BIG CHINO VALLEY GROUND WATER AS THE SOURCE OF THE VERDE RIVER

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ABSTRACT: Debate continues regarding the source of springs that form the base flow at the headwaters of the Verde River near Paulden, Arizona. On one side are communities and land developers who would like to drill wells up-gradient from these springs into the Big Chino Aquifer. On the other side are two groups who believe that ground water pumping will reduce the base flow of the Verde River. One group includes environmentalists concerned about preserving riparian areas and endangered species habitat. The other group includes downstream surface water rights owners. The most sound geologic interpretation is that the springs are the discharge point of ground water flowing through faults and fractures within the Big Chino Aquifer system. Other interpretations have been presented, but data (USGS and others), including potentiometric surface mapping, aquifer mass balance estimates and stable isotope data all suggest a direct hydraulic connection between the springs and the Big Chino Aquifer.
KEY TERMS: Verde River; Big Chino Valley; Spring discharge; Ground water – surface water interaction.

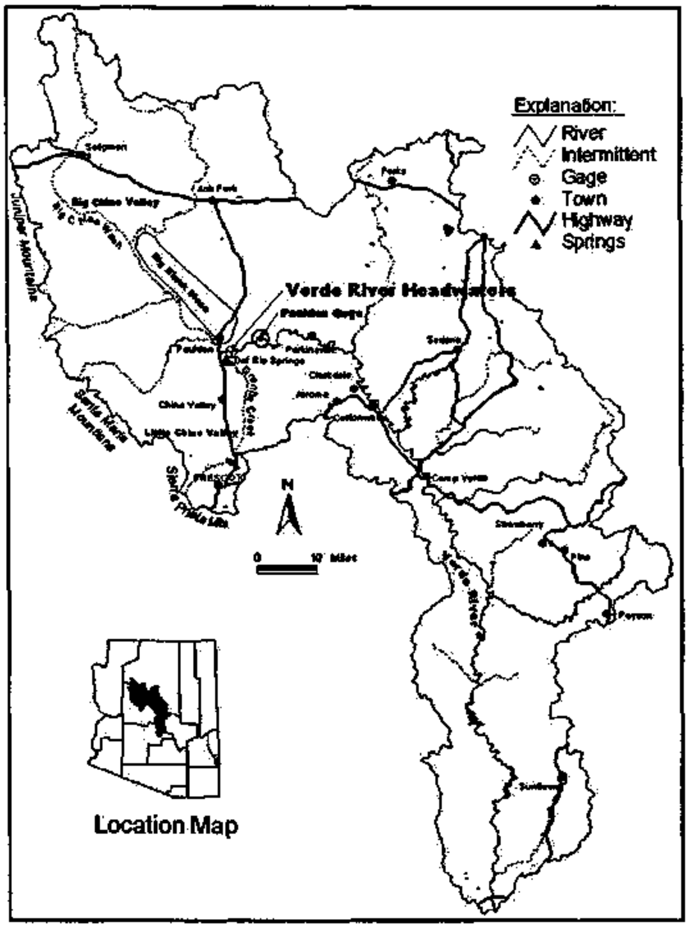

Figure 1. Verde River Watershed

INTRODUCTION

Flow in the Verde River begins from springs in the headwaters area two miles southeast of Paulden (see Figure 1). The base flow of the river, measured at the Paulden Gage, approximately six river miles downstream is approximately 20-30 cfs (see Figure 2). Wirt (2001) reports that the aggregate discharge of the headwaters springs in 2001 was 19 cfs. This is similar to 20.3 cfs measured by the U.S. Bureau of Reclamation (USBR) (Ewing et al, 1994) in 1991 from these springs. From these measurements, it is clear that the spring discharge provides the vast majority of the base flow measured at the Paulden Gage.

