THE VERDE RIVER—A CAUTIONARY TALE OF TWO STREAMGAGES with APPENDIX
By
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The records of two U.S. Geological Survey (USGS) streamgages on the Verde River show the occurrence of irrigation-season stream flows of 30 cubic feet per second (cfs) or less in some years within the past forty years (Figs. 1 and 2) and portend the eventual loss of perennial flow in some reaches of the Verde River.

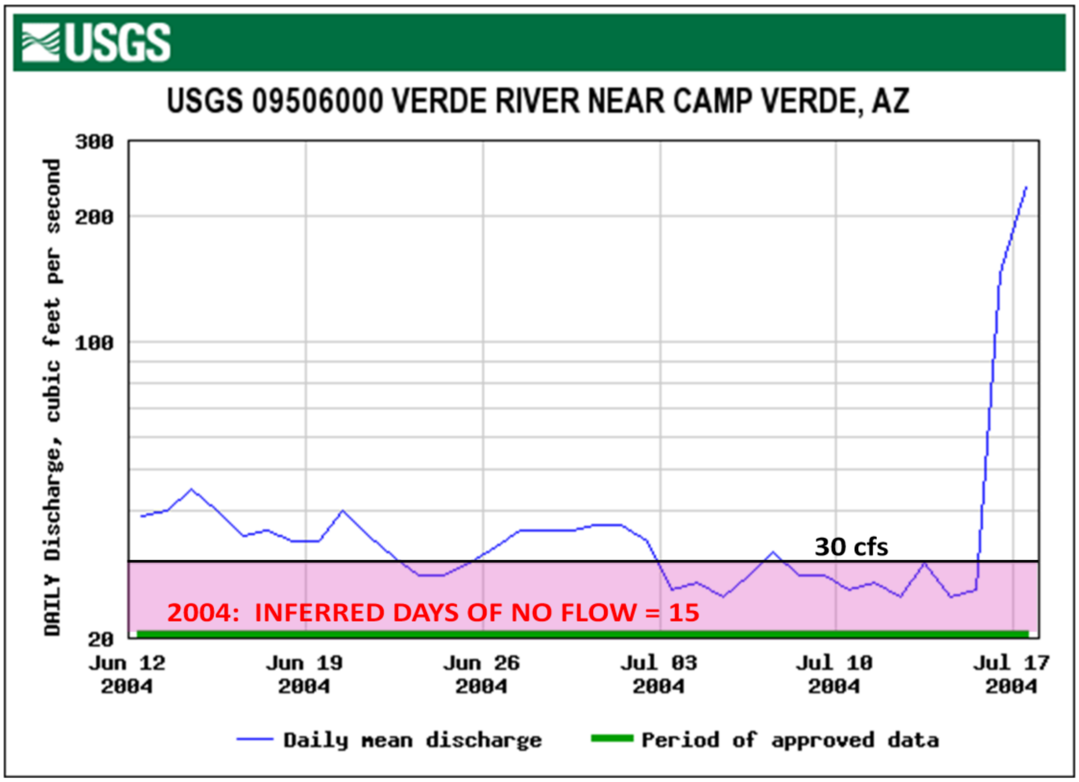

Figure 1. Record of Verde River flow, June 12, 2004, through July 17, 2004, at USGS streamgage 09506000, about 8 miles south of Camp Verde, downstream from Beasley Flat and within the Verde Wild and Scenic River reach. The curve shows the daily mean river flow at the gage in cfs. The top of the colored band represents 30 cfs. Segments of the curve touching or within the colored bar represent periods during June and July of 2004 when a base-flow reduction of 30 cfs would have caused the river to be dry.

Base flow is the component of river flow that is provided by groundwater flowing directly to the river from springs and seeps in the river bed or banks. Without its base flow, the Verde would be an intermittent stream or dry wash that flows only in response to rain or snowmelt events.

The selection of 30 cfs as a potential tipping point for Verde River base flow in coming decades is based on: (1) estimates of future new water use within the upper and middle Verde River watersheds; and (2) recognition that pumping intercepts and removes groundwater that would otherwise reach the river. The effect on base flow is not instantaneous, but eventually the base flow decreases by an amount approximately equal to what is pumped and consumed. (See appendix for detailed supporting data, concepts, and maps).

