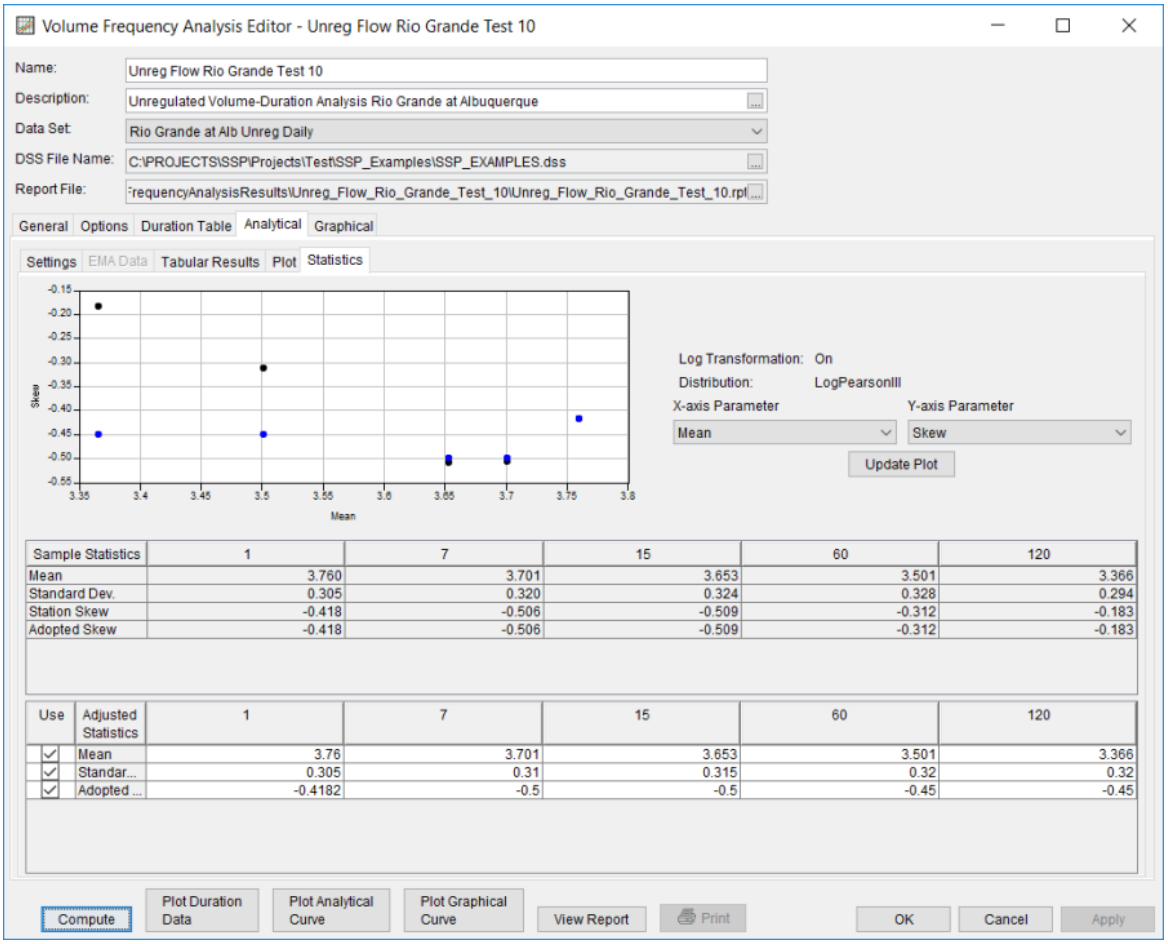
> ⚠ The tabular results use the default computed statistics.

As shown in Figure 7, the **Plot** tab contains a graph of the systematic data and the computed frequency curves. Notice how some of the frequency curves look like they might cross if the lines were extended. The **Statistics** tab can be used to modify the computed statistics to ensure that the frequency curves are consistent.



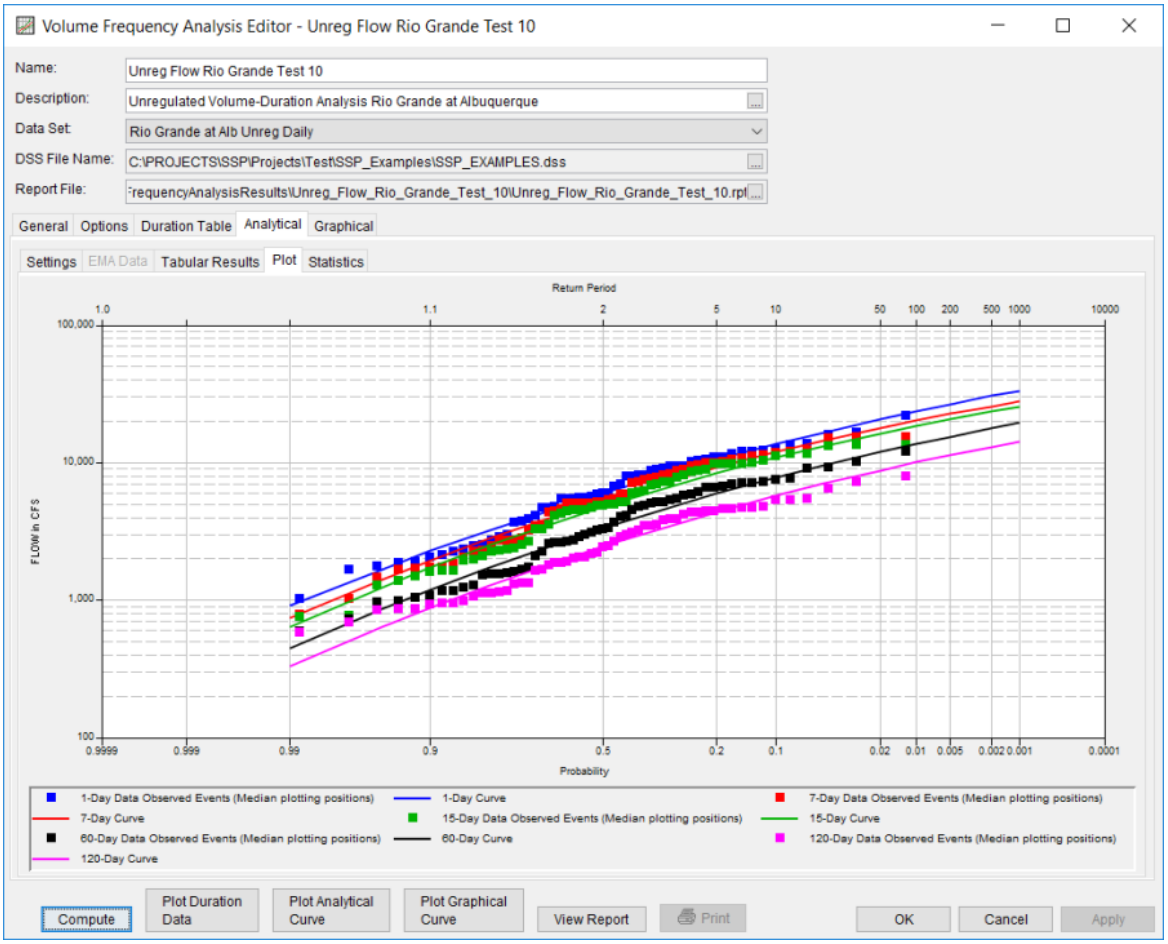
97 Figure 7. Plot tab for Unreg Flow Rio Grande Test 10

For this example, the standard deviation and the adopted skew values were modified to make sure the volume frequency curves were consistent. As shown in Figure 8, the check boxes next to mean, standard deviation, and adopted skew were checked and then user-adjusted statistics were entered into the table for all durations. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to recompute the frequency curves using the user-adjusted statistics.



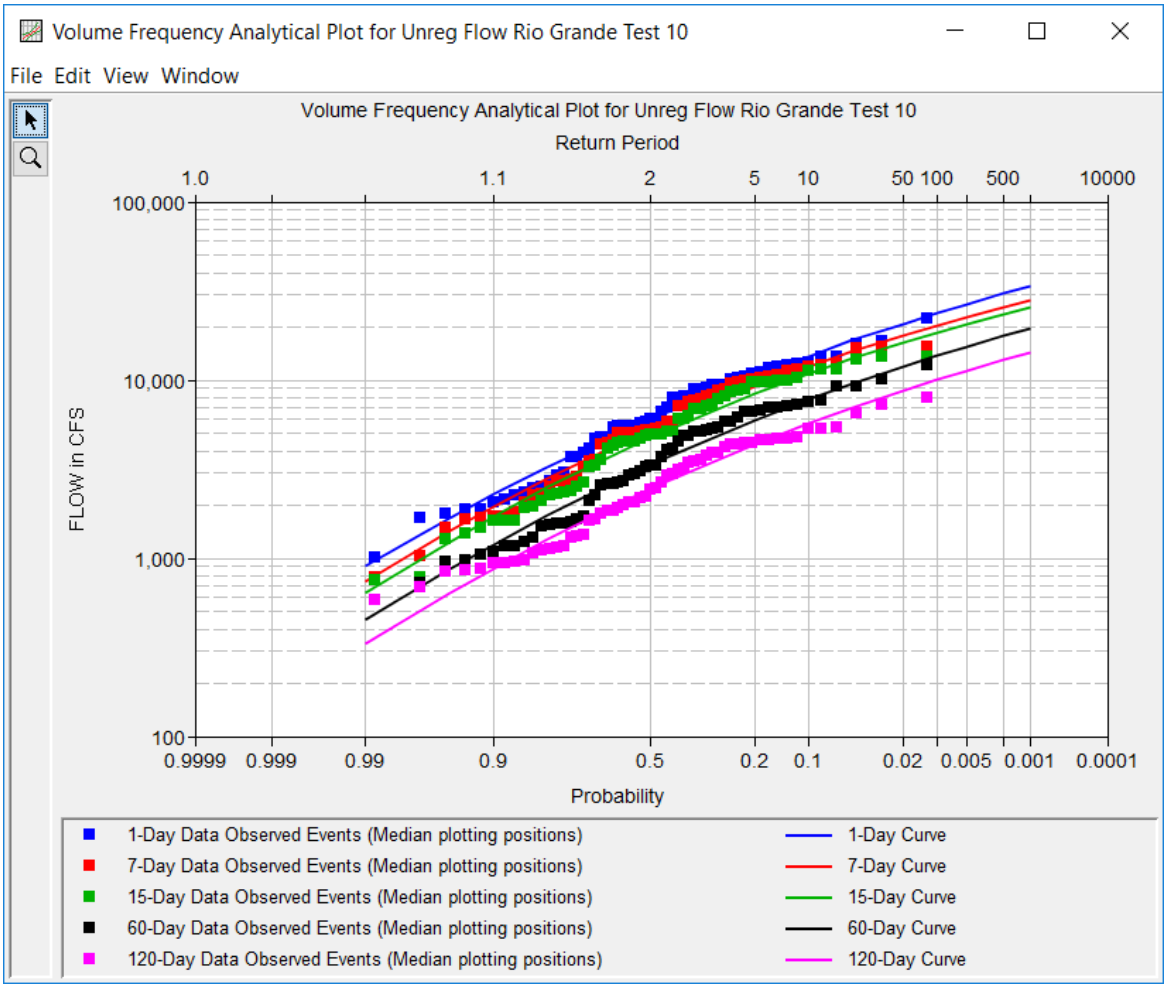
98 Figure 8. Statistics tab for Unreg Flow Rio Grande Test 10

Figure 9 shows the **Plot** tab after the user-adjusted statistics were entered on the **Statistics** tab. Results on the **Tabular Results** tab will also update when user-adjusted statistics are entered on the **Statistics** tab.



99 Figure 9. Plot Tab for Unreg Flow Rio Grande Test 10 After the Statistics were Adjusted on the Statistics tab

In addition to the **Tabular Results** and **Plot** tabs, graphical plots can be opened by selecting the **Plot Duration Data** or **Plot Analytical Curve** buttons at the bottom of the analysis window. A plot of the results for this example is shown in Figure 10.

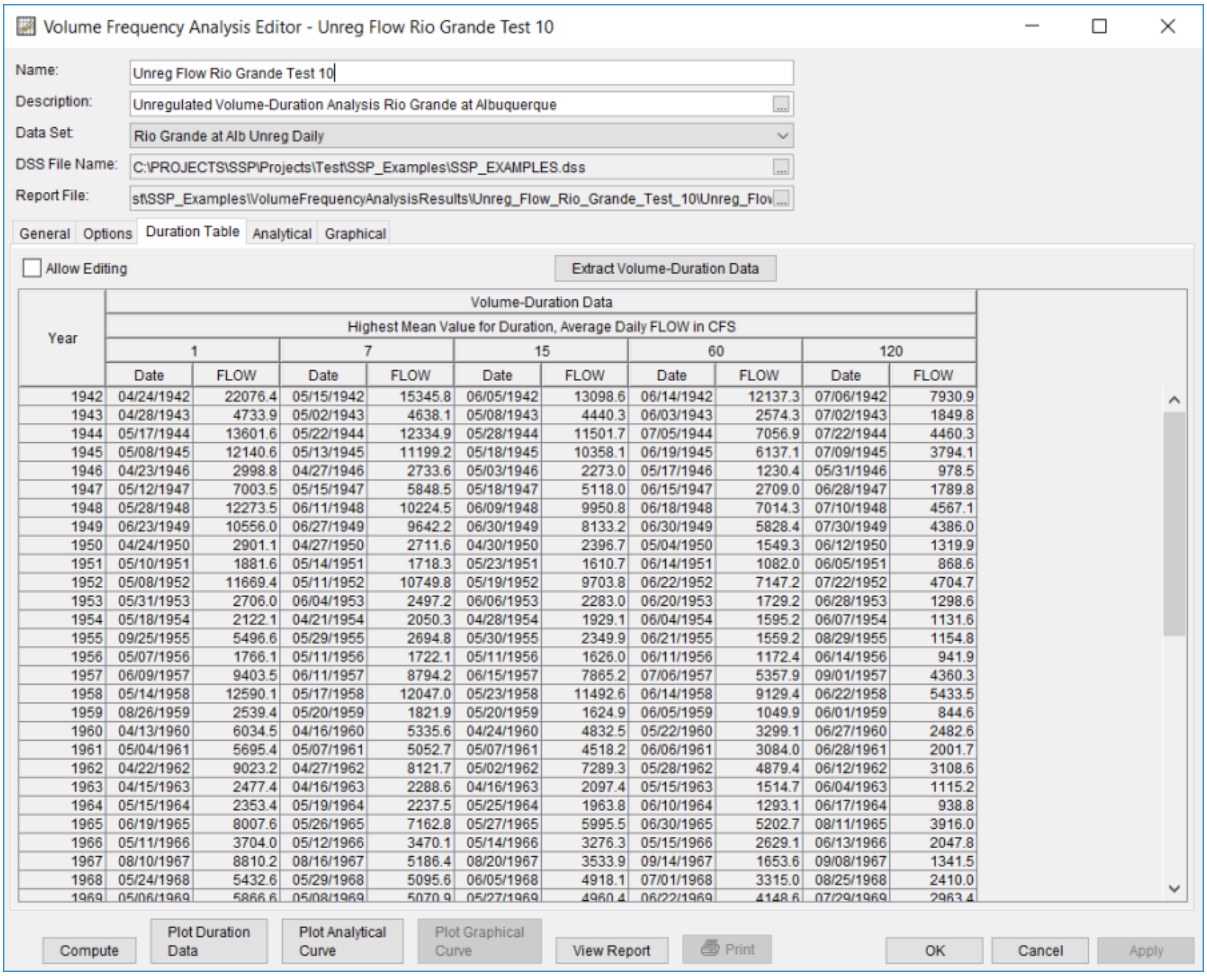


100 Figure 10. Plot of the Frequency Curve Results for Unreg Flow Rio Grande Test 10

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 11 is the report file for **Unreg Flow Rio Grande Test 10**.

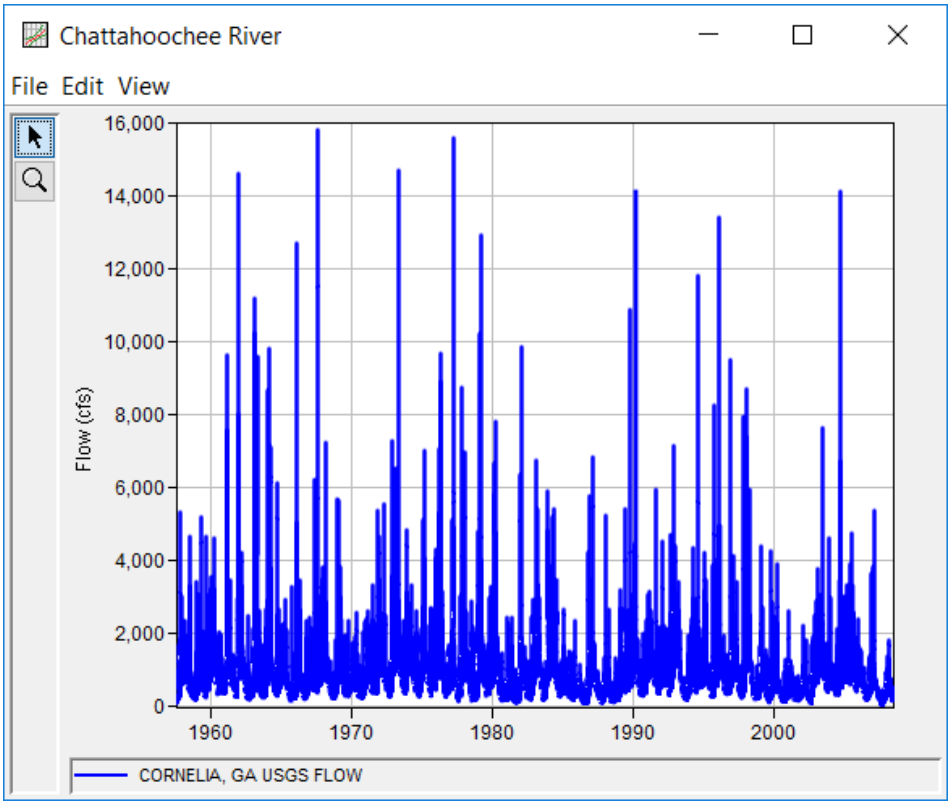
The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



101 Figure 11. Report File for Unreg Flow Rio Grande Test 10

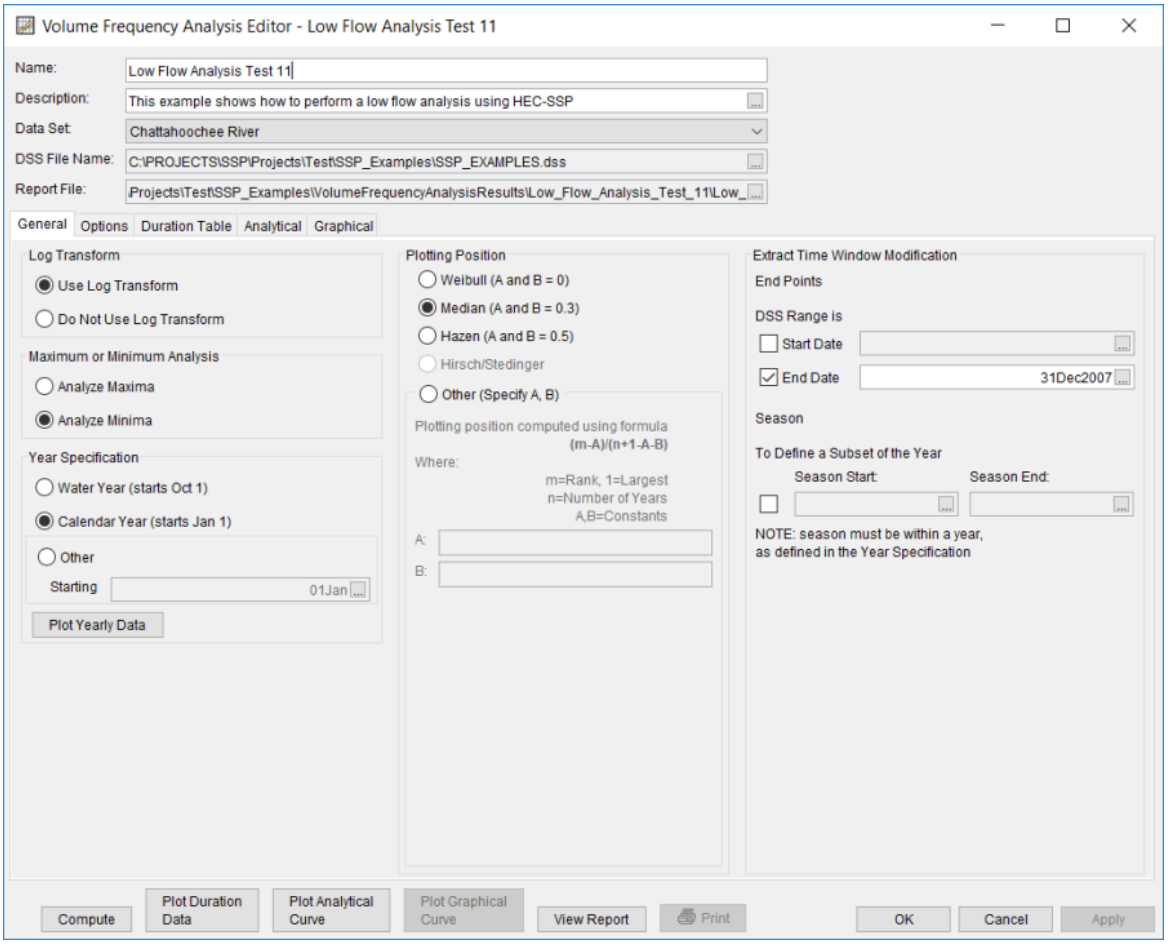
6.2 Example 11. Volume Frequency Analysis, Minimum Flows

This example demonstrates how to create a low flow Volume Frequency analysis. The data for this example was downloaded from the USGS. It is comprised of daily average flow for the Chattahoochee River at Cornelia, Georgia. Drought conditions were occurring in the region at the time of this analysis. Among other things, a low flow analysis can be used to determine the severity of a drought. The period of record for this example is from 1957 to 2007. To view the data, right-click on the data record labeled "**Chattahoochee River**" in the study explorer and then select **Plot**. The data will appear as shown in Figure 1.



102 Figure 1. Plot of Daily Average Flow for Example 11

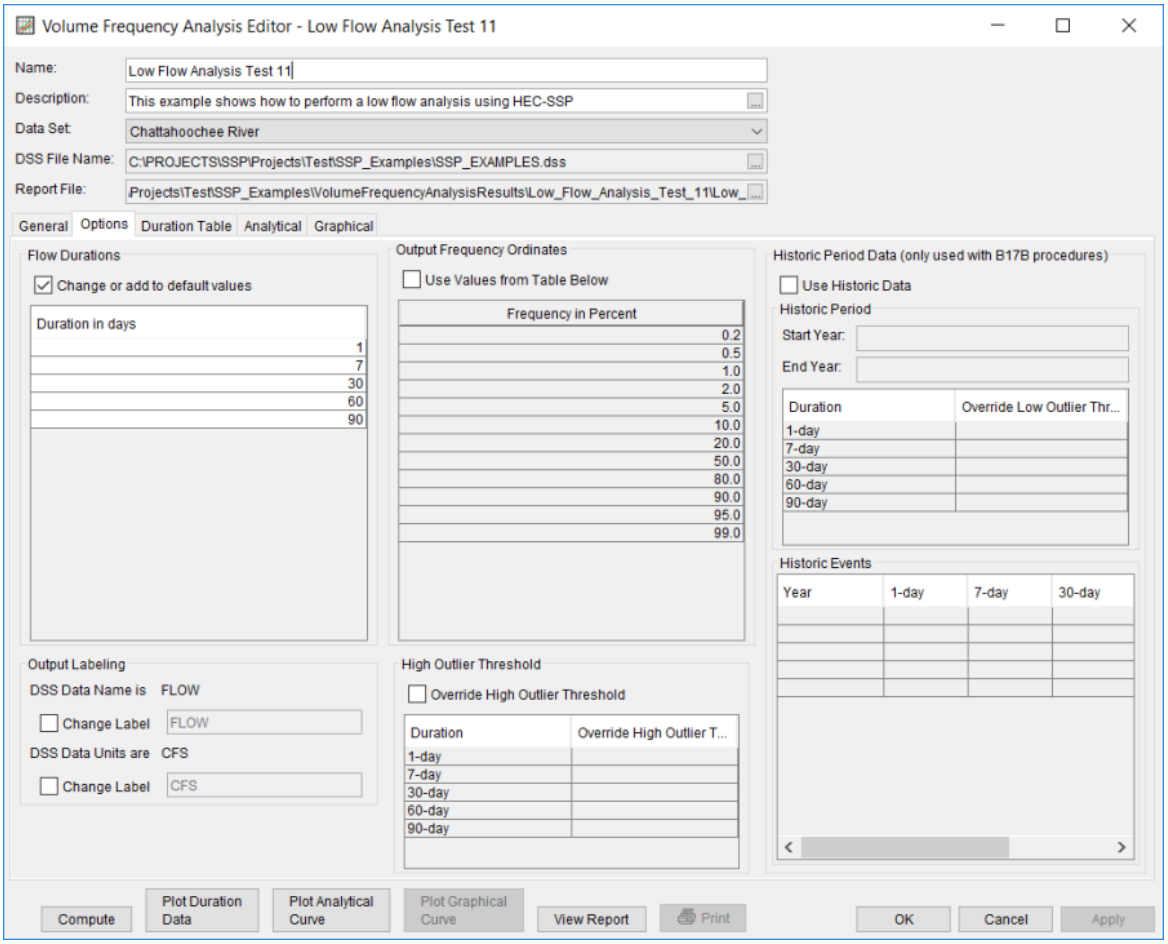
A Volume Frequency analysis has been developed for this example. To open the Volume Frequency Analysis editor for this example, either double-click on the analysis labeled **Low Flow Analysis Test 11** from the study explorer, or from the **Analysis** menu select open, then select **Low Flow Analysis Test 11** from the list of available analyses. When test 11 is opened, the Volume Frequency Analysis editor will appear as shown in Figure 2.



103 Figure 2. Volume Frequency Analysis Editor for Low Flow Analysis Test 11

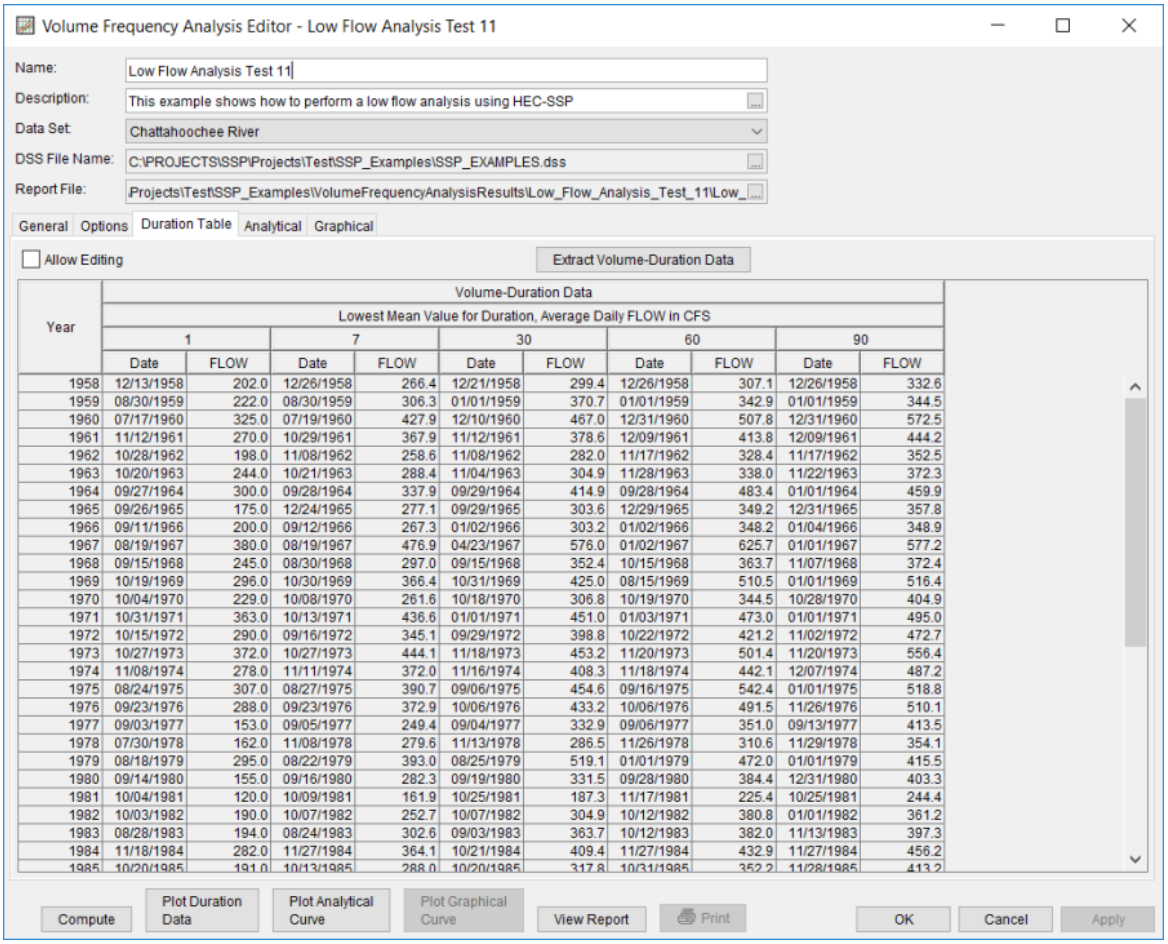
Shown in Figure 2 are the general settings that were used to perform this frequency analysis. For this analysis, the **Use Log Transform** option was selected, the **Weibull** plotting position method was selected, **Analyze Minimums** was selected, and the **Calendar Year** option was selected. The Calendar Year option was selected because low flows are possible in late September, early November. Starting the year on January 1 minimizes the possibility of using the same low flow event in multiple years. An end date of 31 December 2007 was entered in the **Time Window Modification**. This end date was specified because not all the data for the summer of 2008 was available at the time of the analysis.

Shown in Figure 3 is the Volume Frequency Analysis editor with the **Options Tab** selected. Features on this tab include an option to override the default **Flow Duration** values, an option to override the default **Frequency Ordinates**, and **Output Labeling**.



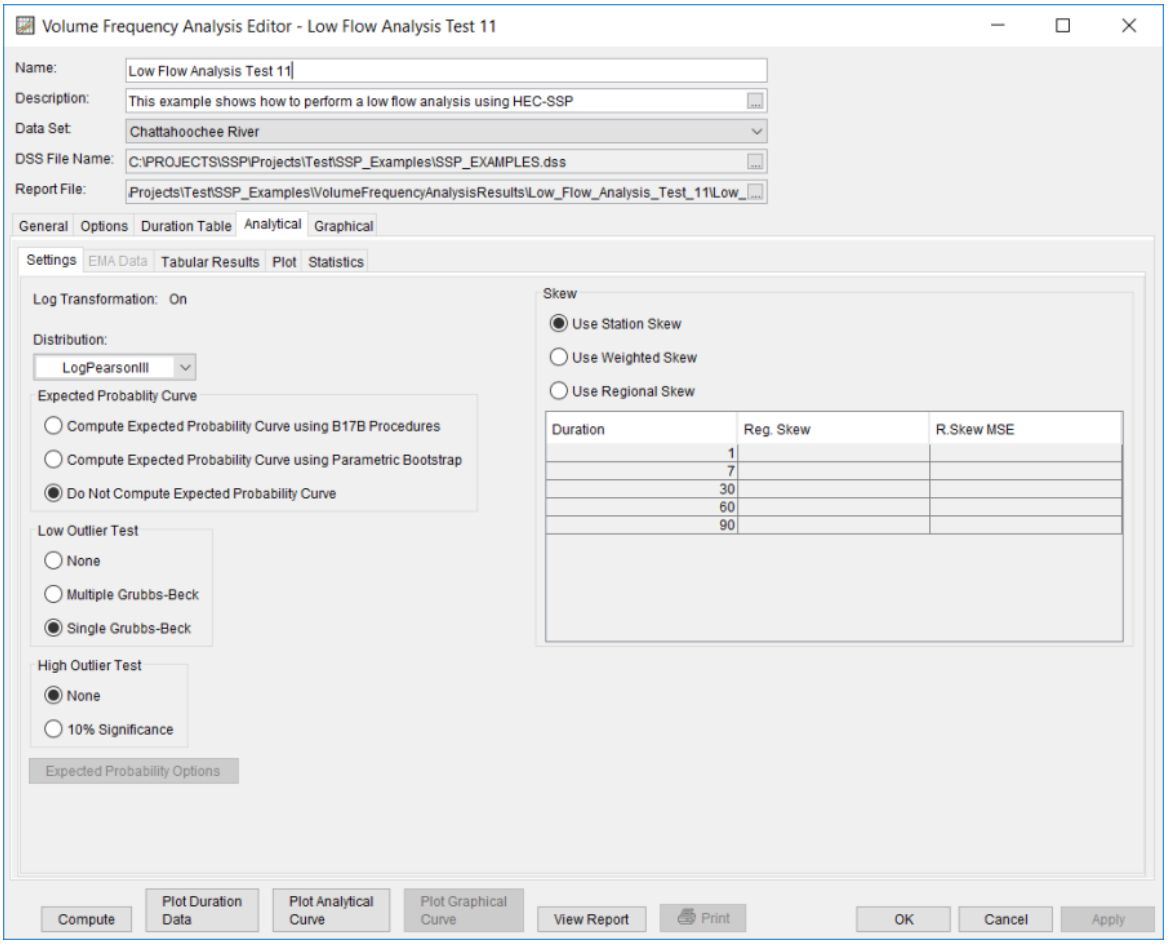
104 Figure 3. Options Tab Shown for Low Flow Analysis Test 11

Once all of the General and Optional settings are set or selected, the user can extract the volume-duration data. Select the **Duration Data** tab and press the **Extract Volume-Duration Data** button at the bottom of the table. The table should then fill with the flow-duration values, as shown in Figure 4.



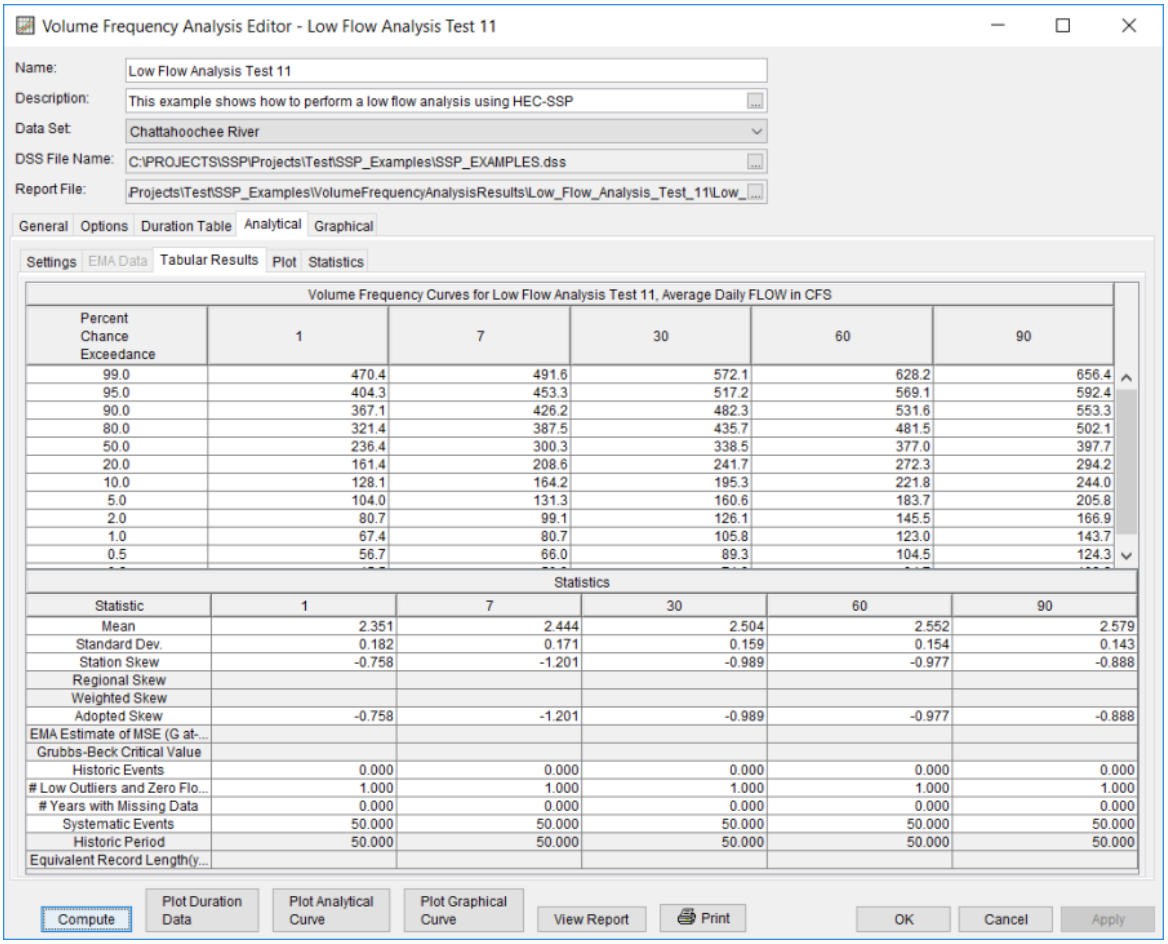
105 Figure 4. Volume-Duration Data Table for Low Flow Analysis Test 11

Once the data has been extracted, the user must choose to perform an Analytical or Graphical analysis. In this example, an analytical analysis was performed. Shown in Figure 5 is the **Settings** tab for the analytical analysis. As shown, the distribution and fitting method combination which was selected for this example is **LogPearsonIII | Product Moments**. The **Do Not Compute Excepted Probability**, **Single Grubbs-Beck**, no high outlier test, and **Use Station Skew** options were selected.



106 Figure 5. Settings Tab Shown for Low Flow Analysis Test 11

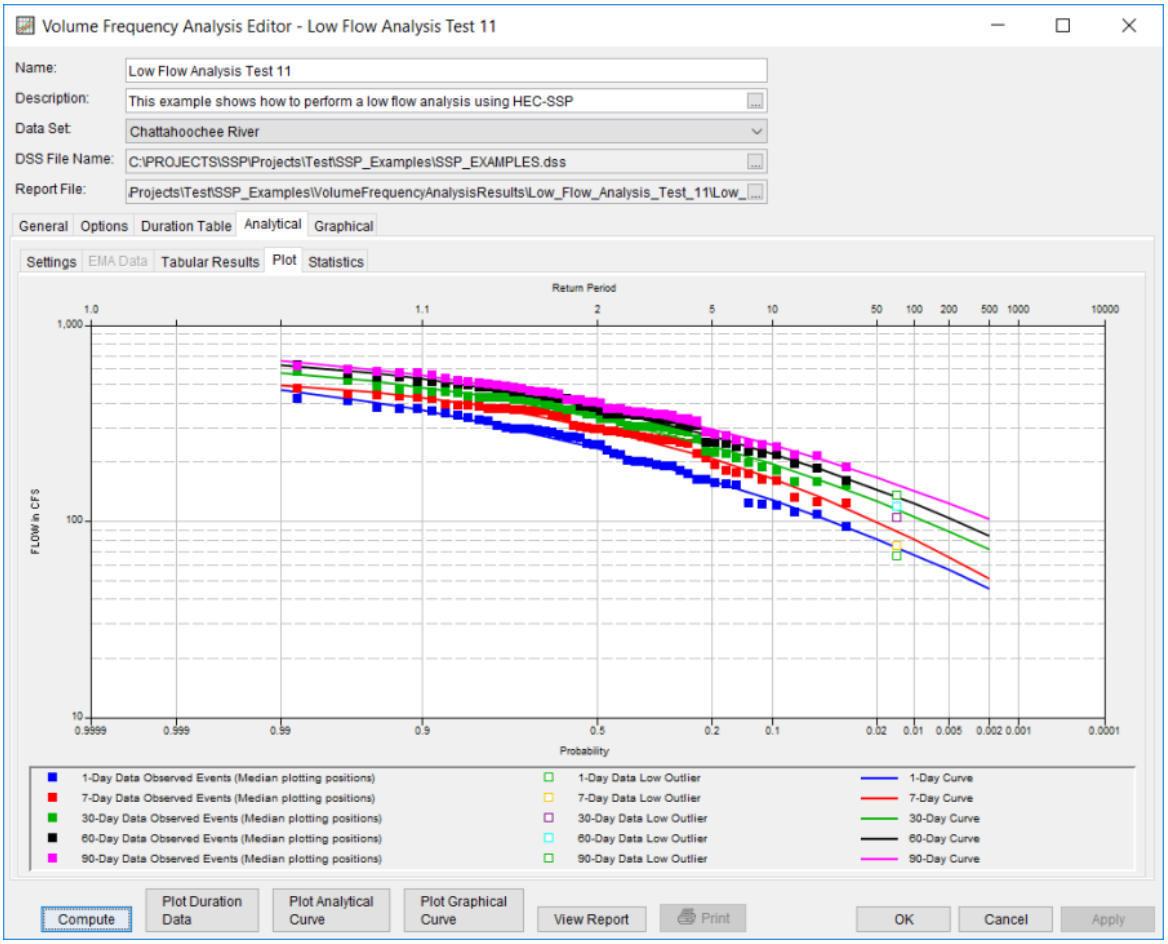
Press the **Compute** button to perform the analysis. A message window will open stating that a few of the annual maxima occurred near the beginning of the year. The message suggests that the user change the year/season specification to better capture independent events. You want to minimize the possibility that the same flood event is used for consecutive years. Press the OK button to finish the computation. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Tabular Results** tab within the analytical analysis. The results table should resemble Figure 6. The top portion of the results table contains the percent chance exceedance for all durations (the report contains confidence limits). The bottom portion of the results table contains the statistics for all durations.



107 Figure 6. Tabular Results Tab for Low Flow Analysis Test 11

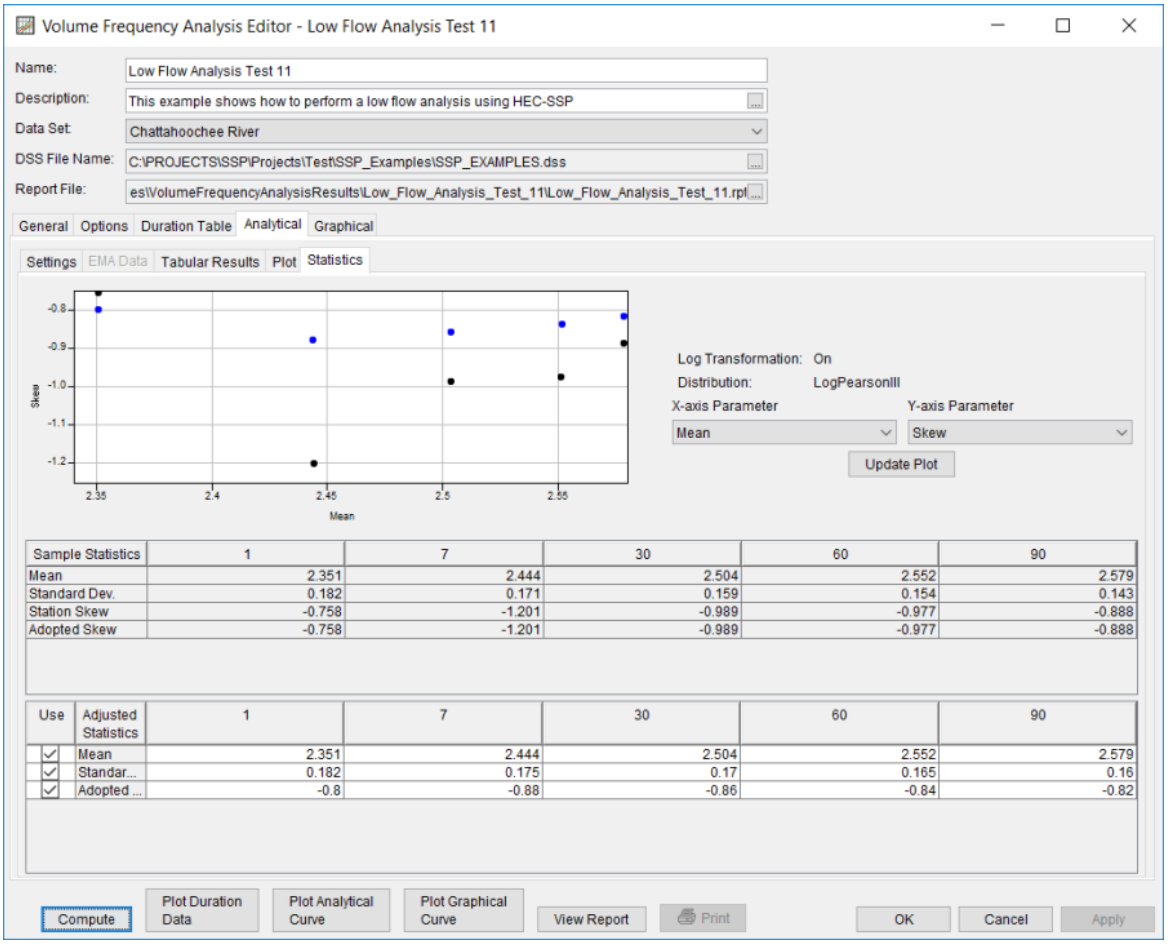
> *These tabular results use the default computed statistics.*

As shown in Figure 7, the **Plot** contains a graph of the systematic data and the computed frequency curves. Notice how some of the frequency curves look like they might cross if the lines were extended. The **Statistics** tab can be used to modify the computed statistics to ensure that the frequency curves are consistent.

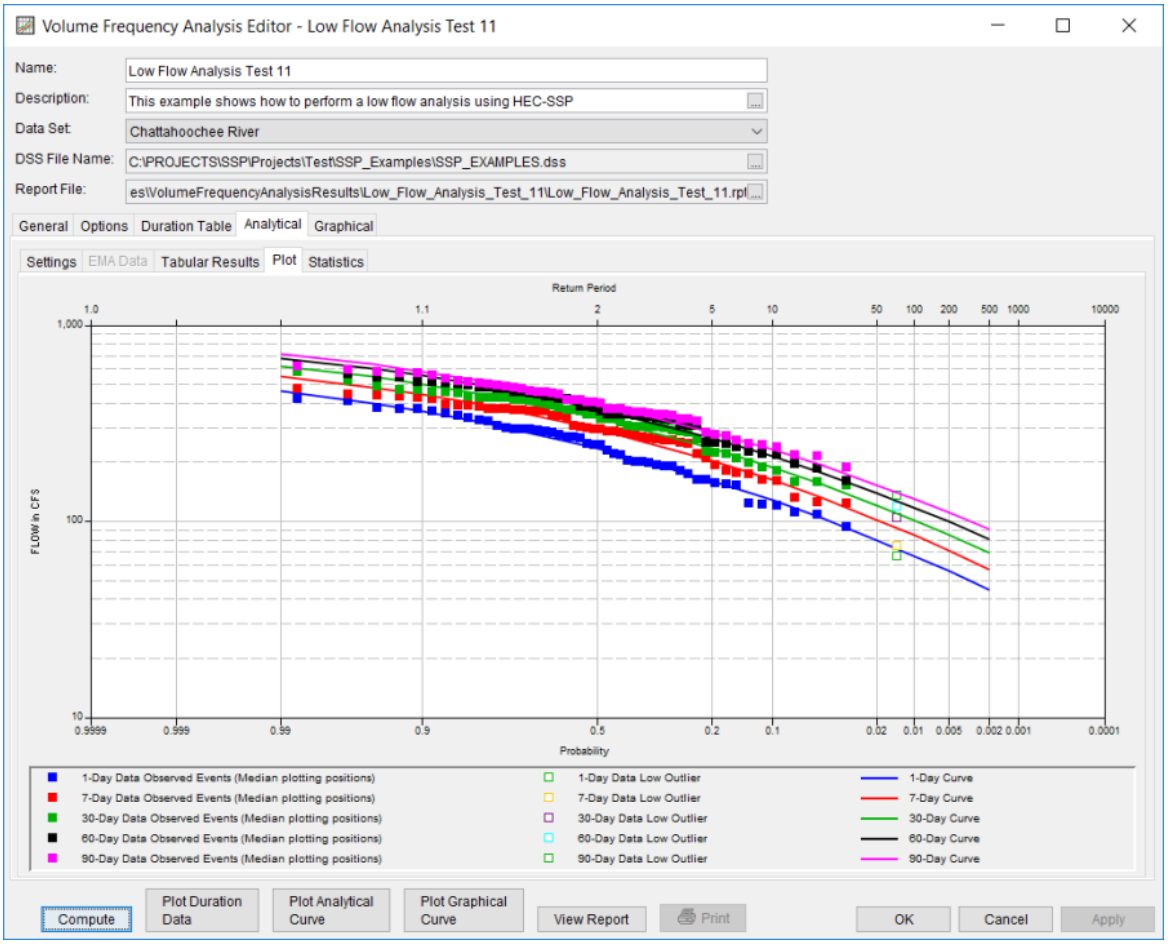


108 Figure 7. Plot for Low Flow Analysis Test 11

For this example, the standard deviation and the adopted skew were modified to make sure the volume frequency curves were consistent. As shown in Figure 8, the check boxes next to mean, standard deviation, and adopted skew were checked and then user-adjusted statistics were entered into the table for all durations. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to recompute the frequency curves using the user-adjusted statistics. Figure 9 shows the **Plot** tab after the user-adjusted statistics were entered on the **Statistics** tab. Results in the **Tabular Results** table will also update when user-adjusted statistics are entered on the **Statistics** tab.

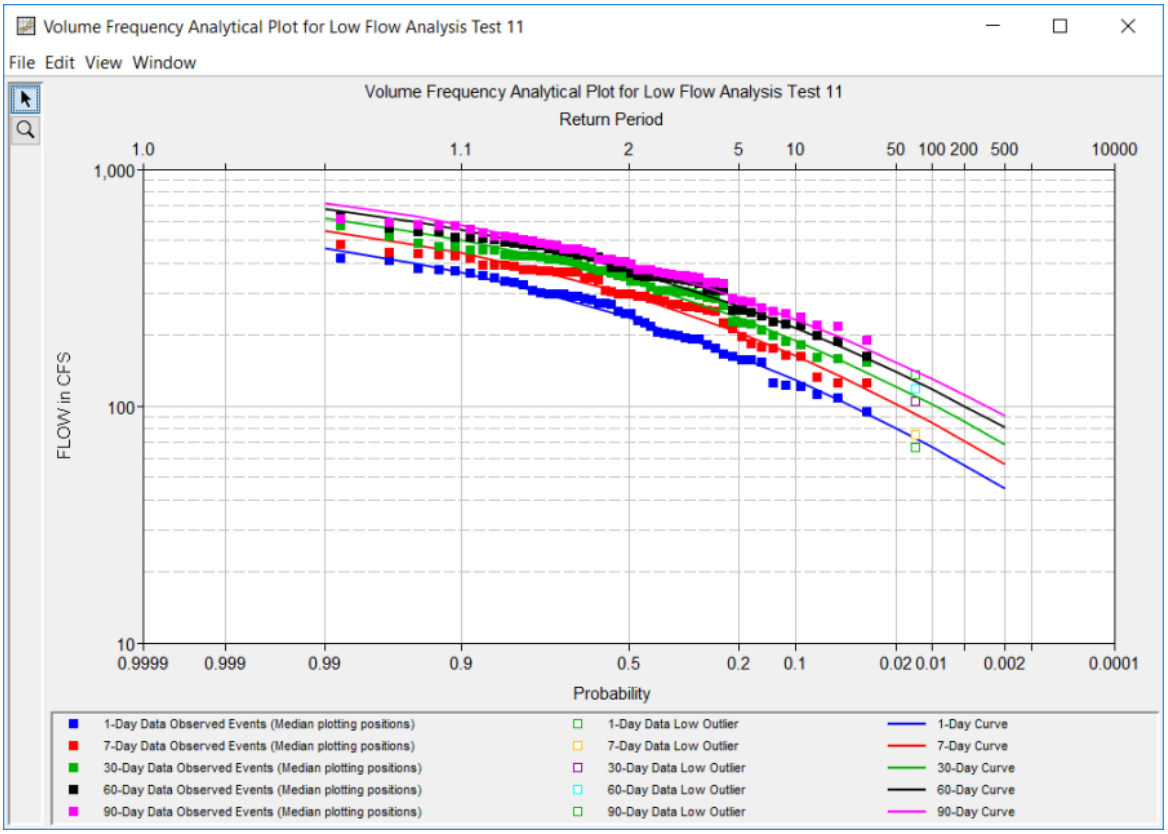


109 Figure 8. Statistics Tab for Low Flow Analysis Test 11



110 Figure 9. Plot Tab for Low Flow Analysis Test 11

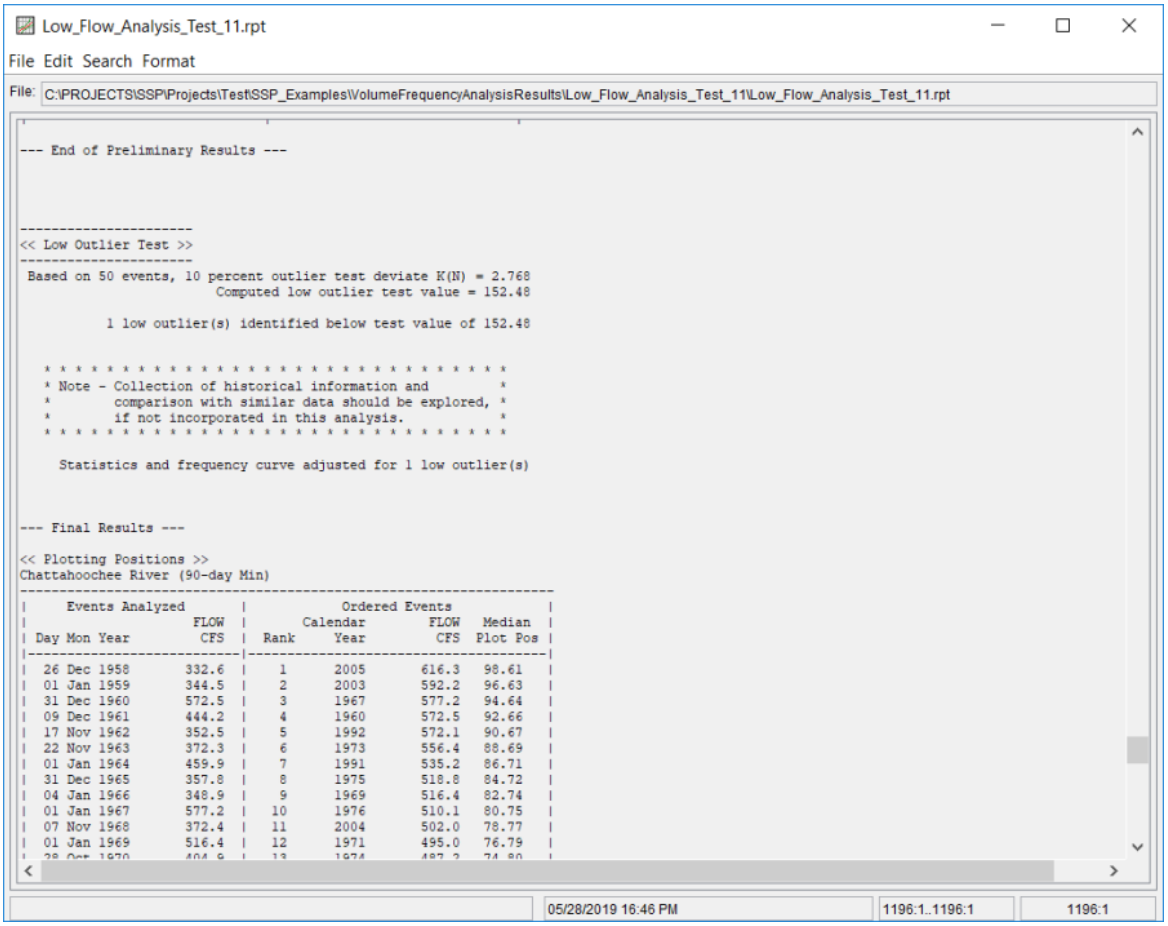
In addition to the Tabular Results and Plot tabs, graphical plots can be opened by selecting the **Plot Duration Data** or **Plot Analytical Curve** buttons at the bottom of the analysis window. A plot of the results for this example is shown in Figure 10.



111 Figure 10. Plot of the Frequency Curve Results for Low Flow Analysis Test 11

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

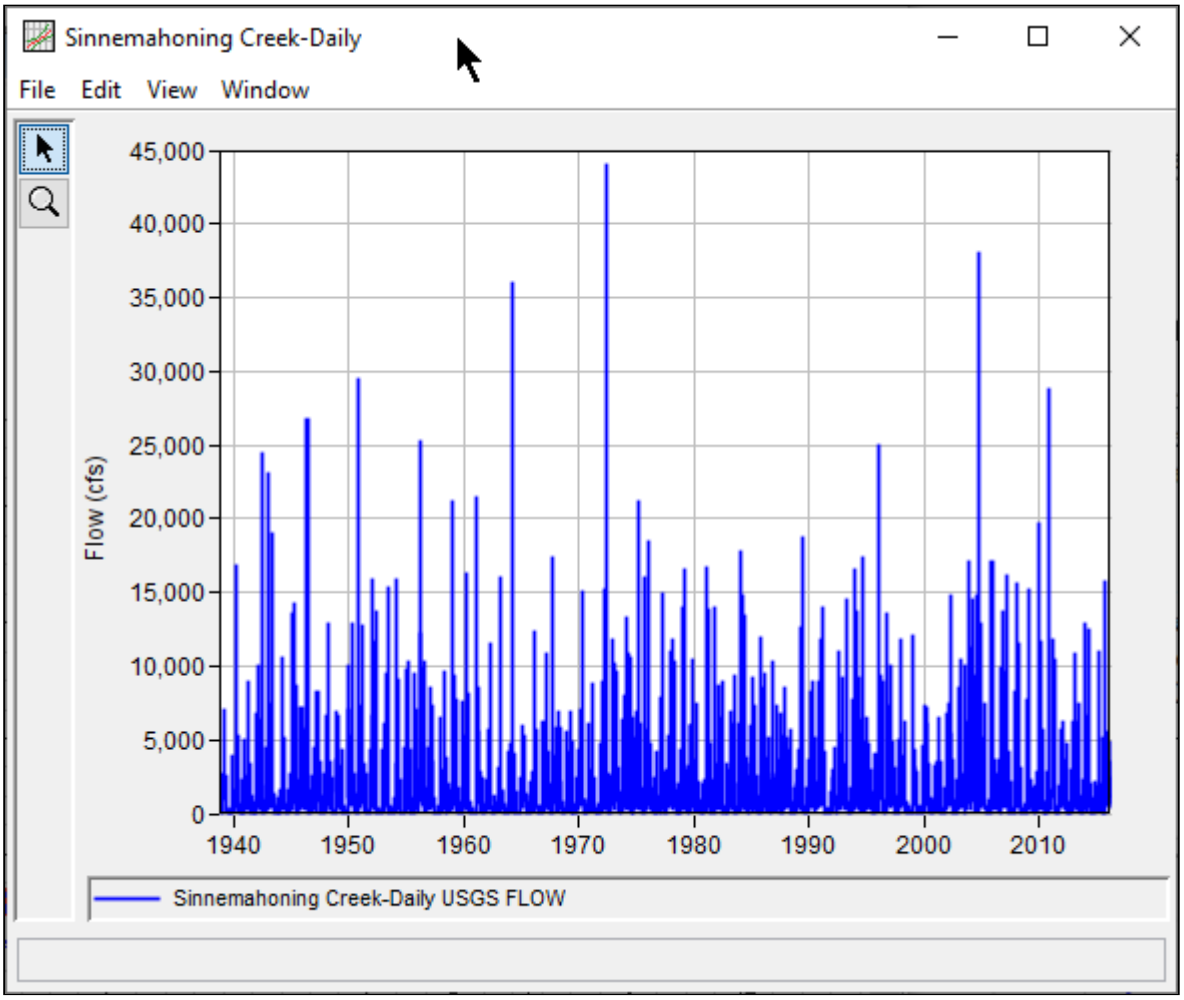
In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 11 is the report file for **Low Flow Analysis Test 11**.
The report file contains a listing of the input data, preliminary results, outlier and historical data tests, additional calculations needed, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



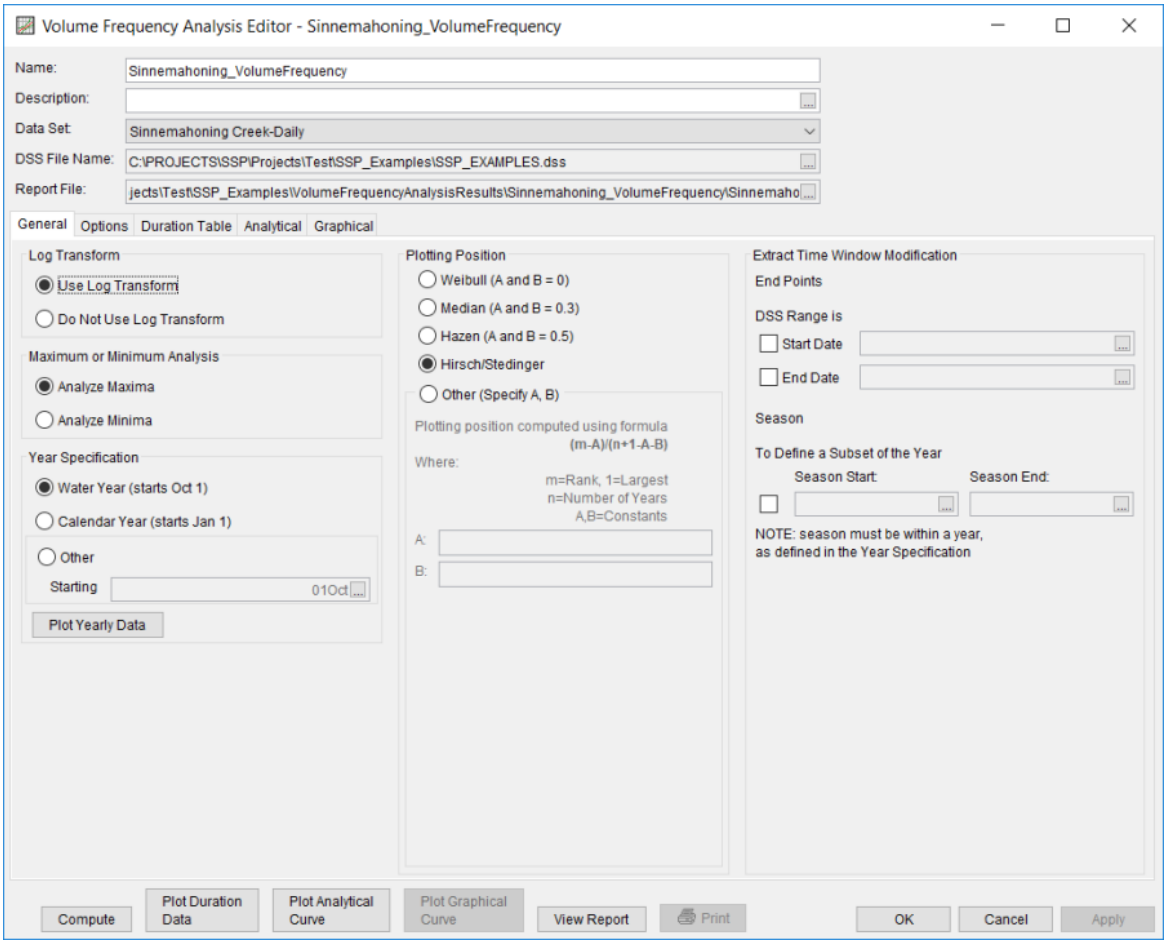
112 Figure 11. Report File for Low Flow Analysis Test 11

6.3 Example 31. Volume Frequency, Fitting a Family of Log Pearson Type III Distributions to Volume-Duration Data using the Expected Moments Algorithm

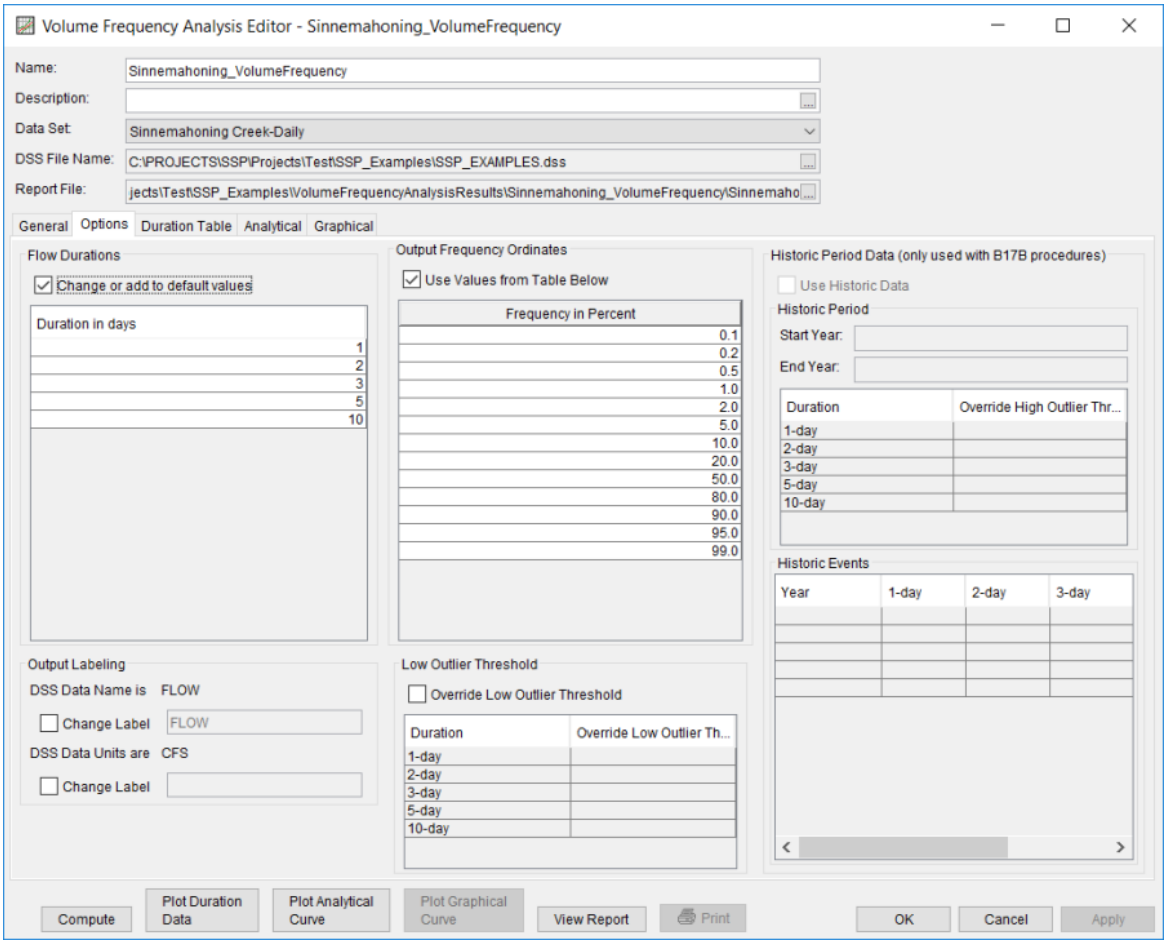
This example demonstrates how to use EMA to fit a family of Log Pearson Type III distributions to volume-duration data within the Volume Frequency analysis. The data for this example consists of daily average streamflow for a location along the Sinnemahoning Creek near Sinnemahoning, PA. This stream gage is operated by the USGS (gage ID: 01543500). The period of record used for this example is from 1938 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Sinnemahoning Creek-Daily**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 248).



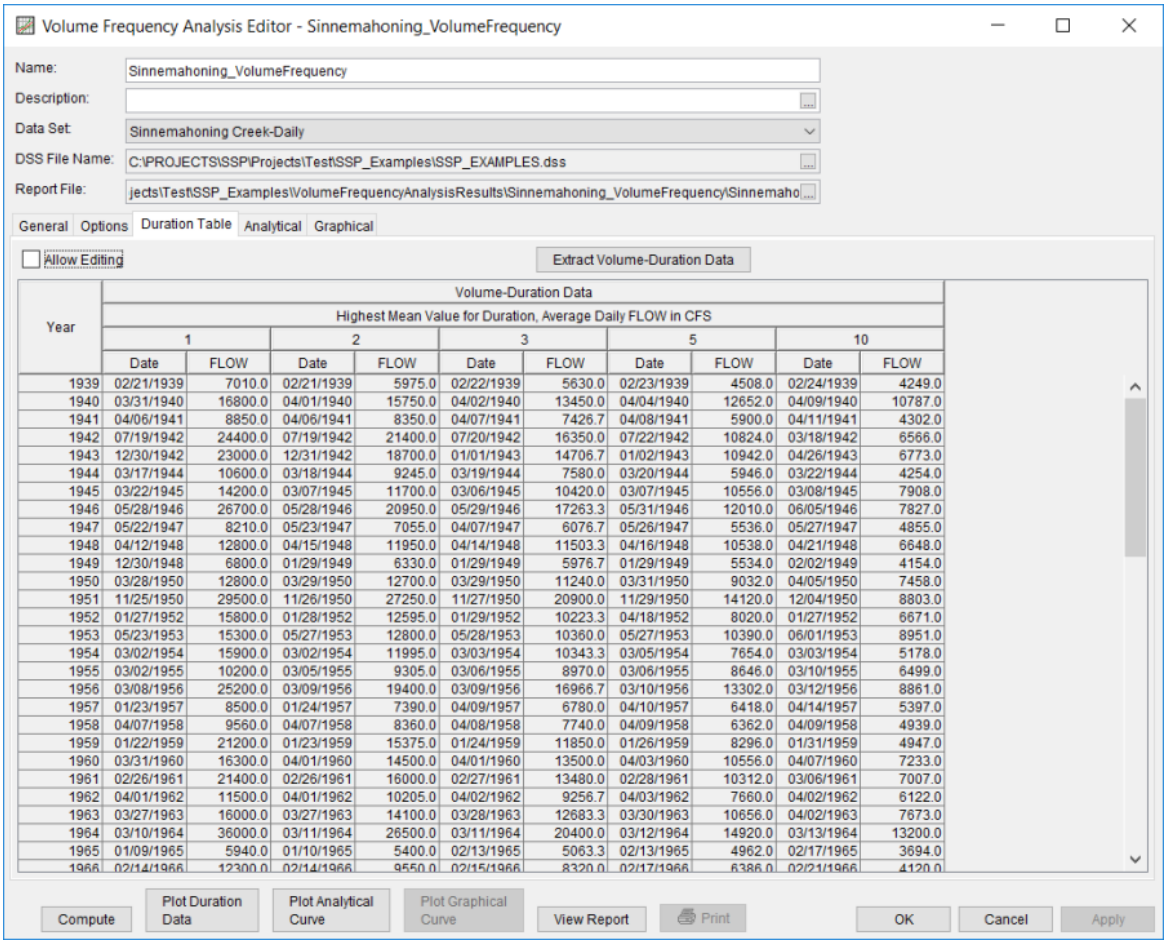
A Volume Frequency analysis has been developed for this example. To open the Volume Frequency Analysis editor for this example, either double-click on the analysis labeled **Sinnemahoning_VolumeFrequency** from the study explorer, or from the **Analysis** menu select open, then select **Sinnemahoning_VolumeFrequency** from the list of available analyses. When the analysis is opened, the Volume Frequency Analysis editor will appear as shown in Figure 2 (see page 248). Shown in Figure 2 (see page 248) are the general settings that were used to perform this frequency analysis. For this analysis, the **Use Log Transform**, **Analyze Maxima**, and **Water Year** options were selected. Also, the **Hirsch/Stedinger** plotting position method was selected within the **Plotting Position** panel (which is only available once the **LogPearsonIII | EMA** distribution and fitting method combination is selected on the **Analytical | Settings** tab). Finally, no modifications were made within the **Extract Time Window Modification** panel.



Shown in Figure 3 (see page 249) is the Volume Frequency Analysis editor with the **Options Tab** selected. Features on this tab include an option to override the default **Flow Duration** values, an option to override the default **Frequency Ordinates**, and **Output Labeling**. Both the flow-duration and frequency ordinate tables were modified. Specifically, the **1-, 2-, 3-, 5-, and 10-day** durations were defined within the **Flow Durations** panel, in addition to the **0.1-**percent ordinate being added within the **Output Frequency Ordinates** panel.

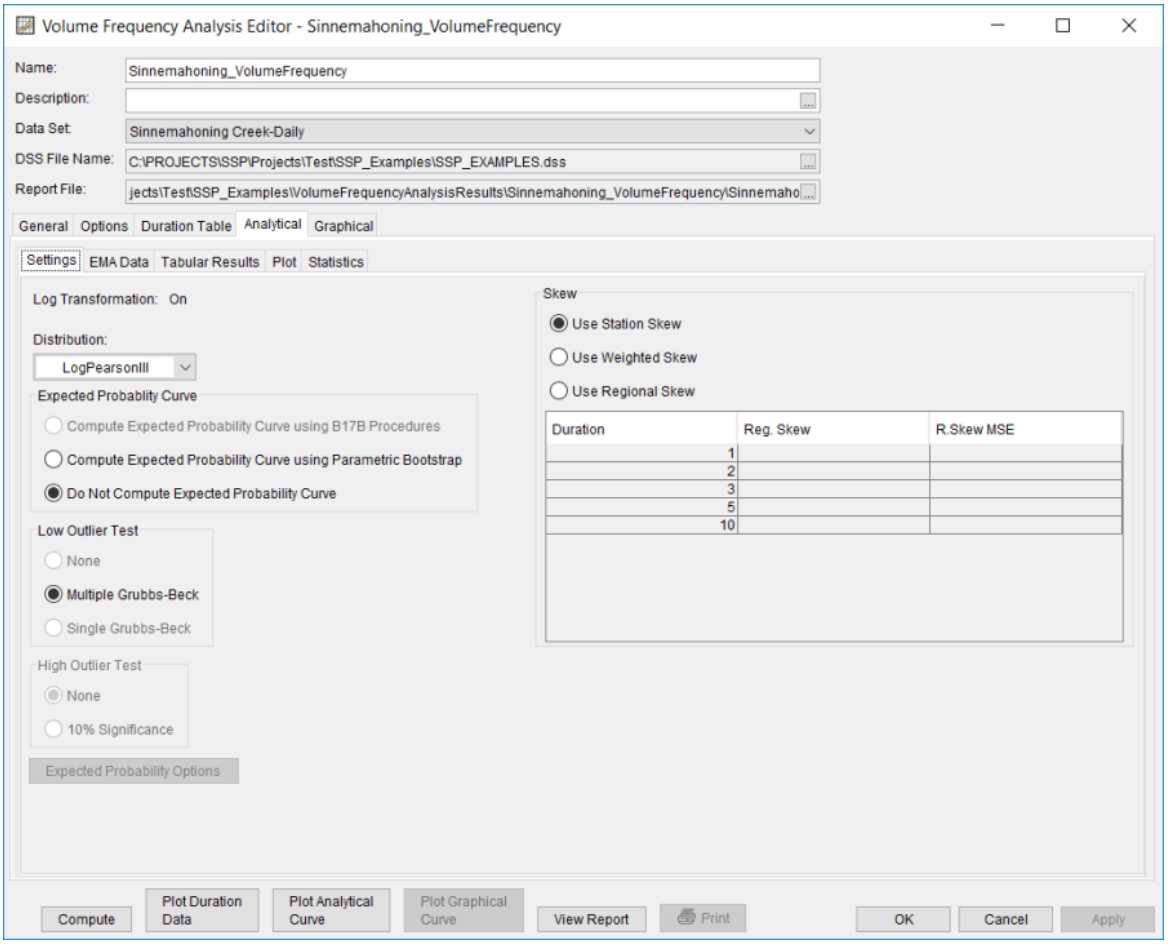


Once all of the General and Optional settings are set or selected, the user can extract the volume-duration data from the time-series of daily flows. Select the **Duration Data** tab and press the **Extract Volume-Duration Data** button at the bottom of the table. The table should then fill with the flow-duration values, as shown in Figure 4 (see page 250).

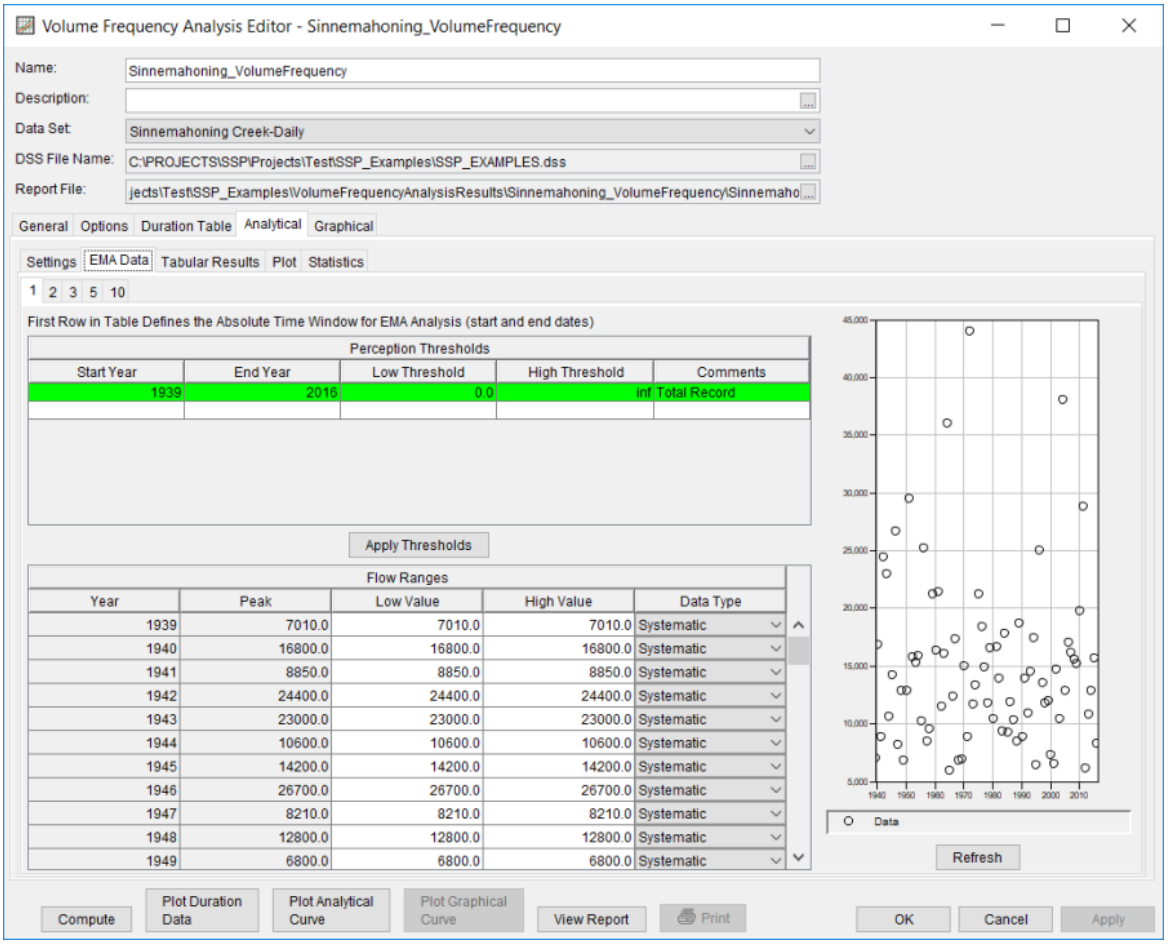


Year	Volume-Duration Data: Highest Mean Value for Duration, Average Daily FLOW in CFS									
	1		2		3		5		10	
	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW
1939	02/21/1939	7010.0	02/21/1939	5975.0	02/22/1939	5630.0	02/23/1939	4508.0	02/24/1939	4249.0
1940	03/31/1940	16800.0	04/01/1940	15750.0	04/02/1940	13450.0	04/04/1940	12652.0	04/09/1940	10787.0
1941	04/06/1941	8850.0	04/06/1941	8350.0	04/07/1941	7426.7	04/08/1941	5900.0	04/11/1941	4302.0
1942	07/19/1942	24400.0	07/19/1942	21400.0	07/20/1942	16350.0	07/22/1942	10824.0	03/18/1942	6566.0
1943	12/30/1942	23000.0	12/31/1942	18700.0	01/01/1943	14706.7	01/02/1943	10942.0	04/26/1943	6773.0
1944	03/17/1944	10600.0	03/18/1944	9245.0	03/19/1944	7580.0	03/20/1944	5946.0	03/22/1944	4254.0
1945	03/22/1945	14200.0	03/07/1945	11700.0	03/06/1945	10420.0	03/07/1945	10556.0	03/08/1945	7908.0
1946	05/28/1946	26700.0	05/28/1946	20950.0	05/29/1946	17263.3	05/31/1946	12010.0	06/05/1946	7827.0
1947	05/22/1947	8210.0	05/23/1947	7055.0	04/07/1947	6076.7	05/26/1947	5536.0	05/27/1947	4855.0
1948	04/12/1948	12800.0	04/15/1948	11950.0	04/14/1948	11503.3	04/16/1948	10538.0	04/21/1948	6648.0
1949	12/30/1948	6800.0	01/29/1949	6330.0	01/29/1949	5976.7	01/29/1949	5534.0	02/02/1949	4154.0
1950	03/28/1950	12800.0	03/29/1950	12700.0	03/29/1950	11240.0	03/31/1950	9032.0	04/05/1950	7458.0
1951	11/25/1950	29500.0	11/26/1950	27250.0	11/27/1950	20900.0	11/29/1950	14120.0	12/04/1950	8803.0
1952	01/27/1952	15800.0	01/28/1952	12595.0	01/29/1952	10223.3	04/18/1952	8020.0	01/27/1952	6671.0
1953	05/23/1953	15300.0	05/27/1953	12800.0	05/28/1953	10360.0	05/27/1953	10390.0	06/01/1953	8951.0
1954	03/02/1954	15900.0	03/02/1954	11995.0	03/03/1954	10343.3	03/05/1954	7654.0	03/03/1954	5178.0
1955	03/02/1955	10200.0	03/05/1955	9305.0	03/06/1955	8970.0	03/06/1955	8646.0	03/10/1955	6499.0
1956	03/08/1956	25200.0	03/09/1956	19400.0	03/09/1956	16966.7	03/10/1956	13302.0	03/12/1956	8861.0
1957	01/23/1957	8500.0	01/24/1957	7390.0	04/09/1957	6780.0	04/10/1957	6418.0	04/14/1957	5397.0
1958	04/07/1958	9560.0	04/07/1958	8360.0	04/08/1958	7740.0	04/09/1958	6362.0	04/09/1958	4939.0
1959	01/22/1959	21200.0	01/23/1959	15375.0	01/24/1959	11850.0	01/26/1959	8296.0	01/31/1959	4947.0
1960	03/31/1960	16300.0	04/01/1960	14500.0	04/01/1960	13500.0	04/03/1960	10556.0	04/07/1960	7233.0
1961	02/26/1961	21400.0	02/26/1961	16000.0	02/27/1961	13480.0	02/28/1961	10312.0	03/06/1961	7007.0
1962	04/01/1962	11500.0	04/01/1962	10205.0	04/02/1962	9256.7	04/03/1962	7660.0	04/02/1962	6122.0
1963	03/27/1963	16000.0	03/27/1963	14100.0	03/28/1963	12683.3	03/30/1963	10656.0	04/02/1963	7673.0
1964	03/10/1964	36000.0	03/11/1964	26500.0	03/11/1964	20400.0	03/12/1964	14920.0	03/13/1964	13200.0
1965	01/09/1965	5940.0	01/10/1965	5400.0	02/13/1965	5063.3	02/13/1965	4962.0	02/17/1965	3694.0
1966	02/14/1966	12300.0	02/14/1966	9550.0	02/15/1966	8320.0	02/17/1966	6386.0	02/21/1966	4120.0

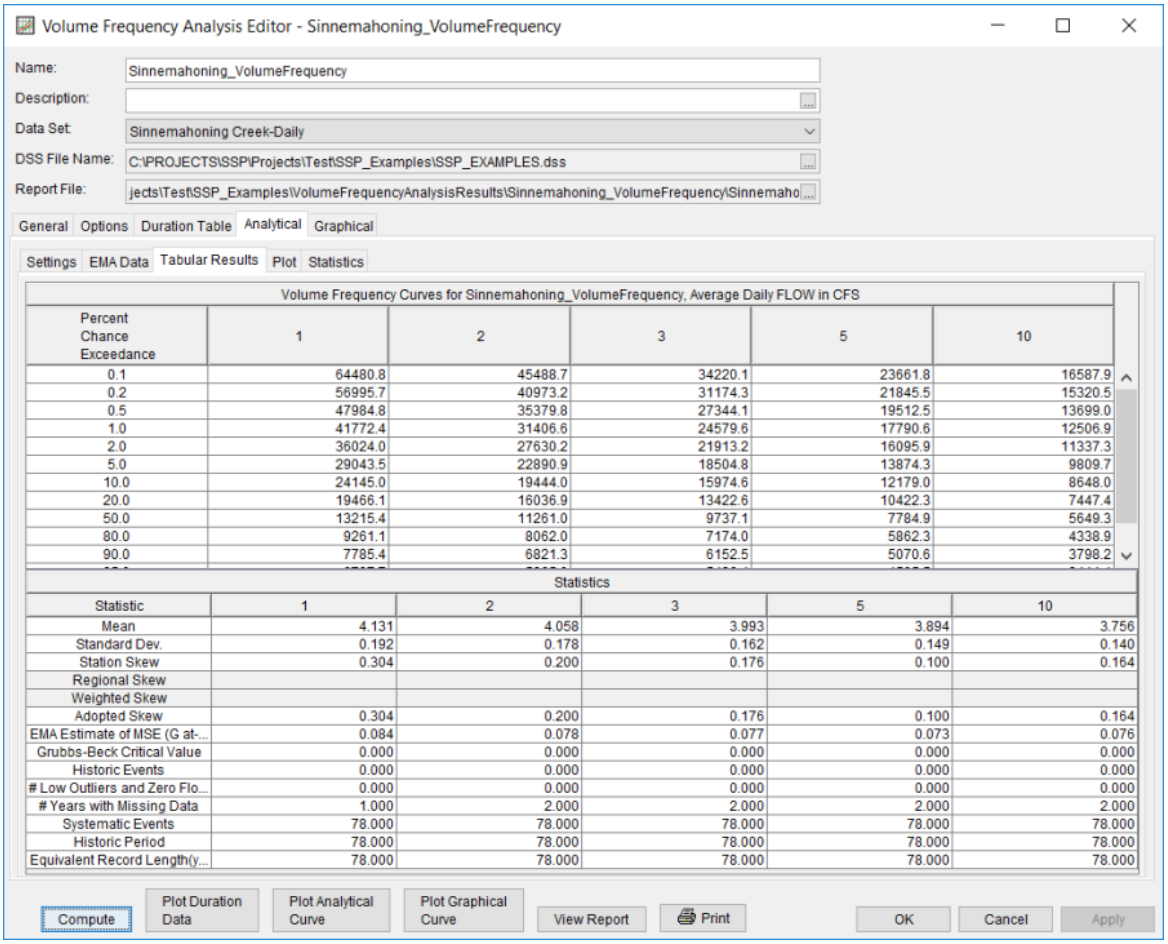
Once the data has been extracted, the user must choose to perform an Analytical or Graphical analysis. In this example, an analytical analysis was performed. Shown in Figure 5 (see page 251) is the **Settings** tab for the analytical analysis. As shown, the distribution selected for this example is **LogPearsonIII | EMA**. The **Do Not Compute Excepted Probability**, Multiple Grubbs-Beck and **Use Station Skew** options were selected.



The 1-day duration **EMA Data** tab for this example is shown in Figure 6 (see page 252). An EMA Data tab will be created for each duration. Flow ranges, perception thresholds, and data types must be entered, as required for the analysis and data set, within each tab. For this example, the data set is comprised entirely of systematic data with a no gaps. Therefore, a single zero – inf perception threshold is adequate for each duration. Additionally, no modifications to the default flow ranges and data types are necessary.



Once all of the **General** and **EMA Data** tab settings are set or selected, the user can press the **Compute** button to perform the analysis. Message windows will open stating the flow value for longer durations are greater than shorter durations for specific water years in addition to a few of the annual maxima occurring near the beginning of the year. The messages suggests that the user change the year/season specification to better capture independent events. You want to minimize the possibility that the same flood event is used for consecutive years or that a flood is divided between years. Press the OK button to finish the compute. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Tabular Results** tab within the analytical analysis. The results table should resemble Figure 7 (see page 253). The top portion of the results table contains the frequency curve for each duration. The confidence limits for each duration can be found within the Report file. The bottom portion of the results table contains the statistics for each duration.



Note: These tabular results use the default computed statistics.

On the **Statistics** tab, the user can modify the computed statistics to ensure that the frequency curves are consistent with each other. For this example, the adopted skew coefficients were modified. As shown in Figure 8 (see page 254), plots of mean, standard deviation, and skew versus duration and each other can be viewed to ensure smooth relationships. The check boxes next to mean, standard deviation, and adopted skew were checked and then user-adjusted statistics were entered into the table for all durations. The **Compute** button must be pressed after adjusted statistics have been entered in order for the program to recompute the frequency curves using the user-adjusted statistics.

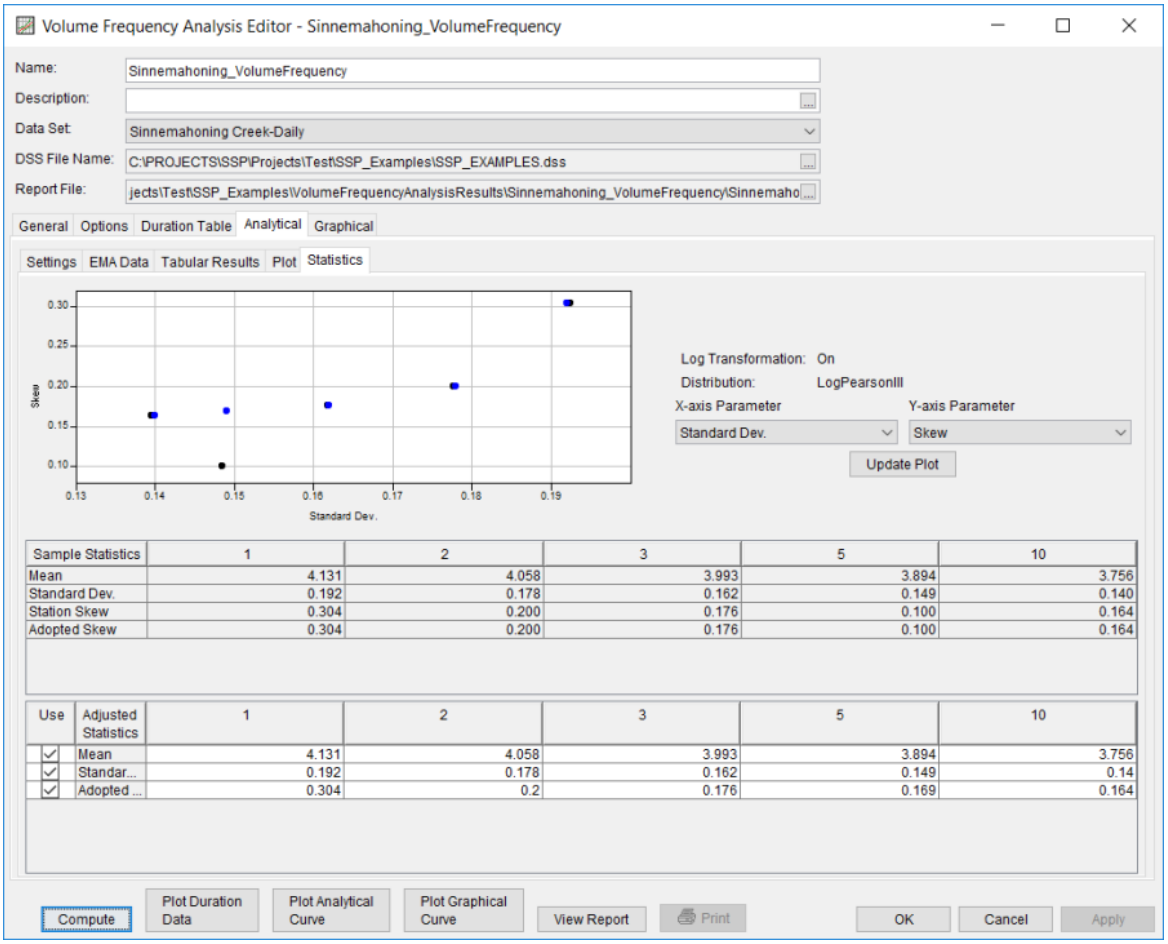
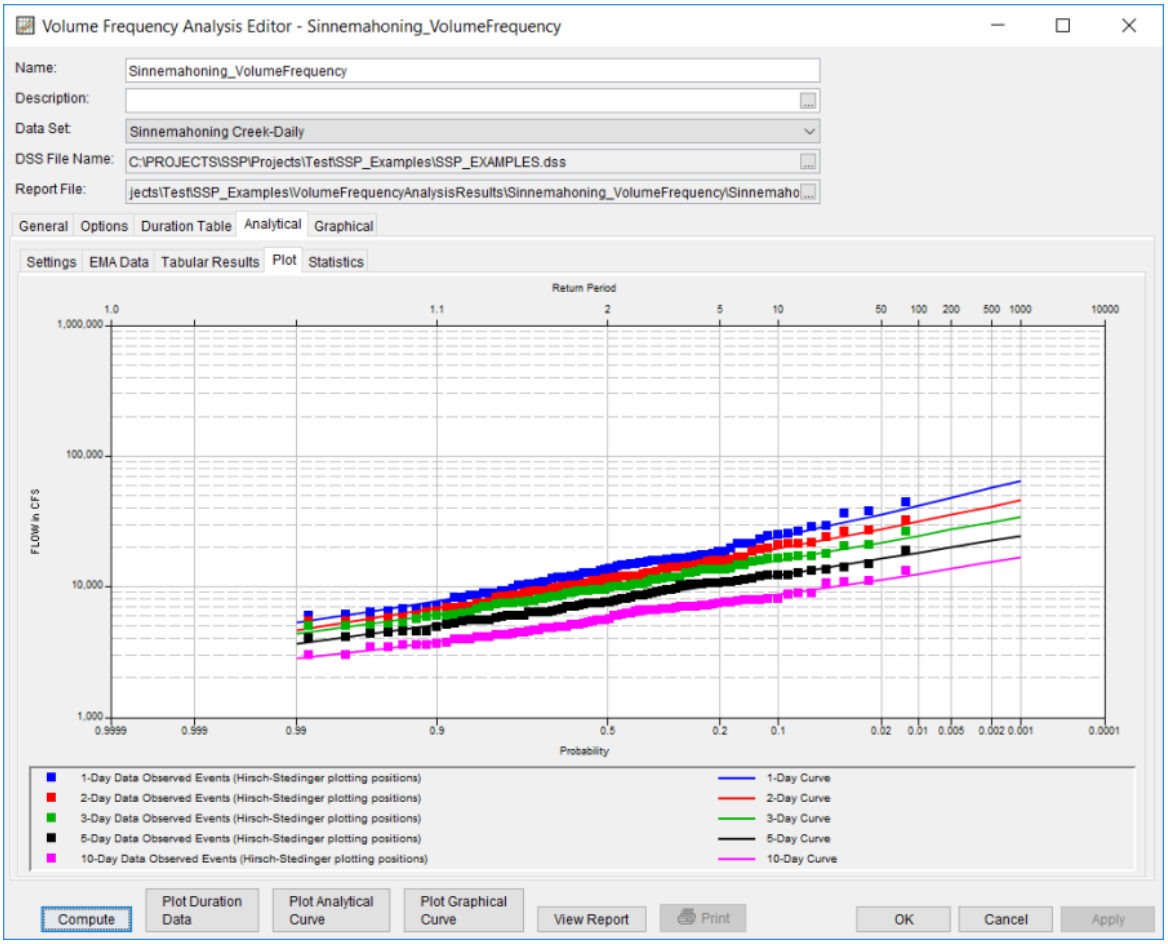
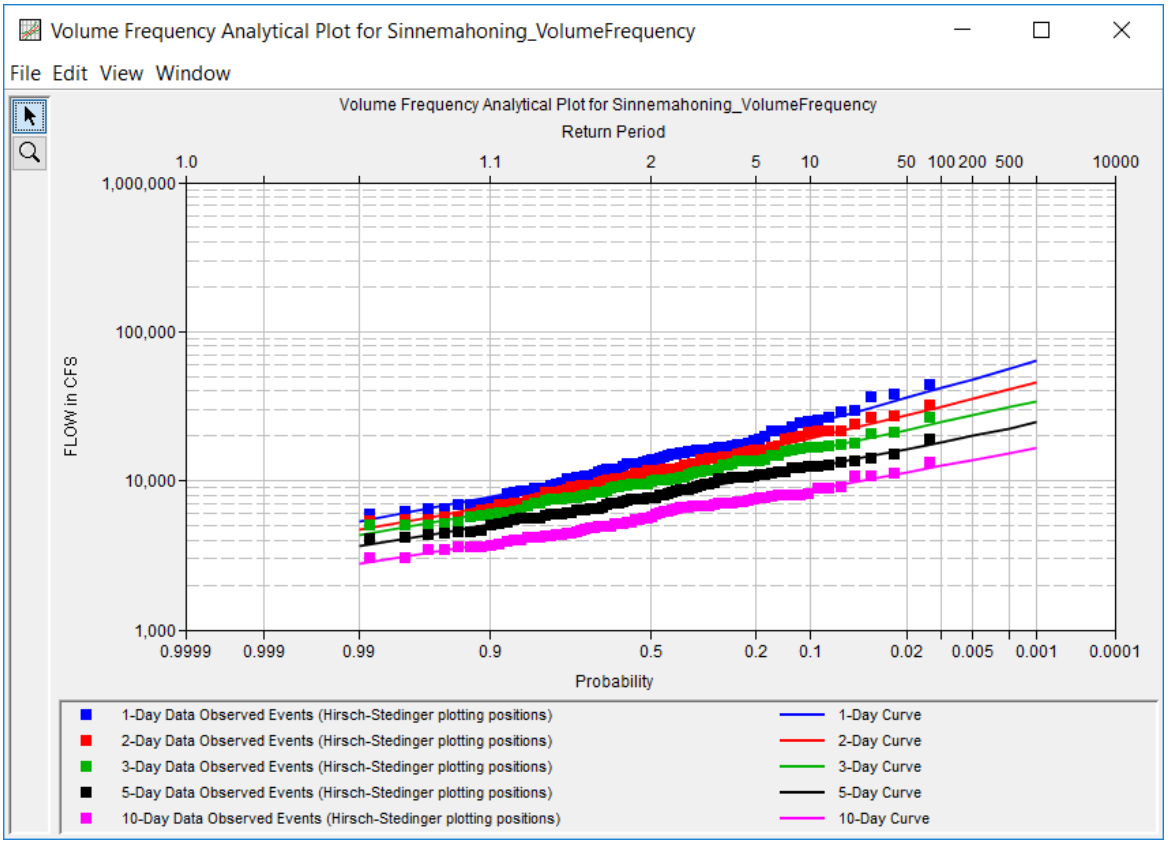


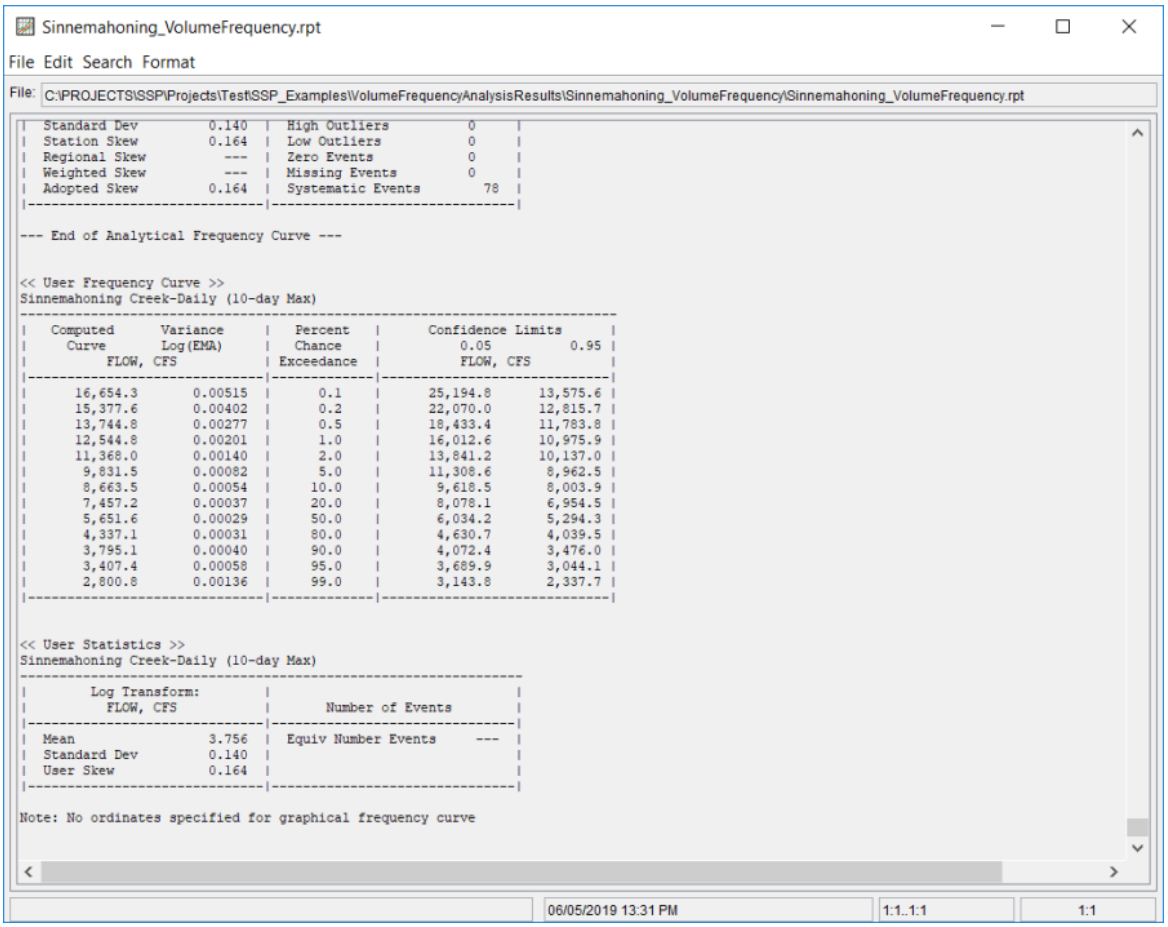
Figure 9 (see page 255) shows the **Plot** tab after the user-adjusted statistics were entered on the **Statistics** tab. Results on the **Tabular Results** tab will also update when user-adjusted statistics are entered on the **Statistics** tab.



In addition to the Tabular Results and Plot tabs, graphical plots can be opened by selecting the **Plot Duration Data** or **Plot Analytical Curve** buttons at the bottom of the analysis window. A plot of the results for this example is shown in Figure 10 (see page 256).



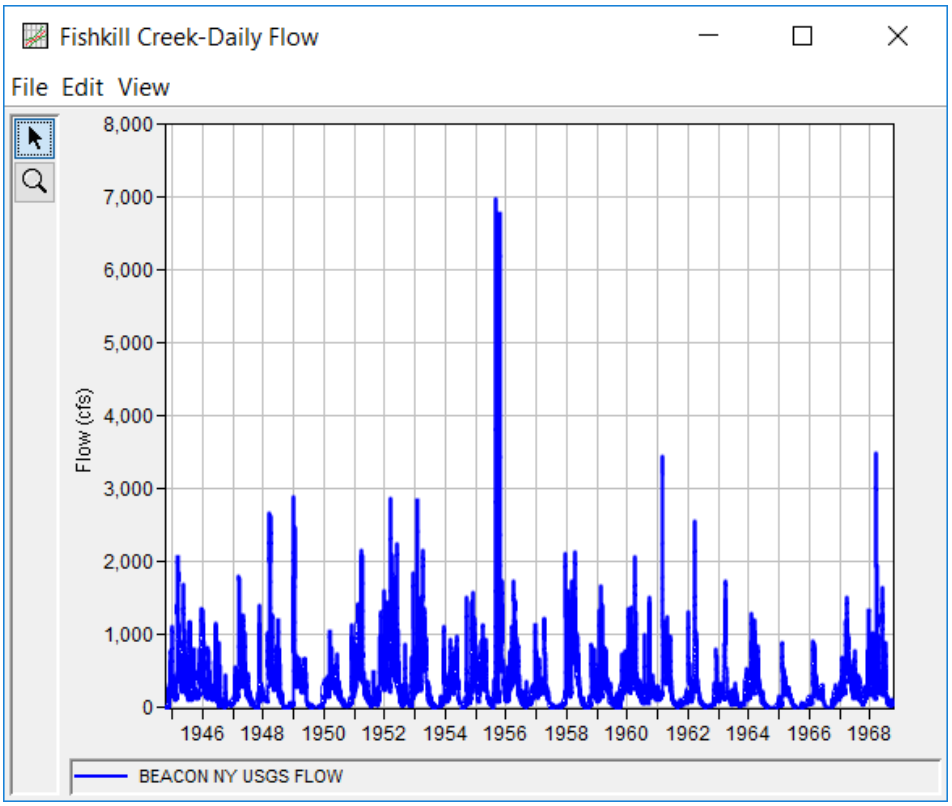
In addition to the tabular and graphical results, there is a report file that shows the order in which the calculations were performed. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 11 (see page 257). The report file contains a listing of the input data, preliminary results, outliers, and the final frequency curve results. Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.


Sinnemahoning_VolumeFrequency.rpt
File Edit Search Format
File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\VolumeFrequencyAnalysisResults\Sinnemahoning_VolumeFrequency\Sinnemahoning_VolumeFrequency.rpt
Standard Dev 0.140	High Outliers 0
Station Skew 0.164	Low Outliers 0
Regional Skew ---	Zero Events 0
Weighted Skew ---	Missing Events 0
Adopted Skew 0.164	Systematic Events 78
--- End of Analytical Frequency Curve ---
<< User Frequency Curve >>
Sinnemahoning Creek-Daily (10-day Max)
Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
16,654.3	0.00515	0.1	25,194.8	13,575.6
15,377.6	0.00402	0.2	22,070.0	12,815.7
13,744.8	0.00277	0.5	18,433.4	11,783.8
12,544.8	0.00201	1.0	16,012.6	10,975.9
11,368.0	0.00140	2.0	13,841.2	10,137.0
9,831.5	0.00082	5.0	11,308.6	8,962.5
8,663.5	0.00054	10.0	9,618.5	8,003.9
7,457.2	0.00037	20.0	8,078.1	6,954.5
5,651.6	0.00029	50.0	6,034.2	5,294.3
4,337.1	0.00031	80.0	4,630.7	4,039.5
3,795.1	0.00040	90.0	4,072.4	3,476.0
3,407.4	0.00058	95.0	3,689.9	3,044.1
2,800.8	0.00136	99.0	3,143.8	2,337.7
<< User Statistics >>
Sinnemahoning Creek-Daily (10-day Max)
Log Transform: FLOW, CFS	Number of Events
Mean 3.756	Equiv Number Events ---
Standard Dev 0.140	
User Skew 0.164	
Note: No ordinates specified for graphical frequency curve
06/05/2019 13:31 PM
1:1..1:1
1:1

7 Duration Analysis Examples

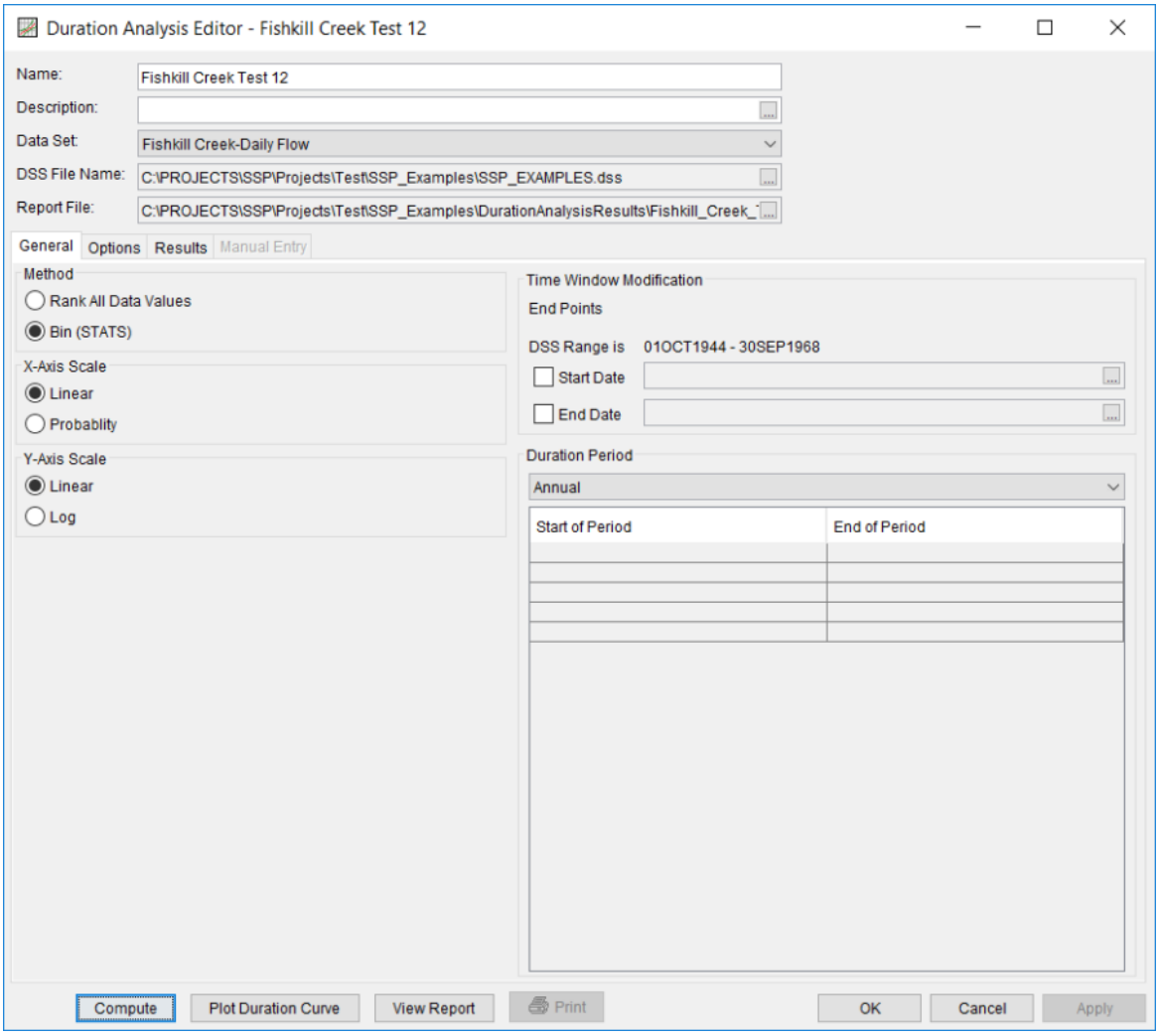
7.1 Example 12. Duration Analysis, BIN (STATS) Method

This example demonstrates how to use the Duration analysis. The data for this example is daily average flow from the Fishkill Creek (Beacon NY) USGS stream gage. The period of record used for this example is from 01 Oct, 1944 to 30 Sep, 1968. To view the data, right-click on the data record labeled "**Fishkill Creek-Daily Flow**" in the study explorer and then select **Plot**. The data will appear as shown in Figure 1.



