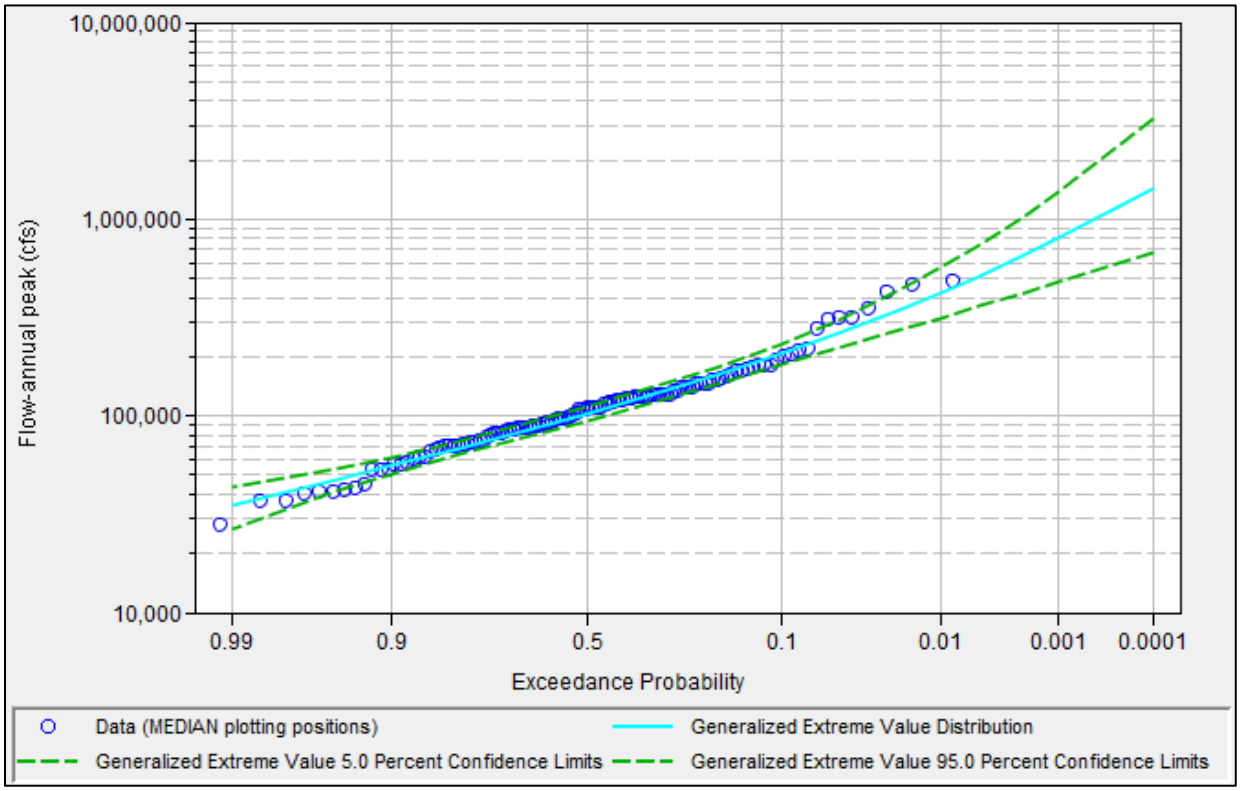
US Army Corps
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Hydrologic Engineering Center

HEC-SSP

Statistical Software Package



User's Manual

Version 2.2

June 2019

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14. ABSTRACT

The Hydrologic Engineering Center's Statistical Software Package (HEC-SSP) allows the user to perform statistical analyses of hydrologic data. The current version of HEC-SSP can perform peak flood flow frequency analysis using Bulletin 17B and 17C procedures, a general frequency analysis using any type of hydrologic data, a volume frequency analysis, a duration analysis, a coincident frequency analysis, a curve combination analysis, a balanced hydrograph analysis, a distribution fitting analysis, and a mixed population analysis. Data storage and management is handled either through the use of text files (ASCII, XML) or the Hydrologic Engineering Center's Data Storage System (HEC-DSS).

15. SUBJECT TERMS
HEC-SSP, flood frequency, statistics, Bulletin 17B, Bulletin 17C, Expected Moments Algorithm, flow, stage, computer program, hydrologic data, volume-duration, statistical analysis, balanced hydrograph, distribution fitting, mixed population, data storage, reporting tools, frequency curves, confidence limits, low outliers, high outliers, potentially influential low flows, regional skews

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Statistical Software Package, HEC-SSP, User's Manual

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Foreword

The U.S. Army Corps of Engineers (USACE), Hydrologic Engineering Center's (HEC) Statistical Software Package (HEC-SSP) is software that allows users to perform statistical analyses of hydrologic data.

The first official version of HEC-SSP (Version 1.0) was released in August of 2008. Version 1.1 was released in April, 2009 and included improvements to data entry, results visualization and reporting, and added capability to the Volume Frequency Analysis. Version 2.0 was released in October 2010 and included three new analyses: a Duration Analysis, a Coincident Frequency Analysis, and a Curve Combination Analysis. Version 2.1, released in July 2016, included improvements to the volume frequency analysis, general frequency analysis, and Bulletin 17 analysis as well as a new Balanced Hydrograph analysis.

Version 2.2, released in June 2019, includes improvements to nearly all previously-released analyses, two new analyses (Distribution Fitting and Mixed Population), a redesigned Curve Combination analysis, and enhanced data usage and manipulation. These new features and options are discussed in the User's Manual for Version 2.2.

The HEC-SSP software was designed by Michael Bartles, Beth Faber, Matthew Fleming, Greg Karlovits, William Lehman, Gary Brunner, and Jeff Harris. The HEC-SSP user interface and computation code was programmed by Resource Management Associates. This manual was written by Michael Bartles, Gary Brunner, Matthew Fleming, Beth Faber, Greg Karlovits, and Julia Slaughter.

CHAPTER 1

Introduction

Welcome to the U.S. Army Corps of Engineers, Hydrologic Engineering Center's (HEC) Statistical Software Package (HEC-SSP). This software allows users to perform statistical analyses of hydrologic data. The current version of HEC-SSP can perform flood flow frequency analysis based on Bulletin 17B (Interagency Advisory Committee on Water Data, 1982) and Bulletin 17C (England, et al., 2018), a generalized frequency analysis on not only flow data but other hydrologic data as well, a volume frequency analysis on high or low flows, a duration analysis, a coincident frequency analysis, a curve combination analysis, a balanced hydrograph analysis, a distribution fitting analysis, and a mixed population analysis.

HEC-SSP has been implemented using software guidelines established at HEC. These guidelines will produce more consistent results when using HEC software in water resources studies. Also, the guidelines facilitate a common graphical user interface and "look and feel" for HEC software in the PC environment. Recent HEC software implemented under these guidelines include: rainfall-runoff analysis (HEC-HMS), river hydraulics (HEC-RAS), reservoir system analysis (HEC-ResSim), flood damage analysis (HEC-FDA), flood impact analysis (HEC-FIA), and ecosystem function analysis (HEC-EFM). HEC software implementation is under the guidance of Christopher N. Dunn, Director, Hydrologic Engineering Center.

This chapter discusses the general philosophy of HEC-SSP and gives a brief overview of the capabilities of the software. An overview of this manual is also provided.

Contents

- General Philosophy of HEC-SSP
- Overview of Program Capabilities
- Overview of this Manual

General Philosophy of HEC-SSP

HEC-SSP is designed for interactive use in a multi-tasking environment. The system is comprised of a graphical user interface (GUI), separate statistical analysis components, data storage and management capabilities, mapping, graphics, and reporting tools.

Over a period of many years, HEC has supported a variety of statistical packages that perform frequency analysis and other statistical computations. Historically, the programs that received the most use within USACE were HEC-FFA (Flood Frequency Analysis) and STATS (Statistical Analysis of Time Series Data). HEC-FFA incorporates Bulletin 17B procedures that are used for flow frequency analysis. The STATS software package is used for statistical analysis of time series data. STATS can provide either analytical or graphical frequency analysis, as specified by the user. STATS has the capability of computing monthly and annual maxima, minima, and mean values along with computing a volume-duration analysis. Two other packages that have received a lot of use within USACE are REGFRQ (Regional Frequency Computation) and MLRP (Multiple Linear Regression Program). REGFRQ performs regional frequency analysis and MLRP is a multiple linear regression analysis tool.

The goal of HEC-SSP is to combine all of the statistical analyses capabilities of HEC-FFA, STATS, REGFRQ and MLRP while advancing the realm of statistical hydrology through cutting-edge techniques (such as the use of the Expected Moments Algorithm). New features and additional capabilities will be added to HEC-SSP in future releases.

Overview of Program Capabilities

HEC-SSP is designed to perform statistical analyses of hydrologic data. The following is a description of the major capabilities of HEC-SSP.

User Interface

The user interacts with HEC-SSP through a graphical user interface (GUI). The main focus in the design of the interface was to make it easy to use the software, while still maintaining a high level of efficiency for the user. The interface provides for the following functions:

- File management
- Data entry, importing, and editing
- Statistical analyses

- Tabulation and graphical displays of results
- Reporting facilities

Statistical Analysis Components

Flow Frequency Analysis (Bulletin 17) – This component of the software allows the user to analytically perform annual peak flow frequency analyses. The software implements two algorithms for computing annual peak flow frequencies. The first is contained within Bulletin 17B, which was published by the Interagency Advisory Committee on Water Data in 1982. The second is contained within Bulletin 17C, which was released by the Subcommittee on Hydrology in 2018.

General Frequency Analysis – This component of the software allows the user to perform frequency analyses on hydrologic data using various methods. Types of data that can be used in this analysis include flow, stage, and/or precipitation.

Volume Frequency Analysis – This component of the software allows the user to perform a volume frequency analyses on daily flow data.

Duration Analysis – This component of the software allows the user to perform a duration analysis on any type of data recorded at regular intervals. The duration analysis can be used to show the percent of time that a hydrologic variable is likely to equal or exceed some specific value of interest.

Coincident Frequency Analysis – This component of the software assists the user in computing the exceedance frequency relationship for a variable that is a function of two other variables.

Curve Combination Analysis – This component of the software allows the user to define a "best fit" empirical distribution using two or more input datasets.

Balanced Hydrograph Analysis – This component of the software provides a tool for the creation of balanced hydrographs of multiple durations using existing flow and volume frequency analyses and input hydrograph shapes.

Distribution Fitting Analysis – This component of the software provides a tool for fitting multiple different analytical distributions using two possible fitting methods. This tool allows the user to assess the uncertainty in distribution/fitting method choice for their data set.

Mixed Population Analysis – This component of the software allows the user to compute a combined frequency distribution given multiple input frequency distributions using the probability of union concept.

Data Storage and Management

Data storage is accomplished through the use of text files (American Standard Code for Information Interchange; ASCII; and Extensible Markup Language; XML), as well as the HEC Data Storage System (HEC-DSS). User input data are stored in flat files under separate categories of study, analyses, and a data storage list. Gage data are stored in a project HEC-DSS file as time series data. Output data is predominantly stored in HEC-DSS, while a summary of the results is written to an XML file. Additionally, an analysis report file is generated whenever a computation is made. This report file is written to a standard ASCII text file.

Data management is accomplished through the user interface. The modeler is required to enter a Name and Description for each study under development. If necessary, a previously imported data set must also be selected. Once the study name is entered and a data set has been selected (if required by the analysis), a directory with that name is created, as well as a study file. Additionally, a set of subdirectories is created with the following names: Bulletin17Results, GeneralFrequencyResults, VolumeFrequencyAnalysisResults, DurationAnalysisResults, CoincidentFreqResults, CurveCombinationAnalysis, BalancedHydrograph, DistributionFitting, MixedPopulation, Layouts, and Maps. As the user creates new analyses, an analysis file is created in the main project directory. The interface provides for renaming and deletion of files on a study-by-study basis.

Graphical and Tabular Output

Graphics include a map window, plots of the data, and plots of analysis results. The map window can be used to display background map layers. Locations of the data being analyzed can be displayed on top of the map layers. Once data are brought into HEC-SSP, they can be plotted for visual inspection. The frequency curve plots show the results of the analyses, which may include the analytically computed curve, the expected probability curve, confidence limits, and the raw data points plotted based on the selected plotting position method. Tabular output consists of tables showing the computed frequency curves, confidence limits, and summary statistics. All graphical and tabular output can be displayed on the screen, sent directly to a printer (or plotter), or passed through the Windows Clipboard to other software, such as a word-processor or spreadsheet.

A report file is available for each analysis. This report file includes options selected by the user, an echo of the input data, processed data, and results. The report file format is similar those generated by legacy applications like HEC-FFA.

Overview of This Manual

This user's manual is the primary documentation on how to use HEC-SSP. The manual is organized as follows:

- Chapters 1-2 provide an introduction and overview of HEC-SSP, as well as instructions on how to install the software.
- Chapter 3 provides an overview on how to use the HEC-SSP software in a step-by-step procedure, including a sample problem that the user can follow.
- Chapter 4 explains in detail how to enter and view data.
- Chapter 5 provides a detailed discussion on how to use the Bulletin 17 Analysis editor.
- Chapter 6 provides a detailed discussion on how to use the General Frequency Analysis editor.
- Chapter 7 provides a detailed discussion on how to use the Volume Frequency Analysis editor.
- Chapter 8 provides a detailed discussion on how to use the Duration Analysis editor.
- Chapter 9 provides a detailed discussion on how to use the Coincident Frequency Analysis editor.
- Chapter 10 provides a detailed discussion on how to use the Curve Combination Analysis editor.
- Chapter 11 provides a detailed discussion on how to use the Balanced Hydrograph Analysis editor.
- Chapter 12 provides a detailed discussion on how to use the Distribution Fitting Analysis editor.
- Chapter 13 provides a detailed discussion on how to use the Mixed Population Analysis editor.
- Appendix A contains a list of references.
- Appendix B has a series of example analyses that demonstrate the various capabilities of HEC-SSP when performing a Bulletin 17 flow frequency analysis, a General Frequency Analysis, a Volume Frequency Analysis, a Duration Analysis, a Coincident Frequency Analysis, a Curve Combination Analysis, a Balanced Hydrograph Analysis, a Distribution Fitting Analysis, and a Mixed Population Analysis.
- Appendix C has a series of example analyses that demonstrate the use of HEC-SSP using the Expected Moments Algorithm (EMA) to fit a Log Pearson Type III distribution to annual maximum flow data sets.

CHAPTER 2

Installing HEC-SSP

The user can install HEC-SSP using the program installation package available from HEC's web site. The setup program installs the software, documentation, and the example applications. This chapter discusses the hardware and system requirements needed to use HEC-SSP, how to install the software, and how to uninstall the software.

Contents

- Hardware and Software Requirements
- Installation Procedure
- Uninstall Procedure

Hardware and Software Requirements

Before installing the HEC-SSP software, make sure that the computer has at least the minimum required hardware and software. In order to get the maximum performance from the HEC-SSP software, recommended hardware and software is shown in parentheses. This version of HEC-SSP will run on a computer that has the following:

- Intel Based PC or compatible machine with Pentium processor or higher (a Pentium 4 or higher is recommended).
- A hard disk with at least 100 megabytes of free space
- A CD-Rom drive (or CD-R, CD-RW, DVD), if installing from a CD.
- A minimum of 512 megabytes of RAM (1 Gigabyte or more is recommended).
- A mouse.
- Color Video Display (Recommend running in 1280x1024 or higher resolution, and as large a monitor as possible). Recommend at least a 17" monitor.
- Microsoft Windows XP or 7 (or later versions).

Installation Procedure

Installation of the HEC-SSP software is accomplished through the use of the Setup program.

To install the software onto your hard disk do the following:

1. Download the HEC-SSP setup program from our web page: www.hec.usace.army.mil.

2. Save the setup file in a temporary directory and then execute the "HEC-SSP_22_Setup.exe" file to run the setup program.

3. Follow the setup instructions on the screen.

The install creates a program group called HEC. This program group will be listed under the Programs menu, which is under the Start menu. The HEC-SSP program icon will be contained within the HEC program group, within the HEC-SSP subdirectory. The user can request that a shortcut icon for HEC-SSP be created on the desktop. If the 32-bit application is installed in the default directory, the HEC-SSP executable can be found in the C:\Program Files (x86)\HEC\HEC-SSP\2.1 directory with the name "HEC-SSP.EXE". If the 64-bit application is installed in the default

directory, the HEC-SSP executable can be found in the C:\Program Files\HEC\HEC-SSP\2.1 directory with the name "HEC-SSP.EXE".

The HEC-SSP User's Manual and example data sets are also installed with the software. The User's Manual can be viewed by selecting **User's Manual** from the **Help** menu. To view the User's Manual, Adobe Acrobat Reader must be installed. This viewer can be obtained for free from the Adobe web page.

A zip file containing the example data sets described in Appendix B and Appendix C have been installed in the "**…\Examples**" folder within the program directory. The example data sets can be installed by selecting the **Install Example Data** option from the **Help** menu. After selecting the appropriate menu option, a window will open to choose a location to install the example data sets. The program will create two subdirectories within your chosen folder called **SSP_Examples** and **Bulletin_17C_Examples**. Project files with an ".ssp" file extension will be contained in both subdirectories. The test data sets can be loaded by using the **Open Study** option from the File menu and then use the file chooser to select either project file.

Uninstall Procedure

The HEC-SSP Setup program automatically registers the software with the Windows operating system. To uninstall the software, do the following:

- From the Start Menu select Control Panel.
- Select Add/Remove Programs from within the Control Panel folder.
- From the list of installed software, select the HEC-SSP program and press the Remove button.
- Follow the uninstall directions on the screen and the software will be removed from the computer.

CHAPTER 3

Working With HEC-SSP – An Overview

HEC-SSP is an integrated package of statistical analysis modules, in which the user interacts with the system through the use of a Graphical User Interface (GUI). In HEC-SSP terminology, a **Study** is a set of files associated with a particular set of data and statistical analyses being performed. The files for a study are categorized as follows: study information, data list, and analysis data.

Contents

- Starting HEC-SSP
- Overview of the Software Layout
- Steps in Performing a Bulletin 17 Analysis using Bulletin 17C Procedures

Starting HEC-SSP

When you run the HEC-SSP Setup program, a new program group called **HEC** and a program icon called **HEC-SSP** are created. They should appear in the start menu under the section called **All Programs**. The user also has the option of creating a shortcut on the desktop. If a shortcut is created, the icon for HEC-SSP will look like Figure 3-1.

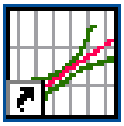


Figure 3-1. The HEC-SSP Icon.

To Start HEC-SSP from Windows:

- Double-click on the HEC-SSP Icon. If you do not have an HEC-SSP shortcut on the desktop, go to the **Start** menu and select **All Programs → HEC → HEC-SSP → HEC-SSP 2.2**.

Overview of the Software Layout

When you first start HEC-SSP, you will see the main window as shown in Figure 3-2, except you will not have any study data on your main window. As shown in Figure 3-2, the main window is laid out with a Menu Bar, a Tool Bar, and four window panes.

The upper right pane (which occupies most of the window area) is the **Desktop Area** (Referred to as the "Desktop" from this point in the manual). This area is used for displaying maps, data editors, and analysis windows.

The upper left pane is called the **Study Explorer**. The Study Explorer acts like an explorer tree for the study. The top level of the tree is the study ("SSP Examples" in this example). Below the study is an analysis branch, a data branch, and a map branch. Under the analysis branch, the first level is the type of analysis. Under each analysis type will be the current user-defined analyses for that type. The data branch lists all of the available data sets that have been brought into the current study. Generally, a data set represents a piece of data at a specific location. For example, all of the peak annual flows at a single stream gage would be stored as a single data set. When an analysis is created, the user selects a data set to be used for that particular analysis. The map branch of the tree contains any maps the user has put together for the study. By default there is automatically a "Base Map" listed under the maps folder.

The lower left pane, and associated tabs, also belongs to the study explorer. This window is used to show additional information about items selected in the study explorer, such as last compute time and last modified time. The tabs are used to switch to different views within the study explorer window. The first tab, labeled Study, shows the explorer view of the study. The second tab, labeled Maps, lists the available maps and map layers associated with each map. The last tab, labeled Files, shows all of the files that make up the current study.

The lower right pane is called the **Message Window**. This window is used to display messages from the software as to what it is doing.

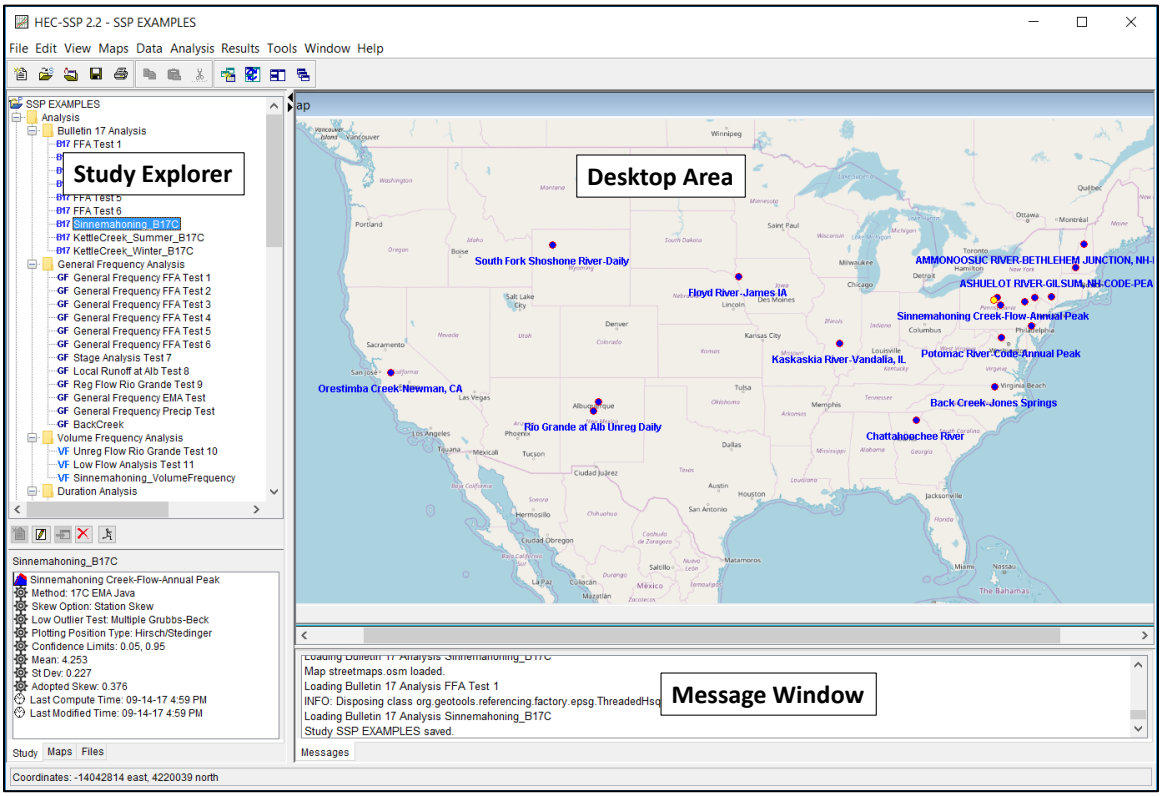
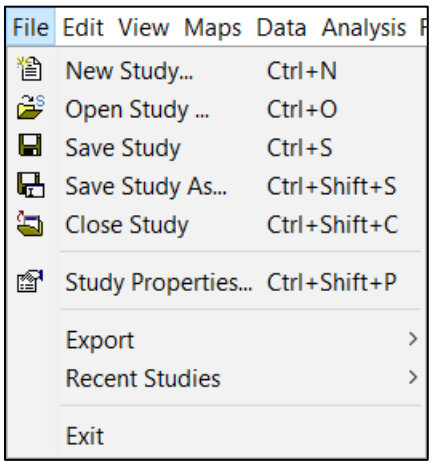


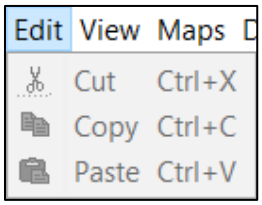
Figure 3-2. The HEC-SSP Main Window.

At the top of the HEC-SSP main window is a Menu bar with the following options:

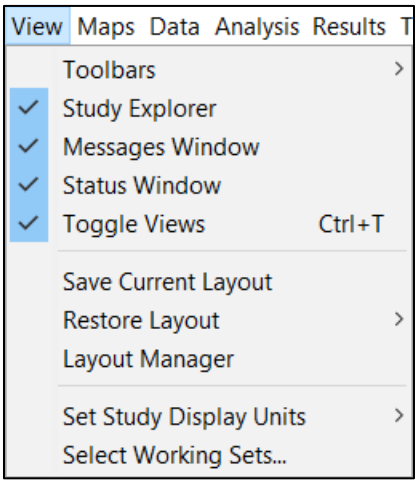
File: This menu is used for file management. Options available under the File menu include New Study, Open Study, Save Study, Save Study As, Close Study, Study Properties, Export, Recent Studies, and Exit. The Study Properties option is used to describe the study. The Export option is used to export HEC-SSP results, stored in the study DSS file, to another DSS file. The Recent Studies option lists the most recently opened studies, which allows the user to quickly open a study that was recently worked on.



Edit: This menu is used for applying the Cut, Copy, and Paste clipboard features to data in editable fields and tables.



View: The View menu allows the user to control display of the toolbars and the study windows. The user can also toggle between viewing all of the panes or just the Main View Pane. The View menu also has options for saving the current layout (currently opened windows and their sizes and locations) and restoring a previously saved layout. The Set Study Display Units option allows the user to switch output between English and metric units.



The Select Working Sets menu option allows the user to group items in each folder and then display only those items in the user interface. For example, Figure 3-3 shows the Bulletin 17 folder in the study explorer. The Edit Working Set editor, Figure 3-4, was used to group all Bulletin 17 analyses that started with "FFA" into one working set. The working set was named "FFA Analyses". This working set was activated by right clicking on top of the Bulletin 17 folder in the study explorer and selecting **Select Working Sets→FFA Analyses**, as shown in Figure 3-5. Only the Bulletin 17 analyses within the working set will then

be displayed in the study explorer, as shown in Figure 3-6. To display all Bulletin 17 analysis, right click on top of the Bulletin 17 folder in the study explorer and select **Select Working Sets→No Working Set**.

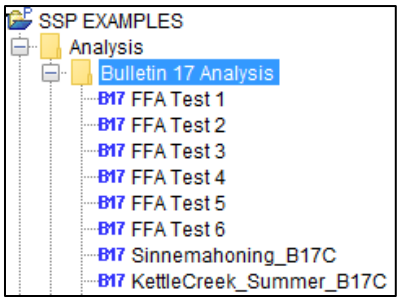


Figure 3-3. Study Explorer before Defining a Working Set.

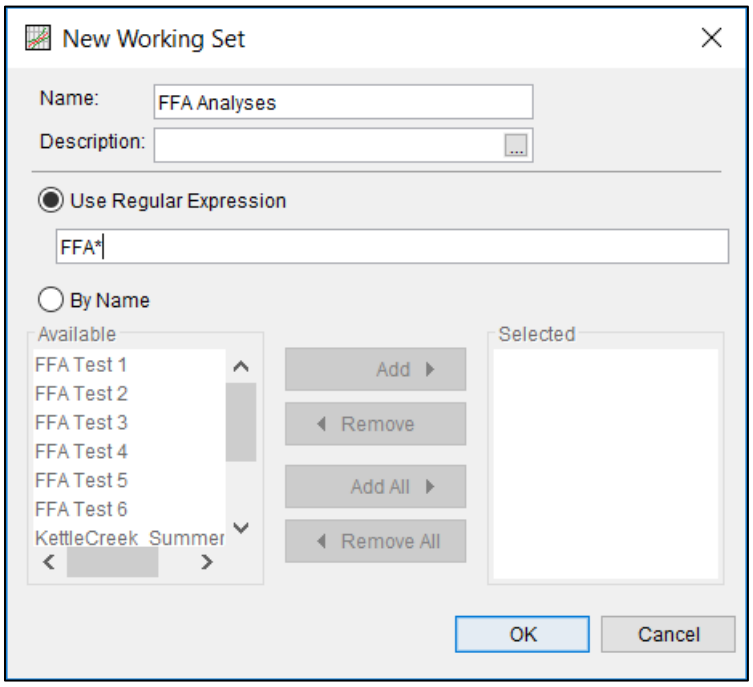


Figure 3-4. Edit Working Set Editor.

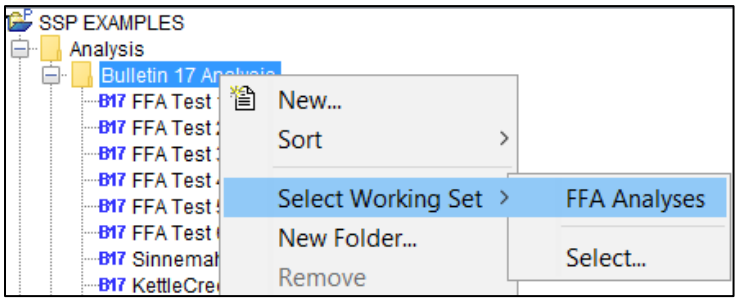


Figure 3-5. Activate a Working Set from the Study Explorer.

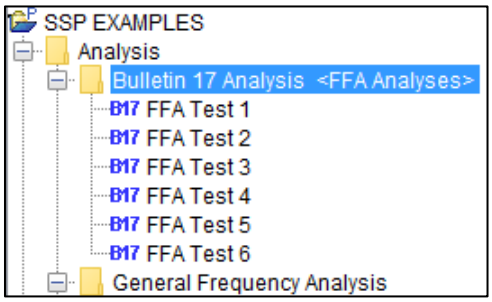
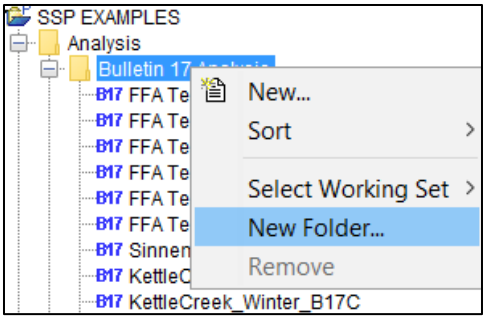
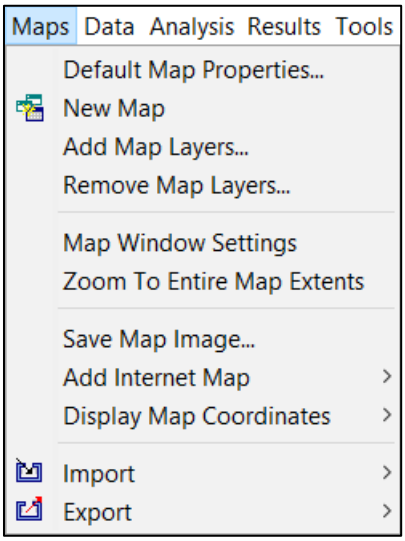


Figure 3-6. Bulletin 17 Folder Only Displays Analyses in Working Set.

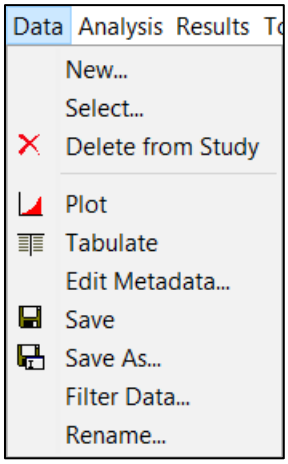


The user may also prefer to group multiple analyses of the same type together using folders. Folders can be created by right clicking on the analysis type of interest and selecting **New Folder…** After the user has named the folder, analyses can be added to the new folder by left clicking on the analysis, holding down the left mouse button, dragging the analysis to the newly created folder, and releasing the left mouse button.

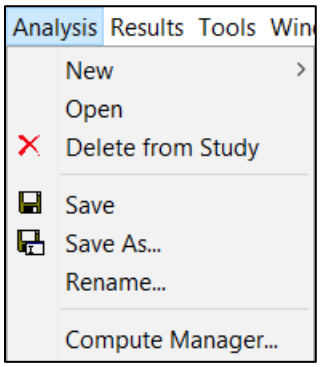


Maps: This menu is used to set the Default Map Properties (Coordinate system, extents, etc…), define a new map, add map layers to the study, and remove a map. Additionally, this menu has the following options available: Map Window Settings (allows the user to turn map layers on and off), Zoom To Entire Map Extents, Save Map Image, Add Internet Map, Display Map Coordinates, Import, and Export. The Zoom To Entire Map Extents option displays the entire set of map layers within the map window. The Save Map Image option can be used to save the current view of the map to a file. The Add Internet Map option can be used to display (or remove) an internet map using Open Street Maps. The Display Map Coordinates option can be used to change between the Watershed coordinates or an Internet projection (i.e. Web Mercator) to allow for the faster display of internet maps.

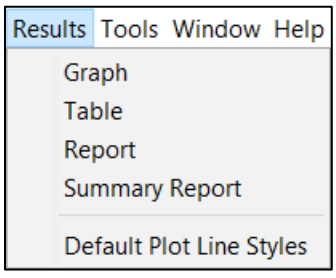
Data: The Data menu allows the user to define a new data set, open the metadata editor, and delete any existing data sets from the data list. Other options include plotting, tabulating, saving data, saving data using a new name, filtering an existing data set to create a new data set, and renaming a data set.



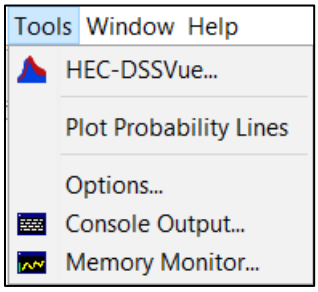
Analysis: The Analysis menu is used to create the various statistical analyses available in the software. Each statistical analysis is saved as a separate file containing the information that is pertinent to that specific analysis type. The current options under this menu item include New, Open, Delete from Study, Save, Save As, Rename, and Compute Manager. The compute manager allows the user to select one, several, or all of the analyses, and then have them all computed as a batch process.



Results: The Results menu allows the user to graph and tabulate any of the existing analyses that have been computed. Additionally, the user can request to view the report file from an analysis. Users must select at least one analysis in the Study Explorer before selecting Graph, Table, Report, or Summary Report. If more than one analysis of the same type are selected (this is accomplished by holding down the control key while clicking on the various analyses), the Graph and Summary Report options will include results from all analyses that are selected. The Default Plot Line Styles menu option lets the user change the default line styles applied to different data types that are plotted in a graph. For example, the user can change the default line style for high outliers so that they are displayed as black triangular data points when a plot is opened.



Tools: The Tools menu includes HEC-DSSVue, Plot Probability Lines, Options, Console Output, and Memory Monitor. The HEC-DSSVue option brings up the HEC-DSSVue program and automatically loads the current study DSS file. HEC-DSSVue is a DSS utility to tabulate, graph, edit, and enter data into DSS. The Plot Probability Lines option opens an editor, shown in Figure 3-7, that lets the user add, delete, or edit the probability lines and axis labels that are displayed in all frequency curve plots. Changes made within the Plot Probability Lines editor will be saved to the computer's registry such that any changes will be retained between sessions. The Options menu item opens the Options editor that allows the user to set default HEC-SSP options. The **Results** tab in the Options editor, shown in Figure 3-8, allows the user to set the number of decimal digits that are displayed for each type of result.



Plot Probability Lines

Label	Return Period	Value
0.9999	1.0	0.9999
0.999		0.999
0.99		0.99
0.9	1.1	0.9
0.5	2	0.5
0.2	5	0.2
0.1	10	0.1
0.02	50	0.02
0.01	100	0.01
0.005	200	0.005
0.002	500	0.002
0.001	1000	0.001
0.0001	10000	1.0E-4
0.00001	100000	1.0E-5
0.000001	1000000	1.0E-6

OK Cancel

Figure 3-7. Plot Probability Lines Editor.

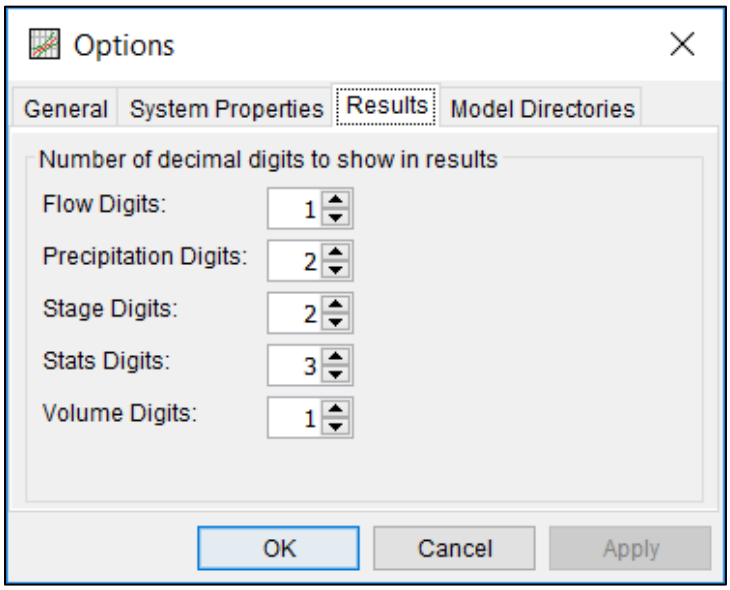
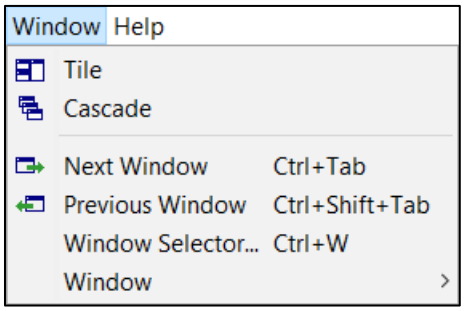
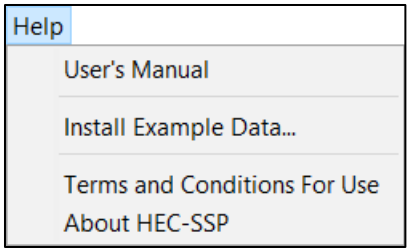


Figure 3-8. Dialog for Controlling the Number of Decimal Digits Shown in Result Tables and Reports.



Window: This menu includes Tile, Cascade, Next Window, Previous Window, Window Selector, and Window. These options are used to control the appearance of the windows in the Desktop area. When more than one window is open (such as a data importer, and various analysis windows), these menu items will help the user organize the windows, or quickly navigate to a specific window. The Tile option can be used to organize all of the currently opened windows in either a vertical or horizontal tile. The Cascade option puts one window on top of the next in a cascading fashion. The Next Window option brings the next window in the list of currently opened windows to the top. The Previous Window brings the last window that was on top back to the top. The Window Selector option brings up a pick list of the currently opened windows and allows you to select the one you want. The Window option has a sub menu list of all the opened windows and allows you to select one.

Help: This menu allows the user to open the HEC-SSP User's Manual, install example data sets, read the terms and conditions of use statement, and display the current version information about HEC-SSP.



Steps in Performing a Bulletin 17 Analysis using Bulletin 17C Procedures

There are five main steps in performing a flow frequency analysis using Bulletin 17C procedures within HEC-SSP. Similar steps are required when performing other statistical analyses.

- Start a new study
- Add a Background Map (Optional)
- Import, Enter, and Edit Data
- Perform the Bulletin 17 Analysis
- View and Print Results

Start a New Study

The first step in performing a flow frequency analysis with HEC-SSP is to establish which directory you wish to work in and to enter a title for the new study. To start a new study, go to the **File** menu and select **New Study**. This will open the **Create New Study** window as shown in Figure 3-9.

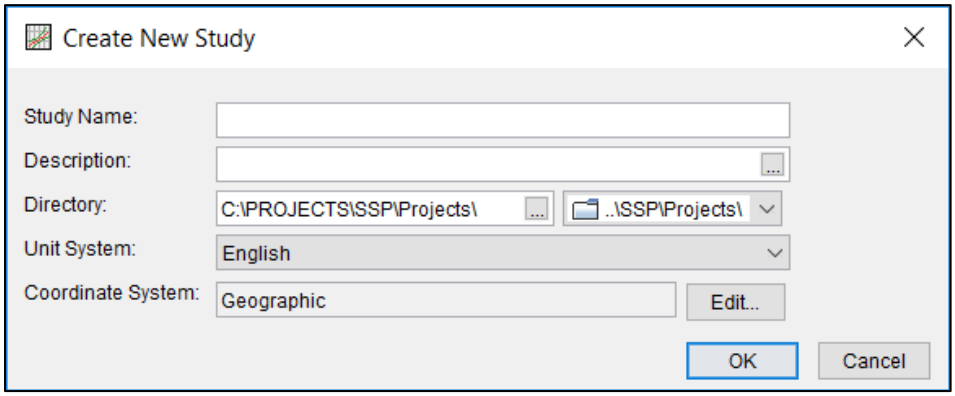


Figure 3-9. New Study Window.

The user is required to enter a name for the study, select a directory to work in (a default location is provided), and select the desired units system. Adding a description of the study is optional. The user should also define a Coordinate System if background spatial data will be plotted. Multiple coordinate systems are provided for use. The choice of a coordinate system will not affect any computed results. Once you have entered all the information, press the **OK** button to have the information accepted. After the **OK** button is pressed, a subdirectory will be created under the user chosen directory. The subdirectory will be labeled with the same name as the user-entered study name. This study directory is where

the HEC-SSP project file, as well as other study files and directories will be located. Additionally, a default map window will appear in the Main View Pane. However, the map window will be blank when it first opens.

Add a Background Map

By default, when you start a new project in HEC-SSP a default map window (called Base Map) will open in the Desktop window. Having a background map is optional in HEC-SSP. Not having a map will not prevent the user from importing and entering data, or performing an analysis and viewing results. The map is mostly a visual aid of the study area. Additionally, when you bring in gage data you can enter the map coordinates of the gage and it will be shown on the map. The user must supply a coordinate system other than X-Y (i.e. Geographic) for imported gage data to be displayed properly. Once a gage is located on the map you can right click on it to open a shortcut menu for viewing the data or graphing and tabulating the results.

To add a map layer to the default map, go to the **Maps** menu and select **Add Map Layers**. When this option is selected a file chooser window will appear, as shown in Figure 3-10, allowing the user to select map layers to bring into the map. The **Create Copy** option on the window will make a copy of the selected map and place it in the Maps subdirectory within the study folder.

Currently, the HEC-SSP software can load the following types of map layers: United States Geologic Survey (USGS) DLG, AutoCAD DXF, shapefile, Raster Image, USGS DEM, Arc Info DEM, ASCII NetTIN, Mr Sid, Open Street Maps, and Keyhole Markup Language (kml).

An example map is shown in Figure 3-11. This map contains a shapefile of state boundaries, data locations, and an internet map (open street map).

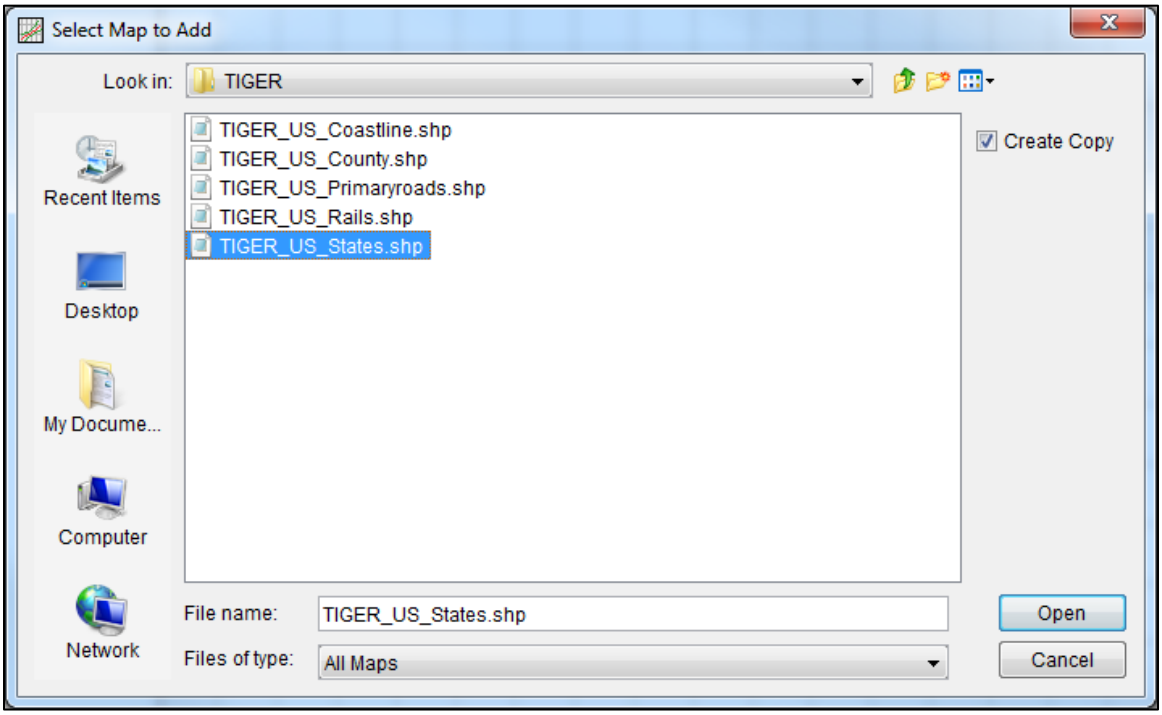


Figure 3-10. Select a Map Layer to add to the Base Map.

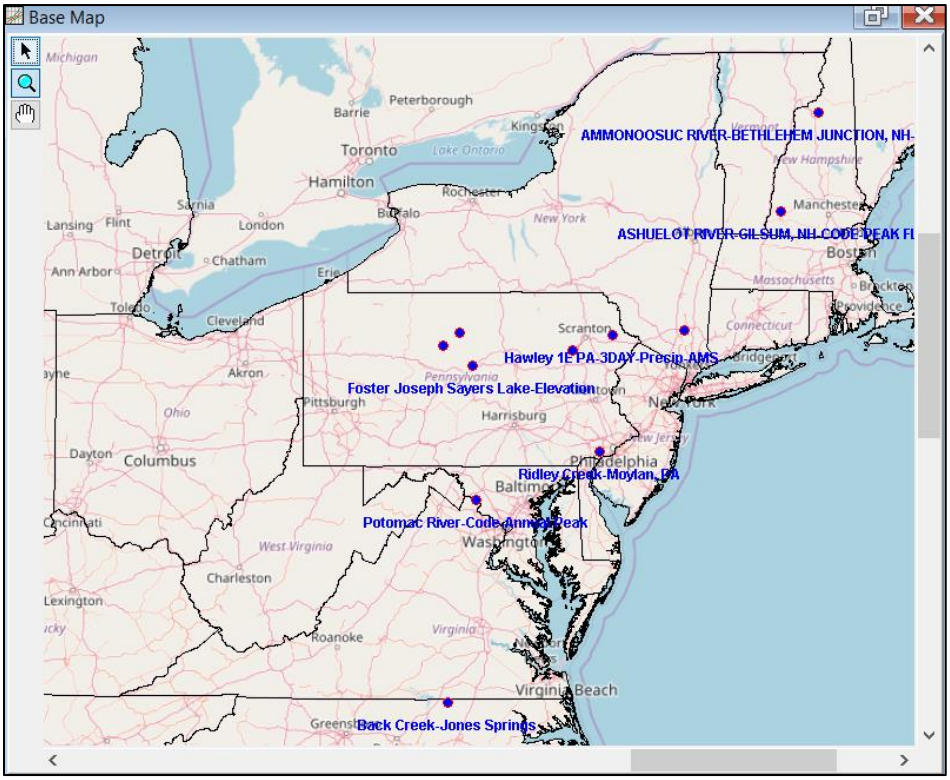


Figure 3-11. Example Background Map.

Import, Enter, and Edit Data

Before any analyses can be performed, the user must bring data into the HEC-SSP study. For a peak flow frequency analysis following guidelines in Bulletin 17C, the data must consist of an annual maximum series of streamflow. To bring data into HEC-SSP, go to the **Data** menu and select **New**. This will bring up the **Data Importer** as shown in Figure 3-12.

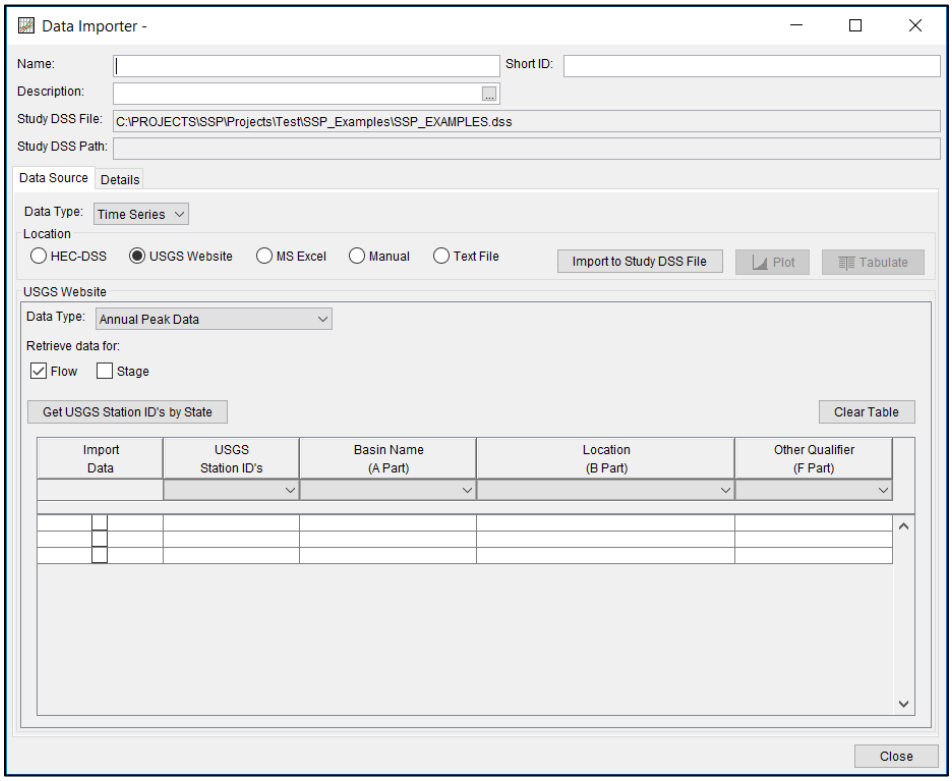


Figure 3-12. HEC-SSP Data Importer.

As shown in Figure 3-12, the Data Importer has fields for the Name, Short Identifier, and the Description of the data at the top of the window. Additionally, it lists the study DSS file name that the data will be stored in once it is brought into the study. The study DSS file is always labeled the same name as your study with the .dss file extension.

The Data Importer contains two tabs, **Data Source** and **Details**. The **Data Source** tab is shown first. This tab is used for selecting and defining a source for bringing data into the HEC-SSP study. Currently, there are five ways to bring data into an HEC-SSP study: import from another HEC-DSS file, import data from the USGS web site, import from a Microsoft Excel spreadsheet, manually enter the data into a table, and import the data from a text file. All of these methods will import data into the study DSS file.

For this example, importing data from the USGS website will be shown. For a complete description of the data importer see Chapter 4. To import data from the USGS website, first select the **USGS Website** option from the list of five options available in the Location panel. Next, select **Annual Peak Data** as the data type and make sure the **Flow** option is selected. The next step is to press the button labeled **Get USGS Station ID's by State**. When this button is pressed a window will appear (Figure 3-13) allowing the user to select a state from which to get data.

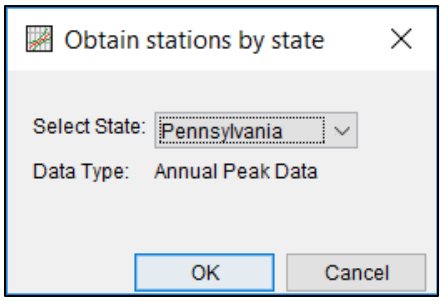


Figure 3-13. Window to Select a State for Downloading Data.

Once a state is selected, press the **OK** button and a list of the available gages from that state will appear in a pick list as shown in Figure 3-14. Check the boxes for all of the gages you would like to import and then press the **Import to Study DSS File** button. Once the import button is pressed, a process will begin during which the data will be downloaded from the USGS website and saved to the study DSS file. HEC-SSP will automatically name the data when importing multiple gages at one time. The USGS import process will download annual peak flow data, and the USGS data quality codes. The quality codes will be added as an addition object to the Data folder.

In addition to the data itself, any metadata that is available will be downloaded and stored with the data. The metadata can be viewed from the **Details** Tab on the Data Importer. Metadata can also be viewed or edited by opening the **Metadata Editor**. To open this editor, place the mouse on top of a data object in the Data folder and click the right mouse button. The shortcut menu contains an **Edit Metadata** option, as shown in Figure 3-15. The metadata editor is shown in Figure 3-16.

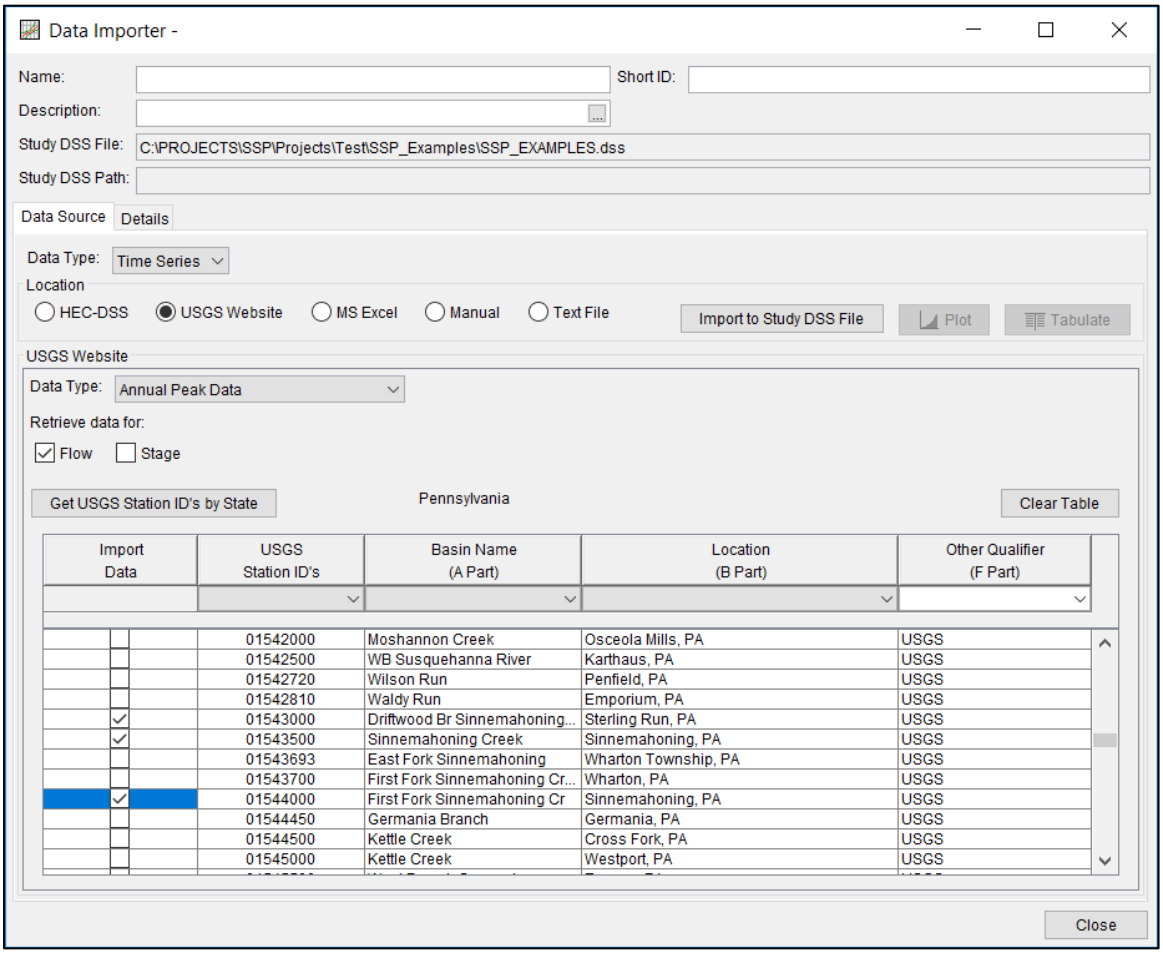


Figure 3-14. Example of Choosing Gages from a USGS State List to Import.

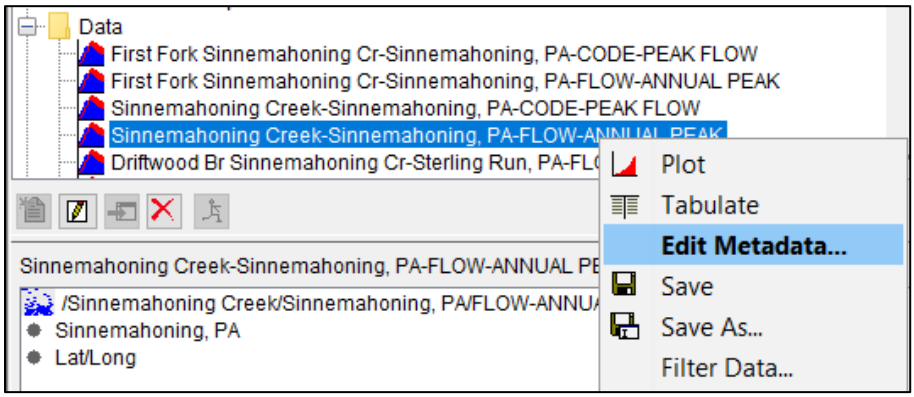


Figure 3-15. Open the Metadata Editor Using the Right Mouse Click Menu.

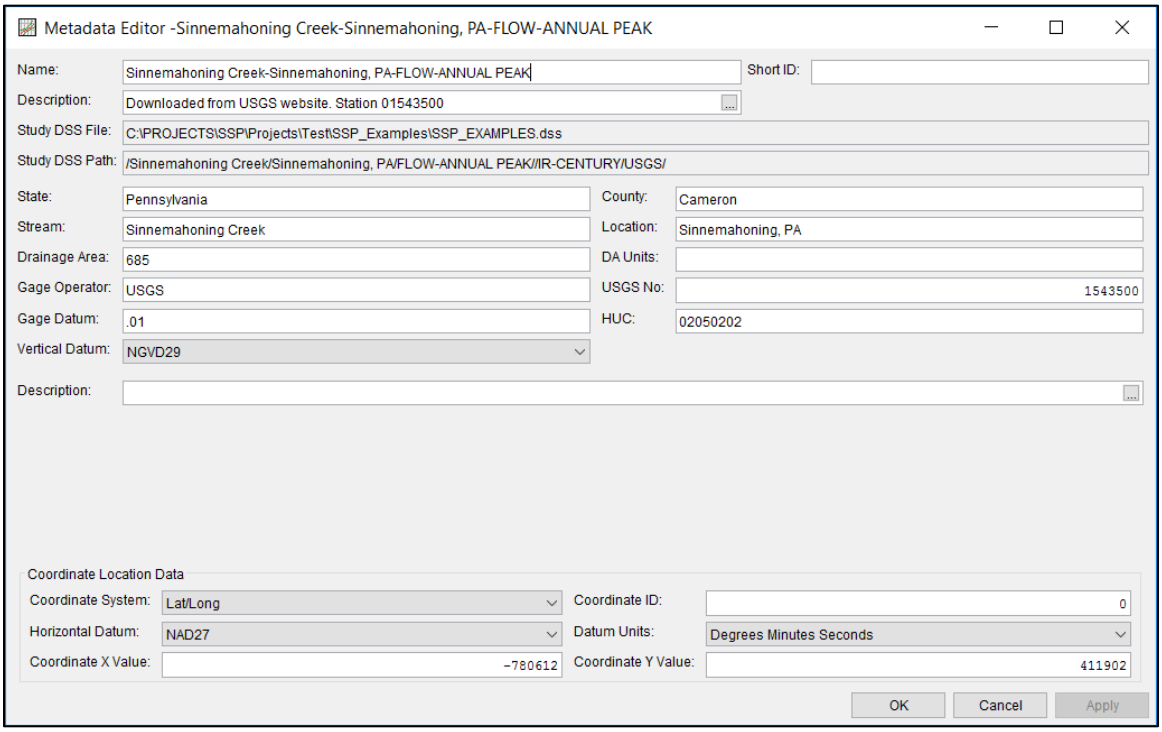


Figure 3-16. Metadata can be Viewed or Edited by Opening the Metadata Editor.

As shown in Figure 3-16, the metadata consists of the State, County, Stream, Location, Drainage Area, DA Units, Gage Operator, USGS Gage No., Gage Datum, HUC (Hydrologic Unit Code), Vertical Datum, and a description field. Additionally, the coordinate location of the data is shown. The coordinate location consists of Coordinate System, Coordinate ID, Horizontal Datum, Datum Units, Coordinate X Value, and Coordinate Y Value. Most of the USGS data is retrieved with the Latitude/Longitude coordinate system as shown in the example. In addition to editing the metadata, the Metadata Editor allows the user to change the name of the data, enter a short identifier, and enter a longer description.

If the metadata does not download automatically, the user has the option to enter any of the information by hand. Metadata will only be automatically generated when downloading data from the USGS website. Therefore, entering the metadata is required if the user wants it to be carried along with the study.

After the data is imported into the study, the user can select any one of the gages in the Data folder and **Plot** or **Tabulate** the data. The plot and tabulate options are available from the Data menu and from a shortcut menu that opens by clicking the right mouse button when the pointer is located on top of the gage object in the Data folder. If you select the **Plot** option, you will get a plot of the peak flow data for that gage. If you

select the **Tabulate** option, you will get a table containing the data. Data values can be edited within the table; however, the editing mode must be turned on. To turn on editing, select the **Edit→Allow Editing** menu option. Use the **File→Save** or **File→Save As** menu option to save the data when you are satisfied with edits.

If the data has coordinate location information, it will then be plotted on top of the background maps. The software will convert the coordinates of the point data to the default coordinate system of the base map. The user can interact with the plotted points by right clicking on the gage icon in the map and a shortcut menu will appear as shown. The user has the option to edit the metadata, plot, tabulate, rename, or delete the data.

Performing the Flow Frequency Analysis

To perform a Bulletin 17 Analysis, go to the **Analysis** menu and select **New → Bulletin 17 Flow Frequency**. This will bring up an empty Bulletin 17 editor. As shown in Figure 3-17, the user must enter a name for the analysis, a description (optional), and select a flow data set (gage data stored in study DSS file). The DSS File Name and Report File are automatically filled in by the program. For now, the DSS File Name will be the study DSS file and the report file will have the same name as the analysis.

The editor window contains four tabs: General, Options, EMA Data, and Tabular Results. The **General** tab contains settings for Generalized Skew, Expected Probability Curve, Method for Computing Statistics and Confidence Limits, Plotting Positions, Confidence limits, a Time Window Modification, and Low Outlier Test. Default settings are already established for each of the options on the General tab; however, the user can change the default settings.

The **Options** tab contains information on Low Outlier Threshold, Historic Period Data (only used with Bulletin 17B procedures), and Output Frequency Ordinates. These options are not required for most analyses but may be necessary depending upon the data.

The **EMA Data** tab contains information specifically related to flow frequency analyses that make use of the procedures contained within Bulletin 17C, which uses the Expected Moments Algorithm (EMA) to compute flow frequency and confidence limits for the associated flow data set. A detailed description of each of the Bulletin 17C settings and options can be found in Chapter 5, Performing a Bulletin 17 Flow Frequency Analysis. The **EMA Data** tab is shown in Figure 3-18.

Once all of the settings and options have been selected, the user can click the **Compute** button to have the computations performed. When the

computations have finished a message window will open stating **Compute Complete**. Press the **OK** button on the message window to close the window. Once the computations have finished the user can begin to look at output.

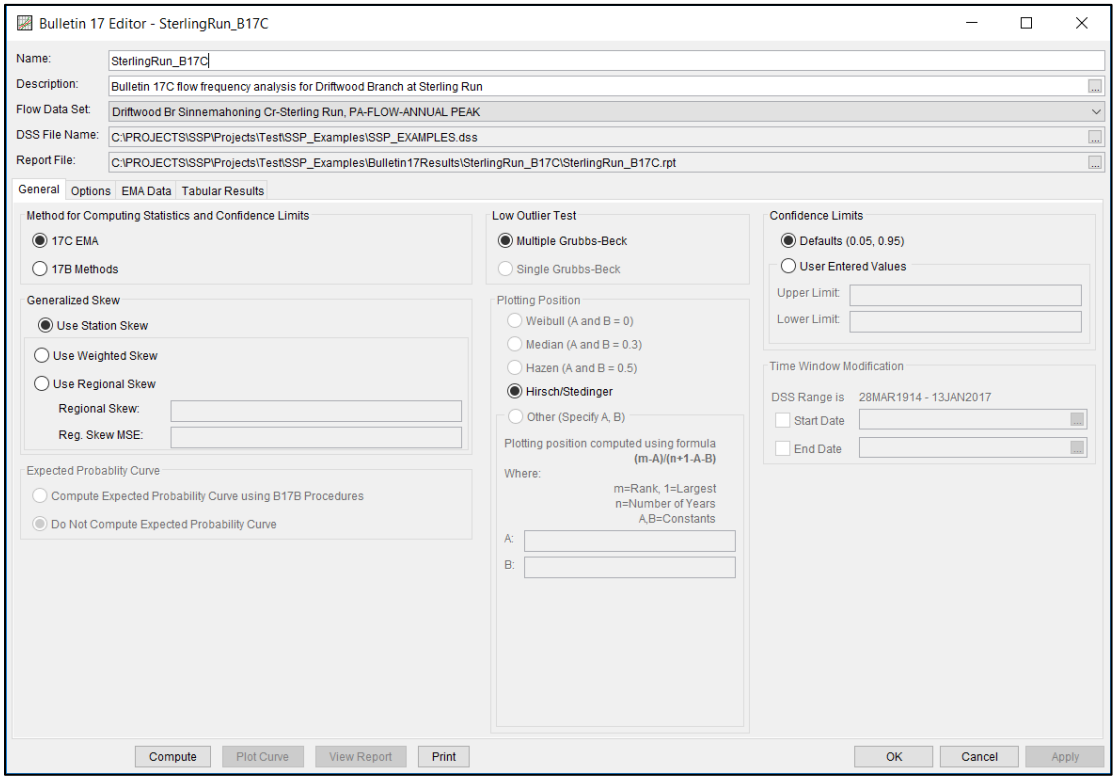


Figure 3-17. Bulletin 17 Flow Frequency Analysis General Tab.

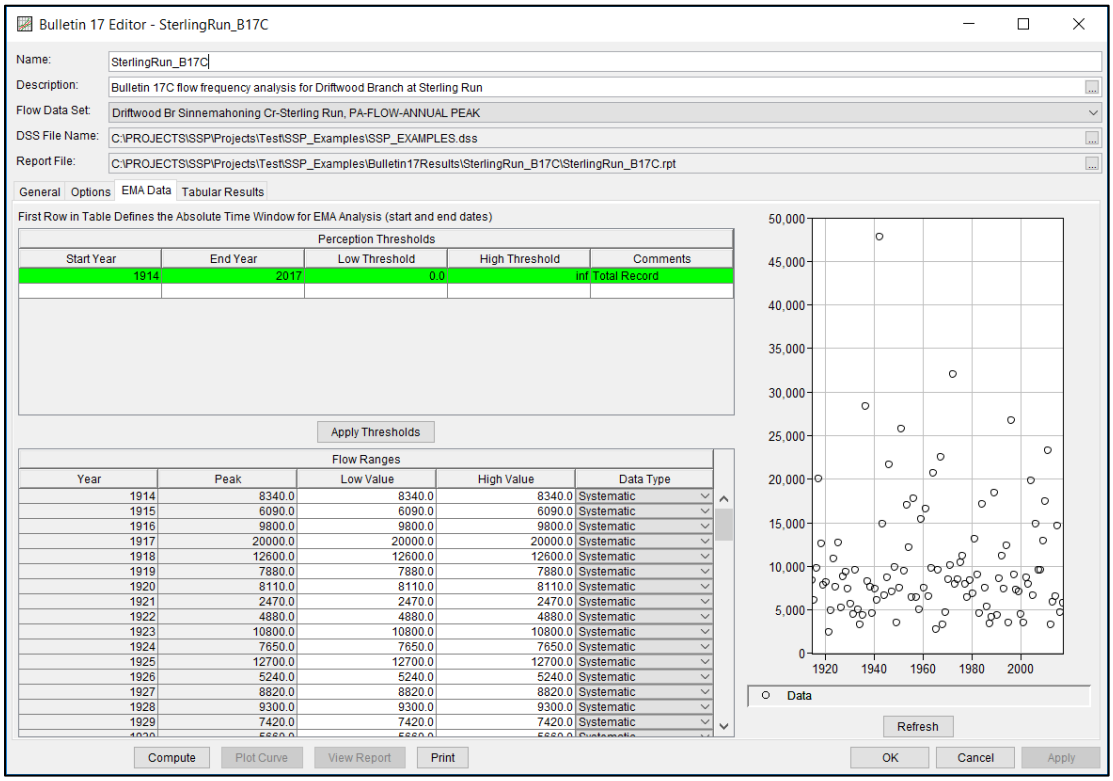


Figure 3-18. Bulletin 17 Flow Frequency Analysis EMA Data Tab.

Viewing and Printing Results

Tabular output can be viewed by selecting the **Tabular Results** tab. When this tab is pressed, a set of tables will appear as shown in Figure 3-19. The primary table on the **Tabular Results** tab consists of data for each frequency ordinate specified on the **Options** tab: the computed flow frequency (i.e. median) curve, the expected probability (i.e. mean) curve (if enabled on the **General** tab), variance (if using Bulletin 17C procedures), and the confidence limits for the two percentiles specified on the **General** tab. The second table (bottom left) contains parameters about the fitted Log Pearson Type III distribution, such as the mean, standard deviation, station skew, regional skew, weighted skew, and the adopted skew of the analysis. The third table (bottom right) contains the number of historic events, high outliers (if using Bulletin 17B procedures), low outliers and zero flows, missing flows, systematic events, the historic period, and the equivalent record length (if using Bulletin 17C procedures). The table can be sent to the printer by pressing the **Print** button at the bottom of the analysis window. The user can control the number of decimal digits shown in the result tables and in reports. Select **Options** from the **Tools** menu and then open the **Results** tab, as shown in Figure 3-19.

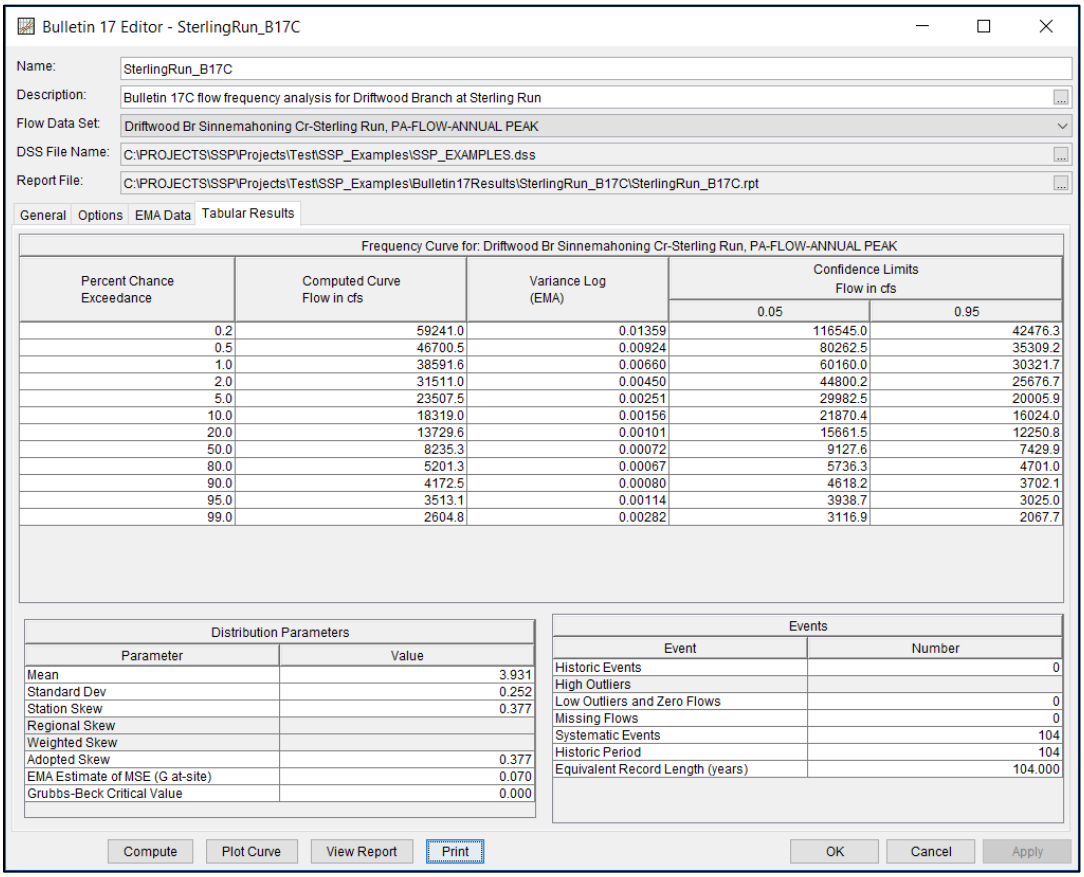


Figure 3-19. Bulletin 17 Flow Frequency Analysis Tabular Results Tab.

Graphical output can be obtained by pressing the **Plot Curve** button at the bottom of the analysis editor. When this button is pressed, a plot will appear like the one in Figure 3-20. This plot contains the computed frequency curve, the expected probability adjusted curve (if enabled on the **General** tab), the confidence limits, and the data points plotted using the plotting position method chosen on the **General** tab. Additionally, a plot title is listed at the top. The plot title is, by default, the user-defined name of the analysis. The user can modify the plot properties by selecting the **Edit→Plot Properties** menu option. A plot properties window will open that lets the user change the line style for each data type, change the axis labels, modify the plot title, and edit other plot properties. The user can also edit line styles by placing the mouse on top of the line or data point in the plot or legend and clicking the right mouse button and selecting **Edit Properties**. Individual curves can be highlighted by left clicking on an item within the legend. The plot can be printed or sent to the windows clipboard by using the **Print** and **Copy to Clipboard** options found under the **File** menu.

Marker lines and/or points can be added to a plot by placing the mouse anywhere in the plot area and clicking the right mouse button. Then select the **Add Marker** option to add a line or **Add Marker Point** to add a point. Draw properties can be edited for these user-defined lines and points by placing the mouse on top of the point or line and clicking the right mouse button. Then select the **Edit Properties** option in the shortcut menu.

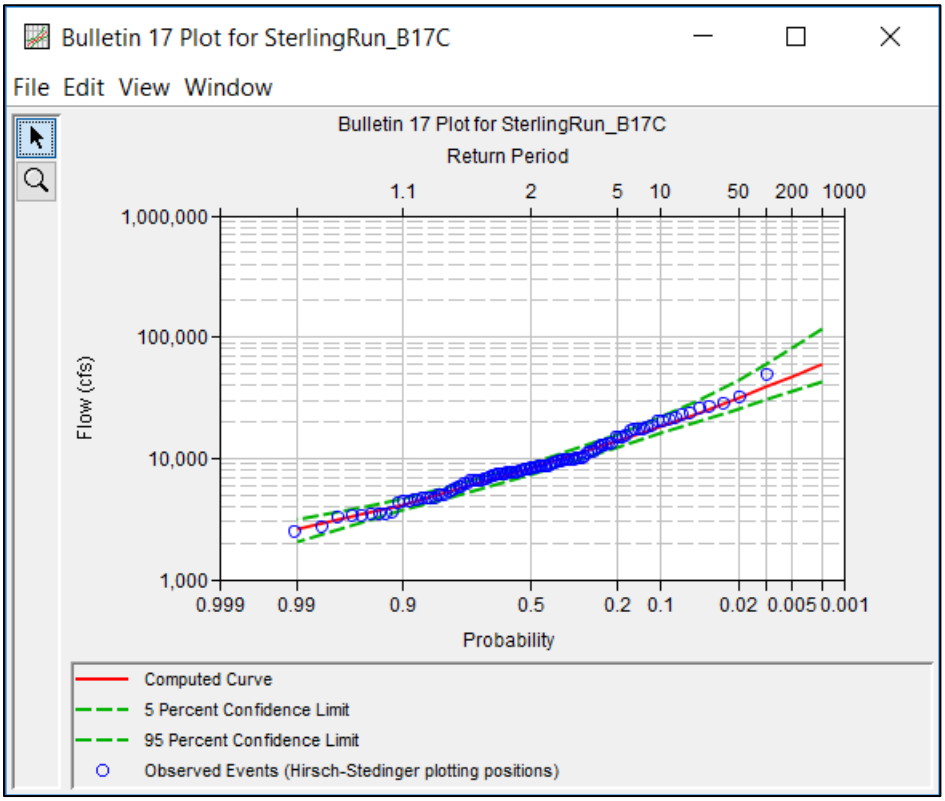


Figure 3-20. Flow Frequency Curve Plot.

The final piece of output available from a flow frequency analysis is a text report file. The report file lists the user settings, the input data, plotting positions of the observed data, intermediate results, each of the various statistical tests performed (i.e. high and low outliers, historical data, etc.), and the final results. This file is often useful for understanding how the final frequency curve was computed. Press the **View Report** button at the bottom of the analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 3-21.

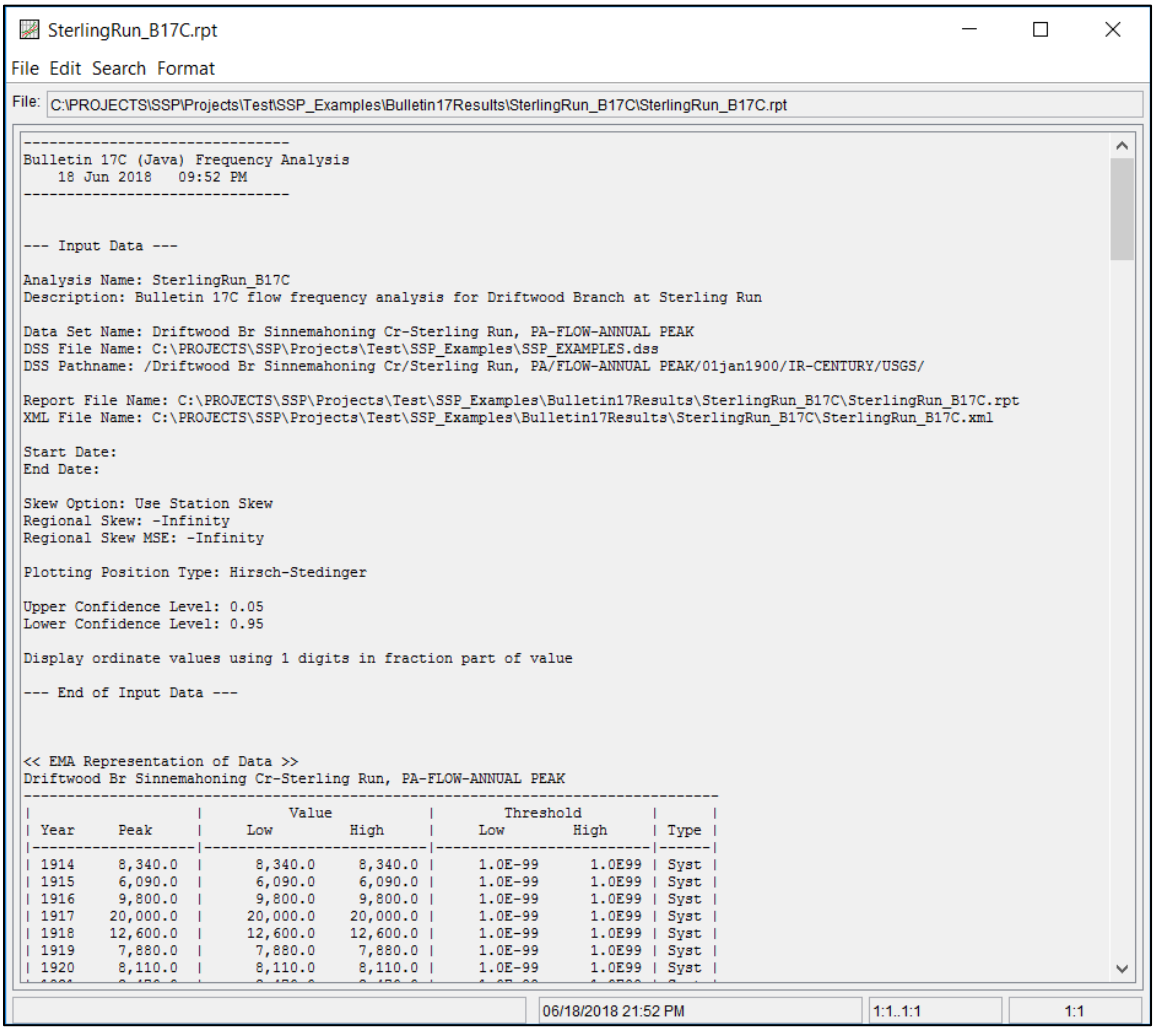


Figure 3-21. Report File from Bulletin 17 Frequency Analysis.

CHAPTER 4

Using the HEC-SSP Data Importer

The HEC-SSP Data Importer is used to import, enter, and view data and the corresponding metadata used in an HEC-SSP study. The current version of HEC-SSP can be used to import irregular data (i.e. annual peak flow data), regular data (i.e. hourly reservoir stages), and paired data (i.e. stage vs. flow).

Contents

- Developing a New Data Set
- Importing Data from an HEC-DSS File
- Importing Data from the USGS Website
- Importing Data from an Excel Spreadsheet
- Entering Data Manually
- Entering Data from a Text File
- Metadata
- Plotting and Tabulating Data

Developing a New Data Set

Before any analyses can be performed in HEC-SSP, the user must import or enter data into the study. Importing, entering, and viewing data is accomplished in the **Data Importer**. To open the data importer, go to the **Data** menu and select **New** from the list of options, which will bring up a data importer as shown in Figure 4-1.

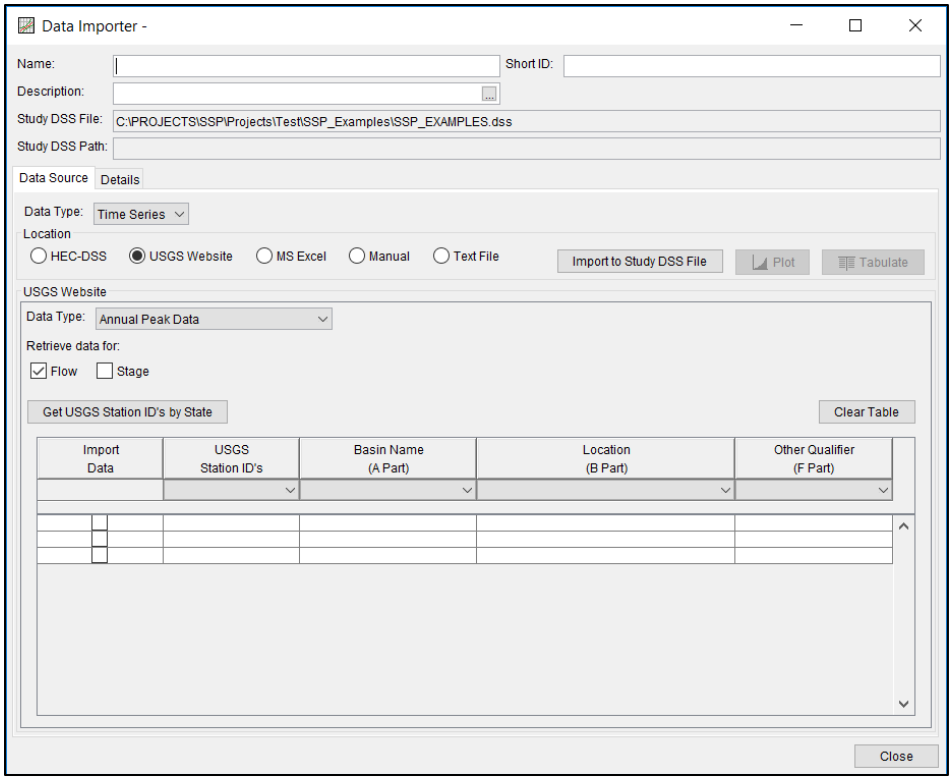


Figure 4-1. HEC-SSP Data Importer.

At the top of the Data Importer, the user can enter a **Name** for the new data set. Optionally, the user can enter a short identifier (limited to 16 characters) and a **Description** of the data set. The study DSS file name is provided. The DSS file is used for storing the data for the study. The user does not have to enter a name when importing or manually entering data. The program will automatically name the data using USGS names or HEC-DSS pathname parts. If a **Name** is entered then it will be combined with the USGS gage name or HEC-DSS pathname parts to create a unique name. The user can rename a data set by selecting the data set in the study explorer and clicking the right mouse button. A shortcut menu should open with a **Rename** menu option. The **Data** menu also contains a **Rename** menu option; however, the data set must be selected in the study explorer before this menu option is active.

The Data Importer contains two main tabs, **Data Source** and **Details**. The **Data Source** tab is used for importing or entering data manually while the **Details** tab is used to describe the data (i.e. metadata). The **Data Source** tab contains five options for getting data into the study DSS file: Importing from an existing HEC-DSS file, importing from the USGS Website, importing from an Excel spreadsheet, entering the data manually, and importing from a text file.

Importing Data from an HEC-DSS File

To import data from an HEC-DSS file into the HEC-SSP study DSS file, first select the **HEC-DSS** radio button on the data importer. Selecting **HEC-DSS** will change the view of the Data Importer to look like Figure 4-2.

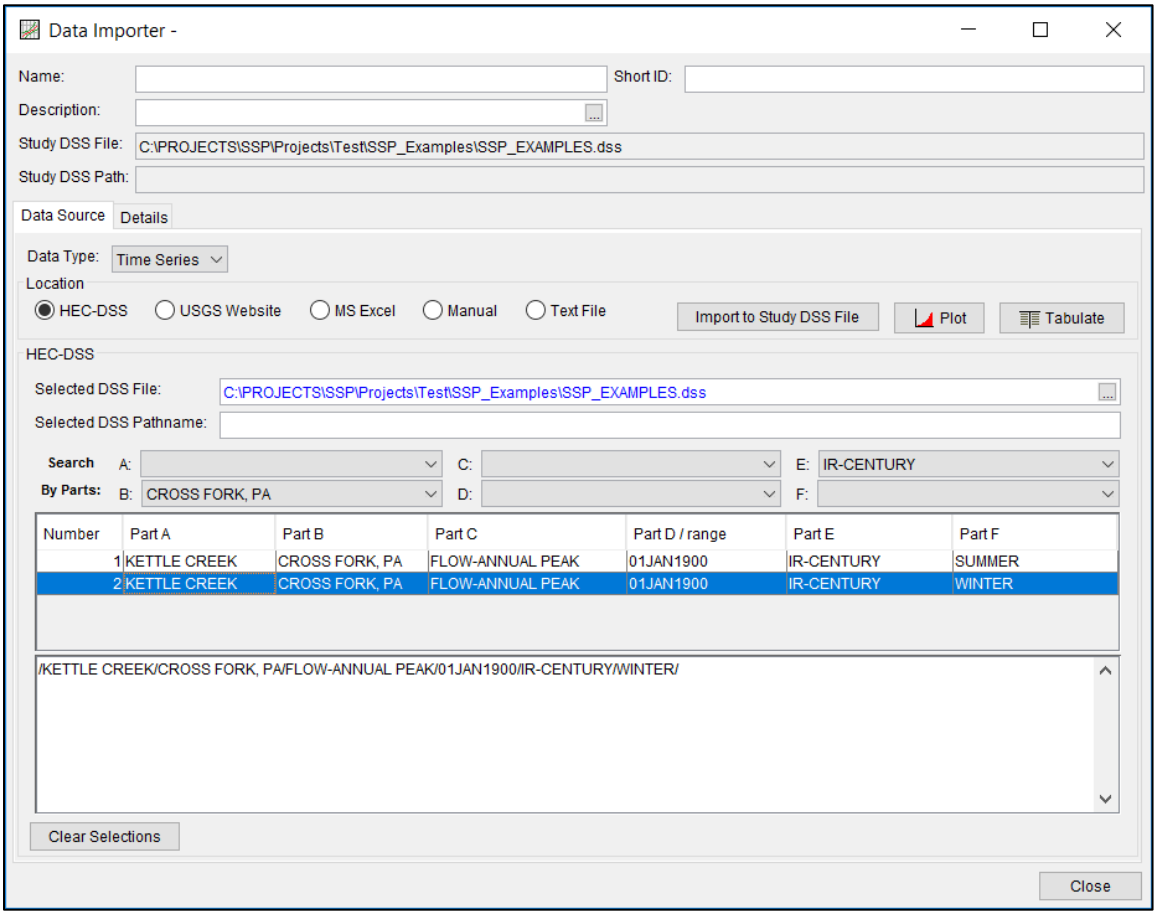


Figure 4-2. Data Importer with HEC-DSS Import Option.

As shown in Figure 4-2, the user first selects a DSS file to import from by typing the path and name or by choosing the file browser at the end of the input field. Once a DSS file is selected, the table of pathnames will be

filled with the records that are contained in that DSS file. The user can reduce the number of listed pathnames by selecting pathname parts to filter in the pathname part selection area just above the table. Any pathname part can be used to filter the list down to a more manageable number of pathnames to select from. The user can then select pathnames to import by double clicking on one or more of the listed pathnames in the table. Each selected pathname will show up in the list below the table. Once the user has selected all of the pathnames that they want to import, pressing the **Import to Study DSS File** button enacts the import process. An HEC-SSP data set will be developed for each pathname that was selected.

Importing Data from the USGS Website

The second way to import data into HEC-SSP is to use the **USGS Website** option. When this option is selected, the data importer will look like Figure 4-3.

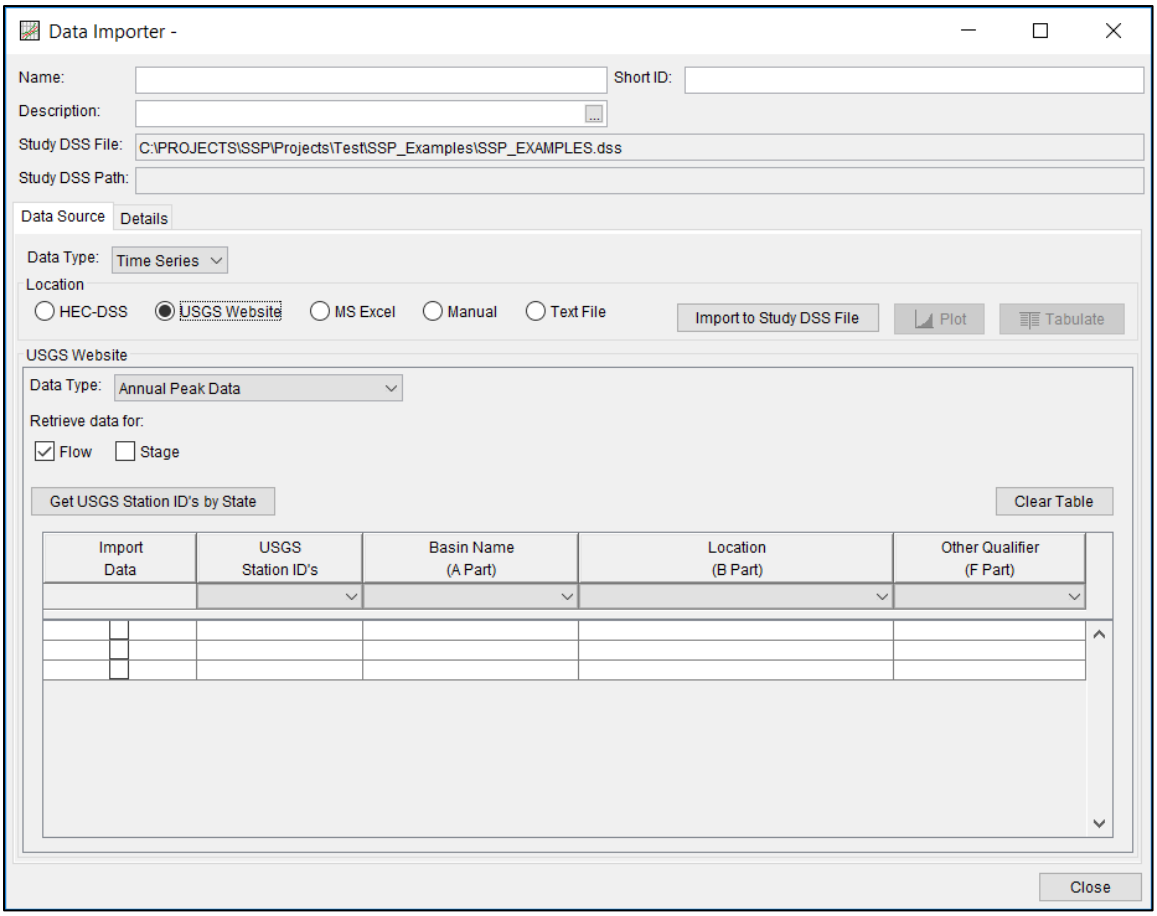


Figure 4-3. HEC-SSP Data Importer with USGS Website Import Option.

When using this data import method, multiple data type choices are provided including Daily, Instantaneous (i.e. 1 hour), Real Time (i.e. the previous 120 days from the current date), and Annual Peak Data. Both **Flow** and **Stage** data can be searched and/or imported. If the Daily or Instantaneous options are selected, a time zone for the data must also be specified. The data will not be converted from one time zone to another; this option merely designates the assumed time zone for the imported data.

When downloading Daily or Instantaneous data from the USGS website, a time window must be provided. As a convenience, a **Retrieve Period of Record** selection is available for use. When this option is selected, the Data Importer will attempt to download the entire period of record available from the USGS website. If the dataset of interest does not include data prior to 01Jan1900, this option will allow for the entire available period of record to be downloaded without entering a start/end date. If the dataset of interest includes data prior to 01Jan1900, a manual time window will need to be entered due to USGS website restrictions. When downloading Real Time data, the number of days prior to the current date must be specified (i.e. Days Back). A value between 1 and 120 days must be entered.

Users can also query the USGS website to find all available stations within one or more states by clicking the **Get USGS Station ID's by State** button. Multiple state searches can be accomplished by clicking this button, selecting a state, clicking **OK**, clicking this button again, searching for an additional state, clicking **OK**, and repeating as many times as necessary. Clicking this button will bring up a window that allows the user to select a state in which to acquire data, as shown in Figure 4-4.

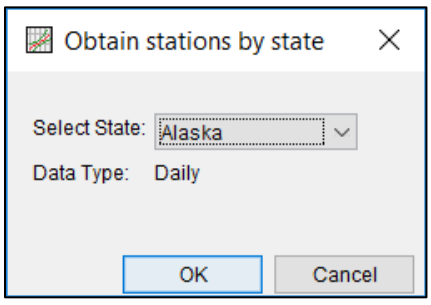


Figure 4-4. Window to Select a State for Importing USGS Data.

Once the user selects a state and presses the **OK** button, a process will begin in which all of the gage locations for that state will be downloaded from the USGS website. A listing of all the gages for that state will then be displayed in the table at the bottom of the data importer. The user can filter the resulting list of gages to a smaller number by using the filter drop down boxes at the top of the table.

An example of the data importer with a list of USGS gages is shown in Figure 4-5. Four state searches were performed for Colorado, Utah, Arizona, and California. The resulting gages were then filtered using a B-part of "Colorado River" to narrow down all of the available gages to only those along the Colorado River within the four previously mentioned states. Additionally, the asterisk (*) can be used as a wildcard to serach for all strings that contain what has been typed. For instance, if the user typed "Colorado R*", a result similar to Figure 4-5 would be produced.

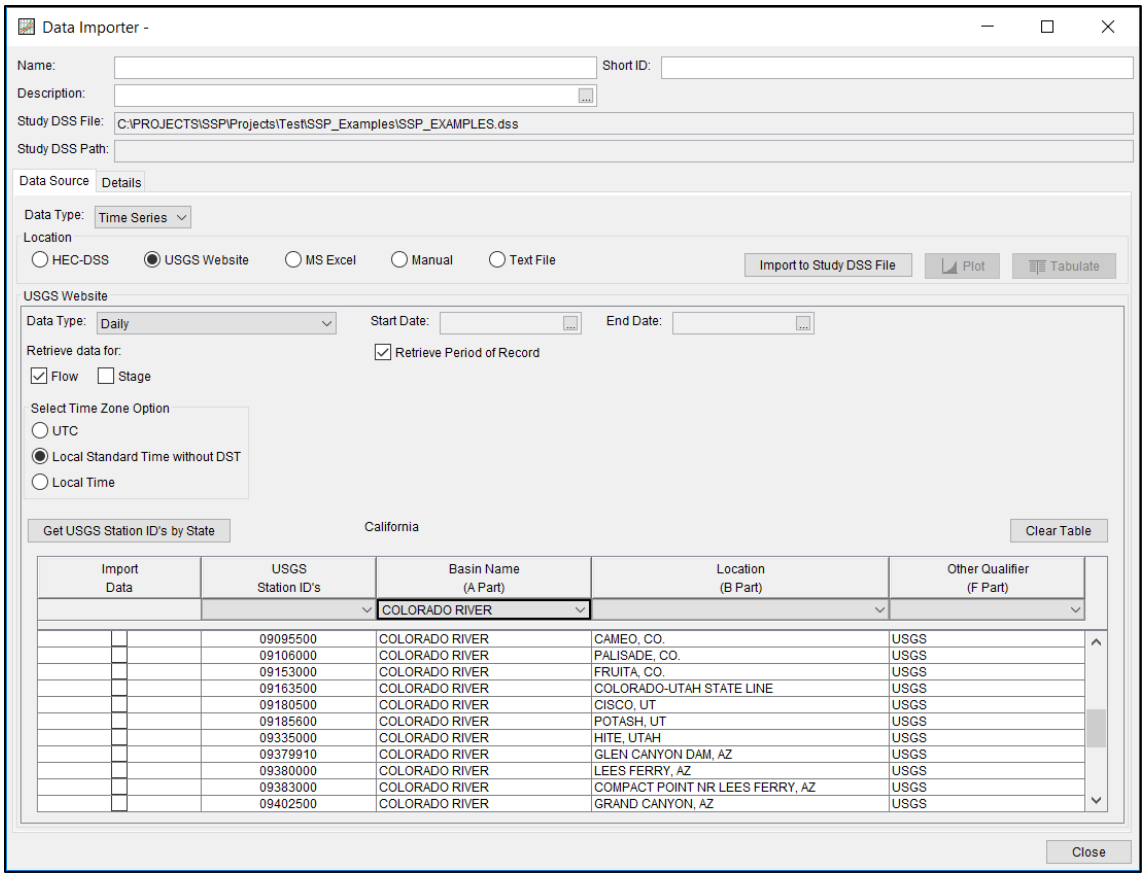


Figure 4-5. Data Importer with USGS Gages Listed in Table.

To select a gage for importing, check the box in the left hand column for each gage location that is to be imported. After all of the desired locations are selected, press the **Import to DSS File** button to import the data into the study DSS file. Pressing this button will start a process of downloading data from the USGS website. For each selected location, the software will download the Data Quality Codes if they are available and the **Annual Peak Data** type is selected. If/when available, the program will issue a message that data quality codes are available and adds the codes as an additional data set to the Data folder.

Warning: all data downloaded from the USGS website should be reviewed to ensure it is appropriate before any analyses are performed on the data. Some data stored on the USGS website are estimated, not measured. The user should check the data on the USGS website and be aware of the quality of all the data before using it. When the **Annual Peak Data** option is selected and quality codes are available, HEC-SSP will import the both the annual peak flow and stage quality codes (the program does not import quality codes for daily, instantaneous, or real time data). A description of the quality codes for annual peak flows is contained in Table 4-1 and a description of the quality codes for annual peak stages are contained in Table 4-2.

Table 4-1. Quality Codes for USGS Annual Peak Flow Data.

Code	Description
1	Discharge is a Maximum Daily Average
2	Discharge is an Estimate
3	Discharge affected by Dam Failure
4	Discharge less than indicated value which is Minimum Recordable Discharge at this site
5	Discharge affected to unknown degree by Regulation or Diversion
6	Discharge affected by Regulation or Diversion
7	Discharge is an Historic Peak
8	Discharge actually greater than indicated value
9	Discharge due to Snowmelt, Hurricane, Ice-Jam or Debris Dam breakup
A	Year of occurrence is unknown or not exact
B	Month or Day of occurrence is unknown or not exact
C	All or part of the record affected by Urbanization, Mining, Agricultural changes, Channelization, or other
D	Base Discharge changed during this year
E	Only Annual Maximum Peak available for this year

Table 4-2. Quality Codes for USGS Annual Peak Stage Data.

Code	Description
1	Gage height affected by backwater
2	Gage height not the maximum for the year
3	Gage height at different site and(or) datum
4	Gage height below minimum recordable elevation
5	Gage height is an estimate
6	Gage datum changed during this year

Importing Data from an Excel Spreadsheet

The third option for importing data into HEC-SSP is **MS Excel** (*.xlsx and *.xls files). When this option is selected, the data importer will change as shown in Figure 4-6. To open an Excel spreadsheet, select the browse button, ..., at the end of the **Excel File** field. Once an Excel file is selected, a data view window will open showing the data contained in the selected spreadsheet. An example Excel® Data Viewer is shown in Figure 4-7.

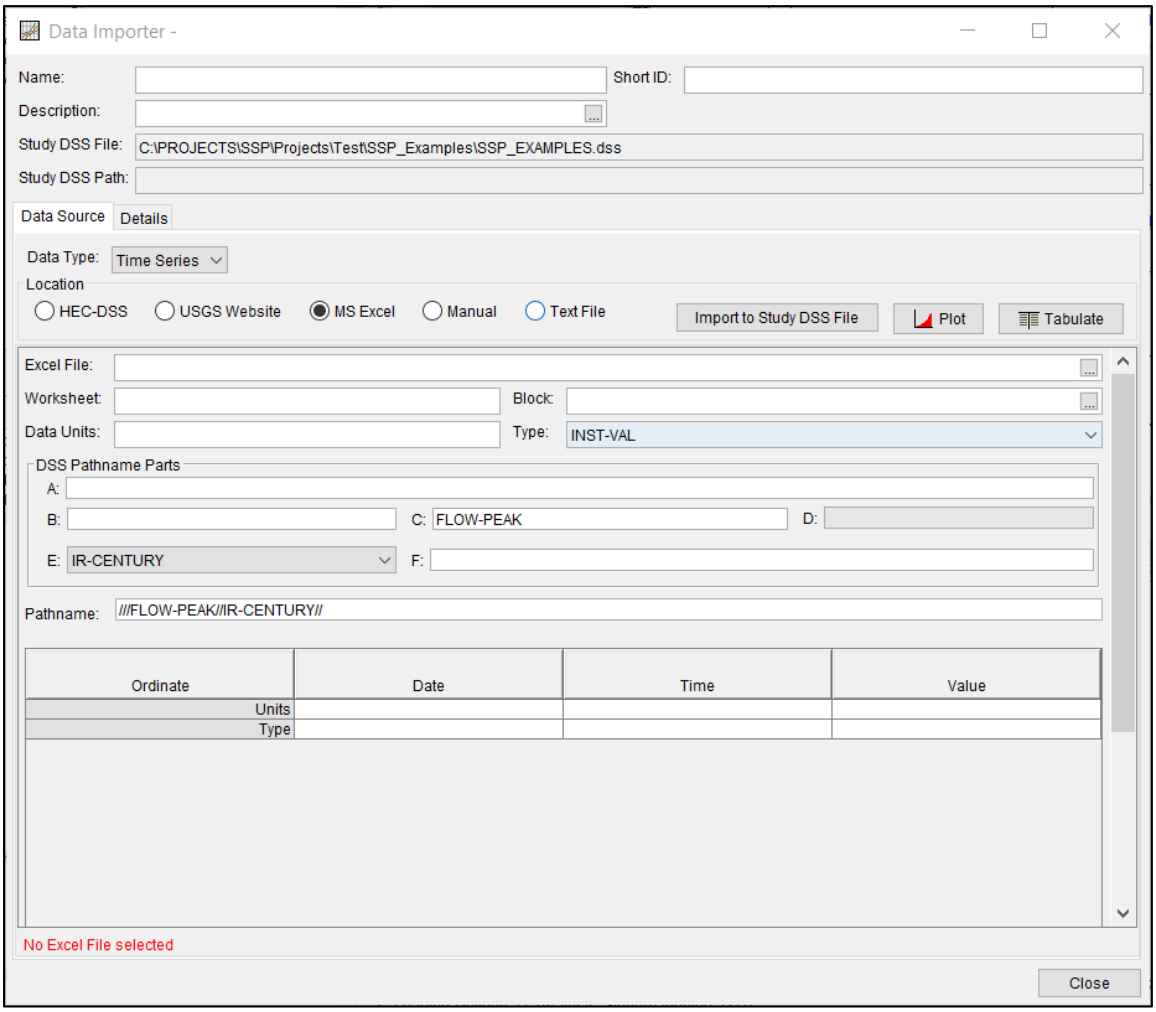


Figure 4-6. Data Importer with MS Excel Import Option Selected.

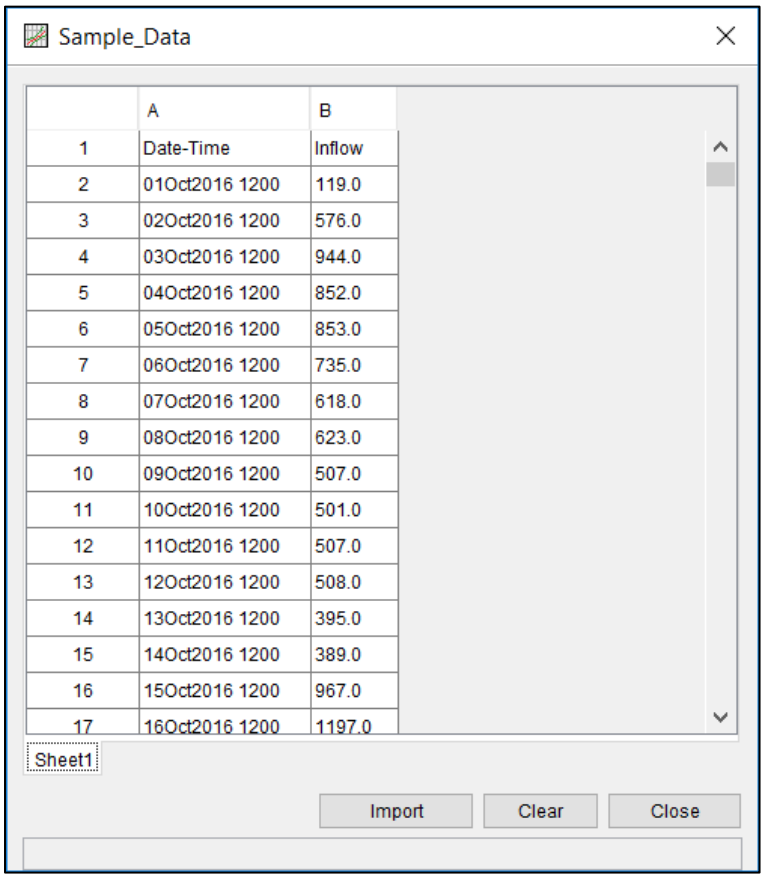


Figure 4-7. Example Excel Data Viewer.

The date and data values to be imported into the study must be selected. This can be accomplished in one of the two following ways:

1. Selecting the array of values by holding the shift key and left clicking. Only the dates, times, and data to be imported should be selected, not the column headings. If there are column headings, they must be identified and excluded from the import process. The **Right Click | Skip Row(s)** menu option can be used to identify and skip a row of column headings, as shown in Figure 4-8. To deselect an already selected cell, use the **Right Click | Deselect** option. Once the desired array of data has been selected, click **Import**. A window similar to Figure 4-12 will be presented. In this window, the DSS pathname parts, units, and data type must be defined. Once these parameters have been appropriately defined, click the **Import to Study DSS File** button to import the data.

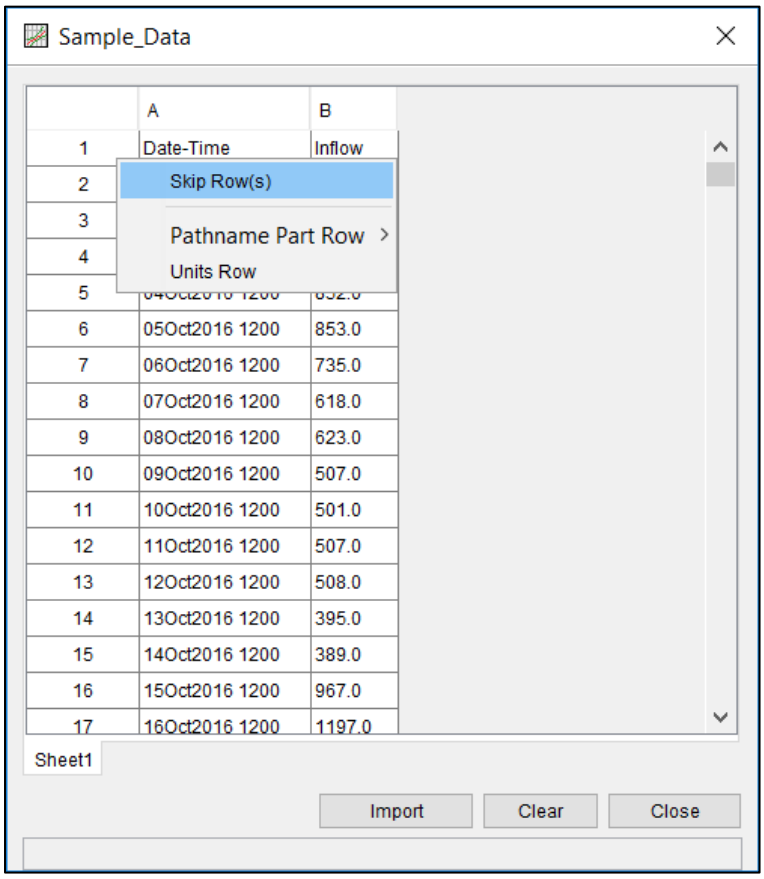


Figure 4-8. Skip Rows that Contain Headings for Excel Import.

2. Identify and set the date, time, and data columns. To identify the date and/or time column(s), place the mouse pointer on the column header, right click, and select a **Date – Time Column** option, as shown in Figure 4-9. Figure 4-9 shows that column 1 will be defined as the date and time column. The data viewer will highlight the date and time columns in green once they have been defined. To identify the data column, place the mouse pointer on the column header, right click, and select Set Data Column, as shown in Figure 4-10. Figure 4-10 shows that column 2 will be defined as the data column. After identifying and setting the data column, the data viewer will automatically close.

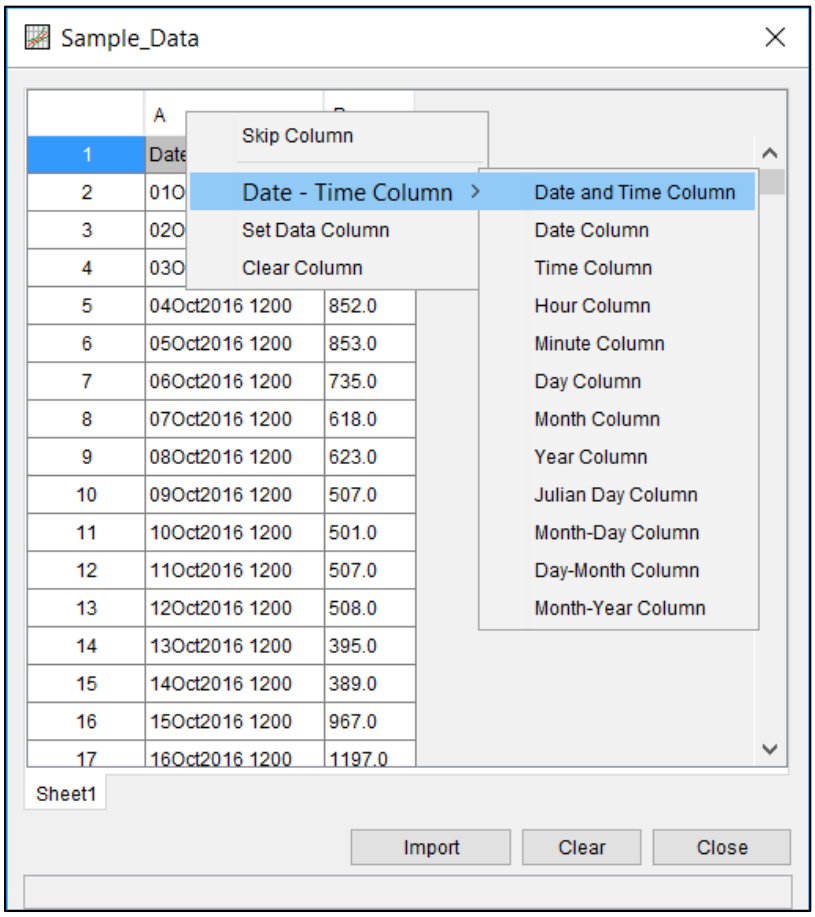


Figure 4-9. Identify and Set Date and Time Column(s) for Excel Import.

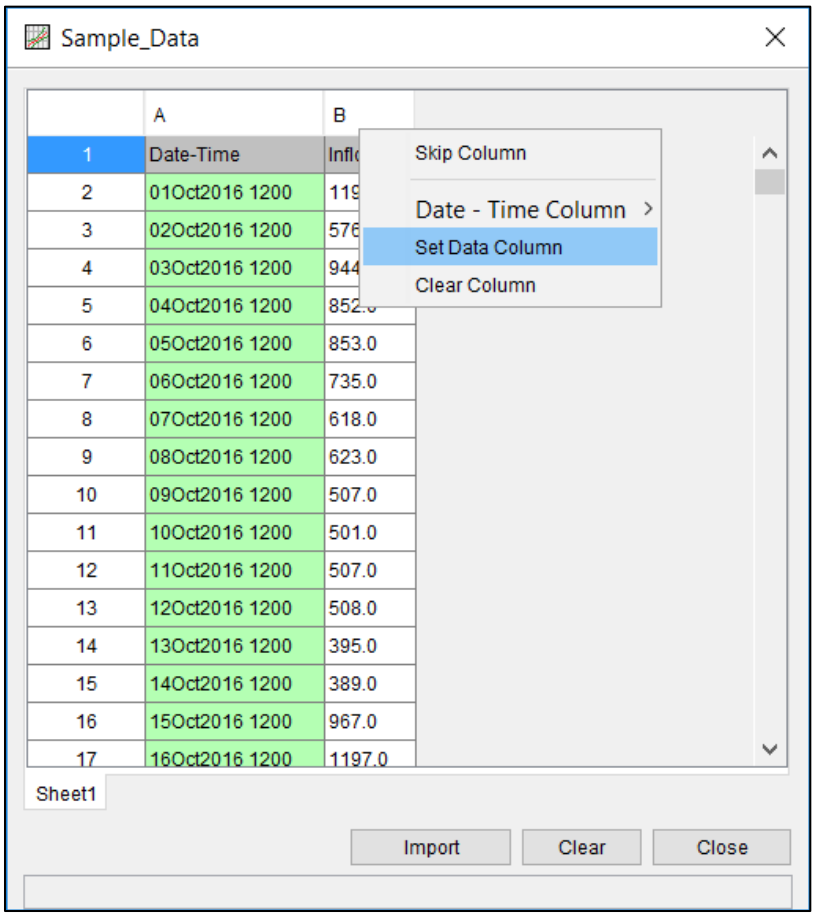


Figure 4-10. Identify and Set a Data Column for Excel Import.

In the subsequent window, the DSS pathname parts, units, and data type must be defined, as shown in Figure 4-11. Once these parameters have been appropriately defined, click the **Import Now** button.

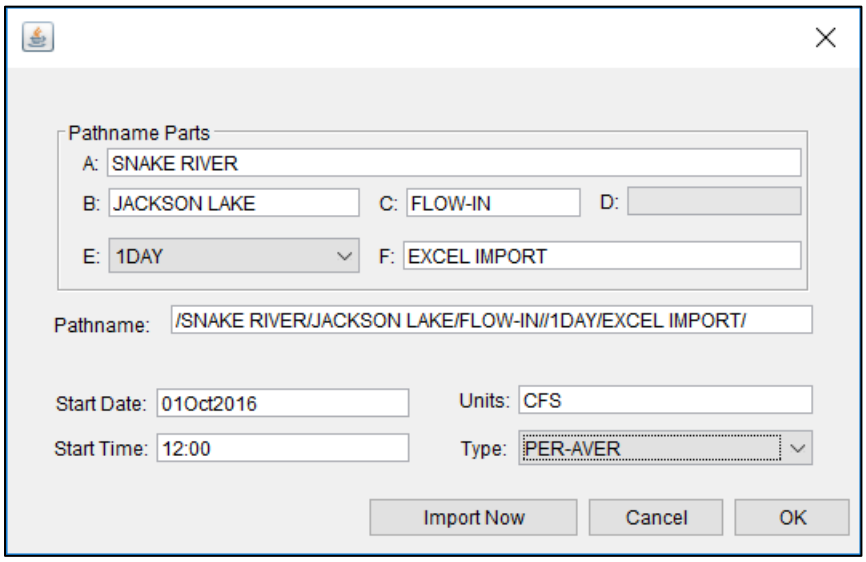


Figure 4-11. Editor for Defining the Data Properties for Excel Import.

Note: Use care when entering the A-, B-, C-, E-, and F-parts. These fields are meant to provide the user with a means to differentiate individual data sets. If more than one data set is created with a non-unique combination of A-, B-, C-, E-, and F-parts (i.e. they are all left blank), data may be overwritten/lost. This is analogous to using the Save As command and specifying a file name that is equivalent to an already-existing file.

A window similar to Figure 4-12 will be shown. Ensure that the DSS pathname parts, units, and data type are set correctly. Click the **Import to Study DSS File** button to finalize the data import process.

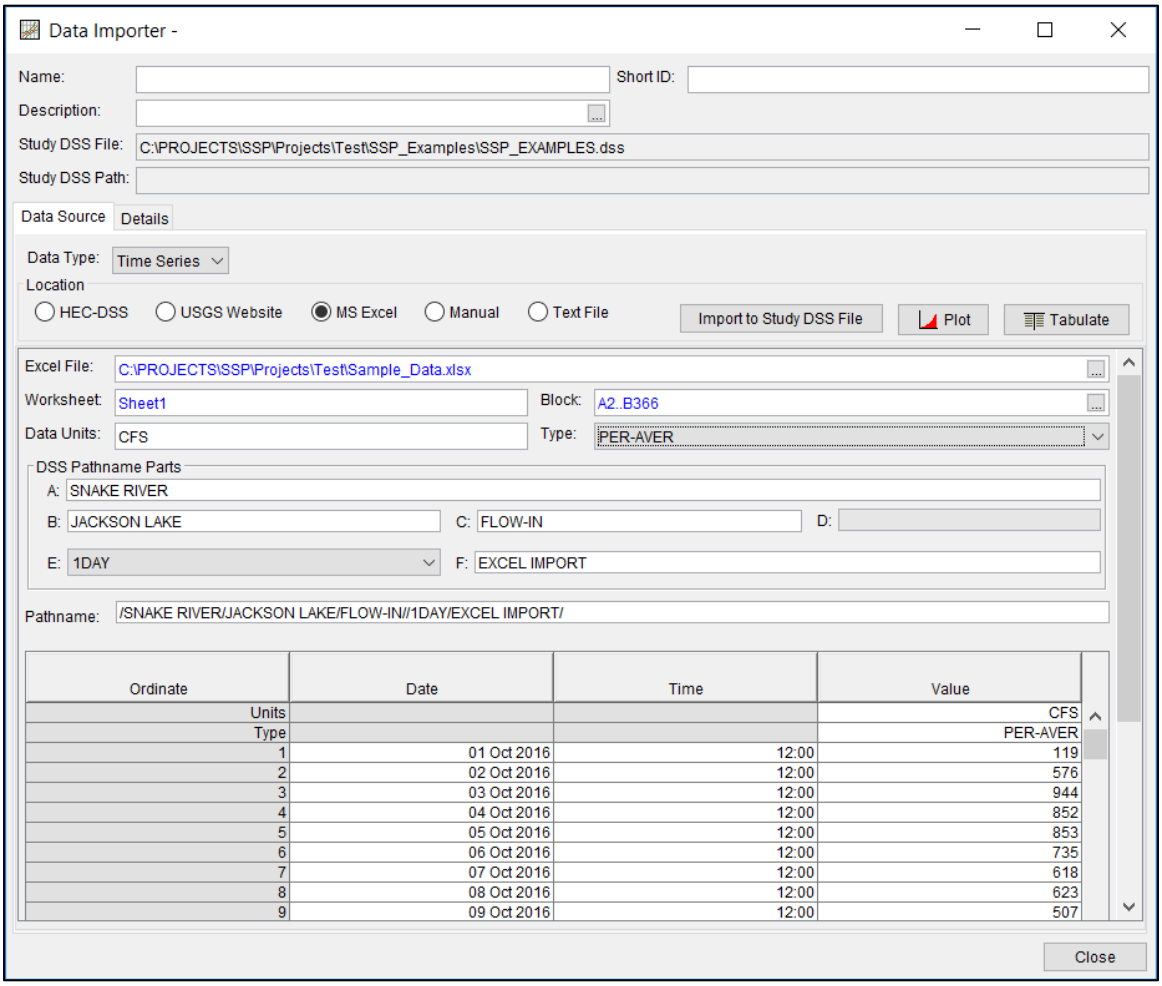


Figure 4-12. Defining DSS Pathname Parts, Units, and Data Type for Excel Import.

Entering Data Manually

Another option for getting data into the study is to enter the data manually. When the **Manual** option is selected, the window will change to what is shown in Figure 4-13.

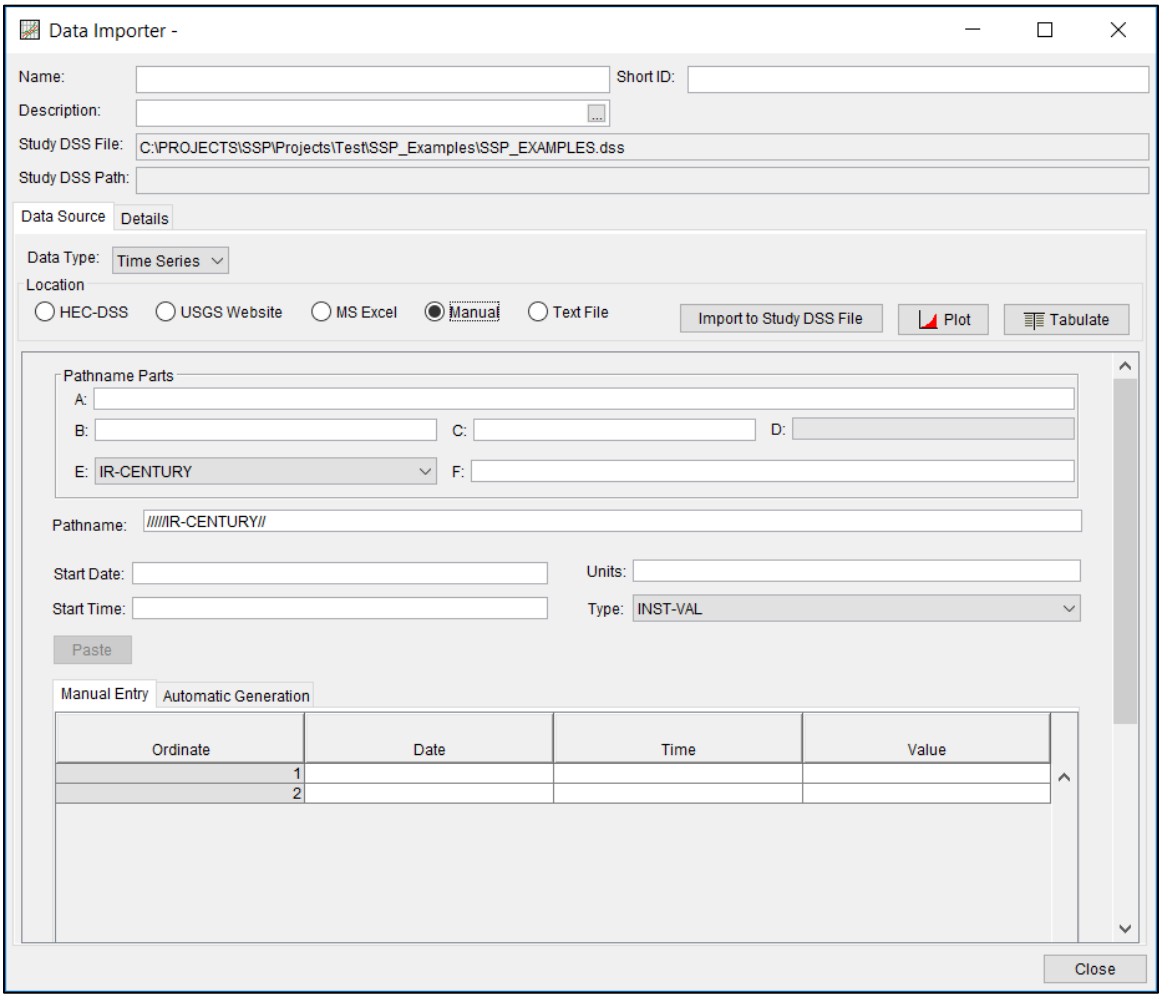


Figure 4-13. Data Importer with Manual Data Entry Option Selected.

To enter data manually, the user may enter a name for the data set at the top, along with a short identifier and a description (optional). However, a starting date and time must be entered. The units of the data must also be defined as well as the data type. Finally, the DSS pathname parts must be specified.

Note: Use care when entering the A-, B-, C-, E-, and F-parts. These fields are meant to provide the user with a means to differentiate individual data sets. If more than one data set is created with a non-unique combination of A-, B-, C-, E-, and F-parts (i.e. they are all left blank), data may be overwritten/lost. This is analogous to using the Save As command and specifying a file name that is equivalent to an already-existing file.

Once all of the data labeling is completed, the data can be entered into the table at the bottom of the editor. The user must enter the **Date**, **Time**, and

Value for each value to be entered. After a Date, Time, and Value are entered into a row, a new row will be generated in the table when the user leaves the Value field.

Note: The data must be in a format of Date in the first column and Data in the second column. The date should be in the Day, Month, Year, Hour, Minute format (ddmmyyyy hhmm)

Another option for getting data into the table is to copy it to the clipboard and then paste it into the table. The table supports pasting data one column at a time or you can paste the date, time, and value information all at once. When all of the data are entered into the table, the user can click the **Import to Study DSS File** button and the data will be stored in the study DSS file.

Importing Data from a Text File

The fifth option for importing data into HEC-SSP is a comma delimited **Text File**. When this option is selected, the data importer will change as shown in Figure 4-14.

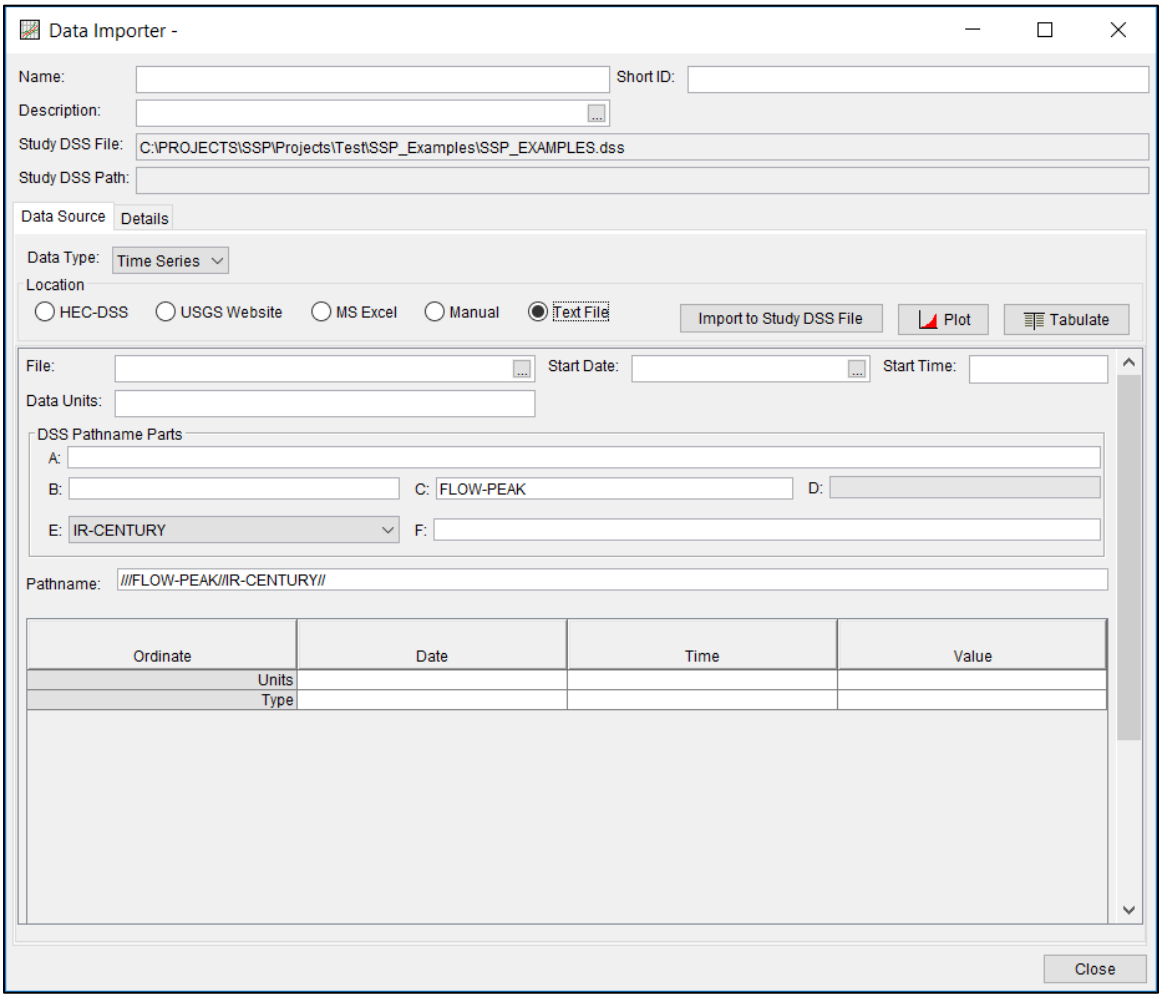


Figure 4-14. Data Importer with Text File Option Selected.

To import data from a comma delimited Text File, click the Select File button at the end of the **File** field, . Once a comma delimited text file is selected, a data view window will open showing the data contained in the selected file. An example text file data viewer is shown in Figure 4-15.

Note: The data must be in a format of Date in the first column and Data in the second column. The date should be in the Day, Month, Year format (i.e. ddmmyyyy). Time should be in the Hour, Minute format (i.e. hhmm). Optionally, the date and time can be defined together in Day, Month, Year, Hour, Minute format (i.e. ddmmmyyyy hhmm).

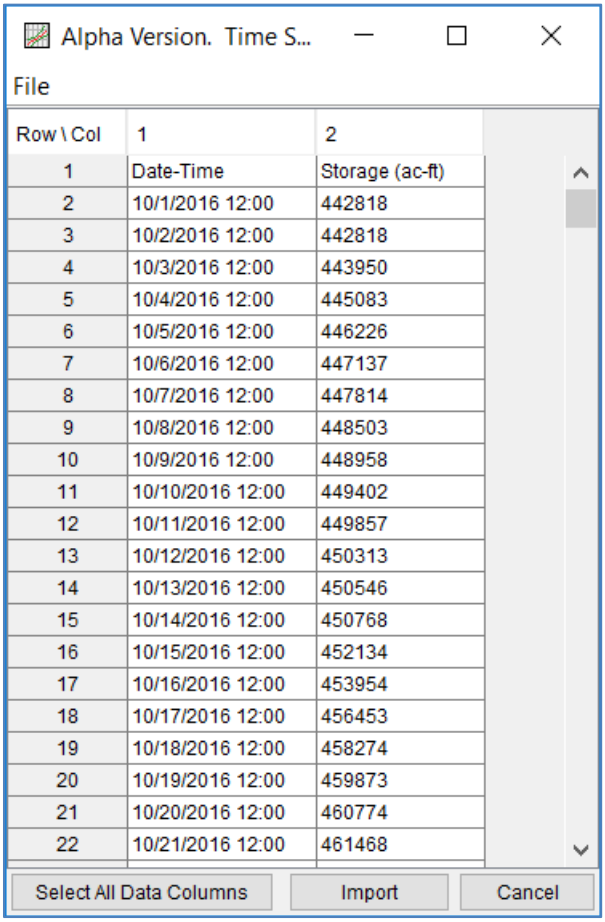


Figure 4-15. Example Text File Data Viewer for Text File Import.

The date and data values to be imported into the study must be selected. This can be accomplished in one of the two following ways:

3. Selecting the array of values by holding the shift key and left clicking. Only the dates, times, and data to be imported should be selected, not the column headings. If there are column headings, they must be identified and excluded from the import process. The **Right Click** | **Skip Row(s)** menu option can be used to identify and skip a row of column headings, as shown in Figure 4-16. To deselect an already selected cell, use the **Right Click** | **Deselect** option. Once the desired array of data has been selected, click **Import**. A window similar to Figure 4-17 will be presented. In this window, the DSS pathname parts, units, and data type must be defined. Once these parameters have been appropriately defined, click the **Save** button to import the data.

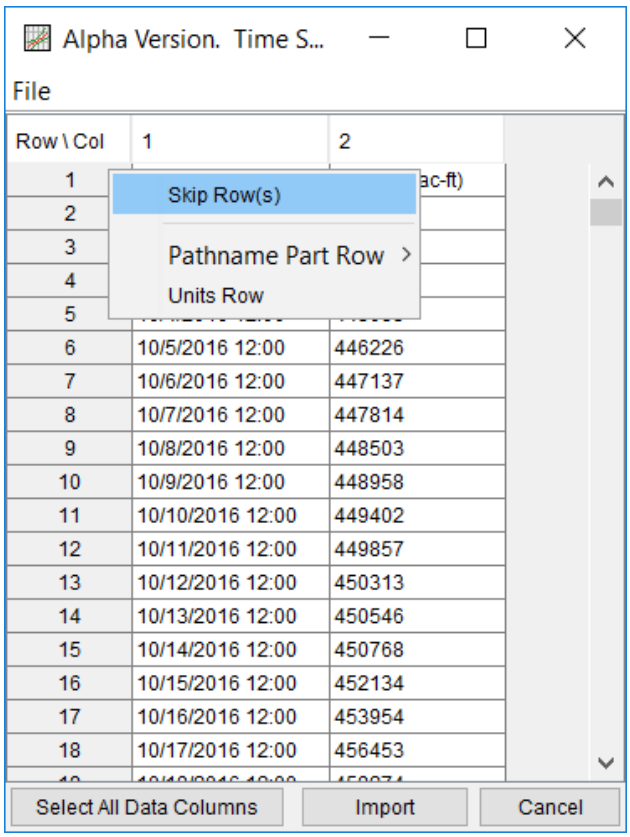


Figure 4-16. Skip Rows that Contain Headings for Text File Import.

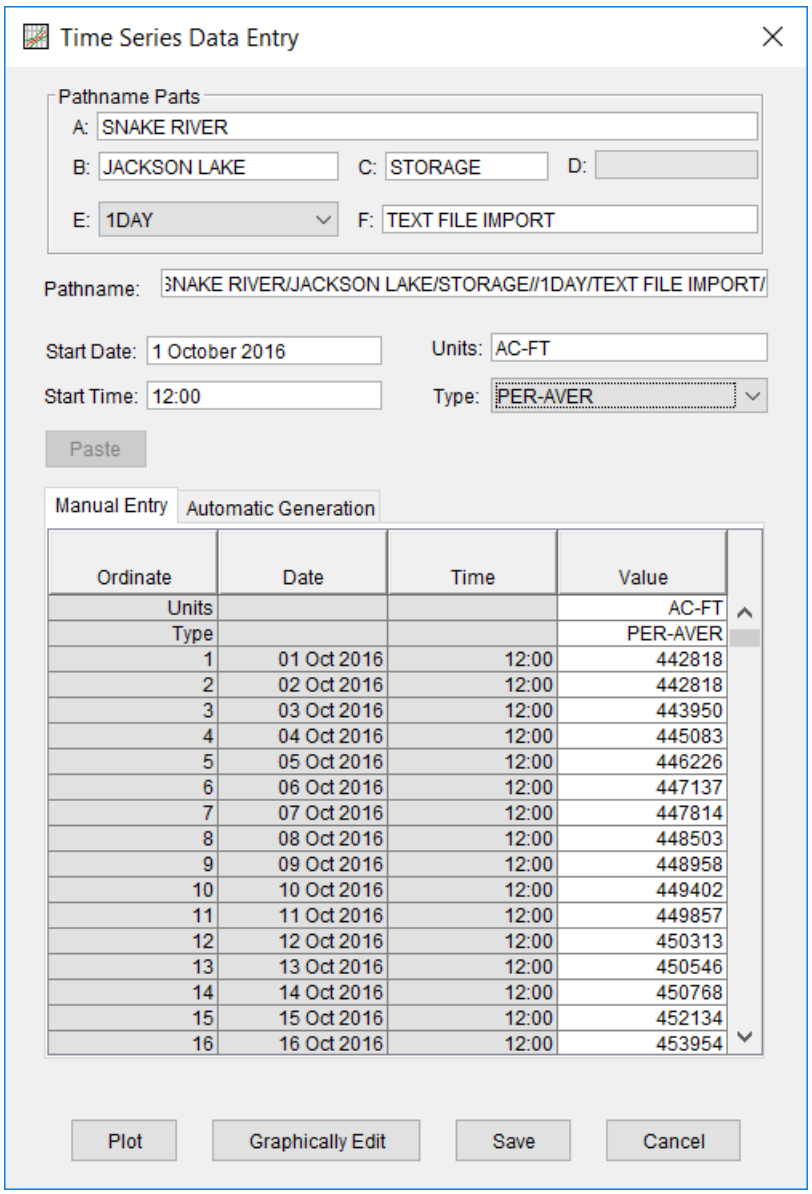


Figure 4-17. Text File Data Import.

4. Identify and set the date, time, and data columns. To identify the date and/or time column(s), place the mouse pointer on the column header, right click, and select a **Date – Time Column** option, as shown in Figure 4-18. Figure 4-18 shows that column 1 will be defined as the date and time column. The data viewer will highlight the date and time columns in green once they have been defined. To identify the data column, place the mouse pointer on the column header, right click, and select Set Data Column, as shown in Figure 4-19. Figure 4-19 shows that column 2 will be defined as the data column. After identifying and setting the data column, the data viewer will automatically close.

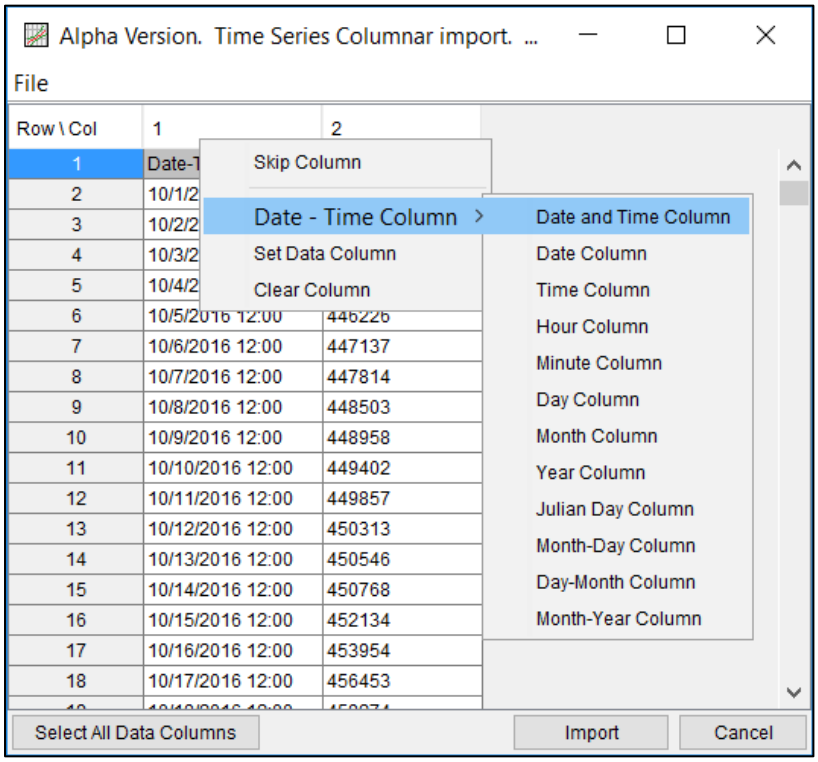


Figure 4-18. Identify and Set Date and Time Column(s) for Text File Import.

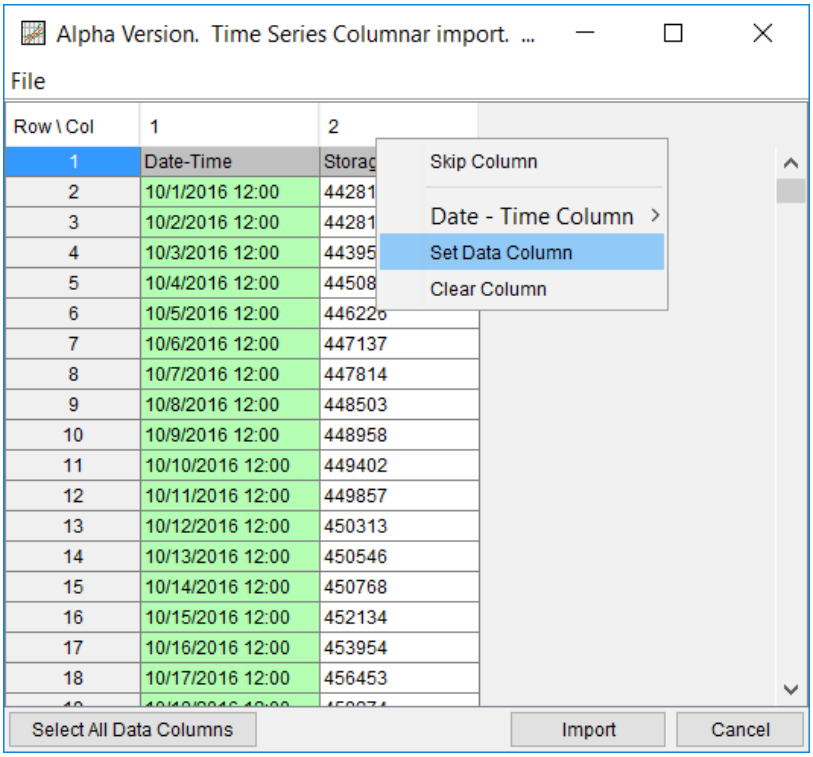


Figure 4-19. Identify and Set a Data Column for Text File Import.

In the subsequent window, the DSS pathname parts, units, and data type must be defined, as shown in Figure 4-20. Once these parameters have been appropriately defined, click the **Import Now** button.

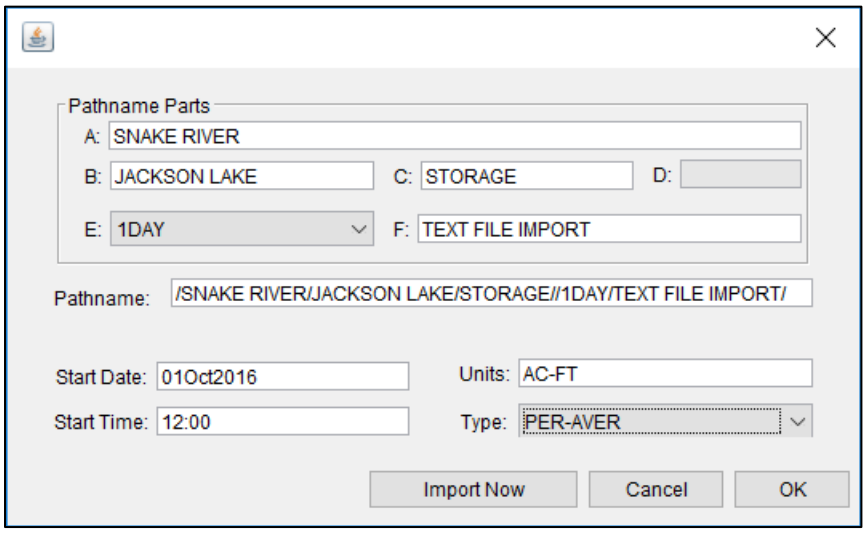


Figure 4-20. Editor for Defining the Data Properties for Text File Import.

Note: Use care when entering the A-, B-, C-, E-, and F-parts. These fields are meant to provide the user with a means to differentiate individual data sets. If more than one data set is created with a non-unique combination of A-, B-, C-, E-, and F-parts (i.e. they are all left blank), data may be overwritten/lost. This is analogous to using the Save As command and specifying a file name that is equivalent to an already-existing file.

A window similar to Figure 4-21 will be shown. Ensure that the DSS pathname parts, units, and data type are set correctly. Click the **Import to Study DSS File** button to finalize the data import process.

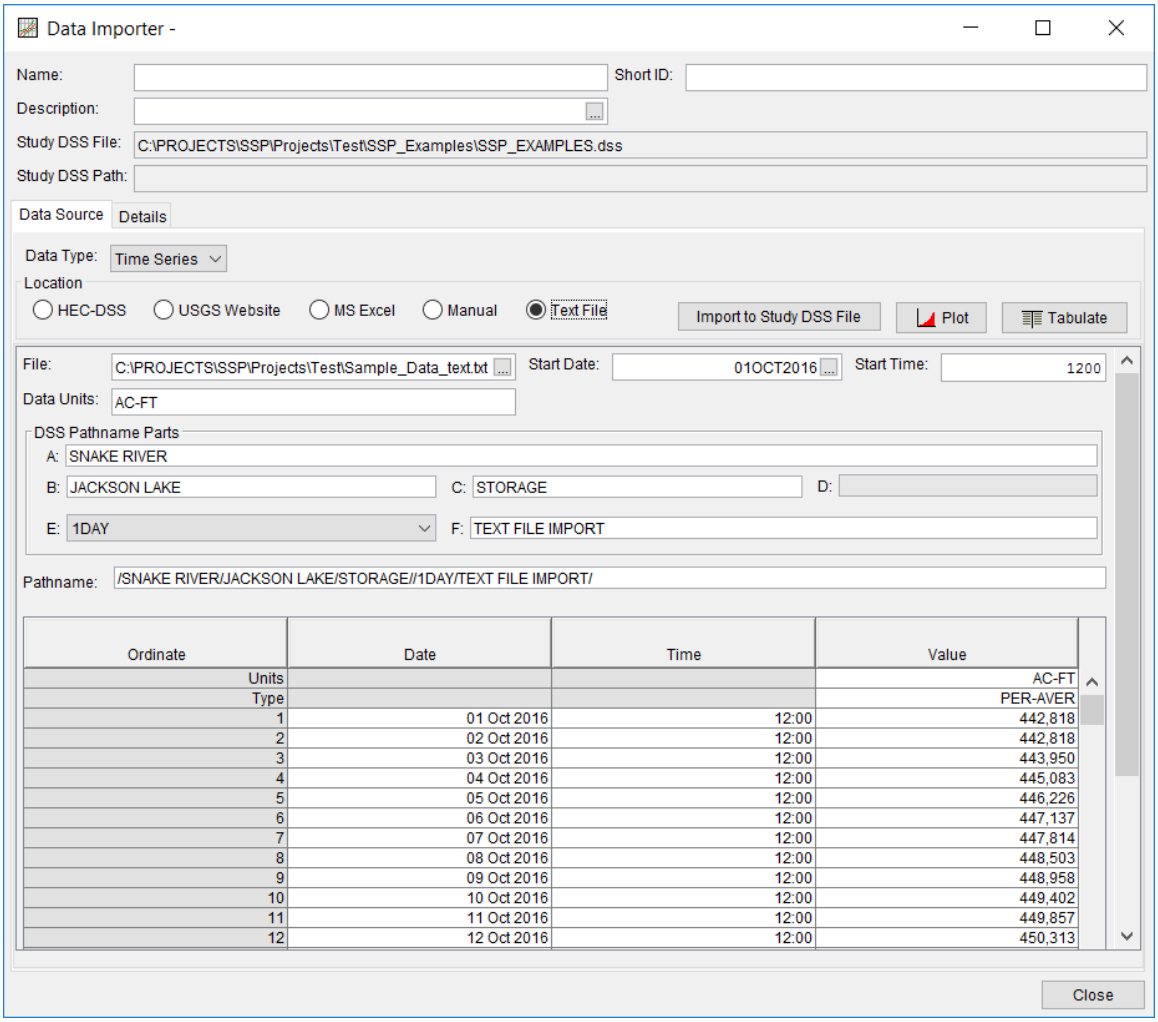


Figure 4-21. Defining DSS Pathname Parts, Units, and Data Type for Text File Import.

Metadata

When downloading data from the USGS website, in addition to the raw data, the software will also attempt to download any metadata available for each gage location. When using one of the other four methods for importing data, the user can manually enter metadata by selecting the **Details** tab, as shown in Figure 4-22. The metadata consists of the State, County, Stream, Location, Drainage Area, DA Units, Gage Operator, USGS Gage No., Gage Datum, HUC (Hydrologic Unit Code), Vertical Datum, and a description field. Additionally, the coordinate location of the data is shown. The coordinate location consists of Coordinate System, Coordinate ID, Horizontal Datum, Datum Units, Coordinate X Value, and Coordinate Y Value. If coordinate system data are entered, data icons and text labels will show up on the background map at the specified locations.

Metadata can be viewed and edited any time after the data has been imported into the study by opening the **Metadata Editor**. To open the Metadata Editor, place the mouse pointer on top of a data set in the Data folder and then click the right mouse button. Choose the **Edit Metadata** option from the shortcut menu, as shown in Figure 4-23. The Metadata Editor will look exactly like the Details tab on the Data Importer. The Metadata Editor can also be opened from the Data menu and from a shortcut menu that opens by right clicking on a data icon in a background map.

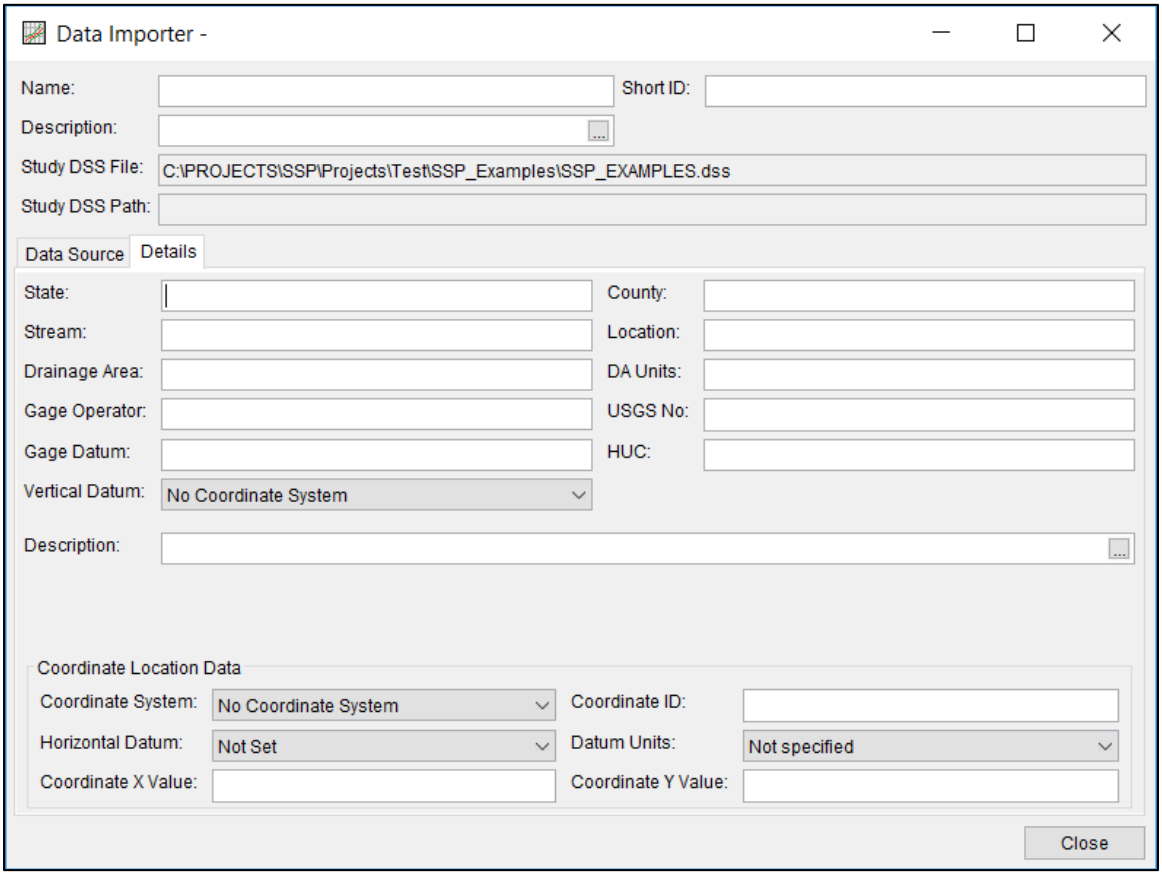


Figure 4-22. Details Tab on the HEC-SSP Data Importer.

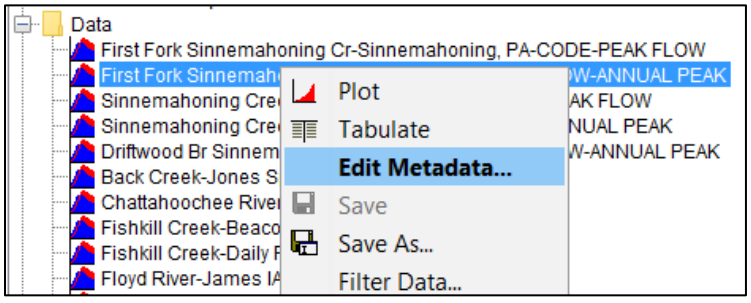


Figure 4-23. Menu Option for Opening the Metadata Editor.

Plotting and Tabulating the Data

After the data is imported into the study, the user can interact with any of the data sets in the study explorer. A shortcut menu will open when clicking the right mouse button while a data set is selected. The shortcut menu contains options to change the name, plot, and tabulate the data. These options are also available from the Data menu; however, one or more data sets must be selected in the study explorer before these options are available.

To plot or tabulate multiple data sets at a time, select the data sets of interest and click **Data** | **Plot** or **Data** | **Tabulate**. If multiple data sets are selected and plotted at the same time, the software will attempt to plot them using common axes. For example, within Figure 4-25, six streamflow annual maximum series along the Connecticut River are plotted within the same viewport using common x- and y-axes. Clicking on a legend item will allow for the selected curve to be highlighted in the plot, as shown in Figure 4-25.

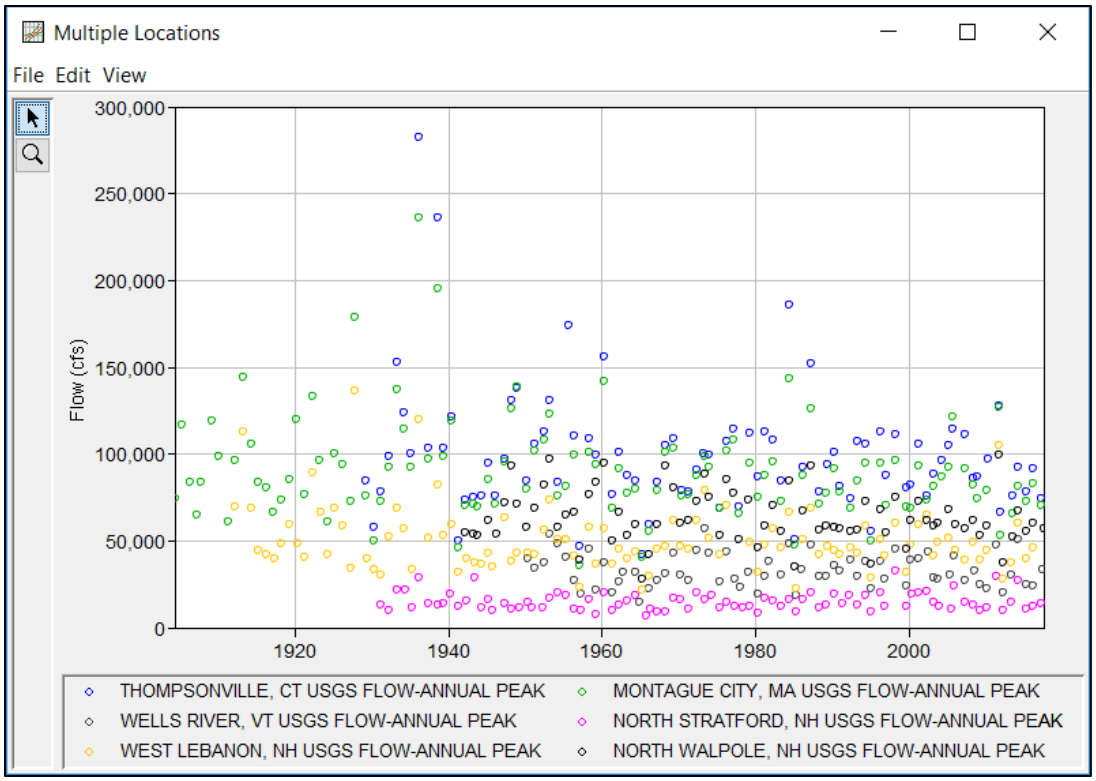


Figure 4-24. Plot of Multiple Streamflow Annual Maximum Series.

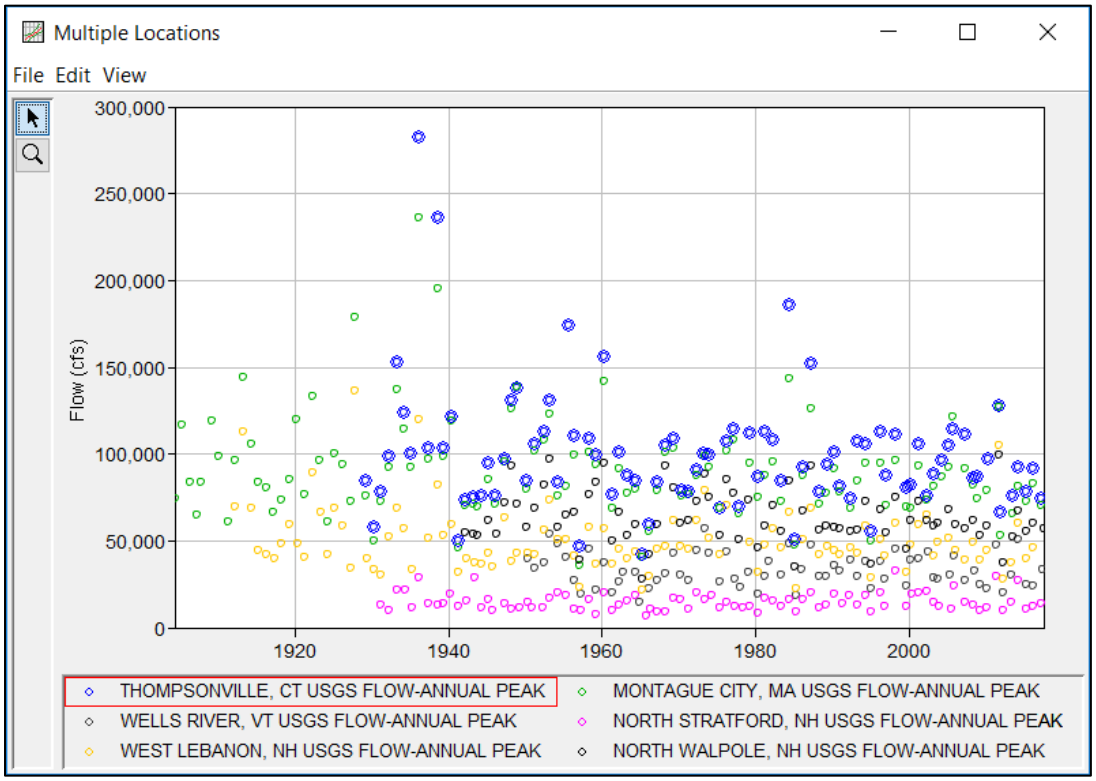
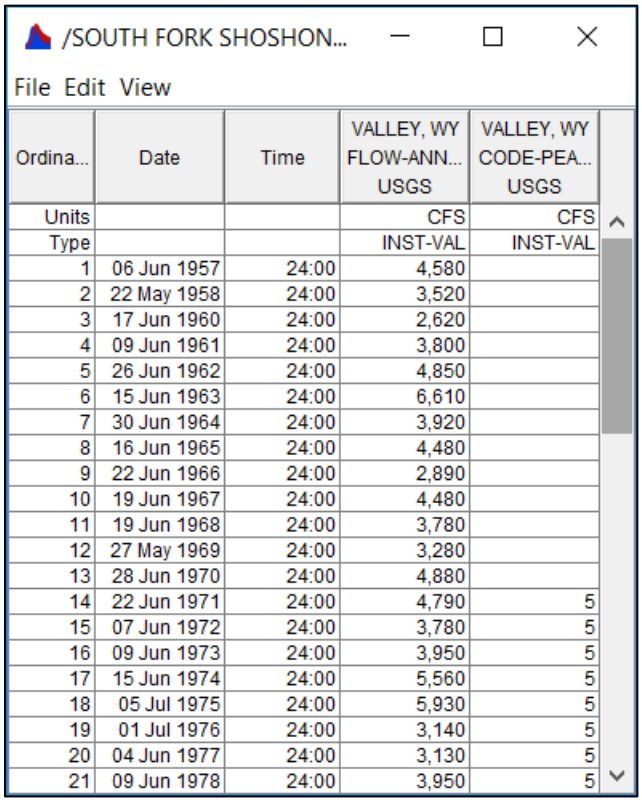


Figure 4-25. Plot of Multiple Streamflow Annual Maximum Series with a Curve Highlighted.

Similarly, if multiple data sets are selected and tabulated at the same time, the software will attempt to tabulate them using common axes. For example, within Figure 4-26, a streamflow annual maximum series and USGS peak flow codes are tabulated using a common date-time axis. Once tabulated, data values in the table can be edited after selecting the **Edit | Allow Editing** menu option. To save any edits, select the **File | Save** menu option.



/SOUTH FORK SHOSHON...

File Edit View

Ordina...	Date	Time	VALLEY, WY FLOW-ANN... USGS	VALLEY, WY CODE-PEA... USGS
Units			CFS	CFS
Type			INST-VAL	INST-VAL
1	06 Jun 1957	24:00	4,580	
2	22 May 1958	24:00	3,520	
3	17 Jun 1960	24:00	2,620	
4	09 Jun 1961	24:00	3,800	
5	26 Jun 1962	24:00	4,850	
6	15 Jun 1963	24:00	6,610	
7	30 Jun 1964	24:00	3,920	
8	16 Jun 1965	24:00	4,480	
9	22 Jun 1966	24:00	2,890	
10	19 Jun 1967	24:00	4,480	
11	19 Jun 1968	24:00	3,780	
12	27 May 1969	24:00	3,280	
13	28 Jun 1970	24:00	4,880	
14	22 Jun 1971	24:00	4,790	5
15	07 Jun 1972	24:00	3,780	5
16	09 Jun 1973	24:00	3,950	5
17	15 Jun 1974	24:00	5,560	5
18	05 Jul 1975	24:00	5,930	5
19	01 Jul 1976	24:00	3,140	5
20	04 Jun 1977	24:00	3,130	5
21	09 Jun 1978	24:00	3,950	5

Figure 4-26. Table Containing Streamflow Annual Maximum Series and USGS Peak Flow Codes.

Filtering Data

After data has been imported into the study, the user can filter the original data set to another data set using one or more filters. For instance, if the user has already imported a daily flow time series from the USGS website and wishes to extract an annual maximum series, this can be accomplished and is demonstrated in Figure 4-27. Filters can be nested as well. For example, using the same daily flow time series from the USGS website, an annual maximum series can be extracted for the time period between 1955 and 2010 using a season spanning 01Apr – 30Nov. The resulting annual maximum series will be comprised of peak flows that occurred between 01Apr and 30Nov in each year between 1955 and 2010.

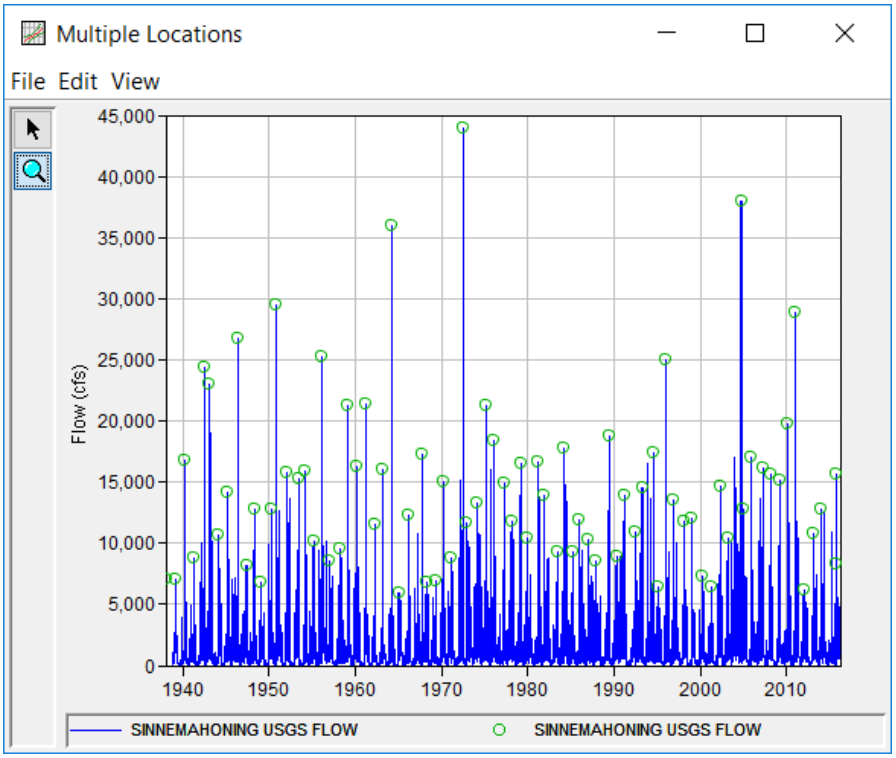


Figure 4-27. Annual Maximum Series Filtered from Daily Flow Time Series.

Filters that are available for use include:

- Time Window
- Season
- Min / Max Threshold
- Annual Maxima
- Peaks Over Threshold (Partial Duration)
- Starting Pool Stage / Elevation

To begin filtering an existing data set, right click on the data set and select **Filter**. Within the **Filter** editor, use the check boxes to enable any desired filters on the **Dates and Threshold** tab, as shown in Figure 4-28.

The **Time Window** filter is meant to screen data using an absolute date-time window. For instance, if an input data set spans 01Oct1920 – 30Apr2018, the **Time Window** filter can be used to create a new data set that spans 01Oct1920 – 30Sep2017. Dates within the **Time Window** panel must be entered using the Day, Month, Year format (i.e. ddmmmyyyy).

The **Seasonal** filter is meant to screen data using a day and month time window. For instance, if an input data set spans 01Oct1920 – 30Apr2018 and the user would like to include only values within the period spanning

15Apr – 30Nov, the **Seasonal** filter can be used to create a new data set that spans 01Oct1920 – 30Apr2018 but only includes values between 15Apr and 30Nov each year. Dates within the **Seasonal** panel must be entered using the DDMMM format.

The **Threshold** filter is meant to screen data using a defined minimum and/or maximum. For instance, if an input flow data set includes values spanning 1500 cfs – 27500 cfs, the **Threshold** filter can be used to screen out all values less than 5000 cfs and/or greater than 18000 cfs.

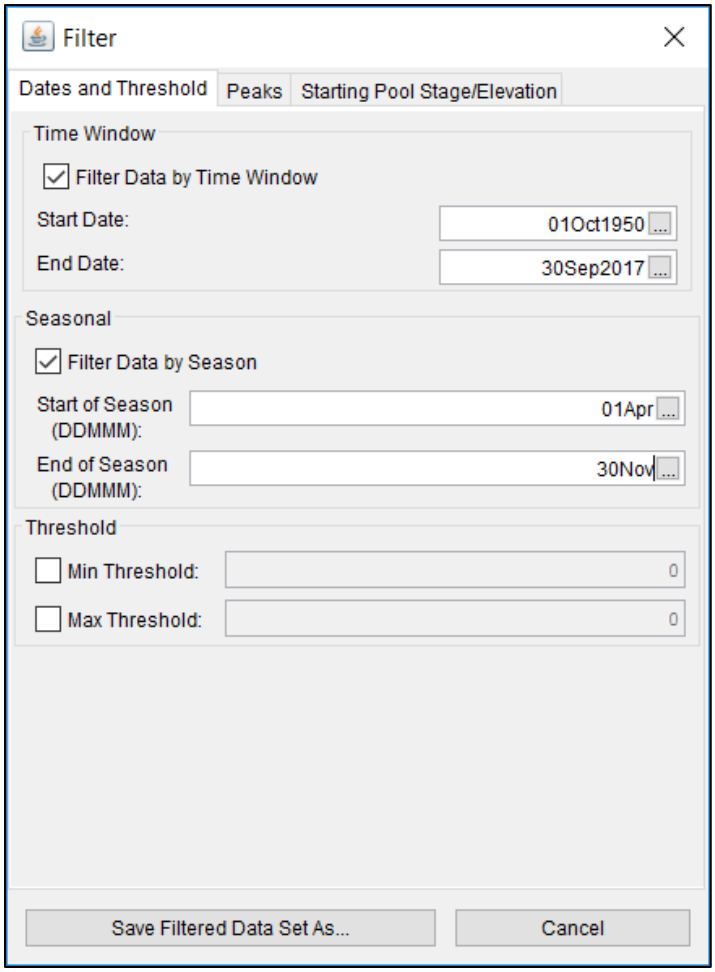


Figure 4-28. Dates and Threshold Filters.

Similarly, use the check boxes to enable any desired filters on the **Peaks** tab, as shown in Figure 4-29. Only one **Peaks** filtering method can be used at a time. If the **Filter to Annual Maxima** checkbox is selected, the **Filter Data by Peaks Over Threshold (Partial Duration)** panel will be disabled (and vice versa).

Dates within the **Annual Maxima** panel must be entered using the Day, Month format (i.e. ddmmm). The date entered within this panel signifies the beginning of the water year. The largest value within the defined water year will then be extracted. If the user enters 01Oct, the water year will be assumed to span 01Oct – 30Sep and the largest value within that time period each year will be extracted. If the user enters 15Apr, the water year will be assumed to span 15Apr – 14Apr and the largest value within that time period each year will be extracted.

If the user elects to use the **Peaks Over Threshold (Partial Duration)** filter, optional arguments can be specified to refine the peaks that will remain after filtering. If specified, an integer value of days must be entered within the **Duration of Time Between Peaks** entry field.

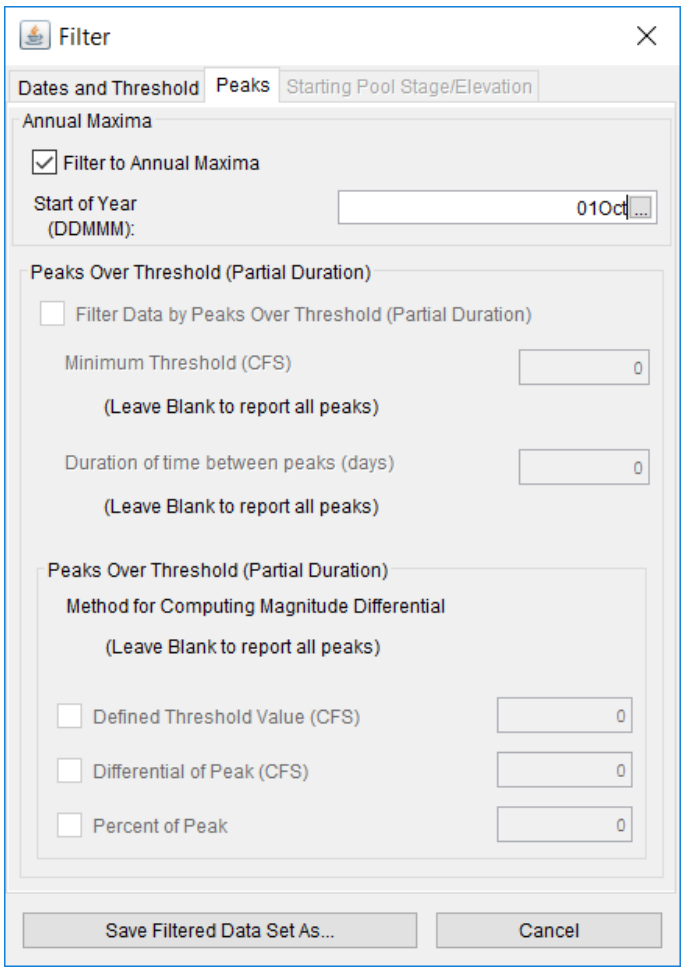


Figure 4-29. Peaks Filters.

The **Peaks Over Threshold (Partial Duration)** filter should be used to determine "hydrologically independent" peaks, as described within EM 1110-2-1415 "Hydrologic Frequency Analysis". Within Figure 4-30, the

peak flow at 09Dec1950 cannot be considered hydrologically independent; the magnitude of this peak was dependent upon the preceding peak on 05Dec1950. The peak on 26Nov1950 can reasonably be considered hydrologically independent. However, it is up to the user to decide whether the peak on 05Dec1950 is hydrologically independent.

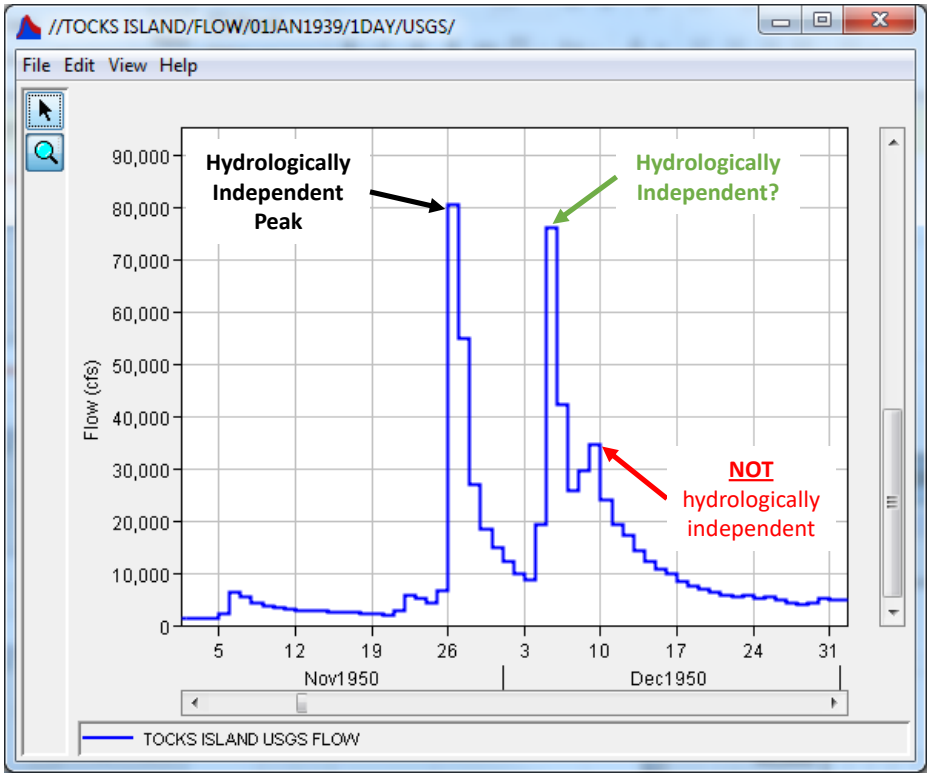


Figure 4-30. Example of Hydrologically Independent Peaks.

Multiple watershed- and/or study-specific arguments can be used to help identify truly independent peaks. These arguments are all optional. If the user doesn't define any of the parameters, every value within the data set will be identified as a peak.

The first two arguments include a **Minimum Threshold** and a **Duration of Time Between Peaks**. In order for a peak to be recognized, the data set must rise above a minimum threshold. Also, a certain amount of time must elapse before another peak can be identified. Examples of their use in the context of a streamflow time series are outlined below.

If "4000" is entered within the **Minimum Threshold** entry field, all peak values greater than 4000 cfs will be carried forward as potential peaks. If the time series never rises above the defined value, no peaks will be identified. If "7" is entered within the **Duration of Time Between Peaks** entry field, all peak values that are separated by a minimum of 7 days from other peaks will be carried forward. If two or more potential peaks

are found to be separated by less than 7 days from one another, the largest of the potential peaks will be carried forward. If the duration of time between peaks is never greater than the defined time, no peaks will be identified. These two arguments are graphically described within Figure 4-31.

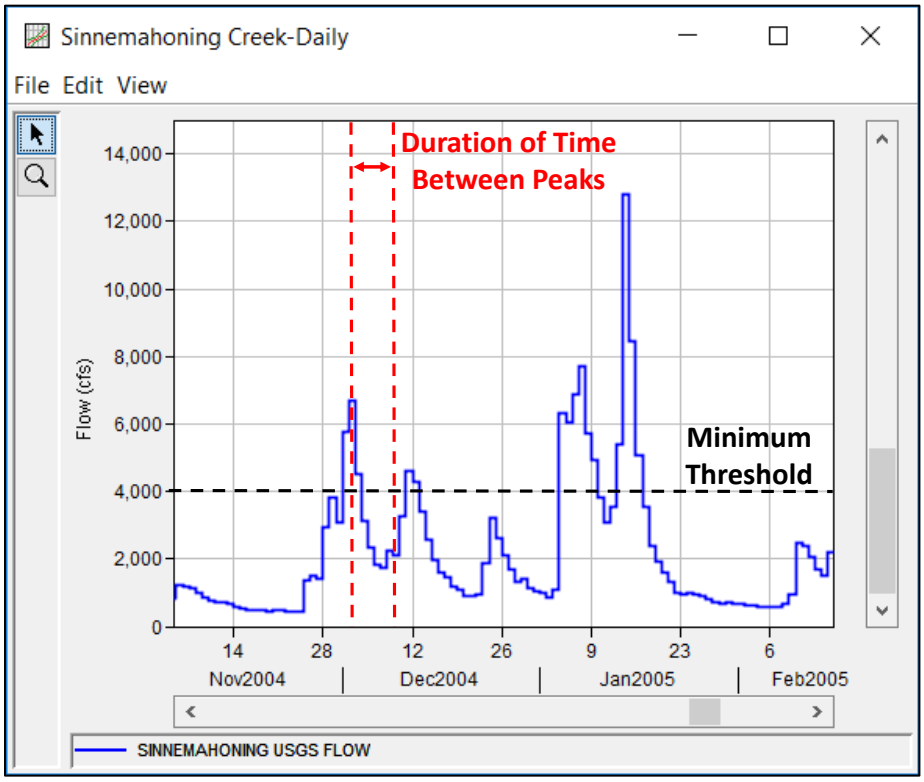


Figure 4-31. Minimum Threshold and Duration of Time Between Peaks.

The second set of arguments that can be used to define truly independent peaks revolve around the concept of a magnitude differential. In essence, these arguments will not allow for a peak to be identified unless the data set decreases by a certain amount relative to the preceding. These arguments are contained within the **Magnitude Differential** panel. Examples of their use in the context of a streamflow time series are outlined below.

If "7500" is entered within the **Defined Threshold Value** entry field, in order for a new peak to be considered, the time series must fall below 7500 cfs from the preceding peak. If "2500" is entered within the **Differential of Peak** entry field, in order for a new peak to be considered, the time series must fall by more than 2500 cfs from the preceding peak. If "10" is entered within the **Percent of Peak** entry field, in order for a new peak to be considered, the time series must fall by more than 10%

from the preceding peak. These three optional arguments are graphically described within Figure 4-32, Figure 4-33, and Figure 4-34.

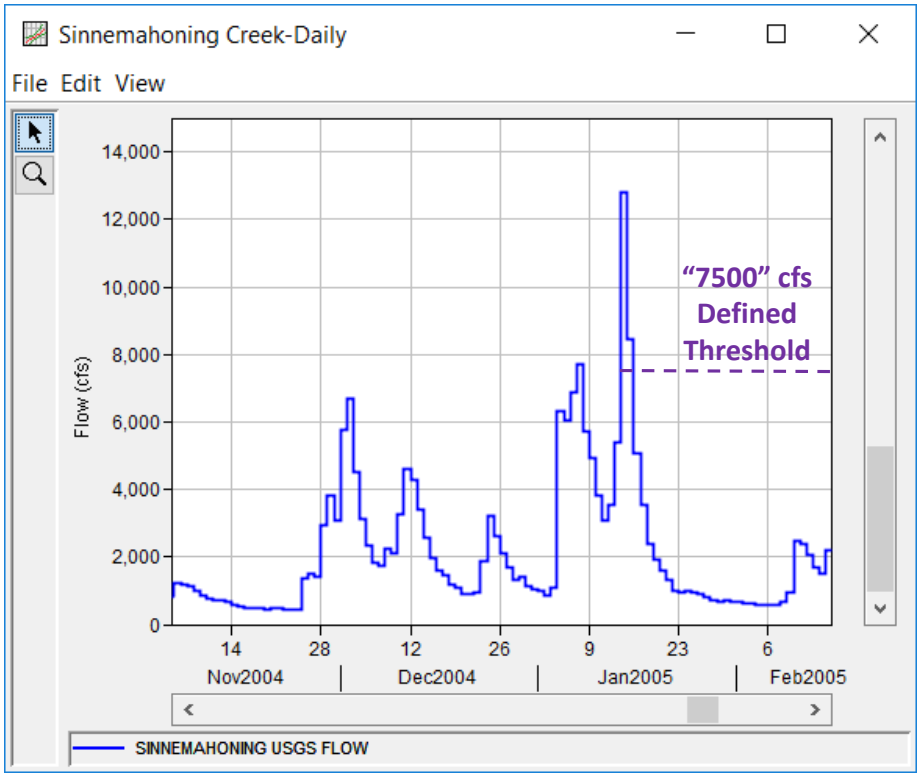


Figure 4-32. Magnitude Differential | Defined Threshold.

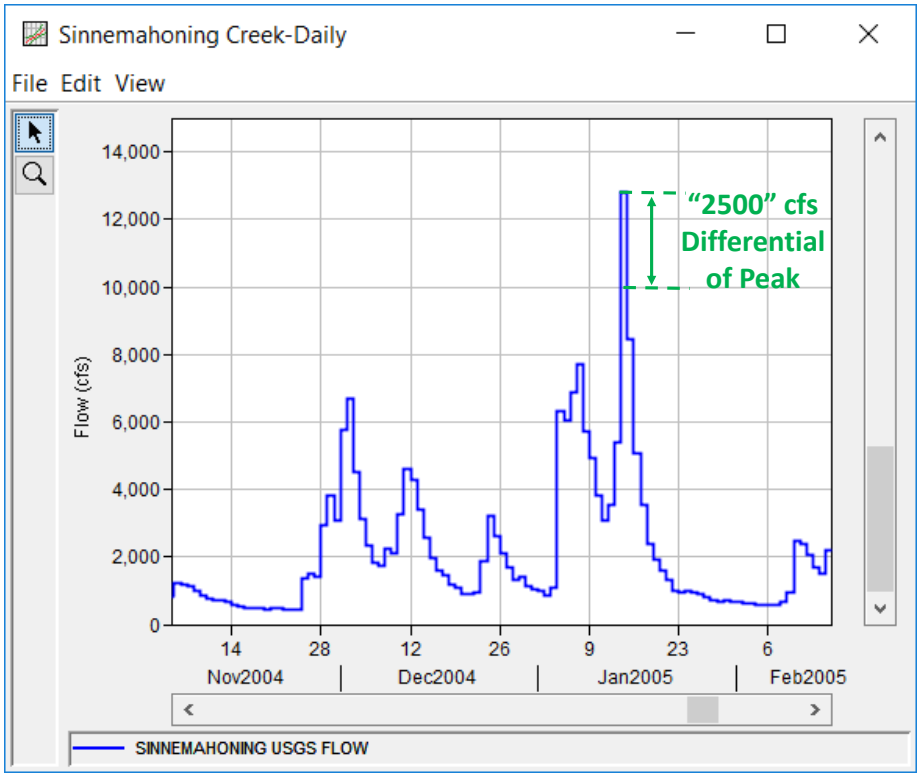


Figure 4-33. Magnitude Differential | Differential of Peak.

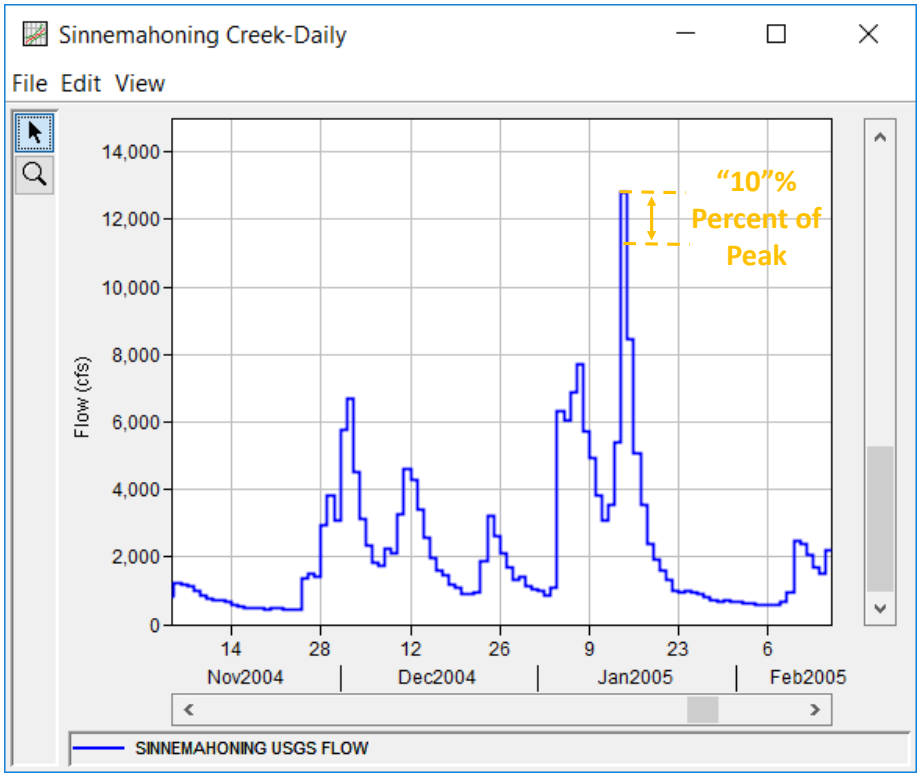


Figure 4-34. Magnitude Differential | Percent of Peak.

Finally, use the check box on the **Starting Pool Stage/Elevation** tab to filter an input stage or elevation time series, as shown in Figure 4-35. If either the **Filter to Annual Maxima** or **Filter Data by Peaks Over Threshold (Partial Duration)** checkboxes on the **Peaks** tab are enabled, this tab will be disabled (and vice versa). This filter is useful when determining reasonable antecedent pool elevations for use as initial conditions in hypothetical precipitation-runoff simulations. Reservoir stages or elevations that occurred during and shortly after the occurrence of another large event should be removed since it takes time for the atmosphere and/or watershed to deliver another large amount of moisture/runoff to the location of interest.

Two watershed- and/or study-specific arguments can be used to help identify appropriate starting pool stages or elevations. These arguments are required and must both be entered. Examples of their use are outlined below. The **Rate of Rise** argument is used as a threshold to demarcate the start of an "event". This value must be entered in feet (or meters) per day. For instance, if "1" is entered in the **Rate of Rise** entry field, "events" will be considered to start when the rate of rise exceeds 1 feet/day. The **Typical High Pool Duration** argument is used to set the length of the "event". This value must be entered in days. For instance, if "7" is entered in the **Typical High Pool Duration** entry field, each "event" will be considered to last 7 days. If the rate of rise is found to exceed 1 ft/day on day 10, then again on day 15, the "event counter" will start over and proceed from day 15. 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.

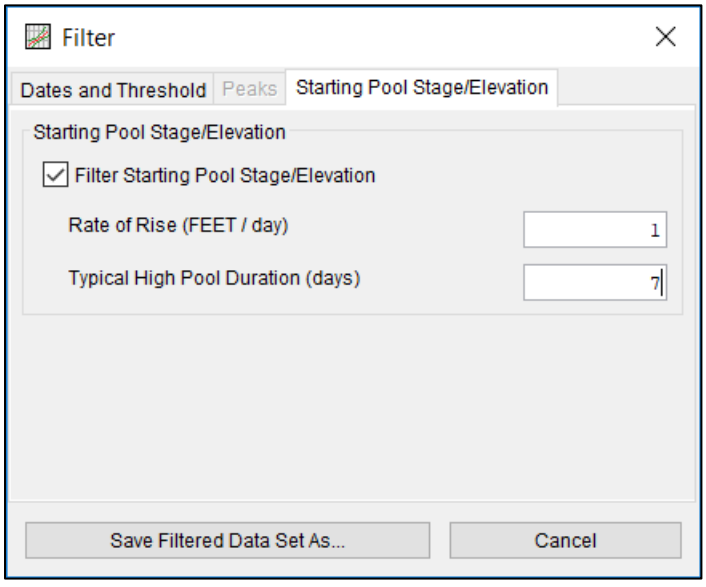


Figure 4-35. Starting Pool Stage/Elevation Filter.

Once the user has entered all of the desired data filtering arguments, the **Save Filtered Data Set As…** button can be clicked. This will open a **Save as New Data Set** window, as shown in Figure 4-36. Within this window, the **Name**, **Description**, and **DSS Pathname Parts** must be defined. The software will attempt to define a unique **Name**, but the user must ensure that the Name is truly unique. If the user attempts to save a data set that isn't uniquely named, an error message will be shown. The **Description** is optional but should be used to differentiate the new data set from others within the study. The software will also attempt to define a unique set of **DSS Pathname Parts** by appending characters to the F-part, but the user must ensure that the **DSS Pathname Parts** are truly unique. If the user attempts to save a data set that isn't uniquely named, an error message will be shown.

The software will attempt to contextually set the E-part drop down menu. For instance, if the user has attempted to filter an input data set to peaks using either the Filter to Annual Maxima or Peaks Over Threshold (Partial Duration) filter, an E-part of IR-CENTURY will be selected by default. If the user has attempted to filter an input data set using only a **Time Window**, **Seasonal**, and/or **Threshold** filter, the software will use the same E-part as the input data set. However, the user should ensure that the correct E-part for the desired filtered data set is used.

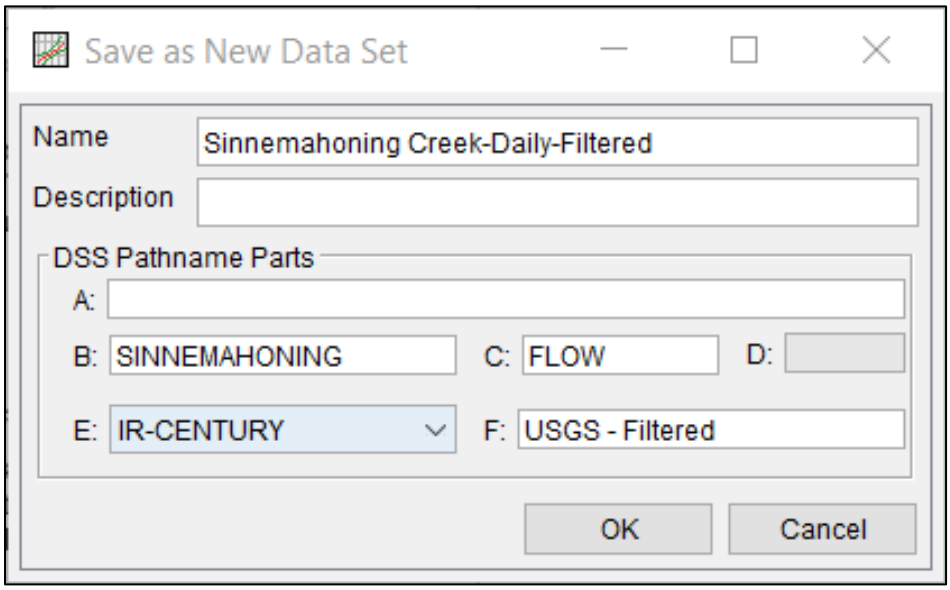


Figure 4-36. Save as New Data Set.

Once a unique **Name**, **Description**, and **DSS Pathname Parts** have been defined, the **OK** button can be clicked to enact the specified filter options and automatically import the data set to the current study. The subsequent

data set can then be plotted, tabulated, edited, filtered again, or used within analyses as shown in Figure 4-37.

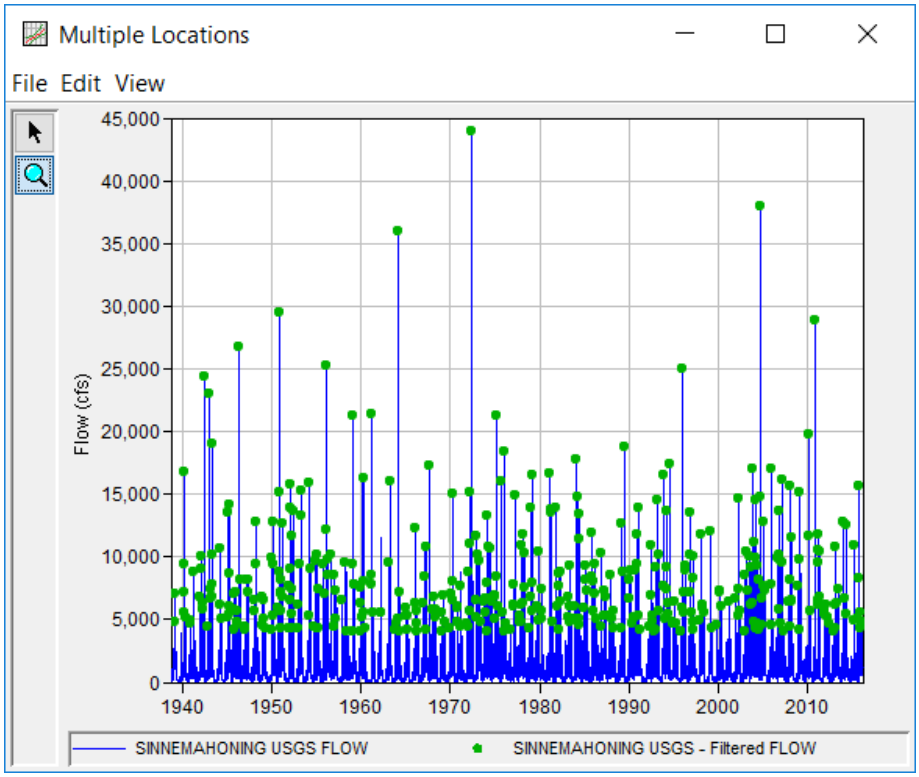


Figure 4-37. Daily Streamflow Time Series Filtered Using Partial Duration (Peaks Over Threshold).

CHAPTER 5

Performing a Bulletin 17 Analysis

The current version of HEC-SSP allows the user to perform flow frequency analyses using two different methodologies which are commonly referred to as Bulletin 17B and Bulletin 17C. This chapter discusses in detail how to perform a flow frequency analysis within HEC-SSP using either method.

Contents

- Bulletin 17B vs. Bulletin 17C
- Starting a New Analysis
- General Settings, Options, and Computations
- Viewing and Printing Results

Bulletin 17B vs. Bulletin 17C

The Bulletin 17B guidance has guided the development of peak flow frequency analyses within the United States since the early 1980's. This guidance recommended the use of the Log Pearson Type III probability distribution for annual peak flows on unregulated streams fit by the Method of Moments (Interagency Advisory Committee on Water Data, 1982). Using the Bulletin 17B methodology, distribution parameters are estimated from the moments of the sample data (i.e. mean, standard deviation and skew). Bulletin 17B also includes adjustments to those parameters for non-standard data (missing years, flows below gage base, or estimated flows), low outliers, and historical events. Adjustments can be made with a series of specified procedures including the conditional probability adjustment and the historical adjustment (weighted moments) procedure. The Bulletin 17B methodology characterizes the peak flow in each year as either (1) part of the systematic (observed) record, for which a point estimate of flow exists or (2) an historical event from a time before a gage was present but for which an estimate of flow can be made.

The Bulletin 17C guidance brings a change to the computation of peak flow frequency within the United States. This guidance incorporates changes motivated by four of the items listed as future work within Bulletin 17B and more than 30 years of post-Bulletin 17B research on flood processes and statistical methods (England, et al., 2018). As part of the Bulletin 17C methodology, the moments/parameters of the Log Pearson Type III distribution are estimated using the Expected Moments Algorithm (EMA). Like Bulletin 17B, the Bulletin 17C/EMA (17C EMA) methodology also estimates distribution parameters based on sample moments, but does so in a more integrated manner that incorporates non-standard, censored, or historical data at once, rather than as a series of adjustment procedures (Cohn, Lane, & Baier, 1997). The use of Bulletin 17C procedures can also provide improved confidence intervals for the resulting frequency curve that incorporate diverse information appropriately, as historical data and censored values impact the uncertainty in the estimated frequency curve (Cohn, Lane, & Stedinger, 2001). Within the 17C EMA methodology, every annual peak flow in the analysis period, whether observed or not, is represented by a flow range. That range might simply be limited to the gaged value when one exists. However it could also reflect an uncertain flow estimate. The analysis period also requires a specified perception threshold in each year.

Starting a New Analysis

A flow frequency analysis can be started in two ways within the software, either by right clicking on the Bulletin 17 folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Bulletin 17 Analysis**. When a new Bulletin 17 Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select an annual peak flow data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The Bulletin 17 Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a Bulletin 17 Analysis will only include those data that have an irregular interval, like IR-CENTURY and IR-YEAR (E-part pathname). Also, only one value per water year may exist within the selected data set. Within the Bulletin 17 Analysis, the water year is assumed to be 01Oct – 30Sep. If the user attempts to compute a Bulletin 17 Analysis using a data set that contains more than one value per water year, an error message will be shown. The General Frequency Analysis described within Chapter 6 can be used to demarcate a different water year (i.e. 01Jan – 31Dec, etc). Once a name is entered and a flow data set is selected, the **DSS File Name** and **Report File** will automatically be populated. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Bulletin 17 Editor is shown in Figure 5-1.

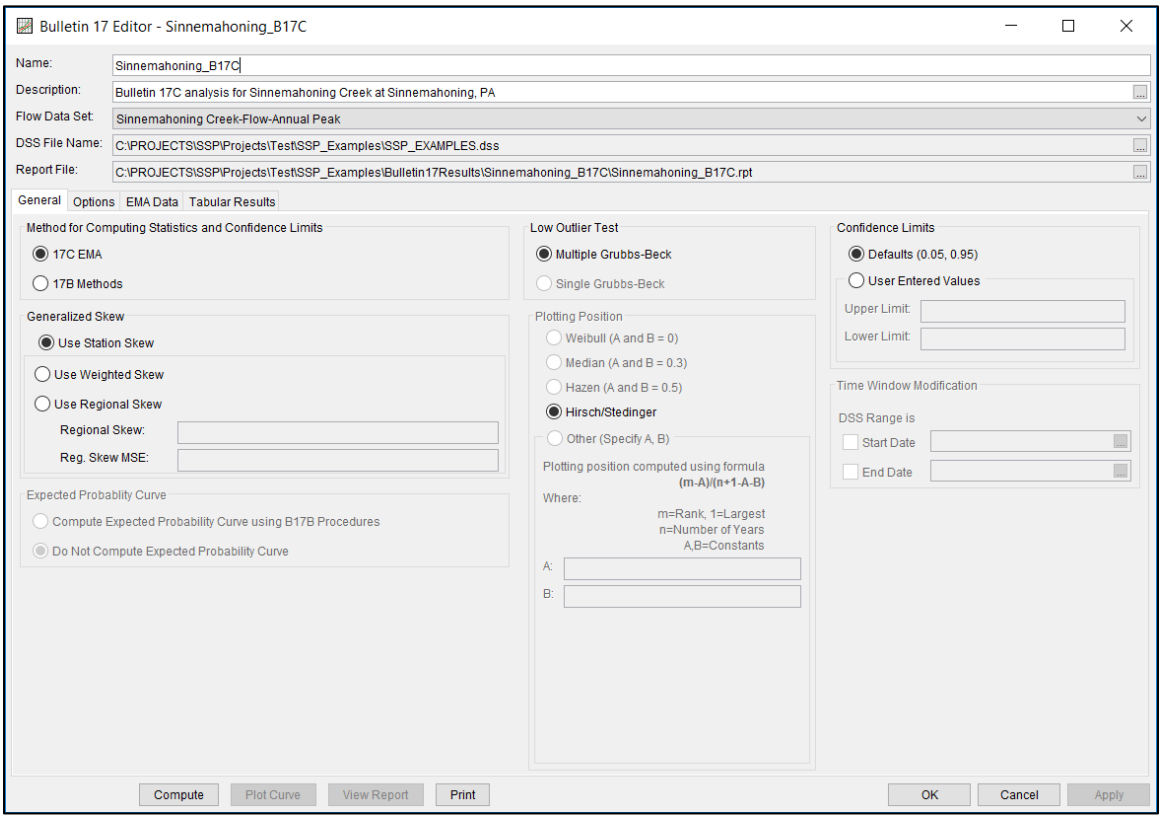


Figure 5-1. Bulletin 17 Analysis Editor.

General Settings, Options, and Computations

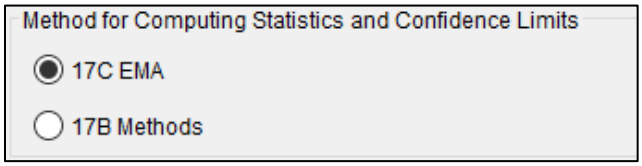
Once the analysis name and flow data set are selected, the user can begin defining the analysis. Four tabs are contained on the Bulletin 17 editor. The tabs are labeled **General**, **Options**, **EMA Data** (which is non-selectable unless the analysis is set to use **17C EMA** methods), and **Tabular Results**.

General Settings

The first tab contains general settings for performing the flow frequency analysis (Figure 5-1). These settings include:

- Method for Computing Statistics and Confidence Limits
- Generalized Skew
- Expected Probability Curve
- Low Outlier Test
- Plotting Positions
- Confidence Limits
- Time Window Modification

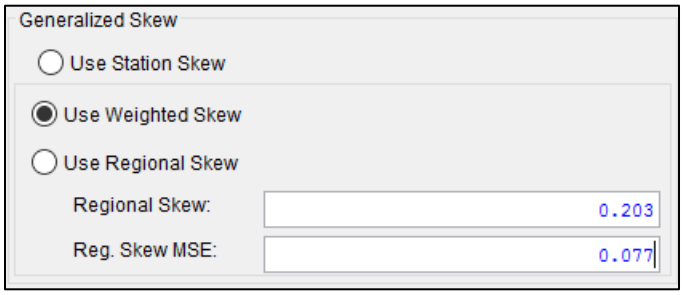
Method for Computing Statistics and Confidence Limits



There are two choices available for computing flow frequency statistics and confidence limits within HEC-SSP: **17C EMA** and **17B Methods**. The user is referred to the Bulletin 17C publication for in depth discussions regarding the differences between Bulletin 17B and Bulletin 17C. In general, 17C EMA will provide the same median flow frequency curve as Bulletin 17B methods when there are no historical events/periods and no low outliers included within the analysis.

Choosing either 17C EMA or 17B Methods will invoke different options throughout the flow frequency analysis (for instance, choosing the 17C EMA method results in the inability to compute the expected probability curve). When opening a new Bulletin 17 Analysis, the user must select a method for computing statistics and confidence limits before proceeding with the analysis. Until a method is selected, all other options will be inactive.

Generalized Skew



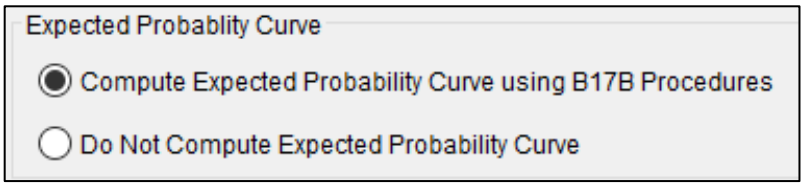
There are three options contained within the generalized skew setting: **Use Station Skew**, **Use Weighted Skew**, and U**se Regional Skew**. The default skew setting is Use Station Skew. With this setting, the skew of the computed curve will be based solely on computing a skew from the data points contained in the data set. No weighting with regional skew will be performed to compute the final skew.

The Use Weighted Skew option requires the user to enter a generalized regional skew and a Mean-Square Error (MSE) of the generalized regional skew. This option weights the computed station skew with the generalized regional skew based upon the inverse of the mean square error in each skew estimate. The equation for performing this weighting can be found in Bulletin 17B (equation 6). If a regional skew is taken from Plate I of Bulletin 17B (the skew map of the United States), the value of MSE = 0.302. Additional estimates of regional skew to be used in peak flow and

flow-duration statistical analyses are being developed by the USGS and others; for example, see (Parrett, et al., 2010).

The last generalized skew option is Use Regional Skew. When this option is selected, the user must enter a generalized regional skew and an MSE for that skew. The program will ignore the computed station skew and use only the regional skew.

Expected Probability Curve

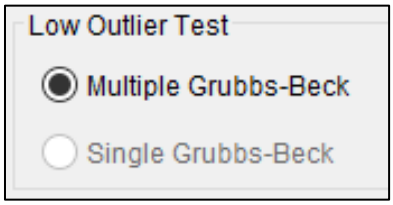


This setting has two options: **Compute the Expected Probability Curve using B17B Procedures** and **Do Not Compute the Expected Probability Curve**. The default setting is to not compute the expected probability curve. When using the **17C EMA** method to compute statistics and confidence limits, the expected probability curve cannot computed. When using the 17B method and computing the expected probability curve, this curve will be shown in both the result tables and the plots as an additional curve. The expected probability adjustment is a correction for bias in the computed frequency curve. The bias is caused by uncertainty due to the shortness of the data record. The method of moments estimation of the Log Pearson III parameters produces a median estimate of each frequency curve quantile, and the adjustment changes to a mean (unbiased) estimate, which is different from the median because of the skewness of the uncertainty distribution. The reader may review the discussion in Bulletin 17B about the expected probability curve adjustment for an explanation of how and why it is computed.

The use of the expected probability curve is a policy decision. The expected probability curve is most often used in establishing design flood criteria. When use of the frequency curve includes uncertainty analysis, the expected probability adjustment is made implicitly. Therefore, the computed flood frequency curve without the expected probability adjustment is the curve used in computation of confidence limits, risk analysis, and in obtaining weighted averages of independent estimates of flood frequency discharge (Interagency Advisory Committee on Water Data, 1982).

Low Outlier Test

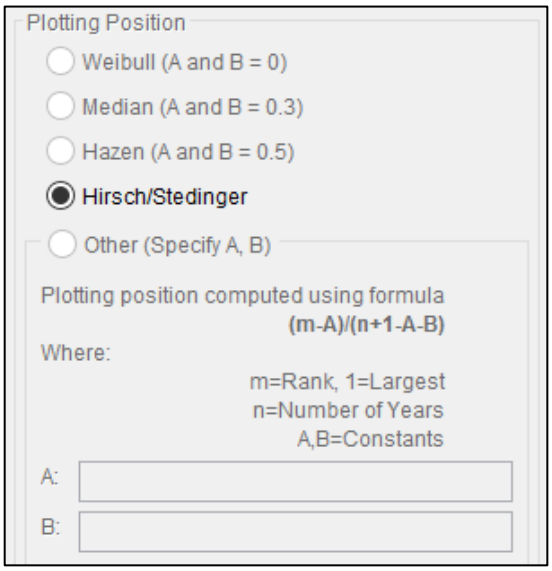
This option allows the user to choose the test that is performed to identify low-value data points that depart significantly from the trend of the remaining data and inappropriately affect the extreme quantiles in the upper tail of the frequency curve. There are two options for testing low outliers within HEC-SSP: **Multiple Grubbs-Beck** and **Single Grubbs-Beck**.



These low-value data points can significantly distort the entire computed flow-frequency curve due to the use of logarithms within both the 17B and 17C EMA methods. These distortions are more severe with the 17C EMA method. As part of the development of the Bulletin 17C methodology, the standard Grubbs-Beck low outlier test was expanded to more successfully identify multiple low outliers (also referred to as potentially influential low floods, or PILFs). Therefore, the only option available when using the 17C EMA method within the Bulletin 17 Analysis is the Multiple Grubbs-Beck test. When low outliers are calculated using the Multiple Grubbs-Beck test, both perception thresholds and flow ranges may be modified within the 17C EMA framework. Example 2 within Appendix C presents an instance where multiple low outliers are identified using the Multiple Grubbs-Beck test and the resulting modification of flow ranges within the 17C EMA framework. When using the 17B methodology, the default test is the Single Grubbs-Beck test.

Plotting Positions

Plotting positions are used for plotting the input flow data set on a probability scale along with the computed frequency curve and confidence limits. There are five options for computing plotting positions within HEC-SSP: **Weibull**, **Median**, **Hazen**, **Hirsch/Stedinger**, and user entered coefficients. The only method available for computing plotting positions when using the 17C EMA method is Hirsch/Stedinger (Hirsch and Stedinger, 1987). When using the Hirsch/Stedinger method, the A and B coefficients will be



set equal to zero. The default method when using the Bulletin 17B method is the Median plotting position formula. When using 17C EMA methods and the Hirsch/Stedinger plotting position formula, flow data screened as low outliers (a.k.a. Potentially Influential Low Floods) are assigned a plotting position using the Median plotting position formula within HEC-SSP.

The generalized plotting position equation is:

$$P = \frac{(m - A)}{(n + 1 - A - B)}$$

where: m = rank of flood values with the largest equal to 1.

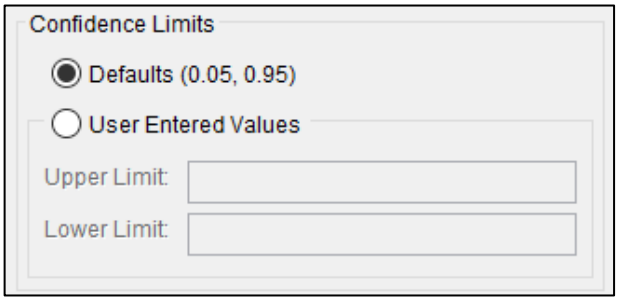
n = number of flood peaks in the data set.

A & B = constants dependent on which equation is used (Weibull A and B=0; Median A and B = 0.3; and Hazen A and B=0.5).

Plotting positions represent estimates of the exceedance probability of each data point (peak flow). Different plotting position formulas can give very different values for the probabilities of the highest and lowest points in the data set. In both the Bulletin 17B and 17C EMA methodologies, the plotting of data on the graph by a plotting position method is only done as a guide to assist in evaluating the computed curve. The plotting position method selected does not have any impact on the computed curve.

Confidence Limits

The computed flow frequency curve is only an estimate of the probability distribution of the parent population. Confidence limits can be used to provide a measure of the uncertainty of the estimated exceedance probability of a selected discharge or a measure of the uncertainty of the discharge at a selected exceedance probability. Confidence limits computed when using the 17C EMA methodology are outlined in Bulletin 17C, Appendix 6. Confidence limits computed when using the 17B methodology are outlined in Bulletin 17B, Appendix 9. Generally speaking, the confidence intervals computed with 17B procedures are less accurate than those computed using the 17C EMA methodology. The 17B

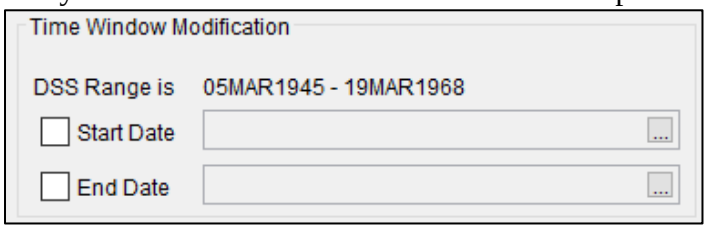


methodology neglects the uncertainty in the estimated skew coefficient and does not incorporate historical information.

By default, HEC-SSP calculates the 90 percent confidence interval for all flow frequency analyses (i.e. the 5% and 95% percentiles). By comparison, the default confidence interval used within the USGS PeakFQ program is 95% (i.e. 2.5% and 97.5% percentiles) (Veilleux, Cohn, Flynn, Mason, & Hummel, 2013). The confidence limits must be entered in decimal form (i.e. 95% = 0.95, and 5% = 0.05). The user has the option to override the default values and enter whatever values they would like for the confidence limits.

Time Window Modification

This option allows the user to narrow the time window used for the analysis. The default is to use all of the annual peak flow data contained in the selected data set. The user can enter either a start date for the analysis, and end date, or both a start and end date. If a start and/or end date are used, they must be dates that are encompassed within the data stored in the selected data set. The date range for the selected data set is shown in the editor just above the **Start Date** field.



Any dates entered within the Time Window Modification will be ignored when using the 17C EMA Method for Computing Statistics and Confidence Limits. When using 17C EMA, changes to the start and end period must be made within the **EMA Data** tab.

Options

In addition to the general settings, there are also several options available to the user for modifying the computation of the frequency curves. These options include:

- Low Outlier Threshold
- Historic Period Data
- Output Frequency Ordinates

When the Options tab is selected, the Bulletin 17 Editor will appear as shown in Figure 5-2.

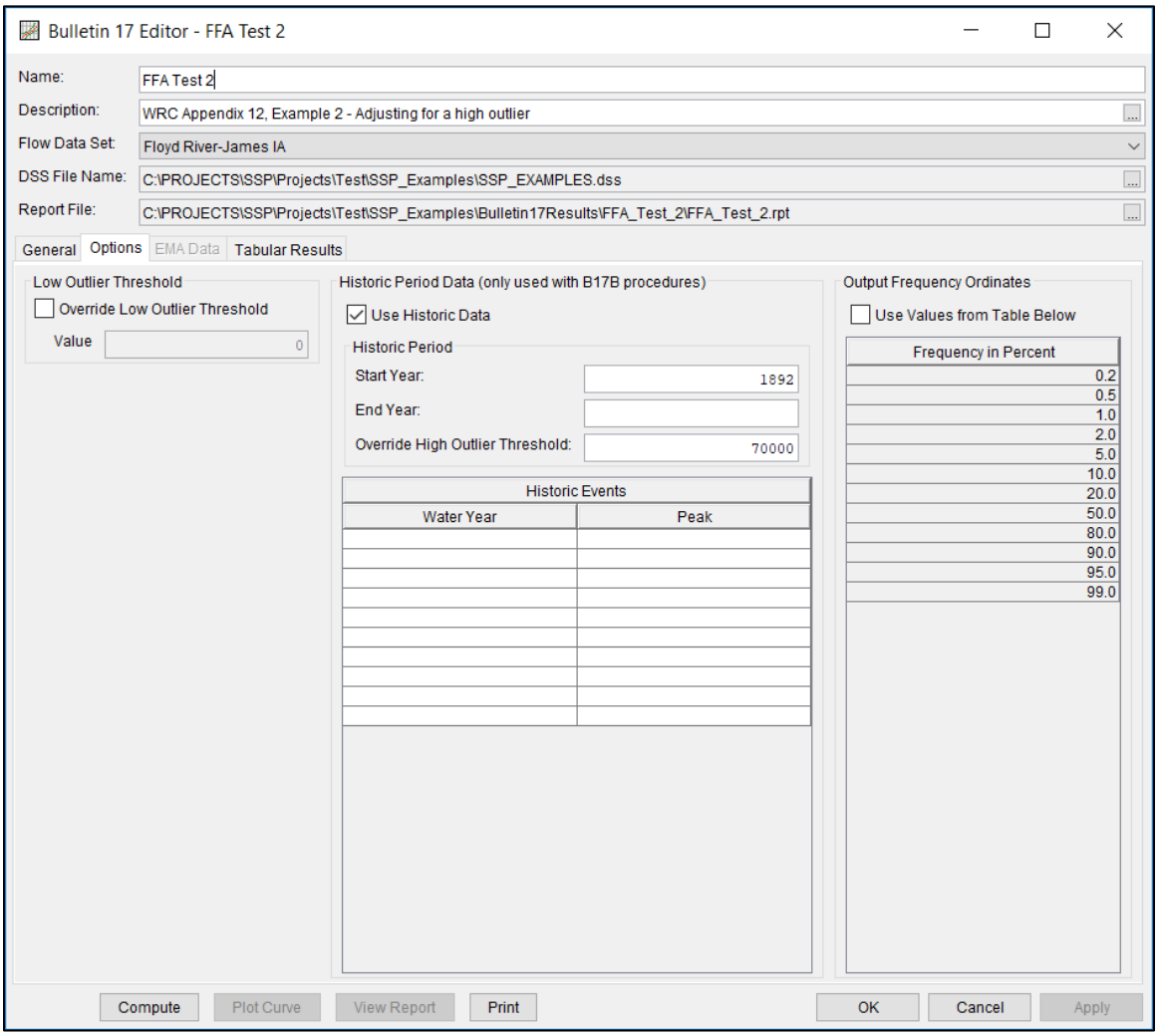
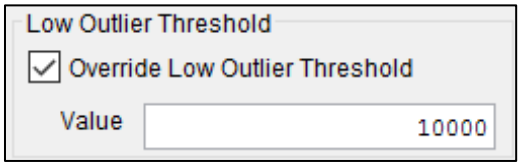


Figure 5-2. Bulletin 17 Editor with Options Tab Selected.

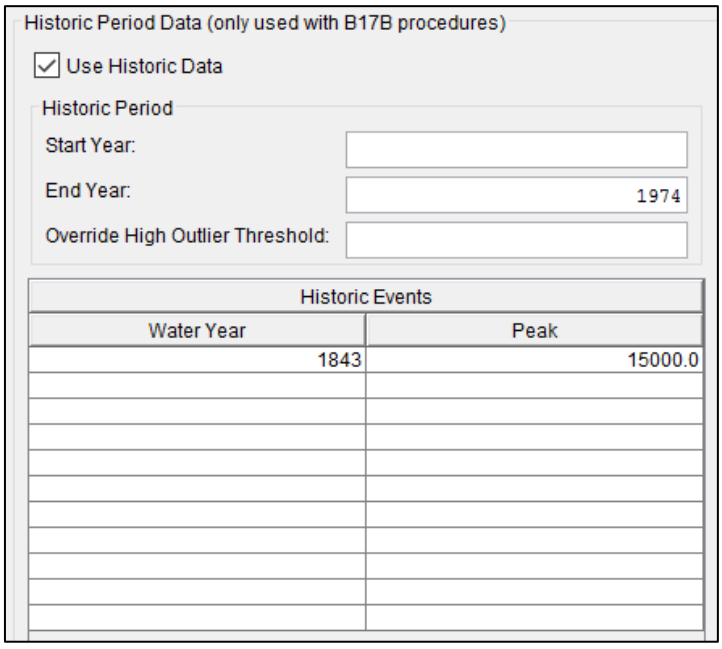
Low Outlier Threshold



The user has the option to enter a value for the low outlier threshold, if desired. If a value is entered for the low outlier threshold, then this value will override the computed value from either the Single or Multiple Grubbs-Beck test. The low outlier threshold cannot be set to a value that would censor more than 50 percent of the values within the data set. To override the computed low outlier threshold, check the box labeled **Override Low Outlier Threshold** and enter the preferred value.

Historic Period Data

All historic data that provides reliable estimates of flood peaks outside the systematic record should be used in order to improve the estimated flood frequency curve. Flood information of large events outside of the systematic record can often be used to extend the record to a historic period much longer than that of the systematic record. HEC-SSP uses historic data specified in this table as recommended in Bulletin 17B.

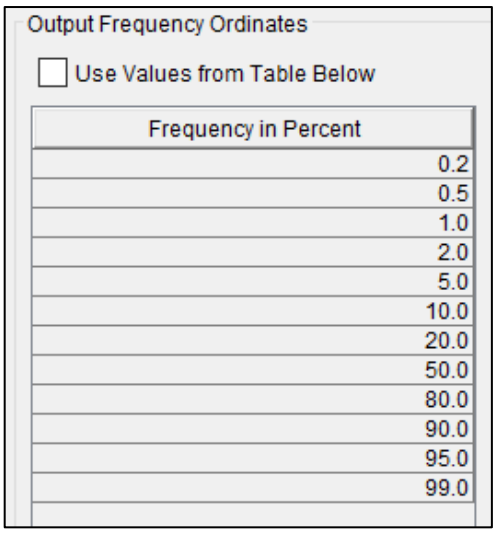


This option is only available when using Bulletin 17B procedures. To make use of historic data within the 17C EMA procedures, this information should be entered on the **EMA Data** tab. To use historic data with Bulletin 17B procedures, check the box labeled **Use Historic Data**. The user can enter a starting year for the historic period, ending year for a historic period, and a high threshold value to override what is computed. If the user enters a high threshold value, then any value in the systematic record greater than that value will also be treated as a historical flood peak. The user can also enter historic flood peaks that are not contained in the systematic record. This is done in the table at the bottom labeled **Historic Flood Peaks**. Only one value per water year may be entered and all years must be entered assuming a water year from October 1 through September 30. If a start year is not entered, then the assumed start year is the earliest year of the systematic record and any historical values that have been entered. If an end year is not entered, then the assumed end year is the latest year in the systematic record and any entered historic values.

Note: The program treats all data in the data set as systematic data when using Bulletin 17B procedures. If historic events are included in the data set, then the user must define the analysis time window (General tab – Time Window Modification) so that it bounds only the systematic record. Then the user must enter the historic events in the Historic Events table.

The user is directed to Example 6 in Appendix B for an instance of using historic data within a Bulletin 17 Analysis.

Output Frequency Ordinates



This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.

EMA Data

The Bulletin 17C methodology represents a shift in the determination of peak flow frequency and how data is used within peak flow frequency analyses. When using the 17C EMA methodology, additional data is required in order to compute peak flow frequency, confidence intervals, and plotting positions. This new information includes perception thresholds and flow ranges. Every year in the analysis period must have perception thresholds and a flow range specified. The additional data that is required for use within a 17C EMA analysis is accessed/input within the EMA Data tab, as shown in Figure 5-3.

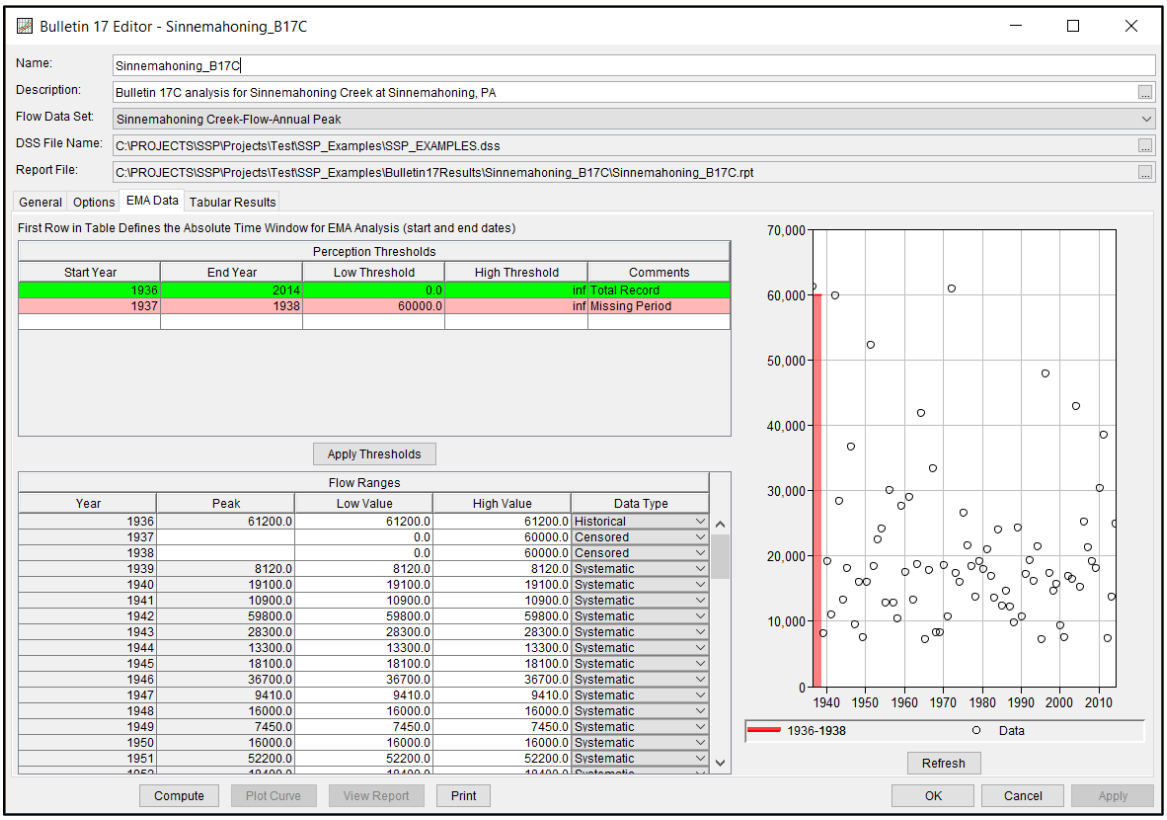


Figure 5-3. Bulletin 17C Analysis EMA Data Tab.

Perception Thresholds

The EMA procedure introduces the new concept of Perception Thresholds. Perception thresholds define the range of streamflow for which a flood event could have been observed. The inherent assumption and consequence is that any year for which an event was not observed and recorded must have had a peak flow rate outside of (usually below) the perception range.

Consider the example of an historical flood in 1882 estimated as 50,000 cfs, and then a gage was installed in 1926. This flood estimate suggests a perception threshold of 50,000 cfs to infinity, because there is evidence that a value as low as 50,000 cfs was noted/perceived (with high water marks, indirect evidence, and/or hydraulic modeling) during the ungaged period. One can further assume that any flow larger than 50,000 cfs would also have been perceived, and so any flow not perceived must have been less than 50,000 cfs. Therefore, for the unobserved period of 1883 to 1925, we assign the complementary flow range of 0 to 50,000 cfs to represent the likely range of peak flows during the unobserved period. The perception threshold and flow range for this hypothetical dataset is shown in Figure 5-4.

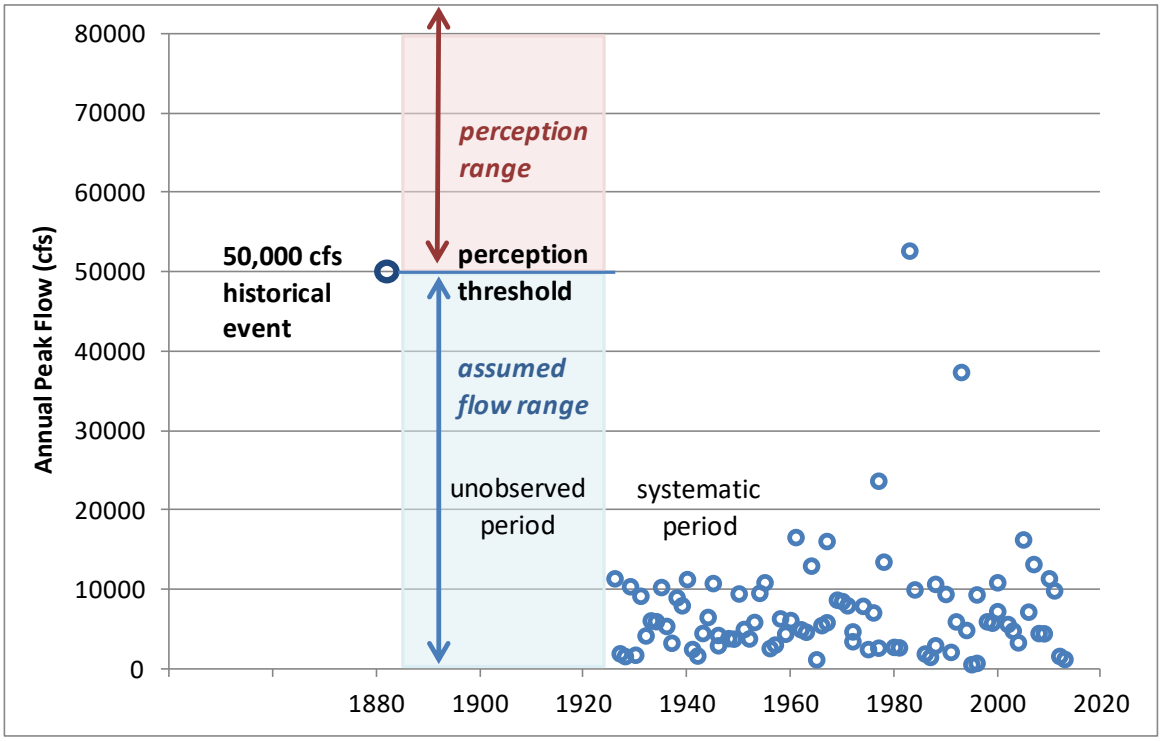
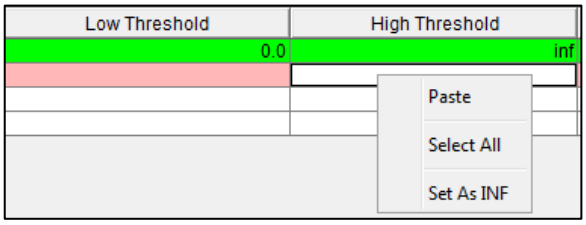


Figure 5-4. Example Showing a Perception Threshold and Flow Range.

The first row within the Perception Thresholds table will automatically be created to span the entire period of record of the selected Flow Data Set. The start and end year of this first perception threshold can be modified to alter the analysis time frame. This first perception threshold must have a low value of 0 and a high value of infinity. Additional rows within the perception threshold table supersede the rows above, for the specified time frame. However, within HEC-SSP, perception threshold time frames should not overlap one another.

For any missing years in the analysis period, perception thresholds other than zero to infinity must be entered after the first row. The reason for this requirement is that a perception threshold of zero and infinity presumes any flow that occurred could have been observed, implying that unobserved years would not be possible. Therefore, unobserved years must have a perception threshold with either a lower bound greater than zero or an upper bound less than infinity. Most commonly, since very large flows do tend to be observed in some way (as historical events are estimated based on some evidence in the watershed), a lower bound greater than zero is chosen.



To assign a value of infinity within the High Threshold column, double left-click to begin editing the desired cell, right-click, and select **Set as INF** (infinity). Use the Comments column to provide a descriptive note to a perception threshold. The use of this column is not required. The comment associated with the first perception threshold will be automatically set to "Total Record".

