Groundwater Toolbox Tutorial

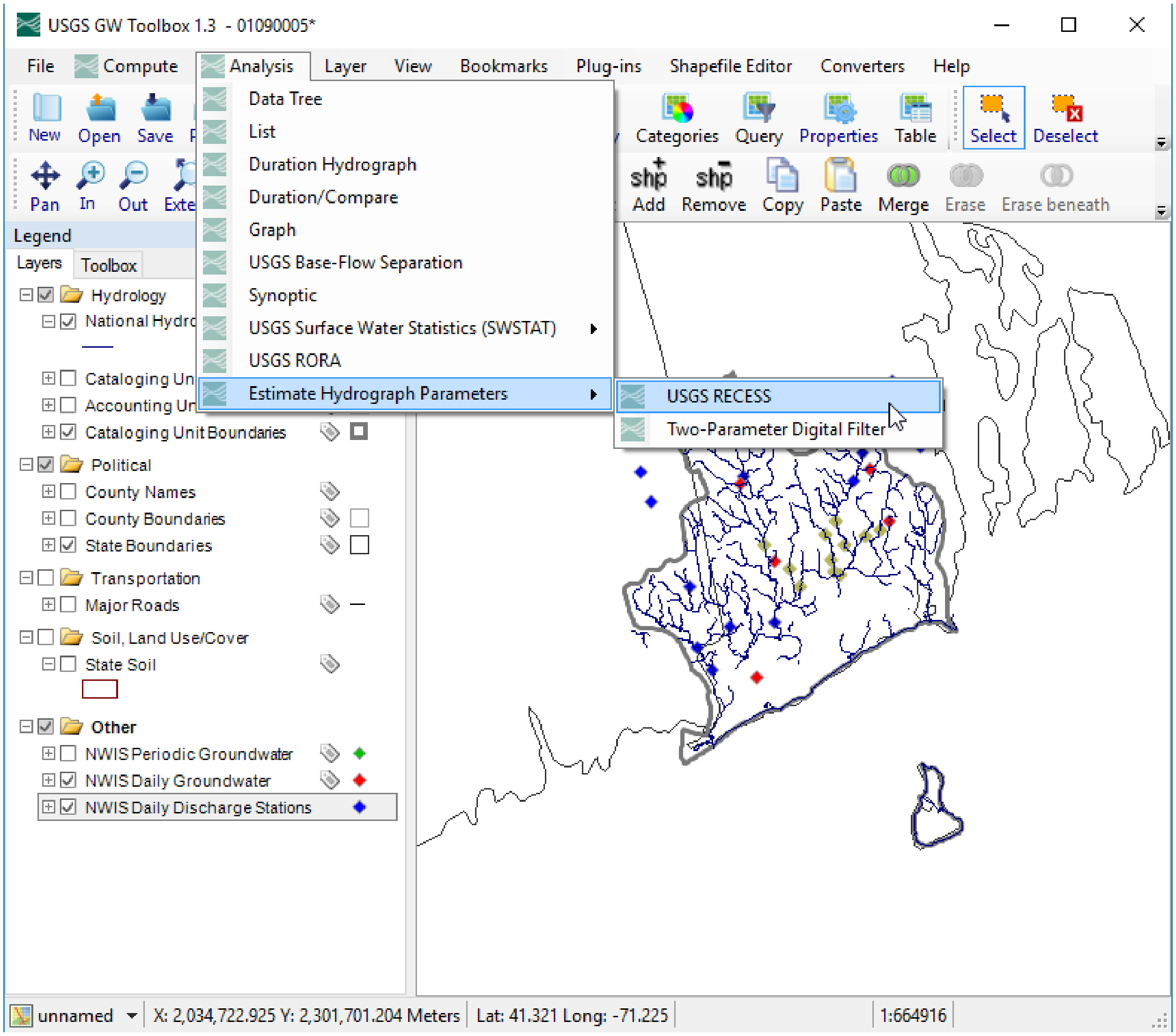
Update to the RECESS functionality to estimate a basin-wide base-flow recession constant and master recession curve

April 15, 2017 (Version 1.3 release)