113 Figure 1. Plot of the Daily Average Flow for Example 12

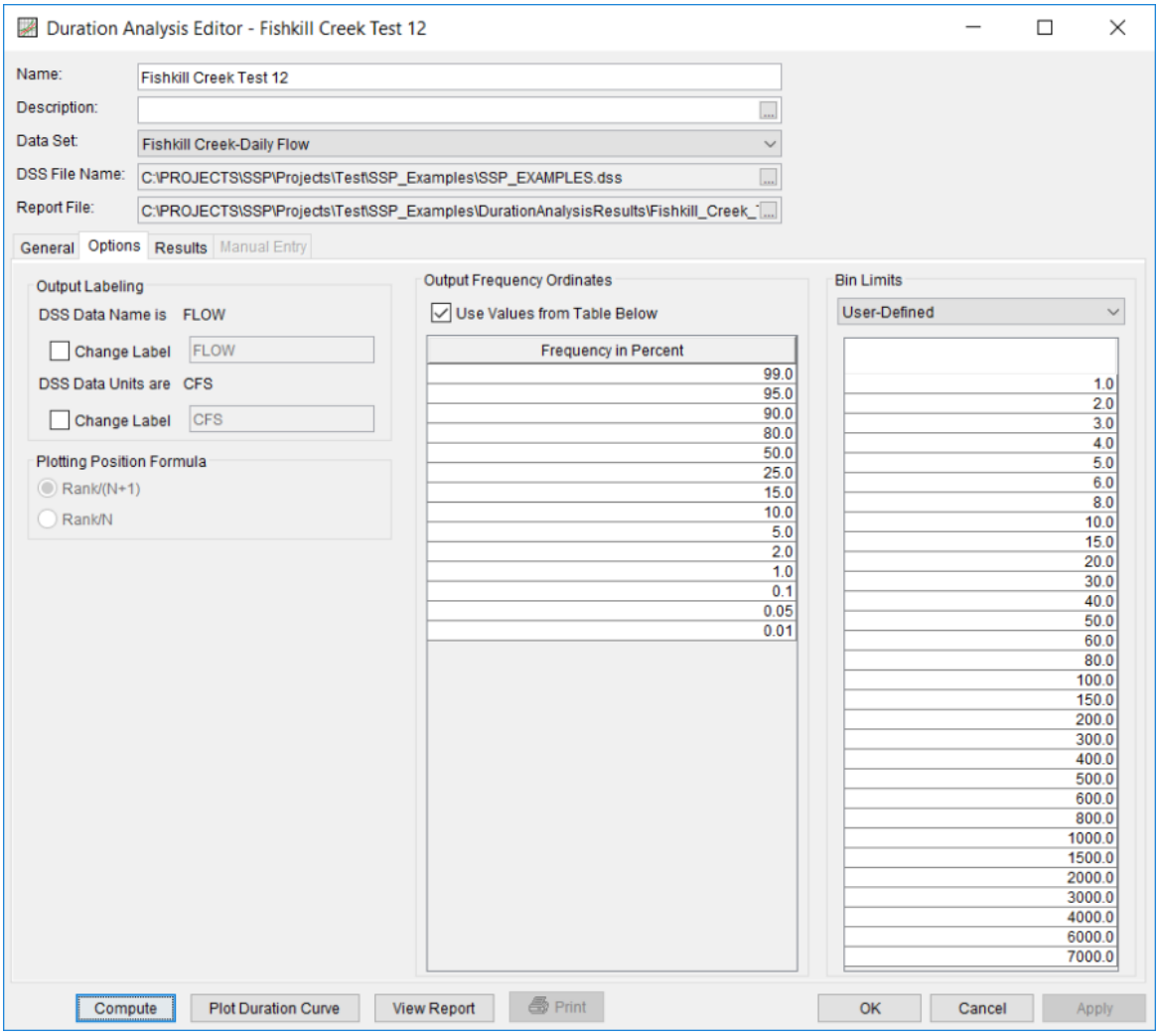
A Duration analysis has been developed for this example. To open the analysis editor for this example, either double-click on the analysis labeled **Fishkill Creek Test 12** from the study explorer, or from the **Analysis** menu select open, then select **Fishkill Creek Test 12** from the list of available analyses. When Test 12 is opened, the duration analysis editor will appear as shown in Figure 2.



114 Figure 2. Duration Analysis Editor for Fishkill Creek Test 12

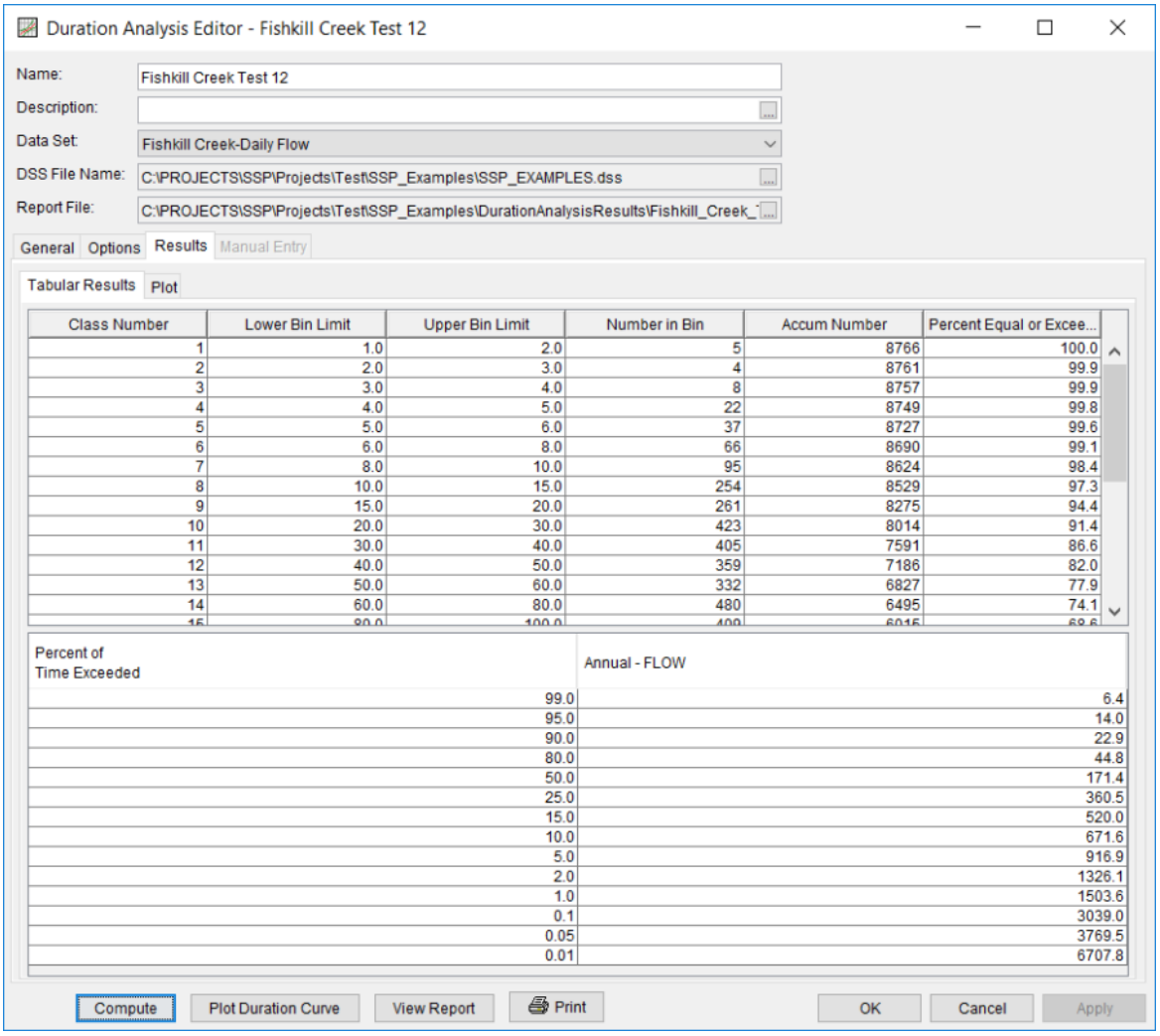
Shown in Figure 2 are the general settings that were used to perform this duration analysis. For this analysis, the **Bin (STATS)** method was selected, the x-axis scale was set to **Linear**, the y-axis scale was set to **Linear**, and the **Annual** duration period was selected.

The **Options Tab** is shown in Figure 3. Features on this tab include **Output Labeling**, the **Percent of Time Exceeded** ordinates, and **Bin Limits**. The Bin Limits panel is active in this example because the Bin (STATS) method was selected on the General tab. The User-Defined bin limits method was selected and the bin limits were entered manually.



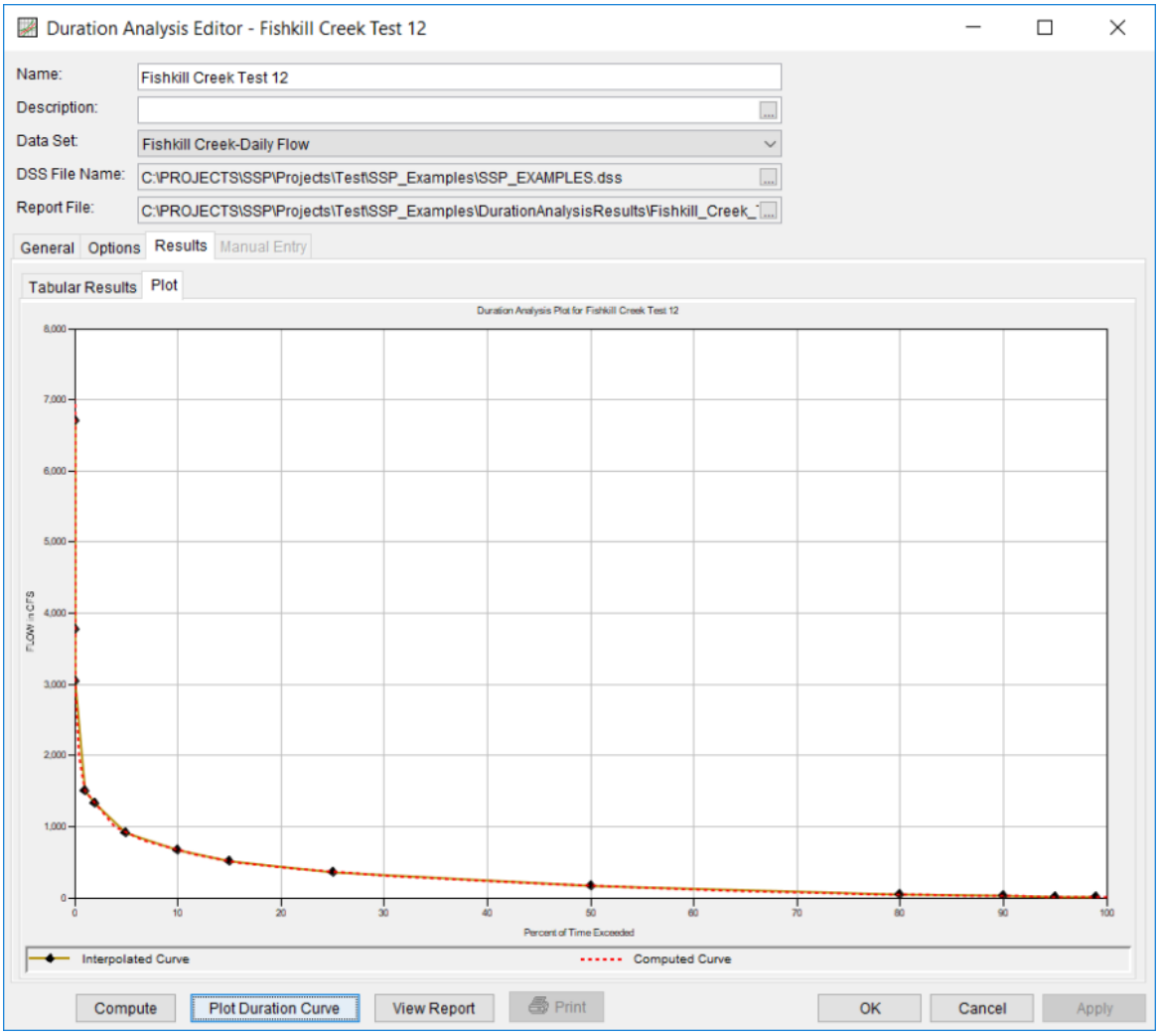
115 Figure 3. Duration Analysis Editor with Options Tab Shown for Fishkill Creek Test 12

Once all of the General and Optional settings are set or selected, the user can choose to compute the analysis by pressing the **Compute** button. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab, shown in Figure 4.



116 Figure 4. The Results Tab for Fishkill Creek Test 12

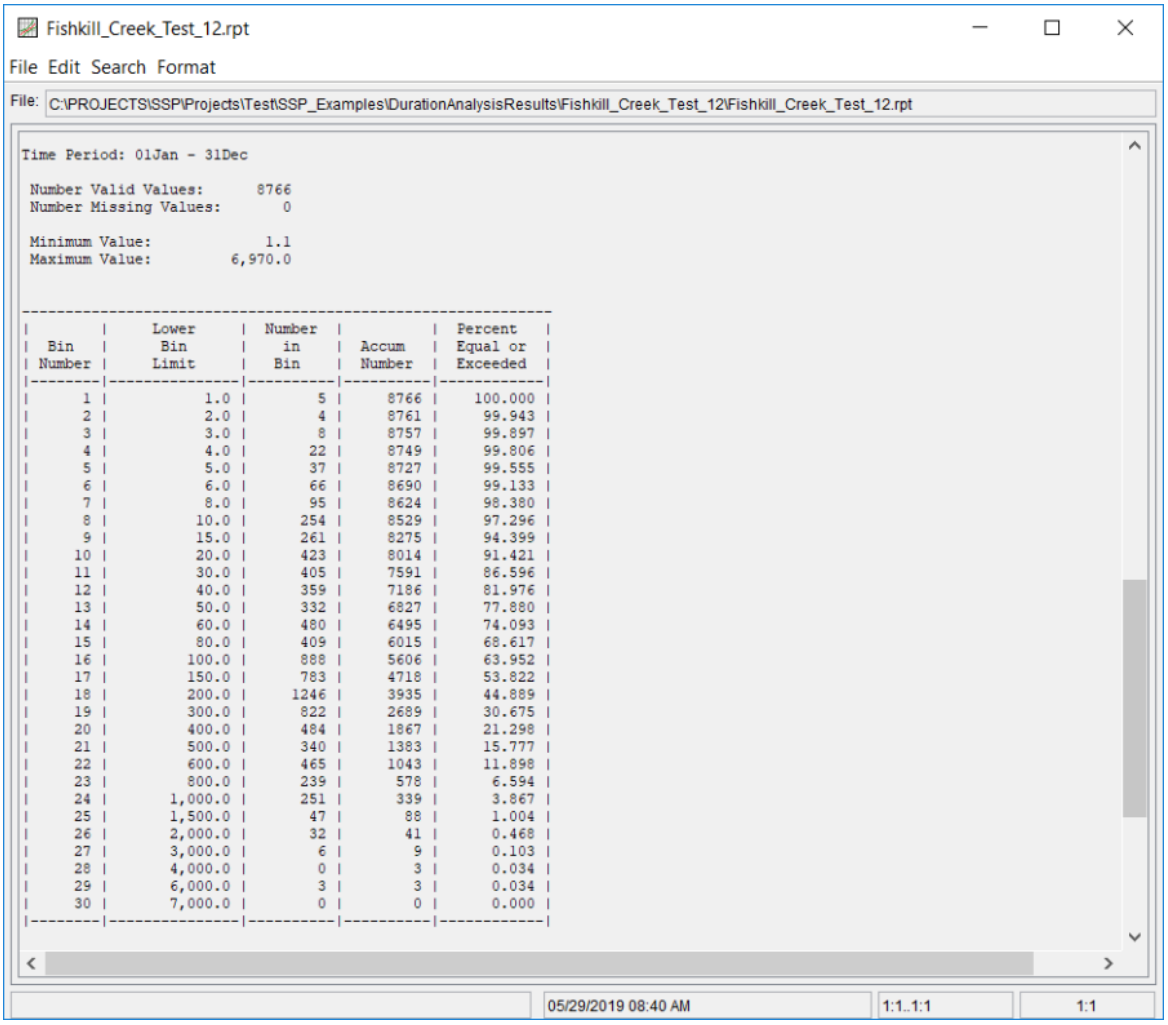
As shown in Figure 4, the **Result** tab contains both tabular and graphical results. The **Tabular Results** tab contains a table with information about the bins, like the lower bin limit, the number of values in the bin, the accumulated number of values greater than or equal to the lower bin limit, and the percent of time equaled or exceeded for each bin. Tabular results also include a table of the duration curve interpolated to the percent of time exceeded ordinates defined on the Options tab. The **Plot** tab contains a graph of the duration curve, shown in Figure 5. The plot includes the computed duration curve and the duration curve interpolated to the user-defined percent of time exceeded ordinates. The duration curve plot can also be opened by pressing the **Plot Duration Curve** button at the bottom of the analysis window.



117 Figure 5. Plot Tab for Fishkill Creek Test 12

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows the input data and results for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 6 is the report file for **Fishkill Creek Test 12**.



Fishkill_Creek_Test_12.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\DurationAnalysisResults\Fishkill_Creek_Test_12\Fishkill_Creek_Test_12.rpt

Time Period: 01Jan - 31Dec

Number Valid Values: 8766
Number Missing Values: 0

Minimum Value: 1.1
Maximum Value: 6,970.0

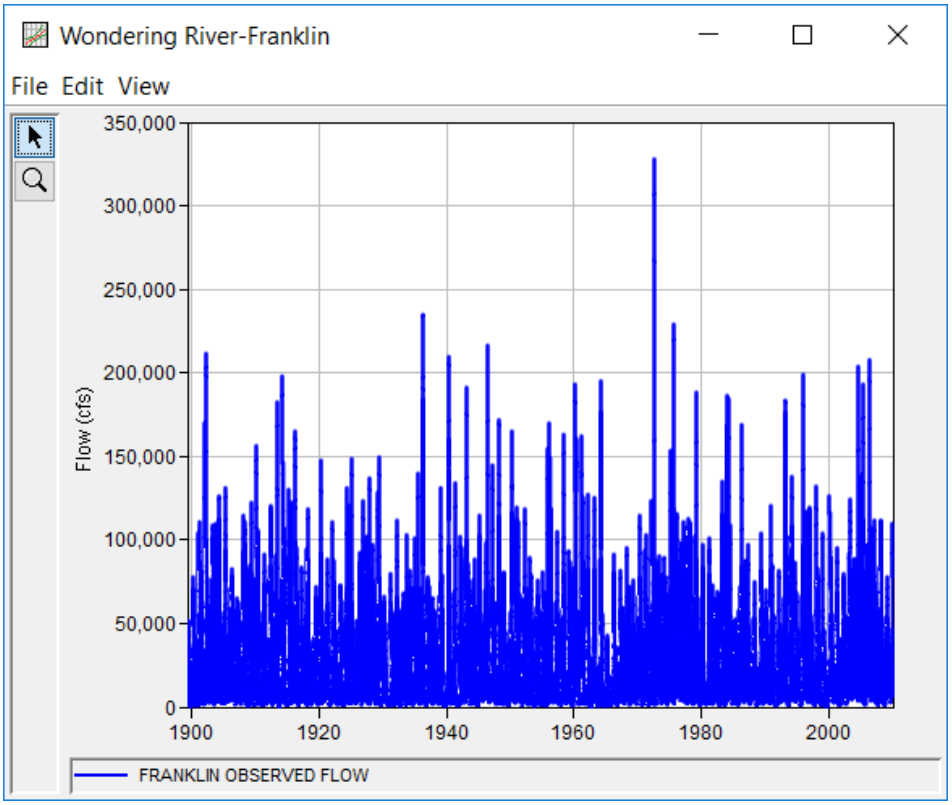
Bin Number	Lower Bin Limit	Number in Bin	Accum Number	Percent Equal or Exceeded
1	1.0	5	8766	100.000
2	2.0	4	8761	99.943
3	3.0	8	8757	99.897
4	4.0	22	8749	99.806
5	5.0	37	8727	99.555
6	6.0	66	8690	99.133
7	8.0	95	8624	98.380
8	10.0	254	8529	97.296
9	15.0	261	8275	94.399
10	20.0	423	8014	91.421
11	30.0	405	7591	86.596
12	40.0	359	7186	81.976
13	50.0	332	6827	77.880
14	60.0	480	6495	74.093
15	80.0	409	6015	68.617
16	100.0	888	5606	63.952
17	150.0	783	4718	53.822
18	200.0	1246	3935	44.889
19	300.0	822	2689	30.675
20	400.0	484	1867	21.298
21	500.0	340	1383	15.777
22	600.0	465	1043	11.898
23	800.0	239	578	6.594
24	1,000.0	251	339	3.867
25	1,500.0	47	88	1.004
26	2,000.0	32	41	0.468
27	3,000.0	6	9	0.103
28	4,000.0	0	3	0.034
29	6,000.0	3	3	0.034
30	7,000.0	0	0	0.000

05/29/2019 08:40 AM 1:1..1:1 1:1

118 Figure 6. Report File for Fishkill Creek Test 12

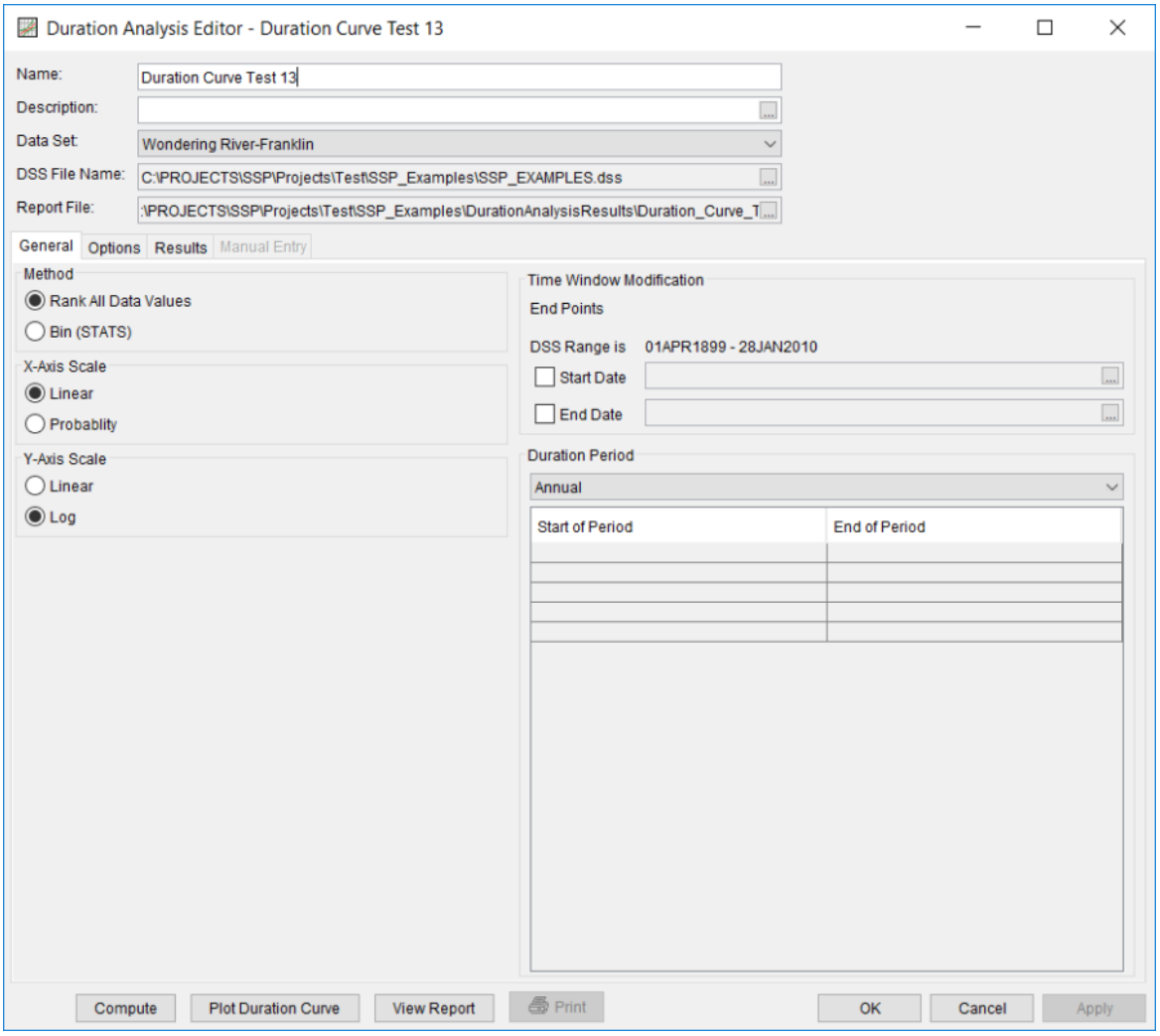
7.2 Example 13. Duration Analysis, Rank All Data Method

This example demonstrates how to use the Duration analysis. The data for this example is daily average flow and the period of record is from 01 Apr, 1899 to 28 Jan, 2010. To view the data, right-click on the data record labeled "**Wondering River-Franklin**" in the study explorer and then select **Plot**. The data will appear as shown in Figure 1.



119 Figure 1. Plot of the Daily Average Flow for Example 13

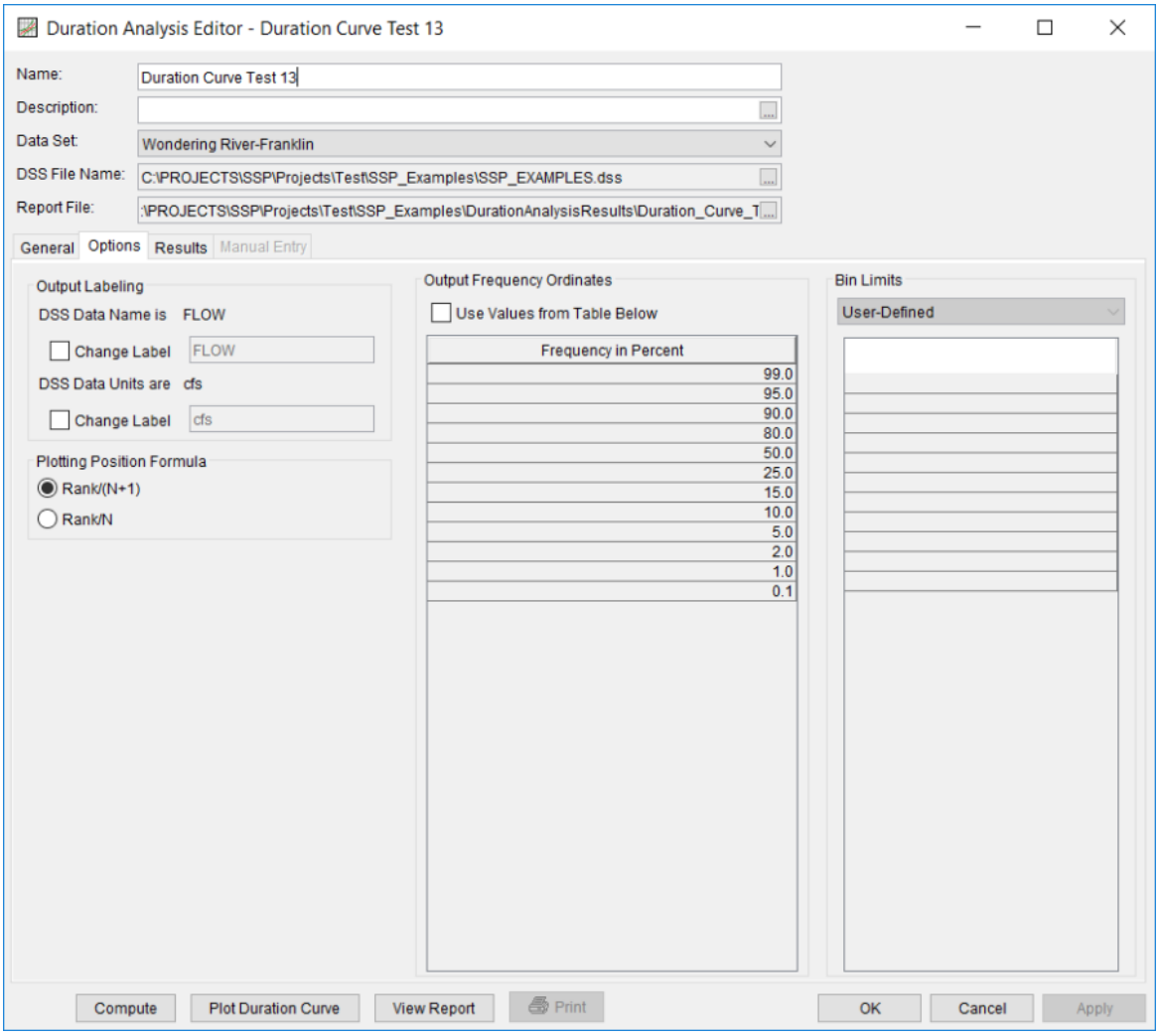
A Duration analysis has been developed for this example. To open the analysis editor for this example, either double-click on the analysis labeled **Duration Curve Test 13** from the study explorer, or from the **Analysis** menu select open, then select **Duration Curve Test 13** from the list of available analyses. When **Duration Curve Test 13** is opened, the duration analysis editor will appear as shown in Figure 2.



120 Figure 2. Duration Analysis Editor for Duration Curve Test 13

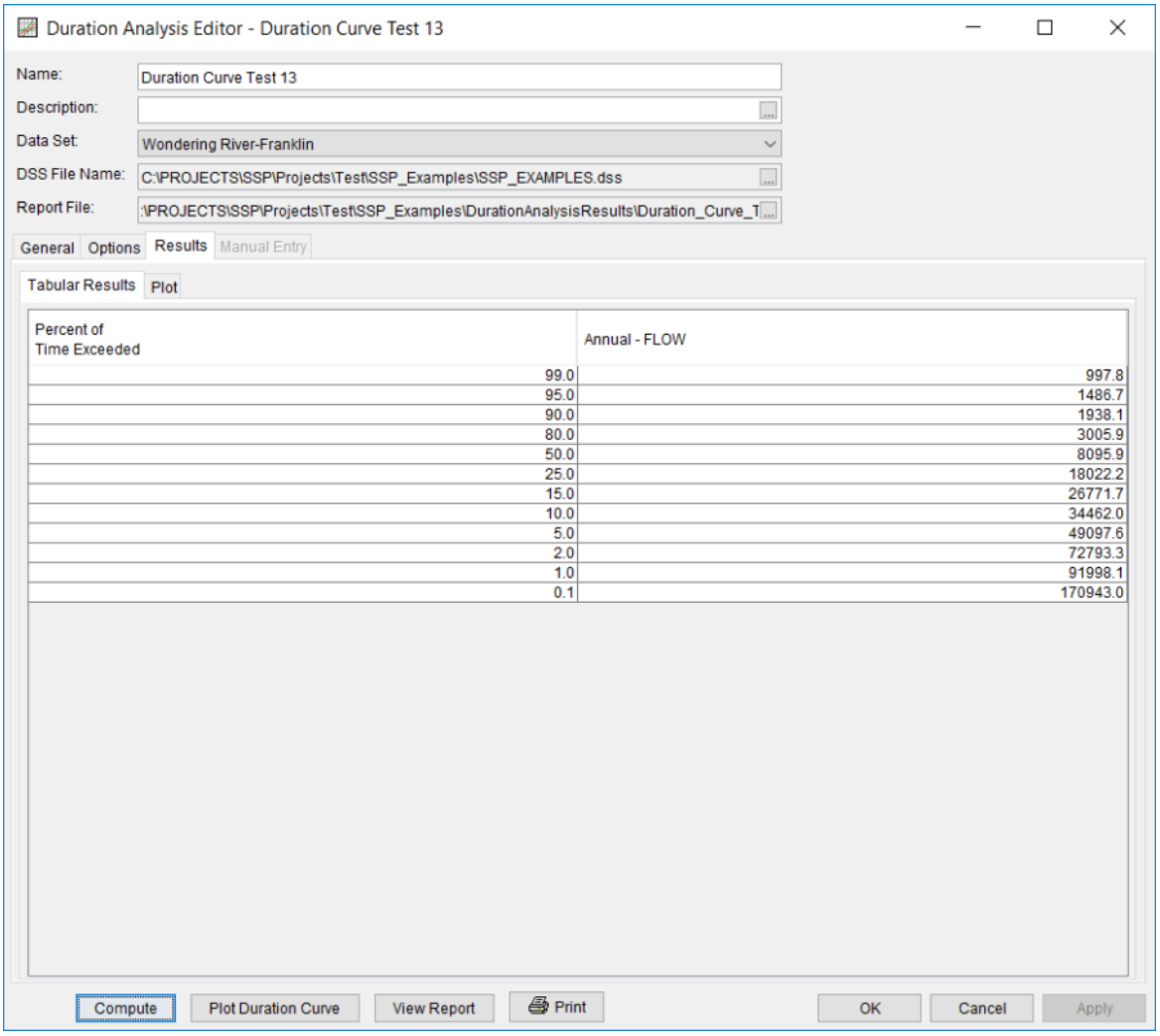
Shown in Figure 2 are the general settings that were used to perform this duration analysis. For this analysis, the **Rank All DataValues** method was selected, x-axis scale was set to **Linear**, the y-axis scale was set to **Log**, and the **Annual** duration period was selected.

The **Options Tab** is shown in Figure 3. Features on this tab include **Output Labeling**, the **Percent of Time Exceeded** ordinates, and **Bin Limits**. The Bin Limits panel is not active in this example because the Bin (STATS) method was not selected on the General tab.



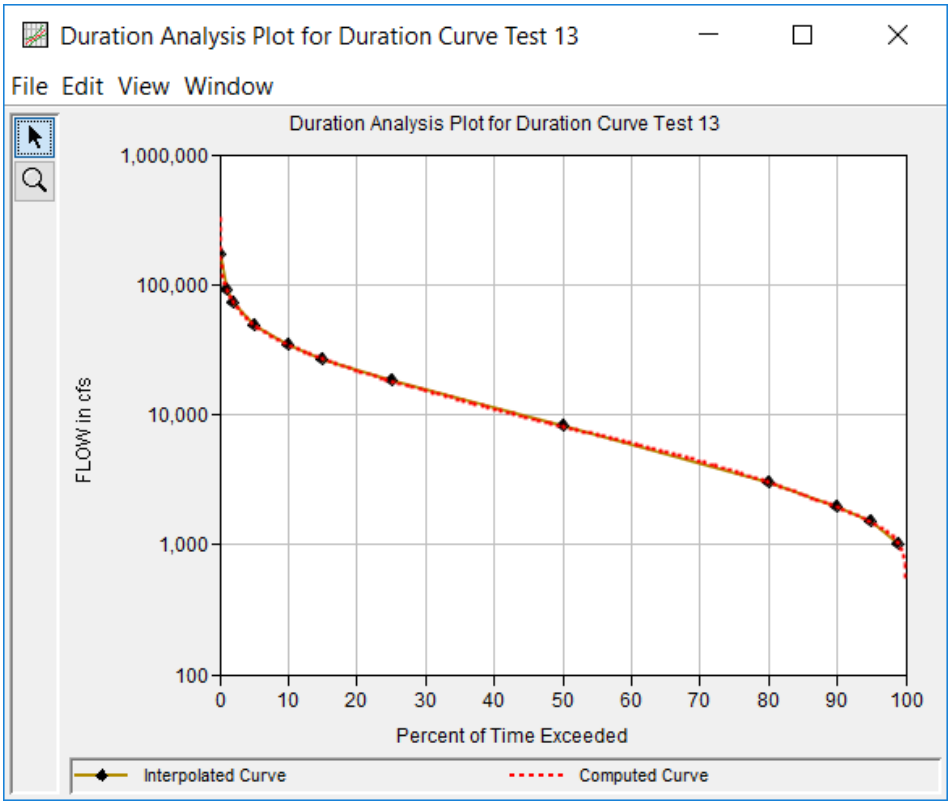
121 Figure 3. Duration Analysis Editor with Options Tab Shown for Duration Curve Test 13

Once all of the General and Optional settings are set or selected, the user can choose to compute the analysis by pressing the **Compute** button. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab, shown in Figure 4.



122 Figure 4. The Results Tab for Duration Curve Test 13

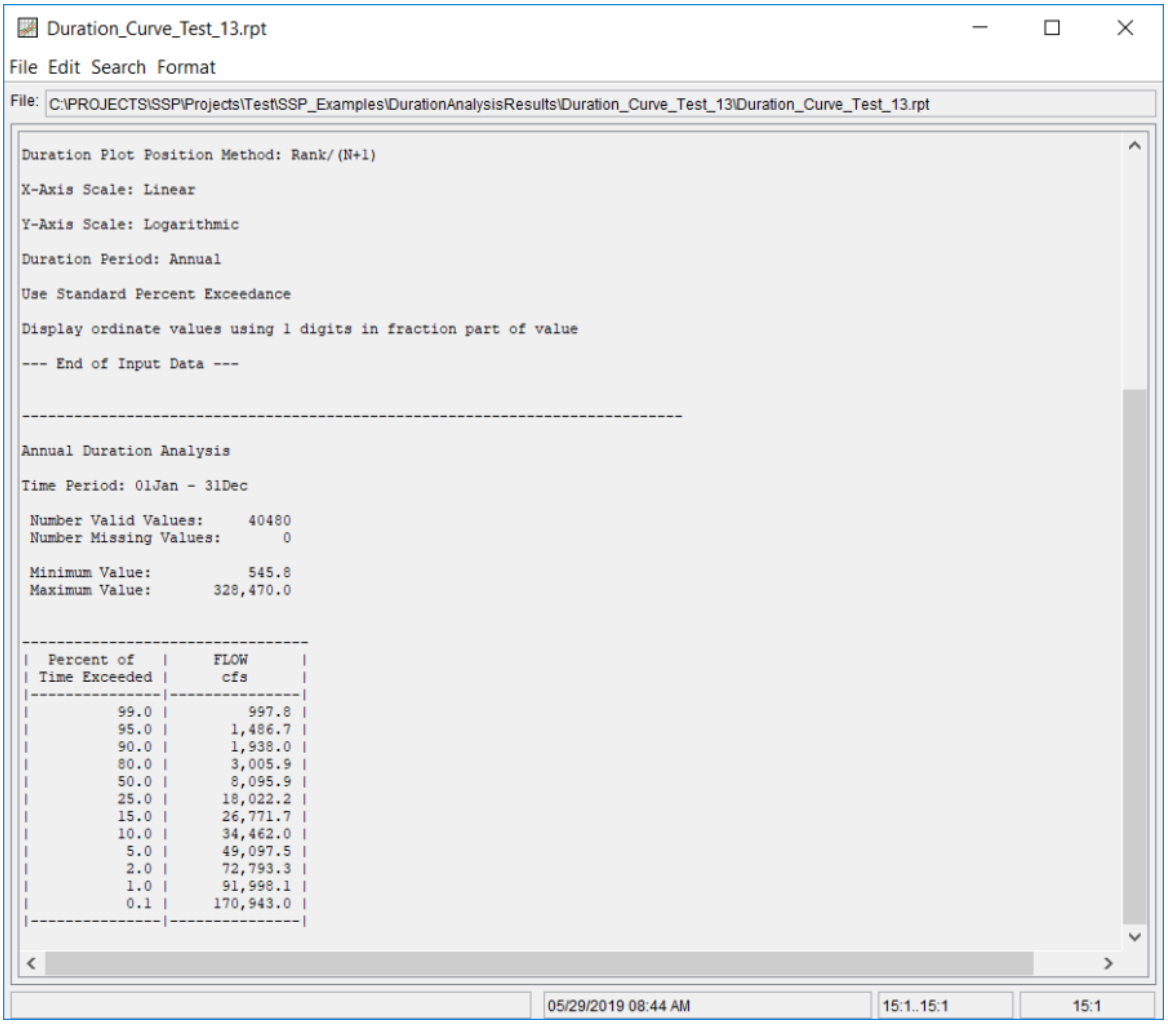
As shown in Figure 4, the **Result** tab contains both tabular and graphical results. The **Tabular Results** tab contains a table of the duration curve interpolated to the percent of time exceeded ordinates defined on the Options tab. The **Plot** tab contains a graph of the duration curve. The plot includes the computed duration curve and the duration curve interpolated to the user-defined percent of time exceeded ordinates. The duration curve plot can also be opened by pressing the **Plot Duration Curve** button at the bottom of the analysis window, shown in Figure 5.



123 Figure 5. Duration Curve Plot for Duration Curve Test 13

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot and then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

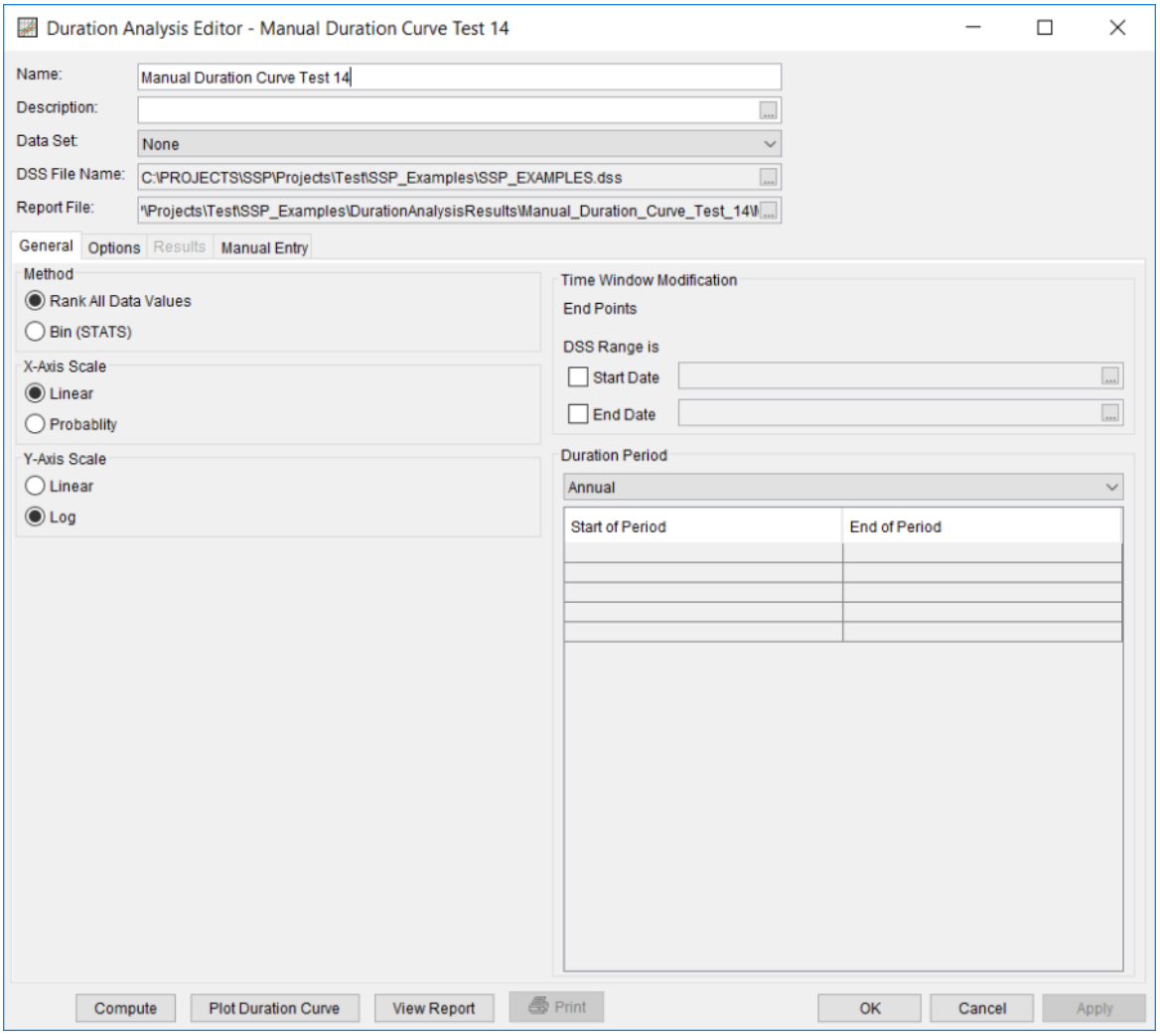
In addition to the tabular and graphical results, there is a report file that shows the input data and results for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 6 is the report file for **Duration Curve Test 13**.



124 Figure 6. Report File for Duration Curve Test 13

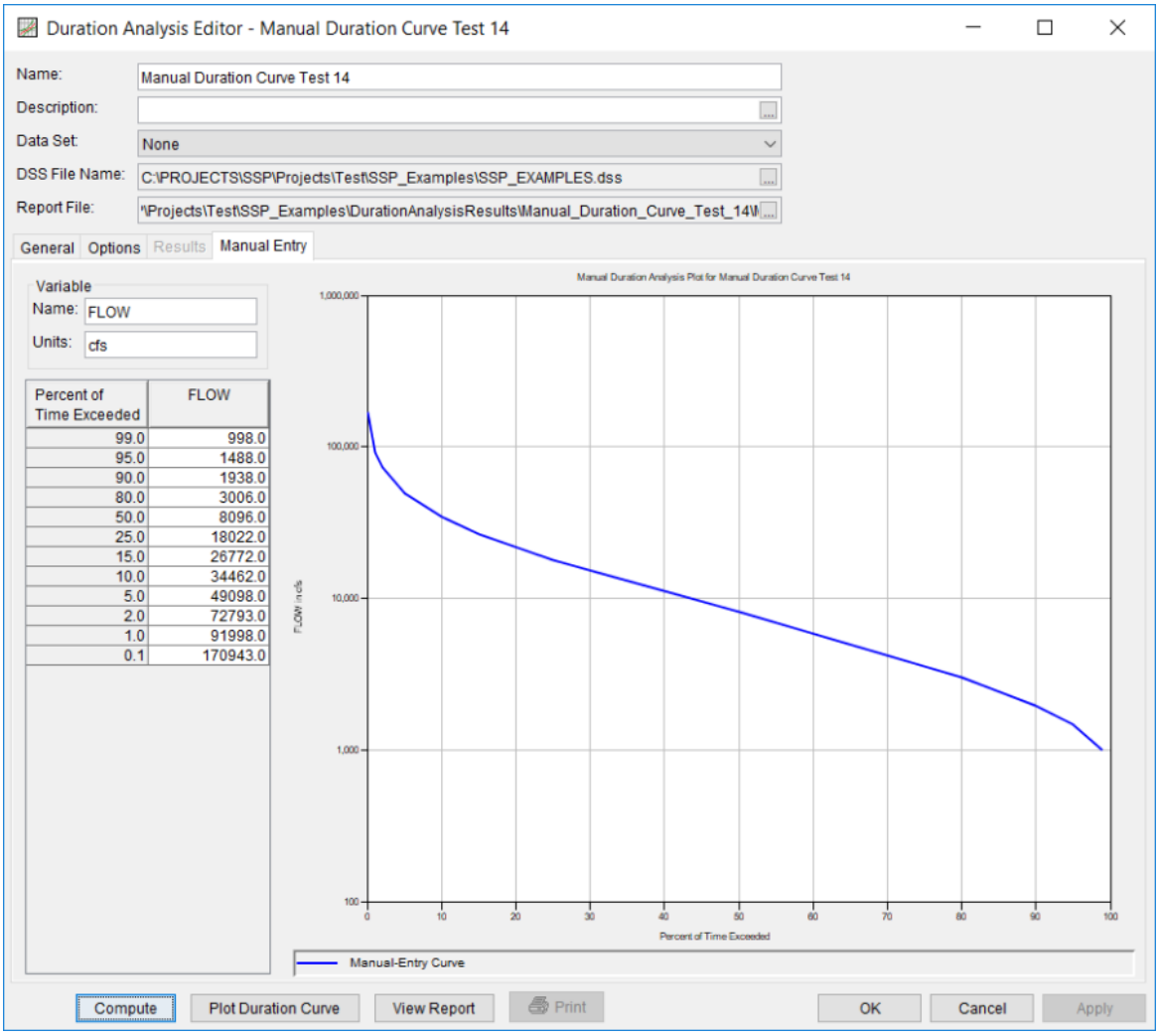
7.3 Example 14. Duration Analysis, Manual Entry

This example demonstrates how to use the Duration analysis and enter the duration curve manually. To open the analysis editor for this example, either double-click on the analysis labeled **Manual Duration Curve Test 14** from the study explorer, or from the **Analysis** menu select open, then select **Manual Duration Curve Test 14** from the list of available analyses. As shown in Figure 1, the "None" data set was selected for this analysis. The **Manual Entry** tab becomes active when the "None" data set is selected (the **Results** tab will become inactive).



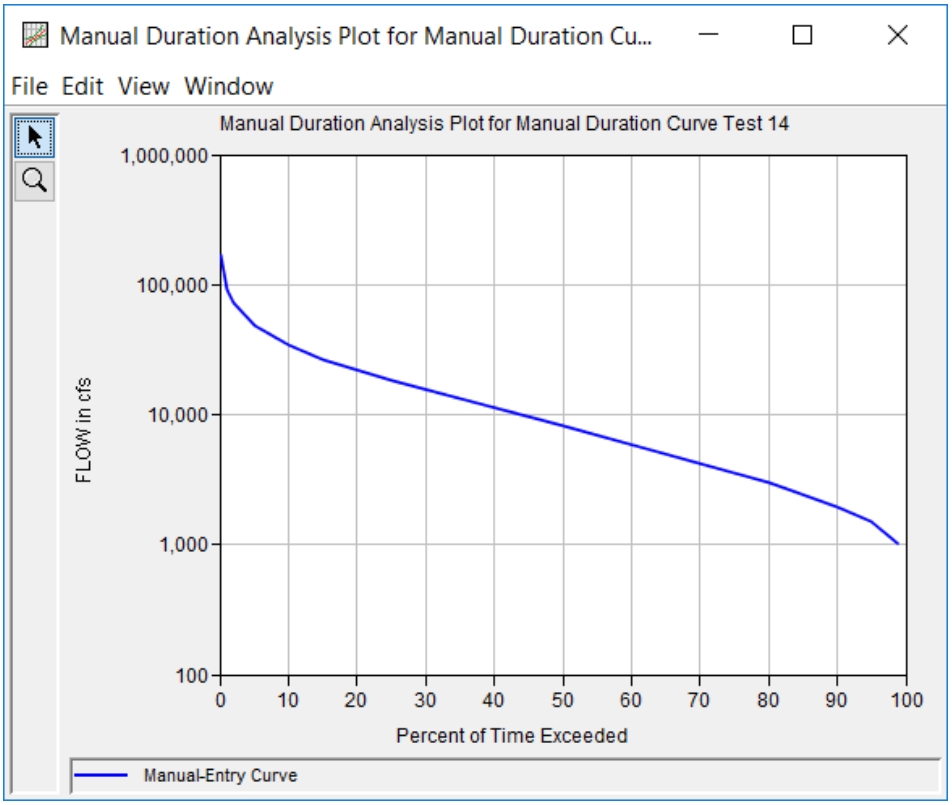
125 Figure 1. Duration Analysis Editor for Manual Duration Curve Test 14

The y-axis scale was set to **Log** while all other default options were selected on the General and Options tabs. Figure 2 shows the **Manual Entry** tab for **Manual Duration Curve Test 14**. A variable name of "FLOW" and units of "cfs" were entered as well as the duration curve. The program will plot the duration curve when the **Compute** button is pressed.



126 Figure 2. Duration Analysis Editor with Options Tab Shown for Manual Duration Curve Test 14

The duration curve plot can also be opened by pressing the **Plot Duration Curve** button at the bottom of the analysis window, shown in Figure 3.

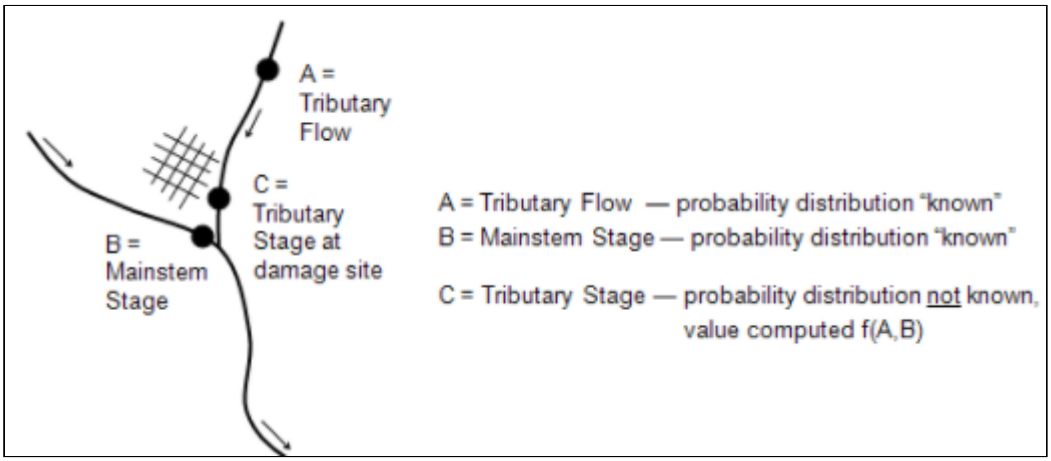


127 Figure 3. Duration Curve Plot for Manual Duration Curve Test 14

8 Coincident Frequency Analysis Examples

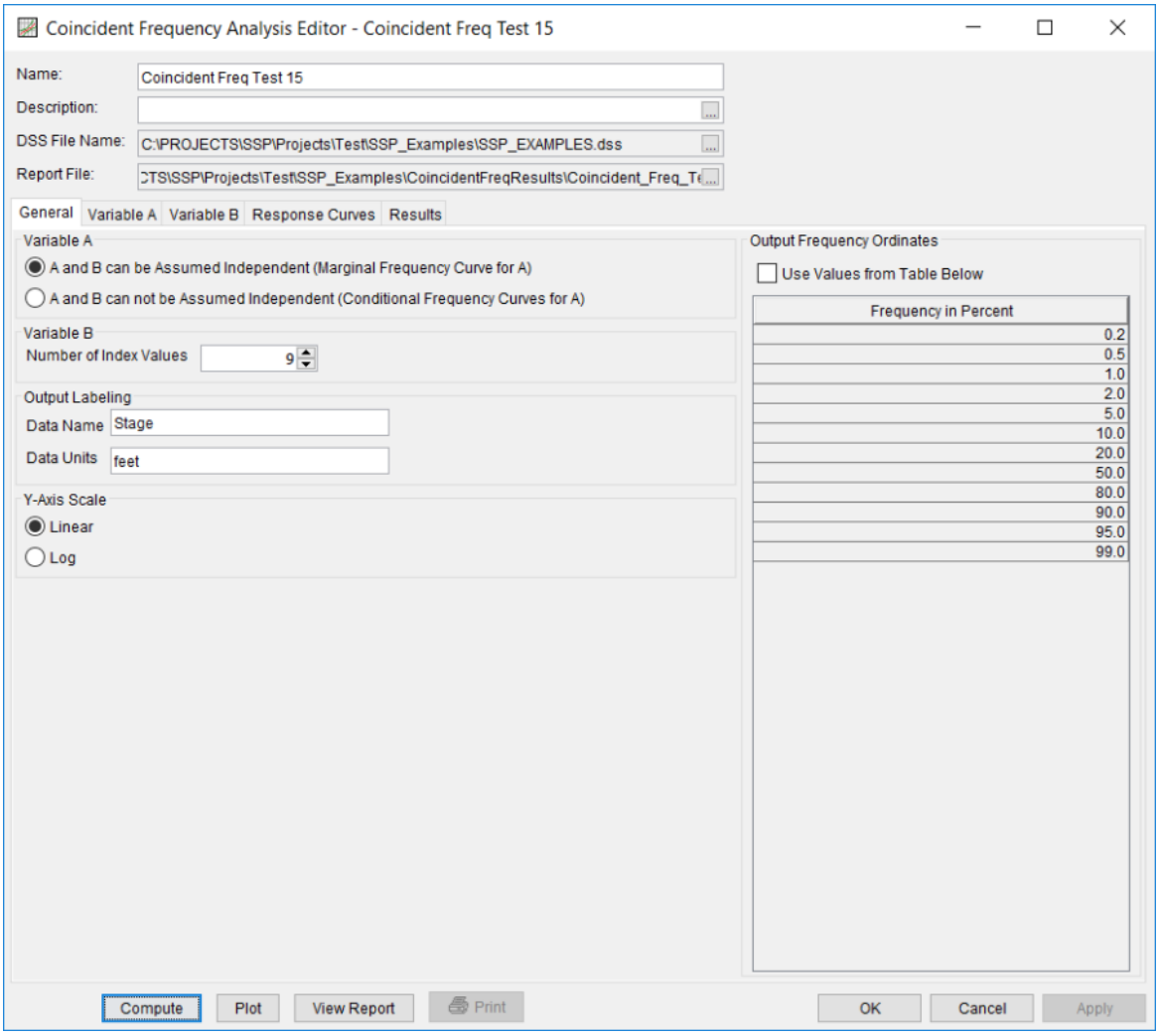
8.1 Example 15. Coincident Frequency Analysis, A and B can be Assumed Independent

This example demonstrates how to create a coincident frequency analysis. Figure 1 illustrates the scenario for **Coincident Freq Test 15**. The goal of this example is to develop a stage-frequency curve at a point along the tributary (variable C) given flows on the tributary (variable A) and flows in the mainstem (variable B). Large flows on the mainstem do cause backwater along the tributary and thus affect the stage at the point of interest. The data for this example comes from an existing flow frequency curve for Variable A and an existing flow duration curve for Variable B. An HEC-RAS model was used to simulate the response of Variable C (stage at the point of interest) for multiple combinations of flow on the tributary and flow in the mainstem.



128 Figure 1. Scenario for Coincident Freq Test 15

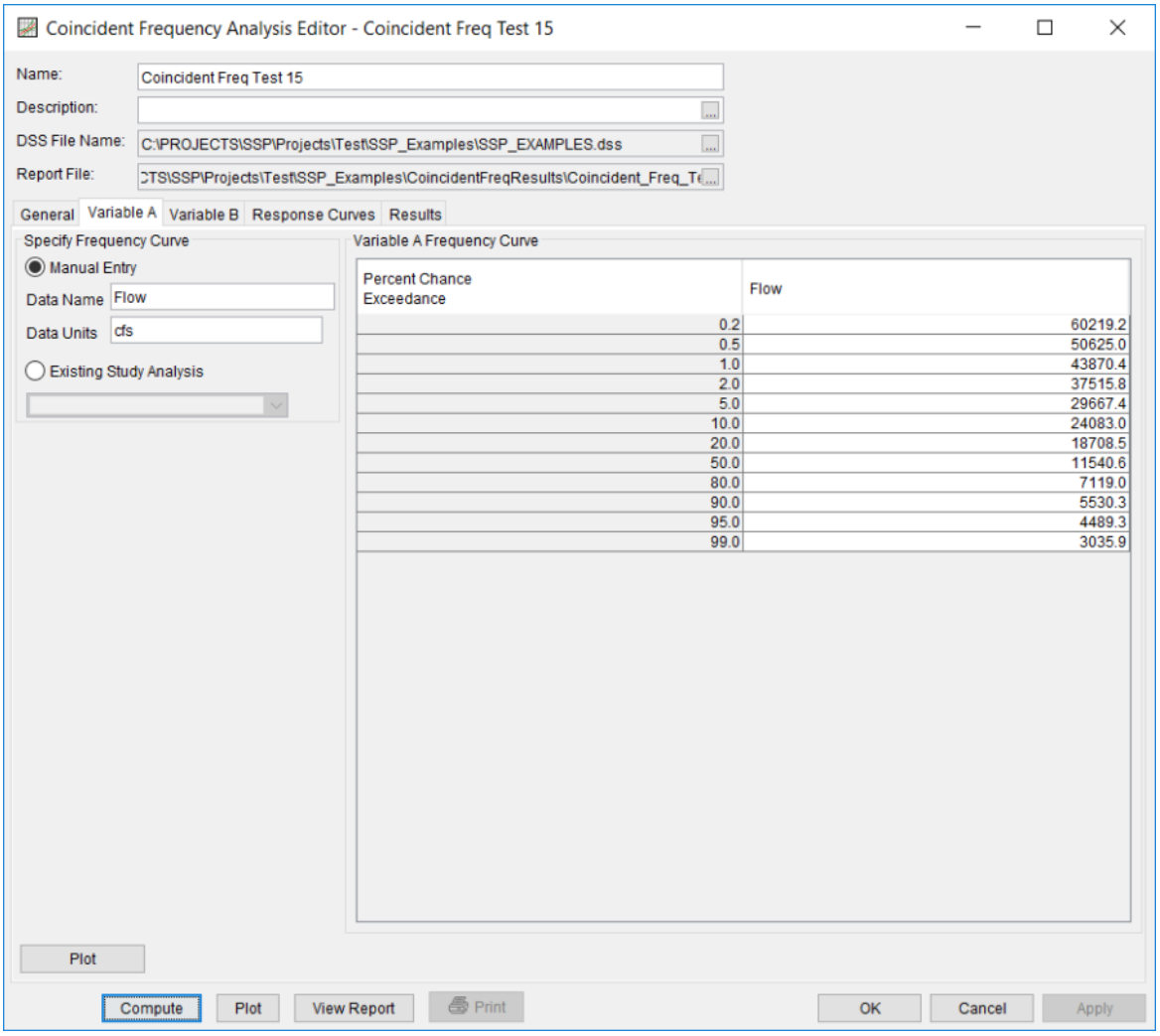
A Coincident Frequency analysis has been developed for this example. To open the Coincident Frequency analysis editor for this example, either double-click on the analysis labeled **Coincident Freq Test 15** from the study explorer, or from the **Analysis** menu select open, then select **Coincident Freq Test 15** from the list of available analyses. When **Coincident Freq Test 15** is opened, the Coincident Frequency Analysis editor will appear as shown in Figure 2.



129 Figure 2. General Tab Shown for Coincident Freq Test 15

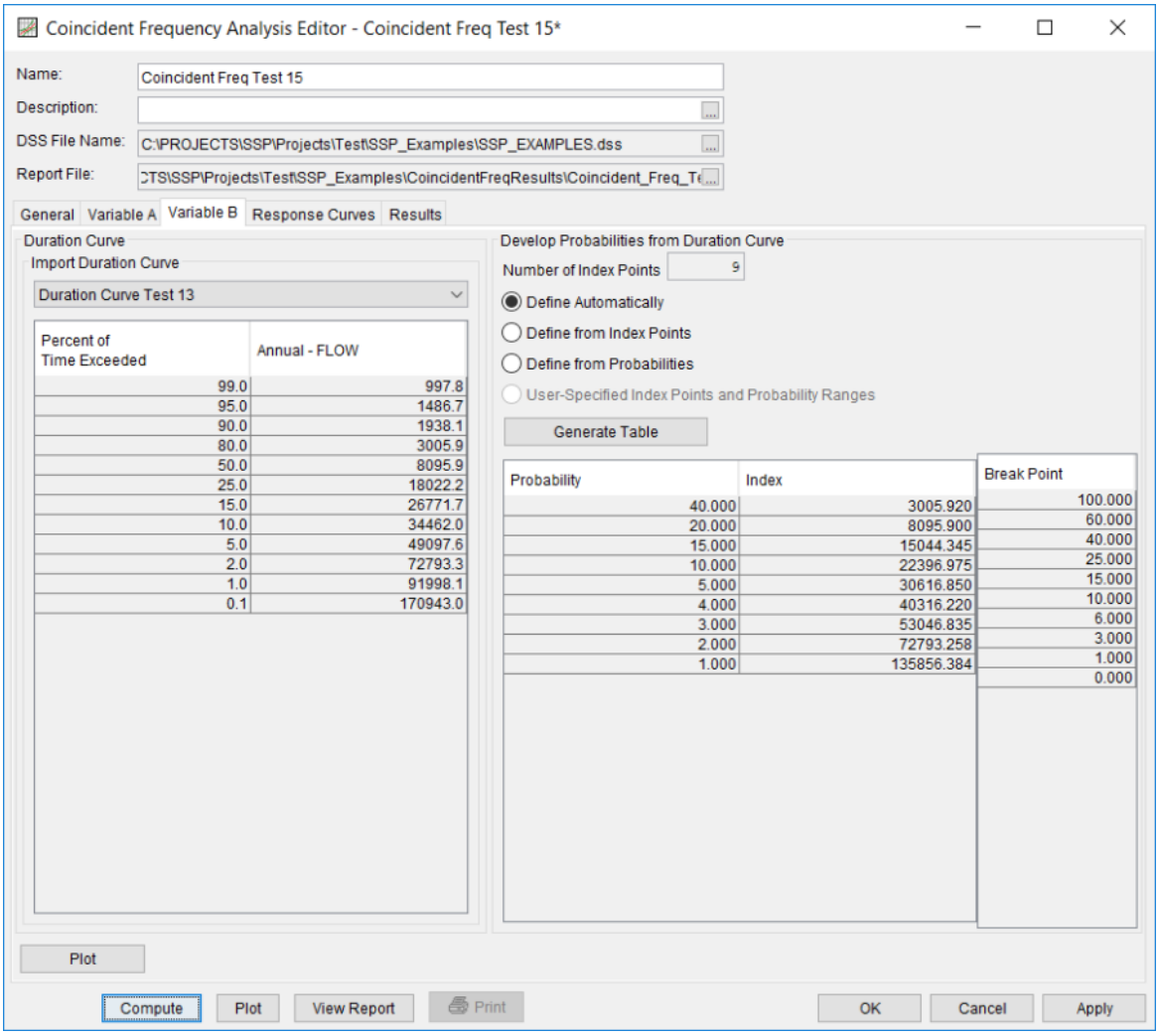
Shown in Figure 2 are the general settings for this coincident frequency analysis. For this analysis, the **A and B can be Assumed Independent (Marginal Frequency Curve for A)** option was selected. This choice would be determined by performing a correlation analysis between variables A and B; little correlation would indicate that variables A and B could be assumed independent. The number of variable B index values was set to 9, the **Data Name** was set to "Stage" and the **Data Units** to "feet", and the y-axis scale was set to **Linear**.

Shown in Figure 3 is the Coincident Frequency Analysis editor with the **Variable A Tab** selected. The **Manual Entry** option was selected and a **Data Name** of "Flow" and **Data Units** of "cfs" were entered. The frequency curve values were manually entered into the **Variable A Frequency Curve** table.



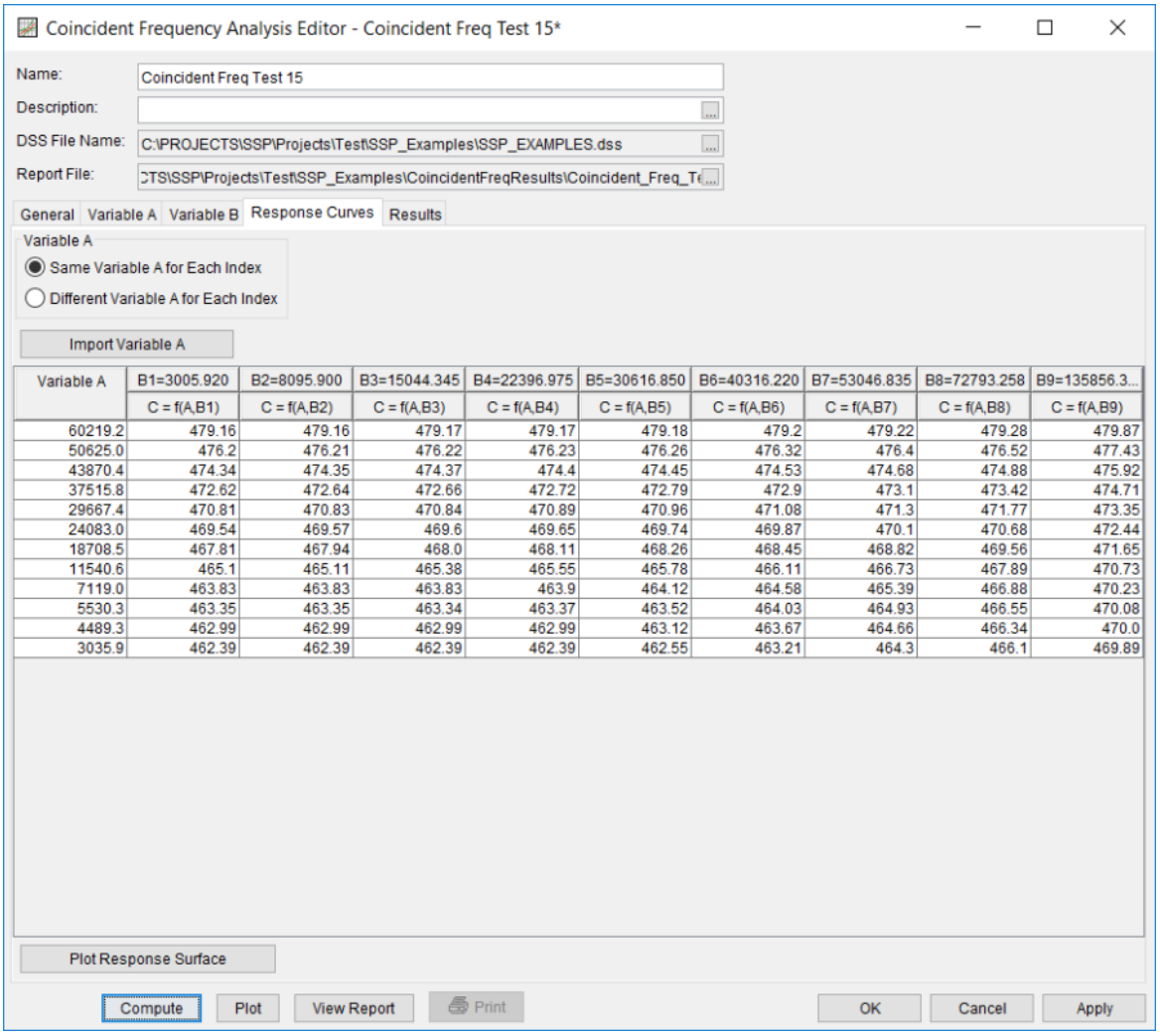
130 Figure 3. Variable A Tab for Coincident Freq Test 15

Shown in Figure 4 is the Coincident Frequency Analysis editor with the **Variable B** tab selected. The Duration Curve from Test 13 was selected in the drop-down list. Once selected, the duration curve table automatically fills with the computed ordinates from the duration curve. In the **Develop Probabilities from Duration Curve** panel, the **Define Automatically** option was selected. This option uses a predefined probability pattern to discretize the duration curve into index points. The **Generate Table** button was pressed in order activate the predefined probability pattern. In this example, the first index value is 3005.92 (cfs). This value is taken at the midpoint between percent of time exceeded values at 100 and 60 percent (from Duration Curve Test 13). This index value is assigned a probability of 40 percent; this flow value is used to represent 40% of the possible outcomes. The second index value is 8095.9. This value is taken at the midpoint between percent of time exceeded values at 60 and 40 percent and is assigned a probability of 20 percent.



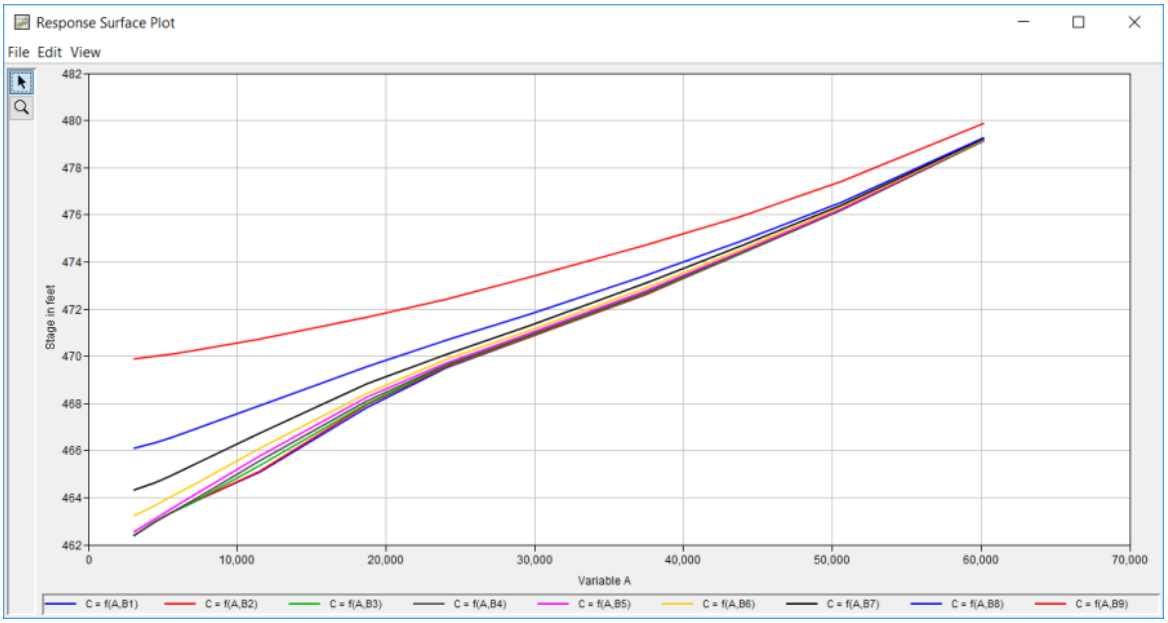
131 Figure 5. Variable B Tab for Coincident Freq Test 15

Once the Variable A and Variable B tabs have been completed, the user can populate the response curves table. Figure 5 shows the Response Curves tab for **Coincident Freq Test 15**. The **Same Variable A for Each Index** option was selected and the **Import Variable A** button was pressed to automatically copy values from the Variable A tab and fill in the **Variable A** column. The remaining columns in the table were populated with results from a hydraulics model. For example, the first value in the second column is 479.16. This value is the stage at the point of interest given a flow of 60219.18 (cfs) on the tributary (variable A) and a flow of 3005.92 (cfs) on the mainstem (variable B). A total of 108 simulations were required from the hydraulics model to fill in the response curves table. Figure 6 shows a plot of the response surface. The plot shows variable A (x-axis) and variable C (y-axis). For this example, the response surface shows that flows greater than 53000 (7th index point) on the mainstem affect the stage at the point of interest on the tributary. When the flow in the mainstem is below 53000 (cfs), only the flow on the tributary affects the stage at the point of interest.



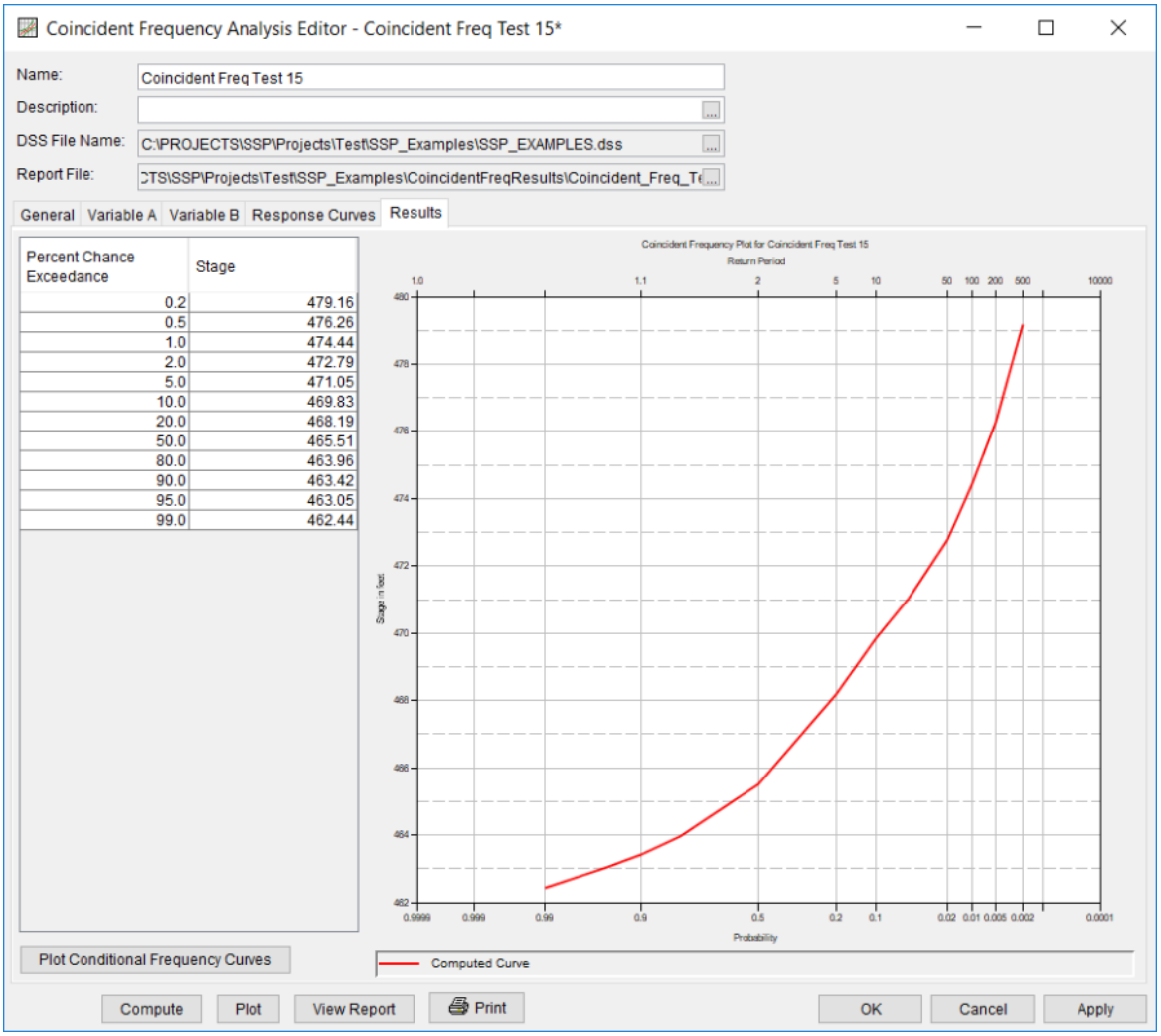
Variable A	B1=3005.920	B2=8095.900	B3=15044.345	B4=22396.975	B5=30616.850	B6=40316.220	B7=53046.835	B8=72793.258	B9=135856.3...
	C = f(A,B1)	C = f(A,B2)	C = f(A,B3)	C = f(A,B4)	C = f(A,B5)	C = f(A,B6)	C = f(A,B7)	C = f(A,B8)	C = f(A,B9)
60219.2	479.16	479.16	479.17	479.17	479.18	479.2	479.22	479.28	479.87
50625.0	476.2	476.21	476.22	476.23	476.26	476.32	476.4	476.52	477.43
43870.4	474.34	474.35	474.37	474.4	474.45	474.53	474.68	474.88	475.92
37515.8	472.62	472.64	472.66	472.72	472.79	472.9	473.1	473.42	474.71
29667.4	470.81	470.83	470.84	470.89	470.96	471.08	471.3	471.77	473.35
24083.0	469.54	469.57	469.6	469.65	469.74	469.87	470.1	470.68	472.44
18708.5	467.81	467.94	468.0	468.11	468.26	468.45	468.82	469.56	471.65
11540.6	465.1	465.11	465.38	465.55	465.78	466.11	466.73	467.89	470.73
7119.0	463.83	463.83	463.83	463.9	464.12	464.58	465.39	466.88	470.23
5530.3	463.35	463.35	463.34	463.37	463.52	464.03	464.93	466.55	470.08
4489.3	462.99	462.99	462.99	462.99	463.12	463.67	464.66	466.34	470.0
3035.9	462.39	462.39	462.39	462.39	462.55	463.21	464.3	466.1	469.89

132 Figure 5. Response Curves Tab for Coincident Freq Test 15



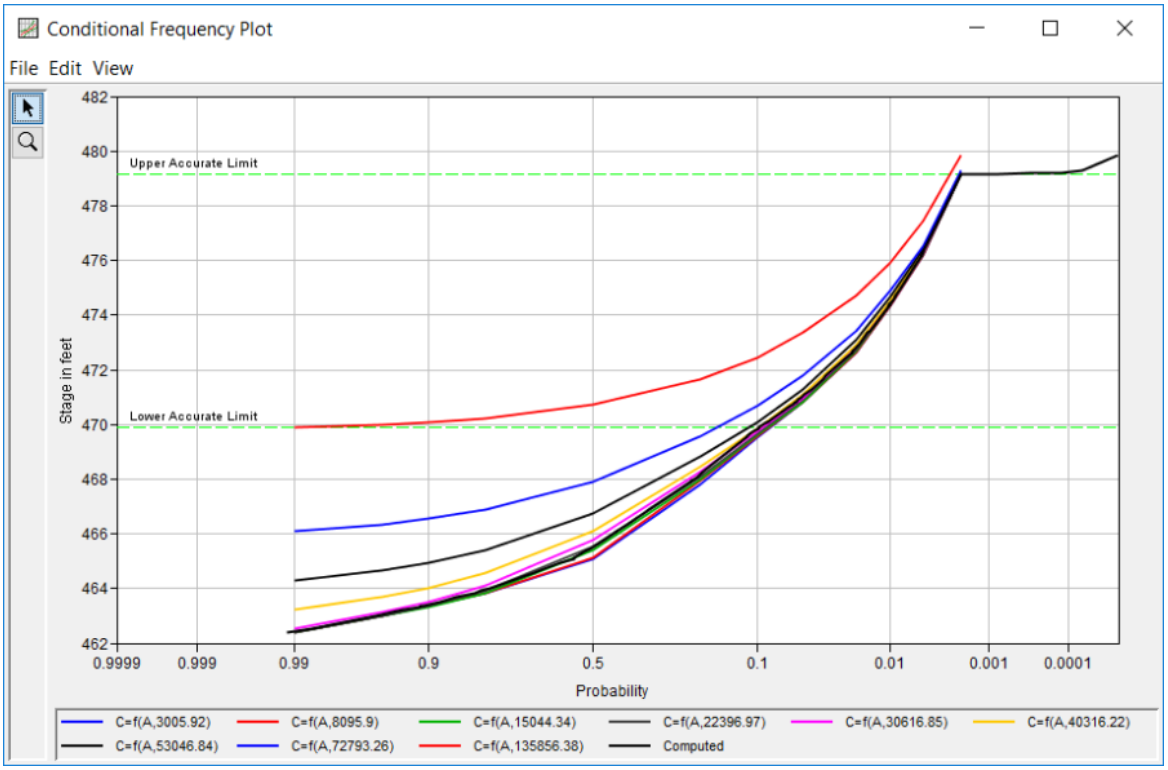
133 Figure 6. Response Curves Plot for Coincident Freq Test 15

Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The results tab should resemble Figure 7. The left portion of the results tab contains the computed variable C frequency curve and the right portion of the results tab contains a plot of the computed variable C frequency curve.



134 Figure 7. Results Tab for Coincident Freq Test 15

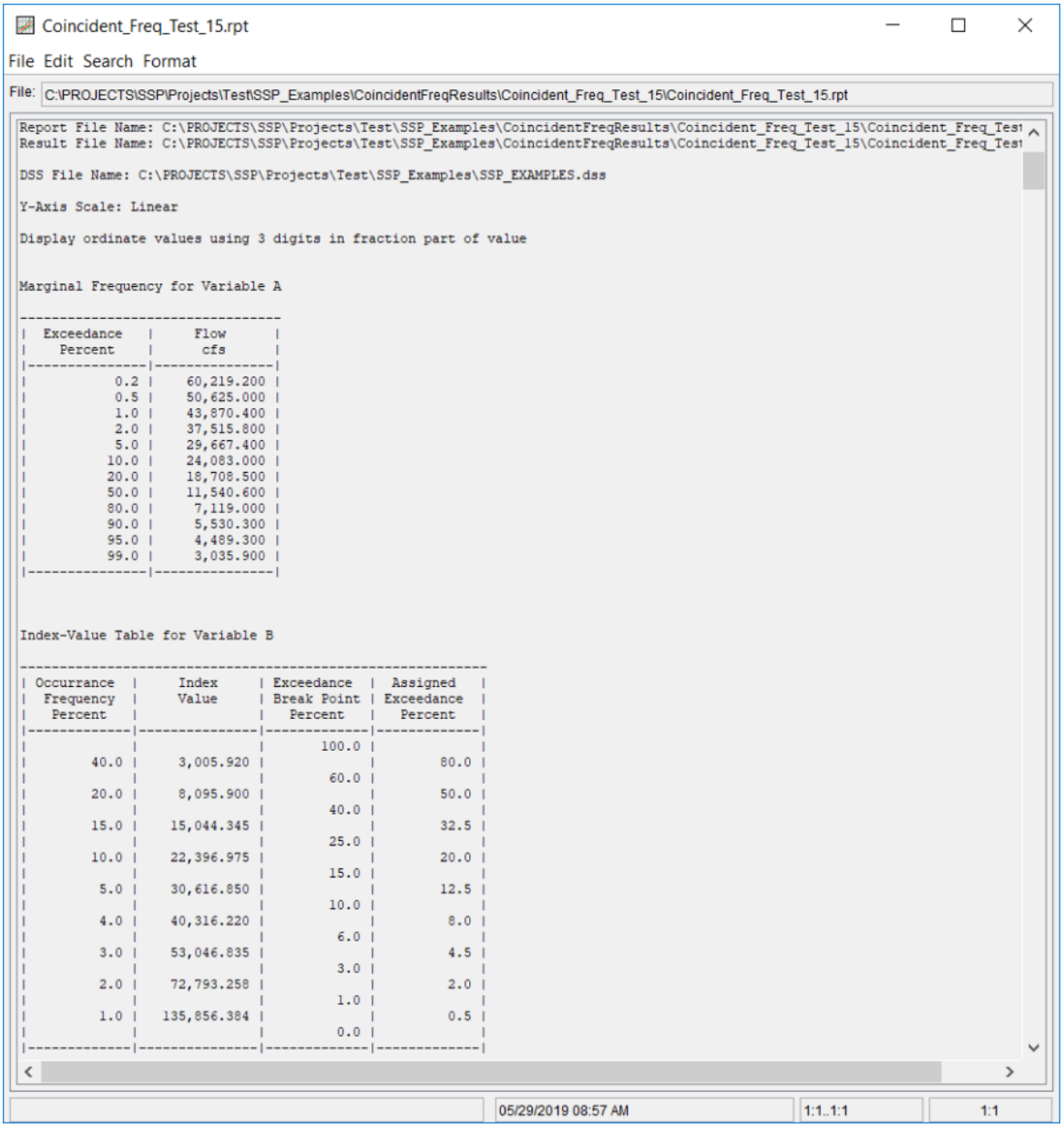
By pressing the **Plot Condition Frequency Curves**, the user can plot the response curves entered on the **Response Curves** tab along with the computed curve and the upper and lower accurate limits, as shown in Figure 8.



135 Figure 8. Conditional Frequency Curves for Coincident Freq Test 15

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot by pressing the **Plot** button from the bottom of the analysis. Then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 9 is the report file for **Coincident Freq Test 15**.



Coincident_Freq_Test_15.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\CoincidentFreqResults\Coincident_Freq_Test_15\Coincident_Freq_Test_15.rpt

```
Report File Name: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\CoincidentFreqResults\Coincident_Freq_Test_15\Coincident_Freq_Test
Result File Name: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\CoincidentFreqResults\Coincident_Freq_Test_15\Coincident_Freq_Test

DSS File Name: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\SSP_EXAMPLES.dss

Y-Axis Scale: Linear

Display ordinate values using 3 digits in fraction part of value


Marginal Frequency for Variable A

---------------------------------
|  Exceedance   |     Flow      |
|    Percent    |      cfs      |
|---------------|---------------|
|           0.2 |    60,219.200 |
|           0.5 |    50,625.000 |
|           1.0 |    43,870.400 |
|           2.0 |    37,515.800 |
|           5.0 |    29,667.400 |
|          10.0 |    24,083.000 |
|          20.0 |    18,708.500 |
|          50.0 |    11,540.600 |
|          80.0 |     7,119.000 |
|          90.0 |     5,530.300 |
|          95.0 |     4,489.300 |
|          99.0 |     3,035.900 |
|---------------|---------------|



Index-Value Table for Variable B

-----------------------------------------------------------
| Occurrance  |     Index     | Exceedance  |  Assigned   |
|  Frequency  |     Value     | Break Point | Exceedance  |
|   Percent   |               |   Percent   |   Percent   |
|-------------|---------------|-------------|-------------|
|             |               |       100.0 |             |
|        40.0 |     3,005.920 |             |        80.0 |
|             |               |        60.0 |             |
|        20.0 |     8,095.900 |             |        50.0 |
|             |               |        40.0 |             |
|        15.0 |    15,044.345 |             |        32.5 |
|             |               |        25.0 |             |
|        10.0 |    22,396.975 |             |        20.0 |
|             |               |        15.0 |             |
|         5.0 |    30,616.850 |             |        12.5 |
|             |               |        10.0 |             |
|         4.0 |    40,316.220 |             |         8.0 |
|             |               |         6.0 |             |
|         3.0 |    53,046.835 |             |         4.5 |
|             |               |         3.0 |             |
|         2.0 |    72,793.258 |             |         2.0 |
|             |               |         1.0 |             |
|         1.0 |   135,856.384 |             |         0.5 |
|             |               |         0.0 |             |
|-------------|---------------|-------------|-------------|
```

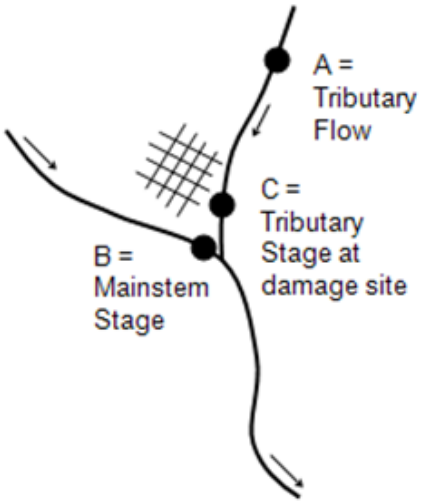
05/29/2019 08:57 AM | 1:1..1:1 | 1:1

136 Figure 9. Report File for Coincident Freq Test 15

8.2 Example 16. Coincident Frequency Analysis, A and B can not be Assumed Independent

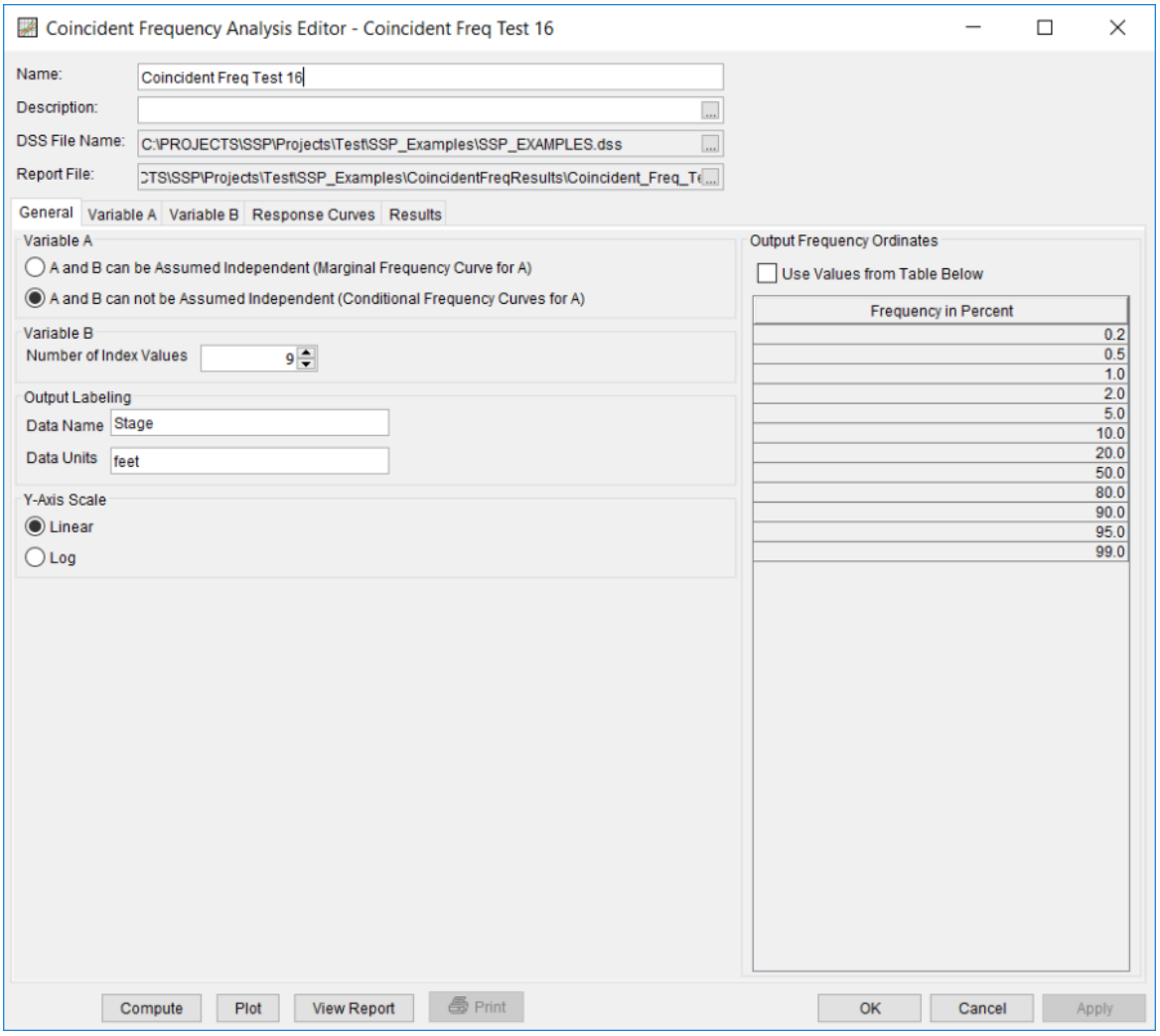
This example demonstrates how to create a coincident frequency analysis when variables A and B are not independent. Figure 1 illustrates the scenario for **Coincident Freq Test 16**. The goal of this example is to develop a stage-frequency curve at a point along the tributary (variable C) given flows on the tributary (variable A) and flows in the mainstem (variable B). Large flows on the mainstem do cause backwater along the tributary and thus affect the stage at the point of interest. The data for this example comes from existing conditional flow frequency curves for Variable A and an existing flow duration curve for variable B. An HEC-

RAS model was used to simulate the response of variable C (stage at the point of interest) for multiple combinations of flow on the tributary and flow in the mainstem.



137 Figure 1. Scenario for Coincident Freq Test 16

A Coincident Frequency analysis has been developed for this example. To open the Coincident Frequency analysis editor for **Coincident Freq Test 16**, either double-click on the analysis labeled **Coincident Freq Test 16** from the study explorer, or from the **Analysis** menu select open, then select **Coincident Freq Test 16** from the list of available analyses. When **Coincident Freq Test 16** is opened, the Coincident Frequency analysis editor will appear as shown in Figure 2.



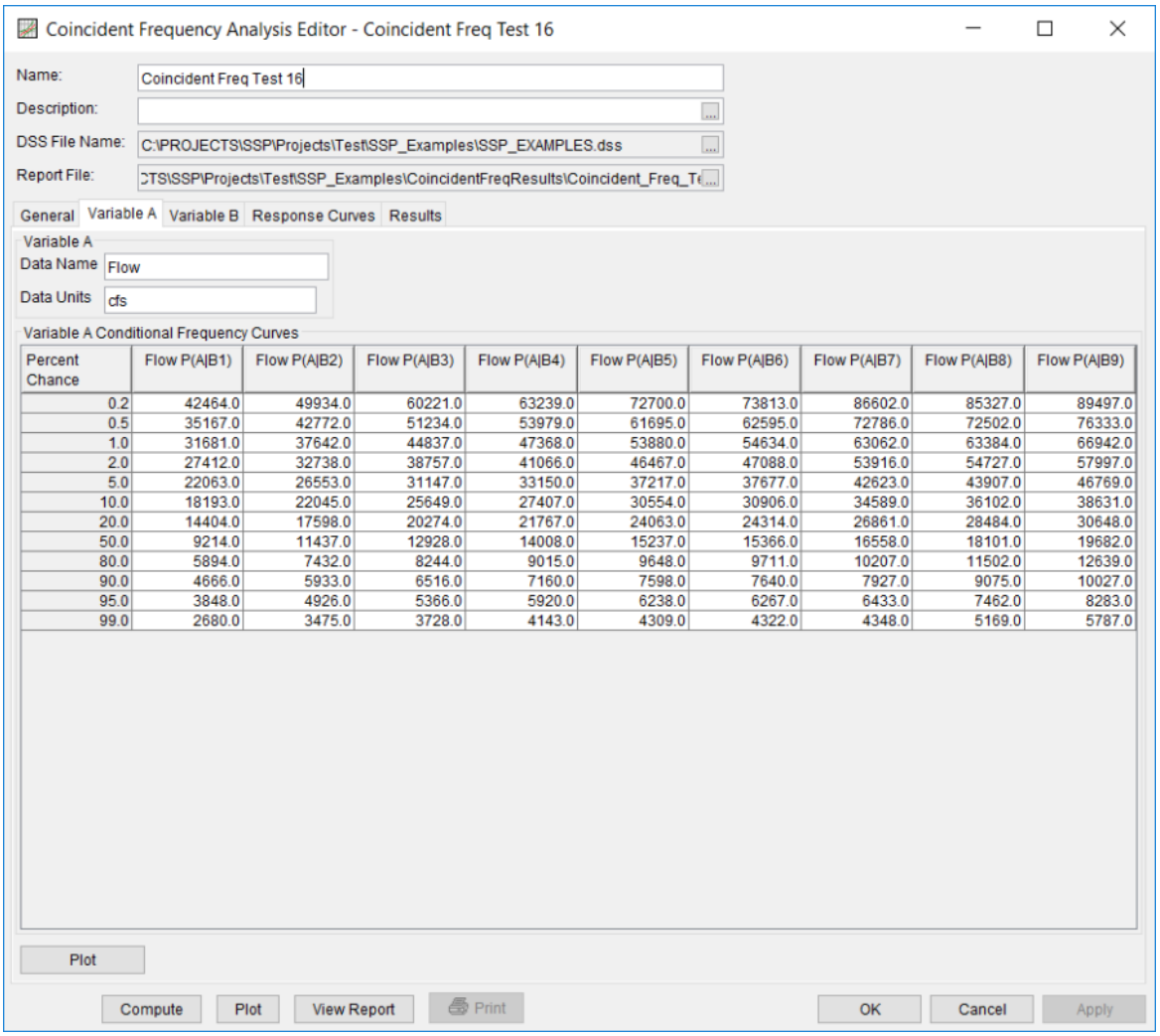
138 Figure 2. General Tab Shown for Coincident Freq Test 16

Shown in Figure 2 are the general settings for this coincident frequency analysis. For this analysis, the **A and B can not be Assumed Independent (Conditional Frequency Curve for A)** option was selected. This choice would be determined by performing a correlation analysis between variables A and B; a correlation coefficient in the range of 0.3 – 0.7 would indicate that variables A and B could not be assumed independent or perfectly correlated. The number of variable B index values was set to 9, the **Data Name** was set to "Stage" and the **Data Units** to "feet", and the Y-Axis scale was set to **Linear**.

Shown in Figure 3 is the Coincident Frequency Analysis editor with the **Variable A Tab** selected. A **Data Name** of "Flow" and **Data Units** of "cfs" were entered. A separate frequency curve for variable A was developed for each index value defined on the Variable B tab. For example, the frequency curve in the "Flow P(A|B1)" column is the variable A frequency curve for the 1st variable B index value. The variable B tab shows the 1st index value, 3005.92, is assigned a proportion of time of 40 percent. Therefore, the 1st variable A frequency curve was developed using annual peak flows on the tributary when flows in the mainstem were in the range of the 1st variable B index value. For this example, a multivariate lognormal[45] random number generator was used to develop a large enough data set so that variable A frequency curves could be computed for each variable B index value. The random numbers were generated using statistics from the annual peak flows

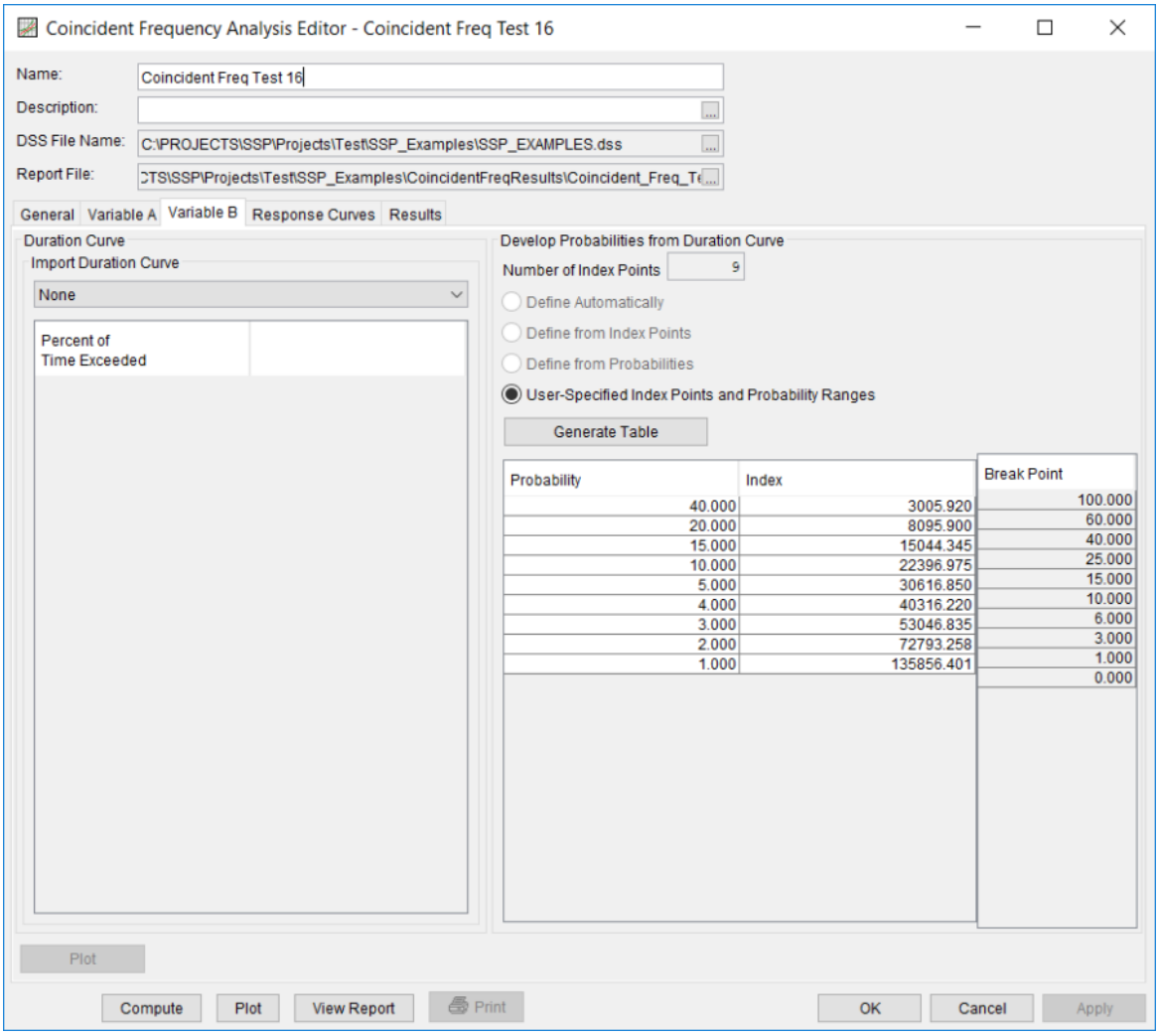
45 http://www.google.com/search?hl=en&&sa=X&ei=Ktp2TObFDI-isQPRmtWgDQ&ved=0CBEQBSgA&q=multivariate+lognormal&spell=1

occurring on the tributary, statistics from the coincident (same day) flows occurring on the main stem, and the covariance between the two datasets.



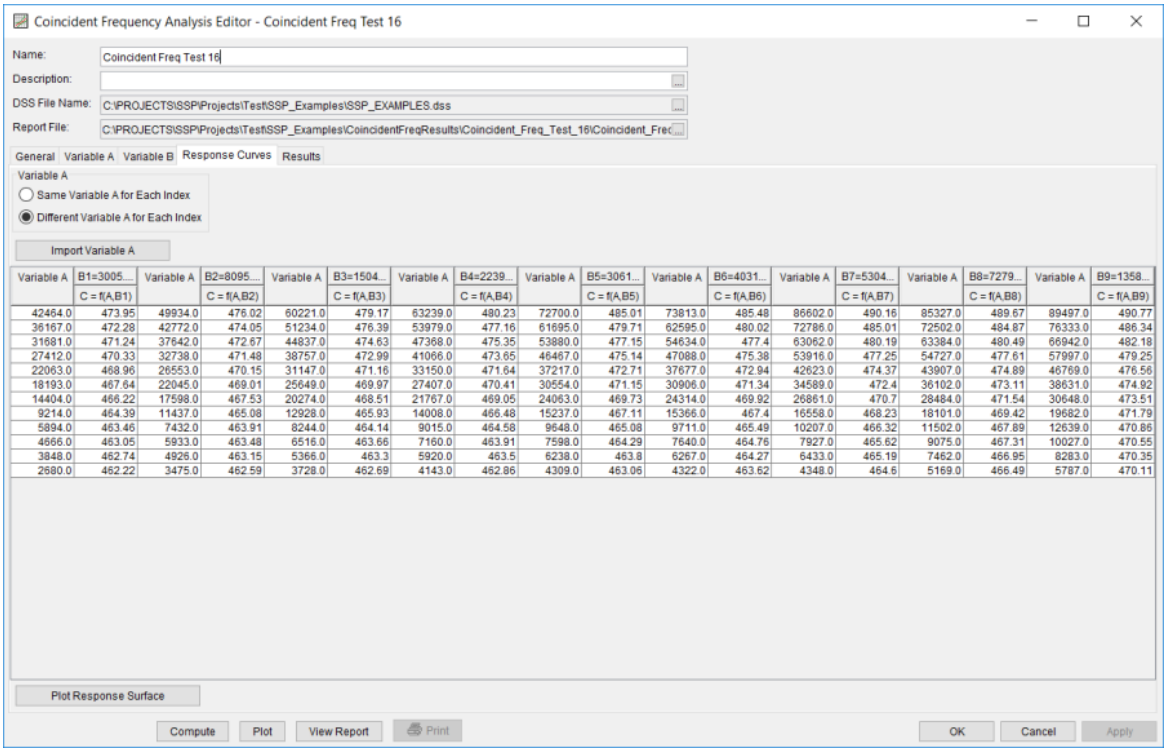
Percent Chance	Flow P(A|B1)	Flow P(A|B2)	Flow P(A|B3)	Flow P(A|B4)	Flow P(A|B5)	Flow P(A|B6)	Flow P(A|B7)	Flow P(A|B8)	Flow P(A|B9)
0.2	42464.0	49934.0	60221.0	63239.0	72700.0	73813.0	86602.0	85327.0	89497.0
0.5	35167.0	42772.0	51234.0	53979.0	61695.0	62595.0	72786.0	72502.0	76333.0
1.0	31681.0	37642.0	44837.0	47368.0	53880.0	54634.0	63062.0	63384.0	66942.0
2.0	27412.0	32738.0	38757.0	41066.0	46467.0	47088.0	53916.0	54727.0	57997.0
5.0	22063.0	26553.0	31147.0	33150.0	37217.0	37677.0	42623.0	43907.0	46769.0
10.0	18193.0	22045.0	25649.0	27407.0	30554.0	30906.0	34589.0	36102.0	38631.0
20.0	14404.0	17598.0	20274.0	21767.0	24063.0	24314.0	26861.0	28484.0	30648.0
50.0	9214.0	11437.0	12928.0	14008.0	15237.0	15366.0	16558.0	18101.0	19682.0
80.0	5894.0	7432.0	8244.0	9015.0	9648.0	9711.0	10207.0	11502.0	12639.0
90.0	4666.0	5933.0	6516.0	7160.0	7598.0	7640.0	7927.0	9075.0	10027.0
95.0	3848.0	4926.0	5366.0	5920.0	6238.0	6267.0	6433.0	7462.0	8283.0
99.0	2680.0	3475.0	3728.0	4143.0	4309.0	4322.0	4348.0	5169.0	5787.0

Shown in Figure 4 is the Coincident Frequency analysis editor with the **Variable B Tab** selected. No duration curve was selected for this example. In the **Develop Probabilities from Duration Curve** panel, the **User-Specified Index Points and Probability Ranges** option was selected. The probabilities and index values were defined manually (they are equivalent to those used within the previous example) and the **Generate Table** button was pressed in order to compute the Break Points.



139 Figure 4. Variable B Tab for Coincident Freq Test 16

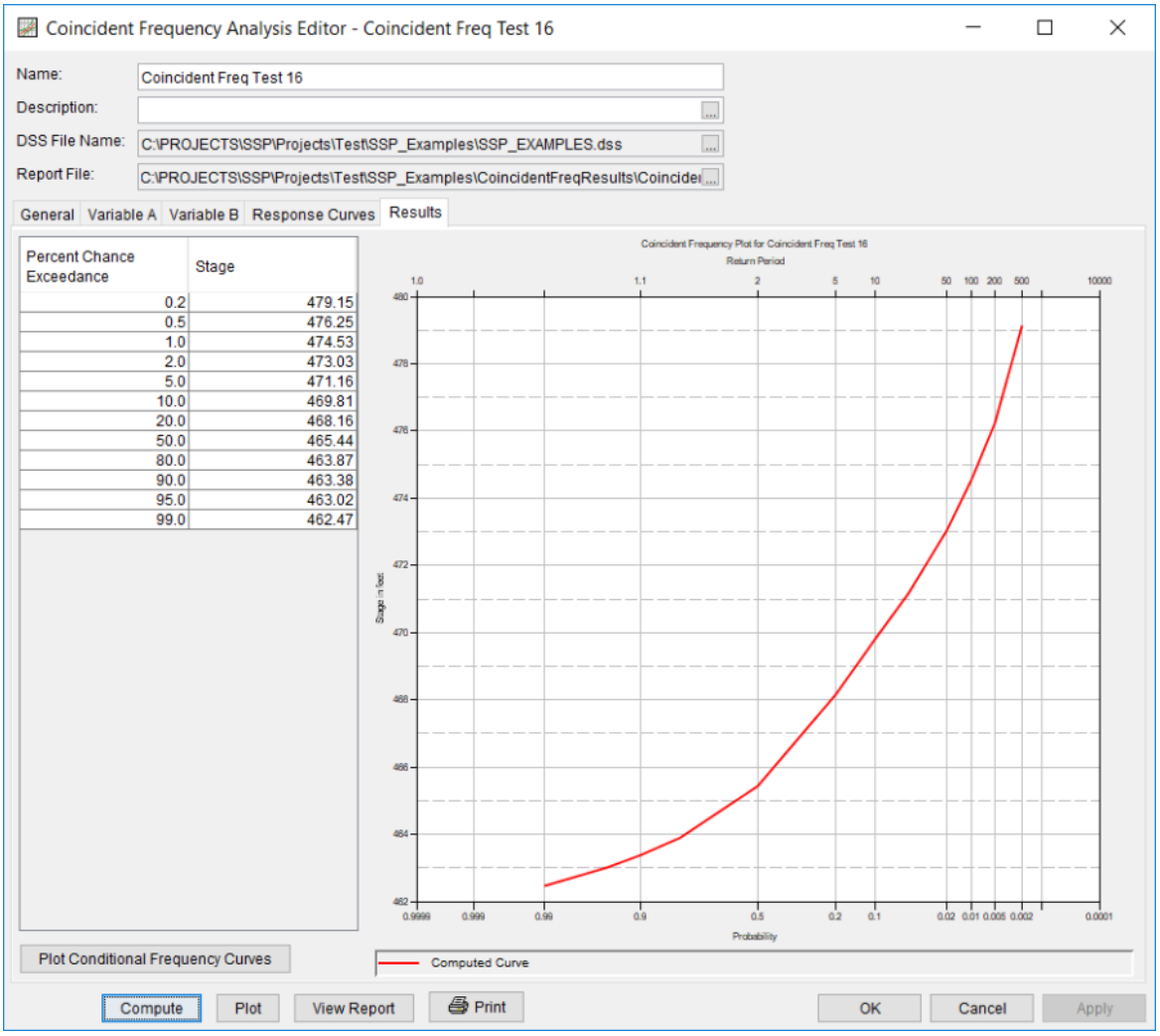
Once the Variable A and Variable B tabs have been completed, the user can populate the response curves table. Figure 5 shows the Response Curves tab for **Coincident Freq Test 16**. The **Different Variable A for Each Index** option was selected. When selected, a separate Variable A column is added for each variable B index value. For example, the first Variable A column is linked to the C = f(A,B1) column. The second variable A column is lined to the C = f(A,B2), and so on. The **Import Variable A** button was pressed to automatically copy values from the Variable A tab to fill in appropriate **Variable A** column. The remaining columns in the table were populated with results from the hydraulics model. For example, the first value in the second column is 473.95. This value is the stage at the point of interest given a flow of 42464 (cfs) on the tributary (variable A) and a flow of 3005.92 (cfs) on the mainstem (variable B). A total of 108 simulations were required from the hydraulics model to fill in the response curves table.