Multiple rows within the Perception Thresholds table can be sorted using chronological order by right-clicking within the table and selecting Sort by Start Year. Similarly, rows can also be inserted or deleted by right-clicking within the table.

When low outliers are detected using the Multiple Grubbs-Beck test, the perception threshold low value for systematic events will be changed to use the smallest non-screened annual peak flow. Further discussion regarding the impacts of low outliers on perception thresholds is contained within the Appendix C EMA examples.

Flow Ranges

The Bulletin 17B methodology limited the use of annual peak flow data to point-value flow estimates or zero flows. The 17C EMA methodology represents each annual peak flow within the analysis period as a range, whether it was observed or not. The flow range for a given year is assumed to be the value itself for an observed value or the complement of the perception threshold for that same year for an unobserved value.

Flow data can be classified within one of three categories: Systematic, Censored, and Historical. This choice is specified in the Data Type column of the Flow Ranges table and can be changed by the user. By default, all flow data contained within the associated Flow Data Set will be set to Systematic while missing years will be set to Censored. Historical data generally refers to flood peaks that occurred outside of the systematic data collection period. Within the USGS NWIS database, a qualification code of "7" will indicate the presence of an historical peak. If this flow data is contained within the associated Flow Data Set, it will be labeled as Systematic by default. The user should change the data type to Historical.

By default, the low and high value for an observed (gaged/systematic) flood event is set equal to the gage estimate. The perception thresholds for these data points are 0 to infinity. However, if there is uncertainty about the flow estimate, the range can expand to represent the possible value(s).

Similar to unobserved years in the historical period, if a crest stage gage is unable to estimate flow below a gage base of perhaps 50 cfs, then the perception thresholds would be 50 cfs to infinity, and the associated flow range for an event marked as "limited by gage base" is 0 to 50 cfs, which is set as the complement of the perception thresholds. The flow range for all three data types can be manually altered by the user. Figure 5-5 demonstrates several possible flow ranges and data types.

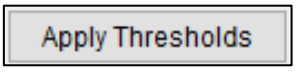
Flow Ranges

Year	Peak	Low Value	High Value	Data Type
1955	260000.0	234000.0	286000.0	Historical
1956		0.0	50000.0	Censored
1957		0.0	50000.0	Censored
1958		0.0	50000.0	Censored
1959		0.0	50000.0	Censored
1960		0.0	50000.0	Censored
1961		0.0	50000.0	Censored
1962		0.0	50000.0	Censored
1963		0.0	50000.0	Censored
1964		0.0	50000.0	Censored
1965	25300.0	25300.0	25300.0	Systematic
1966	22000.0	22000.0	22000.0	Systematic

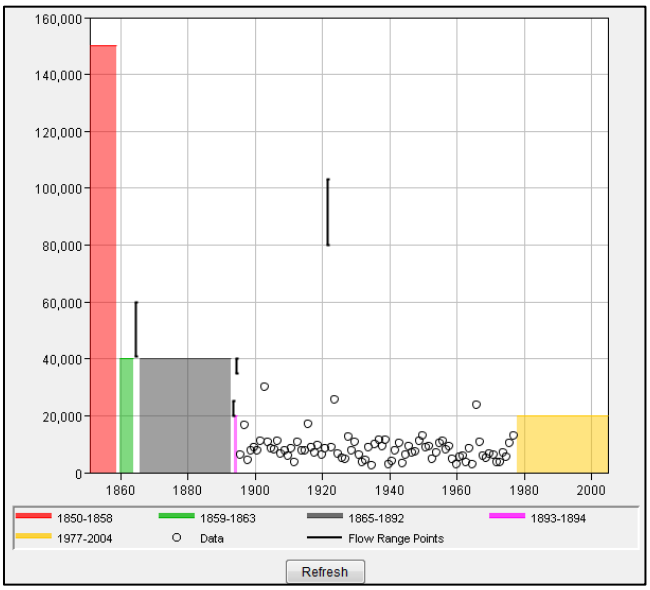
Figure 5-5. Example Flow Range Table with Systematic, Censored, and Historical Data.

When a flow event is reported as only a high and low value, a peak value should be estimated by taking the average of the low and high values. The peak value is only used for plotting the results (if the peak, high, and low values are equivalent). The peak value is not used within the computations.

The **Apply Thresholds** button can be used to automatically fill out the flow range table with the complementary flow ranges. For example, if a perception threshold is specified for a period of missing flow data with a low value of 50,000 cfs and a high value of infinity, the complementary flow range for each missing year would be set to 0 to 50,000 cfs after hitting Apply Thresholds. **The user should ensure that the peak, low, and high values within the flow range table are appropriate for use before computing the analysis.**



The plot within the EMA Data tab contains the flow values and the complementary Flow Ranges (as determined by the input Perception Thresholds) for the analysis period. The Perception Thresholds themselves are not contained within this figure.



The **Refresh** button will update the plot if changes are made to either the flow values or Perception Thresholds/Flow Ranges. The user can double left-click the chart to create a separate window containing the plot. Colors, symbols, and various chart properties can then be edited.

When low outliers are detected using the Multiple Grubbs-Beck test, the high value within the flow range for systematic events will be changed to use the lowest non-screened annual peak flow. Further discussion regarding the impacts of low outliers on flow ranges is contained within the **Bulletin 17C / Expected Moments Algorithm Examples** appendix.

National Water Information System Qualification Codes

HEC-SSP will import the National Water Information System Qualification (NWIS) annual peak flow and stage qualification/quality codes when available (the program does not import quality codes for daily, instantaneous, and real time data). A description of the quality codes for annual peak flows is contained within Table 4-1 and a description of the quality codes for annual peak stages is contained within Table 4-2. These qualification codes can be examined by the user to inform the choice of perception thresholds, flow ranges, and data types.

Figure 5-3 contains an example peak discharge time series and the treatment of the NWIS qualification codes using EMA (Paretti, Kennedy, & Cohn, 2014). Within this example, the shaded area represents the historical period (H) and the nonshaded area represents the systematic record (S). The seven types of peak streamflow data are:

1. Historical discharge (NWIS code 7, Q_{hist}) and historical perception threshold specified with an upper perception threshold (T_1 and $T_{2\ thresh\ upper}$).
2. Mean daily maximum (NWIS code 1) is described with an upper discharge interval bound ($Q_{1\ int\ upper}$) equal to a perception threshold and a known discharge as the lower interval bound ($Q_{1\ int\ lower}$).
3. A recorded gage height, missing the corresponding discharge, could be used to estimate a discharge interval ($Q_{2\ int}$) where both interval bounds are uncertain.
4. Discharge greater than known maximum discharge (NWIS code 8) and used as the lower interval bound ($Q_{3\ int\ lower}$) and an upper interval bound equal to a perception threshold ($Q_{3\ int\ upper}$).
5. Missing peak flow data for a portion of the period of record but a correlated nearby gage could be used to set an upper perception threshold ($T_{3\ thresh\ upper}$).
6. A discharge less than a known recordable gage base flow (NWIS code 4) is describable with a lower interval bound ($Q_{4\ int\ lower}$ = zero) and an upper interval bound ($Q_{4\ int\ upper}$) equal to the minimum gage base discharge.
7. Systematic peak flow discharge (Q_{sys}).

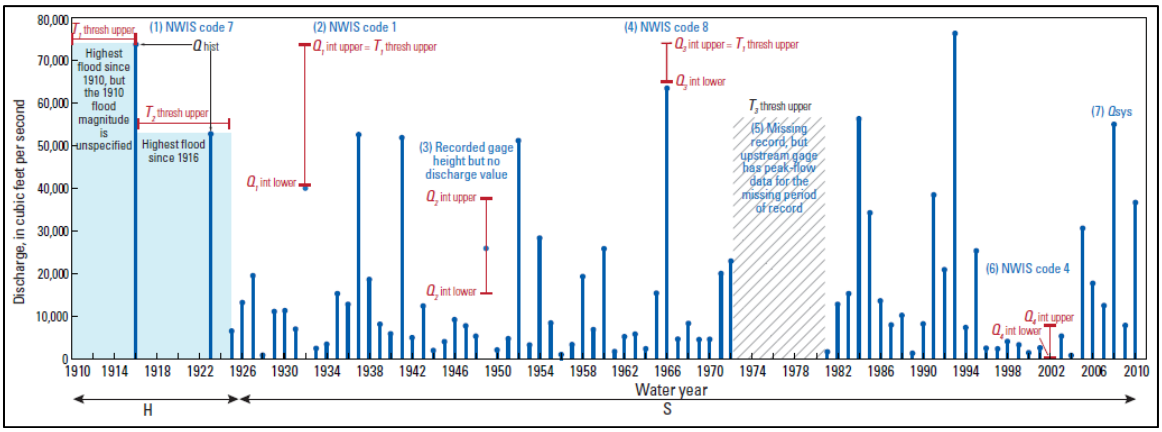


Figure 5-6. Example Peak Discharge Time Series and the Treatment of the NWIS Qualification Codes used within the Expected Moments Algorithm (Paretti, Kennedy, & Cohn, 2014).

Compute

Once the new analysis has been defined, and the user has all of the settings and options defined, performing the computations is simply a matter of pressing the **Compute** button at the bottom of the Bulletin 17 Editor. If the computations are successful, the user will receive a message that says **Compute Complete**. At this point, the user can begin to review the results of the flow frequency analysis.

Multiple Bulletin 17 analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finished computing the analyses.

Viewing and Printing Results

The user can view output from the flow frequency analysis directly from the Bulletin 17 Editor. The output consists of tabular results, a frequency curve plot, and a report documenting the data and computations performed.

Tabular Output

Once the computations for the flow frequency analysis are completed, the user can view tabular output by opening the **Tabular Results** tab. When this tab is pressed, the results will be displayed as shown in Figure 5-7.

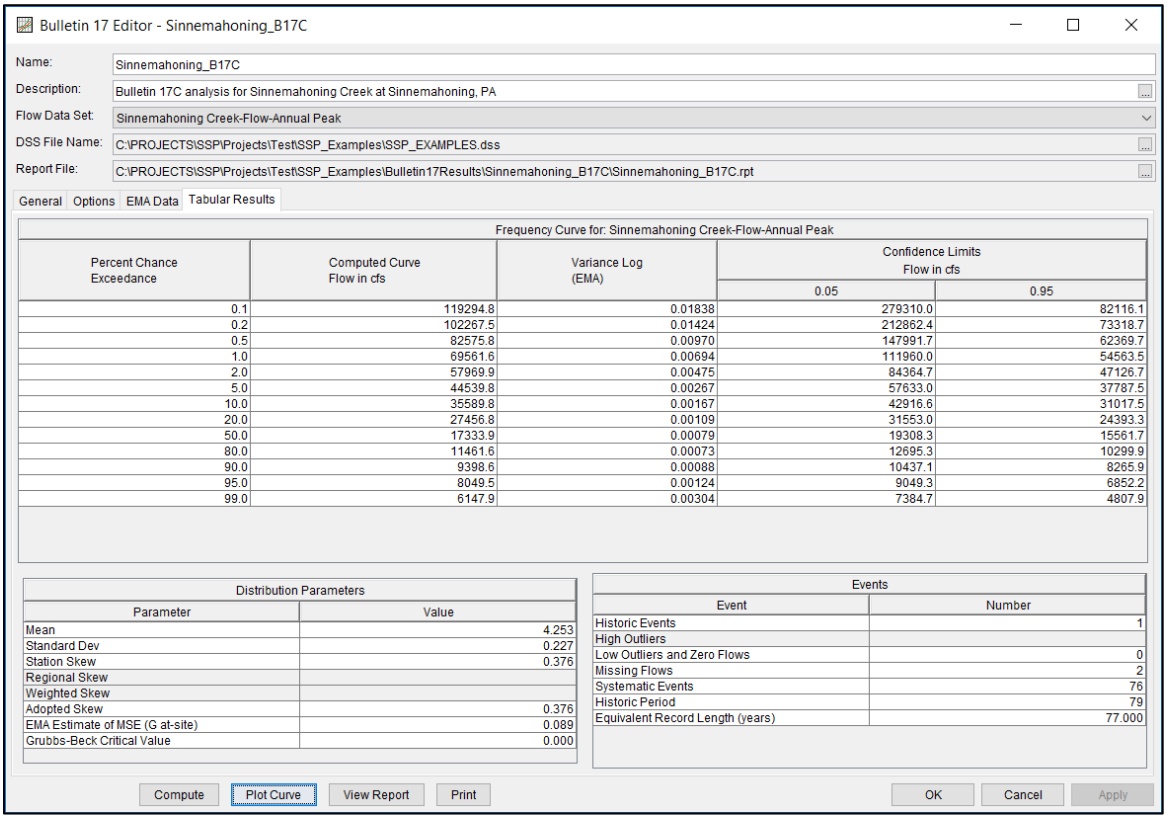


Figure 5-7. Bulletin 17 Editor with Tabular Results Tab Active.

Output on the results tab consists of three tables: Frequency Curves, Distribution Parameters, and Events. The **Frequency Curve** output table contains the percent chance exceedance ordinates, the computed Log Pearson III frequency curve quantiles, the expected probability adjusted frequency curve quantiles (if selected on the General tab), the variance of each quantile (if using 17C EMA), and the computed confidence limits (0.05 and 0.95, by default). Data in the frequency curve table can be sorted in either ascending or descending order by clicking in the column header (two mouse clicks are required the first time). The percent chance exceedance ordinates and frequency curves will sort so that the lowest values are on top or the highest values are on top.

The **Distribution Parameters** table contains (in log space) the mean, standard deviation, and station skew of the data, the user entered regional skew (if entered), weighted skew (weighted between station skew and regional skew), and the adopted skew for the analysis. This table also contains the EMA Estimate of MSE (G at site) and Grubbs-Beck Critical Value.

The **Events** table tabulates the number of historic events, high outliers (not calculated when using 17C EMA), low outliers and zero flows, missing values, systematic events, the number of years in the historic period, and an equivalent record length in years (if using 17C EMA). In an effort to be conservative, the equivalent record length is computed as the number of systematic events plus the number of historical events minus the number of low outliers (an additional equivalent record length computation is detailed within the **Report** file).

The tabular results can be printed by using the **Print** button at the bottom of the Bulletin 17 Editor. When the print button is pressed, a window will appear giving the user options for how they would like the table to be printed.

Graphical Output

Graphical output of the frequency curves can be obtained by pressing the **Plot Curve** button. When the Plot Curve button is pressed, a frequency curve plot will appear in a separate window as shown in Figure 5-8. The user can modify the plot properties by selecting the **Edit→Plot Properties** menu option. A plot properties window will open that lets the user change the line style for each data type, change the axis labels, modify the plot title, and edit other plot properties. The user can also edit line styles by placing the mouse on top of the line or data point in the plot or legend and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse

button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis.

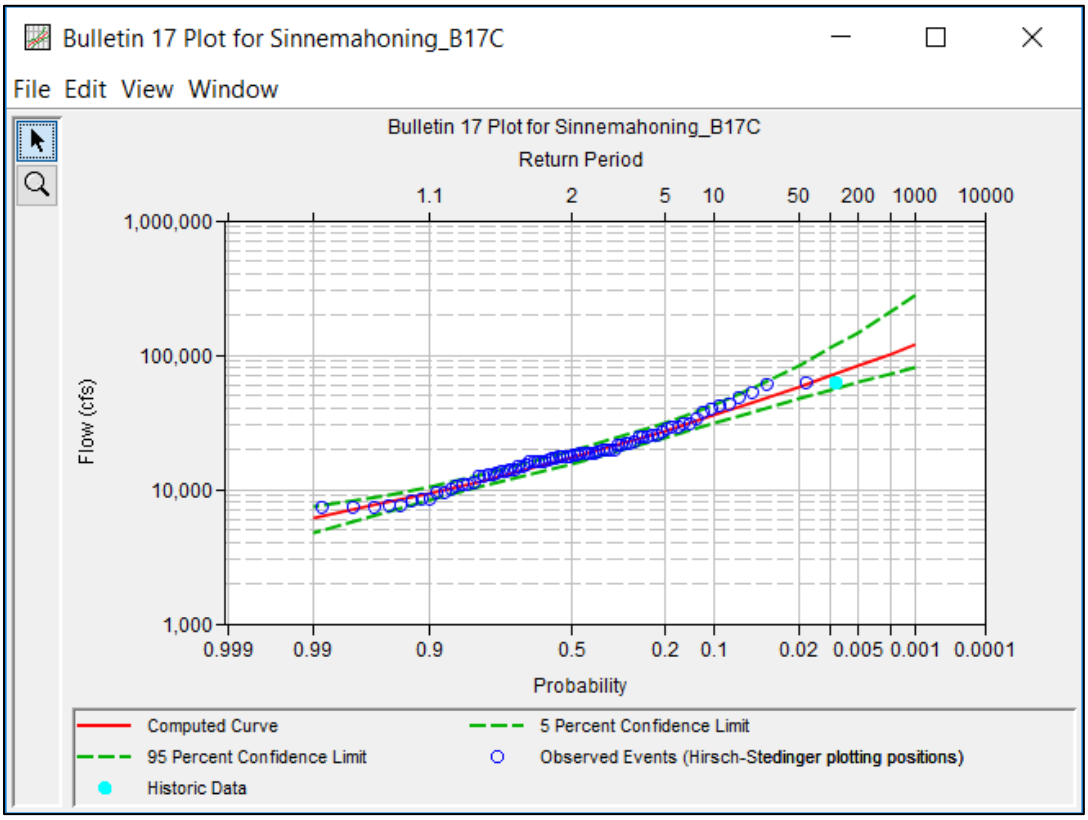


Figure 5-8. Example Frequency Curve Plot.

The frequency curve plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk, windows metafile, postscript, JPEG, and portable network graphic.

The data contained within the plot can also be tabulated by selecting **Tabulate** from the **File** menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the graphics options as a template

(**Save Template)** and applying previously saved templates to the current graphic (**Apply Template**).

The **Edit** menu on the graphic window contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend.

The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing graphics in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

When the Bulletin 17 computations are performed, a report file documenting the statistical computations is created. The report file lists all of the input data and user settings, plotting positions of the data points, intermediate results, each of the various statistical tests performed (i.e. high and low outliers, historical data, etc…), and the final results. This file is often useful for understanding how the software arrived at the final frequency curve.

Press the **View Report** button at the bottom of the Bulletin 17 Analysis editor to view the report file. When this button is pressed a window will appear containing the report as shown in Figure 5-9.

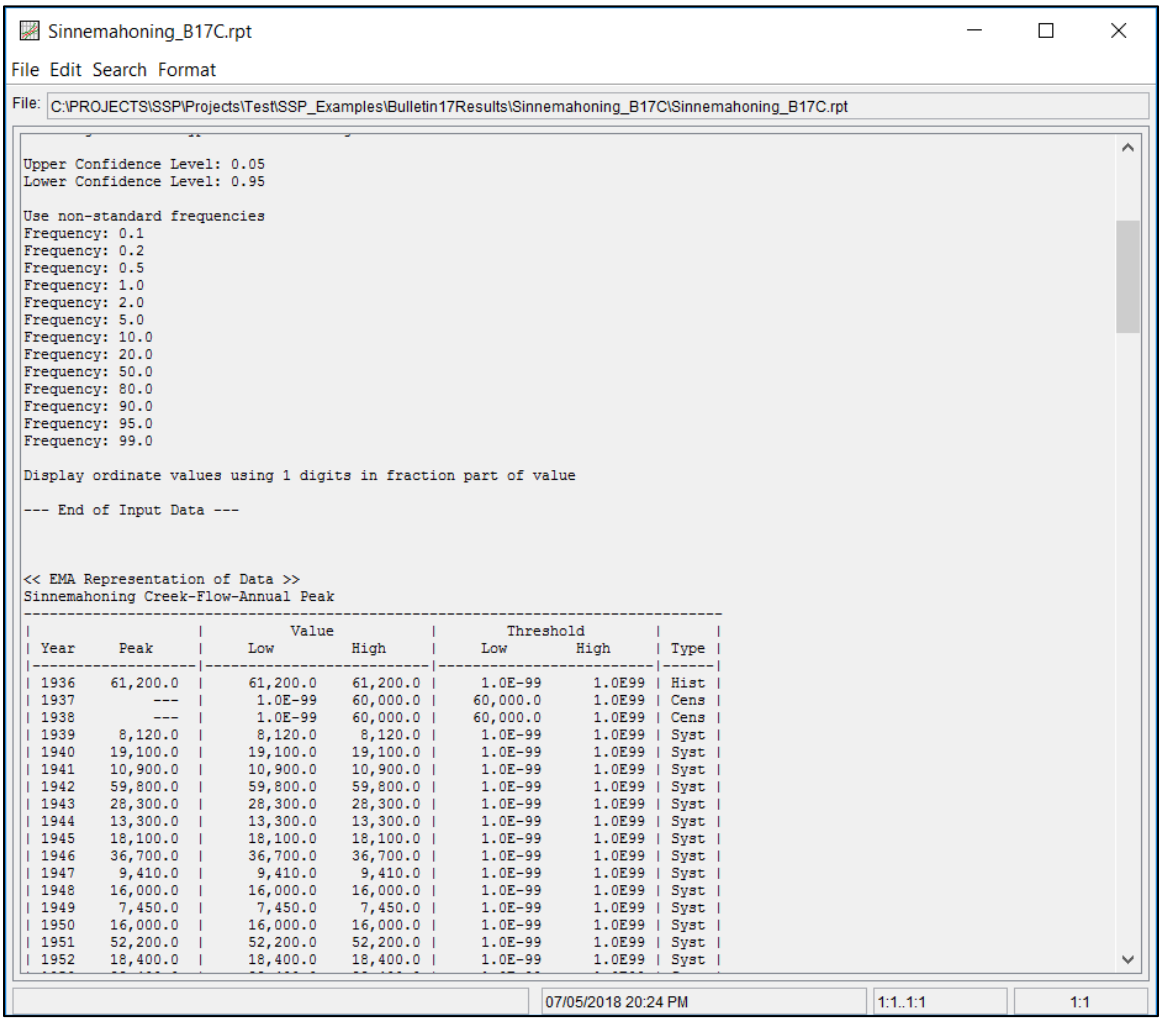


Figure 5-9. Example of the Bulletin 17 Report File.

Plots, tables and reports can also be created by selecting menu options from the **Results** menu. At least one Bulletin 17 Analysis must be selected in the study explorer before selecting one of the menu options on the Results menu. Results from multiple analyses are combined in one graph if they are selected in the study explorer when the **Graph** menu option is selected. The **Results→Summary Report** menu option will create a summary table of statistics and frequency curve ordinates for the selected analyses as shown in Figure 5-10.

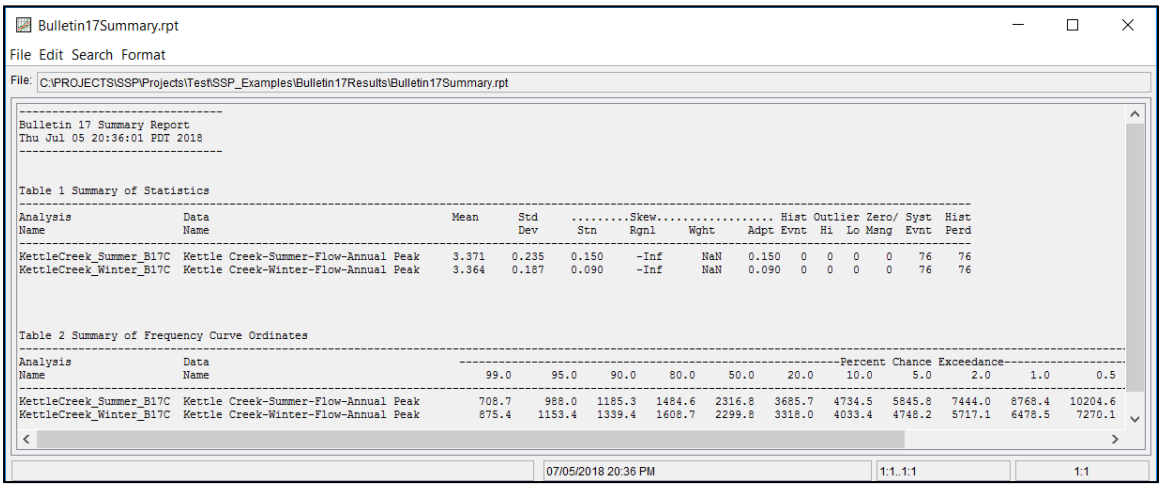


Figure 5-10. Summary Table for Selected Bulletin 17 Analyses.

CHAPTER 6

Performing a General Frequency Analysis

The current version of HEC-SSP allows the user to perform generalized frequency analyses of hydrologic data including, but not limited to, flow, stage, and precipitation data. The user can choose between different analytical distributions or perform a graphical fit to the data. This chapter discusses in detail how to use the General Frequency Analysis editor in HEC-SSP.

Contents

- Starting a New Analysis
- General Settings and Options
- Analytical Frequency Analysis
- Graphical Frequency Analysis
- Viewing and Printing Results

Starting a New Analysis

A general frequency analysis can be started in two ways, either by right clicking on the General Frequency Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **General Frequency Analysis**. When a new General Frequency Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select a data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The General Frequency Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a General Frequency Analysis will only include those data that have an irregular interval, like IR-CENTURY and IR-YEAR (E-part pathname). Once a name is entered and a flow data set is selected, the **DSS File Name** and **Report File** will automatically be populated. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The General Frequency Analysis editor is shown in Figure 6-1.

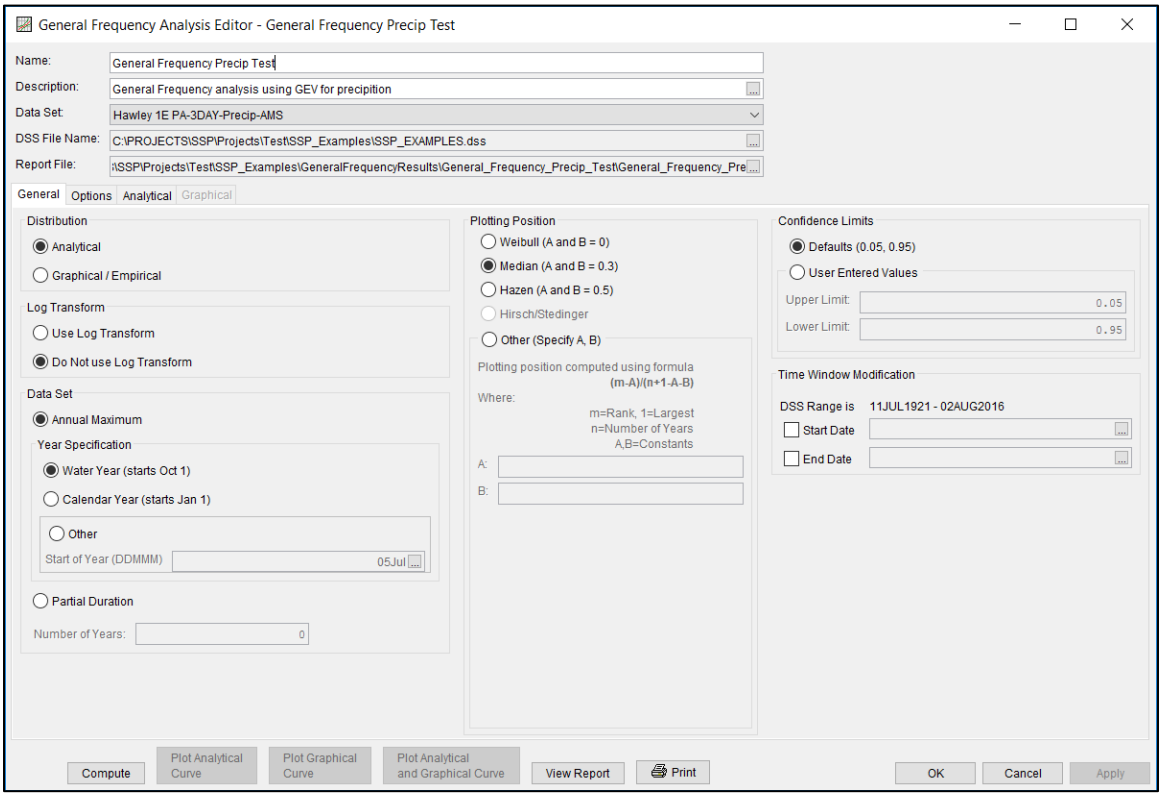


Figure 6-1. General Frequency Analysis Editor.

General Settings and Options

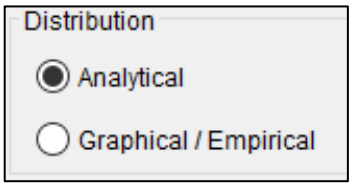
Once the analysis name and data set are selected, the user can begin defining the analysis. Contained on the General Frequency Analysis editor are four tabs. The tabs are labeled **General**, **Options**, **Analytical**, and **Graphical**. This section of the manual explains the use of the General and Options tabs.

General Settings

The first tab contains general settings for performing the frequency analysis (Figure 6-1). These settings include:

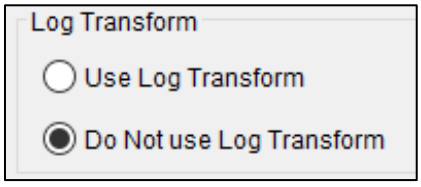
- Log Transforms
- Confidence Limits
- Time Window Modification
- Data Sampling
- Plotting Positions

Distribution



There are two options contained within the **Distribution** setting: **Analytical** and **Graphical / Empirical**. If the user selects **Analytical**, an analytical distribution will be fit to the data when computed. Data and options will need to be selected on the **Analytical** tab. If the user selects **Graphical / Empirical**, an empirical distribution will be fit to the data using graphical techniques. Data and options will need to be provided and selected on the **Graphical** tab. The default setting is **Analytical**.

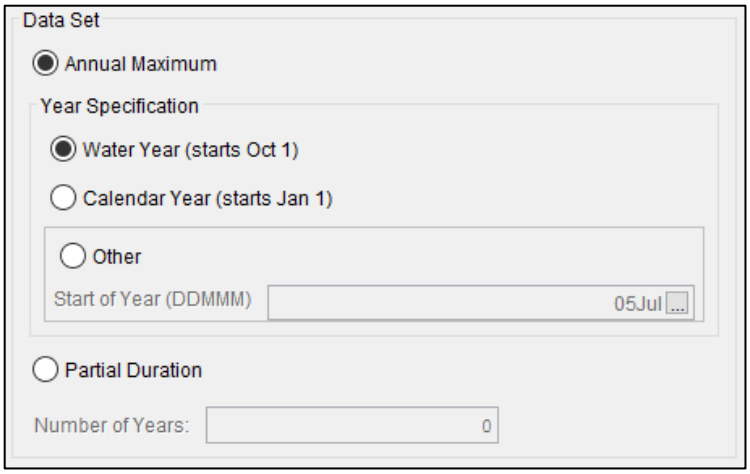
Log Transform



There are two options contained within the **Log Transform** setting: **Use Log Transform** and **Do not use Log Transform**. If the user selects **Use Log Transform** then the logarithms (base 10) of the data will be taken before any computations. If the user selects **Do not use Log Transform**, then the frequency analysis will be performed on the untransformed data values. The default setting is **Use Log Transform**.

Data Set

Two methods are available for specifying data within a General Frequency Analysis: **Annual Maximum** and **Partial Duration**. Annual Maximum is the default.



An annual maximum series is ordinarily used when the primary interest lies in the larger events or when the second, third, fourth… n^{th} largest event in any year is of little concern in the analysis. Conversely, a partial duration series represents the frequency of all independent events of interest, regardless of whether two or more occurred in the same year. Partial duration analyses may be more appropriate for situations where considerable flood damage is wrought by the second or third largest flood events in a given year. However, a flow-frequency curve based upon an annual maximum and a partial duration series will converge to form a single flow frequency curve as exceedance probability decreases. Commonly, this convergence occurs between the 0.1 and 0.02 (i.e. 1/10 and 1/50) annual exceedance probabilities.

Peak flow data is most often represented by an annual maximum series. For instance, choosing to download annual peak data from the USGS website (as is detailed in Chapter 4) will result in the import of an annual maximum series. The user is required to produce an appropriate partial duration series for use in a partial duration analysis. This can be achieved in one of several ways. For instance, the user can manually import independent peaks that have been extracted from another data set. However, it is more expedient to use the data filtering options within HEC-SSP, as discussed within the **Filtering Data** section. Figure 6-2 demonstrates the differences between a daily average flow data set, an annual maximum series, and a partial duration series for a four year span at a particular stream gage.

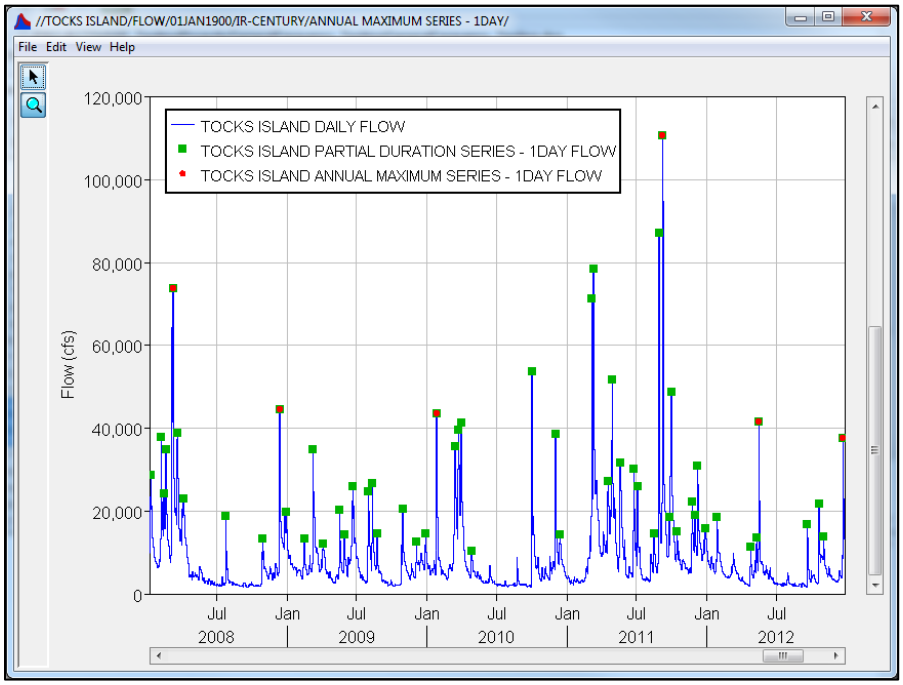


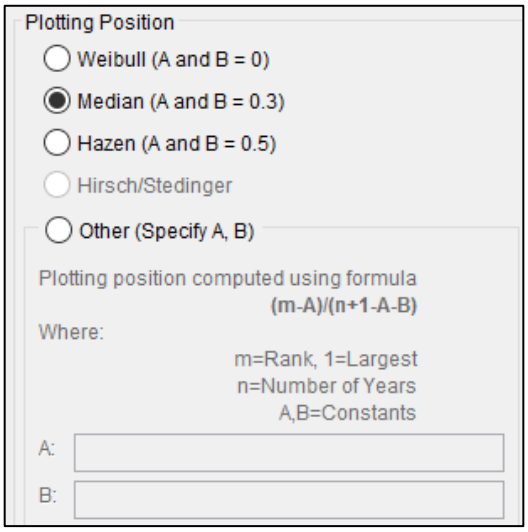
Figure 6-2. Hourly Flow, Annual Maximum, and Partial Duration Series for a Stream Gage.

The **Year Specification** option allows the user to define the beginning and ending date for what will be considered as the analysis year for extracting the data. These dates are used for extracting the annual maxima from the associated data set. It is important to choose a start date that captures all flood events from a certain hydrologic regime. For instance, if high flows generally occur between November and May, then the year should not start between these months. This will minimize the possibility that the same flood event is used for consecutive years. There are three options contained in the Year Specification panel. If **Water Year** is selected, the program uses a starting date of October 1 and an ending date of September 30. If **Calendar Year** is selected, the program uses a starting date of January 1 and an ending date of December 31. The **Other** option lets the user define the starting date. The default is Water Year.

When using a Partial Duration series, the value entered within the **Number of Years** entry field is used to extract ranked data points from the associated data set. For instance, if the Number of Years is set to 50, then the top 50 ranked events will be extracted from the associated data set regardless of how many years is spanned by the partial duration series.

Plotting Positions

Plotting positions are used for plotting the input data set on a probability scale along with the computed frequency curve and (optional) confidence limits. There are five options for computing plotting positions within HEC-SSP: Weibull, Median, Hazen, Hirsch/Stedinger, and user entered coefficients. The default method when using an Analytical distribution is the Median plotting position formula. The default method available for computing plotting positions when using the 17C EMA method is Hirsch/Stedinger. The default method when using the Graphical / Empirical distribution is the Weibull plotting position formula. The Hirsch/Stedinger option is only available for use with the 17C EMA method. However, the user may change the plotting position to any they would like and are available for the selected computation options. When using the Hirsch/Stedinger method, the A and B coefficients will be set equal to zero. When using 17C EMA methods and the Hirsch/Stedinger plotting position formula, flow data screened as low outliers (a.k.a. Potentially Influential Low Floods) are assigned a plotting position using the Median plotting position formula within HEC-SSP.



The generalized plotting position equation is:

$$P = \frac{(m - A)}{(n + 1 - A - B)}$$

where: m = rank of flood values with the largest equal to 1.

n = number of flood peaks in the data set.

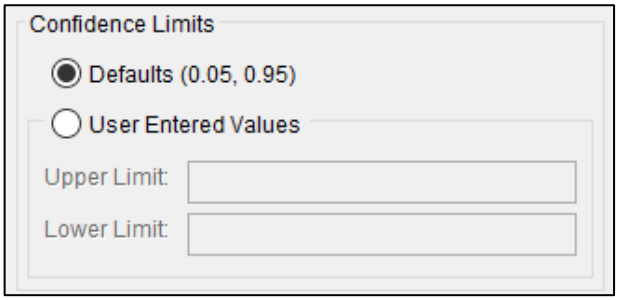
A & B = constants dependent on which equation is used (Weibull A and B=0; Median A and B = 0.3; and Hazen A and B=0.5).

Plotting positions represent estimates of the exceedance probability of each data point (peak flow). Different plotting position formulas can give very different values for the probabilities of the highest and lowest points in the data set. When fitting an analytical distribution, the plotting of data on the graph by a plotting position method is only done as a guide to assist

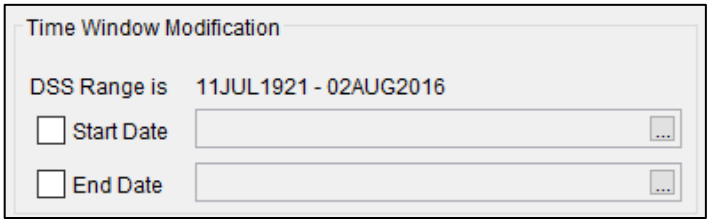
in evaluating the computed curve. The plotting position method selected does not have any impact on the computed curve.

Confidence Limits

The computed flow frequency curve is only an estimate of the probability distribution of the larger parent population. Confidence limits can be used to provide a measure of the uncertainty of the estimated exceedance probability of a selected discharge, stage, precipitation depth, etc or a measure of the uncertainty of the discharge, stage, precipitation depth, etc at a selected exceedance probability. By default, HEC-SSP calculates the 90 percent confidence interval for all flow frequency analyses (i.e. the 5% and 95% confidence limits). The confidence limits must be entered in decimal form (i.e. 95% = 0.95, and 5% = 0.05). The user has the option to override the default values and enter whatever values they would like for the confidence limits.



Time Window Modification



This option allows the user to narrow the time window used for the analysis. The default is to use all of the data contained in the selected data set. The user can enter either a start date for the analysis, and end date, or both a start and end date. If a start and/or end date are used, they must be dates that are encompassed within the data stored in the selected data set. The date range for the selected data set is shown in the editor just above the **Start Date** field.

Any dates entered within the Time Window Modification will be ignored when using the 17C EMA methods. When using 17C EMA, changes to the start and end period should be made within the **EMA Data** tab.

Options

In addition to the general settings, there are also several options available to the user for modifying the computations of the frequency curves. These options include:

- Low Outlier Threshold
- Output Labeling
- Historic Period Data
- Output Frequency Ordinates

When the Options tab is selected, the General Frequency Analysis editor will appear as shown in Figure 6-3.

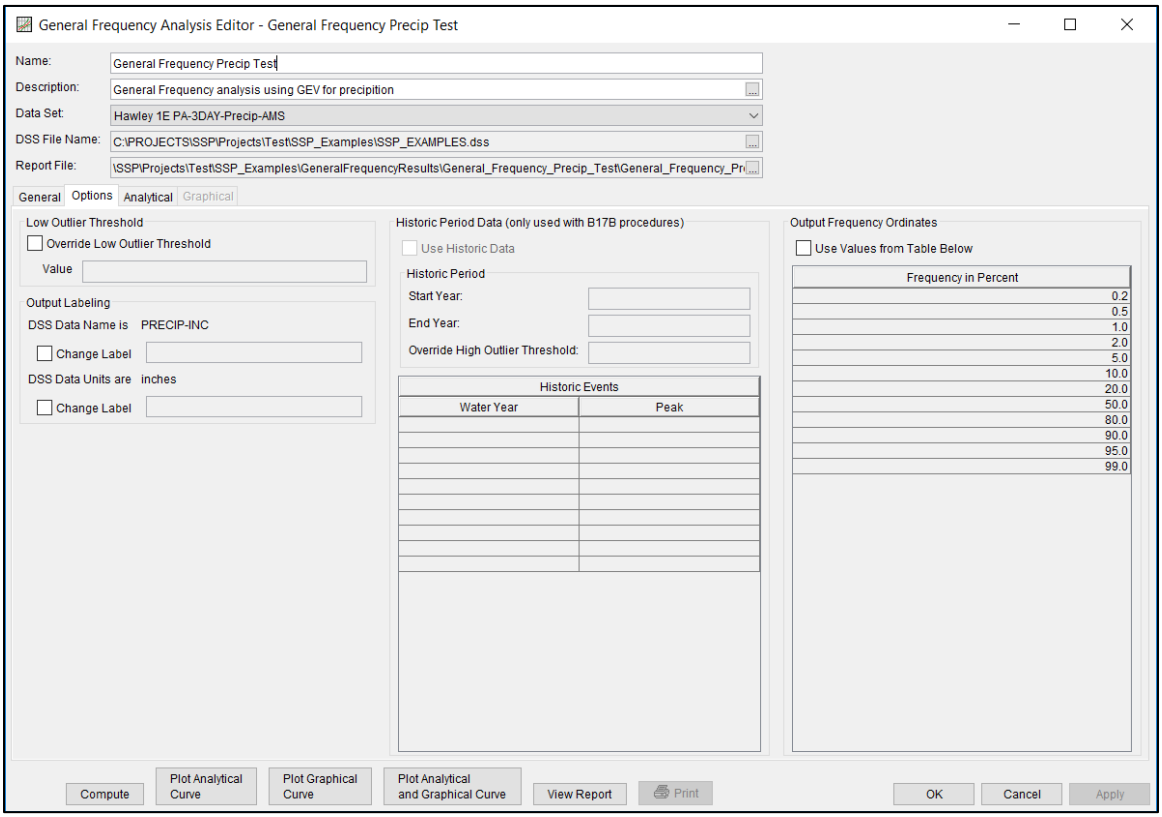
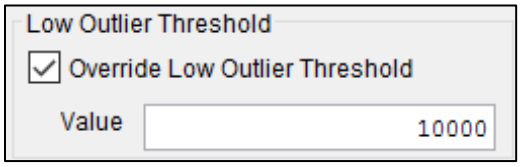


Figure 6-3. General Frequency Editor with Options Tab Selected.

Low Outlier Threshold

The user has the option to enter a different value for the low outlier threshold, if desired. If a value is entered for the low outlier threshold, then this value will override the computed value from either the Single or Multiple Grubbs-Beck test. An error message will be shown if the low outlier threshold is set to a value that would censor more than 50 percent

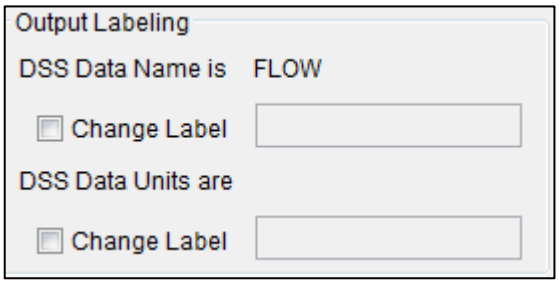


of the values within the data set. To override the computed low outlier threshold, check the box labeled **Override Low Outlier Threshold** and enter the preferred value.

The user may also use this option to screen low outliers when not using either 17B or 17C EMA procedures. However, this option is only available when using analytical distributions. All values less than the user-entered value will then be censored during the computations.

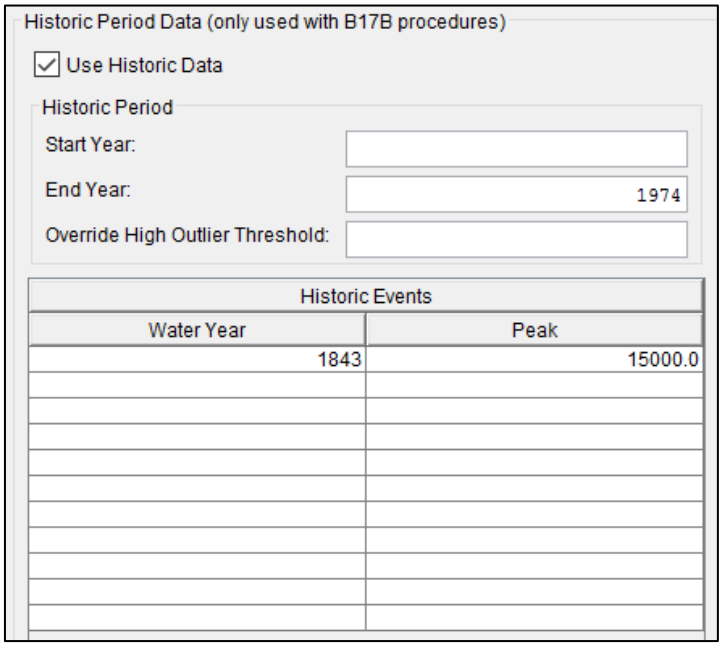
Output Labeling

This option allows the user to change the default labels for data contained in the output tables and plots. The user can change both the name of the data as well as how the units of the data are labeled.



Historic Period Data

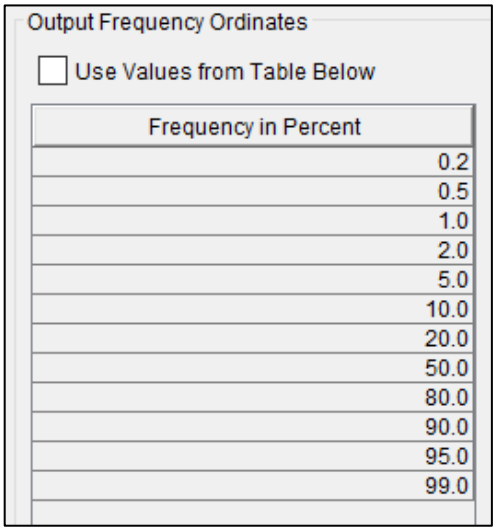
All historic data that provides reliable estimates of flood peaks outside the systematic record should be used in order to improve the estimated flood frequency curve. Flood information of large events outside of the systematic record can often be used to extend the record to a historic period much longer than that of the systematic record. HEC-SSP uses historic data specified in this table as recommended in Bulletin 17B.



This option is only available when using Bulletin 17B procedures. To make use of historic data within the 17C EMA procedures, this information should be entered on the **EMA Data** tab. To use historic data with Bulletin 17B procedures, check the box labeled **Use Historic Data**. The user can enter a starting year for the historic period, ending year for a historic period, and a high threshold value. If the user enters a high threshold value, then any value in the systematic record greater than that value will also be treated as a historical flood peak. The user can also enter historic flood peaks that are not contained in the systematic record. This is done in the table at the bottom labeled **Historic Flood Peaks**. Only one value per water year may be entered and all years must be entered assuming a water year from October 1 through September 30. If a start year is not entered, then the assumed start year is the earliest year of the systematic record and any historical values that have been entered. If an end year is not entered, then the assumed end year is the latest year in the systematic record and any entered historic values.

Note: The program treats all data in the data set as systematic data when using 17B procedures. If historic events are included in the data set, then the user must define the analysis time window (General tab – Time Window Modification) so that it only bounds the systematic record. Then the user must define the historic events in the Historic Events table.

Output Frequency Ordinates



This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact

on the computed frequency curve, but rather only the values of the curve that are reported.

Analytical Frequency Analysis

Once the new analysis has been defined and the user has all of the general settings and options defined, the user can choose between performing an Analytical Frequency analysis or a Graphical Frequency analysis. This section of the manual describes how to use the Analytical Frequency analysis option.

The **Analytical** tab will only be available if the **Analytical** option was selected on the **General** tab. When the user selects the **Analytical** tab on the General Frequency Analysis editor, the window will appear as shown in Figure 6-4. As shown, four additional tabs will appear on the screen: Settings, EMA Data, Tabular Results, and Plot.

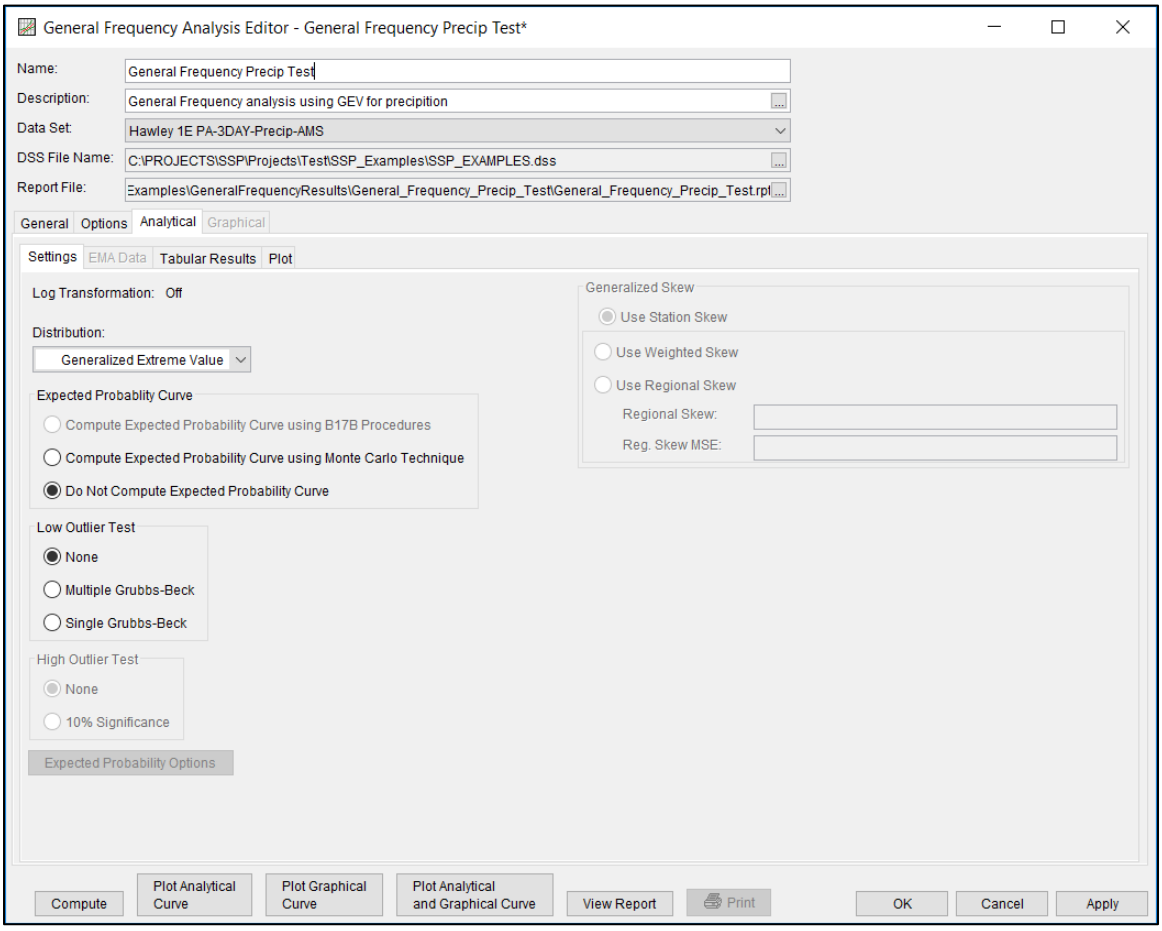


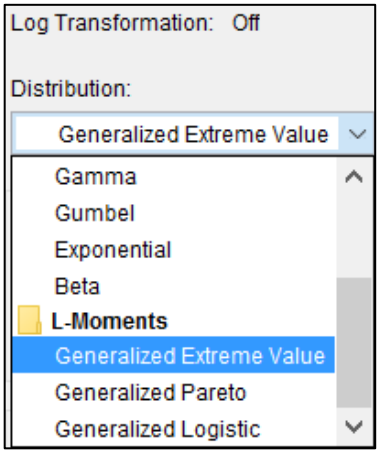
Figure 6-4. Analytical Tab of the General Frequency Analysis Editor.

Settings

The **Settings** tab contains additional settings for the analytical frequency analysis. These settings include:

- Distribution
- Expected Probability Curve
- Expected Probability Options
- Low Outlier Test
- High Outlier Test
- Generalized Skew

Distribution



This option allows the user to select from a list of available fitting methods and analytical distributions to perform the frequency analysis. The current version of HEC-SSP contains multiple choices, depending upon whether the **Use Log Transform** or **Do Not Use Log Transform** option was selected on the **General** tab.

The fitting method | analytical distribution combinations available when the **Use Log Transform** option was selected include:

- None
- Product Moments | LogNormal
- Product Moments | LogPearsonIII
- Product Moments | LogLogistic
- EMA | LogPearsonIII

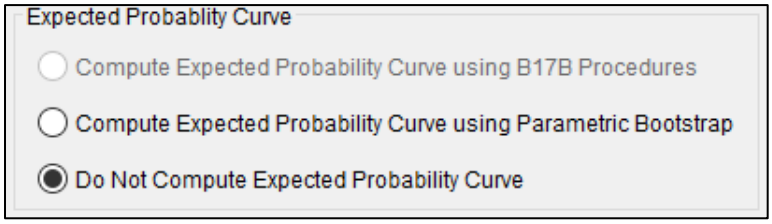
The fitting method | analytical distribution combinations available when the **Do Not Use Log Transform** option was selected include:

- None
- Product Moments | Normal
- Product Moments | PearsonIII
- Product Moments | Logistic
- Product Moments | Gamma
- Product Moments | Gumbel
- Product Moments | Exponential
- Product Moments | Beta
- Linear Moments | Generalized Extreme Value

- Linear Moments | Generalized Pareto
- Linear Moments | Generalized Logistic

See the **Distribution Fitting and Parameter Estimation** section for a description of the aforementioned fitting methods and analytical distributions.

Expected Probability Curve



This setting has three options: **Compute Expected Probability Curve using B17B Procedures**, **Compute Expected Probability Curve using Parametric Bootstrap**, and **Do Not Compute Expected Probability Curve**. The default setting is to not compute the expected probability curve. The **Compute Expected Probability Curve using B17B Procedures** option is only available when using the Product Moments | LogPearsonIII fitting method | analytical distribution. When the **Compute Expected Probability Curve using Parametric Bootstrap** option is selected, the fitted analytical distribution will be resampled many times to estimate the expected probability curve. Inputs to the parametric bootstrap routine used by the software can be accessed through the **Expected Probability Options** button and are detailed in the following section.

When the expected probability curve is computed, the curve will be shown in both the result tables and the plots as an additional curve. The expected probability adjustment is a correction for bias in the computed frequency curve. The bias is caused by uncertainty due to the shortness of the data record. The use of the expected probability curve is a policy decision. The expected probability curve is most often used in establishing design flood criteria. When use of the frequency curve includes uncertainty analysis, the expected probability adjustment is made implicitly. Therefore, the computed flood frequency curve without the expected probability adjustment is the curve used in computation of confidence limits, risk analysis, and in obtaining weighted averages of independent estimates of flood frequency discharge (Interagency Advisory Committee on Water Data, 1982).

Expected Probability Options

Clicking the **Expected Probability Options** button will launch an editor that contains several options pertinent to the parametric bootstrap routine used to estimate the expected probability curve, as shown in Figure 6-5. These options are **not** used within the B17B Procedures option. The parametric bootstrap routine used by the software to estimate the expected probability curve is simplified within the following steps:

1. Using the initially fitted model produced by the chosen fitting method | distribution, sample *n* values.
    a. *n* is the **Equivalent Record Length**.
2. Using the same fitting method, fit the same distribution to the *n* values to produce a new fitted model.
3. Randomly sample a single value from the new fitted model.
4. Repeat *m* times.
    a. *m* is the **Minimum Iterations**.
5. Sort the values and build a representative histogram to store the values.
    a. This histogram can be defined using linear, log, or user defined values.
    b. By default, linear values will be used.
6. Check for convergence using the specified convergence criteria:
    a. The change in **Z Alpha** at all output frequency ordinates specified on the **Options** tab must be less than the **Tolerance**.
    b. **Z Alpha** is a user-specified probability along the probability density function, as shown in Figure 6-6.
7. Repeat steps 1, 2, and 3 and place the single value within the histogram.
8. Check for convergence using the specified convergence criteria:
    a. The change in **Z Alpha** at all output frequency ordinates specified on the **Options** tab must be less than the **Tolerance**.
    b. The number of iterations equals the **Maximum Iterations**.
    c. The **Compute Until Convergence** check box can be used to iterate until all convergence criteria are satisfied.
9. Repeat steps 7 and 8 until convergence is achieved. The resultant values form the expected probability curve.

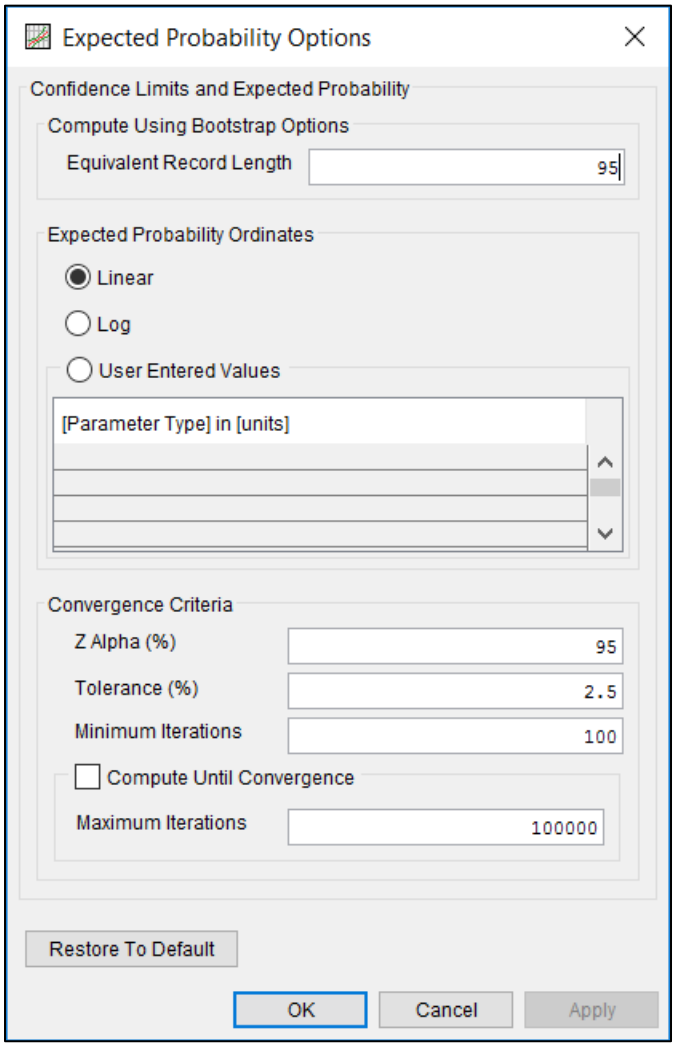


Figure 6-5. Expected Probability Options Editor.

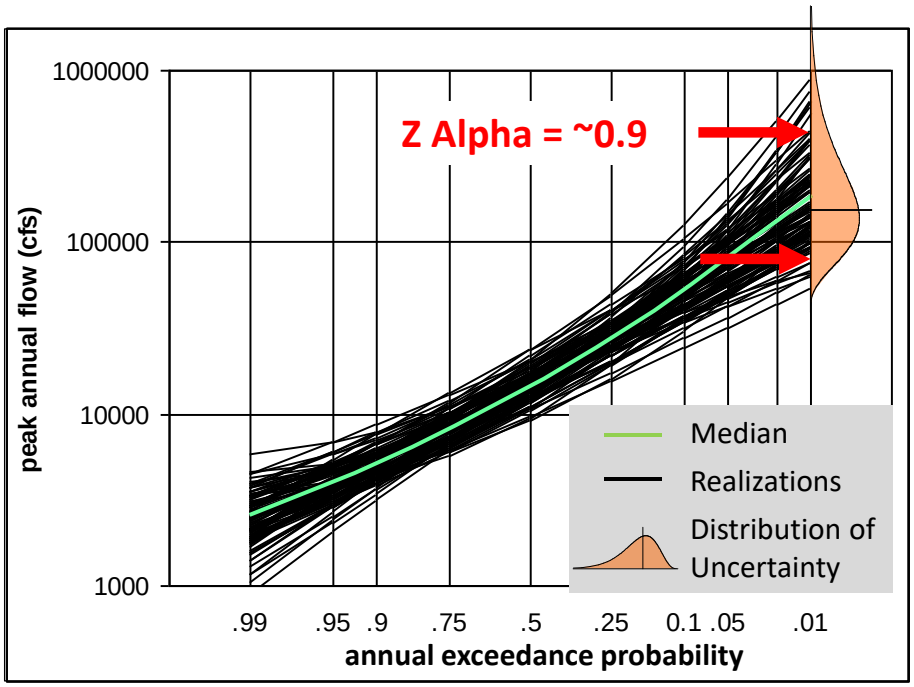
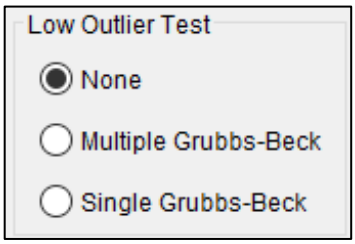


Figure 6-6. Representation of Z Alpha Used in Parametric Bootstrap Computations.

Low Outlier Test

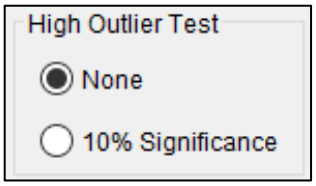
This option allows the user to choose the test that is performed to identify low-value data points that depart significantly from the trend of the remaining data and inappropriately affect the extreme quantiles in the upper tail of the frequency curve. There are three options for testing low outliers within this analysis: **None**, **Multiple Grubbs-Beck**, **Single Grubbs-Beck**.



When using Product Moments | LogPearsonIII, the default test is the Single Grubbs-Beck test. When using EMA | LogPearsonIII, the default (and only) test is the Multiple Grubbs-Beck test. When using any other fitting method | distribution choice, the default selection is None.

High Outlier Test

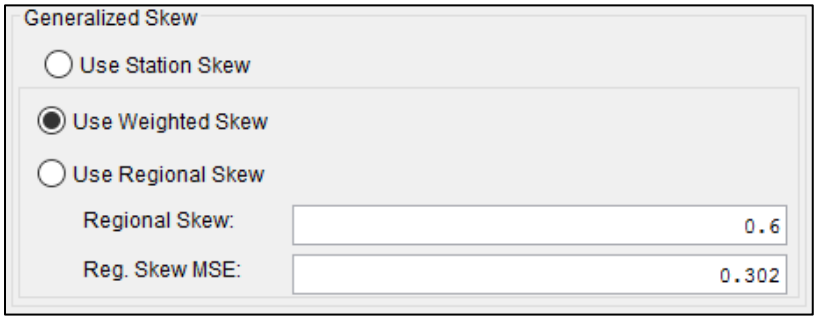
This option allows the user to choose whether a high outlier test will be performed to identify high outliers. The **None** option is the default (and only) test available with any fitting method | analytical distribution except Product Moments | LogPearsonIII. The **10% Significance** test is only available for use when using Product Moments | LogPearsonIII and is outlined within Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). If a high outlier is identified in the data set, the user should try to incorporate historical period information to extend the time period for which the high outlier(s) is considered to be the maximum value(s).



Generalized Skew

This option allows the user to incorporate regional skew information when the PearsonIII or LogPearsonIII distribution will be used. This panel will be disabled when any other distribution is selected for use.

When using the PearsonIII or LogPearsonIII distribution, there are three options contained within the generalized skew setting: Use Station Skew, Use Weighted Skew, and Use Regional Skew. The default skew setting is **Use Station Skew**. With this setting, the skew of the computed curve will be based solely on computing a skew from the data points.



The **Use Weighted Skew** option requires the user to enter a generalized regional skew and a Mean-Square Error (MSE) of the generalized regional skew. This option weights the computed station skew with the generalized regional skew. The equation for performing this weighting can be found in Bulletin 17B (Equation 6). If a regional skew is taken from Plate I of Bulletin 17B (the skew map of the United States), the value of MSE = 0.302.

The last generalized skew option is **Use Regional Skew**. When this option is selected, the user must enter a generalized regional skew and an MSE for that skew. The program will ignore the computed station skew and use only the generalized regional skew.

EMA Data

When using the EMA | LogPearsonIII fitting method | distribution choice, additional data is required. This additional information includes perception thresholds and flow ranges. Every year in the analysis period must have perception thresholds and a flow range specified. The additional data that is required for use is accessed/input within the EMA Data tab. For further detail, see the **EMA Data** section within the Bulletin 17 Analysis chapter.

Tabular Results

The Tabular Results tab contains tables of results for the Analytical Frequency analysis. An example of the results tab is shown in Figure 6-7. Output on the Tabular Results tab consists of three tables: Frequency Curves, Distribution Parameters, and Events.

The **Frequency Curve** output table contains multiple columns. The left-most column contains the percent chance exceedance ordinates specified on the **Options** tab. Moving right, the next columns contain the computed frequency curve quantiles, and other information, if computed (i.e. expected probability curve, variance of each quantile, and the confidence limits). The right-most columns of the **Frequency Curve** output table contain a computed frequency curve (and other data) for an analysis based on user-adjusted statistics. User entered adjusted statistics are an option that the user can set on the **Plot** tab, which is discussed in detail in the next section of this manual. If the user has not entered adjusted statistics, then these columns will be empty. Data in the **Frequency Curve** table can be sorted in either ascending or descending order by clicking in the column header (two mouse clicks are required the first time). The percent chance exceedance ordinates and frequency curves will sort so that the lowest values are on top or the highest values are on top.

The **Distribution Parameters** table contains the parameters of the selected distribution achieved using the selected fitting method. For instance, if using the EMA | LogPearsonIII fitting method | distribution, the (in log space) mean, standard deviation, and station skew of the data, the user entered regional skew (if entered), weighted skew (weighted between station skew and regional skew), and the adopted skew for the analysis. Additionally, when using the EMA | LogPearsonIII fitting method | distribution, this table will also contain the EMA Estimate of MSE (G at site) and Grubbs-Beck Critical Value.

The **Events** table tabulates the number of historic events, high outliers (if using Product Moments | LogPearsonIII or Product Moments | PearsonIII), low outliers and zeroes, missing events, systematic events, the number of years in the historic period, and an equivalent record length in years (if

using EMA | LogPearsonIII). Additionally, the lower right portion of the table will show if Log Transform is On or Off and which fitting method and analytical distribution was selected for the analysis.

The tabular results can be printed by using the **Print** button at the bottom of the Bulletin 17 Editor. When the print button is pressed, a window will appear giving the user options for how they would like the table to be printed.

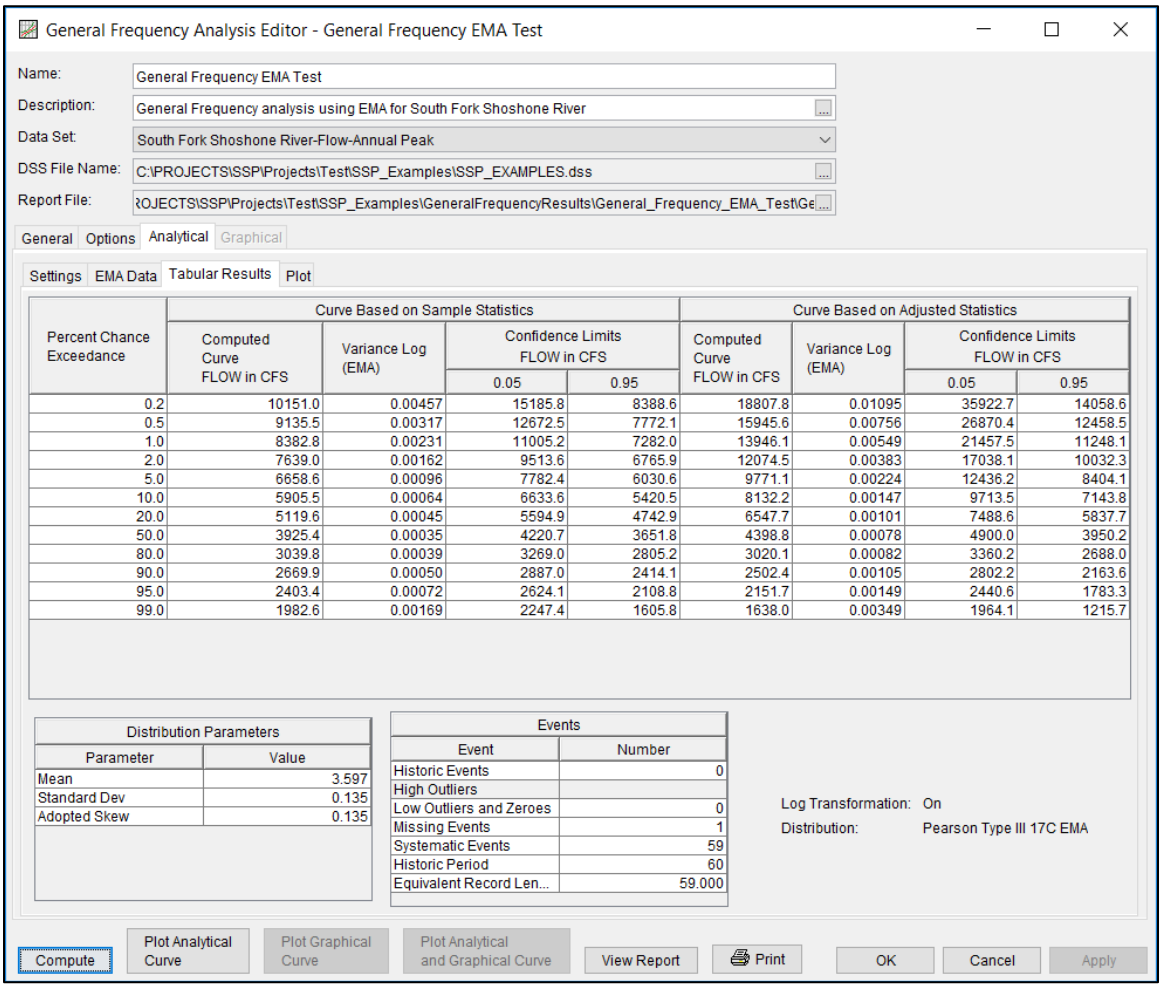


Figure 6-7. Tabular Results Tab for Analytical Analysis.

Plot

In addition to tabular results, a **Plot** tab is available for viewing a graphical plot of both the computed frequency curve as well as a computed curve based on any user-adjusted statistics. When the Plot tab is selected the window will change to resemble Figure 6-8.

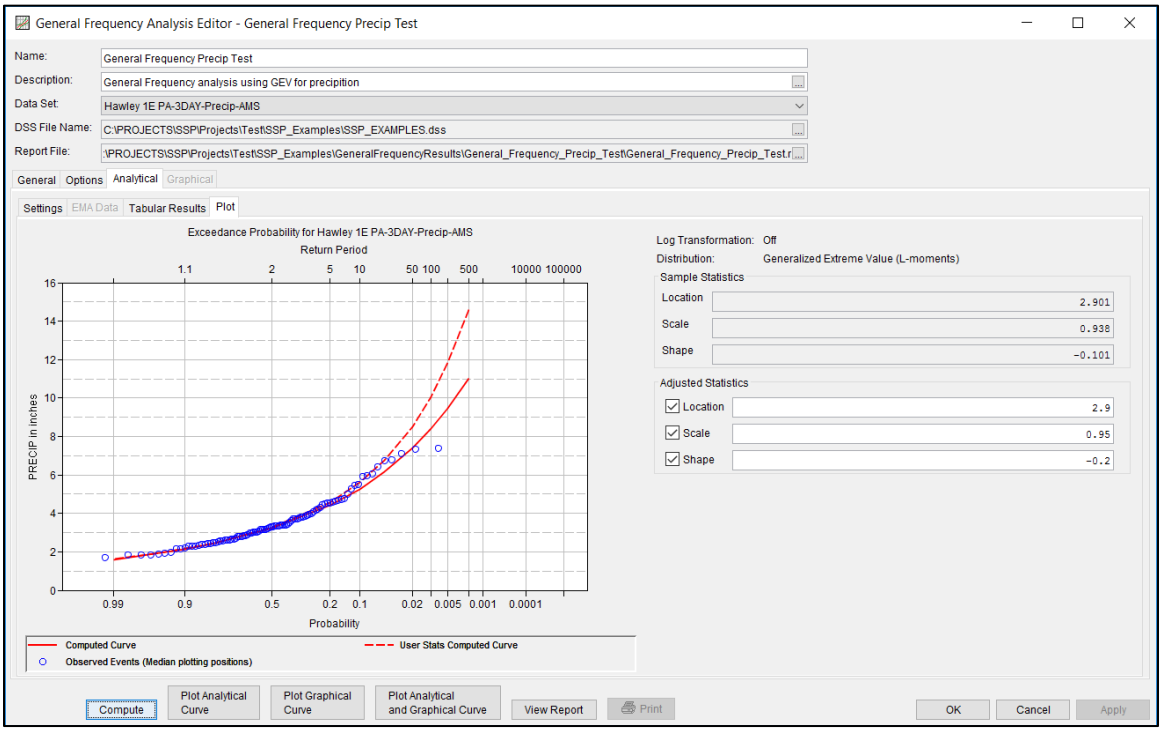


Figure 6-8. Plot Tab of the General Frequency Analytical Analysis.

As shown in Figure 6-8, the plot contains the computed frequency curve, confidence limits (if computed), expected probability curve (if computed), and events plotted with the user selected plotting position. The computed statistics for the selected fitting method | distribution are shown in a table on the right side of the window. Below the computed statistics is a table labeled "Adjusted Statistics". There is a check box and a data entry field for the parameters of the distribution. The user can enter values into any or all of these fields. Turning on the check box then enables that field to be used in computing a curve with the user entered statistic overriding the computed value. The user statistics option allows the user to see how the curve would change if any or all of the statistics were different. When one or more check box is enabled and data is entered into the user statistics fields, the user must press the compute button again in order for the computations to be performed with the user entered statistics. After the compute button is pressed, both the plot and the table on the Tabular Results tab will be updated to reflect any user entered statistics.

Compute

Once the new analysis has been defined, and the user has the requisite information defined, performing the computations is simply a matter of pressing the **Compute** button at the bottom of the General Frequency Analysis editor. If the computations are successful, the user will receive a message that says "[*Distribution Choice*] Compute Complete" where [*Distribution Choice*] is either Analytical or Graphical, as specified on the **General** tab. At this point, the user can begin to review the results of the computations.

Multiple General Frequency analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finishes computing the analyses.

Graphical Frequency Analysis

In addition to an analytical frequency analysis, the user has the option to graphically fit an empirical distribution to the selected data set. A graphical fit can be very useful when the available analytical distributions do not provide an adequate or appropriate fit to the data. One example of when a graphical frequency analysis is most appropriate is when plotting a frequency curve for flow data that is downstream of a flood control reservoir. Analytical frequency distributions are often not appropriate for describing flow data that is significantly regulated. In general, a portion of the flow frequency data for a highly regulated stream will be very flat in the zone in which upstream regulation can control the flows for a range of frequencies. This type of data lends itself to a graphical analysis rather than the use of an analytical distribution. Another example of when a graphical fit may be more appropriate is when trying to compute a frequency curve for annual peak stage data at a point on a river. Often, annual peak stages, when plotted on a normal probability axis, will flatten as exceedance probability decreases due to the presence of overbank/floodplain storage, which is not adequately described with an analytical distribution.

When the **Graphical** tab is selected, the editor will display a plot and table as shown in Figure 6-9. A minimum of three points are required to define a graphical frequency curve. In the plot, the data will be plotted using the user selected plotting position method. The table to the right of the plot allows the user to enter data values for the frequency ordinates defined on the Options tab.

Additionally, the **Multi-Point Edit** tool can be used to define the frequency ordinates by drawing a curve. To use this tool, begin by selecting the tool on the left side of the editor. Then, define the curve by left clicking within the plot window at the desired locations. To finish defining the curve, right click. It should be noted that the Multi-Point Edit tool will not extrapolate frequency information; it will only interpolate to the user-defined frequency ordinates specified on the Options tab. Bold, dashed lines will be displayed on the plot that correspond to the output frequency ordinates defined on the Options tab. These vertical lines help to visually identify the locations where frequency information will be extracted from the drawn curve.



The **Data Type** and **Equivalent Years of Record** options are required to compute confidence limits using the order statistics method that is discussed in ETL 1110-2-537. If the data is not flow or stage (i.e. precipitation), select the **Flow** data type when the graphical frequency curve is approximately analytic for extreme probabilities (frequency curve is not relatively flat for extreme probabilities). Select the **Stage** data type when the graphical frequency curve is relatively flat for extreme probabilities (U.S. Army Corps of Engineers, 1997). The Equivalent Years of Record will be estimated based upon the number of years spanned by the selected data set. This value can be modified by the user.

When using a partial duration series, the **Axis Type** options will become enabled. By default, the **Normal (Top N Events)** will be set as the default. The Normal (Top N Events) option will use the Period of Record Years that was defined on the General Tab to extract and plot the top N events. For instance, if the user defined a Period of Record Years of 79 on the Graphical Tab, the top 79 events within the associated partial duration series will be plotted using the Plotting Position defined on the General tab. When using the **Log (All Events)** axis option, all events will be plotted using the average number of events per year to define the x-axis. The two different plotting options are shown in Figure 6-10.

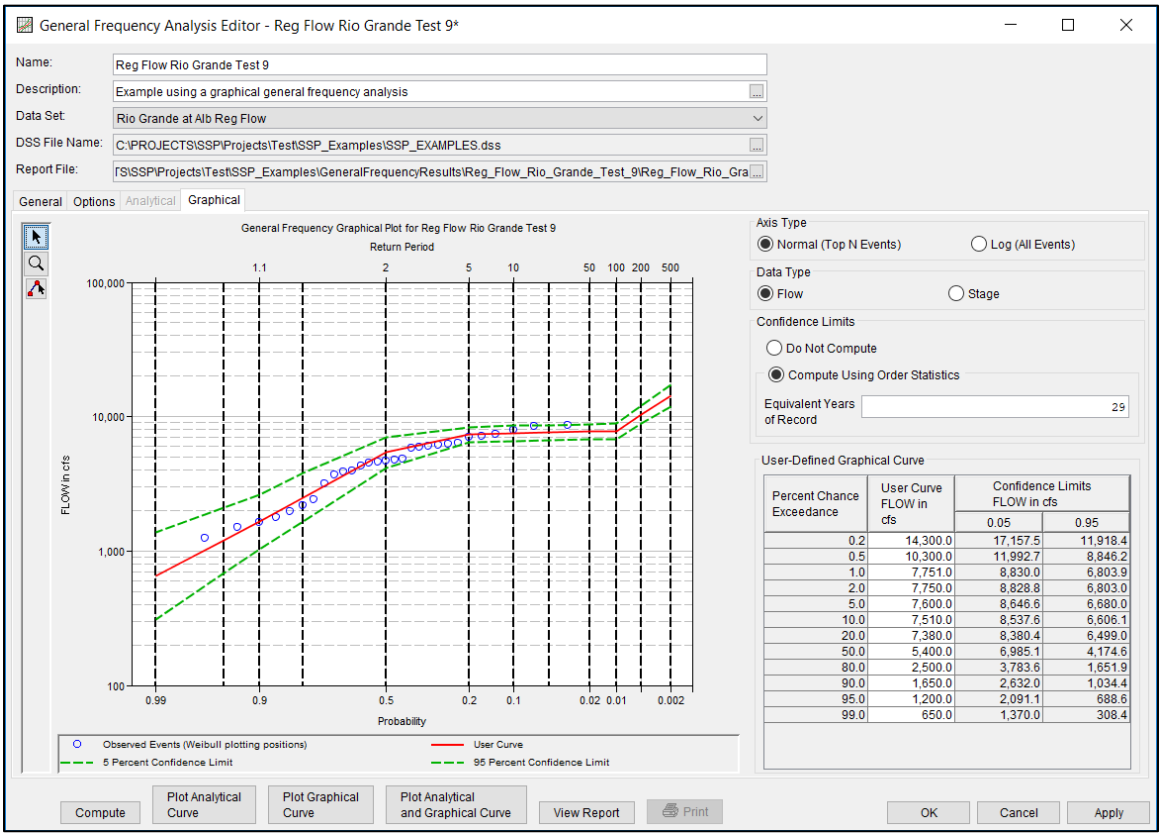
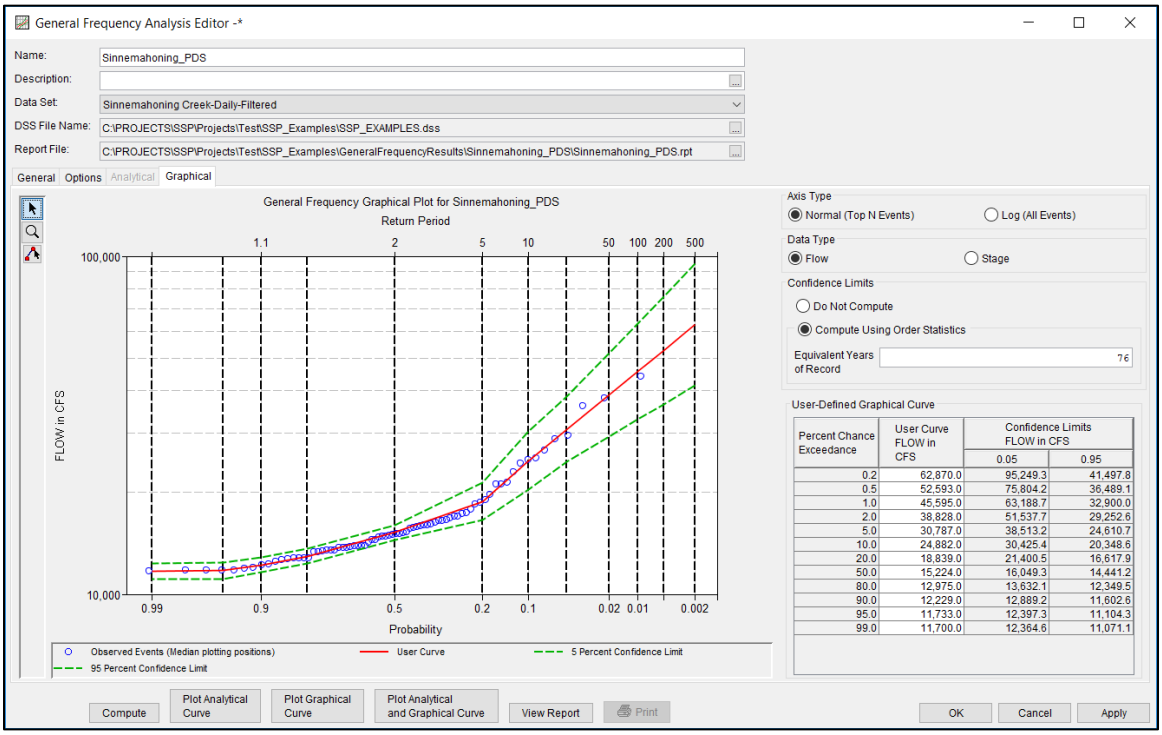


Figure 6-9. Graphical Tab of the General Frequency Analysis Editor.



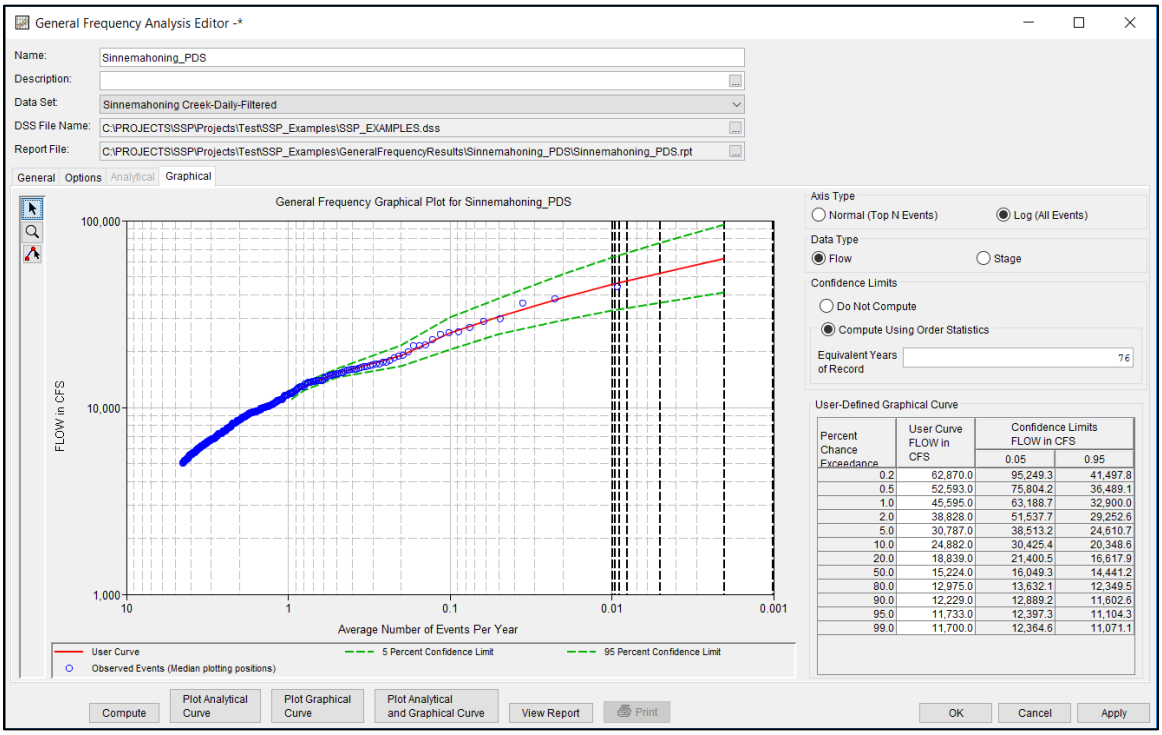


Figure 6-10. Axis Type Options on the Graphical Tab.

Viewing and Printing Results

The user can view output for the frequency analysis directly from the General Frequency Analysis editor (Tabular and Graphical output) or by using the plot and view buttons at the bottom of the editor. The output consists of tabular results, an analytical frequency curve plot, a graphical frequency curve plot, and a report documenting the data and computations performed.

Tabular Output

Once the computations for the analytical frequency analysis are completed, the user can view tabular output by selecting the **Tabular Results** tab under the **Analytical** analysis tab. The details of this table were discussed under the analytical analysis option above.

The tabular results can be printed by using the **Print** button at the bottom of the General Frequency Analysis editor. When the print button is pressed, a window will appear giving the user options for how they would like the table to be printed.

Graphical Output

Graphical output of the analytical frequency curve can be obtained on the **Analytical** | **Plot** tab or by pressing the button labeled **Plot Analytical Curve** at the bottom of the general frequency editor. When the Plot Analytical Curve button is pressed, a frequency curve plot will appear in a separate window as shown in Figure 6-11.

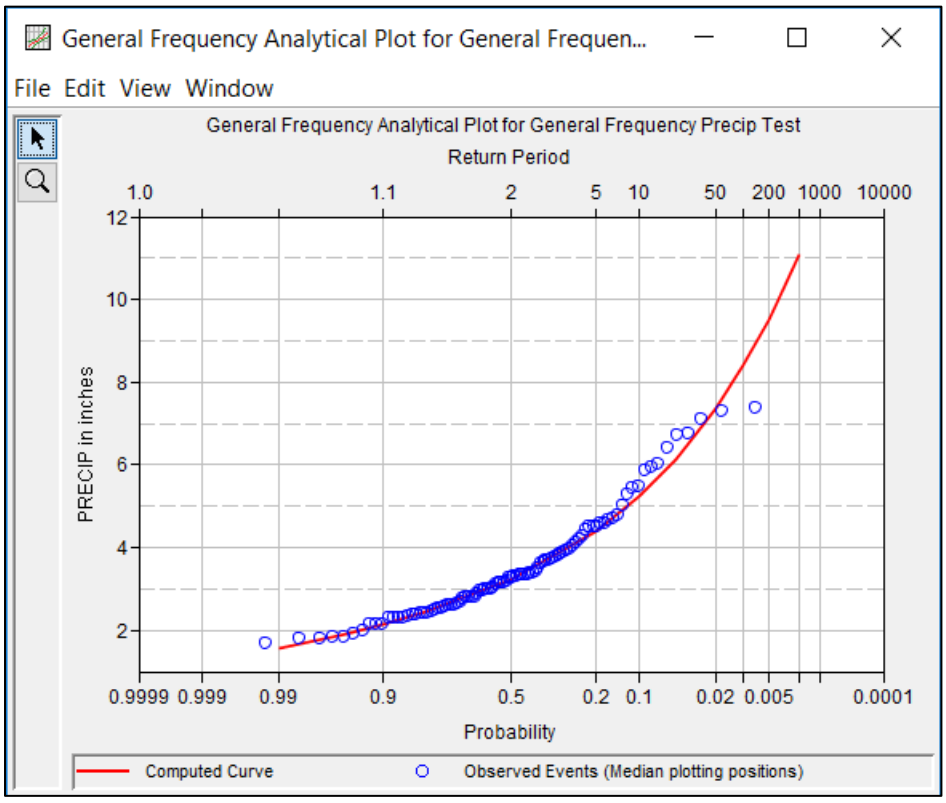


Figure 6-11. Analytical Analysis Frequency Curve Plot.

The analytical frequency curve plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: windows metafile, postscript, JPEG, and portable network graphic.

The data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will

appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

A plot of the graphical frequency curve can be obtained on the **Graphical** tab or by pressing the button labeled **Plot Graphical Curve** at the bottom of the general frequency editor. When the Plot Graphical Curve button is pressed, a frequency curve plot will appear in a separate window as shown in Figure 6-12. All of the same options for tabulating, printing, and sending results to the windows clipboard are available for this plot as they are for the analytical frequency curve plot.

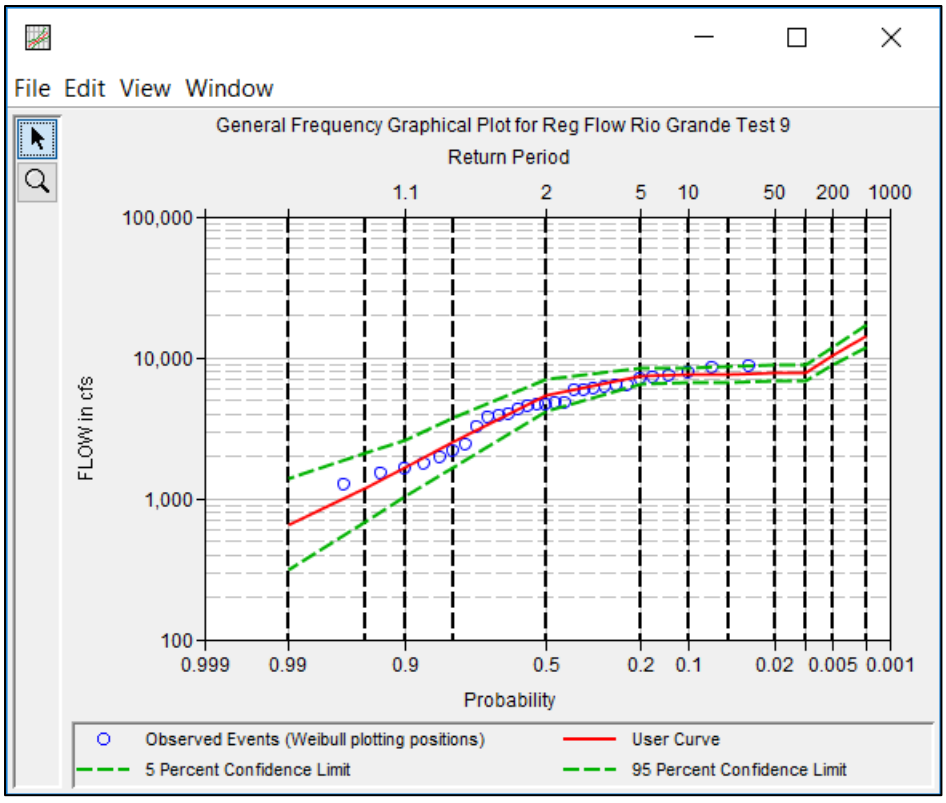


Figure 6-12. Graphical Analysis Frequency Curve Plot.

Viewing the Report File

When the General Frequency Analysis computations are performed, a report file of the statistical computations is created. The report file lists all of the input data and user settings, plotting positions of the data points, intermediate results, each of the various statistical tests performed (i.e. high and low outliers, historical data, etc…), and the final results. This file is often useful for understanding and describing how the software arrived at the final frequency curve.

Press the **View Report** button at the bottom of the General Frequency Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 6-13.

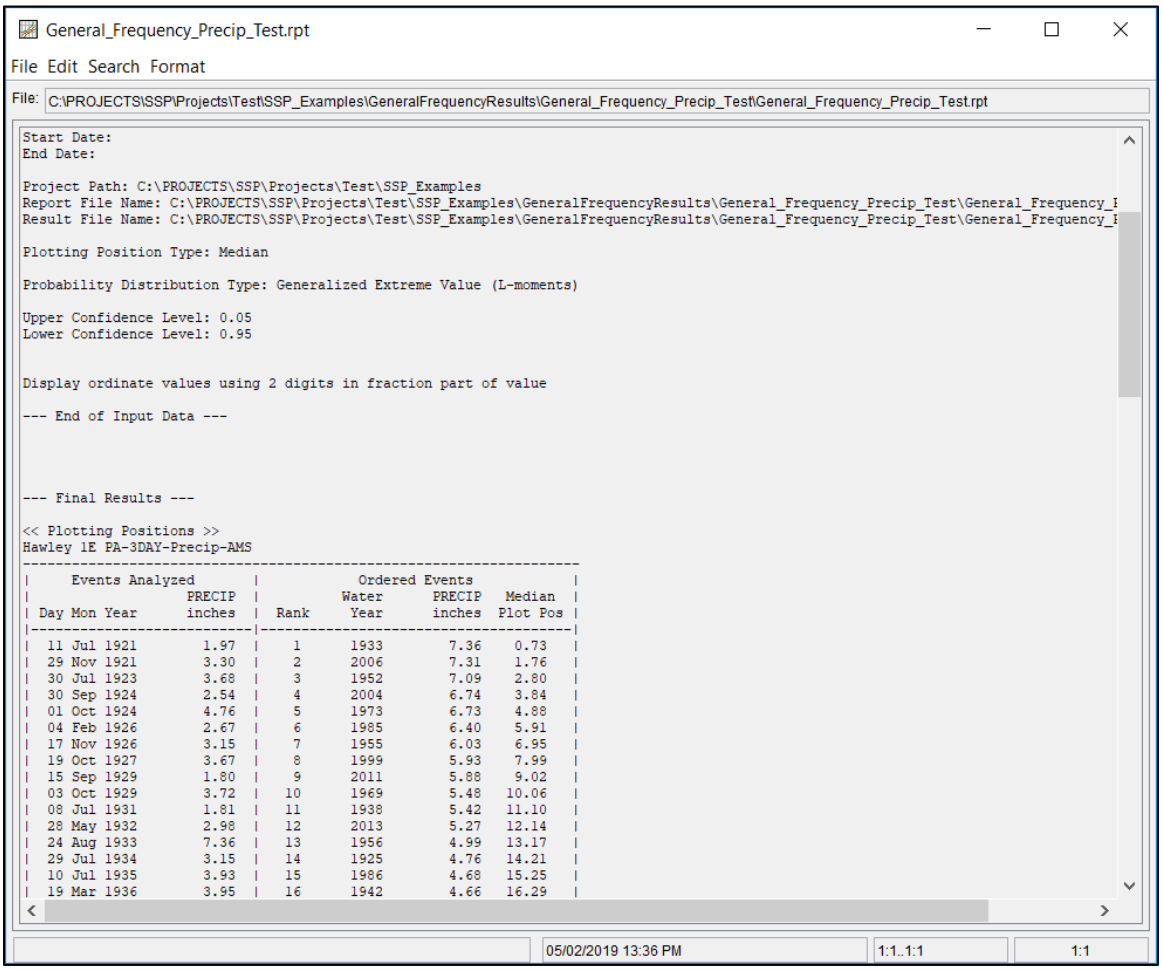


Figure 6-13. General Frequency Analysis Report File.

Plots, tables, and reports can also be created by selecting menu options from the **Results** menu. At least one General Frequency Analysis must be selected in the study explorer before selecting one of the menu options on

the Results menu. Results from multiple analyses are combined in one graph if they are selected in the study explorer when the **Graph** menu option is selected. The **Results→Summary Report** menu option will create a summary table of statistics and frequency curve ordinates for the selected analyses as shown in Figure 6-14.

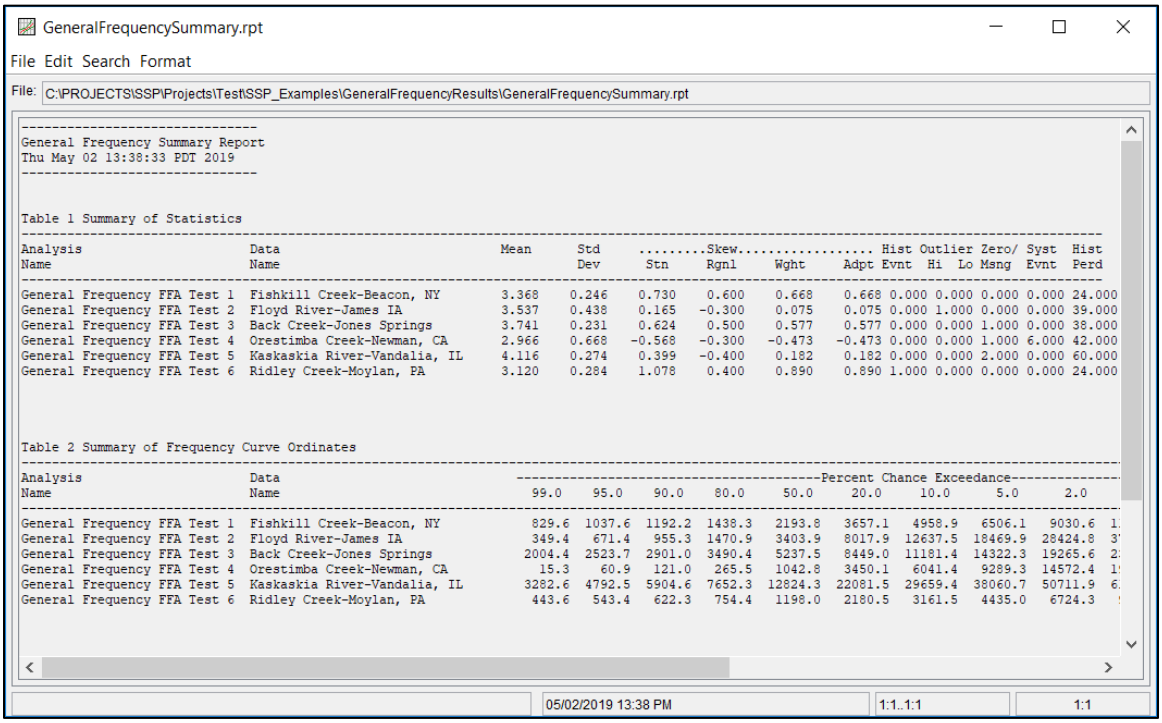


Figure 6-14. Summary Table for Selected General Frequency Analyses.

CHAPTER 7

Performing a Volume Frequency Analysis

The current version of HEC-SSP allows the user to perform a volume frequency analysis of flow data. In this type of analysis, frequency curves are developed using flow time series that are averaged over user-specified durations. Runoff volumes are expressed as average flows over a time duration. For example, the 3-day flow is the average flow over a three day period. The volume from the 3-day flow would be computed by multiplying the 3-day flow (in cfs) by 259,200 seconds (3-days). Typical volume frequency analyses would develop frequency curves for a number of volumes (flow-duration) like the 1-, 3-, 5-, 7-, 10-, and 15-day volumes. The user can choose between different analytical distributions as well as perform a graphical fit to the data. This chapter discusses in detail how to use the Volume Frequency Analysis editor in HEC-SSP.

Contents

- Starting a New Volume Frequency Analysis
- General Settings and Options
- Extracting the Volume-Duration Data
- Analytical Frequency Analysis
- Graphical Frequency Analysis
- Viewing and Printing Results

Starting a New Analysis

A volume frequency analysis can be started in two ways within the software, either by right clicking on the Volume Frequency Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Volume-Frequency Analysis**. When a new Volume Frequency Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select a data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The Volume Frequency Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a Volume Frequency Analysis will only include those data that have a regular interval, like 1HOUR and 1DAY (E-part pathname). Once a **Name** is entered and a data set is selected, the **DSS File Name** and **Report File** will automatically be entered. The DSS filename is by default the same name as the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Volume Frequency Analysis editor is shown in Figure 7-1.

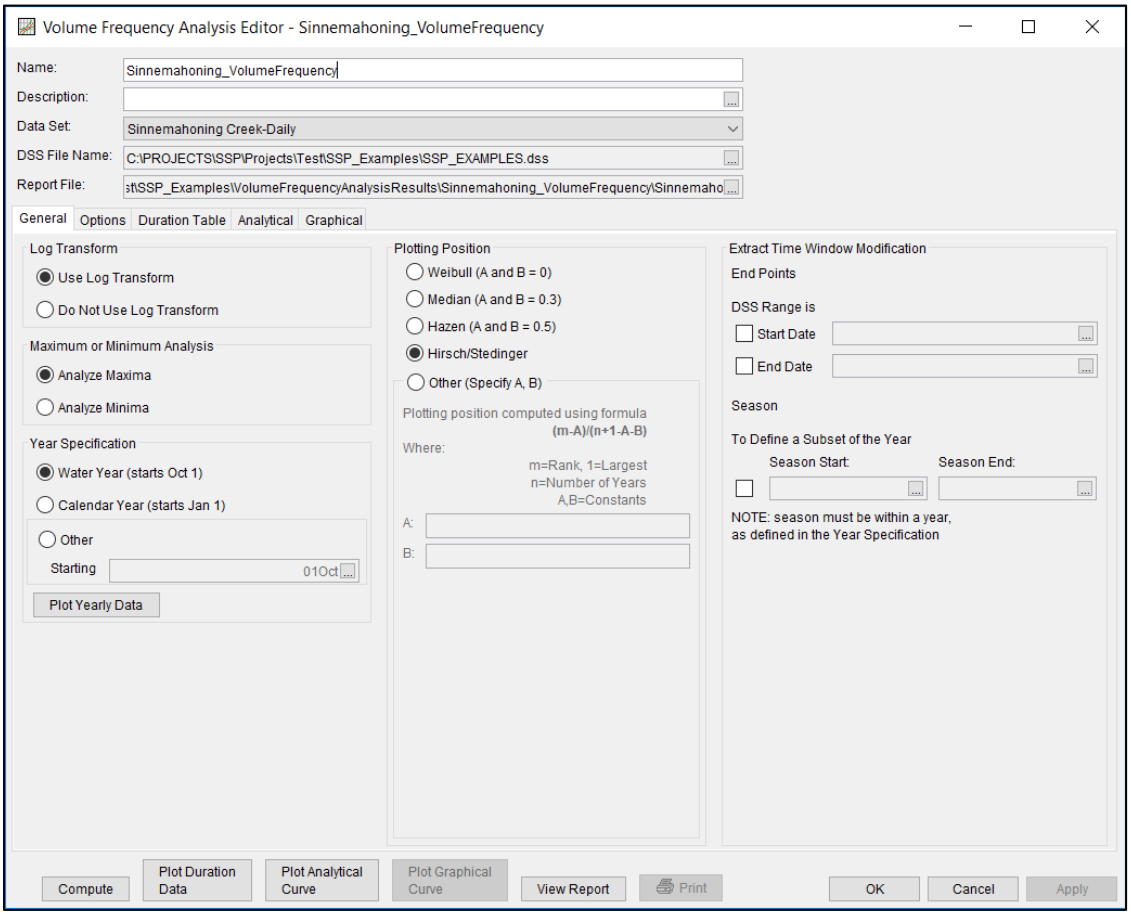


Figure 7-1. Volume Frequency Analysis Editor.

General Settings and Options

Once the analysis name and data set are selected, the user can begin defining the analysis. Five tabs are contained on the Volume Frequency Analysis editor. The tabs are labeled **General**, **Options**, **Duration Table**, **Analytical**, and **Graphical**. This section of the manual explains the use of the General and Options tabs.

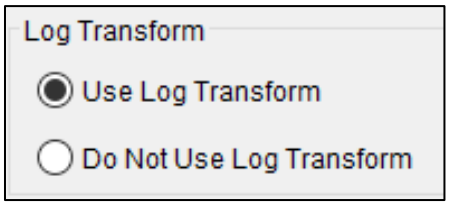
General Settings

The first tab contains general settings for performing the frequency analysis (Figure 7-1). These settings include:

- Log Transform
- Maximum or Minimum Analysis
- Year Specification
- Plotting Positions
- Time Window Modification

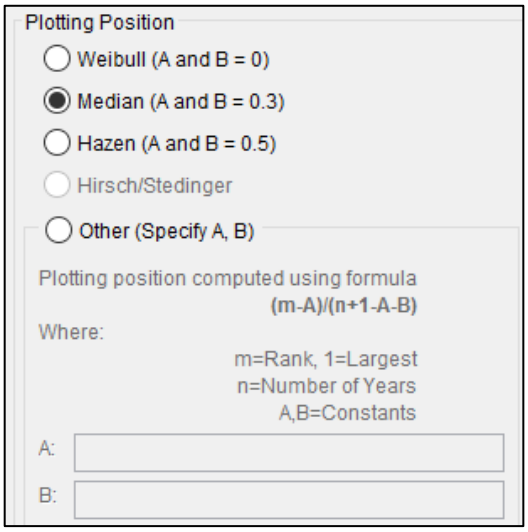
Log Transform

There are two options contained within the Log Transform panel: **Use Log Transform** and **Do not use Log Transform**. If the user selects **Use Log Transform**, then the logs of the data will be computed first, and the frequency analysis will be performed on the logs of the data. If the user selects **Do not use Log Transform**, then the frequency analysis will be performed on the raw data values without taking the logs of the data. The default setting is **Use Log Transform**.



Plotting Positions

Plotting positions are used for plotting the input data set on a probability scale along with the computed frequency curve and (optional) confidence limits. There are five options for computing plotting positions within HEC-SSP: Weibull, Median, Hazen, Hirsch/Stedinger, and user entered coefficients. The default method when an analytical distribution is selected is the Median plotting position formula. The default method for computing plotting positions when using the 17C EMA method is Hirsch/Stedinger. The Hirsch/Stedinger option is only available for use with the 17C EMA method. However, the user may change the plotting position to any they would like and are available for the selected computation options. When using the Hirsch/Stedinger method, the A and B coefficients will be set equal to zero. When using 17C EMA methods and the Hirsch/Stedinger plotting position formula, flow data screened as low outliers (a.k.a. Potentially Influential Low Floods) are assigned a plotting position using the Median plotting position formula within HEC-SSP.



The generalized plotting position equation is:

$$P = \frac{(m - A)}{(n + 1 - A - B)}$$

where: m = rank of flood values with the largest equal to 1.

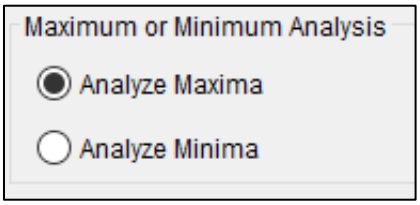
n = number of flood peaks in the data set.

A & B = constants dependent on which equation is used (Weibull A and B=0; Median A and B = 0.3; and Hazen A and B=0.5).

Plotting positions represent estimates of the exceedance probability of each data point (peak flow). Different plotting position formulas can give very different values for the probabilities of the highest and lowest points in the data set. When fitting an analytical distribution, the plotting of data on the graph by a plotting position method is only done as a guide to assist in evaluating the computed curve. The plotting position method selected does not have any impact on the computed curve.

Maximum or Minimum Analysis

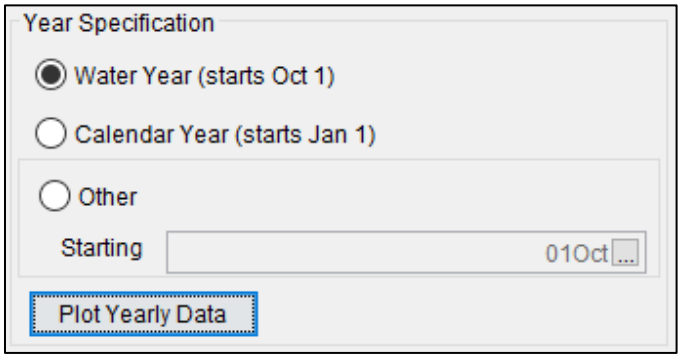
A volume frequency analysis can be performed using annual maxima or minima. There are two options contained in the Maximum or Minimum Analysis panel. If **Analyze Maxima** is selected, then the program will extract annual maximum volumes for each year for each duration. Conversely, if **Analyze Minima** is selected, then the program will extract annual minimum volumes for each year for each duration.



A flow analysis that analyzes annual maxima could be used for determining the amount of reservoir storage required for a flood of specific frequency. Conversely, an analysis that analyzes annual minima could be used determine if a river could supply a given demand. A low flow analysis could also be beneficial for water quality and reservoir storage projects.

Year Specification

This option allows the user to define the beginning and ending date for what will be considered as the analysis year for extracting the data. These dates are used for extracting the annual maxima or minima in order to get one value for each analysis year. It is important to choose a start date that captures all flood events from a certain hydrologic regime. If high flows generally occur between November and May, then the year should not start between these months. This will minimize the possibility that the same flood event is used for consecutive years.



There are three options contained in the Year Specification section. If **Water Year** is selected, the program uses a starting date of October 1 and an ending date of September 30. If **Calendar Year** is selected, the program uses a starting date of January 1 and an ending date of December 31. The **Other** option lets the user define the starting date. The default is Water Year.

When the **Plot Yearly Data** button is pressed, a graph will be created that overlaps the flows for each year on a common x-axis that spans January 1st to December 31st. A vertical, dashed line will be placed at the specified Year Specification date. This plot can be useful when determining the Year Specification date that is most appropriate for the desired analysis. The flows shown in Figure 7-2 are from a location that experiences snowmelt and occasional rain-on-snow floods. Starting the year on October 1 when analyzing annual maxima is appropriate for this data set since no large floods occur near that date. Conversely, if annual minima of are interest, a Year Specification Date of June 15th may be the most appropriate since no low flows occur near that date.

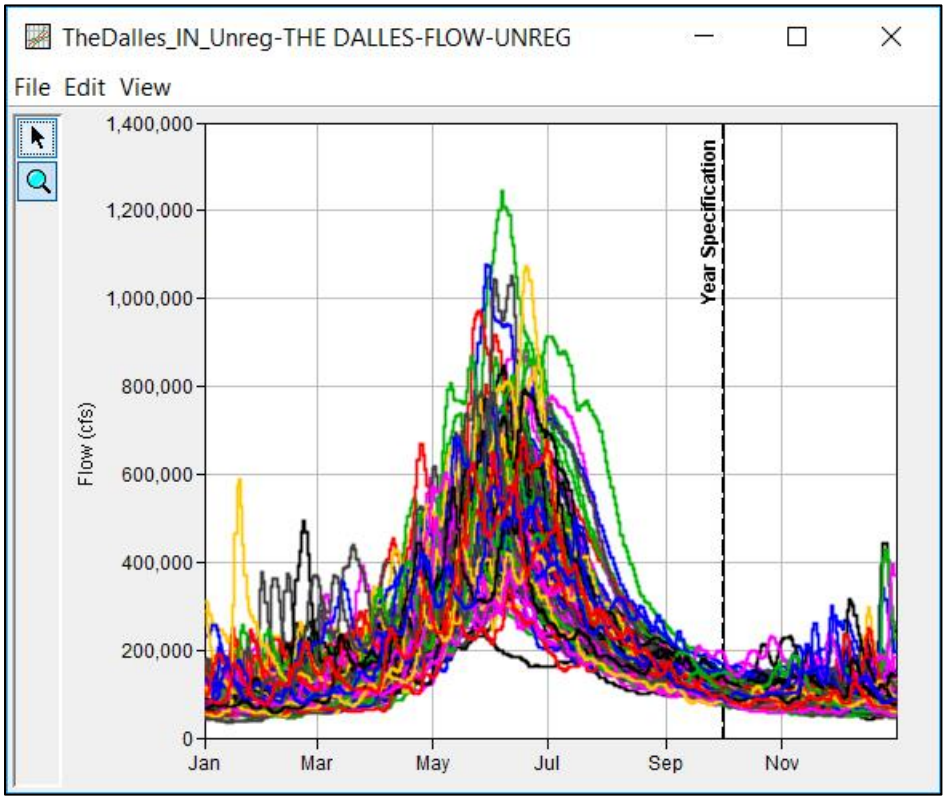
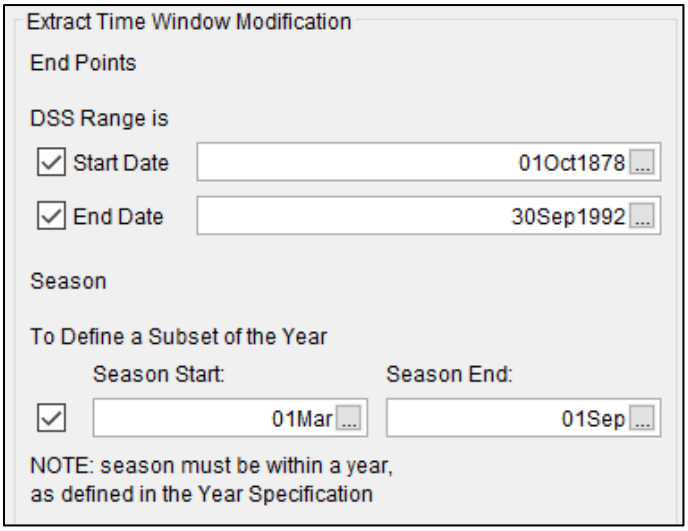


Figure 7-2. Yearly Data Plot.

Time Window Modification

This option allows the user to narrow the time window used for the analysis. When left unchecked, the program will use all of the data contained in the selected data set. The user can enter either a start or end date or both a start and end date. If a start and/or end date are used, they must be dates that are included within the selected data set. The date range for the selected data set is shown in the editor just above the Start Date field.

An additional option at the bottom of the time window modification panel allows the user to define a shorter duration (i.e. a **Season**) within the year in which the program extracts maxima or minima. This option allows the user to analyze events that typically occur during a specific season, like snowmelt floods. When left unchecked, the program will examine all flow records during the year. The season start and end dates must be entered using a two digit day followed by the month (i.e. 15May). The season start and end dates must fall within a year as defined in the Year Specification. The user must enter both start and end dates to define the season subset.



Options

In addition to the general settings, there are also several options available to the user for modifying the computation of the volume-frequency curves. These options include:

- Flow Durations
- Output Labeling
- Output Frequency Ordinates
- Low Outlier Threshold
- Historic Period Data

When the Options tab is selected, the Volume Frequency Analysis editor will appear as shown in Figure 7-3.

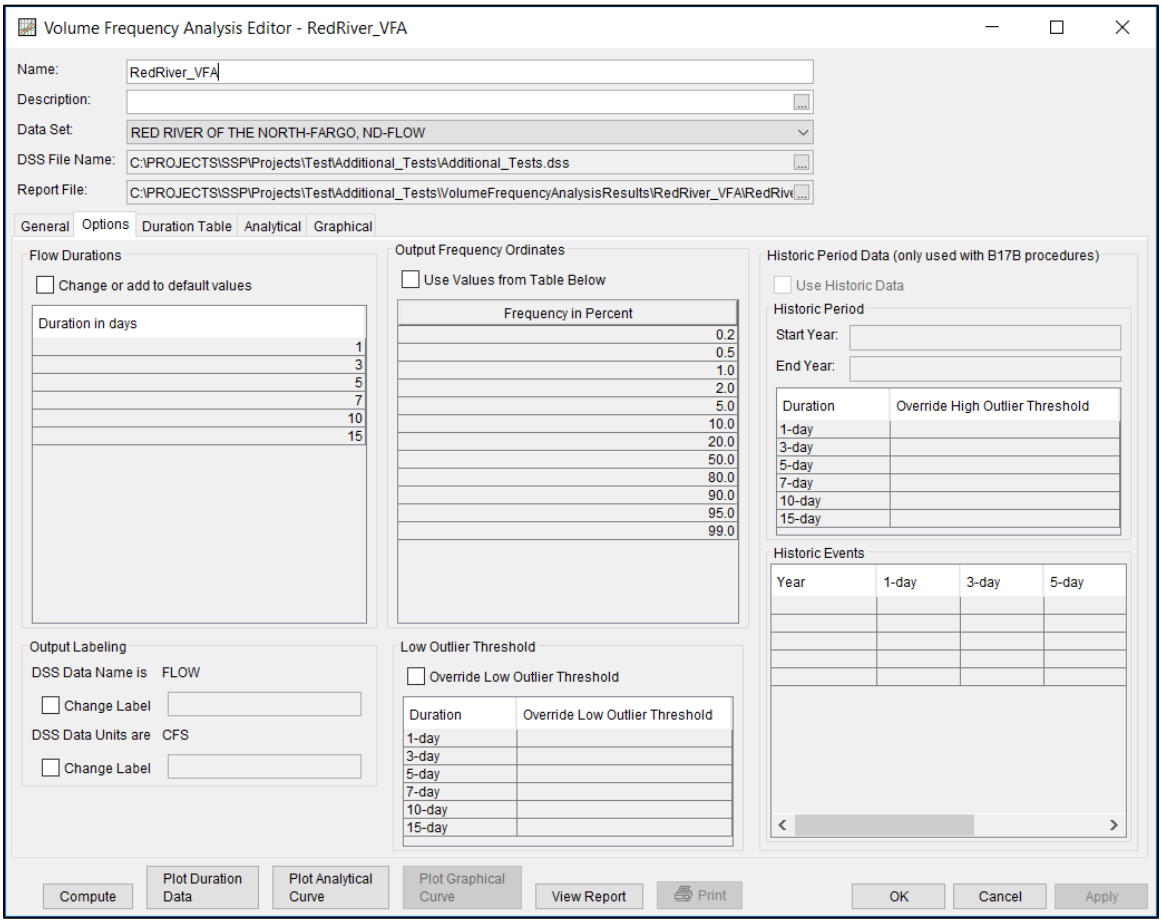
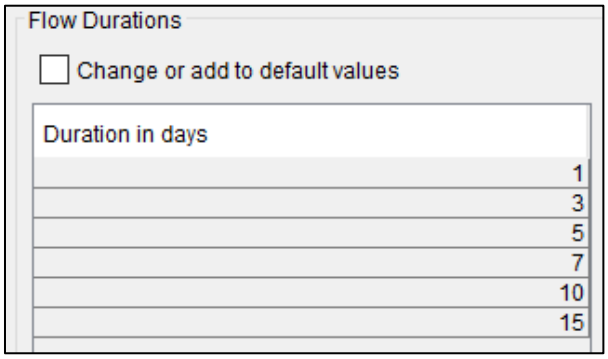


Figure 7-3. Volume Frequency Analysis Editor with Options Tab Selected.

Flow-Durations

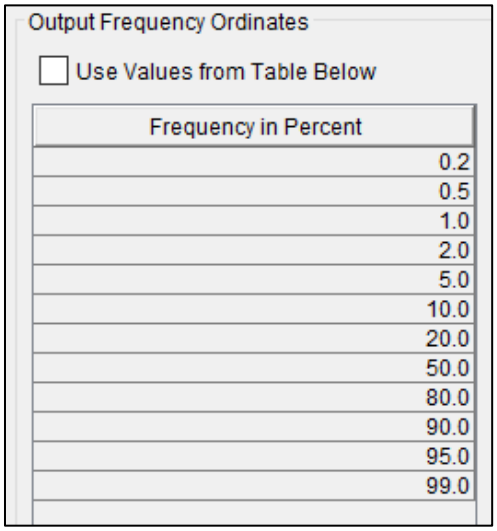
This option lets the user define which durations are used in the volume frequency analysis. The program will extract annual maximum or minimum volumes for each year for each duration based on the durations defined in this table. The default durations are 1-, 3-, 5-, 7-, 10-, and 15-days. Check the box next to **Change or add to default values** to change or add additional durations to the analysis. Once this box is checked, the user can add/remove rows and/or edit the duration values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s)** and **Delete Row(s)**. The program will use the



default durations, even if they are not contained in the table, when the **Change or add to default values** option is not checked.

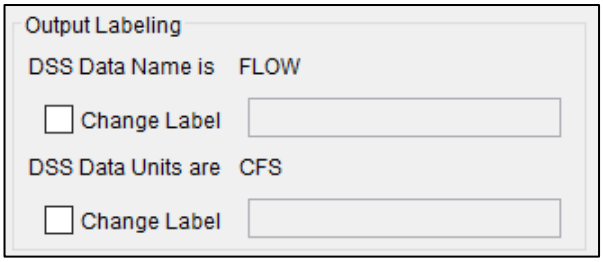
Output Frequency Ordinates

This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.



Output Labeling

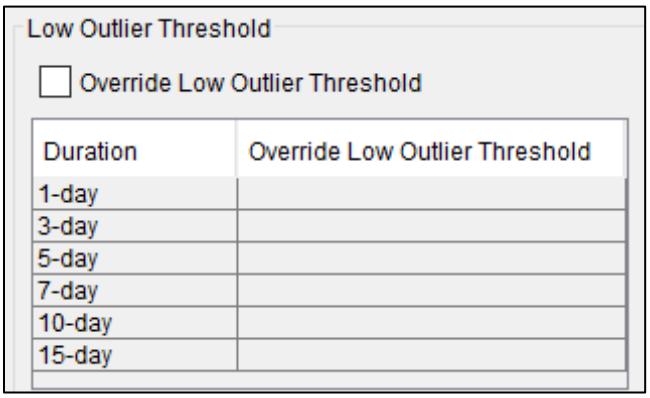
This option allows the user to change the default labels for data contained in the output tables and plots. The user can change both the name of the data and how the units of the data are labeled.



Low Outlier Threshold

The user has the option to enter a different value for the low outlier threshold, if desired. If a value is entered for the low outlier threshold, then this value will override the computed value from either the Single or

Multiple Grubbs-Beck test. An error message will be shown if the low outlier threshold is set to a value that would censor more than 50 percent of the values within the data set. To override the computed low outlier threshold, check the box labeled **Override Low Outlier Threshold** and enter the preferred value. The user may also use this option to screen low outliers when not using either 17B or 17C EMA procedures. All values less than the user-entered value will then be censored during the computations. To use the low outlier threshold, simply check the box and enter a value for one or more durations.



Historic Period Data

All historic data that provides reliable estimates of flood peaks outside the systematic record should be used in order to improve the estimated flood frequency curve. Flood information of large events outside of the systematic record can often be used to extend the record to a historic period much longer than that of the systematic record. HEC-SSP uses historic data specified in this table as recommended in Bulletin 17B.

This option is only available when using Bulletin 17B procedures, as shown in Figure 7-4. To make use of historic data within the 17C EMA procedures, this information should be entered on the **EMA Data** tab. To use historic data with Bulletin 17B procedures, check the box labeled **Use Historic Data**. The user can enter a starting year for the historic period, ending year for a historic period, and a high threshold value. If the user enters a high threshold value, then any value in the systematic record greater than that value will also be treated as a historical flood peak. The user can also enter historic flood peaks that are not contained in the systematic record. This is done in the table at the bottom labeled **Historic Flood Peaks**. Only one value per water year may be entered and all years must be entered assuming a water year from October 1 through September 30. If a start year is not entered, then the assumed start year is the earliest year of the systematic record and any historical values that have been entered. If an end year is not entered, then the assumed end year is the latest year in the systematic record and any entered historic values.

Note: The program treats all data in the data set as systematic data when using Bulletin 17B procedures. If historic events are included in the data

set, then the user must define the analysis time window (General tab – Time Window Modification) so that it only bounds the systematic record. Then the user must define the historic events in the Historic Events table.

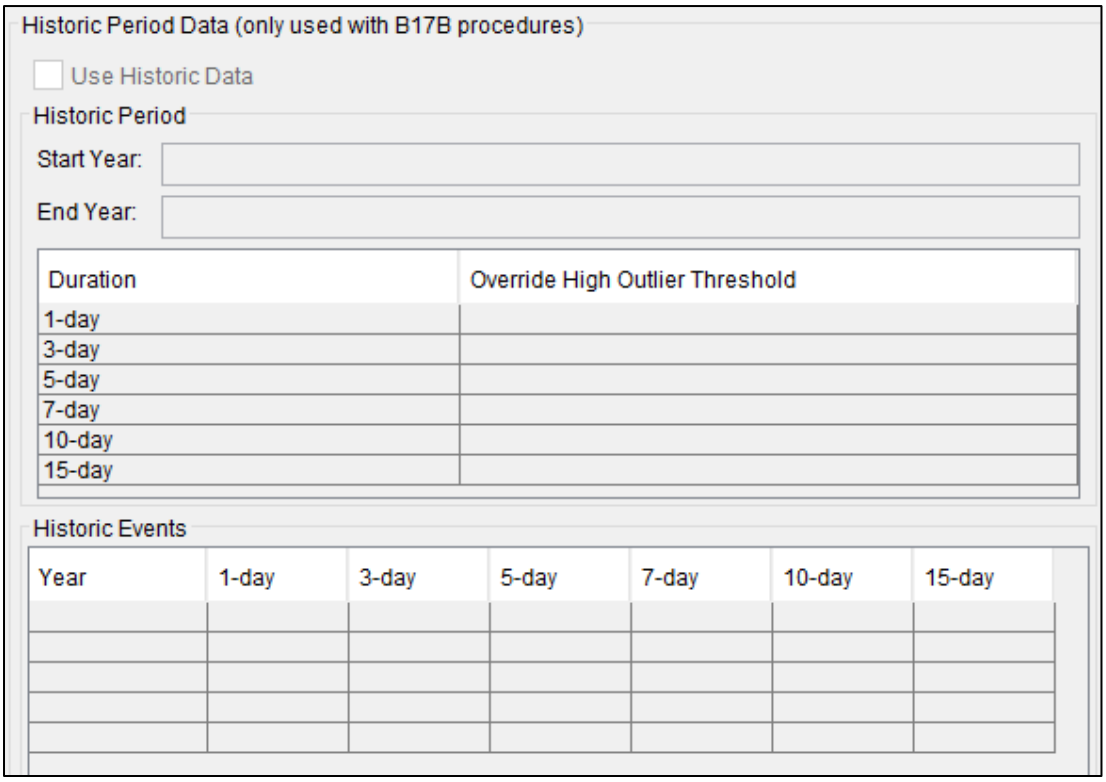


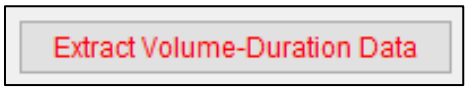
Figure 7-4. Historic Period Data on the Options Tab.

Extracting the Volume-Duration Data

The user can extract the volume-duration data once settings have been defined on the General and Options tabs. When the Duration Table tab is selected, the Volume Frequency Analysis editor will appear as shown in Figure 7-5. The program will compute the annual maximum or minimum average flows for the durations specified on the Options tab when the user presses the **Extract Volume-Duration Data** button at the top of the Duration tab.

The program computes the maximum/minimum flows for each water year by evaluating the flow record as one continuous record. First, the program computes a time-series of average flow for the durations specified on the Options tab. These time-series are written to the study DSS file and can be viewed using HEC-DSSVue. Then, the program extracts the annual maximum/minimum flows for each duration based upon the Year Specification and, if specified, the Season Start/End the on the General tab and populates the duration table.

When starting a new analysis, the volume-duration duration data will be automatically extracted for the default durations. If the Maximum/Minimum Analysis, Year Specification, or Time Window Modification options on the General tab or the Flow Durations on the Options tab are changed after the volume-duration data has been extracted, a red warning message will be shown near the top of the editor. Also, the Extract Volume-Duration Data button will be highlighted in red. Clicking this button to re-extract the volume-duration data will remove the red warning message and reset the button.



The **Allow Editing** checkbox in the upper left portion of the Duration Table tab allows the user to manually edit values in the volume-duration table. The table becomes editable when the **Allow Editing** box is checked. The user may then overwrite the extracted volume-duration data. If the **Allow Editing** box is checked, the program will no longer extract annual maxima from the selected data set when the compute button is pressed. Instead, the specified values within the table will be used.

When computing the analysis, the program will issue a warning message if any of the maxima/minima occur a specific number of days after the beginning of the Year Specification date. The number of days is determined by the duration plus five days. For example, for a 15-day duration, the program issues a warning if any of the maxima/minima is within twenty days after the beginning of the Year Specification date. If water year is chosen as the Year Specification date, then the program issues a warning if any of the maxima/minima occurs between October 1 – October 20. This warning is an attempt to let the user know if a specific maximum or minimum flow is generated by an event that began in the previous year. The goal is to prevent a scenario in which the same flow event causes maxima/minima flows in consecutive years.

General | Options | Duration Table | Analytical | Graphical

☐ Allow Editing Extract Volume-Duration Data

Year	Volume-Duration Data											
	Highest Mean Value for Duration, Average Daily FLOW in CFS											
	1		3		5		7		10		15	
	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW
1979	03/05/1979	39000.0	03/07/1979	29700.0	03/09/1979	23620.0	03/11/1979	20171.4	03/13/1979	16948.0	03/17/1979	13854.0
1980	11/27/1979	20800.0	11/28/1979	15500.0	04/02/1980	13322.0	04/04/1980	11832.9	04/03/1980	10693.0	04/04/1980	10778.0
1981	02/21/1981	14900.0	02/22/1981	13933.3	02/24/1981	13500.0	02/25/1981	12654.3	02/27/1981	11099.0	02/26/1981	8921.3
1982	10/28/1981	18800.0	06/08/1982	15833.3	06/10/1982	13606.0	06/11/1982	11404.3	03/22/1982	9172.0	03/27/1982	9288.0
1983	04/25/1983	13200.0	04/27/1983	10900.0	04/28/1983	9558.0	05/01/1983	8800.0	05/03/1983	8776.0	05/05/1983	7705.3
1984	04/05/1984	30100.0	04/07/1984	26200.0	04/09/1984	22040.0	04/10/1984	19242.9	04/12/1984	15909.0	04/17/1984	12614.7
1985	02/25/1985	13800.0	02/26/1985	11570.0	02/28/1985	8722.0	03/01/1985	7147.1	04/03/1985	5983.0	04/07/1985	5392.0
1986	03/15/1986	24000.0	03/17/1986	16533.3	03/19/1986	14680.0	03/20/1986	13101.4	03/20/1986	11171.0	03/25/1986	8300.0
1987	04/07/1987	18100.0	04/07/1987	17533.3	04/09/1987	16100.0	04/10/1987	13875.7	04/10/1987	11410.0	04/14/1987	9084.0
1988	05/20/1988	16100.0	05/21/1988	12533.3	05/23/1988	10788.0	05/25/1988	9100.0	05/28/1988	7165.0	05/31/1988	5197.3
1989	05/11/1989	26100.0	05/13/1989	21366.7	05/14/1989	16614.0	05/17/1989	16110.0	05/18/1989	13693.0	05/21/1989	11084.0
1990	04/11/1990	17500.0	02/18/1990	13550.0	02/19/1990	10146.0	02/17/1990	9121.4	02/18/1990	9395.0	02/17/1990	8000.0
1991	12/31/1990	21000.0	03/06/1991	15966.7	03/07/1991	12758.0	03/09/1991	10552.9	01/02/1991	9055.0	10/26/1990	8855.3
1992	03/27/1992	18400.0	03/29/1992	14693.3	03/31/1992	11588.0	04/02/1992	10281.4	04/05/1992	8556.0	04/10/1992	7178.7
1993	04/01/1993	29600.0	04/02/1993	27633.3	04/03/1993	26260.0	04/04/1993	25014.3	04/06/1993	22970.0	04/11/1993	21220.0
1994	03/25/1994	29100.0	03/26/1994	24166.7	03/28/1994	22300.0	03/29/1994	20271.4	04/01/1994	17322.0	04/06/1994	16408.0
1995	01/21/1995	20000.0	01/22/1995	14900.0	01/24/1995	11964.0	01/26/1995	9562.9	01/29/1995	7398.0	01/29/1995	5712.7
1996	01/19/1996	42000.0	01/21/1996	26900.0	01/23/1996	22540.0	01/25/1996	20485.7	01/28/1996	18300.0	02/02/1996	13590.7
1997	11/09/1996	28000.0	11/10/1996	22000.0	11/12/1996	19300.0	11/14/1996	16685.7	11/17/1996	13482.0	11/22/1996	9847.3
1998	01/08/1998	27600.0	01/10/1998	22300.0	01/12/1998	19440.0	01/13/1998	16484.3	01/13/1998	14538.0	01/18/1998	10961.3
1999	01/24/1999	19500.0	01/26/1999	13723.3	01/27/1999	10454.0	01/29/1999	8484.3	02/01/1999	6507.0	02/06/1999	5187.3
2000	02/28/2000	19300.0	02/28/2000	18400.0	02/29/2000	16820.0	03/01/2000	14128.6	03/04/2000	11404.0	03/09/2000	8598.7
2001	04/08/2001	25900.0	04/09/2001	24666.7	04/11/2001	22120.0	04/12/2001	19471.4	04/14/2001	15999.0	04/13/2001	12786.0
2002	05/14/2002	16500.0	06/08/2002	13366.7	06/09/2002	9934.0	05/19/2002	9741.4	05/22/2002	8258.0	05/24/2002	6396.7
2003	03/18/2003	24500.0	03/19/2003	21433.3	03/21/2003	20800.0	03/23/2003	19814.3	03/26/2003	18250.0	03/30/2003	14468.0
2004	09/09/2004	31600.0	09/11/2004	22366.7	09/13/2004	17876.0	09/24/2004	14490.0	09/18/2004	13675.0	09/23/2004	13323.3
2005	04/03/2005	28300.0	04/04/2005	21600.0	04/06/2005	20540.0	04/07/2005	18871.4	04/07/2005	17750.0	04/10/2005	14976.0
2006	09/03/2006	27700.0	12/02/2005	18633.3	12/03/2005	14006.0	01/20/2006	11530.0	01/23/2006	9709.0	01/25/2006	7814.7

Figure 7-5. Volume-Duration Table.

The user must **Compute** the analysis before viewing a frequency plot of the volume-duration data. The plot created by pressing the **Plot Duration Data** button, located at the bottom of a Volume Frequency Analysis editor, shows the annual maxima/minima plotted using the user specified plotting position method, as shown in Figure 7-6.

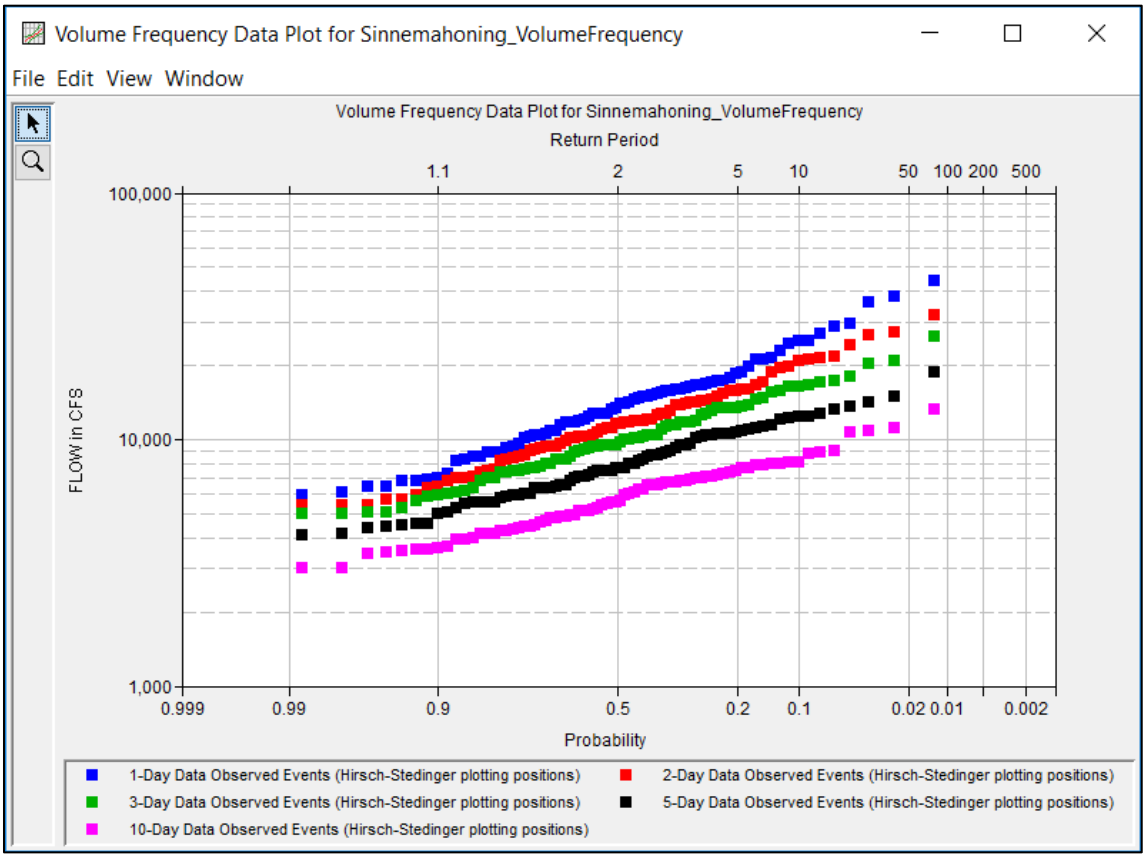


Figure 7-6. Plot of Volume-Duration Data.

Analytical Frequency Analysis

The user can choose between performing an Analytical Frequency Analysis or a Graphical Frequency Analysis once settings have been defined on the General and Options tabs. The duration data must be extracted before computing an analysis. If the duration data is out of date, a red warning message will be shown near the top of the editor. Also, the Extract Volume-Duration Data button will be highlighted in red. Clicking this button to re-extract the volume-duration data will remove the red warning message and reset the button. This section of the manual describes how to compute and view results for an Analytical Frequency Analysis.

When the user selects the **Analytical** tab on the Volume Frequency Analysis editor, the window will appear as shown in Figure 7-7. As shown, four additional tabs will appear on the screen: Settings, Tabular Results, Plot, and Statistics.

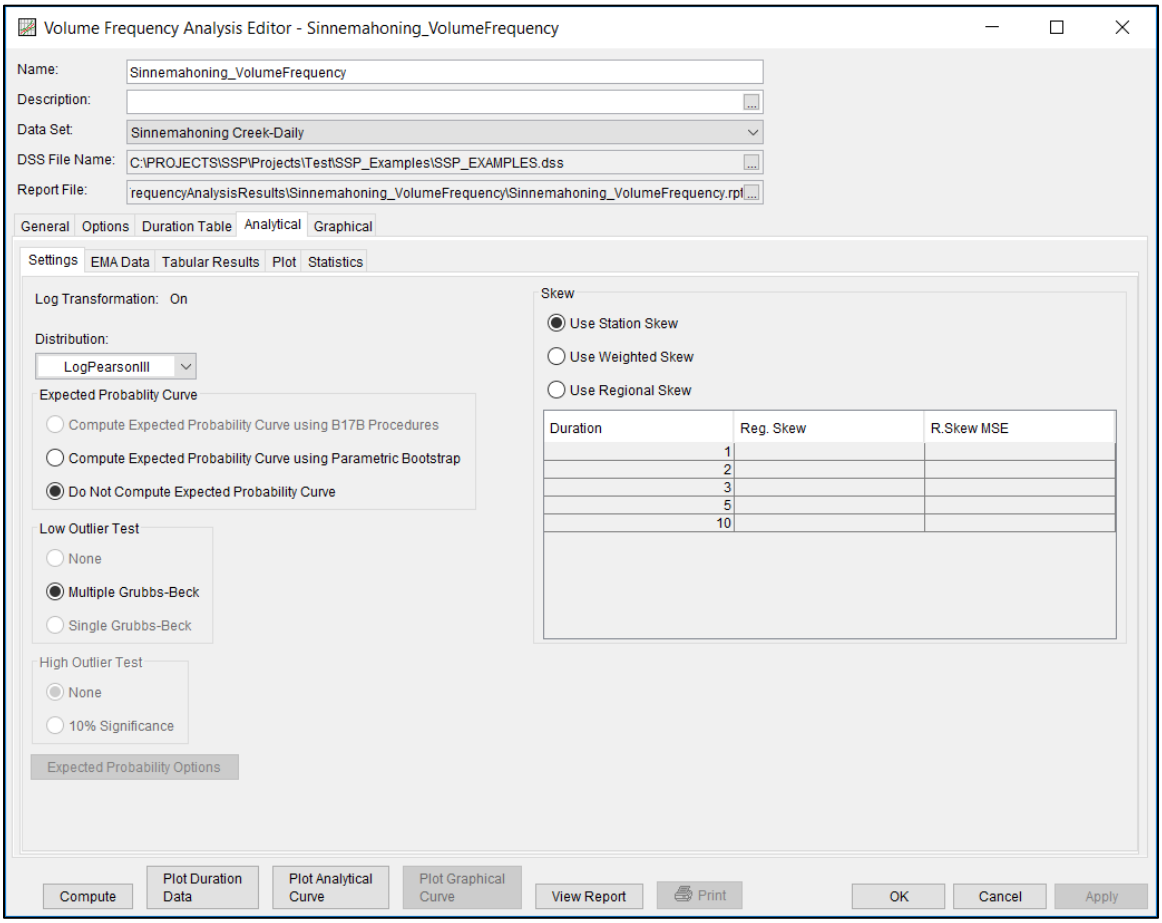


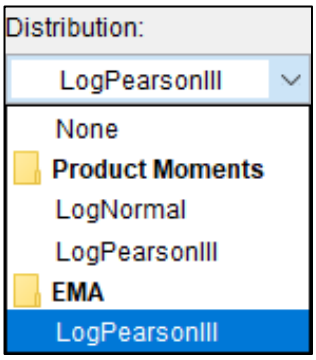
Figure 7-7. Analytical Tab of the Volume Frequency Analysis Editor.

Settings

In addition to settings on the General and Options tabs, there are more options on the Analytical | Settings tab the user must define in order to perform an Analytical Frequency analysis on the volume-duration data. These settings include:

- Distribution
- Expected Probability Curve
- Low Outlier Test
- High Outlier Test
- Skew

Distribution



This option allows the user to select from a list of available fitting methods and analytical distributions to perform the frequency analysis. The current version of HEC-SSP contains multiple choices, depending upon whether the **Use Log Transform** or **Do Not Use Log Transform** option was selected on the **General** tab.

The fitting method | analytical distribution combinations available when the **Use Log Transform** option was selected include:

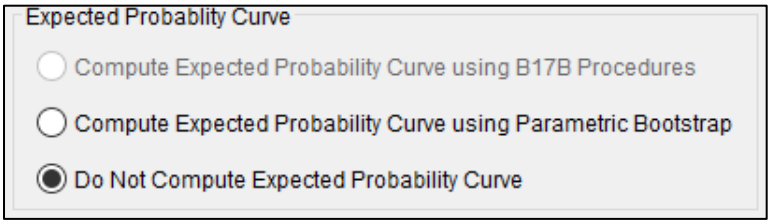
- None
- Product Moments | LogNormal
- Product Moments | LogPearsonIII
- EMA | LogPearsonIII

The fitting method | analytical distribution combinations available when the **Do Not Use Log Transform** option was selected include:

- None
- Product Moments | Normal
- Product Moments | PearsonIII

See the **Distribution Fitting and Parameter Estimation** section for a description of the aforementioned fitting methods and analytical distributions.

Expected Probability Curve



This setting has three options: **Compute Expected Probability Curve using B17B Procedures**, **Compute Expected Probability Curve using Parametric Bootstrap**, and **Do Not Compute Expected Probability Curve**. The default setting is to not compute the expected probability curve. The **Compute Expected Probability Curve using B17B Procedures** option is only available when using the Product Moments | LogPearsonIII fitting method | analytical distribution. When the **Compute Expected Probability Curve using Parametric Bootstrap** option is selected, the fitted analytical distribution will be resampled many times to

estimate the expected probability curve. Inputs to the parametric bootstrap routine used by the software can be accessed through the **Expected Probability Options** button and are detailed in the following section.

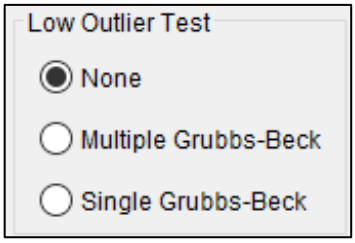
When the expected probability curve is computed, the curve will only be shown in the Report File. The expected probability adjustment is a correction for bias in the computed frequency curve. The bias is caused by uncertainty due to the shortness of the data record. The use of the expected probability curve is a policy decision. The expected probability curve is most often used in establishing design flood criteria. When use of the frequency curve includes uncertainty analysis, the expected probability adjustment is made implicitly. Therefore, the computed flood frequency curve without the expected probability adjustment is the curve used in computation of confidence limits, risk analysis, and in obtaining weighted averages of independent estimates of flood frequency discharge (Interagency Advisory Committee on Water Data, 1982).

Expected Probability Options

Clicking the **Expected Probability Options** button will launch an editor that contains several options pertinent to the parametric bootstrap routine used to estimate the expected probability curve. These options are **not** used within the B17B Procedures option. The parametric bootstrap routine used by the software to estimate the expected probability curve is detailed in the **General Frequency | Expected Probability Options** section.

Low Outlier Test

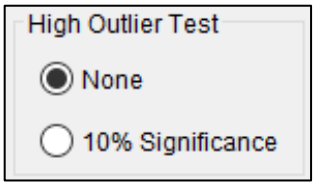
This option allows the user to choose the test that is performed to identify low-value data points that depart significantly from the trend of the remaining data and inappropriately affect the extreme quantiles in the upper tail of the frequency curve. There are three options for testing low outliers within this analysis: **None**, **Multiple Grubbs-Beck**, **Single Grubbs-Beck**.



When using Product Moments | LogPearsonIII, the default test is the Single Grubbs-Beck test. When using EMA | LogPearsonIII, the default (and only) test is the Multiple Grubbs-Beck test. When using any other fitting method | distribution choice, the default selection is None. The selected low outlier test will be used to analyze the annual maxima/minima for each duration.

High Outlier Test

This option allows the user to choose whether a high outlier test will be performed to identify high outliers. The **None** option is the default (and only) test available with any fitting method | analytical distribution except Product Moments | LogPearsonIII. The **10% Significance** test is only available for use when using Product Moments | LogPearsonIII and is outlined within Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). If a high outlier is identified in the data set, the user should try to incorporate historical period information to extend the time period for which the high outlier(s) is considered to be the maximum value(s). The selected high outlier test will be used to analyze the annual maxima/minima for each duration.



Skew

This option allows the user to incorporate regional skew information when the PearsonIII or LogPearsonIII distribution will be used, as shown in Figure 7-8. This panel will be disabled when any other distribution is selected for use. When using the PearsonIII or LogPearsonIII distribution, there are three options contained within the generalized skew setting: Use Station Skew, Use Weighted Skew, and Use Regional Skew.

The default skew setting is **Use Station Skew**. The **Use Station Skew** option will use the computed station skew for each duration. The **Use Weighted Skew** option requires the user to enter a generalized regional skew and a mean-square error (MSE) of the generalized regional skew for each duration. This option weights the computed station skew with the generalized regional skew. The **Use Regional Skew** option requires the user to enter a generalized regional skew and a mean-square error (MSE) of the generalized regional skew. The program will ignore the computed station skew and use only the generalized regional skew.

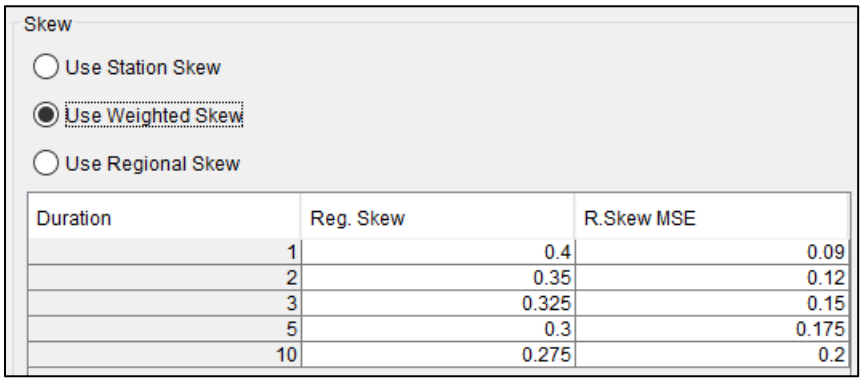


Figure 7-8. Skew Panel for the Volume Frequency Analysis Editor.

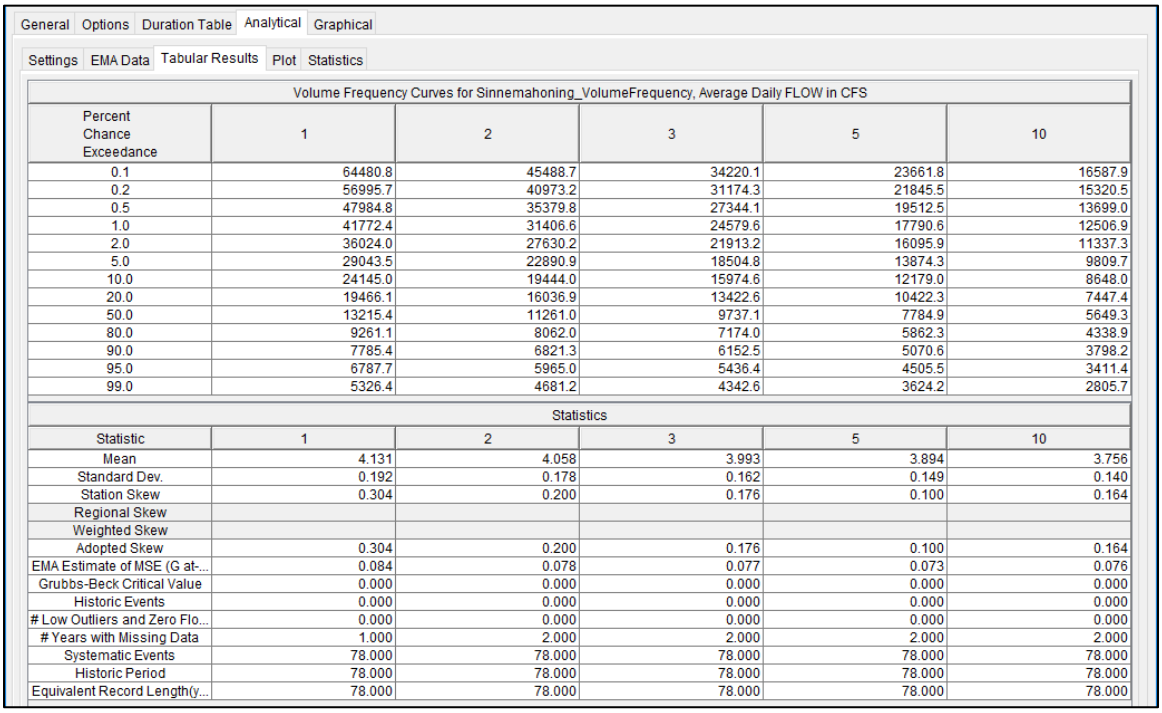
EMA Data

When using the EMA | LogPearsonIII fitting method | distribution choice, additional data is required for each duration. This additional information includes perception thresholds and flow ranges. Every year in the analysis period must have perception thresholds and a flow range specified. The additional data that is required for use is accessed/input within the EMA Data | duration tabs. For further detail, see the **EMA Data** section within the Bulletin 17 Analysis chapter.

Tabular Results

The **Tabular Results** tab contains a table of results for the analytical frequency analysis. An example of the results table is shown in Figure 7-8. The top portion of this table contains the analytical frequency curves for each duration. Data in the frequency curves can be re-sorted. Click the **Percent Chance Exceedance** column header (two mouse clicks are required the first time). The percent chance exceedance ordinates, along with the frequency curves, will sort so that the lowest values are on top or the highest values are on top. The statistics of the analytical frequency curves are contained below the frequency curve ordinates. The statistics include the mean, standard deviation, station skew, regional skew, weighted skew, adopted skew, number of years of record, and number of years with zero or missing flow.

User-adjusted statistics can be defined by the user on the **Statistics** tab. If the user has not entered statistics on the Statistics tab, then the results table will look similar to Figure 7-9. If the user does enter statistics on the Statistics tab, then the results table will include the adjusted mean, adjusted standard deviation, and adjusted skew. If specified by the user, the program will use the user-adjusted statistics when computing the analytical curves.



General | Options | Duration Table | Analytical | Graphical

Settings | EMA Data | Tabular Results | Plot | Statistics

Volume Frequency Curves for Sinnemahoning_VolumeFrequency, Average Daily FLOW in CFS

Percent Chance Exceedance	1	2	3	5	10
0.1	64480.8	45488.7	34220.1	23661.8	16587.9
0.2	56995.7	40973.2	31174.3	21845.5	15320.5
0.5	47984.8	35379.8	27344.1	19512.5	13699.0
1.0	41772.4	31406.6	24579.6	17790.6	12506.9
2.0	36024.0	27630.2	21913.2	16095.9	11337.3
5.0	29043.5	22890.9	18504.8	13874.3	9809.7
10.0	24145.0	19444.0	15974.6	12179.0	8648.0
20.0	19466.1	16036.9	13422.6	10422.3	7447.4
50.0	13215.4	11261.0	9737.1	7784.9	5649.3
80.0	9261.1	8062.0	7174.0	5862.3	4338.9
90.0	7785.4	6821.3	6152.5	5070.6	3798.2
95.0	6787.7	5965.0	5436.4	4505.5	3411.4
99.0	5326.4	4681.2	4342.6	3624.2	2805.7

Statistics

Statistic	1	2	3	5	10
Mean	4.131	4.058	3.993	3.894	3.756
Standard Dev.	0.192	0.178	0.162	0.149	0.140
Station Skew	0.304	0.200	0.176	0.100	0.164
Regional Skew					
Weighted Skew					
Adopted Skew	0.304	0.200	0.176	0.100	0.164
EMA Estimate of MSE (G at-...	0.084	0.078	0.077	0.073	0.076
Grubbs-Beck Critical Value	0.000	0.000	0.000	0.000	0.000
Historic Events	0.000	0.000	0.000	0.000	0.000
# Low Outliers and Zero Flo...	0.000	0.000	0.000	0.000	0.000
# Years with Missing Data	1.000	2.000	2.000	2.000	2.000
Systematic Events	78.000	78.000	78.000	78.000	78.000
Historic Period	78.000	78.000	78.000	78.000	78.000
Equivalent Record Length(y...	78.000	78.000	78.000	78.000	78.000

Figure 7-9. Tabular Results for a Volume Frequency Analysis.

Plot

In addition to tabular results, a Plot tab is available for viewing results, as shown in Figure 7-10. The results graph includes the systematic annual maximum/minimum volumes, plotted using the specified plotting position method, and the analytical frequency curves. The analytical frequency curves are based on the computed statistics or user-adjusted statistics if they are defined on the Statistics tab.

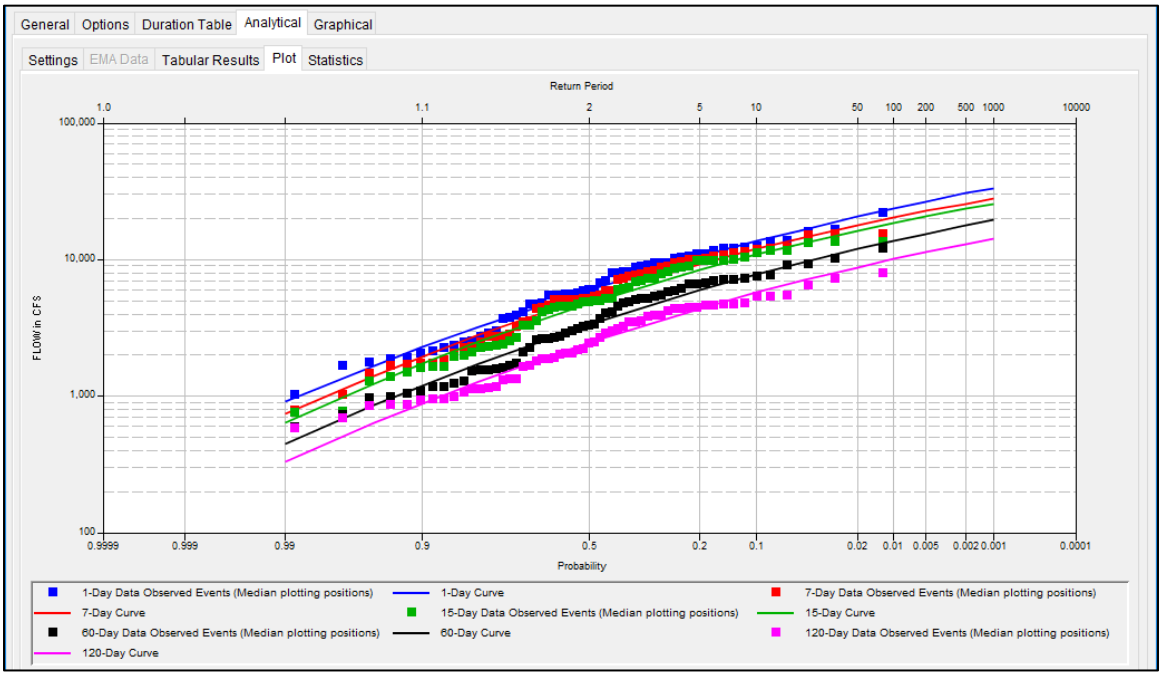


Figure 7-10. Plot of Analytical Results for a Volume Frequency Analysis.

Statistics

As discussed in EM 1110-2-1415, a necessary step in a volume-frequency analysis is to make sure the analytical frequency curves are consistent across all durations (USACE, 1993). In some situations, frequency curves from different durations might cross one another. The **Statistics** tab contains tools allowing the user to modify the mean, standard deviation, and skew to make sure frequency curves do not cross one another.

When the user selects the **Statistics** tab, the window will appear as shown in Figure 7-11. The upper portion of the Statistics tab contains a plot of the computed and user-adjusted statistics. The user has the option of choosing the parameter to be plotted in the comparison graph. Computed statistics are plotted as black data points and user-adjusted statistics are plotted as blue data points. The first table, **Sample Statistics**, contains the statistics computed from the systematic data. In addition, the adopted skew value in this table can be the station skew, weighted skew, or regional skew. The adopted skew is set by the user on the **Settings** tab. The lower table is where the user enters the adjusted statistics. Before entering adjusted statistics, the user must check the box in Column 1. User-adjusted statistics entered in this table are used when the program computes the analytical frequency curve.

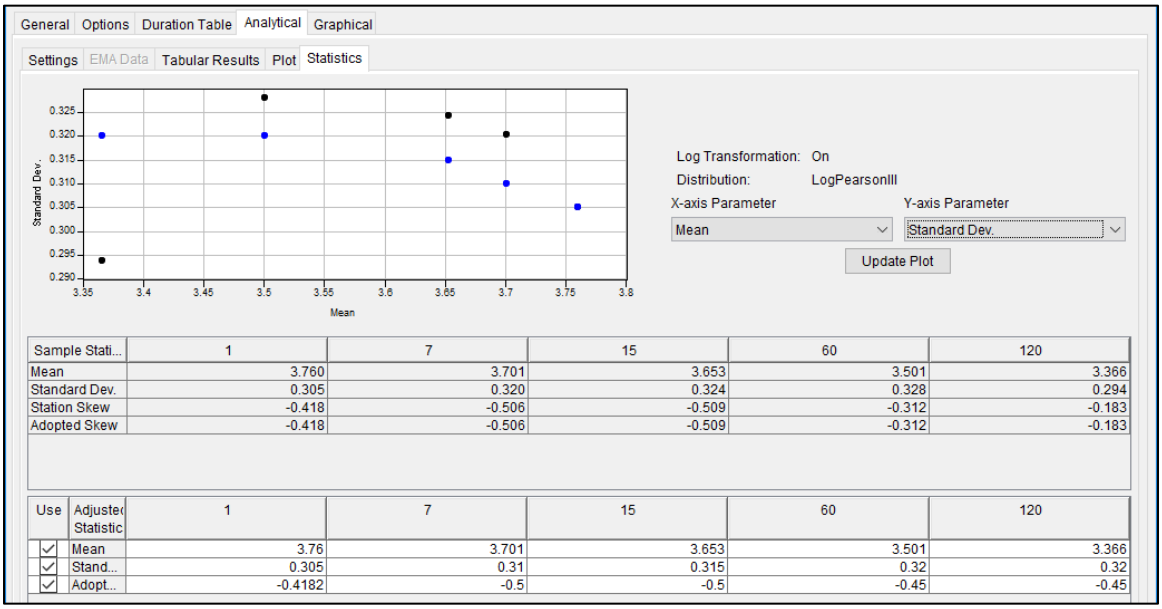


Figure 7-11. Statistics Tab in the Volume Frequency Analysis Editor.

Compute

Once the new analysis has been defined, and the user has the requisite information defined, performing the computations is simply a matter of pressing the **Compute** button at the bottom of the Volume Frequency Analysis editor. If the computations are successful, the user will receive a message that says "Compute Complete". At this point, the user can begin to review the results of the computations.

Multiple Volume Frequency analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finishes computing the analyses.

Graphical Frequency Analysis

In addition to an analytical frequency analysis, the user has the option to graphically fit a frequency curve to the data. A graphical curve can be very useful when the available analytical distributions do not provide a good fit. One example of when a graphical frequency analysis is more appropriate is when plotting a frequency curve for flow data that is downstream of a flood control reservoir. Analytical frequency distributions are often not appropriate for fitting flow data that is significantly regulated by upstream reservoirs. In general, a portion of the flow frequency data for a highly regulated stream will be very flat in the

zone in which upstream regulation can control the flow. This type of data lends itself to a graphical fit.

When the **Graphical** tab is selected on the Volume Frequency Analysis editor, the window will appear as shown in Figure 7-12. As indicated, two additional tabs will appear on the screen, **Curve Input** and **Plot**.

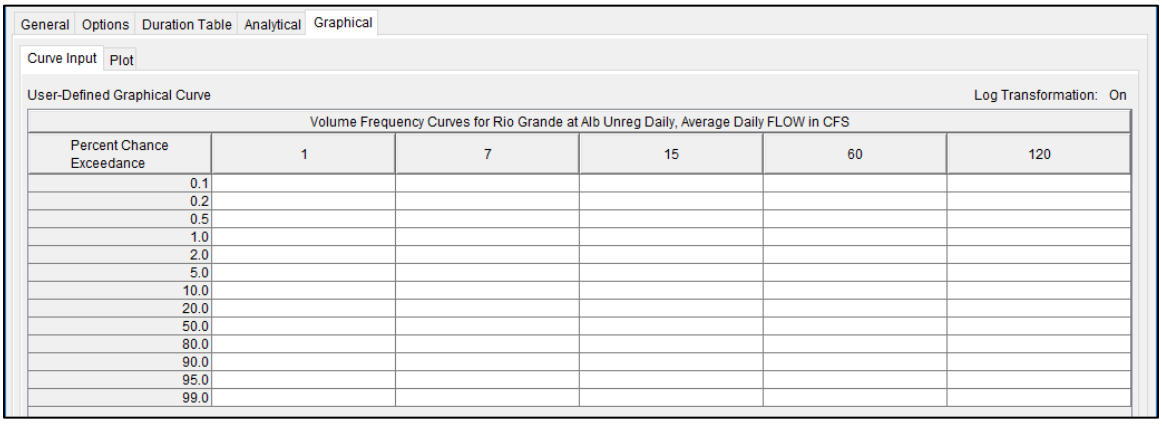


Figure 7-12. Graphical Curve Table for a Volume Frequency Analysis.

Curve Input

The user manually enters the frequency ordinates for all durations in the table on the **Curve Input** tab. As previously mentioned, the number of frequency ordinates and durations are set on the Options tab. The idea is to enter values in the table that will create a best fit line of the data, based on the user's judgment. Data entered in the graphical curve table will be plotted as a line in the graph on the **Plot** tab after the **Compute** button is pressed.

Plot

The graphical analysis **Plot** tab is available for viewing results, as shown in Figure 7-13. The results graph includes the historic annual maximum/minimum flows, plotted using the specified plotting position method, and the user-defined graphical curve, which was entered in the table on the **Curve Input** tab.

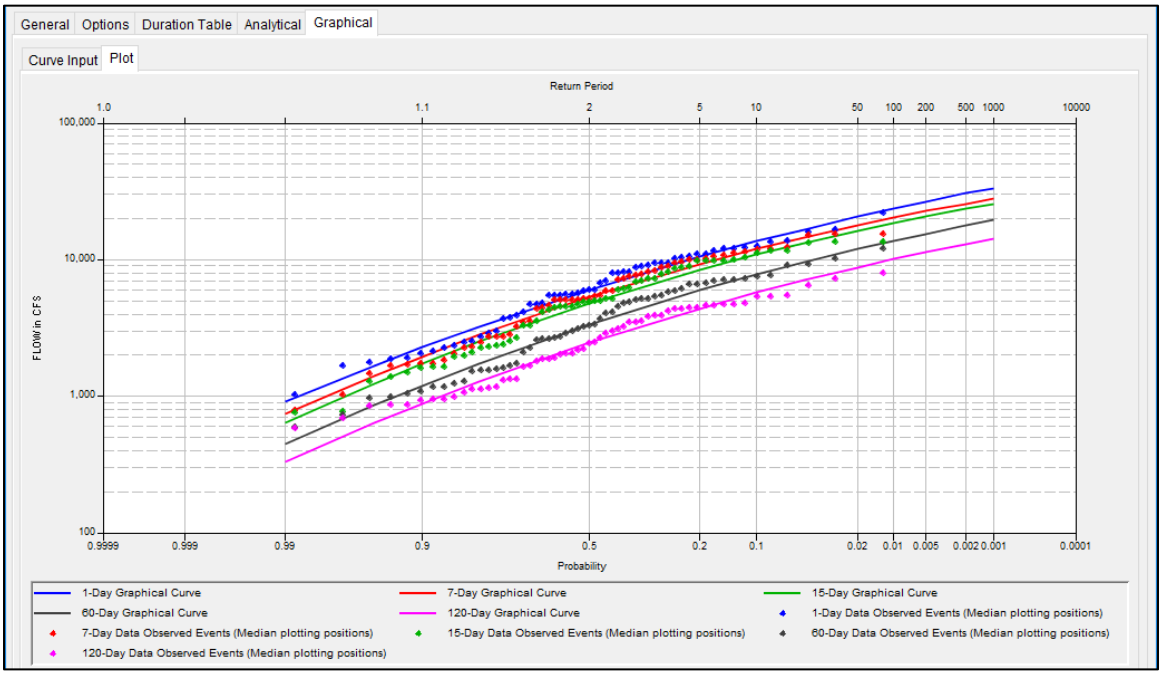


Figure 7-13. Plot Tab for a Graphical Analysis.

Viewing and Printing Results – Volume Frequency Analysis

The user can view output for the frequency analysis directly from the Volume Frequency Analysis editor (Tabular and Graphical output) or by using the plot and view report buttons at the bottom of the editor. The output consists of tabular results, an analytical frequency curve plot, a graphical frequency curve plot, and a report documenting the data and computations performed.

Tabular Output

Once the computations for the analytical frequency analysis are completed, the user can view tabular output by opening the **Tabular Results** tab under the **Analytical** analysis tab. The details of this table were discussed above. The tabular results can be printed by using the **Print** button at the bottom of the Volume Frequency Analysis editor. When the print button is pressed, a window will appear, giving the user options for how the table is to be printed.

Graphical Output

Graphical output can be opened by selecting one of the plot buttons at the bottom of the Volume Frequency Analysis editor or by selecting the **Plot**

tab under the Analytical or Graphical tabs. There are three plot buttons at the bottom of the Volume Frequency Analysis editor, Plot Duration Data, Plot Analytical Curve, and Plot Graphical Curve. Pressing the Plot Duration Data button will open a new window containing a graph showing the systematic data plotted using the user-defined plotting position method. Pressing the Plot Analytical Curve button will open a new window containing a graph with both the systematic data and the computed analytical frequency curves, as shown in Figure 7-14. Pressing the Plot Graphical Curve button will open a new window containing a graph with both the systematic data and the user-defined frequency curves.

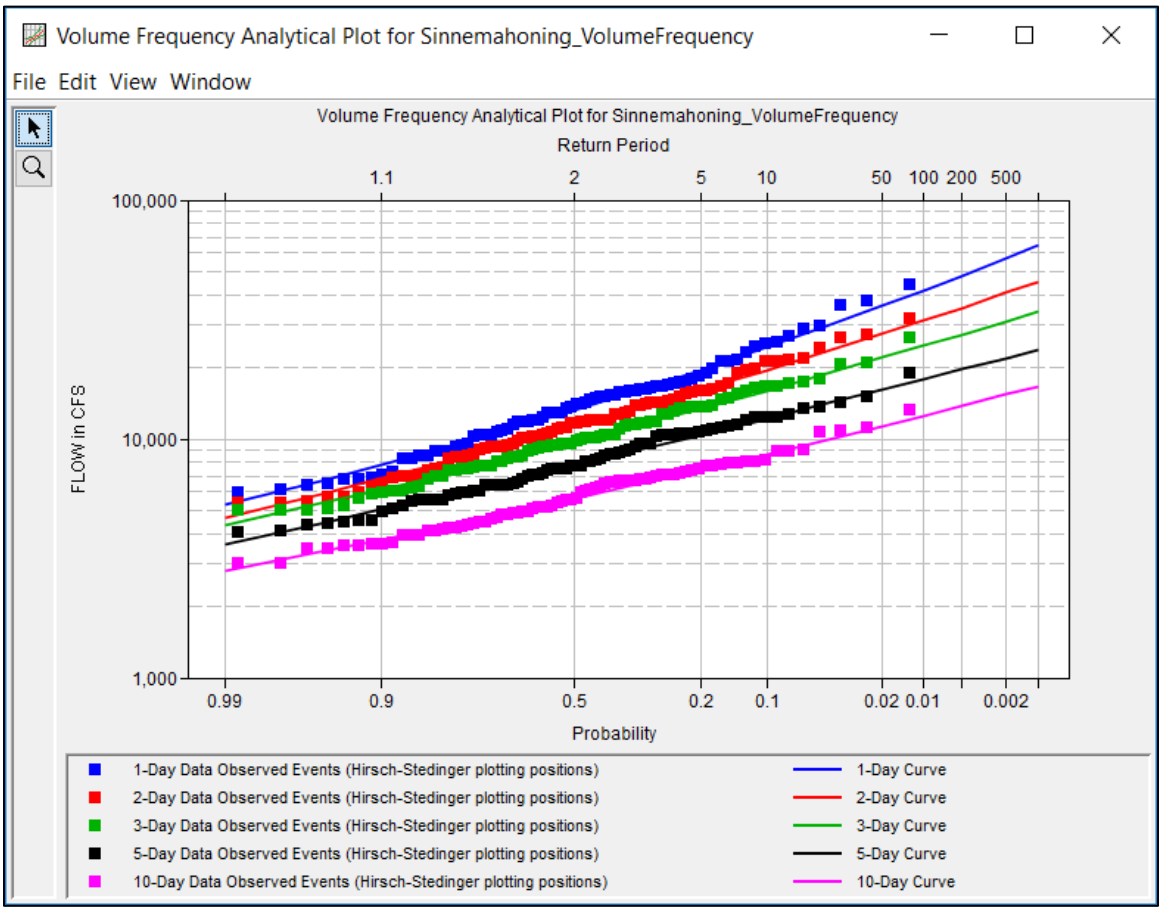


Figure 7-14. Plot of Data and Analytical Frequency Curves.

All plots opened by selecting one of the plot buttons at the bottom of the Volume Frequency Analysis editor contain menu options for printing, editing, and saving the plots.

Plots can be sent to the printer by selecting the **Print** option located on the **File** menu. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The plot can also be sent to the Windows

Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the plot to disk: windows metafile, postscript, JPEG, and portable network graphic. The data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot properties as a template (**Save Template**) and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the plot properties. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, the user can right-click on a line or data point in the plot area or in the legend and a shortcut menu will open with customization options. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

Computational results for a volume frequency analysis are written to a report file. The report file lists all of the input data and user settings, plotting positions of the data points, intermediate results, each of the various statistical tests performed (i.e. high and low outliers, historical data, etc…), and the final results. This file is often useful for understanding how the software arrived at the final frequency curves. Press the **View Report** button at the bottom of the Volume Frequency Analysis editor to open the report, as shown in Figure 7-15.

Sinnemahoning_VolumeFrequency.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\VolumeFrequencyAnalysisResults\Sinnemahoning

```
----------------------------
Volume-Duration Analysis
   18 Jan 2019   03:47 PM
----------------------------


--- Input Data ---

Analysis Name: Sinnemahoning_VolumeFrequency
Description:

Data Set Name: Sinnemahoning Creek-Daily
DSS File Name: C:/PROJECTS/SSP/Projects/Test/SSP_Examples/SSP_EXAMPLES.dss
DSS Pathname: //SINNEMAHONING/FLOW//1DAY/USGS/

Project Path: C:\PROJECTS\SSP\Projects\Test\SSP_Examples
Report File Name: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\VolumeFrequencyAnalys
Result File Name: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\VolumeFrequencyAnalys

Analyze Maxima

Analysis Year: Water Year

Record Start Date: 01 Oct 1938
Record End Date:   06 Mar 2016


User-Specified Durations
   Duration:   1 day
   Duration:   2 days
   Duration:   3 days
   Duration:   5 days
   Duration:  10 days

Plotting Position Type: Hirsch-Stedinger

Probability Distribution Type: Pearson Type III 17C EMA
Use Log Transform

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

User-Specified Frequencies
   Frequency: 0.1
   Frequency: 0.2
   Frequency: 0.5
   Frequency: 1.0
   Frequency: 2.0
   Frequency: 5.0
   Frequency: 10.0
   Frequency: 20.0
   Frequency: 50.0
   Frequency: 80.0
   Frequency: 90.0
   Frequency: 95.0
   Frequency: 99.0

Skew Option: Use Station Skew

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---
```

Figure 7-15. Volume Frequency Analysis Report.

Plots, tables and reports can also be created by selecting menu options from the **Results** menu. At least one volume frequency analysis must be selected in the study explorer before selecting one of the menu options on the Results menu. Results from multiple analyses are combined in one graph if they are selected in the study explorer when the **Graph** menu option is selected. The **Results→Summary Report** menu option will create a summary table of statistics and frequency curve ordinates for the selected analyses as shown in Figure 7-16.

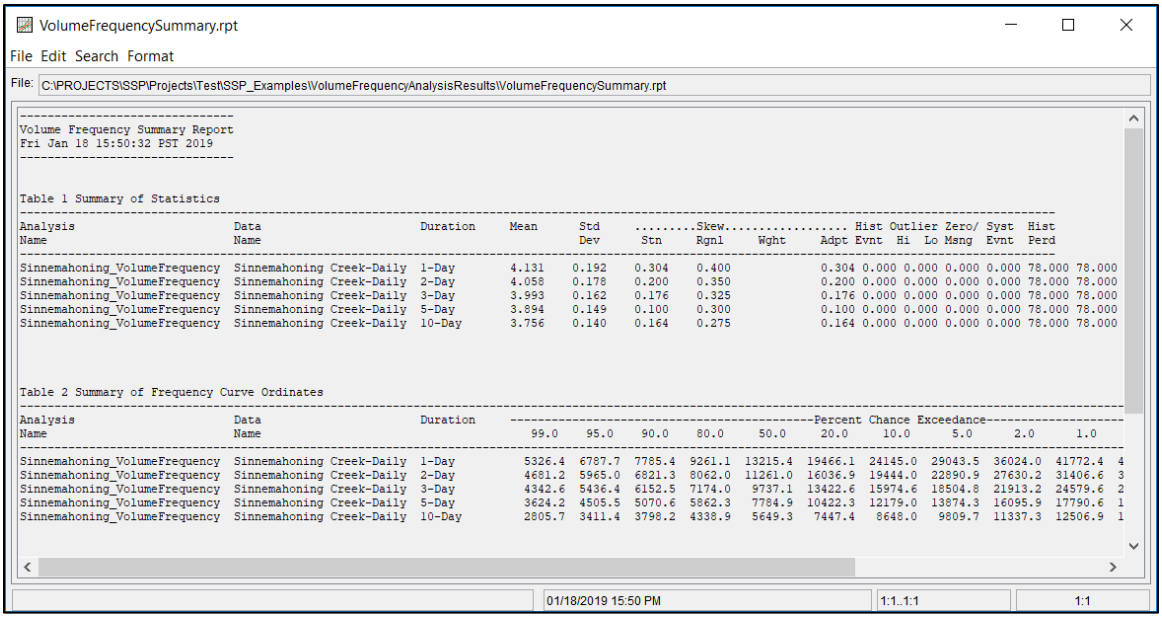


Figure 7-16. Summary Table for a Volume Frequency Analysis.

CHAPTER 8

Performing a Duration Analysis

This chapter discusses in detail how to use the Duration Analysis editor in HEC-SSP. A duration analysis can be performed on flow and stage data as well as other data types. All regular interval data can be used in a duration analysis and an option is included to manually define a duration curve.

Contents

- Starting a New Analysis
- General Settings and Options
- Analytical Duration Analysis
- Manual Analysis
- Viewing and Printing Results

Starting a New Analysis

A duration analysis can be started in two ways, either by right clicking on the Duration Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Duration Analysis**. When a new Duration Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select a data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The Duration Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a duration analysis will only include those data that have a regular interval, like 1HOUR and 1DAY (E-part pathname). Choose "None" for the Data Set when defining the duration curve manually on the **Manual Entry** tab. Once a Name is entered and a data set is selected, the **DSS File Name** and **Report File** will automatically be filled out. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Duration Analysis editor is shown in Figure 8-1.

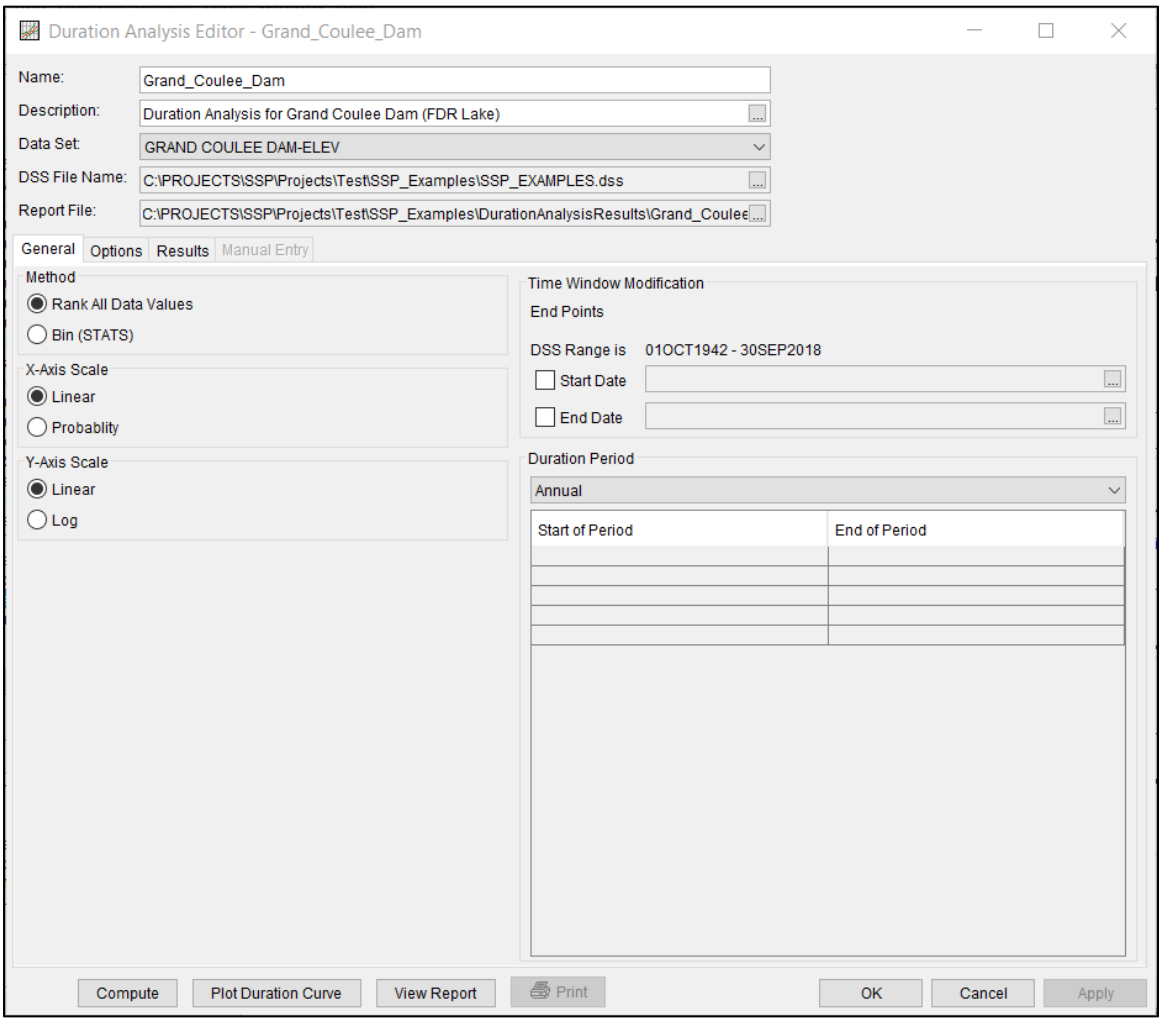


Figure 8-1. Duration Analysis Editor.

General Settings and Options

Once the analysis name and data set are selected, the user can begin defining the analysis. Contained on the Duration Analysis editor are four tabs. The tabs are labeled **General**, **Options**, **Results**, and **Manual Entry**. This section of the manual explains the use of the General and Options tabs.

General

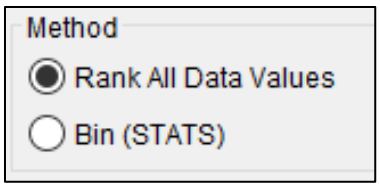
The first tab contains general settings for performing the duration analysis (Figure 8-1). These settings include:

- Method
- X-Axis Scale

- Y-Axis Scale
- Time Window Modification
- Duration Period

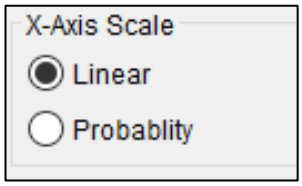
Method

This option allows the user to choose the **Rank All Data Values** or **Bin (STATS)** method for computing the duration analysis; the rank all data values method is the preferred choice. This method computes the duration curve by sorting the data from largest to smallest, ranking the values from 1 to n, and using the generalized plotting position formula. The Bin method uses a similar procedure as in the STATS program for computing the duration curve (U.S. Army Corps of Engineers, 1996). The data is grouped into bins (classes) and the duration curve is computed using the number of data in each bin.



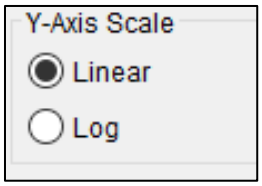
X-Axis Scale

This option allows the user to choose the scale of the x-axis. The options are **Linear** and **Probability**. This option will affect the x-axis scale in the duration curve plot and how the "interpolated" frequency curve is computed. The program will use a probability scale when interpolating the final duration curve to the user specified exceedance ordinates.



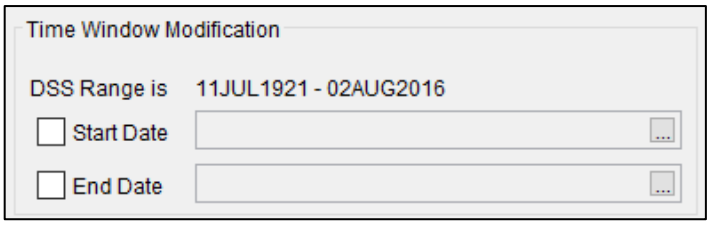
Y-Axis Scale

This option allows the user to choose the scale of the y-axis. The options are **Linear** and **Log**. This option will affect the y-axis scale in the duration curve plot, how the program computes evenly spaced bins when the Bin (Stats) method is selected, and how the "interpolated" frequency curve is computed. One option for computing bins is to let the program define the bins at evenly spaced intervals between the minimum and maximum values from the selected data set. When **Log** is set as the y-axis scale, the program will convert the minimum and maximum values to log space before computing the evenly spaced bin limits. Also, the program will use log scale when interpolating the final duration curve to the user specified exceedance ordinates.



Time Window Modification

This option allows the user to narrow the time window used for the analysis. The default is to use all of the data contained in the selected data set. The user can enter either a start date for the analysis, and end date, or both a start and end date. If a start and/or end date are used, they must be dates that are encompassed within the data stored in the selected data set. The date range for the selected data set is shown in the editor just above the **Start Date** field.



Duration Period

This option allows the user to compute multiple duration curves for different time windows within the year, as shown in Figure 8-2. If **Annual** is selected, then the program uses all the data when computing the duration curve. If **Quarterly** is selected, then the program separates the data into quarters and computes a separate duration curve for each quarter. For example, a duration curve for the 1st quarter includes all data measured from Jan 1 – March 31. The program will compute a separate duration curve for each month of the year when the **Monthly** option is selected. The **User-Defined** option lets the user define one or multiple periods within the year. Then the program will perform the duration analysis using data only measured during the user-defined period(s).

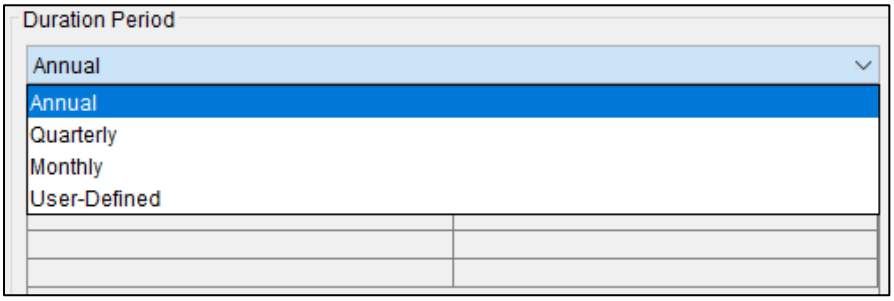


Figure 8-2. Duration Period Option.

Options

In addition to the general settings, there are also several options available to the user for modifying the computations of the duration curve. These options include:

- Output Labeling
- Plotting Position Formula

- Output Frequency Ordinates
- Bin Limits

When the Options tab is selected, the Duration Analysis editor will appear as shown in Figure 8-3.

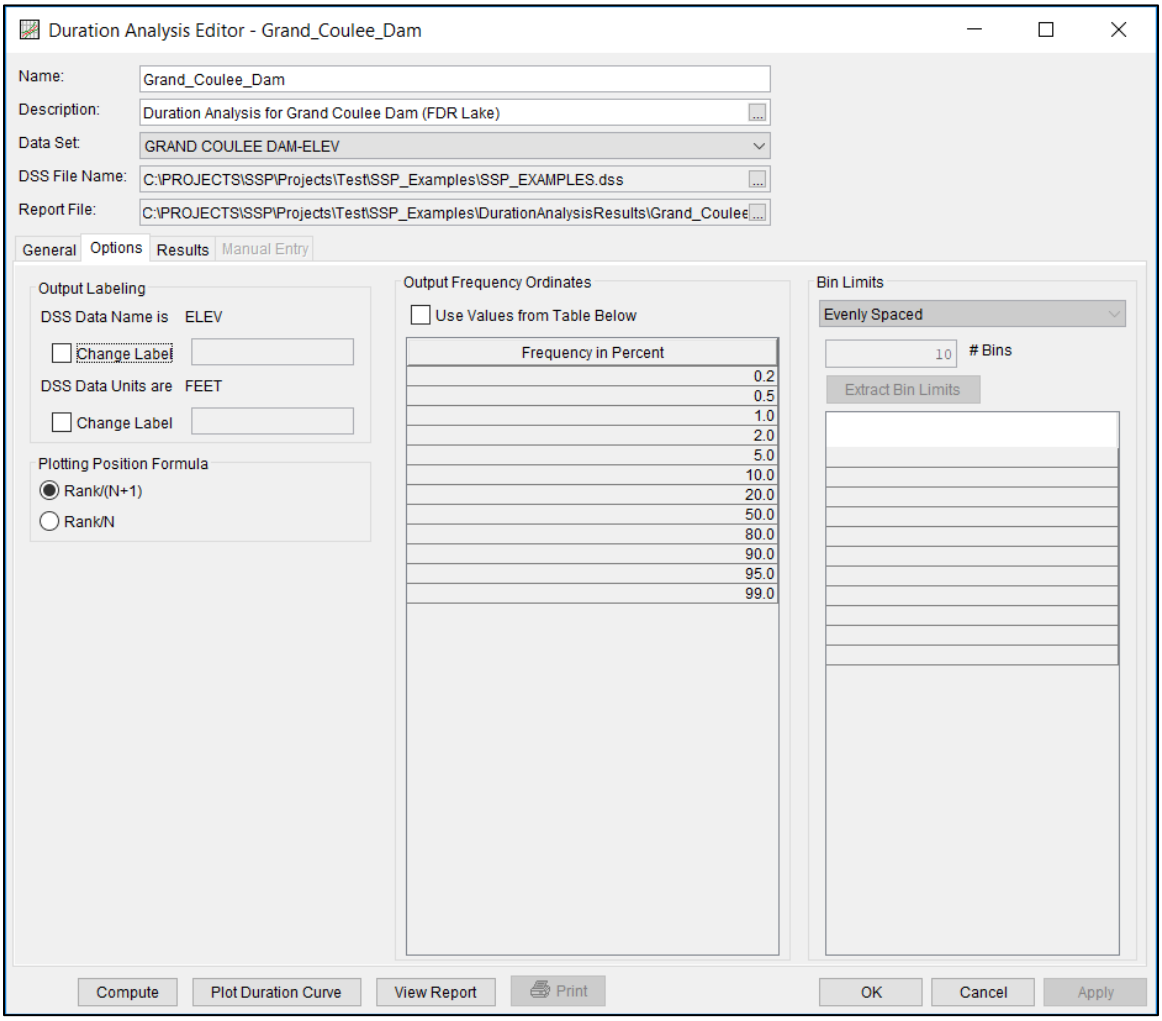
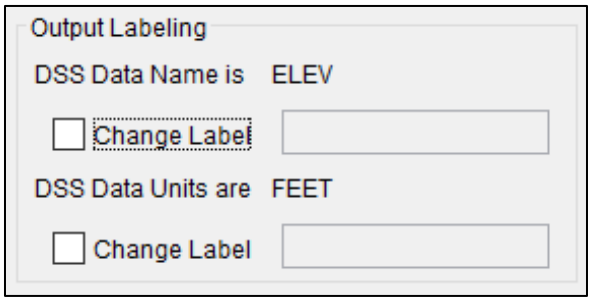


Figure 8-3. Duration Analysis Editor with Options Tab Selected.

Output Labeling

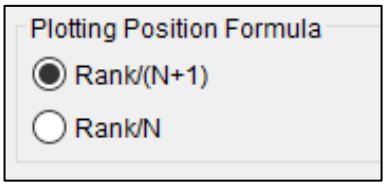
This option allows the user to change the default labels for data contained in the output tables and plots. The user can change both the name of the data as well as the units of the data. The output labeling does not result in the conversion of data from one unit system



to another; it only affects what is displayed on table headings and the y-axis of the results plot.

Plotting Position Formula

This option allows the user to choose how the duration curve is computed (this option is not available when the **Bin** method is selected). When



Rank/(N+1) is selected the program will compute the duration curve by sorting the data from largest to smallest, ranking the values from 1 to n, and using the generalized plotting position formula and Weibull criteria:

$$P = 100 * \frac{m}{(n+1)}$$

where: m = rank of values with the largest equal to 1.

n = number of values in the data set.

When **Rank/N** is selected the program will compute the duration curve using:

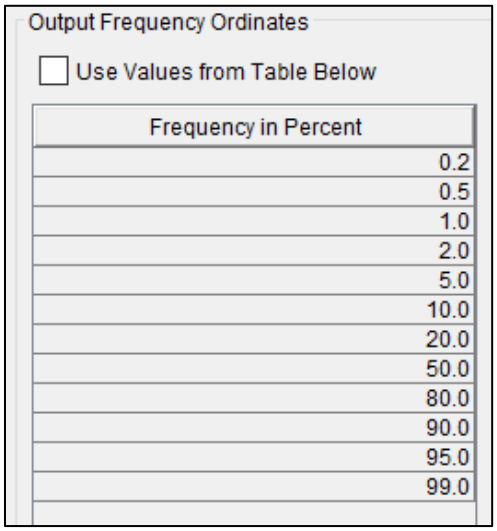
$$P = 100 * \frac{m}{n}$$

where: m = rank of values with the largest equal to 1.

n = number of values in the data set.

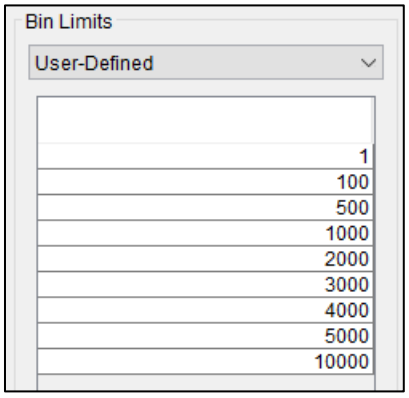
Output Frequency Ordinates

This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.



Bin Limits

The **Bin Limits** panel is only active when the **Bin (STATS)** method is selected on the General tab. This option helps the user to define the limits, the minimum and maximum values, for each bin. There are two options; **Evenly Spaced** and **User-Defined**. When **Evenly Spaced** is selected the user must also enter the number of bins. The **Extract Bin Limits** button will automatically populate the bin limits table by first extracting the minimum and maximum values from the data set and then linearly interpolating evenly spaced bin limits. If Log is selected as the Y-axis scale on the General tab, then the program converts the minimum and maximum values to log space before computing the evenly spaced bin limits. The **User-Defined** option lets the user manually enter the bin limits. The user must ensure the minimum and maximum values from the data set are contained in the bin limits table. For example, if the minimum



flow from the data set is 100.0 then the first row in the table must be less than or equal to 100.0. Additional rows can be added to the table. Place the mouse pointer on top of the table and click the right mouse button. Then select the **Insert Row(s)…** menu option to open an editor for specifying the number of rows to insert into the table.

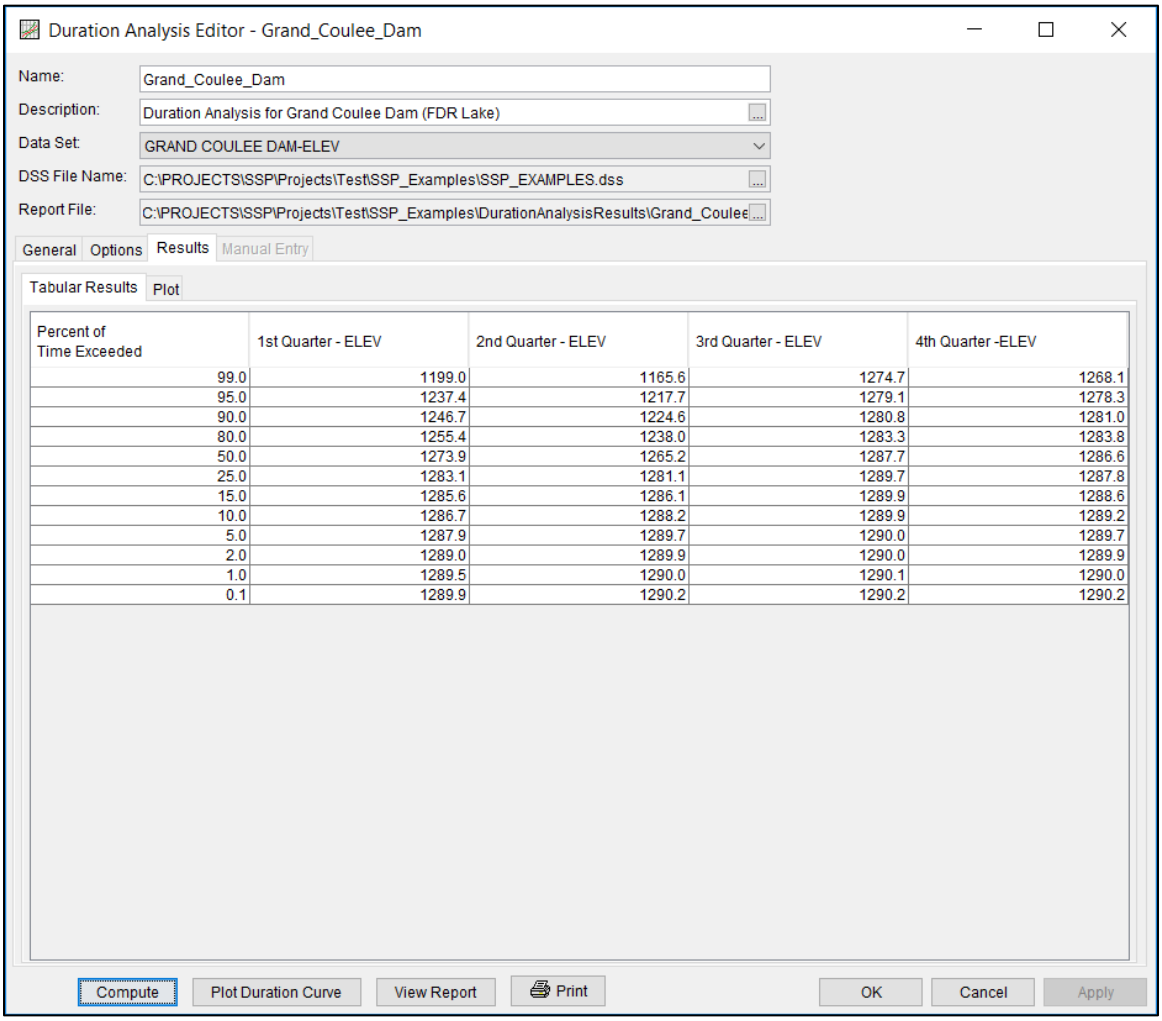
Compute

Once the new analysis has been defined, and the user has all of the General and Options information selected the way they want, performing the computations is simply a matter of pressing the **Compute** button at the bottom of the Duration Analysis editor. If the computations are successful, the user will receive a message that says "Compute Complete". At this point, the user can begin to review the results.

Multiple Duration analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finished computing the analyses.

Results

This section of the manual describes results that are available for the Duration Analysis. When the user selects the **Results** tab on the Duration Analysis editor, the window will appear as shown in Figure 8-4. As shown, two additional tabs will appear on the screen: **Tabular Results** and **Plot**.



Percent of Time Exceeded	1st Quarter - ELEV	2nd Quarter - ELEV	3rd Quarter - ELEV	4th Quarter -ELEV
99.0	1199.0	1165.6	1274.7	1268.1
95.0	1237.4	1217.7	1279.1	1278.3
90.0	1246.7	1224.6	1280.8	1281.0
80.0	1255.4	1238.0	1283.3	1283.8
50.0	1273.9	1265.2	1287.7	1286.6
25.0	1283.1	1281.1	1289.7	1287.8
15.0	1285.6	1286.1	1289.9	1288.6
10.0	1286.7	1288.2	1289.9	1289.2
5.0	1287.9	1289.7	1290.0	1289.7
2.0	1289.0	1289.9	1290.0	1289.9
1.0	1289.5	1290.0	1290.1	1290.0
0.1	1289.9	1290.2	1290.2	1290.2

Figure 8-4. Results Tab of the Duration Analysis Editor.

Tabular Results

The **Tabular Results** tab will bring up a table of results for the duration analysis. The tabular results are different for the **Rank All Data Values** and **Bin (STATS)** methods. An example of tabular results for a **Rank All Data Values** analysis is shown in Figure 8-4. The results table will contain multiple duration curves if the Quarterly, Monthly, or the User Defined options are selected as the Duration Period. Data in the duration curve table can be re-sorted. Click the **Percent of Time Exceeded** column header (two mouse clicks are required the first time). The percent of time exceeded ordinates, along with the duration curve values, will sort so that the lowest values are on top or the highest values are on top.

The tabular results tab will look different when the **Bin (STATS)** method is used to compute the duration analysis. As shown in Figure 8-5, there

are two tables. The first table contains summary information about the bins and the second table contains the interpolated duration curve.

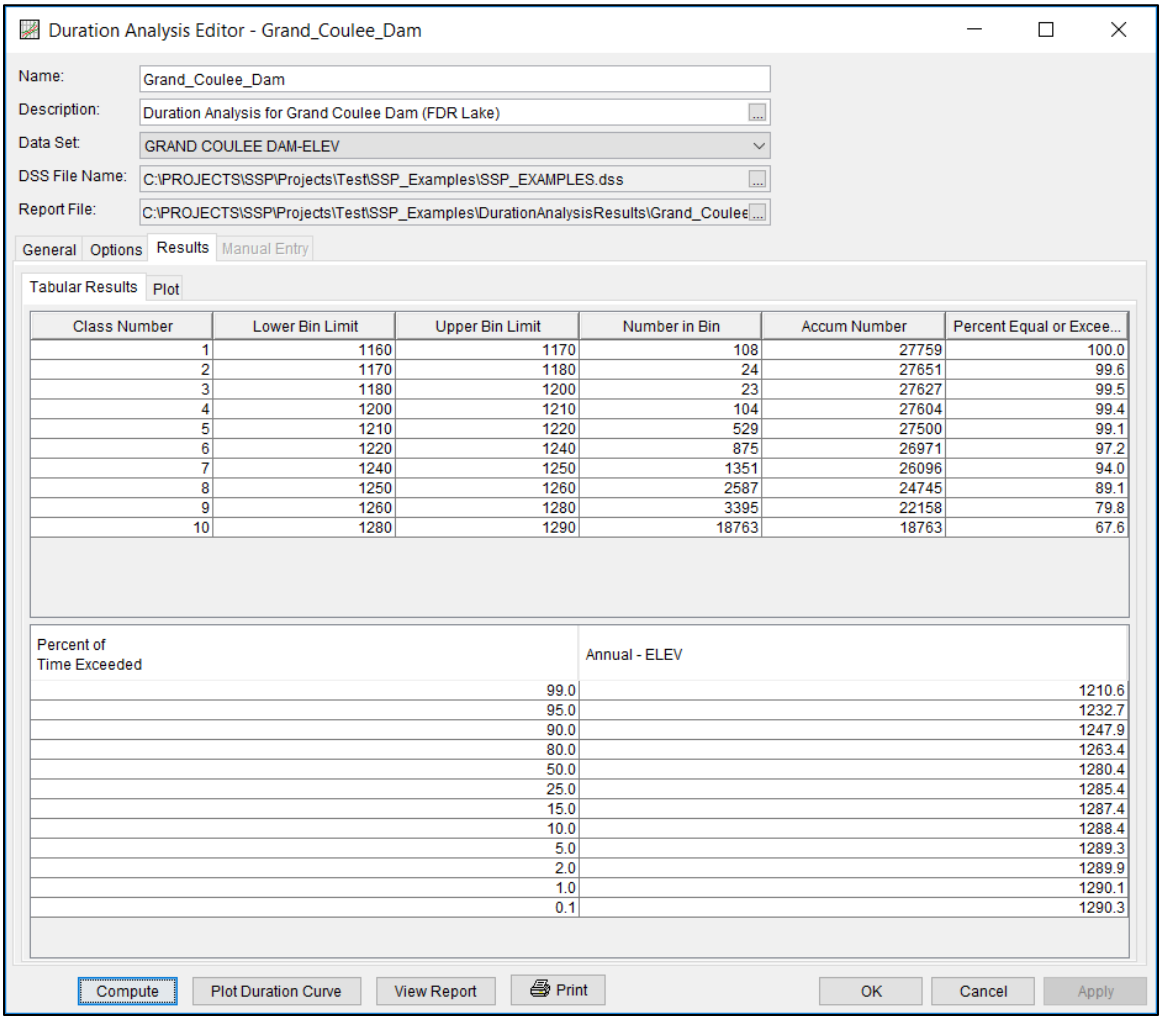


Figure 8-5. Results Tab for a Bin (STATS) analysis.

Plot

In addition to tabular results, a **Plot** tab is available for viewing a graphical plot of the duration curves. When the Plot tab is selected the window will change to what is shown in Figure 8-6. The plot contains the computed duration curve and the duration curve interpolated to the user-defined ordinates (defined on the Options tab). Multiple duration curves will be graphed if the Quarterly, Monthly, or User Defined options are selected as the duration period.

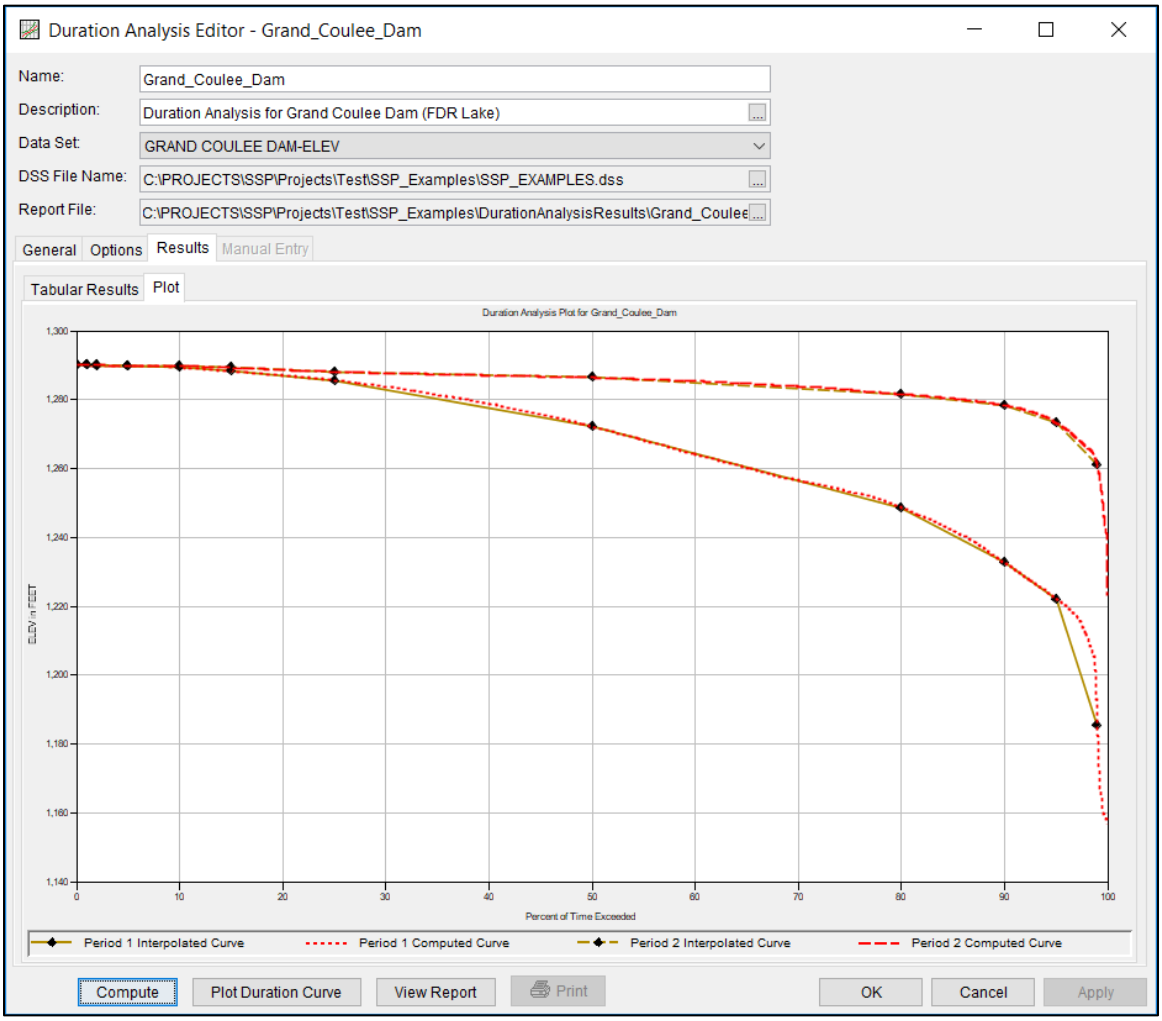


Figure 8-6. Plot Tab of the Duration Analysis.

Manual Duration Analysis

The user has the option to manually define a duration curve. This option would be used when a duration curve has been computed outside of HEC-SSP. The "None" data set must be selected in order to define a duration curve manually. When the **Manual Entry** tab is selected, the editor will display a plot and table as shown in Figure 8-7. The table allows the user to enter data values for the percent of time exceedance ordinates defined on the Options tab. When the user enters values in this table, those values will be plotted as a line on the plot after the **Compute** button is pressed.

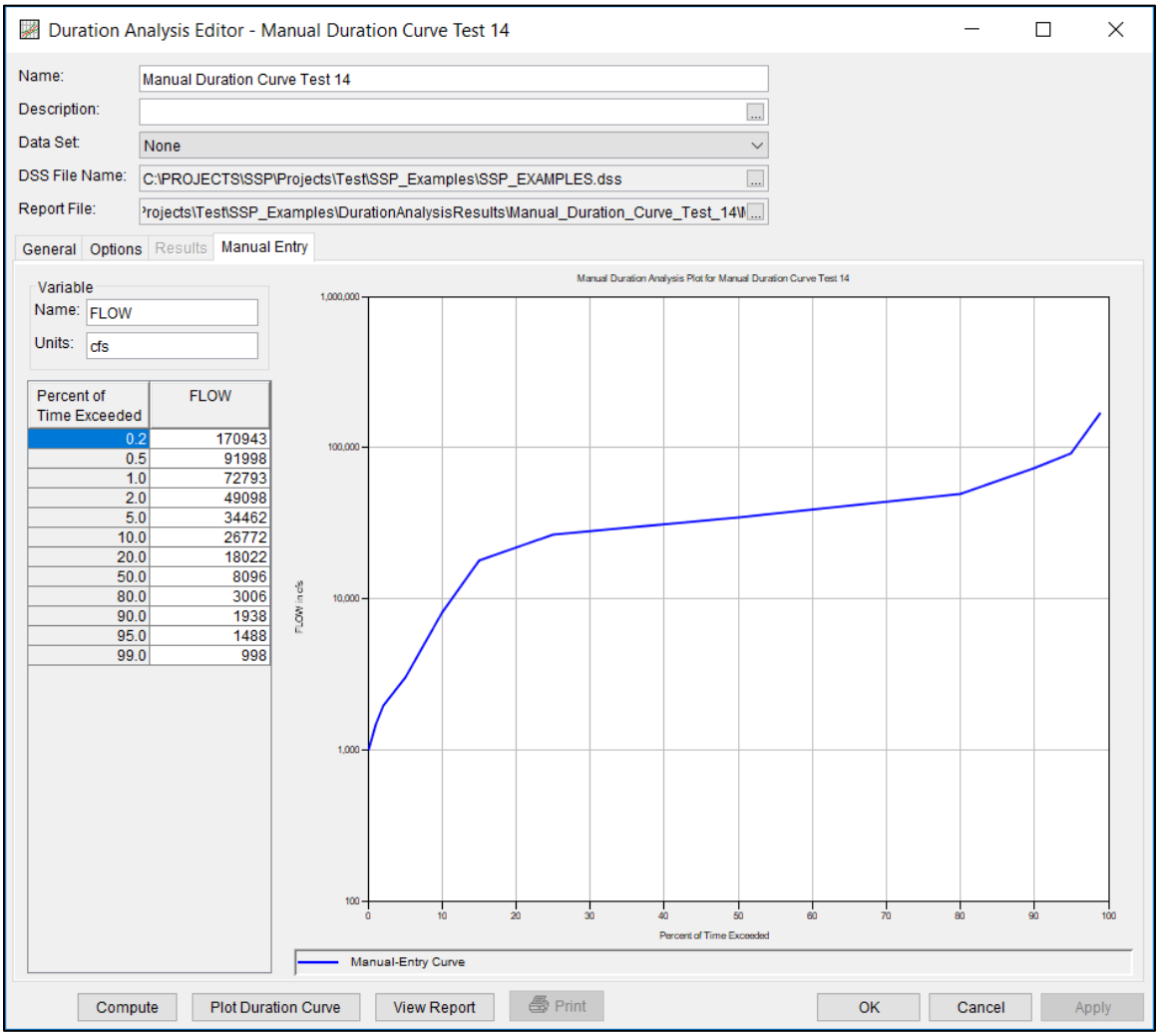


Figure 8-7. Manual Entry Tab of the Duration Analysis Editor.

Viewing and Printing Results

The user can view output for the duration analysis directly from the Duration Analysis editor (Tabular and Graphical output) or by using the buttons at the bottom of the editor. Results can also be opened by selecting the duration analysis in the study explorer and then choosing the **Graph**, **Table**, or **Report** option available from the **Results** menu.

Tabular Output

Once the computations for the duration analysis are completed, the user can view tabular output by selecting the **Tabular Results** tab under the **Results** tab. The details of this table were discussed above.

The tabular results can be printed by using the **Print** button at the bottom of the Duration Analysis editor. When the print button is pressed, a window will appear giving the user options for how they would like the table to be printed.

Graphical Output

Graphical output of the duration curve can be obtained by selecting either the **Plot** tab under the results tab, or by pressing the button labeled **Plot Duration Curve** at the bottom of the Duration Analysis editor. When the Plot Duration Curve button is pressed, a duration curve plot will appear in a separate window as shown in Figure 8-8.

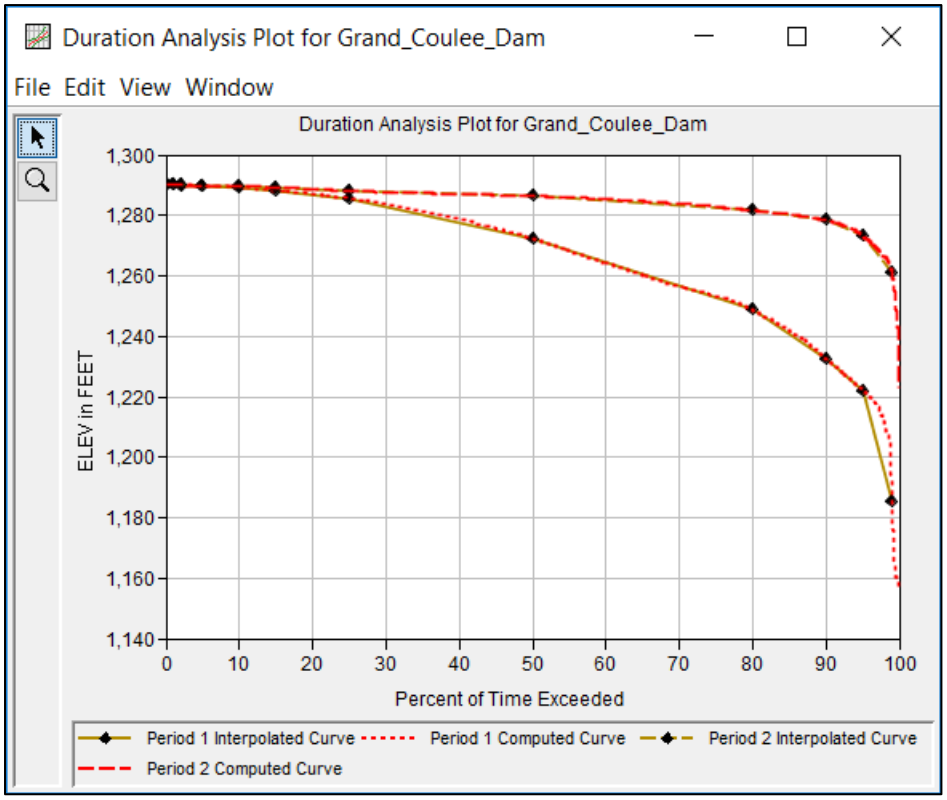


Figure 8-8. Duration Curve Plot.

The duration curve plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a

directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: windows metafile, postscript, JPEG, and portable network graphic.

The data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the duration analysis computations are performed. The report file contains information about the duration analysis and the final results. To view the report file press the **View Report** button at the bottom of the Duration Analysis editor. When this button is pressed, a window will appear containing the report as shown in Figure 8-9.

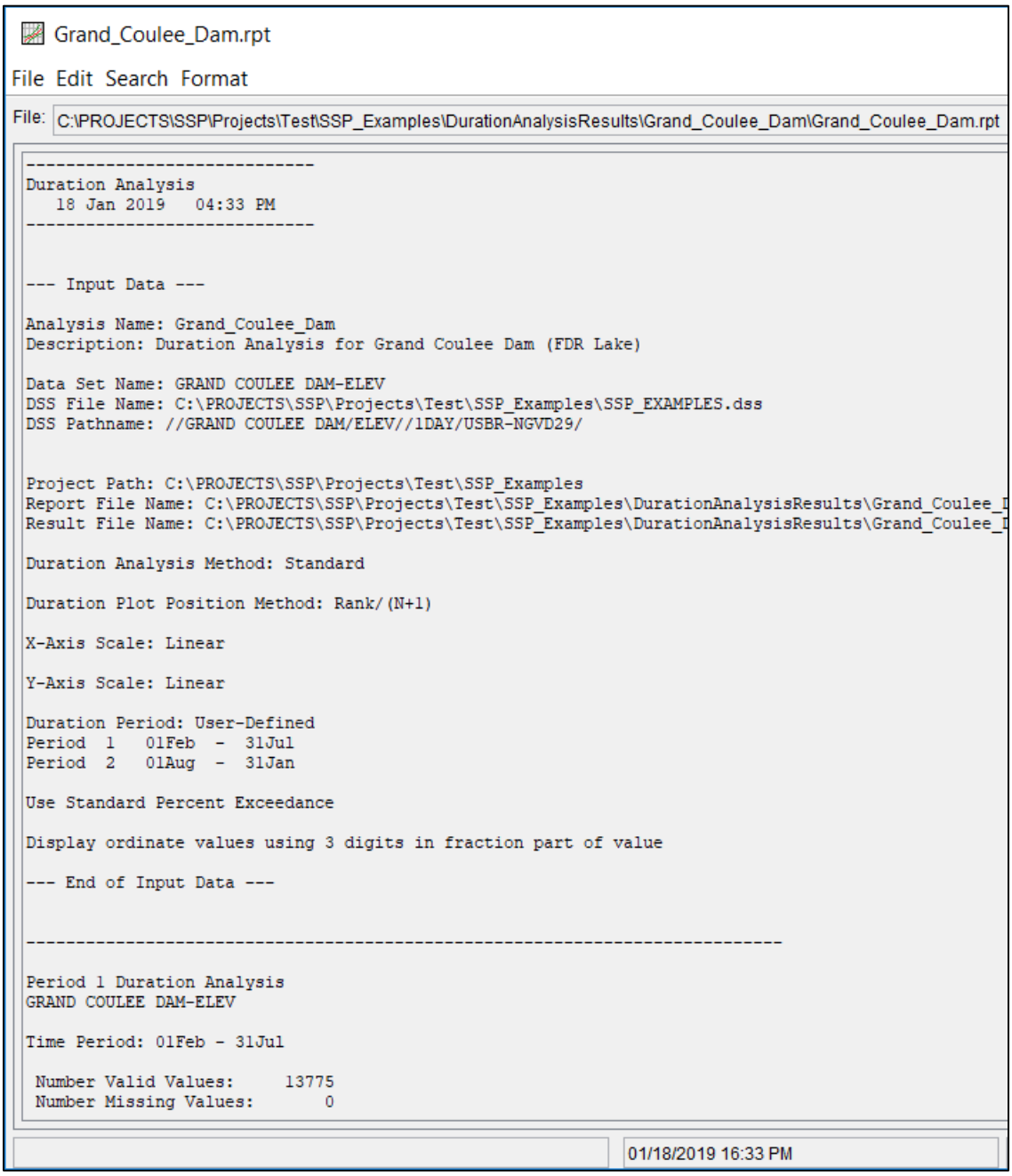


Figure 8-9. Duration Analysis Report File.

CHAPTER 9

Performing a Coincident Frequency Analysis

This chapter discusses in detail how to use the Coincident Frequency Analysis editor in HEC-SSP. A coincident frequency analysis can be performed on any data type; flow, stage, precipitation, wind, etc. The coincident frequency analysis requires both duration and frequency curves. These can be computed by existing analyses in the HEC-SSP study or they can be entered manually in the Coincident Frequency Analysis editor.

The Coincident Frequency Analysis is designed following guidelines in EM 1110-2-1415. This analysis tool can be used to compute the exceedance frequency relationship for a variable that is a function of two other variables. An example is illustrated in Figure 9-1. In this example, the stage at the damage site on the tributary, variable C, is a function of stream flow from the tributary, variable A, and the stage in the mainstem river, variable B.

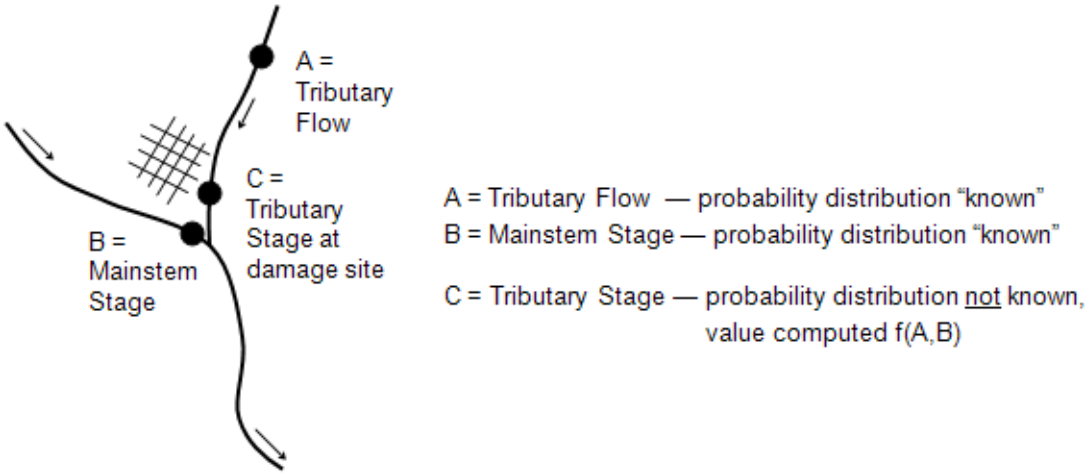


Figure 9-1. Example Application of the Coincident Frequency Analysis.

The general procedure for performing a coincident frequency analysis, using HEC-SSP is described below.

1) Develop a duration curve for variable B. This can be done using the Duration Analysis editor or it can be defined manually in the

Coincident Frequency Analysis editor. Then, discretize the duration curve to determine index values for variable B. The index values should be defined so that the area under the discretized duration curve approximates the original duration curve. Figure 9-2 shows a flow duration curve that has been discretized using 10 index points. The index points are taken at the midpoint of each discrete segment and there are more index points along the steeper portion of the duration curve. The Coincident Frequency Analysis editor can be used to define the index points and to estimate the proportion of time for each index point. For example, the 10th index point in Figure 9-2 is taken at the midpoint for the discrete segment from 100 to 70 percent of time exceeded. The flow value at this point represents the variable B index occurring 30 percent of the time. The 9th index point is taken at the midpoint for the discrete segment from 70 to 50 percent of time exceeded. The flow value at this point represents the variable B index occurring 20 percent of the time. The proportion of time assigned to each index point will be used to compute the variable C frequency curve.

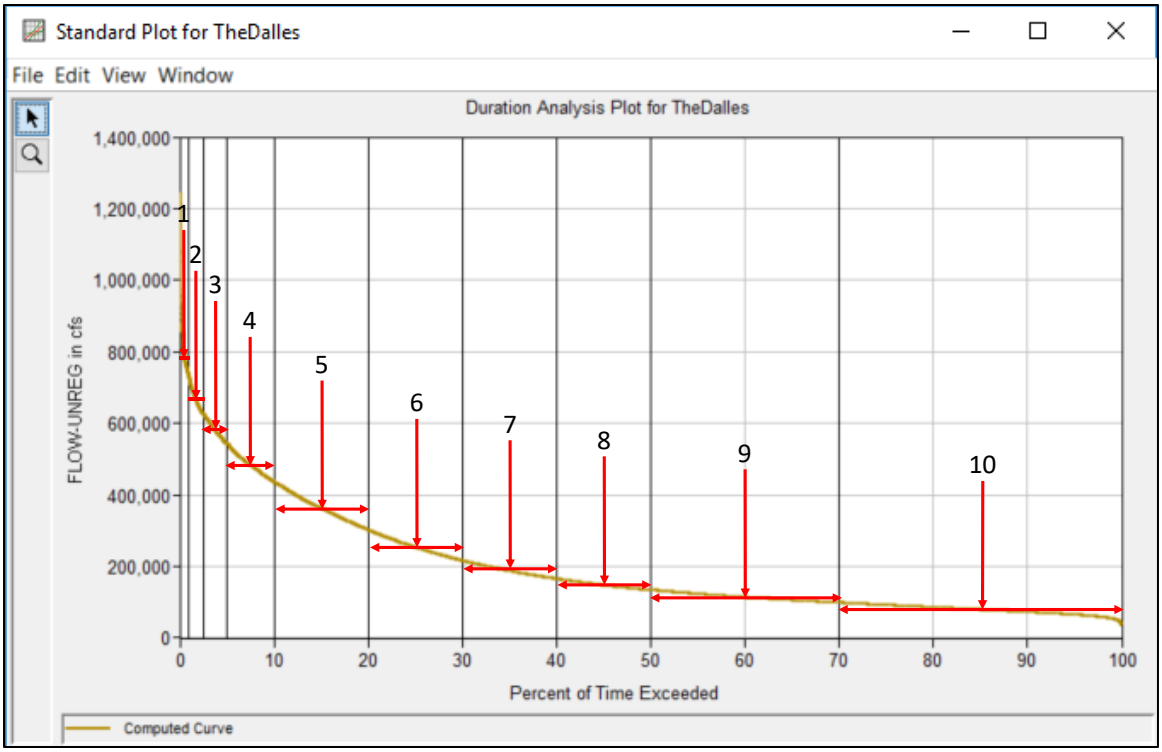
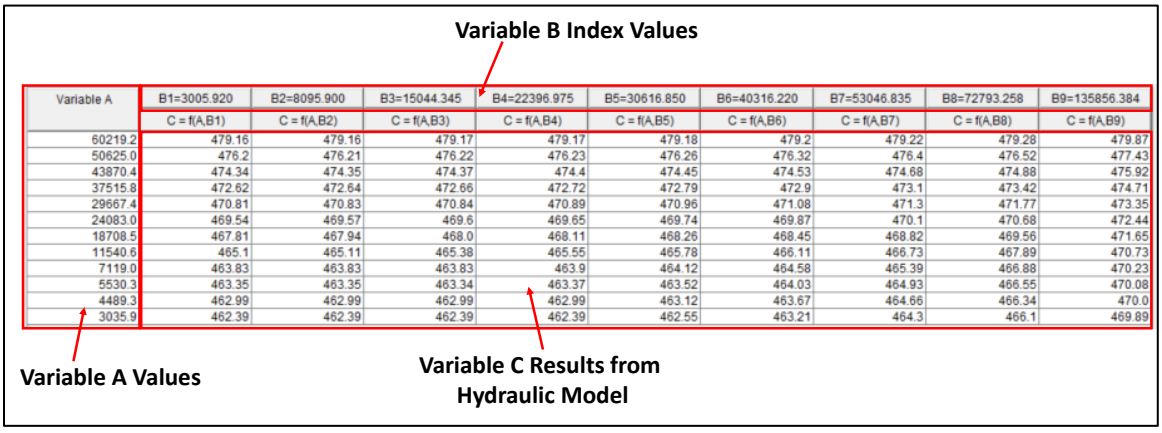


Figure 9-2. Variable B Duration Curve Divided into Discrete Segments.

2) Different procedures are required depending on whether variables A and B are independent or not independent of one another. When variables A and B are assumed independent of one another, develop a frequency curve of variable A. The frequency curve can come from an

existing Bulletin 17 or General Frequency Analysis or it can be defined manually in the Coincident Frequency Analysis editor. If variables A and B are not independent of one another, then develop a frequency curve of variable A for each variable B index value. In this case, the variable A frequency curves must be defined manually in the Coincident Frequency Analysis editor. This involves extracting annual peak values for variable A that occur for each discrete range identified on the variable B duration curve and performing a separate frequency analysis on each set of variable A data.

3) Develop the response of variable C for combinations of variable A and variable B. This could be done using a hydrologic or hydraulic model. For the example shown in Figure 9-1, a flow value from the variable A frequency curve would be applied to the tributary and the index flow (or stage) from the variable B duration curve would be applied to the mainstem. The hydrologic or hydraulic model would be used to compute the variable C stage at some reference point on the tributary. This model simulation would be computed for many combinations of variable A and variable B. Figure 9-3 shows example output from a hydraulic model. The model was used to generate output from multiple combinations of variable A and B values. In this example, there were 12 variable A values and 9 index values from variable B. This resulted in 108 simulation results. The table shown in Figure 9-3 is referred to as the Response Curves table in HEC-SSP and these values must be entered by the user.



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=135856.384
	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

Figure 9-3. Response of Variable C for Combinations of Variable A and Variable B.

4) The program computes the variable C frequency curve by first using the response curves to compute conditional frequency curves of variable C. This is done by assigning the same frequency from the variable A value to the corresponding variable C value. Then, for a selected value of

variable C, the frequency value from each conditional frequency curve is multiplied by the corresponding proportion of time (probability) from the variable B index value. The values are summed to obtain the frequency of the selected value of variable C. This is done for a number of values of variable C until a complete frequency curve is created.

