

## **Low Flow Frequency Analysis Tool**

### **Version 1.0**

Flow frequency is an expression of the minimum average stream flow lasting a specified period of consecutive days, and occurring at a specified return frequency of years. Flow frequency statistics are often represented in the form:  $\#_{\text{days}}Q\#\text{years}$ , where Q refers to flow, the number before the Q ( $\#_{\text{days}}$ ) is the number of consecutive days on which the statistic is calculated, and the number after the Q ( $\#\text{years}$ ) represents how often that low flow would be expected to occur, on average. For example, a common hydrologic flow frequency statistic is the 7Q10, the lowest 7-day average flow that occurs on average once every 10 years. Having a return period of 10 years should not be interpreted to mean the minimum average flow will occur only once every ten years; rather, it means the flow would occur *on average* every ten years for that location. It is possible for a 10-year return flow to occur two years in a row, or more than 10 years apart, but over a long period of time, the frequency averages out to once in 10 years. For any given stream, there will be a 1/10 or 10% probability that the annual minimum 7 day average flow in any 1 year will be less than its 7Q10 value.

#### **What the tool is**

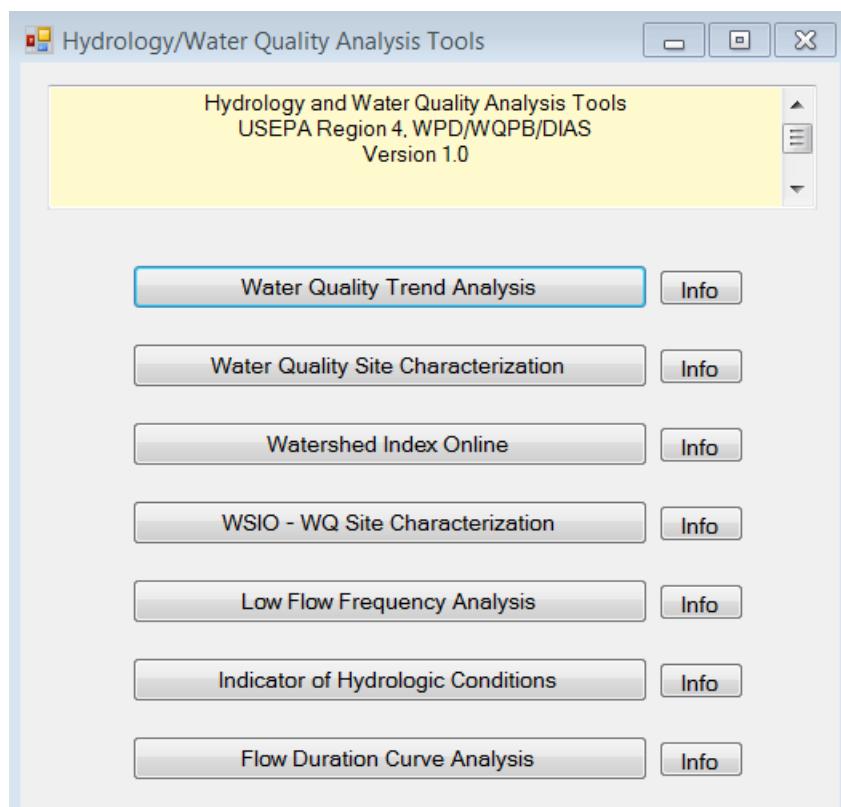
The Low Flow Frequency Analysis Tool calculates the magnitude and frequency of low flow events for active and inactive gaged monitoring locations, with corresponding upper and lower confidence limits around each estimate. The tool also has the capability of performing a regional flow analysis, which may be used to estimate the probability of low flows corresponding to various return periods for ungaged sites. The tool also generates flow duration graphs, which show the percentage of time that a specified flow will be equaled or exceeded during a given time period. The tool was designed using the protocols described in USGS Bulletin 17B (USGS, 1982), with enhancements for estimating and fitting the parameters of a log-Pearson Type III distribution, as well as for regional analysis of multiple gages, developed subsequent to the original USGS-published protocol. The Frequency Analysis tool includes a GIS mapping routine that allows the option of selecting flow gages from a map.

