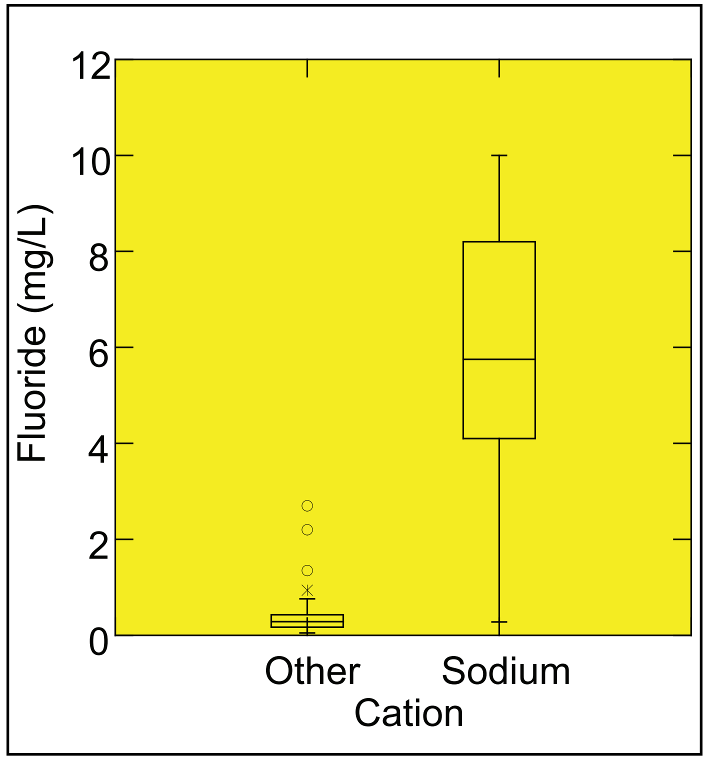


*Figure 5 – Fluoride concentrations are significantly higher in samples having sodium chemistry than in calcium or mixed water chemistry samples. If groundwater is depleted in calcium, large concentrations of dissolved fluoride may occur through precipitation or dissolution of the mineral fluorite.[4]*

*Figure 6 – Although completed in water-bearing schist, this 280-foot deep well north of Lake Pleasant did not have sodium chemistry or associated elevated concentrations of arsenic and fluoride like other wells and springs producing water from this geologic stratum.[3]*

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Maps by Nicholas Moore

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ADEQ
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# FACT SHEET

# Ambient Groundwater Quality of the Agua Fria Basin: A 2004-2006 Baseline Study – July 2008

## INTRODUCTION

A baseline groundwater quality study of the Agua Fria basin was conducted from 2004 through 2006 by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program. ADEQ conducted this monitoring pursuant to Arizona Revised Statutes §49-225. This fact sheet is a synopsis of the ADEQ Open File Report 08-02.[1]

The Agua Fria groundwater basin is located between the metropolitan areas of Phoenix and Prescott in central Arizona. The basin encompasses the drainage of the Agua Fria River from below the Prescott Active Management Area to Lake Pleasant. This lightly populated basin consists primarily of federal land (U.S. Forest Service and Bureau of Land Management), State Trust land and private land including the communities of Mayer and Crown King in the Bradshaw Mountains and Cordes Junction and Black Canyon City along Interstate 17.

*Figure 1 – The basin's main drainage, the Agua Fria River, is shown at the confluence of Badger Springs Wash.*

## HYDROLOGY

The basin's main drainage is the Agua Fria River (Figure 1), which flows north to south before it reaches Lake Pleasant. Lake Pleasant was created by the new Waddell Dam, operated by the U.S. Bureau of Reclamation, to store flow from the Agua Fria River and Colorado River water transported via the Central Arizona Project's Hayden-Rhodes Aqueduct. Major tributaries to the Agua Fria River are Big Bug Creek, Silver Creek, Sycamore Creek, and Yellow Jacket Creek. These watercourses are generally intermittent streams except for some perennial stretches where submerged bedrock forces groundwater to the surface.[2]

