Yavapai County Water Advisory Committee (WAC)

Information Series* 2009 #2: **How much water is there?**

*Informational Series Background: This is intended as an informational item for the Yavapai County Water Advisory Committee (WAC) and the public. This document is prepared by the WAC Coordinator in consultation with the Technical Committee of the WAC.

The Informational Reports Series is a result of the WAC's desire to systematically address questions raised by the WAC member representatives. This document does not fully explore the complexities and implications of any given question. Thus it is not necessarily intended to "stand alone". This is intended to provide fundamental information to aid in understanding this regions water resource.

The question is interpreted by the TAC of the WAC to ask: How much ground water is in storage and potentially available for recovery?

Groundwater in storage:
Due to definite physical and indefinite chemical limitations, not all underground water can be recovered and used for domestic supplies. Recoverable groundwater is the amount of water that can be physically and economically withdrawn from storage. Some groundwater that can be withdrawn is of poor quality.

Notwithstanding the above statements, Table 1 below shows a range of available stored groundwater in the Big Chino, Little Chino, and Verde Valley basin-fill aquifers (based on specific yield). The calculations are based on the estimated amount of saturated sediments from the Blasch and others 2006 report (source data is Langenheim *et al*, 2005) and estimated *specific yields* of 4% and 10% (from Corkhill, November 2007 Big Chino Discussion). *Specific yield* is related to the amount of water that is physically available to pumps (within the potential limitations listed in the notes associate with Table 1, above). (Also see the "Background" section for more information)

The location and approximate extent of saturated sediments for which the calculations are made is shown in the map figure below (Fig 22 from Blasch *et al* 2006).

Table 1: Groundwater Storage Estimates for Little Chino, Big Chino, and Verde Valley Subbasins (SEE NOTES BELOW)**

Verde Watershed Subbasin	Saturated Thickness (Blasch et al, 2005; Table 13, p46)	Water in Storage using 4% specific yield	Water in Storage using 10% specific yield
Big Chino	155 million ac ft	6.2 million ac ft	15.5 million ac ft
Little Chino	33 million ac ft	1.3 million ac ft	3.3 million ac ft
Verde Valley	112 million ac ft	4.5 million ac ft	11.2 million ac ft

**<u>Notes (Table 1)</u>:

1. Due to inherent uncertainty in aquifer properties, storage estimates are appropriately expressed as a range.

2. Not all water held in storage can be released from the aquifer. Some water will be held in the pore spaces due to surface attraction. Specific yield is more representative of water available by pumping than storage capacity (and is thus used for this calculation). However,

3. Other factors may limit the amount of recoverable water from storage by pumping wells (and the ability to use the water):

   Aquifer permeability
   Aquifer heterogeneity
   Drilling costs
   Infrastructure costs
   Water Quality
   Legal concerns
   Environmental concerns

4. This table does not include storage values for other aquifers, such as the Paleozoic rocks (e.g. limestone) beneath the basin fill, and rocks of the Colorado Plateau. The granite rocks, ("basement") which underlie most of our region, are not considered viable as aquifers.

Aquifer storage capacity is defined as the maximum amount of water that can be stored in an aquifer. Storage capacity is related to the material properties of the aquifer, such as pore space. Water in storage is held in the open pore spaces within an aquifer. *Specific yield* is related to the amount of water that is physically available to pumps (within the potential limitations listed in the notes associate with Table 1, above; and see definition in "Background" section, below).

The map below shows the thickness of saturated sediments in the Verde River sub basins (modified from Blasch *et al*, 2006, Figure 22, p. 55). The water is accessible through wells drilled into the saturated materials (aquifers). The locations and water-in-storage values in Table 1 correspond to the colored areas on this map.

The basin-fill sediments, illustrated by thickness (colors) in the figure below, are the major aquifers as determined by interpretation of geophysical information (Langenheim *et al*, 2005; Blasch *et al*, 2006 (Figure 22)). The exact boundaries are not discernable at the scale of the map. The saturated areas are the places (aquifers) where water is collected and stored until it is pumped, consumptively used by vegetation, or discharged to an outflow point such as a spring. The areas depicted in the figure are the areas corresponding to the calculations in Table 1.