Contents

- Starting a New Analysis
- General Settings
- Variable A
- Variable B
- Response Curves
- Viewing and Printing Results

Starting a New Analysis

A coincident frequency analysis can be started in two ways, either by right clicking on the Coincident Frequency Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Coincident Frequency Analysis**. When a new Coincident Frequency Analysis is selected, the user is required to first enter a **Name** for the analysis and an optional **Description**. The Coincident Frequency Analysis editor will not allow further edits by the user until the name is defined. Once a Name is entered, the **DSS File Name** and **Report File** will automatically be filled out. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Coincident Frequency Analysis editor is shown in Figure 9-4.

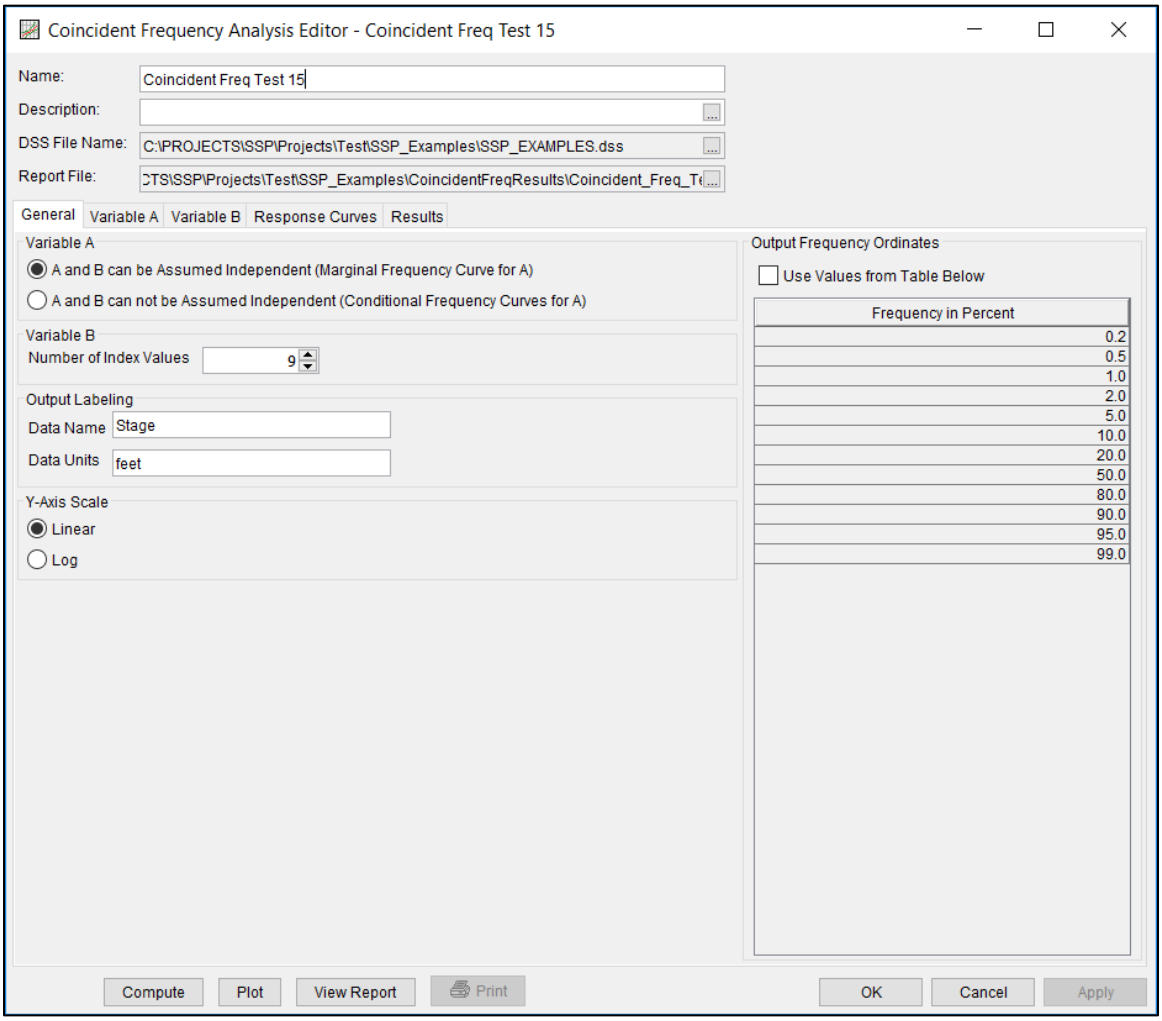


Figure 9-4. Coincident Frequency Analysis Editor.

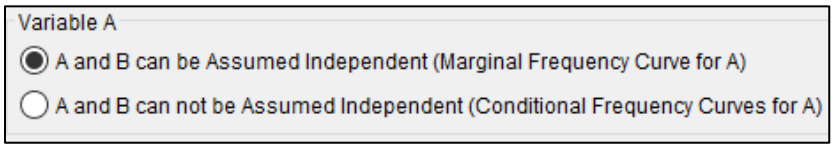
General Settings

Once the analysis name has been entered, the user can begin defining the analysis. Contained on the Coincident Frequency Analysis editor are five tabs. The tabs are labeled **General**, **Variable A**, **Variable B**, **Response Curves**, and **Results**. The first tab contains general settings for performing the coincident frequency analysis (Figure 9-4). These settings include:

- Variable A
- Variable B
- Output Labeling
- Y-Axis Scale
- Output Frequency Ordinates

Variable A

This option allows the user to choose whether the coincident frequency analysis assumes variables A and B are independent or dependent. When variables A and B can be assumed independent, there will be only one frequency curve for variable A. A conditional variable A frequency curve assumes variables A and B are not independent, so there will be a separate variable A frequency curve for each variable B index value.



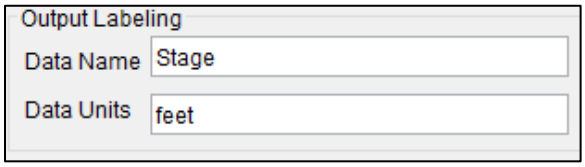
Variable B

This option allows the user to define the number of index values for variable B. The index points are used to discretize the duration curve. A probability, or a proportion of time, will be assigned to each index point.



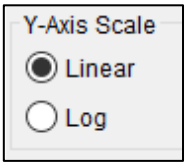
Output Labeling

This option allows the user to enter labels for data contained in the output tables and plots. The user must enter the name of the data as well as the data units. The output labeling does not result in the conversion of data from one unit system to another; it only affects what is displayed on table headings and the y-axis of the results plot.

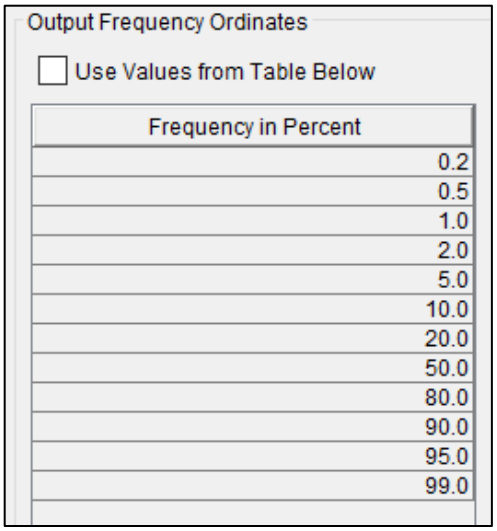


Y-Axis Scale

This option allows the user to choose the scale of the y-axis. The options are **Linear** and **Log**. This option will affect the y-axis scale in the coincident frequency curve plot.



Output Frequency Ordinates

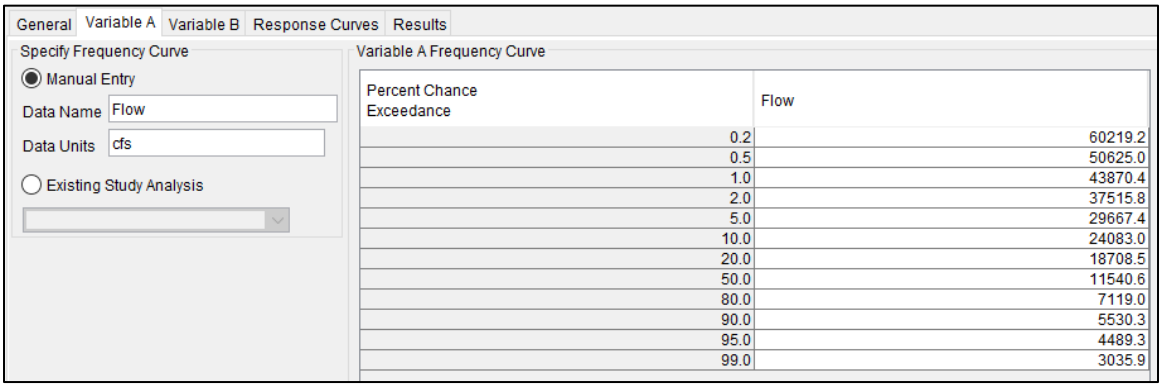


This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.

Variable A

The **Variable A** tab is used to define the frequency curve for variable A. This tab will look different based on the user's selection on the General Tab. The Variable A tab will look like Figure 9-5 when "A and B can be Assumed Independent" is selected on the General tab. Since variables A and B are independent, there will only be one frequency curve for variable A.

As shown in Figure 9-5, the user can choose to define the curve manually or select an existing study analysis. When the **Manual Entry** option is selected, the user must define the **Data Name** and **Data Units**. Then the user must enter the frequency curve for variable A. A frequency curve value must be defined for each percent chance exceedance ordinate in the table. When the **Existing Study Analysis** option is selected, the dropdown list will be active and the user can choose any Bulletin 17 or General Frequency Analysis in the HEC-SSP study. The variable A frequency curve table will be populated with the frequency curve when an analysis is selected. The program uses the statistics from the selected analysis and computes the frequency curve that populates the table.

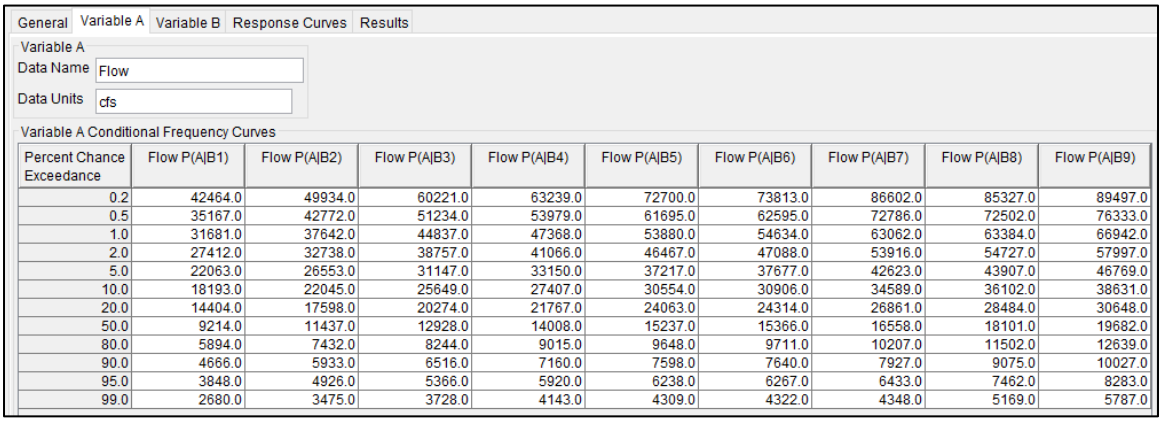


Percent Chance Exceedance	Flow
0.2	60219.2
0.5	50625.0
1.0	43870.4
2.0	37515.8
5.0	29667.4
10.0	24083.0
20.0	18708.5
50.0	11540.6
80.0	7119.0
90.0	5530.3
95.0	4489.3
99.0	3035.9

Figure 9-5. Variable A Tab when Variable A and B are Independent.

The Variable A tab will look like Figure 9-6 when "A and B can not be Assumed Independent" is selected on the General tab. A conditional variable A frequency curve assumes variables A and B are not independent, so there will be a separate variable A frequency curve for each variable B index value.

As shown in Figure 9-6, the user must define the **Data Name** and **Data Units**. Then the user must manually enter the variable A frequency curve for each index value of variable B. This involves extracting the annual peak values for variable A that occur for each discrete range identified on the variable B duration curve and performing a separate frequency analysis on each set of variable A data. Also, a frequency curve value must be defined for each Percent Chance Exceedance ordinate in the table.



Percent Chance Exceedance	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

Figure 9-6. Variable A Tab when Variable A and B are not Independent.

Press the **Plot** button located at the lower left corner of the Variable A tab to open a plot of the variable A frequency curve(s).

Variable B

The **Variable B** tab is used to define the duration curve for variable B and the index points with an associated probability. The index points will be used by the user when developing the response curves (response of variable C to each combination of variables A and B). The associated probability represents the proportion of time that each index point can be expected to occur.

As shown in Figure 9-7, the left side of the variable B tab is used to select the duration curve from an existing Duration Analysis. Once selected, the program populates the duration curve table. Press the **Plot** button located at the lower left corner of the Variable B tab to open a plot of the variable B duration curve.

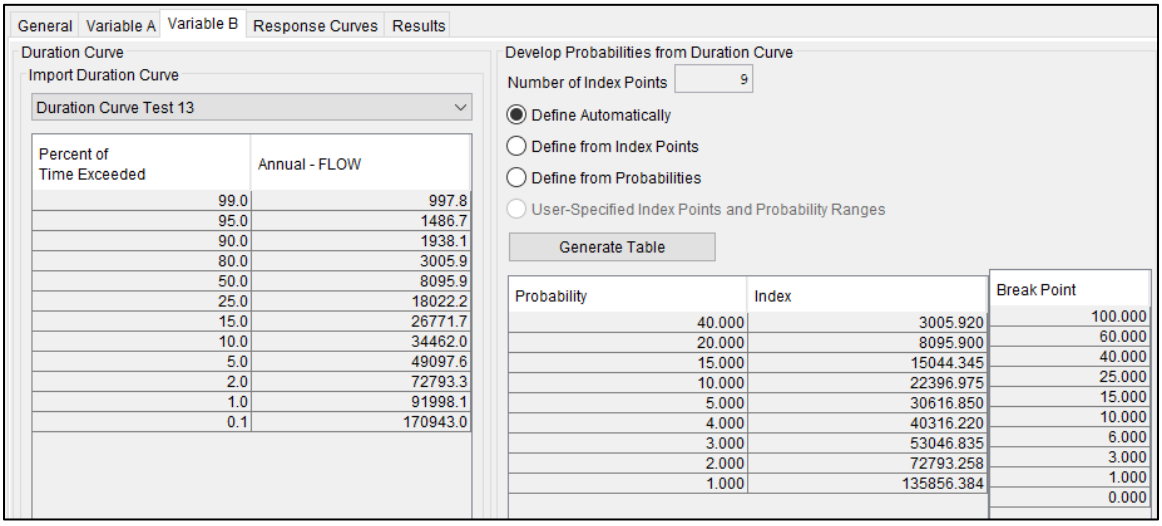


Figure 9-7. Variable B Tab.

After the duration curve has been selected, the right side of the variable B tab is used to define the index points and associated probabilities used to discretize the duration curve. The number of index points is defined on the General tab and is included on the Variable B tab to let the user know how many index points must be defined in the table. There are 4 methods for defining the index values and the associated probabilities. The user selects one of the methods, edits the table, and then clicks the **Generate Table** button in order for the program to finish populating the table. The following text describes each method.

Define Automatically. The program will use a predefined pattern of probability ranges when this option is selected, as contained in Table 9-1, to populate the **Probability** column. The pattern is dependent on the number of index points and the default probability patterns do not extend

beyond nine index points. If more than nine index points have been selected for the analysis, then use one of the other methods for defining the index points and associated probabilities. The program will compute the **Index** and **Break Point** columns when the **Generate Table** button is pressed. The **Break Point** column is computed using the probability pattern. The first row in this column is always 100. The second break point is computed by subtracting the first probability value from the first break point value. The third break point is computed by subtracting the second probability value from the second break point value. This procedure is followed until the last break point is computed; it should always have a value of 0. The **Index** values are taken from the duration curve at the midpoint between each break point range. For example, if the first break point was 100 and the second was 60 then the first **Index** value would be the value from the duration curve at 80 percent time exceeded.

Table 9-1. Default Probability Patterns.

	Number of Index Points						
Index	3	4	5	6	7	8	9
1	20	15	45	35	35	35	40
2	60	35	40	30	25	20	20
3	10	35	10	20	20	15	15
4		15	4	10	10	10	10
5			1	4	6	10	5
6				1	3	6	4
7					1	3	3
8						1	3
9							1

Define from Index Points. The number of rows is set by the number of index points. In this case, the **Index** column is edited by the user; the user must enter an index value in each row. When the **Generate Table** button is pressed, the program will compute the **Break Point** and the **Probability** values. First, the program will use the selected duration curve and interpolate a percent of time exceeded for each user-defined index value. Then break points are computed so that they are half way between the percent of time exceeded values (the first and last break points will be 100 and 0). The probability values are computed based on the break points. For example, the first probability value is computed by subtracting the second break point value from the first. The second probability value is computed by subtracting the third break point value from the second. This procedure is followed until the last probability value is computed.

Define from Probabilities. The number of rows is set by the number of index points. In this case, the **Probability** column is edited by the user; the user must enter a probability value in each row (the probability values should add up to 100). When the **Generate Table** button is pressed, the **Break Point** column is computed using the user-entered probability pattern. For example, the first row in the break point column is 100; therefore, the second break point is computed by subtracting the first probability value from the first break point value. The third break point is computed by subtracting the second probability value from the second break point value. This procedure is followed until the last break point is computed; it should always have a value of 0. The **Index** values are taken from the duration curve at the midpoint between each break point range. For example, if the first break point was 100 and the second was 60 then the first **Index** value would be the value from the duration curve at 80 percent time exceeded.

User-Specified Index Points and Probability Ranges. This option can only be selected when the user does not select an existing Duration Curve to import. This would be applicable for the case where the user developed the duration curve outside of HEC-SSP and developed the index points and associated probabilities. As shown in Figure 9-8, the user must specify both the **Probability** and **Index** values; the user must enter values in each row. When the **Generate Table** button is pressed, the **Break Point** column is computed using the user-entered probability pattern. For example, the first row in the break point column is 100; therefore, the second break point is computed by subtracting the first probability value from the first break point value. The third break point is computed by subtracting the second probability value from the second break point value. This procedure is followed until the last break point is computed; it should always have a value of 0.

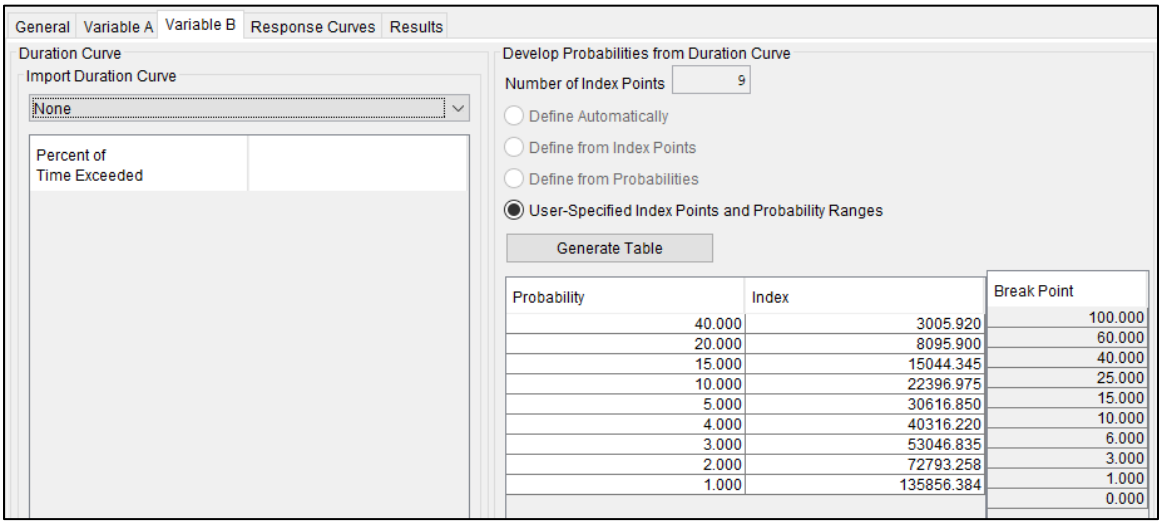


Figure 9-8. User-Specified Option to Define Index Points and Probability Ranges.

Response Curves

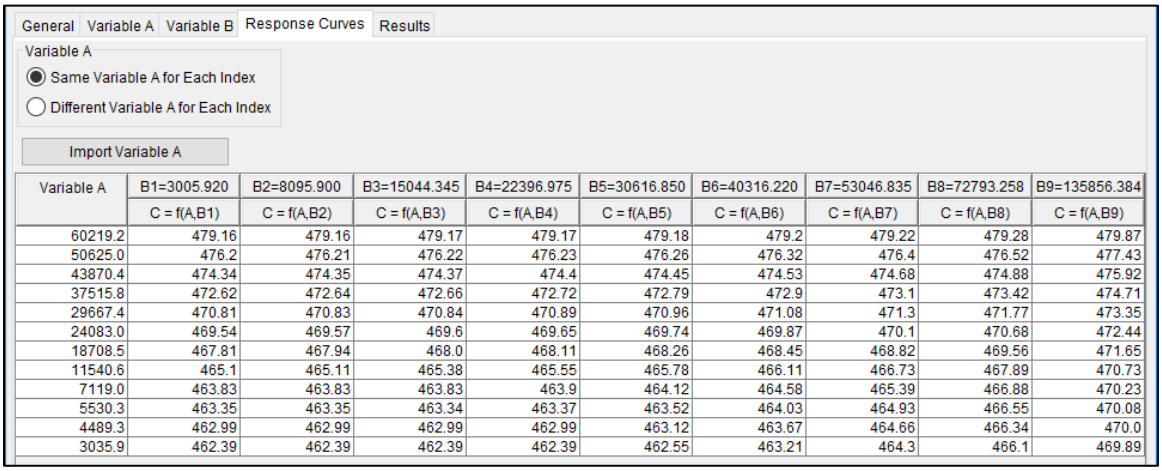
The Response Curves tab is used to define the response of variable C to each combination of variable A and variable B. This analysis is performed outside of HEC-SSP. For example, a hydraulics model could be used to apply flow values from the variable A frequency curve to the tributary and the index flow (or stage) from the variable B duration curve would be applied to the mainstem. The hydraulics model would be used to compute the variable C stage at some reference point on the tributary for multiple combinations of variable A and variable B. The peak variable C stage is the value to input into the Response Curves table.

As shown in Figure 9-9, there are two options for the Response Curves table; **Same Variable A for each index** or **Different Variable A for each index**. When the **Same Variable A for each index** option is selected, there is only one **Variable A** column in the response curves table. The user can manually fill in the values for Variable A or press the **Import Variable A** button. When the button is pressed, the program will import the values on the Variable A tab. The user can edit the Variable A values after they are imported. When the **Different Variable A for each index** option is selected, there is a separate **Variable A** column for each variable B index value, as shown in Figure 9-10. The user can manually fill in the values for Variable A or press the **Import Variable A** button. When the button is pressed, the program will import the values from the Variable A tab. The user can edit the Variable A values after they are imported. In most cases, the Different Variable A for each index options will be used when performing a conditional analysis (variables A and B can not be assumed independent). In this case, a separated variable A frequency

curve was defined for each variable B index value; therefore, when the **Import Variable A** button is pressed the program will import the corresponding frequency curve into the response curves table.

The user must compute the variable C value given the combinations of variables A and B. Figure 9-9 contains 12 values of variable A and 9 index values for variable B. Therefore, the user would have 108 combinations of variables A and B to compute values of variable C. Once computed, the user would manually enter the variable C values into the response curves table. For example, the first value in the first variable C column in Figure 9-9 is 481.38. This was computed using a variable A value of 66039 and a variable B value of 3005.92.

The **Plot Response Surface** button will open a plot similar to the one shown in Figure 9-11. Each line in the response surface plot shows the variable C versus variable A relationship for a given variable B index value.



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=135856.384
	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

Figure 9-9. Response Curves Tab for Same Variable A for Each Variable B Index.

General | Variable A | Variable B | Response Curves | Results

Variable A

Same Variable A for Each Index

Different Variable A for Each Index

Import Variable A

Variable A	B1=3005.920 C = f(A,B1)	Variable A	B2=8095.900 C = f(A,B2)	Variable A	B3=15044.345 C = f(A,B3)	Variable A	B4=22396.975 C = f(A,B4)
42464.0	473.95	49934.0	476.02	60221.0	479.17	63239.0	480.23
36167.0	472.28	42772.0	474.05	51234.0	476.39	53979.0	477.16
31681.0	471.24	37642.0	472.67	44837.0	474.63	47368.0	475.35
27412.0	470.33	32738.0	471.48	38757.0	472.99	41066.0	473.65
22063.0	468.96	26553.0	470.15	31147.0	471.16	33150.0	471.64
18193.0	467.64	22045.0	469.01	25649.0	469.97	27407.0	470.41
14404.0	466.22	17598.0	467.53	20274.0	468.51	21767.0	469.05
9214.0	464.39	11437.0	465.08	12928.0	465.93	14008.0	466.48
5894.0	463.46	7432.0	463.91	8244.0	464.14	9015.0	464.58
4666.0	463.05	5933.0	463.48	6516.0	463.66	7160.0	463.91
3848.0	462.74	4926.0	463.15	5366.0	463.3	5920.0	463.5
2680.0	462.22	3475.0	462.59	3728.0	462.69	4143.0	462.86

Figure 9-10. Response Curves Tab for Different Variable A for Each Variable B Index.

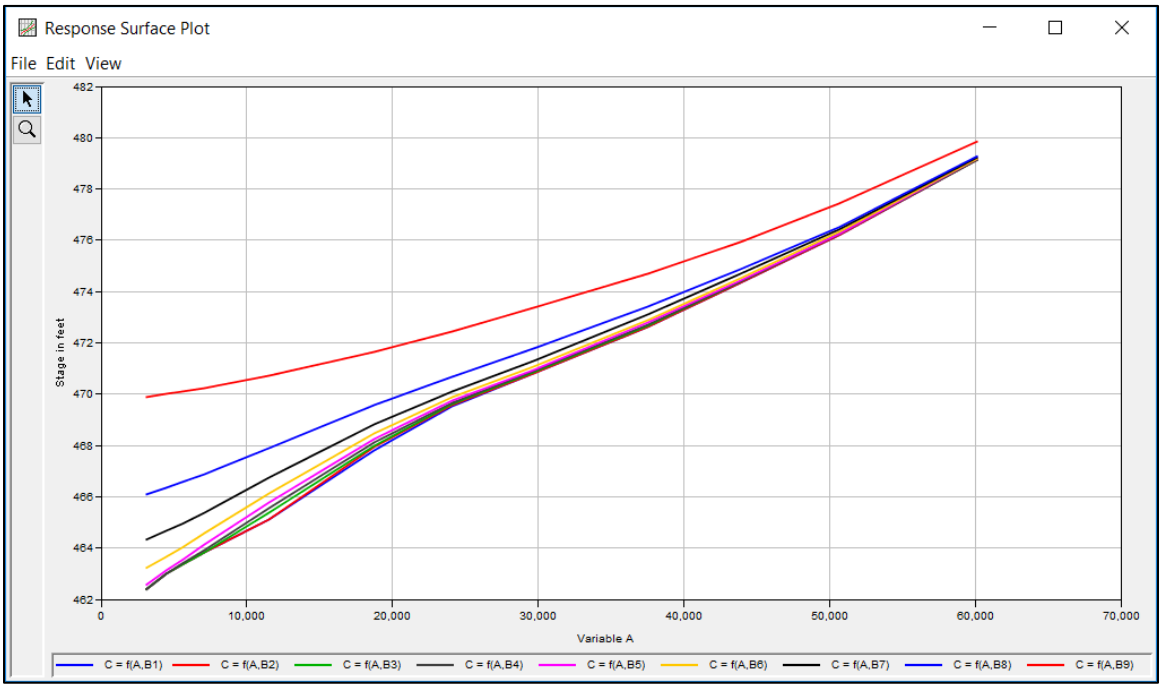


Figure 9-11. Plot of Response Curves.

Compute

Once the new analysis has been defined, and the user has all of the information defined on the General, Variable A, Variable B, Response Curves tabs, performing the computations is simply a matter of pressing the **Compute** button at the bottom of the Coincident Frequency Analysis editor. If the computations are successful, the user will receive a message that says "Compute Complete". At this point, the user can begin to review the results.

The following describes how the variable C coincident frequency curve is computed.

1) The program uses the variable A frequency curve(s) and the variable A values in the response curves table to assign a frequency of exceedance to each variable C value in the response curves table.

2) The program finds the minimum and maximum values of variable C in the response curves table.

3) The program defines 100 evenly spaced values of variable C in-between the minimum and maximum values (100 values include the minimum and maximum values).

4) For each variable C from step 3, the program will look-up the exceedance frequency value from each response curve in step 1 and multiply by the corresponding proportion of time (using the probability defined on the Variable B tab) obtained from the variable B index value. These "weighted" values from each response curve are summed to compute the variable C frequency curve.

5) The curve is interpolated to the selected exceedance ordinates defined on the General tab.

Multiple coincident frequency analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finishes computing the analyses.

Results

This section of the manual describes results that are available for the Coincident Frequency Analysis. When the user selects the **Results** tab on the Coincident Frequency Analysis editor, the window will appear as shown in Figure 9-12. Both tabular and graphical results are included. The percent chance exceedance ordinates are the same as those defined on

the General tab. In addition, the Data Name and Data Units defined on the General tab are used in the column header in the results table and the y-axis label in the plot.

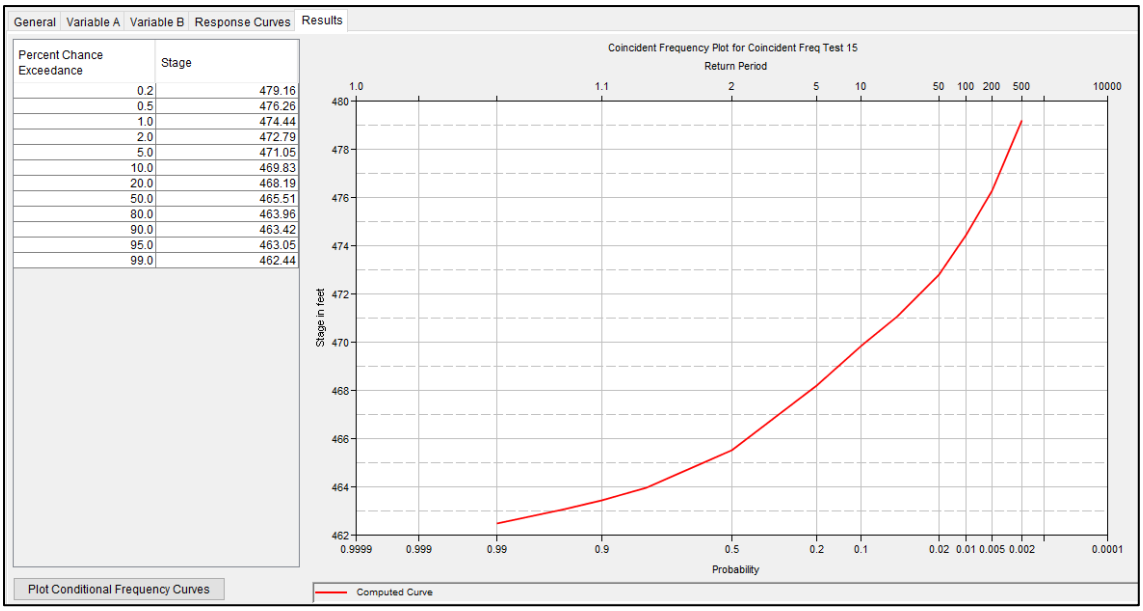


Figure 9-12. Results Tab of the Coincident Frequency Analysis Editor.

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.

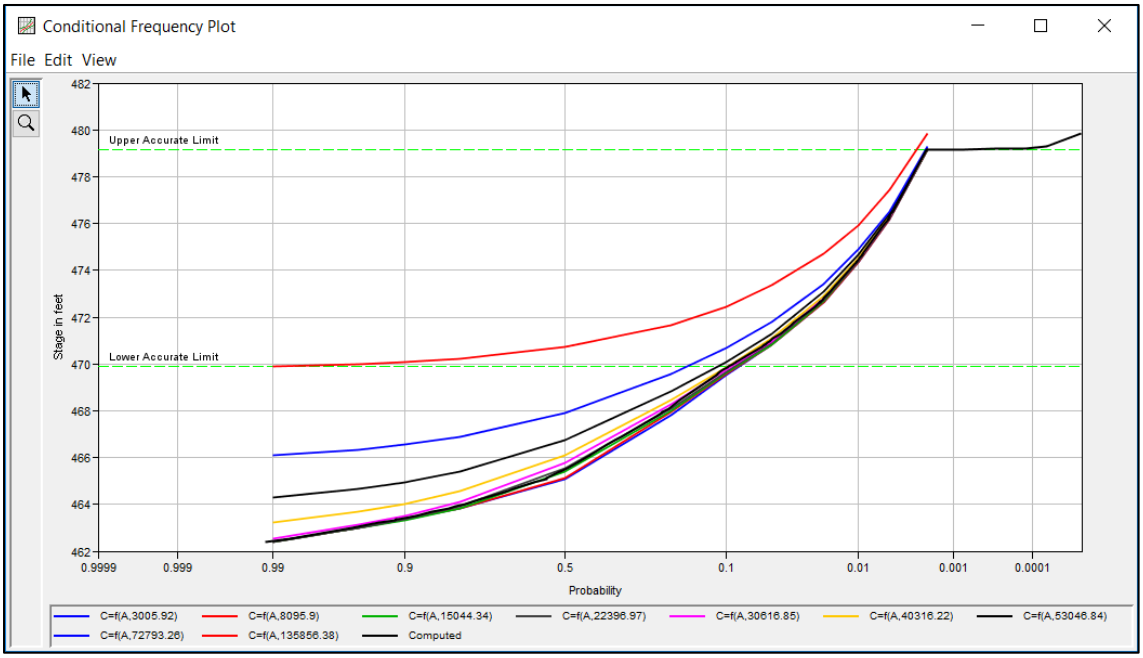


Figure 9-13. Plot of Conditional Frequency Curves.

Data in the frequency curve table can be re-sorted. Click the **Percent Chance Exceedance** column header (two mouse clicks are required the first time). The percent chance exceedance ordinates, along with frequency values, will sort so that the lowest values are on top or the highest values are on top.

Viewing and Printing Results

The user can view output for the coincident frequency analysis directly from the Coincident Frequency Analysis editor (tabular and graphical output) or by using the buttons at the bottom of the editor.

Tabular Output

Once the computations for the coincident frequency analysis are completed, the user can view tabular output by selecting the **Results** tab. The tabular results can be printed by using the **Print** button at the bottom of the coincident frequency analysis editor. When the print button is pressed, a window will appear giving the user options for how they would like the table to be printed. Result tables can also be created from the **Results** menu. At least one coincident frequency analysis must be selected in the study explorer before selecting the **Results→Table** option.

Graphical Output

Graphical output of the coincident frequency analysis can be obtained by selecting either the **Results** tab, or by pressing the **Plot** button at the bottom of the coincident frequency analysis editor. When the Plot button is pressed, a frequency curve plot will appear in a separate window as shown in Figure 9-14. Result graphs can also be created from the **Results** menu. At least one coincident frequency analysis must be selected in the study explorer before selecting the **Results→Graph** option. Results will be graphed in the same plot if multiple coincident frequency analyses are selected in the study explorer when opening a graph from the **Results** menu.

The coincident frequency curve plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu.

When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: windows metafile, postscript, JPEG, and portable network graphic.

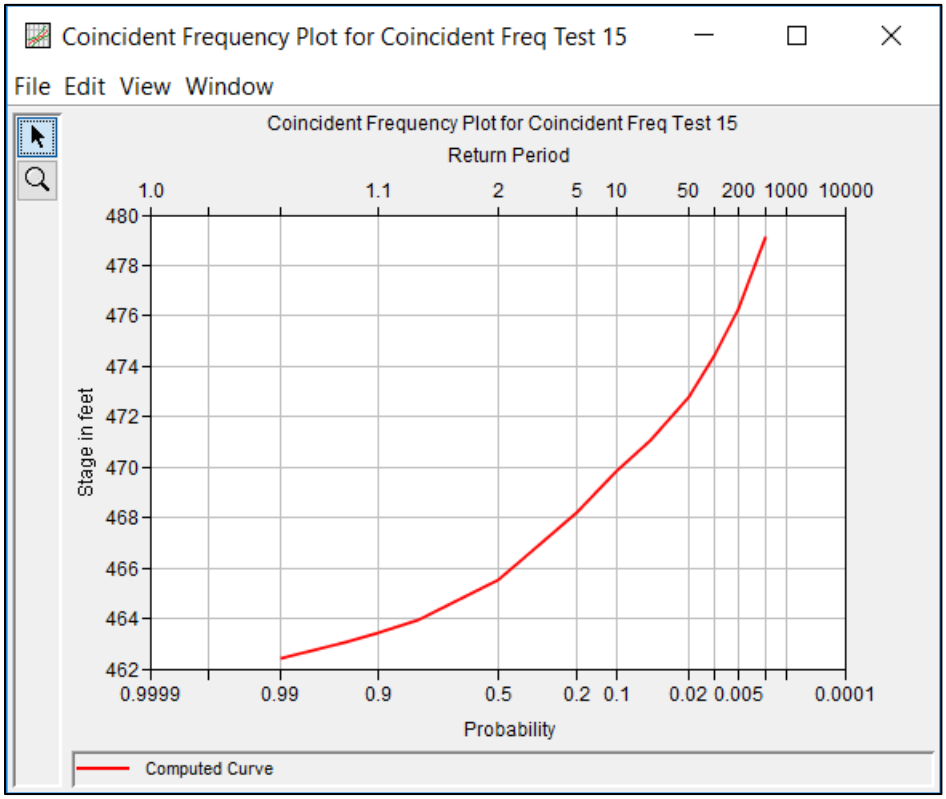


Figure 9-14. Coincident Frequency Analysis Plot.

The data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also

somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the coincident frequency analysis computations are performed. The report file lists the input data, user settings, and the final results. This file is often useful for understanding how the software arrived at the final frequency curve.

Press the **View Report** button at the bottom of the Coincident Frequency Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 9-15.

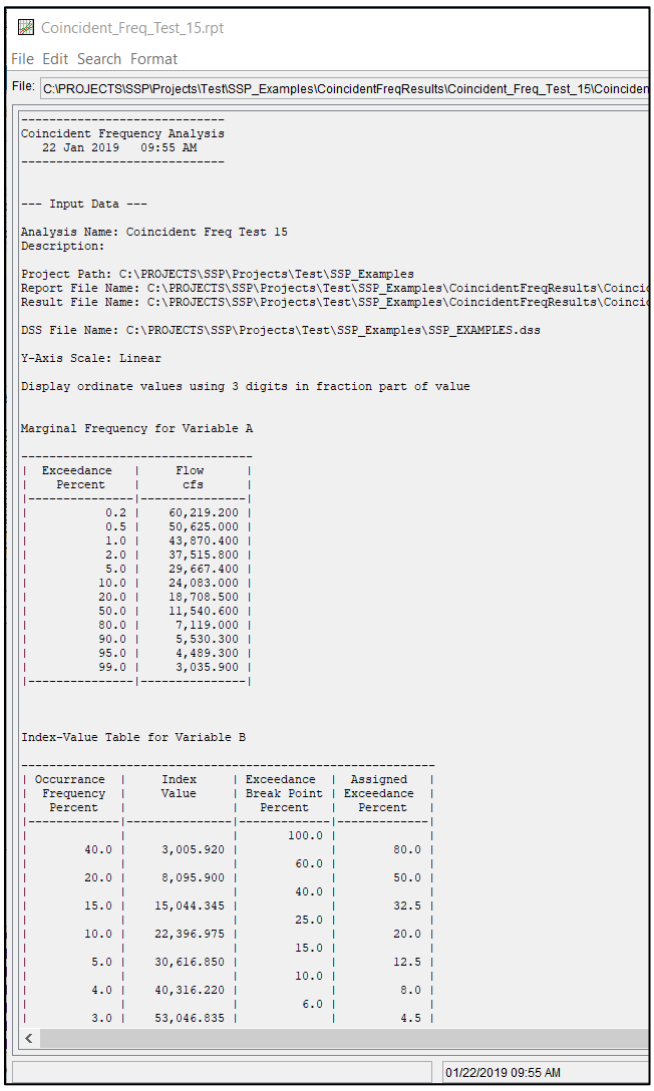


Figure 9-15. Coincident Frequency Analysis Report File.

CHAPTER 10

Performing a Curve Combination Analysis

This chapter discusses in detail how to use the Curve Combination Analysis editor in HEC-SSP. A curve combination analysis can be used to estimate a best fit frequency curve from multiple sources. Curve combination analyses can be used with nearly any type of data that can be stored within DSS. This includes flow, stage, precipitation depth, and wind speed data as well as other data types. Results from previously-computed Bulletin 17 and General Frequency analyses can be imported in a curve combination analysis. Also, frequency curves can be manually defined.

Contents

- Starting a New Analysis
- General Settings and Options
- Frequency Curves
- Graphical Tab
- Viewing and Printing Results

Starting a New Analysis

A curve combination analysis can be started in two ways, either by right clicking on the Curve Combination Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Curve Combination Analysis**. When a new Curve Combination Analysis is selected, the user is required to first enter a **Name** for the analysis and an optional **Description**. The Curve Combination Analysis editor will not allow further edits by the user until the name is defined. Once a Name is entered, the **DSS File Name** and **Report File** will automatically be filled out. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Curve Combination Analysis editor is shown in Figure 10-1.

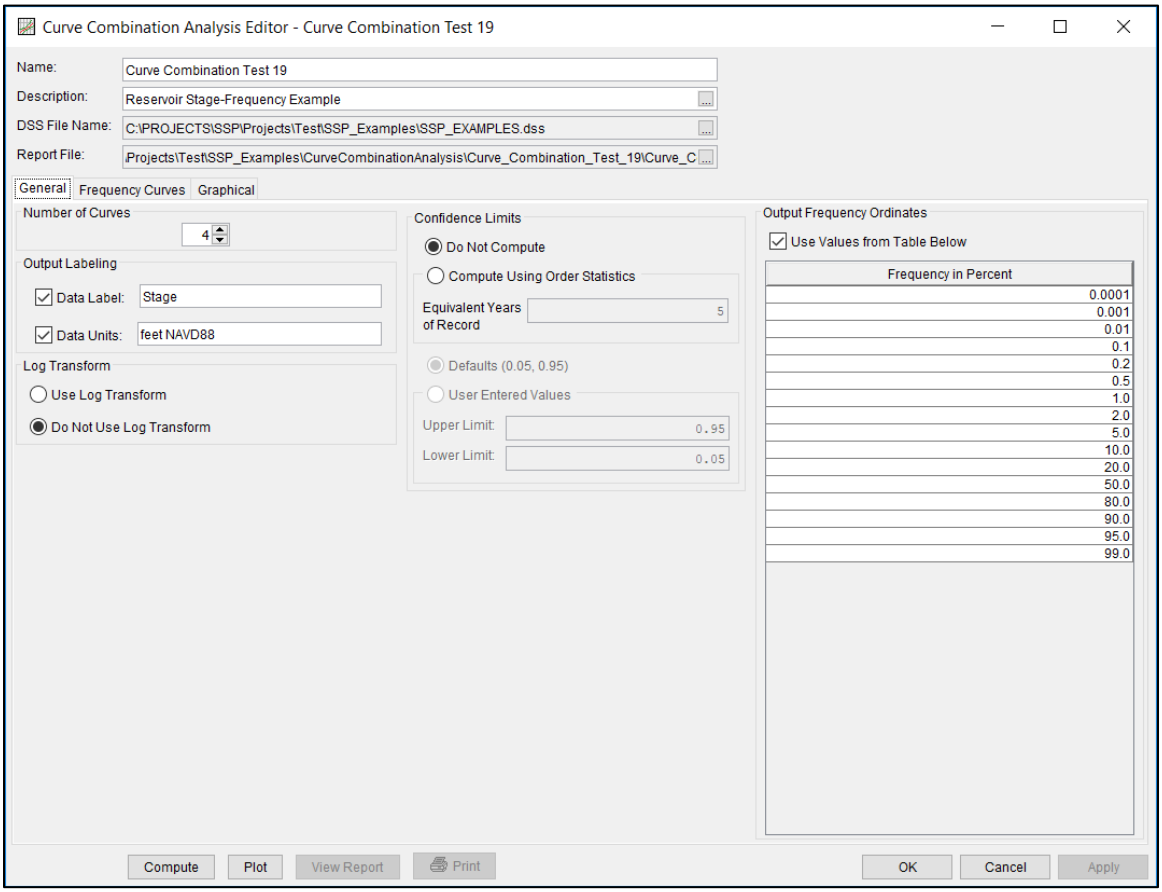


Figure 10-1. Curve Combination Analysis Editor.

General Settings

Once the analysis name has been entered, the user can begin defining the analysis. Contained on the Curve Combination Analysis editor are four

tabs. The tabs are labeled **General**, **Frequency Curves**, and **Graphical**. The first tab contains general settings for performing the curve combination analysis (Figure 10-2). These settings include:

- Number of Curves
- Output Labeling
- Log Transform
- Confidence Limits
- Output Frequency Ordinates

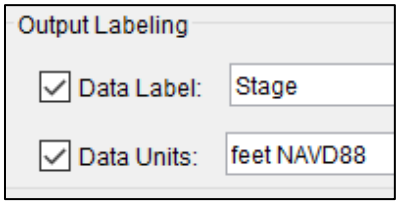
Number of Curves

This option lets the user choose the number of frequency curves to combine. The Frequency Curves tab will update based on the number of curves.

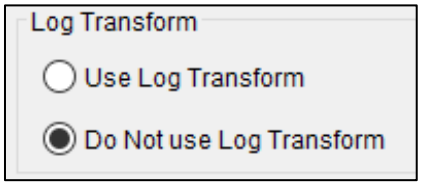


Output Labeling

This option allows the user to enter labels for data contained in the output tables and plots. The user must enter the name of the data as well as the data units. The output labeling does not result in the conversion of data from one unit system to another; it only affects what is displayed on table headings and the y-axis of the results plot.

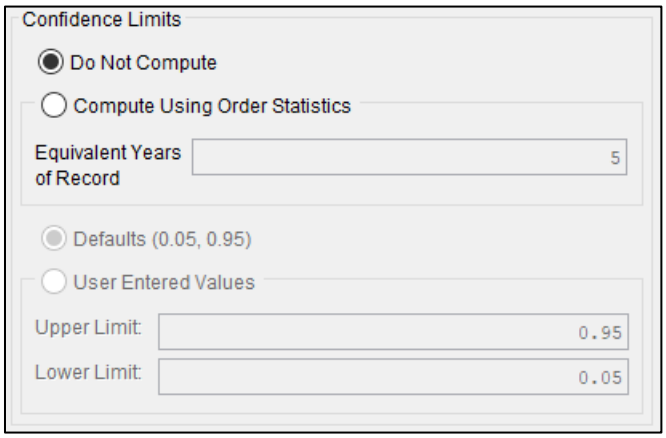


Log Transform



There are two options contained within the **Log Transform** setting: **Use Log Transform** and **Do not use Log Transform**. This setting only affects the y-axis of subsequent plots. If the user selects **Use Log Transform**, the y-axis of all plots will use a logarithmic scale (base 10). If the user selects **Do Not Use Log Transform**, the y-axis of all plots will use a linear scale. This option does not affect any of the computations. The default setting is **Do Not Use Log Transform**.

Confidence Limits



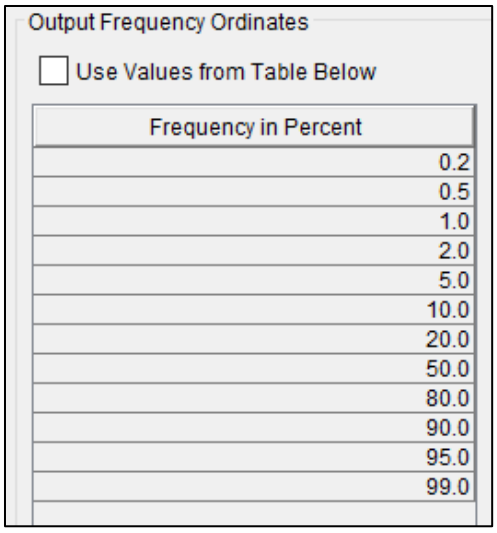
The computed frequency curve is only an estimate of the probability distribution of the larger parent population. Confidence limits can be used to provide a measure of the uncertainty of the estimated exceedance probability of a selected discharge, stage, precipitation depth, etc or a measure of the uncertainty of the discharge, stage, precipitation depth, etc at a selected exceedance probability.

By default, confidence limits will not be computed within a Curve Combination Analysis. However, the user has the option to compute confidence limits using the order statistics method, which is discussed in ETL 1110-2-537. The **Equivalent Years of Record** must be defined when using this method.

When computing confidence limits, the default interval will be 90 percent confidence (i.e. the 5% and 95% confidence limits). The confidence limits must be entered in decimal form (i.e. 95% = 0.95, and 5% = 0.05). The user has the option to override the default values and enter whatever values they would like for the confidence limits.

Output Frequency Ordinates

This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse



over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.

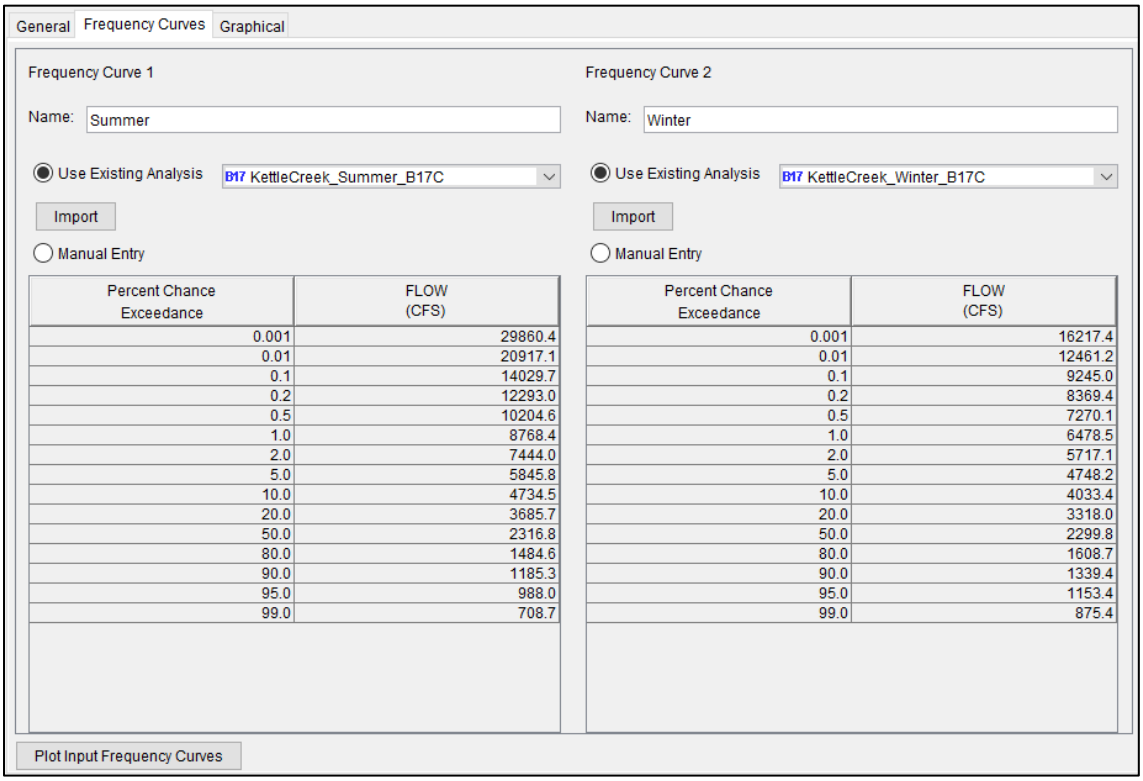
Frequency Curves

The Frequency Curves tab is used to define the frequency curves used within the analysis. As shown in Figure 10-3, the Frequency Curves tab contains a panel for each frequency curve; the number of frequency curves is defined on the General tab.

The user has the option to enter the frequency curve manually or to import the results of an existing Bulletin 17 or General Frequency Analysis. If **Use Existing Analysis** is selected, an existing analysis is designated, and the **Import** button is clicked, the program will import the resultant frequency curve to populate the table. The program will NOT import the statistics from the selected analysis. If the selected Bulletin 17 or General Frequency Analysis is modified or recomputed after being imported, a red warning message will be shown near the top of the editor informing the user that the imported results are out of date. Also, the Import button will highlighted red. Upon clicking the Import button, the table will be updated, the message will disappear, and the button highlighting will be removed. When importing the results from an existing analysis, the frequency curve ordinates in the **Percent Chance Exceedance** columns will be the same as those in the Bulletin 17 or General Frequency Analysis.

If **Manual Entry** is selected, the frequency curve table will become interactive and editable. Initially, the **Percent Chance Exceedance** column will be populated with the Output Frequency ordinates which were specified on the General tab. The user may add/remove/modify these ordinates.

The Plot Input Frequency Curves button will open a graph showing all frequency curves defined on the frequency curves tab, as show in Figure 10-4.



Percent Chance Exceedance	FLOW (CFS)
0.001	29860.4
0.01	20917.1
0.1	14029.7
0.2	12293.0
0.5	10204.6
1.0	8768.4
2.0	7444.0
5.0	5845.8
10.0	4734.5
20.0	3685.7
50.0	2316.8
80.0	1484.6
90.0	1185.3
95.0	988.0
99.0	708.7

Percent Chance Exceedance	FLOW (CFS)
0.001	16217.4
0.01	12461.2
0.1	9245.0
0.2	8369.4
0.5	7270.1
1.0	6478.5
2.0	5717.1
5.0	4748.2
10.0	4033.4
20.0	3318.0
50.0	2299.8
80.0	1608.7
90.0	1339.4
95.0	1153.4
99.0	875.4

Figure 10-2. Curve Combination Analysis Frequency Curves Tab.

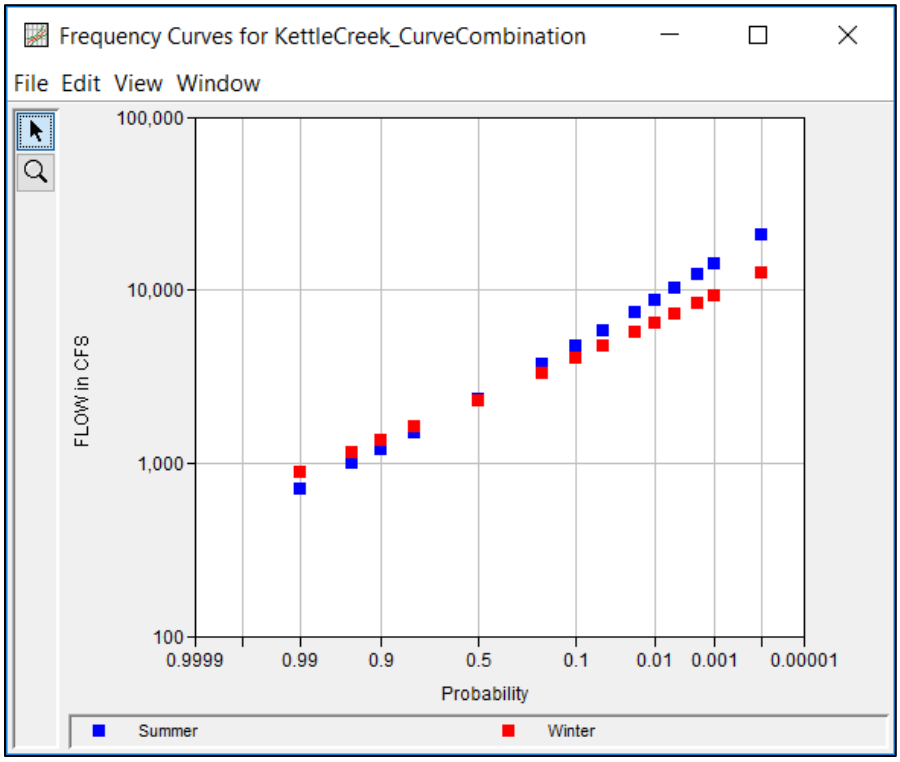


Figure 10-3. Plot of Frequency Curves Defined on the Frequency Curves Tab.

Graphical Tab

Within the Curve Combination Analysis, the user must define the best fit curve graphically. When the **Graphical** tab is selected, the editor will display a plot and table as shown in Figure 10-4. A minimum of three points are required to define a graphical frequency curve. In the plot, the frequency curves defined on the Frequency Curves tab will be plotted. The table to the right of the plot allows the user to manually enter data values for the frequency ordinates defined on the General tab.



Additionally, the **Multi-Point Edit** tool can be used to define the frequency ordinates by drawing a curve. To use this tool, begin by selecting the tool on the left side of the editor. Then, define the curve by left clicking within the plot window at the desired locations. To finish defining the curve, right click. It should be noted that the Multi-Point Edit tool will not extrapolate frequency information; it will only interpolate to the user-defined frequency ordinates specified on the General tab. Bold, dashed lines will be displayed on the plot that correspond to the output frequency ordinates defined on the General tab. These vertical lines help to visually identify the locations where frequency information will be extracted from the drawn curve.

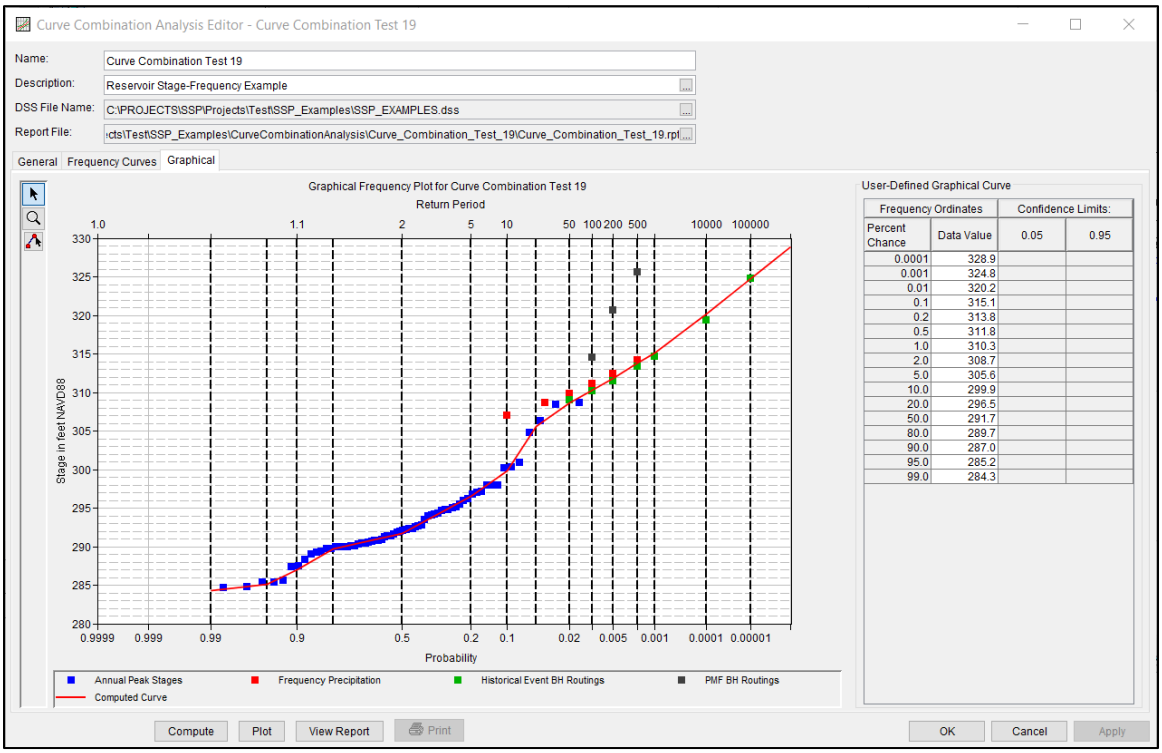


Figure 10-4. Curve Combination Analysis Graphical Tab.

Compute

Once the new analysis has been defined, and the user has all of the information defined on the General, Frequency Curves, Graphical tabs, performing the computation is simply a matter of pressing the **Compute** button at the bottom of the Curve Combination Analysis editor. If the computations are successful, the user will receive a message that says "Compute Complete". At this point, the user can begin to review the results.

Multiple curve combination analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finished computing the analyses.

Results

This section describes results that are available for the Curve Combination Analysis. When the user selects the **Results** tab on the Curve Combination Analysis editor, the window will appear as shown in Figure 11-4. Both tabular and graphical results are included. The frequency ordinates for the output are the same as those that were defined on the General tab. In addition, when the Output Labeling options are defined on the General tab, they will be used in the y-axis label in the plot.

Viewing and Printing Results

The user can view output for the curve combination analysis directly from the Curve Combination Analysis editor on the Graphical tab or by using the buttons at the bottom of the editor.

Tabular Output

Once the computations for the curve combination analysis are completed, the user can view tabular output on the **Graphical** tab, as shown in Figure 10-5.

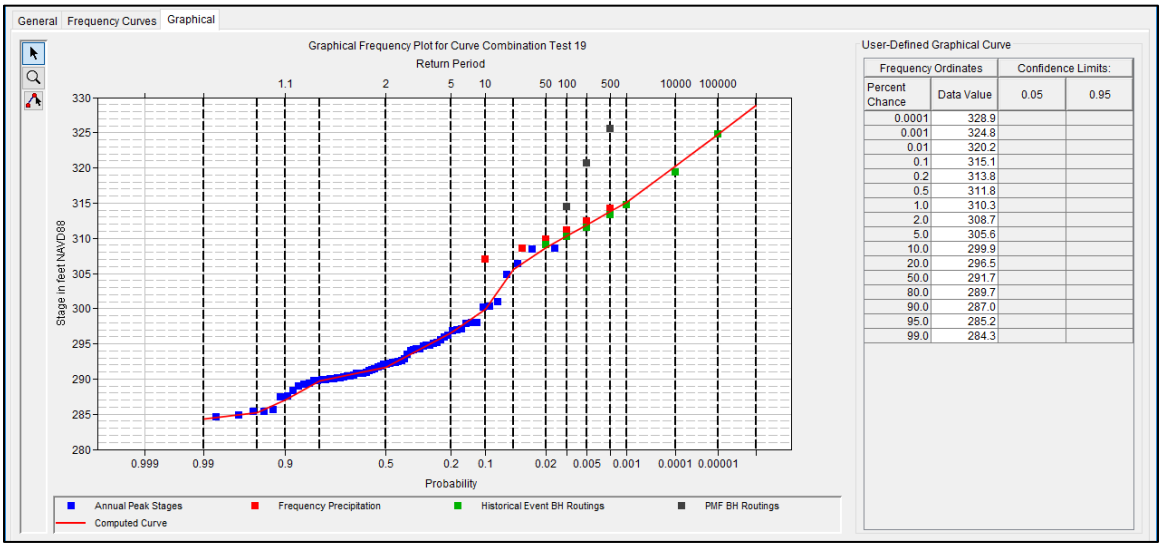


Figure 10-5. Curve Combination Analysis Tabular Results.

Graphical Output

Graphical output of the curve combination analysis can be obtained by double clicking on the plot within the Graphical tab or by pressing the **Plot** button at the bottom of the curve combination analysis editor. When the Plot button is pressed, a frequency curve plot will appear in a separate window as shown in Figure 10-6. Result graphs can also be created from the **Results** menu. At least one curve combination analysis must be selected in the study explorer before selecting the **Results→Graph** option. Results will be graphed in the same plot if multiple curve combination analyses are selected in the study explorer when opening a graph from the **Results** menu.

The curve combination frequency curve plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: windows metafile, postscript, JPEG, and portable network graphic.

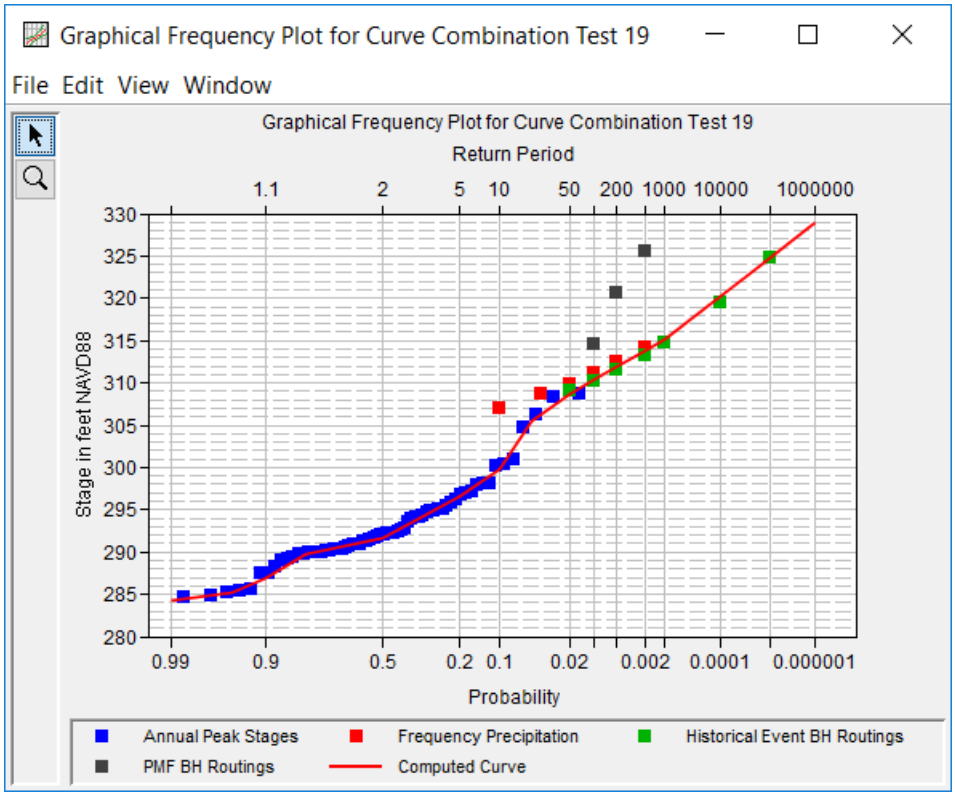


Figure 10-6. Curve Combination Analysis Plot.

The data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the curve combination analysis computations are performed. The report file lists the input data, user settings, and the final results. Press the **View Report** button at the bottom of the Curve Combination Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 10-7.

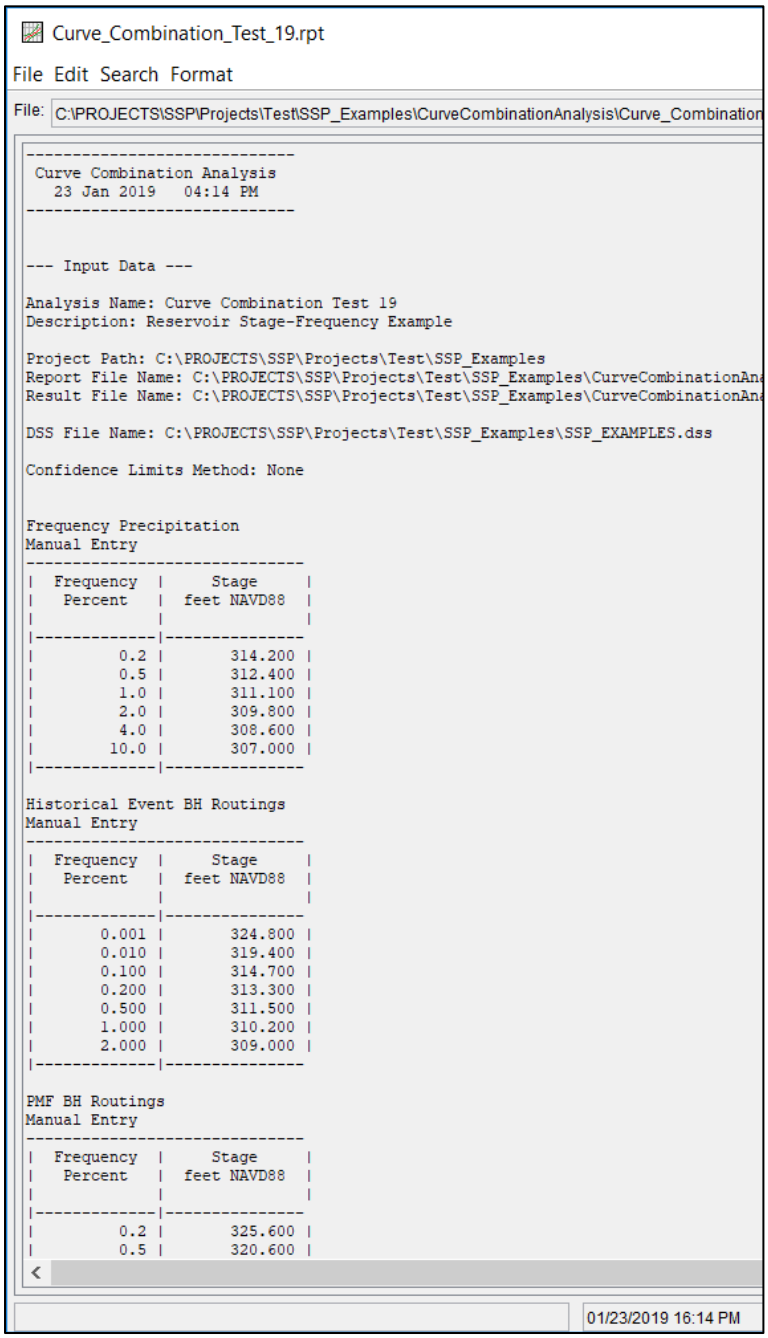


Figure 10-7. Curve Combination Analysis Report File

CHAPTER 11

Performing a Balanced Hydrograph Analysis

The current version of HEC-SSP allows the user to compute balanced hydrographs. In this type of analysis, observed data, flow, and volume-frequency curves are used to create a hypothetical hydrograph that "balances" flow rates, volumes, and frequency. Within a balanced hydrograph, the flow and/or volume across multiple durations satisfies the relation between flow/volume and duration for a given frequency. For example, a 5-day 0.2 percent annual chance exceedance (ACE) balanced hydrograph would have individual hydrograph ordinates arranged in such a way that the flow volumes for the 1-hr, 1-day, …, 5-day durations would each equal the 0.2 percent ACE flow rates and/or volumes. Although such hydrographs do not necessarily preserve the random character of natural hydrographs, use of balanced hydrographs ensures an appropriate flow rate and/or volume (in terms of frequency), regardless of the characteristics of a particular watershed or location. This chapter discusses in detail how to use the Balanced Hydrograph Analysis editor within HEC-SSP.

Contents

- Starting a New Analysis
- General Settings
- Frequency Curves
- Viewing and Printing Results

Starting a New Analysis

A balanced hydrograph analysis can be started in two ways, either by right clicking on the Balanced Hydrograph Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Balanced Hydrograph Analysis**. When a new Balanced Hydrograph Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select a data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The Balanced Hydrograph Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a balanced hydrograph analysis will only include those data that have a regular interval, like 15MIN, 1HOUR, or 1DAY (E-Part pathname). This data set could be comprised of daily measurements or those of a shorter duration. Generally speaking, shorter duration datasets (such as 1HOUR or 15MIN) should be used in lieu of daily durations. Once a Name is entered, the **DSS File Name** and **Report File** will automatically be filled out. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Balanced Hydrograph Analysis Editor is shown in Figure 11-1.

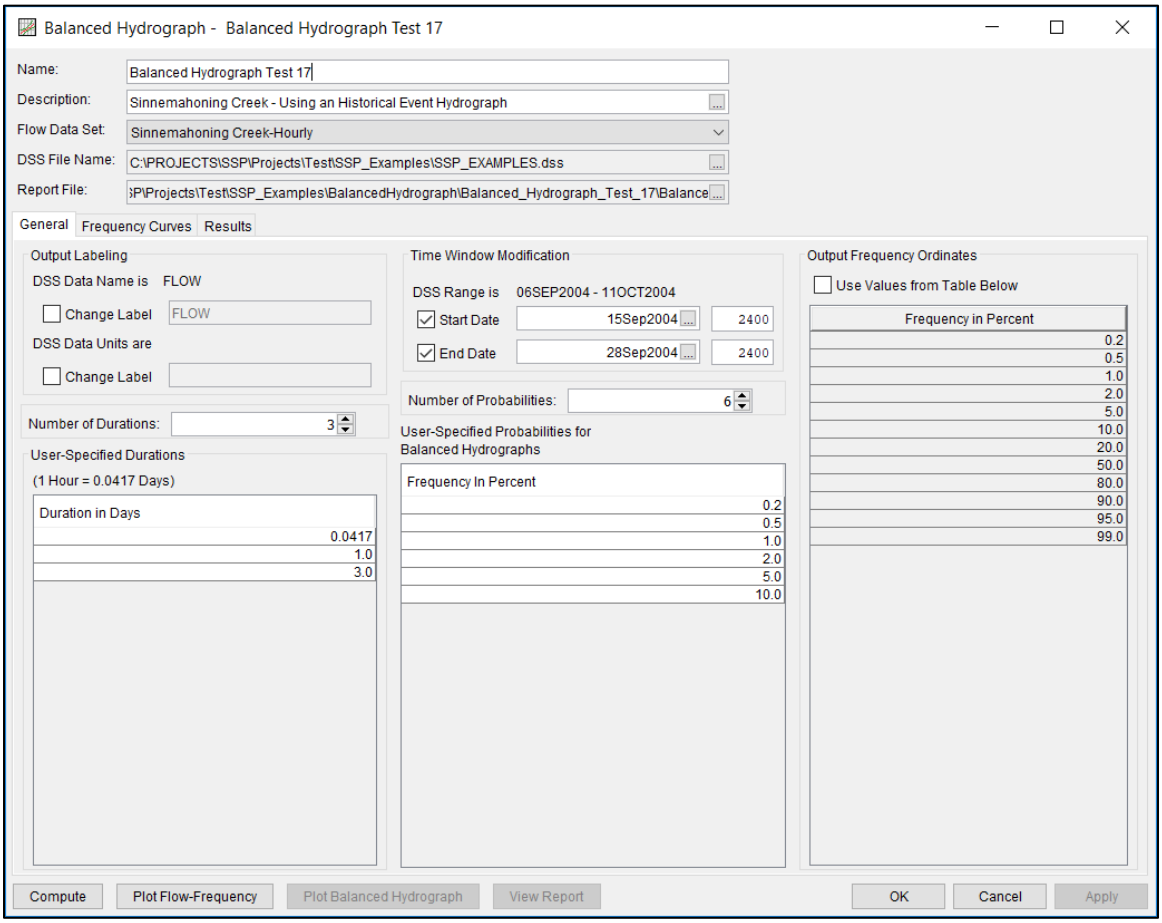


Figure 11-1. Balanced Hydrograph Analysis Editor.

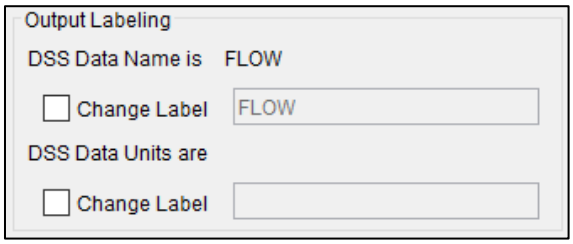
General Settings

Once the analysis name has been entered, the user can begin defining the analysis. Contained on the Balanced Hydrograph Analysis editor are three tabs. The tabs are labeled **General**, **Frequency Curves**, and **Results**. The first tab contains general settings for performing the balanced hydrograph analysis (Figure 11-1). These settings include:

- Output Labeling
- Number of Durations
- User-Specified Durations
- Time Window Modification
- Number of Probabilities
- User-Specified Probabilities for Balanced Hydrographs
- Output Frequency Ordinates

Output Labeling

This option allows the user to change the default labels for data contained in the output tables and plots. The user can change both the name of the data as well as the units of the data. The output labeling does not result in the conversion of data from one unit system to another; it only affects what is displayed on table headings and the y-axis of the results plot.



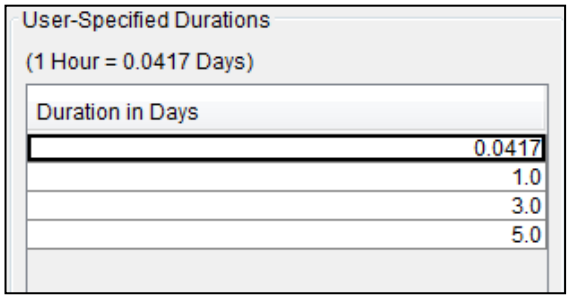
Number of Durations

This option allows the user to set the number of frequency curve durations that will be used to construct the balanced hydrographs. The number entered will modify the number of rows contained within the User-Specified Durations. Typically, balanced hydrographs are constructed using more than one duration. However, as the number of durations is increased, the resulting hydrographs will preserve less of the random character of natural hydrographs. At a minimum, the number of durations must be set equal to one.



User-Specified Durations

The **User-Specified Durations** table automatically adjusts the number of rows based on the defined number of durations. After the user sets the number of durations, the user must input the durations for which the balanced hydrographs will be created. The program will arrange hydrograph ordinates to "balance" the flow-durations (i.e. volumes) using the durations defined within this table. Note that the units for each duration is days. For example, a one hour duration is equivalent to 0.0417 days.

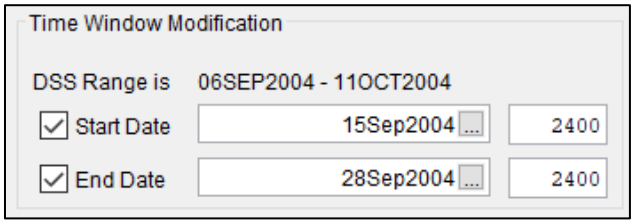


There are no default durations. A typical listing of durations includes both shorter and longer durations. Durations should be listed in descending

order with shorter durations listed first followed by longer durations. The smallest duration should be equal to or greater than the time step of the input flow data set. For example, a 1DAY flow data set cannot be used in conjunction with a specified duration of 0.0417 days.

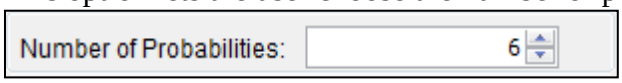
Time Window Modification

This option allows the user to define a time window used for the analysis. The time window should correspond to the period within the Flow Data Set that the user wishes to use as a "template" hydrograph shape. The default is to use all of the data contained within the selected data set. If the default time window is used, HEC-SSP will identify the event with the greatest peak flow rate within the selected flow data set and use that as the "template" hydrograph shape. If a start and/or end date are used, they must be dates that are contained within the data stored in the selected data set. The date range for the selected data set is shown in the editor just above the **Start Date** field. Finally, if missing values are found within the Flow Data Set between the start/end date, an error message will be shown informing the user than either the time window needs to be changed or the missing values must be estimated.



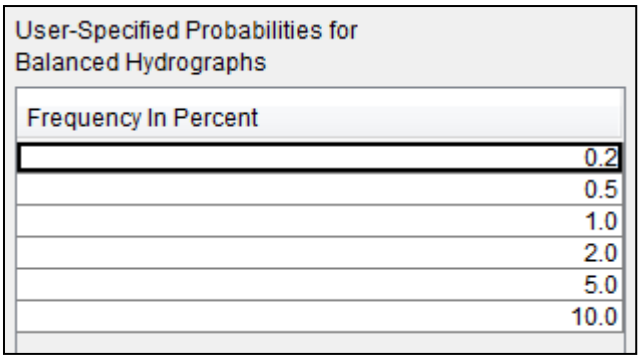
Number of Probabilities

This option lets the user choose the number of probabilities that will be used to construct the balanced hydrographs. The default setting is "1" probability. Using the default will result in the creation of a single balanced hydrograph.

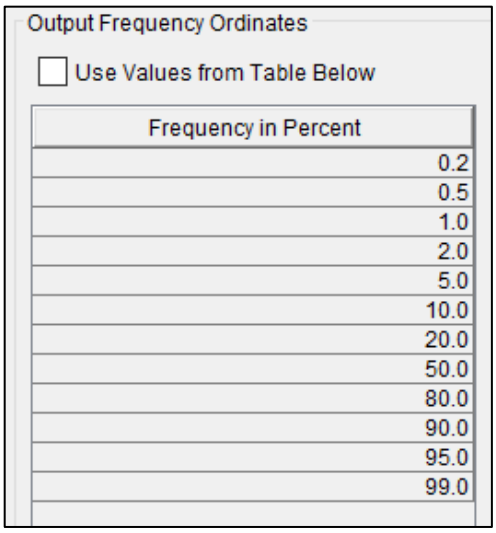


User-Specified Probabilities for Balanced Hydrographs

The **User-Specified Probabilities** table automatically adjusts the number of rows based on the defined number of probabilities. After the user sets the number of probabilities, the user must input the probabilities for the balanced hydrograph analysis. This listing should be entered in ascending order (i.e. 0.2, 0.5, 1.0, etc). The input listing cannot use frequencies outside of the Output Frequency Ordinates. The input frequencies should have units of percent.



Output Frequency Ordinates



This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed results, but rather only the values of the frequency curves that are used within the balanced hydrograph analysis.

Frequency Curves

The Frequency Curves tab is used to define the flow- and/or volume-frequency curves for each of the User-Specified Durations. As shown in Figure 11-2, the Frequency Curves tab contains a panel for each frequency curve; the number of frequency curves is defined on the General tab. Three options are available to define these flow-frequency curves. First, the user can select an existing Bulletin 17, General Frequency, or Volume Frequency Analysis and import the results of said analysis. Second, the user can input the flow-frequency information for *all* of the frequency ordinates. Third, the user can select either Log Normal (base 10), Generalized Extreme Values, or the Log Pearson III analytical distribution, define their required inputs, and compute the resultant flow-frequency relationship. Users can use one or more forms of input within any balanced hydrograph analysis.

If **Use Existing Analysis** is selected, an existing analysis is designated, and the **Import** button is clicked, the program will import the resultant frequency curve to populate the table. The program will NOT import the statistics from the selected analysis. If the selected Bulletin 17, General Frequency, or Volume Frequency Analysis is modified or recomputed after being imported, a red warning message will be shown near the top of the editor informing the user that the imported results are out of date. Also, the Import button will be highlighted red. Upon clicking the Import button, the table will be updated, the message will disappear, and the button highlighting will be removed. When importing the results from an existing analysis, the frequency curve ordinates in the **Percent Chance Exceedance** columns will be the same as those in the Bulletin 17, General Frequency, or Volume Frequency Analysis, which may or may not match the Output Frequency ordinates for the Balanced Hydrograph Analysis which were defined on the General tab.

When importing from a Volume Frequency Analysis, the program will automatically search for the corresponding duration before importing any frequency curves. For instance, if a Volume Frequency Analysis is computed to provide frequency curves for the 1-, 2-, 3-, 5-, and 10-day durations and selected within a Balanced Hydrograph Analysis that has user-specified durations that include the 1- and 3-day duration, the program will automatically import the results for the correct duration(s). If the selected Volume Frequency Analysis does not contain the necessary duration information, a message will be shown informing the user of the error.

If **Manual Entry** is selected, the frequency curve table will become interactive and editable. Initially, the **Percent Chance Exceedance**

column will be populated with the Output Frequency ordinates which were specified on the General tab. The user may add/remove/modify these ordinates. However, if the program cannot find one or more probability ordinates (which were entered on the General tab), the compute will attempt to interpolate the required information. However, the program will not extrapolate. If the required information has not been adequately defined, a warning message will be shown informing the user of the problem.

If **Analytical Distribution** is selected, the drop down menu will become interactive and allow the user to select one of three analytical distributions: Log Normal (base 10), Generalized Extreme Values, or Log Pearson III. The required inputs must then be entered and the Compute button (located immediately above the frequency curve table) pressed to fill out the frequency curve table. The **Percent Chance Exceedance** column will be populated with the Output Frequency ordinates which were specified on the General tab. The user cannot add, remove, or modify these ordinates except through changes to the General tab.

Clicking the **Plot Flow-Frequency** button will open a graph showing all of the flow-frequency curves defined on the frequency curves tab, as show in Figure 11-3.

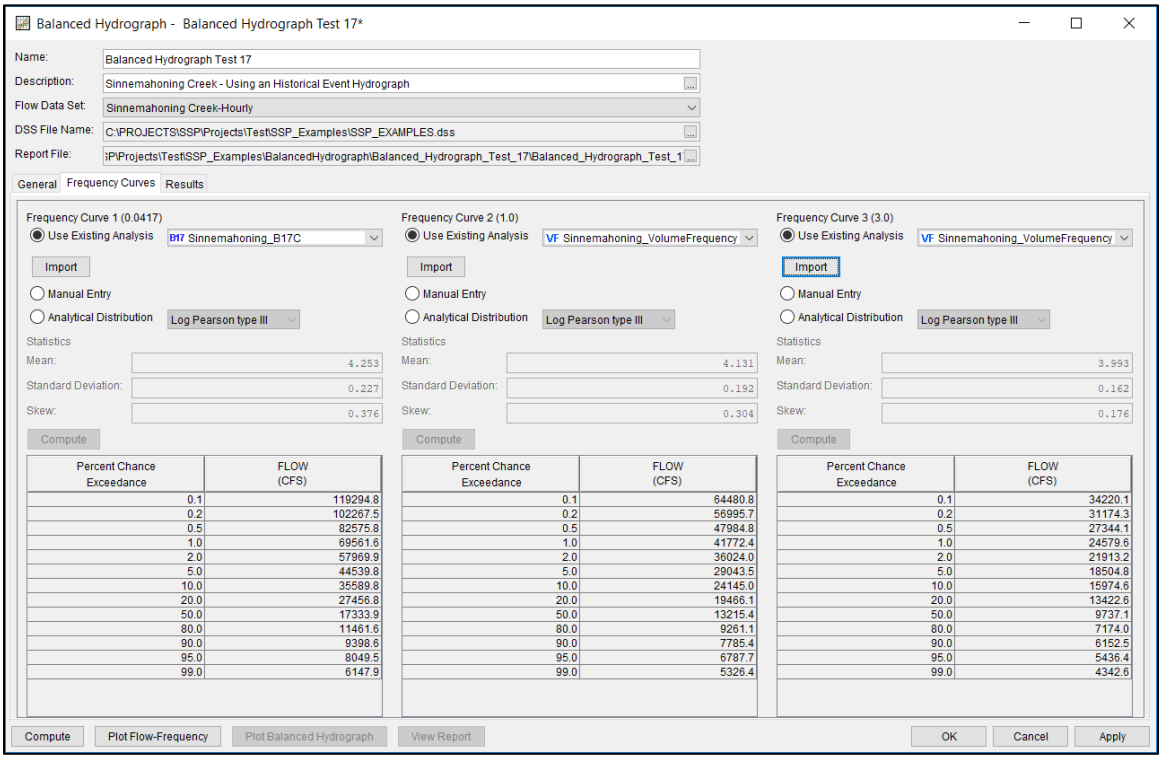


Figure 11-2. Balanced Hydrograph Analysis Frequency Curves Tab.

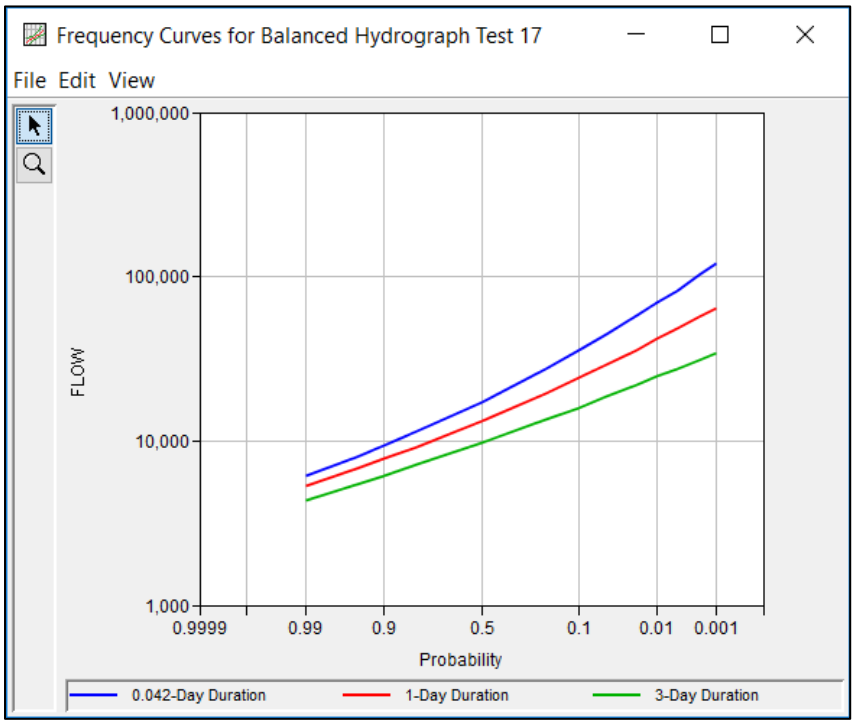


Figure 11-3. Plot of Frequency Curves Defined in the Frequency Curves Tab.

Compute

Press the **Compute** button, located at the bottom of the Balanced Hydrograph Analysis editor, once options have been set on the General tab and the required input has been entered on the Frequency Curves tabs. If the compute is successful, the user will receive a message that says **Compute Complete**. At this point, the user can begin to review the results.

Multiple Balanced Hydrograph analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finishes computing the analyses.

Results

This section describes results that are available for the Balanced Hydrograph Analysis. When the user selects the **Results** tab on the Balanced Hydrograph Analysis editor, the window will appear as shown

in Figure 11-4. Both tabular and graphical results are included. The durations and probabilities for the balanced hydrographs are the same as those defined on the General tab. In addition, when the Output Labeling options are defined on the General tab, they will be used in the y-axis label in the plot.

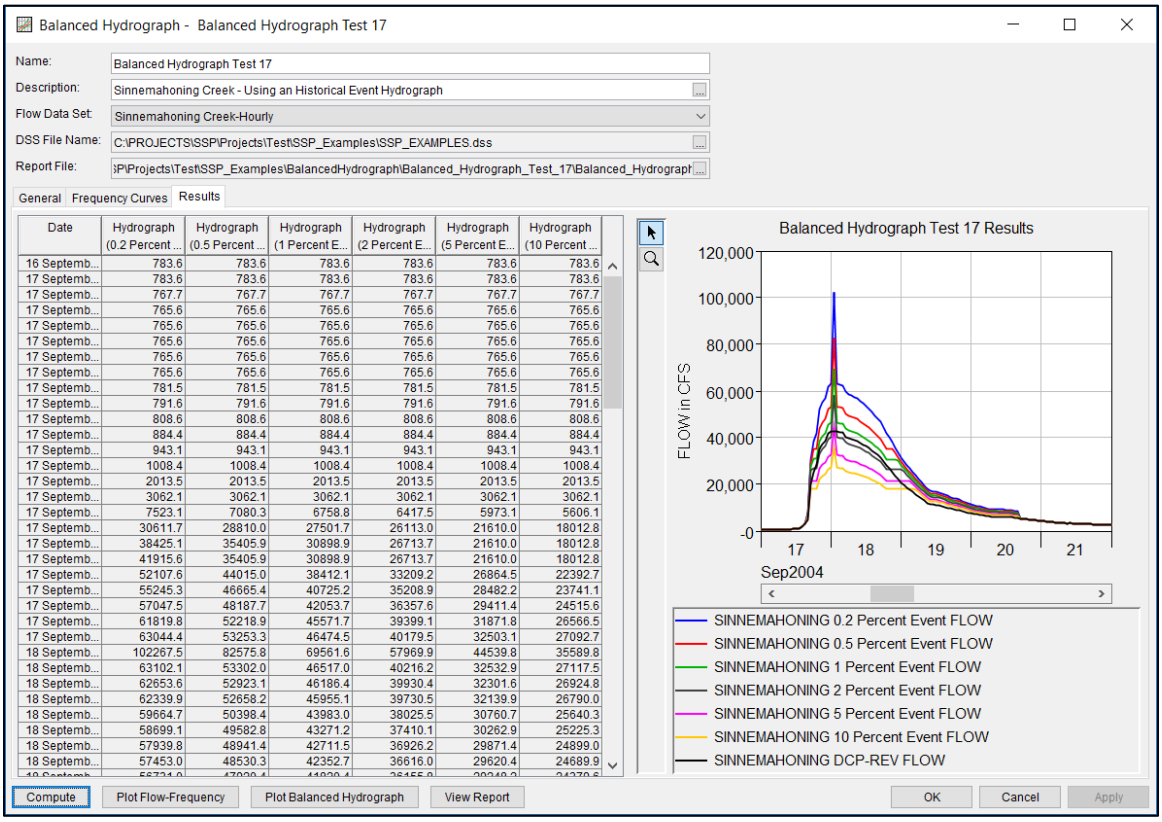


Figure 11-4. Results Tab of the Balanced Hydrograph Analysis Editor.

Viewing and Printing Results

The user can view the output for the balanced hydrograph analysis directly from the Balanced Hydrograph Analysis editor (tabular and graphical output) or by using the buttons at the bottom of the editor.

Tabular Output

Once the computations for the balanced hydrograph analysis are completed, the user can view the tabular output by selecting the **Results** tab. Tabular results can be opened after clicking the **Plot Balanced Hydrograph** button and selecting **File→Tabulate** or by double clicking on the balanced hydrograph plot in the **Results** tab and in the opened plot

selecting **File→Tabulate**. The balanced hydrograph table can also be printed once opened in a new window using the **File→Print** option. An additional printing option available from the File menu is Print Preview. The table can also be exported by selecting **Export…** from the File menu. When the Export option is selected, a window will appear allowing the user to select the Field Delimiter and additional Table Export Options. Currently five field delimiter formats are available for exporting the table: **TAB**, **SPACE**, **COMMA**, **COLON** and **SEMI-COLON**.

Graphical Output

Graphical output of the balanced hydrograph analysis can be obtained by selecting either the **Results** tab, or by pressing the **Plot Balanced Hydrograph** button at the bottom of the balanced hydrograph analysis editor. When the Plot Balanced Hydrograph button is pressed, a balanced hydrograph plot will appear in a separate window as shown in Figure 11-5. The example balanced hydrograph plot in Figure 11-5 was created after modifying the Time-Window (in the **General** tab). The user can modify the Time-Window to obtain balanced hydrographs for a specific maximum peak in the dataset.

The balanced hydrograph plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: **windows metafile**, **postscript**, **JPEG**, and **portable network graphic**.

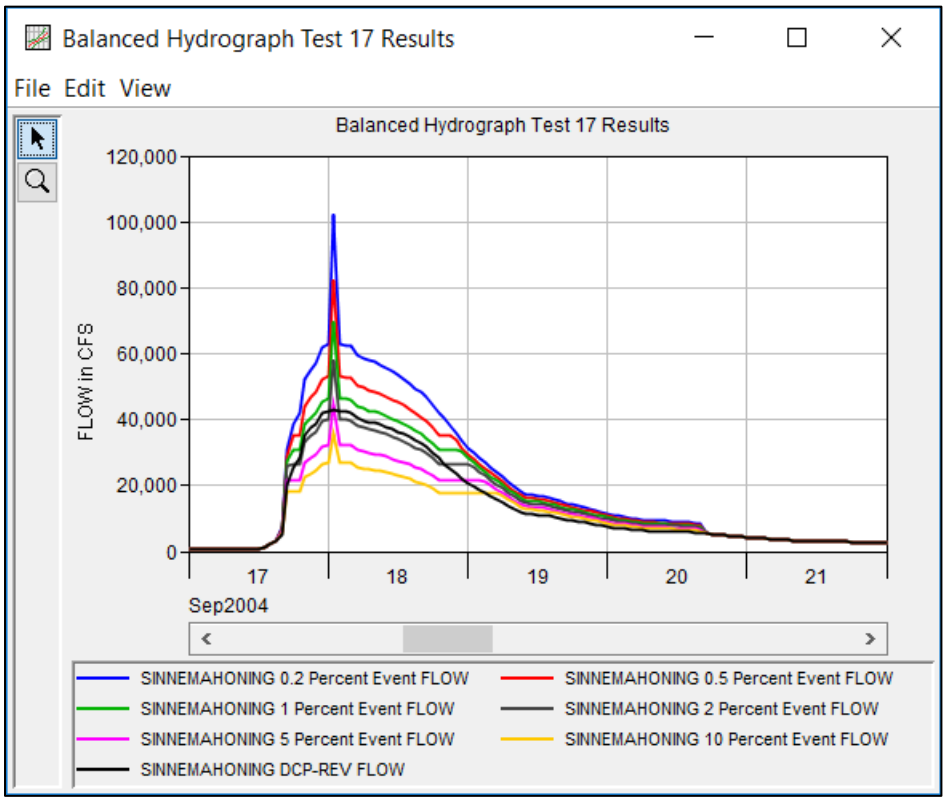


Figure 11-5. Balanced Hydrograph Analysis Plot.

As explained previously, the data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. Also, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue

and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the balanced hydrograph analysis computations are performed. The report file lists the input data, user settings, and the final results. This file is often useful for understanding how the software arrived at the balanced hydrograph.

Press the **View Report** button at the bottom of the Balanced Hydrograph Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 11-6.

The computations that were used to create the balanced hydrographs are contained within the **Report** output. Specifically, the base, required, and final flow-duration values are detailed along with the percent error for each duration and frequency. Additionally, the balanced hydrograph report can be opened using the **Results→Report** option in the Results dropdown menu at the top of the SSP window.

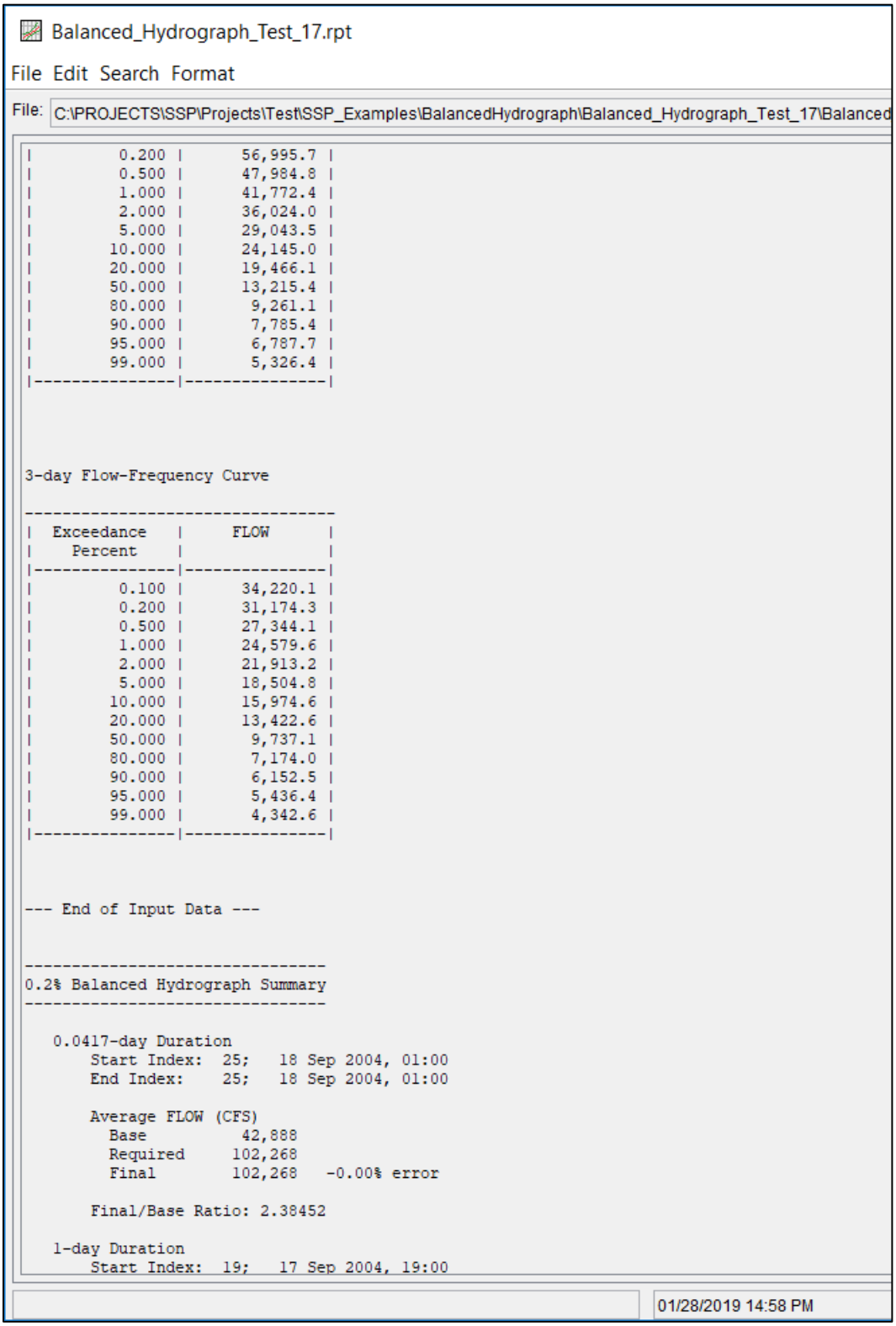


Figure 11-6. Balanced Hydrograph Analysis Report File.

CHAPTER 12

Performing a Distribution Fitting Analysis

The current version of HEC-SSP allows the user to infer probability distributions for nearly any type of data that can be stored in DSS format. Specifically, up to 19 different analytical distributions can be parameterized using two different fitting methods. Common hydrologic analyses attempt to estimate flow, stage, or precipitation depth (amongst other variables) for a given annual exceedance probability (AEP) or estimate the probability that a given flow, stage, or precipitation depth will exceed a particular value. In order to answer these questions, fully parameterized analytical probability distributions are often used. Additionally, depending upon the application, different sources of uncertainty may result in varying estimates of the necessary information. These sources of uncertainty can include (but are not limited to) small sample sizes, measurement uncertainty, choice of probability distribution, and/or choice of parameterization (fitting method). The Distribution Fitting Analysis is a tool that can be utilized to answer the previously noted questions as well as multiple sources of uncertainty. This chapter discusses in detail how to use the Distribution Fitting Analysis editor within HEC-SSP.

Contents

- Starting a New Analysis
- Data Manipulation and Visualization
- Analyzing Probability Distributions
- Distribution Fitting and Parameter Estimation
- Goodness of Fit Tests
- Viewing Results

Starting a New Analysis

A distribution fitting analysis can be started in two ways, either by right clicking on the Distribution Fitting Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Distribution Fitting Analysis**. When a new Distribution Fitting Analysis is selected, the user is required to first enter a **Name** for the analysis, enter an optional **Description**, and select a data set from the available data sets stored in the current study DSS file (see chapter 4 for importing data into the study). The Distribution Fitting Analysis editor will not allow further edits by the user until the name is defined and the data set is selected. The list of data that can be selected for a Distribution Fitting Analysis includes nearly all types of DSS data including both time series and paired data (gridded DSS data is not supported). When using time series, data with an irregular interval, like IR-CENTURY and IR-YEAR (E-part pathname), as well as a regular interval, such as 1HOUR and 1DAY can be selected. When using paired data, currently only single column paired data sets are supported within HEC-SSP. Therefore, if a paired data set is selected within the Distribution Fitting Analysis, only the values within the y-column will be imported and an “index” value will be assumed for the x-value. Once a **Name** is entered and a data set is selected, the **DSS File Name** and **Report File** will automatically be entered. The DSS filename is by default the same name as the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Distribution Fitting Analysis editor is shown in Figure 12-1.

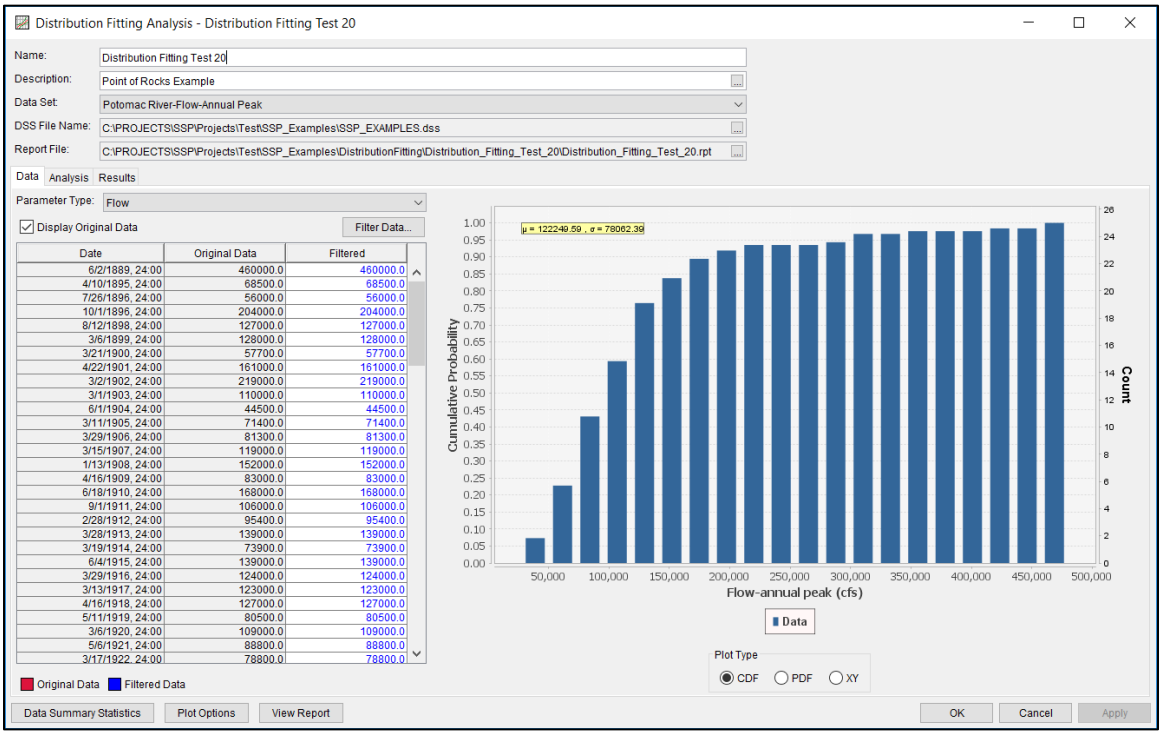


Figure 12-1. Distribution Fitting Analysis Editor.

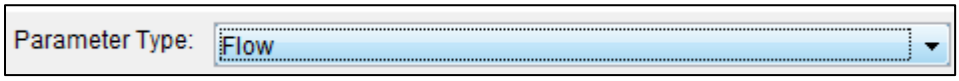
Data Manipulation and Visualization

Once the analysis name has been entered and a data set selected, the user can begin to analyze and manipulate the data. Contained on the Distribution Fitting Analysis editor are three tabs. The tabs are labeled **Data**, **Analysis**, and **Results**.

The first tab contains settings, information, and options related to the data that will be used within the analysis and to generate the results. These settings include:

- Parameter Type
- Data Filtering
- Data Table
- Data Summary Statistics
- Plots
- Plot Options

Parameter Type



This option allows the user to change the default distributions that will be available on the **Analysis** tab, axis labels, and precision for which results will be displayed. Parameter types that are available for use include:

- Precipitation
- Flow
- Stage
- Flood Season
- Other

By default, the Distribution Fitting Analysis editor will look within the Data Set to determine if a typical C-part pathname has been used (i.e. FLOW, PRECIP-INC, STAGE, ELEV, etc.). If the C-part of the Data Set contains one of these commonly used strings, the Parameter Type will be automatically selected. However, the user has the option to override the default selection. In addition, if a commonly used C-part is not used, the "Other" Parameter Type designation will be made for the user. If the Flood Season parameter type is selected, the x-axis values used within the **CDF** and **PDF** plots as well as output shown within the **Results** tab will be replaced with dates.

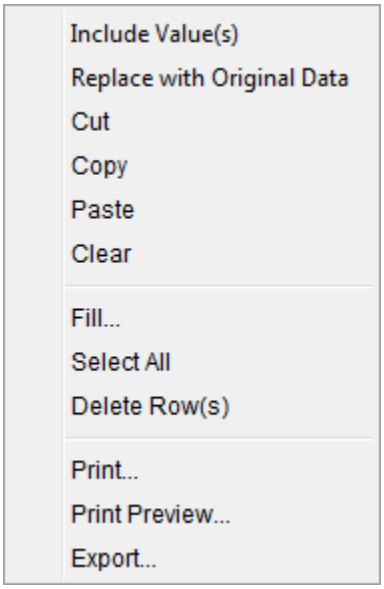
Data Filtering

Data filtering allows the user to interact with, modify, exclude, or include certain input data values for use within the subsequent analysis. The means and methods by which data can be filtered were previously described in the **Filtering Data** section. Filters that are available for use within the Distribution Fitting Analysis include:

- Time Window
- Season
- Min / Max Threshold
- Annual Maxima
- Peaks Over Threshold (Partial Duration)
- Starting Pool Stage / Elevation

To begin filtering an existing data set, click on the **Filter Data…** button. Within the **Filter** editor, use the check boxes to enable any desired filters

Data Table

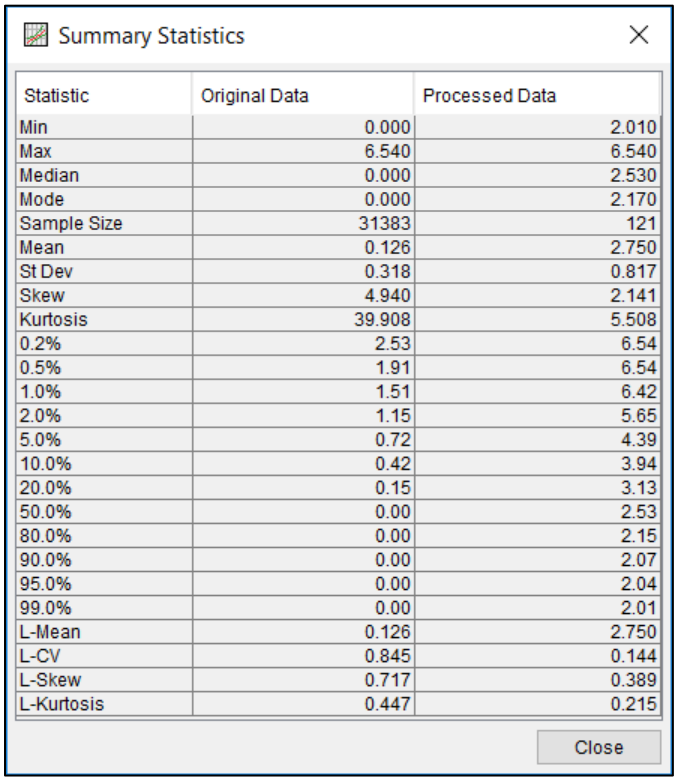


The data table contains the original and filtered data that will be used throughout the analysis. When time series data is selected, the first column will contain dates. However, when paired data is selected, the first column will contain "index" values.

The user can also interact with data in the Filtered column by selecting and manually defining a value as well as right-clicking. Upon a right-click option, the user is provided with numerous options including **Include Value(s)**, **Replace with Original Data**, **Cut**, **Copy**, **Paste**, **Clear**, **Fill**, **Select All**, **Delete Row(s)**. When data is excluded from the analysis, it will be shown in red text. Conversely, when data is included, it will be shown in blue text. Tool tips explaining why a certain value was excluded (i.e. which selected Data Filter caused the data to be excluded) can be accessed by hovering the mouse over the value within the Filtered column.

Data Summary Statistics

This option allows the user to summarize both the original and processed data. The processed data is determined by applying all filters and user-defined criteria. Statistical metrics that are available include: **Min**, **Max**, **Median**, **Mode**, **Sample Size**, **Mean**, **Standard Deviation**, **Skew**, **Kurtosis**, **0.2- … 99.0-percent values**, **L-Mean**, **L-CV**, **L-Skew**, and **L-Kurtosis**. To access the data summary statistics, click the **Data Summary Statistics** button near the bottom of the Distribution Fitting Analysis editor. The Data Summary Statistics window is shown in Figure 12-2.



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	31383	121
Mean	0.126	2.750
St Dev	0.318	0.817
Skew	4.940	2.141
Kurtosis	39.908	5.508
0.2%	2.53	6.54
0.5%	1.91	6.54
1.0%	1.51	6.42
2.0%	1.15	5.65
5.0%	0.72	4.39
10.0%	0.42	3.94
20.0%	0.15	3.13
50.0%	0.00	2.53
80.0%	0.00	2.15
90.0%	0.00	2.07
95.0%	0.00	2.04
99.0%	0.00	2.01
L-Mean	0.126	2.750
L-CV	0.845	0.144
L-Skew	0.717	0.389
L-Kurtosis	0.447	0.215

Figure 12-2. Data Summary Statistics.

Plots

Three different plot types are available for use within the **Data** tab: **CDF**, **PDF**, and **XY**. The CDF plot displays the cumulative distribution function while the PDF plot displays the probability density function of the data. Within both the CDF and PDF plots, a legend will display the sample mean (μ) and standard deviation (σ) of the processed data. Finally, the XY plot displays the contents of the Data Table. When time series data is being used, the x-axis will contain dates. When paired data is selected, the x-axis will contain "index" values. Original data will be shown in red while the processed (i.e. filtered) data will be shown in blue. Examples of all three plot types are shown in Figure 12-3, Figure 12-4, and Figure 12-5.

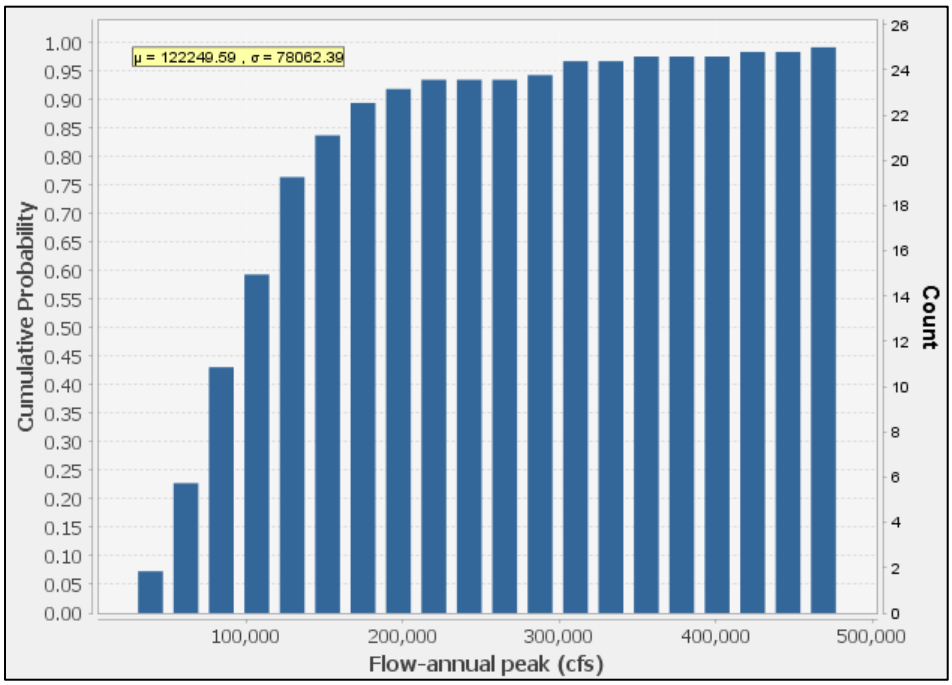


Figure 12-3. Data Tab CDF Plot.

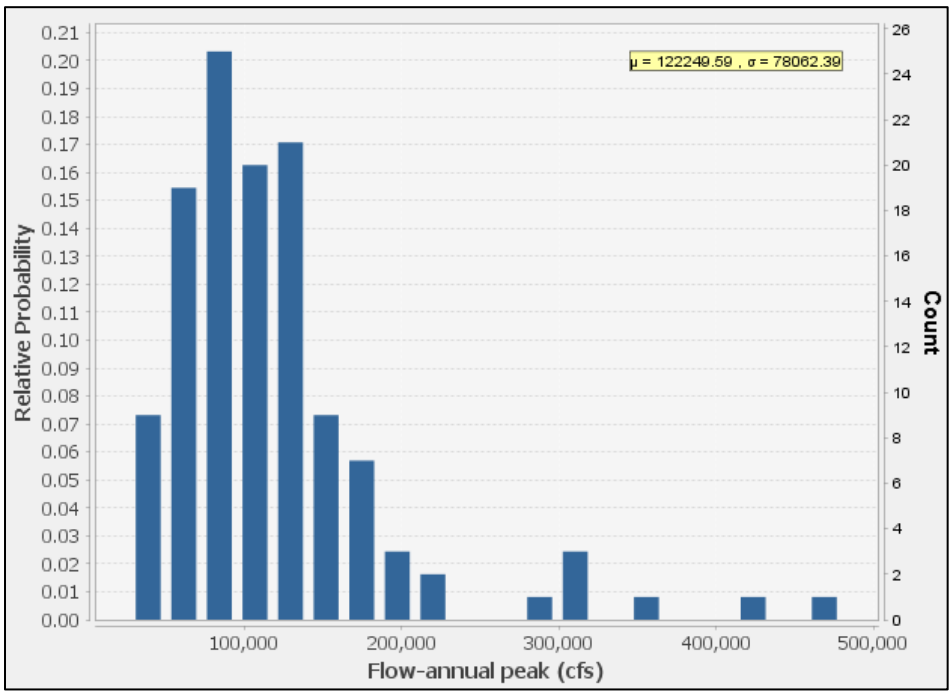


Figure 12-4. Data Tab PDF Plot.

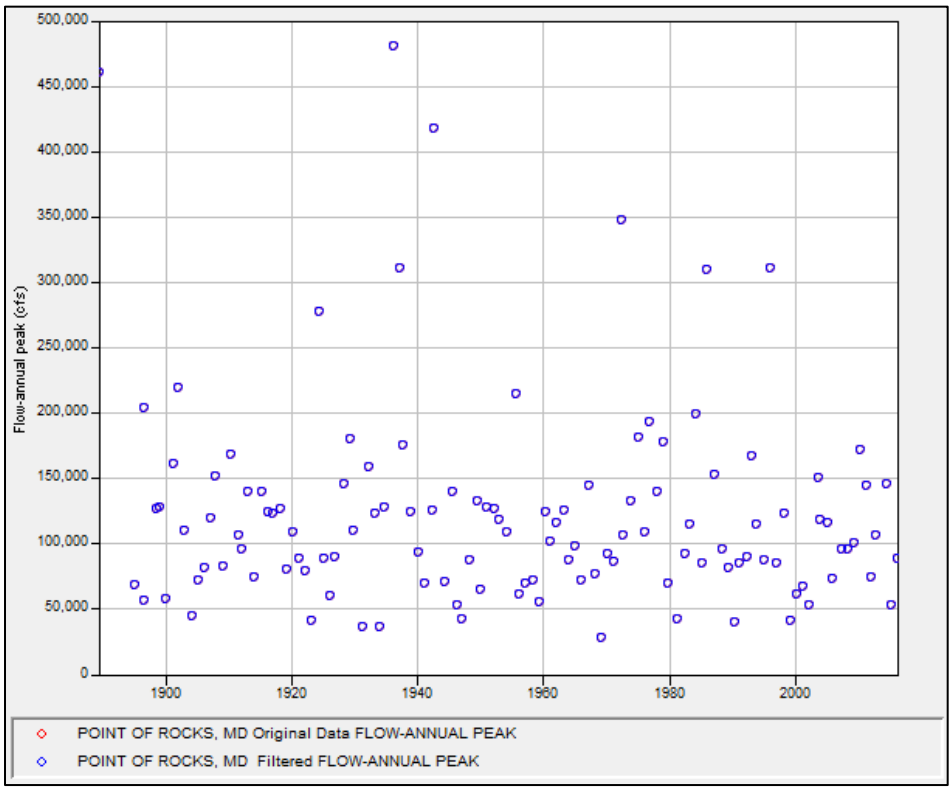


Figure 12-5. Data Tab XY Plot.

Plot Options

The selections contained within the Plot Options window allow the user to modify the way in which data is visualized within the accompanying plots. These options can be accessed by clicking the **Plot Options** button near the bottom of the Distribution Fitting Analysis editor. The Plot Options window is shown in Figure 12-6.

Plot option settings that are available include:

- Output Labeling
- Plotting Position
- Output Frequency Ordinates
- Advanced Histogram Options

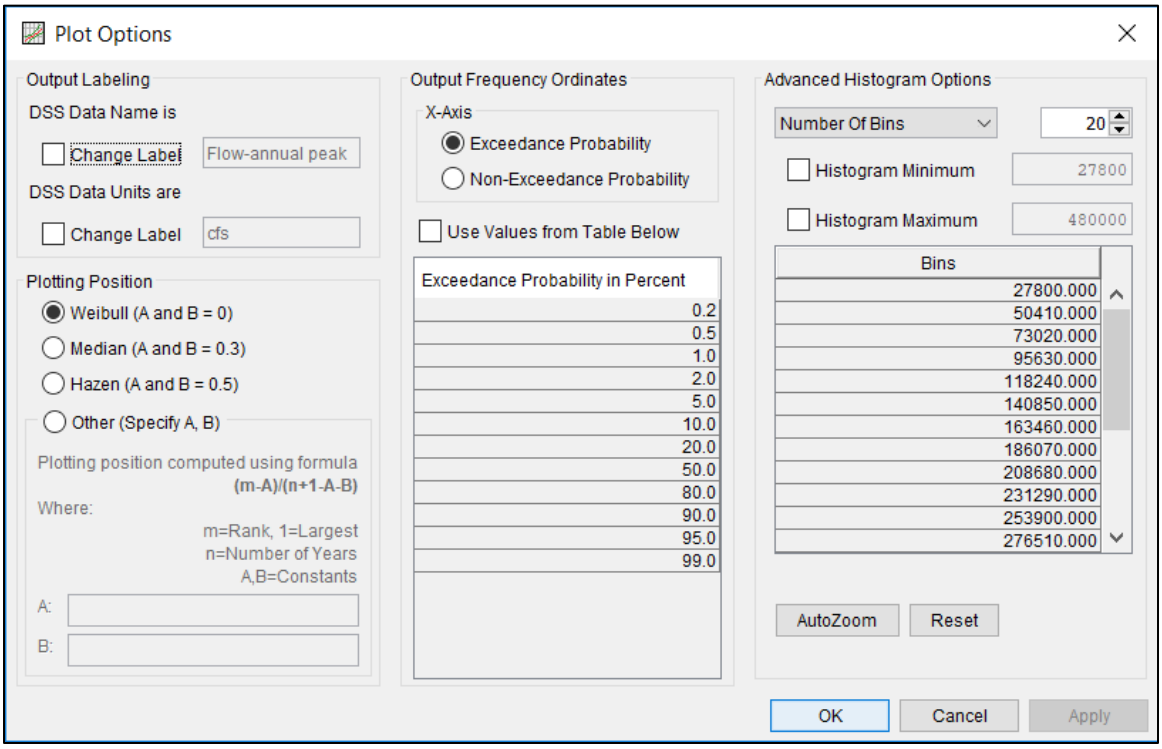
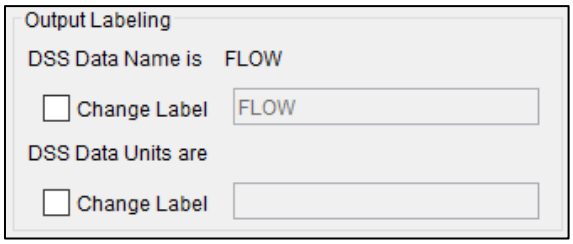


Figure 12-6. Plot Options.

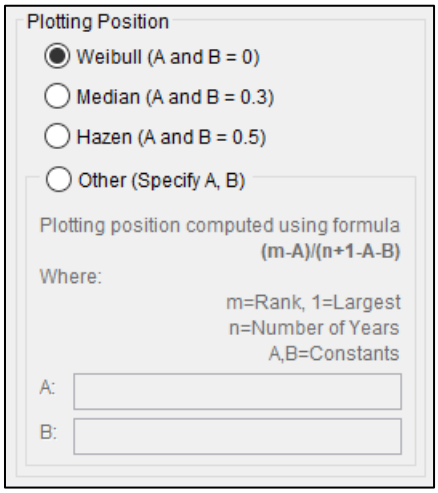
Output Labeling

This option allows the user to change the default labels for data contained in the output tables and plots. The user can change both the name of the data as well as the units of the data. The output labeling does not result in the conversion of data from one unit system to another; it only affects what is displayed on table headings and the y-axis of the results plot.



Plotting Position

Plotting positions are used for plotting the original and/or processed data set on a probability scale. There are four options for computing plotting positions within the Distribution Fitting Analysis: Weibull, Median, Hazen, and user entered coefficients. The default method within the Distribution Fitting Analysis is the Median plotting position formula. The generalized plotting position equation is:



$$P = \frac{(m - A)}{(n + 1 - A - B)}$$

where: m = rank of flood values with the largest equal to 1.

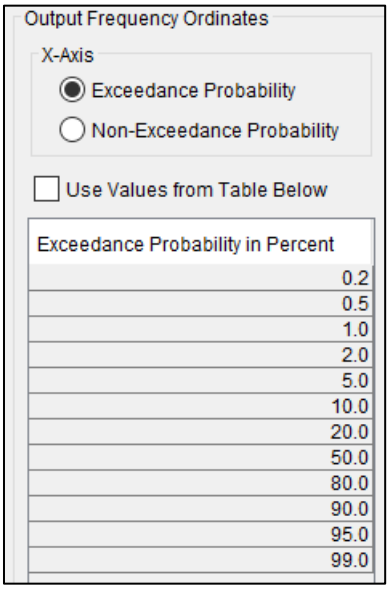
n = number of flood peaks in the data set.

A & B = constants dependent on which equation is used (Weibull A and B = 0; Median A and B = 0.3; and Hazen A and B = 0.5).

Plotting positions represent estimates of the exceedance (or non-exceedance) probability of each data point. The probabilities of the highest and lowest points in the data set are the most sensitive to choice of plotting position estimator. When fitting an analytical distribution, the plotting of data on the graph by a plotting position method is only done as a guide to assist in evaluating the computed curve. The plotting position method selected does not have any impact on the computed curve.

Output Frequency Ordinates

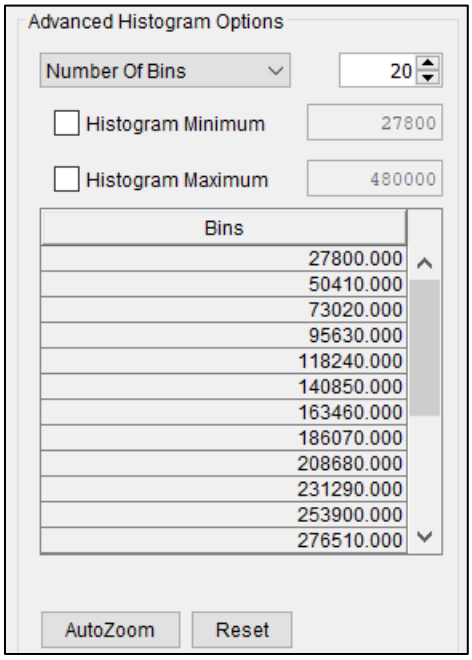
The options contained within the Output Frequency Ordinates panel allow the user to modify the way in which the data is represented in probability space. Two x-axis options are presented for use: **Exceedance Probability** or **Non-Exceedance Probability**. Depending upon the selection, the x-axis within the plots on each tab will change to display exceedance (i.e. probability of equaling or exceeding a defined value) or non-exceedance probability. In addition, the choice in this panel results in the table below displaying either percent exceedance or non-exceedance probability. Exceedance probability, which is the complement of non-exceedance probability (i.e. Exc. Prob. = 1 – [Non-Exc. Prob.]) is the default option.



The user can change or add to the frequency ordinates for which the resulting frequency curves are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table Below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and **Delete Row(s)**. The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.

Advanced Histogram Options

The choices contained within the Advanced Histogram Options panel affect the number and size of bins used within the **Cumulative Distribution Function (CDF)** and **Probability Density Function (PDF)** plots. Normally, the bins will be displayed using the range of values contained within the Filtered Data. However, if the **Parameter Type** was previously defined as **Flood Season**, the bin values will change to display dates (DDMMM). The user can choose to demarcate bins automatically using the **Number of Bins** option, define a **Bin Size,** and automatically determine the number of bins, or manually define the bins using the **User-Defined** option. **Histogram Minimum** and/or **Histogram Maximum** can be used to constrain



the bins to a minimum and/or maximum value(s). Clicking the **Reset** button will remove all changes and return each selection/value to the default entry.

Analyzing Probability Distributions

Once the data set has been analyzed and accepted, the user can begin to analyze multiple probability distributions and fitting methods within the **Analysis** tab. As shown in Figure 12-7, the Analysis tab contains settings, information, and options related to the available frequency distributions and fitting methods that will be used to generate the results. These settings include:

- Distribution Filter
- Distribution | Fitting Method Table
- Goodness of Fit Summary Statistics
- Confidence Limits and Expected Probability Options
- Accept Selected Distribution
- Plots

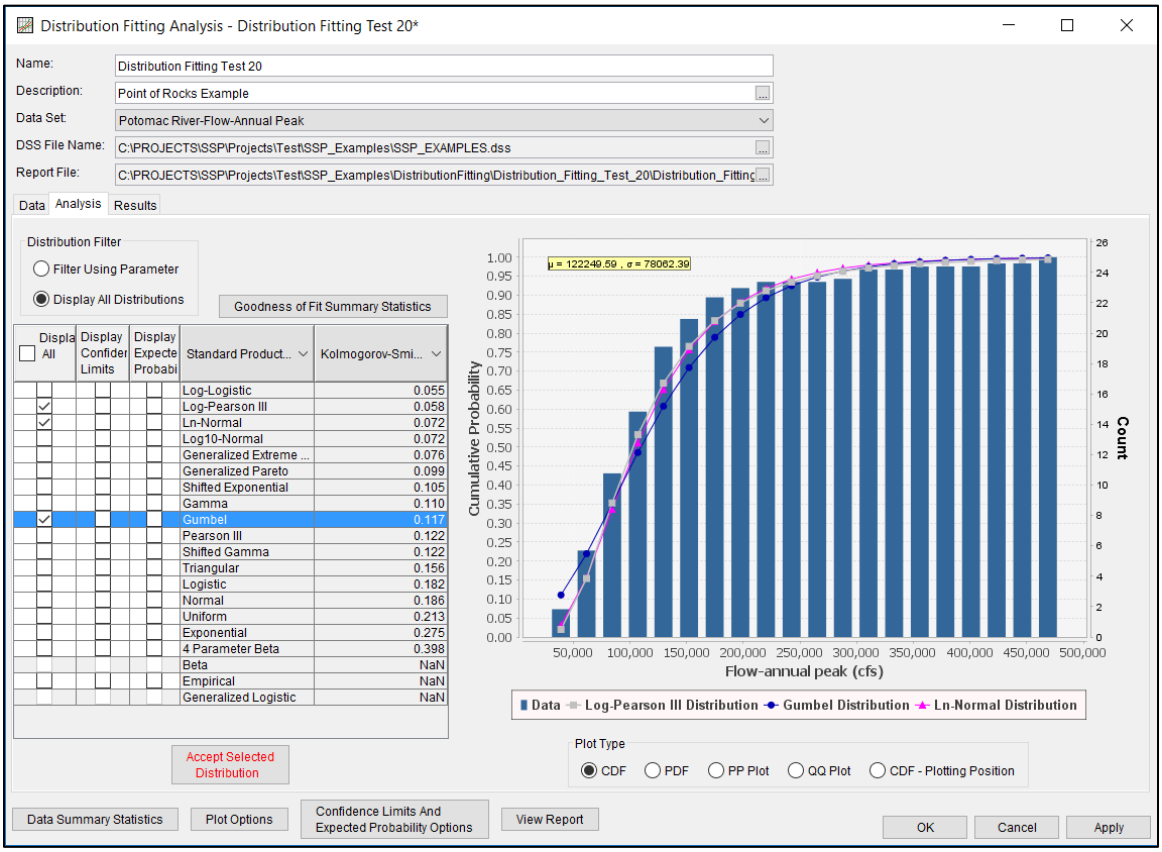


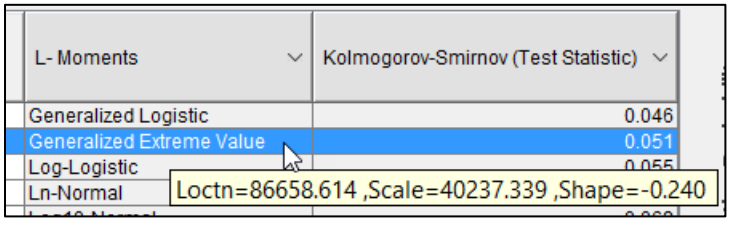
Figure 12-7. Distribution Fitting Analysis Tab.

Distribution Filter

This option allows the user to change the listing of distributions that will be available within the **Distribution | Fitting Method Table**. When the **Filter Using Parameter** option is selected, only those distributions commonly associated with the chosen **Parameter Type** on the **Data** tab will be available. When the **Display All Distributions** option is selected, all currently available probability distributions will be shown.

Distribution | Fitting Method Table

The **Distribution | Fitting Method** table contains a list of the available distributions, options to display and/or compute various curves, options to



change the fitting method, and goodness of fit test statistics for each distribution | fitting method, as shown in Figure 12-8. The contents of the table will be sorted in ascending order using the computed goodness of fit test statistic. Tool tips containing the parameters of the each distribution | fitting method combination can be accessed by hovering the mouse over the distribution within the **Fitting Method** column. Not all distribution | fitting method combinations will converge to and result in real-space parameter estimations when subjected to different data sets. Distribution | fitting method combinations that do not converge will be greyed out and not available for selection. The user can also interact with the available distribution | fitting method combinations in several ways:

- Display All Curves
- Display Confidence Limits
- Display Expected Probability
- Fitting Method
- Goodness of Fit Test

Display All Curves	Display Confidence Limits	Display Expected Probability	L- Moments	Kolmogorov-Smirnov (Test Statistic)
☐	☐	☐	Generalized Logistic	0.046
☑	☑	☑	Generalized Extreme Value	0.051
☐	☐	☐	Log-Logistic	0.055
☐	☐	☐	Ln-Normal	0.069
☐	☐	☐	Log10-Normal	0.069
☐	☐	☐	Generalized Pareto	0.086
☐	☐	☐	Shifted Exponential	0.086
☐	☐	☐	Gamma	0.110
☐	☐	☐	Gumbel	0.111
☐	☐	☐	Triangular	0.138
☐	☐	☐	Logistic	0.176
☐	☐	☐	Normal	0.180
☐	☐	☐	Uniform	0.194
☐	☐	☐	Exponential	0.275
			Beta	NaN
			4 Parameter Beta	NaN
☐	☐	☐	Empirical	NaN
			Pearson III	NaN
			Log-Pearson III	NaN
			Shifted Gamma	NaN

Figure 12-8. Distribution | Fitting Method Table.

Display All Curves

The **Display All Curves** option, which is available as a checkbox within the left-most column header, can be used to display and/or remove the median curves for each distribution that is currently shown in the Distribution | Fitting Method table within the currently selected plot type.

Display Confidence Limits

The **Display Confidence Limits** option can be used to display and/or remove the confidence limits for the selected row / distribution within the currently selected plot type. Options controlling the confidence limit computations and results are contained within the **Confidence Limits and Expected Probability Options** menu.

Confidence limits cannot be plotted within the **PDF**, **PP**, and/or **QQ** plot. In addition, only one set of confidence limits can be displayed at a time. When this button is pressed, if the confidence limits for the selected distribution | fitting method have not been computed, they will be computed prior to display. If the confidence limits for the selected distribution | fitting method have previously been computed, they will be displayed without being recomputed. In addition, if the parametric bootstrap computations that estimate the confidence limits fail to converge using the specified convergence criteria, an error message will be shown stating, "Compute failed to converge." If this error message is encountered, please check the specified convergence criteria. However, the **Results** tab will still be populated with the available information.

Display Expected Probability

The **Display Expected Probability** option can be used to display and/or remove the expected probability (mean) curve for the selected row / distribution within the currently selected plot type. Options controlling the expected probability computations and results are contained within the **Confidence Limits and Expected Probability Options** menu.

Expected probability curves cannot be plotted within the **PDF**, **PP**, and/or **QQ** plot. In addition, only one expected probability curve can be displayed at a time. When this button is pressed, if the expected probability curve for the selected distribution | fitting method has not been computed, it will be computed prior to display. If the expected probability curve for the selected distribution | fitting method has previously been computed, it will be displayed without being recomputed. In addition, if the parametric bootstrap computations that estimate the expected probability curve fail to converge using the specified convergence criteria, an error message will be shown stating, "Compute failed to converge." If this error message is encountered, please check the specified convergence criteria. However, the **Results** tab will still be populated with the available information.

Fitting Method

Two distribution fitting method choices are available for use: **Standard Product Moments** and **Linear Moments**. When the **Fitting Method** column header is clicked, a drop down menu will be presented containing these choices, as shown in Figure 12-9.

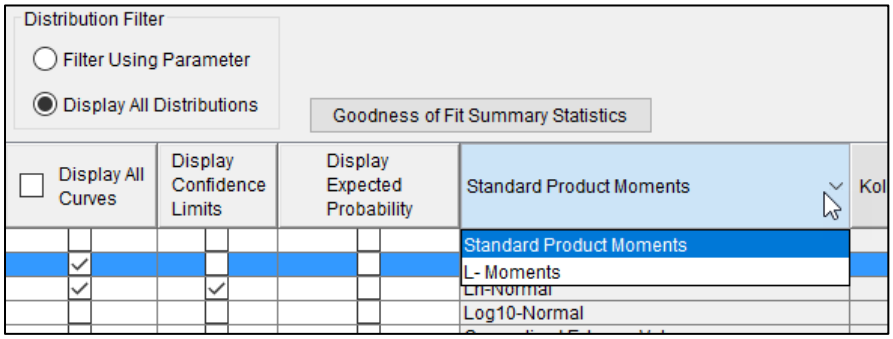


Figure 12-9. Fitting Method Drop Down Menu.

Goodness of Fit Test

Two goodness of fit tests are available for use: **Kolmogorov-Smirnov** and (Pearson's) **Chi-Square**. When the **Goodness of Fit** column header is clicked, a drop down menu will be presented containing these choices, as shown in Figure 12-10. Both goodness of fit tests will present results in terms of a test statistic. It is up to the user to interpret these results for their specific application.

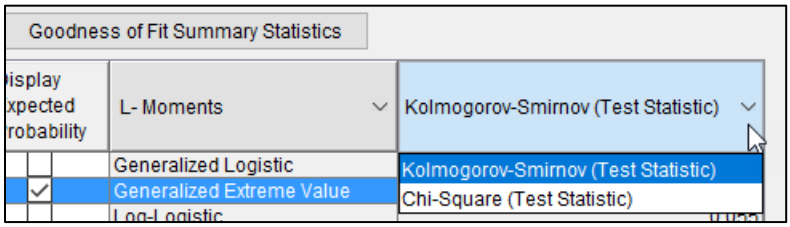
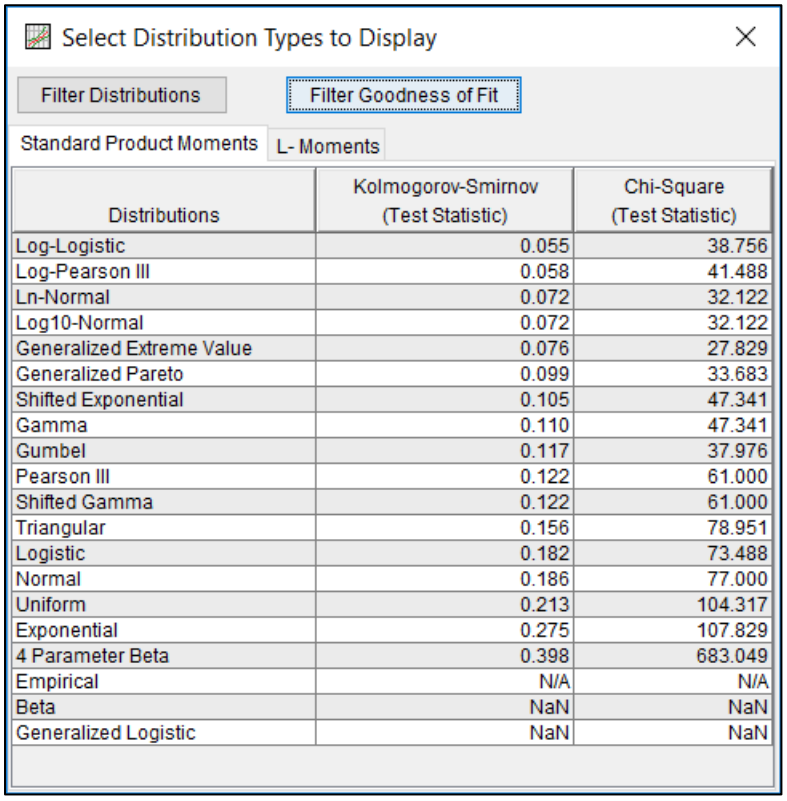


Figure 12-10. Goodness of Fit Drop Down Menu.

Goodness of Fit Summary Statistics

The **Goodness of Fit Summary Statistics** option, which is available as a button above the Distribution | Fitting Method table, can be used to summarize the goodness of fit test statistics for all of the distribution | fitting method combinations. Tabs for **Standard Product Moments** and **Linear Moments** are included. The **Filter Distributions** button allows the user to include or remove distributions from the results. The **Filter Goodness of Fit** button allows the user to include or remove goodness of

fit tests from the results. The Goodness of Fit Summary Statistics window is shown in Figure 12-11.



Distributions	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Log-Logistic	0.055	38.756
Log-Pearson III	0.058	41.488
Ln-Normal	0.072	32.122
Log10-Normal	0.072	32.122
Generalized Extreme Value	0.076	27.829
Generalized Pareto	0.099	33.683
Shifted Exponential	0.105	47.341
Gamma	0.110	47.341
Gumbel	0.117	37.976
Pearson III	0.122	61.000
Shifted Gamma	0.122	61.000
Triangular	0.156	78.951
Logistic	0.182	73.488
Normal	0.186	77.000
Uniform	0.213	104.317
Exponential	0.275	107.829
4 Parameter Beta	0.398	683.049
Empirical	N/A	N/A
Beta	NaN	NaN
Generalized Logistic	NaN	NaN

Figure 12-11. Goodness of Fit Summary Statistics.

Confidence Limits and Expected Probability Options

Clicking the **Confidence Limits and Expected Probability Options** button will launch an editor that contains several options pertinent to the parametric bootstrap routine used to estimate confidence limits and expected probability curves for each distribution | fitting method combination. The parametric bootstrap routine used by the software to estimate the expected probability curve is detailed in the **General Frequency | Expected Probability Options** section. The Confidence Limits and Expected Probability Options window is shown in Figure 12-12.

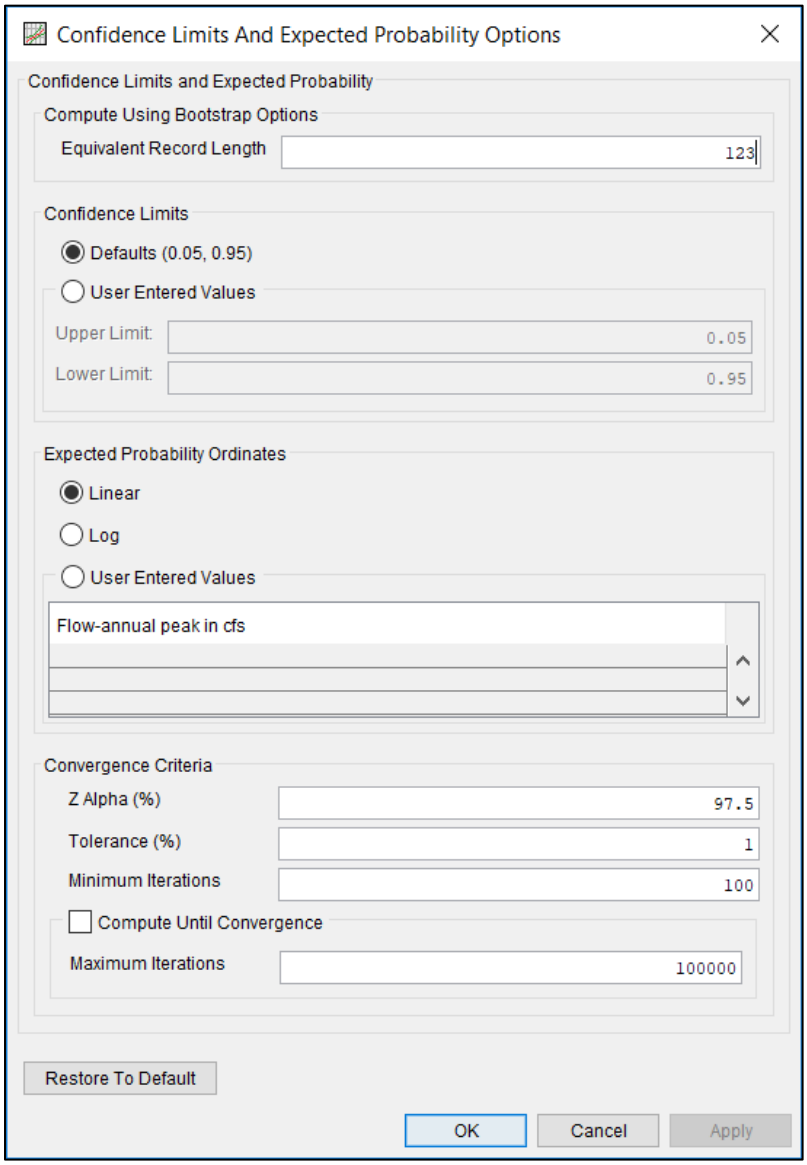
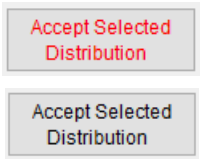


Figure 12-12. Confidence Limits and Expected Probability Options.

Accept Selected Distribution

This option allows the user to accept the currently selected distribution and populate the **Results** tab with relevant output. When a distribution has not been, or is currently not accepted, the button will be highlighted in red. When a distribution has been accepted, the button highlighting will be removed and the selected distribution | fitting method combination row will be highlighted in green, as shown in Figure 12-13.



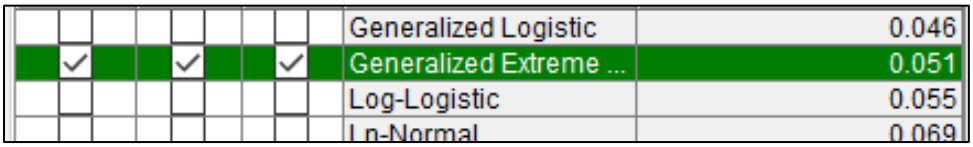


Figure 12-13. Selected Distribution | Fitting Method.

When this button is pressed, the confidence limits and/or expected probability curve for the selected distribution | fitting method will be computed (if they have not been computed already). If the confidence limits and/or expected probability curve for the selected distribution | fitting method have previously been computed, they will be displayed without being recomputed. In addition, if the parametric bootstrap computations that estimate the confidence limits and expected probability curve fail to converge using the specified convergence criteria, an error message will be shown stating, "Compute failed to converge." If this error message is encountered, please check the specified convergence criteria. However, the **Results** tab will still be populated with the available information.

Plots

Five different plot types are available for use within the **Analysis** tab: **CDF**, **PDF**, **PP**, **QQ**, and **CDF-Plotting Position**. The CDF plot displays the cumulative histogram of the data in addition to the median, confidence limits, and/or expected probability curves of the distribution(s), as selected and/or computed by the user. The PDF plot displays the histogram of the data in addition to the median curve(s) of the distribution(s), as selected by the user. Within both the CDF and PDF plots, a legend will display the sample mean (μ) and standard deviation (σ) of the processed data. If the user wishes to modify the number or size of the bins used within the either the CDF or PDF plots, the changes should be made on the Data tab. This will ensure that the analytical distributions shown within either plot are the most up to date. The PP plot displays the empirical probability of the data (using the chosen plotting position formula) against the inferred (analytical) probability derived from the distribution | fitting method combination. The QQ plot displays the data against the inferred (analytical) values derived from the distribution | fitting method combination. Both the PP and QQ plots contain a 1:1 line and utilize linear x- and y-axes. Finally, the CDF-Plotting Position plot displays the empirical probability of the data (using the chosen plotting position formula) in addition to the median curve, confidence limits, and/or expected probability curves, as selected and/or computed by the user. This plot utilizes a normal probability x-axis. Examples of all five plot

types are shown in Figure 12-14, Figure 12-15, Figure 12-16, Figure 12-17, and Figure 12-18.

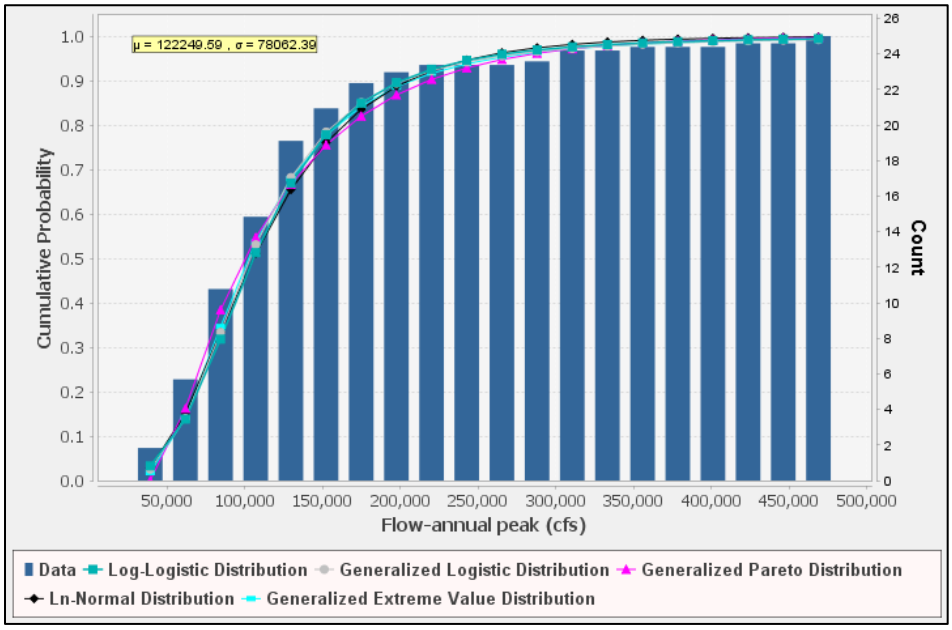


Figure 12-14. Analysis Tab CDF Plot.

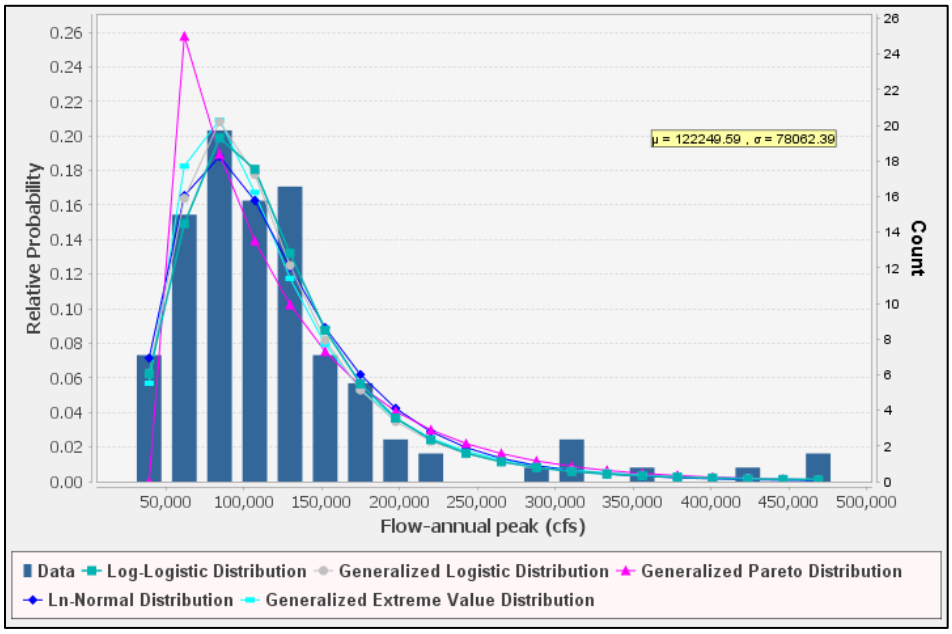


Figure 12-15. Analysis Tab PDF Plot.

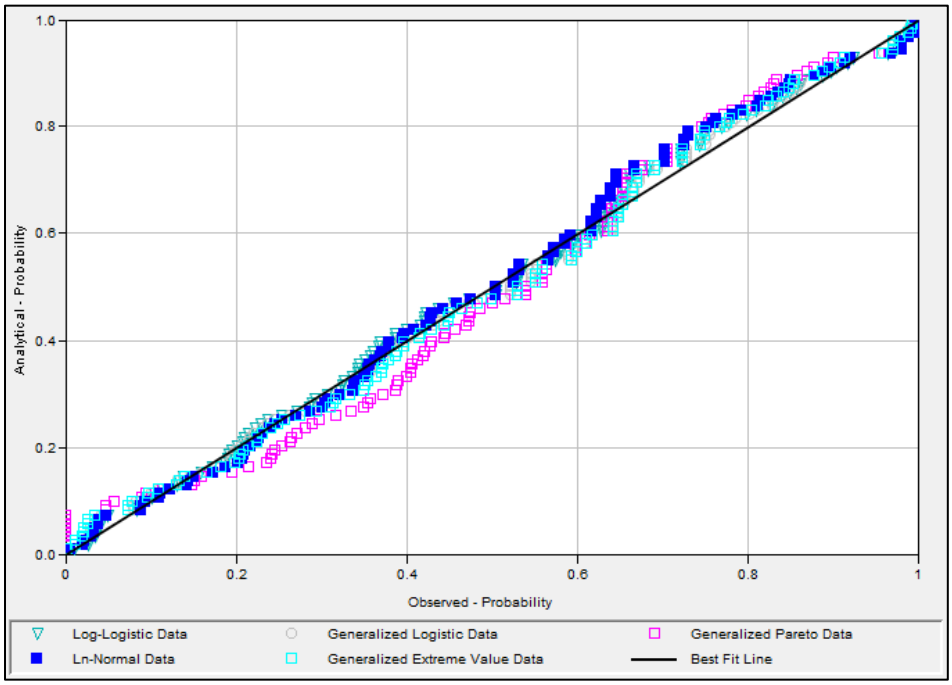


Figure 12-16. Analysis Tab PP Plot.

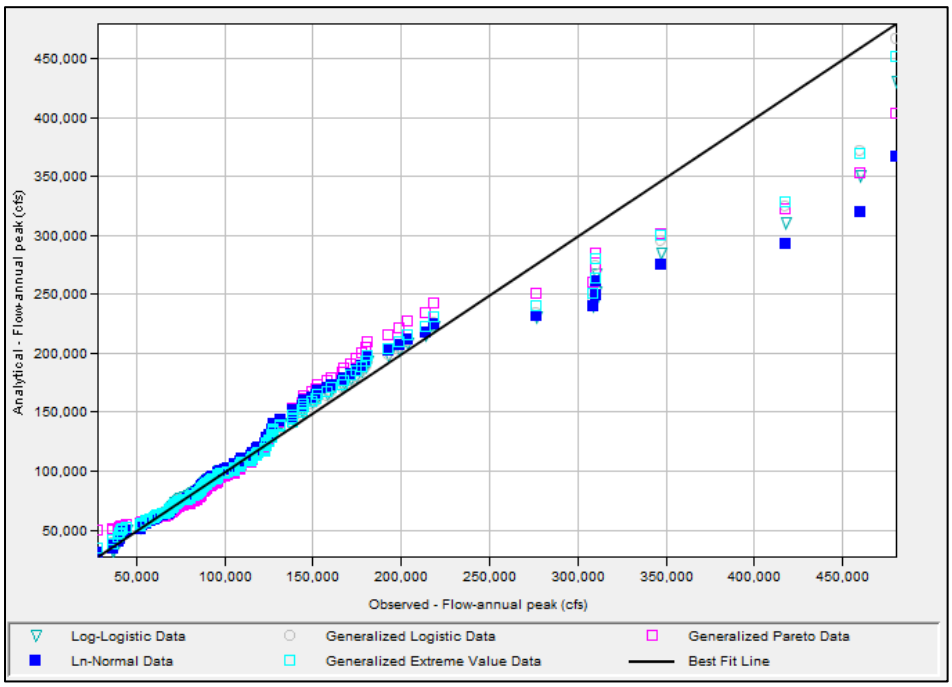


Figure 12-17. Analysis Tab QQ Plot.

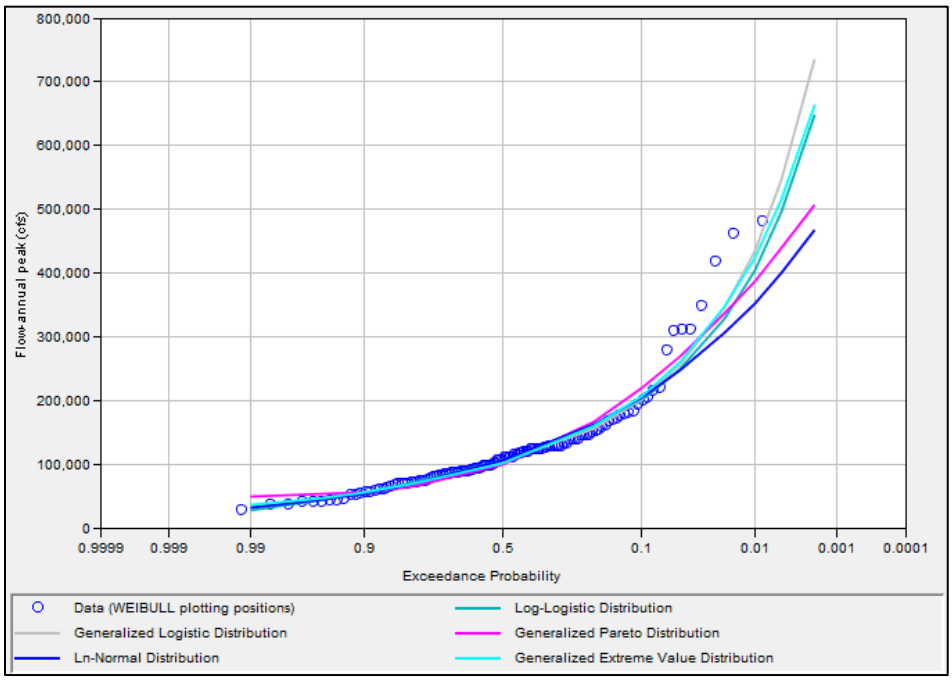


Figure 12-18. Analysis Tab CDF-Plotting Position Plot.

Distribution Fitting and Parameter Estimation

Distribution fitting is the art of choosing a probability model for an unknown and unknowable population, and calibrating that model using a representative sample from the population. Such a model allows for inferences about the population to be made despite not knowing all of its properties. Uncertainty will always be part of the inference because of a limited sample size. However, choice of an appropriate model for the population can result in better inferences about its properties.

Calibration of the selected model, also called parameter estimation in the distribution-fitting context, relies on the assumption that the observed data are in some way representative of the larger population. For moments-based methods discussed below, the assumption is that the moments of the sample are equal to the moments of the population. Any method for estimating model parameters for the population that makes this assumption is called the Method of Moments.

Moments are a numerical description of the shape of a dataset or model, and two types of moments are used within HEC-SSP for this purpose. The first is the more common *product moments* and the other is *linear moments* or *L-moments* (Hosking, 1990). Both product moments and L-moments describe various shape properties of a dataset or model, as shown in Table 12-1. For samples, the difference between the two

methods is that product moments give equal weights to transformations of observations and L-moments give unequal weights to order statistics of observations based on the rank of the observation. Functionally, the difference is that L-moments give less weight to extreme observations. They are sometimes thought to be a more robust alternative to product moments, especially for higher-order moments (e.g. skew and kurtosis). Additionally, in cases where higher-order product moments do not exist (e.g. variance and higher moments of a generalized extreme-value distribution with a shape parameter $\leq -\frac{1}{2}$) L-moments exist as long as the mean is finite. The order of a moment is associated with a particular shape descriptor and in general, population moments of a higher order are harder to estimate from a small sample. Moments of order greater than 4 do exist but are rarely used in practice.

Table 12-1. Description of Properties and Moments

Order	Property	Product Moment	Linear Moment
1	Central Tendency	Mean	*L*-Mean
2	Dispersion	Variance	*L*-CV
3	Asymmetry	Skew	*L*-Skew
4	Tail Thickness	Kurtosis	*L*-Kurtosis

Unique moment-based estimators for the parameters of a probability distribution are achieved by solving a system of equations. Moments of a probability distribution can be computed from the probability density function, which result in equations for the moments in terms of the parameters of the distribution. Solving for the parameters in terms of the moments results in the moments-based estimators. Generally, the number of moments needed to estimate the parameters of a distribution is equal to the number of parameters in the distribution. As a guideline, higher-order moments are generally associated with shape parameters of a distribution if it has them; second-order moments are generally associated with scale parameters, and the first-order moment is generally associated with the location parameter. Moments of a higher order than the number of distribution parameters are usually fixed (with exceptions).

Currently, 19 probability distributions and two fitting methods are available for use within the Distribution Fitting Analysis. These distribution choices range from simple (for example, the uniform distribution) to complex (for example, the four-parameter beta distribution). Each of the probability distributions available in the Distribution Fitting Analysis is continuous but has varying support. A short description of each distribution and some common uses are

contained below. Within each description, common notation for the probability density, cumulative distribution, and quantile functions will be utilized as shown in Table 12-2. Additionally, common notation for the moments of each distribution will be utilized as shown in Table 12-3.

Table 12-2. Notation for Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\theta) =$
Cumulative Distribution Function	$F(x\|\theta) =$
Quantile Function	$F^{-1}(p\|\theta) =$

Table 12-3. Notation for Moments.

Mean	$E[X] =$
Variance	$Var[X] =$
Skewness	$Skew[X] =$

Beta Distribution

The Beta Distribution is a two-parameter distribution with continuous support on the closed interval [0, 1]. In practice, the Beta Distribution is used to model continuous outcomes where the minimum and maximum values are known to be 0 and 1, respectively. Random variables on any arbitrary closed interval [a, c] can be transformed using an affine transformation:

$$y = \frac{x - a}{c - a}$$

Where x is any random variable bounded by the interval [a, c] and y is a random variable bounded by [0, 1]. This transformation makes the Beta useful for effectively truncating a random variable by fixing the interval over which outcomes may occur. Take for example a seasonality analysis in which the frequency of events occurring by month has a bell-curve shape. While the Normal Distribution may provide a good fit to the data due to their shape, outcomes less than 1 or greater than 12 do not make sense, and a Normal model would have to be truncated. Instead, using an affine transformation would allow the Beta Distribution to be used as a model for the outcomes.

Bayesian inference places great importance on the Beta Distribution as a means to describe information contained in a proportion or probability. This is useful for describing one's opinion about the probability of an event occurring including uncertainty, also called a *prior distribution.*

The Beta also appears in a project/program management technique called PERT, which leads to a particular but different parameterization of the Beta Distribution being called the PERT Distribution.

The Beta Distribution has two parameters, α and β, which are both shape parameters. Both α and β are strictly positive ($\alpha, \beta > 0$). However, a case that sometimes appears in Bayesian statistics as a prior is when $\alpha = \beta = 0$, which is an improper (degenerate) distribution sometimes referred to as the *Haldane prior.* When $\alpha > \beta$, the distribution is left-skewed, when $\alpha = \beta$ the distribution is symmetrical, and when $\alpha < \beta$ the distribution is right-skewed. In the case of $\alpha = \beta = 1$, the distribution reduces to the Uniform Distribution.

The Beta Distribution uses the Probability Density Function and Cumulative Distribution Function (the Quantile Function has no closed form) as shown in Table 12-4. Both parameters of the distribution control all of its moments. Fitting the Beta Distribution to a sample using the Method of Moments requires solution of a system of equations. The first three moments of the Beta Distribution are shown in Table 12-5.

Table 12-4. Beta Density, Distribution, and Quantile Functions.

Probability Density Function	$$f(x\|\alpha,\beta) = \frac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha,\beta)}$$ where $B(\cdot,\cdot)$ is the Beta Function.
Cumulative Distribution Function	$$F(x\|\alpha,\beta) = \frac{\int_0^x t^{\alpha-1}(1-t)^{\beta-1}\,dt}{B(\alpha,\beta)}$$ where $B(\cdot,\cdot)$ is the Beta Function. The numerator is the Incomplete Beta Function.
Quantile Function	No closed form.

Table 12-5. Beta Distribution Moments.

Mean	$E[X] = \frac{\alpha}{\alpha + \beta}$
Variance	$Var[X] = \frac{\alpha\beta}{(\alpha + \beta)^2(\alpha + \beta + 1)}$
Skewness	$Skew[X] = \frac{2(\beta - \alpha)\sqrt{\alpha + \beta + 1}}{(\alpha + \beta + 2)\sqrt{\alpha\beta}}$

4-Parameter Beta Distribution

The 4-Parameter Beta Distribution is identical to the Beta Distribution above, except it is over any interval [a, c] and the interval endpoints a and c are estimated from the data. It is also sometimes called the Pearson type I Distribution. Because this distribution has four parameters, any moments-based parameter estimation method requires involvement of the fourth moment (kurtosis). Population kurtosis is exceedingly challenging to estimate from a small sample, even more so than skew (the third moment.) Thus, it should be cautioned that if the user knows the data endpoints in the first place that using the 2-parameter Beta Distribution with an affine transformation of the data could produce better results.

The 4-Parameter Beta Distribution uses the Probability Density Function and Cumulative Distribution Function (the Quantile Function has no closed form) as shown in Table 12-6. Fitting the 4-Parameter Beta Distribution to a sample using the Method of Moments requires solution of a system of equations that includes the fourth moment (kurtosis.) The first three moments are contained within Table 12-7.

Table 12-6. 4-Parameter Beta Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\alpha,\beta,a,c) = \frac{y^{\alpha-1}(1-y)^{\beta-1}}{B(\alpha,\beta)}$ Where $B(\cdot,\cdot)$ is the Beta Function $y = \frac{x-a}{c-a}$ is the affine transformation.
Cumulative Distribution Function	$F(x\|\alpha,\beta,a,c) = \frac{\int_0^y t^{\alpha-1}(1-t)^{\beta-1}\,dt}{B(\alpha,\beta)}$ The numerator is the Incomplete Beta Function.
Quantile Function	No closed form.

Table 12-7. 4-Parameter Beta Distribution Moments.

Mean	$E[X] = \frac{\alpha c + \beta a}{\alpha + \beta}$
Variance	$Var[X] = \frac{\alpha\beta(c-a)^2}{(\alpha+\beta)^2(\alpha+\beta+1)}$
Skewness	$Skew[X] = \frac{2(\beta-\alpha)\sqrt{\alpha+\beta+1}}{(\alpha+\beta+2)\sqrt{\alpha\beta}}$

Empirical Distribution

The Empirical Distribution is a non-parametric method for estimating the Cumulative Distribution Function of a set of data. It should be noted that this distribution is not an analytical distribution. However, it is included here for convenience.

In literature, the Empirical Distribution is sometimes called the Empirical Cumulative Distribution Function, abbreviated as eCDF. Construction of an eCDF assumes that all observations are equally likely and assigns some probability to each based on the sample size of the dataset. A traditional choice is to assign a probability of $\frac{1}{n}$ to each observation, where *n* is the sample size. Then, the eCDF at each observation is the discrete sum

$F(x) = \sum_{i=1}^{j} \frac{1}{n}$ where j is the rank of the data (ascending, $j = 1$ is the smallest); which simplifies to $(x) = \frac{j}{n}$. This results in the largest observation ($j = n$) having a non-exceedance probability of 1. In most cases, it is not reasonable to assume that the largest observation on record is the population maximum. A compromise is to use the plotting position formula $F(x|A, B) = \frac{j-A}{n+1-A-B}$ where A and B are user-selected constants with specific motivations; see Table 18.3.1 of the *Handbook of Hydrology* for several examples (Maidment, 1993). The Distribution Fitting Analysis includes three commonly-used default values; $A = B = 0$ is the Weibull plotting position, $A = B = 0.3175$ is the Median plotting position, and $A = B = 0.5$ is the Hazen plotting position. Other defensible choices depending on use include the Gringorten plotting position $A = B = 0.44$, the Blom plotting position $A = B = 0.375$, and the Cunnane plotting position $A = B = 0.4$. Note that this is not an exhaustive list. Also note that, by default, plotting positions (and other values) are output using exceedance probability and rank is defined descending ($j = 1$ is largest), which corresponds to the Complementary Cumulative Distribution Function, also known as the Survival Function.

Exponential Distribution

The Exponential Distribution is a one-parameter, positively-skewed distribution with semi-infinite continuous support for all non-negative real numbers; $x \in [0, \infty)$.

Due to its one parameter and fixed positive skewness of 2, the Exponential is not a flexible distribution. However, for particular kinds of modeling, the Exponential possesses a property that no other continuous distribution does, a property called “memorylessness”. This property can be very important in the fields of survival analysis, reliability analysis, and stochastic processes. For applications in hydrology, this is less important. For non-negative, highly skewed variables, there is no simpler or more parsimonious model than the Exponential Distribution.

Some notational ambiguity may arise with the Exponential Distribution as it is commonly parameterized in two different ways; the first is with a rate parameter λ; the second with a scale parameter β. It is often more convenient to parameterize the distribution in terms of the scale parameter β as it is equal to the mean and the standard deviation of the distribution. It is also the specification commonly used in survival analysis and actuarial science. The λ (rate) parameterization is more common in stochastic processes, and naturally relates to the Poisson distribution. The

parameterization used in HEC-SSP is the β (scale) parameterization. β is strictly positive.

The Exponential (β) Distribution uses the Probability Density Function, Cumulative Distribution Function, and Quantile Function shown in Table 12-8. The moments for this distribution are simple in terms of the parameters, as shown in Table 12-9.

Table 12-8. Exponential Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\beta) = \beta^{-1} exp\left(-\frac{x}{\beta}\right) x \geq 0$
Cumulative Distribution Function	$F(x\|\beta) = 1 - exp\left(-\frac{x}{\beta}\right) x \geq 0$
Quantile Function	$F^{-1}(p\|\beta) = -\beta ln(1-p)$

Table 12-9. Exponential Distribution Moments.

Mean	$E[X] = \beta$
Variance	$Var[X] = \beta^2$
Skewness	$Skew[X] = 2.$

Shifted Exponential Distribution

The Shifted Exponential Distribution is a two-parameter, positively-skewed distribution with semi-infinite continuous support with a defined lower bound; $x \in [\tau, \infty)$.

By adding a second (location) parameter to the Exponential Distribution, the lower bound of the distribution can be non-zero. The shift increases the mean of the distribution but leaves the higher moments the same. The Shifted Exponential is also a special case of the Generalized Pareto Distribution when its shape parameter (κ) is equal to zero. Adding a shift makes this distribution useful for modeling highly positively skewed data that have a non-zero lower bound. The location parameter can take on any real value; $\tau \in [-\infty, \infty)$.

The same notational ambiguity arises with the Shifted Exponential Distribution as it does with the conventional Exponential Distribution; see the **Exponential Distribution** section for discussion regarding

parameterization. The HEC-SSP implementation of the Shifted Exponential also uses the scale parameter convention.

The Shifted Exponential (β) Distribution uses the Probability Density Function, Cumulative Distribution Function, and Quantile Function shown in Table 12-10. The moments for this distribution are simple in terms of the parameters, as shown in Table 12-11.

Table 12-10. Shifted Exponential Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\beta,\tau) = \beta^{-1} exp\left(-\frac{x-\tau}{\beta}\right) x \geq 0$
Cumulative Distribution Function	$F(x\|\beta,\tau) = 1 - exp\left(-\frac{x-\tau}{\beta}\right) x \geq 0$
Quantile Function	$F^{-1}(p\|\beta,\tau) = \tau - \beta ln(1-p)$

Table 12-11. Shifted Exponential Distribution Moments.

Mean	$E[X] = \beta + \tau$
Variance	$Var[X] = \beta^2$
Skewness	$Skew[X] = 2.$

Gamma Distribution

The Gamma Distribution is a two-parameter, positively-skewed distribution with support for all positive real numbers; $x \in (0, \infty)$.

Flexible and strictly positive, the Gamma Distribution is a popular choice for modeling many kinds of data with mild positive skew and a lower endpoint of zero. An extension of the distribution with a non-zero lower endpoint is the Shifted Gamma Distribution. A re-parameterization of the Shifted Gamma that uses moments as parameters produces the Pearson type III Distribution.

There are two common parameterizations of the Gamma Distribution which leads to extensive notational ambiguity; HEC-SSP uses the shape-scale parameterization with shape κ and scale θ. Both κ and θ are strictly positive. For $\kappa \rightarrow \infty$ the distribution converges to a Normal distribution.

The alternative Gamma(α, β) or shape-rate parameterization is more common in Bayesian inference.

When κ is an integer, the distribution is known as the Erlang Distribution which is used extensively in stochastic processes and queuing theory; it is the distribution of the sum of κ independent Exponential Distributions each with scale parameter θ.

The Gamma(κ, θ) Distribution uses the Probability Density Function and Cumulative Distribution Function (the Quantile Function has no closed form) shown in Table 12-12. The first three moments of the Gamma(κ, θ) Distribution are shown in Table 12-13.

Table 12-12. Gamma Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\kappa,\theta) = \frac{x^{\kappa-1} exp\left(-\frac{x}{\theta}\right)}{\Gamma(\kappa)\theta^{\kappa}}$ where $\Gamma(\cdot)$ is the complete gamma function.
Cumulative Distribution Function	$F(x\|\kappa,\theta) = \frac{\int_0^{\frac{x}{\theta}} t^{\kappa-1} exp(-t)dt}{\Gamma(\kappa)}$ where $\Gamma(\cdot)$ is the complete gamma function. The numerator is the Lower Incomplete Gamma Function, sometimes written $\gamma(\cdot,\cdot)$.
Quantile Function	No closed form.

Table 12-13. Gamma Distribution Moments.

Mean	$E[X] = \kappa\theta$
Variance	$Var[X] = \kappa\theta^2$
Skewness	$Skew[X] = \frac{2}{\sqrt{\kappa}}$

Shifted Gamma Distribution

The Shifted Gamma Distribution is a three-parameter distribution with continuous but variable support on the interval $x \in (\tau, \infty)$ where τ is the

shift (location) parameter of the distribution. When $\tau = 0$ the distribution reduces to the 2-parameter Gamma Distribution. If the Shifted Gamma Distribution is parameterized by its mean, standard deviation and skew instead of location, scale, and shape, it is referred to as the Pearson type III Distribution.

The Shifted Gamma(κ, θ, τ) Distribution uses the Probability Density Function and Cumulative Distribution Function (the Quantile Function has no closed form) shown in Table 12-14. The first three moments of the Shifted Gamma(κ, θ, τ) Distribution are shown in Table 12-15.

Table 12-14. Shifted Gamma Density, Distribution, and Quantile Functions.

Probability Density Function	$$f(x\|\kappa,\theta,\tau) = \frac{(x-\tau)^{\kappa-1} exp\left(-\frac{(x-\tau)}{\theta}\right)}{\Gamma(\kappa)\theta^{\kappa}}$$ where $\Gamma(\cdot)$ is the complete gamma function.
Cumulative Distribution Function	$$F(x\|\kappa,\theta,\tau) = \frac{\int_0^{\frac{x}{\theta}} (y-\tau)^{\kappa-1} exp\big(-(y-\tau)\big)dy}{\Gamma(\kappa)}$$ where $\Gamma(\cdot)$ is the complete gamma function. The numerator is the Lower Incomplete Gamma Function, sometimes written $\gamma(\cdot,\cdot)$.
Quantile Function	No closed form.

Table 12-15. Shifted Gamma Distribution Moments.

Mean	$E[X] = \tau + \kappa\theta$
Variance	$Var[X] = \kappa\theta^2$
Skewness	$Skew[X] = \frac{2}{\sqrt{\kappa}}$

Hosking's Location-Scale-Shape Family

The following three distributions (Generalized Extreme Value, Generalized Logistic, and Generalized Pareto) belong to a family of three-parameter distributions with a common parameterization scheme devised

by Hosking and Wallis (Hosking & Wallis, 1997). Each has location ξ, scale α and shape κ. It is an unwritten rule in mathematics texts that the Greek letter "xi" (ξ), the most difficult to write and to pronounce, should appear at least once (Klugman, Panjer, & Willmot, 2012). The shape parameter κ is important for determining the behavior of the distributions, including their boundedness and the weight of the right tail. It also indicates which other probability distribution has been subsumed by the generalized distribution. Occasionally, these distributions will appear in literature with other parameterizations but the same name, so it is important to check which parameterization is being used.

Generalized Extreme Value Distribution

The Generalized Extreme Value (GEV) Distribution is a flexible three-parameter distribution which subsumes the three extreme-value distributions: the Gumbel (extreme-value type I), Fréchet (extreme-value type II) and Weibull (extreme-value type III) distributions. Which distribution it represents is dependent on the value of the shape parameter κ (kappa).

Precipitation frequency analysis most frequently employs the GEV distribution, or sometimes one of the other members of this location-scale-shape family. In nations other than the United States, GEV is the model of choice for flood frequency analysis. Indeed, the GEV distribution is directly derived by taking the maximum of repeated independent samples from a homogeneous population.

The GEV distribution arises because of the Fisher-Tippett-Gnedenko Theorem, also known as the First Extreme Value Theorem. It states that the distribution of the maximum of repeated samples from a homogenous population converge in distribution to one of three distributions: extreme value I, II, or III. The extreme value distribution to which the maxima converge is dependent on the tail behavior of the population from which the samples are drawn. Roughly, maxima drawn from thin-tailed or upper-bounded distributions tend to be in the Weibull (extreme-value III) domain of attraction; maxima drawn from exponential-tailed populations tend to be in the Gumbel (extreme-value I) domain of attraction; maxima drawn from thick- or heavy-tailed populations tend to be in the Fréchet (extreme-value II) domain of attraction. In practice, the convergence of these samples may occur very slowly, requiring many repeated samples from the population for the limit-state extreme-value distribution to become apparent.

The convention used in HEC-SSP is that the $\kappa < 0$ case is for the extreme-value type II distribution with fixed lower bound and no upper bound and

$\kappa > 0$ is the extreme-value type III distribution with no lower bound and fixed upper bound. Other sources may adopt the opposite convention, where a negative value for the shape parameter implies an upper bound and the type III extreme value distribution. It is important to check which parameterization is being used.

Among this location-scale-shape family, the GEV can be recognized as the double-exponential form. The double-exponential nature is apparent when inspecting its distribution function. In fact, another name for the Gumbel (extreme-value type I) Distribution is the double-exponential distribution. The Probability Density Function, Cumulative Distribution Function, and Quantile Function for the GEV distribution are shown in Table 12-16. The first three moments of the GEV distribution are shown in Table 12-17. It may be noted that the practical range of *kappa* is limited by the possibility of encountering infinite moments.

Table 12-16. GEV Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\xi,\alpha,\kappa) = a^{-1}exp\left(-(1-\kappa)y - exp(-y)\right)$ where $y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$
Cumulative Distribution Function	$F(x\|\xi,\alpha,\kappa) = exp\left(-exp(-y)\right)$ where $y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$
Quantile Function	$F^{-1}(p\|\xi,\alpha,\kappa) = \begin{cases} \xi + \frac{\alpha\left[1-\left(-ln(p)\right)^{\kappa}\right]}{\kappa}, \kappa \neq 0 \\ \xi - \alpha ln\left(-ln(p)\right), \kappa = 0 \end{cases}$

Table 12-17. GEV Distribution Moments.

Mean	$$E[X] = \begin{cases} \xi + \alpha\kappa^{-1}(g_1 - 1), \kappa \neq 0, \kappa > -1 \\ \xi + \alpha\gamma, \kappa = 0 \\ \infty, \kappa \leq -1 \end{cases}$$ where $$g_r = \Gamma(1 - r\kappa)$$ $\Gamma(\cdot)$ is the gamma function. $$\gamma = 0.57721 \ldots$$ γ is the Euler-Mascheroni constant.
Variance	$$Var[X] = \begin{cases} \alpha^2\kappa^{-2}(g_2 - g_1^2), \kappa \neq 0, \kappa > -\frac{1}{2} \\ \alpha^2 \frac{\pi^2}{6}, \kappa = 0 \\ \infty, \kappa \leq -\frac{1}{2} \end{cases}$$ where $$\pi = 3.14159 \ldots$$
Skewness	$$Skew[X] = \begin{cases} sgn(\kappa) \frac{g_3 - 3g_2g_1 + 2g_1^3}{(g_2 - g_1^2)^{\frac{3}{2}}}, \kappa \neq 0, \kappa > -\frac{1}{3} \\ \frac{12\sqrt{6}\zeta(3)}{\pi^3} \approx 1.14, \kappa = 0 \\ \infty, \kappa \leq -\frac{1}{3} \end{cases}$$ where $\zeta(\cdot)$is the Riemann zeta function.

Generalized Logistic Distribution

The Generalized Logistic Distribution (GLO) is a heavy-tailed probability distribution with support dependent on the shape parameter κ (kappa). Positive κ implies an upper bounded distribution while negative κ implies a lower bound, with the $\kappa = 0$ case being unbounded. The $\kappa = 0$ case is the Logistic Distribution, which is symmetrical.

Due to the heavy-tailed nature of the GLO, it is useful for modeling data where extreme deviations from the mean are to be expected more often

than under other distributions. The $\kappa = 0$ case (Logistic Distribution) is often used as a heavy-tailed alternative to the Normal Distribution. GLO most frequently appears in precipitation frequency analysis alongside the GEV and GPA.

There are many distributions referred to as the "Generalized Logistic Distribution," and this is simply another version of it. As implemented in HEC-SSP, it was meant to align with the definitions of the Generalized Extreme Value and Generalized Pareto Distributions generalized by Hosking and Wallis (1996) with location ξ, scale α, and shape κ.

The Probability Density Function, Cumulative Distribution Function, and Quantile Function are shown in Table 12-18. The logit function $log\left(\frac{p}{1-p}\right)$ is at the heart of the quantile function, which is the source of the name for the distribution. The first three moments of the GLO are shown in Table 12-19.

Table 12-18. GLO Density, Distribution, and Quantile Functions.

Probability Density Function	$$f(x\|\xi,\alpha,\kappa) = \frac{a^{-1}exp(-(1-\kappa)y)}{\left(1+exp(-y)\right)^2}$$ where $$y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$$
Cumulative Distribution Function	$$F(x\|\xi,\alpha,\kappa) = \left(1+exp(-y)\right)^{-1}$$ where $$y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$$
Quantile Function	$$F^{-1}(p\|\xi,\alpha,\kappa) = \begin{cases} \xi + \frac{\alpha\left[1-\left(\frac{p}{1-p}\right)^{\kappa}\right]}{\kappa}, \kappa \neq 0 \\ \xi - \alpha ln\left(\frac{p}{1-p}\right), \kappa = 0 \end{cases}$$

Table 12-19. GLO Distribution Moments.

Mean	$$E[X] = \begin{cases} \xi + \alpha\kappa^{-1}(1 - h_1), \kappa \neq 0, \kappa > -1 \\ \xi, \kappa = 0 \\ \infty, \kappa \leq -1 \end{cases}$$ where $$h_r = \frac{r\pi\kappa}{sin(r\pi\kappa)}$$ $$\pi = 3.14159 \ldots$$
Variance	$$Var[X] = \begin{cases} \alpha^2\kappa^{-2}(1 - 2h_1 + h_2), \kappa \neq 0, \kappa > -\frac{1}{2} \\ \frac{\alpha^2\pi^2}{3}, \kappa = 0 \\ \infty, \kappa \leq -\frac{1}{2} \end{cases}$$
Skewness	$$Skew[X] = \begin{cases} sgn(\kappa)\frac{1 - 3h_1 + 3h_2 - h_3}{(1 - 2h_1 + h_2)^{\frac{3}{2}}}, \kappa \neq 0, \kappa > -\frac{1}{3} \\ 0, \kappa = 0 \\ \infty, \kappa \leq -\frac{1}{3} \end{cases}$$

Generalized Pareto Distribution

The Generalized Pareto Distribution (GPA, for consistency with Hosking's notation; sometimes GPD elsewhere) is a flexible three-parameter probability distribution with fixed lower bound and location parameter ξ (xi). The distribution may also be upper bounded when the shape parameter κ (kappa) is positive. When κ is zero, the distribution reduces to a shifted exponential distribution, which makes it useful for modeling exponential variates with lower bound ξ instead of zero.

A feature of the GPA is the control provided by the location parameter ξ, which determines the lower bound of the distribution. In some applications, the GPA is treated as a two-parameter distribution where ξ is known and specified by the user. Alternatively, it may be estimated from the data. ξ may be referred to as the "threshold" for the GPA, which comes from the derivation of the distribution.

The GPA arises as a result of the Pickands-Balkema-de Haan Theorem, also known as the Second Extreme Value Theorem. The theorem states that subsamples exceeding a sufficiently high threshold from repeated

samples of a homogeneous population converge in distribution to the GPA Distribution. In other words, if repeated independent samples are taken from a population, and only the values in those samples that are greater than a selected value are retained, then those retained values will follow the GPA distribution.

In hydrology, the GPA allows for straightforward analysis of partial duration series (peaks-over-threshold) flood series. Rainfall frequency analysis frequently makes use of the GPA, especially in cases where only rainfall maxima exceeding a selected threshold are retained. It also gets extensive use in actuarial science as a model for payouts when claims exceed a deductible.

The form of the Probability Density, Cumulative Distribution, and Quantile functions are functionally very similar for the GEV, GLO, and GPA distributions (by design) and are shown in Table 12-20. The GPA uses the first three moments shown in Table 12-21.

Table 12-20. GPA Density, Distribution, and Quantile Functions.

Probability Density Function	$$f(x\|\xi,\alpha,\kappa) = a^{-1}exp(-(1-\kappa)y)$$ where $$y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$$
Cumulative Distribution Function	$$F(x\|\xi,\alpha,\kappa) = 1 - exp(-y)$$ where $$y = \begin{cases} -\kappa^{-1}ln\left[1-\frac{\kappa(x-\xi)}{\alpha}\right], \kappa \neq 0 \\ \frac{(x-\xi)}{\alpha}, \kappa = 0 \end{cases}$$
Quantile Function	$$F^{-1}(p\|\xi,\alpha,\kappa) = \begin{cases} \xi + \frac{\alpha[1-(1-p)^{\kappa}]}{\kappa}, \kappa \neq 0 \\ \xi - \alpha ln(1-p), \kappa = 0 \end{cases}$$

Table 12-21. GPA Distribution Moments.

Mean	$E[X] = \begin{cases} \xi + \alpha(1+\kappa)^{-1}, \kappa > -1 \\ \infty, \kappa \leq -1 \end{cases}$
Variance	$Var[X] = \begin{cases} \dfrac{\alpha^2}{(1+\kappa)^2(1+2\kappa)}, \kappa > -\frac{1}{2} \\ \infty, \kappa \leq -\frac{1}{2} \end{cases}$
Skewness	$Skew[X] = \begin{cases} \dfrac{2(1-\kappa)\sqrt{1+2\kappa}}{(1+3\kappa)}, \kappa > -\frac{1}{3} \\ \infty, \kappa \leq -\frac{1}{3} \end{cases}$

Gumbel Distribution

The Gumbel, or Extreme-Value type I Distribution, is a two-parameter distribution with continuous infinite support and fixed positive skewness ≈ 1.14. The Generalized Extreme Value (GEV) distribution converges to a Gumbel Distribution as its shape parameter approaches zero. Use of the Gumbel Distribution instead of the GEV is often at the user's discretion. For data with a small sample size and GEV κ close to zero, the Gumbel makes a sane and parsimonious choice. Gumbel is a particularly safe choice when modeling maxima of an exponential-tail population, as those populations tend to lie within the extreme-value I maximum domain of attraction. For the Probability Density Function, Cumulative Distribution Function, Quantile Function and moments, see the GEV Distribution with $\kappa = 0$.

Logistic Distribution

The Logistic Distribution is a two-parameter distribution with continuous infinite support. It is symmetrical and nearly bell-shaped like the Normal Distribution, with heavier tails; it has fixed excess kurtosis = 1.2 (Normal excess kurtosis ≡ 0).

Historically, the Logistic Distribution was sometimes used in place of the Normal Distribution for computational convenience, as neither the Cumulative Distribution Function nor the Quantile Function of the Normal Distribution has closed forms, while they do for the Logistic. For non-extreme values of the distributions, inferences made from the Logistic are close to that of the Normal. However, when continuing into the tails of the distributions, the difference between the two can be profound. Its

primary use in modern statistics is as the random error term in logistic regression.

The Logistic Distribution's two parameters are μ (location) and s (scale). It uses the Probability Density Function, Cumulative Distribution Function, and Quantile Function shown in Table 12-22. The logit function appears in the Quantile Function. The first three moments of the Logistic Distribution are found in Table 12-23.

Table 12-22. Logistic Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\mu,s) = \frac{exp\left(-\frac{x-\mu}{s}\right)}{s\left(1+\exp\left(-\frac{x-\mu}{s}\right)\right)^2}$
Cumulative Distribution Function	$F(x\|\mu,s) = \left(1+exp\left(-\frac{x-\mu}{s}\right)\right)^{-1}$
Quantile Function	$F^{-1}(p\|\mu,s) = \mu + s\ ln\left(\frac{p}{1-p}\right)$

Table 12-23. Logistic Distribution Moments.

Mean	$E[X] = \mu$
Variance	$Var[X] = \frac{s^2\pi^2}{3}$
Skewness	$Skew[X] = 0$

Log-Logistic Distribution

The Log-Logistic Distribution is a two-parameter positively-skewed distribution that describes random variables whose logarithm is Logistic-distributed. It has continuous support for all non-negative real numbers. It is similar to the Log-Normal Distribution, except it has heavier tails. When used in econometrics it is referred to as the Fisk Distribution and used to model the distribution of income.

HEC-SSP reports the parameters of the Log-Logistic Distribution as the location and scale parameters μ and s of a Logistic Distribution fit to the natural logarithm of the input dataset. Taking $y = ln(x)$, the Probability

Density Function, Cumulative Distribution Function and Quantile Function of the Log-Logistic Distribution are shown in Table 12-24. The most straightforward way to obtain the real-space moments of the Log-Logistic Distribution is to use the transform $\alpha = exp(\mu), \beta = \frac{1}{s}$ which changes the parameterization to scale-shape, and compute (noting that moments only exist if their order is less than β), as shown in Table 12-25.

Table 12-24. Log-Logistic Density, Distribution, and Quantile Functions.

Probability Density Function	$f(y\|\mu,s) = \frac{exp\left(-\frac{y-\mu}{s}\right)}{s\left(1+\exp\left(-\frac{y-\mu}{s}\right)\right)^2}$
Cumulative Distribution Function	$F(y\|\mu,s) = \left(1+exp\left(-\frac{y-\mu}{s}\right)\right)^{-1}$
Quantile Function	$F^{-1}(p\|\mu,s) = \mu + s\ ln\left(\frac{p}{1-p}\right)$

Table 12-25. Log-Logistic Distribution Moments.

Mean	$E[X] = \frac{\pi\alpha}{\beta} csc\left(\frac{\pi}{\beta}\right)$ where $\pi = 3.14159\ ...$ $csc(\cdot)$ is the cosecant function.
Variance	$Var[X] = \frac{2\pi\alpha^2}{\beta} csc\left(\frac{2\pi}{\beta}\right) - \frac{\pi^2\alpha^2}{\beta^2} csc\left(\frac{\pi}{\beta}\right)^2$
Skewness	$Skew[X] = \frac{2\pi^3\alpha^3}{\beta^3} csc\left(\frac{\pi}{\beta}\right)^3 - \frac{6\pi^2\alpha^3}{\beta^2} csc\left(\frac{\pi}{\beta}\right) csc\left(\frac{2\pi}{\beta}\right) + \frac{3\pi\alpha^3}{\beta} csc\left(\frac{3\pi}{\beta}\right)$

Normal Distribution

The ubiquitous Normal Distribution is a two-parameter symmetrical distribution with infinite support. It has two parameters, location $\mu \in \mathbb{R}$

and squared-scale $\sigma^2 > 0$, which also happen to be the moments of the distribution. For symmetrical data, the Normal Distribution is generally an user's first choice as a model and is reasonable for a wide range of applications. Note that the support is infinite, so for strictly positive data, inference using the Normal Distribution will result in non-zero probability assigned to negative-valued outcomes. When $\mu = 0, \sigma^2 = 1$ the distribution is said to be Standard Normal, usually notated as Z. Normally-distributed data with any mean and variance can be transformed to Standard Normal using the transform $Z \equiv \frac{x-\mu}{\sigma}$. The Probability Density Function, Cumulative Distribution Function, and Quantile Function of the Normal Distribution are shown in Table 12-26. The moments are straightforward and are shown in Table 12-27.

Table 12-26. Normal Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\mu,\sigma^2) = \frac{1}{\sqrt{2\pi\sigma^2}} exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$ where $\pi = 3.14159 \ldots$
Cumulative Distribution Function	No closed form.
Quantile Function	No closed form.

Table 12-27. Normal Distribution Moments.

Mean	$E[X] = \mu$
Variance	$Var[X] = \sigma^2$
Skewness	$Skew[X] = 0$

Excess kurtosis is defined in terms of the Normal Distribution, which has a standard kurtosis of 3. Thus, excess kurtosis is the amount by which a distribution exceeds the kurtosis of the Normal Distribution. Probability distributions with positive excess kurtosis are heavier-tailed than the Normal Distribution and are called leptokurtic. Distributions with negative excess kurtosis are thinner-tailed than the Normal and are called

platykurtic. Those with excess kurtosis close to zero are called mesokurtic.

Log-Normal Distribution

The Log-Normal Distribution is a two-parameter positively skewed distribution that describes random variables whose logarithm is Normal-distributed. It has continuous support for all non-negative real numbers. For certain applications, a different base of logarithm may be desired, with the most common being log base *e* (natural log) and base 10. They are functionally identical, and will be shown below generically using the function $log_b(\cdot)$ where *b* is the base. The parameters μ and σ are not location and scale parameters for a Log-Normal distributed random variable, they are the location and scale parameters of a Normal-distributed logarithm $log_b(x)$. The Probability Density Function, Cumulative Distribution Function and Quantile Function of the Log-Normal Distribution are shown in Table 12-28. The moments are shown in Table 12-29.

Table 12-28. Log-Normal Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|\mu,\sigma^2) = \frac{1}{x\sqrt{2\pi\sigma^2}} b^{-\frac{(log_b(x)-\mu)^2}{2\sigma^2}}$ where $\pi = 3.14159 \ldots$
Cumulative Distribution Function	No closed form.
Quantile Function	No closed form.

Table 12-29. Log-Normal Distribution Moments.

Mean	$E[X] = b^{\mu}$
Variance	$Var[X] = \left[b^{\sigma^2} - 1\right] b^{2\mu+\sigma^2}$
Skewness	$Skew[X] = \left(b^{\sigma^2} + 2\right)\sqrt{b^{\sigma^2} - 1}$

Pearson Type III Distribution

The Pearson Type III distribution is one of the seven distributions in the Pearson family. The Pearson Type III (PE3) is a flexible, three parameter distribution with skewness controlled by its shape parameter γ (gamma). PE3 converges to a Normal Distribution as its shape parameter approaches zero. The distribution is an extension of the Gamma Distribution that gives explicit control over the model's support and as a result its symmetry. When the shape parameter is positive, the model is lower-bounded and right (positive) skewed; conversely, when it is negative the model is upper-bounded and left (negative) skewed. As the shape parameter approaches zero, the distribution becomes more symmetrical and the upper (or lower) bound approaches infinity (negative infinity) until the result is a normal distribution.

PE3 is parameterized by its moments, mean μ, standard deviation σ, and skewness γ. When $\gamma = 0$ the PE3 reduces to a Normal Distribution with mean μ and variance σ^2. For the Probability Density Function, Cumulative Distribution Function and Quantile Function, use the following transforms and see the Shifted Gamma Distribution: $\kappa = \frac{4}{\gamma^2}, \theta = \frac{\sigma\gamma}{2}, \tau = \mu - 2\frac{\sigma}{\gamma}$.

The distribution has been described occasionally in literature as a "skewed normal" distribution, but this terminology has been used to describe many generalizations or extensions of the normal distribution that allow for a third (shape) parameter. Its most common usage is for modeling annual maximum stream discharge, where it is applied to logarithmically transformed values and referred to as the Log-Pearson Type III Distribution. However, it may be used without first logarithmically transforming the data.

Log-Pearson Type III Distribution

The Log-Pearson Type III Distribution (LP3) is a flexible three-parameter distribution that models random variables whose logarithms are Pearson Type III-distributed. LP3originally arose as a solution to fitting a model to annual maximum stream discharges that did not form a straight line on normal probability paper with a logarithmically transformed ordinate. Generally, LP3is applied with the base-10 logarithm and the moments are expressed as the mean, standard deviation and skewness of the logarithmically-transformed data. After taking $y = log_{10}(x)$ find the mean, standard deviation, and skewness of the sample y and proceed to fitting the PE3 Distribution.

Note that Bulletin 17 procedures include additional considerations for differing types of data in the input, and should be thought of as a

parameter estimation procedure similar to, but not the same as, the method of moments for the LP3 Distribution.

Uniform Distribution

The Uniform Distribution is a simple, symmetrical probability distribution that assigns equal probability density to all outcomes on the closed interval [*A*, *B*]. HEC-SSP includes the Uniform Distribution as a convenience, but it is rarely used in practice. Its most common usage is in Bayesian inference as a prior distribution when little to no information is known about the parameter. It has no mode and may also be called the Rectangular Distribution, contrasting the Triangular Distribution below. The most common usage of the Uniform Distribution is with $A = 0, B = 1$ which is usually notated as *U*(0, 1) and referred to as the Standard Uniform Distribution. Through a property called the Probability Integral Transform, any random variable can be transformed to a Standard Uniform Distribution and vice versa. The consequence of this transform is that random samples can be drawn from any probability distribution with a Quantile Function by supplying samples from a *U*(0, 1) random variable as the argument *p*. Random number generation algorithms generally provide *U*(0, 1) random variables, and inverse transform sampling then allows for random samples of many probability distributions to be generated. The Probability Density Function, Cumulative Distribution Function, and Quantile Function of the Uniform Distribution are shown in Table 12-30. The moments of the Uniform Distribution are shown in Table 12-31.

Table 12-30. Uniform Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|A,B) = \frac{1}{B-A}$
Cumulative Distribution Function	$F(x\|A,B) = \begin{cases} 0, x < A \\ \frac{x-A}{B-A}, x \in [A,B) \\ 1, x \geq B \end{cases}$
Quantile Function	$F^{-1}(p\|A,B) = (B-A)p + A$

Table 12-31. Uniform Distribution Moments.

Mean	$E[X] = \frac{A + B}{2}$
Variance	$Var[X] = \frac{(B - A)^2}{12}$
Skewness	$Skew[X] = 0$

Triangular Distribution

The Triangular Distribution is a continuous, unimodal distribution on the closed interval [*A*, *B*] generally used as a means for expressing subjective probability about outcomes that can be specified by a minimum, maximum and most likely value. It is an extension of the Uniform Distribution that adds a third parameter, $C \in [A, B]$ which is the location of the mode of the distribution, noting that the mode can be at one of the endpoints. The Probability Density Function, Cumulative Distribution Function, and Quantile Function of the Triangular Distribution are shown in Table 12-32. The moments of the Triangular Distribution are shown in Table 12-33.

Table 12-32. Triangular Density, Distribution, and Quantile Functions.

Probability Density Function	$f(x\|A,B,C) = \begin{cases} \frac{2(x-A)}{(B-A)(C-A)}, x \le C \\ \frac{2(B-x)}{(B-A)(B-C)}, x > C \end{cases}$
Cumulative Distribution Function	$F(x\|A,B,C) = \begin{cases} \frac{(x-A)^2}{(B-A)(C-A)}, x \le C \\ 1 - \frac{(B-x)^2}{(B-A)(B-C)}, x > C \end{cases}$
Quantile Function	$F^{-1}(p\|A,B,C) = \begin{cases} A + \sqrt{p(B-A)(C-A)}, x \le \frac{C-A}{B-A} \\ B - \sqrt{(1-p)(B-A)(B-C)}, x > \frac{C-A}{B-A} \end{cases}$

Table 12-33. Triangular Distribution Moments.

Mean	$E[X] = \frac{A + B + C}{3}$
Variance	$Var[X] = \frac{1}{18}(A^2 - A(B + C) + B^2 - BC + C^2)$
Skewness	$Skew[X] = \frac{1}{270}(A + B - 2C)(2A - B - C)(A - 2B + C)$

Goodness of Fit Tests

Goodness of fit tests are intended to inform the user if there are large deviations in the data away from the selected and calibrated probability model. The tests are not an indication that the data necessarily come from the selected probability distribution, just that the data do not significantly deviate from it. The choice of a probability distribution and fitting method to model data should not be based solely on the results of comparing goodness of fit tests; there should always be a mathematical basis for selecting a probability distribution as a model for data. The tests outlined below may help rule out one or more distributions when multiple are valid for the data being modeled.

Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov, or K-S Test, is a nonparametric method for checking equality of two continuous probability distributions. When the distribution of data is approximated with an empirical distribution, equality can be checked between the empirical distribution and an alternative model for the data. The K-S Test behaves by finding the maximum difference in CDF between the proposed model for the data and the empirical distribution of the data. The program will provide a test statistic which is the result of previously-mentioned computations. In practice, if the difference is large based on the sample size, the null hypothesis that the data come from the proposed model would be rejected.

Chi-Squared Test

The Chi-Squared Test (more specifically, Pearson's Chi-Squared Test) is a parametric goodness of fit test. The test behaves by creating a number of discrete classes or "bins" for the data, and comparing the observed

proportion of the data in each bin compared to the expected proportion of the data according to the model. Similar to the K-S test, the program will provide a test statistic which is the result of previously-mentioned computations. In practice, if the proportions are significantly different, then the null hypothesis that the data arise from the proposed model would be rejected. The name for the test comes from the distribution of the differences of the proportion, which follow the Chi-Squared Distribution. The critical value for rejection can be computed from a Chi-Squared Distribution with $k - 1$ degrees of freedom, where k is the number of bins used in the test.

Results

Once a distribution | fitting method combination has been accepted, the user can view output within the **Results** tab. When the user selects the **Results** tab, the window will appear as shown in Figure 12-19. Both tabular and graphical results are included. The Results tab contains information related to the original data, filtered data, and selected parametric model. This information includes:

- Statistics
- Distribution Parameters
- Goodness of Fit
- Frequency Curves
- Plots

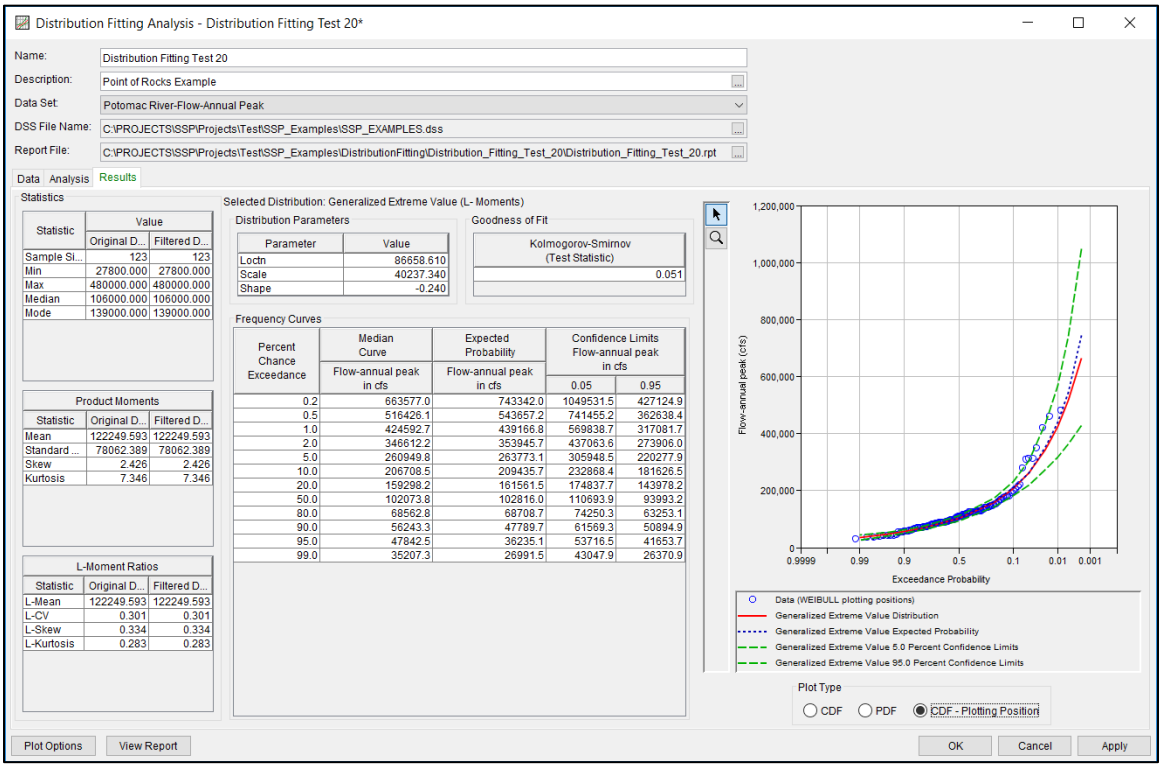


Figure 12-19. Distribution Fitting Results Tab.

Viewing and Printing Results

The user can view the output for the distribution fitting analysis directly from the Distribution Fitting Analysis editor (tabular and graphical output).

Tabular Output

Once a distribution | fitting method combination has been accepted, the user can view the tabular output by selecting the **Results** tab. Tabular results can be opened by double clicking on the plot in the **Results** tab and in the opened plot selecting **File→Tabulate**.

Graphical Output

Graphical output of the distribution fitting analysis can be obtained by selecting the **Results** tab. The CDF, PDF, and/or CDF-Plotting Position plot can be opened in a new window by double clicking on the plot, as shown in Figure 12-20. The distribution fitting plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the

window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: **windows metafile**, **postscript**, **JPEG**, and **portable network graphic**.

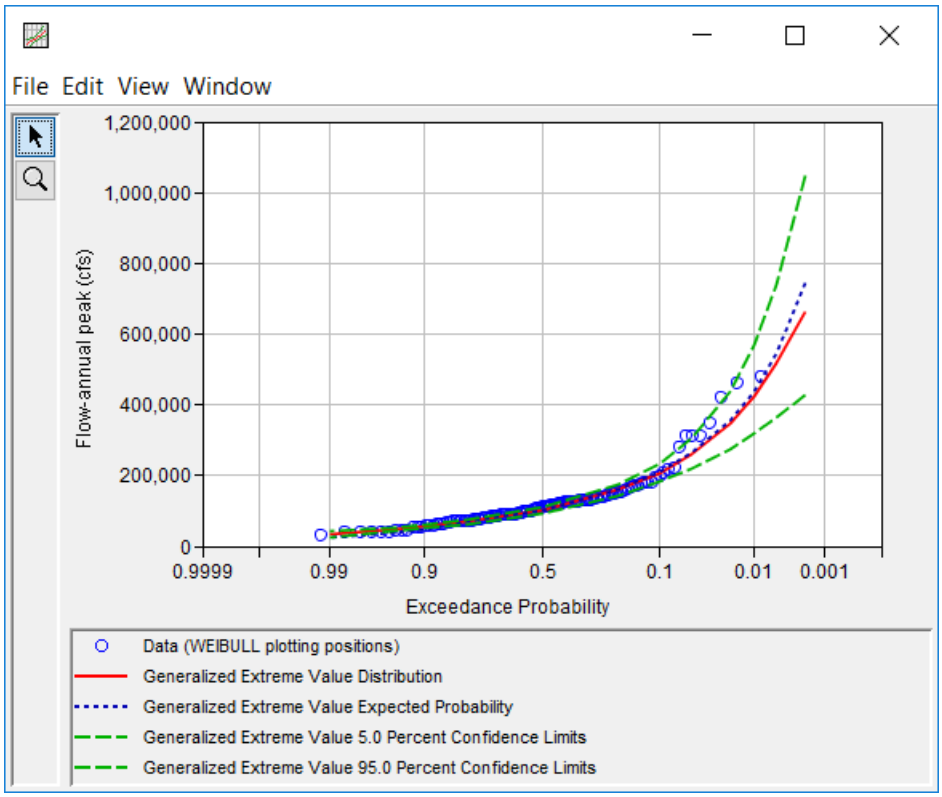


Figure 12-20. Distribution Fitting Results CDF-Plotting Position Plot.

As explained previously, the data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. In addition, a shortcut menu will

appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of the axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the distribution fitting analysis computations are performed. The report file lists the input data, user settings, and the results.

Press the **View Report** button at the bottom of the Distribution Fitting Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 12-21.

The original data, filtered data, parameterized distributions, goodness of fit test statistics, and accepted distribution | fitting method combination is contained within the **Report** output. Additionally, the distribution fitting report can be opened using the **Results→Report** option in the Results dropdown menu at the top of the SSP window.

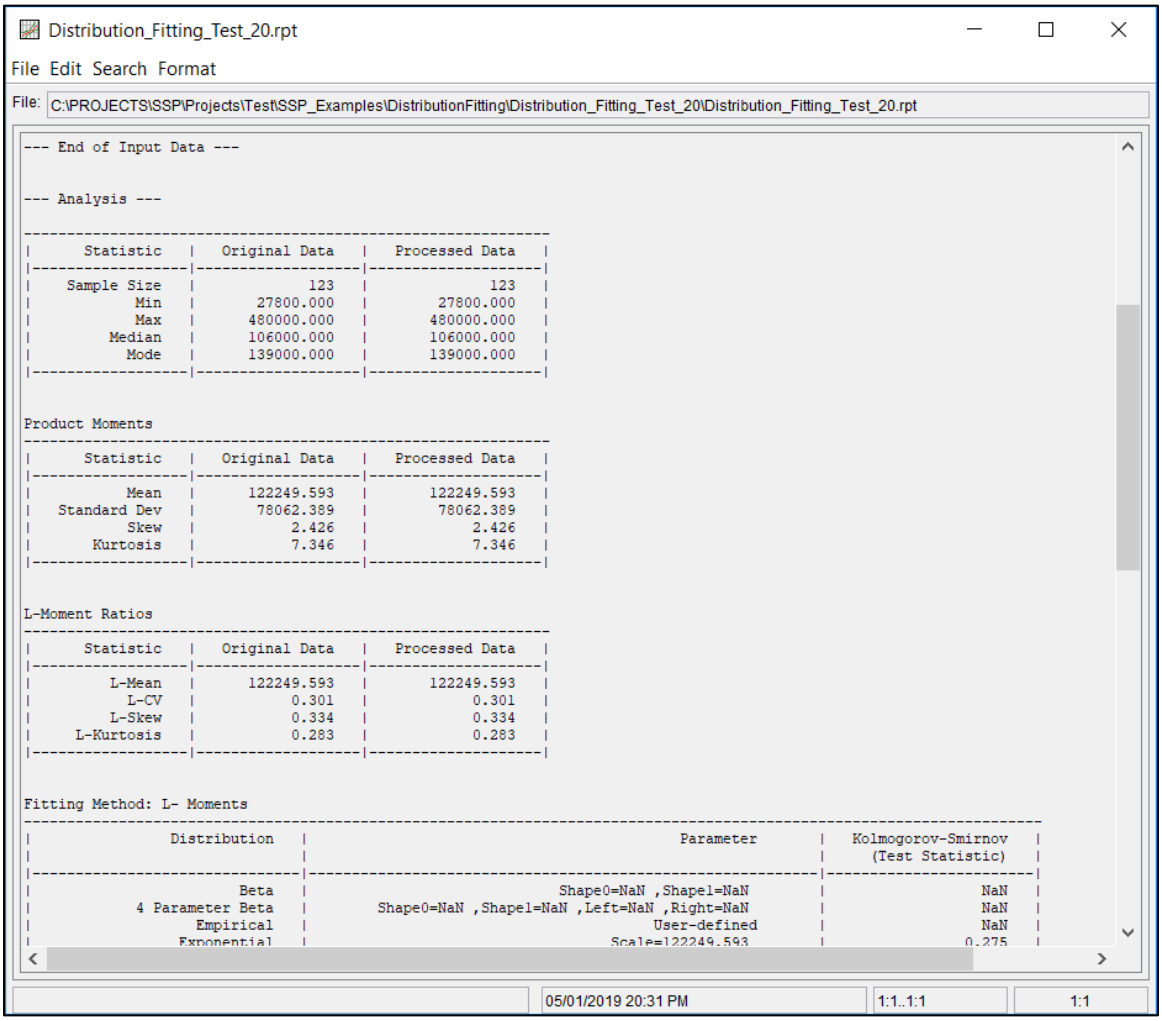


Figure 12-21. Distribution Fitting Analysis Report File.

CHAPTER 13

Performing a Mixed Population Analysis

The current version of HEC-SSP allows the user to compute mixed population curves. In this type of analysis, multiple frequency curves (that are representative of different causal mechanisms) can be combined using the probability of union concept to compute a frequency curve that reflects the occurrence of more than one type of flood in a year. In many watersheds, multiple types of flood-causing mechanisms are capable of generating large flows in a given year. The annual maximum flood for a given year is the largest of these flows. Generally, the annual maximum series (AMS) for a stream is analyzed without regard for the type of flood that caused each individual annual maximum; however, in many cases the AMS may be made of a mixture of floods of varying cause. A foundational assumption to estimating a population probability distribution from a limited sample is that the sample is representative of the population and made of independent and identically distributed (IID) observations. When multiple flood types create the AMS, the assumption of identical distribution can become tenuous, affecting the ability to make inferences about rare floods. Additionally, the behavior of the right-hand tail typically used in hydrologic studies may be controlled largely by a type of flood mechanism that is less dominant in the more-frequent part of the annual maximum flood frequency curve. Treating multiple flood types as separate, IID samples of floods of a particular cause allows for examination of the frequency of floods per type of flood. Once frequency curves are fit to each mechanism, they can be combined within a mixed population analysis to estimate the occurrence of more than one type of flood in a year. This chapter discusses in detail how to use the Mixed Population Analysis editor within HEC-SSP.

Contents

- Starting a New Analysis
- General Settings
- Frequency Curves
- Viewing and Printing Results

Starting a New Analysis

A Mixed Population Analysis can be started in two ways, either by right clicking on the Mixed Population Analysis folder in the study explorer and selecting **New**, or by going to the **Analysis** menu and selecting **New** and then **Mixed Population Analysis**. When a new Mixed Population Analysis is selected, the user is required to first enter a **Name** for the analysis and an optional **Description**. The Mixed Population Analysis editor will not allow further edits by the user until the name is defined. Once a Name is entered, the **DSS File Name** and **Report File** will automatically be filled out. The DSS filename is by default the study DSS file. The report file is given the same name as the analysis with the extension ".rpt". The Mixed Population Analysis editor is shown in Figure 13-1.

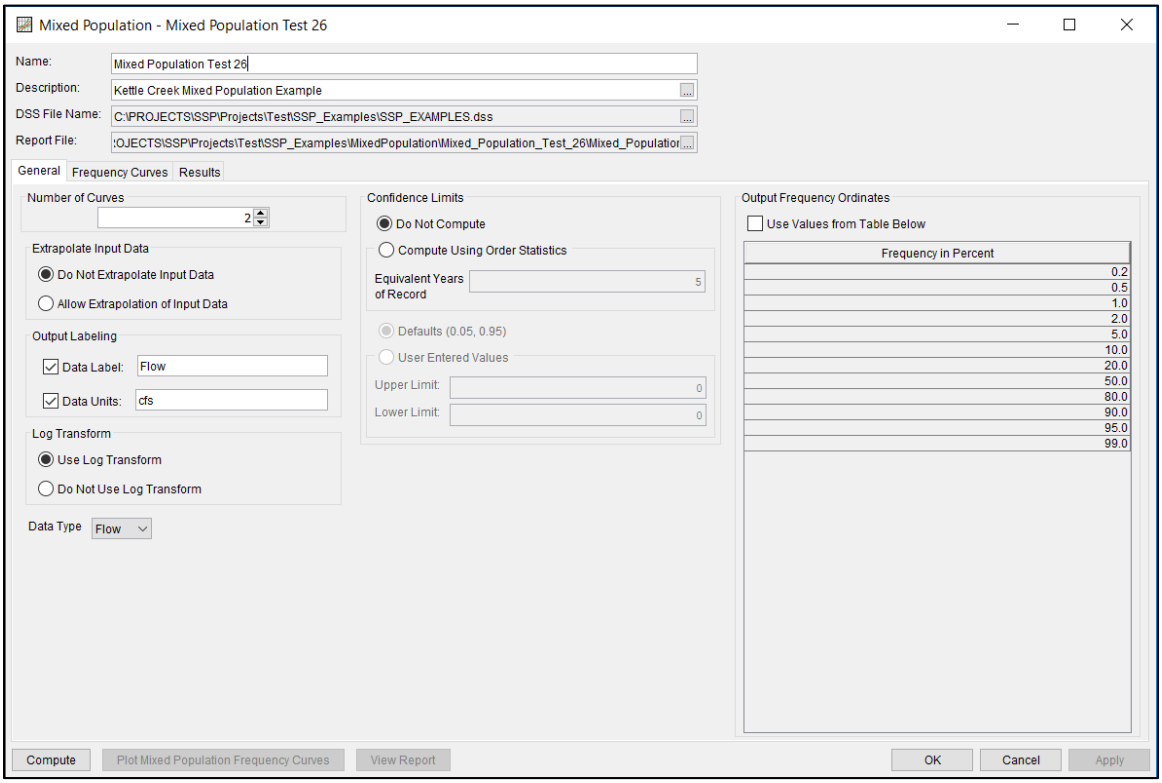


Figure 13-1. Mixed Population Analysis Editor.

General Settings

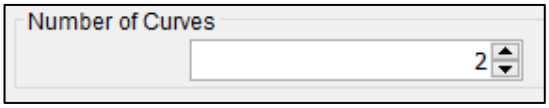
Once the analysis name has been entered, the user can begin defining the analysis. Contained on the Mixed Population Analysis editor are three tabs. The tabs are labeled **General**, **Frequency Curves**, and **Results**.

The first tab contains general settings for performing the Mixed Population Analysis. These settings include:

- Number of Curves
- Extrapolate Input Data
- Output Labeling
- Log Transform
- Data Type
- Confidence Limits
- Output Frequency Ordinates

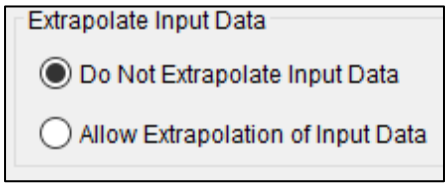
Number of Curves

This option lets the user choose the number of input frequency curves that will be used to compute a mixed population frequency curve. The Frequency Curves tab will update based on the number of curves specified in this panel.



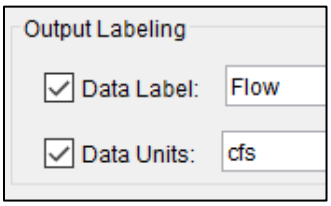
Extrapolate Input Data

This option allows the user to choose whether the imported data may be extrapolated during the mixed population computations. When using either imported results from an Existing Analysis or Manual Entry, the computations will not extrapolate input data, by default. If one or more input frequency curves do not contain enough information to compute a mixed population curve for the specific output frequency ordinates, the results will be left blank. When this extrapolation of the input data is allowed (and imported results from an Existing Analysis and/or Manual Entry are being used), a probability of 1.0 will be assumed for all values that are less than the smallest entered value. Conversely, a probability of 0 will be assumed for all values that are greater than the largest entered value. When using analytical distributions, extrapolation can be performed automatically.

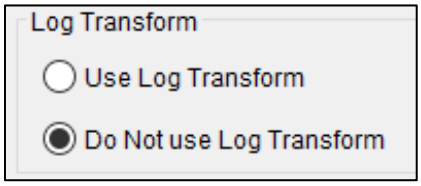


Output Labeling

This option allows the user to enter labels for data contained in the output tables and plots. The user can enter the name of the data as well as the data units. The output labeling does not result in the conversion of data from one unit system to another; it only affects what is displayed on table headings and the y-axis of the results plot.



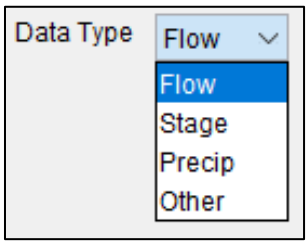
Log Transform



There are two options contained within the **Log Transform** setting: **Use Log Transform** and **Do not use Log Transform**. This setting only affects the y-axis of subsequent plots. If the user selects **Use Log Transform**, the y-axis of all plots will use a logarithmic scale (base 10). If the user selects **Do Not Use Log Transform**, the y-axis of all plots will use a linear scale. This option does not affect any of the computations. The default setting is **Do Not Use Log Transform**.

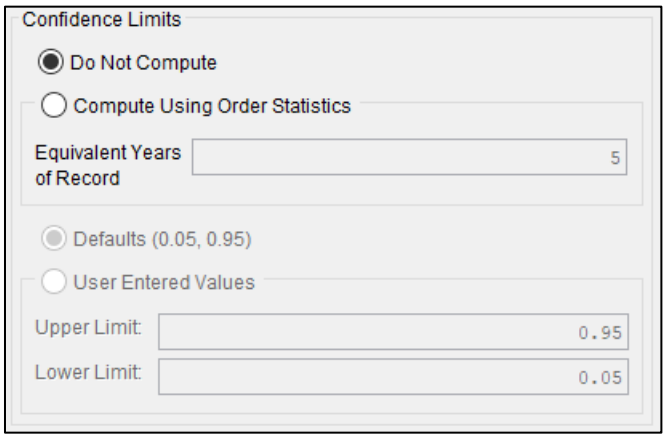
Data Type

The **Data Type** selection is used, in conjunction with the settings on the Tools | Options | Results tab, to define the precision of tabular data on both the Frequency Curves and Results tabs. In addition, the Data Type is used (in conjunction with the **Equivalent Years of Record** option) to compute confidence limits (when requested by the user) using the order statistics method that is discussed in ETL 1110-2-537. The default Data Type is **Flow**. To select a different data type, click the drop down menu and select either **Stage**, **Precip** (Precipitation), or **Other**.



Confidence Limits

The computed mixed population curve is only an estimate of the probability distribution of the larger parent population. Confidence limits can be used to provide a measure of the uncertainty of the estimated



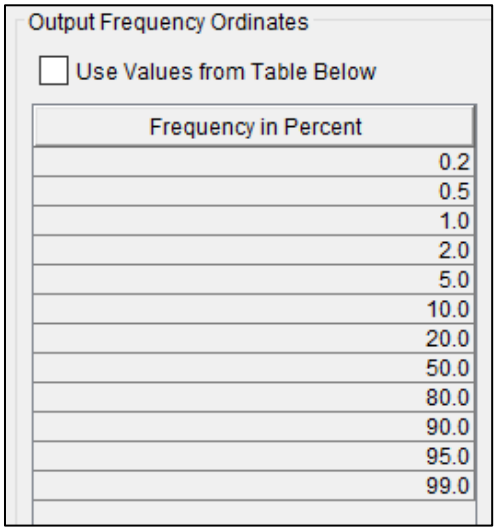
exceedance probability of a selected discharge, stage, precipitation depth, etc. or a measure of the uncertainty of the discharge, stage, precipitation depth, etc. at a selected exceedance probability.

By default, confidence limits will not be computed within a Mixed Population Analysis. However, the user has the option to compute confidence limits using the order statistics method, which is discussed in ETL 1110-2-537. The **Equivalent Years of Record** must be defined when using this method.

When computing confidence limits, the default interval will be 90 percent confidence (i.e. the 5% and 95% confidence limits). The confidence limits must be entered in decimal form (i.e. 95% = 0.95, and 5% = 0.05). The user has the option to override the default values and enter whatever values they would like for the confidence limits.

Output Frequency Ordinates

This option allows the user to change or add to the frequency ordinates for which the resulting frequency curve and confidence limits are computed. The default values listed in percent chance exceedance are 0.2, 0.5, 1, 2, 5, 10, 20, 50, 80, 90, 95, and 99. Check the box next to **Use Values from Table below** to change or add additional values. Once this box is checked, the user can add/remove rows and edit the frequency values. To add or remove a row from the table, select the row(s), place the mouse over the highlighted row(s) and click the right mouse button. The shortcut menu contains options to **Insert Row(s), Append a Row**, and



Delete Row(s). The program will use the default values, even if they are not contained in the table, when the **Use Values from Table below** option is not checked. Finally, all values in the table must be between 0 and 100. Note that these values have no impact on the computed frequency curve, but rather only the values of the curve that are reported.

Frequency Curves

The Frequency Curves tab is used to define the input frequency curves for that will be used to compute the mixed population curve. As shown in Figure 13-2, the Frequency Curves tab contains a panel for each frequency curve; the number of frequency curves is defined on the General tab. Three options are available to define these flow-frequency curves. First, the user can select an existing Bulletin 17 or General Frequency Analysis and import the results of said analysis. Second, the user can input the frequency information for *all* of the required ordinates. Third, the user can select either Log Normal (base 10), Generalized Extreme Value, or the Log Pearson III distribution, define their required inputs, and compute the resultant frequency curve. Users can use one or more forms of input within any Mixed Population Analysis.

If **Use Existing Analysis** is selected, an existing analysis is designated, and the **Import** button is clicked, the program will import the resultant frequency curve to populate the table. The program will NOT import the statistics from the selected analysis. If the selected Bulletin 17 or General Frequency Analysis is modified or recomputed after being imported, a red warning message will be shown near the top of the editor informing the user that the imported results are out of date. In addition, the Import button will be highlighted red. Upon clicking the Import button, the table will be updated, the message will disappear, and the button highlighting will be removed. When importing the results from an existing analysis, the frequency curve ordinates in the **Percent Chance Exceedance** columns will be the same as those in the Bulletin 17 or General Frequency Analysis, which may or may not match the Output Frequency ordinates for the Mixed Population Analysis that were defined on the General tab.

If **Manual Entry** is selected, the frequency curve table will become interactive and editable. Initially, the **Percent Chance Exceedance** column will be populated with the Output Frequency ordinates that were specified on the General tab. The user may add/remove/modify these ordinates. However, if the program cannot find one or more probability ordinates (which were entered on the General tab), the compute will attempt to interpolate the required information. However, the program

will not extrapolate unless the Allow Extrapolation of Input Data option was selected on the General tab.

If **Analytical Distribution** is selected, the drop down menu will become interactive and allow the user to select one of three probability distributions: Log Normal (base 10), Generalized Extreme Value, or Log Pearson III. The required inputs must then be entered and the Compute button (located immediately above the frequency curve table) pressed to fill out the frequency curve table. The **Percent Chance Exceedance** column will be populated with the Output Frequency ordinates that were specified on the General tab. The user cannot add, remove, or modify these ordinates except through changes to the General tab.

Clicking the **Plot Input Frequency Curves** button will open a graph showing all of the frequency curves defined on the Frequency Curves tab, as show in Figure 13-3.

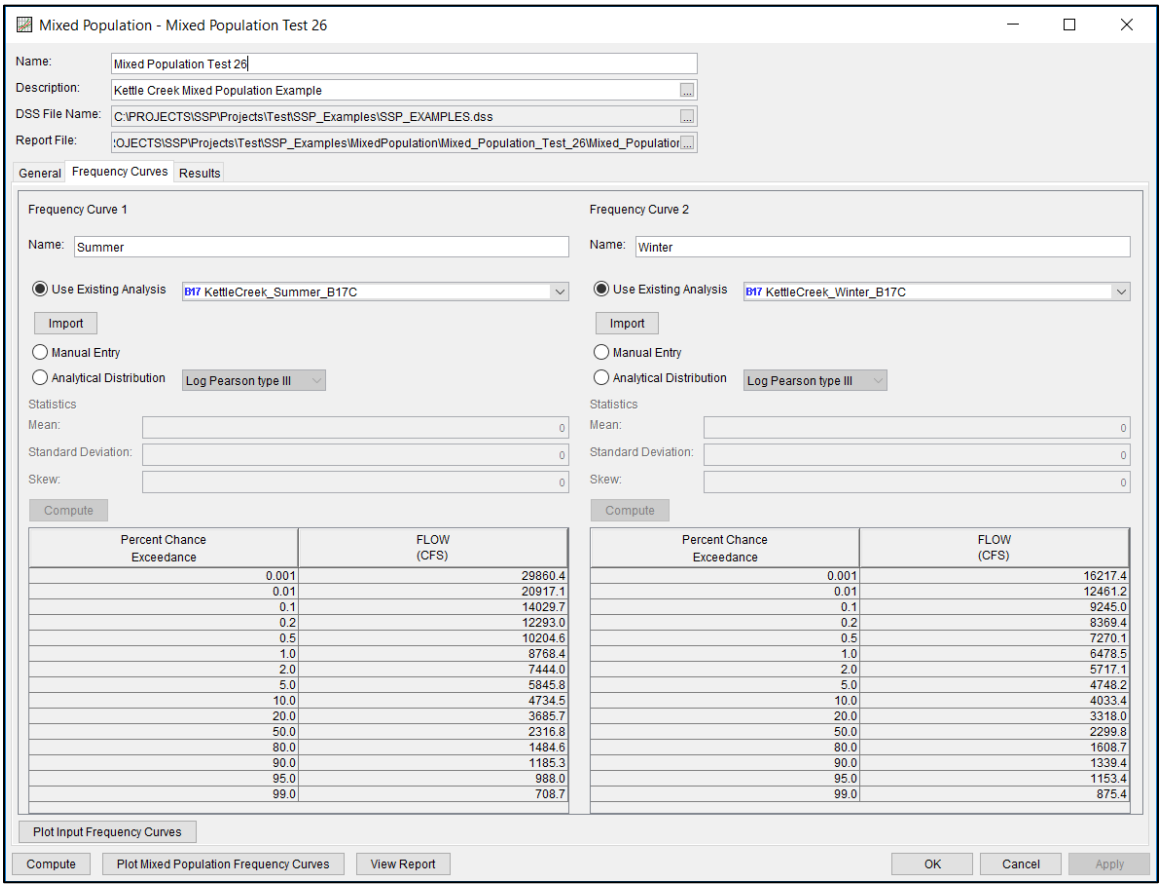


Figure 13-2. Mixed Population Analysis Frequency Curves Tab.