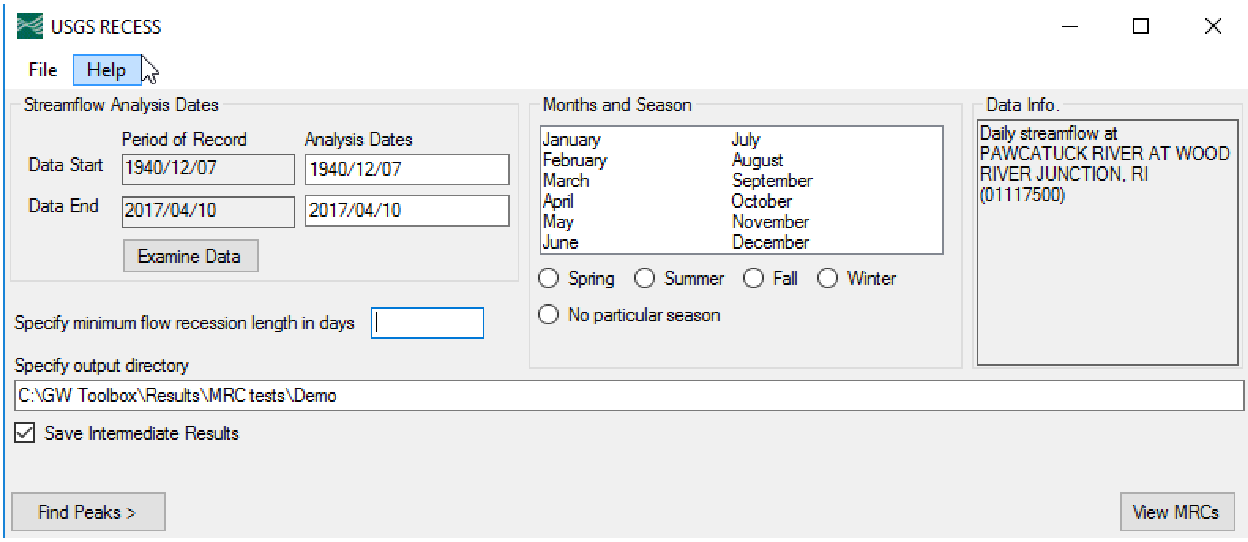
This tutorial describes changes that have been made to the RECESS functionality of the Groundwater (GW) Toolbox. These changes have been made to improve the analysis of base-flow recession constants and the master recession curves. The original RECESS program is described by Rutledge (1998) and its implementation 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).

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 "**USGS RECESS**" option from the "**Analysis>Estimate Hydrograph Parameters**" menu option:

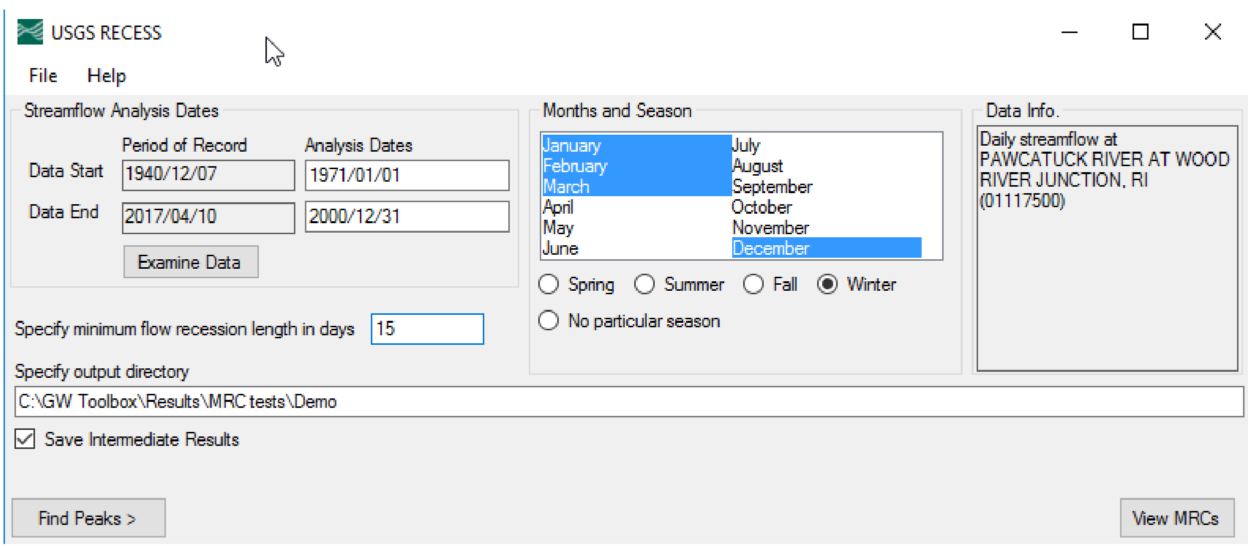


Selection of the "**USGS RECESS**" option takes the user to the "Select Daily Streamflow for Analysis" dialog box, where the user selects a streamflow record for analysis (see pages 11-12 and figure 8 in Barlow and others, 2014). Selection of a streamflow record brings the user to the following dialog box:

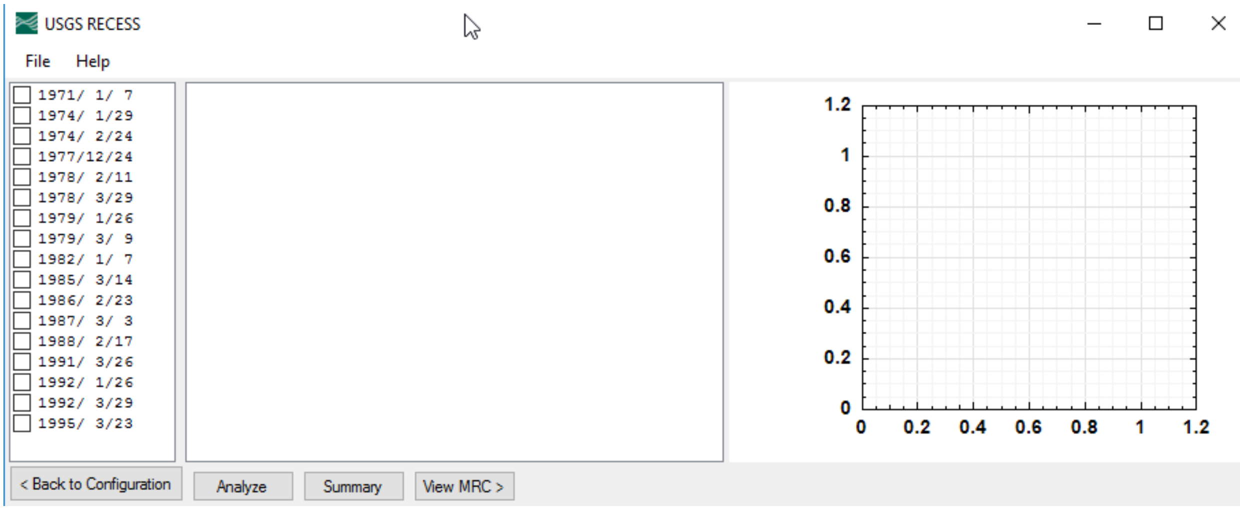


The dialog box is nearly exactly the same as in previous versions of the software, except a “View MRCs” button has been added that allows the user to go directly to the MRC functionality (assuming that information necessary to plot the MRCs has already been generated). This functionality is described 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 (see Barlow and others, 2014, for details on these inputs). For this analysis, the following inputs were specified in the dialog box:

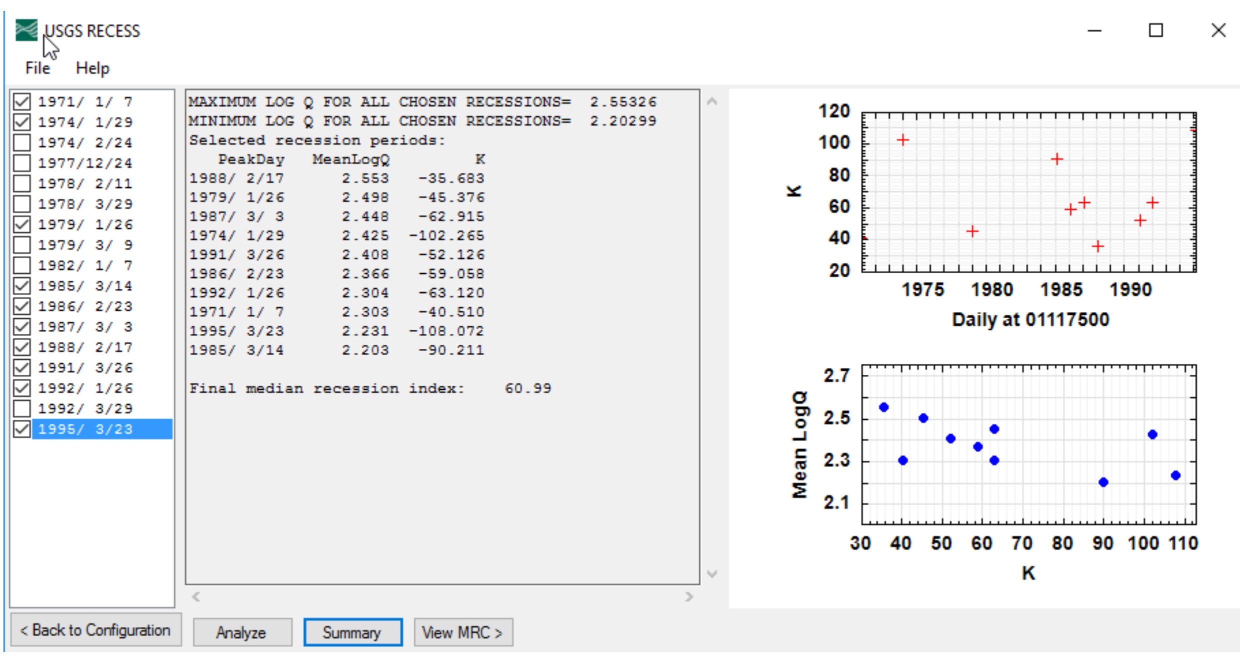


The user then clicks the “Find Peaks >” button, which brings up the list of recession periods that fit the minimum requirement of days of recession following a streamflow peak:



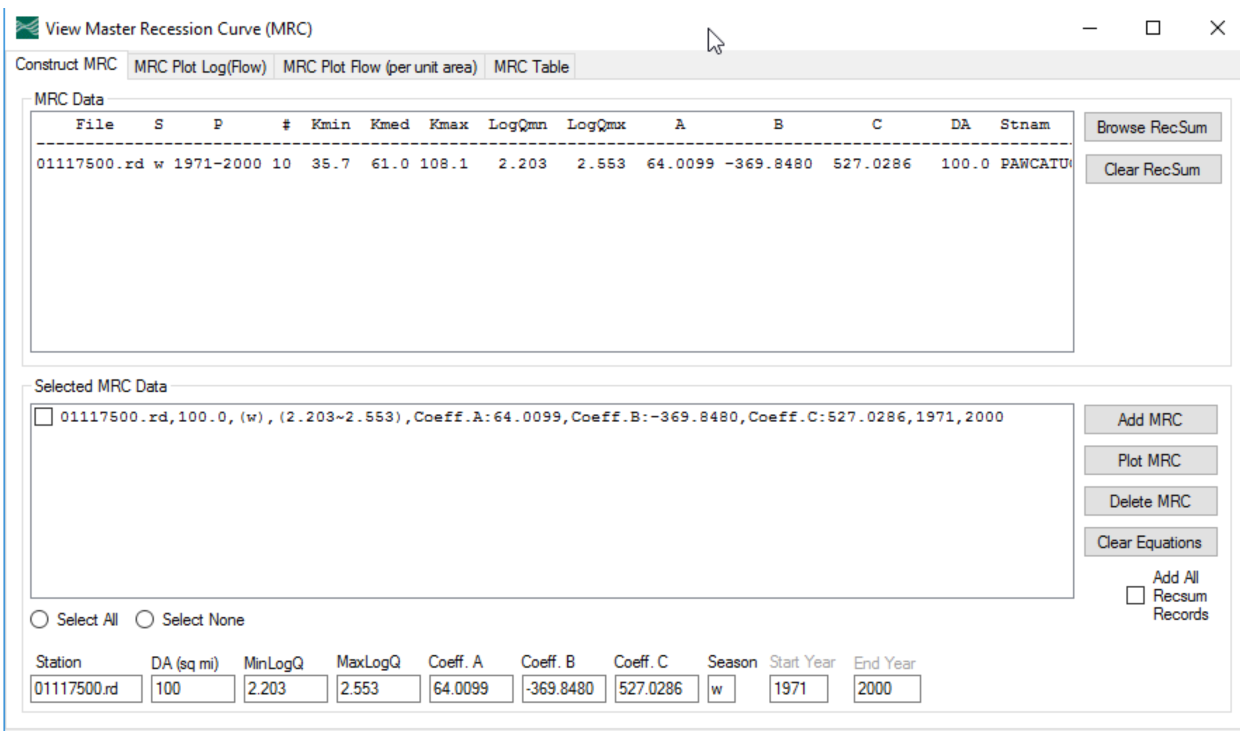
For this example, 17 recession periods are listed, the first having had a peak streamflow on January 7, 1971. This dialog box is unchanged from previous versions of the software and the user is directed to Barlow and others (2014, p. 18-20) for a description of the approach used to estimate recession constants for each of the individual recession periods.

For this example analysis, a minimum of three 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. A total of 10 recession periods were analyzed, which, after clicking on the "Summary" button, resulted in a median recession constant (K) of 60.99 days per log cycle:



Note that this dialog box is slightly changed from previous versions of the software, which included only a single plot showing K as a function of time. The updated functionality shows 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 these 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 >”



