VERDE RIVER

Basin area	5828 square miles
Gage elevation	1800 feet
Average water year flow	441392 acre feet

VERDE RIVER

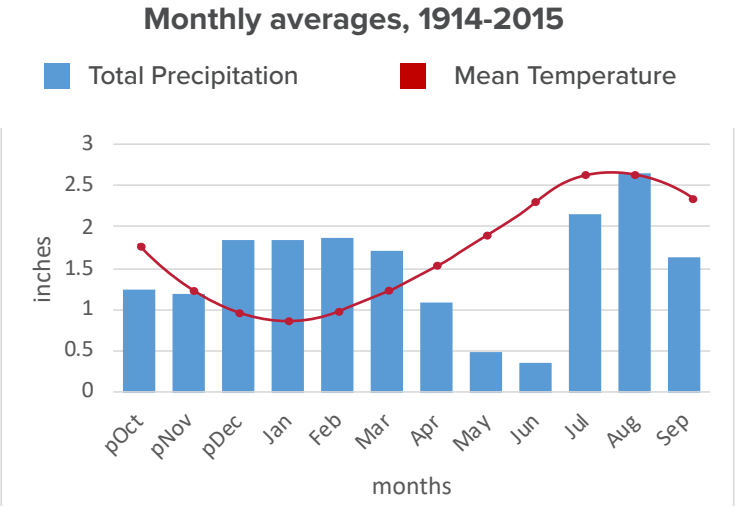
Relationships between Climate and Streamflow

Verde River: Relationships between Climate and Streamflow

What are the main climatic controls on Verde River water year streamflow?

The relationship between water year streamflow and monthly or seasonal temperature and precipitation for the Verde River watershed was examined for the years 1914-2015, along with shorter snowpack records, to determine the most important climatic influences on streamflow (data on P. 5). After identifying the most important climate factors related to water year flow, stepwise linear regression was used to determine the variance in streamflow accounted for by specific climate variables (P. 2). Trends in streamflow and climate were then assessed (P. 3). Droughts were identified, along with the average climate conditions that occurred during the years of each multi-year drought (P. 4). Finally, years for which streamflow and climate conditions were unusual were examined in greater detail (P. 5).

The climate of the basin is characterized by two peaks in precipitation: the cool season (October-March) and the monsoon (June-September). Average temperatures range from 36F in January to 73F in July.

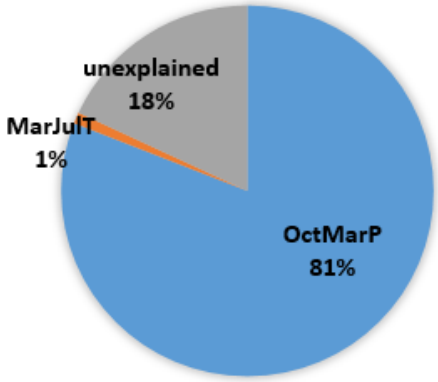


Summary of Main Findings

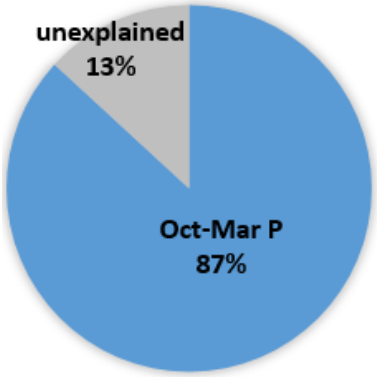
- When all years are considered, cool season (October-March) precipitation is the most important influence on streamflow, accounting for 81% of the variance in flow.
- In years with below median flow, monsoon season temperatures become an important factor, explaining a small but significant portion of the variability in flow.
- There is no evidence of long-term trends in precipitation or SWE, but a decreasing trend in flow is evident, driven by high flows at the beginning of the record; significant warming has occurred over the past 100 years.
- Multi-year droughts are largely controlled by cool season precipitation; interestingly, monsoons are wet during some of these drought periods.
- In some individual years, the monsoon is likely to have had a positive impact on flow relative to cool season precipitation, along with wetter falls and/or springs, and cooler temperatures.
- Cool season precipitation is certainly important for water year streamflow, but fall, spring, and monsoon precipitation can help make up for a very dry winter, and seasonal temperatures can have an influence on streamflow as well.