The springs are located immediately southeast of the Big Chino Valley, a ground water basin filled with unconsolidated Tertiary age clastic sediments and interlayered extrusive volcanic rocks that are underlain by Paleozoic limestones and dolomites (Ewing et al, 1994). Big Black Mesa, which lies immediately north and northwest of the spring area and is the eastern boundary of the basin, is an upland area underlain by the same Paleozoic rocks that underlie the basin (Krieger, 1965). Little Chino Valley, which is also a ground water basin similar to the Big Chino Valley, lies to the south. Each of these features (see Figure 1) has been proposed as a source for the springs.

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Identifying the source of the springs has long been debated because lava flows exposed at the surface generally obscure geologic contacts and faults at the southern end of the basin in the vicinity of the Verde River headwaters (see Figure 4). Historically, subsurface relationships have been interpreted based only upon the limited exposures of non-volcanic rocks and from drill hole data. Drill hole data are almost entirely limited to drillers' logs of water wells. These logs, because they were prepared by various drillers with varying knowledge of geology, are sometimes inaccurate and often times confusing. Interpreting the source of the springs is much less uncertain if other data including potentiometric surface mapping, stable isotope data and aquifer mass balance estimates are also considered.

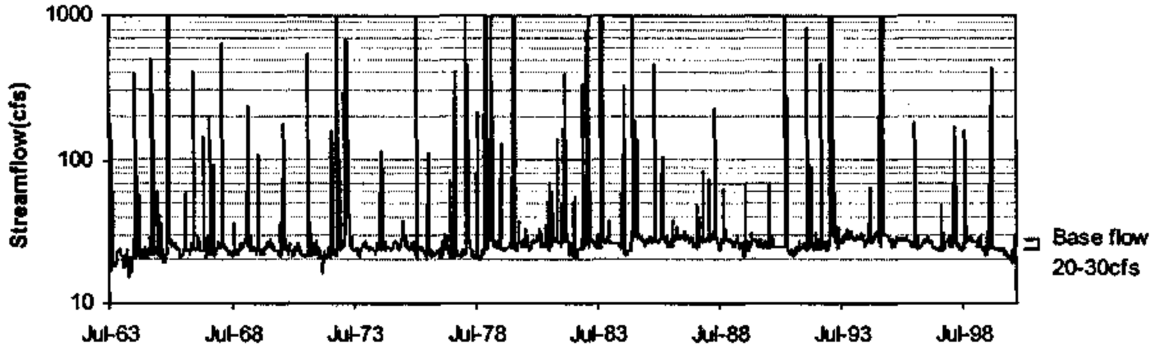

Figure 2. Verde River at the Paulden Gage

LITTLE CHINO VALLEY AS THE SOURCE

The easiest alternative to eliminate as the source of the springs is ground water discharging from the Little Chino Valley. Prescott, the Town of Chino Valley and agricultural irrigators have pumped considerable ground water (18,000 af/yr; 25 cfs) from the Little Chino Valley approximately five miles south of the Verde River headwaters area since the 1940's (ADWR, 1998). Over the intervening period of time, the discharge of Del Rio Springs located at the north end of the Little Chino Basin (see Figure 1) has decreased from 3.9 cfs to about 2.5 cfs and water levels in wells have dropped more than 75 feet in the area (ADWR, 1998). Most of the decline in discharge of the Del Rio Springs has occurred since the mid 1960's. However, over that same period, the flow of the springs in the Verde River headwaters, as indicated by the base flow of the Verde River, has remained constant or increased slightly (see Figure 2). This indicates that ground water from the Little Chino Valley is not a significant source for the springs at the Verde River headwaters.

The Arizona Department of Water Resources (ADWR) (Brown et al, 2000) estimates the ground water discharge from the Little Chino Valley to be about 2,100 af/yr; 3cfs (1990-1997). This estimate is based upon computer modeling of the ground water basin. Thus, ground water discharging from the Little Chino Valley could, at the most, only account for 3 cfs out of the 20 cfs discharging from the Verde River headwaters springs.

BIG BLACK MESA AS THE SOURCE

Knauth and Greenbie (1997) conducted a stable isotope analysis of surface and ground water in the vicinity of the Verde River headwaters. Based solely upon their interpretation of stable isotope data and not considering any other data, they concluded that the source of the springs at the Verde River headwaters is ground water that originated as precipitation recharge to Big Black Mesa.

