WATER COMMITMENTS IN THE PRESCOTT ACTIVE MANAGEMENT AREA AND IMPLICATIONS FOR THE UPPER VERDE AND UPPER AGUA FRIA RIVERS

By William Meyer and Edward W. Wolfe – March 30, 2004

Introduction

The cities of Prescott, Prescott Valley, and the town of Chino Valley, commonly referred to as the Tri-Cities, currently rely almost exclusively on ground water from the Prescott Active Management Area (Prescott AMA) for their domestic water supply (fig.1). The Prescott AMA is also a source of water for agricultural use. At the present time, the AMA is being seriously over-pumped and has been for a number of years. Over-pumping has caused ground-water levels to continually decline in most of the Prescott AMA and has led to a continuing decline in the amount of water that naturally discharges from it to Del Rio Springs (water that once discharged to the upper Verde River), to the ground-water system of Big Chino Valley (which, in turn, discharges to the upper Verde River) and to the upper Agua Fria River. Ultimately, the amount of ground water that can be withdrawn from the Prescott AMA must be seriously reduced in order to be able to continue to withdraw water from it on a long-term continuing basis. Otherwise, someday, there will be no water. The state of Arizona assumes that the maximum amount of water that can be withdrawn from an aquifer on a long-term basis, referred to as "safe yield", is equal to the rate of recharge to the aquifer, and the Ground Water Management Act of 1980 mandates that pumping from the Prescott AMA be brought into safe yield by 2025 .

The Central Arizona Project, which delivers water from the Colorado River to southern Arizona via a canal, was initiated to enhance water supplies in the southern part of the State. Although Prescott was allocated water from this project, this was in reality a paper allocation owing to the fact the city is located more than 4,000 ft above the canal and cannot economically obtain water from it as a result. Given this, Prescott sold its allocation and, under ARS 45-555, was given the right to withdraw up to 8,717 ac-ft/yr (letter from H.R. Guenther, Director of Arizona Department of Water Resources, August 21, 2003) of ground water from the Big Chino Valley and transport this water to the City to supplement the water it is entitled to pump from the Prescott AMA. Thus, Prescott currently has an option to purchase land (the CV Ranch) in the Big Chino Valley from which it plans to pump 8,717 ac-ft/yr of ground water. In addition, import of an additional 2,136 ac-ft/yr may be permitted from retirement of irrigation on an estimated 712 acres (unpublished Yavapai County Water Advisory Committee data, February, 2004) at a rate of 3 ac-ft/yr/acre. Thus, the estimated total volume of water that the City can import annually is about 10,850 ac-ft.

Ground water from the CV Ranch would be used by Prescott and presumably the Tri-Cities to support continued population growth and to permit ground-water withdrawal from the Prescott AMA to be reduced to safe yield by 2025, as required by current State