Verde River: Climatic Controls on Streamflow

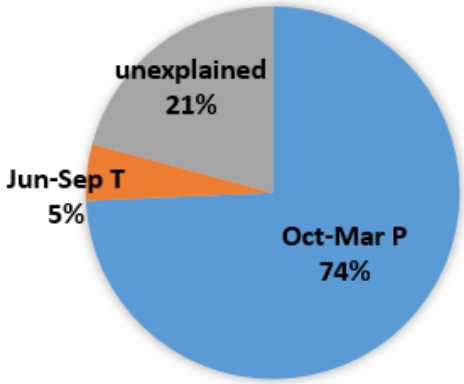
Pie charts below show the seasonal precipitation and temperature variables that are most important for water year streamflow.



All years

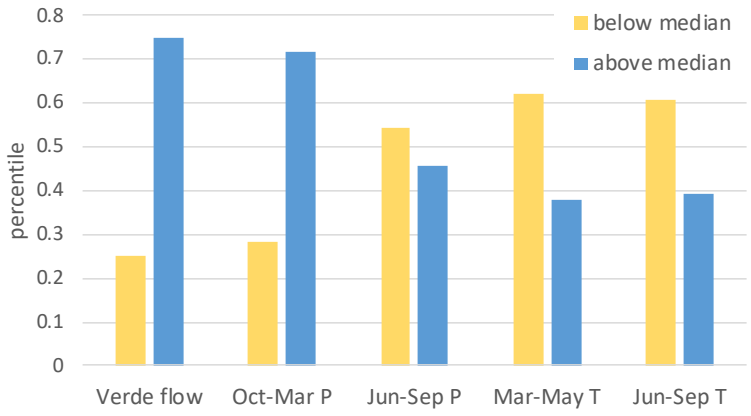


Above median years (high flow)

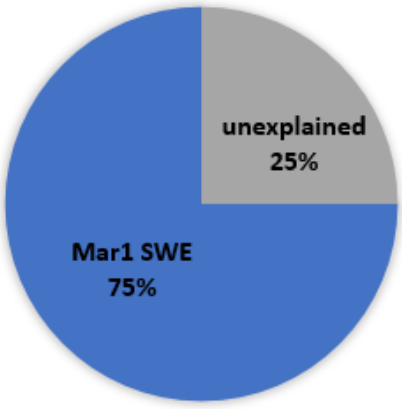


Below median years (low flow)

Climate averages (in percentile) for streamflow years above and below the median indicate that lower flow years are very dry in the cool season, and warm in both spring and monsoon seasons. However, monsoon precipitation is slightly above median in lower flow years and below median in higher flow years.



What about snow?
The snow water equivalent (SWE) of snowpack on March 1 averaged from Snow Bowl, Williams Ski Run, and Baker Butte #2 snow course sites explains 75% of the variance in flow, over the years 1981-2015.



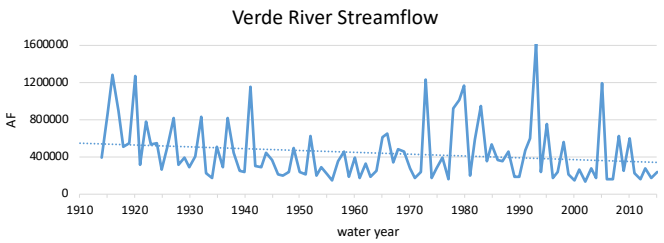
Main findings

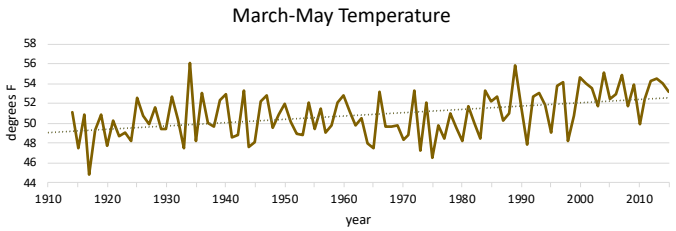
All years: cool season precipitation explains most of the variance in flow, with 1% explained by March-July temperatures.

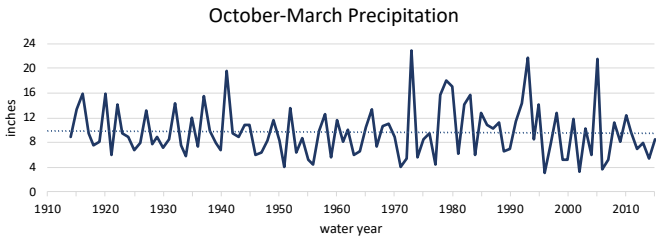
Above median flow years: cool season precipitation is the only climate variable that explains a significant amount of streamflow variability.

