Candidate Indicators for Long Term Persistence of Stream Flow Losses for the Lower Colorado River in Texas

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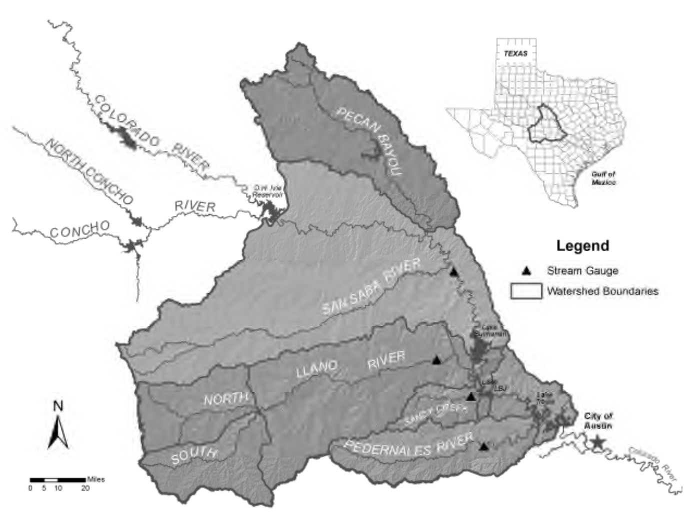
Background

The Lower Colorado River Authority operates two of the Highland Lakes in Central Texas – lakes Buchanan and Travis – to provide water supply for municipal, industrial, agricultural users and environmental flows for the lower Colorado River and Matagorda Bay. The lower Colorado River basin is subject to extended droughts interrupted by intense rainfall.

The basin recently experienced a historic drought. La Niña was present in 2011. La Niña generally contributes to lower-than-average precipitation in Central Texas. In early spring 2011, an intense high pressure ridge set up over the south central U.S., and kept rain and storms away from almost all of Texas. An exceptional drought developed, fed by unprecedented dry and hot weather conditions. Central Texas experienced about 90 days of temperatures at or above 100 degrees Fahrenheit in the summer of 2011.

While precipitation and evaporation were typical in the recent drought, streamflow into the Highland Lakes was as much as 60 percent less than other periods. This research investigates the quantity of streamflow losses in the recent drought period.



Approach

Multi-linear regression models were developed to describe long term and catchment-wide monthly streamflow relationships from 1940 to the present. A combination of high and low streamflow relationships describes three fourths (R^2=76%) of the variation in runoff based on the following predictive variables:

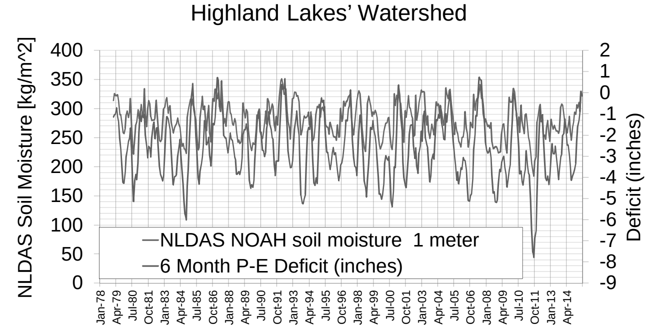
- Monthly areal precipitation (+).
- One month prior areal precipitation (+).
- Monthly areal evaporation (-).
- Cumulative six and 12 month areal precipitation and evaporation deficits (-).
- Persistent streamflow losses as represented by dummy variables (-).

