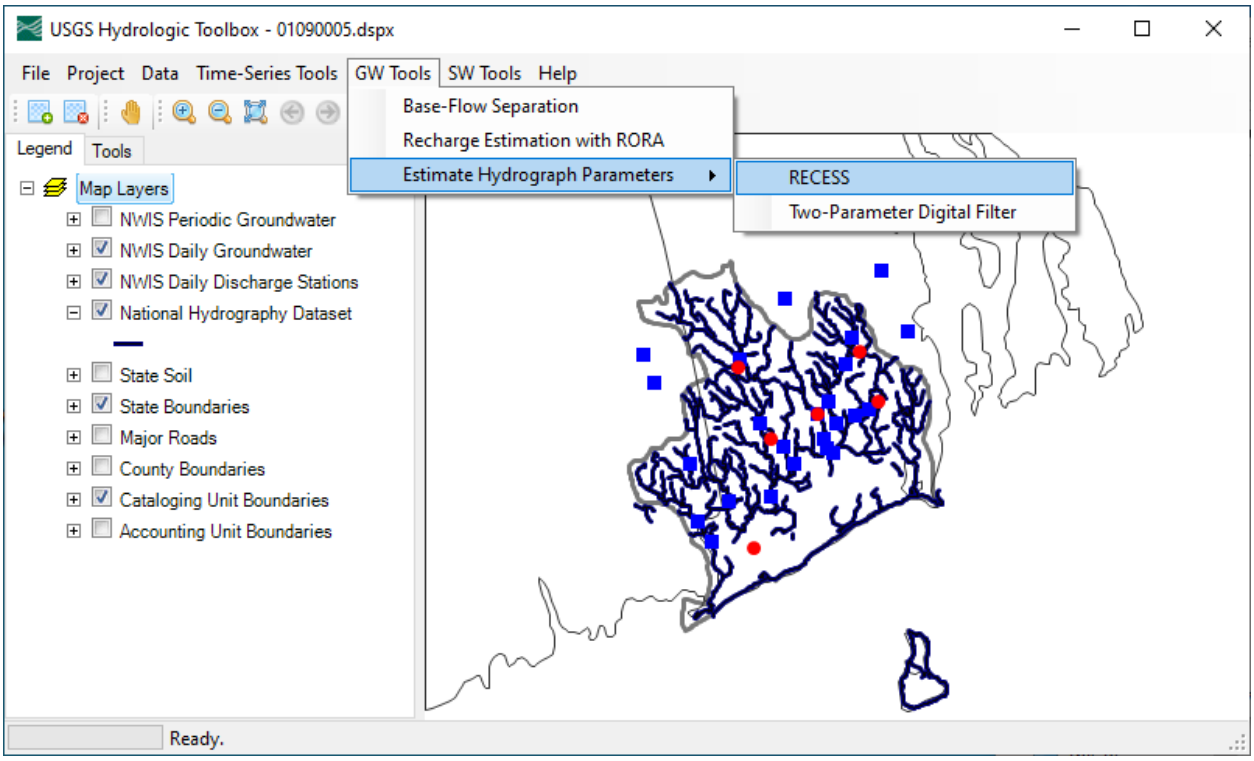
Update to the RECESS functionality to estimate a basin-wide base-flow recession constant and master recession curve

Hydrologic Toolbox, Version 1.0 Release

This tutorial describes changes that were made to the RECESS functionality for the Groundwater Toolbox and later adapted for the Hydrologic Toolbox. These changes were made to improve the analysis of base-flow recession constants and the master recession curves. The original RECESS program is described by Rutledge (1998) and its implementation in the Groundwater Toolbox by Barlow and others (2014, p. 17-21). Much of the functionality that is used to determine recession constants is unchanged from previous versions of the software; therefore, users are encouraged to review the document by Barlow and others (2014) as background to this tutorial. Most of the changes to the functionality have been made to the display of the master recession curves (MRCs). This tutorial describes use of the RECESS functionality with the Hydrologic Toolbox.

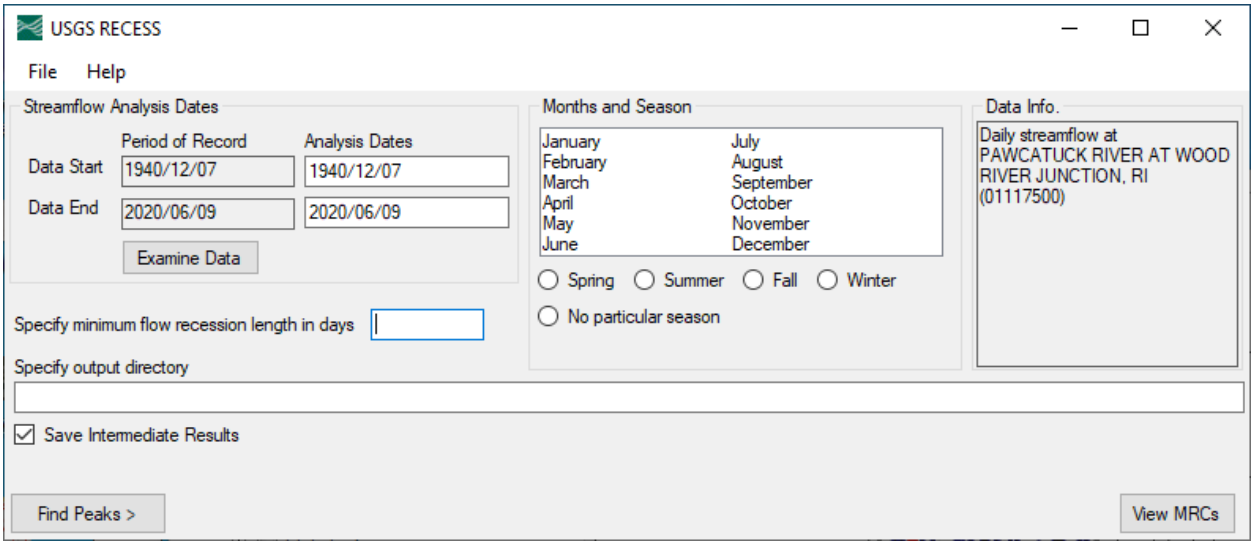
The streamflow record for the Pawcatuck River at Wood River Junction, Rhode Island (USGS streamgage 01117500), will be used to demonstrate the functionality.

