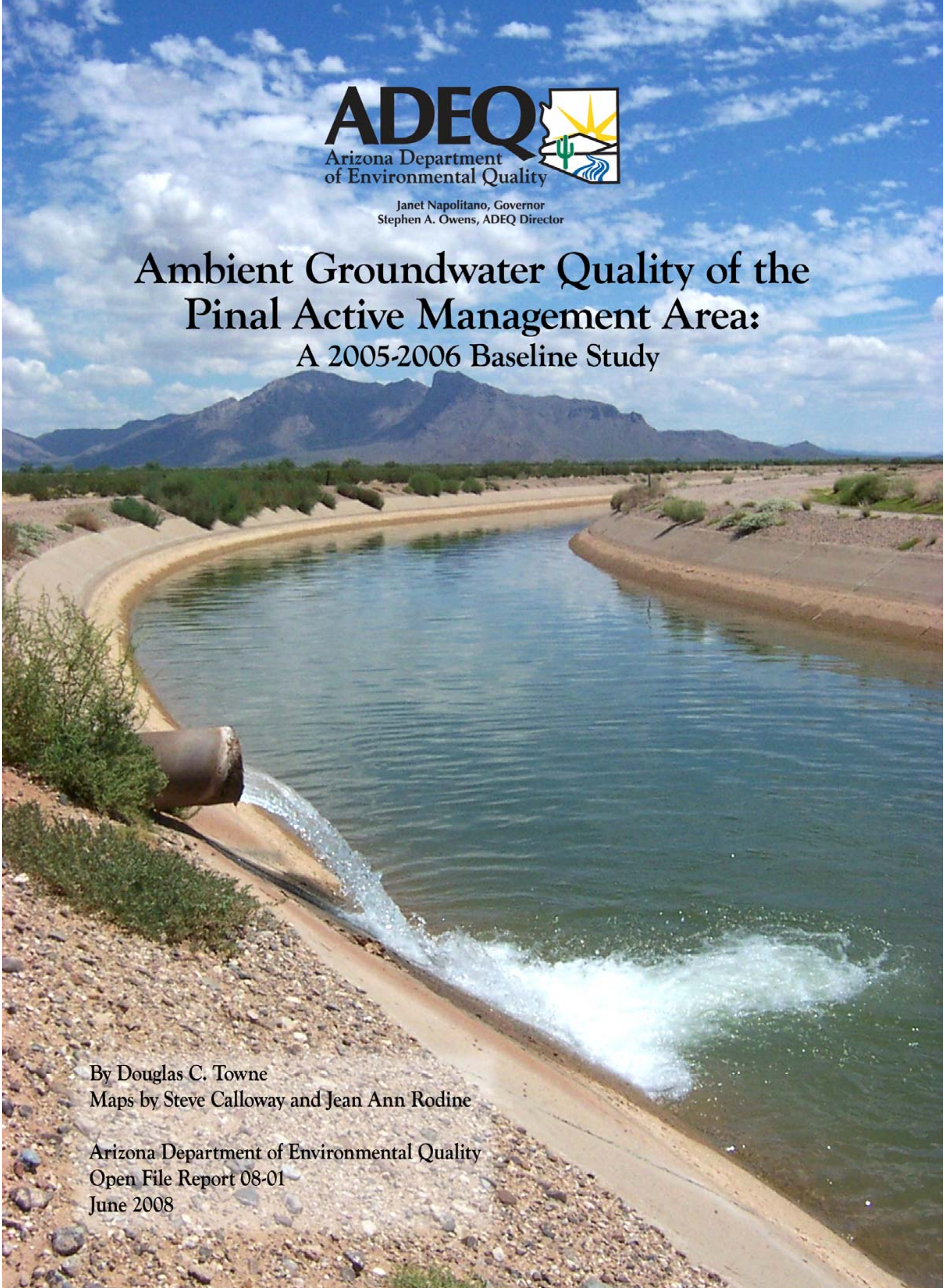

ADEQ
Arizona Department of Environmental Quality

Janet Napolitano, Governor
Stephen A. Owens, ADEQ Director

Ambient Groundwater Quality of the Pinal Active Management Area:

A 2005-2006 Baseline Study

By Douglas C. Towne
Maps by Steve Calloway and Jean Ann Rodine

Arizona Department of Environmental Quality
Open File Report 08-01
June 2008

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Thanks:

Field Assistance: Aiko Condon, Melissa Garcia, and Aneddail Torres-Ayala. Special recognition is extended to the many well owners who were kind enough to give permission to collect groundwater data on their property.

Review Assistance: Aiko Condon, Karyn Hanson and Jason Jones

Photo Credits: Douglas Towne

Report Cover: Groundwater from Well C-33 #1, a 1,200-foot-deep irrigation well operated by the Central Arizona Irrigation and Drainage District (CAIDD), supplements Colorado River water flowing in the Central Main Canal. Water from the canal irrigates crops, most commonly upland cotton, within the CAIDD in the Santa Cruz Flats south of the Town of Eloy. The Samaniego Hills form the backdrop to the bucolic agricultural scene in Pinal County.

Other Publications of the ADEQ Ambient Groundwater Monitoring Program

ADEQ Ambient Groundwater Quality Open-File Reports (OFR):

Hualapai Valley Basin	OFR 07-05, March 2007, 53 p.
Big Sandy Basin	OFR 06-09, October 2006, 66 p.
Lake Mohave Basin	OFR 05-08, October 2005, 66 p.
Meadview Basin	OFR 05-01, January 2005, 29 p.
San Simon Sub-Basin	OFR 04-02, October 2004, 78 p.
Detrital Valley Basin	OFR 03-03, November 2003, 65 p.
San Rafael Basin	OFR 03-01, February 2003, 42 p.
Lower San Pedro Basin	OFR 02-01, July 2002, 74 p.
Willcox Basin	OFR 01-09, November 2001, 55 p.
Sacramento Valley Basin	OFR 01-04, June 2001, 77 p.
Upper Santa Cruz Basin	OFR 00-06, Sept. 2000, 55 p. (With the U.S. Geological Survey)
Prescott Active Management Area	OFR 00-01, May 2000, 77 p.
Upper San Pedro Basin	OFR 99-12, July 1999, 50 p. (With the U.S. Geological Survey)
Douglas Basin	OFR 99-11, June 1999, 155 p.
Virgin River Basin	OFR 99-04, March 1999, 98 p.
Yuma Basin	OFR 98-07, September, 1997, 121 p.

ADEQ Ambient Groundwater Quality Fact sheets (FS):

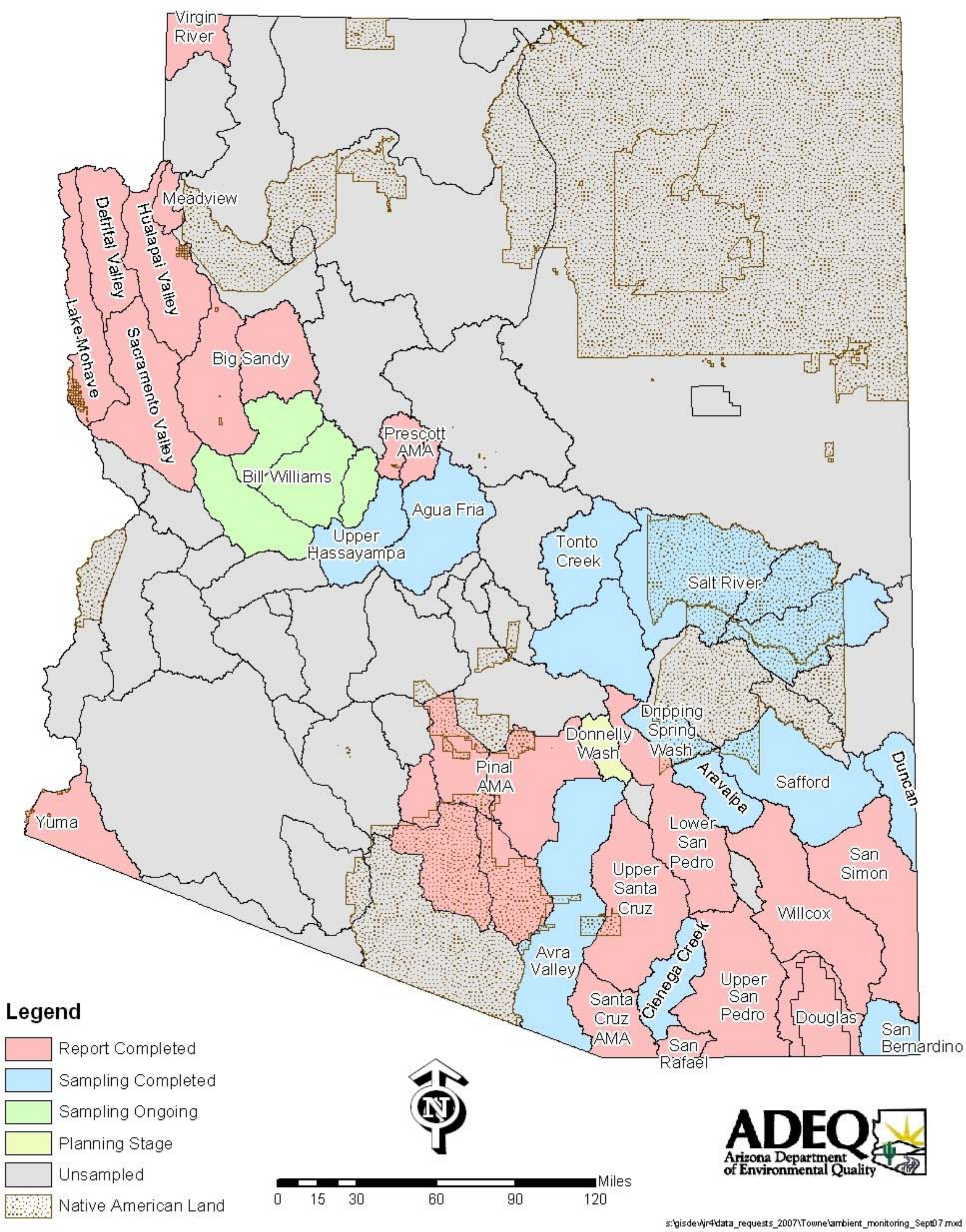
Pinal Active Management Area	FS 07-27, October 2007, 7 p.
Hualapai Valley Basin	FS 07-10, March 2007, 4 p.
Big Sandy Basin	FS 06-24, October, 2006, 4 p.
Lake Mohave Basin	FS 05-21, October 2005, 4 p.
Meadview Basin	FS 05-01, January 2005, 4 p.
San Simon Sub-basin	FS 04-06, October 2004, 4 p.
Detrital Valley Basin	FS 03-07, November 2003, 4 p.
San Rafael Basin	FS 03-03, February 2003, 4 p.
Lower San Pedro Basin	FS 02-09, August 2002, 4 p.
Willcox Basin	FS 01-13, October 2001, 4 p.
Sacramento Valley Basin	FS 01-10, June 2001, 4 p.
Yuma Basin	FS 01-03, April 2001, 4 p.
Virgin River Basin	FS 01-02, March 2001 4 p.
Prescott Active Management Area	FS 00-13, December 2000, 4 p.
Douglas Basin	FS 00-08, September 2000, 4 p.
Upper San Pedro Basin	FS 97-08, August 1997, 2 p. (With the U.S. Geological Survey)

These publications are available on-line.
Visit the ADEQ Ambient Groundwater Monitoring Program at:

www.azdeq.gov/environ/water/assessment/ambient.html

ADEQ Ambient Groundwater Monitoring Program Studies

September 2007



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Abbreviations

amsl	above mean sea level
ac-ft	acre-feet
af/yr	acre-feet per year
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
AMA	Active Management Area
ARRA	Arizona Radiation Regulatory Agency
AZGS	Arizona Geological Survey
As	arsenic
bls	below land surface
BLM	U.S. Department of the Interior Bureau of Land Management
^oC	degrees Celsius
$CI_{0.95}$	95 percent Confidence Interval
Cl	chloride
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpm	gallons per minute
HCl	hydrochloric acid
LLD	Lower Limit of Detection
Mn	manganese
MCL	Maximum Contaminant Level
ml	milliliter
msl	mean sea level
ug/L	micrograms per liter
um	micron
uS/cm	microsiemens per centimeter at 25° Celsius
mg/L	milligrams per liter
MRL	Minimum Reporting Level
MTBE	Methyl tertiary-Butyl Ether
ns	not significant
ntu	nephelometric turbidity unit
pCi/L	picocuries per liter
Pinal AMA	Pinal Active Management Area
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
SAR	Sodium Adsorption Ratio
SDW	Safe Drinking Water
SC	Specific Conductivity
su	standard pH units
SO_4	sulfate
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
USGS	U.S. Geological Survey
VOC	Volatile Organic Compound
*	significant at $p \leq 0.05$ or 95% confidence level
**	significant at $p \leq 0.01$ or 99% confidence level
***	for information only, statistical test for this constituent invalid because detections fewer than 50 percent

Ambient Groundwater Quality of the Pinal Active Management Area: A 2005-06 Baseline Study

Abstract - In 2005-06, the Arizona Department of Environmental Quality (ADEQ) conducted a baseline groundwater quality study of the Pinal Active Management Area (AMA) located between Phoenix and Tucson in south-central Arizona. To characterize regional groundwater quality, samples were collected from 86 sites located on non-tribal lands. Roughly two-thirds of the sampled sites were irrigation wells using turbine pumps with the remainder mostly domestic wells using submersible pumps. All sites were sampled for inorganic constituents and oxygen and deuterium isotopes. At selected sites, samples were also collected for radon (41), radiochemistry (21) and organics (semi-volatile compounds, chlorinated pesticides, and organo-phosphorus pesticides) (14). Among Pinal AMA's five sub-basins, the majority of groundwater samples were collected in Eloy (50 sites) and Maricopa-Stanfield (27 sites) with the remainder in Aguirre Valley (5 sites) and Vekol Valley (4 sites).

Analytical results indicate that of the 86 sites sampled, 60 sites (70 percent) had concentrations of at least one constituent that exceeded a health-based, federal or State water-quality standard. These enforceable standards define the maximum concentrations of constituents allowed in water supplied to the public and are based on a lifetime daily consumption of two liters per person.[3, 40, 44] Health-based exceedances included arsenic (33 sites), fluoride (7 sites), gross alpha (5 sites), nitrate (23 sites), and uranium (2 sites). These health-based exceedances appear to be naturally occurring with the exception of nitrate whose concentrations are impacted by fertilizer and both human and animal wastewater. At 59 sites (69 percent), concentrations of at least one constituent exceeded an aesthetics-based, federal water-quality guideline. These are unenforceable guidelines that define the maximum concentration of a constituent that can be present in drinking water without an unpleasant taste, color, odor, or other effect.[40, 44] Aesthetics-based exceedances included chloride (25 sites), fluoride (19 sites), iron (2 sites), pH-field (8 sites), sulfate (26 sites), and total dissolved solids or TDS (50 sites). There were no detections of organic compounds in the 14 organic samples. Both irrigation wells and drinking water wells had similar frequencies of water quality standard exceedances.

Groundwater in the Pinal AMA basin was found to be generally *slightly alkaline*, *fresh*, and *hard*-to-*very hard* as indicated by pH values and TDS and hardness concentrations.[16, 23] Groundwater chemistry varied but tended to be calcium-sulfate/chloride in the upper water zone and sodium-bicarbonate in the lower water zone.[22] Statistically-significant patterns were found among groundwater sub-basins, land uses, irrigation districts and groundwater zones (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). Of the water quality patterns found, the most numerous are those involving irrigation districts and water zones.

Analytical results were compared among samples collected in three irrigation and drainage districts: the Central Arizona (CAIDD), Maricopa-Stanfield (MSIDD) and San Carlos (SCIDD). Groundwater depth, temperature, pH-field and pH-lab were higher in the CAIDD and MSIDD than in SCIDD. TDS, SC-field, SC-lab, hardness, calcium, magnesium, potassium, chloride, sulfate, TKN and boron were higher in the SCIDD than in CAIDD and MSIDD. Seven constituents had unique patterns: sodium, bicarbonate, fluoride, arsenic, radon, oxygen and deuterium.

Analytical results were compared among samples collected in three water zones within the Eloy and Maricopa-Stanfield sub-basins: lower main water zone, upper main water zone and local water zones. Well depth, groundwater depth, temperature, pH-field and pH-lab were higher in the lower main water zone than in upper and local water zones. TDS, SC-field, SC-lab, hardness, calcium, magnesium, sodium, chloride, sulfate and nitrate were higher in the upper and local water zones than in the lower main water zones. Potassium, TKN and boron were higher in the upper main water zone than in the lower main water zone.

Several factors contribute to these patterns, including evaporate deposits, such as gypsum, salt and gypsiferous mudstone but their specific impacts are difficult to quantify.[22] The greatest impact however, appears to be the effect of salts and calcite concentrated by evaporation during irrigation and then recharged to the upper main or local water zones.[12, 13] Since water from the Gila River is the main source of irrigation for the SCIDD, its importation maintains relatively shallow groundwater levels in this irrigation district. Thus, there is little lag time before the highly saline recharge from irrigation applications percolates to the aquifer and impacts groundwater quality in the SCIDD.[13] In contrast, before 1987 the CAIDD and the MSIDD used groundwater as the sole source of irrigation water.[7] This has led to declining groundwater depths in these districts, but has probably protected the groundwater from the full impacts of saline recharge from irrigation applications because of the increased distance necessary for this water to percolate to the aquifer.

INTRODUCTION

Purpose and Scope

The Pinal Active Management Area (AMA) is located within Pinal, Pima and Maricopa counties in south-central Arizona roughly halfway between Phoenix and Tucson. Historically an area that has undergone extensive groundwater development for irrigated agriculture, the Pinal AMA was created by the Arizona Groundwater Management Act of 1980 to better manage its diminishing groundwater resources.[7]

The Pinal AMA covers approximately 4,100 square miles and five incorporated communities are found within it: Casa Grande, Coolidge, Eloy, Florence and Maricopa. These communities had a combined population of approximately 70,000 in 2004.[1, 32] (Map 1). Approximately half of the Pinal AMA (2,100 square miles) is composed of tribal lands including portions of the Gila River Indian Community and the entire Ak Chin Indian Community in the north and portions of the Tohono O'odham Nation to the south (Figure 1).

Both surface water, from the Gila River and the Colorado River, and groundwater are used for irrigation which is the largest water use in the Pinal AMA. Groundwater is the primary source for municipal and domestic supply.[7]

The Pinal AMA was selected for study by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring program to characterize the current (2005-2006) groundwater quality conditions in the Pinal AMA because it is rapidly transitioning from agricultural to residential land use (Figures 2 and 3).

Sampling by the ADEQ Ambient Groundwater Monitoring program, which coducts monitoring pursuant to Arizona Revised Statutes §49-225, specifically:

"*...ongoing monitoring of waters of the state, including...aquifers to detect the presence of new and existing pollutants, determine compliance with applicable water quality standards, determine the effectiveness of best management practices, evaluate the effects of pollutants on public health or the environment, and determine water quality trends*."[3]

This ADEQ study sought to:

- Provide information on baseline groundwater quality conditions in the Pinal AMA in preparation for potential large population increases which will rely upon this resource as a municipal or domestic source.[17]

- Determine if there are portions of the Pinal AMA where groundwater does not currently meet U.S. Environmental Protection Agency (EPA) Safe Drinking Water Act (SDWA) water quality standards.[40, 44]

- Examine water quality differences among sub-basins, land uses, irrigation districts and water zones in the Pinal AMA.

- Support the Arizona Department of Water Resources (ADWR) Pinal AMA's office request for continuing groundwater quality assessments to provide the data needed to ensure effective management of the area's groundwater resources.[7]

Benefits of Study – This study, which utilizes accepted sampling techniques and quantitative analyses, is designed to provide the following benefits:

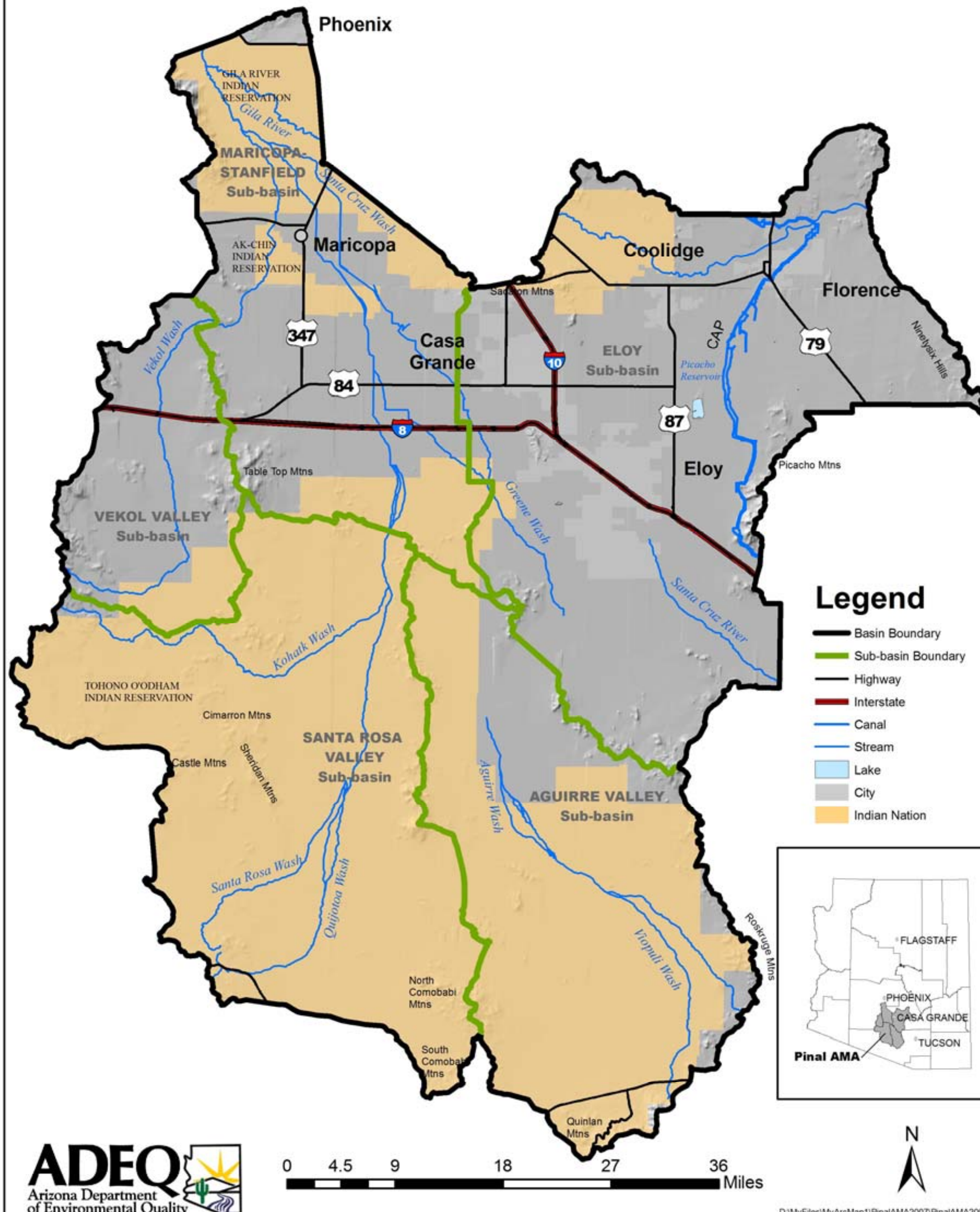
- A general characterization of regional groundwater quality. Testing all private wells for a wide variety of groundwater quality concerns is not appropriate or cost effective. A valid and reasonable alternative is a statistically-based groundwater study which describes regional groundwater quality and identifies areas with impaired conditions.[24]

- A process for evaluating potential groundwater quality impacts arising from a variety of sources including mineralization, mining, agriculture, livestock, septic tanks, and poor well construction.

- A guide for identifying future locations of public supply wells.

- A guide for determining areas where further groundwater quality research is needed.

Map 1 - Pinal AMA



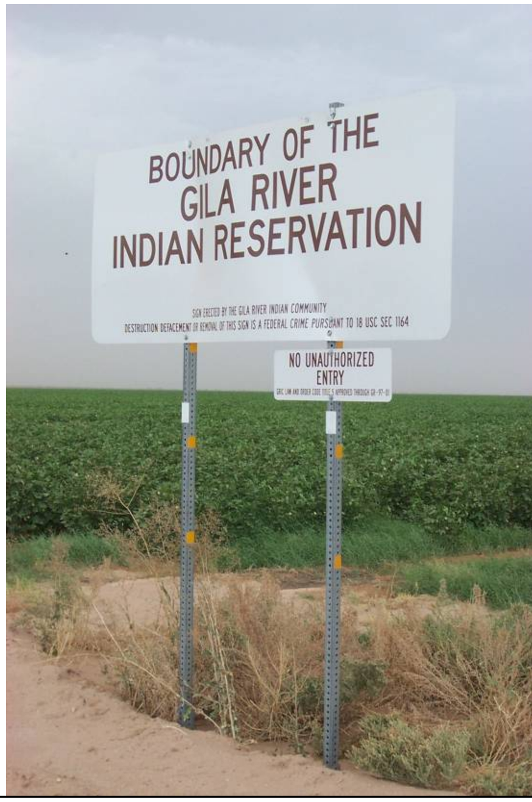


Figure 1. About 51 percent of the Pinal AMA's 4,100 square miles consist of tribal lands including the Ak-Chin Indian Community as well as portions of the Gila River Indian Community and Tohono O'odham Indian Nation. Indian agriculture used 13 percent of water use in Pinal AMA in 1995. [7]

Figure 2. Although non-tribal agriculture used 75 percent of water in the Pinal AMA in 1995, farming is declining in the area as shown by this abandoned cotton gin near the city of Maricopa.[7] Urban land use is spreading to many parts of AMA influenced by the growth of the Phoenix and Tucson metropolitan areas.

Figure 3. Both desert and farmland in the Pinal AMA is rapidly being converted to residential subdivisions and associated commercial centers. The formerly irrigated field pictured here now grows a bumper crop of tumbleweeds in preparation for its probable transition into housing sites. Residential subdivisions such as this use much less water than irrigated farmland. [7]

Physical and Cultural Characteristics

Geography – The Pinal AMA is located within the Basin and Range physiographic province which is characterized by broad alluvial filled basins separated by elongated, northwest-southeast trending fault-block mountain ranges.[6]

The AMA is bounded to the north by the Santan, Sacaton, and South Mountains and to the east by the Picacho, Waterman, and Roskruge Mountains. The southern boundary is formed by the Quinlan, Comobabi, and Quijotoa Mountains. The western boundary is formed by the Castle, Sand Tank, and Sierra Estrella Mountains.[6]

Mountain elevations range from about 2,700 feet above mean sea level (amsl) at Sacaton Peak in the Sacaton Mountains to over 6,800 feet amsl at Kitt Peak in the Quinlan Mountains. [6] Basin floor elevations range from about 1,200 feet amsl in the northwestern section to 3,000 feet amsl in the southeastern section of the AMA.

Approximately half of the 4,100 square miles within the Pinal AMA consists of tribal lands. The remainder consists of private land, federal land managed by either the U.S. Bureau of Land Management (BLM) or Barry M. Goldwater Air Force Range, State Trust land and small parcels of various local or state parks.[6]

Climate - The climate of the Pinal AMA is semiarid, characterized by hot summers and mild winters. At the Casa Grande National Monument near Coolidge, precipitation averages almost 9 inches per year while temperature averages almost 70 degrees Fahrenheit.[6]

Precipitation occurs in the late summer from July to September as high intensity thunderstorms of short duration; winter precipitation occurs from December to March and typically consists of gentle, long-lasting rains or snow produced by low-intensity storms. [7]

Surface Water –The major drainages in the Pinal AMA include the Gila River, the Santa Cruz River, Aguirre Wash, Santa Rosa Wash, and Vekol Wash. Flows in the Gila and Santa Cruz Rivers recorded just downstream of the Pinal AMA result primarily from drainage and return flow from land irrigated mostly with groundwater. [32] There is no recorded natural perennial flow in any of the other gauged drainages in the AMA though normally dry watercourses can quickly turn into raging streams after heavy monsoon storms (Figure 9).[6]

The headwaters of the Gila River are in New Mexico and the watercourse is extensively diverted near Safford, Arizona for irrigation use before being impounded behind Coolidge Dam, forming San Carlos Lake. Water is released from the lake according to irrigation needs where it is diverted at the Ashurst-Hayden Dam (Figure 5) into the Florence-Casa Grande Canal (Figure 6) for irrigation use in the within the Pinal AMA. Downstream of the Ashurst-Hayden Dam, the Gila River is an ephemeral watercourse (Figure 7).[6]

The Santa Cruz River is intermittent within the Pinal AMA; flows are often the result of effluent releases from wastewater treatment plants in the Tucson area (Figure 8).[6]

Surface water from the Colorado River is also used in the Pinal AMA for agriculture use. The water is transported via the Central Arizona Project (CAP), a 336-mile aqueduct designed to carry about 1.5 million acre-feet of surface water annually from the Colorado River for use in Maricopa, Pinal and Pima Counties. From 1990 through 2004, over 6.4 million acre-feet of Colorado River water had been delivered to the Pinal AMA with slightly more than half delivered to the Maricopa-Stanfield sub-basin and the remainder to the Eloy sub-basin. [6]

Water Development – The majority of water used in the Pinal AMA has been for agriculture; even as recently as 1995, 75 percent of water use was for non-tribal agriculture, 13 percent for tribal agriculture, and 6 percent for canal losses with only 2.3 percent used for municipal and industrial.[7] Cotton is the most important crop followed by alfalfa and grains.[22] Large-scale groundwater pumping started in the early 1930s (Figure 10) and since that time, withdrawals have greatly exceeded recharge. [22]

Approximately 87 percent of farms within the non-tribal portion of the Pinal AMA are served by four large irrigation and drainage districts: Central Arizona (CAIDD), Maricopa-Stanfield (MSIDD), Hohokam (HIDD), and San Carlos (SCIDD). [7] All are located in the Eloy sub-basin with the exception of the MSIDD which is located in the Maricopa-Stanfield sub-basin (Figure 4).

Since 1987, the CAIDD, MSIDD, and HIDD have received and distributed Colorado River water provided though the CAP. [7] Formerly these three

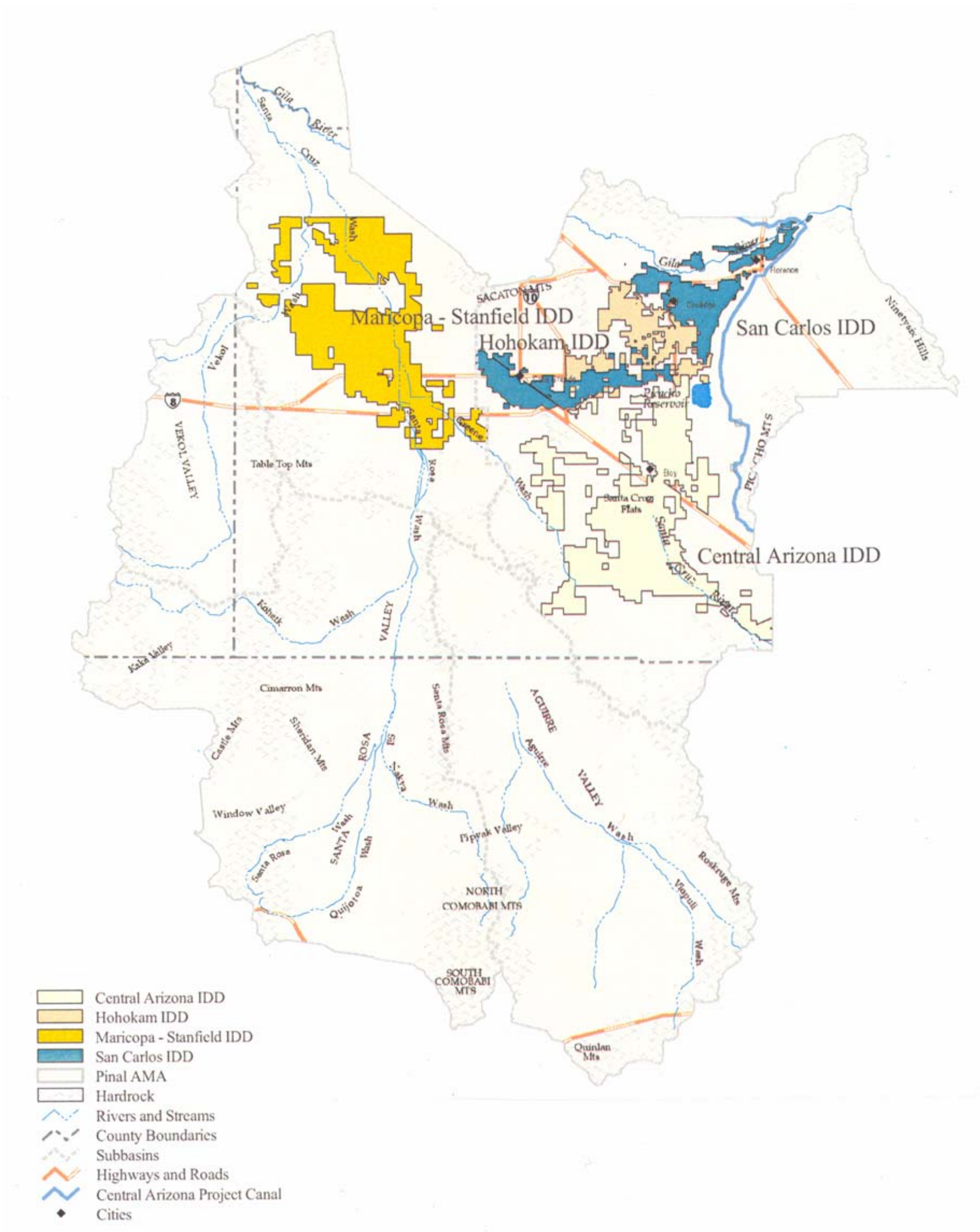


Figure 4. The boundaries of the four largest irrigation and drainage districts in the Pinal AMA are shown: Central Arizona (CAIDD), Hohokam (HIDD), Maricopa-Stanfield (MSIDD) and San Carlos (SCIDD).[7]

Figure 5. South Butte lies upriver from the Ashurst-Hayden Dam which has diverted water from the Gila River for irrigation use since 1922. Since 1928, the Gila River has been controlled upriver by Coolidge Dam built as part of the San Carlos Irrigation Project. The stored water is shared between tribal entities and the San Carlos Irrigation and Drainage District (SCIDD); both also use groundwater to supplement their irrigation needs. [6]

Figure 6. Water from the Gila River is diverted into the Florence-Coolidge Canal before being applied to crops. This resource is distributed by the San Carlos Irrigation and Drainage District (SCIDD) through a largely unlined system that loses high amounts of water. [6]

Figure 7. A perennial stream until the late 1800's, the Gila River downstream of the Ashurst-Hayden Dam is now typically dry. Pre-development flows in the watercourse are estimated to have been about 500,000 acre-feet per year. [6]

Figure 8. Flows in the Santa Cruz River normally are the result of effluent releases from a wastewater treatment plant in Tucson. Those pictured here, where the waterway intersects SASCO Road, are supplemented by runoff from monsoon storms. Portions of this flow are diverted near the town of Red Rock for irrigation.[6] Because of the changing course of the Santa Cruz River, the installation of a permanent gaging station to measure flow into the Pinal AMA has not been feasible.[6]

Figure 9. Greene Wash carries a heavy, turbid flow towards the Sawtooth Mountains as a result of heavy monsoon rains. If sufficient, these flows will reach the Santa Rosa Wash and eventually the Gila River.

