ADEQ
Arizona Department of Environmental Quality
Janice K. Brewer, Governor
Henry R. Darwin, Director

FACT SHEET

Ambient Groundwater Quality of the Bill Williams Basin: A 2003-2009 Baseline Study – January 2012

INTRODUCTION

A baseline groundwater quality study of the Bill Williams Basin was conducted from 2003 through 2009 by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program. ADEQ carried out this task pursuant to Arizona Revised Statutes §49-225 that mandates ongoing monitoring of waters of the state including aquifers. The fact sheet is a synopsis of the ADEQ Open File Report 11-06.[1]

The Bill Williams groundwater basin covers approximately 3,200 square miles in west-central Arizona within La Paz, Mohave, and Yavapai Counties (Map 1).[2] Although lightly populated, the large basin includes the communities of Bagdad, Hillside, Kirkland, Kirkland Junction, Peeples Valley, and Skull Valley. Extensive portions of the basin are largely inaccessible because few roads have been constructed through the rugged terrain. Elevations range from 7,244 feet above mean sea level (amsl) at Bear Mountain in the northeast part of the basin to approximately 500 feet amsl near where the Bill Williams River crosses into the Parker groundwater basin.

Most of the basin consists of federal land managed by the Bureau of Land Management in the western two-thirds of the basin, with swaths of State Trust and federal land managed by the Forest Service in the eastern third. Interspersed throughout the federal and State lands are scattered parcels of private land.

Major economic activities in the Bill Williams basin include the Freeport-McMoRan Bagdad copper mine, which imports water from the Big Sandy basin; otherwise ranching is the main economic activity.[3]