The user first selects the "**RECESS**" option from the "**GW Tools>Estimate Hydrograph Parameters**" menu option:



Selection of the "**RECESS**" option takes the user to the "Select Daily Streamflow for Analysis" dialog box, where the user selects a streamflow record for analysis. For this analysis, the record for the Pawcatuck River at Wood River Junction, Rhode Island (USGS streamgage 01117500), was selected.

Selection of a streamflow record brings the user to the following dialog box:



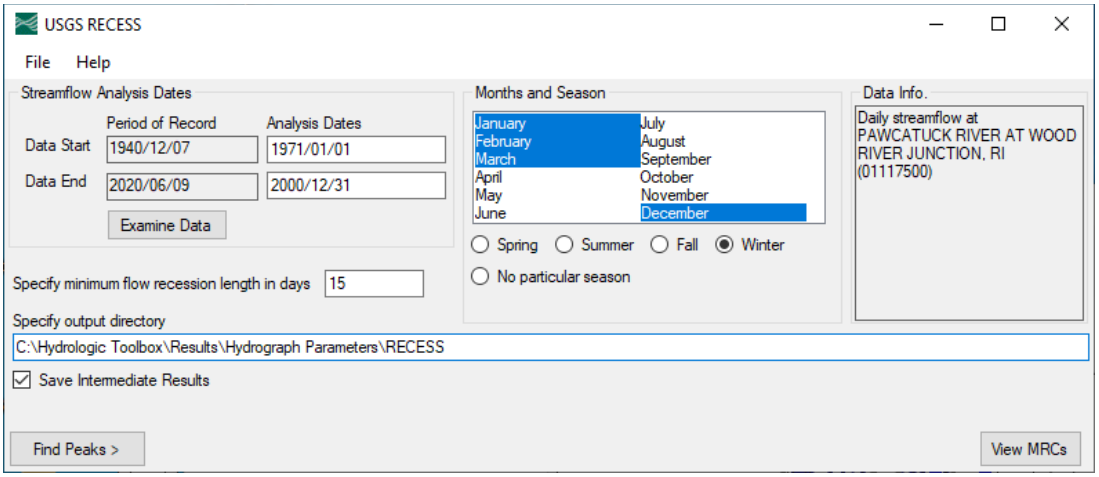
The dialog includes the "View MRCs" button that allows the user to go directly to the MRC functionality (assuming that information necessary to plot the MRCs has already been generated). This functionality is described later in the tutorial.

The first step for estimating recession constants and master recession curves is to enter the required information for the analysis dates, months and seasons, minimum flow-recession length, and output directory. For this analysis, the dates of analysis were specified as January 1, 1971 through December 31, 2000.

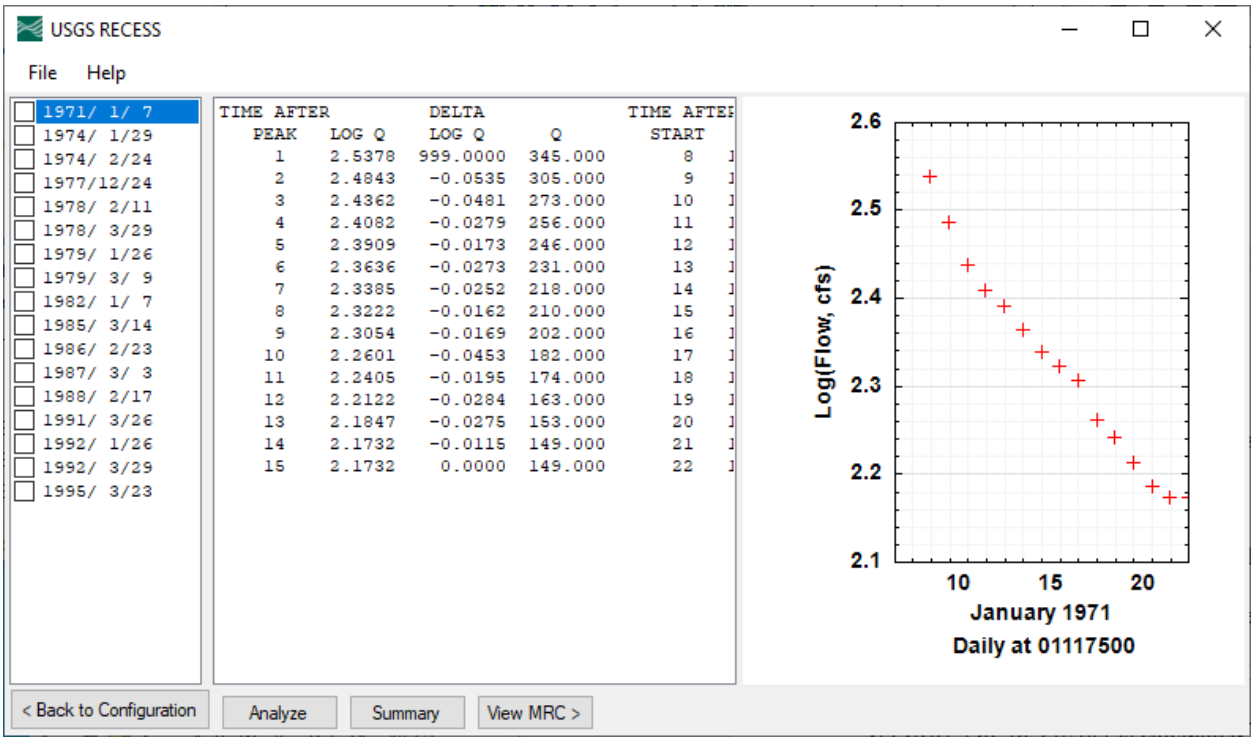
The "Months and Seasons" are those for which recession periods will be analyzed; the program will select only those recession periods that begin in the selected months. For this analysis, only the four winter months from December through March were selected for analysis, because it is assumed that riparian evapotranspiration is negligible during these months. Riparian evapotranspiration can create nonlinearity in a recession graph of the logarithm of streamflow as a function of time. The "Winter" radio button also has been selected to coincide with the four selected months; selection of a season is used only to insert a text entry in the output files and does not affect the results.