Variable A	B1=3005... C = f(A,B1)	Variable A	B2=8095... C = f(A,B2)	Variable A	B3=1504... C = f(A,B3)	Variable A	B4=2239... C = f(A,B4)	Variable A	B5=3061... C = f(A,B5)	Variable A	B6=4031... C = f(A,B6)	Variable A	B7=5304... C = f(A,B7)	Variable A	B8=7279... C = f(A,B8)	Variable A	B9=1358... C = f(A,B9)
42464.0	473.95	49934.0	476.02	60221.0	479.17	63239.0	480.23	72700.0	485.01	73813.0	485.48	86602.0	490.16	85327.0	489.67	89497.0	490.77
36167.0	472.28	42772.0	474.05	51234.0	476.39	53979.0	477.16	61695.0	479.71	62595.0	480.02	72786.0	485.01	72502.0	484.87	76333.0	486.34
31681.0	471.24	37642.0	472.67	44837.0	474.63	47368.0	475.35	53880.0	477.15	54634.0	477.4	63062.0	480.19	63384.0	480.49	66942.0	482.18
27412.0	470.33	32738.0	471.48	38757.0	472.99	41066.0	473.65	46467.0	475.14	47088.0	475.38	53916.0	477.25	54727.0	477.61	57997.0	479.25
22063.0	468.96	26553.0	470.15	31147.0	471.16	33150.0	471.64	37217.0	472.71	37677.0	472.94	42623.0	474.37	43907.0	474.89	46769.0	476.56
18193.0	467.64	22045.0	469.01	25649.0	469.97	27407.0	470.41	30554.0	471.15	30906.0	471.34	34589.0	472.4	36102.0	473.11	38631.0	474.92
14404.0	466.22	17598.0	467.53	20274.0	468.51	21767.0	469.05	24063.0	469.73	24314.0	469.92	26861.0	470.7	28484.0	471.54	30648.0	473.51
9214.0	464.39	11437.0	465.08	12928.0	465.93	14008.0	466.48	15237.0	467.11	15366.0	467.4	16558.0	468.23	18101.0	469.42	19682.0	471.79
5894.0	463.46	7432.0	463.91	8244.0	464.14	9015.0	464.58	9648.0	465.08	9711.0	465.49	10207.0	466.32	11502.0	467.89	12639.0	470.86
4666.0	463.05	5933.0	463.48	6516.0	463.66	7160.0	463.91	7598.0	464.29	7640.0	464.76	7927.0	465.62	9075.0	467.31	10027.0	470.55
3848.0	462.74	4926.0	463.15	5366.0	463.3	5920.0	463.5	6238.0	463.8	6267.0	464.27	6433.0	465.19	7462.0	466.95	8283.0	470.35
2680.0	462.22	3475.0	462.59	3728.0	462.69	4143.0	462.86	4309.0	463.06	4322.0	463.62	4348.0	464.6	5169.0	466.49	5787.0	470.11

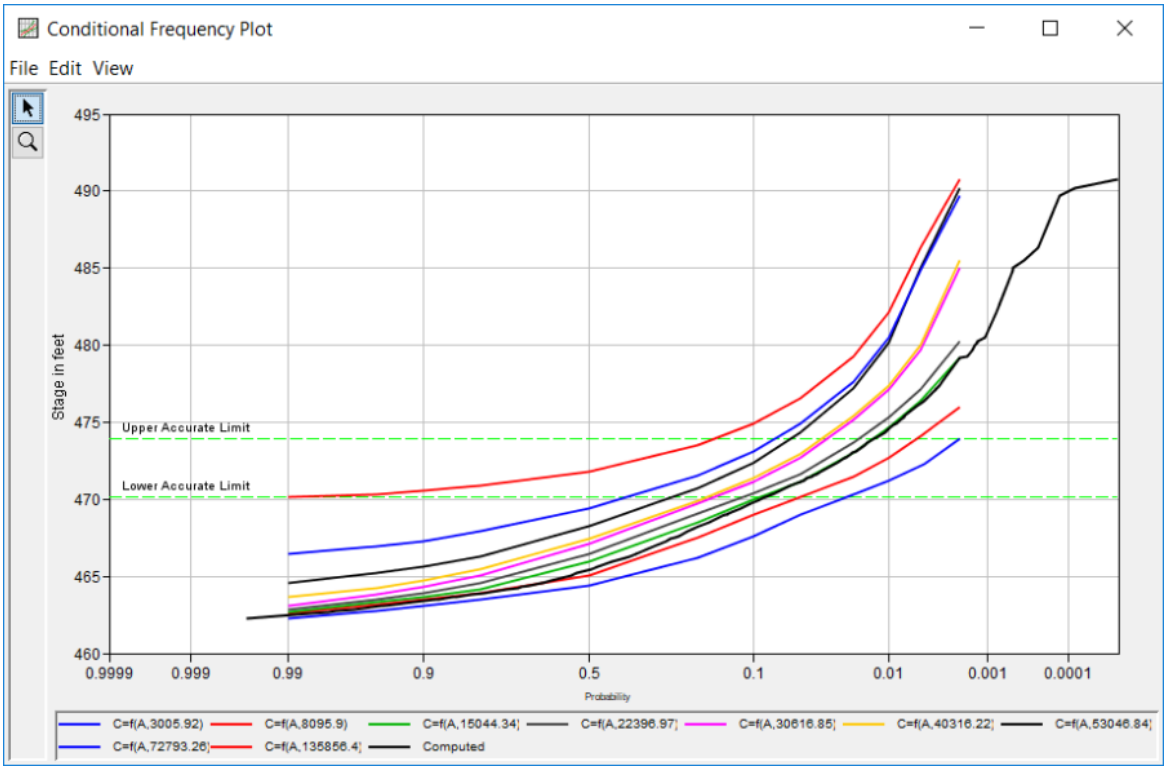
140 Figure 5. Response Curves Tab for Coincident Freq Test 16

Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The **Results** tab should resemble Figure 6. The left portion of the results tab contains the computed variable C frequency curve and the right portion of the results tab contains a plot of the computed variable C frequency curve.



141 Figure 6. Results Tab for Coincident Freq Test 16

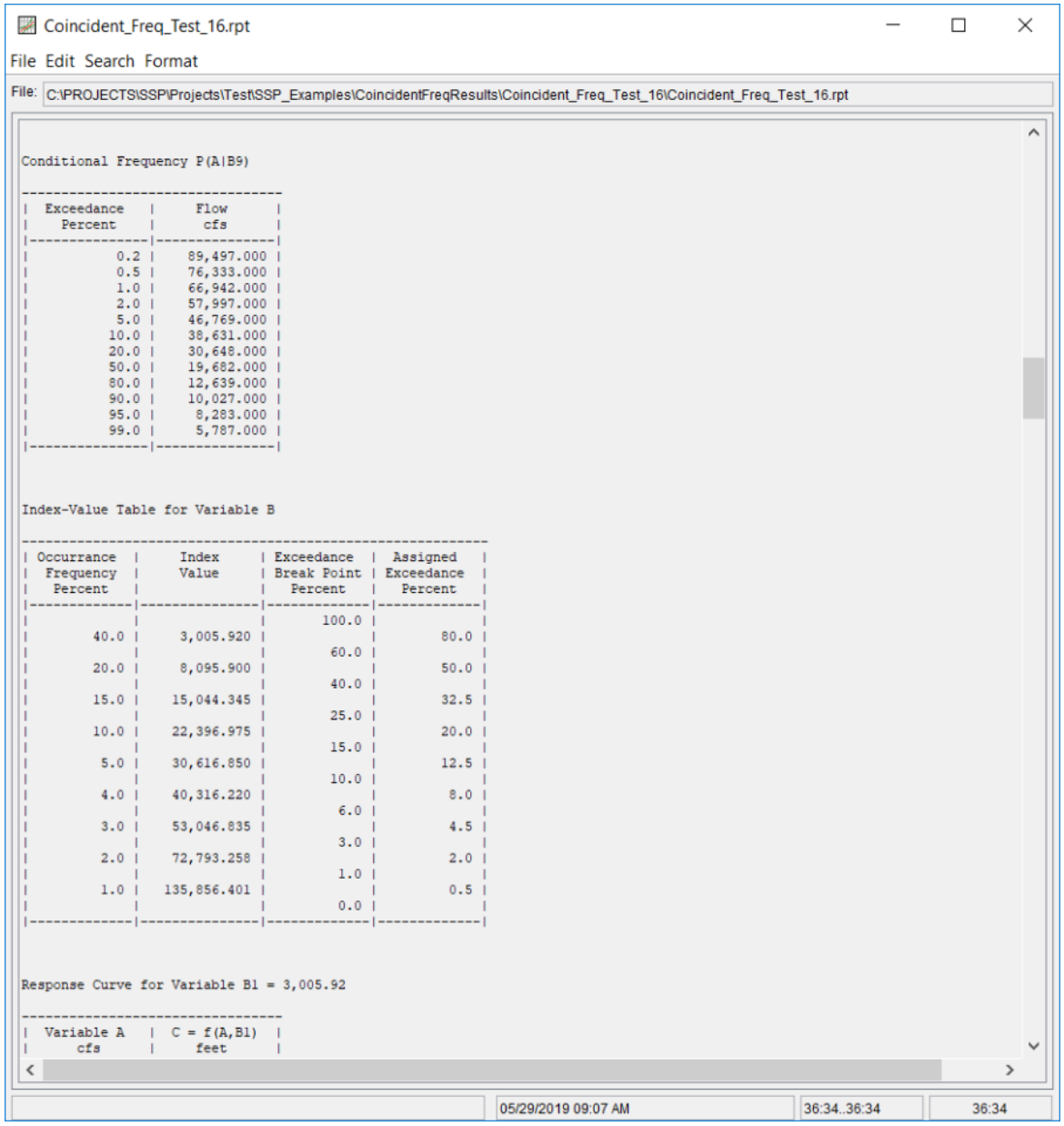
By pressing the **Plot Condition Frequency Curves**, the user can plot the response curves entered on the **Response Curves** tab along with the computed curve and the upper and lower accurate limits, as shown in Figure 7.



142 Figure 7. Conditional Frequency Curves for Coincident Freq Test 16

The tabular and graphical results can be sent to the printer or the windows clipboard for transfer into another piece of software. To print the tabular results, select **Print** from the bottom of the analysis window. To send the tabular results to the windows clipboard, highlight the data you want to send to the clipboard and then press the Control-C key sequence. To print the graphical results, first bring up the graphical plot by pressing the **Plot** button from the bottom of the analysis. Then select **Print** from the **File** menu. To send the graphic to the windows clipboard, select **Copy to Clipboard** from the **File** menu.

In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 8 is the report file for **Coincident Freq Test 16**.

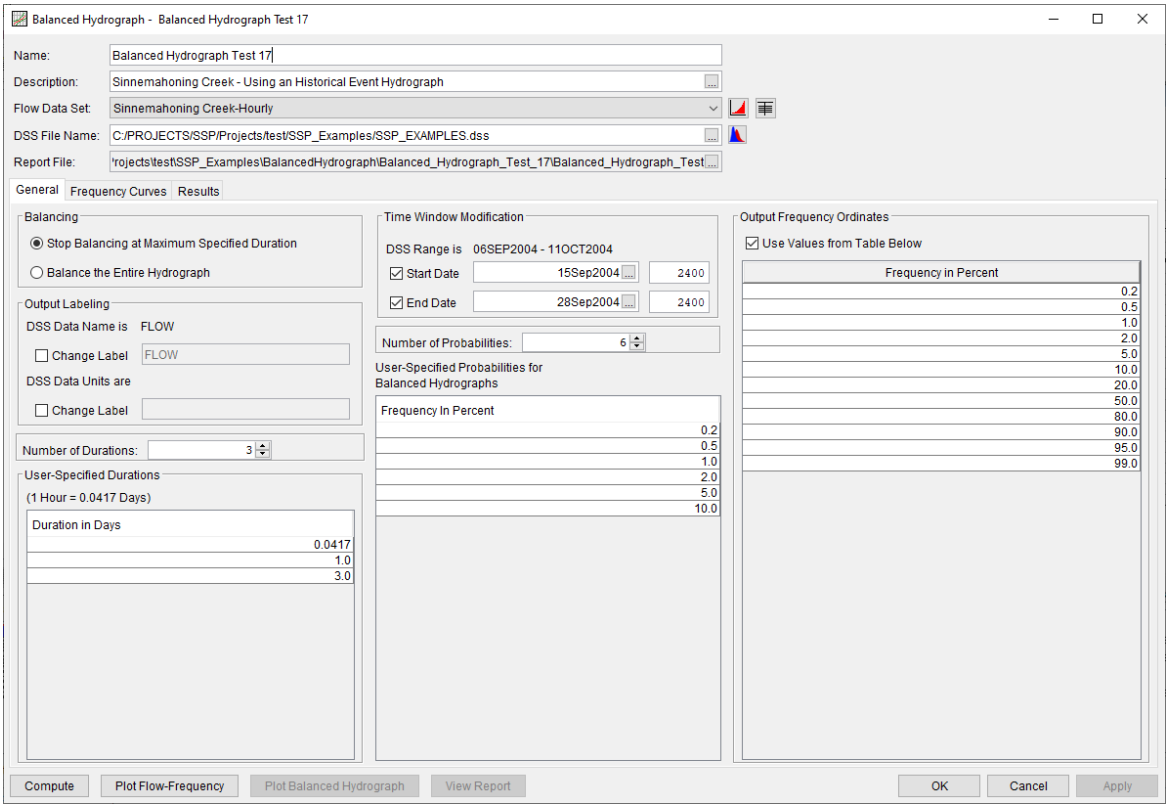


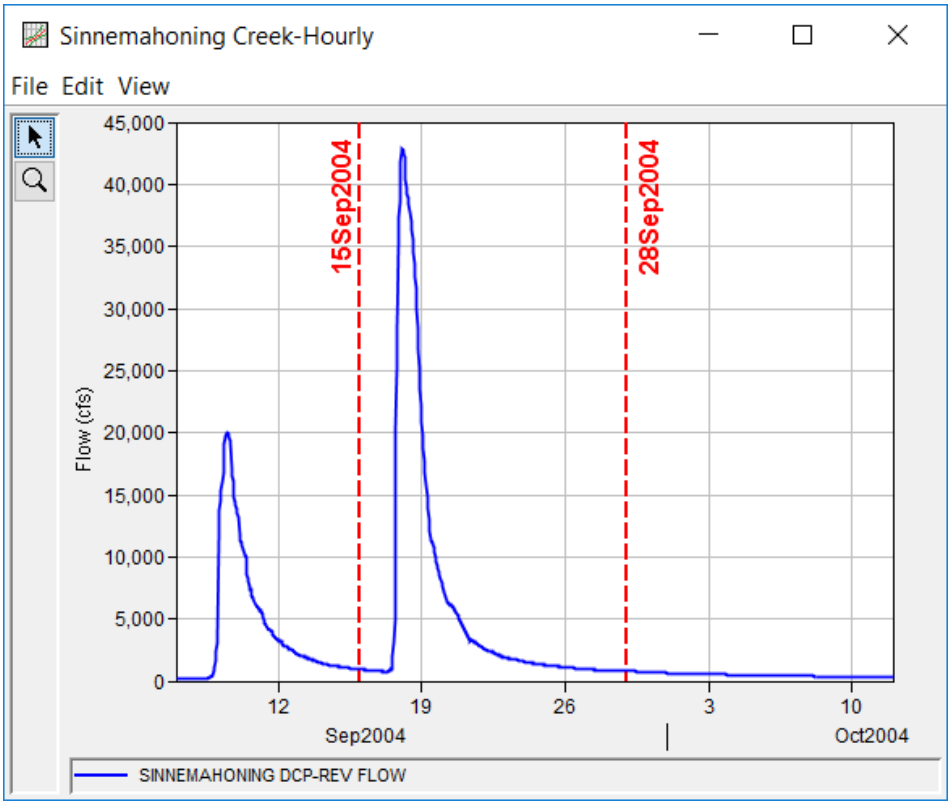
143 Figure 8. Report File for Coincident Freq Test 16

9 Balanced Hydrograph Analysis Examples

9.1 Example 17. Balanced Hydrograph Analysis, Using an Historical Event Hydrograph

This example demonstrates how to create a **Balanced Hydrograph** analysis using an historical event hydrograph shape. In this example, information from previously-computed Bulletin 17 and Volume Frequency analyses will be used along with an historical event to create numerous balanced hydrographs which are "balanced" across multiple durations. A Balanced Hydrograph analysis has been developed for this example. To open the Balanced Hydrograph analysis editor for this example, either double-click on the analysis labeled **Balanced Hydrograph Test 17** from the study explorer, or from the **Analysis** menu select open, then select **Balanced Hydrograph Test 17** from the list of available analyses. When the analysis is opened, the Balanced Hydrograph Analysis editor will appear as shown in Figure 1 (see page 292).
Shown in Figure 1 (see page 292) are the general settings for this balanced hydrograph analysis. The Number of Durations was set to three: 0.0417-days (1-hour), 1-day, and 3-days. These three durations are those which will be used to "balance" throughout the analysis. The Time Window was set to 15Sep2004 24:00 through 28Sep2004 24:00, which corresponded to the passage of the remnants of Tropical Storm Ivan, as shown in Figure 2 (see page 292). The number of probabilities was set to six: 0.2, 0.5, 1, 2, 5, and 10 percent frequencies. Using six probabilities will result in the creation of six balanced hydrographs. The frequency ordinates were left as the default values.





Shown in Figure 3 (see page 292) is the Balanced Hydrograph analysis editor with the **Frequency Curves** tab selected. The frequency curve for Frequency Curve 1 (1-hour or 0.0417-day duration) was imported from the results of an existing Bulletin 17 analysis (Sinnemahoning_B17C). The frequency curve for Frequency Curve 2 (1-day duration) was imported from the results of an existing Volume Frequency analysis (Sinnemahoning_VolumeFrequency). The frequency curve for Frequency Curve 3 (3-day duration) was imported from the results of an existing Volume Frequency analysis (Sinnemahoning_VolumeFrequency). For the 1- and 3-day durations, which were imported from a Volume Frequency Analysis, the program automatically imported the results for the correct duration(s). It should be noted that if the selected Volume Frequency Analysis did not contain the necessary duration information, a message would have been shown informing the user of the error.

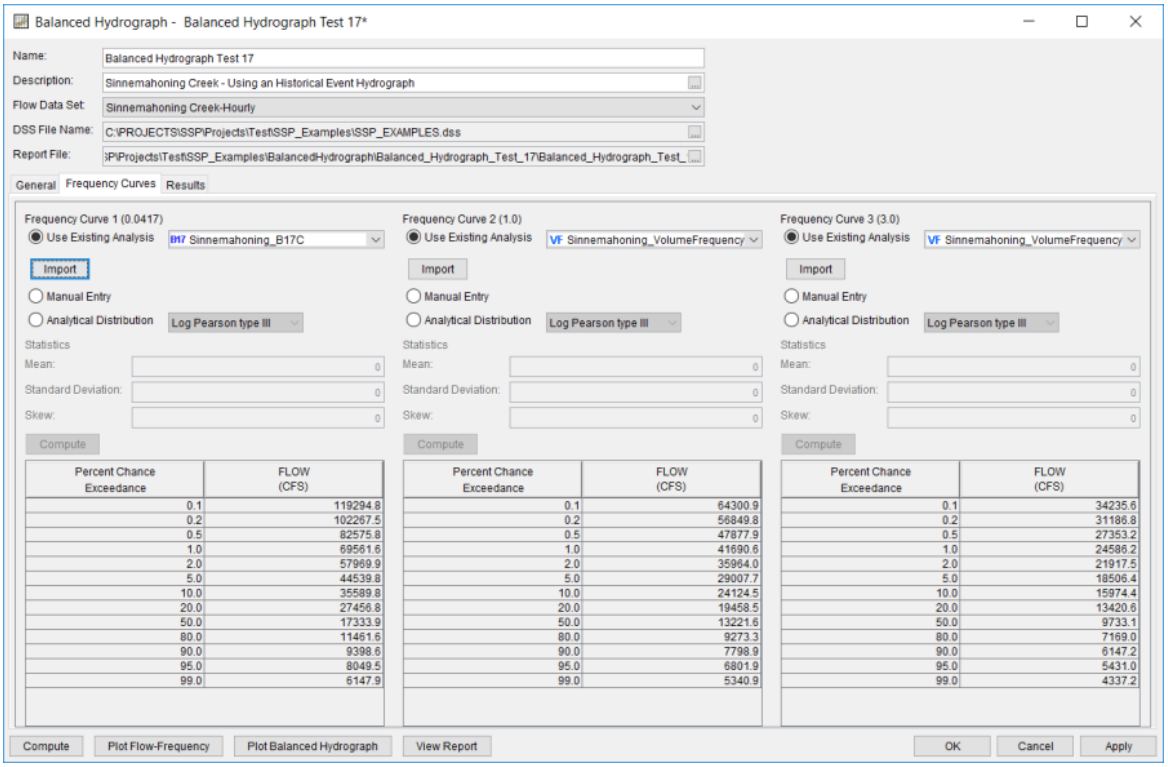
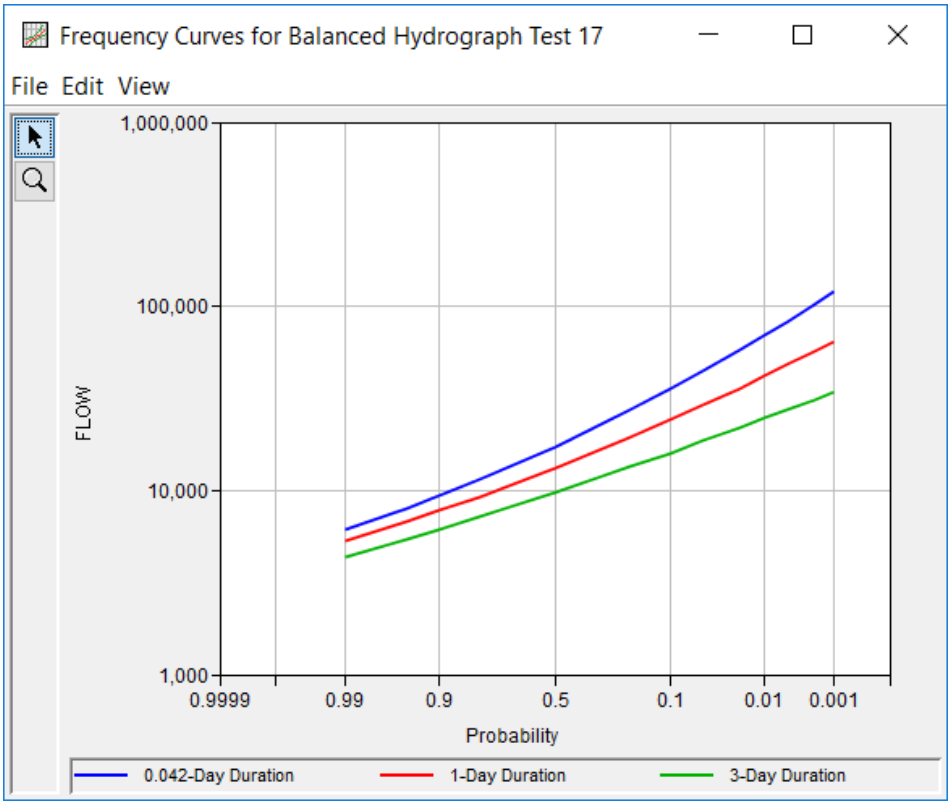
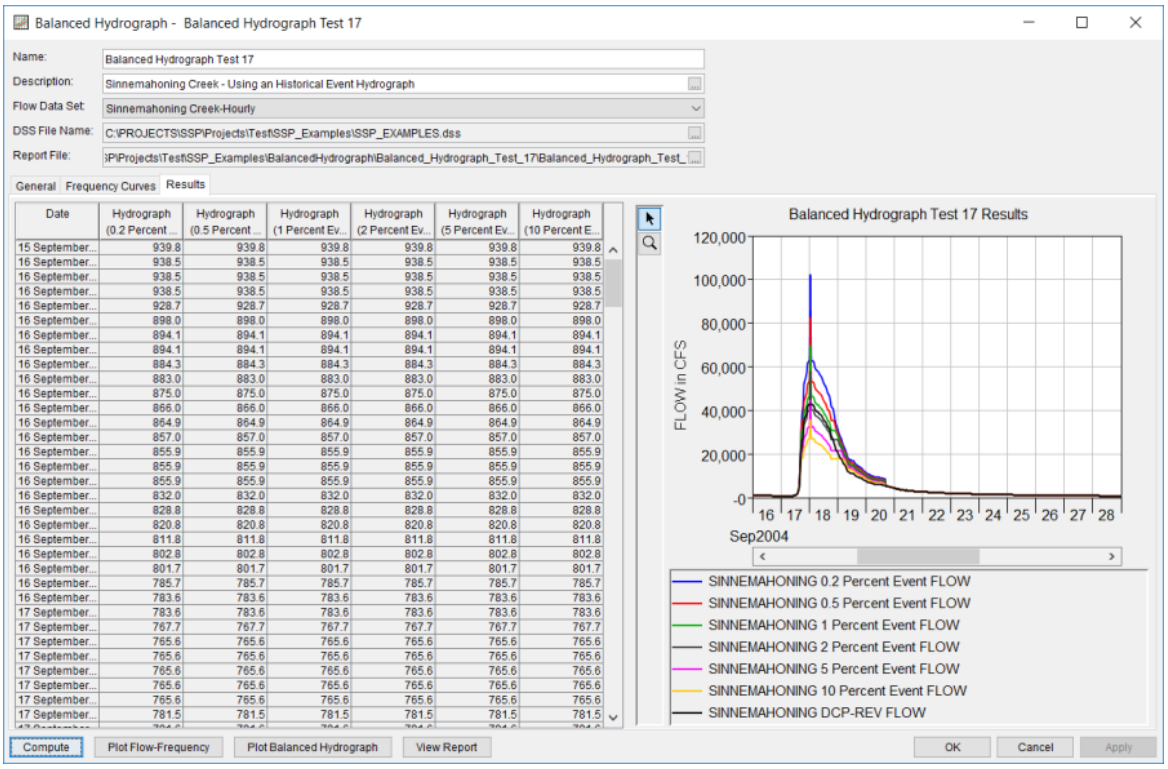


Figure 4 (see page 293) shows the plotted frequency curves for this analysis.

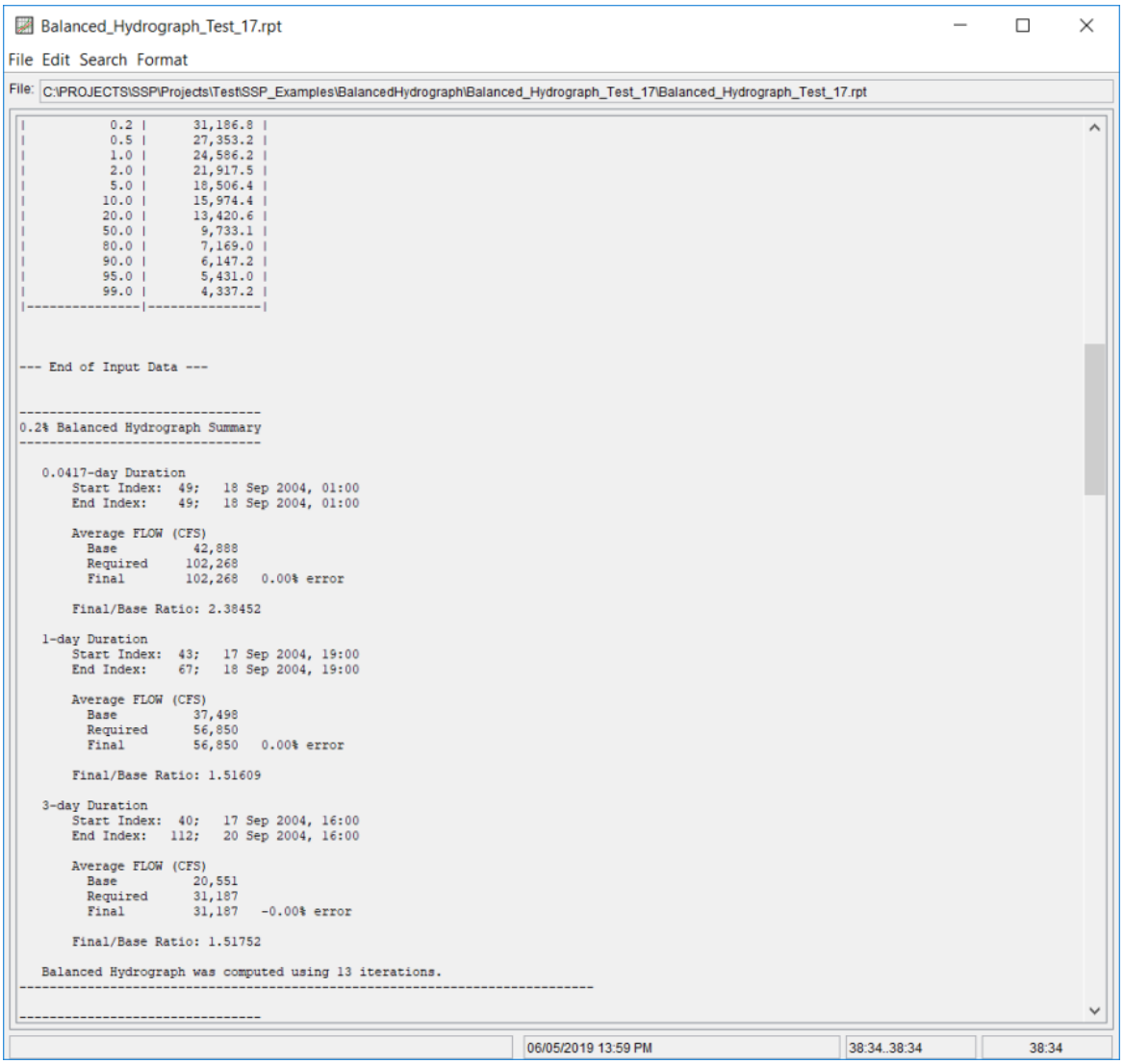


Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The results

tab should resemble Figure 5 (see page 294). The left portion of the Results tab window displays the computed balanced hydrographs in a table using the six frequencies that were previously defined on the General tab. The right portion of the Results tab displays all six balanced hydrographs in a plot. To view the balanced hydrographs in a separate window, either click **Plot Balanced Hydrograph** or double click on the plot within the Results tab.



In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 6 (see page 294) is the report file for **Balanced Hydrograph Test 17**.

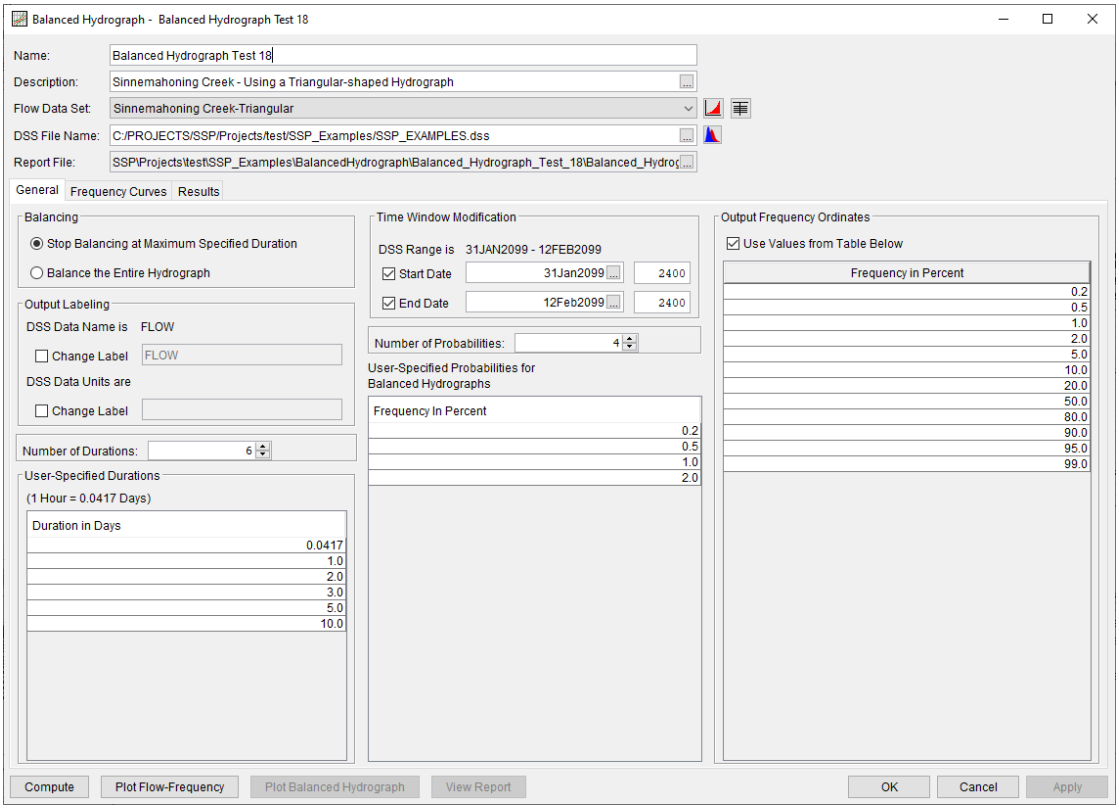


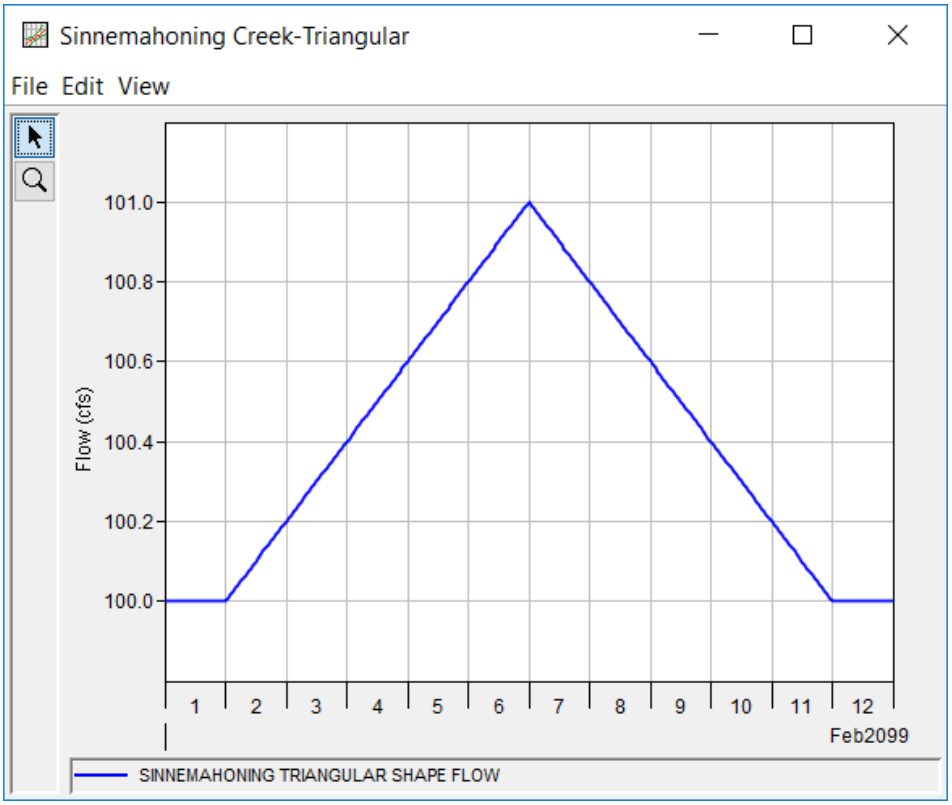
9.2 Example 18. Balanced Hydrograph Analysis, Using a Triangular-shaped Hydrograph

This example demonstrates how to create a **Balanced Hydrograph** analysis using a hypothetical triangular hydrograph shape. In this example, information from previously-computed Bulletin 17 and Volume Frequency analyses will be used along with a hypothetical triangular-shaped template hydrograph to create numerous balanced hydrographs which are "balanced" across multiple durations. A Balanced Hydrograph analysis has been developed for this example. To open the Balanced Hydrograph analysis editor for **Balanced Hydrograph Test 18**, either double-click on the analysis labeled **Balanced Hydrograph Test 18** from the study explorer, or from the **Analysis** menu select open, then select **Balanced Hydrograph Test 18** from the list of available analyses. When the analysis is opened, the Balanced Hydrograph Analysis editor will appear as shown in Figure 1 (see page 296).

Shown in Figure 1 (see page 296) are the general settings for this balanced hydrograph analysis. The Number of Durations was set to six: 0.0417-days (1-hour), 1-day, 2-days, 3-days, 5-days, and 10-days. These six

durations are those which will be used to "balance" throughout the analysis. The DSS Range was set to 31Jan2099 through 12Feb2099, which is used to signify the hypothetical nature of the triangular hydrograph shape. This triangular hydrograph was created using HEC-DSSVue and initially starts at 100 cfs and increases to a peak of 101 cfs and then decreases to 100 cfs over the course of 10 days, as shown in Figure 2 (see page 0). The number of probabilities was set to four: 0.2, 0.5, 1, and 2 percent frequencies. Using four probabilities will result in the creation of four balanced hydrographs. The frequency ordinates were left as the default values.





Shown in Figure 3 (see page 0) is the Balanced Hydrograph analysis editor with the **Frequency Curves** tab selected. The frequency curve for Frequency Curve 1 (1-hour or 0.0417-day duration) was imported from the results of an existing Bulletin 17 analysis (Sinnemahoning_B17C). The frequency curves for Frequency Curve 2 (1-day duration), Frequency Curve 3 (2-day duration), Frequency Curve 4 (3-day duration), Frequency Curve 5 (5-day duration), and Frequency Curve 6 (10-day duration) were imported from the results of an existing Volume Frequency analysis (Sinnemahoning_VolumeFrequency). For the 1-, 2-, 3-, 5-, and 10-day durations, which were imported from a Volume Frequency Analysis, the program automatically imported the results for the correct duration(s). It should be noted that if the selected Volume Frequency Analysis did not contain the necessary duration information, a message would have been shown informing the user of the error.

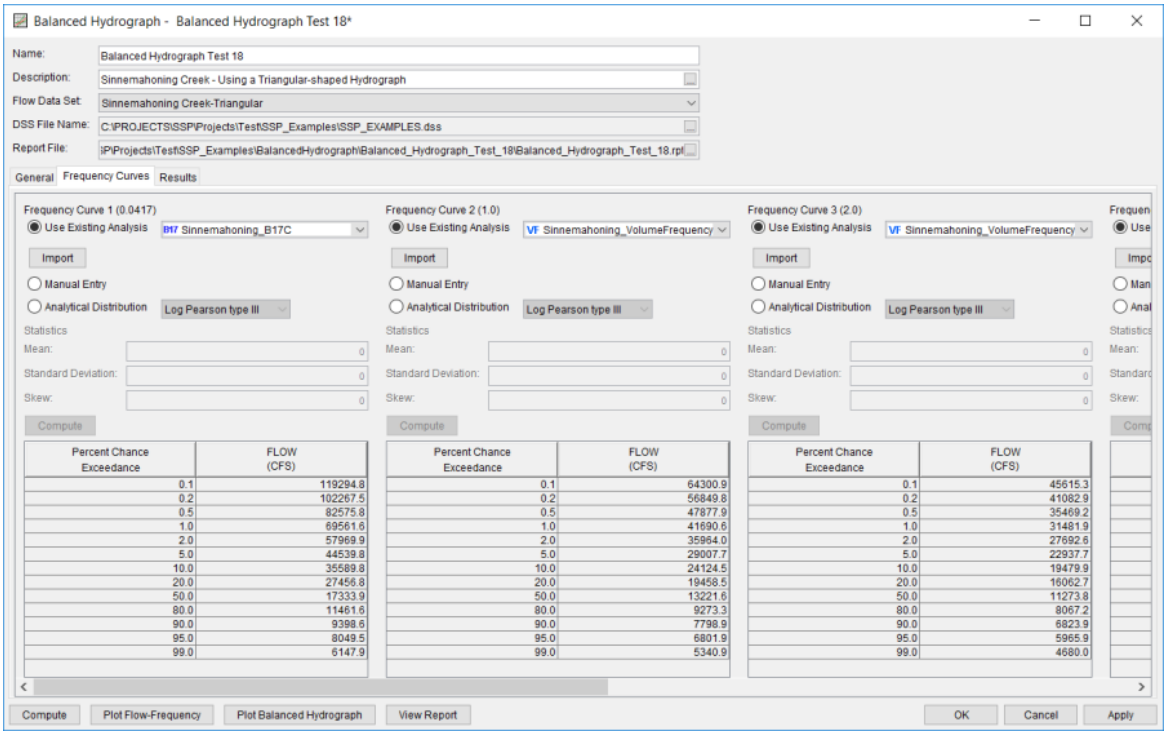
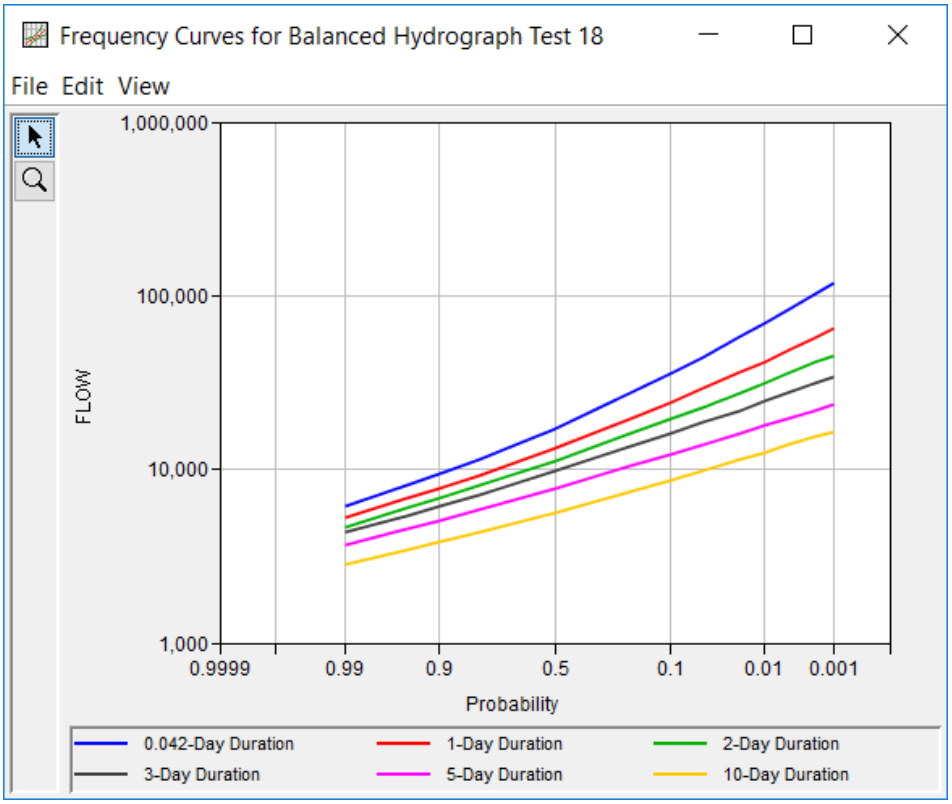
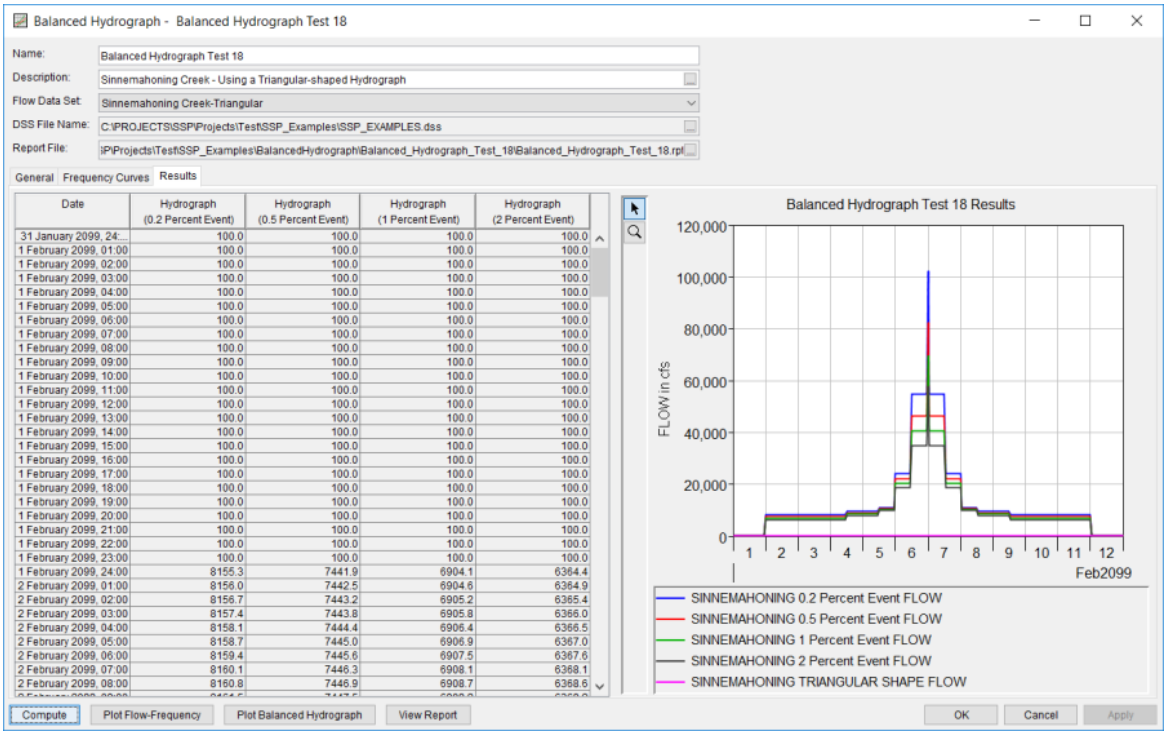


Figure 4 (see page 298) shows the plotted frequency curves for this analysis.

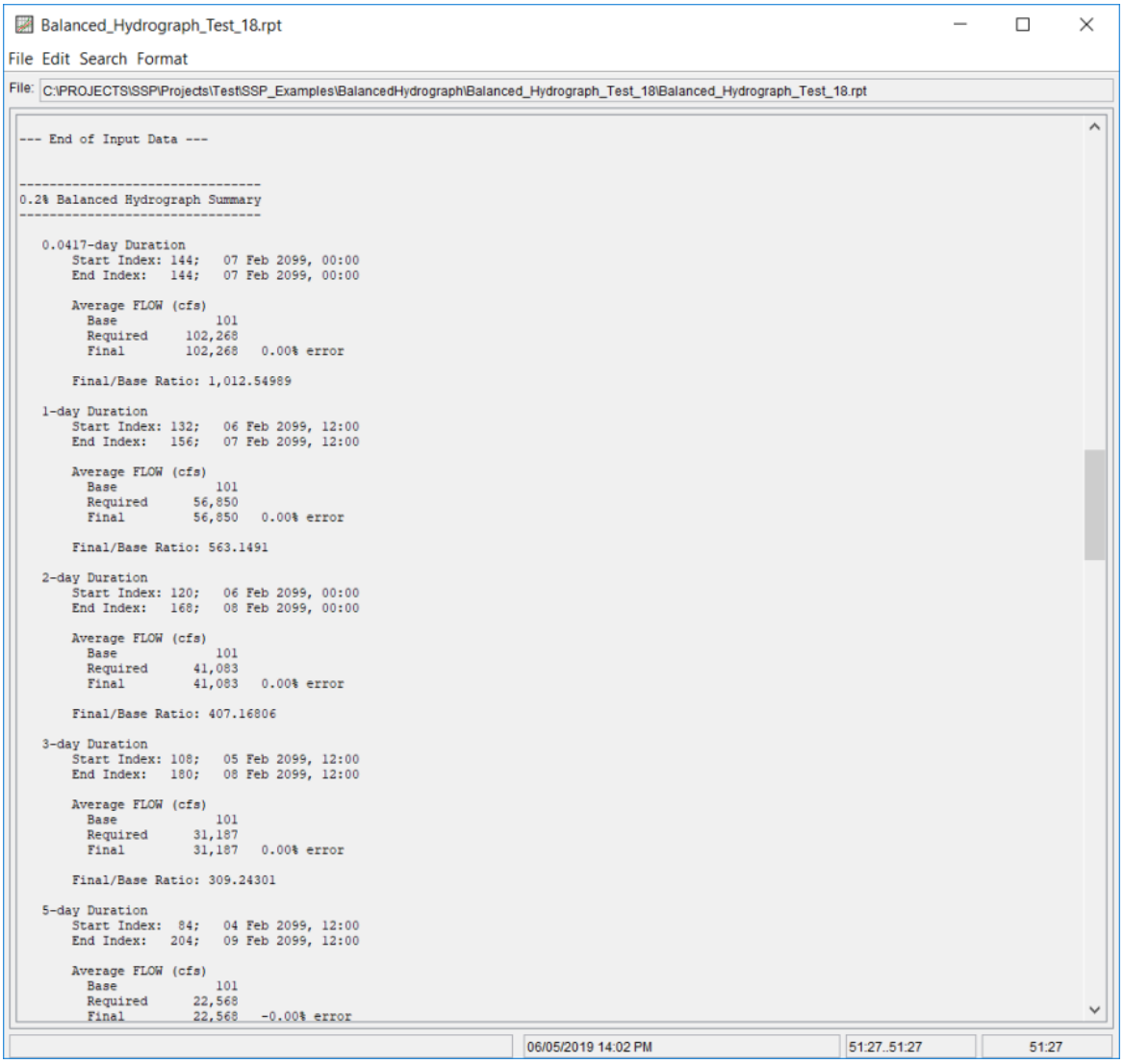


Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The results tab should resemble Figure 5 (see page 298). The left portion of the Results tab window displays the computed

balanced hydrographs in a table using the four frequencies that were previously defined on the General tab. The right portion of the Results tab displays all four balanced hydrographs in a plot. To view the balanced hydrographs in a separate window, either click **Plot Balanced Hydrograph** or double click on the plot within the Results tab.



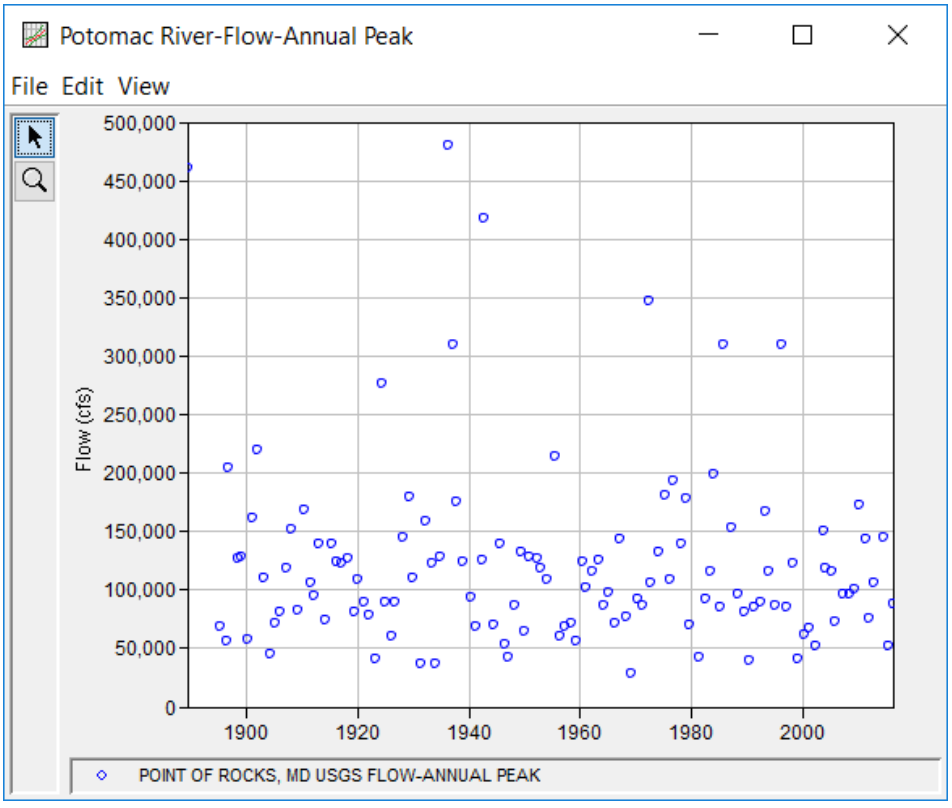
In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 6 (see page 299) is the report file for **Balanced Hydrograph Test 18**.


Balanced_Hydrograph_Test_18.rpt
File Edit Search Format
File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\BalancedHydrograph\Balanced_Hydrograph_Test_18\Balanced_Hydrograph_Test_18.rpt
--- End of Input Data ---
0.2% Balanced Hydrograph Summary
0.0417-day Duration
Start Index: 144; 07 Feb 2099, 00:00
End Index: 144; 07 Feb 2099, 00:00
Average FLOW (cfs)
Base 101
Required 102,268
Final 102,268 0.00% error
Final/Base Ratio: 1,012.54989
1-day Duration
Start Index: 132; 06 Feb 2099, 12:00
End Index: 156; 07 Feb 2099, 12:00
Average FLOW (cfs)
Base 101
Required 56,850
Final 56,850 0.00% error
Final/Base Ratio: 563.1491
2-day Duration
Start Index: 120; 06 Feb 2099, 00:00
End Index: 168; 08 Feb 2099, 00:00
Average FLOW (cfs)
Base 101
Required 41,083
Final 41,083 0.00% error
Final/Base Ratio: 407.16806
3-day Duration
Start Index: 108; 05 Feb 2099, 12:00
End Index: 180; 08 Feb 2099, 12:00
Average FLOW (cfs)
Base 101
Required 31,187
Final 31,187 0.00% error
Final/Base Ratio: 309.24301
5-day Duration
Start Index: 84; 04 Feb 2099, 12:00
End Index: 204; 09 Feb 2099, 12:00
Average FLOW (cfs)
Base 101
Required 22,568
Final 22,568 -0.00% error
06/05/2019 14:02 PM
51:27..51:27
51:27

10 Distribution Fitting Analysis Examples

10.1 Example 20. Distribution Fitting, Analyzing Model Uncertainty Using a Time Series of Annual Maximum Streamflow

This example demonstrates how to use the Distribution Fitting analysis to analyze model uncertainty (i.e. choice of analytical distribution and fitting method) using a time series of annual maximum streamflow. The data for this example consists of an instantaneous peak annual maximum series of streamflow for a location along the Potomac River near Point of Rocks, MD[46]. This stream gage is operated by the USGS (gage ID: 01638500). The period of record used for this example is from 1889 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Potomac River-Flow-Annual Peak**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1.

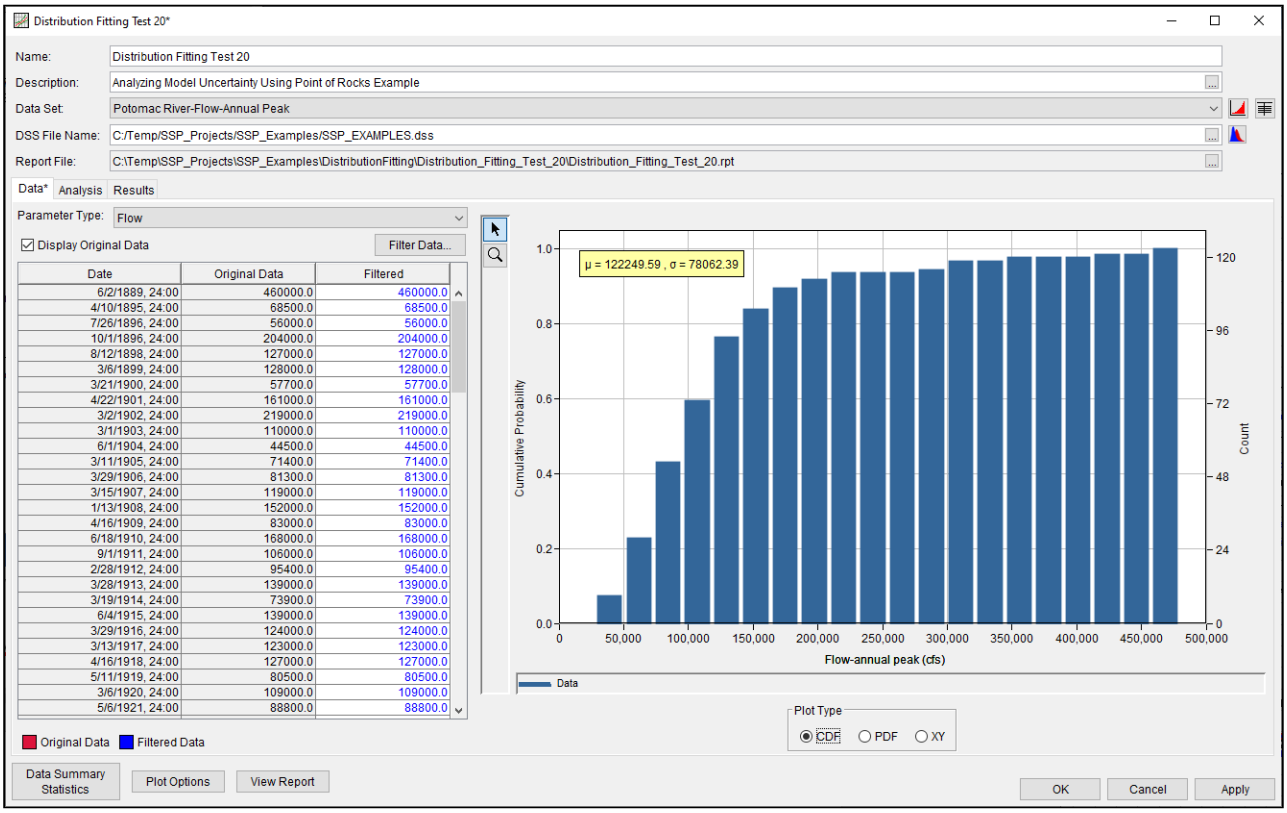


144 Figure 1. Plot of the Peak Flow Data for Point of Rocks.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 20** from

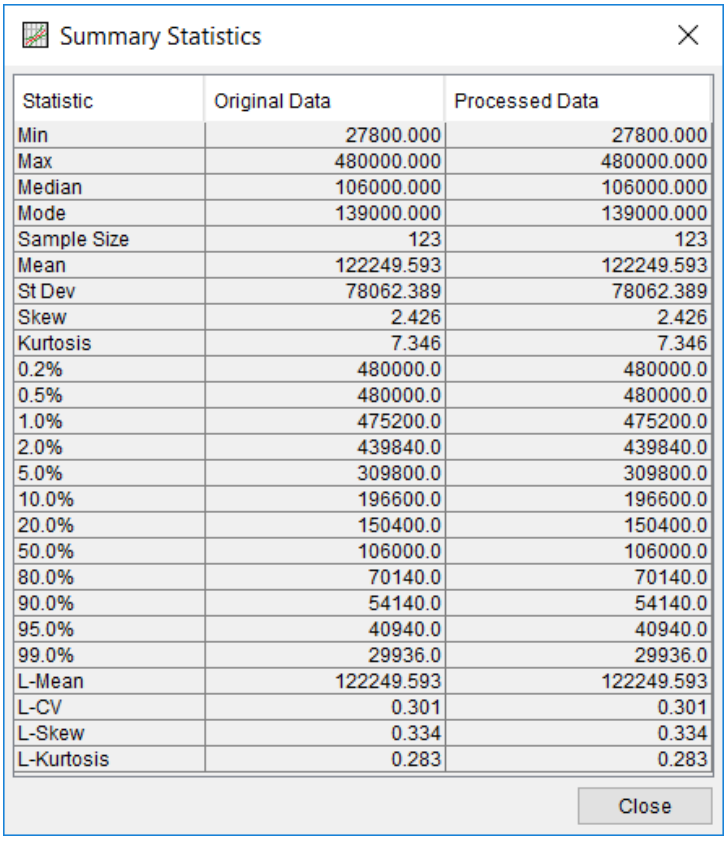
46 https://waterdata.usgs.gov/nwis/uv?site_no=01638500

the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 20** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2.



145 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 20.

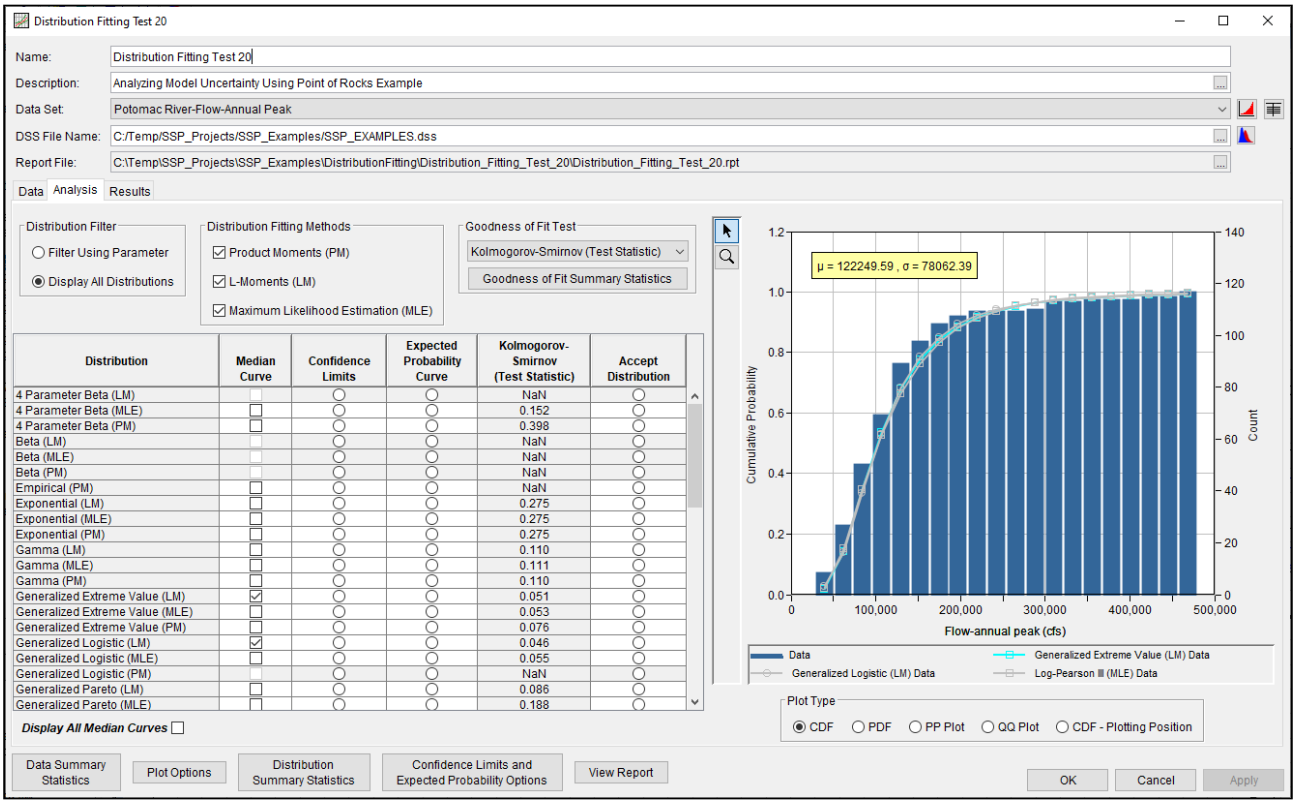
For this analysis, the instantaneous peak streamflow data was used without modifications. Summary statistics of the data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 3.



Statistic	Original Data	Processed Data
Min	27800.000	27800.000
Max	480000.000	480000.000
Median	106000.000	106000.000
Mode	139000.000	139000.000
Sample Size	123	123
Mean	122249.593	122249.593
St Dev	78062.389	78062.389
Skew	2.426	2.426
Kurtosis	7.346	7.346
0.2%	480000.0	480000.0
0.5%	480000.0	480000.0
1.0%	475200.0	475200.0
2.0%	439840.0	439840.0
5.0%	309800.0	309800.0
10.0%	196600.0	196600.0
20.0%	150400.0	150400.0
50.0%	106000.0	106000.0
80.0%	70140.0	70140.0
90.0%	54140.0	54140.0
95.0%	40940.0	40940.0
99.0%	29936.0	29936.0
L-Mean	122249.593	122249.593
L-CV	0.301	0.301
L-Skew	0.334	0.334
L-Kurtosis	0.283	0.283

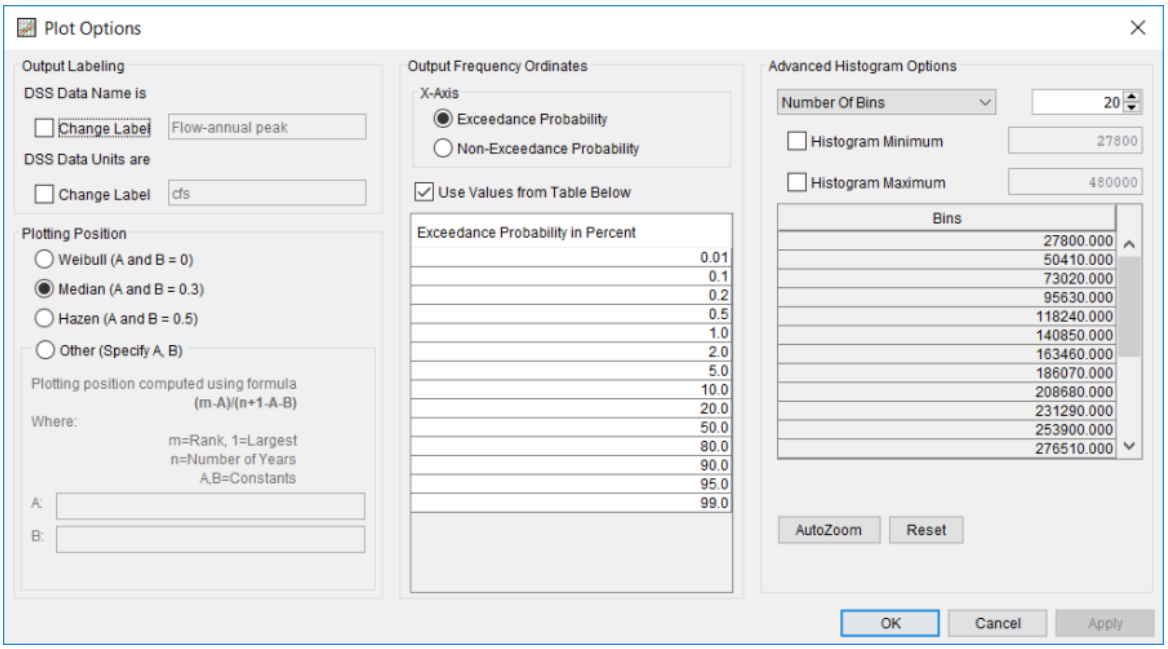
146 Figure 3. Data Summary Statistics for Distribution Fitting Test 20.

On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 4, the **Display All Distributions** radio button was selected within the Distribution Filter panel. The Product Moments, L-Moments, and Maximum Likelihood Estimation methods were selected in the Distribution Fitting Methods panel. The **Kolmogorov-Smirnov** test statistics was selected in the Goodness of Fit Test panel. Select distributions were selected in the list of available distributions, Generalized Extreme Value (LM), Generalized Logistic (LM), and Log-Pearson III (MLE).



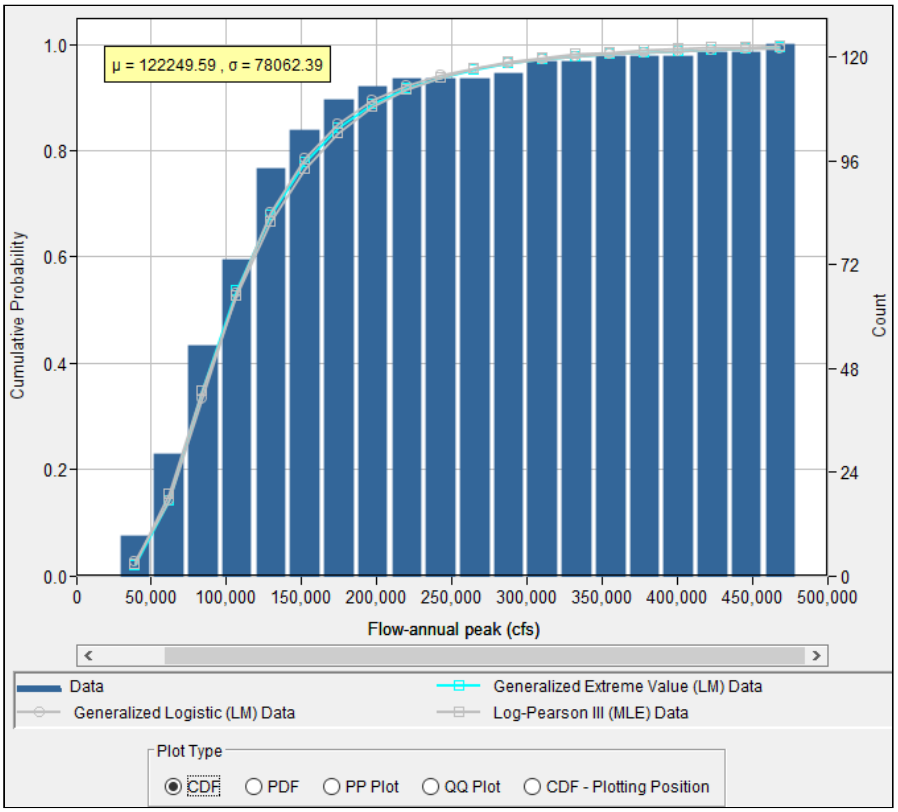
147 Figure 4. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 20.

Additional output frequency ordinates were specified by clicking on the **Plot Options** button and adding them within the **Output Frequency Ordinates** panel, as shown in Figure 5.

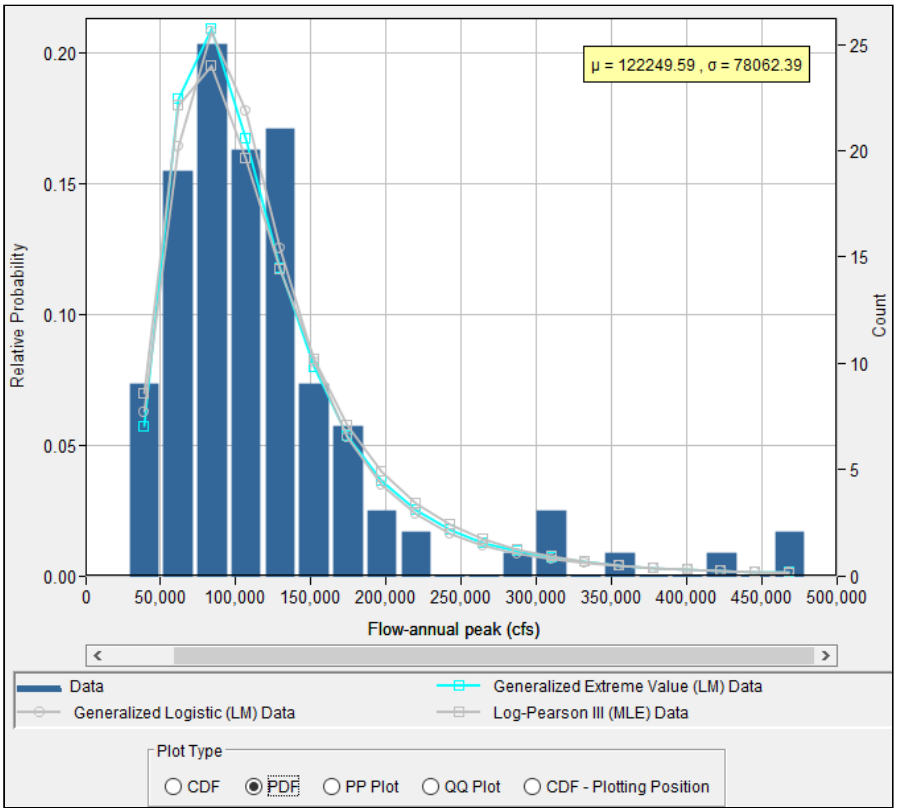


148 Figure 5. Plot Options for Distribution Fitting Test 20.

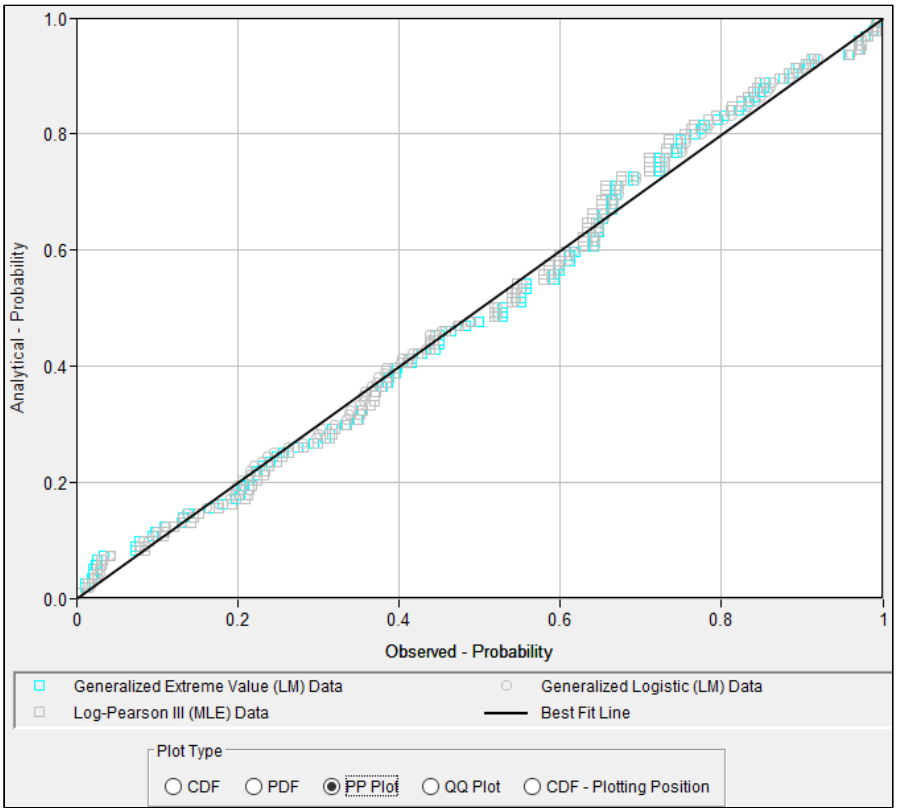
CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing the selected distributions are shown in Figure 6, Figure 7, Figure 8, Figure 9, and Figure 10.



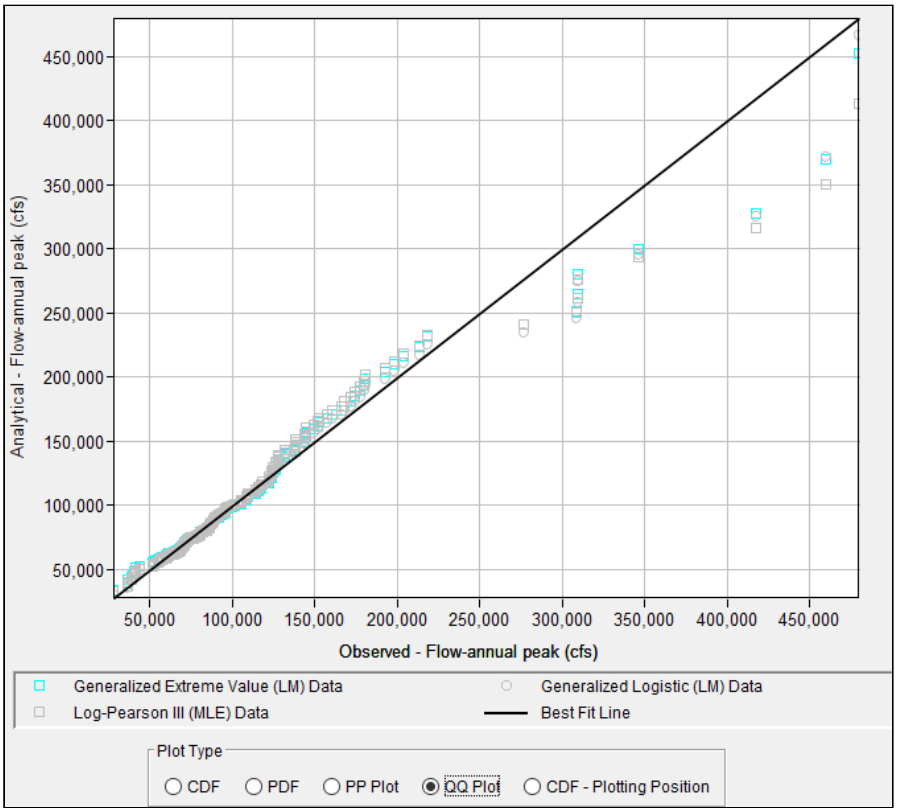
149 Figure 6. CDF Plot for Distribution Fitting Test 20.



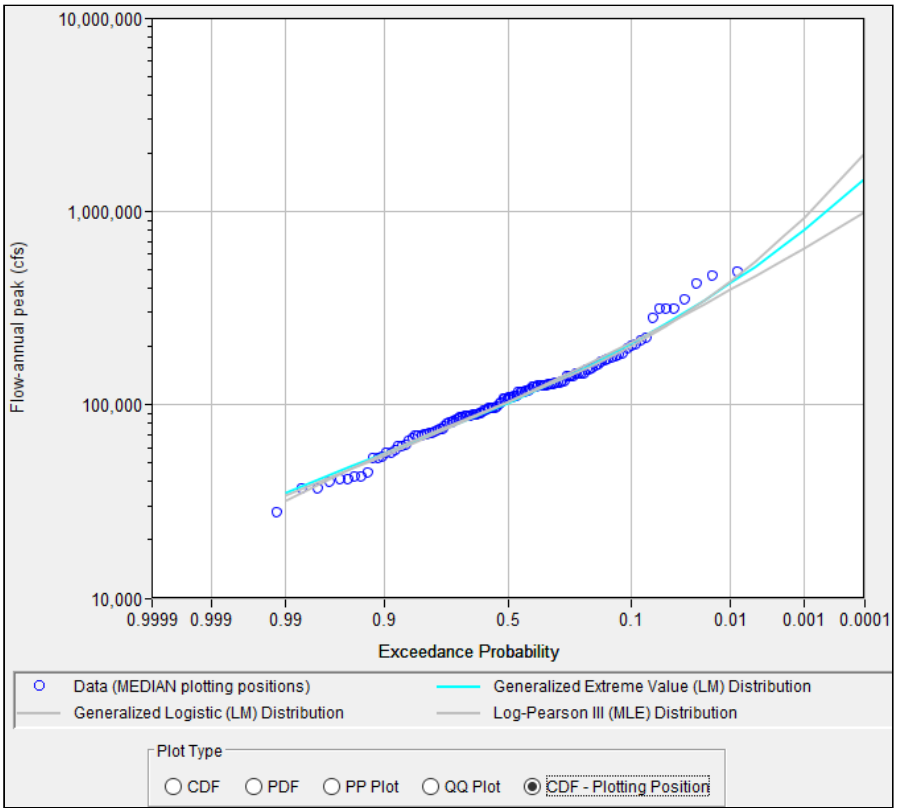
150 Figure 7. PDF Plot for Distribution Fitting Test 20.



151 Figure 8. PP Plot for Distribution Fitting Test 20.

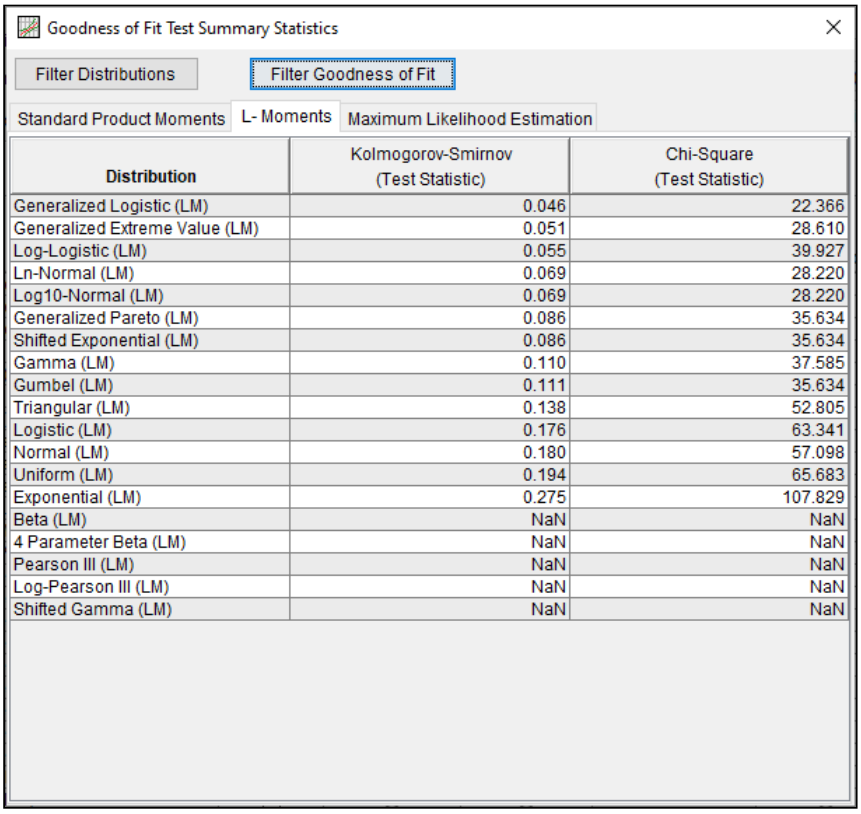


152 Figure 9. QQ Plot for Distribution Fitting Test 20.



153 Figure 10. CDF-Plotting Position Plot for Distribution Fitting Test 20.

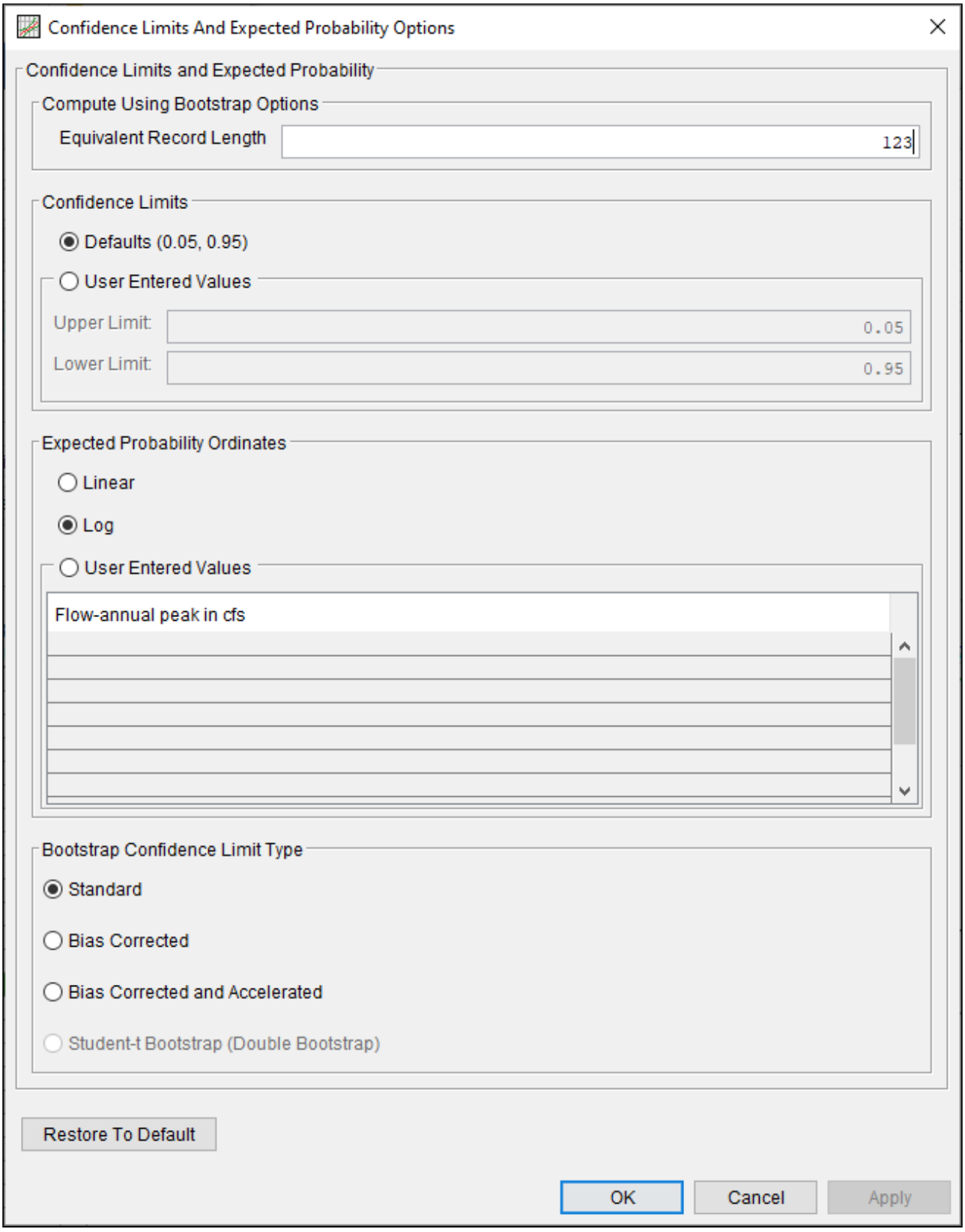
Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 11.



Distribution	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Generalized Logistic (LM)	0.046	22.366
Generalized Extreme Value (LM)	0.051	28.610
Log-Logistic (LM)	0.055	39.927
Ln-Normal (LM)	0.069	28.220
Log10-Normal (LM)	0.069	28.220
Generalized Pareto (LM)	0.086	35.634
Shifted Exponential (LM)	0.086	35.634
Gamma (LM)	0.110	37.585
Gumbel (LM)	0.111	35.634
Triangular (LM)	0.138	52.805
Logistic (LM)	0.176	63.341
Normal (LM)	0.180	57.098
Uniform (LM)	0.194	65.683
Exponential (LM)	0.275	107.829
Beta (LM)	NaN	NaN
4 Parameter Beta (LM)	NaN	NaN
Pearson III (LM)	NaN	NaN
Log-Pearson III (LM)	NaN	NaN
Shifted Gamma (LM)	NaN	NaN

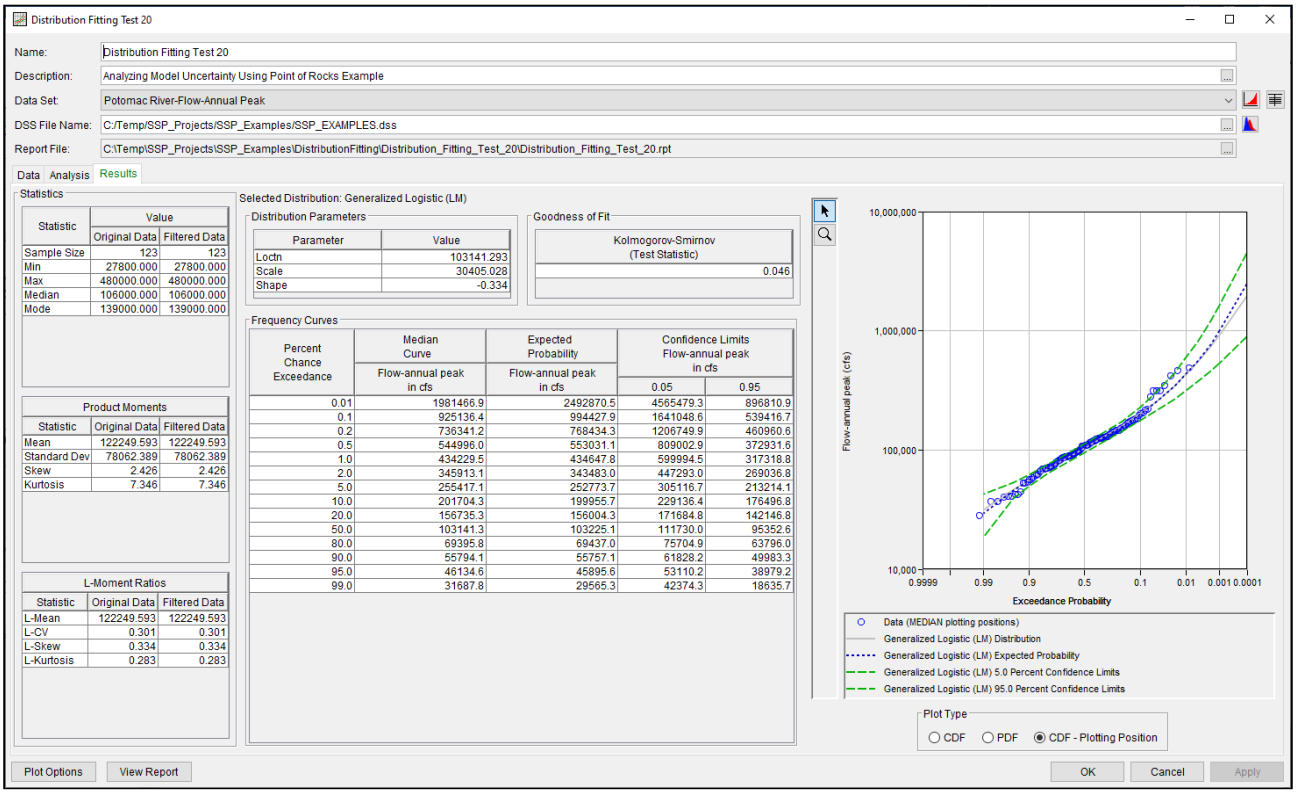
154 Figure 11. Goodness of Fit Summary Statistics for Distribution Fitting Test 20.

In this example, select the Accept Distribution button for the Generalized Logistic Distribution fit using L-Moments. Upon clicking this button, confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. However, the default confidence limits and expected probability options were modified by clicking on the **Plot Options** and **Confidence Limits and Expected Probability Options** buttons near the bottom of the Distribution Fitting editor. Specifically, the **Log** option was selected within the **Expected Probability Ordinates** panel (which computes the expected probability curve using log base 10 values), the **Standard** Bootstrap Confidence Limit Type Method was selected, as shown in Figure 12. Upon clicking the **OK** button, updated confidence limits and an expected probability curve were recomputed.



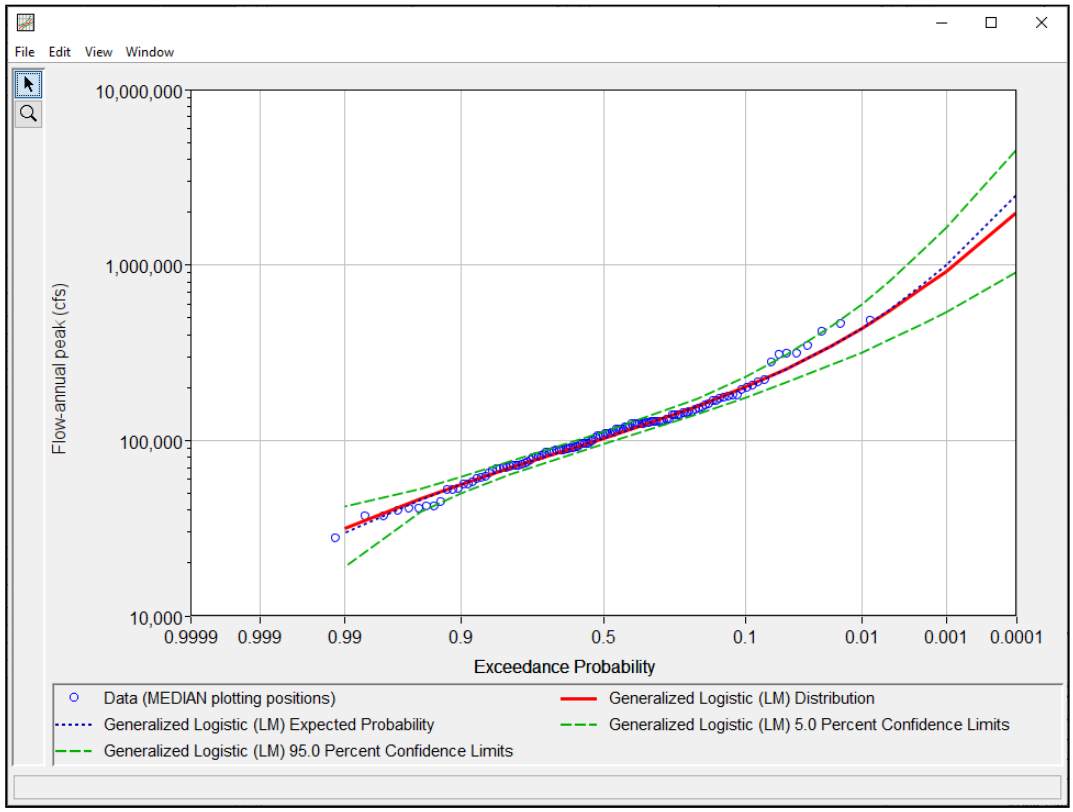
155 Figure 12. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 20.

The accepted distribution | fitting method was used to populate the **Results** tab, as shown in Figure 13.



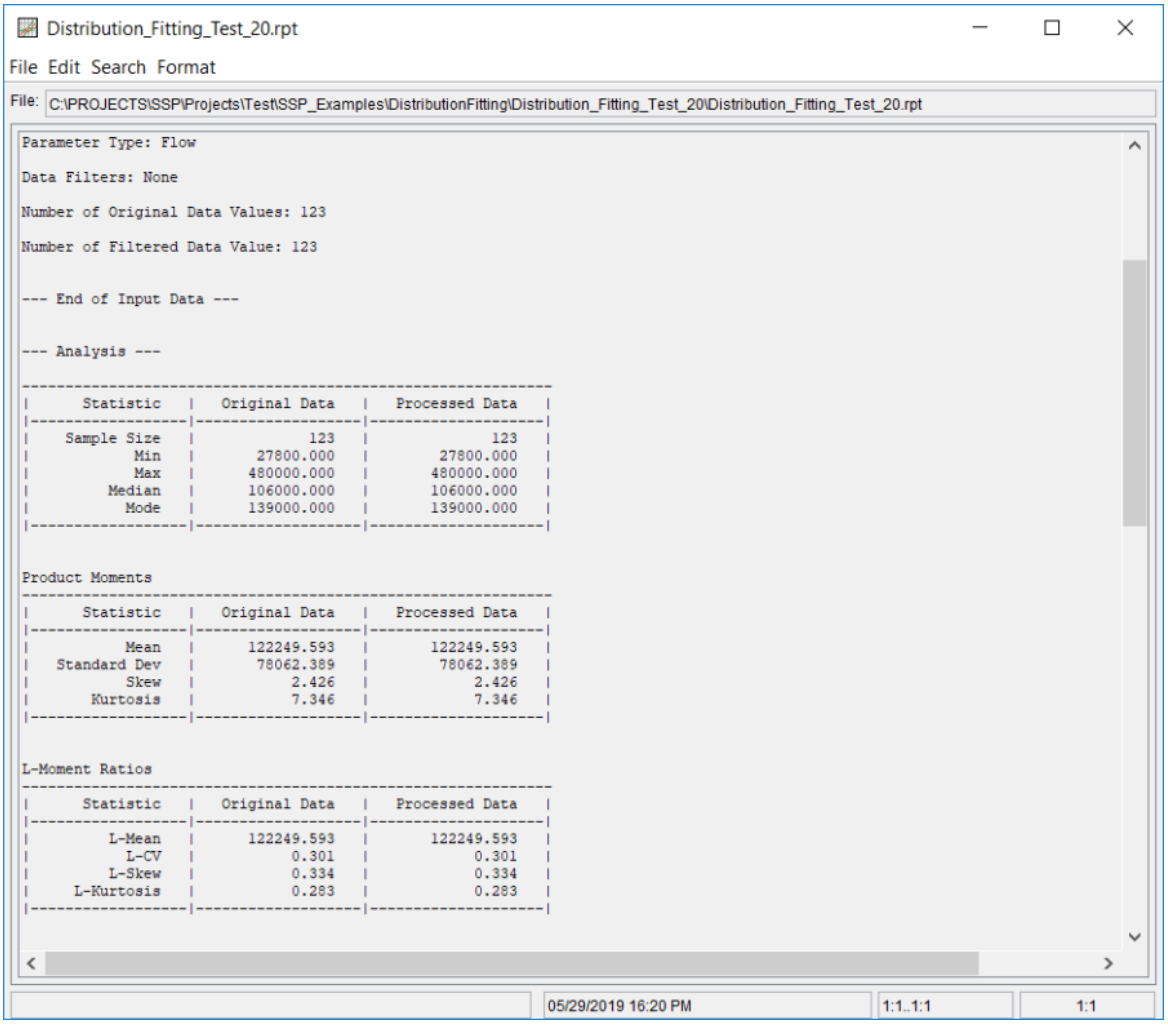
156 Figure 13. Distribution Fitting Results Tab Shown for Distribution Fitting Test 20.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 14.



157 Figure 14. Distribution Fitting Plot Shown for Distribution Fitting Test 20.

In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 15.

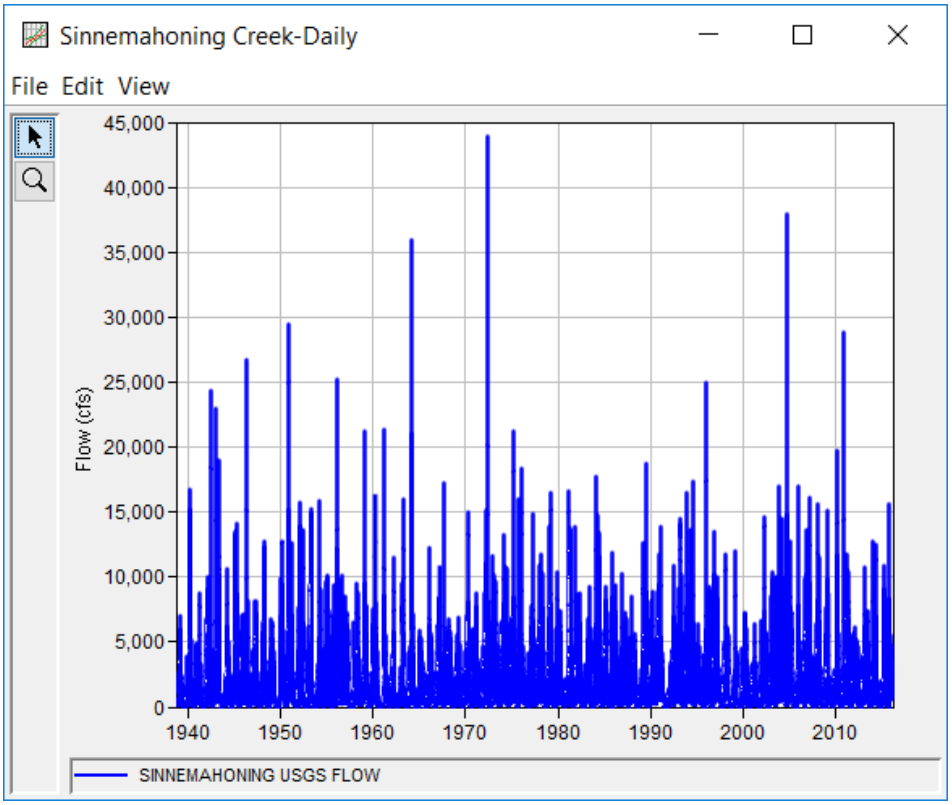


158 Figure 15. Report File for Distribution Fitting Test 20.

10.2 Example 21. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Annual Maxima Filtering

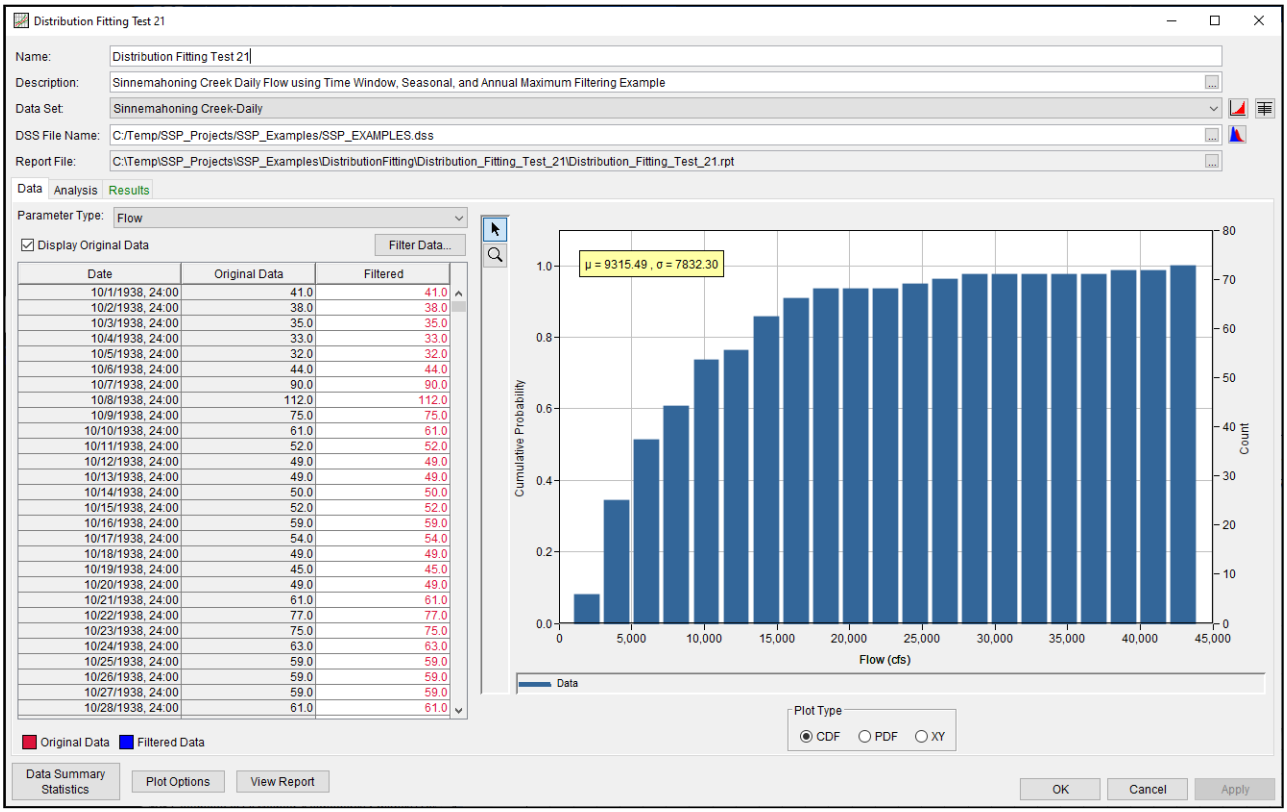
This example demonstrates how to use the Distribution Fitting analysis to analyze a time series of daily average flow using time window, seasonal and annual maxima filtering. The data for this example consists of daily average streamflow for a location along the Sinnemahoning Creek near Sinnemahoning, PA[47]. This stream gage is operated by the USGS (gage ID: 01543500). The period of record used for this example is from 1938 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Sinnemahoning Creek-Daily**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1.

47 https://waterdata.usgs.gov/nwis/uv?site_no=01543500



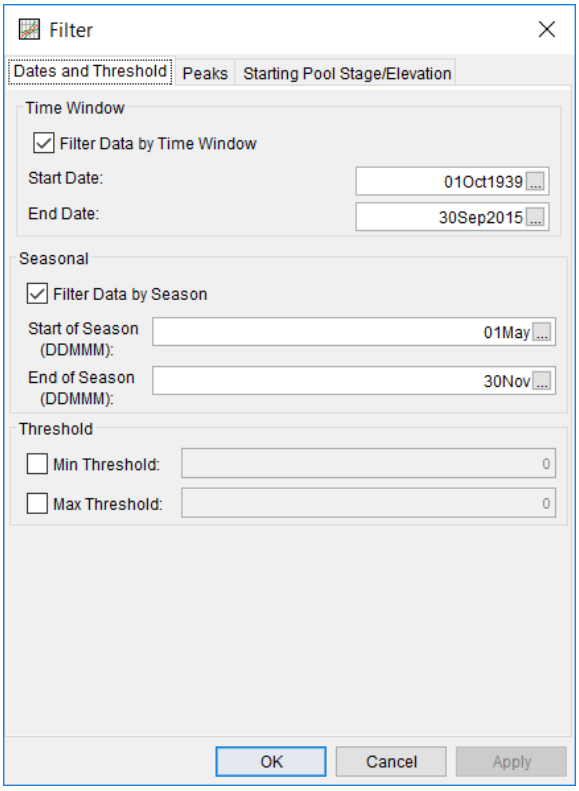
159 Figure 1. Plot of the Daily Average Flow Data for Sinnemahoning Creek.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 21** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 21** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2.

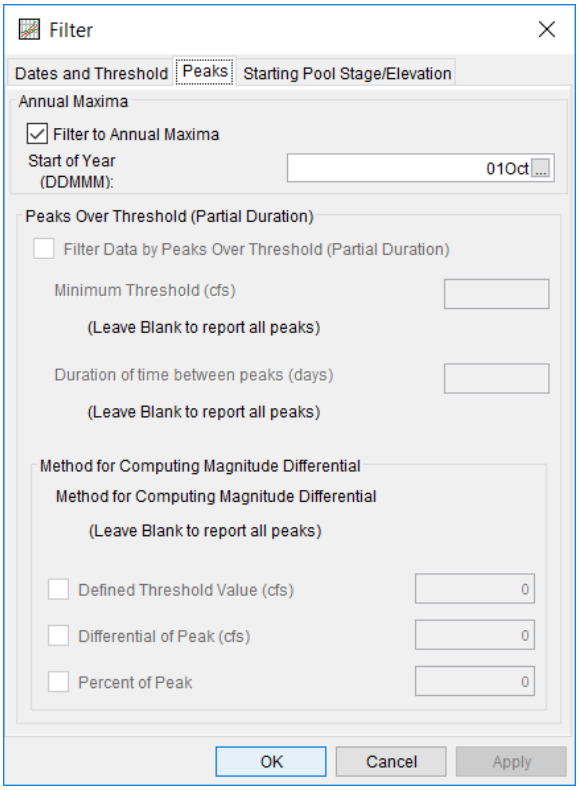


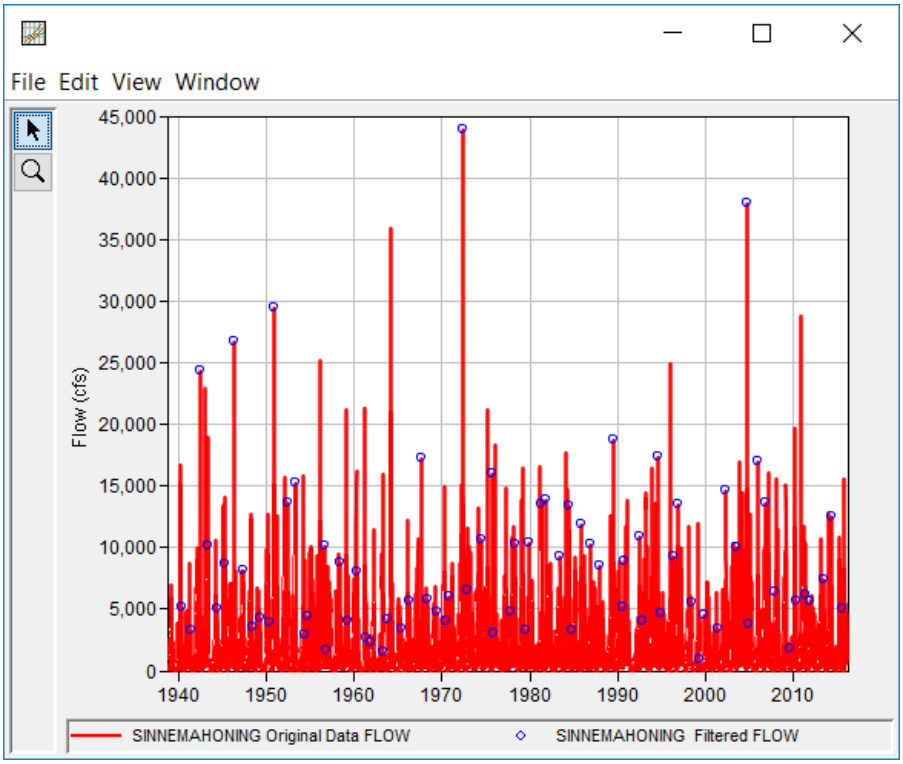
160 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 21.

For this analysis, the daily average streamflow data was revised using several filters. First, a **Time Window** filter was applied spanning **01Oct1939** through **30Sep2015** (i.e. water year 1940 – water year 2015). Second, a seasonal filter was applied spanning 01May – 30Nov (i.e. discard all values outside of this range). Finally, an annual maximum series was extracted using a water year demarcation of 01Oct (i.e. extract annual maxima between 01Oct – 30Sep). Out of the original 28269 values, 76 values remained after data filtering. These 76 values constitute an annual maximum series of daily average streamflow occurring between 01May and 30Nov (i.e. summer and fall months). The filters used within this analysis are shown in Figure 3. The original data as well as the filtered data is shown in Figure 4.



