EFFECT OF GROUND-WATER PUMPING ON SPRING FLOW TO THE VERDE RIVER
(A more technical and complete replacement of Musings of November 12, 2009 and with the same conclusion)

By Hjalmar W Hjalmarson, PE
March 30 , 2010

How quickly will the base flow in the Verde River be impacted by Prescott's proposed pumping of groundwater of the Big Chino Valley?

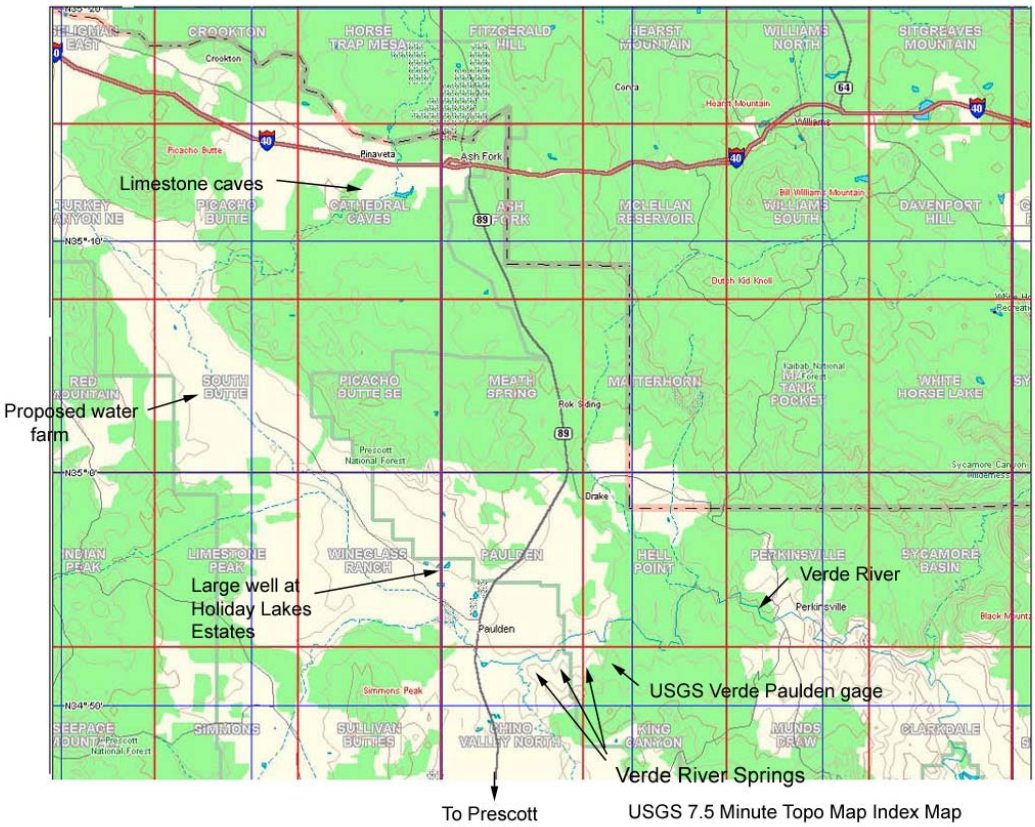
Speculation and wishful thinking abound in the Big Chino pipeline issue at the headwaters of the Verde River. Newspaper accounts for at least the past 13 years describe a conflict known as the Big Chino water war. Clear thinking and science have often been set aside by screwy Arizona water law on which the Arizona Department of Water Resources is founded. ADWR and active management areas (AMAs) were created by the state legislature in 1980 to get a handle on the state's overdraft of groundwater. Conversely, the legislature recognized groundwater was an important resource and encouraged landowners outside of AMAs to use groundwater as an independent single resource for beneficial use. As the groundwater and surface water resources have been developed it is apparent that because these resources are dependent, conflicts have arisen.

At the heart of the Big Chino conflict is the claim that the baseflow of the Verde River is not fed by the Big Chino aquifer and even if it was, the aquifer contribution is small and will not be affected for a long period of time by withdrawal of groundwater for the proposed Big Chino pipeline to Prescott . The hydrologic data of the USGS do not support this claim. Arizona Superior Court Judge Sheddon's recent decision to allow the pipeline gives little confidence that the water resource will be available in both the long and short term to users with water rights--especially to users of the Verde River. Common sense and at least two important facts clearly show the spring flow to the Verde River is quickly affected by groundwater extraction in the Big Chino Aquifer.

Background

As an engineer in the 1960s and early 1970s I worked for the USGS in the watershed of the Verde River. I performed the initial estimates of the huge amount of groundwater stored in the Big Chino, Little Chino and Verde Valleys. My duties also included the collection and analysis of both groundwater and surface water data in the upper watershed. Along with geologist Jay Gillespie,

another USGS professional, we located the site of the present USGS streamflow gage (09503700) near Paulden (see following map).



With the guidance of USGS geologist Spade Cooley I learned that the Big Chino aquifer consisted of a complex mix of clay, sand, gravel, volcanics and limestone. Spade had spent much of his career with the USGS studying Holocene and Quaternary sediments, or laymen's dirt, that included much of the aquifer in the Big Chino. Many of his field notes are in my possession. More recently USGS scientists Laurie Wirt and Ed DeWitt (Wirt, DeWitt, and Langenheim, 2005) contributed to my understanding of the Big Chino aquifer.