Figure 10. Like monoliths left by an advanced prehistoric society, rusting diesel motors, like this one pictured near Friendly Corners to the west of Picacho Mountain, once powered irrigation pumps throughout the Pinal AMA. These mammoth motors are testimony to groundwater serving irrigated farmland needs for nearly a century in the area. [6]

irrigation districts were completely dependent on groundwater for irrigation though groundwater is still pumped to supplement the water supply. The SCIDD receives and distributes surface water from the Gila River supplemented by groundwater for its irrigation supply. [7]

San Carlos Irrigation and Drainage District - The SCIDD is the oldest irrigation and drainage district in the Pinal AMA. Located in the northern part of the Eloy sub-basin, it encompasses a J-shaped swath stretching from Florence through Coolidge, south to Picacho Reservoir and then west to Casa Grande.

Historically, the Gila River was used by the Pima and Maricopa tribes to irrigate their native lands which included some areas within the present Pinal AMA. [27] Non-tribal water users upstream of these tribes began diverting water from the river in the mid-1860s, with almost the entire flow of the Gila River diverted by 1886 in the Florence Canal and Land Company. [27]

The San Carlos Irrigation Project (SCIP) was created to equitably provide water to both tribal and non-Indian settlers. Funds were appropriated for the Ashurst-Hayden Diversion Dam located about 10 miles east of Florence and completed in 1922, a delivery system to supply water to 35,000 acres of Indian land and 27,000 acres of private land which later became the SCIDD.[27] Included in this water delivery network was Picacho Reservoir, an impoundment able to store up to 24,500 acre-feet of water in order to regulate flow in the Florence-Casa Grande Canal. To provide a renewable water source for the SCIP, Coolidge Dam, a storage dam located upstream on the lands of the San Carlos Apache Tribe was completed in 1928.[27]

The SCIP is operated by three agencies: the Bureau of Indian Affairs provides water for Gila River Indian Community lands, water for private lands is provided by the SCIDD and these two entities share various facilities known as the joint works.[27] To supplement surface water, a well drilling program was initiated in the early 1930s. Wells were drilled chiefly on canal banks adjacent to both tribal and non-tribal lands with the pumped groundwater distributed equally between both users (Figure 11). [27]

Hohokam Irrigation and Drainage District - Also located in the northern part of the Eloy sub-basin, the HIDD consists of 26,661 acres that is bordered on the east and south by the SCIDD. Formed in 1972 to contract the construction, operation, and maintenance of a distribution system to deliver CAP water, farmers had previously been completely dependent on groundwater for irrigation. HIDD landowners retain control of their wells using CAP water to supplement pumped groundwater. [7]

The Central Arizona Irrigation and Drainage District - The CAIDD is located in the southern part of the Eloy sub-basin and consists of approximately 87,600 acres. It was organized in 1964 to obtain supplemental CAP water. From the 1920's until CAP water became available in 1989, these lands were irrigated with groundwater. Approximately 350 wells are still used in the distribution network, operated and maintained by the CAIDD under long term lease agreements with landowners (Figure 13). Prior to receiving CAP water, the CAIDD experienced a reduction in the amount of land under cultivation partially because of the increased cost of pumping water due to the decline in the groundwater table. [11]

The Maricopa-Stanfield Irrigation and Drainage District - The MSIDD is composed of 87,199 acres in the Maricopa-Stanfield sub-basin. Organized in 1962 to obtain supplemental water from the CAP, the MSIDD distribution system was completed in 1989. The network includes 80 wells leased from landowners that are tied to the distribution system in addition to 330 wells that only supply individual farms (Figure 12). [7]

Figure 11. The San Carlos Irrigation and Drainage District (SCIDD) supplements surface water from the Gila River with groundwater pumped from wells such as #111 shown above. The SCIDD has a limited well network; historically, groundwater has seldom exceeded 20 percent of the SCIDD's total water use. [7]

Figure 12. Formerly dependent on groundwater, the Maricopa-Stanfield Irrigation and Drainage District (MSIDD) was organized in 1962 to obtain Central Arizona Project (CAP) water. Since 1987, 45 percent of its 234,000 acre-feet of irrigation requirements have been from the CAP while groundwater from 410 leased wells, such as C-120 #1 shown above, provide the remainder. [7]

Figure 13. The Central Arizona Irrigation and Drainage District (CAIDD) was formed in 1964 to obtain Central Arizona Project (CAP) water to supplement groundwater pumping. From the 1920s until 1989, groundwater was the sole source of water for irrigation. Over 350 wells leased from land owners are still operated and maintained by the CAIDD to supplement water from the Colorado River for irrigation. [7]

HYDROGEOLOGY

The Pinal AMA consists of thousands of feet of accumulated sediment surrounded by relatively low elevation mountains that are primarily composed of Precambrian granitic and metamorphic rocks with some Tertiary volcanics and other rocks.[22] Basin sediments in the Pinal AMA consist primarily of alluvial fill extending up to several thousand feet in thickness.

Geologic Units

Geological units having the potential to yield groundwater have been divided into, in ascending order, hydrologic bedrock, lower basin fill, upper basin fill and stream alluvium. [22]

Hydrologic Bedrock – this is a consolidated unit consisting mostly of well-cemented sedimentary rocks underlying the more unconsolidated sediments.[22] Hydrologic bedrock is generally overlain by hundreds to thousands of feet of later sediments but does form buried ridges that partially define the geohydrologic system. These include the Casa Grande Ridge between the Sacaton and Sawtooth Mountains forming the hydrologic boundary between the Eloy and Maricopa-Stanfield sub-basins as well as another ridge between Picacho Peak and the Silver Bell Mountains.[22] The hydrologic bedrock is generally not very permeable but small to moderate amounts of water may be yielded to wells where the unit is fractured. [22]

Lower Basin Fill – this includes the Lower Conglomerate unit as well as the lower part of the Middle Fine-grained unit. Two fine-grained facies compose this unit along with thick evaporate deposits and gypsiferous mudstones.[22] The fine-grained facies, though storing much groundwater, do not readily yield groundwater to wells; however, coarse sediments such as sand and gravel lenses can be encountered near the basin margins that can be significance sources of groundwater. [22]

Upper Basin Fill – this includes the upper part of the Middle Fine-grained Unit and the Upper Alluvial unit except for stream alluvium.[22] In general, the upper basin fill is coarser grained than the lower basin fill, although some fine-grained deposits are present and some evaporates are present. The upper basin fill is the most significant source of groundwater although parts of it have been dewatered, particularly in the Maricopa-Stanfield sub-basin. [22]

Stream Alluvium – this consists of sediments deposited along the Gila and Santa Cruz Rivers and can be at least 100 feet thick. Rather than being a major source of water to wells, the stream alluvium primarily serves as a conduit for water moving through to underlying sediments. [22]

Groundwater Zones

Prior to about 1900, the Pinal AMA groundwater system was in dynamic equilibrium with roughly equal amounts of water entering and exiting the groundwater system. Since then, excess groundwater withdrawals have lowered groundwater levels. [22]

In the Eloy and Maricopa-Stanfield sub-basins, a lower main water zone, upper main water zone, and three local water zones have been identified.[22]

Lower Water Zone – this is the most extensive zone in the two sub-basins and is contained in the lower basin fill except along the sub-basin margins where it may be partially in the upper basin fill. Most recharge to the lower main water zone is probably from natural sources. Recharge also occurs from overlying saturated sediments, especially around some of the margins of the upper main zone, and from the release of water in the fine-grained facies. [22]

Upper Water Zone – this is the most productive zone for wells in the two sub-basins and is contained mostly within the upper basin fill and overlies the extensive, fine-grained facies. The upper main water zone does not appear to exist in the area south and east of the town of Stanfield in the Maricopa-Stanfield sub-basin. [22] Part of this zone is probably contained within the stream alluvium in the Gila River sediments east of Florence in the Eloy sub-basin and in the northern part of the Maricopa-Stanfield sub-basin. [22]

Local Water Zone - at least three significant local water zones occur in the Pinal AMA: the Casa Grande zone, the Picacho Reservoir zone, and the Friendly Corners water zone.[6] The local water zones are recharged by leakage from the San Carlos Irrigation Project's canal and reservoir system and by incidental recharge from agricultural irrigation.[6]

INVESTIGATION METHODS

The ADEQ Ambient Groundwater Monitoring Program collected samples from 86 groundwater sites to characterize regional groundwater quality in the Pinal AMA. Specifically, the following types of samples were collected:

- inorganic suites at 86 sites
- oxygen and deuterium isotopes at 86 sites
- radon at 41 sites
- radiochemistry (unstable elements such as uranium, thorium, or radium that release radioactivity in the form of alpha, beta and gamma radiation) at 25 sites
- organics (semi-volatile compounds, chlorinated pesticides, and organophosphorus pesticides) at 14 sites
- In addition, 10 isotopes were collected and analyzed from surface water sources.

No bacteria sampling was conducted because microbiological contamination problems in groundwater are often transient and subject to a variety of changing environmental conditions including soil moisture content and temperature.[21]

Sampling Strategy

This study focused on regional groundwater quality conditions that are large in scale and persistent in time. The quantitative estimation of regional groundwater quality conditions requires the selection of sampling locations that follow scientific principles for probability sampling.[24]

Sampling followed a systematic, stratified, random site-selection approach. This is an efficient method because it requires sampling relatively few sites to make valid statistical statements about the conditions of large areas. This systematic element requires that the selected wells be spatially distributed while the random element ensures that every well within a cell has an equal chance of being sampled. This strategy also reduces the possibility of biased well selection and assures adequate spatial coverage throughout the study area.[24]

Wells pumping groundwater for irrigation, stock and domestic purposes were sampled for this study, provided each well met ADEQ requirements. A well was considered suitable for sampling if the well owner gave permission to sample, if a sampling point existed near the wellhead, and if the well casing and surface seal appeared to be intact and undamaged.[8] Other factors such as casing access to determine groundwater depth and construction information were preferred but not essential.

For this study, ADEQ personnel sampled 86 groundwater sites that consisted of wells with the following types of pumps: turbine pumps (58 wells) (Figure 11, 12, 13, 14, 15 and 17), submersible pumps (27 wells) (Figure 16, 18 and 20), and pump jacks (1 well) (Figure 19). The turbine pumps produced water for irrigation use, the submersible pumps generally for municipal, domestic and/or stock use and the pump jack for stock use. Additional information on these groundwater sample sites is provided in Appendix A.

Well information compiled from the ADWR well registry is found in Appendix A.

Several factors were considered to determine sample size for this study. Aside from administrative limitations on funding and personnel, this decision was based on three factors related to the conditions in the area:

- Amount of groundwater quality data already available;
- Extent to which impacted groundwater is known or believed likely to occur; and
- Hydrologic complexity and variability of the basin.[24]

For the Pinal AMA study, 86 sites were sampled which was a large number compared to other ADEQ ambient groundwater studies. The sample number was particularly influenced by both the known extent of impacted groundwater and the hydrologic complexity of the Pinal AMA.

Sample Collection

The sample collection methods for this study conformed to the Quality Assurance Project Plan (QAPP)[2] and the Field Manual For Water Quality Sampling.[8] While these sources should be consulted as references to specific sampling questions, a brief synopsis of the procedures involved in collecting a groundwater sample is provided.

After obtaining permission from the owner to sample the well, the volume of water needed to purge the well three bore-hole volumes was calculated from well log and on-site information. Physical parameters—temperature, pH, and specific conductivity—were monitored at least every five minutes using an YSI multi-parameter instrument.

Figure 14. Sixty-seven (67) percent of sample sites consisted of high-production, electrically-powered turbine wells such as this 1,325-foot irrigation well (C-24 #4) operated by the Central Arizona Irrigation and Drainage District (CAIDD).

Figure 15. Turbine wells in the Pinal AMA can be very productive as shown by a pump rate of 1,600 gallons per minute on this 1305-foot deep well (E-10-2 #1)operated by the Maricopa–Stanfield Irrigation and Drainage District (MSIDD) near the city of Maricopa.

Figure 16. Thirty (30) percent of sample sites consisted of wells equipped with submersible pumps such as this 900-foot domestic well located in the Maricopa-Stanfield sub-basin. These wells were also used for municipal and stock use. Aiko Condon and Aneddail Torres-Ayala from the Arizona Department of Health Services (ADHS) assist with the well sampling.

Figure 17. Melissa Garcia, on loan from ADHS, samples this electric turbine well (PNL-78 or North Well) serving the City of Coolidge Airport. She will later conduct some of the water tests at the ADHS lab.

Figure 18. Antelope Well is among the 30 percent of sample sites using submersible pumps. A portable generator is periodically used to power the pump to supply water for stock. This now-unused Aeromotor windmill is located south of Interstate 8 in the Vekol Valley sub-basin.

Figure 19. Santa Rosa Well (PNL-90) consists of a pump jack—a mechanism now rarely used to pump groundwater—supplying a former railroad tanker that now stores water for stock use. The well is located south of Interstate 8 near Santa Rosa Wash.

Figure 20. Solar cells power a submersible pump in this remote domestic well (PNL-96) located in the Vekol Valley sub-basin. Solar power is economical for pumping relatively shallow (less than 250 feet bls) groundwater.

Typically to assure obtaining fresh water from the aquifer, after three bore volumes had been pumped and physical parameter measurements were stable within 10 percent, a sample representative of the aquifer was collected from a point as close to the wellhead as possible. In certain instances, it was not possible to purge three bore volumes. In these cases, at least one bore volume was evacuated and the physical parameters had stabilized within 10 percent.

Sample bottles were filled in the following order:

1. Organic
2. Radon
3. Inorganic
4. Radiochemistry
5. Isotope

Organic samples were collected in a one gallon, amber glass bottle.

Radon samples were collected in two unpreserved, 40-ml clear glass vials. Radon samples were carefully filled in to minimize volatilization and subsequently sealed so that no headspace remained.[18]

The inorganic constituents were collected in three, 1-liter polyethylene bottles: samples to be analyzed for dissolved metals were delivered to the laboratory unfiltered and unpreserved where they were subsequently filtered into bottles using a positive pressure filtering apparatus with a 0.45 micron (µm) pore size filter and preserved with 5 ml nitric acid (70 percent). Samples to be analyzed for nutrients were preserved with 2 ml sulfuric acid (95.5 percent). Samples to be analyzed for other parameters such as general mineral characteristics were unpreserved.[34]

Radiochemistry samples were collected in two collapsible 4-liter plastic containers and preserved with 5 ml nitric acid to reduce the pH below 2.5 su. [19]

Isotope samples were collected in a 500 ml polyethylene bottle with no preservative.

All samples were kept at $4^{o}C$ with ice in an insulated cooler, with the exception of the isotope and radiochemistry samples. Chain of custody procedures were followed in sample handling. Samples for this study were collected during ten field trips between August 2005 and May 2006.

Laboratory Methods

The inorganic and organic analyses for this study were conducted by the Arizona Department of Health Services (ADHS) Laboratory in Phoenix, Arizona. Inorganic sample splits analyses were conducted by Del Mar Laboratory in Phoenix, Arizona. A complete listing of inorganic parameters, including laboratory method, EPA water method and Minimum Reporting Level (MRL) for each laboratory is provided in Table 1. The analyte list for the organic samples is provided in Table 2 and Table 3.

Radon samples were analyzed by Radiation Safety Engineering, Inc. Laboratory in Chandler, Arizona.

Radiochemistry samples were analyzed by the Arizona Radiation Regulatory Agency Laboratory in Phoenix and radiochemistry splits by the Radiation Safety Engineering, Inc. Laboratory. The following EPA SDW protocols were used: Gross alpha was analyzed, and if levels exceeded 5 picocuries per liter (pCi/L), then radium-226 was measured. If radium-226 exceeded 3 pCi/L, radium-228 was measured. If gross alpha levels exceeded 15 pCi/L initially, then radium-226/228 and total uranium were measured. [19]

Isotope samples were analyzed by the Department of Geosciences, Laboratory of Isotope Geochemistry located at the University of Arizona in Tucson, Arizona.

Table 1. ADHS/Del Mar/ARRA Laboratory Water Methods and Minimum Reporting Levels Used in the Pinal AMA Study

Constituent	Instrumentation	ADHS / Del Mar Water Method	ADHS / Del Mar Minimum Reporting Level
Physical Parameters and General Mineral Characteristics			
Alkalinity	Electrometric Titration	SM232OB	2 / 5
SC (uS/cm)	Electrometric	EPA 120.1/ SM2510B	-- / 1
Hardness	Titrimetric, EDTA	EPA 130.2 / SM2340B	10 / 1
Hardness	Calculation	Calculation	--
pH (su)	Electrometric	EPA 150.1	0.1
TDS	Gravimetric	EPA 160.1 / SM2540C	10 / 20
Turbidity (NTU)	Nephelometric	EPA 180.1	0.01 / 1
Major Ions			
Calcium	ICP-AES	EPA 200.7	1 / 2
Magnesium	ICP-AES	EPA 200.7	1 / 0.5
Sodium	ICP-AES	EPA 200.7 / EPA 273.1	1 / 5
Potassium	Flame AA	EPA 200.7 / EPA 258.1	0.5 / 1
Bicarbonate	Calculation	Calculation	2
Carbonate	Calculation	Calculation	2
Chloride	Potentiometric Titration	SM 4500 CL D	5 / 0.5
Sulfate	Colorimetric	EPA 375.4	1 / 0.5
Nutrients			
Nitrate as N	Colorimetric	EPA 353.2	0.02 / 0.1
Nitrite as N	Colorimetric	EPA 353.2	0.02 / 0.1
Ammonia	Colorimetric	EPA 350.1/ EPA 350.3	0.02 / 0.5
TKN	Colorimetric	EPA 351.2 / SM4500	0.05 / 0.5
Total Phosphorus	Colorimetric	EPA 365.4 / EPA 365.3	0.02 / 0.05

All units are mg/L except as noted
Source [18, 34]

Table 1. ADHS/Del Mar/ARRA Laboratory Water Methods and Minimum Reporting Levels Used in the Study--Continued

Constituent	Instrumentation	ADHS / Del Mar Water Method	ADHS / Del Mar Minimum Reporting Level
Trace Elements			
Antimony	Graphite Furnace AA	EPA 200.9	0.005 / 0.004
Arsenic	Graphite Furnace AA	EPA 200.9	0.01 / 0.003
Barium	ICP-AES	EPA 200.7	0.1 / 0.01
Beryllium	Graphite Furnace AA	EPA 200.9	0.0005
Boron	ICP-AES	EPA 200.7	0.1 / 0.5
Cadmium	Graphite Furnace AA	EPA 200.9	0.001 / 0.0005
Chromium	Graphite Furnace AA	EPA 200.7	0.01 / 0.004
Copper	Graphite Furnace AA	EPA 200.7 / EPA 200.9	0.01 / 0.004
Fluoride	Ion Selective Electrode	SM 4500 F-C	0.1 / 0.1
Iron	ICP-AES	EPA 200.7	0.1 / 0.2
Lead	Graphite Furnace AA	EPA 200.9	0.005 / 0.002
Manganese	ICP-AES	EPA 200.7	0.05 / 0.02
Mercury	Cold Vapor AA	SM 3112 B / EPA 245.1	0.0002 / 0.0002
Nickel	ICP-AES	EPA 200.7	0.1 / 0.05
Selenium	Graphite Furnace AA	EPA 200.9	0.005 / 0.004
Silver	Graphite Furnace AA	EPA 200.9 / EPA 200.7	0.001 / 0.005
Thallium	Graphite Furnace AA	EPA 200.9	0.002
Zinc	ICP-AES	EPA 200.7	0.05
Radiochemicals			
Gross alpha beta	Gas flow proportional counter	EPA 900.0	varies
Co-Precipitation	Gas flow proportional counter	EPA 00.02	varies
Radium 226	Gas flow proportional counter	EPA 903.0	varies
Radium 228	Gas flow proportional counter	EPA 904.0	varies
Uranium	Kinetic phosporimeter	EPA Laser Phosphorimetry	varies

All units are mg/L
Source [18, 19, 34]

Table 2. Semi-Volatile Compound Analyte List for the Pinal AMA Study

Acenaphthene	1,4-Dichlorobenzene	2-Nitrophenol*
Acenaphthylene	2,4-Dichlorophenol*	4-Nitrophenol*
Aniline	Diethyl Phthalate	N-Nitrosodipropylamine
Anthracene	2,4-Dimethylphenol	Pentachlorophenol**
Azobenzene	Dimethyl Phthalate	Phenanthrene
Benzo(A)Anthracene	Di-N-Butyl Phthalate	Phenol
Benzo(B)Fluoranthene	4,6-Dinitro-2-Methylphenol*	Pyrene
Benzo(K)Fluoranthene	2,4-Dinitrophenol	1,2,4-Trichlorobenzene
Benzo(G,H,I)Perylene	2,4-Dinitrotoluene	2,4,5-Trichlorophenol
Benzo(A)Pyrene	2,6-Dinitrotoluene	2,4,6-Trichlorophenol
Bis(2-Chloroethoxy)Methane	Di-N-Octyl Phthalate	
Bis(2-Chloroethyl)Ether	Fluoranthene	
Bis(2-Chloroisopropyl)Ether	Fluorene	
Bis(2-Ethylhexyl)Phthalate	Hexachlorobenzene	
4-Bromophenyl Phenyl Ether	Hexachlorobutadiene	
Butyl Benzyl Phthalate	Hexachlorocyclopentadiene*	
Carbazole	Hexachloroethane	
4-Chloroaniline*	Indeno(1,2,3-CD)Pyrene	
4-Chloro-3-Methylphenol	Isophorone	
2-Chloronaphthalene*	2-Methylnapthalene	
2-Chlorophenol	2-Methylphenol	
4-Chlorophenyl Phenyl Ether	4-Methylphenol*	
Chrysene	Naphthalene	
Dibenz(A,H)Anthracene	2-Nitroaniline*	
Dibenzofuran	3-Nitroaniline*	
1,2-Dichlorobenzene	4-Nitroaniline*	
1,3-Dichlorobenzene	Nitrobenzene	

Minimum Reporting Levels for all compounds are 10 ug/L except for * = 50 ug/L and ** = 100 ug/L [34]

Table 3. Pesticide Analyte List for the Pinal AMA Study

Pesticides, Chlorinated	Pesticides, Organophosphorus	Surrogates
Aldrin	Azinphos-Methyl	2-Fluorophenol (62%)
Alpha-BHC	Chlorpyrifos	Phenol-D6 (51%)
Beta-BHC	Coumaphos	Nitrobenzene-D5 (75%)
Delta-BHC	Demeton-O	2-Fluorobiphenyl (52%)
Gamma-BHC (Lindane)	Demeton-S	2,4,6-Tribromophenol (82%)
4,4-DDD	Diazinon	P-Terphenyl-D14 (87%)
4,4-DDE	Dichlovos (DDVP)	
4,4-DDT	Disulfoton	
Dieldrin	Ethroprophos	
Endosulfan II	Fensulfothion	
Endosulfan Sulfate	Fenthion	
Endrin	Merphos	
Endrin Aldehyde	Methyl Parathion	
Endrin Ketone	Mevinphos	
Heptachlor	Naled	
Heptachlor Epoxide	Phorate	
Methoxychlor	Prothiofos	
	Ronnel	
	Stirofos	
	Sulprofos	
	Trichloronate	
	Dimethoate	
	EPN	
	Malathion	
	Monorotophos	
	Parathion	
	Sulfotep	
	Tetraethyl Pyrophosphate	

Minimum Reporting Levels for all compounds are 10 ug/L except for % Recovery for Surrogates [34]

DATA EVALUATION

ADEQ followed quality-assurance procedures to minimize the potential for bias and variability of the environmental data during sample collection and analysis.

Quality Assurance

Quality-assurance (QA) procedures were followed and quality-control (QC) samples were collected to quantify data bias and variability for the Pinal AMA study. The design of the QA/QC plan was based on recommendations included in the *Quality Assurance Project Plan* (*QAPP*) and *the Field Manual For Water Quality Sampling*.[2, 8] Types and numbers of QC samples collected for this study are as follows:

Inorganic: (6 duplicates, 9 splits, and 8 blanks).

Organic: (no QC samples).

Radiochemical: (1 split).

Radon: (2 duplicates).

Isotope: (9 duplicates)

Based on the QA/QC results, sampling procedures and laboratory equipment did not significantly affect the groundwater quality samples of this study.

Blanks - Equipment blanks for inorganic analyses were collected to ensure adequate decontamination of sampling equipment, and that the filter apparatus and/or de-ionized water were not impacting the groundwater quality sampling.[8]

Equipment blank samples for major ion and nutrient analyses were collected by filling unpreserved and sulfuric acid preserved bottles with de-ionized water. Equipment blank samples for trace element analyses were collected with de-ionized water that had been filtered into nitric acid preserved bottles.

Systematic contamination was judged to occur if more than 50 percent of the equipment blank samples contained measurable quantities of a particular groundwater quality constituent.[24] The equipment blanks contained specific conductivity-lab (SC-lab) and turbidity contamination at levels expected due to impurities in the source water used for the samples. The blank results, however, did not indicate systematic contamination.

Specific conductivity (SC) was detected in 7 equipment blanks, turbidity in 4 equipment blanks, total phosphorus in 3 samples, and nitrate in 1 sample.

For SC, equipment blanks had a mean (2.8 uS/cm) which was less than 1 percent of the SC mean concentration for the study. The SC detections may be explained in several ways: water passed through a de-ionizing exchange unit will normally have an SC value of at least 1 uS/cm, and carbon dioxide from the air can dissolve in de-ionized water with the resulting bicarbonate and hydrogen ions imparting the observed conductivity.[31] The SC detections may also have been an instrumental error since the meter was calibrated with 1,400 uS/cm and 12,800 uS/cm standard solution. This program was changed in early 2006 to reduce errors in the low range.[34]

Similarly for turbidity, equipment blanks had a mean level (0.025 ntu) less than 1 percent of the turbidity median level for the study. Testing indicates turbidity is present at 0.01 ntu in the de-ionized water supplied by the ADHS laboratory, and levels increase with time due to storage in ADEQ carboys.[34]

Duplicate Samples - Duplicate samples are identical sets of samples collected from the same source at the same time and submitted to the same laboratory. Data from duplicate samples provide a measure of variability from the combined effects of field and laboratory procedures.[8]

Duplicate samples were collected from sampling sites that were believed to have elevated constituent concentrations as judged by field SC values. Six duplicate samples were collected in this study.

Analytical results indicate that of the 21 constituents that had concentrations above the MRL, the maximum variation between duplicates was less than 6 percent (Table 4). The only exceptions were nitrate (47%), phosphorus (16%), and turbidity (95%). These three constituent duplicates had fairly minor concentration differences nitrate as nitrogen (1 mg/L), phosphorus (0.01 mg/L) and turbidity (0.36 ntu). The median variation between duplicates was less than 6 percent except with turbidity (9%).

Both radon (2 duplicates) and isotope (9 duplicates) samples showed with the maximum variation between duplicates less than 5 percent.

Table 4. Summary Results of Pinal AMA Duplicate Samples from the ADHS Laboratory

Parameter	Number	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Physical Parameters and General Mineral Characteristics							
Alk., Total	6	0 %	0 %	0 %	0	0	0
SC (uS/cm)	6	0 %	0 %	0 %	0	0	0
Hardness	6	0 %	0 %	0 %	0	0	0
pH (su)	6	0 %	1 %	0 %	0	0.1	0
TDS	6	0 %	5 %	0 %	0	30	0
Turb. (ntu)	6	0 %	95 %	9 %	0	0.36	0.08
Major Ions							
Bicarbonate	6	0 %	0 %	0 %	0	0	0
Calcium	6	0 %	0 %	0 %	0	0	0
Magnesium	6	0 %	1 %	0 %	0	1	0
Sodium	6	0 %	6 %	1 %	0	50	2
Potassium	6	0 %	4 %	2 %	0	0.1	0.1
Chloride	6	0 %	1 %	0 %	0	3	0
Sulfate	6	0 %	4 %	0 %	0	10	1
Nutrients							
Nitrate (as N)	6	0 %	47 %	5 %	0	1	0.6
Phosphorus	2	11 %	16 %	-	0.006	0.01	-
TKN	2	5 %	6 %	-	0.007	0.007	-
Trace Elements							
Arsenic	2	0 %	3 %	-	0	0.001	-
Barium	1	-	-	4 %	0	0	0.1
Boron	5	0 %	1 %	0 %	0	0.01	0
Copper	1	-	-	6 %	-	-	0.02
Fluoride	6	0 %	1 %	0 %	0	0.1	0

All concentration units are mg/L except as noted with certain physical parameters.
Ammonia and chromium were detected near the MRL in one duplicate sample and not detected in the other duplicate sample.

Split Samples - Split samples are identical sets of samples collected from the same source at the same time that are submitted to two different laboratories to check for laboratory differences.[8] Nine inorganic split samples were collected and analytical results were evaluated by examining the variability in constituent concentrations in terms of absolute levels and as the percent difference.

Analytical results indicate that of the 36 constituents examined, only 22 had concentrations above MRLs for both ADHS and Del Mar laboratories (Table 5). The maximum difference between split constituent only exceeded 20 percent for magnesium (40%), potassium (26%), fluoride (23 %) and total kjeldahl nitrogen (TKN) (89%).

Split samples were also evaluated using the non-parametric Sign test to determine if there were any significant ($p \leq 0.05$) differences between ADHS laboratory and Del Mar laboratory analytical results.[22] Results of the Sign test revealed a significant difference involving potassium with constituent concentrations reported by the ADHS laboratory less than those reported by Del Mar laboratory. This finding is in contrast to two, joint studies ADEQ conducted with the USGS in the late 1990s in which potassium concentrations determined by the ADHS laboratory were significantly higher than those determined by the USGS National Water-Quality Laboratory. [12]

Split results reported by Del Mar laboratory detected copper (in one sample), iron (in one sample) and TKN (in two samples) at concentrations above ADHS laboratory MRLs that were reported as non-detections by the latter laboratory. The opposite pattern occurred in two samples with the ADHS laboratory detecting total phosphorus at concentrations above Del Mar laboratory MRL that were reported as non-detections by the latter laboratory. The radiochemistry split samples had a variation of less than 5 percent.

Based on the results of blanks, duplicates and the split sample collected for this study, no significant QA/QC problems were apparent with the groundwater quality collected for this study.

Data Validation

The analytical work for this study was subjected to the following five QA/QC correlations. [23, 26]

Cation/Anion Balances - In theory, water samples exhibit electrical neutrality. Therefore, the sum of milliequivalents per liter (meq/L) of cations must equal the sum of meq/L of anions. This neutrality rarely occurs due to unavoidable variation inherent in all water quality analyses. Still, if the cation/anion balance is found to be within acceptable limits, it can be assumed there are no gross errors in concentrations reported for major ions.[26] Overall, cation/anion meq/L balances of Pinal AMA samples were significantly correlated (regression analysis, $p \leq 0.01$) and were within acceptable limits (90 - 110 percent).