Knauth and Greenbie's conclusion cannot be correct, because it is not possible for there to be enough recharge occurring on Big Black Mesa for it to be the source of the Verde River headwaters springs. Various studies including Maxey and Eakin (1949) have shown that recharge is proportional to the combination of annual precipitation and elevation. This is because as elevation increases, precipitation increases and evapotranspiration decreases. Because Big Black Mesa is an upland area, recharge is undoubtedly greater there than on the Big Chino Valley floor.

Big Black Mesa is approximately 25 miles long between the Verde River on the south and Partridge Creek on the north and about four miles wide (see Figure 1). It ranges in elevation from 5,000 to 6,000 and receives 12 to 18 inches of precipitation per year depending upon elevation. Big Black Mesa is bounded on the west by the Big Chino Valley, and on the east by Limestone Canyon, a south-flowing intermittent tributary to the Verde River, and Butcher Knife Canyon, a north-flowing intermittent tributary to Partridge Creek. For comparison, the combination of the

Juniper Mountains, Santa Maria Mountains, and Sierra Prieta Mountains extend for more than 70 miles along the west side of Big Chino Valley. In these mountains, elevations range from 5000 to more than 7,000 feet and precipitation ranges from 14 to more than 25 inches per year.

Based upon calibration of a ground water flow computer model, the USBR (Ewing et al, 1994) estimated the recharge to the Big Chino ground water basin to be 23,700 acre-feet per year (af/yr). Their model included inflow from the Little Chino Basin as precipitation recharge. When the Little Chino Basin inflow is subtracted (2,100 af/yr from ADWR, Brown et al, 2000) the estimated precipitation recharge is 21,600 af/yr. ADWR (Brown et al, 2000) has estimated the precipitation recharge to be 25,300 af/yr. Neither the USBR nor ADWR reported estimates of recharge to Big Black Mesa.

Using the average of the two estimates (23,400 af/yr), we estimated the recharge to Big Black Mesa and the Big Chino basin as shown on Table 1 using the following simplifying assumptions:

1) Recharge is zero on the valley floor (semi-arid grasslands); and
2) All of the recharge occurs in upland areas of the drainage basin (defined as mixed conifer forest where the precipitation is greater than 12 inches per year).

Table 1. Estimated Precipitation Recharge

Big Chino Valley (including Big Black Mesa)				**Big Black Mesa**			
Precipitation (in/yr)	**Recharge Rate (in/yr)**	**Area (acres)**	**Recharge (af/yr)**	**Precipitation (in/yr)**	**Recharge Rate (in/yr)**	**Area (acres)**	**Recharge (af/yr)**
12-16	0.27	606565	13535	12-16	0.27	37616	839
16-20	0.36	227265	6840	16-20	0.36	14106	425
20-25	0.47	56425	2196	20-25	0.47	0	0
25+	0.53	18808	830	25+	0.53	0	0
		Total	23400			Total	1264

Because Big Black Mesa is a relatively small portion of the upland area in the drainage basin and because precipitation only ranges from 12-18 inches per year, the recharge is small when compared to that of other recharge areas where the precipitation is as much as 25 inches per year. We estimate that the recharge to Big Black Mesa is approximately 1,250 af/yr (1.7 cfs). This is approximately 5 percent of the total basin recharge.

Because there is very little ground water pumping on Big Black Mesa, ground water discharge approximately equals recharge. If all of the ground water flows southeast along the axis of the mesa and discharges to the Verde River, the maximum contribution to the Verde River Headwaters springs is Big Black Mesa only about 1.7 cfs. More probably, however, the dominant ground water flow directions are to the southwest into the Big Chino Valley and to the northeast into Limestone Canyon and to Butcher Knife Canyon. Thus, there is only a very limited amount of ground water flowing along the mesa axis to the Verde River. Consequently, ground water discharging from Big Black Mesa likely contributes far less than 1.7 cfs to the Verde River headwaters springs.