The Big Chino aquifer and the Verde River are interconnected in that water from the aquifer discharges to the river (Wirt and Hjalmarson, 2000). With my friend and colleague Laurie Wirt, we found that about 80 percent of the baseflow in the upper Verde River was ground-water discharge from the Big Chino aquifer. This

finding means that river gains from this discharge will decrease in response to ground water withdrawal from the Big Chino aquifer regardless of the position of withdrawal. If the withdrawal is a significant part of the discharge from the Big Chino aquifer or exceeds it, baseflow of the river will be significantly reduced or depleted altogether.

Well driller's logs in the USGS files show numerous large underground voids or caverns. (See for example Appendices A and B). These logs, and aquifer test, although limited in amount, also demonstrate that the transmissivity of the Big Chino aquifer is relatively high while the coefficient of storage is relatively low because of the presence of silt and clay that is found throughout the area. This means that the decline in ground-water levels associated with pumping will spread rapidly away from pumpage quickly extending over a relatively large area. For instance, the pumping of one large well at the Holiday Lakes Estates land sales located 6 miles from the gaining section of the Verde River, caused a significant drop in the baseflow of the river in 1964 and 1972. It was obvious the Big Chino aquifer was large and yielded large amounts of water to both wells and the headwater springs of the Verde River.

Over the years I've been privileged to be part of the USGS with many colleagues like Robert M. Hirsch, former Chief Hydrologist who wrote: "Traditionally, management of water resources has focused on surface water or ground water as if they were separate entities. As development of land and water resources increases, it is apparent that development of either of these resources affects the quantity and quality of the other. Nearly all surface-water features (streams, lakes, reservoirs, wetlands, and estuaries) interact with ground water." (USGS, from USGS Circular 1139-- Ground Water And Surface Water: A Single Resource). We teach our children that springflow comes from the ground and even I learned this as a graduate student at Arizona State University.

Common Sense

There is something to be said for how simple the groundwater of the Big Chino aquifer is connected to the springs that feed the Verde river. Meyer and Wolfe (2004) focused on this simplicity of how ground-water flow beneath Williamson Valley joins the Big Chino Valley ground-water flow several miles north and west of Paulden (as presented by Wallace and Laney in 1976), and discharges into the Verde River. USGS friend and colleague Dr. Robert Laney, who studied the Big Chino, felt strongly that the Verde River drained most of the ground-water that fell in the Verde River watershed. With the exception of much of the area (at least 350 square miles) north of interstate highway 40, all, or nearly all, of the upper watershed of the Verde River (drainage area 2,150 square miles) contributes water to the Big Chino aquifer that is subsequently drained by the Verde River. Both the groundwater potentiometric surface and the land surface slope toward the headwater springs of the Verde River.

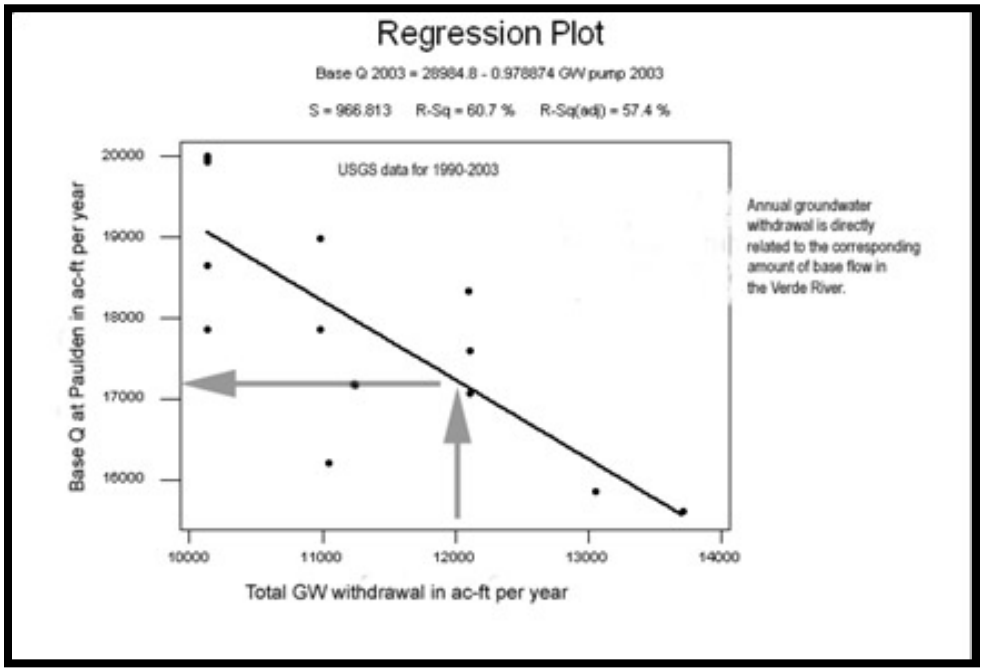
The interaction between water of the Big Chino aquifer and the headwater springs that supply the baseflow to the Verde River is an important fact that must be considered for reasonable and prudent management of the water resource. A focus on this hydrologically simple fact is needed because of the debilitating Arizona laws that have trumped the obvious effect of gravity on water movement. Past arguments by ADWR and elected officials that there is no groundwater - surface water interaction defy the law of gravity, responsible management of the resource, and common sense. We need to move beyond the unsound concepts of past thinking to prudent management of the water resource.