SC/TDS - The SC and total dissolved solids (TDS) concentrations measured by contract laboratories were significantly correlated as were field-SC and TDS concentrations (regression analysis, $r = 0.99$, $p \leq 0.01$). Typically, the TDS concentration in mg/L should be from 0.55 to 0.75 times the SC in µS/cm for groundwater up to several thousand TDS mg/L.[26] Groundwater in which the ions are mostly bicarbonate and chloride will have a multiplication factor near the lower end of this range and groundwater high in sulfate may reach or even exceed the higher factor. The relationship of TDS to SC becomes undefined for groundwater with very high or low concentrations of dissolved solids.[26]

Hardness - Concentrations of laboratory-measured and calculated values of hardness were significantly correlated (regression analysis, $r = 0.99$, $p \leq 0.01$). Hardness concentrations were calculated using the following formula: [(Calcium x 2.497) + (Magnesium x 4.118)]. [26]

SC - The SC measured in the field using a YSI meter at the time of sampling was significantly correlated with the SC measured by contract laboratories (regression analysis, $r = 0.99$, $p \leq 0.01$).

pH - The pH value is closely related to the environment of the water and is likely to be altered by sampling and storage.[26] Even so, the pH values measured in the field using a YSI meter at the time of sampling were significantly correlated with laboratory pH values (regression analysis, $r = 0.75$, $p \leq 0.01$).

Temperature / GW Depth /Well Depth – Groundwater temperature measured in the field was compared to groundwater depth and well depth. Groundwater temperature should increase with depth, about 3 degrees Celsius with every 100 meters or 328 feet.[9] Temperature was significantly correlated (regression analysis, $p \leq 0.01$) with both groundwater depth ($r = 0.53$) and well depth ($r = 0.42$).

The analytical work conducted for this study was considered valid based on the quality control samples and the QA/QC correlations.

Table 5. Summary Results of Pinal AMA Split Samples From ADHS/Del Mar Labs

Parameter	Number	Difference in Percent		Difference in Levels		Significance
		Minimum	Maximum	Minimum	Maximum	
Physical Parameters and General Mineral Characteristics						
Alkalinity, total	8	0 %	4 %	0	10	ns
SC (uS/cm)	8	0 %	2 %	0	100	ns
Hardness	8	0 %	5 %	0	100	ns
pH (su)	8	1 %	5 %	0.17	0.68	ns
TDS	8	0 %	6 %	0	200	ns
Turbidity (ntu)	1	2 %	2 %	0.1	0.1	ns
Major Ions						
Calcium	9	0 %	5 %	0	20	ns
Magnesium	9	2 %	40 %	0.2	3	ns
Sodium	9	0 %	19 %	0	90	ns
Potassium	9	3 %	26 %	0.1	1.6	**
Chloride	8	0 %	8 %	0	200	ns
Sulfate	8	1 %	19 %	1	100	ns
Nutrients						
Nitrate as N	8	0 %	14 %	0	8.5	ns
Phosphorus, T.	1	14 %	14 %	0.022	0.022	ns
TKN	3	65 %	89 %	0.44	1.04	ns
Trace Elements						
Arsenic	2	7 %	16 %	0.0028	0.003	ns
Boron	3	3 %	17 %	0	0.4	ns
Cadmium	1	10 %	10 %	0.0007	0.0007	ns
Copper	1	0 %	0 %	0	0	ns
Fluoride	8	0 %	23 %	0	0.3	ns
Lead	1	20 %	20 %	0.0021	0.0021	ns
Zinc	4	0 %	7 %	0.016	0.02	ns

All units are mg/L except as noted ns = No significant ($p \leq 0.05$) difference between labs ** = significant at $p \leq 0.01$
Copper, iron and TKN (twice) was detected in the Del Mar sample near the MRL and not detected in the ADHS sample; the opposite pattern occurred with total phosphorus (in two split sample). Total phosphorus was detected in the ADHS samples near the MRL and not detected in the ADHS samples.

Statistical Considerations

Various methods were used to complete the statistical analyses for the groundwater quality data of this study. All statistical tests were conducted on a personal computer using SYSTAT software.[45]

Data Normality: Data associated with 31 constituents were tested for non-transformed normality using the Kolmogorov-Smirnov one-sample test with the Lilliefors option.[10] Results of this test revealed that 5 of the 31 constituents (or 16 percent) examined were normally distributed. These normally distributed parameters constituents included well depth, temperature, pH-field, oxygen, and deuterium.

Results of the log-transformed test revealed that 16 of the 29 constituents (or 55 percent, oxygen and deuterium are negative numbers and could not be log-transformed) examined were normally distributed. These normally distributed constituents included temperature, pH-field, TDS, hardness, calculated hardness, calcium, magnesium, potassium, total alkalinity, bicarbonate, chloride, sulfate, fluoride, radon, gross alpha, and gross beta.

Spatial Relationships: The non-parametric Kruskal-Wallis test using untransformed data was applied to investigate the hypothesis that constituent concentrations from groundwater sites having different water sources were the same. The Kruskal-Wallis test uses the differences, but also incorporates information about the magnitude of each difference.[45] The null hypothesis of identical mean values for all data sets within each test was rejected if the probability of obtaining identical means by chance was less than or equal to 0.05. Comparisons conducted using the Kruskal Wallis test include sub-basins, land uses, irrigation districts, and water zones.

If the null hypothesis was rejected for any of the tests conducted, the Tukey method of multiple comparisons on the ranks of data was applied. The Tukey test identified significant differences between constituent concentrations when compared to each possibility with each of the tests.[24]

Both the Kruskal-Wallis and Tukey tests are not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[24] The Kruskal-Wallis tests were applied to arsenic and TKN even though the result was not considered statistically valid in order to highlight possible significant differences. Highlights of these statistical tests are summarized in the groundwater quality section. The Kruskal-Wallis test was not calculated for trace parameters or nutrients rarely detected, such as ammonia, antimony, barium, beryllium, cadmium, carbonate, chromium, copper, iron, lead, manganese, mercury, nickel, nitrite, phenolphthalein alkalinity, radium, selenium, silver, thallium, total phosphorus, uranium and zinc.

Correlation Between Constituent Concentrations: In order to assess the strength of association between constituents, their concentrations were compared to each other using the Pearson Correlation Coefficient test.

The Pearson correlation coefficient varies between -1 and +1, with a value of +1 indicating that a variable can be predicted perfectly by a positive linear function of the other, and vice versa. A value of -1 indicates a perfect inverse or negative relationship. The results of the Pearson Correlation Coefficient test were then subjected to a probability test to determine which of the individual pair wise correlations were significant.[45] The Pearson test is not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[24] Consequently, Pearson Correlation Coefficients were not calculated for the same constituents as in spatial relationships.

GROUNDWATER SAMPLING RESULTS

Water Quality Standards/Guidelines

The ADEQ ambient groundwater monitoring program characterizes regional groundwater quality. An important determination ADEQ makes concerning the collected samples is how the analytical results compare to various drinking water quality standards. ADEQ used three sets of drinking water standards to evaluate the suitability of groundwater in the basin for drinking water use. These standards reflect the best current scientific and technical judgment available on the suitability of water for drinking water use:

- Federal Safe Drinking Water (SDW) Primary Maximum Contaminant Levels (MCLs). These enforceable health-based standards establish the maximum concentration of a constituent allowed in water supplied by public systems.[40, 44]

- State of Arizona Aquifer Water Quality Standards. These apply to aquifers that are classified for drinking water protected use.[3] All aquifers within Arizona are currently classified and protected for drinking water use unless otherwise reclassified. To date no aquifers have been reclassified. These enforceable State standards are almost identical to the federal Primary MCLs.

- Federal SDW Secondary MCLs. These non-enforceable aesthetics-based guidelines define the maximum concentration of a constituent that can be present without imparting unpleasant taste, color, odor, or other aesthetic effects on the water.[40, 44]

Health-based drinking water quality standards (such as Primary MCLs) are based on a lifetime consumption of two liters of water per day and, as such, are chronic not acute standards.[40] Exceedances of specific constituents for each groundwater site is found in Appendix B.

Pinal AMA Sites - Of the 86 sites sampled for the Pinal AMA study, 11 (13 percent) met all SDW Primary and Secondary MCLs.

Health-based Primary MCL water quality standards and State aquifer water quality standards were exceeded at 60 of 86 sites (70 percent; Map 2; Table 6). Constituents exceeding Primary MCLs include arsenic (33 sites), fluoride (7 sites), gross alpha (5 sites), nitrate (23 sites), and uranium (2 sites). Potential health effects of these chronic Primary MCL exceedances are provided in Table 6.[40, 44]

Aesthetics-based Secondary MCL water quality guidelines were exceeded at 59 of 86 sites (69 percent; Map 2; Table 7). Constituents above Secondary MCLs include chloride (25 sites), fluoride (19 sites), iron (2 sites), pH (8 sites), sulfate (26 sites), and TDS (50 sites). Potential impacts of these Secondary MCL exceedances are provided in Table 7.[40, 44]

Samples for semi-volatile compounds, chlorinated pesticides and organophosphorus pesticide analysis, the specific analytes of which are provided in Table 2 and Table 3, were collected at 14 sites all within active agricultural areas. There were no detections of any semi-volatile compounds or pesticides in any of the samples.

Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206.[14] Different opinions exist on the risk assessment of radon in drinking water, with proposed drinking water standards varying from 300 to 4,000 picocuries per liter (piC/L).[14] Of the 41 sites sampled for radon, 22 sites exceeded the proposed 300 pCi/L standard; 2 sites exceeded the proposed 4,000 pCi/L standard.

Map 2 - Water Quality Status
Pinal AMA

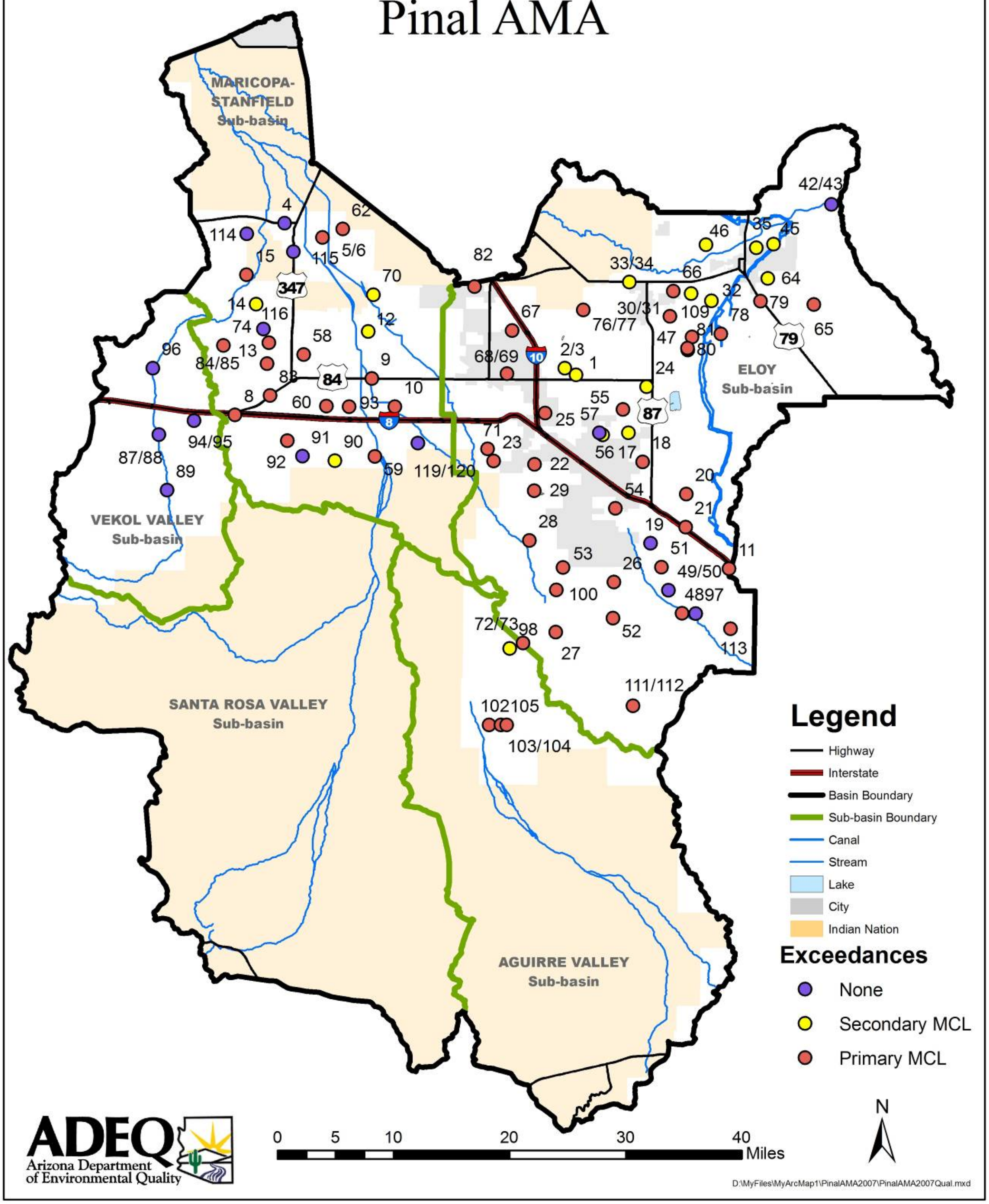


Table 6. Pinal AMA Sites Exceeding Health-Based (Primary MCL) Water Quality Standards

Constituent	Primary MCL	Number of Sites Exceeding Primary MCL	Concentration Range of Exceedances	Potential Health Effects of MCL Exceedances *
		Nutrients		
Nitrite (NO_2-N)	1.0	0	-	
Nitrate (NO_3-N)	10.0	**23**	10 – 31	Methemoglobinemia
		Trace Elements		
Antimony (Sb)	0.006	0	-	
Arsenic (As)	0.01	**33**	0.010 – 0.046	Dermal and nervous system toxicity
Barium (Ba)	2.0	0	-	
Beryllium (Be)	0.004	0	-	
Cadmium (Cd)	0.005	0	-	
Chromium (Cr)	0.1	0	-	
Copper (Cu)	1.3	0	-	
Fluoride (F)	4.0	**7**	4.1 – 8.15	Skeletal damage
Lead (Pb)	0.015	0	-	
Mercury (Hg)	0.002	0	-	
Nickel (Ni)	0.1	0	-	
Selenium (Se)	0.05	0	-	
Thallium (Tl)	0.002	0	-	
		Radiochemistry Constituents		
Gross Alpha	15	**5**	23 – 110	Cancer
Ra-226+Ra-228	5	0	-	
Uranium	30	**2**	34 – 74	Cancer and kidney toxicity

All units are mg/L except gross alpha and radium-226+228 (pCi/L), and uranium (ug/L).

* Health-based drinking water quality standards are based on a lifetime consumption of two liters of water per day over a 70-year life span.[40, 44]

Table 7. Pinal AMA Sites Exceeding Aesthetics-Based (Secondary MCL) Water Quality Standards

Constituents	Secondary MCL	Number of Sites Exceeding Secondary MCLs	Concentration Range of Exceedances	Aesthetic Effects of MCL Exceedances
		Physical Parameters		
pH - field	6.5 to 8.5	**8**	8.54 – 9.46	Corrosive water
		General Mineral Characteristics		
TDS	500	**50**	530 – 4,500	Unpleasant taste
		Major Ions		
Chloride (Cl)	250	**25**	258 – 1300	Salty taste
Sulfate (SO_4)	250	**26**	250 – 1550	Rotten-egg odor, unpleasant taste and laxative effect
		Trace Elements		
Fluoride (F)	2.0	**19**	2.3 – 8.15	Mottling of teeth enamel
Iron (Fe)	0.3	**2**	0.32 – 0.37	Rusty color, reddish stains and metallic tastes
Manganese (Mn)	0.05	0	-	Black stains and bitter taste
Silver (Ag)	0.1	0	-	-
Zinc (Zn)	5.0	0	-	-

All units mg/L except pH is in standard units (su). Source: [26, 40, 44]

Suitability for Irrigation

The groundwater at each sample site was assessed as to its suitability for irrigation use based on salinity and sodium hazards. Excessive levels of sodium are known to cause physical deterioration of the soil and vegetation.[42] Irrigation water may be classified using specific conductivity (SC) and the Sodium Adsorption Ratio (SAR) in conjunction with one another.[42]

Groundwater sites in the Pinal AMA display a wide range of irrigation water classifications with salinity hazards generally greater than sodium hazards. The 86 sample sites are divided into the following salinity hazards: low or C1 (0), medium or C2 (31), high or C3 (43), and very high or C4 (12). The 86 sample sites are divided into the following sodium or alkali hazards: low or S1 (59), medium or S2 (16), high or S3 (8), and very high or S4 (3).

Analytical Results

Analytical inorganic and radiochemistry results of the 86 Pinal AMA sample sites are summarized (Table 8) using the following indices: minimum reporting levels (MRLs), number of sample sites over the MRL, upper and lower 95 percent confidence intervals ($CI_{95\%}$), median, and mean. Confidence intervals are a statistical tool which indicates that 95 percent of a constituent's population lies within the stated confidence interval.[24] Specific constituent information for each groundwater site is found in Appendix B.

Table 8. Summary Statistics for Pinal AMA Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)	Number of Samples Over MRL	Lower 95% Confidence Interval	Median	Mean	Upper 95% Confidence Interval
			Physical Parameters			
Temperature (C)	0.1	85	27.5	28.4	28.2	28.9
pH-field (su)	0.01	85	7.68	7.76	7.79	7.91
pH-lab (su)	0.01	86	8.09	8.15	8.18	8.21
Turbidity (ntu)	0.01	83	0.22	0.08	0.55	0.88
			General Mineral Characteristics			
T. Alkalinity	2.0	86	144	145	156	168
Phenol. Alk.	2.0	12		> 50% of data below MRL		
SC-field (uS/cm)	N/A	86	1093	983	1301	1509
SC-lab (uS/cm)	N/A	86	1120	995	1336	1552
Hardness-lab	10.0	84	217	170	288	359
TDS	10.0	86	707	605	861	1015
			Major Ions			
Calcium	5.0	86	66	51	88	111
Magnesium	1.0	78	12	11	16	20
Sodium	5.0	86	138	100	164	191
Potassium	0.5	86	2.9	2.9	3.3	3.7
Bicarbonate	2.0	86	173	175	188	203
Carbonate	2.0	12		> 50% of data below MRL		
Chloride	1.0	86	138	115	180	222
Sulfate	10.0	86	169	130	225	281
			Nutrients			
Nitrate (as N)	0.02	85	6.5	6.0	8.1	9.7
Nitrite (as N)	0.02	0		> 50% of data below MRL		
Ammonia	0.02	0		> 50% of data below MRL		
TKN	0.05	29		> 50% of data below MRL		
T. Phosphorus	0.02	34		> 50% of data below MRL		

Table 8. Summary Statistics for Pinal AMA Groundwater Quality Data—Continued

Constituent	Minimum Reporting Limit (MRL)	Number of Samples Over MRL	Lower 95% Confidence Interval	Median	Mean	Upper 95% Confidence Interval
Trace Elements						
Antimony	0.005	0	> 50% of data below MRL			
Arsenic	0.01	37	> 50% of data below MRL			
Barium	0.1	12	> 50% of data below MRL			
Beryllium	0.0005	0	> 50% of data below MRL			
Boron	0.1	77	0.32	0.22	0.45	0.58
Cadmium	0.001	1	> 50% of data below MRL			
Chromium	0.01	16	> 50% of data below MRL			
Copper	0.01	4	> 50% of data below MRL			
Fluoride	0.20	86	1.12	0.82	1.45	1.79
Iron	0.1	2	> 50% of data below MRL			
Lead	0.005	1	> 50% of data below MRL			
Manganese	0.05	0	> 50% of data below MRL			
Mercury	0.0005	0	> 50% of data below MRL			
Nickel	0.1	0	> 50% of data below MRL			
Selenium	0.005	3	>50% of data below MRL			
Silver	0.001	0	> 50% of data below MRL			
Thallium	0.005	0	> 50% of data below MRL			
Zinc	0.05	12	> 50% of data below MRL			
Radiochemical Constituents						
Radon*	Varies	40	402	462	799	1197
Gross Alpha*	Varies	25	5.3	6.0	15.2	25.2
Gross Beta*	Varies	25	4.6	5.5	9.1	13.6
Ra-226*	Varies	3	> 50% of data below MRL			
Uranium**	Varies	6	> 50% of data below MRL			

All units mg/L except where noted or * = pCi/L, ** = ug/L, and *** = 0/00

GROUNDWATER COMPOSITION

General Summary

Groundwater from the 86 sample sites (Map 3) varied widely but was most commonly a sodium-mixed (40 sites) chemistry (Figure 21). Other water chemistry types found in the basin include mixed-mixed (18 sites) calcium-mixed (11 sites), sodium-bicarbonate (9 sites), sodium-chloride (4 sites), mixed-bicarbonate and mixed-chloride (2 sites each) and sodium-sulfate (1 site).

The dominant cations at the 86 sampled sites consist of sodium (52 sites), calcium (11 sites) and magnesium (0 sites). There was no dominant cation at 23 sites (Figure 21). The dominant anions at the 86 sites consist of bicarbonate (11 sites), chloride (6 sites), and sulfate (1 site). There was no dominant anion at 68 sites (Figure 21).

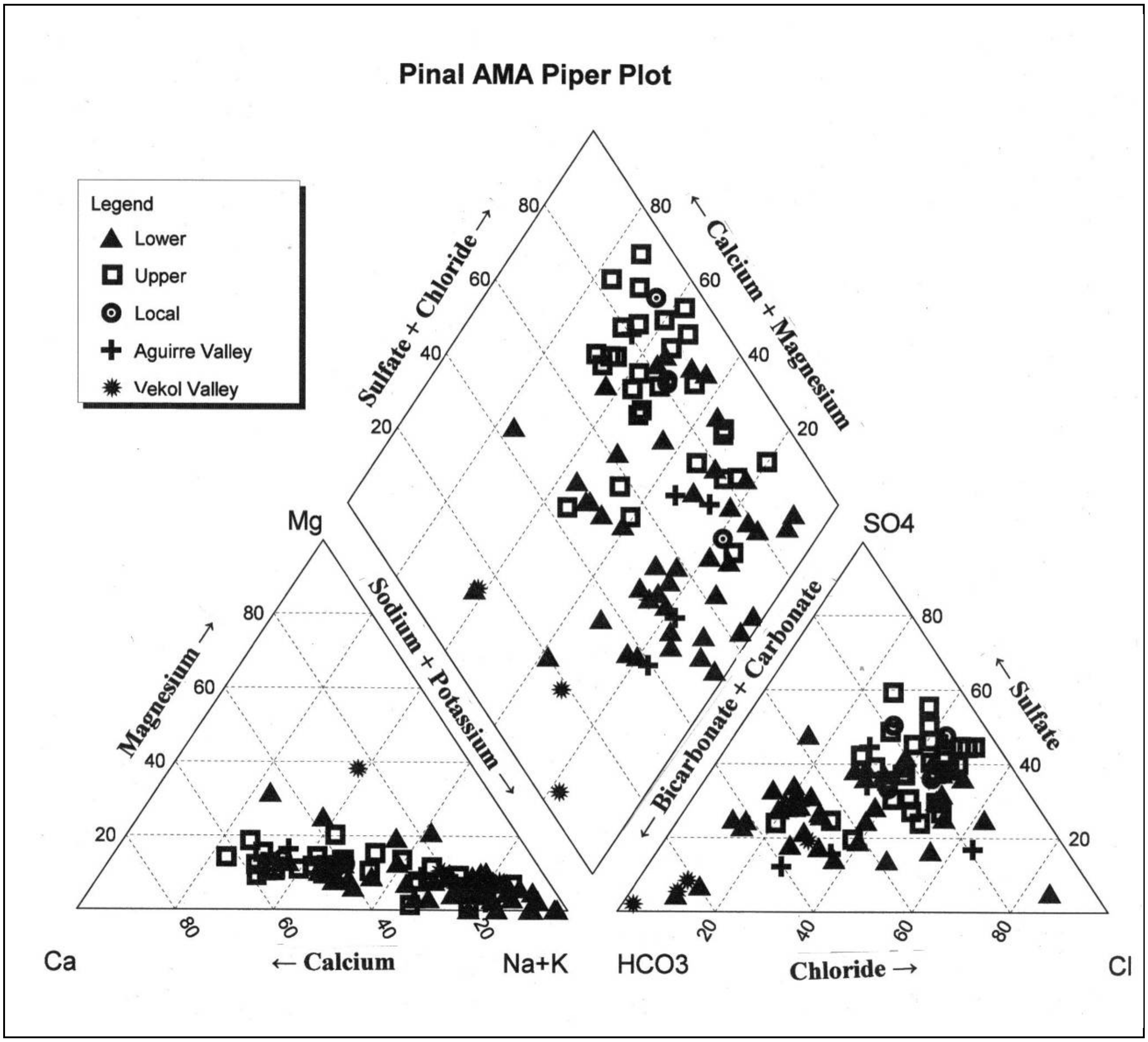
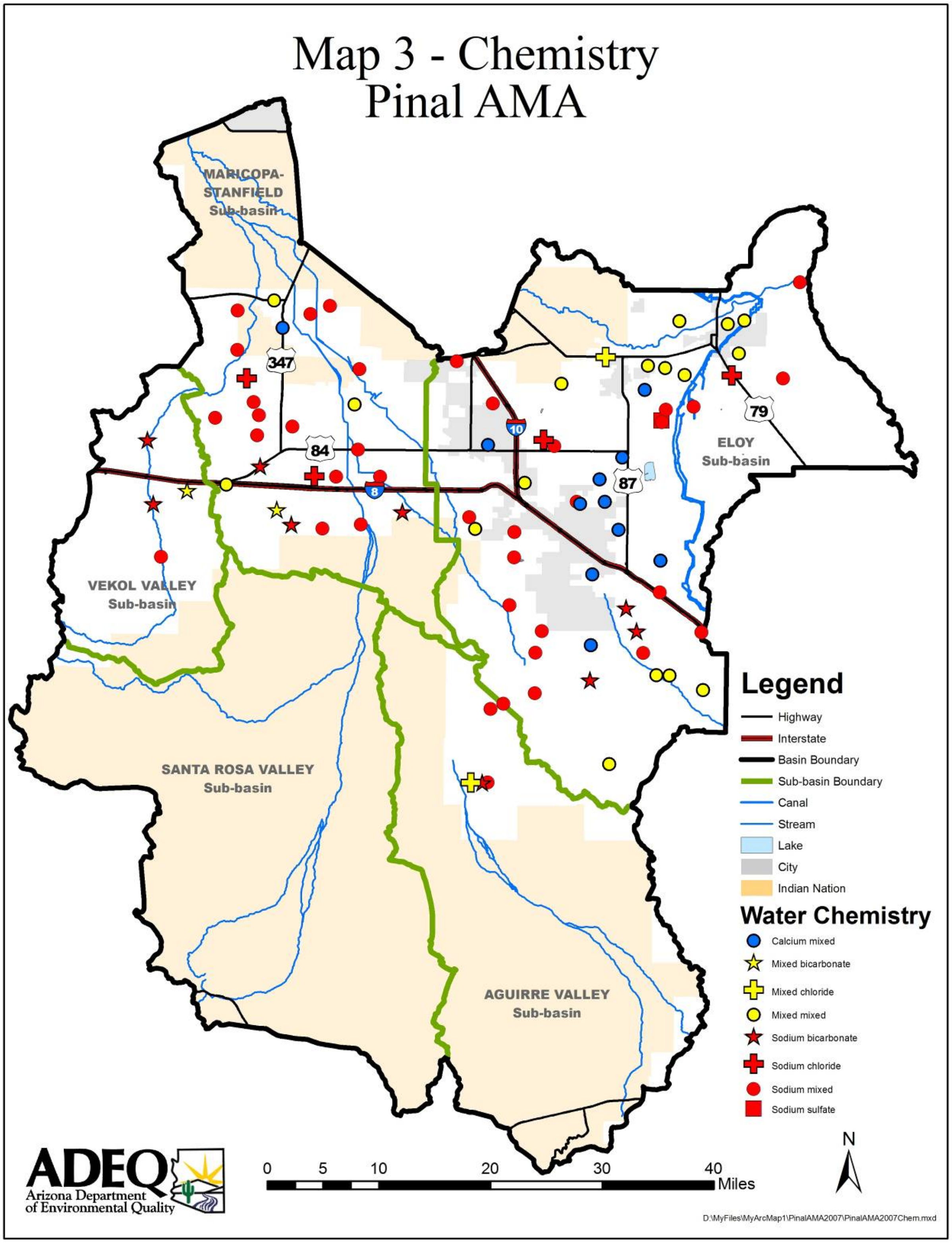


Figure 21. The piper diagram plotting the water chemistry of all 86 sample sites in the Pinal AMA illustrates two broad patterns found among groundwater zones in the Eloy and Maricopa-Stanfield sub-basins: upper water zone samples tend to have a calcium-sulfate/chloride water chemistry while those in the lower water zone generally have a sodium-bicarbonate water chemistry.


Map 3 - Chemistry
Pinal AMA
MARICOPA-
STANFIELD
Sub-basin
VEKOL VALLEY
Sub-basin
SANTA ROSA VALLEY
Sub-basin
AGUIRRE VALLEY
Sub-basin
ELOY
Sub-basin
347
84
8
10
87
79
Legend
Highway
Interstate
Basin Boundary
Sub-basin Boundary
Canal
Stream
Lake
City
Indian Nation
Water Chemistry
Calcium mixed
Mixed bicarbonate
Mixed chloride
Mixed mixed
Sodium bicarbonate
Sodium chloride
Sodium mixed
Sodium sulfate
0 5 10 20 30 40
Miles
N
ADEQ
Arizona Department
of Environmental Quality
D:\MyFiles\MyArcMap1\PinalAMA2007\PinalAMA2007Chem.mxd

Groundwater in the Pinal AMA basin was *slightly alkaline*, *fresh*, and *hard*-to-*very hard* as indicated by pH values and TDS and hardness concentrations. Levels of pH were *slightly alkaline* (above 7 su) at all 82 sites and slightly acidic (below 7 su) at 3 sites.[21] TDS concentrations were considered *fresh* (below 1,000 mg/L) at 59 sites, *slightly saline* (1,000 to 3,000 mg/L) at 26 sites, *moderately saline* (3,000 to 10,000 mg/L) at 1 site (Map 4 and Figure 22).[23] Hardness concentrations were divided into *soft* (below 75 mg/L) at 25 sites, *moderately hard* (75 – 150 mg/L) at 13 sites, *hard* (150 – 300 mg/L) at 18 sites, and *very hard* (above 300 mg/L) at 30 sites (Map 5 and Figure 23).[16]

Nitrate, TKN, and total phosphorus were nutrients detected at more than 20 percent of the sites. Nitrate (as nitrogen) concentrations were divided into natural background (4 sites < 0.2 mg/L), may or may not indicate human influence (19 sites between 0.2 - 3.0 mg/L), may result from human activities (40 sites between 3.0 - 10 mg/L), and probably result from human activities (23 sites ≥ 10 mg/L).[30]

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

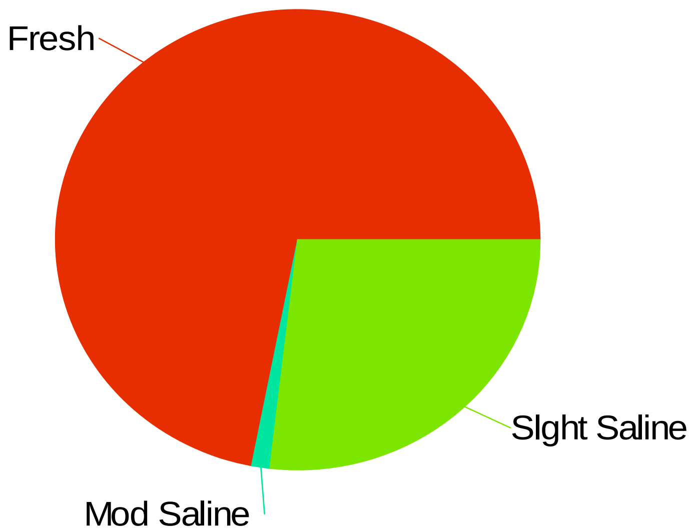


Figure 22. The graph to the left illustrates that although 69 percent of groundwater samples in the Pinal AMA were considered fresh water (TDS > 1000 mg/L), 31 percent were considered either slightly saline water (TDS at 1,000 to 3,000 mg/L) or moderately saline water (TDS > 3,000 mg/L) according to a U.S. Geological Survey classification system.[23]

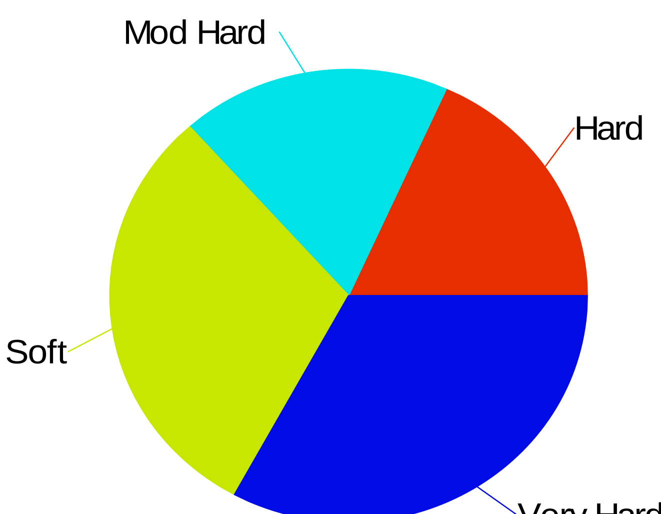
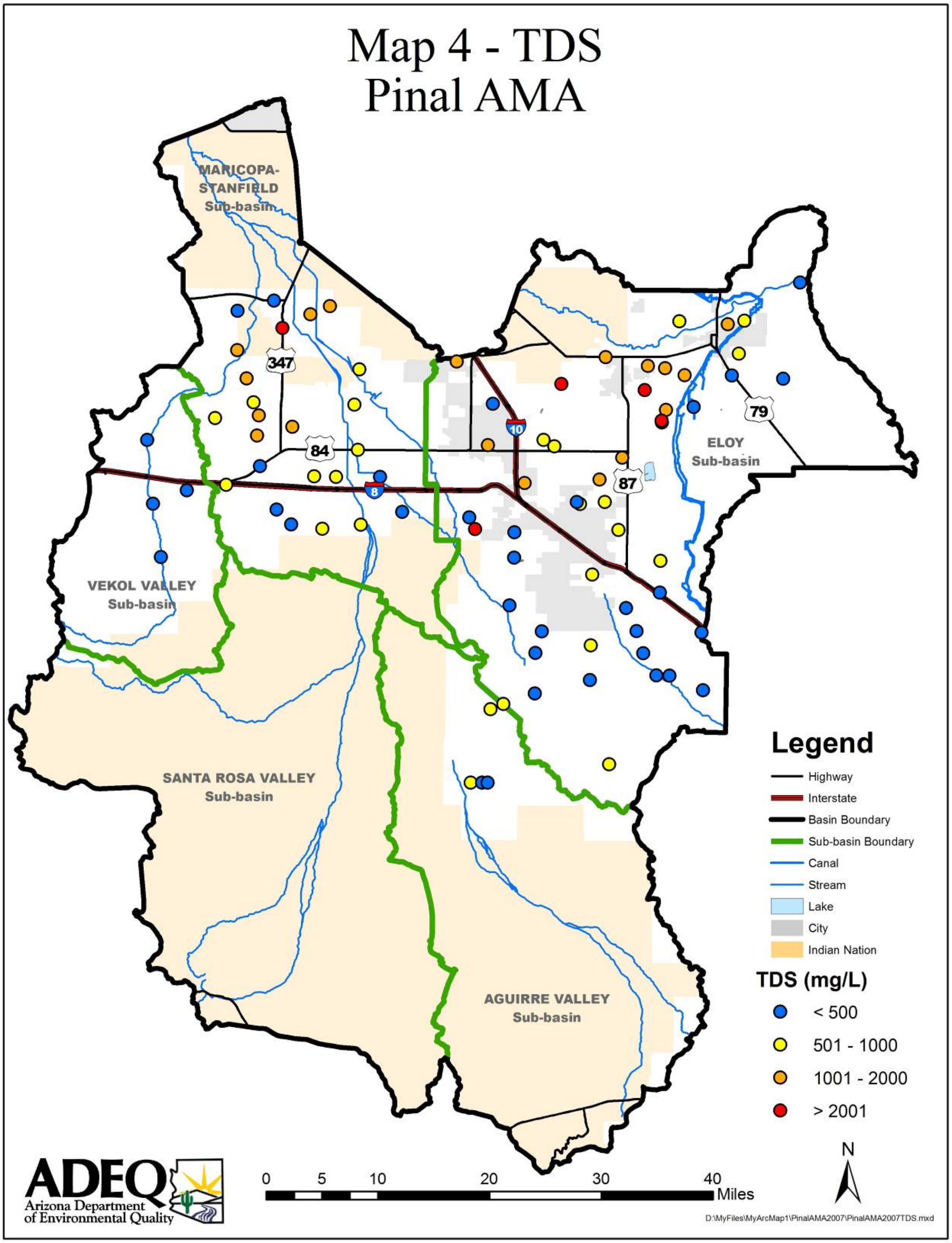


Figure 23. The graph to the left illustrates that hardness concentrations of groundwater samples in the Pinal AMA can be categorized in the following manner: soft (29 percent), moderately hard (15 percent), hard (21 percent), and very hard (35 percent).[16] Samples characterized as very hard (over 300 mg/L) can rise very high—eleven samples had hardness concentrations of 600 mg/L or over with the highest at 1,950 mg/L.