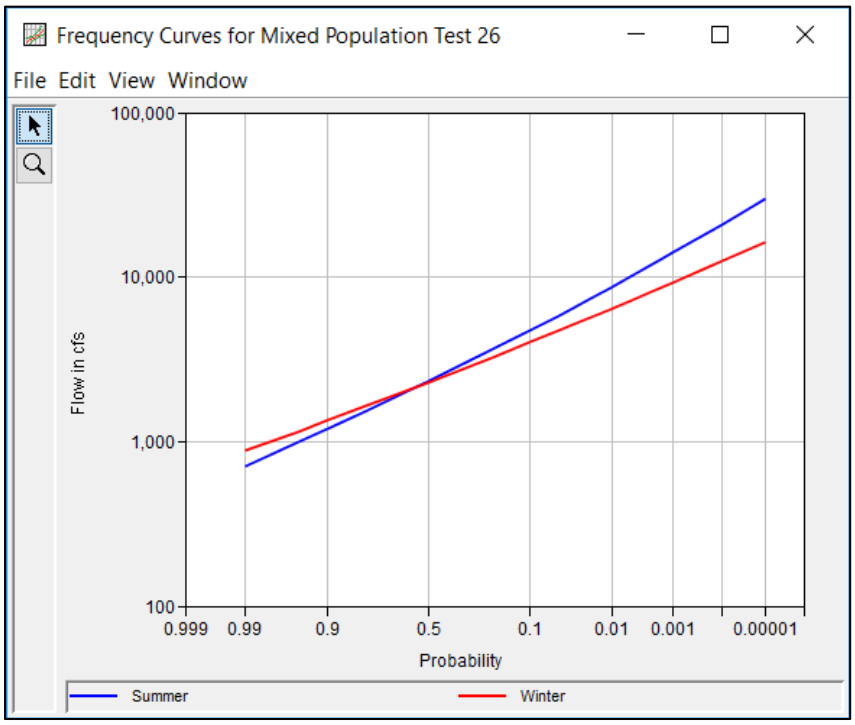


Figure 13-3. Plot of Frequency Curves Defined in the Frequency Curves Tab.

Compute

Press the **Compute** button, located at the bottom of the Mixed Population Analysis editor, once options have been set on the General tab and the required input has been entered on the Frequency Curves tabs. If the compute is successful, the user will receive a message that says **Compute Complete**. At this point, the user can begin to review the results.

Multiple Mixed Population Analyses can be computed using the **Compute Manager**. Select the **Analysis→Compute Manager** menu option to open the Compute Manager. Select the analyses to be computed, and then press the **Compute** button. Close the compute dialogs and Compute Manager when the program finishes computing the analyses.

Results

This section describes results that are available for the Mixed Population Analysis. When the user selects the **Results** tab on the Mixed Population Analysis editor, the window will appear as shown in Figure 13-4. Both tabular and graphical results are included. The frequency ordinates for the output are the same as those that were defined on the General tab. In

addition, when the Output Labeling options are defined on the General tab, they will be used in the y-axis label in the plot.

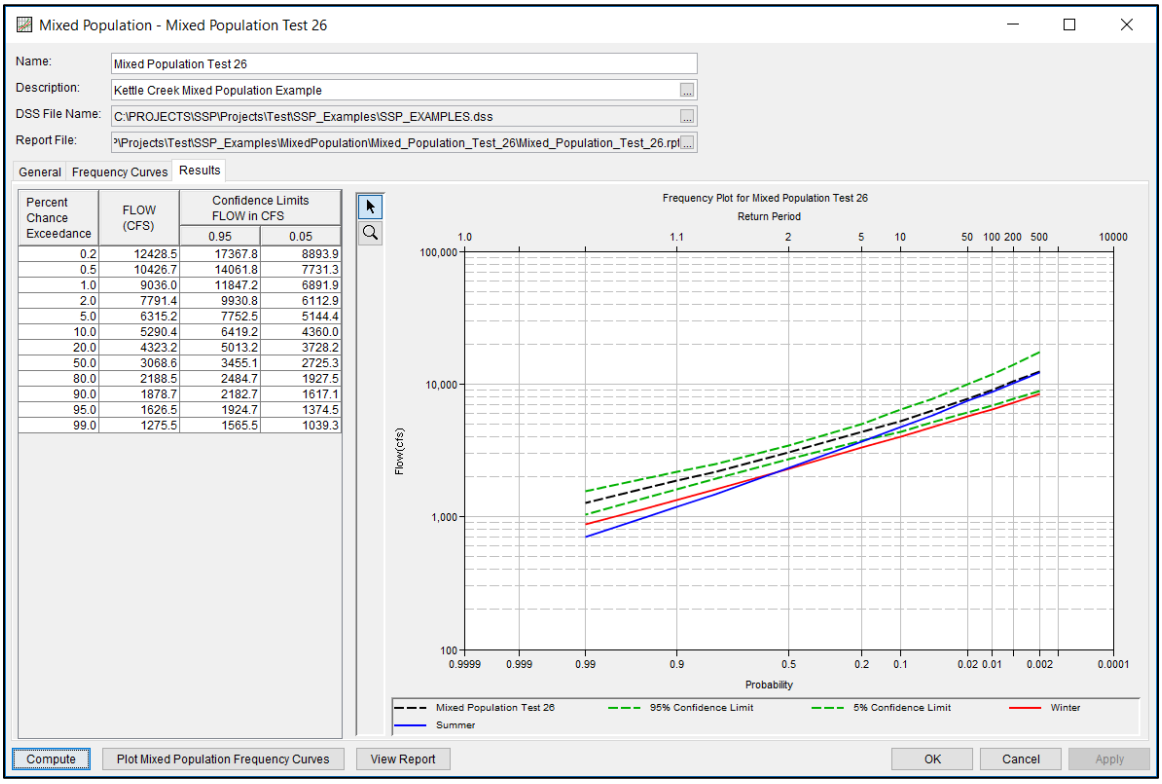


Figure 13-4. Results Tab of the Mixed Population Analysis Editor.

Viewing and Printing Results

The user can view the output directly from the Mixed Population Analysis editor (tabular and graphical output) or by using the buttons at the bottom of the editor.

Tabular Output

Once the computations for the Mixed Population Analysis are completed, the user can view the tabular output by selecting the **Results** tab. Tabular results can be opened after clicking the **Plot Mixed Population Frequency Curves** button and selecting **File→Tabulate** or by double clicking on the mixed population plot in the **Results** tab and in the opened plot selecting **File→Tabulate**. The Mixed Population table can also be printed once opened in a new window using the **File→Print** option. An additional printing option available from the File menu is Print Preview. The table can also be exported by selecting **Export…** from the File menu.

When the Export option is selected, a window will appear allowing the user to select the Field Delimiter and additional Table Export Options. Currently five field delimiter formats are available for exporting the table: **TAB**, **SPACE**, **COMMA**, **COLON,** and **SEMI-COLON**.

Graphical Output

Graphical output of the Mixed Population Analysis can be obtained either by selecting the **Results** tab, or by pressing the **Plot Mixed Population Frequency Curves** button at the bottom of the Mixed Population Analysis editor. When the Plot Mixed Population Frequency Curves button is pressed, a plot will appear in a separate window as shown in Figure 13-5.

The mixed population plot can be sent to the printer by selecting the **Print** option from the **File** menu at the top of the window. Additional printing options available from the File menu are Page Setup, Print Preview, and Print Multiple (used for printing multiple graphs on the same page). The graphic can also be sent to the Windows Clipboard by selecting **Copy to Clipboard** from the File menu. Additionally, the plot can be saved to a file by selecting the **Save As** option from the File menu. When the Save As option is selected, a window will appear allowing the user to select a directory, enter a filename, and select the format for saving the file. Currently, four file formats are available for saving the graphic to disk: **windows metafile**, **postscript**, **JPEG**, and **portable network graphic**.

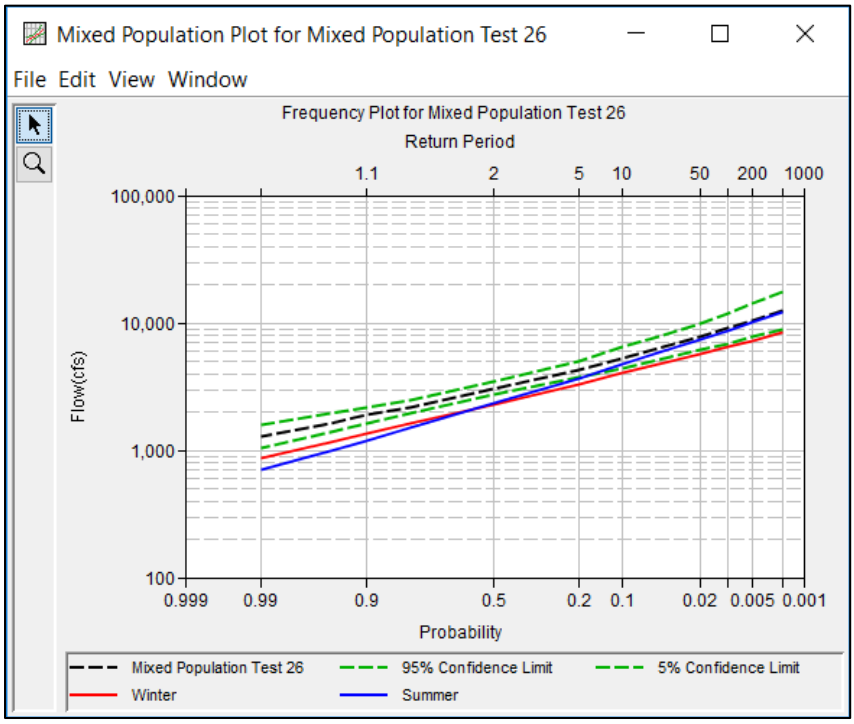


Figure 13-5. Mixed Population Analysis Plot.

As explained previously, the data contained within the plot can also be tabulated by selecting **Tabulate** from the File menu. When this option is selected, a separate window will appear with the data tabulated. Additional options are available from the File menu for saving the plot options as a template (**Save Template)** and applying previously saved templates to the current plot (**Apply Template**).

The **Edit** menu contains several options for customizing the graphic. These options include Plot Properties, Configure Plot Layout, Default Line Styles, and Default Plot Properties. In addition, a shortcut menu will appear with further customizing options when the user right-clicks on a line on the graph or the legend. Both the Y and X-axis properties can be edited by placing the mouse on top of axis and clicking the right mouse button. Then select the **Edit Properties** menu option in the shortcut menu. For example, the user can turn on minor tic marks for the y-axis and modify the minimum and maximum scale for the x-axis. The graphic customizing capabilities within HEC-SSP are very powerful, but are also somewhat complex to use. The code used in developing the plots in HEC-SSP is the same code that is used for developing plots in HEC-DSSVue and several other HEC software programs. Please refer to the HEC-DSSVue User's Manual for details on customizing plots.

Viewing the Report File

A report file is created when the Mixed Population Analysis computations are performed. The report file lists the input data, user settings, and the results. This file is often useful for understanding how the software arrived at the output.

Press the **View Report** button at the bottom of the Mixed Population Analysis editor to view the report file. When this button is pressed, a window will appear containing the report as shown in Figure 13-6.

The computations that were used to create the output are contained within the **Report** output. Additionally, the Mixed Population report can be opened using the **Results→Report** option in the Results dropdown menu at the top of the SSP window.

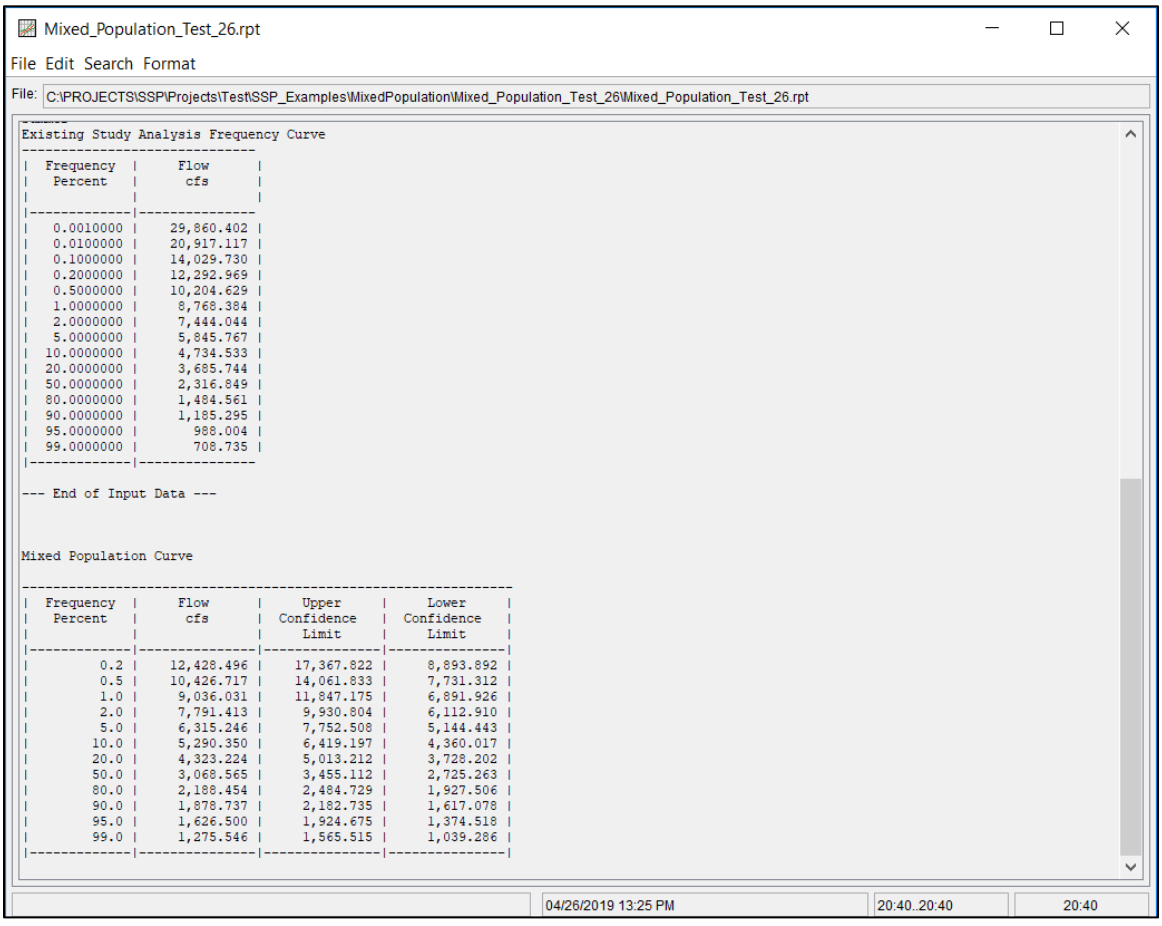


Figure 13-6. Mixed Population Analysis Report File.

APPENDIX A

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APPENDIX B

Example Data Sets

The input and output for 35 examples are provided to illustrate the use of selected options and to assist in verifying the correct execution of the program.

The first six examples are the same as those found within the HEC-FFA program documentation. These examples were duplicated with a Bulletin 17 and General Frequency Analysis. This manual only shows these examples using the Bulletin 17 Analysis; however, the example data sets show that results are the same whether a Bulletin 17 or General Frequency Analysis was performed. As shown in the example data sets, the HEC-SSP software produces the same results as HEC-FFA for these six data sets. All of these examples are provided with the software as a single HEC-SSP study labeled "SSP 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. 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).

The example problems shown in this section are entitled:

1. Fitting the Log-Pearson Type III Distribution.
2. Analysis with High Outliers.
3. Testing and Adjusting for a Low Outlier.
4. Zero Flood Years.
5. Confidence Limits and Low Threshold Discharge.
6. Use of Historic Data.
7. Analyzing Stage Data.
8. Using User-Adjusted Statistics.
9. General Frequency - Graphical Analysis.
10. Volume Frequency Analysis, Maximum Flows.

11. Volume Frequency Analysis, Minimum Flows.
12. Duration Analysis, Bin (STATS) Method.
13. Duration Analysis, Rank All Data Method.
14. Duration Analysis, Manual Entry.
15. Coincident Frequency Analysis, A and B can be Assumed Independent.
16. Coincident Frequency Analysis, A and B cannot be Assumed Independent.
17. Balanced Hydrograph Analysis, Using an Historical Event Hydrograph.
18. Balanced Hydrograph Analysis, Using a Triangular-shaped Hydrograph.
19. Curve Combination Analysis, Combining Multiple Frequency Curves using Graphical Techniques.
20. Distribution Fitting, Analyzing Model Uncertainty Using a Time Series of Annual Maximum Streamflow
21. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Annual Maxima Filtering
22. Distribution Fitting, Analyzing a Time Series of Daily Average Flow Using Time Window, Seasonal, and Peaks Over Threshold Filtering
23. Distribution Fitting, Analyzing a Time Series of Daily Precipitation Accumulation Using Peaks Over Threshold Filtering
24. Distribution Fitting, Analyzing a Time Series of Daily Average Snow Water Equivalent Using Annual Maxima Filtering
25. Distribution Fitting, Analyzing a Time Series of Daily Average Flow to Estimate Flood Seasonality
26. Distribution Fitting, Analyzing a Paired Data Record of Hydrologic Model Output
27. Mixed Population, Combining Two Frequency Curves using the Probability of Union Concept
28. Mixed Population, Combining Three Frequency Curves using the Probability of Union Concept

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

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

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

32. Data Filtering, Extracting an Annual Maximum Series

33. Data Filtering, Extracting a Partial Duration Series

34. Data Filtering, Using Multiple Filters

35. Data Filtering, Starting Pool/Elevation Filtering

When the "SSP Examples" study file is open, the screen will appear as shown in Figure B-1. There are 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. Appendix C details ten additional examples which make use of the Expected Moments Algorithm and Bulletin 17C procedures.

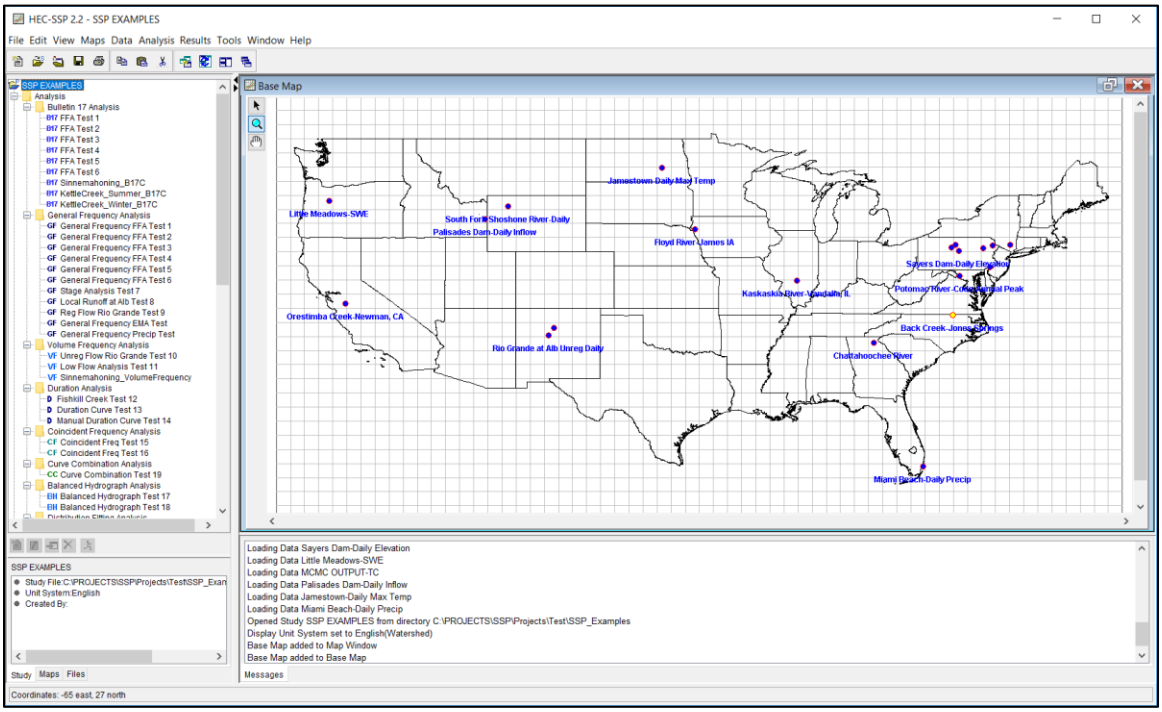
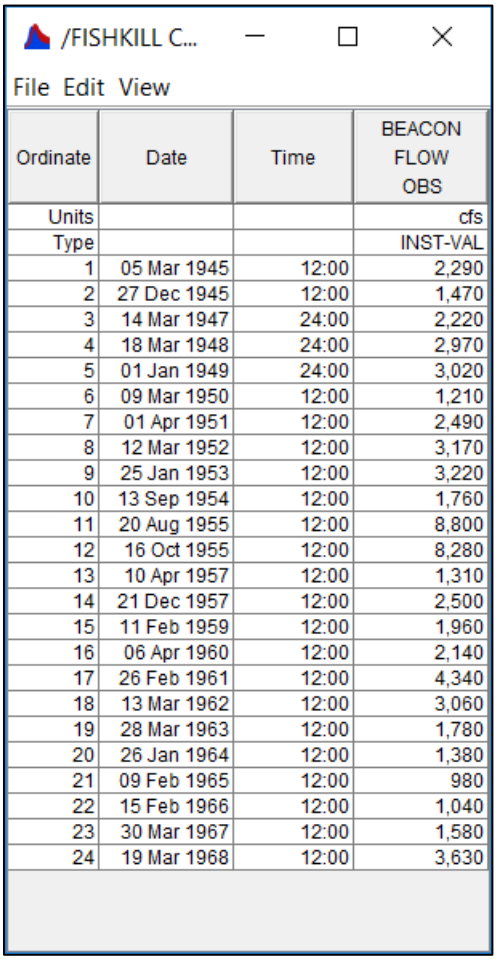


Figure B-1. SSP Examples Study.

Example 1: Fitting the Log-Pearson Type III Distribution

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

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 B-2.



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

Figure B-2. 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 B-3.

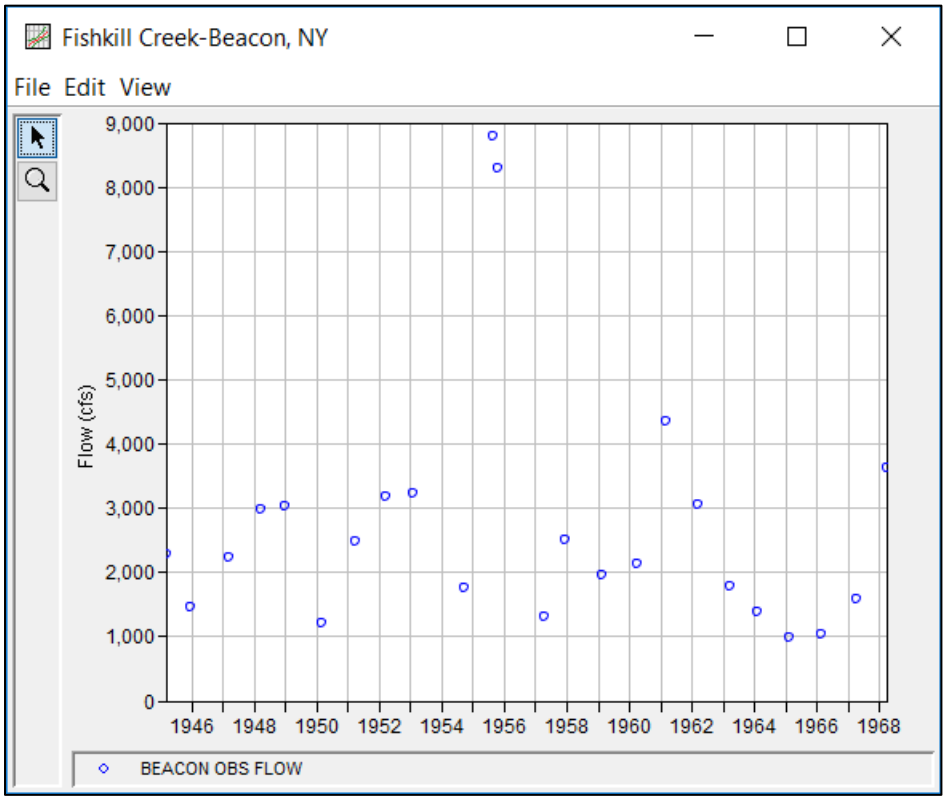


Figure B-3. Plot of the Fishkill Creek Data.

A Bulletin 17 and a General Frequency analysis have been developed for this example. To open the Bulletin 17 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 B-4.

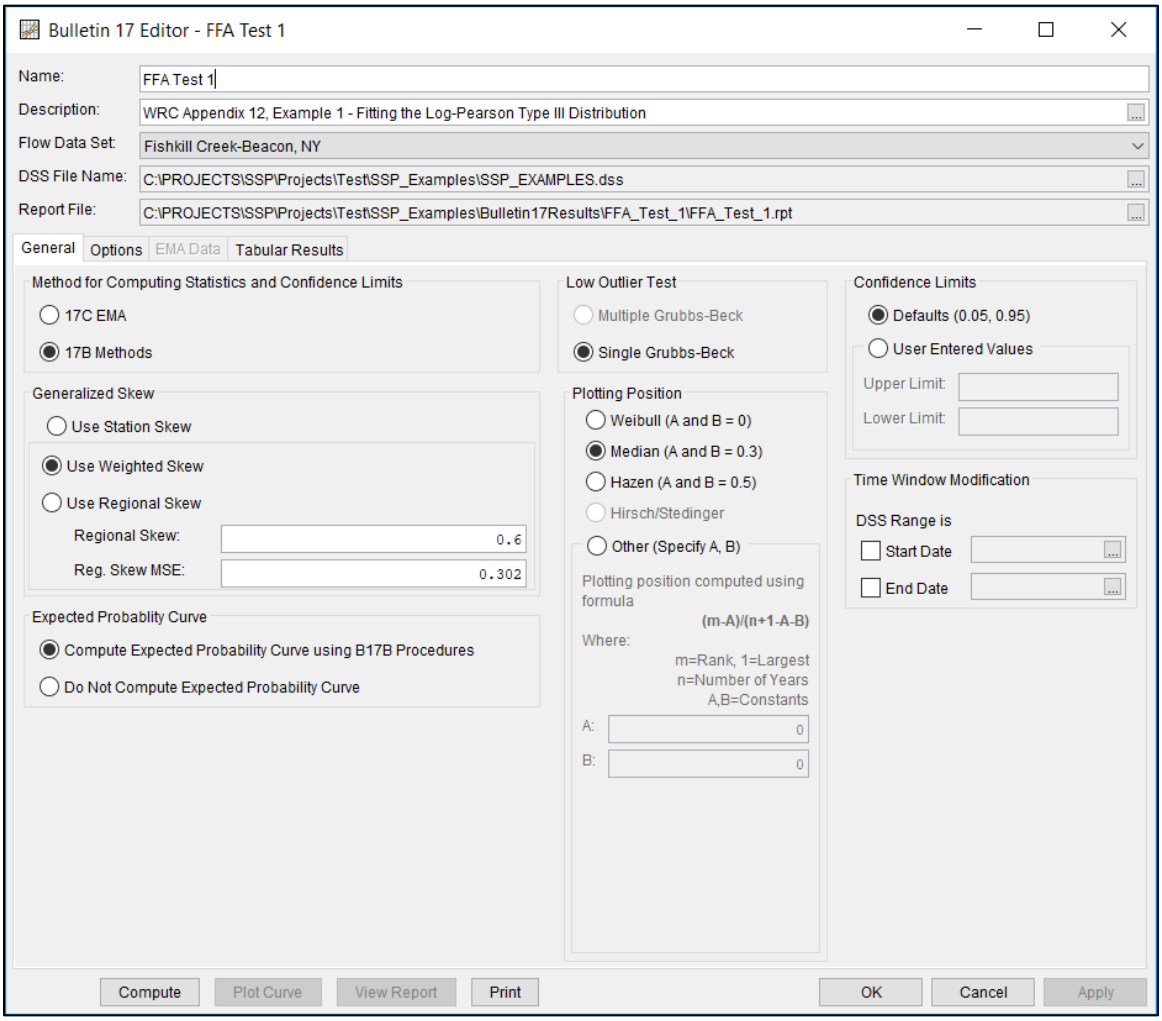


Figure B-4. Bulletin 17 Analysis Editor with FFA Test 1 Data Set.

Shown in Figure B-4 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.

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** of 0.05 (5 percent chance exceedance) and

0.95 (95% chance exceedance). Shown in Figure B-5 is the Bulletin 17 editor with the **Options Tab** selected.

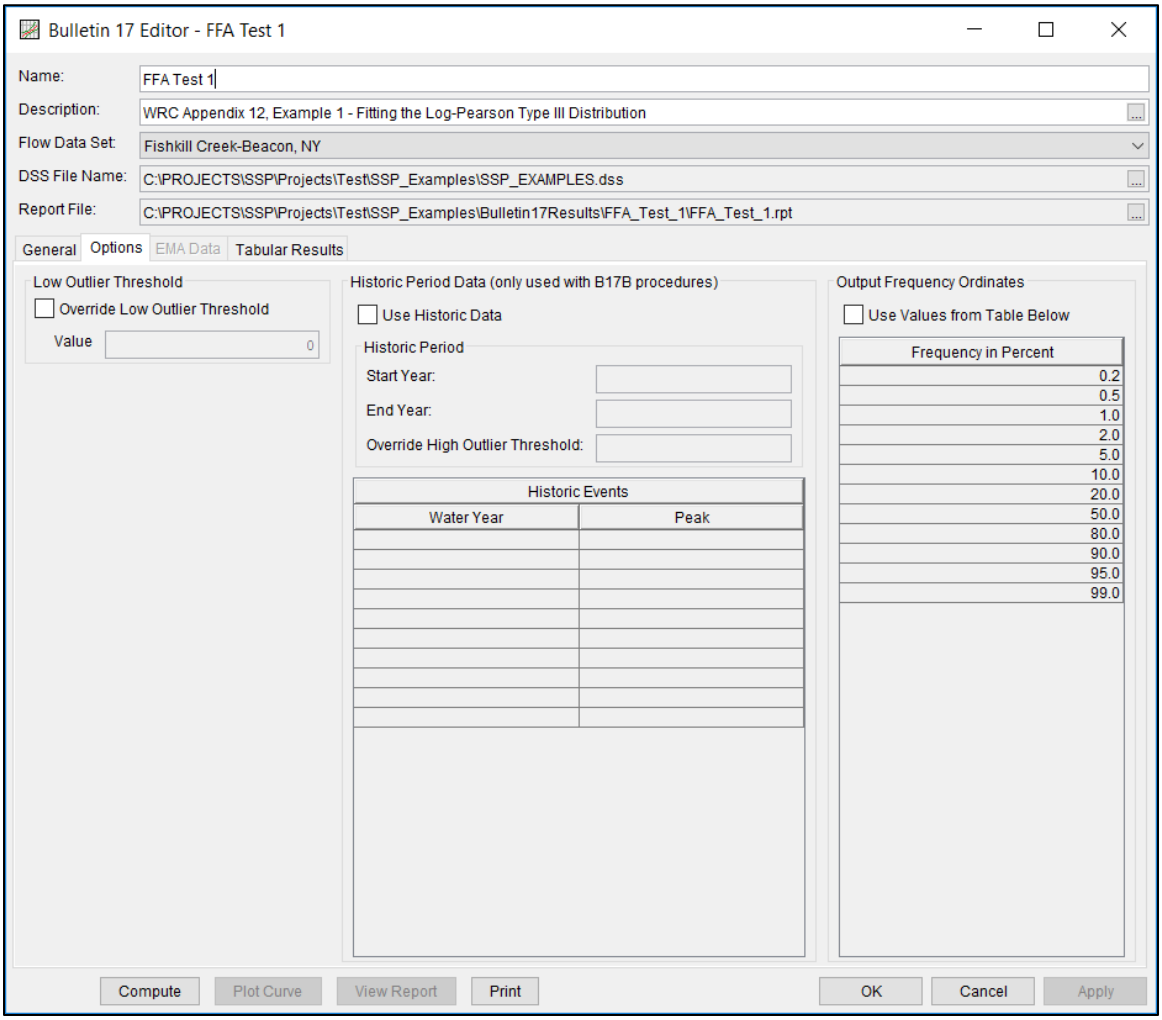


Figure B-5. Bulletin 17 Editor with Options Tab Selected for FFA Test 1.

As shown in Figure B-5, 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.

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 B-6.

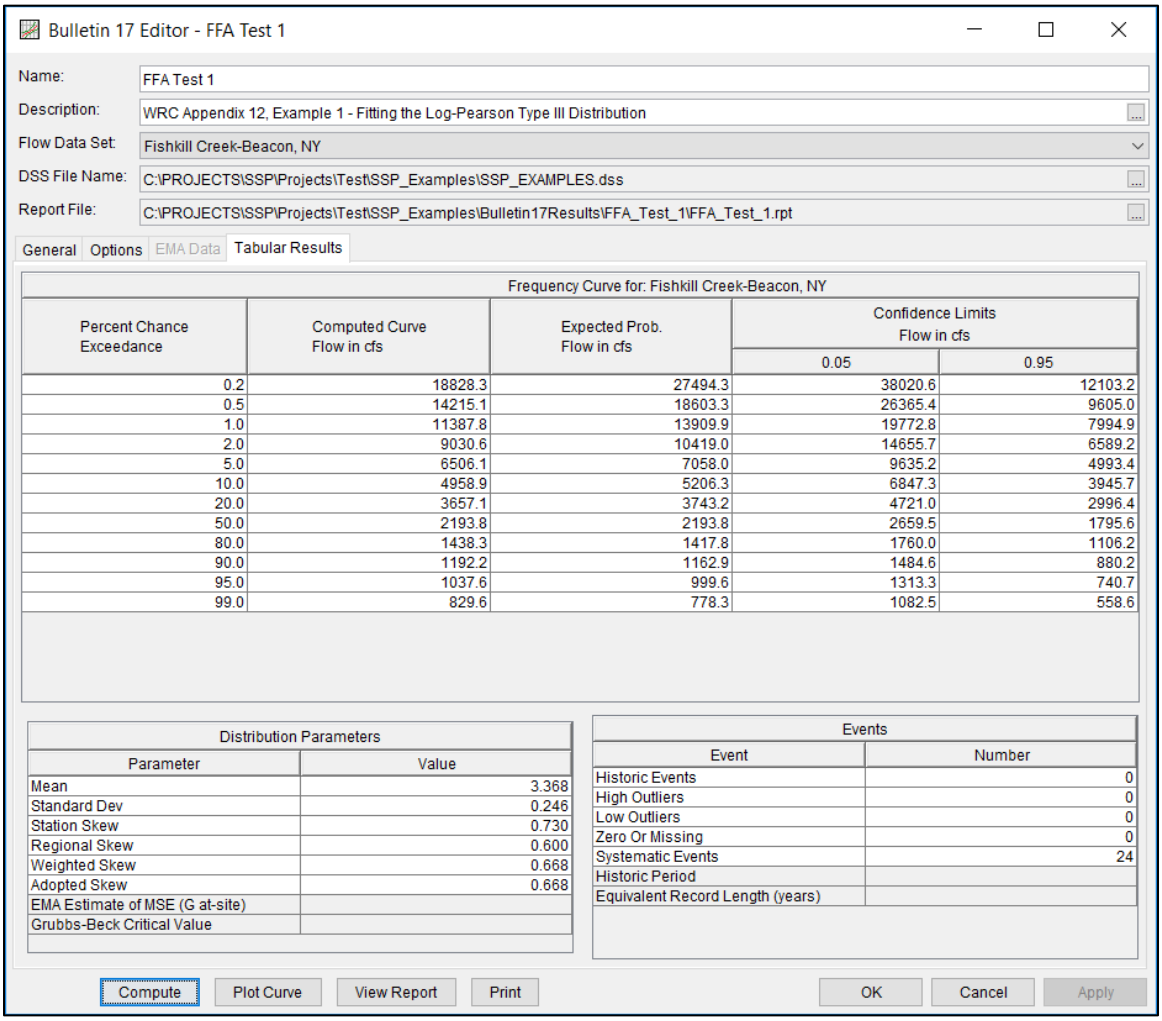


Figure B-6. Bulletin 17 Analysis Window with Results Tab Shown for FFA Test 1.

As shown in Figure B-6, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (5% and 95% chance exceedance curves)

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 B-7.

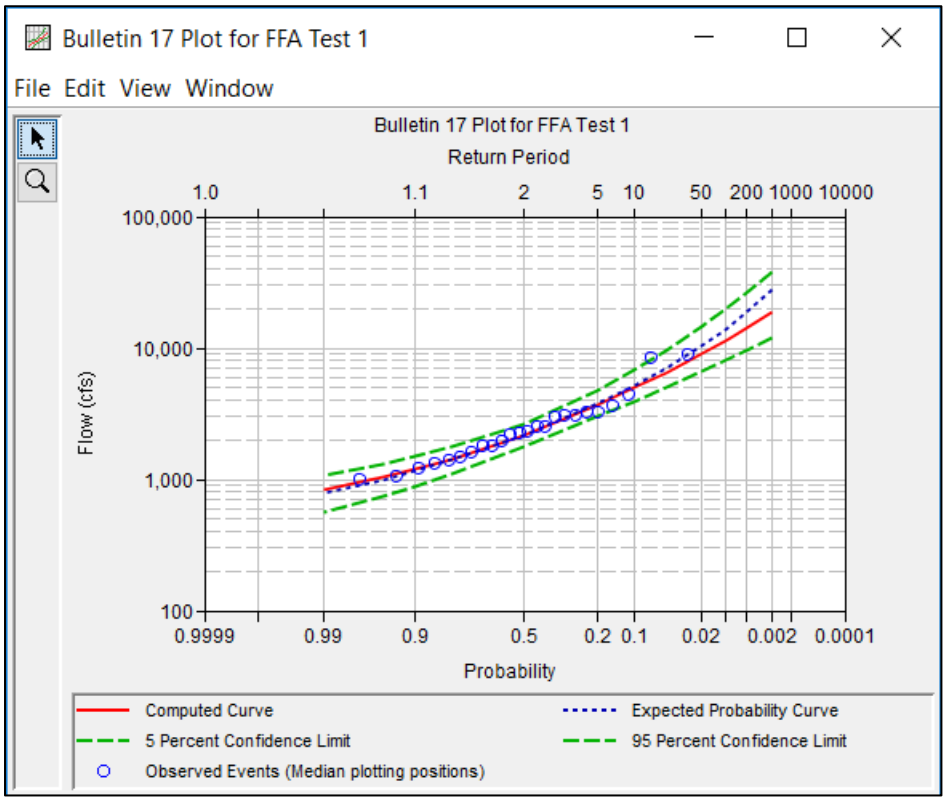


Figure B-7. Plotted Frequency Curves for FFA Test 1.

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 B-8 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.

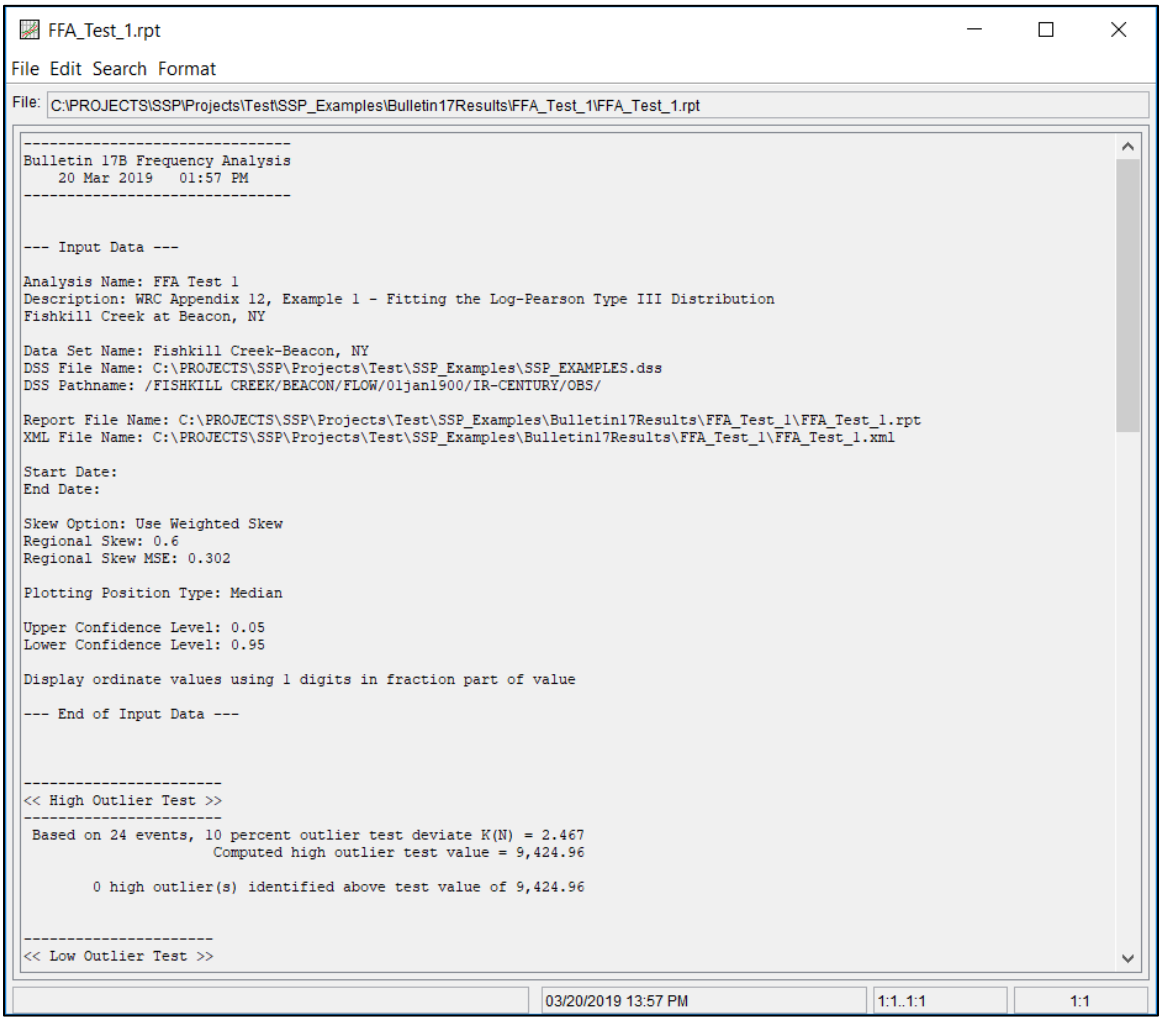


Figure B-8. FFA Test 1 Report File.

Example 2: Analysis with High Outliers

The input data for **FFA Test 2** is the same as that for Example 2 in Appendix 12, Guidelines for Determining Flood Flow Frequency, Water Resources Council Bulletin 17B. Example 2 illustrates the application to data with a high outlier.

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 B-9.

/FLOYD RIV...

File Edit View

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

Figure B-9. 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 B-10.

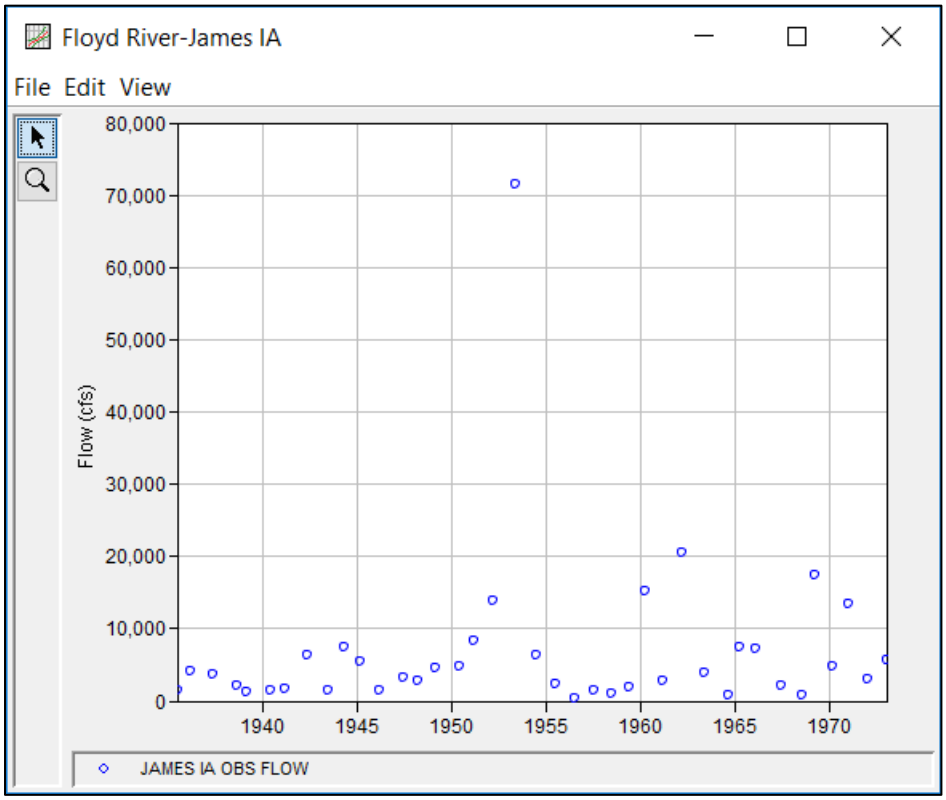


Figure B-10. Plot of Floyd River Data

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for **FFA Test 2**, either double-click on the analysis labeled **FFA Test 2** from the study pane, or from the **Analysis** menu select open and then select **FFA Test 2** from the list of available analyses. When **FFA Test 2** is selected, the Bulletin 17 analysis editor will appear as shown in Figure B-11.

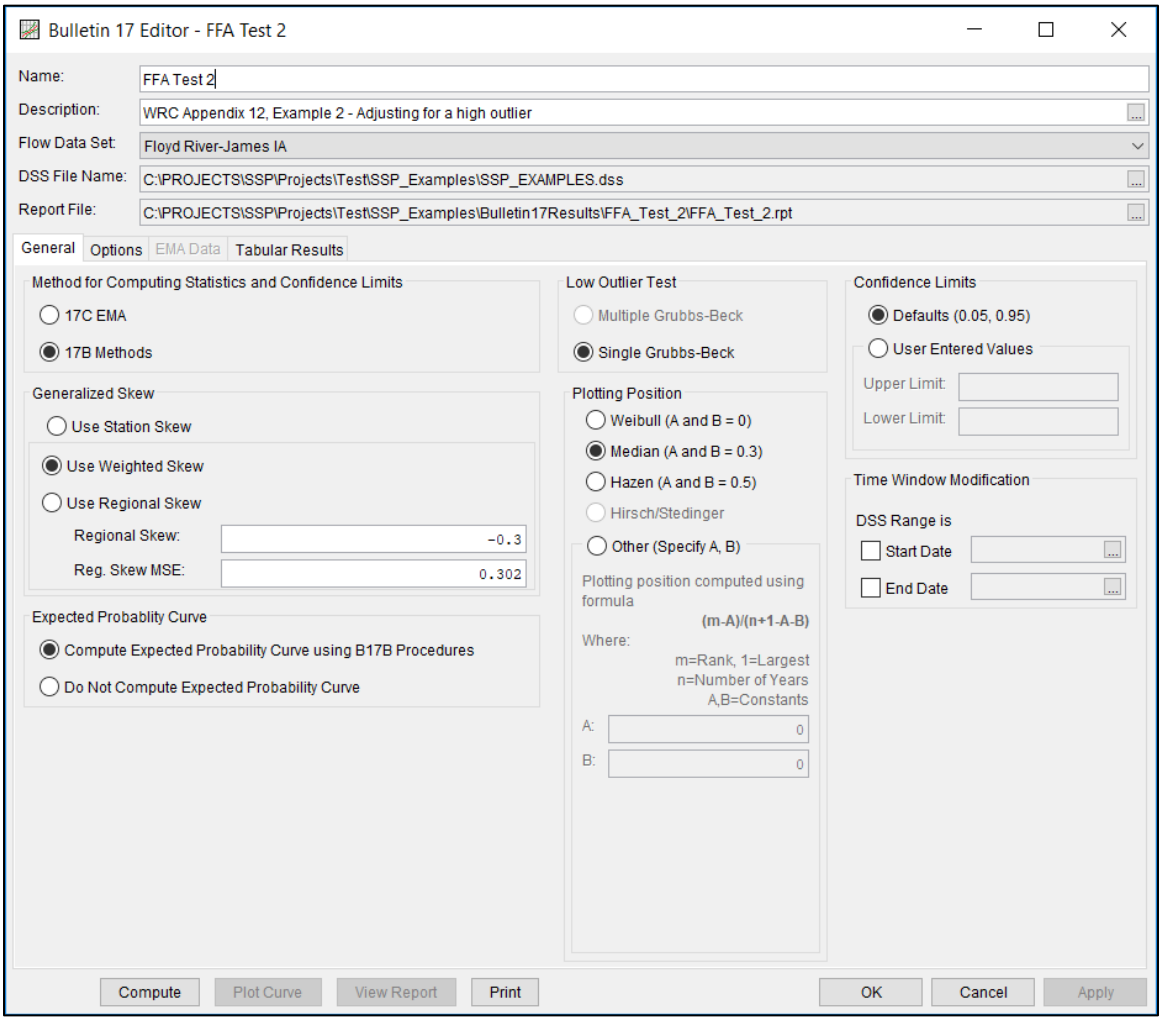


Figure B-11. Bulletin 17 Analysis Editor with FFA Test 2 Data Set.

Shown in Figure B-11 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 -0.3 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.

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** of 0.05 (5 percent chance exceedance) and

0.95 (95% chance exceedance). Shown in Figure B-12 is the Bulletin 17 editor with the **Options Tab** selected.

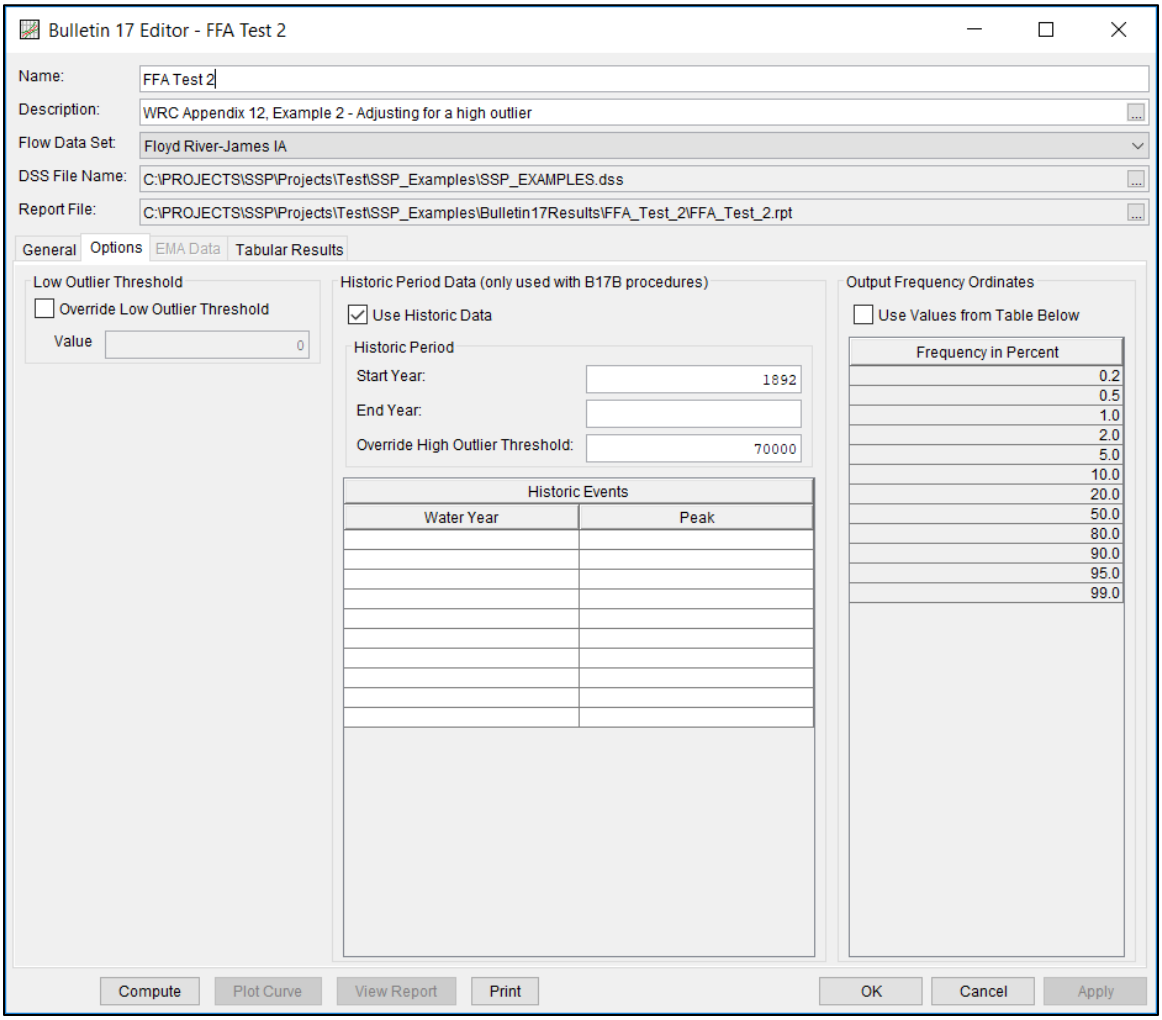


Figure B-12. Bulletin 17 Editor with Options Tab Selected for FFA Test 2.

As shown in Figure B-12, 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, a **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. 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.

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 B-13.

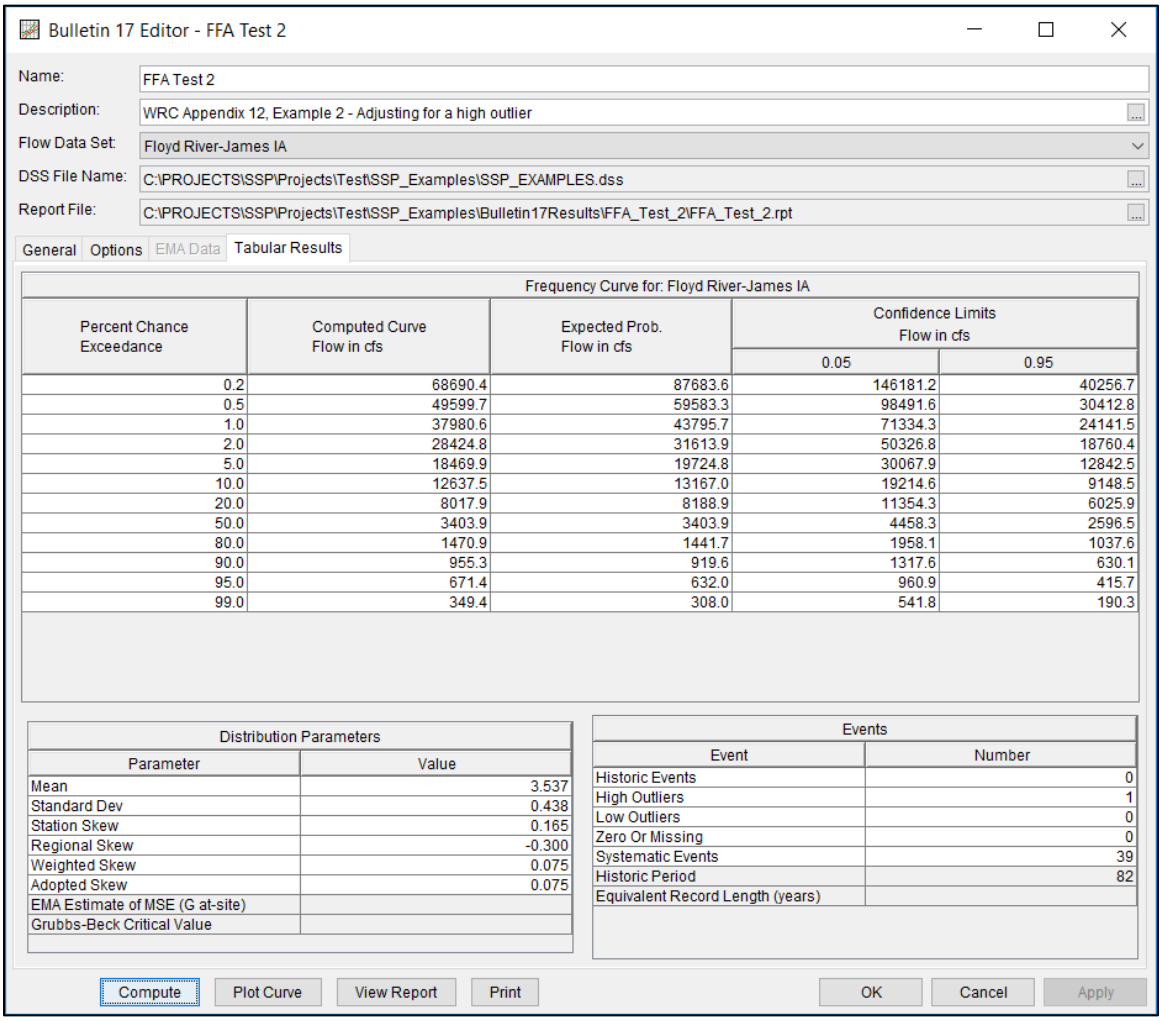


Figure B-13. Bulletin 17 Editor with Results Tab Selected for FFA Test 2.

As shown in Figure B-13, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (5% and 95% chance exceedance curves)

On the bottom left-hand side of the results tab is the Statistics table 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 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 at the bottom of the analysis window. A plot of the results for this example is shown in Figure B-14.

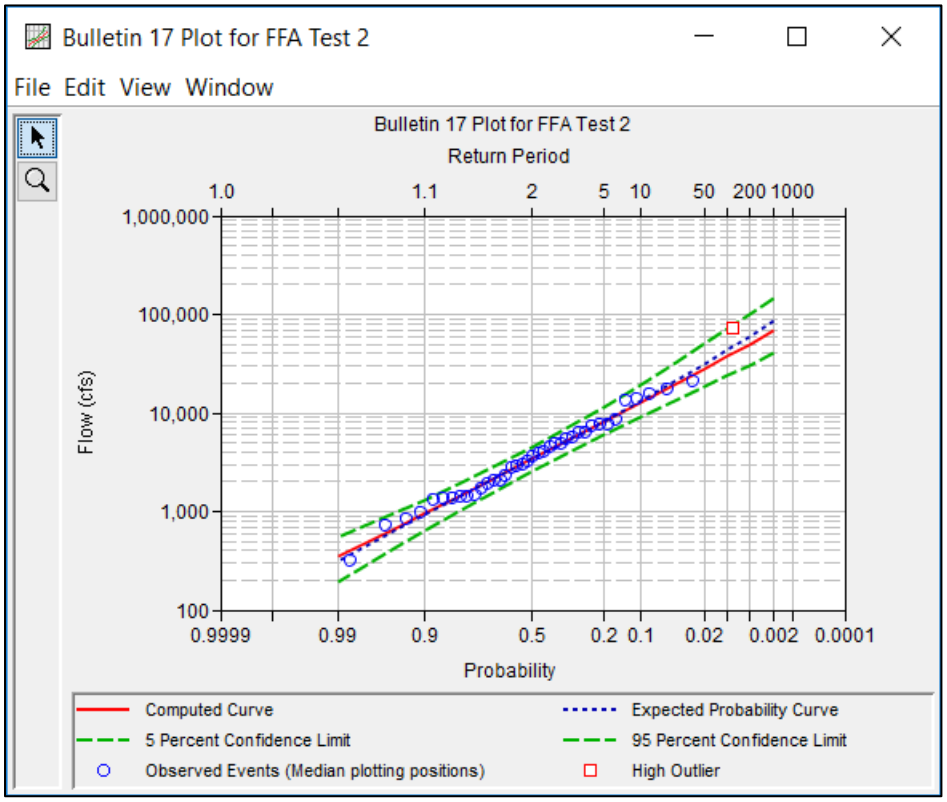


Figure B-14. Plotted Frequency Curves for FFA Test 2.

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 B-15 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.

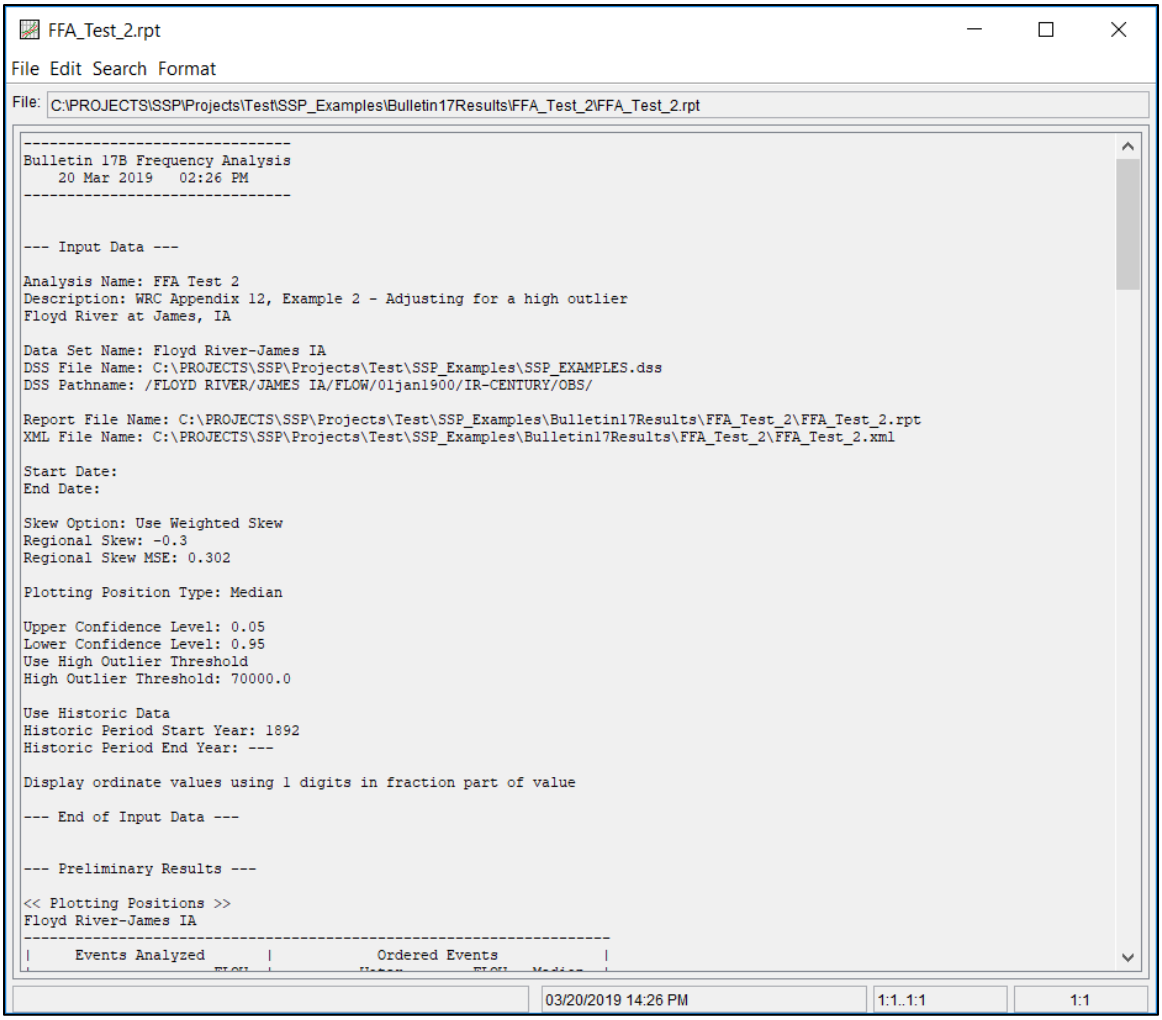
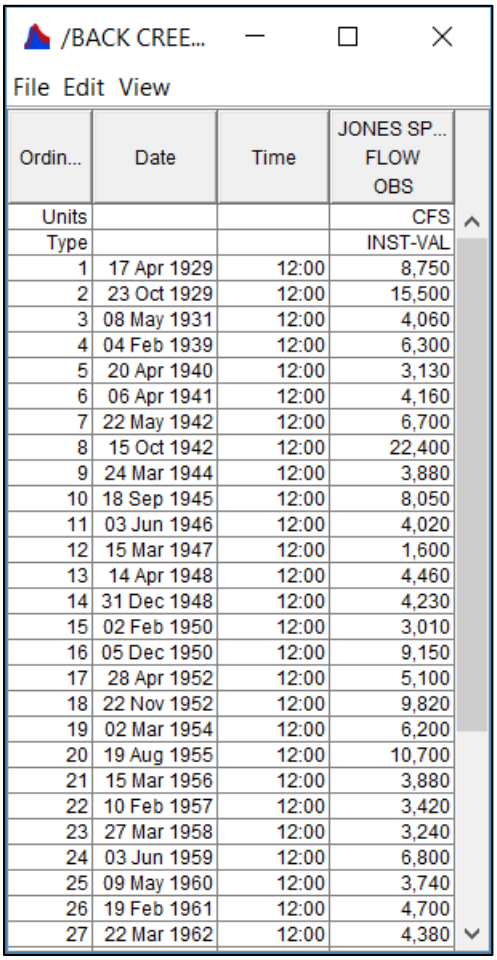


Figure B-15. FFA Test 2 Report File.

Example 3: Testing and Adjusting for a Low Outlier

The input data for **FFA Test 3** are the same as that for Example 3 in Appendix 12 of the WRC Guidelines. **FFA Test 3** illustrates the application to data with a low outlier. Note that the program 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, right-click on the data record labeled "**Back Creek-Jones Springs**" in the study pane and then select **Tabulate**. The data will appear as shown in Figure B-16.



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

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

To plot the data for this example, right-click on the data record and select **Plot**. A plot of the data will appear as shown in Figure B-17.

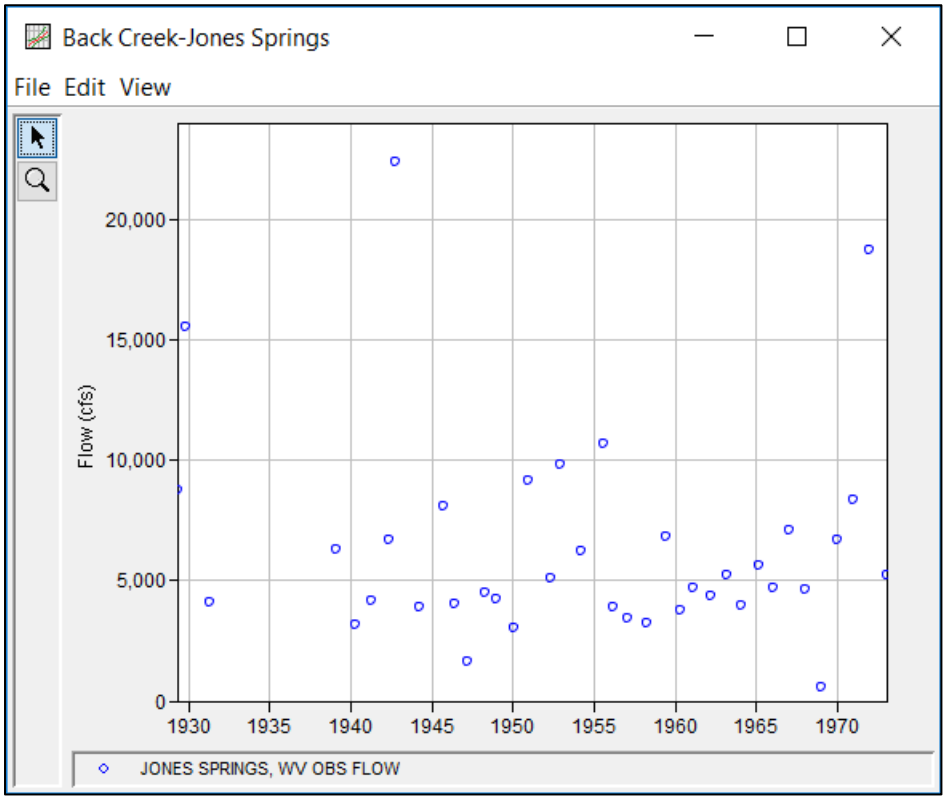


Figure B-17. Plot of Back Creek Data.

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for **FFA Test 3**, either double-click on the analysis labeled **FFA Test 3** from the study explorer, or from the **Analysis** menu select open and then select **FFA Test 3** from the list of available analyses. When **FFA Test 3** is selected, the Bulletin 17 analysis editor will appear as shown in Figure B-18.

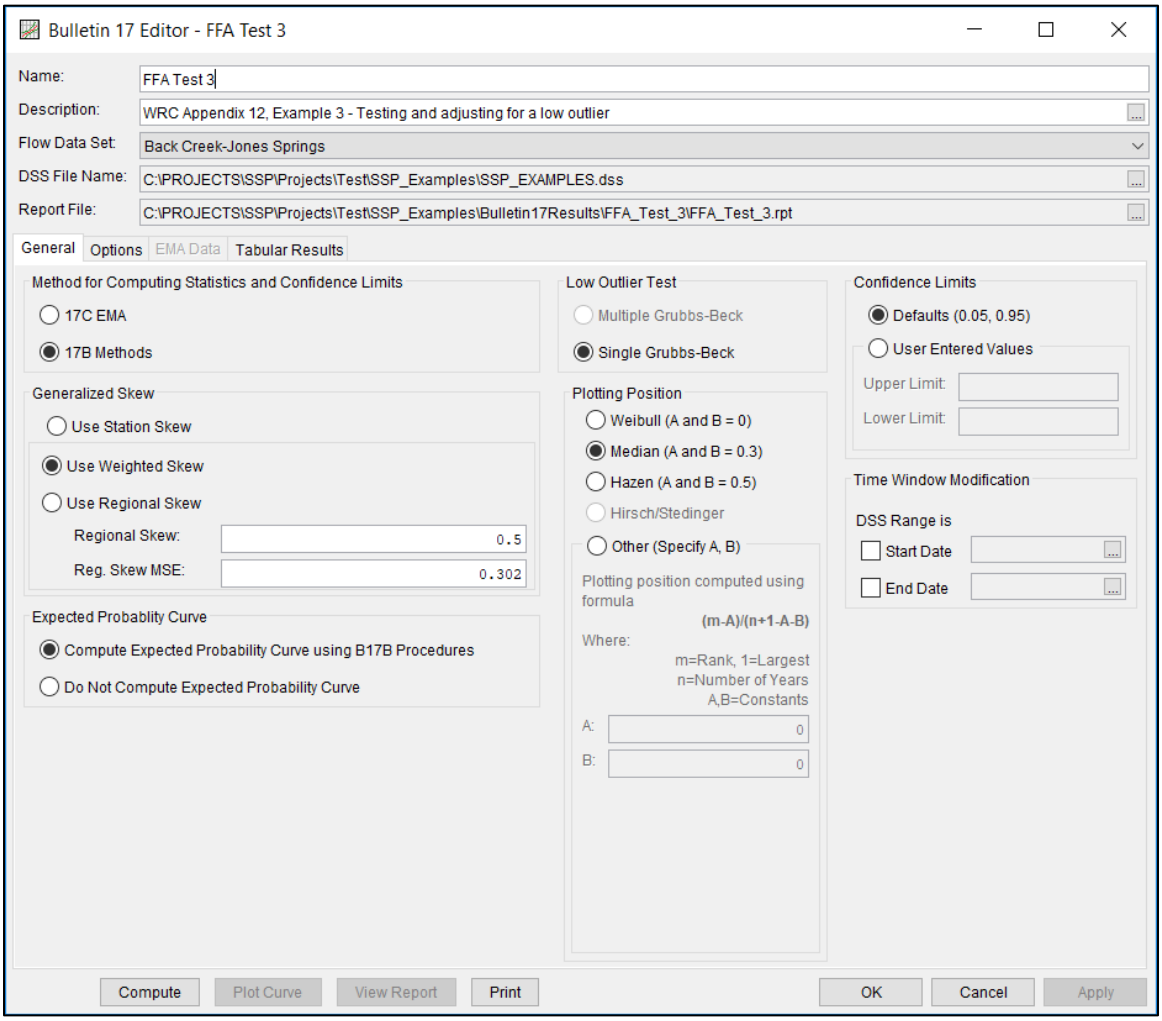


Figure B-18. Bulletin 17 Analysis Editor with FFA Test 3 Data Set.

Shown in Figure B-18 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 0.5 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.

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** of 0.05 (5 percent chance exceedance) and

0.95 (95% chance exceedance). Shown in Figure B-19 is the Bulletin 17 editor with the **Options Tab** selected.

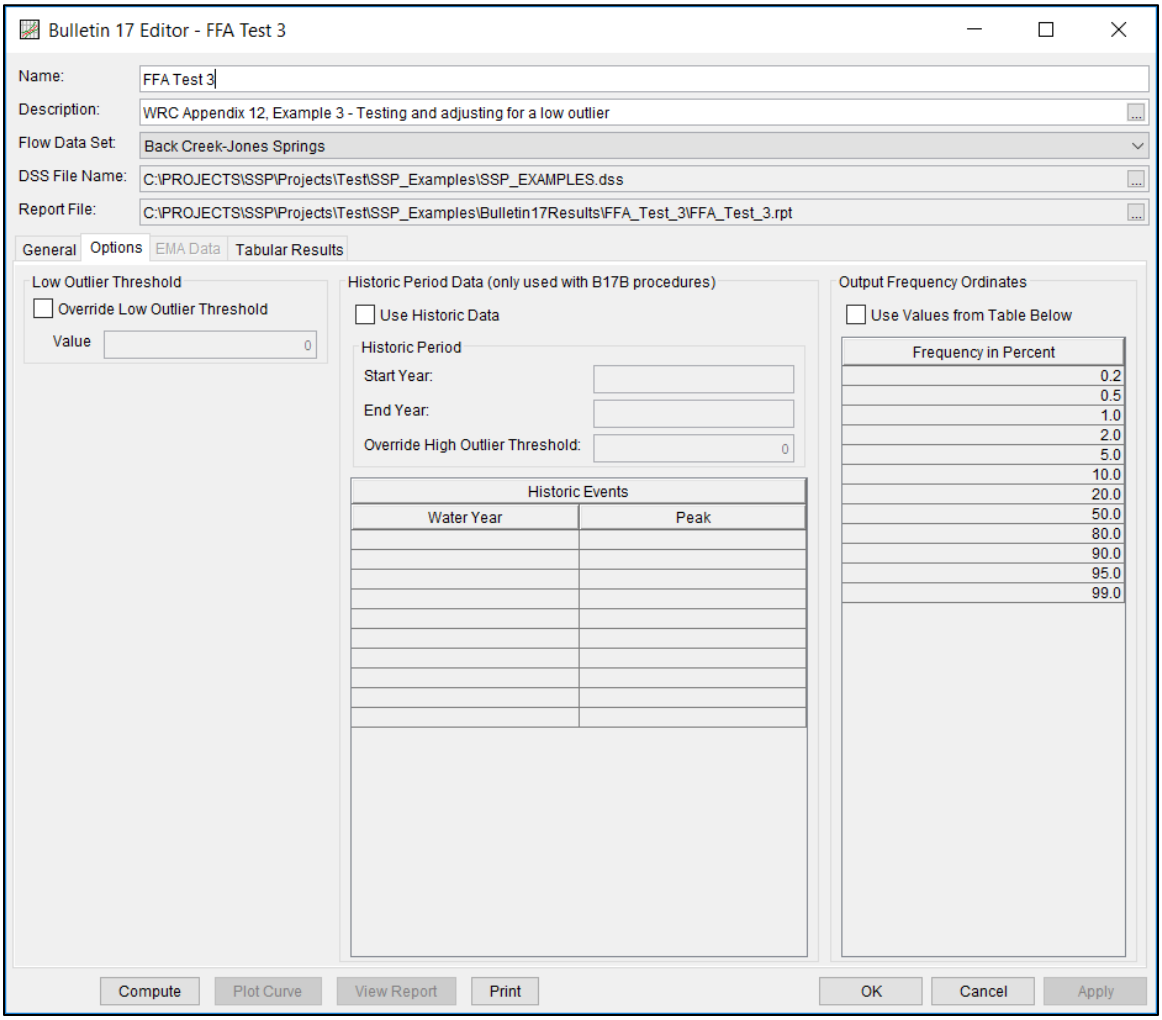


Figure B-19. Bulletin 17 Editor with the Options Tab Selected for FFA Test 3.

As shown in Figure B-19, 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.

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 select the **Tabular Results** tab. The analysis window should resemble Figure B-20.

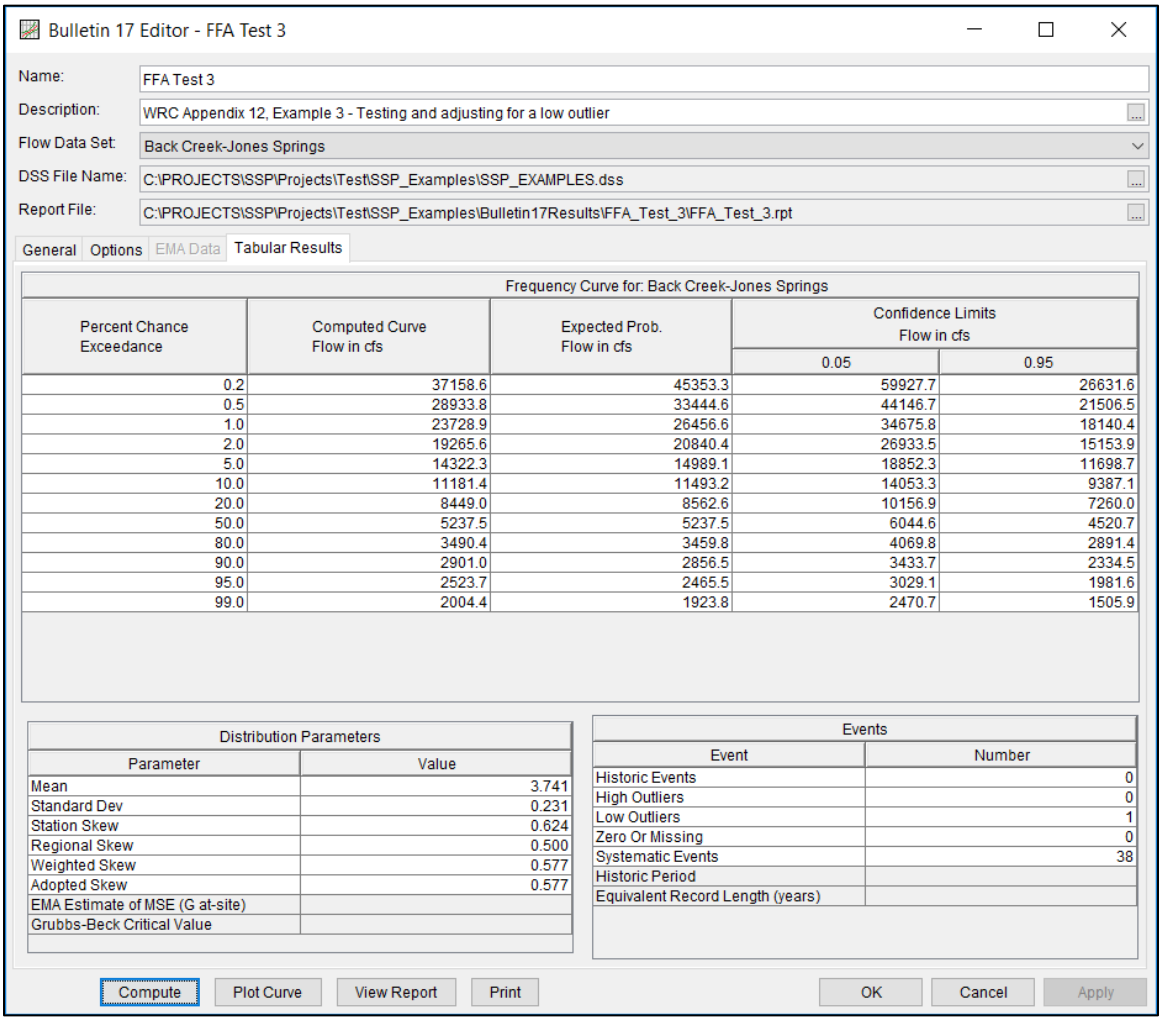


Figure B-20. Bulletin 17 Editor with the Results Tab Selected for FFA Test 3.

As shown in Figure B-20, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (5% and 95% chance exceedance curves)

On the bottom left-hand 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-hand side of the results tab is a table of Number of Events 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 B-21.

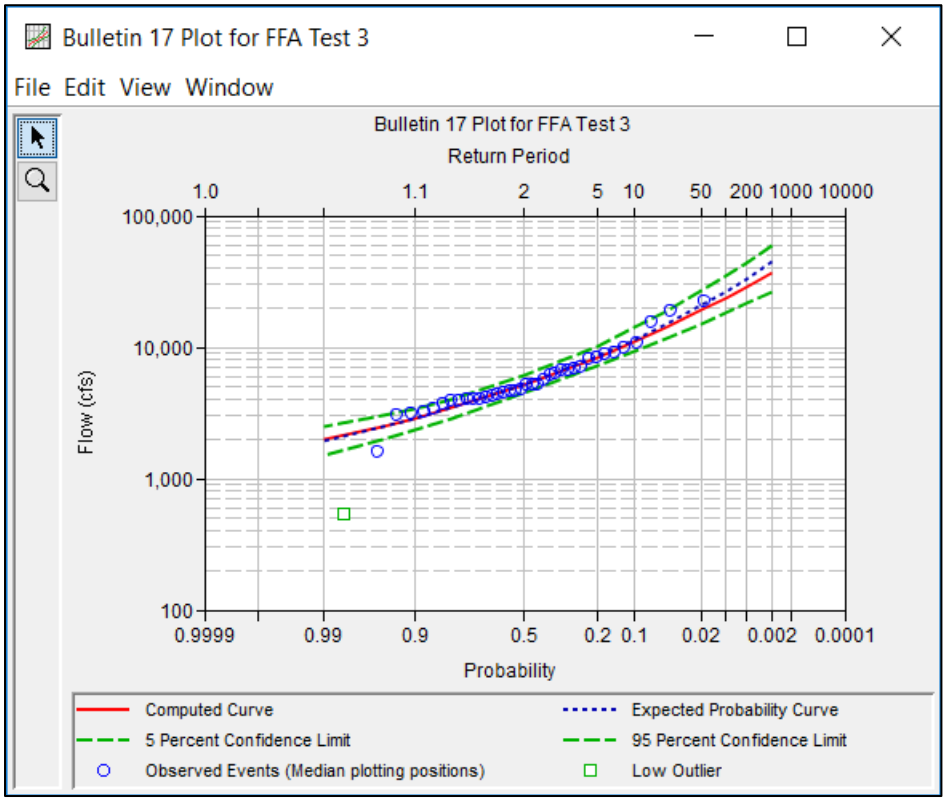


Figure B-21. Pot for FFA Test 3.

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 B-22 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.

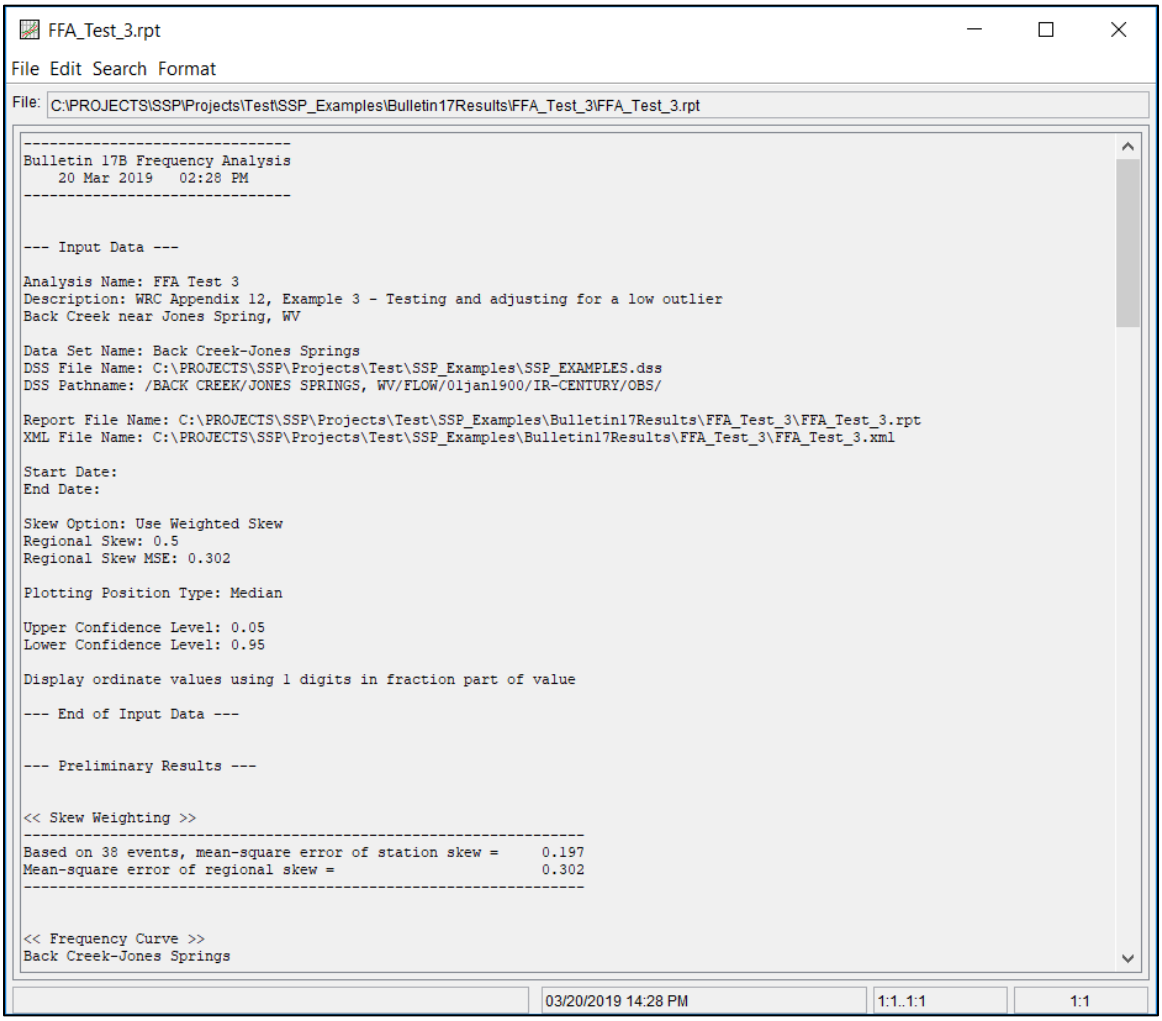
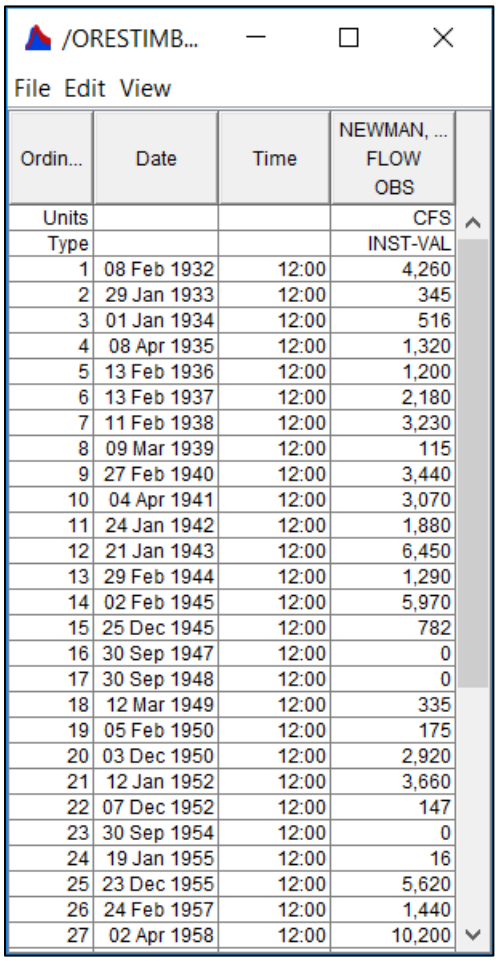


Figure B-22. Report File for FFA Test 3.

Example 4: Zero-Flood Years

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

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 from HEC-SSP, right-click on the data record labeled "**Orestimba Creek-Newman, CA**" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure B-23.



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

Figure B-23. 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 B-24. The years with peak flows measuring zero are visible.

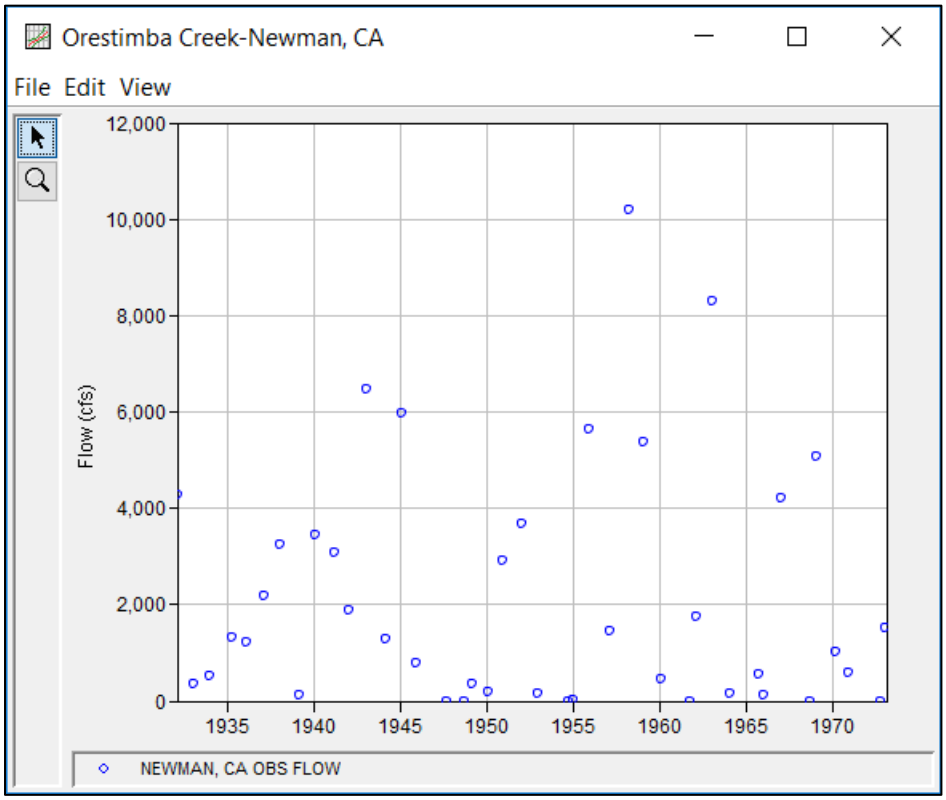


Figure B-24. Plot of Orestimba Creek Data.

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for **FFA Test 4**, either double-click on the analysis labeled **FFA Test 4** from the study explorer, or from the **Analysis** menu select open, then select **FFA Test 4** from the list of available analyses. When **FFA Test 4** is selected, the Bulletin 17 analysis editor will appear as shown in Figure B-25.

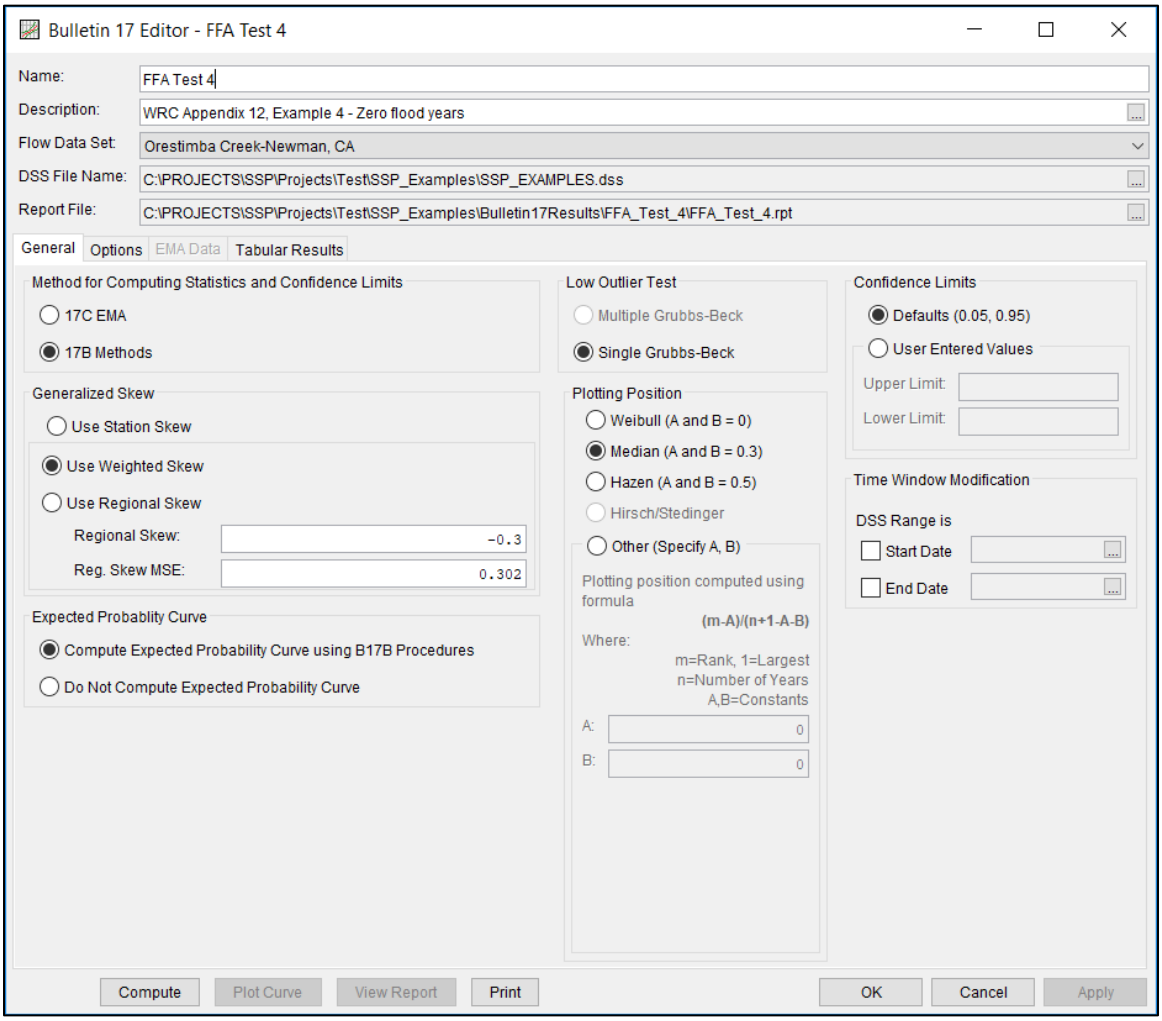


Figure B-25. Bulletin 17 Analysis Editor with FFA Test 4 Data Set.

Shown in Figure B-25 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 -0.3 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.

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** of 0.05 (5 percent chance exceedance) and

0.95 (95% chance exceedance). Shown in Figure B-26 is the Bulletin 17 editor with the **Options Tab** selected.

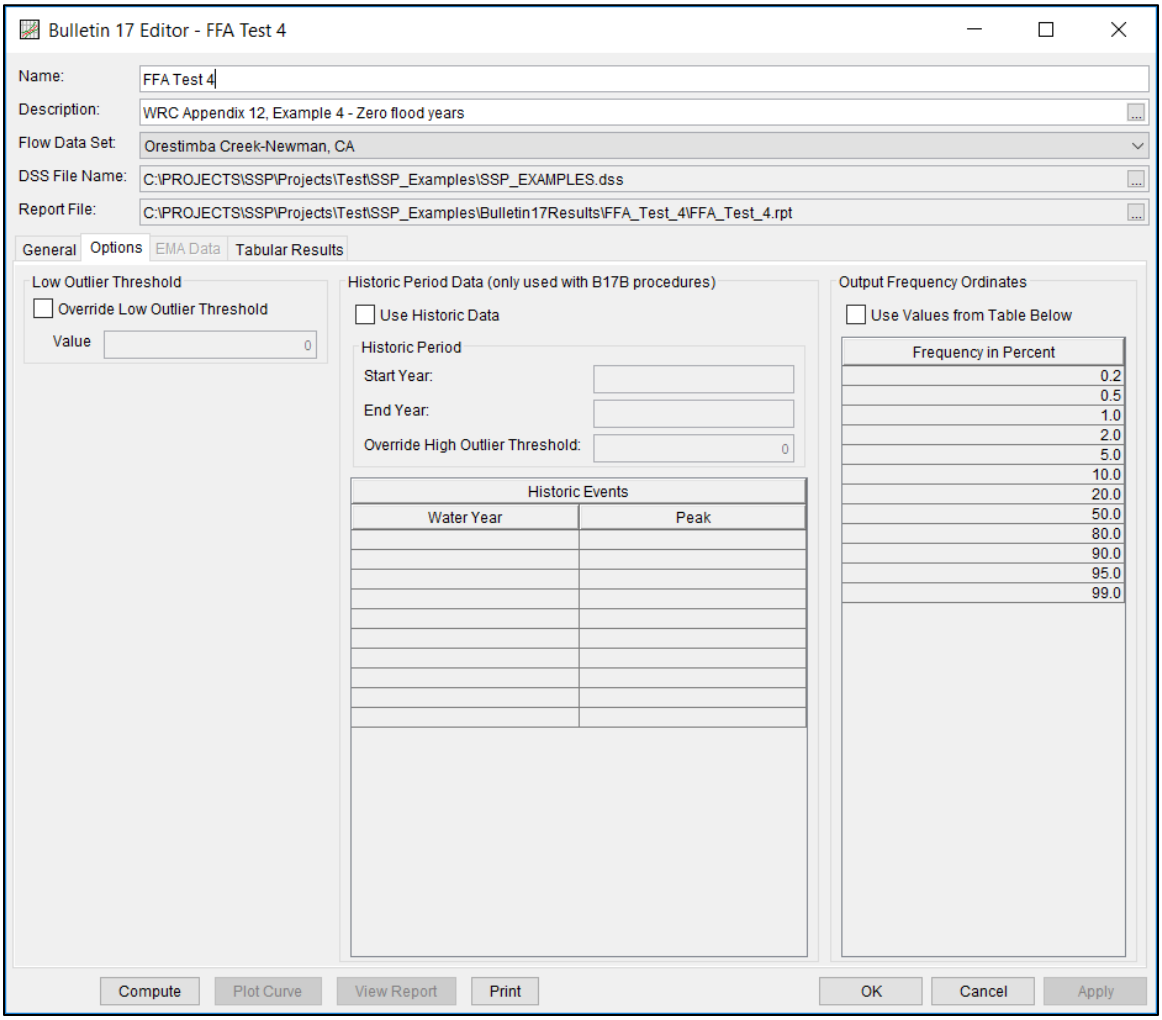


Figure B-26. Bulletin 17 Editor with the Options Tab Selected for FFA Test 4.

As shown in Figure B-26, 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.

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 B-27.

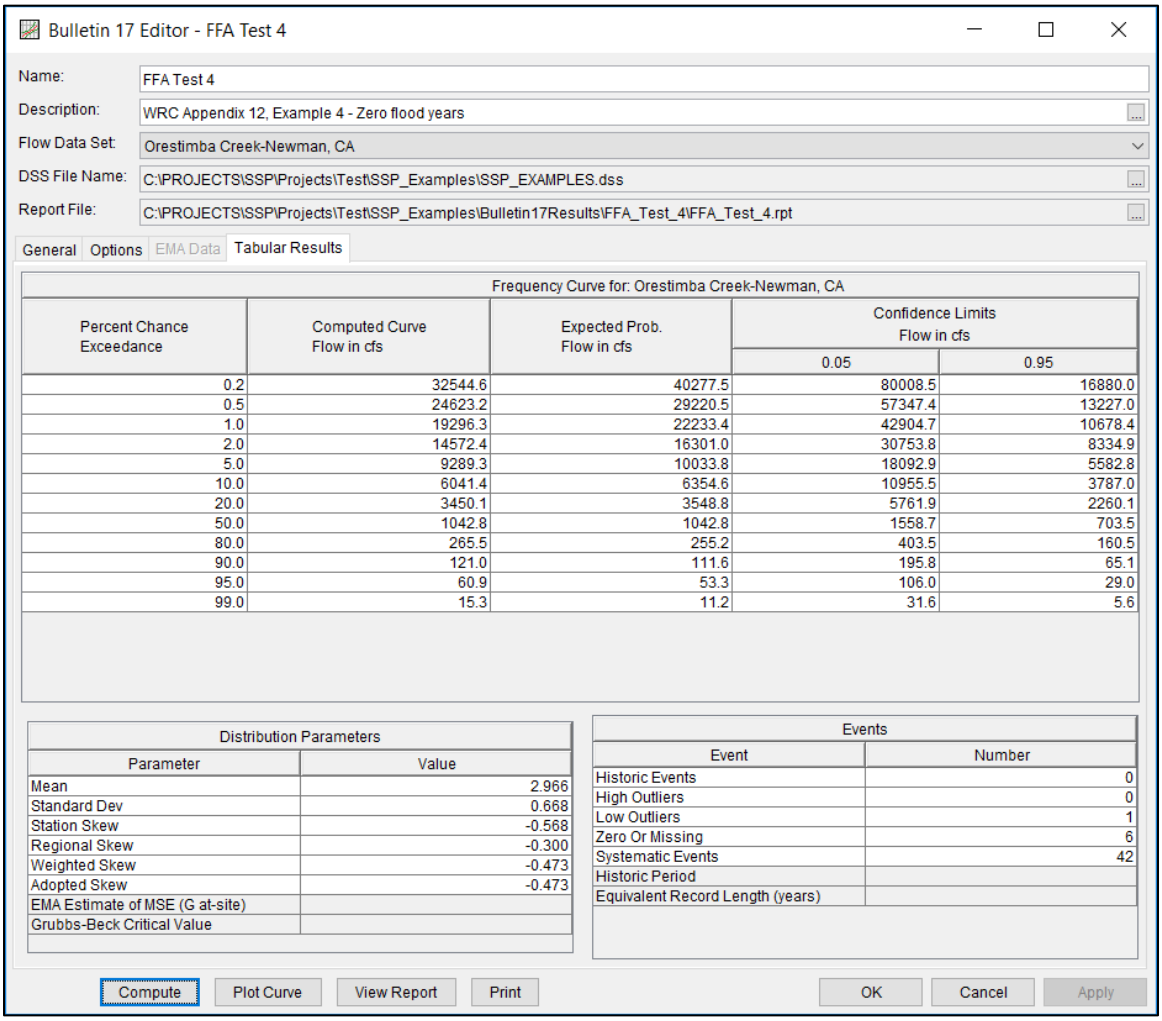


Figure B-27. Bulletin 17 Editor with the Results Tab Selected for FFA Test 4.

As shown in Figure B-27, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (5% and 95% chance exceedance curves)

On the bottom left-hand 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-hand side of the results tab is a table of Number of Events 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 B-28.

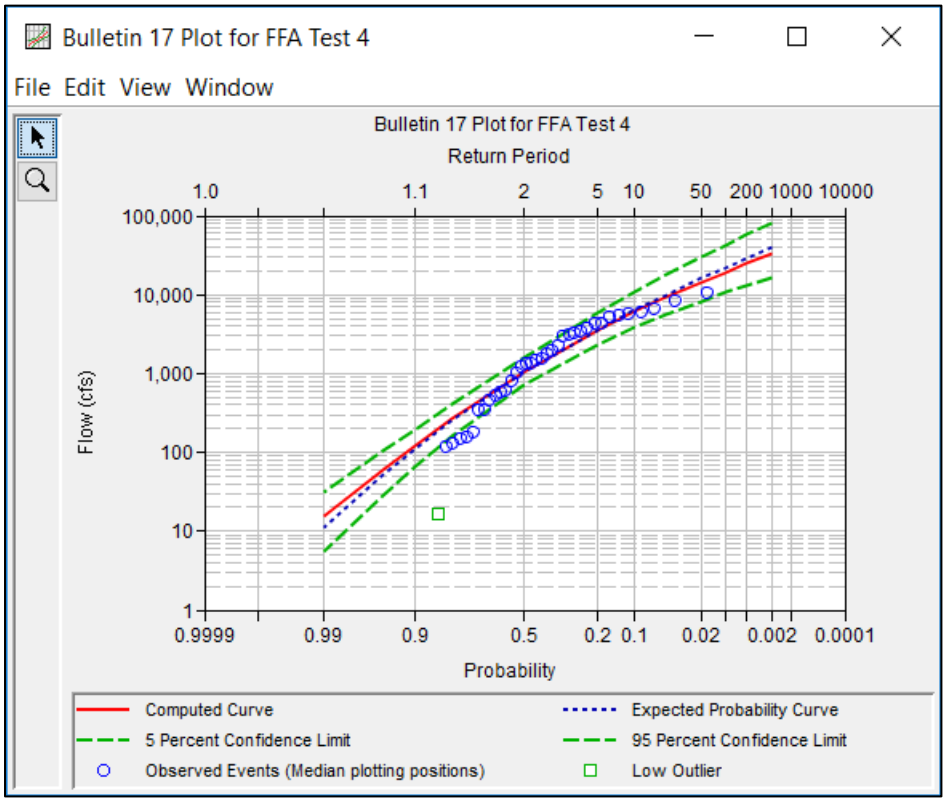


Figure B-28. Plot of FFA Test 4 Results.

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 B-29 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.

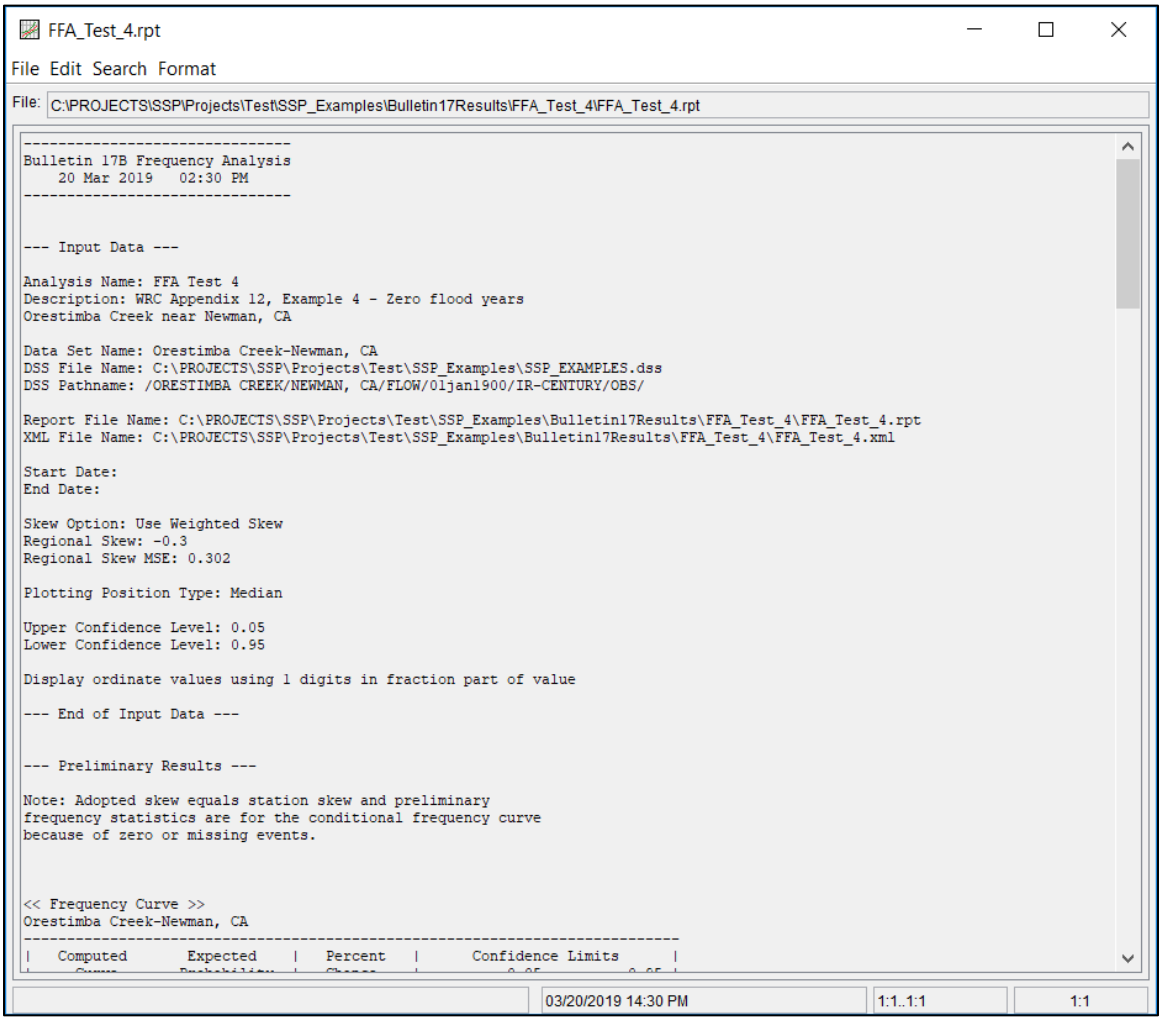
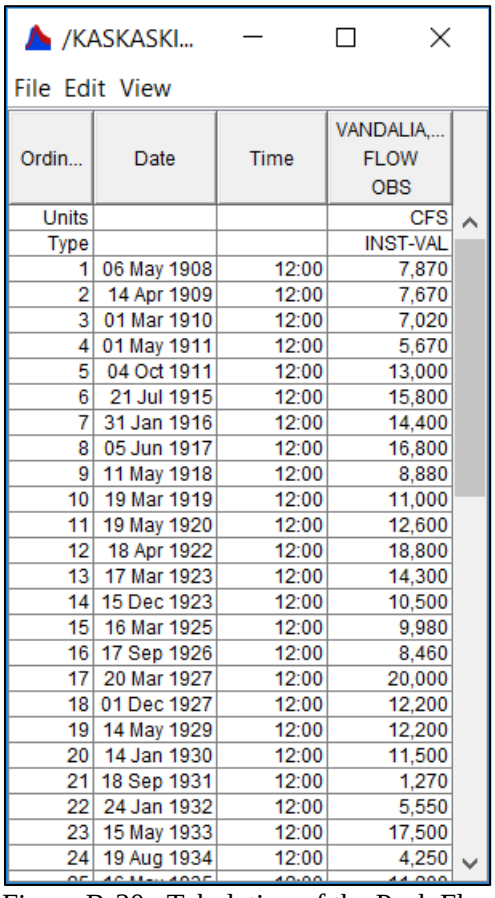


Figure B-29. Report File for FFA Test 4.

Example 5: Confidence Limits and Low Threshold Discharge

This example illustrates the use of user-entered confidence limits. Probabilities of .01 and .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. This example therefore also demonstrates the use of a user-entered low outlier threshold set to be higher than both values.

The data for this 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 from HEC-SSP, right-click on the data record labeled "**Kaskaskia River-Vandalia, IL**" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure B-30.



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

Figure B-30. 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 B-31.

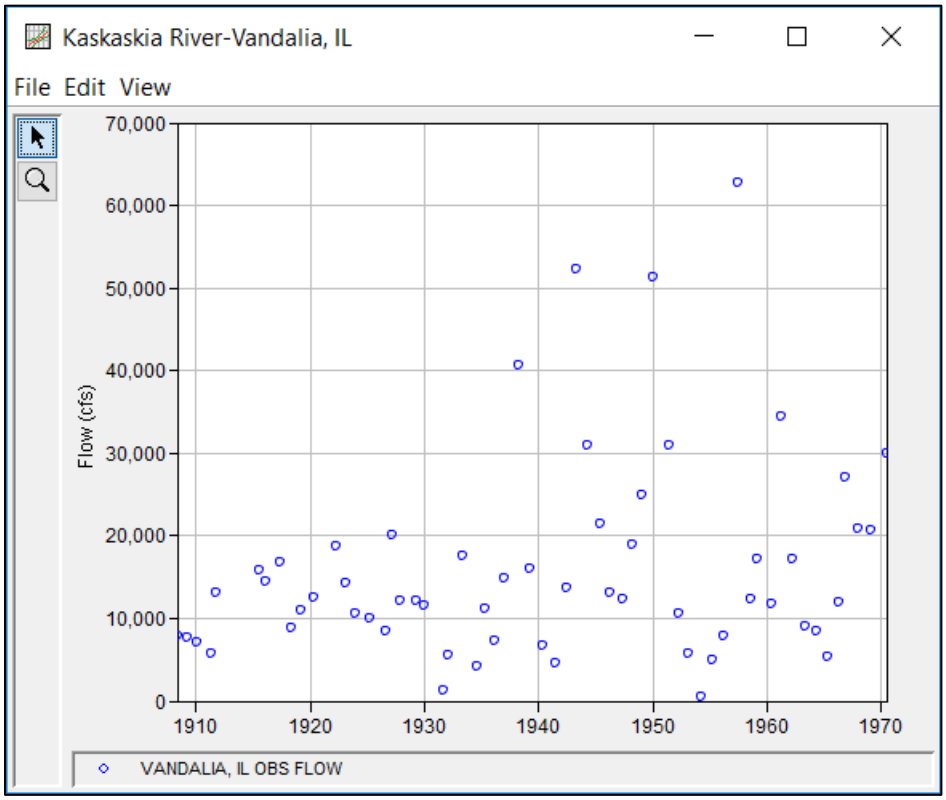


Figure B-31. HEC-SSP Plot of the Kaskaskia River Data.

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for **FFA Test 5**, either double-click on the analysis labeled **FFA Test 5** from the study explorer, or from the **Analysis** menu select **Open** and then select **FFA Test 5** from the list of available analyses. When **FFA Test 5** is selected, the Bulletin 17 analysis editor will appear as shown in Figure B-32.

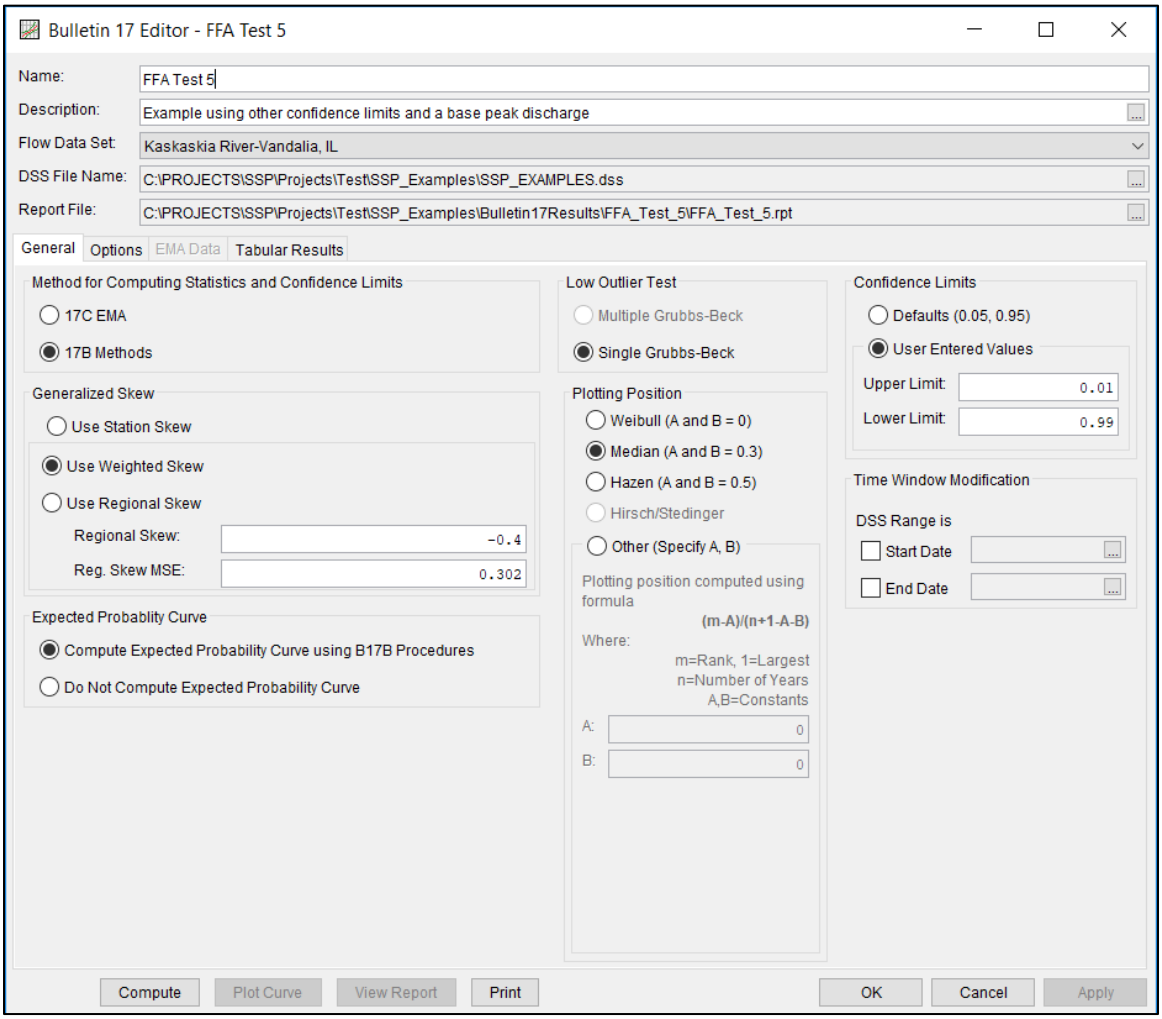


Figure B-32. Bulletin 17 Analysis Editor for FFA Test 5.

Shown in Figure B-32 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 -0.4 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.

Also for this 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 (.05 and .95) were changed to

0.01 (1 percent chance exceedance) and 0.99 (99% chance exceedance). Shown in Figure B-33 is the Bulletin 17 editor with the **Options Tab** selected.

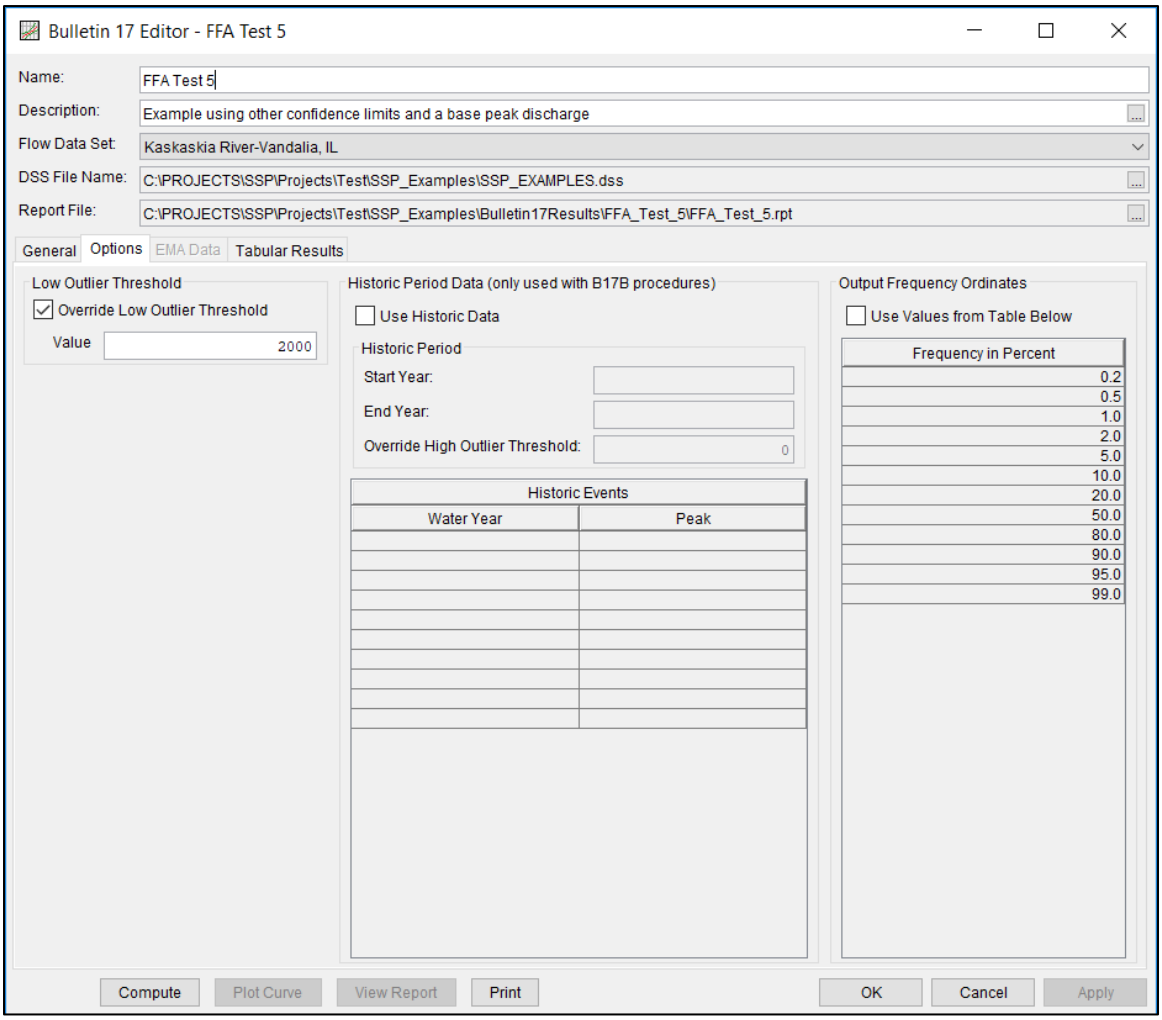


Figure B-33. Bulletin 17 Editor with the Options Tab Shown for FFA Test 5.

As shown in Figure B-33, 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 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.

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 B-34.

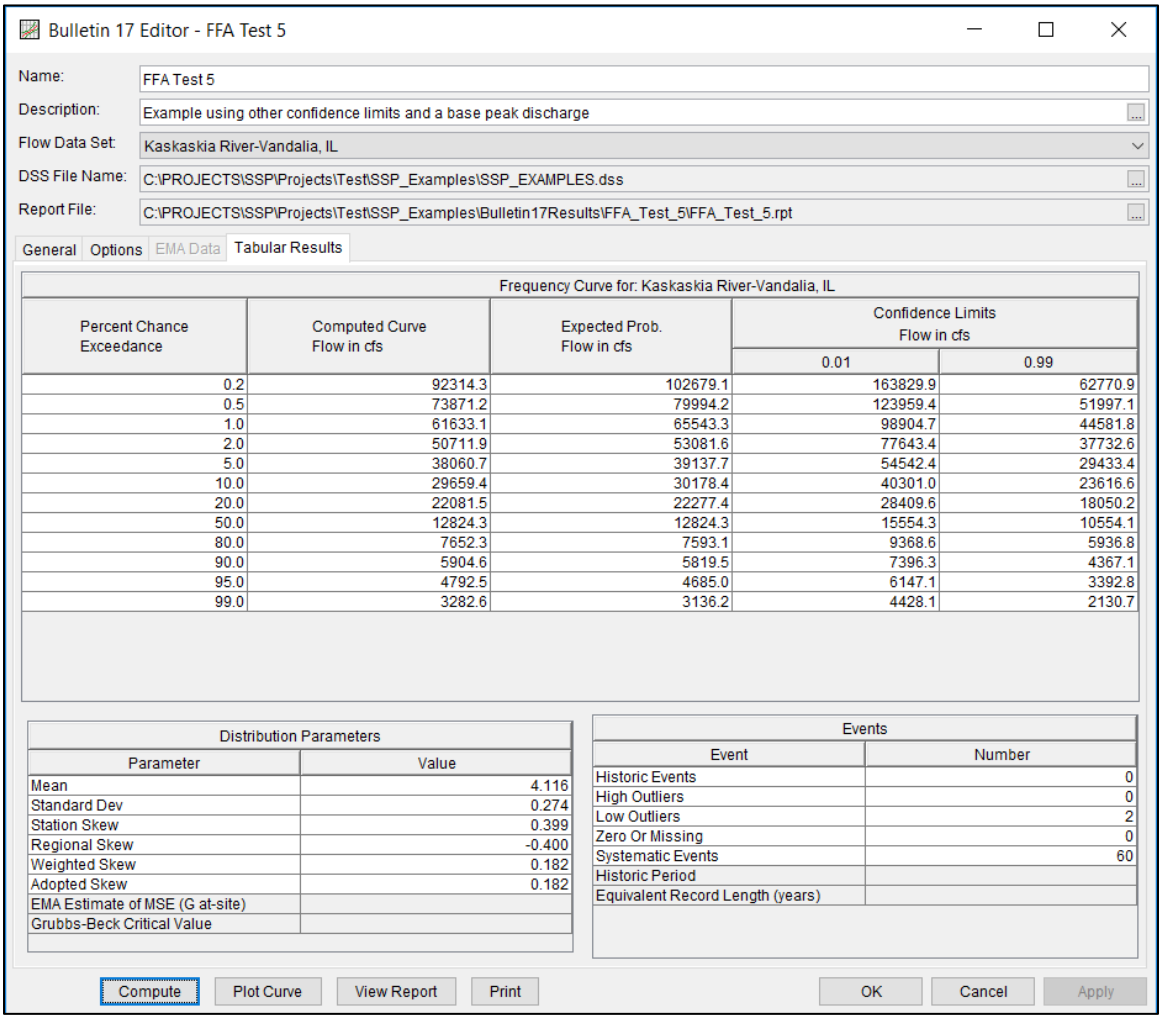


Figure B-34. Bulletin 17 Editor with the Results Tab Selected for FFA Test 5.

As shown in Figure B-34, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (1% and 99% chance exceedance curves)

On the bottom left-hand 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-hand side of the results tab is a table of Number of Events 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 B-35.

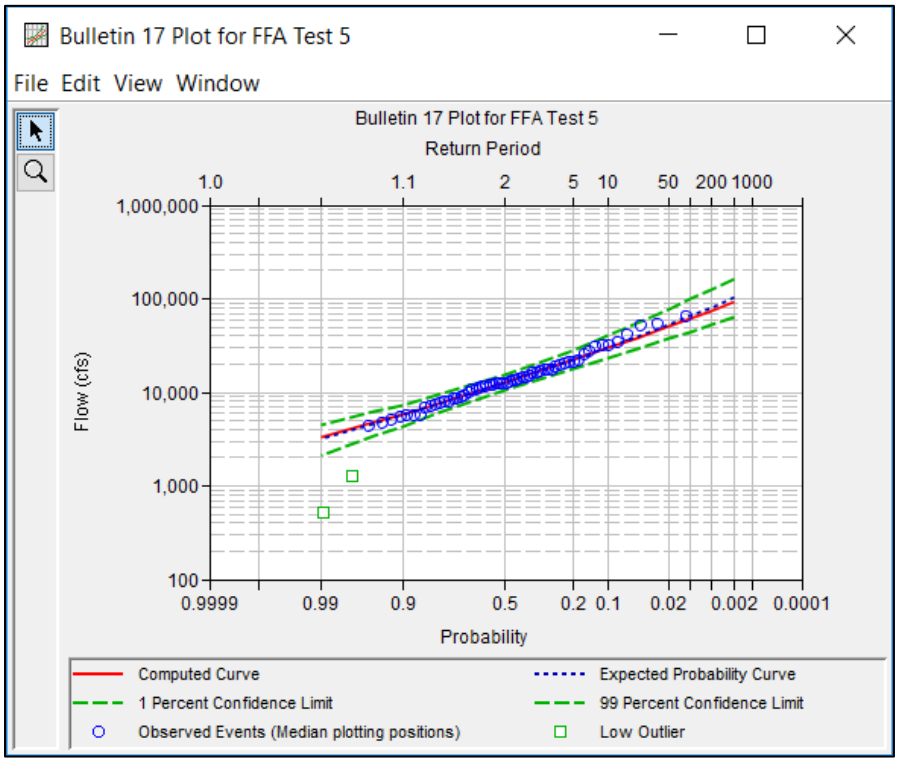


Figure B-35. Plot of the Frequency Curve Results for FFA Test 5.

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 B-36 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.

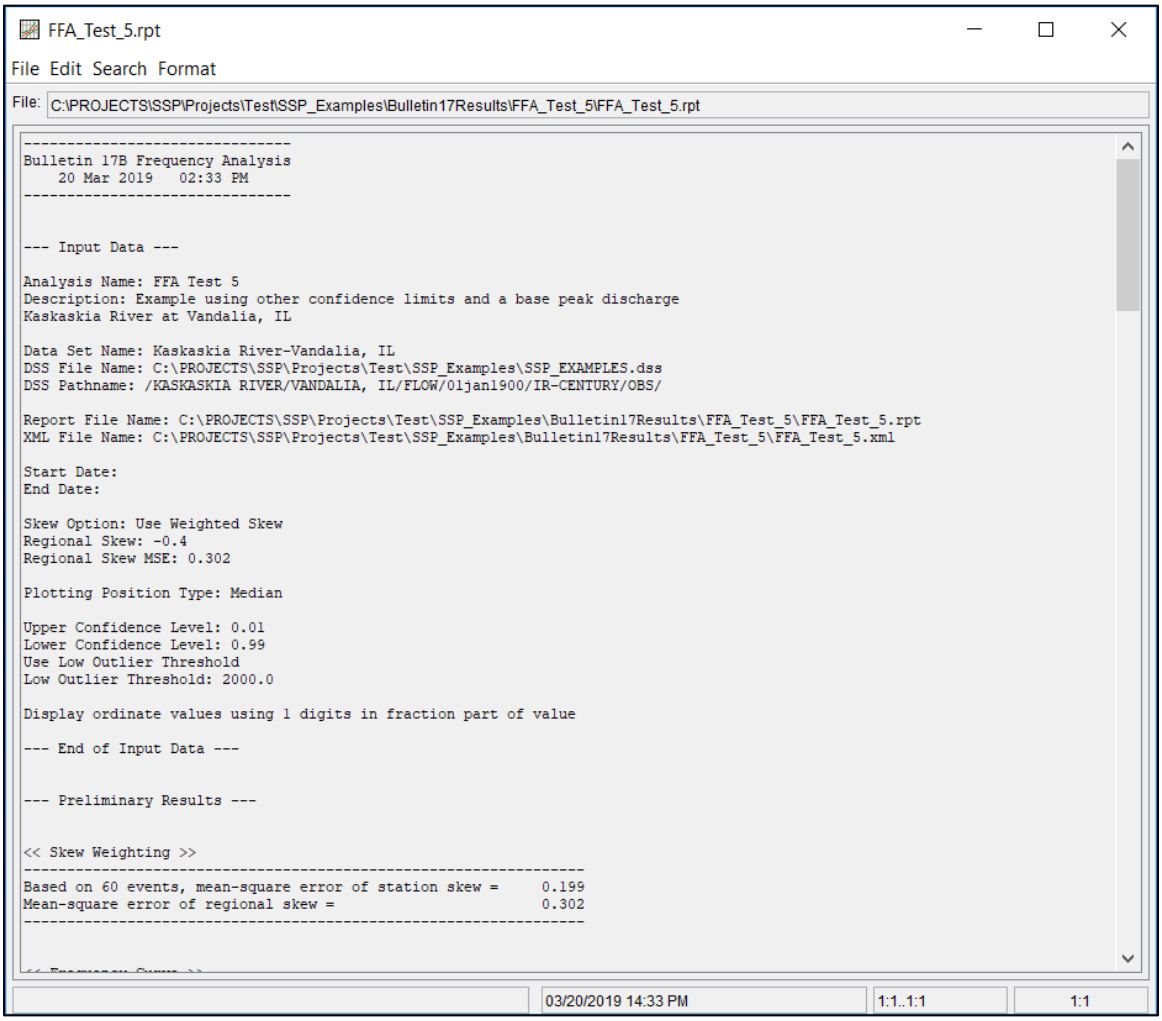
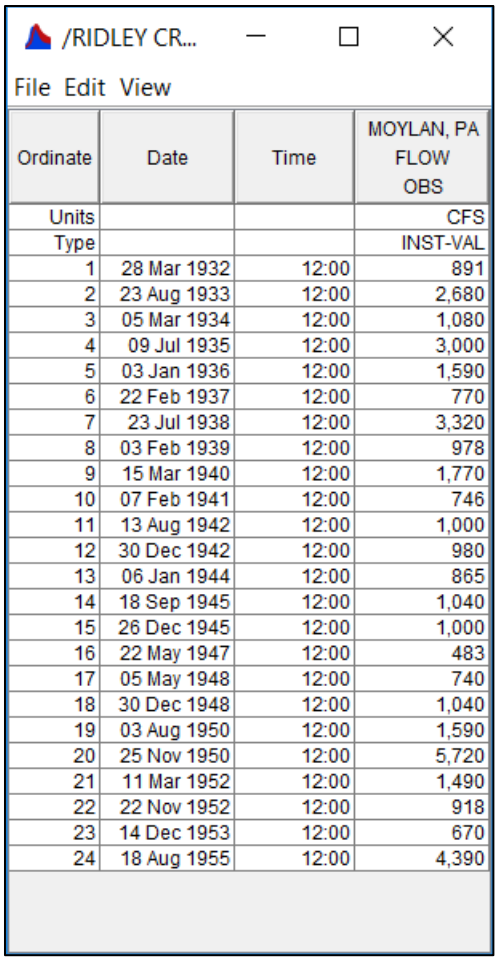


Figure B-36. Report File for FFA Test 5.

Example 6: Use of Historic Data

This example 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.

The data for this 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 from HEC-SSP, right-click on the data record labeled "**Ridley Creek-Moylan, PA**" in the study explorer and then select **Tabulate**. The data will appear as shown in Figure B-37.



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

Figure B-37. 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 B-38.

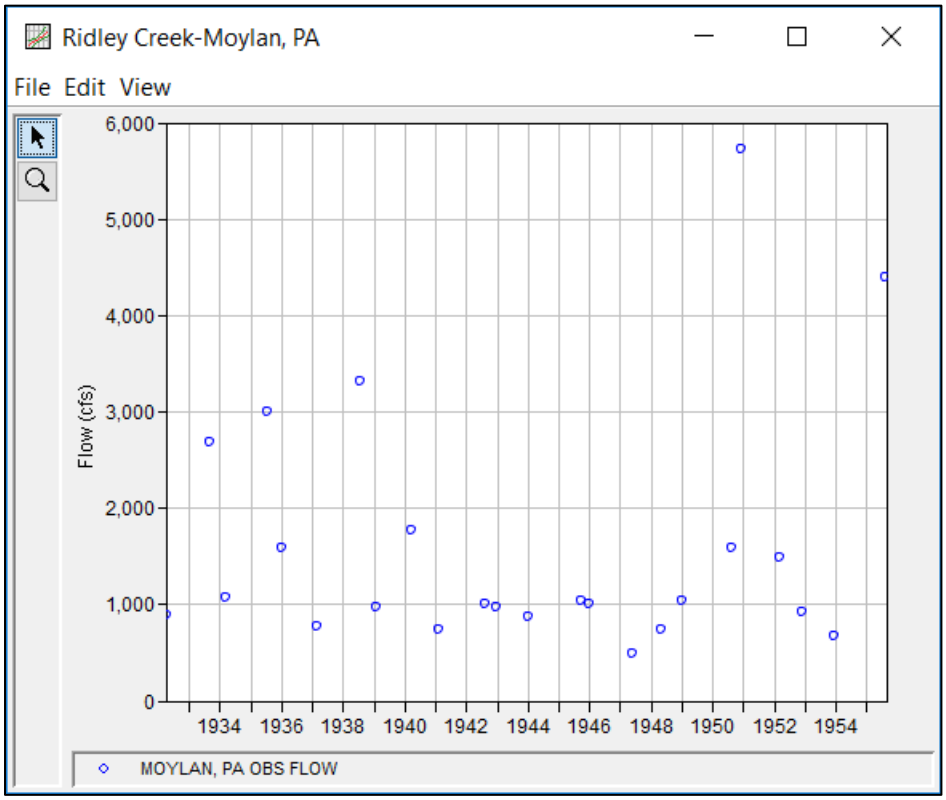


Figure B-38. Plot of the Ridley Creek Data.

A Bulletin 17 and General Frequency analysis have been developed for this example. To open the Bulletin 17 analysis editor for **FFA Test 6**, either double-click on the analysis labeled **FFA Test 6** from the study explorer, or from the **Analysis** menu select open, then select **FFA Test 6** from the list of available analyses. When **FFA Test 6** is selected, the Bulletin 17 analysis editor will appear as shown in Figure B-39.

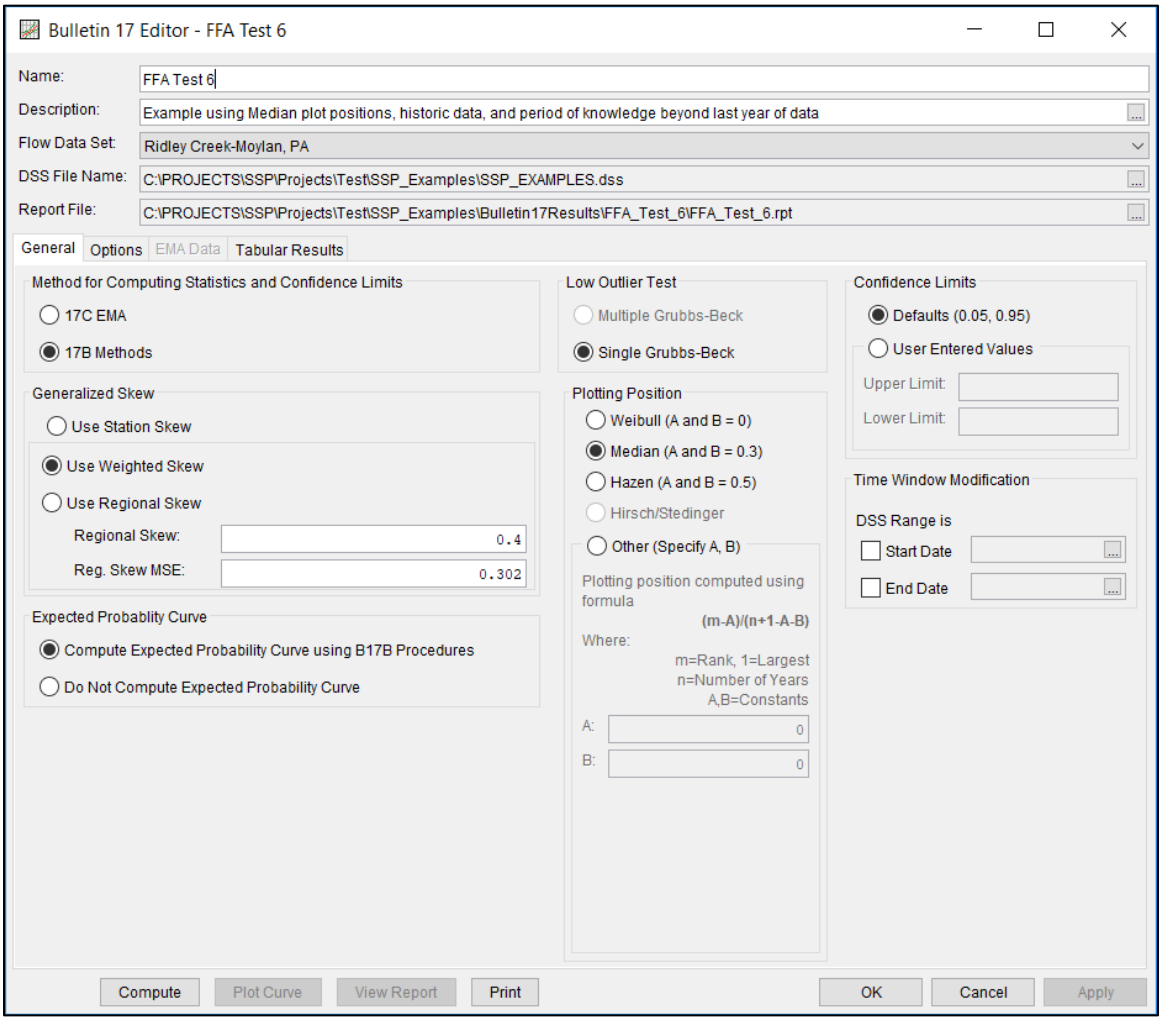


Figure B-39. Bulletin 17 Analysis Editor for FFA Test 6.

Shown in Figure B-39 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 0.4 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.

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** of 0.05 (5 percent chance exceedance) and

0.95 (95% chance exceedance). Shown in Figure B-40 is the Bulletin 17 editor with the **Options Tab** selected.

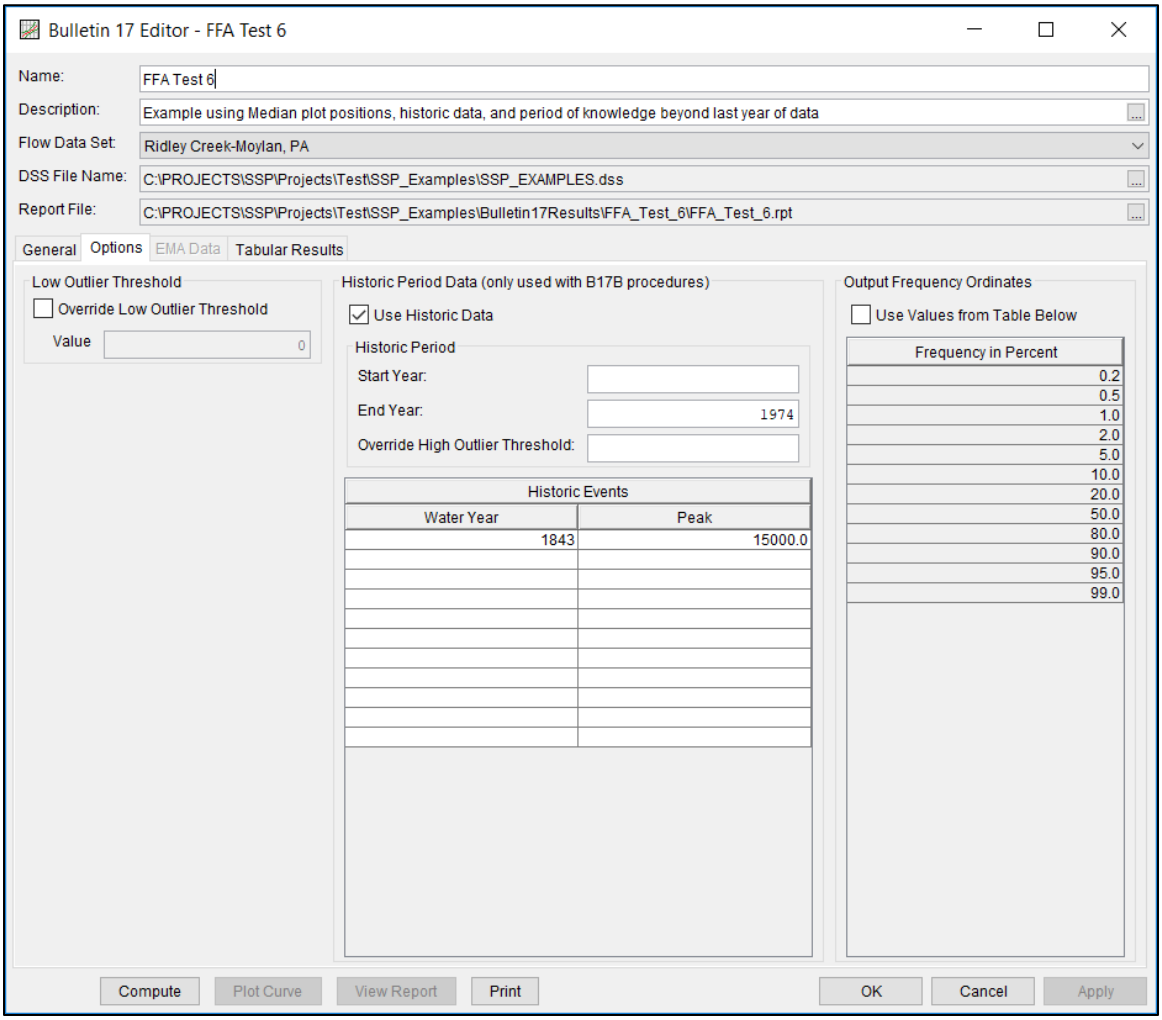


Figure B-40. Bulletin 17 Analysis Editor with Options Tab Shown for FFA Test 6.

As shown in Figure B-40, 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 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 this tab include the **Low Outlier Threshold** and the option to override the default **Frequency Ordinates**. Neither option is selected in this example.

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 B-41.

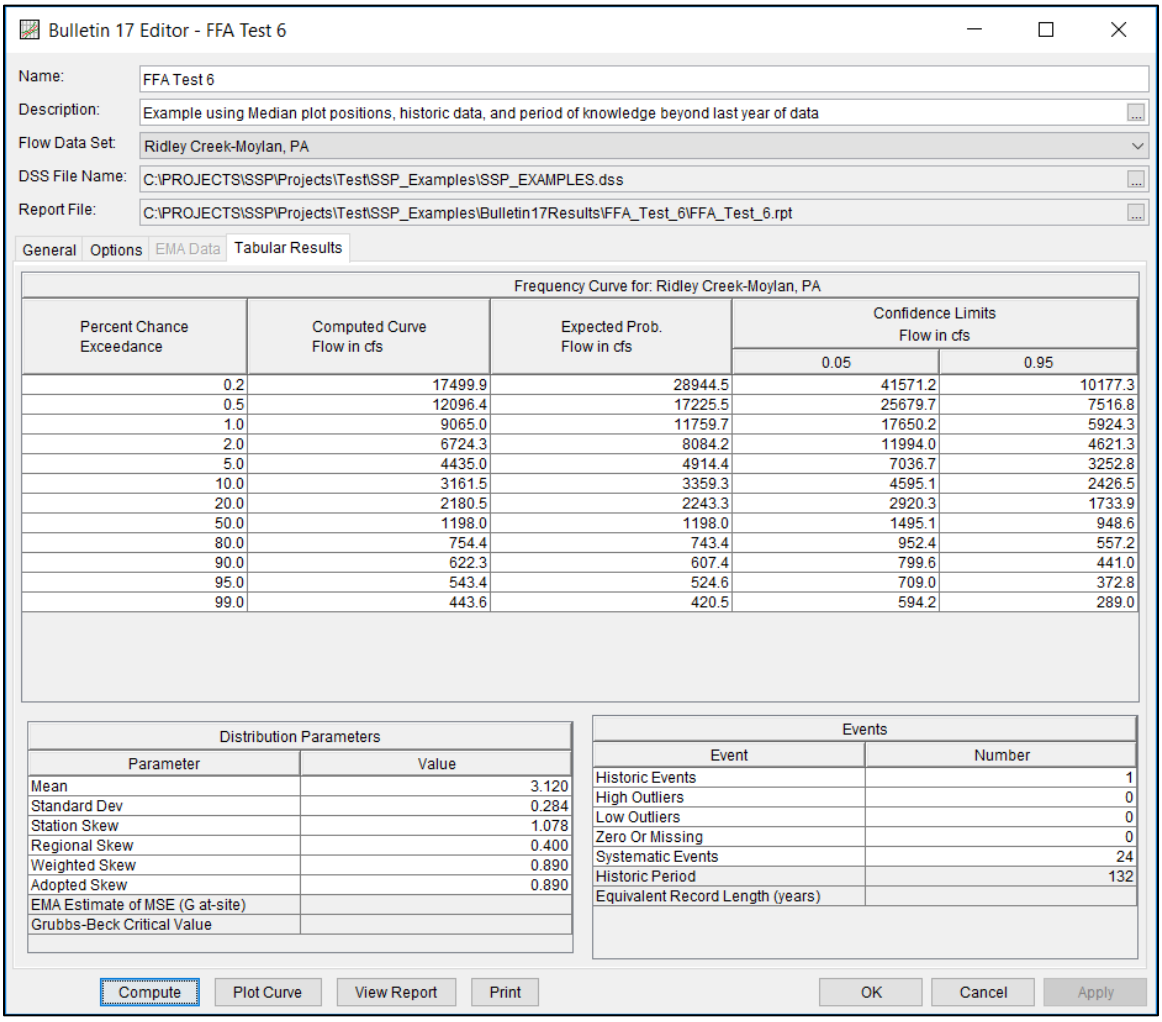


Figure B-41. Bulletin 17 Editor with the Results Tab Selected for FFA Test 6.

As shown in Figure B-41, the Frequency Curve table contains the following results:

Percent Chance Exceedance

Computed Curve (Log-Pearson III results)

Expected Probability Curve

Confidence Limits (5% and 95% chance exceedance curves)

On the bottom left-hand 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-hand side of the results tab is a table of Number of Events 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).

This 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 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 B-42.

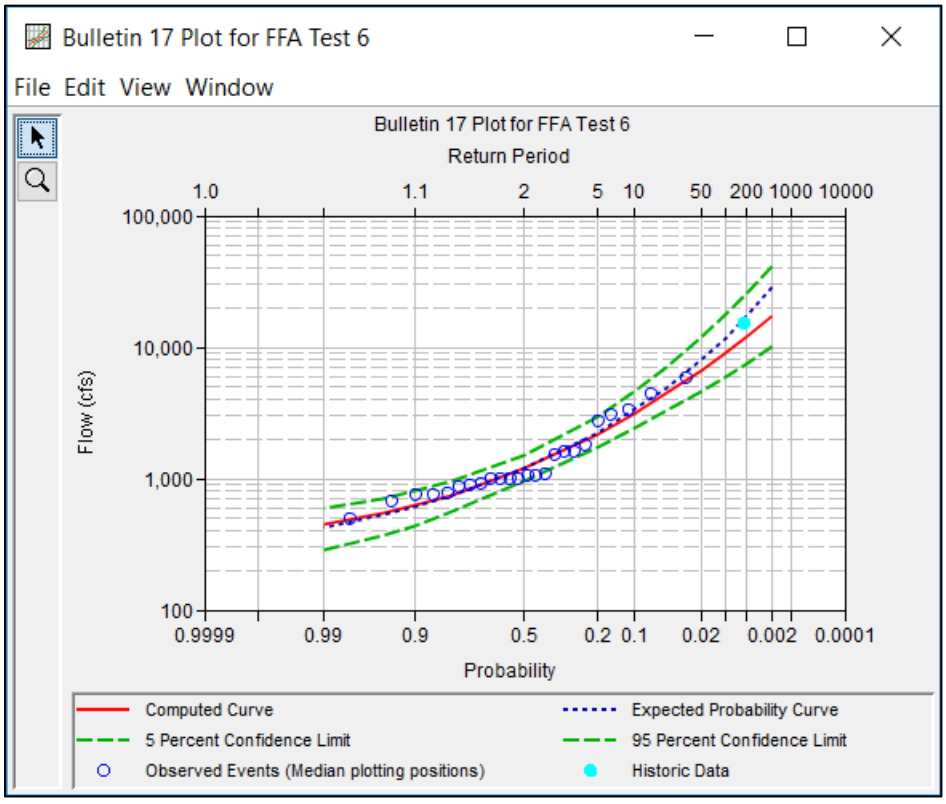


Figure B-42. Plot of the Frequency Curve Results for FFA Test 6.

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 B-43 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.

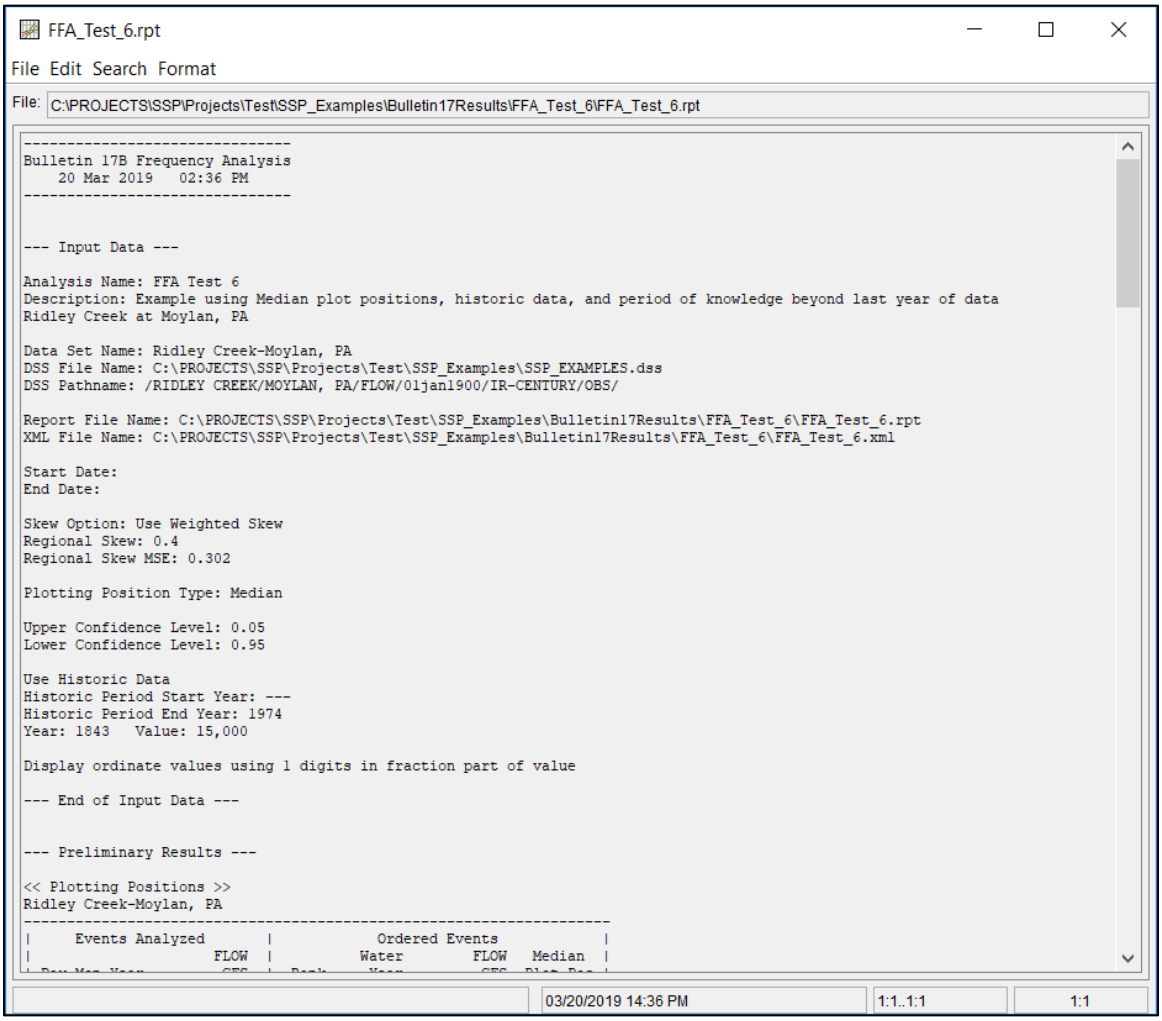
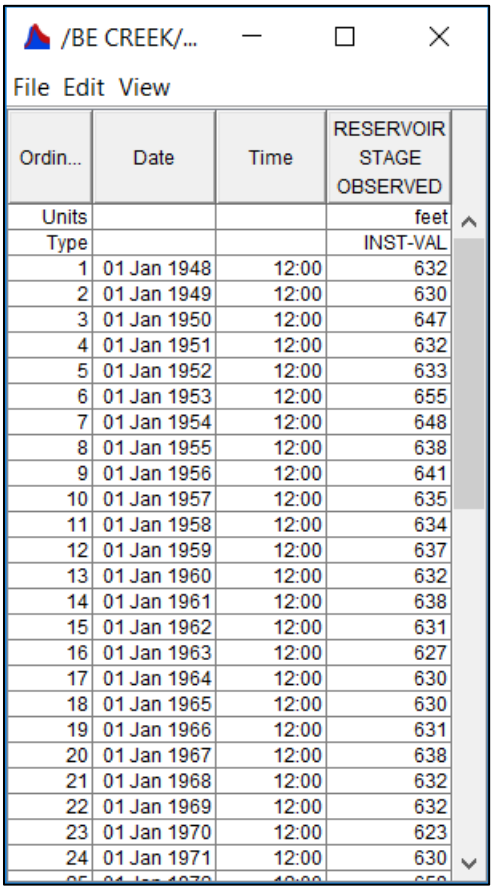


Figure B-43. Report File for FFA Test 6.

Example 7: Analyzing Stage Data

This example demonstrates how to use the General Frequency analysis to analyze stage data. The data 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 B-44.



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

Figure B-44. Tabulation of the Peak Stage Data for Example 7.

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 B-45.

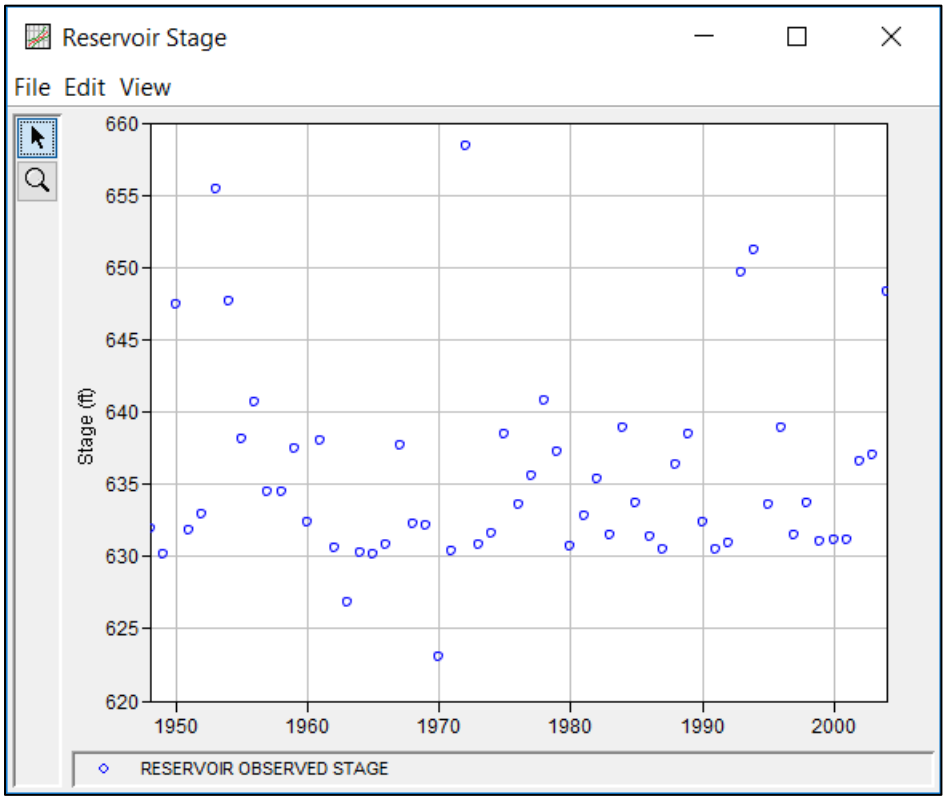


Figure B-45. Plot of the Reservoir Stage Data.

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, or 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 B-46. 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.

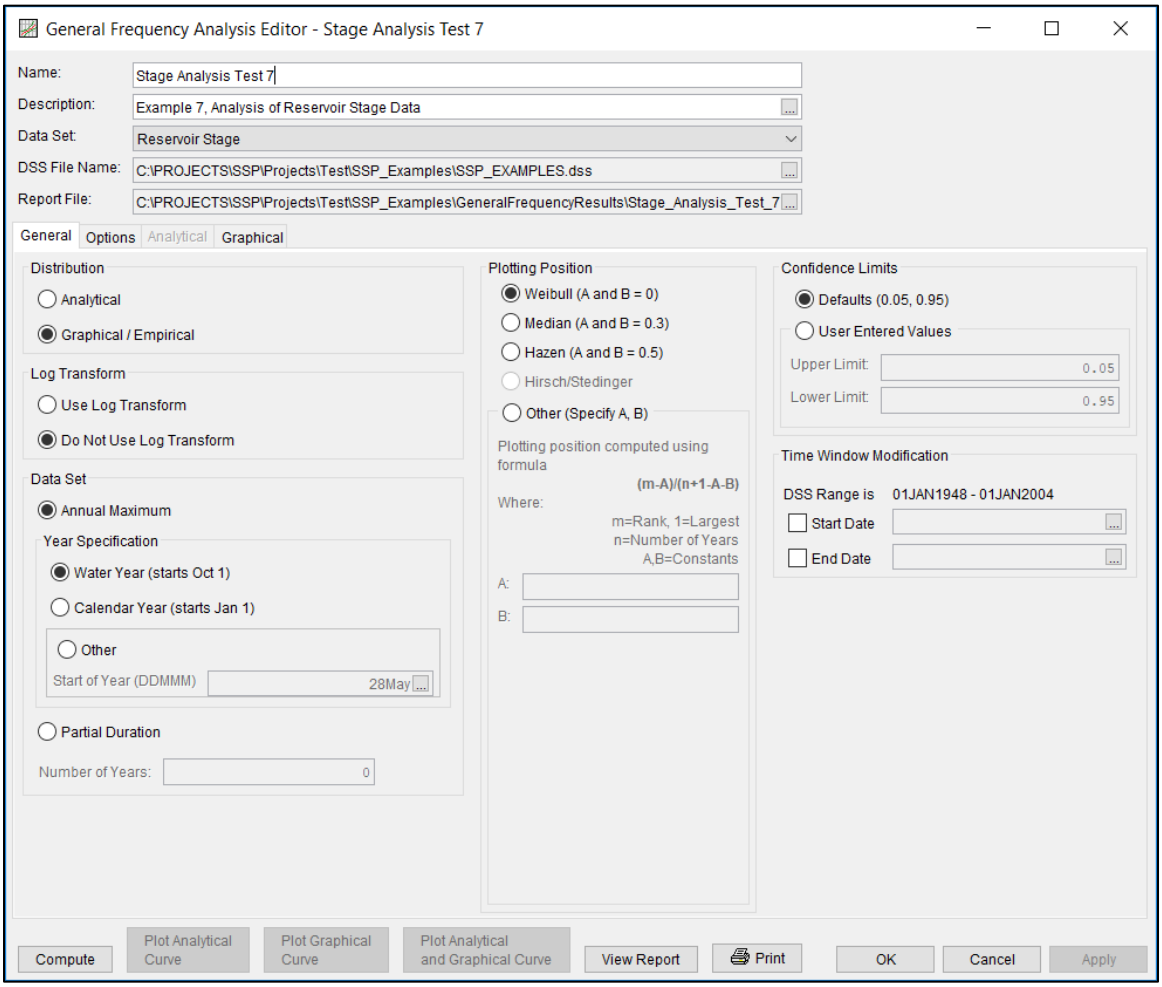


Figure B-46. General Frequency Analysis Editor for Stage Analysis Test 7.

Shown in Figure B-47 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.

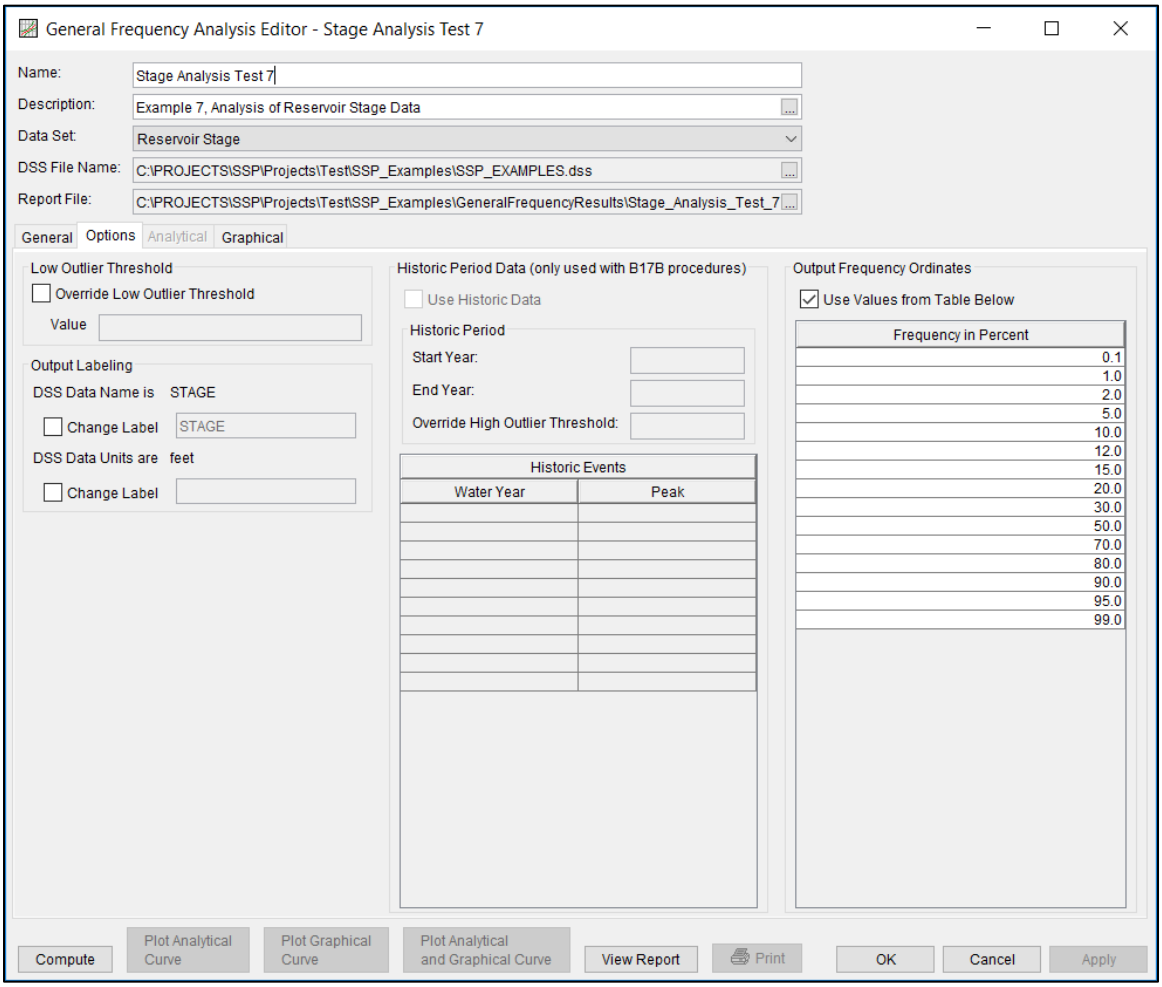


Figure B-47. General Frequency Analysis Editor with Options Tab Shown for Stage Analysis Test 7.

In this example, a graphical analysis was performed on the peak stage data. Shown in Figure B-48 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.

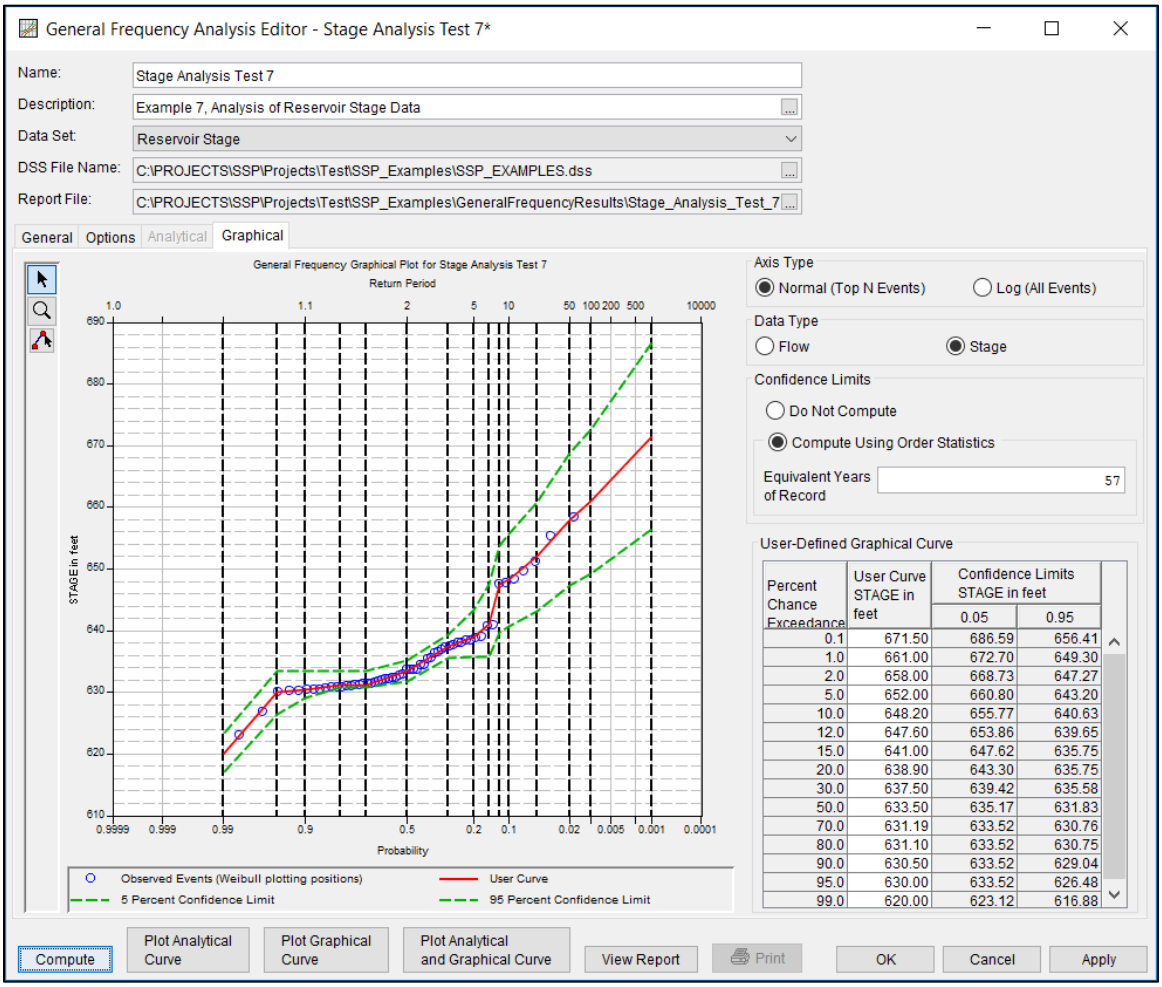


Figure B-48. General Frequency Graphical Tab Shown for Stage Analysis Test 7.

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 B-49.

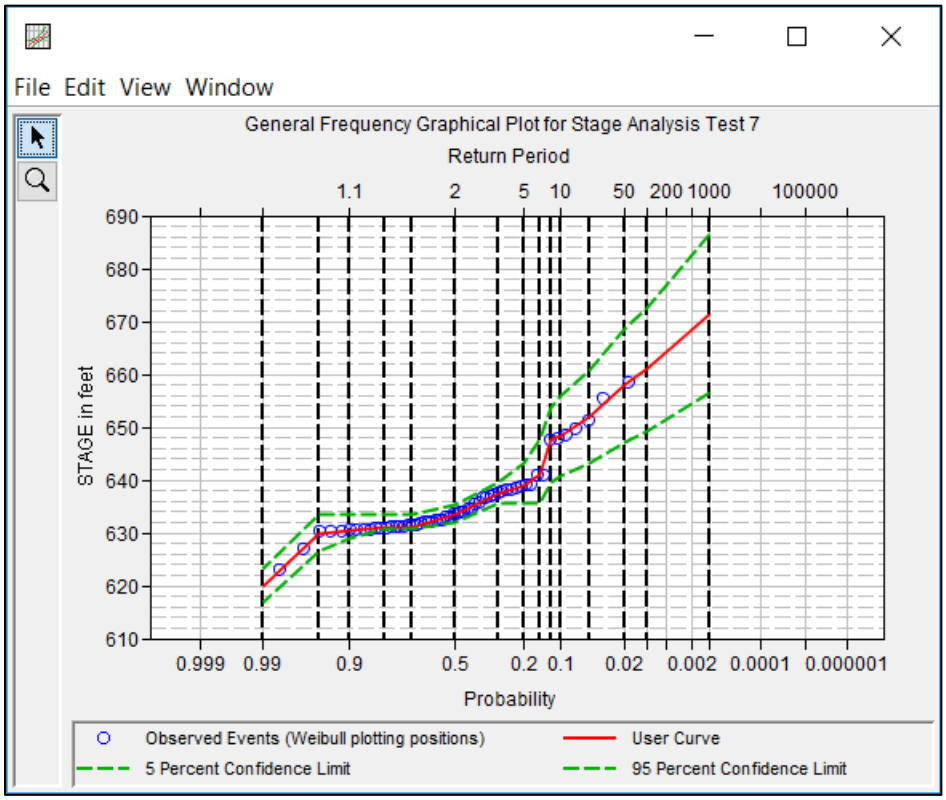


Figure B-49. Plot of the Frequency Curve Results for Stage Analysis Test 7.

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 B-50 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.

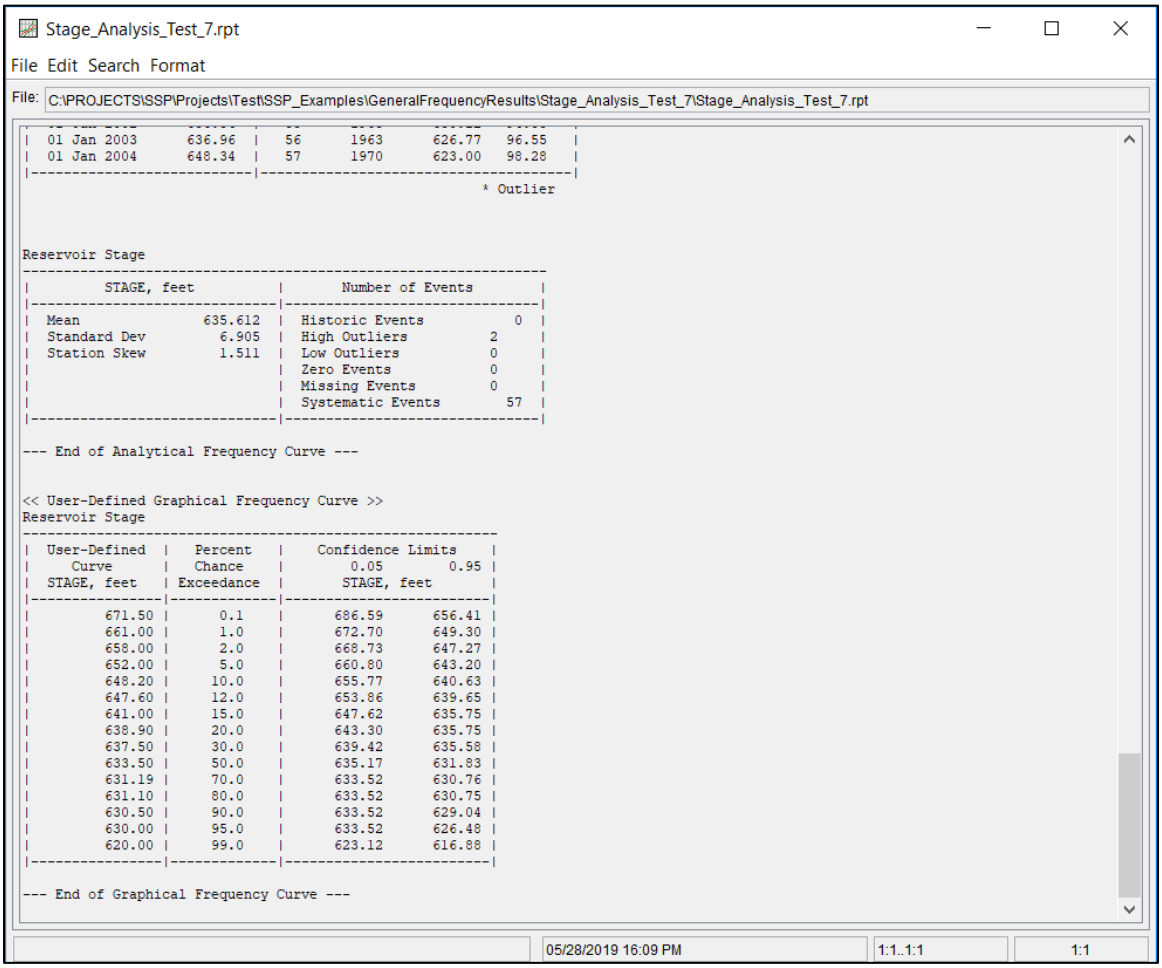
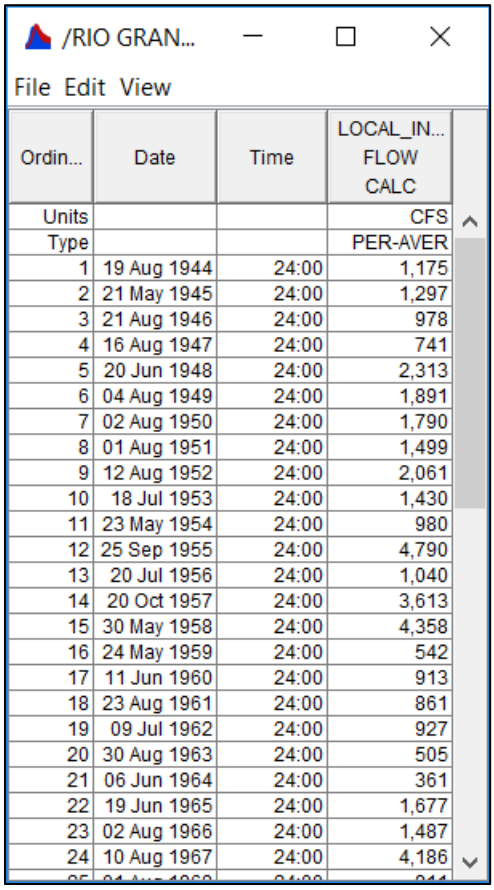


Figure B-50. Report File for Stage Analysis Test 7.

Example 8: Using User-Adjusted Statistics

This 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 B-51.



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

Figure B-51. 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 B-52.

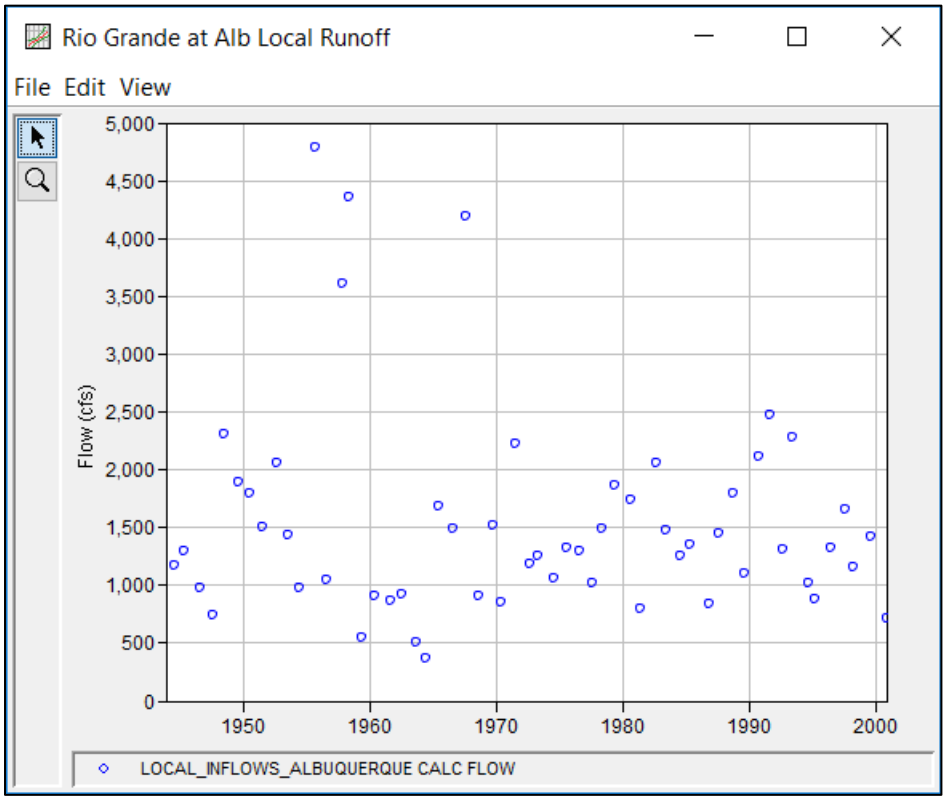


Figure B-52. Plot of Data for Example 8.

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 B-53.

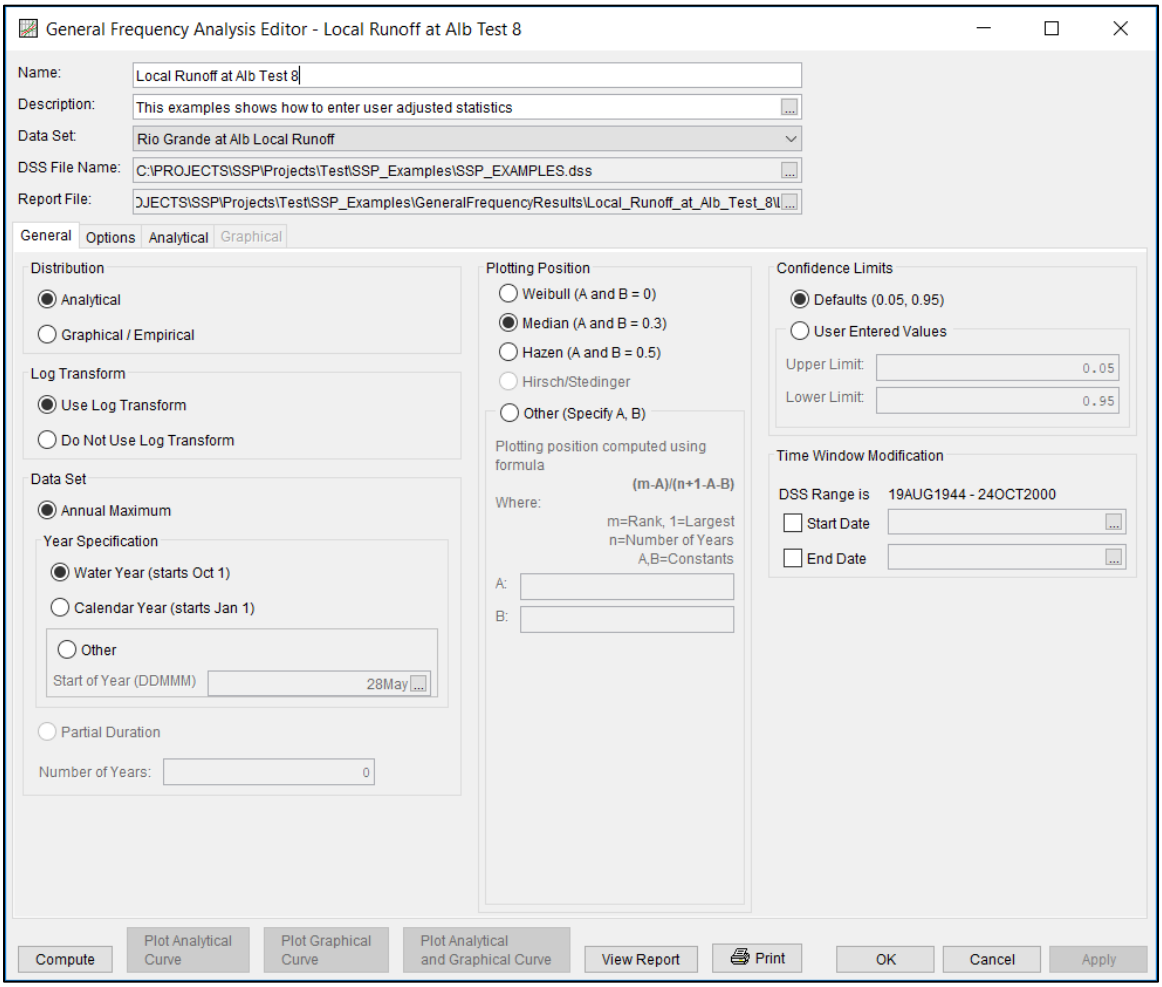


Figure B-53. General Frequency Analysis Editor for Local Runoff at Alb Test 8.

Shown in Figure B-53 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 B-54 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.

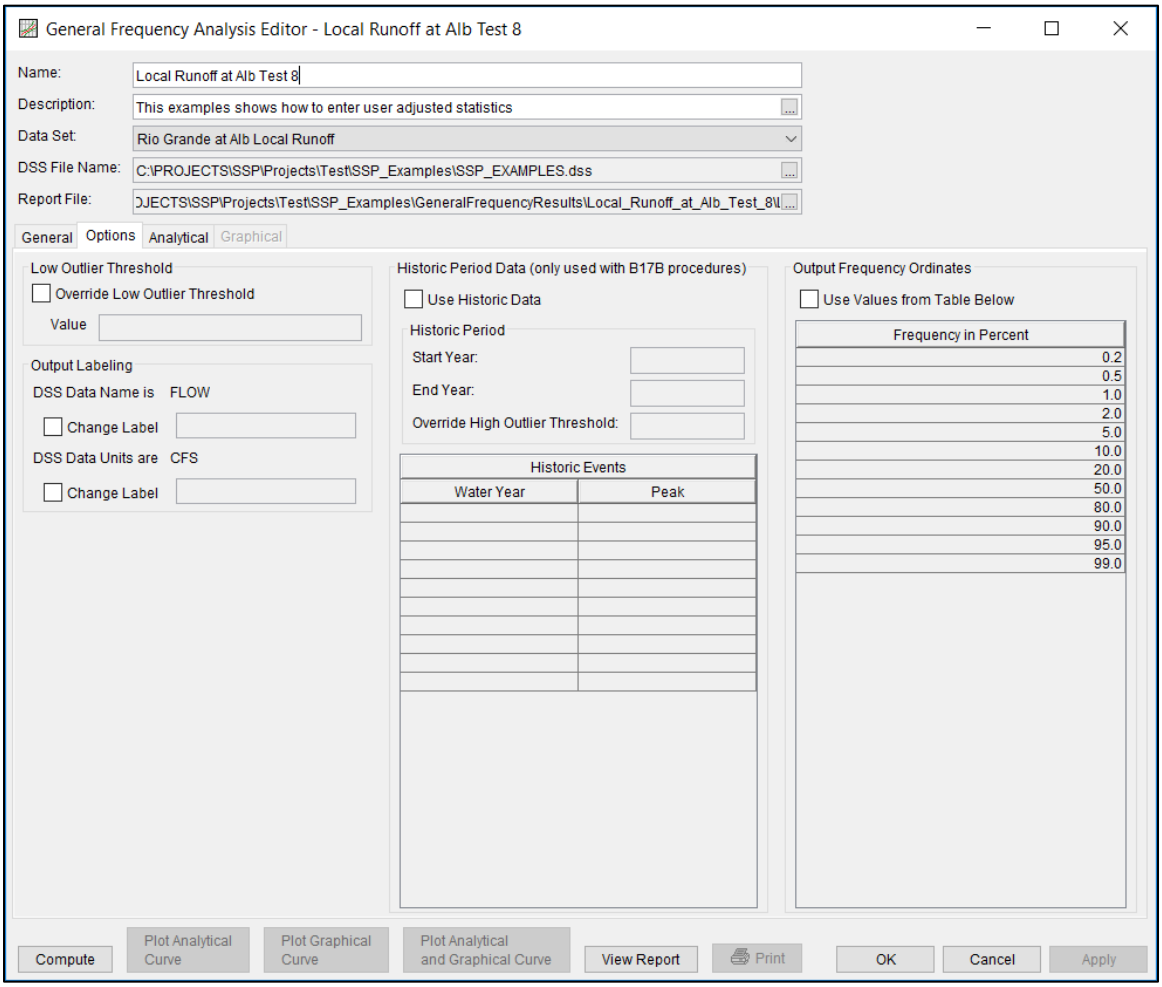


Figure B-54. General Frequency Analysis Editor with Options Tab Shown for Local Runoff at Alb Test 8.

In this example, an analytical analysis was performed. Shown in Figure B-55 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**.

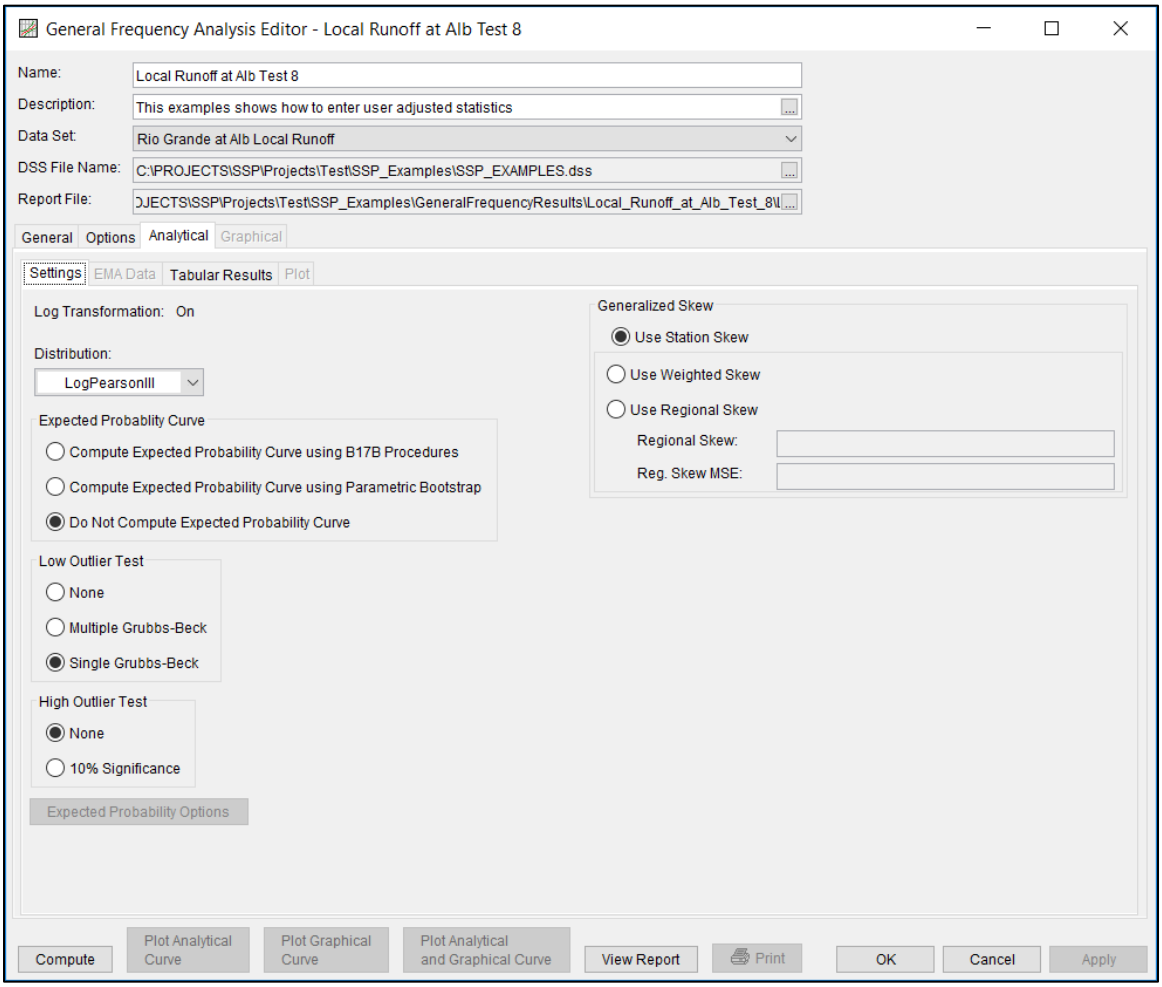


Figure B-55. General Frequency Analysis Editor with Settings Tab Shown for Local Runoff at Alb Test 8.

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 B-56.

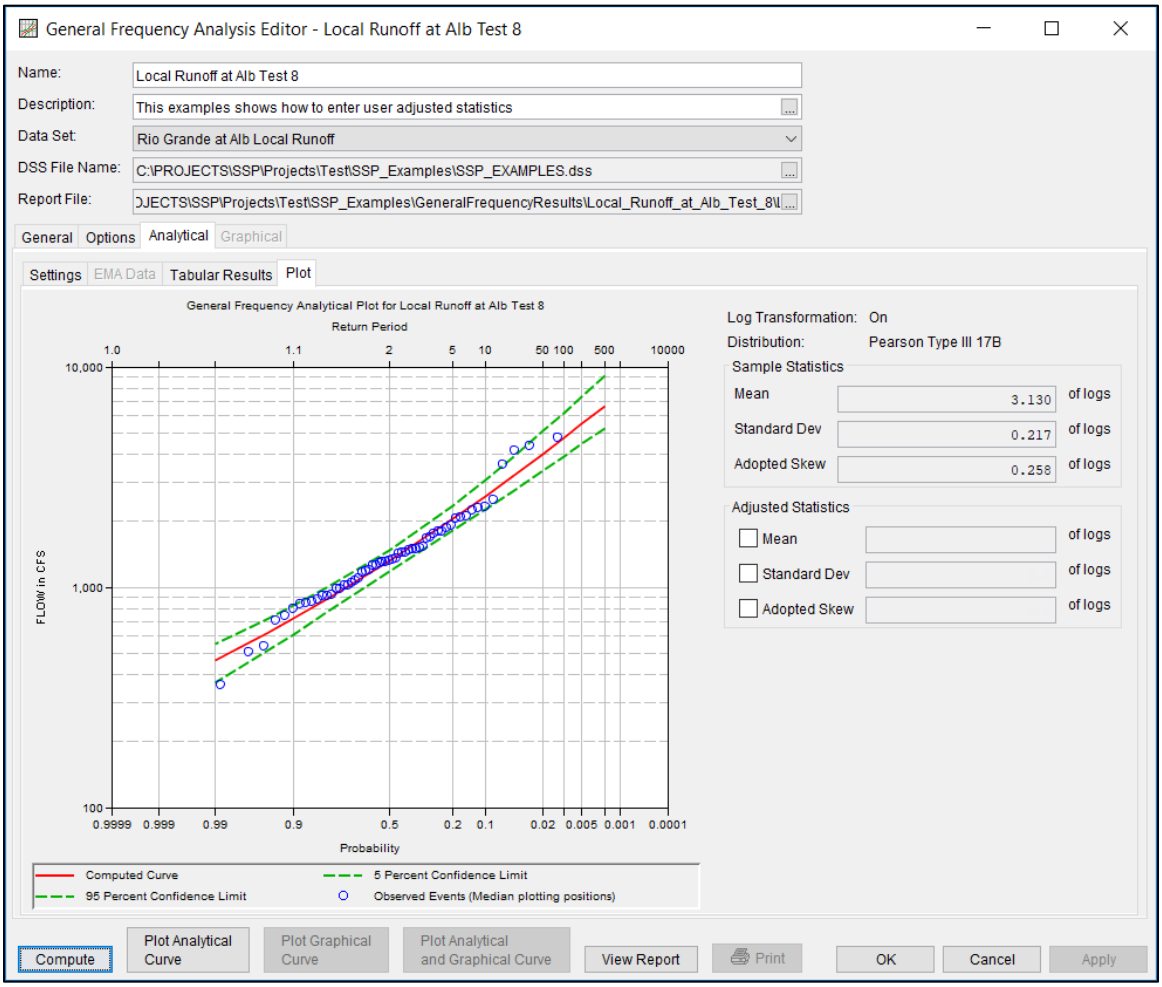


Figure B-56. The Plot Tab for Local Runoff at Alb Test 8.

As shown in Figure B-56, 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 B-57 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.

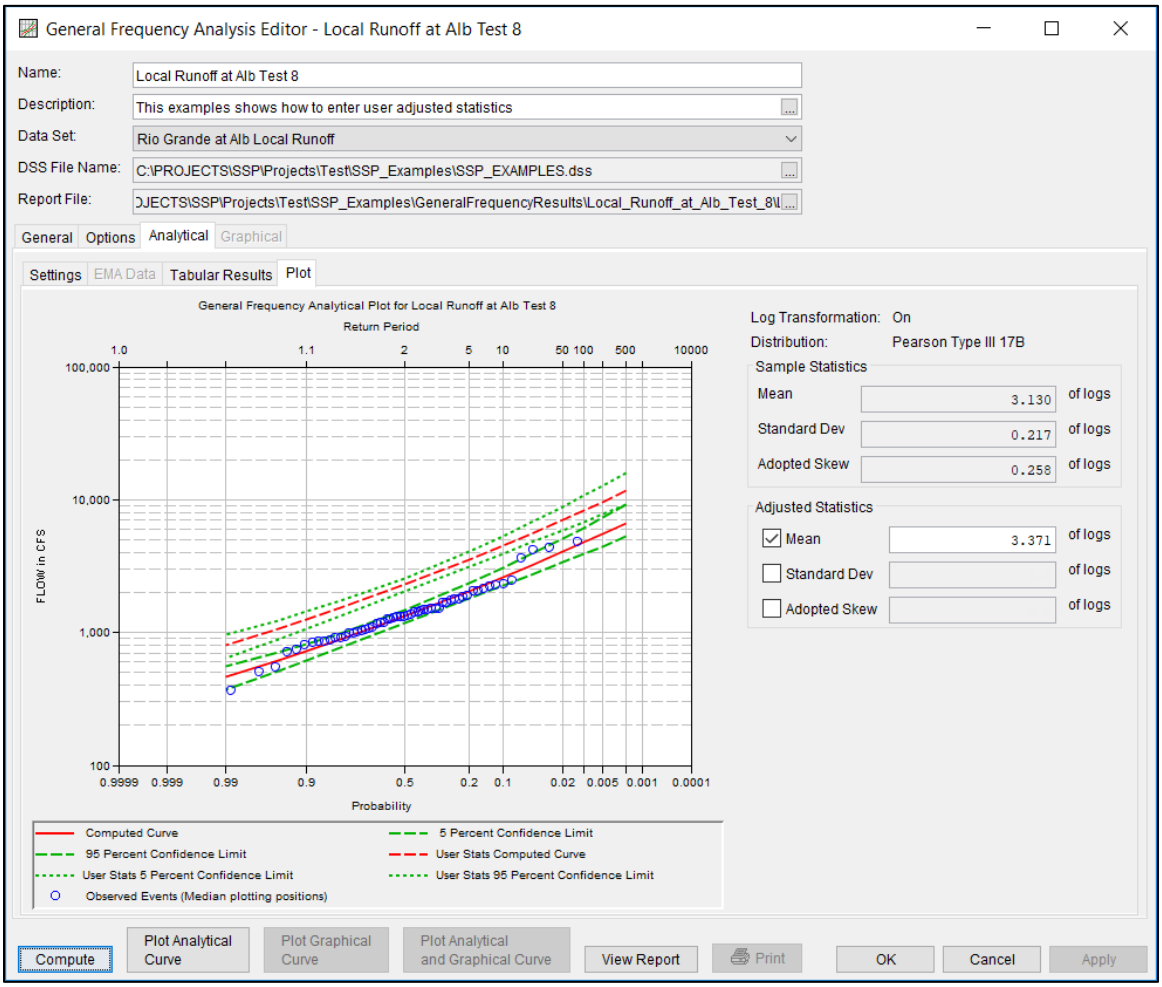


Figure B-57. Plot Tab with User Adjusted Statistics and Frequency Curves for Local Runoff at Alb Test 8.

Select the **Tabular Results** tab to see information for both the computed and user-adjusted frequency curves. As shown in Figure B-58, 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 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 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).

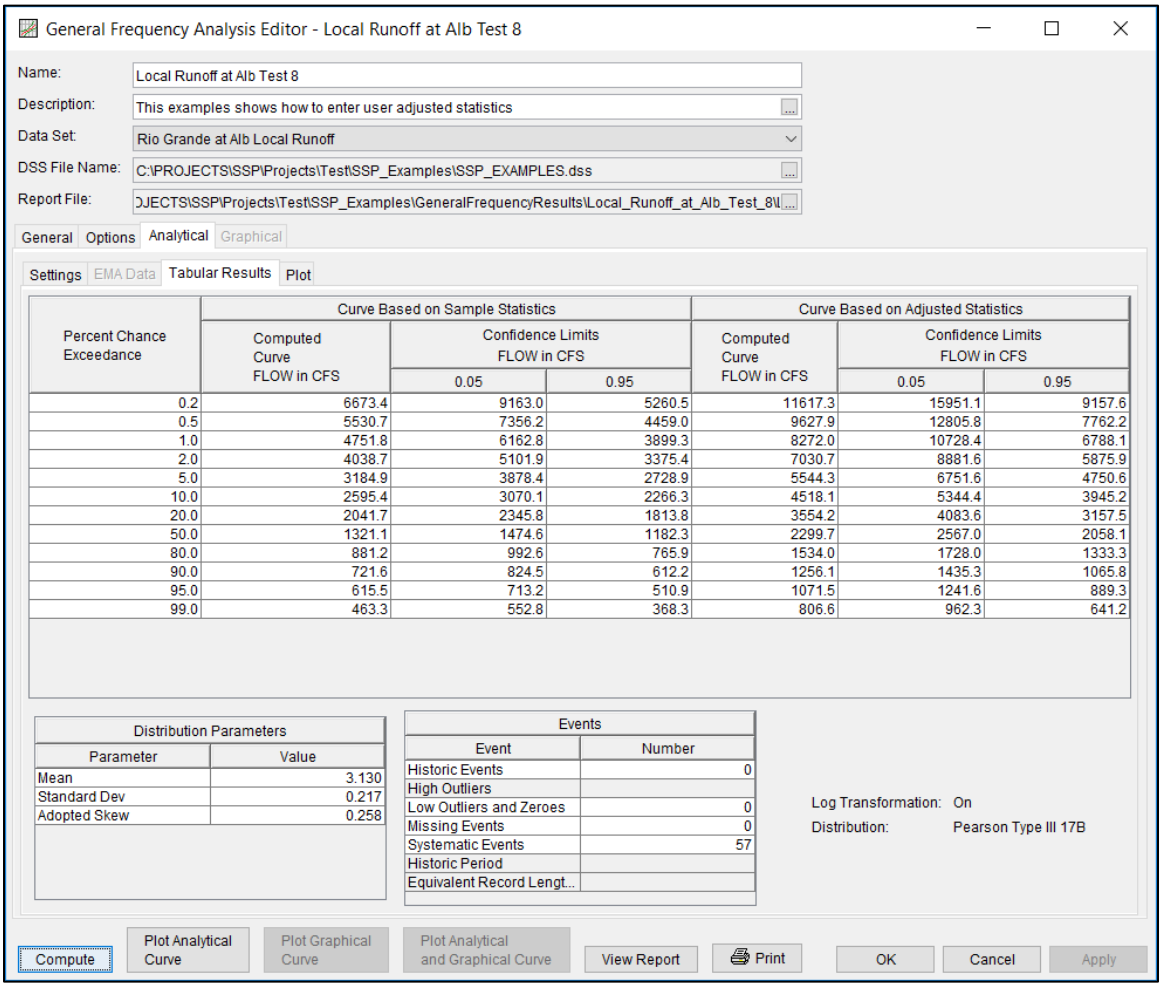


Figure B-58. General Frequency Editor with Results Tab Selected for Local Runoff at Alb Test 8.

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 B-59.

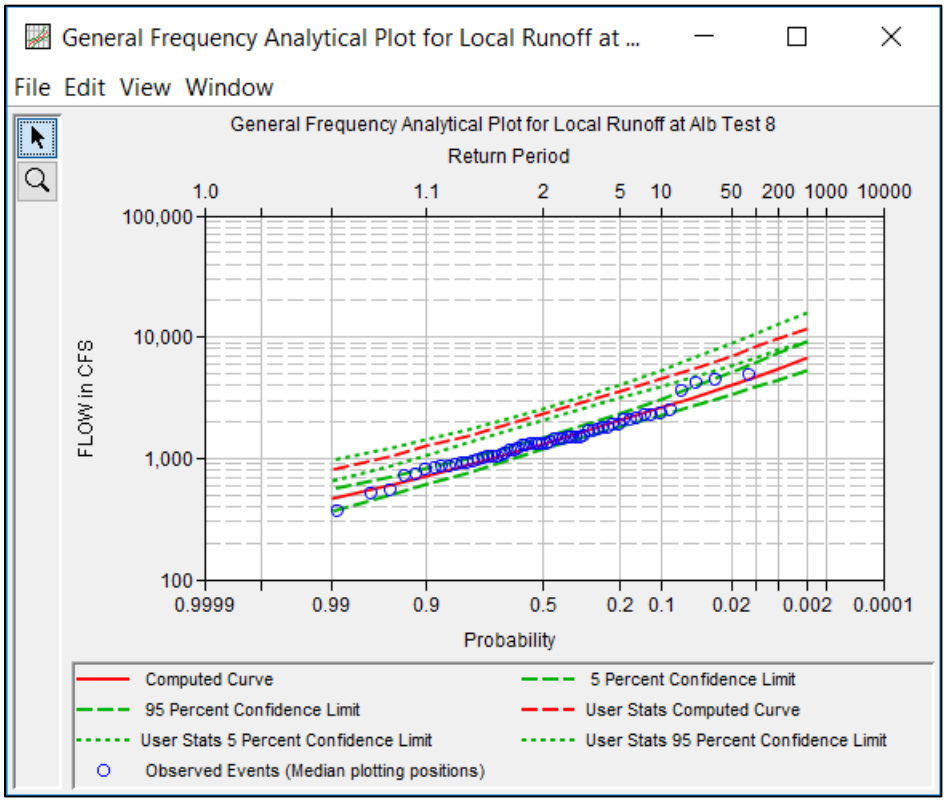
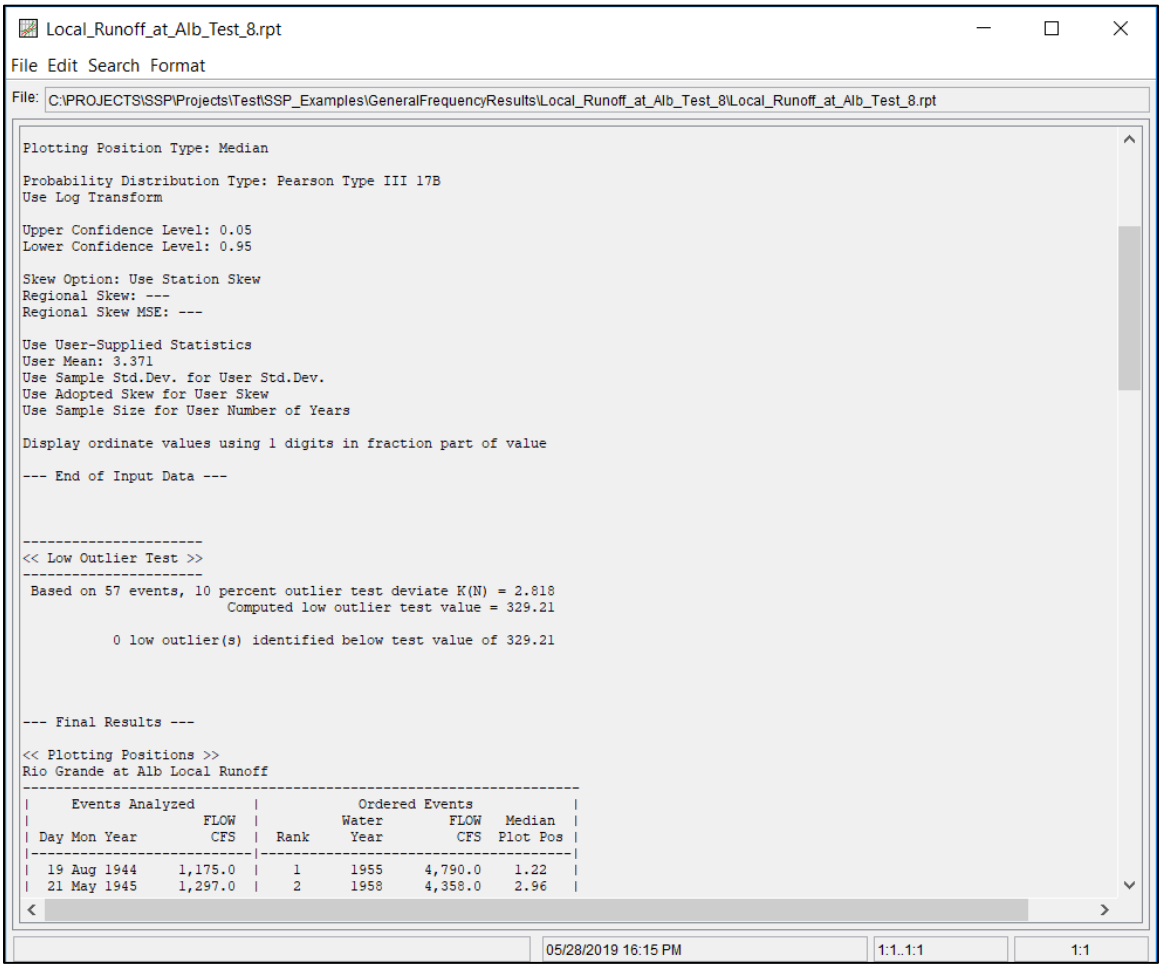


Figure B-59. Plot of the Frequency Curve Results for Local Runoff at Alb Test 8.

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 B-60 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.



Local_Runoff_at_Alb_Test_8.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\GeneralFrequencyResults\Local_Runoff_at_Alb_Test_8\Local_Runoff_at_Alb_Test_8.rpt

```
Plotting Position Type: Median

Probability Distribution Type: Pearson Type III 17B
Use Log Transform

Upper Confidence Level: 0.05
Lower Confidence Level: 0.95

Skew Option: Use Station Skew
Regional Skew: ---
Regional Skew MSE: ---

Use User-Supplied Statistics
User Mean: 3.371
Use Sample Std.Dev. for User Std.Dev.
Use Adopted Skew for User Skew
Use Sample Size for User Number of Years

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---



----------------------
<< Low Outlier Test >>
----------------------
 Based on 57 events, 10 percent outlier test deviate K(N) = 2.818
                       Computed low outlier test value = 329.21

          0 low outlier(s) identified below test value of 329.21



--- Final Results ---

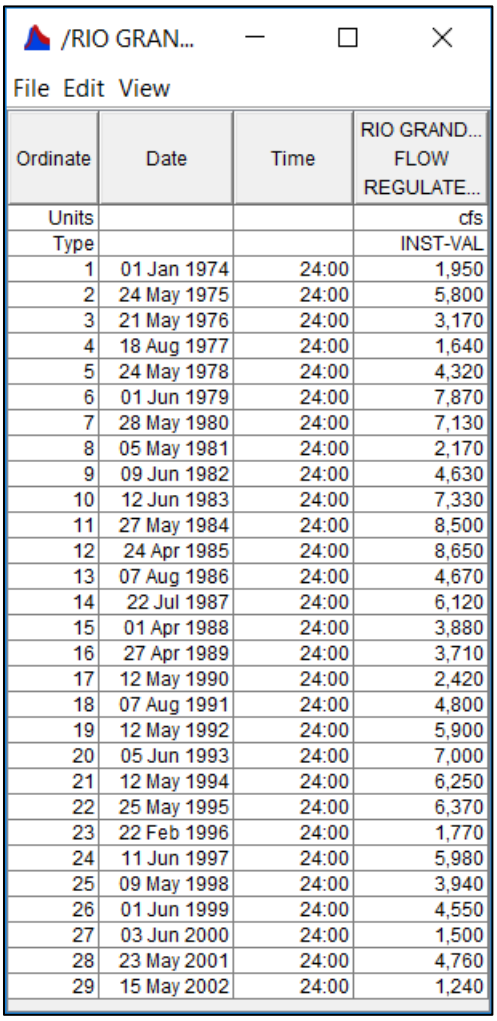
<< Plotting Positions >>
Rio Grande at Alb Local Runoff
-------------------------------------------------------------------------
|     Events Analyzed       |            Ordered Events            |
|                     FLOW  |          Water        FLOW   Median  |
| Day Mon Year         CFS  |  Rank     Year         CFS  Plot Pos |
|---------------------------|--------------------------------------|
|  19 Aug 1944     1,175.0  |    1      1955     4,790.0    1.22   |
|  21 May 1945     1,297.0  |    2      1958     4,358.0    2.96   |
```

05/28/2019 16:15 PM 1:1..1:1 1:1

Figure B-60. Report File for Local Runoff at Alb Test 8.

Example 9: General Frequency – Graphical Analysis

This 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 B-61.



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

Figure B-61. 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 B-62.

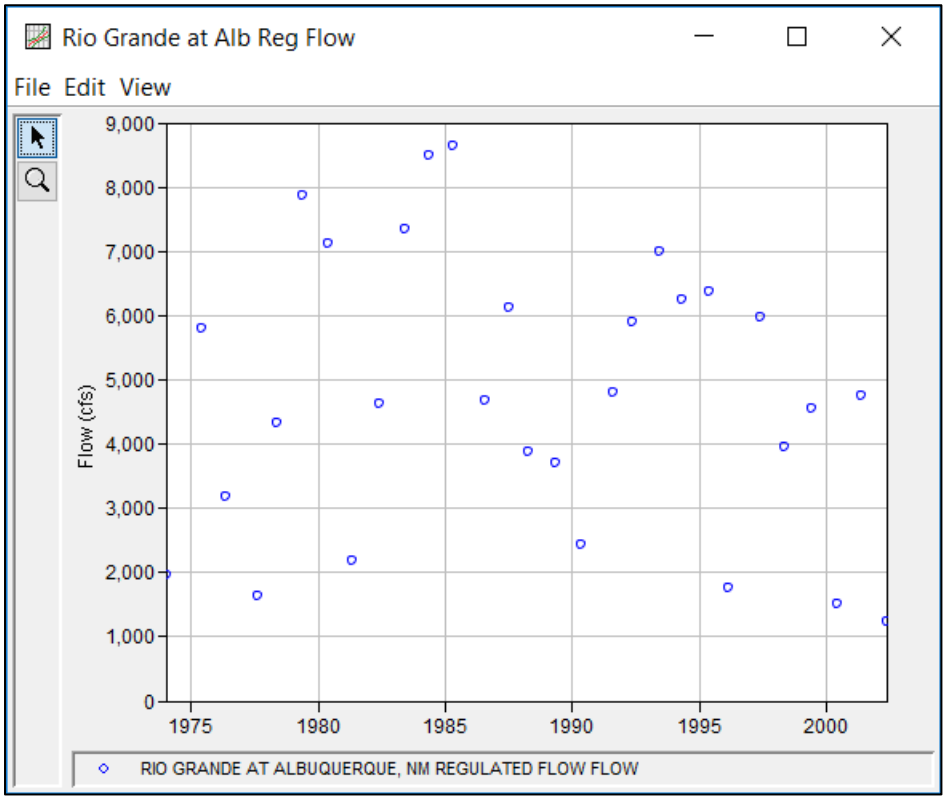


Figure B-62. Plot of Data for Example 9.

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 B-63.

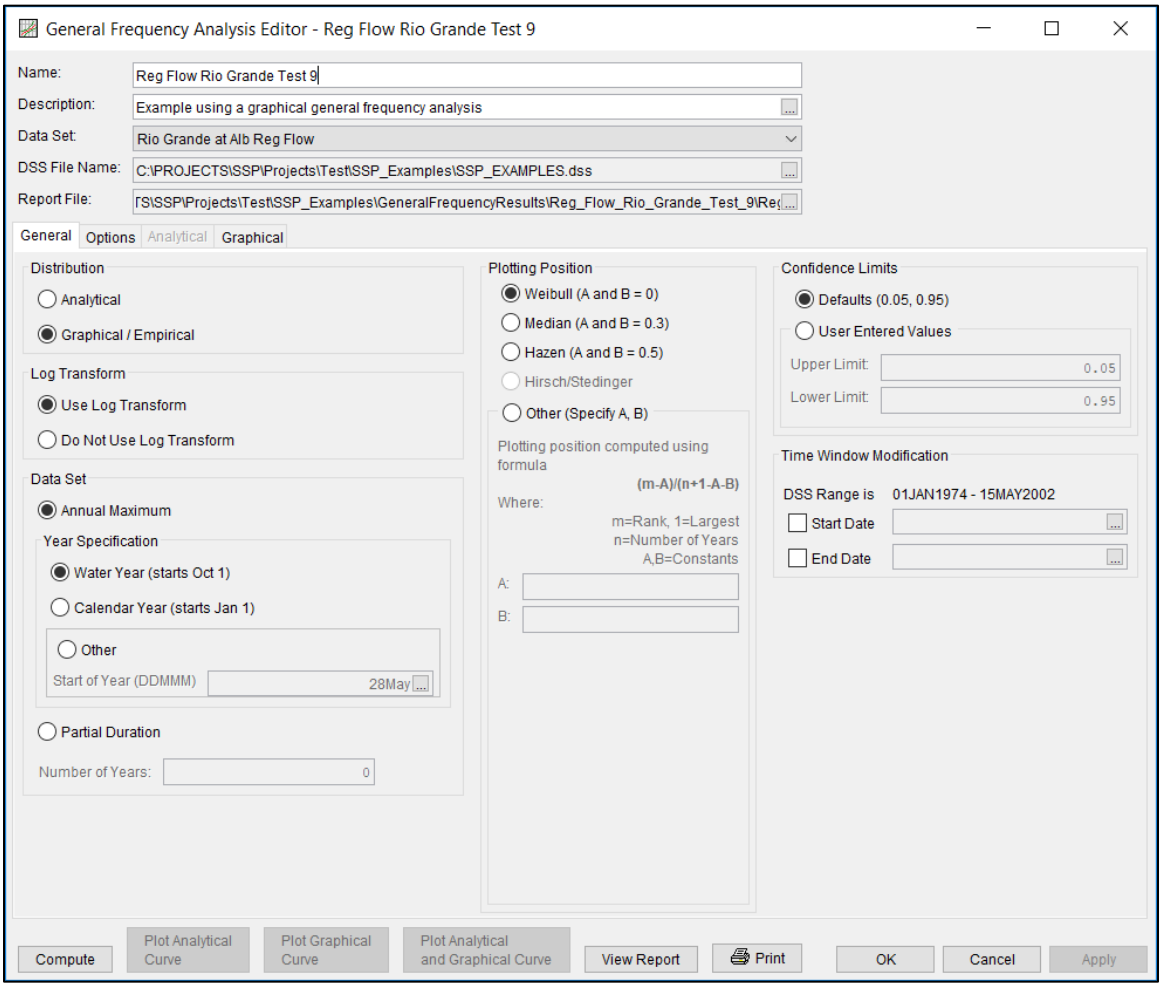


Figure B-63. General Frequency Analysis Editor for Reg Flow Rio Grande Test 9.

Shown in Figure B-63 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 B-64 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.

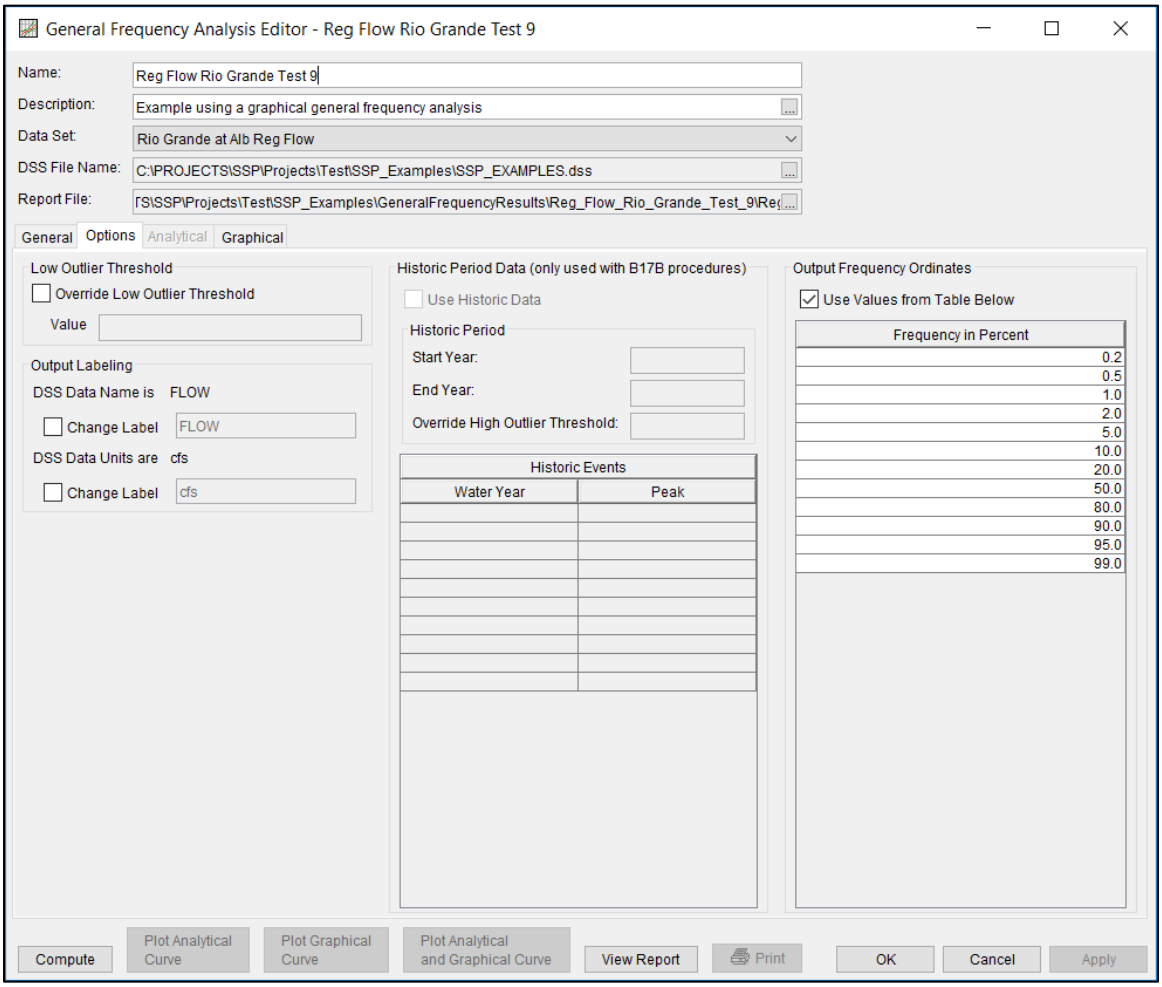


Figure B-64. General Frequency Analysis Editor with Options Tab Shown for Reg Flow Rio Grande Test 9.

In this example, a graphical analysis was performed. Shown in Figure B-65 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.

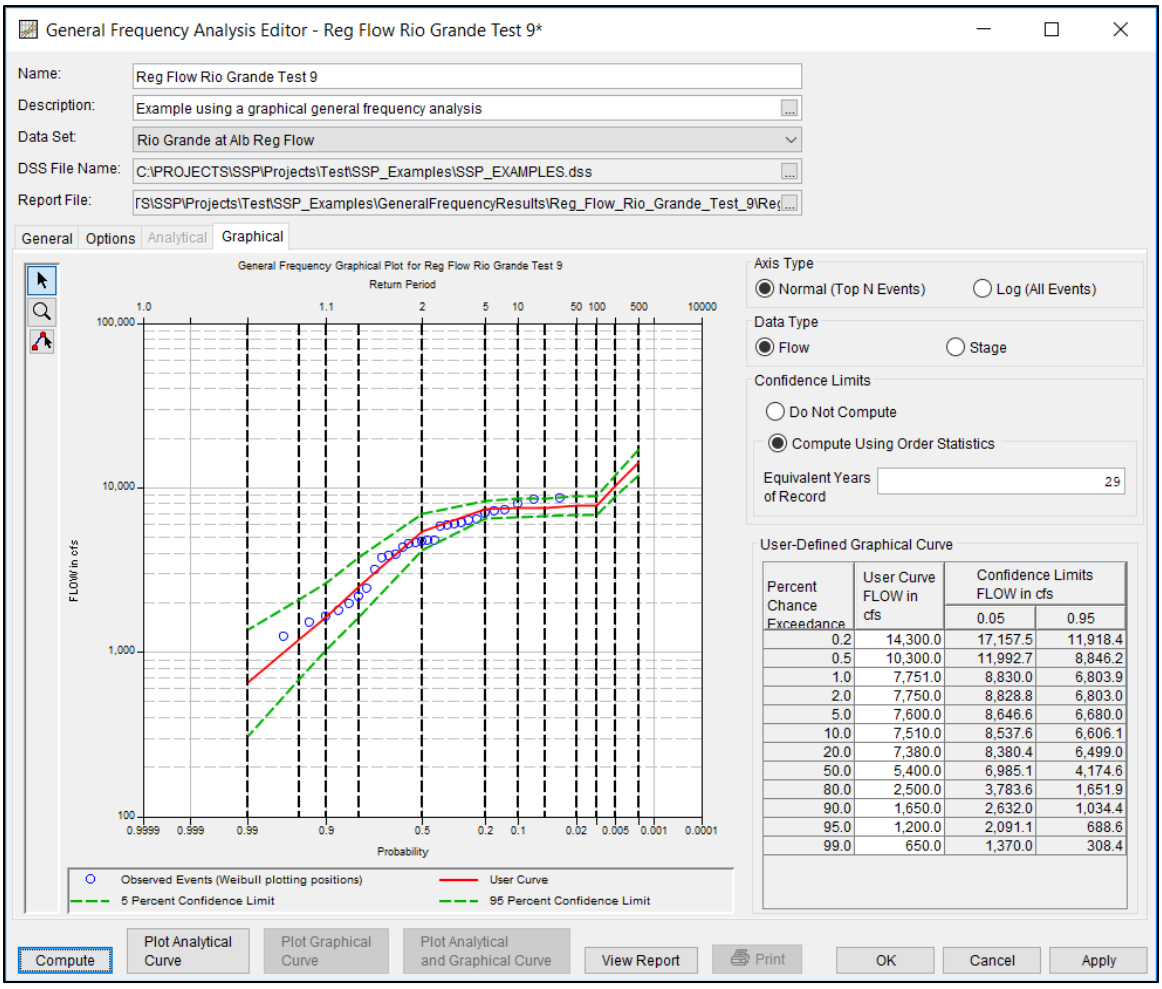


Figure B-65. Graphical Tab Shown for Reg Flow Rio Grande Test 9.

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 B-66.

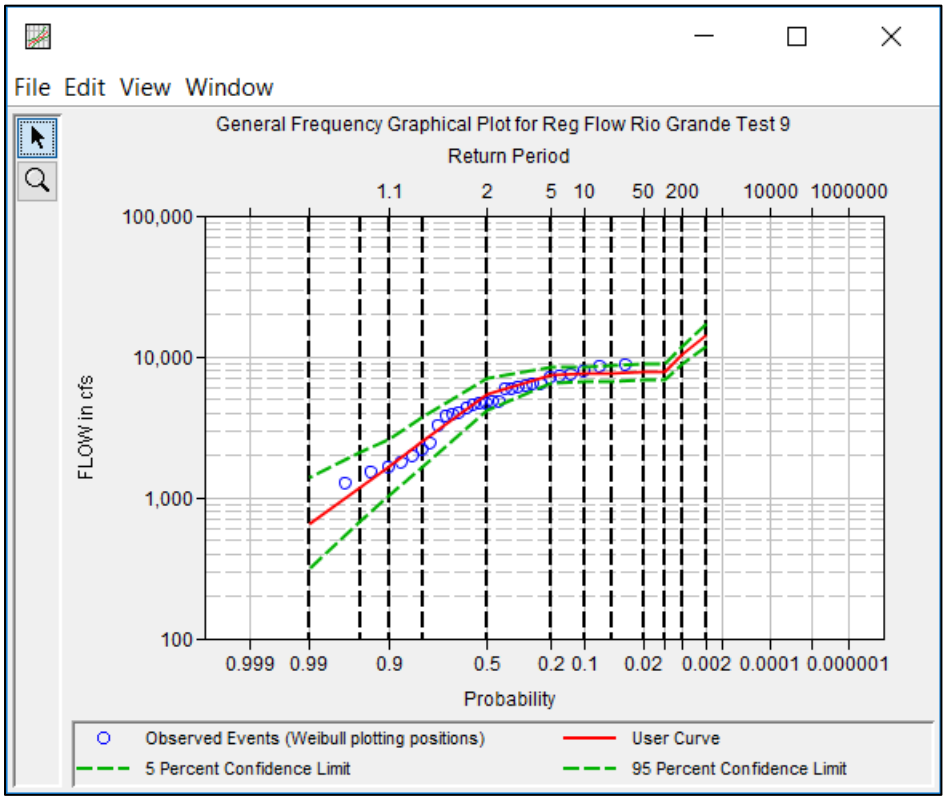


Figure B-66. Plot of the Frequency Curve Results for Reg Flow Rio Grande Test 9.

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 B-67 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.

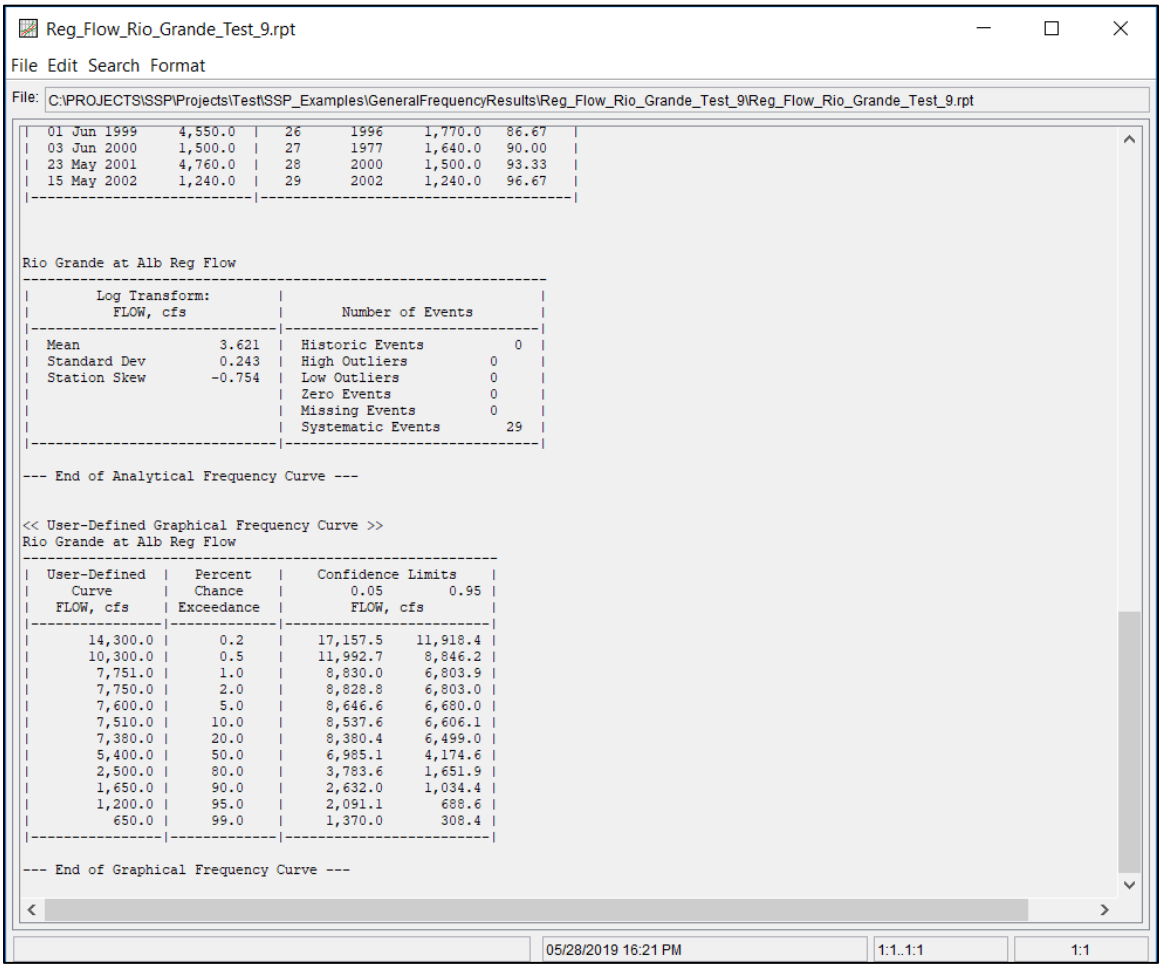


Figure B-67. Report File for Reg Flow Rio Grande Test 9.