Finally, the user specifies the minimum number of days required for detection of a recession period. Rutledge (1998) notes that if the number of days selected is too large (too restrictive), few recession periods will be detected in the record; however, if the number is too small, then many recession periods will be detected and some may need to be omitted, because they

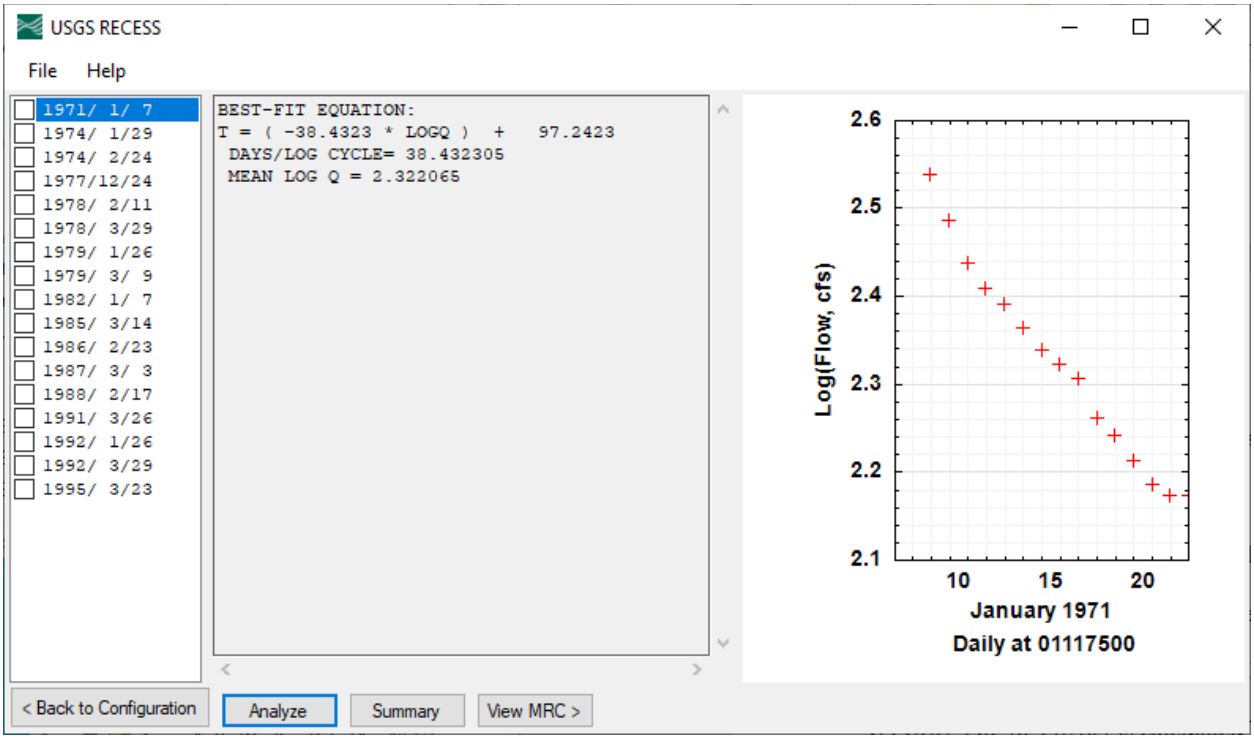
would not span a recession period long enough for the user to derive an accurate value of *K*. Rutledge (1998) suggests a minimum of 10 to 20 days when analyzing a record of 40 years. Values of 10 and 15 days were tested for this example; results for the 15-day requirement are illustrated here.



For this example, 17 recession periods are listed, the first having had a peak streamflow on January 7, 1971. Clicking on the date ("1971/ 1/ 7" in this example) brings up a list of the streamflows during this recession period, beginning one day after the peak (January 8) and continuing for 15 days (through January 22) until the next increase in streamflow on January 23. A semilogarithmic plot of the streamflow data is shown on the right of the dialog box.

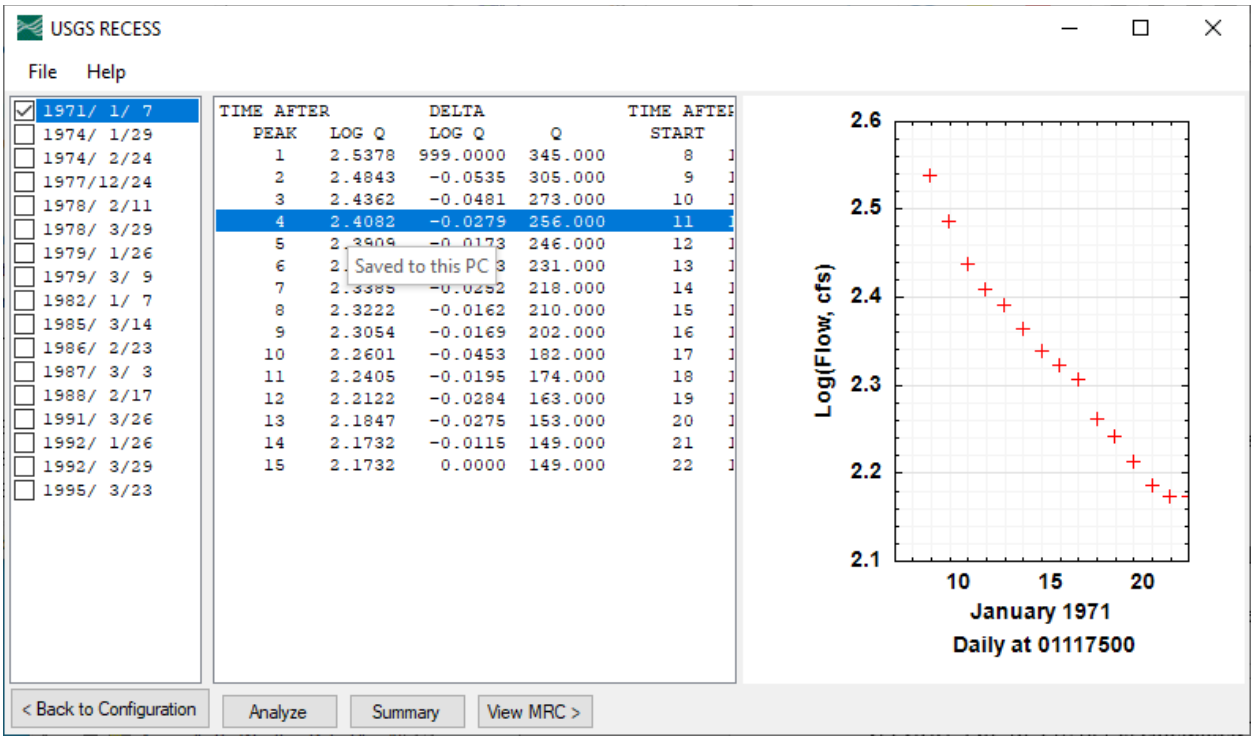


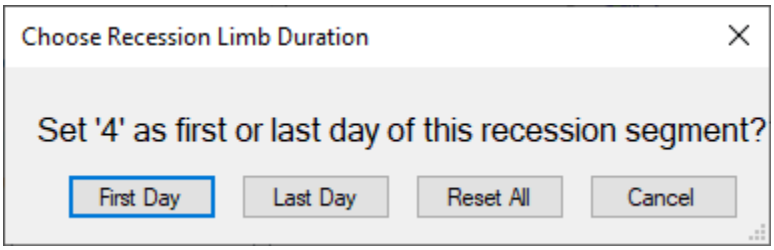
The user can now either “Analyze” the streamflow data for the full recession period or eliminate some of the data if any part of the recession graph looks nonlinear. For this example, both approaches are illustrated. First, by clicking “Analyze” with all data selected, a recession index (“DAYS/LOG CYCLE”) of 38.432305 is calculated by RECESS.



