The drought analysis begins by calculating annual flow values from available average daily flow data. Then a drought limit is calculated as the long-term average of annual flow data. Figure 1 contains an annual time series of the flow data along with the calculated drought limit as a reference.

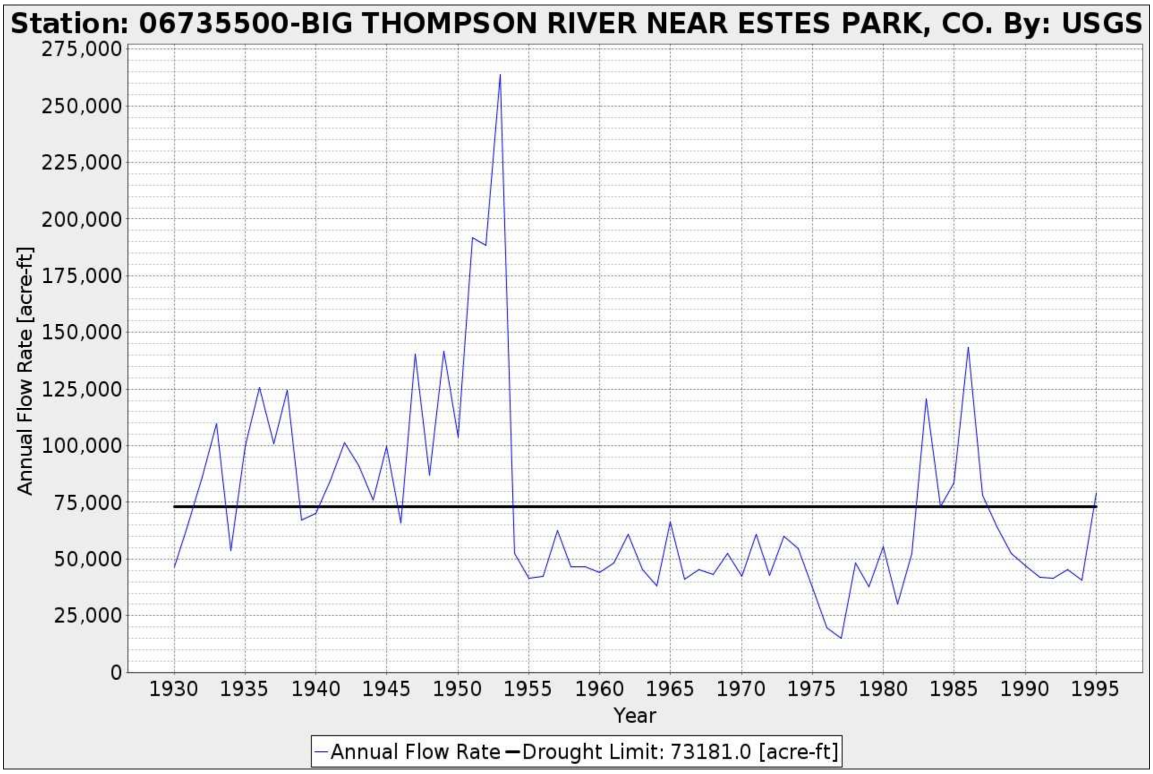

Figure 1: Annual Flow Rate and Drought Limit

Figure 2 contains a second time series containing the annual surplus or deficit between the supplied annual flow and the drought demand limit; this is meant to highlight the occurrence of droughts.

