

## Ambient Groundwater Quality of the Tonto Creek Basin: A 2002-2012 Baseline Study – November 2013

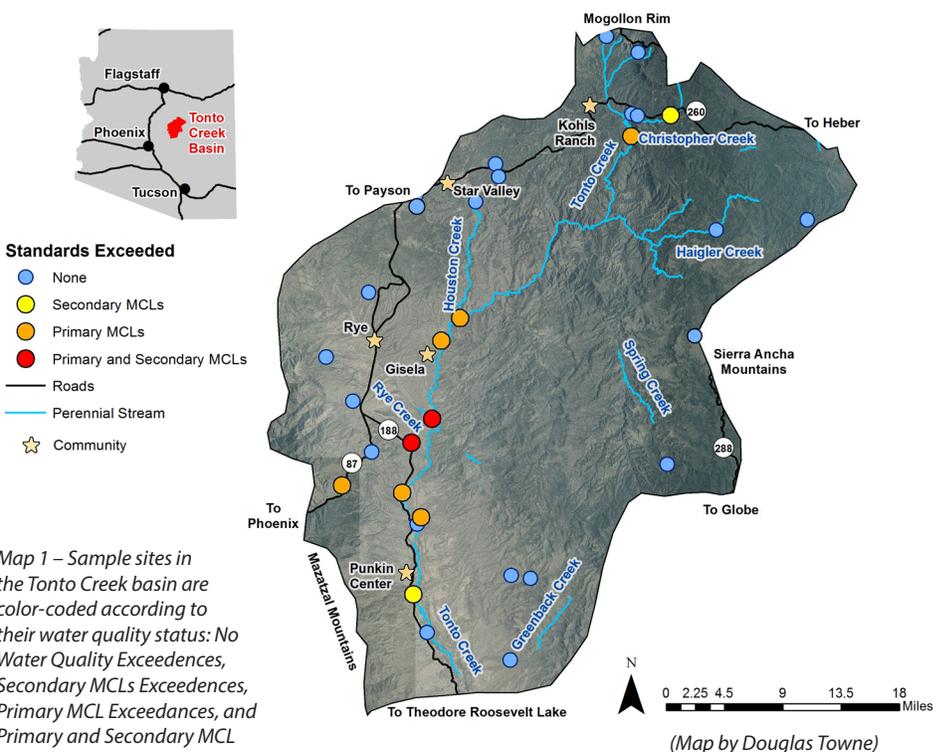
### Introduction

A baseline groundwater quality study of the Tonto Creek basin was conducted from 2002 to 2012 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 its aquifers. The fact sheet is a synopsis of the ADEQ Open File Report 13-04.<sup>1</sup>

Located 40 miles northeast of Phoenix, the Tonto Creek groundwater basin contains approximately 955 square miles within Gila County (Map 1).<sup>2</sup> More than 97 percent of the basin consists of federal land managed by the U.S. Forest Service Tonto National Forest. Low-intensity livestock grazing and recreational activi-



Figure 1 – Tonto Creek, shown upgradient of Gisela, has perennial flow throughout the basin which it exits just before emptying into Theodore Roosevelt Lake in the Salt River basin.<sup>2</sup>



ties are the predominant forest uses with the remaining private lands being used for residential homes or ranches. Small communities include Gisela, Kohl's Ranch, Punkin Center, Rye, and the Town of Star Valley; the Town of Payson is located just to the northwest of the basin.

### Hydrology

The basin is drained by Tonto Creek, a perennial tributary to the Salt River, which flows from north to south discharging an average of 105,000 acre-feet annually into Theodore Roosevelt Lake (Figure 1).<sup>2</sup> Major tributaries to Tonto Creek include Rye Creek to the west and Spring and Haigler creeks flowing from the eastern

portion of the basin. Other perennial streams include Houston, Christopher, and Greenback creeks.