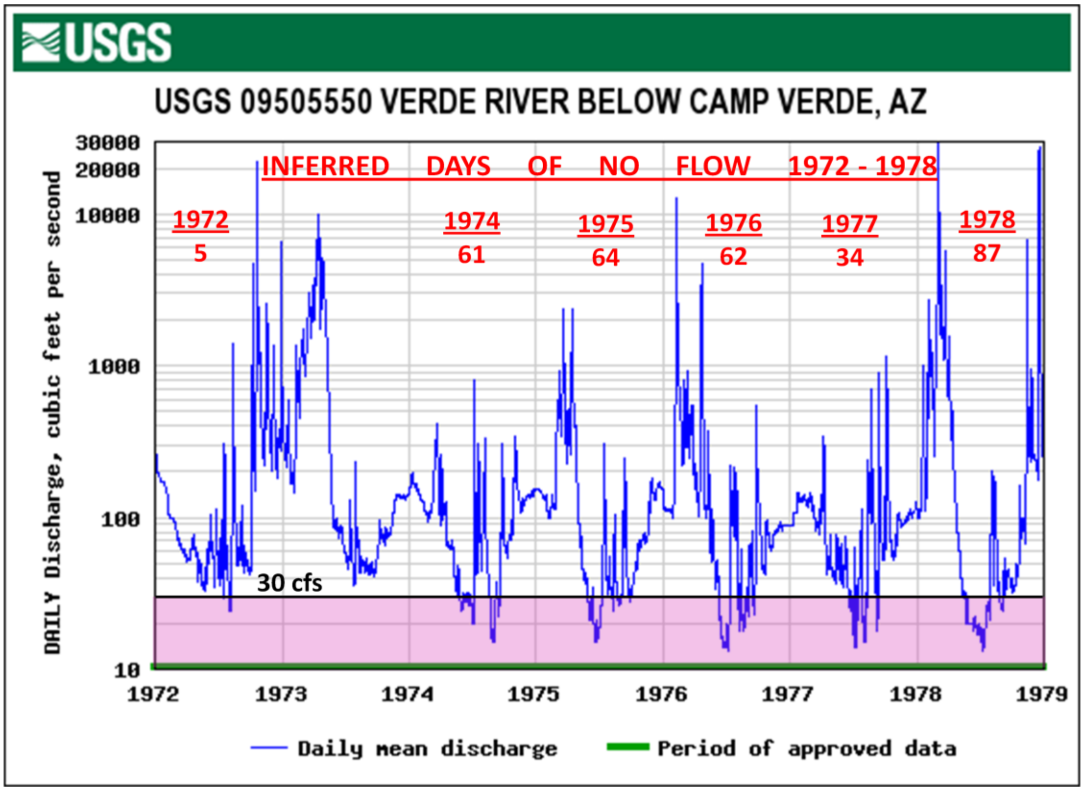

Figure 2. Record of Verde River flow, 1972 through 1978, at the former USGS streamgage at White Bridge, where AZ 260 crosses the Verde River. The gage recorded continuous data from late 1971 through 1978. The curve shows the river flow at the gage in cfs. The top of the colored band represents 30 cfs. Thus, segments of the river-flow curve within the colored band represent periods during the summer and fall months of 1972 through 1978 when a base-flow reduction of 30 cfs would have caused the river to be dry.

Groundwater coming from the upper Verde watershed passes the USGS streamgage near Paulden and provides all or nearly of the base flow in the upper 25 miles of the river. In recent years the summer base flow recorded at the gage has been about 20 cfs; for this analysis summer base flow is of primary concern because, owing to irrigation demands in the Verde Valley, summer is the time of lowest base flow. Springs above the Paulden gage provide all or nearly all of the base flow measured at the gage. Potential as-yet-unmet water demands in the upper Verde River watershed (Prescott Active Management Area and Big Chino and Williamson Valleys) substantially exceed the current 20-cfs summer base flow. If that future demand is met by additional groundwater pumping in the upper Verde River watershed, the result would be the loss of approximately 16 cfs of the Verde River base flow that now enters the Verde Valley above Clarkdale.

In addition, a recent projection of potential unmet water demand owing to population growth in the Verde Valley is approximately 14 cfs by 2050. Additional pumping of groundwater to meet this demand would eventually cause a base-flow reduction of approximately 14 cfs. Added to the loss of approximately 16 cfs of base flow supplied by the upper Verde River, the total potential decrease of flow in the Verde is approximately 30 cfs.

A projected hypothetical 30-cfs reduction of base flow at the gage below Beasley Flat would have caused 15 days of no flow in 2004; it also would have caused 2 days of no river flow in 2007. At White Bridge, the same hypothetical reduction in base flow would have caused 5 days of no flow in 1972, and 61, 64, 62, 34, and 87 days of no measurable flow in 1974, 1975, 1976, 1977, and 1978, respectively (Fig. 2).

There is, of course, an oversimplification in this analysis—that the irrigation diversions would continue to operate as normal. However, if there was no water flowing in the river in the southern part of the Verde Valley, there would be no river water available there to divert. On the other hand, reduction of the amount of river flow diverted for irrigation could reduce the likelihood of having periods of no river flow at White Bridge or at the current USGS gage below Beasley Flat.

Elimination of perennial flow in Arizona rivers because of over-commitment of the groundwater and their conversion to intermittent washes that flow only after storms or when snow is melting has been a common occurrence in Arizona. Is it too late to prevent parts of the Verde River from becoming intermittent like its southern Arizona counterparts, the Santa Cruz River (Fig. 3) and, recently, part of the upper San Pedro River? Barring heroic mitigation, expected demand over the coming decades for water to support the growing populations in the Prescott Active Management Area, the Big Chino and Williamson Valleys, and the Verde Valley will eventually doom perennial flow in some reaches of the Verde River.

Figure 3. Dry streambed of a formerly perennial reach of the Santa Cruz River on Guevavi Ranch, southeastern Arizona. (Courtesy of Dan Campbell of The Nature Conservancy).