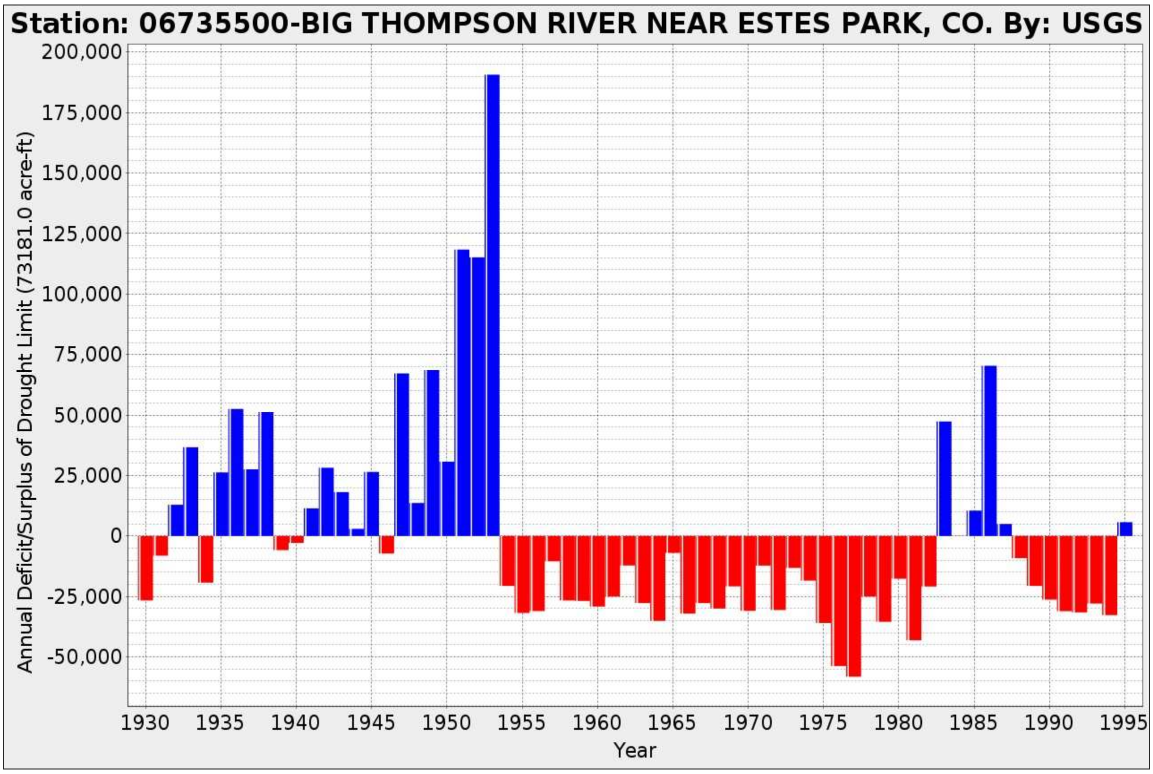

Figure 2: Annual Flow Deficit/Surplus

Then the annual flow data is converted to only its stochastic component (stochastic data = (annual data - mean)/standard deviation). Subsequently, a Box-Cox transformation converts the stochastic data into a normally distributed dataset. Thereafter, an Auto-Regressive, AR(p), model is fitted to the dataset. This allows a forecasting of the minimal observed data to a larger sample size, which in turn allows for a statistical analysis of the droughts. Equation 1 below is the form of the fitted AR(p) model.

Equation 1: AR(p) Model

$$\hat{y}_t = \sum_{i=1}^{p} \varphi_i \hat{y}_{t-i} + error_t$$

Figure 3 contains a plot of the original annual data verses the predicted model data to illustrate the correlation between the datasets. If the correlation is poor then further modifications need to be made to the regression model in order to improve the reliability of the drought analysis.