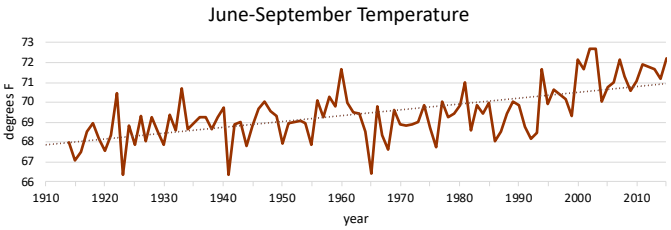
Below median flow years: cool season precipitation explains less of the variance than in higher flow years, and monsoon season temperatures add an additional 5% explained variance.

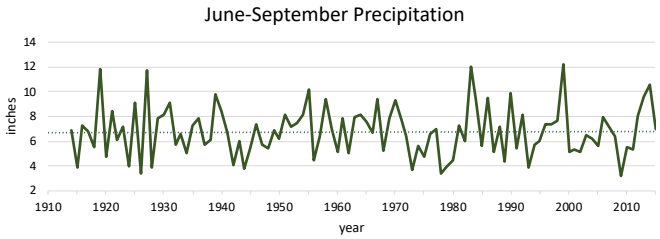
Verde River Streamflow and Climate: Trends Over Time?

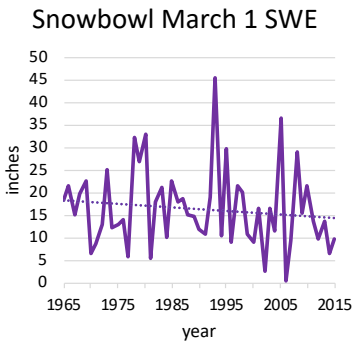








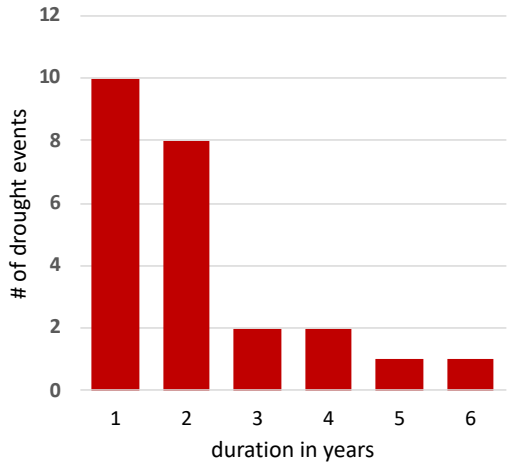




Main findings

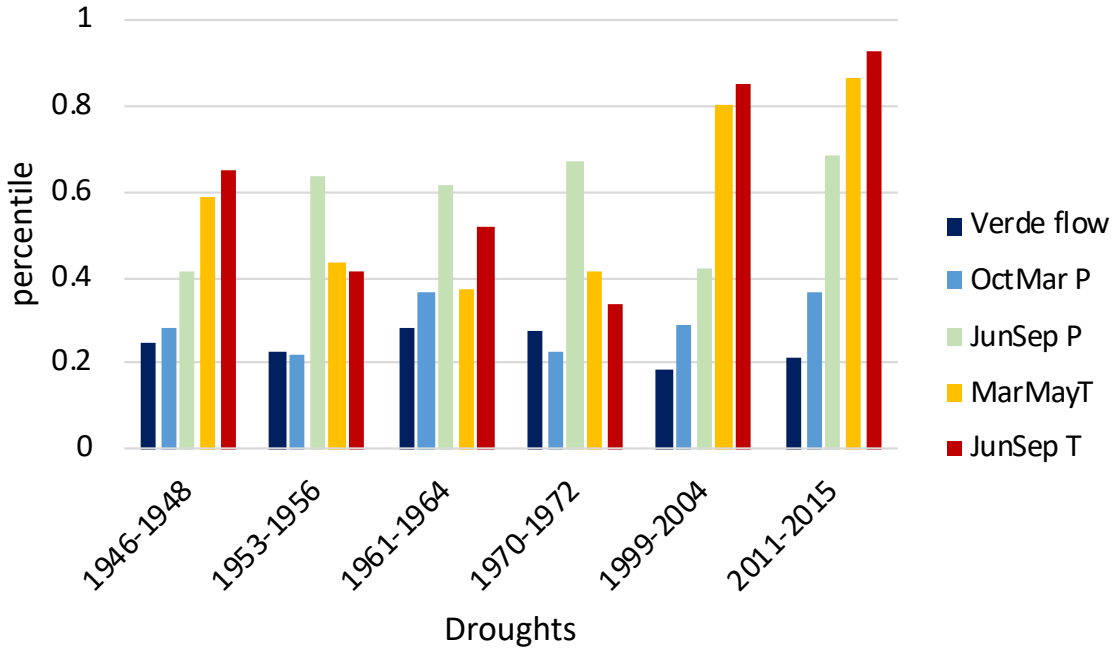
- **Streamflow:** A decreasing trend is significant at the 93% level.
- **Seasonal precipitation:** No significant trends.
- **March 1 snow water equivalent (SWE):** No statistically significant trend in this shorter record (starts in 1965) yet, although a non-significant decreasing SWE trend is visible.
- **Seasonal temperature:** Positive and statistically significant (> 99%) warming trends in both spring and monsoon season temperatures.
- **Warming** has been about 0.33°F/decade in the spring and 0.29°F/decade in summer.