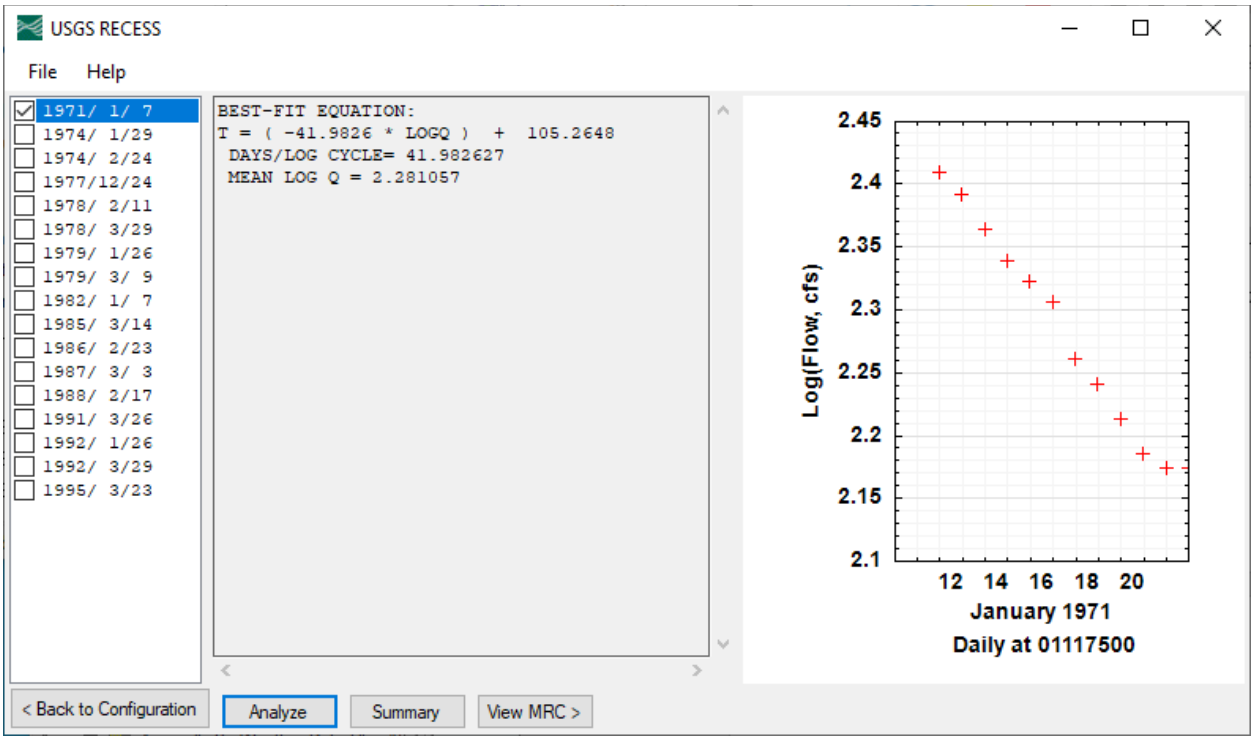
In the second approach, the user may limit the analysis to periods of the recession that are nearly linear on the semilogarithmic plot. For this example analysis, a minimum of 3 days (variable N_{sr}) of recession was required before each period was analyzed. This value was determined from the equation $N_{sr} = A^{0.2}$ (equation 1 in Barlow and others, 2014), in which A is the drainage area of the basin in square miles. In this example, A equals 100 square miles and N_{sr} was rounded up from 2.51 to 3 days.

The user selects “4” as the “First Day” of analysis. This action restricts the number of days that will be analyzed to days 4 through 15.