Example 10: Volume Frequency Analysis, Maximum Flows

This 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 B-68.

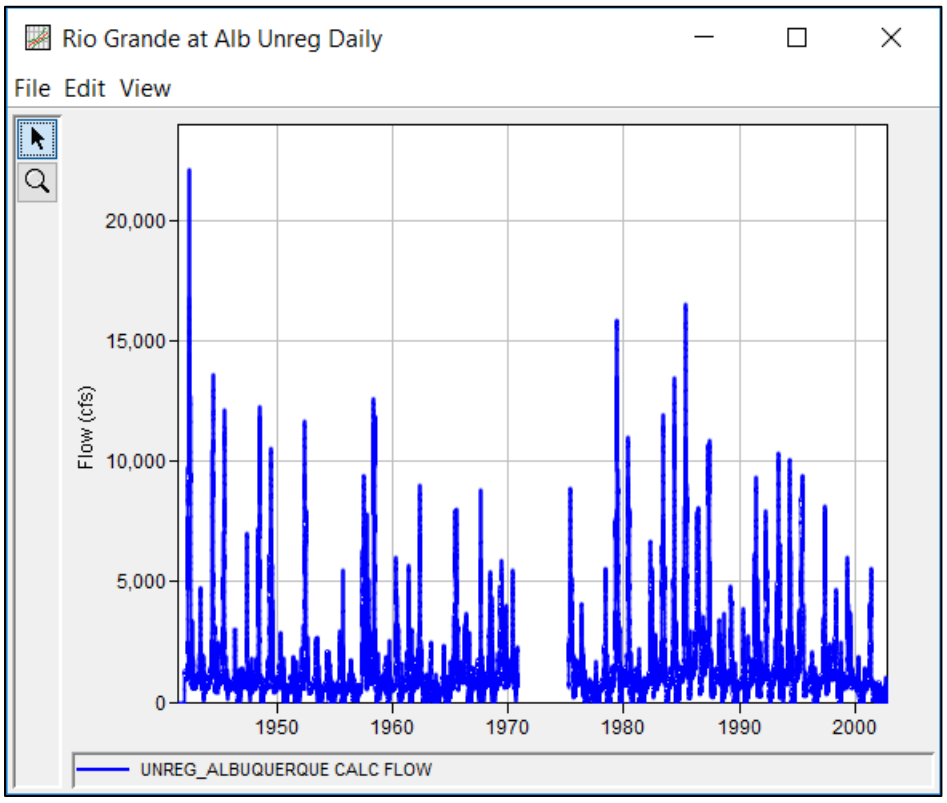


Figure B-68. Plot of Daily Average Flow for Example 10.

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 B-69.

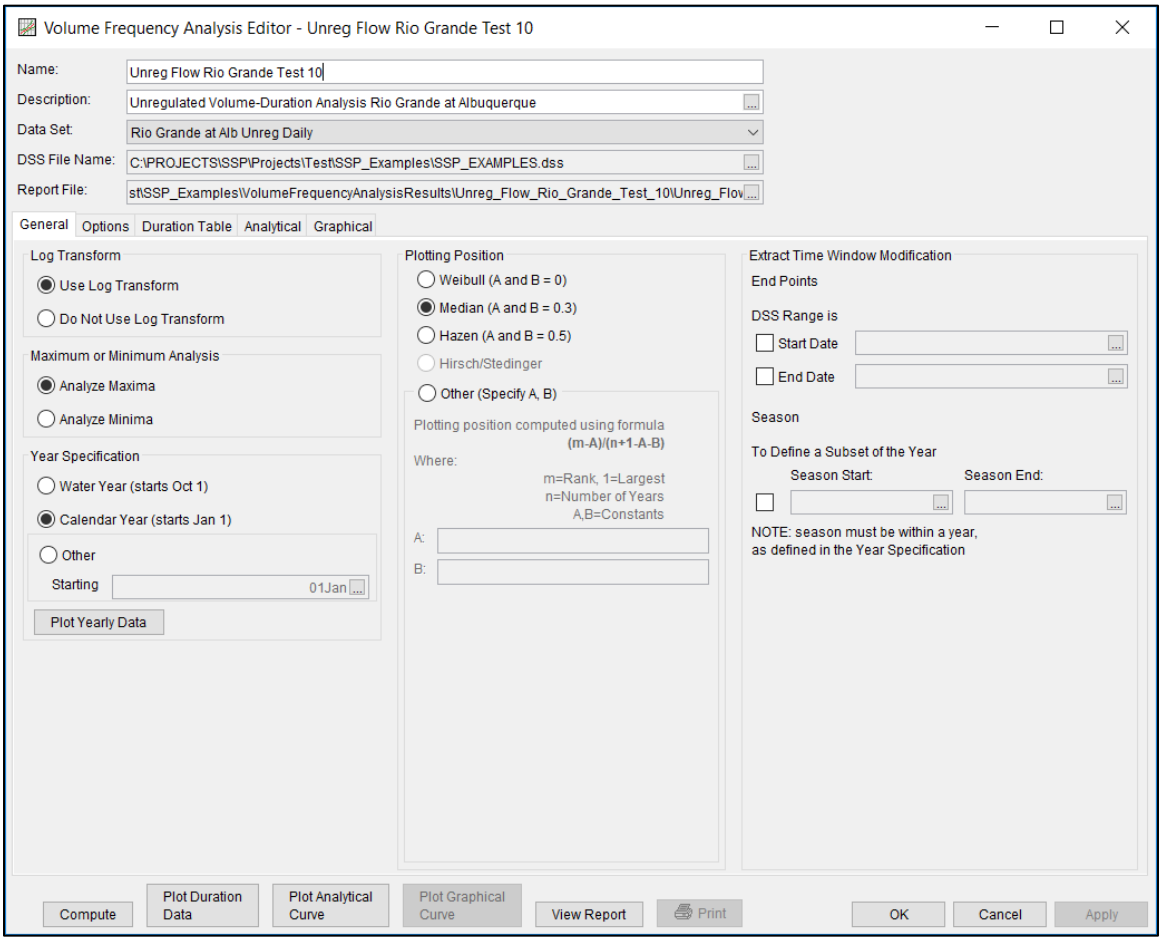


Figure B-69. Volume Frequency Analysis Editor for Unreg Flow Rio Grande Test 10.

Shown in Figure B-69 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 B-70 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.

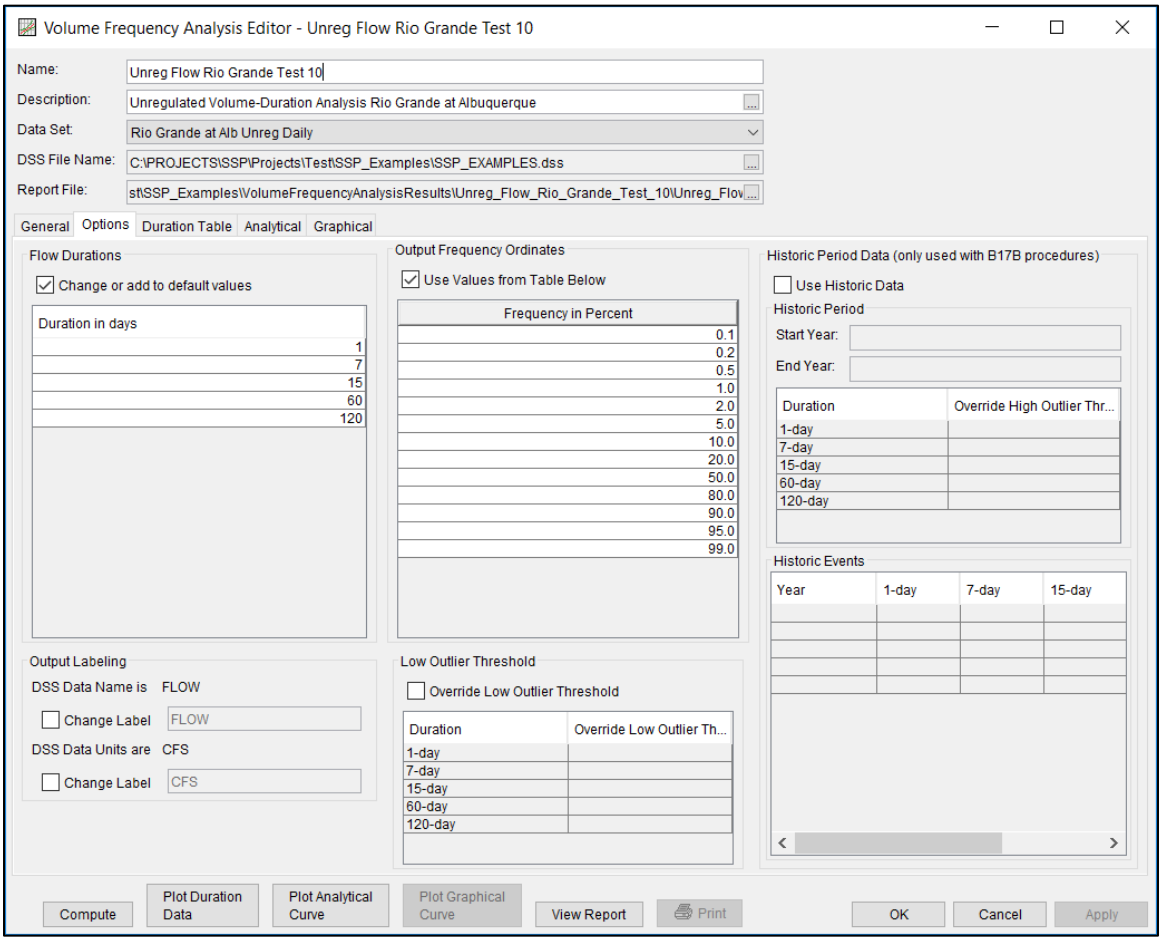
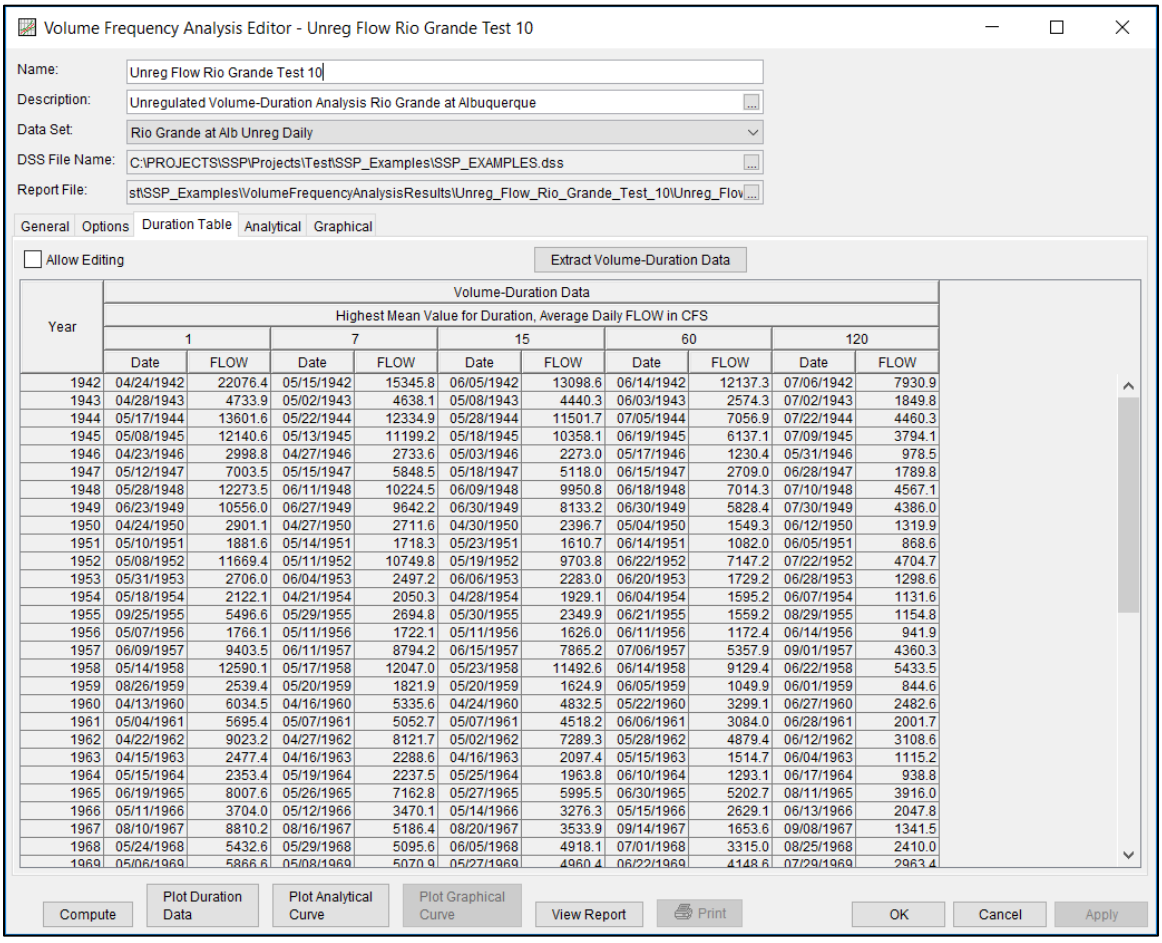


Figure B-70. Options Tab Shown for Unreg Flow Rio Grande Test 10.

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 B-71.



Year	Volume-Duration Data: Highest Mean Value for Duration, Average Daily FLOW in CFS									
	1		7		15		60		120	
	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW
1942	04/24/1942	22076.4	05/15/1942	15345.8	06/05/1942	13098.6	06/14/1942	12137.3	07/06/1942	7930.9
1943	04/28/1943	4733.9	05/02/1943	4638.1	05/08/1943	4440.3	06/03/1943	2574.3	07/02/1943	1849.8
1944	05/17/1944	13601.6	05/22/1944	12334.9	05/28/1944	11501.7	07/05/1944	7056.9	07/22/1944	4460.3
1945	05/08/1945	12140.6	05/13/1945	11199.2	05/18/1945	10358.1	06/19/1945	6137.1	07/09/1945	3794.1
1946	04/23/1946	2998.8	04/27/1946	2733.6	05/03/1946	2273.0	05/17/1946	1230.4	05/31/1946	978.5
1947	05/12/1947	7003.5	05/15/1947	5848.5	05/18/1947	5118.0	06/15/1947	2709.0	06/28/1947	1789.8
1948	05/28/1948	12273.5	06/11/1948	10224.5	06/09/1948	9950.8	06/18/1948	7014.3	07/10/1948	4567.1
1949	06/23/1949	10556.0	06/27/1949	9642.2	06/30/1949	8133.2	06/30/1949	5828.4	07/30/1949	4386.0
1950	04/24/1950	2901.1	04/27/1950	2711.6	04/30/1950	2396.7	05/04/1950	1549.3	06/12/1950	1319.9
1951	05/10/1951	1881.6	05/14/1951	1718.3	05/23/1951	1610.7	06/14/1951	1082.0	06/05/1951	868.6
1952	05/08/1952	11669.4	05/11/1952	10749.8	05/19/1952	9703.8	06/22/1952	7147.2	07/22/1952	4704.7
1953	05/31/1953	2706.0	06/04/1953	2497.2	06/06/1953	2283.0	06/20/1953	1729.2	06/28/1953	1298.6
1954	05/18/1954	2122.1	04/21/1954	2050.3	04/28/1954	1929.1	06/04/1954	1595.2	06/07/1954	1131.6
1955	09/25/1955	5496.6	05/29/1955	2694.8	05/30/1955	2349.9	06/21/1955	1559.2	08/29/1955	1154.8
1956	05/07/1956	1766.1	05/11/1956	1722.1	05/11/1956	1626.0	06/11/1956	1172.4	06/14/1956	941.9
1957	06/09/1957	9403.5	06/11/1957	8794.2	06/15/1957	7865.2	07/06/1957	5357.9	09/01/1957	4360.3
1958	05/14/1958	12590.1	05/17/1958	12047.0	05/23/1958	11492.6	06/14/1958	9129.4	06/22/1958	5433.5
1959	08/26/1959	2539.4	05/20/1959	1821.9	05/20/1959	1624.9	06/05/1959	1049.9	06/01/1959	844.6
1960	04/13/1960	6034.5	04/16/1960	5335.6	04/24/1960	4832.5	05/22/1960	3299.1	06/27/1960	2482.6
1961	05/04/1961	5695.4	05/07/1961	5052.7	05/07/1961	4518.2	06/06/1961	3084.0	06/28/1961	2001.7
1962	04/22/1962	9023.2	04/27/1962	8121.7	05/02/1962	7289.3	05/28/1962	4879.4	06/12/1962	3108.6
1963	04/15/1963	2477.4	04/16/1963	2288.6	04/16/1963	2097.4	05/15/1963	1514.7	06/04/1963	1115.2
1964	05/15/1964	2353.4	05/19/1964	2237.5	05/25/1964	1963.8	06/10/1964	1293.1	06/17/1964	938.8
1965	06/19/1965	8007.6	05/26/1965	7162.8	05/27/1965	5995.5	06/30/1965	5202.7	08/11/1965	3916.0
1966	05/11/1966	3704.0	05/12/1966	3470.1	05/14/1966	3276.3	05/15/1966	2629.1	06/13/1966	2047.8
1967	08/10/1967	8810.2	08/16/1967	5186.4	08/20/1967	3533.9	09/14/1967	1653.6	09/08/1967	1341.5
1968	05/24/1968	5432.6	05/29/1968	5095.6	06/05/1968	4918.1	07/01/1968	3315.0	08/25/1968	2410.0
1969	05/06/1969	5866.6	05/08/1969	5070.9	05/27/1969	4960.4	06/22/1969	4148.6	07/29/1969	2963.4

Figure B-71. 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 B-72 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.

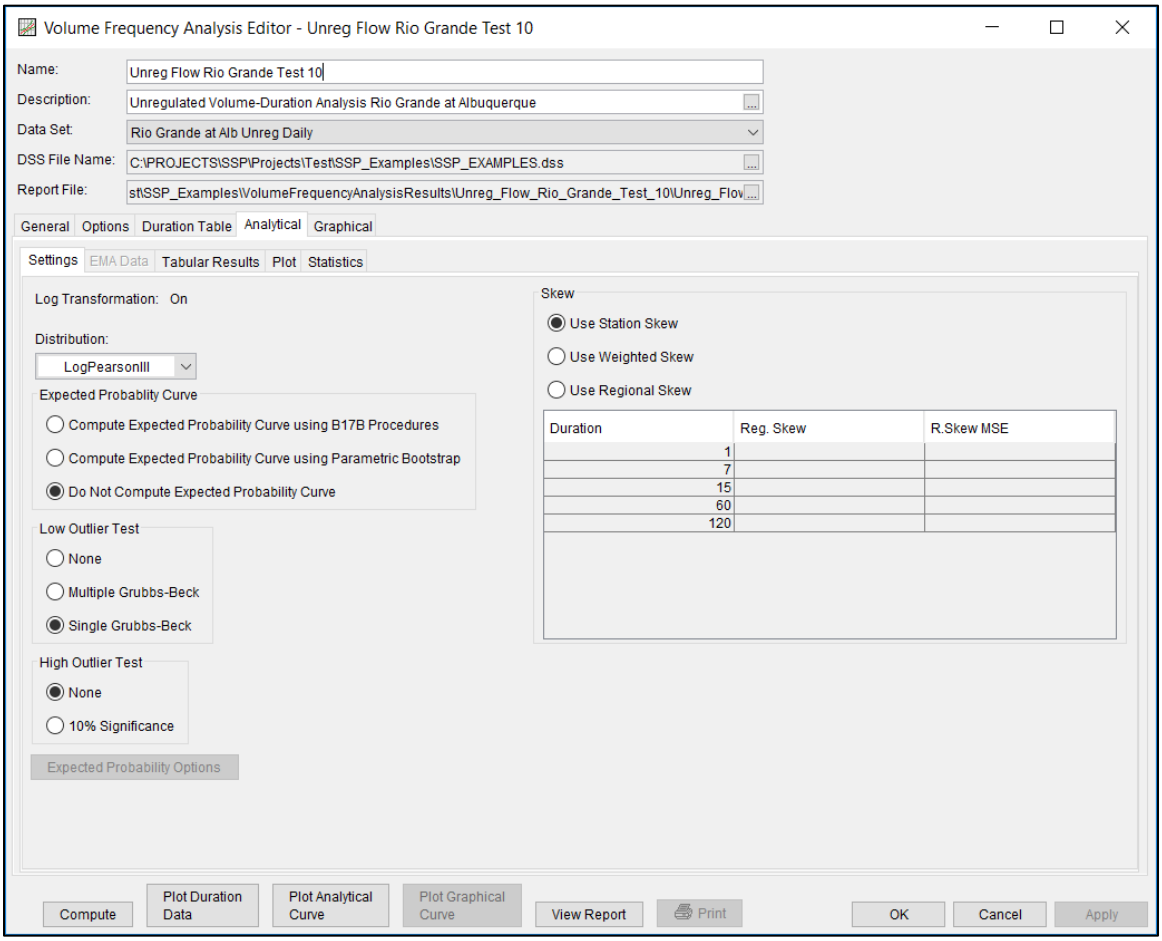


Figure B-72. Settings Tab Shown for Unreg Flow Rio Grande Test 10.

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 B-73. 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.

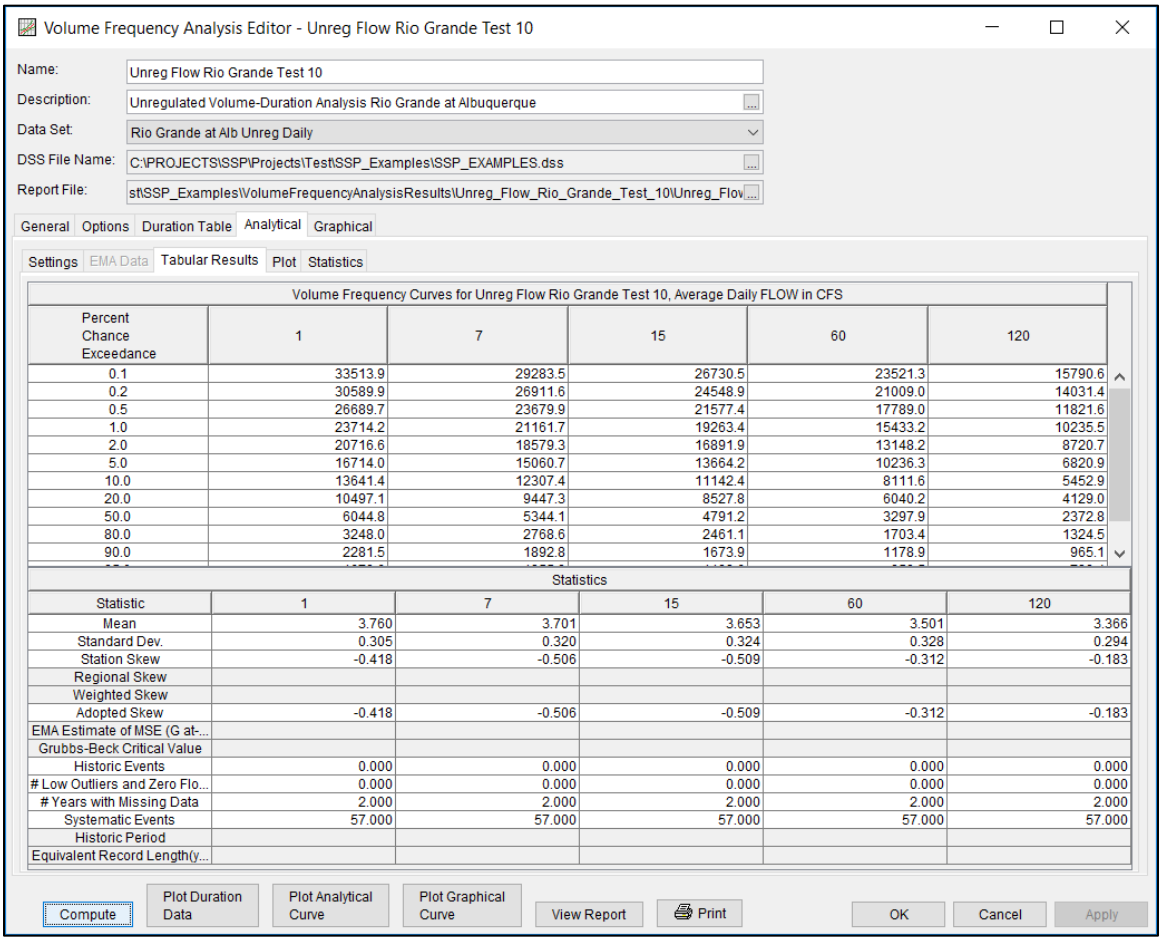


Figure B-73. Tabular Results Tab for Unreg Flow Rio Grande Test 10.

Note: These tabular results use the default computed statistics.

As shown in Figure B-74, 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.

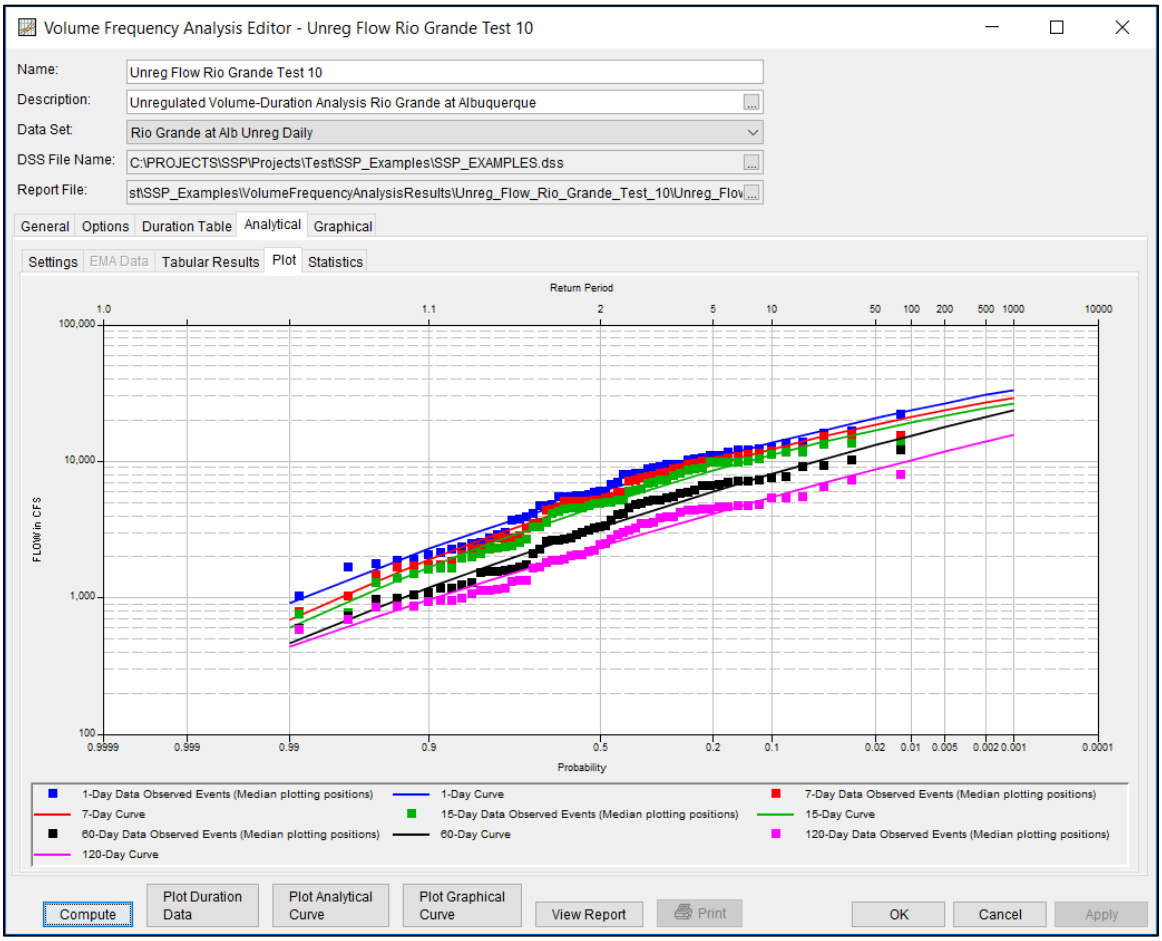


Figure B-74. Plot Tab for Unreg Flow Rio Grande Test 10.

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 B-75, 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 B-76 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.

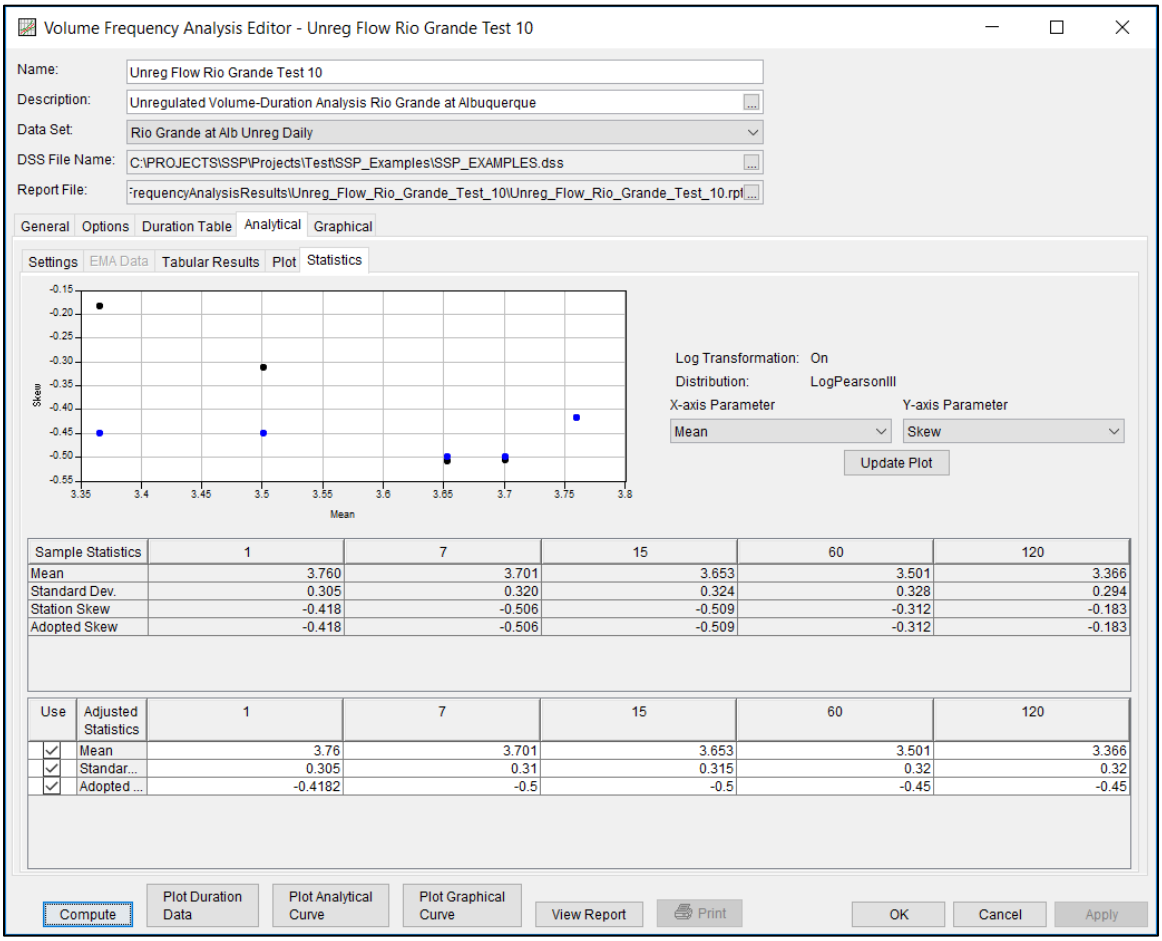


Figure B-75. Statistics Tab for Unreg Flow Rio Grande Test 10.

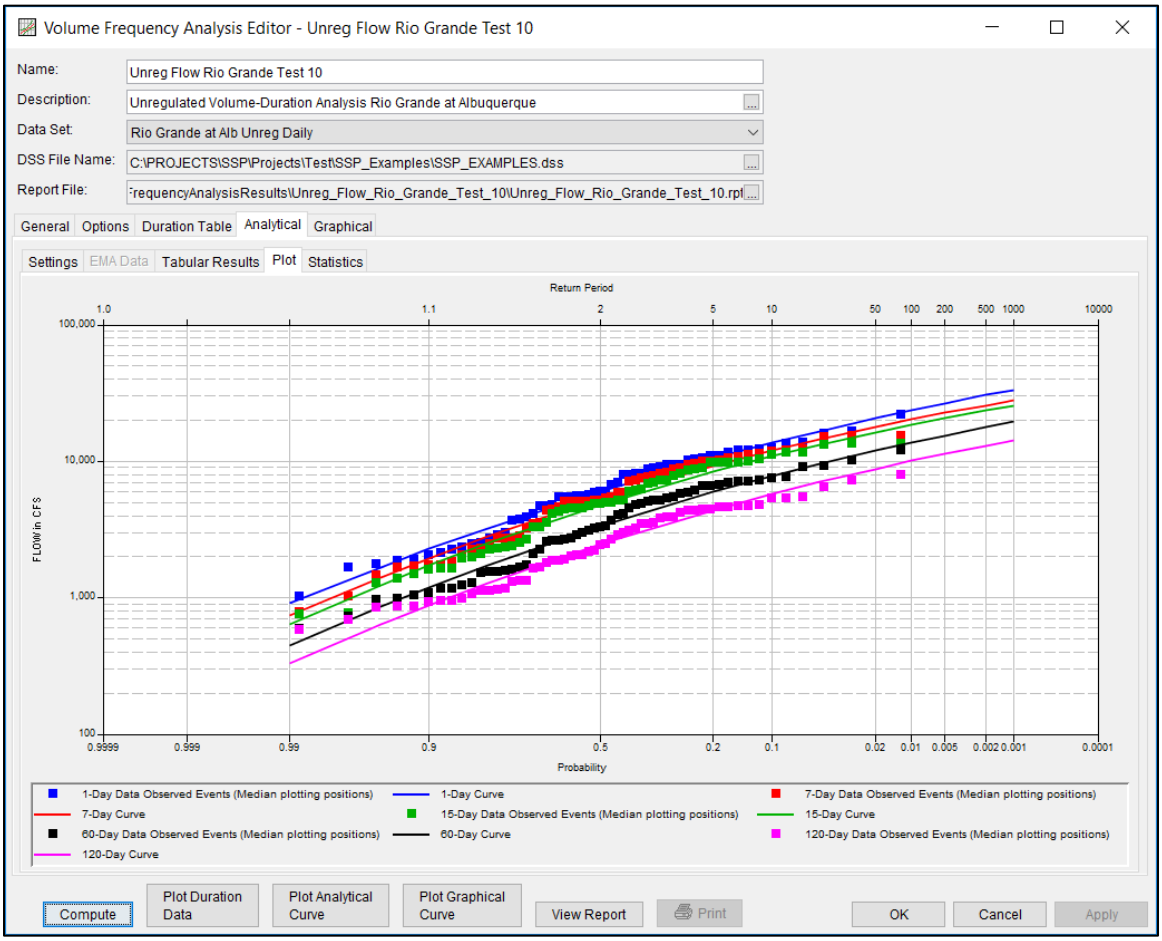


Figure B-76. Plot Tab for Unreg Flow Rio Grande Test 10 After the Statistics were Adjusted on the Statistics Tab.

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 B-77.

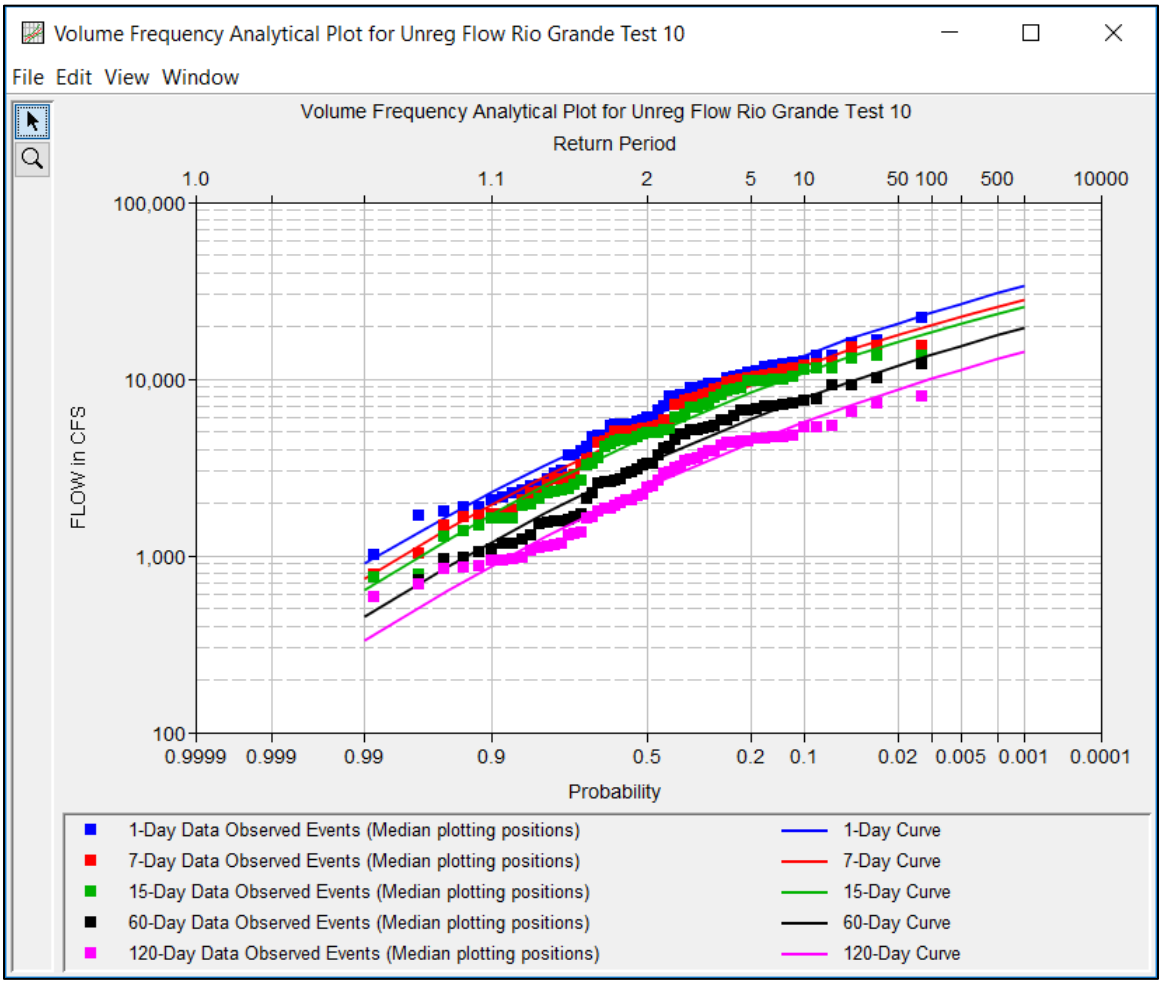


Figure B-77. Plot of the Frequency Curve Results for Unreg Flow Rio Grande Test 10.

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 B-78 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.

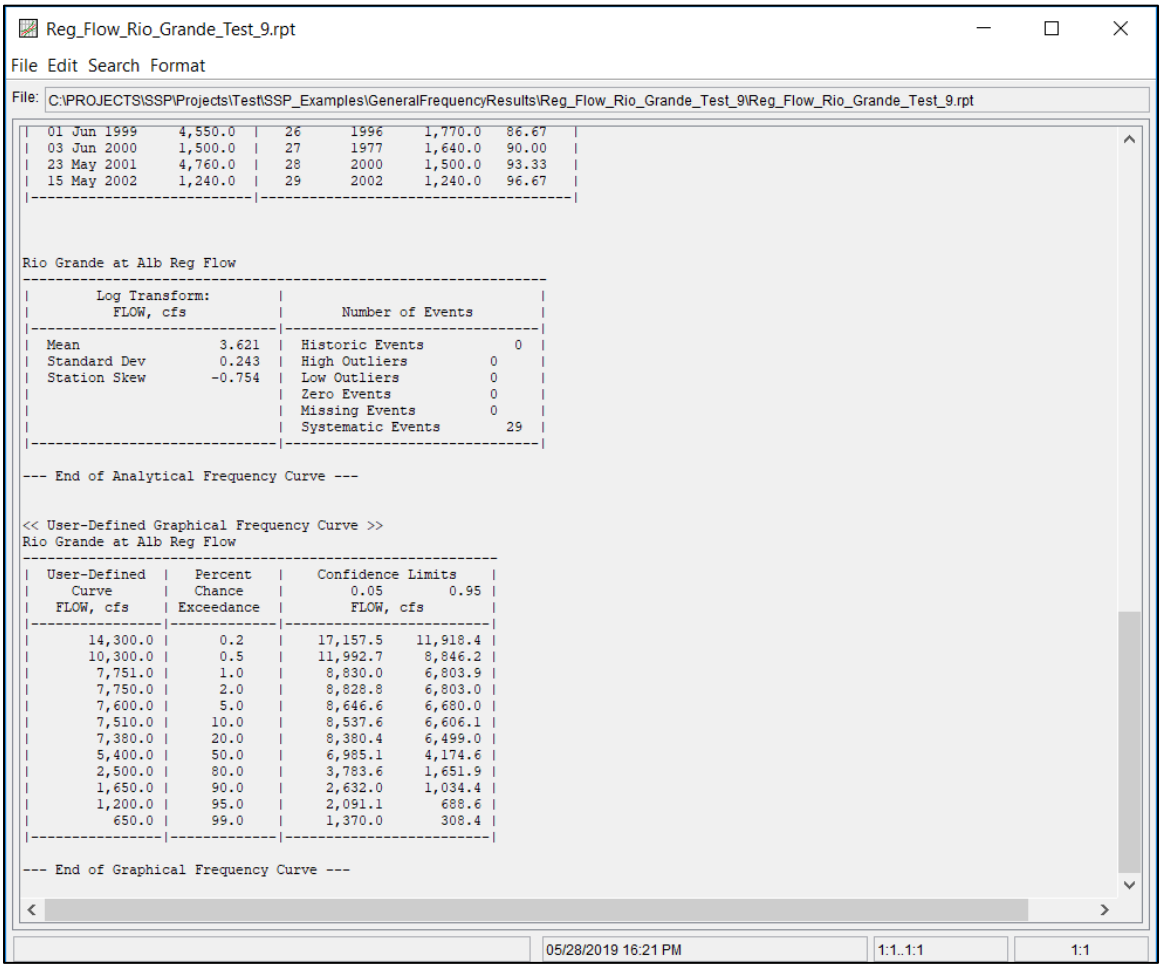


Figure B-78. Report File for Unreg Flow Rio Grande Test 10.

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 B-79.

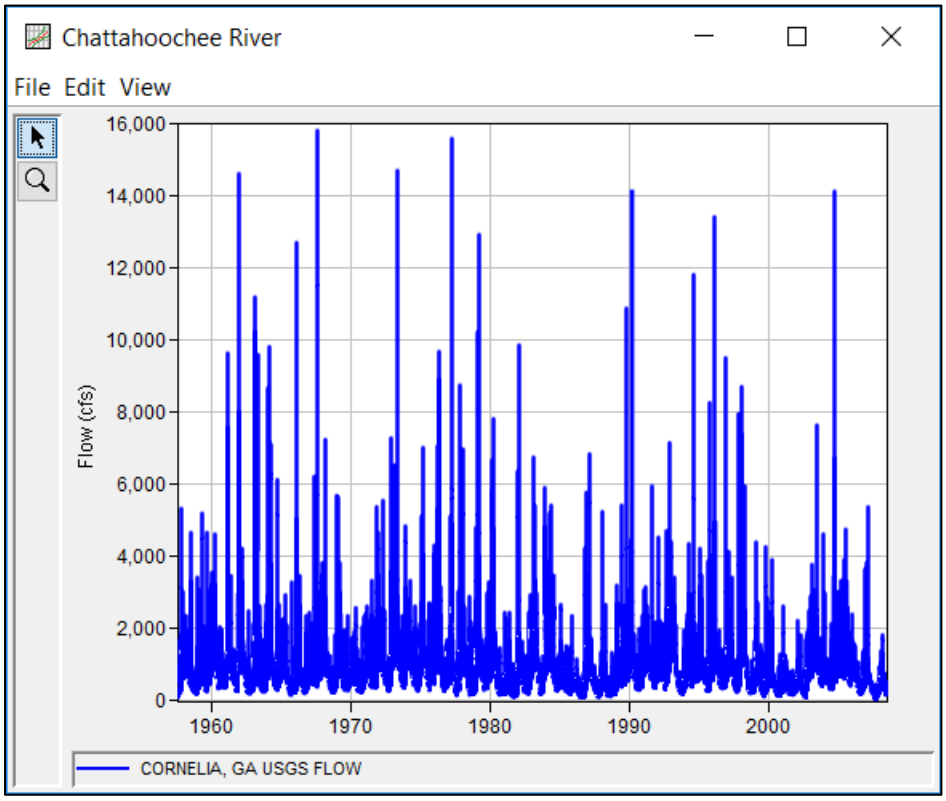


Figure B-79. Plot of Daily Average Flow for Example 11.

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 B-80.

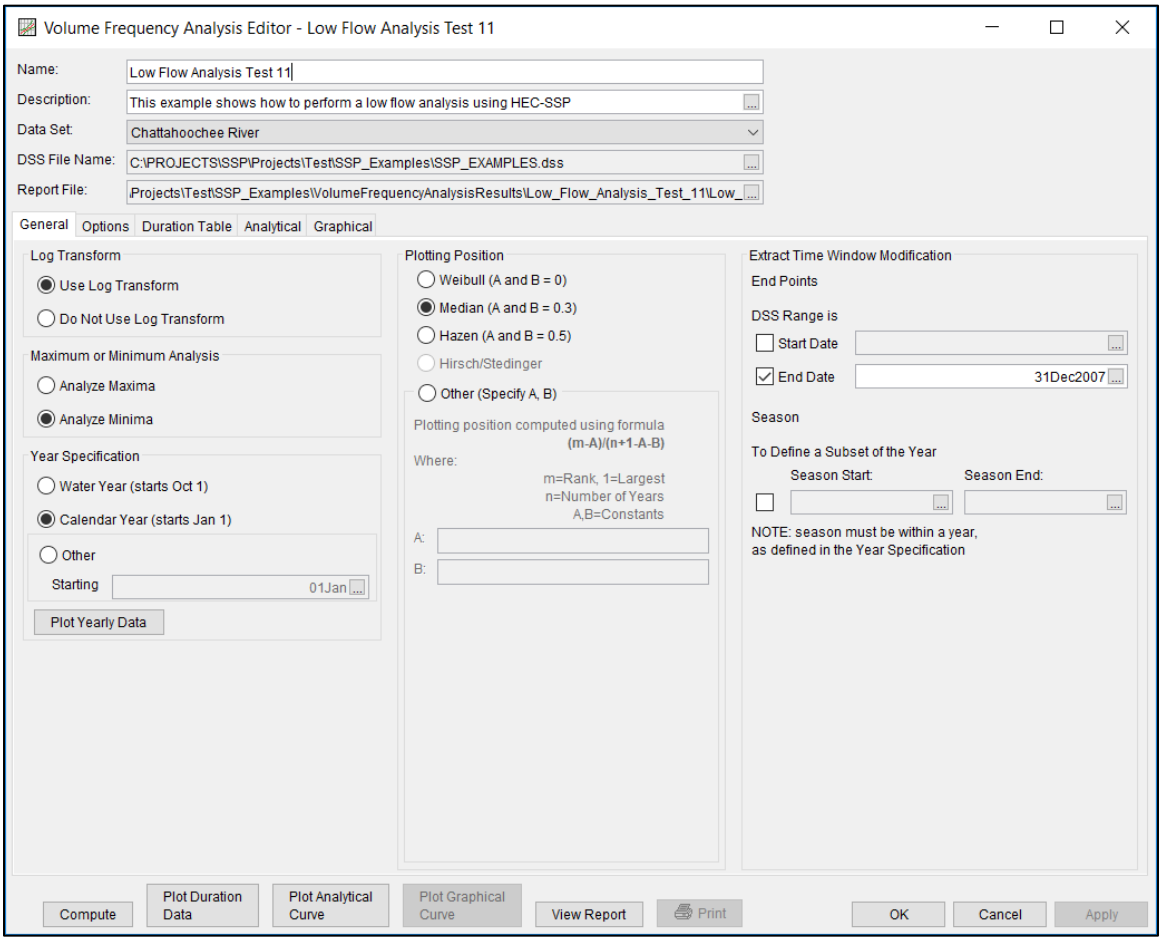


Figure B-80. Volume Frequency Analysis Editor for Low Flow Analysis Test 11.

Shown in Figure B-80 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 B-81 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**.

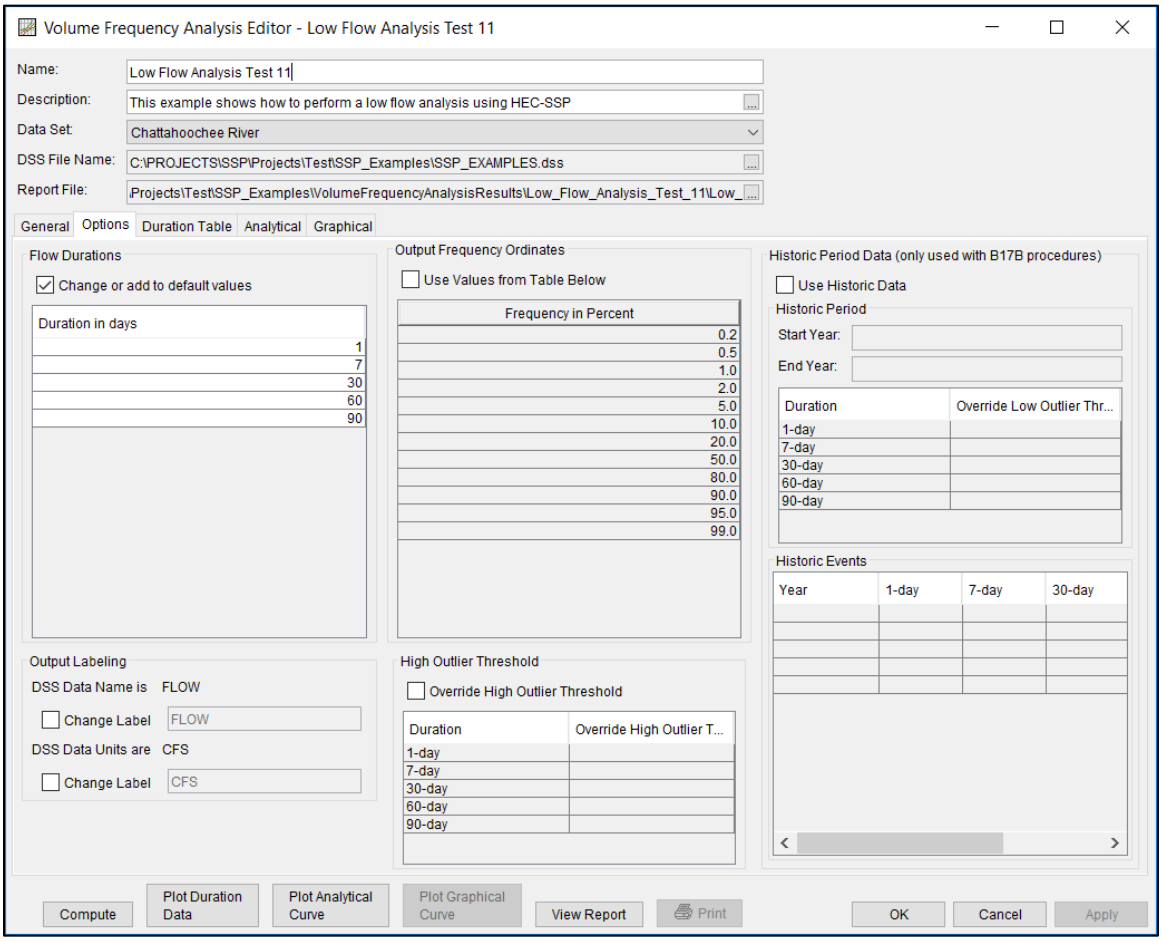
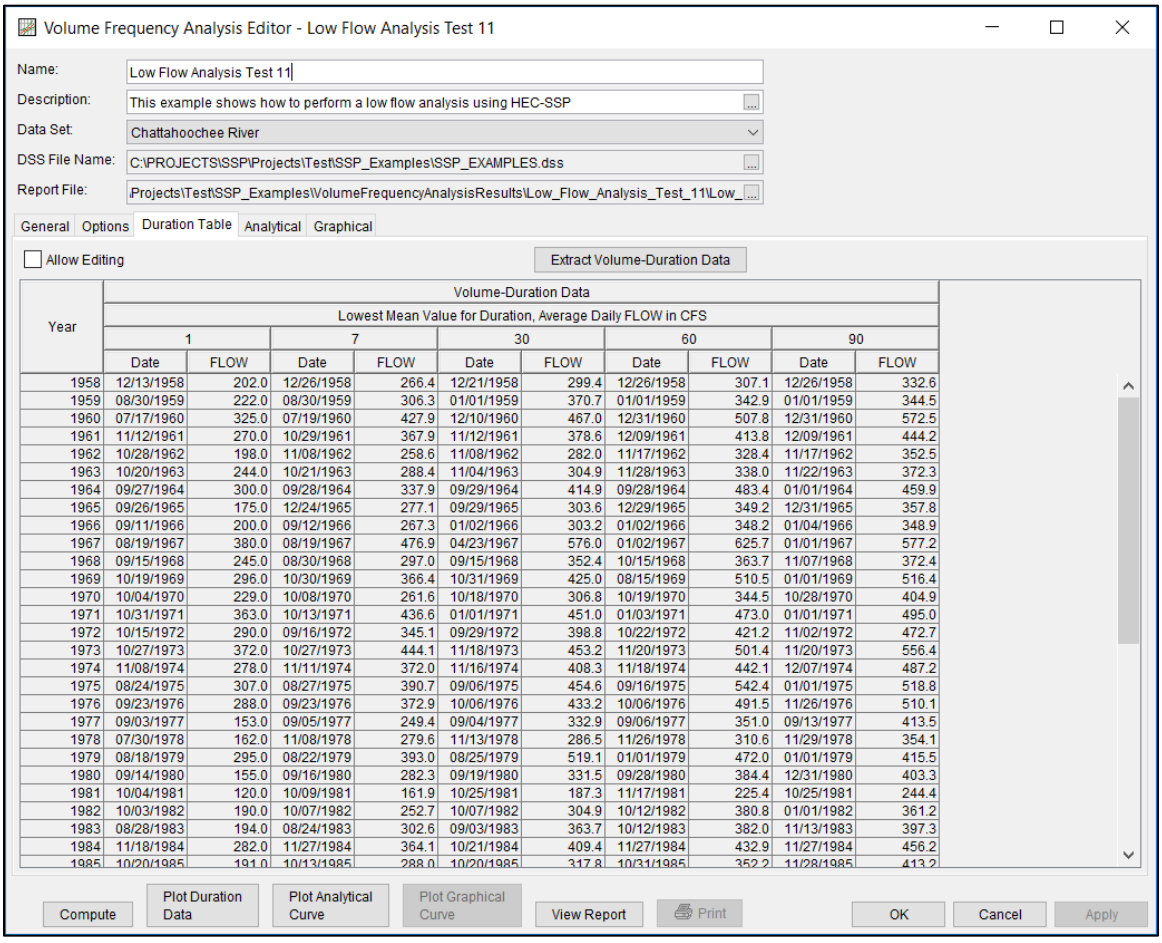


Figure B-81. Options Tab Shown for Low Flow Analysis Test 11.

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 B-82.



Year	Volume-Duration Data									
	Lowest Mean Value for Duration, Average Daily FLOW in CFS									
	1		7		30		60		90	
	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW	Date	FLOW
1958	12/13/1958	202.0	12/26/1958	266.4	12/21/1958	299.4	12/26/1958	307.1	12/26/1958	332.6
1959	08/30/1959	222.0	08/30/1959	306.3	01/01/1959	370.7	01/01/1959	342.9	01/01/1959	344.5
1960	07/17/1960	325.0	07/19/1960	427.9	12/10/1960	467.0	12/31/1960	507.8	12/31/1960	572.5
1961	11/12/1961	270.0	10/29/1961	367.9	11/12/1961	378.6	12/09/1961	413.8	12/09/1961	444.2
1962	10/28/1962	198.0	11/08/1962	258.6	11/08/1962	282.0	11/17/1962	328.4	11/17/1962	352.5
1963	10/20/1963	244.0	10/21/1963	288.4	11/04/1963	304.9	11/28/1963	338.0	11/22/1963	372.3
1964	09/27/1964	300.0	09/28/1964	337.9	09/29/1964	414.9	09/28/1964	483.4	01/01/1964	459.9
1965	09/26/1965	175.0	12/24/1965	277.1	09/29/1965	303.6	12/29/1965	349.2	12/31/1965	357.8
1966	09/11/1966	200.0	09/12/1966	267.3	01/02/1966	303.2	01/02/1966	348.2	01/04/1966	348.9
1967	08/19/1967	380.0	08/19/1967	476.9	04/23/1967	576.0	01/02/1967	625.7	01/01/1967	577.2
1968	09/15/1968	245.0	08/30/1968	297.0	09/15/1968	352.4	10/15/1968	363.7	11/07/1968	372.4
1969	10/19/1969	296.0	10/30/1969	366.4	10/31/1969	425.0	08/15/1969	510.5	01/01/1969	516.4
1970	10/04/1970	229.0	10/08/1970	261.6	10/18/1970	306.8	10/19/1970	344.5	10/28/1970	404.9
1971	10/31/1971	363.0	10/13/1971	436.6	01/01/1971	451.0	01/03/1971	473.0	01/01/1971	495.0
1972	10/15/1972	290.0	09/16/1972	345.1	09/29/1972	398.8	10/22/1972	421.2	11/02/1972	472.7
1973	10/27/1973	372.0	10/27/1973	444.1	11/18/1973	453.2	11/20/1973	501.4	11/20/1973	556.4
1974	11/08/1974	278.0	11/11/1974	372.0	11/16/1974	408.3	11/18/1974	442.1	12/07/1974	487.2
1975	08/24/1975	307.0	08/27/1975	390.7	09/06/1975	454.6	09/16/1975	542.4	01/01/1975	518.8
1976	09/23/1976	288.0	09/23/1976	372.9	10/06/1976	433.2	10/06/1976	491.5	11/26/1976	510.1
1977	09/03/1977	153.0	09/05/1977	249.4	09/04/1977	332.9	09/06/1977	351.0	09/13/1977	413.5
1978	07/30/1978	162.0	11/08/1978	279.6	11/13/1978	286.5	11/26/1978	310.6	11/29/1978	354.1
1979	08/18/1979	295.0	08/22/1979	393.0	08/25/1979	519.1	01/01/1979	472.0	01/01/1979	415.5
1980	09/14/1980	155.0	09/16/1980	282.3	09/19/1980	331.5	09/28/1980	384.4	12/31/1980	403.3
1981	10/04/1981	120.0	10/09/1981	161.9	10/25/1981	187.3	11/17/1981	225.4	10/25/1981	244.4
1982	10/03/1982	190.0	10/07/1982	252.7	10/07/1982	304.9	10/12/1982	380.8	01/01/1982	361.2
1983	08/28/1983	194.0	08/24/1983	302.6	09/03/1983	363.7	10/12/1983	382.0	11/13/1983	397.3
1984	11/18/1984	282.0	11/27/1984	364.1	10/21/1984	409.4	11/27/1984	432.9	11/27/1984	456.2
1985	10/20/1985	191.0	10/13/1985	288.0	10/20/1985	317.8	10/31/1985	352.2	11/28/1985	413.2

Figure B-82. 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 B-83 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.

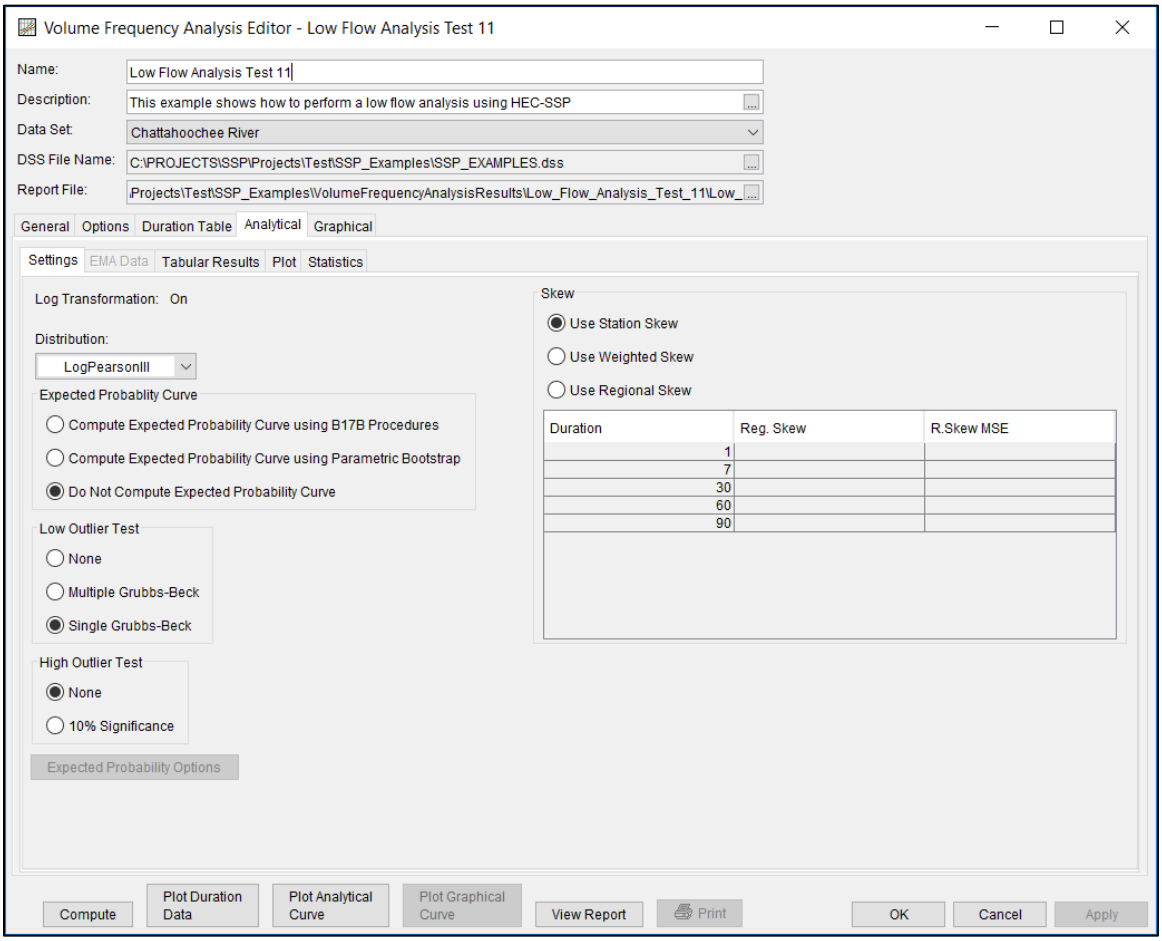


Figure B-83. Settings Tab Shown for Low Flow Analysis Test 11.

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 B-84. 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.

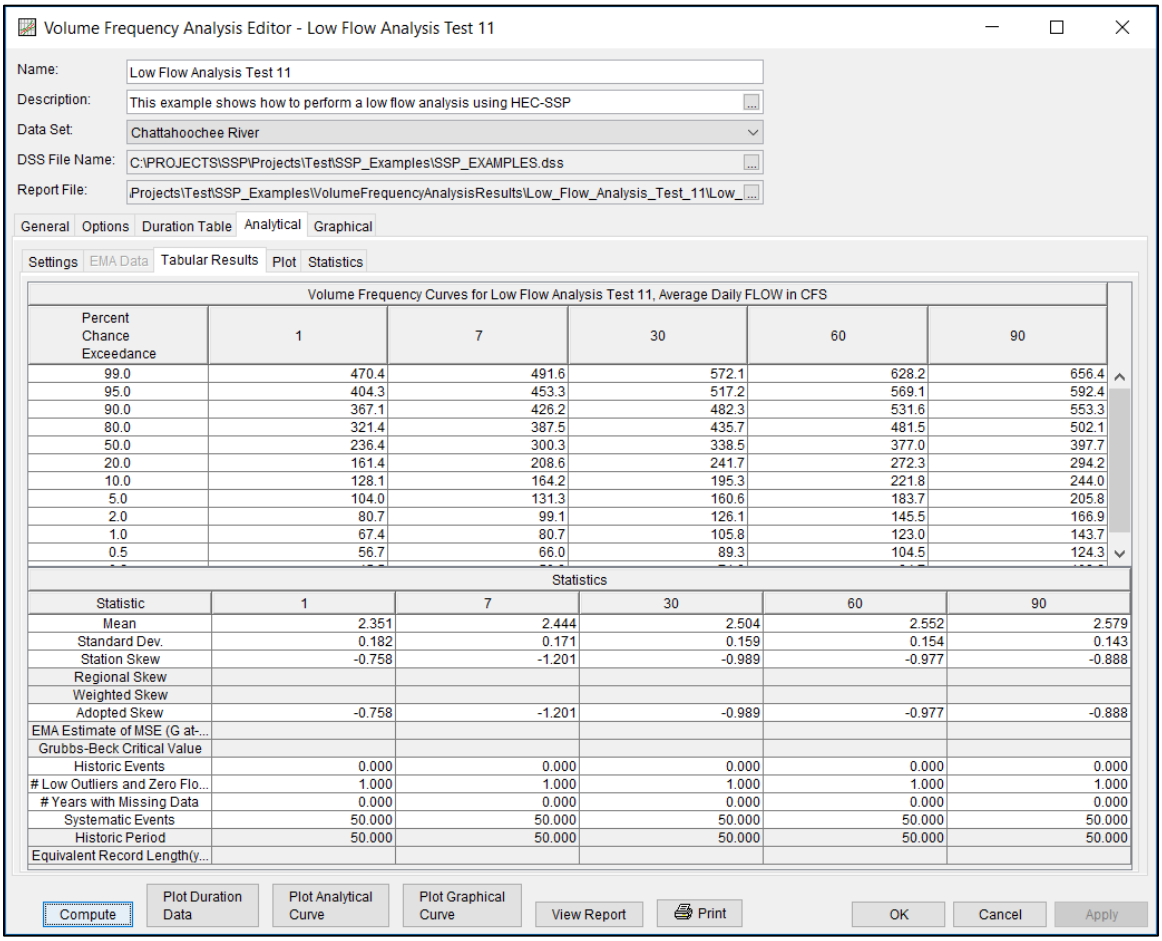


Figure B-84. Tabular Results Tab for Low Flow Analysis Test 11.

Note: These tabular results use the default computed statistics.

As shown in Figure B-85, 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.

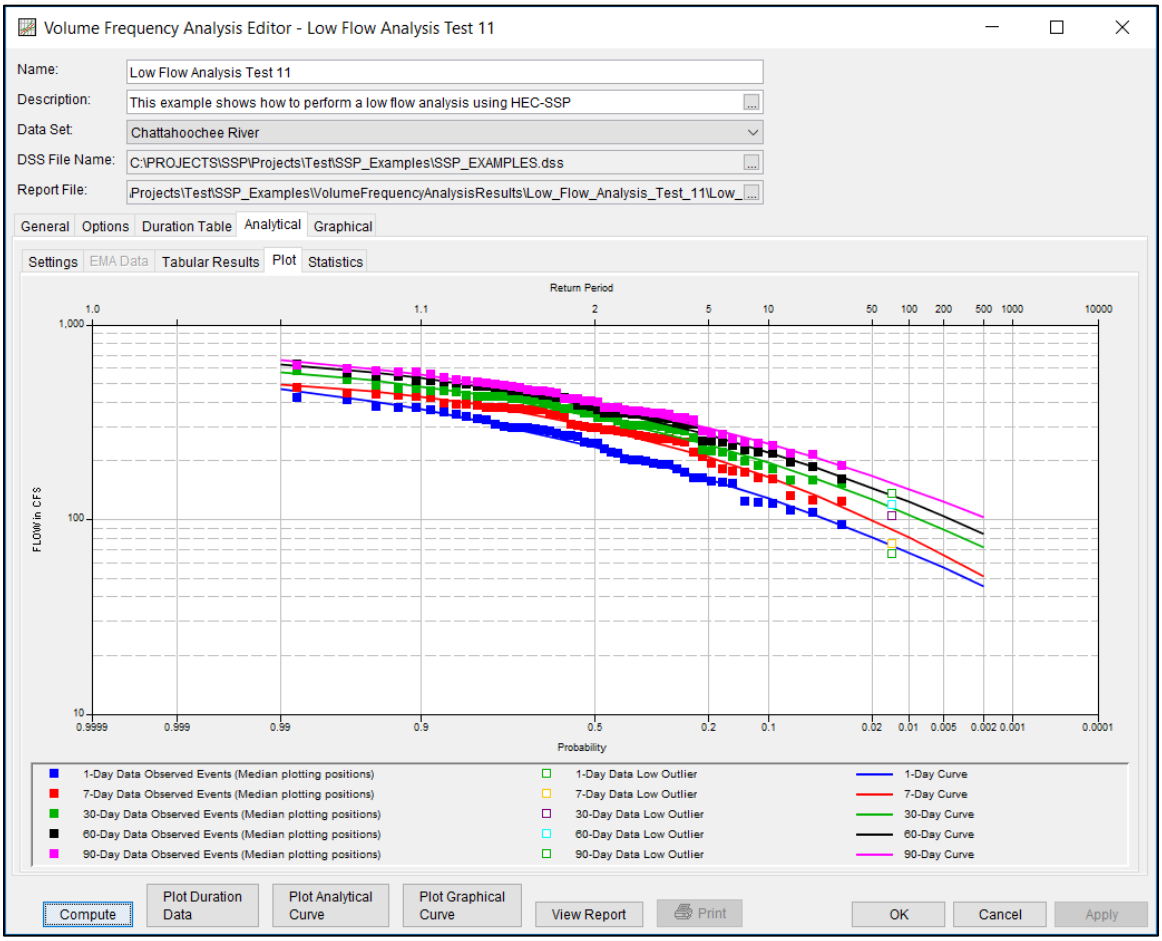


Figure B-85. Plot for Low Flow Analysis Test 11.

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 B-86, 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 B-87 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.

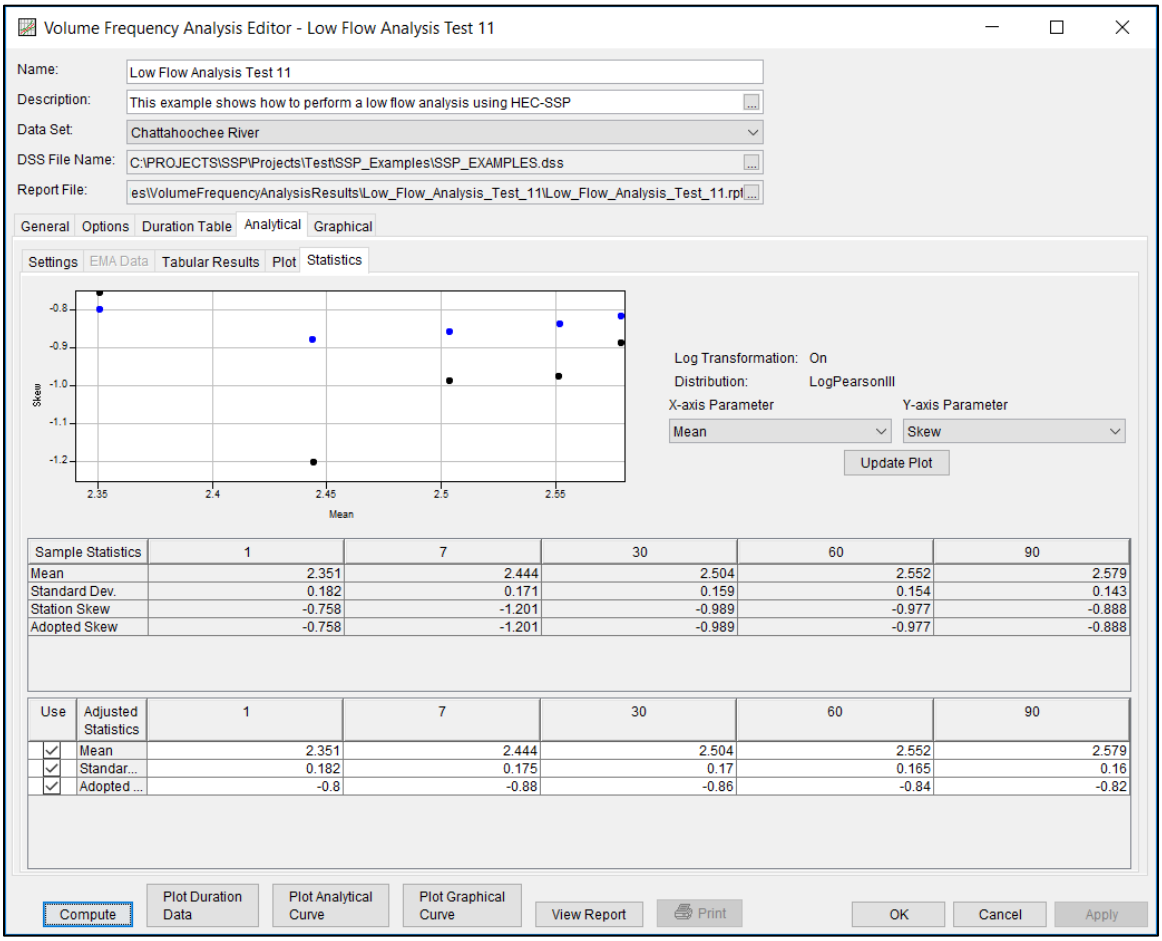


Figure B-86. Statistics Tab for Low Flow Analysis Test 11.

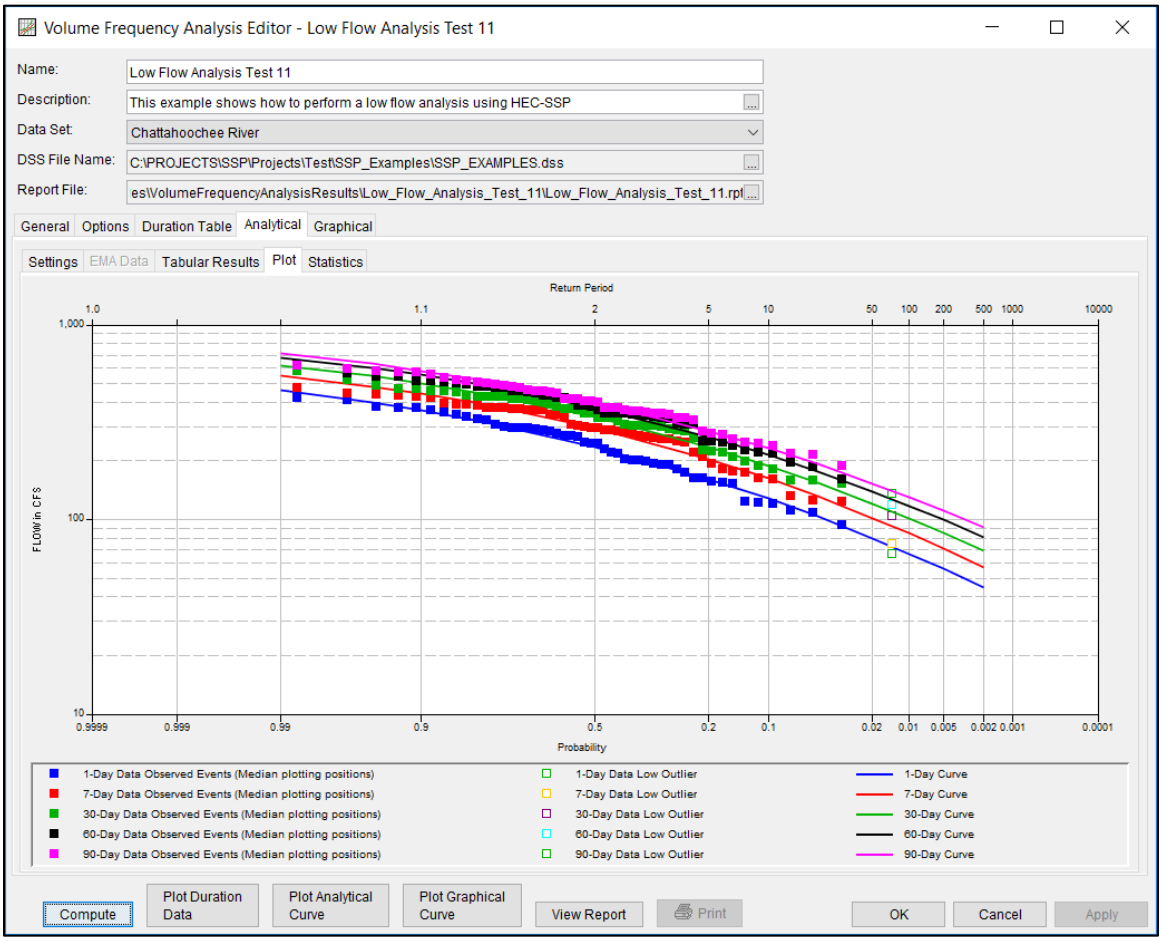


Figure B-87. Plot Tab for Low Flow Analysis Test 11.

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 B-88.

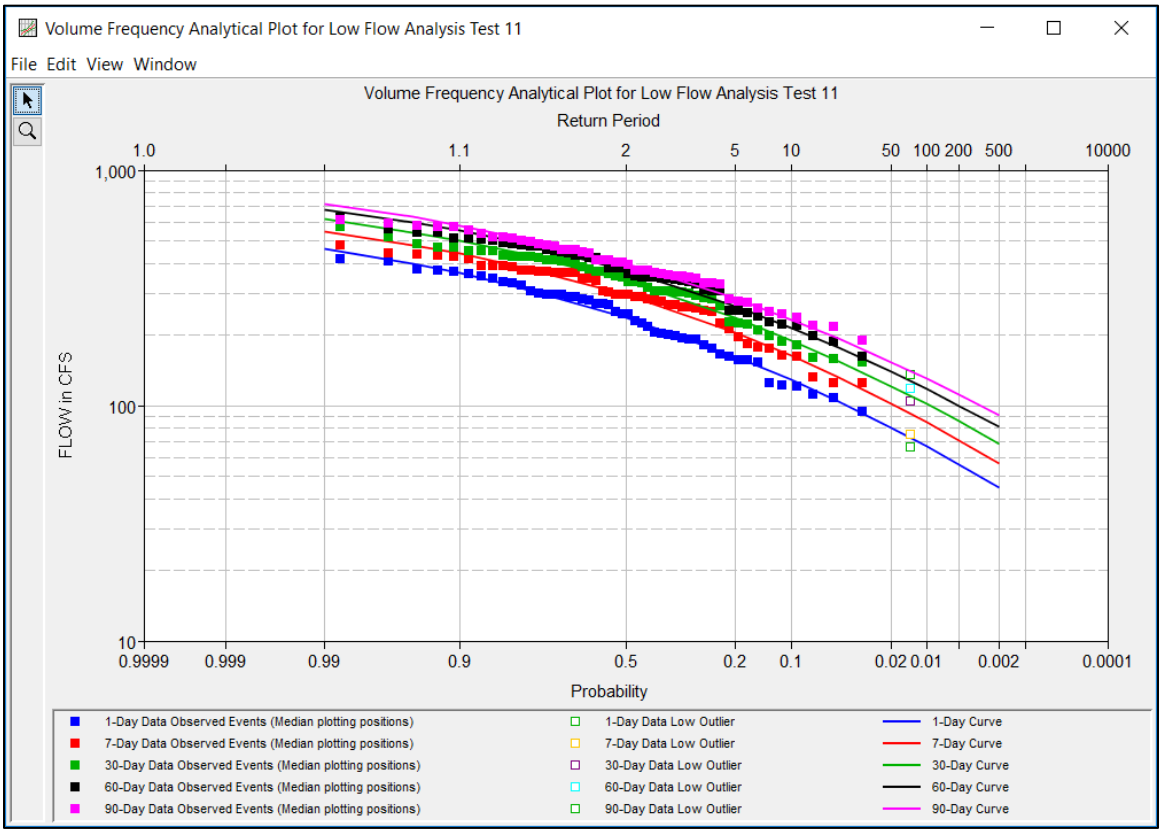


Figure B-88. Plot of the Frequency Curve Results for Low Flow Analysis Test 11.

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 B-89 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.

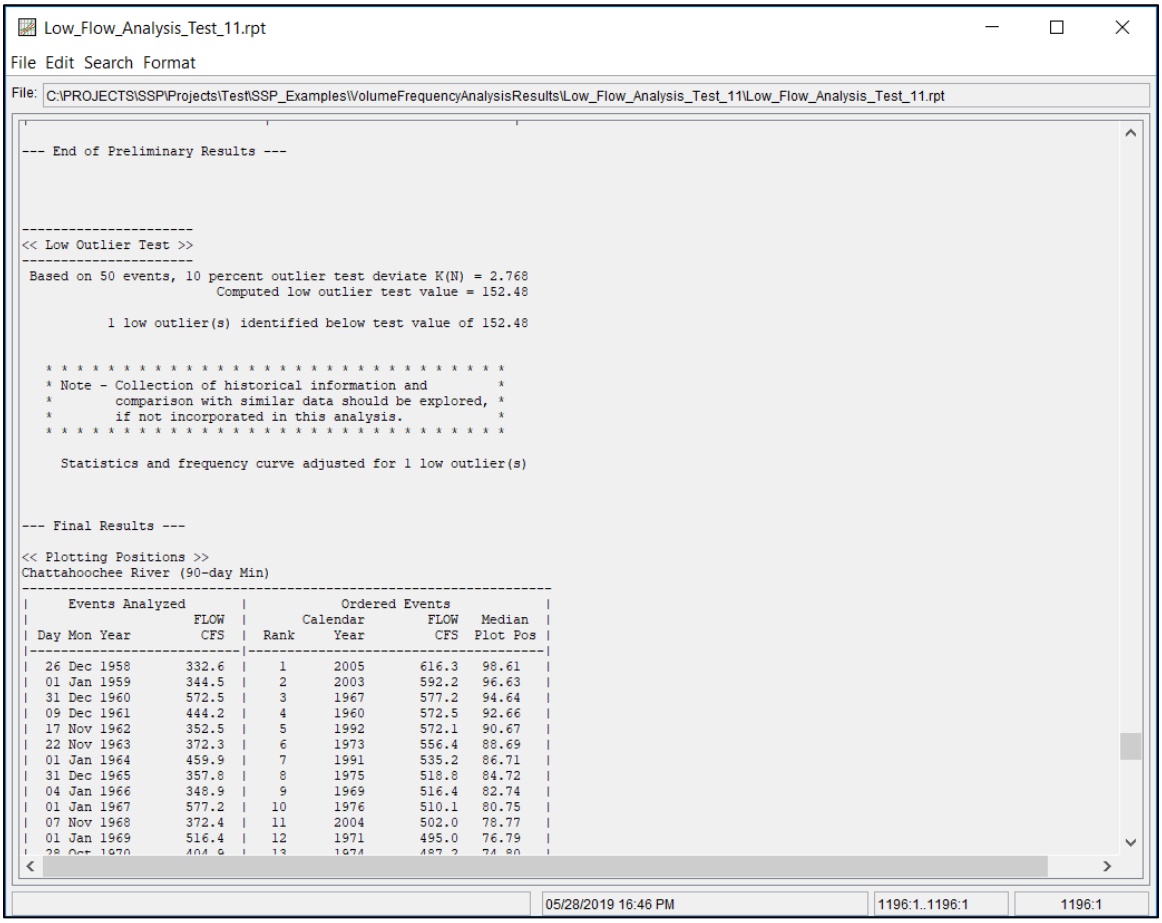


Figure B-89. Report File for Low Flow Analysis Test 11.

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 B-90.

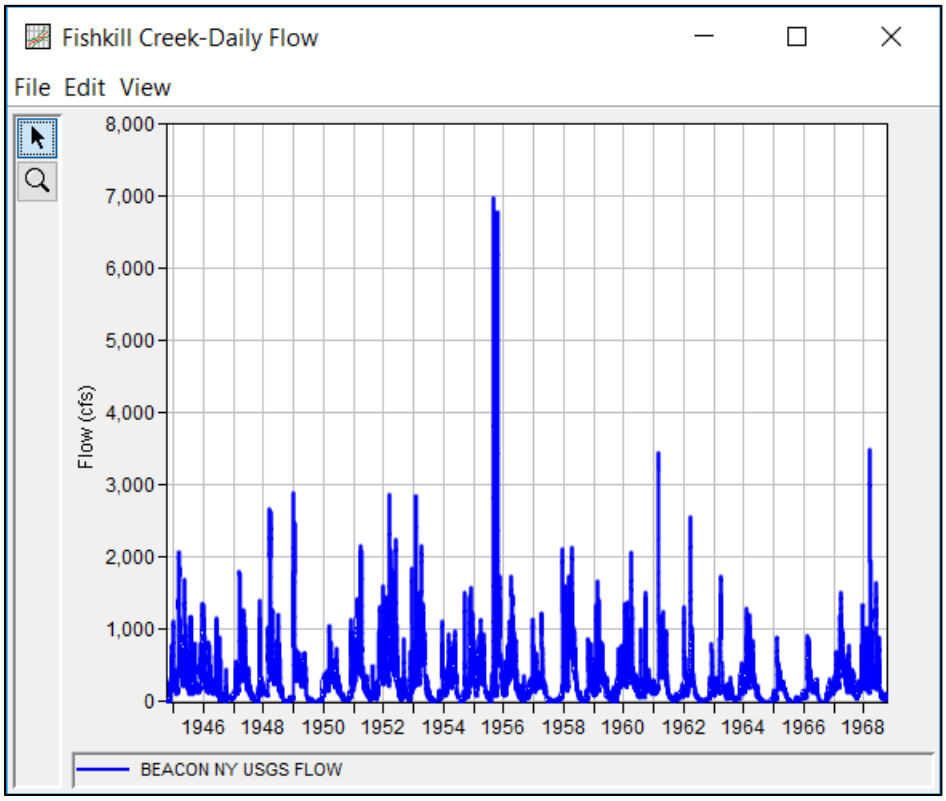


Figure B-90. Plot of the Daily Average Flow for Example 12.

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 B-91.

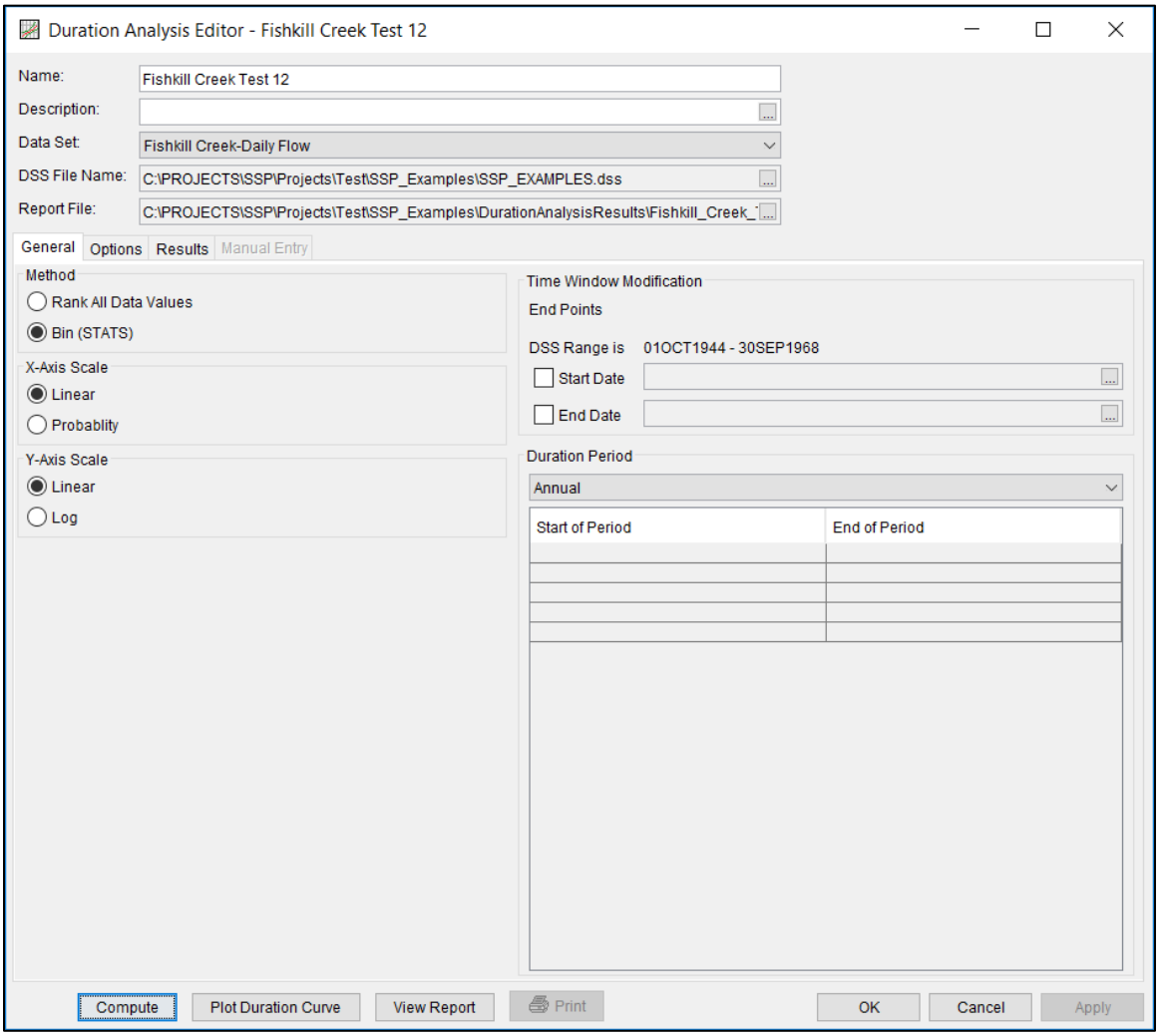


Figure B-91. Duration Analysis Editor for Fishkill Creek Test 12.

Shown in Figure B-91 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 B-92. 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.

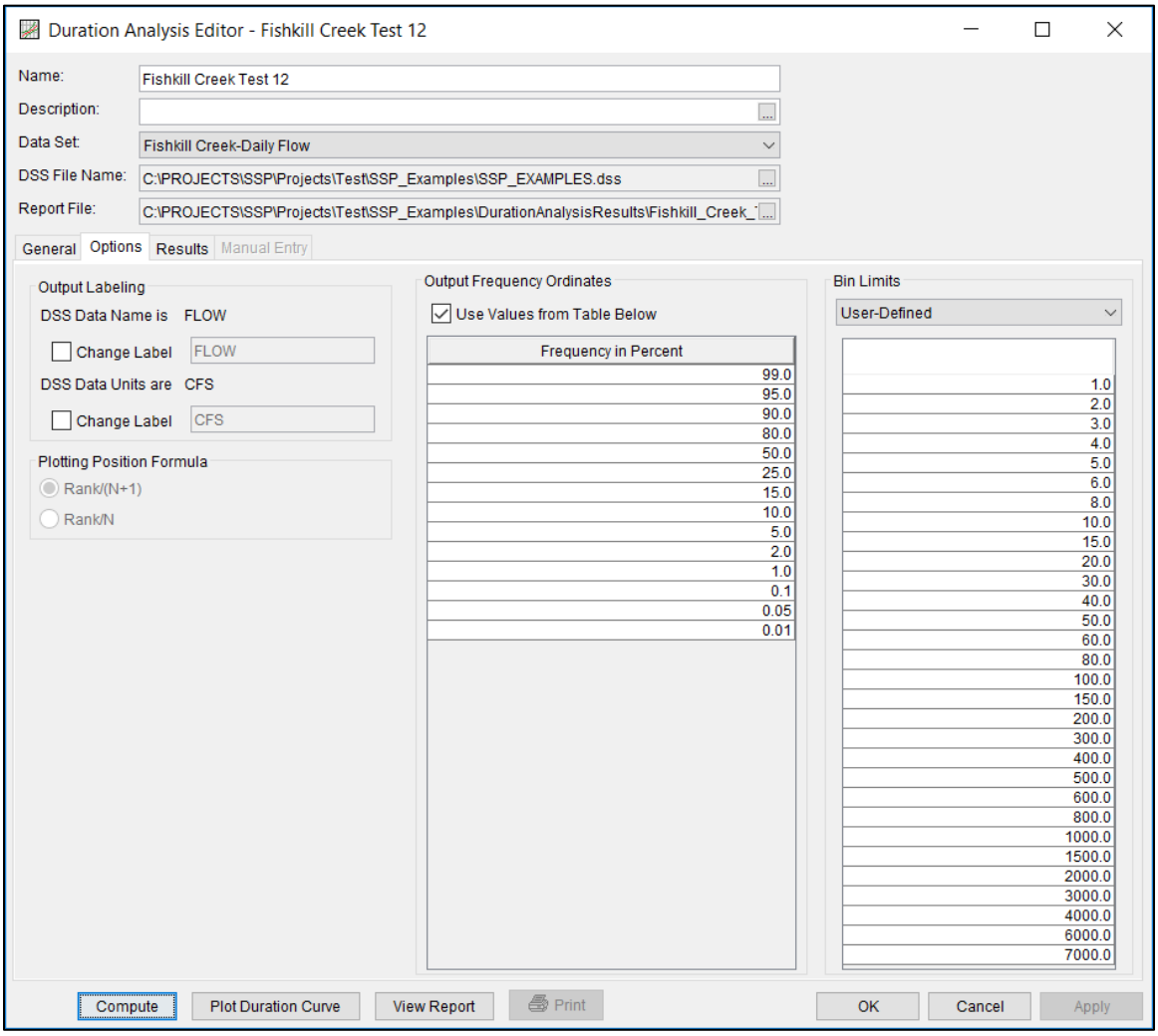


Figure B-92. Duration Analysis Editor with Options Tab Shown for Fishkill Creek Test 12.

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 B-93.

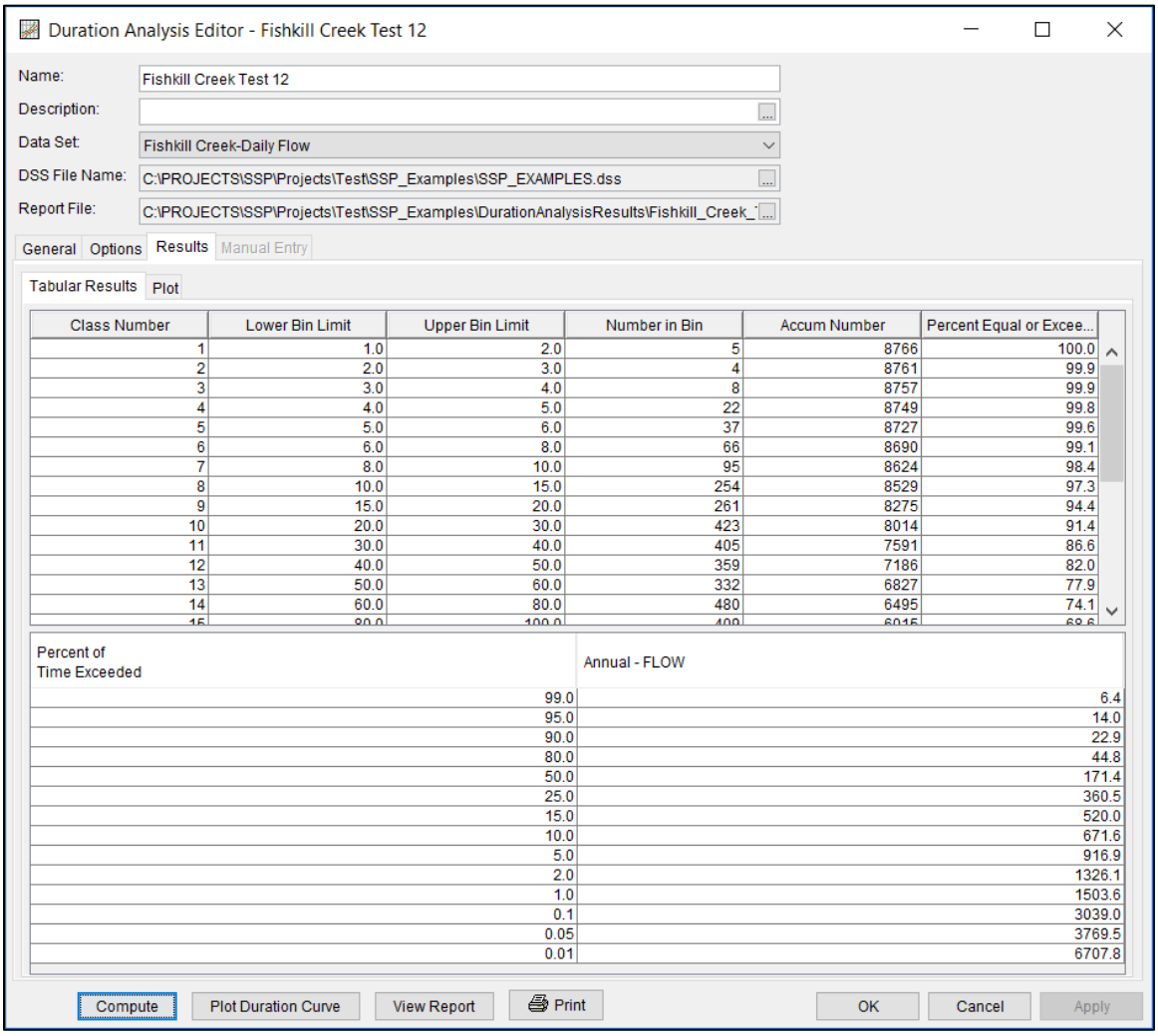


Figure B-93. The Results Tab for Fishkill Creek Test 12.

As shown in Figure B-93, 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 B-94. 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.

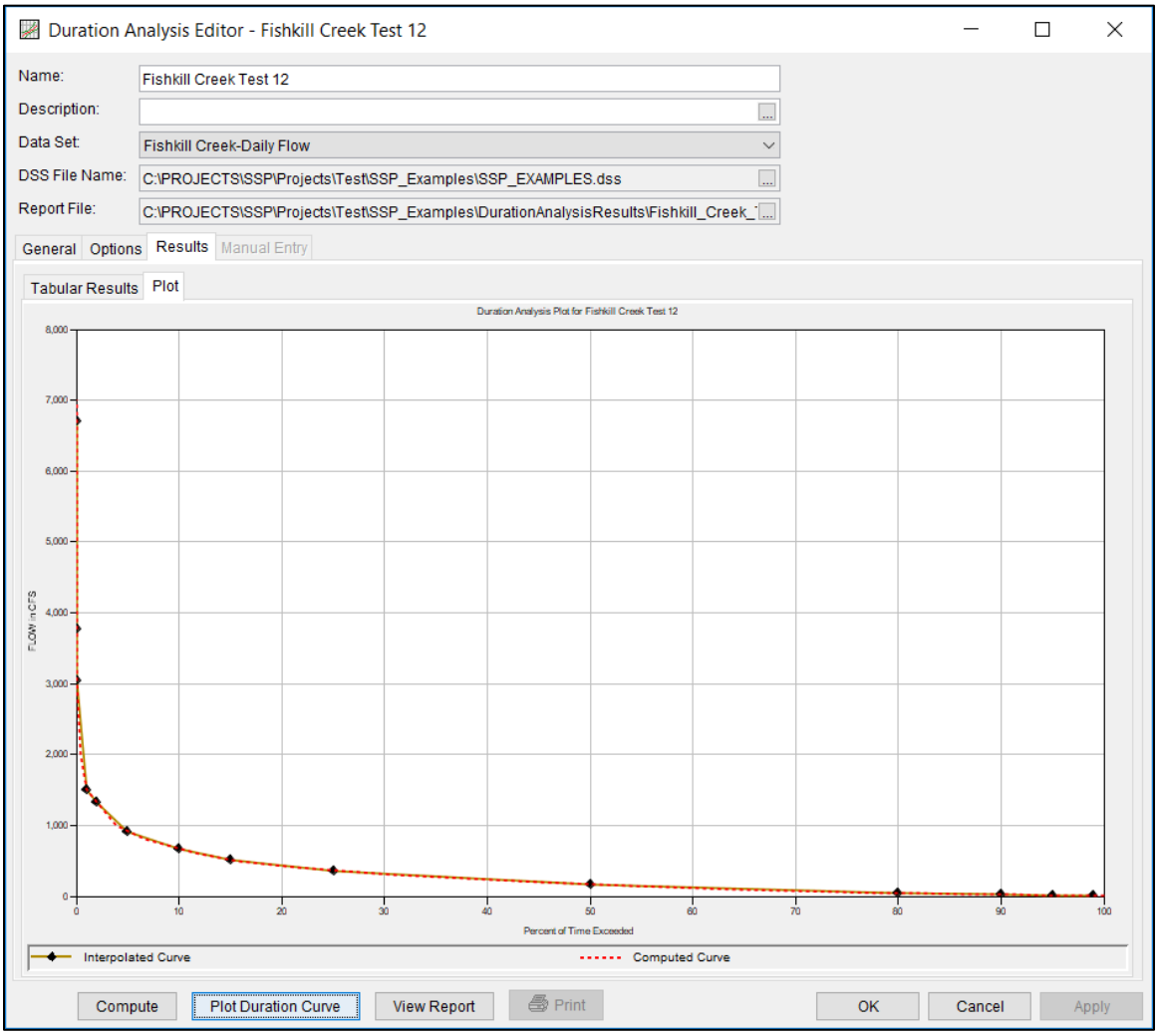


Figure B-94. Plot Tab for Fishkill Creek Test 12.

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 B-95 is the report file for **Fishkill Creek Test 12**.

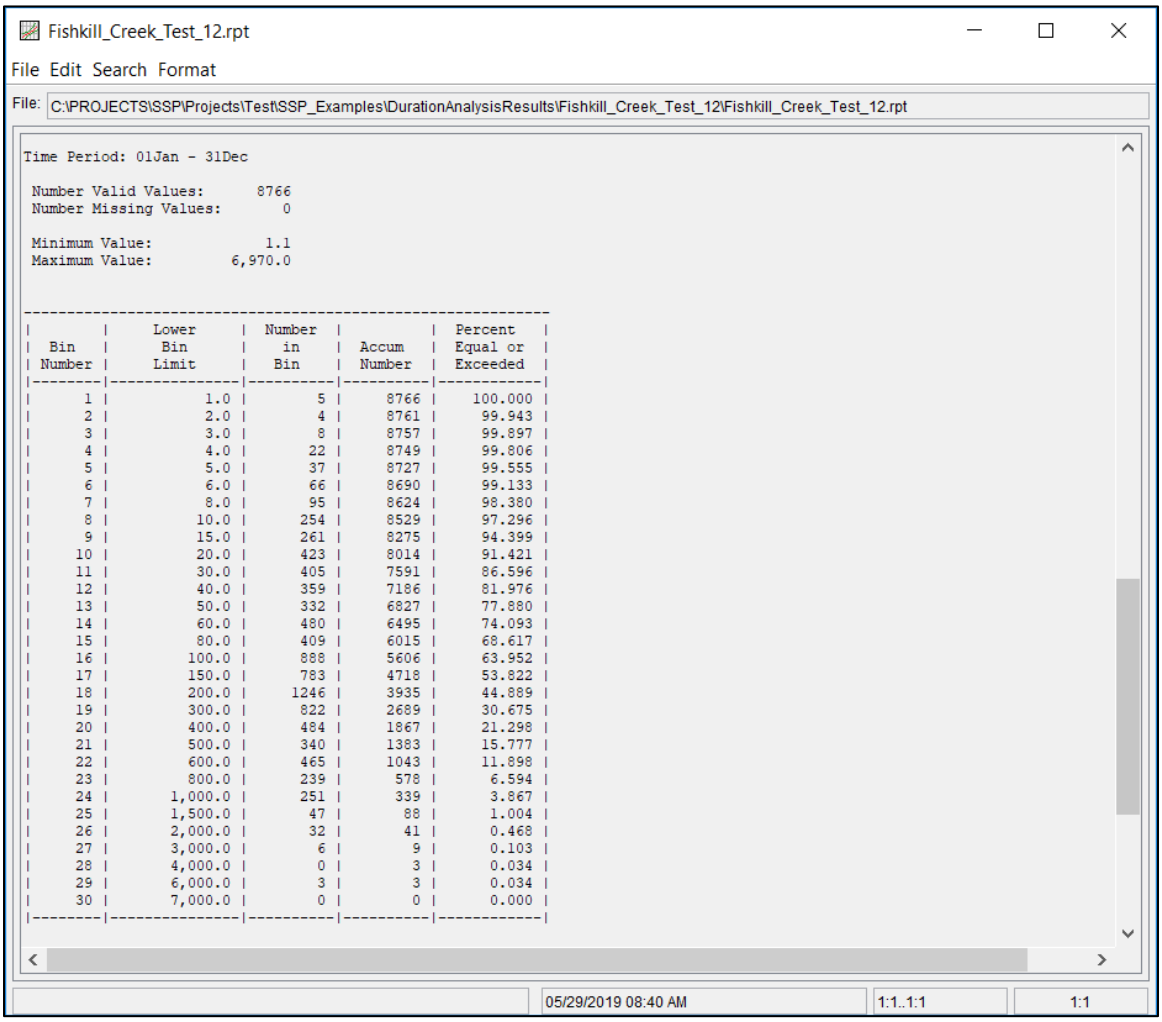


Figure B-95. Report File for Fishkill Creek Test 12.

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 B-96.

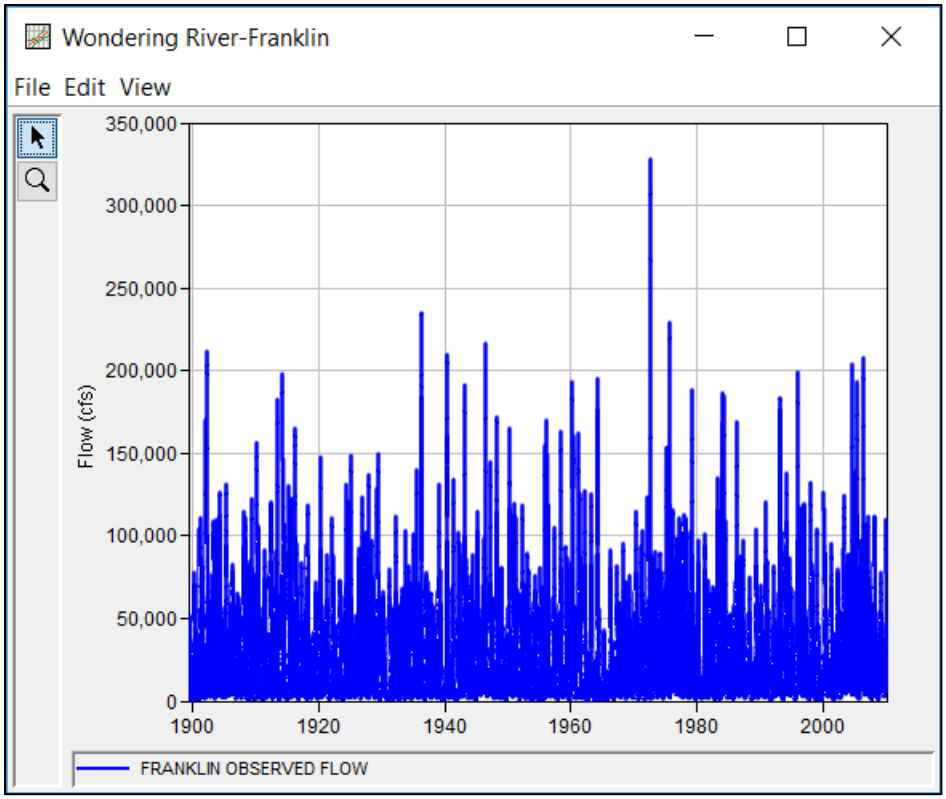


Figure B-96. Plot of the Daily Average Flow for Example 13.

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 B-97.

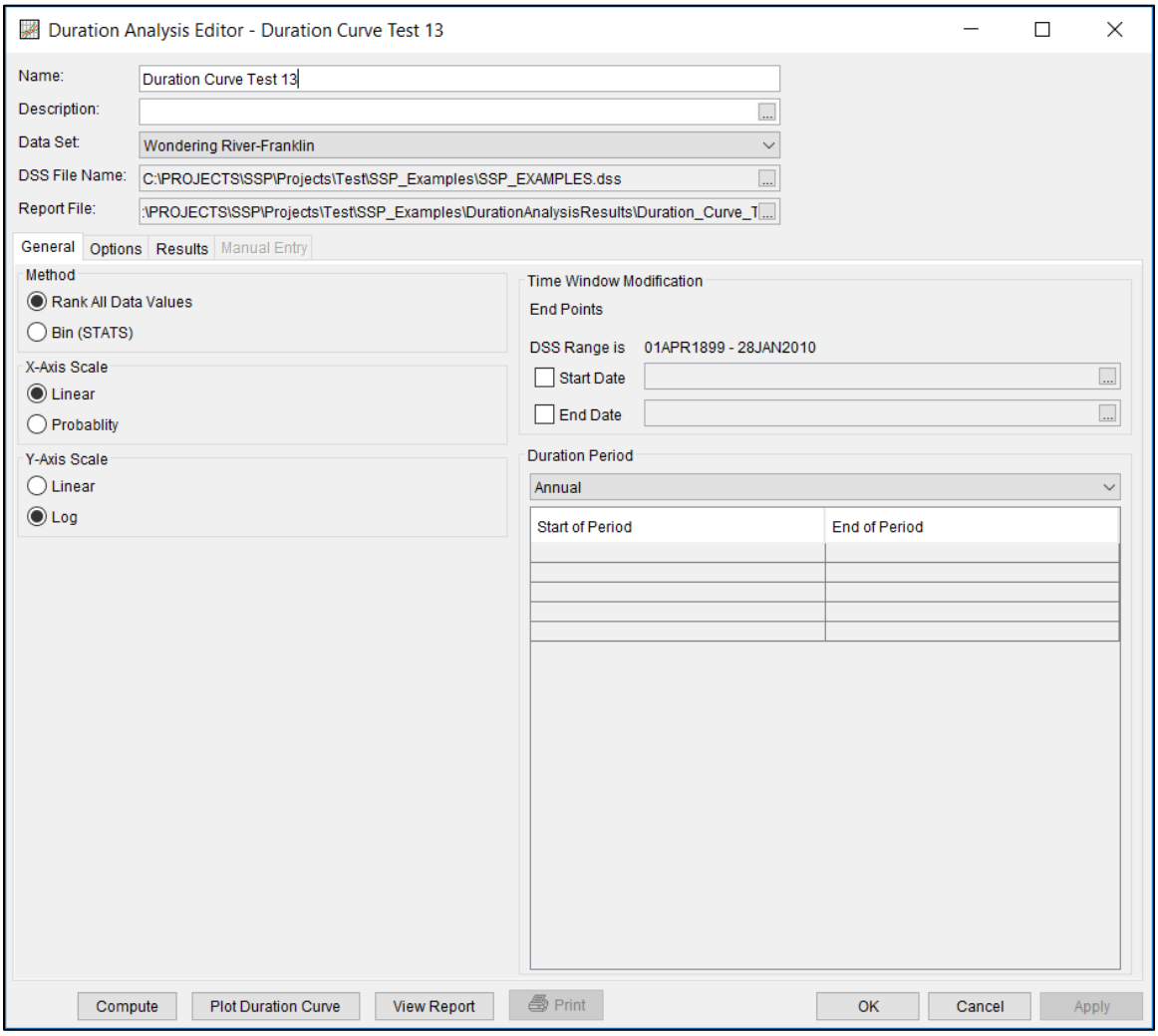


Figure B-97. Duration Analysis Editor for Duration Curve Test 13.

Shown in Figure B-97 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 B-98. 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.

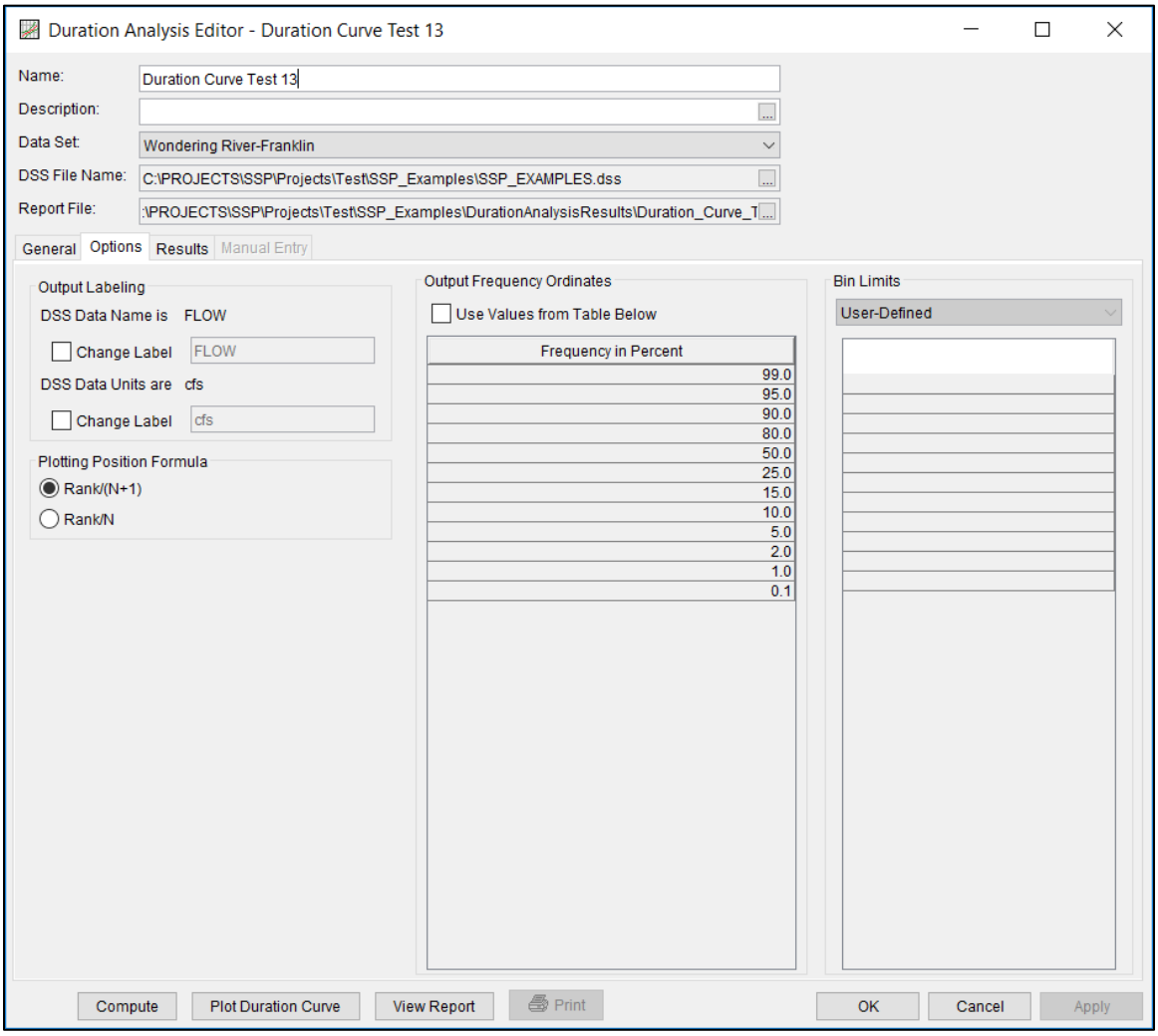


Figure B-98. Duration Analysis Editor with Options Tab Shown for Duration Curve Test 13.

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 B-99.

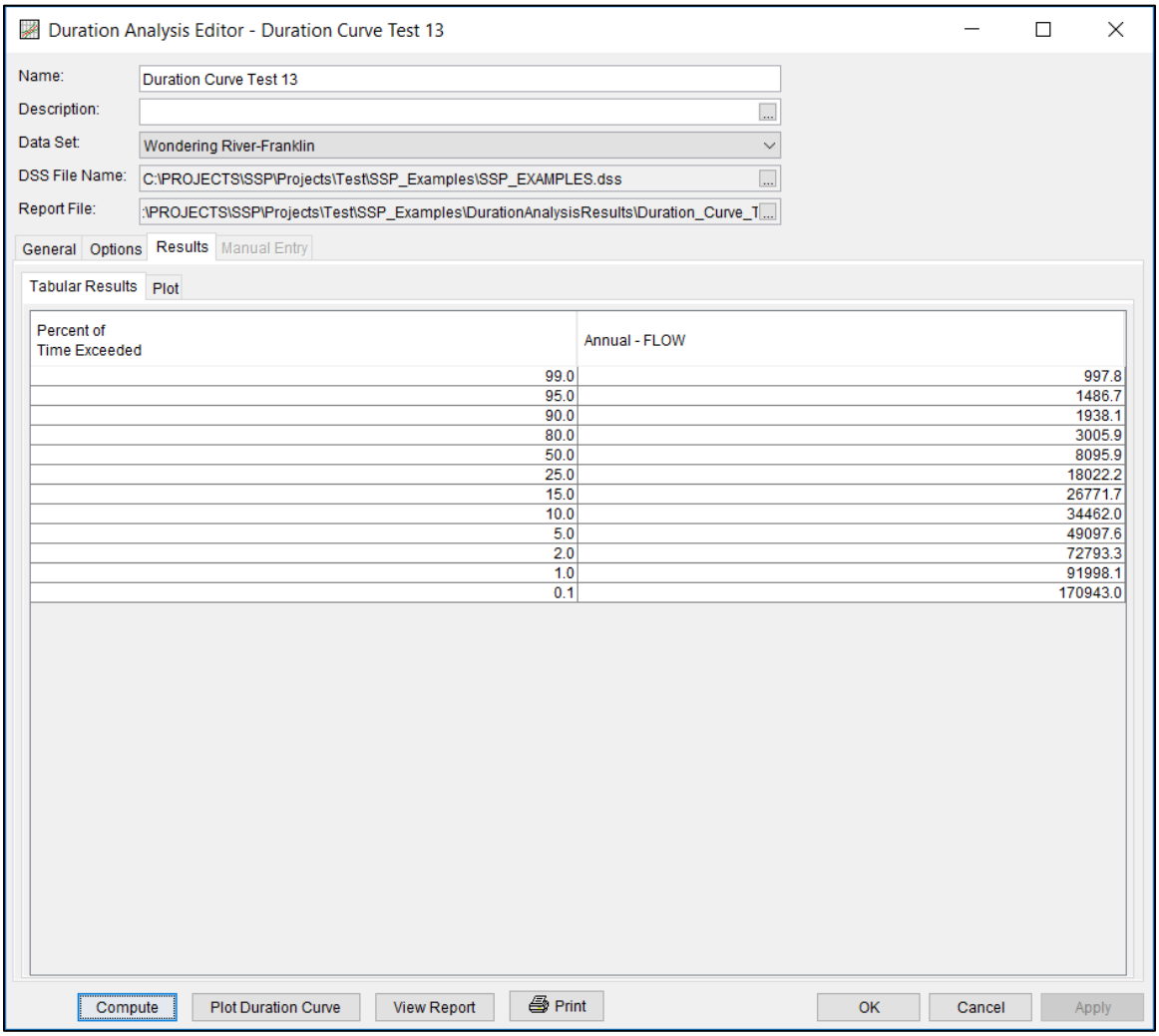


Figure B-99. The Results Tab for Duration Curve Test 13.

As shown in Figure B-99, 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 B-100.

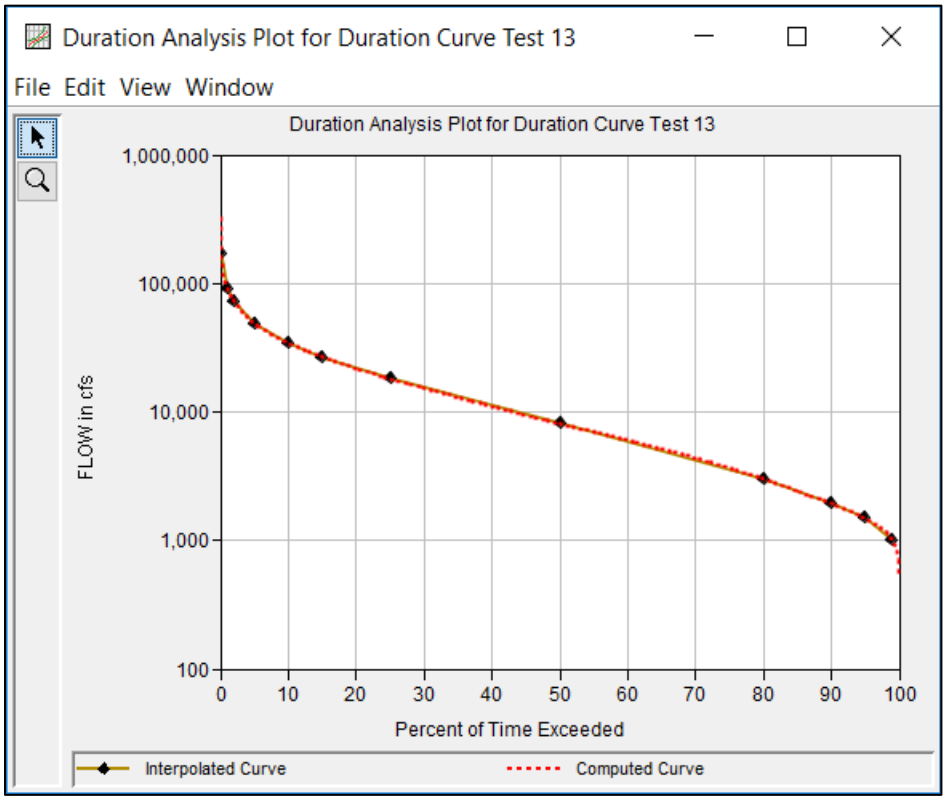
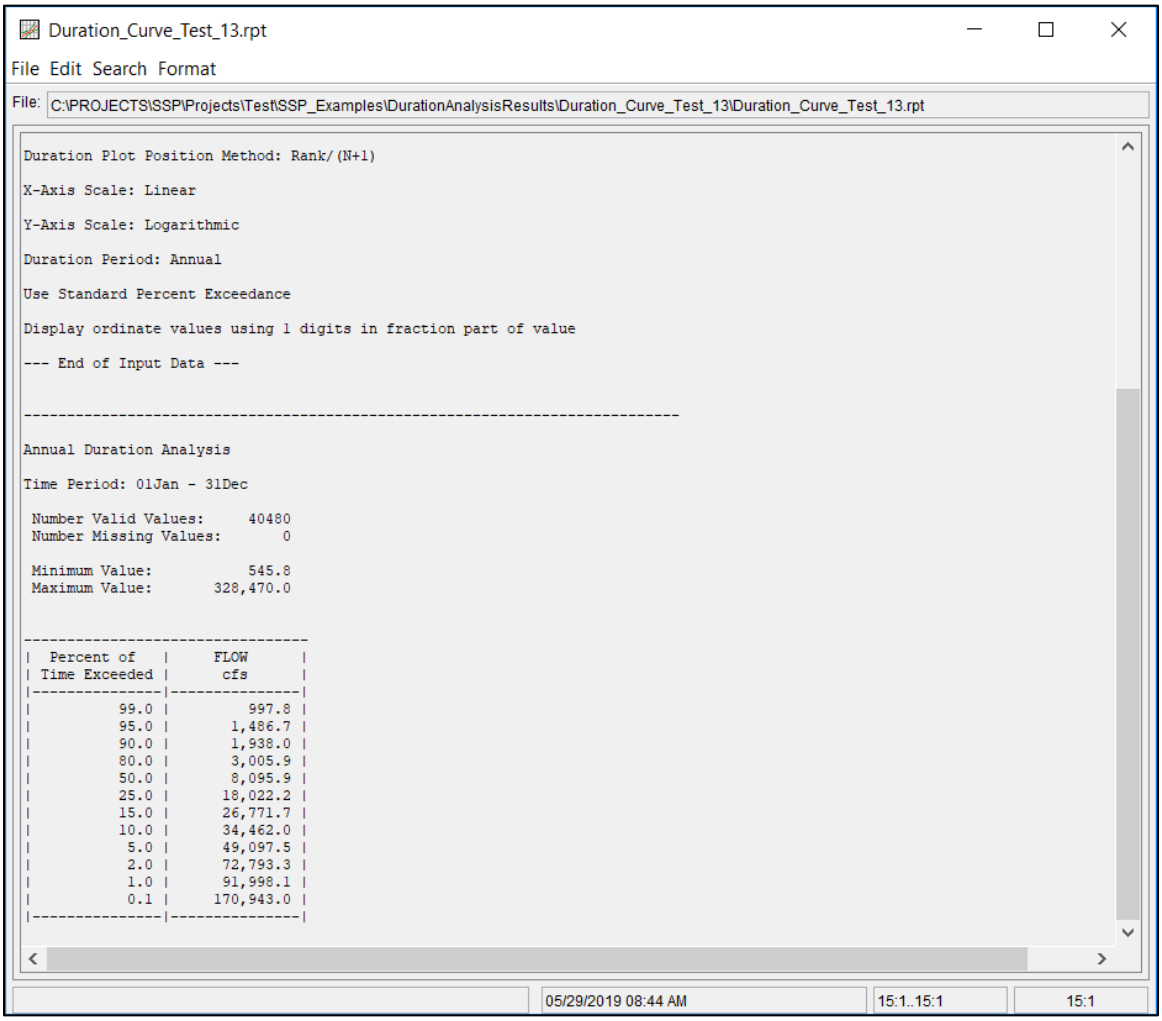


Figure B-100. Duration Curve Plot for Duration Curve Test 13.

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 B-101 is the report file for **Duration Curve Test 13**.



Duration_Curve_Test_13.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\SSP_Examples\DurationAnalysisResults\Duration_Curve_Test_13\Duration_Curve_Test_13.rpt

```
Duration Plot Position Method: Rank/(N+1)

X-Axis Scale: Linear

Y-Axis Scale: Logarithmic

Duration Period: Annual

Use Standard Percent Exceedance

Display ordinate values using 1 digits in fraction part of value

--- End of Input Data ---


--------------------------------------------------------------------------------

Annual Duration Analysis

Time Period: 01Jan - 31Dec

 Number Valid Values:     40480
 Number Missing Values:       0

 Minimum Value:           545.8
 Maximum Value:       328,470.0


---------------------------------
|  Percent of   |     FLOW      |
| Time Exceeded |      cfs      |
|---------------|---------------|
|          99.0 |         997.8 |
|          95.0 |       1,486.7 |
|          90.0 |       1,938.0 |
|          80.0 |       3,005.9 |
|          50.0 |       8,095.9 |
|          25.0 |      18,022.2 |
|          15.0 |      26,771.7 |
|          10.0 |      34,462.0 |
|           5.0 |      49,097.5 |
|           2.0 |      72,793.3 |
|           1.0 |      91,998.1 |
|           0.1 |     170,943.0 |
|---------------|---------------|
```

05/29/2019 08:44 AM | 15:1..15:1 | 15:1

Figure B-101. Report File for Duration Curve Test 13.

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 B-102, 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).

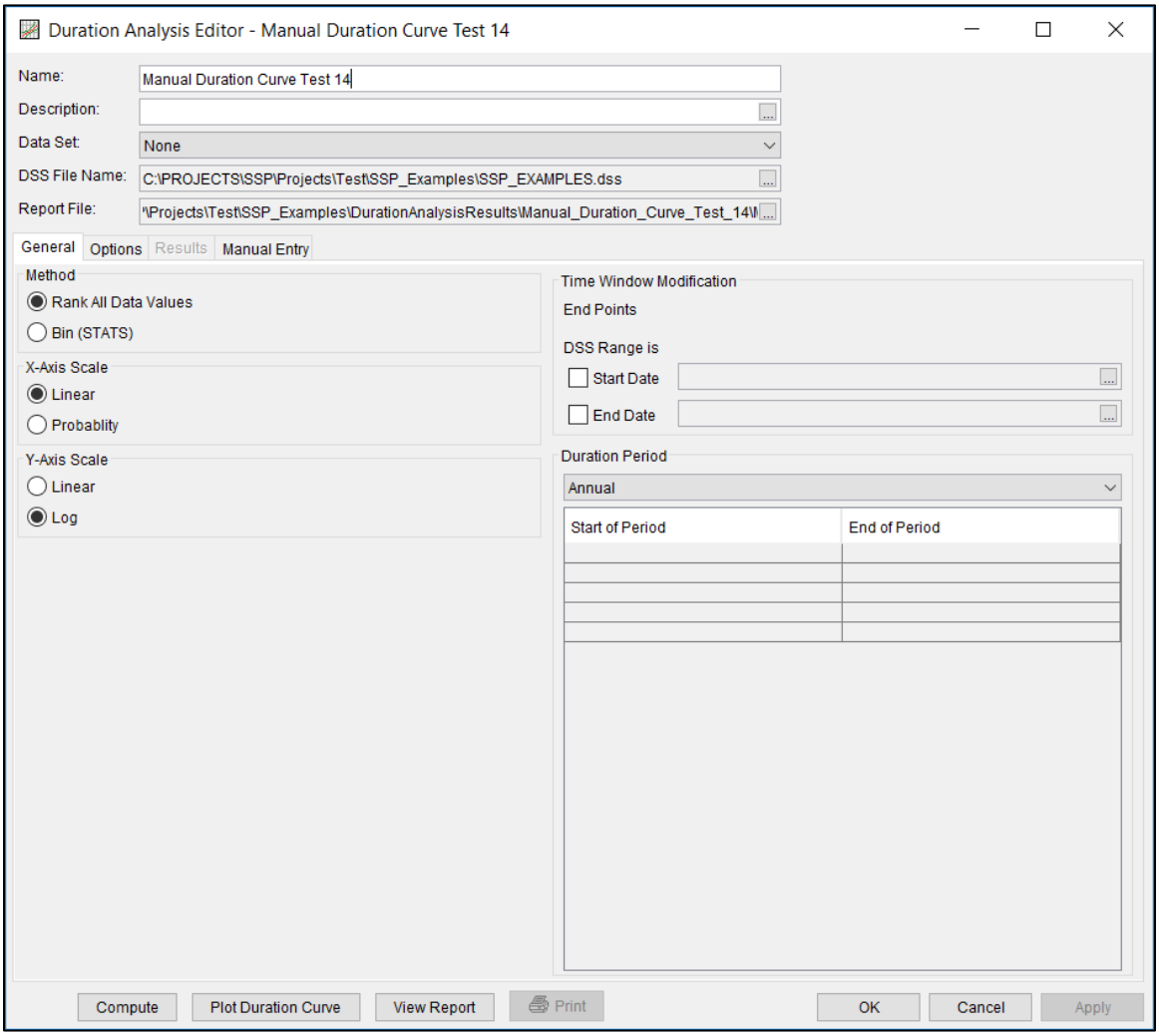


Figure B-102. Duration Analysis Editor for Manual Duration Curve Test 14.

The y-axis scale was set to **Log** while all other default options were selected on the General and Options tabs. Figure B-103 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.

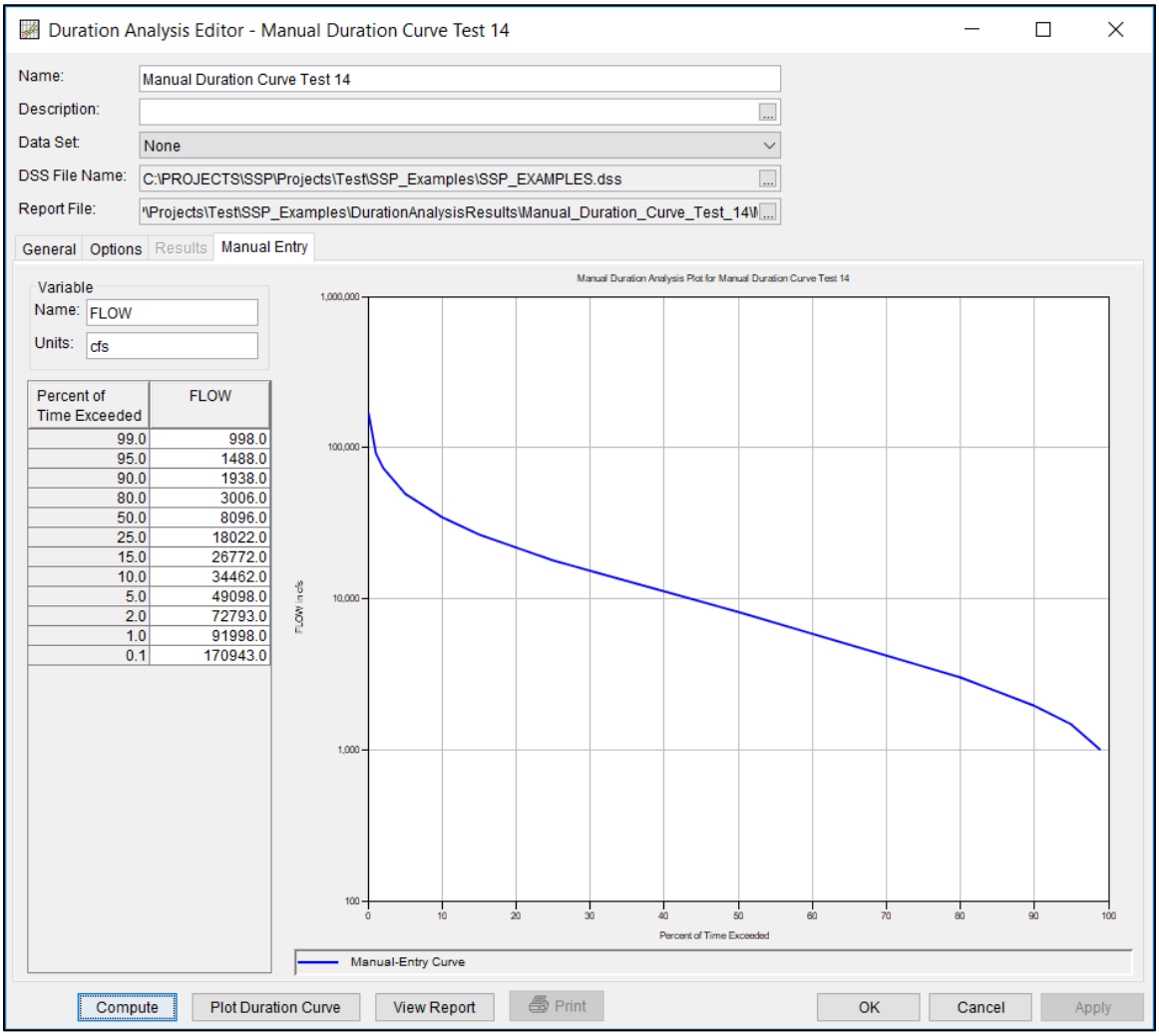


Figure B-103. Duration Analysis Editor with Options Tab Shown for Manual Duration Curve Test 14.

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 B-104.

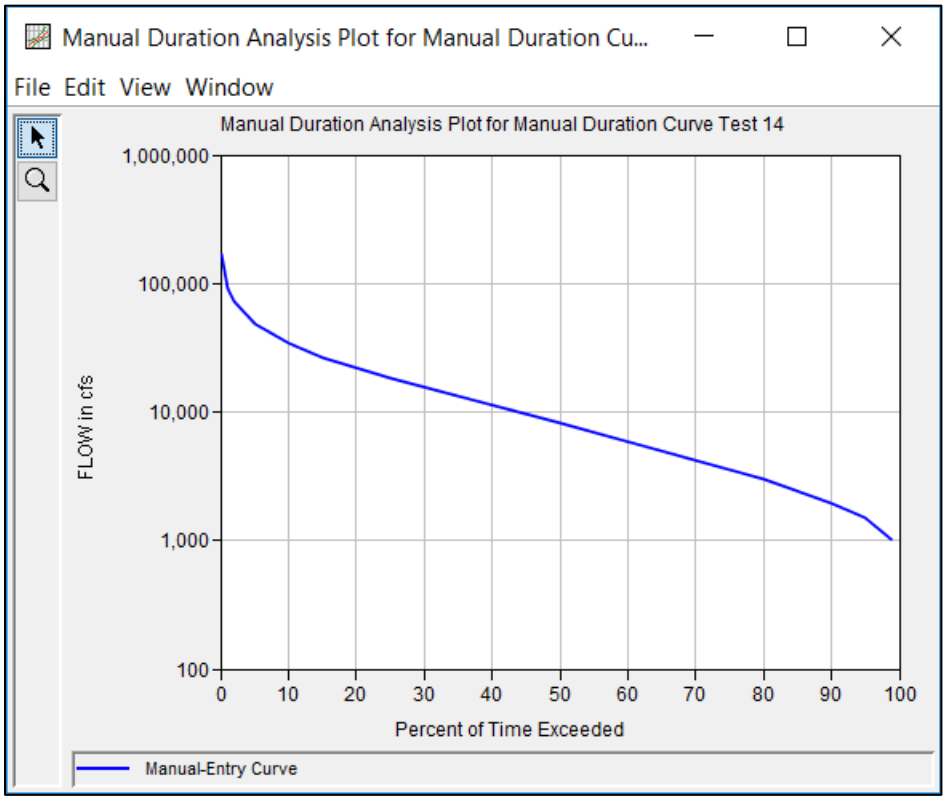


Figure B-104. Duration Curve Plot for Manual Duration Curve Test 14.

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

This example demonstrates how to create a coincident frequency analysis. Figure B-105 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.

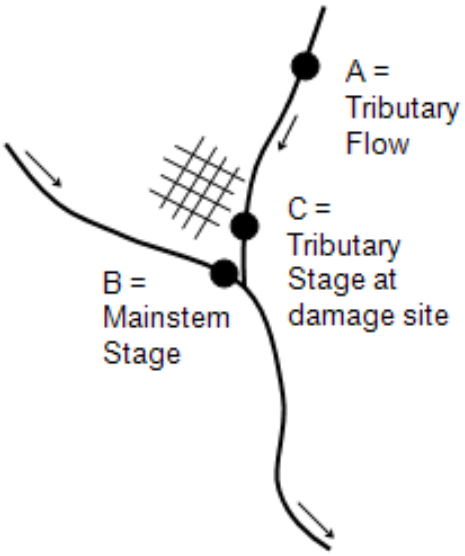


Figure B-105. Scenario for **Coincident Freq Test 15**.

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 B-106.

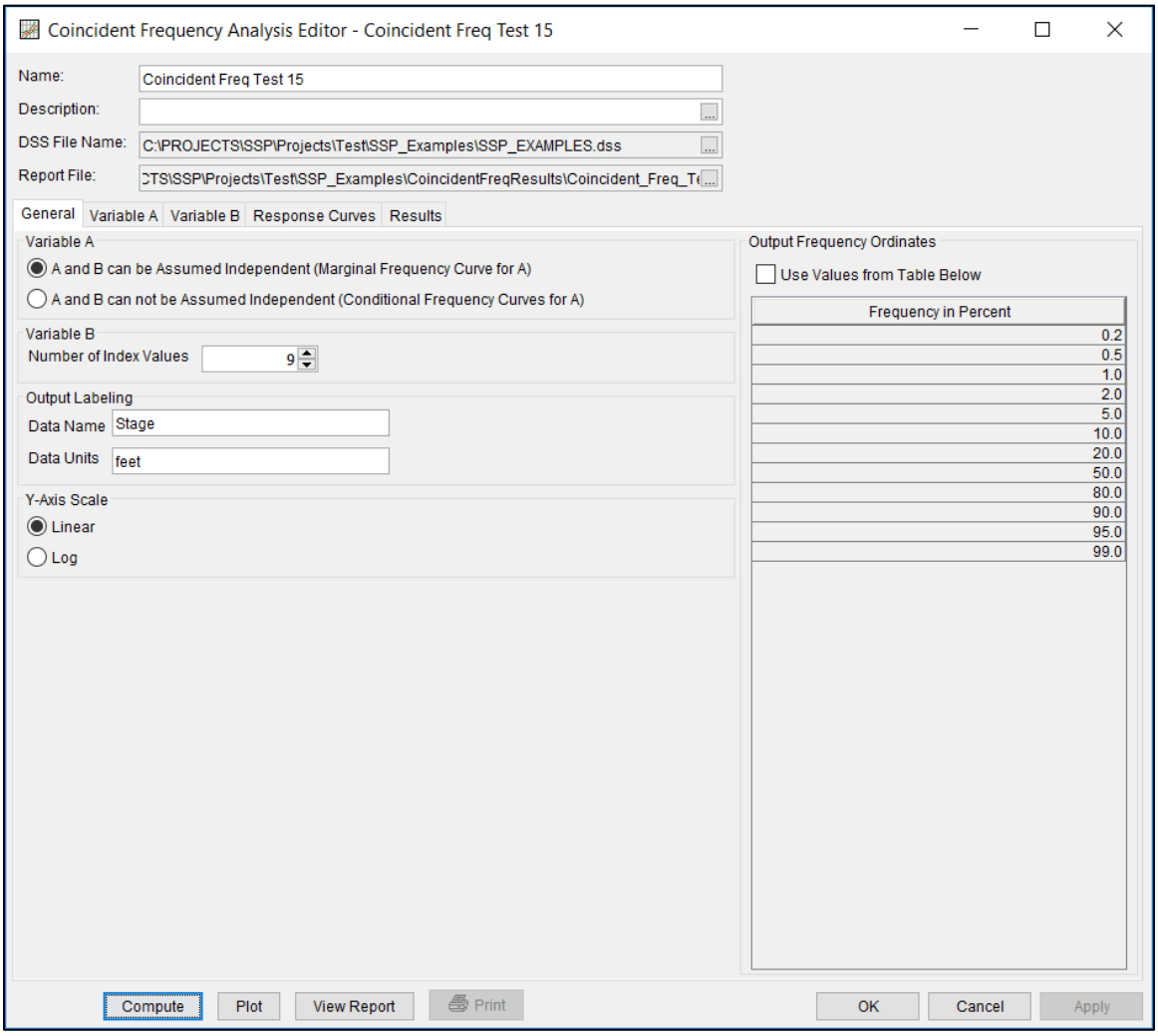


Figure B-106. General Tab Shown for Coincident Freq Test 15.

Shown in Figure B-106 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 B-107 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.

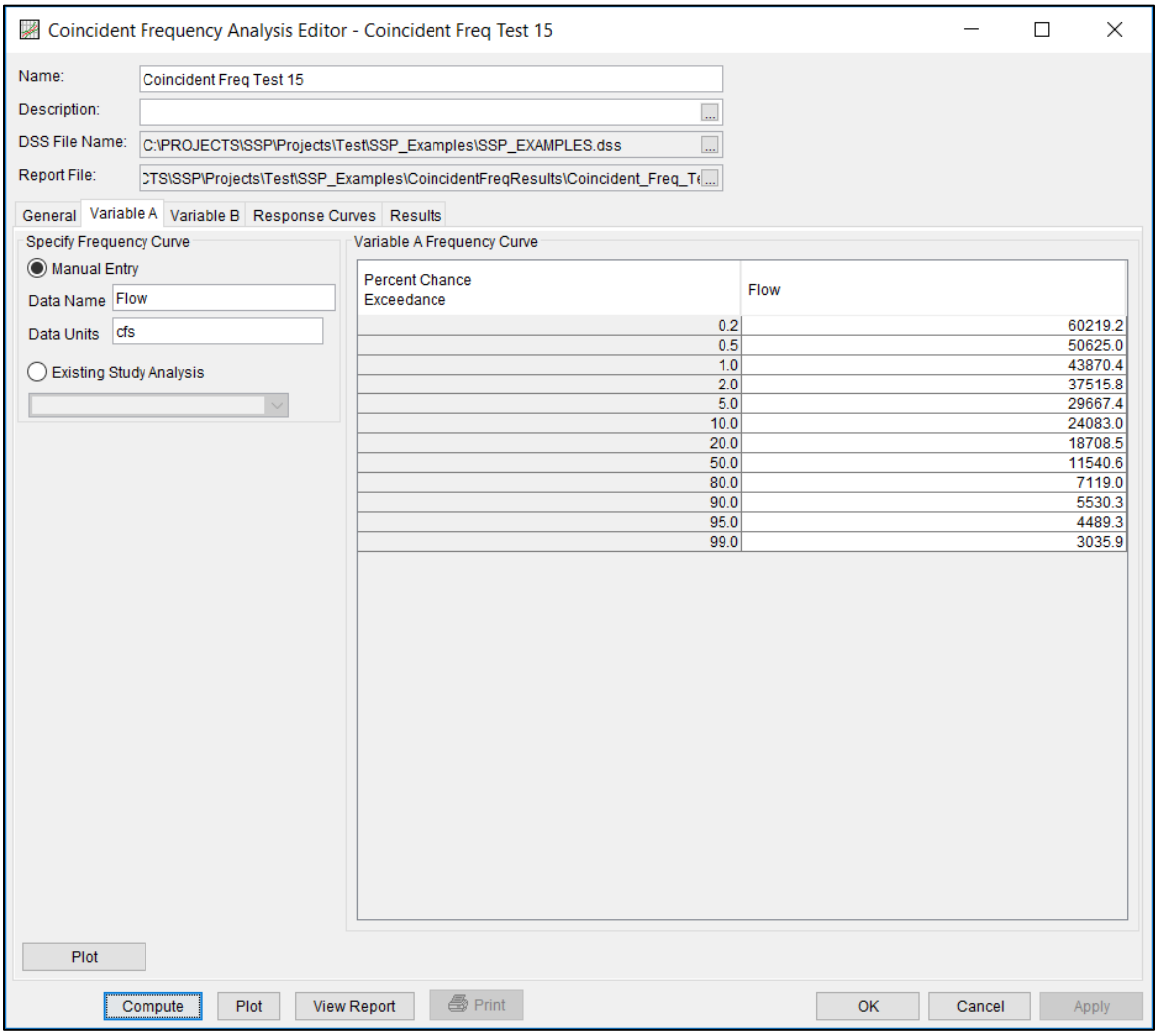


Figure B-107. Variable A Tab for Coincident Freq Test 15.

Shown in Figure B-108 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.

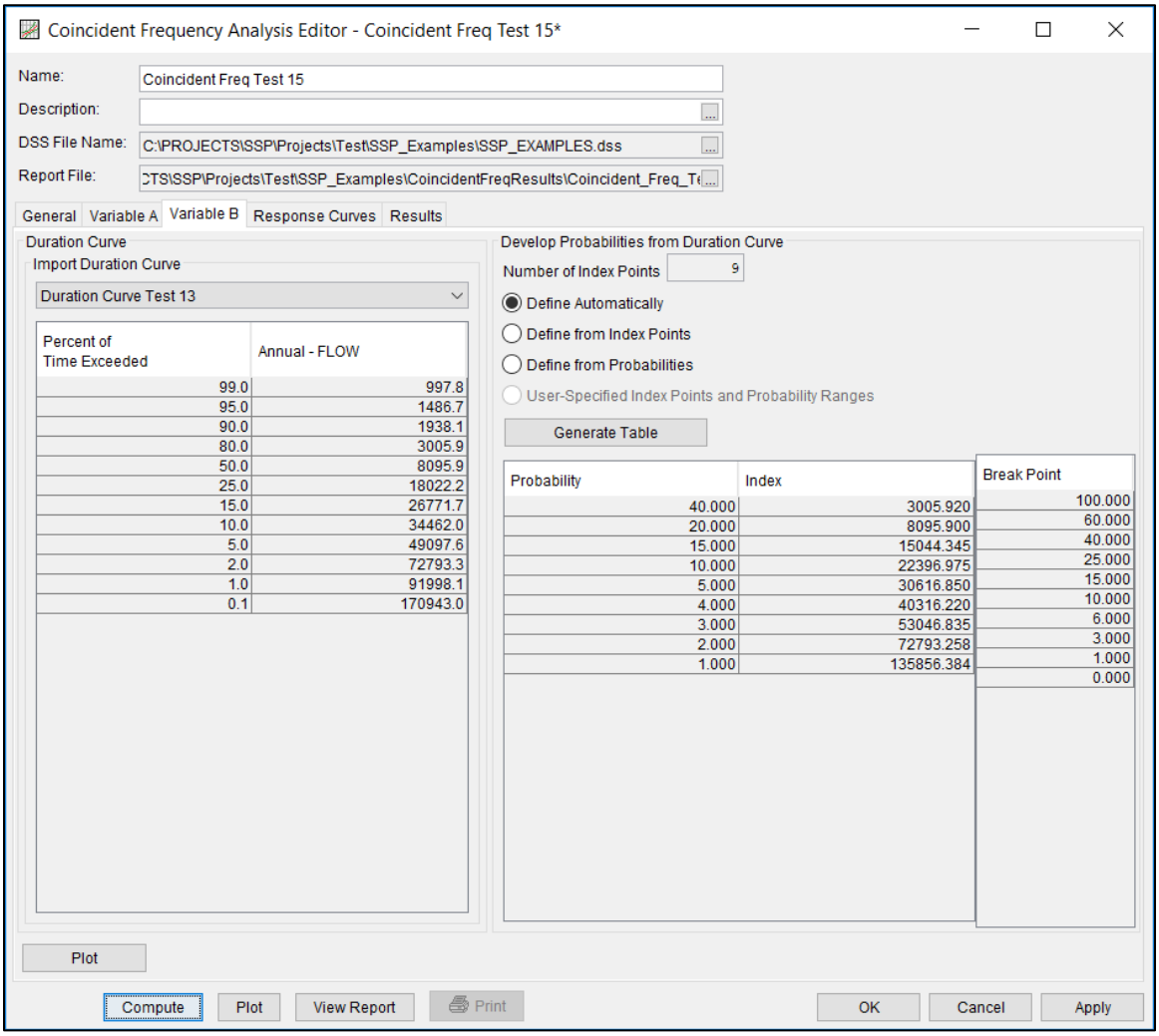
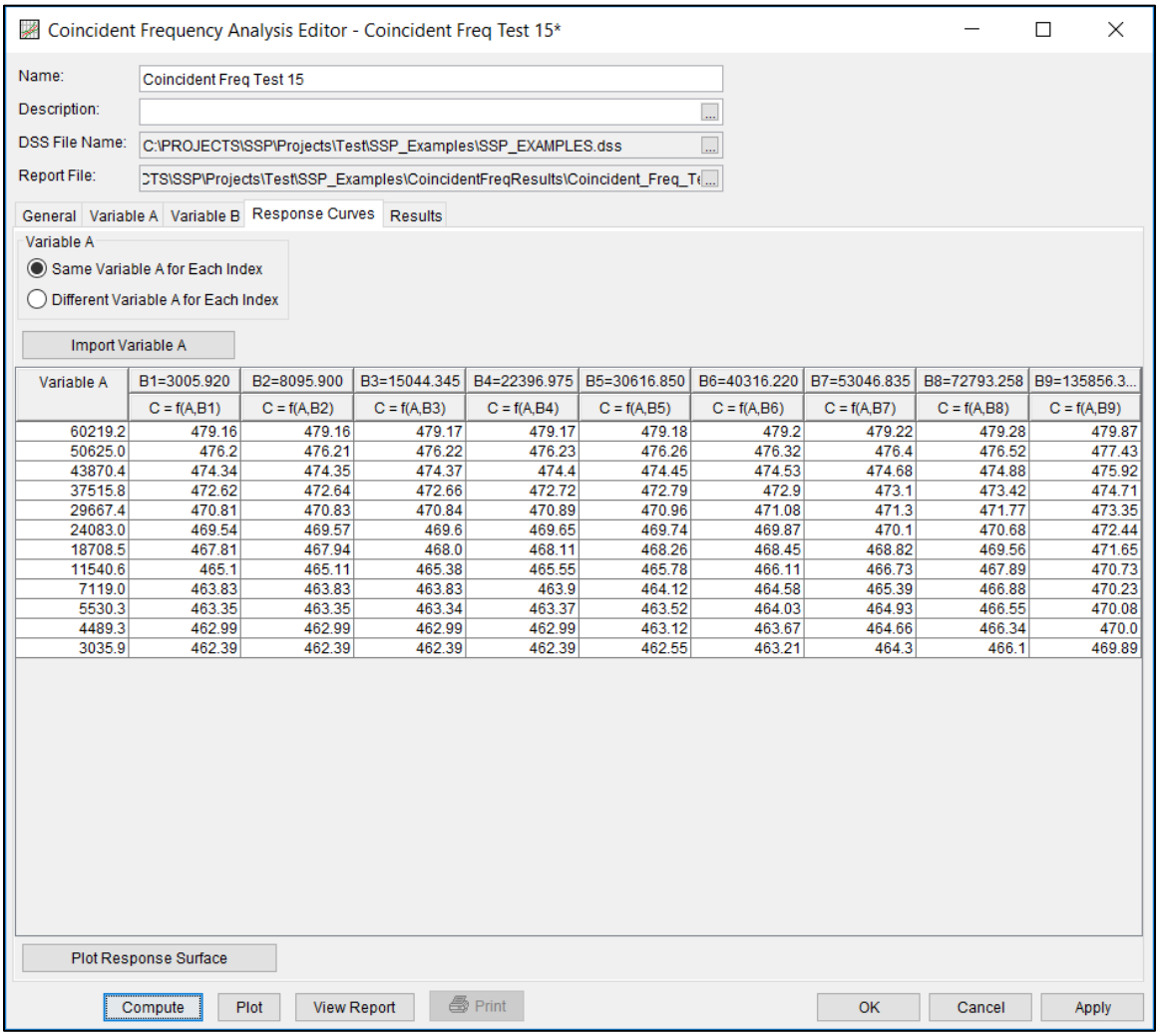


Figure B-108. Variable B Tab for Coincident Freq Test 15.

Once the Variable A and Variable B tabs have been completed, the user can populate the response curves table. Figure B-109 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 B-110 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

Figure B-109. Response Curves Tab for Coincident Freq Test 15.

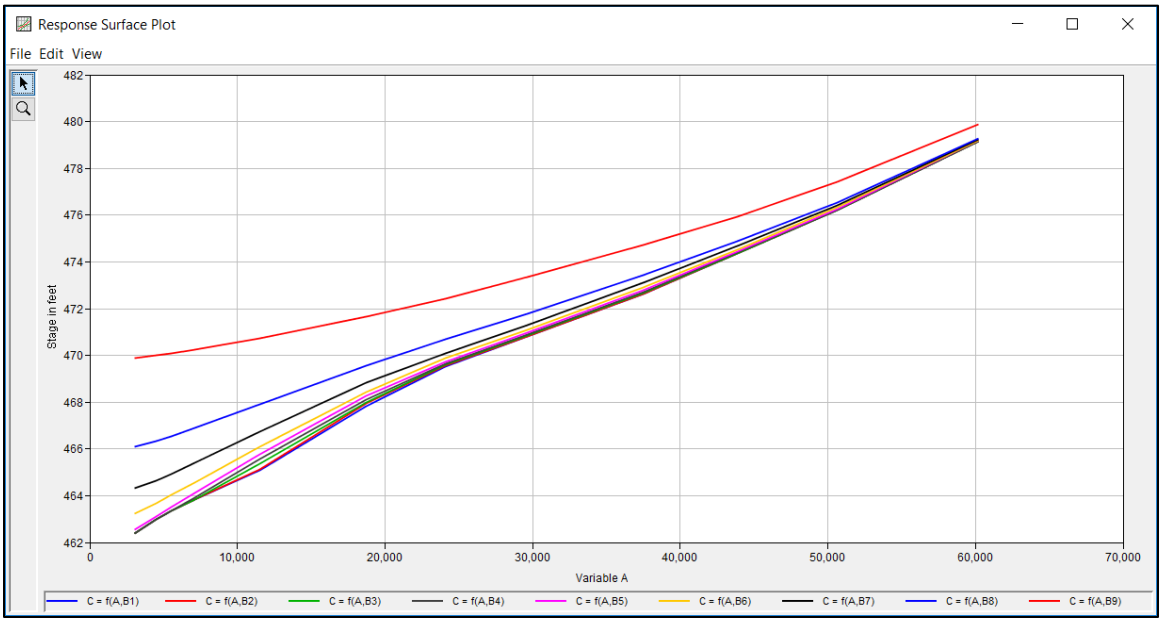


Figure B-110. Response Curves Plot for Coincident Freq Test 15.

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 B-111. 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.

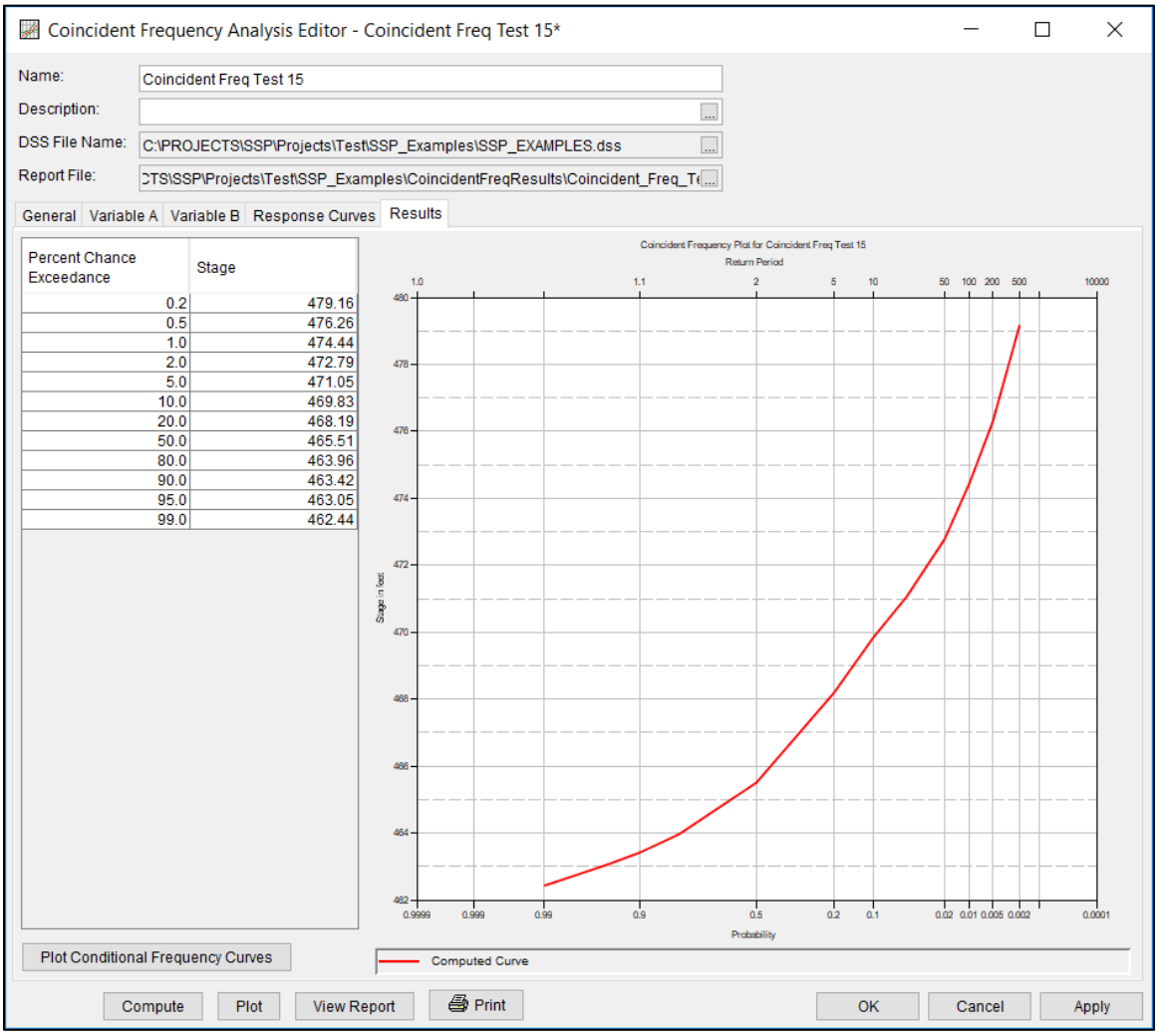


Figure B-111. Results Tab for Coincident Freq Test 15.

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 B-112.

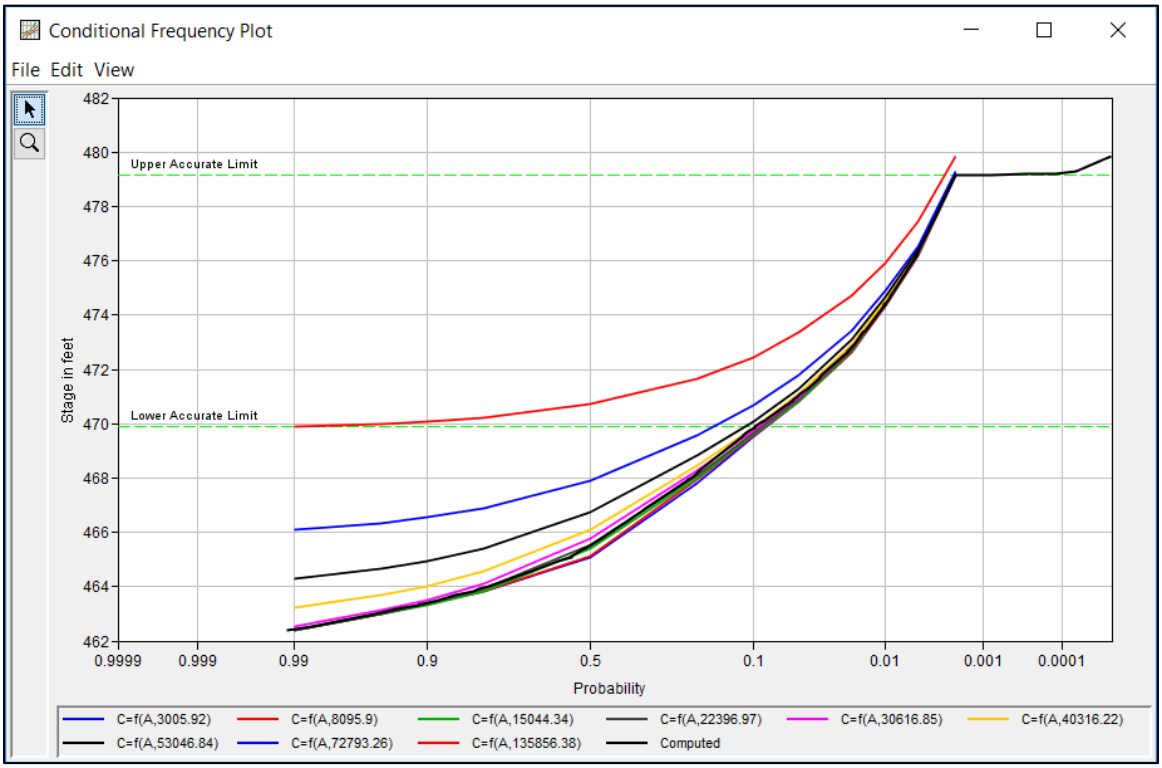
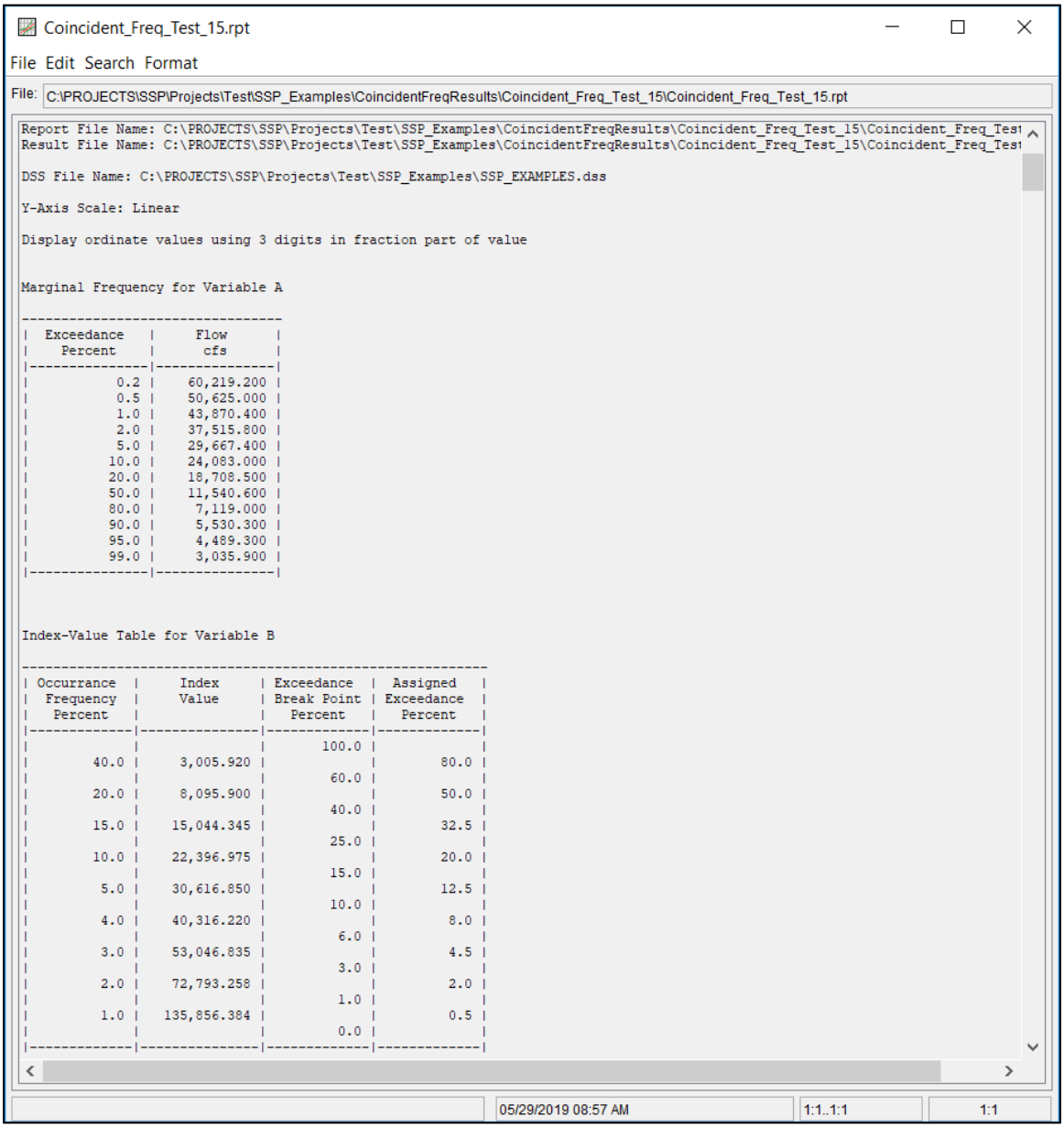


Figure B-112. Conditional Frequency Curves for Coincident Freq Test 15.

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 B-113 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

Figure B-113. Report File for Coincident Freq Test 15.

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 B-114 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.

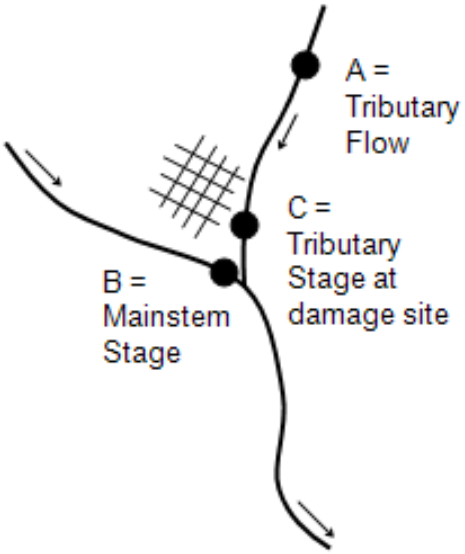


Figure B-114. Scenario for **Coincident Freq Test 16**.

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 B-115.

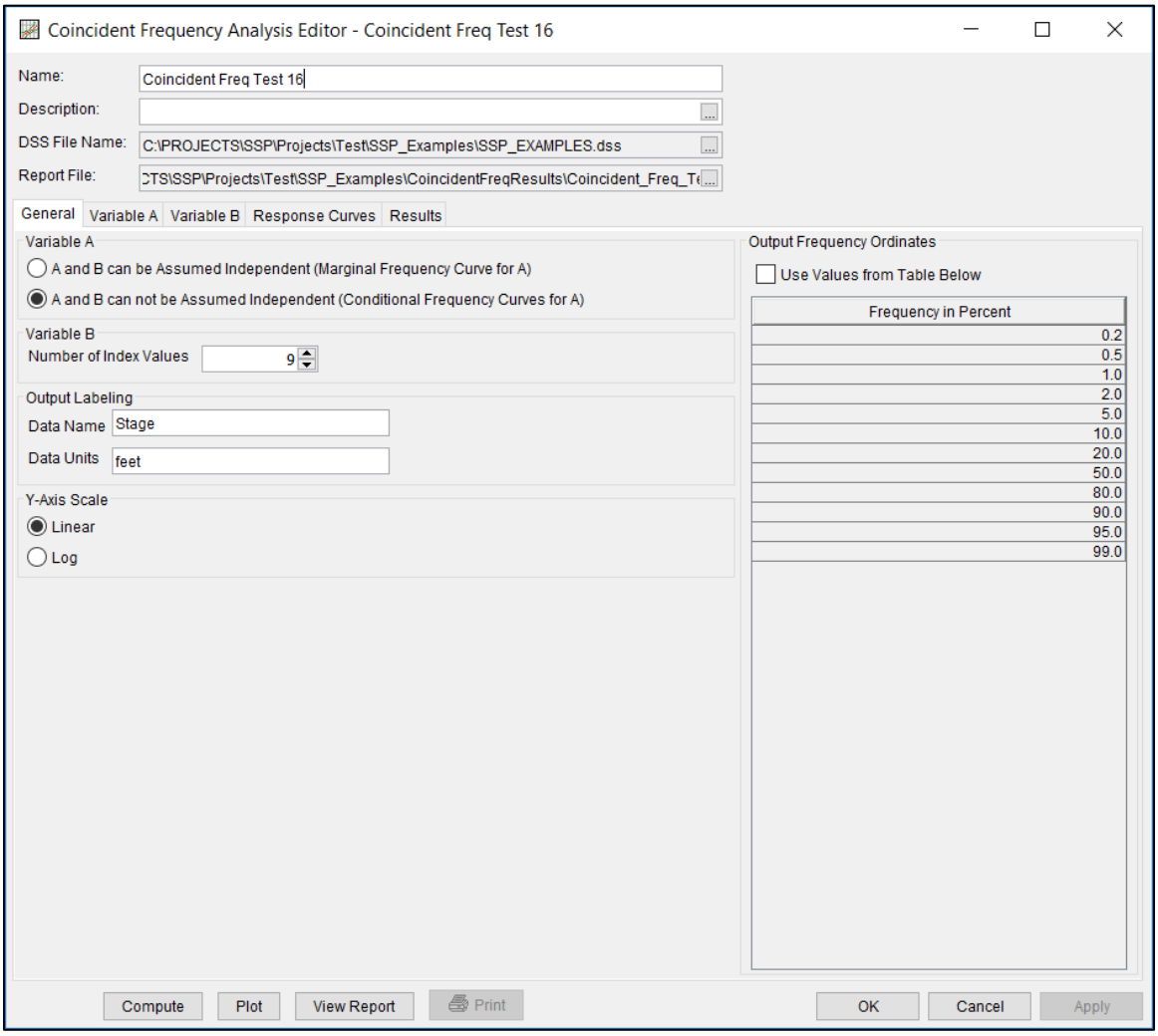
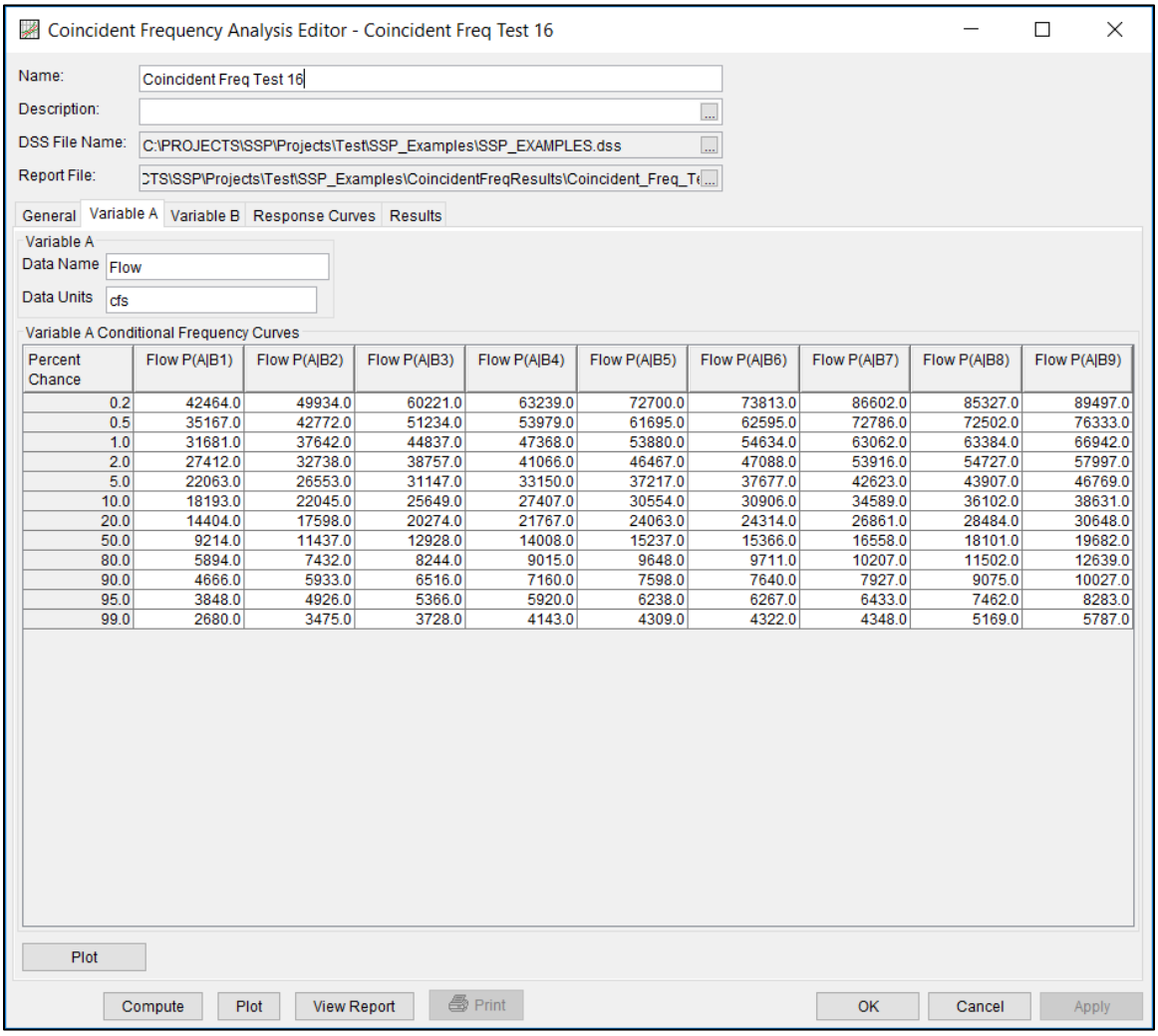


Figure B-115. General Tab Shown for Coincident Freq Test 16.

Shown in Figure B-115 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 B-116 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 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 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

Figure B-116. Variable A Tab for Coincident Freq Test 16.

Shown in Figure B-117 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.

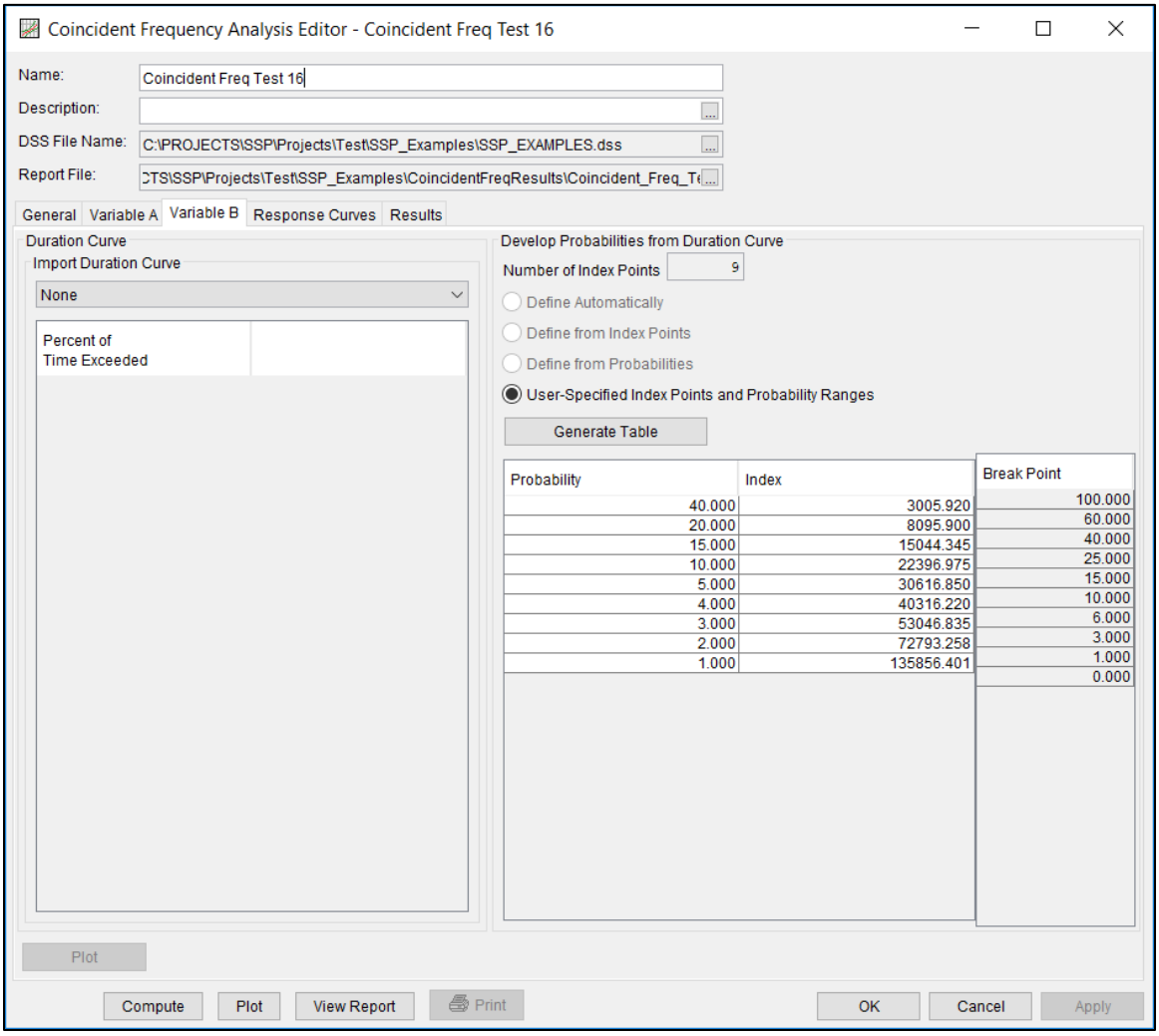
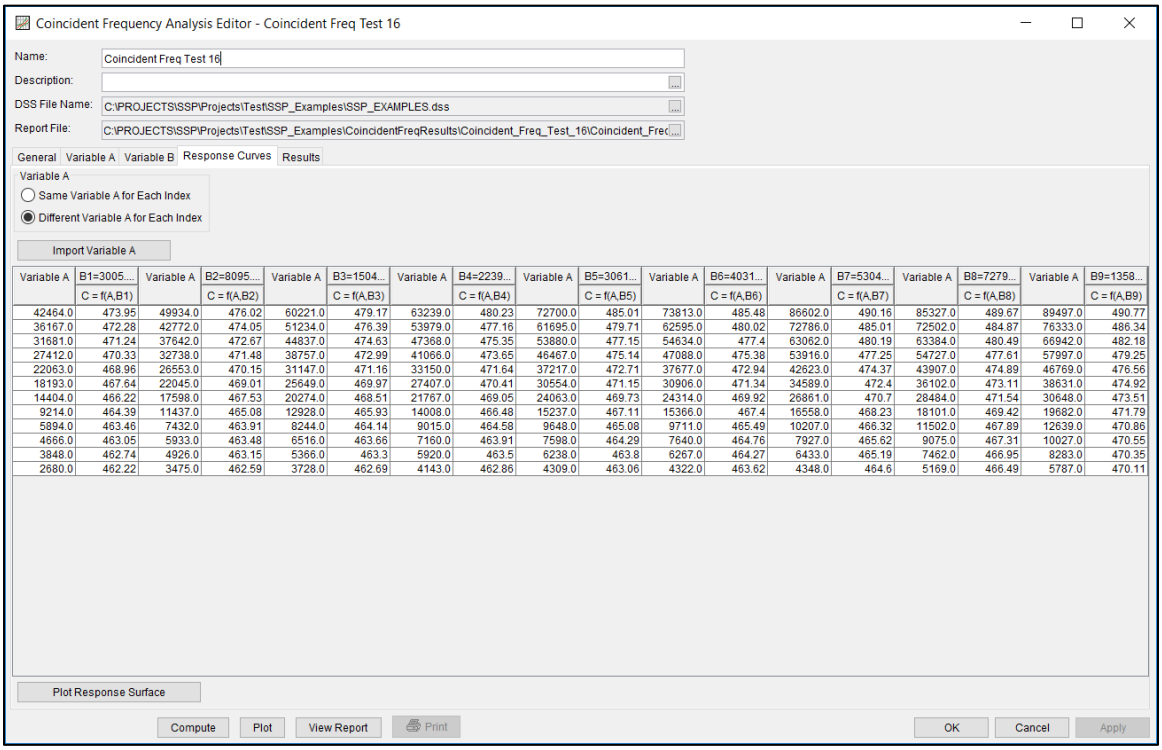


Figure B-117. Variable B Tab for Coincident Freq Test 16.

Once the Variable A and Variable B tabs have been completed, the user can populate the response curves table. Figure B-118 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....	Variable A	B2=8095....	Variable A	B3=1504...	Variable A	B4=2239...	Variable A	B5=3061...	Variable A	B6=4031...	Variable A	B7=5304...	Variable A	B8=7279...	Variable A	B9=1358...
	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)
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

Figure B-118. 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 B-119. 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.

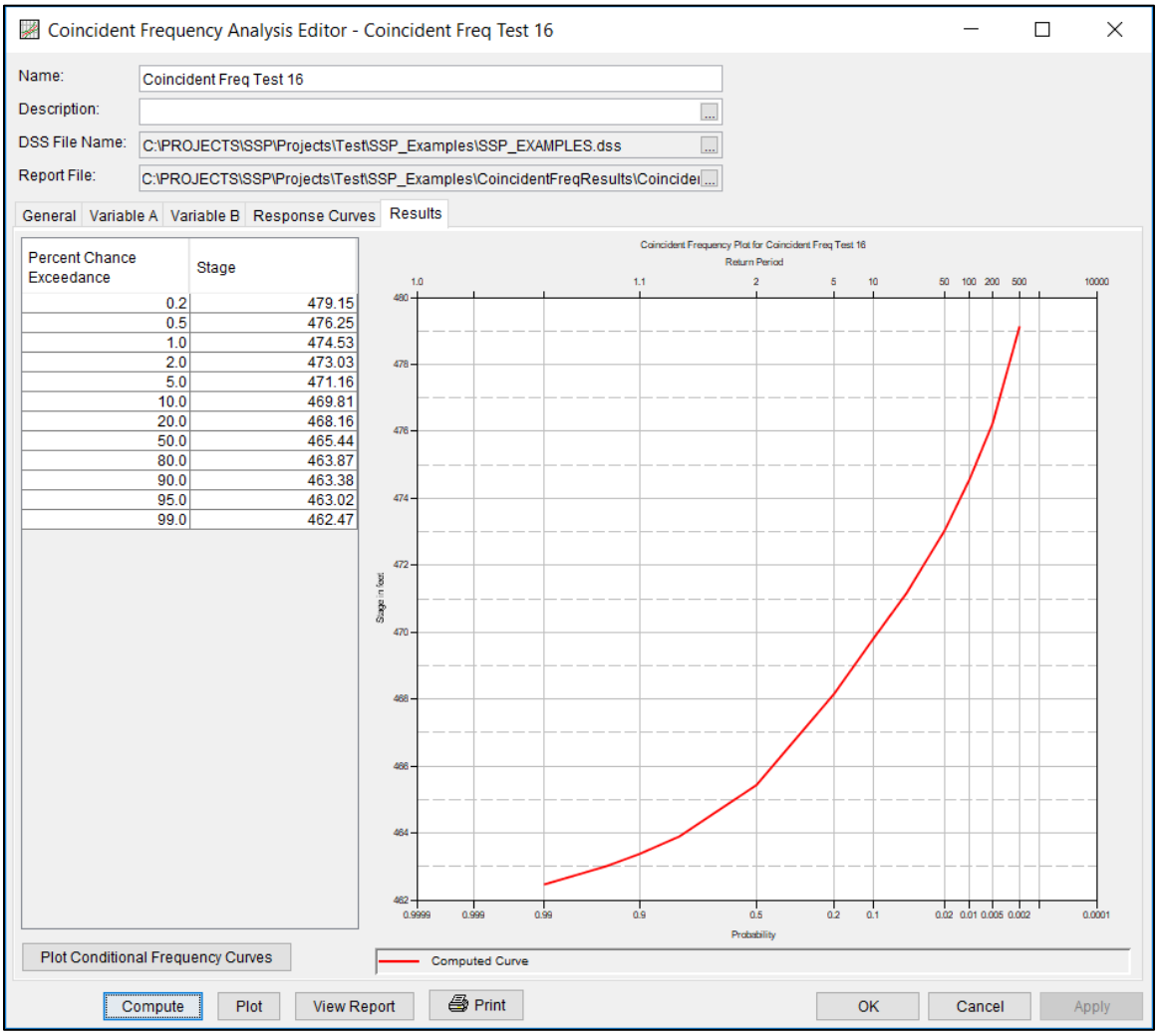


Figure B-119. Results Tab for Coincident Freq Test 16.

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 B-120.

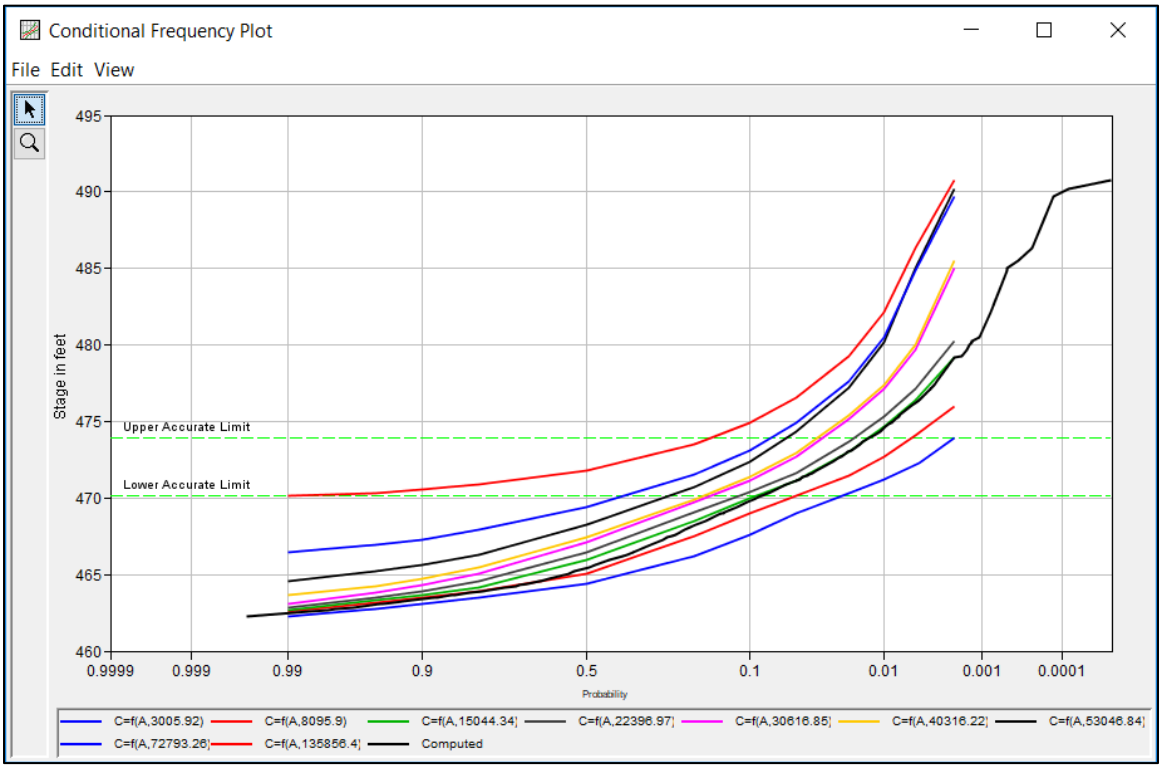


Figure B-120. Conditional Frequency Curves for Coincident Freq Test 16.

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 B-121 is the report file for **Coincident Freq Test 16**.

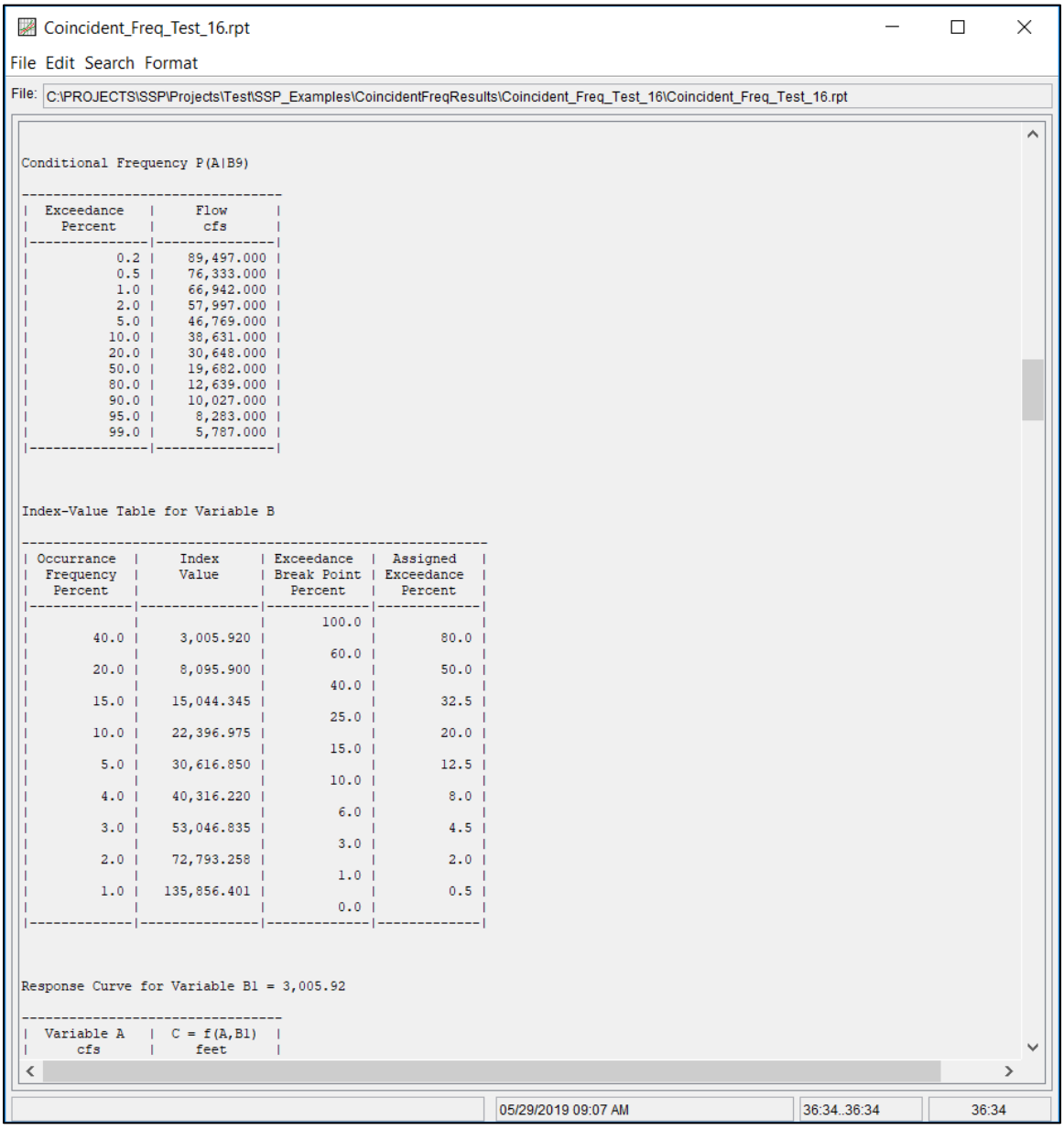


Figure B-121. Report File for Coincident Freq Test 16.

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 B-122.

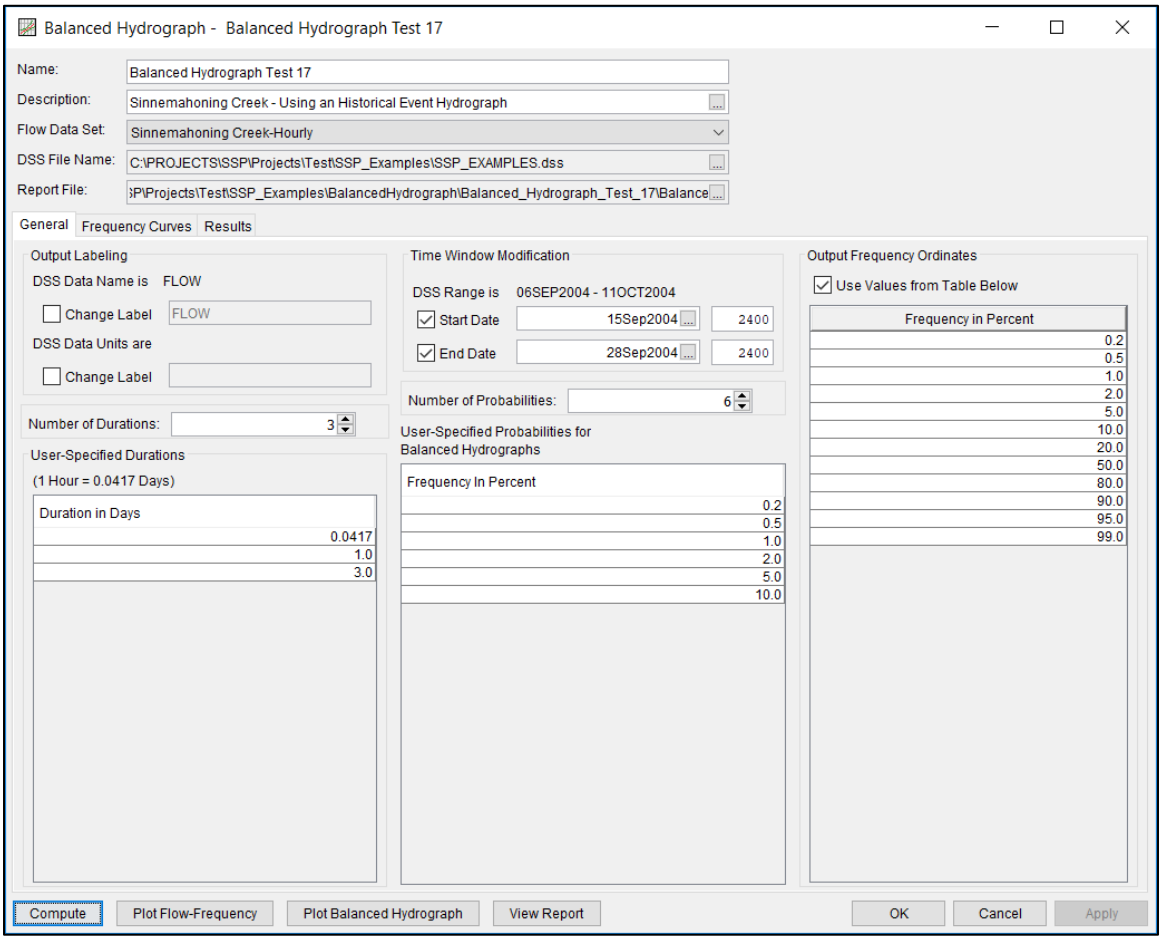


Figure B-122. General Tab Shown for Balanced Hydrograph Test 17.

Shown in Figure B-122 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 B-123.

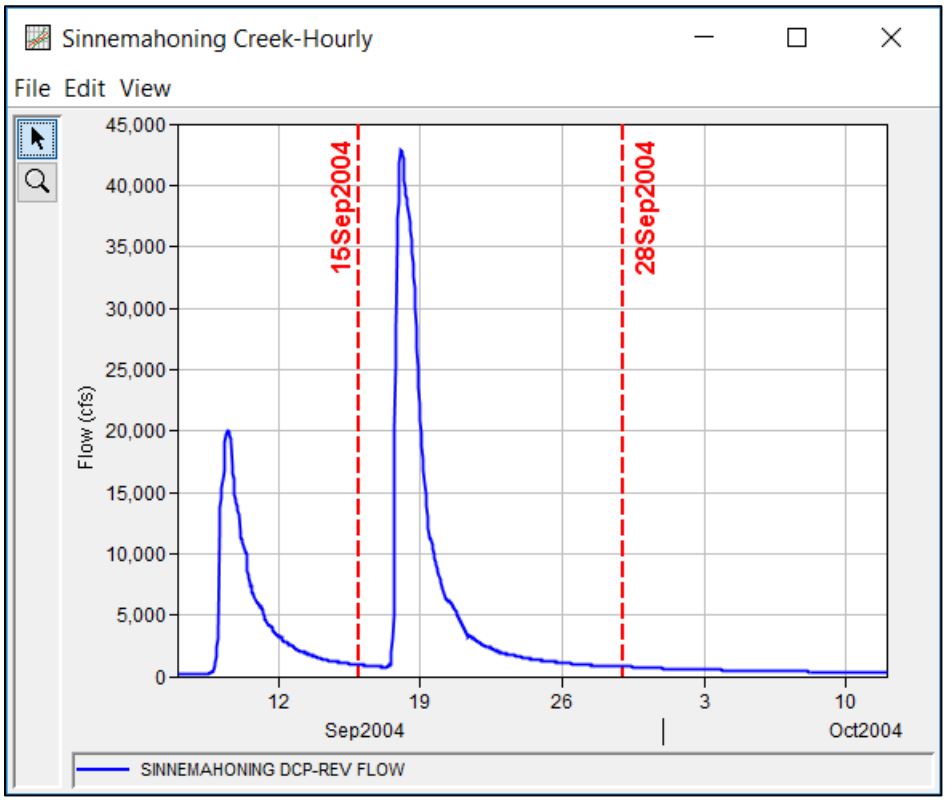


Figure B-123. Time Window Used within Balanced Hydrograph Test 17.

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 B-124 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 B-125 shows the plotted frequency curves for this analysis.

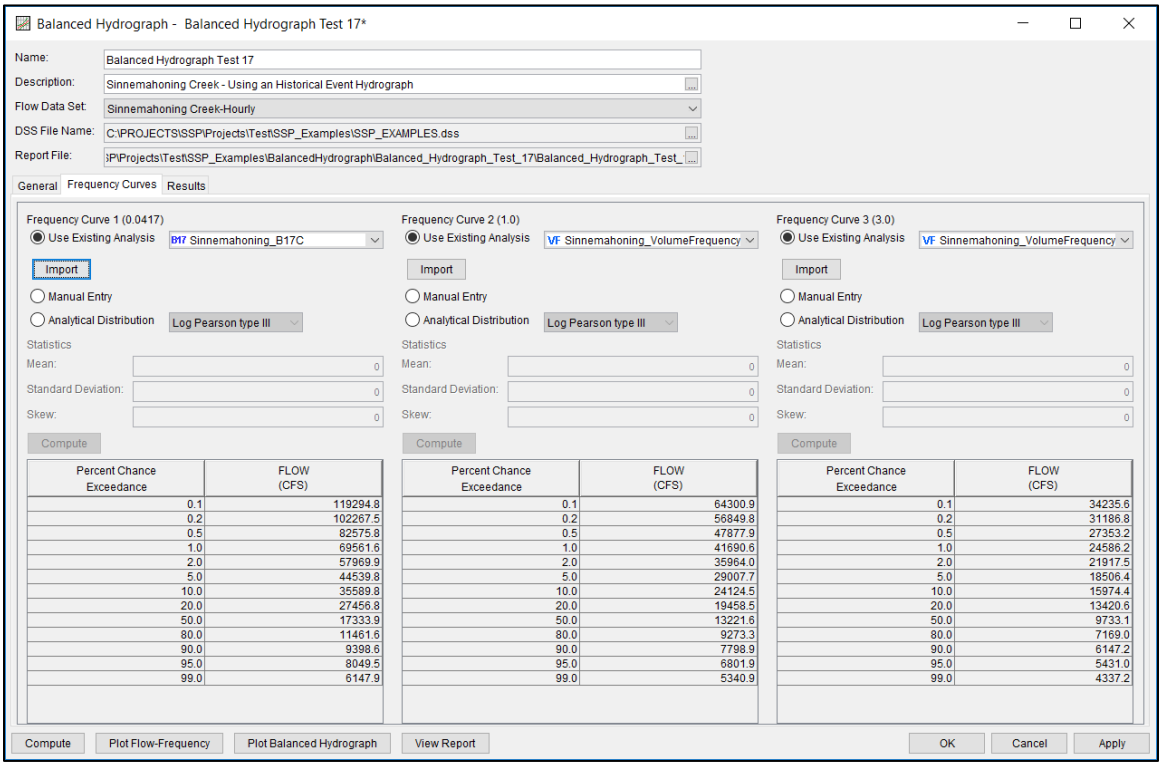


Figure B-124. Frequency Curves Tab for Balanced Hydrograph Test 17.

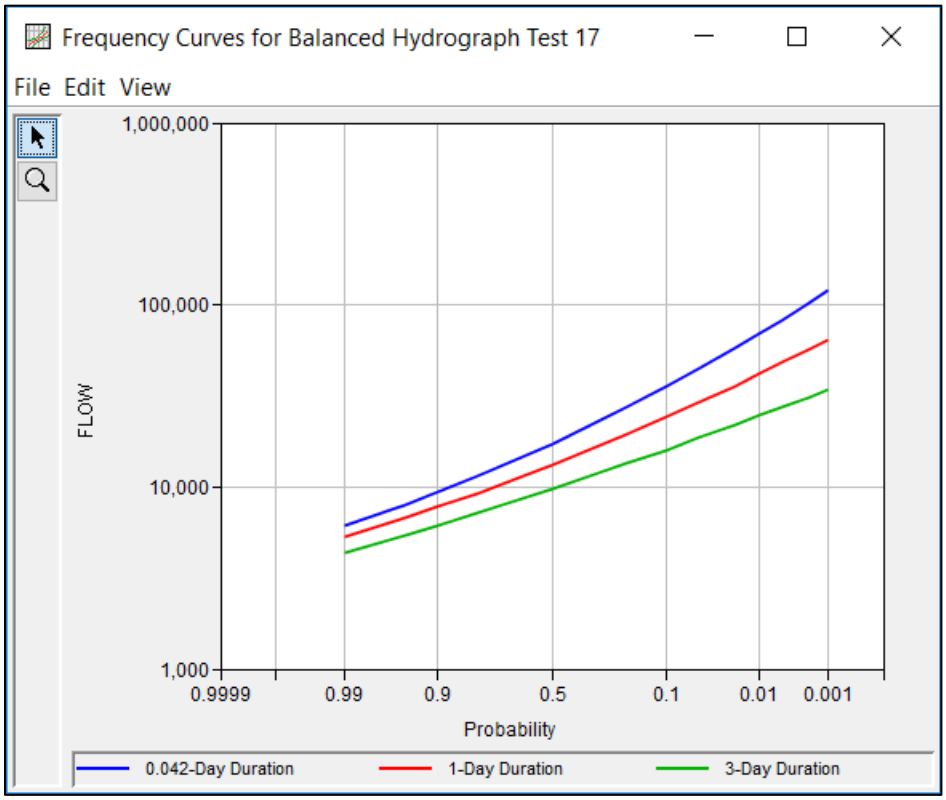


Figure B-125. Plotted Frequency Curves for Balanced Hydrograph Test 17.

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 B-126. 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.

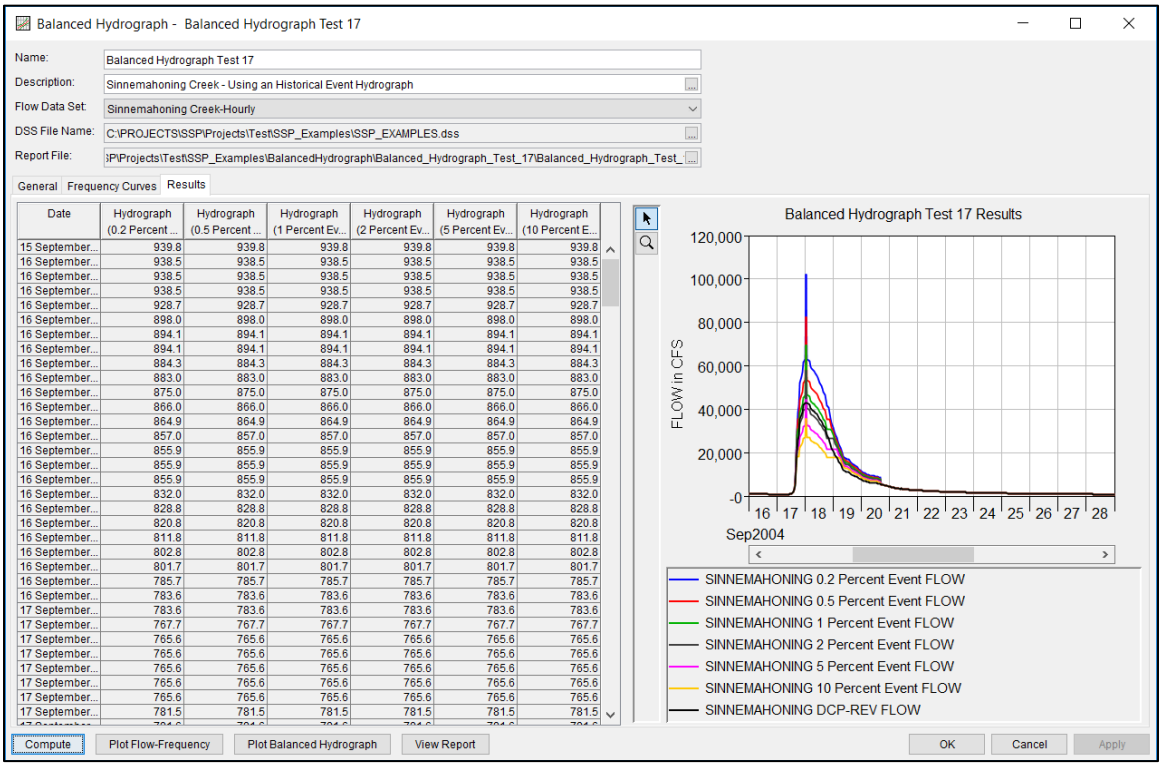


Figure B-126. Results tab for Balanced Hydrograph Test 17.

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 B-127 is the report file for **Balanced Hydrograph Test 17**.

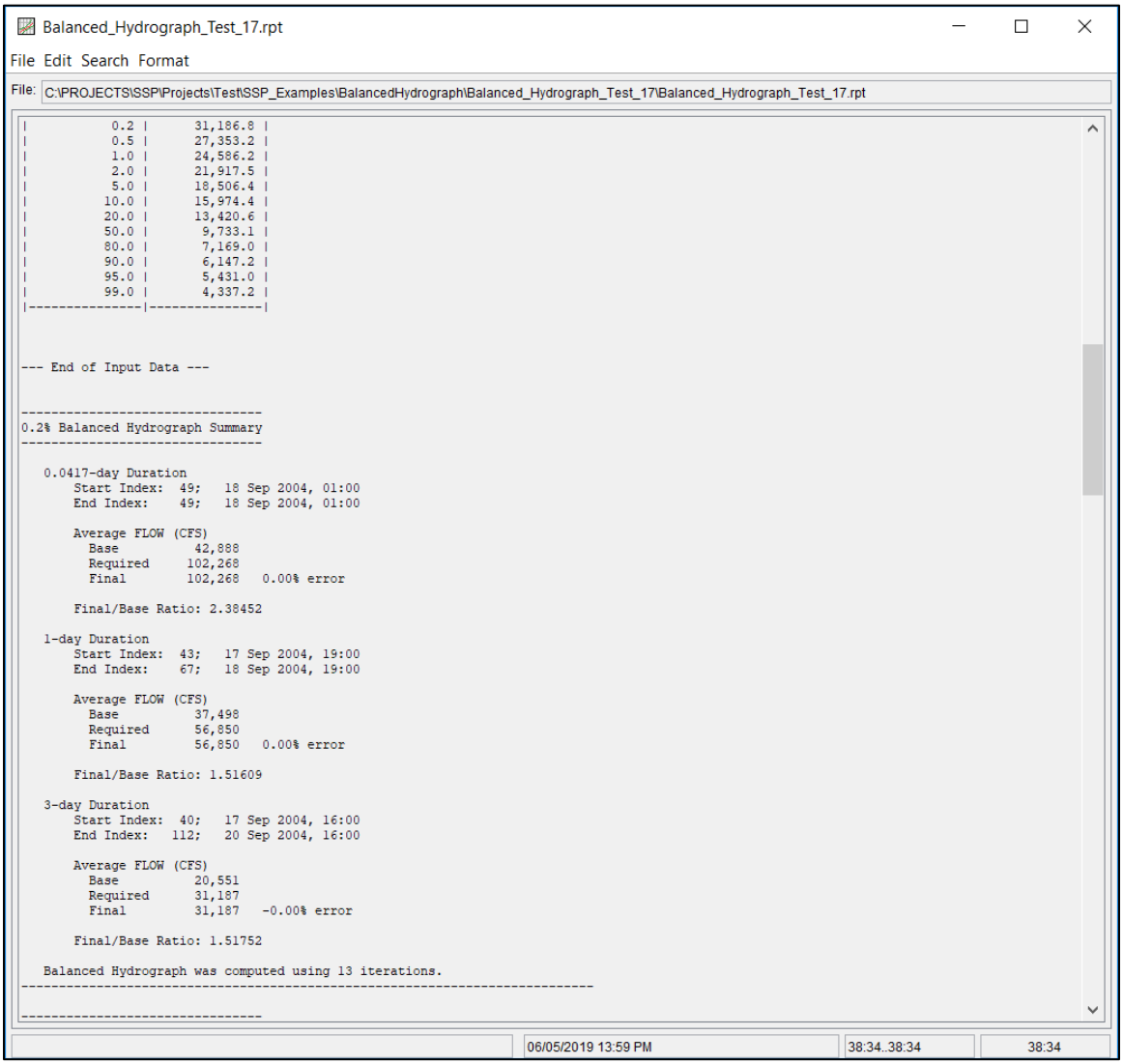


Figure B-127. Report File for Balanced Hydrograph Test 17.

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 B-128.

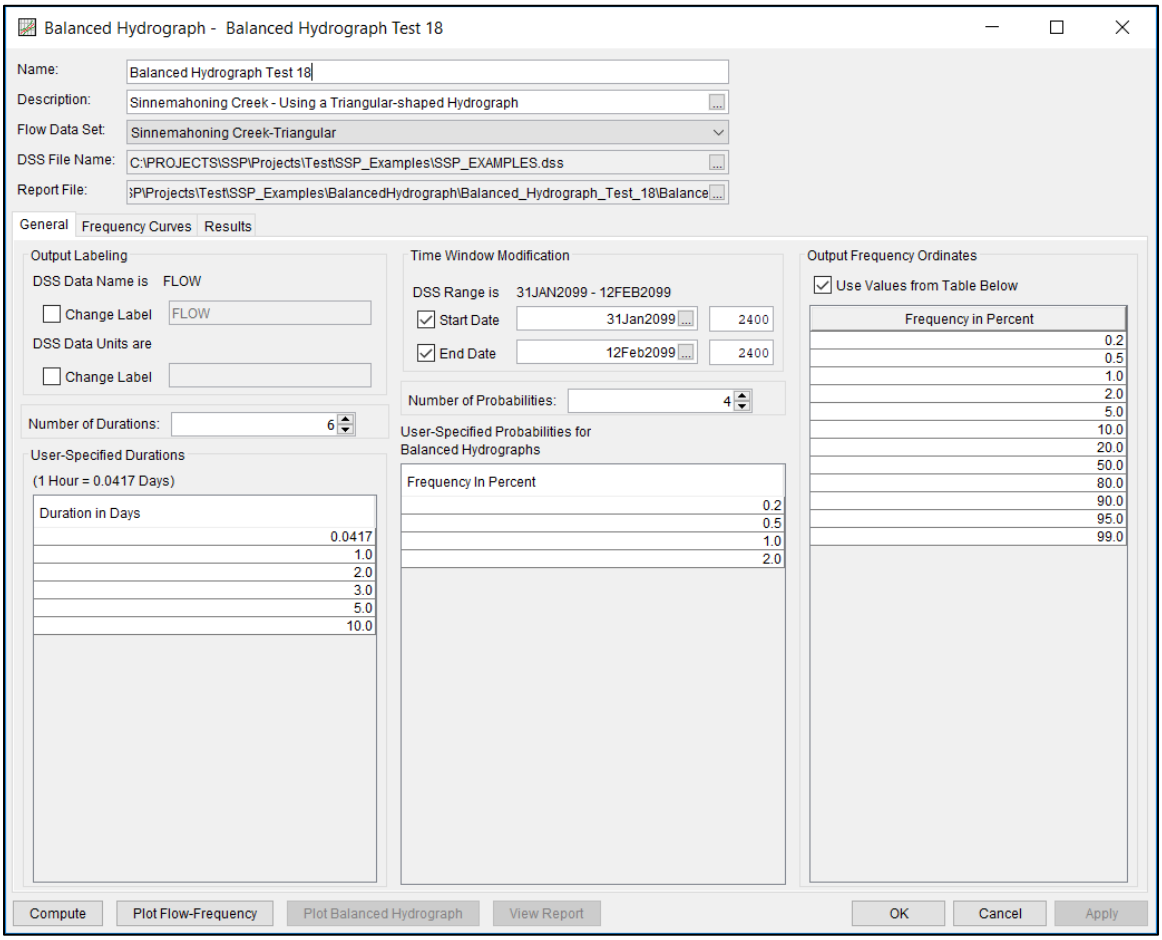


Figure B-128. General Tab Shown for Balanced Hydrograph Test 18.

Shown in Figure B-128 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 B-129.

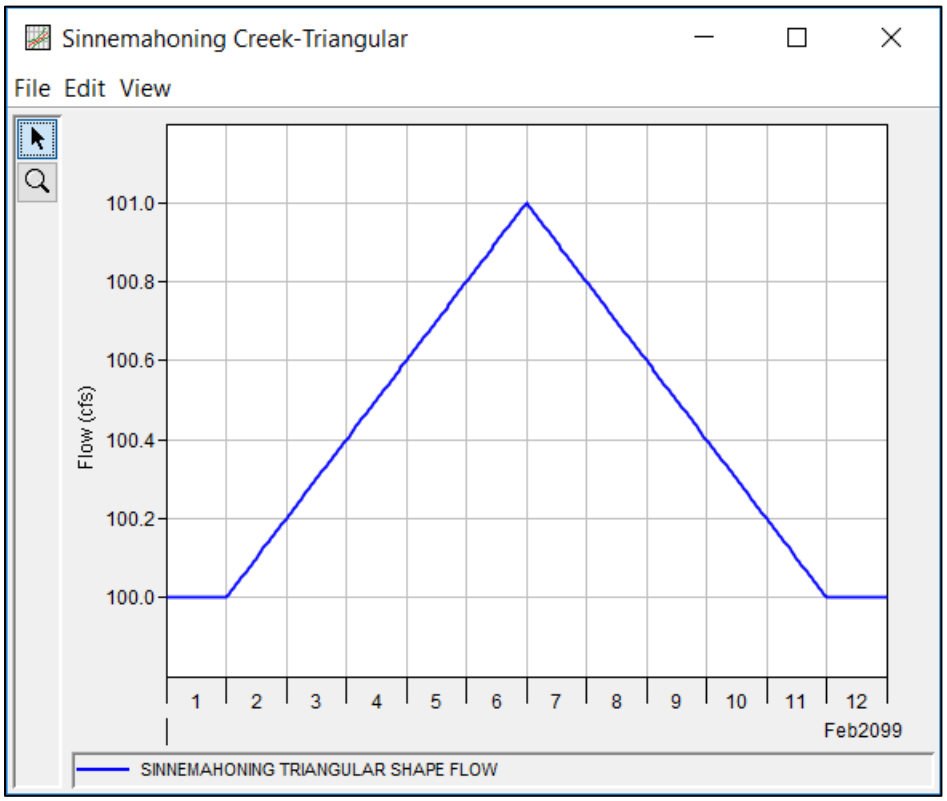


Figure B-129. Hypothetical Triangular Hydrograph Used within Balanced Hydrograph Test 18.

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 B-130 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 B-131 shows the plotted frequency curves for this analysis.

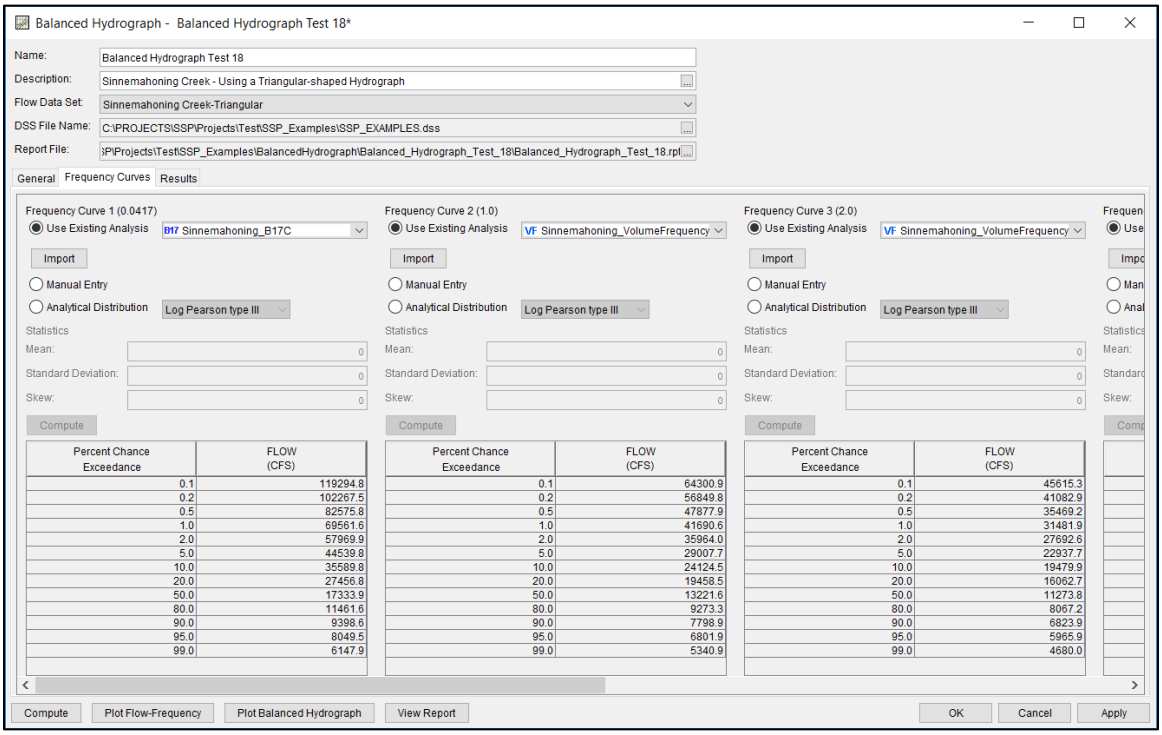


Figure B-130. Frequency Curves Tab for Balanced Hydrograph Test 18.

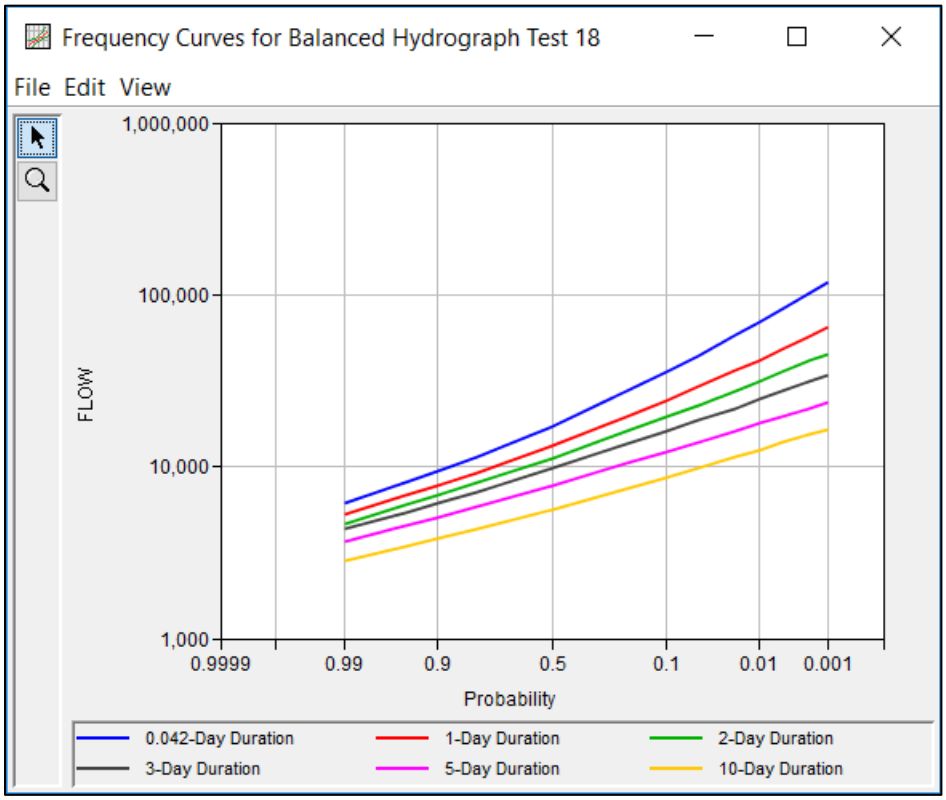


Figure B-131. Plotted Frequency Curves for Balanced Hydrograph Test 18.

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 B-132. 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.

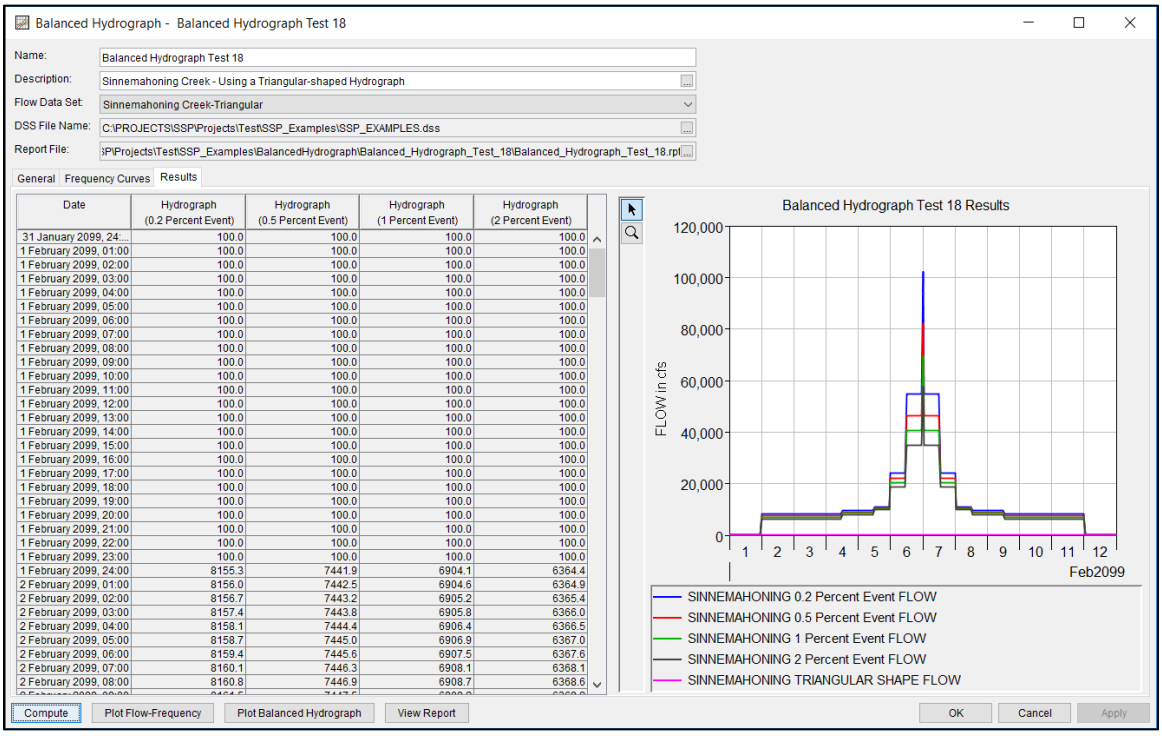


Figure B-132. Results tab for Balanced Hydrograph Test 18.

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 B-133 is the report file for **Balanced Hydrograph Test 18**.

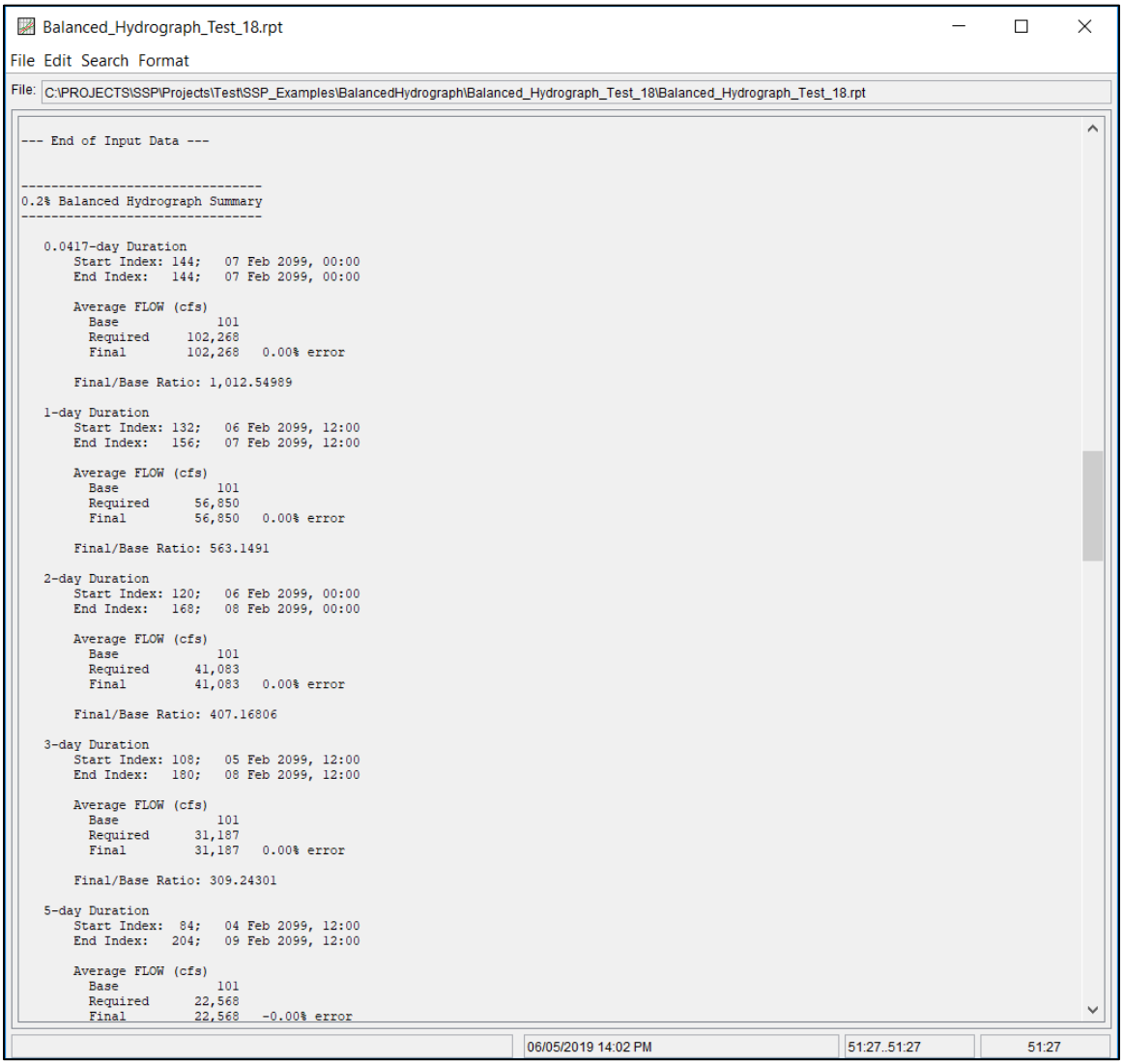


Figure B-133. Report File for Balanced Hydrograph Test 18.

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 17 is opened, the Curve Combination Analysis editor will appear as shown in Figure B-134.

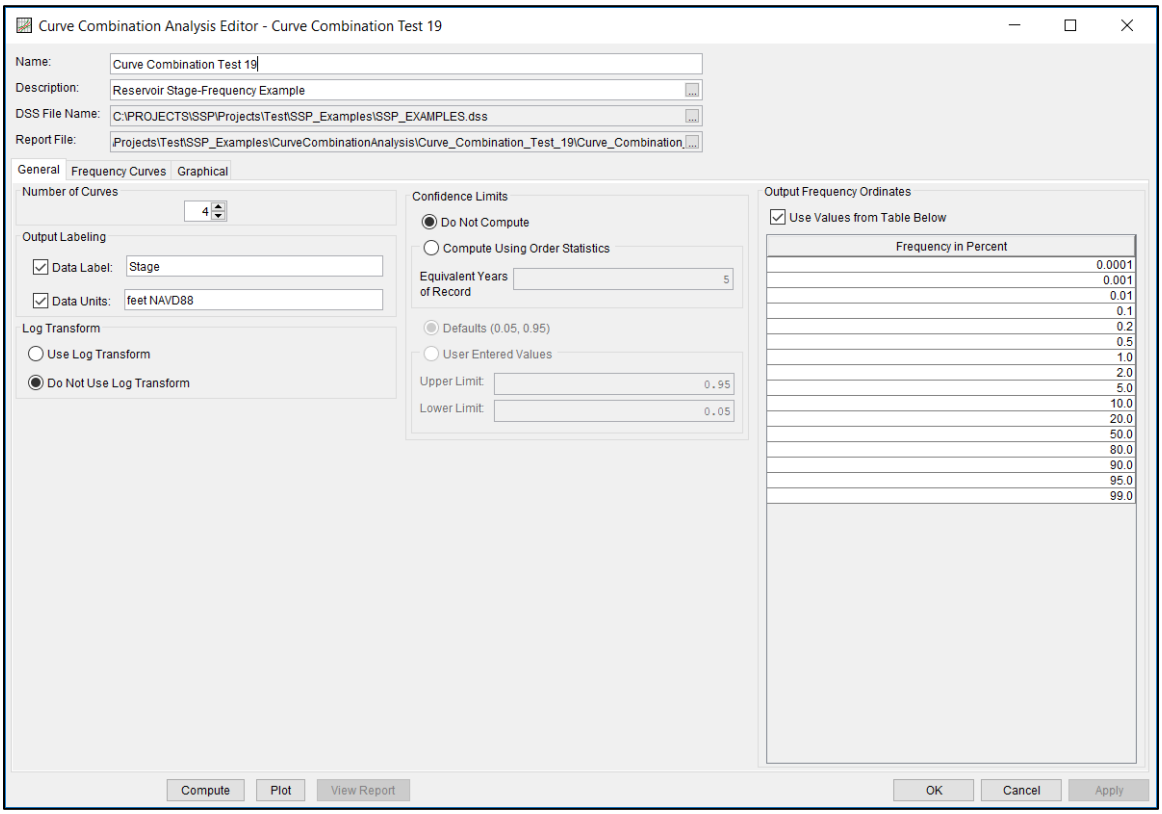


Figure B-134. General Tab Shown for Curve Combination Test 19.