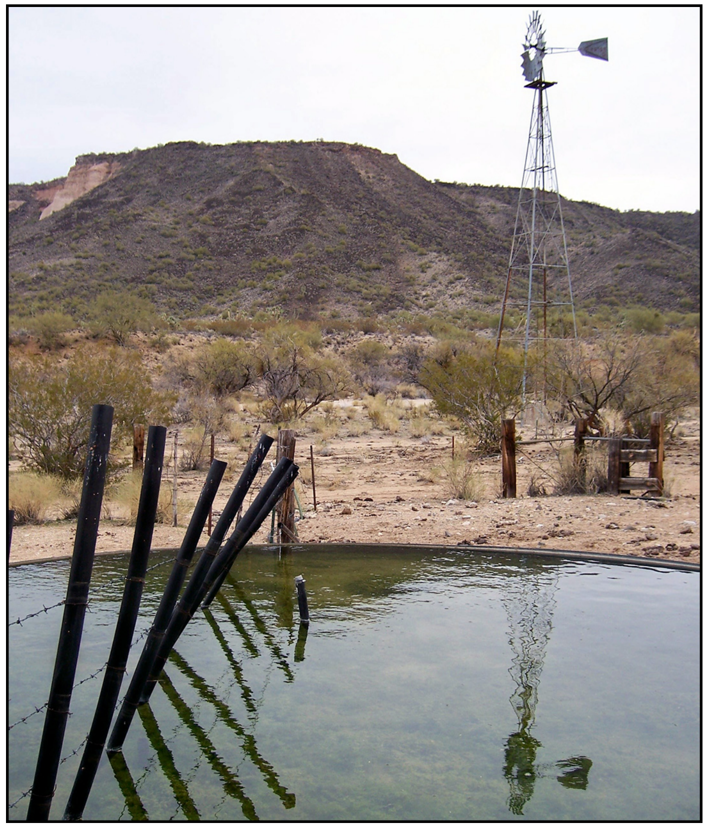


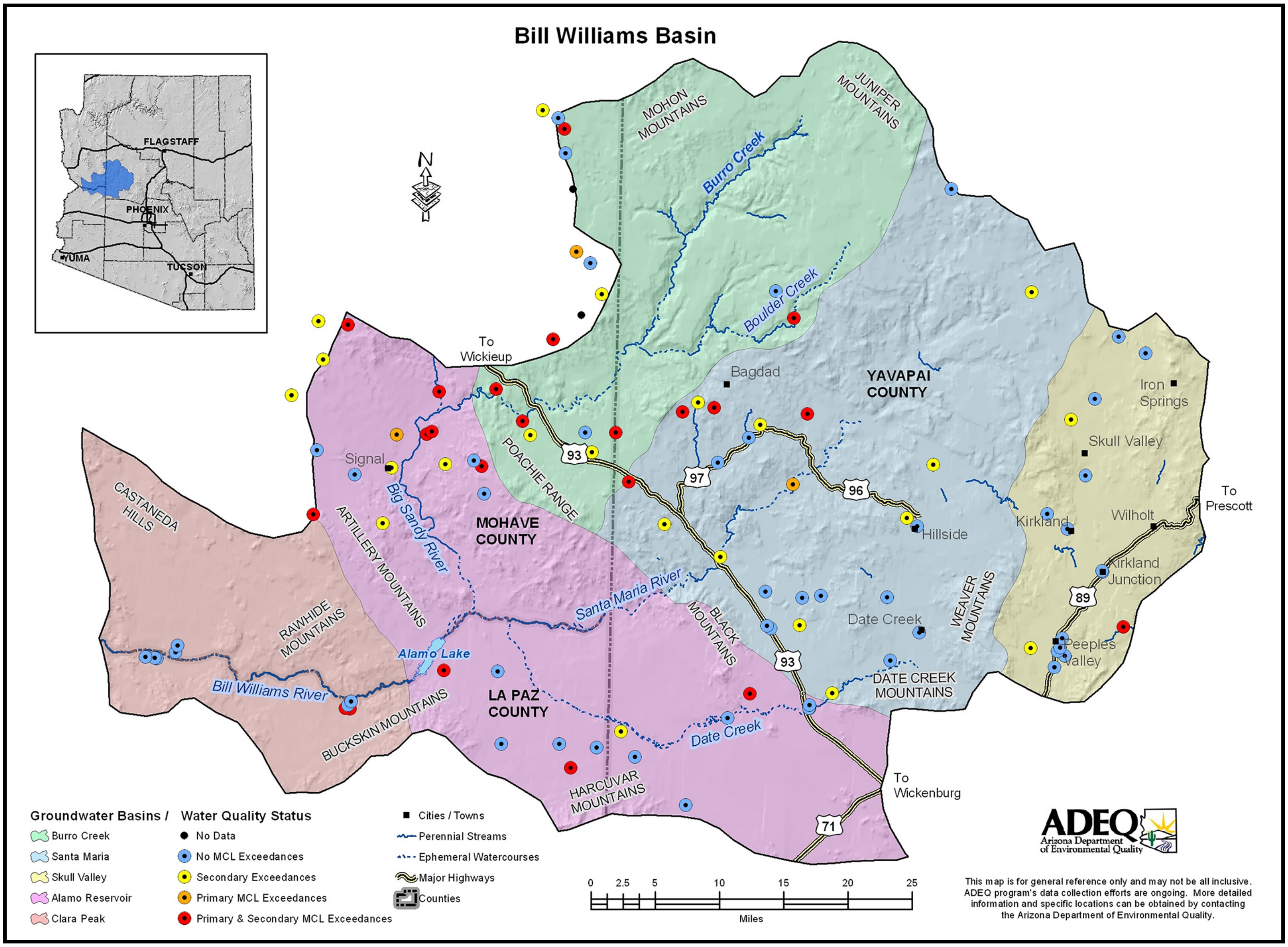
Figure 1. Located near Malpais Mesa in the Santa Maria sub-basin, Broken Windmill is very much operational as evidenced by the overflowing water tank that serves two grazing allotments separated by the leaning fence.