Two examples that further demonstrate the groundwater-surface water connection between the Big Chino aquifer and the Verde River follow.

Demonstrated evidence No. 1

The recent USGS WRD report (by Blasch and others, 2007) shows a relation between groundwater withdrawals in the Big Chino Valley and the baseflow of the Verde River. A similar relation was also found in previous work by Wirt and Hjalmarson (2000) but only the relation in Blasch and others (2007) need be discussed here. Because much of the groundwater withdrawals are from the proposed water farm area, the relation is a great means of estimating the impact of the water export via the proposed pipeline on the Verde River.

The regression plot shown below is the linear relation between groundwater withdrawals and the baseflow of the Verde. The data are for 1990-2003 and are part of the USGS conceptual model of the Big Chino aquifer. The groundwater withdrawal data were furnished by John Munderloh (See my review of his work in Appendix C) and the streamflow data are from the USGS gage near Paulden.



Other factors such as annual recharge to the aquifer are neglected because of an insignificant effect of the information on the subject regression relation. The data are given in appendix 9 of the USGS report by Blasch, and others (2007).

The regression plot is the relation between groundwater withdrawals (Munderloh's furnished data) and the baseflow of the Verde River at the Paulden gage. Data are for 1990-2003 and are part of the USGS conceptual model of the Big Chino aquifer. *A* 1 to 1 relation is shown where the implication is that annual GW withdrawals affect the annual amount of baseflow of the Verde River. According to USGS studies there is a 1 to 1 relation between annual baseflow in the Verde River and annual groundwater withdrawals in the Big Chino. A 1,000 ac-ft per year increase in groundwater extraction ultimately results in a 1,000 ac-ft per year decrease in baseflow of the Verde River.

It's important to note that a strict 1 to 1 relationship between groundwater extraction and baseflow on a yearly basis is impossible regardless of where the extraction is located. Because all or nearly all of the extraction was, and is, in the basin fill it’s impossible to account for such a rapid response time given the lithologic nature of basin fill. Such a response time between groundwater extraction and baseflow would require a virtually unlimited transmissivity throughout the basin fill in Big Chino Valley. Of importance is there is an annual relationship between extraction and reduction in baseflow that shows pumpage will reduce the baseflow of the river and the effect of pumpage will be seen in a relatively short time measured in years, not centuries.

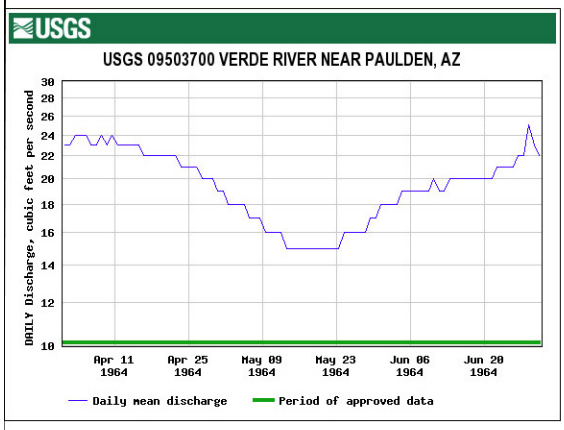
Demonstrated evidence 2

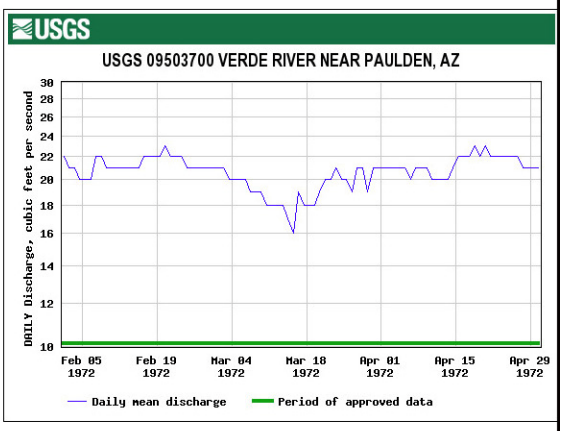
The collective discharge of all the springs is typically more than 20 cfs and less than 27 cfs as measured at the Paulden gage. This baseflow is rather constant for an Arizona River fluctuating only a few cfs from year to year and seasonally depending upon natural weather patterns and the pumping effects for irrigation mostly in the upper Big Chino Valley. The baseflow is so steady that when it abruptly dropped to 15 cfs in 1964 and 16 cfs in 1973 the USGS investigated the cause (see the following hydrographs). The decline in baseflow for these two periods directly relates to the initiation of ground-water withdrawal for the purpose of filling man-made lake at the Holiday Lakes Estates land sales located at the southeastern end of Big Chino Valley.