Shown in Figure B-134 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 B-136 shows the plotted frequency curves for this analysis.

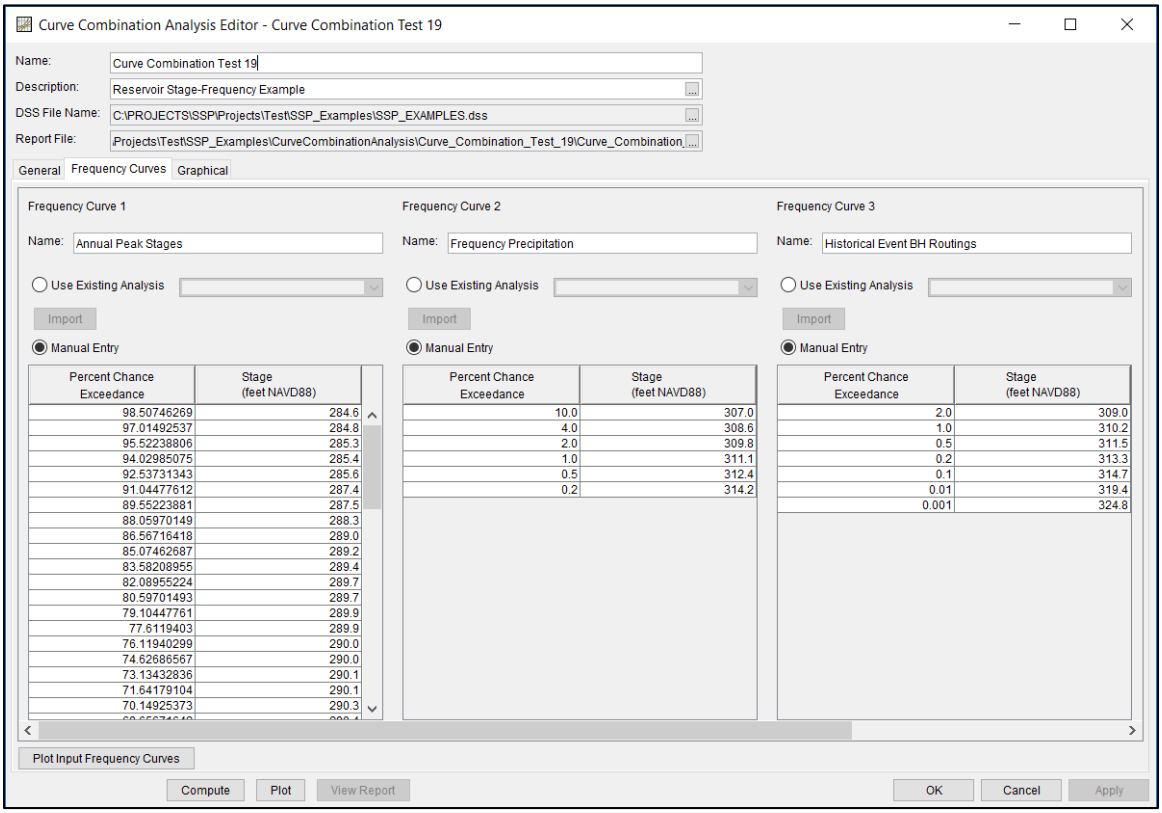


Figure B-135. Frequency Curves Tab for Curve Combination Test 19.

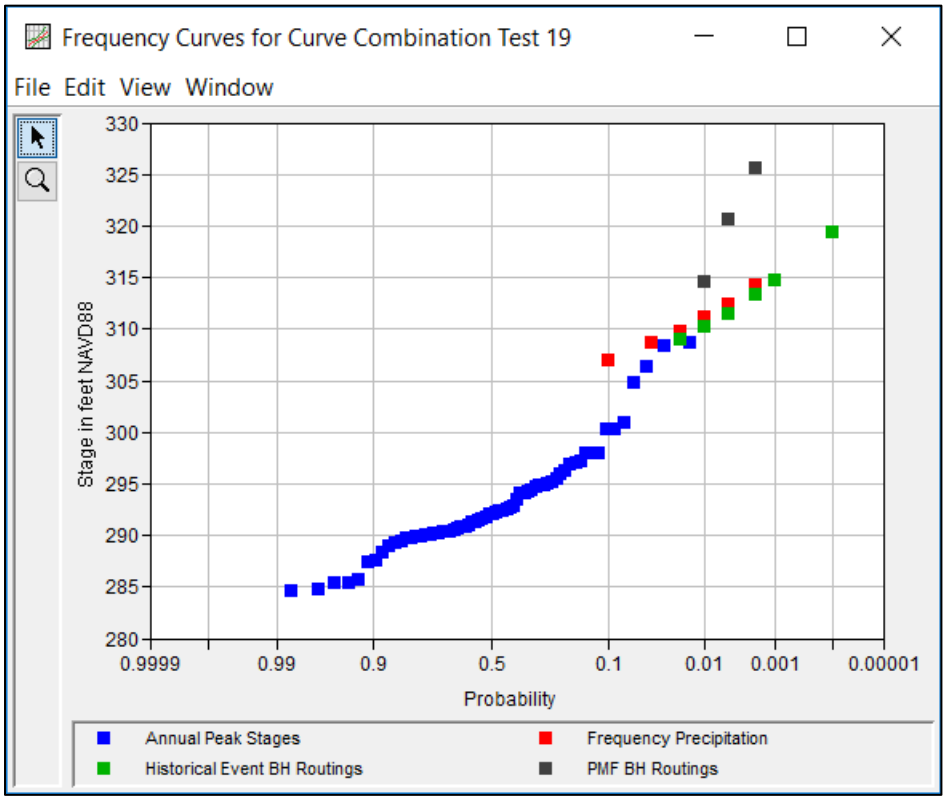


Figure B-136. Plotted Frequency Curves for Curve Combination Test 19.

Once all of the options and frequency curve inputs are set or selected, the user can graphically fit an empirical distribution. Shown in Figure B-137 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.

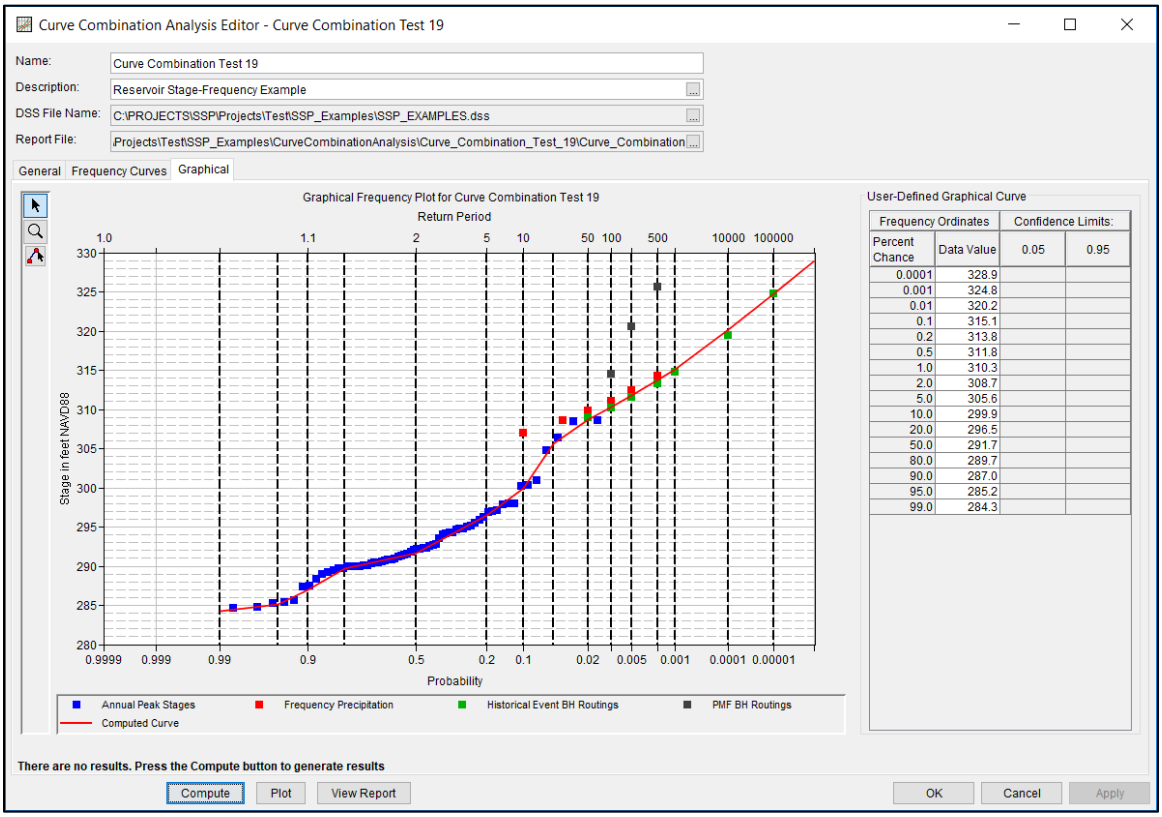


Figure B-137. Graphical tab for Curve Combination Test 19.

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 B-138 is the report file for **Curve Combination Test 19**.

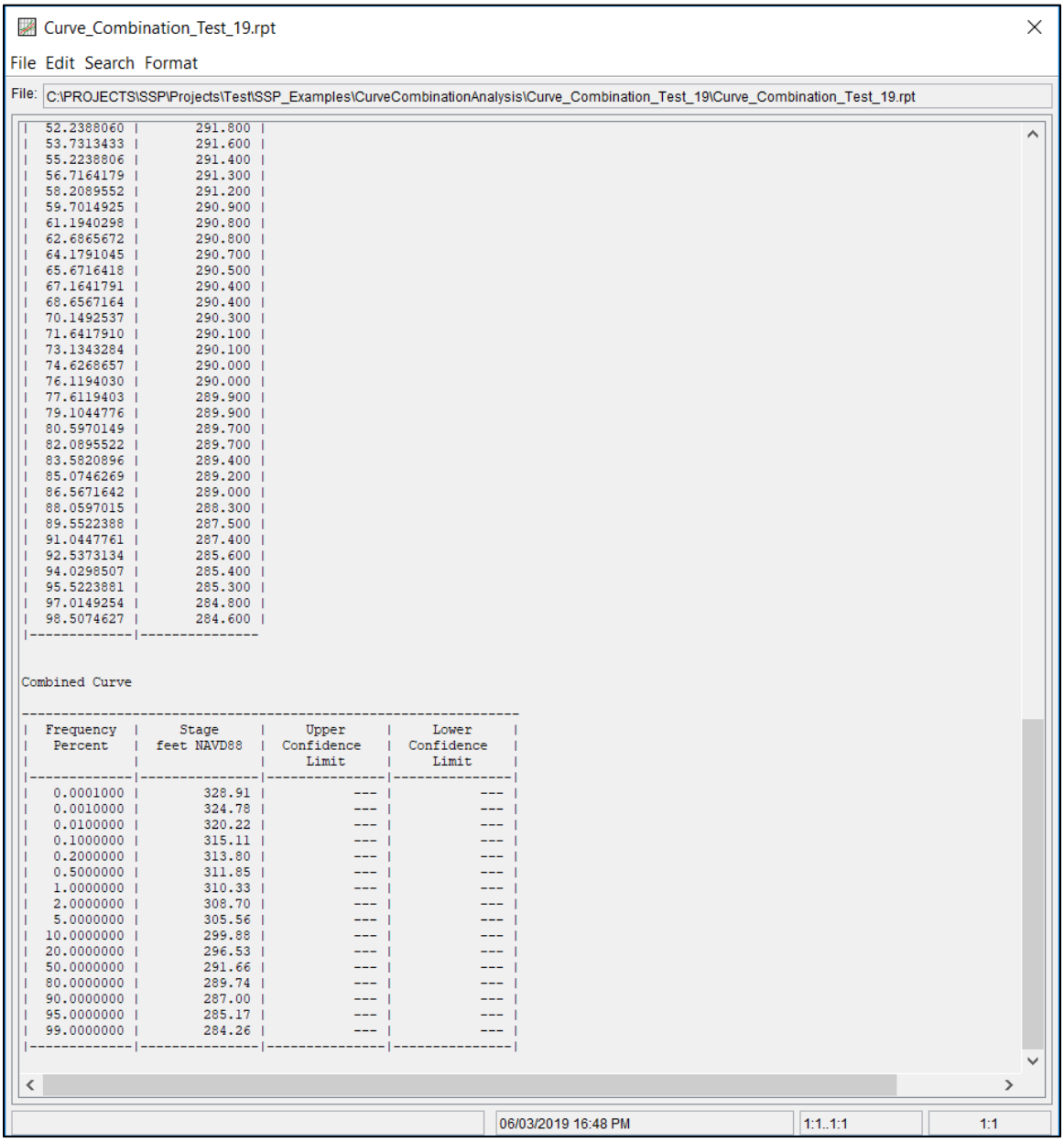


Figure B-138. Report File for Curve Combination Test 19.

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. 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 B-139.

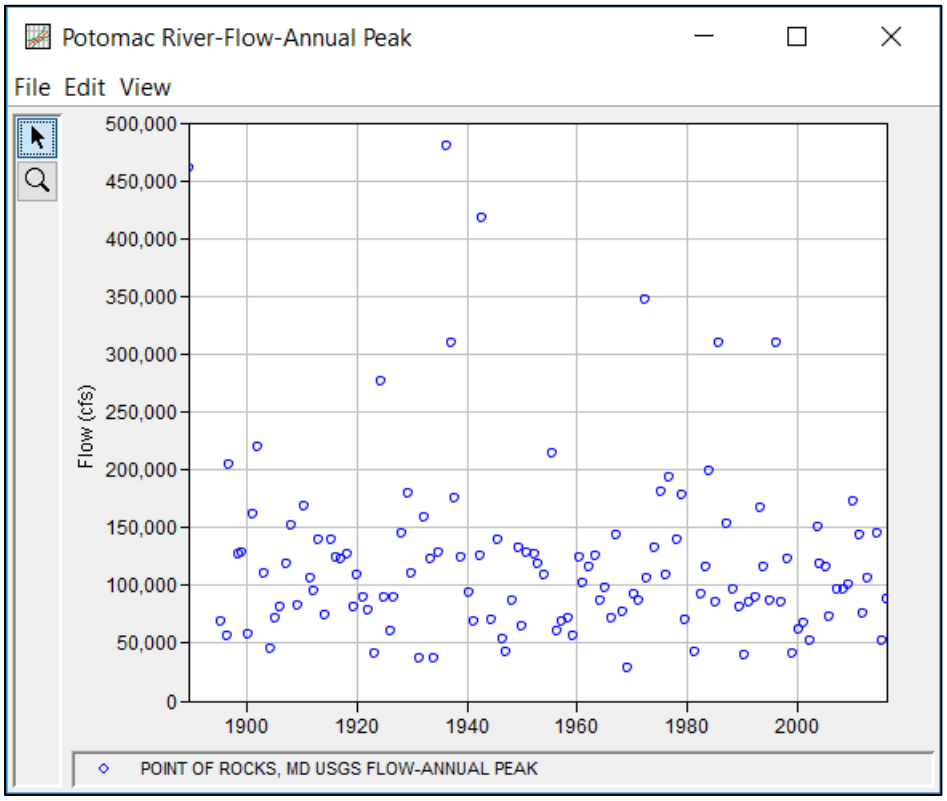


Figure B-139. Plot of the Peak Flow Data for Point of Rocks.

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 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 B-140.

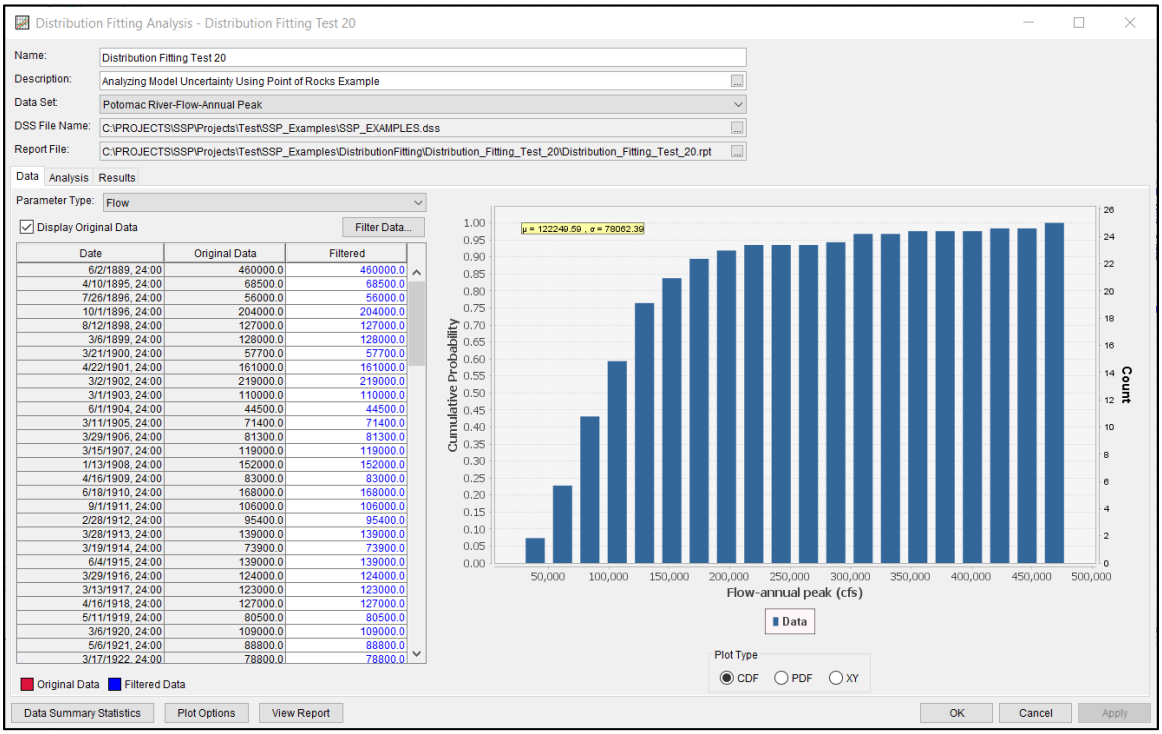
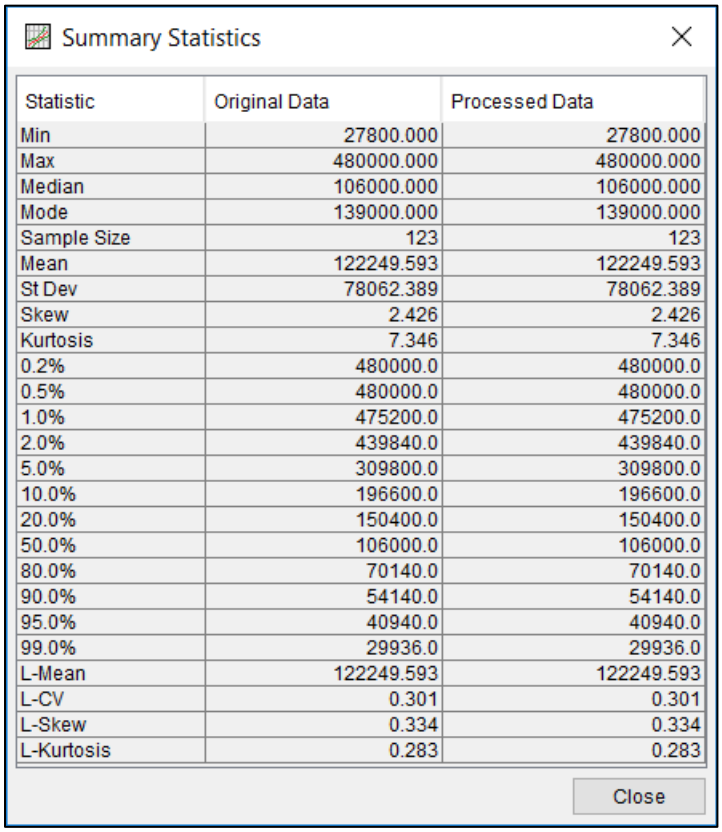


Figure B-140. Distribution Fitting Analysis Editor for Distribution Fitting Test 20.

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 B-141.



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

Figure B-141. 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 B-142, 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 changed to L-Moments by clicking on the column header and selecting **L-Moments**. The Chi-Square goodness of fit test was selected by clicking on the column header and selecting **Chi-Square**. 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 B-143. 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 B-144, Figure B-145, Figure B-146, Figure B-147, and Figure B-148.

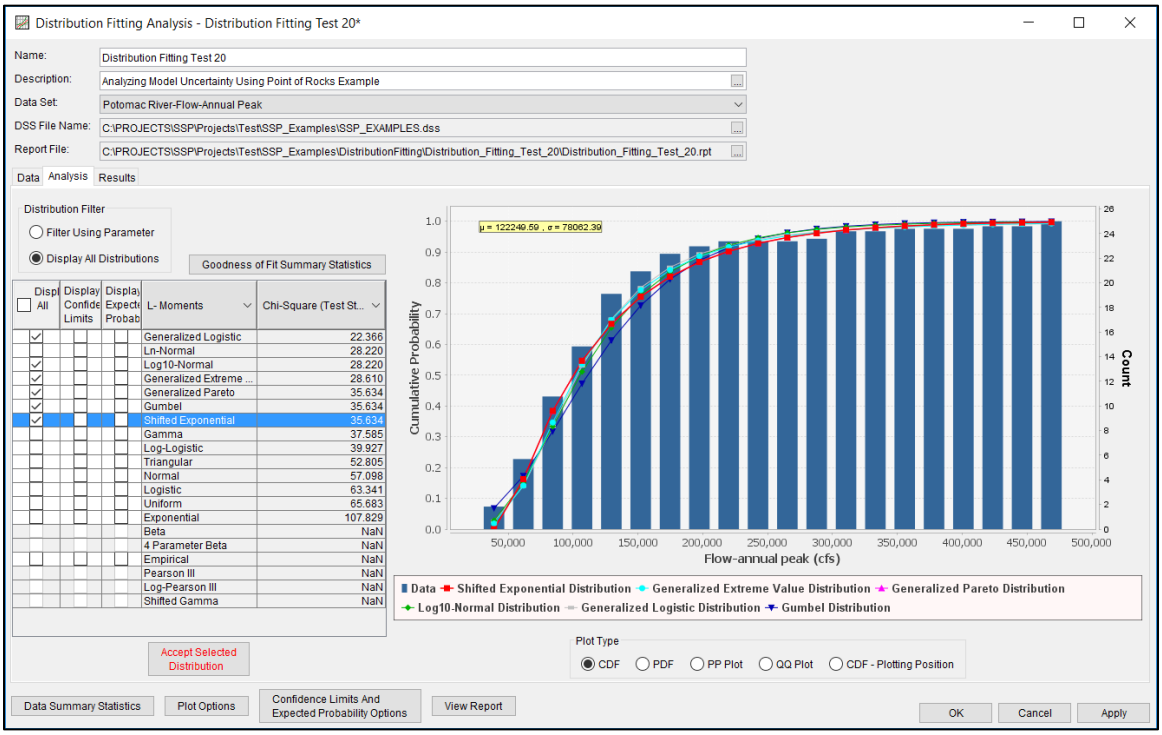


Figure B-142. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 20.

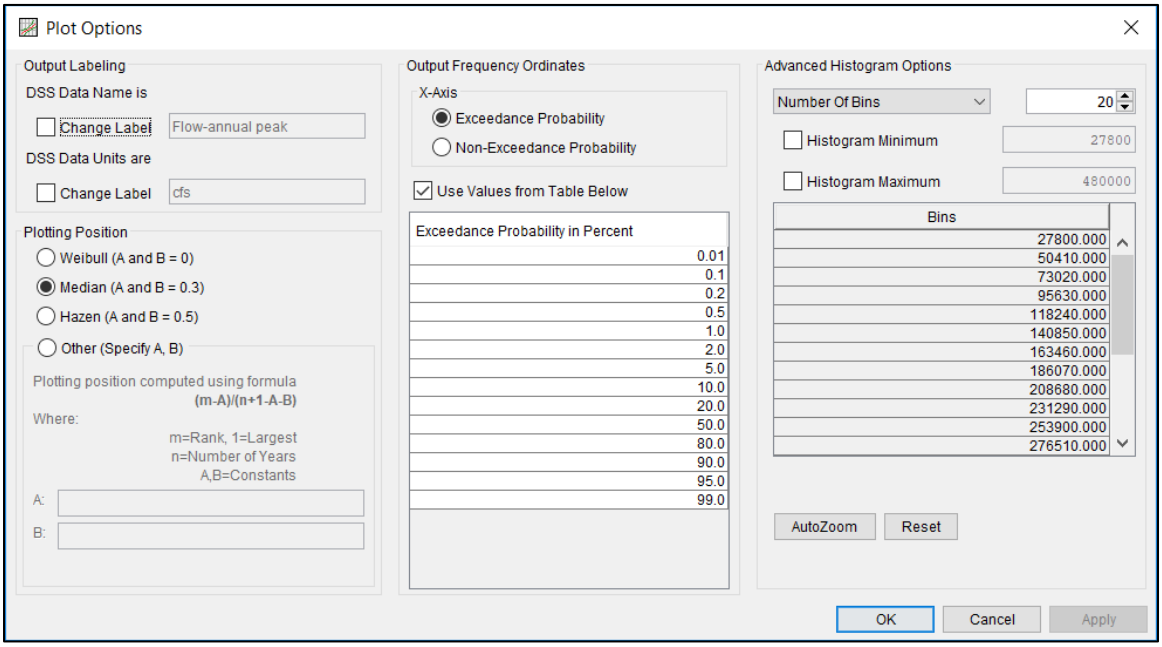


Figure B-143. Plot Options for Distribution Fitting Test 20.

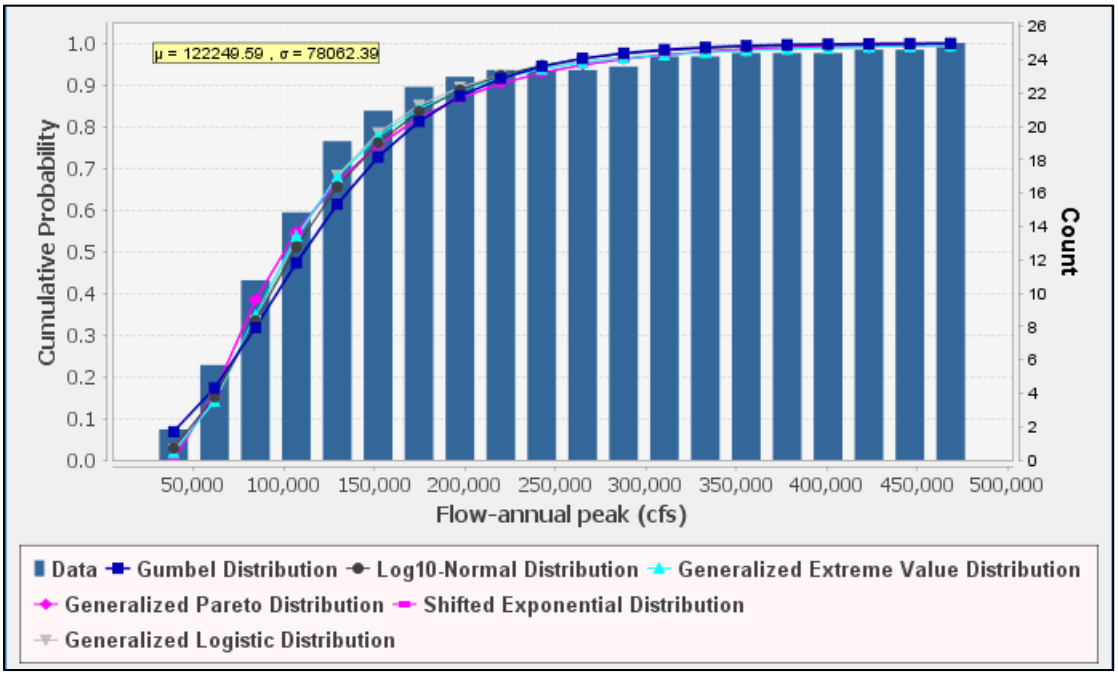


Figure B-144. CDF Plot for Distribution Fitting Test 20.

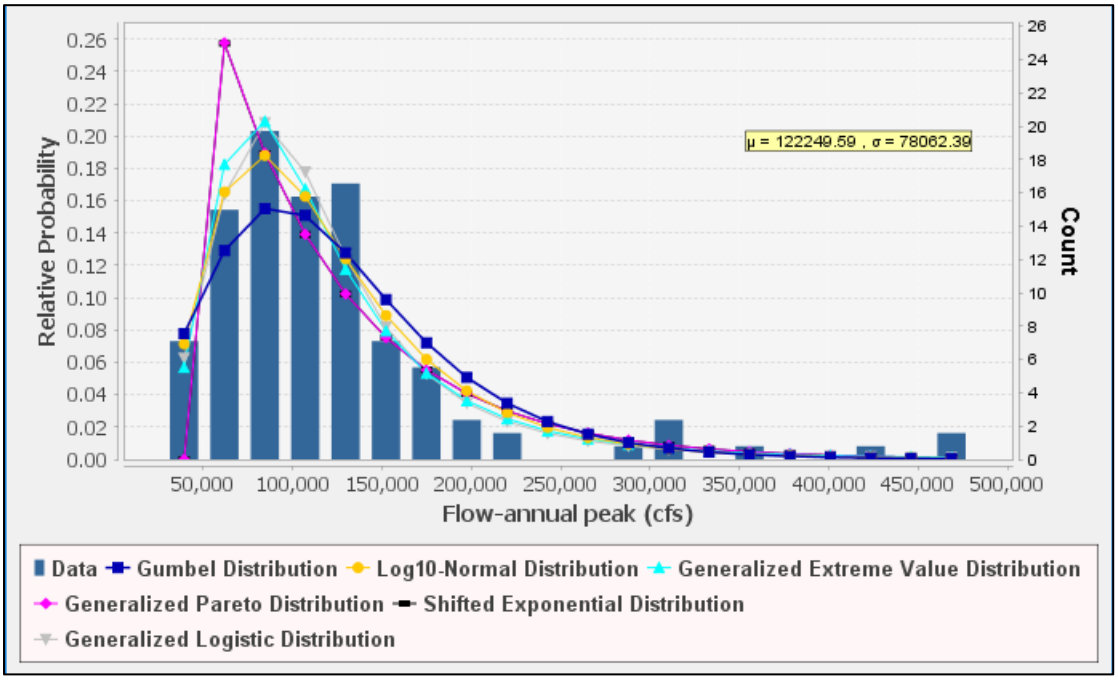


Figure B-145. PDF Plot for Distribution Fitting Test 20.

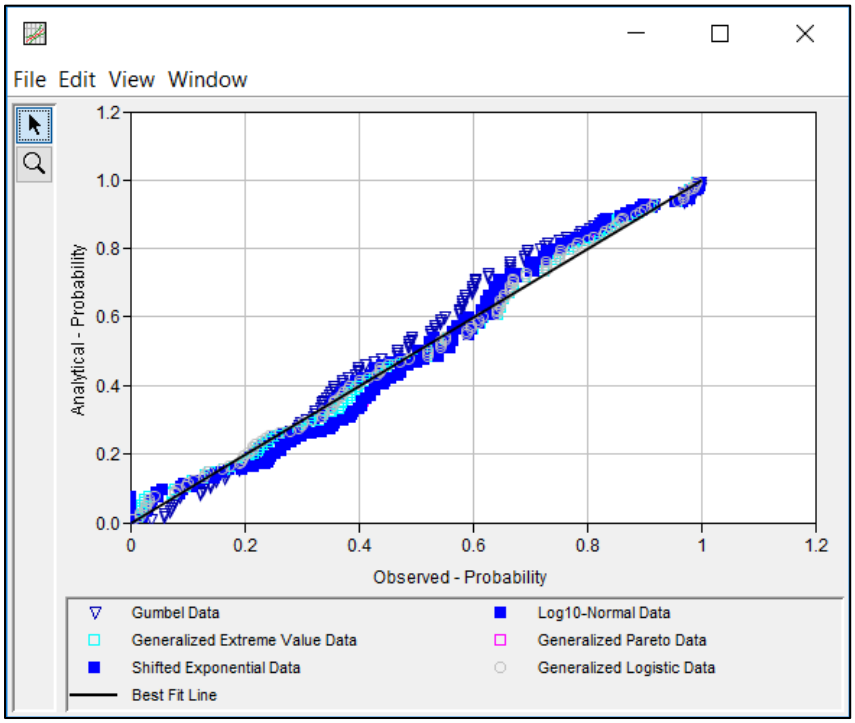


Figure B-146. PP Plot for Distribution Fitting Test 20.

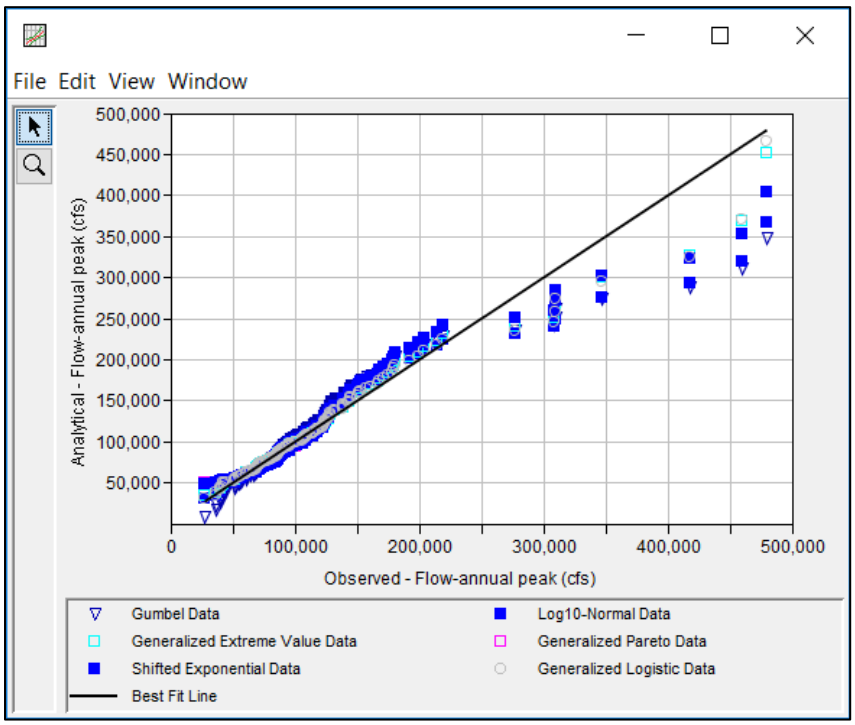


Figure B-147. QQ Plot for Distribution Fitting Test 20.

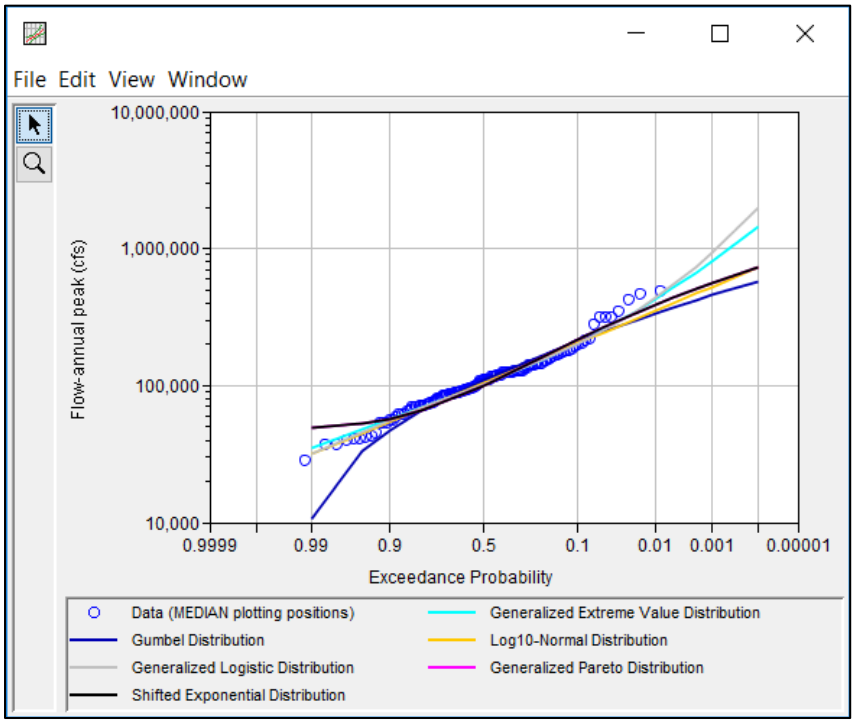
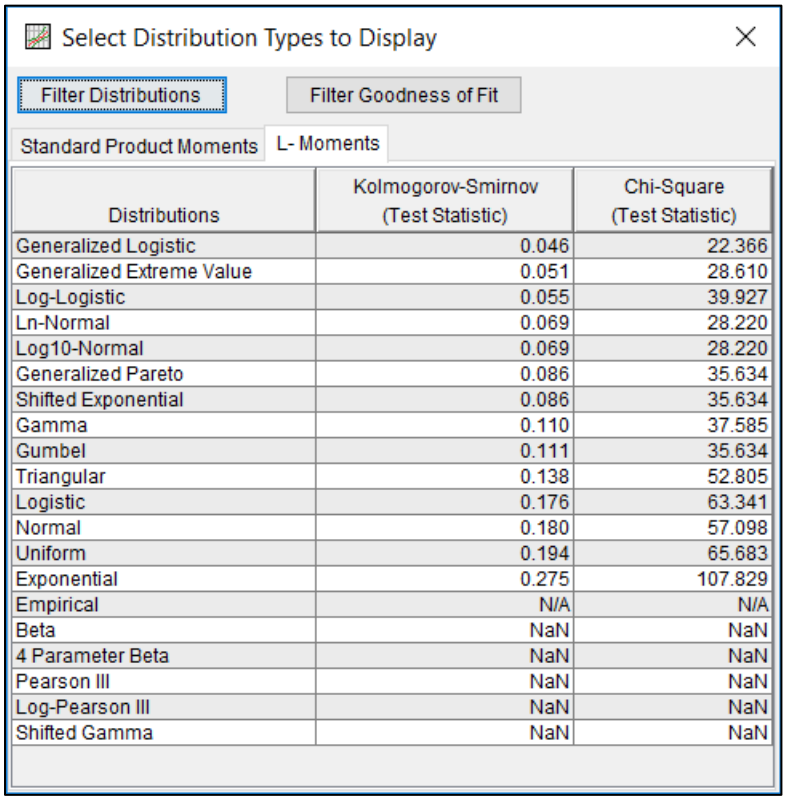


Figure B-148. CDF-Plotting Position Plot for Distribution Fitting Test 20.

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 B-149.



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

Figure B-149. Goodness of Fit Summary Statistics for Distribution Fitting Test 20.

In this example, the Generalized Logistic Distribution fit using L-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, 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 **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 1,000,000, as shown in Figure B-150. Upon clicking the **OK** button, 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 B-151.

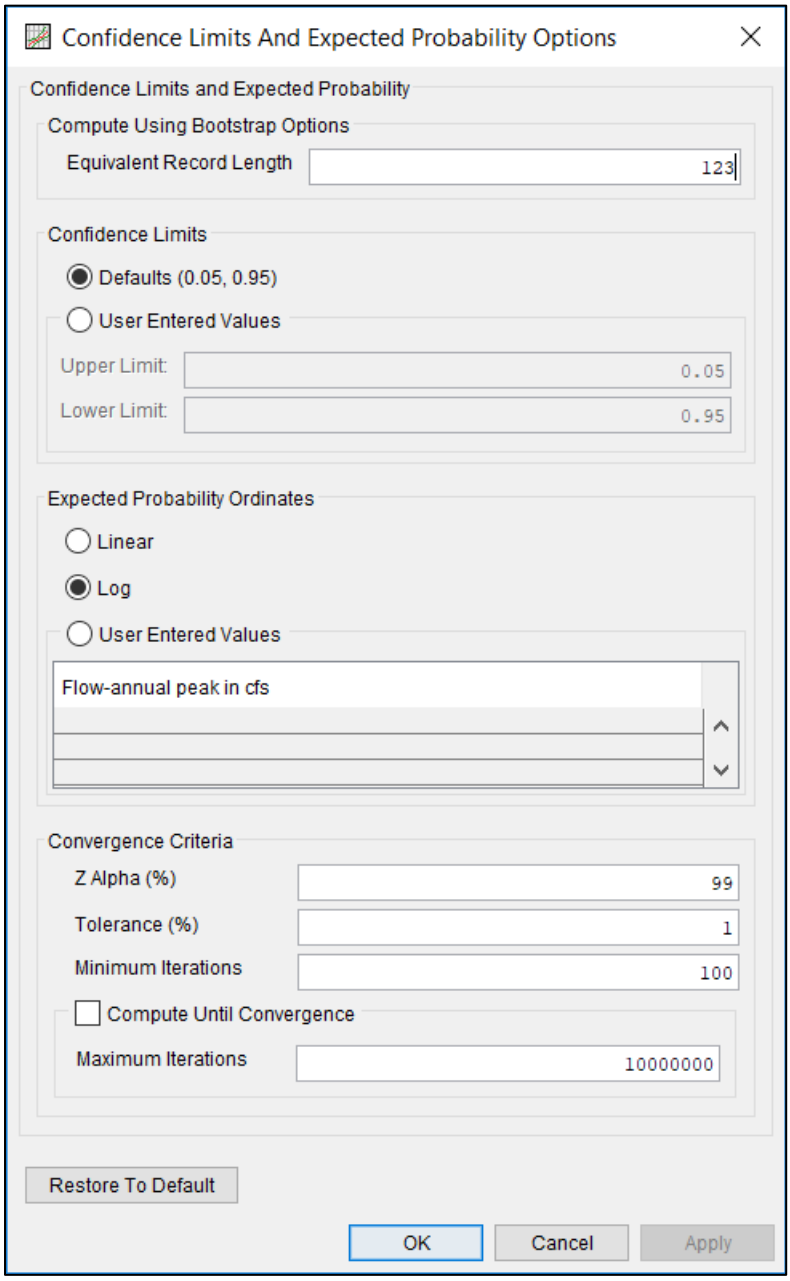


Figure B-150. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 20.

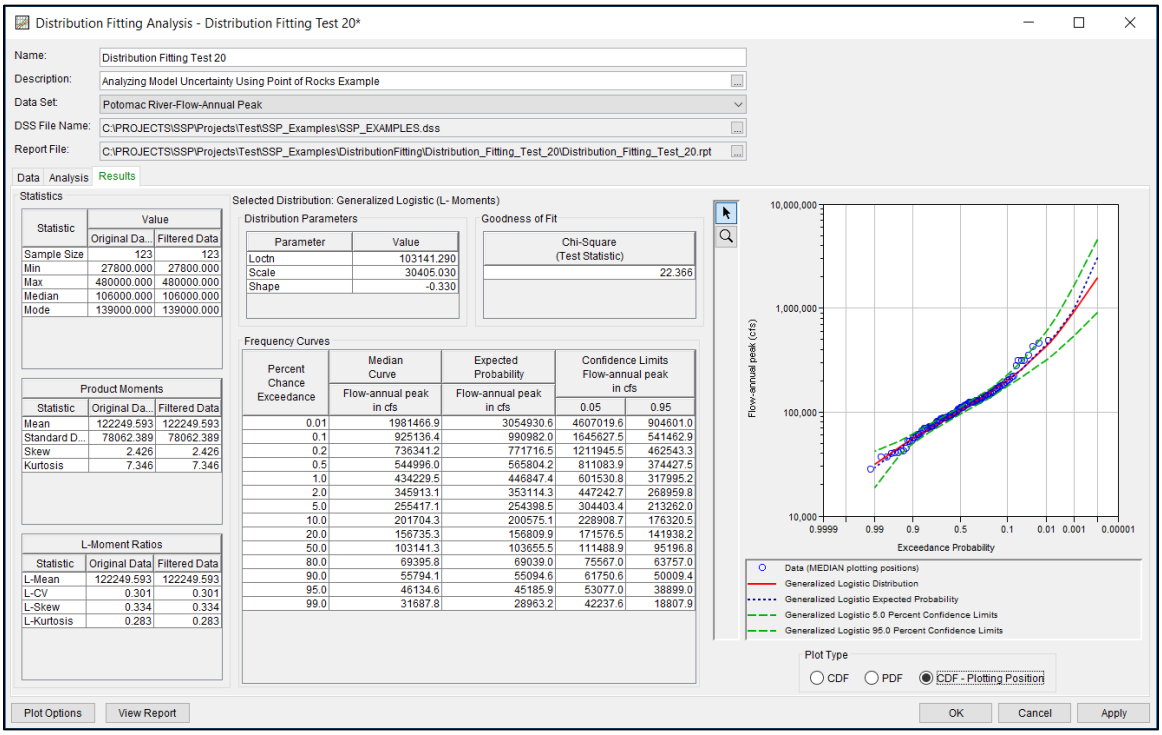


Figure B-151. Distribution Fitting Results Tab Shown for Distribution Fitting Test 20.

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 B-152.

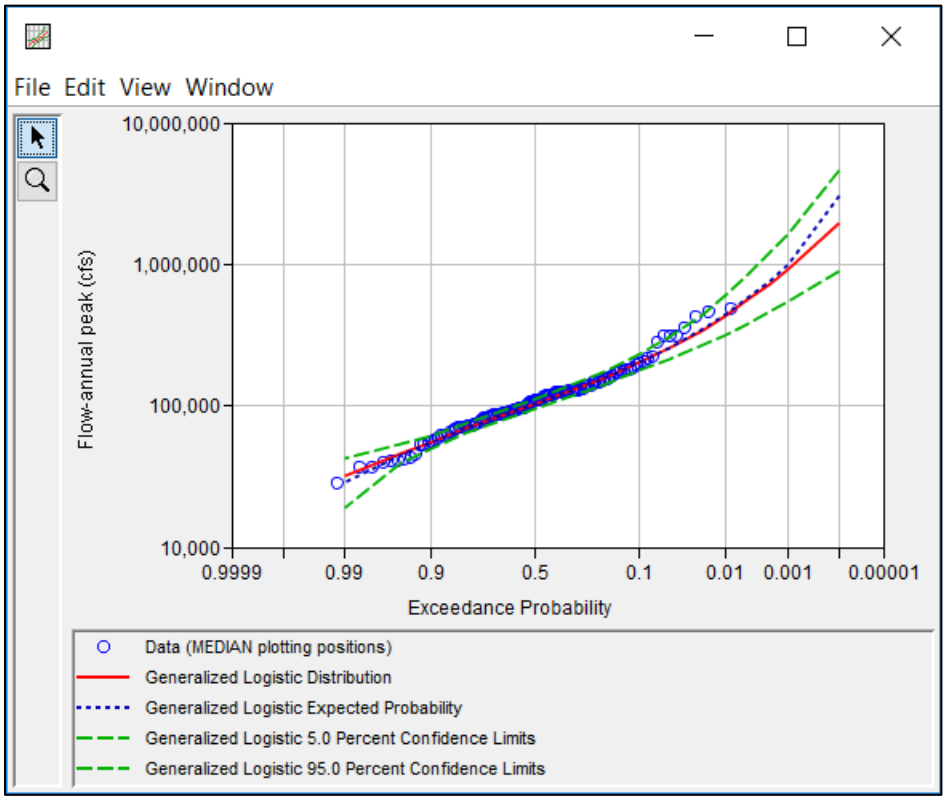


Figure B-152. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 20.

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 B-153.

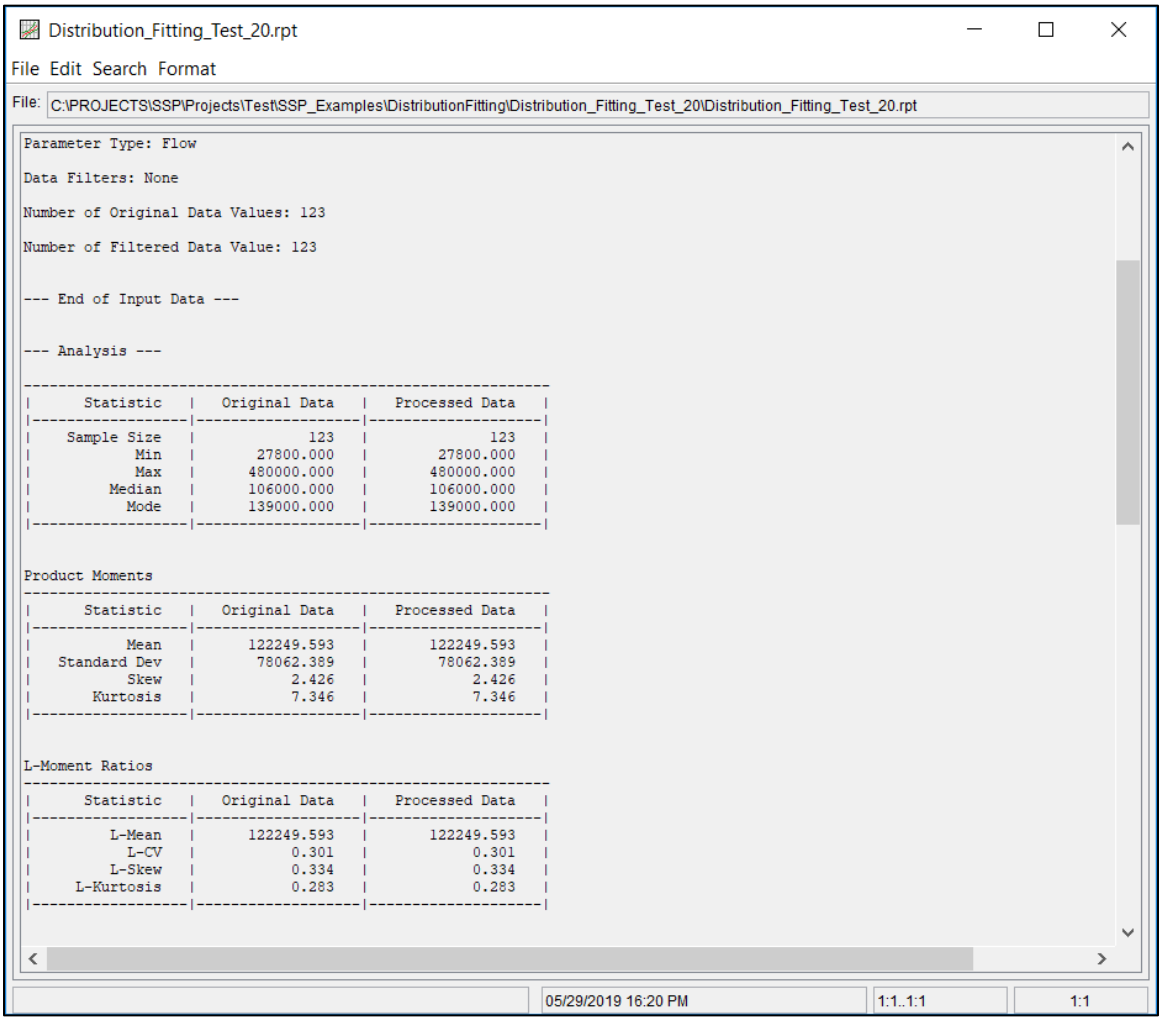


Figure B-153. Report File for Distribution Fitting Test 20.

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. 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 B-154.

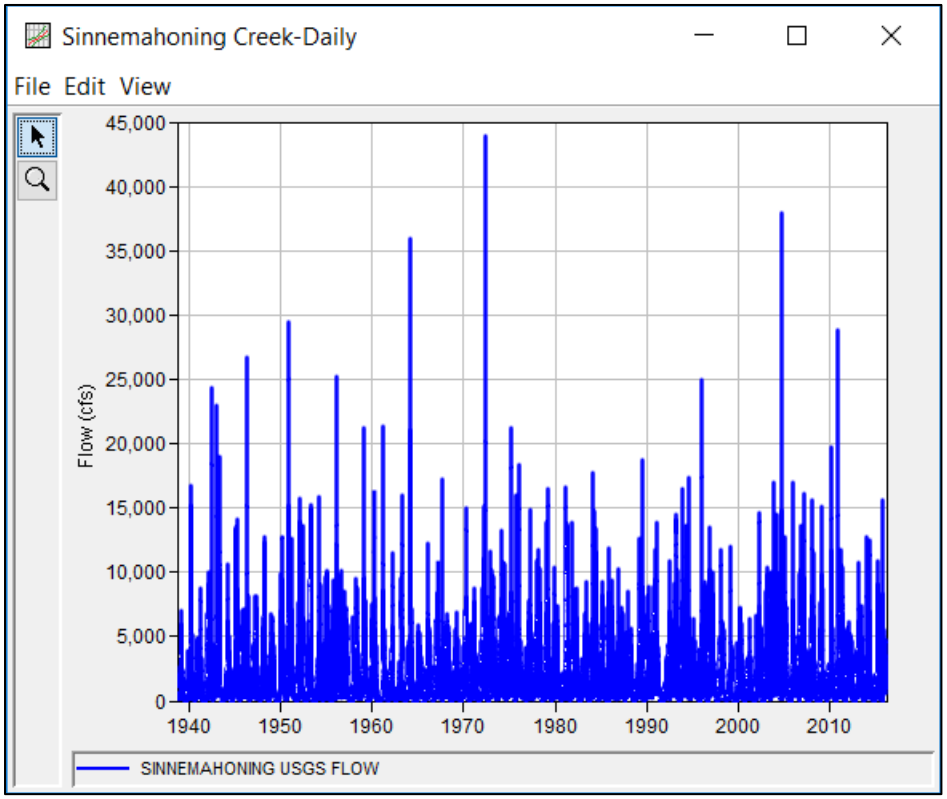


Figure B-154. Plot of the Daily Average Flow Data for Sinnemahoning Creek.

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 B-155.

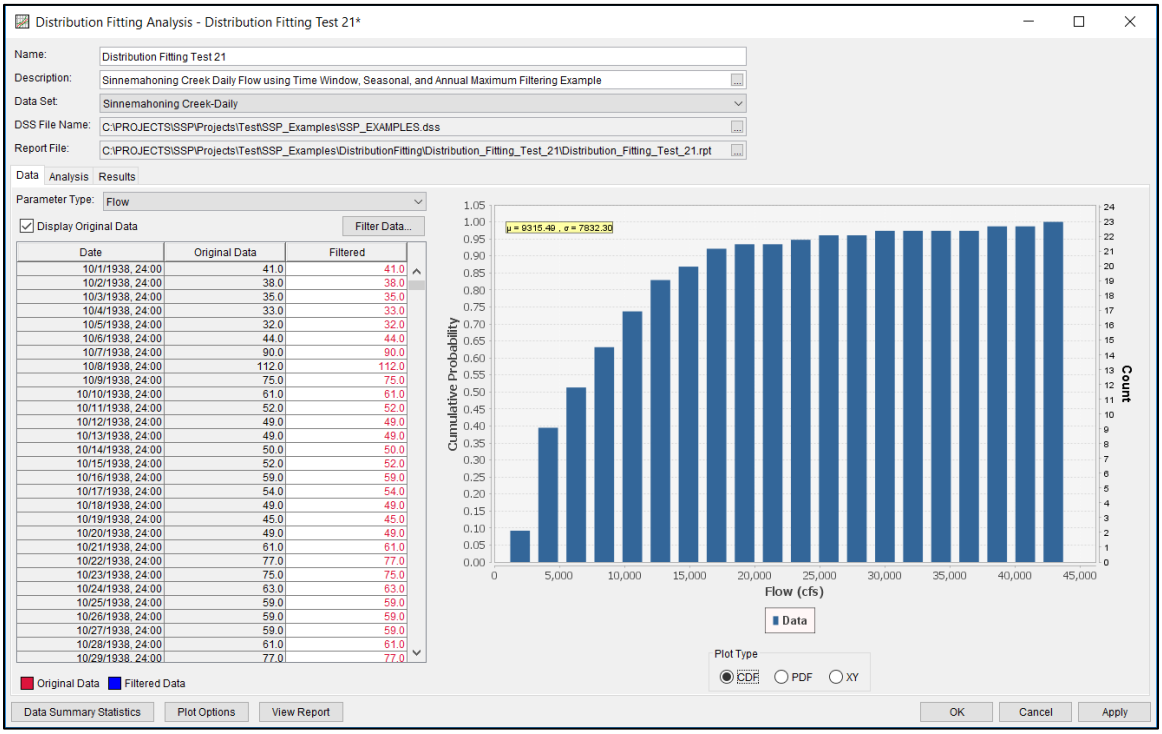


Figure B-155. Distribution Fitting Analysis Editor for Distribution Fitting Test 21.

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 B-156. The original data as well as the filtered data is shown in Figure B-157.

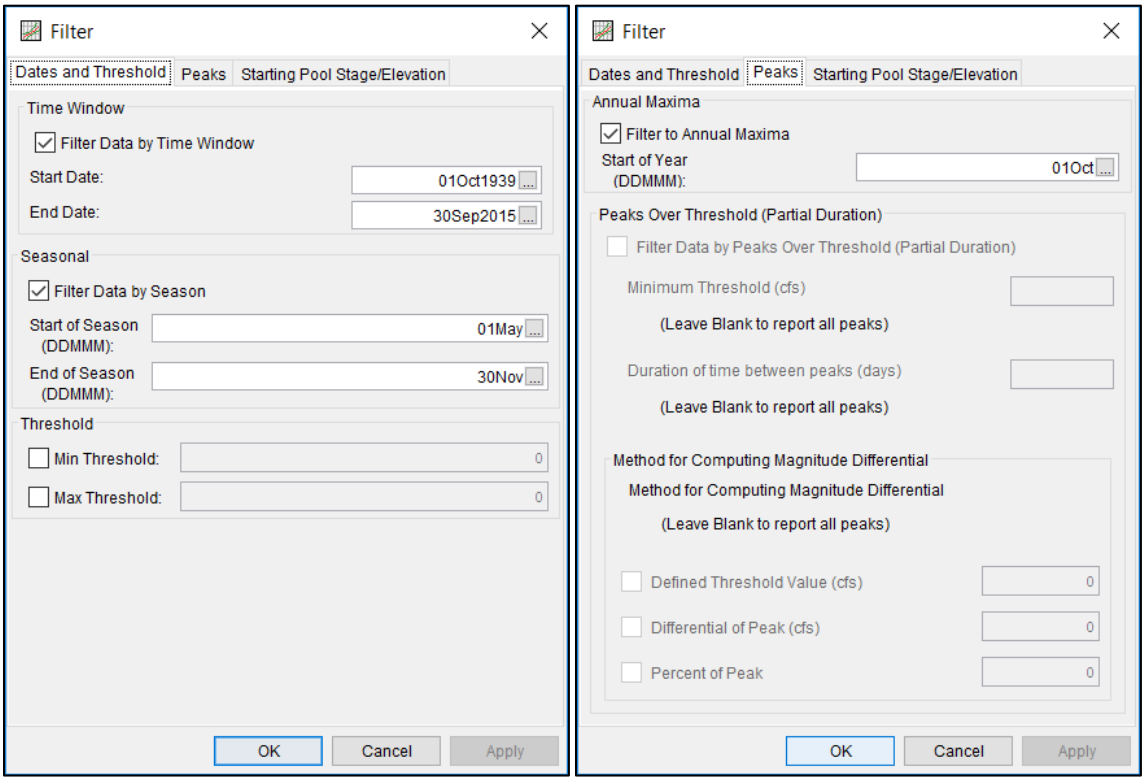


Figure B-156. Data Filters Used within Distribution Fitting Test 21.

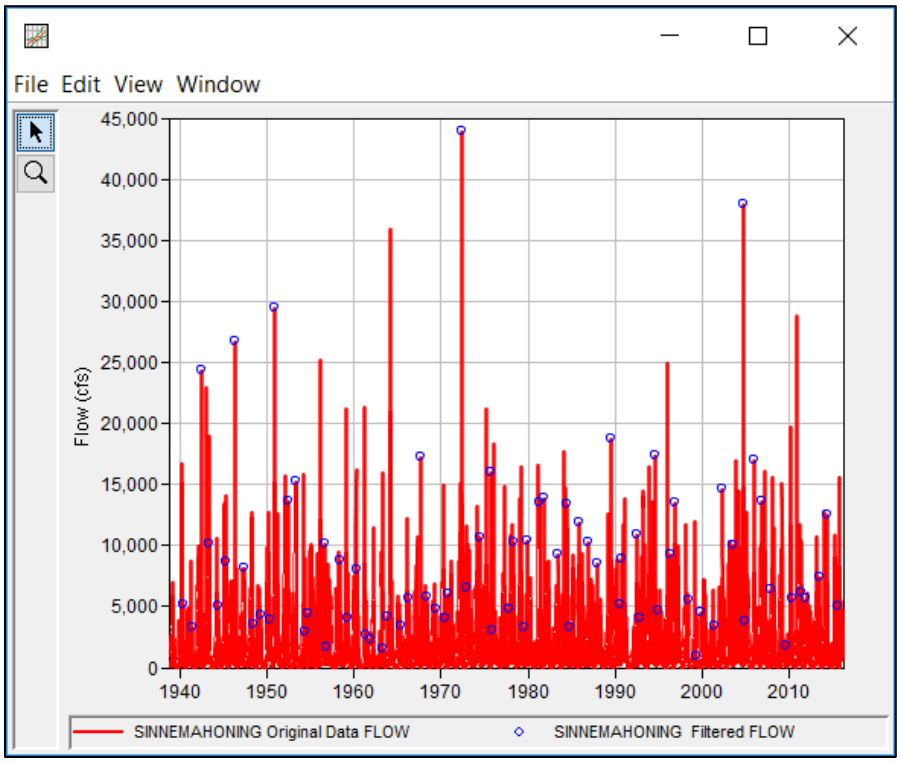
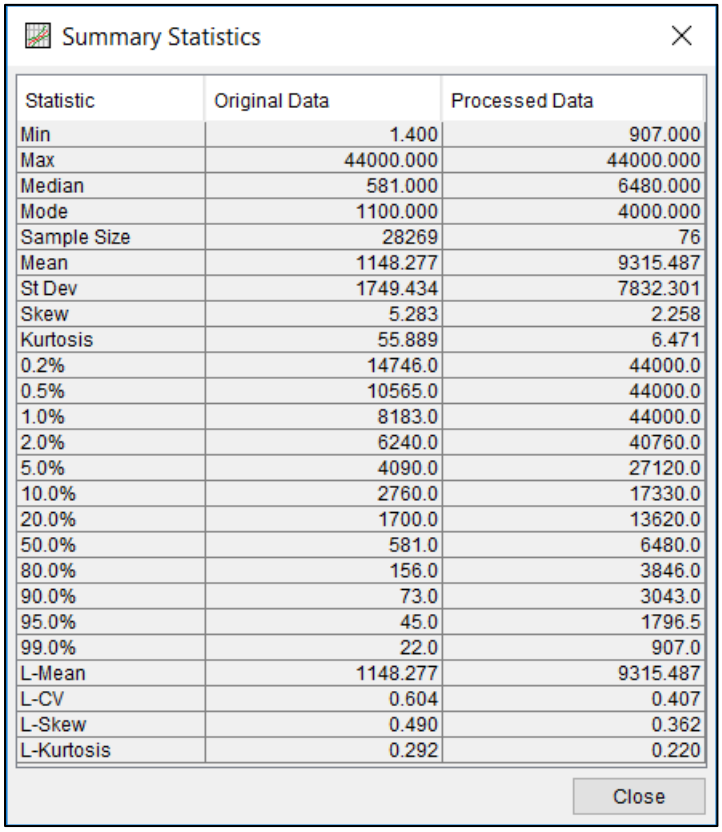


Figure B-157. Original and Filtered Data within Distribution Fitting Test 21.

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 B-158.



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

Figure B-158. 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 B-159, 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 B-160, Figure B-161, Figure B-162, Figure B-163, and Figure B-164.

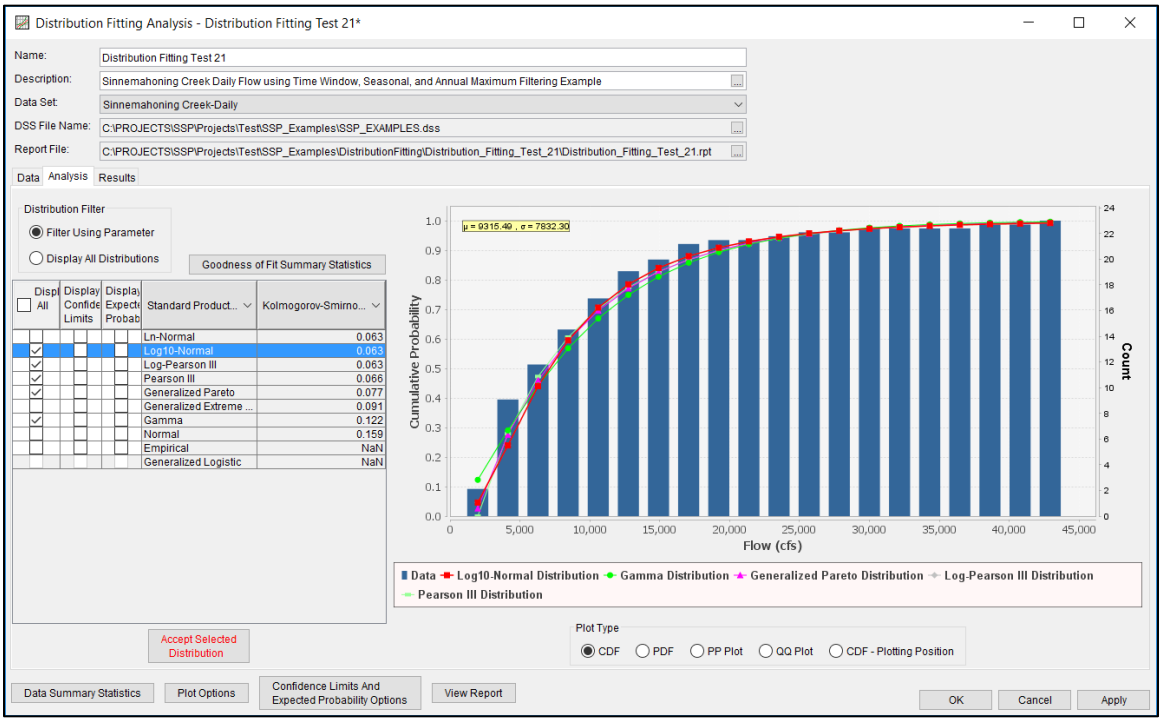


Figure B-159. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 21.

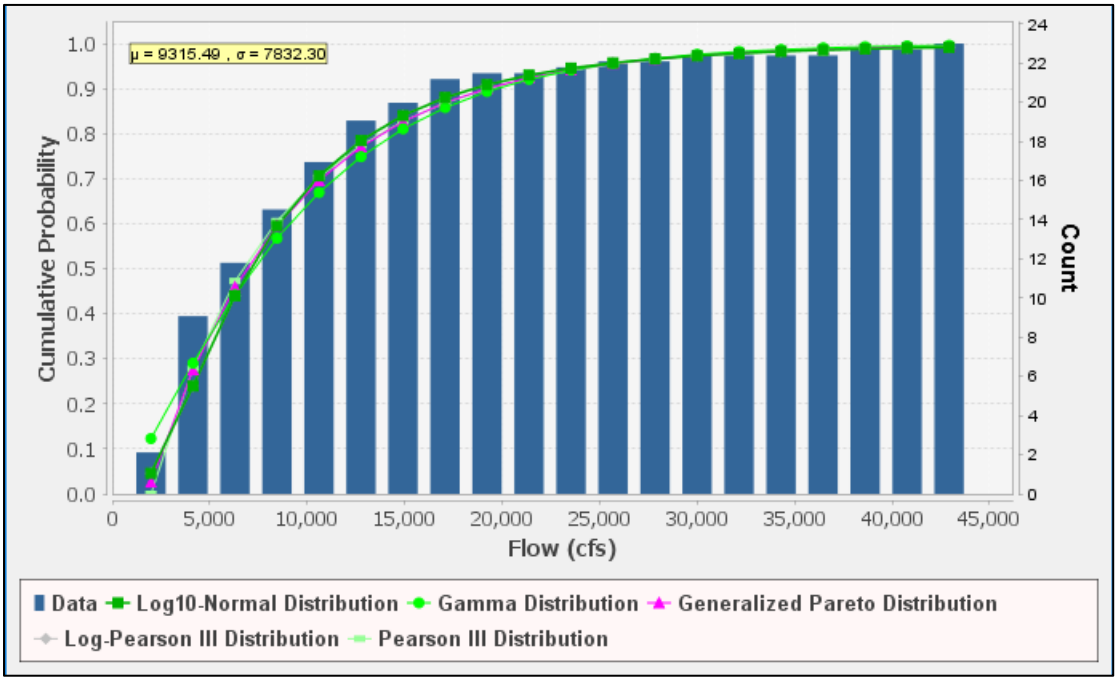


Figure B-160. CDF Plot for Distribution Fitting Test 21.

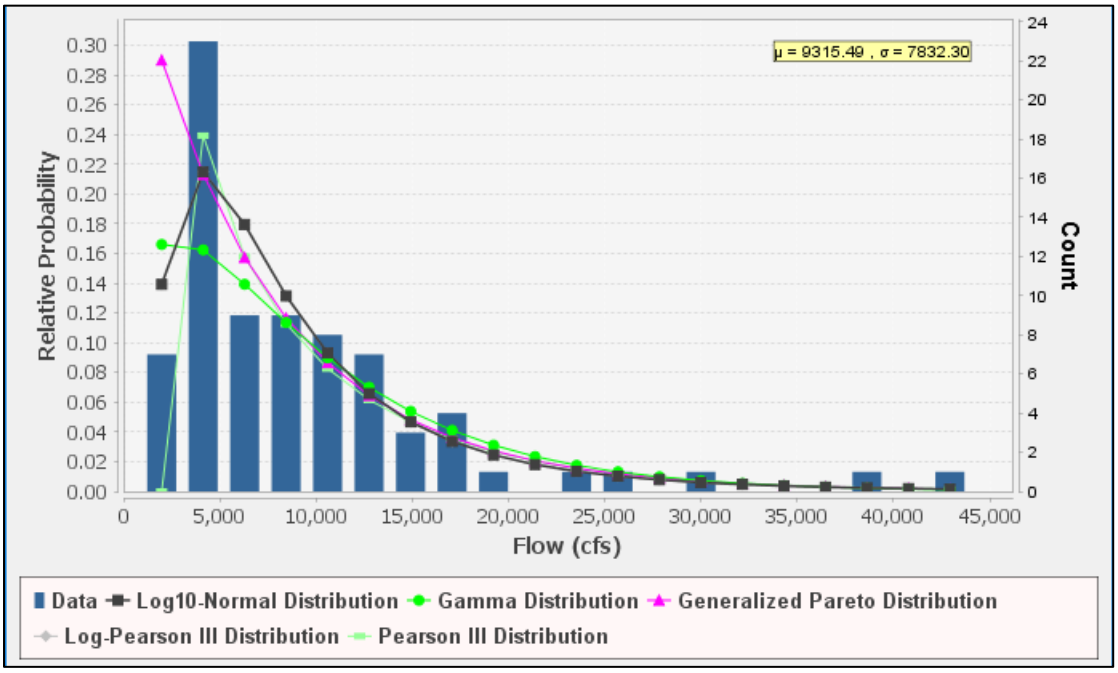


Figure B-161. PDF Plot for Distribution Fitting Test 21.

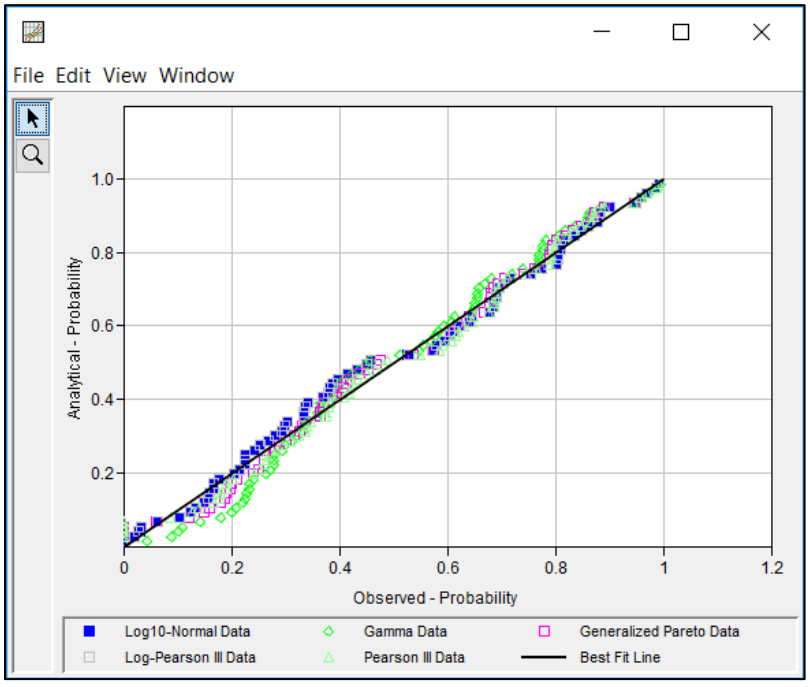


Figure B-162. PP Plot for Distribution Fitting Test 21.

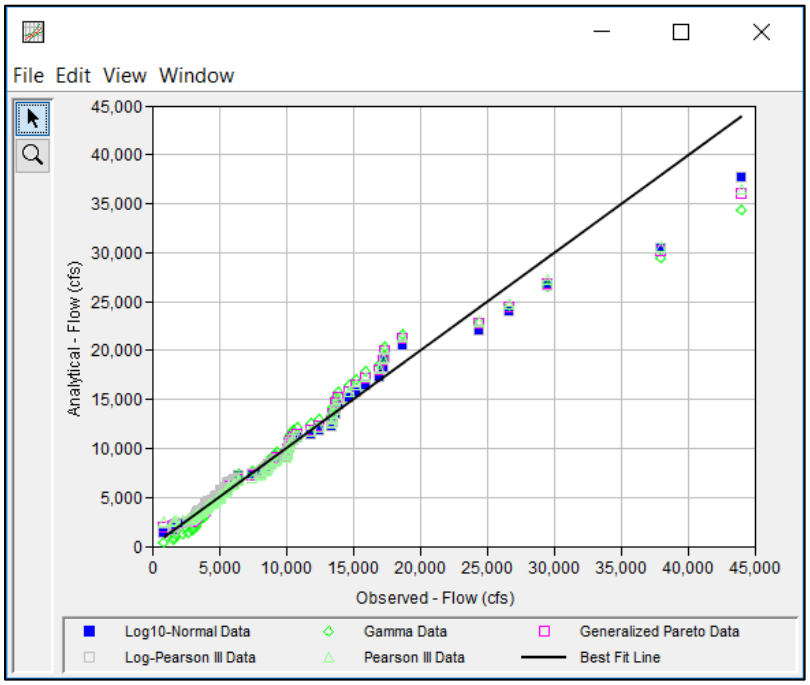


Figure B-163. QQ Plot for Distribution Fitting Test 21.

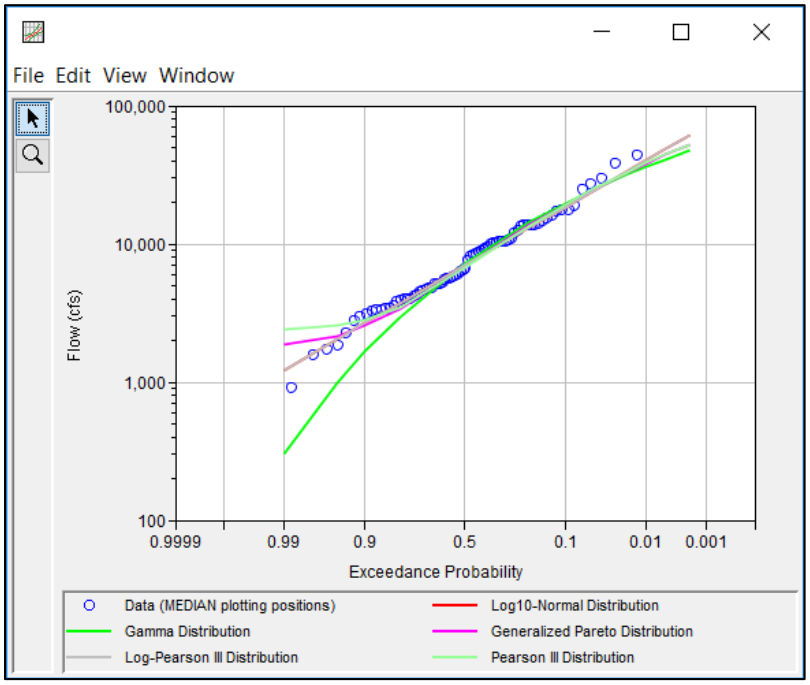
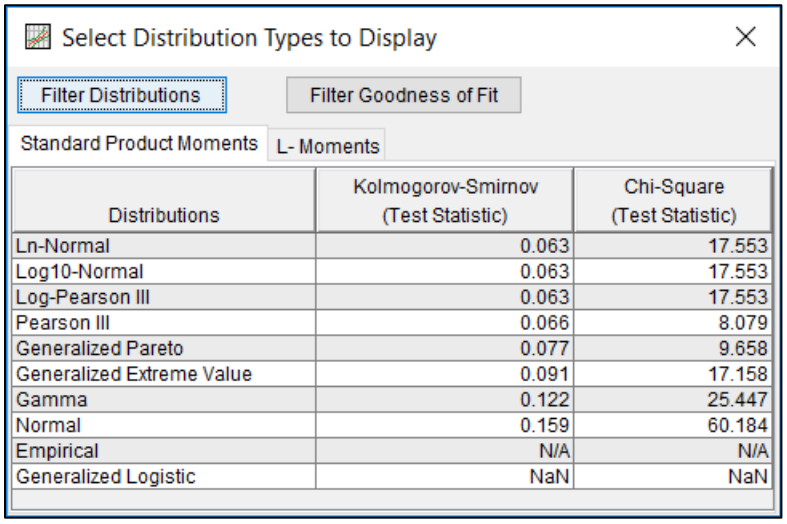


Figure B-164. CDF-Plotting Position Plot for Distribution Fitting Test 21.

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 B-165.



Distributions	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Ln-Normal	0.063	17.553
Log10-Normal	0.063	17.553
Log-Pearson III	0.063	17.553
Pearson III	0.066	8.079
Generalized Pareto	0.077	9.658
Generalized Extreme Value	0.091	17.158
Gamma	0.122	25.447
Normal	0.159	60.184
Empirical	N/A	N/A
Generalized Logistic	NaN	NaN

Figure B-165. Goodness of Fit Summary Statistics for Distribution Fitting Test 21.

In this example, the Log10Normal 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, 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 **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 1,000,000, as shown in Figure B-166. Upon clicking the **OK** button, 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 B-167.

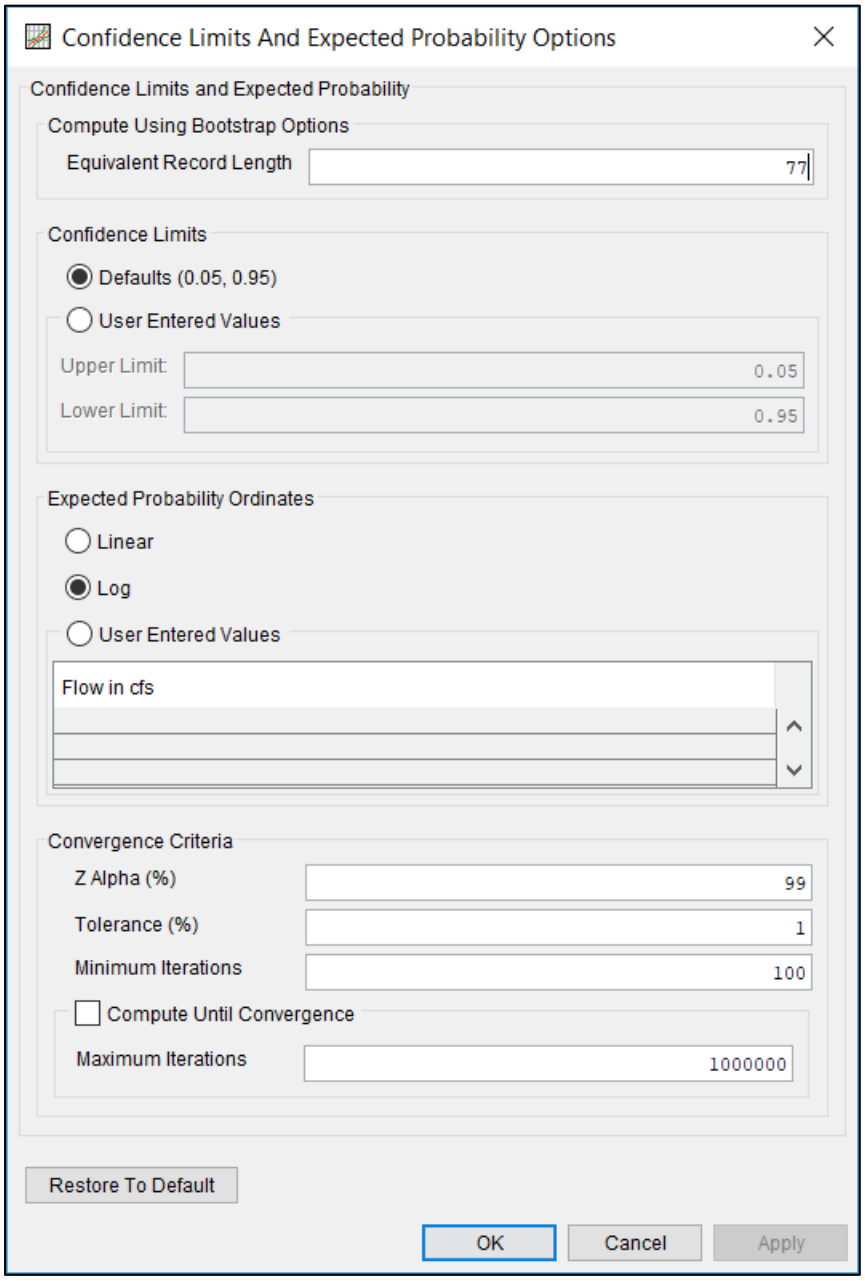


Figure B-166. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 21.

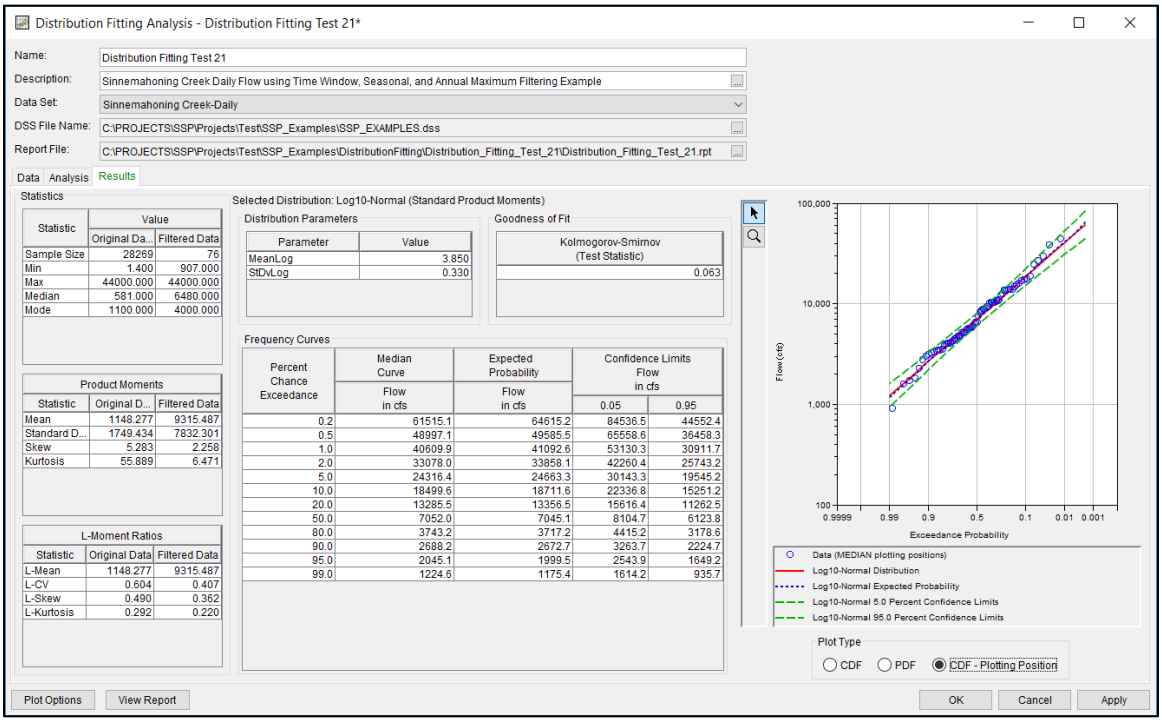


Figure B-167. Distribution Fitting Results Tab Shown for Distribution Fitting Test 21.

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 B-168.

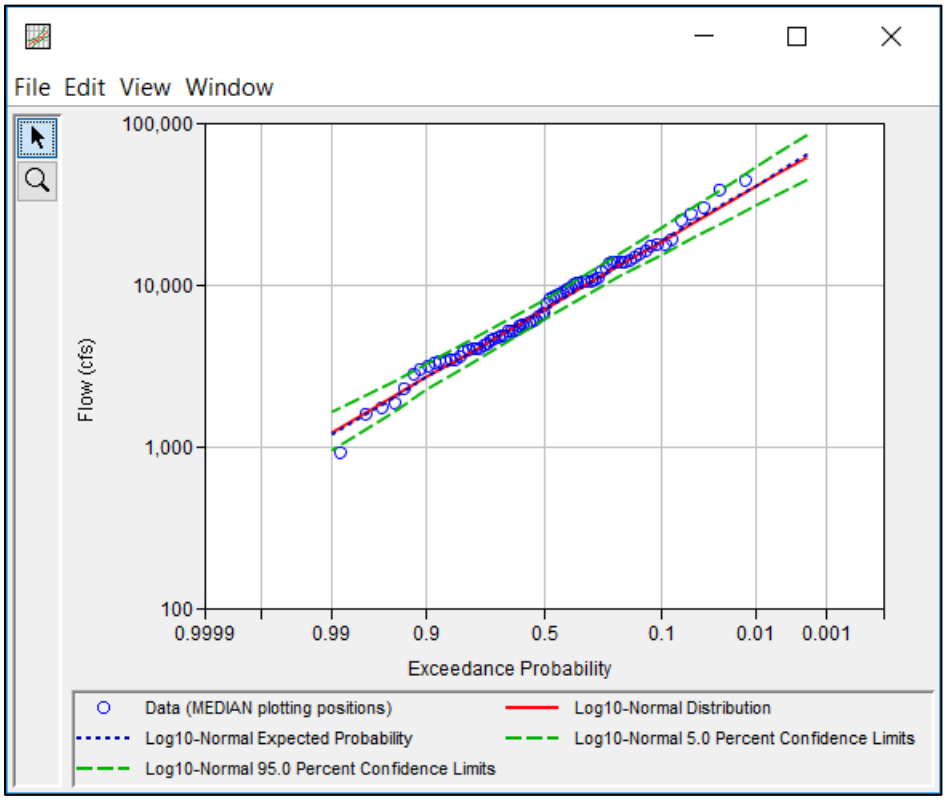


Figure B-168. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 21.

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 B-169.

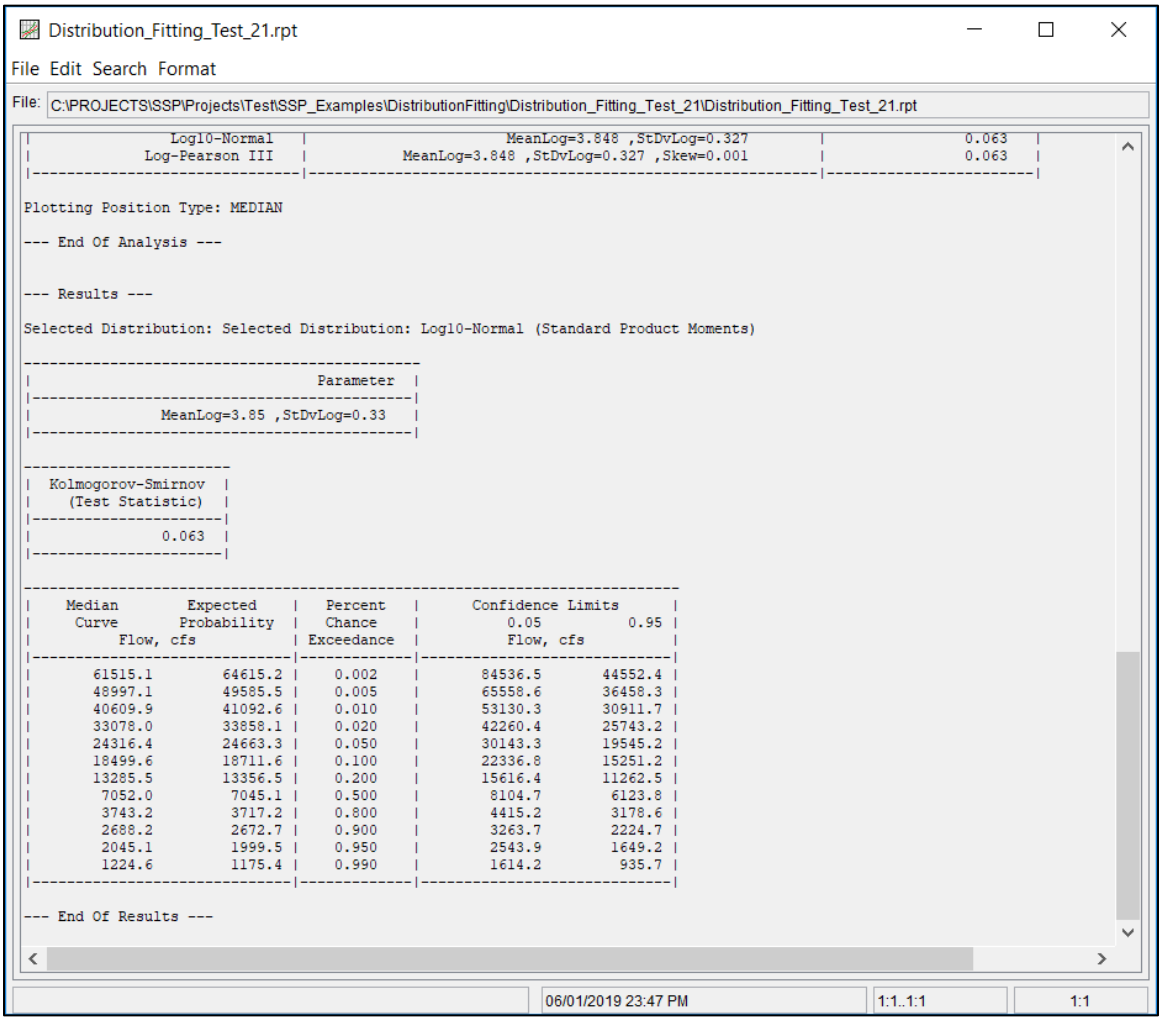


Figure B-169. Report File for Distribution Fitting Test 21.

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. 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 B-170.

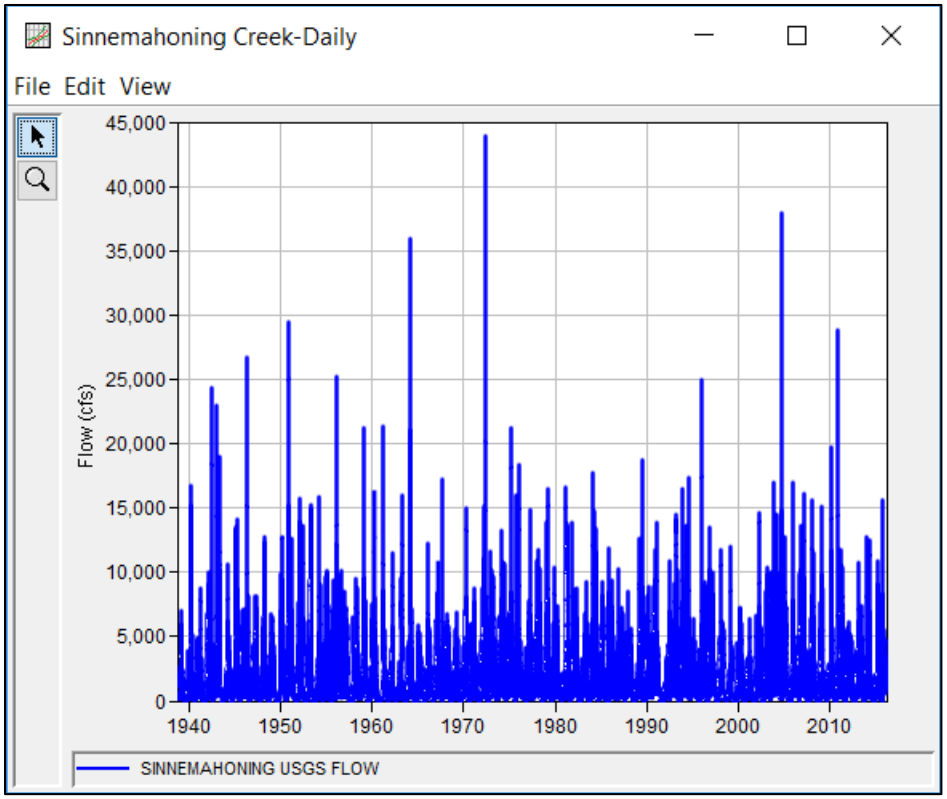


Figure B-170. Plot of the Daily Average Flow Data for Sinnemahoning Creek.

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 B-171.

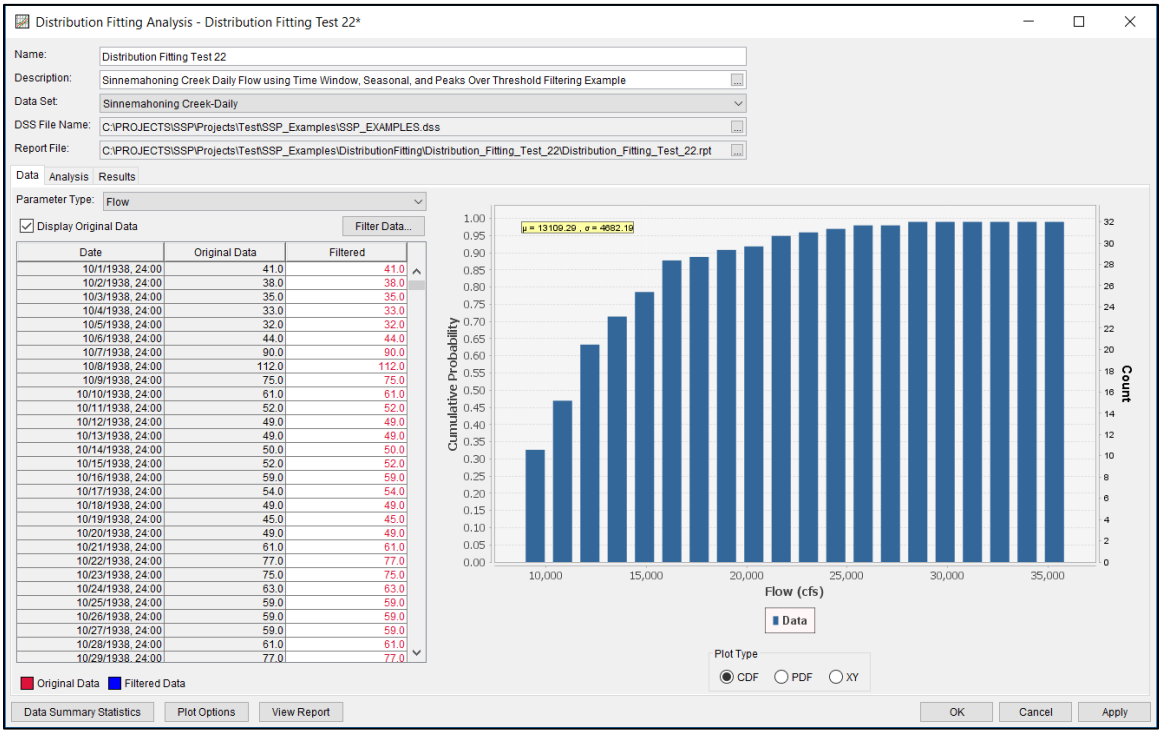


Figure B-171. Distribution Fitting Analysis Editor for Distribution Fitting Test 22.

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 B-172. The original data as well as the filtered data is shown in Figure B-173.

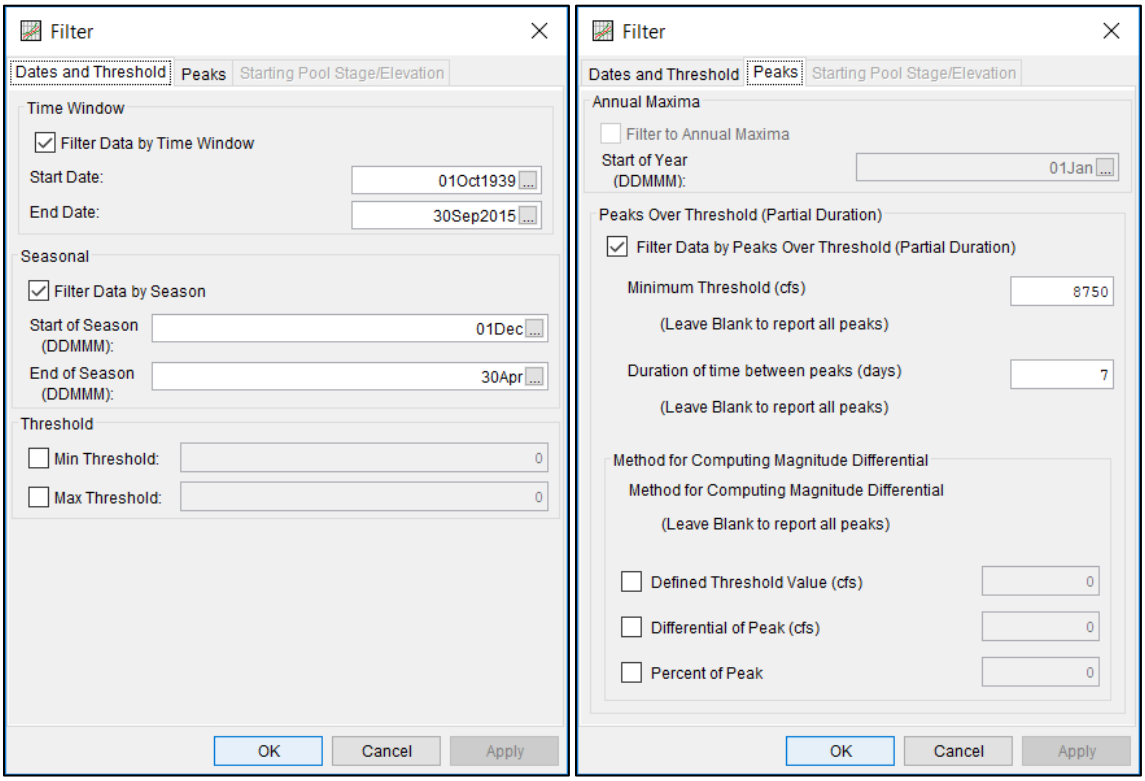


Figure B-172. Data Filters Used within Distribution Fitting Test 22.

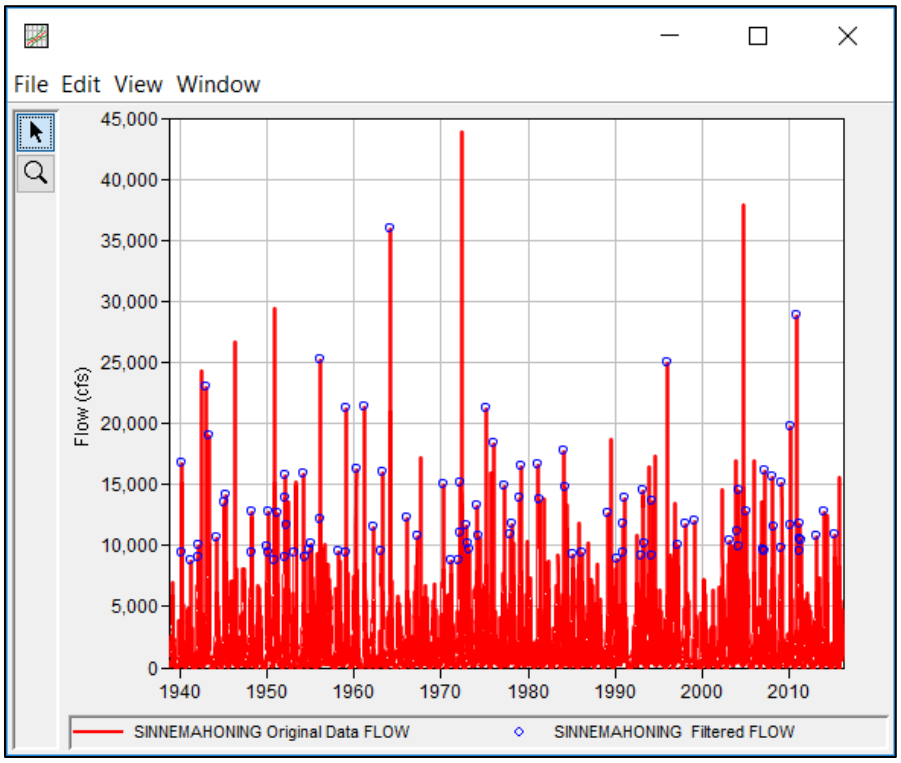
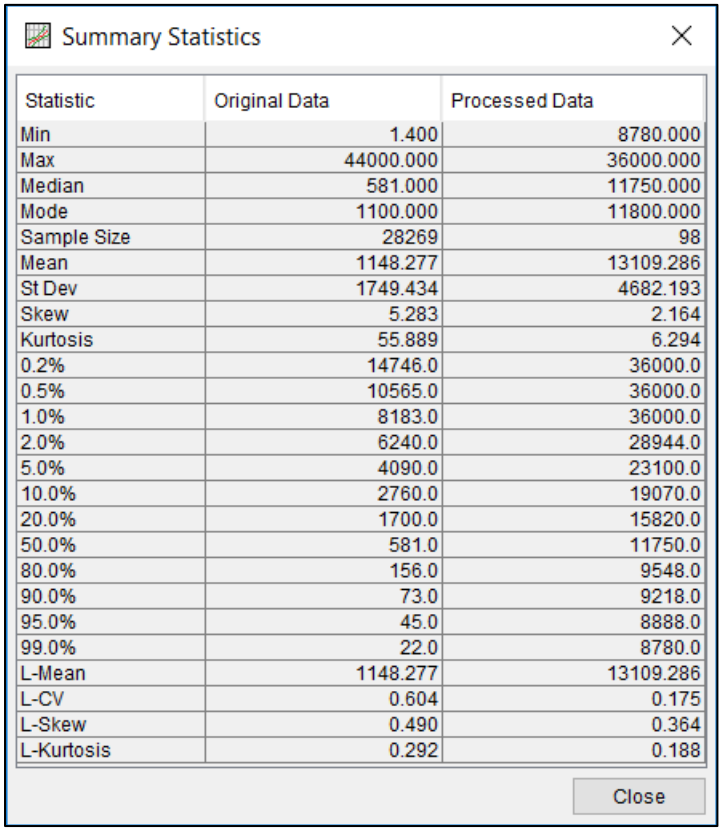


Figure B-173. Original and Filtered Data within Distribution Fitting Test 22.

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 B-174.



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	28269	98
Mean	1148.277	13109.286
St Dev	1749.434	4682.193
Skew	5.283	2.164
Kurtosis	55.889	6.294
0.2%	14746.0	36000.0
0.5%	10565.0	36000.0
1.0%	8183.0	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	1148.277	13109.286
L-CV	0.604	0.175
L-Skew	0.490	0.364
L-Kurtosis	0.292	0.188

Figure B-174. 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 B-175, 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 changed to L-Moments by clicking on the column header and selecting **L-Moments**. 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 B-176, Figure B-177, Figure B-178, Figure B-179, and Figure B-180.

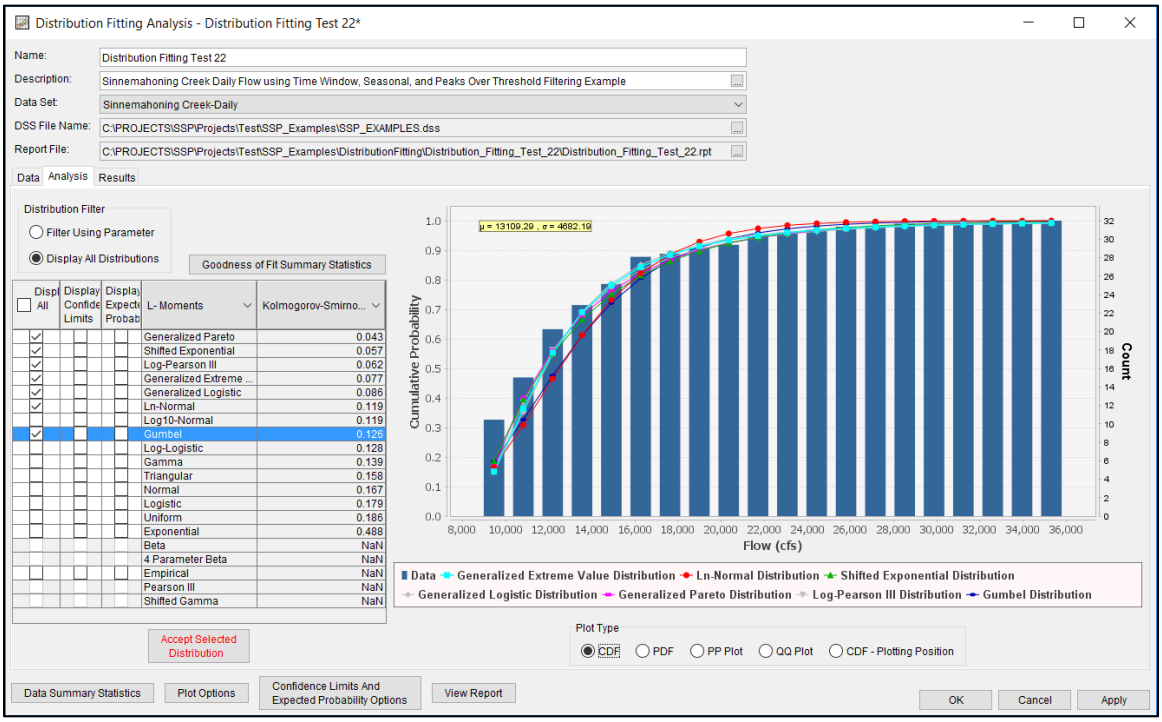


Figure B-175. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 22.

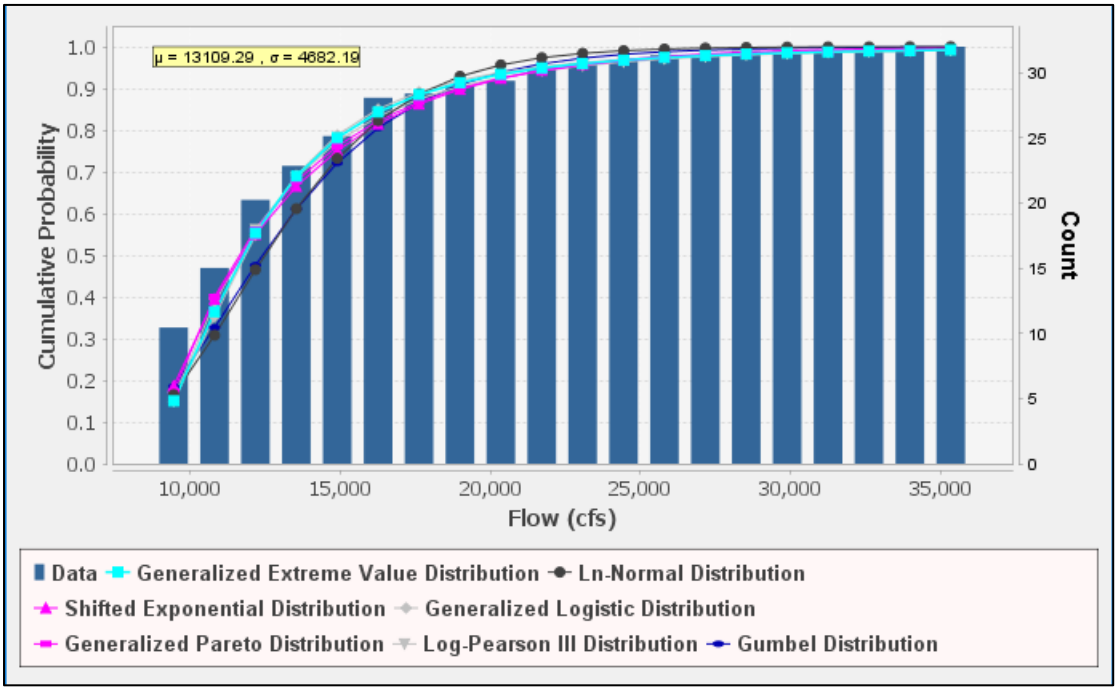


Figure B-176. CDF Plot for Distribution Fitting Test 22.

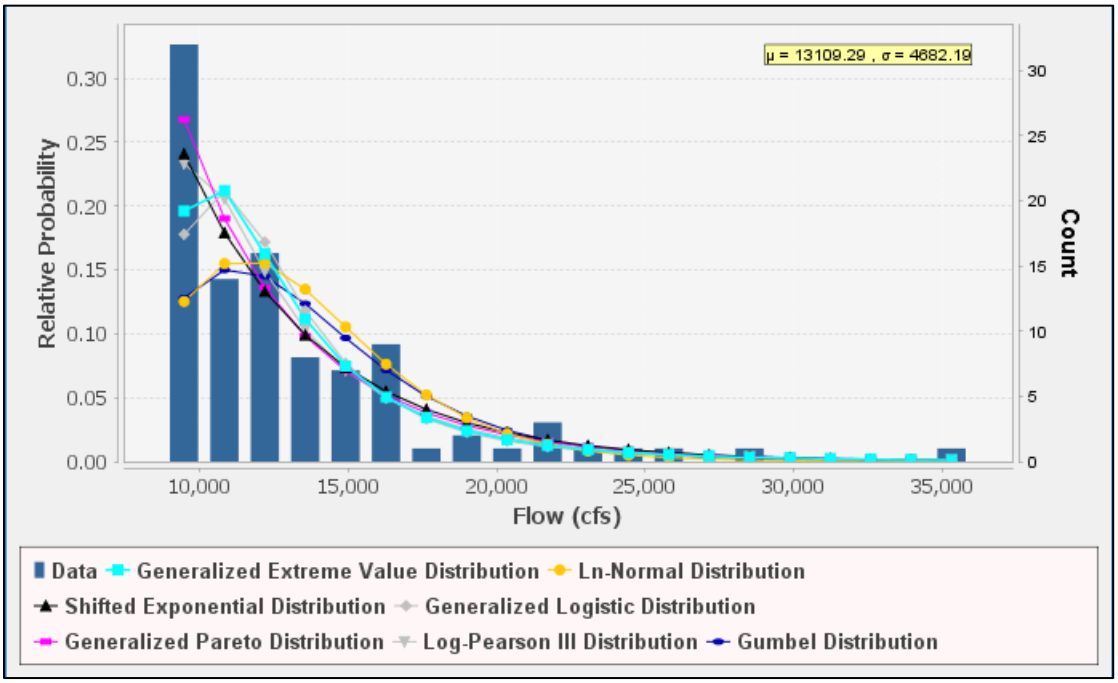


Figure B-177. PDF Plot for Distribution Fitting Test 22.

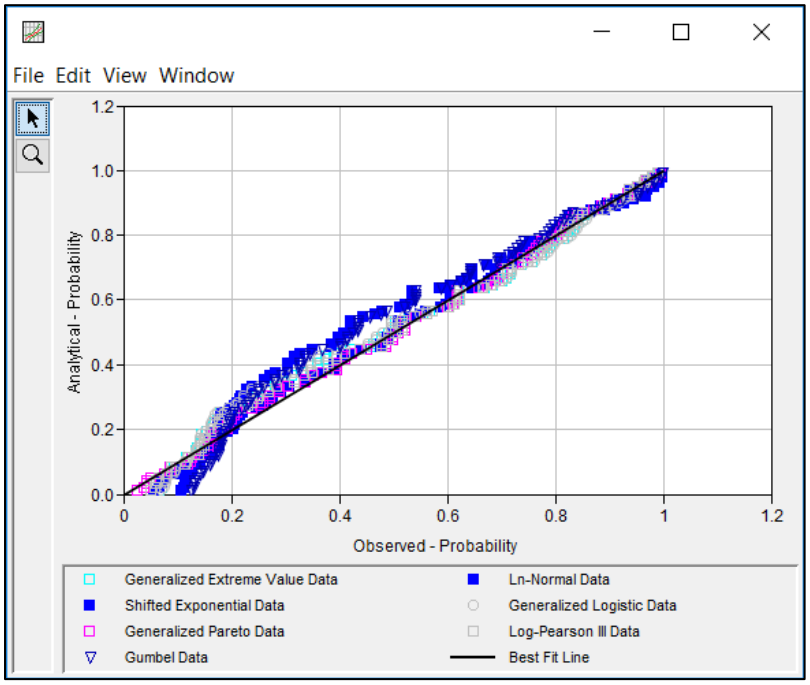


Figure B-178. PP Plot for Distribution Fitting Test 22.

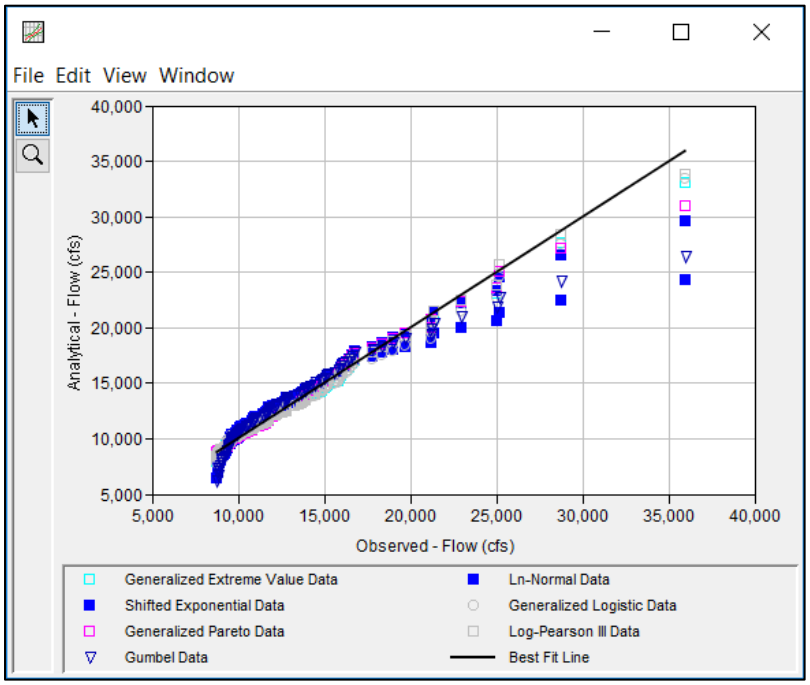


Figure B-179. QQ Plot for Distribution Fitting Test 22.

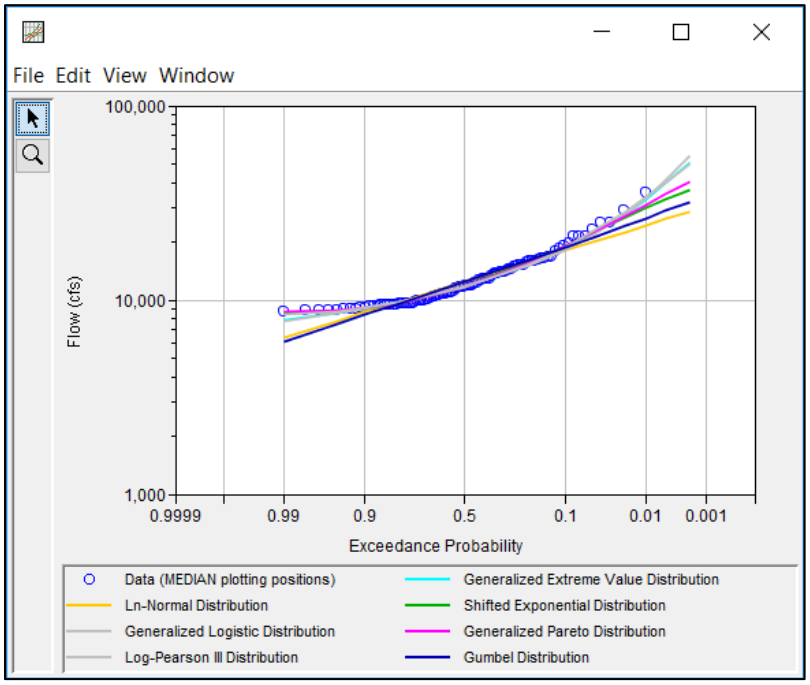
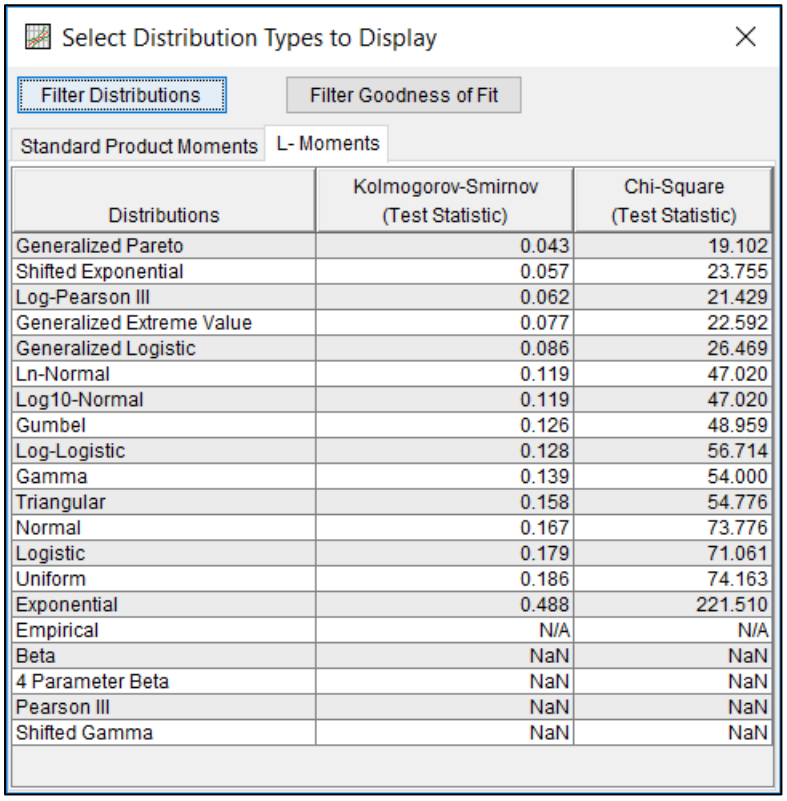


Figure B-180. CDF-Plotting Position Plot for Distribution Fitting Test 22.

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 B-181.



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

Figure B-181. 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 Selected Distribution** button near the bottom of the Distribution Fitting editor while having that row selected on the Analysis tab. 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 **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 1,000,000, as shown in Figure B-182. Upon clicking the **OK** button, 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 B-183.

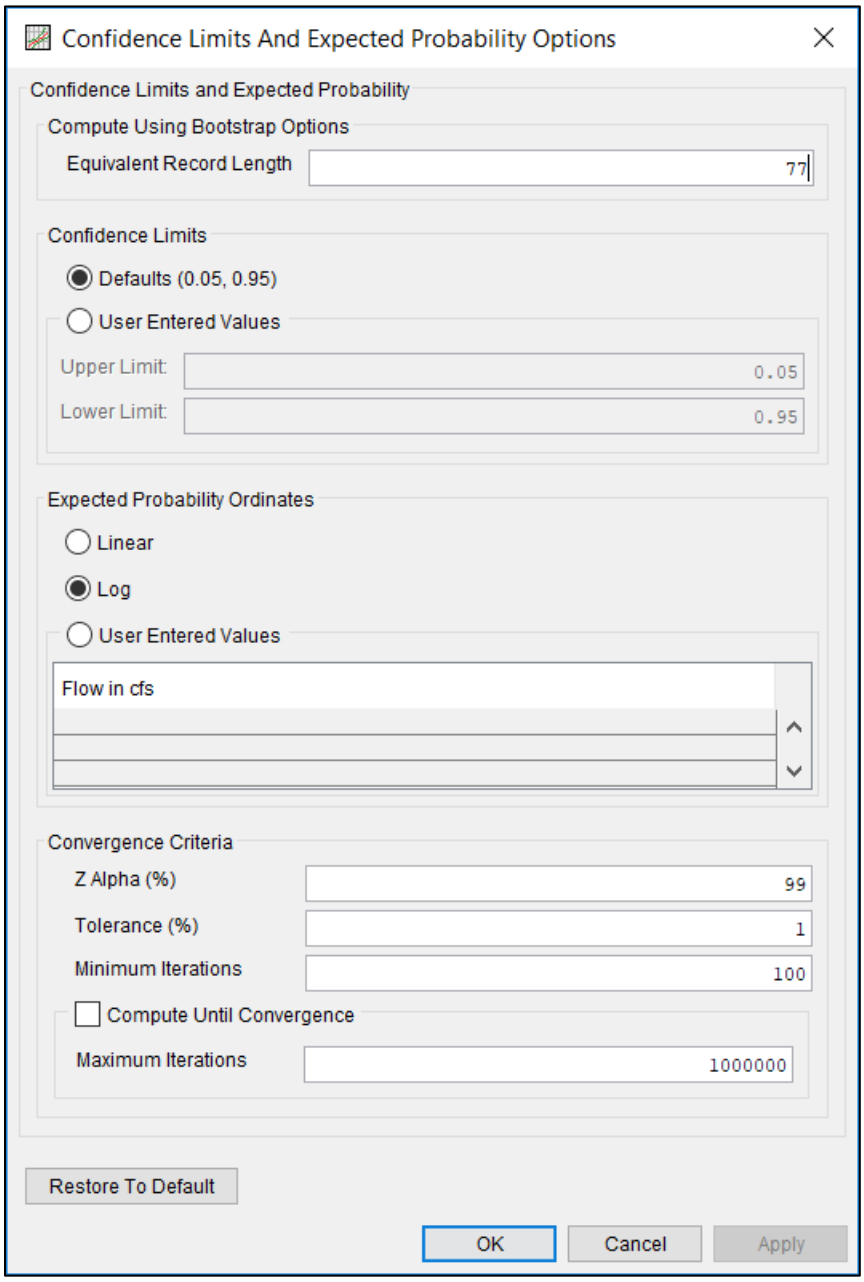


Figure B-182. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 22.

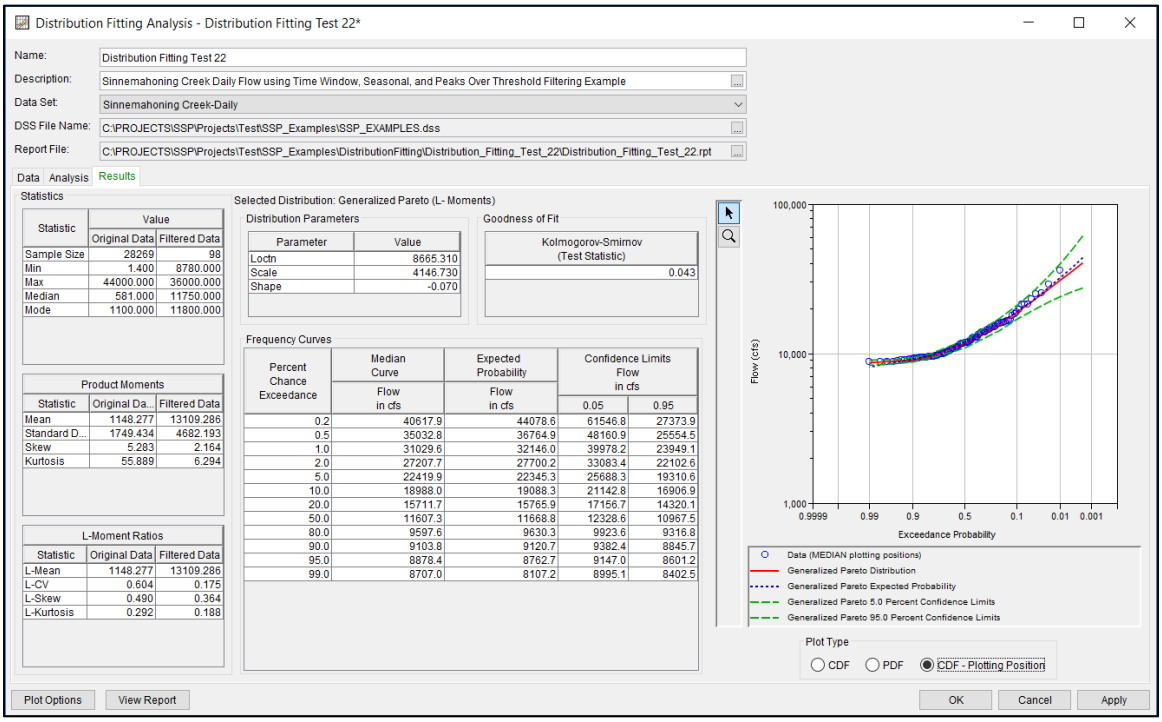


Figure B-183. Distribution Fitting Results Tab Shown for Distribution Fitting Test 22.

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 B-184.

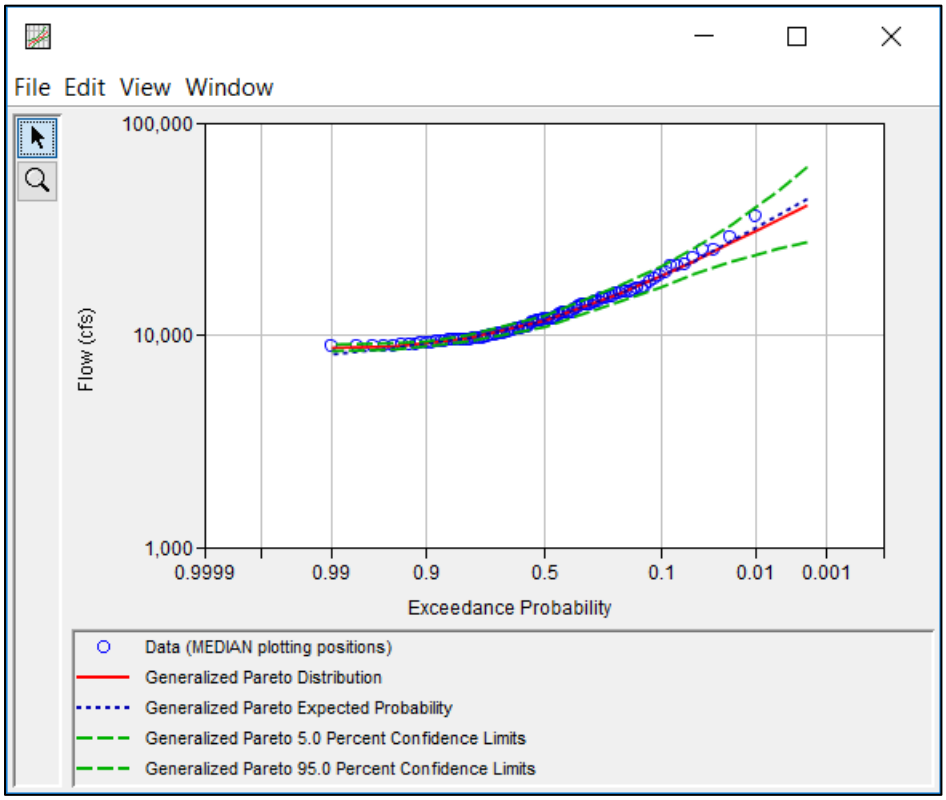


Figure B-184. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 22.

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 B-185.

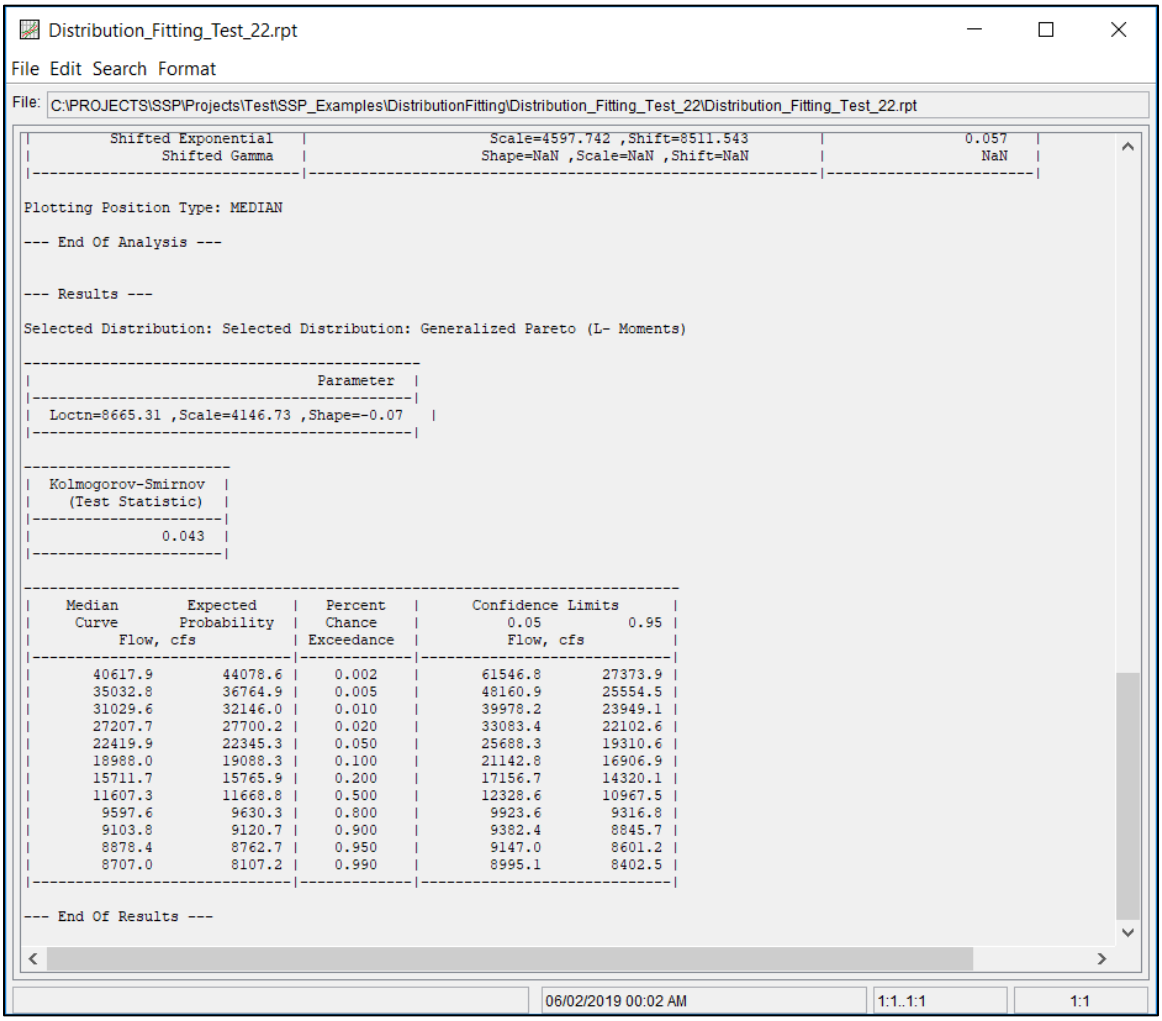


Figure B-185. Report File for Distribution Fitting Test 22.

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. 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 B-186.

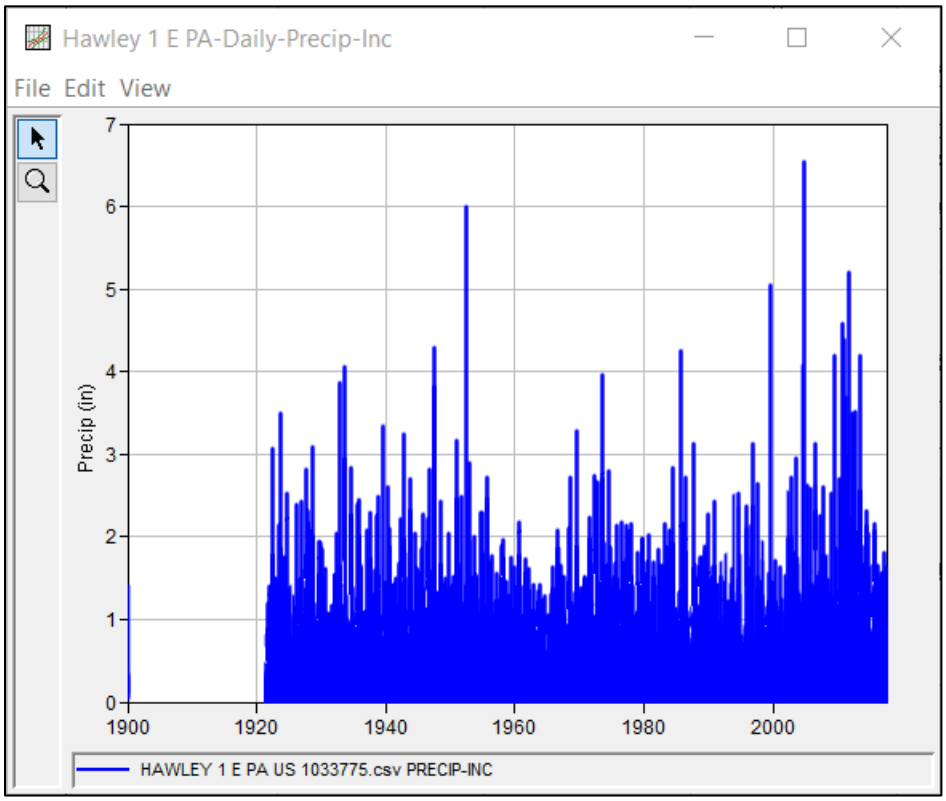


Figure B-186. Plot of the Daily Precipitation Accumulation for Hawley 1E.

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 B-187.

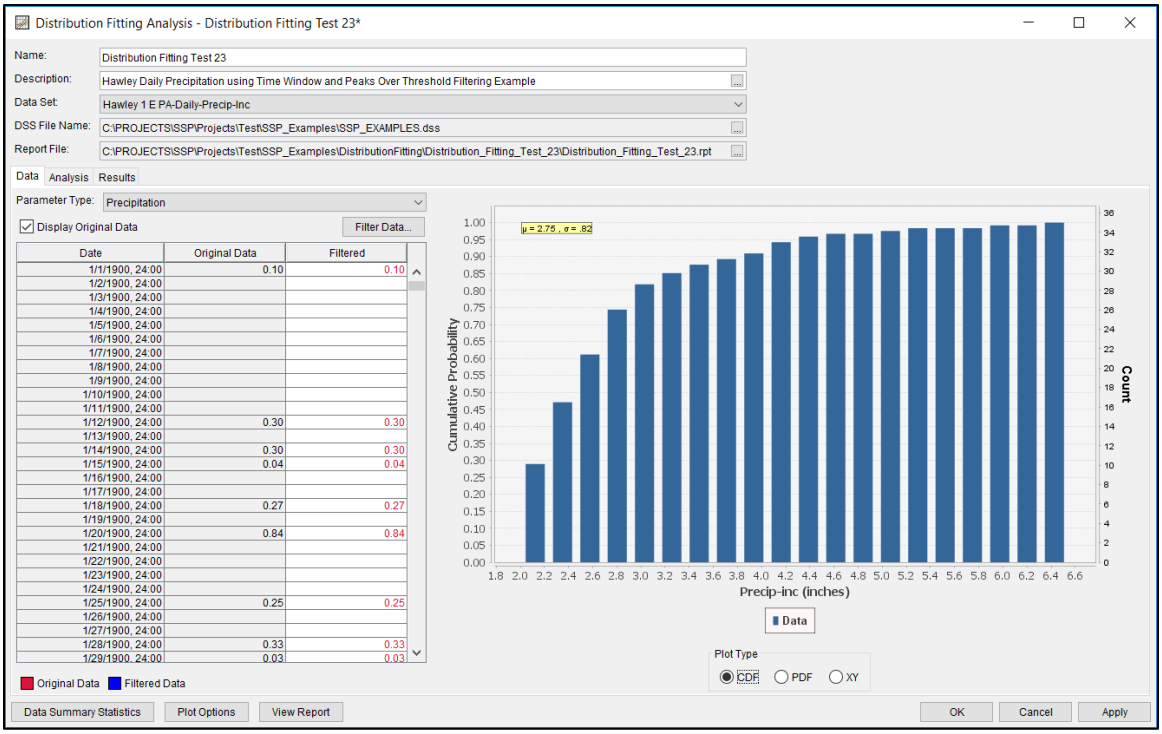


Figure B-187. Distribution Fitting Analysis Editor for Distribution Fitting Test 23.

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 B-188. The original data as well as the filtered data is shown in Figure B-189.

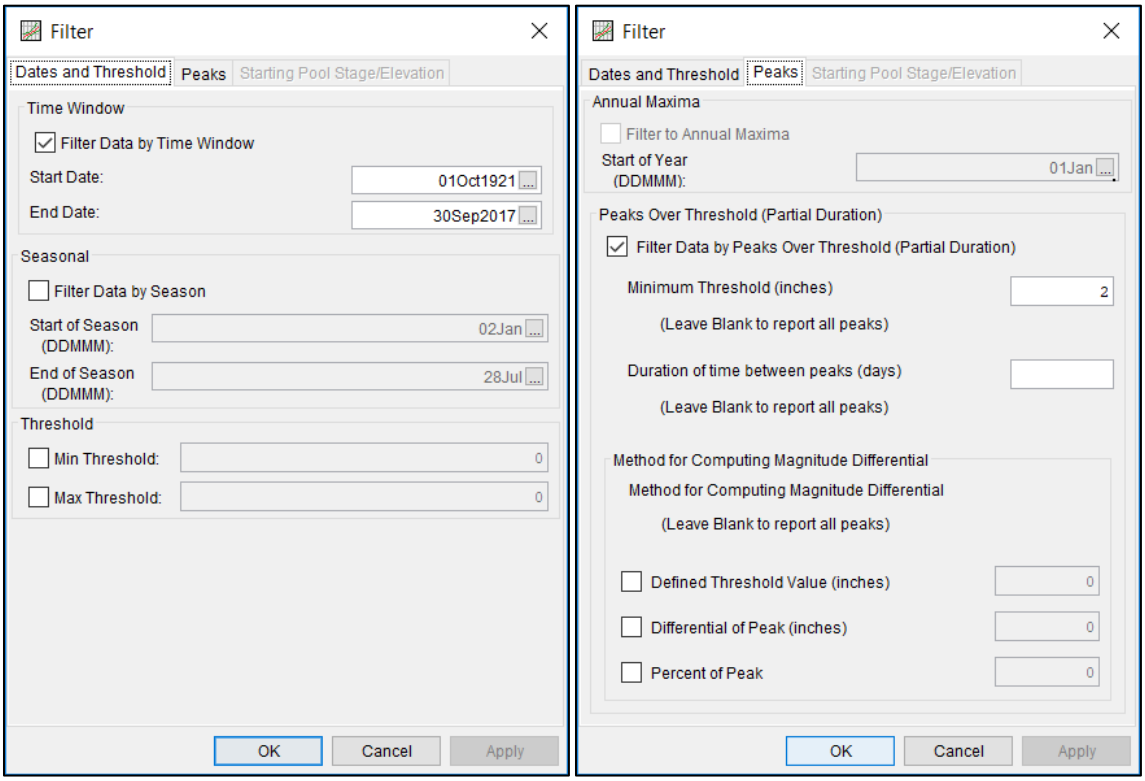


Figure B-188. Data Filters Used within Distribution Fitting Test 23.

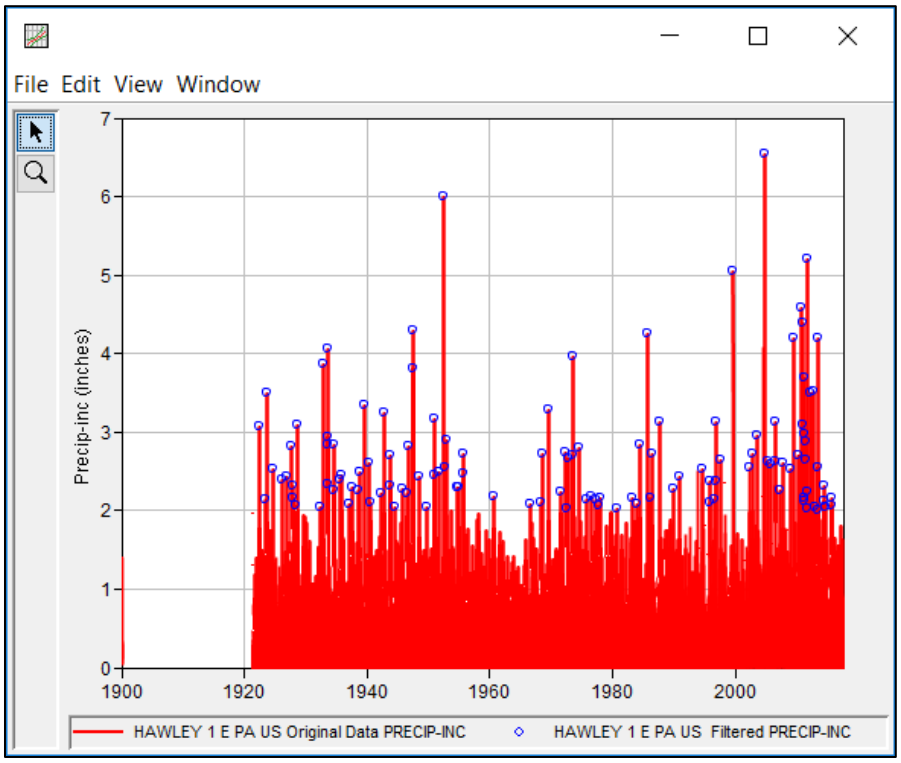
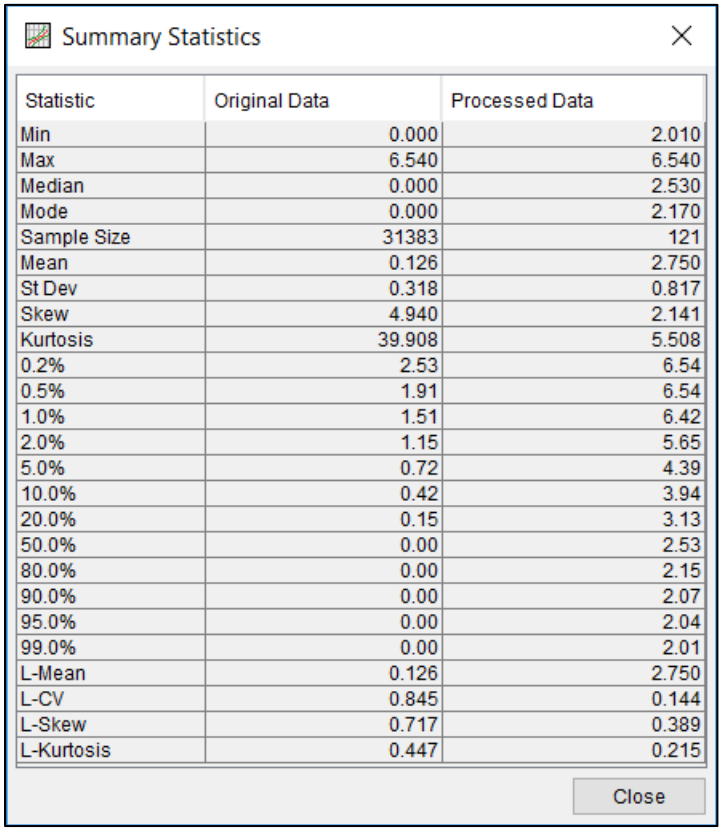


Figure B-189. Original and Filtered Data within Distribution Fitting Test 23.

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 B-190.



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	31383	121
Mean	0.126	2.750
St Dev	0.318	0.817
Skew	4.940	2.141
Kurtosis	39.908	5.508
0.2%	2.53	6.54
0.5%	1.91	6.54
1.0%	1.51	6.42
2.0%	1.15	5.65
5.0%	0.72	4.39
10.0%	0.42	3.94
20.0%	0.15	3.13
50.0%	0.00	2.53
80.0%	0.00	2.15
90.0%	0.00	2.07
95.0%	0.00	2.04
99.0%	0.00	2.01
L-Mean	0.126	2.750
L-CV	0.845	0.144
L-Skew	0.717	0.389
L-Kurtosis	0.447	0.215

Figure B-190. 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 B-191, 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 changed to L-Moments by clicking on the column header and selecting **L-Moments**. 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 B-192, Figure B-193, Figure B-194, Figure B-195, and Figure B-196.

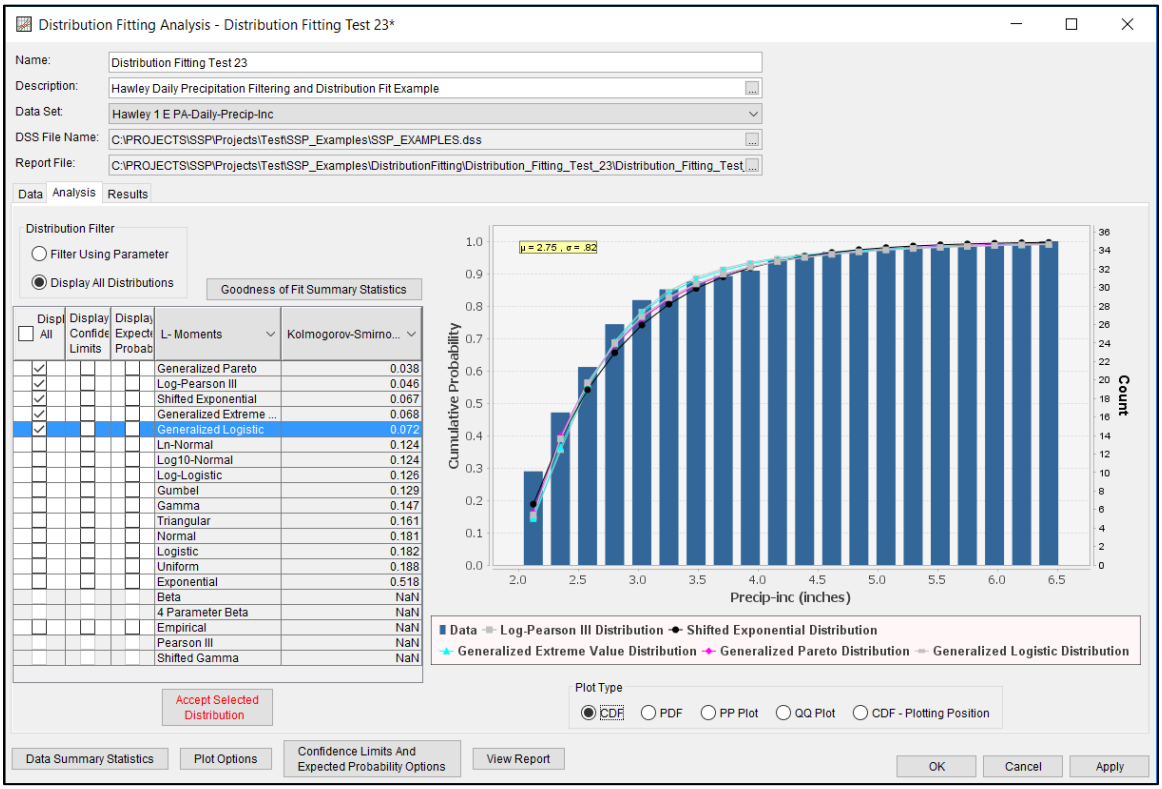


Figure B-191. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 23.

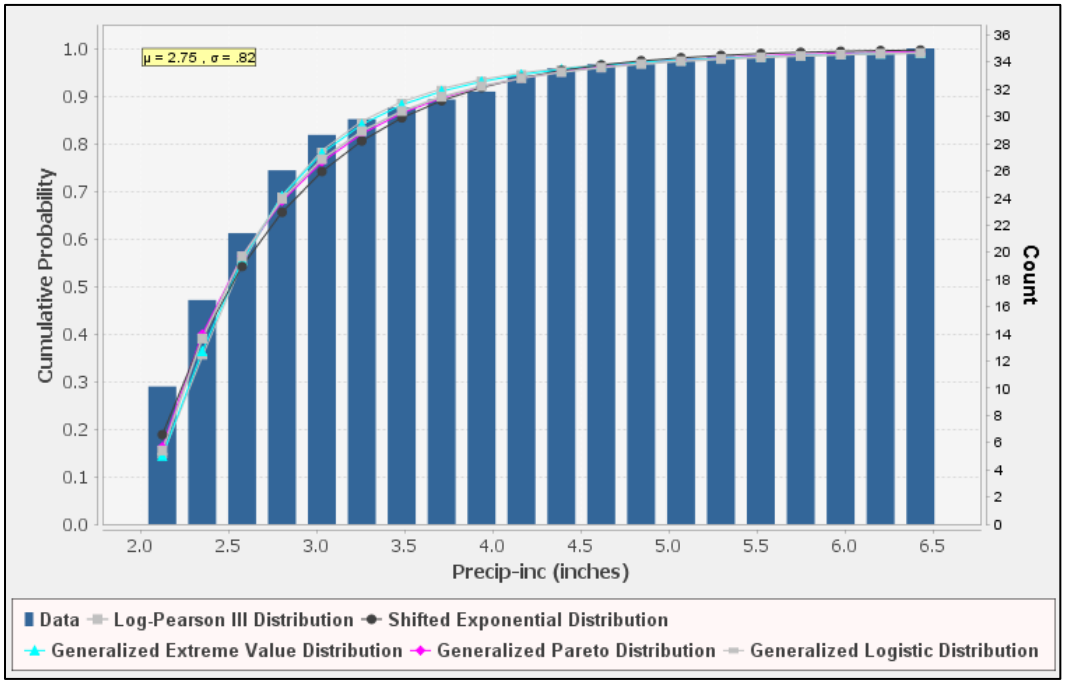


Figure B-192. CDF Plot for Distribution Fitting Test 23.

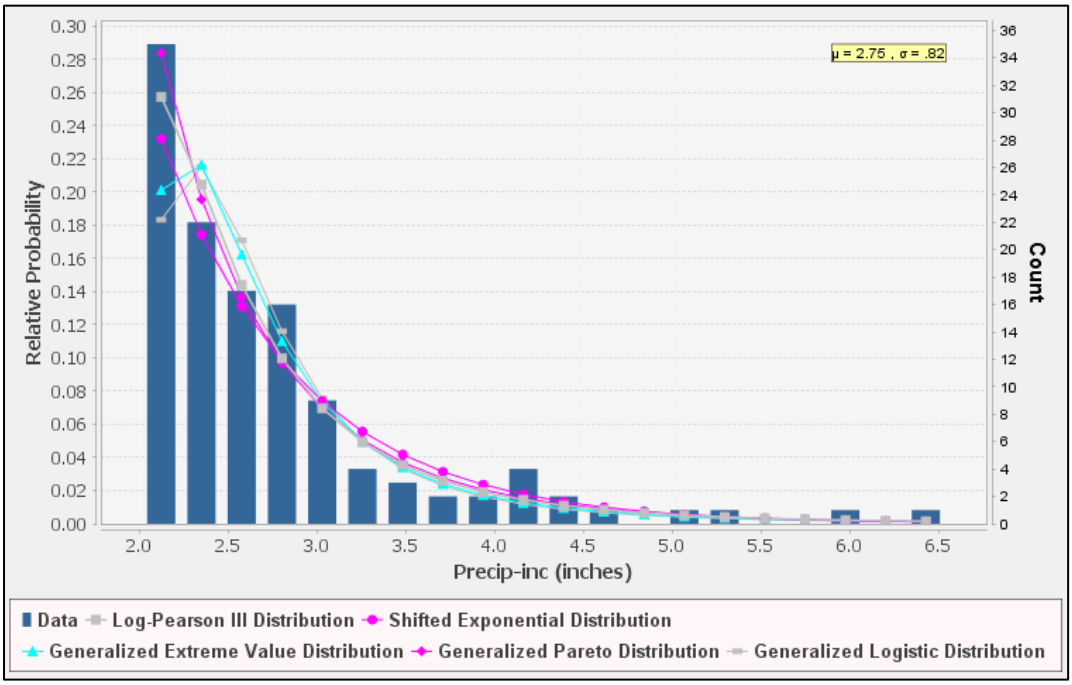


Figure B-193. PDF Plot for Distribution Fitting Test 23.

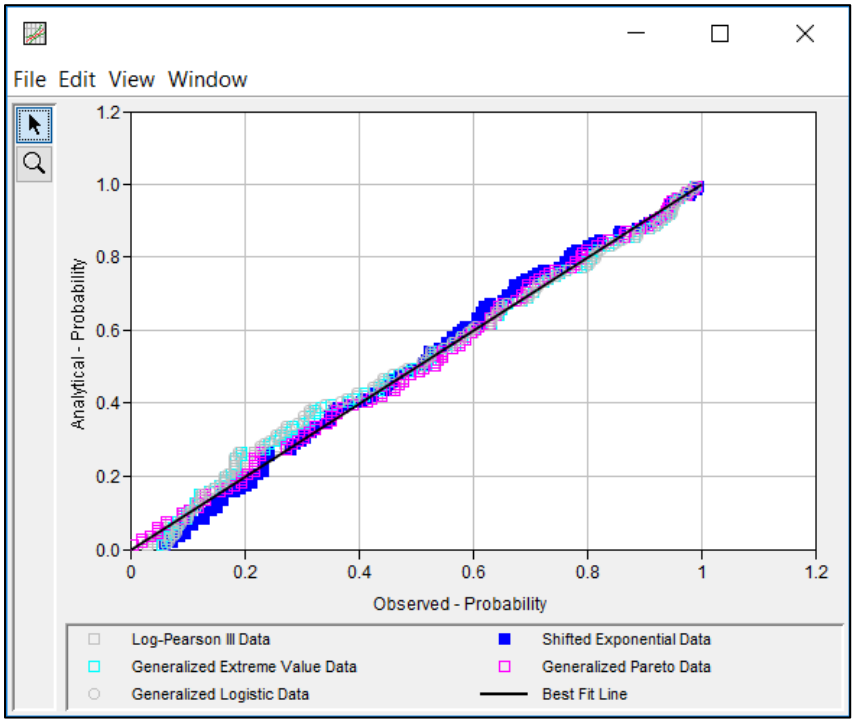


Figure B-194. PP Plot for Distribution Fitting Test 23.

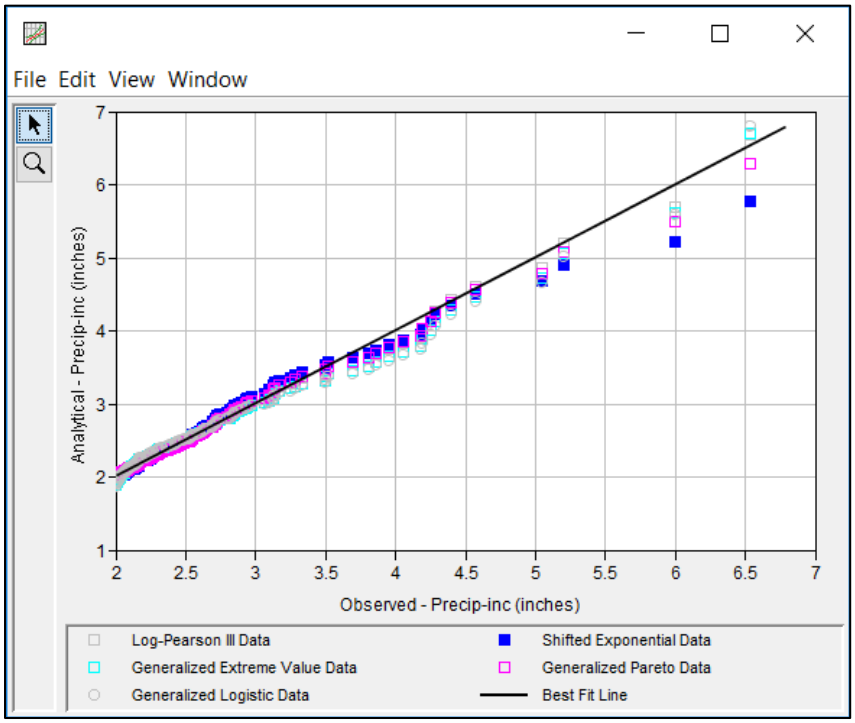


Figure B-195. QQ Plot for Distribution Fitting Test 23.

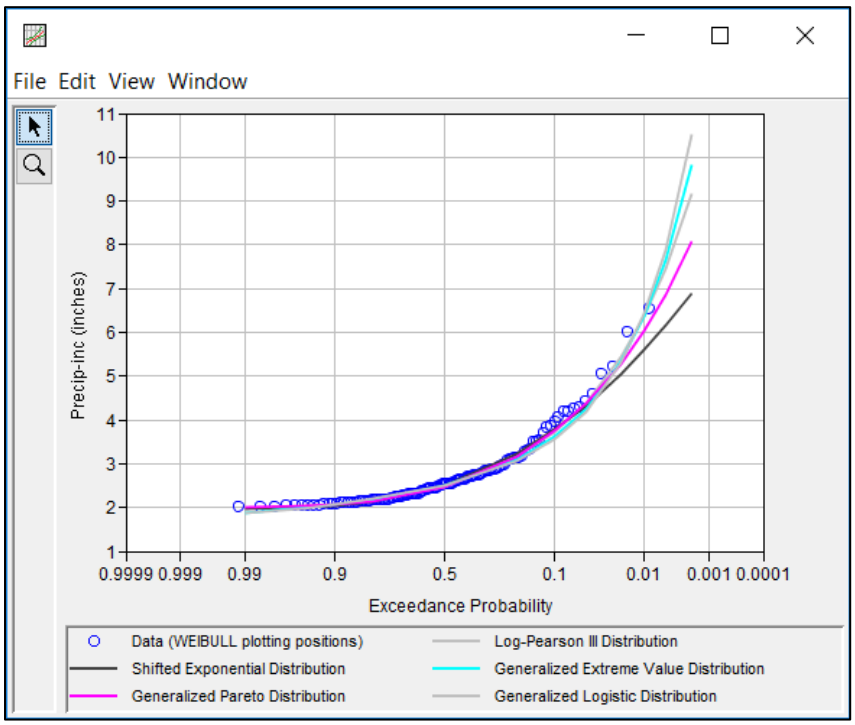
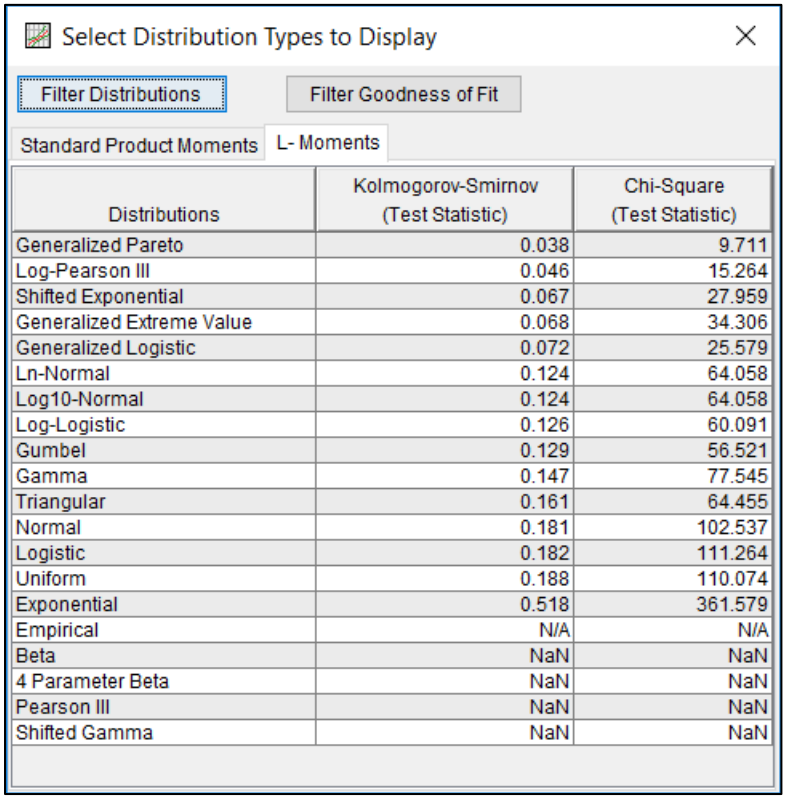


Figure B-196. CDF-Plotting Position Plot for Distribution Fitting Test 23.

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 B-197.



Distributions	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Generalized Pareto	0.038	9.711
Log-Pearson III	0.046	15.264
Shifted Exponential	0.067	27.959
Generalized Extreme Value	0.068	34.306
Generalized Logistic	0.072	25.579
Ln-Normal	0.124	64.058
Log10-Normal	0.124	64.058
Log-Logistic	0.126	60.091
Gumbel	0.129	56.521
Gamma	0.147	77.545
Triangular	0.161	64.455
Normal	0.181	102.537
Logistic	0.182	111.264
Uniform	0.188	110.074
Exponential	0.518	361.579
Empirical	N/A	N/A
Beta	NaN	NaN
4 Parameter Beta	NaN	NaN
Pearson III	NaN	NaN
Shifted Gamma	NaN	NaN

Figure B-197. 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 Selected Distribution** button near the bottom of the Distribution Fitting editor while having that row selected on the Analysis tab. 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 **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 1,000,000, as shown in Figure B-198. Upon clicking the **OK** button, 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 B-199.

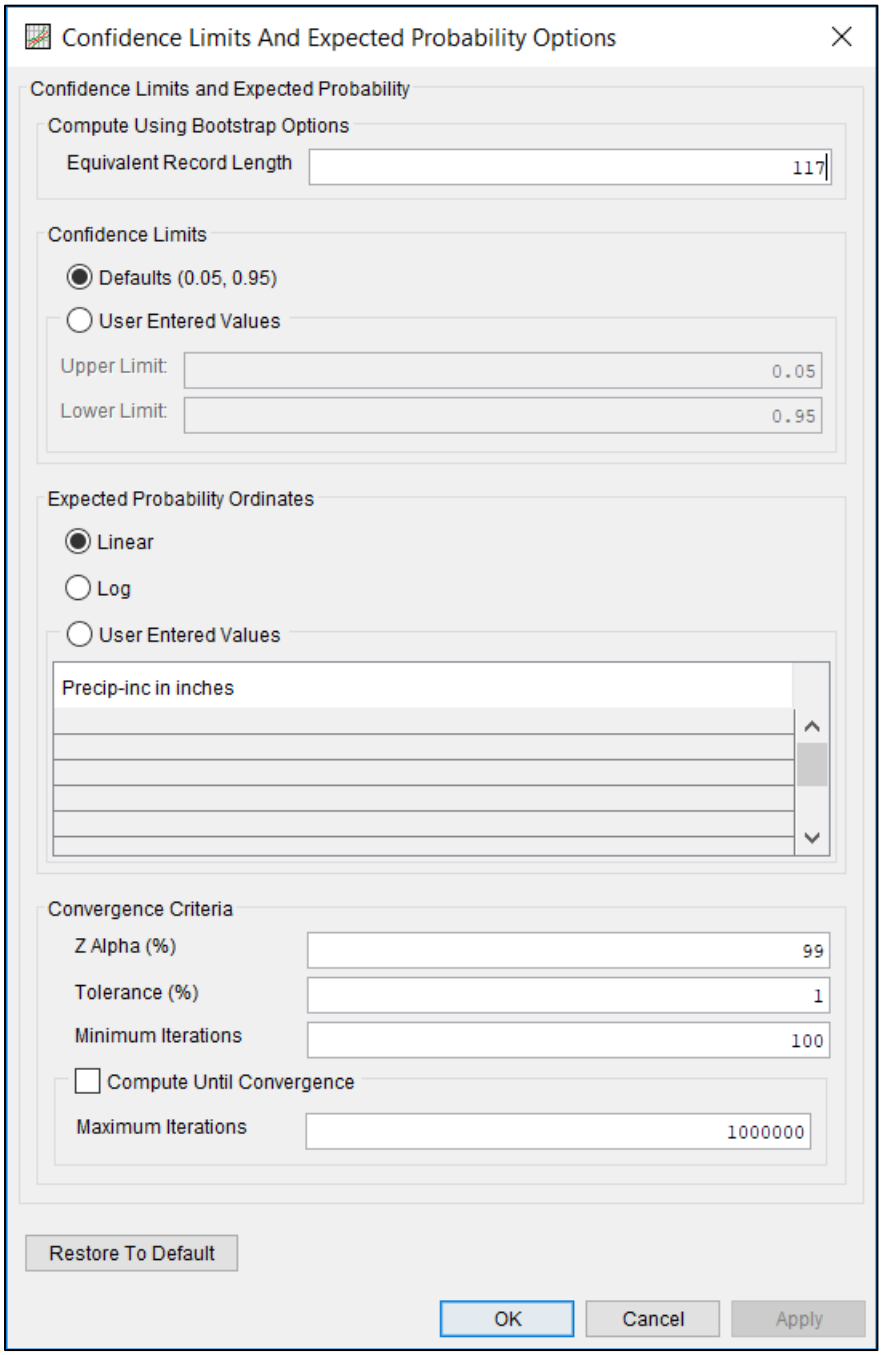


Figure B-198. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 23.

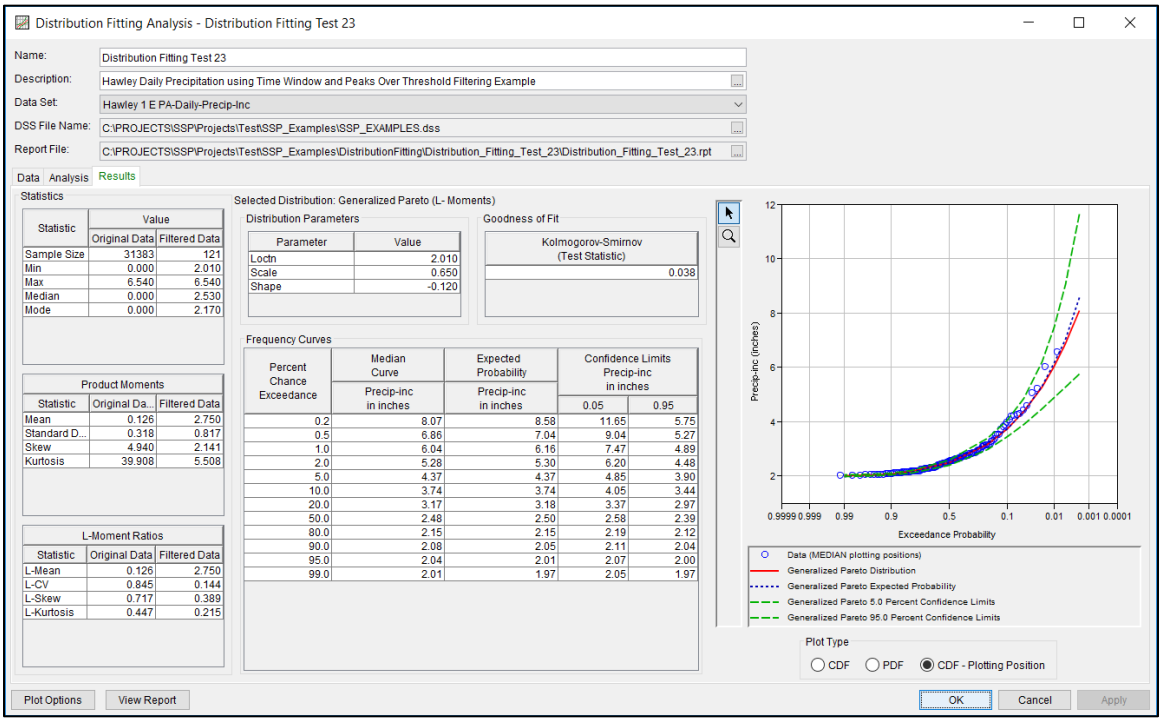


Figure B-199. Distribution Fitting Results Tab Shown for Distribution Fitting Test 23.

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 B-200.

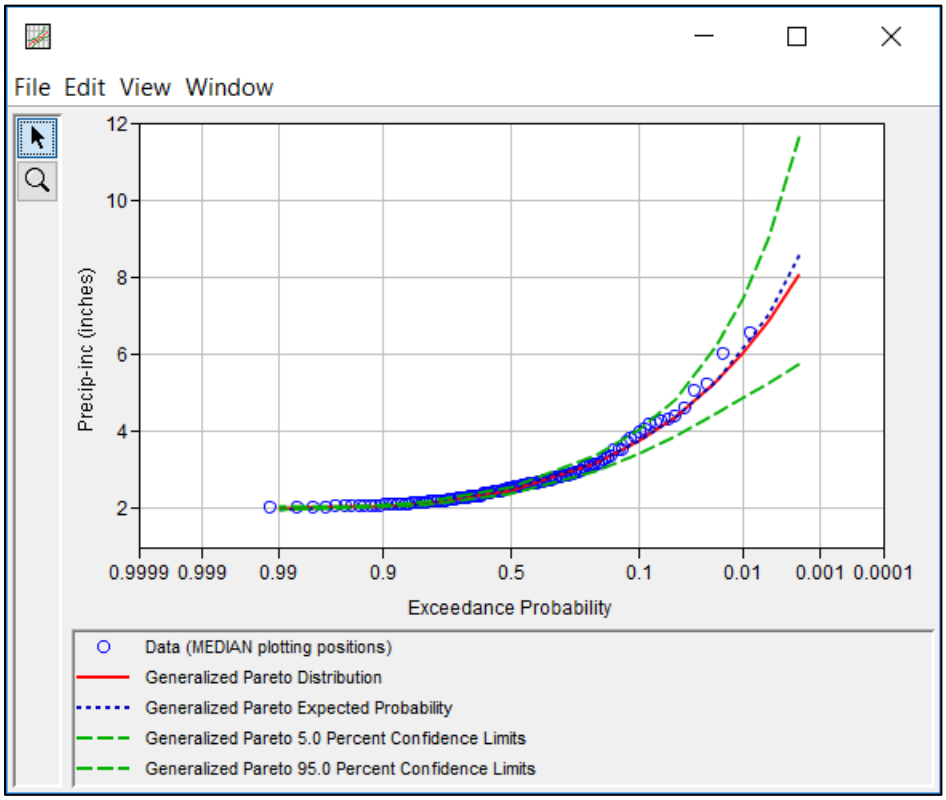


Figure B-200. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 23.

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 B-201.

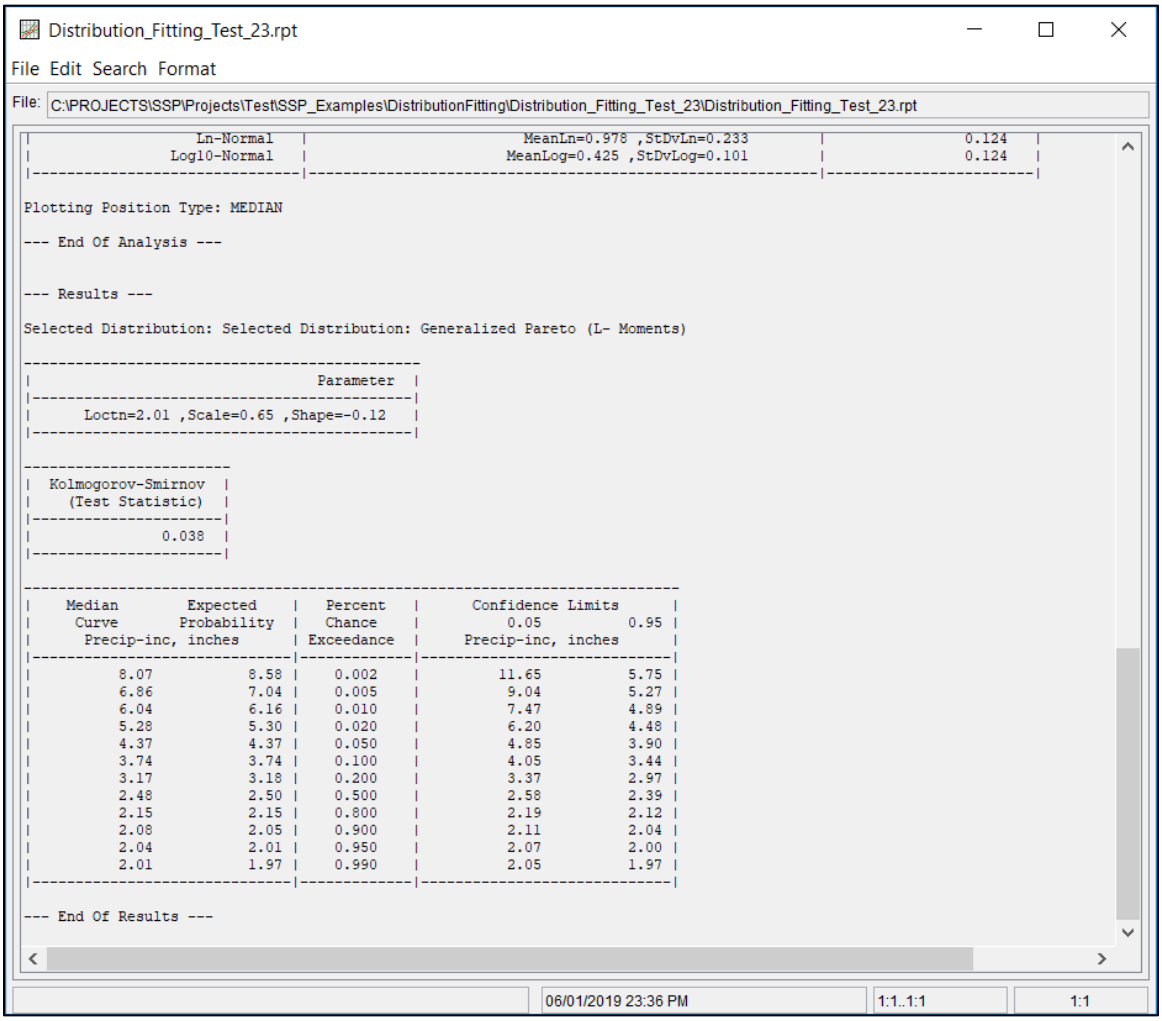


Figure B-201. Report File for Distribution Fitting Test 23.

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 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 B-202.

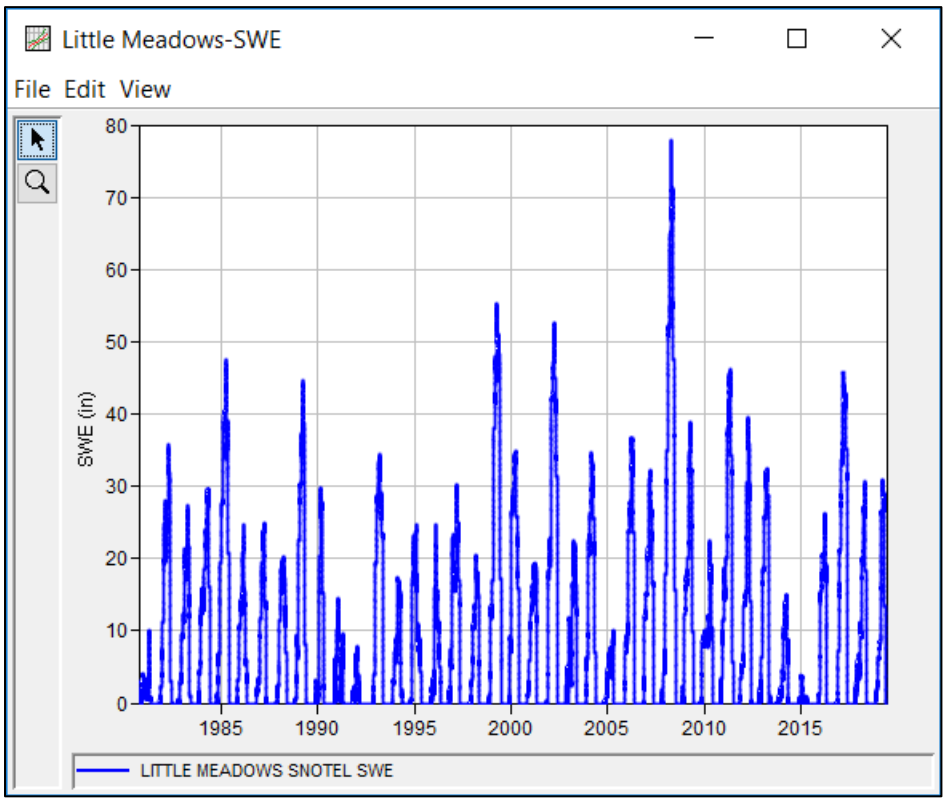


Figure B-202. Plot of the Little Meadows SWE Data.

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 B-203.

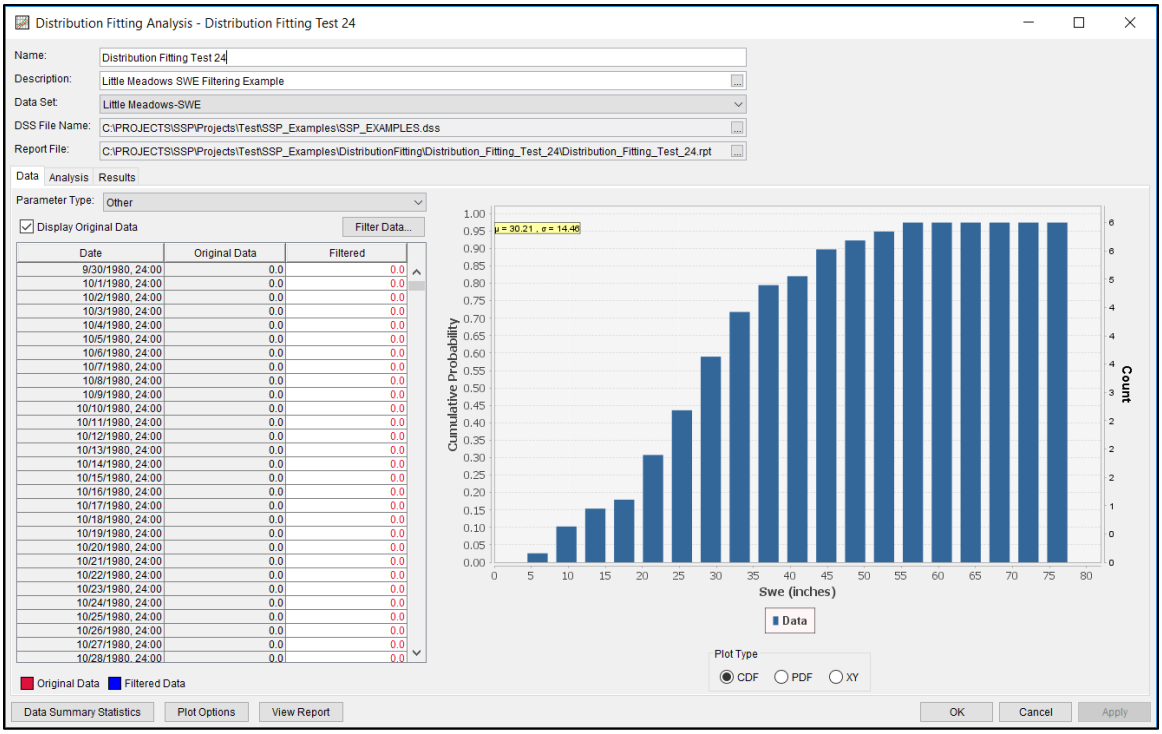


Figure B-203. Distribution Fitting Analysis Editor for Distribution Fitting Test 24.

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 B-204. The original data as well as the filtered data is shown in Figure B-205.

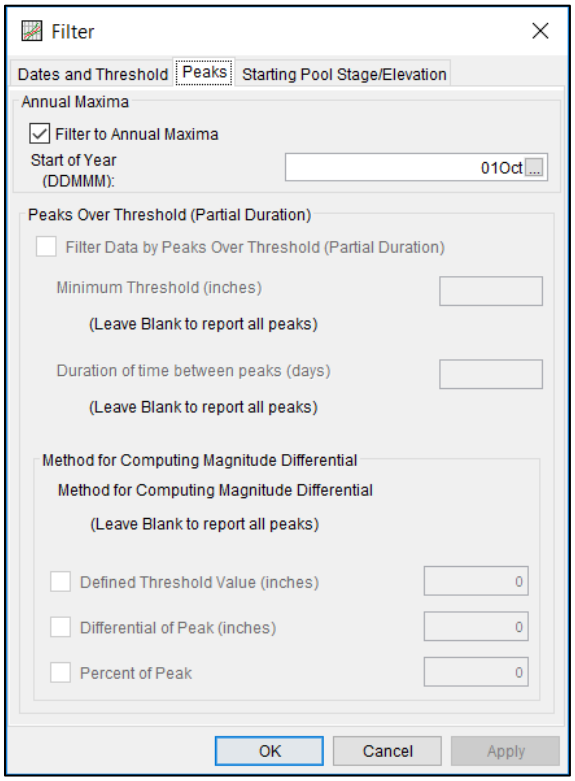


Figure B-204. Data Filters Used within Distribution Fitting Test 24.

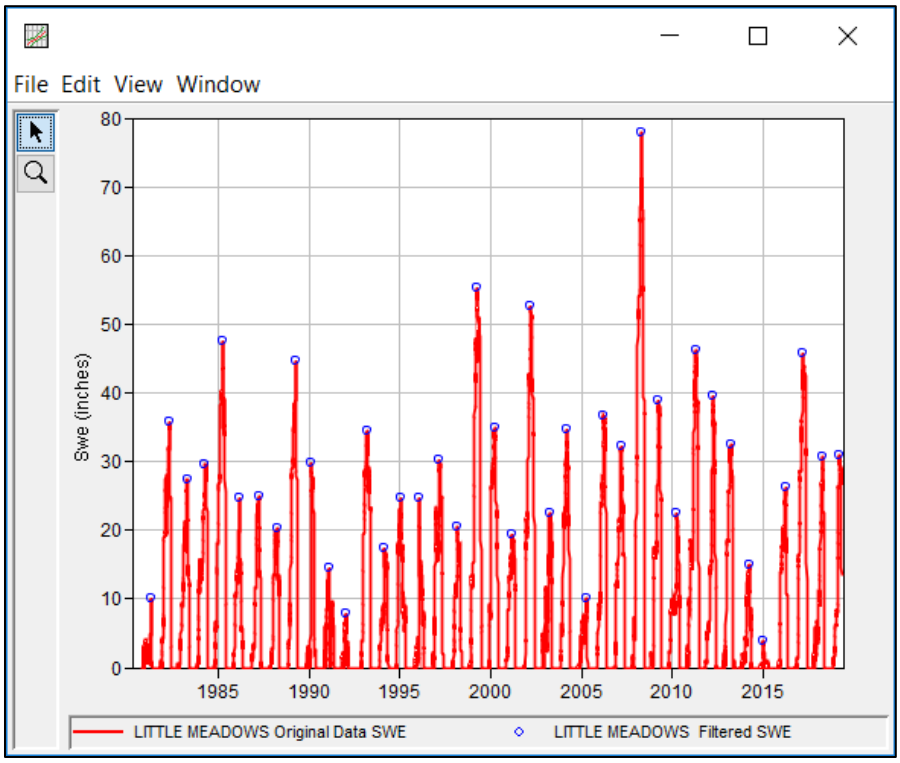
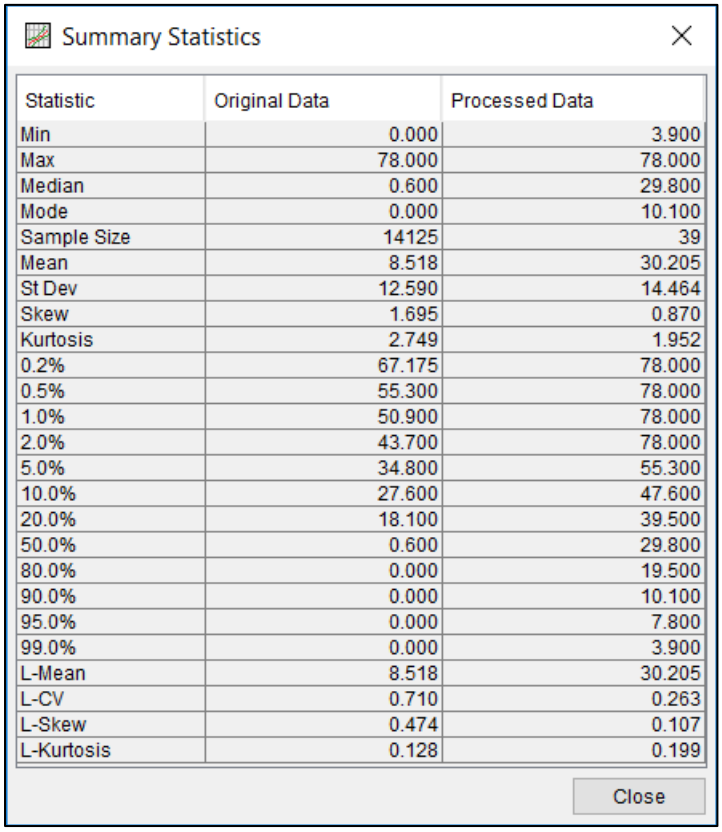


Figure B-205. Original and Filtered Data within Distribution Fitting Test 24.

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 B-206.



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

Figure B-206. 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 B-207, the **Filter Using Parameter** radio button was selected within the Distribution Filter panel. The default Product Moments fitting method was changed to L-Moments by clicking on the column header and selecting **L-Moments**. 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, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure B-208, Figure B-209, Figure B-210, Figure B-211, and Figure B-212.

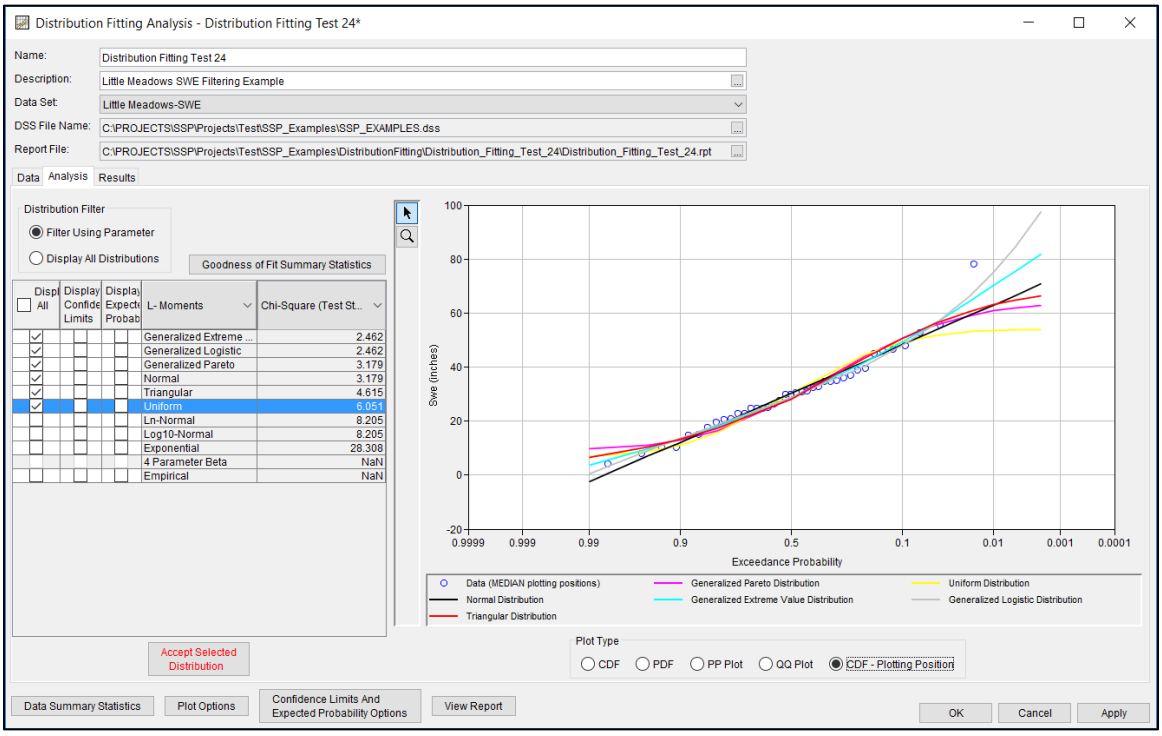


Figure B-207. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 24.

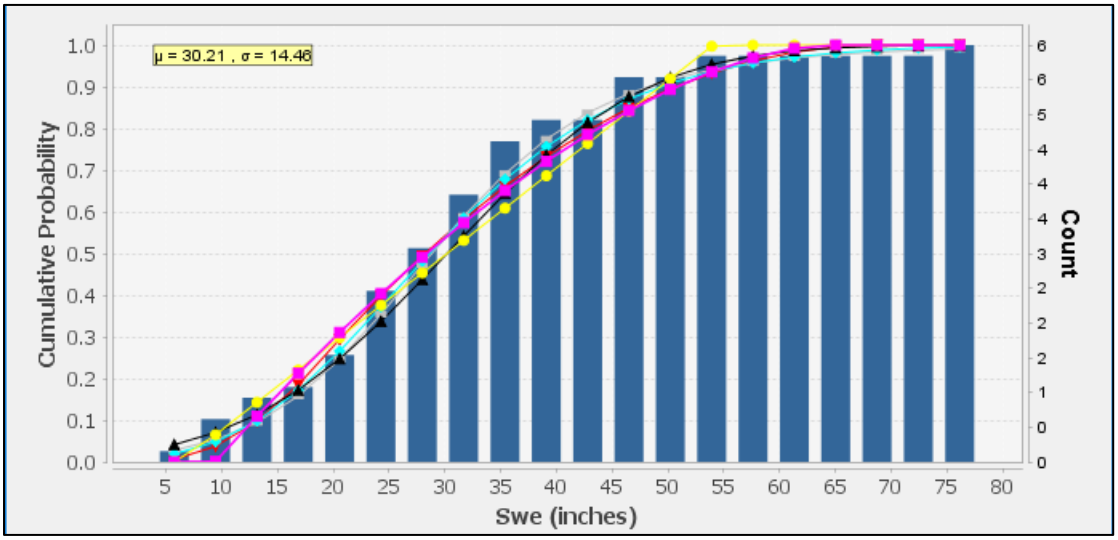


Figure B-208. CDF Plot for Distribution Fitting Test 24.

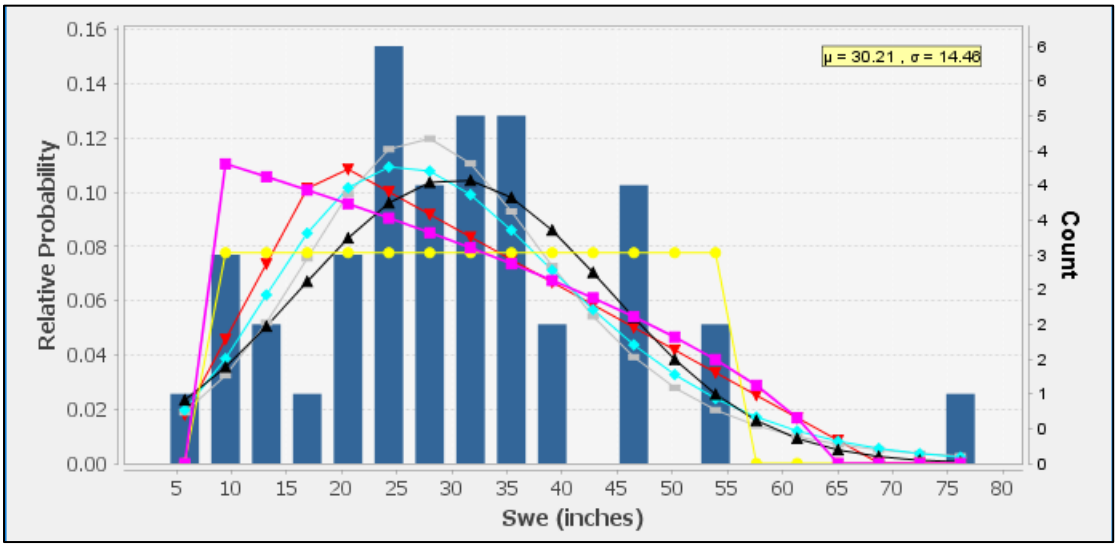


Figure B-209. PDF Plot for Distribution Fitting Test 24.

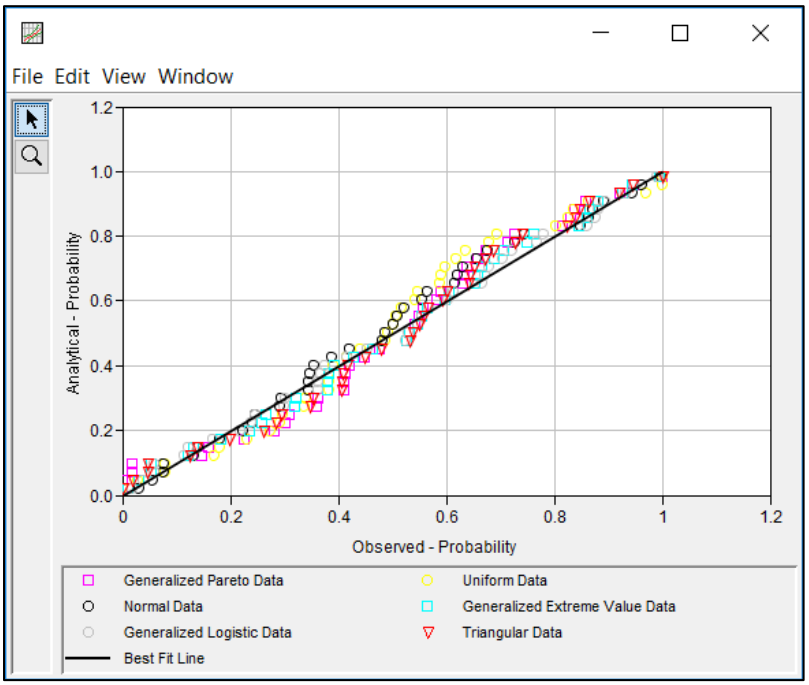


Figure B-210. PP Plot for Distribution Fitting Test 24.

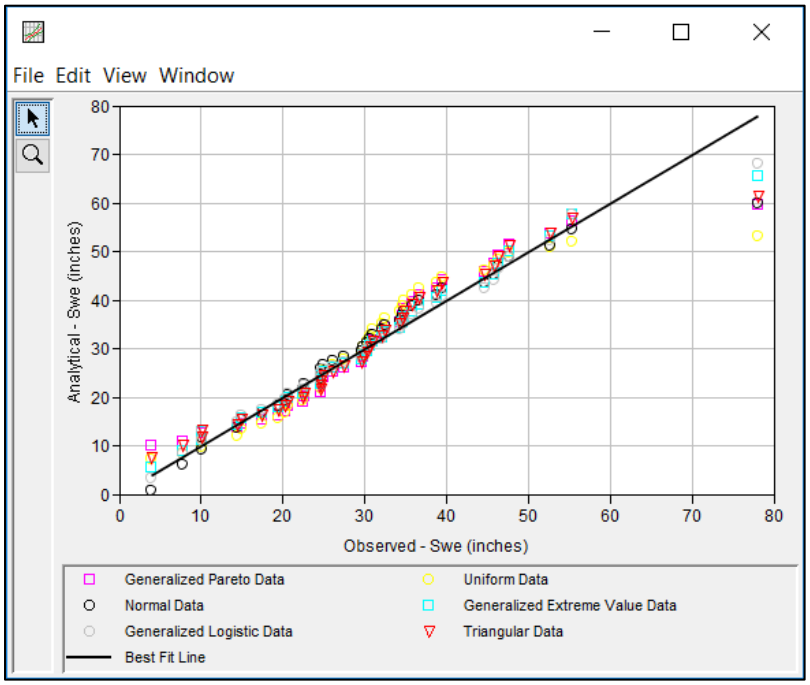


Figure B-211. QQ Plot for Distribution Fitting Test 24.

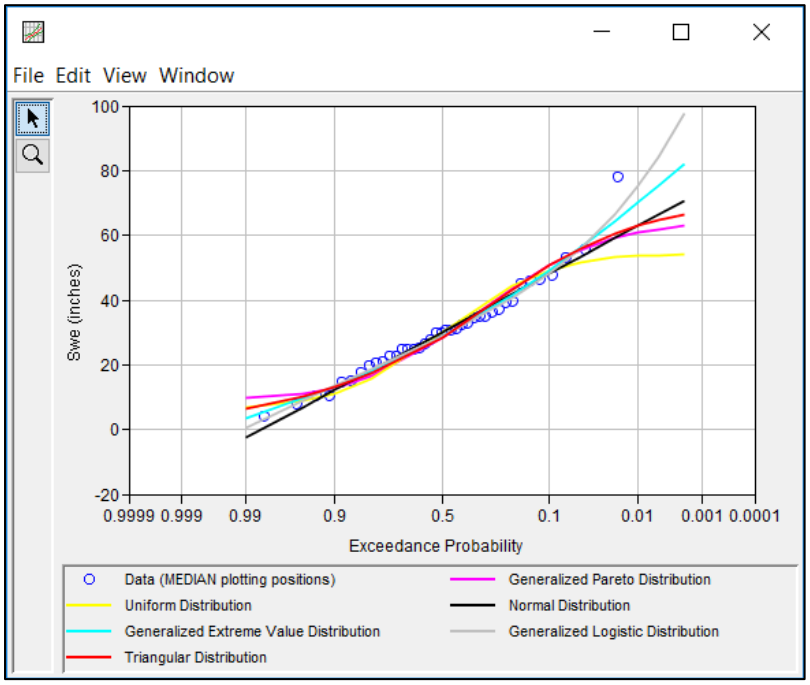
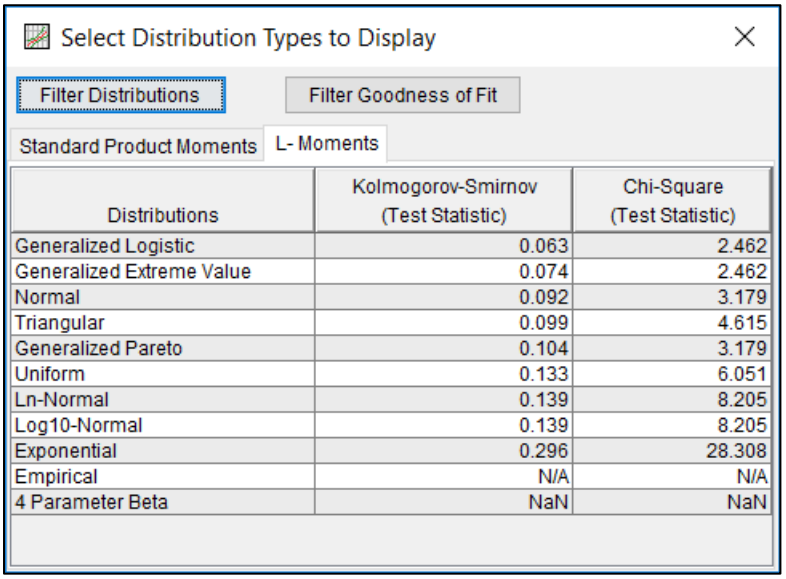


Figure B-212. CDF-Plotting Position Plot for Distribution Fitting Test 24.

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 B-213.



Distributions	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Generalized Logistic	0.063	2.462
Generalized Extreme Value	0.074	2.462
Normal	0.092	3.179
Triangular	0.099	4.615
Generalized Pareto	0.104	3.179
Uniform	0.133	6.051
Ln-Normal	0.139	8.205
Log10-Normal	0.139	8.205
Exponential	0.296	28.308
Empirical	N/A	N/A
4 Parameter Beta	NaN	NaN

Figure B-213. 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 Selected Distribution** button near the bottom of the Distribution Fitting editor while having that row selected on the Analysis tab. 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 **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 10,000,000, as shown in Figure B-214. Upon clicking the **OK** button, 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 B-215.

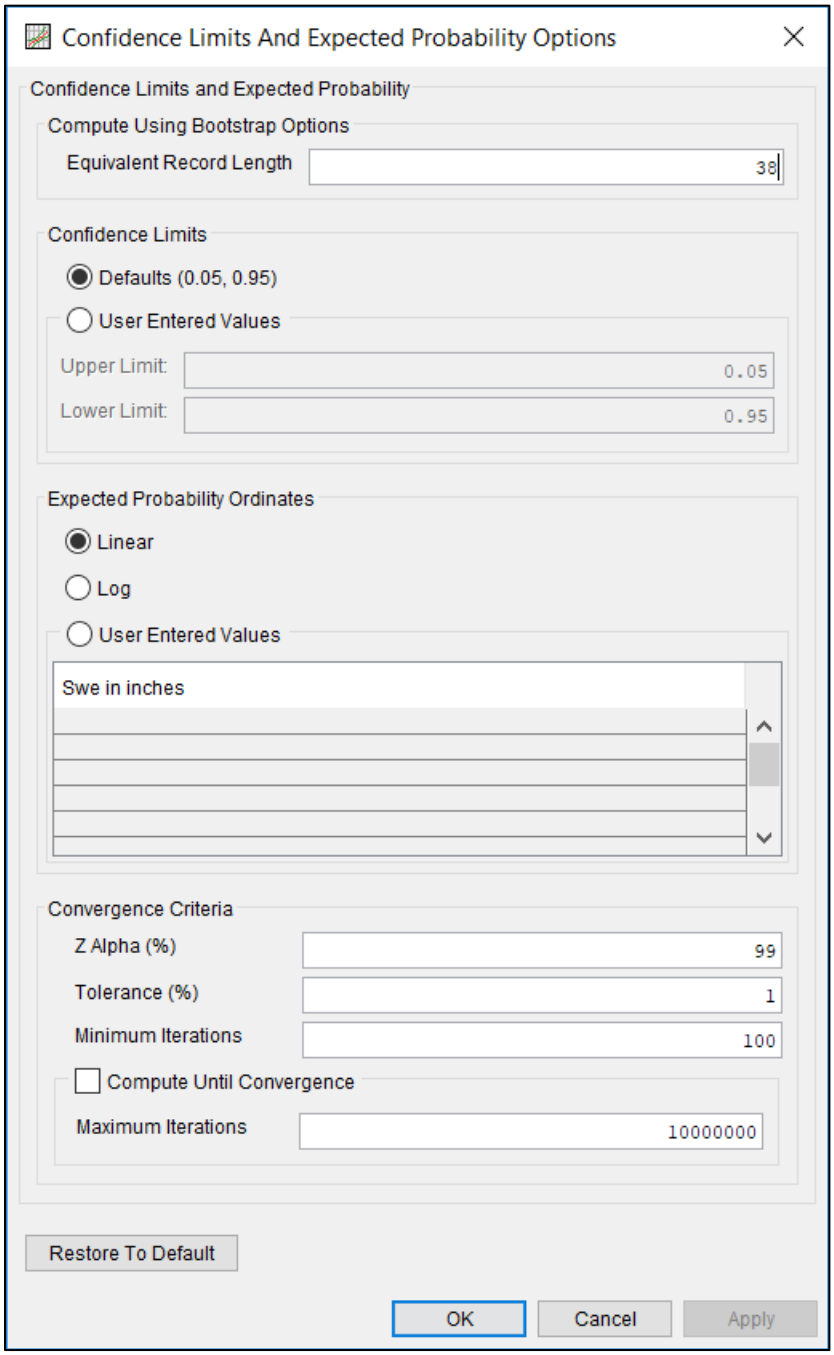


Figure B-214. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 24.

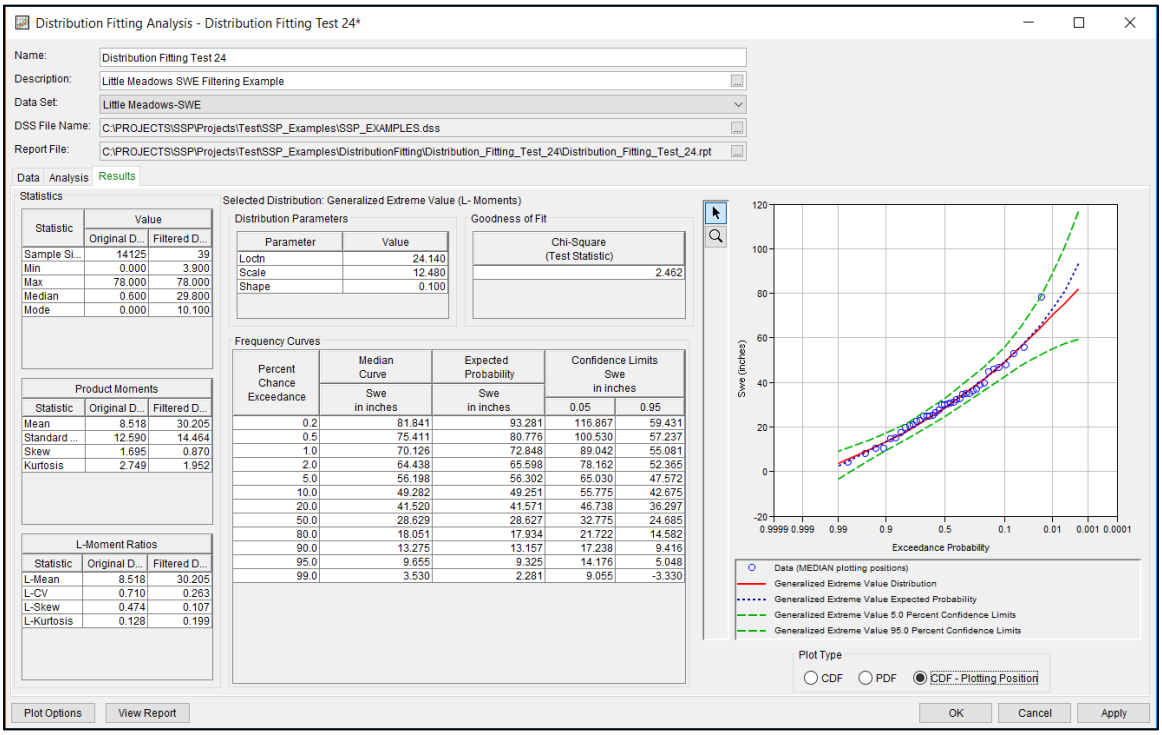


Figure B-215. Distribution Fitting Results Tab Shown for Distribution Fitting Test 24.

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 B-216.

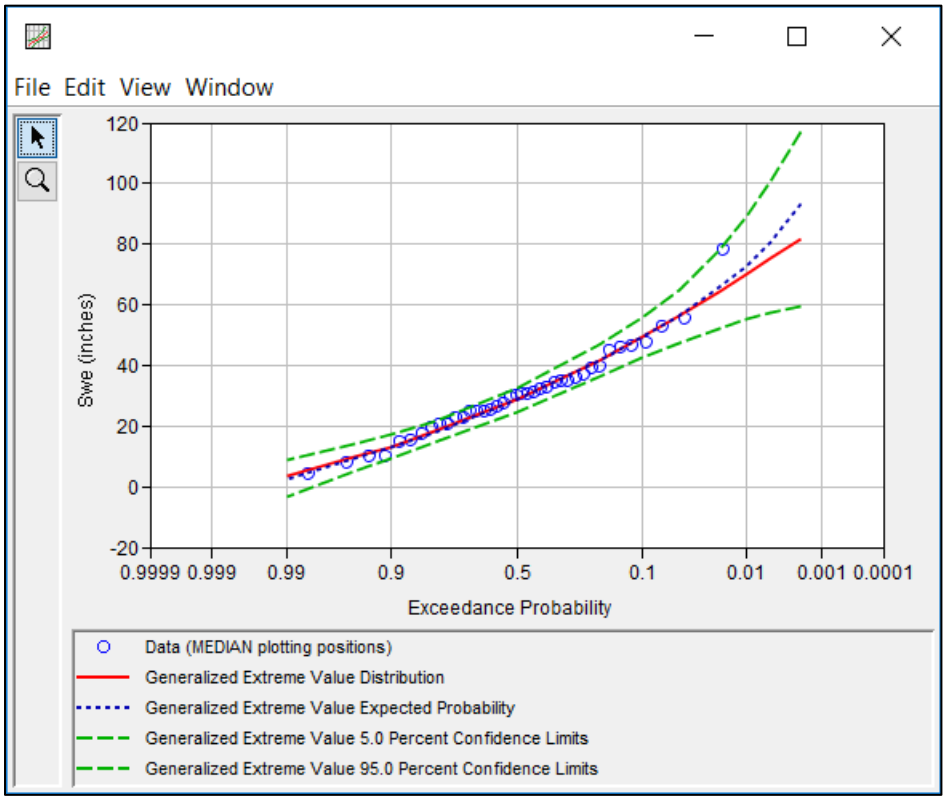


Figure B-216. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 24.

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 B-217.

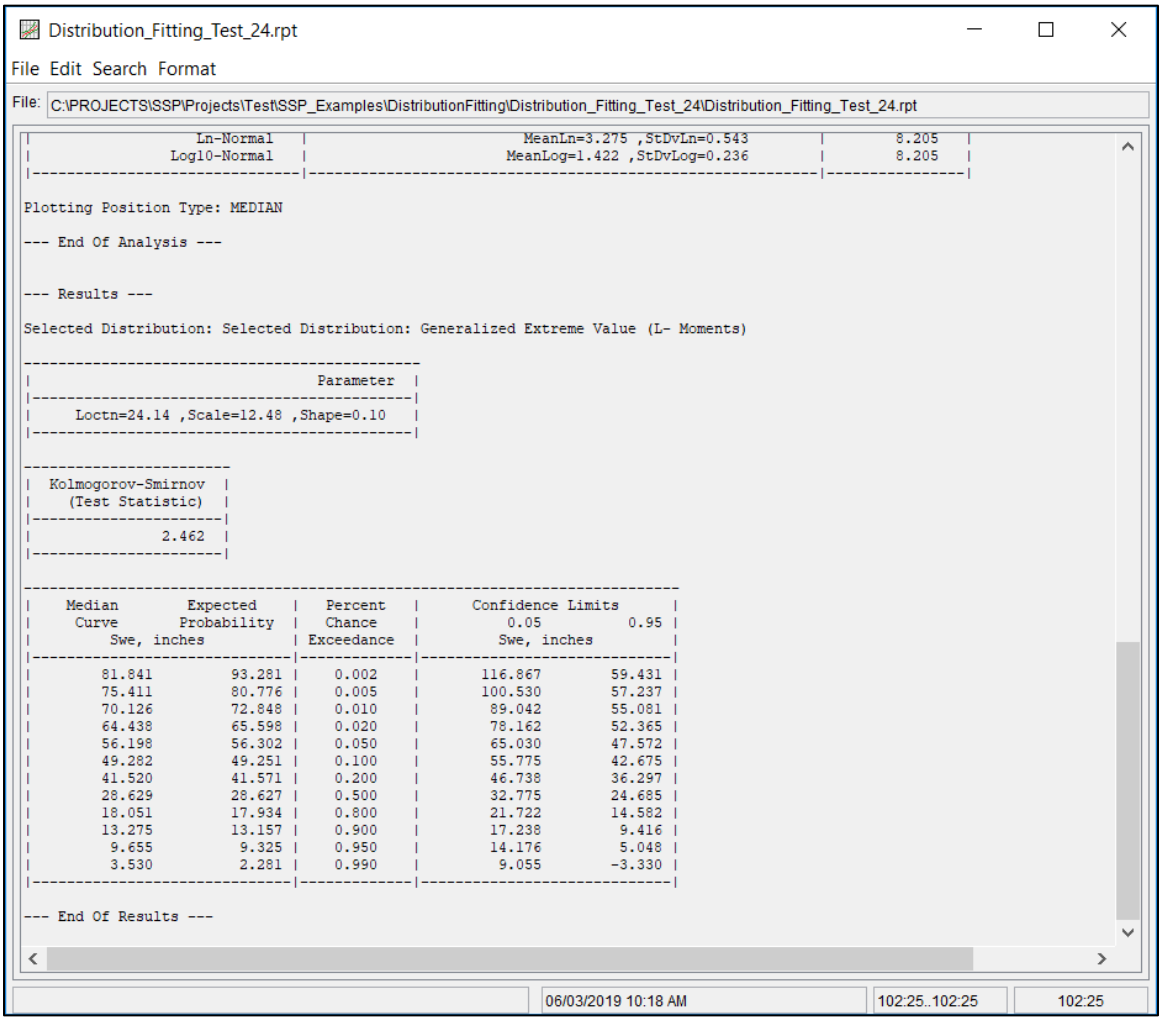


Figure B-217. Report File for Distribution Fitting Test 24.

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. 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 B-218.

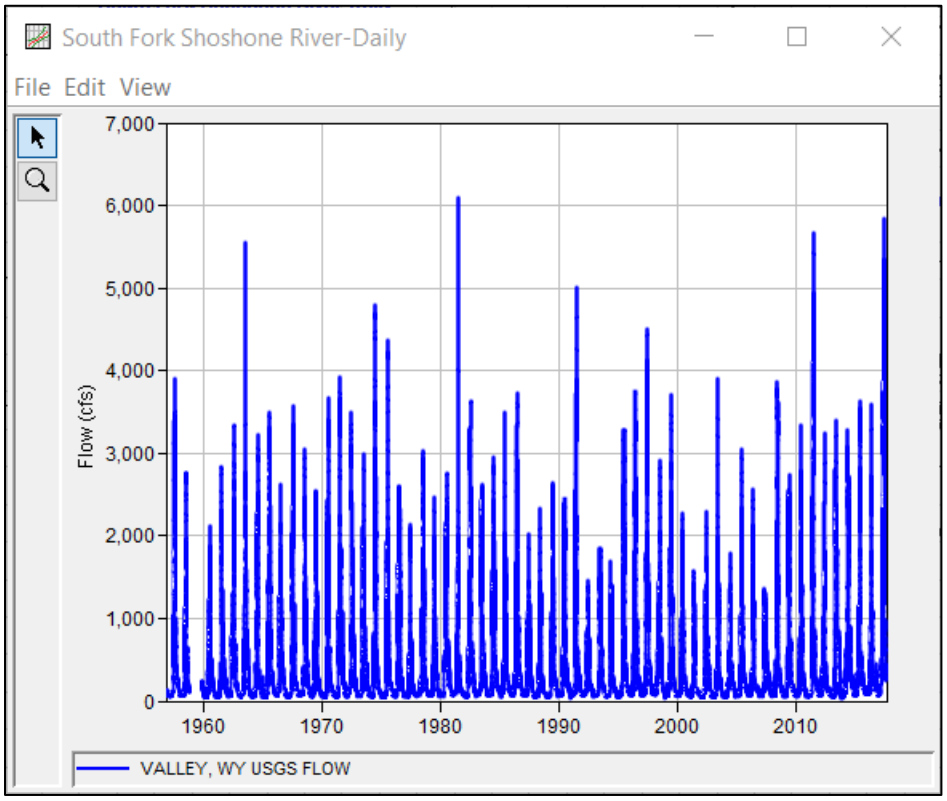


Figure B-218. Plot of the Daily Average Flow Data for South Fork Shoshone River.

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 B-219.

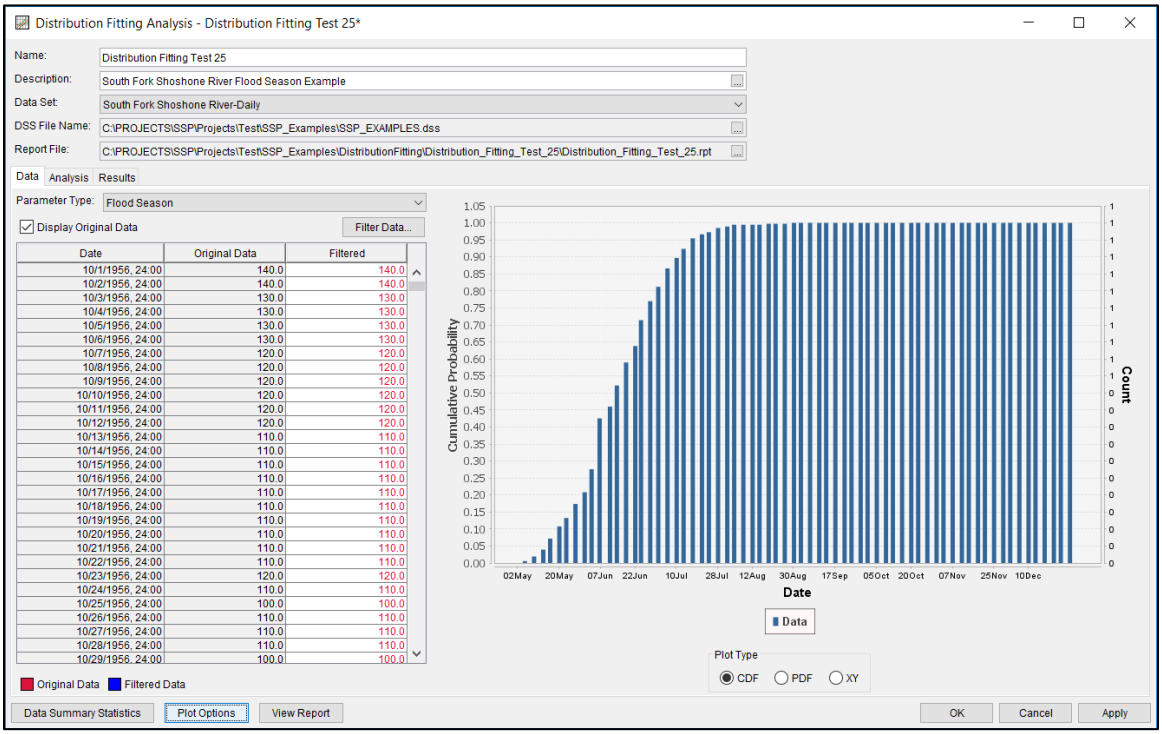


Figure B-219. Distribution Fitting Analysis Editor for Distribution Fitting Test 25.

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 B-220. 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 B-221. The original data as well as the filtered data is shown in Figure B-222.

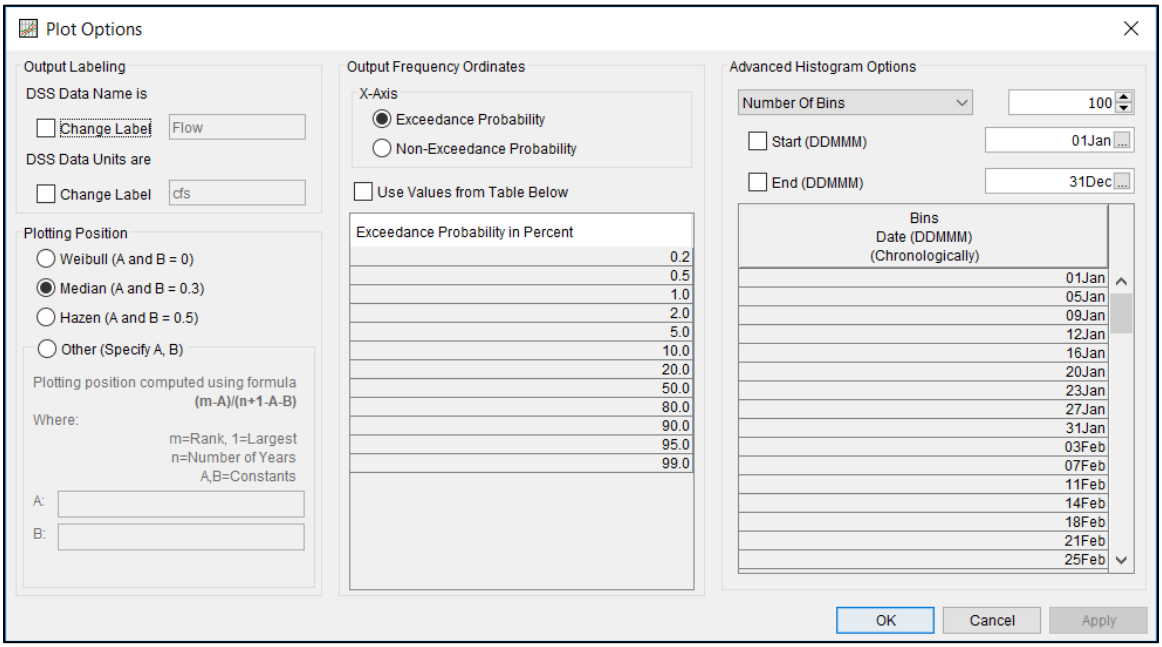


Figure B-220. Plot Options for Distribution Fitting Test 25.

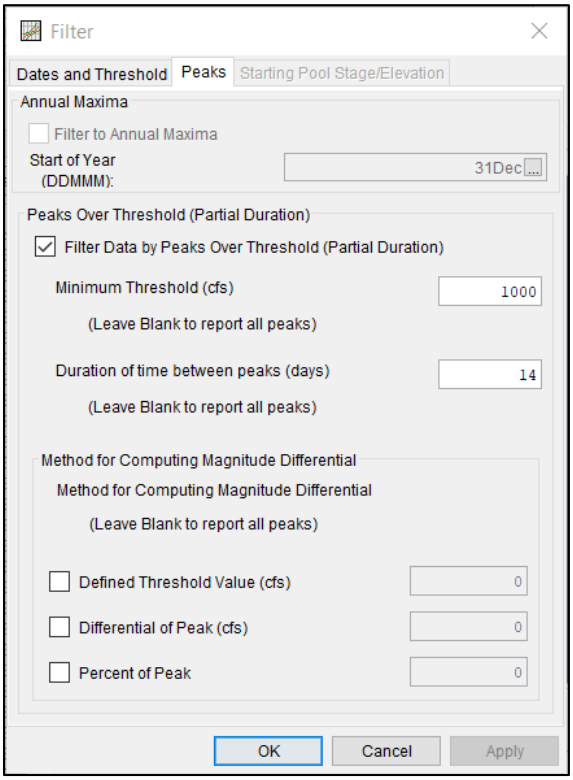


Figure B-221. Data Filters Used within Distribution Fitting Test 25.

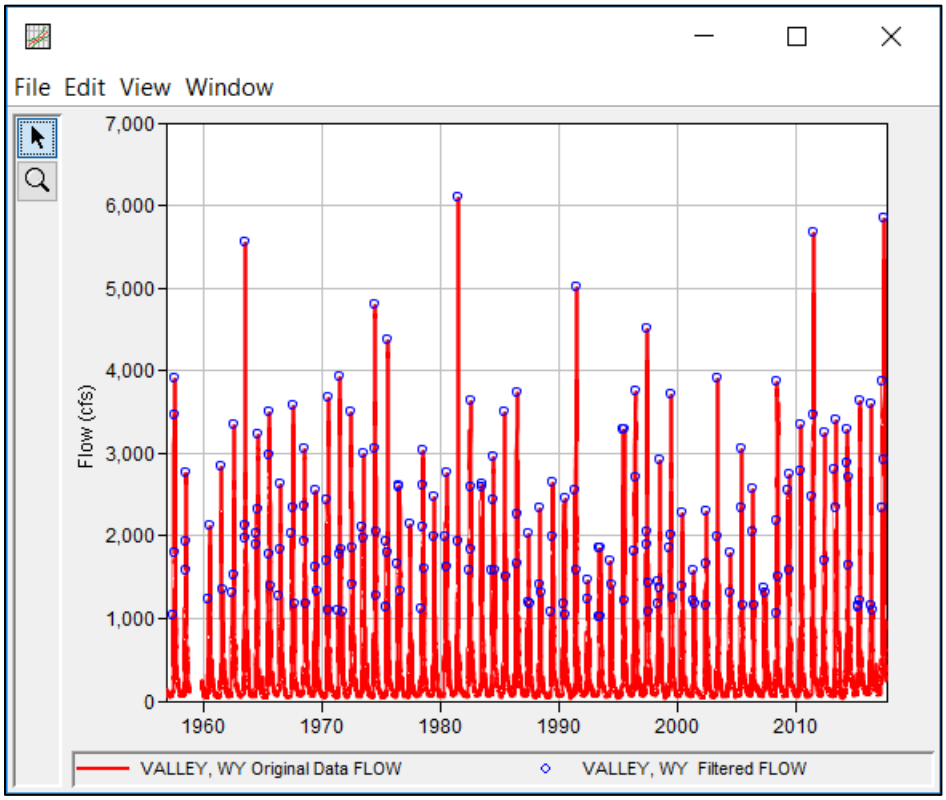
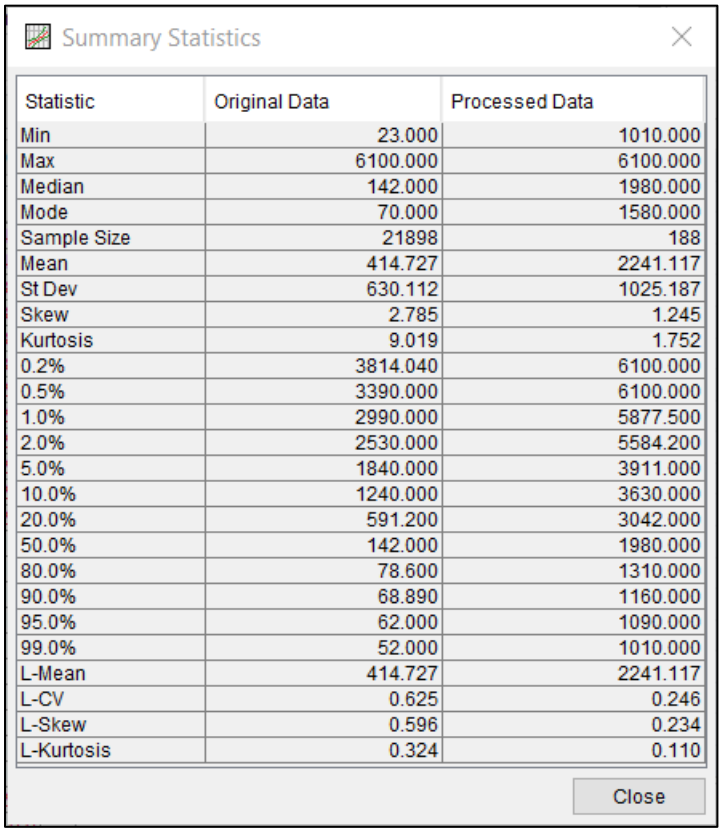


Figure B-222. Original and Filtered Data within Distribution Fitting Test 25.

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 B-223.



Statistic	Original Data	Processed Data
Min	23.000	1010.000
Max	6100.000	6100.000
Median	142.000	1980.000
Mode	70.000	1580.000
Sample Size	21898	188
Mean	414.727	2241.117
St Dev	630.112	1025.187
Skew	2.785	1.245
Kurtosis	9.019	1.752
0.2%	3814.040	6100.000
0.5%	3390.000	6100.000
1.0%	2990.000	5877.500
2.0%	2530.000	5584.200
5.0%	1840.000	3911.000
10.0%	1240.000	3630.000
20.0%	591.200	3042.000
50.0%	142.000	1980.000
80.0%	78.600	1310.000
90.0%	68.890	1160.000
95.0%	62.000	1090.000
99.0%	52.000	1010.000
L-Mean	414.727	2241.117
L-CV	0.625	0.246
L-Skew	0.596	0.234
L-Kurtosis	0.324	0.110

Figure B-223. 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 B-224, 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, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure B-225, Figure B-226, Figure B-227, Figure B-228, and Figure B-229. 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.

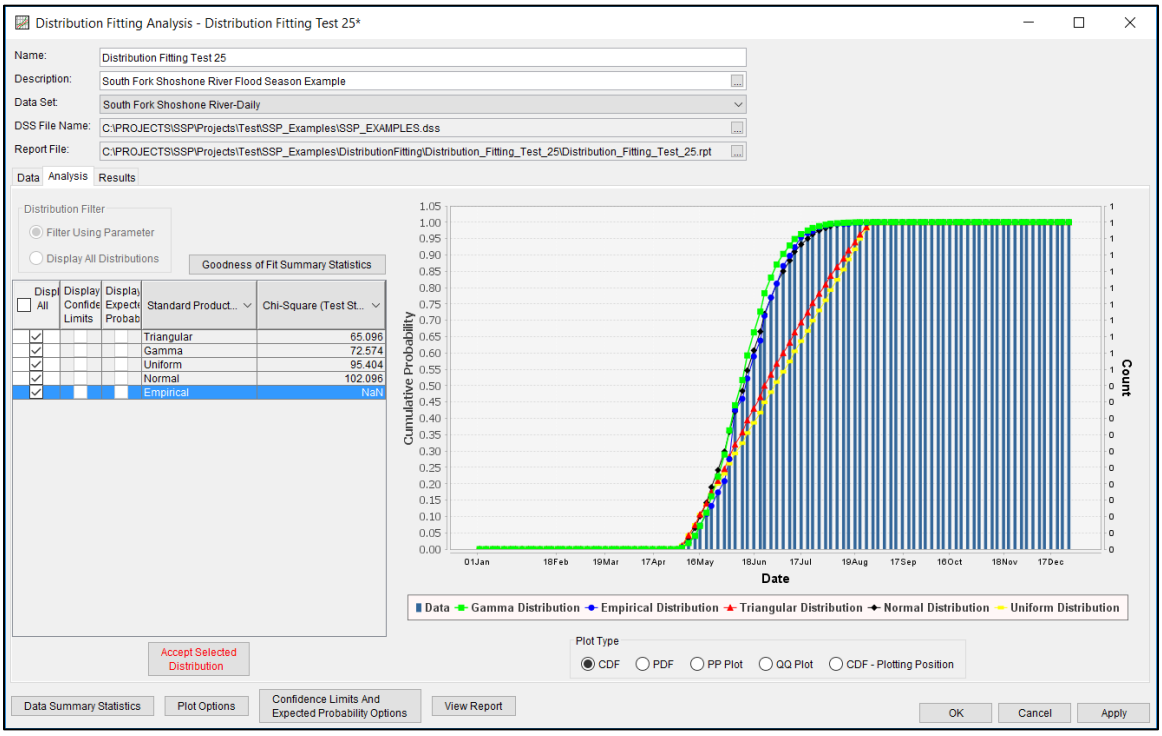


Figure B-224. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 25.