Groundwater occurs in four geologic formations: stream alluvium, basin-fill sediments, Paleozoic sedimentary rocks, and Precambrian igneous, metamorphic, and sedimentary rocks.<sup>2</sup> The primary aquifer is composed of unconsolidated sediments including stream alluvium (along Tonto Creek and its major tributaries) and basin fill that underlie much of the basin south of Rye. The basin fill is divided into two parts: a lower and an upper unit with the latter consisting of coarse-grained and fine-grained depositional components. The coarse-grained depositional component is moderately permeable but is

generally located above the water table. The fine-grained depositional component is largely impermeable, although thin sand layers yield small amounts of water to wells near Punkin Center.<sup>3,4</sup>

Paleozoic sedimentary rocks along the Mogollon Rim can also produce abundant water from a limestone aquifer whose source is the C-aquifer in the adjacent Little Colorado River basin. This limestone aquifer is the source of many of the basin's 10 springs that have discharges exceeding 10 gallons per minute (gpm) including the largest, Tonto Spring, which flows at 1,291 gpm (Figure 2). Precambrian igneous, metamorphic, and sedimentary rocks in the basin's margins sometimes produce limited groundwater.<sup>2,3,4</sup>

Groundwater flows generally from north to south. Depth to groundwater varies significantly across the basin from just 40 feet below land surface (bls) along stretches of the lower Tonto Creek to more than 100 feet bls in most other areas of the basin.<sup>2</sup>

Groundwater development in the basin is limited because of its rugged topography and predominant federal land

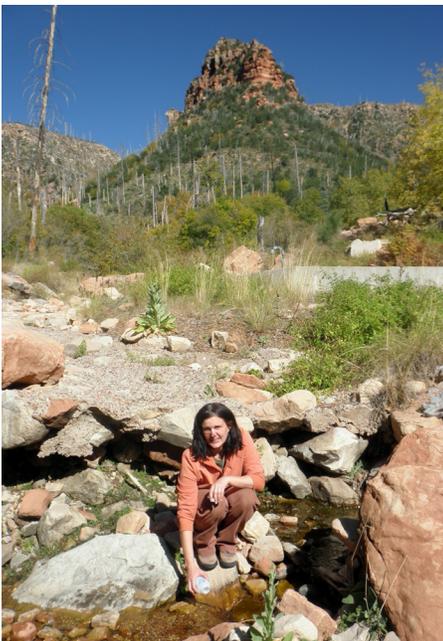


Figure 2 – Former ADEQ employee Susan Determann collects a sample from Tonto Spring just below the Mogollon Rim. Tonto is the largest spring in the basin with an average discharge of 1,291 gpm.<sup>2</sup>

ownership. Most wells are low-yield domestic and stock wells, though some irrigation wells in the stream alluvium along the lower reaches of Tonto Creek produce up to 2,500 gpm.<sup>3,4</sup> There are an estimated 170 springs in the basin.<sup>2</sup> Groundwater is used for all public water supply and domestic uses and most irrigation and stock uses in the basin. Small diversions on Tonto Creek and its tributaries supply surface water for irrigation use, such as near Gisela.

### Methods of Investigation

To characterize regional groundwater quality, samples were collected from 31 sites (20 wells and 11 springs). Of the 20 wells, 17 used submersible pumps, two were windmills (Figure 3), and one was a turbine pump. Samples for inorganic constituents were collected from all 31 sites while at selected sites, radionuclide (19 sites), oxygen and deuterium isotopes (10 sites), volatile organic compounds or VOCs (eight sites), and radon (five sites) samples were collected. Sampling protocol followed the ADEQ Quality Assurance Project Plan (see [www.azdeq.gov/function/programs/lab/](http://www.azdeq.gov/function/programs/lab/)). The effects of sampling equipment and

procedures were not significant based on quality assurance/quality control evaluations.

### Water Quality Sampling Results

Groundwater sample results were compared with the Safe Drinking Water Act (SDW) health and aesthetics-based water quality standards.<sup>5</sup>

Public drinking water systems must meet health-based, water quality standards, called Primary Maximum Contaminant Levels (MCLs), when supplying water to their customers. These enforceable standards are based on a lifetime (70 years) consumption of two liters per day.<sup>5</sup> Primary MCLs were exceeded at eight of the 31 sites (26 percent). Constituents exceeding Primary MCLs include arsenic (six sites), gross alpha (two sites), and one site each for nitrate, radium-226+228, and uranium.