At the start of pumping for these two periods, 100 percent of the water supplied to the well came from ground-water storage. As pumping continued it began to divert ground-water that would have discharged to the Verde River into the well. This diversion increased over time and ultimately the diversion would have represented all of the water being withdrawn from the wells. This process is documented in numerous ground-water reports of the USGS and others and is

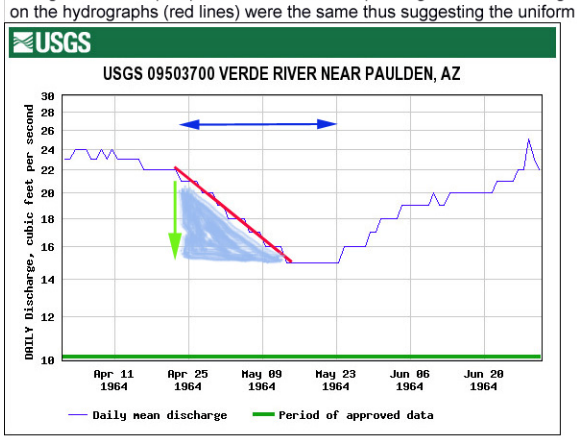
generally referred to as capture. The capture of groundwater destined for the Verde River is further described in Appendix D.

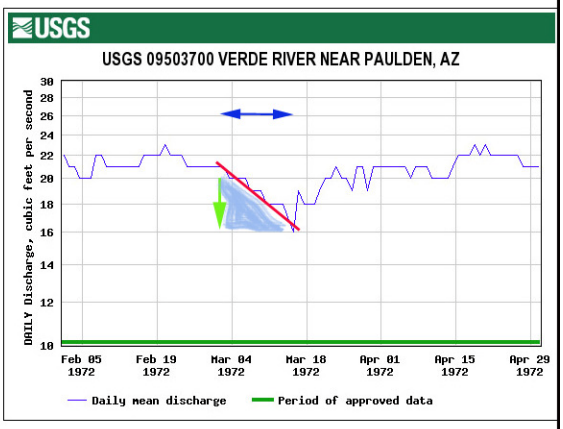
Mean daily discharge at the USGS Verde River near Paulden gage for two periods when there was pumping of the large well located near the center of section 20, township 18 north and range 2 west. The measured decreas of base flow is where incoming springflow to the Verde River was captured by groundwater pump ıng to fill manmade lakes at the Holiday Lakes Estates land sales business.





The diesel powered pump was operating at approximately 4,000 gallons per minute or more during the periods in 1964 and 1972 as shown by the blue arrows. The drop in the hydrograph represents incoming springflow that was intercepted by the pumping to fill the artificial lakes in section 20, T18N, R2W . When the pump was first turned on most of the discharge to the lakes was from groundwater storage. As pumping continued more discharge was intercepted ground water that was on it's way to the Verde River. If there was no water removed from stored groundwater the flow in the Verde River would have dropped much steeper as roughly shown by the green arrow. The light blue areas roughly represents the water that left storage. When the pump was turned off the depleted groundwater storage was filled as the base flow returned to the pre-pumping level. The slope on the hydrographs (red lines) were the same thus suggesting the uniform pumping rates, or the same well, for both periods.





I'm guessing that the limestone in and adjacent to the Big Chino Aquifer is fractured with dissolution enhancement including large conduits. The conduits may have formed in the Redwall and Martin Limestone millions of years ago (during the Mississippi era) and as evidenced by the Cathedral Caves to the north, could be large (Appendix A). There probably is more fracturing and voids along the faults. I've been inside the Martin Formation at a few places on Mingus Mountain and also experienced the siphon spring that is part of the Jerome water supply. Several complicated processes may have been involved in the formation of the conduits that are beyond the scope of this analysis. Of importance, the

fractured limestone undoubtedly is structurally complex, full of large openings and variable in hydraulic properties.

The measured drop of baseflow for Feb. thru Apr., 1972 in conjunction with lake filling at Holiday Lakes Estates affords an opportunity to define the effects of pumping a single well in the Big Chino aquifer on ground-water discharge to the Verde River. Typically it would be difficult to isolate the effects of a single well unless the rate of withdrawal was significant compared to the baseflow of the river and other pumpage. But based on the aerial photography of May 25, 1972 there was no other observable pumping in the Big Chino at that time.

The removal of baseflow from the Verde River by groundwater pumping closely resembles the effect of a well pumping from a confined aquifer as shown in studies along the Snake River in Idaho and elsewhere (for example Alley and others, 1999). The measured capture of spring discharge increased linearly (the capture would actually be logarithmic) and rather rapidly. The nature of the capture was similiar in both 1964 and 1972. When the pump was turned off there was a corresponding rapid recovery of baseflow in the Verde River as groundwater storage in the aquifer was replenished and discharge to the headwater springs was restored.

Discussion using common sense and demonstrated evidence 1 and 2

The hydrologic data for the Big Chino Valley demonstrates a relatively rapid connection (clearly in days and not years) between the ground-water withdrawal in the lower or eastern part of the Big Chino aquifer and baseflow of the Verde River at the Paulden gage from the response time generally assumed for an unconfined aquifer. Published USGS data also indicate a hydrologic connection between annual amounts of ground-water withdrawn from the upper Big Chino Valley and the baseflow of the Verde River. Thus, unless the amount of groundwater that is diverted to Prescott at the proposed water farm is offset by a decrease in the groundwater withdrawal for farming, the baseflow of the Verde River is expected to decrease within one year of groundwater pumping at the Prescott water farm.