Map 4 - TDS
Pinal AMA
MARICOPA-STANFIELD Sub-basin
ELOY Sub-basin
VEKOL VALLEY Sub-basin
SANTA ROSA VALLEY Sub-basin
AGUIRRE VALLEY Sub-basin
347
84
8
10
87
79
Legend
Highway
Interstate
Basin Boundary
Sub-basin Boundary
Canal
Stream
Lake
City
Indian Nation
TDS (mg/L)
< 500
501 - 1000
1001 - 2000
> 2001
N
0 5 10 20 30 40 Miles
ADEQ
Arizona Department of Environmental Quality
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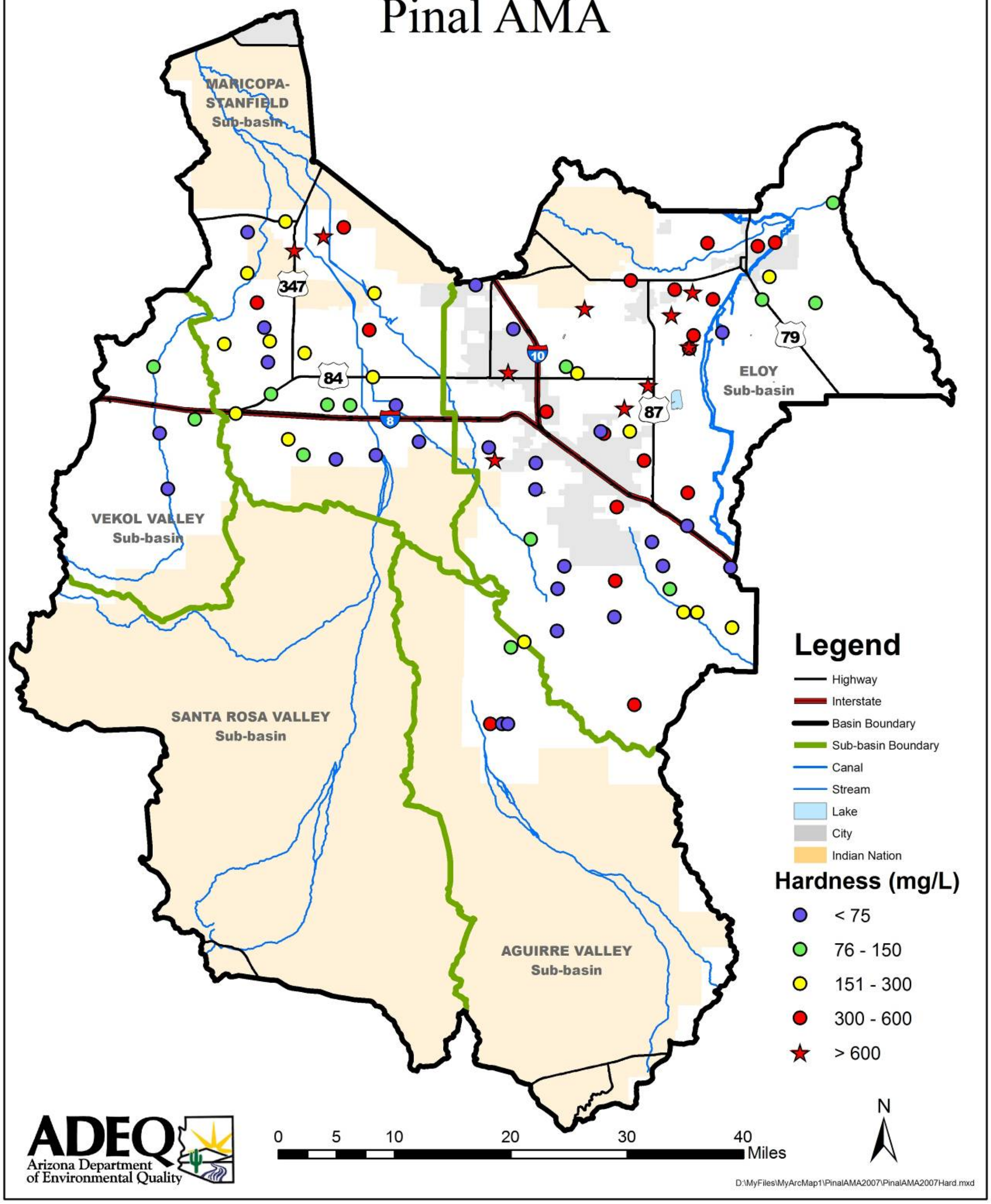
Map 5 - Hardness
Pinal AMA



Constituent Co-Variation

The co-variation of constituent concentrations was determined to scrutinize the strength of the association. The results of each combination of constituents were examined for statistically-significant positive or negative correlations. A ***positive correlation*** occurs when, as the level of a constituent increases or decreases, the concentration of another constituent also correspondingly increases or decreases. A ***negative correlation*** occurs when, as the concentration of a constituent increases, the concentration of another constituent decreases, and vice-versa. A positive correlation indicates a direct relationship between constituent concentrations; a negative correlation indicates an inverse relationship.[45]

Many significant correlations occurred among the 86 sample sites (Table 9, Pearson Correlation Coefficient test, $p \leq 0.05$). Three groups of correlations were identified:

- Negative correlations occurred between temperature and pH-field and the following constituents: SC, TDS, hardness (Figure 24), calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, nitrate and TKN.

- Positive correlations occurred among SC, TDS, hardness, calcium, magnesium, sodium, potassium, bicarbonate, chloride, sulfate, nitrate, TKN and boron.

- Negative correlations occurred between arsenic and fluoride and the following constituents: temperature, hardness (Figure 25), calcium, magnesium, and potassium.

TDS concentrations are best predicted among major ions by sodium concentrations (standard coefficient = 0.47), among cations by calcium concentrations (standard coefficient = 0.52) and among anions, chloride (standard coefficient = 0.85) (multiple regression analysis, $p \leq 0.01$).

Many significant correlations occurred among the 42 sample sites in the lower water zone (Table 10, Pearson Correlation Coefficient test, $p \leq 0.05$). Two groups of correlations were identified:

- Negative correlations occurred between pH-field and the following constituents: hardness, calcium, magnesium, and bicarbonate. The latter four constituents were all positively correlated with one another.

- Positive correlations occurred among TDS, SC, sodium, potassium, chloride, sulfate, nitrate, and boron.

TDS concentrations are best predicted among major ions by sodium concentrations (standard coefficient = 0.48), among cations by sodium concentrations (standard coefficient = 0.80) and among anions, chloride (standard coefficient = 0.83) (multiple regression analysis, $p \leq 0.01$).

Many significant correlations occurred among the 29 sample sites in the upper water zone (Table 11, Pearson Correlation Coefficient test, $p \leq 0.05$). One group of correlations was identified:

- Positive correlations occurred among sodium, nitrate, boron, and fluoride.

TDS concentrations are best predicted among major ions by sulfate concentrations (standard coefficient = 0.51), among cations by calcium concentrations (standard coefficient = 0.50) and among anions, sulfate (standard coefficient = 0.62) (multiple regression analysis, $p \leq 0.01$).

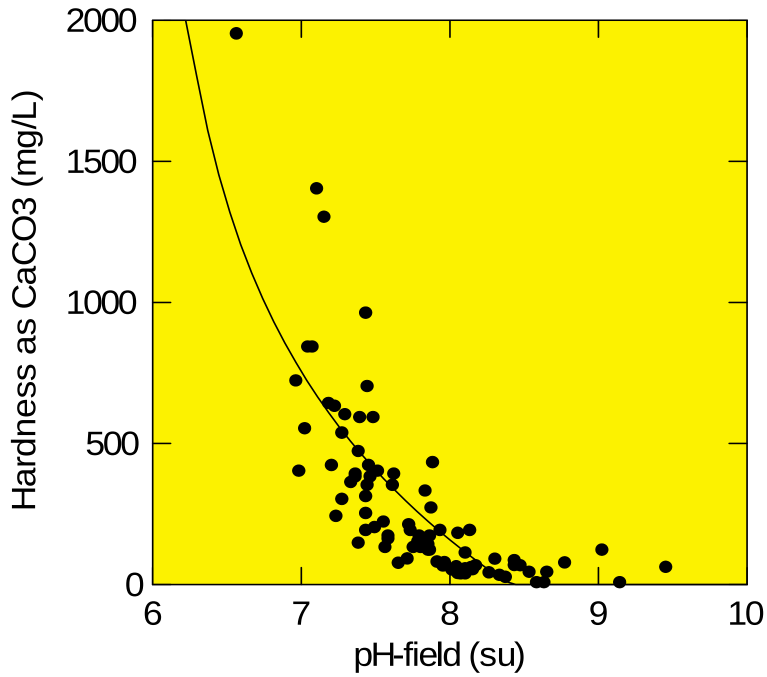


Figure 24. This graph illustrates a negative correlation between two constituents: as pH-field values increase, hardness concentrations tend to decrease in the 86 samples collected in the Pinal AMA. This relationship was found to be statistically significant ($p \leq 0.01$). The pH – hardness relationship has been found in other Arizona groundwater basins and is likely related to precipitation of calcite in response to increases in pH.[36, 37, 38]

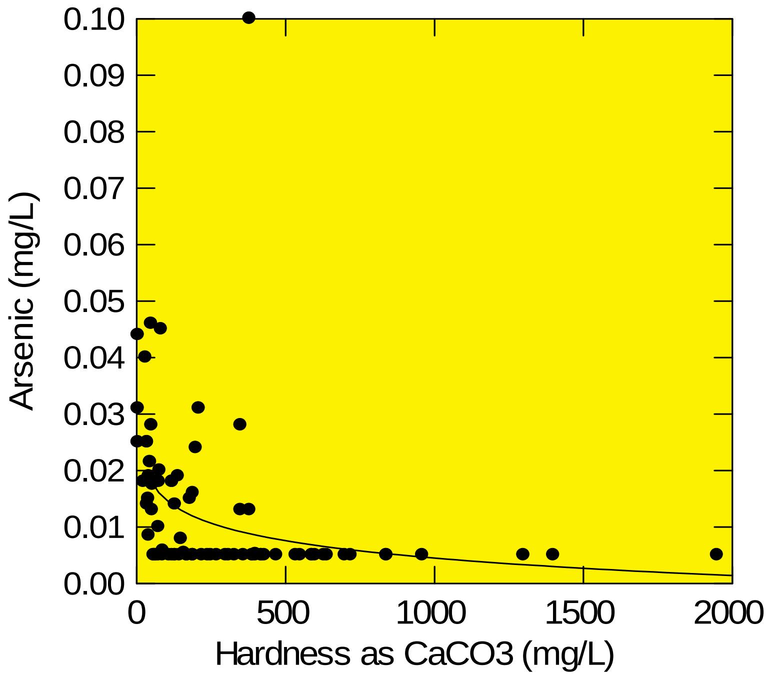


Figure 25. The graph to the left illustrates a negative correlation between two constituents: as hardness concentrations increase, arsenic concentrations tend to decrease. This relationship was found to be statistically significant ($p \leq 0.01$). Arsenic is not detected in samples in which hardness concentrations are above 400 mg/L.

Table 9. Correlation Among Pinal AMA Groundwater Quality Constituent Concentrations Using Pearson Correlation Probabilities

Constituent	Temp	pH-f	Turb	SC-f	TDS	Hard	Ca	Mg	Na	K	Bic	Cl	SO_4	NO_3	TKN	As	B	F
Physical Parameters																		
Temperature		**		++	++	++	++	++	++	++	++	++	++	++	++	+		+
pH-field				++	++	++	++	++	++	++	++	++	++	++	++	**		**
Turbidity																		
General Mineral Characteristics																		
SC-field					**	**	**	**	**	**	**	**	**	**	**		**	
TDS						**	**	**	**	**	**	**	**	**	**		**	
Hardness							**	**	**	**	**	**	**	**	**	++	**	+
Major Ions																		
Calcium								**	**	**	**	**	**	**	**	++	**	+
Magnesium									**	**	**	**	**	**	**	+	**	+
Sodium										**	**	**	**	**	*		**	**
Potassium												**	**	**	**	++		++
Bicarbonate													**	**	*		**	
Chloride													**	**	**		**	
Sulfate														**	**		**	
Nutrients																		
Nitrate															*		**	
TKN																		
Trace Elements																		
Arsenic																		
Boron																		**
Fluoride																		

Blank cell = not a significant relationship between constituent concentrations
* = Significant positive relationship at $p \leq 0.05$
** = Significant positive relationship at $p \leq 0.01$
+ = Significant negative relationship at $p \leq 0.05$
++ = Significant negative relationship at $p \leq 0.01$

Table 10. Correlation Among Lower Main Water Zone Groundwater Quality Constituent Concentrations Using Pearson Correlation Probabilities

Constituent	Temp	pH-f	Turb	SC-f	TDS	Hard	Ca	Mg	Na	K	Bic	Cl	SO_4	NO_3	TKN	As	B	F
Physical Parameters																		
Temperature		*																
pH-field						++	++	++			++							
Turbidity																		
General Mineral Characteristics																		
SC-field					**				**	**		**	**	**		+	**	
TDS									**	**		**	**	**		+	**	
Hardness							**	**			**							
Major Ions																		
Calcium								**			**							
Magnesium											**							
Sodium										*		**	**	**			**	
Potassium												**	*	**		+	*	
Bicarbonate																		
Chloride													**	*		+	**	
Sulfate														**			**	
Nutrients																		
Nitrate																		
TKN																		
Trace Elements																		
Arsenic																		
Boron																		*
Fluoride																		

Blank cell = not a significant relationship between constituent concentrations
* = Significant positive relationship at $p \leq 0.05$
** = Significant positive relationship at $p \leq 0.01$
+ = Significant negative relationship at $p \leq 0.05$
++ = Significant negative relationship at $p \leq 0.01$

Table 11. Correlation Among Upper Main Water Zone Groundwater Quality Constituent Concentrations Using Pearson Correlation Probabilities

Constituent	Temp	pH-f	Turb	SC-f	TDS	Hard	Ca	Mg	Na	K	Bic	Cl	SO_4	NO_3	TKN	As	B	F
Physical Parameters																		
Temperature					**						+							
pH-field								++			+							
Turbidity																		
General Mineral Characteristics																		
SC-field									**					**			*	**
TDS											+							
Hardness																		
Major Ions																		
Calcium																		
Magnesium											*		+					
Sodium														*			*	**
Potassium																		
Bicarbonate																		
Chloride																		
Sulfate																	*	
Nutrients																		
Nitrate																	*	*
TKN																		
Trace Elements																		
Arsenic																		
Boron																		**
Fluoride																		

Blank cell = not a significant relationship between constituent concentrations
* = Significant positive relationship at $p \leq 0.05$
** = Significant positive relationship at $p \leq 0.01$
+ = Significant negative relationship at $p \leq 0.05$
++ = Significant negative relationship at $p \leq 0.01$

Sub-Basin Variation

The Pinal AMA has been divided into five sub-basins by ADWR.[7] Analytical results were compared between groundwater samples collected in the five sub-basins: Aguirre Valley (5 sites), Eloy (50 sites), Maricopa-Stanfield (27 sites), Santa Rosa Valley (0 sites) and Vekol Valley (4 sites).

Significant concentration differences were found with five constituents (Table 12). Temperature was higher in the Aguirre Valley sub-basin than in the Eloy sub-basin, fluoride (Figure 26) and pH-field (Figure 27), were higher in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin, and oxygen and deuterium were higher in both the Maricopa-Stanfield and Vekol Valley sub-basins than in the Eloy sub-basin (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 13.

Many other constituents such as calcium, sodium, chloride, sulfate, and radon had significant concentration differences as revealed by the Kruskal-Wallis test ($p \leq 0.05$). However, there were no sub-basin differences when the Tukey test was applied ($p \leq 0.05$).

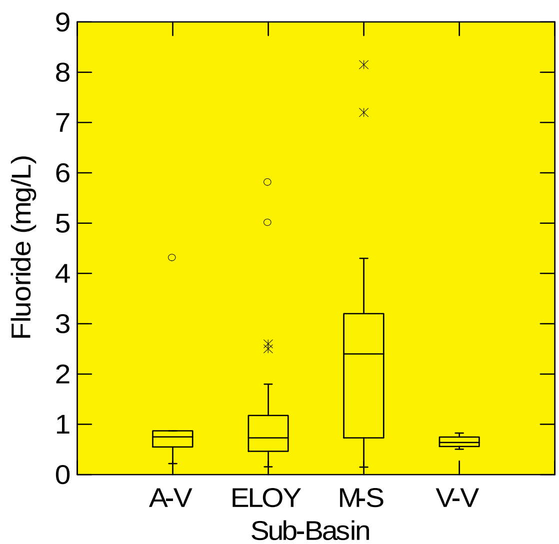


Figure 26. Fluoride concentrations in the Pinal AMA are significantly higher in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin; those in the Aguirre Valley and Vekol Valley are not significantly different from any other sub-basins (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

Fluoride concentrations are frequently low in recharge areas and increase along with pH in downgradient areas (Map 6).[35] Although calcium can be an important control on fluoride, this constituent's relatively low concentrations in the Pinal AMA (≤ 5 mg/L) suggest hydroxyl ion exchange or sorption/de-sorption reactions are important controls.[35]

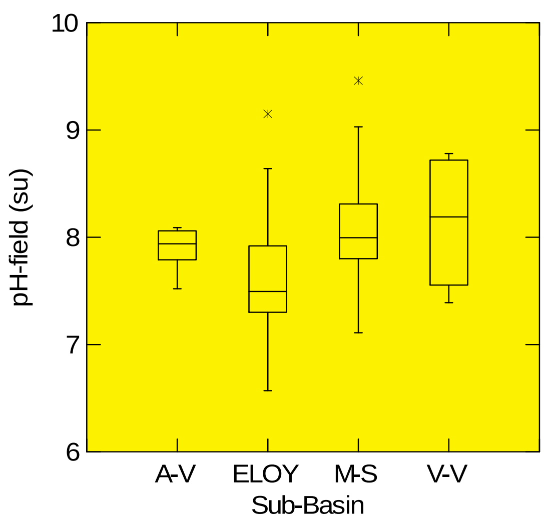


Figure 27. Like fluoride, levels of pH (field-sampled) in the Pinal AMA are significantly higher in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin; those in the Aguirre Valley and Vekol Valley are not significantly different from any other sub-basins (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

This pattern shows the important influence of pH levels on fluoride concentrations.[35] A few other constituents (temperature, pH-field, oxygen and deuterium) had significant concentration differences between sub-basins but generally these groundwater boundaries were not major factors in differentiating water quality variations.

Table 12. Variation in Groundwater Quality Constituent Concentrations Among Four Pinal AMA Sub-Basins Using Kruskal-Wallis Test with the Tukey Test.

Constituent	Significance	Differences Among Groundwater Zones
Well Depth	ns	-
Groundwater Depth	ns	-
Temperature - f	**	Aguirre Valley > Eloy
pH – field	** / *	Maricopa-Stanfield > Eloy
pH – lab	ns	-
SC - field	ns	-
SC - lab	ns	-
TDS	ns	-
Turbidity	ns	-
Hardness	ns	-
Calcium	ns	-
Magnesium	ns	-
Sodium	ns	-
Potassium	ns	-
Bicarbonate	ns	-
Chloride	ns	-
Sulfate	ns	-
Nitrate (as N)	ns	-
TKN ***	ns	-
Arsenic***	ns	-
Boron	ns	-
Fluoride	**	Maricopa-Stanfield > Eloy
Oxygen	* / **	Maricopa-Stanfield ** & Vekol Valley * > Eloy
Deuterium	**	Maricopa-Stanfield & Vekol Valley > Eloy
Gross Alpha	ns	-
Gross Beta	ns	-
Radon	ns	-

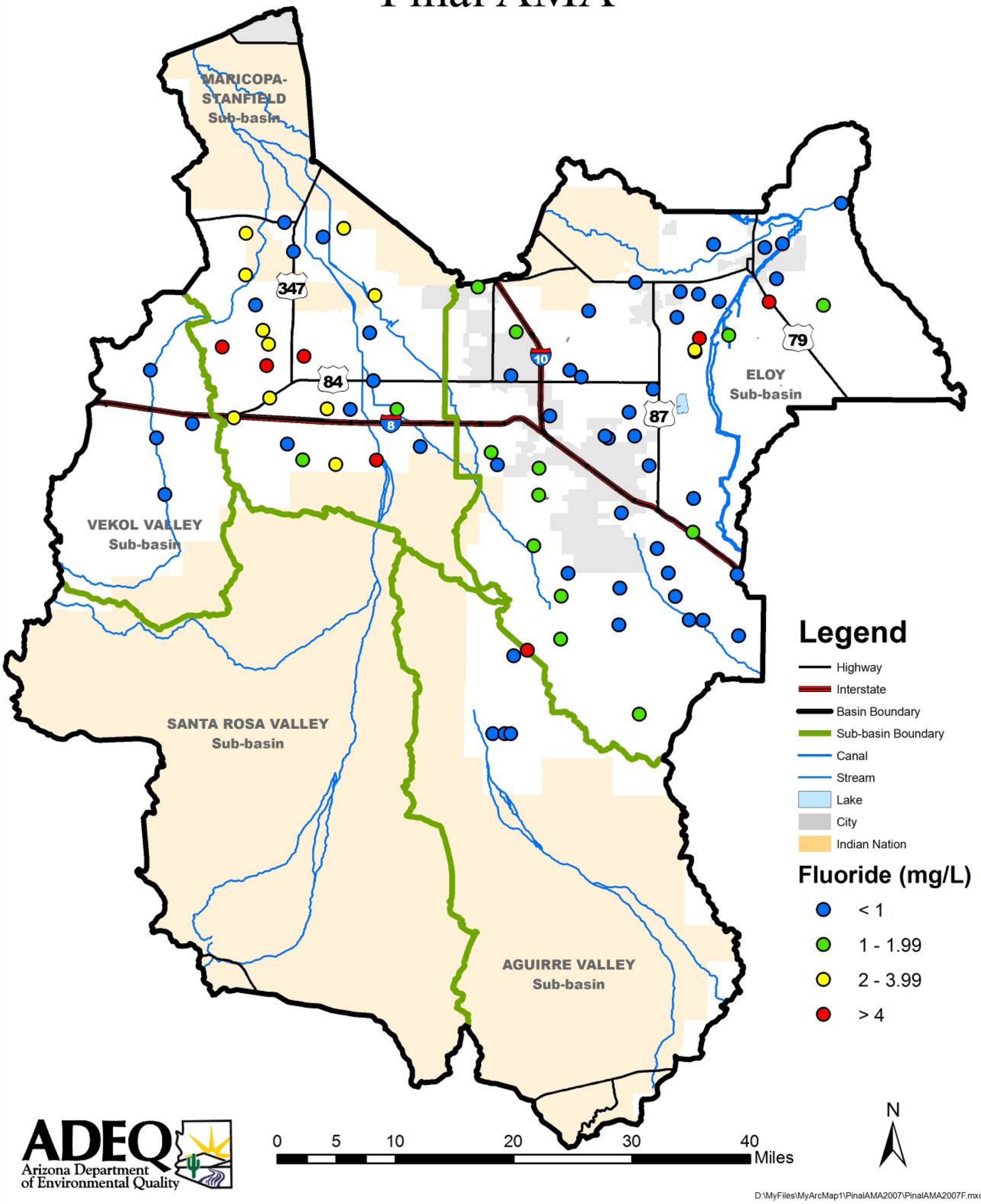
ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Table 13. Summary Statistics (95% Confidence Intervals) for Pinal AMA Sub-Basin Groundwater Quality Constituents With Significant Concentration Differences

Constituent	Significance	Aguirre Valley Sub-Basin	Eloy Sub-Basin	Maricopa-Stanfield Sub-Basin	Vekol Valley Sub-Basin
Well Depth	ns	-	-	-	-
Groundwater Depth	ns	-	-	-	-
Temperature - f	**	27 to 37	26 to 28	-	-
pH – field	** / *	-	7.47 to 7.76	7.85 to 8.24	-
pH – lab	ns	-	-	-	-
SC - field	ns	-	-	-	-
SC - lab	ns	-	-	-	-
TDS	ns	-	-	-	-
Turbidity	ns	-	-	-	-
Hardness	ns	-	-	-	-
Calcium	ns	-	-	-	-
Magnesium	ns	-	-	-	-
Sodium	ns	-	-	-	-
Potassium	ns	-	-	-	-
Bicarbonate	ns	-	-	-	-
Chloride	ns	-	-	-	-
Sulfate	ns	-	-	-	-
Nitrate (as N)	ns	-	-	-	-
TKN ***	ns	-	-	-	-
Arsenic***	ns	-	-	-	-
Boron	ns	-	-	-	-
Fluoride	**	-	0.7 to 1.3	1.6 to 3.2	-
Oxygen	* / **	-	-8.6 to -8.2	-8.1 to -7.6	-7.8 to -7.4
Deuterium	**	-	-62 to -60	-58 to -55	-56 to -50
Gross Alpha ***	ns	-	-	-	-
Gross Beta ***	ns	-	-	-	-
Radon	ns	-	-	-	-

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level ** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non- detects.

Map 6 - Fluoride
Pinal AMA



Eloy / Maricopa-Stanfield Sub-Basin Variation

These mixed test results led to additional constituent concentration analysis between the two sub-basins that were the focus of the study and accounted for almost 90 percent of study sites: the Eloy sub-basin (59 percent of study sites) and the Maricopa-Stanfield sub-basin (30 percent of study sites). Groundwater quality data from the 9 sites (11 percent) in either the Aguirre Valley or the Vekol Valley were left out of this subsequent analysis.

Significant concentration differences were found with eleven constituents (Table 14). Groundwater depth, temperature, pH-field, pH-lab, sodium (Figure 28), fluoride, radon, gross beta, oxygen and deuterium were higher in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin. Calcium (Figure 29) and boron were higher in the Eloy sub-basin than in the Maricopa-Stanfield sub-basin (Kruskal-Wallis test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 14.

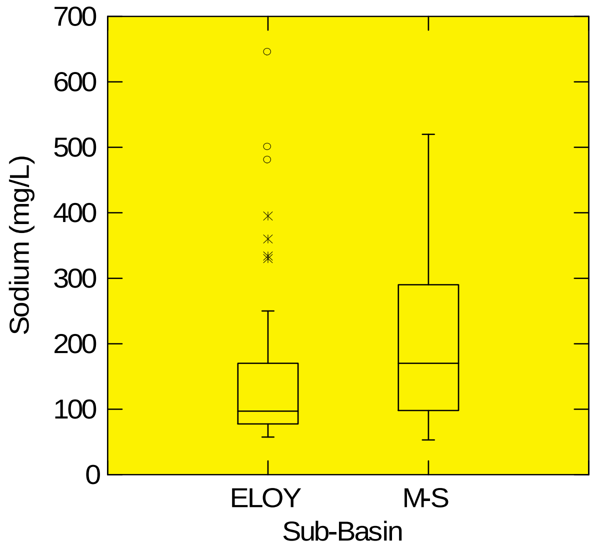


Figure 28. Sodium concentrations in the Pinal AMA are significantly higher in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin (Kruskal-Wallis test, $p \leq 0.05$). Low concentrations of sodium are typically present in recharge areas; in downgradient areas sodium often becomes the dominant cation usually as the result of silicate weathering and halite dissolution along with limited ion exchange. [35]

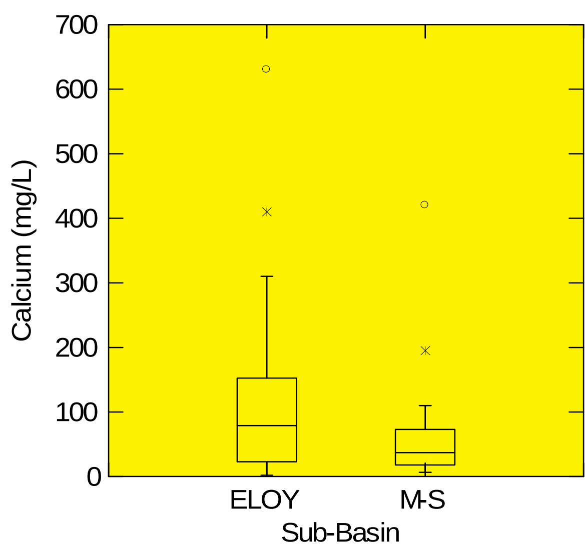


Figure 29. Calcium concentrations in the Eloy sub-basin are significantly higher than in the Maricopa-Stanfield sub-basin (Kruskal-Wallis test, $p \leq 0.05$). Most recharge in the northern Eloy sub-basin is a result of irrigation applications by the San Carlos Irrigation and Drainage District of water from the Gila River. This contributes to this water quality pattern as calcium is the dominant cation in water from the Gila River. [41]

Table 14. Variation in Groundwater Quality Constituent Concentrations Between Two Pinal AMA Sub-Basins Using Kruskal-Wallis Test and 95 Percent Confidence Intervals

Constituent	Significance	Differences Between Sub-Basins	Eloy Sub-Basin	Maricopa-Stanfield Sub-Basin
Well Depth	ns	-	-	-
Groundwater Depth	**	Maricopa-Stanfield > Eloy	245 to 337	325 to 485
Temperature - f	**	Maricopa-Stanfield > Eloy	26 to 28	28 to 30
pH – field	**	Maricopa-Stanfield > Eloy	7.47 to 7.76	7.85 to 8.24
pH – lab	**	Maricopa-Stanfield > Eloy	8.03 to 8.20	8.12 to 8.29
SC - field	ns	-	-	-
SC - lab	ns	-	-	-
TDS	ns	-	-	-
Turbidity	ns	-	-	-
Hardness	ns	-	-	-
Calcium	*	Eloy > Maricopa-Stanfield	78 to 145	29 to 95
Magnesium	ns	-	-	-
Sodium	*	Maricopa-Stanfield > Eloy	121 to 194	148 to 244
Potassium	ns	-	-	-
Bicarbonate	ns	-	-	-
Chloride	ns	-	-	-
Sulfate	ns	-	-	-
Nitrate (as N)	ns	-	-	-
TKN ***	ns	-	-	-
Arsenic***	ns	-	-	-
Boron	*	Eloy > Maricopa-Stanfield	0.28 to 0.71	0.30 to 0.51
Fluoride	**	Maricopa-Stanfield > Eloy	0.7 to 1.3	1.6 to 3.2
Oxygen	**	Maricopa-Stanfield > Eloy	-8.6 to -8.2	-8.1 to -7.6
Deuterium	**	Maricopa-Stanfield > Eloy	-62.3 to -59.9	-58.0 to -54.7
Gross Alpha ***	ns	-	-	-
Gross Beta ***	*	Maricopa-Stanfield > Eloy	2.9 to 6.5	6.0 to 16.7
Radon	**	Maricopa-Stanfield > Eloy	227 to 640	-82 to 2682

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Land Use Variation

Groundwater in the Eloy and Maricopa-Stanfield sub-basin was characterized as having in general, lower chemical contaminant levels in the undeveloped portions of the sub-basin than in the areas in the vicinity of agricultural property.[6] To further examine this conclusion, samples collected in agricultural areas (62 sites) were compared with samples collected in non-agricultural areas (15 sites).

