Ambient Groundwater Quality of the Lower Gila Basin: A 2013-2017 Baseline Study – May 2017

Introduction

The Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring Program conducted a baseline study to characterize the groundwater quality of the Lower Gila Basin from 2013 to 2017. ADEQ carried out this task under Arizona Revised Statutes §49-225 that mandates monitoring of waters of the state including its aquifers. The fact sheet is a synopsis of the ADEQ Open-File Report 17-??[1]

The basin comprises 7,309 square miles within Yuma, Maricopa, Pima, and La Paz counties and consists of desert plains and valleys surrounded by low elevation mountains in southwestern Arizona. The basin extends from Painted Rock Dam near Gila Bend west to the Gila Mountains and Colorado River located along Arizona's border with California (Figure 1).

The basin includes the communities of Ajo, Dateland, Ligurta, Martinez Lake, Hyder, Sentinel, Tacna, Wellton, and Why. The land is used for military ranges, wildlife refuges, recreation, livestock grazing, and, especially along the Gila River, irrigated agriculture and residential purposes.

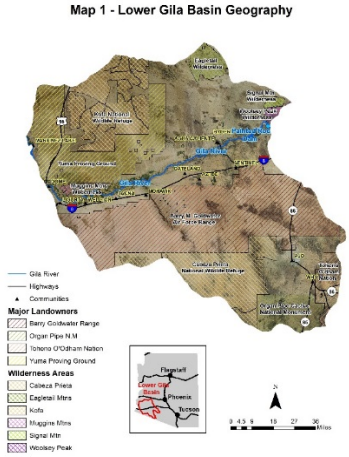

Figure 1 - Geography of the Lower Gila Basin.

Hydrology

The basin is composed of elongated fault-block mountain ranges with intervening alluvial valleys. The Gila River, an ephemeral stream, drains the basin and runs east to west through the central portion. The river is typically dry except where agricultural discharge, major storms, or releases from Painted Rock Dam creates flow.[2] All natural waterways are ephemeral, except the perennial Colorado River which forms a short stretch of the basin's western boundary.

Groundwater occurs primarily in the floodplain alluvium and basin fill. Alluvial deposits of sand, gravel and larger sediments compose the floodplain of the Gila River and larger washes. Floodplain alluvium deposits can be as think as 110 feet along the Gila River.[3]

Basin-fill deposits have three units: an upper sandy unit, which averages 200-380 feet thick; a middle fine-grained unit, which averages 250-750 feet thick, and a lower unit, which has an extremely variable thickness with well-cemented zones that extends to the bedrock.[4]

The basin is divided into eastern and western sections near Dateland, and into three hydrologic sub-basins: Childs Valley, Dendora Valley (Figure 2), and Wellton-Mohawk.

Figure 2 – ADEQ's Elizabeth Boettcher samples an irrigation well in the Dendora Valley sub-basin.

Eastern Section - Groundwater development has occurred primarily for irrigation in the area's broad alluvial plains: Hyder Valley, Dendora Valley, Palomas Plain, and Sentinel Plain. Depth to groundwater ranges from 10 feet below the land surface (bls) near the Gila River to more than 700 feet in the Kofa Wildlife Refuge and 800 feet near Why.[5]

Groundwater initially moved from the north and southeast toward the Gila River and then downstream to the southwest. Heavy irrigation pumping has created cones of depression that have changed the groundwater flow direction in some areas. Recharge in this section occurs from runoff, underflow, irrigation applications, and precipitation.[6]

Western Section - Groundwater development has occurred mainly in the Gila River floodplain. The primary aquifer is the streambed alluvium with two shallow units, an upper sandy unit, and a lower gravel unit. The streambed alluvium, which is up to 150 feet thick, overlies a thick, fine-grained unit composed of clay, silt, and sand lenses, which typically doesn't provide sufficient water for irrigation wells.

Groundwater development began in the Gila River floodplain in 1915, but the increasingly saline water was unsuitable for irrigation. Fresh Colorado River water has been diverted and pumped uphill through the 18.5-mile Wellton-Mohawk Canal for use in the Wellton-Mohawk Irrigation and Drainage District beginning in 1952.