Based on conversations with Laurie Wirt and Ed Dewitt of the USGS, generally speaking the basin-fill material and basalts that mainly compose the Big Chino aquifer are highly transmissive to ground-water flow. The water enters a buried paleochannel east of Paulden and then travels through a network of NW-striking fractures and minor caves in the Martin to the springs along the upper Verde River. Along the path through the basal part of the Martin the water comes in contact with the shaly Chino Valley Formation, which supplies elevated concentrations of B, Li, and As to the springs.

Generally speaking again, based on my experience and conversations with Laurie Wirt, Ed DeWitt, Bill Meyer and others, there is not some magical barrier

that restricts passage of water to the limestone that underlies the basin-fill and interbedded basalts in the upper and middle parts of Big Chino Valley and also from the basin fill and basalts into the adjoining limestone in the lower part of the valley where the basin fill terminates.

The magnitude and timing of pumping effects in the Big Chino aquifer on the baseflow of the Verde River appear to be highly dependent on where the ground water pumping is located and whether the basin fill or limestone aquifer is being tapped. There appears to be a relatively rapid aquifer response time in terms of the spread of the cone of depression due to (1) the high transmissiviity and low storage of the basin fill and (2)confinement of the limestone below the basin fill and playa deposit. Wells tapping the basin fill near the eastern end of the Big Chino aquifer will impact the baseflow more quickly than wells tapping the basin fill near the head of the Big Chino aquifer. Even so, pumpage in the basin fill in the upper part of the valley will induce water level changes in the basin fill of the lower part of the valley as well as water level changes in the underlying limestone. Collectively these declines will ultimately, and relatively rapidly, extend to the gaining areas of the Verde River. The location of the proposed water farm is at the northwestern or upper end of Big Chino Valley to facilitate a minimum near term groundwater extraction effect on the springs that supply the Verde River, but available information suggest that the withdrawal will still reduce the baseflow of the Verde in a relatively short time.

In the case of extractions in 1964 and 1972 from the Big Chino aquifer by Holiday Lakes Estates, as stated above, the baseflow of the Verde River decreased significantly shortly after the pumpage started. For three weeks in April and May of 1964 baseflow of the Verde river was reduced by 1/3 or 7 cfs. For two weeks shortly following groundwater withdrawal was initiated for lake filling in March 1972 baseflow was reduced by about 1/4. This rapid reduction in baseflow is significant and demonstrates how quickly the baseflow of the river can be reduced by ground-water withdrawal. This observed response cannot be shoved under the carpet by ADWR and Arizona water laws.

Talk about a great connection between the well and the headwater springs feeding the base flow of the Verde River. When the extractions in 1964 and 1972 stopped, the baseflow returned to near pre-extraction levels within several days. And yes, as Yogi would say about the following conclusion "It's like déjà vu all over again."

The impact of significant groundwater extractions on the baseflow of the Verde River, existing water rights and living things clearly will be sooner rather than later.

Postscript : We teach our children the source of springs is groundwater.

Judge Shedden said "Water in underground tributary aquifers is not a part of the surface stream and may not be considered" part of the stream (i.e., surface water). "This is true even though given enough time all extractions from a tributary aquifer will cause a more-or-less corresponding depletion from stream flow volume. *See Gila IV."*

I wonder what time has to do with such a scientifically absurd law. In the case of the Verde River springs the honorable judge need not wait long for the effect of extractions from the Big Chino aquifer to show up at the Verde River.

Suggested reading available on the net:

Marder, Meredith K., 2009, The battle to save the Verde: How Arizona's water law could destroy one of its last free-flowing rivers, Arizona Law Review, VOL. 51:175.

Tellman, Barbara, 1996, Why has integrated management succeeded in some states but not others?: Universities Council on Water Resources, Issue No. 106: 18 p.

References

Alley, W. M. and others, 1999.,Sustainability of ground-water resources:U.S. Geological Survey circular 1186, 79p.

Blasch, .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, 102 p., 3 plates. V. 2, May 04, 2007.

Meyer, William and Wolfe, Ed., 2004,The Potential Impact on the Verde River of Pumping 10,850 Acre-Feet per Year at the CV Ranch, Big Chino Valley, 35 p, unpublished report.

Robertson, F. K. 1991. Geochemistry of ground water in alluvial basins of Arizona and adjacent parts of Nevada, New Mexico, and California: U.S. Geological Survey Professional Paper 1406-C, 90 p.

Wallace, B. L. and Laney, R. L. 1976. Maps showing ground-water conditions in the lower Big Chino Valley and Williamson Valley areas, Yavapai and Coconino Counties, Arizona - 1975-76: U.S. Geological Survey Water Resources Investigations 76-78 Open File Report, 2 maps.

Wirt, Laurie, Ed DeWitt, and Victoria E. Langenheim, Hydrogeologic Framework (Section D), Geologic Framework of Aquifer Units and Ground-Water Flowpaths, Verde River Headwaters, North-Central Arizona, USGS Open-File Report 2004-1411, 2005.