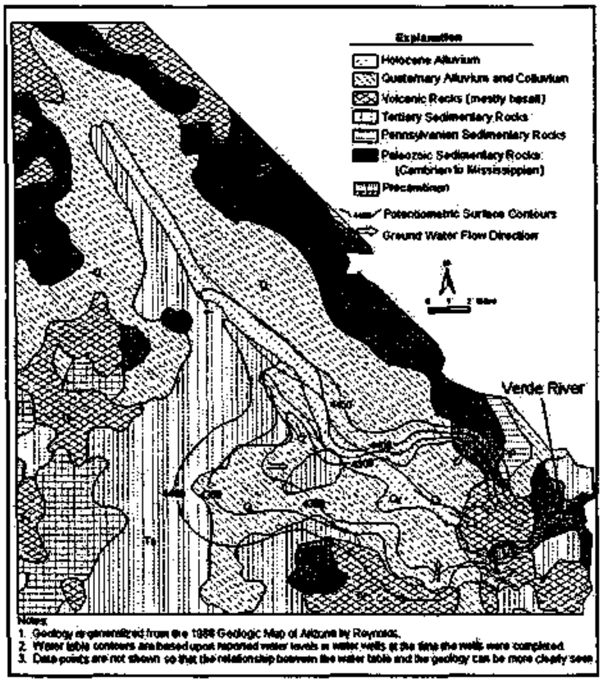

Figure 3. Potentiometric Surface Map

BIG CHINO VALLEY AS THE SOURCE

Figure 3 is a potentiometric surface map of the Big Chino Valley that we prepared using water levels reported by well drillers at the time the wells were drilled. Two conditions must be generally met for this map to represent the potentiometric surface. First, the basin must be in approximate equilibrium so that water level measurements made at different times do not affect the contouring. Second, the measurements must be reasonably accurate. We believe that the basin is, and has been, in approximate equilibrium over the years, and we believe based upon years of using drillers' water level measurements that they are usually accurate enough to prepare this kind of map.

Figure 3 shows that ground water flows from the upland areas on both sides of the basin into the basin, and then it flows to the southeast to the Verde River. At the southern end of the basin, Figure 4 (an enlargement of Figure 3