APPENDIX

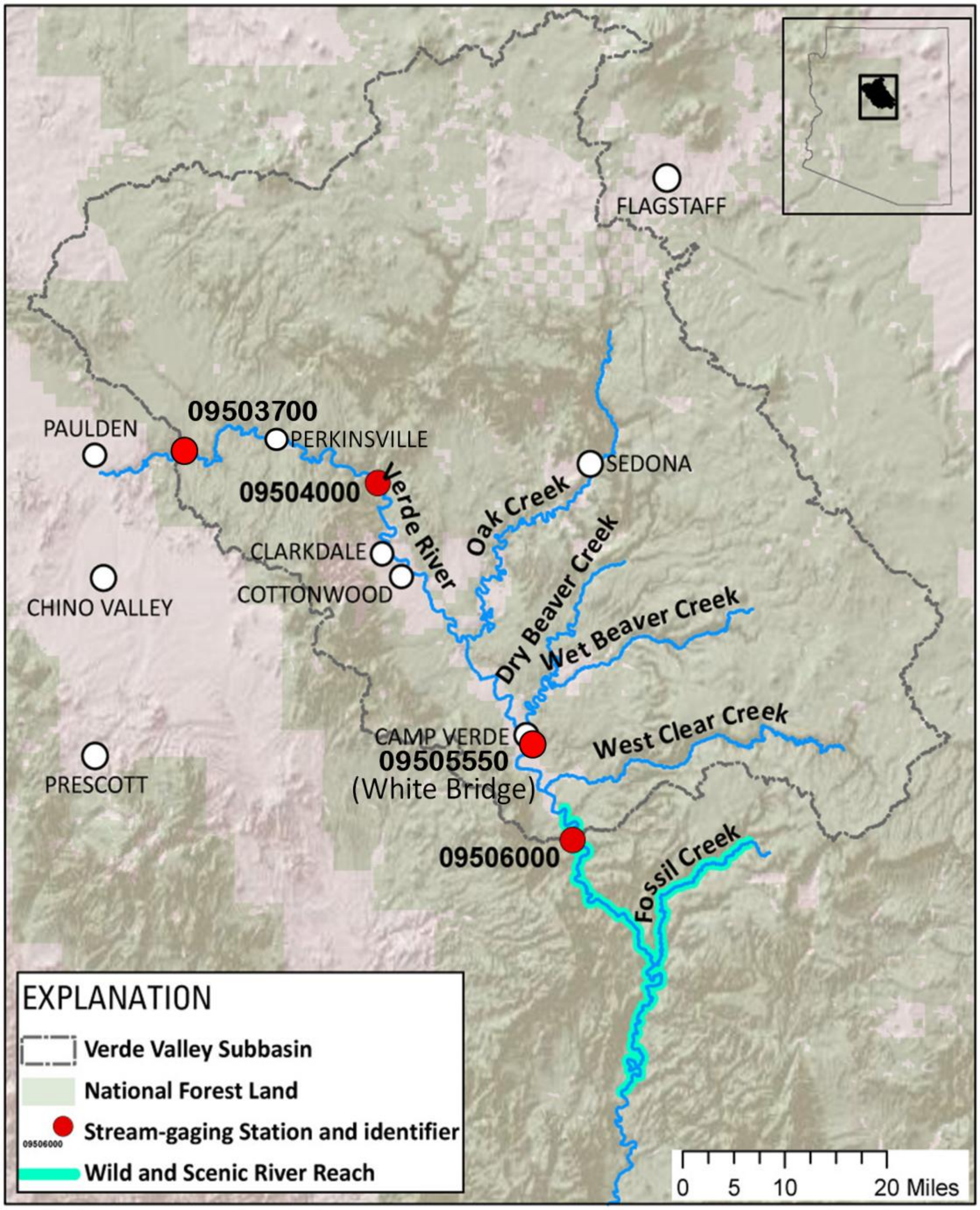

Figure 4. Map of the upper and middle Verde River watersheds showing the locations of USGS streamgages and identifying specifically the Verde River near Paulden (09503700), Verde River near Clarkdale (09504000), and Verde River near Camp Verde (09506000) gages.

Potential Future Groundwater Demand in the Upper and Middle Verde Watersheds

Projections of the Central Yavapai Highlands Water Resources Management Study (CYHWRMS), Phase 1-Demand Analysis, completed in 2010 and available on the website of the Yavapai County Water Advisory Committee (http://www.co.yavapai.az.us/Content.aspx?id=20562), estimate substantial increases in population and water demand from 2006 to 2050 (table 1).

Area	2006 Population	2050 Population	Population Change x	2006 Water Supply af/y	2050 Water Demand af/y	2050 Unmet Demand af/y
PrAMA	121,629	352,940	2.9	25,416	57,411	31,995
Big Chino sb	9,124	58,379	6.4	10,012	13,159	3,148
Verde Valley sb	70,281	183,073	2.6	36,675	46,811	10,136
Total	201,034	594,392	3.0	72,103	117,381	45,279

Table 1. Summary, from data of Central Yavapai Highlands Water Resources Management Study, Phase-1 (CYHWRMS, 2010), of estimated 2006 population and water supply in study area sub-basins and projected 2050 population, water demand, and unmet water demand. PrAMA, Prescott Active Management Area, includes Little Chino and Upper Agua Fria Sub-basins; sb, sub-basin. For additional detail, see CYHWRMS at http://www.co.yavapai.az.us/Content.aspx?id=20562. See figure 5 for location of sub-basins and PrAMA.