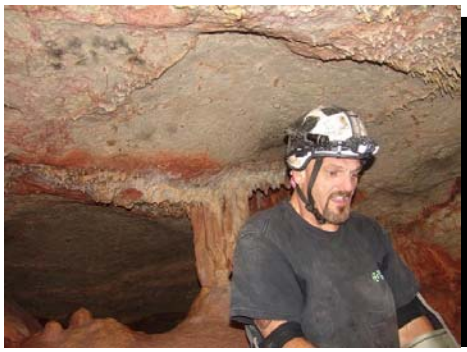
Wirt. L., and Hjalmarson, H.W., 2000, Sources of springs supplying baseflow to the Verde River headwaters, Yavapai County, Arizona: U.S. Geological Survey, Open-File Report 99-0378, 50 p.

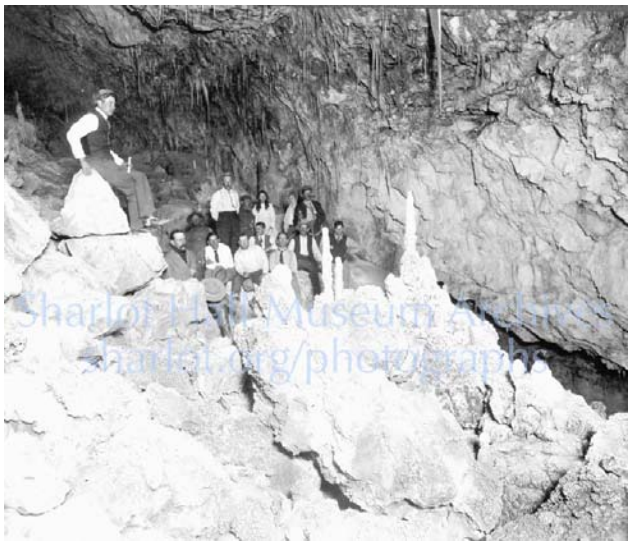
Appendix A: Misc Photographs of Limestone in the Upper Verde River watershed

The photo below is of the Martin Limestone (Dm) a few tenths of a mile downstream of Sullivan Lake.

Wirt, L., 2005, The Verde River headwaters, Yavapai Count, Arizona *in* Wirt, Laurie, DeWitt, Ed, and Langenheim, V.E., eds., Geologic Framework of Aquifer Units and Ground-Water Flowpaths, Verde River Headwaters, North-Central Arizona: U.S Geological Survey Open-File Report 2004-1411, 33 p.

The following photos are of the Redwall Limestone in the Cathedral Caves area of the upper Verde River watershed near Ashfork.




Sharlot Hall Museum Archives
sharlot.org/photographs

Appendix B.- Comments by Ed McGavock, Geologist

On April 1, 2002 Win Hjalmarson and Ed McGavock were discussing the Martin Dolomite in the Verde River watershed. Among other things, Win asked about a well near Page Springs that Ed had been working on. Ed McGavock's response clearly supports the presence of numerous caves in the Limestone part of the Big Chino aquifer.

Ed McGavock to Win Hjalmarson 4-3-2002

> "The Jerome water supply is captured from a number of small caves close to the base of the Martin Dolomite, just above its contact with the Tapeats Sandstone. From the two of these that I have observed up close (Allen Springs and a spring above the Copper Chief mine) they exhibit small cave openings with narrow, upward extending solution-enlarged joints that would permit easy downward-draining water flow from a higher cave opening in the overlying Redwall Limestone. Roaring Springs on the north side of the Grand Canyon also shows narrow solution-enlarged fractures in carbonate/dolomite beds underlying the Redwall Limestone."
>
> "My guess is that the Drake well taps into one of these solution-enlarged fractures that permit rapid drainage of water from a higher water table, possibly within the Redwall Limestone. This type of intercept would indicate to me that the static water must be well above the cited fractured depth in the hole of 692 feet. It would be useful to know what the elevation of that static head is compared to the Paulden area."
>
> "In the Sedona area I do know that some wells have produced small yields after being drilled, but there are a few that have clearly hit open, through-going water-filled cave systems. A friend of ours used to work for the local water company and told us about hearing rushing water sounds

> at the wellhead at one of the West Sedona wells, even though the water table lies hundreds of feet below ground level. The recent LoloMai well, in my opinion, merely taps directly into the water-filled solution cave system just up-gradient from the Page Springs outlet. The artesian flow must be simply tapping into the natural "pipe" leading into Page Springs. No sooner had this well been drilled than the outflow at Page Springs diminished. It appears that the LoloMai and Drake wells have both pierced into a confined, open conduit aquifer that is producing artesian flow."
>
> "Mind you, this is coming from a geologist, not a hydrologist! This is about all I know on the subject. Hope there are some useful tidbits here."

On January 25, 1998 in a article WATER FIGHT! Solution to Prescott Valley growth concerns could leave Verde River high and dry by Krista Schlwer, the following appeared in the Camp Verde Bugle newspaper:

> "Pumping from the Big Chino may affect Verde River baseflows enough to deplete the river and cause problems for wildlife", according to retired U.S. Geological Survey Hydrologist Edwin McGavock.
>
> "Absolutely. Yes. No question about it," said McGavock, who has studied Verde River hydrology for several years.

Appendix C.- Review of: Historical and Current Water Uses and Water Use Projections, Big Chino Subbasin,Yavapai County Water Advisory Committee, February, 2004

As asked by John Munderloh.

Review by By Win Hjalmarson, PE, Consulting Hydrologist

I must apologize in advance for departing form what might be considered an objective review of the subject report. I've been unable to refrain from expressing my impressions of this estimate of pumpage in the Big Chino Valley that I consider to be Stone-Age stupid. Comments are numbered.

