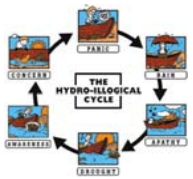
Drought-Influenced Low-Flow Non-Exceedance Plots for Selected USGS Gauges in Oklahoma

Ron Miller, Ph.D., and Garey A. Fox, Ph.D., P.E., D.WRE

Oklahoma State University, Department of Biosystems and Agricultural Engineering

Introduction

Planning for water use during drought periods is an important public good that is rarely achieved.



© National Drought Mitigation Center

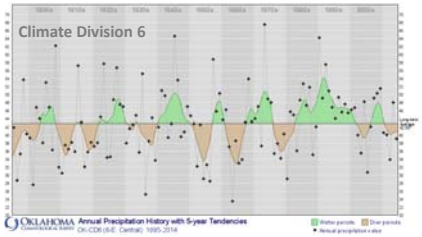
Climate change predictions for Oklahoma include shifts from the current norm precipitation regime to include long dry periods and drought, interspersed with intense wet periods (AMS, 2012). Additionally, projected warming trends will likely mean reduced snowpack depths in mountain areas, and thus changes in the volume and timing of snowmelt to streams (AMS, 2013). These changes and others are likely to manifest themselves in Oklahoma streamflows. Published streamflow statistics for Oklahoma do not account for the influences of drought (Lewis and Esralew, 2009).

The objective of this project was to begin to develop streamflow models and tools that will allow Oklahoma planners and citizens to estimate the effects of drought on streams, and therefore help in planning for the effects of drought.

Oklahoma Climate Divisions

Oklahoma Climate Divisions Based on:

- Precipitation (gradient increasing west to east-southeast)
- Temperature (gradient increasing northwest to southeast)
- Dominant crop types (Guttman and Quayle, 1995)



Each Climate Division has a Precipitation History

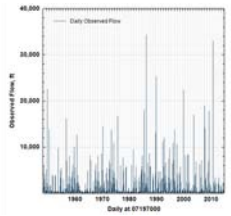
- Based on station records 1894 - 2014
- 5-year moving average
- Brown tones show deficits relative to long-term average

This work was supported by the National Science Foundation under Grant No. IIA-1301789.

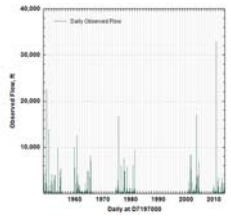
Drought-Influenced Streamflow

Barren Fork Creek near Eldon, OK Streamflow Record

Barren Fork Creek watershed is 312 mi² in the Ozark region of eastern Oklahoma and western Arkansas and is designated both as an Oklahoma Scenic River and a USGS reference stream (no dams or significant water diversions). It has continuous streamflow record from 1948 to the present (66 years).



Daily Average Flow for Entire Record



30 Years of Drought-Influenced Daily Flow, based on Climate Division 6 Years of Precipitation Deficit

Two Questions About Drought-influenced Streamflows

1 - Are Low Flows Lower?

Is there a difference in the lowest streamflows that would be important for planning?

What are Low Flow Non-exceedance Plots?

A statistical estimate of the annual lowest streamflows based on the existing record of streamflows. The plots produce probability and recurrence intervals for 7, 10, or 30-day moving averages.

How are Low Flow Non-exceedance Plots Used?

Any time an estimate of the *risk of low flow occurrence* is required, such as when assessing threats to aquatic organisms and their stream habitat, or maintaining water quality.

Example: Regulatory Low Flow The water quality of receiving waters depends on the dilution of the wastewater. In Oklahoma the *7-day averaged low flow with a 2-year return interval* (7Q2) is used to calculate the WQ sampling regime for wastewater discharges based on the risk of low flow volumes relative to discharge volume.

2 - Are All Flows Lower?

Flow Duration Curves graphically display the probability of streamflow magnitude. Is there a difference between drought-influenced and full-record streamflow that could be important for planning?

What is a Flow Duration Plot?

- Uses entire record of daily mean flows
- Shows relative frequency of all recorded flows
- Shape of a duration plot related to stream hydrology:
  - Steep portion indicates high variability: e.g. "Flashy" runoff
  - Shallow indicate stable flows; e.g. Spring-fed or dam release

References

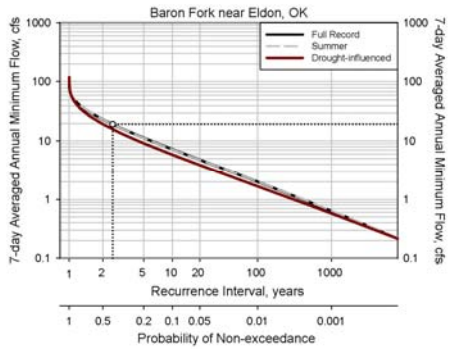
AMS, 2012. Climate Change: An Information Statement of the American Meteorological Society, Adopted 20132, Accessed 11/2015. URL: https://www2.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/climate-change/

AMS, 2013,. Drought: An Information Statement of the American Meteorological Society, Adopted 2013, Accessed 11/2015. URL: https://www2.ametsoc.org/ams/index.cfm/about-ams/ams-statements/statements-of-the-ams-in-force/drought/

Guttman, N. B. and R. G. Quayle. 1996. A Historical Perspective on Climate Divisions. Bull Amer. Meteor. Soc. 77(2). Pp. 293-303.