Significant concentration differences were found with eleven constituents (Table 15). Well depth, TDS (Figure 30), hardness, calcium, magnesium, potassium, chloride and sulfate were higher in the irrigated areas than in non-irrigated areas. In contrast, temperature, pH-field, pH-lab, turbidity, and fluoride (Figure 31) were higher in non-irrigated areas than in irrigated areas (Kruskal-Wallis test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 15.

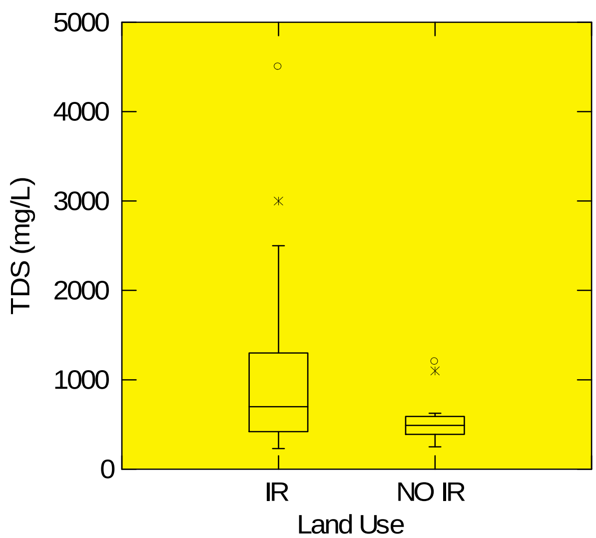


Figure 30. In the Eloy and Maricopa-Stanfield sub-basins of the Pinal AMA, TDS concentrations are higher in the irrigated areas than in the non-irrigated areas (Kruskal-Wallis test, $p \leq 0.05$). Recharge of highly saline water from irrigation applications likely contributes to this pattern. [12] Concentrations of nitrate and pesticides in irrigation recharge water can be reduced by utilizing best management practices but these methods cannot reduce salt loadings. [13]

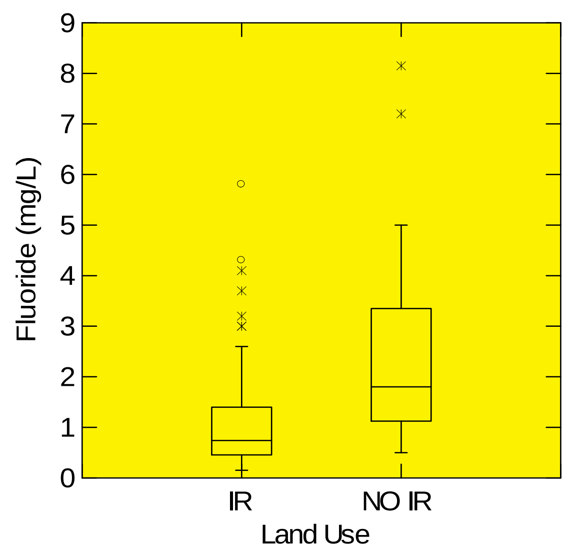


Figure 31. In the Eloy and Maricopa-Stanfield sub-basins of the Pinal AMA, fluoride concentrations are higher in the non-irrigated areas than in the irrigated areas (Kruskal-Wallis test, $p \leq 0.05$). Previous assessments had characterized the non-irrigated portions of these sub-basins as having lower constituent levels.[6] This ADEQ study however, found some parameters such as fluoride actually had significantly higher concentrations in the non-irrigated portions compared to the irrigated areas.

Table 15. Variation in Groundwater Quality Constituent Concentrations Between Irrigated and Non-Irrigated Areas Using Kruskal-Wallis Test and 95 Percent Confidence Intervals

Constituent	Significance	Differences Between Sub-Basins	Irrigated	Non-Irrigated
Well Depth	**	Irrigated > Non-Irrigated	840 to 1050	335 to 883
Groundwater Depth	ns	-	-	-
Temperature - f	*	Non-Irrigated > Irrigated	26.8 to 28.5	28.2 to 30.9
pH – field	**	Non-Irrigated > Irrigated	7.55 to 7.80	7.82 to 8.49
pH – lab	*	Non-Irrigated > Irrigated	8.05 to 8.19	8.12 to 8.40
SC - field	ns	-	-	-
SC - lab	ns	-	-	-
TDS	*	Irrigated > Non-Irrigated	788 to 1192	404 to 700
Turbidity	*	Non-Irrigated > Irrigated	0.08 to 0.70	-0.19 to 2.63
Hardness	*	Irrigated > Non-Irrigated	255 to 442	75 to 191
Calcium	*	Irrigated > Non-Irrigated	78 to 137	23 to 52
Magnesium	*	Irrigated > Non-Irrigated	14 to 23	4 to 16
Sodium	ns	-	-	-
Potassium	**	Irrigated > Non-Irrigated	3.09 to 4.05	1.49 to 3.05
Bicarbonate	ns	-	-	-
Chloride	*	Irrigated > Non-Irrigated	158 to 268	59 to 150
Sulfate	**	Irrigated > Non-Irrigated	201 to 348	51 to 165
Nitrate (as N)	ns	-	-	-
TKN ***	ns	-	-	-
Arsenic***	ns	-	-	-
Boron	ns	-	-	-
Fluoride	**	Non-Irrigated > Irrigated	0.9 to 1.5	1.4 to 4.0
Oxygen	ns	-	-	-
Deuterium	ns	-	-	-
Gross Alpha ***	ns	-	-	-
Gross Beta ***	ns	-	-	-
Radon	ns	-	-	-

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Eloy Sub-Basin Land Use Variation

Groundwater in the Eloy sub-basin was characterized as having in general, lower chemical contaminant levels in the non-irrigated portions of the sub-basin than in the areas in the vicinity of agricultural property.[6] To further examine this conclusion, samples collected in irrigated areas (42 sites) were compared with samples collected in non-irrigated areas (8 sites).

Significant concentration differences were found with eight constituents (Table 15). Well depth, hardness, calcium, potassium, and sulfate (Figure 32) were higher in the agricultural areas than in the non-irrigated areas. In contrast, pH-field, pH-lab and fluoride (Figure 33) were significantly higher in non-irrigated areas than in agricultural areas in the Eloy sub-basin (Kruskal-Wallis test, $p \leq 0.05$).

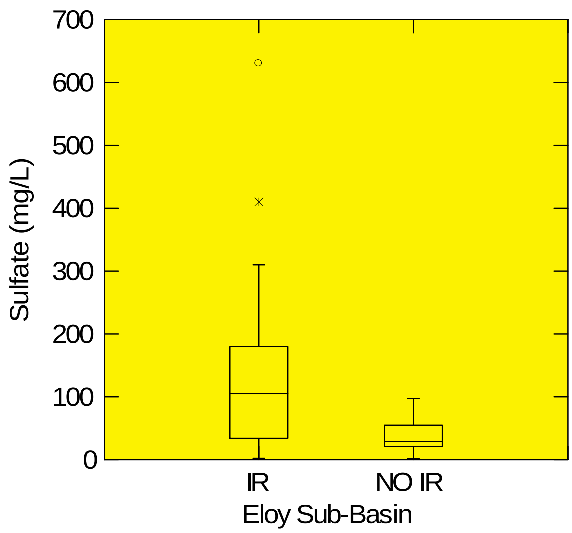


Figure 32. In the Eloy sub-basin of the Pinal AMA, sulfate concentrations are higher in the irrigated portions than in the non-irrigated portions (Kruskal-Wallis test, $p \leq 0.05$). A probable source for the higher sulfate concentrations is the dissolution of salts (including gypsum) concentrated by evaporation during irrigation of farmland that subsequently recharges the groundwater. [12, 13]

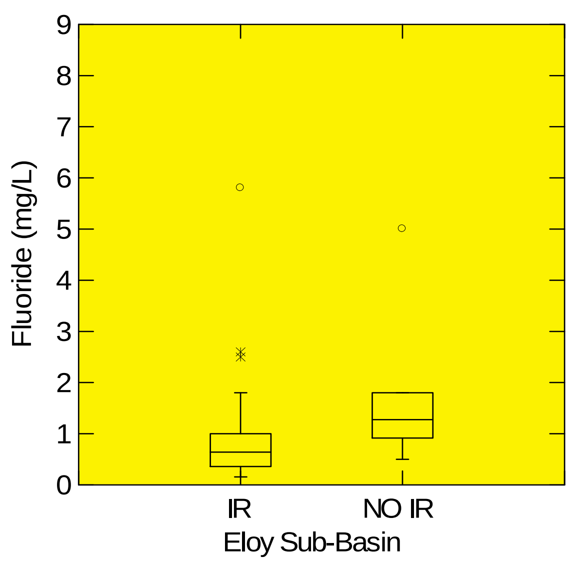


Figure 33. In the Eloy sub-basin of the Pinal AMA, fluoride concentrations are higher in the non-irrigated portions than in the irrigated portions (Kruskal-Wallis test, $p \leq 0.05$). High fluoride concentrations have been associated with proximity to fluoride-bearing minerals in igneous rocks where the groundwater also has a low concentration of calcium. [22] A similar pattern with pH levels in the Eloy sub-basin indicates hydroxide ions on certain clay minerals may be subject to ion exchange by fluoride ions.[35]

Table 16. Variation in Groundwater Quality Constituent Concentrations Between Irrigated and Non-Irrigated Areas In the Eloy Sub-Basin Using Kruskal-Wallis Test with 95 % Confidence Intervals

Constituent	Significance	Differences Between Areas	Irrigated Areas	Non-Irrigated Areas
Well Depth	**	Irrigated > Non-Irrigated	805 to 1083	383 to 662
Groundwater Depth	ns	-	-	-
Temperature - f	ns	-	-	-
pH – field	*	Non-Irrigated > Irrigated	7.41 to 7.71	7.52 to 8.30
pH – lab	*	Non-Irrigated > Irrigated	7.99 to 8.18	8.01 to 8.56
SC - field	ns	-	-	-
SC - lab	ns	-	-	-
TDS	ns	-	-	-
Turbidity	ns	-	-	-
Hardness	*	Irrigated > Non-Irrigated	278 to 517	28 to 250
Calcium	*	Irrigated > Non-Irrigated	87 to 164	12 to 65
Magnesium	ns	-	-	-
Sodium	ns	-	-	-
Potassium	*	Irrigated > Non-Irrigated	3.2 to 4.5	1.3 to 3.6
Bicarbonate	ns	-	-	-
Chloride	ns	-	-	-
Sulfate	*	Irrigated > Non-Irrigated	195 to 393	17 to 188
Nitrate (as N)	ns	-	-	-
TKN ***	ns	-	-	-
Arsenic***	ns	-	-	-
Boron	ns	-	-	-
Fluoride	**	Non-Irrigated > Irrigated	0.6 to 1.2	0.5 to 2.9
Oxygen	ns	-	-	-
Deuterium	ns	-	-	-
Gross Alpha ***	ns	-	-	-
Gross Beta ***	ns	-	-	-
Radon	ns	-	-	-

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Maricopa-Stanfield Sub-Basin Land Use Variation

Groundwater in the Maricopa-Stanfield sub-basin was characterized as having in general, lower chemical contaminant levels in the non-irrigated portions of the sub-basin than in the areas in the vicinity of agricultural property.[6] To further examine this conclusion, samples collected in irrigated areas (20 sites) were compared with samples collected in non-irrigated areas (7 sites).

Significant concentration differences were found with five constituents (Table 16). Potassium and arsenic (Figure 34 and Map 7) were higher in the irrigated areas than in the non-irrigated areas. In contrast, pH-field, turbidity and fluoride (Figure 35) were significantly higher in non-irrigated areas than in irrigated areas in the Maricopa-Stanfield sub-basin (Kruskal-Wallis test, $p \leq 0.05$).

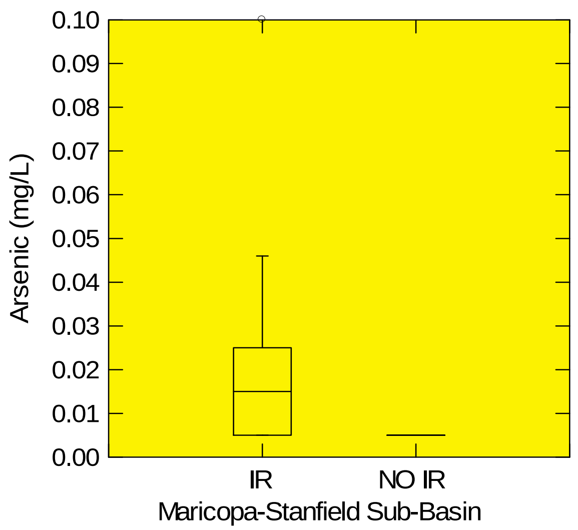


Figure 34. In the Maricopa-Stanfield sub-basin of the Pinal AMA, arsenic concentrations are higher in the irrigated portions than in the non-irrigated portions (Kruskal-Wallis test, $p \leq 0.05$). One potential factor in this pattern could be the historic use of various arsenic compounds as pesticides in the irrigated areas. Although the use of most arsenic pesticides has been discontinued in the U.S., the arsenic compounds may still be present in the groundwater. [12]

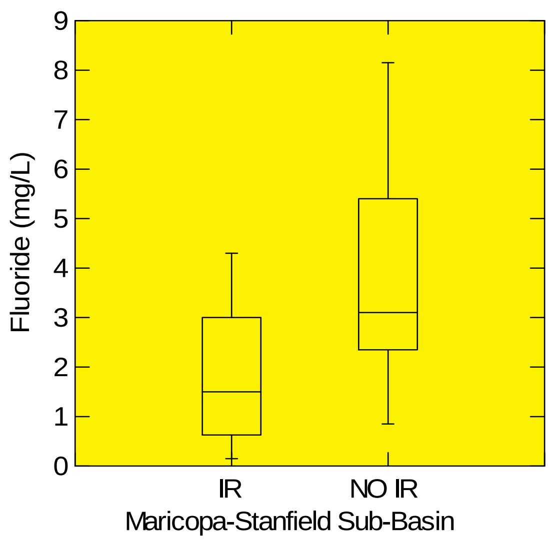


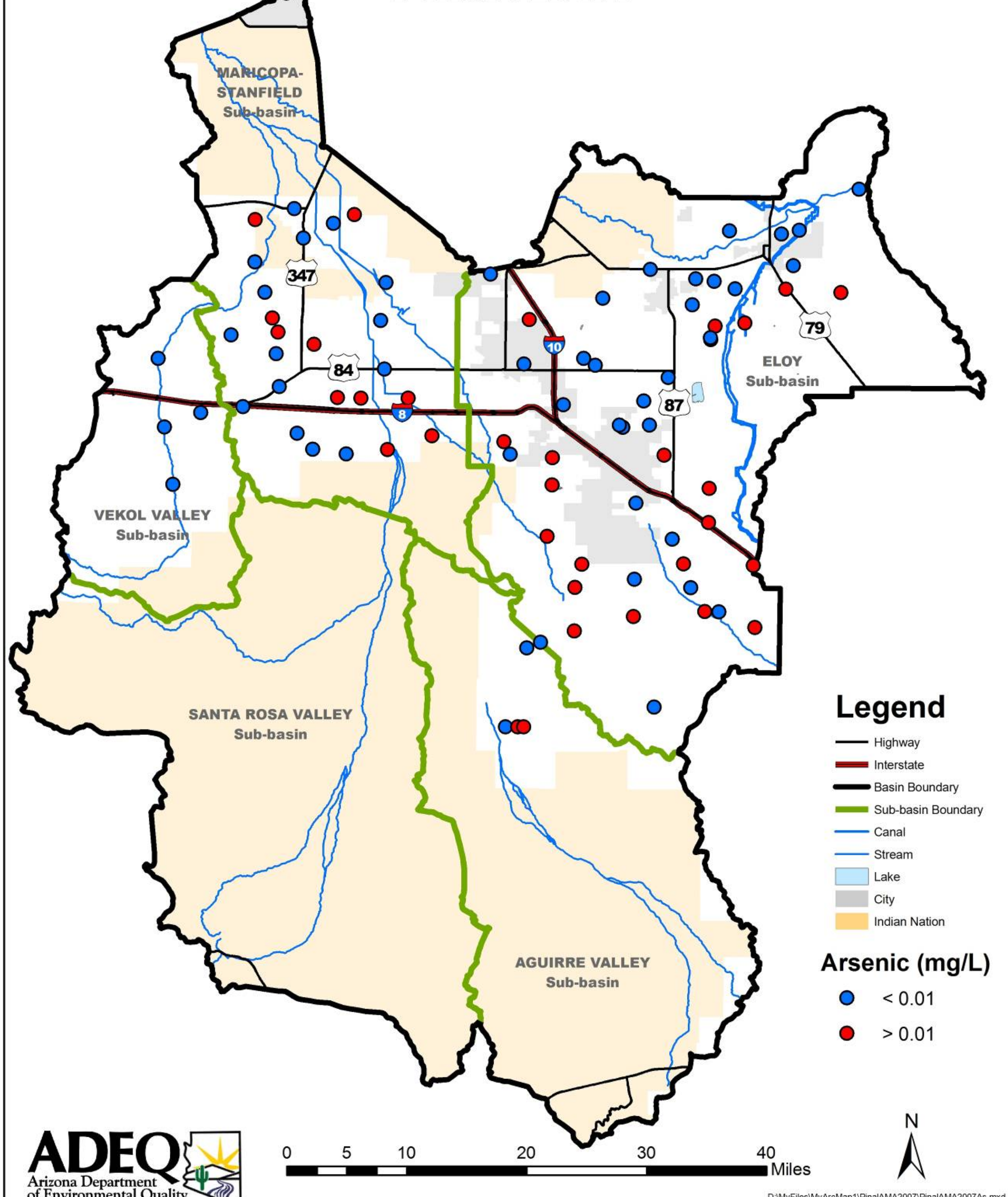
Figure 35. As in the Eloy sub-basin, the Maricopa-Stanfield sub-basin of the Pinal AMA has fluoride concentrations that are higher in the non-irrigated areas than in the irrigated areas (Kruskal-Wallis test, $p \leq 0.05$). High fluoride concentrations have been associated with proximity to fluoride-bearing minerals in igneous rocks where the groundwater also has a low concentration of calcium.[22] A similar pattern with pH levels in the Eloy sub-basin indicates hydroxide ions on certain clay minerals maybe be subject to ion exchange by fluoride ions. [35]

Table 17. Variation in Groundwater Quality Constituent Concentrations Between Irrigated and Non-Irrigated Areas In the M-S Sub-Basin Using Kruskal-Wallis Test with 95 % Confidence Intervals

Constituent	Significance	Differences Between Areas	Irrigated Areas	Non-Irrigated Areas
Well Depth	ns	-	-	-
Groundwater Depth	ns	-	-	-
Temperature - f	ns	-	-	-
pH – field	*	Non-Irrigated > Irrigated	7.74 to 8.07	7.82 to 9.03
pH – lab	ns	-	-	-
SC - field	ns	-	-	-
SC - lab	ns	-	-	-
TDS	ns	-	-	-
Turbidity	**	Non-Irrigated > Irrigated	-0.4 to 1.4	-0.19 to 1.8
Hardness	ns	-	-	-
Calcium	ns	-	-	-
Magnesium	ns	-	-	-
Sodium	ns	-	-	-
Potassium	*	Irrigated > Non-Irrigated	2.4 to 3.6	0.7 to 3.6
Bicarbonate	ns	-	-	-
Chloride	ns	-	-	-
Sulfate	ns	-	-	-
Nitrate (as N)	ns	-	-	-
TKN ***	ns	-	-	-
Arsenic***	**	Irrigated > Non-Irrigated	0.01 to 0.03	.005 to .005
Boron	ns	-	-	-
Fluoride	*	Non-Irrigated > Irrigated	1.2 to 2.5	1.4 to 6.5
Oxygen	ns	-	-	-
Deuterium	ns	-	-	-
Gross Alpha ***	ns	-	-	-
Gross Beta ***	ns	-	-	-
Radon	ns	-	-	-

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level ** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Map 7 - Arsenic
Pinal AMA



Irrigation District Variation

The Pinal AMA can be separated into three irrigation districts: the Central Arizona Irrigation and Drainage District (CAIDD) in the southern part of the Eloy sub-basin, the Maricopa-Stanfield Irrigation and Drainage District (MSIDD) in the Maricopa-Stanfield sub-basin, and Hohokam Irrigation and Drainage District (HIDD) and the San Carlos Irrigation and Drainage District (SCIDD) in the northern part of the Eloy sub-basin. Since the latter two districts have somewhat intermingled boundaries and both are north of the groundwater ridge which extends approximately along the Casa Grande Canal dividing the Eloy sub-basin, the samples collected in the HIDD were combined with those collected in the SCIDD to reflect conditions in the northern section of the Eloy sub-basin.[22] Wells controlled by, or within, each irrigation district were included in this analysis.

Analytical results were compared between groundwater samples collected in the three irrigation districts: CAIDD (22 sites), MSIDD (19 sites) and SCIDD (18 sites).

Significant concentration differences were found with many constituents (Table 17). Groundwater depth, temperature, pH-field and pH-lab were higher in the CAIDD and MSIDD than in SCIDD. TDS (Figure 36), SC-field, SC-lab, hardness, calcium, magnesium, potassium, chloride, sulfate, TKN and boron were higher in the SCIDD than in CAIDD and MSIDD. Sodium, bicarbonate, arsenic (Figure 37), fluoride, radon, oxygen and deuterium have unique significant patterns (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 18.

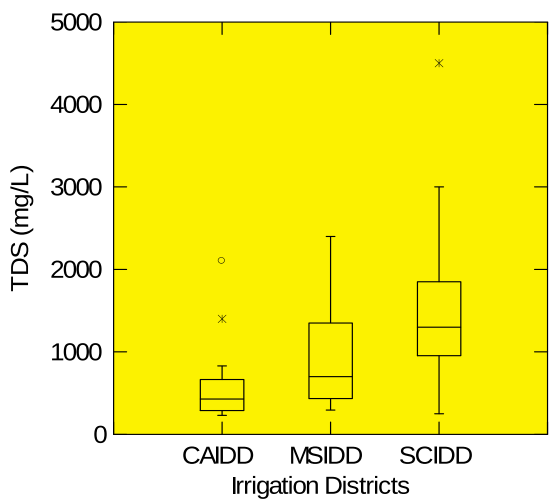


Figure 36. In a common pattern, TDS concentrations in the SCIDD are significantly higher than in both the MSIDD and the CAIDD; there is no significant difference between TDS concentrations in the CAIDD and the MSIDD (Kruskal-Wallis with Tukey test, $p \leq 0.05$). The higher TDS concentrations in the SCIDD are probably due to a combination of evaporate deposits and saline recharge from irrigation water that quickly impacts the aquifer because of shallow groundwater levels maintained by the importation of surface water by the SCIDD. [13, 22]

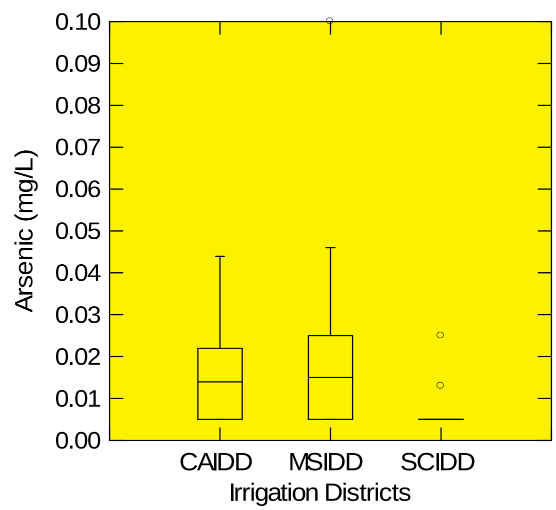


Figure 37. Arsenic concentrations were significantly higher in the MSIDD than in the SCIDD; those in the CAIDD are not significantly different from the other two irrigation districts (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Elevated arsenic concentrations have been previously associated with the Lower water zone and sources such as volcanic rocks, evaporate deposits, and geothermal waters. [43]

Table 18. Variation in Groundwater Quality Constituent Concentrations Among Three Irrigation Districts Using Kruskal-Wallis Test with the Tukey Test.

Constituent	Significance	Differences Among Irrigation Districts
Well Depth	ns	-
Groundwater Depth	* / **	CAIDD * & MSIDD ** > SCIDD
Temperature - f	**	CAIDD & MSIDD > SCIDD
pH – field	* / **	CAIDD * & MSIDD ** > SCIDD
pH – lab	* / **	CAIDD ** & MSIDD * > SCIDD
SC - field	* / **	SCIDD > CAIDD ** & MSIDD *
SC - lab	* / **	SCIDD > CAIDD ** & MSIDD *
TDS	* / **	SCIDD > CAIDD ** & MSIDD *
Turbidity	ns	-
Hardness	**	SCIDD > CAIDD & MSIDD
Calcium	**	SCIDD > CAIDD & MSIDD
Magnesium	* / **	SCIDD > CAIDD ** & MSIDD *
Sodium	**	MSIDD & SCIDD > CAIDD
Potassium	**	SCIDD > CAIDD & MSIDD
Bicarbonate	*	SCIDD > CAIDD
Chloride	* / **	SCIDD > CAIDD ** & MSIDD *
Sulfate	**	SCIDD > CAIDD & MSIDD
Nitrate (as N)	ns	-
TKN ***	* / **	SCIDD > CAIDD ** & MSIDD *
Arsenic***	**	MSIDD > SCIDD
Boron	* / **	SCIDD > CAIDD ** & MSIDD *
Fluoride	**	MSIDD > CAIDD
Oxygen	**	MSIDD & SCIDD > CAIDD
Deuterium	**	MSIDD > CAIDD & SCIDD
Gross Alpha ***	ns	-
Gross Beta ***	ns	-
Radon	*	MSIDD > SCIDD

ns = not significant   * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Table 19. Summary Statistics (95% Confidence Intervals) for Pinal AMA Irrigation Districts With Groundwater Quality Concentration Differences

Constituent	Significant Differences	CAIDD	MSIDD	SCIDD
Well Depth	ns	-	-	-
Groundwater Depth	* / **	269 to 391	330 to 532	152 to 247
Temperature - f	**	28 to 30	28 to 30	24 to 27
pH – field	* / **	7.53 to 8.00	7.74 to 8.07	7.20 to 7.57
pH – lab	* / **	8.10 to 8.36	8.09 to 8.30	7.82 to 8.10
SC - field	* / **	593 to 1078	1031 to 1841	1584 to 2769
SC - lab	* / **	602 to 1115	1062 to 1895	1644 to 2864
TDS	* / **	375 to 746	641 to 1219	1048 to 1966
Turbidity	ns	-	-	-
Hardness	**	117 to 308	99 to 393	386 to 795
Calcium	**	38 to 100	26 to 115	118 to 250
Magnesium	* / **	5 to 14	7 to 25	21 to 41
Sodium	**	67 to 119	155 to 273	172 to 314
Potassium	**	2.2 to 3.1	2.4 to 3.6	4.0 to 6.1
Bicarbonate	*	136 to 178	-	178 to 245
Chloride	* / **	51 to 120	129 to 293	223 to 479
Sulfate	**	76 to 197	132 to 334	291 to 638
Nitrate (as N)	ns	-	-	-
TKN ***	* / **	0.02 to 0.04	0.02 to 0.09	0.06 to 0.24
Arsenic***	**	-	0.010 to 0.031	0.004 to 0.009
Boron	* / **	0.08 to 0.24	0.26 to 0.52	0.39 to 1.33
Fluoride	**	0.5 to 0.9	1.2 to 2.5	-
Oxygen	**	-8.77 to -8.41	-8.08 to -7.72	-8.29 to -7.76
Deuterium	**	-61.6 to-59.4	-58.2 to -55.6	-63.0 to -58.9
Gross Alpha ***	ns	-	-	-
Gross Beta ***	ns	-	-	-
Radon	*	-	348 to 855	137 to 351

All units in milligrams per liter (mg/L) unless otherwise noted
ns = not significant * = significant at p ≤ 0.05 or 95% confidence level ** = significant at p ≤ 0.01 or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Water Zone Variation

Two sub-basins within the Pinal AMA, the Eloy sub-basin and the Maricopa-Stanfield sub-basin, contain three groundwater zones: a lower main water zone (lower), an upper main water zone (upper), and various local water zones (local).[22] Wells were placed into these three groundwater zones based on six factors: water-level changes from 1984-85 to 1988-89, water-level altitudes in 1988-89, water level altitudes in 1984-85, water-level changes from 1976-77 to 1988-89, recent water-quality data, and well construction information.[22]

Analytical results were compared between groundwater samples collected in the three water zones: lower water zone (42 sites), upper water zone (29 sites) and local water zone (4 sites).

Significant concentration differences were found with many constituents (Table 19). Well depth, groundwater depth, temperature, pH-field (Figure 38) and pH-lab were higher in the lower than in upper and local. TDS, SC-field, SC-lab, hardness, calcium, magnesium, sodium, chloride, sulfate and nitrate (Figure 39 and Map 8) were higher in the upper and local than in the lower. Potassium, TKN and boron were higher in the upper than in the lower. (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 20.

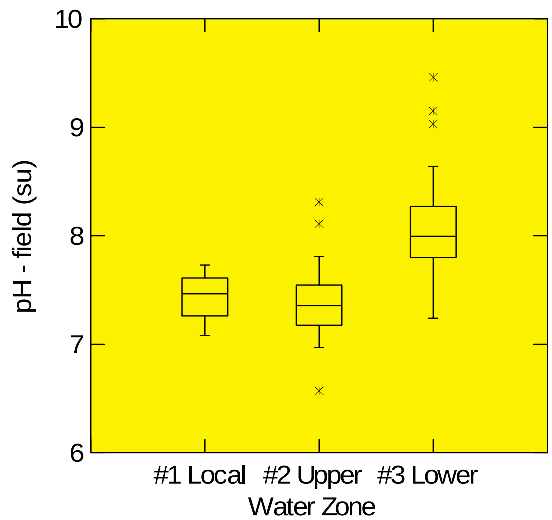


Figure 38. When compared among Pinal AMA groundwater zones, pH-field values were significantly higher in the lower zone than in either the upper or local zones (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Similar pH-field patterns have been found in other groundwater basins in Arizona including the Lower San Pedro and San Simon.[36, 37] The upper and local zones are considered chemically open hydrologic systems because they receive recharge from various sources. [35] The lower water zone is likely a chemically closed hydrologic system in which the aqueous chemistry is determined solely by the reactions of the initial recharge water with the various minerals as it moves downgradient. [35]

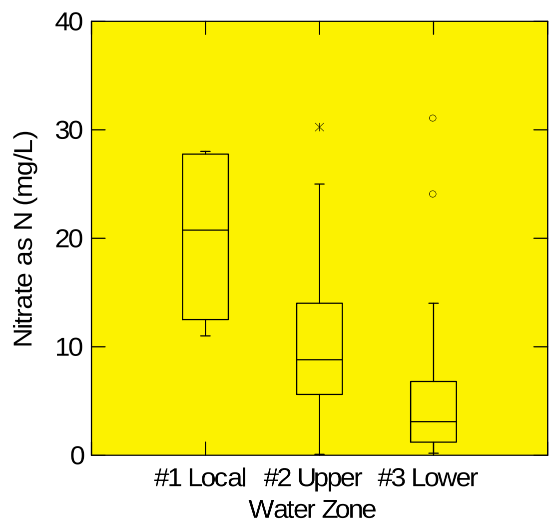


Figure 39. When compared among Pinal AMA groundwater zones, nitrate concentrations were significantly higher in the upper or local zones than in the lower zone (Kruskal-Wallis with Tukey test, $p \leq 0.05$). A similar nitrate pattern was found in the San Simon sub-basin of the Safford basin.[37] The elevated nitrate concentrations found in the local and upper water zones are likely the result of several sources including excess saline recharge that also carries nitrates as a result of nitrogen fertilizer applied to irrigated fields. [12, 13] Other likely nitrate sources include septic systems and confined animal feedlots. [43]

Table 20. Variation in Groundwater Quality Constituent Concentrations Among Three Pinal AMA Water Zones Using Kruskal-Wallis Test with the Tukey Test.

