ADEQ Arizona Department of Environmental Quality

WATER QUALITY DIVISION

White Paper: Analysis of snowpack for estimating flow regimes in Arizona

Prepared by Hans Huth, Dr. Matthew Pace, Patti Spindler, Meghan Smart, and Dr. Erin Jordan

January 2022

Background

The State of Arizona has over 100,000 known miles of surface water at medium resolution hydrography (USGS, n.d.). These surface waters are divided into segments, known individually as a reach. According to the U.S. Geological Survey (USGS), a reach is a section of a stream or river along which similar hydrologic conditions exist. These hydrologic conditions are described as flow regimes in the Arizona Revised Statutes § 49-201 as follows:

- Perennial means a surface water or portion of surface water that flows continuously throughout the year.
- Intermittent means a surface water or portion of surface water that flows continuously during certain times of the year and more than in direct response to precipitation, such as when it receives water from a spring, elevated groundwater table or another surface source, such as melting snowpack.
- Ephemeral means a surface water or portion of surface water that flows or pools only in direct response to precipitation.

ADEQ assigns each surface water reach, lake, pond or other type of surface water an identification number known as a Waterbody Identification Number or WBID. Through analysis of available and credible data, the Arizona Department of Environmental Quality (ADEQ) assigns each WBID one of the flow regimes. A WBID with insufficient data to determine flow regime is assigned an "Undetermined" flow regime. If there is no flow regime data for the WBID, it is assigned as "Null'. As of August 2021, approximately 23 percent of WBIDs in Arizona are assigned a perennial, intermittent or ephemeral flow regime.

With about 77 percent of Arizona WBIDs with an "Undetermined" or "Null" flow regime, ADEQ recognized that additional analysis of available and credible data could be critical to assigning additional flow regimes and verifying the others[1]. After a thorough review of peer-reviewed research and an analysis of readily available data specific to Arizona, ADEQ determined a methodology for estimating intermittent flow regime through analysis of snowpack data. This methodology is applied in the Snowpack Tool.

[1] Flow regimes are not static and can change based on, but not limited to, analysis of additional credible data, shifts in climate, and changes in water use, such as diversion or new discharges to a WBID.

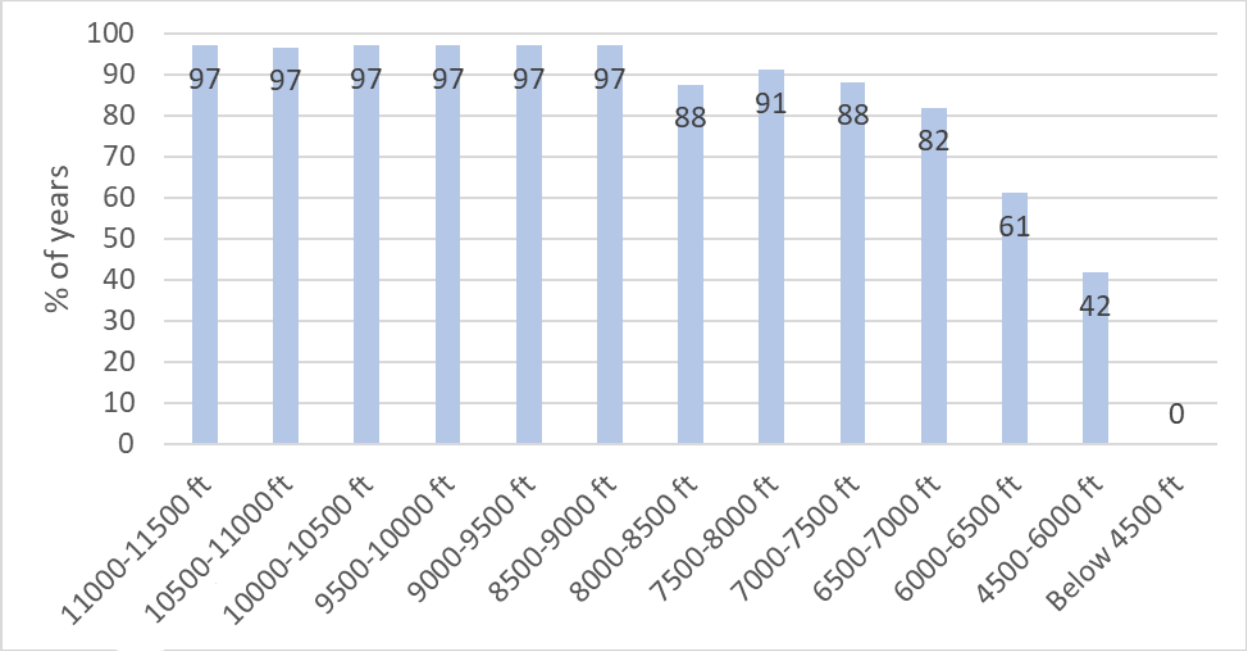
Research and Analysis

Much of Arizona is located in the Basin and Range Province, which is defined by abrupt changes in elevation. For example, in southern Arizona, the city of Tucson sits at an elevation of around 2400 feet, while nearby Mount Lemmon, which is only 17 miles away from downtown as the crow flies, is above 9100 feet. This change in elevation leads to varied climate conditions, and it has often been quoted that driving from Tucson to Mt. Lemmon is comparable to traveling from the Mexican border to the Canadian border in about an hour.