Groundwater levels, which rose into the plant's root zone, hindered crop production. Drainage wells averaging 100 feet in depth were drilled for dewatering purposes starting in 1961. The wells discharge saline irrigation recharge into the concrete-lined Wellton-Mohawk Main Conveyance Channel (Figure 3), which discharges the drainage water into the Santa Clara Cienega, an ecologically valuable wetland in Mexico.[7]

Groundwater flow is towards the Gila River, then downstream to the west but has been impacted locally by groundwater mounding from irrigation applications of Colorado River water.[8] Like in the Eastern section, recharge occurs from runoff, underflow, precipitation, and irrigation applications, with the latter being the most important.

Figure 3 - ADEQ's Elizabeth Boettcher samples one of the 90 Wellton-Mohawk Irrigation and Drainage District drainage wells that empty into the Wellton-Mohawk Conveyance Channel.

Investigation Methods

ADEQ personnel collected samples from 108 wells (Figure 4) to characterize regional groundwater quality, divided into the following three sub-basins: Childs Valley (9), Dendora Valley (9), and Wellton-Mohawk (90). Inorganic constituents and stable isotopes of oxygen, deuterium, and nitrogen were collected at all wells. Other samples collected include radon at 51 wells and radionuclides at 39 wells.

Sampling protocol followed the *ADEQ Quality Assurance Project Plan* (see www.azdeq.gov/function/programs/lab/).[9] The effects of sampling equipment and procedures were not significant based on quality assurance/quality control evaluations.

Figure 4 – Darby Well located south of Ajo produces water for endangered Sonoran pronghorns.

Water Quality Sampling Results

Public drinking water systems are mandated by the Safe Drinking Water Act (SDWA) to 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.[10]

Public drinking water systems are encouraged by the SDWA 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 create unwanted cosmetic or laundry effects but is not considered a health concern. [11]

Public drinking water quality standards and guidelines are summarized in Table 1. Groundwater sample results were compared with the SDWA health and aesthetics-based water quality standards.

Of the 108 wells sampled, nine (eight percent) met all drinking water quality standards. Health-based, Primary Maximum Contaminant Levels (MCLs) were exceeded at 78 sites (76 percent). Aesthetics-based Secondary MCL water quality guidelines were exceeded at 97 sites (90 percent) (Figure 5).

Table 1 – Sampled sites exceeding public drinking water quality standards and guidelines

Constituent	Number of Wells Exceeding Standards	Percentage of Wells Exceeding Standards
Primary Maximum Contaminant Levels (Health-based Standards)		
Arsenic	72	67 %
Fluoride	34	32 %
Nitrate	10	9 %
Secondary Maximum Contaminant Levels (Aesthetics-based Guidelines)		
TDS	95	88 %
Chloride	77	71 %
Fluoride	66	61 %
Sulfate	62	57 %
Manganese	22	20 %
Iron	14	13 %
pH-field	6	6 %

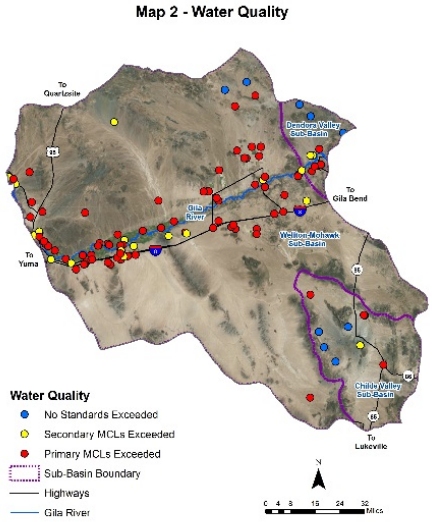

Figure 5 - Water quality status of sampled sites in the Lower Gila basin.

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206. Of the 51 sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard, while 23 sites (45 percent) exceeded the proposed 300 pCi/L standard.[12]

Groundwater Composition

Groundwater characteristics are summarized in Table 2.