Constituent	Significance	Differences Among Groundwater Zones
Well Depth	**	Lower > Upper & Local
Groundwater Depth	**	Lower > Upper & Local
Temperature - f	**	Lower > Upper & Local
pH – field	** / *	Lower > Upper ** & Local *
pH – lab	**	Lower > Upper & Local
SC - field	**	Upper & Local > Lower
SC - lab	**	Upper & Local > Lower
TDS	**	Upper & Local > Lower
Turbidity	ns	-
Hardness	**	Upper & Local > Lower
Calcium	**	Upper & Local > Lower
Magnesium	**	Upper & Local > Lower
Sodium	** / *	Upper ** & Local * > Lower
Potassium	**	Upper > Lower
Bicarbonate	**	Upper & Local > Lower
Chloride	** / *	Upper ** & Local * & Lower
Sulfate	**	Upper & Local & Lower
Nitrate (as N)	**	Upper & Local > Lower
TKN ***	**	Upper > Lower
Arsenic***	ns	-
Boron	**	Upper > Lower
Fluoride	ns	-
Oxygen	ns	-
Deuterium	ns	-
Gross Alpha ***	ns	-
Gross Beta ***	ns	-
Radon	ns	-

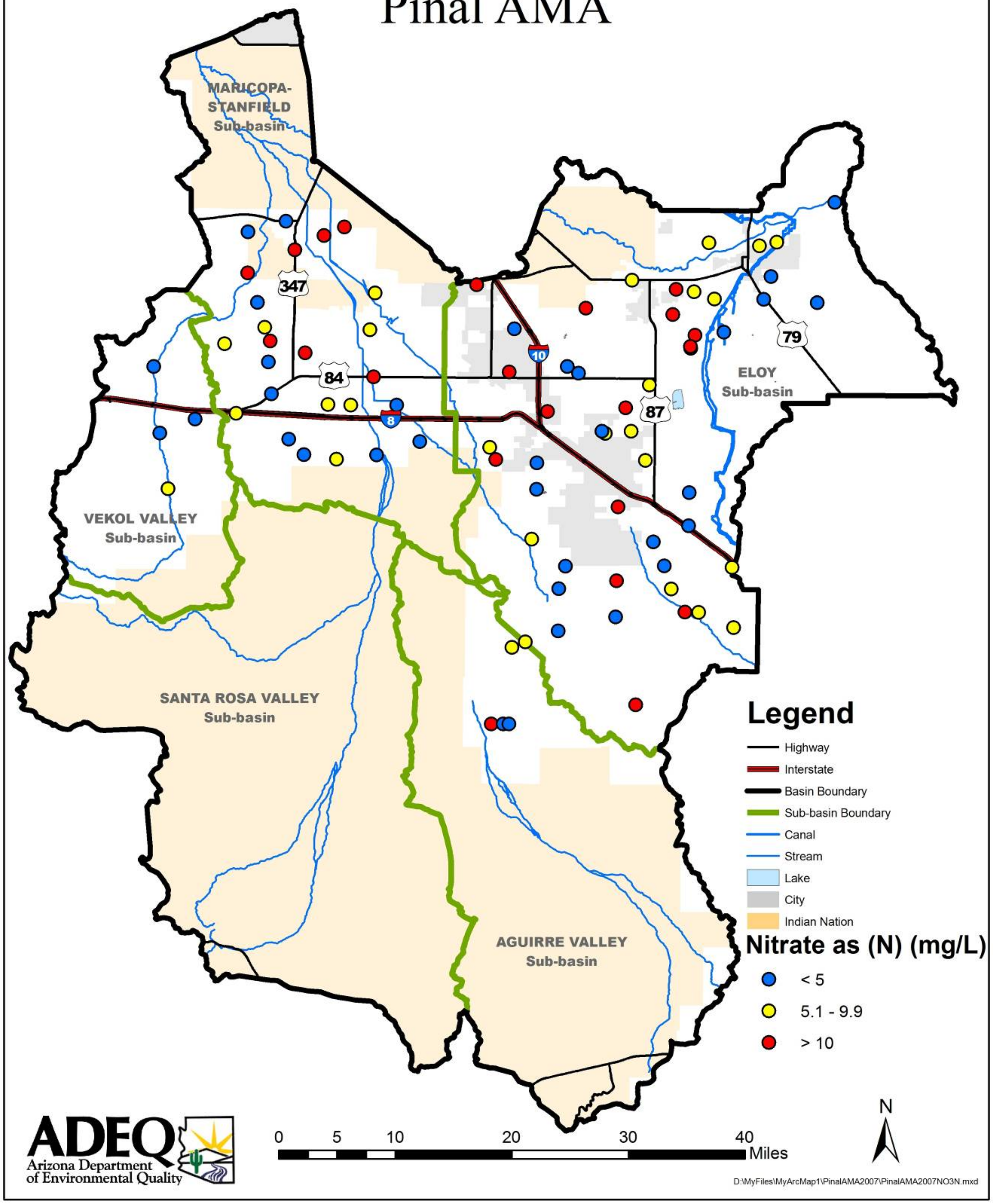
ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level ** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

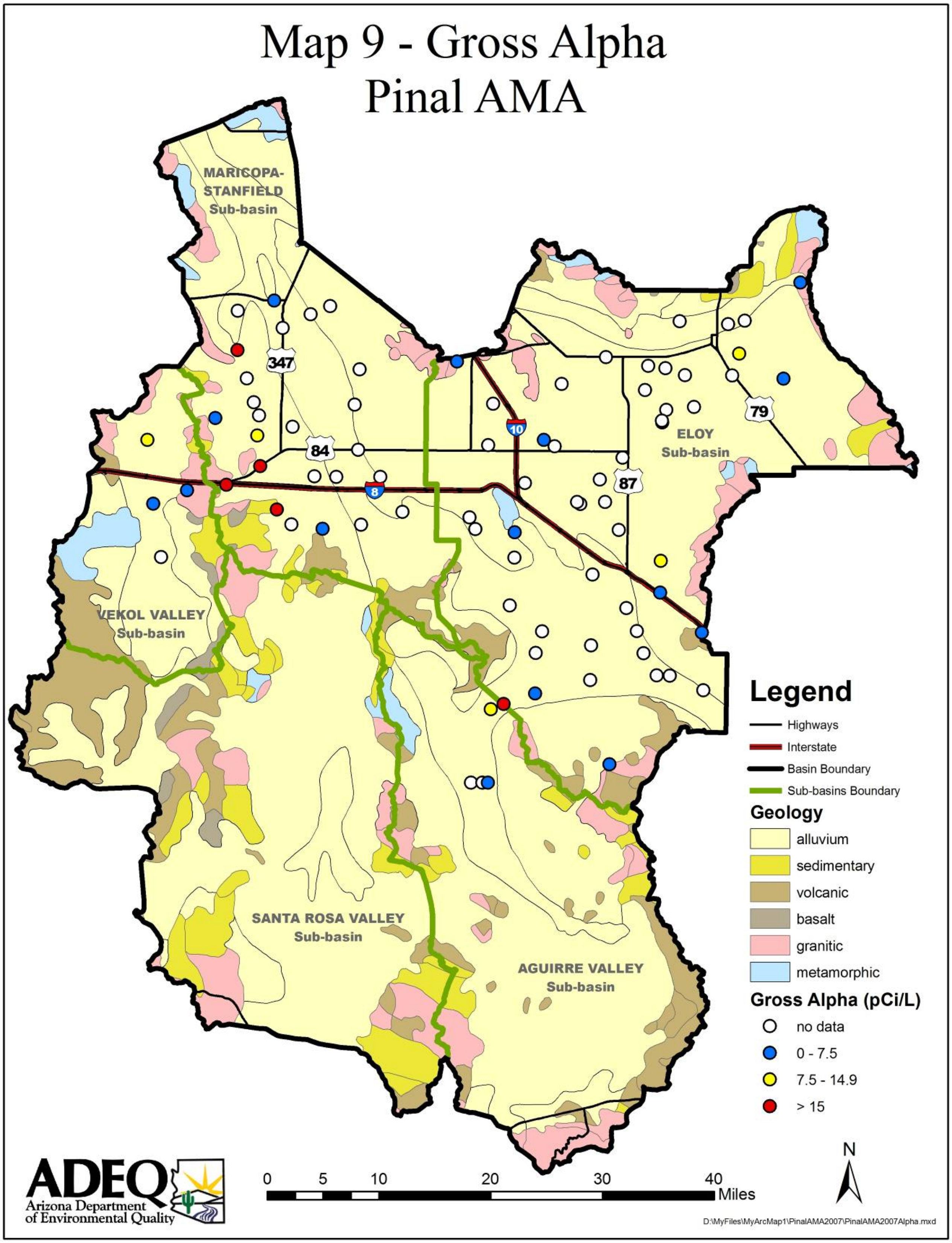
Table 21. Summary Statistics (95% Confidence Intervals) for Pinal AMA Groundwater Quality Constituents With Significant Concentration Differences Among Three Water Zones

Constituent	Significant Differences	Local Water Zone	Upper Water Zone	Lower Water Zone
Well Depth (feet)	**	-223 to 1050	602 to 875	913 to 1146
Groundwater Depth (feet)	**	20 to 175	164 to 230	398 to 484
Temperature – field (C)	**	24 to 26	25 to 27	29 to 31
pH – field (su)	** / *	7.01 to 7.86	7.24 to 7.51	7.91 to 8.20
pH – lab (su)	**	7.55 to 8.22	7.90 to 8.07	8.21 to 8.36
SC – field (uS/cm)	**	1926 to 3078	1424 to 2363	749 to 1061
SC – lab (uS/cm)	**	1893 to 3206	1478 to 2445	765 to 1096
TDS	**	1124 to 2326	958 to 1669	462 to 664
Turbidity (ntu)	ns	-	-	-
Hardness	**	123 to 1177	360 to 680	94 to 165
Calcium	**	30 to 381	111 to 212	28 to 49
Magnesium	**	8 to 58	19 to 35	5 to 11
Sodium	** / *	186 to 439	147 to 267	110 to 165
Potassium	**	-	3.3 to 5.0	2.3 to 3.2
Bicarbonate	**	124 to 437	180 to 232	143 to 180
Chloride	** / *	264 to 446	190 to 389	80 to 149
Sulfate	**	254 to 781	261 to 528	89 to 148
Nitrate (as N)	**	6 to 34	8 to 13	3 to 7
TKN***	**	-	0.05 to 0.18	0.03 to 0.04
Arsenic***	ns	-	-	-
Boron	**	-	0.32 to 1.00	0.19 to 0.31
Fluoride	ns	-	-	-
Oxygen (0/00)	ns	-	-	-
Deuterium (0/00)	ns	-	-	-
Gross Alpha (pCi/L) ***	ns	-	-	-
Gross Beta (pCi/L) ***	ns	-	-	-
Radon (pCi/L)	ns	-	-	-

All units in milligrams per liter (mg/L) unless otherwise noted   ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level   ** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Map 8 - Nitrate
Pinal AMA





Map 9 - Gross Alpha
Pinal AMA
MARICOPA-STANFIELD Sub-basin
ELOY Sub-basin
VEKOL VALLEY Sub-basin
SANTA ROSA VALLEY Sub-basin
AGUIRRE VALLEY Sub-basin
347
84
8
10
87
79
Legend
Highways
Interstate
Basin Boundary
Sub-basins Boundary
Geology
alluvium
sedimentary
volcanic
basalt
granitic
metamorphic
Gross Alpha (pCi/L)
no data
0 - 7.5
7.5 - 14.9
> 15
ADEQ
Arizona Department of Environmental Quality
0 5 10 20 30 40
Miles
N
D:\MyFiles\MyArcMap1\PinalAMA2007\PinalAMA2007Alpha.mxd

Eloy Sub-Basin Groundwater Zone Variation

The three groundwater zones, a lower main water zone, an upper main water zone, and various local water zones were examined within the Eloy sub-basin.[22] Analytical results were compared between groundwater samples collected in the three water zones: lower (22 sites), upper (23 sites) and local (3 sites).

Significant concentration differences were found with many constituents (Table 21). Patterns were generally similar to those found in the previous Pinal AMA groundwater zone variation analysis except for one important addition: arsenic (Figure 40) was significantly higher in the lower main water zone than in the upper main water zone (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 22.

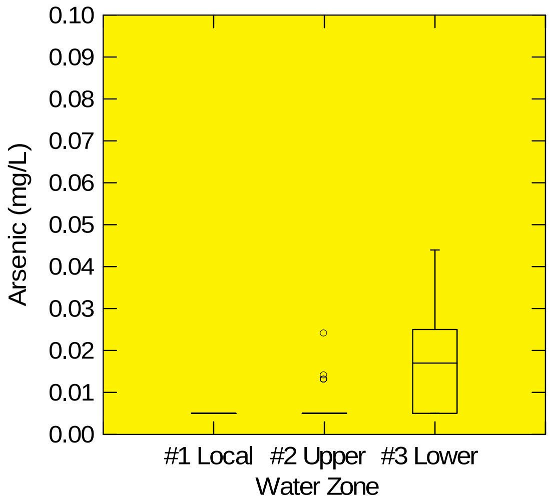


Figure 40. When compared among Eloy sub-basin groundwater zones, arsenic concentrations were significantly higher in the lower zone than in the upper zones; the local zone was not significantly different from either of the other two zones (Kruskal-Wallis with Tukey test, $p \leq 0.05$). A similar arsenic pattern was found in the San Simon sub-basin.[37] Arsenic concentrations in groundwater are influenced by factors such as groundwater residence time, lithology, and clay mineralogy of the aquifer.[35]

Maricopa-Stanfield Sub-basin Groundwater Zone Variation

The three groundwater zones, a lower main water zone, an upper main water zone, and various local water zones were examined within the Maricopa-Stanfield sub-basin.[22] Analytical results were compared between groundwater samples collected in the three water zones: lower (20 sites), upper (6 sites) and local (1 site).

Significant concentration differences were found with many constituents (Table 23). Well depth, groundwater depth and temperature (Figure 41) were higher in the lower than in upper and local. In contrast, calcium and TKN were higher in the upper than in the lower (Kruskal-Wallis test with Tukey test, $p \leq 0.05$). For constituents having significantly different concentrations between sub-basins, 95 percent confidence intervals are provided in Table 24.

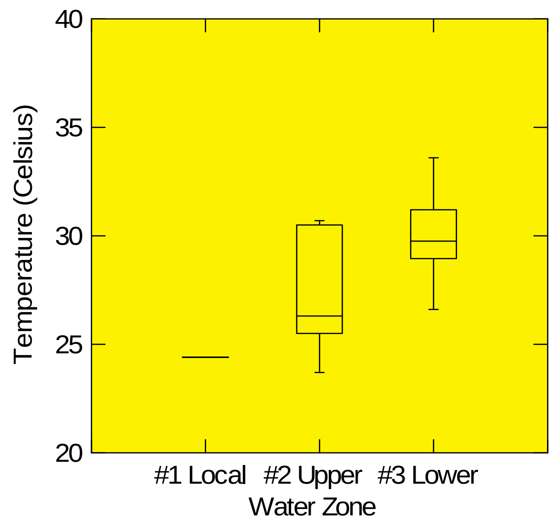


Figure 41. When compared among Maricopa-Stanfield sub-basin groundwater zones, temperature was significantly higher in the lower zone than in both the upper and local Zones (Kruskal-Wallis with Tukey test, $p \leq 0.05$). A similar temperature pattern was found in the San Simon sub-basin.[37] Groundwater temperature should increase with depth, approximately 3 degrees Celsius with every 100 meters or 328 feet.[9]

Table 22. Variation in Groundwater Quality Constituent Concentrations Among Three Eloy Sub-Basin Water Zones Using Kruskal-Wallis Test with the Tukey Test.

Constituent	Significance	Differences Among Groundwater Zones
Well Depth	Ns	-
Groundwater Depth	**	Lower > Upper & Local
Temperature - f	**	Lower > Upper & Local
pH – field	** / *	Lower > Upper ** & Local *
pH – lab	**	Lower > Upper & Local
SC - field	**	Upper & Local > Lower
SC - lab	**	Upper & Local > Lower
TDS	**	Upper & Local > Lower
Turbidity	ns	-
Hardness	**	Upper & Local > Lower
Calcium	**	Upper & Local > Lower
Magnesium	**	Upper & Local > Lower
Sodium	*	Upper & Local > Lower
Potassium	**	Upper > Lower
Bicarbonate	**	Upper & Local > Lower
Chloride	**	Upper > Lower
Sulfate	** / *	Upper ** & Local * & Lower
Nitrate (as N)	**	Upper & Local > Lower
TKN ***	ns	-
Arsenic***	**	Lower > Upper
Boron	**	Upper > Lower
Fluoride	ns	-
Oxygen	ns	-
Deuterium	ns	-
Gross Alpha ***	ns	-
Gross Beta ***	ns	-
Radon	ns	-

ns = not significant   * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Table 23. Summary Statistics (95% Confidence Intervals) for Eloy Sub-Basin Groundwater Quality Constituents With Significant Concentration Differences Among Three Water Zones

Constituent	Significant Differences	Local Water Zone	Upper Water Zone	Lower Water Zone
Well Depth (feet)	ns	-	-	-
Groundwater Depth (feet)	**	30 to 204	160 to 229	354 to 445
Temperature – field (C)	**	23 to 27	254to 26	29 to 31
pH – field (su)	** / *	6.78 to 7.89	7.18 to 7.42	7.73 to 8.15
pH – lab (su)	**	7.71 to 7.86	7.89 to 8.05	8.17 to 8.45
SC – field (uS/cm)	**	1672 to 3527	1354 to 2448	557 to 908
SC – lab (uS/cm)	**	1632 to 3701	1407 to 2536	564 to 940
TDS	**	893 to 2774	905 to 1741	343 to 576
Turbidity (ntu)	ns	-	-	-
Hardness	**	328 to 1266	357 to 710	69 to 172
Calcium	**	88 to 419	109 to 224	23 to 56
Magnesium	**	21 to 61	18 to 35	3 to 8
Sodium	*	118 to 449	131 to 270	77 to 128
Potassium	**	-	3.6 to 5.4	2.0 to 3.3
Bicarbonate	**	44 to 443	182 to 235	124 to 159
Chloride	**	-	175 to 411	48 to 1416
Sulfate	** / *	180 to 960	237 to 553	65 to 139
Nitrate (as N)	**	3 to 43	8 to 14	2 to 6
TKN***	ns	-	-	-
Arsenic***	**	-	0.005 to 0.009	0.011 to 0.21
Boron	**	-	0.26 to 1.12	0.12 to 0.23
Fluoride	ns	-	-	-
Oxygen (0/00)	ns	-	-	-
Deuterium (0/00)	ns	-	-	-
Gross Alpha (pCi/L) ***	ns	-	-	-
Gross Beta (pCi/L) ***	ns	-	-	-
Radon (pCi/L)	ns	-	-	-

All units in milligrams per liter (mg/L) unless otherwise noted   ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Table 24. Variation in Groundwater Quality Constituent Concentrations Among Three Maricopa-Stanfield Sub-Basin Water Zones Using Kruskal-Wallis Test with the Tukey Test.

Constituent	Significance	Differences Among Water Sources
Well Depth	**	Lower > Upper & Local
Groundwater Depth	**	Lower > Upper & Local
Temperature - f	*	Lower > Upper & Local
pH – field	ns	-
pH – lab	ns	-
SC - field	ns	-
SC - lab	ns	-
TDS	ns	-
Turbidity	ns	-
Hardness	ns	-
Calcium	**	Upper > Lower
Magnesium	ns	-
Sodium	ns	-
Potassium	ns	-
Bicarbonate	ns	-
Chloride	ns	-
Sulfate	ns	-
Nitrate (as N)	ns	-
TKN ***	*	Upper > Lower
Arsenic***	ns	-
Boron	ns	-
Fluoride	ns	-
Oxygen	ns	-
Deuterium	ns	-
Gross Alpha ***	ns	-
Gross Beta ***	ns	-
Radon	ns	-

ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Table 25. Summary Statistics (95% Confidence Intervals) for Maricopa-Stanfield Sub-Basin Groundwater Quality Constituents With Significant Concentration Differences Among Three Water Zones

Constituent	Significant Differences	Local Water Zone	Upper Water Zone	Lower Water Zone
Well Depth (feet)	**	112	394 to 825	877 to 1160
Groundwater Depth (feet)	**	38	90 to 321	413 to 561
Temperature – field (C)	*	24	24 to 30	29 to 31
pH – field (su)	ns	-	-	-
pH – lab (su)	ns	-	-	-
SC – field (uS/cm)	ns	-	-	-
SC – lab (uS/cm)	ns	-	-	-
TDS	ns	-	-	-
Turbidity (ntu)	ns	-	-	-
Hardness	ns	-	-	-
Calcium	**	-	-16 to 299	23 to 52
Magnesium	ns	-	-	-
Sodium	ns	-	-	-
Potassium	ns	-	-	-
Bicarbonate	ns	-	-	-
Chloride	ns	-	-	-
Sulfate	ns	-	-	-
Nitrate (as N)	ns	-	-	-
TKN***	*	-	-0.02 to 0.23	0.02 to 0.04
Arsenic***	ns	-	-	-
Boron	ns	-	-	-
Fluoride	ns	-	-	-
Oxygen (0/00)	ns	-	-	-
Deuterium (0/00)	ns	-	-	-
Gross Alpha (pCi/L) ***	ns	-	-	-
Gross Beta (pCi/L) ***	ns	-	-	-
Radon (pCi/L)	ns	-	-	-

All units in milligrams per liter (mg/L) unless otherwise noted
ns = not significant * = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level
*** = for information only, statistical test not valid because of the large number of non-detects

Isotope Comparison

Groundwater characterizations using oxygen and hydrogen isotopic data may be made with respect to the climate and/or elevation where the water originated, residence within the aquifer, and whether or not the water was exposed to evaporation prior to collection.[15] The Global Meteoric Water Line (GMWL) is the standard by which water samples are compared and represents the best fit of isotopic analyses collected from samples worldwide.[15] The GMWL is described by the linear equation: $\delta D = 8^{18}O + 10$.

Isotopic groundwater data from the Pinal AMA was plotted to create a Local Meteoric Water Line described by the linear equation: $\delta D = 6.4^{18}O - 6.7$ (Figure 42). Groundwater from arid environments is typically subject to evaporation, which enriches δD and $\delta^{18}O$ resulting in a lower slope value than the GMWL's slope of 8.

Further investigations concerning groundwater isotope values are found in graphs using surface water isotope values collected within the Pinal AMA (Figure 43), and plotting the groundwater isotope values by sub-basin (Figure 44) and irrigation district (Figure 45).

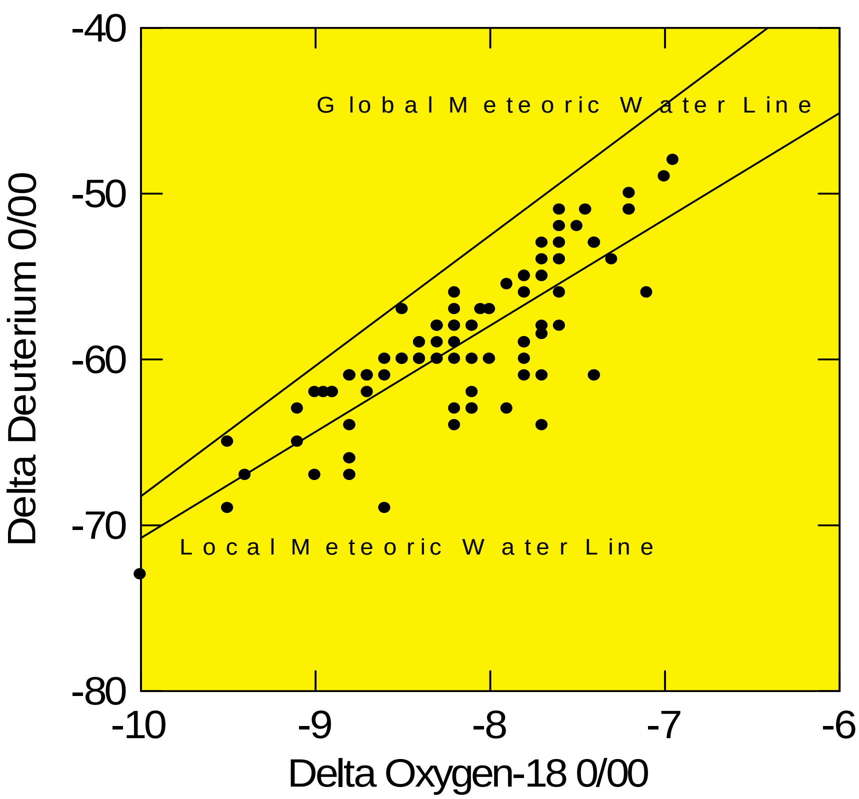


Figure 42. Groundwater from arid environments typically has a slope less than the Global Meteoric Water Line's slope of 8.[15] The Local Meteoric Water Line (LMWL) for the Pinal AMA follows this pattern having a slope of 6.4. Comparing LMWL's of recent ADEQ ambient groundwater studies, the Lake Mohave basin had a slope of 7.8, but most basin's had lower slopes: San Simon (6.5), Big Sandy (6.1), Sacramento Valley (5.5), Meadview (5.5), Detrital Valley (5.2), and San Rafael (4.6).[36, 37, 38]

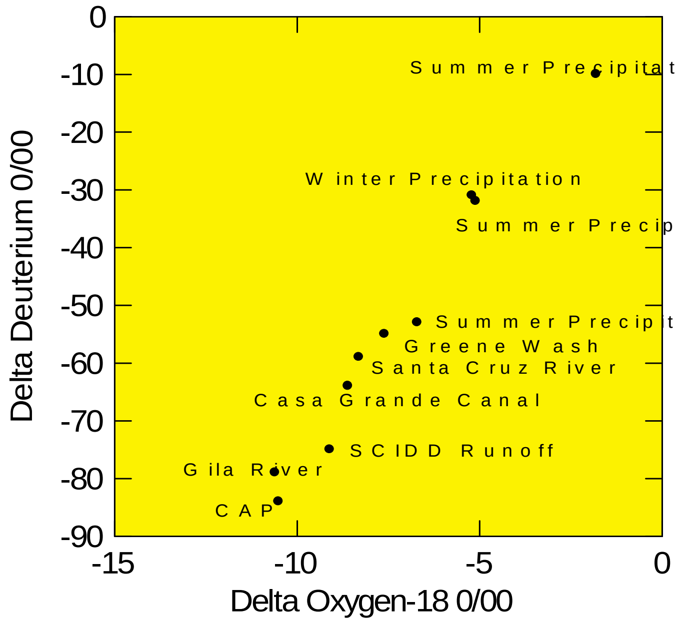


Figure 43. Ten surface water isotope samples were collected as part of the Pinal AMA study. The isotopes that are the heaviest have as their source the Colorado River (via the CAP) and the Gila River (including diversions into canals and the associated runoff from fields) since these waters have been exposed to evaporation through reservoir storage. Lighter isotopes have the Santa Cruz River as their source, a waterway without storage reservoirs that typically flows as a result of discharges from a wastewater treatment plant. The lightest isotopes are the result of precipitation events.[38]

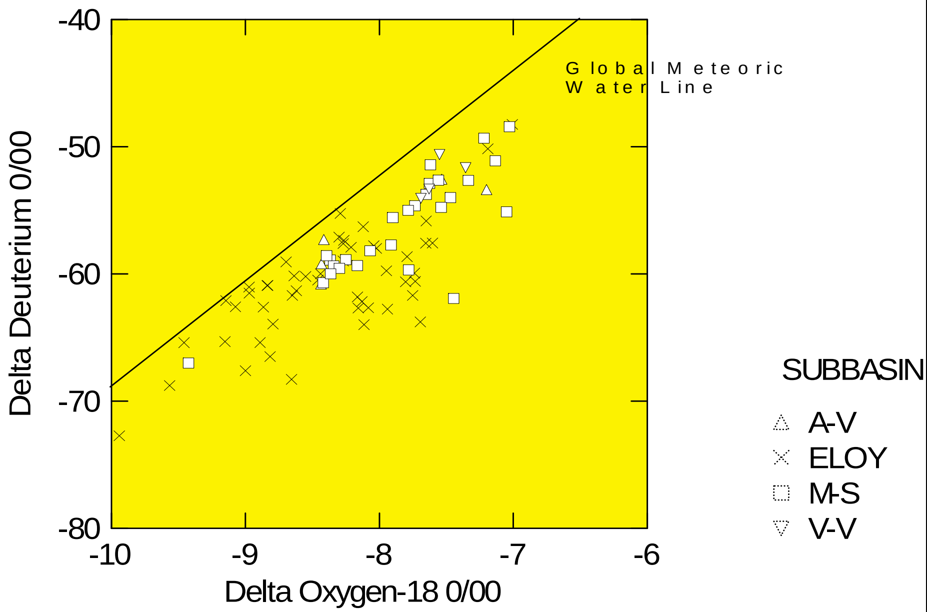


Figure 44. Several significant differences with oxygen and hydrogen isotope values were found among Pinal AMA sub-basins. Both oxygen-18 and deuterium values were greater in the Maricopa-Stanfield (M-S) and Vekol Valley (V-V) sub-basins than in the Eloy sub-basin; values in the Aguirre Valley (A-V) were not significantly different from the other sub-basin (Kruskal-Wallis with Tukey test, $p \leq 0.05$). These isotope patterns appear to be influenced by the application of water from the Gila River for irrigation in the Eloy sub-basin.

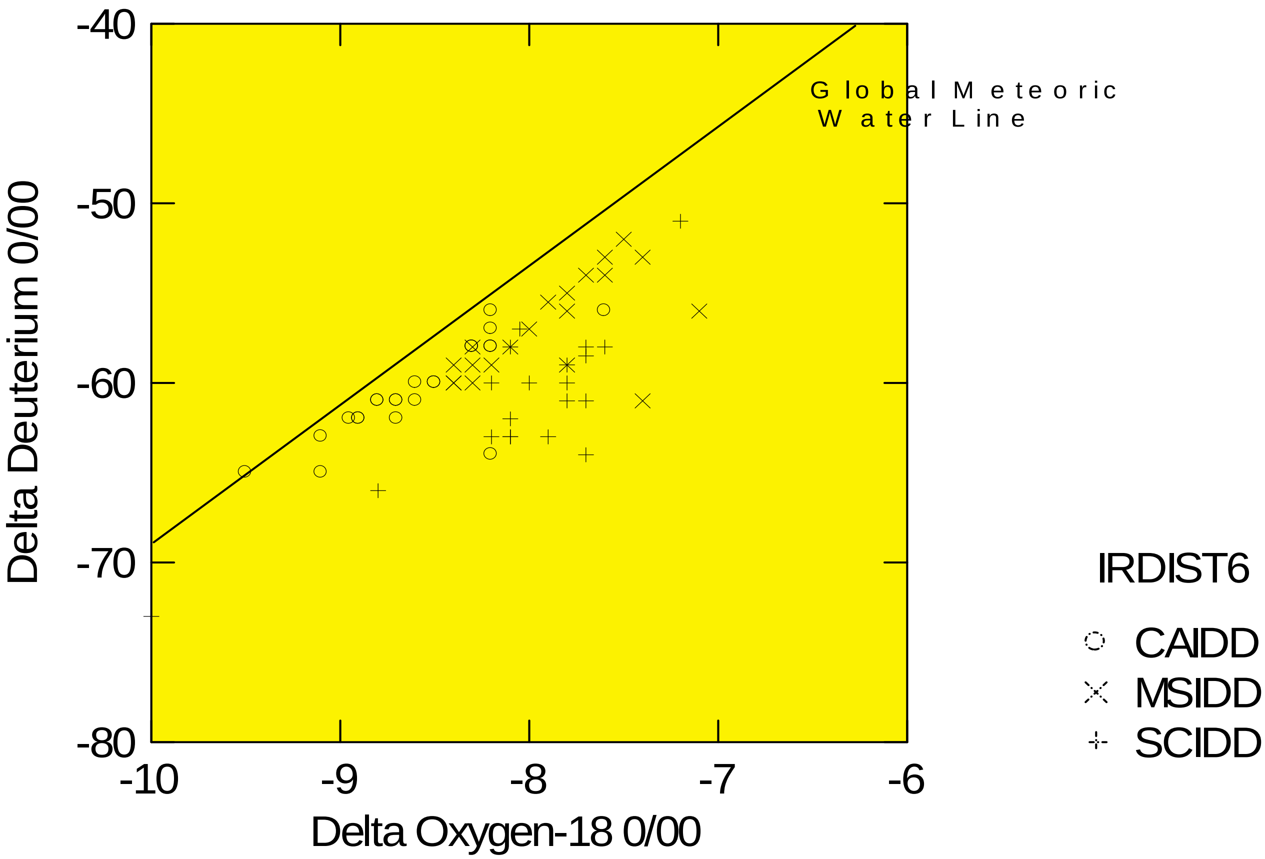


Figure 45. Further refining the patterns revealed when comparing isotope values by sub-basin, oxygen-18 and deuterium were also compared by irrigation districts. Two patterns emerged with the irrigation and drainage districts: deuterium was greater in the Maricopa-Stanfield (MSIDD) then in the Central Arizona (CAIDD) and San Carlos (SCIDD); in contrast oxygen-18 was greater in the MSIDD and SCIDD then in the CAIDD (Kruskal-Wallis with Tukey test, $p \leq 0.05$). This pattern again suggests the evaporation effects of Gila River water stored in San Carlos Lake before used for irrigation by the SCIDD. Reasons for differences between the isotopically heavier groundwater in the CAIDD and the isotopically lighter MSIDD are not as readily apparent.