Lewis, J.M., and Esralew, R.A., 2009. Statistical Summaries of Streamflow in and near Oklahoma Through 2007: U.S. Geological Survey Scientific Investigations Report 2009–5135, 633 p.

Drought-Influenced Low Flow



7-Day Non-exceedance plot for Barren Fork near Eldon, OK

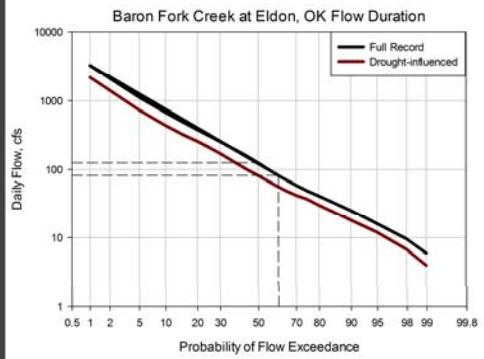
- Regular 7Q2: 23.1 cfs
- Drought 7Q2: 19.3 cfs
- Recurrence interval of 19.3 cfs is 2.6 years (0.4 probability)
- *2.6 years* is approximate value across the state

What does this say about drought-influenced low streamflows?

- The difference between 2-year and 2.6-year is statistically but not functionally significant.
- Slight difference result of difference in number of years and range of flows in record.
- Regular record already has drought years included as lowest annual flows

CONCLUSION: Low-flow drought risk can be estimated without Drought-influenced flow record.

Drought-Influenced Flow Duration



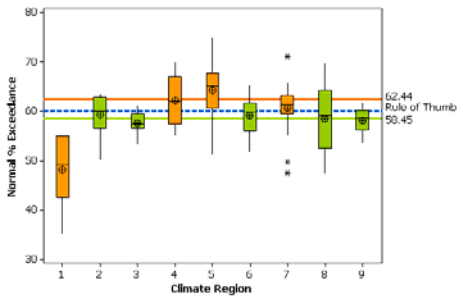
50% Exceedance (Median) Flow

- Full Record (black line) flow: 125 cfs
- Drought-influenced (red line) flow: 82 cfs
  - 2/3 of "normal"

"Normal" exceedance of 82 cfs : 61%

- Are there similar differences between drought and full-record median exceedance flows at other gauges and in other climate divisions?

Comparison of "Normal" Exceedance



Comparison of Drought-Influenced and Full-Record Median Flow for USGS Gauges from each Climate Division

Brown line: Mean of Climate Divisions (1), 4, 5, 7
Green line: Mean of Climate Divisions 2, 3, 6, 8, 9
Blue line: "Rule of Thumb" Approximation

"Normal" Exceedance of Drought Median Flow

- Greater difference between drought and full record shows *greater influence of drought* on flow record
- Significant difference between means of Western/Central Climate Divisions and Eastern Divisions
- Climate Division 1 shows mean "Normal" Exceedance of drought-influenced median less than 50, indicates **increased** drought flows, which is unlikely. It was removed from the mean averaging (brown line), but colored brown since it is expected to behave in a manner similar to other western Climate Divisions.

A Simple Tool for Estimating Drought Flows

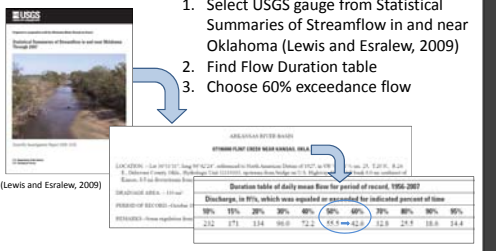
Flow Duration Conclusion

There is a difference between full-record and drought-influenced median flows

The 60% exceedance flow from Flow Duration table is an approximation of "drought influenced" median flow

"Rule of Thumb" Median Drought flow estimate

Low-flow risk can be estimated without creating the drought-influenced flow record.



(Lewis and Esralew, 2009)

1. Select USGS gauge from Statistical Summaries of Streamflow in and near Oklahoma (Lewis and Esralew, 2009)
2. Find Flow Duration table
3. Choose 60% exceedance flow

This simple tool is intended to help in the initial stages of drought planning by allowing a rough estimate for the expected reduction in streamflow magnitude. A subsequent hydrologic study would provide more specific information better suited to final decisions.