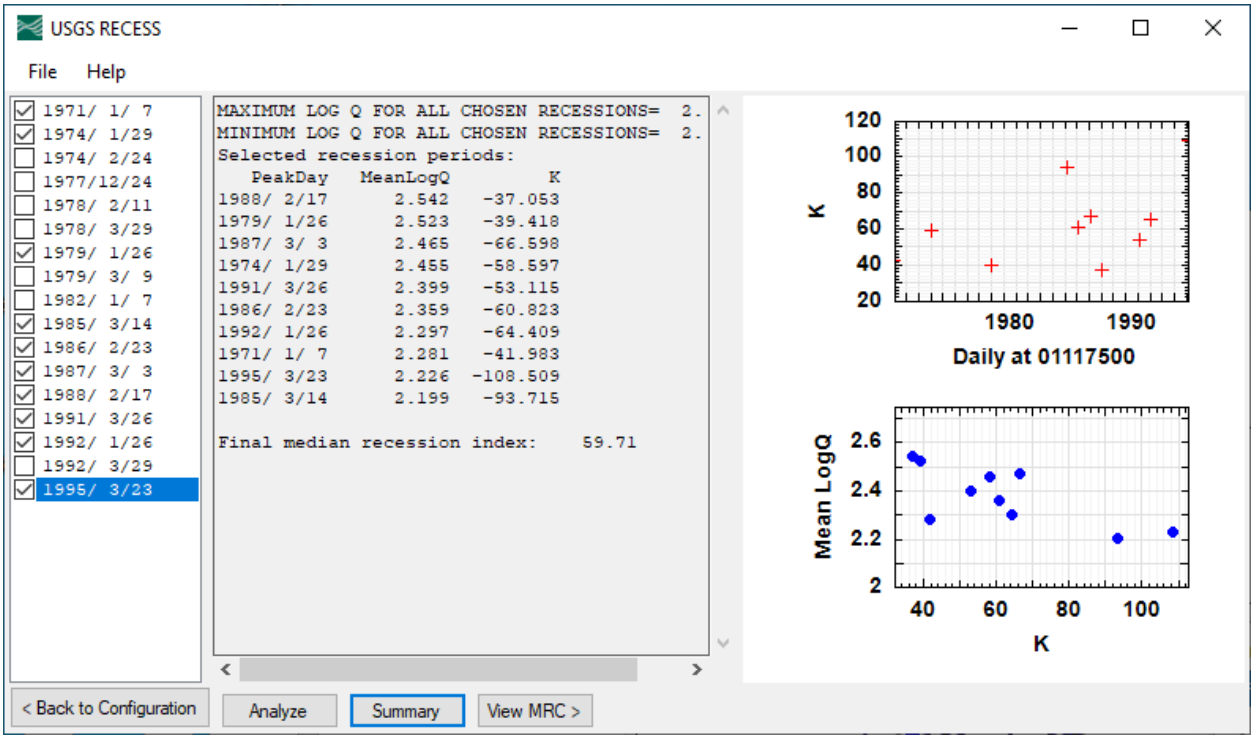




With these days selected, a slightly higher recession index of 41.982627 was calculated for this 12-day period. Selecting the check box next to the start date of the recession period (that is, to the left of “1971/ 1/ 7”) will save the recession index for later use.

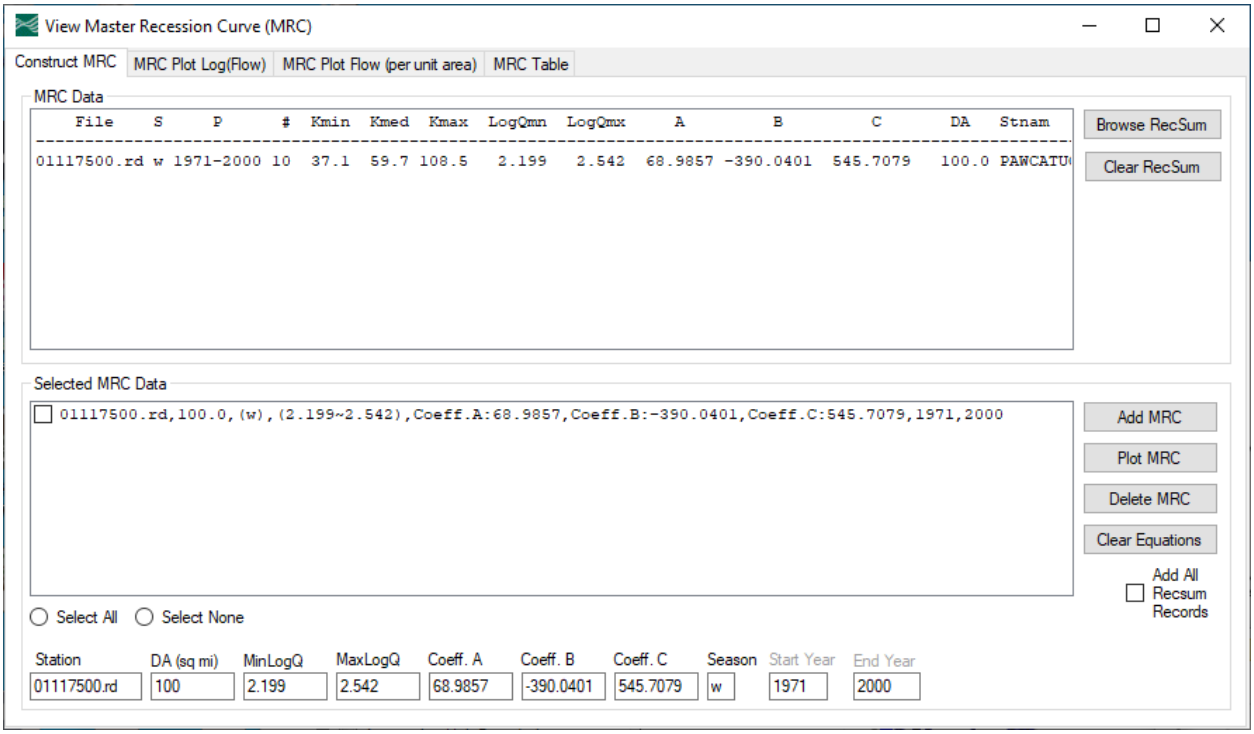


A total of 10 recession periods were analyzed, which, after clicking on the "Summary" button, resulted in a median recession constant (K) of 59.71 days per log cycle:



The plots on the right show K as a function of time on top and the logarithm of the mean streamflow (MeanLogQ) for each recession period anlayzed as a function of K on the bottom. As explained in Rutledge (1998, p.12), the relation between K and MeanLogQ is used by RECESS to determine the MRC, which is a second-order polynomial expression for time as a function of logQ. Note that for this particular station there is a general trend of increasing values of K with decreasing streamflow, which is consistent with the discussion in Rutledge (1998) and with many of the MRCs presented in Rutledge and Mesko (1996). The fact that K is a function of streamflow is due to the underlying nonlinearity of the stream-aquifer system being analyzed; these nonlinearities are described in detail in many publications (see, for example, Hall, 1968; Brutsaert and Nieber, 1977; Tallaksen, 1995; Rutledge, 1998; Stoelzle and others, 2013; and references cited in those papers).

Now that the individual recession periods have been analyzed and RECESS has calculated an MRC based on this analysis, the user can click "View MRC >" to view the MRC that has been calculated, as well as other previously calculated MRCs. The following dialog box results from clicking "View MRC >"