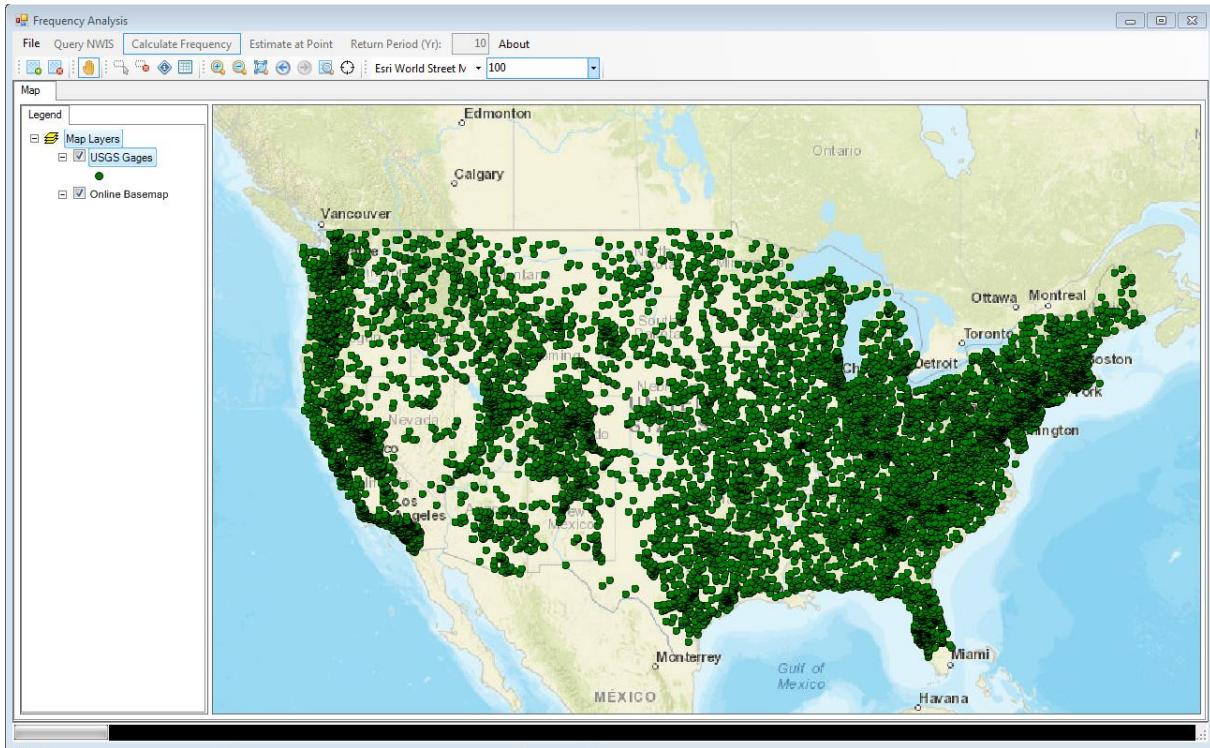
Flow frequency estimates are affected by the techniques used to calculate them (for example, how zero or negative flows are handled, whether the record is extended, etc.), as well as by the flow record itself (i.e. how long and how complete the flow record is, the range of hydrologic conditions the record represents, etc.). There are many uses for low-flow statistics, including the development of TMDLs and NPDES permits, water quality standards development and/or assessment, and management of water resources. Users should employ this tool and interpret the results mindful of stream/gage characteristics that influence the estimates. For example, comparing or combining gages on free-flowing streams with gages located

downstream of a regulated dam release may be problematic. If the dam is regulated in a somewhat consistent manner, low flow statistics may be a good predictor of future flows, but if the stream flow is non-natural (i.e. stream flow is less influenced by when and how much water is released by the dam, and not as much a factor of precipitation patterns) and if dam releases are not consistently regulated, flow frequencies calculated based on past management may not predict future flows well. Similarly, the user should be aware of any gages that are tidally-influenced such that they experience reverse flow past a gage. The tool does not attempt to extend the flow records for any gage; therefore, the flow estimate is based only on the available flow record. Consequently, a flow frequency estimate at one gage may be calculated from a different time period, or shorter time period, than the same estimate at a different gage.