1. It so happens the USBR published the Chino Valley Unit Appraisal Report in April 1974. On page 79 (Table 8) the estimated current (1974) annual water use for Big Chino Valley is given as 994 ac-ft. However, the WAC says 12,500 ac-ft was used at that time. While the WAC may think there is not a big difference in these amounts, I'm sure most of us would disagree. Also,

why wasn't this USBR report referenced? Surely a literature search was made before consulting with farmer Olsen.

2. The authors failed to recognize that USGS Open-File Report 94-476 is the source of the ground-water withdrawal (GWW) for the Big Chino (BIC) and Williamson Valley (WMN). Anning and Duet (See last 2 pages of this review) summarize the pumping data that is common to all authors except the WAC. It is incomprehensible for me to believe the author(s) of the DRAFT did not recognize this common source of the data. Based on the inaccurate reference to the pumpage used in the Wirt report, I see no reason to trust any of the other pumpage information presented in the subject report.

3. Apparently only selected published reports are given or are used for the analysis. For example, it seems great reliance is given to farmer Olsen but published reports, USBR Appraisal report of 1974 and probably others are ignored. This is truly amazing to me especially when I've listened to farmer Olsen speak publicly more than once for the export of BC water to Prescott. He sounded real biased to me. So, it seems some good old boys put this DRAFT together to suit their needs and bias.

4. It is VERY difficult to determine land that is under irrigation during the growing season depicted on aerial photos. There are many reports on aerial photo interpretation that clearly describe the difficulty and methods that should be used. Land under irrigation also is very difficult to distinguish from other land that was previously irrigated/cultivated. Therefore, field inspections made for each particular year estimated used to verify the active irrigation for each year should be given (published) along with the aerial photos that were used. In regard to documentation of methods and conversations with local farmers, this information should be presented perhaps in an appendix. Precisely who (farmer Olsen) said what about a particular parcel of land at a particular time should be documented and given in the report.

5. The reference for the photo interpretation techniques should be given. Precisely how was the interpretation accomplished? How did you account for camera and sun angle, crop type, reflectance, surface texture, etc.

6. The characteristics (scale, quality, BW or color or color IR, etc.) of the photos presented in Table 1 should be given.

7. Precisely what sources of aerial photography were consulted and precisely what photography was requested?—USGS, NRCS, Whittier College, Uof A, ASU, etc.

8. Precisely why wasn't the GWW that was estimated by the USGS used?

9. No mention of the irrigation by surface-water diversion in the Big Chino is given. It is a fact that fields were irrigated by diversion of flow in Big Chino Wash. How did you separate these fields from the fields irrigated by GWW? Are you aware of the reports of fish in Big Chino Wash?

10. Where are the results of the literature search and where are the references used or consulted?

11. The 20,000 ac ft GWW for 1950-66 are very rough estimates that were furnished to the USGS by the Yavapai Co Ag. Agent. When I collected data for the USGS in the 1960s the agent was Mr. Alvin Allen. After I visited the Big Chino a couple of times while collecting ground-water data I realized that there was no way 20,000 ac-ft was used for crops. I discussed my concern with Mr. Allen. Some time later he agreed the pumping was much less and he furnished the 9,000 ac-ft estimate for 1967 that I agreed with. The estimates from 1950-66 are real gross and typically much too great. This is why Wirt-Hjalmarson did not use the data in USGS Open-File Report 99-0378.

    I was not involved with the ground-water data program very much after about 1970 so I cannot render any information about the GWW data from 1970-present for basins in Yavapai County. The USGS used to write annual ground-water reports for each basin that explained how data were collected and so forth. These “basin analyses” should be consulted before you toss out the data.

12. This report appears sloppy and unprofessional. USGS GWW data were conveniently ignored for no clear reason. The WAC estimates appear baseless and Stone-Age stupid.

A more complete review was not made because of the above reasons.

Win Hjalmarson 3 4 2004

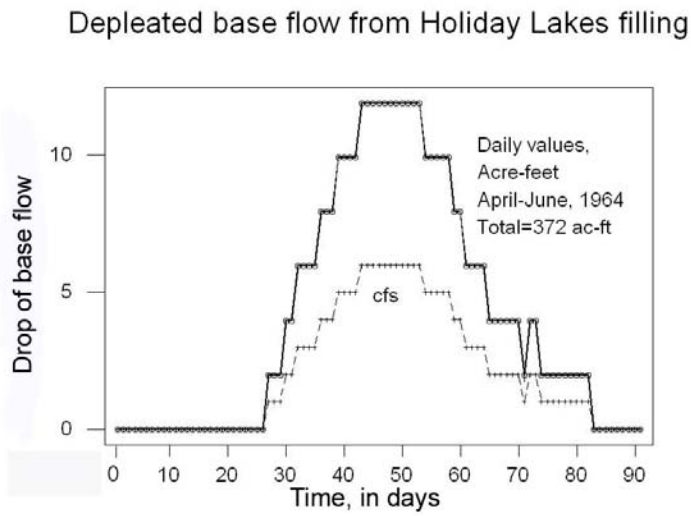
Note:
At the Feb 2004 WAC meeting Munderloh said the report is “The report is…well.. sort of ..to guide the USGS”.