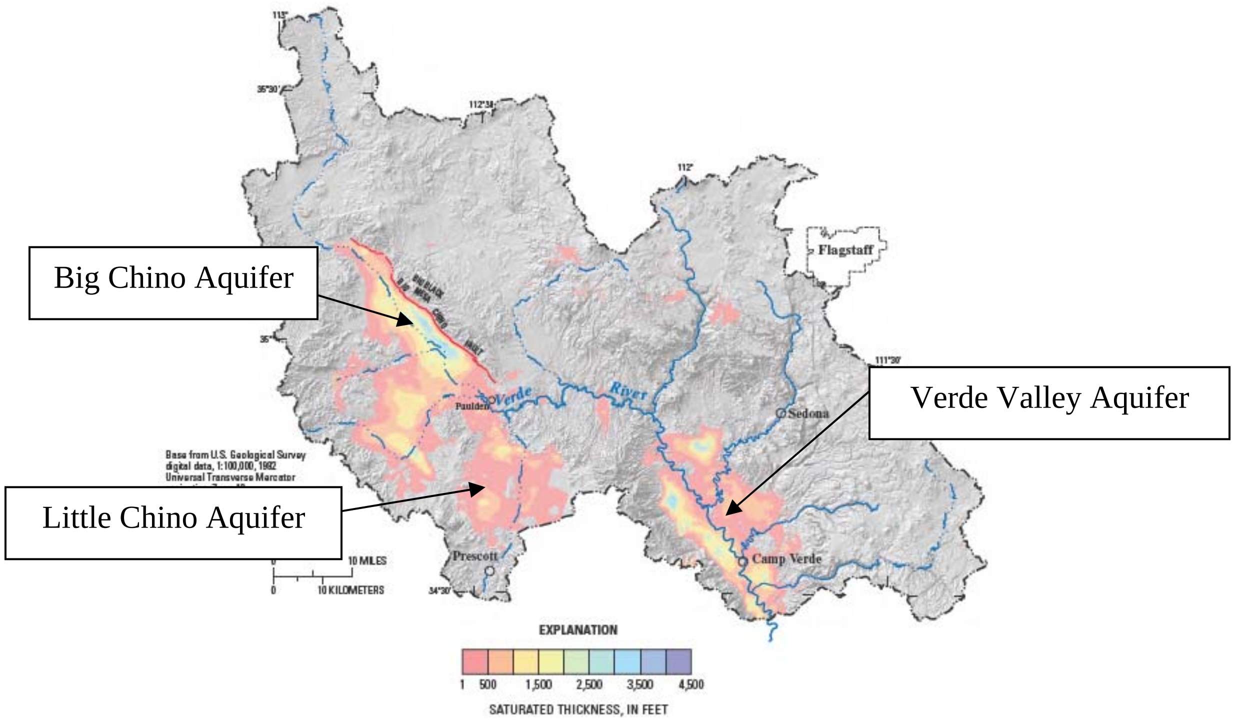

Figure 22. Thickness of saturated Cenozoic sediments and volcanic rocks, upper and middle Verde River watersheds, central Arizona. Thickness data from Langenheim and others, 2005.

Conclusions, Caveats and Potential Implications

Based on referenced information and specific yield calculations, the Big Chino subbasin aquifer has from about 6 million to 15 million acre feet of water available for pumping. Some of it may be of poor quality or subject to other limitations imposed by aquifer properties, legal, environmental, or economic issues. The Little Chino subbasin aquifer has from 1.3 to 3.3 million acre feet, and the Verde has from about 4.5 to 11 million acre feet (with same types of potential limitations as Big Chino).

The information herein is based on published reports and a presentation by Frank Corkhill of ADWR. The information used in the reports is based on data records and geologic/geophysical interpretations. The volume of saturated sediments, published in the Blasch report is considered the best available information to date, and should be considered *representative* of the actual value. The specific yield values from which the water volumes are calculated are estimated based on professional judgment and empirical evidence from other areas of the country. The range of values used is considered reasonable for the types of materials known to exist in the sedimentary fill aquifer portions of the Verde, Big and Little Chino subbasins. The amount of water in these areas is best expressed as a potential range.

The values presented in this summary may be used by water resource managers to understand implications of ongoing or planned activities. For instance, the values can be compared to potential groundwater withdrawal rates and recharge estimates. In applying these values, nuances and specific consideration will likely be required for each application due to geographic and aquifer variations, or other implications imposed by the factors listed in note #3 attached to Table 1, above. Therefore, it is difficult to draw complex predictive conclusions solely from the numbers in Table 1. However, the numbers are meant to be representative, and the true value of water in storage (from specific yield) is likely to be within the range in Table 1.

Other Watersheds

Little or no information was found for storage estimates for the other watersheds in the County (Agua Fria, Hassayampa, and Bill Williams). Some information is available for the Upper Agua Fria water budget. This provides insight to the Upper Agua Fria system but does not quantify the in-storage amount (see the Information Series for water budgets (Info Series #3)).