Potential water demand in the Little Chino Sub-basin:

The CYHWRMS Phase-1 analysis estimates that total unmet water demand in 2050 in the PrAMA could be 31,995 acre-feet per year (af/y). Part of the PrAMA is in the Little Chino Sub-basin of the upper Verde River watershed, and part is in the Upper Agua Fria Sub-basin, which is outside of the upper and middle Verde River watersheds. CYHWRMS planning areas (including the municipalities of Prescott and Chino Valley) that are entirely within the Little Chino Sub-basin bear an estimated unmet 2050 water demand of 14,555 af/y. The other planning areas in the PrAMA (including the municipalities of Prescott Valley and Dewey-Humboldt) acquire either all or part of their water from the Little Agua Fria Sub-basin or from both the Little Chino and Upper Agua Fria Sub-basins. Thus 14,555 af/y represents a minimum estimate for unmet 2050 water demand in the Little Chino Sub-basin.

Potential water demand in the Big Chino Sub-Basin:

The CHYWRMS estimate of unmet water demand in 2050 for the Big Chino Sub-basin is 3,148 af/y. This estimated unmet demand in 2050 reflects an estimated increase from 1,681 af/y in 2006 to 8,989 af/y in 2050 in municipal/domestic water needs offset by an estimated 50 percent reduction (4,162 af/y) in water use for agricultural irrigation. The intent of the CYHWRMS

Phase-1 study was to address unmet water demand related within each planning area only to the demands of municipal and domestic use, commercial and industrial use, and agricultural use.

However, there are potential additional demands for Big Chino groundwater that could eventually materialize either in full or in part and thus merit consideration. Arizona State law provides for importation at an unspecified future time of approximately 18,000 af/y of groundwater from the Big Chino Sub-basin to the municipalities of the PrAMA. Importation of groundwater from the Big Chino Sub-basin to the PrAMA is planned for consideration in a later phase of the CYHRWMS analysis. Importation of a part of that 18,000 af/y requires retirement of irrigated agriculture in the Big Chino Sub-basin. Combining an 18,000 af/y exportation of groundwater to the PrAMA, a 3,148 af/yr unmet CYHWRMS phase-1demand in 2050, and an offset to those demands from retirement of all remaining irrigation (4,162 af/yr) would give a resulting eventual unmet demand of 16,986 af/yr for the Big Chino Sub-basin.

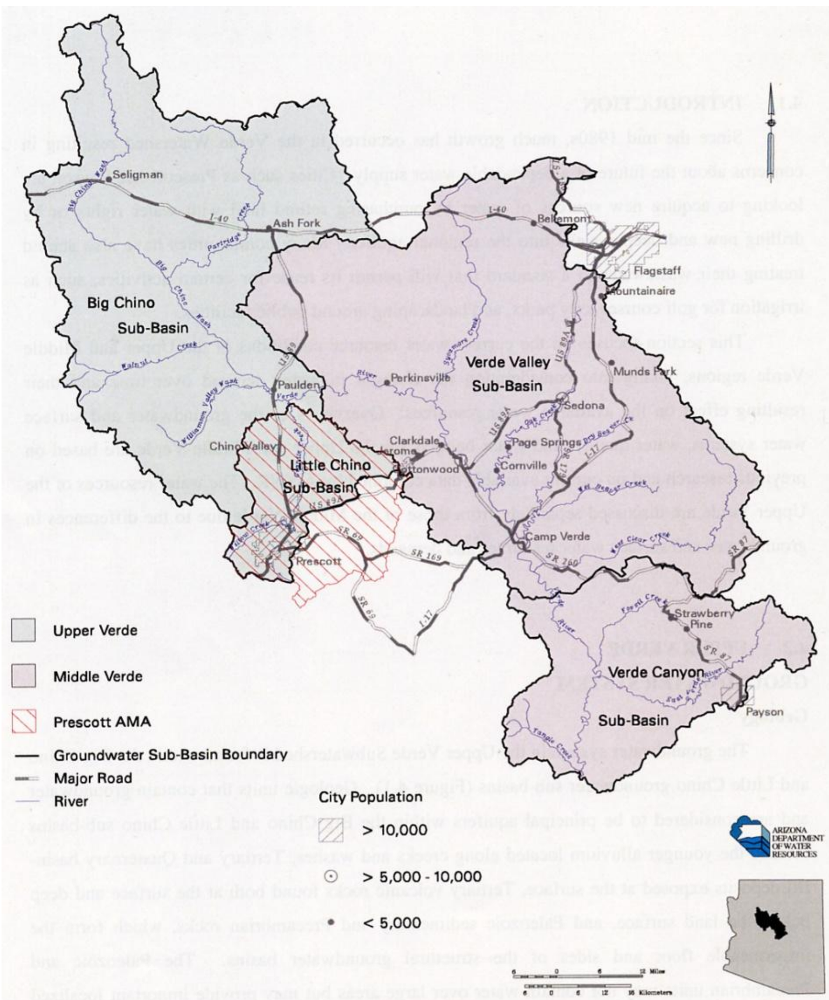

Figure 5. Ground-water sub-basins of the upper and middle Verde River Watershed. (Arizona Department of Water Resources, 2000, Verde River Watershed Study, fig 4.1).