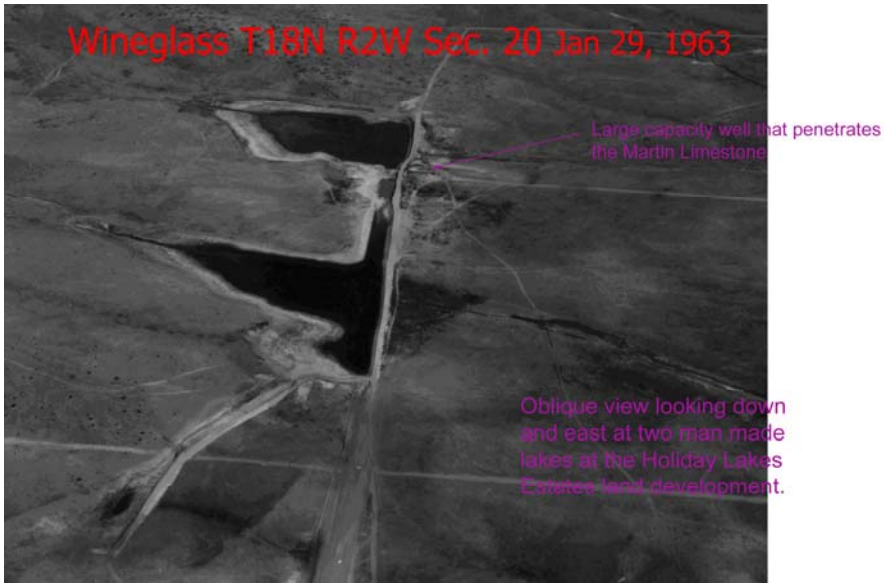
In response to a question from Greg Kornrumph of the Salt River Project. Munderloh said “Authors don’t intend the study to be legal evidence to prove exactly how much water that state law allows Prescott to import.”

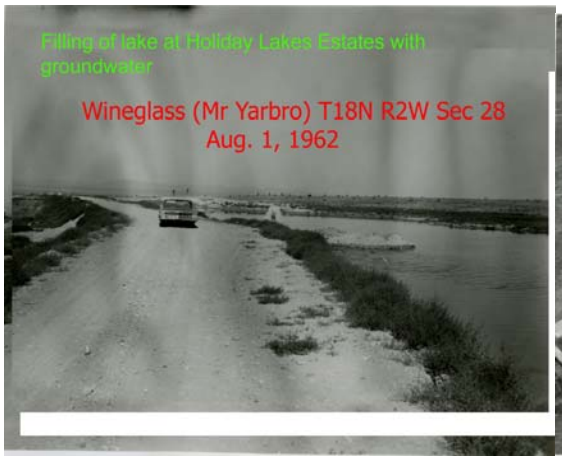
Further note:
Under oath for ADWR hearing at Prescott—he said he alone wrote the report and did not mention if it had been reviewed.

Appendix D.- Stream capture in 1964 and 1972 by groundwater pumping at Holiday Lakes Estates

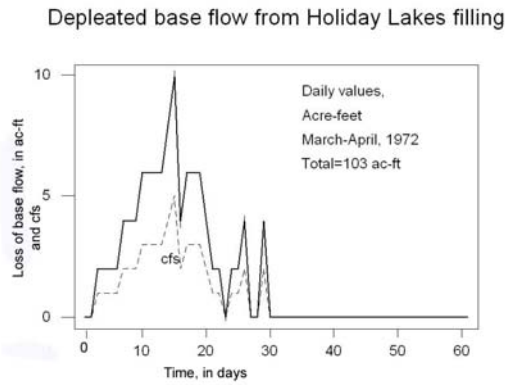
My recent testimony on June 15, 2009 at the ADWR hearing at Prescott included the effects of groundwater pumping at a land development known as "Holiday Lake Estates" that I witnessed. During one lake-filling episode in 1964 the flow in the Verde River dropped to 15 cfs. The hydrograph at the USGS streamflow gage near Paulden is shown in Figure 9 of the Wirt/Hjalmarson (2000) report. Nearly 400 ac-ft was indirectly taken, or captured, from the baseflow of the Verde River during this period of lake filling (captures water is shown below).

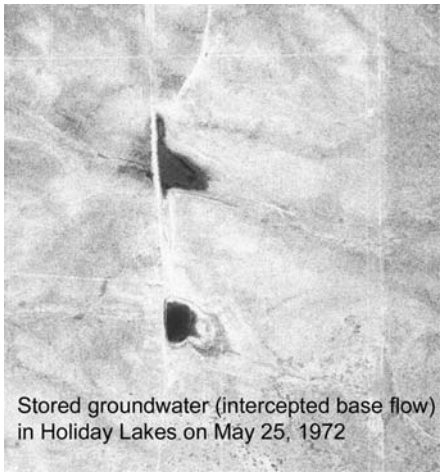






A similar period of lake filling at Holiday Lakes in 1972, where about 100 ac-ft was indirectly taken from the baseflow of the Verde River, is shown below.





Based on the shape of the graphs, in particular the rapid capture of flow, and aerial photographs of the Holiday Lakes like that shown above, the baseflow in the Verde River dropped within days of the lake filling in 1964 and 1972.