HYDROLOGY

The basin's main drainage is the Bill Williams River which is formed by the convergence of the Big Sandy and Santa Maria Rivers. About five miles downstream of the confluence, Alamo Dam forms Alamo Reservoir. Streams in the basin with perennial reaches include the Big Sandy River, Burro Creek, Boulder Creek, Date Creek, Kirkland Creek, and the Santa Maria River.[3]

Groundwater is the primary source for both domestic, stock and irrigation use. There are five groundwater sub-basins within the Bill Williams basin. The Burro Creek, Santa Maria and Skull Valley sub-basins are located in the basin's headwaters; downgradient is the Alamo Reservoir sub-basin, and further downgradient is the Clara Peak sub-basin.[3] In general, groundwater movement is the same direction as stream flow.[4]

The basin consists of a heterogeneous mix of mountainous areas interspersed with limited expanses of alluvial deposits. Groundwater occurs in younger alluvial deposits, in basin-fill deposits, and in fractured and porous volcanic, metamorphic, sedimentary, and granitic rock. The younger alluvium has high water-yielding potential but is only found along limited stretches of some major streams and in Peeples Valley located in the Skull Valley sub-basin. Wells tapping the younger alluvium usually produce sufficient quantities for irrigation use. Basin-fill deposits, consisting of conglomerate, siltstone and tuff are the basin's main water-bearing unit. These deposits range in depth from approximately 200 feet to over 5,000 feet below ground surface in the Date Creek area.



Map 1. Sample sites in the Bill Williams basin are color-coded according to their water quality status.

Hard rock such as volcanic, schist, gneiss, and granite where sufficiently fractured or decomposed, may produce enough well water for stock or domestic use.[2]

METHODS OF INVESTIGATION

To characterize regional groundwater quality in the Bill Williams basin, samples were collected from 100 sites consisting of 84 domestic, stock, and irrigation wells and 16 springs located throughout the basin. In many areas, there were limited wells and springs available for sampling which resulted in few samples collected in some parts of the basin as well as clustering of sample sites in some developed areas.

Inorganic constituents and oxygen and deuterium isotopes were collected at all 100 sites. Other samples collected include radionuclide at 55 sites, radon at 47 sites, ultra-clean mercury at 28 sites and perchlorate at 27 sites. Sampling protocol followed the *ADEQ Quality Assurance Project Plan* (www.azdeq.gov/function/programs/lab/). The effects of sampling equipment and procedures were not found to be significant based on seven quality assurance/quality control tests.

WATER QUALITY SAMPLING RESULTS

Groundwater sample results were compared with the Safe Drinking Water Act (SDWA) water quality standards. Public drinking 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 (70 years) consumption of two liters of water.[4] Of the 100 sites sampled, 28 sites had constituent concentrations that exceeded Primary MCLs. Constituents above Primary MCLs include arsenic (10 sites), cadmium (1 site), chromium (1 site), fluoride (4 sites), gross alpha (16 sites), lead (1 site), nitrate (3 sites), radium 226+228 (4 sites), and uranium (7 sites).

Groundwater sample results were also compared with SDWA water quality guidelines. Public drinking water systems are encouraged by the SDWA 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.[4]

Figure 2 – A domestic well near Date Creek is being purged prior to sampling at the wellhead. In many remote areas of the basin, there were limited wells and springs available for sampling.

Of the 100 sites sampled, 49 had constituent concentrations that exceeded Secondary MCLs. Constituents above Secondary MCLs include chloride (5 sites), fluoride (23 sites), iron (2 sites), manganese (11 sites), pH (4 sites), sulfate (6 sites), and TDS (32 sites).

Overall, of the 100 sites sampled in the Bill Williams study, 48 sites met all health-based and aesthetic-based, water quality standards.

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the 47 sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes a multimedia program to address the health risks from radon in indoor air. Twenty-eight (28) sites exceeded the proposed 300 pCi/L standard that would apply if Arizona does not develop a multimedia program.[4]

Of the 27 sites sampled for perchlorate, none exceeded the 0.006 mg/L drinking water quality standard adopted by the State of California.

GROUNDWATER COMPOSITION

Groundwater in the Bill Williams basin was predominantly of calcium/mixed/sodium-bicarbonate chemistry. Levels of pH-field were *slightly alkaline* (above 7 su) at 96 sites and *slightly acidic* (below 7 su) at 4 sites. TDS concentrations were considered *fresh* (below 1,000 mg/L) at 92 sites and *slightly saline* (1,000 – 3,000 mg/L) at 8 sites. Hardness concentrations were *soft* (below 75 mg/L) at 6 sites, *moderately hard* (75 – 150 mg/L) at 16 sites, *hard* (150 – 300 mg/L) at 49 sites, *very hard* (above 300 mg/L) at 22 sites, and *extremely hard* (above 600 mg/L) at 7 sites.