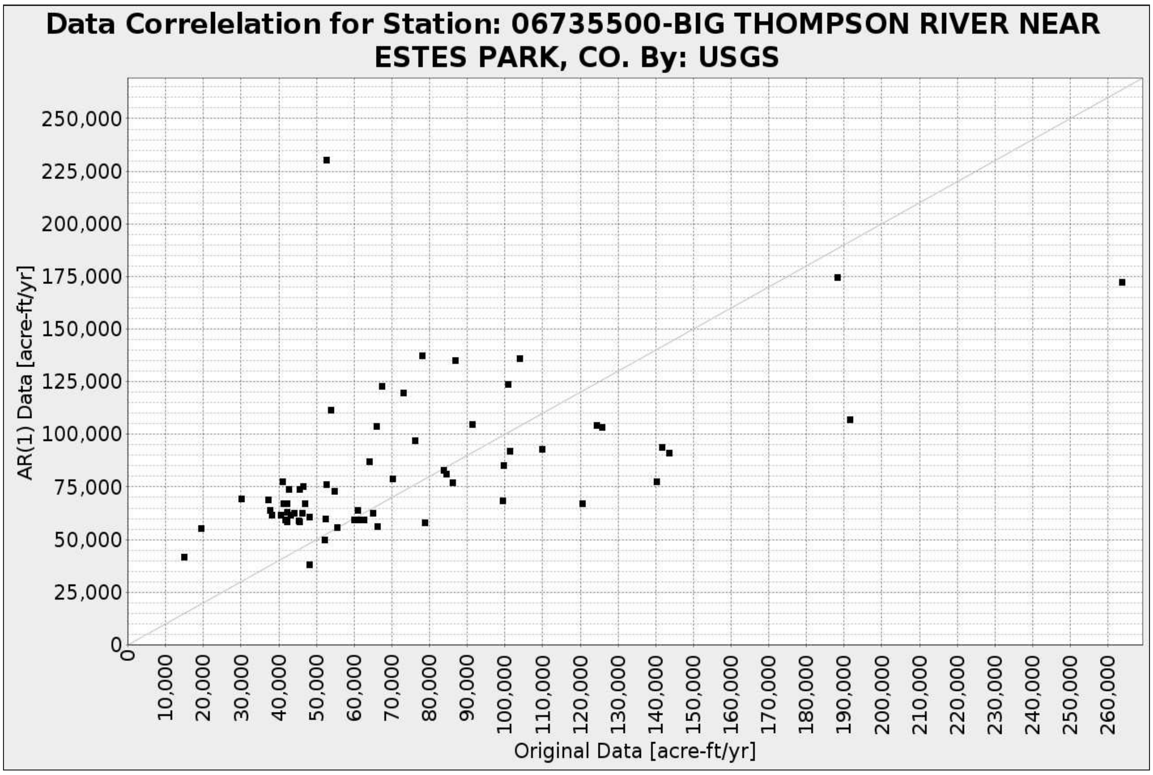

Figure 3: Fit of AR(p) Model to Original Dataset

Figure 4 contains a plot of the original data and the first portion of the 100,000 year projected dateset used to analyze the drought impacts. This projected dataset is large to allow sufficient 'droughts' to occur illustrating high recurrence interval droughts that cannot be calculated from minimal observed data. The first 100 years of this dataset are not used in the analysis and a dropped as a model warm-up period. This allows for the model to operate independent of initial conditions.

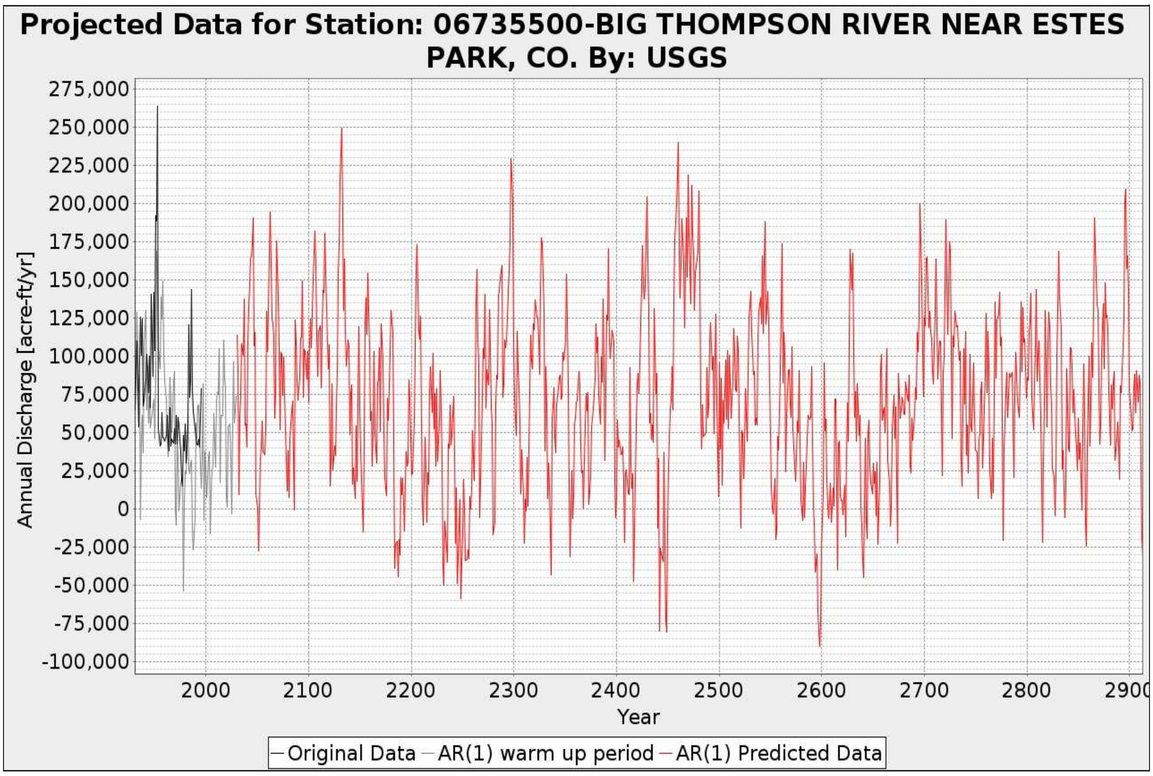

Figure 4: AR(p) Model Prediction with Original Dataset and Model Warm-Up Period

Next the drought analysis uses the projected dateset to calculate the average recurrence interval of the 1yr, 2yr, 3yr, etc. droughts. These droughts are then categorized by their amount of drought deficit (supplied annual flow - drought demand limit) and illustrated in Figure 5. The original data and its corresponding recurrence intervals are included in Figure 5 as well to illustrate the fit of the predicted data to that of the observed data. If the fit is poor, a better correlation of the regression model will likely improve the fit of the drought recurrence intervals.