Public drinking water systems are encouraged by the SDW to meet 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.<sup>5</sup> Secondary MCLs were exceeded at four of the 31 sites (13 percent). Constituents exceeding Secondary MCLs include fluoride (one site), manganese (one site), and total dissolved solids or TDS (three sites).

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the five 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.<sup>5</sup> Five sites (100 percent) exceeded the proposed 300 pCi/L standard that would apply if Arizona does not develop a multimedia program.<sup>5</sup> There were no detections of any of the 34 VOCs in the eight samples.



Figure 3 – Clover Well consists of a windmill, storage tank, and pipelines transporting water to troughs for livestock use. The windmill is located west of Rye at the base of the Mazatzal Mountains overlooking the Tonto Creek basin.

## Groundwater Composition

Groundwater quality varied throughout the basin in the following ways:

- Groundwater chemistry in the basin is predominantly calcium-bicarbonate or mixed-bicarbonate (Figure 4).
- Levels of pH measured in the field were slightly alkaline (above seven standard units ranging from 7.20 – 7.90 su) except for six sample sites that were slightly acidic (below seven standard units ranging from 6.98 - 6.80 su).
- Total dissolved solids (TDS) concentrations were all considered fresh (below 999 mg/L).
- Hardness concentrations were soft (below 75 mg/L) at one site, moderately hard (75 - 150 mg/L) at six sites, hard (151 - 300 mg/L) at 17 sites, very hard (301 – 600 mg/L) at seven sites.
- Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities and were

divided into natural background (19 sites at <0.2 mg/L) may or may not indicate human influence (11 sites at 0.2 – 3.0 mg/L), and probably result from human activities (one site > 10 mg/L).<sup>6</sup>

- Most trace elements such as aluminum, antimony, beryllium, boron, cadmium, chromium, iron, lead, manganese, mercury, nickel, selenium, silver, and thallium were rarely detected. Only arsenic, barium, copper, fluoride, strontium, and zinc were detected at more than one-third of the sites.

Oxygen and deuterium isotope values at most sites appear to be a product of the elevation at which the sample sites were located. The two samples that experienced the most evaporation were characterized as enriched and were collected from shallow wells located along the lower reach of Tonto Creek. The remaining eight samples were more depleted, suggesting the water from these higher elevation sites was subject to much less evaporation.<sup>7</sup>

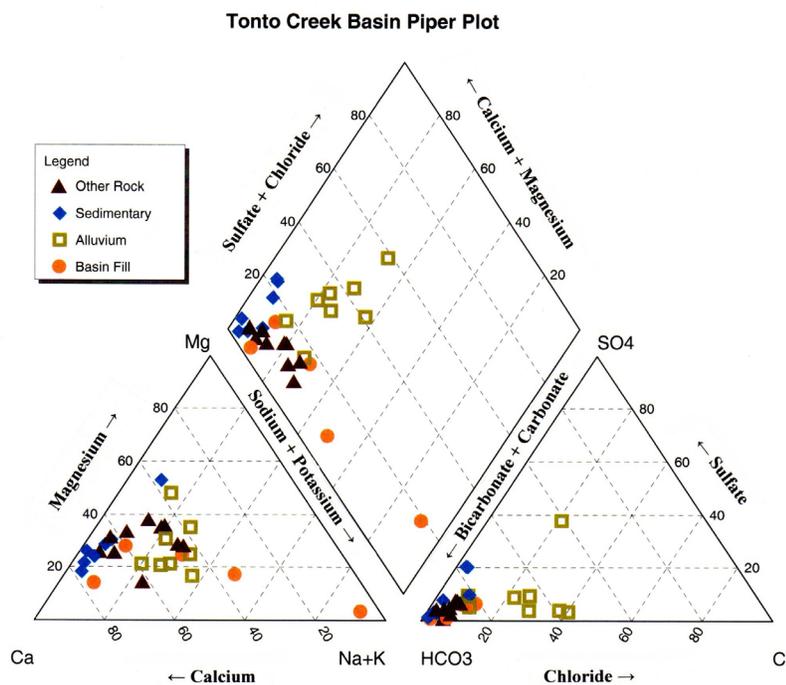


Figure 4 – Groundwater samples are predominantly a calcium-bicarbonate or mixed-bicarbonate chemistry which is reflective of young groundwater that has been recently recharged.<sup>8</sup> The exception was one sample with a sodium-bicarbonate chemistry that appears to produce water from the fine-grained depositional component of the upper unit of the basin-fill aquifer.