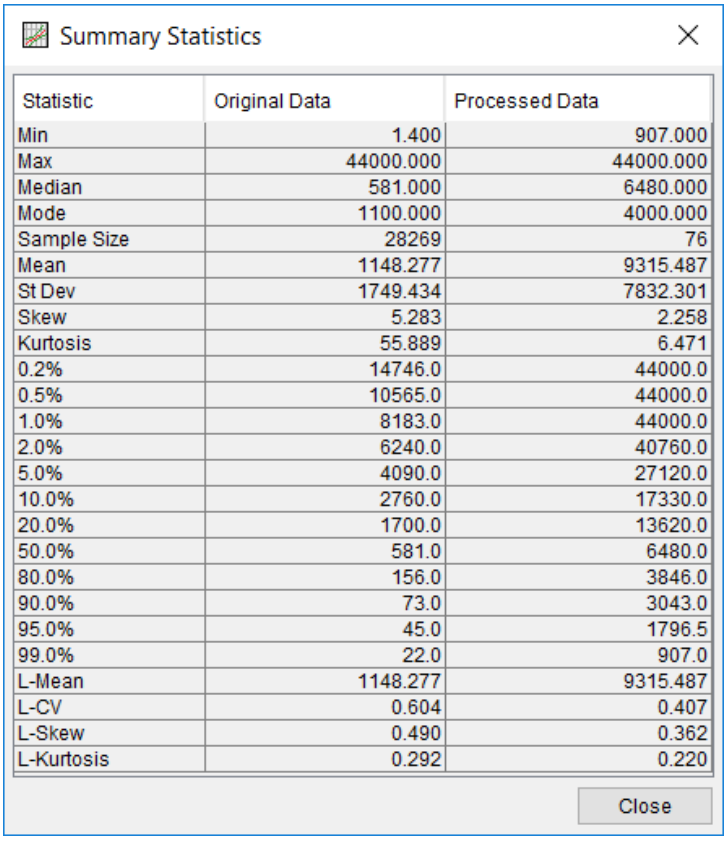
161 Figure 3. Data Filters Used within Distribution Fitting Test 21.





162 Figure 4. Original and Filtered Data within Distribution Fitting Test 21.

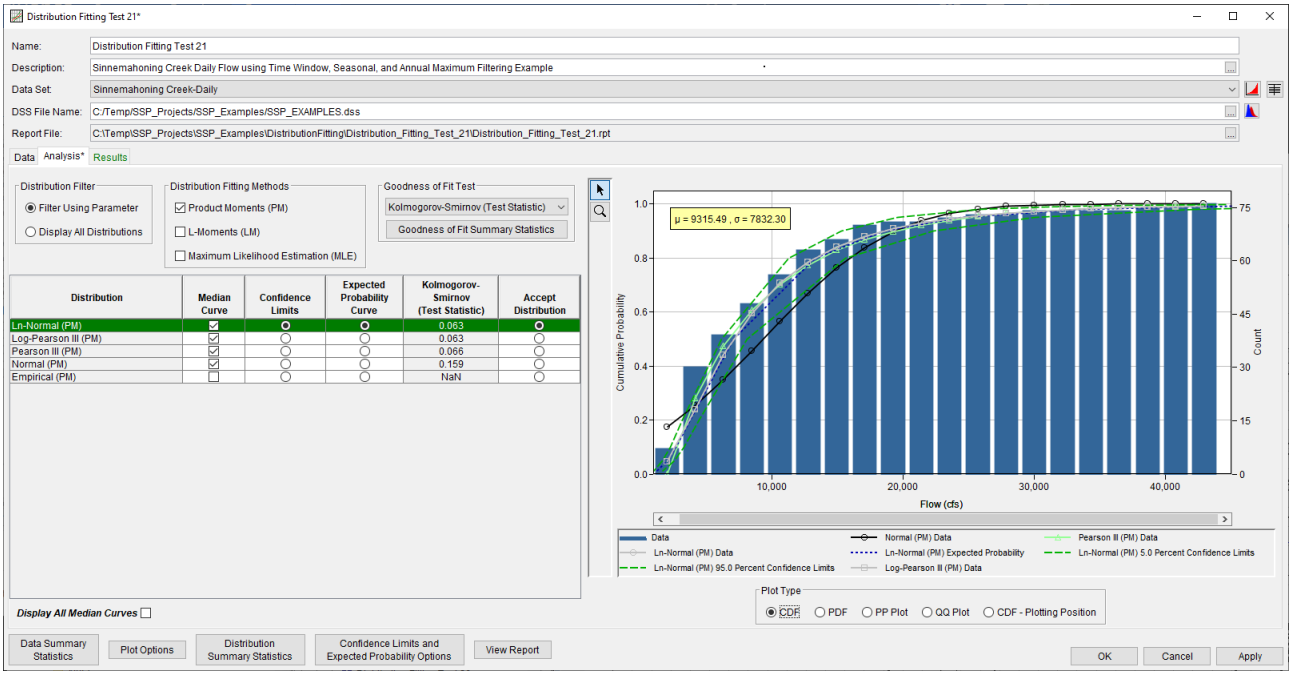
Summary statistics of the original and filtered/processed data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 5.



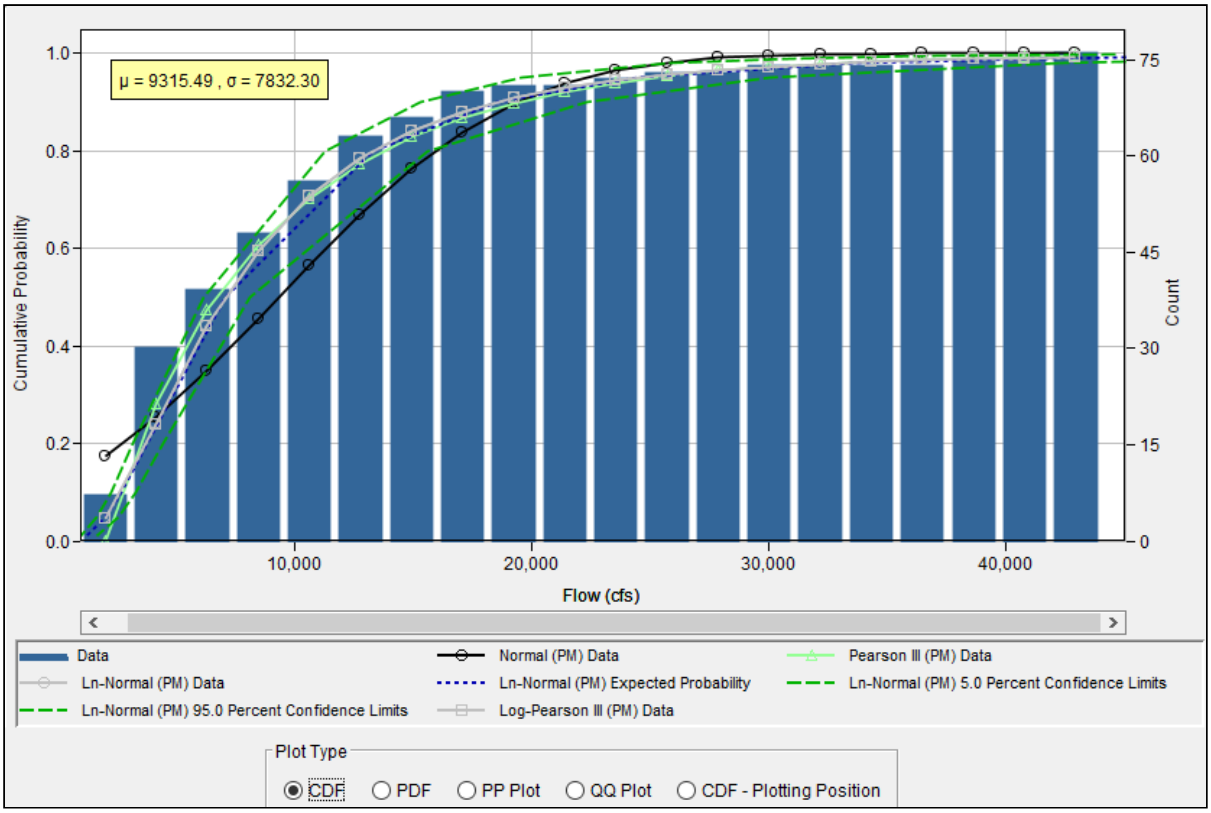
Statistic	Original Data	Processed Data
Min	1.400	907.000
Max	44000.000	44000.000
Median	581.000	6480.000
Mode	1100.000	4000.000
Sample Size	28269	76
Mean	1148.277	9315.487
St Dev	1749.434	7832.301
Skew	5.283	2.258
Kurtosis	55.889	6.471
0.2%	14746.0	44000.0
0.5%	10565.0	44000.0
1.0%	8183.0	44000.0
2.0%	6240.0	40760.0
5.0%	4090.0	27120.0
10.0%	2760.0	17330.0
20.0%	1700.0	13620.0
50.0%	581.0	6480.0
80.0%	156.0	3846.0
90.0%	73.0	3043.0
95.0%	45.0	1796.5
99.0%	22.0	907.0
L-Mean	1148.277	9315.487
L-CV	0.604	0.407
L-Skew	0.490	0.362
L-Kurtosis	0.292	0.220

163 Figure 5. Data Summary Statistics for Distribution Fitting Test 21.

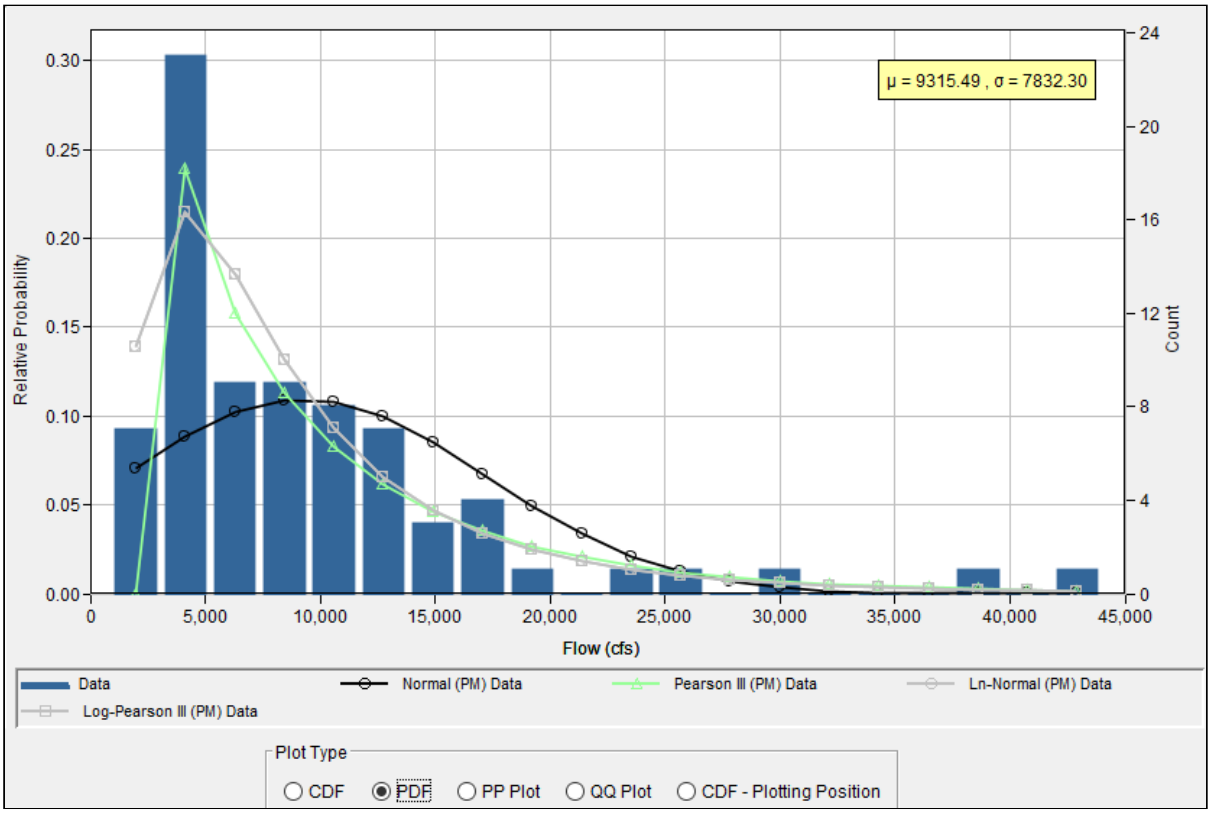
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 6, the **Filter Using Parameter** radio button was selected within the Distribution Filter panel. The default **Product Moments** fitting method was left unchanged. The default **Kolmogorov-Smirnov** goodness of fit test was left unchanged. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11.



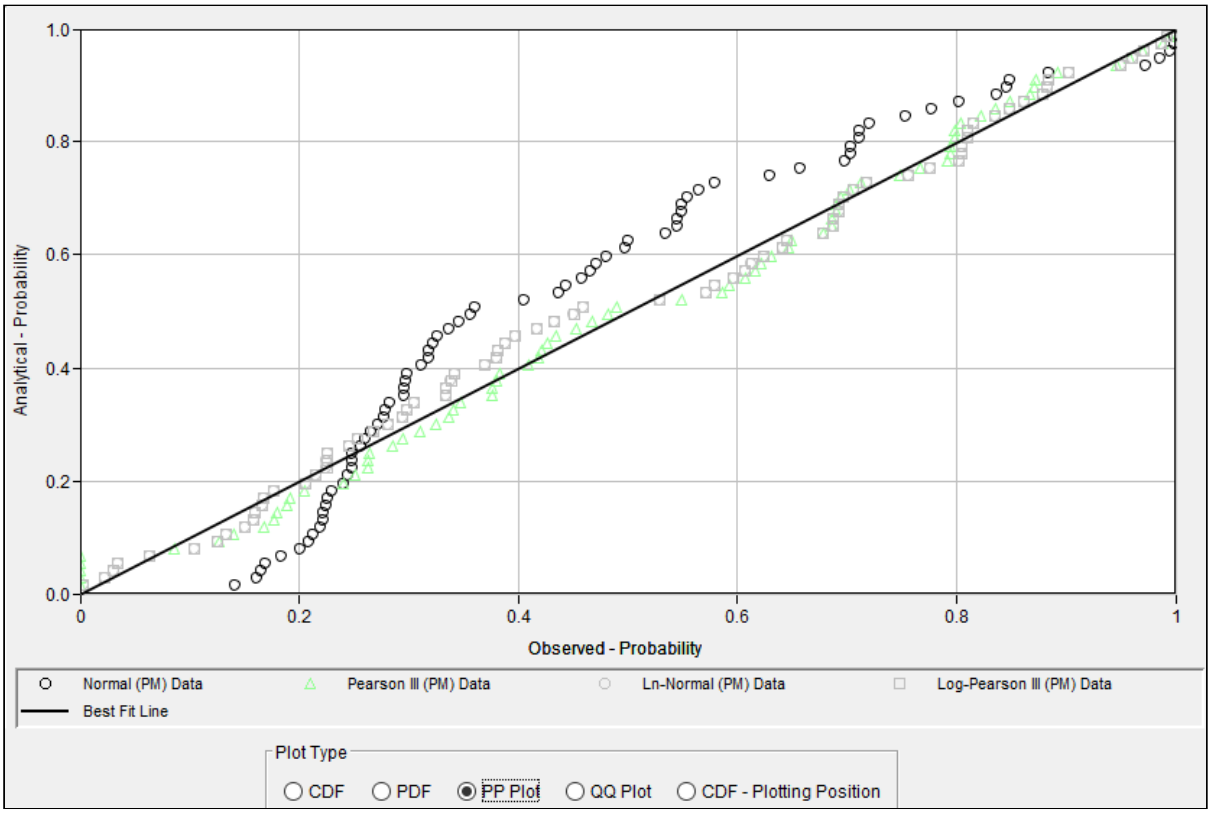
164 Figure 6. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 21.



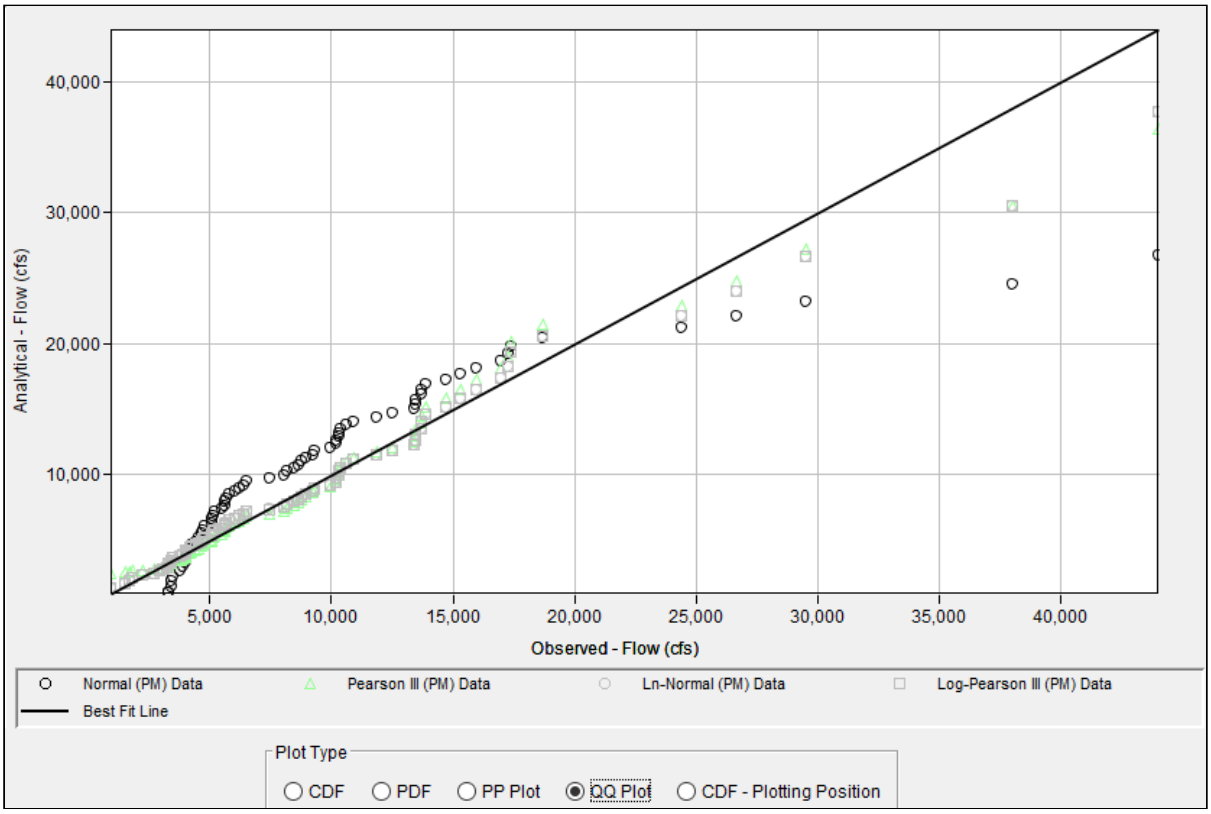
165 Figure 7. CDF Plot for Distribution Fitting Test 21.



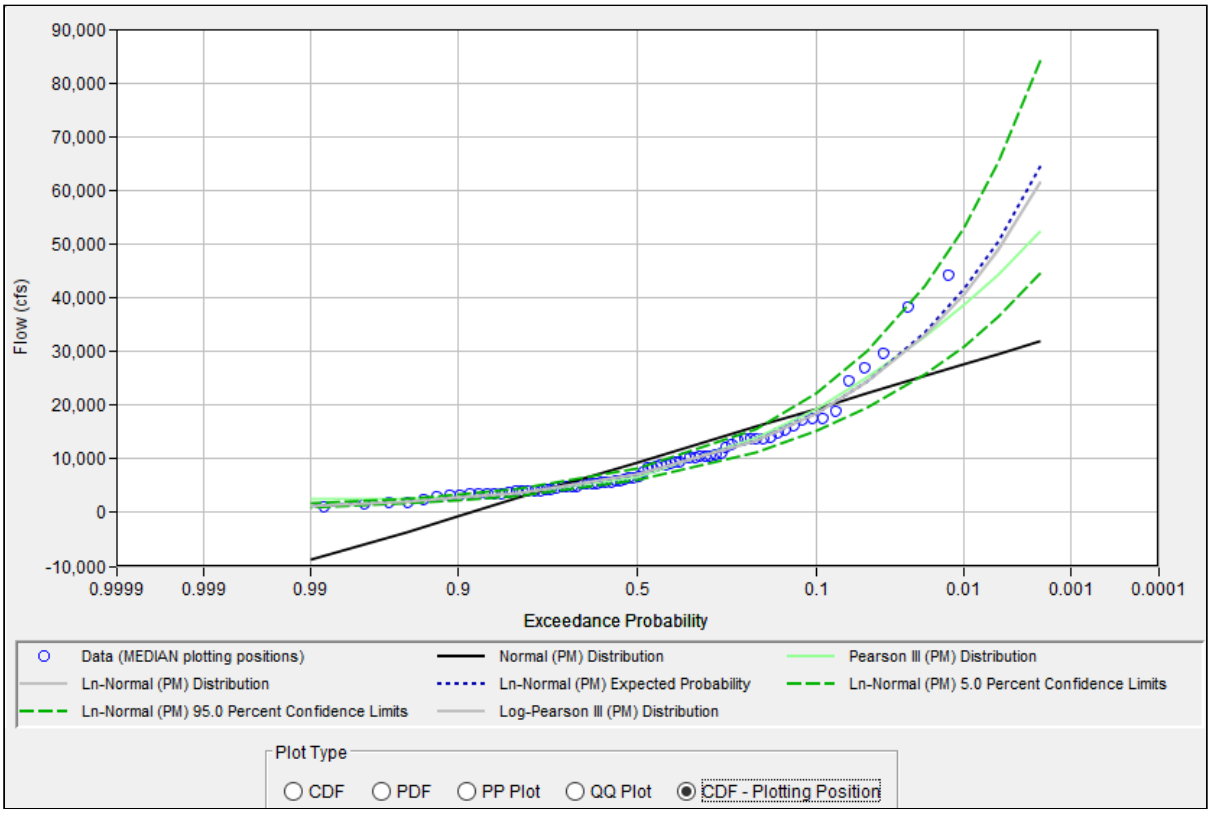
166 Figure 8. PDF Plot for Distribution Fitting Test 21.



167 Figure 9. PP Plot for Distribution Fitting Test 21.

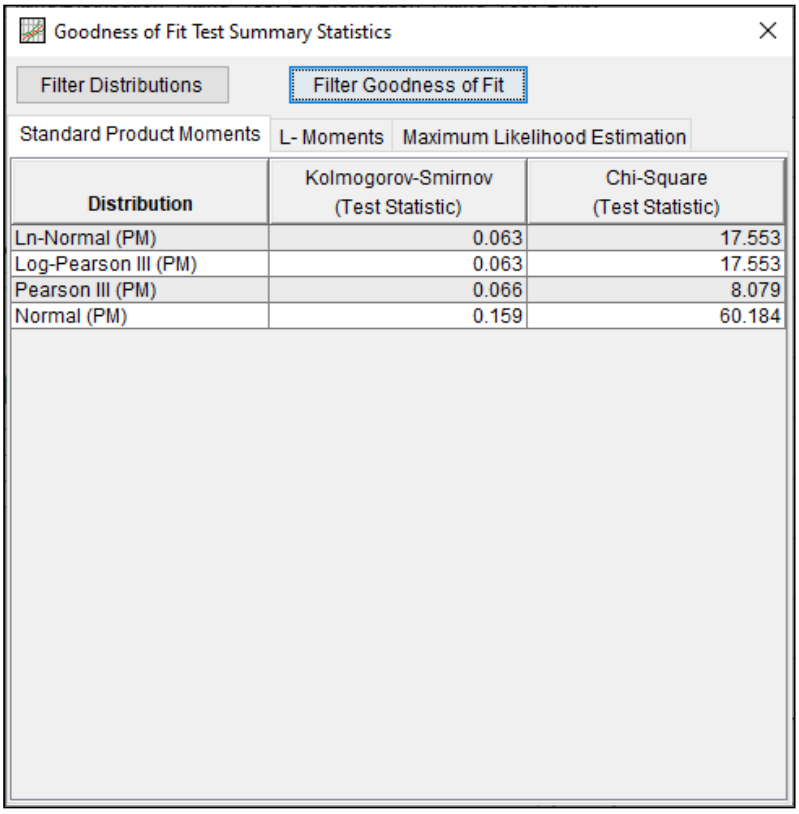


168 Figure 10. QQ Plot for Distribution Fitting Test 21.



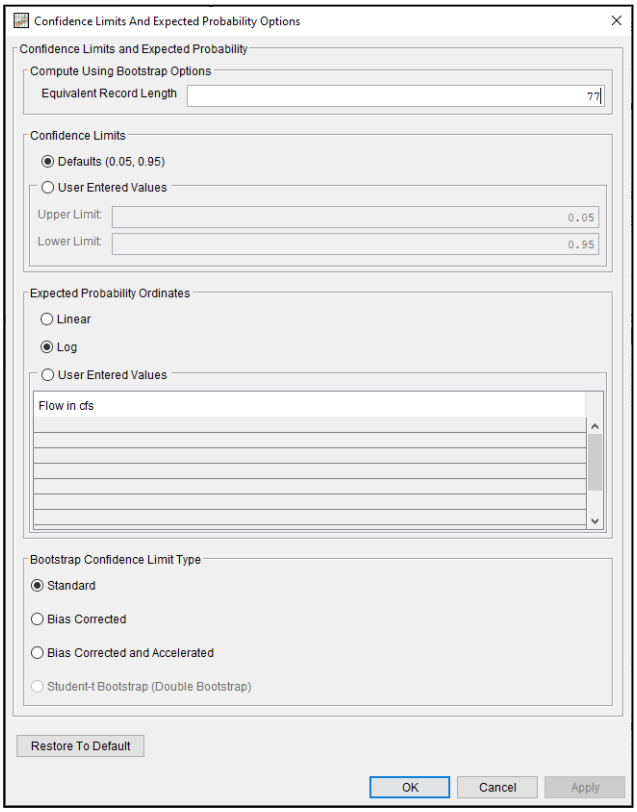
169 Figure 11. CDF-Plotting Position Plot for Distribution Fitting Test 21.

Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 12.

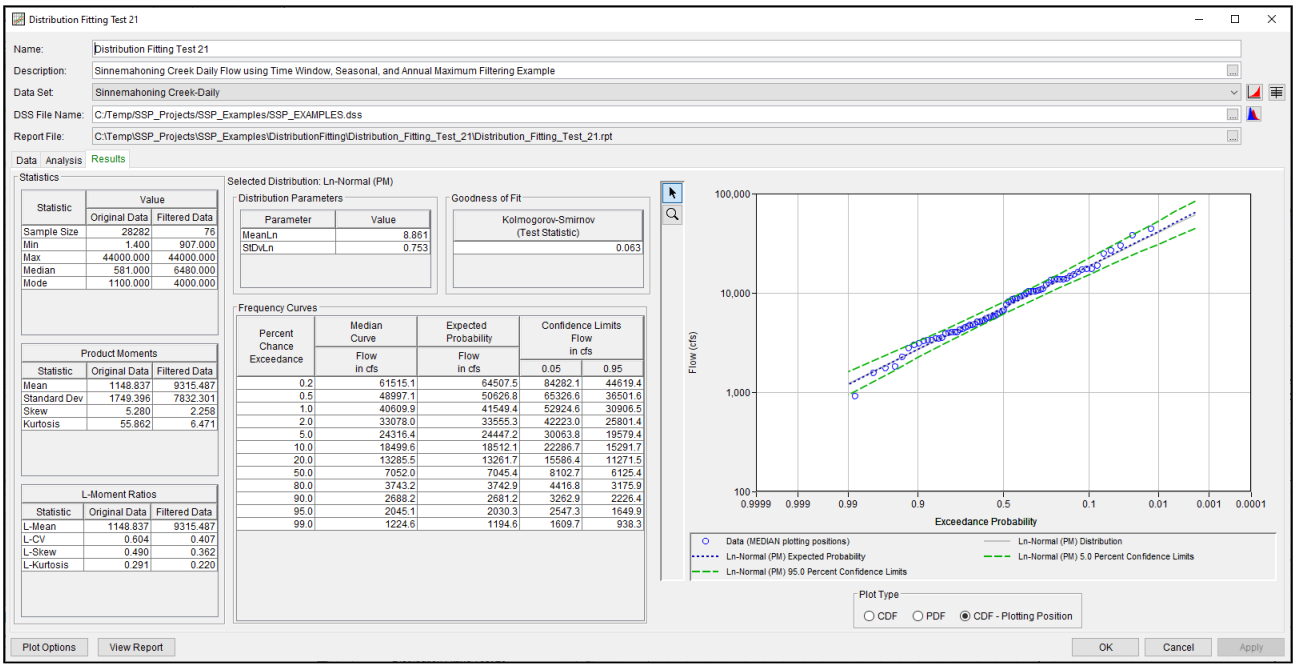


170 Figure 12. Goodness of Fit Test Summary Statistics for Distribution Fitting Test 21.

In this example, the **Accept Distribution** button was selected for the Ln-Normal Distribution using Product Moments. Confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. Specifically, the **Log** option was selected within the **Expected Probability Ordinates** panel (which computes the expected probability curve using log base 10 values), the **Standard** Bootstrap Confidence Limit Type Method was selected, as shown in Figure 13.

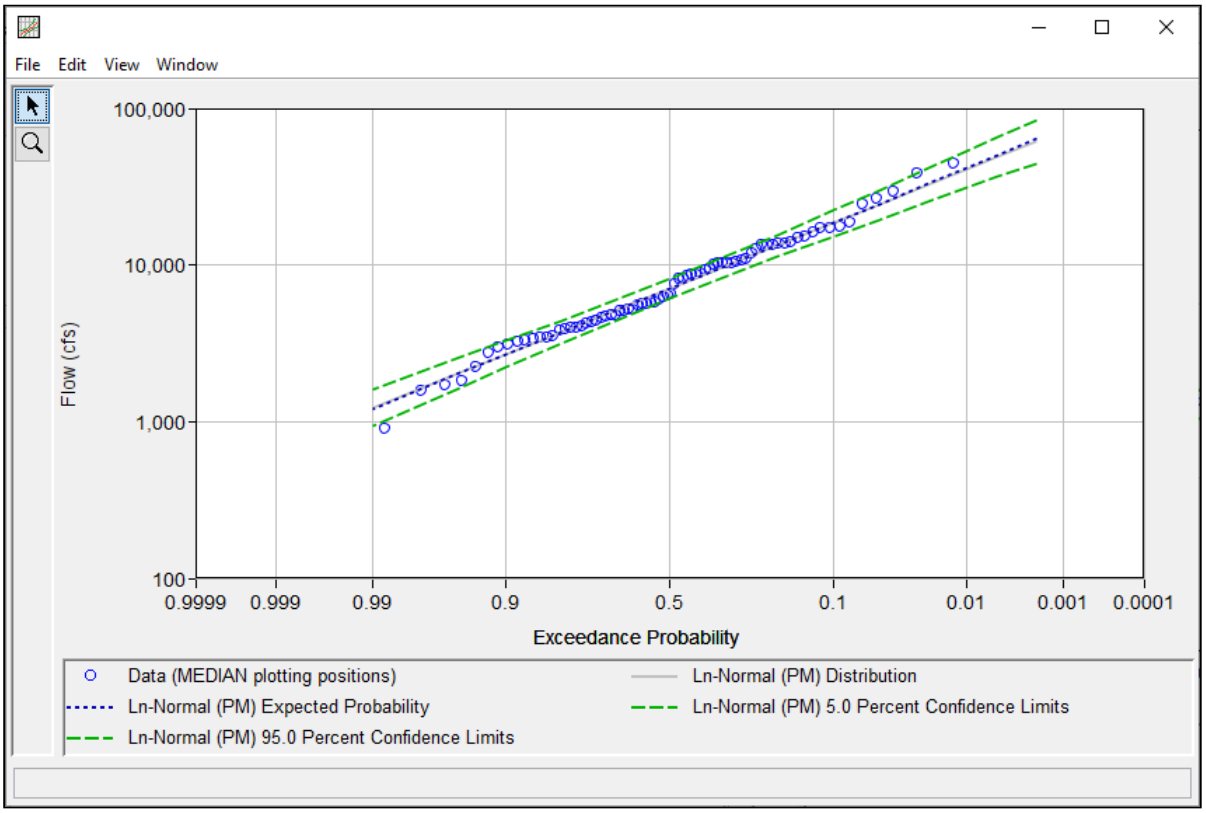


The accepted distribution | fitting method was used to populate the **Results** tab, as shown in Figure 14.



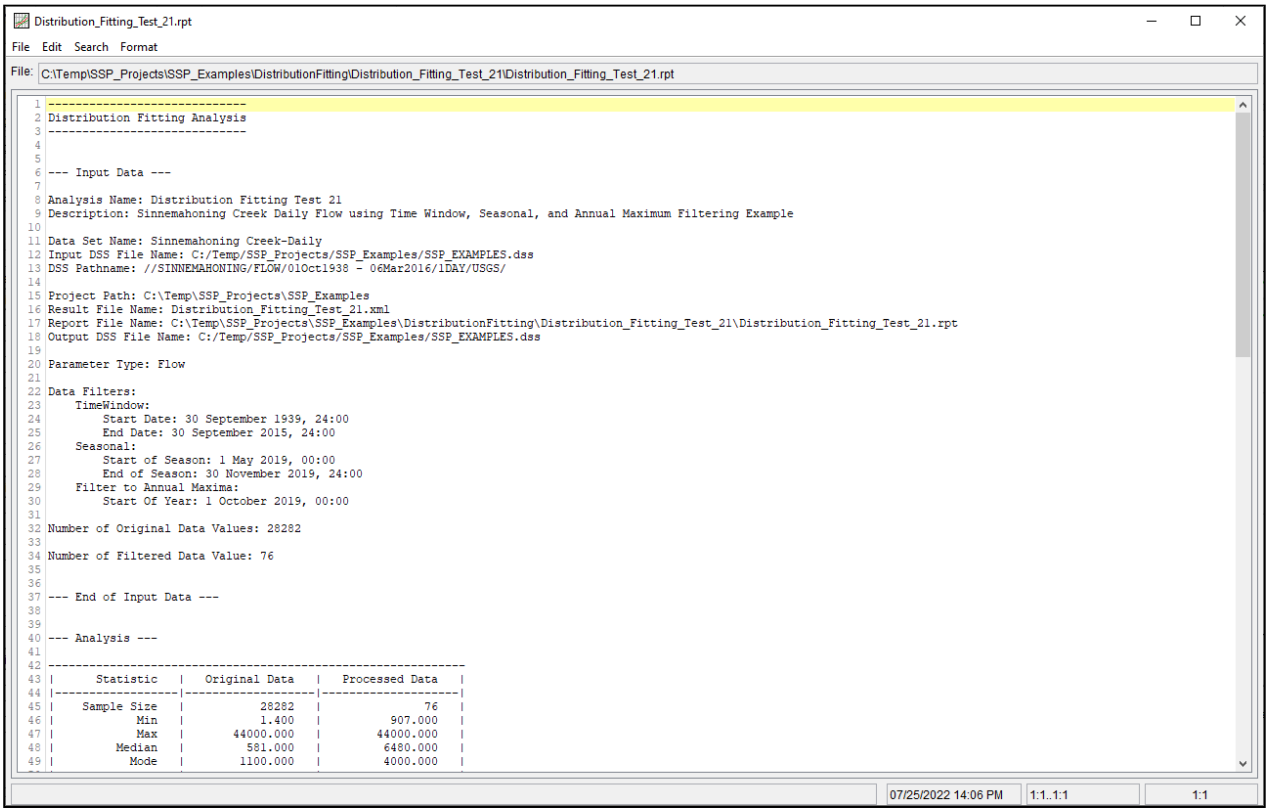
171 Figure 14. Distribution Fitting Results Tab Shown for Distribution Fitting Test 21.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 15.



172 Figure 15. Distribution Fitting Results Plot Shown for Distribution Fitting Test 21.

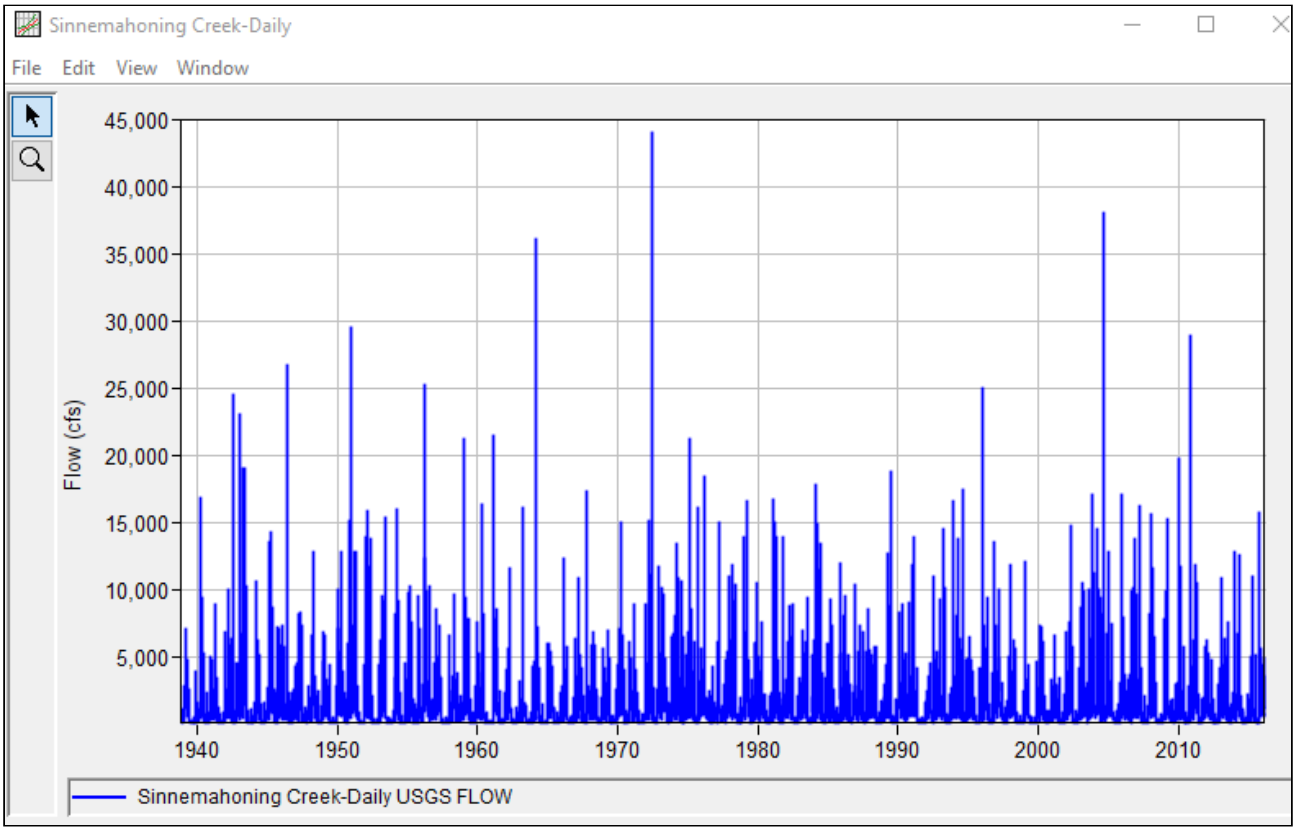
In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 16.



10.3 Example 22. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Peaks Over Threshold Filtering

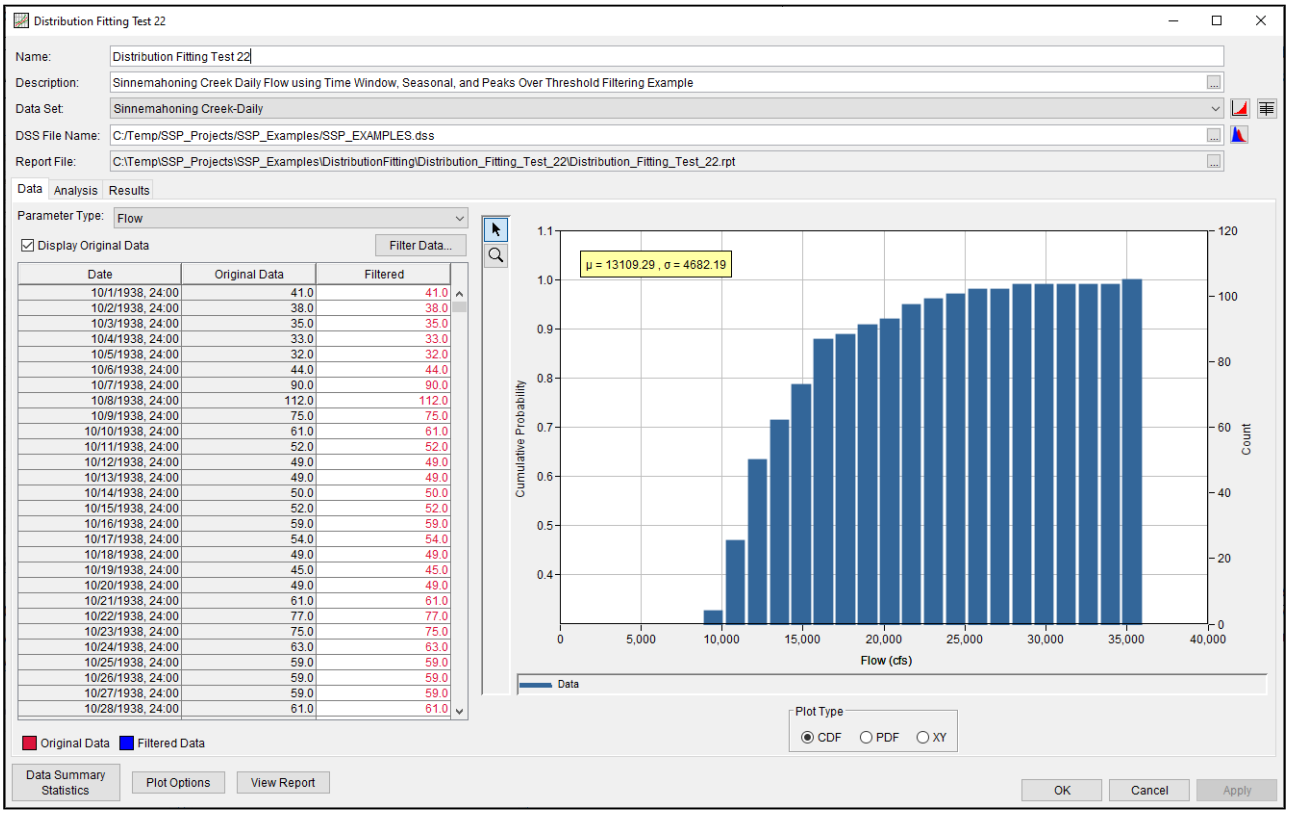
This example demonstrates how to use the Distribution Fitting analysis to analyze a time series of daily average flow using time window, seasonal and annual maximum filtering. The data for this example consists of daily average streamflow for a location along the Sinnemahoning Creek near Sinnemahoning, PA[48]. This stream gage is operated by the USGS (gage ID: 01543500). The period of record used for this example is from 1938 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Sinnemahoning Creek-Daily**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1.

48 https://waterdata.usgs.gov/nwis/uv?site_no=01543500



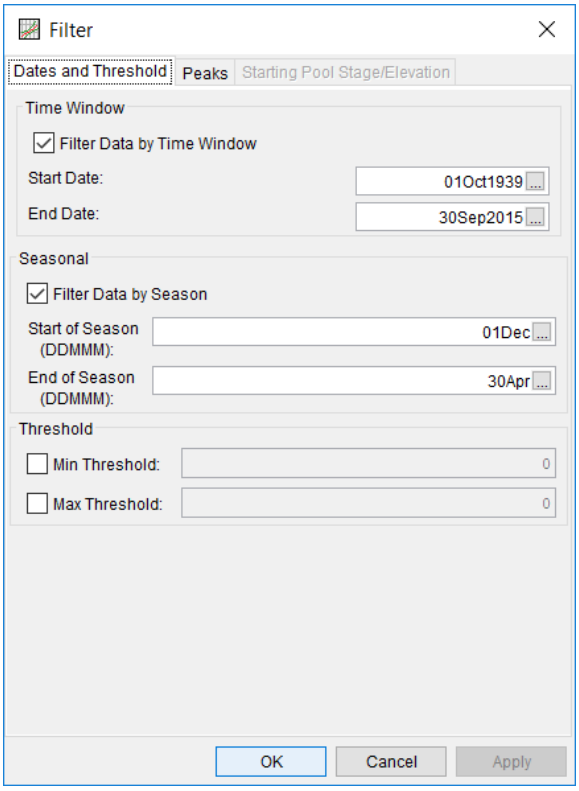
173 Figure 1. Plot of the Daily Average Flow Data for Sinnemahoning Creek.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 22** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 22** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2.

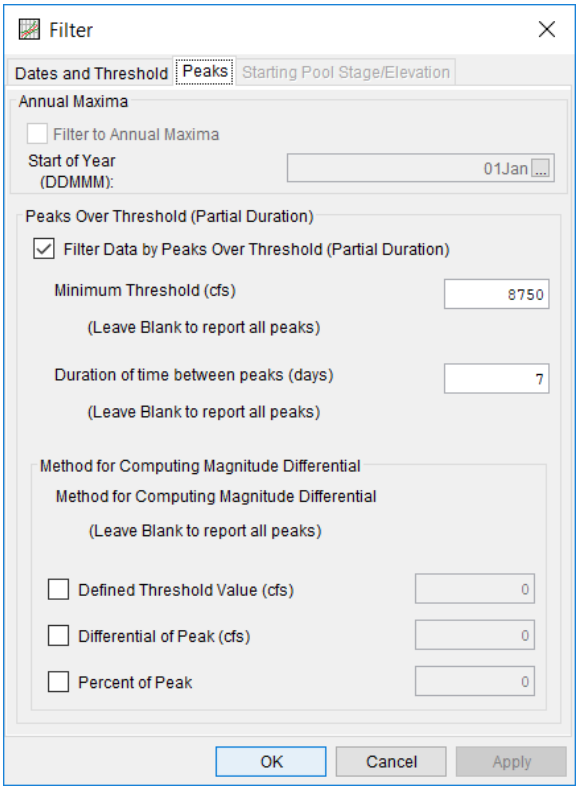


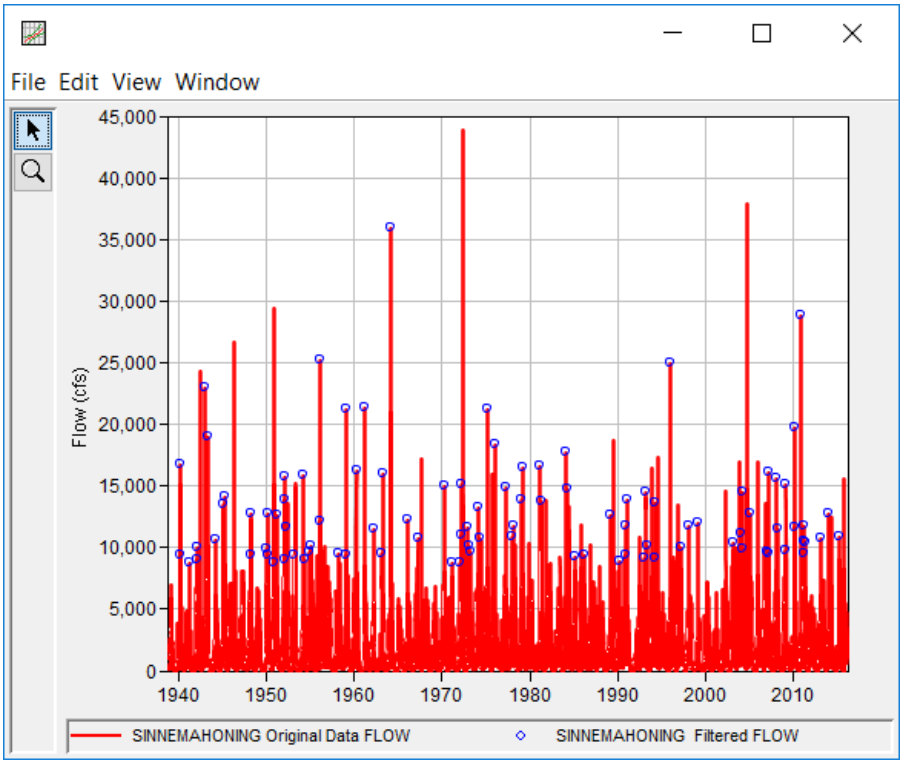
174 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 22.

For this analysis, the daily average streamflow data was revised using several filters. First, a **Time Window** filter was applied spanning **01Oct1939** through **30Sep2015** (i.e. water year 1940 – water year 2015). Second, a seasonal filter was applied spanning 01Dec – 30Apr (i.e. discard all values outside of this range). Finally, peaks were extracted from the remaining daily average streamflow values using a minimum threshold of 8750 cfs and a duration of times between peaks of 7 days. Out of the original 28269 values, 98 values remained after data filtering. These 98 values constitute a partial duration series of daily average streamflow peaks greater than 8750 cfs that occurred between 01Dec and 30Apr (i.e. winter and spring months). The filters used within this analysis are shown in Figure 3. The original data as well as the filtered data is shown in Figure 4.



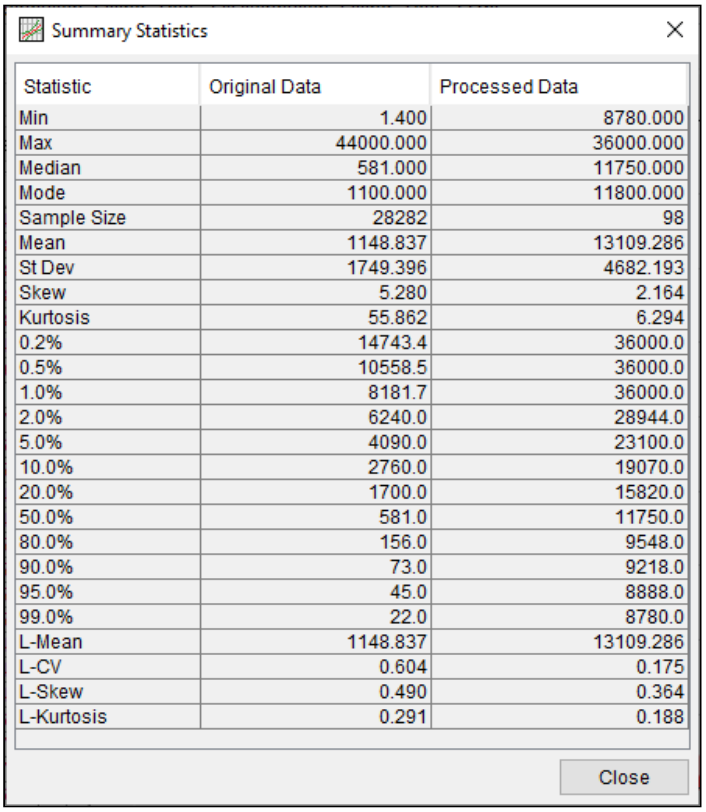
175 Figure 3. Data Filters Used within Distribution Fitting Test 22.





176 Figure 4. Original and Filtered Data within Distribution Fitting Test 22.

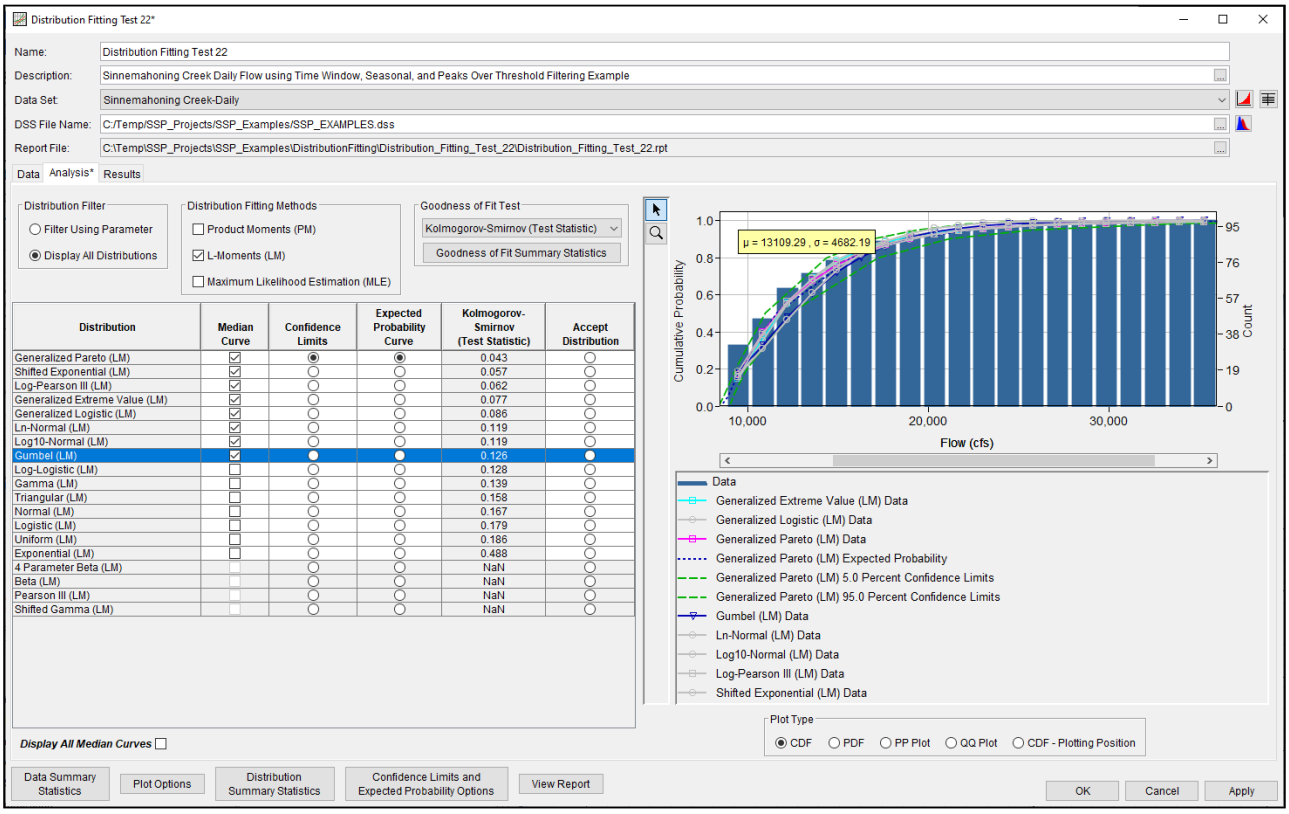
Summary statistics of the original and filtered/processed data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 5.



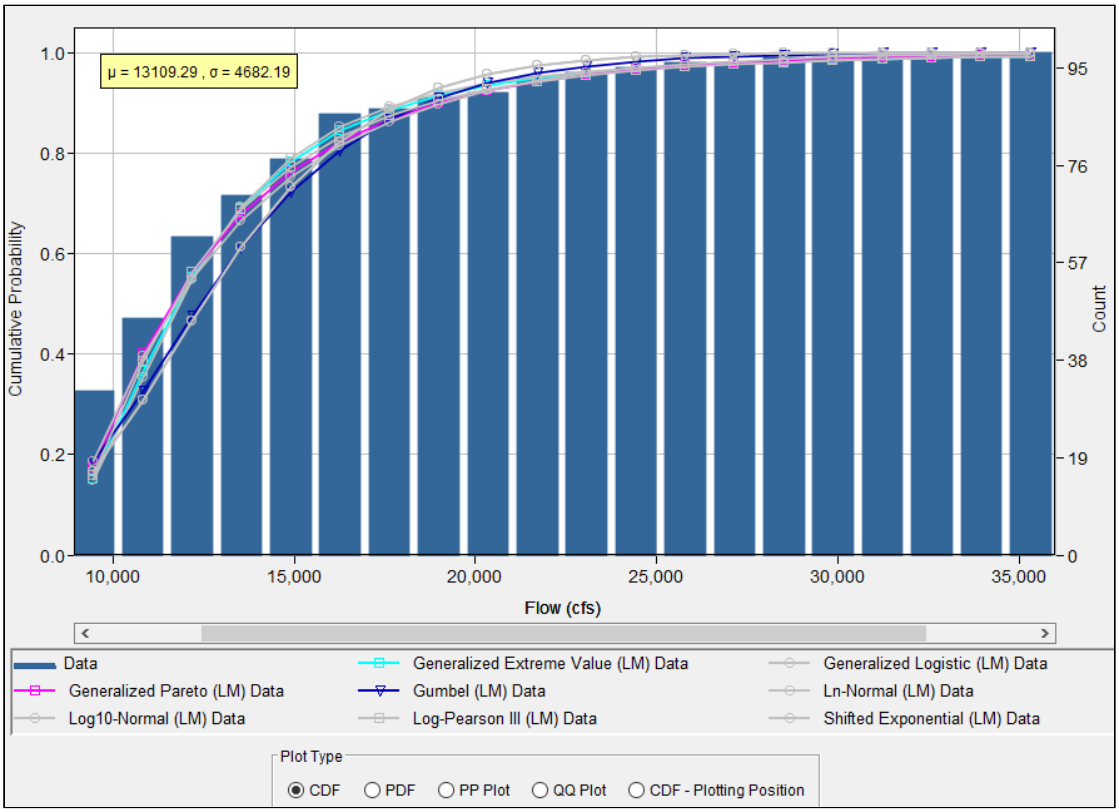
Statistic	Original Data	Processed Data
Min	1.400	8780.000
Max	44000.000	36000.000
Median	581.000	11750.000
Mode	1100.000	11800.000
Sample Size	28282	98
Mean	1148.837	13109.286
St Dev	1749.396	4682.193
Skew	5.280	2.164
Kurtosis	55.862	6.294
0.2%	14743.4	36000.0
0.5%	10558.5	36000.0
1.0%	8181.7	36000.0
2.0%	6240.0	28944.0
5.0%	4090.0	23100.0
10.0%	2760.0	19070.0
20.0%	1700.0	15820.0
50.0%	581.0	11750.0
80.0%	156.0	9548.0
90.0%	73.0	9218.0
95.0%	45.0	8888.0
99.0%	22.0	8780.0
L-Mean	1148.837	13109.286
L-CV	0.604	0.175
L-Skew	0.490	0.364
L-Kurtosis	0.291	0.188

177 Figure 5. Data Summary Statistics for Distribution Fitting Test 22.

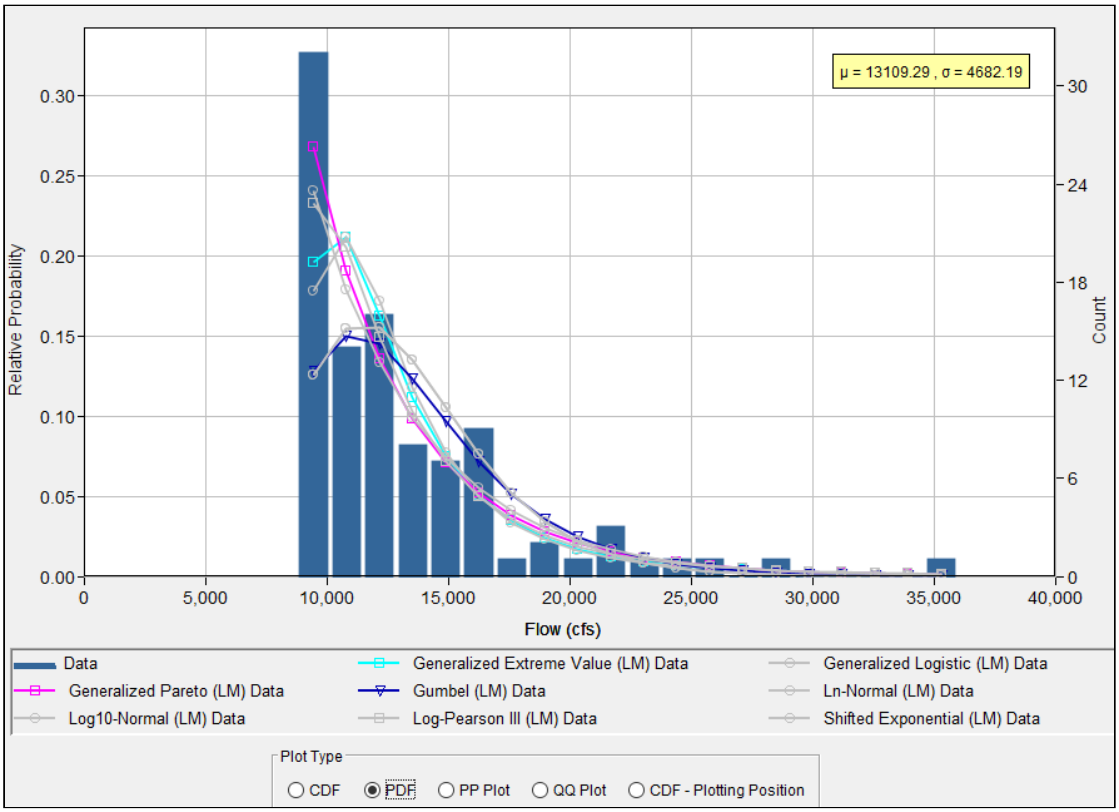
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 6, the **Display All Distributions** radio button was selected within the Distribution Filter panel to display all of the available analytical distributions while L-Moments Distribution Fitting Method was selected. The default Kolmogorov-Smirnov goodness of fit test was left unchanged. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11.



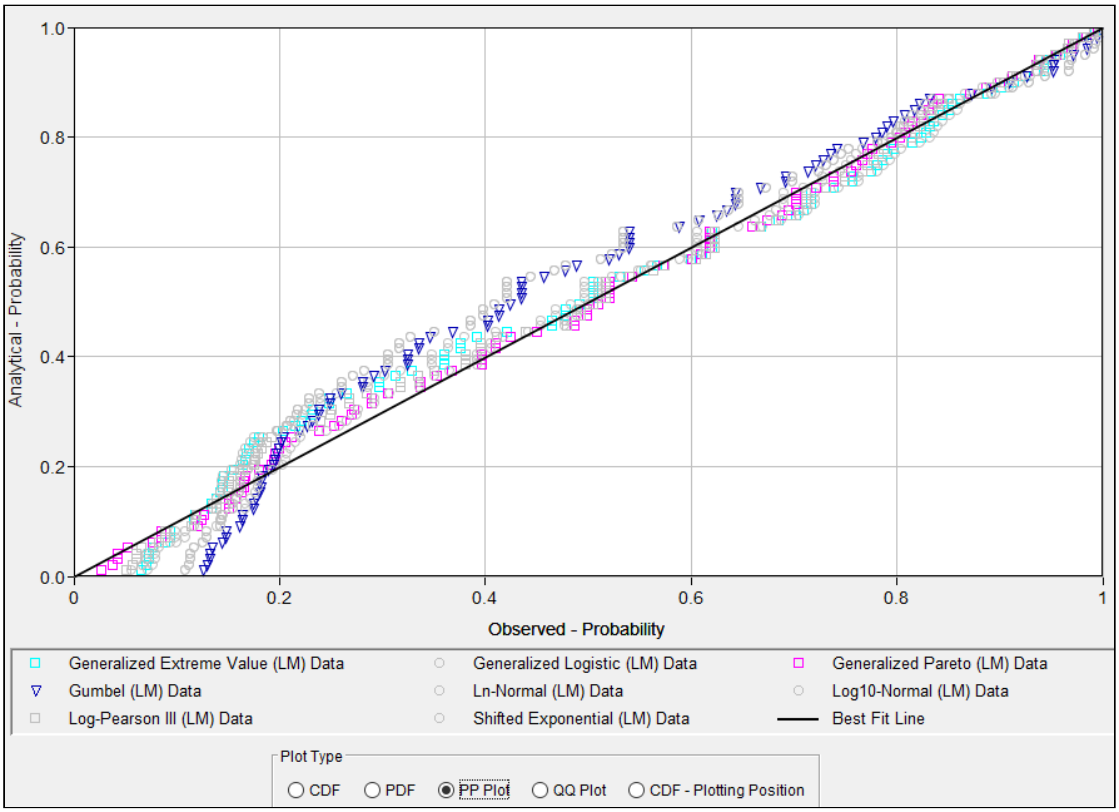
178 Figure 6. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 22.



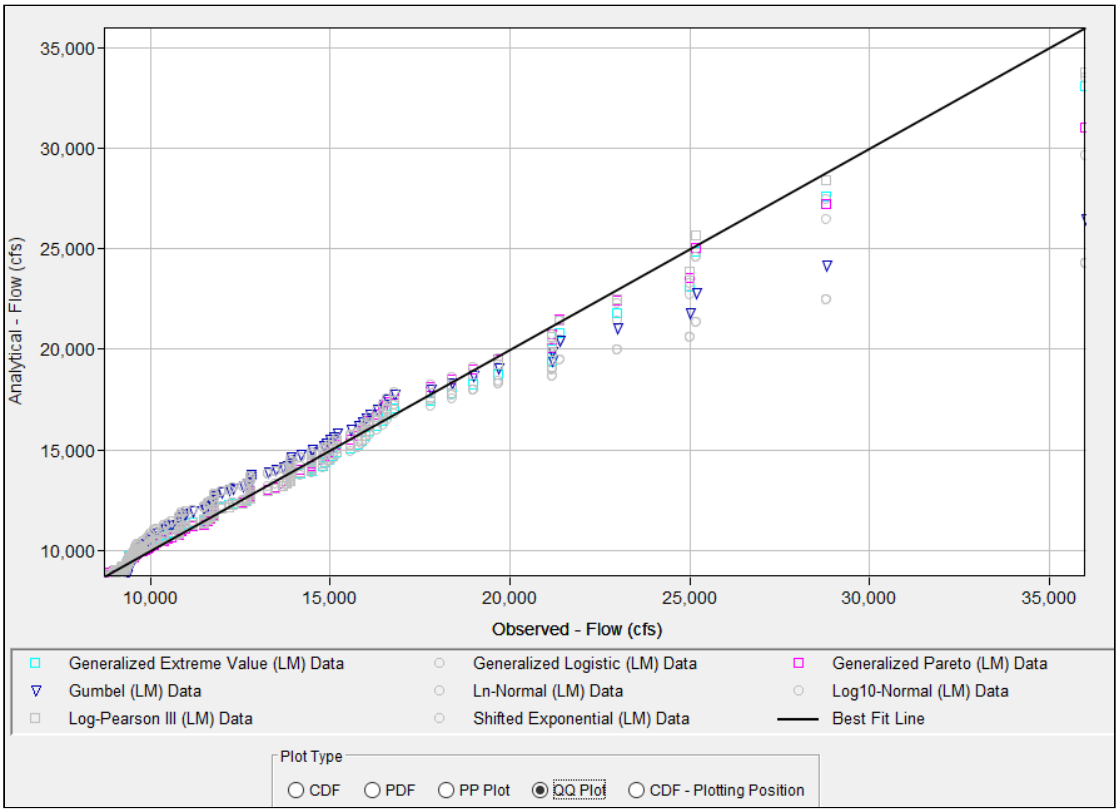
179 Figure 7. CDF Plot for Distribution Fitting Test 22.



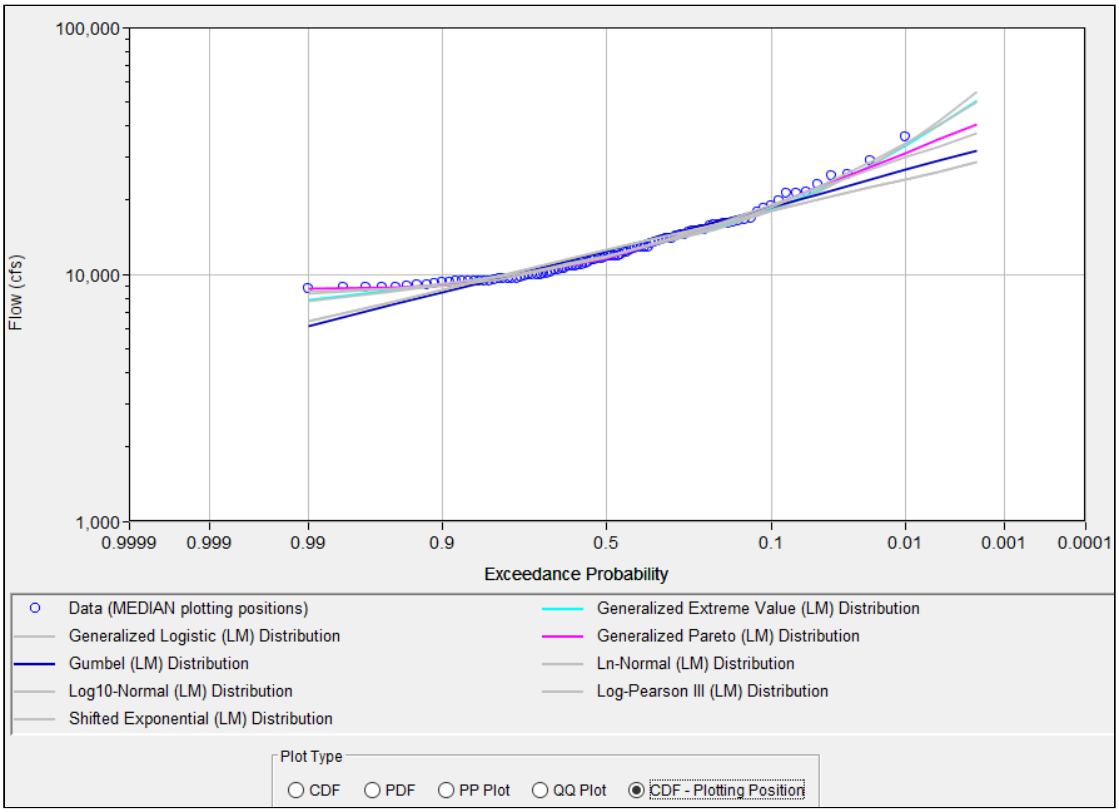
180 Figure 8. PDF Plot for Distribution Fitting Test 22.



181 Figure 9. PP Plot for Distribution Fitting Test 22.

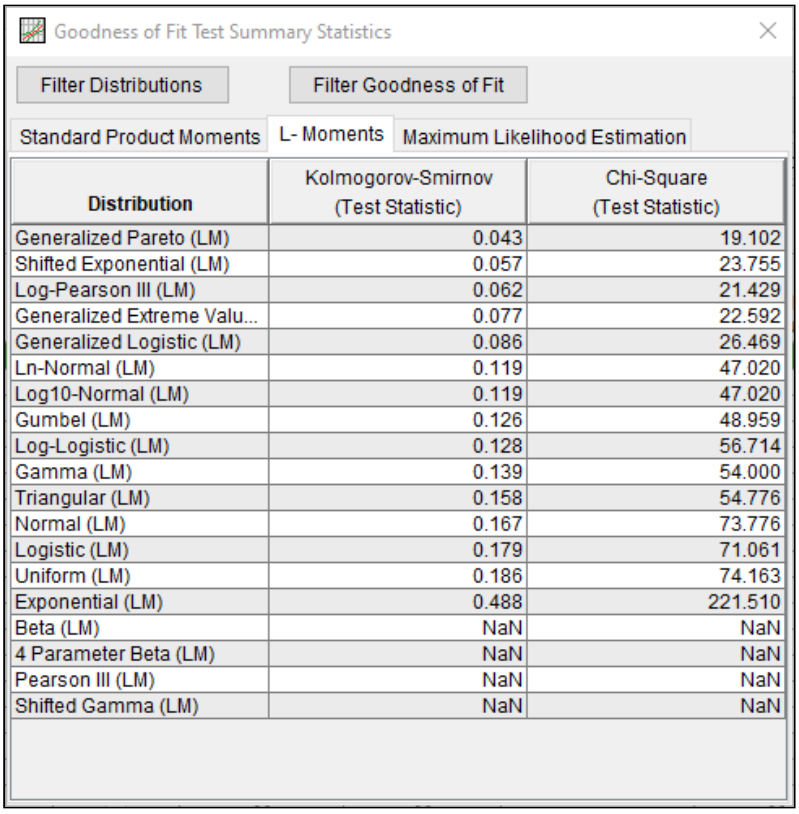


182 Figure 10. QQ Plot for Distribution Fitting Test 22.



183 Figure 11. CDF-Plotting Position Plot for Distribution Fitting Test 22.

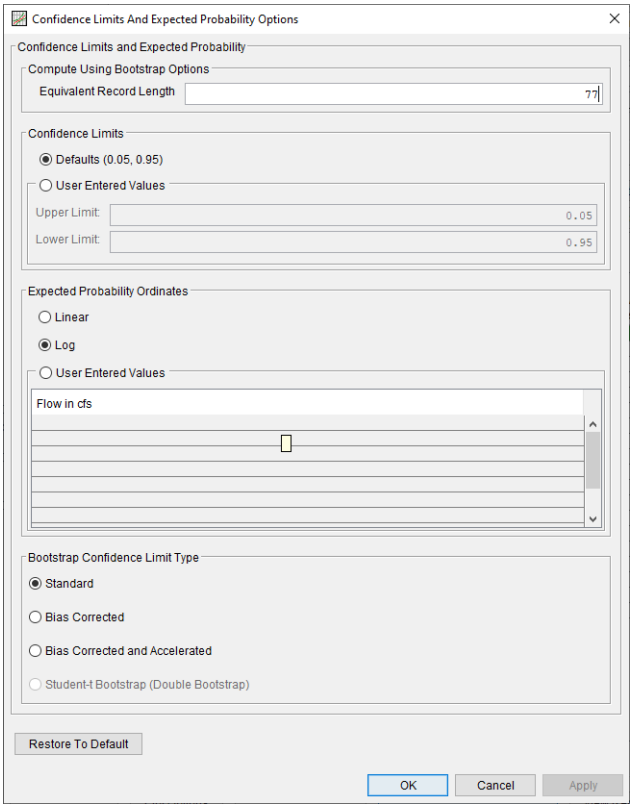
Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 12.



Distribution	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Generalized Pareto (LM)	0.043	19.102
Shifted Exponential (LM)	0.057	23.755
Log-Pearson III (LM)	0.062	21.429
Generalized Extreme Valu...	0.077	22.592
Generalized Logistic (LM)	0.086	26.469
Ln-Normal (LM)	0.119	47.020
Log10-Normal (LM)	0.119	47.020
Gumbel (LM)	0.126	48.959
Log-Logistic (LM)	0.128	56.714
Gamma (LM)	0.139	54.000
Triangular (LM)	0.158	54.776
Normal (LM)	0.167	73.776
Logistic (LM)	0.179	71.061
Uniform (LM)	0.186	74.163
Exponential (LM)	0.488	221.510
Beta (LM)	NaN	NaN
4 Parameter Beta (LM)	NaN	NaN
Pearson III (LM)	NaN	NaN
Shifted Gamma (LM)	NaN	NaN

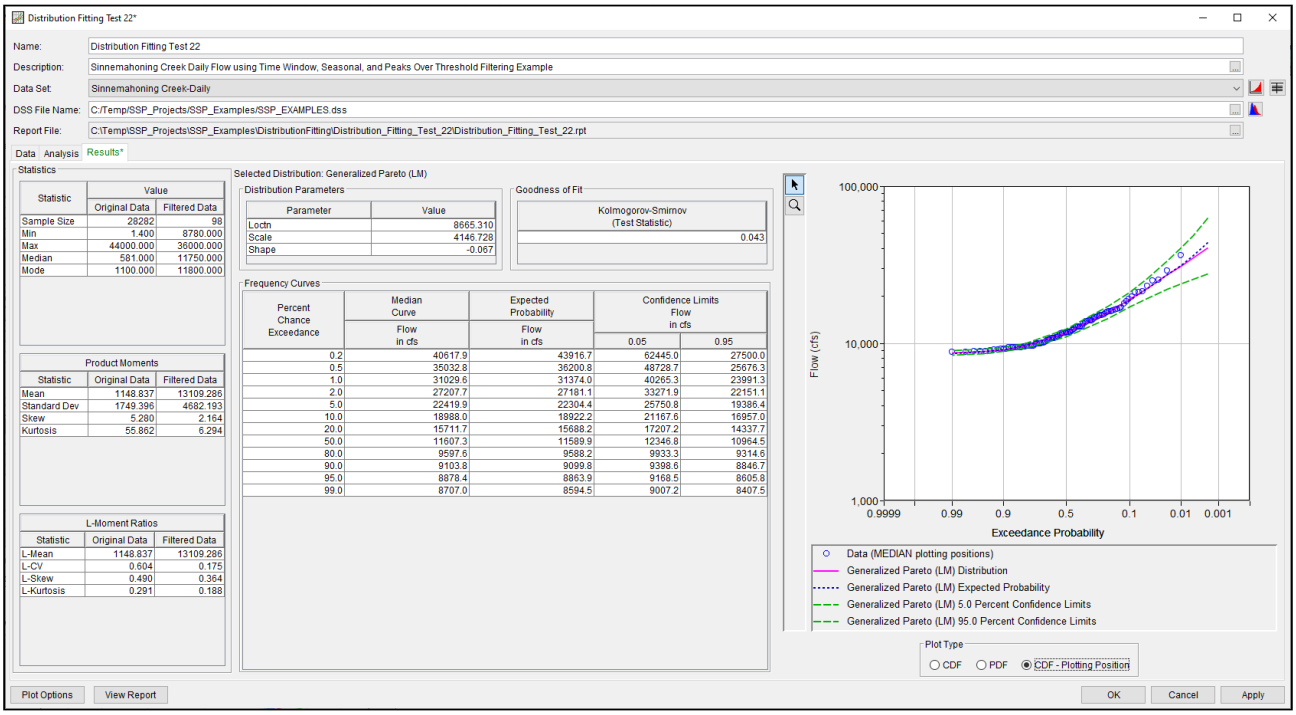
184 Figure 12. Goodness of Fit Summary Statistics for Distribution Fitting Test 22.

In this example, the Generalized Pareto Distribution fit using L-Moments was selected by clicking the **Accept Distribution** button in the distribution table. Upon clicking this button, confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. The default confidence limits and expected probability options were modified by clicking on the **Confidence Limits and Expected Probability Options** buttons near the bottom of the Distribution Fitting editor. Specifically, the **Log** option was selected within the **Expected Probability Ordinates** panel (which computes the expected probability curve using log base 10 values), the **Standard** Bootstrap Confidence Limit Type Method was selected, as shown in Figure 13.



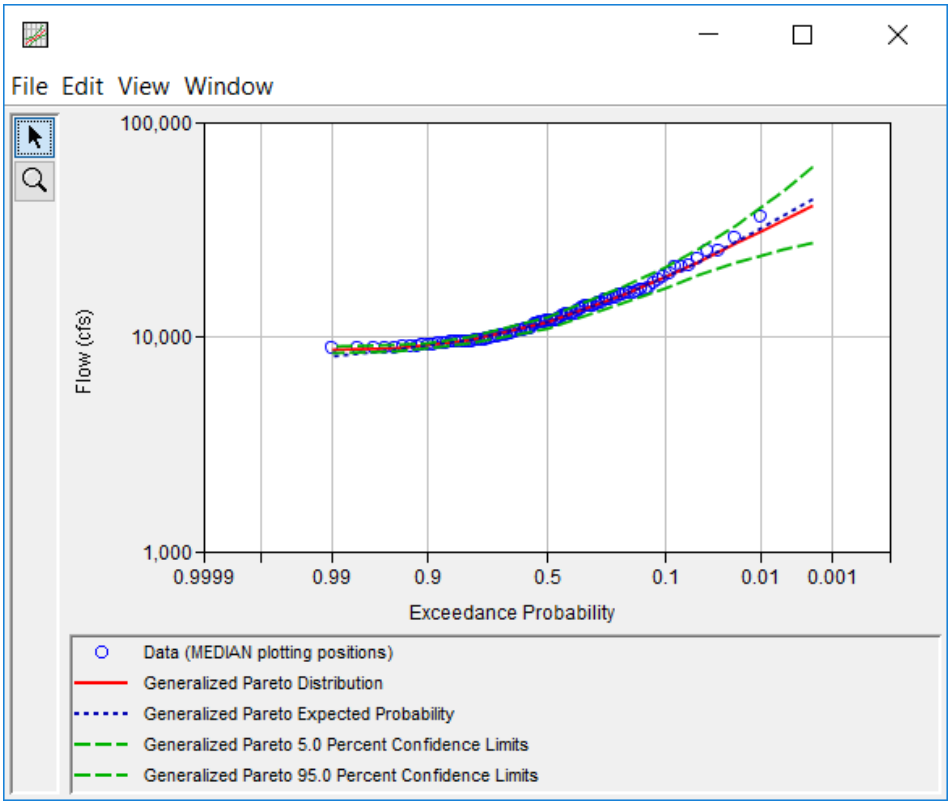
185 Figure 13. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 22.

The accepted distribution | fitting method was used to populate the Results tab, as shown in Figure 14.



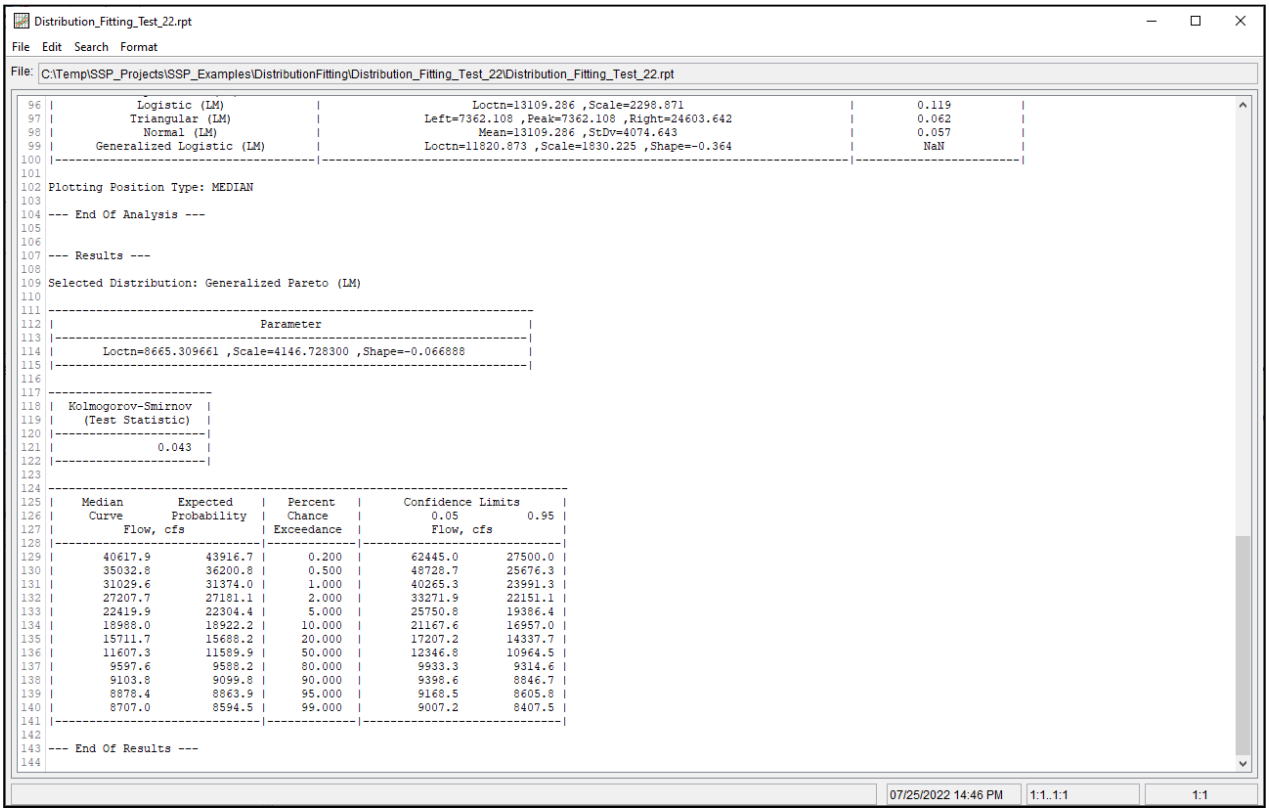
186 Figure 14. Distribution Fitting Results Tab Shown for Distribution Fitting Test 22.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 15.



187 Figure 15. Distribution Fitting Plot Shown for Distribution Fitting Test 22.

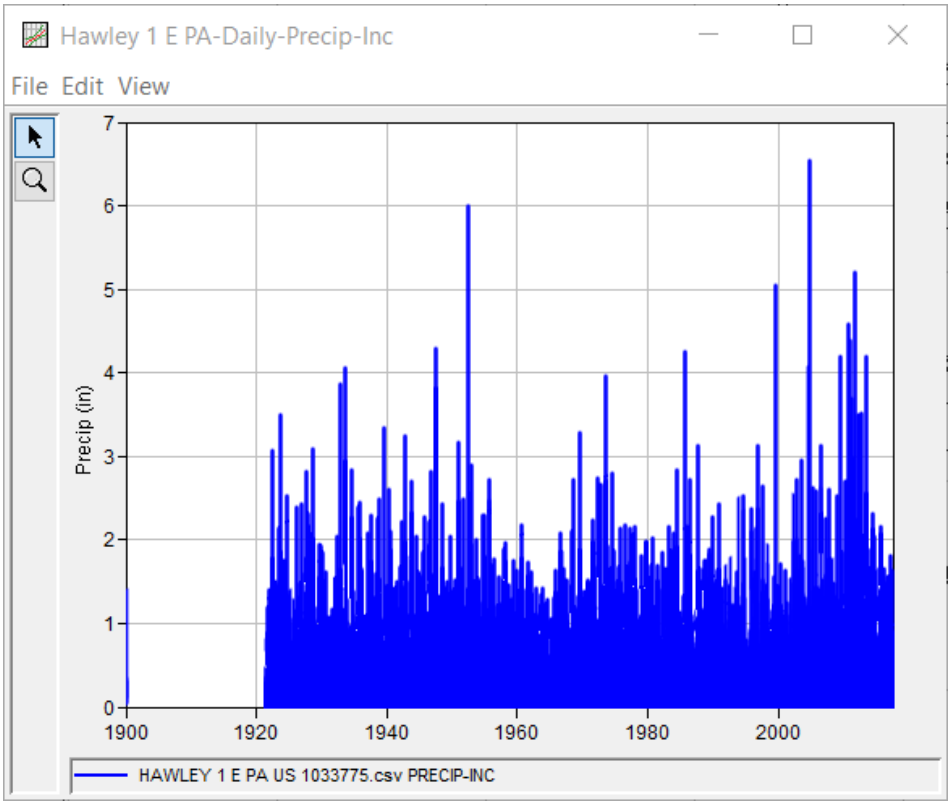
In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 16.



10.4 Example 23. Distribution Fitting, Analyzing a Time Series of Daily Precipitation Accumulation Using Peaks Over Threshold Filtering

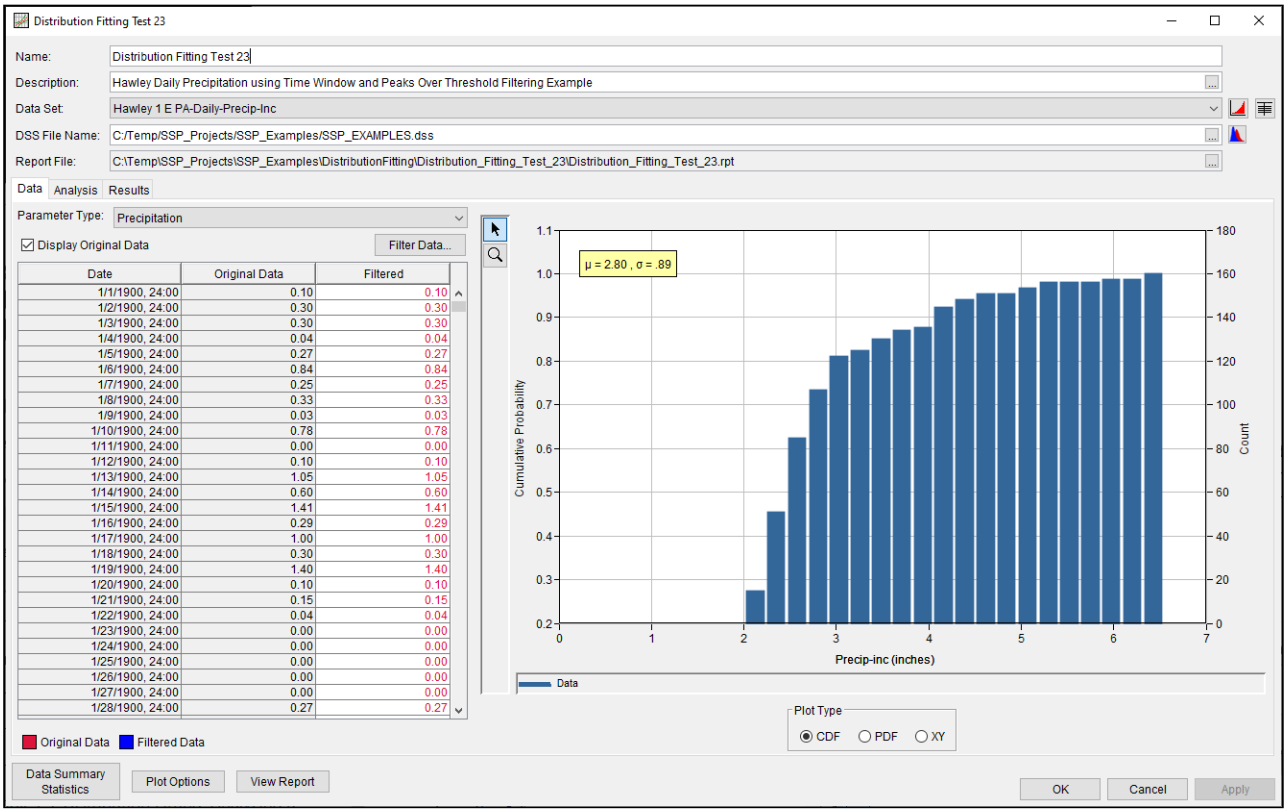
This example demonstrates how to use the Distribution Fitting analysis to analyze a time series of daily precipitation accumulation using peaks over threshold filtering. The data for this example consists of a daily precipitation accumulation time series for a precipitation gage located near Hawley, Pennsylvania[49]. This precipitation gage is operated by the National Weather Service (NWS). The precipitation data was downloaded from the NWS website ("https://www.ncdc.noaa.gov/") as a comma separated values (.csv) file and ingested to the study using an HEC-DSSVue plugin. The period of record used for this example is from January 1900 to July 2017. To view the data, right-click on the data record labeled "**Hawley 1 E PA-Daily-Precip-Inc**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1.

49 https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:USC00363758/detail



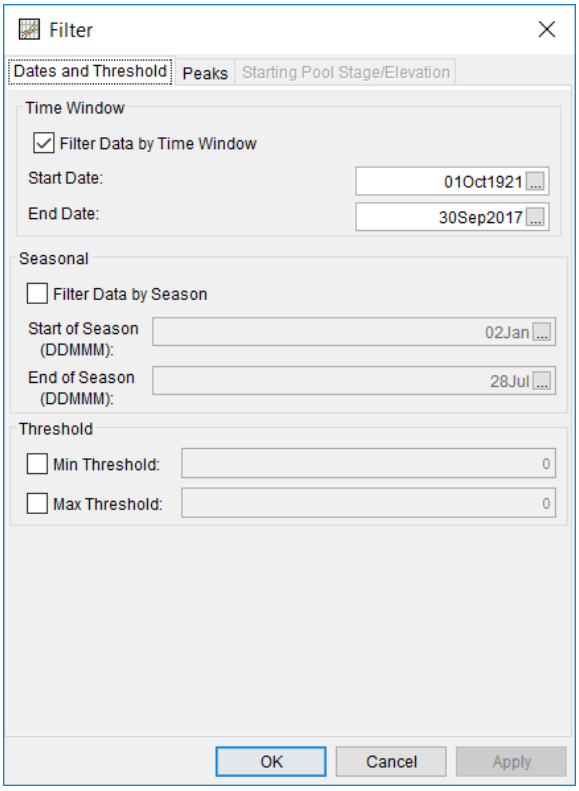
188 Figure 1. Plot of the Daily Precipitation Accumulation for Hawley 1E.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 23** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 23** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2.

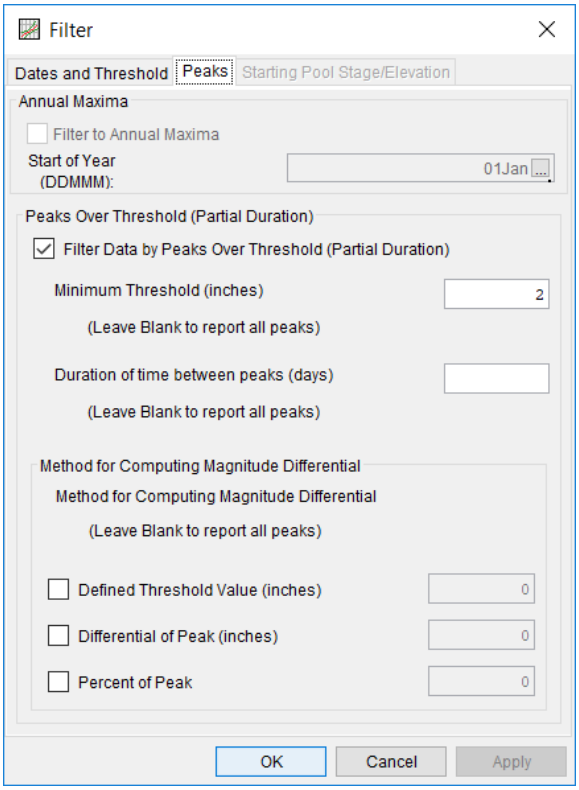


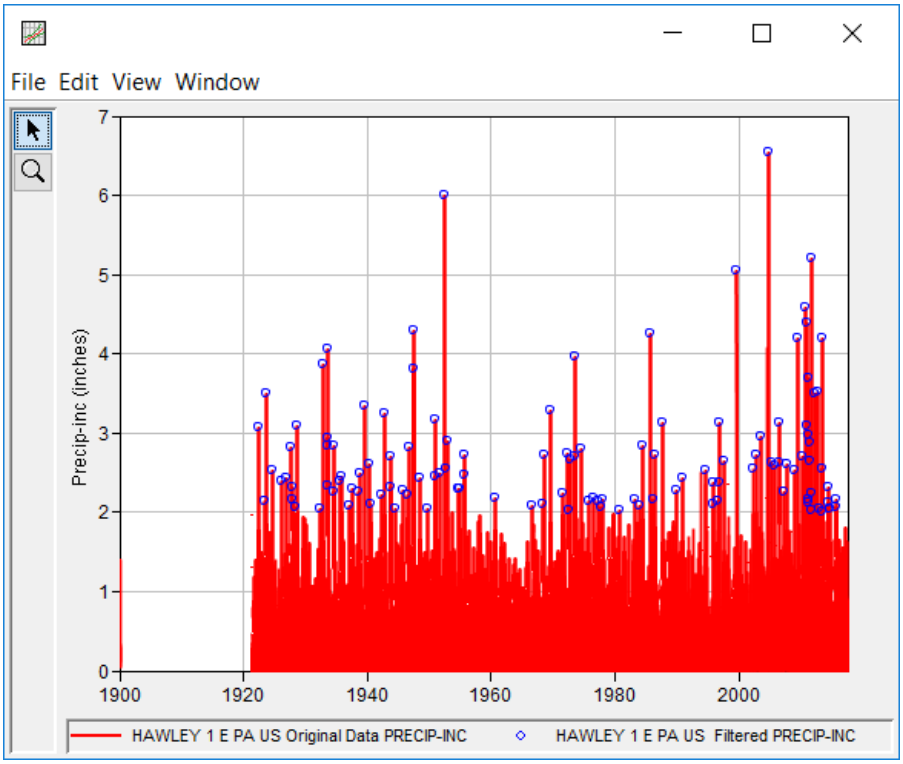
189 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 23.

For this analysis, the daily precipitation data was revised using several filters. First, a **Time Window** filter was applied spanning **01Oct1921** through **30Sep2017** (i.e. water year 1922 – water year 2017). Second, peaks were extracted from the remaining daily precipitation accumulations using a minimum threshold of 2 inches. Out of the original 31383 values, 121 values remained after data filtering. These 121 peak values constitute a partial duration series of daily precipitation accumulations in excess of 2 inches. The filters used within this analysis are shown in Figure 3. The original data as well as the filtered data is shown in Figure 4.



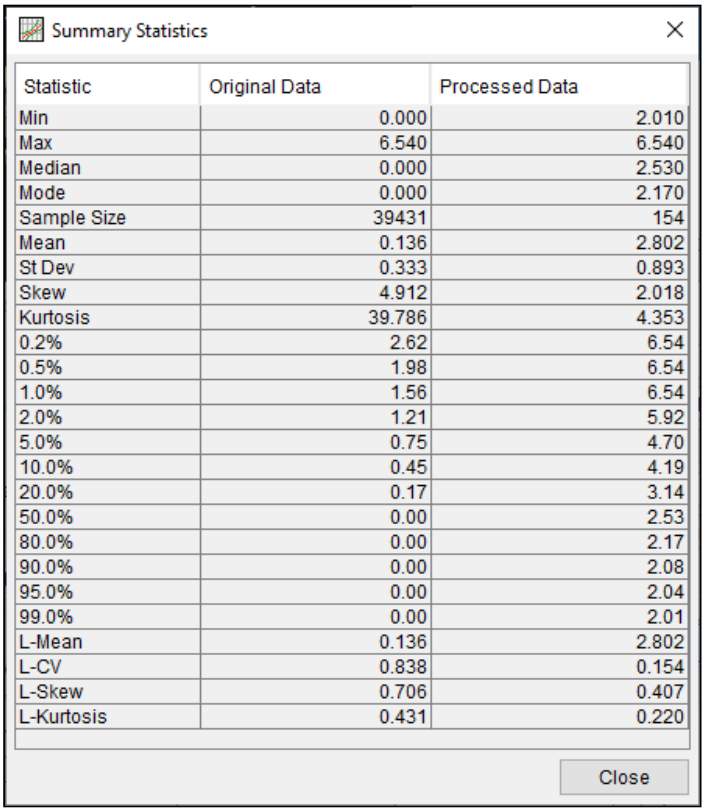
190 Figure 3. Data Filters Used within Distribution Fitting Test 23.





191 Figure 4. Original and Filtered Data within Distribution Fitting Test 23.

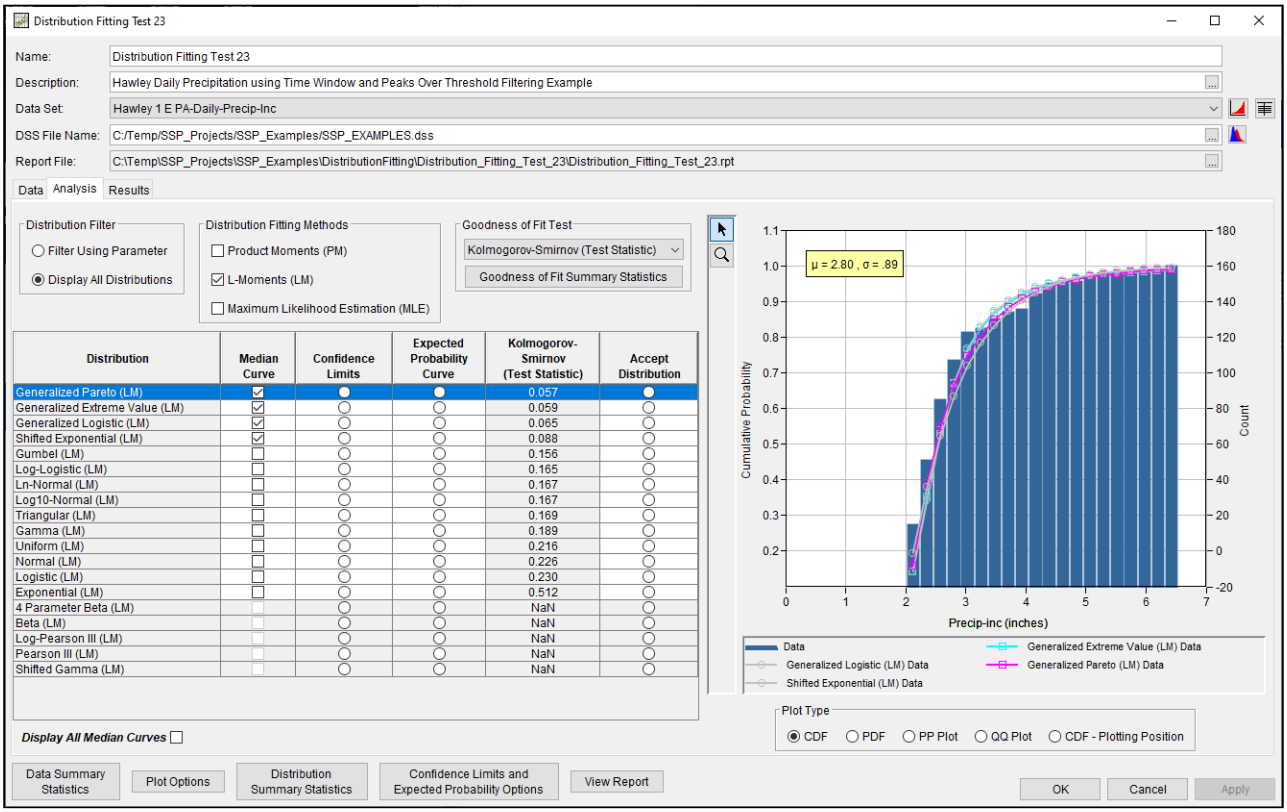
Summary statistics of the original and filtered/processed data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 5.



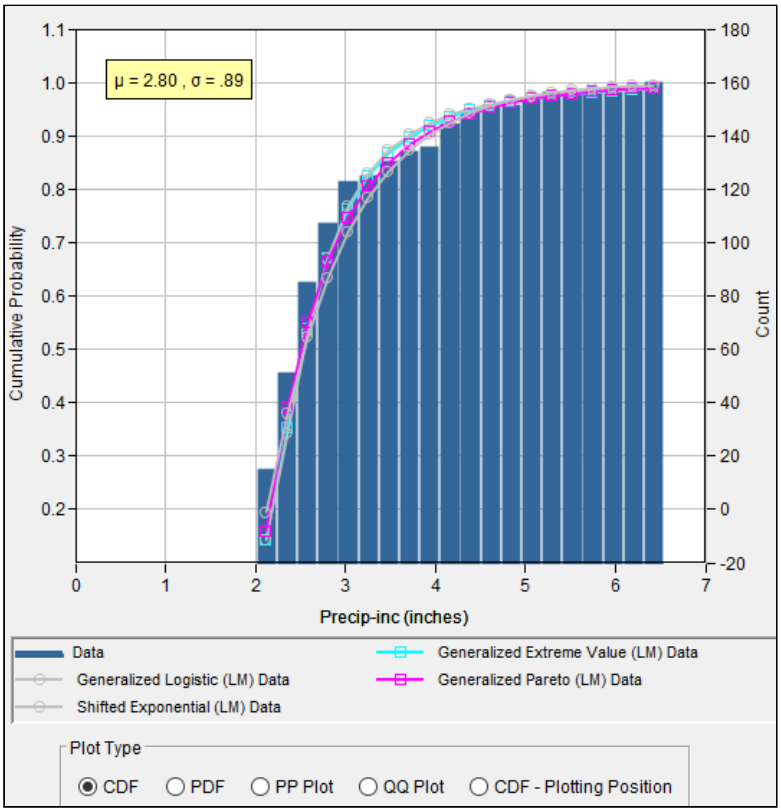
Statistic	Original Data	Processed Data
Min	0.000	2.010
Max	6.540	6.540
Median	0.000	2.530
Mode	0.000	2.170
Sample Size	39431	154
Mean	0.136	2.802
St Dev	0.333	0.893
Skew	4.912	2.018
Kurtosis	39.786	4.353
0.2%	2.62	6.54
0.5%	1.98	6.54
1.0%	1.56	6.54
2.0%	1.21	5.92
5.0%	0.75	4.70
10.0%	0.45	4.19
20.0%	0.17	3.14
50.0%	0.00	2.53
80.0%	0.00	2.17
90.0%	0.00	2.08
95.0%	0.00	2.04
99.0%	0.00	2.01
L-Mean	0.136	2.802
L-CV	0.838	0.154
L-Skew	0.706	0.407
L-Kurtosis	0.431	0.220

192 Figure 5. Data Summary Statistics for Distribution Fitting Test 23.

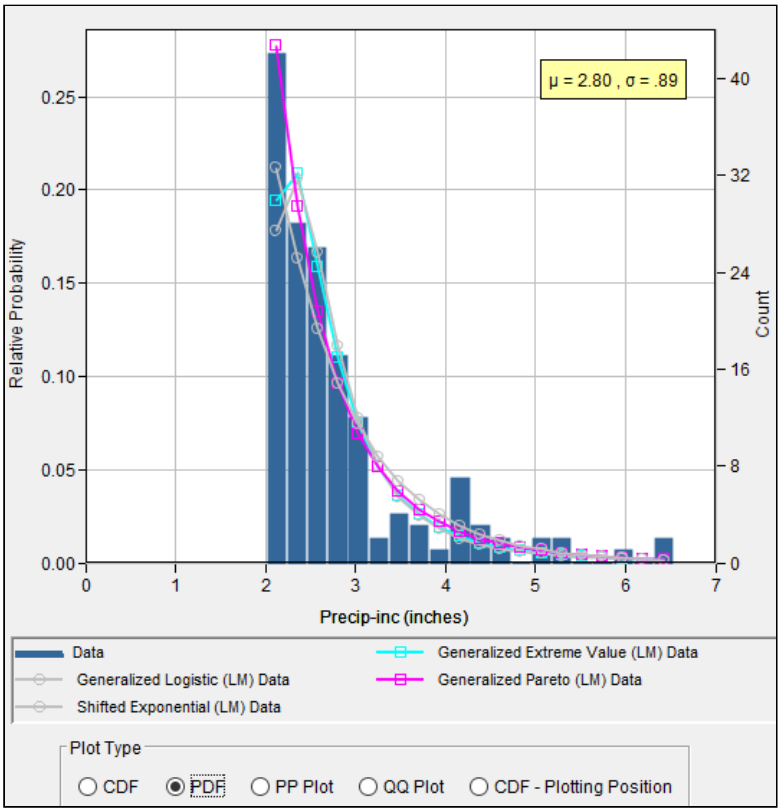
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 6, the **Display All Distributions** radio button was selected within the Distribution Filter panel to display all of the available analytical distributions. The L-Moments Fitting method was selected. The default Kolmogorov-Smirnov goodness of fit test was left unchanged. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure 7, Figure 8. Figure 9, Figure 10, and Figure 11.



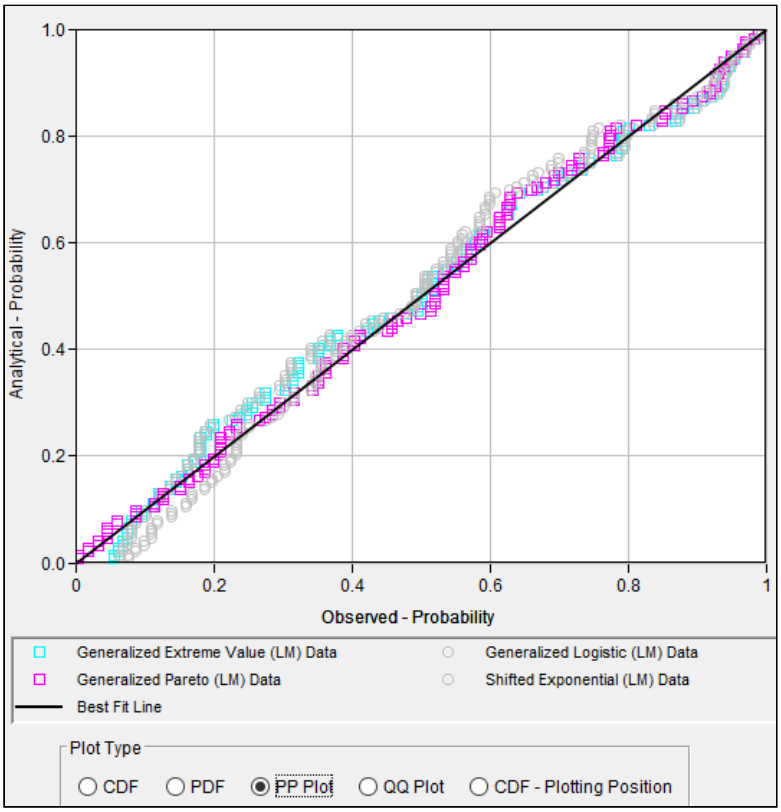
193 Figure 6. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 23.



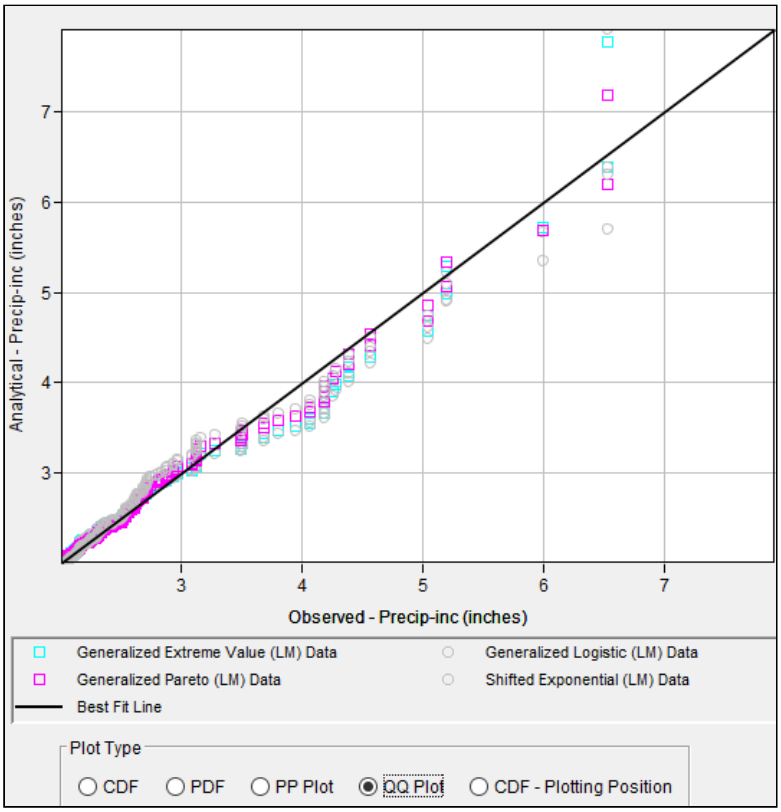
194 Figure 7. CDF Plot for Distribution Fitting Test 23.