A possible further eventual demand in the Big Chino Sub-basin stems from potential real estate development in the Big Chino and Williamson Valleys beyond that projected by CHYRWMS phase 1. Approximately the lower 16 miles of Williamson Valley Wash and the lower 34 miles of Big Chino Wash flow through a broad alluvial basin filled with alluvial and volcanic deposits that host the host the basin-fill aquifer, or, as identified in figure 6, the principal aquifer in the alluvial portion of the basin. About ⅞ of the area directly overlying the basin-fill aquifer, or about 235 square miles, consists of contiguous private land and State Trust land. The terrain is primarily grass land with gentle relief, and groundwater occurs throughout at depths that range from a few feet to several hundred feet (Blasch, K.W., Hoffmann, J.P., Graser, L.F., Bryson, J.R., and Flint, A.L., 2006, Hydrogeology of the upper and middle Verde River watersheds, central Arizona: U.S. Geological Survey Scientific Investigations Report 2005–5198, 101 p., 3 plates; Schwab, K.J., 1995, Maps showing groundwater conditions in the Big Chino sub-basin of the Verde River basin Coconino and Yavapai Counties, Arizona-1992, Arizona Department of Water Resources Hydrologic Map Series Report No. 28).

Development of all the private and State Trust land that overlies the basin-fill aquifer would result in approximately 75,000 homes if the average density were one home for every two acres. Residence of an average of 2.5 people per home in this area would amount to 187,500 citizens. Water delivery to these citizens at a rate of 137 gallons per citizen per day (which is the CYHWRMS projected average daily demand per person for 2050 in the Big Chino Sub-basin) would amount to an annual demand of approximately 29,000 af/y. There is no assurance, of course, that all or even part of this private and State Trust land will be developed at some future time. However, with its mild climate, moderate topographic relief, and available groundwater, it comprises a vast area of desirable land that could be developed with relative ease.

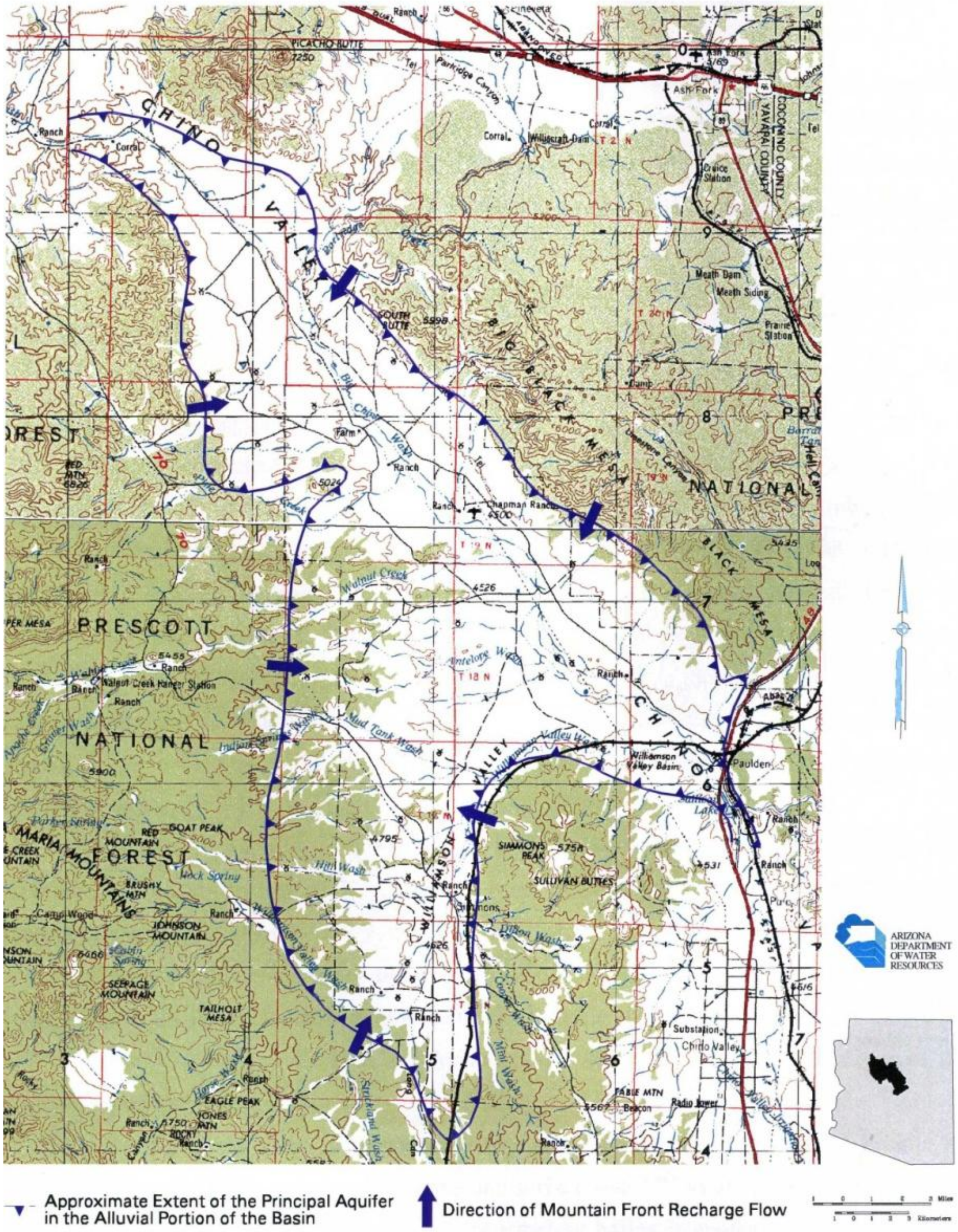

Figure 6. Boundary of the basin-fill aquifer in the Big Chino Sub-basin (Arizona Department of Water Resources, 2000, Verde River Watershed Study, fig 4.3)