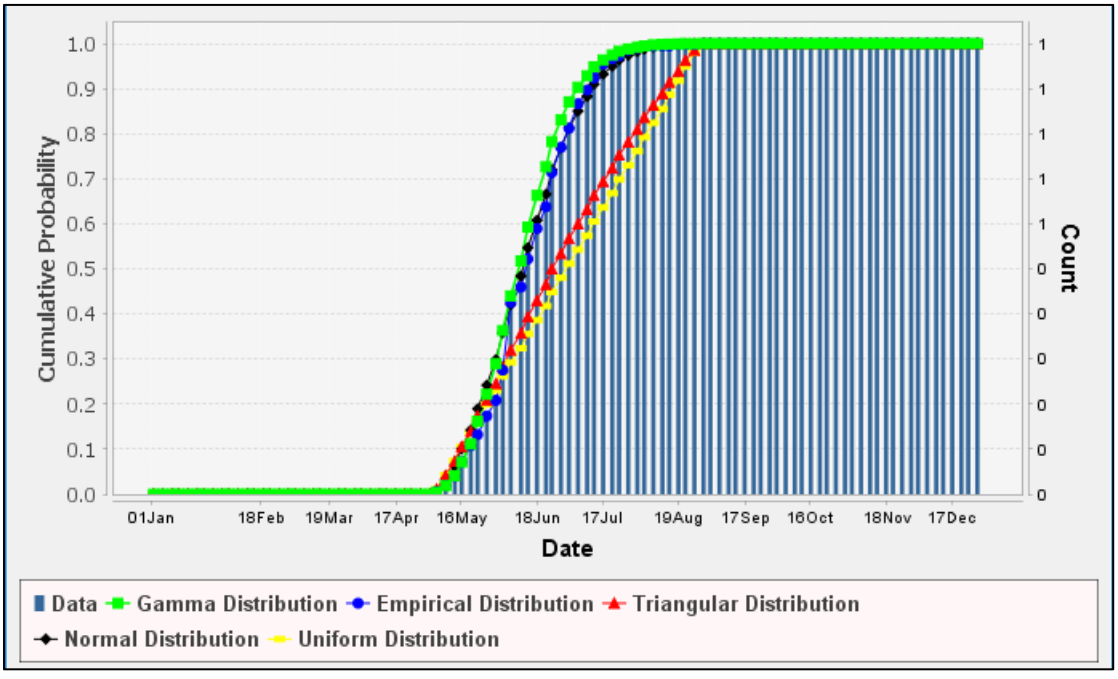


Figure B-225. CDF Plot for Distribution Fitting Test 25.

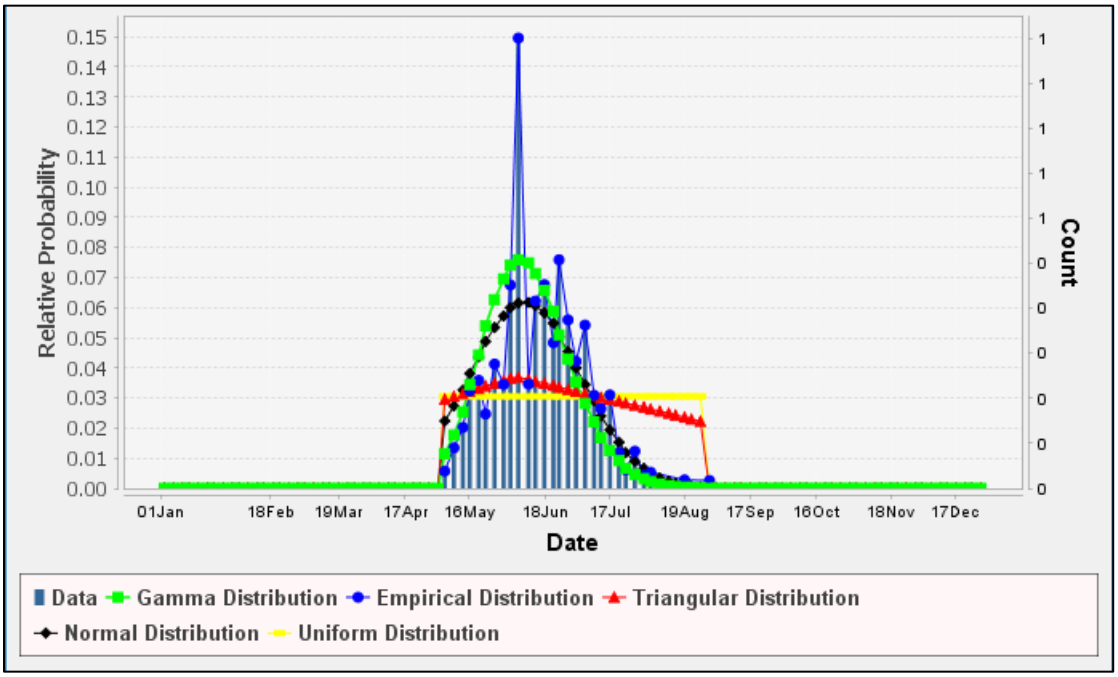


Figure B-226. PDF Plot for Distribution Fitting Test 25.

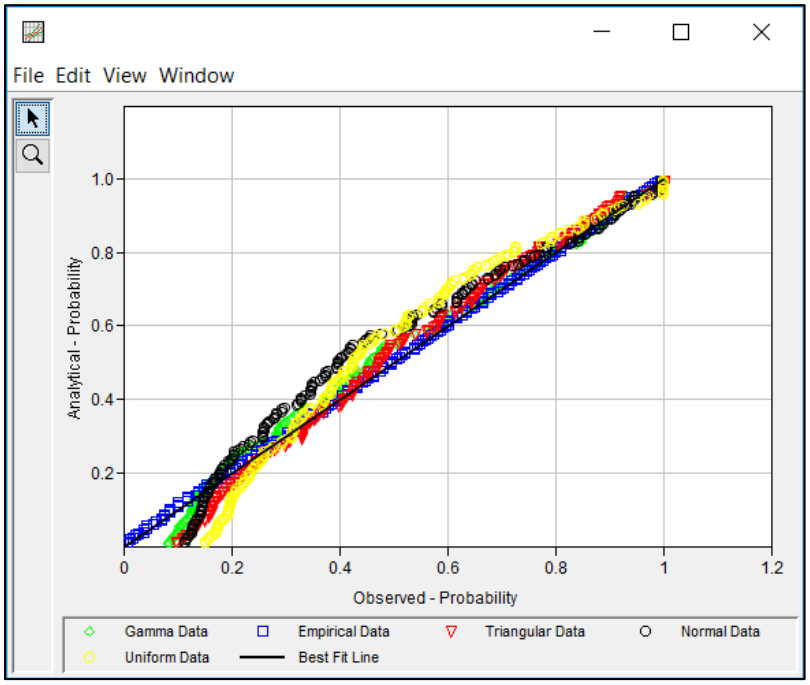


Figure B-227. PP Plot for Distribution Fitting Test 25.

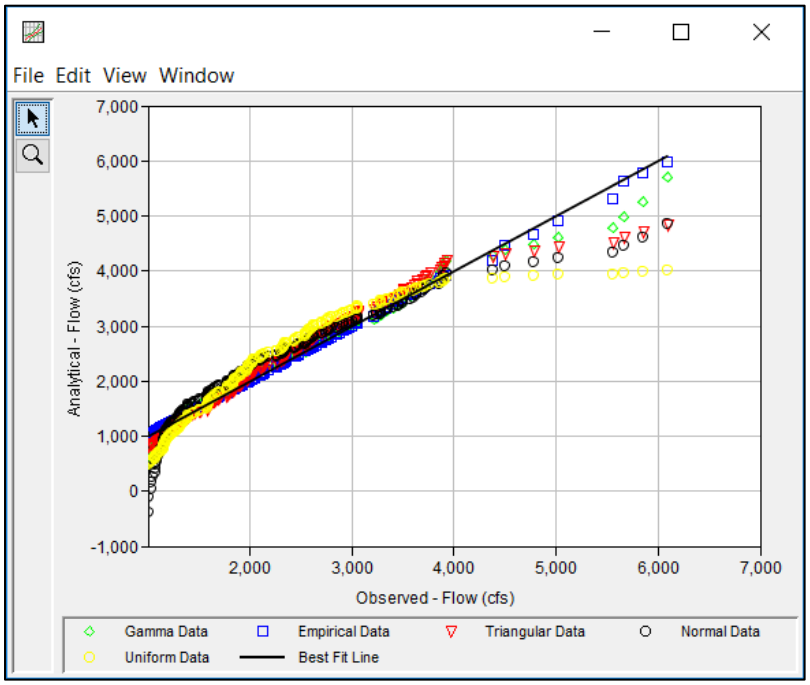


Figure B-228. QQ Plot for Distribution Fitting Test 25.

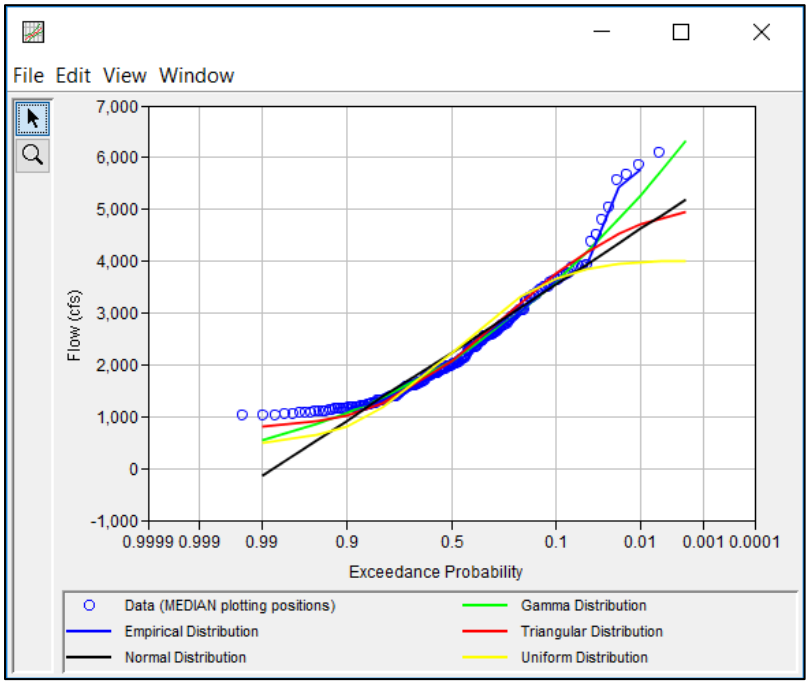


Figure B-229. CDF-Plotting Position Plot for Distribution Fitting Test 25.

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 B-230.

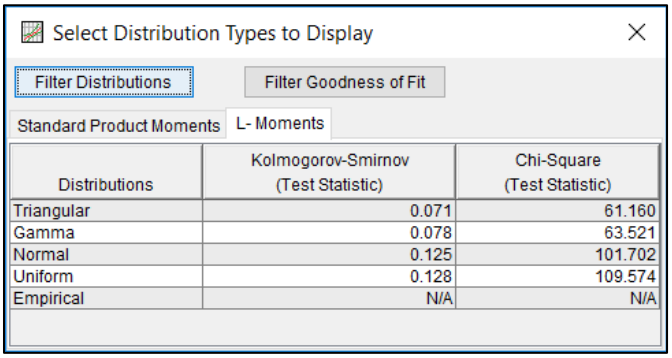


Figure B-230. Goodness of Fit Summary Statistics for Distribution Fitting Test 25.

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 B-231. 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.

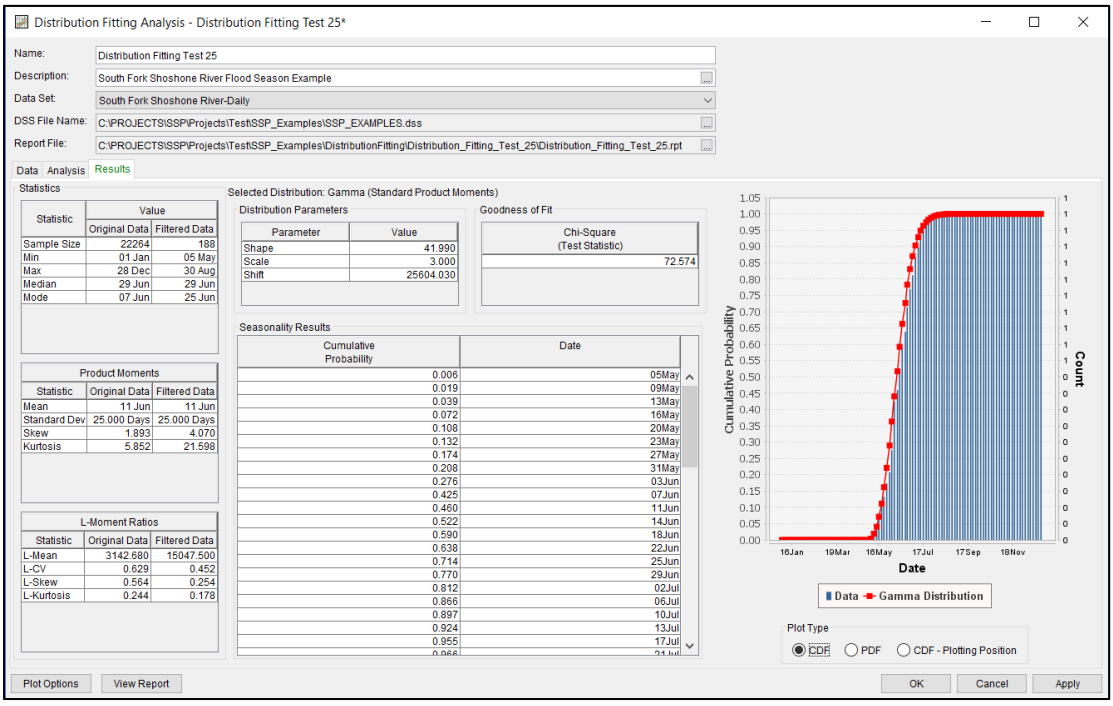


Figure B-231. Distribution Fitting Results Tab Shown for Distribution Fitting Test 25.

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 B-232.

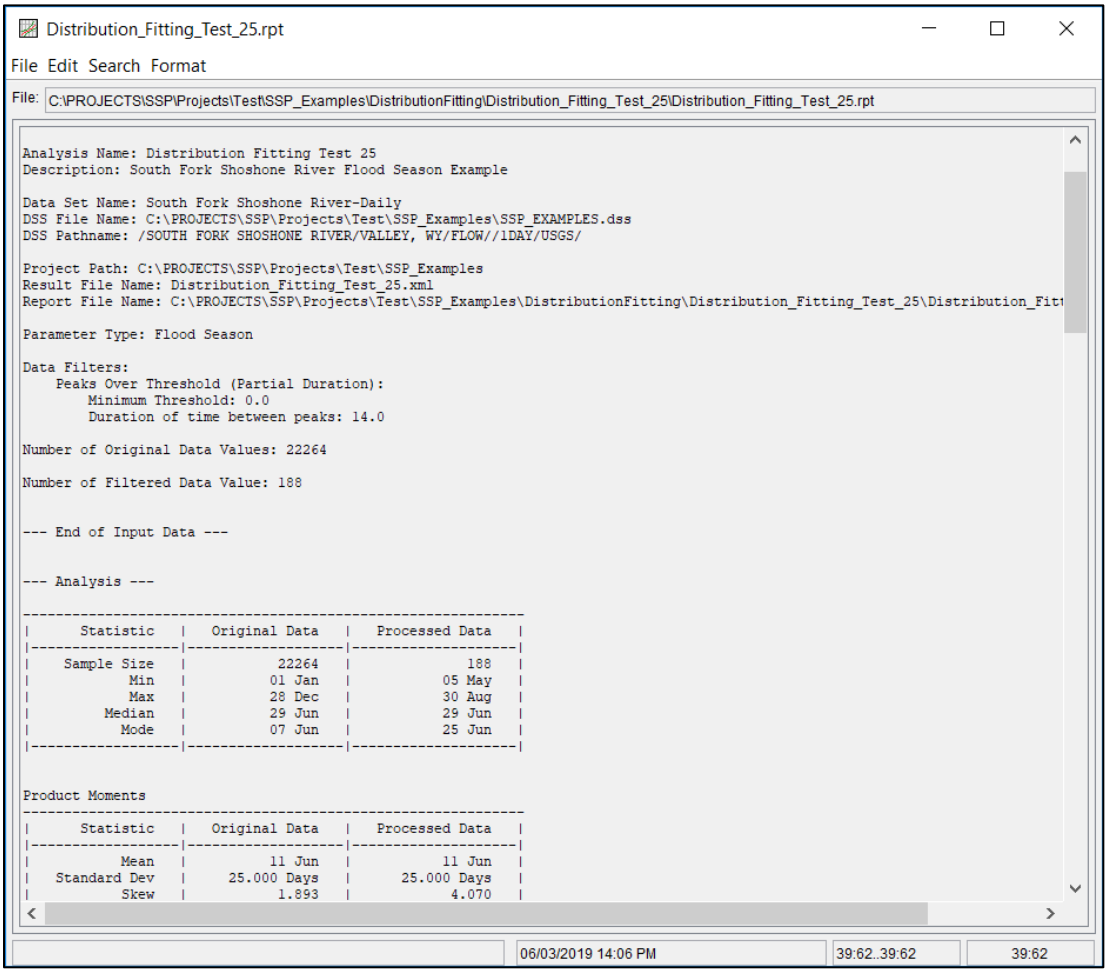


Figure B-232. Report File for Distribution Fitting Test 25.

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 B-233.

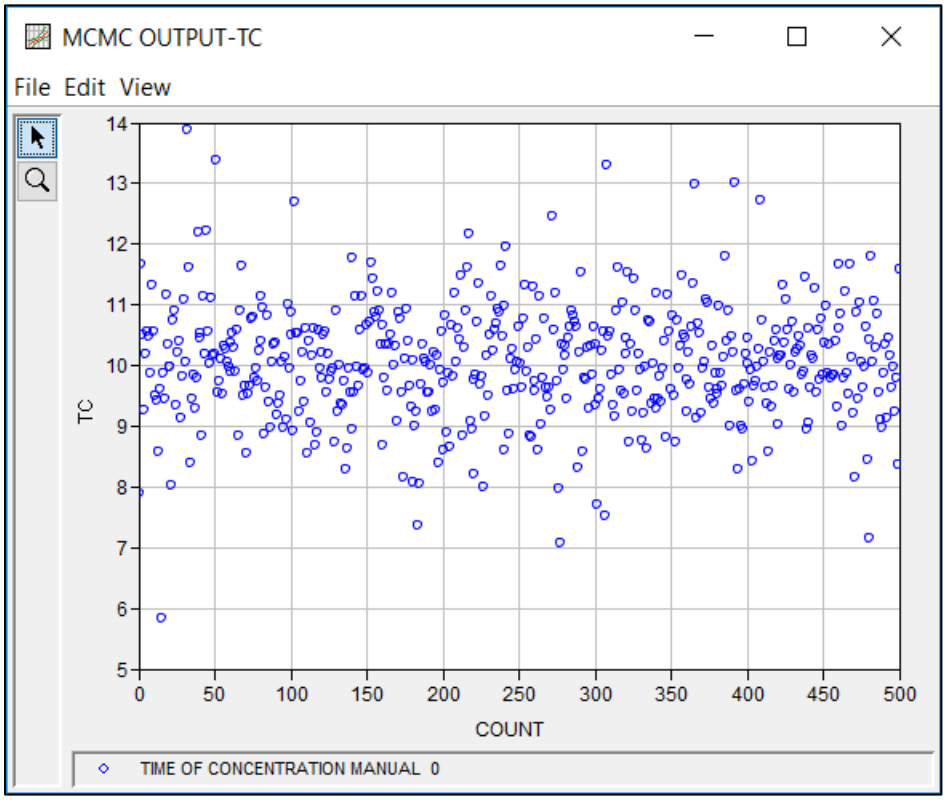


Figure B-233. Plot of the Time of Concentration Data.

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 B-234.

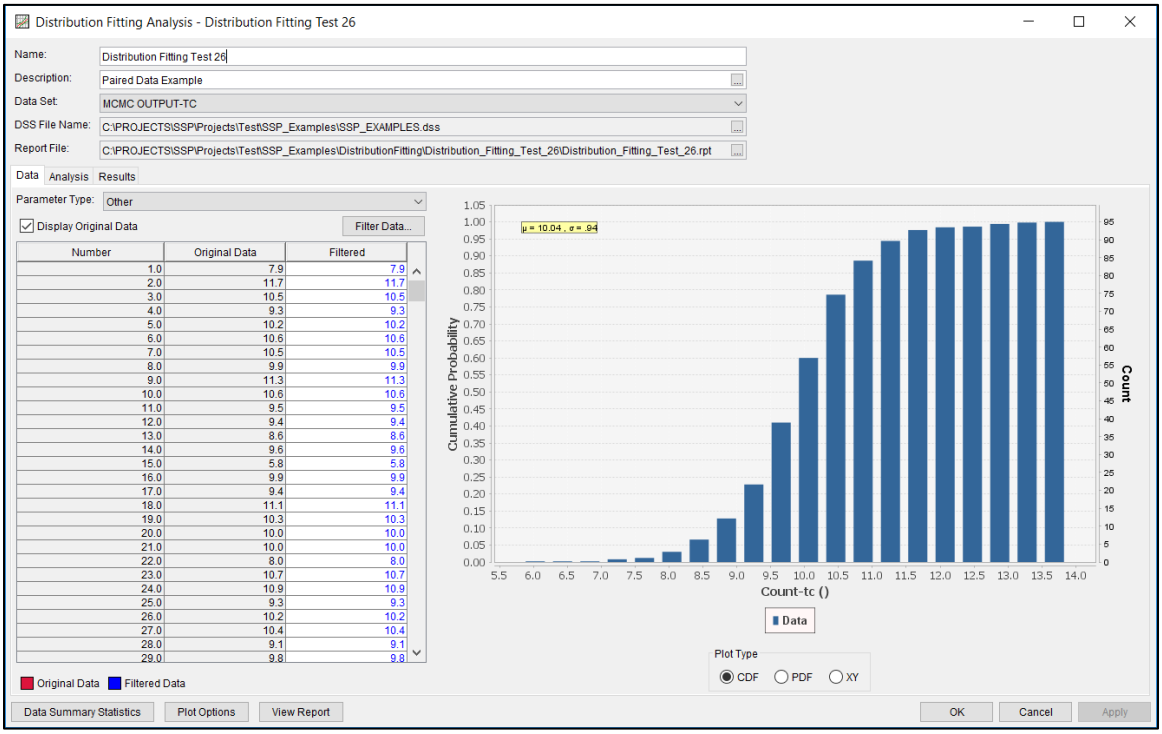
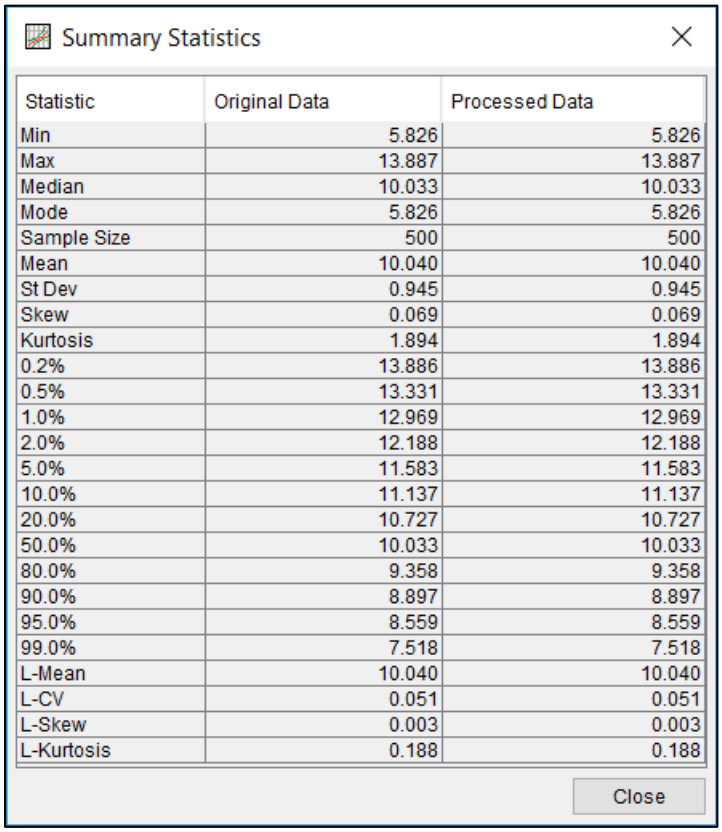


Figure B-234. Distribution Fitting Analysis Editor for Distribution Fitting Test 26.

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 B-235.



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

Figure B-235. 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 B-236, 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 changed to L-Moments by clicking on the column header and selecting **L-Moments**. 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, QQ, and CDF-Plotting Position plots comparing these distributions are shown in Figure B-237, Figure B-238, Figure B-239, Figure B-240, and Figure B-241. 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.

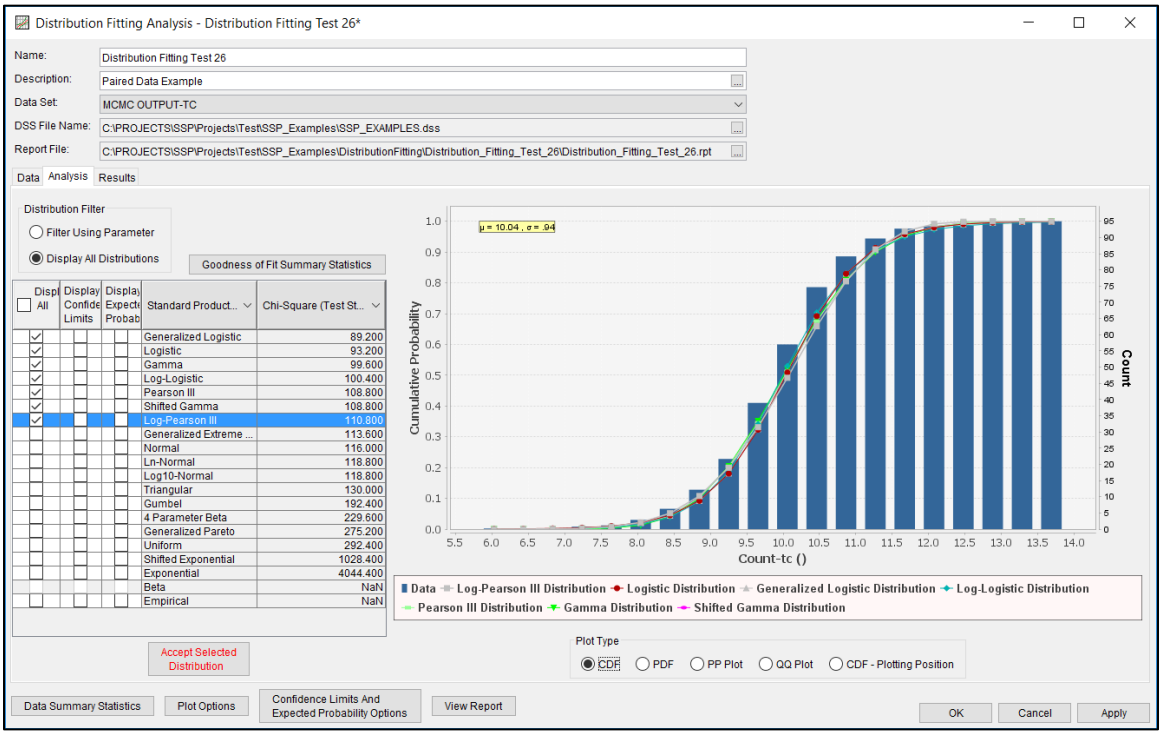


Figure B-236. Distribution Fitting Analysis Editor with Analysis Tab Shown for Distribution Fitting Test 26.

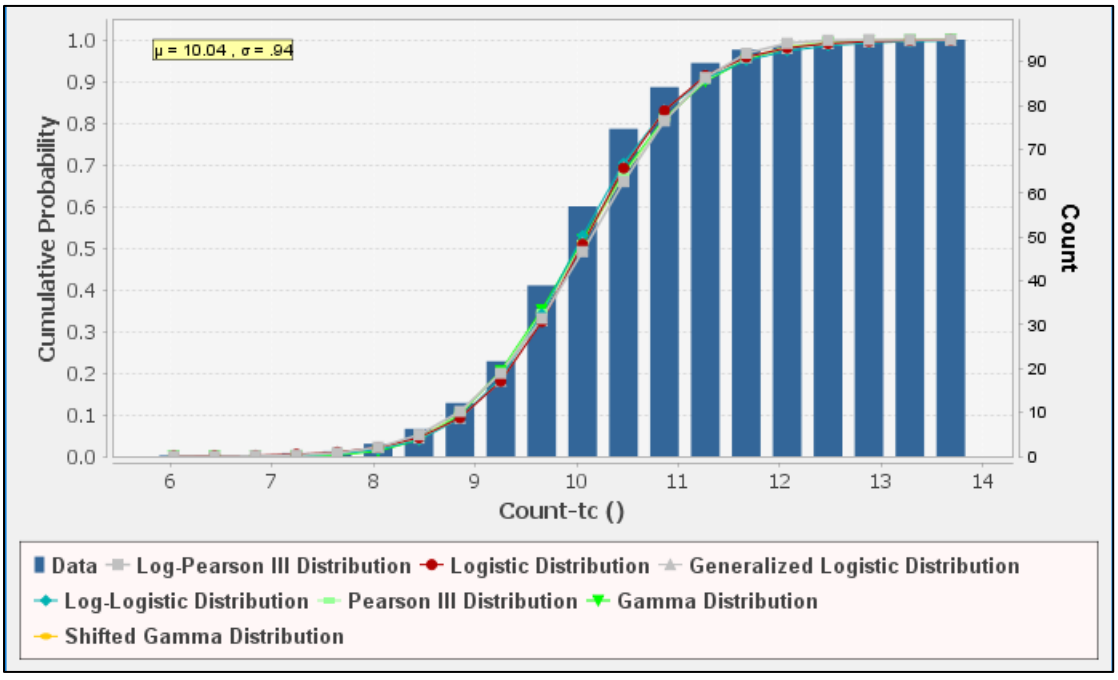


Figure B-237. CDF Plot for Distribution Fitting Test 26.

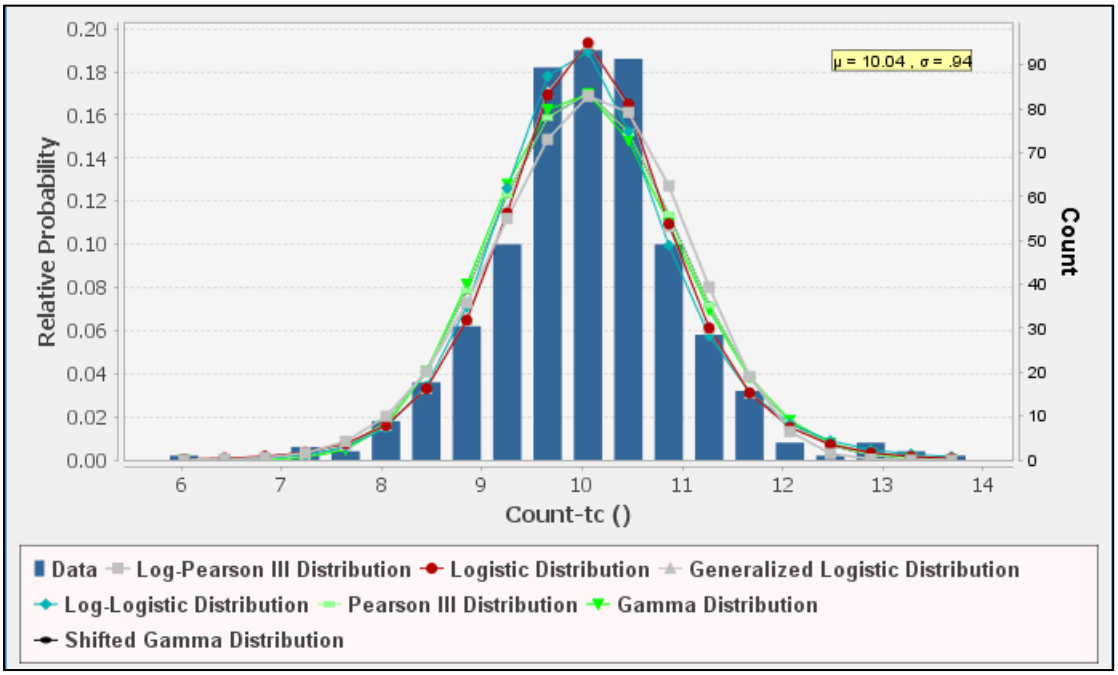


Figure B-238. PDF Plot for Distribution Fitting Test 26.

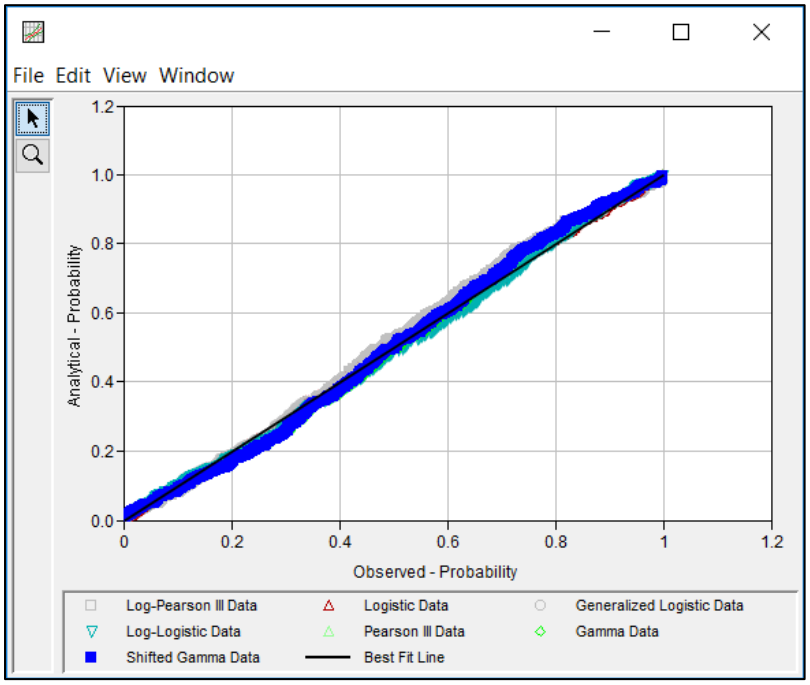


Figure B-239. PP Plot for Distribution Fitting Test 26.

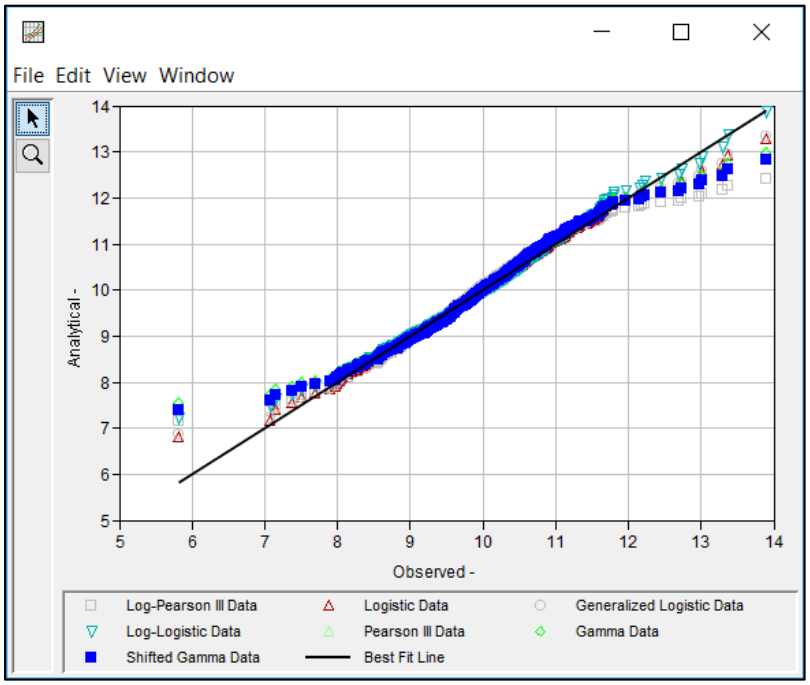


Figure B-240. QQ Plot for Distribution Fitting Test 26.

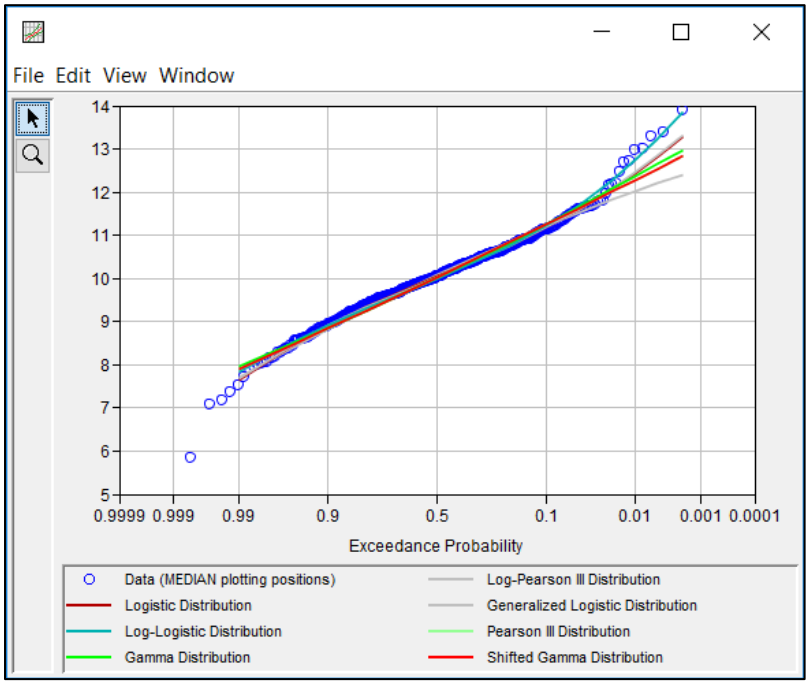
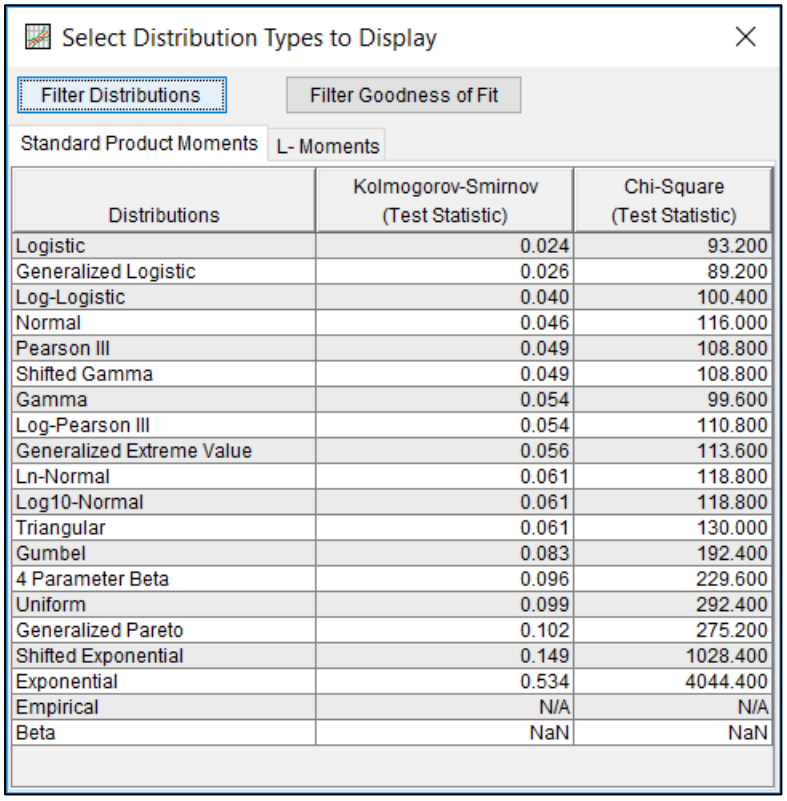


Figure B-241. CDF-Plotting Position Plot for Distribution Fitting Test 26.

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 B-242.



Distributions	Kolmogorov-Smirnov (Test Statistic)	Chi-Square (Test Statistic)
Logistic	0.024	93.200
Generalized Logistic	0.026	89.200
Log-Logistic	0.040	100.400
Normal	0.046	116.000
Pearson III	0.049	108.800
Shifted Gamma	0.049	108.800
Gamma	0.054	99.600
Log-Pearson III	0.054	110.800
Generalized Extreme Value	0.056	113.600
Ln-Normal	0.061	118.800
Log10-Normal	0.061	118.800
Triangular	0.061	130.000
Gumbel	0.083	192.400
4 Parameter Beta	0.096	229.600
Uniform	0.099	292.400
Generalized Pareto	0.102	275.200
Shifted Exponential	0.149	1028.400
Exponential	0.534	4044.400
Empirical	N/A	N/A
Beta	NaN	NaN

Figure B-242. Goodness of Fit Summary Statistics for Distribution Fitting Test 26.

In this example, the Logistic 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, 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 **Confidence Limits and Expected Probability Options** button near the bottom of the Distribution Fitting editor. Specifically, the **Equivalent Record Length** was set to 50, the **Z Alpha** value was set to 99%, and the **Maximum Iterations** were set to 10,000,000, as shown in Figure B-243. Upon clicking the **OK** button, 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 B-244.

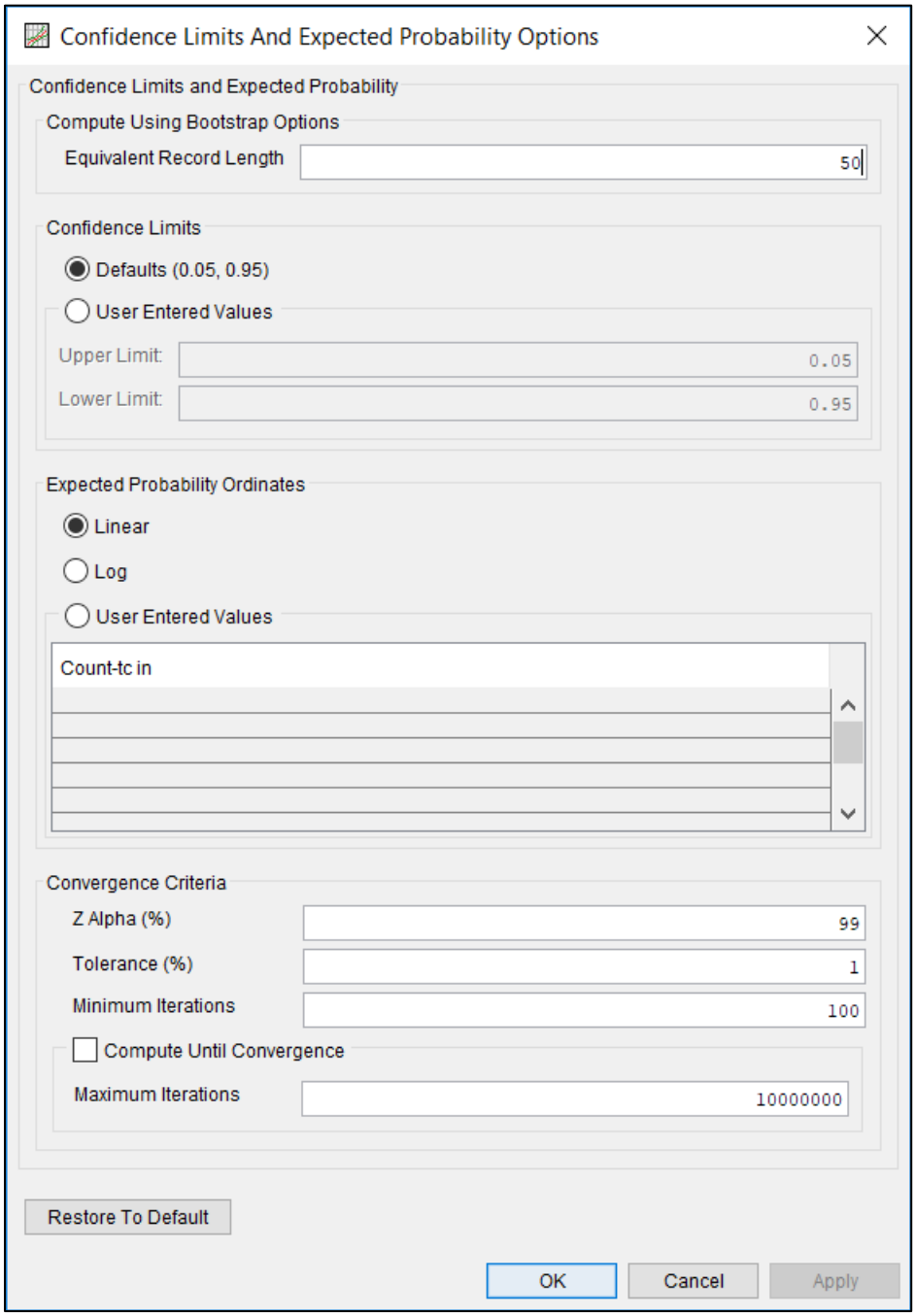


Figure B-243. Confidence Limits and Expected Probability Options Editor for Distribution Fitting Test 26.

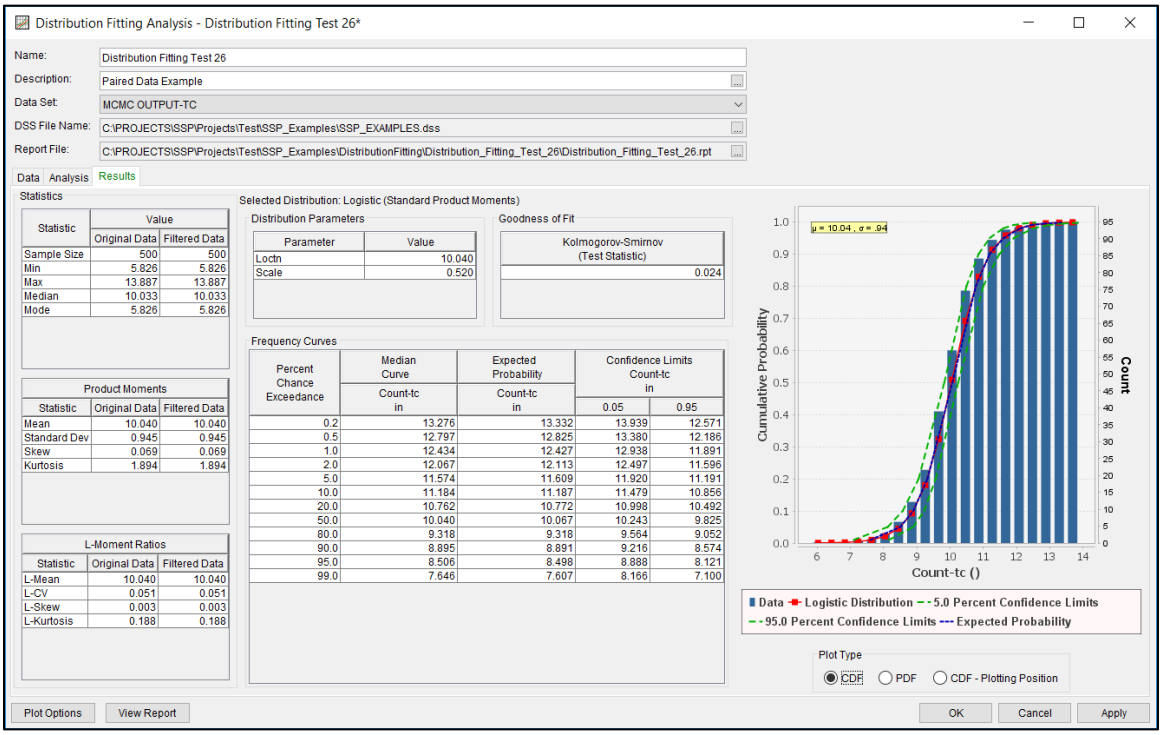


Figure B-244. Distribution Fitting Results Tab Shown for Distribution Fitting Test 26.

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 B-245.

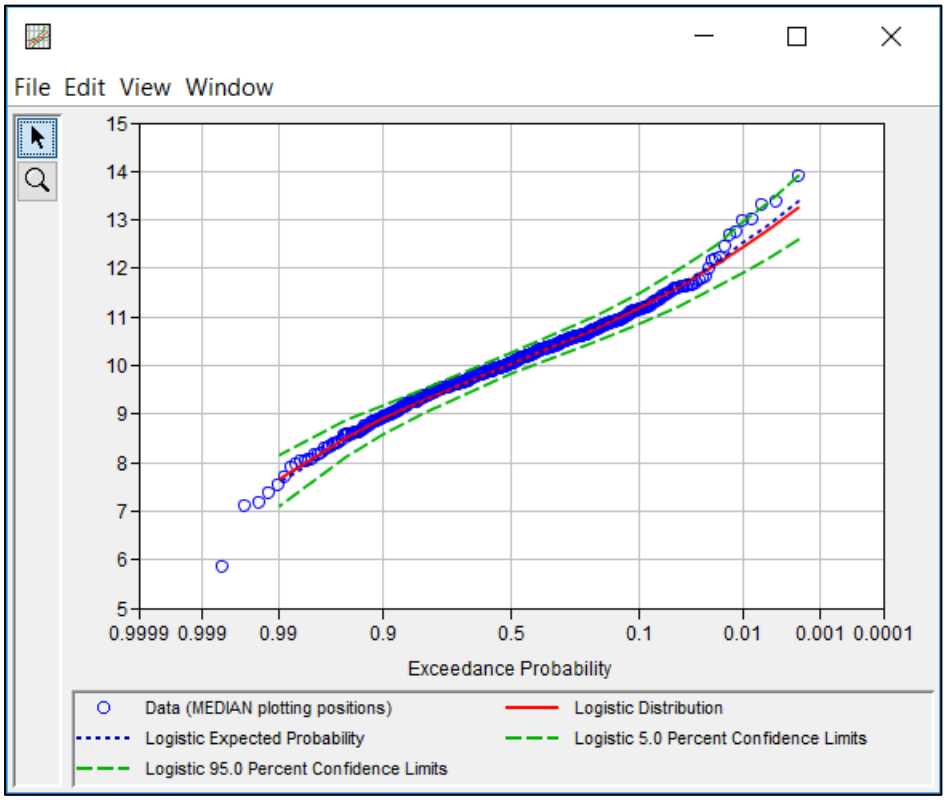


Figure B-245. Plot of the Data and Accepted Distribution | Fitting Method for Distribution Fitting Test 26.

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 B-246.

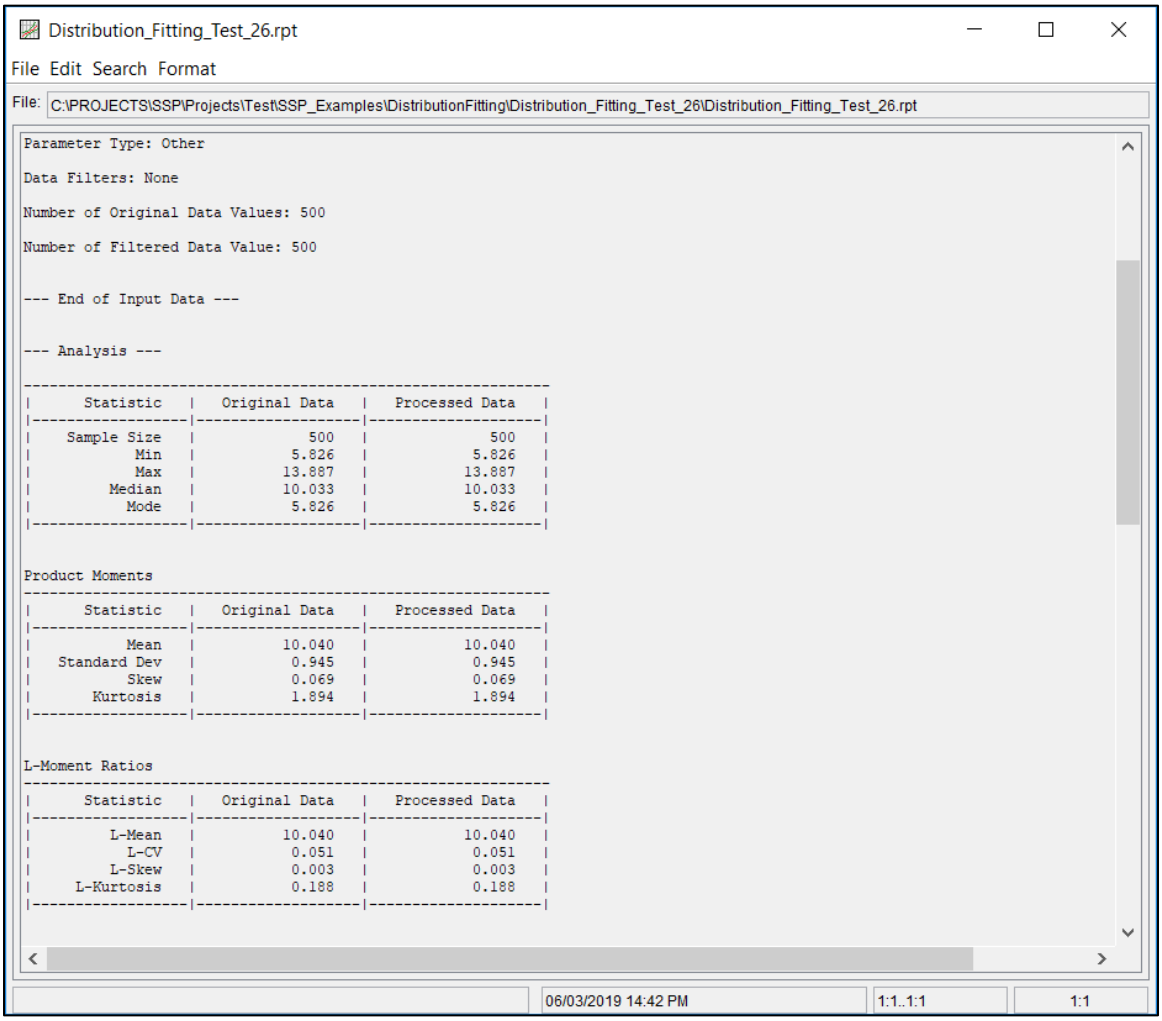


Figure B-246. Report File for Distribution Fitting Test 26.

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.

A Mixed Population analysis has been developed for this example. 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 B-247.

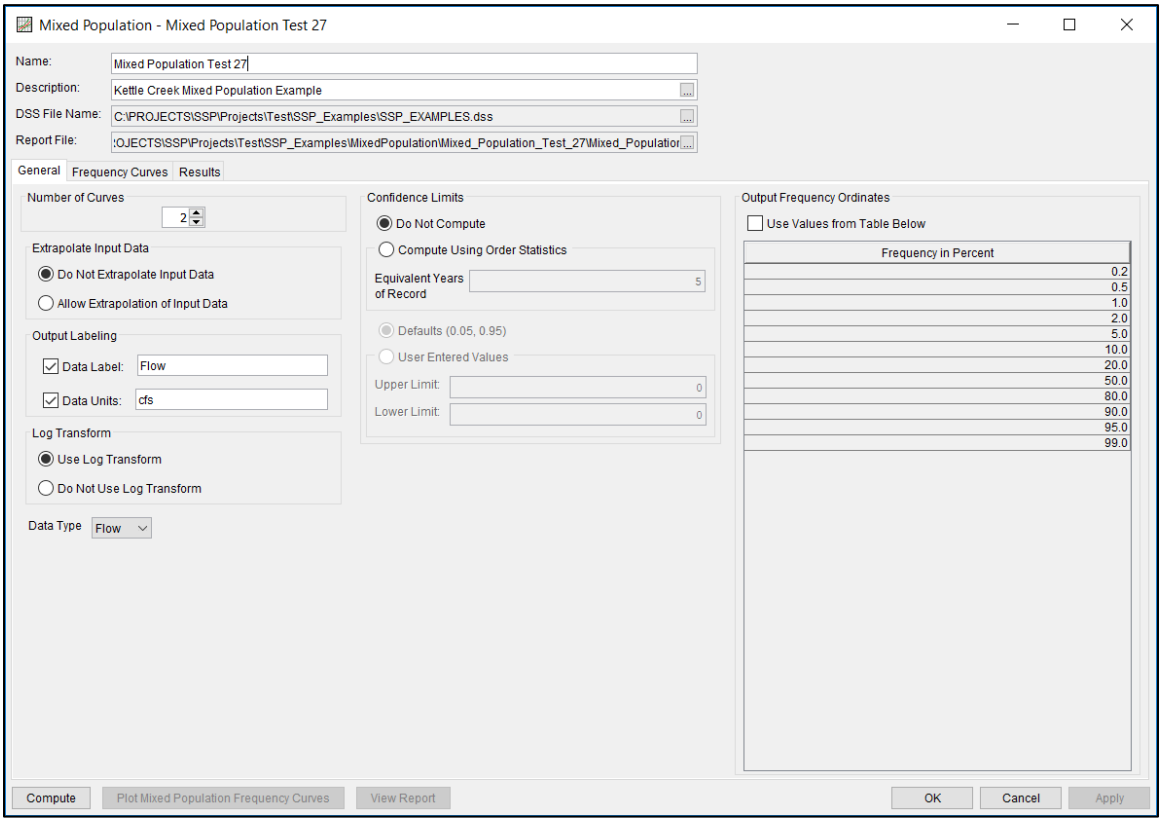


Figure B-247. General Tab Shown for Mixed Population Test 27.

Shown in Figure B-247 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 B-248 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 B-249 shows the plotted frequency curves for this analysis.

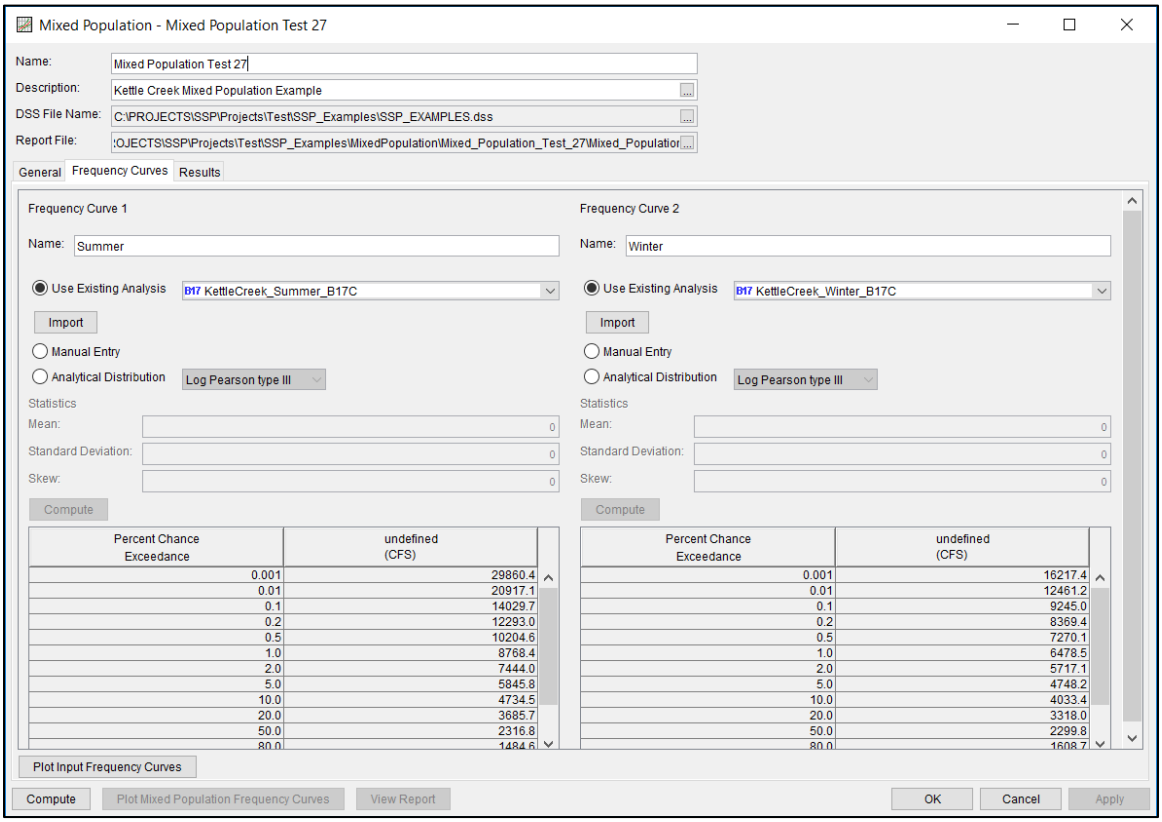


Figure B-248. Frequency Curves Tab for Mixed Population Test 27.

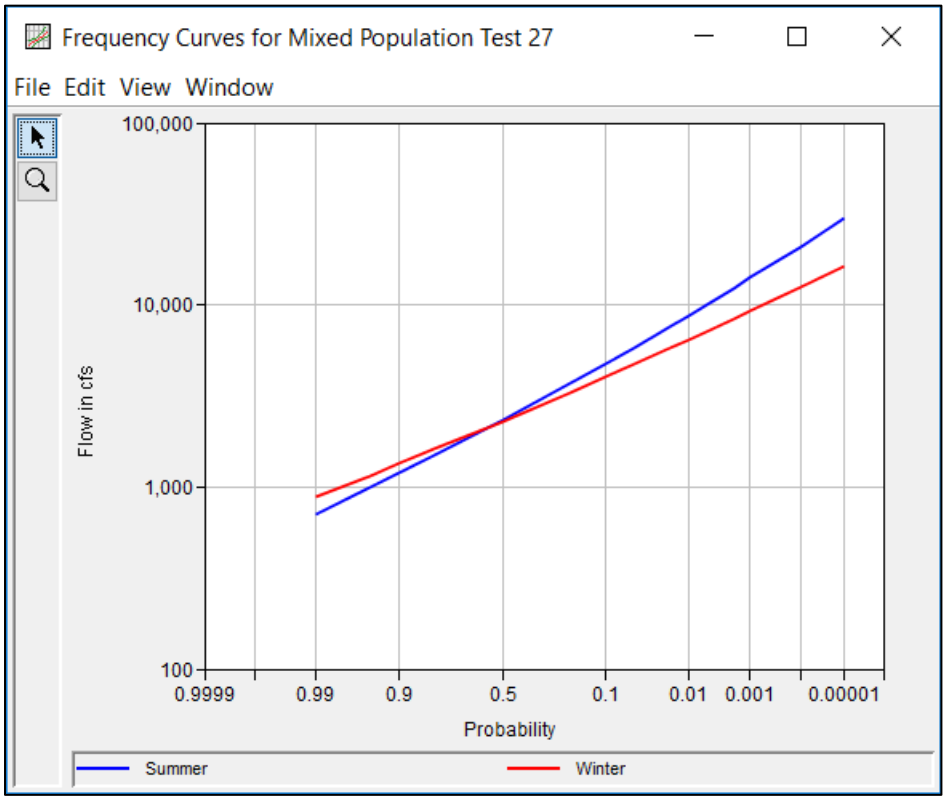


Figure B-249. Plotted Frequency Curves for Mixed Population Test 27.

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 B-250. 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.

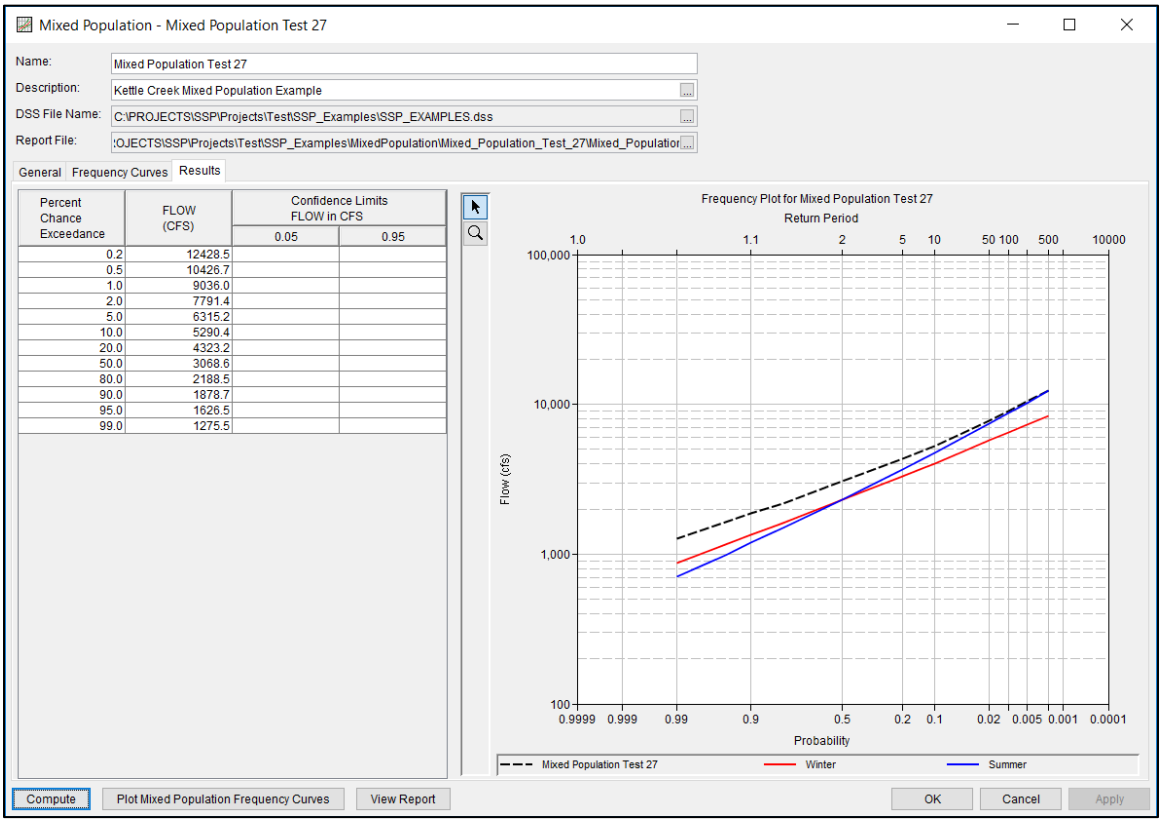


Figure B-250. Results tab for Mixed Population Test 27.

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 B-251 is the report file for **Mixed Population Test 27**.

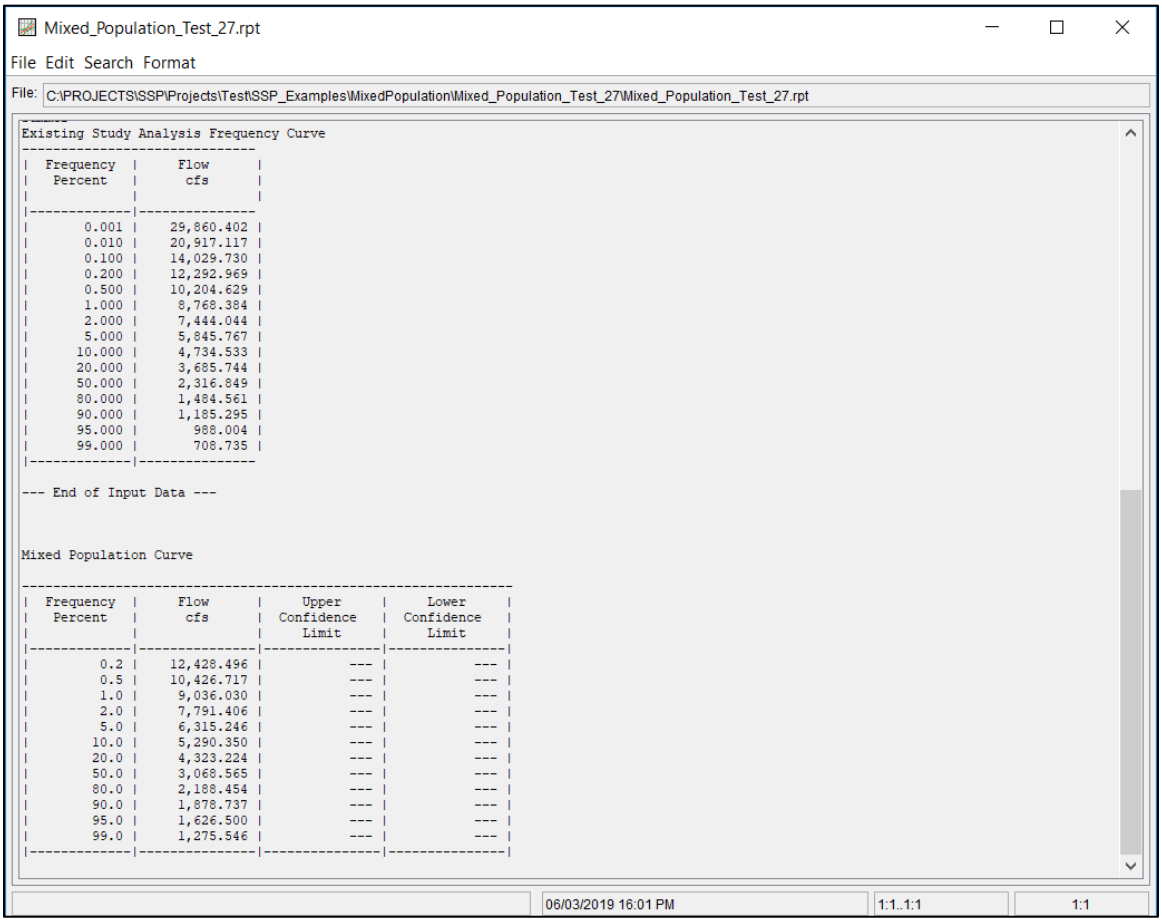


Figure B-251. Report File for Mixed Population Test 27.

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.

A Mixed Population analysis has been developed for this example. 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 B-252.

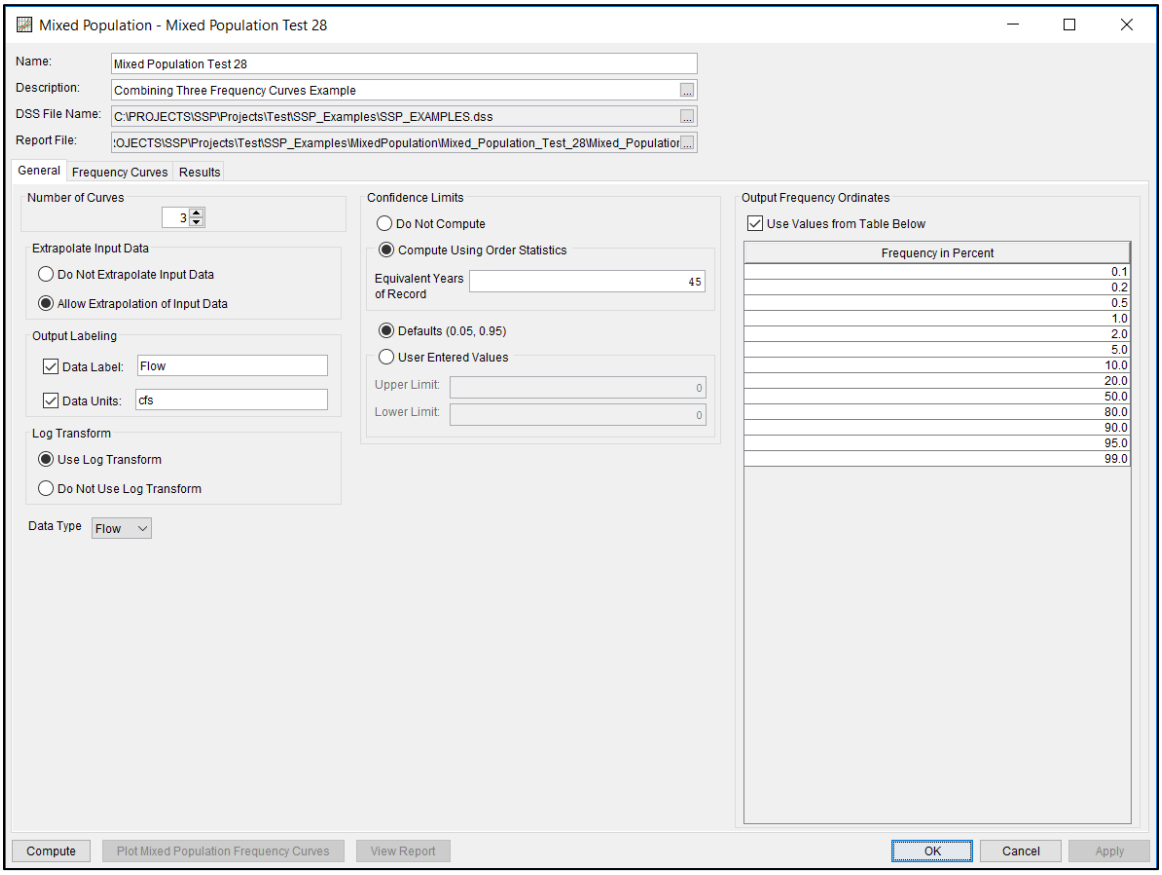


Figure B-252. General Tab Shown for Mixed Population Test 28.

Shown in Figure B-252 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 B-253 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 B-254 shows the plotted frequency curves for this analysis.

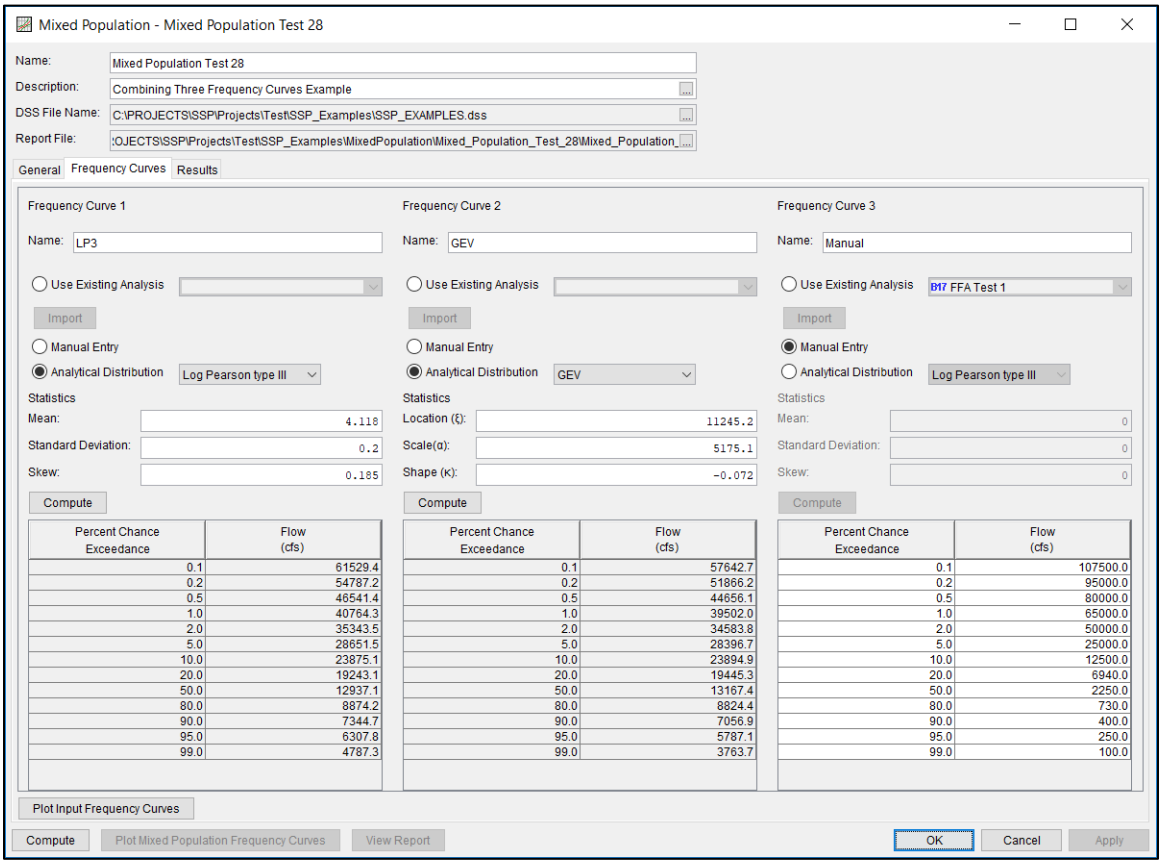


Figure B-253. Frequency Curves Tab for Mixed Population Test 28.

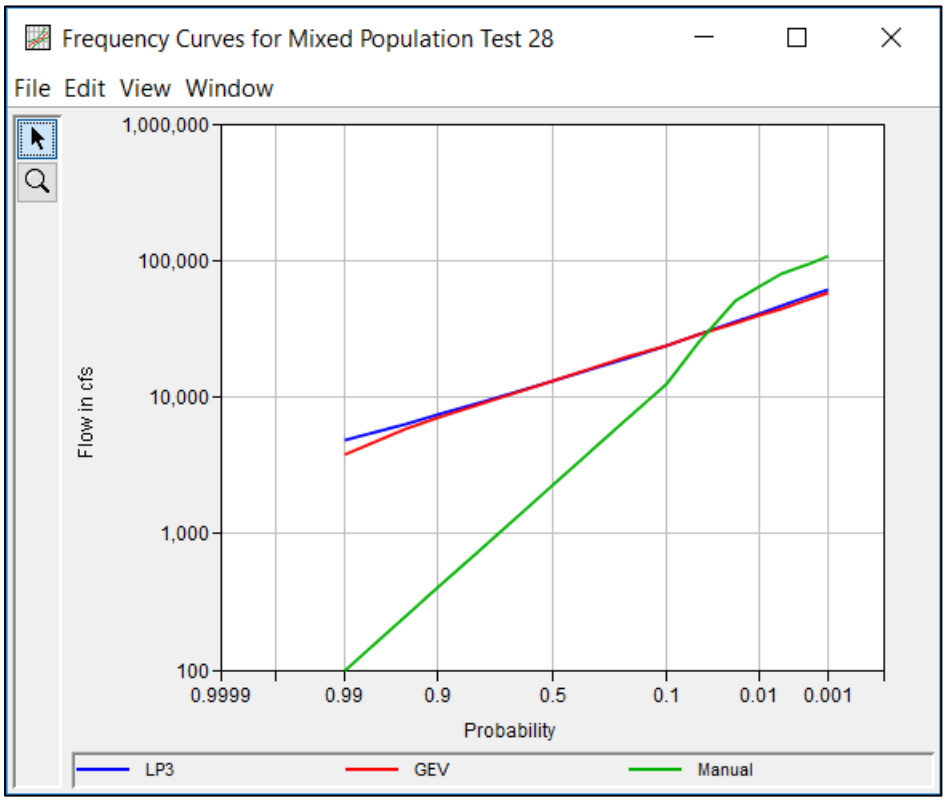


Figure B-254. Plotted Frequency Curves for Mixed Population Test 28.

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 B-255. 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.

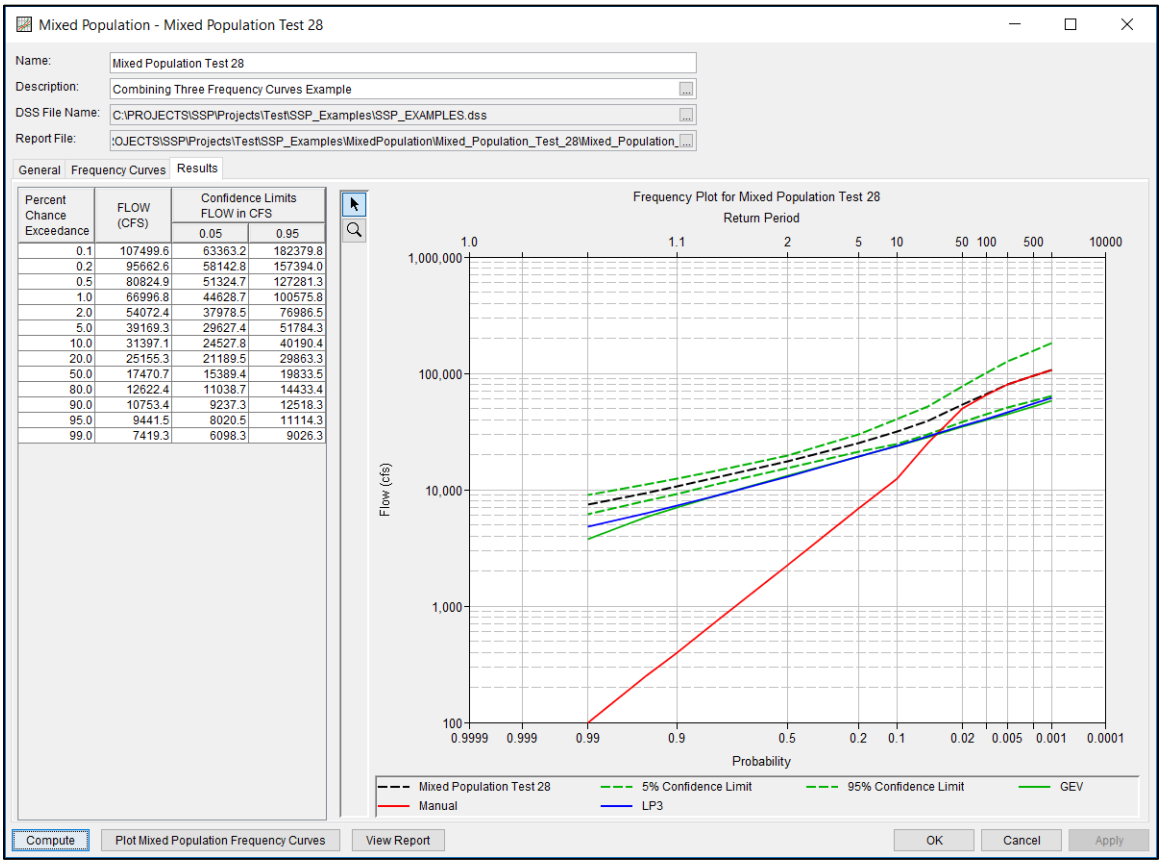


Figure B-255. Results tab for Mixed Population Test 28.

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 B-256 is the report file for **Mixed Population Test 28**.

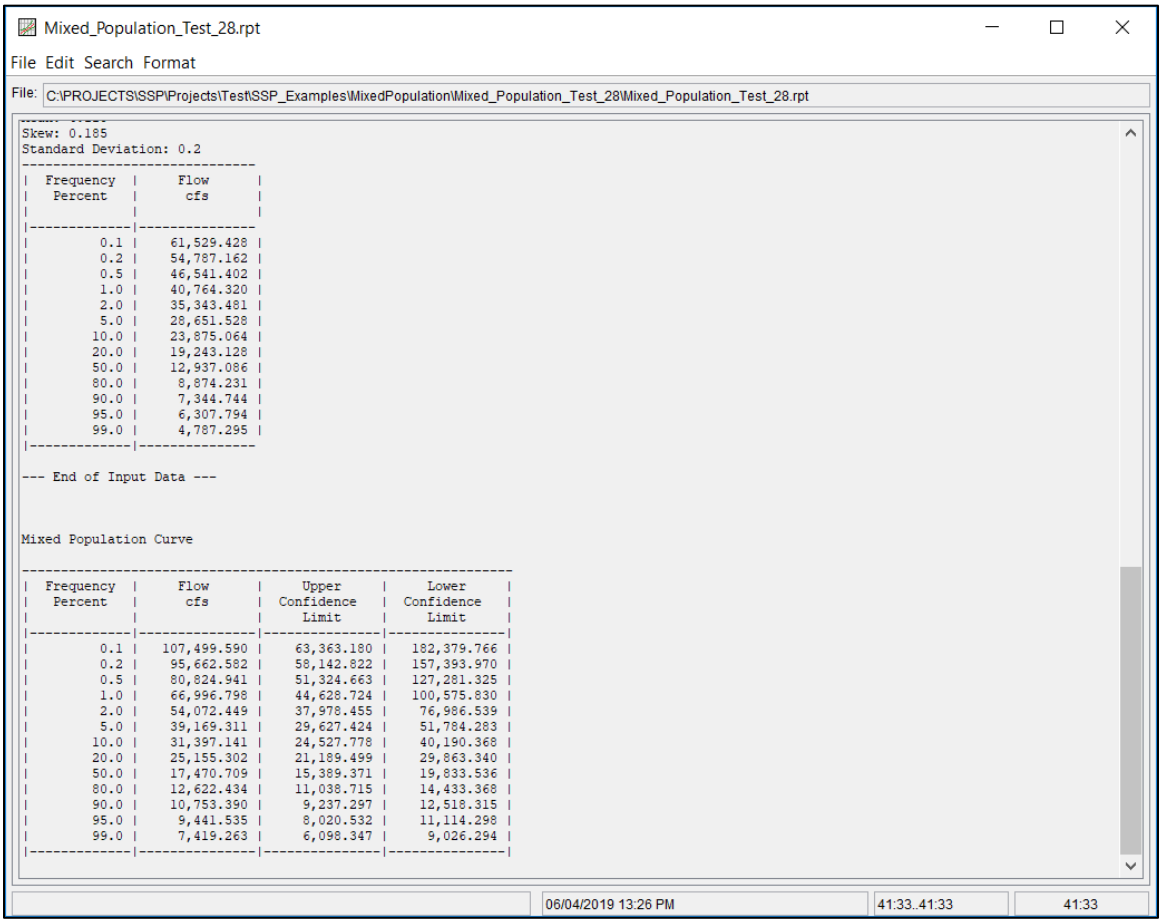


Figure B-256. Report File for Mixed Population Test 28.

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. 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 B-257.

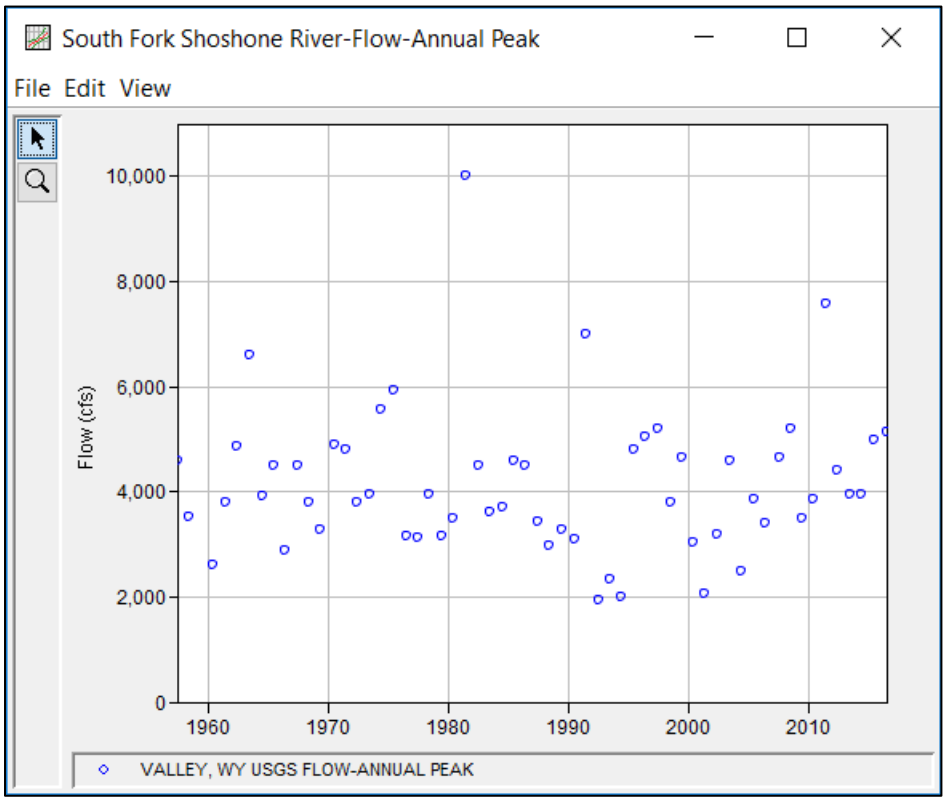


Figure B-257. Plot of the Peak Flow Data for South Fork Shoshone River.

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 B-258.

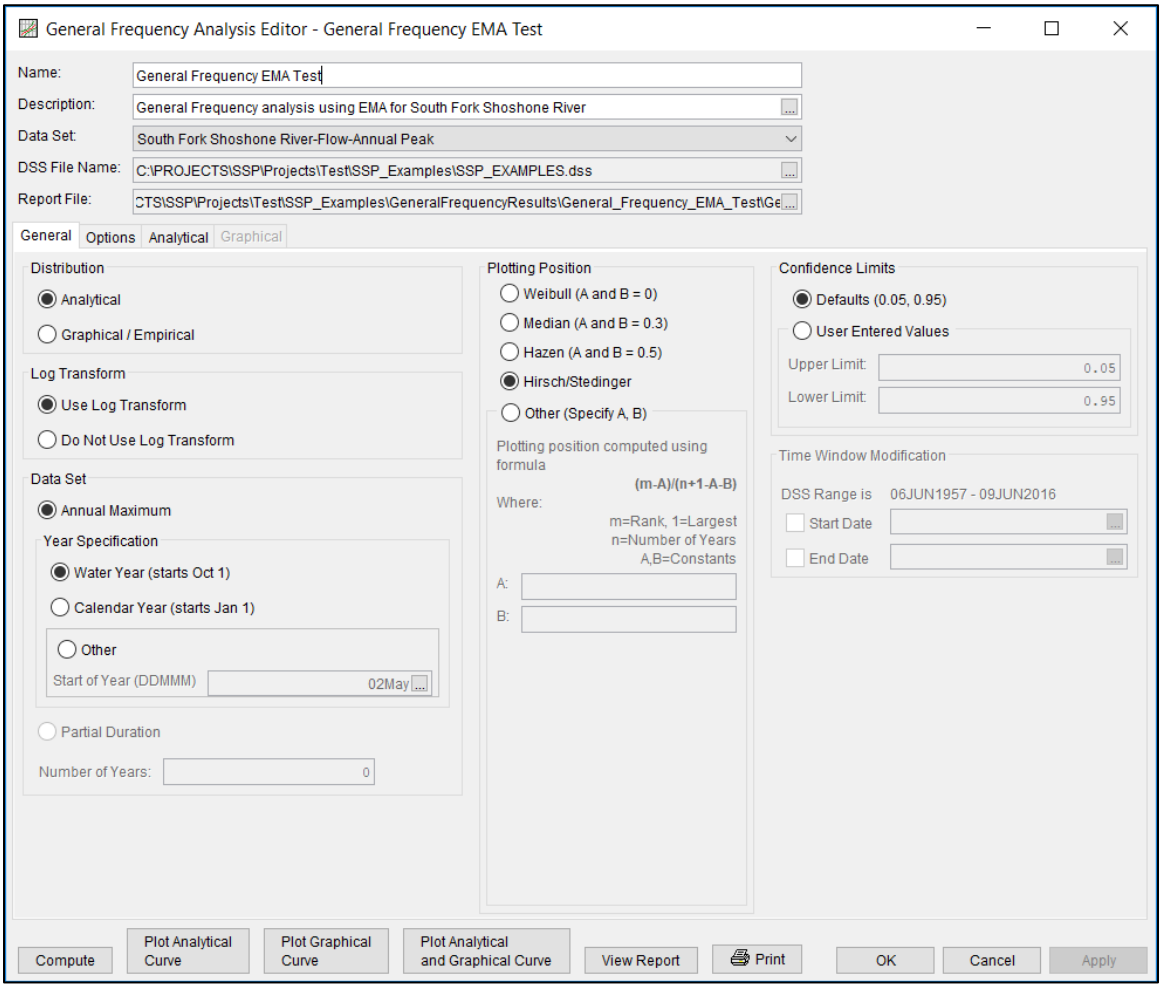


Figure B-258. General Frequency Analysis Editor for General Frequency EMA Test.

Shown in Figure B-258 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 B-259 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.

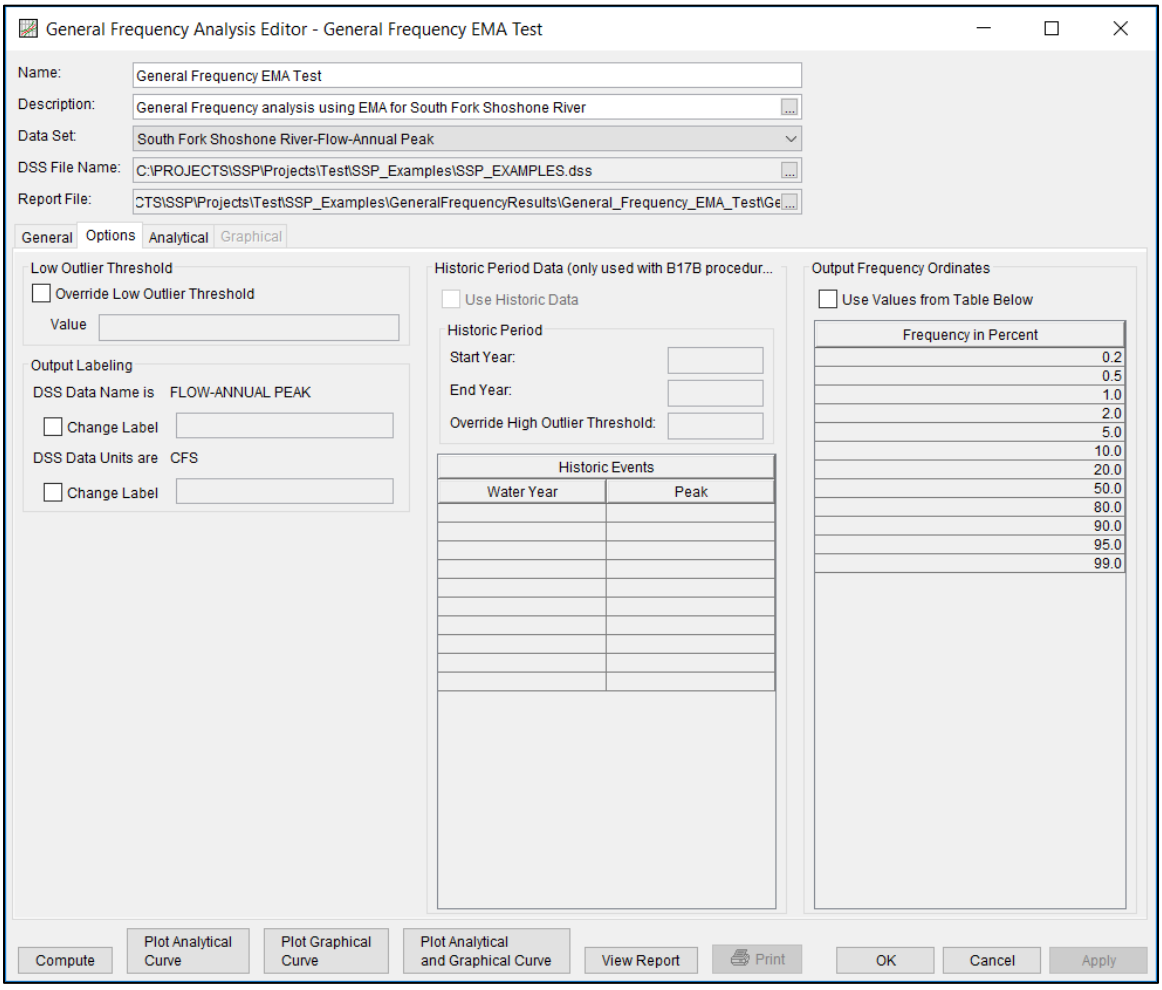


Figure B-259. General Frequency Analysis Editor with Options Tab Selected for General Frequency EMA Test.

In this example, an analytical analysis was performed. Shown in Figure B-260 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**.

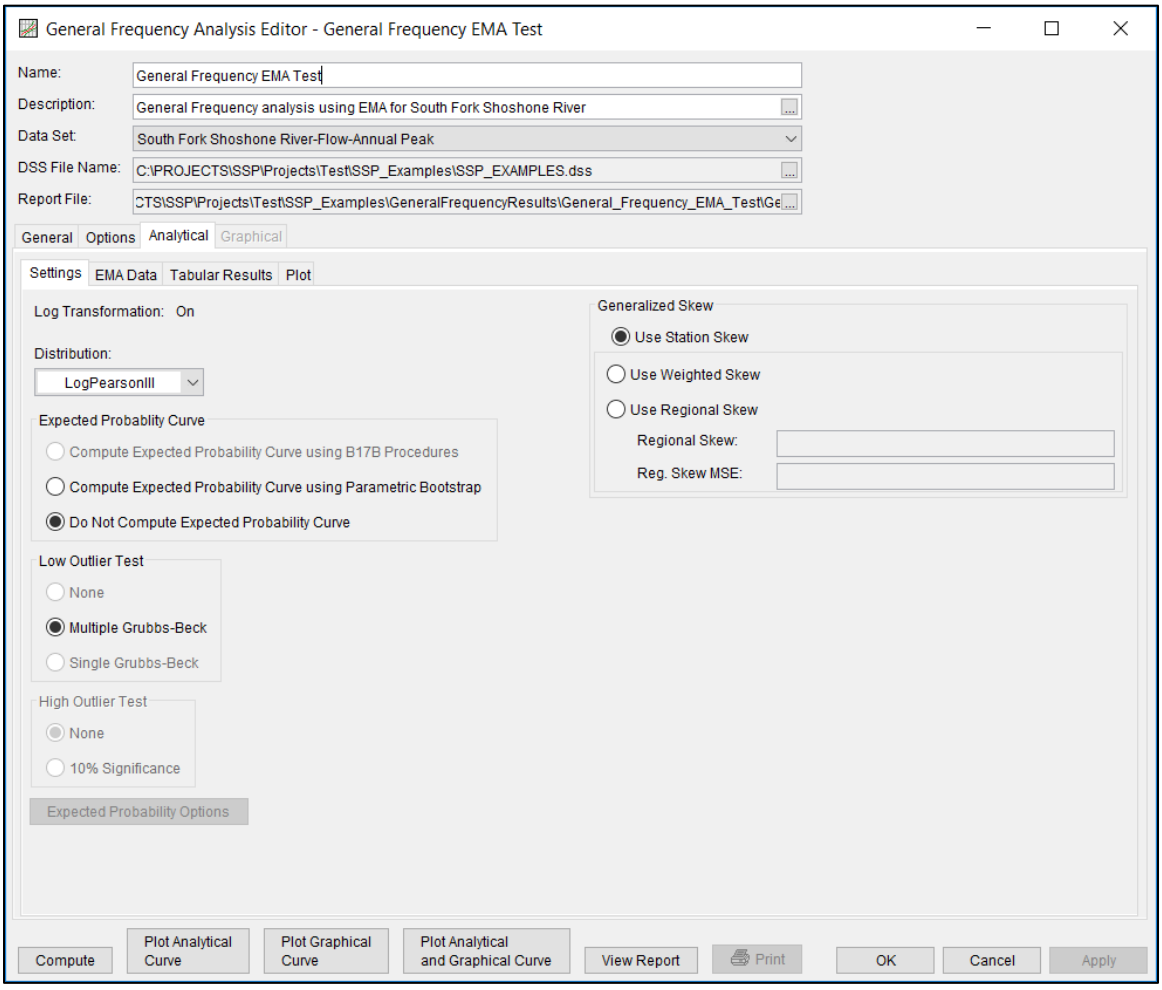


Figure B-260. General Frequency Analysis Editor with Analytical | Settings Tab Selected for General Frequency EMA Test.

The **Analytical | EMA Data** tab for this example is shown in Figure B-261. Data required for the EMA computations is entered on this tab. 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.

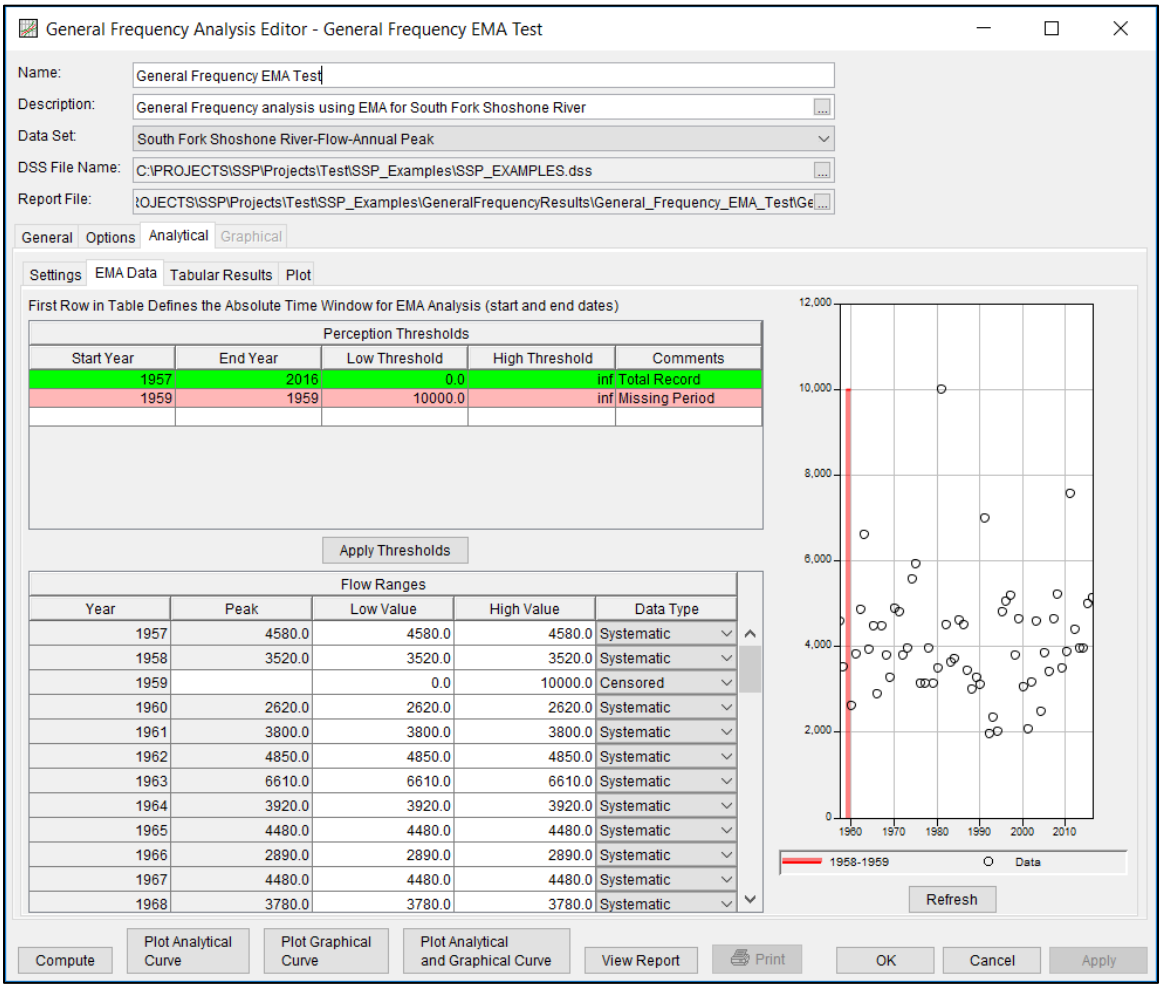


Figure B-261. General Frequency Analysis Editor with Analytical | EMA Data Tab Selected for General Frequency EMA Test.

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 B-262.

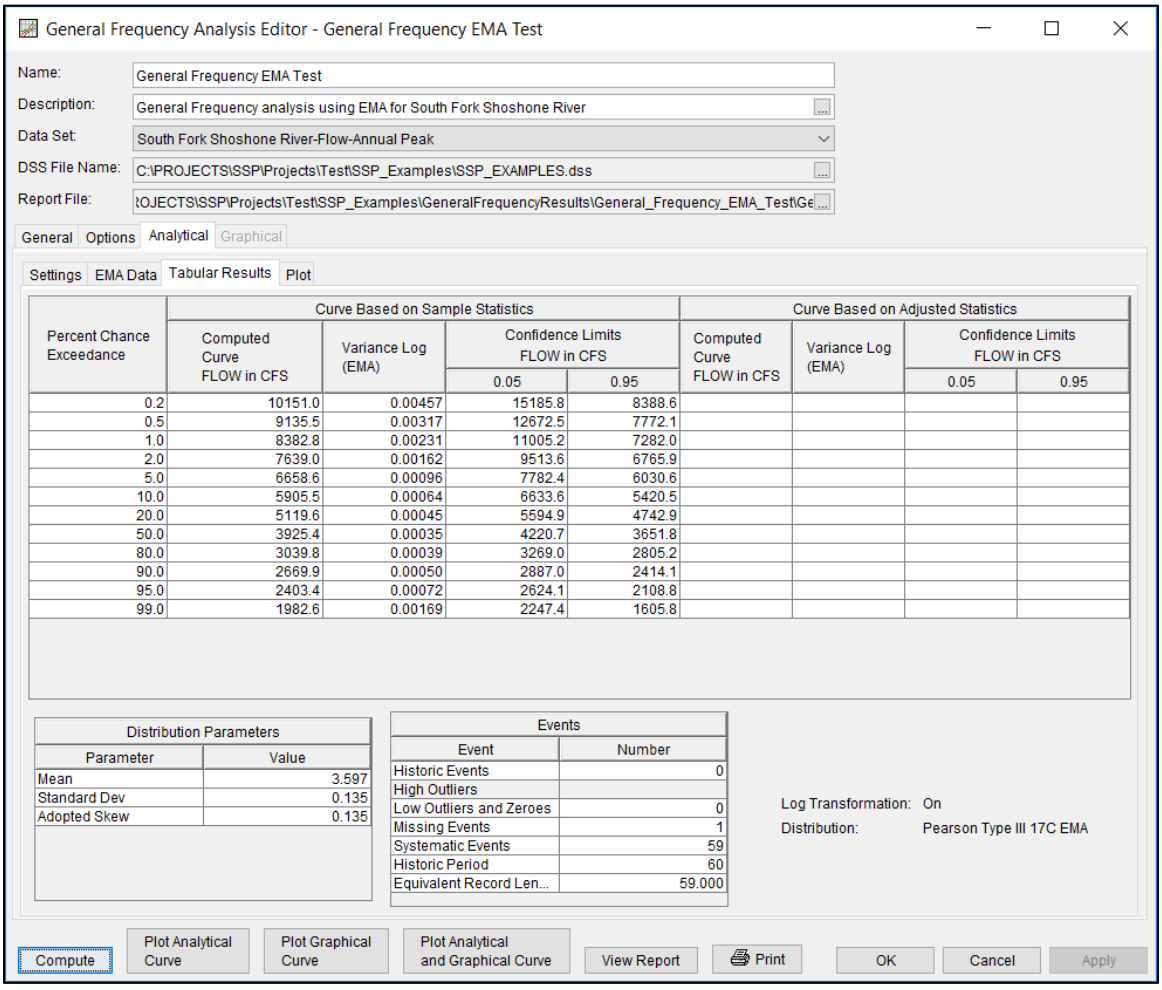


Figure B-262. General Frequency Analysis Editor with Tabular Results Tab Selected for General Frequency EMA Test.

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 B-263.

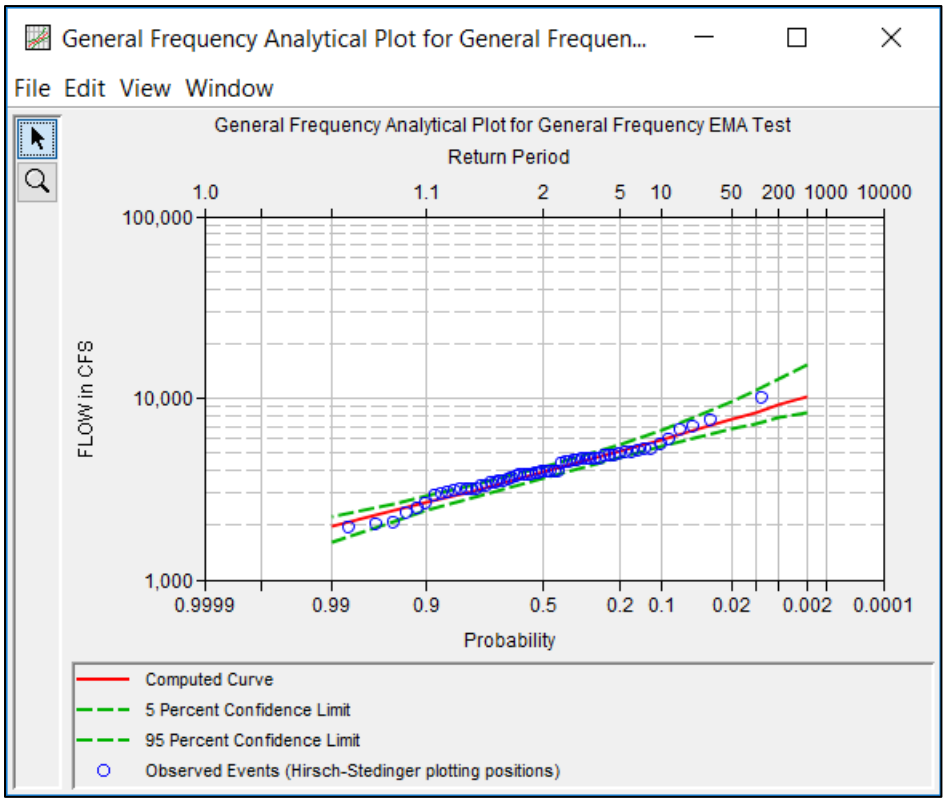


Figure B-263. Plotted Frequency Curves for General Frequency EMA Test.

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 B-264.

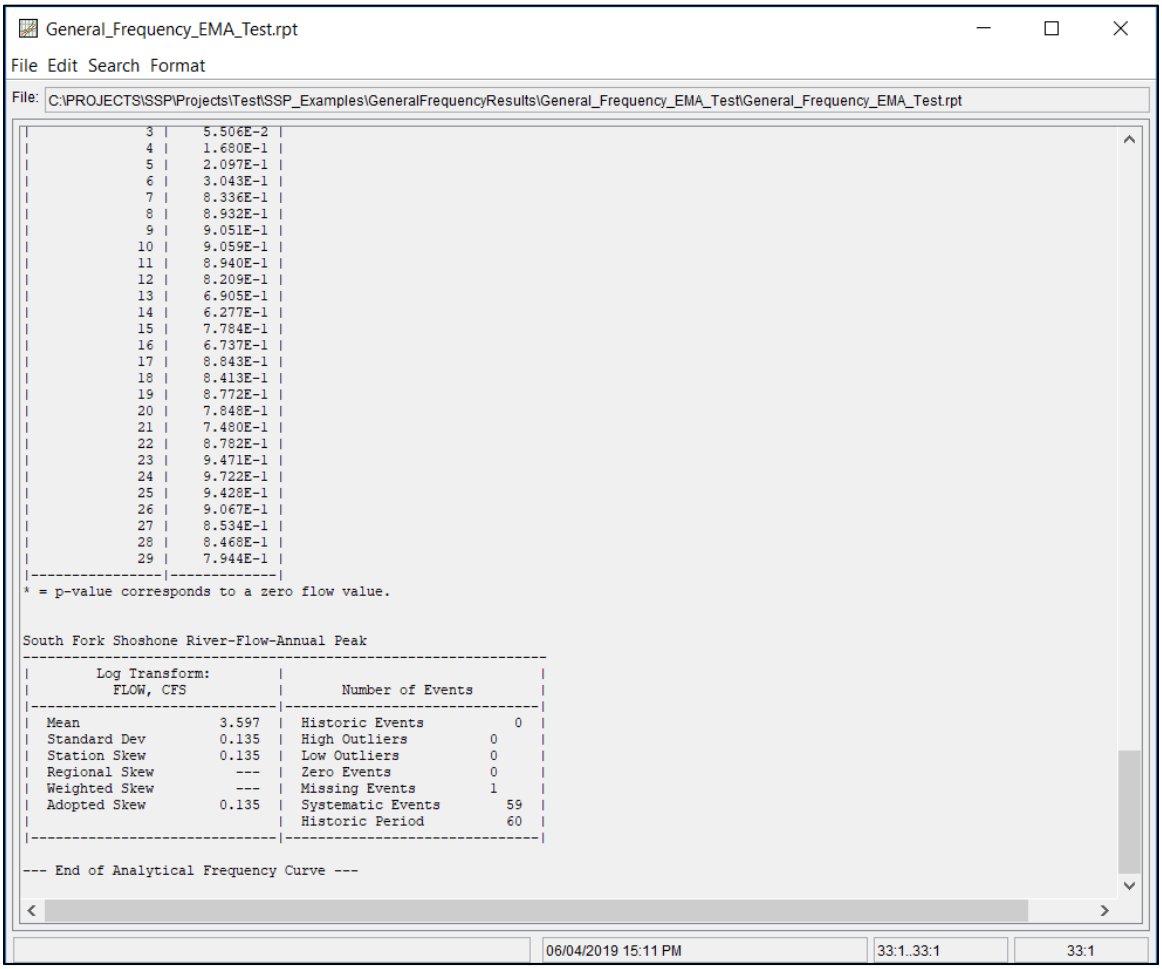


Figure B-264. General Frequency EMA Test Report File.

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 B-265.

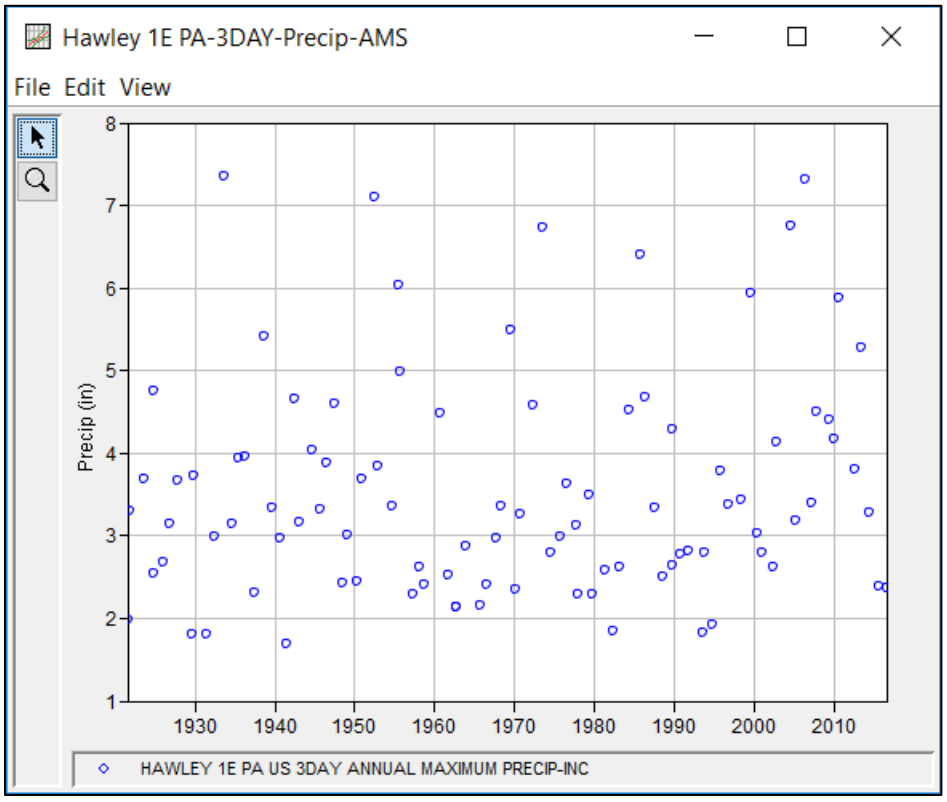


Figure B-265. Plot of the Precipitation Data for Hawley 1E PA 3DAY.

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 B-266.

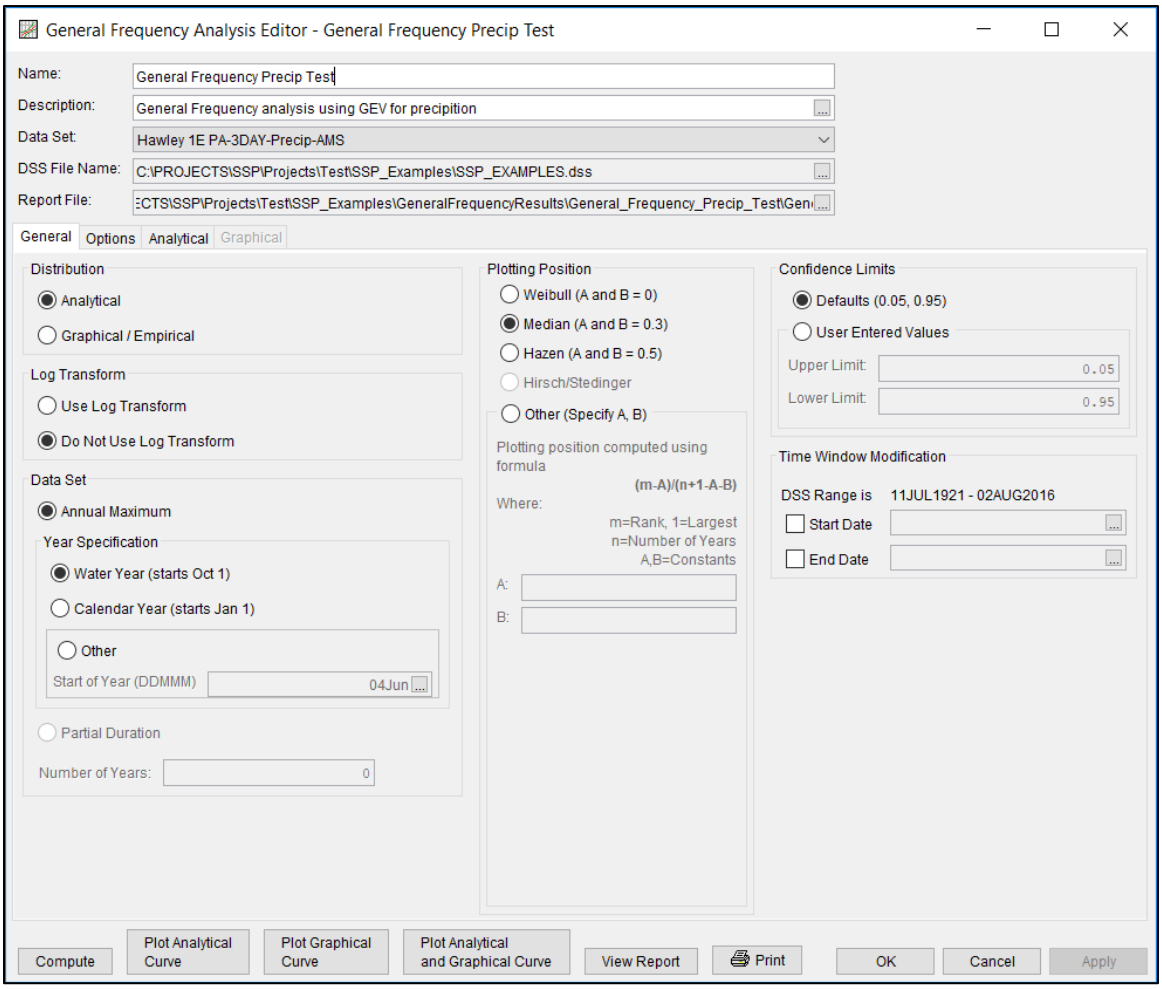


Figure B-266. General Frequency Analysis Editor for General Frequency Precip Test.

Shown in Figure B-266 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 B-267 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.

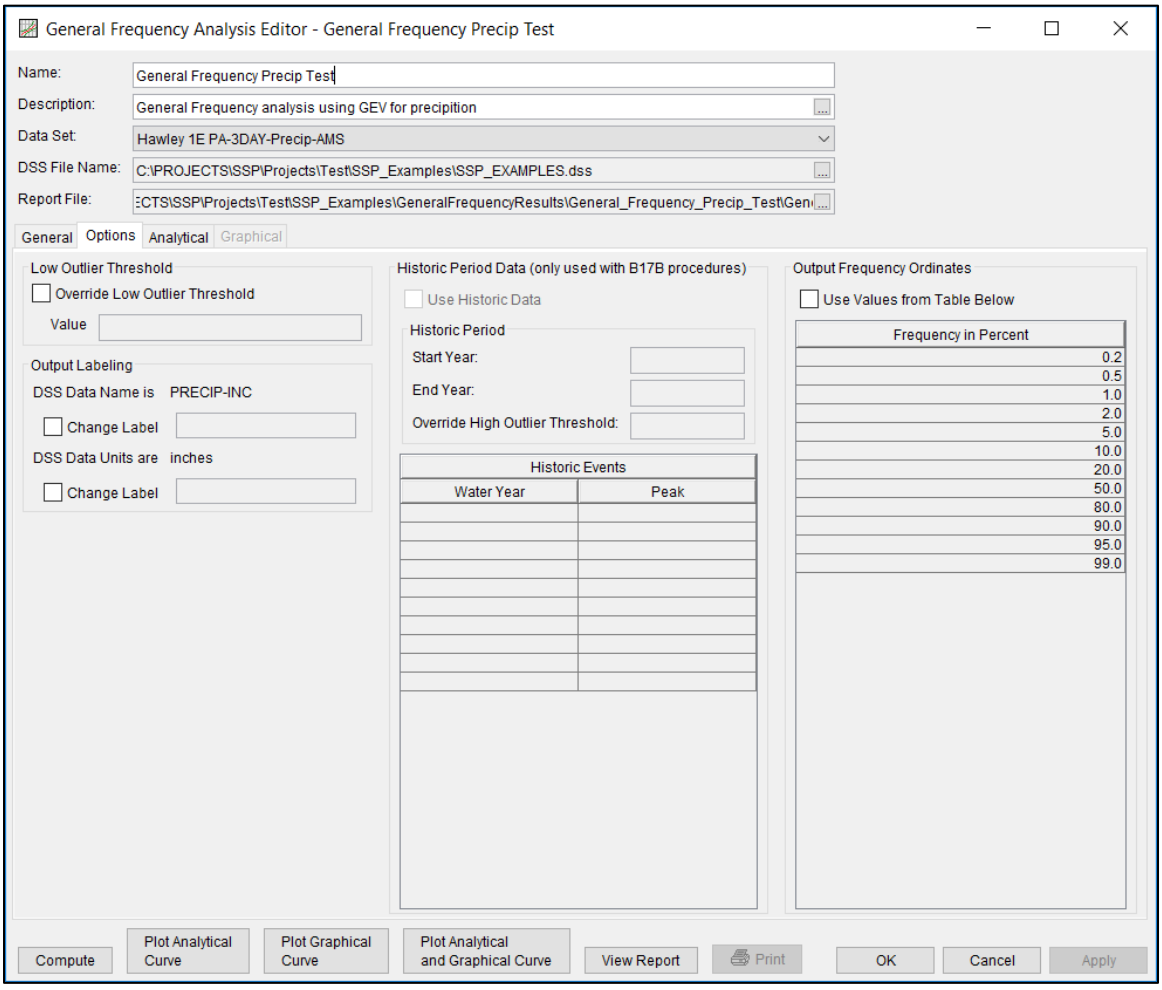


Figure B-267. General Frequency Analysis Editor with Options Tab Selected for General Frequency Precip Test.

In this example, an analytical analysis was performed. Shown in Figure B-268 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.

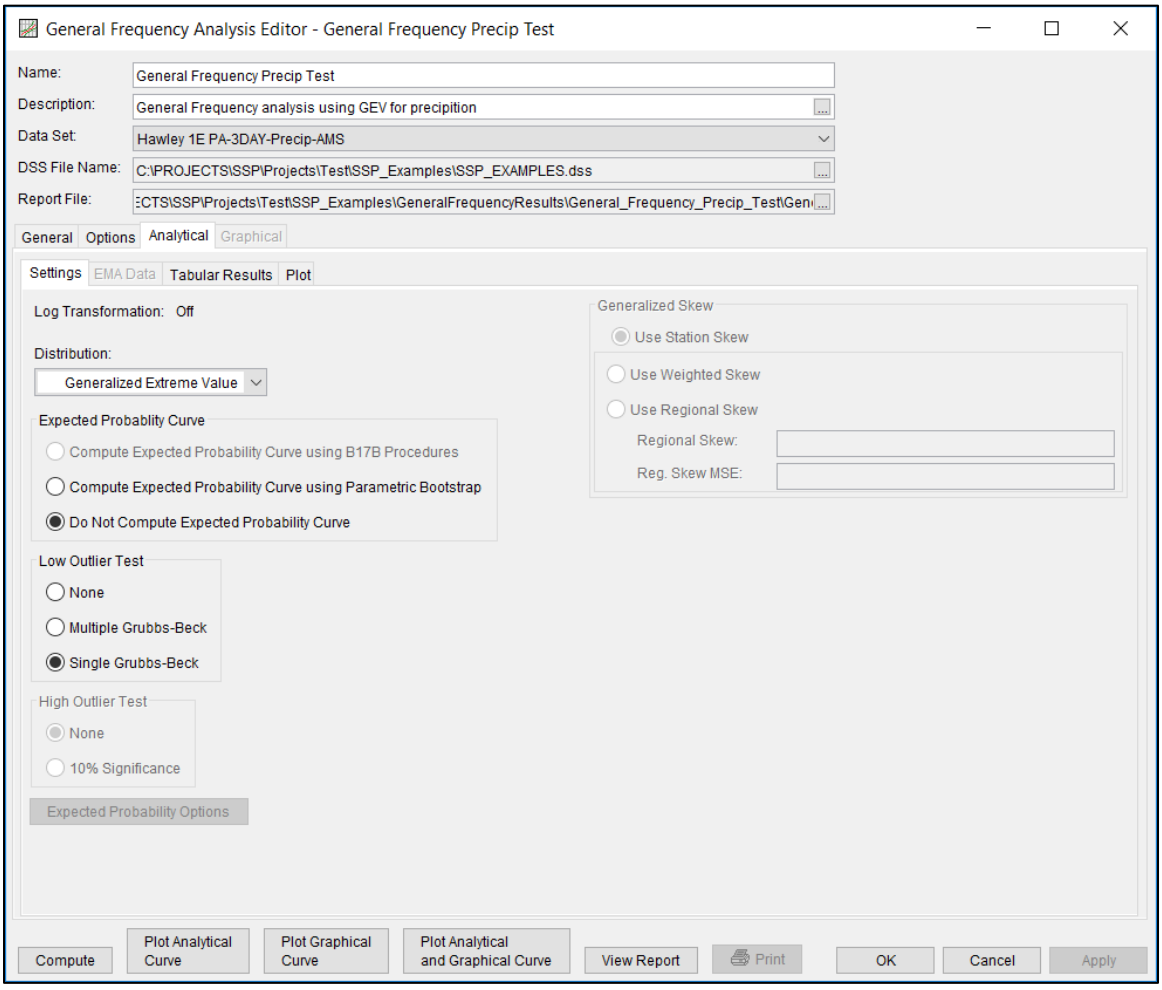


Figure B-268. General Frequency Analysis Editor with Analytical | Settings Tab Selected for General Frequency Precip Test.

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 B-269.

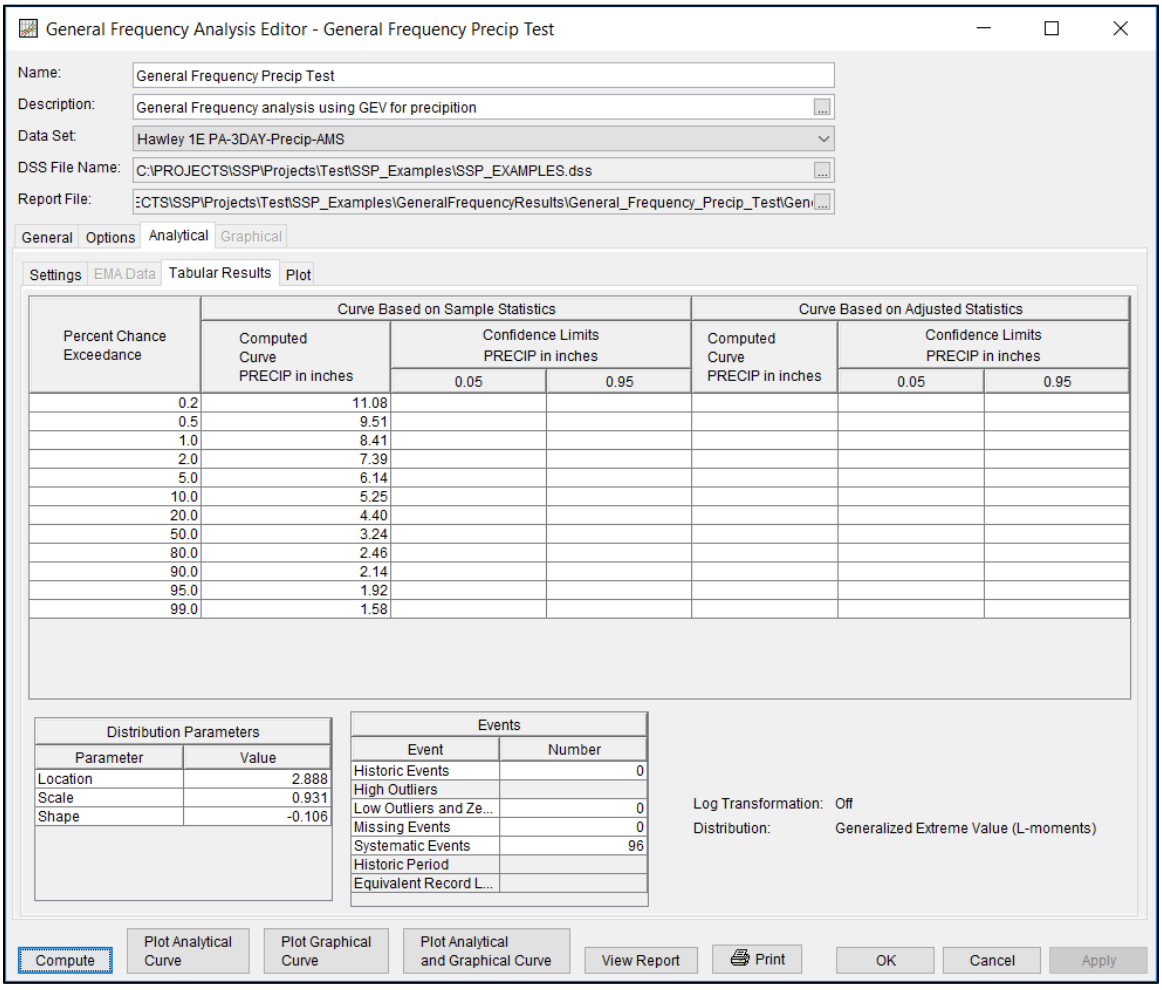


Figure B-269. General Frequency Analysis Editor with Tabular Results Tab Selected for General Frequency Precip Test.

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 B-270.

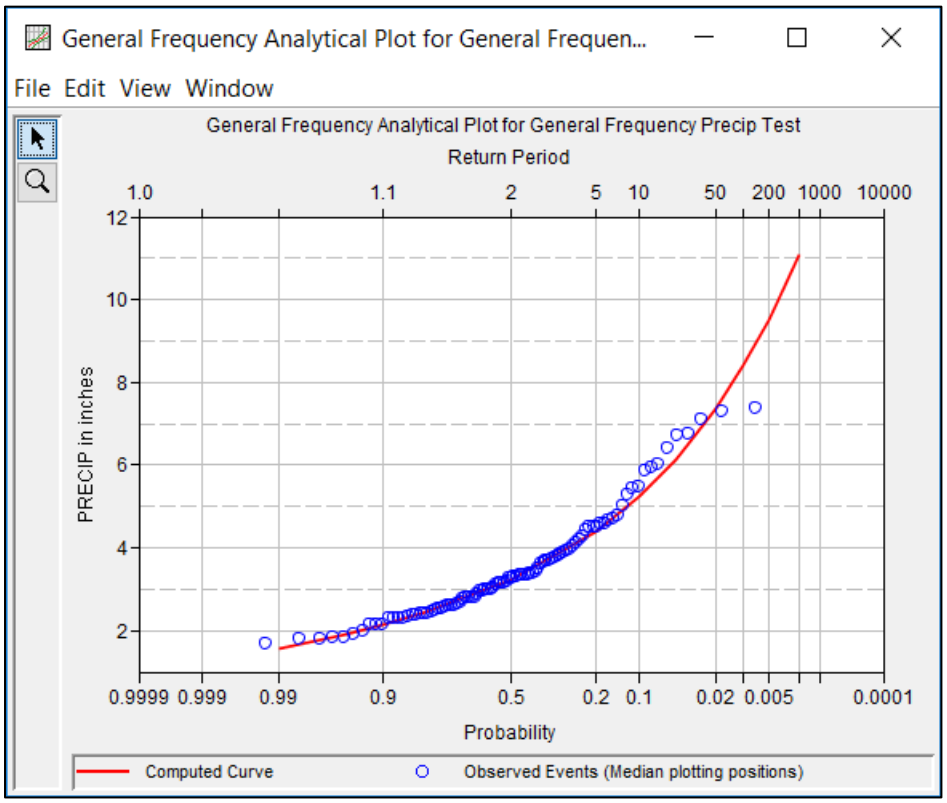


Figure B-270. Plotted Frequency Curves for General Frequency Precip Test.

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 B-271.

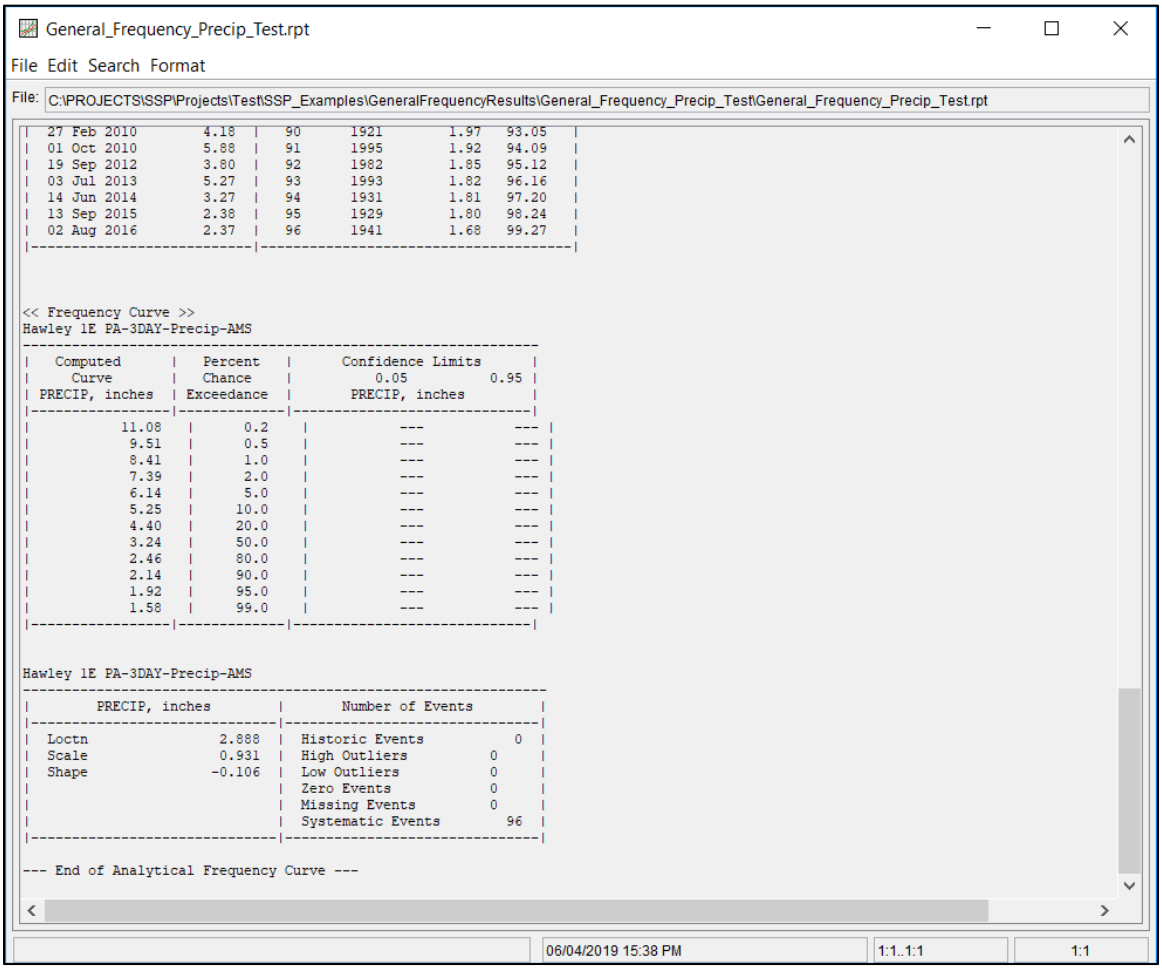


Figure B-271. General Frequency Precip Test Report File.

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 B-272.

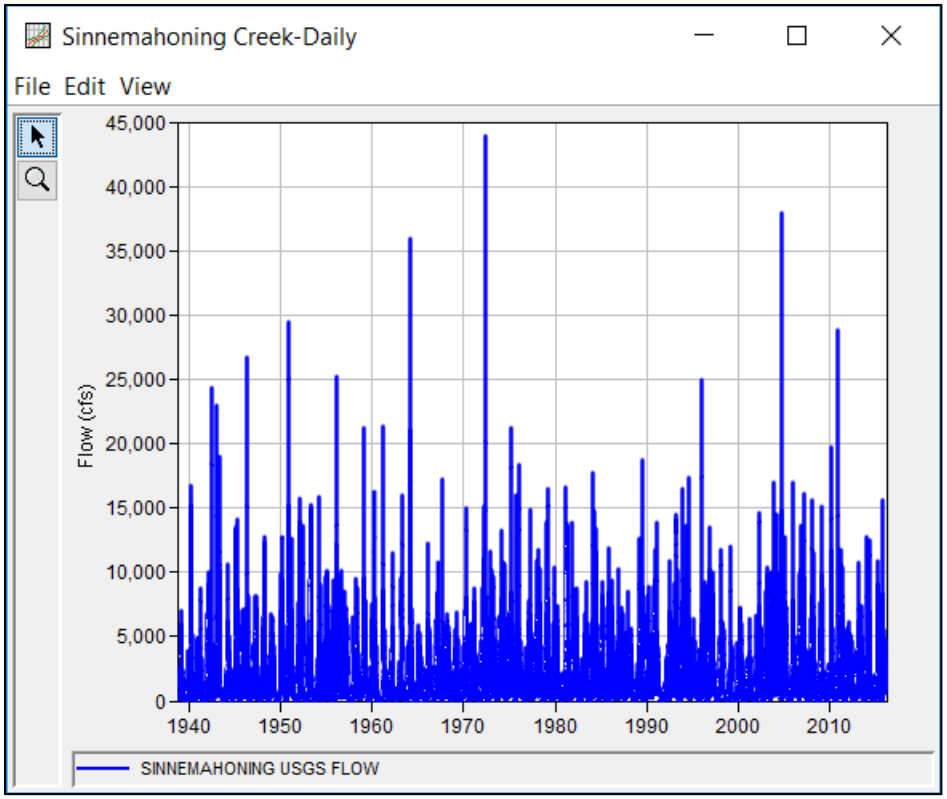


Figure B-272. Plot of the Daily Average Flow Data for Sinnemahoning Creek.

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 B-273.

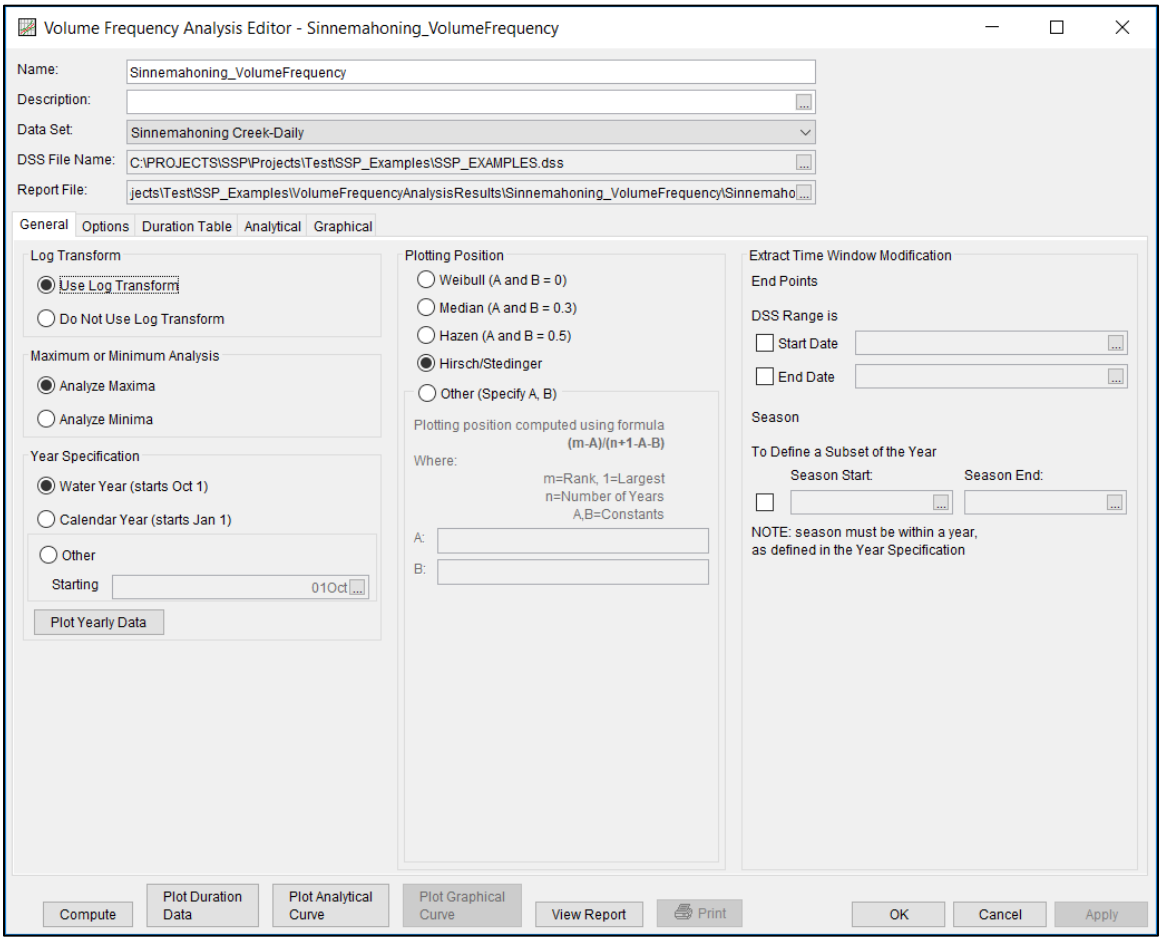


Figure B-273. Volume Frequency Analysis Editor for Sinnemahoning_VolumeFrequency.

Shown in Figure B-273 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 B-274 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.

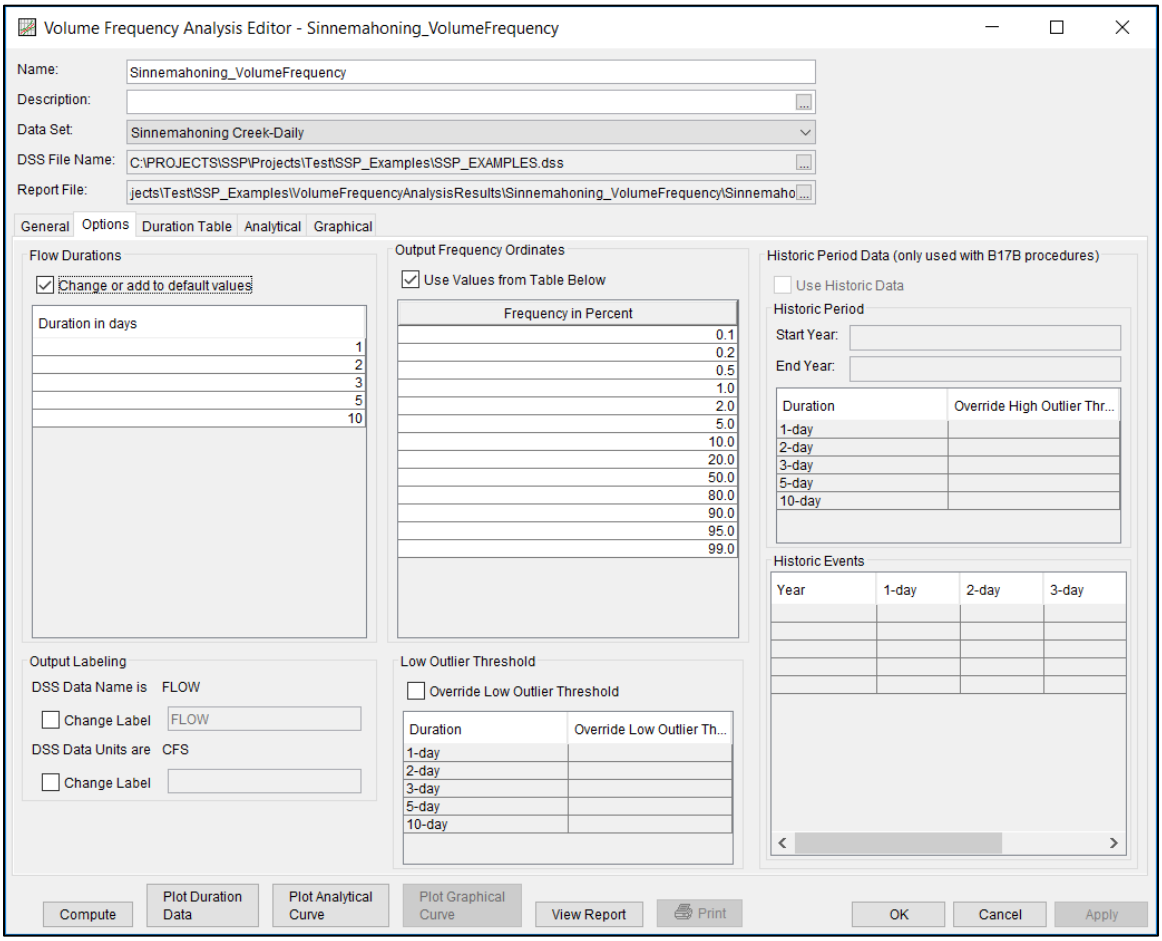
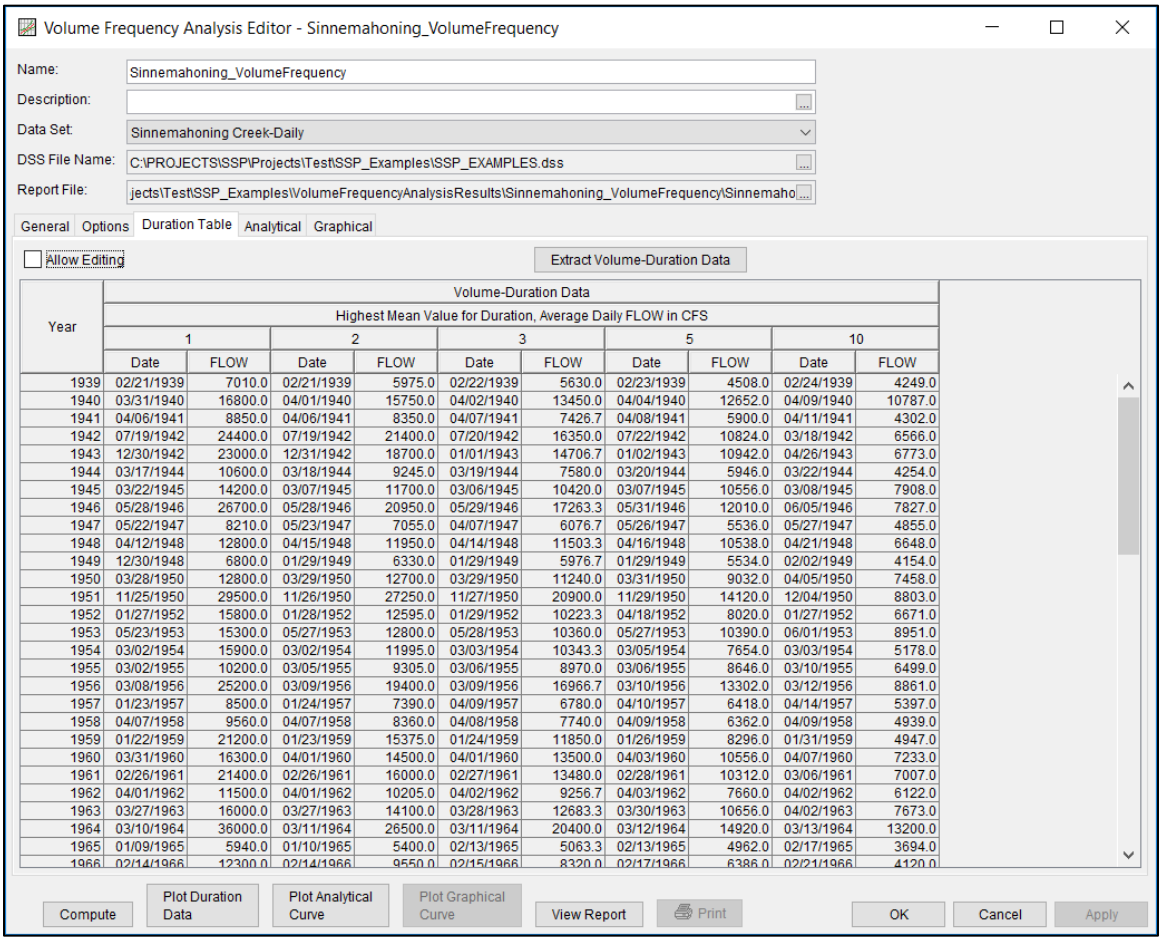


Figure B-274. Options Tab Shown for Sinnemahoning_VolumeFrequency.

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 B-275.



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

Figure B-275. Volume-Duration Data Table for Sinnemahoning_VolumeFrequency.

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 B-276 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.

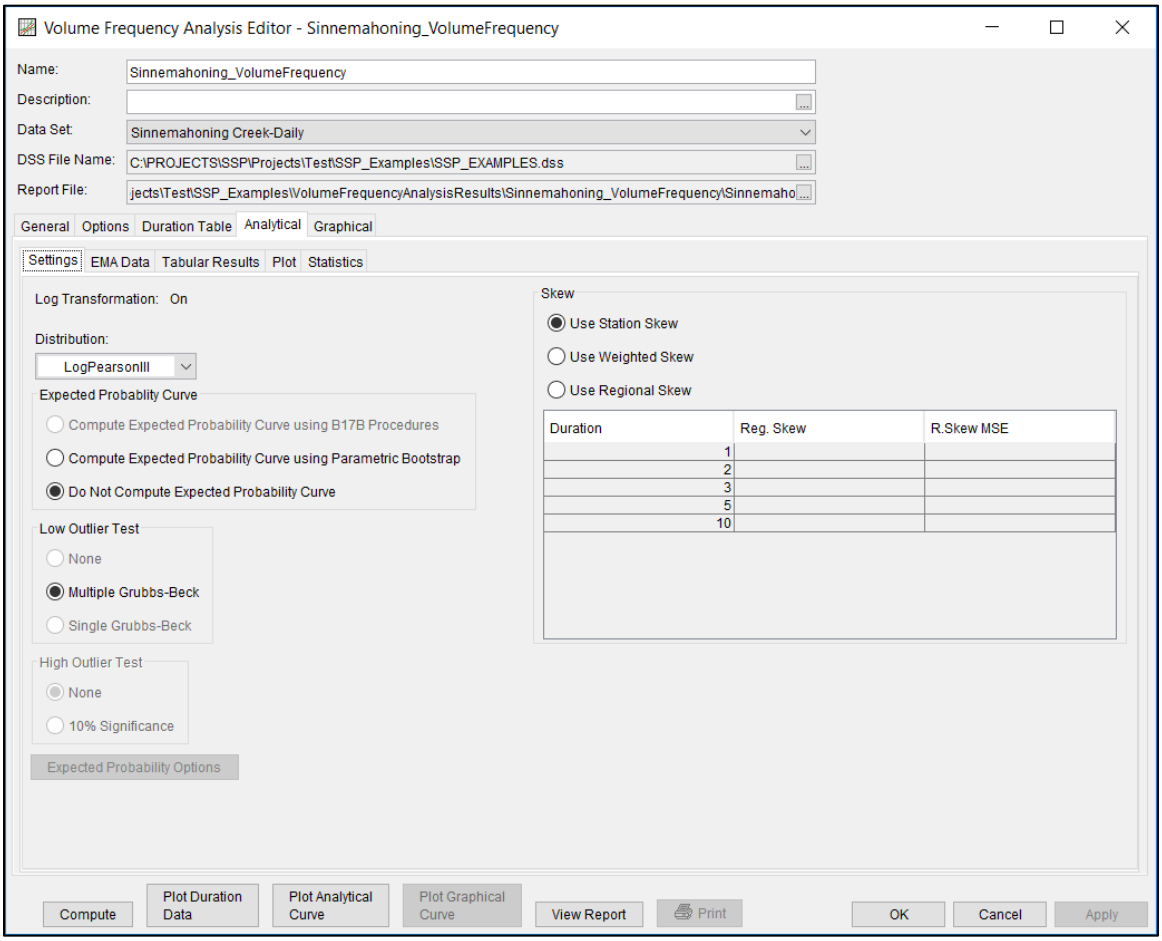


Figure B-276. Settings Tab Shown for Sinnemahoning_VolumeFrequency.

The 1-day duration **EMA Data** tab for this example is shown in Figure B-277. 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.

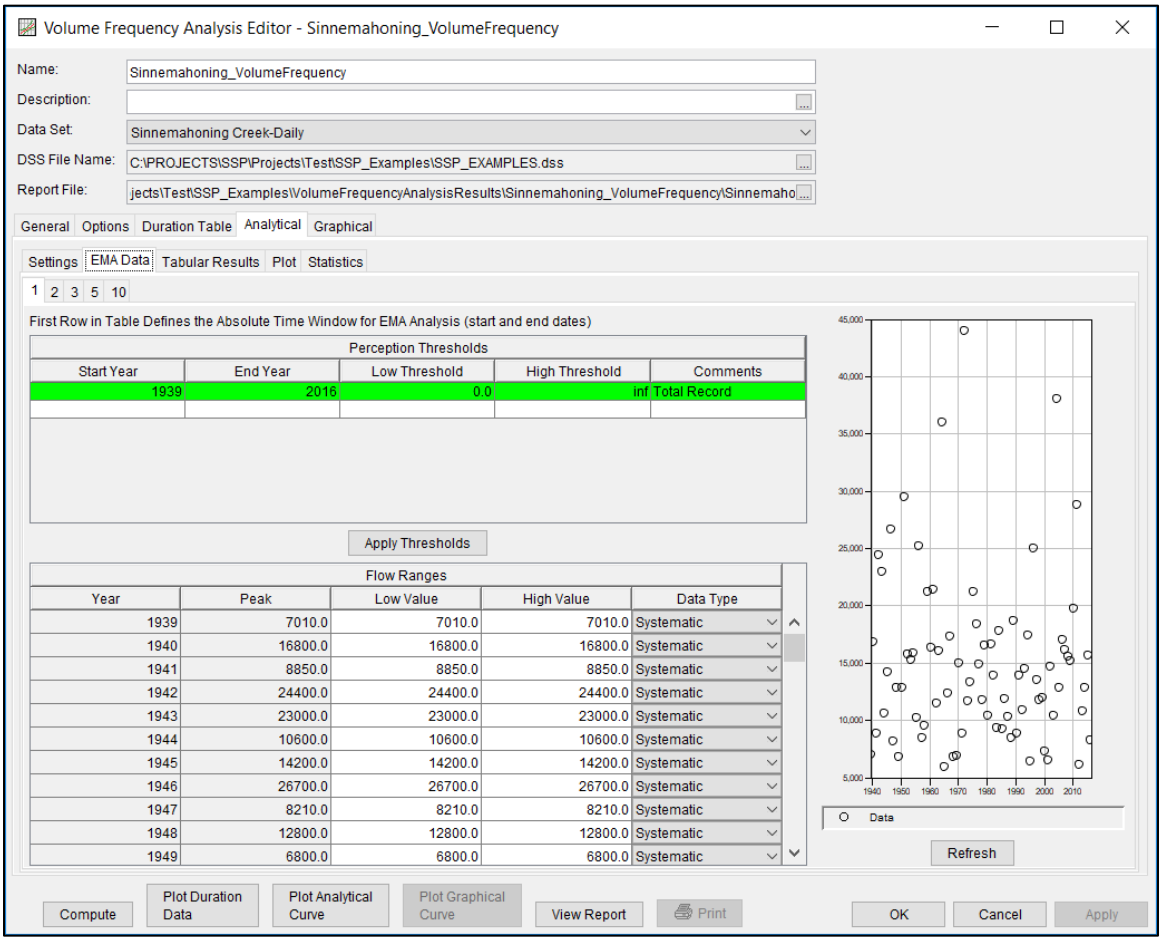


Figure B-277. EMA Data Tabs Shown for Sinnemahoning_VolumeFrequency.

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 B-278. 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.

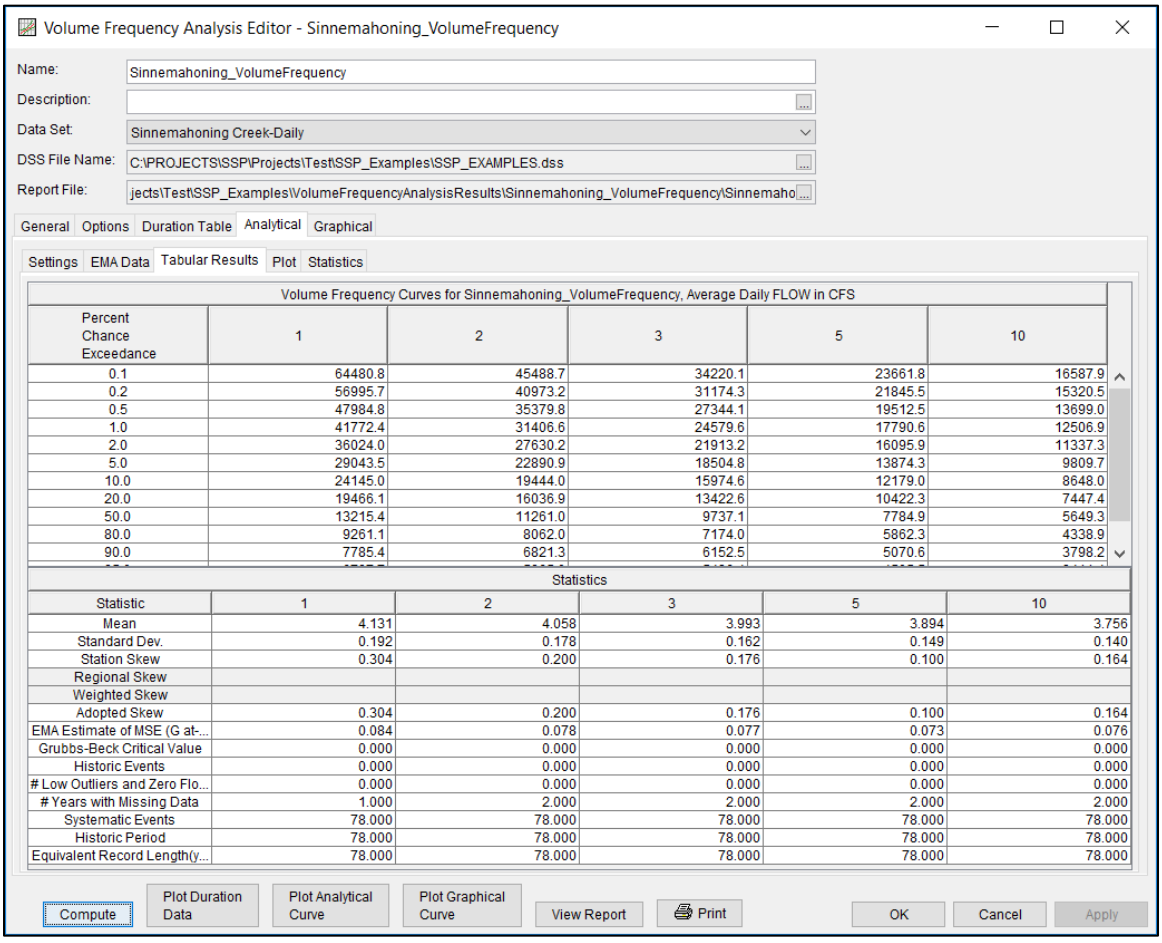


Figure B-278. Tabular Results Tab for Sinnemahoning_VolumeFrequency.

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 B-279, 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 B-280 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.

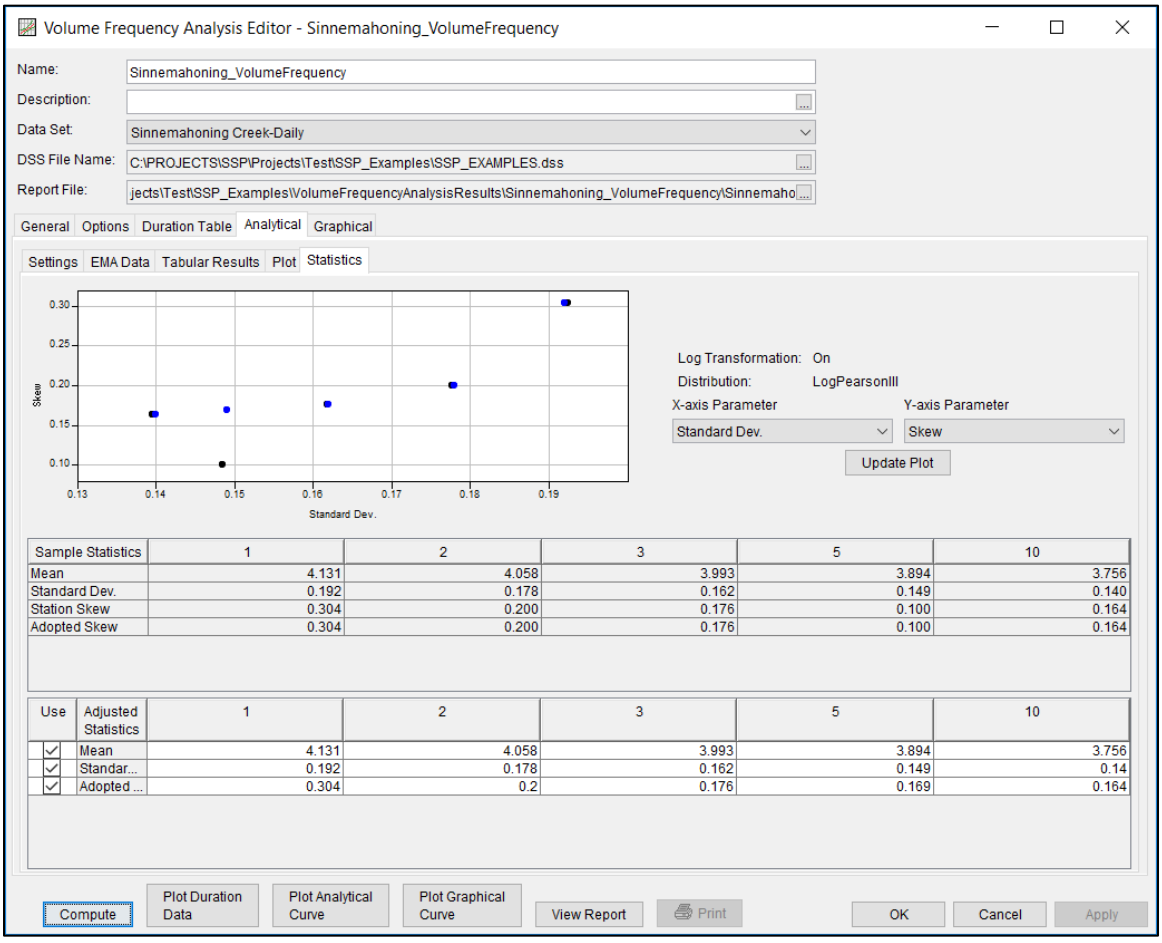


Figure B-279. Statistics Tab for Sinnemahoning_VolumeFrequency.

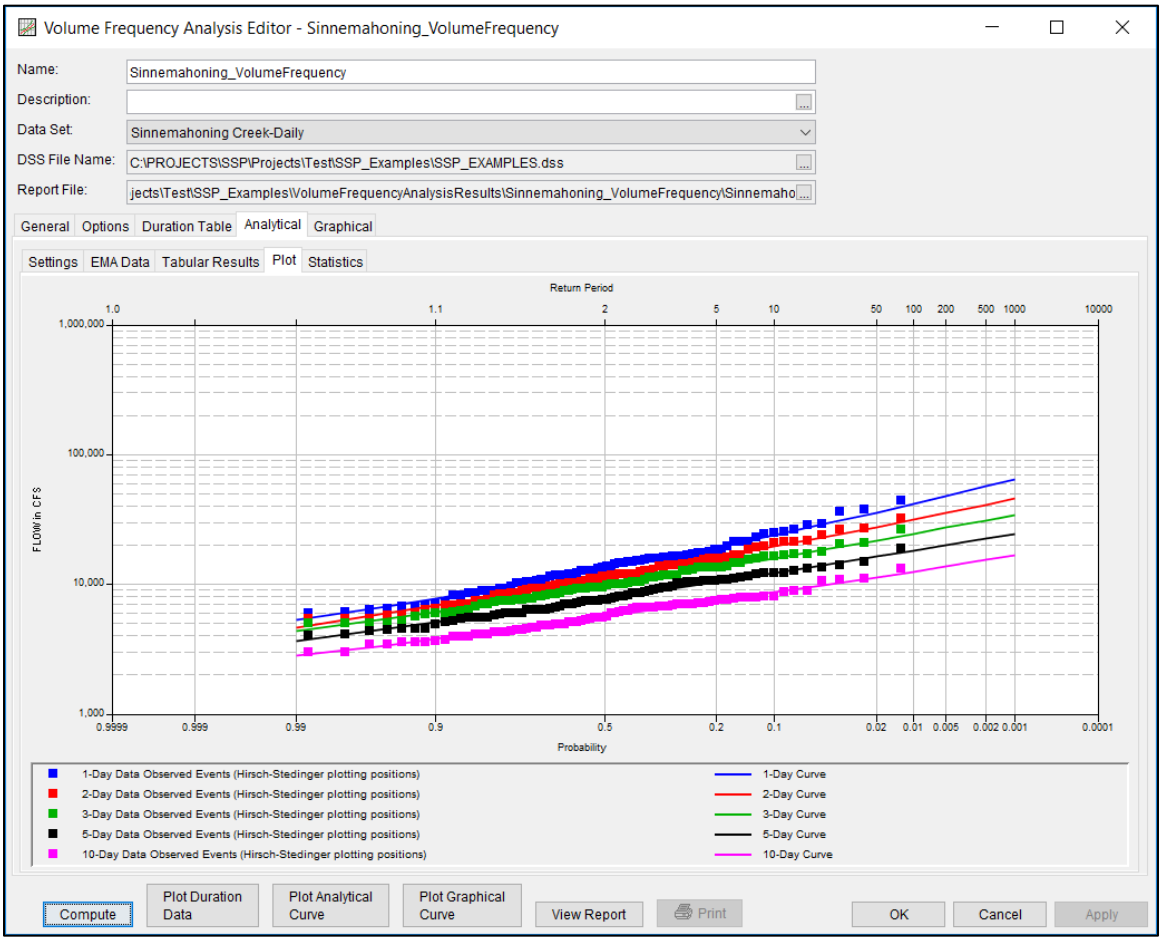


Figure B-280. Plot Tab for Sinnemahoning_VolumeFrequency after the Statistics were Adjusted on the Statistics Tab.

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 B-281.

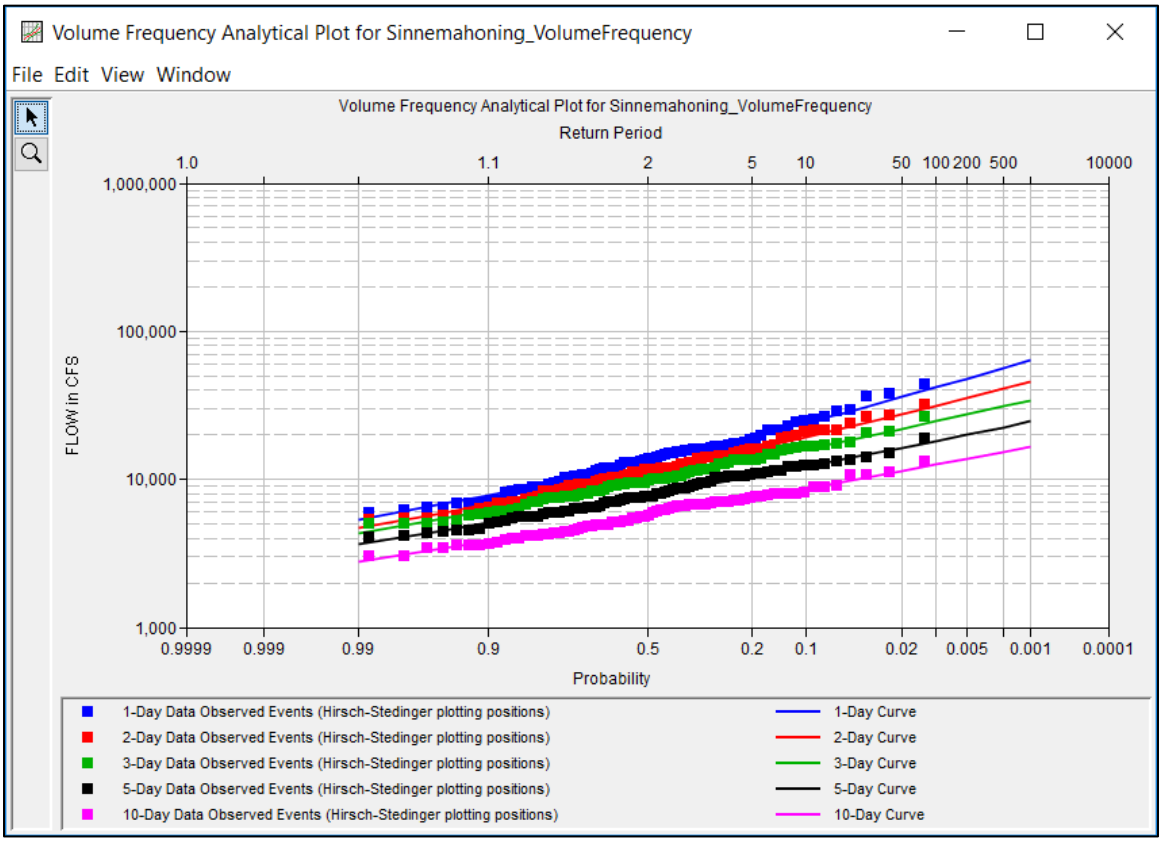


Figure B-281. Plot of the Frequency Curve Results for Sinnemahoning_VolumeFrequency.

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 B-282.

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.

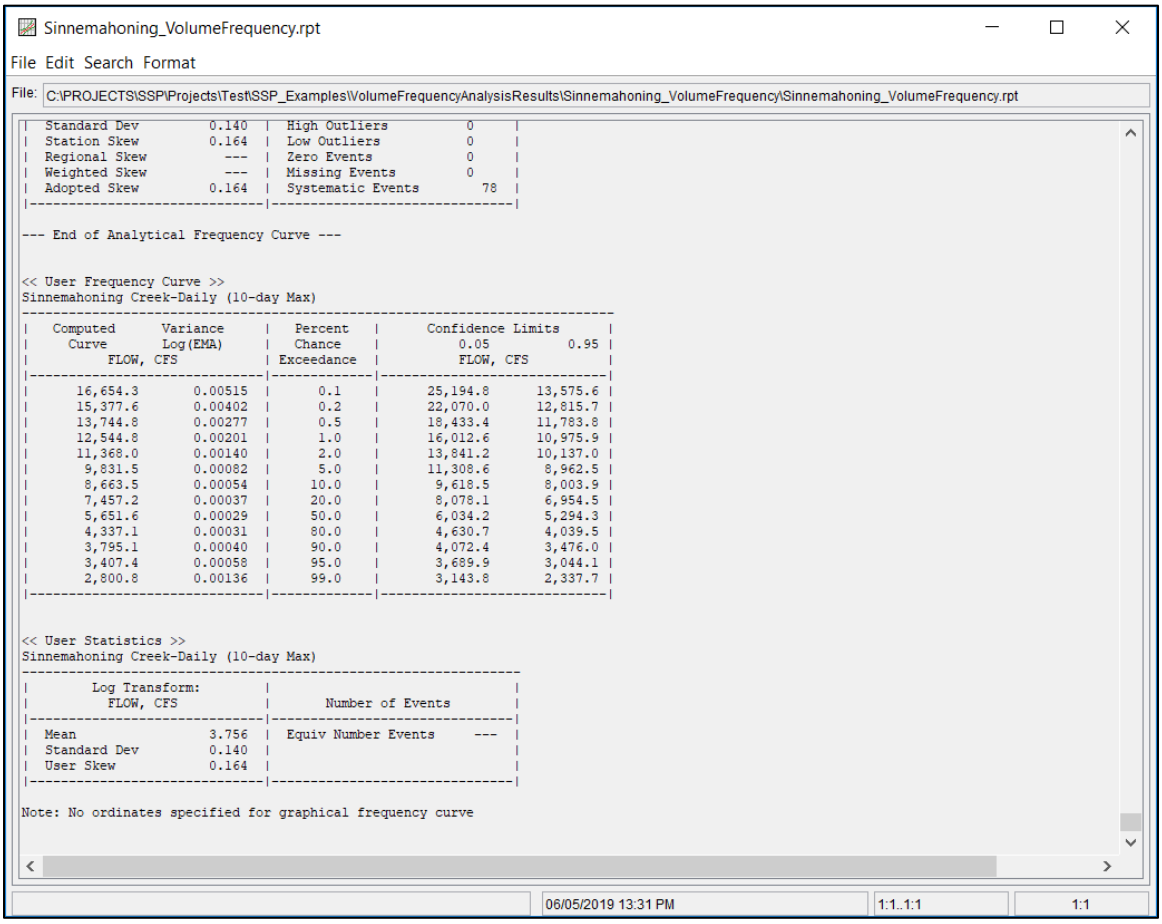


Figure B-282. Report File for Sinnemahoning_VolumeFrequency.

Example 31: 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 B-283.

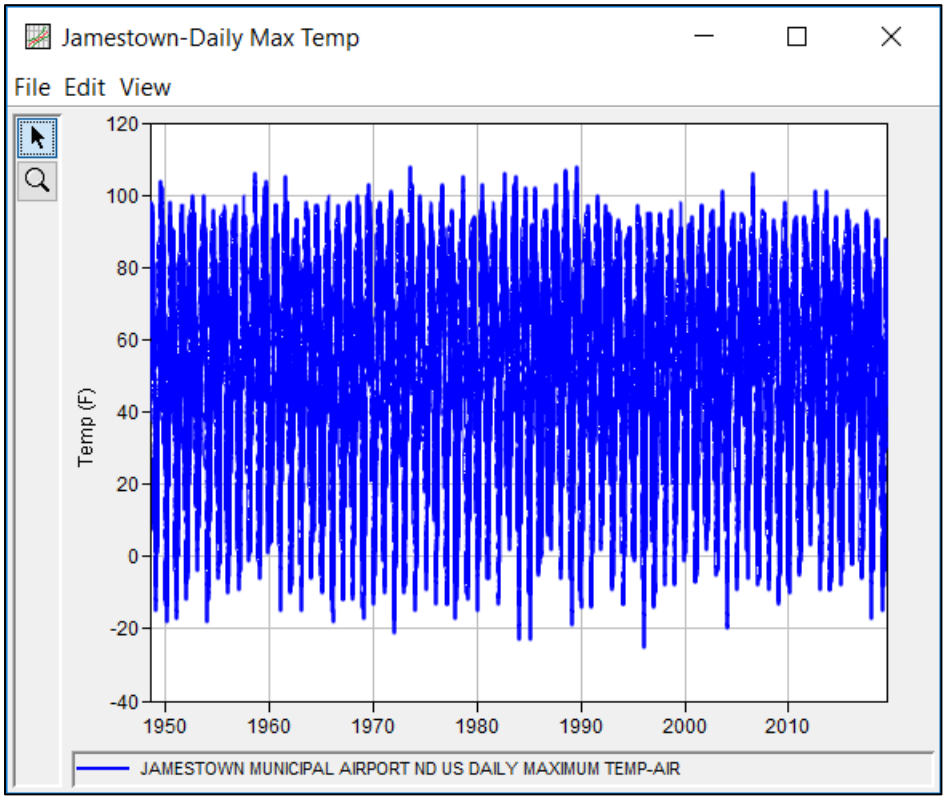


Figure B-283. Plot of the Daily Maximum Temperature Data for Jamestown, ND Municipal Airport.

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 B-284.

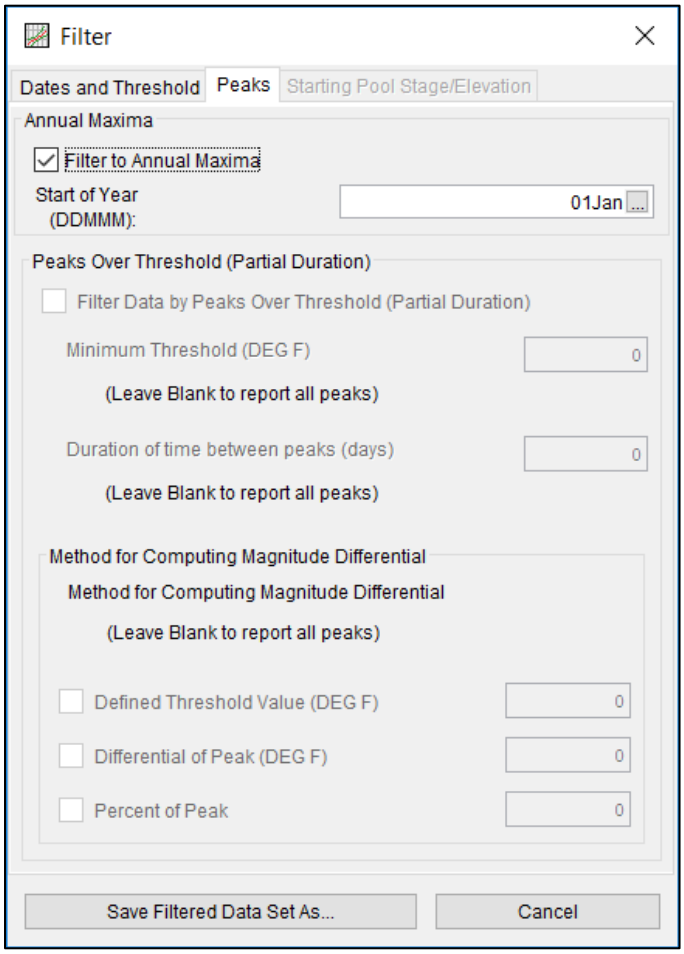


Figure B-284. Data Filters Used for Jamestown Temperature.

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 B-285.

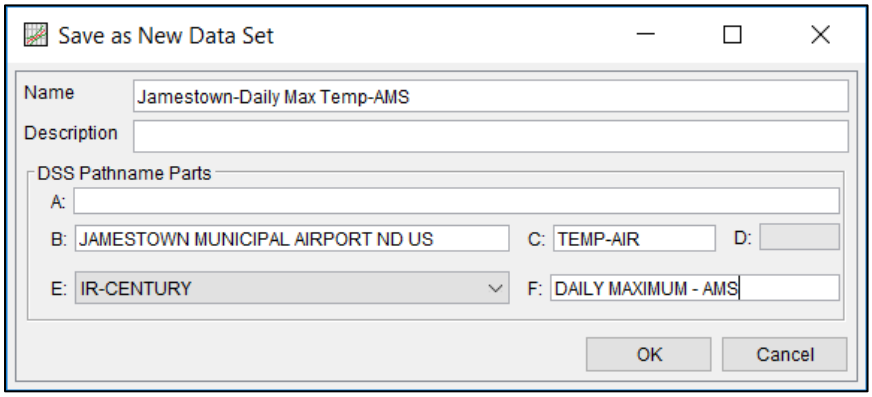


Figure B-285. Name and DSS Pathname Parts for Jamestown Temperature.

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 B-286.

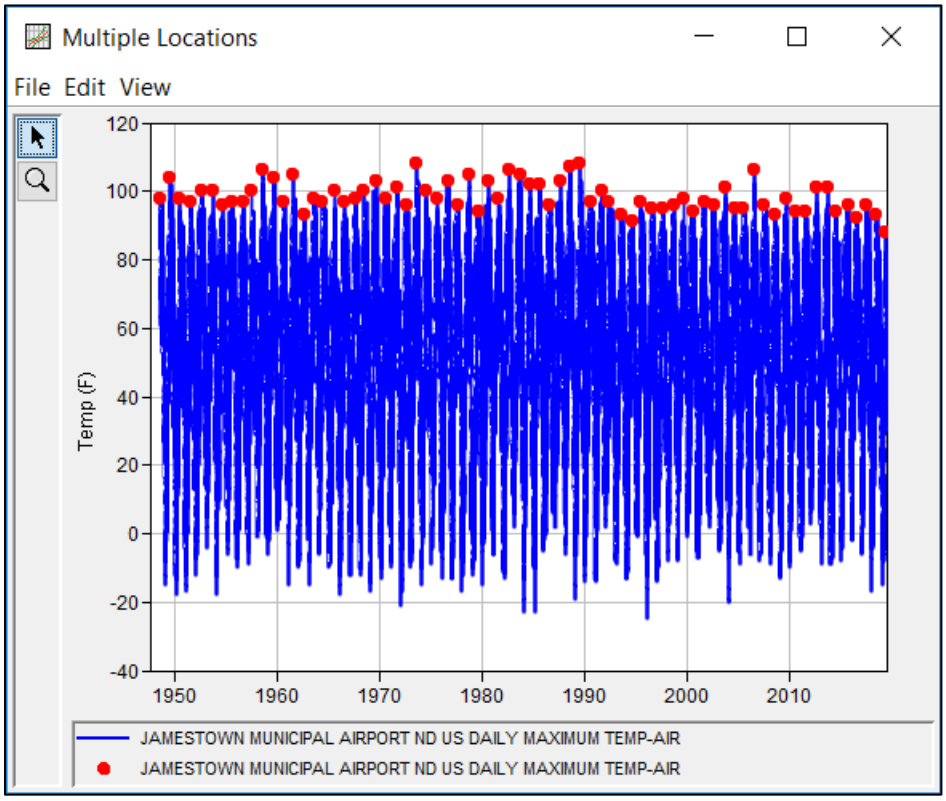


Figure B-286. Original and Filtered Jamestown Temperature Data.

Example 32: 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 B-287.

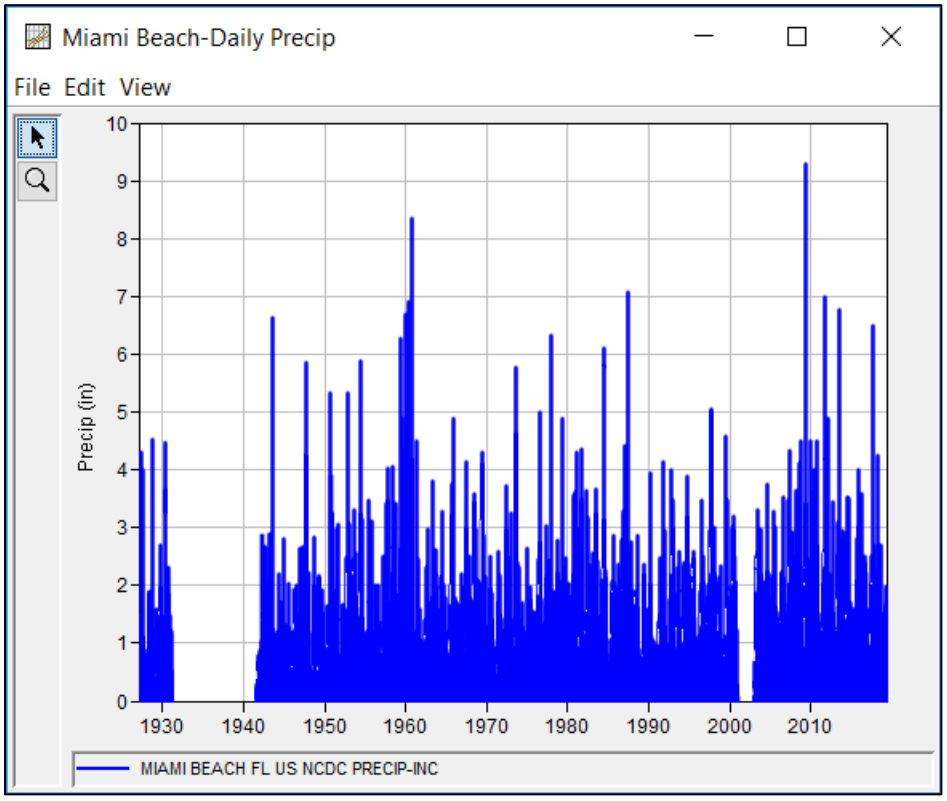


Figure B-287. Plot of the Daily Precipitation Data for Miami Beach, FL.

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 B-288.

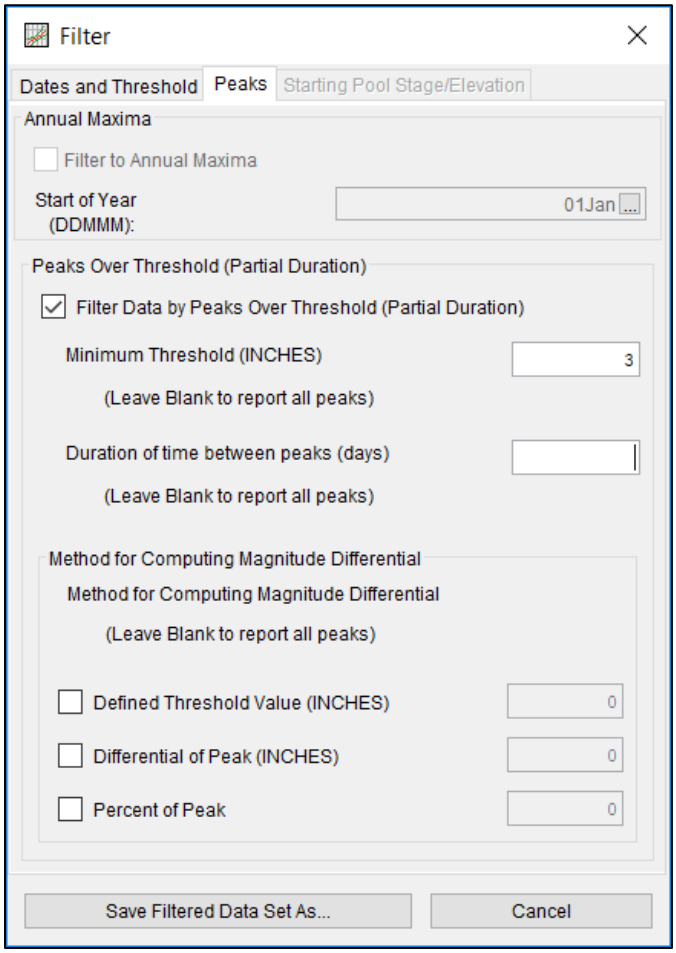


Figure B-288. Data Filters Used for Miami Beach Precipitation.

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 B-289.

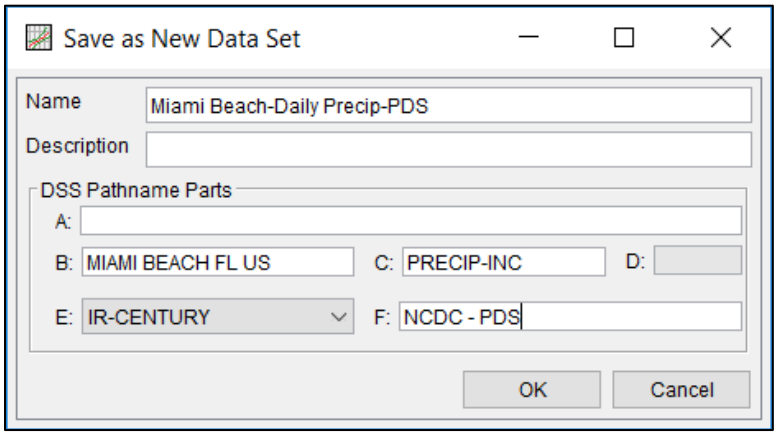


Figure B-289. Name and DSS Pathname Parts for Miami Beach Precipitation.

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 B-290.

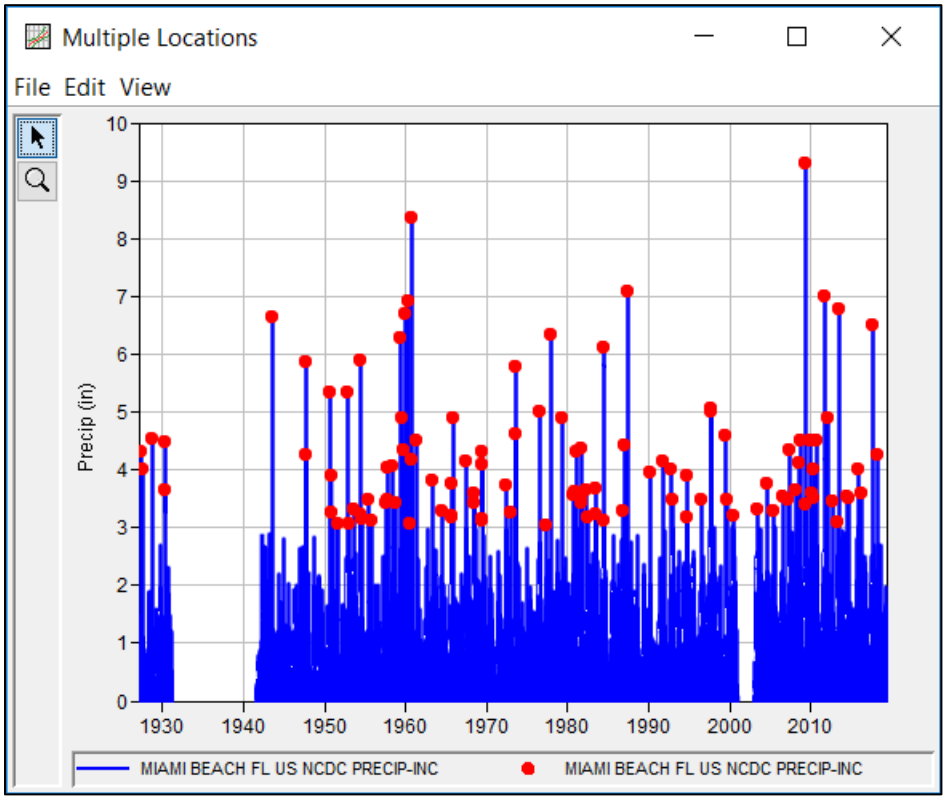


Figure B-290. Original and Filtered Miami Beach Precipitation Data.

Example 33: 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 B-291.

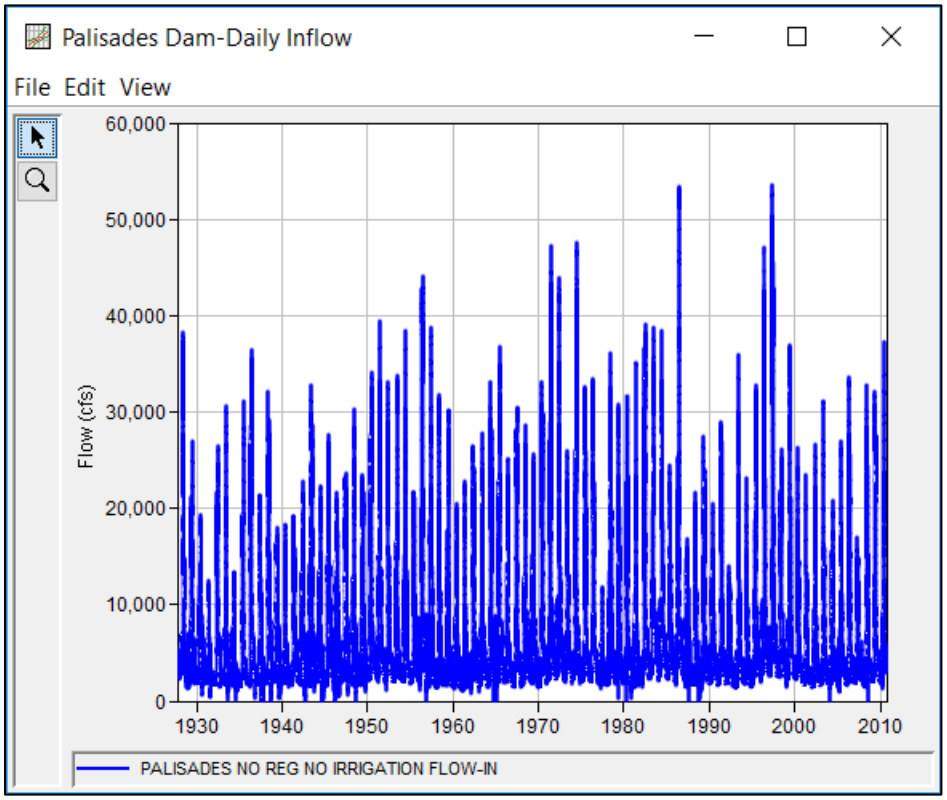


Figure B-291. Plot of the Daily Average Inflow Data for Palisades Lake.

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 B-292.

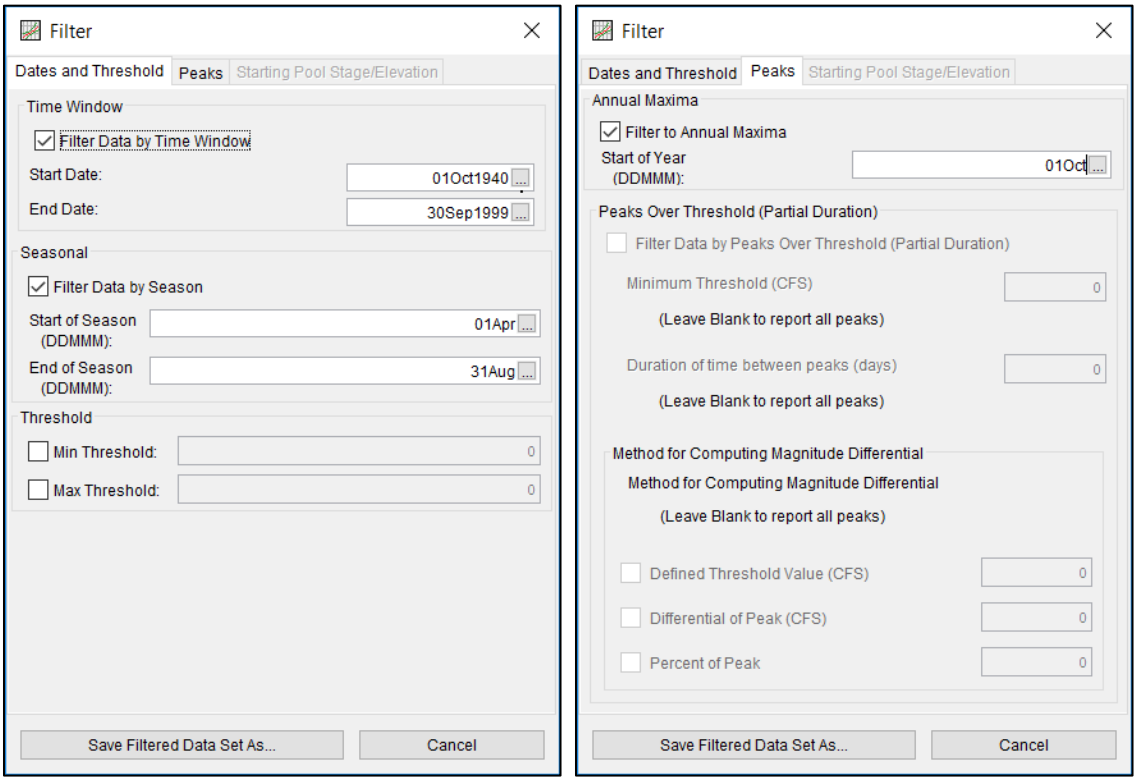


Figure B-292. Data Filters Used for Palisades Lake Inflow.

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 B-293.

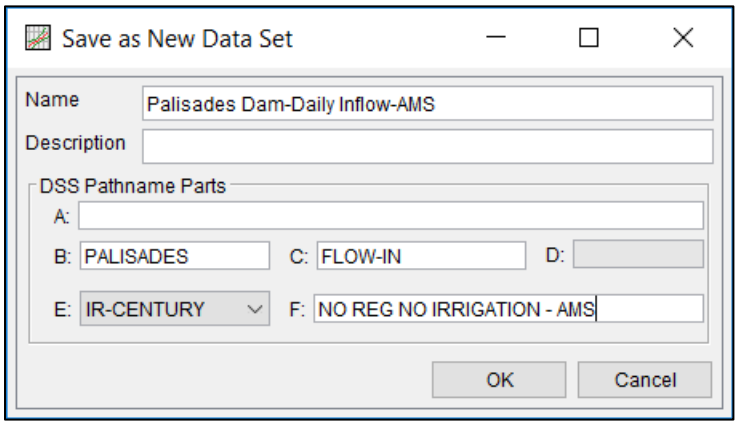


Figure B-293. Name and DSS Pathname Parts for Palisades Lake Inflow.

After clicking the **OK** button, a new data set will be added to the study. Out of the original 30224 values, 70 values remained after applying the

aforementioned data filters. These 70 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 B-294.

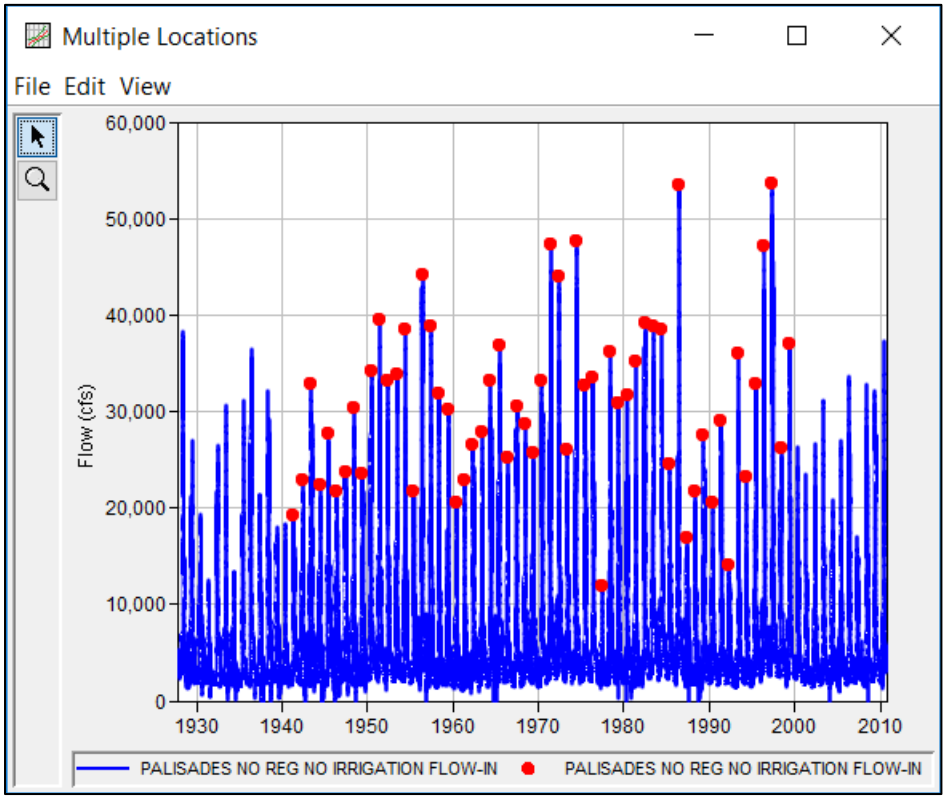


Figure B-294. Original and Filtered Palisades Lake Inflow Data.

Example 34: 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 B-295.

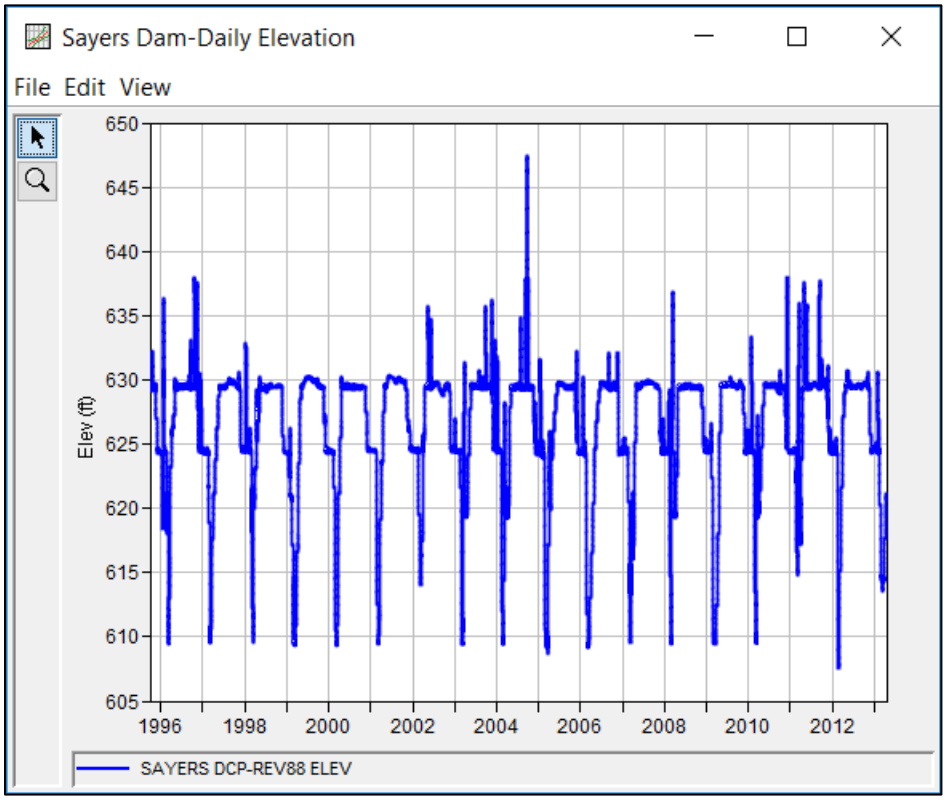


Figure B-295. Plot of the Daily Average Pool Elevation for Sayers Dam.

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 B-296.

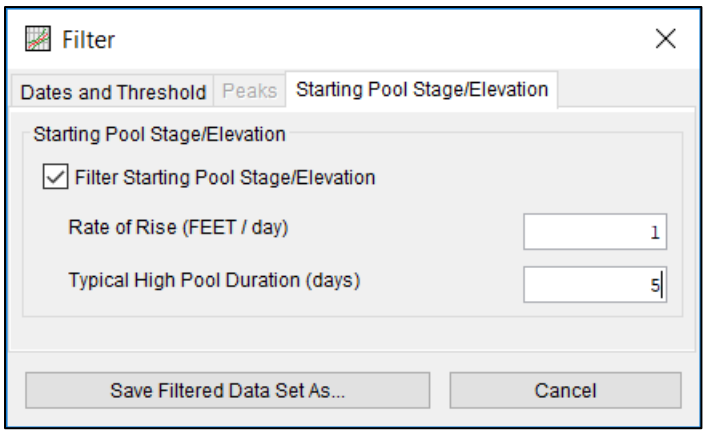


Figure B-296. Data Filters Used for Sayers Dam Starting Pool.

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 B-297.

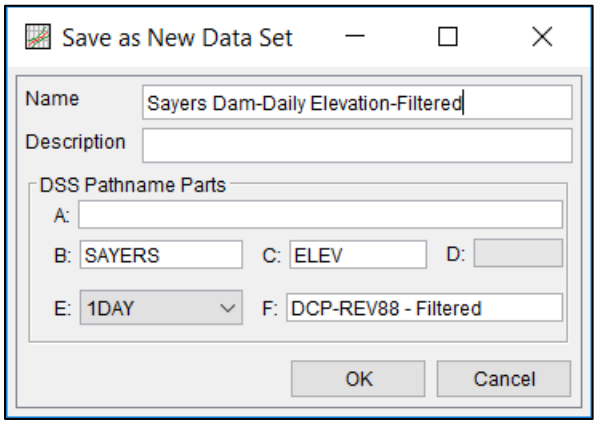


Figure B-297. Name and DSS Pathname Parts for Sayers Dam Starting Pool.

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 B-298. A more detailed view of the filtered time series is shown in Figure B-299. 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 B-300.

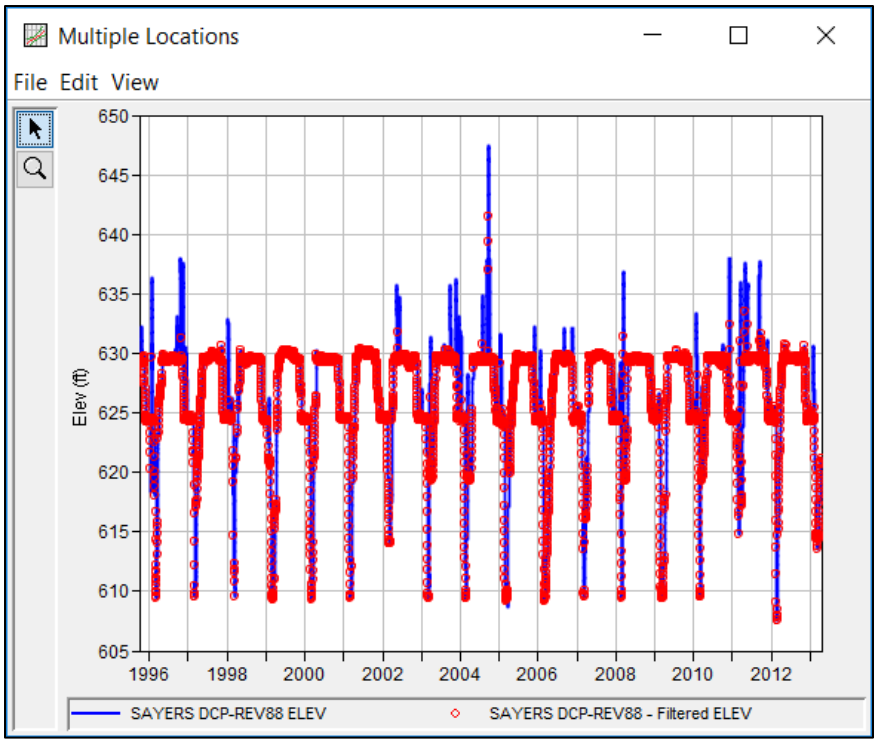


Figure B-298. Original and Filtered Sayers Dam Pool Elevation Data.

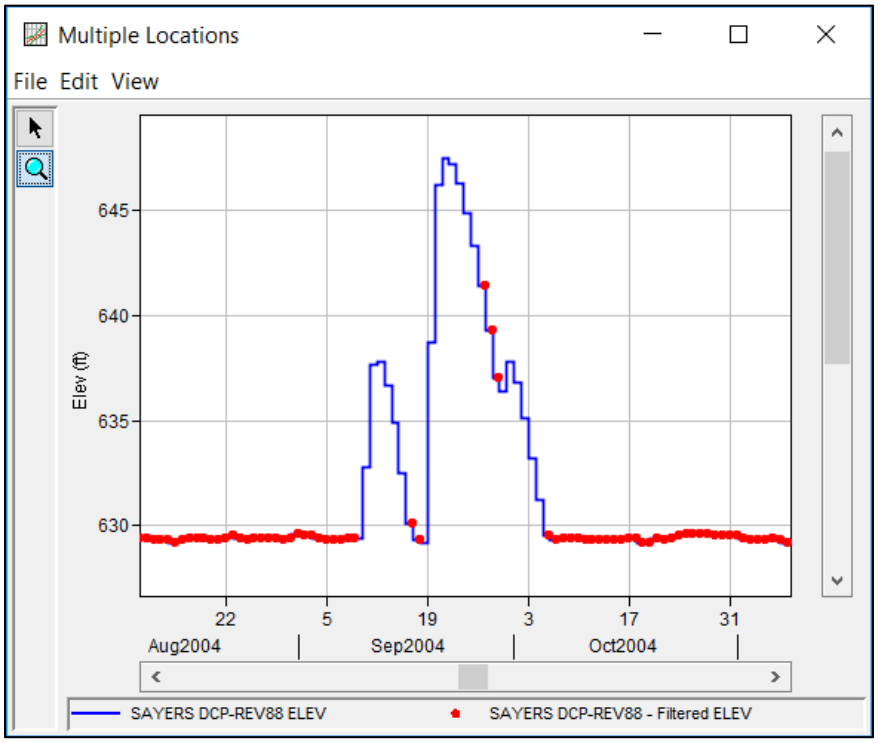


Figure B-299. Detailed View of Original and Filtered Sayers Dam Data.

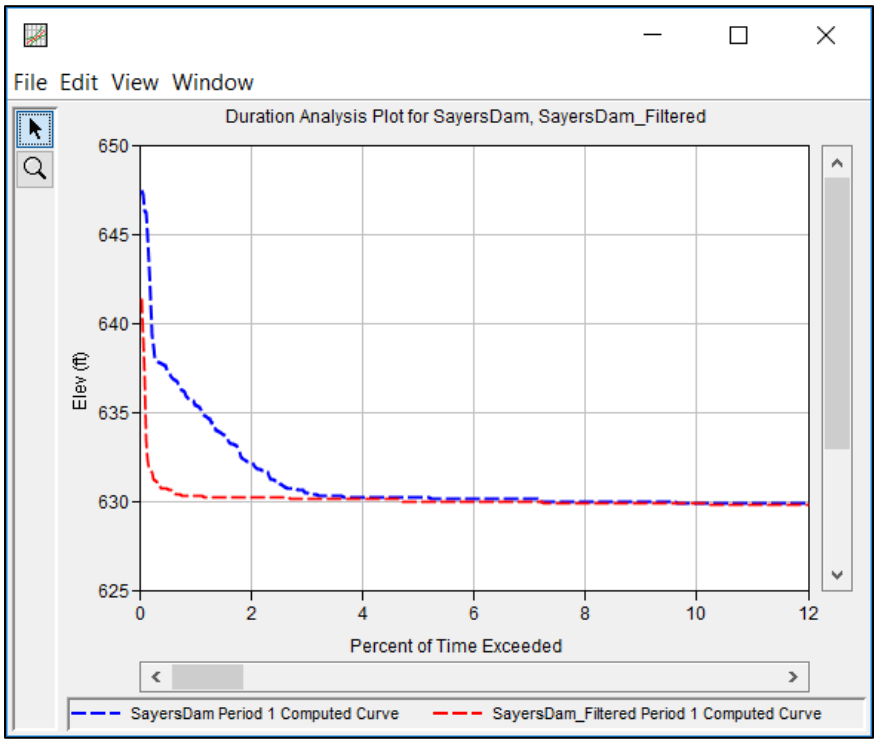


Figure B-300. Original and Filtered Sayers Dam Pool Elevation Duration Curves.

APPENDIX C

Bulletin 17C / Expected Moments Algorithm Examples

This Appendix provides ten examples using 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 C-1. The following sections document each of the example data sets.

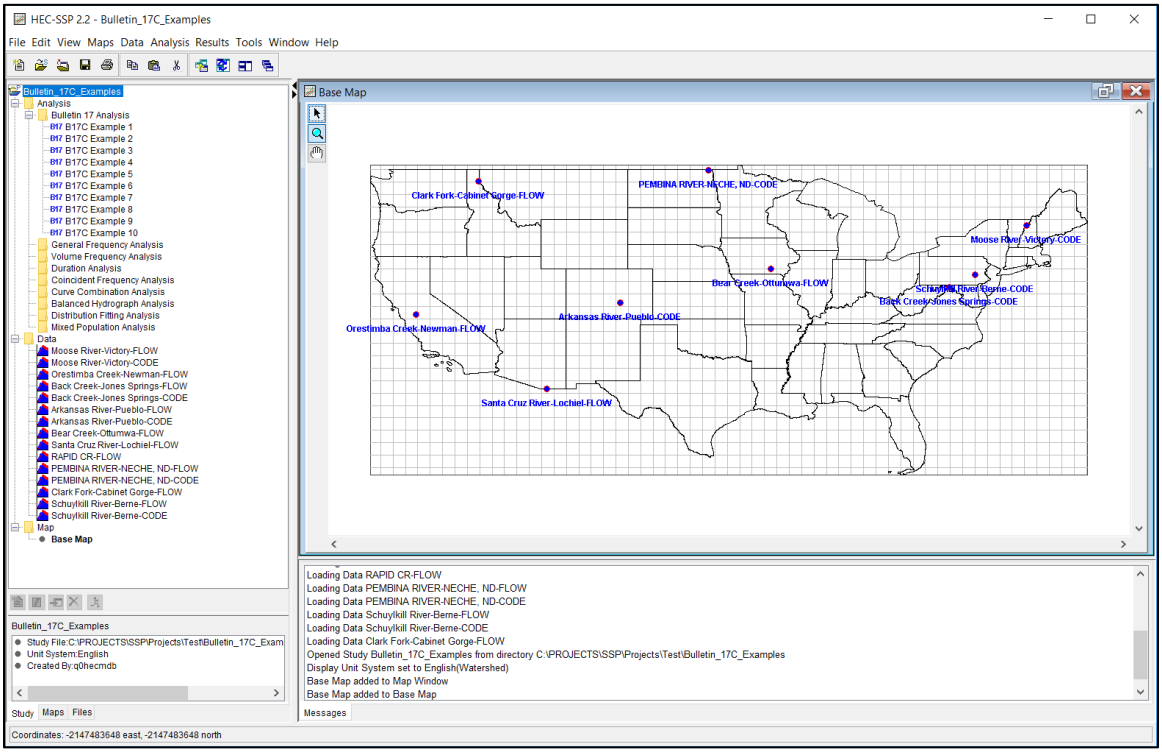


Figure C-1. Bulletin 17C Examples Study.

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 C-2. The annual peak flow record is tabulated within Table C-1.

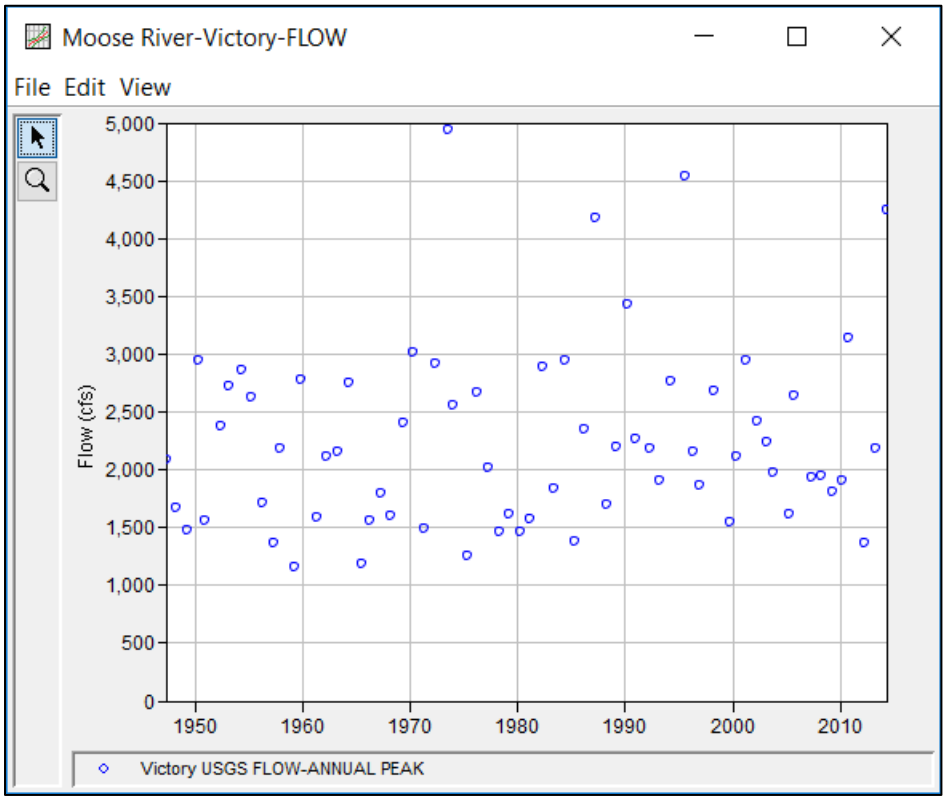


Figure C-2. Moose River at Victory, VT Annual Peak Flow Record.

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

Date	Flow (cfs)	Date	Flow (cfs)
13 Apr 1947	2080	21 Feb 1981	1570
28 Mar 1948	1670	18 Apr 1982	2890
28 Mar 1949	1480	04 May 1983	1840
21 Apr 1950	2940	31 May 1984	2950
05 Dec 1950	1560	17 Apr 1985	1380
02 Jun 1952	2380	31 Mar 1986	2350
27 Mar 1953	2720	31 Mar 1987	4180
23 Apr 1954	2860	06 Apr 1988	1700
15 Apr 1955	2620	06 Apr 1989	2200
30 Apr 1956	1710	18 Mar 1990	3430
22 Apr 1957	1370	24 Dec 1990	2270
21 Dec 1957	2180	23 Apr 1992	2180
04 Apr 1959	1160	17 Apr 1993	1900
29 Nov 1959	2780	17 Apr 1994	2760
24 Apr 1961	1580	06 Aug 1995	4536
08 Apr 1962	2110	24 Apr 1996	2160
22 Apr 1963	2160	02 Dec 1996	1860
15 Apr 1964	2750	31 Mar 1998	2680
14 Jun 1965	1190	18 Sep 1999	1540
26 Mar 1966	1560	11 May 2000	2110
03 Apr 1967	1800	25 Apr 2001	2950
24 Mar 1968	1600	14 Apr 2002	2410
29 Apr 1969	2400	30 Mar 2003	2230
25 Apr 1970	3010	28 Oct 2003	1980
04 May 1971	1490	04 Apr 2005	1610
05 May 1972	2920	17 Oct 2005	2640
01 Jul 1973	4940	24 Apr 2007	1930
22 Dec 1973	2550	20 Apr 2008	1940
20 Apr 1975	1250	04 Apr 2009	1810
02 Apr 1976	2670	24 Mar 2010	1900
31 Mar 1977	2020	01 Oct 2010	3140
10 May 1978	1460	20 Mar 2012	1370
26 Mar 1979	1620	20 Apr 2013	2180
10 Apr 1980	1460	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 C-3. 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.

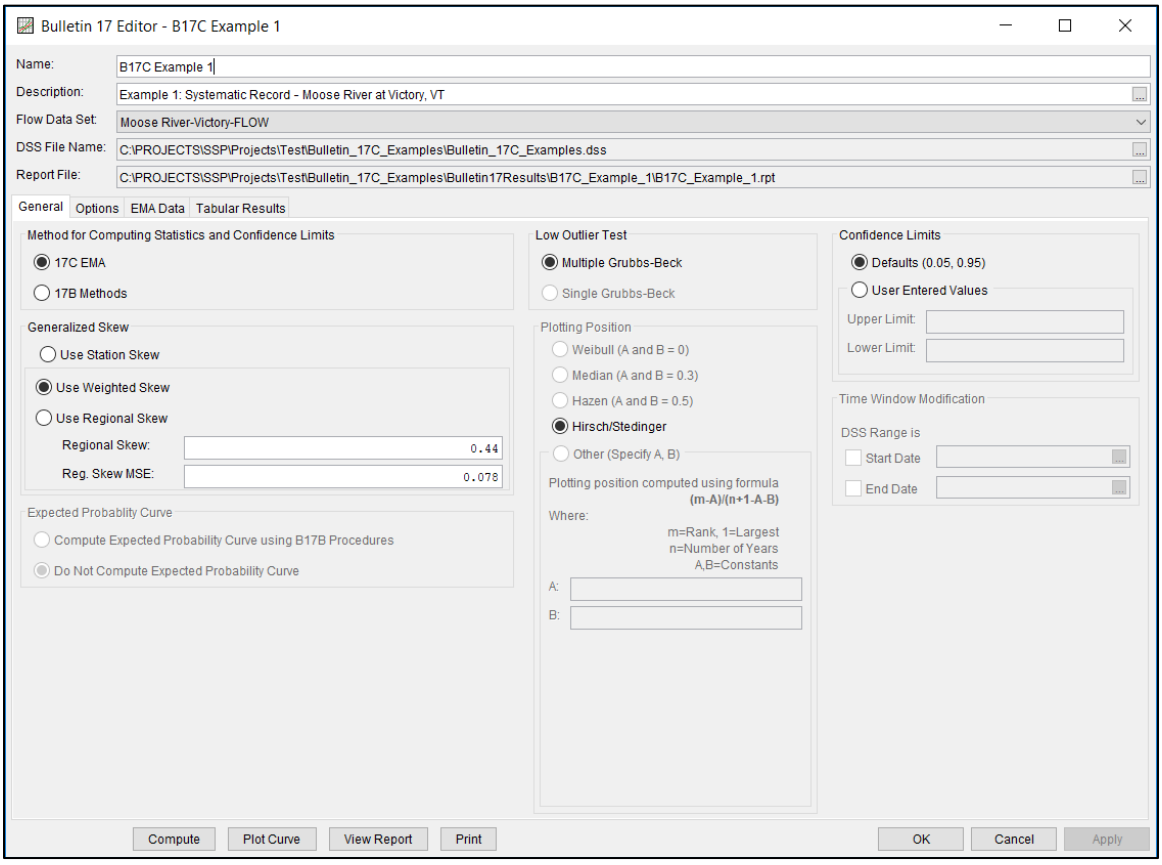


Figure C-3. Bulletin 17 Analysis General Tab for B17C Example 1.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-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.

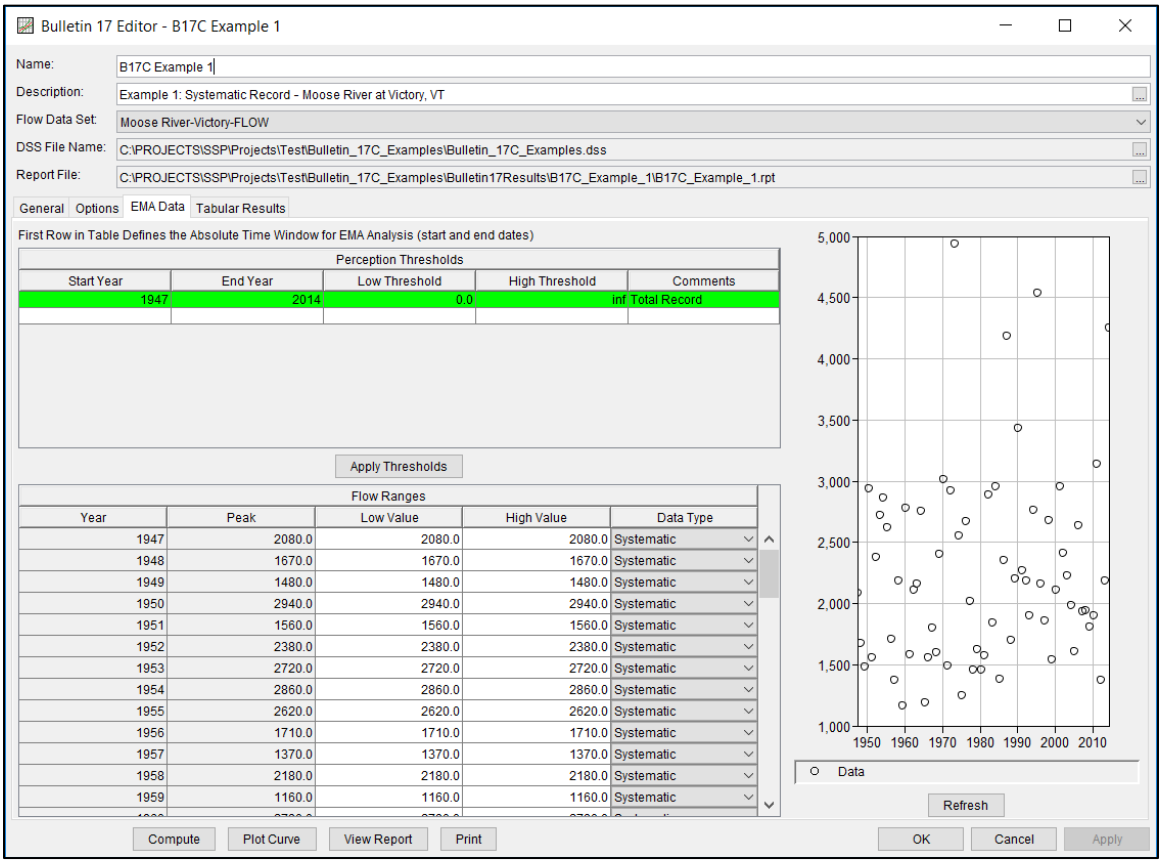


Figure C-4. Bulletin 17 Analysis EMA Data Tab for B17C Example 1.

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 C-5.

As shown in Figure C-5, 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 years.

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 C-6.

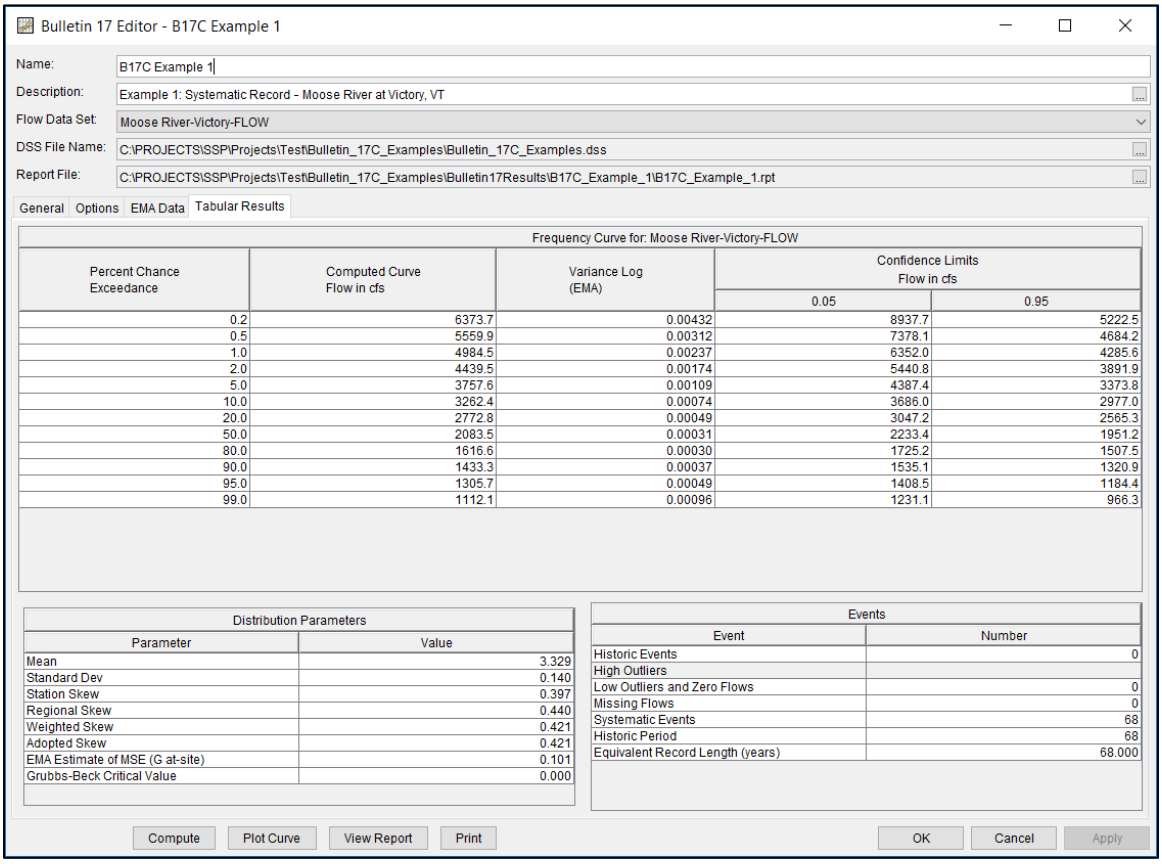


Figure C-5. Bulletin 17 Analysis Tabular Results Tab for B17C Example 1.