CONCLUSIONS

Water Quality Standards

This ADEQ study revealed that 70 percent of the 86 sites sampled did not meet health-based Primary MCL water quality standards. Previous assessments of groundwater quality in the Pinal AMA indicated that, aside from a few wells having high concentrations of nitrate and fluoride, there were no major issues affecting water quality.[7] There are several reasons for these different conclusions:

- Much of the disparity between these two assessments can be attributed to the lowering of the arsenic standard from 0.05 mg/l to 0.01 mg/l in 2006, a change that resulted in exceedances at 33 sites—instead of 1 site—for arsenic in the ADEQ study.[44]

- With the exception of two constituents, TDS and nitrate, the sample size of the ADEQ study was almost twice as large.[7]

- The ADEQ study had sample sites spatially distributed throughout much of non-Indian lands compared to the sample sites clustered near the town of Eloy in the previous assessment.[7]

Selenium, along with arsenic, have previously been cited as the primary trace element found above drinking water standards in the both the Eloy and Maricopa-Stanfield sub-basins.[6] This constituent did not appear to be a water quality issue in the Pinal AMA as selenium was not detected above drinking water standards at any of the 86 samples sites and was only detected above the MRL in samples from 3 sites.

Arsenic, fluoride, gross alpha and uranium health-based water quality exceendances appear to be from naturally occurring sources.

Elevated arsenic concentrations appear to be associated with the lower water zone and sources such as volcanic rocks, evaporate deposits, and geothermal waters.[43] The highest concentrations of arsenic are typically associated with the central parts of basins whose chemistries have evolved under chemically closed conditions.[43]

There appear to be multiple controls on fluoride concentrations. Previous studies have cited hydroxyl ion exchange as providing controls on lower (< 5 mg/L) concentrations of fluoride. As pH values increase downgradient, greater levels of hydroxyl ions may affect an exchange for fluoride ions thereby increasing the concentrations of fluoride in solution.[43] In this study, pH-field and fluoride concentrations are significantly correlated ($p \leq 0.01$) which supports this assertion. With higher fluoride concentrations (> 5 mg/L), calcium concentrations are the main control through precipitation or dissolution of the mineral fluorite. Under equilibrium conditions, smaller concentrations of calcium permit higher fluoride concentrations in solution.[43] Thus, if a source of fluoride ions is available for dissolution, large concentrations of dissolved fluoride may occur if the groundwater is depleted in calcium. In this study, fluoride concentrations are significantly positively correlated ($p \leq 0.01$) with sodium and significantly negatively correlated ($p \leq 0.05$) which supports this assertion.

Radiochemical samples were collected at roughly 30 percent of sampling sites; this limited sampling revealed exceedances involving gross alpha and uranium. Available sources indicate these radiochemistry constituents are typically elevated in areas of granite rocks.[29] Sampling by ADEQ in other Arizona groundwater basins has also found elevated concentrations of gross alpha in or near areas of granite rock.[37 38] In the Pinal AMA study, gross alpha and uranium health-based water quality exceedances conformed to this pattern. All five sites with exceedances were located in or near granite rock: the Palo Verde Mountains, the Table Top Mountains, and the West Silver Bell Mountains.

Nitrate appears to the exception with elevated concentrations the result of anthropomorphic activities including agricultural sources (crop fertilizer and confined animal feeding operations) and from non-agricultural sources (septic systems) as well as some that occurs from natural soil organic matter.

Groundwater Quality Patterns

Statistically-significant patterns were found among groundwater sub-basins, land uses, irrigation districts and water zones (Kruskal-Wallis with Tukey test, $p \leq 0.05$). This finding concurs with previous water quality studies that found chemical and physical characteristics of groundwater in the Pinal AMA tended to be variable both horizontally and vertically.[22]

Differences Among Sub-Basins - There were relatively few statistically significant patterns among the four groundwater sub-basins sampled but these relationships did highlight important differences between the Eloy and Maricopa-Stanfield sub-basins.

Fluoride, pH-field, oxygen and deuterium were all greater in the Maricopa-Stanfield sub-basin than in the Eloy sub-basin. These constituents tend to be higher in older groundwater.[35] This conclusion is supported by both water usage history and results from comparing only the Eloy and Maricopa-Stanfield sub-basins.

Until recently with the use of CAP water for irrigation, the Maricopa-Stanfield sub-basin has not received inputs of surface water for irrigation. In contrast, water diverted from the Gila River has long been used for irrigation in the Eloy sub-basin.[7]

Calcium, a cation indicative of recent recharge, was significantly higher in the Eloy sub-basin; in contrast, sodium, a cation indicative of older, evolved groundwater was significantly higher in the Maricopa-Stanfield sub-basin. The U.S. Geological Survey also noted this difference, characterizing the Eloy sub-basin as predominantly calcium-mixed anion chemistry and the Maricopa-Stanfield sub-basin as predominantly sodium-bicarbonate chemistry.[20]

Differences Between Land Uses – Previous assessments stated that, in general, chemical constituent concentrations are lowest in the undeveloped portions of both the Eloy and Maricopa-Stanfield sub-basins and highest in the vicinity of irrigated agriculture.[6]

This study confirmed this conclusion with TDS and many major ions, patterns which are likely the result of excess irrigation water and its large salt load recharged to the aquifer.[13]

Some constituents such as pH and fluoride had the opposite pattern with higher concentrations in the undeveloped areas. Elevated fluoride concentrations have been associated with wells that penetrate bedrock such as those outside irrigated areas.[28] Igneous rocks having fluoride-bearing minerals where groundwater has a low concentration of calcium may contribute to the elevated fluoride concentrations.[28]

This study also revealed no significant difference between nitrate concentrations in undeveloped areas and agricultural areas. This finding is important because it appears to indicate that nitrate results from both agricultural sources (crop fertilizer and confined animal feeding operations) and from non-agricultural sources (septic systems).

Differences Among Irrigation Districts - Analytical results were compared among groundwater samples collected in three irrigation districts: CAIDD, MSIDD and SCIDD. The most important factor impacting water quality patterns among irrigation districts appeared to be the irrigation source.

Since water from the Gila River is the main source of irrigation for the SCIDD, its importation maintains relatively shallow groundwater levels in this irrigation district.[7] Thus, there is little lag time before the highly saline recharge from irrigation applications percolates to the aquifer and impacts groundwater quality in the SCIDD. This is supported by results from this study which show groundwater depth, temperature and pH-field are greater in the CAIDD and MSIDD than in the SCIDD.

In contrast, before 1987, the CAIDD and the MSIDD used groundwater as the sole source of irrigation water.[7] This has led to declining groundwater depths in these districts, but has probably protected the groundwater from the full impacts of saline recharge from irrigation applications because of the increased distance necessary for this water to percolate to the aquifer. This is supported by results from this study that show the SCIDD generally had significantly higher concentrations of TDS, hardness, TKN, boron and major ions (calcium, magnesium, potassium, bicarbonate, chloride and sulfate) than either the CAIDD or the MSIDD.

Differences Among Water Zones - There were numerous statistically significant patterns with constituent concentrations among the three groundwater zones. Most of these water quality differences are related to the recharge sources of each water zone.

The upper water zone appears to be an open hydrologic system in which the aqueous chemistry is determined both by reactions of various minerals (including evaporate deposits) and additional recharge sources (from irrigation, the Gila River, and the local water zone) as it moves along the flow path.[22, 35]

These factors have contributed to the upper water zone having generally significantly higher concentrations of TDS, hardness, nitrate, boron and major ions (calcium, magnesium, sodium, potassium, bicarbonate, chloride and sulfate) than the lower water zone.

The local water zone appears to also be an open hydrologic system. [35] Nitrates, sulfates and other compounds commonly found in agricultural fertilizers and chemicals have been cited as degrading the Casa Grande local water zone. [6] Septic systems have been cited as a possible source of high nitrate concentrations near Casa Grande. [43]

In contrast, the lower water zone is likely a closed hydrologic system in which the aqueous chemistry is determined solely by the reactions of the initial recharge water with the various minerals as it moves downgradient. [35]

These findings are supported by water chemistry differences as shown by the semi-quantitative Piper tri-linear diagram. Generally, samples collected from the upper and local water zones have calcium-chloride/sulfate chemistry while those in the Lower zone have sodium-bicarbonate chemistry. Previous studies have supported this finding that deep groundwater samples tend to have sodium as the dominant cation. [25]

RECOMENDATIONS

Based on interpretations of the analytical results from groundwater samples collected for this study, the following recommendations are offered for domestic well owners in the Pinal AMA:

- ADEQ encourages well owners to periodically collect samples, with the assistance of certified laboratories, for analysis of the full range of constituents having Safe Drinking Water standards. A list of certified labs can be obtained from the ADHS Environmental Laboratory Licensure and Certification Section. Call (602) 255-3454 or see http://www.azdhs.gov/lab/license/env.htm.

- ADEQ encourages well owners to inspect and, if necessary, repair faulty surface seals, degraded casing or other factors that may affect well integrity.

Based on interpretations of the analytical results from groundwater samples collected for this study, the following recommendations are offered for those drilling drinking water wells in the Pinal AMA:

- An examination of historic groundwater quality data is important before drilling drinking water wells. This will increase chances of locating water that meets drinking water standards. The four constituents (arsenic, nitrate, fluoride and gross alpha) that most often exceed water quality standards in the Pinal AMA have conflicting patterns making examining the data in the vicinity of potential well locations essential.

Based on interpretations of the analytical results from groundwater samples collected for this study, the following recommendations are offered for future hydrologic studies in the Pinal AMA:

- Groundwater sampling for pesticides should be concentrated in the northern portion of the Eloy sub-basin where shallow groundwater levels are more likely to receive recharge from excess irrigation water containing residues from pesticide applications.

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Appendix A. Data for Sample Sites, Pinal AMA, 2005-2006

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
1st Field Trip, August 10-11, 2005 – Towne (Equipment Blank, PNL-7)									
PNL-1	D(6-7)21caa turbine	32°53'08.508" 111°37'37.821"	605442	29992	Near Well	Inorganic, Organics Radon, O & H Isotopes	1400'	295'	Eloy
PNL-2/3	D(6-7)20abb turbine	32°53'38.299" 111°38'38.934"	605444	65366	Far Well	Inorganic, Radiochem Organics, O,H isotopes	1400'	350'	Eloy
PNL-4	D(4-3)21bbc submersible	33°04'19.483" 112°03'37.897"	562284	59024	Maricopa Water	Inorganic, Radiochem Organics, Radon O, H isotopes	800'	86'	M-S
PNL-5/6	D(4-3)25bad submersible	33°03'17.215" 112°00'15.502"	638592	27334	7 Ranches Well	Inorganic Radon, O, H isotopes	238'	124'	M-S
PNL-8	D(7-2)11ccb submersible	32°49'56.542" 112°07'52.539"	596837	45580	Saguaro RV Park	Inorganic, Radiochem Radon, O, H isotopes	785'	230'	M-S
PNL-9	D(6-4)21ddd turbine	32°52'46.603" 111°55'46.429"	615413	29499	E5-3#1	Inorganic, Organics Radon, O, H isotopes	1237'	545'	M-S
PNL-10	D(7-4)01daa turbine	32°50'40.927" 111°53'42.007"	625524	31320	E3A1-1	Inorganic, Organics O, H isotopes	1458'	545'	M-S
PNL-11	D(9-9)15aab submersible	32°38'42.425" 111°23'58.862"	597899	65164	Picacho Peak Park	Inorganic, Radiochem Radon, O, H isotopes	800'	720'	Eloy
PNL-12	D(5-4)34ddc turbine	32°56'17.475" 111°56'07.406"	502756	000779	E9-3-#2	Inorganic, Radon O, H isotopes	1025'	400'	M-S
PNL-13	D(6-3)6ccc turbine	32°55'22.723" 112°04'55.864"	625621	29310	WM4-1	Inorganic O, H isotopes	1040'	614'	M-S
PNL-14	D(5-2)25aab turbine	32°58'14.315" 112°06'06.454"	623822	28036	W01- #5	Inorganic O, H isotopes	1000'	600'	M-S
PNL-15	D(5-2)11add turbine	33°00'26.057" 112°06'59.943"	623849	28002	WR1- #2	Inorganic, Radiochem Radon, O, H isotopes	1200'	600'	M-S
PNL-16	near Highway 84	-	-	-	Summer Precip.	O, H isotopes	-	-	M-S
2nd Field Trip, August 17-18, 2005 – Towne (Equipment Blank, PNL-36)									
PNL-17	D(7-8)18add turbine	32°48'50.913" 111°32'57.599"	605536	31704	N-21 #2	Inorganic, Organics Radon, O, H isotopes	735'	200'	Eloy
PNL-18	D(7-8)28ccd turbine	32°46'40.464" 111°31'40.543"	623934	31738	C-29 #2	Inorganic, Organics O, H isotopes	-	335'	Eloy
PNL-19	D(8-8)33ddd turbine	32°40'35.025" 111°30'57.497"	615522	002056	C-33 #1	Inorganic, Organics Radon, O, H isotopes	1200'	469'	Eloy
PNL-20	D(8-8)12dad turbine	32°44'16.791" 112°27'48.957"	086835	32976	C-24 #4	Inorganic, Radiochem Organics, Radon O, H isotopes	1325'	300'	Eloy
PNL-21	D(8-8)25daa turbine	32°41'48.674" 111°27'50.554"	605783	33021	C-31 #2	Inorganic, Radiochem Radon, O, H isotopes	1325'	271'	Eloy
PNL-22	D(7-6)35aad turbine	32°46'26.349" 111°41'16.473"	604510	31513	N-41 #1	Inorganic, Radiochem Organics, Radon O, H isotopes	825'	300'	Eloy
PNL-23	D(7-6)29cdd turbine	32°46'39.753" 111°44'53.505"	619549	31470	N-46 #4	Inorganic, Radon O, H isotopes	222'	150'	Eloy
PNL-24	D(6-8)28dbb turbine	32°52'17.458" 111°31'22.263"	621921	30239	#81	Inorganic, Organics O, H isotopes	1212'	119'	Eloy
PNL-25	D(7-6)01dda turbine	32°50'16.110" 111°40'22.200"	621916	31403	#91	Inorganic, Radon O, H isotopes	893'	308'	Eloy
PNL-26	D(9-7)24ada turbine	32°37'40.017" 111°34'10.769"	628571	33681	C-102 #3	Inorganic, Organics O, H isotopes	1000'	203'	Eloy
PNL-27	D(10-7)8ddd turbine	32°33'53.561" 111°39'18.019"	612751	34167	C-122 #1	Inorganic, Radiochem Radon, O, H isotopes	1000'	495'	Eloy
PNL-28	D(8-6)35dca turbine	32°40'44.582" 111°54140.408"	622140	32812	C-74 #1	Inorganic O, H isotopes	850'	150'	Eloy
PNL-29	D(8-6)11add turbine	32°44'28.142" 111°41'17.637"	618434	32751	C-80 #2	Inorganic O, H isotopes	1777'	450'	Eloy
PNL-30/31	D(6-9)6acb turbine	32°56'01.872" 111°27'21.260"	621903	30375	#133	Inorganic, Organics O & H Isotopes	982'	173'	Eloy

Appendix A. Data for Sample Sites, Pinal AMA, 2005-2006—Continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
2nd Field Trip, August 17-18, 2005 – Towne (Equipment Blank, PNL-36)									
PNL-32	D(5-9)21dcb turbine	32°58'44.682" 111°25'38.114"	621927	28793	#74B	Inorganic O, H isotopes	1175'	270'	Eloy
PNL-33/34	D(5-8)17abb turbine	33°00'07.215" 111°32'57.675"	621936	65224	#31	Inorganic, Organics O, H isotopes	1473'	152'	Eloy
PNL-35	D(4-10)29dad turbine	33°03'00.614" 111°20'08.421"	621940	27684	#2	Inorganic, Radon O, H isotopes	622'	174'	Eloy
PNL-37	-	-	-	-	Summer Precip.	O, H isotopes	-	-	Eloy
PNL-38	-	-	-	-	SCIDD Runoff	O, H isotopes	-	-	Eloy
PNL-39	-	-	-	-	Summer Precip.	O, H isotopes	-	-	Eloy
PNL-40	-	-	-	-	CAP Canal	O, H isotopes	-	-	Eloy
PNL-41	-	-	-	-	Casa Grande Canal	O, H isotopes	-	-	Eloy
3rd Field Trip, August 31-September 1, 2005 – Towne & Garcia (Equipment Blank, PNL-63)									
PNL-42/43	D(4-11)7acb turbine	33°05'58.849" 111°15'00.694"	621944	27697	6-C	Inorganic, Radiochem Radon, O, H isotopes	140'	38'	Eloy
PNL-44	-	-	-	-	Gila River	O, H isotopes	-	-	Eloy
PNL-45	D(4-10)31abb turbine	33°02'43.787" 111°21'40.051"	621943	45549	#5	Inorganic O, H isotopes	350'	-	Eloy
PNL-46	D(4-9)28cdb turbine	33°02'56.911" 111°26'09.200"	621948	006225	#9	Inorganic O, H isotopes	500'	201'	Eloy
PNL-47	D(5-8)25ccc turbine	32°57'33.595" 111°29'19.717"	621938	45548	28B	Inorganic, Radon O, H isotopes	1235'	182'	Eloy
PNL-48	D(9-8)36dcd turbine	32°35'21.345" 111°28'08.500"	622966	33832	S-15 #1	Inorganic, Radon O, H isotopes	775'	-	Eloy
PNL-49/50	D(9-8)23cdd turbine	32°37'04.160" 111°29'20.440"	610181	33773	S-18 #2	Inorganic O, H isotopes	1086'	535'	Eloy
PNL-51	D(9-8)10dcd turbine	32°38'48.445" 111°29'59.044"	615585	33746	S-21 #1	Inorganic O, H isotopes	1600'	481'	Eloy
PNL-52	D(10-7)1aaa turbine	32°34'57.585" 111°34'14.148"	626907	34169	S-39 #1	Inorganic O, H isotopes	900'	475'	Eloy
PNL-53	D(9-7)17bba turbine	32°38'44.773" 111°38'42.090"	612237	33656	C-112 #2	Inorganic O, H isotopes	1688'	363'	Eloy
PNL-54	D(8-7)13ddd turbine	32°43'10.984" 111°34'04.090"	610566	32857	C-50 #1	Inorganic O, H isotopes	1100'	380'	Eloy
PNL-55	D(7-8)6acc turbine	32°50'35.131" 111°33'27.655"	612215	31668	N-16 #1	Inorganic O, H isotopes	515'	149'	Eloy
PNL-56	D(7-7)14dbb turbine	32°48'49.622" 111°35'31.982"	617933	31590	N-30 #2	Inorganic O, H isotopes	1200'	200'	Eloy
PNL-57	D(6-3)10ccc turbine	32°54'30.591" 112°01'50.824"	625531	31591	WI 2-8	Inorganic O, H isotopes	1122'	-	M-S
PNL-58	D(6-5)27aaa turbine	32°52'44.348" 111°55'25.877"	801143	29335	-	Inorganic O, H isotopes	112'	38'	M-S
PNL-59	D(7-4)26cdc turbine	32°46'56.348" 111°55'25."877	626458	31303	SRC-4 #2	Inorganic, Radon O, H isotopes	-	650'	M-S
PNL-60	D(7-4)6cbc turbine	32°50'40.295" 111°59'46.044"	622187	49079	WHI - #1	Inorganic O, H isotopes	1153'	665'	M-S
PNL-61	D(5-4)8dcd turbine	32°59'57.870" 111°58'27.971"	605058	28243	E10-2 #1	Inorganic O, H isotopes	1305'	400'	M-S
PNL-62	D(4-4)20bdc turbine	33°03'55.915" 111°58'27.971"	605945	002153	E13-7 #2	Inorganic O, H isotopes	625'	150'	M-S

Appendix A. Data for Sample Sites, Pinal AMA, 2005-2006—Continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
4th Field Trip, September 21, 2005 – Towne, l Torres-Ayala & Condon (Equipment Blank, PNL-75)									
PNL-64	D(5-10)8dbc submersible	33°00'25.46" 111°20'39.08"	547401	65244	Stock Well	Inorganic, Radiochem Radon, O, H isotopes	500'	320'	Eloy
PNL-65	D(5-10)24dcc submersible	32°58'29.57" 111°16'32.74"	599728	65245	Schubert Well	Inorganic, Radiochem Radon, O, H isotopes	678'	615'	Eloy
PNL-66	D(5-8)13cdb turbine	32°59'29.40" 111°28'56.16"	621929	28582	#20	Inorganic O, H isotopes	1000'	121'	Eloy
PNL-67	D(5-6)34dda submersible	32°56'26.37" 111°43'19.81"	573725	68197	Jones Well	Inorganic O, H isotopes	420'	375'	Eloy
PNL-68/69	D(6-6)21acc turbine	32°53'13.07" 111°43'46.98"	804456	65246	Bolt Well	Inorganic O, H isotopes	320'	80'	Eloy
PNL-70	D(5-4)23bbb submersible	32°59'02.08" 111°55'41.33"	620626	28283	C. Grande Well	Inorganic O, H isotopes	908'	400'	M-S
PNL-71	D(7-6)20cca submersible	32°47'36.47" 111°45'20.97"	589850	31448	Trout Well	Inorganic O, H isotopes	250'	205'	Eloy
PNL-72/73	D(10-6)13ccd submersible	32°33'04.18" 111°42'12.05"	515775	65247	Williams Well	Inorganic, Radiochem Radon, O, H isotopes	480'	380'	A-V
PNL-74	D(6-2)10cbb submersible	32°55'07.69" 112°08'58.28"	900908	29270	Patten Well	Inorganic, Radiochem Radon, O, H isotopes	900'	373'	M-S
5th Field Trip, November 3, 2005 – Towne & Garcia (Equipment Blank, PNL-86)									
PNL-76/77	D(5-7)26bbb submersible	32°58'00.268" 111°37'01.726"	638516	65426	Gustafson Well	Inorganic, Radon O, H isotopes	568'	195'	Eloy
PNL-78	D(6-9)04aa submersible	32°56'16.434" 111°24'47.040"	620899	30376	North Well	Inorganic, Radon O, H isotopes	545'	296'	Eloy
PNL-79	D(5-10)25ccc submersible	32°35'21.41" 111°28'08.58"	569199	65427	Williams Well	Inorganic, Radon O, H isotopes	510'	340'	Eloy
PNL-80	D(6-9)7 submersible	32°55'03.643" 111°27'43.252"	-	65466	Campbell Well #1	Inorganic, Radon O, H isotopes	'	'	Eloy
PNL-81	D(6-9)7 submersible	32°55'11.246" 111°27'44.579"	-	65467	Campbell Well #2	Inorganic O, H isotopes	'	'	Eloy
PNL-82	D(5-6)18aba submersible	32°59'41.853" 111°46'43.142"	578361	65428	Guthrie Well	Inorganic, Radiochem Radon, O, H isotopes	485'	400'	Eloy
PNL-83	D(6-3)31cac submersible	32°51'25.171" 112°04'47.637"	583234	65429	Turmac Well	Inorganic, Radiochem O, H isotopes	456'	300'	M-S
PNL-84/85	D(6-2)24aad submersible	32°53'47.879" 112°05'05.018"	592602	65430	Wheeler Well	Inorganic, Radiochem Radon, O, H isotopes	900'	655'	M-S
6th Field Trip, January 11, 2006 – Towne									
PNL-87/88	D(7-2)24aa submersible	32°48'24.105" 112°14'36.806"	801514	65430	HQ Well	Inorganic, Radiochem Radon, O, H isotopes	570'	-	V-V
PNL-89	D(8-1)14ba submersible	32°4415.285" 112°13'49.890"	640518	32689	South Vekol Well	Inorganic, Radon O, H isotopes	400'	318'	V-V
PNL-90	D(7-4)31aa pump jack	32°46'35.746" 111°58'58.267"	601920	65526	Santa Rosa Well	Inorganic, Radiochem O, H isotopes	1400'	360'	M-S
PNL-91	D(7-3)35bbb submersible	32°46'54.691" 112°01'51.611"	601919	31261	Well #3	Inorganic, Radon O, H isotopes	300'	200'	M-S
PNL-92	D(7-3)21ddb submersible	32°48'03.839" 112°03'13.233"	601921	31260	Art's Well	Inorganic, Radiochem O, H isotopes	400'	220'	M-S
PNL-93	D(7-4)4cbc turbine	32°50'38.969" 111°57'44.684"	631258	31266	WGA1-1	Inorganic O, H isotopes	1000'	500'	M-S

Appendix A. Data for Sample Sites, Pinal AMA, 2005-2006—Continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Sub-basin
7th Field Trip, January 18, 2006 – Towne (Equipment Blank, PNL-99)									
PNL-94/95	D(7-1)18aba windmill	32°49'28.827" 112°11'30.829"	634115	31256	Antelope Well	Inorganic, Radiochem Radon, O, H isotopes	340'	295'	V-V
PNL-96	D(6-1)22bcb submersible	32°53'22.663" 112°15'12.831"	623565	65546	Hett Well	Inorganic, Radiochem Radon, O, H isotopes	270'	225'	V-V
PNL-97	D(9-9)31ddd turbine	32°35'20.40" 111°28'56.16"	615624	33848	S-13	Inorganic O, H isotopes	690'	494'	Eloy
PNL-98	D(10-6)23bcc submersible	32°32'39.359" 111°43'21.951"	599200	34155	Well #3	Inorganic, Radiochem Radon, O, H isotopes	800'	174'	A-V
PNL-100	D(9-7)19ddd turbine	32°37'03.714" 111°39'16.507"	507861	65547	C-120-#1	Inorganic O, H isotopes	1555'	491'	Eloy
PNL-101	-	-	-	-	Santa Cruz River	O, H isotopes	-	-	Eloy
8th Field Trip, March 15 , 2006 – Towne (Equipment Blank, PNL-108)									
PNL-102	D(11-6)21cdd turbine	32°26'55.345" 111°45'07.671"	606226	34476	Well #4	Inorganic, Radon O, H isotopes	1000'	260'	A-V
PNL-103/04	D(11-6)22ddd turbine	32°26'55.326" 111°43'35.287"	615753	34480	Well #1	Inorganic, Radiochem Radon, O, H isotopes	1300'	540'	A-V
PNL-105	D(11-6)22cdd turbine	32°26'55.265" 111°44'06.166"	615752	34479	Well #2	Inorganic O, H isotopes	420'	340'	A-V
PNL-106	-	-	-	-	Greene Wash	O, H isotopes	-	-	Eloy
PNL-107	-	-	-	-	Winter Precip.	O, H isotopes	-	-	Eloy
9th Field Trip, April 27 , 2006 – Towne									
PNL-109	D(5-9)19aab turbine	32°59'17.332" 111°27'27.209"	621945	28784	#111	Inorganic, Radon O, H isotopes	800'	195'	Eloy
PNL-110	D(6-8)4dad turbine	32°55'48.970" 111°30'56.412"	605732	30592	Alfalfa Well	Inorganic O, H isotopes	375'	165'	Eloy
PNL-111/12	D(11-8)16cb submersible	32°28'24.559" 111°32'25.453"	632574	66196	Stump Mine Well	Inorganic, Radiochem Radon, O, H isotopes	240'	30'	Eloy
PNL-113	D(10-9)10aaa turbine	32°34'12.712" 111°23'51.041"	620606	34205	S-10A #1	Inorganic O, H isotopes	752'	165'	Eloy
10th Field Trip, May 2 , 2006 – Towne (Equipment Blank, PNL-118)									
PNL-114	D(4-2)24ccc turbine	33°03'30.596" 112°07'01.048"	622487	27268	Dairy Well	Inorganic O, H isotopes	960'	480'	M-S
PNL-115	D(4-3)33add turbine	33°02'11.454" 112°02'50.806"	622128	27354	E-10-12 #1	Inorganic O, H isotopes	500'	200'	M-S
PNL-116	D(5-3)31dcd turbine	32°56'23.009" 112°05'26.920"	801350	28185	WNB1-1	Inorganic O, H isotopes	1200'	650'	M-S
PNL-119/20	D(7-5)19add turbine	32°47'57.393" 111°51'37.410"	613934	31362	WC1-1	Inorganic O, H isotopes	960'	540'	M-S

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006

Site #	**MCL Exceedances**	**Temp** (ºC)	**pH-field** (su)	**pH-lab** (su)	**SC-field** (uS/cm)	**SC-lab** (uS/cm)	**TDS** (mg/l)	**Hard** (mg/l)	**Hard - cal** (mg/l)	**Turb** (ntu)
PNL-1	TDS	31.9	7.56	*8.0*	1053	1100	**680**	220	220	*0.14*
PNL-2/3	TDS	29.7	7.76	*8.15*	890	940	**545**	130	130	*0.08*
PNL-4	-	26.9	7.74	*8.1*	760	810	490	190	190	*0.03*
PNL-5/6	TDS, Cl, SO_4, NO_3,	25.7	7.23	*7.55*	2578	2700	**1800**	630	640	*0.18*
PNL-8	TDS, F, Gross α	30.3	7.44	8.0	901	930	**570**	250	260	0.54
PNL-9	TDS, NO_3,	28.3	7.87	8.2	830	870	**530**	170	180	0.00
PNL-10	As	30.1	8.34	8.5	502	530	320	31	37	0.01
PNL-11	As	33.0	8.44	8.4	609	640	390	66	69	0.80
PNL-12	TDS	29.0	7.84	8.1	1229	1300	**770**	330	340	0.04
PNL-13	TDS, SO_4, NO_3, As, F	29.4	8.06	8.3	1656	1700	**1100**	180	180	0.00
PNL-14	TDS, Cl	29.2	7.89	8.1	2018	2100	**1300**	430	410	0.04
PNL-15	TDS, Cl, SO_4, NO_3, F, Gross α	32.0	7.88	8.2	2243	2400	**1500**	270	270	0.01
PNL-17	TDS	27.8	7.28	8.0	902	950	**600**	300	300	0.03
PNL-18	TDS, As	28.8	7.37	8.0	1132	1200	**830**	380	370	0.76
PNL-19	-	29.0	8.05	8.2	377	390	240	61	63	0.47
PNL-20	TDS, As	29.0	7.45	8.0	1058	1100	**700**	350	340	0.02
PNL-21	As	33.6	8.16	8.2	431	440	270	51	54	0.00
PNL-22	pH-field, As	36.0	**9.15**	9.1	539	550	340	ND	ND	0.02
PNL-23	TDS, Cl, SO_4, NO_3,	24.5	7.08	7.8	2889	3000	**2100**	840	830	0.04
PNL-24	TDS, Cl, SO_4,	26.7	7.19	7.8	1873	2000	**1300**	640	620	0.05
PNL-25	TDS, Cl, SO_4, NO_3,	24.9	7.40	7.9	1884	2000	**1300**	590	580	0.08
PNL-26	TDS, NO_3,	25.4	7.37	7.9	1136	1200	**760**	390	400	0.03
PNL-27	As	29.9	7.92	8.3	567	580	350	78	78	0.10
PNL-28	As	28.7	7.81	8.2	637	660	420	130	130	0.13
PNL-29	pH-field, As	35.1	**8.64**	9.0	433	440	270	ND	ND	0.00
PNL-30/31	TDS, Cl, SO_4, NO_3, As, **F**	26.4	7.62	8.0	2404	2500	**1700**	350	320	0.50
PNL-32	TDS, Cl, SO_4,	26.9	7.39	8.0	1683	1800	**1100**	470	470	0.01
PNL-33/34	TDS, Cl, SO_4,	25.6	7.28	7.65	2012	2100	**1300**	535	500	0.18

bold = constituent level exceeds Primary or Secondary MCL
F = fluoride concentration exceeds both Primary and Secondary MCLs

italics = constituent exceeded holding time
F = fluoride concentration exceeds only Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	MCL Exceedances	Temp (ºC)	pH-field (su)	pH-lab (su)	SC-field (uS/cm)	SC-lab (uS/cm)	TDS (mg/l)	Hard (mg/l)	Hard - cal (mg/l)	Turb (ntu)
PNL-35	TDS	21.4	7.21	*7.9*	1485	1600	**970**	420	400	*0.01*
PNL-42/43	-	25.2	7.59	*7.99*	763	770	460	170	180	0.08
PNL-45	TDS, Cl, SO_4	21.8	7.03	*7.9*	1839	1900	**1200**	550	560	0.01
PNL-46	TDS, SO_4	21.8	6.99	*8.0*	1453	1500	**940**	400	400	0.04
PNL-47	TDS, Cl, SO_4, NO_3	24.4	7.05	*8.0*	3082	3100	**2200**	840	830	0.30
PNL-48	As, NO_3	29.1	7.44	*8.1*	751	770	490	190	190	0.02
PNL-49/50	-	28.9	7.57	*8.2*	581	590	370	130	130	0.19
PNL-51	As	31.8	8.08	*8.4*	364	360	230	36	35	0.03
PNL-52	As	31.3	7.96	*8.3*	465	460	300	64	64	0.01
PNL-53	As	28.4	8.11	8.4	458	450	280	36	36	0.00
PNL-54	TDS, NO_3	25.8	7.34	8.0	1043	1100	**680**	360	360	0.45
PNL-55	TDS, Cl, SO_4, NO_3	25.9	6.97	8.0	1814	1900	**1400**	720	700	0.12
PNL-56	TDS	28.1	7.44	8.2	983	1000	**650**	310	300	0.01
PNL-57	-	27.9	8.15	8.4	536	540	320	58	60	0.04
PNL-58	TDS, Cl, SO_4 NO_3, **F**, As	24.4	7.73	8.2	2209	2200	**1400**	210	200	0.00
PNL-59	TDS, **F**, As	31.0	8.02	8.4	1064	1100	**630**	50	49	0.01
PNL-60	TDS, Cl, F, As	31.4	7.86	8.3	1773	1800	**1000**	140	130	0.01
PNL-61	As	32.7	8.27	8.4	606	600	350	40	37	0.01
PNL-62	TDS, Cl, SO_4, F, NO_3, As	23.7	7.47	8.1	2968	3000	**2000**	380	370	0.43
PNL-64	TDS	29.0	7.24	8.1	968	1000	**570**	240	240	0.01
PNL-65	As	31.8	7.86	8.3	587	600	360	120	120	0.79
PNL-66	TDS, Cl, SO_4, NO_3	24.3	7.49	7.8	2178	2200	**1400**	590	590	0.33
PNL-67	pH-field, As, Fe	28.6	**8.59**	9.0	421	420	250	ND	ND	10
PNL-68/69	TDS, Cl, SO_4, NO_3	25.9	7.44	7.75	2732	2800	**2000**	960	980	0.605
PNL-70	TDS, F	31.8	7.80	8.1	1137	1200	**700**	170	170	0.01
PNL-71	As	-	-	8.4	767	760	450	53	54	0.22
PNL-72/73	TDS, Cl, **F** Gross α, U	29.6	7.94	7.76	1608	1600	**1000**	190	180	ND
PNL-74	TDS, **F**	30.7	8.31	8.3	926	950	**560**	88	90	0.02
PNL-76/77	TDS, Cl, SO_4, NO_3	22.9	6.57	*7.44*	5920	6150	**4500**	1950	2000	*0.21*