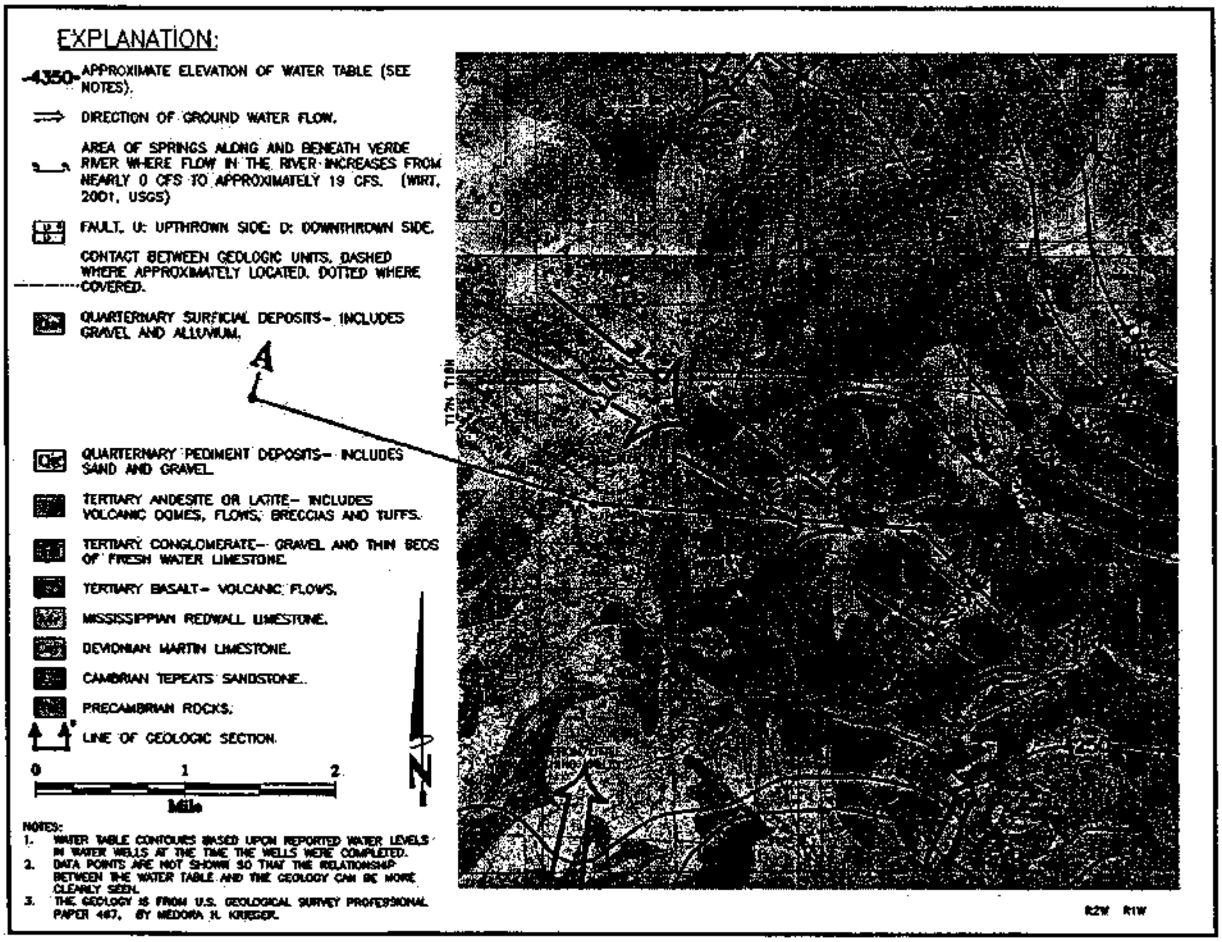

Figure 4. Potentiometric Surface at the Southern End of Big Chino Valley

overlain on Krieger's (1965) geologic map) shows that the ground water flows from the basin fill sediments into an area of volcanic rocks and then into Paleozoic rocks (mostly limestones and dolomites) before discharging to the Verde River. Both Figures 3 and 4 show recharge entering the basin from Big Black Mesa and also show where recharge enters the basin from the Little Chino Valley.

For the ground water flow path to be viable, both the volcanic rocks and the Paleozoic rocks must be highly transmissive. Water Resources Associates (1990 and 1991) conducted pumping tests of two wells that we have incorporated into a geologic cross section that generally follows the flow path (Figure 5). Table 2 shows the results of those tests.

Table 2. Reported Aquifer Transmissivity and Lithology Along Flow Path

#	Well Name	Transmissivity (gpd/ft)	Reported Producing Lithology
2	Dugan	1.6×10^6	Fractured Basalt and Alluvium
3	HR-2	1.2×10^5	Limestone