## Groundwater Patterns

Groundwater constituent concentrations were influenced by geology. Constituents such as temperature, Specific Conductivity (SC)-field, SC-lab, TDS (Figure 5), sodium, potassium, chloride, strontium, oxygen-18, and deuterium had significantly higher constituent concentrations at sites in unconsolidated sediment than at sites in consolidated rocks (Kruskal-Wallis test,  $p \leq 0.05$ ). Constituents such as temperature, SC-field, SC-lab, TDS, sodium, potassium, chloride (Figure 6), strontium, oxygen-18, and gross alpha generally had significantly greater concentrations in sites located in stream alluvium than in basin fill, and consolidated or sedimentary rock (Kruskal-Wallis test,  $p \leq 0.05$ ).

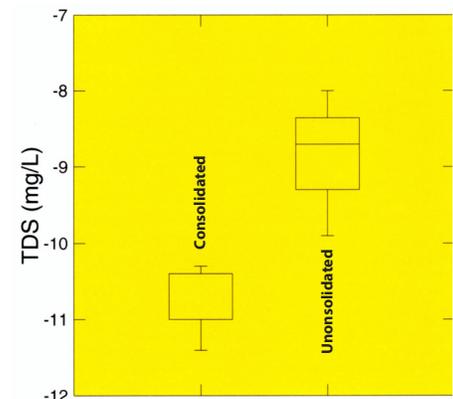


Figure 5 – Samples collected from sites in unconsolidated sediment have significantly higher TDS concentrations than samples collected from sites in consolidated rock that are often upgradient (Kruskal-Wallis,  $p \leq 0.05$ ). Factors such as low rock solubility, limited carbon dioxide, and few human impacts influence this trend.<sup>8</sup>

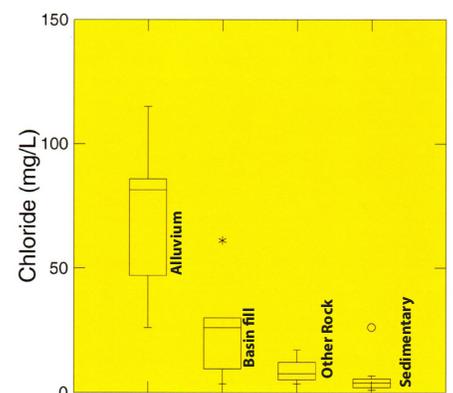


Figure 6 – Samples collected from sites in stream alluvium have significantly higher chloride concentrations than sample sites collected from basin-fill sediments, sedimentary or other consolidated rock (Kruskal-Wallis,  $p \leq 0.05$ ). Downgradient areas often evolve towards sodium-chloride chemistry as TDS concentrations increase.<sup>8</sup>

## Discussion

Groundwater in the Tonto Creek basin is generally suitable for drinking water uses based on results from this ADEQ study and earlier research by the U.S. Geological Survey.<sup>3,4</sup> Samples were predominantly of calcium or mixed-bicarbonate chemistry which is characteristic of recently recharged groundwater having low concentrations of TDS, nutrients, and trace elements.<sup>8</sup> The limestone aquifer along the Mogollon Rim, in particular, produces especially high-quality water.

Samples from 22 of the 31 sites (71 percent) met all water quality standards.<sup>5</sup> Of the remaining nine sample sites, the constituents that most commonly impacted the acceptability of water for drinking purposes were arsenic and, to a lesser degree, radionuclides and nitrate. These are three of the four constituents that most commonly exceed health-based water quality standards in Arizona.<sup>9</sup>

Gross alpha exceeded health-based, water quality standards in radionuclide samples collected from two of 19 sites (11 percent). The two exceedances were located at sites in or near granitic geology which is often associated with elevated radionuclide concentrations in groundwater.<sup>10</sup> This correlation is not strong however, since other radionuclide samples collected from sites in granitic geology did not exceed water quality standards.