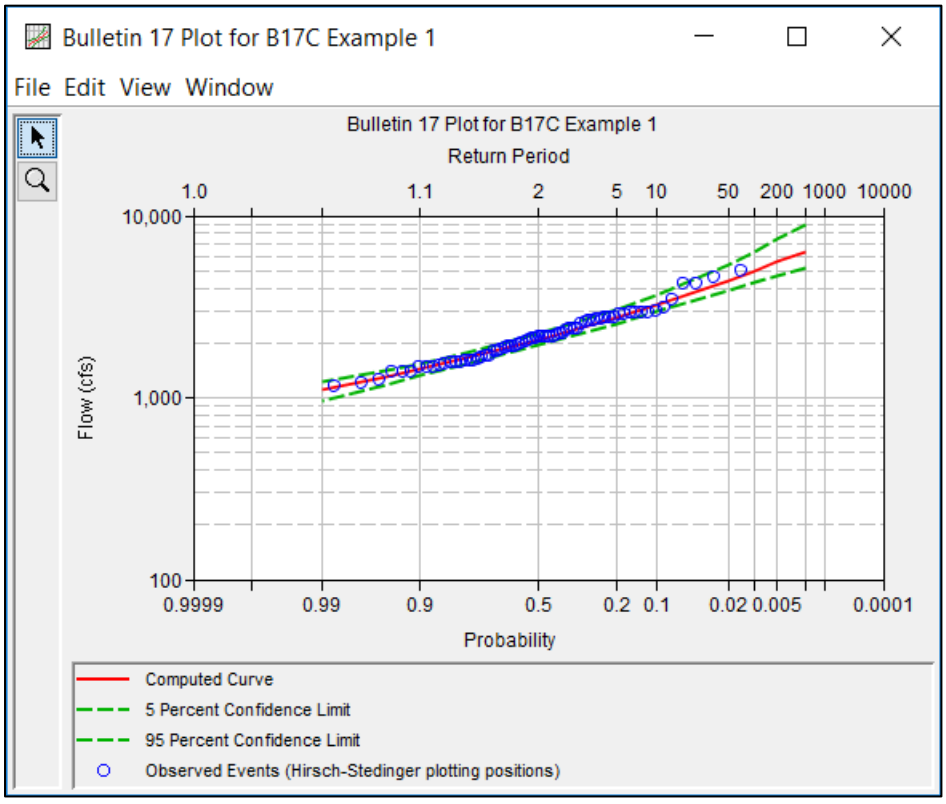
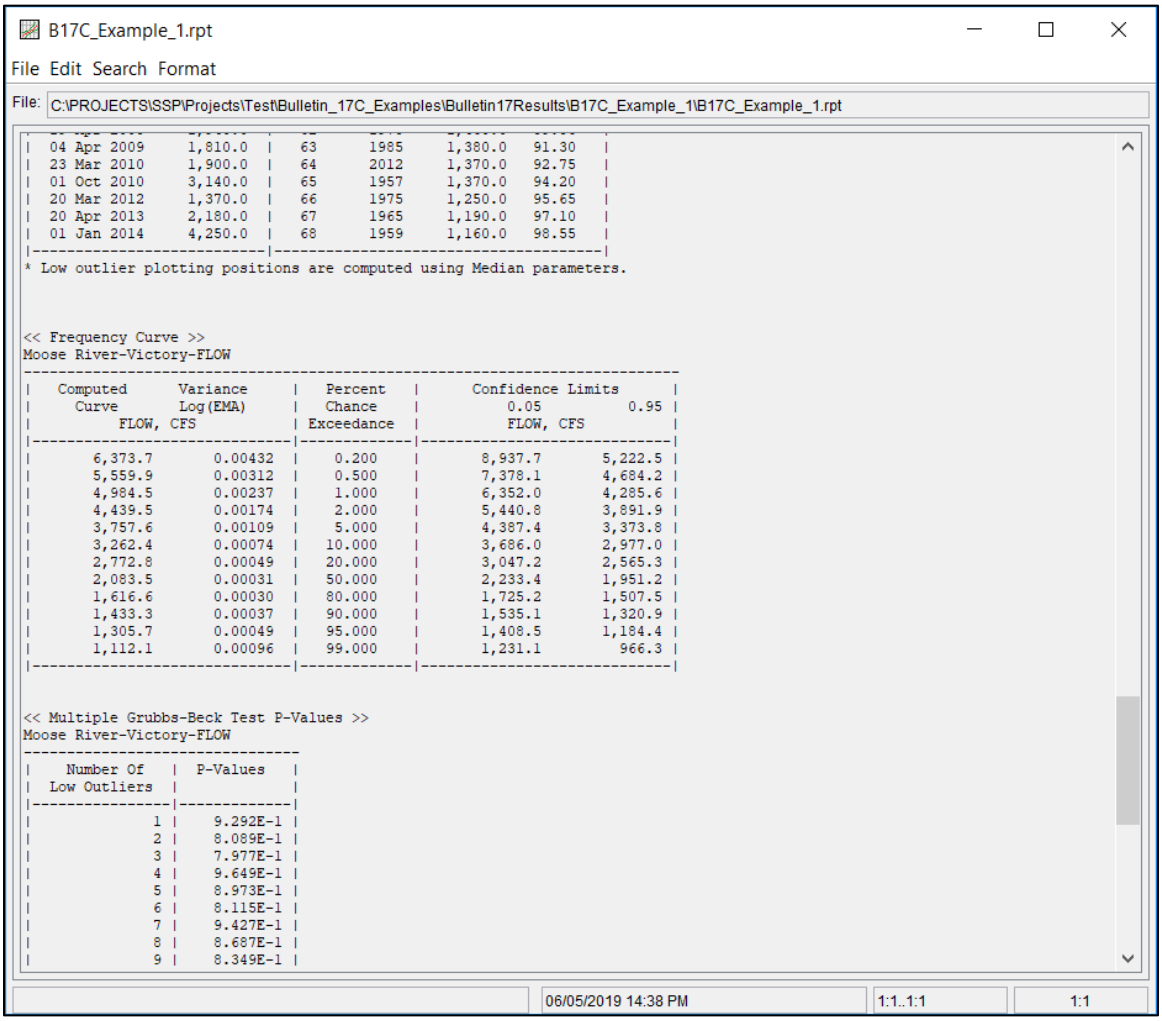


Figure C-6. Plotted Frequency Curves for B17C Example 1.

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 C-7 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.



B17C_Example_1.rpt

File Edit Search Format

File: C:\PROJECTS\SSP\Projects\Test\Bulletin_17C_Examples\Bulletin17Results\B17C_Example_1\B17C_Example_1.rpt

04 Apr 2009	1,810.0	63	1985	1,380.0	91.30	
23 Mar 2010	1,900.0	64	2012	1,370.0	92.75	
01 Oct 2010	3,140.0	65	1957	1,370.0	94.20	
20 Mar 2012	1,370.0	66	1975	1,250.0	95.65	
20 Apr 2013	2,180.0	67	1965	1,190.0	97.10	
01 Jan 2014	4,250.0	68	1959	1,160.0	98.55	

* Low outlier plotting positions are computed using Median parameters.

<< Frequency Curve >>
Moose River-Victory-FLOW

Computed Curve FLOW, CFS	Variance Log(EMA)	Percent Chance Exceedance	Confidence Limits 0.05 FLOW, CFS	0.95
6,373.7	0.00432	0.200	8,937.7	5,222.5
5,559.9	0.00312	0.500	7,378.1	4,684.2
4,984.5	0.00237	1.000	6,352.0	4,285.6
4,439.5	0.00174	2.000	5,440.8	3,891.9
3,757.6	0.00109	5.000	4,387.4	3,373.8
3,262.4	0.00074	10.000	3,686.0	2,977.0
2,772.8	0.00049	20.000	3,047.2	2,565.3
2,083.5	0.00031	50.000	2,233.4	1,951.2
1,616.6	0.00030	80.000	1,725.2	1,507.5
1,433.3	0.00037	90.000	1,535.1	1,320.9
1,305.7	0.00049	95.000	1,408.5	1,184.4
1,112.1	0.00096	99.000	1,231.1	966.3

<< Multiple Grubbs-Beck Test P-Values >>
Moose River-Victory-FLOW

Number Of Low Outliers	P-Values
1	9.292E-1
2	8.089E-1
3	7.977E-1
4	9.649E-1
5	8.973E-1
6	8.115E-1
7	9.427E-1
8	8.687E-1
9	8.349E-1

06/05/2019 14:38 PM 1:1..1:1 1:1

Figure C-7. Report File for B17C Example 1.

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 C-8 and tabulated in Table C-2.

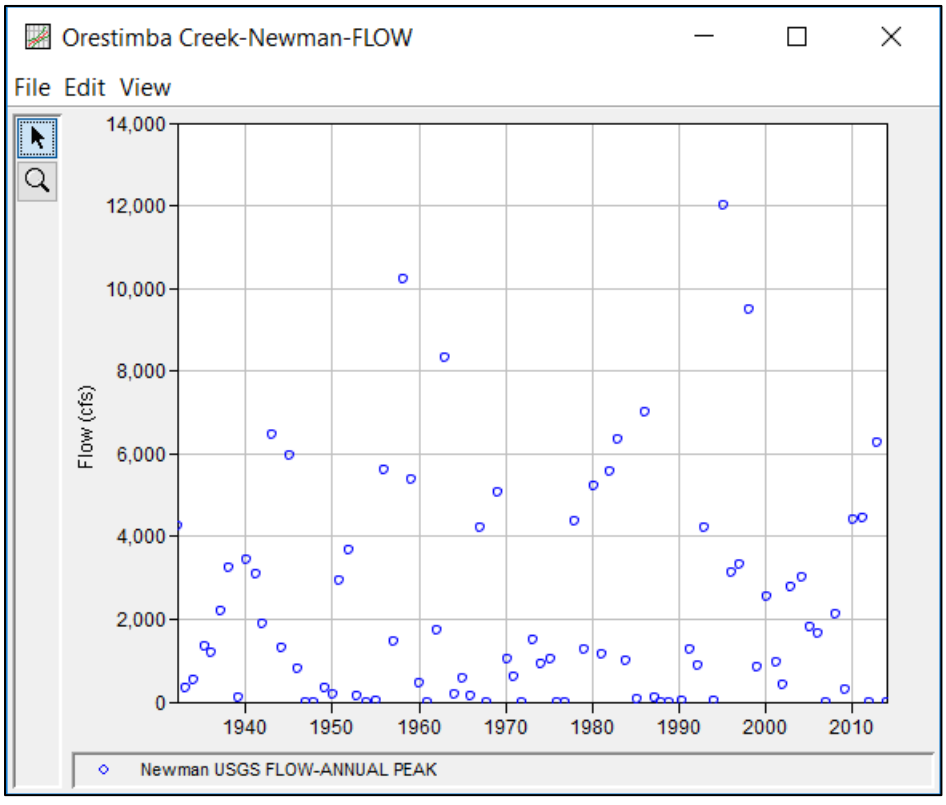


Figure C-8. Orestimba Creek near Newman, CA Annual Peak Flow Record.

Table C-2. Orestimba Creek near Newman, CA Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
08 Feb 1932	4260	10 Feb 1960	448	30 Nov 1987	0
29 Jan 1933	345	30 Nov 1960	0	30 Nov 1988	0
01 Jan 1934	516	15 Feb 1962	1740	28 May 1990	4
08 Apr 1935	1320	01 Feb 1963	8300	24 Mar 1991	1260
13 Feb 1936	1200	22 Jan 1964	156	15 Feb 1992	888
13 Feb 1937	2180	06 Jan 1965	560	13 Jan 1993	4190
11 Feb 1938	3230	30 Dec 1965	128	20 Feb 1994	12
09 Mar 1939	115	24 Jan 1967	4200	10 Mar 1995	12000
27 Feb 1940	3440	30 Nov 1967	0	19 Feb 1996	3130
04 Apr 1941	3070	25 Jan 1969	5080	23 Jan 1997	3320
24 Jan 1942	1880	01 Mar 1970	1010	03 Feb 1998	9470
21 Jan 1943	6450	21 Dec 1970	584	09 Feb 1999	833
29 Feb 1944	1290	30 Nov 1971	0	14 Feb 2000	2550
02 Feb 1945	5970	11 Feb 1973	1510	05 Mar 2001	958
25 Dec 1945	782	03 Mar 1974	922	03 Jan 2002	425
30 Nov 1946	0	08 Mar 1975	1010	16 Dec 2002	2790
30 Nov 1947	0	30 Nov 1975	0	25 Feb 2004	2990
12 Mar 1949	335	30 Nov 1976	0	16 Feb 2005	1820
05 Feb 1950	175	17 Jan 1978	4360	02 Jan 2006	1630
03 Dec 1950	2920	21 Feb 1979	1270	30 Nov 2006	0
12 Jan 1952	3660	16 Feb 1980	5210	25 Jan 2008	2110
07 Dec 1952	147	29 Jan 1981	1130	17 Feb 2009	310
30 Nov 1953	0	05 Jan 1982	5550	20 Jan 2010	4400
19 Jan 1955	16	24 Jan 1983	6360	24 Mar 2011	4440
23 Dec 1955	5620	25 Dec 1983	991	30 Nov 2011	0
24 Feb 1957	1440	09 Feb 1985	50	24 Dec 2012	6250
02 Apr 1958	10200	19 Feb 1986	6990		
16 Feb 1959	5380	06 Mar 1987	112		

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 C-9. As shown, the **Skew** option was set to use the **Station Skew**.

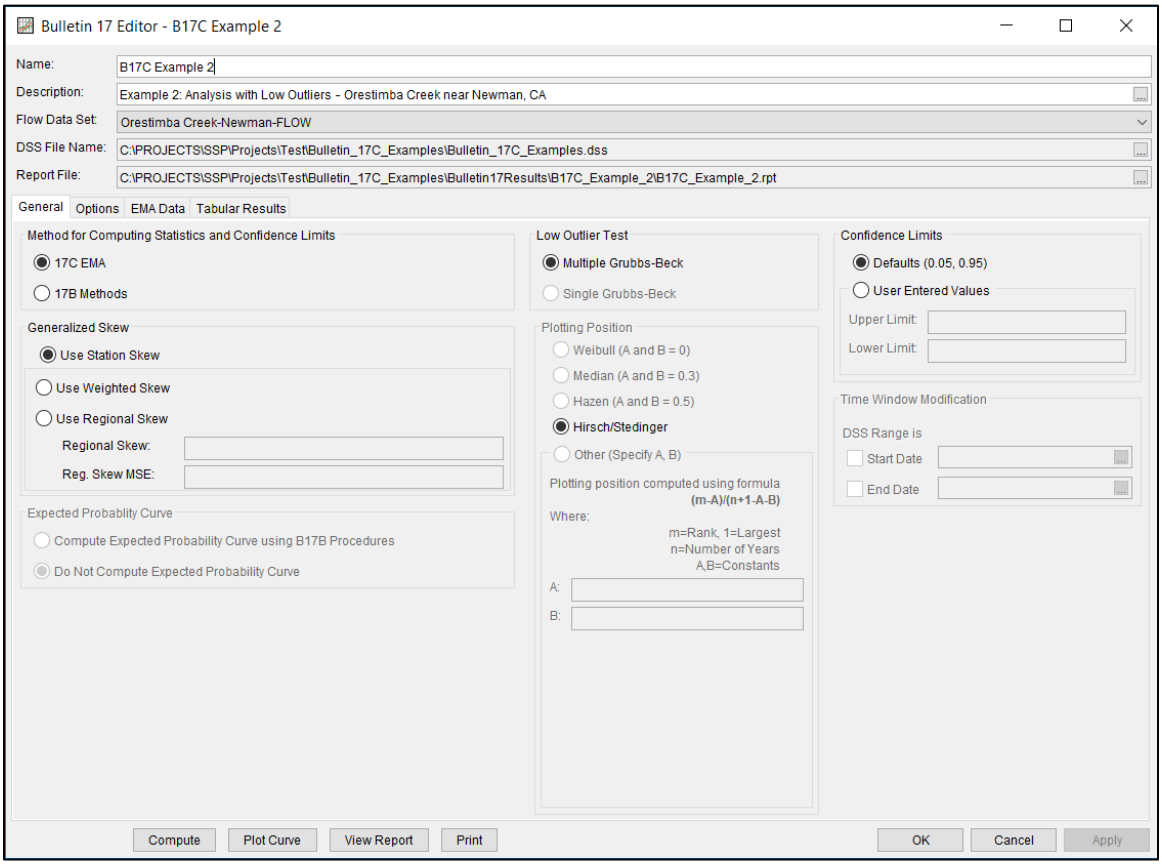


Figure C-9. Bulletin 17 Analysis General Tab for B17C Example 2.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-10. 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.

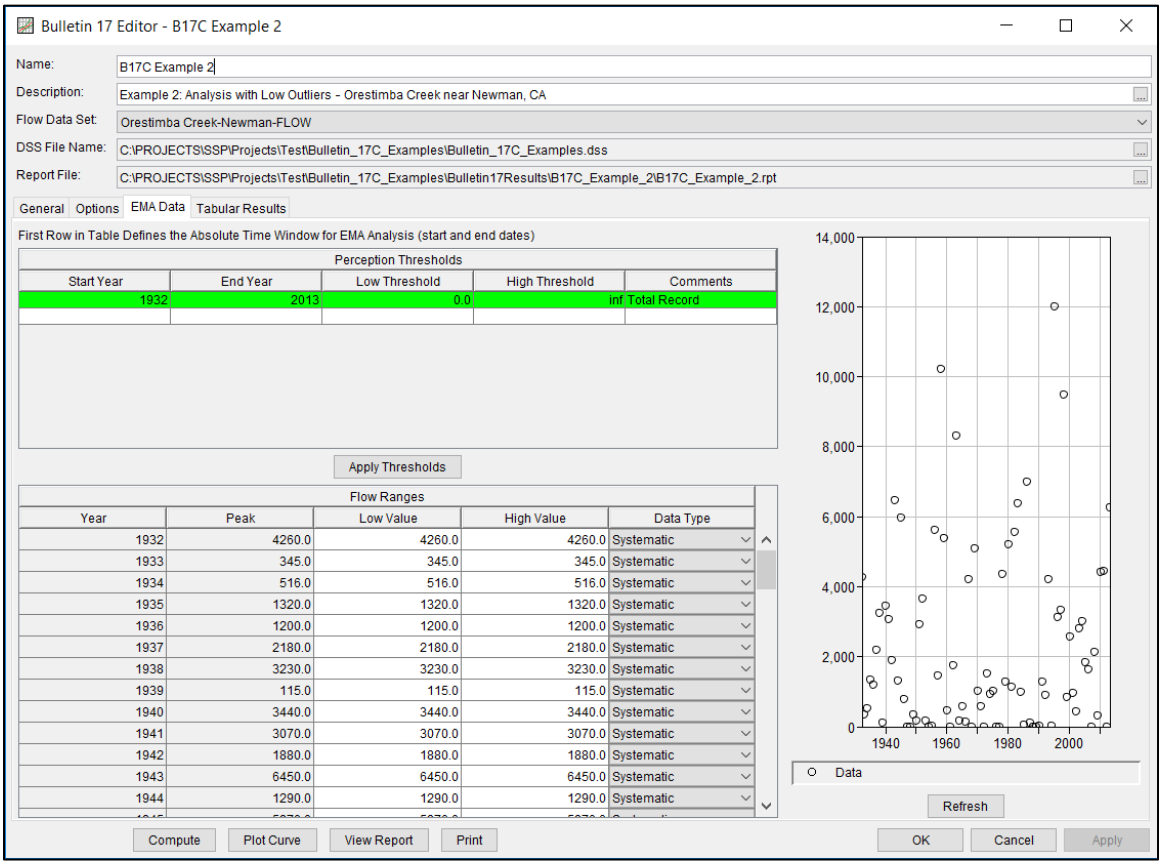
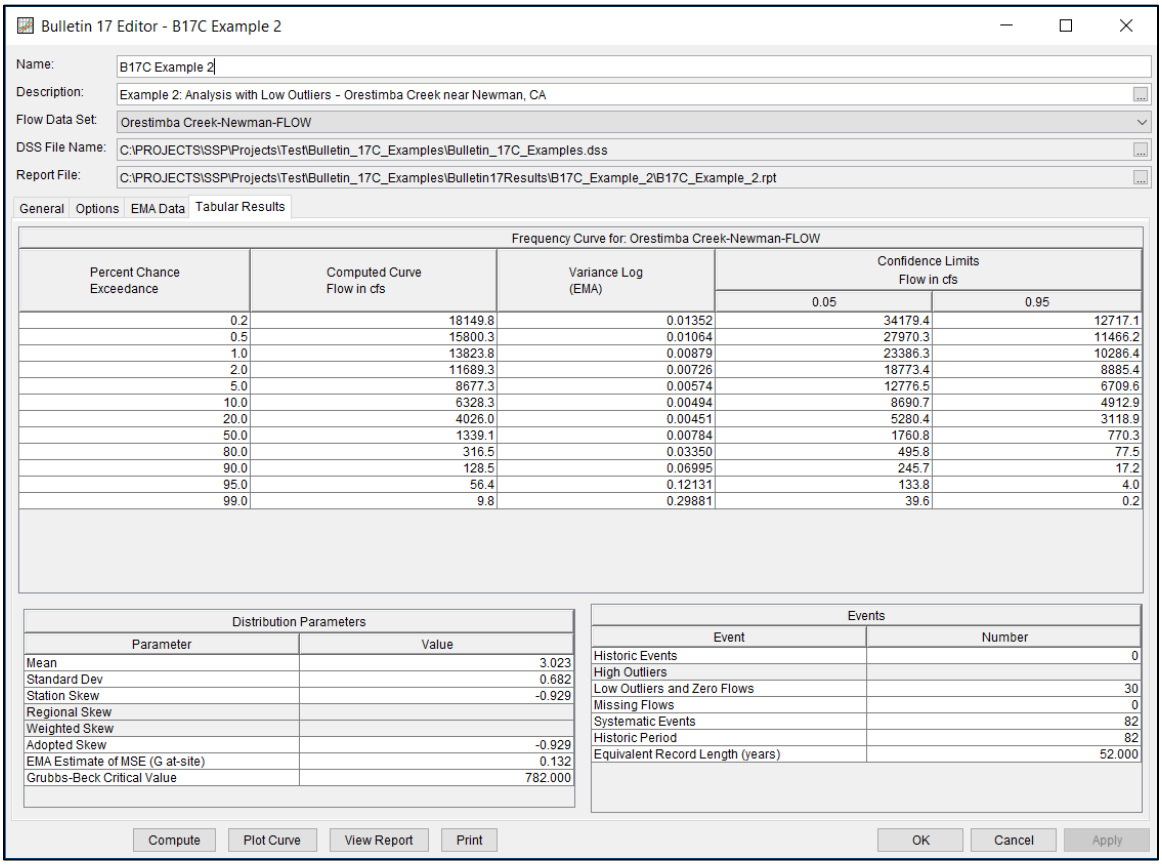


Figure C-10. Bulletin 17 Analysis EMA Data Tab for B17C Example 2.

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 C-11.

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 C-12.



Frequency Curve for: Orestimba Creek-Newman-FLOW

Percent Chance Exceedance	Computed Curve Flow in cfs	Variance Log (EMA)	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	18149.8	0.01352	34179.4	12717.1
0.5	15800.3	0.01064	27970.3	11466.2
1.0	13823.8	0.00879	23386.3	10286.4
2.0	11689.3	0.00726	18773.4	8885.4
5.0	8677.3	0.00574	12776.5	6709.6
10.0	6328.3	0.00494	8690.7	4912.9
20.0	4026.0	0.00451	5280.4	3118.9
50.0	1339.1	0.00784	1760.8	770.3
80.0	316.5	0.03350	495.8	77.5
90.0	128.5	0.06995	245.7	17.2
95.0	56.4	0.12131	133.8	4.0
99.0	9.8	0.29881	39.6	0.2

Distribution Parameters

Parameter	Value
Mean	3.023
Standard Dev	0.682
Station Skew	-0.929
Regional Skew	
Weighted Skew	
Adopted Skew	-0.929
EMA Estimate of MSE (G at-site)	0.132
Grubbs-Beck Critical Value	782.000

Events

Event	Number
Historic Events	0
High Outliers	
Low Outliers and Zero Flows	30
Missing Flows	0
Systematic Events	82
Historic Period	82
Equivalent Record Length (years)	52.000

Figure C-11. Bulletin 17 Analysis Tabular Results Tab for B17C Example 2.

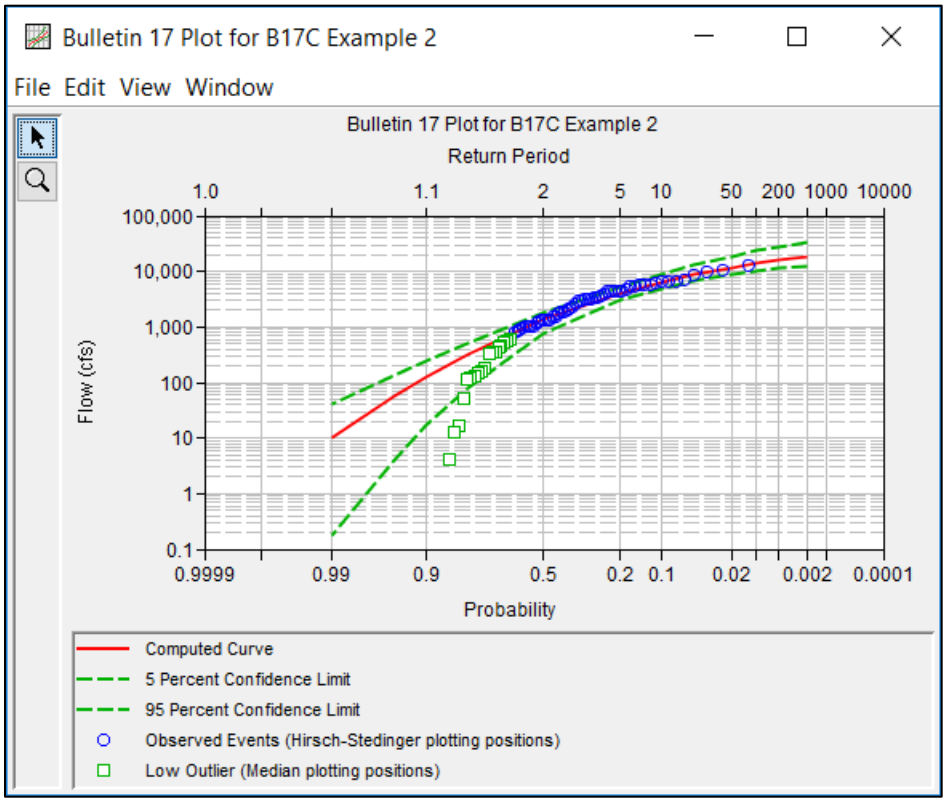


Figure C-12. Plotted Frequency Curves for B17C Example 2.

As shown in Figure C-12, 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 C-13. These annual peak flows were then recoded to have a flow interval of zero – 782. The perception threshold for the entire historical period was also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold. Consequently, the perception threshold was changed from zero – inf to 782 – inf, as shown in Figure C-14.

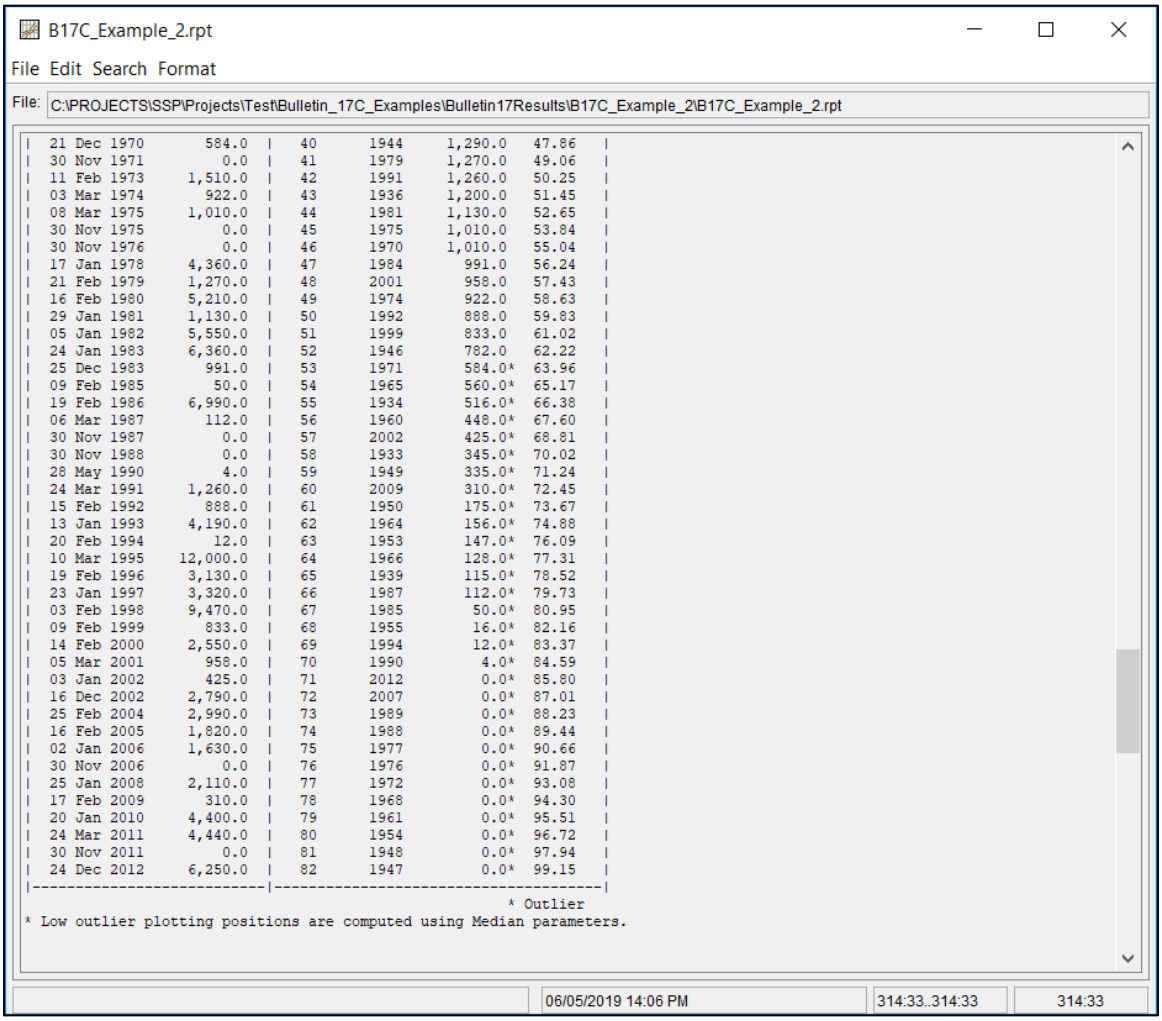
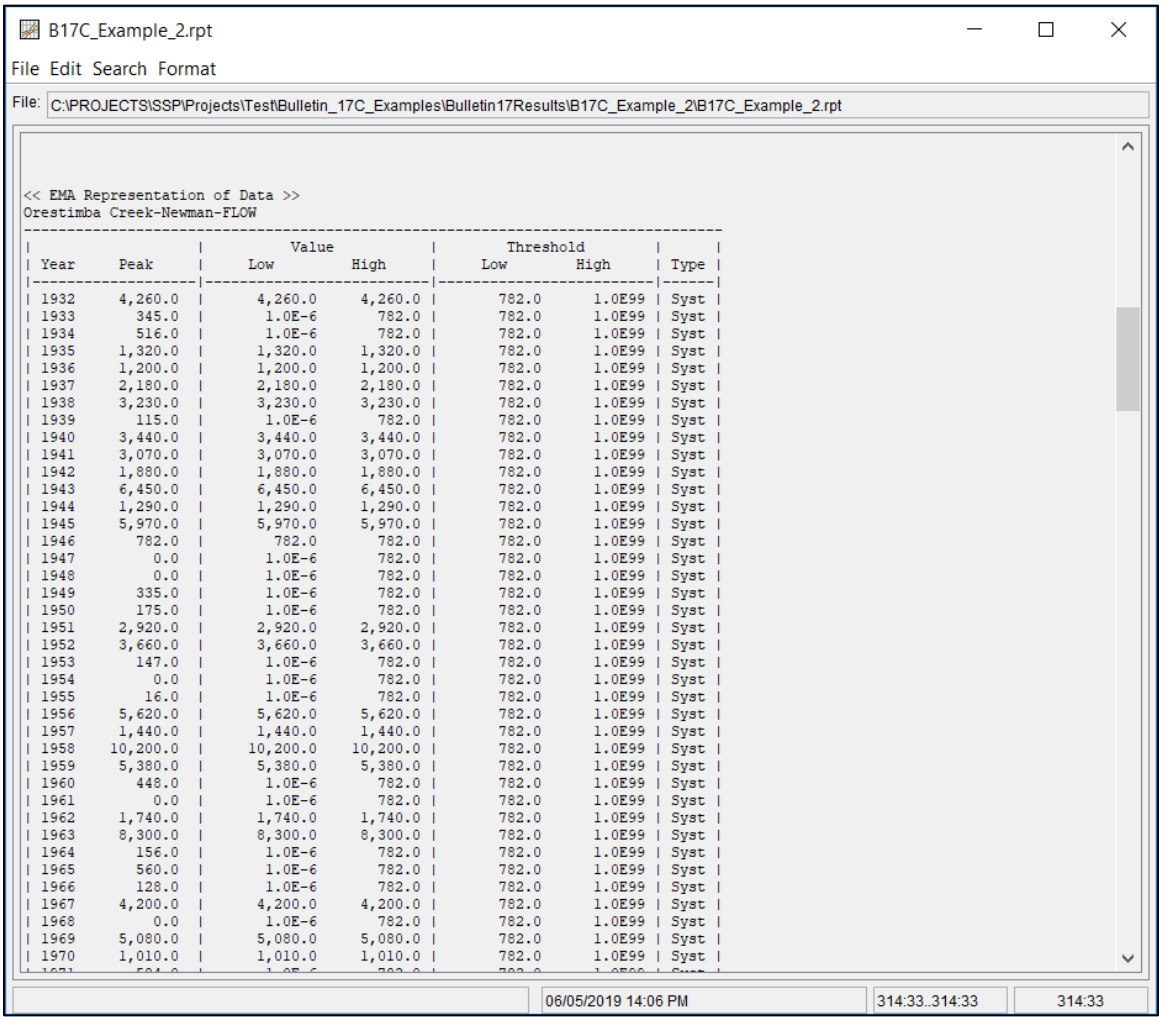


Figure C-13. Report File for B17C Example 2 showing censored low outliers and zero flows.



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

06/05/2019 14:06 PM 314:33..314:33 314:33

Figure C-14. Report File for B17C Example 2 showing recoded perception thresholds.

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 C-15 and tabulated in Table C-3.

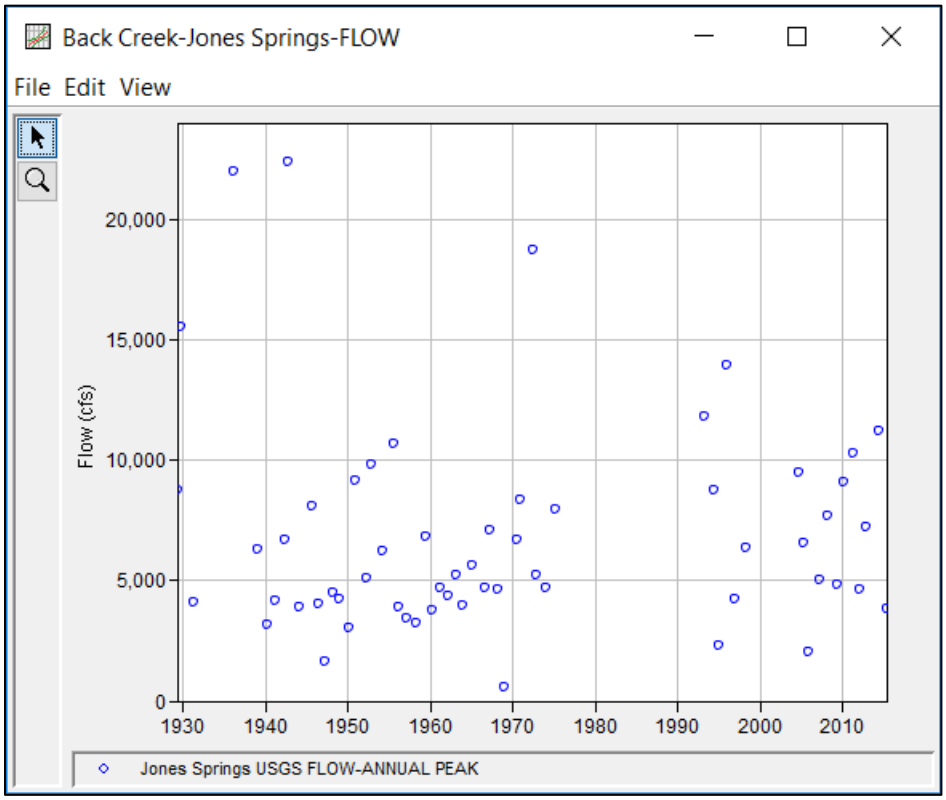


Figure C-15. Back Creek near Jones Springs, WV Annual Peak Flow Record.

Table C-3. Back Creek near Jones Springs, WV Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)
17 Apr 1929	8750	20 Mar 1963	5190
23 Oct 1929	15500	10 Jan 1964	3960
08 May 1931	4060	06 Mar 1965	5600
17 Mar 1936	22000	21 Sep 1966	4670
04 Feb 1939	6300	08 Mar 1967	7080
20 Apr 1940	3130	17 Mar 1968	4640
06 Apr 1941	4160	02 Feb 1969	536
22 May 1942	6700	10 Jul 1970	6680
15 Oct 1942	22400	13 Nov 1970	8360
24 Mar 1944	3880	22 Jun 1972	18700
18 Sep 1945	8050	09 Dec 1972	5210
03 Jun 1946	4020	27 Dec 1973	4680
15 Mar 1947	1600	20 Mar 1975	7940
14 Apr 1948	4460	05 Mar 1993	11800
31 Dec 1948	4230	08 May 1994	8730
02 Feb 1950	3010	16 Jan 1995	2300
05 Dec 1950	9150	19 Jan 1996	13900
28 Apr 1952	5100	09 Nov 1996	4190
22 Nov 1952	9820	21 Mar 1998	6370
02 Mar 1954	6200	29 Sep 2004	9460
19 Aug 1955	10700	29 Mar 2005	6560
15 Mar 1956	3880	30 Nov 2005	2000

Date	Flow (cfs)
10 Feb 1957	3420
27 Mar 1958	3240
03 Jun 1959	6800
09 May 1960	3740
19 Feb 1961	4700
22 Mar 1962	4380

Date	Flow (cfs)
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 C-16. As shown, the **Skew** option was set to use the **Station Skew**.

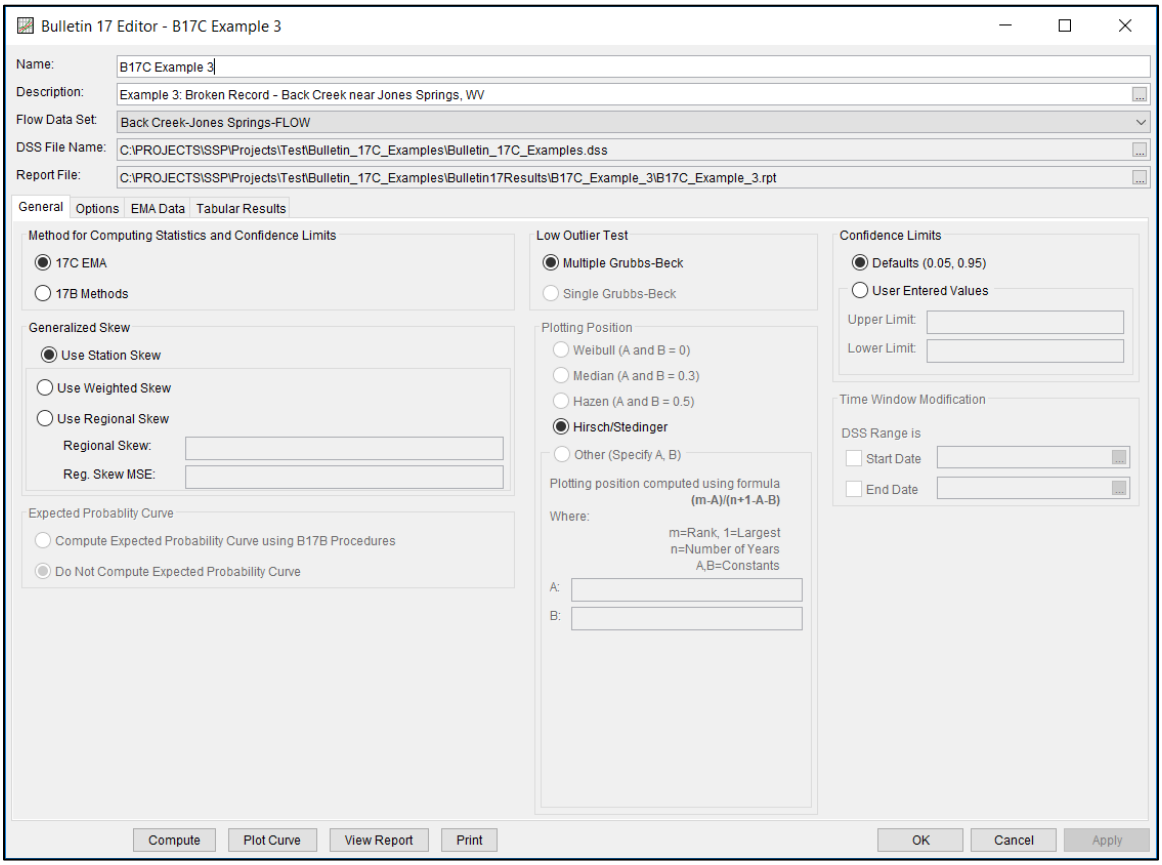


Figure C-16. Bulletin 17 Analysis General Tab for B17C Example 3.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-17. 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 C-17, 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.

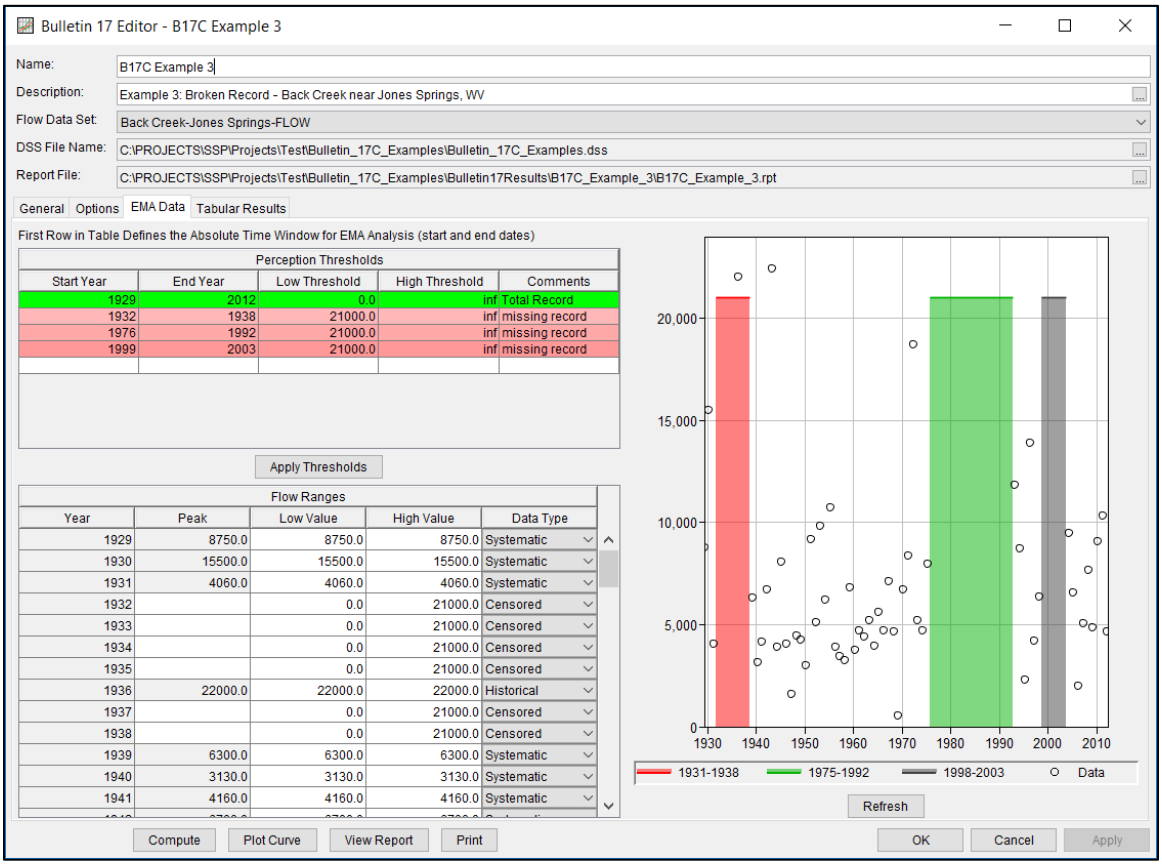


Figure C-17. Bulletin 17 Analysis EMA Data Tab for B17C Example 3.

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 C-18.

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 C-19.

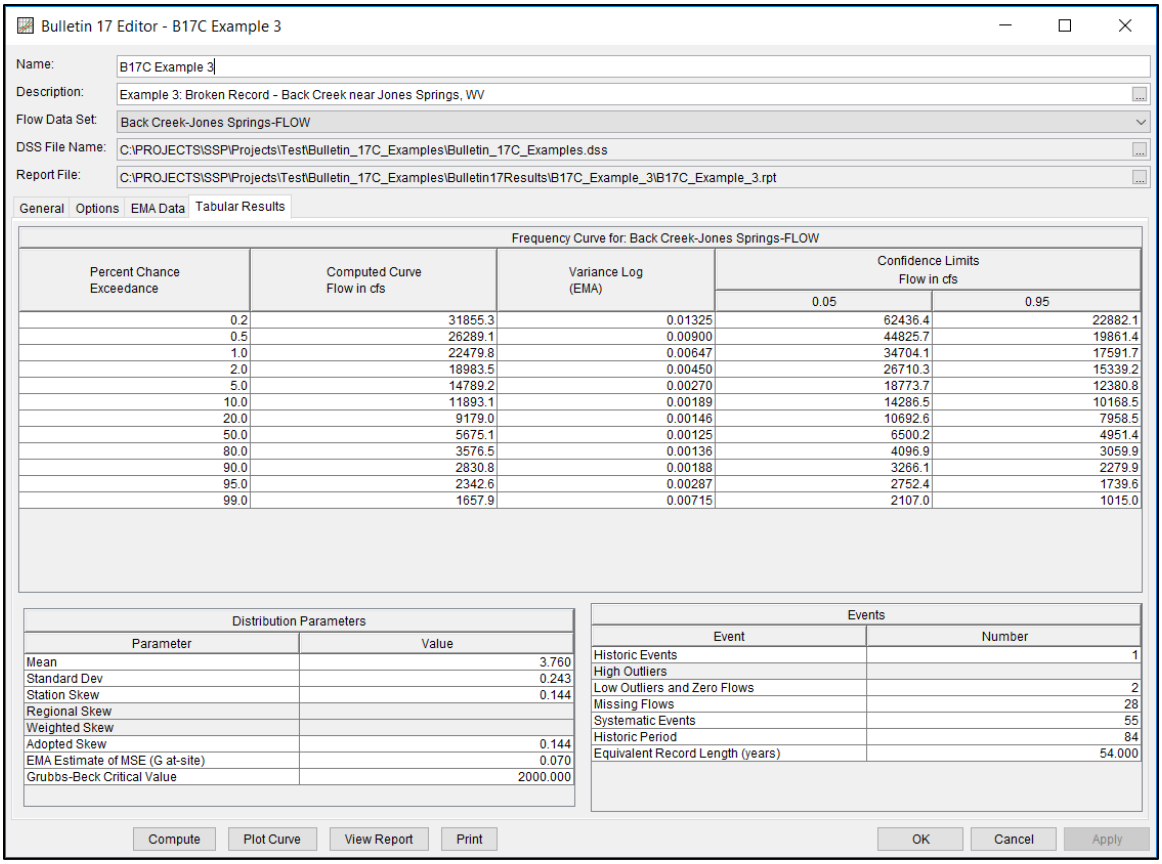


Figure C-18. Bulletin 17 Analysis Tabular Results Tab for B17C Example 3.

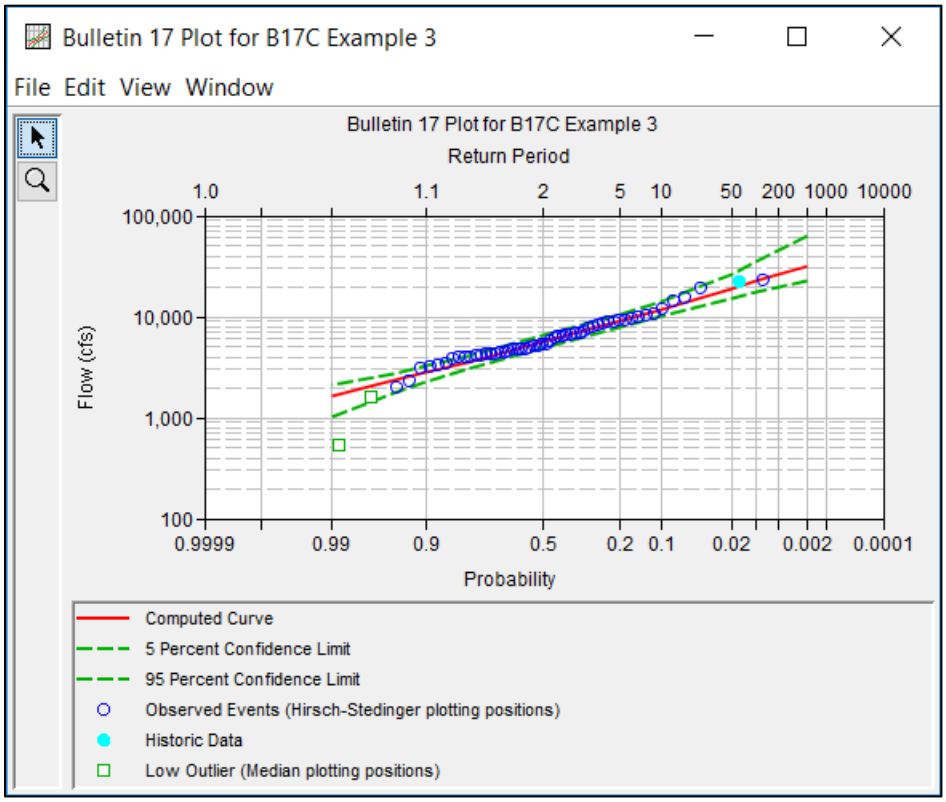


Figure C-19. Plotted Frequency Curves for B17C Example 3.

As shown in Figure C-19, 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 C-20. These annual peak flows were then recoded to have a flow interval of zero – 2000. The perception thresholds for the years in which an annual peak flow was recorded were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (critical value). Consequently, these perception thresholds were changed from zero – inf to 2000 – inf, as shown in Figure C-21.

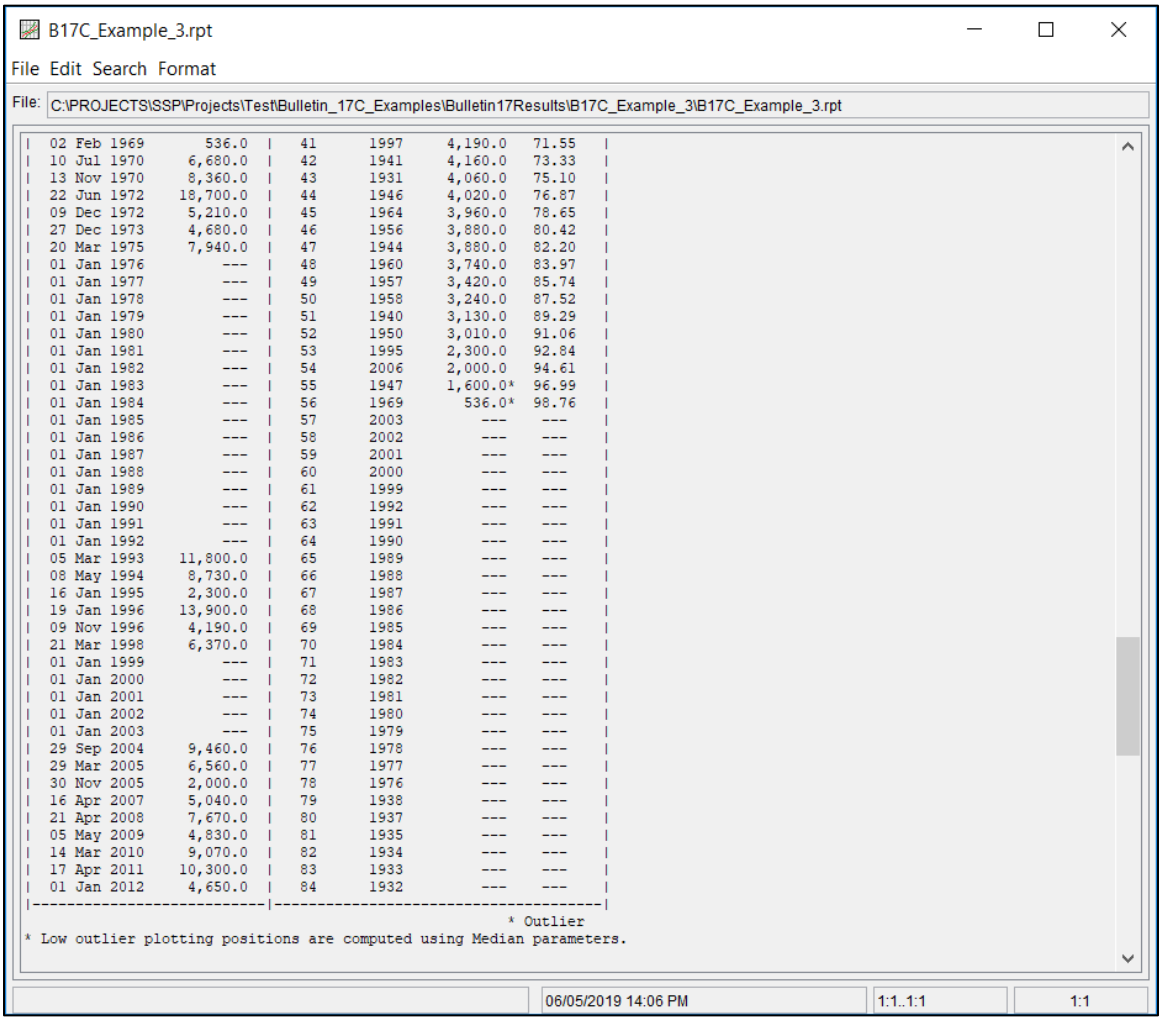
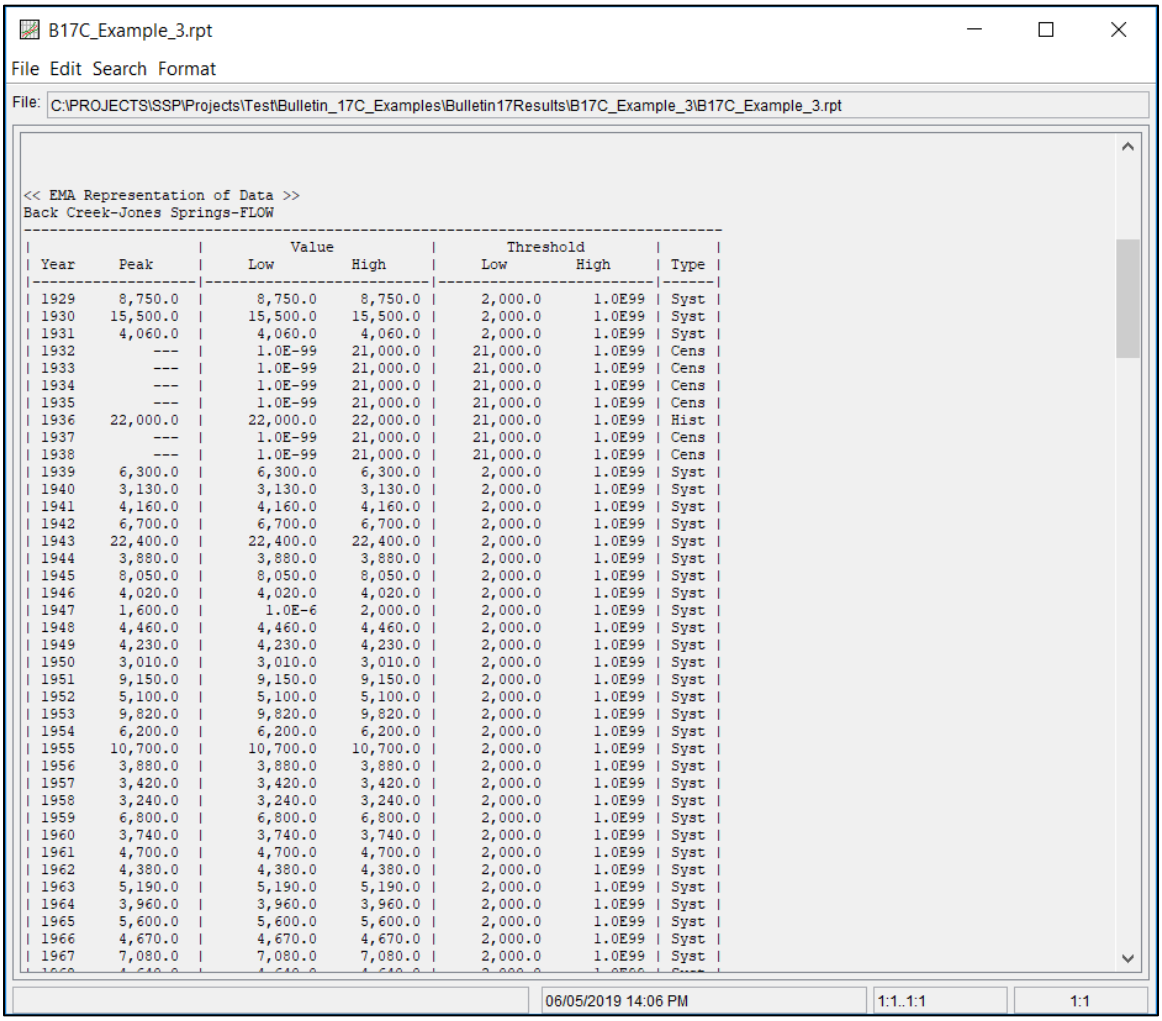


Figure C-20. Report File for B17C Example 3 showing censored low outliers.



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

06/05/2019 14:06 PM 1:1..1:1 1:1

Figure C-21. Report File for B17C Example 3 showing recoded perception thresholds.

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 C-22 and tabulated in Table C-4.

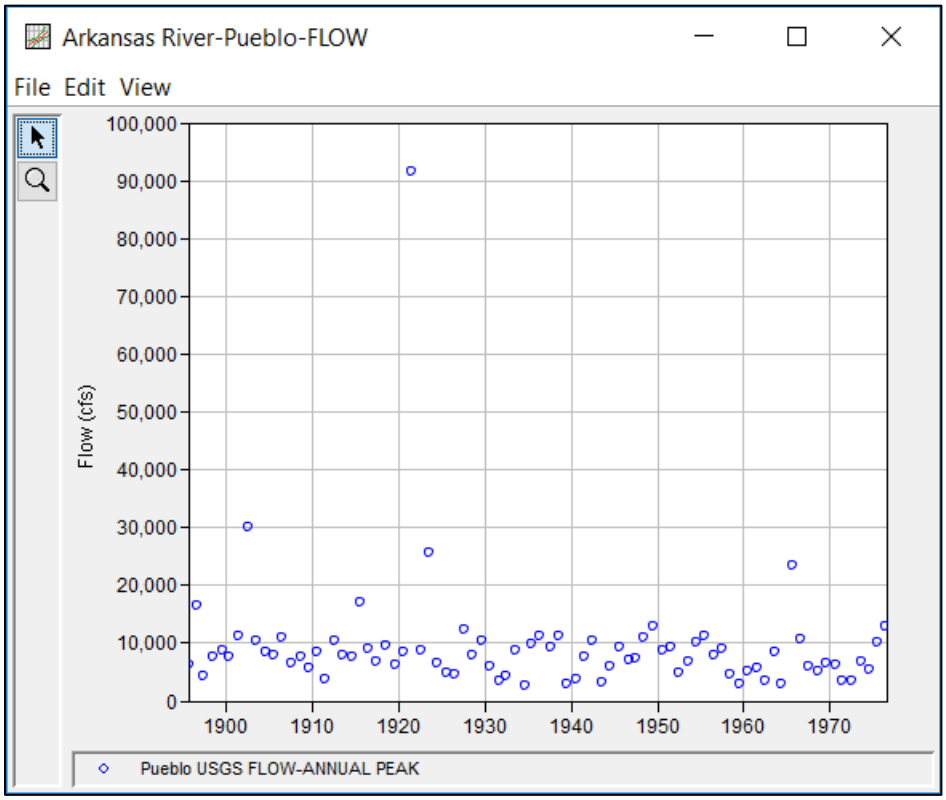


Figure C-22. Arkansas River near Pueblo, CO Annual Peak Flow Record (Modified).

Table C-4. Arkansas River near Pueblo, CO Annual Peak Flow Record (Modified).

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
31 Jul 1895	6100	12 Jul 1923	25600	03 Aug 1951	9300
18 Aug 1896	16500	15 Jun 1924	6510	08 Jun 1952	4740
02 Jun 1897	4300	03 Jul 1925	4930	21 Jul 1953	6770
13 Jul 1898	7500	14 Jun 1926	4520	30 Jun 1954	10200
14 Aug 1899	8800	22 Jul 1927	12400	19 May 1955	11100
20 May 1900	7600	21 Jul 1928	7800	01 Aug 1956	8010
21 May 1901	11100	28 Jul 1929	10500	29 Jun 1957	9070
05 Aug 1902	30000	28 Aug 1930	6050	05 Jun 1958	4540
09 Jun 1903	10500	01 Sep 1931	3560	17 Jun 1959	2820
15 Aug 1904	8500	26 Jun 1932	4380	08 Jun 1960	5260
06 Aug 1905	8000	02 Aug 1933	8630	02 Aug 1961	5760
13 Jun 1906	11000	03 Aug 1934	2580	08 Jul 1962	3540
28 Jul 1907	6600	18 May 1935	9880	14 Aug 1963	8360
01 Aug 1908	7600	24 May 1936	11200	27 May 1964	2840
18 Aug 1909	5800	29 Aug 1937	9300	22 Aug 1965	23500
29 Jul 1910	8400	26 Aug 1938	11200	01 Aug 1966	10600
28 May 1911	3700	01 Jun 1939	2910	18 Jul 1967	5870
31 Jul 1912	10500	19 Aug 1940	3860	10 Aug 1968	5190
23 Jul 1913	7800	19 Jul 1941	7560	23 Aug 1969	6620
03 Aug 1914	7500	08 Jun 1942	10300	11 Aug 1970	6300
24 Jun 1915	17000	18 Aug 1943	3320	07 Jun 1971	3360

Date	Flow (cfs)
17 Jun 1916	8900
19 Jun 1917	6800
23 Jun 1918	9600
04 Sep 1919	6300
18 Jul 1920	8500
03 Jun 1921	91500
06 Aug 1922	8850

Date	Flow (cfs)
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

Date	Flow (cfs)
28 Jun 1972	3360
30 Jul 1973	6760
23 Jul 1974	5440
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 C-23. As shown, the **Skew** option was set to use the **Station Skew**.

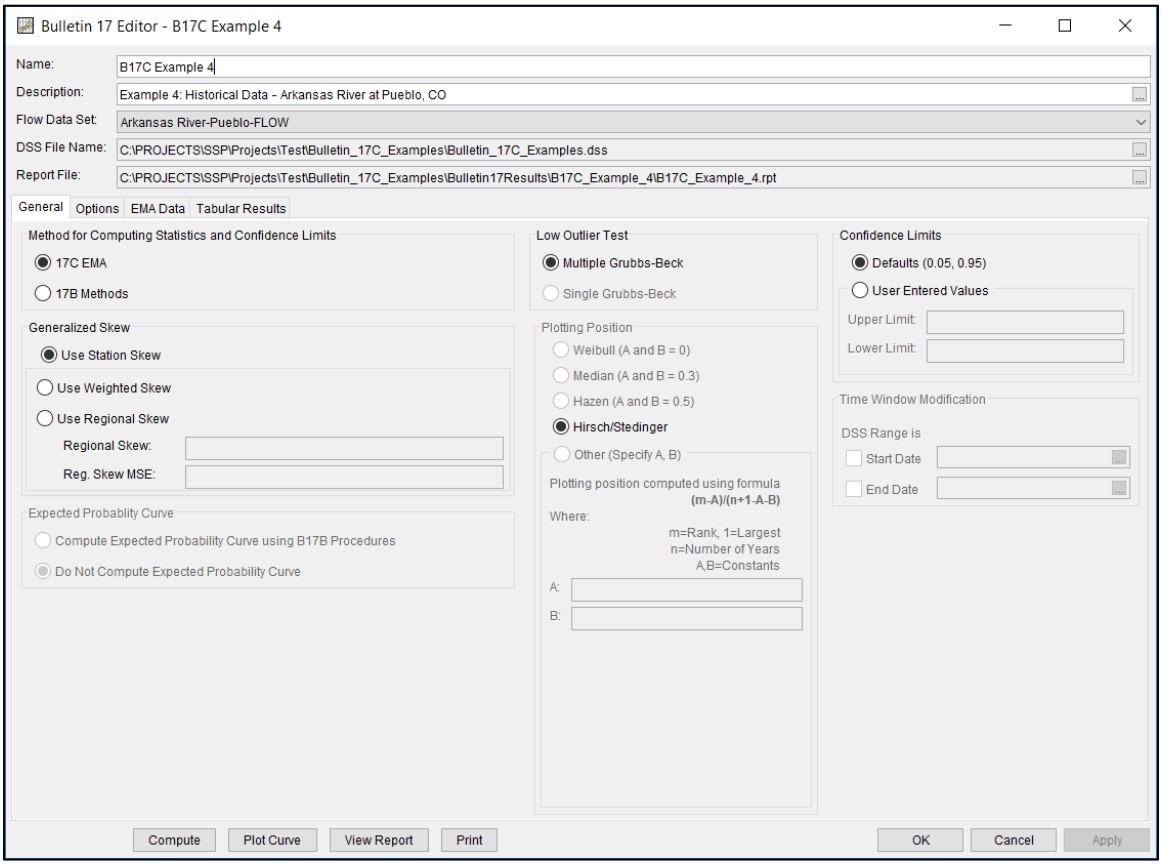


Figure C-23. Bulletin 17 Analysis General Tab for B17C Example 4.

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 C-24. It should be noted that estimating the frequency curve for these probabilities requires extrapolation far beyond the gaged data. However, the inclusion of paleo data makes this extrapolation more supportable.

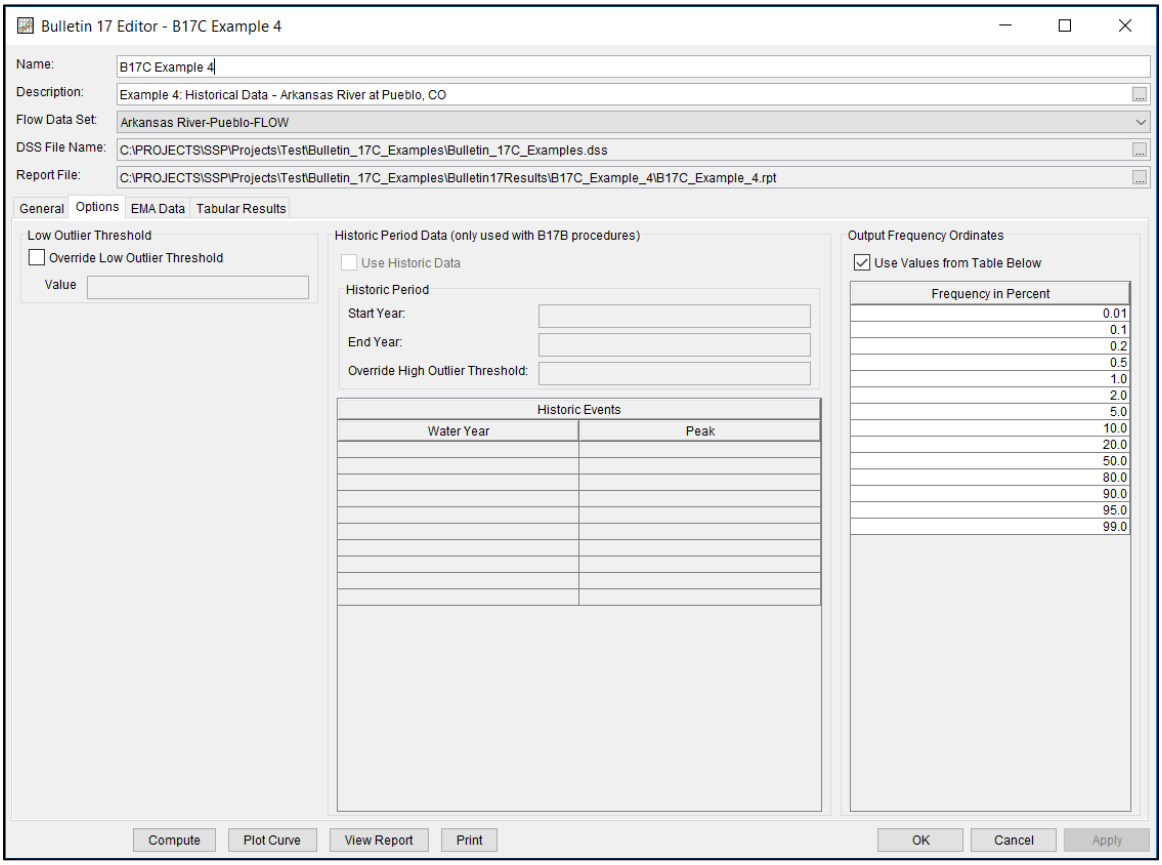


Figure C-24. Bulletin 17 Analysis Options Tab for B17C Example 4.

The **EMA Data** tab for this example is shown in Figure C-25. 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 C-25, click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

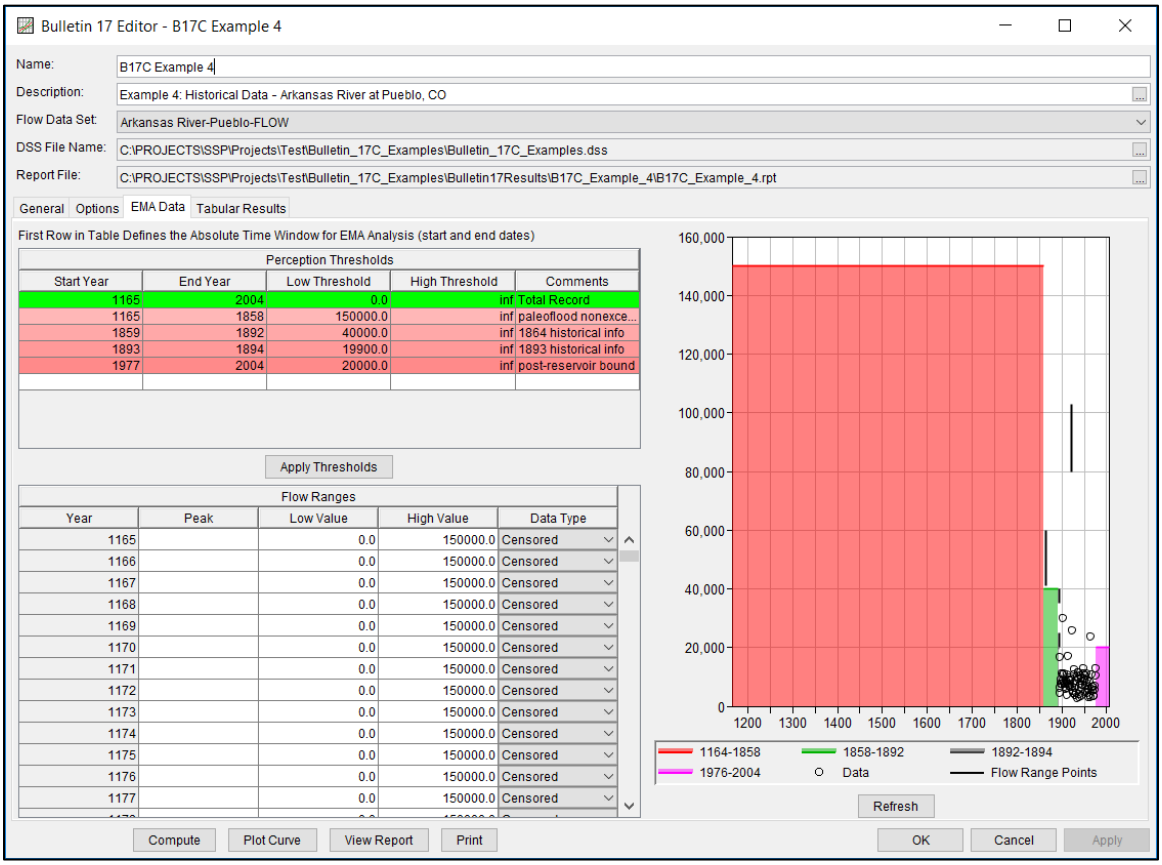
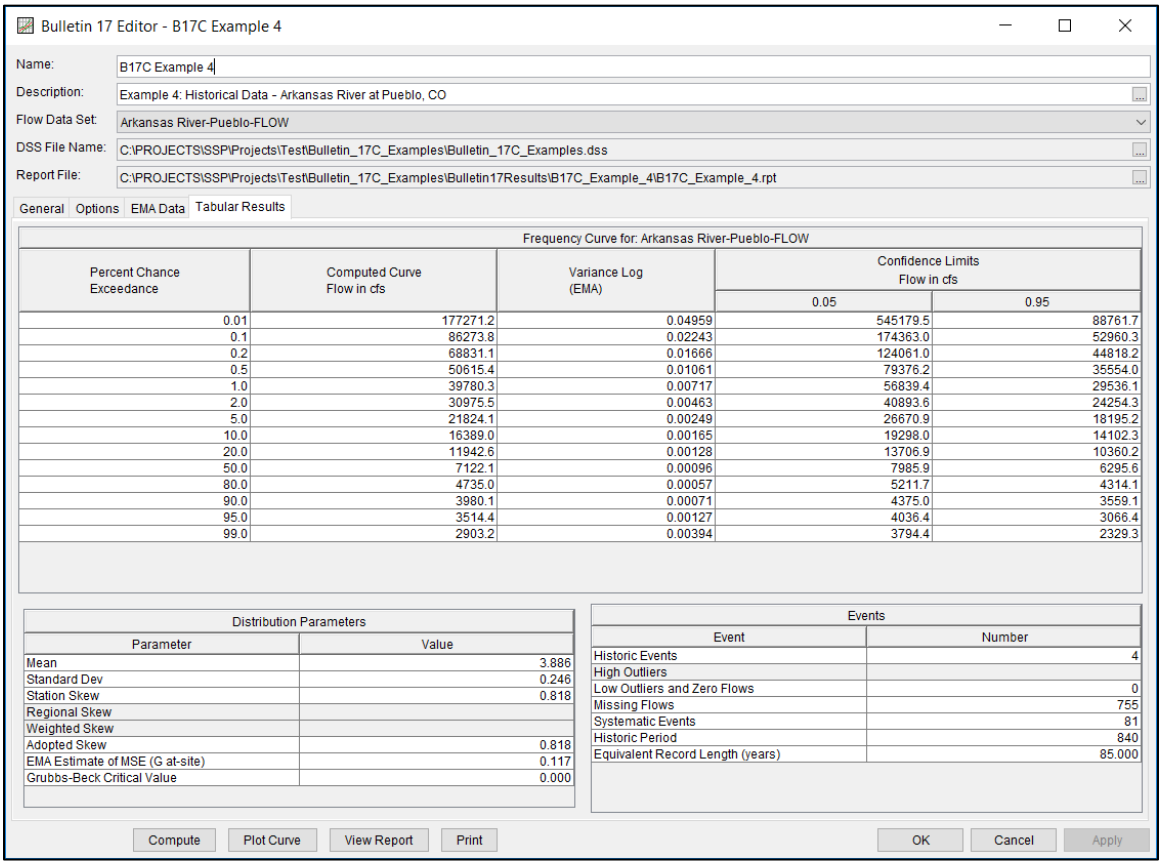


Figure C-25. Bulletin 17 Analysis EMA Data Tab for B17C Example 4.

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 C-26.

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 C-27.



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	0.04959	545179.5	88761.7
0.1	86273.8	0.02243	174363.0	52960.3
0.2	68831.1	0.01666	124061.0	44818.2
0.5	50615.4	0.01061	79376.2	35554.0
1.0	39780.3	0.00717	56839.4	29536.1
2.0	30975.5	0.00463	40893.6	24254.3
5.0	21824.1	0.00249	26670.9	18195.2
10.0	16389.0	0.00165	19298.0	14102.3
20.0	11942.6	0.00128	13706.9	10360.2
50.0	7122.1	0.00096	7985.9	6295.6
80.0	4735.0	0.00057	5211.7	4314.1
90.0	3980.1	0.00071	4375.0	3559.1
95.0	3514.4	0.00127	4036.4	3066.4
99.0	2903.2	0.00394	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)	85.000

Figure C-26. Bulletin 17 Analysis Tabular Results Tab for B17C Example 4.

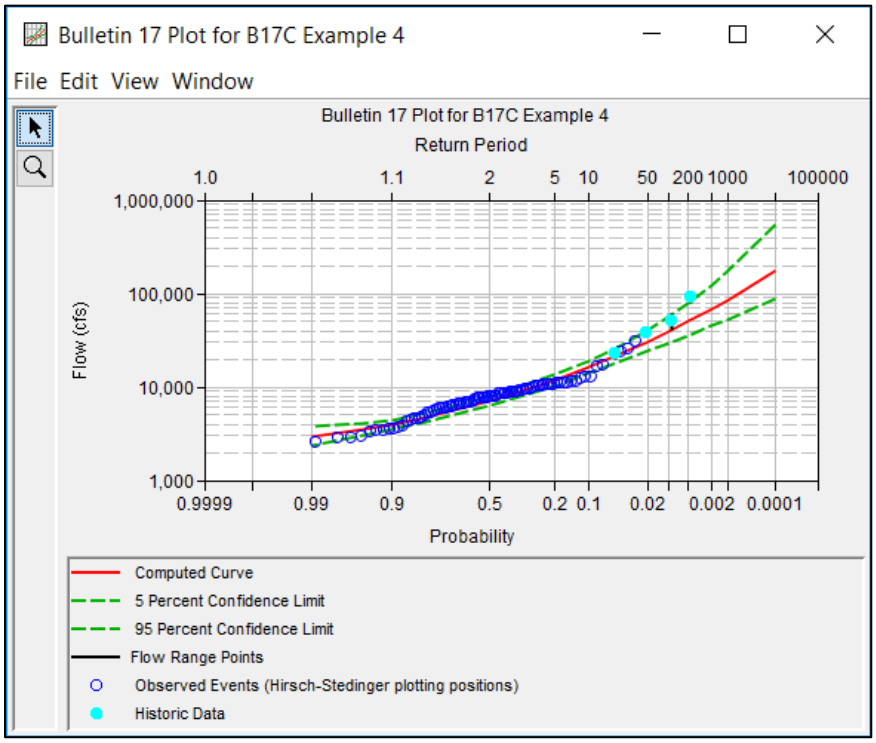


Figure C-27. Plotted Frequency Curves for B17C Example 4.

As is shown in Figure C-27, 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.

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 C-28 and tabulated in Table C-5.

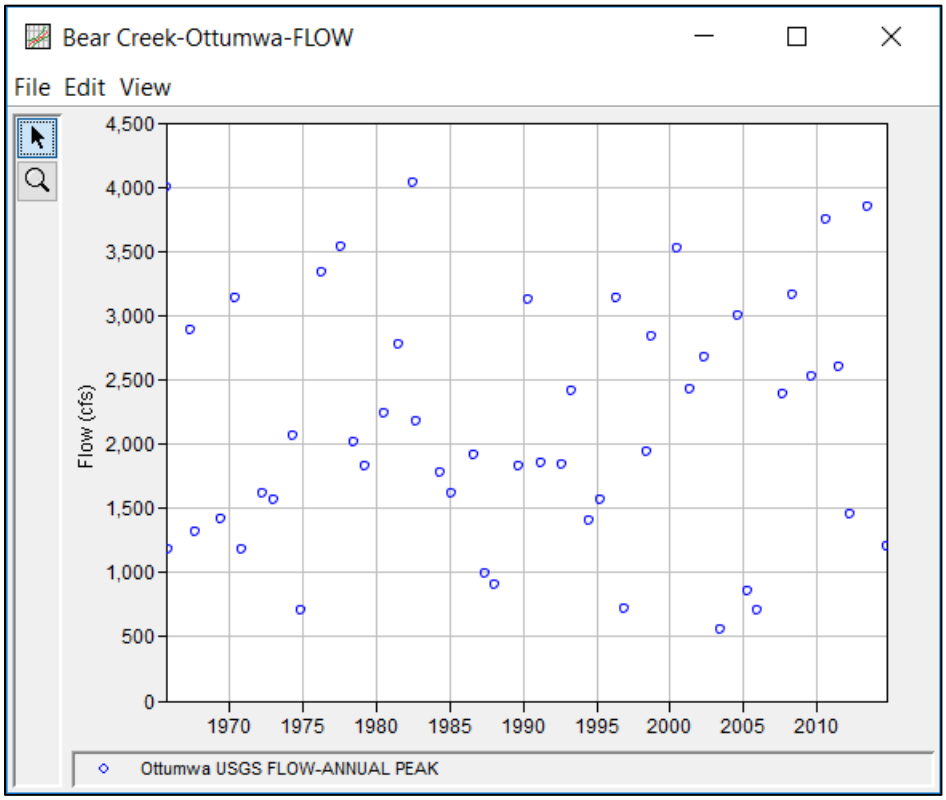


Figure C-28. Bear Creek at Ottumwa, IA Annual Peak Flow Record.

Table C-5. Bear Creek at Ottumwa, IA Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)
21 Sep 1965	4000	25 May 1990	3120
30 Nov 1965	1180	18 Apr 1991	1850
09 Jun 1967	2880	15 Sep 1992	1840
15 Oct 1967	1310	07 May 1993	2410
05 Jul 1969	1420	23 Jun 1994	1400
24 Jun 1970	3130	11 Apr 1995	1560
30 Nov 1970	1180	28 May 1996	3130
08 May 1972	1620	30 Nov 1996	714
19 Jan 1973	1570	18 Jun 1998	1940
19 May 1974	2060	05 Oct 1998	2840
30 Nov 1974	705	23 Jun 2000	3520
24 Apr 1976	3340	15 May 2001	2430
07 Aug 1977	3530	11 May 2002	2670
21 Jul 1978	2010	26 Jun 2003	560
29 Mar 1979	1830	27 Aug 2004	3000
17 Aug 1980	2240	12 Apr 2005	859
04 Jul 1981	2770	30 Nov 2005	710
03 Jul 1982	4030	23 Aug 2007	2390
08 Oct 1982	2180	11 May 2008	3160
08 Jun 1984	1780	27 Aug 2009	2520
04 Mar 1985	1610	09 Aug 2010	3750
19 Sep 1986	1910	14 Jun 2011	2600
31 May 1987	990	14 Apr 2012	1450

Date	Flow (cfs)
20 Feb 1988	899*
09 Sep 1989	1820
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 C-29. As shown, the **Skew** option was set to use the **Station Skew**.

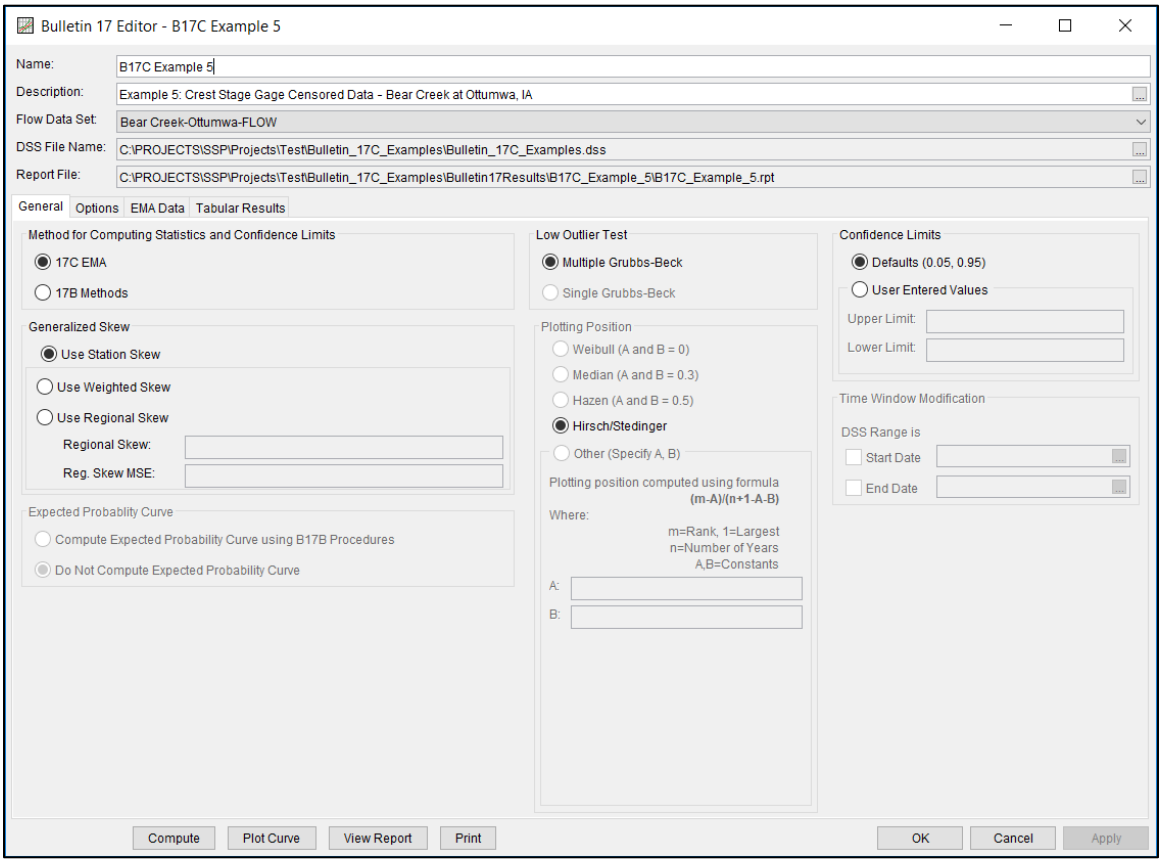


Figure C-29. Bulletin 17 Analysis General Tab for B17C Example 5.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-30. 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 five perception thresholds have been entered as shown in Figure C-30, 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 C-30. 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.

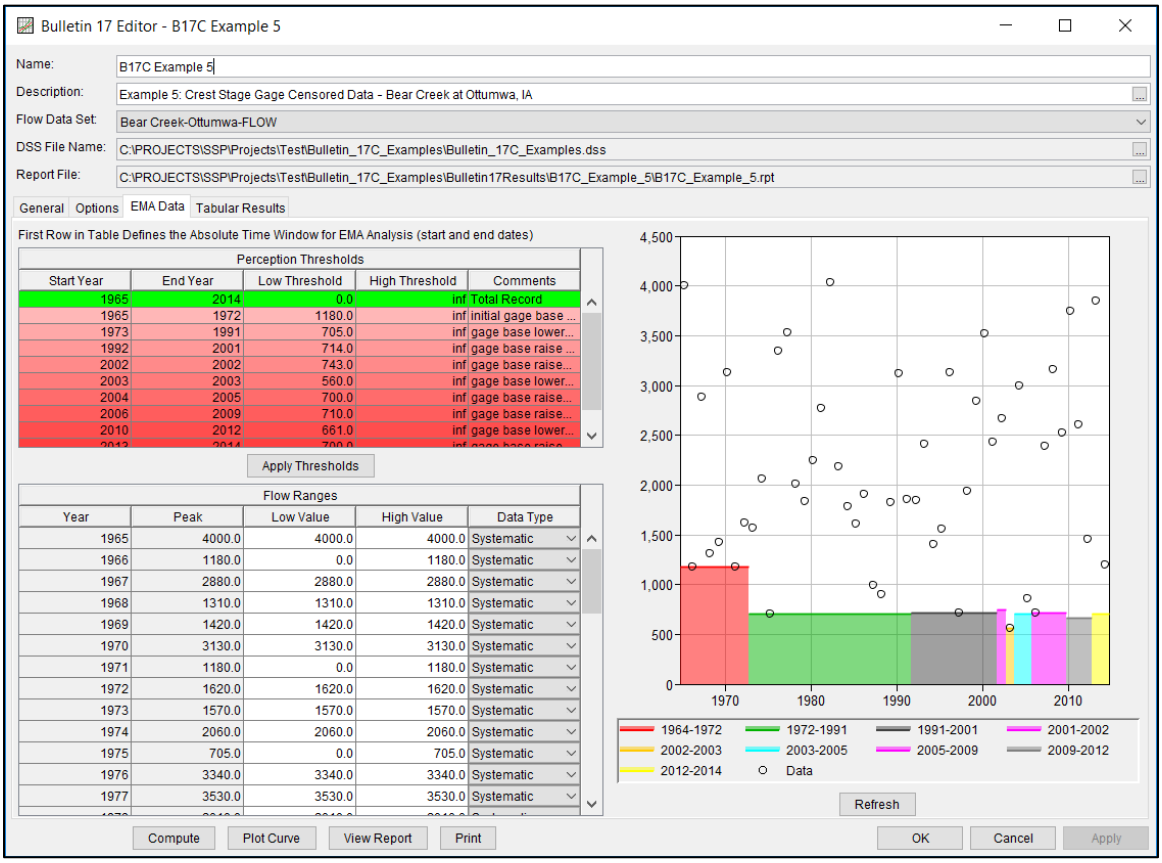


Figure C-30. Bulletin 17 Analysis EMA Data Tab for B17C Example 5.

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 C-31.

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 C-32.

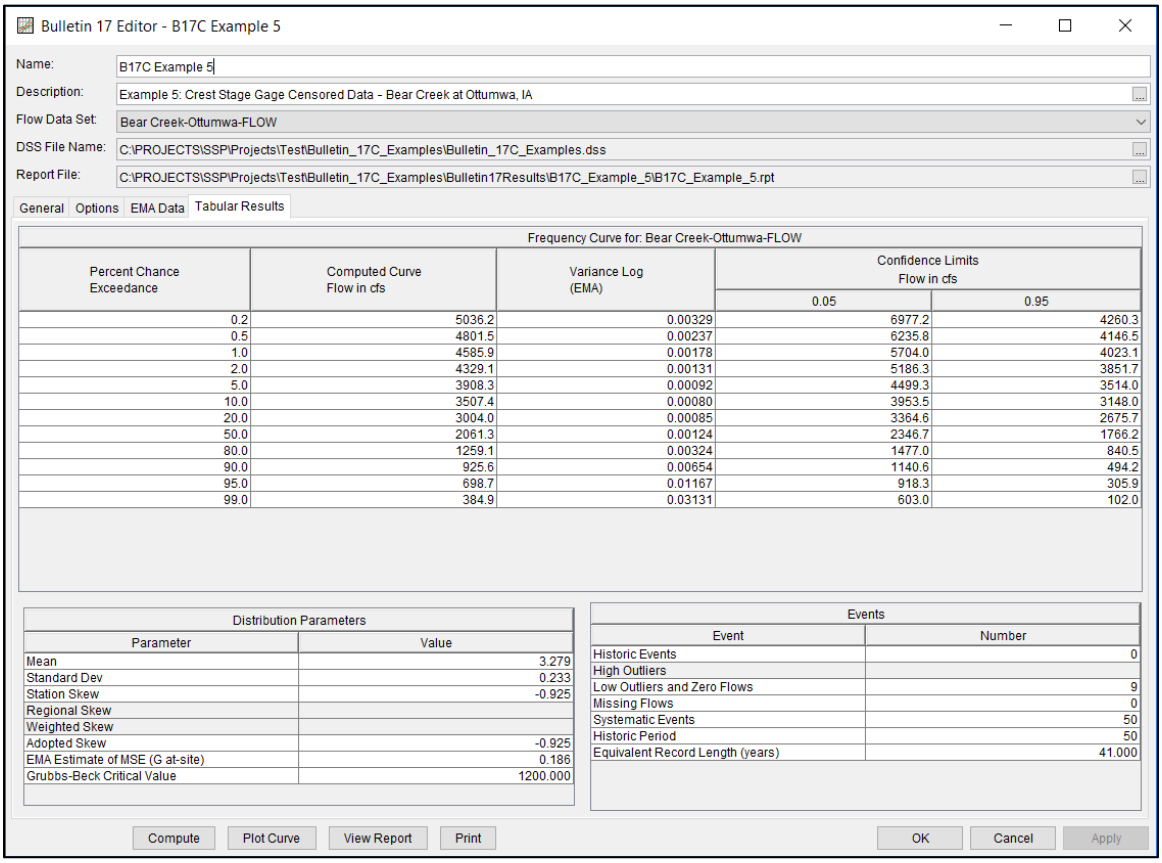


Figure C-31. Bulletin 17 Analysis Tabular Results Tab for B17C Example 5.

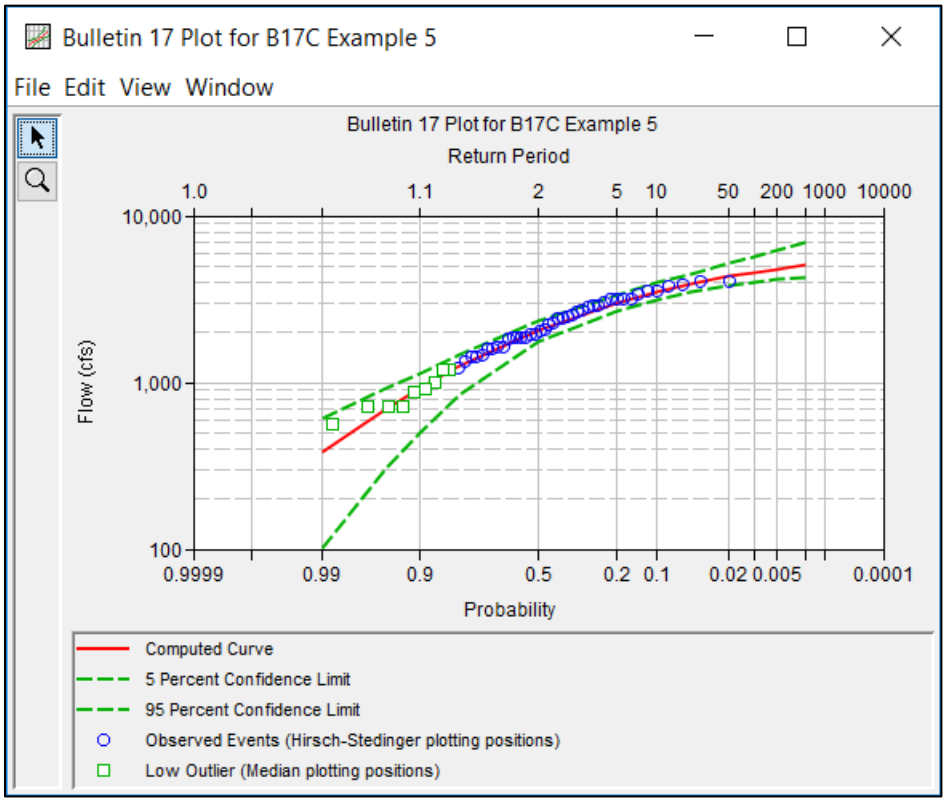


Figure C-32. Plotted Frequency Curves for B17C Example 5.

As shown in Figure C-33, 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 C-32. These annual peak flows were then recoded to have a flow interval of zero – 1200. The perception thresholds for the years in which an annual peak flow was recorded were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (critical value). Consequently, these perception thresholds were changed from zero – inf to 1200 – inf, as shown in Figure C-34.

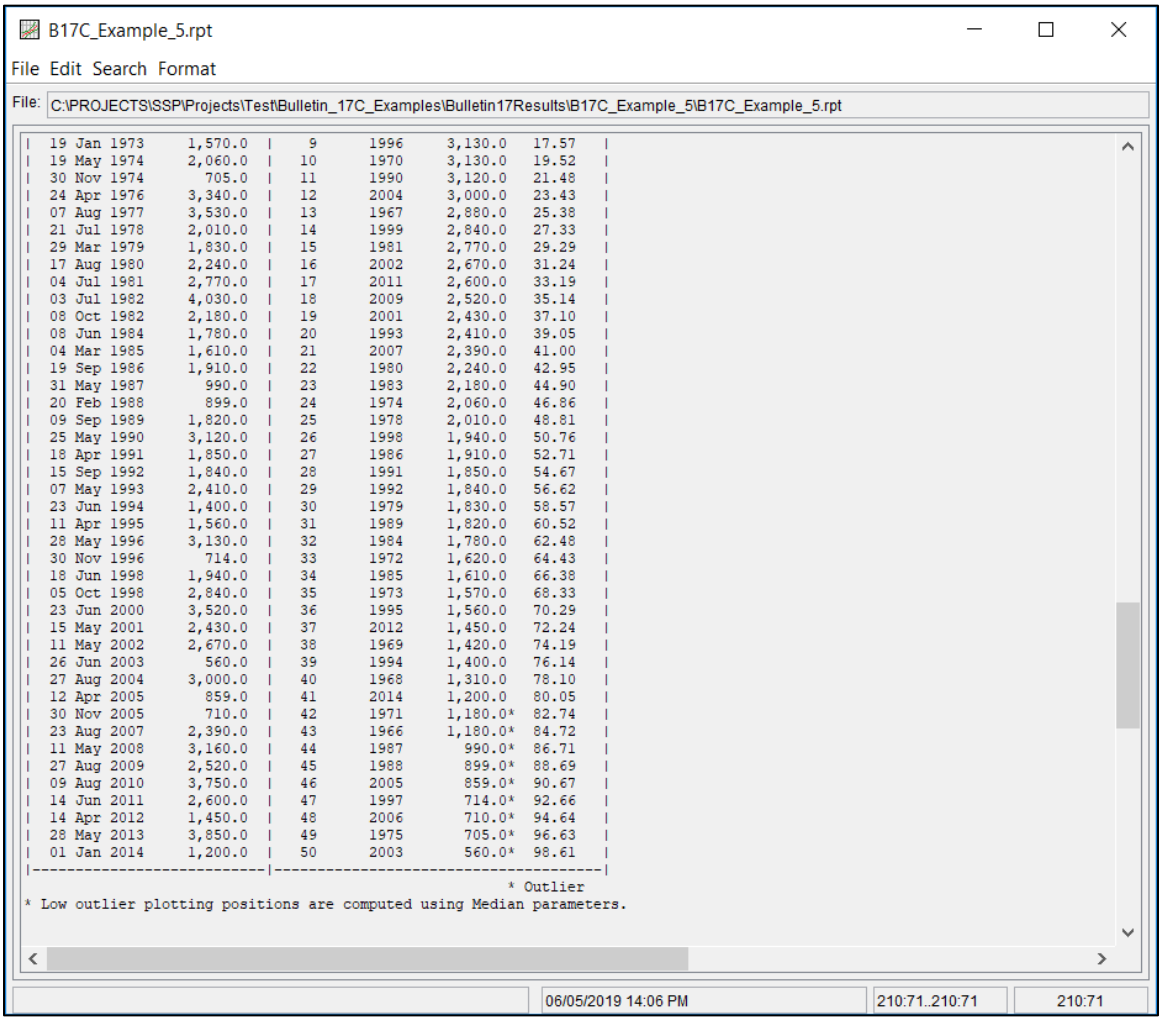
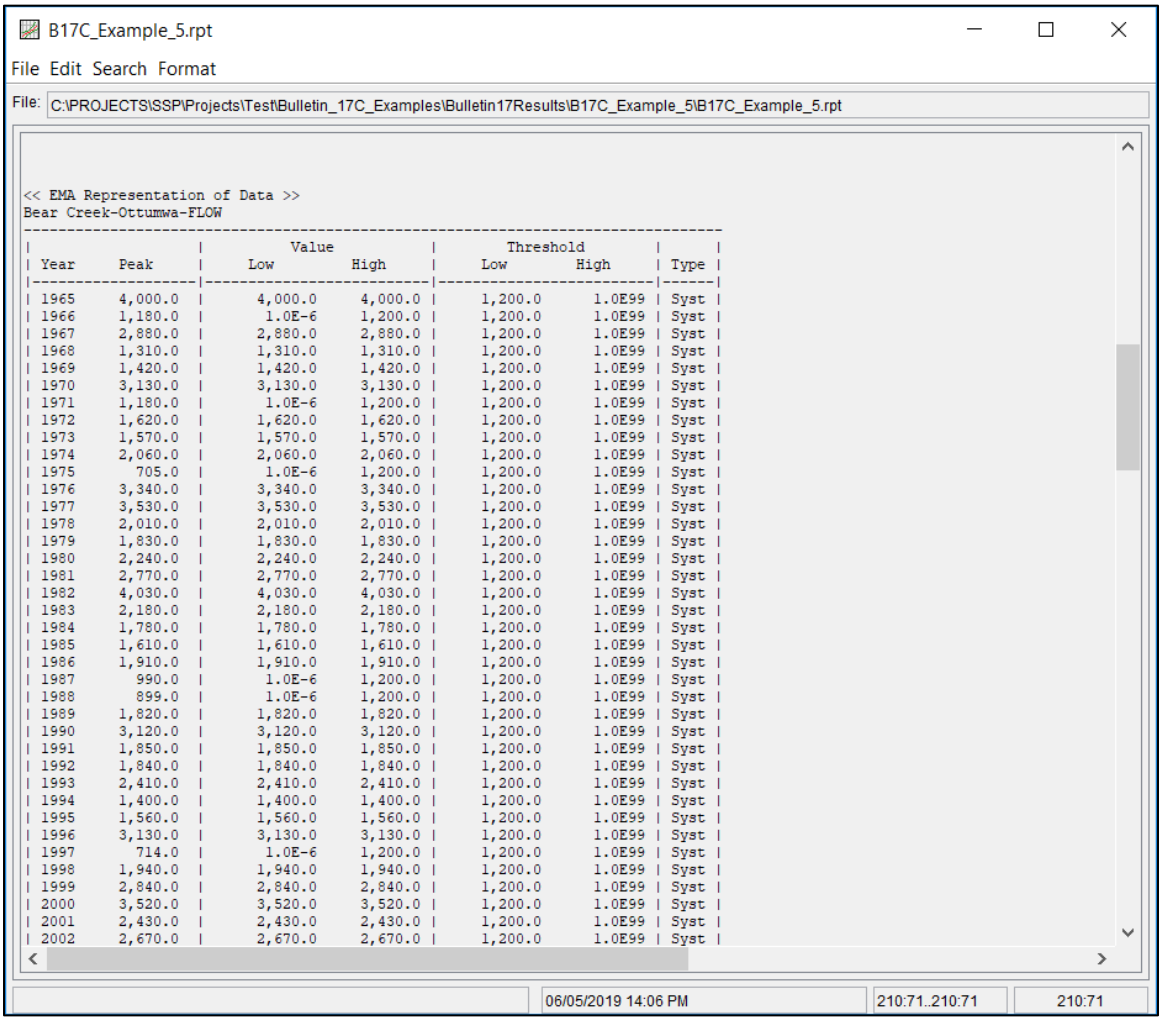


Figure C-33. Report File for B17C Example 5 showing censored low outliers.



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

06/05/2019 14:06 PM 210:71..210:71 210:71

Figure C-34. Report File for B17C Example 5 showing recoded perception thresholds.

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 C-35 and tabulated in Table C-6.

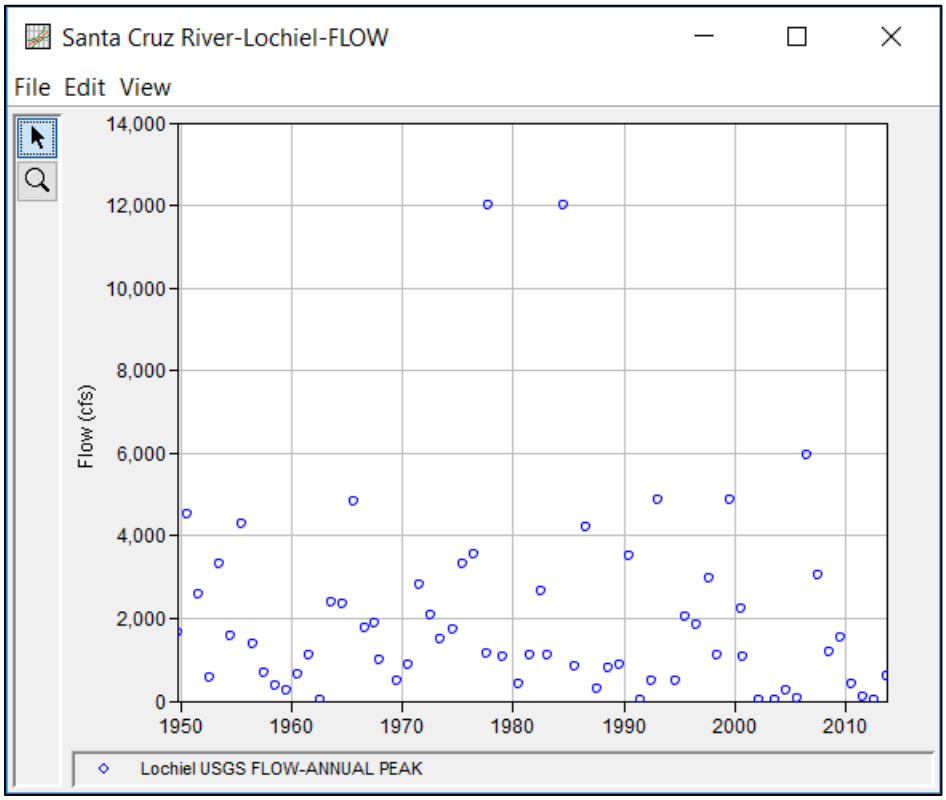


Figure C-35. Santa Cruz River at Lochiel, AZ Annual Peak Flow Record.

Table C-6. Santa Cruz River at Lochiel, AZ Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
13 Sep 1949	1650	10 Aug 1971	2830	18 Jan 1993	4880
30 Jul 1950	4520	16 Jul 1972	2070	30 Aug 1994	478
02 Aug 1951	2560	30 Jun 1973	1490	12 Jul 1995	2020
16 Aug 1952	550	04 Aug 1974	1730	10 Jul 1996	1860
14 Jul 1953	3320	22 Jul 1975	3330	11 Sep 1997	2970
22 Jul 1954	1570	22 Jul 1976	3540	07 Jul 1998	1110
06 Aug 1955	4300	05 Sep 1977	1130	28 Jul 1999	4870
17 Jul 1956	1360	09 Oct 1977	12000	06 Aug 2000	2240
09 Aug 1957	688	25 Jan 1979	1060	22 Oct 2000	1080
07 Aug 1958	380	30 Jun 1980	406	04 Mar 2002	2
14 Aug 1959	243	15 Jul 1981	1110	14 Aug 2003	22
30 Jul 1960	625	11 Aug 1982	2640	05 Aug 2004	256
08 Aug 1961	1120	04 Mar 1983	1120	23 Aug 2005	73
29 Jul 1962	8	15 Aug 1984	12000	08 Aug 2006	5940
25 Aug 1963	2390	19 Jul 1985	850	19 Jul 2007	3060
09 Sep 1964	2330	29 Aug 1986	4210	23 Jul 2008	1180
12 Sep 1965	4810	10 Aug 1987	291	01 Jul 2009	1530
18 Aug 1966	1780	23 Aug 1988	804	31 Jul 2010	392
03 Aug 1967	1870	04 Aug 1989	871	13 Aug 2011	95
20 Dec 1967	986	17 Jul 1990	3510	28 Jul 2012	12
05 Aug 1969	484	26 Jul 1991	17	08 Sep 2013	612
03 Aug 1970	880	01 Aug 1992	483		

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 C-36. As shown, the **Skew** option was set to use the **Station Skew**.

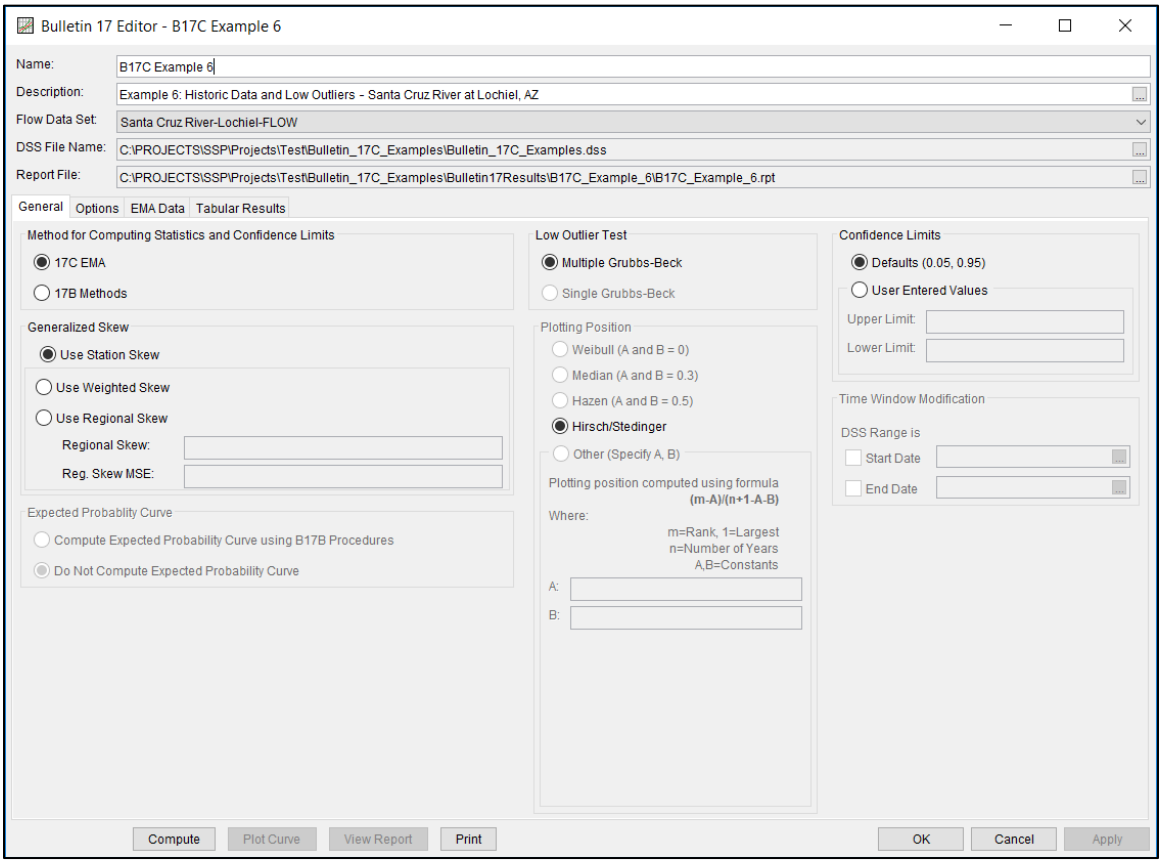


Figure C-36. Bulletin 17 Analysis General Tab for B17C Example 6.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-37. 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 C-37. 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.

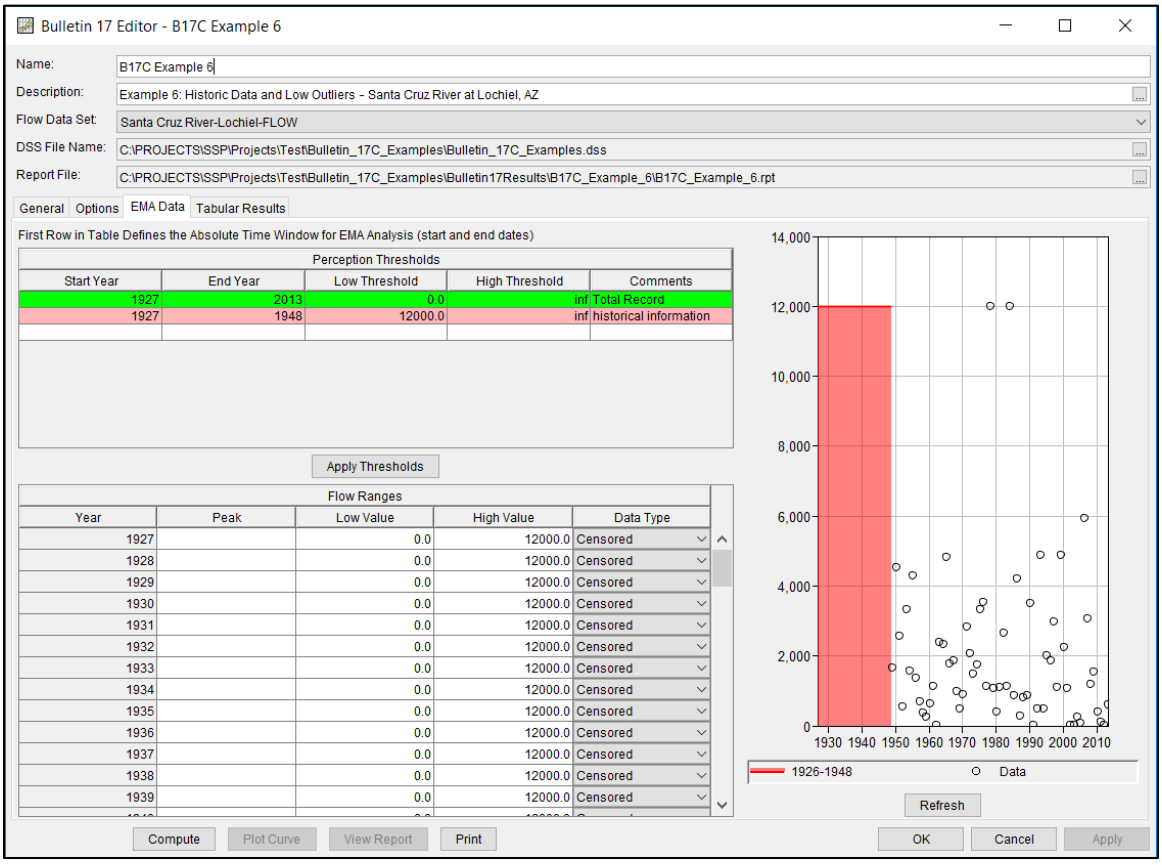


Figure C-37. Bulletin 17 Analysis EMA Data Tab for B17C Example 6.

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 C-31.

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 C-32.

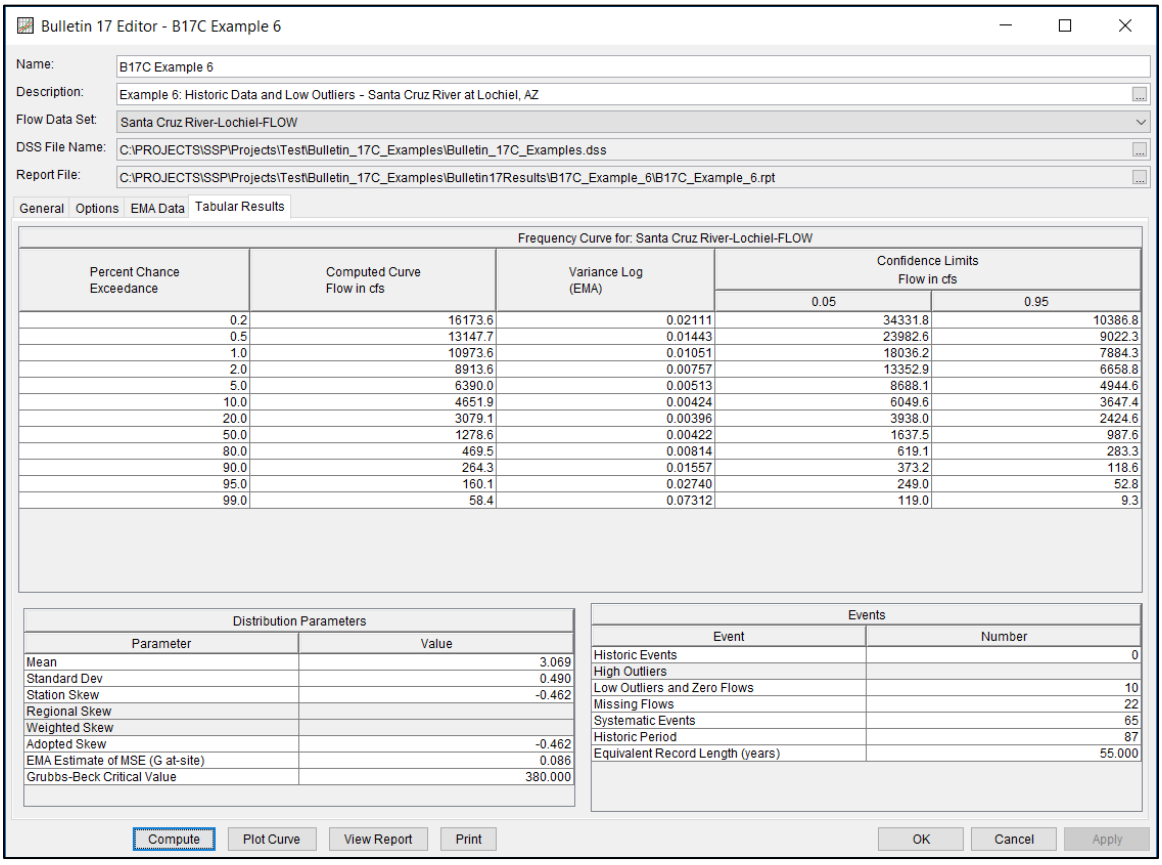


Figure C-38. Bulletin 17 Analysis Tabular Results Tab for B17C Example 6.

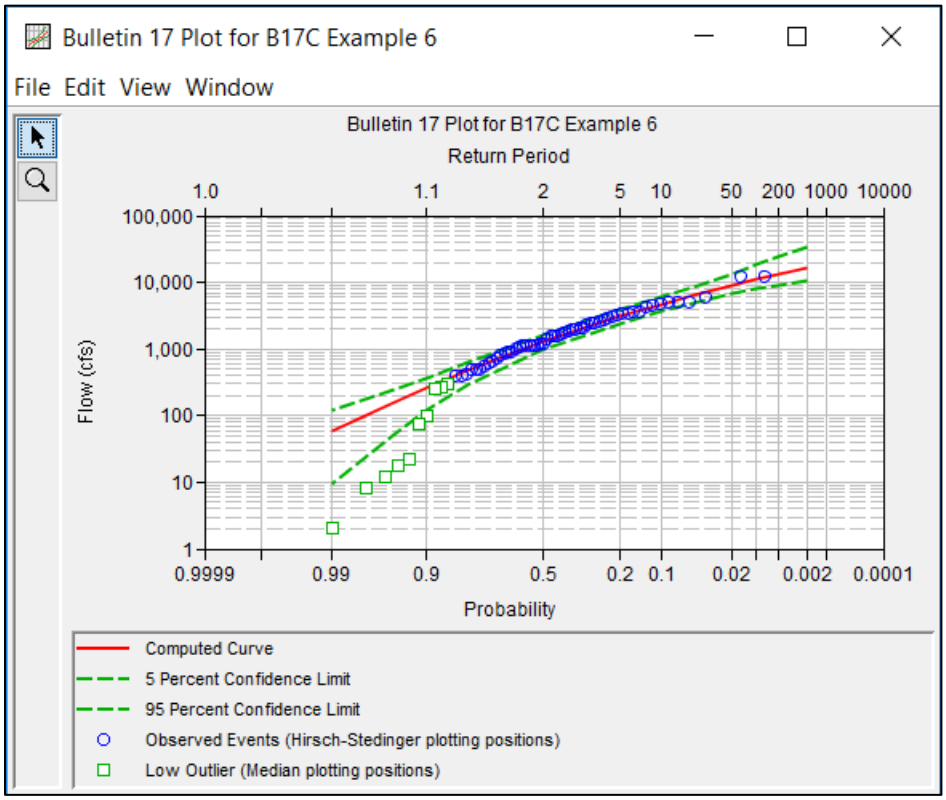
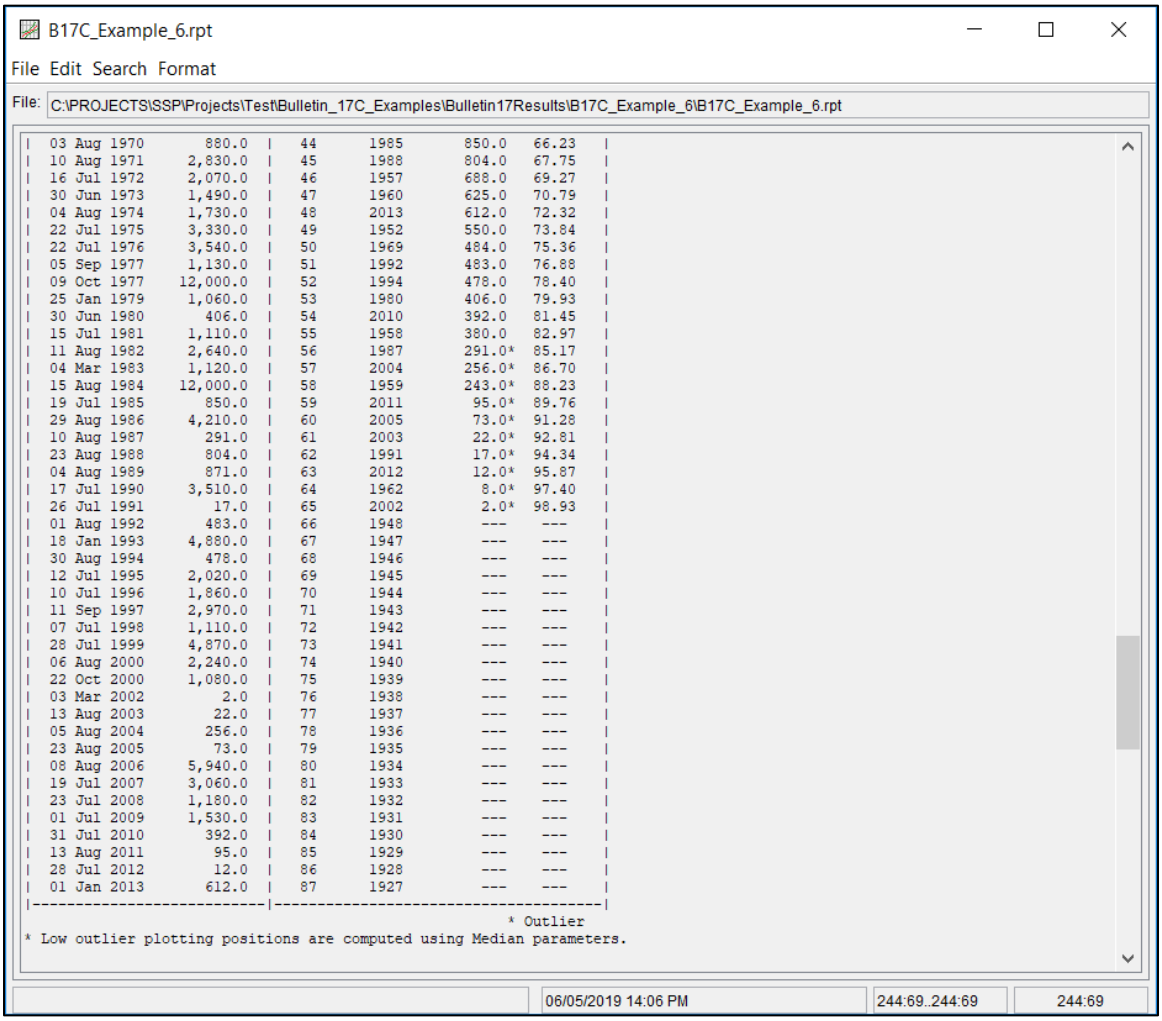


Figure C-39. Plotted Frequency Curves for B17C Example 6.

As shown in Figure C-40, 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 C-39. These annual peak flows were then recoded to have a flow interval of zero – 380. The perception thresholds for the years in which an annual peak flow was recorded were also adjusted to correspond with the Multiple Grubbs-Beck Test low outlier threshold (critical value). Consequently, these perception thresholds were changed from zero – inf to 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 C-41.



B17C_Example_6.rpt

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

03 Aug 1970	880.0	44	1985	850.0	66.23	
10 Aug 1971	2,830.0	45	1988	804.0	67.75	
16 Jul 1972	2,070.0	46	1957	688.0	69.27	
30 Jun 1973	1,490.0	47	1960	625.0	70.79	
04 Aug 1974	1,730.0	48	2013	612.0	72.32	
22 Jul 1975	3,330.0	49	1952	550.0	73.84	
22 Jul 1976	3,540.0	50	1969	484.0	75.36	
05 Sep 1977	1,130.0	51	1992	483.0	76.88	
09 Oct 1977	12,000.0	52	1994	478.0	78.40	
25 Jan 1979	1,060.0	53	1980	406.0	79.93	
30 Jun 1980	406.0	54	2010	392.0	81.45	
15 Jul 1981	1,110.0	55	1958	380.0	82.97	
11 Aug 1982	2,640.0	56	1987	291.0*	85.17	
04 Mar 1983	1,120.0	57	2004	256.0*	86.70	
15 Aug 1984	12,000.0	58	1959	243.0*	88.23	
19 Jul 1985	850.0	59	2011	95.0*	89.76	
29 Aug 1986	4,210.0	60	2005	73.0*	91.28	
10 Aug 1987	291.0	61	2003	22.0*	92.81	
23 Aug 1988	804.0	62	1991	17.0*	94.34	
04 Aug 1989	871.0	63	2012	12.0*	95.87	
17 Jul 1990	3,510.0	64	1962	8.0*	97.40	
26 Jul 1991	17.0	65	2002	2.0*	98.93	
01 Aug 1992	483.0	66	1948	---	---	
18 Jan 1993	4,880.0	67	1947	---	---	
30 Aug 1994	478.0	68	1946	---	---	
12 Jul 1995	2,020.0	69	1945	---	---	
10 Jul 1996	1,860.0	70	1944	---	---	
11 Sep 1997	2,970.0	71	1943	---	---	
07 Jul 1998	1,110.0	72	1942	---	---	
28 Jul 1999	4,870.0	73	1941	---	---	
06 Aug 2000	2,240.0	74	1940	---	---	
22 Oct 2000	1,080.0	75	1939	---	---	
03 Mar 2002	2.0	76	1938	---	---	
13 Aug 2003	22.0	77	1937	---	---	
05 Aug 2004	256.0	78	1936	---	---	
23 Aug 2005	73.0	79	1935	---	---	
08 Aug 2006	5,940.0	80	1934	---	---	
19 Jul 2007	3,060.0	81	1933	---	---	
23 Jul 2008	1,180.0	82	1932	---	---	
01 Jul 2009	1,530.0	83	1931	---	---	
31 Jul 2010	392.0	84	1930	---	---	
13 Aug 2011	95.0	85	1929	---	---	
28 Jul 2012	12.0	86	1928	---	---	
01 Jan 2013	612.0	87	1927	---	---	

* Outlier

* Low outlier plotting positions are computed using Median parameters.

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Figure C-40. Report File for B17C Example 6 showing censored low outliers.

B17C_Example_6.rpt

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

		Value		Threshold		
Year	Peak	Low	High	Low	High	Type
1927	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1928	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1929	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1930	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1931	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1932	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1933	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1934	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1935	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1936	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1937	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1938	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1939	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1940	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1941	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1942	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1943	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1944	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1945	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1946	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1947	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1948	---	1.0E-99	12,000.0	12,000.0	1.0E99	Cens
1949	1,650.0	1,650.0	1,650.0	380.0	1.0E99	Syst
1950	4,520.0	4,520.0	4,520.0	380.0	1.0E99	Syst
1951	2,560.0	2,560.0	2,560.0	380.0	1.0E99	Syst
1952	550.0	550.0	550.0	380.0	1.0E99	Syst
1953	3,320.0	3,320.0	3,320.0	380.0	1.0E99	Syst
1954	1,570.0	1,570.0	1,570.0	380.0	1.0E99	Syst
1955	4,300.0	4,300.0	4,300.0	380.0	1.0E99	Syst
1956	1,360.0	1,360.0	1,360.0	380.0	1.0E99	Syst
1957	688.0	688.0	688.0	380.0	1.0E99	Syst
1958	380.0	380.0	380.0	380.0	1.0E99	Syst
1959	243.0	1.0E-6	380.0	380.0	1.0E99	Syst
1960	625.0	625.0	625.0	380.0	1.0E99	Syst
1961	1,120.0	1,120.0	1,120.0	380.0	1.0E99	Syst
1962	8.0	1.0E-6	380.0	380.0	1.0E99	Syst
1963	2,390.0	2,390.0	2,390.0	380.0	1.0E99	Syst
1964	2,330.0	2,330.0	2,330.0	380.0	1.0E99	Syst
1965	4,810.0	4,810.0	4,810.0	380.0	1.0E99	Syst

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Figure C-41. Report File for B17C Example 6 showing recoded perception thresholds.

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 (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 C-42 and tabulated in Table C-7.

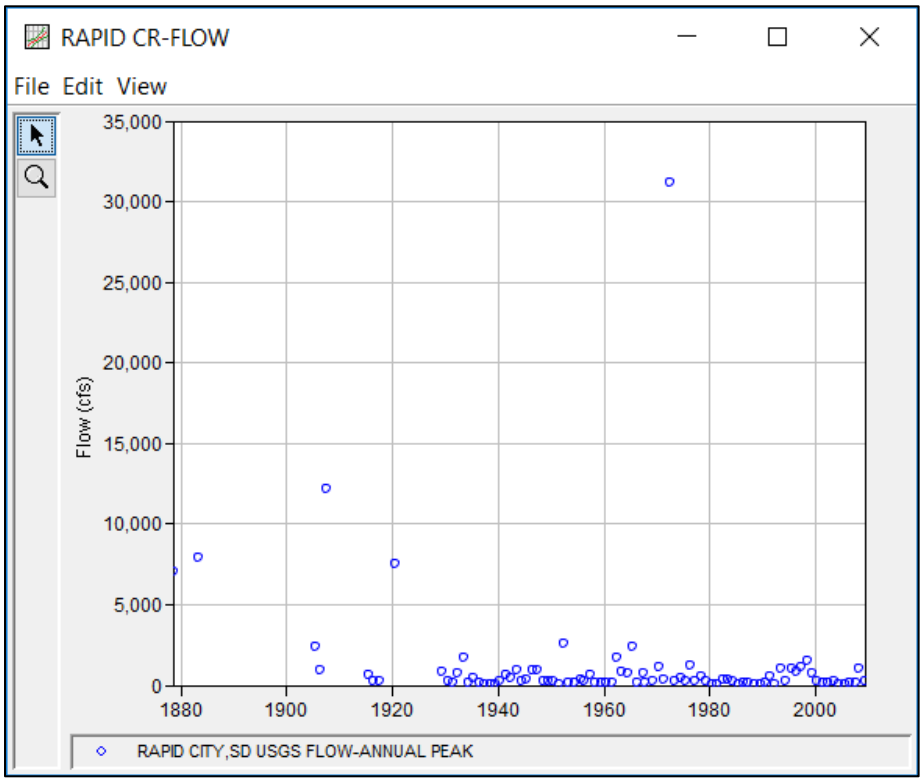


Figure C-42. Rapid Creek above Canyon Lake near Rapid City, SD Annual Peak Flow Record.

Table C-7. Rapid Creek above Canyon Lake near Rapid City, SD Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
1878	7060	15 Apr 1950	209	16 Jul 1980	87
1883	7900	15 Jun 1951	77	13 Jul 1981	96
1905	2350	23 May 1952	2600	22 Jul 1982	384
1906	922	16 Jun 1953	152	11 May 1983	303
1907	12200	12 Aug 1954	140	15 Jun 1984	229
1915	654	29 Jul 1955	326	15 Jul 1985	87
1916	217	29 May 1956	203	04 Jun 1986	142
1917	287	14 Jul 1957	595	29 May 1987	115
1920	7540	30 May 1958	131	03 Aug 1988	80
1929	870	30 Jun 1959	169	12 Jul 1989	64
1930	213	16 Jul 1960	135	07 Jul 1990	108
1931	170	01 Jul 1961	111	11 May 1991	487
1932	747	13 Jul 1962	1700	21 May 1992	64
1933	1690	06 Jun 1963	827	20 Jun 1993	1000
1934	128	11 Jun 1964	735	29 Apr 1994	227
1935	479	19 May 1965	2380	09 Jun 1995	1020
1936	110	22 Mar 1966	174	01 Jun 1996	823
1937	92	15 Jun 1967	726	02 Jun 1997	1090
1938	94	04 Oct 1967	123	24 Jun 1998	1490
1939	68	20 May 1969	246	16 Jun 1999	698
1940	268	14 Jun 1970	1150	20 May 2000	264
1941	592	26 Apr 1971	353	15 Jul 2001	131
1942	448	09 Jun 1972	31200	06 Jul 2002	159
1943	882	09 May 1973	196	21 Jun 2003	243
1944	254	22 Aug 1974	476	01 Jul 2004	67
1945	359	07 Jun 1975	253	10 Jul 2005	61
1946	943	15 Jun 1976	1220	07 Aug 2006	104
23 Jun 1947	950	08 May 1977	216	17 Aug 2007	177
22 Jun 1948	245	21 May 1978	498	24 May 2008	1000
15 Aug 1949	290	17 Jun 1979	200	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 C-43. 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.

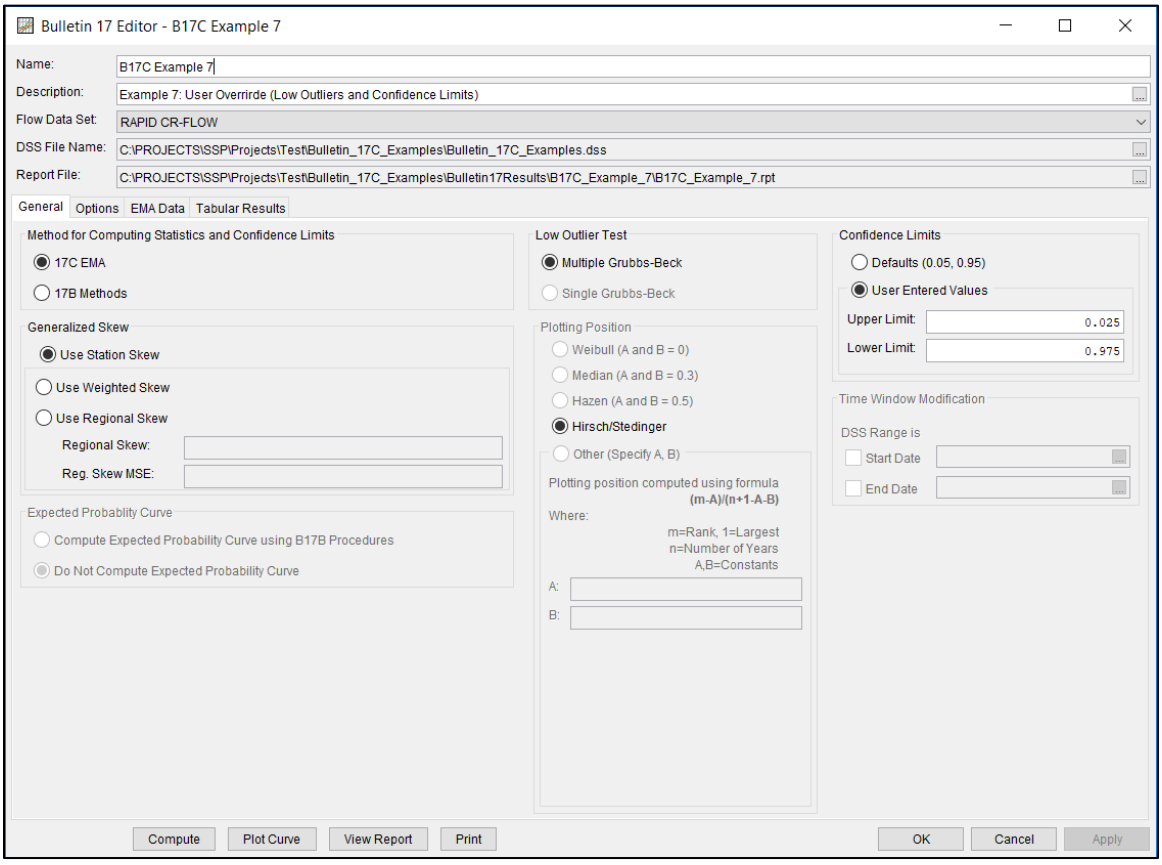


Figure C-43. Bulletin 17 Analysis General Tab for B17C Example 7.

A low outlier threshold of **100** cfs was specified on the **Options** tab, as shown in Figure C-44. 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.

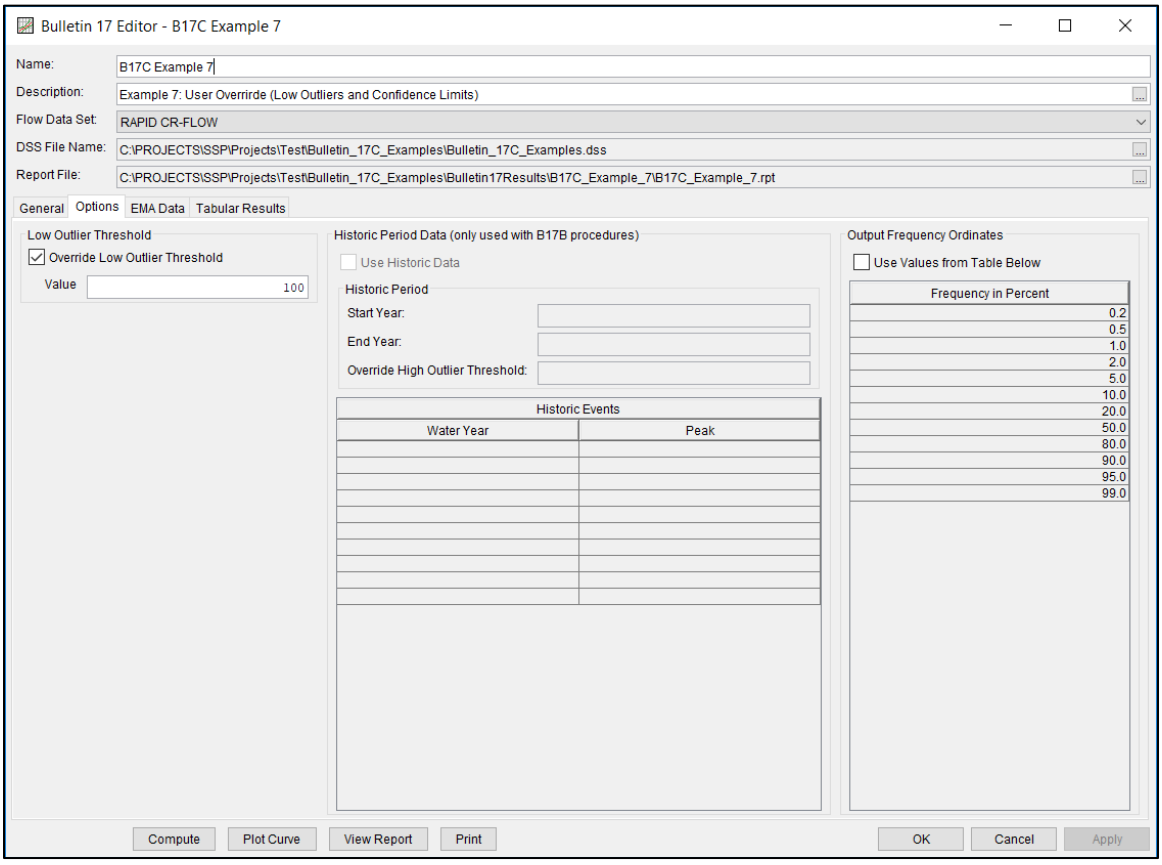


Figure C-44. Bulletin 17 Analysis Options Tab for B17C Example 7.

The **EMA Data** tab for this example is shown in Figure C-45. 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 C-45, click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

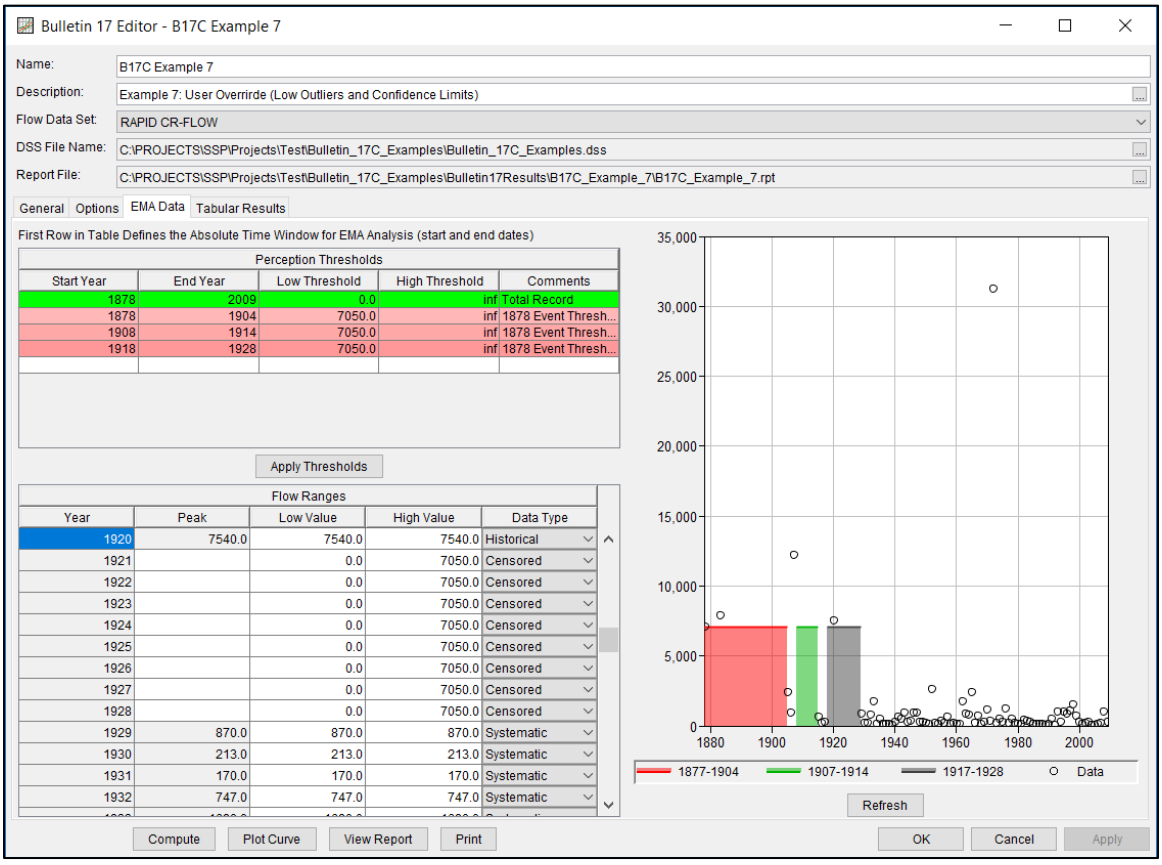


Figure C-45. Bulletin 17 Analysis EMA Data Tab for B17C Example 7.

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 C-46.

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 C-47.

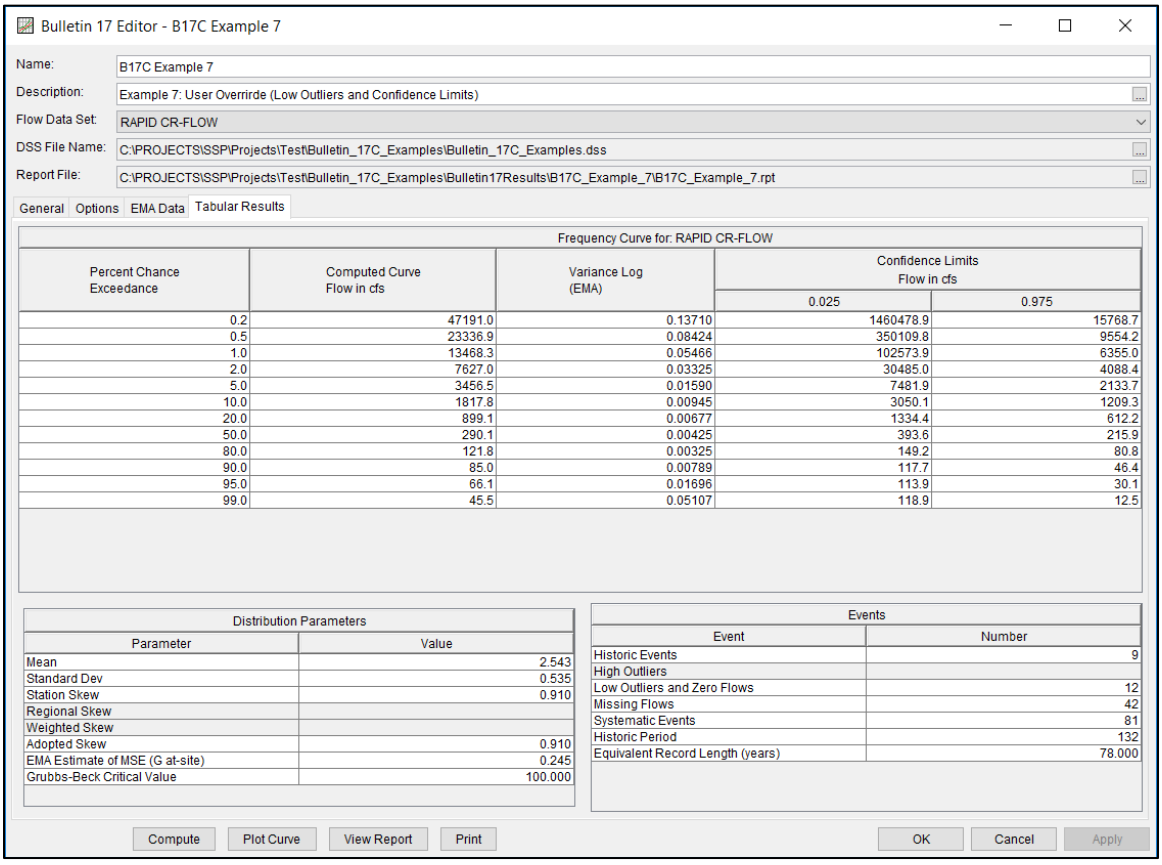


Figure C-46. Bulletin 17 Analysis Tabular Results Tab for B17C Example 7.

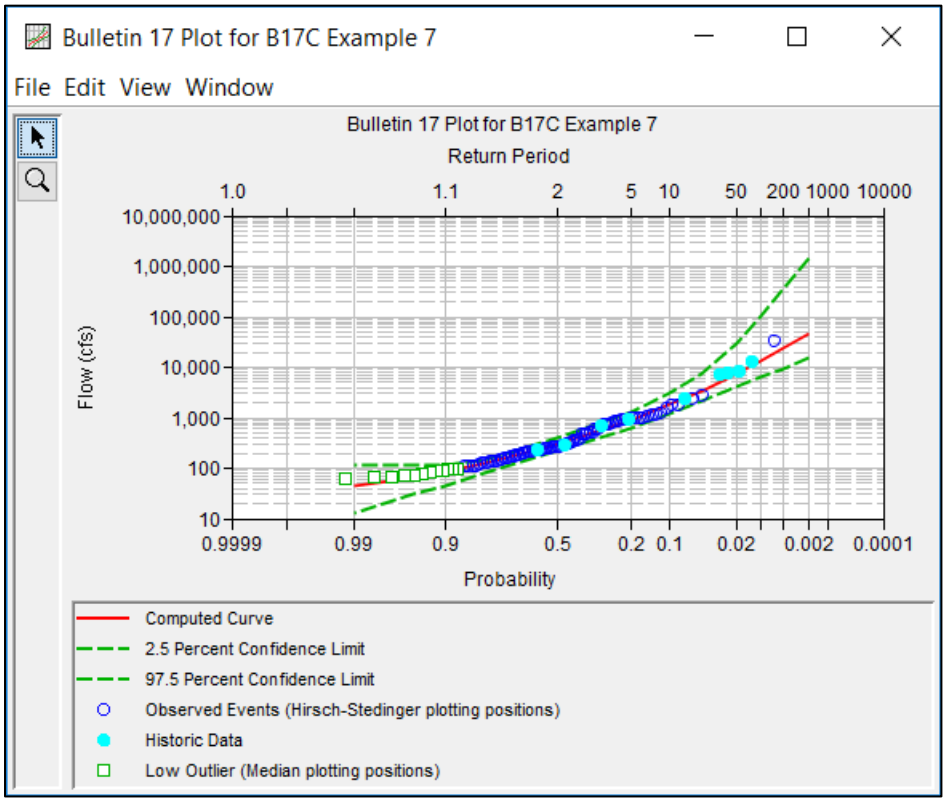


Figure C-47. Plotted Frequency Curves for B17C Example 7.

As shown in Figure C-48, 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 thresholds for the years in which an annual peak flow was recorded were also adjusted to correspond with the defined low outlier threshold. Consequently, these perception thresholds were changed from zero – inf to 100 – inf, as shown in Figure C-49.

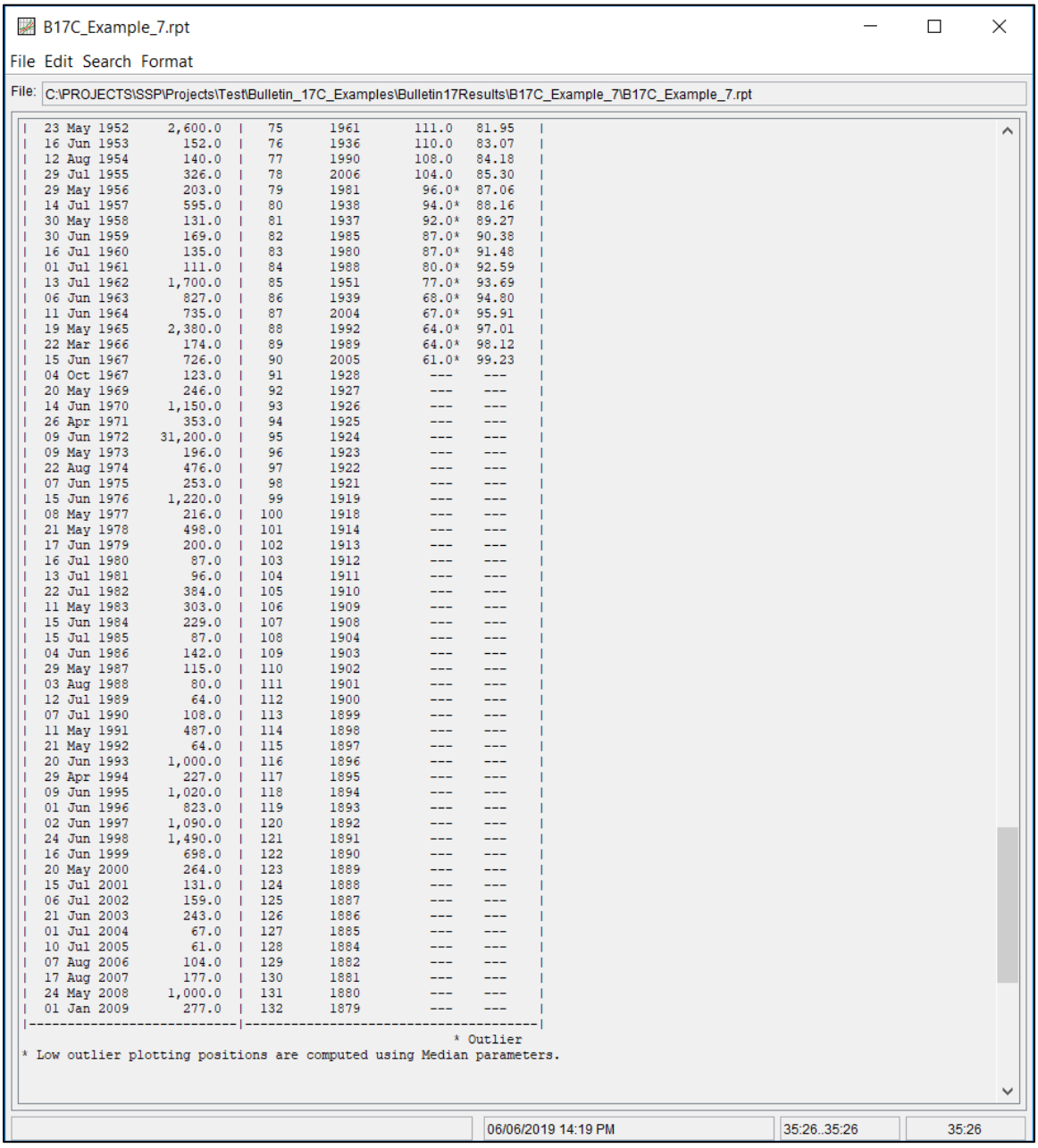
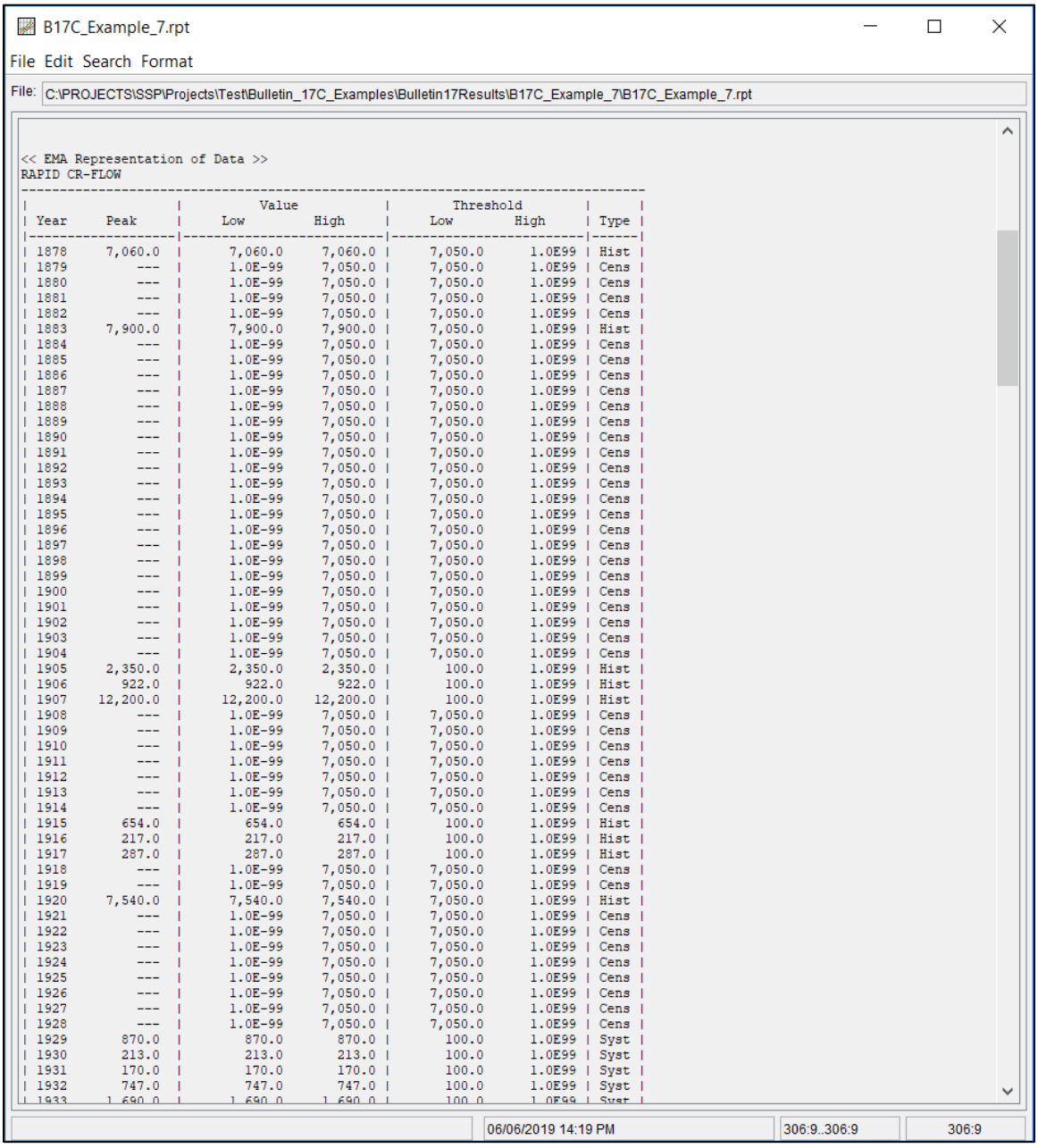


Figure C-48. Report File for B17C Example 7 showing censored low outliers.



B17C_Example_7.rpt

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

		Value		Threshold		
Year	Peak	Low	High	Low	High	Type
1878	7,060.0	7,060.0	7,060.0	7,050.0	1.0E99	Hist
1879	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1880	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1881	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1882	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1883	7,900.0	7,900.0	7,900.0	7,050.0	1.0E99	Hist
1884	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1885	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1886	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1887	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1888	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1889	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1890	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1891	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1892	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1893	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1894	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1895	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1896	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1897	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1898	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1899	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1900	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1901	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1902	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1903	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1904	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1905	2,350.0	2,350.0	2,350.0	100.0	1.0E99	Hist
1906	922.0	922.0	922.0	100.0	1.0E99	Hist
1907	12,200.0	12,200.0	12,200.0	100.0	1.0E99	Hist
1908	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1909	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1910	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1911	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1912	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1913	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1914	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1915	654.0	654.0	654.0	100.0	1.0E99	Hist
1916	217.0	217.0	217.0	100.0	1.0E99	Hist
1917	287.0	287.0	287.0	100.0	1.0E99	Hist
1918	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1919	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1920	7,540.0	7,540.0	7,540.0	7,050.0	1.0E99	Hist
1921	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1922	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1923	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1924	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1925	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1926	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1927	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1928	---	1.0E-99	7,050.0	7,050.0	1.0E99	Cens
1929	870.0	870.0	870.0	100.0	1.0E99	Syst
1930	213.0	213.0	213.0	100.0	1.0E99	Syst
1931	170.0	170.0	170.0	100.0	1.0E99	Syst
1932	747.0	747.0	747.0	100.0	1.0E99	Syst
1933	1,690.0	1,690.0	1,690.0	100.0	1.0E99	Syst

06/06/2019 14:19 PM 306:9..306:9 306:9

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

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. The annual maximum series is plotted in Figure C-50 and tabulated in Table C-8.

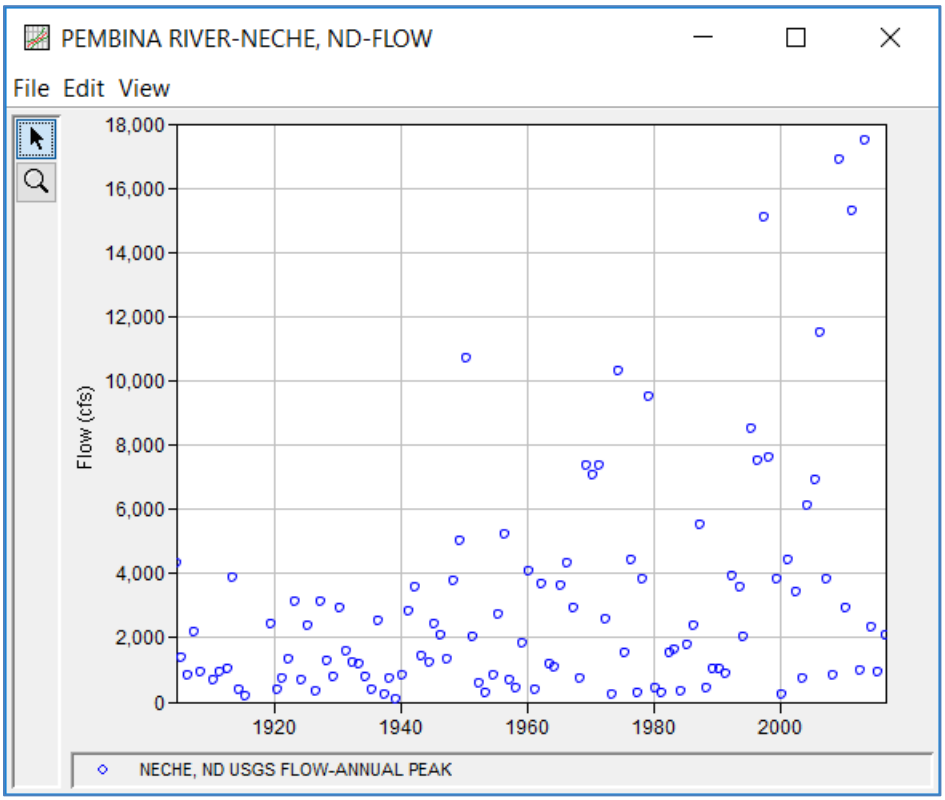


Figure C-50. Pembina River at Neche, ND Annual Peak Flow Record.

Table C-8. Pembina River at Neche, ND Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)	Date	Flow (cfs)
02 May 1904	4300	06 Aug 1944	1200	07 Apr 1980	435
05 Apr 1905	1372	29 Mar 1945	2440	01 Apr 1981	285
04 Apr 1906	800	24 Mar 1946	2070	08 Jun 1982	1520
14 May 1907	2190	11 Apr 1947	1320	09 Apr 1983	1630
10 Apr 1908	927	21 Apr 1948	3770	07 Apr 1984	312
15 Mar 1910	685	22 Apr 1949	5010	20 Mar 1985	1750
23 Mar 1911	900	20 Apr 1950	10700	24 Mar 1986	2390
29 Jul 1912	1000	07 Apr 1951	2000	07 Apr 1987	5510
07 Apr 1913	3870	03 Apr 1952	550	06 Apr 1988	420
18 Apr 1914	388	10 Jun 1953	250	17 Apr 1989	1000
07 Apr 1915	180	07 Jul 1954	846	03 Apr 1990	1000
15 Apr 1919	2430	05 Apr 1955	2700	16 Jun 1991	888
19 Apr 1920	361	27 Apr 1956	5200	01 Apr 1992	3900
13 Apr 1921	733	27 Mar 1957	661	30 Jul 1993	3580
07 Apr 1922	1300	07 Apr 1958	442	02 Apr 1994	2040
20 Apr 1923	3120	05 Apr 1959	1800	23 Apr 1995	8500
20 Apr 1924	674	14 Apr 1960	4040	18 Apr 1996	7500
28 Mar 1925	2350	03 Apr 1961	372	27 Apr 1997	15100
06 Jul 1926	318	21 Apr 1962	3650	16 Apr 1998	7620
12 May 1927	3110	28 Jul 1963	1150	02 Jun 1999	3790
25 Mar 1928	1270	17 Apr 1964	1080	22 Mar 2000	208
21 Mar 1929	750	13 Apr 1965	3600	22 Apr 2001	4420
08 Apr 1930	2900	03 Apr 1966	4300	12 Jun 2002	3440
09 Apr 1931	1580	23 Apr 1967	2900	20 May 2003	712
09 Apr 1932	1240	28 Mar 1968	734	01 Apr 2004	6120
26 May 1933	1180	21 Apr 1969	7360	02 Jul 2005	6890
09 Apr 1934	780	27 Apr 1970	7070	17 Apr 2006	11500
18 Jun 1935	364	12 Apr 1971	7350	30 Mar 2007	3800
15 Apr 1936	2530	16 Apr 1972	2550	13 Apr 2008	847
08 Jun 1937	237	27 Mar 1973	224	20 Apr 2009	16900
20 Mar 1938	730	28 Apr 1974	10300	04 Apr 2010	2900
04 Apr 1939	52	18 May 1975	1500	19 Apr 2011	15300
20 Apr 1940	816	19 Apr 1976	4430	05 Jul 2012	991
14 Apr 1941	2830	21 May 1977	261	21 May 2013	17500
07 Apr 1942	3550	11 Apr 1978	3800	13 Apr 2014	2300
27 Mar 1943	1400	20 Apr 1979	9500	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 C-51. As shown, the **Skew** option was set to use the **Station Skew**.

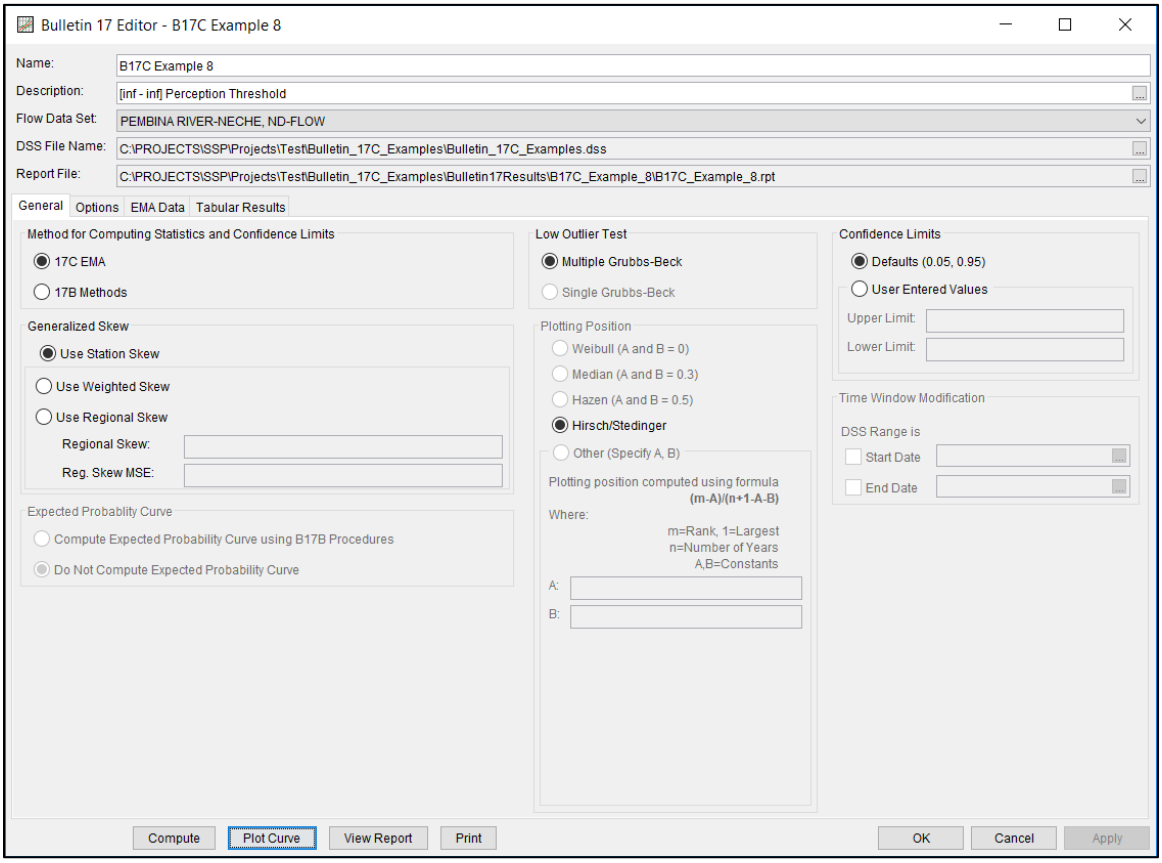


Figure C-51. Bulletin 17 Analysis General Tab for B17C Example 8.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-52. 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 C-52, click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

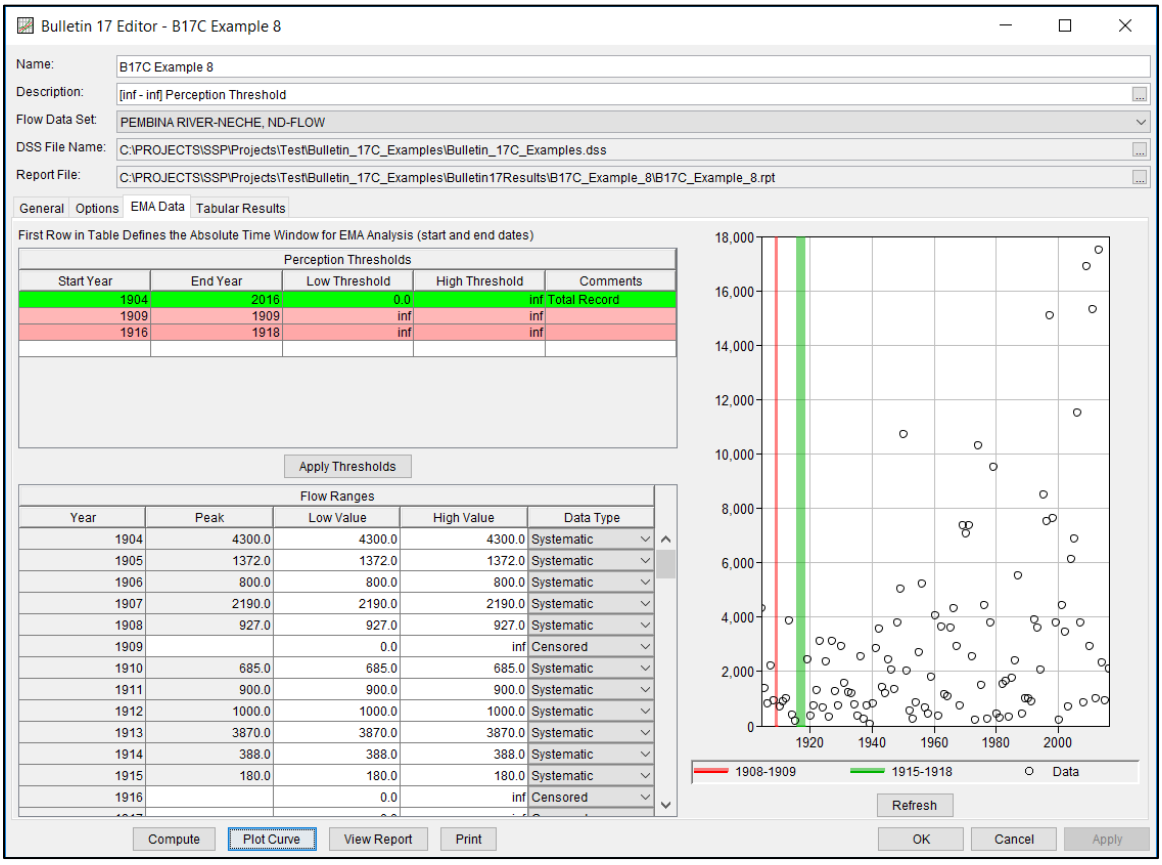
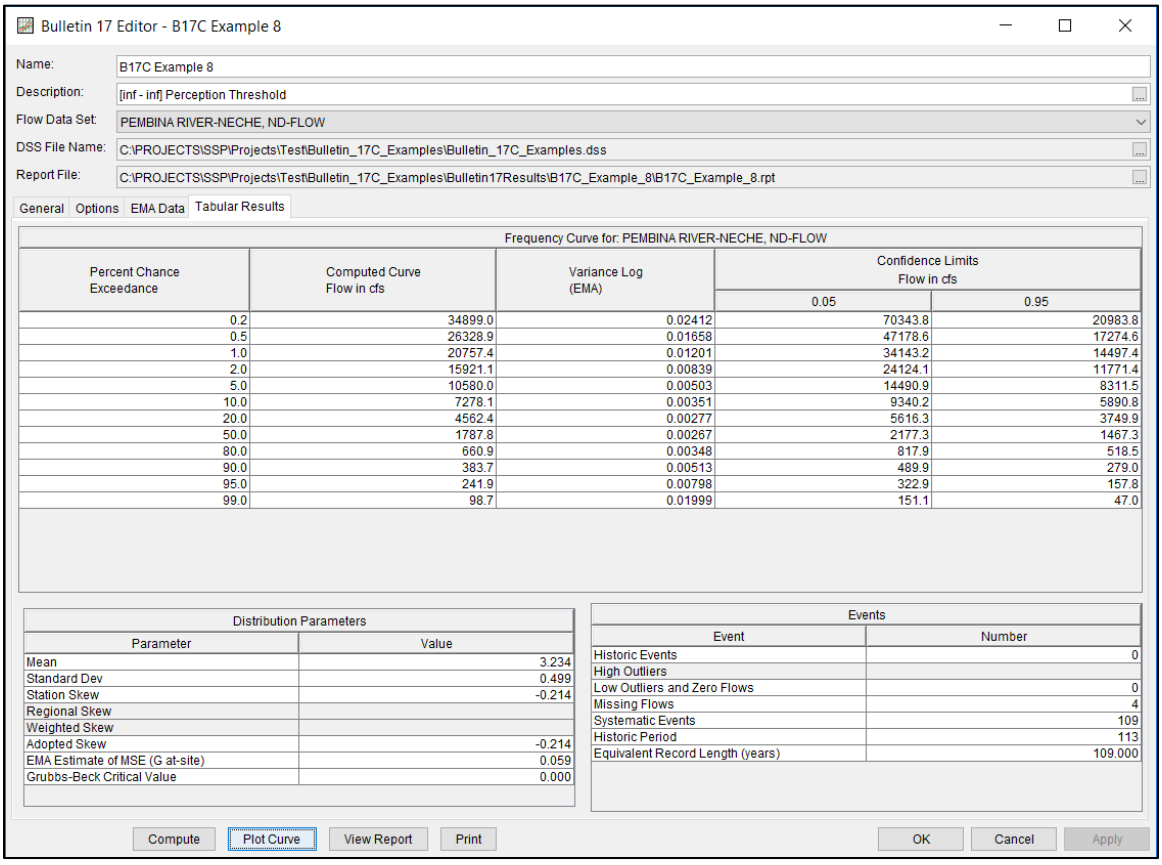


Figure C-52. Bulletin 17 Analysis EMA Data Tab for B17C Example 8.

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 C-53.

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 C-54.



Frequency Curve for: PEMBINA RIVER-NECHE, ND-FLOW

Percent Chance Exceedance	Computed Curve Flow in cfs	Variance Log (EMA)	Confidence Limits Flow in cfs	
			0.05	0.95
0.2	34899.0	0.02412	70343.8	20983.8
0.5	26328.9	0.01658	47178.6	17274.6
1.0	20757.4	0.01201	34143.2	14497.4
2.0	15921.1	0.00839	24124.1	11771.4
5.0	10580.0	0.00503	14490.9	8311.5
10.0	7278.1	0.00351	9340.2	5890.8
20.0	4562.4	0.00277	5616.3	3749.9
50.0	1787.8	0.00267	2177.3	1467.3
80.0	660.9	0.00348	817.9	518.5
90.0	383.7	0.00513	489.9	279.0
95.0	241.9	0.00798	322.9	157.8
99.0	98.7	0.01999	151.1	47.0

Distribution Parameters

Parameter	Value
Mean	3.234
Standard Dev	0.499
Station Skew	-0.214
Regional Skew	
Weighted Skew	
Adopted Skew	-0.214
EMA Estimate of MSE (G at-site)	0.059
Grubbs-Beck Critical Value	0.000

Events

Event	Number
Historic Events	0
High Outliers	
Low Outliers and Zero Flows	0
Missing Flows	4
Systematic Events	109
Historic Period	113
Equivalent Record Length (years)	109.000

Figure C-53. Bulletin 17 Analysis Tabular Results Tab for B17C Example 8.

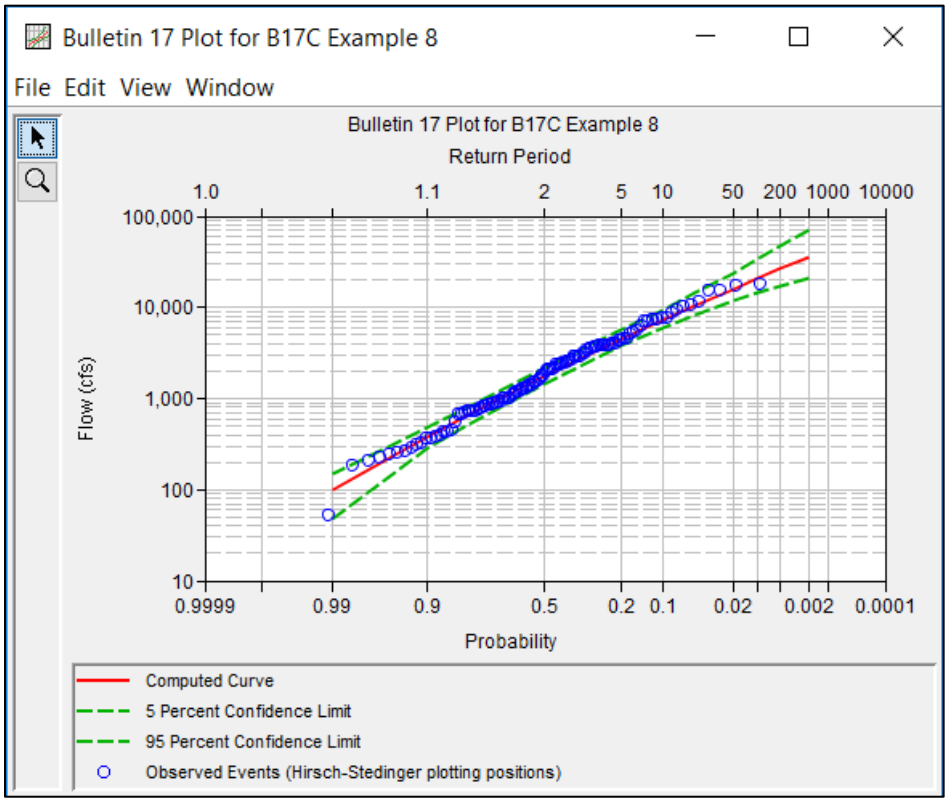


Figure C-54. Plotted Frequency Curves for B17C Example 8.

As shown in Figure C-55, 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 C-56.

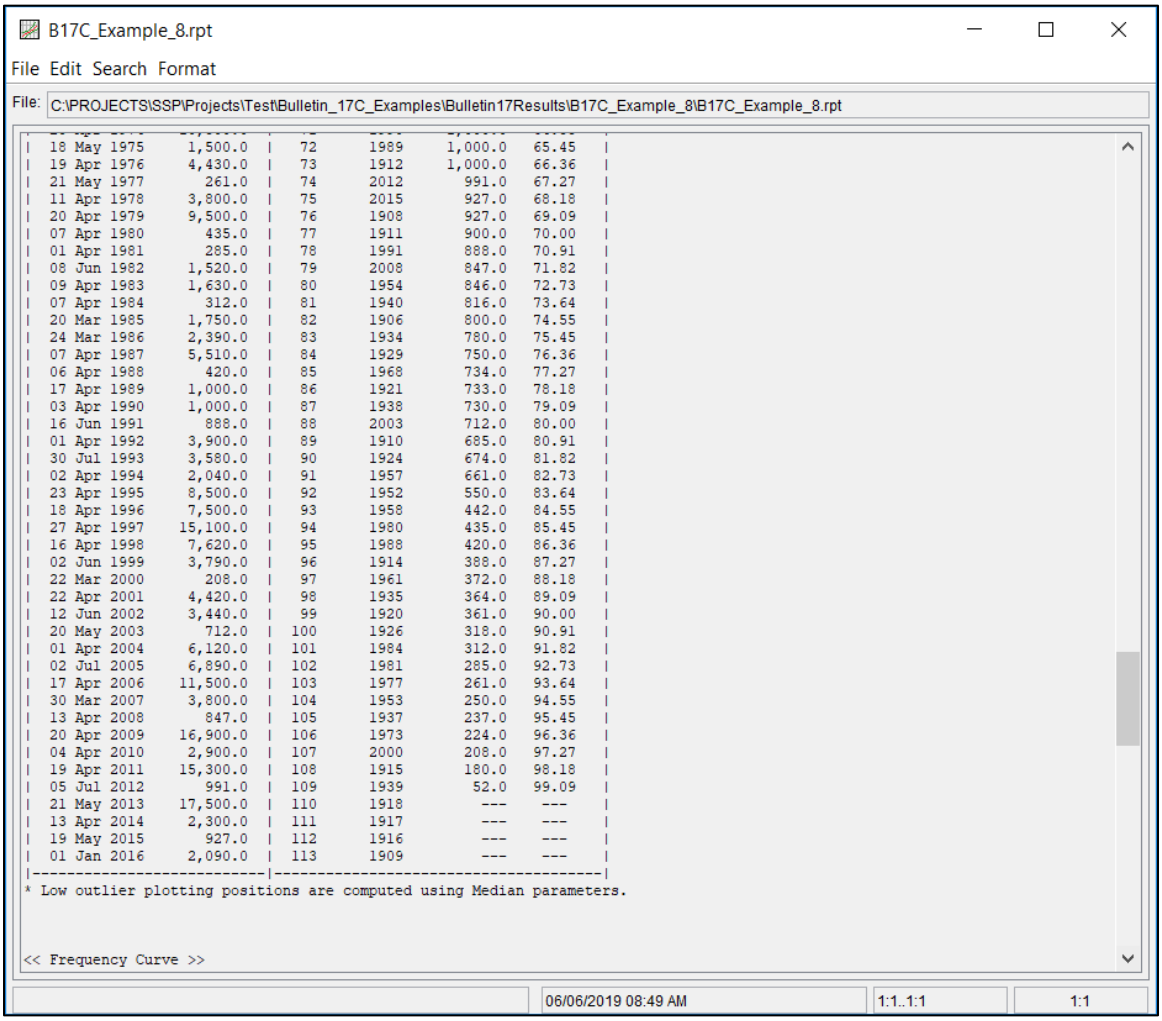
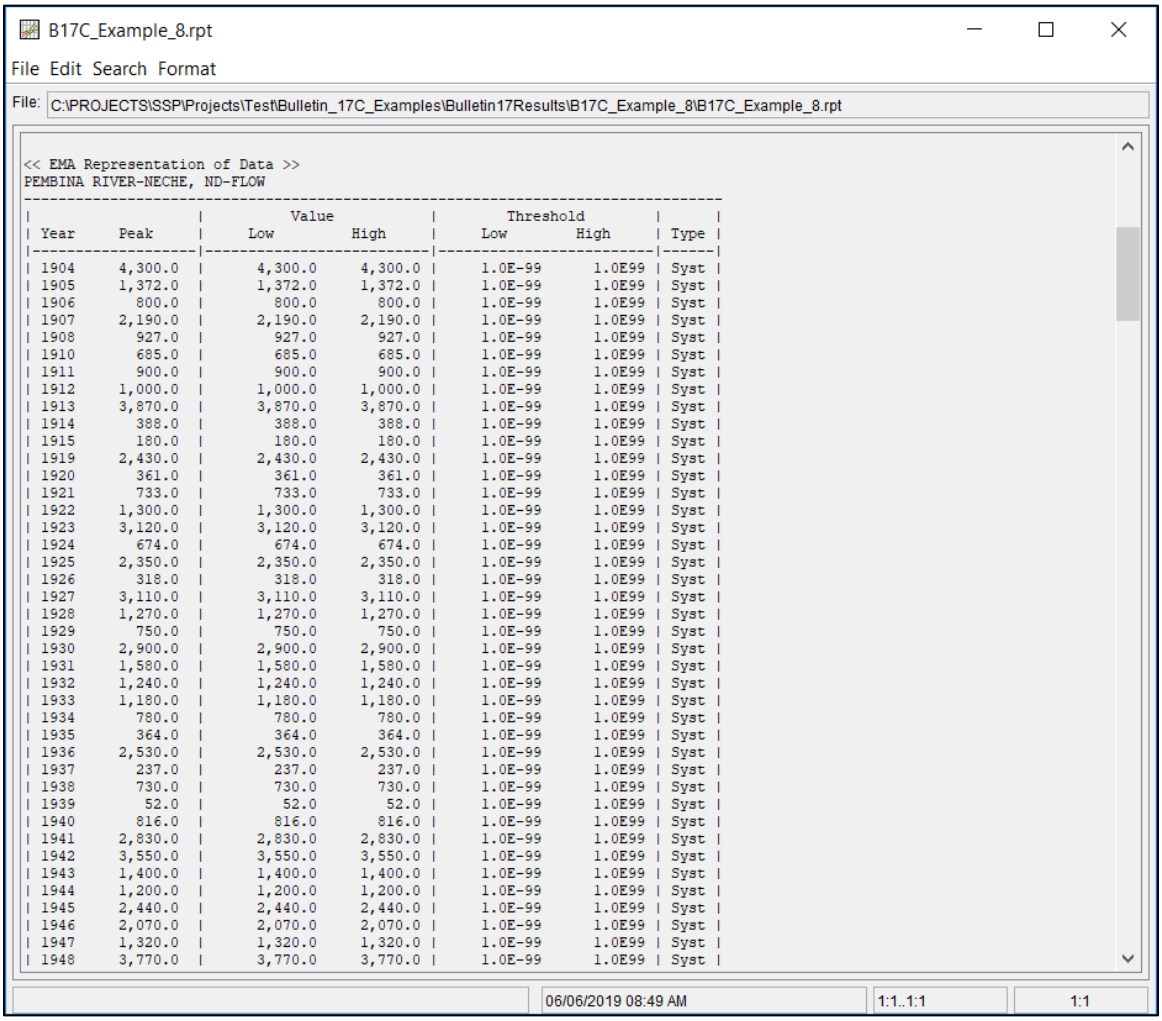


Figure C-55. Report File for B17C Example 8 showing missing periods.



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		Threshold		
Year	Peak	Low	High	Low	High	Type
1904	4,300.0	4,300.0	4,300.0	1.0E-99	1.0E99	Syst
1905	1,372.0	1,372.0	1,372.0	1.0E-99	1.0E99	Syst
1906	800.0	800.0	800.0	1.0E-99	1.0E99	Syst
1907	2,190.0	2,190.0	2,190.0	1.0E-99	1.0E99	Syst
1908	927.0	927.0	927.0	1.0E-99	1.0E99	Syst
1910	685.0	685.0	685.0	1.0E-99	1.0E99	Syst
1911	900.0	900.0	900.0	1.0E-99	1.0E99	Syst
1912	1,000.0	1,000.0	1,000.0	1.0E-99	1.0E99	Syst
1913	3,870.0	3,870.0	3,870.0	1.0E-99	1.0E99	Syst
1914	388.0	388.0	388.0	1.0E-99	1.0E99	Syst
1915	180.0	180.0	180.0	1.0E-99	1.0E99	Syst
1919	2,430.0	2,430.0	2,430.0	1.0E-99	1.0E99	Syst
1920	361.0	361.0	361.0	1.0E-99	1.0E99	Syst
1921	733.0	733.0	733.0	1.0E-99	1.0E99	Syst
1922	1,300.0	1,300.0	1,300.0	1.0E-99	1.0E99	Syst
1923	3,120.0	3,120.0	3,120.0	1.0E-99	1.0E99	Syst
1924	674.0	674.0	674.0	1.0E-99	1.0E99	Syst
1925	2,350.0	2,350.0	2,350.0	1.0E-99	1.0E99	Syst
1926	318.0	318.0	318.0	1.0E-99	1.0E99	Syst
1927	3,110.0	3,110.0	3,110.0	1.0E-99	1.0E99	Syst
1928	1,270.0	1,270.0	1,270.0	1.0E-99	1.0E99	Syst
1929	750.0	750.0	750.0	1.0E-99	1.0E99	Syst
1930	2,900.0	2,900.0	2,900.0	1.0E-99	1.0E99	Syst
1931	1,580.0	1,580.0	1,580.0	1.0E-99	1.0E99	Syst
1932	1,240.0	1,240.0	1,240.0	1.0E-99	1.0E99	Syst
1933	1,180.0	1,180.0	1,180.0	1.0E-99	1.0E99	Syst
1934	780.0	780.0	780.0	1.0E-99	1.0E99	Syst
1935	364.0	364.0	364.0	1.0E-99	1.0E99	Syst
1936	2,530.0	2,530.0	2,530.0	1.0E-99	1.0E99	Syst
1937	237.0	237.0	237.0	1.0E-99	1.0E99	Syst
1938	730.0	730.0	730.0	1.0E-99	1.0E99	Syst
1939	52.0	52.0	52.0	1.0E-99	1.0E99	Syst
1940	816.0	816.0	816.0	1.0E-99	1.0E99	Syst
1941	2,830.0	2,830.0	2,830.0	1.0E-99	1.0E99	Syst
1942	3,550.0	3,550.0	3,550.0	1.0E-99	1.0E99	Syst
1943	1,400.0	1,400.0	1,400.0	1.0E-99	1.0E99	Syst
1944	1,200.0	1,200.0	1,200.0	1.0E-99	1.0E99	Syst
1945	2,440.0	2,440.0	2,440.0	1.0E-99	1.0E99	Syst
1946	2,070.0	2,070.0	2,070.0	1.0E-99	1.0E99	Syst
1947	1,320.0	1,320.0	1,320.0	1.0E-99	1.0E99	Syst
1948	3,770.0	3,770.0	3,770.0	1.0E-99	1.0E99	Syst

06/06/2019 08:49 AM 1:1..1:1 1:1

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

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 spanning, 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. The annual maximum series is plotted in Figure C-57 and tabulated in Table C-9.

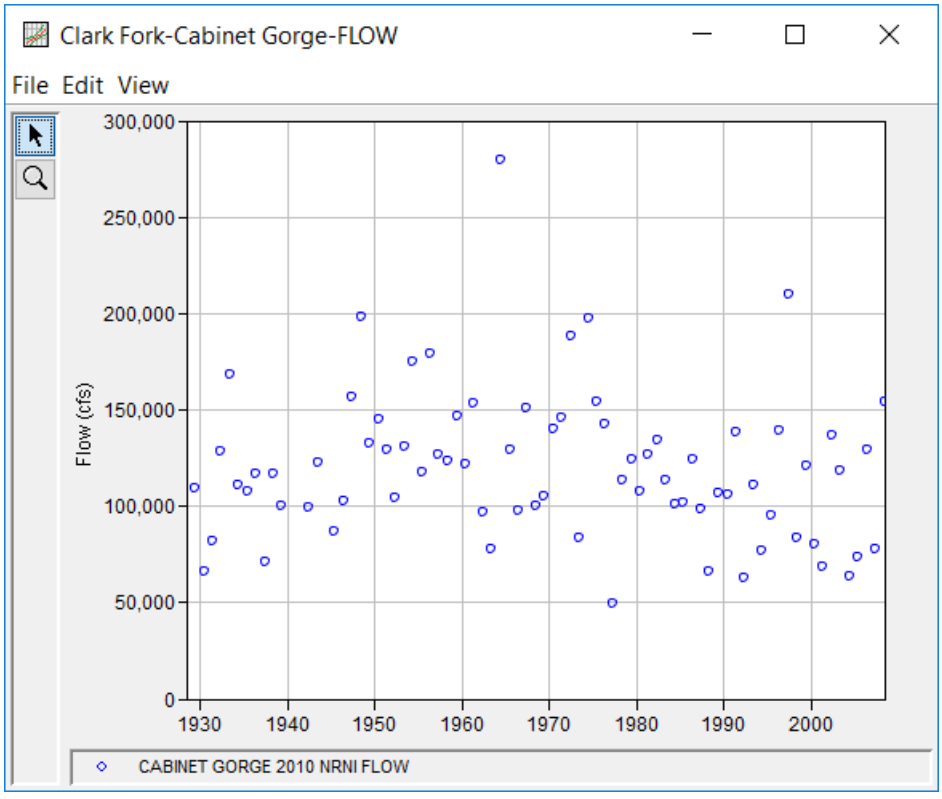


Figure C-57. Clark Fork River below Cabinet Gorge Dam, ID Annual Peak Flow Record.

Table C-9. 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
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
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
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
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 C-58. As shown, the **Skew** option was set to use the **Station Skew**.

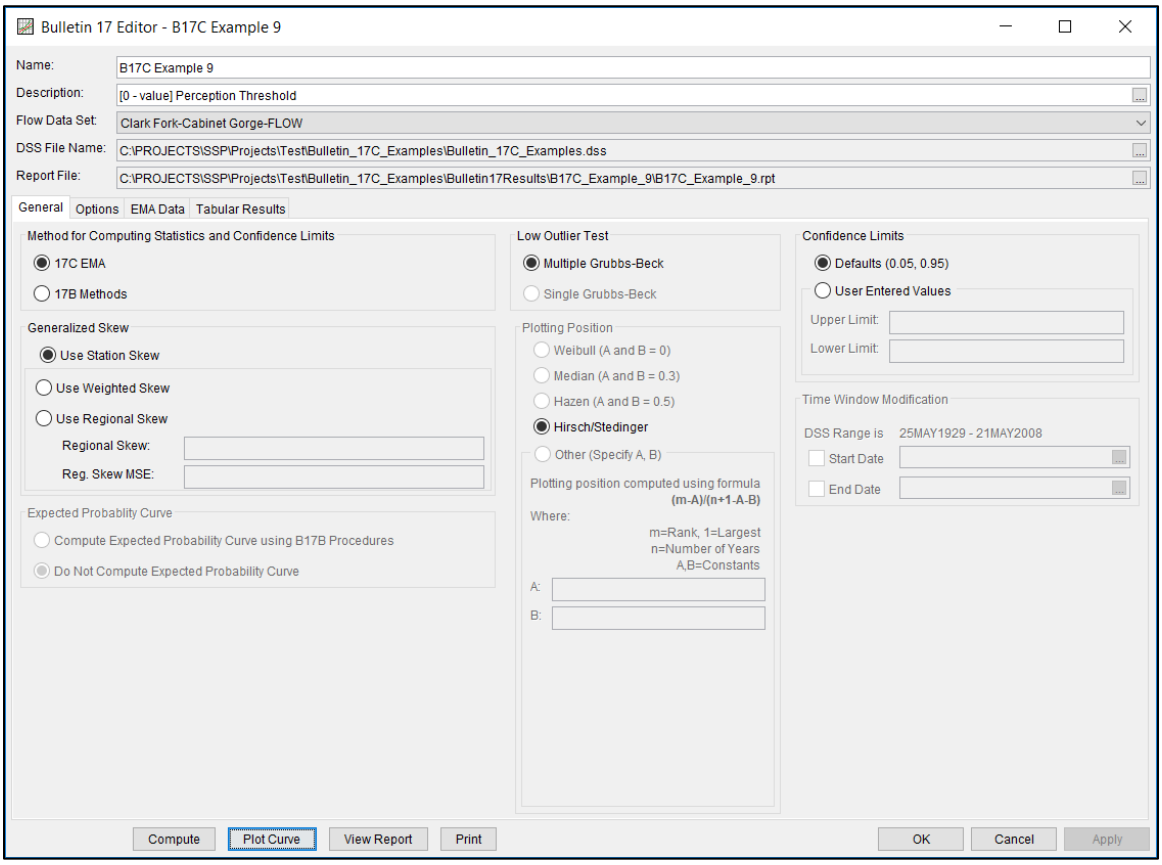


Figure C-58. Bulletin 17 Analysis General Tab for B17C Example 9.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-59. 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 C-59, click the **Apply Thresholds** button to assign the complementary flow ranges for the periods of missing data.

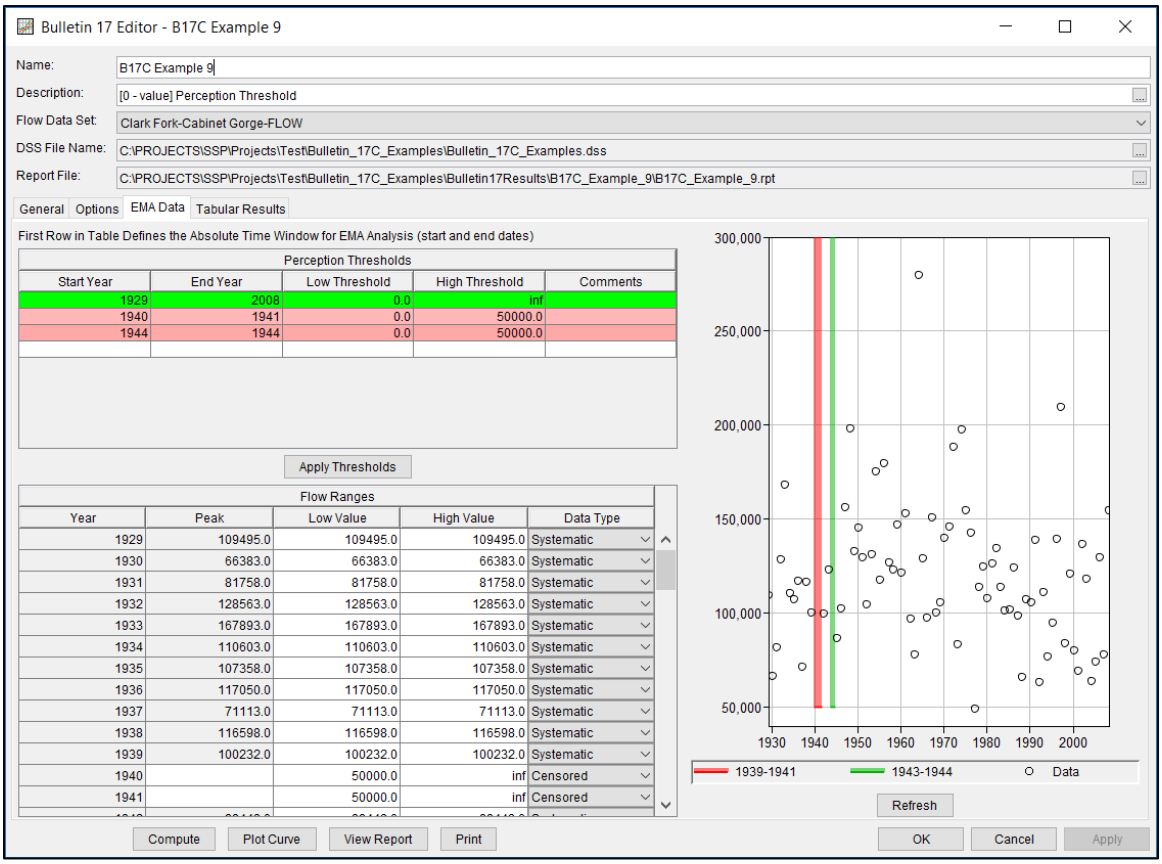


Figure C-59. Bulletin 17 Analysis EMA Data Tab for B17C Example 9.

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 C-60.

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 C-61.

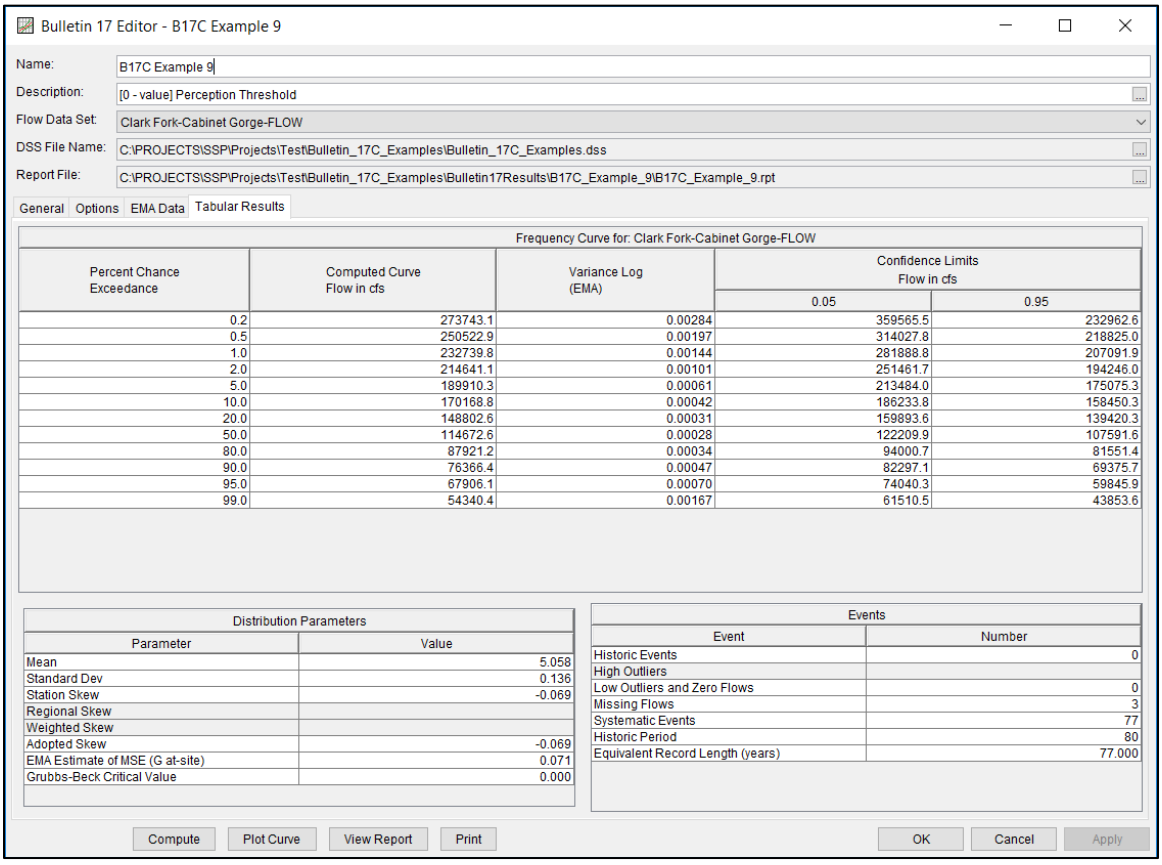


Figure C-60. Bulletin 17 Analysis Tabular Results Tab for B17C Example 9.

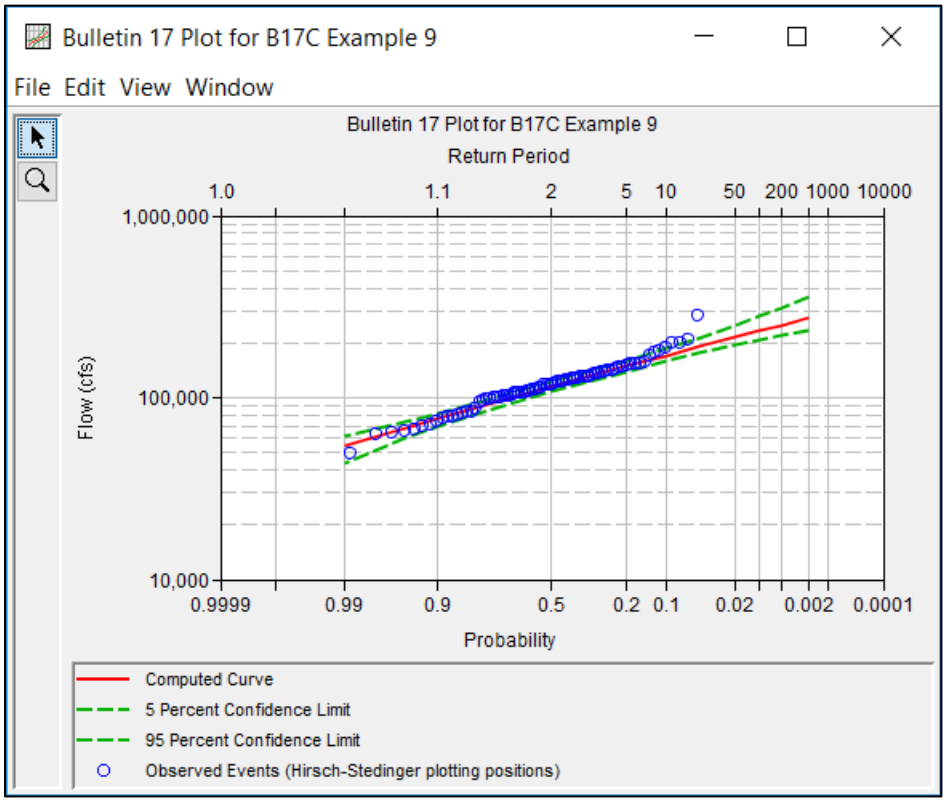
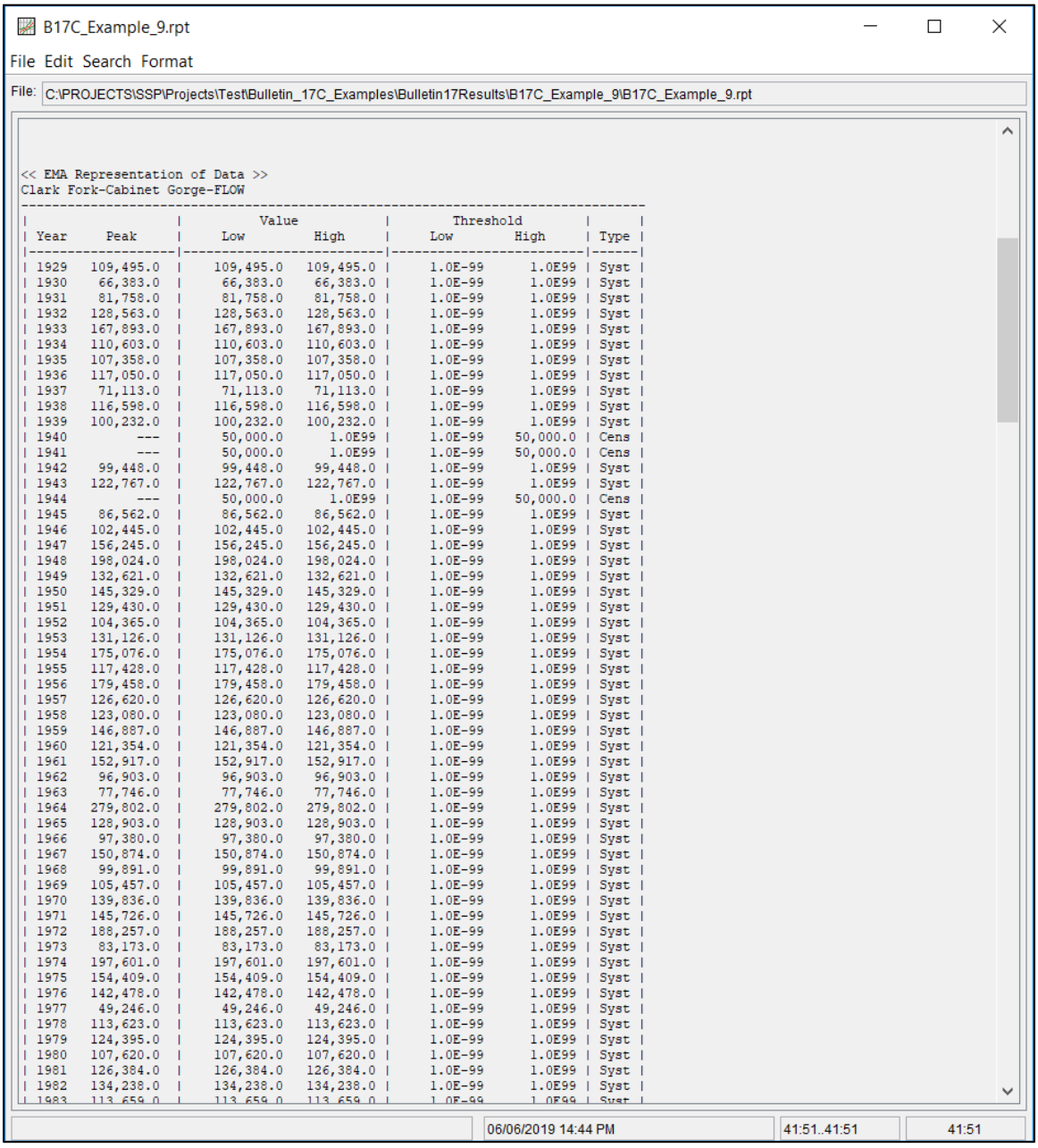


Figure C-61. Plotted Frequency Curves for B17C Example 9.

As shown in Figure C-62, 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		Threshold		
Year	Peak	Low	High	Low	High	Type
1929	109,495.0	109,495.0	109,495.0	1.0E-99	1.0E99	Syst
1930	66,383.0	66,383.0	66,383.0	1.0E-99	1.0E99	Syst
1931	81,758.0	81,758.0	81,758.0	1.0E-99	1.0E99	Syst
1932	128,563.0	128,563.0	128,563.0	1.0E-99	1.0E99	Syst
1933	167,893.0	167,893.0	167,893.0	1.0E-99	1.0E99	Syst
1934	110,603.0	110,603.0	110,603.0	1.0E-99	1.0E99	Syst
1935	107,358.0	107,358.0	107,358.0	1.0E-99	1.0E99	Syst
1936	117,050.0	117,050.0	117,050.0	1.0E-99	1.0E99	Syst
1937	71,113.0	71,113.0	71,113.0	1.0E-99	1.0E99	Syst
1938	116,598.0	116,598.0	116,598.0	1.0E-99	1.0E99	Syst
1939	100,232.0	100,232.0	100,232.0	1.0E-99	1.0E99	Syst
1940	---	50,000.0	1.0E99	1.0E-99	50,000.0	Cens
1941	---	50,000.0	1.0E99	1.0E-99	50,000.0	Cens
1942	99,448.0	99,448.0	99,448.0	1.0E-99	1.0E99	Syst
1943	122,767.0	122,767.0	122,767.0	1.0E-99	1.0E99	Syst
1944	---	50,000.0	1.0E99	1.0E-99	50,000.0	Cens
1945	86,562.0	86,562.0	86,562.0	1.0E-99	1.0E99	Syst
1946	102,445.0	102,445.0	102,445.0	1.0E-99	1.0E99	Syst
1947	156,245.0	156,245.0	156,245.0	1.0E-99	1.0E99	Syst
1948	198,024.0	198,024.0	198,024.0	1.0E-99	1.0E99	Syst
1949	132,621.0	132,621.0	132,621.0	1.0E-99	1.0E99	Syst
1950	145,329.0	145,329.0	145,329.0	1.0E-99	1.0E99	Syst
1951	129,430.0	129,430.0	129,430.0	1.0E-99	1.0E99	Syst
1952	104,365.0	104,365.0	104,365.0	1.0E-99	1.0E99	Syst
1953	131,126.0	131,126.0	131,126.0	1.0E-99	1.0E99	Syst
1954	175,076.0	175,076.0	175,076.0	1.0E-99	1.0E99	Syst
1955	117,428.0	117,428.0	117,428.0	1.0E-99	1.0E99	Syst
1956	179,458.0	179,458.0	179,458.0	1.0E-99	1.0E99	Syst
1957	126,620.0	126,620.0	126,620.0	1.0E-99	1.0E99	Syst
1958	123,080.0	123,080.0	123,080.0	1.0E-99	1.0E99	Syst
1959	146,887.0	146,887.0	146,887.0	1.0E-99	1.0E99	Syst
1960	121,354.0	121,354.0	121,354.0	1.0E-99	1.0E99	Syst
1961	152,917.0	152,917.0	152,917.0	1.0E-99	1.0E99	Syst
1962	96,903.0	96,903.0	96,903.0	1.0E-99	1.0E99	Syst
1963	77,746.0	77,746.0	77,746.0	1.0E-99	1.0E99	Syst
1964	279,802.0	279,802.0	279,802.0	1.0E-99	1.0E99	Syst
1965	128,903.0	128,903.0	128,903.0	1.0E-99	1.0E99	Syst
1966	97,380.0	97,380.0	97,380.0	1.0E-99	1.0E99	Syst
1967	150,874.0	150,874.0	150,874.0	1.0E-99	1.0E99	Syst
1968	99,891.0	99,891.0	99,891.0	1.0E-99	1.0E99	Syst
1969	105,457.0	105,457.0	105,457.0	1.0E-99	1.0E99	Syst
1970	139,836.0	139,836.0	139,836.0	1.0E-99	1.0E99	Syst
1971	145,726.0	145,726.0	145,726.0	1.0E-99	1.0E99	Syst
1972	188,257.0	188,257.0	188,257.0	1.0E-99	1.0E99	Syst
1973	83,173.0	83,173.0	83,173.0	1.0E-99	1.0E99	Syst
1974	197,601.0	197,601.0	197,601.0	1.0E-99	1.0E99	Syst
1975	154,409.0	154,409.0	154,409.0	1.0E-99	1.0E99	Syst
1976	142,478.0	142,478.0	142,478.0	1.0E-99	1.0E99	Syst
1977	49,246.0	49,246.0	49,246.0	1.0E-99	1.0E99	Syst
1978	113,623.0	113,623.0	113,623.0	1.0E-99	1.0E99	Syst
1979	124,395.0	124,395.0	124,395.0	1.0E-99	1.0E99	Syst
1980	107,620.0	107,620.0	107,620.0	1.0E-99	1.0E99	Syst
1981	126,384.0	126,384.0	126,384.0	1.0E-99	1.0E99	Syst
1982	134,238.0	134,238.0	134,238.0	1.0E-99	1.0E99	Syst
1983	113,659.0	113,659.0	113,659.0	1.0E-99	1.0E99	Syst

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Figure C-62. Report File for B17C Example 9 showing EMA Representation of Data.

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 searched, 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 C-63 and tabulated in Table C-10.

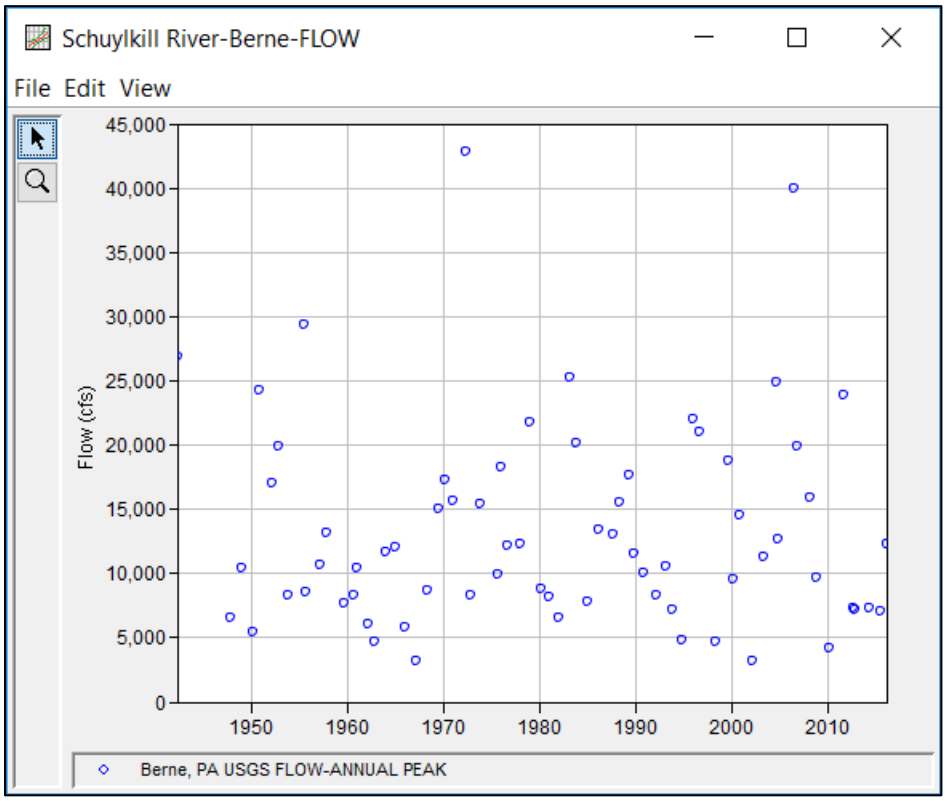


Figure C-63. Schuylkill River at Berne, PA Annual Peak Flow Record.

Table C-10. Schuylkill River at Berne, PA Annual Peak Flow Record.

Date	Flow (cfs)	Date	Flow (cfs)
30 Apr 1942	26900	03 Feb 1982	6600
08 Nov 1947	6500	16 Apr 1983	25300
30 Dec 1948	10400	14 Dec 1983	20100
23 Mar 1950	5430	12 Feb 1985	7850
04 Dec 1950	24200	15 Mar 1986	13400
11 Mar 1952	17000	13 Sep 1987	13000
22 Nov 1952	19900	19 May 1988	15500
07 Dec 1953	8290	06 May 1989	17600
19 Aug 1955	29400	16 Nov 1989	11500
15 Oct 1955	8580	04 Dec 1990	10000
06 Apr 1957	10700	27 Mar 1992	8280
21 Dec 1957	13100	11 Apr 1993	10500
03 Sep 1959	7710	05 Dec 1993	7210
20 Sep 1960	8290	28 Nov 1994	4820
26 Feb 1961	10400	19 Jan 1996	22000
12 Mar 1962	6010	19 Oct 1996	21000
10 Nov 1962	4720	12 May 1998	4720
25 Jan 1964	11700	16 Sep 1999	18700
08 Feb 1965	12000	22 Mar 2000	9530
14 Feb 1966	5850	17 Dec 2000	14500
06 Mar 1967	3220	15 Apr 2002	3230
31 May 1968	8640	21 Jun 2003	11300
02 Aug 1969	15000	18 Sep 2004	24900
02 Apr 1970	17300	28 Nov 2004	12700
13 Feb 1971	15600	28 Jun 2006	39900
22 Jun 1972	42800	17 Nov 2006	19900
08 Nov 1972	8290	05 Mar 2008	15900
21 Dec 1973	15400	12 Dec 2008	9720
26 Sep 1975	9920	14 Mar 2010	4210
26 Jan 1976	18300	08 Sep 2011	23900
09 Oct 1976	12100	18 Sep 2012	7240
26 Jan 1978	12300	21 Dec 2012	7220
25 Jan 1979	21700	16 May 2014	7240
21 Mar 1980	8780	01 Jul 2015	7040
11 Feb 1981	8110	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 C-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 MSE. In this example, a regional skew of 0.001 was used along with a Regional Skew MSE of 0.064.

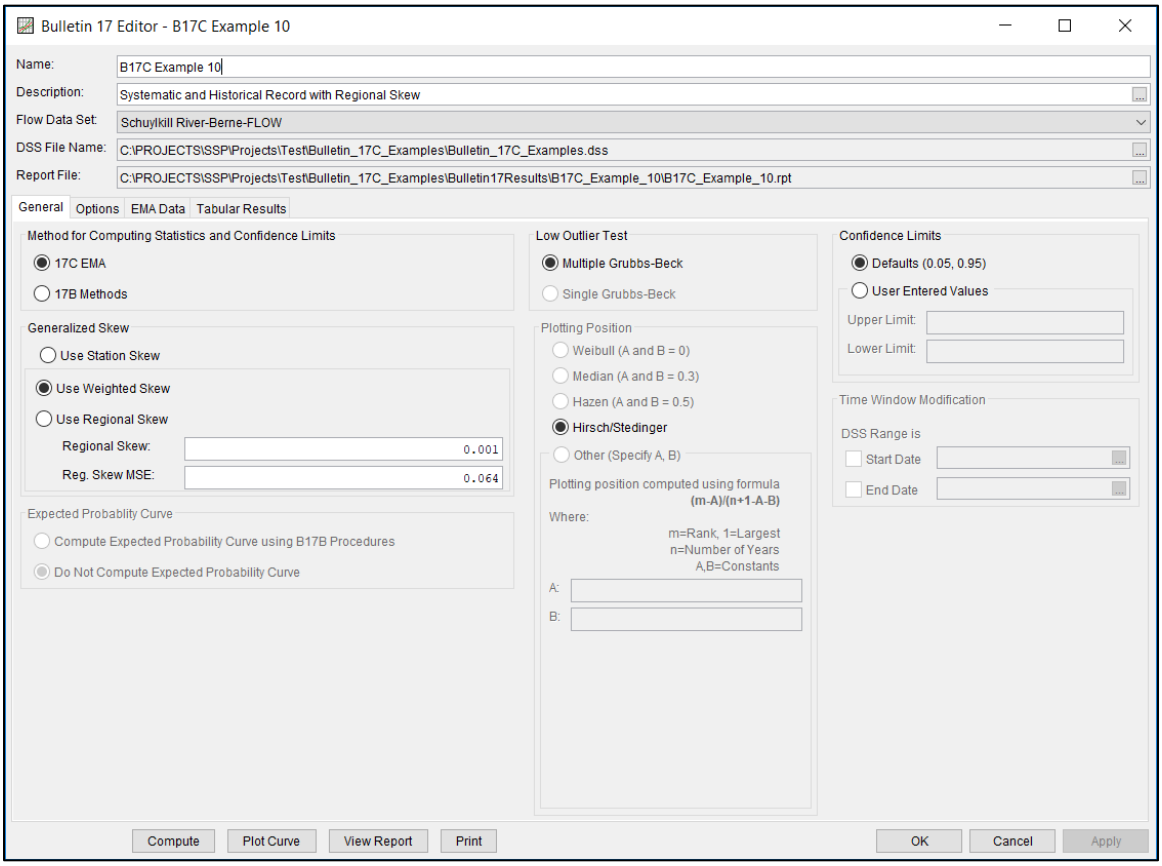


Figure C-64. Bulletin 17 Analysis General Tab for B17C Example 10.

No changes to the **Options** tab are necessary. The **EMA Data** tab for this example is shown in Figure C-65. 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 wasn't directly measured, the perception threshold should span 1942 – 1947.

Once the perception thresholds have been entered as shown in Figure C-65, 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".

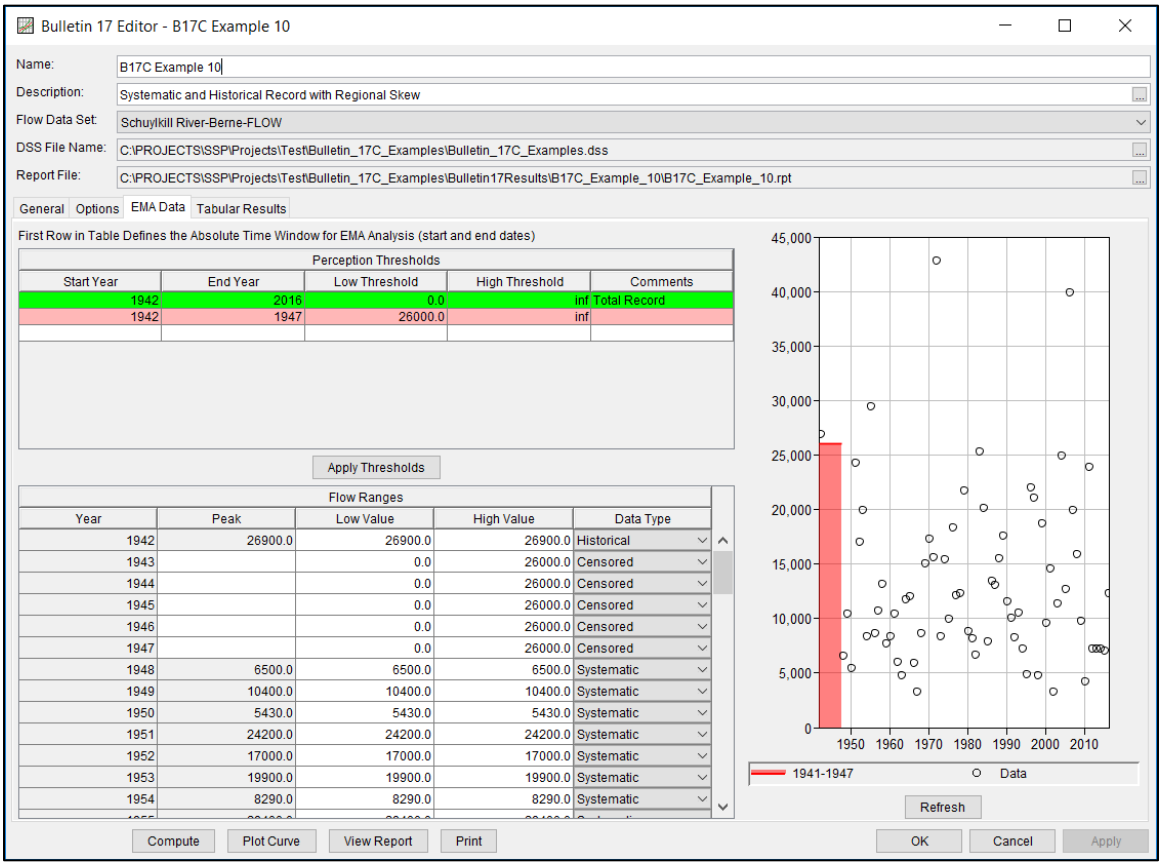


Figure C-65. Bulletin 17 Analysis EMA Data Tab for B17C Example 10.

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 C-66.

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 C-67.

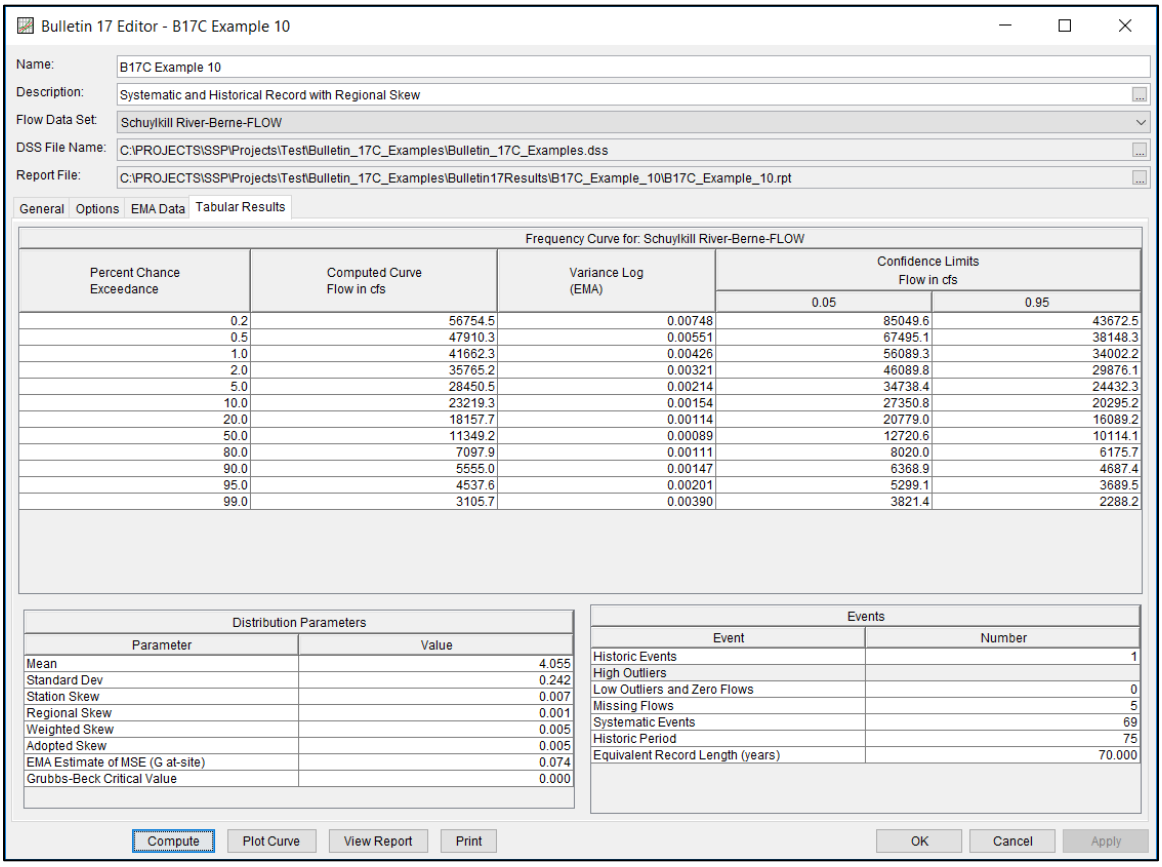


Figure C-66. Bulletin 17 Analysis Tabular Results Tab for B17C Example 10.

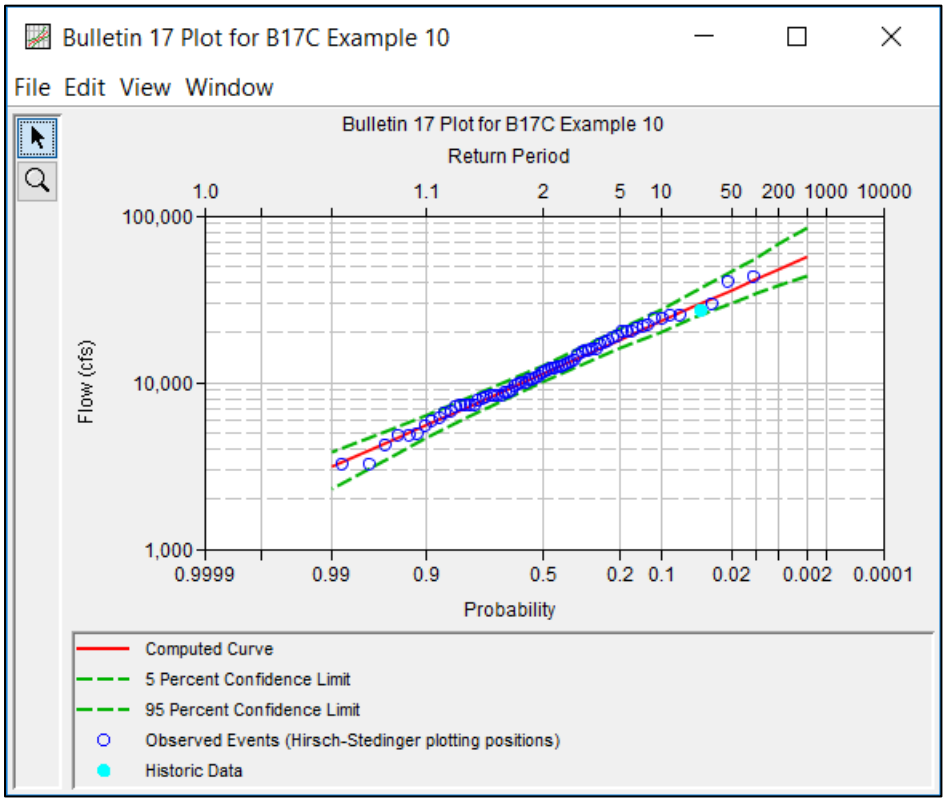
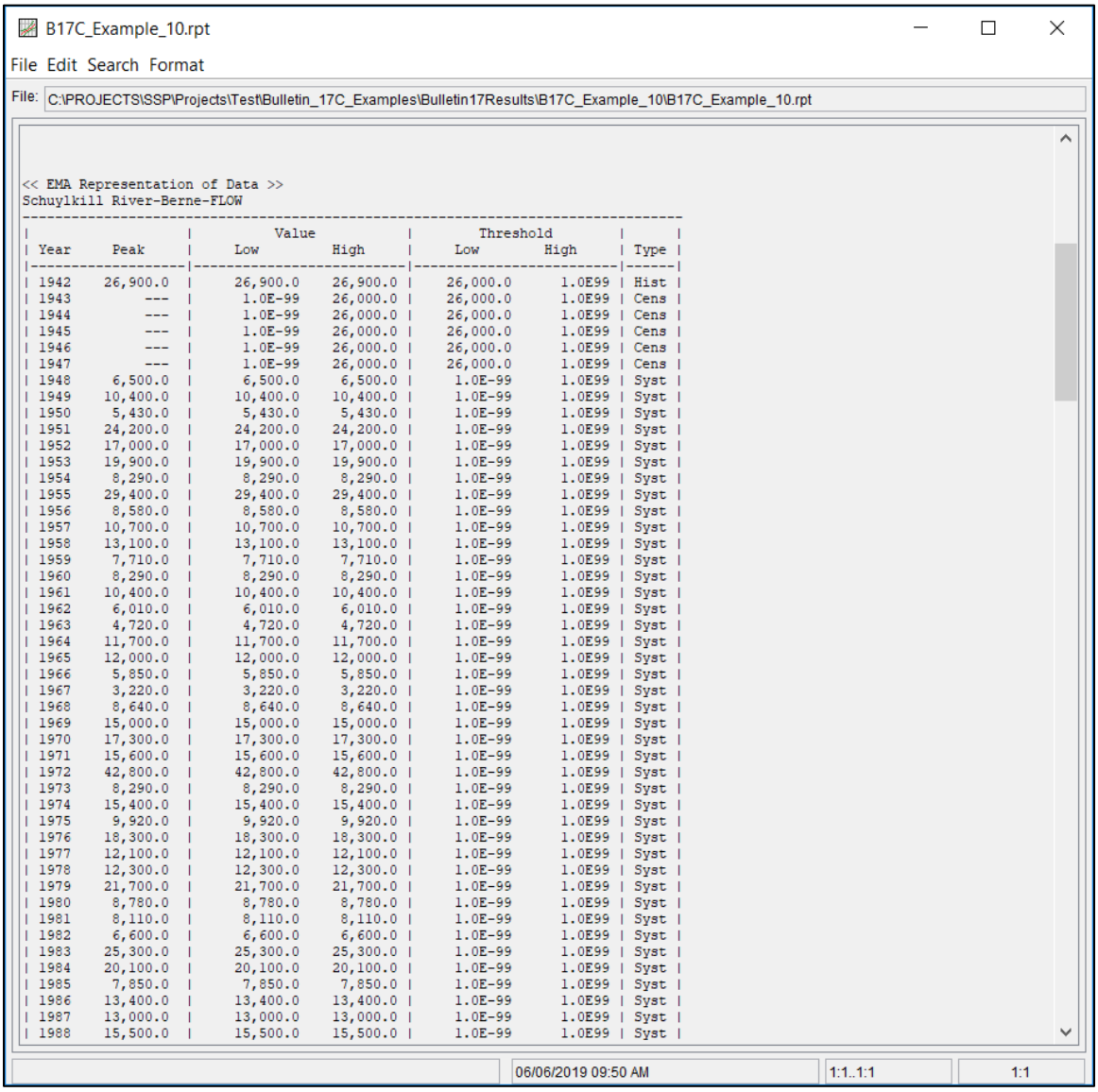


Figure C-67. Plotted Frequency Curves for B17C Example 10.

As shown in Figure C-68, 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

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

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

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Figure C-68. Report File for B17C Example 10 showing EMA Representation of Data.