Groundwater is the main source of water in the basin. Although water use is increasing in the basin, minimal water development has occurred except in populated areas such as Mayer, Cordes Junction and Black Canyon City where many shallow, small capacity wells have been drilled.[3] Rock units in the Agua Fria basin can be divided into four broad categories based on their geologic character and their ability to yield water. From youngest to oldest, the units are basin-fill sands and gravels, volcanic rocks, conglomerates, and crystalline (igneous and metamorphic) rocks.[2] Although groundwater occurs in all four rock units, the main water-bearing units are the basin-fill and conglomerates; volcanic and crystalline rocks yield only small amounts of water.[2]

## METHODS OF INVESTIGATION

To characterize regional groundwater quality in the Agua Fria basin, 46 groundwater samples were collected from 29 wells (Figure 2) and 17 springs (Figure 3). All sites were sampled for inorganic constituents. Samples for oxygen and deuterium isotopes (44), radiochemistry (unstable elements such as uranium, thorium, or radium that release radioactivity in the form of alpha, beta and gamma radiation) (33), and radon (30) were also collected at selected sites. In addition, nine isotopes were collected from surface water sources.

Sampling protocol followed the *ADEQ Quality Assurance Project Plan*. The effects of sampling equipment and procedures were not found to be significant

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*Figure 2 – Most wells in the Agua Fria basin, such as Johnson Wash Windmill, are shallow, low capacity domestic and stock wells.*

based on seven quality assurance/quality control tests.

## WATER QUALITY SAMPLING RESULTS

Groundwater sample results were compared with the Safe Drinking Water Act (SDW) water quality standards and Arizona aquifer water quality standards. Public water systems must meet these enforceable, health-based water quality standards, called primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. primary MCLs are based on a daily lifetime consumption of two liters of water. Of the 46 sites sampled, 14 sites (30 percent) had concentrations of at least one constituent that exceeded a primary MCL (Map 1). Constituents exceeding primary MCLs included arsenic (12 sites), fluoride (five sites), gross alpha (one site), and nitrate (one site).

Groundwater sample results were also compared with SDWA water quality guidelines. Public water systems are encouraged to meet these unenforceable, aesthetics-based water quality guidelines, called secondary MCLs, when supplying water to their customers. Water exceeding secondary MCLs may be unpleasant to drink and/or create unwanted cosmetic or laundry effects but is not considered a health concern. Of the 46 sites sampled, 31 sites (67 percent) had concentrations of at least one constituent that exceeded a secondary MCL (Map 1). Constituents that exceeded secondary MCLs included chloride (four sites), fluoride (seven sites), iron (two sites), manganese (nine sites), pH (one site), sulfate (three sites), and TDS (26 sites).

## GROUNDWATER COMPOSITION

Groundwater quality throughout the Agua Fria basin is similar in many aspects. Most sample sites are of *calcium-bicarbonate* or *mixed-bicarbonate* chemistry, have concentrations of TDS that typically vary between 450 to 625 milligrams per Liter (mg/L), have *hard to very hard* water (hardness concentrations greater than 150 mg/L as CaCO3), and have few occurrences of trace elements other than fluoride and arsenic. Radiochemistry constituents were generally low, exceeding health-based water quality standards only once in 33 samples.

The exception to the uniformity of the basin's groundwater quality involves a limited subgroup of sample sites that have sodium as their major cation and are almost devoid of calcium and magnesium (Figure 4). The sodium chemistry sites tend to occur, interspersed spatially with calcium or mixed chemistry sites, in the southern portion of the basin along the flanks of the Bradshaw Mountains stretching to the floodplain of the Agua Fria River.