Table 2 - Groundwater characteristics of sampled sites.

pH-field	
Slightly Acidic (< 7 su)	1
Slightly Alkaline (7 – 8 su)	66
Moderately Alkaline (> 8 su)	41
TDS	
Fresh (< 1,000 mg/L)	42
Slightly Saline (1,000 – 3,000 mg/L)	46
Saline (3,000 – 10,000 mg/L)	19
Very Saline (10,000 – 35,000 mg/L)	1
Hardness	
Soft (<75 mg/L)	25
Moderately Hard (75 – 150 mg/L)	13
Hard (151 - 300 mg/L)	19
Very Hard (301 - 600 mg/L)	21
Extremely Hard (> 600 mg/L)	30
Water Chemistry	
Sodium-Chloride	60
Sodium-Mixed	23
Sodium-Sulfate	7
Other Types	18
Nitrate	
Natural Background (<0.2 mg/L)	6
May or May Not be from Human Influence (0.2-3.0 mg/L)	62
May Result from Human Influence (3.0 - 10 mg/L)	30
Probably Result from Human Influence (> 10 mg/L)	10
Trace Elements	
Detected at less than 50 percent of sites	aluminum, antimony, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, thallium, and zinc
Detected at more than 50 percent of sites	arsenic, barium, boron, fluoride, and strontium.

Stable isotopes of oxygen-18 and deuterium values at wells in the Lower Gila basin appear to reflect four recharge sources: local precipitation, Gila River, Colorado River-natural, and Colorado River-artificial (Figure 6). Some mixing, however, is evident between the groups. Usually, local rainfall recharge samples are the most evaporated, Gila River recharge occurring at higher elevations in Arizona is less evaporated, and Colorado River recharge that occurs at higher elevations in Wyoming and Colorado is the least evaporated.

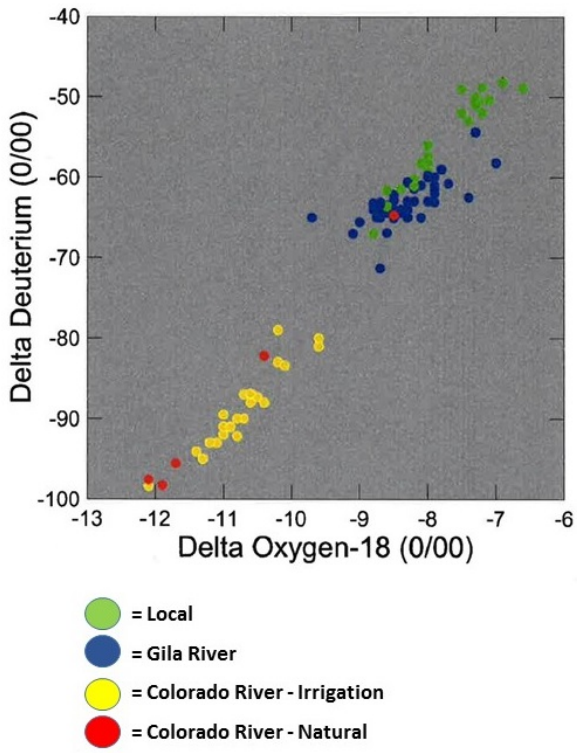

Figure 6 - Stable isotopes of oxygen and hydrogen illustrate the four groundwater recharge sources.

Nitrogen-15 ($\delta^{15}N$) results indicate that the nitrogen source is predominantly either organic soil matter or animal waste. Some samples, usually with Gila River recharge as their source, have very high $\delta^{15}N$ values with accompanying low nitrate concentrations. Nitrate reduction may be occurring at these sites from bacterial activity, which would leave heavy isotopes behind such as $\delta^{15}N$. [13]

Spatial Variation

A few constituent had significantly different concentrations by sub-basin, such as fluoride (Figure 7), along with the stable isotopes of oxygen-18 and deuterium (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

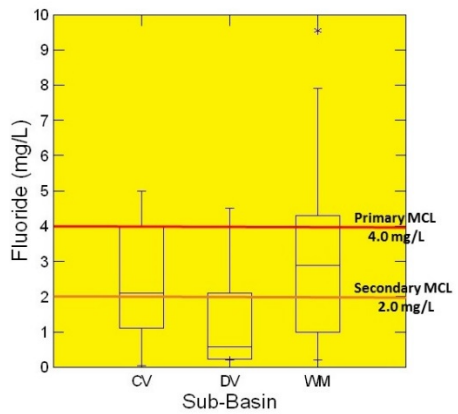

Figure 7 - Fluoride concentrations are significantly higher in the Wellton-Mohawk sub-basin than in the Dendora Valley sub-basin.

Many constituent concentrations were significantly different when compared by recharge source. Colorado River water recharged from irrigation applications typically had higher constituent concentrations than Gila River recharge, which was significantly higher than local precipitation (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Constituents following this general pattern include TDS (Figure 8), major ions, boron, and strontium.