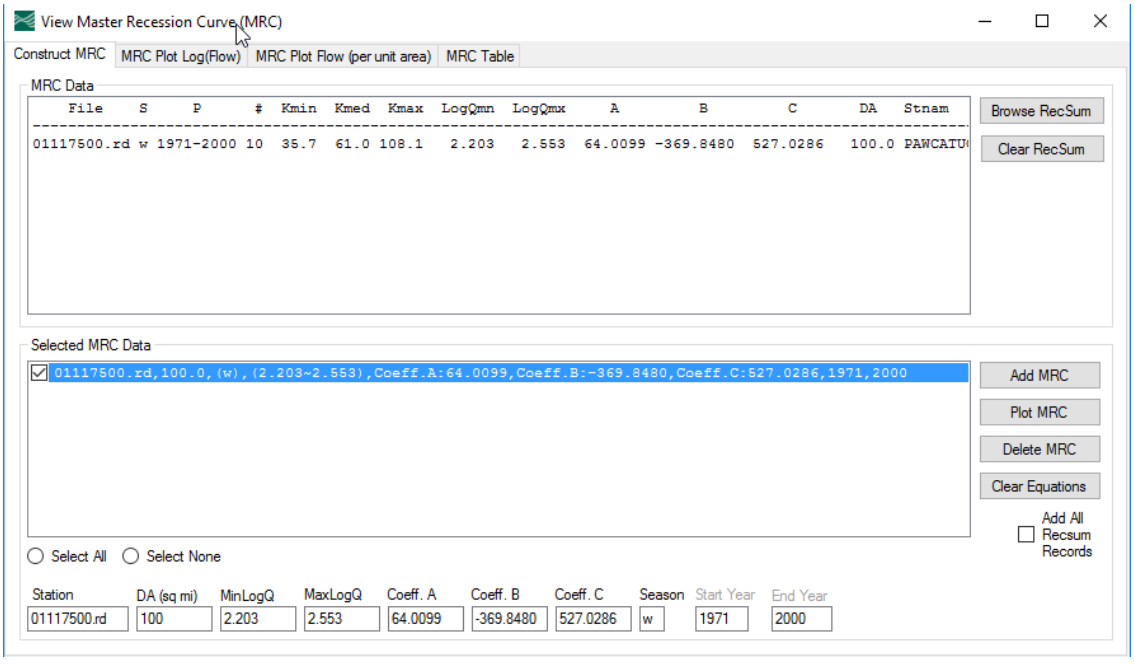
The dialog box consists of three main sections. The middle section, "Selected MRC Data," consists of information that is used to create the MRC for each station selected from the "MRC Data" panel. In this example, the information shown in both panels was generated in the previous recession-analysis step. The information also has been saved in a file named 'recsum.txt,' which is located in the output directory specified in the initial RECESS dialog box. The contents of this file are slightly different from the 'recsum.txt' file created by the original RECESS program (Rutledge, 1998) in that each line of the 'recsum.txt' file created by the Hydrologic Toolbox includes the drainage area and name of the station for which the master

recession curve has been generated. These two pieces of information were previously read from the 'station.txt' file used by the original RECESS program; the 'station.txt' file is not needed for the Hydrologic Toolbox. Each time the user chooses the "Summary" option to calculate the median recession constant in the previous dialog box, the RECESS program will write a line of output to the bottom of the specified 'recsum.txt' file. For the analysis completed above, the 'recsum.txt' file consists of the following single-line entry:

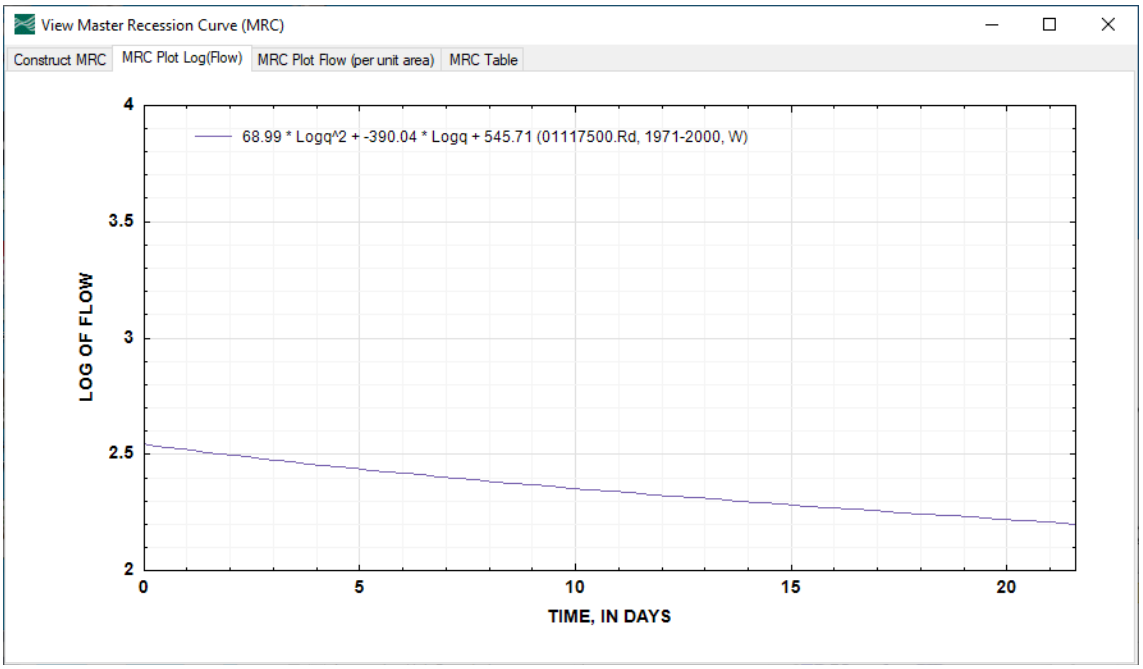
01117500.rd w 1971-2000 10 37.1 59.7 108.5 2.199 2.542 68.9857 -390.0401 545.7079 100.0 PAWCATUCK_RIVER_AT_WOOD_RIVER_JUNCTION__RI

Each entry consists of the following information: station number (or identifier); season of analysis; beginning and ending years of analysis; number of recession segments analyzed; minimum, median, and maximum values of the recession constants calculated for the analysis; minimum and maximum values of the mean logQ for each recession segment; the three coefficients of the MRC calculated by RECESS; the drainage area of the basin (in square miles); and the station name. RECESS will use this information to create plots of the MRCs. RECESS also creates an 'index.txt' file, which stores the median value of the recession constant (59.71 days per log cycle, for this example); a file that begins with the letter 'x,' which gives details about each execution of the RECESS program; and a file that begins with the letter 'y,' which gives details about each of the recession segments that were analyzed. Rutledge (1998) provides a description of the 'x' and 'y' files.