### How To

1. Run the **R4TOOLS.exe** and click on the **Low Flow Frequency Analysis** button to run the frequency tool.

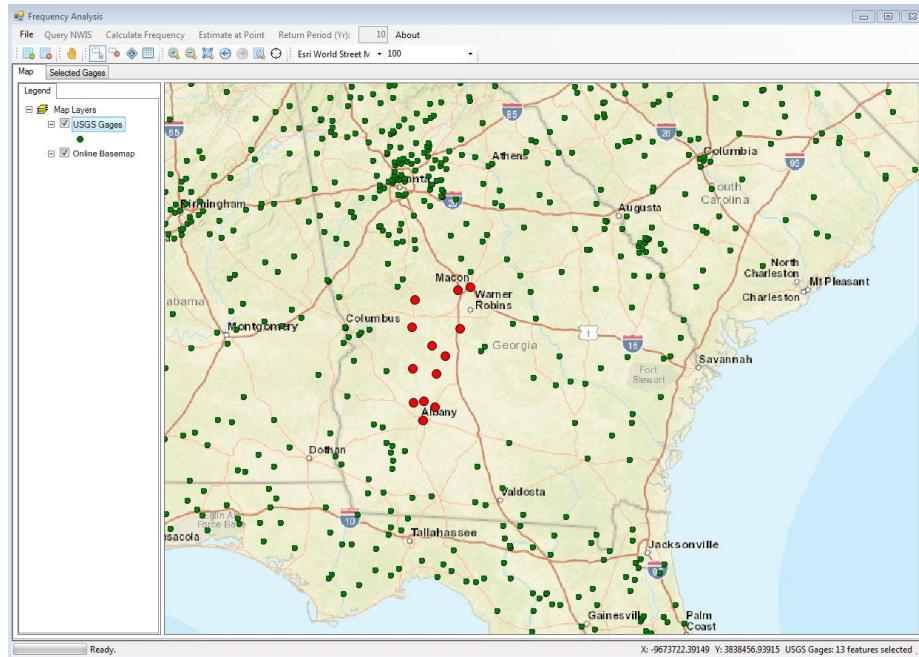




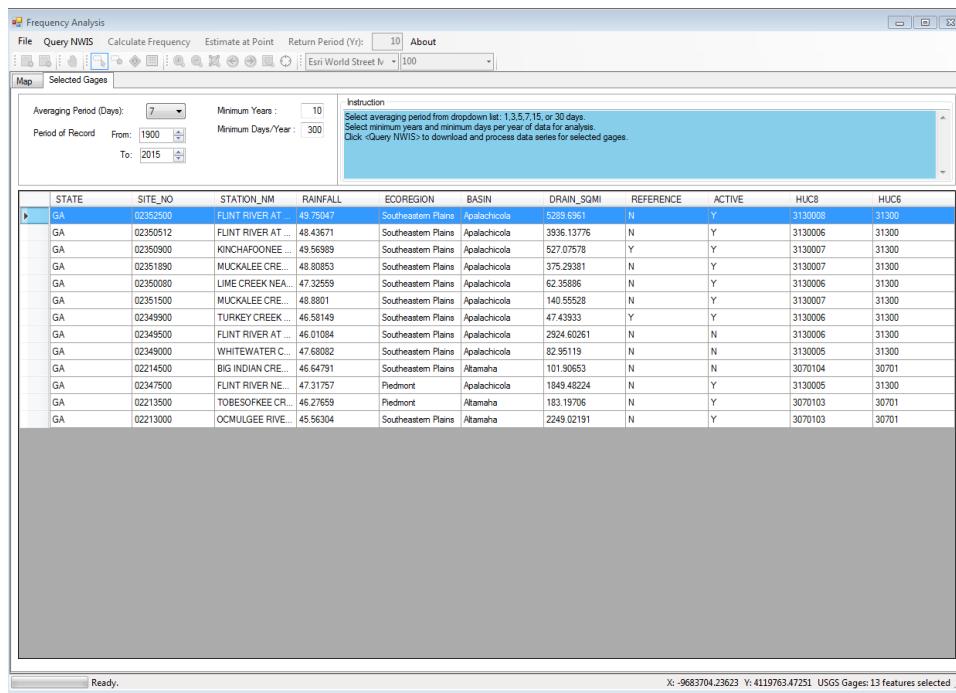
**Figure 1: Frequency Analysis Station Map**

2. Select Gages and Set Parameters:

- a. Select USGS Gages using the Select Tool ( ) from the map or use the attribute table of the **USGS Gages** layer to make selections. The selected gages will be highlighted in red. After selecting gages, click on the **Selected Gages** tab which provides a table of the selected gages along with detailed information (See Figure 3).