Verde River Streamflow and Climate: Drought



Droughts are defined as single or consecutive years below the median water year flow. Drought duration and number of events are shown to the left.

The **major climate drivers of the six drought events that last three or more years are examined in the graph** (below). Flow is averaged over the drought years, along with corresponding season temperature and precipitation. Values are in percentile.



Main findings

- **Droughts typically last** 1-2 years. The longest drought is a 6-year event, 1999-2004.
- **Cool season** precipitation averages are always low, but higher relative to flows during most droughts.
- **Monsoon precipitation** is above the median in 4 of 6 drought events.
- **Warm summers may play a role in reducing flows** relative to winter precipitation deficits.
- The **warmest droughts** are the two most recent drought, **1999-2004 and 2011-2015.**

Verde River Streamflow and Climate: Unusual Years

Are the driest winters always followed by years with the lowest flows?

Usually, but in 7 of the 20 driest winters, Verde R. flow was higher relative to the extremely dry winter. In all but 2 of these years, the monsoon was extremely wet. In addition, falls and/or springs were usually wet, and temperatures tended to be cool in some or all seasons.

				Precipitation					Temperature			
WY	Verde flow	**Oct-Mar P**		Oct-Nov	Dec-Mar	Apr-May	Jun-Sep		Oct-Nov	Dec-Mar	Apr-May	Jun-Sep
1921												
1984												
1946												
1951												
1955												
1972												
1999												

Can a wet monsoon make up for a dry winter in terms of water year streamflow?

An extremely wet monsoon has never coincided with high flow after a dry winter. However, of the 13 monsoon years in the wettest category that followed extremely or very dry winters, in 6 of these years, flow was higher relative to the low cool season precipitation. As above, these years also appear to have some combination of wet falls or springs, and/or cooler temperatures in one or more seasons.

					Precipitation				Temperature			
WY	Verde flow	**Oct-Mar P**	**Jun-Sep P**		Oct-Nov	Dec-Mar	Apr-May		Oct-Nov	Dec-Mar	Apr-May	Jun-Sep
1921												
1967												
1984												
1951												
1955												
1999												

Color code legend and corresponding percentile values

precip/flow	0-19	20-39	40-59	60-79	80-99
temp	0.19	20.39	40-59	60-79	80-99

Main findings

- The driest winters are *usually* followed by years with the lowest flow, but there are exceptions: 35% of the driest winters had flows that were not in the lowest flow category.
- A wet monsoon cannot make up for a dry winter, but it may moderate the impact of a dry winter, although cooler temperatures, a wet fall and/or wet spring may also be moderating factors.

DATA USED IN THESE ANALYSES

Water Year Streamflow	
Verde River below Bartlett Dam (USGS Gage 09510000)	1914-1944
Verde River below Tangle Creek/above Horseshoe Dam (USGS Gage 09508500)	1945-2015
March 1 snow water equivalent (SWE)	
Snow Bowl	1965-2015
Williams Ski Run	1967-2015
Baker Butte #2	1972-2015
Monthly precipitation & temperature	
PRISM gridded data, area above gage	1914-2015

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Climate Assessment for the Southwest
A NOAA RISA TEAM

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