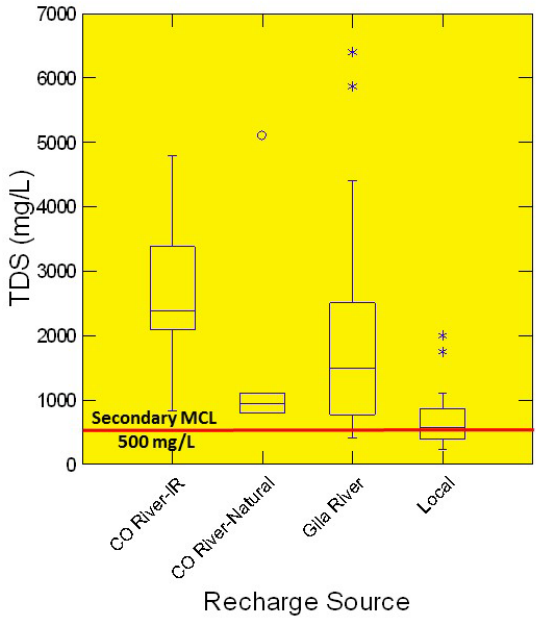

Figure 8 - TDS concentrations are highest in groundwater recharged from Colorado River or Gila River are significantly higher than from local recharge.

Discussion

The Lower Gila basin comprises most of southwestern Arizona. Groundwater in most areas of the basin is not suitable for drinking water use without treatment (Figure 9). The basin contains some of the most challenging groundwater in Arizona, as judged by water quality standard exceedances and salinity levels.

Figure 9 - ADEQ's Elizabeth Boettcher samples a domestic well near the Mohawk Mountains.

The results of this ADEQ study support the findings of previous ADEQ groundwater quality studies in Arizona. Arsenic, fluoride, and nitrate concentrations commonly exceeded Primary MCLs and are the three most prevalent groundwater contaminants in the state.[14]

Elevated concentrations of arsenic and fluoride naturally occur in groundwater. Arsenic concentrations are affected by reactions with hydroxyl ions and are influenced by factors such as an oxidizing environment, lithology, and aquifer residence time.[15] Calcium often controls fluoride concentrations in groundwater through precipitation or dissolution of the mineral fluorite. Dissolved fluoride concentrations exceeding 5 mg/L may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution.[16] This occurs commonly in the basin, as sodium was the dominant cation in 96 of the 108 well samples.

Although nitrate water quality standards were exceeded at nine percent of the wells sampled, nitrate concentrations are generally lower than would be expected in a basin with extensive development of irrigated agriculture. The generally low nitrate concentrations are likely due to the rapid movement of groundwater, especially in the Wellton-Mohawk area. The constant irrigation water applications, subsequent recharge, and then withdrawal by drainage wells is not conducive to elevated concentrations of nitrate in groundwater. The Yuma basin, located to the west, has similar groundwater movement and low nitrate concentrations.[17] Nitrogen isotopes suggest the dominant source of nitrate at the majority of wells is naturally occurring soil organic matter or animal waste.[18]

TDS concentrations were considered marginal for most uses in the Wellton-Mohawk area even prior to widespread irrigation development, which began in the 1920s. Irrigation recharge to the groundwater

gradually increased the already high salinity.[19] To improve farming conditions, Colorado River water was used in the Wellton-Mohawk area for irrigation starting in 1952.

This ADEQ study revealed that TDS and major ion concentrations in groundwater recharged by the Colorado River is significantly higher than in recharge from Gila River or local precipitation. Recharge from the Gila River was typically also significantly higher for these constituents than in recharge from local precipitation (Kruskal-Wallis and Tukey tests, $p \leq 0.05$).

Local precipitation is preferred for public water or domestic uses in the Lower Gila basin as more than a third of wells sampled met all health and aesthetics-based water quality standards (Table 3). In contrast, not a single well producing water recharged by the Gila River or Colorado River met all water quality standards.

Table 3 - Water Quality Standard Exceedances by Recharge Source

Recharge Source	Number of Wells Exceeding Primary Standards	Number of Wells Exceeding Only Secondary Standards	Percentage of Wells Without Standard Exceedances
Local Precipitation	13	2	9
Gila River	41	12	0
Colorado River - Irrigation	22	4	0
Colorado River - Natural	2	3	0
Total	78	21	9

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