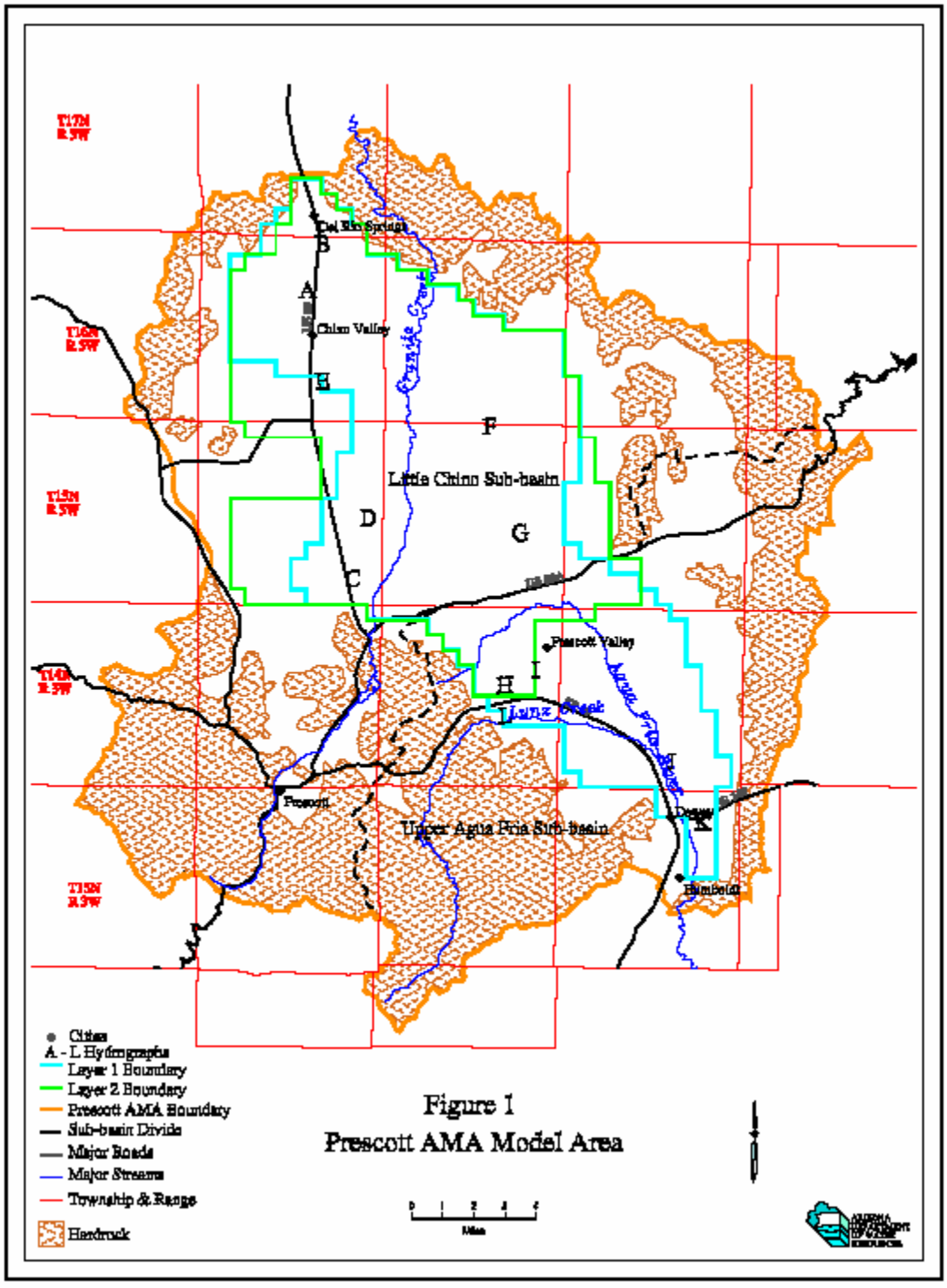

Figure 1. Map of the Prescott Active Management Area (Nelson, 2003).

law. Population projections for the Prescott AMA published by the Arizona Department of Water Resources (ADWR, 1997) indicate a 2002 population (by interpolation) of 88,537 and a 2025 population of 147,680.

Yavapai County has the goal (as stated in the Goals and Objectives of the Yavapai County Water Advisory Committee) of managing growth in a manner that assures a sustainable supply of water while at the same time protecting "baseline flow" in the County's rivers and streams. In fact, the water demand associated with the 2025 projected population of the Prescott AMA will not allow all of these goals to be met. Development of the required amount of water to meet projected growth will ultimately cause perennial flow in the headwaters of the Verde and Agua Fria Rivers to disappear.

2002 Water Usage

Total ground-water pumpage from the AMA in 2002 was 23,515 ac-ft (ADWR, 2003). This included 21,815 ac-ft pumped from non-exempt wells and an estimated 1,700 ac-ft from exempt wells. Not included in these figures is pumpage of approximately 1,400 ac-ft from exempt wells constructed in crystalline rock located within the boundaries of the AMA (fig.1). ADWR considers this water to be derived solely from storage and not part of the regional ground-water system of the AMA proper. An estimated 6,220 ac-ft was pumped for agricultural use leaving 17,295 ac-ft used to serve an estimated population of 88,537. This usage equates to an average use of approximately 175 gallons per day per person (gpd/p; table 1).