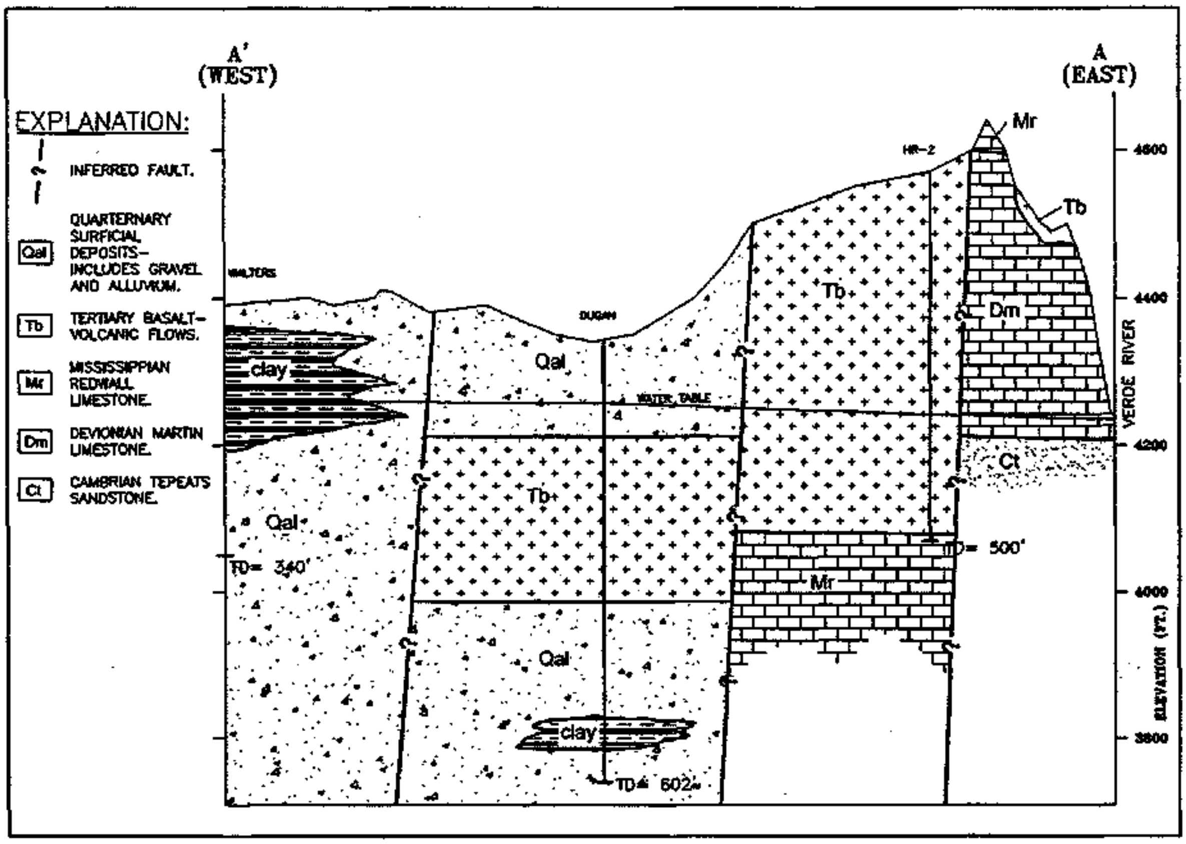

Figure 5. Geologic Cross Section along Flow Path

The tests show that the wells are highly transmissive. We believe that the high transmissivity results from the development of an open fracture network and solution caverns. Water Resources Consultants (1990) interpreted numerous faults in the vicinity of the flow path using the results of geophysical surveys. Fractures and lost circulation zones are reported on drillers' logs in the area.

At the present time ground water pumping in the Big Chino Valley is relatively small. ADWR (Brown et al, 2000) estimated the pumping to be approximately 4,000 to 5,000 af/yr in 1990. It may have been even higher in the 1960's and 1970's when a development, that has since failed, was pumping ground water to fill artificial lakes (Wirt and Hjalmarson, 2000).

The net depletion resulting from the 1990 pumping is on the order of 2,000 af/yr. Therefore, the discharge from the basin is the recharge (23,400 af/yr) minus the net depletion (2,000 af/yr) or approximately 21,400 af/yr (29.5 cfs). This is approximately equivalent to the 1990-1993 gaged base flow of 24 to 29 cfs (see Figure 2).

SUMMARY

We conclude for the following reasons that the source of the springs that provide the base flow of the Verde River is ground water discharging from the Big Chino ground water basin:

1) The estimated discharge from both the Little Chino Valley and Big Black Mesa are far too low to be the major source of the Verde River springs
2) The estimated recharge to the Big Chino Valley is nearly equivalent to the spring discharge; and
3) The potentiometric surface map shows that ground water flows through the Big Chino Valley and discharges to the Verde River.

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