Nitrate exceeded health-based, water quality standards in duplicate samples collected from a well located at a remote ranch surrounded by U.S. Forest Service lands north of Punkin Center along Tonto Creek. The sample also had the study's highest TDS and chloride concentrations. The elevated nitrate concentration is likely due to septic system discharge as this also elevates TDS and chloride concentrations.<sup>11</sup>

Arsenic exceedances in the Tonto Creek basin all occurred in samples collected from six sites located in unconsolidated sediment (basin fill or stream alluvium) downgradient from Gisela. Not all of the

samples collected in the southern portion of Tonto Creek basin however, had arsenic concentrations exceeding water quality standards. An oxidizing environment and lithology appear to be factors in the five Primary MCL exceedances that narrowly exceeded the 0.01 mg/L arsenic standard.<sup>8</sup>

Aquifer residence time appears to cause the basin's highest arsenic concentration, which was found in a split sample collected from a well located near Punkin Center.<sup>8</sup> The sample also had unusual sodium-bicarbonate chemistry and aesthetics-based water quality exceedances of fluoride and TDS. Although no isotope sample was collected from the site, the sample's water chemistry make it likely the well is producing water that was recharged long ago. The same phenomena were detailed in an earlier U.S. Geological Survey study when a sample collected from a well in the same general area also had a sodium chemistry and exceeded water quality standards for arsenic, fluoride, and TDS.<sup>4,5</sup> Both wells appear to be tapping groundwater from the fine-grained depositional component of the upper part of the basin fill, which should be avoided as a drinking water source in the basin.

## References Cited

<sup>1</sup> Towne, D.C., 2013, *Ambient groundwater quality of the Tonto Creek basin: A 2002 - 2012 baseline study: Arizona Department of Environmental Quality Open File Report 13-04*, 49 p.

<sup>2</sup> Arizona Department of Water Resources website, [www.azwater.gov/azdwr/default.aspx](http://www.azwater.gov/azdwr/default.aspx), accessed 09/26/13.

<sup>3</sup> Dennis, E.E., 1981, *Maps showing ground-water conditions in the Tonto Basin area, Gila County, Arizona—1979: U.S. Geological Survey Water Resources Investigations 82-116, 1 sheet, scale, 1:250,000.*

<sup>4</sup> Schumann, H.H. and Thomsen, B.W., 1972, *Hydrologic regimen of Lower Tonto Creek Basin, Gila County, Arizona: A reconnaissance study: Arizona Water Commission Bulletin #3*, 39 p.

<sup>5</sup> U.S. Environmental Protection Agency website, [www.epa.gov/water-science/criteria/humanhealth/](http://www.epa.gov/water-science/criteria/humanhealth/), accessed 09/19/13.

<sup>6</sup> 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

<sup>7</sup> 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.

<sup>8</sup> 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*, 94 p.

<sup>9</sup> Towne, D.C. and Jones, J., 2011, *Groundwater quality in Arizona: A 15-year overview of the ADEQ ambient groundwater quality program (1995-2009): Arizona Department of Environmental Quality Open File Report 11-04*, 44 p.

<sup>10</sup> Lowry, J.D. and Lowry, S.B., 1988, "Radionuclides in Drinking Waters," in *American Water Works Association Journal*, 80 (July), pp. 50-64.

<sup>11</sup> Bedient, P.B. Rifai, H.S. and Newell, C.J., 1994, *Ground Water Contamination: Transport and Remediation: Englewood Cliffs, N.J., Prentice-Hall, Inc.*

### For More Information Contact:

Douglas C. Towne  
Hydrologist, ADEQ Monitoring Unit  
1110 W. Washington St. #5330D  
Phoenix, AZ 85007  
email: [dct@azdeq.gov](mailto:dct@azdeq.gov)  
[www.azdeq.gov/environ/water/assessment/ambient.html#studies](http://www.azdeq.gov/environ/water/assessment/ambient.html#studies)  
Publication Number: FS-13-18