The pumpage from non-exempt wells was appreciably greater in 2002 than during the trend of the preceding decade (fig. 2) and may reflect an unusually high rate water use for watering of trees to protect them from bark-beetle infestation. In order to account for this possibility, a linear regression was used (fig. 2) to arrive at a 2002 estimated pumpage of 18,800 ac-ft for non-exempt wells. This rate of withdrawal is assumed to equal the non-exempt pumpage that would have occurred in the absence of a drought. Addition to this value of the 1,700 ac-ft for exempt-well pumpage gives a total for the amount withdrawn for non-drought conditions equal to 20,500. Subtracting the 6,220 ac-ft for agricultural use leaves 14,280 ac-ft to meet the 2002 population demand. This estimated usage results in an average use of approximately 144 gpd/p (table 1).

Table 1. Per capita domestic water usage in the Prescott AMA in 2002

2002	Actual	Normalized[1]
Population	88,537	88,537
Pumpage, ac-ft	23,515	20,500
Agricultural use, ac-ft	-6,220	-6,220
Net for domestic use, ac-ft	17,315	14,280
Per capita domestic use gal/day	175	144

[1] Adjusted for hypothetical non-drought conditions

Safe Yield and the Prescott AMA

Safe Yield for any aquifer in Arizona has been defined by the State as the condition in which the volume of ground water pumped from an aquifer on an annual basis is equal to the sum of natural and artificial recharge. This amount of water is assumed to be available for withdrawal from the aquifer on a long-term continuing basis. A withdrawal

rate greater than safe yield represents a situation in which ground water is being mined; as a result, long-term withdrawal of water beyond safe yield is not sustainable. Overdrafts from the Prescott AMA have been continuous for many years, resulting in the Arizona Department of Water Resources declaring the AMA to be out of safe yield in 1999.