Findings

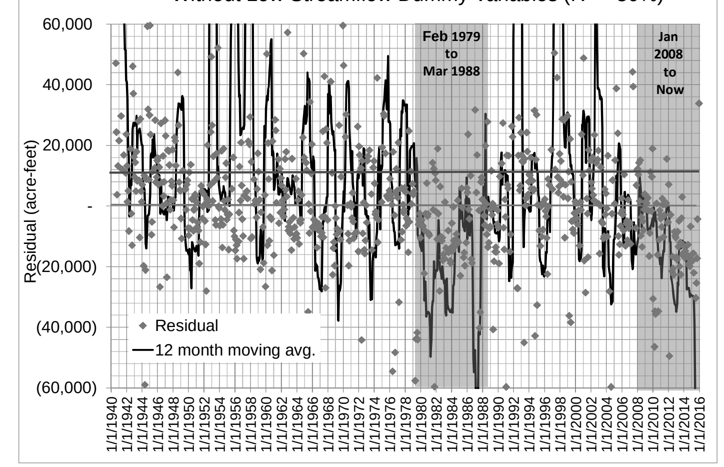
i. Analysis of residual suggests two periods of persistently low streamflow not otherwise explained by the climate predictor variables – 1978 to 1988 and 2007 to present. The finding suggests the current period of persistently low streamflow initiated prior to the extreme events in 2011.
ii. Unexplained persistently low streamflow does not appear to be larger after the 2011 extreme events than before.
iii. Cumulative evaporation and precipitation deficits appear to reflect the soil moisture signal well when compared to NLDAS reanalysis (corr.=74%). This extends the period of record back to 1940 and before the anomalous streamflow periods.
iv. Soil moisture (< 1 meter) alone does not appear to explain the periods of persistent low streamflow.

Neither seasonality nor ENSO variables offered additional predictive skill for streamflow.

Soil Moisture Measurement in the Highland Lakes' Watershed

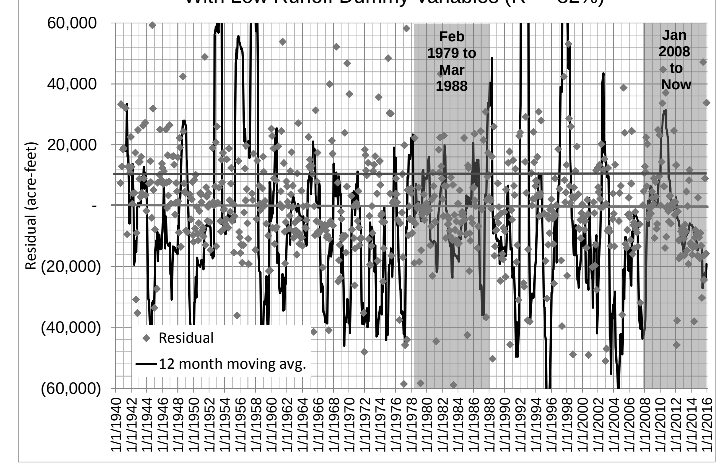


Residuals of Predicted vs Actual Runoff
Without Low Streamflow Dummy Variables (R^2 = 80%)



Observed low run-off bias in actual observations for two extended periods unless a low run-off persistence dummy variables are used.

Residuals of Predicted vs Actual Runoff
With Low Runoff Dummy Variables (R^2 = 82%)



Estimated Streamflow Losses

Period	Low Est.* (Acre-feet)	High Est.* (Acre-feet)
1979-1988	2,500,000	5,700.000
2008-2015	1,800,000	4,100,000

Period	Low Est.* (Average acre-feet/year)	High Est.* (Average acre-feet/year)
1978-1988	280,000	650.000
2007-2015	240,000	540,000

* Estimates based on a 90 percent level of confidence

Candidate Indicators

Indicator Lag	False Positives	False Positive Impact	False Positive Rate
1 year	8	moderate	12%
2 year	3	moderate	10%
3 year	1	low	5%
4 year	0	n/a	0%

Possible Causes of Persistent Low Streamflow

1. Deep soil moisture (> 1 meter) depletion.
2. Groundwater depletion.
3. Inflow estimation error.
4. Unfavorable temporal distribution of rainfall.
5. Persistently small rainfall events (< 2 inches).
6. Spatial shift in rainfall to lower in the basin.
7. Increased interception.

Next Steps

a. Continue monitoring streamflow.
b. Evaluate and possibly isolate low streamflow persistence for smaller catchment areas.
c. Evaluate diagnostics for onset and termination of persistently low streamflow.
d. Incorporate low streamflow persistence state into water supply projection methods.

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