Nitrate concentrations were divided into natural background (15 sites at <0.2 mg/L), may or may not indicate human influence (59 sites at 0.2 – 3.0 mg/L), may result from human activities (23 sites at 3.0 – 10 mg/L), and probably result from human activities (3 sites >10mg/L).[5]

Most trace elements such as antimony, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely–if ever—detected. Only arsenic, barium, boron, fluoride and zinc were detected at more than 20 percent of the sites.

Oxygen and deuterium isotope samples collected in the basin have a slope of 5.3, with the Local Meteoric Water Line described by the linear equation: $\delta D = 5.3 \delta ^{18}O - 18.7$, which would be expected in an arid environment (Figure 5). Generally, samples collected from higher elevation sites such as in the Skull Valley sub-basin tended to be lighter, less evaporated, and more depleted. In contrast, samples collected from lower elevation sites such as in the Clara Peak and Alamo Reservoir sub-basins were heavier, more evaporated and more enriched. Samples collected from sites in the Burro Creek and Santa Maria sub-basins tended to fall on a continuum between the two groups depending on elevation.

However, some samples had isotope values that do not conform to what would be expected from recharge originating at the site's elevation. For example, the lightest sample in the study, collected from Kaiser Warm Spring, appears to be far more depleted than is possible given the basin's elevation. Kaiser Warm Spring likely consists of paleowater predominantly recharged 8,000-12,000 years ago when the climate was cooler and subject to less evaporation.[6] The potential contribution of paleowater may explain other samples that appear to be more depleted than is possible from their elevations.

Figure 3 – An alfalfa field at Lincoln Ranch along the Bill Williams River is irrigated from a shallow well tapping the younger alluvium. Four wells were sampled at the ranch; the wells closest to the river had much lower TDS concentrations.

GROUNDWATER PATTERNS

Statistically significant groundwater quality patterns were found among the five sub-basins and between two geological classifications. Groundwater samples collected from Skull Valley sub-basin had significantly lower concentrations of sodium, fluoride, boron, oxygen-18 and deuterium than the other four sub-basins (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

Groundwater samples collected from sites located in hard rock areas had significantly higher concentrations of hardness, calcium, magnesium, bicarbonate and zinc than alluvial areas; the opposite pattern occurred with pH-lab, potassium, boron, oxygen-18, and deuterium. (Kruskal-Wallis test, $p \leq 0.05$).

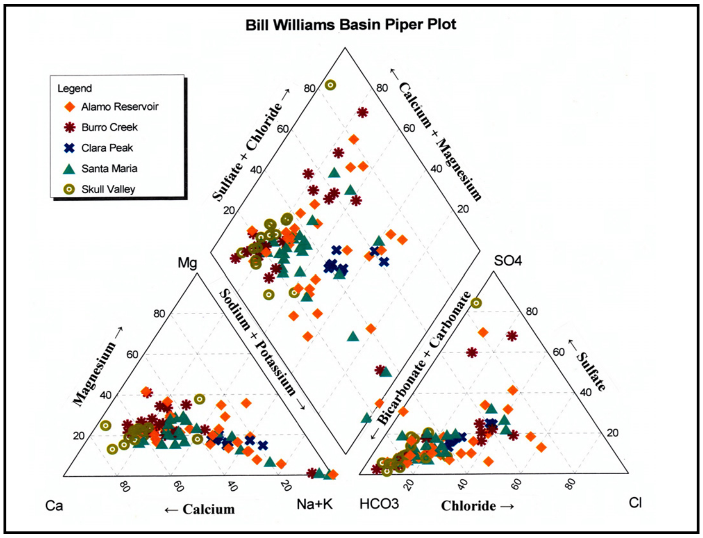


Figure 4 – Groundwater samples collected in the Bill Williams basin were predominantly of calcium-bicarbonate chemistry and evolve on a flow path into to mixed-bicarbonate, sodium-bicarbonate or other water chemistry.