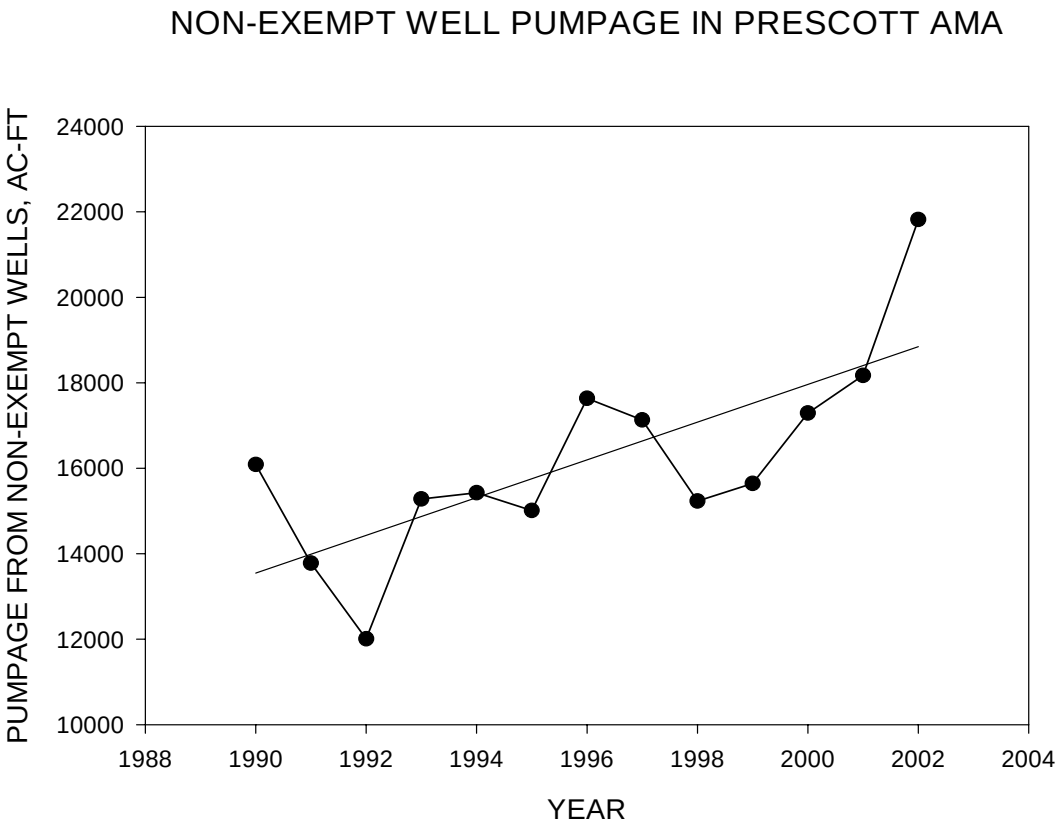

Figure 2. Non-exempt well pumpage in the Prescott AMA for the years 1900 through 2002 (data from ADWR, 2003). Straight line represents a linear regression through the data. The regression gives a value of approximately 18,800 ac-ft for pumpage from non-exempt wells in 2002.

As shown in figure 1, the Prescott AMA encompasses the Little Chino Sub-basin and the upper Agua Fria River watershed. Natural ground-water recharge to Little Chino Sub-basin was estimated by Nelson (2002, p. 13) to be about 7,400 acre-ft/yr. This water exited the AMA below Del Rio Springs (4,400 ac-ft/yr) and as underflow from the Prescott AMA to the Big Chino Sub-basin. Natural ground-water recharge to that part of the Agua Fria River drainage area contained within the Prescott AMA was estimated by Nelson to be about 2,300 ac-ft/yr. This water exited the AMA as baseflow in the Agua Fria River near Humboldt. Without any source of artificial recharge then, the maximum

amount of water that can be developed from the Prescott AMA on a long-term sustainable basis, or safe yield, equals 9,700 ac-ft/yr.

2002 Domestic Water Use in Safe-Yield Terms

The safe yield of the Prescott AMA in 2002 equaled 16,070 ac-ft. Long-term natural recharge provided 9,700 ac-ft of this amount while artificial recharge accounted for the remaining 6,370 ac-ft. Of the later amount, the Cities of Prescott and Prescott Valley returned 3,260 ac-ft to the aquifer system as artificial recharge of recovered sewage effluent, and 3,110 ac-ft, was returned to the aquifer as agricultural return flow (ADWR, 2003). Subtracting the 2002 pumpage for agriculture gives a balance of 9,870 ac-ft available for domestic use under the safe-yield limitations (table 2).

Table 2. Hypothetical Prescott AMA water budget for 2002 under safe-yield limitation

	Usage based on normalized 2002 pumpage	Usage based on actual 2002 pumpage
Pumpage of new ground water, ac-ft	9,700	9,700
Used for agriculture, ac-ft	-6,200	-6,200
Agricultural return flow, ac-ft	3,110	3,110
Artificial recharge, ac-ft	3,260	3,260
Water available for domestic use, ac-ft	9,870	9,870
Per capita domestic use, gpd/p	144	175
Supportable population	61,190	50,350
Estimated population	88,537	88,537
Unsupported population	27,347	38,187
Commitment beyond safe yield, ac-ft	4,411	7,486

At a per capita water-usage rate of 144 gpd/p, determined from the lower, normalized, AMA pumpage value, the water available under safe-yield limitations would support 61,190 people or only 69 percent of the estimated 2002 AMA population of 88,537. At a per capita water-usage rate of 175 gpd/p, determined from the volume of water actually pumped for domestic use in the AMA in 2002, the water available under safe-yield limitations would support 50,350 people, which is only 57 percent of the estimated 2002 AMA population of 88,537 (Table 2).

In terms of the actual amount of water pumped for domestic use in 2002, water usage in the AMA exceeded safe yield by nearly 7,500 ac-ft (table 2).

Projected 2025 Water Use

Assuming that 10,850 ac-ft of water is imported from the Big Chino Valley, and also assuming no agricultural use of water in 2025 and that artificial recharge increases from the 2002 value in direct proportion to the population, the total amount of water available for domestic use equals 25,988 ac-ft (table 3). Using a per capita domestic-use value for the normalized 2002 pumpage, which minimizes any continuing drought impact on water usage, we have sufficient water to support a population of about 160,000—about 13 percent larger than the projected AMA population for 2025. On the other hand, using a per capita domestic-use value derived from the actual 2002 pumpage data, which projects a continuing drought impact, we have insufficient water to support the projected population. The supply falls short by about 10 percent. The data suggest that the maximum population that the AMA can support under safe-yield limitations and without a wholly new source of imported water (other than the importation currently permitted from Big Chino Valley) is somewhere between about 130,000 and 160,000.