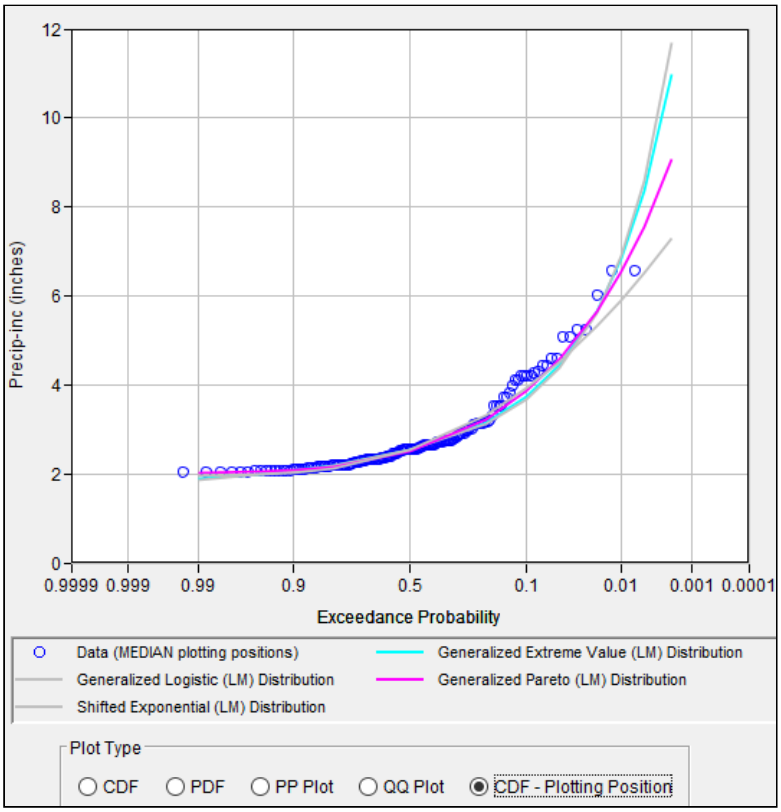
195 Figure 8. PDF Plot for Distribution Fitting Test 23.



196 Figure 9. PP Plot for Distribution Fitting Test 23.

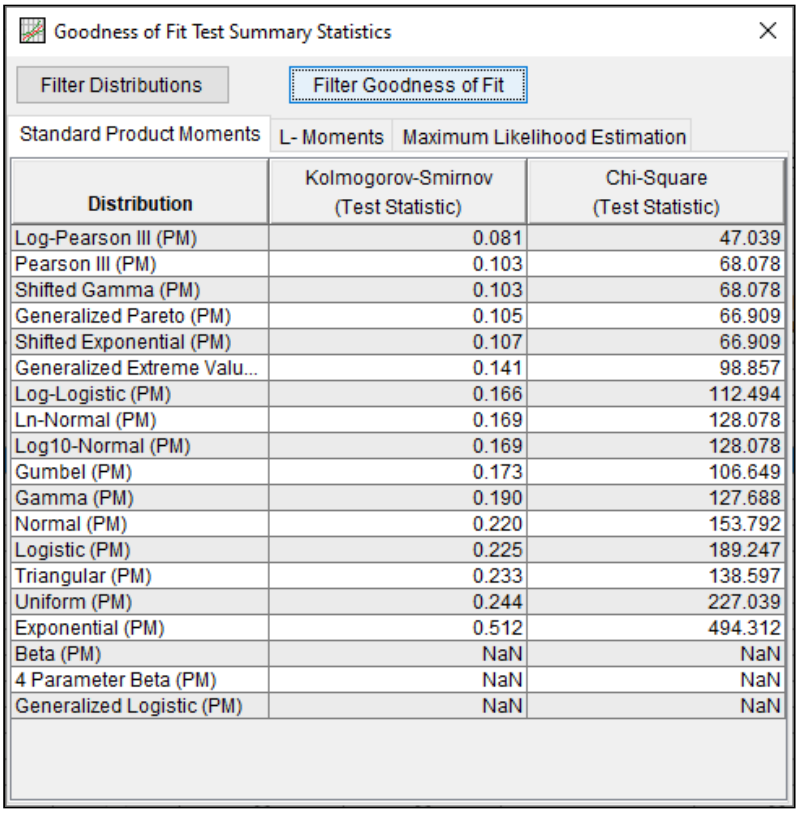


197 Figure 10. QQ Plot for Distribution Fitting Test 23.



198 Figure 11. CDF-Plotting Position Plot for Distribution Fitting Test 23.

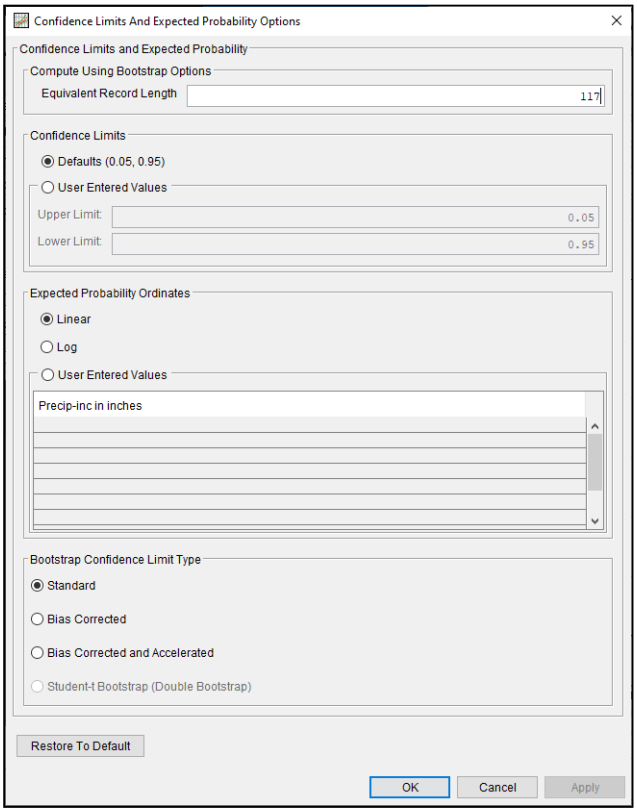
Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 12.



Distribution	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Log-Pearson III (PM)	0.081	47.039
Pearson III (PM)	0.103	68.078
Shifted Gamma (PM)	0.103	68.078
Generalized Pareto (PM)	0.105	66.909
Shifted Exponential (PM)	0.107	66.909
Generalized Extreme Valu...	0.141	98.857
Log-Logistic (PM)	0.166	112.494
Ln-Normal (PM)	0.169	128.078
Log10-Normal (PM)	0.169	128.078
Gumbel (PM)	0.173	106.649
Gamma (PM)	0.190	127.688
Normal (PM)	0.220	153.792
Logistic (PM)	0.225	189.247
Triangular (PM)	0.233	138.597
Uniform (PM)	0.244	227.039
Exponential (PM)	0.512	494.312
Beta (PM)	NaN	NaN
4 Parameter Beta (PM)	NaN	NaN
Generalized Logistic (PM)	NaN	NaN

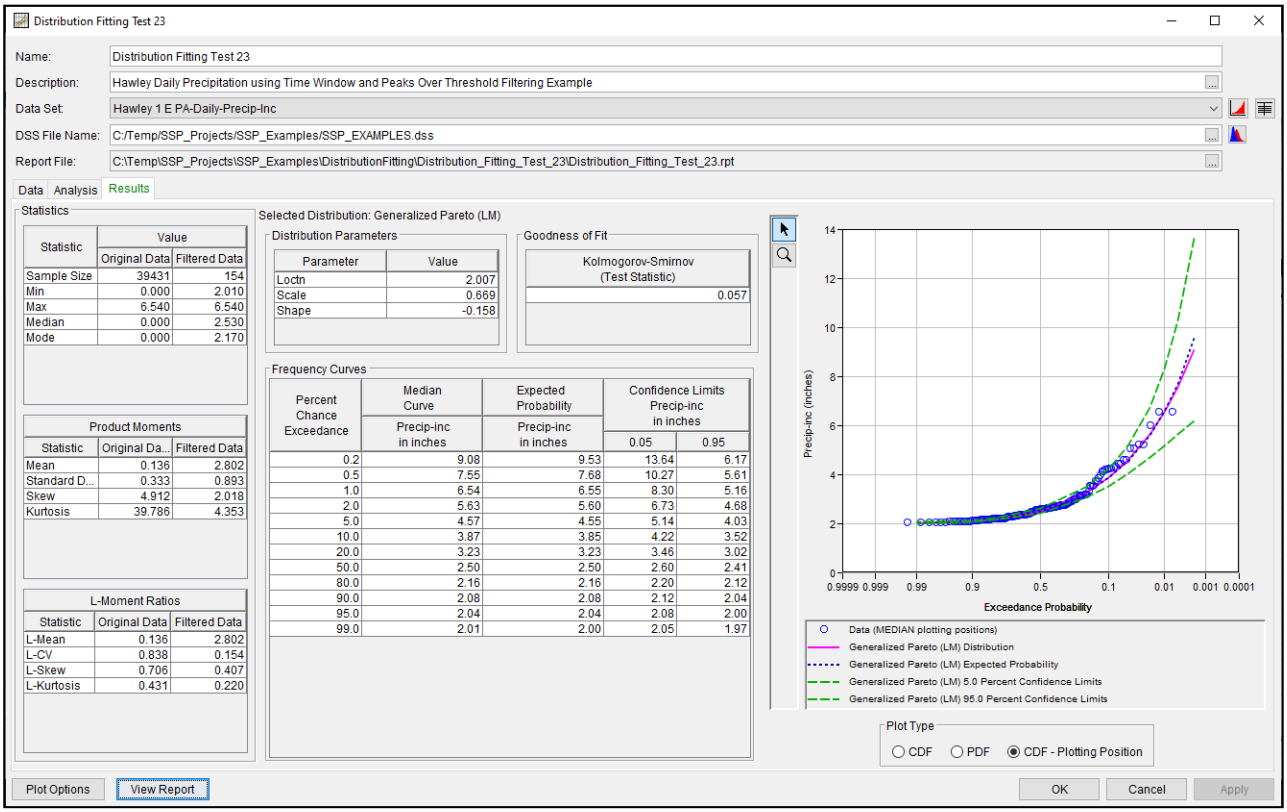
199 Figure 12. Goodness of Fit Summary Statistics for Distribution Fitting Test 23.

In this example, the Generalized Pareto Distribution fit using L-Moments was selected by clicking the **Accept Distribution** button. Upon clicking this button, confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. The default confidence limits options were selected, as shown in Figure 13.



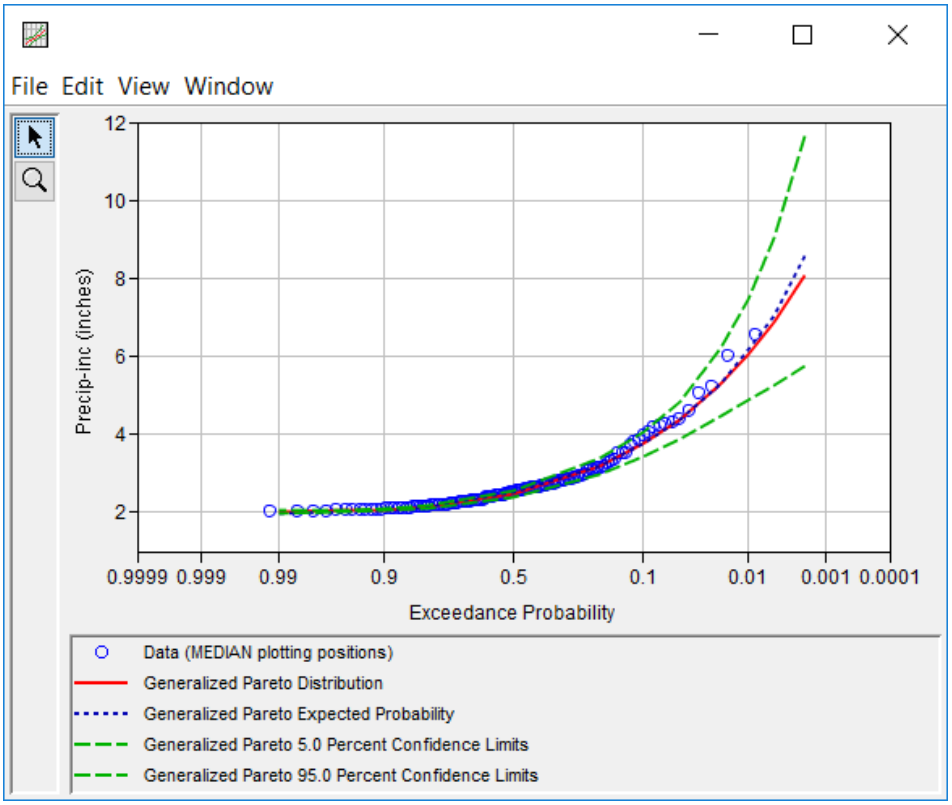
200 Figure 13. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 23.

The accepted distribution | fitting method was used to populate the Results tab, as shown in Figure 14.



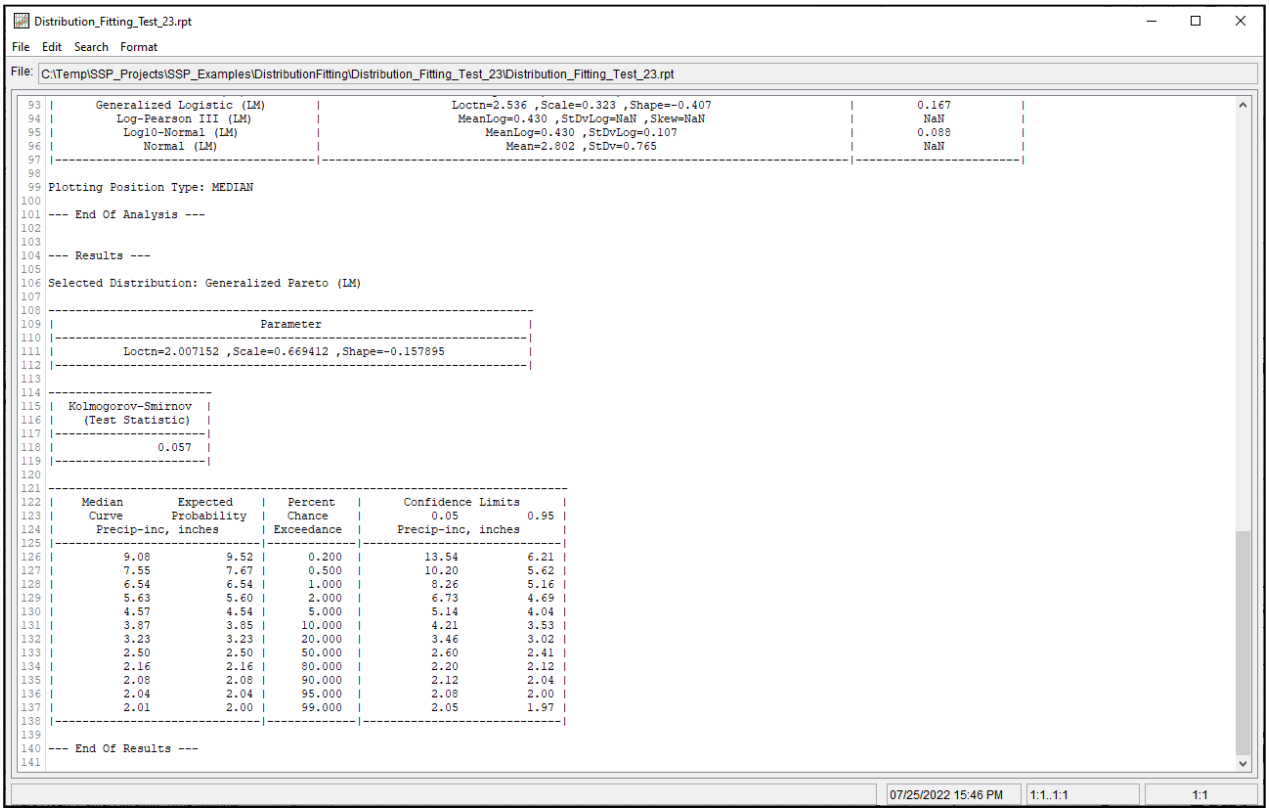
201 Figure 14. Distribution Fitting Results Tab Shown for Distribution Fitting Test 23.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 15.



202 Figure 15. Distribution Fitting Results Plot Shown for Distribution Fitting Test 23.

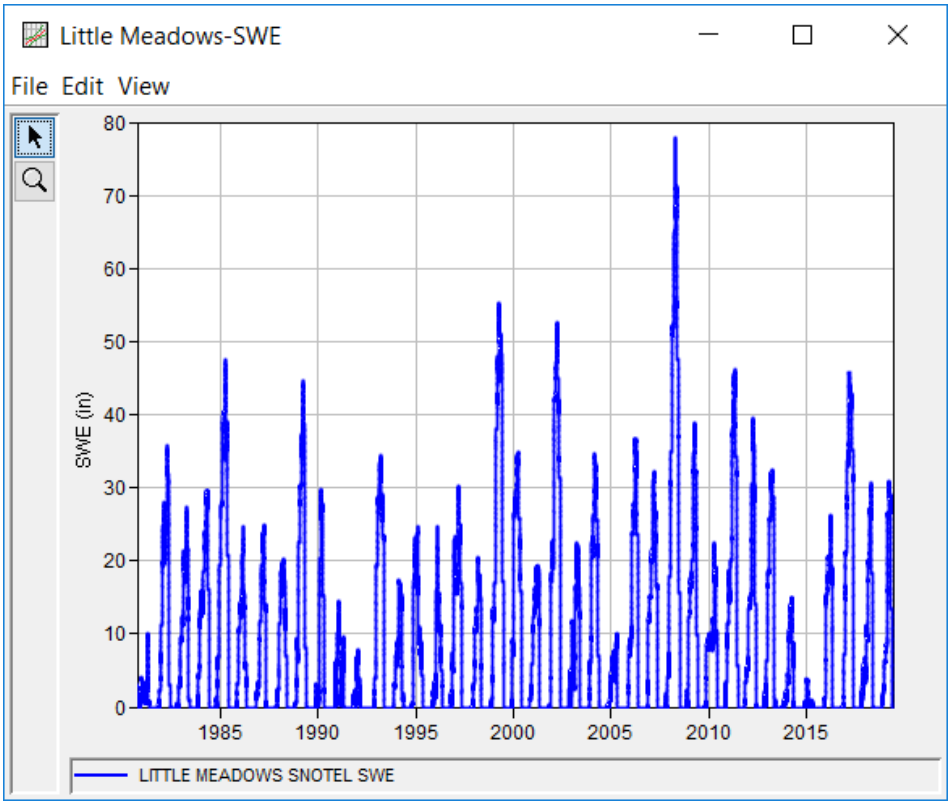
In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 16.



10.5 Example 24. Distribution Fitting, Analyzing a Time Series of Daily Average Snow Water Equivalent Using Annual Maxima Filtering

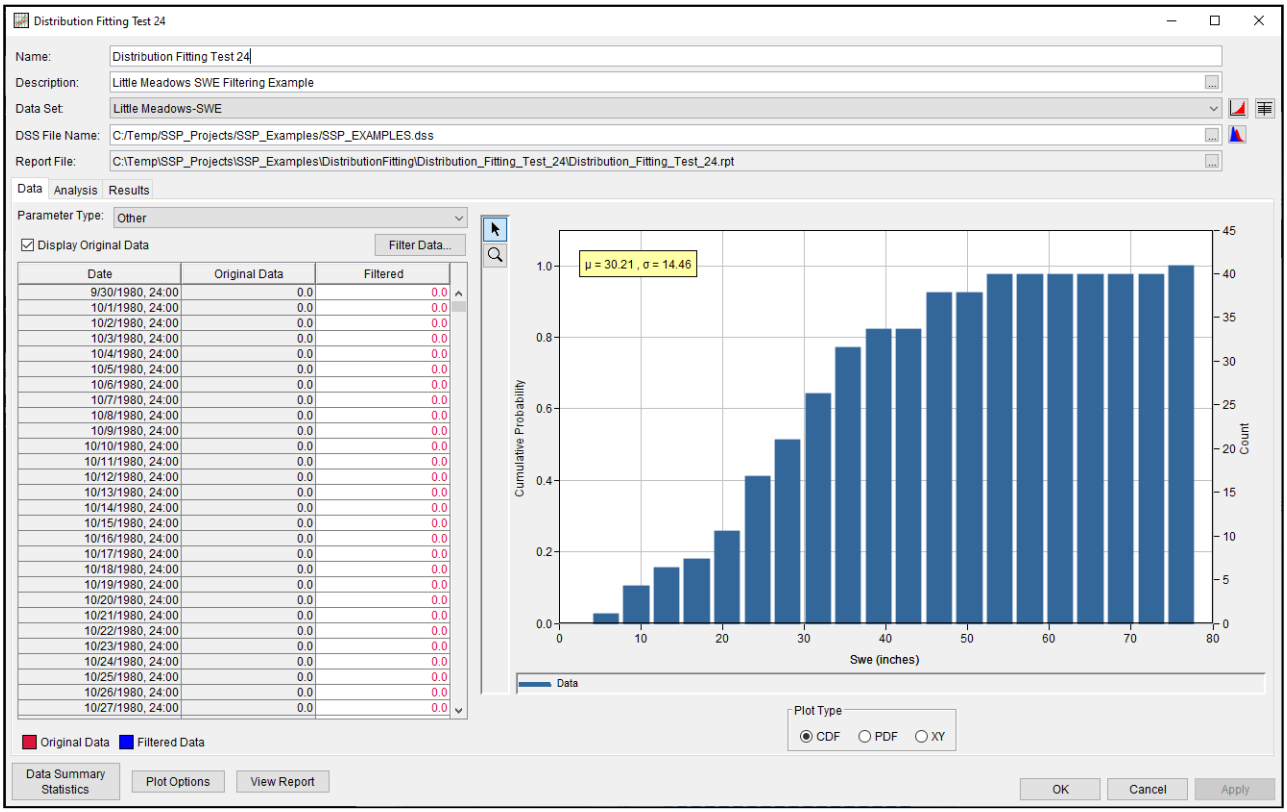
This example demonstrates how to use the Distribution Fitting analysis to analyze a time series of daily average snow water equivalent (SWE) annual maxima filtering. The data for this example consists of a daily average SWE time series for the Little Meadows Snow Telemetry (SNOTEL) station[50] located near Detroit Dam along the North Santiam River in Oregon. This SNOTEL gage is operated by the Natural Resources Conservation Service (NRCS). The data available for this station, which includes precipitation, temperature, and snow data, was downloaded using an HEC-DSSVue plugin. The period of record used for this example is from September 1980 to June 2019. To view the data, right-click on the data record labeled "**Little Meadows-SWE**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1.

50 https://wcc.sc.egov.usda.gov/nwcc/site?sitenum=584



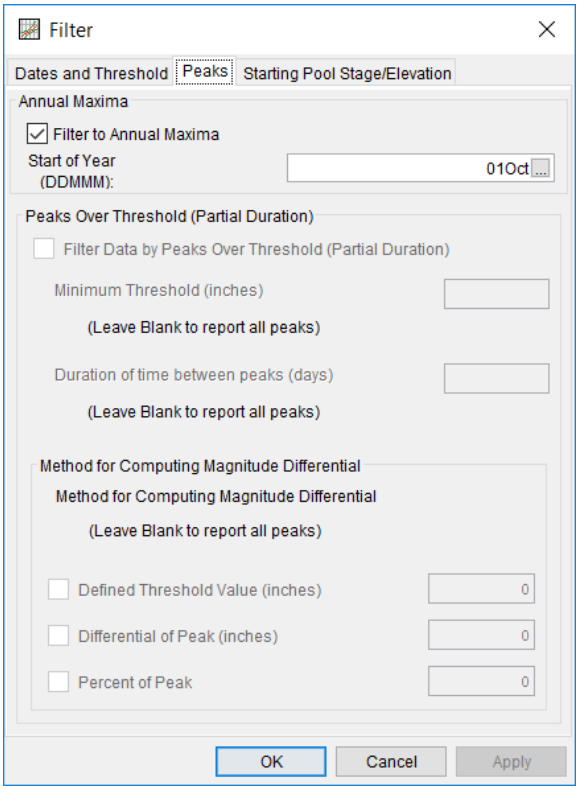
203 Figure 1. Plot of the Little Meadows SWE Data.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 24** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 24** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2.

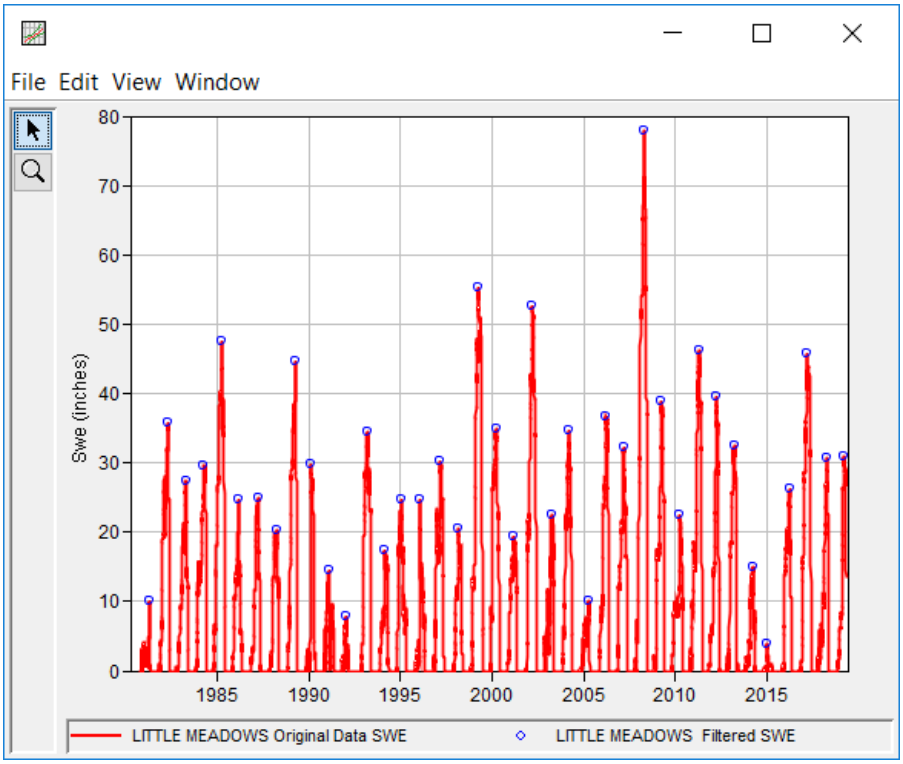


204 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 24.

For this analysis, an annual maximum series was extracted from the original daily average SWE data using a water year demarcation of 01Oct (i.e. extract annual maxima between 01Oct – 30Sep). Out of the original 14125 values, 39 values remained after data filtering. These 39 peak values constitute an annual maximum series of daily average SWE. The filters used within this analysis are shown in Figure 3. The original data as well as the filtered data is shown in Figure 4.

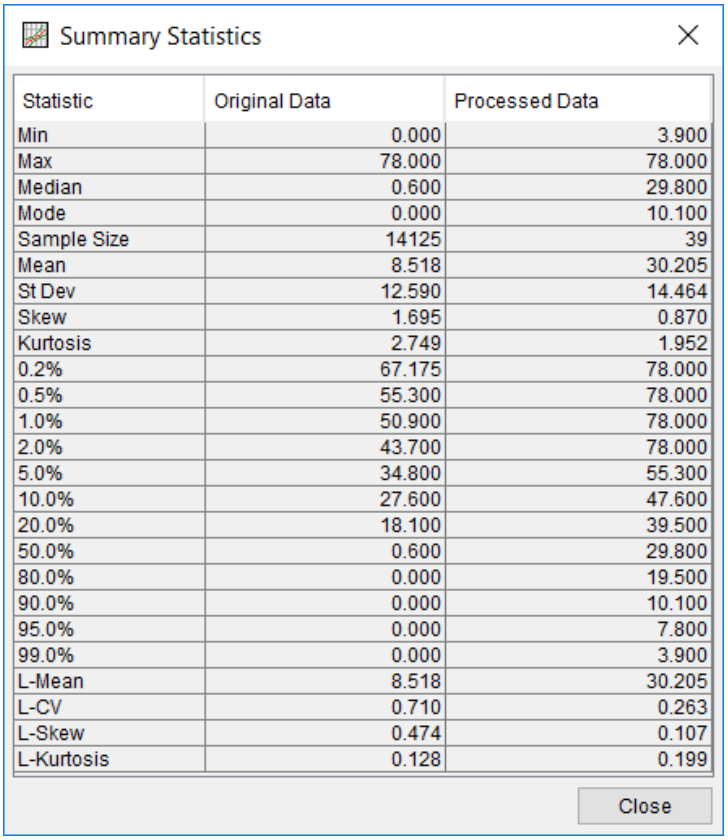


205 Figure 3. Data Filters Used within Distribution Fitting Test 24.



206 Figure 4. Original and Filtered Data within Distribution Fitting Test 24.

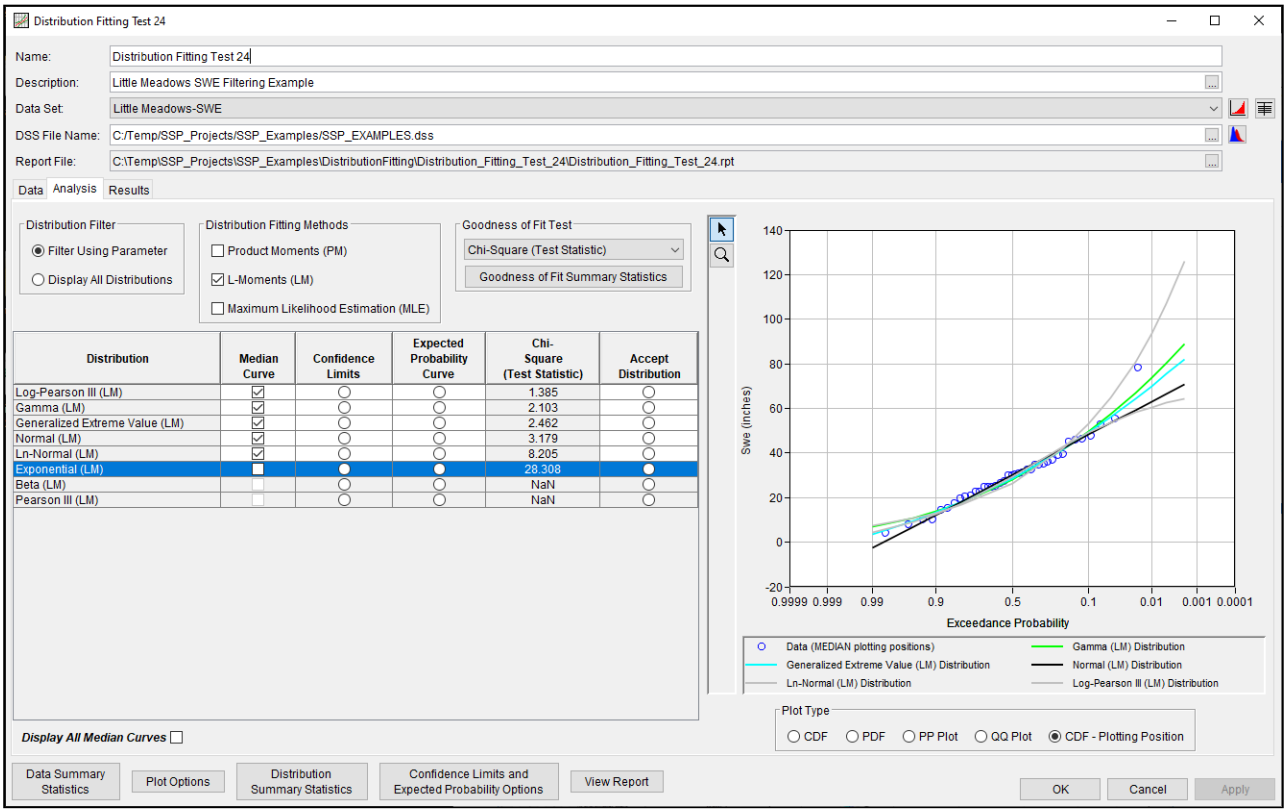
Summary statistics of the original and filtered/processed data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 5.



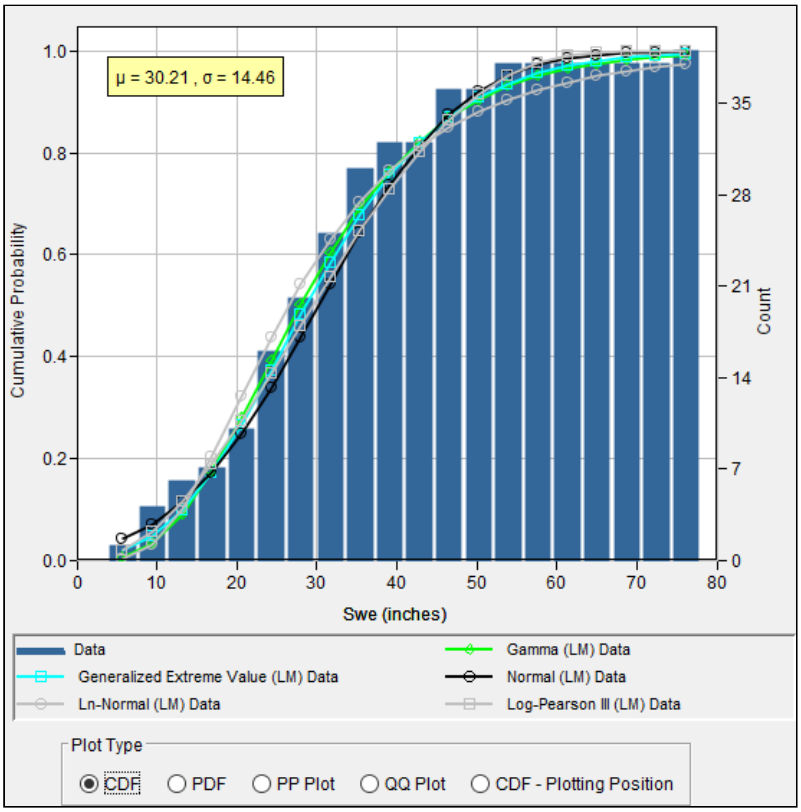
Statistic	Original Data	Processed Data
Min	0.000	3.900
Max	78.000	78.000
Median	0.600	29.800
Mode	0.000	10.100
Sample Size	14125	39
Mean	8.518	30.205
St Dev	12.590	14.464
Skew	1.695	0.870
Kurtosis	2.749	1.952
0.2%	67.175	78.000
0.5%	55.300	78.000
1.0%	50.900	78.000
2.0%	43.700	78.000
5.0%	34.800	55.300
10.0%	27.600	47.600
20.0%	18.100	39.500
50.0%	0.600	29.800
80.0%	0.000	19.500
90.0%	0.000	10.100
95.0%	0.000	7.800
99.0%	0.000	3.900
L-Mean	8.518	30.205
L-CV	0.710	0.263
L-Skew	0.474	0.107
L-Kurtosis	0.128	0.199

207 Figure 5. Data Summary Statistics for Distribution Fitting Test 24.

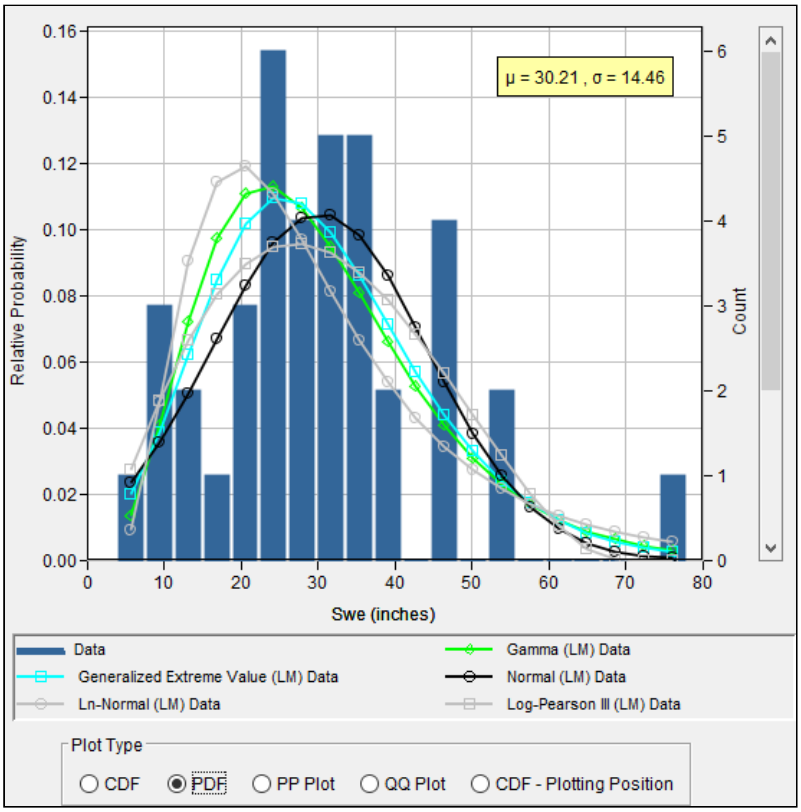
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 6, the **Filter Using Parameter** radio button was selected within the Distribution Filter panel. The L-Moments distribution fitting method was selected. The Chi-Square goodness of fit test was selected in the Goodness of Fit Test panel. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure 7, Figure 8, Figure 9, Figure 10, and Figure 11.



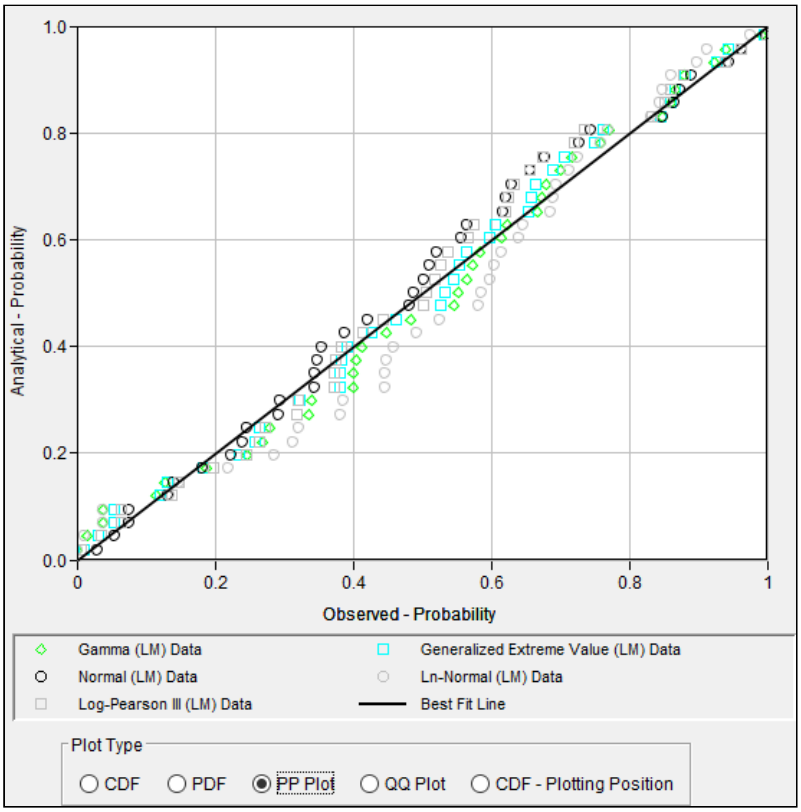
208 Figure 6. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 24.



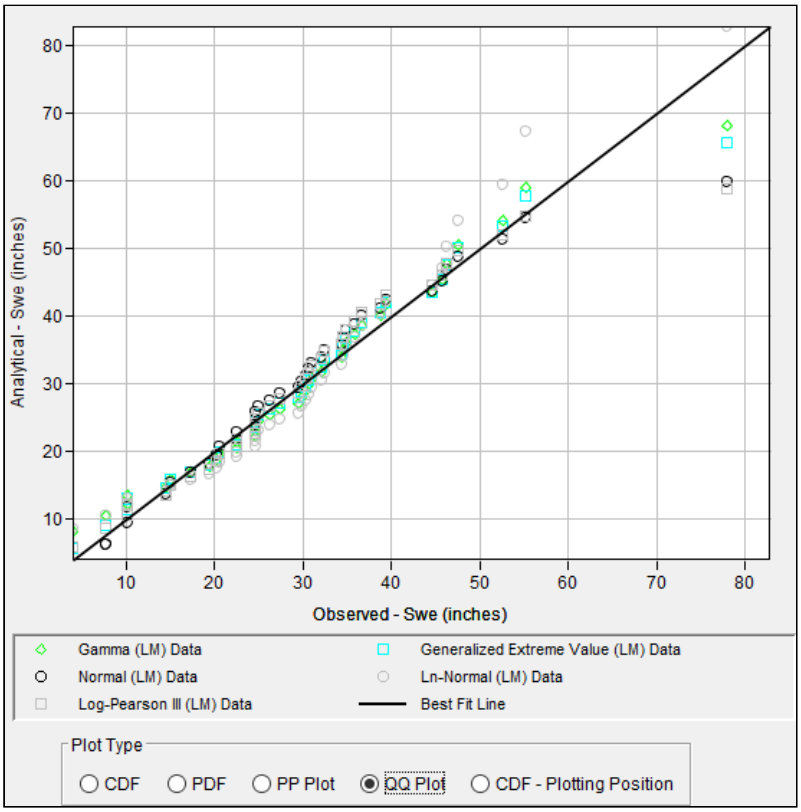
209 Figure 7. CDF Plot for Distribution Fitting Test 24.



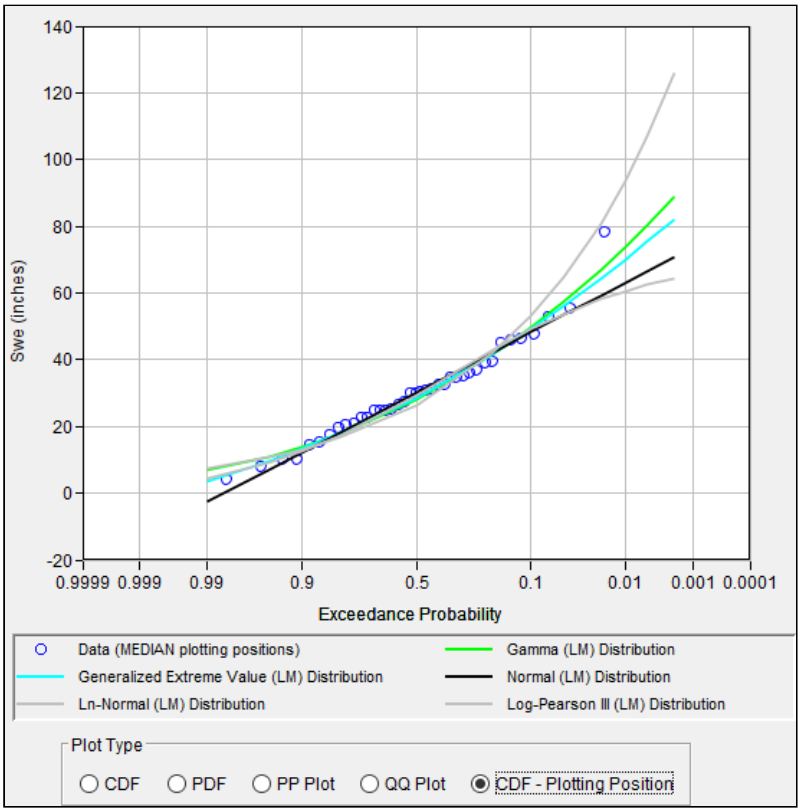
210 Figure 8. PDF Plot for Distribution Fitting Test 24.



211 Figure 9. PP Plot for Distribution Fitting Test 24.

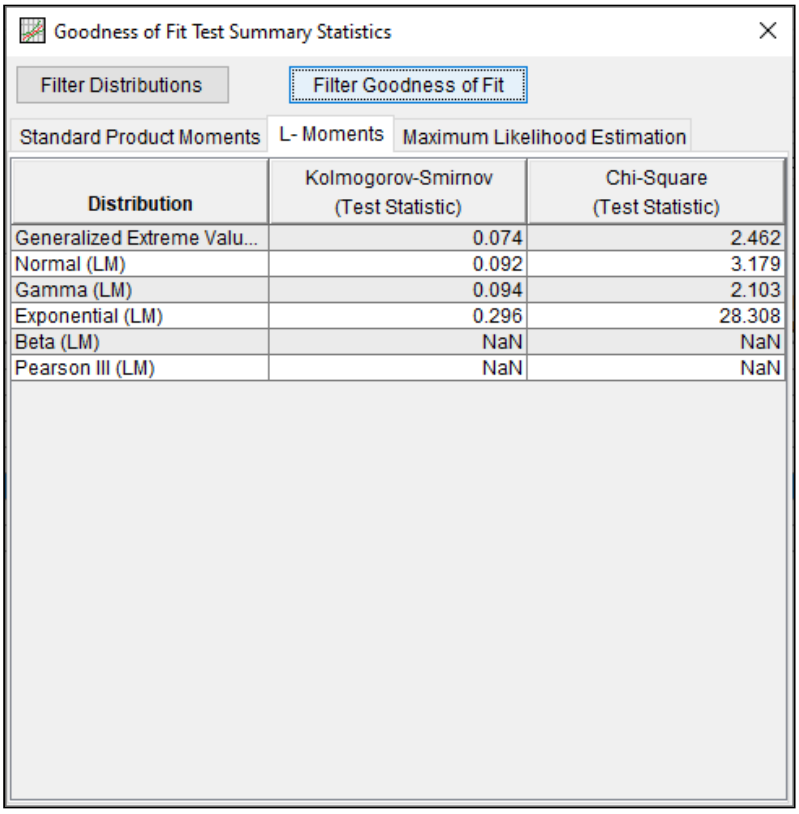


212 Figure 10. QQ Plot for Distribution Fitting Test 24.



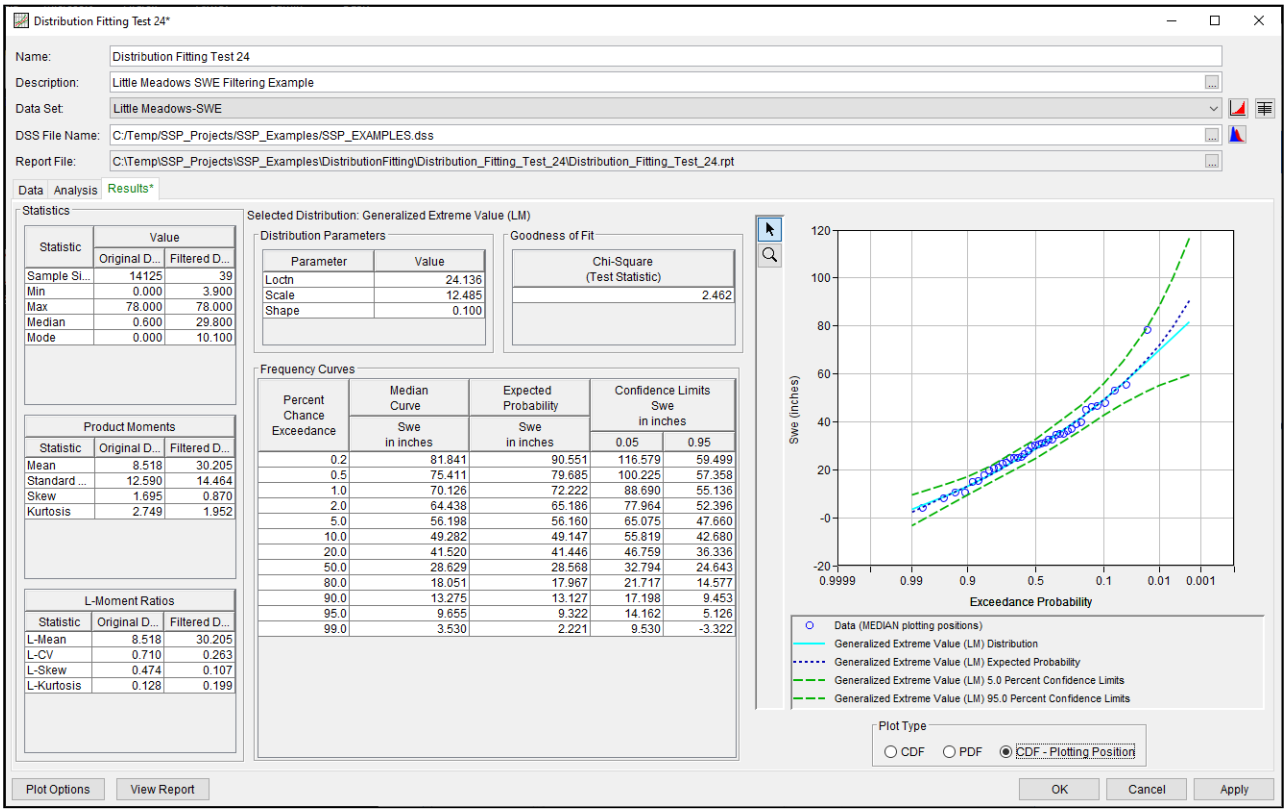
213 Figure 11. CDF-Plotting Position Plot for Distribution Fitting Test 24.

Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 12.



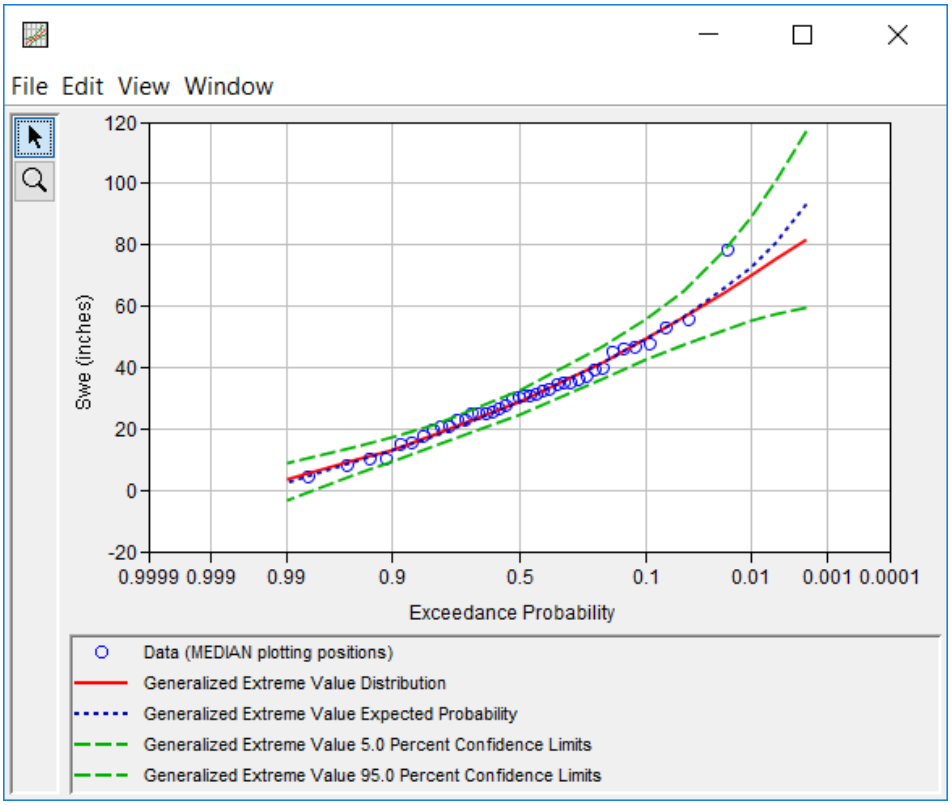
214 Figure 12. Goodness of Fit Summary Statistics for Distribution Fitting Test 24.

In this example, the Generalized Extreme Value Distribution fit using L-Moments was selected by clicking the **Accept Distribution**. Upon clicking this button, confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. The accepted distribution | fitting method was used to populate the Results tab, as shown in Figure 13.



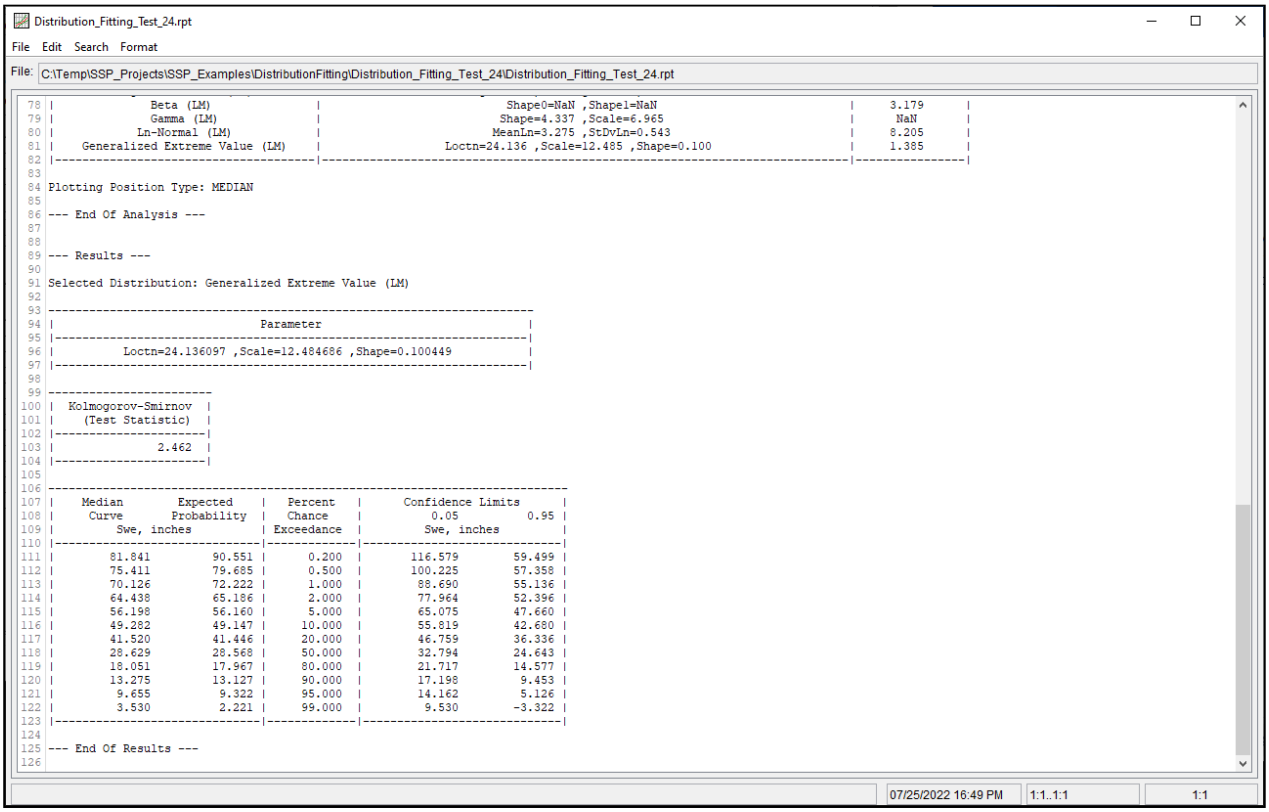
215 Figure 13. Distribution Fitting Results Tab Shown for Distribution Fitting Test 24.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 14.



216 Figure 14. Distribution Fitting Results Plot Shown for Distribution Fitting Test 24.

In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 15.

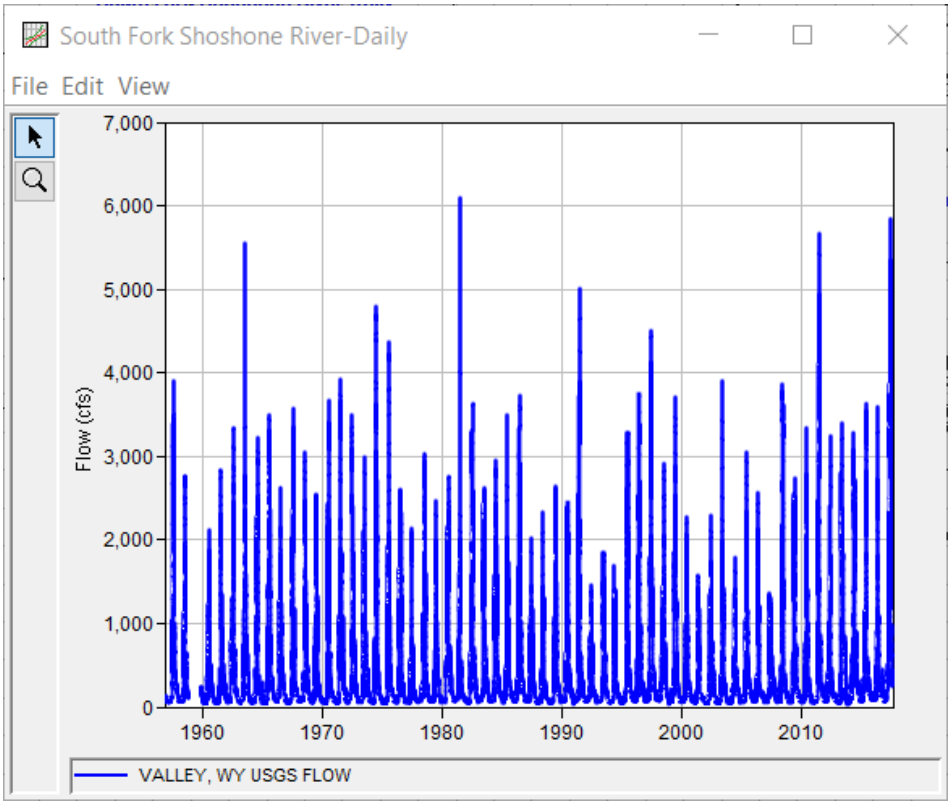


217 Figure 15. Report File for Distribution Fitting Test 24.

10.6 Example 25. Distribution Fitting, Analyzing a Time Series of Daily Average Flow to Estimate Flood Seasonality

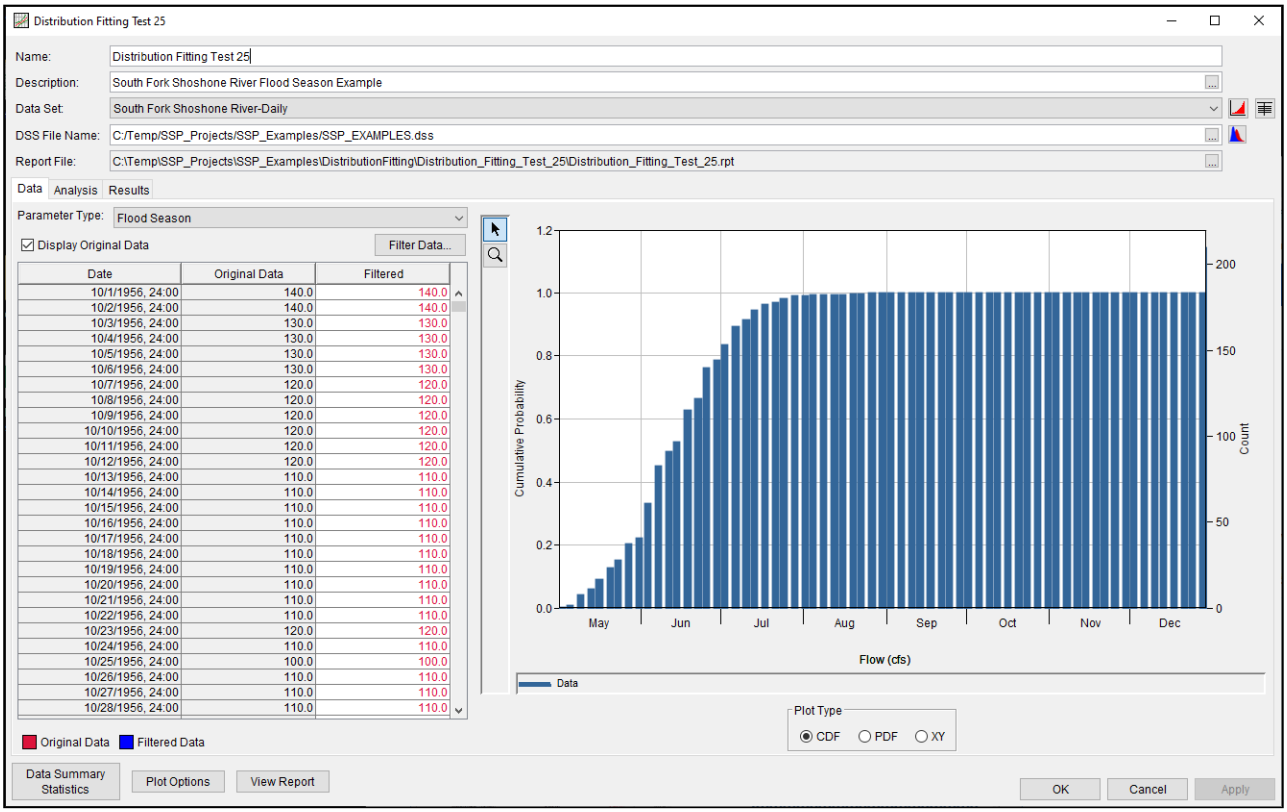
This example demonstrates how to use the Distribution Fitting analysis to analyze a time series of daily average streamflow using peaks over threshold filtering to estimate flood seasonality (or when floods occur throughout the year). The data for this example consists of daily average streamflow for a location along the South Fork Shoshone River near Valley, WY[51]. This stream gage is operated by the USGS (gage ID: 06280300). The period of record used for this example is from 1956 to 2017. To view the data from HEC-SSP, right-click on the data record labeled "**South Fork Shoshone River-Daily**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 375).

51 https://waterdata.usgs.gov/wy/nwis/uv/?site_no=06280300



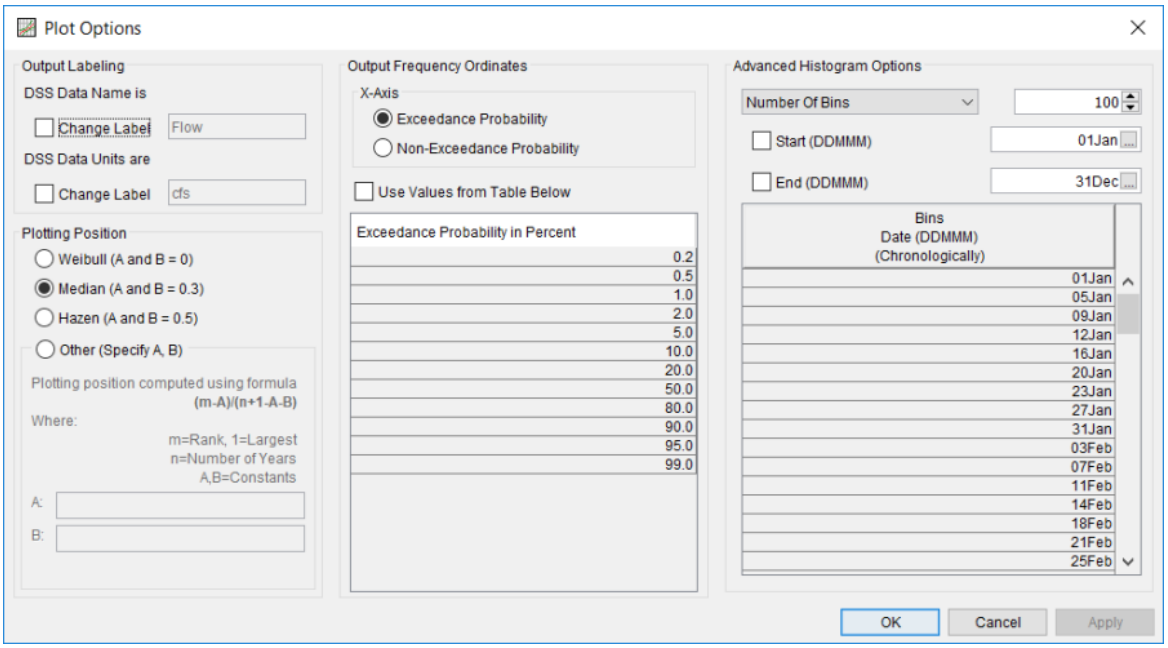
218 Figure 1. Plot of the Daily Average Flow Data for South Fork Shoshone River.

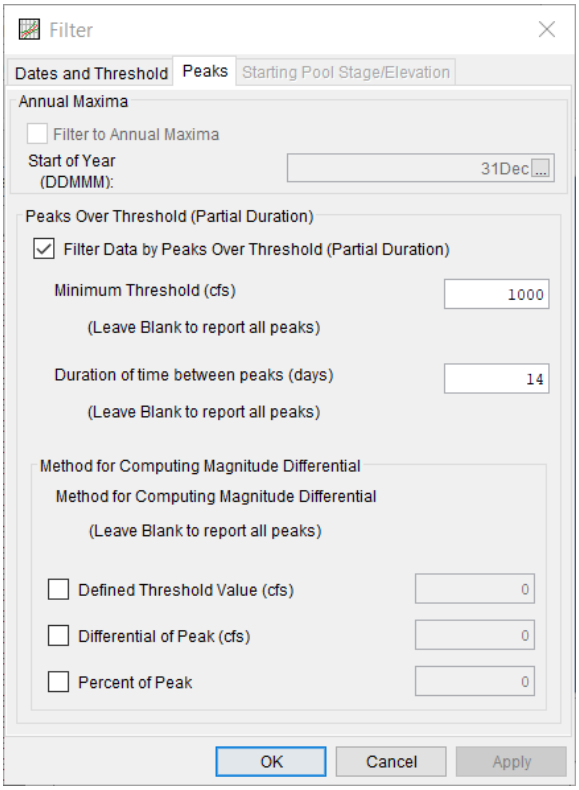
A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 25** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 25** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2 (see page 376).



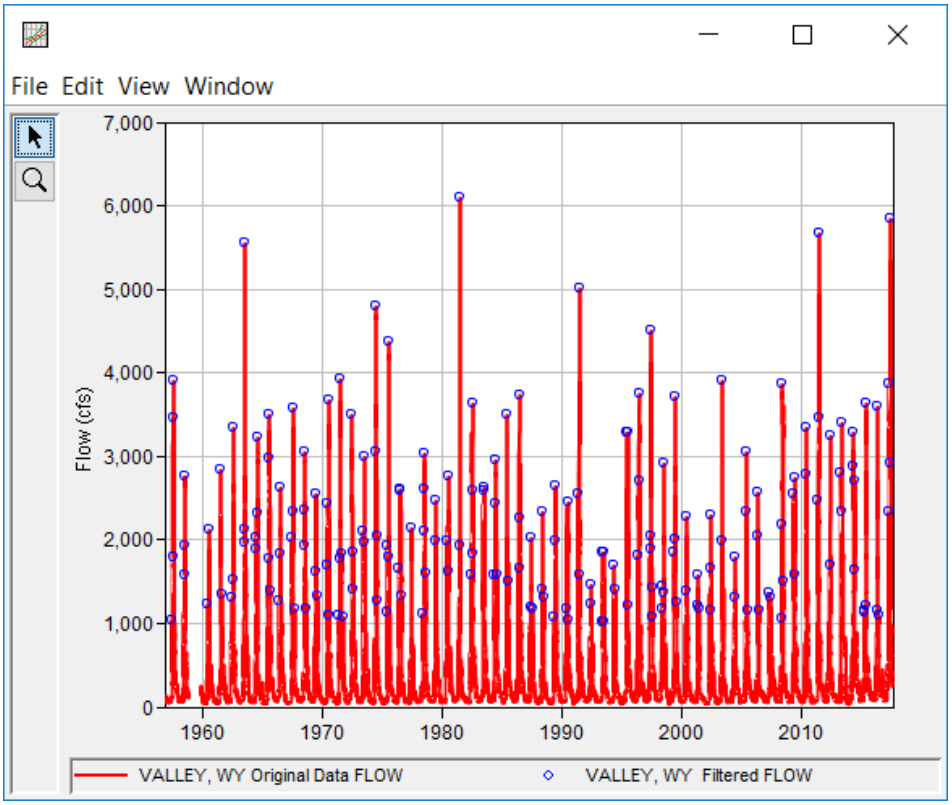
219 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 25.

For this analysis, the **Parameter Type** was changed to **Flood Season**, which enables different settings that aren't available when other parameter types are selected. First, alternative plot settings will be used within subsequent **CDF** and **PDF** plots. The dates of each value (and selected distributions) will be used in lieu of the actual values. Also, supplementary plot options that can be accessed by clicking the **Plot Options** button. Specifically, 100 bins was specified within the **Advanced Histogram Options** panel, as shown in Figure 3 (see page 377). Also, peaks greater than 1000 cfs and a minimum of 14 days apart from one another were extracted from the original daily average streamflow data. Out of the original 21898 values, 188 values remained after data filtering. These 188 peak values constitute a partial duration series of daily average streamflow peaks greater than 1000 cfs. The filters used within this analysis are shown in Figure 4 (see page 377). The original data as well as the filtered data is shown in Figure 5 (see page 377).



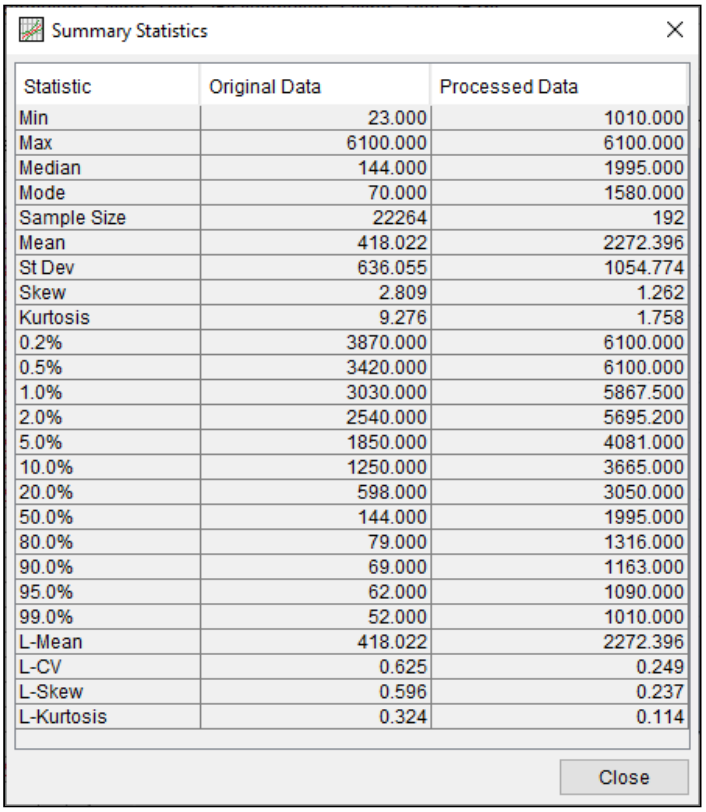


220 Figure 4. Data Filters Used within Distribution Fitting Test 25.



221 Figure 5. Original and Filtered Data within Distribution Fitting Test 25.

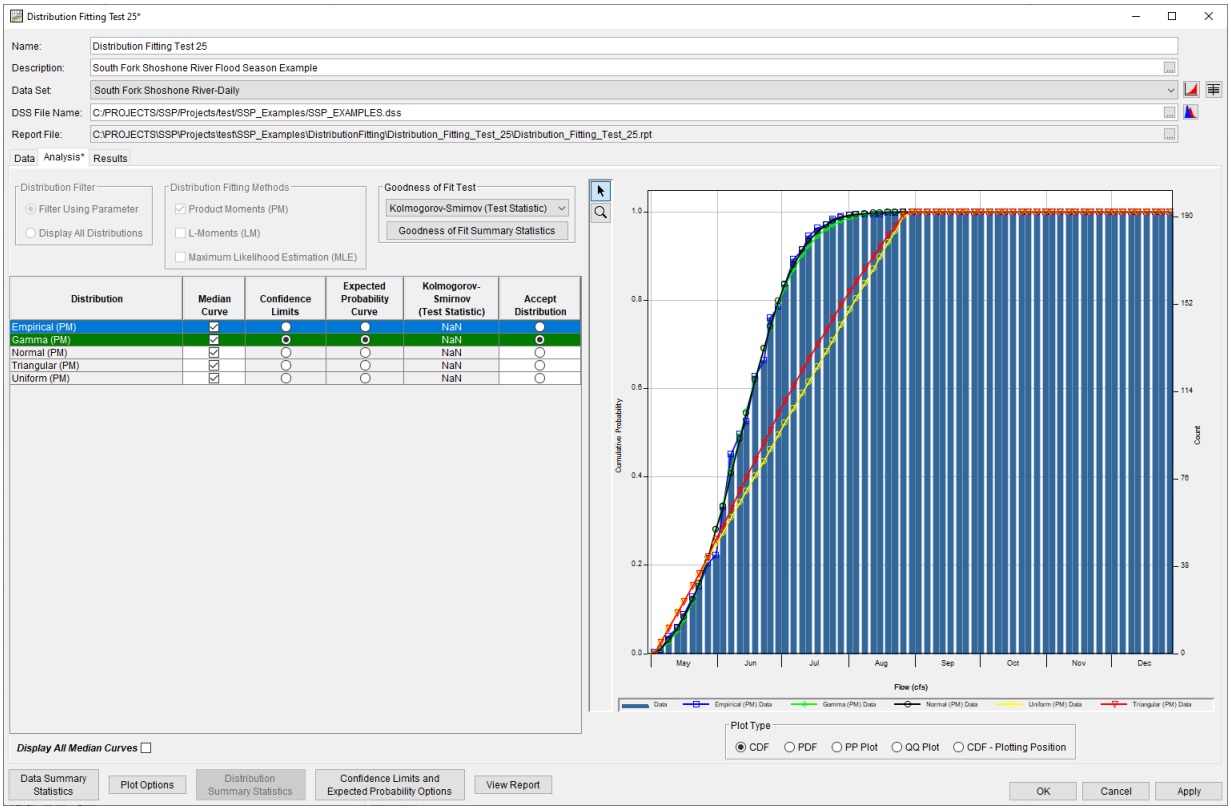
Summary statistics of the original and filtered/processed data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 6 (see page 379).



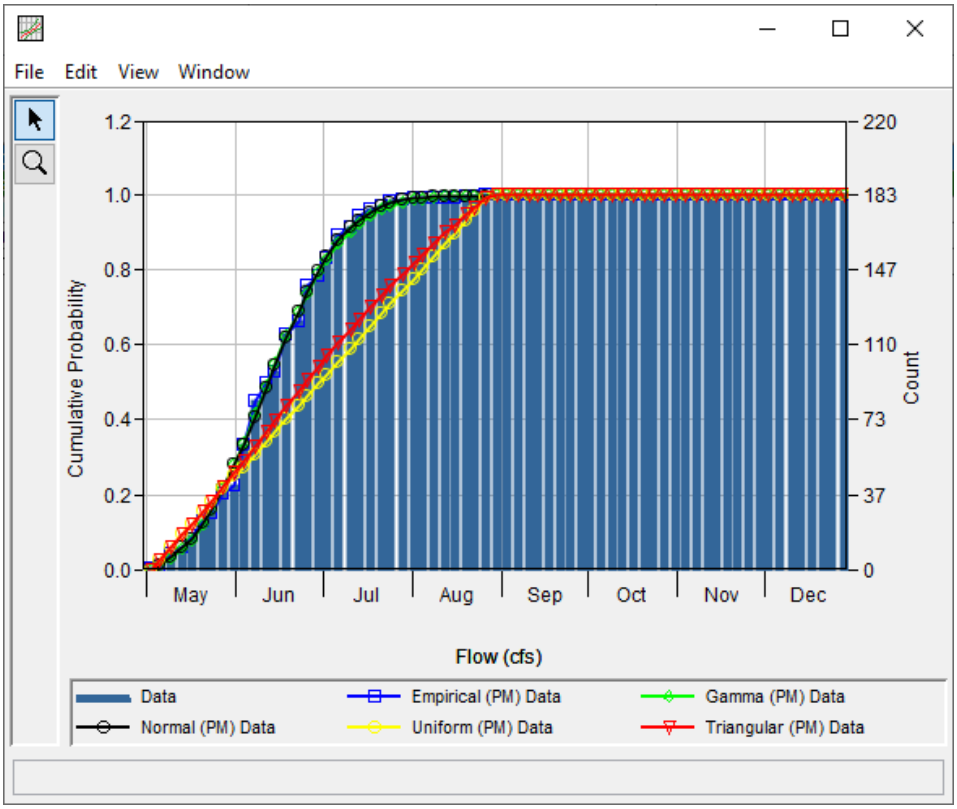
Statistic	Original Data	Processed Data
Min	23.000	1010.000
Max	6100.000	6100.000
Median	144.000	1995.000
Mode	70.000	1580.000
Sample Size	22264	192
Mean	418.022	2272.396
St Dev	636.055	1054.774
Skew	2.809	1.262
Kurtosis	9.276	1.758
0.2%	3870.000	6100.000
0.5%	3420.000	6100.000
1.0%	3030.000	5867.500
2.0%	2540.000	5695.200
5.0%	1850.000	4081.000
10.0%	1250.000	3665.000
20.0%	598.000	3050.000
50.0%	144.000	1995.000
80.0%	79.000	1316.000
90.0%	69.000	1163.000
95.0%	62.000	1090.000
99.0%	52.000	1010.000
L-Mean	418.022	2272.396
L-CV	0.625	0.249
L-Skew	0.596	0.237
L-Kurtosis	0.324	0.114

222 Figure 6. Data Summary Statistics for Distribution Fitting Test 25.

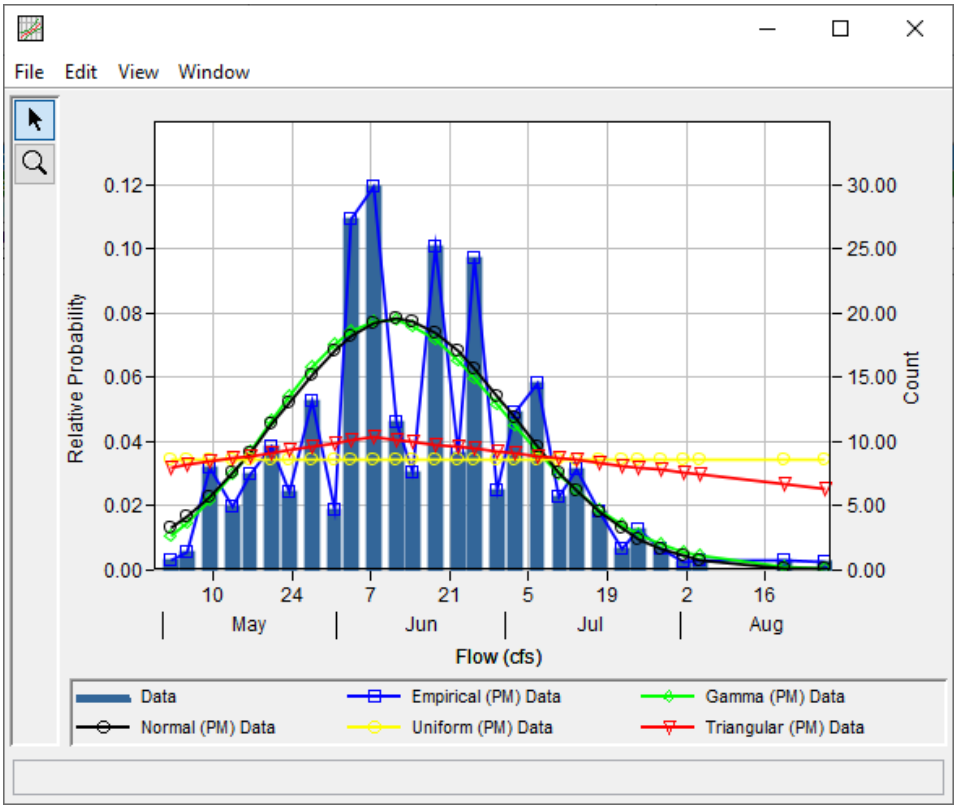
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 7 (see page 380), the default Product Moments fitting method was left unchanged. The Chi-Square goodness of fit test was selected by clicking on the column header and selecting **Chi-Square**. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, and QQ plots comparing these distributions are shown in Figure 8 (see page 380), Figure 9 (see page 380), Figure 10 (see page 380), and Figure 11 (see page 380). If a different number of bins are desired within either the CDF or PDF plots, the change should be made on the Data tab to ensure that the analytical distributions shown within either plot are the most up to date.



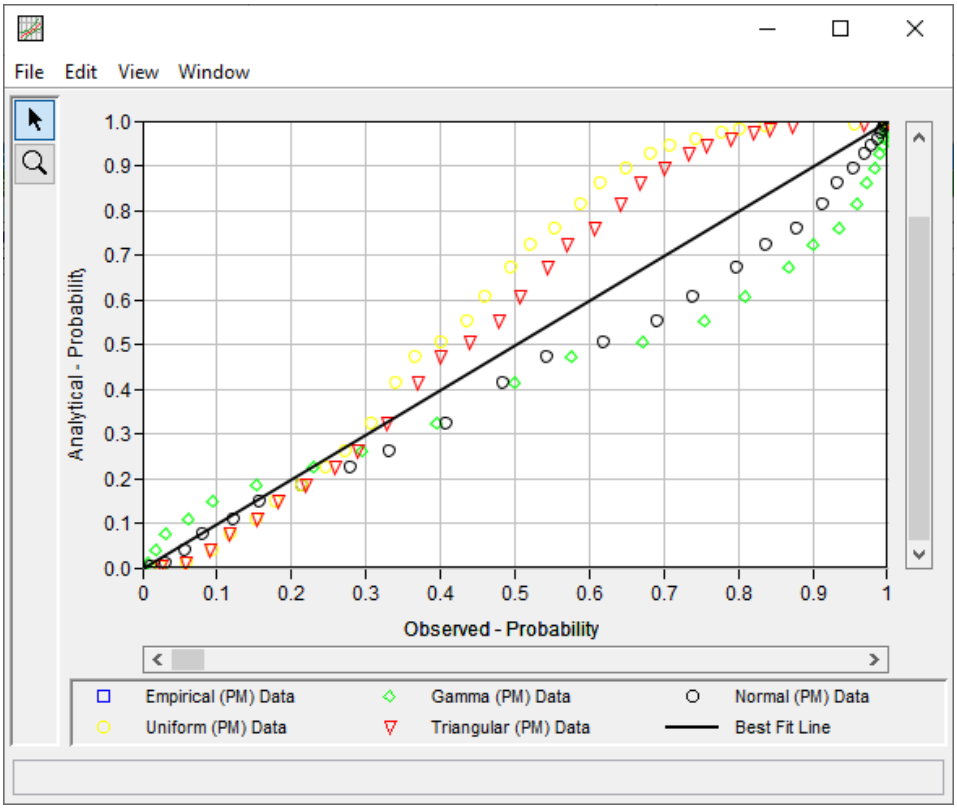
223 Figure 7. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 25.



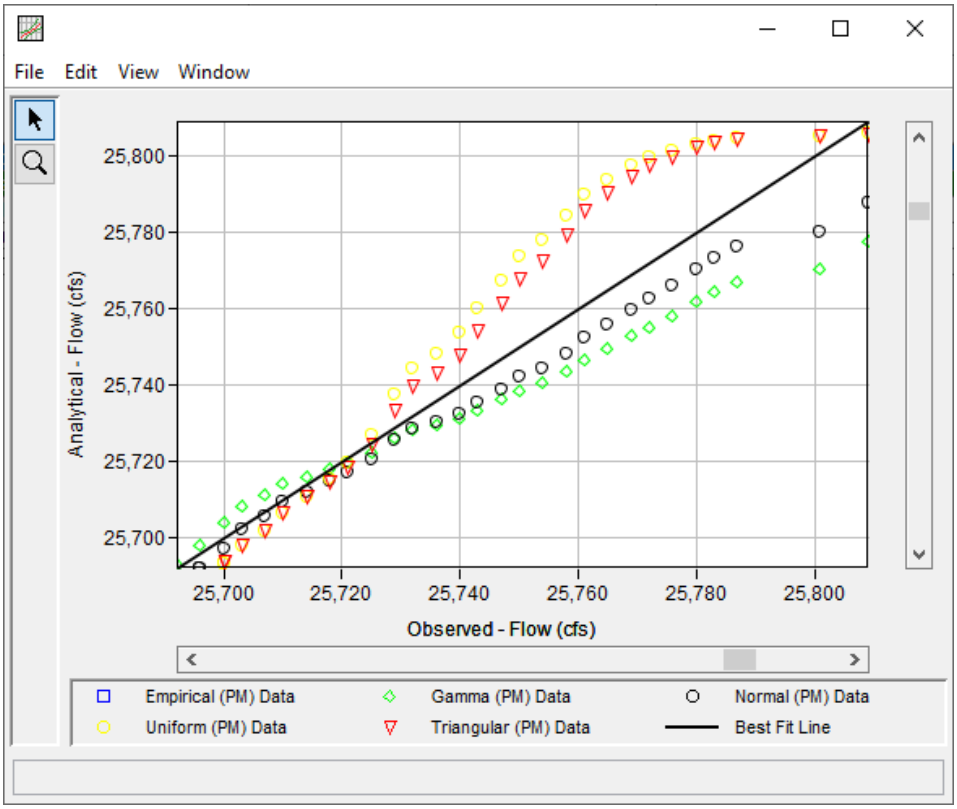
224 Figure 8. CDF Plot for Distribution Fitting Test 25.



225 Figure 9. PDF Plot for Distribution Fitting Test 25.

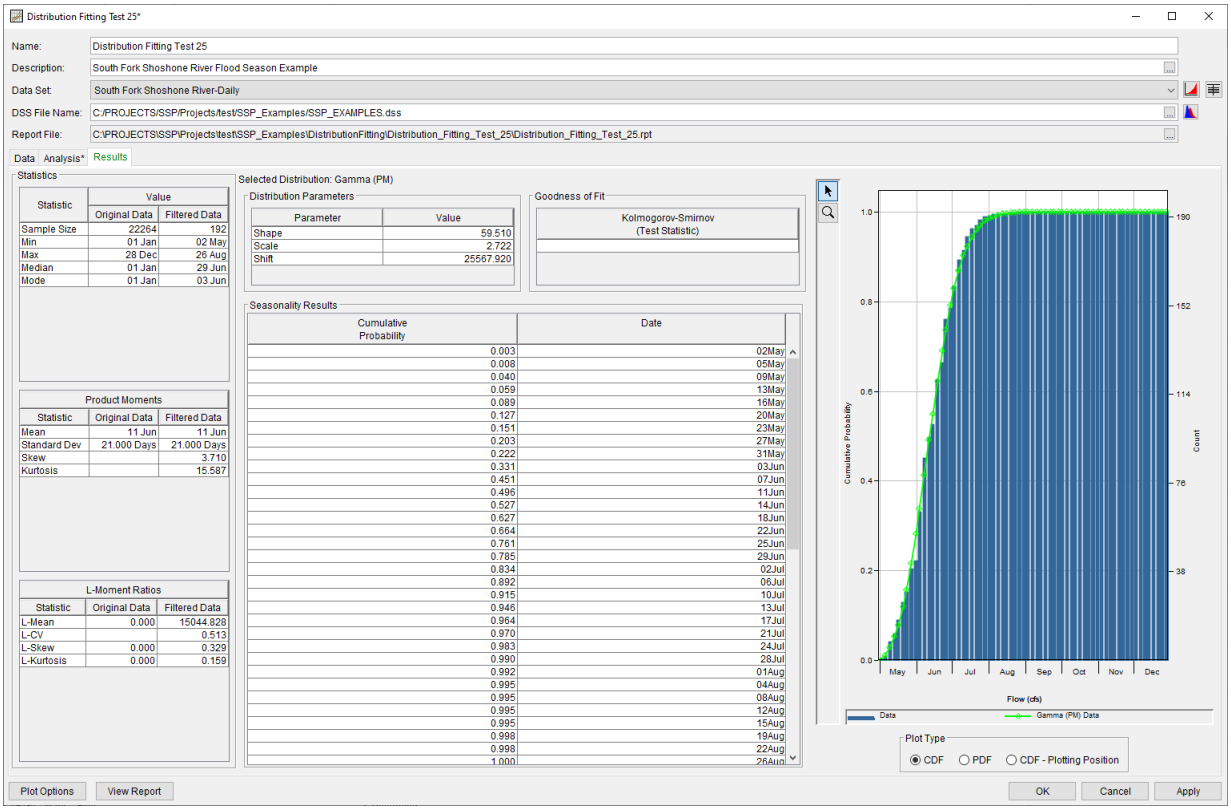


226 Figure 10. PP Plot for Distribution Fitting Test 25.



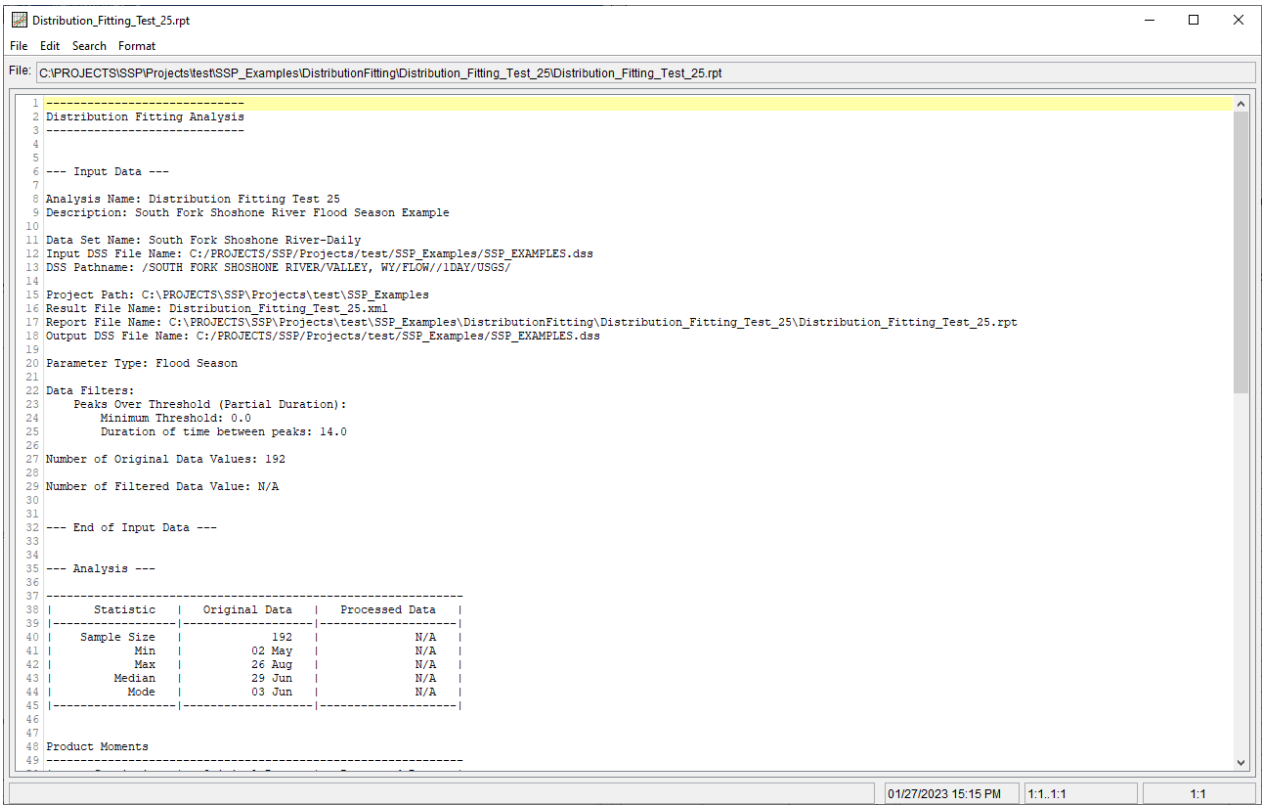
227 Figure 11. QQ Plot for Distribution Fitting Test 25.

In this example, the Gamma Distribution fit using Product Moments was selected by clicking the **Accept Selected Distribution** button near the bottom of the Distribution Fitting editor while having that row selected on the Analysis tab. Upon clicking this button, the accepted distribution | fitting method was used to populate the Results tab, as shown in Figure 12 (see page 385). Notice that various statistics, parameters, and probability distribution results are presented in terms of dates due to selection of the **Flood Season** parameter on the **Data** tab.



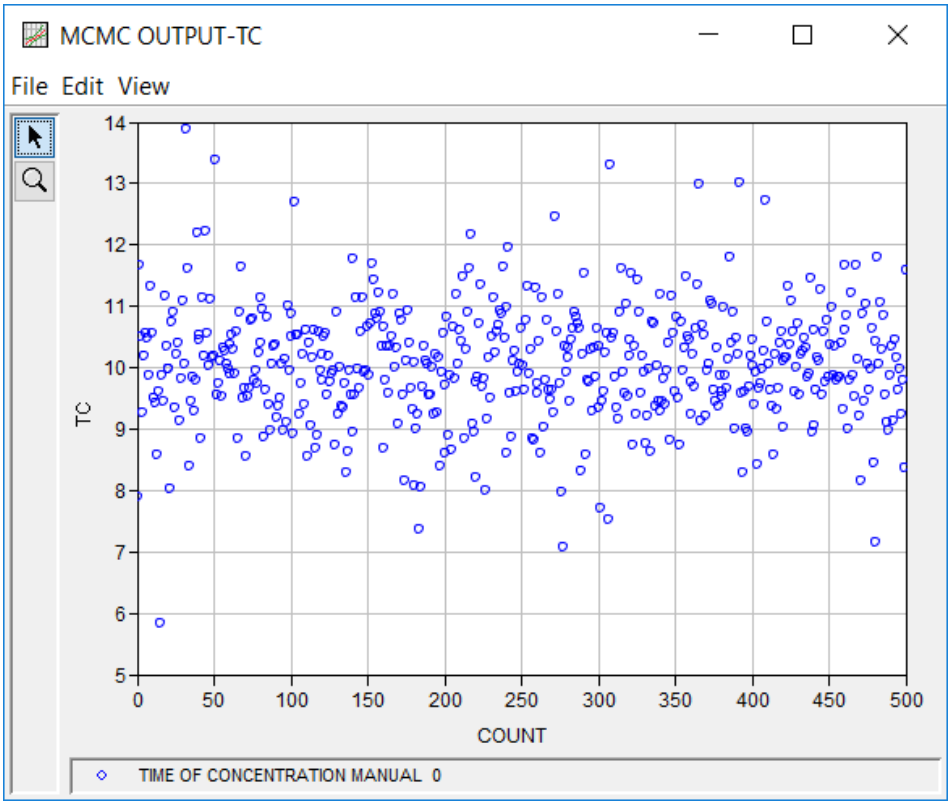
228 Figure 14. Distribution Fitting Results Tab Shown for Distribution Fitting Test 25.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. Finally, a report file is was generated which shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 13 (see page 386).



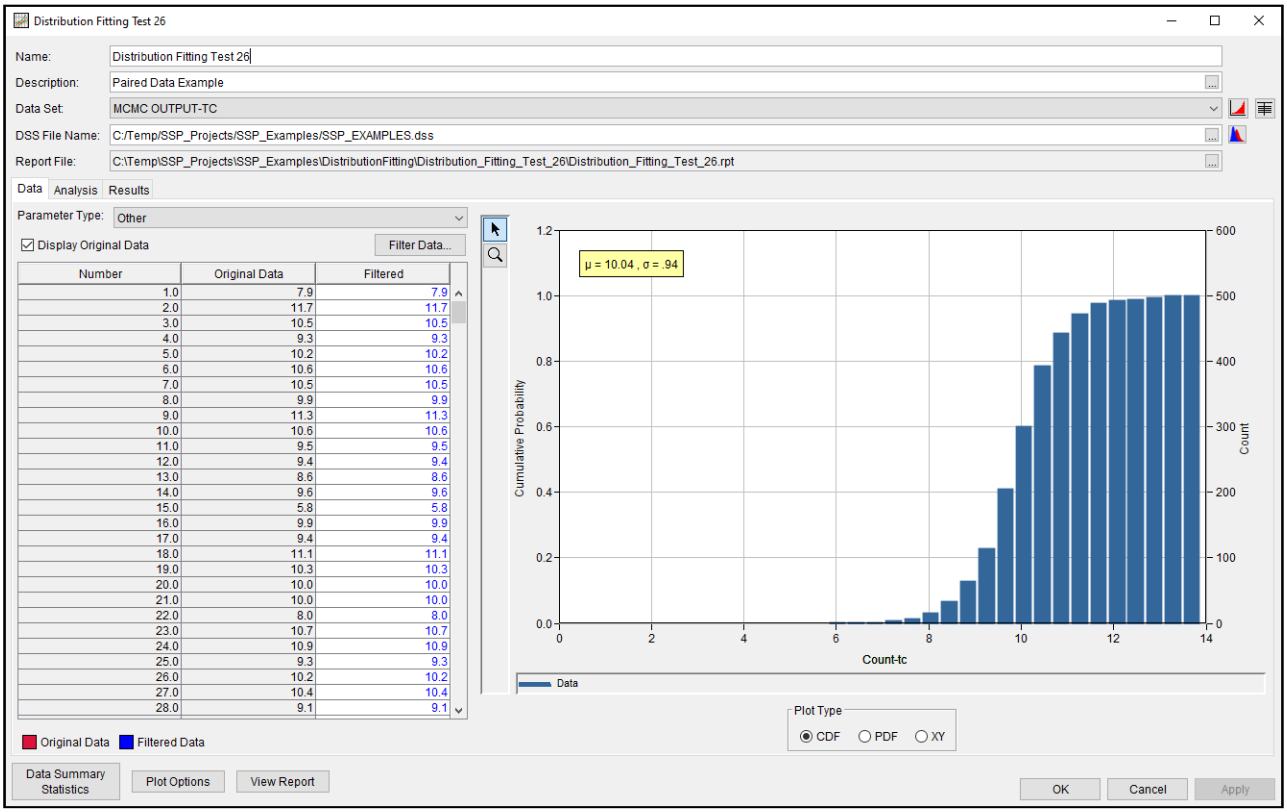
10.7 Example 26. Distribution Fitting, Analyzing a Paired Data Record of Hydrologic Model Output

This example demonstrates how to use the Distribution Fitting analysis to analyze a paired data record consisting of output from a hydrologic model. The data for this example consists of paired data which was generated using the Markov Chain Monte Carlo (MCMC) Optimization Analysis contained within the Hydrologic Modeling System (HEC-HMS). Specifically, the paired data record contains estimates of time of concentration (T_C) for a subbasin. To view the data from HEC-SSP, right-click on the data record labeled "**MCMC OUTPUT-TC**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 387).



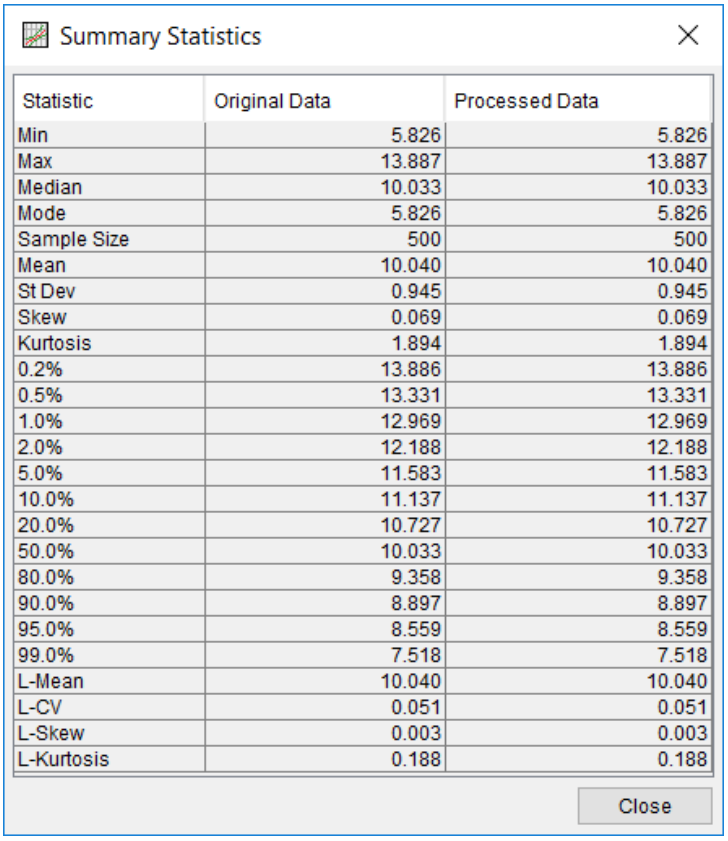
229 Figure 1. Plot of the Time of Concentration Data.

A Distribution Fitting analysis has been developed for this example. A distribution | fitting method combination has not been selected within the SSP Examples study. To visualize, inspect, and select a distribution | fitting method combination, the following steps should be used. To open the Distribution Fitting analysis editor for this example, either double-click on the analysis labeled **Distribution Fitting Test 26** from the study explorer, or from the **Analysis** menu, select open, then select **Distribution Fitting Test 26** from the list of available analyses. When this analysis is opened, the Distribution Fitting editor will appear as shown in Figure 2 (see page 388).



230 Figure 2. Distribution Fitting Analysis Editor for Distribution Fitting Test 26.

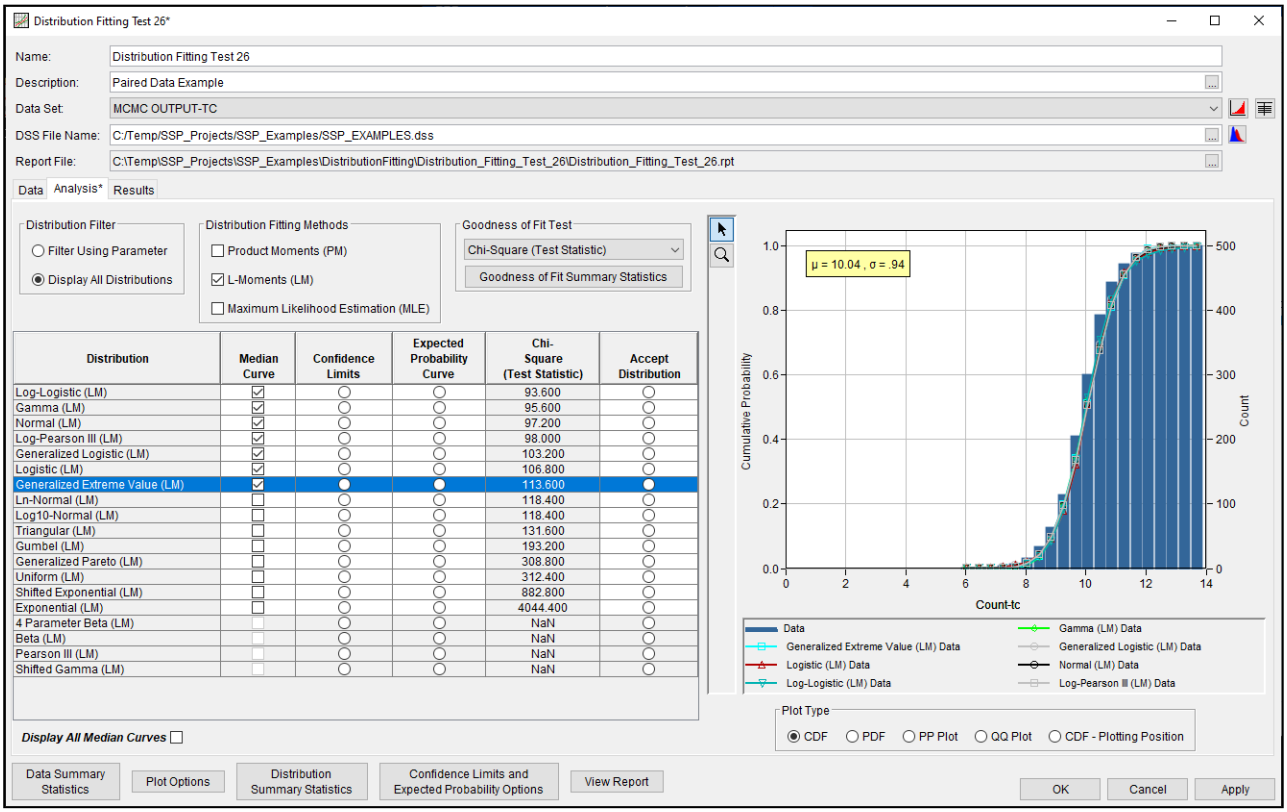
For this analysis, the paired data record was used without modifications. Summary statistics of the data can be accessed by pressing the **Data Summary Statistics** button near the bottom of the Distribution Fitting editor while on the Data tab, as shown in Figure 3 (see page 389).



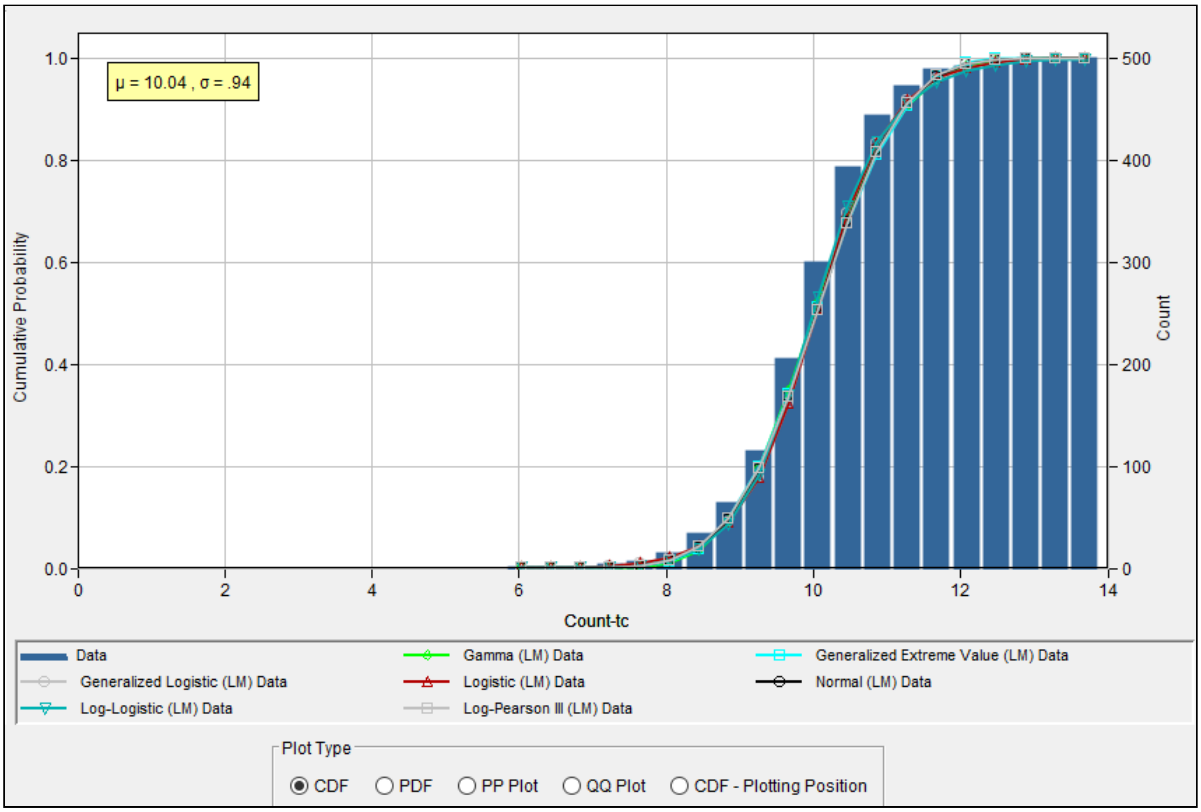
Statistic	Original Data	Processed Data
Min	5.826	5.826
Max	13.887	13.887
Median	10.033	10.033
Mode	5.826	5.826
Sample Size	500	500
Mean	10.040	10.040
St Dev	0.945	0.945
Skew	0.069	0.069
Kurtosis	1.894	1.894
0.2%	13.886	13.886
0.5%	13.331	13.331
1.0%	12.969	12.969
2.0%	12.188	12.188
5.0%	11.583	11.583
10.0%	11.137	11.137
20.0%	10.727	10.727
50.0%	10.033	10.033
80.0%	9.358	9.358
90.0%	8.897	8.897
95.0%	8.559	8.559
99.0%	7.518	7.518
L-Mean	10.040	10.040
L-CV	0.051	0.051
L-Skew	0.003	0.003
L-Kurtosis	0.188	0.188

231 Figure 3. Data Summary Statistics for Distribution Fitting Test 26.

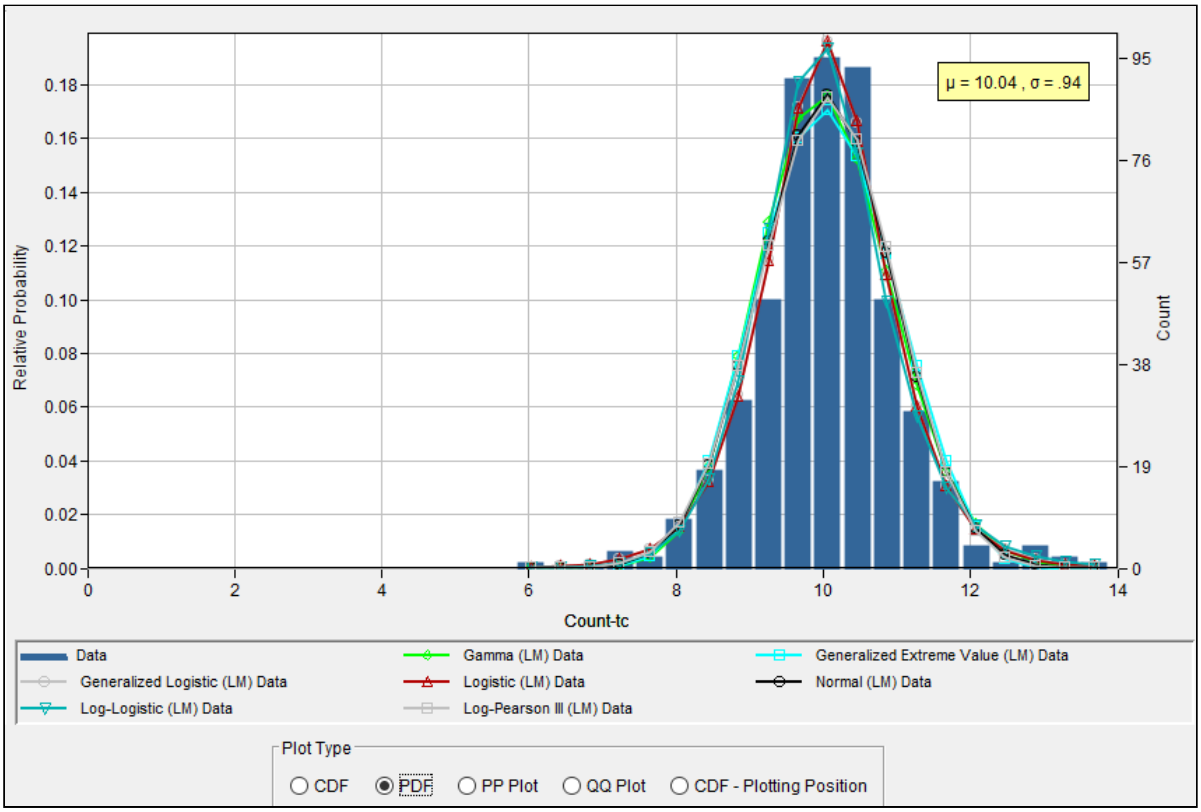
On the Analysis tab, several analytical distributions and fitting methods are available for selection. As shown in Figure 4 (see page 390), the **Display All Distributions** radio button was selected within the Distribution Filter panel to display all of the available analytical distributions while the default Product Moments fitting method was set to **L-Moments**. The Chi-Square goodness of fit test was selected. Several analytical distributions (some which poorly fit the data as well as some that fit the data well) were then selected and compared. CDF, PDF, PP, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure 5 (see page 390), Figure 6 (see page 390), Figure 7 (see page 390), Figure 8 (see page 390), and Figure 9 (see page 390). If a different number of bins are desired within either the CDF or PDF plots, the change should be made on the Data tab to ensure that the analytical distributions shown within either plot are the most up to date.