The user can now Plot the MRC by clicking on the box to the left of the line of entry:

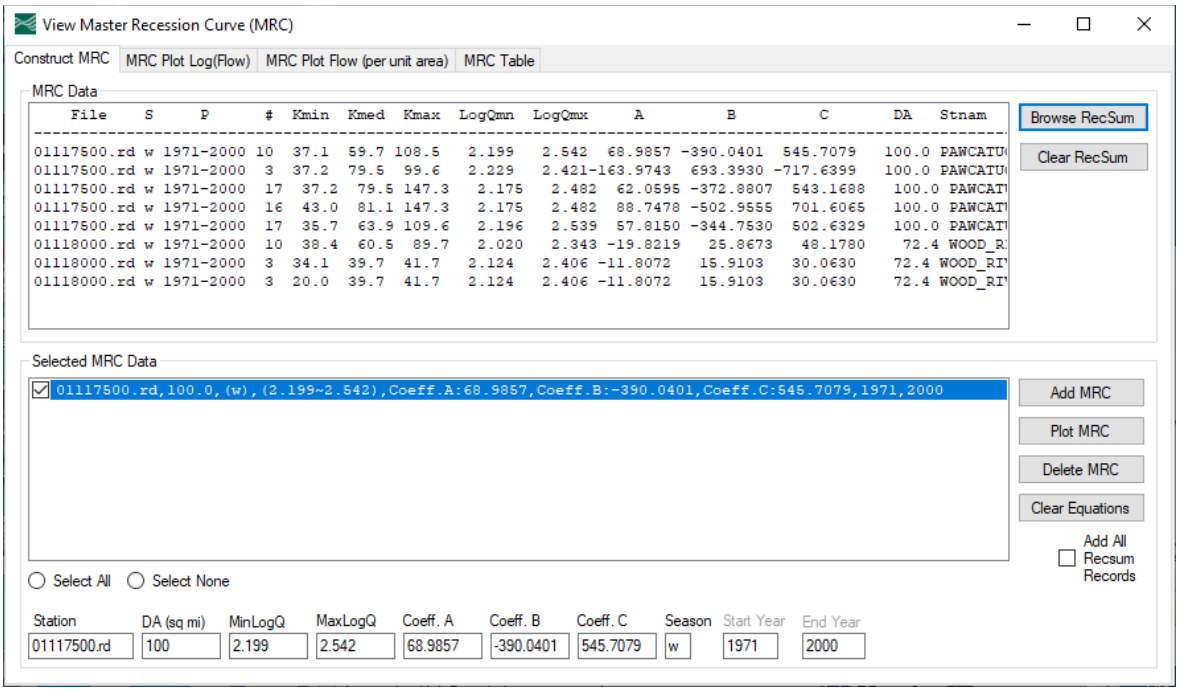


Doing so results in the following plot:

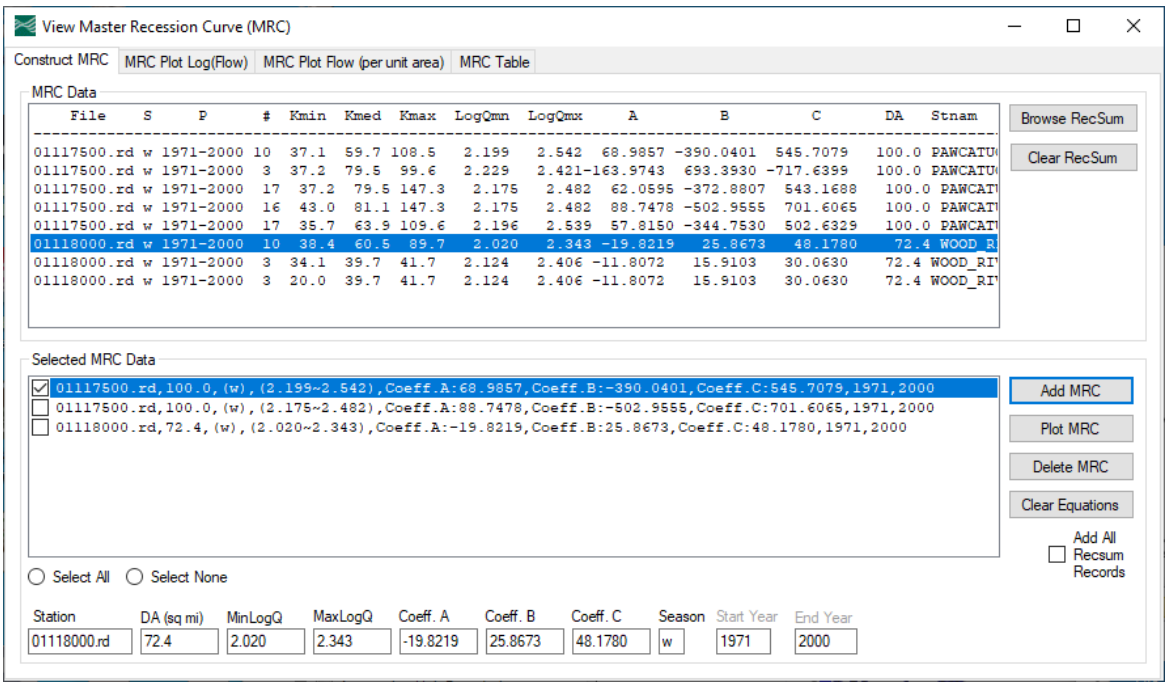


Other options for viewing the MRC also are available at the top of the Plot screen, such as plotting the MRC as a function of flow per unit drainage area (in units of cubic feet per second per square mile), which can be useful for comparing the MRC of multiple stations, or viewing the MRC Table.

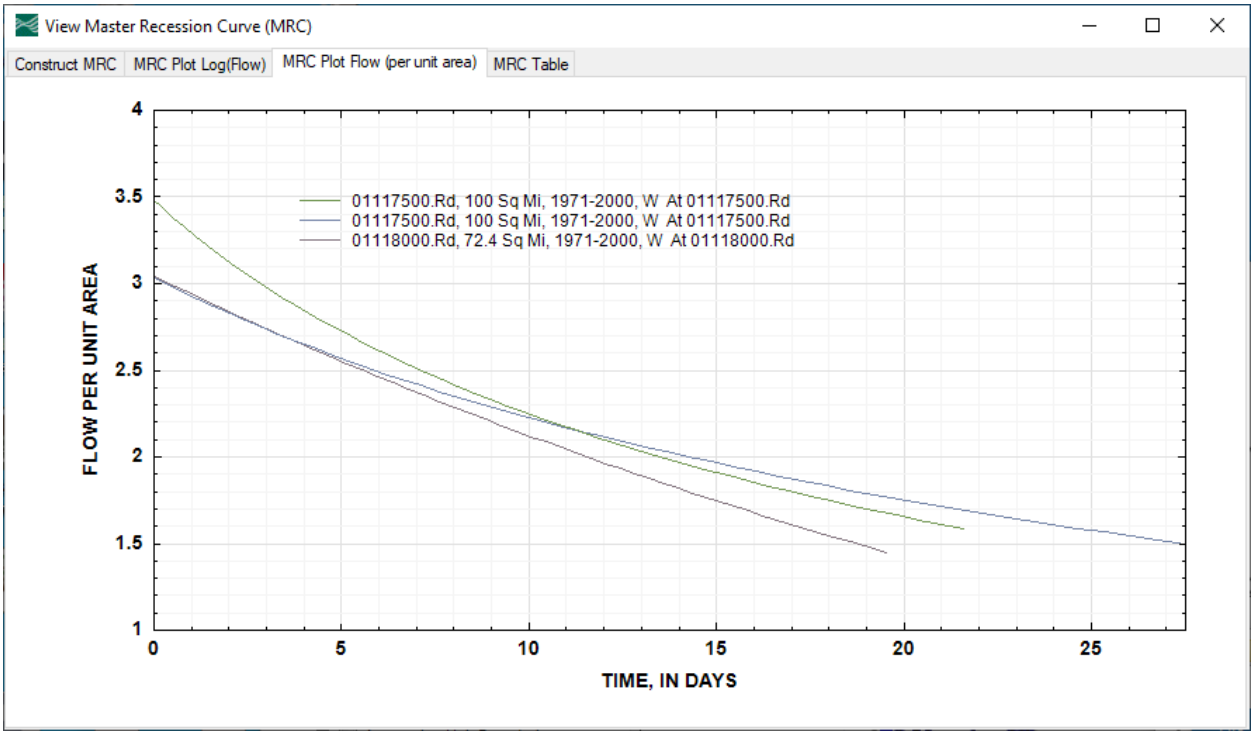
The user also can use the main MRC dialog box to open 'recsum.txt' files that have been previously generated and saved. This is done using the "Browse RecSum" option. For this example, "Browse RecSum" was used to find a previously generated 'recsum.txt' file consisting of seven unique MRC records for two gaging stations (the Pawcatuck River at Wood River Junction, RI, and the Wood River at Hope Valley, RI):