Potential water demand in the Verde Valley Sub-basin:

The CYHWRMS estimate for unmet water demand for 2050 in the Verde Valley Sub-basin is 10,136 af/y. This estimate reflects a postulated greater than two-fold increase in municipal/domestic (household) water demand—from an estimated 13,519 af/y in 2006 to a postulated 29,231 af/y in 2050—and a ⅓ reduction in agricultural irrigation—from an estimated17,818 af/y in 2006 to a postulated 11,889 af/y in 2050. Agricultural irrigation in the Verde Valley depends primarily on diversion of water from the Verde River and its major perennial tributaries. Presumably the postulated intent is to meet a part of the increased municipal/domestic demand in 2050 by diversion and use of surface water that is now used for agricultural irrigation.

Summary of potential water demands in the upper and middle Verde watersheds

CYHWRMS postulates unmet water demands in 2050 of ≥14,555 af/y or ≥20 cubic feet per second (cfs) in the Little Chino Sub-basin, 3,148 af/yr (4 cfs) in the Big Chino Sub-basin, and 10,136 af/yr (14 cfs) in the Verde Valley Sub-basin. Potential additional future demands in the Big Chino Valley that were not considered in the CYHWRMS phase-1 analysis are: (1) legally sanctioned importation of approximately 18,000 af/y (25 cfs) of groundwater from the Big Chino Valley to the PrAMA to alleviate over-pumping of the Little Chino Sub-basin aquifer system and to support continuing development; and (2) the possibility of eventual intensive development in the Big Chino Sub-basin that could demand as much as 29,000 af/y (40 cfs) of Big Chino Sub-basin groundwater.

Eventual Effect on Verde River Flow of Past, Current, and Potential New Water Demands

Groundwater in the aquifer systems of the upper and middle Verde River watersheds flows under the force of gravity and exits at the Verde River. Prior to development and the first water wells, groundwater was discharged from the aquifers only through evapotranspiration via riparian vegetation and through natural discharge to springs and seeps both above and below the beds of the river and its tributaries. Before development, the sum of discharge of groundwater from the aquifer to the river and its tributaries and to evapotranspiration was, on average, essentially equal to the natural recharge from infiltration to the aquifers of water from rainfall and snowmelt.

The groundwater exiting to the river provides the base flow, which is the consistent year-round flow that makes the river perennial. More voluminous flow events occur only in response to storms or snowmelt. Pumping intercepts and removes groundwater that would otherwise reach the river. Without its base flow, the river would be a dry wash that flows only in response to storms and snowmelt.

Part of the pumped groundwater used for irrigation infiltrates below the root zone and eventually returns to the aquifer. In addition, some municipalities return treated wastewater to the aquifer. The effect on base flow—either from the pumping itself or from return of part of the pumped water to the aquifer—is not instantaneous, but eventually the base flow decreases by an amount approximately equal to what is pumped and consumed. To read more about this concept see the recent USGS report: *Simulated Effects of Groundwater Pumping and Artificial Recharge on Surface-Water Resources and Riparian Vegetation in the Verde Valley Sub-Basin, Central Arizona* (U.S. Geological Survey Scientific Investigations Report 2010-5147; the report is available online at: http://pubs.usgs.gov/sir/2010/5147/.

Although the preceding analysis addresses only the possible impacts of potential new groundwater demands on Verde River base flow, it is important to recognize that some part of the effect of past and current groundwater consumption on the base flow has not yet materialized. The analysis addresses only summertime river-flow data because summer is the time of maximum diversion of river water for irrigation in the Verde Valley.

The contribution of groundwater passing the USGS Paulden gage represents, at face value, both historically and recently, about ⅓ of the base flow entering the Verde Valley at the USGS Clarkdale gage. In recent years the summer base flow recorded at the Paulden gage is about 20 cfs; for this analysis summer base flow is of primary concern because, owing to irrigation demands in the Verde Valley, summer is the time of lowest Verde Valley base flow. Wirt (2005, Sources of base flow in the upper Verde River: *in* Wirt, Laurie, DeWitt, Ed, and Langenheim, V.E., eds., Geologic framework of aquifer units and ground-water flow paths, Verde River headwater north-central Arizona: U.S. Geological Survey Open-File Report 2004-1411, p. F1-F34) estimated that between 94 and 100 percent of the base flow recorded at the Paulden gage is provided by discharge of groundwater from the Big Chino and Little Chino Sub-basins. Thus, for this analysis, between 18.8 and 20 cfs is considered as the contribution of the Big Chino and Little Chino Sub-basins to summer base flow measured at the Paulden gage.