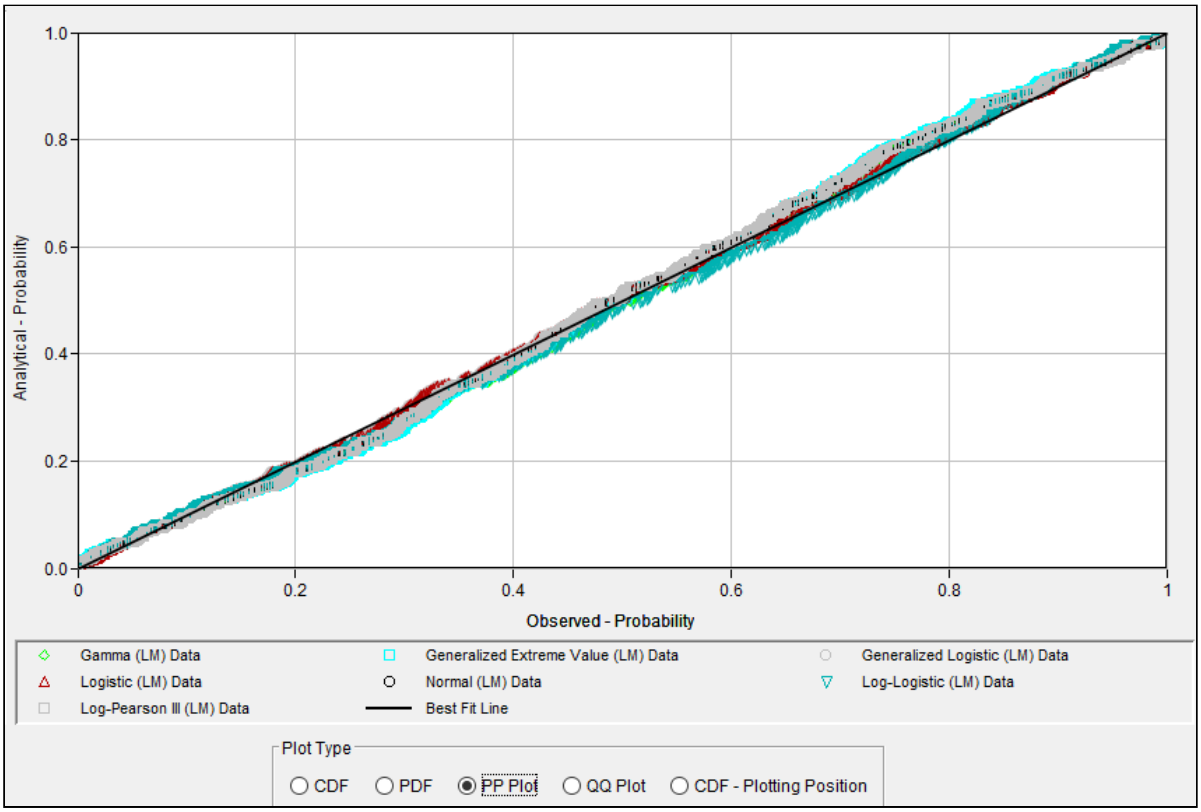
232 Figure 4. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 26.



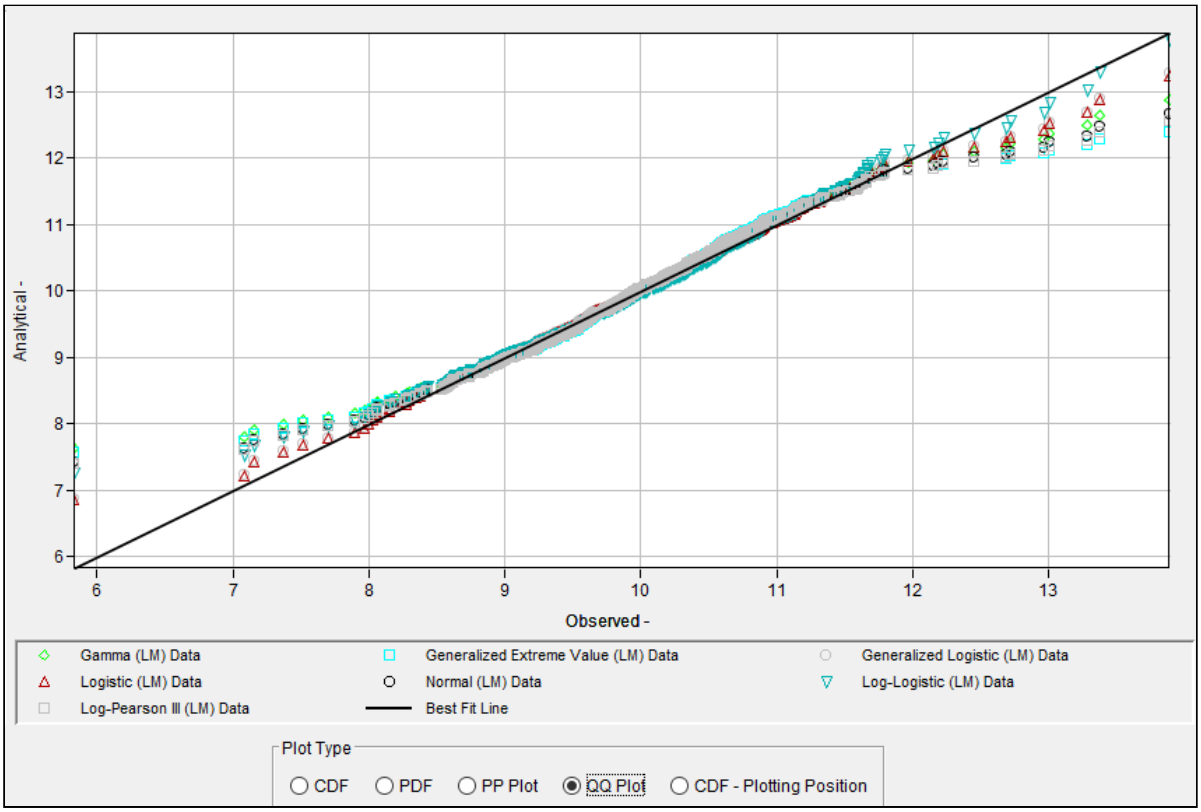
233 Figure 5. CDF Plot for Distribution Fitting Test 26.



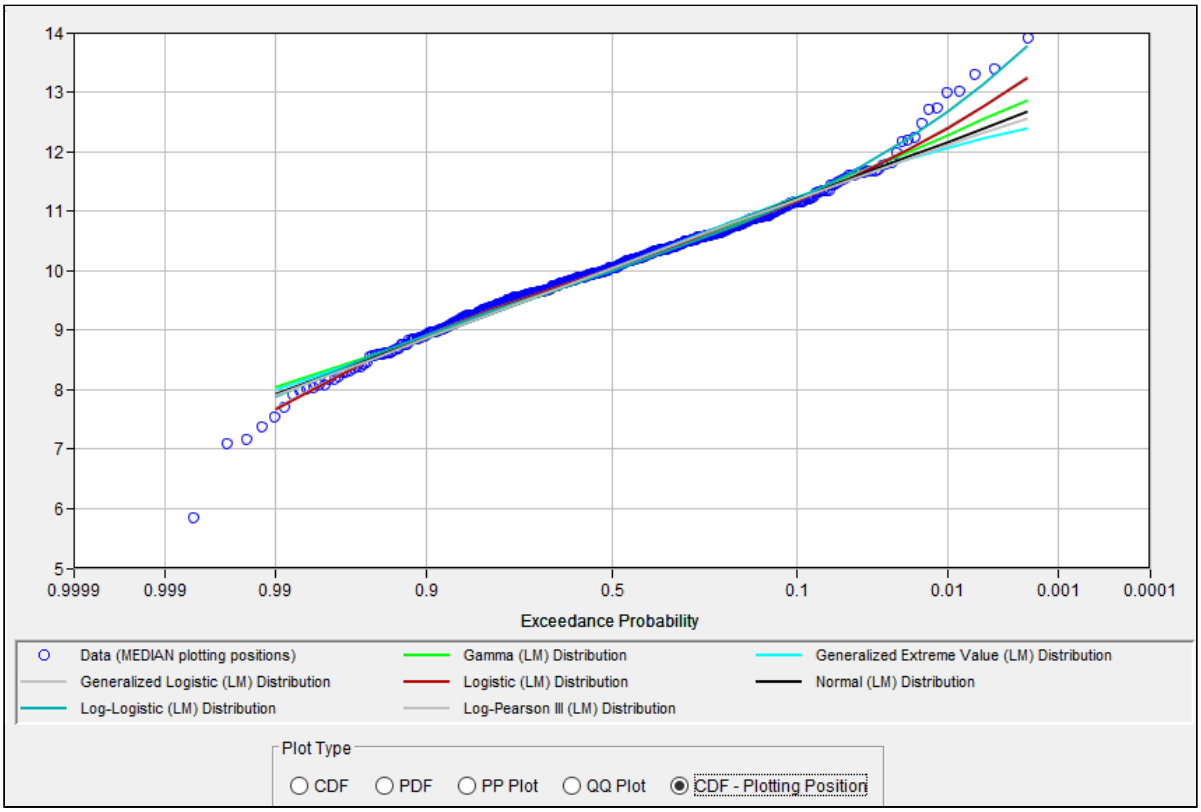
234 Figure 6. PDF Plot for Distribution Fitting Test 26.



235 Figure 7. PP Plot for Distribution Fitting Test 26.

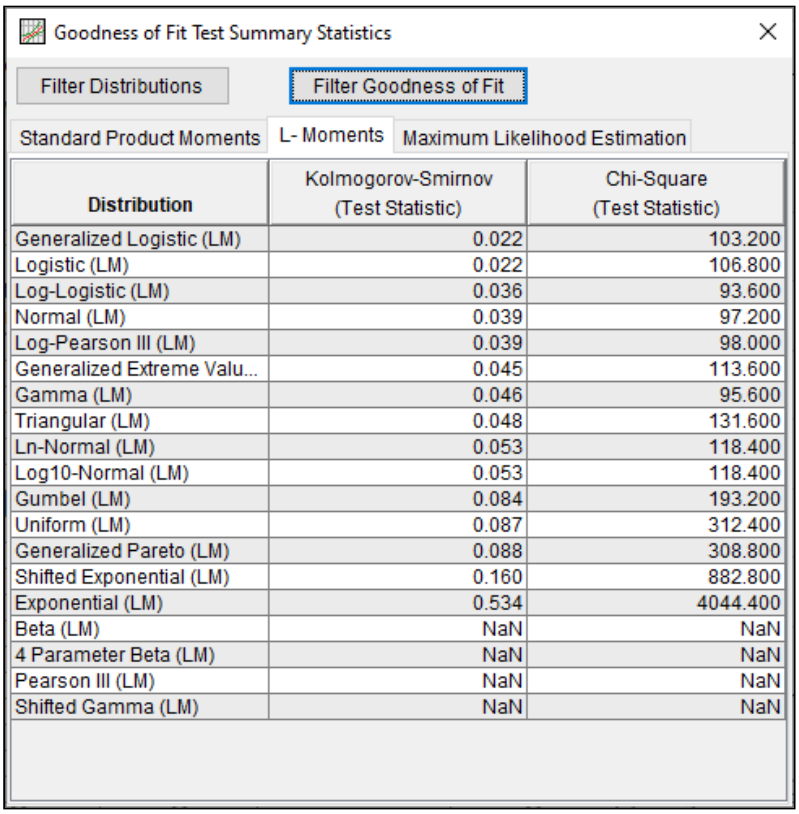


236 Figure 8. QQ Plot for Distribution Fitting Test 26.



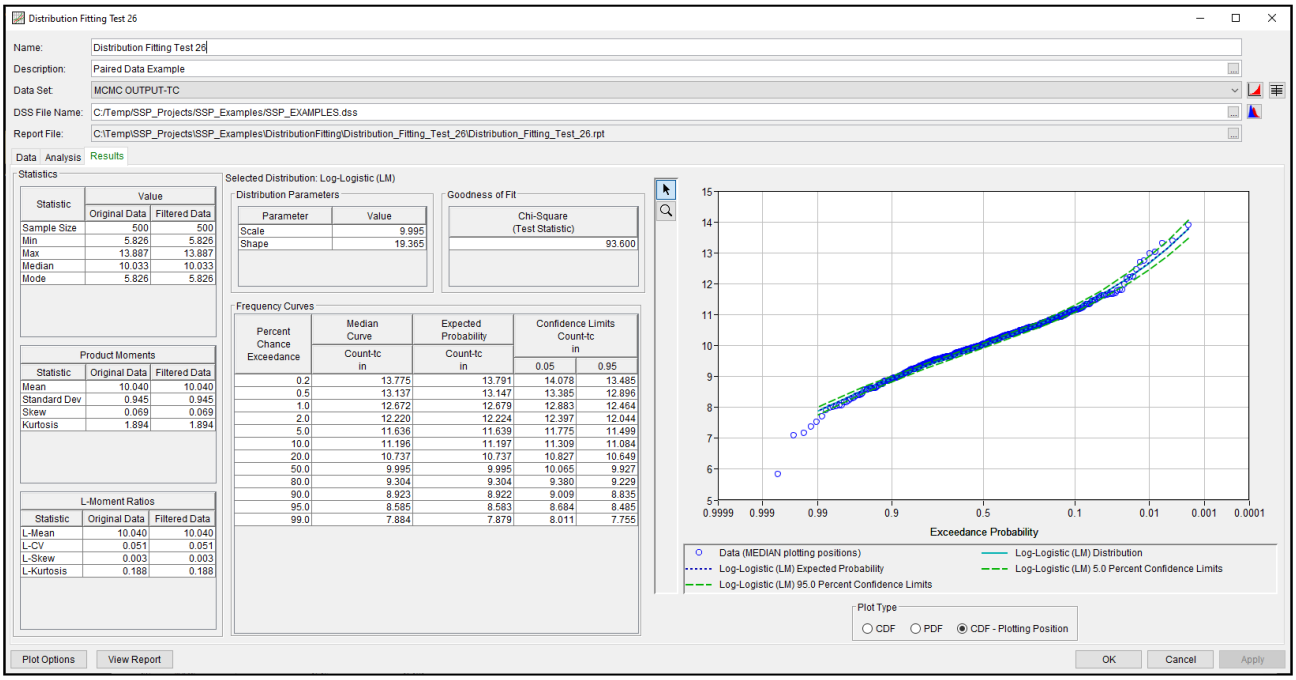
237 Figure 9. CDF-Plotting Position Plot for Distribution Fitting Test 26.

Kolmogorov-Smirnov and Chi-Square summary statistics can be accessed by pressing the **Goodness of Fit Summary Statistics** button near the top of the Distribution Fitting editor while on the Analysis tab, as shown in Figure 10 (see page 396).



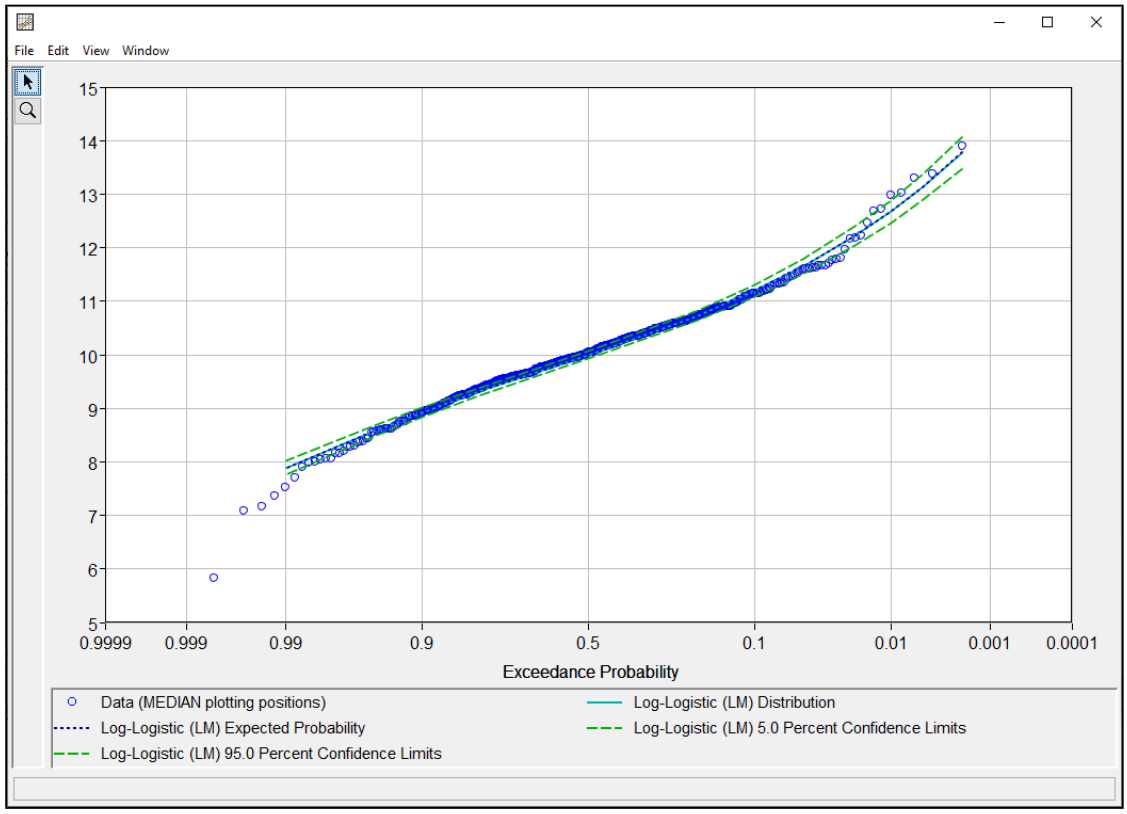
Distribution	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Generalized Logistic (LM)	0.022	103.200
Logistic (LM)	0.022	106.800
Log-Logistic (LM)	0.036	93.600
Normal (LM)	0.039	97.200
Log-Pearson III (LM)	0.039	98.000
Generalized Extreme Valu...	0.045	113.600
Gamma (LM)	0.046	95.600
Triangular (LM)	0.048	131.600
Ln-Normal (LM)	0.053	118.400
Log10-Normal (LM)	0.053	118.400
Gumbel (LM)	0.084	193.200
Uniform (LM)	0.087	312.400
Generalized Pareto (LM)	0.088	308.800
Shifted Exponential (LM)	0.160	882.800
Exponential (LM)	0.534	4044.400
Beta (LM)	NaN	NaN
4 Parameter Beta (LM)	NaN	NaN
Pearson III (LM)	NaN	NaN
Shifted Gamma (LM)	NaN	NaN

In this example, the Logistic Distribution fit using L-Moments was selected. Upon clicking this button, confidence limits and an expected probability curve were automatically computed using the options specified within the **Plot Options** and **Confidence Limits and Expected Probability Options** editors. The updated confidence limits and an expected probability curve were recomputed. The accepted distribution | fitting method was used to populate the **Results** tab, as shown in Figure 11 (see page 397).



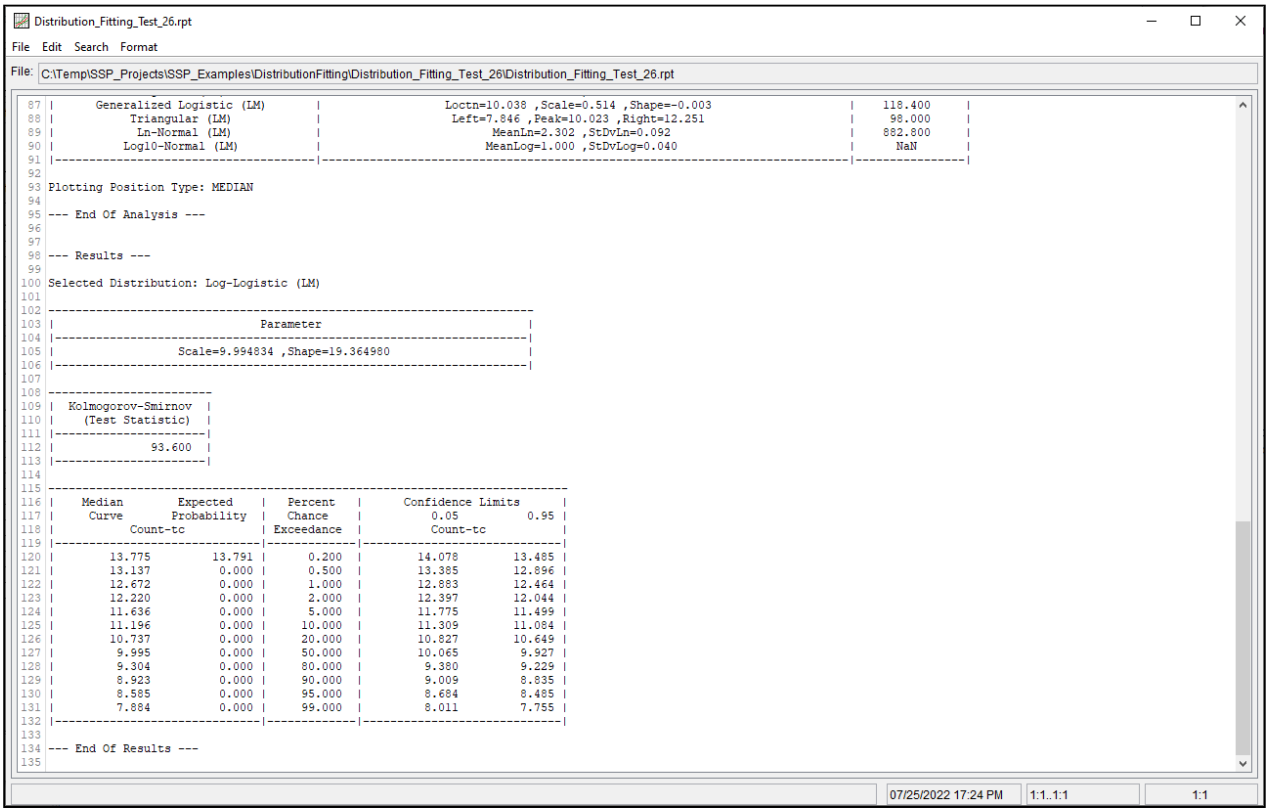
238 Figure 11. Distribution Fitting Results Tab Shown for Distribution Fitting Test 26.

In addition to the tables and plot available on the Results tab, CDF, PDF, and CDF-Plotting Position plots of the data and accepted distribution | fitting method can be obtained by double left-clicking on the plot of interest. The CDF-Plotting Position plot of the data and accepted distribution | fitting method is shown in Figure 12 (see page 398).



239 Figure 12. Distribution Fitting Plot Shown for Distribution Fitting Test 26.

In addition to the tabular and graphical results, there is a report file that shows the input data, data filters that were applied, processed data, data summary statistics, all available analytical distributions for the selected fitting method and their corresponding parameters, selected goodness of fit summary scores for each analytical distribution, and the accepted distribution | fitting method. Different types and amounts of information will be contained within the report file depending upon the data and the options that have been selected for the analysis. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 13 (see page 399).

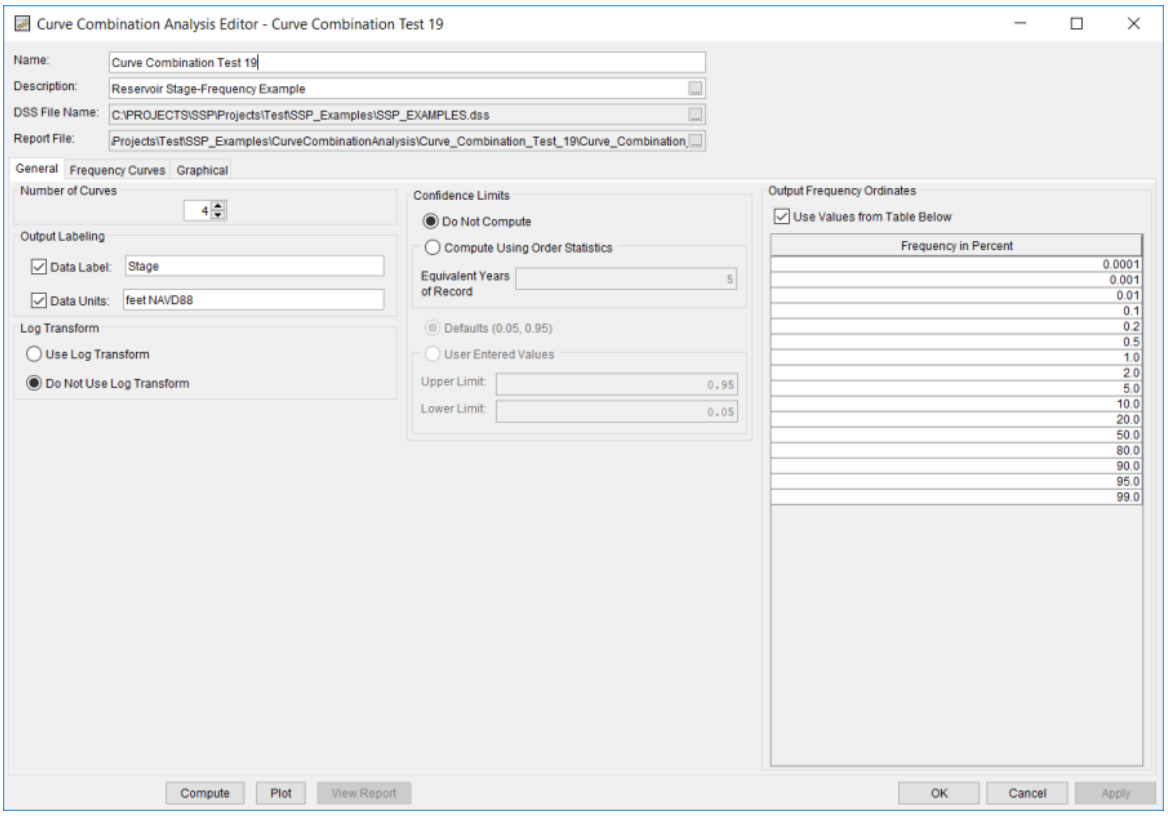


240 Figure 13. Report File for Distribution Fitting Test 26.

11 Curve Combination Analysis Examples

11.1 Example 19. Curve Combination Analysis, Combining Multiple Frequency Curves Using Graphical Techniques

This example demonstrates how to create a **Curve Combination** analysis that combines multiple input frequency curves using graphical techniques. In this example, a "best-fit" empirical distribution will be created using multiple reservoir stage-frequency curves.
A Curve Combination analysis has been developed for this example. To open the Curve Combination analysis editor for this example, either double-click on the analysis labeled **Curve Combination Test 19** from the study explorer, or from the **Analysis** menu select open, then select **Curve Combination Test 19** from the list of available analyses. When Test 19 is opened, the Curve Combination Analysis editor will appear as shown in Figure 1 (see page 401).
Shown in Figure 1 (see page 401) are the general settings for this curve combination analysis. "Stage" and "feet NAVD88" were entered for the **Data Label** and **Data Units**, respectively. The **Do Not Use Log Transform** and **Do Not Compute** confidence limits options were selected. Finally, the 0.1-, 0.01-, 0.001, and 0.0001-percent ordinates were added to the list of **Output Frequency Ordinates**.



Shown in Figure 2 (see page 401)are the general settings for this curve combination analysis. "Stage" and "feet NAVD88" were entered for the **Data Label** and **Data Units**, respectively. The **Do Not Use Log Transform** and **Do Not Compute** confidence limits options were selected. Finally, the 0.1-, 0.01-, 0.001, and 0.0001-percent ordinates were added to the list of **Output Frequency Ordinates**. Shown in Figure B-135 is the Curve

Combination analysis editor with the **Frequency Curves** tab selected. A name of "Annual Peak Stages" was entered for Frequency Curve 1, a name of "Frequency Precipitation" was entered for Frequency Curve 2, a name of "Historical Event BH Routings" was entered for Frequency Curve 3, and a name of "PMF BH Routings" was entered for Frequency Curve 4. All four frequency curves were set to utilize manually-entered empirical distributions. However, each frequency curve utilized different probability ordinates and stages.

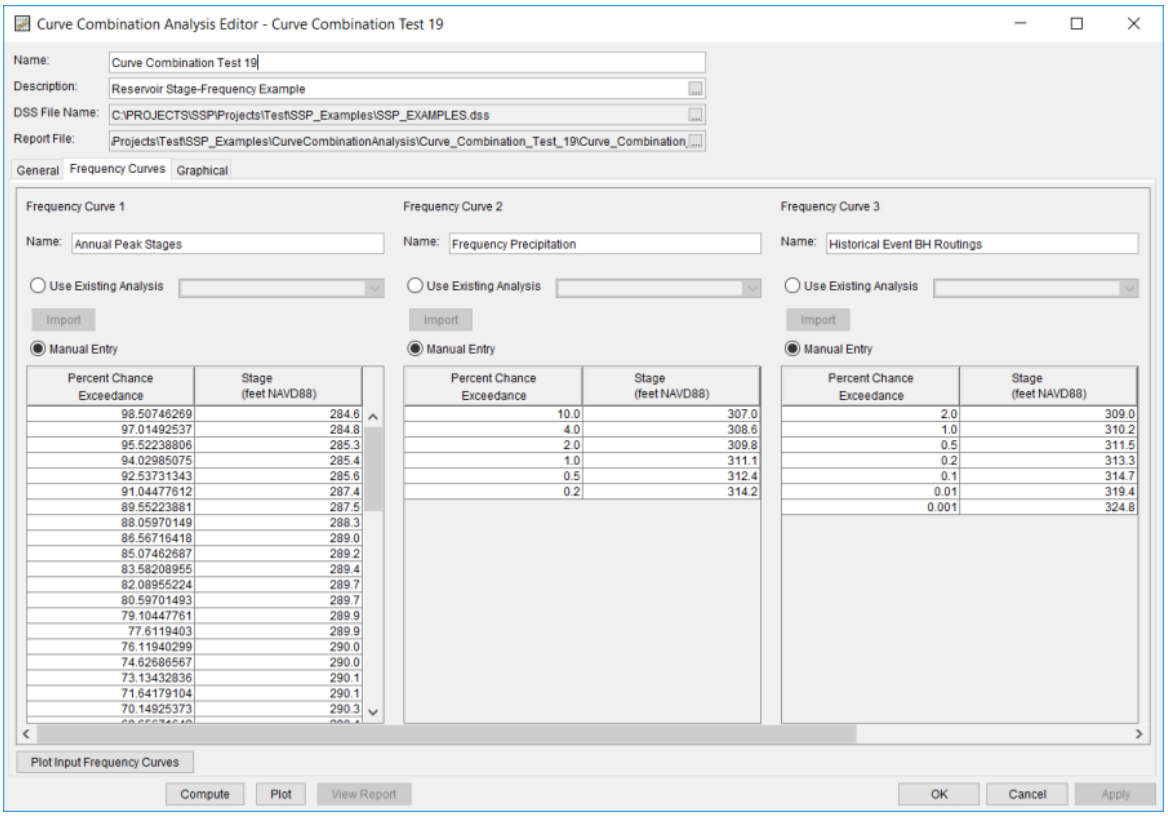
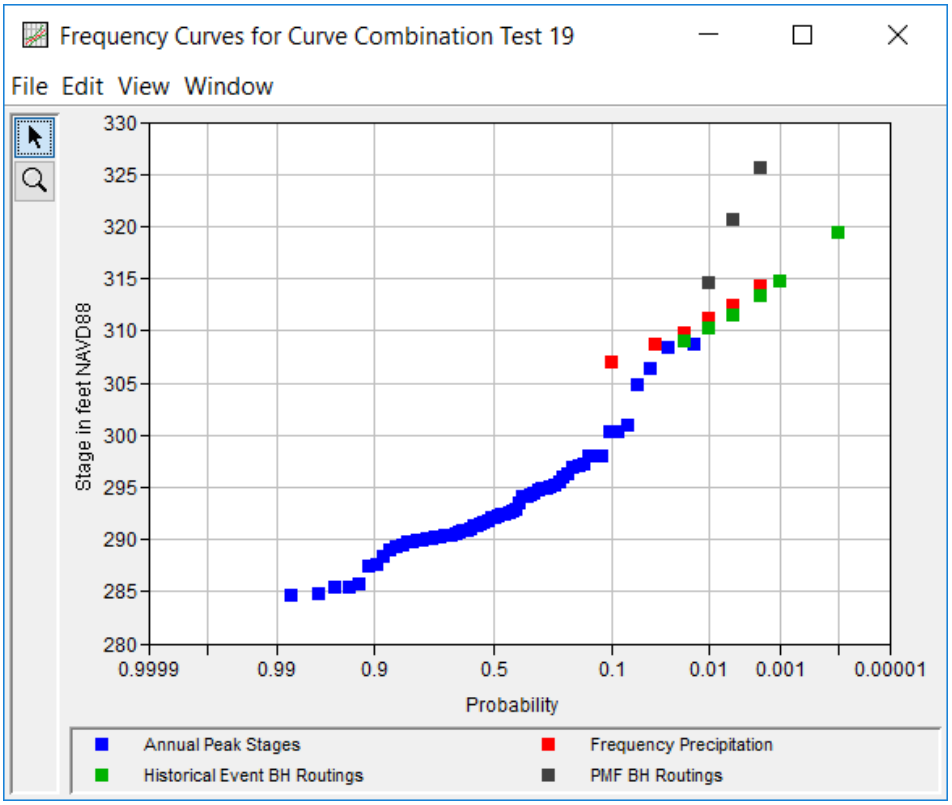
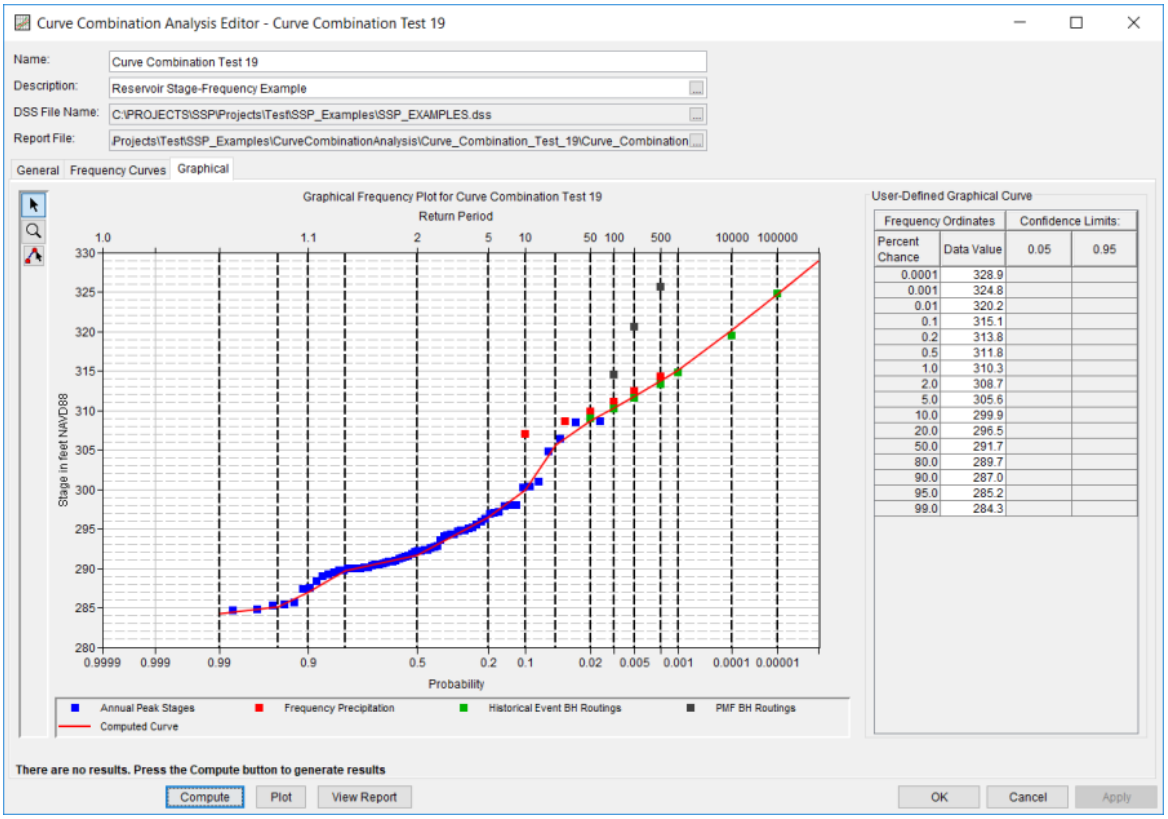


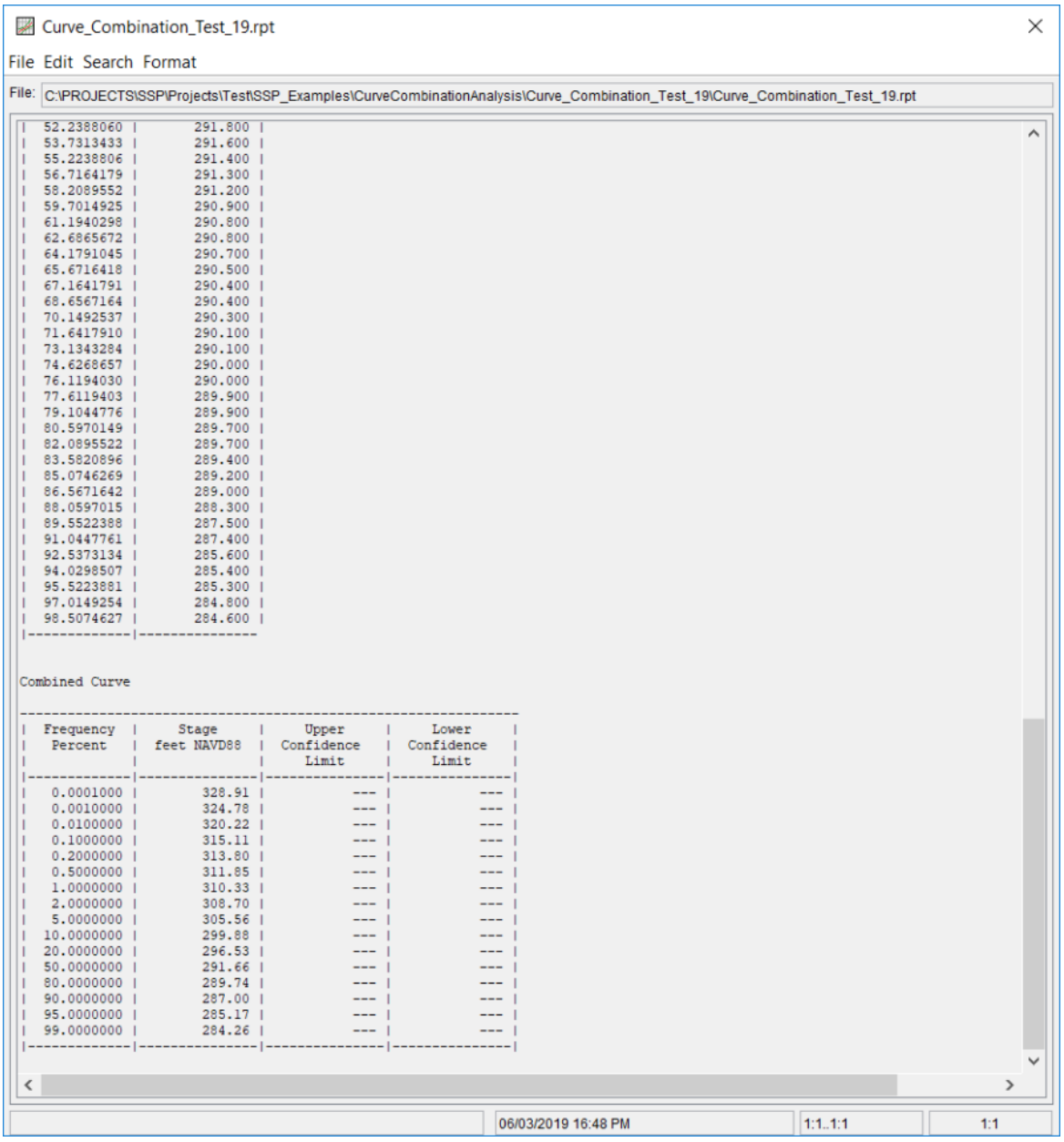
Figure 3 (see page 401) shows the plotted frequency curves for this analysis.



Once all of the options and frequency curve inputs are set or selected, the user can graphically fit an empirical distribution. Shown in Figure 4 (see page 402) is the **Graphical** tab. As shown, a graph containing the input frequency curves along with a graphical curve is on the left side and a table containing the user-entered frequency curve is on the right side of the window. The frequency curve was entered using the multi-point edit tool, values were extracted at the specified output frequency ordinates (signified with vertical dashed marker lines), and placed within the **User-Defined Graphical Curve** table. When the **Compute** button is pressed, a message window will open stating **Compute Complete**. The program will then plot the graphical frequency curve (and computes the confidence limits, if specified). Within this example, the best fit pool stage-frequency curve was defined to closely follow the Frequency Precipitation and Historical Event BH Routings frequency curves. To view the graphical curve in a separate window, either click the **Plot** button or double click on the plot within the Graphical tab.



In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 5 (see page 403) is the report file for **Curve Combination Test 19**.


Curve_Combination_Test_19.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\CurveCombinationAnalysis\Curve_Combination_Test_19\Curve_Combination_Test_19.rpt

52.2388060	291.800
53.7313433	291.600
55.2238806	291.400
56.7164179	291.300
58.2089552	291.200
59.7014925	290.900
61.1940298	290.800
62.6865672	290.800
64.1791045	290.700
65.6716418	290.500
67.1641791	290.400
68.6567164	290.400
70.1492537	290.300
71.6417910	290.100
73.1343284	290.100
74.6268657	290.000
76.1194030	290.000
77.6119403	289.900
79.1044776	289.900
80.5970149	289.700
82.0895522	289.700
83.5820896	289.400
85.0746269	289.200
86.5671642	289.000
88.0597015	288.300
89.5522388	287.500
91.0447761	287.400
92.5373134	285.600
94.0298507	285.400
95.5223881	285.300
97.0149254	284.800
98.5074627	284.600

Combined Curve

Frequency Percent	Stage feet NAVD88	Upper Confidence Limit	Lower Confidence Limit
0.0001000	328.91	---	---
0.0010000	324.78	---	---
0.0100000	320.22	---	---
0.1000000	315.11	---	---
0.2000000	313.80	---	---
0.5000000	311.85	---	---
1.0000000	310.33	---	---
2.0000000	308.70	---	---
5.0000000	305.56	---	---
10.0000000	299.88	---	---
20.0000000	296.53	---	---
50.0000000	291.66	---	---
80.0000000	289.74	---	---
90.0000000	287.00	---	---
95.0000000	285.17	---	---
99.0000000	284.26	---	---

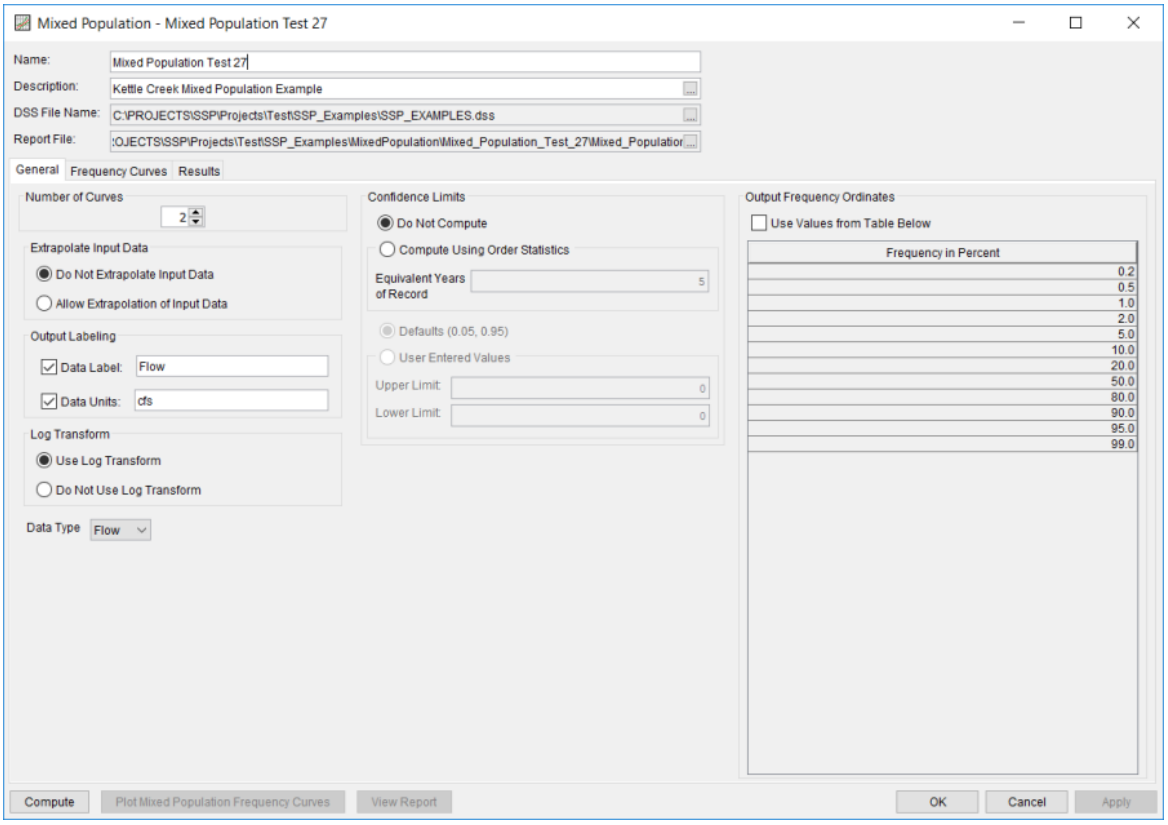
06/03/2019 16:48 PM 1:1..1:1 1:1

12 Mixed Population Analysis Examples

12.1 Example 27. Mixed Population Analysis, Combining Two Frequency Curves using the Probability of Union Concept

This example demonstrates how to create a **Mixed Population** analysis that combines two frequency curves from previously-computed analyses using the probability of union concept. Specifically, information from two previously-computed Bulletin 17 analyses will be used to compute a flow-frequency curve that incorporates the likelihood of more than one type of flood in a year. To open the Mixed Population analysis editor for this example, either double-click on the analysis labeled **Mixed Population Test 27** from the study explorer, or from the **Analysis** menu select open, then select **Mixed Population Test 27** from the list of available analyses. When the analysis is opened, the Mixed Population Analysis editor will appear as shown in Figure 1 (see page 406).

Shown in Figure 1 (see page 406) are the general settings for this mixed population analysis. The Number of Curves was set to two. These two curves are representative of different flood causal mechanisms (i.e. populations) that occur within the Kettle Creek watershed in north-central Pennsylvania upstream of Alvin R. Bush Dam. Specifically, the first population was meant to represent floods that occur in winter and spring months (i.e. snowmelt and rain-on-snow floods) while the second population was meant to represent floods that occur in summer and fall months (i.e. thunderstorms and tropical storm remnants). The default **Do Not Extrapolate Input Data**, **Use Log Transform**, **Flow** Data Type, **Do Not Compute** confidence limits, and **Output Frequency Ordinates** were not modified. However, "Flow" and "cfs" were entered for the **Data Label** and **Data Units**, respectively.



Shown in Figure 2 (see page 406) is the Mixed Population analysis editor with the **Frequency Curves** tab selected. A name of "Summer" was entered for Frequency Curve 1 while a name of "Winter" was entered for Frequency Curve 2. The results of an existing Bulletin 17 analysis was imported for both frequency curves; Summer utilizes the KettleCreek_Summer_B17C analysis while Winter utilizes the KettleCreek_Winter_B17C analysis.

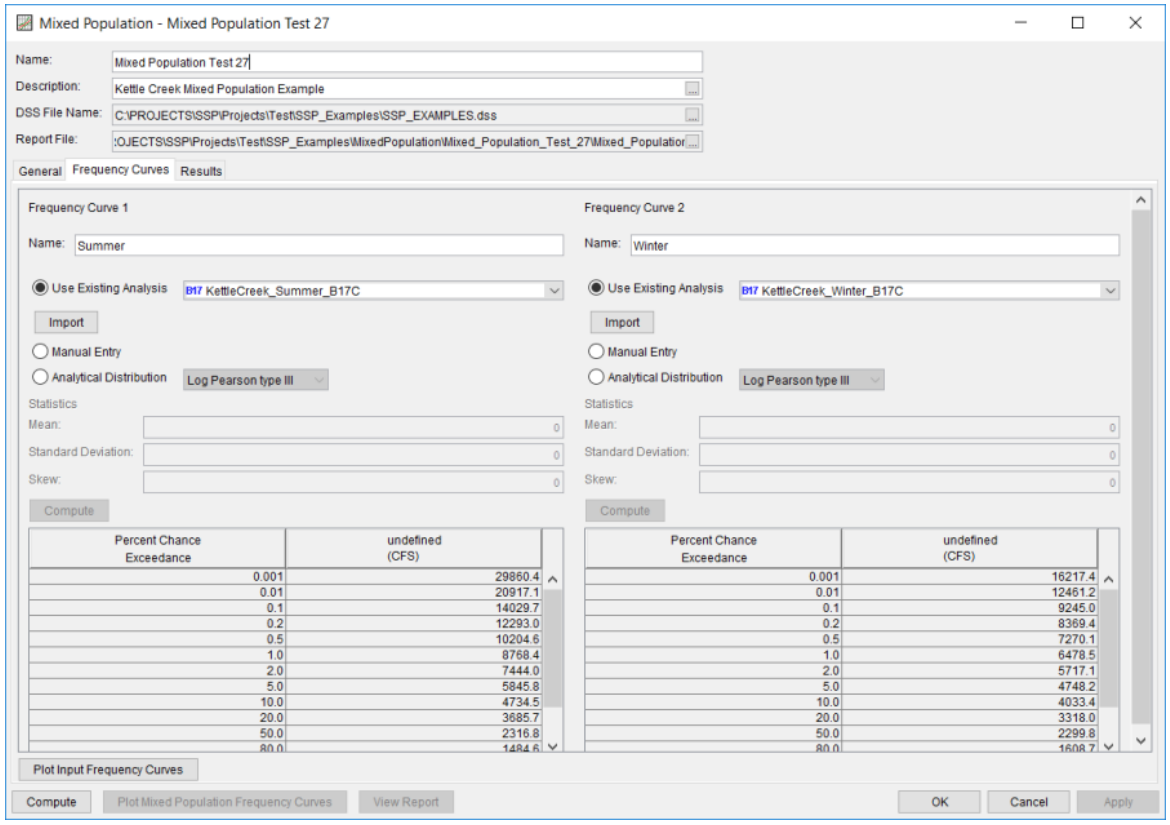
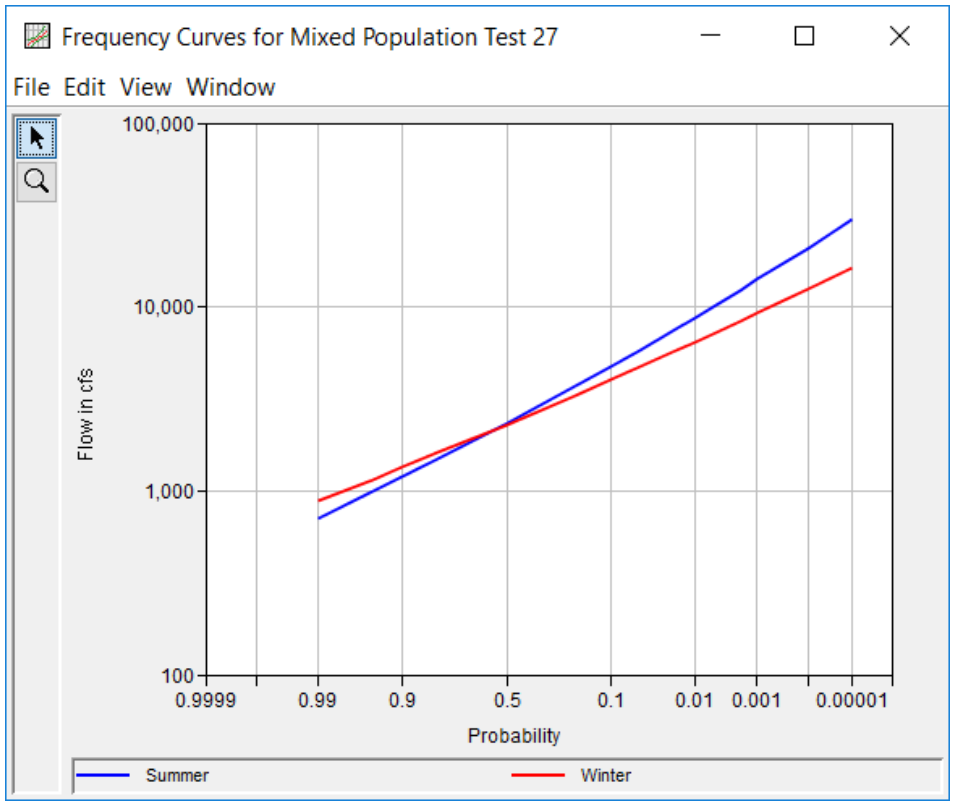
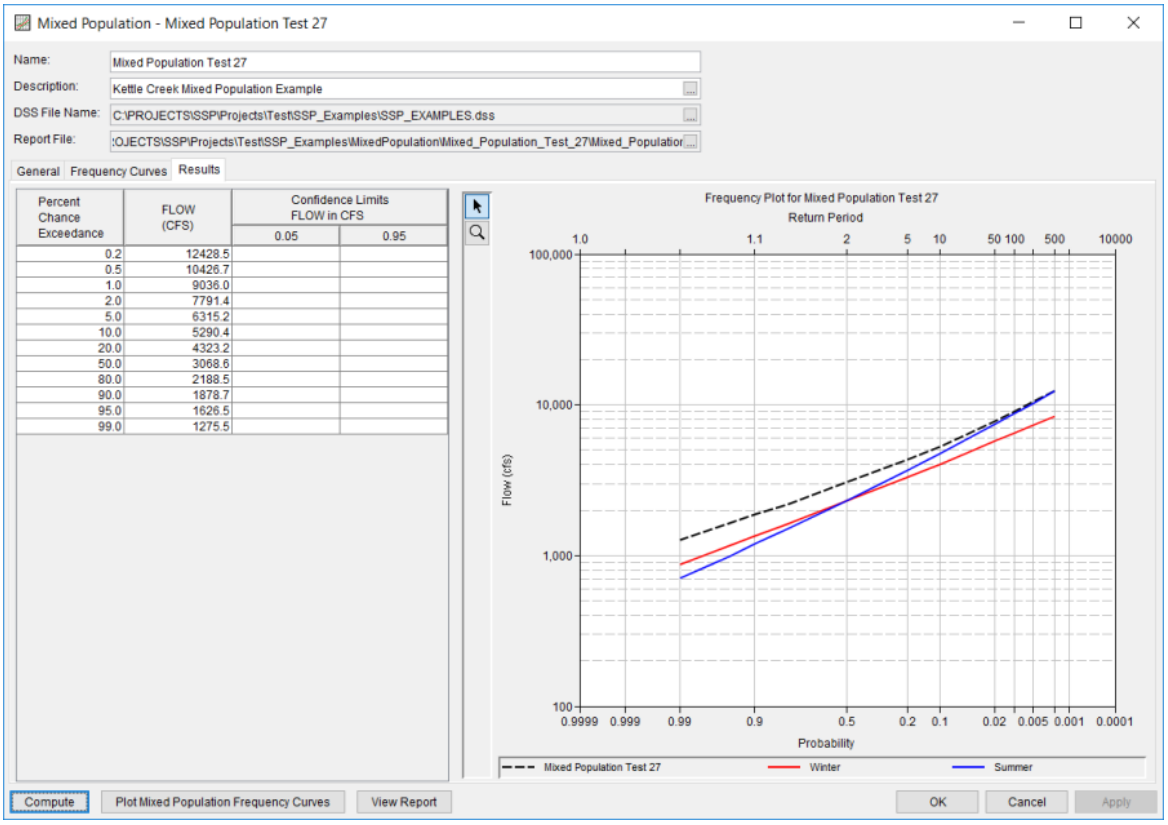


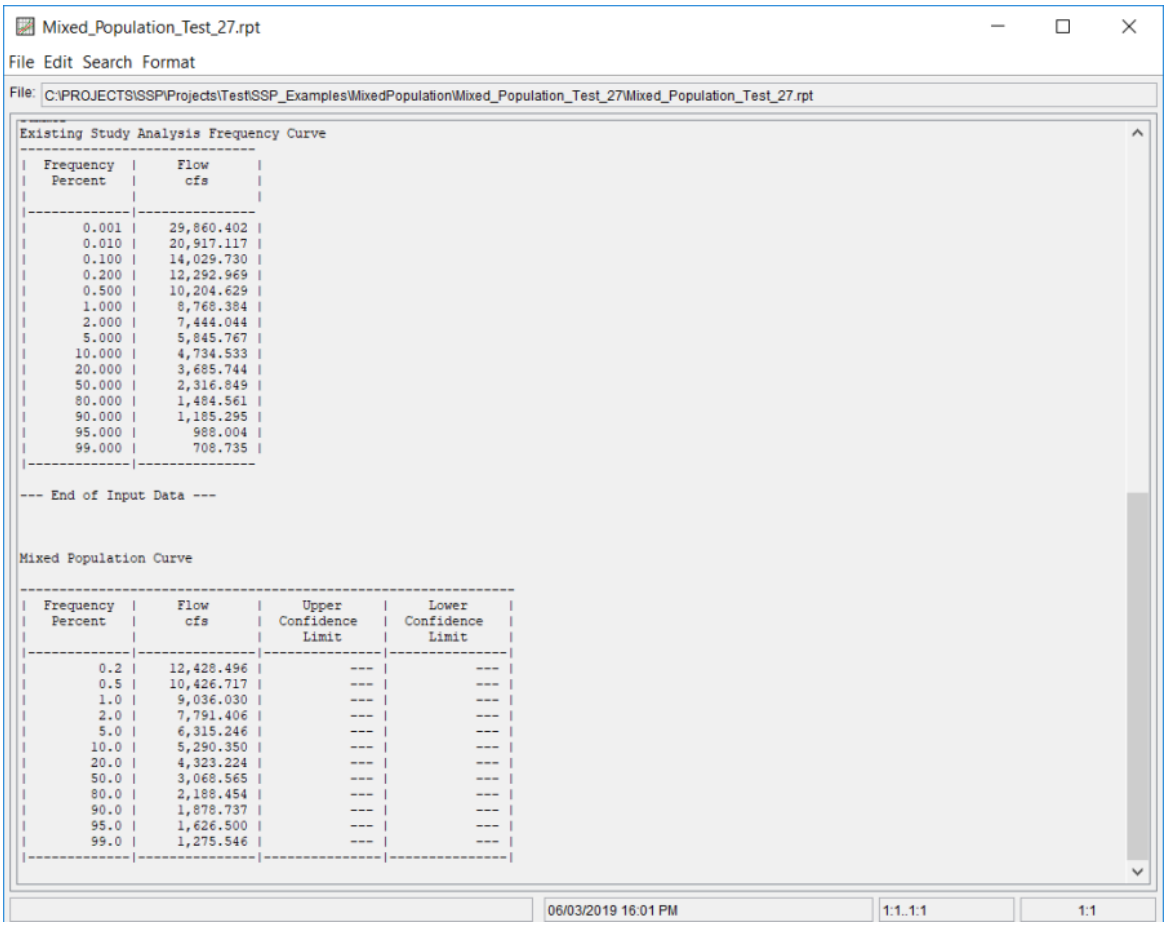
Figure 3 (see page 407) shows the plotted frequency curves for this analysis.



Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The results tab should resemble Figure 4 (see page 408). The left portion of the Results tab window displays the computed mixed population frequency curve. The right portion of the Results tab displays the input frequency curves in addition to the computed mixed population frequency curve in a plot. To view the input and results in a separate window, either click **Plot Mixed Population Frequency Curves** button or double click on the plot within the Results tab.



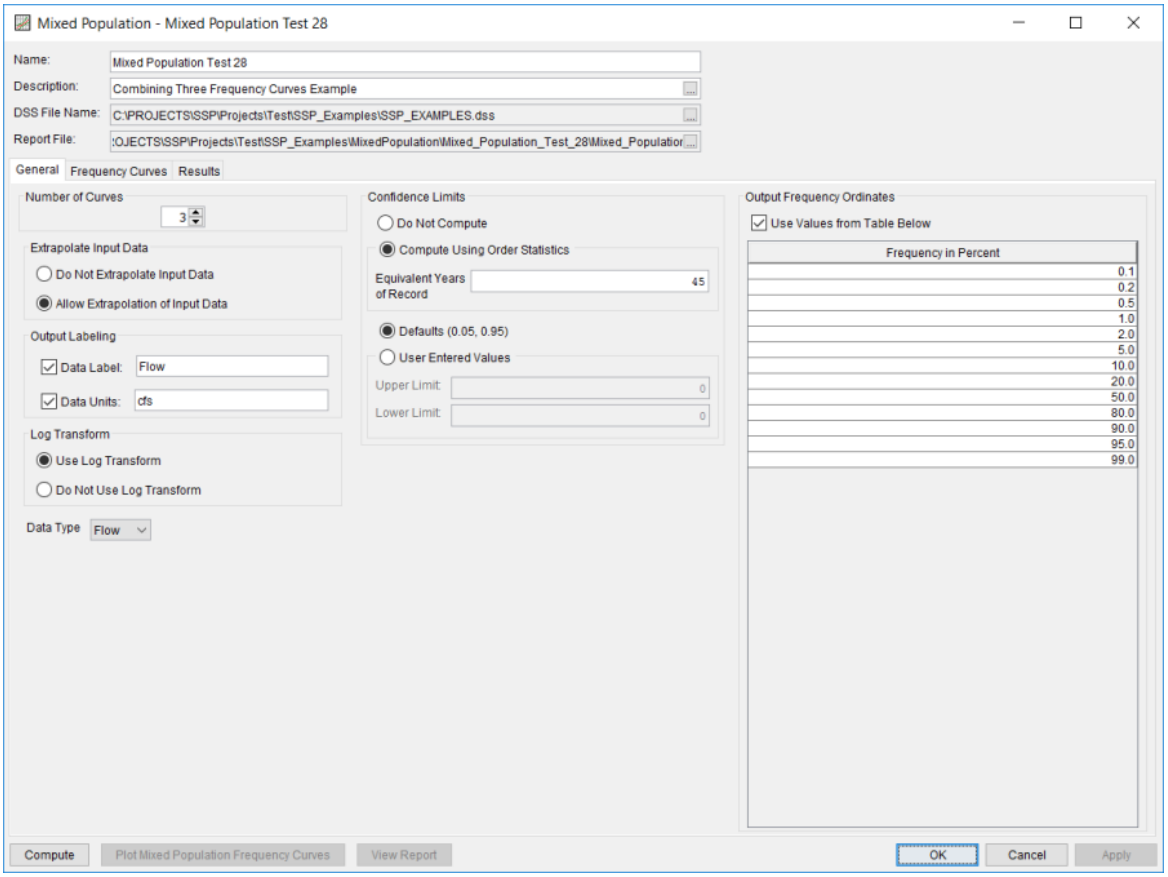
In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 5 (see page 408)is the report file for **Mixed Population Test 27**.



12.2 Example 28. Mixed Population Analysis, Combining Three Frequency Curves using the Probability of Union Concept

This example demonstrates how to create a **Mixed Population** analysis that combines three frequency curves using the probability of union concept. Specifically, two parameterized analytical distributions along with a single manually-defined empirical distribution will be used to compute a flow-frequency curve that incorporates the likelihood of more than one type of flood in a year. To open the Mixed Population analysis editor for this example, either double-click on the analysis labeled **Mixed Population Test 28** from the study explorer, or from the **Analysis** menu select open, then select **Mixed Population Test 28** from the list of available analyses. When the analysis is opened, the Mixed Population Analysis editor will appear as shown in Figure 1 (see page 0).

Shown in Figure 1 (see page 410) are the general settings for this mixed population analysis. The Number of Curves was set to three. These three curves are representative of different flood causal mechanisms (i.e. populations). The default **Allow Extrapolation of Input Data** option was selected. Also, "Flow" and "cfs" were entered for the **Data Label** and **Data Units**, respectively. The **Use Log Transform** and **Flow** Data Type were selected. The **Compute Using Order Stats** confidence limits option was selected and an Equivalent Years of Record of 45 was entered. The default 5 and 95% confidence limits were selected. Finally, the 0.1-percent ordinate was added to the list of **Output Frequency Ordinates**.



Shown in Figure 2 (see page 410) is the Mixed Population analysis editor with the **Frequency Curves** tab selected. A name of "LP3" was entered for Frequency Curve 1, a name of "GEV" was entered for Frequency Curve 2, and a name of "Manual" was entered for Frequency Curve 3. The LP3 frequency curve was set to utilize a Log Pearson Type III distribution and the required parameters were entered. Similarly, the GEV frequency curve was set to utilize a Generalized Extreme Values distribution and the required parameters were entered. Finally, the Manual frequency curve was set to utilize a manually-entered empirical distribution.

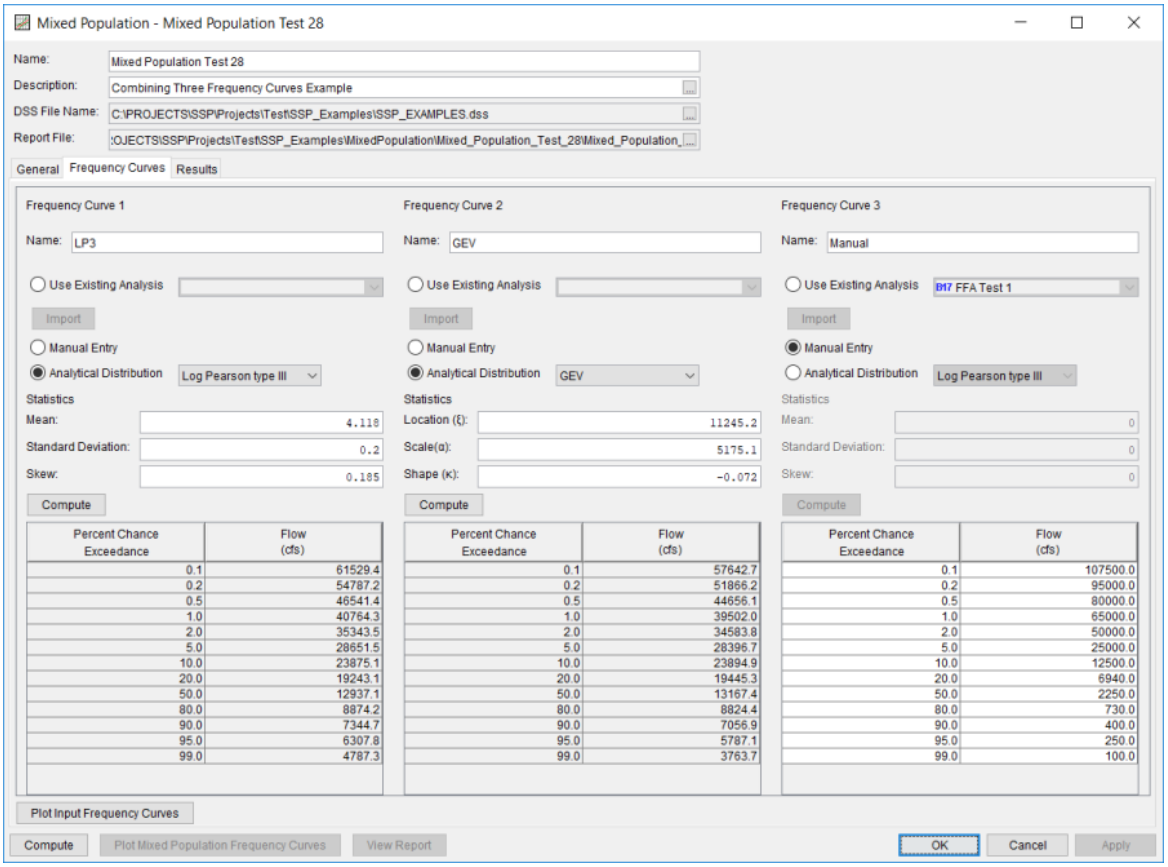
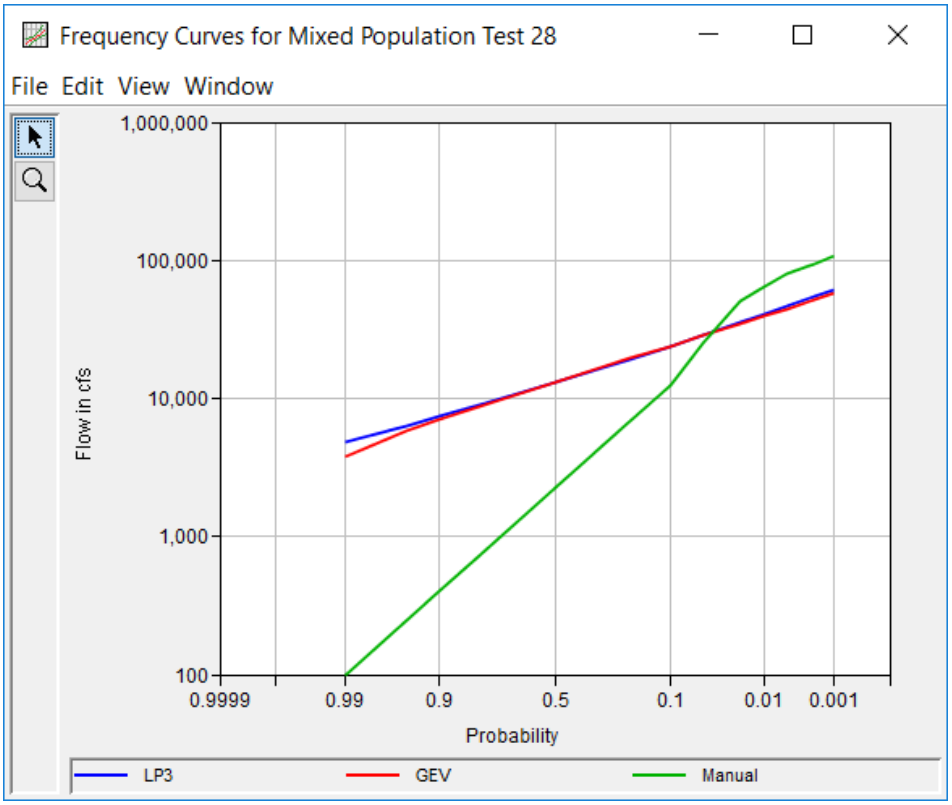
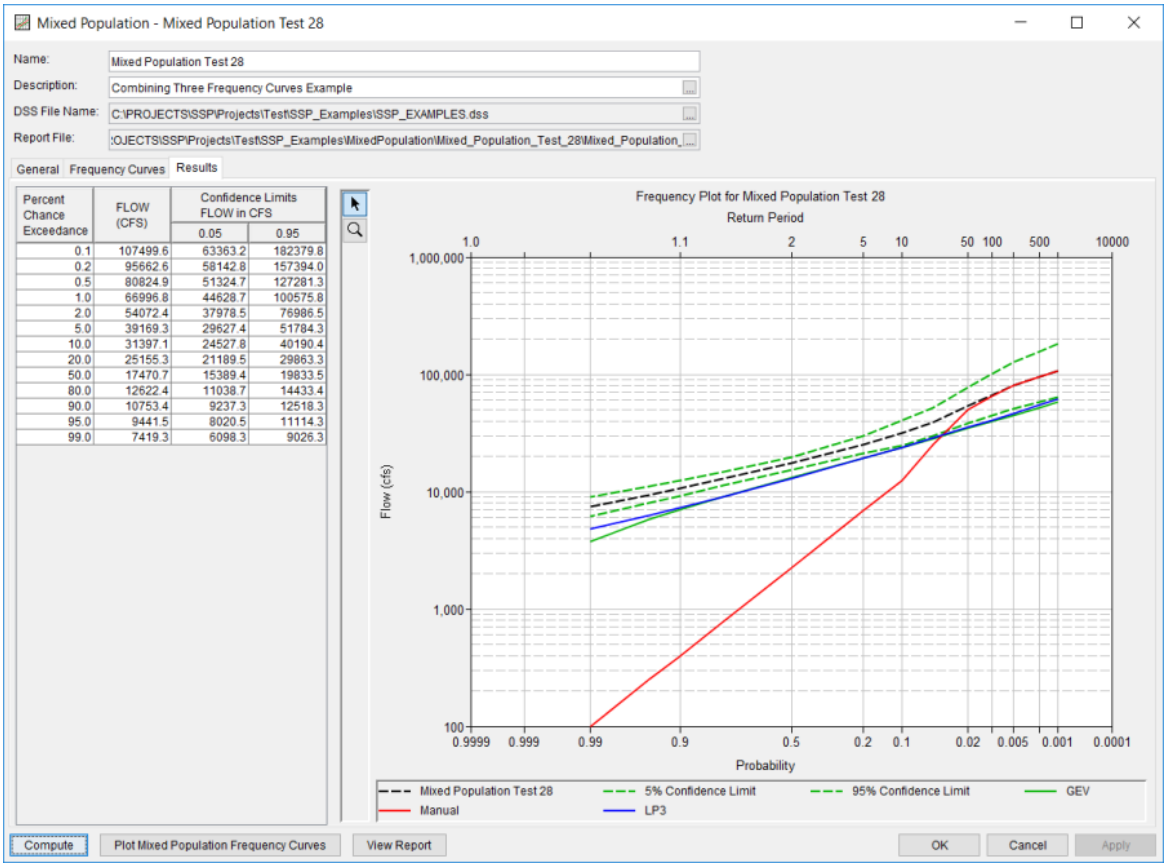


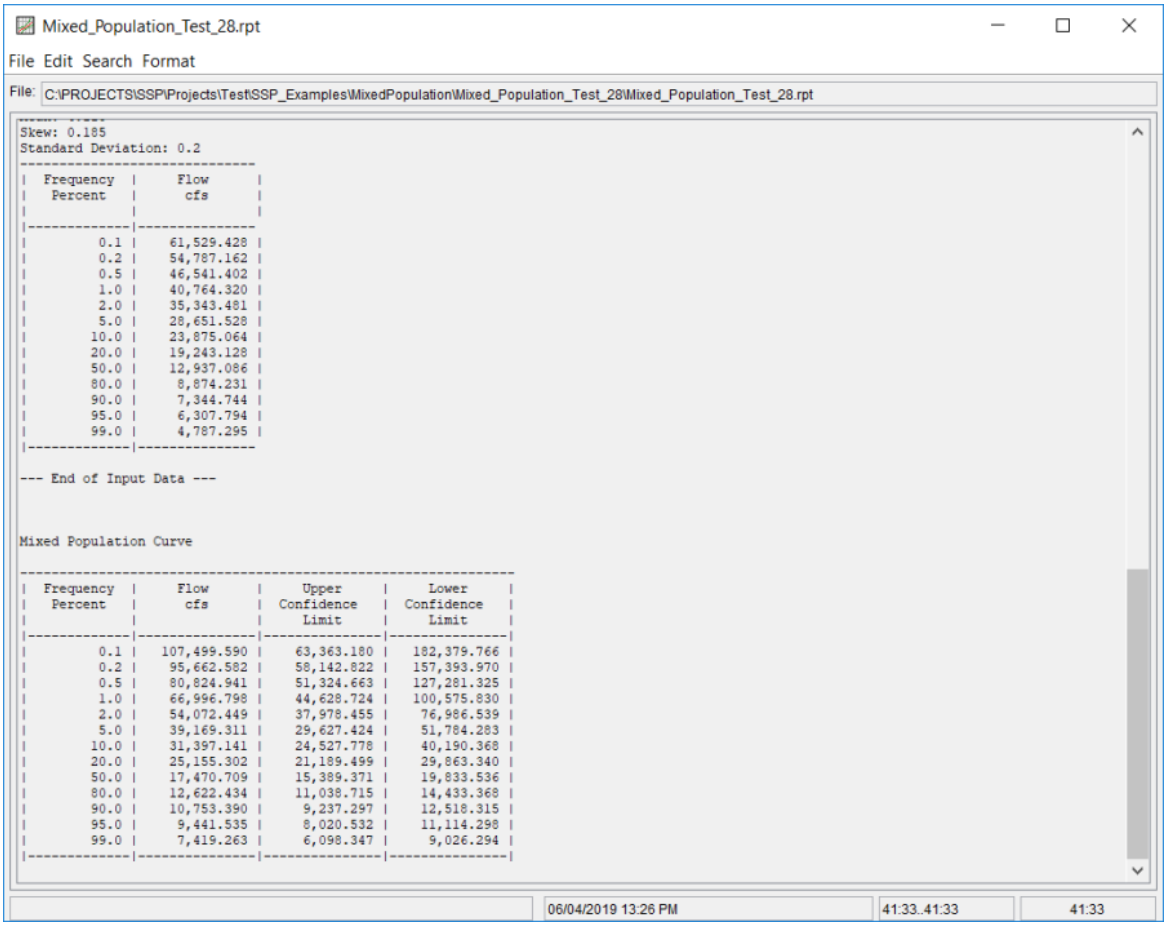
Figure 3 (see page 411) shows the plotted frequency curves for this analysis.



Press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete.** Close this window and then select the **Results** tab. The results tab should resemble Figure 4 (see page 412). The left portion of the Results tab window displays the computed mixed population frequency curve and confidence limits. The right portion of the Results tab displays the input frequency curves in addition to the computed mixed population frequency curve and confidence limits within a plot. To view the input and results in a separate window, either click **Plot Mixed Population Frequency Curves** button or double click on the plot within the Results tab.



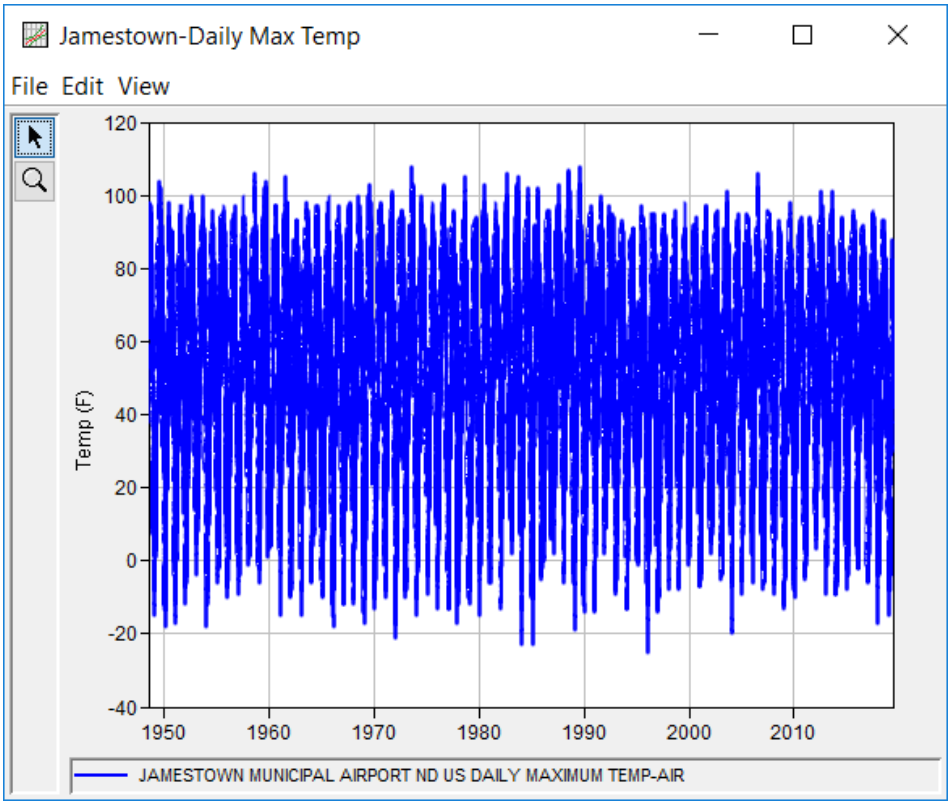
In addition to the tabular and graphical results, there is a report file that shows input data and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen. Shown in Figure 5 (see page 413) is the report file for **Mixed Population Test 28**.


Mixed_Population_Test_28.rpt
File Edit Search Format
File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\MixedPopulation\Mixed_Population_Test_28\Mixed_Population_Test_28.rpt
Skew: 0.185
Standard Deviation: 0.2
Frequency Percent	Flow cfs
0.1	61,529.428
0.2	54,787.162
0.5	46,541.402
1.0	40,764.320
2.0	35,343.481
5.0	28,651.528
10.0	23,875.064
20.0	19,243.128
50.0	12,937.086
80.0	8,874.231
90.0	7,344.744
95.0	6,307.794
99.0	4,787.295
--- End of Input Data ---
Mixed Population Curve
Frequency Percent	Flow cfs	Upper Confidence Limit	Lower Confidence Limit
0.1	107,499.590	63,363.180	182,379.766
0.2	95,662.582	58,142.822	157,393.970
0.5	80,824.941	51,324.663	127,281.325
1.0	66,996.798	44,628.724	100,575.830
2.0	54,072.449	37,978.455	76,986.539
5.0	39,169.311	29,627.424	51,784.283
10.0	31,397.141	24,527.778	40,190.368
20.0	25,155.302	21,189.499	29,863.340
50.0	17,470.709	15,389.371	19,833.536
80.0	12,622.434	11,038.715	14,433.368
90.0	10,753.390	9,237.297	12,518.315
95.0	9,441.535	8,020.532	11,114.298
99.0	7,419.263	6,098.347	9,026.294
06/04/2019 13:26 PM
41:33..41:33
41:33

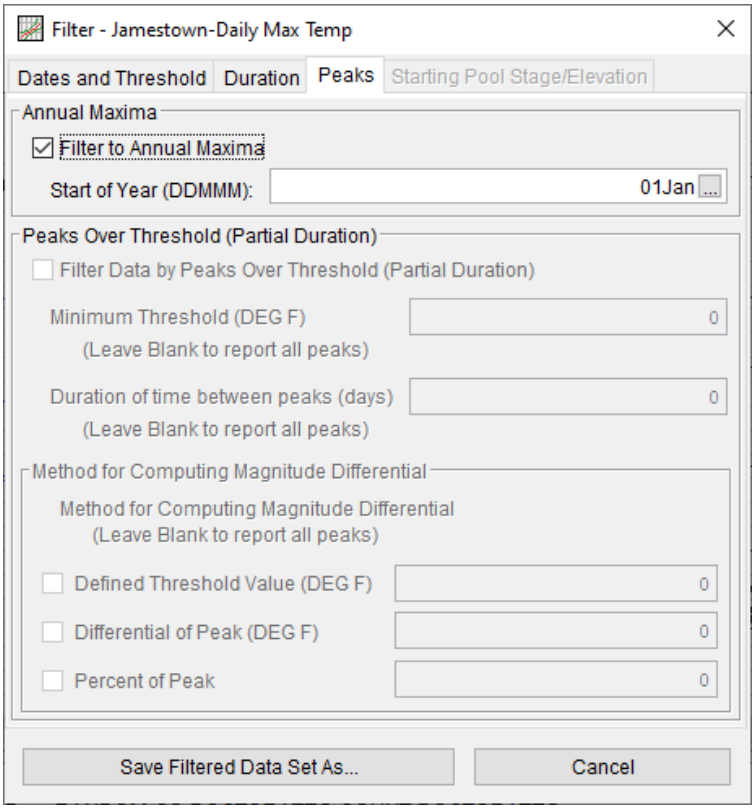
13 Data Filtering Examples

13.1 Data Filtering, Extracting an Annual Maximum Series

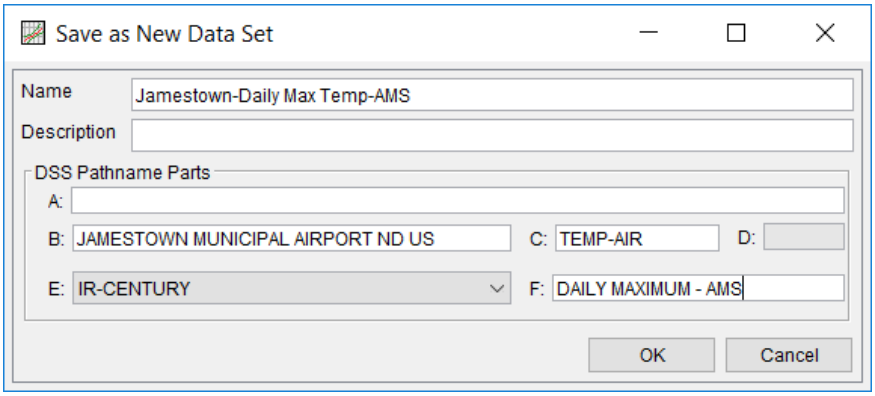
This example demonstrates how to extract an annual maximum series from another time series. The original data for this example consists of daily maximum temperatures as recorded by a weather station at the Jamestown, ND Municipal Airport. This weather station is operated by the NWS. Daily temperature data was downloaded from the NWS website ("https://www.ncdc.noaa.gov/") as a .csv file and ingested to the study using an HEC-DSSVue plugin. The period of record used for this example is from 1948 to 2019. To view the data from HEC-SSP, right-click on the data record labeled "**Jamestown-Daily Max Temp**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 416).



To begin extracting an annual maximum series, right click on the Jamestown-Daily Max Temp data record and select **Filter Data**. Within the **Filter** editor, click on the **Peaks** tab. Within the Annual Maxima panel, click the **Filter to Annual Maxima** check box and enter a **Start of Year** of **01Jan**, as shown in Figure 2 (see page 416).

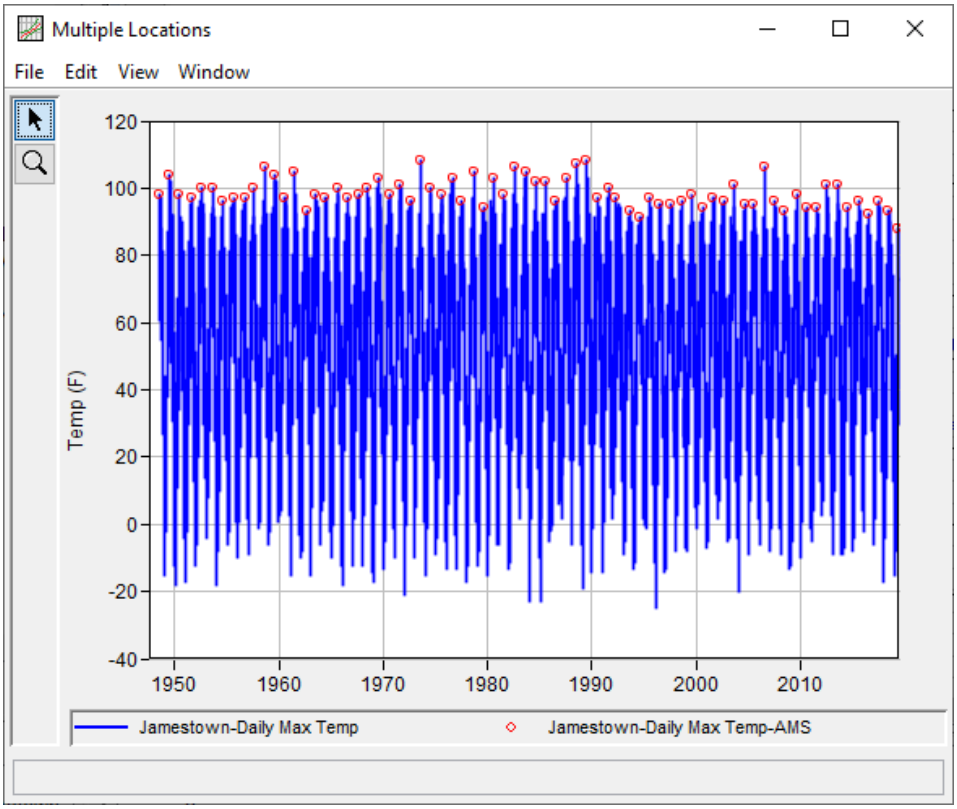


After clicking the **Save Filtered Data Set As** button, enter a **Name** of "**Jamestown-Daily Max Temp-AMS**", ensure the **E-part** is set to **IR-CENTURY**, and the **F-Part** is defined as "**DAILY MAXIMUM – AMS**", as shown in Figure 3 (see page 416).



241 Figure 3. Name and DSS Pathname Parts for Jamestown Temperature.

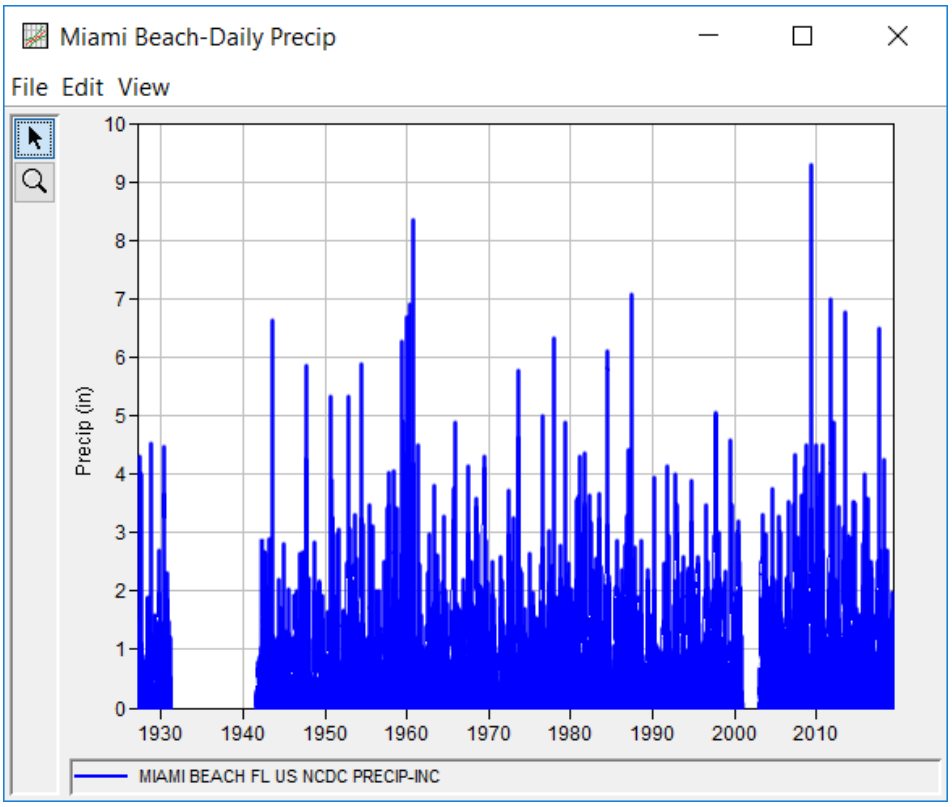
After clicking the **OK** button, a new data set will be added to the study. Out of the original 25870 values, 72 values remained after applying the aforementioned data filter. These 72 values constitute an annual maximum series of daily maximum temperature. The original data as well as the filtered data is shown in Figure 4 (see page 417).



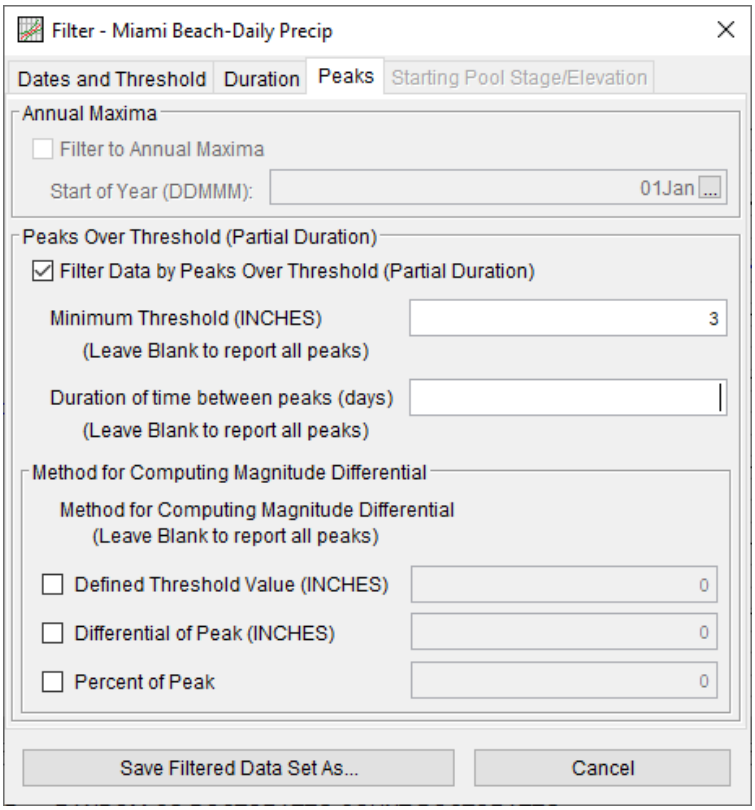
242 Figure 4. Original and Filtered Jamestown Temperature Data.

13.2 Data Filtering, Extracting a Partial Duration Series

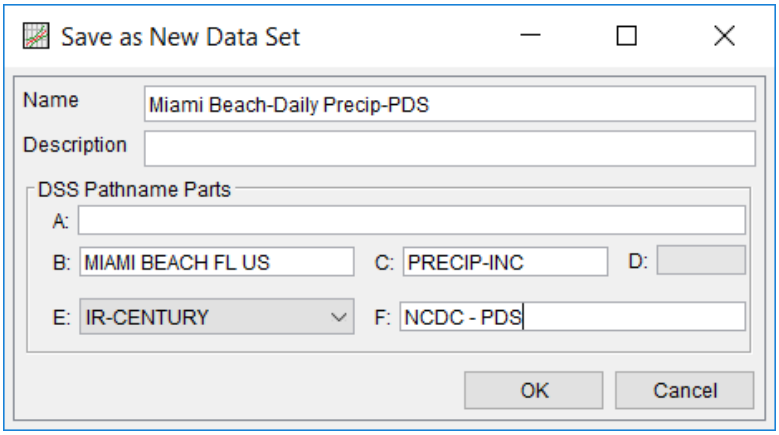
This example demonstrates how to extract a partial duration series from another time series. The original data for this example consists of daily precipitation accumulations as recorded by a precipitation gage located near Miami Beach, FL. This precipitation gage is operated by the NWS. Daily precipitation data was downloaded from the NWS website ("https://www.ncdc.noaa.gov/") as a .csv file and ingested to the study using an HEC-DSSVue plugin. The period of record used for this example is from 1927 to 2019. To view the data from HEC-SSP, right-click on the data record labeled "**Miami Beach-Daily Precip**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 418).



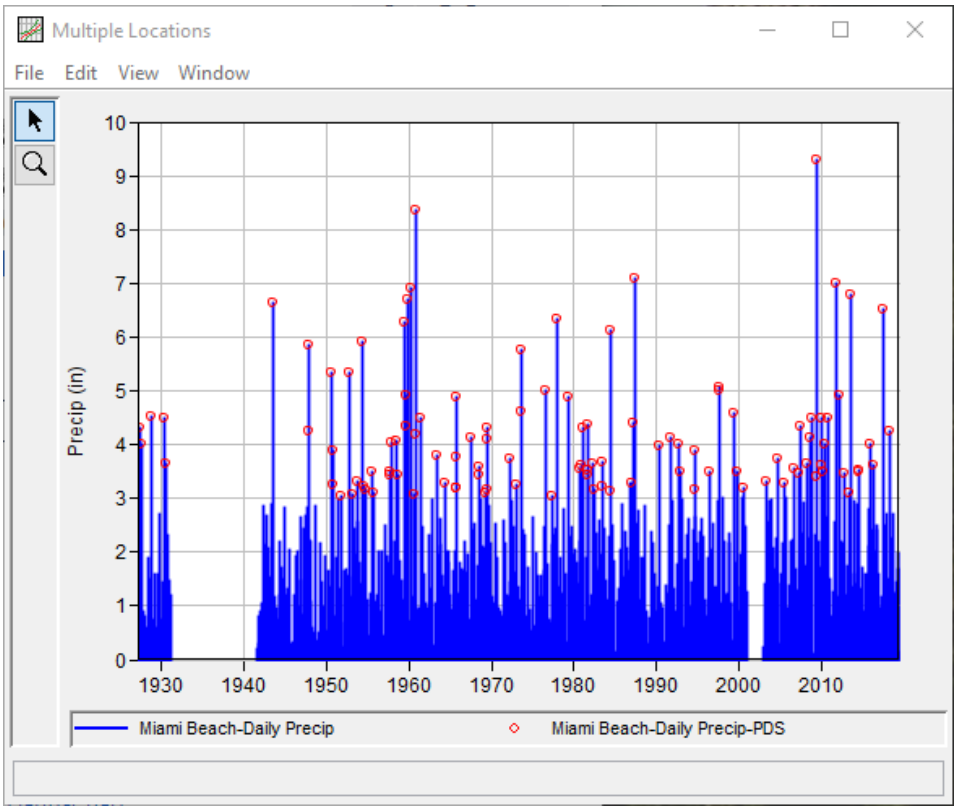
To begin extracting an annual maximum series, right click on the Miami Beach-Daily Precip data record and select **Filter Data**. Within the **Filter** editor, click on the **Peaks** tab. Within the Peaks Over Threshold (Partial Duration) panel, click the **Filter Data by Peaks Over Threshold (Partial Duration)** check box and enter a **Minimum Threshold** of 3 inches. Additionally, delete the contents of the **Duration of time between peaks** entry field, as shown in Figure 2 (see page 419).



After clicking the **Save Filtered Data Set As** button, enter a **Name** of "**Miami Beach-Daily Precip-PDS**", ensure the **E-part** is set to **IR-CENTURY**, and the **F-Part** is defined as "**NCDC – PDS**", as shown in Figure 3 (see page 420).

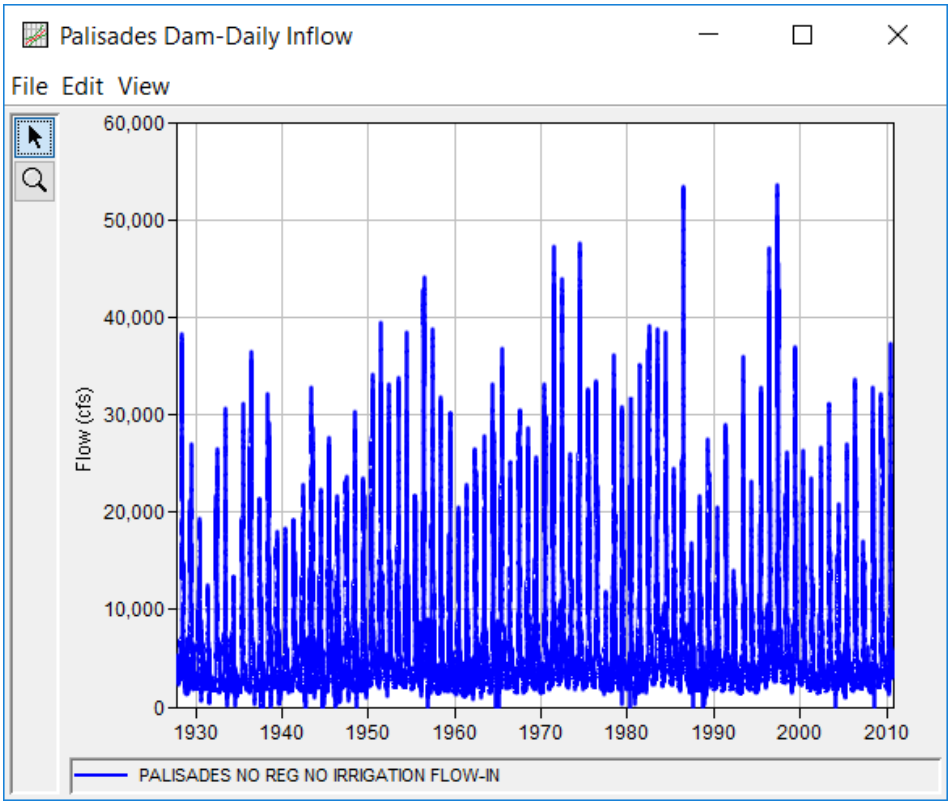


After clicking the **OK** button, a new data set will be added to the study. Out of the original 28481 values, 109 values remained after applying the aforementioned data filter. These 109 peak values constitute a partial duration series of daily precipitation accumulations in excess of 3 inches. The original data as well as the filtered data is shown in Figure 4 (see page 420).

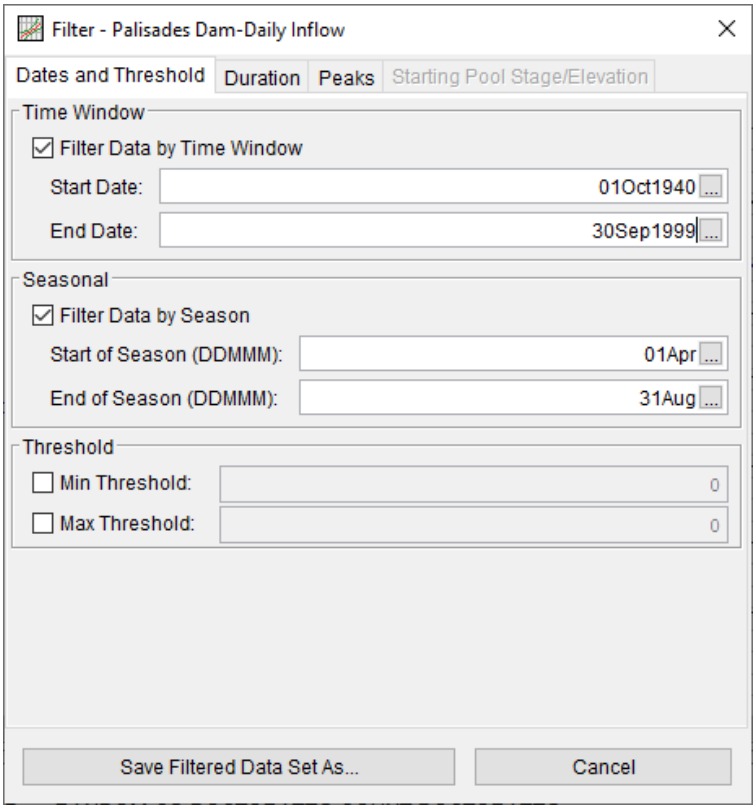


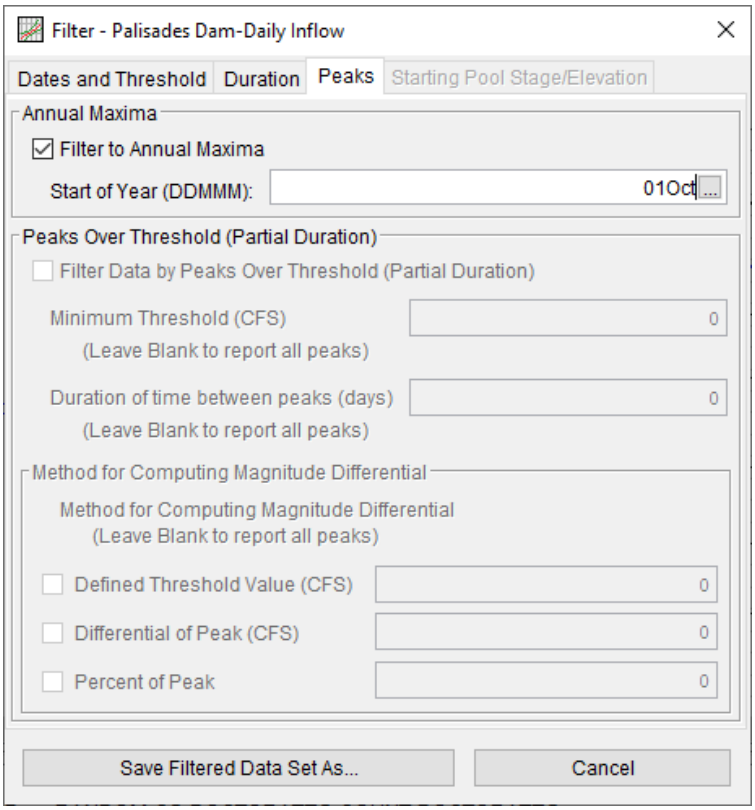
13.3 Data Filtering, Using Multiple Filters

This example demonstrates how to use multiple nested filters to extract an annual maximum series from another time series. The original data for this example consists of unregulated daily average inflows to Palisades Lake which is located along the Snake River near Irwin, ID. The period of record used for this example is from 1927 to 2010. To view the data from HEC-SSP, right-click on the data record labeled "**Palisades Dam-Daily Inflow**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 421).



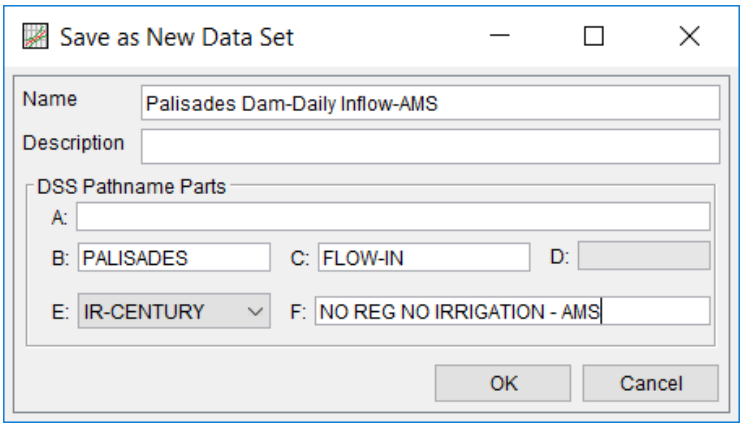
To begin extracting an annual maximum series, right click on the Palisades Dam-Daily Inflow data record and select **Filter Data**. Within the **Filter** editor, click the **Filter Data by Time Window** check box and enter a **Start Date** of **01Oct1940** and an **End Date** of **30Sep1999**. Also, click the **Filter Data by Season** check box and enter a **Start of Season** of **01Apr** and an **End of Season** of **31Aug**. On the **Peaks** tab, within the Annual Maxima panel, click the **Filter to Annual Maxima** check box and enter a **Start of Year** of **01Oct**, as shown in Figure 2 (see page 421).



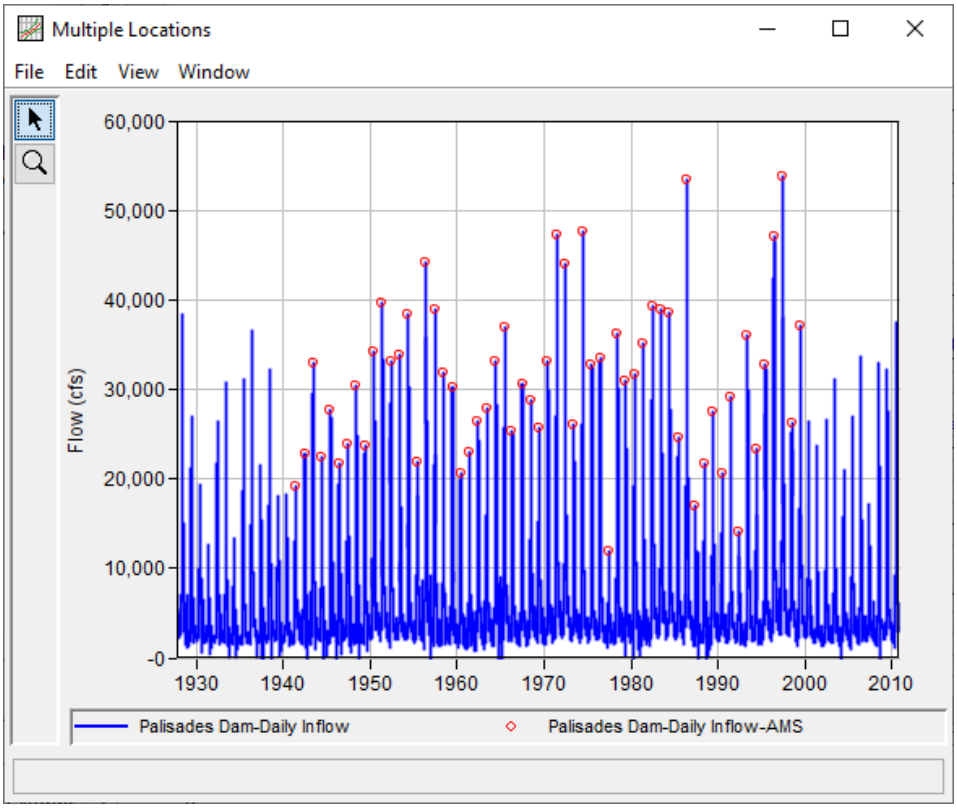


After clicking the **Save Filtered Data Set As** button, enter a **Name** of "**Palisades Dam-Daily Inflow-AMS**", ensure the **E-part** is set to **IR-CENTURY**, and the **F-Part** is defined as "**NO REG NO IRRIGATION - AMS**", as

shown in Figure 3 (see page 423).



After clicking the **OK** button, a new data set will be added to the study. Out of the original 30224 values, 59 values remained after applying the aforementioned data filters. These 59 values constitute an annual maximum series of daily average streamflow occurring between 01Apr and 31Aug. The original data as well as the filtered data is shown in Figure 4 (see page 423).

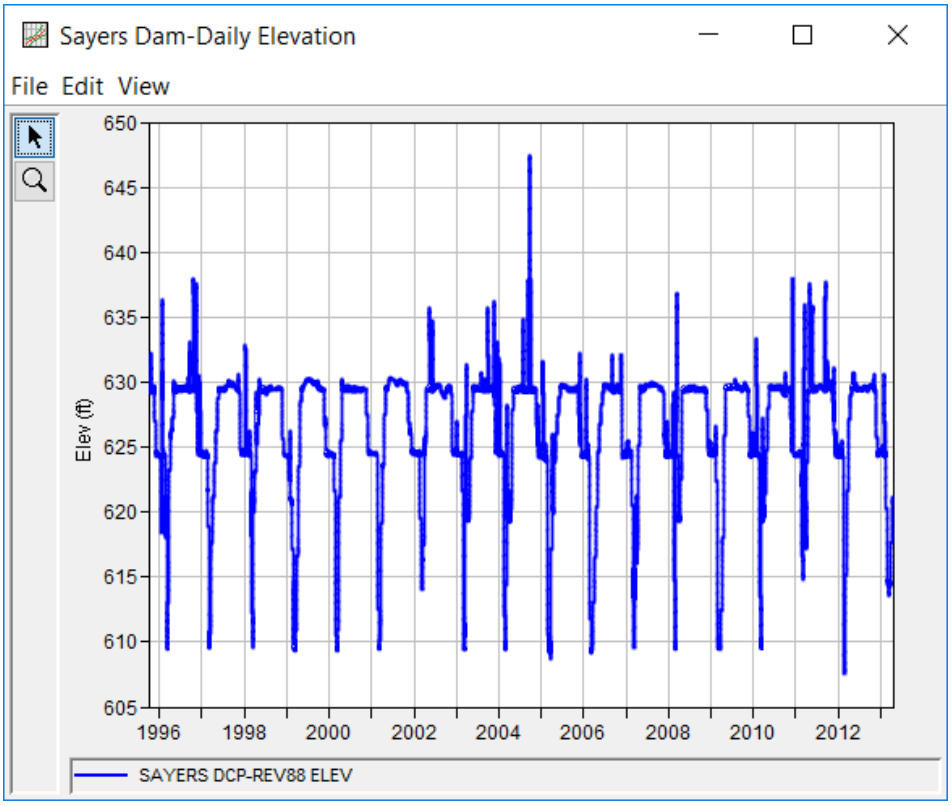


13.4 Data Filtering, Starting Pool - Elevation Filtering

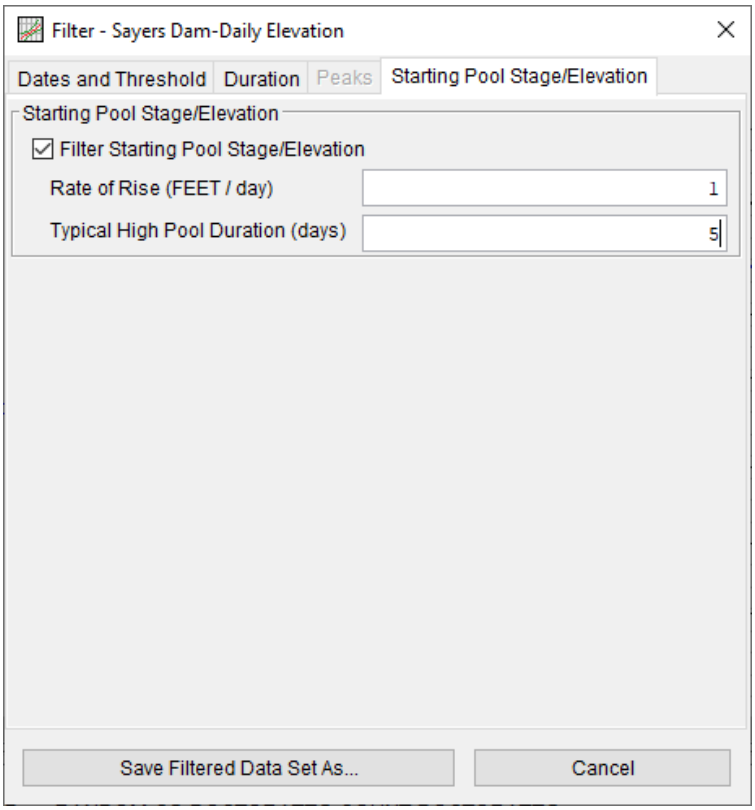
This example demonstrates how to extract a time series of pool stage or elevation that is appropriate for use when estimating antecedent conditions within extreme event simulations. When determining a reasonable

antecedent pool elevation for use in routing extreme events, it may be beneficial to remove pool elevations that occurred during or shortly after the occurrence of another large event since it takes time for the atmosphere and/or watershed to "deliver" another large amount of moisture/runoff to the location of interest.