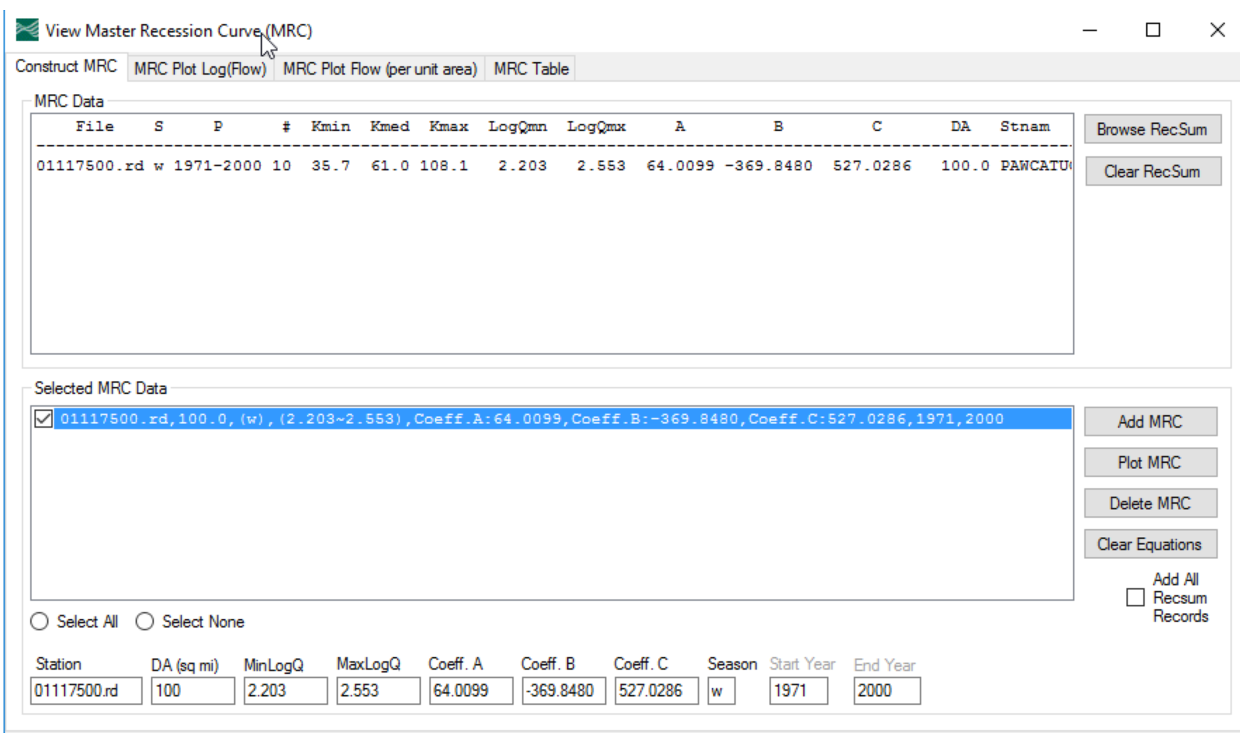
The dialog box consists of three main sections. The middle section, “Selected MRC Data,” consists of information that is used to create the MRC for each station selected from the “MRC Data” panel. In this example, the information shown in both panels was generated in the previous recession-analysis step. 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 GW 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 GW 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:

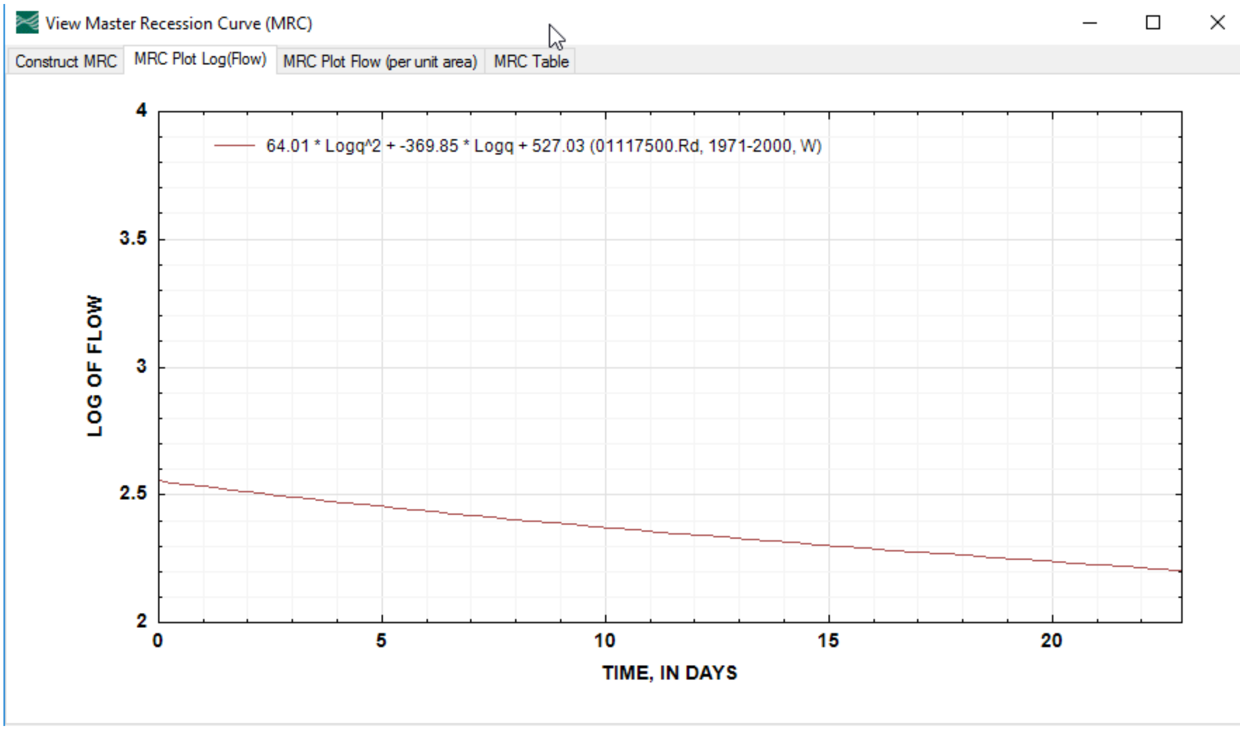
```
01117500.rd w 1971-2000 10  35.7  61.0 108.1   2.203   2.553  64.0099 -369.8480  527.0286
100.0 PAWCATUCK_RIVER_AT_WOOD_RIVER_JUNCTION__RI
```