At the high elevations of the Basin and Range Province, snowpack in the winter is common. If sustained for a month or longer, melting of snowpack in the spring leads to seasonal flow in streams originating the mountains (Svoma, 2011; Hunsaker et al., 2012). Snowpack measured at elevations of 1095 to 2166 meters (3593 to 7106 feet) in the Salt and Verde River watersheds contribute significantly to streamflow supporting drinking water reservoirs at lower elevations (Svoma, 2011). Hunsaker et al. (2012) found that snowmelt in the southern Sierra Nevada mountain range contributed to seasonal flow in elevations 1839 to 2410 meters (6033 to 7907 feet). In a study covering the western U.S., including the Basin and Range Province, Knowles et al. (2006) determined that climate conditions below 2000 meters (6562 feet) generally did not sustain seasonal snowpack.

Analyzing data from the Flagstaff Pulliam Airport between 2000 and 2020, ADEQ determined the average time period for two snow storms moving through the region was 20 to 24 days. Based on this analysis, ADEQ selected a conservative value of 30 days for continuous snow on the ground as an assumption for seasonal snowpack in Arizona. ADEQ then consulted with the Salt River Project, which manages water resources for public use in the Verde and Salt River watersheds, to select locations at which to model probable snowpack in Arizona. Applying the methodology in Broxton, van Leeuwen & Biederman (2019) to the selected locations, ADEQ calculated the percent of years with snowpack at various elevations utilizing data from Broxton, Zeng & Dawson (2019) (Figure 1).

Figure 1. Percentages of years of snowpack by elevation.



For elevations at or greater than 6500 feet, snowpack was present in more than 82 percent of the years. At elevations below 6500 feet there is a noticeable change in reliable snowpack years. Based on the data analysis and published research, ADEQ selected a 6500-foot threshold to evaluate a WBID for potential intermittent flow influenced by seasonal snowmelt.

Application of the Tool

ADEQ applies the Snowpack Tool with the 6500 foot or higher threshold to estimate an intermittent flow regime for a WBID. If the origin of a WBID is below 6500, the Snowpack Tool may not be not relevant and therefore is not applied to evaluate the WBID flow regime.

ADEQ recognizes that there may be some uncertainty in application of the tool. For example, north-facing drainages in mountain ranges with greater annual snowpack (i.e. Bradshaw or White Mountains) may experience intermittent flow from snowmelt at elevations lower than 6500'. To account for uncertainty at elevations lower than 6500', definitive flow regimes are not assigned using the tool. The Snowpack Tool is only an indicator of flow regime for a WBID at this time. To assign a flow regime, ADEQ requires additional empirical data, including, but not limited to, flow gauge data, information from field visits, analysis of imagery (i.e. game cameras, satellite imagery, etc.), or results of a streamflow duration assessment methodology (SDAM) survey. Results of the tool can assist ADEQ with prioritization of additional data gathering efforts.

Conclusion

Knowledge of flow regimes is critical for federal and state jurisdictional evaluations of Arizona surface waters. With no flow regime assigned to about 77 percent of Arizona WBIDs, ADEQ needs tools to assist with these evaluations for purposes of assessing and permitting surface

waters. Research and data indicate the methodology applied in the Snowpack Tool is effective for estimating flow regime of Arizona WBIDs. The Snowpack Tool is one of multiple tools ADEQ utilizes for this purpose.

References

Broxton, P.D., van Leeuwen, W.J.D., Biederman, J.A. (2019). *Improving Snow Water Equivalent Maps With Machine Learning of Snow Survey and Lidar Measurements*. Water Resources Research, 55(5), 3739-3757. https://doi.org/10.1029/2018WR024146.

Broxton, P., Zeng, X., Dawson, N. (2019). *Daily 4 km Gridded SWE and Snow Depth from Assimilated In-Situ and Modeled Data over the Conterminous US, Version 1*. Boulder, Colorado USA. NASA National Snow and Ice Data Center Distributed Active Archive Center. https://doi.org/10.5067/0GGPB220EX6A. Retrieved September 2020 from https://nsidc.org/data/NSIDC-0719/versions/1.

Hunsaker, C.T., Whitaker, T.W., Bales, R.C. (2012). *Snowmelt Runoff and Water Yield Along Elevation and Temperature Gradients in California's Southern Sierra Nevada*. Journal of the American Water Resources Association (JAWRA) 48(4), 667-678. https://doi.org/10.1111/j.1752-1688.2012.00641.x.

Knowles, N., Dettinger, M.D., Cayan. D.R. (2006). *Trends in Snowfall versus Rainfall in the Western United States*. *J. Climate* 19(18), 4545–4559. https://doi.org/10.1175/JCLI3850.1.

Svoma, B.M. (2011). *Trends in snow level elevation in the mountains of central Arizona*. International Journal of Climatology 31(1), 87-94. https://doi.org/10.1002/joc.2062.

USGS. (n.d.) *USGS*. Retrieved from National Hydrography Dataset: https://www.usgs.gov/national-hydrography/national-hydrography-dataset?qt-science_support_page_related_con=0#qt-science_support_page_related_con.