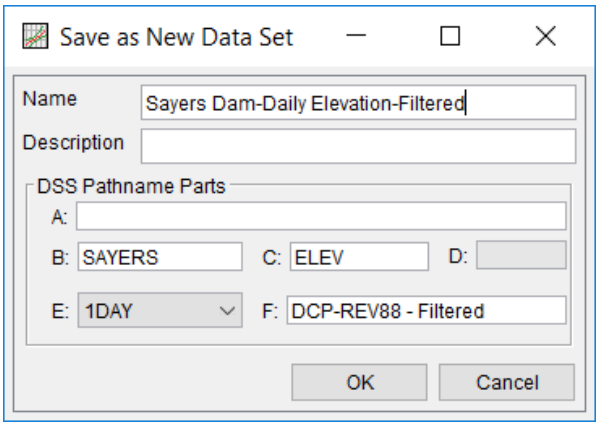
The original data for this example consists of daily average pool elevations within the lake formed by Foster Joseph Sayers Dam which is located along Bald Eagle Creek near Blanchard, PA. The period of record used for this example is from 1995 to 2013. To view the data from HEC-SSP, right-click on the data record labeled "**Sayers Dam-Daily Elevation**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 425).



To begin extracting a time series of pool stage or elevation that is appropriate for use when estimating antecedent conditions within extreme event simulations, right click on the Sayers Dam-Daily Elevation data record and select **Filter Data**. Within the **Filter** editor, click on the **Starting Pool Stage/Elevation** tab. Within the Starting Pool Stage/Elevation panel, click the **Filter Starting Pool Stage/Elevation** check box, enter a **Rate of Rise** of **1** ft/day, and a **Typical High Pool Duration** of **5** days as shown in Figure 2 (see page 425).



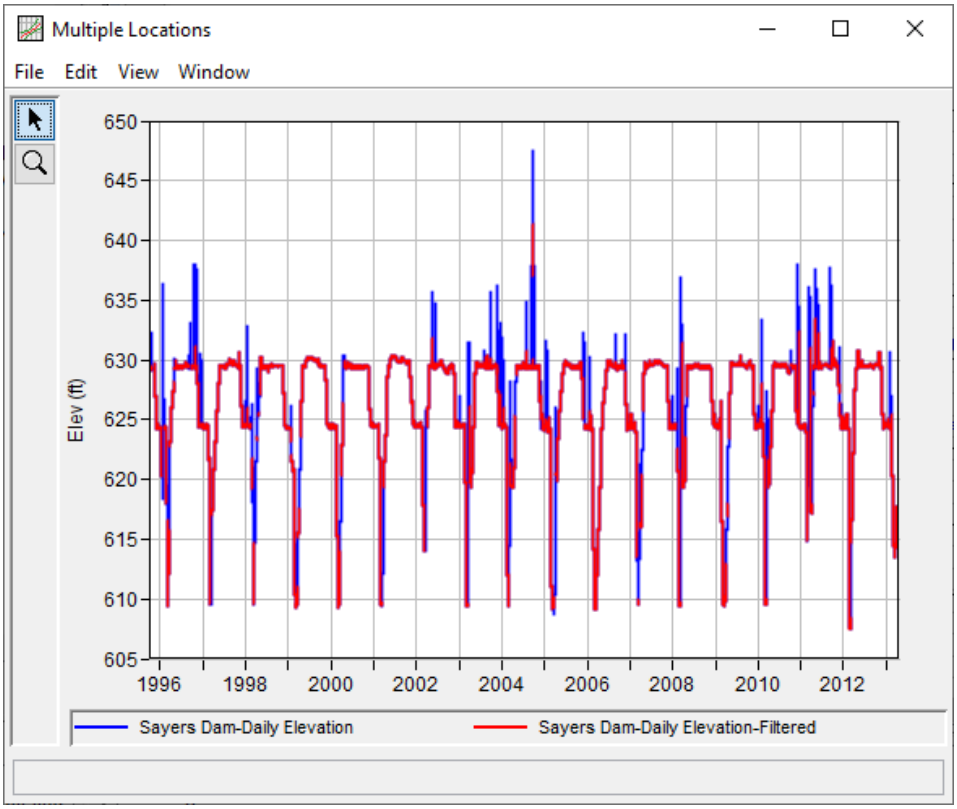
After clicking the **Save Filtered Data Set As** button, enter a **Name** of "**Sayers Dam-Daily Elevation-Filtered**", ensure the **E-part** is set to **1DAY**, and the **F-Part** is defined as "**DCP-REV88 - Filtered**", as shown in Figure 3 (see page 426).

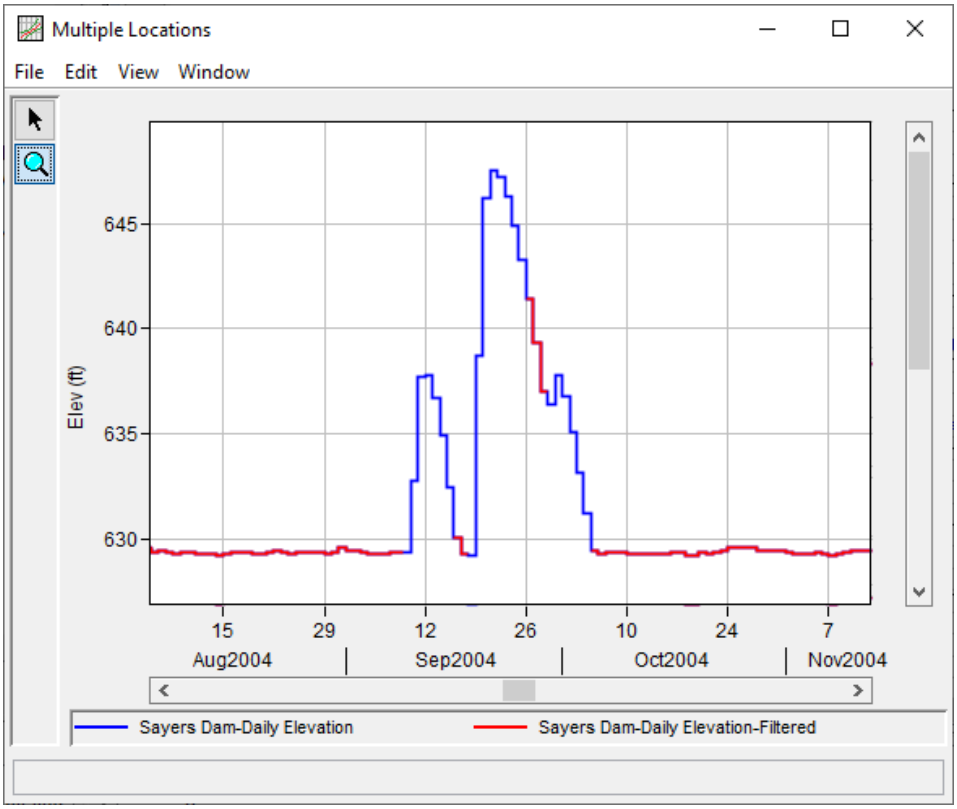


After clicking the **OK** button, a new data set will be added to the study. Given these inputs, "events" will be considered to start when the rate of rise exceeds 1 feet/day and "last" for 5 days. Also, if the rate of rise is found to exceed 1 ft/day on day 4, then again on day 8, the "event counter" will restart. Values between the start and end of the "event" will be discarded. The remaining values can be considered reasonable to use when determining appropriate antecedent pool elevations.

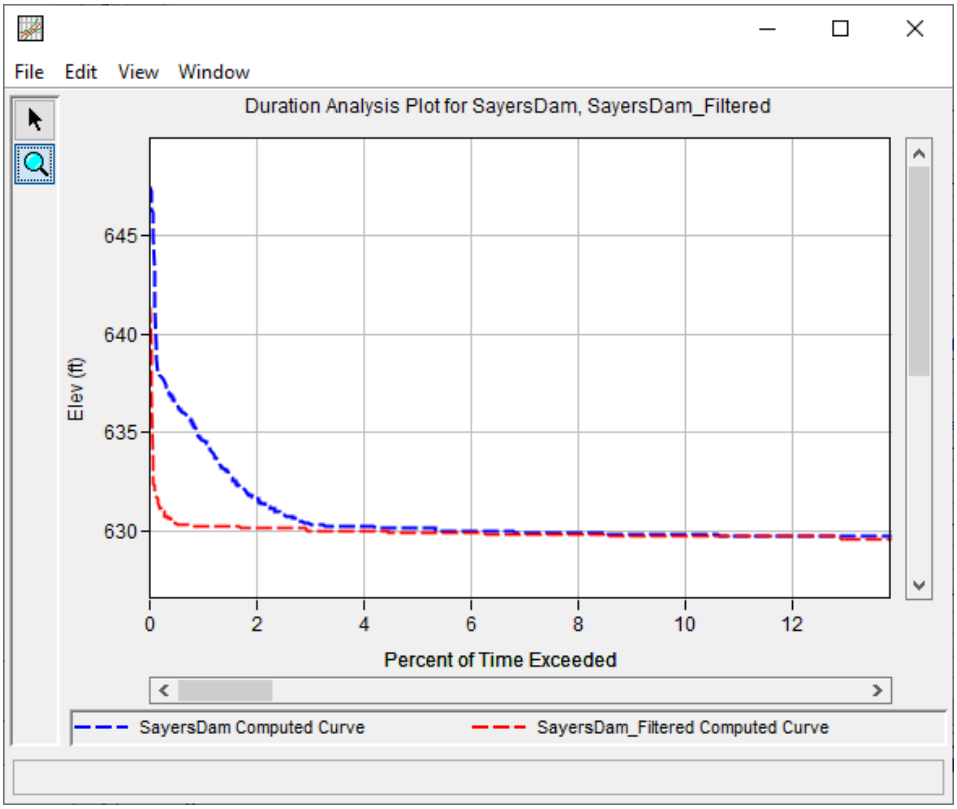
Out of the original 6409 values, 5784 values remained after applying the aforementioned data filter. These 5784 values form a time series that does not include pool elevations that occurred during or shortly after the occurrence of a large event. The original data as well as the filtered data is shown in Figure 4 (see page 426). A

more detailed view of the filtered time series is shown in Figure 5 (see page 426). As shown, the three largest remaining values (after applying the filter) occurred within a single event in September 2004. The filtered time series can be used to estimate a more appropriate pool elevation duration curve, as shown within Figure 6 (see page 426).





243 Figure 5. Detailed View of Original and Filtered Sayers Dam Data.

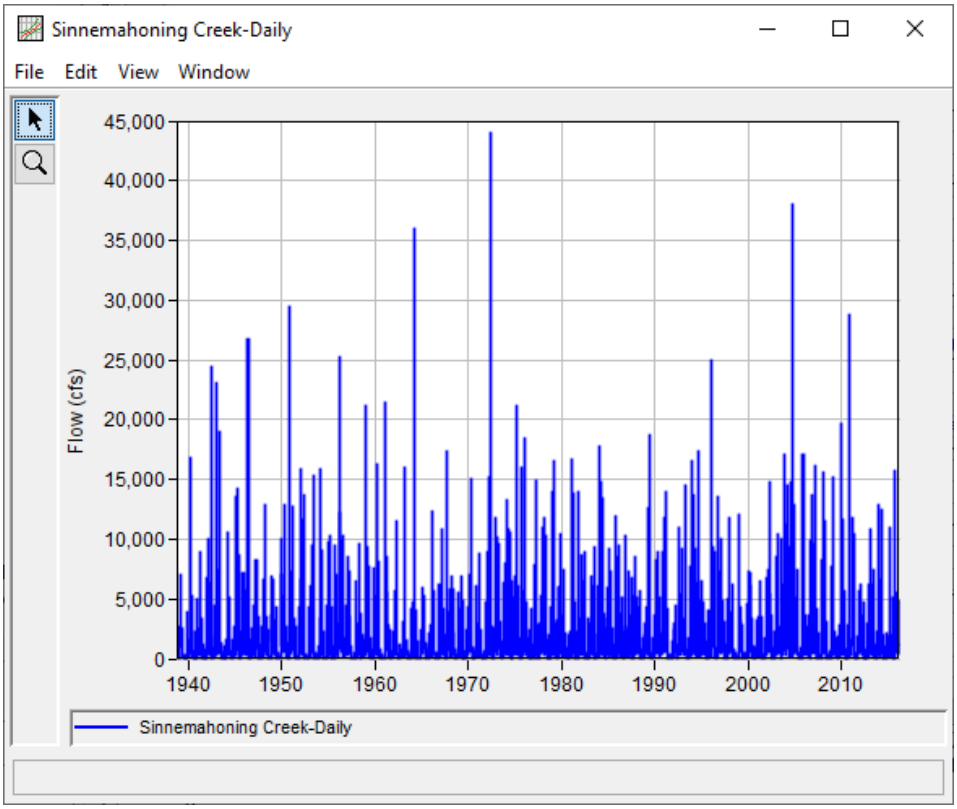


244 Figure 6. Original and Filtered Sayers Dam Pool Elevation Duration Curves

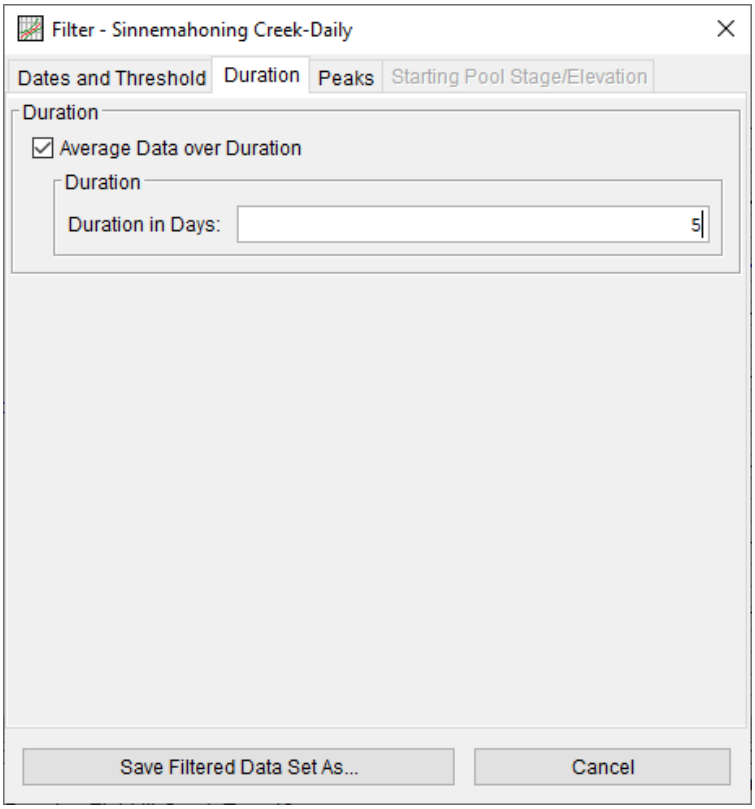
13.5 Data Filtering, Extracting an n-Day Duration Time Series

This example demonstrates how to extract an n-day duration time series from another time series. The original data for this example consists of daily average streamflow at the Sinnemahoning Creek at Sinnemahoning, PA stream gage[52]. This stream gage is operated by the USGS. The period of record used for this example is from 1938 to 2016. To view the data from HEC-SSP, right-click on the data record labeled "**Sinnemahoning Creek-Daily**" in the study explorer and then select **Plot**. A plot of the data will appear as shown in Figure 1 (see page 429).

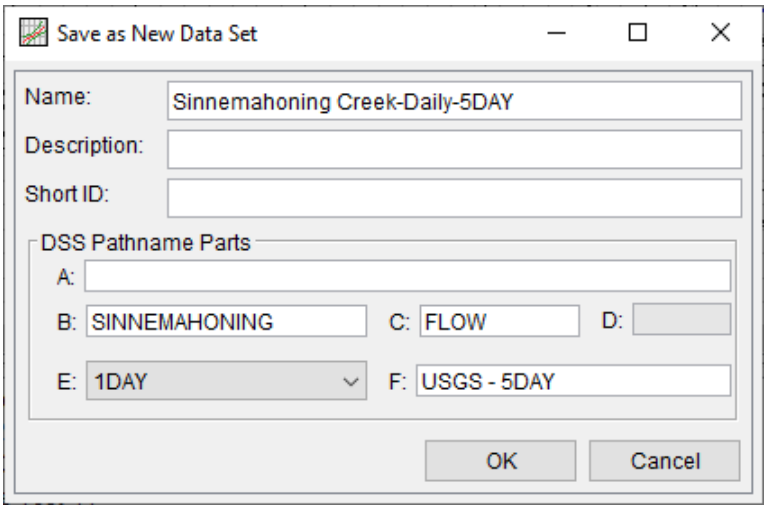
52 https://waterdata.usgs.gov/nwis/uv?site_no=01543500



To begin extracting an n-day duration time series, right click on the Sinnemahoning Creek-Daily data record and select **Filter Data**. Within the **Filter** editor, click on the **Duration** tab. For this example, a 5-day duration time series will be extracted. Within the Duration panel, click the **Average Data over Duration** check box and enter a **Duration** of **5 days**, as shown in Figure 2 (see page 429).

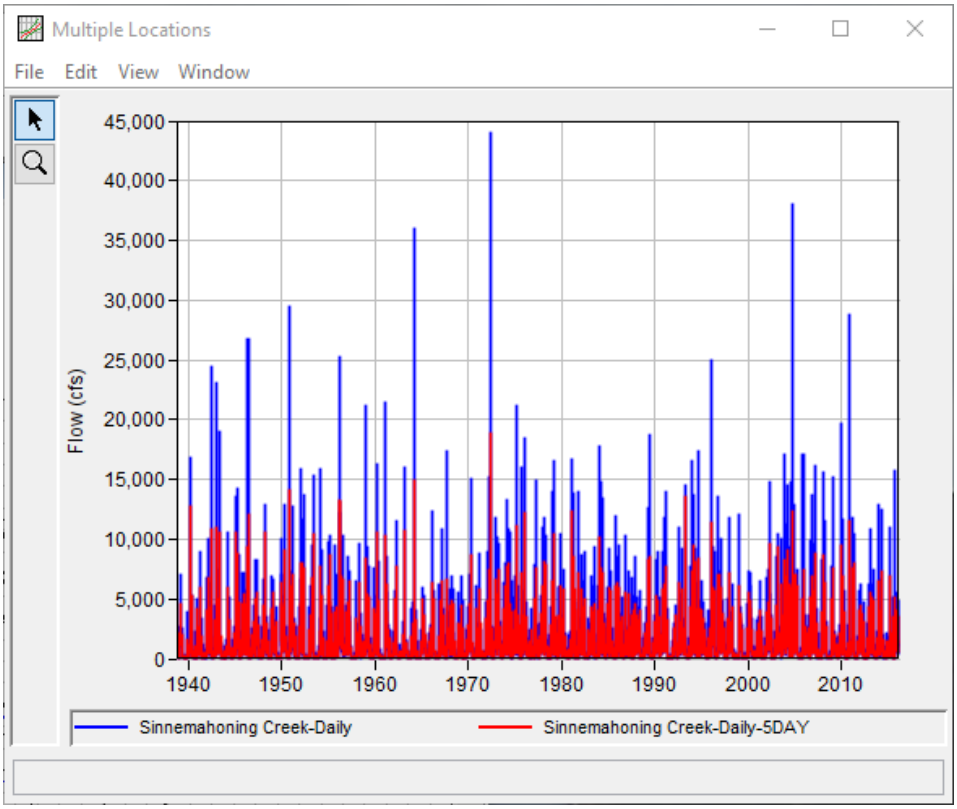


After clicking the **Save Filtered Data Set As** button, enter a **Name** of "**Sinnemahoning Creek-Daily-5DAY**", ensure the **E-part** is set to **1DAY**, and the **F-Part** is defined as "**USGS – 5DAY**", as shown in Figure 3 (see page 430).



245 Figure 3. Name and DSS Pathname Parts

After clicking the **OK** button, a new data set will be added to the study. The original data as well as the filtered data is shown in Figure 4 (see page 431).



A sample of the computations for the first ten days are shown in Table 1. As shown within this table, the filtered data set contains four fewer values than the original data set. This was necessary in order to compute a 5-day average for the first 5 days of the time series. The 5-day average is computed on day 5 using the following formula:

$$35.8 = \frac{(41+38+35+33+32)}{5}$$

Similarly, the 5-day average is computed on day 7 using the following formula:

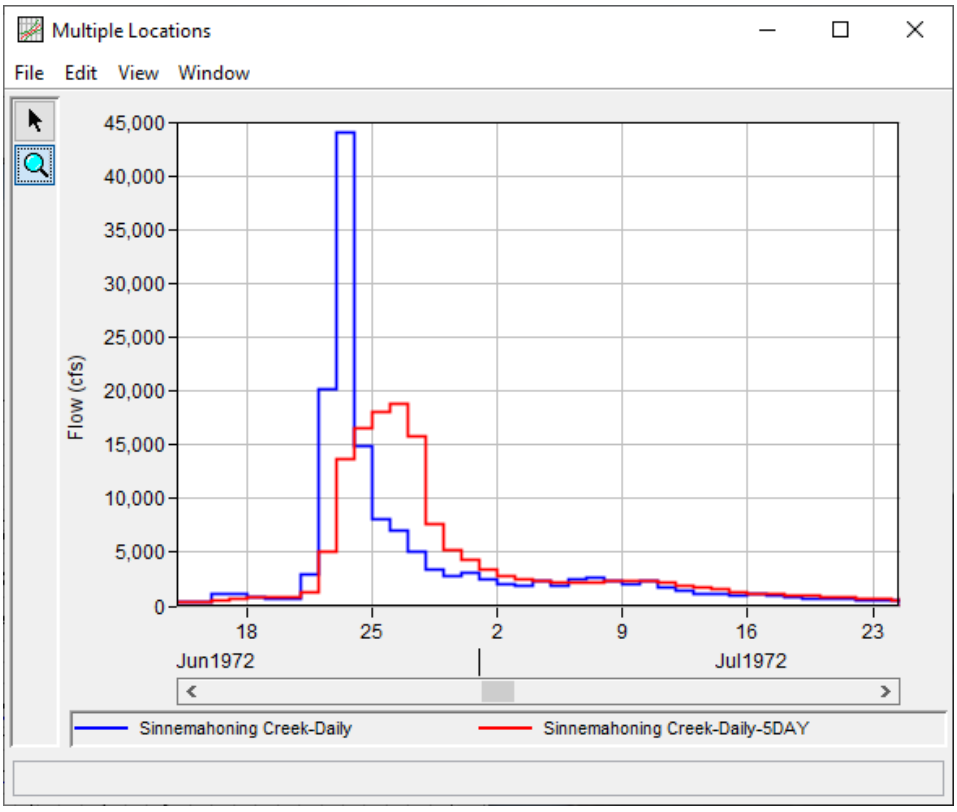
$$36.4 = \frac{(38+35+33+32+44)}{5}$$

Table 1. First Ten Days of Original and Filtered Data

Date	Original Data (cfs)	Filtered Data (cfs)
01 Oct 1938, 24:00	41	-
02 Oct 1938, 24:00	38	-
03 Oct 1938, 24:00	35	-
04 Oct 1938, 24:00	33	-
05 Oct 1938, 24:00	32	35.8

Date	Original Data (cfs)	Filtered Data (cfs)
06 Oct 1938, 24:00	44	36.4
07 Oct 1938, 24:00	90	46.8
08 Oct 1938, 24:00	112	62.2
09 Oct 1938, 24:00	75	70.6
10 Oct 1938, 24:00	61	76.4

A detailed view of the original data as well as the filtered data for the June 1972 time period is shown in Figure 5 (see page 433). The filtered data set constitutes a moving 5-day daily average streamflow time series.



246 Figure 5. Original and Filtered Data for June 1972

14 Correlation Analysis Examples

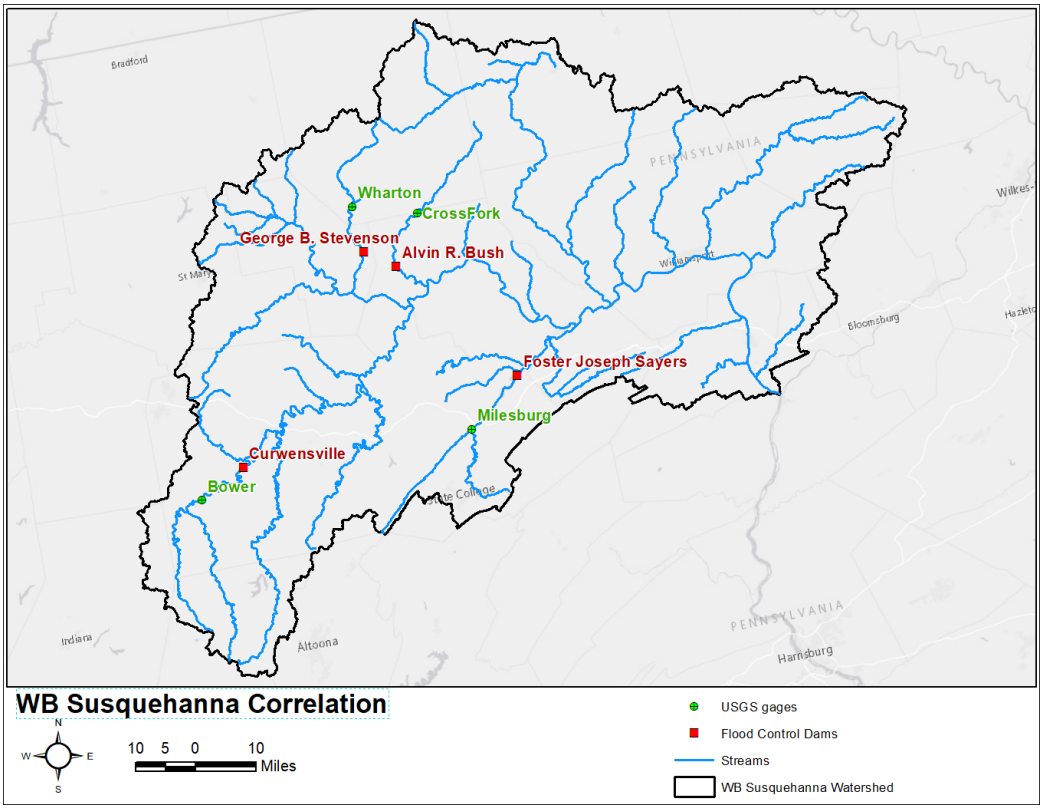
14.1 Coincident Events - West Branch Susquehanna River

The ***WBSusquehanna_Correlation*** example demonstrates the usage of the Correlation Analysis in order to determine how closely related annual maximum peak discharges at several stream gages are to one another.

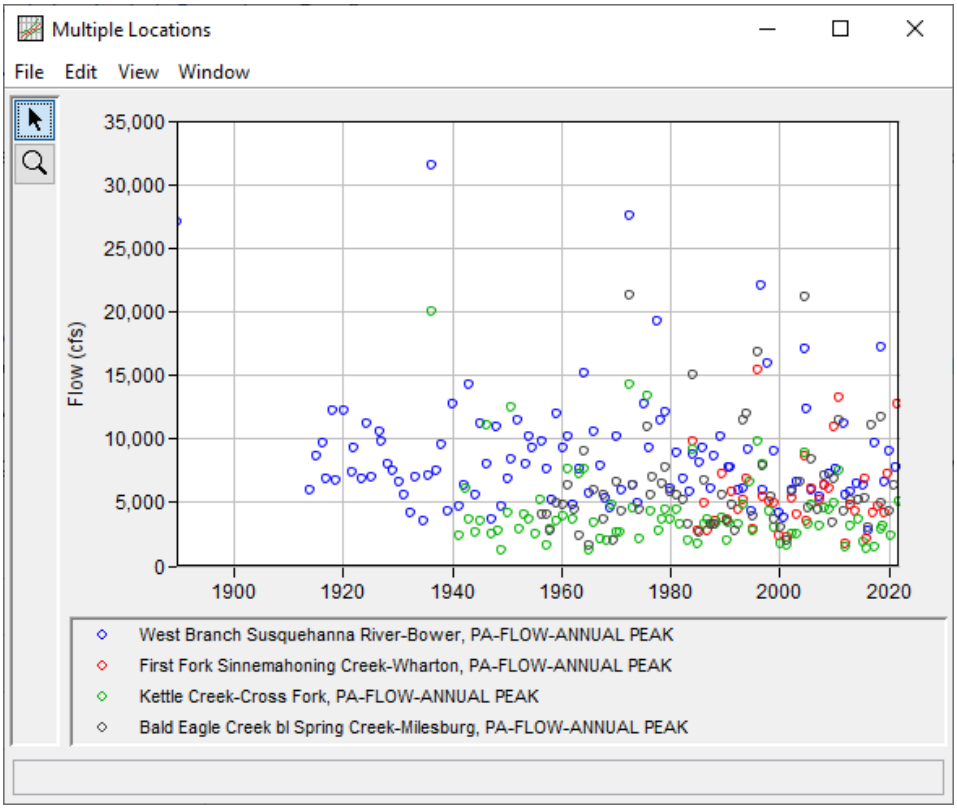
14.1.1 Input Data

In this example, time series representing annual maximum inflow to four multi-purpose reservoir projects within the West Branch Susquehanna River watershed are analyzed. The first time series is from the West Branch Susquehanna River at Bower, PA[53] stream gage, which is located just upstream of Curwensville Dam. The second time series is from the First Fork Sinnemahoning Creek at Wharton, PA[54] stream gage, which is located just upstream of George B. Stevenson Dam. The third time series is from the Kettle Creek at Cross Fork, PA[55] stream gage, which is located just upstream of Alvin R. Bush Dam. The fourth time series is from the Bald Eagle Creek bl Spring Creek at Milesburg, PA[56] stream gage, which is located just upstream of Foster Joseph Sayers Dam. The location of these stream gages is shown in Figure 1. The time series are plotted within Figure 2 and tabulated within Table 1.

53 https://waterdata.usgs.gov/nwis/uv/?site_no=01541000&agency_cd=USGS
54 https://waterdata.usgs.gov/pa/nwis/uv/?site_no=01543700&PARAmeter_cd=00065,00060,00010
55 https://waterdata.usgs.gov/usa/nwis/uv?01544500
56 https://waterdata.usgs.gov/nwis/uv?01547200



247 Figure 1. Stream Gage Locations



248 Figure 2. Input Time Series for WBSusquehanna_Correlation Example

Table 1. Input Time Series for WBSusquehanna_Correlation Example

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
31 May 1889	27000			
09 Nov 1913	5900			
07 Jan 1915	8640			
03 Jun 1916	9600			
22 Jan 1917	6800			
20 Feb 1918	12200			

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
31 Oct 1918	6680			
12 Mar 1920	12200			
08 Aug 1921	7300			
29 Nov 1921	9320			
13 May 1923	6850			
29 Jun 1924	11200			
09 Feb 1925	6960			
05 Sep 1926	10500			
22 Jan 1927	9810			
30 Mar 1928	7940			
26 Feb 1929	7440			
26 Feb 1930	6550			
04 Apr 1931	5500			
01 Apr 1932	4160			
15 Mar 1933	6930			
30 Sep 1934	3540			
25 Jul 1935	7120			

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
18 Mar 1936	31500		20000	
22 Jan 1937	7520			
18 Dec 1937	9490			
15 Feb 1939	4320			
31 Mar 1940	12700			
06 Apr 1941			2370	
05 Jun 1941	4600			
09 Mar 1942	6320			
22 May 1942			6100	
30 Dec 1942	14300		3660	
17 Mar 1944	5500			
08 May 1944			2580	
07 Mar 1945	11200			
18 Mar 1945			3520	
28 May 1946			11000	
13 Jun 1946	8000			
06 Apr 1947			2470	

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
26 Apr 1947	3660			
14 Apr 1948	10900			
15 Apr 1948			2800	
27 Jan 1949	4600			
16 Feb 1949			1260	
28 Mar 1950	6850			
05 Apr 1950			4180	
05 Nov 1950	8410			
25 Nov 1950			12400	
27 Jan 1952	11400			
06 Apr 1952			2850	
24 Mar 1953			4050	
31 May 1953	8000			
02 Mar 1954	10200		3670	
16 Oct 1954	9270			
05 Mar 1955			2460	
08 Mar 1956			5140	

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
03 Jul 1956	9720			
06 Aug 1956				4000
06 Apr 1957	7600		1620	
09 Apr 1957				4000
21 Dec 1957			2850	
26 Dec 1957				2810
08 May 1958	5190			
22 Jan 1959	11900		3550	
10 Feb 1959				4880
31 Mar 1960	9270		3920	
23 May 1960				4770
25 Feb 1961	10200			
26 Feb 1961			7600	6340
28 Feb 1962	4740			
31 Mar 1962			3670	
07 Apr 1962				4400
17 Mar 1963				2410

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
18 Mar 1963	7600			
27 Mar 1963			7200	
10 Mar 1964	15200		7600	8950
03 Jan 1965	5720			
13 Feb 1965			1240	
24 Mar 1965				1640
13 Feb 1966				5910
14 Feb 1966	10600		3400	
06 Mar 1967	7800			
29 Mar 1967			2080	
29 Sep 1967				5620
25 Oct 1967				3630
31 Jan 1968	5250			
23 Mar 1968			1960	
30 Jan 1969	4590			
20 May 1969			4770	
23 Jul 1969				1990

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
02 Apr 1970	10100		2610	6530
16 Nov 1970			2600	
21 Feb 1971	5920			
27 Feb 1971				4330
23 Jun 1972	27500		14300	21300
02 Feb 1973	6270		4540	6290
19 Jan 1974	4950			
04 Apr 1974			2090	4400
24 Feb 1975	12700			
26 Sep 1975			13400	
27 Sep 1975				10900
17 Feb 1976	9270			
20 Jun 1976			4230	
21 Jun 1976				5620
09 Oct 1976				6920
20 Jul 1977	19200			
25 Sep 1977			2700	

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
15 Mar 1978	11400			
14 May 1978			3590	
15 May 1978				6500
05 Mar 1979	12100			
06 Mar 1979			4430	7760
26 Nov 1979	6020		3640	5780
20 Feb 1981			4360	
21 Feb 1981	8820			
23 Feb 1981				5500
28 Oct 1981			3210	
13 Mar 1982	6820			
05 Jun 1982				5180
21 Mar 1983				3310
22 Mar 1983			1990	
21 Jun 1983	5790			
14 Feb 1984		9810	9080	15000
15 Feb 1984	8790			

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
25 Feb 1985		2790	1730	
29 Mar 1985	8140			
01 Apr 1985				2630
16 Nov 1985	9210			
20 Jan 1986		4880		
15 Mar 1986			3280	6730
27 Nov 1986		2770	3680	
05 Apr 1987	6120			3210
02 Feb 1988	8620			3200
19 May 1988		3510	3220	
31 Mar 1989	10100			
21 Jun 1989		7190	3770	5590
11 Apr 1990		3620	2010	
09 Jun 1990				3450
12 Jul 1990	7690			
11 Oct 1990			3370	
30 Dec 1990	7730			

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
04 Mar 1991		5830		4740
03 Dec 1991				2790
14 Jul 1992	5920			
15 Jul 1992		4390		
17 Jul 1992			3240	
28 Mar 1993	6020			
01 Apr 1993		5160	4760	
16 Apr 1993				11400
28 Nov 1993		6870		11900
25 Mar 1994	9150			
18 Aug 1994			6530	
28 Nov 1994	4320			
20 Jan 1995				3880
21 Jan 1995		2860	2740	
19 Jan 1996		15400	9820	16800
19 Jul 1996	22000			
08 Nov 1996	6000		7960	7870

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
09 Nov 1996		5400		
08 Nov 1997	15900			
08 Jan 1998		5100	4280	
09 Apr 1998				5380
24 Jan 1999	8960	4890	3000	3650
26 Nov 1999	4100	2420		
04 Apr 2000			1730	
17 Apr 2000				3060
18 Oct 2000	3730			
22 Mar 2001				2000
10 Apr 2001		2240	1640	
26 Mar 2002	5880			5840
13 May 2002		5340	2480	
02 Jan 2003	6640			
21 Mar 2003			2550	
22 Mar 2003		3980		
28 Sep 2003				6630

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
18 Sep 2004	17100	8590	8880	21100
06 Jan 2005	12300			
14 Jan 2005		3500		
29 Mar 2005				4490
03 Apr 2005			3280	
29 Nov 2005	5990			
30 Nov 2005		6080	4750	8380
16 Nov 2006				4370
15 Mar 2007	5480	5230	3070	
06 Feb 2008		6330	4570	
05 Mar 2008	6310			7070
25 Dec 2008	7260			
09 Mar 2009		6020	4380	
31 Jul 2009				3340
25 Jan 2010		10900	4940	6830
14 Mar 2010	7600			
01 Dec 2010		13200	7410	11400

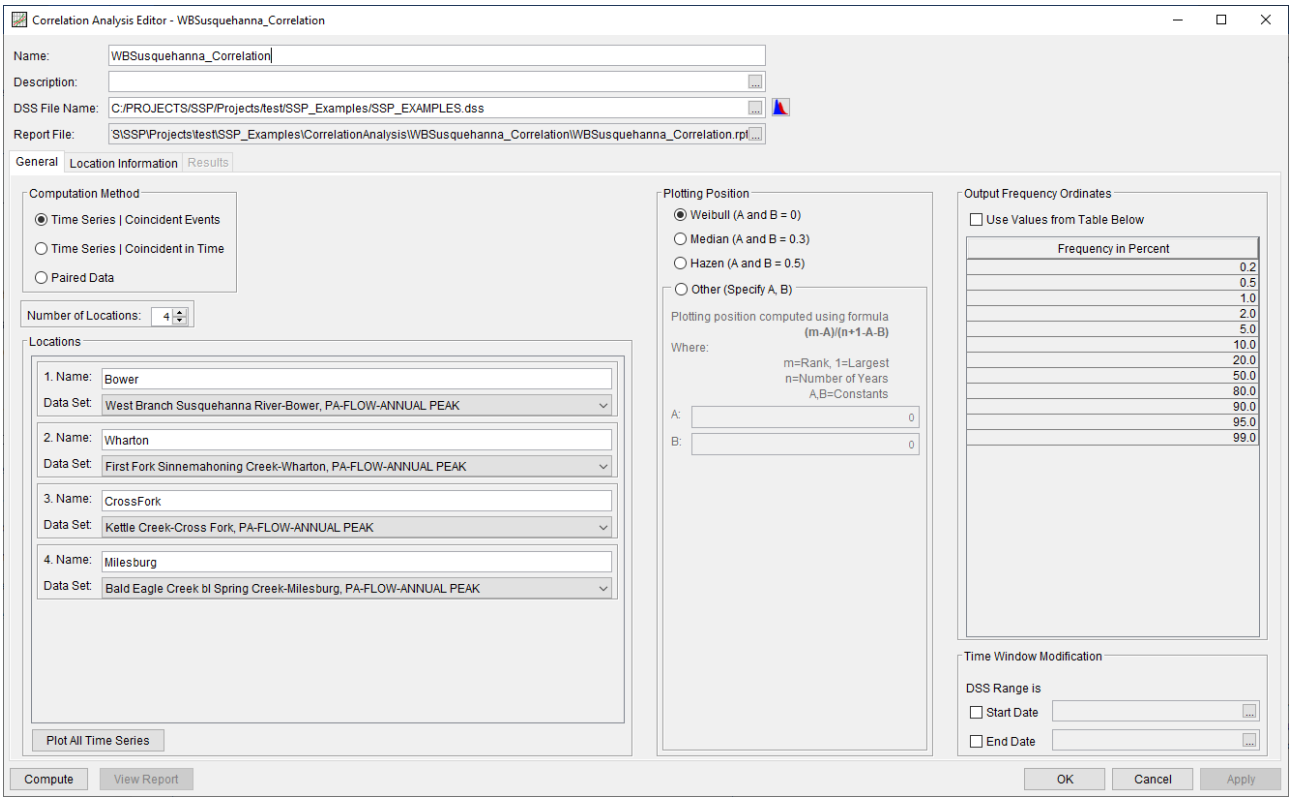
Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
10 Sep 2011	11200			
23 Nov 2011				4280
23 Dec 2011		1770	1530	
27 Jan 2012	5540			
31 Jan 2013	5770	4770	3120	5190
22 Dec 2013		4250		
13 Mar 2014	6450			
16 May 2014				5140
16 May 2014			3650	
15 Mar 2015	6310			
10 Apr 2015			1840	
18 Jul 2015				5300
30 Sep 2015		6860		
29 Oct 2015		2080		
11 Nov 2015			1350	
03 Feb 2016				3040
03 Feb 2016	2750			

Date	Flow (cfs)			
	Bower	**Wharton**	**Cross Fork**	**Milesburg**
21 Oct 2016				11100
13 Jan 2017		4140		
06 May 2017			1500	
29 May 2017	9590			
13 Jan 2018		4630		
10 Sep 2018	17200			
10 Sep 2018				11700
11 Sep 2018			2830	
03 Oct 2018				4950
22 Dec 2018			3150	
08 Feb 2019	6550			
08 Feb 2019		4140		
01 Nov 2019		7220		
28 Mar 2020	8990			
29 Mar 2020				4270
01 May 2020			2420	
25 Dec 2020				6370

Date	Flow (cfs)			
	Bower	Wharton	Cross Fork	Milesburg
10 May 2021	7790			
19 Aug 2021		12700		
23 Sep 2021			5100	

14.1.2 General Tab

A Correlation Analysis has been developed for this example. To open the analysis, either double-click on the analysis labeled **WBSusquehanna_Correlation** from the study explorer or from the **Analysis** menu select open, then select **WBSusquehanna_Correlation** from the list of available analyses. When **WBSusquehanna_Correlation** is opened, the **General** tab within the Correlation Analysis editor will appear as shown in Figure 3. For this analysis, the *Time Series* | *Coincident Events* computational method was selected and four locations were defined. The default *Plotting Position* formula (*Weibull*) and *Output Frequency Ordinates* were left unchanged. No modifications were made to the time window.



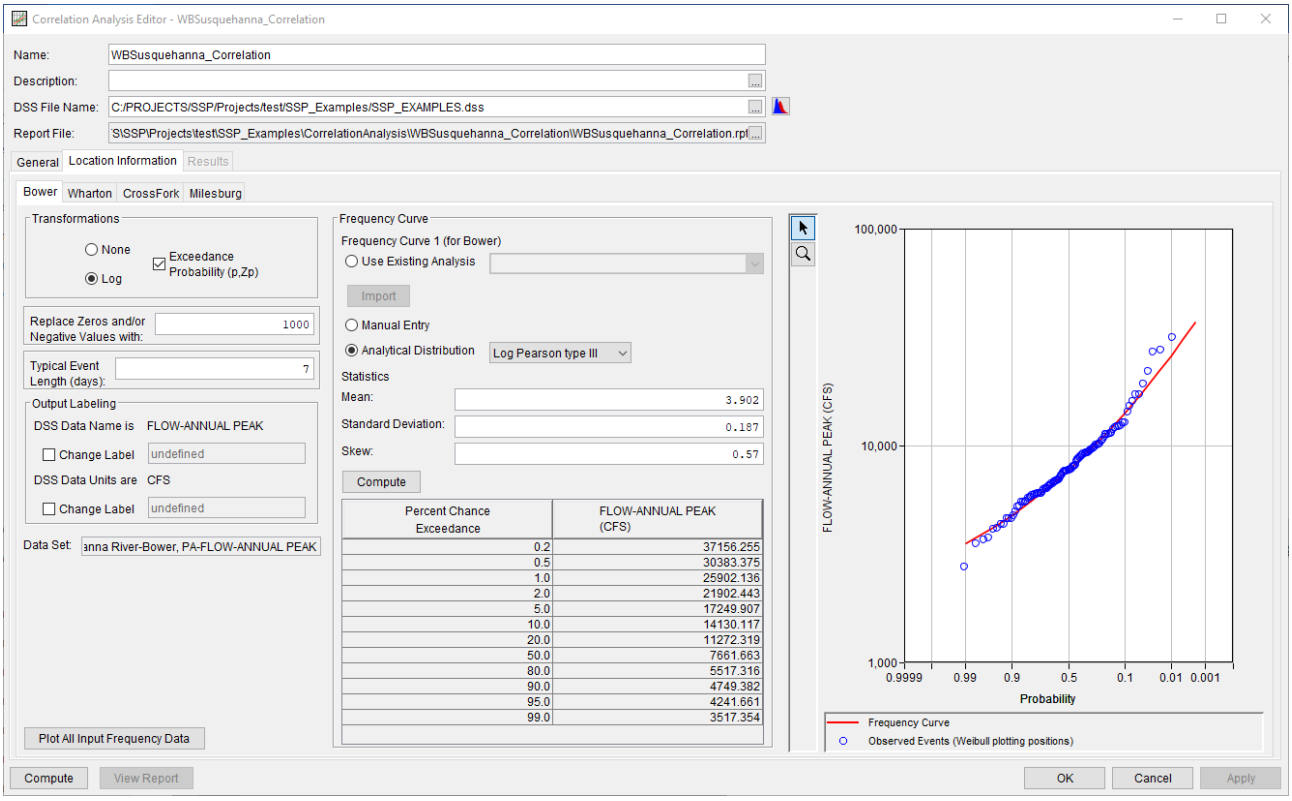
249 Figure 3. General Tab

14.1.3 Location Information Tab

The **Location Information** tab contains four sub-tabs, one for each of the previously defined locations.

14.1.3.1 Bower

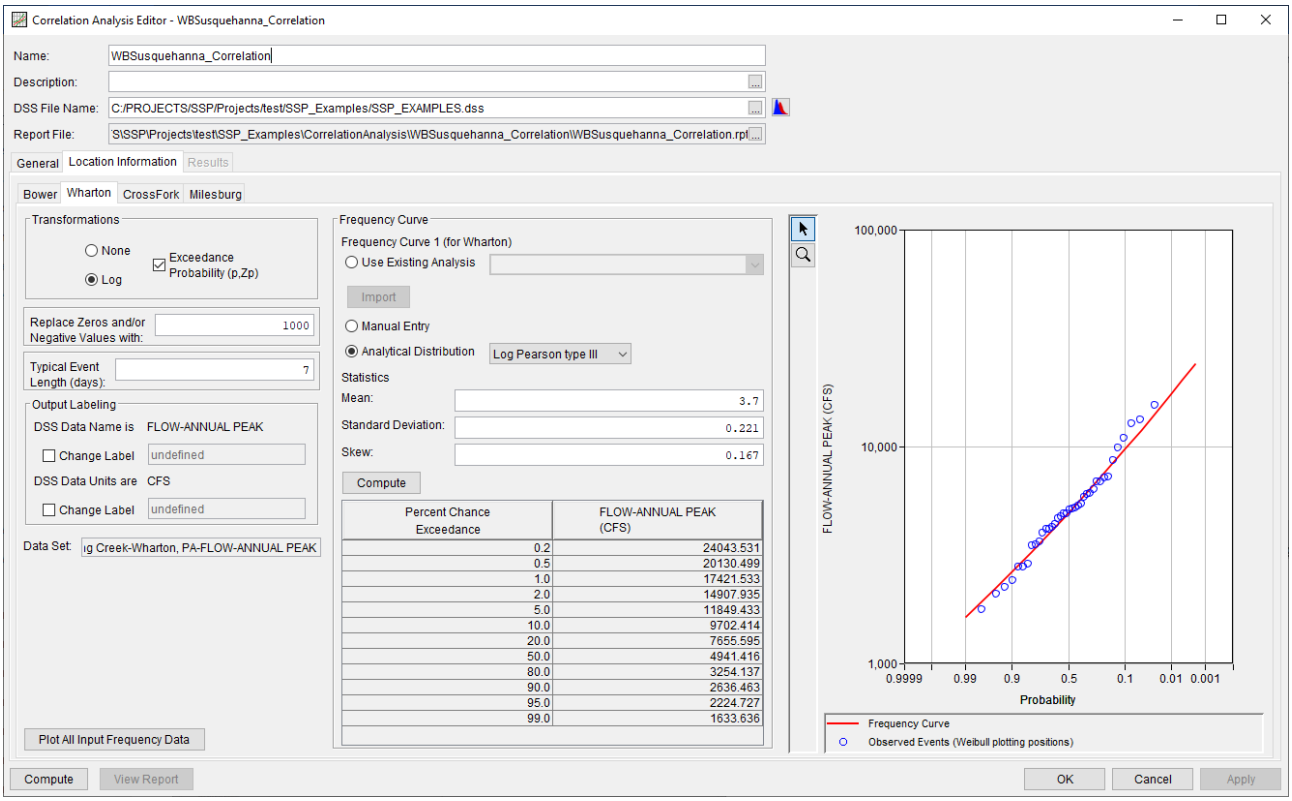
On the **Bower** sub-tab, the *Log* and *Exceedance Probability (p, Zp)* transformations were selected, as shown in Figure 4. 1000 cfs was entered as the replacement value if/when zeroes or negatives were encountered. A typical event length of 7 days was also defined. The default *Output Labeling* was left unchanged. Finally, a frequency curve that was fit to the Bower time series was defined using a *Log Pearson Type III (LPIII)* distribution and the flow-frequency curve was computed.



250 Figure 4. Bower Location Information Tab

14.1.3.2 Wharton

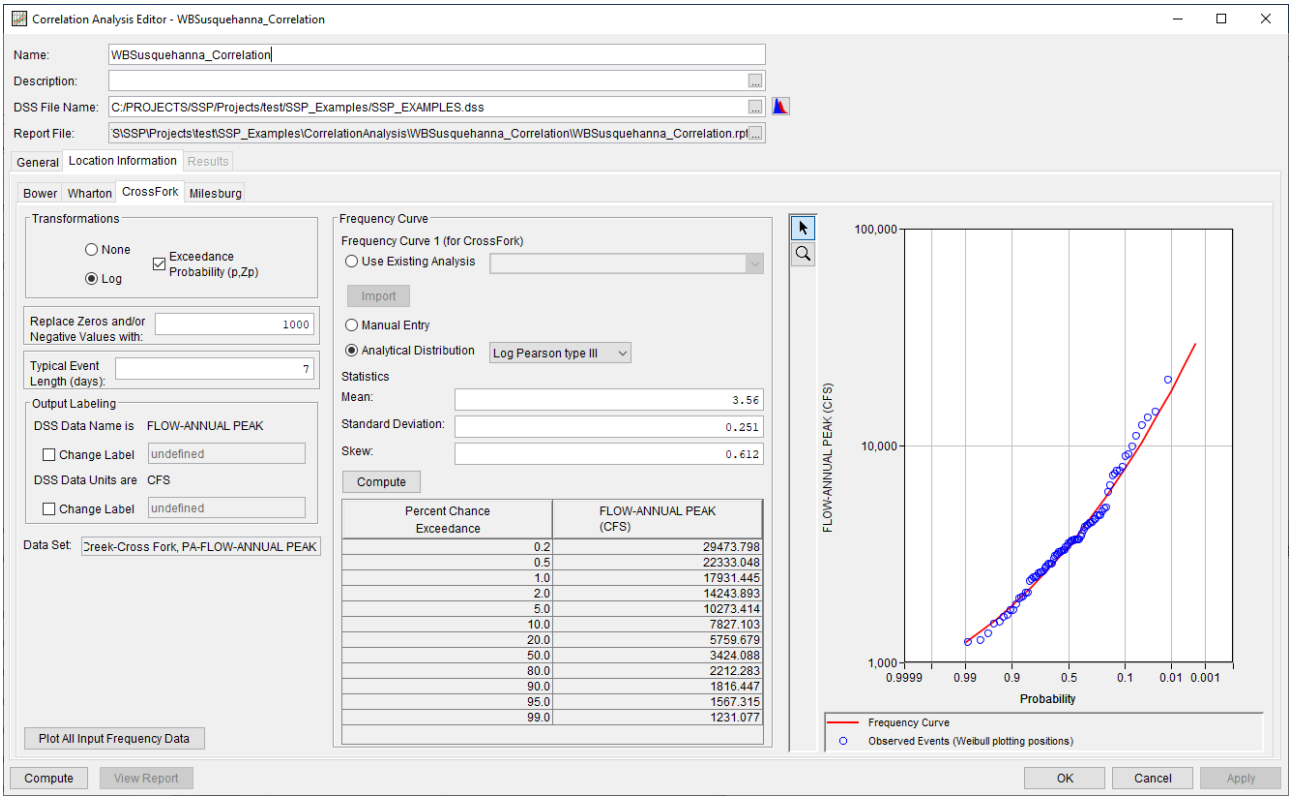
On the **Wharton** sub-tab, the *Log* and *Exceedance Probability (p, Zp)* transformations were selected, as shown in Figure 5. 1000 cfs was entered as the replacement value if/when zeroes or negatives were encountered. A typical event length of 7 days was also defined. The default *Output Labeling* was left unchanged. Finally, a frequency curve that was fit to the Wharton time series was defined using a *Log Pearson Type III (LPIII)* distribution and the flow-frequency curve was computed.



251 Figure 5. Wharton Location Information Tab

14.1.3.3 Cross Fork

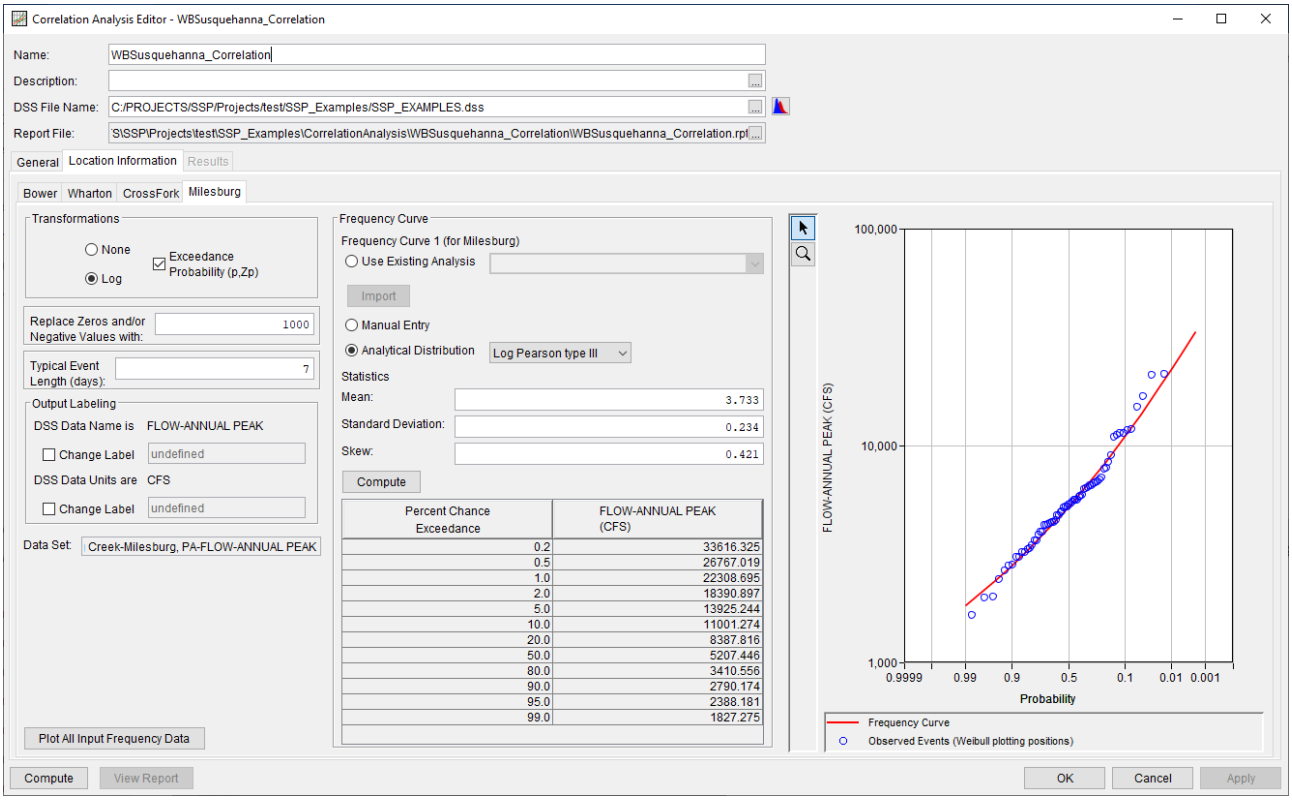
On the **Cross Fork** sub-tab, the *Log* and *Exceedance Probability (p, Zp)* transformations were selected, as shown in Figure 6. 1000 cfs was entered as the replacement value if/when zeroes or negatives were encountered. A typical event length of 7 days was also defined. The default *Output Labeling* was left unchanged. Finally, a frequency curve that was fit to the Cross Fork time series was defined using a *Log Pearson Type III (LPIII)* distribution and the flow-frequency curve was computed.



252 Figure 6. CrossFork Location Information Tab

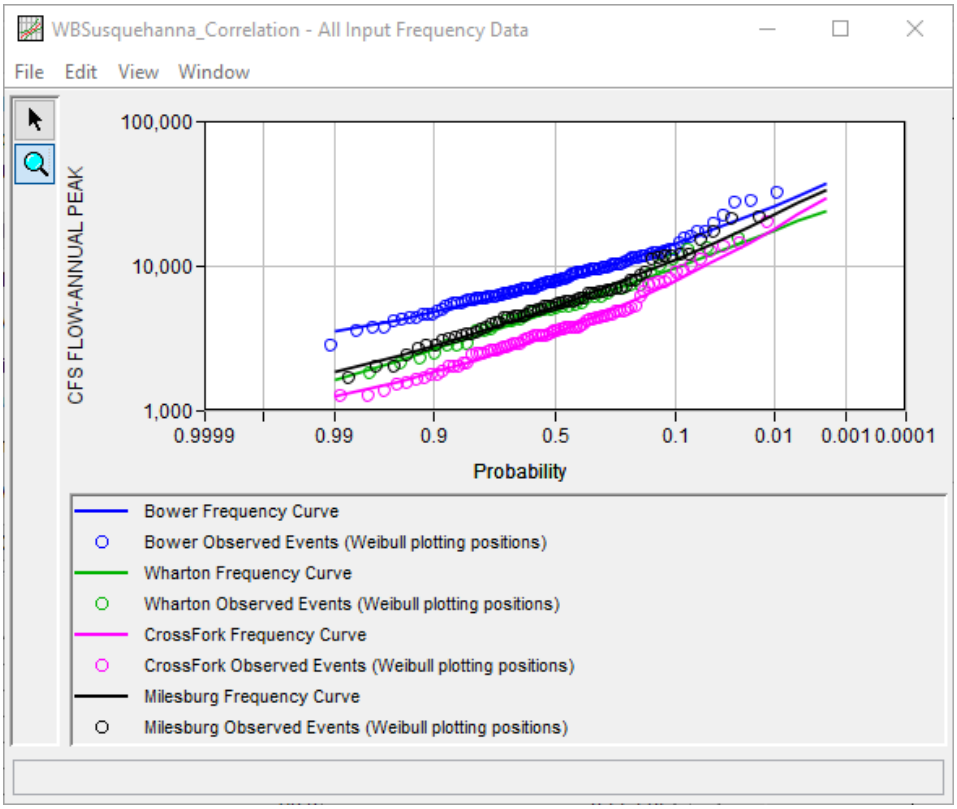
14.1.3.4 Milesburg

On the **Milesburg** sub-tab, the *Log* and *Exceedance Probability (p, Zp)* transformations were selected, as shown in Figure 7. 1000 cfs was entered as the replacement value if/when zeroes or negatives were encountered. A typical event length of 7 days was also defined. The default *Output Labeling* was left unchanged. Finally, a frequency curve that was fit to the Milesburg time series was defined using a *Log Pearson Type III (LPIII)* distribution and the flow-frequency curve was computed.



253 Figure 7. Milesburg Location Information Tab

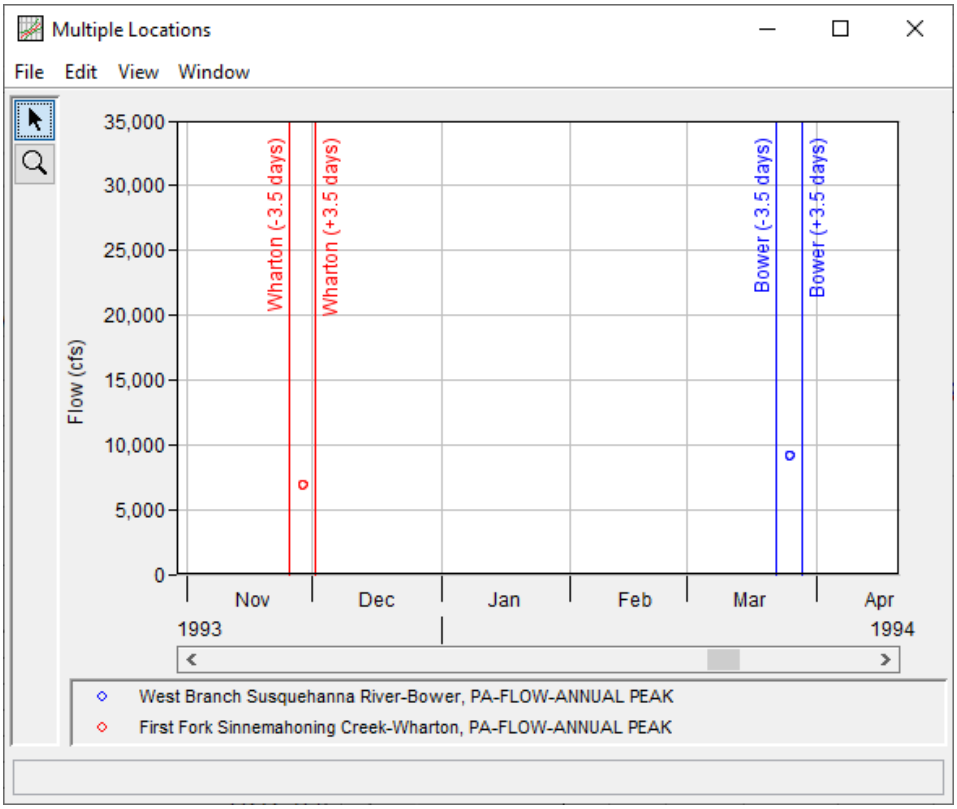
Each of the previously mentioned time series and frequency curves can be plotted by pressing the **Plot All Input Frequency Data** button, as shown in Figure 8.



254 Figure 8. Plot All Input Frequency Data

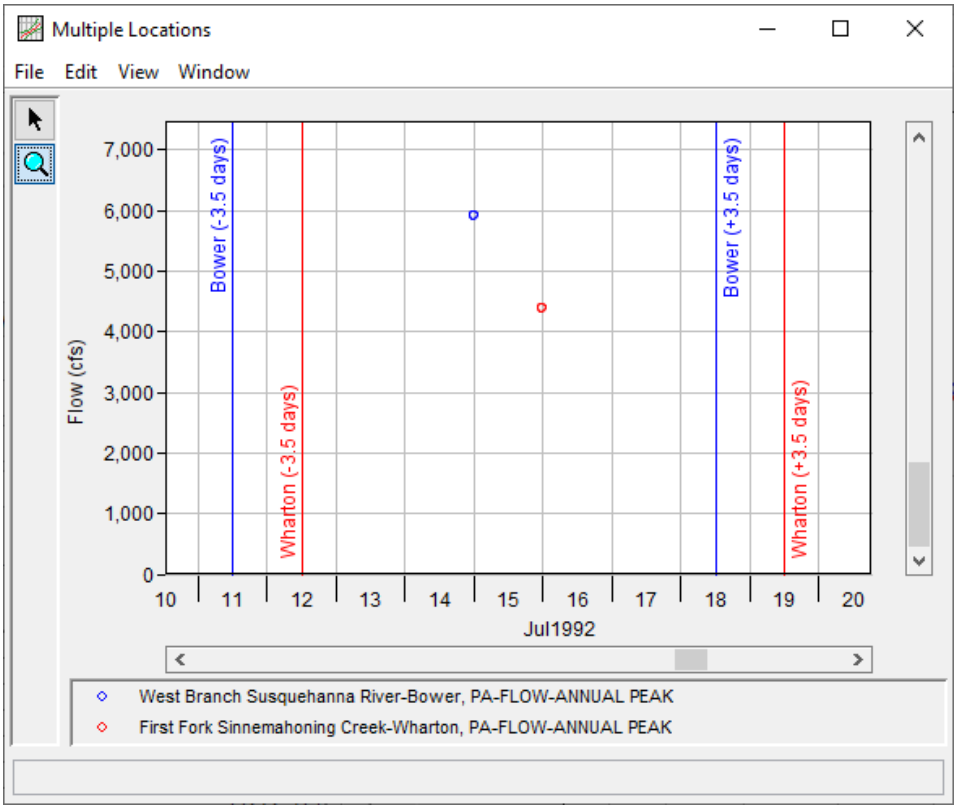
14.1.4 Computing the Analysis

Once all of the **General** and **Location Information** details have been selected and/or defined, the user can press the **Compute** button to perform the analysis. A *Compute Warnings* message will be shown noting that some values for each pair of time series were removed from consideration within the correlation calculations. For instance, when comparing the Bower and Wharton time series, 98 values were removed from consideration. This was partly due to the fact that the Bower time series begins in 1889 while the Wharton time series begins in 1984. However, several values within the Bower time series could not be found within the *Typical Event Length* of 7 days, which was defined on the Location Information sub-tab, when compared against the Wharton time series. This is visualized within Figure 9, these values for the 1994 water year were removed from the analysis since the measurements were not recorded within 7 days of one another.



255 Figure 9. Example of Events That Were Removed from Consideration

Only events like those shown within Figure 10, which both fell within the *Typical Event Length* of 7 days were used within the correlation computations.



256 Figure 9. Example of Events That Were Considered in the Correlation Computations

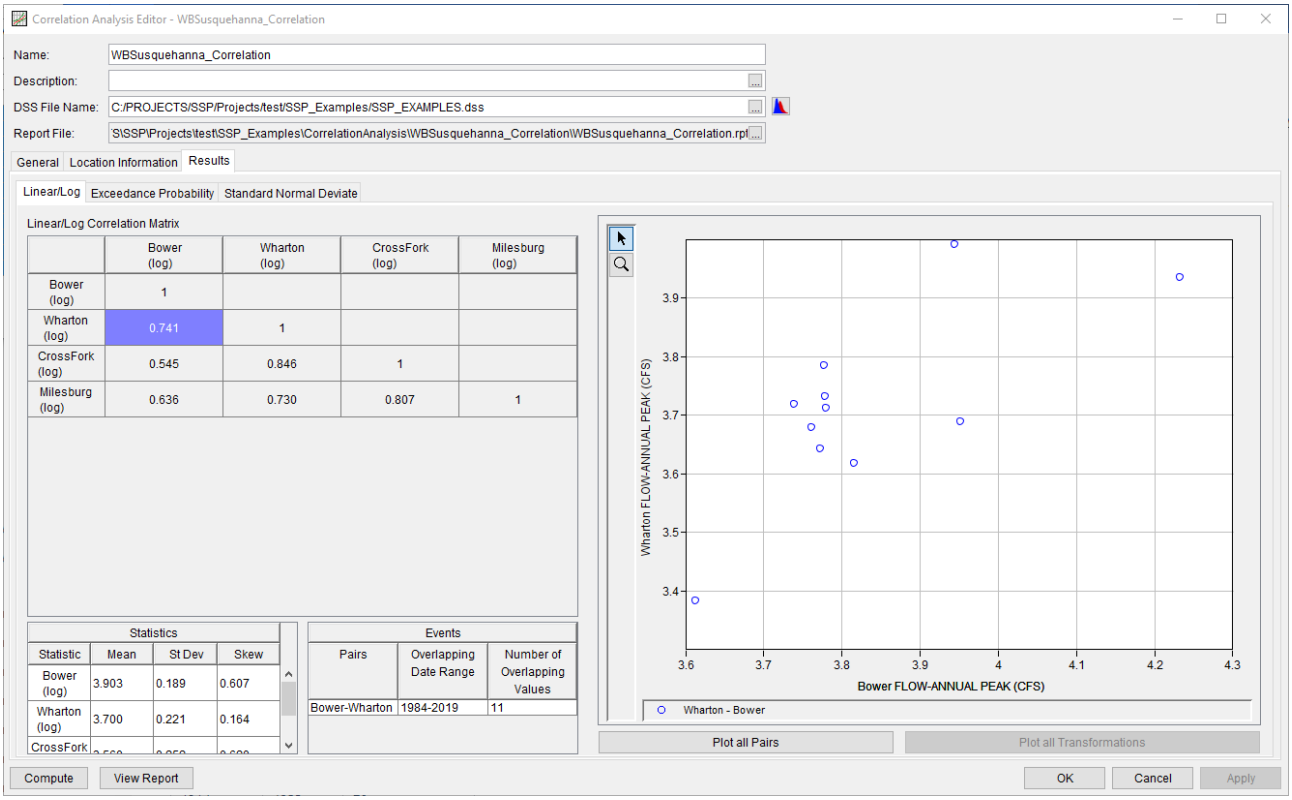
Once the computations have been completed, a message window will open stating **Compute Complete**.

14.1.5 Results Tab

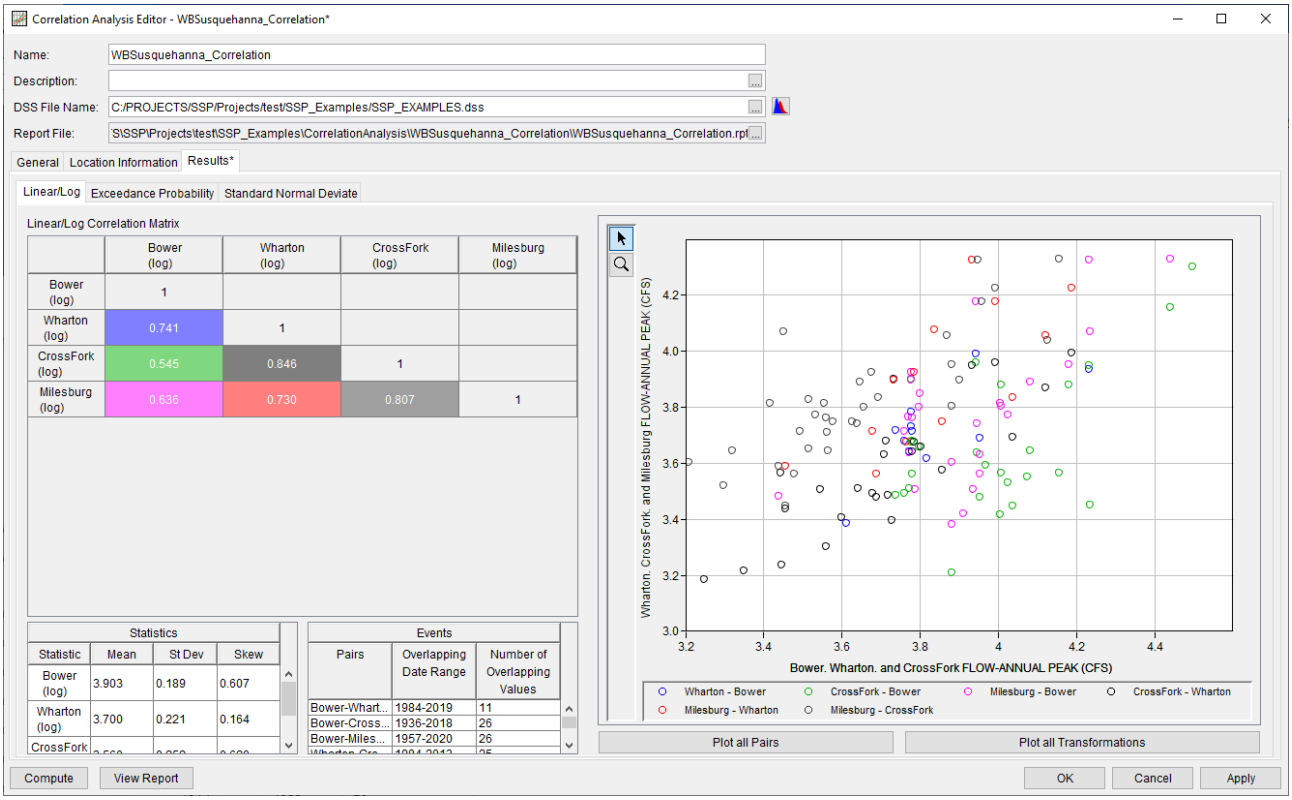
Upon a successful compute, the **Results** tab will become selectable. The Results tab contains three sub-tabs, one for each of the previously defined transformations.
Within each transformation sub-tab, results will be presented consisting of:

- A **Correlation Matrix** of computed correlation coefficients,
- A plot of the selected pair(s),
- A **Statistics** table of the entire time series (all values are considered within these statistics), and
  An **Events** table consisting of the overlapping date range and number of values that were considered
- within the correlation computations for the selected pair(s).

One or more pairs within the correlation matrix can be selected. By default, the upper-left most cell will be selected upon navigating to these sub-tabs for the first time, as shown in Figure 11. However, if more than one cell is selected, additional information will be shown within the plot as well as the Events table, as shown in Figure 12.



257 Figure 11. Linear/Log Tab with One Selected Pair



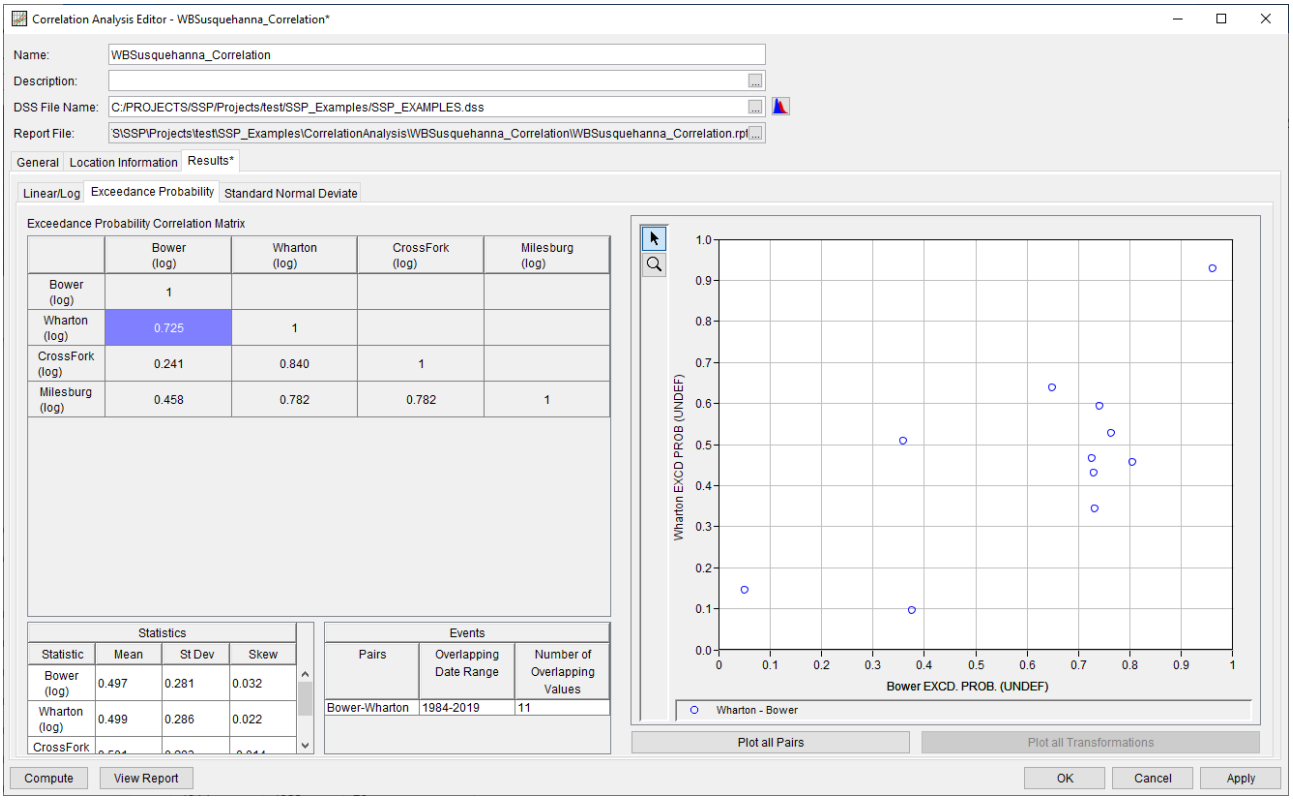
258 Figure 12. Linear/Log Tab with Multiple Selected Pairs

14.1.5.1 Log

The results using the **Linear** or **Log** transformation will be shown on this sub-tab, as shown within Figure 11.

14.1.5.2 Exceedance Probability

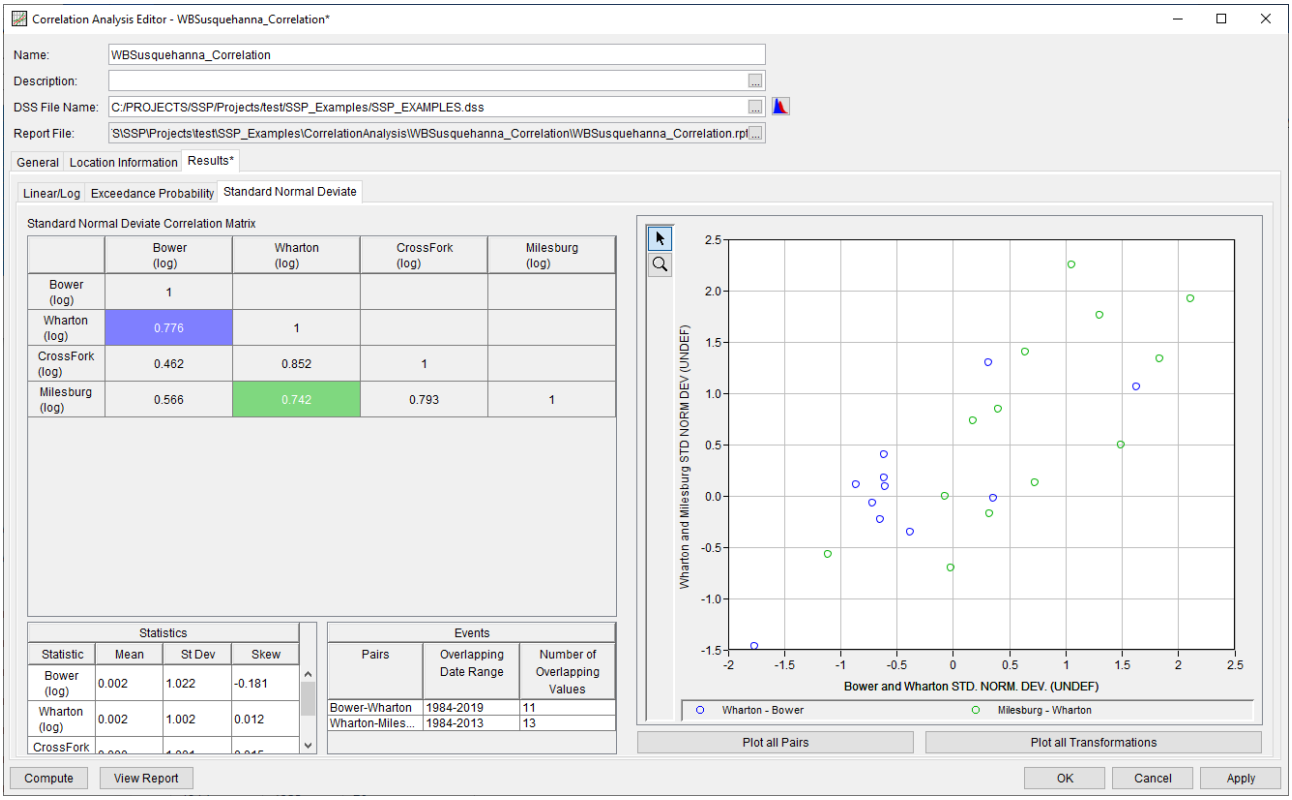
The results using the **Exceedance Probability** transformation will be shown on this sub-tab, as shown within Figure 13.



259 Figure 13. Exceedance Probability Tab

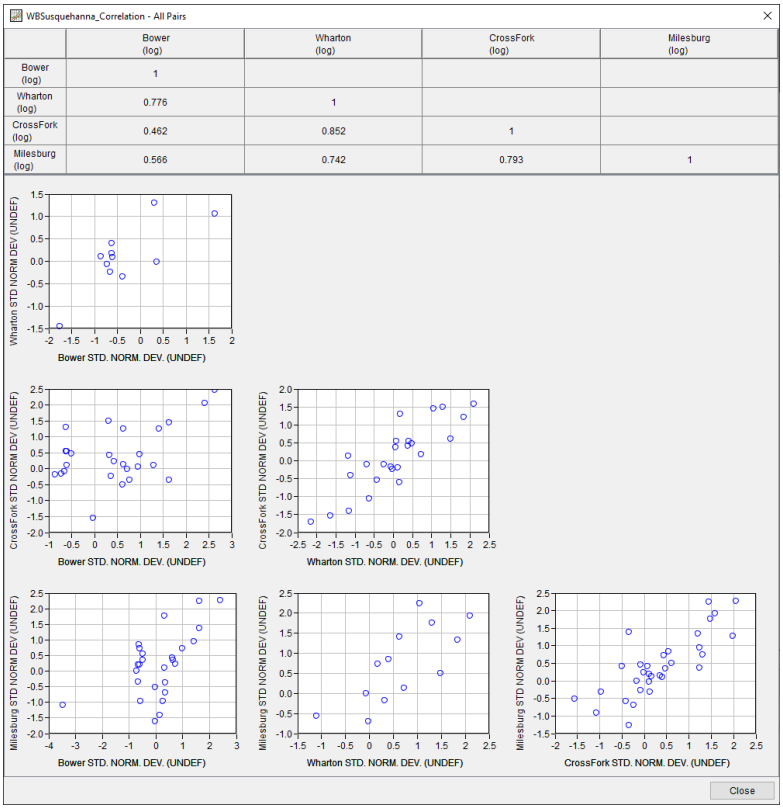
14.1.5.3 Standard Normal Deviate

The results using the **Standard Normal Deviate** transformation will be shown on this sub-tab, as shown within Figure 14.



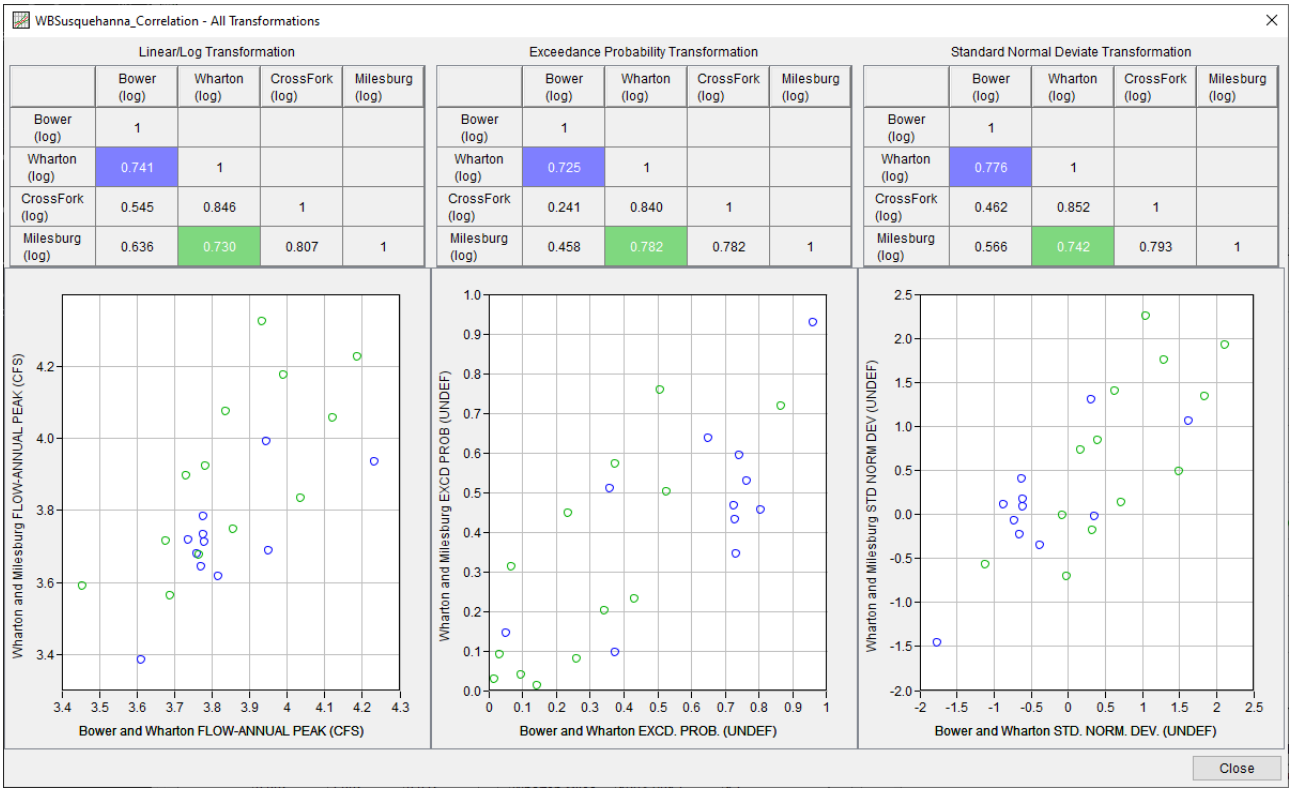
260 Figure 14. Standard Normal Deviate Tab

In addition to the tables and plots on each sub-tab, two buttons are available to create summary plots for all data and transformations: **Plot all Pairs** and **Plot all Transformations**. When the **Plot all Pairs** is clicked, a figure is created that shows the correlation matrix at the top with multiple plots below, one for every pair of time series, as shown in Figure 15. The results for this plot will be shown for the currently-selected tab.



261 Figure 15. All Pairs Plot for Standard Normal Deviate Tab

When the **Plot all Transformations** button is pressed,
a figure will be created that has the correlation matrix and one plot containing the data pairs for all the currently selected cells in the correlation matrix for every selected transform. For example, when the Bower-Wharton and Milesburg-Wharton pairs are selected for this study, the Plot all Transformations button will generate a plot that resembles Figure 16.



262 Figure 16. All Transformations Plot for Two Selected Pairs

The **Plot all Transformations** button will only be active when the **Exceedance Probability** transform has been selected for at least 2 time series on the **Location Information** tab and a compute has been successfully completed.

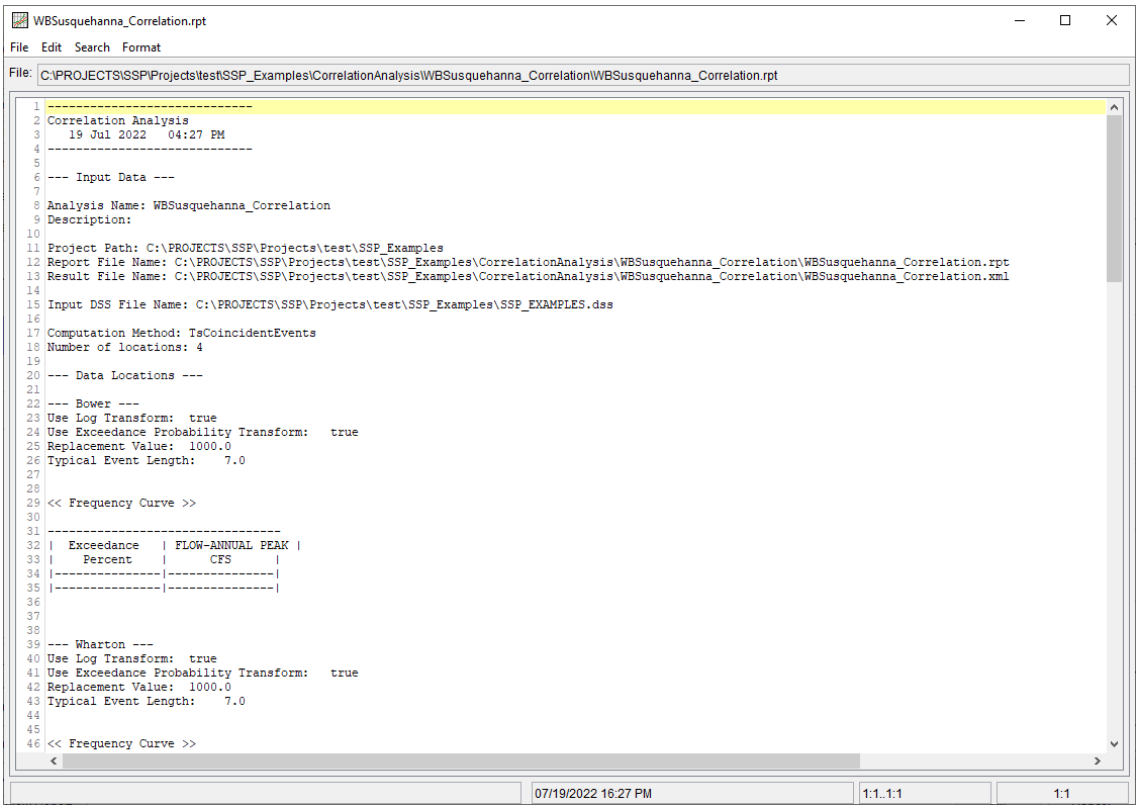
The correlation coefficients computed for this example are very strong. Per EM 1110-2-1415[57], datasets are often considered well correlated when the absolute value of the correlation coefficient is greater than 0.4. Also, Bulletin 17C[58] recommends the usage of data with high cross correlation when performing record extension, an example of which can be found here[59].

57 https://www.publications.usace.army.mil/LinkClick.aspx?fileticket=rKeAcMVfr2g%3d&tabid=16439&portalid=76&mid=43544
58 https://pubs.usgs.gov/tm/04/b05/tm4b5.pdf
59 https://www.hec.usace.army.mil/confluence/display/SSPTutorialsGuides/Annual+Peak+Flow+Record+Extension

14.1.6 Report File

In addition to the tabular and graphical results, there is a report file that echoes the input data, selected computational options, and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 17.

> Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



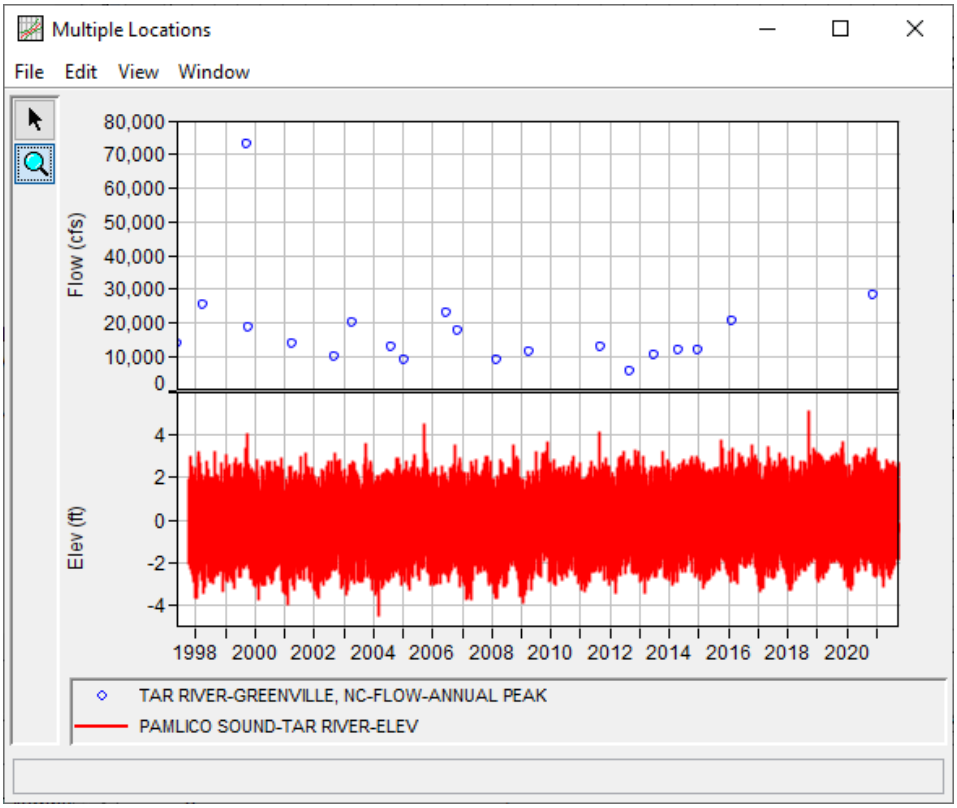
263 Figure 17. Report File

14.2 Coincident in Time - Tar River

The ***TarRiver_Correlation*** example demonstrates the usage of the Correlation Analysis to determine how closely related annual maximum peak discharge within a river is with tidal stages within a receiving body of water.

14.2.1 Input Data

The primary time series is from the Tar River at Greenville, NC[60] stream gage. The secondary time series represents hourly stage within the Pamlico Sound. The actual data for this time series was taken from the Beaufort, Duke Marine Lab, NC[61] tide buoy. The time series are plotted within Figure 1.

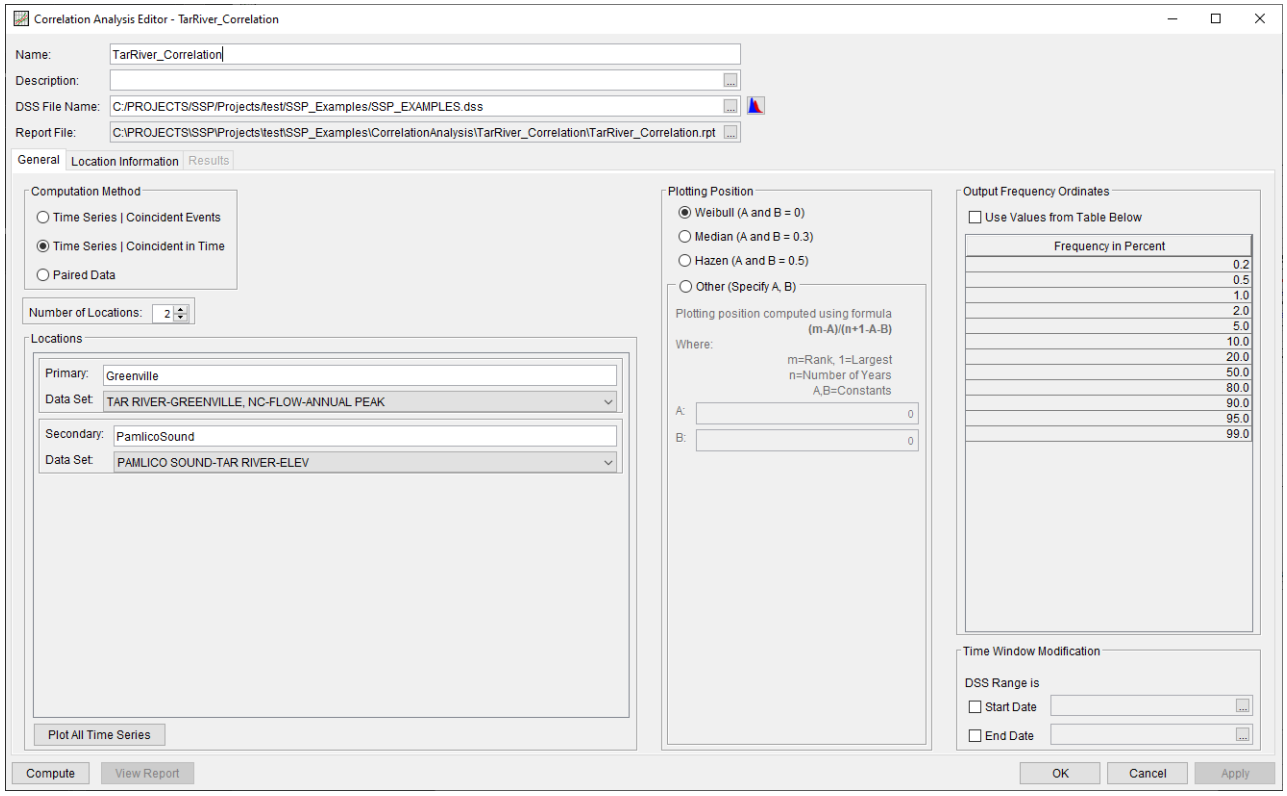


264 Figure 1. Input Time Series for TarRiver_Correlation Example

General Tab

A Correlation Analysis has been developed for this example. To open the analysis, either double-click on the analysis labeled **TarRiver_Correlation** from the study explorer or from the **Analysis** menu select open, then select **TarRiver_Correlation** from the list of available analyses. When **TarRiver_Correlation** is opened, the **General** tab within the Correlation Analysis editor will appear as shown in Figure 2. For this analysis, the *Time Series | Coincident in Time* computational method was selected and two locations were defined. The default *Plotting Position* formula (*Weibull*) and *Output Frequency Ordinates* were left unchanged. No modifications were made to the time window.

60 https://waterdata.usgs.gov/nc/nwis/uv?site_no=02084000
61 https://tidesandcurrents.noaa.gov/stationhome.html?id=8656483



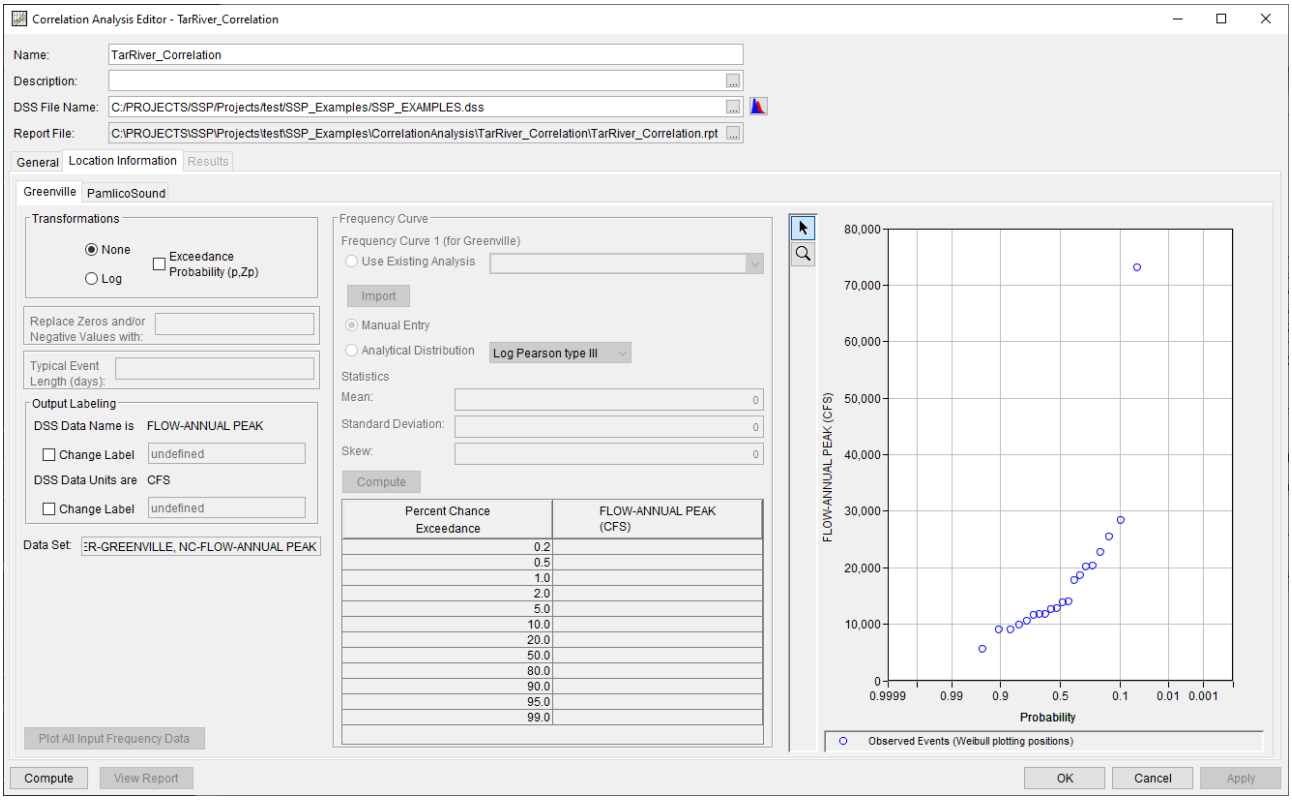
265 Figure 2. General Tab

14.2.2 Location Information Tab

The **Location Information** tab contains two sub-tabs, one for each of the previously defined locations.

14.2.2.1 Greenville

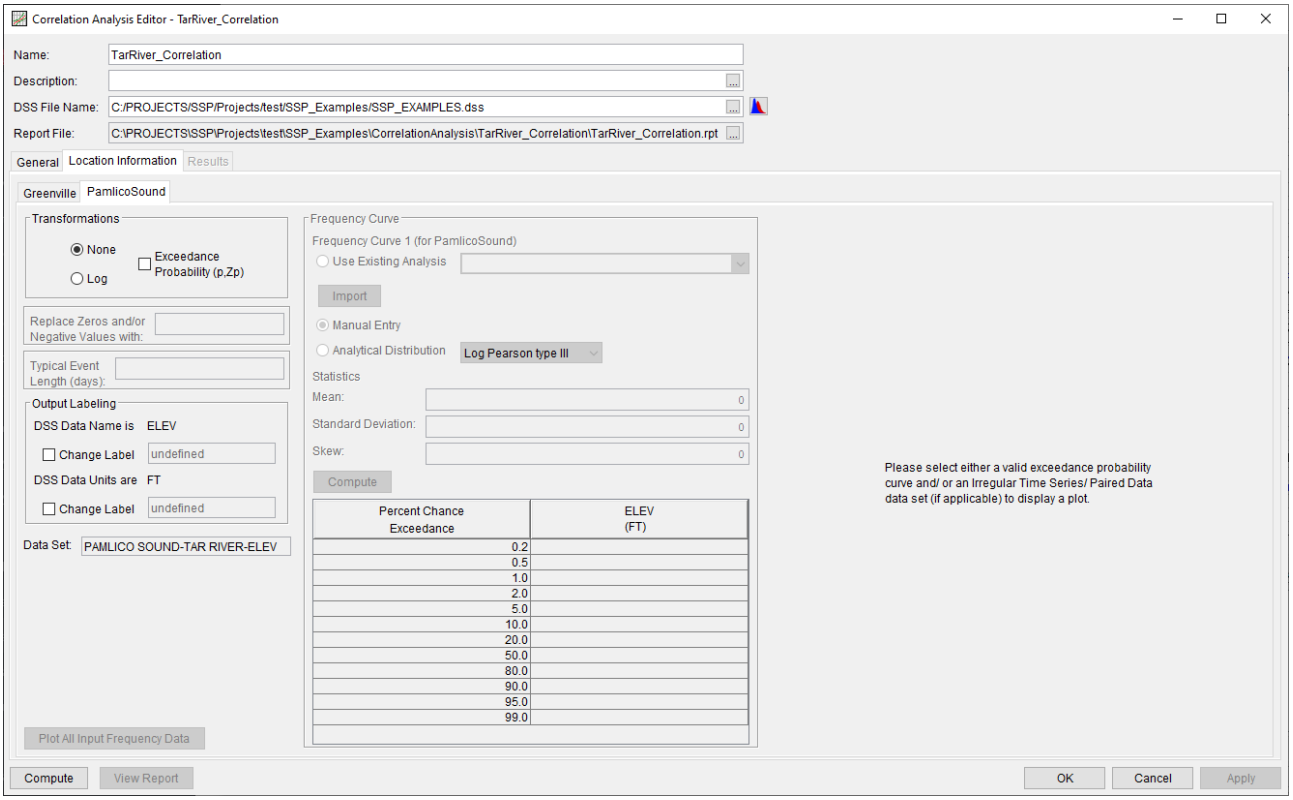
On the **Greenville** sub-tab, the *None* transformation was selected, as shown in Figure 3. All other default settings were retained.



266 Figure 3. Greenville Location Information Tab

14.2.2.2 Pamlico Sound

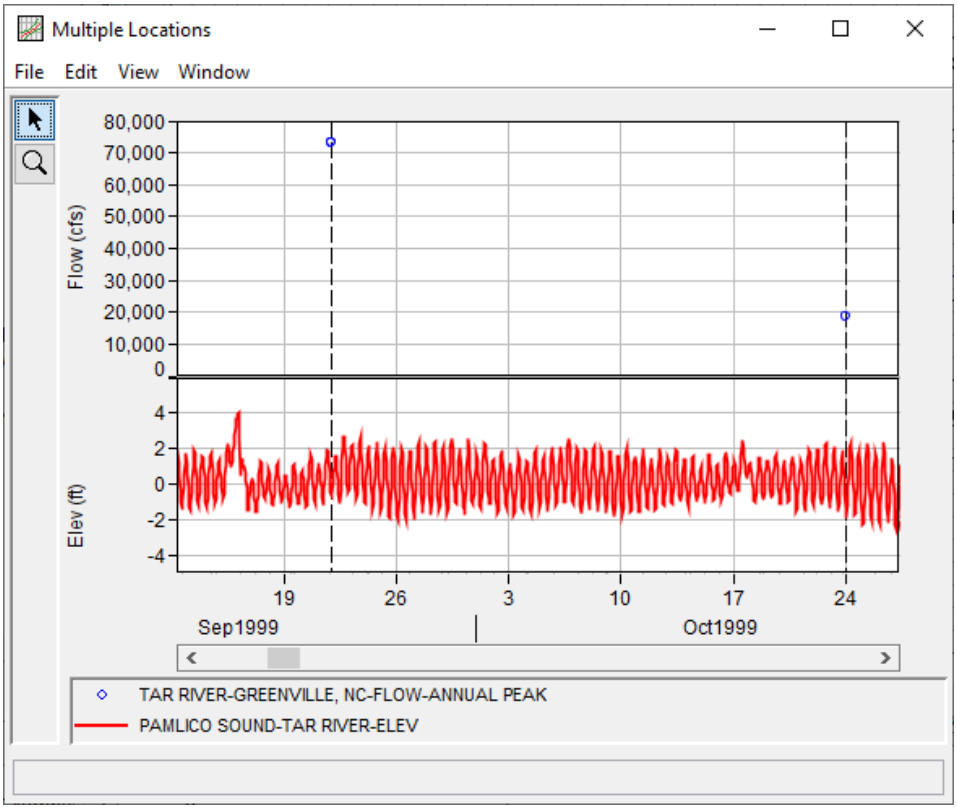
On the **PamlicoSound** sub-tab, the *None* transformation was selected, as shown in Figure 4. All other default settings were retained.



267 Figure 4. PamlicoSound Location Information Tab

14.2.3 Computing the Analysis

Once all of the **General** and **Location Information** details have been selected and/or defined, the user can press the **Compute** button to perform the analysis. A *Compute Warnings* message will be shown noting that one value within the only Primary-Secondary pair was removed from consideration within the correlation calculations. This was solely due to the fact that the Greenville time series begins one year prior to the start of the PamlicoSound time series. Values from the Secondary time series (i.e. PamlicoSound) were extracted at the same time as each of the values within the Primary time series (i.e. Greenville), as shown within Figure 5. These values were then carried forward within the correlation computations.



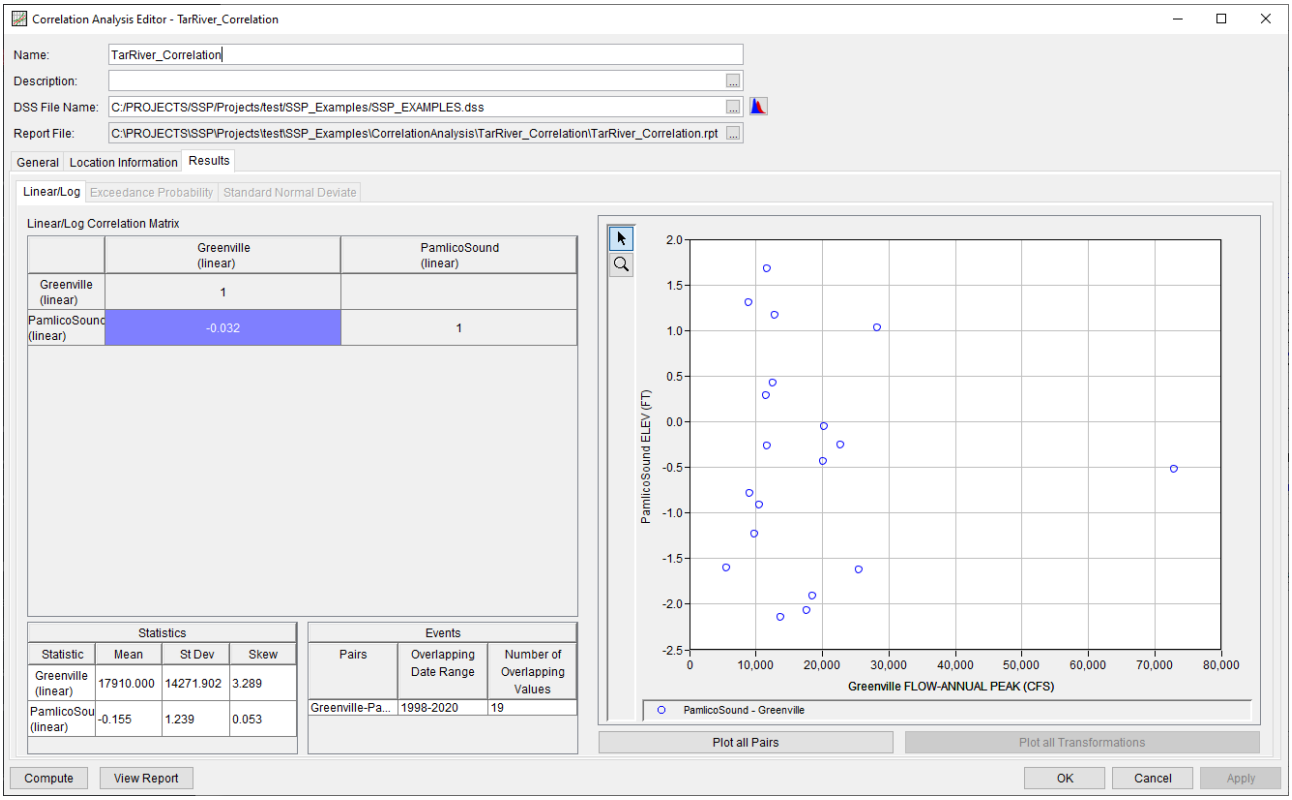
268 Figure 5. Example of Events That Were Considered in the Correlation Computations

Once the computations have been completed, a message window will open stating **Compute Complete**.