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 (60.99 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:

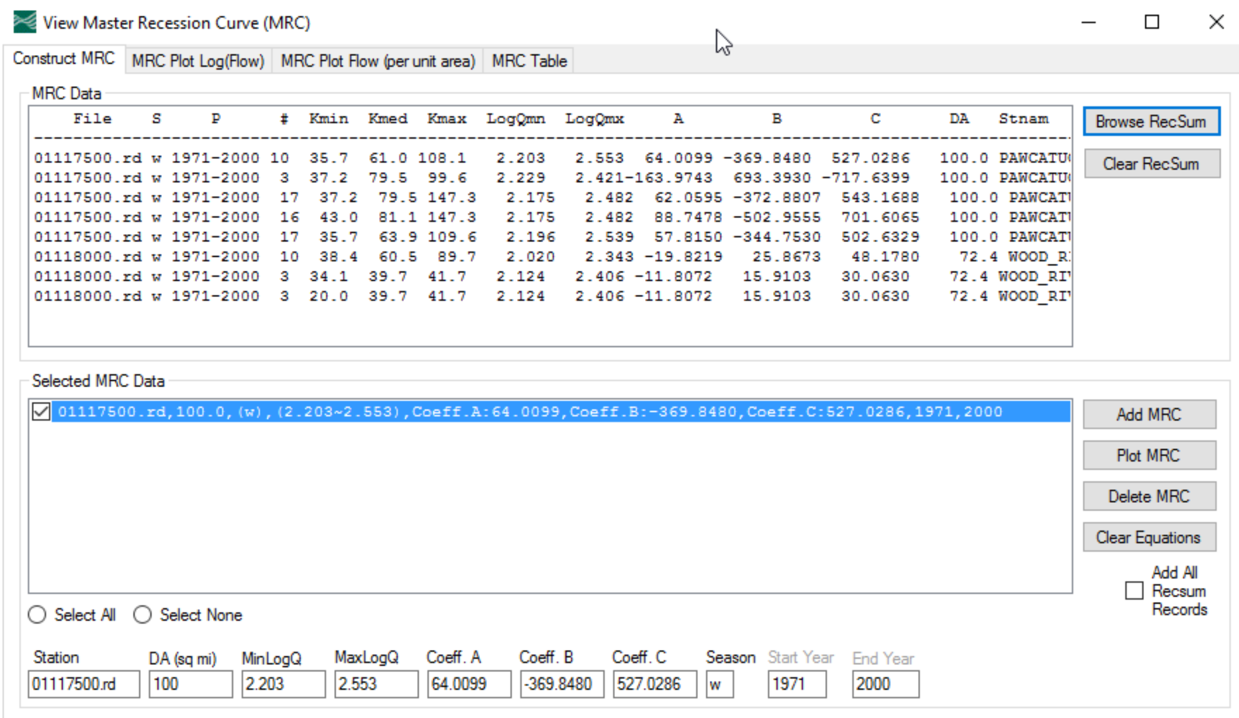


Doing so results in the following plot:

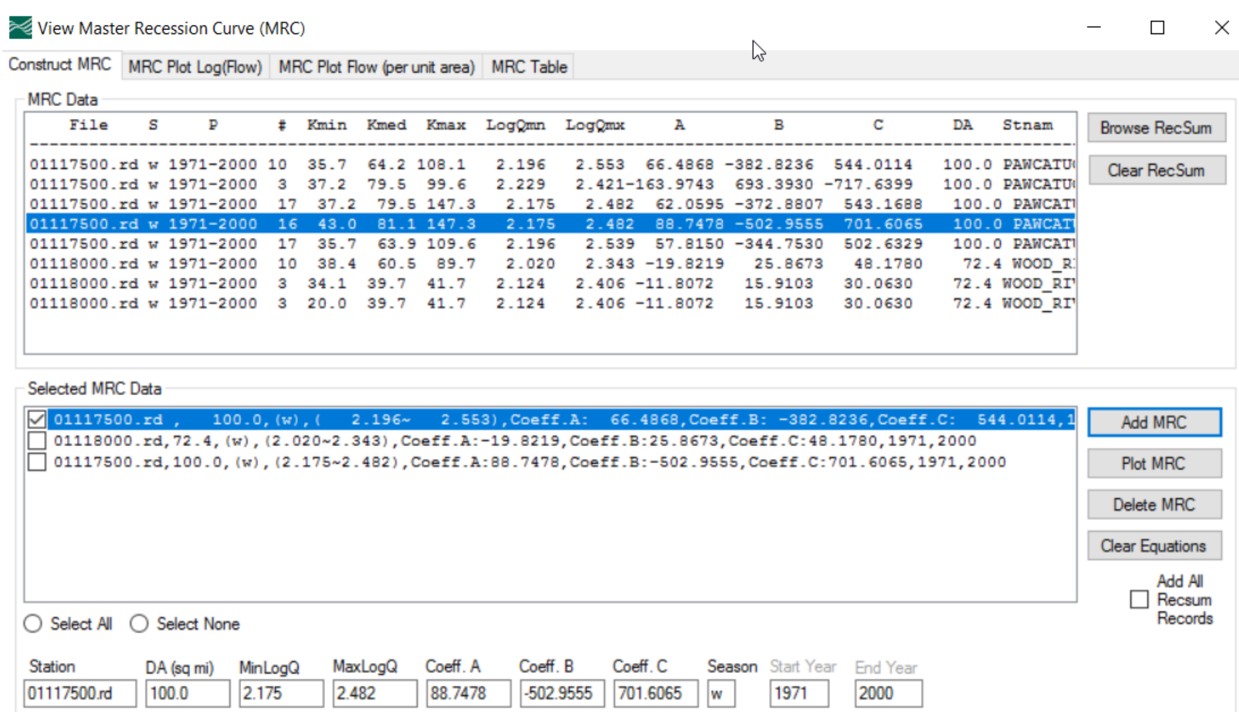


Other options for viewing the MRC also are available at the top of the Plot screen, such as plotting the MRC as a function of flow per unit drainage area (in units of cubic feet per second per square mile), which can be useful for comparing the MRC of multiple stations, or viewing the MRC Table.

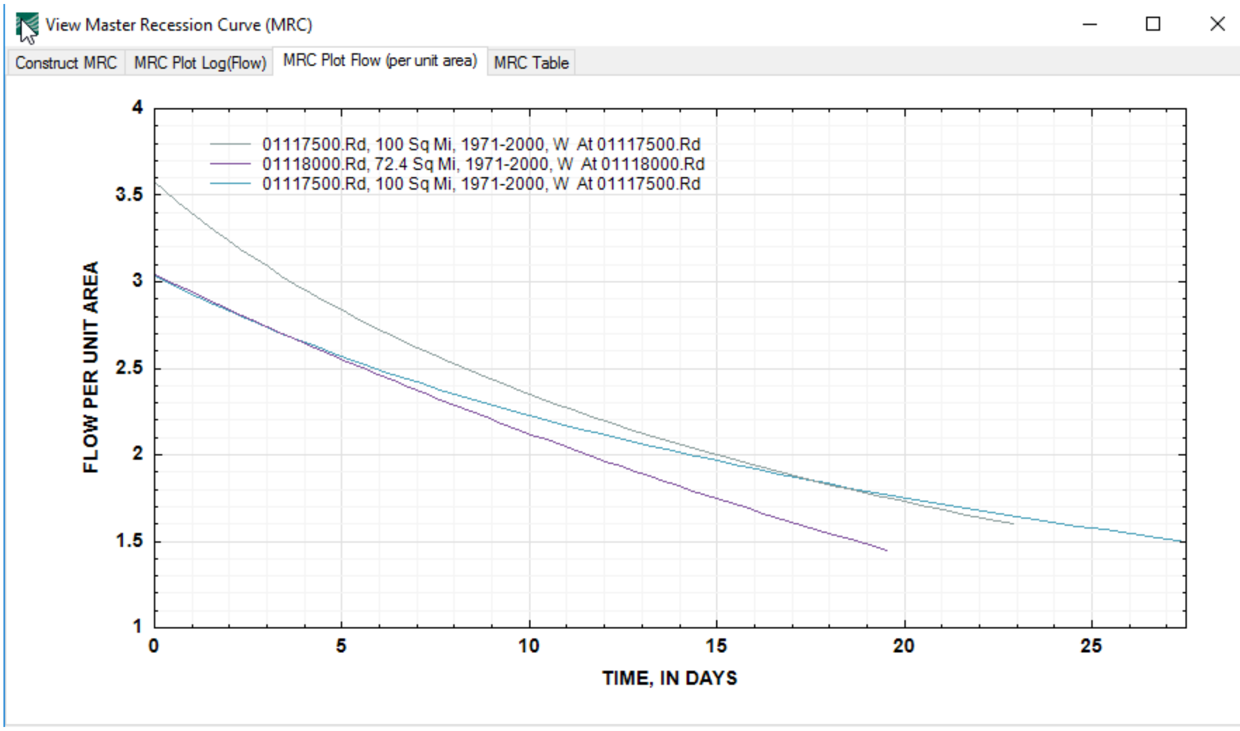
The user also can use the main MRC dialog box to open 'recsum.txt' files that have been previously generated and saved. This is done using the "Browse RecSum" option. For this example, "Browse RecSum" was used to find a previously generated 'recsum.txt' file consisting of seven unique MRC records for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