However, a portion of the base flow entering the upper Verde River at the Paulden gage is lost to evapotranspiration (ET) in its transit from the Paulden gage to the Clarkdale gage, which is at the upstream end of the Verde Valley and, thus records Verde River flow entering the Verde Valley. Blasch and others (2006) estimated that the rate of ET between the Paulden and Clarkdale gages is approximately 0.1 cfs per mile, which implies a total loss to ET of approximately 4 cfs between the two gages. Although the river's base flow decreases over the approximately 15-mile reach between the Paulden gage and Perkinsville, there is substantial gain in base flow in the reach between Perkinsville and the Clarkdale streamgage. Algebraically apportioning the loss of base flow to ET between the summer base flow measured at the Paulden gage and the additional base flow that enters the river below Perkinsville, I estimate that ET reduces the Paulden-gage component of the base flow by approximately 2.4 cfs between the two gages. Thus, the summer groundwater contribution from the Big and Little Chino Sub-basins to the Verde River as it enters the Verde Valley is between about 16.4 and 17.6 cfs. For this analysis, I choose the lower limit of this range and round it to 16 cfs.

Clearly, the future demands projected for both the Big Chino and Little Chino Sub-basins exceed 20 cfs summer base flow in the upper Verde River and must eventually reduce Verde River base flow in the Verde Valley by at least 16 cfs.

The major water demands of the Verde Valley, irrigation and municipal/domestic use, are met, respectively, by diversion of water from the Verde River and its perennial tributaries and groundwater pumping. The marked proliferation of water wells in recent years (Fig. 7) suggests that normal practice is to meet increased municipal/domestic demand by adding new wells and that the impacts of many of these wells on base flow in the Verde River have not yet been fully realized. For simplicity in the following analysis, the 14 cfs unmet 2050 demand estimate of the CYHRWMS phase-1 study is used as the basis for illustrating the possible eventual impact on Verde River base flow of future water demand in the Verde Valley.