**Figure 2: USGS Gages Selected**

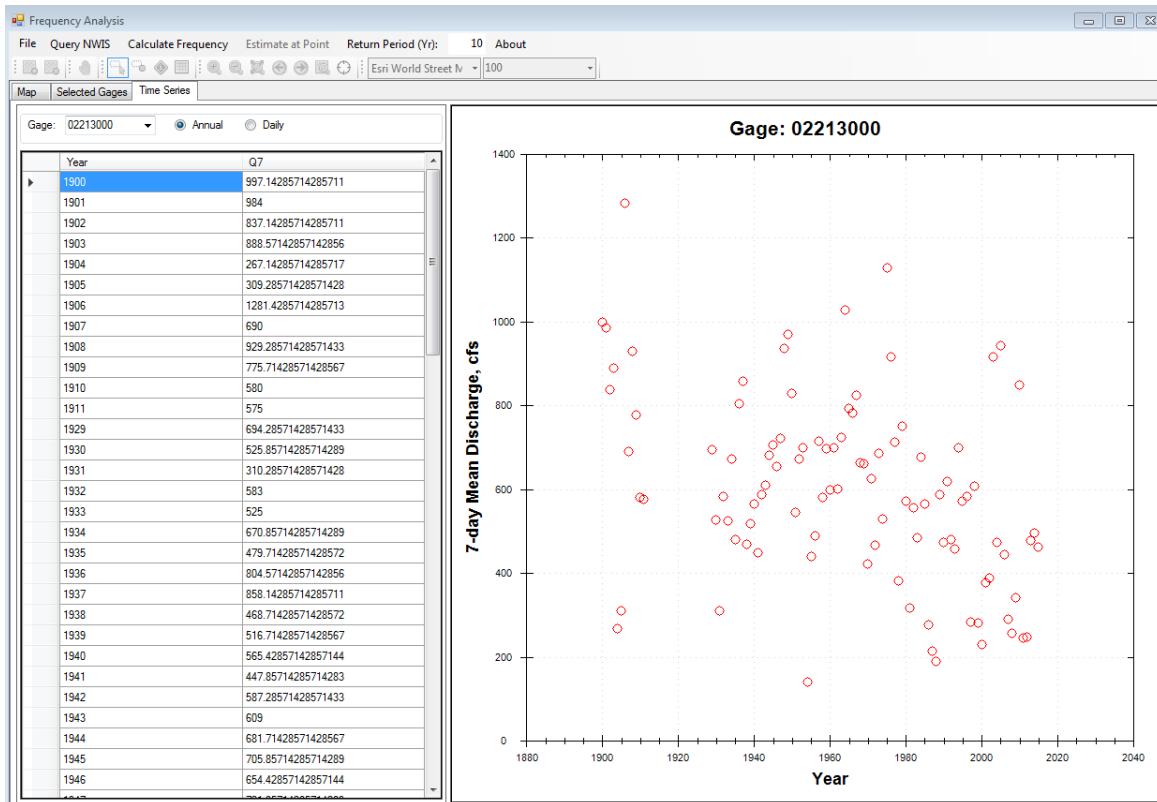


**Figure 3: Selected Gage Tab**

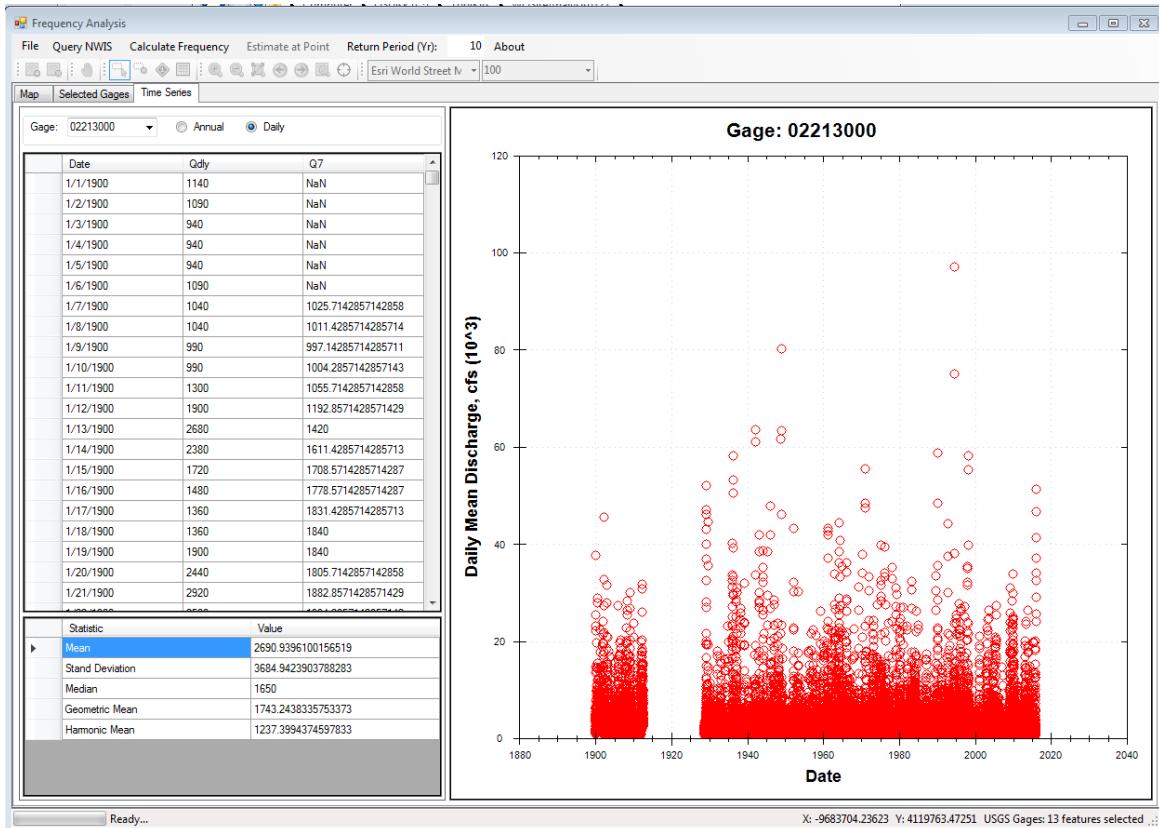
- On the upper left panel of the **Selected Gages** tab, specify properties of the analysis: 1) **Averaging Period (Days)** to use. Choices are: 1, 3, 5, 7, 15 or 30 days. This represents the consecutive period of time for which the low-flow statistic will be calculated, 2) **Minimum Years** of record to include in the analysis. There is no upper limit, but

minimum is ten years. The tool uses calendar years (as opposed to “water years”), 3) **Minimum Days/Year** a record should have to be included in the analysis. The value selected cannot be less than 300, and cannot be greater than 365, and 4) **Period of Record** to use.

3. Once the desired gages are selected, click on the **Query NWIS** button in the main menu bar. The tool will then retrieve the available data for the selected gage(s) from the USGS NWIS website (<http://waterservices.usgs.gov/>). The **Time Series** tab will display the data in a table and on a chart (Figure 4). If multiple gages were queried, the gage can be changed out using the drop-down list at the top of the data table. From the data record and chart, it is possible to see the years of record. The default is to show the n-day flows for each year of record, where n is the averaging period selected by the user. For example, if the tool is set to estimate a 7-day average , the new window will show a table of Q7, the lowest average discharge in cubic feet per second (cfs) maintained over 7-consecutive days at that gage, for each year of record. A radio button at the top can be moved to display **Daily (Qdly)**, the average daily flow, instead of n-day annual flows (Figure 5).