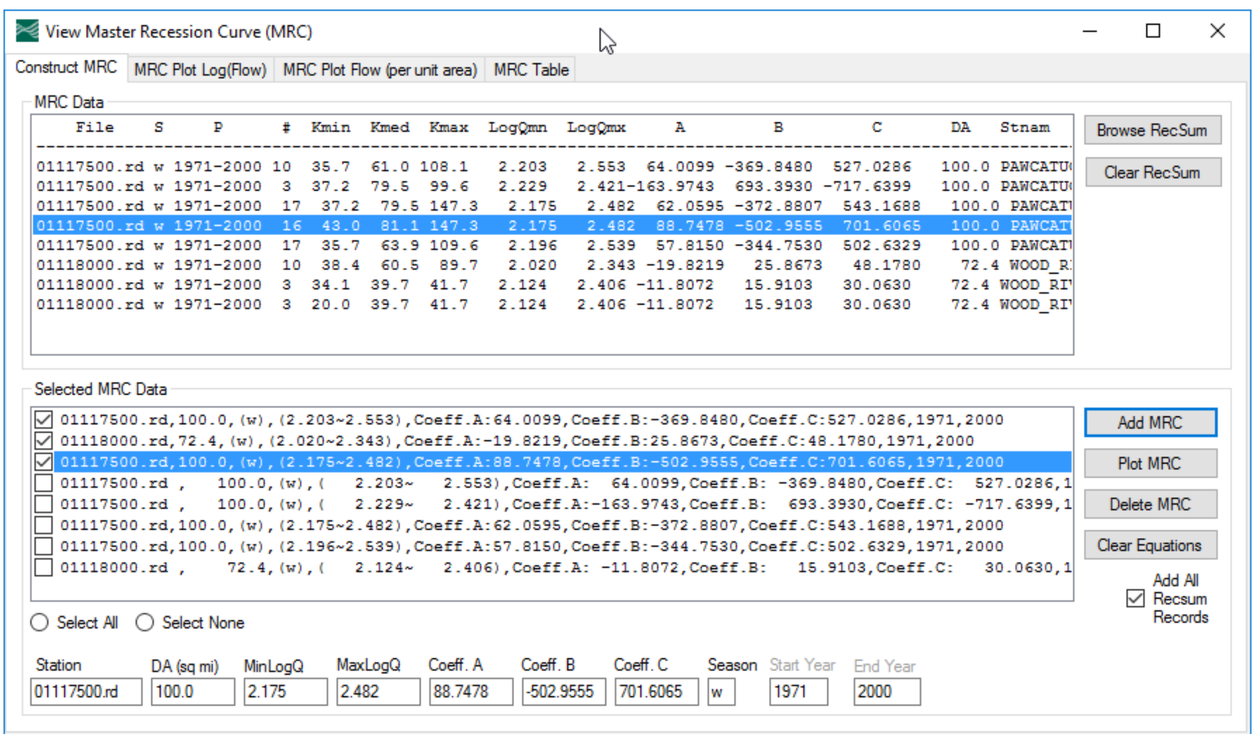
The user can now 'Add MRC' records from the top panel ("MRC Data") to the middle panel for analysis:



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.

Rutledge, A.T., 1998, Computer programs for describing the recession of ground-water discharge and for estimating mean ground-water recharge and discharge from streamflow records—Update: U.S. Geological Survey Water-Resources Investigations Report 98–4148, 43 p., http://pubs.usgs.gov/wri/wri984148/.

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.

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