Table 3. Hypothetical Prescott AMA water budget for 2025 under safe-yield limitation

	Usage based on normalized 2002 pumpage	Usage based on actual 2002 pumpage
Pumpage of new ground water, ac-ft	9,700	9,700
Water imported from Big Chino Valley, ac-ft	10,850	10,850
Used for agriculture, ac-ft	0	0
Agricultural return flow, ac-ft	0	0
Artificial recharge, ac-ft	5,438	5,438
Water available for domestic use, ac-ft	25,988	25,988
Per capita domestic use, gpd/p	144	175
Supportable population	161,115	132,574
Projected population	147,680	147,680

The net loss of ground-water to agriculture in 2002 was estimated at 3,110 ac-ft. The same amount of net agricultural ground-water use in 2025 would reduce the water available for domestic use to 22,878 ac-ft. At the normalized 2002 per capita consumption rate (144 gpd/p), the domestic water supply would support only 141,384 people, about 6,000 fewer than the projected AMA population in 2025. At the actual 2002 per capita consumption rate (175 gpd/p), the domestic water supply would support only 116,709 people, about 31,000 fewer than the projected AMA population in 2025.

Continued pumping of ground water at a rate greater than safe yield—so as to support a population larger than projected—will eventually deplete the AMA aquifer system sufficiently that not all of the populace can be supported. Furthermore, even under safe-yield conditions, the inevitable consequence, as shown below, of supporting our water

demands within the Prescott AMA will be virtual elimination of ground-water discharge and loss of perennial flow to the upper parts of the Verde and Agua Fria Rivers.

The Effect of Ground-Water Withdrawals from the Prescott AMA and Big Chino Valley on the Upper Verde and Upper Agua Fria Rivers

All ground water that enters an aquifer ultimately discharges from it, and, on a long-term basis, recharge to an aquifer or ground-water system equals discharge from it. The introduction of pumping by man removes water that otherwise would have naturally discharged from an aquifer, so that **the amount of water withdrawn by wells eventually results in an equal reduction in discharge**.

The upper Verde River becomes perennial near the mouth of Granite Creek as a result of ground-water inflow to the river from Big Chino Valley and from Little Chino Valley. The U.S. Bureau of Reclamation (Ewing, Osterberg, and Talbot, 1994) estimated that the long-term contribution of ground water from the Big Chino Valley equals about 23,800 ac-ft/yr, and the ADWR (Nelson, 2002) estimated that the long-term contribution of ground water from Little Chino Valley is approximately 7,400 ac-ft/yr. These results imply a combined long-term average baseflow of 31,200 ac-ft/yr in the uppermost Verde River. The average baseflow of the upper Verde River as measured at the Paulden gage from 1963 through 1997 averaged only 18,000 ac-ft/yr, however, which suggests that pumpage from the two valleys has reduced the natural long-term contribution of ground water from the two valleys by approximately 13,200 ac-ft/yr, or 40 percent.

Nelson (2002, p.19) concluded that, as of 1999, pumping from the Prescott AMA reduced natural discharge from the AMA to the upper parts of the Verde and Agua Fria Rivers by approximately 5,000 ac-ft/yr. Discharge from Del Rio Springs, which flowed to the upper Verde River, was reduced from 4,400 ac-ft/yr to 1,800 ac-ft/yr. Ground-water movement from the Little Chino Valley into Big Chino Valley—and ultimately to the Verde River—was reduced from 3,000 ac-ft/yr to about 1,800 ac-ft/yr. The combined loss in natural discharge from the Little Chino Valley (3,800 ac-ft/yr, 5.3 cfs) has or will ultimately manifest itself as a loss of baseflow in the upper Verde River. Given the inferred total reduction of 13,200 ac-ft /yr in baseflow above the Paulden gage, this result suggests that pumpage from the Big Chino Valley has potentially reduced the long-term natural flow of the upper Verde River by as much as 9,400 ac-ft/yr.