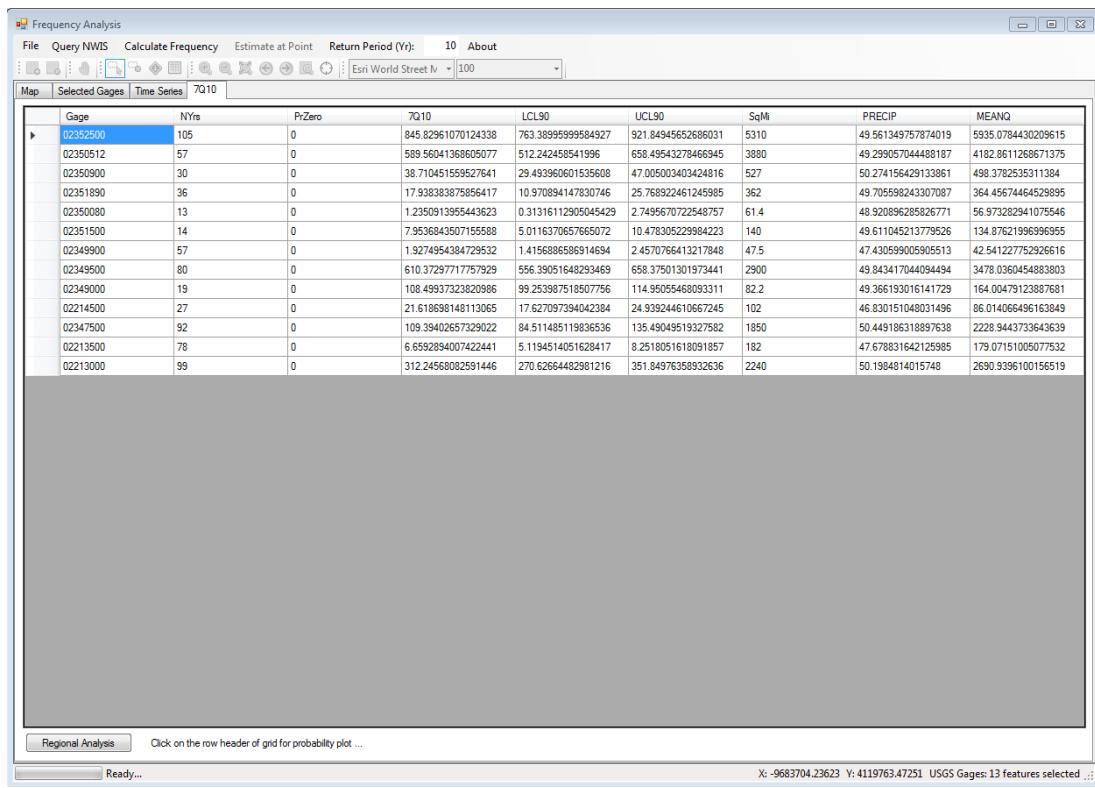


**Figure 4: Time Series Tab**

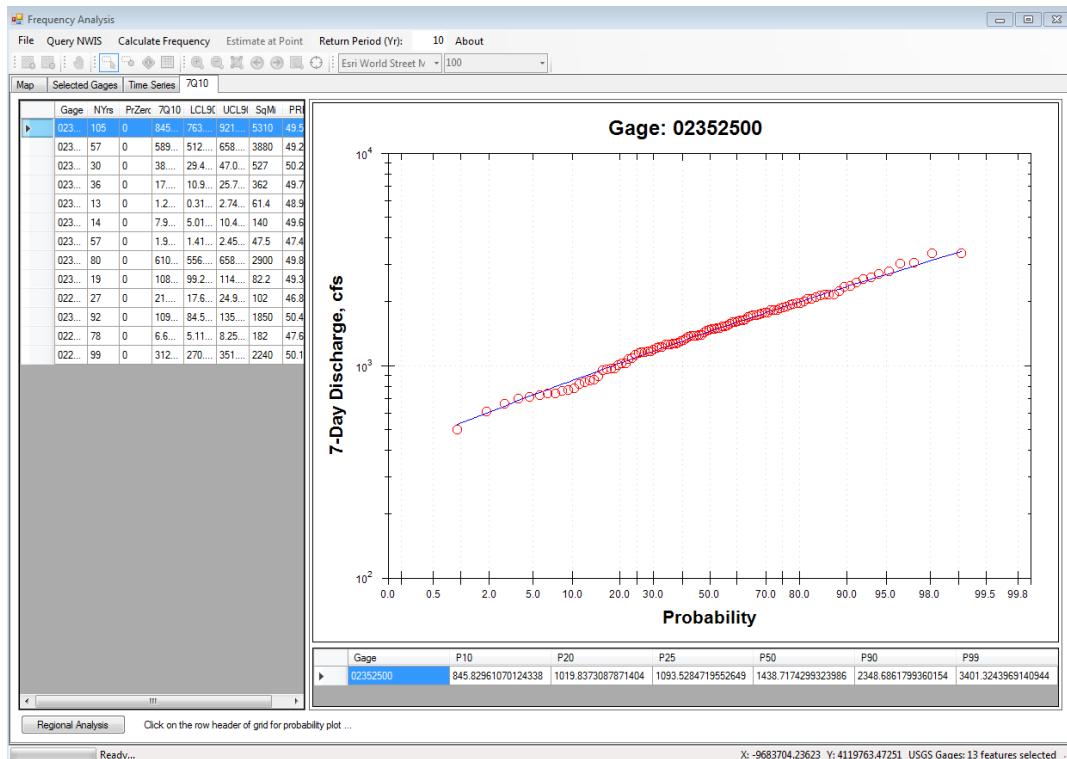


**Figure 5: Time Series Tab – Daily Values Depicted**

- Set the **Return Period (Years)** to use (in the main menu). This is the average interval between the low flow estimates. The default selection is 10, but it should be based on the desired statistic and application then click on the **Calculate Frequency** button from the menu bar. A new tab, named for the flow frequency selected (e.g. 7Q10, 1Q10 or 3Q5) will be displayed. The tab will contain a data table listing each gage analyzed in a row, with the number of years of flow record (**NYrs**), probability of zero flows (**PrZero**), the flow frequency value in cfs (e.g. **7Q10**), the 90% Lower Confidence Limit (**LCL90**), the 90% Upper Confidence Limit (**UCL90**), the USGS estimate of the number of square miles draining to that gage (**SqMi**) and an estimate of average annual precipitation (**Precip**) and mean daily flow (**MeanQ**) over the years of record (Figure 6). Clicking on a gage will change the window to show a probability plot of the Q7 data for the selected gage (Figure 7). Users may right-click on the chart to open the option of copying and/or saving the graph image. When a row is highlighted, pressing **Ctrl+C** to copy the data will allow it to be pasted into a blank worksheet.

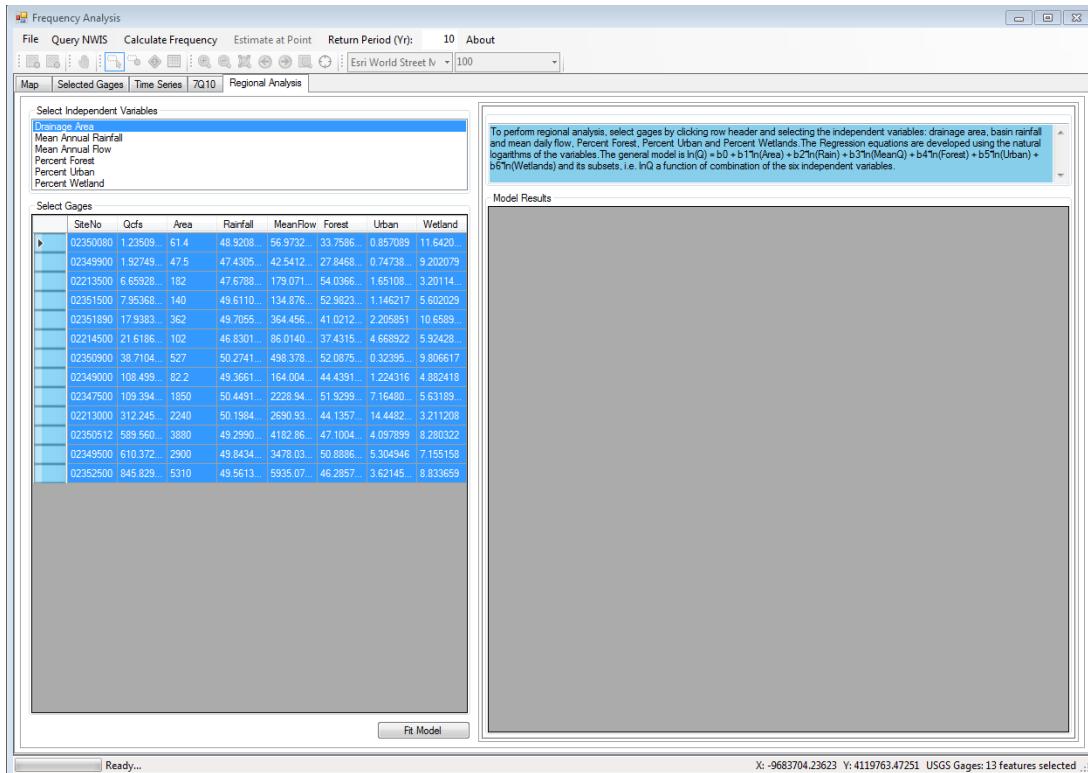


**Figure 6: Calculate Frequency**



**Figure 7: Calculate Frequency with Probability Plot**

5. Clicking on the **Regional Analysis** button at the bottom of the **7Q10** (i.e. Flow Frequency) tab will open a **Regional Analysis** tab. Select the gages to include in the analysis by clicking on the header of that gage's row. Select independent variables at the top by clicking on one or more of the available options: **Drainage Area**, **Mean Annual Rainfall**, **Mean Annual Flow**, **Percent Forest**, **Percent Urban or Percent Wetland**. When done, click on the **Fit Model** button at the bottom of the screen. Model results will appear in the split-screen window on the right and will include the general **Model**- i.e. on which variables was the regression run (e.g.  $Q=fn(Rain, MeanQ)$ ) and the number of sites that were included (**N**). The results are in the form of a regression equation, with the constant (**b0**), and parameters **b1**, **b2**, and **b3**, as well as the **R-squared**. If only one variable is included, only b0 and b1 will be provided; if only two variables are included, only b0, b1, and b2 will be given. The resulting equation can be used, along with values for the independent variables for an ungaged location, to estimate low-flows for the ungaged location. Clicking on the left cell in the Model Results row to show diagnostics plots of the selected regression model.