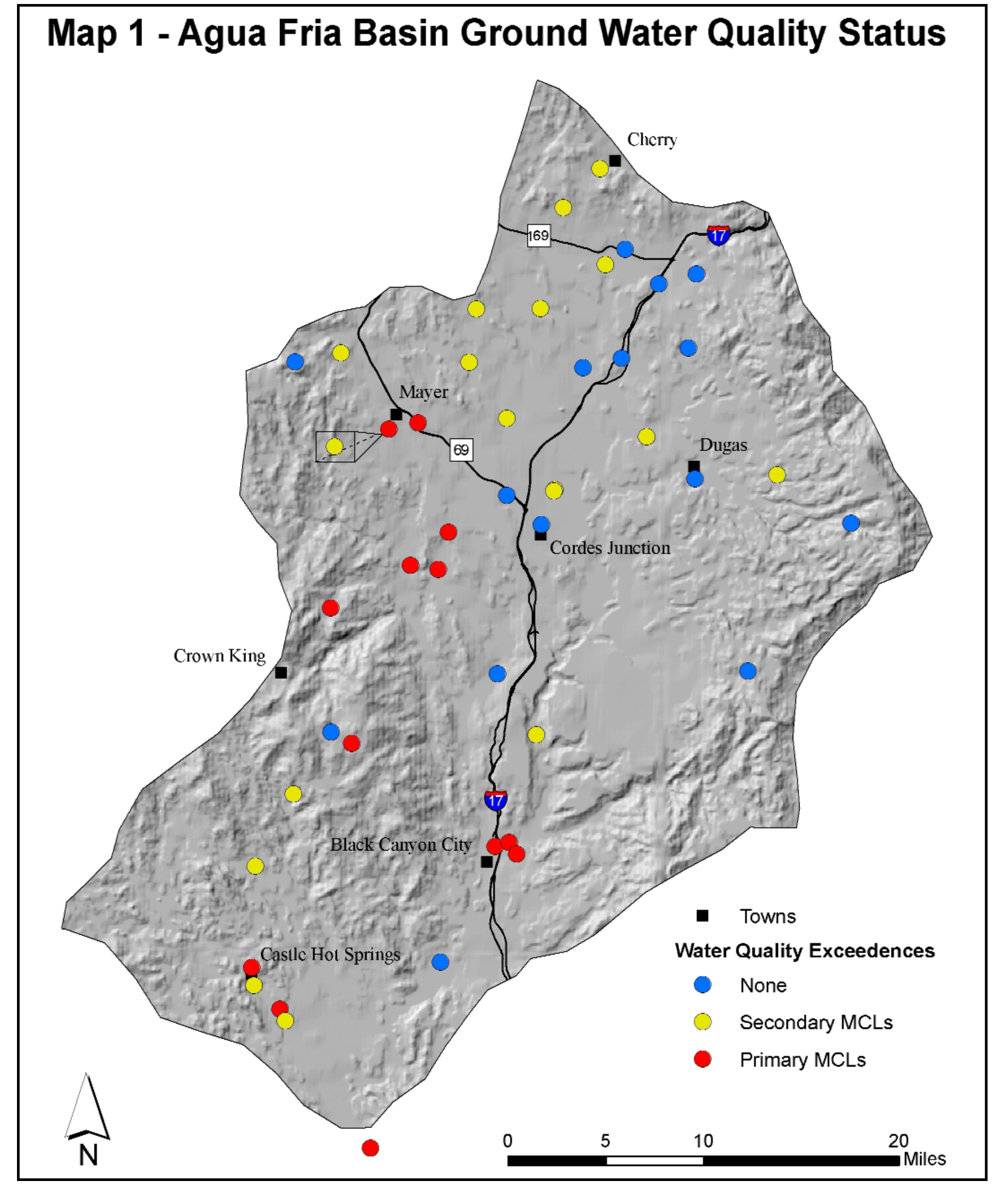
Besides very different water chemistry, the sodium chemistry sites tend to have significantly higher TDS, chloride, sulfate, fluoride (Figure 5) and arsenic concentrations than the calcium or mixed chemistry sites (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). The arsenic and fluoride concentrations at these sodium chemistry sites are typically above health-based, water quality standards, often by several orders of magnitude. One of the highest arsenic concentrations ever found in groundwater in Arizona, 2.25 mg/L (the health-based water quality standard is 0.01 mg/L), was collected from a well near Black Canyon City.