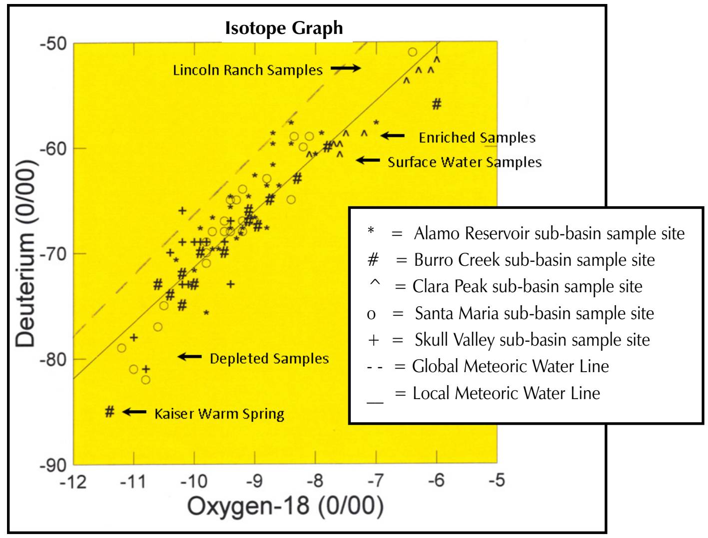


Figure 5 – Water samples from sites in the Bill Williams basin are plotted according to their oxygen and hydrogen isotope values. The lowest points along the Local Meteoric Water Line (LMWL) have the lightest signatures and have undergone the least evaporation prior to sampling; the highest points have the heaviest signatures and have undergone the most evaporation prior to sampling.

SUMMARY AND CONCLUSIONS

Although this ADEQ factsheet and the associated hydrologic report represent the most complete, current water quality analysis of the Bill Williams groundwater basin, the conclusions of the study should be interpreted cautiously. The basin's inherent size, geologic complexity and remoteness of make it difficult to comprehensively assess its groundwater quality.

Groundwater in the higher elevation areas of the basin tends to start as a calcium/mixed-bicarbonate chemistry and, on a flowpath, evolves into a mixed/sodium-bicarbonate/mixed chemistry when it reaches lower elevation areas. However, there are inconsistencies to this pattern from local influences.

Interpretation of the analytical results indicates approximately three-fourths of the 100 groundwater sites meet health-based, drinking water standards. Gross alpha, arsenic and fluoride most commonly exceeded health-based water quality standards and their elevated concentrations appear to be the result of natural chemical reactions.[7]

The few nitrate exceedances, two of which had concentrations of 110 mg/L, were probably due to natural organic nitrogen, effluent from malfunctioning septic systems and/or waste associated with livestock in corrals adjacent to sampled wells.

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Maps by Jean Ann Rodine

Figure 6 – Located along Kaiser Spring Wash, the flow of Kaiser Warm Spring has been partially impounded to allow recreationalists to soak in its 35 degree Celsius (or 95 degree Fahrenheit) waters. Isotope samples from the site were the lightest or most depleted in the basin.

References Cited

1 Towne, D.C., 2011, Ambient groundwater quality of the Bill Williams basin: A 2003-2009 baseline study: Arizona Department of Environmental Quality Open File Report 11-06, 73 p.

2 Sanger, H.W. and Littin, G. R., 1981, Maps showing groundwater conditions in the Bill Williams Area, Mohave, Yavapai, and Yuma Counties, Arizona—1980: U.S. Geologic Survey Water-Resources Investigations Open File Report 82-87, 2 sheets, scale, 1:125,000.

3 Arizona Department of Water Resources website, 2011, www.azwater.gov/azdwr/default.aspx, accessed 07/5/11.

4 U.S. Environmental Protection Agency Web site: www.epa.gov/waterscience/criteria/humanhealth/ accessed 5/25/10.

5 Madison, R.J., and Brunett, J.O., 1984, Overview of the occurrence of nitrate in ground water of the United States, in National Water Summary 1984-Water Quality Issues: U.S. Geological Survey Water Supply Paper 2275, pp. 93-105.

6 Earman, Sam, et al, 2003, An investigation of the properties of the San Bernardino groundwater basin, Arizona and Sonora, Mexico: Hydrology program, New Mexico Institute of Mining and Technology, 283 p.

7 Robertson, F.N., 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.