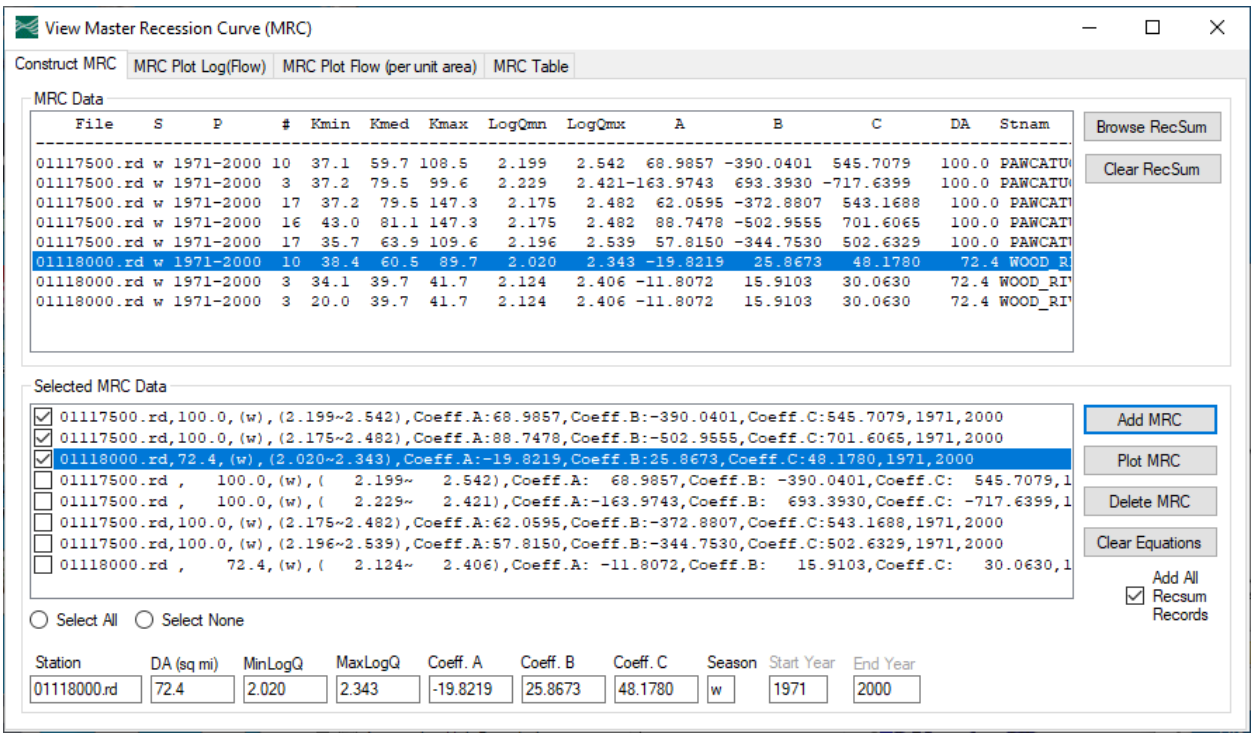
The user can now 'Add MRC' records from the top panel ("MRC Data") to the middle panel for analysis:



All three records from the middle panel can now be selected for plotting (in this case, the flow per unit drainage area option has been selected):



Additional options for selecting MRC curves are provided on the "Construct MRC" dialog box. For example, a user can enter information for an MRC curve directly into the bottom line of cells, beginning with "Station" and "DA (sq mi)." The user also can check the "Add All RecSum Records" box and then the "Add MRC" button to bring all MRCs listed in the "MRC Data" panel into the "Selected MRC Data" panel:



References

Barlow, P.M., Cunningham, W.L., Zhai, Tong, and Gray, Mark, 2014, U.S. Geological Survey Groundwater Toolbox, a graphical and mapping interface for analysis of hydrologic data (version 1.0)—User guide for estimation of base flow, runoff, and groundwater recharge from streamflow data: U.S. Geological Survey Techniques and Methods, book 3, chap. B10, 27 p., *http://dx.doi.org/10.3133/tm3B10*.

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Hall, F.R., 1968, Base-Flow Recessions—A review: Water Resources Research, v. 4, no. 5, p. 973-983.

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Rutledge, A.T., and Mesko, T.O., 1996, Estimated hydrologic characteristics of shallow aquifer systems in the Valley and Ridge, the Blue Ridge, and the Piedmont Physiographic Provinces based on analysis of streamflow recession and base flow: U.S. Geological Survey Professional Paper 1422-B, 58 p.

Stoelzle, M., Stahl, K., and Weiler, M., 2013, Are streamflow recession characteristics really characteristic?: Hydrology and Earth System Sciences, v. 17, p. 817-828, doi:10.5194/hess-17-817-2013.

Tallaksen, L.M., 1995, A review of baseflow recession analysis: Journal of Hydrology, v. 165, p. 349-370.