According to Nelson (2002), natural discharge to the upper Agua Fria River has been reduced by approximately 900 ac-ft/yr, a reduction of 39 percent from the estimated natural discharge of 2,300 ac-ft/yr.

Assuming continued pumping from the Prescott AMA to meet existing and future needs of the AMA through 2025, Nelson estimated that natural discharge from the Prescott AMA in 2025 will be reduced to approximately 3,300 ac-ft/yr. Del Rio Springs will be become dry in about 2025, and ground-water discharge to Big Chino Valley would be reduced to approximately 1,100 ac-ft/yr. Overall the loss in ground-water discharge from Little Chino Valley to the headwaters of the Verde River will equal 6,300 ac-ft/yr (8.7

cfs). This loss represents approximately 20 percent of the long-term perennial flow in the upper Verde River discussed above.

Even if the Prescott AMA is brought into safe yield by 2025, as required by law, pumpage from the AMA will still reduce all natural discharge from the AMA to zero. This would not occur immediately, but it would ultimately be the case. This would mean that Del Rio Springs would still go dry, and that the movement of ground-water from the Little Chino Sub-basin into the Big Chino Sub-basin would cease. The combined loss of Del Rio Springs and underflow to Big Chino Sub-basin would reduce baseflow in the upper Verde River by approximately 24 percent of its long-term pre-development baseflow.

Meyer and Wolfe (2004) have shown that the withdrawal of 10,850 ac-ft/yr from the CV Ranch in Big Chino Valley would begin to reduce baseflow in the headwaters of the Verde River within 5 years after the initiation of pumpage. They estimate that after 30 years baseflow would be reduced by about 16 to 24 percent and after 50 years it would be reduced by about 24 to 31 percent. Eventually, baseflow of the upper Verde River will be reduced by an amount equal to the rate water is being withdrawn at the ranch, 10,850 ac-ft/yr or 15.0 cfs.

Ultimately then, ground-water withdrawal from the Prescott AMA at a rate equal to safe yield and from the CV Ranch located in Big Chino Valley at a rate equal to 10,850 ac-ft/yr will reduce the rate of ground-water inflow into the upper Verde River by 18,250 ac-ft/yr (10,850 ac/ft-yr plus natural recharge to the Little Chino Sub-basin of 7,400 ac-ft/yr), which is almost identical to the average baseflow measured in the river from 1963 through 1997. This would cause the upper reaches of the river, above the Paulden gage, which now are perennial, to become dry or nearly dry.

In order to allay citizens' concerns about the potential impact to the Verde River resulting from the combination of the expected growth in the Prescott AMA and the importation of ground water from Big Chino Valley, some representatives of Tri-City municipalities (for example, L. Tarkowski in a talk to the League of Women Voters of Central Yavapai County, March 13, 2004) refer to a mitigation plan that has been formulated to assure preservation of springs and streams. The unmentioned flaw in any mitigation plan is that, in order to maintain the average upper Verde River baseflow determined for the period 1963 through 1997 and the natural discharge to the upper Agua Fria River, the Prescott AMA will eventually have to return—either as artificial recharge or as direct flow into the upper Verde and Agua Fria Rivers—all of the water it is permitted to pump from the AMA and from Big Chino Valley. Clearly, a mitigation plan that truly protects the two rivers that drain the AMA is a pipedream if the currently envisioned population growth in the AMA materializes.

Summary

- The Tri-Cities of Prescott, Prescott Valley, and Chino Valley currently obtain almost all of their water supplies from ground water in the Prescott Active Management Area (Prescott AMA).

- Ground-water pumpage from the AMA has seriously exceeded the rate of ground-water replenishment for many years. As a consequence, water levels have declined in the AMA, and ground-water discharge that ultimately supplies perennial flow (baseflow) in the upper parts of the Verde and Agua Fria Rivers has been substantially diminished.