Background:

General –water in storage:

Groundwater flows through, and is stored in pore spaces and cracks in the subsurface. The geologic units that have underground water in sufficient quantities for wells are known as aquifers. The amount of water in aquifers is dependent on the storage properties of the aquifer (geology). The following is an excerpt from a "Groundwater Storage and Flow" by R. W. Buddemeier, J. A. Schloss (2000) http://www.kgs.ku.edu/HighPlains/atlas/apgengw.htm

> **Groundwater Storage, Porosity, and Specific Yield:** Groundwater occupies the cracks and pore spaces between rocks and mineral grains below the land surface. In the saturated zone, essentially all of the pores are filled with water. If a volume of saturated aquifer material is completely dried, the water volume removed reflects the total *porosity* of the material, or the fraction of pore space within the total volume of solids plus open spaces. This number can be surprisingly large; some minerals and rock formations can have total porosities in excess of 50%. In the unsaturated, or vadose, zone there can be significant amounts of water present, but the voids are not completely filled (see appendix on **saturated thickness**).
>
> However, some of the pore spaces may be too small or too poorly connected to permit the water they contain to flow out easily. The effective porosity can be thought of as the volume of pore space that will drain in a reasonable period of time under the influence of gravity. Effective porosity is always less than total porosity, sometimes (as in the case of clays) much less. "Good aquifers" tend to have values of effective porosity in the range of 10-30%, although examples of higher and lower values can be found. Figure 1 illustrates the relationship among the types of porosity and the volume of water in storage.

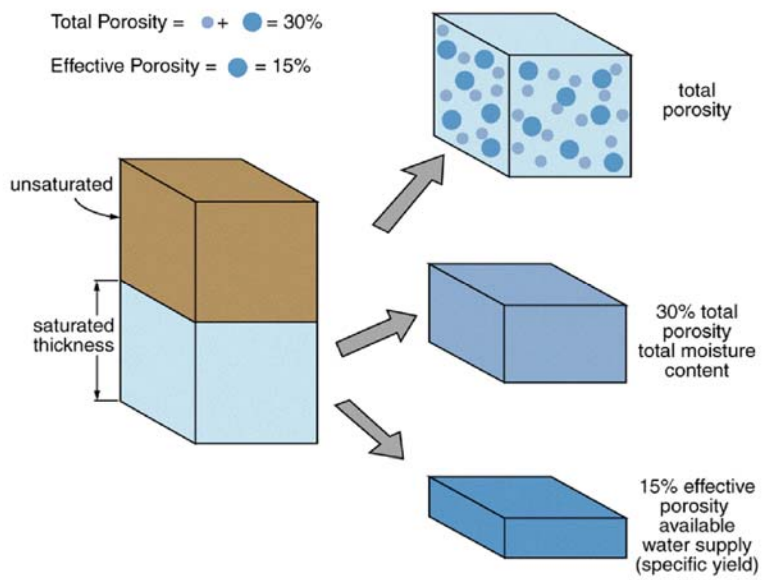

Figure 1: A schematic illustration of an aquifer in which the total porosity in the saturated zone is 30%, half of which is tightly held in small pores or mineral associations, and half of which is in large pores that drain relatively easily. The latter fraction can be pumped out, and is the effective porosity or specific yield. Illustration not to scale.

A characteristic closely related to effective porosity is the ***specific yield*** of the aquifer, which is the volume of water per unit volume of aquifer that can be extracted by pumping. Although there are some technical distinctions, effective porosity and specific yield can be thought of as equivalent for most non-technical purposes.
Specific yield (SY) is clearly an important factor in water availability, and is the factor that is used to convert saturated thickness (ST) to the actual volume of groundwater available; **Volume = Area x ST x SY**

Figure 1 compares the water available for extraction with the total water and aquifer volumes.

At any given location, the porosity of the formation remains essentially constant, but the volume of water in storage, the average local porosity, and the specific yield all vary with changes in saturated thickness (water table elevation). Some of this variation can be explained (and quantitatively predicted) on the basis of straightforward physical principles, but some of it is due to local variations in the aquifer structure. This hydrogeologic variability is difficult to predict or measure with detailed accuracy.

-End of excerpt-

References and Related Information Sources:

The primary reference for the Verde Basin is the USGS report by Blasch *et al*, 2006 (SIR 2005-5198) “Hydrogeology of the Upper and Middle Verde River Watersheds, Central Arizona”. (This is the conceptual report; the WAC has received presentations and it serves as a basis for the Northern Arizona Regional Groundwater Flow Model in preparation by the USGS).

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