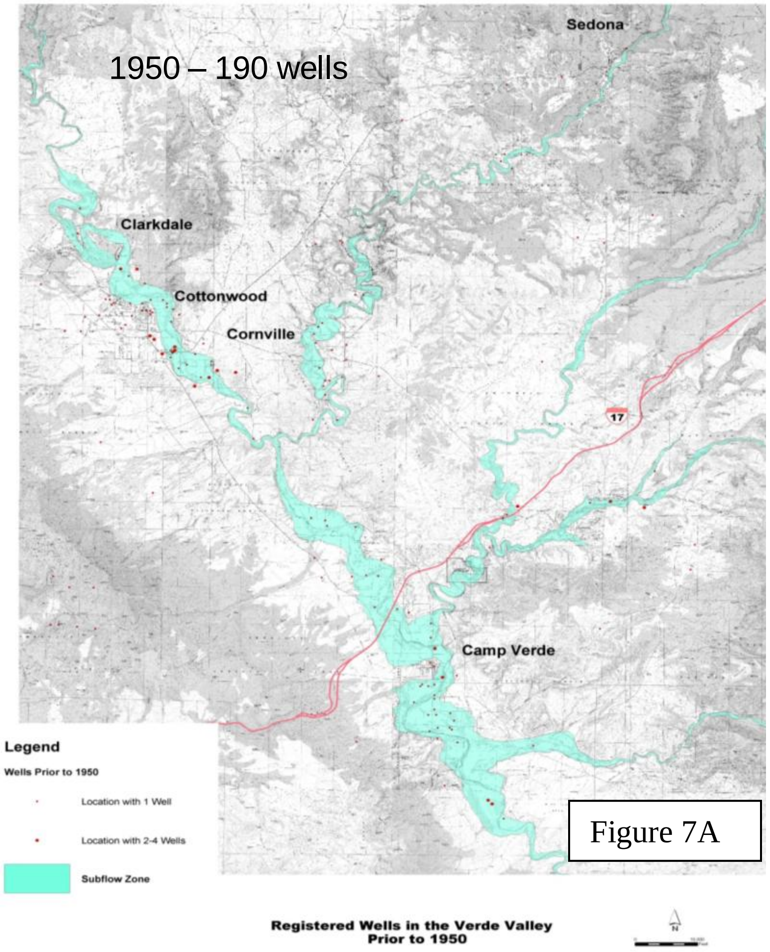

Figure 7A

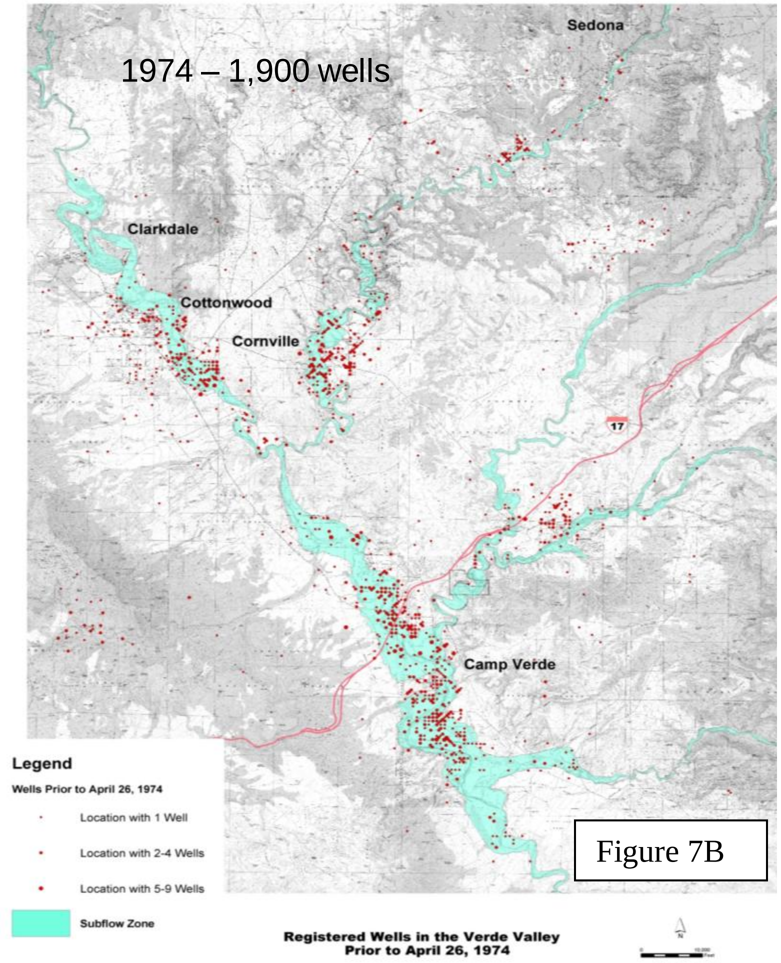

Figure 7B

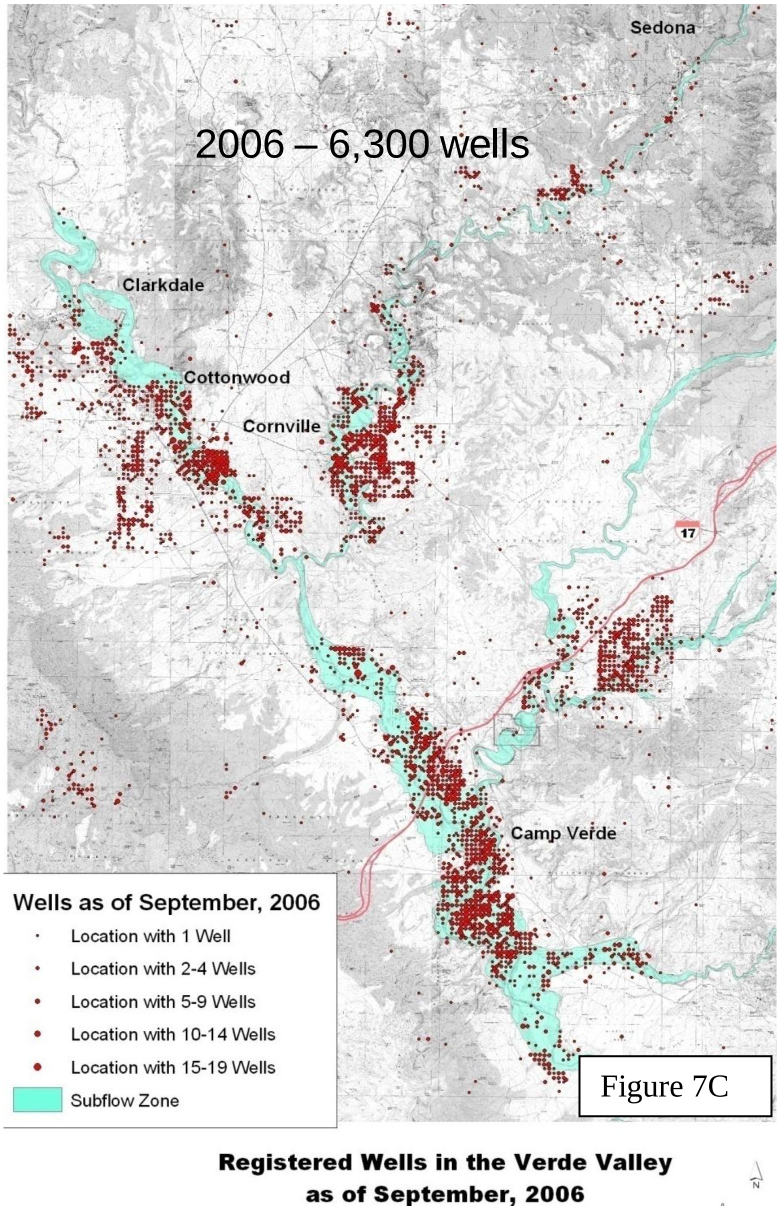

Figure 7. Numbers and locations of water wells in the Verde Valley in 1950, 1974, and 2006. Courtesy of the Salt River Project. The distribution of Holocene river alluvium along the Verde as recently mapped by geologists of the Arizona Geological Survey (Cook, J.P., Pearthree, P.A., Onken, J.A., Youberg, Ann, and Bigio, Erica R., 2010, Mapping of Holocene river alluvium along the Verde River, Central Arizona: Arizona Geological Survey, Report to the Adjudication and Technical Support Unit, Surface Water Division, Arizona Department of Water Resources, 1:24,000; see http://www.azwater.gov/AzDWR/SurfaceWater/Adjudications/default.htm) differs in some detail from the earlier portrayal of subflow zone (above) by the Salt River Project.