14.2.4 Results Tab

Upon a successful compute, the **Results** tab will become selectable. The Results tab contains a single sub-tab since the *None* transformation was previously selected for all locations, as shown in Figure 6.
Within this sub-tab, results are presented consisting of:

- A **Correlation Matrix** of computed correlation coefficients,
- A plot of the selected pair,
- A **Statistics** table of the entire time series (all values are considered within these statistics), and
  An **Events** table consisting of the overlapping date range and number of values that were considered
- within the correlation computations for the selected pair.



269 Figure 6. Results Tab



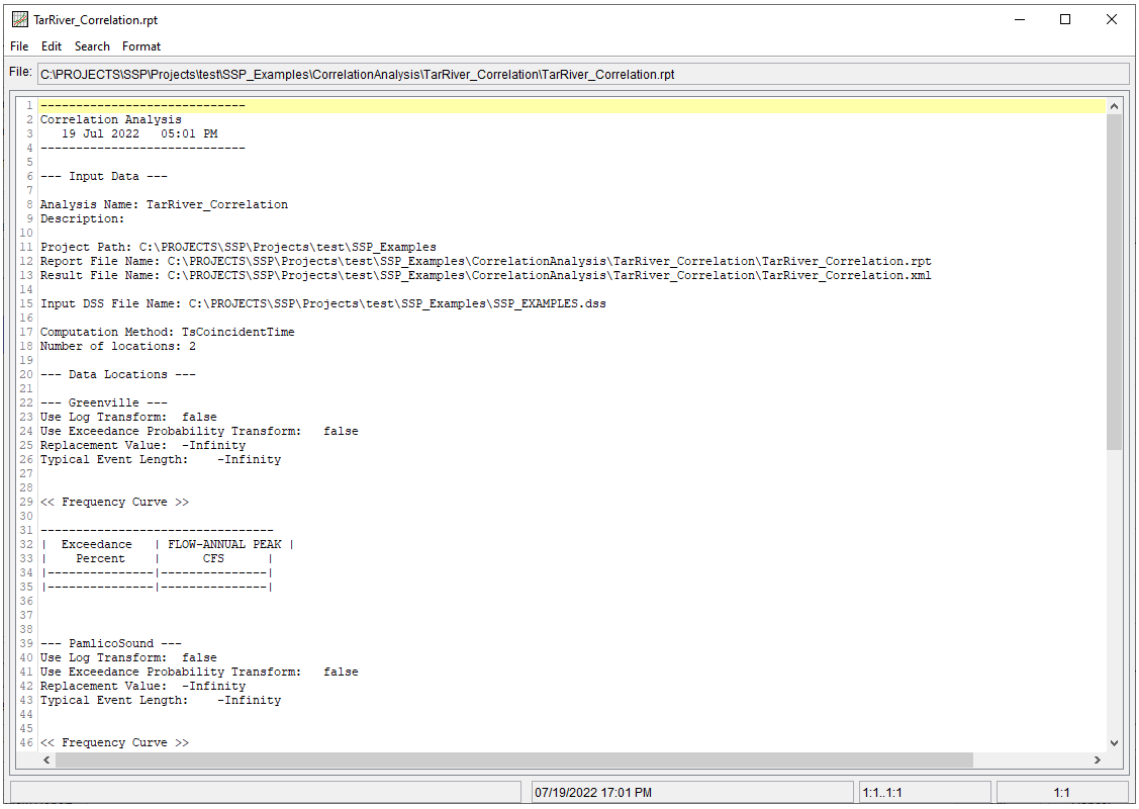
The correlation coefficient computed for this example is very weak. Per EM 1110-2-1413[62], datasets are often considered effectively independent when the absolute value of the correlation coefficient is less than 0.4. In this case, it appears the annual maximum peak discharge for the Tar River at Greenville, NC has no relationship to the water level within the Pamlico Sound. This makes physical sense since the Pamlico Sound is a much larger body of water, compared to the Tar River, that can drain/fill through many connections to the Atlantic Ocean. This is very valuable information for a flood risk management study, as the assumption of independence greatly simplifies a coincident frequency analysis that is likely the next step in the project.

14.2.5 Report File

In addition to the tabular and graphical results, there is a report file that echoes the input data, selected computational options, and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 7.

62 https://www.publications.usace.army.mil/Portals/76/Users/227/19/2019/EM_1110-2-1413.pdf?ver=2018-09-13-125346-687

Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



270 Figure 7. Report File

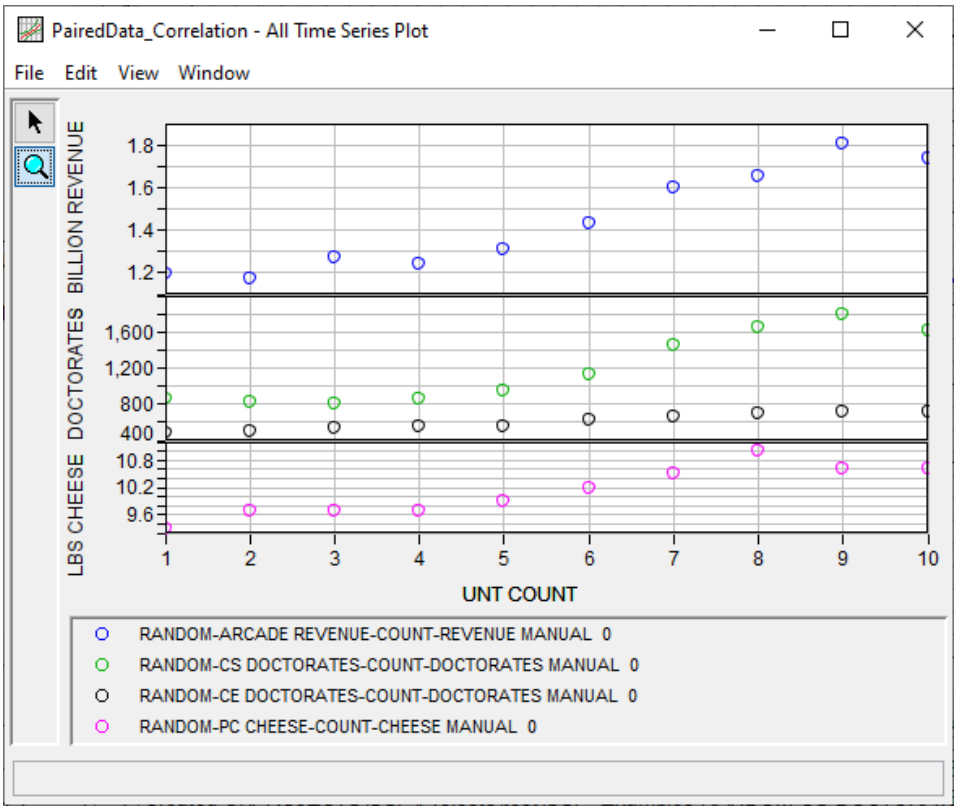
14.3 Paired Data

The ***PairedData_Correlation*** example demonstrates the usage of the Correlation Analysis to determine how closely related the values within paired data curves (i.e. curves with no date/time axis) are with one another.

14.3.1 Input Data

The paired data used within this example were made available by the Census Bureau[63] and National Science Foundation[64]. The four paired data curves represent arcade revenue ($ billion), Computer Science doctorates awarded, per capita cheese consumption, and Civil Engineering doctorates awarded (all within the U.S.). The paired data are plotted within Figure 1 and tabulated within Table 1.

63 https://www.census.gov/library/publications/2011/compendia/statab/131ed.html
64 https://www.nsf.gov/statistics/infbrief/nsf11305/



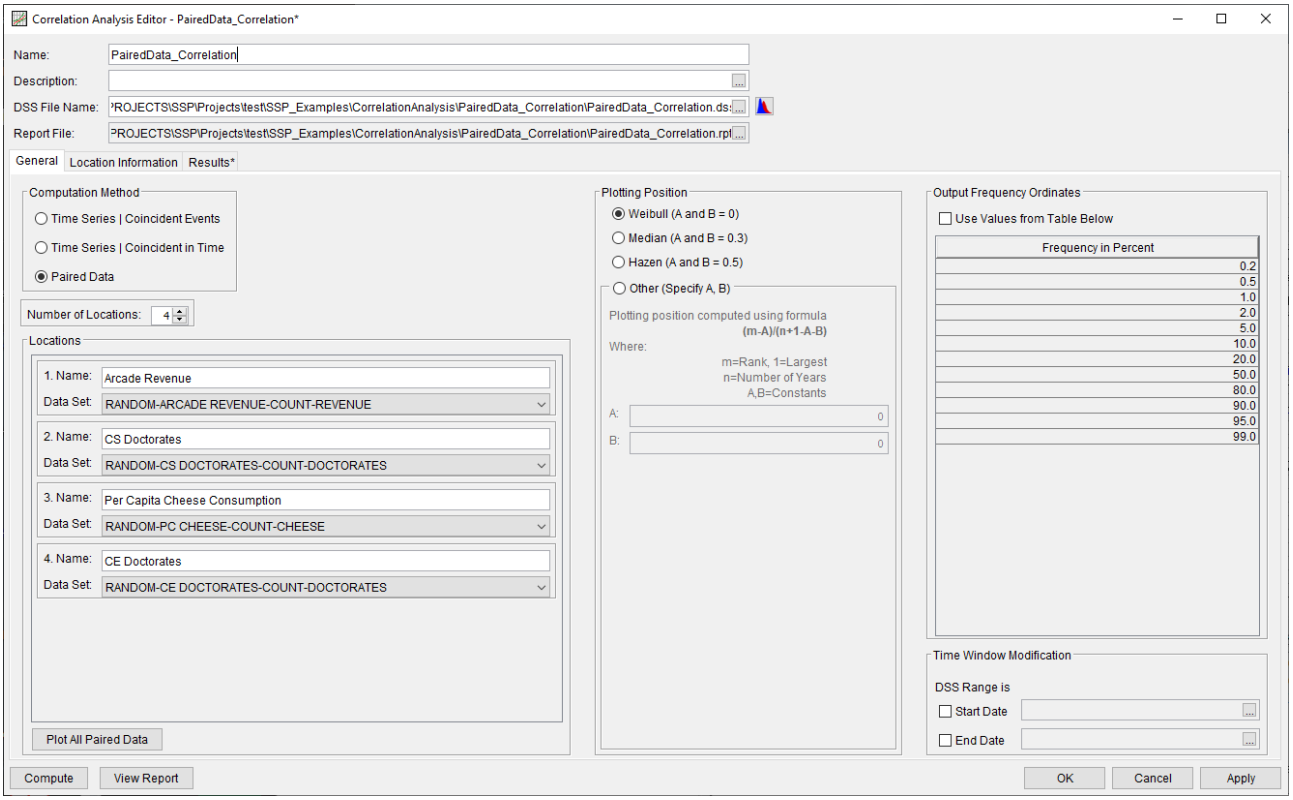
271 Figure 1. Input Time Series for PairedData_Correlation Example

Count	Arcade Revenue ($ billion)	Computer Science Doctorates Awarded	Per Capita Consumption of Mozzarella Cheese (lbs)	Civil Engineering Doctorates Awarded
1	1.196	861	9.3	480
2	1.176	830	9.7	501
3	1.269	809	9.7	540
4	1.24	867	9.7	552
5	1.307	948	9.9	547
6	1.435	1129	10.2	622

Count	Arcade Revenue ($ billion)	Computer Science Doctorates Awarded	Per Capita Consumption of Mozzarella Cheese (lbs)	Civil Engineering Doctorates Awarded
7	1.601	1453	10.5	655
8	1.654	1656	11	701
9	1.803	1787	10.6	712
10	1.734	1611	10.6	708

14.3.2 General Tab

A Correlation Analysis has been developed for this example. To open the analysis, either double-click on the analysis labeled **PairedData_Correlation** from the study explorer or from the **Analysis** menu select open, then select **PairedData_Correlation** from the list of available analyses. When **PairedData_Correlation** is opened, the **General** tab within the Correlation Analysis editor will appear as shown in Figure 2. For this analysis, the *Paired Data* computational method was selected and four locations were defined. The default *Plotting Position* formula (*Weibull*) and *Output Frequency Ordinates* were left unchanged. No modifications were made to the time window.



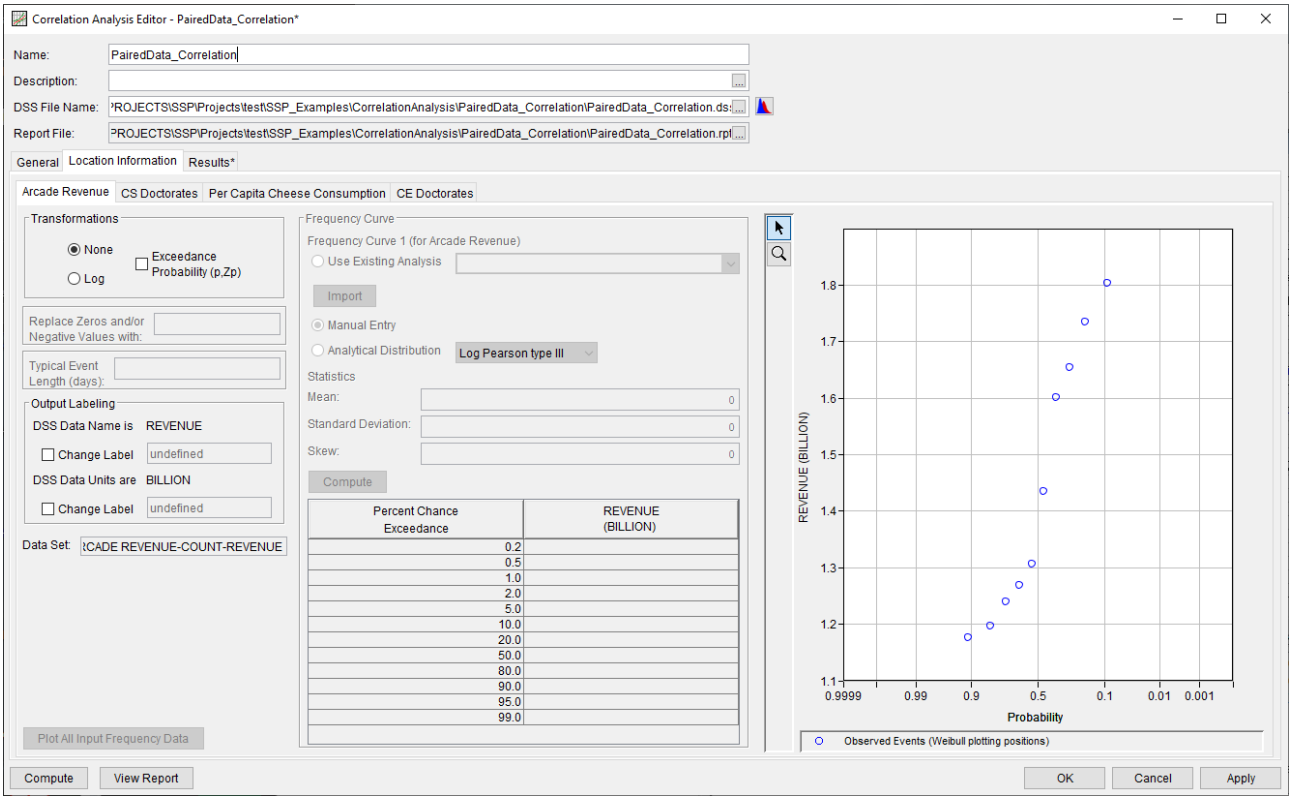
272 Figure 2. General Tab

14.3.3 Location Information Tab

The **Location Information** tab contains four sub-tabs, one for each of the previously defined locations.

14.3.3.1 Arcade Revenue

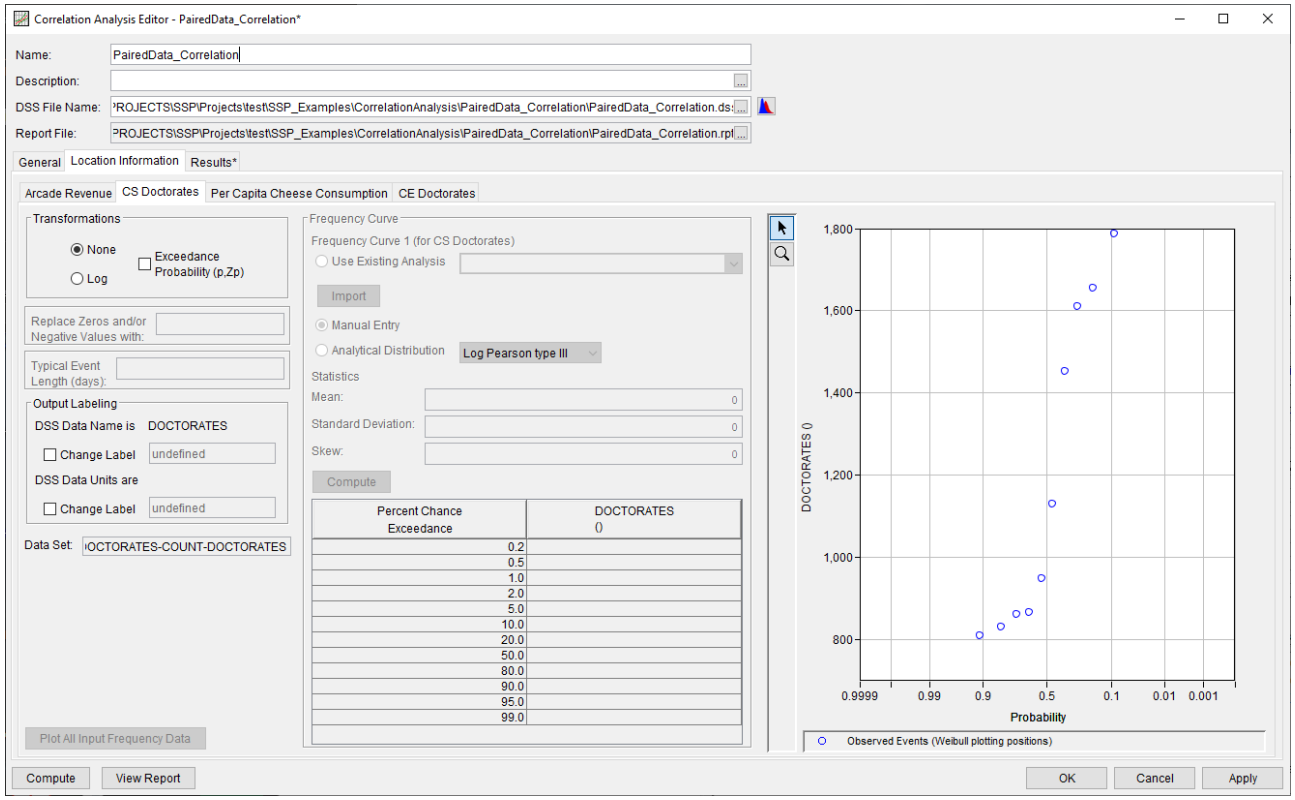
On the **Arcade Revenue** sub-tab, the *None* transformation was selected, as shown in Figure 3. All other default settings were retained.



273 Figure 3. Arcade Revenue Location Information Tab

14.3.3.2 CS Doctorates

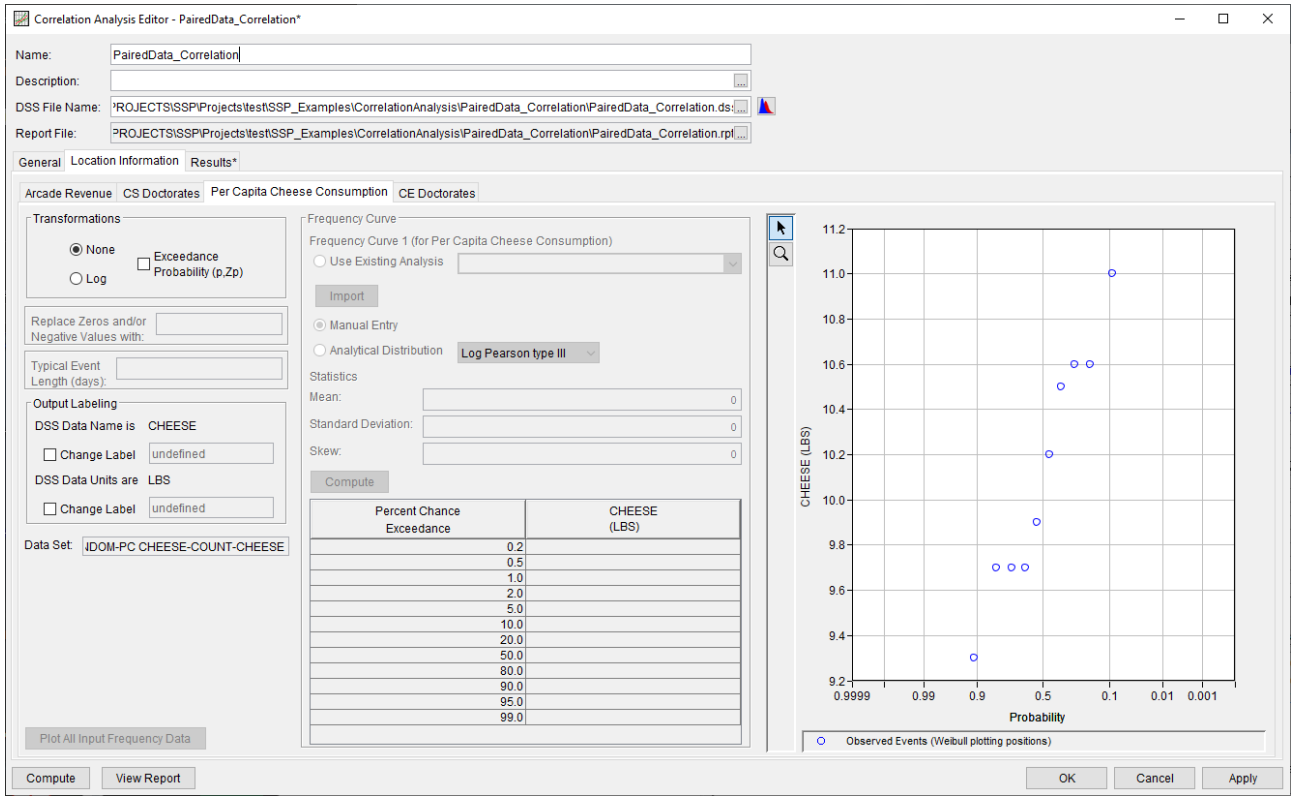
On the **CS Doctorates** sub-tab, the *None* transformation was selected, as shown in Figure 4. All other default settings were retained.



274 Figure 4. CS Doctorates Location Information Tab

14.3.3.3 Per Capita Cheese Consumption

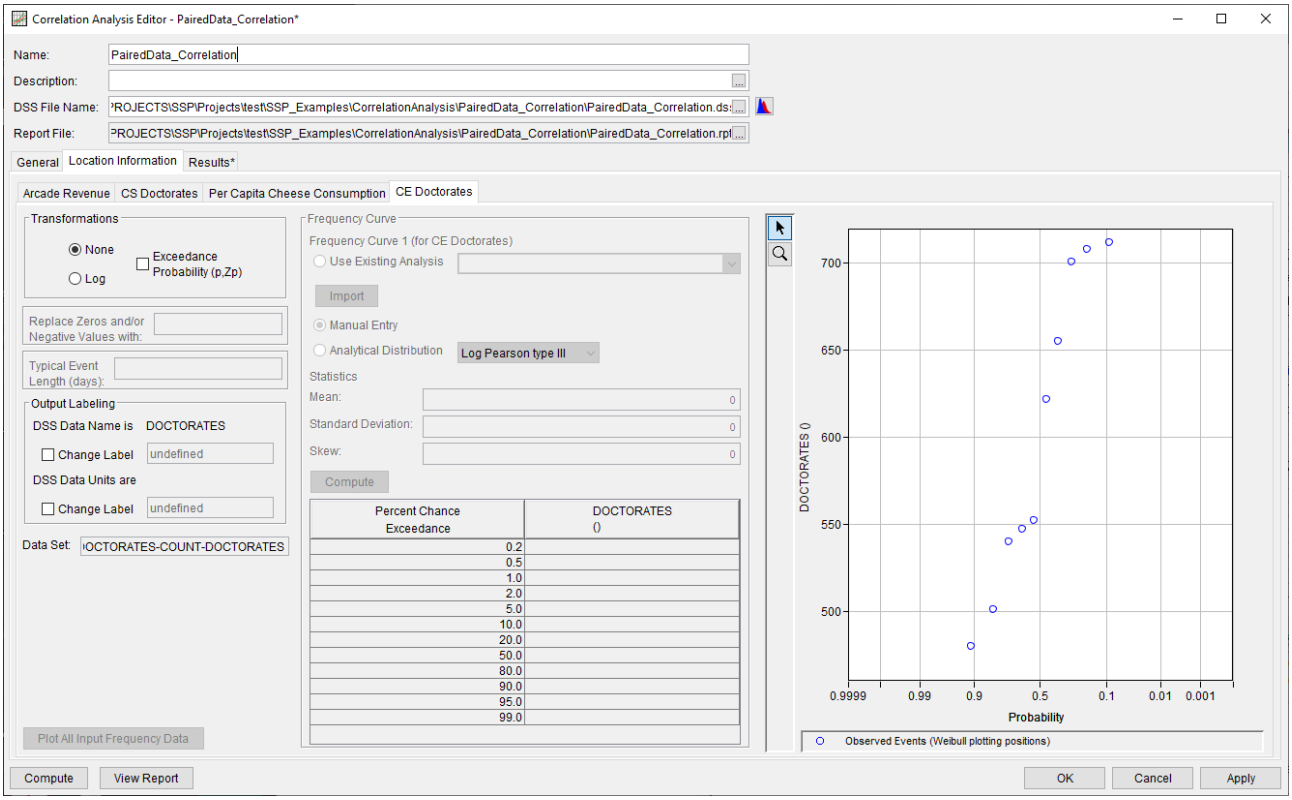
On the **Per Capita Cheese Consumption** sub-tab, the *None* transformation was selected, as shown in Figure 5. All other default settings were retained.



275 Figure 5. Per Capita Cheese Consumption Location Information Tab

14.3.3.4 CE Doctorates

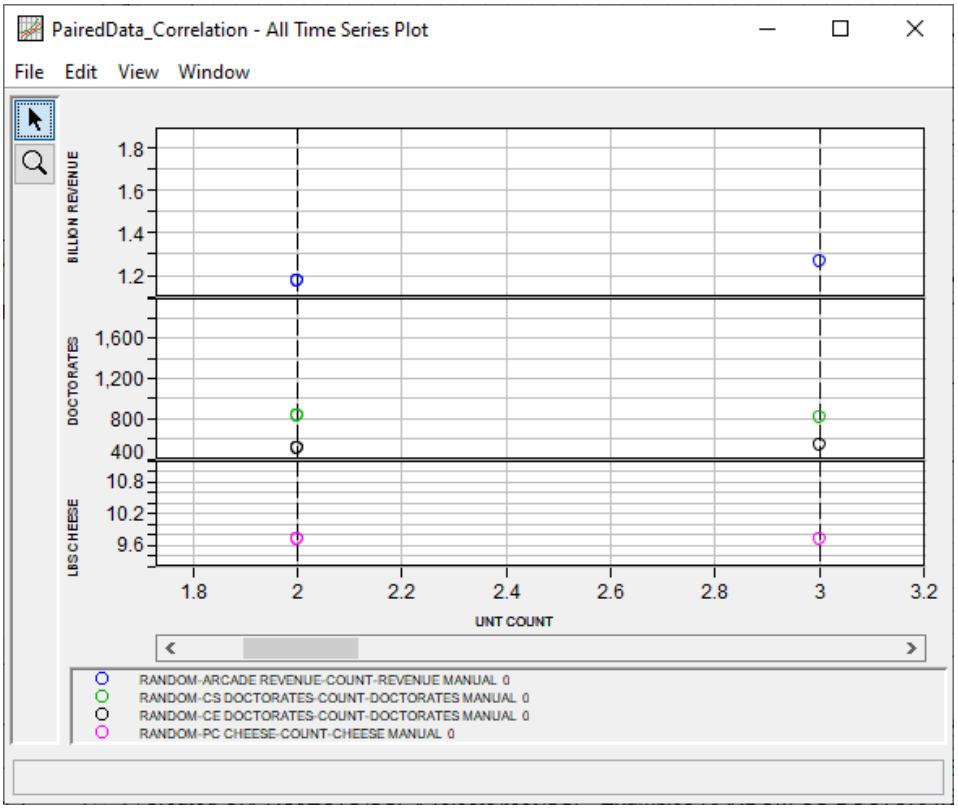
On the **CE Doctorates** sub-tab, the *None* transformation was selected, as shown in Figure 6. All other default settings were retained.



276 Figure 6. CE Doctorates Location Information Tab

14.3.4 Computing the Analysis

Once all of the **General** and **Location Information** details have been selected and/or defined, the user can press the **Compute** button to perform the analysis. Values from each paired data curve are compared against each other "1 for 1", as shown within Figure 7. These values were then carried forward within the correlation computations.



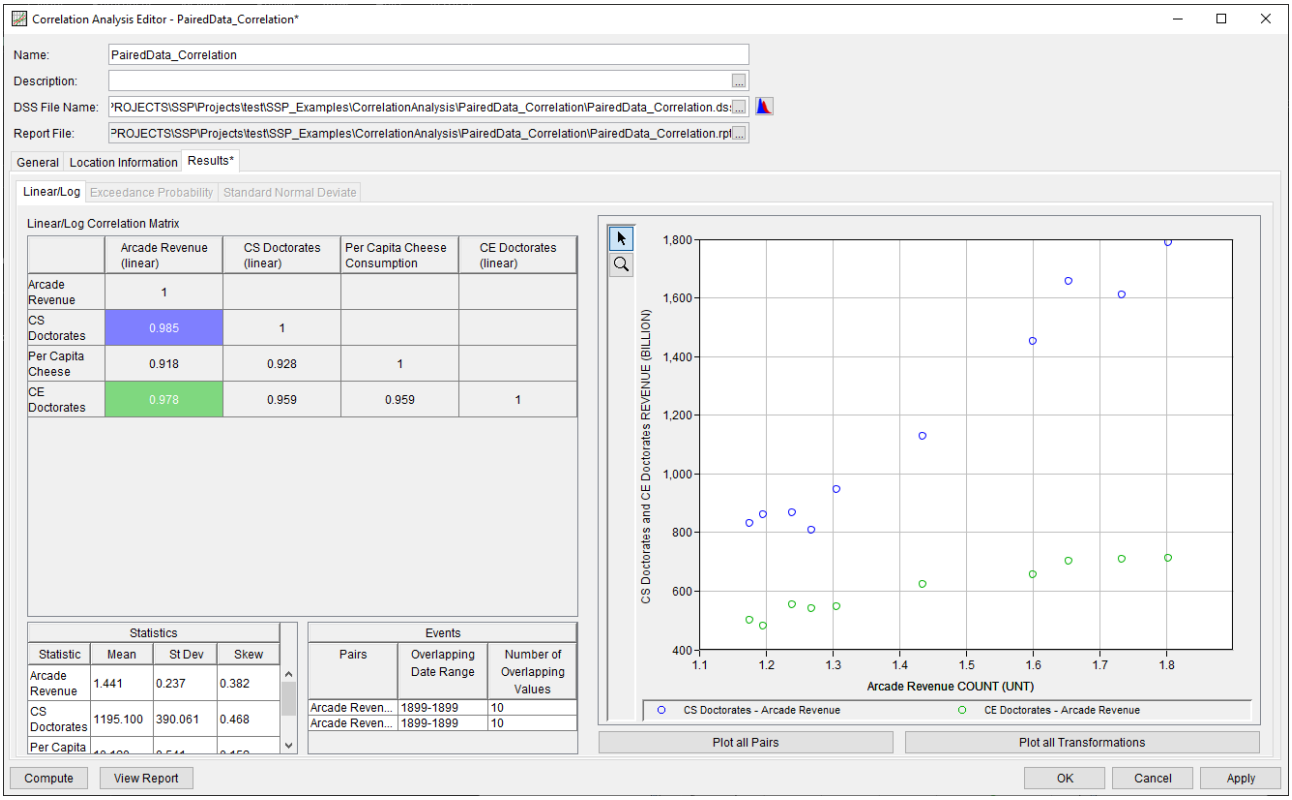
277 Figure 7. Values That Were Considered in the Correlation Computations

Once the computations have been completed, a message window will open stating **Compute Complete**.

14.3.5 Results Tab

Upon a successful compute, the **Results** tab will become selectable. The Results tab contains a single sub-tab since the *None* transformation was previously selected for all locations, as shown in Figure 8.
Within this sub-tab, results are presented consisting of:

- A **Correlation Matrix** of computed correlation coefficients,
- A plot of the selected pair,
- A **Statistics** table of the entire time series (all values are considered within these statistics), and
  An **Events** table consisting of the overlapping date range and number of values that were considered
- within the correlation computations for the selected pair.



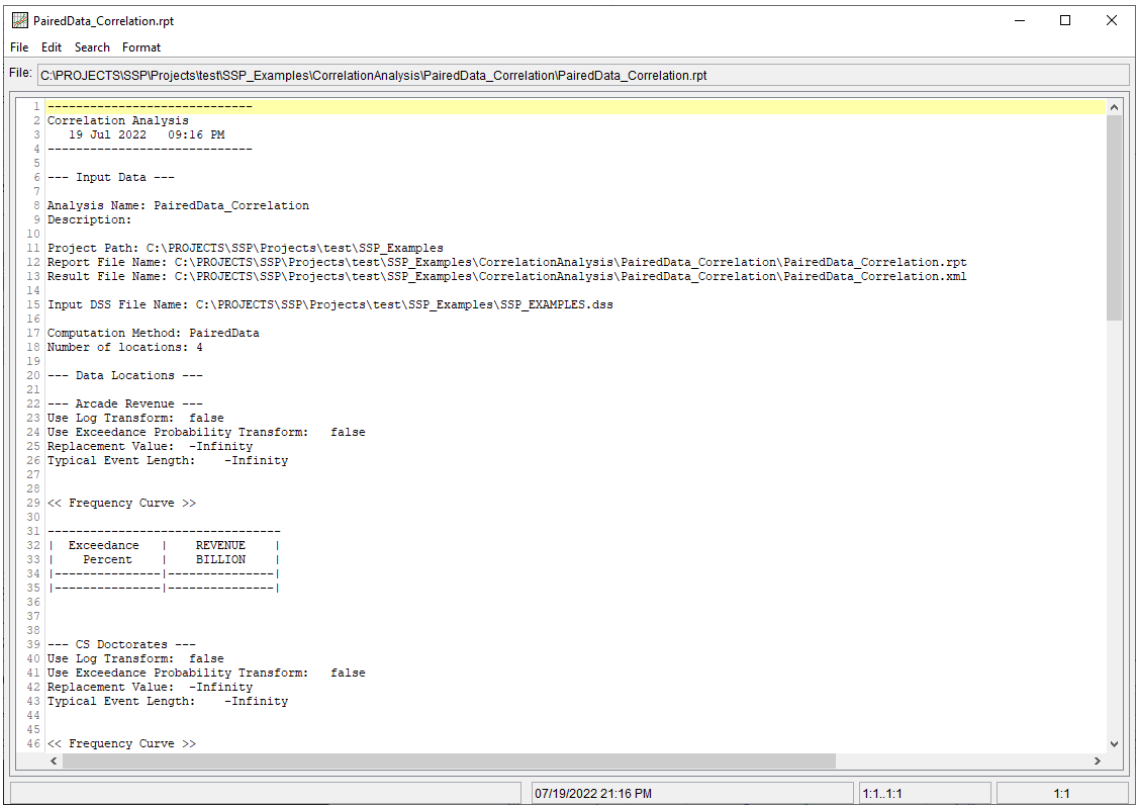
278 Figure 8. Results Tab

> The seemingly random values considered within this example are all very well correlated with one another (r > 0.9). For example, as arcade revenue increases, the number of computer science doctorates awarded within the U.S. increase. However, the sample sizes considered in this example are all small and may not be adequately large to predict the long-term behavior of each data type.

14.3.6 Report File

In addition to the tabular and graphical results, there is a report file that echoes the input data, selected computational options, and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 9.

> Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



279 Figure 9. Report File

15 Record Extension Analysis Examples

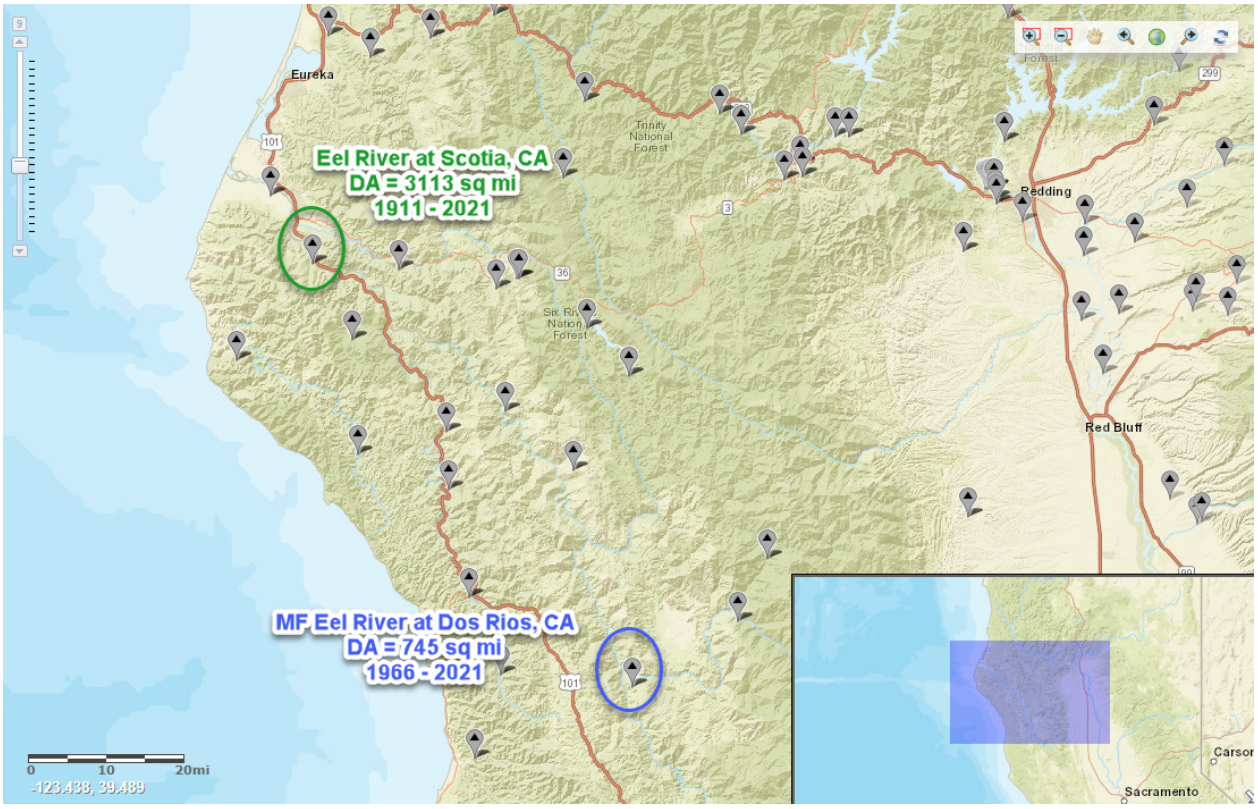
15.1 Annual Peak Record Extension - MF Eel River

The ***MFEelRiver_RecordExtension*** example demonstrates the usage of the Record Extension Analysis in order to extend a shorter annual maximum flow time series using a site with a longer period of record.

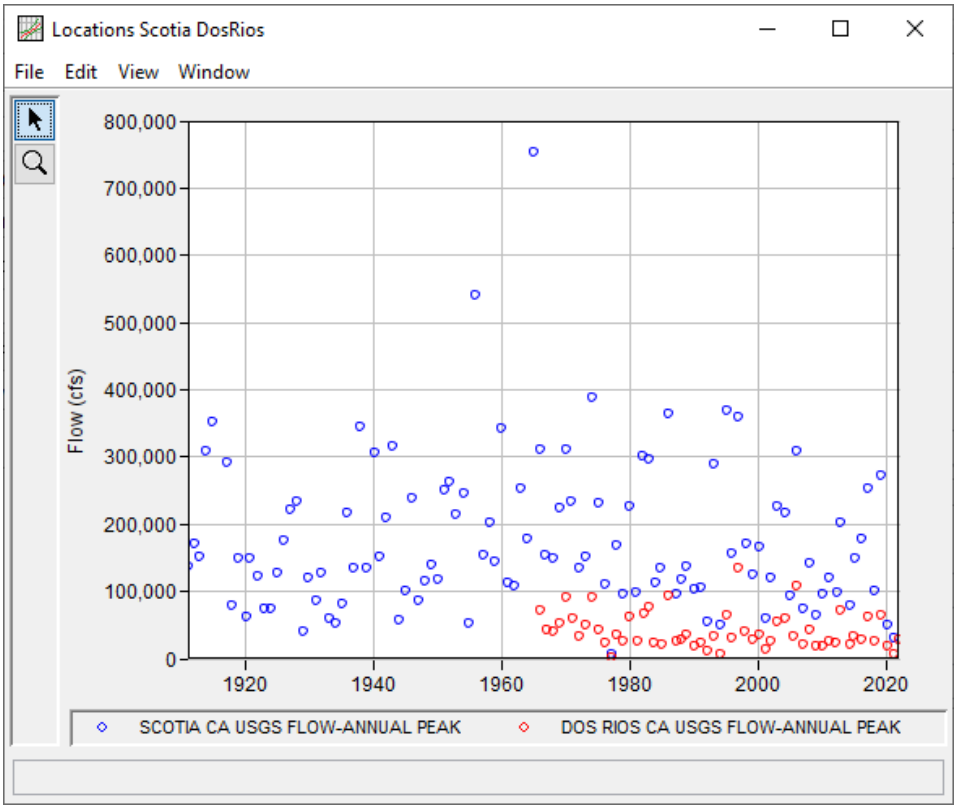
15.1.1 Input Data

In this example, time series representing annual maximum flow at two locations within the Eel River watershed in California are analyzed. The primary (i.e. long record) time series is from the Eel River at Scotia, CA[65] stream gage, which has a drainage area of approximately 3113 square miles (sq mi) and a period of record from 1911 - 2021. The secondary (i.e. short record) time series is from the M[66]iddle Fork Eel River near Dos Rios, CA[67] stream gage, which has a drainage area of approximately 745 sq mi and a period of record from 1966 - 2021. The location of these stream gages is shown in Figure 1. The time series are plotted within Figure 2 and tabulated within Table 1.

65 https://waterdata.usgs.gov/usa/nwis/uv?11477000
66 https://waterdata.usgs.gov/pa/nwis/uv/?site_no=01543700&PARAmeter_cd=00065,00060,00010
67 https://waterdata.usgs.gov/nwis/uv?site_no=11473900



280 Figure 1. Stream Gage Locations



281 Figure 2. Input Time Series for MFEelRiver_RecordExtension Example

Table 1. Input Time Series for MFEelRiver_RecordExtension Example

Date	Flow (cfs)	
	Scotia	Dos Rios
20 Jan 1911	136000	
26 Jan 1912	170000	
18 Jan 1913	150000	
22 Jan 1914	309000	
02 Feb 1915	351000	
25 Feb 1917	292000	

Date	Flow (cfs)	
	Scotia	Dos Rios
07 Feb 1918	78600	
17 Jan 1919	149000	
16 Apr 1920	62000	
19 Nov 1920	148000	
19 Feb 1922	123000	
28 Dec 1922	73400	
08 Feb 1924	73400	
06 Feb 1925	127000	
04 Feb 1926	176000	
21 Feb 1927	221000	
27 Mar 1928	233000	
04 Feb 1929	41000	
15 Dec 1929	120000	
23 Jan 1931	87000	
27 Dec 1931	127000	
17 Mar 1933	58100	
29 Mar 1934	50900	

Date	Flow (cfs)	
	Scotia	Dos Rios
08 Apr 1935	79900	
16 Jan 1936	216000	
05 Feb 1937	134000	
11 Dec 1937	345000	
03 Dec 1938	133000	
28 Feb 1940	305000	
24 Dec 1940	150000	
06 Feb 1942	209000	
21 Jan 1943	315000	
04 Mar 1944	57800	
03 Feb 1945	99100	
27 Dec 1945	239000	
12 Feb 1947	86100	
08 Jan 1948	114000	
18 Mar 1949	140000	
18 Jan 1950	117000	
22 Jan 1951	249000	

Date	Flow (cfs)	
	Scotia	Dos Rios
27 Dec 1951	262000	
09 Jan 1953	215000	
17 Jan 1954	245000	
31 Dec 1954	52400	
22 Dec 1955	541000	
25 Feb 1957	153000	
25 Feb 1958	202000	
12 Jan 1959	145000	
08 Feb 1960	343000	
11 Feb 1961	113000	
14 Feb 1962	107000	
01 Feb 1963	252000	
21 Jan 1964	178000	
23 Dec 1964	752000	
04 Jan 1966		70200
05 Jan 1966	311000	
05 Dec 1966	154000	

Date	Flow (cfs)	
	Scotia	Dos Rios
29 Jan 1967		42600
14 Jan 1968		40000
15 Jan 1968	148000	
13 Jan 1969	223000	
20 Jan 1969		52300
23 Jan 1970		90500
24 Jan 1970	310000	
04 Dec 1970	234000	
16 Jan 1971		59900
23 Jan 1972	133000	33000
16 Jan 1973	152000	49200
16 Jan 1974	387000	89500
18 Mar 1975	231000	
25 Mar 1975		41700
26 Feb 1976	109000	23700
21 Feb 1977		1470
10 Mar 1977	5790	

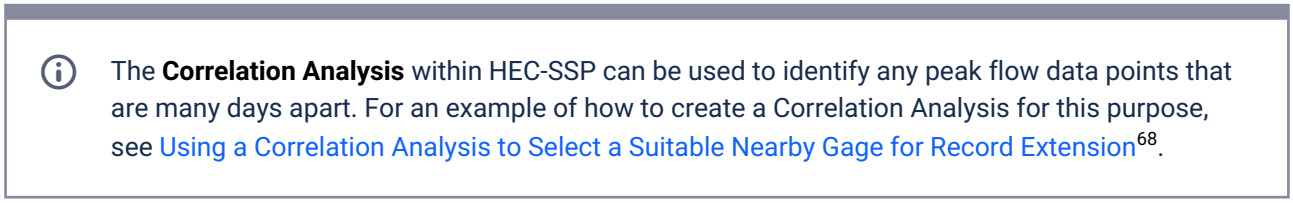
Date	Flow (cfs)	
	Scotia	Dos Rios
09 Jan 1978		35800
17 Jan 1978	169000	
11 Jan 1979	96100	25100
13 Jan 1980		61700
14 Jan 1980	226000	
28 Jan 1981	98700	
14 Feb 1981		25100
20 Dec 1981	300000	
16 Feb 1982		67000
26 Jan 1983		76800
27 Jan 1983	296000	
10 Nov 1983		23600
09 Dec 1983	112000	
12 Nov 1984	133000	
08 Feb 1985		20200
17 Feb 1986	364000	93100
12 Mar 1987		25000

Date	Flow (cfs)	
	Scotia	Dos Rios
13 Mar 1987	94500	
10 Dec 1987	118000	27000
23 Nov 1988	137000	33900
08 Jan 1990	102000	18800
04 Mar 1991		22700
05 Mar 1991	105000	
20 Feb 1992	54200	10800
20 Jan 1993		33700
21 Jan 1993	290000	
23 Jan 1994		7220
24 Jan 1994	48500	
09 Jan 1995	368000	65000
12 Dec 1995	155000	30000
01 Jan 1997	360000	135000
12 Jan 1998		40300
17 Jan 1998	170000	
08 Feb 1999	125000	

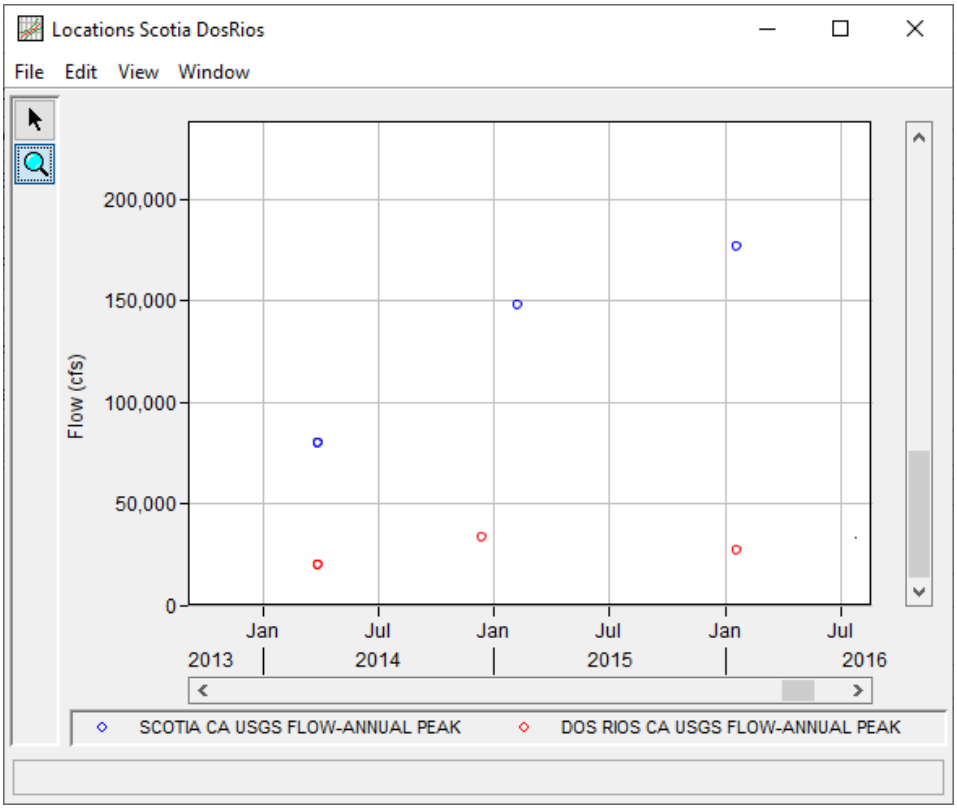
Date	Flow (cfs)	
	Scotia	Dos Rios
09 Feb 1999		27500
14 Feb 2000	166000	34600
05 Mar 2001	59000	13000
02 Jan 2002	119000	24800
16 Dec 2002	226000	53700
17 Feb 2004		59700
18 Feb 2004	217000	
08 Dec 2004	93800	
18 May 2005		32600
30 Dec 2005		107000
31 Dec 2005	307000	
26 Dec 2006		20600
27 Dec 2006	74900	
04 Jan 2008		42500
05 Jan 2008	142000	
24 Feb 2009	64300	
02 Mar 2009		18300

Date	Flow (cfs)	
	Scotia	Dos Rios
25 Jan 2010		17700
26 Jan 2010	94400	
29 Dec 2010	119000	24700
21 Jan 2012		21800
28 Mar 2012	98000	
02 Dec 2012	202000	70300
29 Mar 2014	79500	19400
11 Dec 2014		33000
07 Feb 2015	148000	
18 Jan 2016	177000	27000
08 Jan 2017		61600
11 Jan 2017	252000	
07 Apr 2018	101000	26000
27 Feb 2019	272000	62900
26 Jan 2020	50200	17500
02 Feb 2021	30100	5560
24 Oct 2021		28400

Inspecting the 56 years of overlapping data, it is evident that some of the annual peaks are not "truly" concurrent (i.e. the annual peak for a given water year at the long term site occurred during a different runoff event when compared to the short term site), as shown in Figure 4. Per Bulletin 17C: "For the purposes of record extension, concurrent flood peaks are those that occurred in the same water year, not on the same flood event." As such, the entire overlapping record was considered concurrent within this example.



The **Correlation Analysis** within HEC-SSP can be used to identify any peak flow data points that are many days apart. For an example of how to create a Correlation Analysis for this purpose, see Using a Correlation Analysis to Select a Suitable Nearby Gage for Record Extension[68].



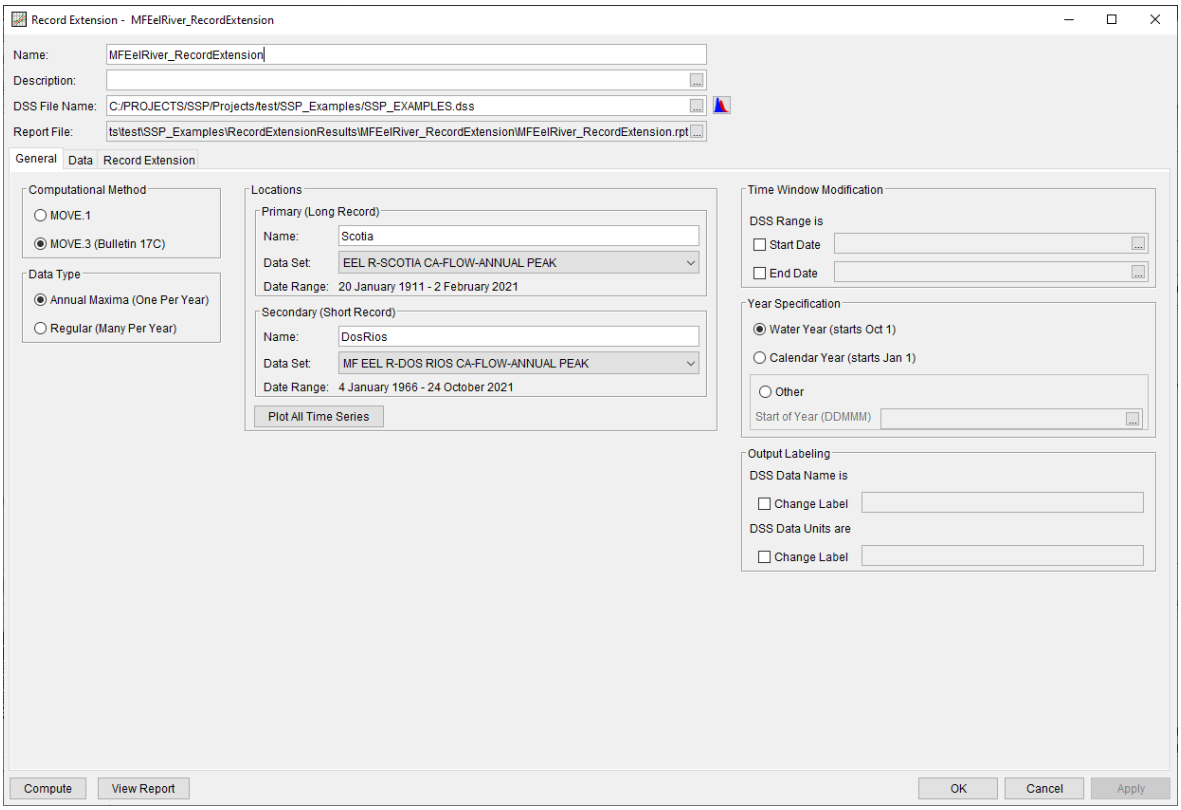
282 Figure 3. Example of Annual Peaks That Are Not From the Same Event

15.1.2 General Tab

A Record Extension Analysis has been developed for this example. To open the analysis, either double-click on the analysis labeled **MFEelRiver_RecordExtension** from the study explorer or from the **Analysis** menu select open, then select **MFEelRiver_RecordExtension** from the list of available analyses. When **MFEelRiver_RecordExtension** is opened, the **General** tab within the Record Extension Analysis editor will

68 https://www.hec.usace.army.mil/confluence/display/SSPTutorialsGuides/Using+a+Correlation+Analysis+to+Select+a+Suitable+Nearby+Gage+for+Record+Extension

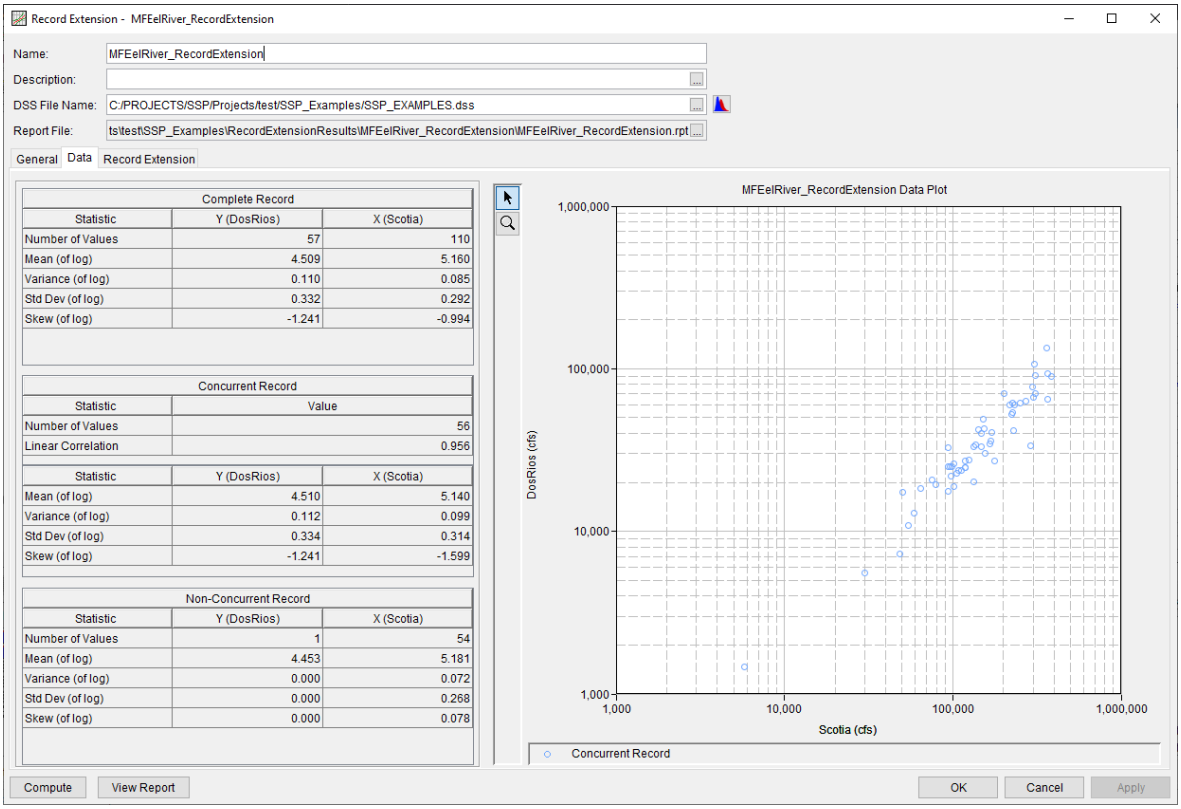
appear as shown in Figure 4. For this analysis, the *MOVE.3 (Bulletin 17C)* computational method and the *Annual Maximum (One Per Year)* data type was selected. The Scotia time series was selected as the *Primary (Long Record)* while the Dos Rios time series was selected as the *Secondary (Short Record)*. The default Year Specification (*Water Year*) was left unchanged. No modifications were made to the time window or the output labeling.



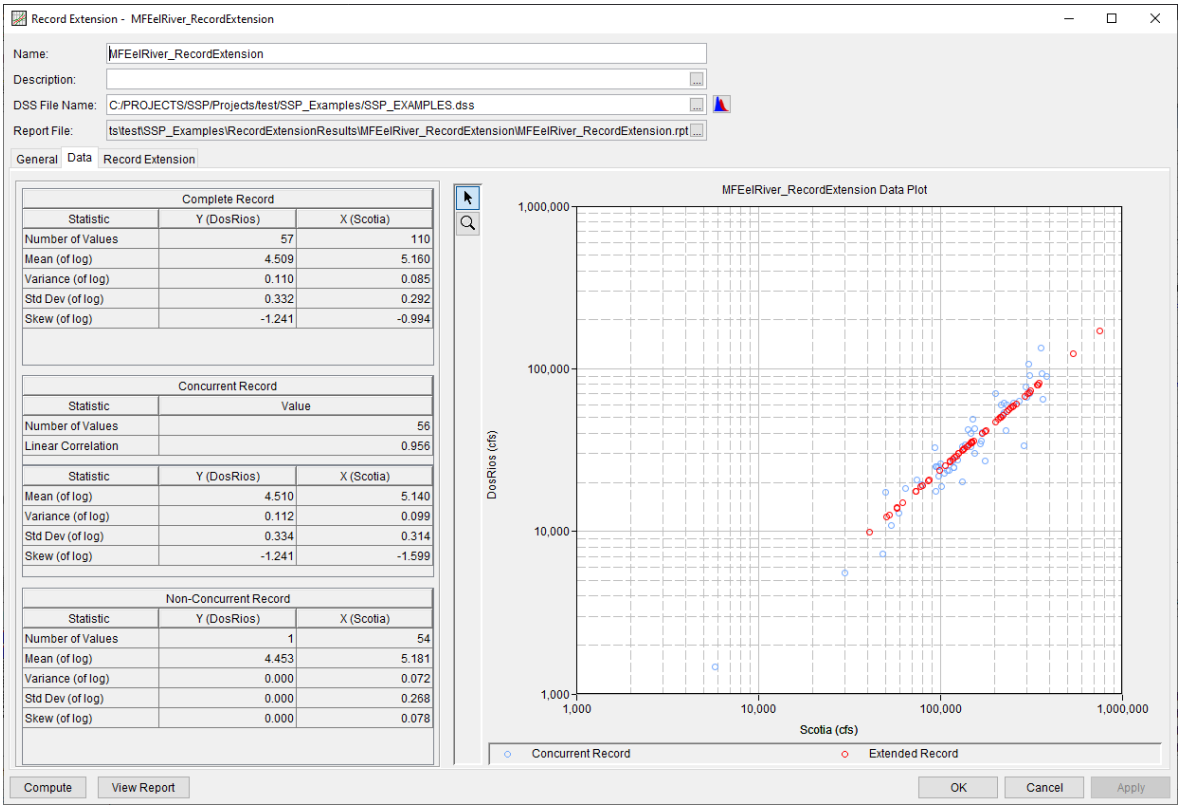
283 Figure 4. General Tab

15.1.3 Data Tab

The **Data** tab contains several tables detailing the complete, concurrent (i.e. overlapping), and non-concurrent (i.e. non-overlapping) records. Additionally, a plot showing the concurrent record is included. The primary record (Scotia) is shown on the x-axis while the secondary record (Dos Rios) is shown on the y-axis. Prior to a successful compute, the plot will only contain the concurrent record (blue circles), as shown in Figure 5. Following a successful compute, the extended record (red circles) will be added to the plot, as shown in Figure 6.



284 Figure 5. Data Tab Prior to a Successful Compute



285 Figure 6. Data Tab Following a Successful Compute

15.1.4 Computing the Analysis

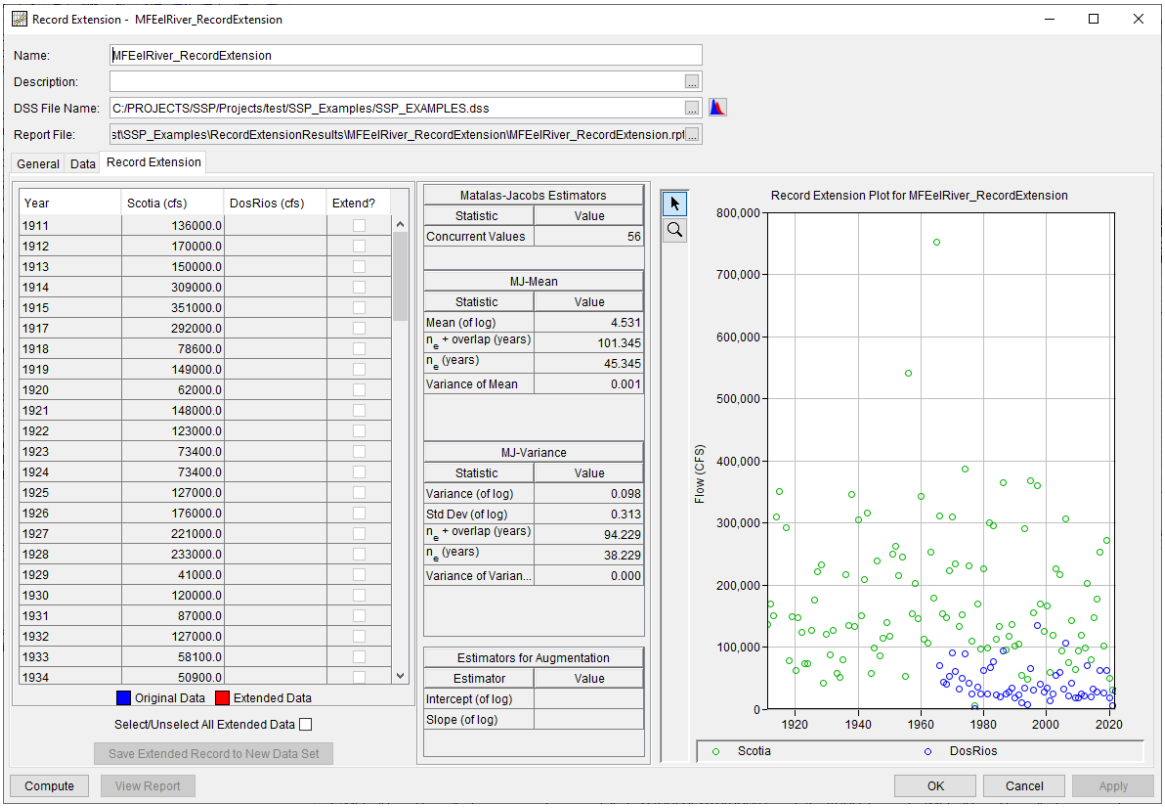
Once all of the **General** information has been selected and the data reviewed on the **Data** tab, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**.

> The Record Extension Analysis will use all values within the concurrent time period when computing correlation coefficients, estimators for augmentation, and the extended record. No values will be removed from consideration even though they may not have resulted from the same runoff event, as was mentioned above.

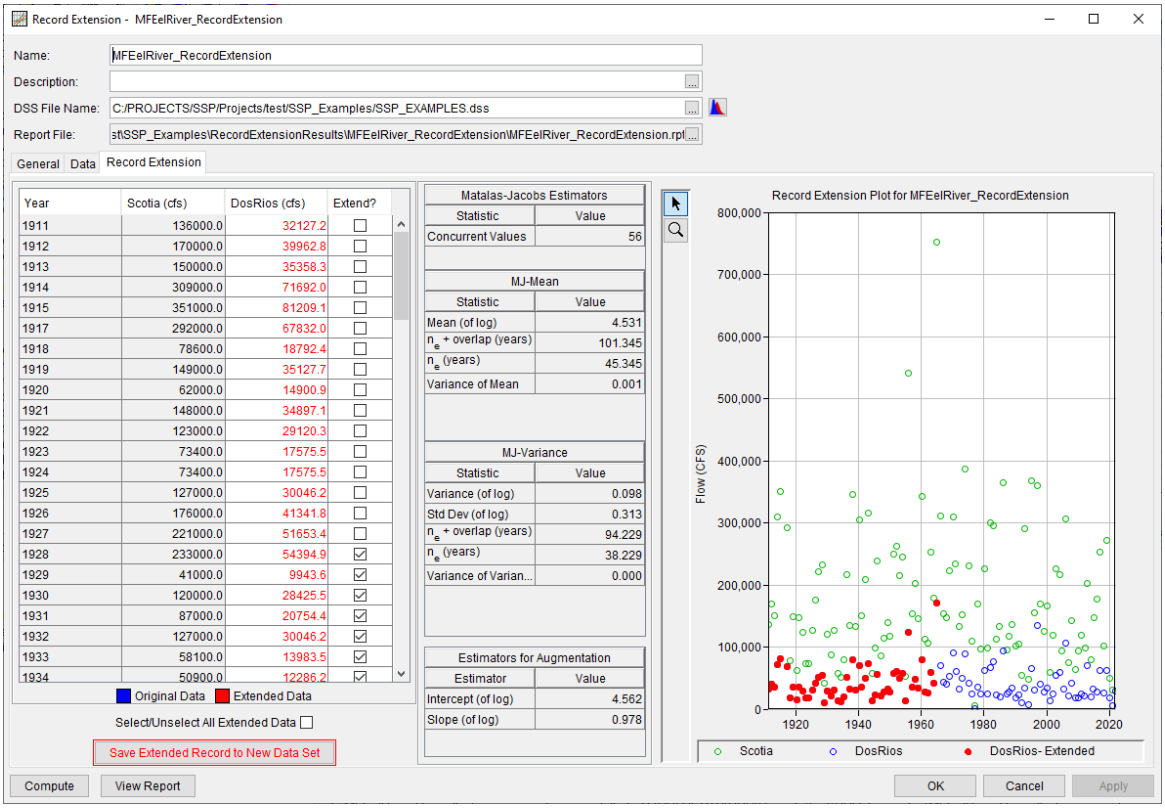
15.1.5 Record Extension Tab

The **Record Extension** tab contains several tables detailing the *Matalas-Jacobs Estimators* (*MJ-Mean* and *MJ-Variance*), the *Estimators for Augmentation*, and statistics of the extended record. Additionally, a plot showing the input time series is included. Prior to a successful compute, the plot will only contain the primary record (Scotia; green circles) and the secondary record (Dos Rios; blue circles), as shown in Figure 7.

Following a successful compute, the extended record (red circles) will be added to the plot, as shown in Figure 8.



286 Figure 7. Results Tab Prior to a Successful Compute



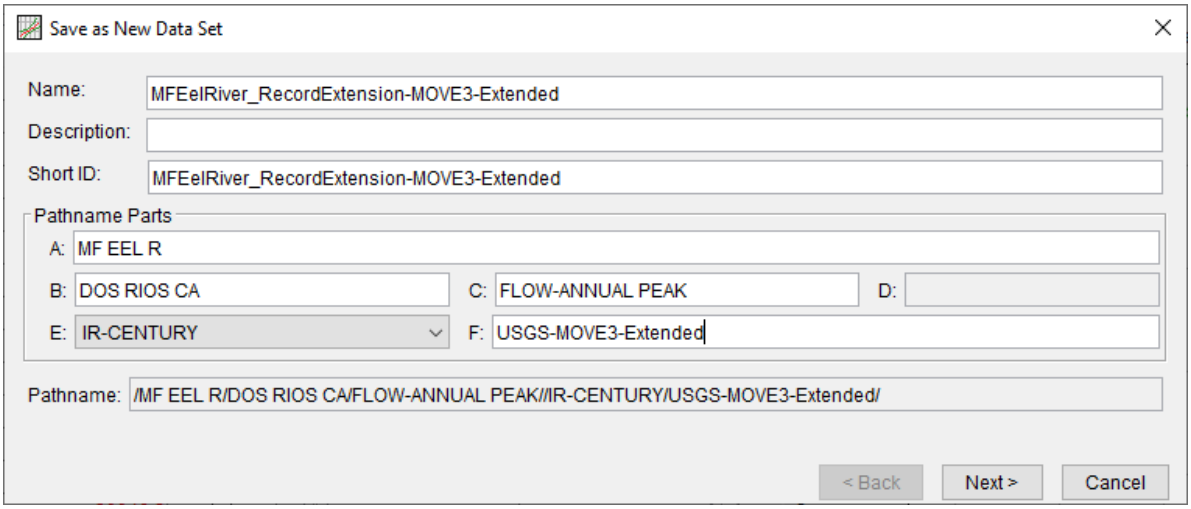
287 Figure 8. Results Tab Following a Successful Compute

Since this example made use of the *MOVE.3 (Bulletin 17C)* computational method and the *Annual Maximum (One Per Year)* data type, following a successful compute, the effective record length (n_e) of the variance will be used to select data for extension. Specifically, the most recent n_e years will be selected and the **Save Extended Record to New Data Set** button will become enabled.

The user may select a different portion of the extended record to save to a new data set. However, the *Estimators for Augmentation* were computed using the most recent n_e years. As such, choosing a different portion of the extended record will **not** result in the Matalas-Jacobs estimators being reproduced within the extended record. It is recommended that the user selects the default extended record when saving to a new data set.

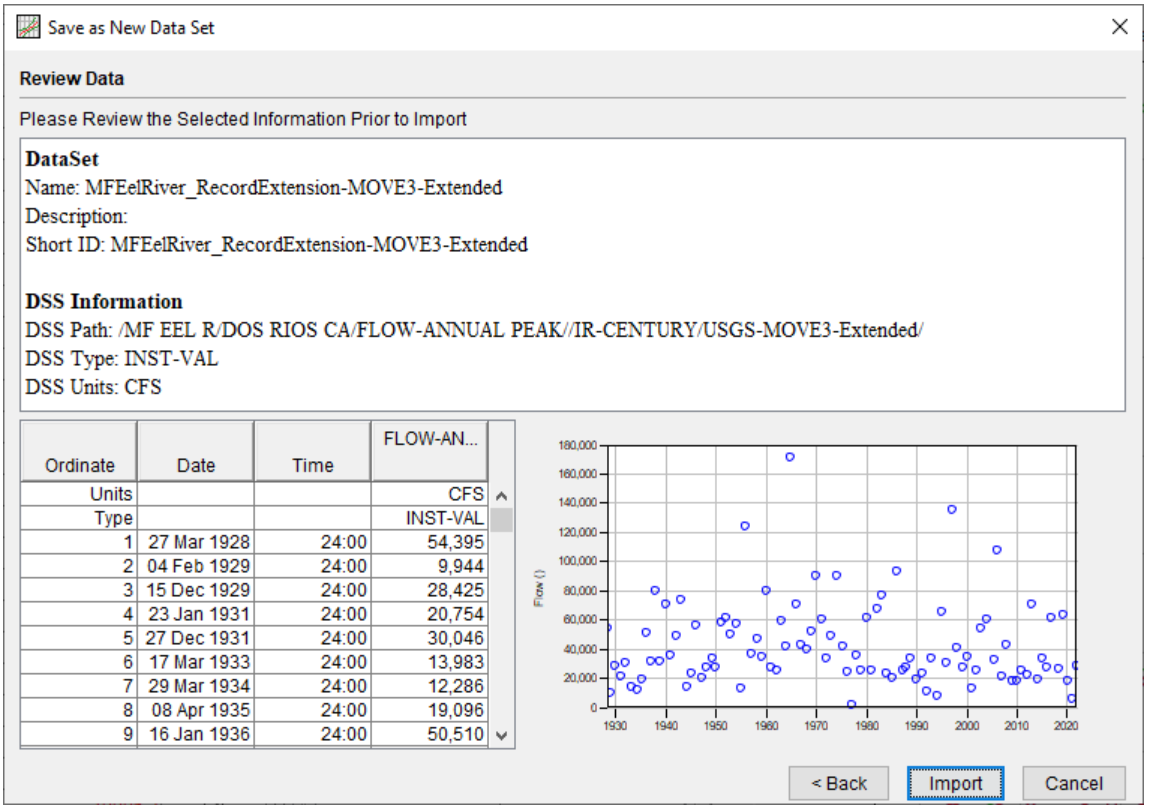
The **Save Extended Record to New Data Set** button will only be active following a successful compute.

When the **Save Extended Record to New Data Set** is clicked, a dialog will be presented allowing for the definition of a *Name*, *Description*, *Short ID*, and *DSS Pathname Parts* for the new data set, as shown within Figure 9.



288 Figure 9. Save As New Data Set Dialog

Upon clicking the *Next* button, a
Save As New Data Set Summary dialog will be shown allowing the user to review the metadata of the new data set as well as
a tabulation and plot of the data that is about to be imported, as shown in Figure 10.



289 Figure 10. Save As New Data Set Summary Dialog

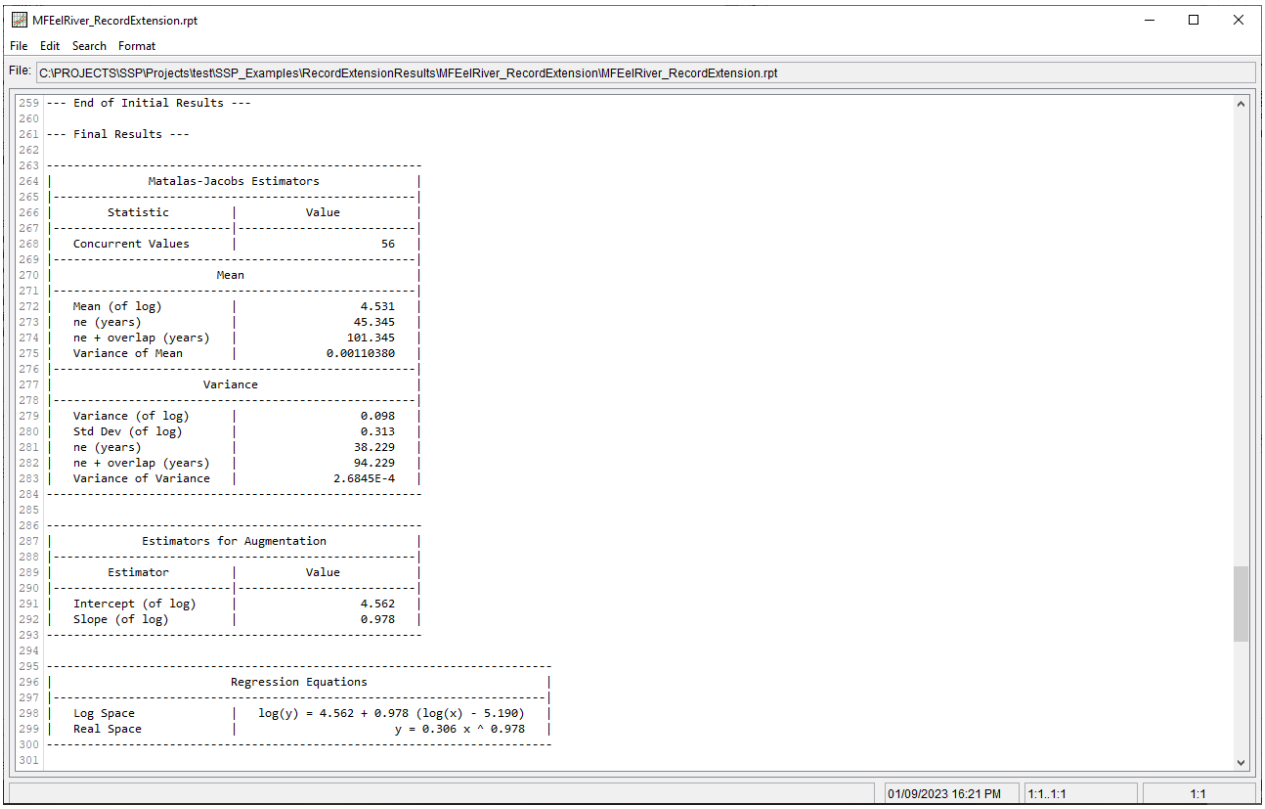
Once the extended record is saved to a new data set, it can be used to compute updated flow-frequency information. An example of this type of application is shown here[69].

15.1.6 Report File

In addition to the tabular and graphical results, there is a report file that echoes the input data, selected computational options, and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 11.

Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.

69 https://www.hec.usace.army.mil/confluence/display/SSPTutorialsGuides/Task+5.+Fit+an+LPIII+Distribution+to+the+Extended+Data+and+Compare+the+Results



290 Figure 11. Report File

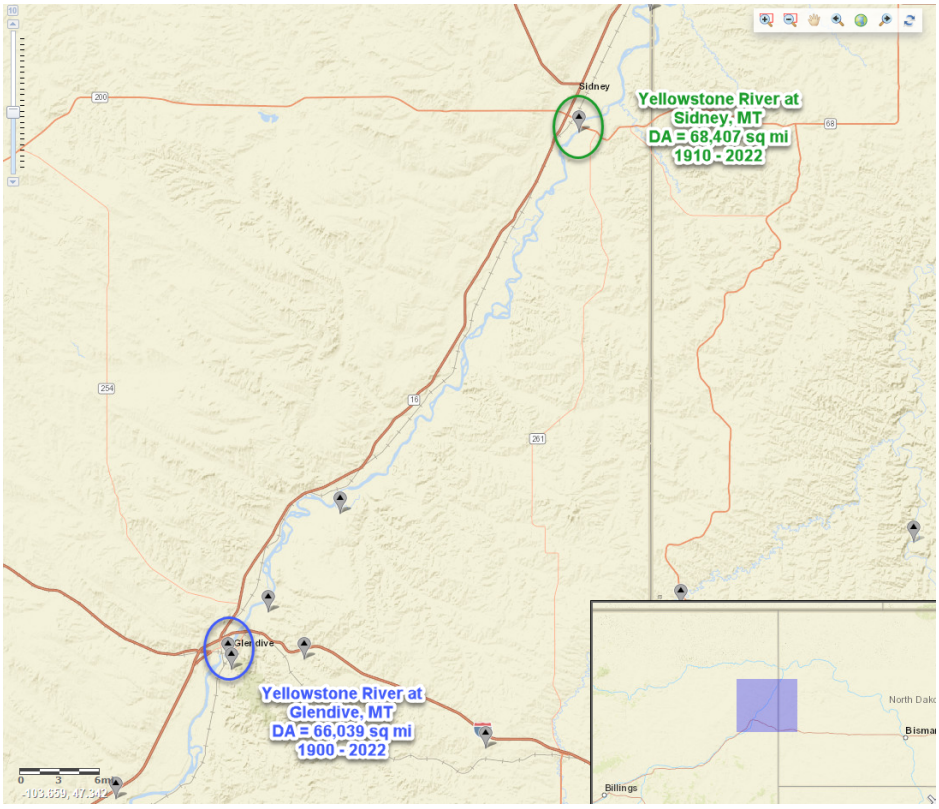
15.2 Daily Average Record Extension - Yellowstone River

The ***Yellowstone_RecordExtension*** example demonstrates the usage of the Record Extension Analysis in order to extend a shorter daily average flow time series using a site with a longer period of record.

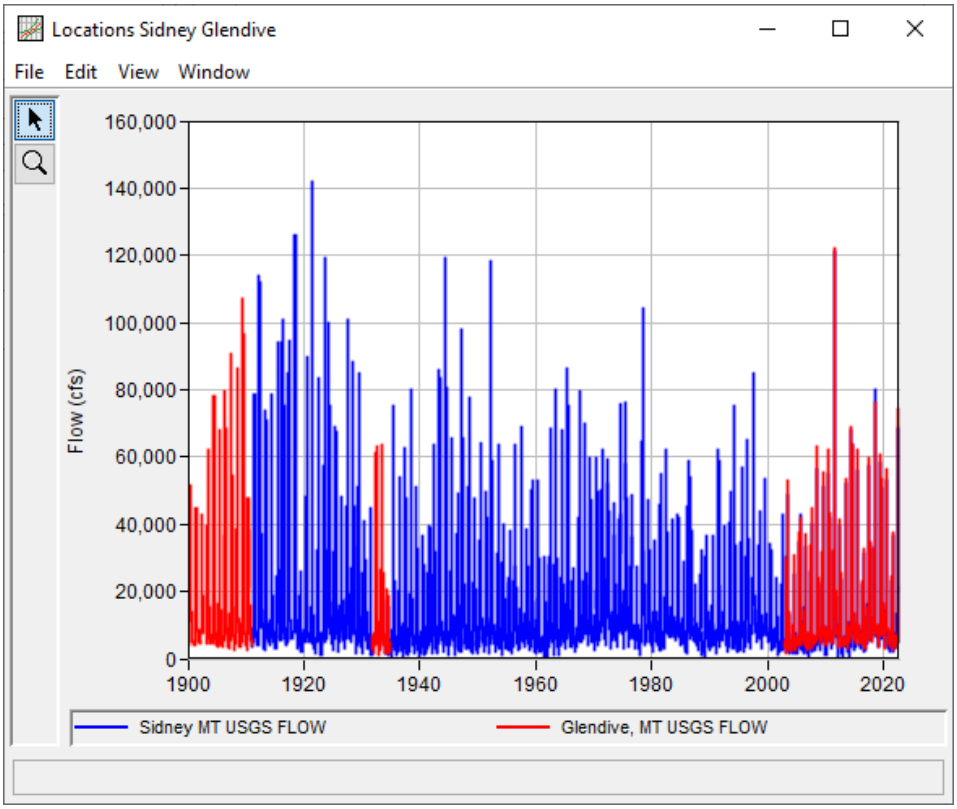
15.2.1 Input Data

In this example, time series representing daily average flow at two locations within the Yellowstone River watershed in Montana are analyzed. The primary (i.e. long record) time series is from the Yellowstone River at Sidney, MT[70] stream gage, which has a drainage area of approximately 68,407 square miles (sq mi) and a period of record from 1910 - 2022. The secondary (i.e. short record) time series is from the Yellowstone River at Glendive, MT[71] stream gage, which has a drainage area of approximately 66,039 sq mi and a period of record from 1900 - 2022. However, the Glendive record has significant missing periods spanning 1911 - 1931 and 1934 - 2002. The location of these stream gages is shown in Figure 1. The time series are plotted within Figure 2.

70 https://waterdata.usgs.gov/nwis/uv?site_no=06329500
71 https://waterdata.usgs.gov/nwis/uv?06327500



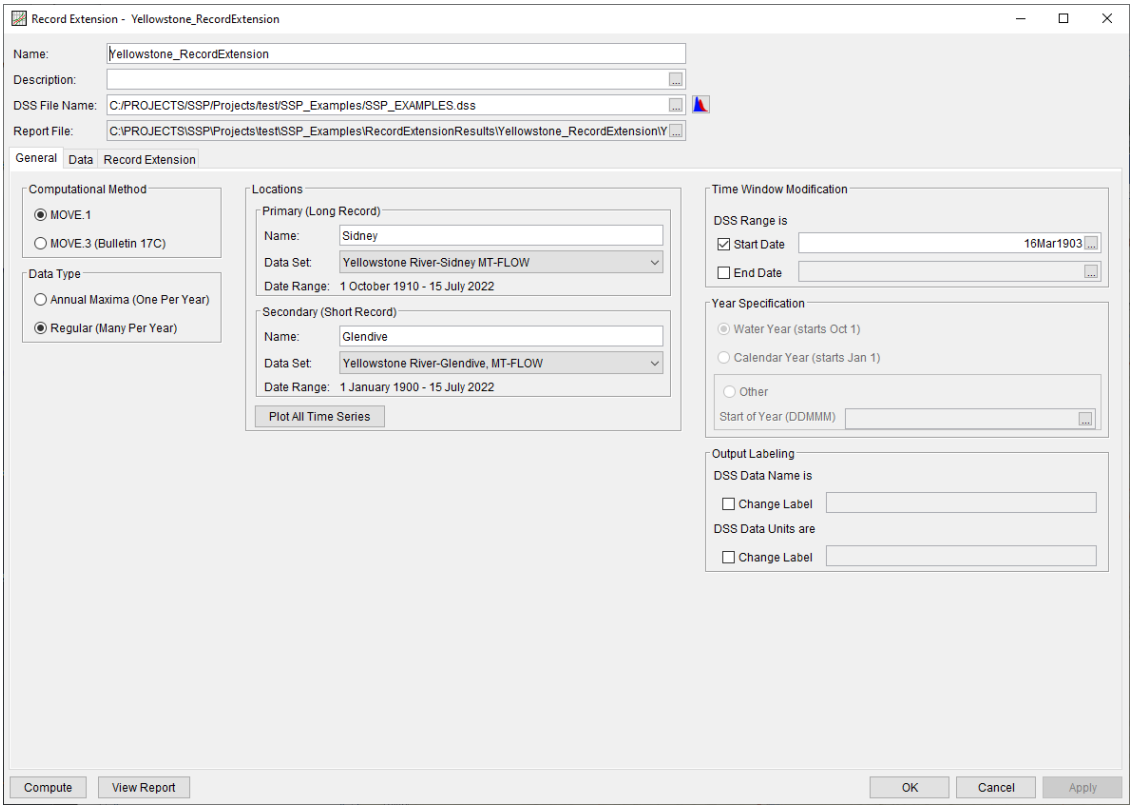
291 Figure 1. Stream Gage Locations



292 Figure 2. Input Time Series for Yellowstone_RecordExtension Example

15.2.2 General Tab

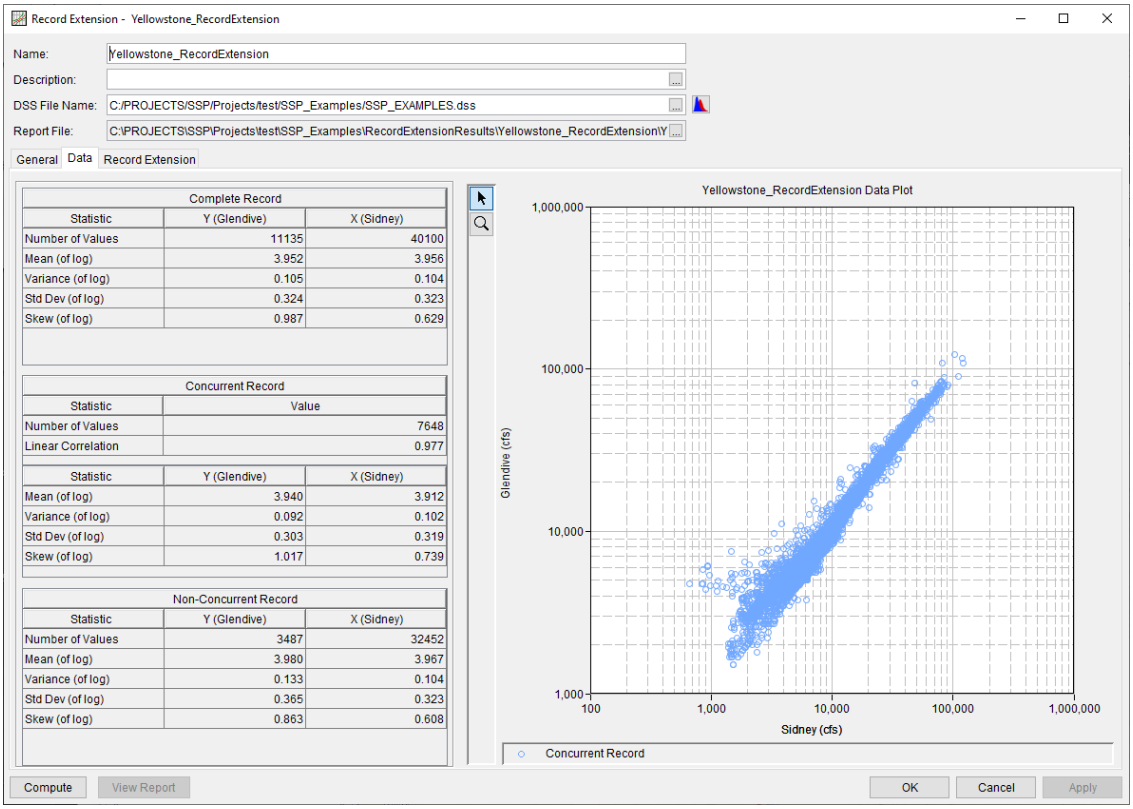
A Record Extension Analysis has been developed for this example. To open the analysis, either double-click on the analysis labeled **Yellowstone_RecordExtension** from the study explorer or from the **Analysis** menu select open, then select **Yellowstone_RecordExtension** from the list of available analyses. When **Yellowstone_RecordExtension** is opened, the **General** tab within the Record Extension Analysis editor will appear as shown in Figure 3. For this analysis, the *MOVE.1* computational method and the *Regular (Many Per Year)* data type was selected. The Sidney time series was selected as the *Primary (Long Record)* while the Glendive time series was selected as the *Secondary (Short Record)*. The time window was modified to start on 16Mar1903. No modifications were made to the year specification or the output labeling.



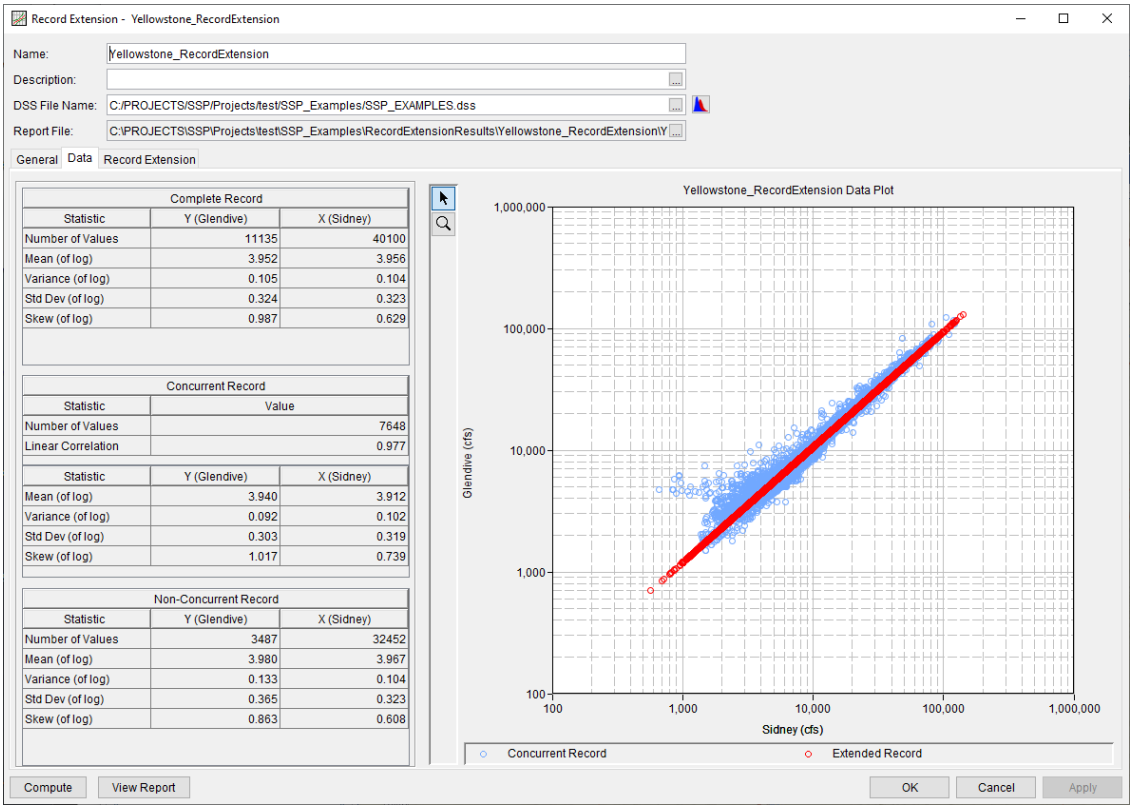
293 Figure 3. General Tab

15.2.3 Data Tab

The **Data** tab contains several tables detailing the complete, concurrent (i.e. overlapping), and non-concurrent (i.e. non-overlapping) records. Additionally, a plot showing the concurrent record is included. The primary record (Scotia) is shown on the x-axis while the secondary record (Dos Rios) is shown on the y-axis. Prior to a successful compute, the plot will only contain the concurrent record (blue circles), as shown in Figure 4. Following a successful compute, the extended record (red circles) will be added to the plot, as shown in Figure 5.



294 Figure 4. Data Tab Prior to a Successful Compute



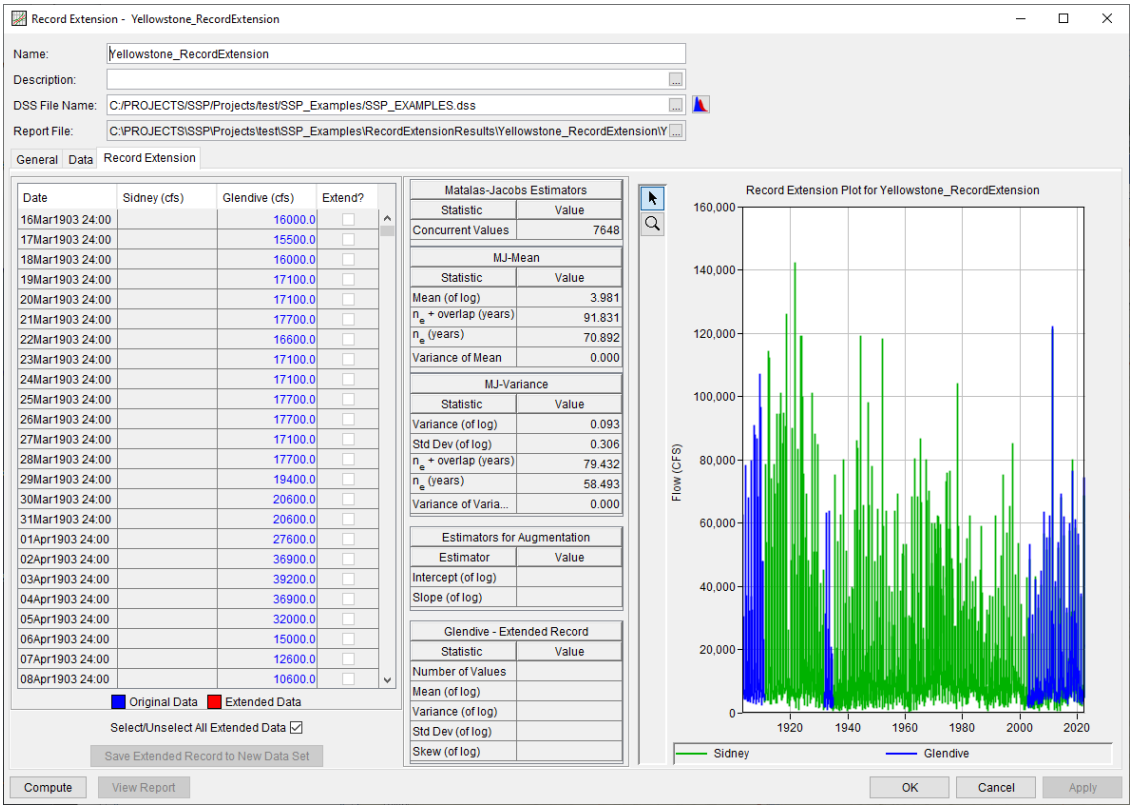
295 Figure 5. Data Tab Following a Successful Compute

15.2.4 Computing the Analysis

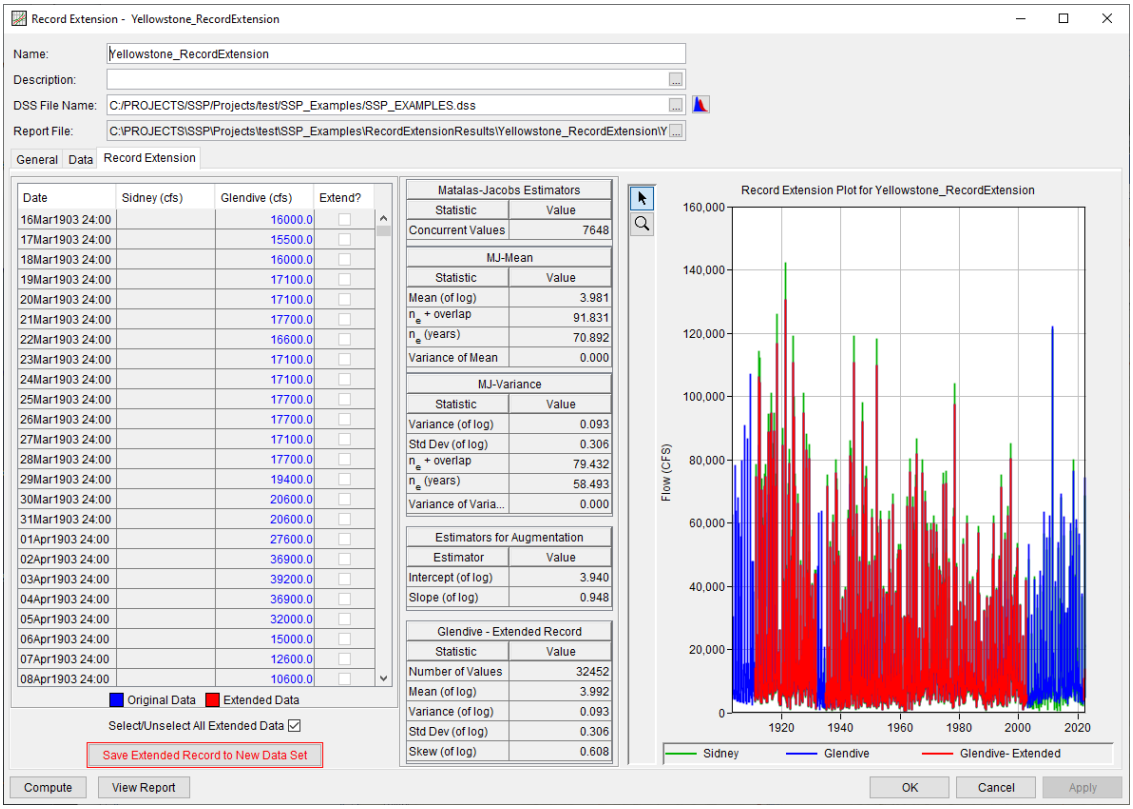
Once all of the **General** information has been selected and the data reviewed on the **Data** tab, the user can press the **Compute** button to perform the analysis. Once the computations have been completed, a message window will open stating **Compute Complete**.

15.2.5 Results Tab

The **Results** tab contains several tables detailing the *Matalas-Jacobs Estimators* (*MJ-Mean* and *MJ-Variance*), the *Estimators for Augmentation*, and statistics of the extended record. Additionally, a plot showing the input time series is included. Prior to a successful compute, the plot will only contain the primary record (Sidney; green bars) and the secondary record (Glendive; blue bars), as shown in Figure 6. Following a successful compute, the extended record (red bars) will be added to the plot, as shown in Figure 7.



296 Figure 6. Results Tab Prior to a Successful Compute

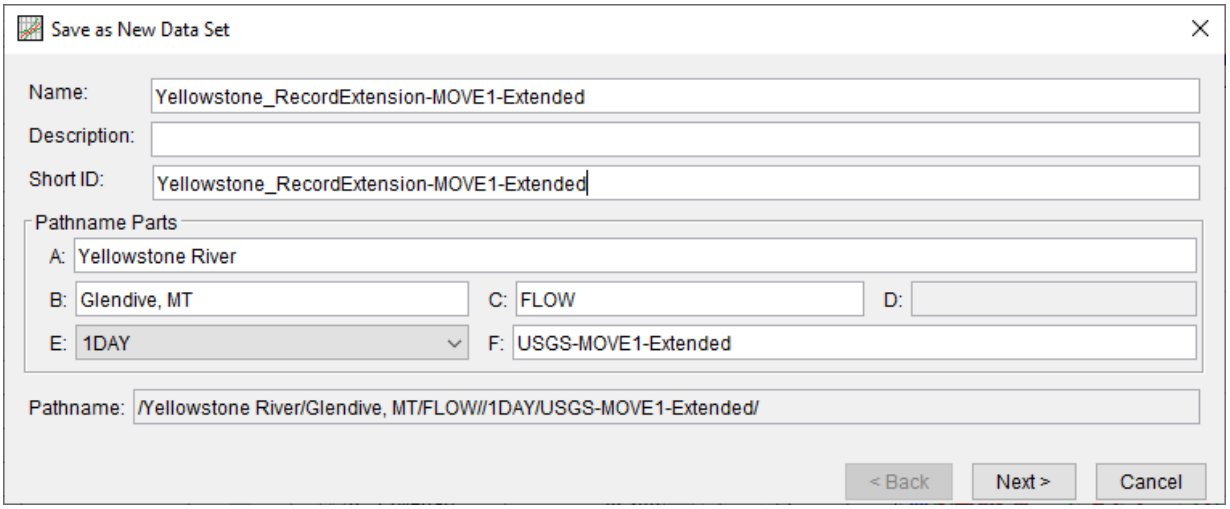


297 Figure 7. Results Tab Following a Successful Compute

Since this example made use of the *MOVE.1* computational method and the *Regular (Many Per Year)* data type, following a successful compute, the entire extended record will selected for extension and the **Save Extended Record to New Data Set** button will become enabled.

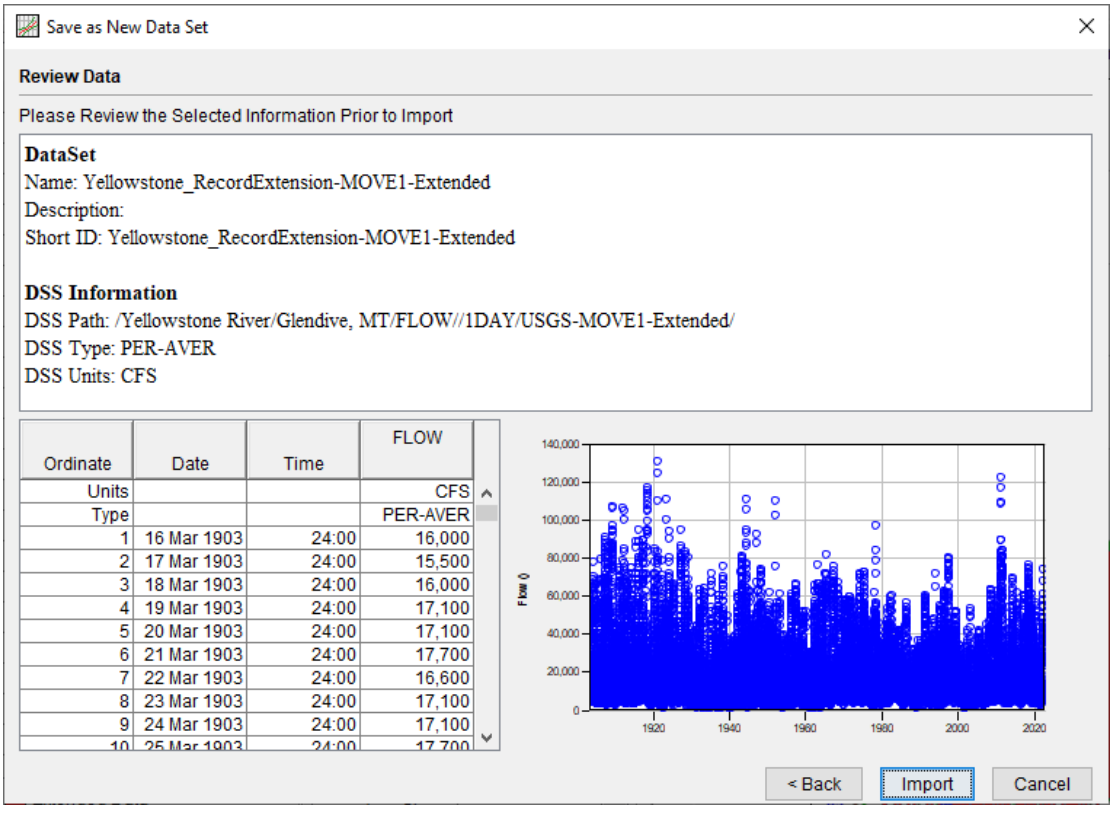
> The **Save Extended Record to New Data Set** button will only be active following a successful compute.

When the **Save Extended Record to New Data Set** is clicked, a dialog will be presented allowing for the definition of a *Name*, *Description*, *Short ID*, and *DSS Pathname Parts* for the new data set, as shown within Figure 8.



298 Figure 8. Save As New Data Set Dialog

Upon clicking the *Next* button, a
Save As New Data Set Summary dialog will be shown allowing the user to review the metadata of the new data set as well as
a tabulation and plot of the data that is about to be imported, as shown in Figure 9.



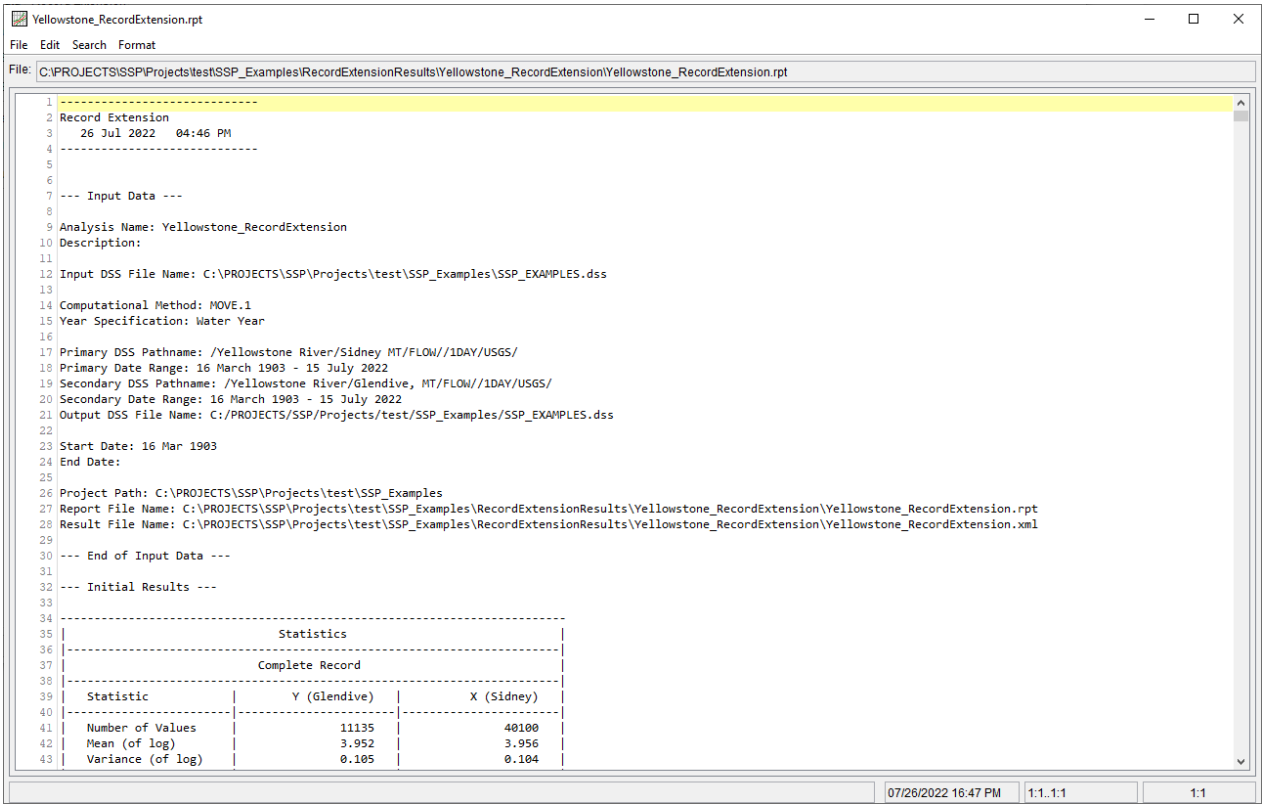
299 Figure 9. Save As New Data Set Summary Dialog

> Once the extended record is saved to a new data set, it can be used to compute updated flow-frequency and/or flow-duration information. An example of this type of application is shown here[72].

15.2.6 Report File

In addition to the tabular and graphical results, there is a report file that echoes the input data, selected computational options, and results. To review the report file, press the **View Report** button at the bottom of the analysis window. When this button is selected a text viewer will open the report file and display it on the screen, as shown in Figure 10.

> Different types and amounts of information will show up in the report file depending on the data and the options that have been selected for the analysis.



300 Figure 10. Report File

72 https://www.hec.usace.army.mil/confluence/display/SSPTutorialsGuides/Daily+Flow+Record+Extension+with+MOVE.1