## CONCLUSIONS

Water chemistry differences appear to be influenced by a thick confining layer of clay and silica-rich caliche 100-to-200 feet that separates the unconsolidated deposits of the Agua Fria River in the Black Canyon City area from the underlying, water-bearing schist.[4] Water produced from the schist tends

*Figure 3 – The basin's most famous water source is Castle Hot Springs, a former resort hotel where guests once soaked in thermal waters which discharge at 200 gallons per minute.*






*Map 1 – All the health-based water quality exceedances are found at sample sites located in the Bradshaw Mountains.*

to be of a sodium chemistry and contains elevated concentrations of TDS, fluoride and arsenic while water produced from shallower wells that only penetrate the overlying gravel, sand and silt have a calcium or mixed chemistry and have significantly lower concentrations of these constituents.[4] The schist deposits are also present in areas north of Lake Pleasant between French Creek and the Agua Fria River.[4] An exception to this pattern was found in a 280-foot-deep well north of Lake Pleasant that, according to the driller's log, was perforated in schist yet the sample collected from it had a mixed cation chemistry with low concentrations of arsenic and fluoride (Figure 6).[3]

The elevated fluoride samples all occur at sites with sodium as the dominant cation. While fluoride concentrations below 5 mg/L are often controlled by pH levels, the main control on these higher fluoride concentrations appears to be calcium concentrations through precipitation or dissolution of the mineral fluorite. If a source of fluoride ions is available for dissolution, large concentrations of dissolved fluoride may occur if the groundwater is depleted of calcium.[5]

The elevated arsenic samples, generally located in the Bradshaw Mountains, are less predictable in occurrence. Although sites with sodium as the dominant cation had the highest concentrations, health-based water quality standards were also exceeded at sites at which the dominant cation was calcium or mixed. The cause of the elevated arsenic concentrations is uncertain, although in Arizona such conditions are often associated with clay-rich sediments, volcanic rocks, geothermal environments and/or areas with gold deposits.[6]

Nitrate does not appear to be a major water quality issue in the basin. Eighty-three percent of the sample sites had nitrate concentrations (less than 3 mg/L) thought not to be impacted by human activities.[7] The one site with nitrate concentrations over the health-based standard was a 285-foot-deep well located near the town of Mayer that is most likely affected by nearby septic systems.[3]

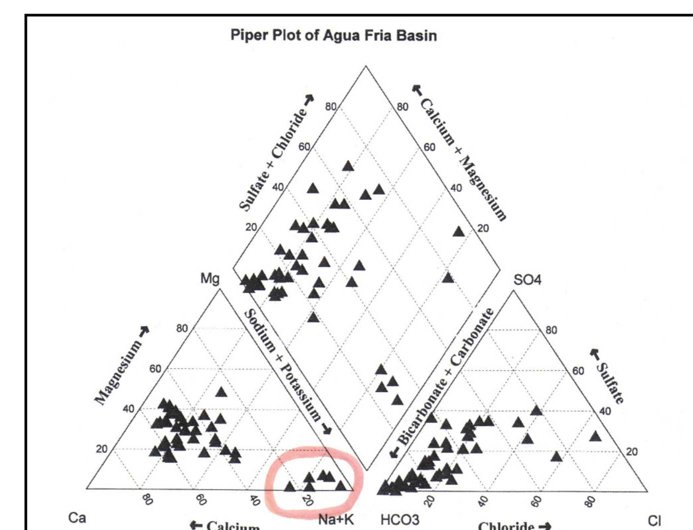



*Figure 4 – The dominant cation at the most sites is either calcium or mixed; however, six sites (circled) have a very different sodium chemistry that is almost devoid of any calcium or magnesium ions.*