- State law requires that ground-water pumping from the Prescott AMA be reduced to safe yield by 2025. Safe yield means that the amount of water withdrawn from the aquifer system by pumping cannot exceed the volume recharged to the aquifer system.

- Prescott is permitted by State Law to import up to 8,717 ac-ft/yr from Big Chino Valley plus some 2,136 ac-ft/yr from retirement of irrigation on an estimated 712 acres at a rate of 3 ac-ft/yr/acre to supplement the ground water it is permitted to pump from the AMA. Thus, the estimated total volume that the City can import annually from Big Chino Valley is about 10,850 ac-ft.

- Accordingly, Prescott has an option to purchase land (CV Ranch) in Big Chino Valley. The ground water imported from Big Chino Valley would be used by Prescott and, presumably, the Tri-Cities to support continued population growth and to permit ground-water withdrawal from the AMA to be reduced to safe yield by 2025.

- Population projections for the Prescott AMA by the Arizona Department of Water Resources indicate a 2002 population (by interpolation) of 88,537 and a 2025 population of 147,680.

- Yavapai County has the goal, as stated in the Goals and Objectives of the Yavapai County Water Advisory Committee, of managing growth in a manner that assures a sustainable supply of water while protecting "baseline flow" in the County's rivers and streams. However, the water demand associated with the 2025 projected population of the Prescott AMA will eventually cause the headwaters of the Verde River to become dry or nearly so.

- Current water usage in the Prescott AMA seriously exceeds safe yield.

- Importation of water from the Big Chino Valley, reduction of agriculture, and increased effluent recharge make it possible to supply water for an AMA population between about 130,000 and 160,000 in 2025 within safe-yield

limitations. The population can never exceed that level unless a wholly new source of imported water is tapped.

- An unfortunate hydrologic fact is that the amount of water that is withdrawn by wells ~~is~~ eventually an equal reduction discharge to springs and streams.

- Ground-water extraction from the AMA has already severely reduced discharge from the Little Chino Basin.

- Even under the condition of safe yield, pumpage from the Prescott AMA will eventually reduce all ground-water discharge from the AMA to zero.

- Withdrawal of 10,850 ac-ft/yr from Big Chino Valley will eventually also reduce baseflow in the upper Verde River by 10,850 ac-ft/yr.

- Ground-water withdrawal from the Prescott AMA at a rate equal to safe yield and from Big Chino Valley at a rate equal to 10,850 ac-ft/yr cause the upper reaches of the Verde River, now perennial, to become dry or nearly dry.

- There is no mitigation plan that can maintain perennial flow in the upper reaches of the Verde and Agua Fria Rivers. In order to maintain the current baseflow, the Prescott AMA will eventually have to return—either as artificial recharge or direct flow into the rivers—all of the water it is permitted to pump from the AMA and Big Chino Valley.

References

ADWR, 1997, Population projections (1997-2050) for use in statewide water planning: Arizona Department of Water Resources, September 1997.

ADWR, 2003, Prescott Active Management Area 2002-2003 hydrologic monitoring report, Arizona Department of Water Resources, Hydrology Division, 21 p.

Ewing, D.B., Osterberg, J.C., and Talbot, W.R., 1994, Groundwater study of the Big Chino Valley, Technical Report, Section III of III, U.S. Bureau of Reclamation.

Meyer, William, and Wolfe, E. W., 2004, The potential impact on the Verde River of pumping 10,850 acre-feet per year at the CV Ranch, Big Chino Valley: unpublished ms., 45 p.

Nelson, Keith, 2002, Application of the Prescott Active Management Area groundwater flow model planning scenario 1999-2025: Arizona Department of Water Resources, Modeling Report no. 12, 49 p.

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Both authors are retired U.S. Geological Survey scientists. Meyer, a hydrologist, was trained at the University of Arizona and is an expert on the physics of ground-water movement and ground-water modeling. He has considerable experience in modeling the presence of low permeability features in ground-water systems. Wolfe is a geologist. In the course of his career, he has published studies on the geology of northern and central Arizona, as well as on the Pacific Northwest and Hawaii.