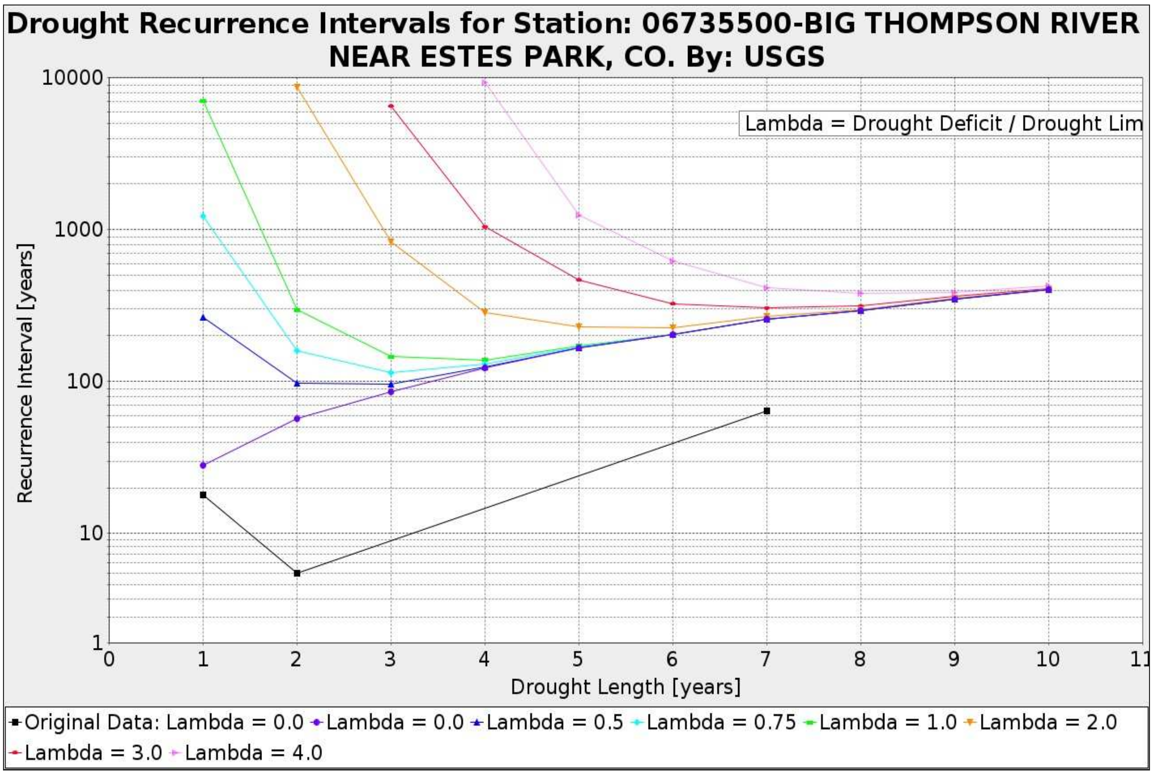

Figure 5: Predicted Drought Recurrence Interval, Length, and Deficit-(relative to the drought limit)

Analysis Summary:

- Total Observations: 23833
- Start: 1930-07-01
- End: 1995-09-30

Comments:

References:

Stream flow data and water quality test data courtesy of the U.S. Geological Survey, National Water Information System: Web Interface. http://waterdata.usgs.gov/nwis, accessed 01/24/2014

Salas, Jose D., Chongjin Fu, Antonino Cancelliere, Dony Dustin, Dennis Bode, Andy Pineda, and Esther Vincent. 2005. "Characterizing the Severity and Risk of Drought in the Poudre River, Colorado." *Journal of Water Resources Planning and Management* 131(5): 383-393.

Salas, Jose D. 1993. "Chapter 19: Analysis and Modeling of Hydrologic Time Series." *The McGraw Hill handbook of hydrology.* D. R. Maidment, ed., McGraw-Hill New York

The primary purpose of these graphs is to help indentify possible flow and pollutant problems. The developers of eRAMS are not liable for use of this model (indlucing but not limited to information extracted and results).