**Figure 8: Regional Analysis Tab**

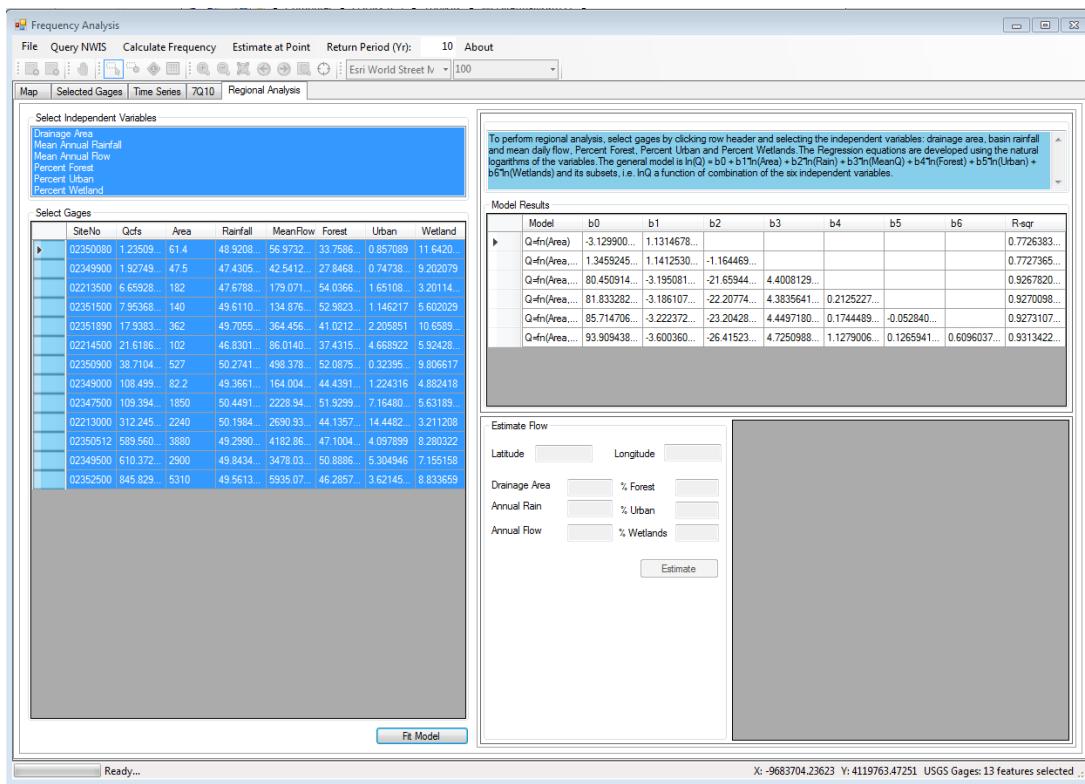


Figure 9: Regional Analysis with Model Results

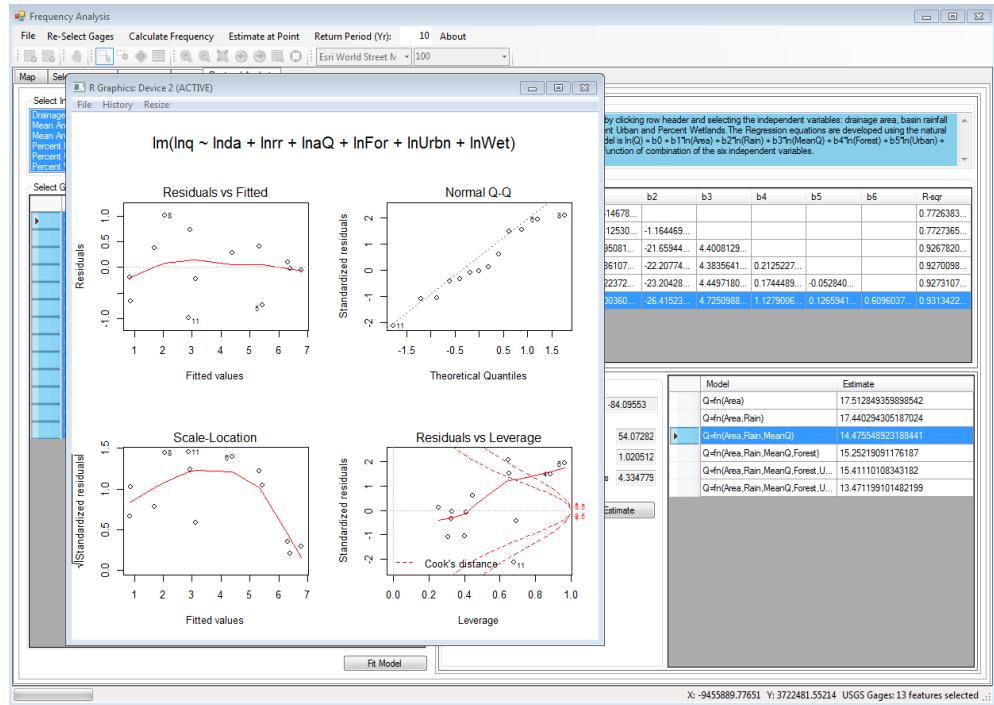
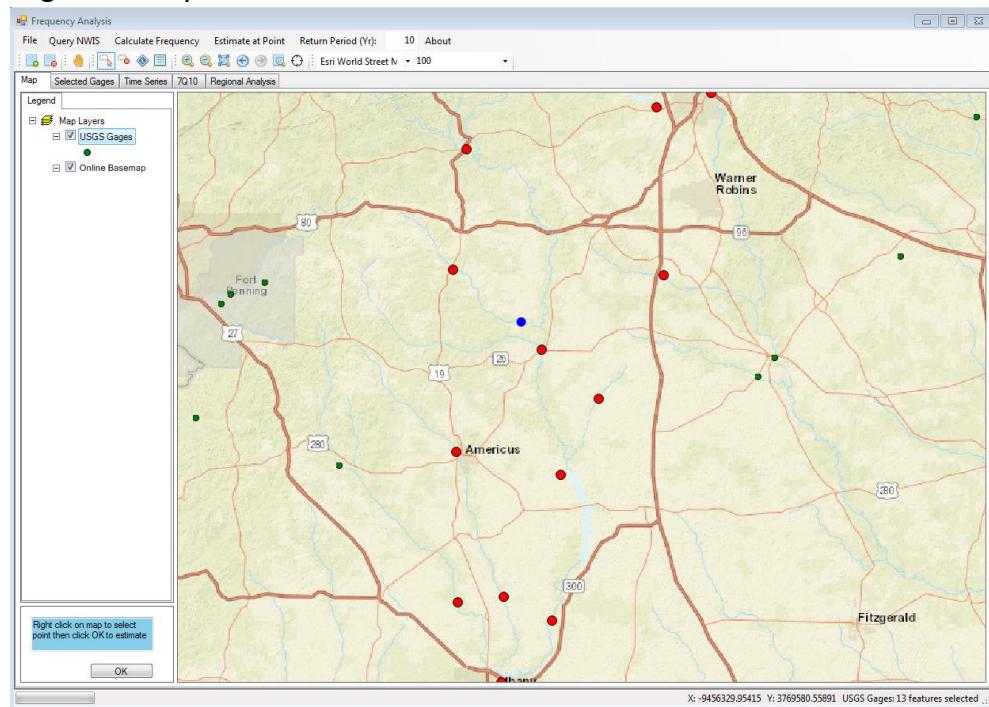
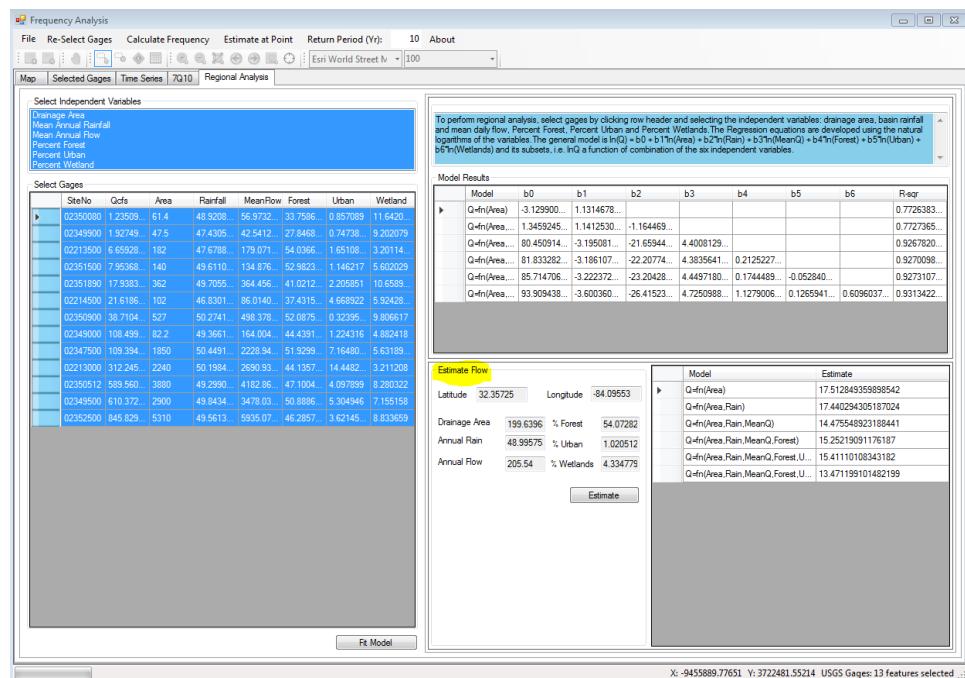


Figure 10: Regional Analysis with Diagnostics Plots

6. Click on the **Estimate at Point** button from the menu bar to estimate flow at an ungauged location using any of the regional curves. Right click on the map to select a point and click **OK** when done (selected location is displayed as a **blue dot**). All the fitted regression models are used to estimate the flow at the ungauged location from which the user can select the best estimate. The red dots are the stations used in the regional analysis.



**Figure 11: Estimate at Point Selection Map**



***Figure 12: Regional Analysis – Estimate Flow***

7. Save results for pasting into tables or reports. Selecting all rows from any table, and clicking **Ctrl-C** copies the grid data which can then be pasted into an excel spreadsheet. Right click on the graph pane to export graph for reports.

**Reference**

USGS, 1982. Guidelines for determining Flood Flow Frequency. Bulletin 17B of the Hydrology Subcommittee. US Department of Interior, Reston, VA.

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