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	MCL Exceedances	Temp (ºC)	pH-field (su)	pH-lab (su)	SC-field (uS/cm)	SC-lab (uS/cm)	TDS (mg/l)	Hard (mg/l)	Hard - cal (mg/l)	Turb (ntu)
PNL-78	As	27.0	7.66	*8.3*	645	670	390	74	73	*0.98*
PNL-79	**F**, As	29.9	7.87	*8.1*	859	890	490	120	120	*ND*
PNL-80	TDS, Cl, SO_4, **F**	23.9	7.63	*8.1*	2233	2300	**1500**	390	380	*0.26*
PNL-81	TDS, Cl, SO_4, F, NO_3	24.5	7.45	*8.0*	3271	3400	**2500**	700	670	*4.8*
PNL-82	TDS, SO_4, NO_3	26.2	8.18	8.2	1833	1900	**1200**	65	60	0.21
PNL-83	F, Gross α, U	30.5	8.11	8.4	648	670	420	110	110	0.06
PNL-84/85	TDS, Cl, SO_4, **F**	33.6	8.48	8.3	1852	1900	**1100**	65	60	*0.535*
PNL-87/88	pH-field	26.8	**8.66**	8.31	462	470	315	41.5	44	*0.12*
PNL-89	pH-field	27.6	**8.78**	8.2	642	660	390	75	77	*0.03*
PNL-90	pH-field , TDS, F	30.6	**9.46**	8.4	1025	1040	**610**	59	59	*3.1*
PNL-91	pH-field	29.2	**9.03**	8.2	622	620	390	120	120	*0.73*
PNL-92	Gross α	27.5	8.14	8.0	606	590	350	190	190	*0.54*
PNL-93	TDS, As	26.6	8.44	8.3	987	990	**610**	83	83	*8.30*
PNL-94/95		28.0	7.39	8.11	437	420	280	145	140	2.25
PNL-96		27.2	7.72	8.3	571	570	360	89	90	1.8
PNL-97		27.5	7.59	8.2	667	660	430	160	170	1.7
PNL-98	TDS	29.2	7.79	8.2	983	980	**600**	150	150	0.23
PNL-100	pH-field, As	24.7	**8.54**	8.3	491	430	260	42	43	0.04
PNL-102	TDS, Cl, NO_3	28.4	7.52	8.3	1474	1300	**820**	400	400	-
PNL-103/04	As	35.5	8.09	8.14	608	560	350	46.5	49	0.14
PNL-105	As	37.1	8.06	8.4	512	470	270	37	38	0.06
PNL-109	TDS, Cl, SO_4	23.8	7.30	8.0	2067	2100	**1300**	600	600	0.18
PNL-110	TDS, Cl, NO_3 SO_4	24.4	7.16	7.8	4285	4400	**3000**	1300	1300	1.6
PNL-111/12	TDS, NO_3	24.9	7.46	7.9	1028	1100	**625**	420	400	ND
PNL-113	As	26.9	7.50	8.1	730	750	470	200	200	0.09
PNL-114	As, F	29.1	8.38	8.4	649	660	380	24	25	0.04
PNL-115	TDS, NO_3, Cl, SO_4	25.5	7.11	7.8	3319	3400	**2400**	1400	1400	0.33
PNL-116	TDS, As, F	30.6	7.97	8.2	1189	1200	**700**	76	75	0.03
PNL-119/20	As	28.9	8.11	8.3	470	470	295	54	53	0.015

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	T. Alk (mg/l)	Bicarbonate (mg/l)	Carbonate (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
PNL-1	79	5.6	130	5.1	80	98	ND	150	190
PNL-2/3	46	4.1	130	2.85	75	92	ND	150	110
PNL-4	57	11	83	3.0	130	160	ND	100	88
PNL-5/6	195	34	305	2.8	195	230	ND	**405**	**620**
PNL-8	81	13	90	1.8	210	260	ND	97	71
PNL-9	57	8.6	100	3.4	95	120	ND	92	130
PNL-10	10	2.8	95	1.3	130	150	4.0	31	61
PNL-11	19	5.2	97	0.86	110	130	4.2	72	47
PNL-12	110	15	120	4.0	110	130	ND	210	180
PNL-13	38	20	290	2.9	180	220	ND	220	**300**
PNL-14	93	43	230	4.8	84	100	ND	**530**	43
PNL-15	73	20	420	5.6	160	200	ND	**330**	**410**
PNL-17	100	11	66	3.3	120	140	ND	140	110
PNL-18	130	12	78	4.1	110	134	ND	190	150
PNL-19	23	1.4	58	2.4	130	150	ND	15	46
PNL-20	110	17	89	3.5	160	200	ND	120	180
PNL-21	18	2.1	70	1.8	100	130	ND	40	43
PNL-22	2.2	ND	110	0.62	95	82	16	43	76
PNL-23	270	38	360	5.4	260	320	ND	**310**	**680**
PNL-24	210	24	150	5.1	160	200	ND	**320**	**350**
PNL-25	190	25	170	5.1	100	130	ND	**340**	**370**
PNL-26	130	18	88	3.5	150	180	ND	100	200
PNL-27	21	6.3	87	2.1	120	140	ND	51	63
PNL-28	34	10	83	2.5	130	150	ND	61	65
PNL-29	2.2	ND	92	0.71	110	100	13	26	51
PNL-30/31	85	26	395	2.65	240	290	ND	**258.5**	**545**
PNL-32	150	23	170	6.8	130	160	ND	**290**	**310**
PNL-33/34	155	31.5	210	7.1	200	250	ND	**365**	**250**

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	T. Alk (mg/l)	Bicarbonate (mg/l)	Carbonate (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
PNL-35	120	24	160	4.8	220	270	ND	220	220
PNL-42/43	47	13.5	86.5	4.9	160	200	ND	104	71.5
PNL-45	170	33	180	5.4	240	290	ND	**290**	**360**
PNL-46	120	24	160	4.7	220	270	ND	210	**270**
PNL-47	260	44	160	7.1	190	230	ND	**440**	**780**
PNL-48	64	7.2	82	3.0	160	200	ND	48	90
PNL-49/50	46	4.1	67	2.7	130	160	ND	41	71.5
PNL-51	14	ND	62	2.0	110	130	ND	17	41
PNL-52	18	4.6	70	2.6	110	140	ND	24	70
PNL-53	12	1.5	80	1.9	110	130	2.1	30	56
PNL-54	120	15	70	3.5	130	160	ND	90	180
PNL-55	230	31	95	3.9	150	180	ND	**280**	**350**
PNL-56	100	12	71	3.4	120	140	ND	140	130
PNL-57	15	5.5	86	2.2	110	130	ND	40	71
PNL-58	62	12	400	2.4	320	390	ND	**310**	**360**
PNL-59	10	5.9	210	2.7	240	280	4.3	100	130
PNL-60	29	14	310	3.8	170	200	ND	**300**	190
PNL-61	15	ND	100	2.4	74	89	ND	54	90
PNL-62	110	22	520	2.1	260	310	ND	**390**	**630**
PNL-64	74	14	100	4.8	180	220	ND	160	63
PNL-65	33	8.9	77	2.4	140	170	ND	40	97
PNL-66	180	34	250	6.8	200	250	ND	**370**	**390**
PNL-67	2.1	ND	87	0.70	90	90	9.8	21	91
PNL-68/69	310	49.5	240	3.2	130	160	ND	**430**	**640**
PNL-70	61	4.2	180	3.0	110	130	ND	140	210
PNL-71	12	5.9	140	1.5	100	120	2.2	81	130
PNL-72/73	54.5	11.5	235	3.1	200	250	ND	160	**330**
PNL-74	36	ND	160	1.2	36	44	ND	100	210
PNL-76/77	630	94.5	645	10.25	190	230	ND	**1300**	**1550**

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	T. Alk (mg/l)	Bicarbonate (mg/l)	Carbonate (mg/l)	Chloride (mg/l)	Sulfate (mg/l)
PNL-78	23	3.7	100	3.4	140	170	ND	75	39
PNL-79	36	7.2	120	2.0	100	130	ND	150	60
PNL-80	120	20	330	2.0	260	310	ND	**300**	**380**
PNL-81	200	41	480	2.2	250	310	ND	**330**	**1000**
PNL-82	25	ND	334	3.1	84	100	ND	240	**350**
PNL-83	29	8.9	98	1.4	240	280	4.5	31	40
PNL-84/85	24	ND	345	5.65	120	140	ND	**290**	**310**
PNL-87/88	9.9	4.4	88	3.2	235	280	3.8	3.7	4.0
PNL-89	24	4.1	100	2.4	150	190	ND	62	55
PNL-90	18	3.4	180	1.6	98	110	2.7	160	130
PNL-91	22	16	88	1.6	250	310	ND	30	21
PNL-92	47	19	53	1.6	260	320	ND	21	13
PNL-93	20	8.1	160	2.5	150	180	ND	120	120
PNL-94/95	22.5	21.5	40	1.2	185	230	ND	15	11
PNL-96	24	7.2	88	3.1	230	280	ND	20	22
PNL-97	57	6.1	70	2.7	160	190	ND	42	86
PNL-98	45	9.2	130	3.0	150	180	ND	110	150
PNL-100	14	2.0	72	1.6	96	120	ND	30	58
PNL-102	120	24	96	4.1	120	140	ND	**270**	95
PNL-103/04	16.5	1.2	96	2.9	125	150	ND	64	37.5
PNL-105	13	1.3	84	2.7	130	160	ND	42	25
PNL-109	190	31	220	6.5	140	170	ND	**340**	**410**
PNL-110	410	62	500	7.6	190	230	ND	**790**	**1000**
PNL-111/12	97.5	41.5	57.5	1.95	235	290	ND	79	73.5
PNL-113	67	8.5	75	2.5	180	220	ND	46	210
PNL-114	6.6	2	140	1.6	150	180	2.9	49	83
PNL-115	420	84	220	5.6	130	150	ND	**630**	**770**
PNL-116	16	8.3	230	2.4	210	250	ND	150	130
PNL-119/20	12	5.65	82	1.35	150	180	ND	23	51.5

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Nitrate-Nitrite-N (mg/l)	Nitrate-N (mg/l)	Nitrite-N (mg/l)	TKN (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)	SAR (value)	Irrigation Quality
PNL-1	0.93	0.93	*ND*	0.085	ND	ND	3.8	C3-S1
PNL-2/3	0.19	0.19	*ND*	0.058	ND	0.027	4.9	C3-S1
PNL-4	0.074	0.074	*ND*	0.067	ND	0.040	2.6	C3-S1
PNL-5/6	**14**	**14**	*ND*	ND	ND	ND	5.9	C4-S2
PNL-8	6.0	6.0	ND	ND	ND	0.028	2.4	C3-S1
PNL-9	**11**	**11**	ND	ND	ND	ND	3.3	C3-S1
PNL-10	2.3	2.3	ND	ND	ND	0.094	6.8	C2-S1
PNL-11	9.6	9.6	ND	ND	ND	0.022	5.1	C2-S1
PNL-12	7.7	7.7	ND	ND	ND	0.031	2.8	C3-S1
PNL-13	**14**	**14**	ND	ND	ND	0.021	9.5	C3-S2
PNL-14	0.34	0.34	ND	ND	ND	0.032	4.9	C3-S2
PNL-15	**31**	**31**	ND	ND	ND	0.16	11.2	C4-S3
PNL-17	5.2	5.2	ND	0.050	ND	ND	1.7	C3-S1
PNL-18	9.6	9.6	ND	ND	ND	0.11	1.8	C3-S1
PNL-19	0.91	0.91	ND	ND	ND	ND	2.8	C2-S1
PNL-20	4.5	4.5	ND	0.094	ND	ND	2.1	C3-S1
PNL-21	1.2	1.2	ND	ND	ND	0.027	4.2	C2-S1
PNL-22	3.1	3.1	ND	ND	ND	0.020	20.4	C2-S4
PNL-23	**28**	**28**	ND	ND	ND	ND	5.4	C4-S2
PNL-24	8.8	8.8	ND	0.15	ND	0.060	2.6	C3-S1
PNL-25	**10**	**10**	ND	0.12	ND	0.22	3.1	C3-S1
PNL-26	**23**	**23**	ND	ND	ND	ND	1.9	C3-S1
PNL-27	3.0	3.0	ND	ND	ND	ND	4.3	C2-S1
PNL-28	6.8	6.8	ND	ND	ND	0.020	3.2	C2-S1
PNL-29	1.0	1.0	ND	0.089	ND	0.048	17.1	C2-S3
PNL-30/31	**17**	**17**	ND	ND	ND	0.032	10.2	C4-S3
PNL-32	5.1	5.1	ND	0.11	ND	0.028	3.4	C3-S1
PNL-33/34	9.25	9.25	ND	0.87	ND	0.056	4.5	C3-S1
PNL-35	5.0	5.0	*ND*	0.12	ND	0.060	3.5	C3-S1

bold = constituent level exceeds Primary or Secondary MCL *italics* = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Nitrate-Nitrite-N (mg/l)	Nitrate-N (mg/l)	Nitrite-N (mg/l)	TKN (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)	SAR (value)	Irrigation Quality
PNL-42/43	0.074	0.074	*ND*	0.19	ND	0.091	2.9	C3-S1
PNL-45	6.2	6.2	*ND*	0.089	ND	0.019	3.3	C3-S1
PNL-46	7.1	7.1	*ND*	0.066	ND	ND	3.5	C3-S1
PNL-47	**13**	**13**	ND	ND	ND	ND	2.4	C4-S1
PNL-48	**13**	**13**	ND	ND	ND	ND	2.6	C3-S1
PNL-49/50	6.2	6.2	ND	ND	ND	ND	2.5	C2-S1
PNL-51	1.1	1.1	ND	ND	ND	ND	4.6	C2-S1
PNL-52	0.76	0.76	ND	ND	ND	ND	3.8	C2-S1
PNL-53	1.4	1.4	ND	ND	ND	ND	5.8	C2-S1
PNL-54	**25**	**25**	ND	ND	ND	0.053	1.6	C3-S1
PNL-55	**11**	**11**	ND	ND	ND	ND	1.6	C3-S1
PNL-56	5.6	5.6	ND	ND	ND	ND	1.8	C3-S1
PNL-57	4.8	4.8	ND	ND	ND	0.021	4.8	C2-S1
PNL-58	**11**	**11**	ND	0.094	ND	0.40	12.2	C3-S3
PNL-59	3.1	3.1	ND	0.050	ND	ND	13.0	C3-S3
PNL-60	7.8	7.8	ND	ND	ND	0.027	11.8	C3-S3
PNL-61	3.1	3.1	ND	ND	ND	ND	7.1	C2-S1
PNL-62	**16**	**16**	ND	0.15	ND	0.026	11.8	C4-S3
PNL-64	0.48	0.48	ND	ND	ND	ND	2.8	C3-S1
PNL-65	2.7	2.7	ND	ND	ND	ND	3.1	C2-S1
PNL-66	**14**	**14**	ND	0.24	ND	0.024	4.5	C3-S1
PNL-67	0.26	0.26	ND	ND	ND	0.026	16.5	C2-S3
PNL-68/69	**27.5**	**27.5**	ND	ND	ND	ND	3.3	C4-S1
PNL-70	8.5	8.5	ND	ND	ND	0.023	6.0	C3-S2
PNL-71	5.2	5.2	ND	ND	ND	ND	8.3	C3-S2
PNL-72/73	9.55	9.55	ND	ND	ND	0.023	9.2	C3-S2
PNL-74	5.9	5.9	ND	ND	ND	0.021	7.3	C3-S2
PNL-76/77	**30.25**	**30.25**	*ND*	0.30	ND	ND	6.6	C4-S2

bold = constituent level exceeds Primary or Secondary MCL *italics* = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Nitrate-Nitrite-N (mg/l)	Nitrate-N (mg/l)	Nitrite-N (mg/l)	TKN (mg/l)	Ammonia (mg/l)	Total Phosphorus (mg/l)	SAR (value)	Irrigation Quality
PNL-78	4.3	4.3	*ND*	ND	ND	0.020	5.1	C2-S1
PNL-79	1.0	1.0	*ND*	ND	ND	ND	4.8	C3-S1
PNL-80	2.2	2.2	*ND*	0.068	ND	ND	7.3	C4-S2
PNL-81	**13**	**13**	ND	0.080	ND	ND	8.1	C4-S2
PNL-82	**24**	**24**	ND	ND	ND	ND	18.4	C3-S4
PNL-83	2.1	2.1	ND	ND	ND	ND	4.1	C2-S1
PNL-84/85	2.6	2.6	ND	0.0675	ND	ND	19.1	C3-S4
PNL-87/88	3.5	3.5	*ND*	0.31	ND	ND	6.2	C2-S1
PNL-89	7.9	7.9	*ND*	0.03	ND	ND	5.0	C2-S1
PNL-90	9.1	9.1	*ND*	ND	ND	ND	10.2	C3-S2
PNL-91	3.5	3.5	*ND*	ND	ND	ND	3.5	C2-S1
PNL-92	3.9	3.9	*ND*	ND	ND	ND	1.6	C2-S1
PNL-93	9.6	9.6	*ND*	ND	ND	ND	7.6	C3-S2
PNL-94/95	3.2	3.2	ND	ND	ND	ND	1.4	C2-S1
PNL-96	4.5	4.5	ND	ND	ND	ND	4.0	C2-S1
PNL-97	6.8	6.8	ND	ND	ND	0.020	2.4	C2-S1
PNL-98	5.9	5.9	ND	ND	ND	ND	4.6	C3-S1
PNL-100	3.1	3.1	ND	ND	ND	ND	4.8	C2-S1
PNL-102	**10**	**10**	ND	ND	ND	ND	2.1	C3-S1
PNL-103/04	4.4	4.4	ND	ND	ND	ND	5.9	C2-S1
PNL-105	ND	ND	ND	ND	ND	ND	5.9	C2-S1
PNL-109	8.4	8.4	ND	0.094	ND	ND	3.9	C3-S1
PNL-110	**20**	**20**	ND	0.25	ND	ND	6.1	C4-S2
PNL-111/12	**28.5**	**28.5**	ND	0.34	ND	ND	1.2	C3-S1
PNL-113	7.5	7.5	ND	ND	ND	ND	2.3	C2-S1
PNL-114	2.1	2.1	ND	ND	ND	ND	12.3	C2-S2
PNL-115	**18**	**18**	ND	0.33	ND	ND	2.6	C4-S1
PNL-116	6.7	6.7	ND	0.093	ND	ND	11.6	C3-S2
PNL-119/20	1.7	1.7	ND	ND	ND	ND	4.9	C2-S1

bold = constituent level exceeds Primary or Secondary MCL   *italics* = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Antimony (mg/l)	Arsenic (mg/l)	Barium (mg/l)	Beryllium (mg/l)	Boron (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Fluoride (mg/l)
PNL-1	ND	ND	ND	ND	0.21	ND	ND	ND	0.29
PNL-2/3	ND	ND	ND	ND	0.13	ND	ND	ND	0.455
PNL-4	ND	ND	ND	ND	0.13	ND	ND	ND	0.73
PNL-5/6	ND	ND	ND	ND	0.69	ND	ND	ND	0.82
PNL-8	ND	ND	ND	ND	0.23	ND	ND	ND	**3.1**
PNL-9	ND	ND	ND	ND	0.11	ND	ND	ND	0.36
PNL-10	ND	**0.040**	ND	ND	0.18	ND	0.016	ND	1.3
PNL-11	ND	**0.018**	ND	ND	2.4	ND	ND	ND	0.73
PNL-12	ND	ND	ND	ND	0.18	ND	ND	ND	0.15
PNL-13	ND	**0.015**	ND	ND	0.52	ND	ND	ND	**2.6**
PNL-14	ND	ND	0.36	ND	0.19	ND	ND	ND	0.61
PNL-15	ND	ND	ND	ND	0.63	ND	ND	ND	**2.5**
PNL-17	ND	ND	0.13	ND	ND	ND	ND	ND	0.21
PNL-18	ND	**0.013**	0.12	ND	ND	ND	ND	ND	0.27
PNL-19	ND	ND	ND	ND	ND	ND	ND	ND	0.54
PNL-20	ND	**0.028**	ND	ND	0.19	ND	ND	ND	0.57
PNL-21	ND	**0.028**	0.15	ND	0.10	ND	ND	ND	1.2
PNL-22	ND	**0.044**	ND	ND	0.20	ND	0.019	ND	1.8
PNL-23	ND	ND	ND	ND	1.0	ND	ND	ND	0.25
PNL-24	ND	ND	ND	ND	0.22	ND	ND	ND	0.26
PNL-25	ND	ND	ND	ND	0.18	ND	ND	ND	0.36
PNL-26	ND	ND	ND	ND	0.10	ND	ND	ND	0.30
PNL-27	ND	**0.020**	ND	ND	0.20	ND	ND	ND	1.6
PNL-28	ND	**0.014**	ND	ND	0.17	ND	ND	ND	1.2
PNL-29	ND	**0.031**	ND	ND	0.16	ND	0.027	ND	1.4
PNL-30/31	ND	**0.013**	ND	ND	3.0	ND	ND	ND	**5.8**
PNL-32	ND	ND	ND	ND	0.34	ND	ND	ND	0.45
PNL-33/34	ND	ND	ND	ND	0.25	ND	ND	ND	0.64

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Antimony (mg/l)	Arsenic (mg/l)	Barium (mg/l)	Beryllium (mg/l)	Boron (mg/l)	Cadmium (mg/l)	Chromium (mg/l)	Copper (mg/l)	Fluoride (mg/l)
PNL-35	ND	ND	ND	ND	0.23	ND	ND	ND	0.87
PNL-42/43	ND	ND	ND	ND	0.10	ND	ND	0.011	0.925
PNL-45	ND	ND	ND	ND	0.21	ND	ND	ND	0.65
PNL-46	ND	ND	ND	ND	0.17	ND	ND	ND	0.75
PNL-47	ND	ND	ND	ND	1.9	ND	ND	ND	0.79
PNL-48	ND	**0.016**	0.11	ND	0.10	ND	ND	ND	0.54
PNL-49/50	ND	ND	0.115	ND	ND	ND	ND	ND	0.48
PNL-51	ND	**0.025**	ND	ND	0.21	ND	ND	ND	0.64
PNL-52	ND	**0.018**	ND	ND	0.14	ND	0.012	ND	0.95
PNL-53	ND	**0.014**	ND	ND	0.14	ND	0.017	ND	0.79
PNL-54	ND	ND	ND	ND	ND	ND	ND	ND	0.18
PNL-55	ND	ND	ND	ND	0.16	ND	ND	ND	0.23
PNL-56	ND	ND	ND	ND	ND	ND	ND	ND	0.29
PNL-57	ND	ND	ND	ND	0.19	ND	0.018	ND	0.89
PNL-58	ND	**0.031**	ND	ND	0.96	ND	ND	ND	**4.1**
PNL-59	ND	**0.046**	ND	ND	0.61	ND	0.015	ND	**4.3**
PNL-60	ND	**0.019**	ND	ND	0.53	ND	ND	ND	**3.0**
PNL-61	ND	**0.015**	ND	ND	0.13	ND	ND	ND	1.7
PNL-62	ND	**0.10**	ND	ND	1.0	ND	ND	ND	**3.2**
PNL-64	ND	ND	ND	ND	0.12	ND	ND	ND	0.50
PNL-65	ND	**0.018**	ND	ND	0.14	ND	ND	ND	1.8
PNL-66	ND	ND	ND	ND	0.75	ND	ND	ND	0.94
PNL-67	ND	**0.025**	ND	ND	0.12	ND	ND	ND	1.8
PNL-68/69	ND	ND	ND	ND	0.615	ND	ND	0.017	0.62
PNL-70	ND	ND	ND	ND	0.29	ND	ND	ND	**3.0**
PNL-71	ND	**0.013**	ND	ND	0.26	ND	0.013	ND	1.2
PNL-72/73	ND	ND	ND	ND	1.55	ND	ND	ND	**4.3**
PNL-74	ND	ND	ND	ND	0.85	ND	0.035	ND	**7.2**
PNL-76/77	ND	ND	ND	ND	1.2	ND	ND	ND	0.155

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	**Antimony** (mg/l)	**Arsenic** (mg/l)	**Barium** (mg/l)	**Beryllium** (mg/l)	**Boron** (mg/l)	**Cadmium** (mg/l)	**Chromium** (mg/l)	**Copper** (mg/l)	**Fluoride** (mg/l)
PNL-78	ND	**0.010**	0.088	ND	0.23	ND	ND	ND	1.4
PNL-79	ND	**0.018**	0.080	ND	0.30	ND	ND	ND	**5.0**
PNL-80	ND	ND	ND	ND	1.8	ND	ND	ND	**2.6**
PNL-81	ND	ND	ND	ND	3.3	ND	ND	ND	**2.5**
PNL-82	ND	ND	ND	ND	0.63	ND	ND	ND	1.1
PNL-83	ND	ND	ND	ND	0.34	ND	ND	ND	**2.8**
PNL-84/85	ND	ND	ND	ND	0.865	ND	ND	ND	**8.15**
PNL-87/88	ND	0.0085	ND	ND	0.25	ND	ND	ND	0.825
PNL-89	ND	ND	ND	ND	0.23	ND	0.013	ND	0.61
PNL-90	ND	ND	ND	ND	0.34	ND	0.074	ND	**3.6**
PNL-91	ND	ND	ND	ND	0..31	ND	0.013	ND	1.9
PNL-92	ND	ND	0.12	ND	0.23	ND	ND	ND	0.85
PNL-93	ND	**0.045**	ND	ND	0.25	ND	0.012	ND	0.63
PNL-94/95	ND	ND	ND	ND	ND	ND	ND	ND	0.505
PNL-96	ND	0.0058	ND	ND	0.24	ND	ND	ND	0.67
PNL-97	ND	0.0054	ND	ND	ND	ND	ND	ND	0.47
PNL-98	ND	0.0079	ND	ND	0.34	ND	ND	ND	0.87
PNL-100	ND	**0.019**	ND	ND	ND	ND	0.012	ND	1.0
PNL-102	ND	0.0052	0.16	ND	0.11	ND	ND	0.010	0.22
PNL-103/04	ND	**0.0215**	ND	ND	0.15	ND	ND	ND	0.55
PNL-105	ND	**0.025**	ND	ND	0.14	ND	ND	ND	0.75
PNL-109	ND	ND	ND	ND	0.38	ND	ND	ND	0.71
PNL-110	ND	ND	ND	ND	2.0	ND	ND	ND	1.1
PNL-111/12	ND	ND	0.0865	ND	0.12	0.00345	ND	0.014	1.15
PNL-113	ND	**0.024**	0.10	ND	0.12	ND	ND	ND	0.59
PNL-114	ND	**0.018**	ND	ND	0.26	ND	0.020	ND	**2.3**
PNL-115	ND	ND	ND	ND	0.28	ND	ND	ND	0.36
PNL-116	ND	**0.018**	ND	ND	0.49	ND	0.010	ND	**3.7**
PNL-119/20	ND	**0.0175**	ND	ND	0.14	ND	ND	ND	0.625

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Iron (mg/l)	Lead (mg/l)	Manganese (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Selenium (mg/l)	Silver (mg/l)	Thallium (mg/l)	Zinc (mg/l)
PNL-1	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-2/3	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-4	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-5/6	ND	ND	ND	ND	ND	ND	ND	ND	0.135
PNL-8	ND	ND	ND	ND	ND	ND	ND	ND	0.41
PNL-9	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-10	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-11	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-12	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-13	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-14	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-15	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-17	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-18	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-19	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-20	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-21	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-22	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-23	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-24	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-25	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-26	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-27	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-28	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-29	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-30/31	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-32	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-33/34	**0.32**	ND	ND	ND	ND	ND	ND	ND	ND
PNL-35	ND	ND	ND	ND	ND	ND	ND	ND	ND

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Iron (mg/l)	Lead (mg/l)	Manganese (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Selenium (mg/l)	Silver (mg/l)	Thallium (mg/l)	Zinc (mg/l)
PNL-42/43	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-45	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-46	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-47	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-48	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-49/50	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-51	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-52	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-53	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-54	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-55	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-56	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-57	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-58	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-59	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-60	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-61	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-62	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-64	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-65	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-66	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-67	**0.38**	ND	ND	ND	ND	ND	ND	ND	ND
PNL-68/69	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-70	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-71	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-72/73	ND	ND	ND	ND	ND	0.0042	ND	ND	0.16
PNL-74	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-76/77	ND	ND	ND	ND	ND	ND	ND	ND	ND

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Iron (mg/l)	Lead (mg/l)	Manganese (mg/l)	Mercury (mg/l)	Nickel (mg/l)	Selenium (mg/l)	Silver (mg/l)	Thallium (mg/l)	Zinc (mg/l)
PNL-78	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-79	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-80	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-81	ND	ND	ND	ND	ND	ND	ND	ND	0.13
PNL-82	ND	ND	ND	ND	ND	ND	ND	ND	0.11
PNL-83	ND	ND	ND	ND	ND	ND	ND	ND	0.19
PNL-84/85	ND	ND	ND	ND	ND	ND	ND	ND	0.0515
PNL-87/88	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-89	ND	ND	ND	ND	ND	ND	ND	ND	0.069
PNL-90	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-91	ND	ND	ND	ND	ND	ND	ND	ND	0.30
PNL-92	ND	ND	ND	ND	ND	ND	ND	ND	0.30
PNL-93	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-94/95	ND	ND	ND	ND	ND	ND	ND	ND	0.15
PNL-96	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-97	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-98	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-100	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-102	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-103/04	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-105	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-109	ND	ND	ND	ND	ND	0.0063	ND	ND	ND
PNL-110	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-111/12	ND	0.0053	ND	ND	ND	ND	ND	ND	0.0955
PNL-113	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-114	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-115	ND	ND	ND	ND	ND	0.0093	ND	ND	ND
PNL-116	ND	ND	ND	ND	ND	ND	ND	ND	ND
PNL-119/20	ND	ND	ND	ND	ND	ND	ND	ND	ND

bold = constituent level exceeds Primary or Secondary MCL

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	**Radon-222** (pCi/L)	**Alpha** (pCi/L)	**Beta** (pCi/L)	**Ra-226** (pCi/L)	**Uranium** (µg/l)	**Pesticides** (µg/l)	**δ^{18} O** ($^0/_{00}$)	**δ D** ($^0/_{00}$)	**Type of Chemistry**
PNL-1	441	-	-	-	-	ND	-8.1	-58	sodium-mixed
PNL-2/3	-	4.5	4.4	-	-	ND	-8.05	-57	sodium-chloride
PNL-4	303	5.4	5.3	< LLD	< LLD	ND	-7.6	-54	mixed-mixed
PNL-5/6	307	-	-	-	-	-	-7.8	-59	sodium-mixed
PNL-8	6757	**49**	17	< LLD	14	-	-7.2	-50	mixed-mixed
PNL-9	818	-	-	-	-	ND	-7.8	-55	sodium-mixed
PNL-10	-	-	-	-	-	ND	-8.0	-57	sodium-mixed
PNL-11	2192	4.1	1.8	-	-	-	-8.8	-67	sodium-mixed
PNL-12	617	-	-	-	-	-	-8.3	-58	mixed-mixed
PNL-13	-	-	-	-	-	-	-8.3	-59	sodium-mixed
PNL-14	-	-	-	-	-	-	-7.6	-53	sodium-chloride
PNL-15	745	**23**	17	< LLD	11	-	-8.2	-59	sodium-mixed
PNL-16	-	-	-	-	-	-	-5.1	-32	-
PNL-17	290	-	-	-	-	-	- 9.1	- 63	calcium-mixed
PNL-18	-	-	-	-	-	-	- 8.9	- 62	calcium-mixed
PNL-19	382	-	-	-	-	-	- 8.7	- 61	sodium-bicarbonate
PNL-20	271	12	6.6	< LLD	-	ND	- 9.1	- 65	calcium-mixed
PNL-21	1086	2.5	1.5	-	-	-	- 9.5	- 65	sodium-mixed
PNL-22	791	2.2	1.7	-	-	ND	- 8.5	- 60	sodium-mixed
PNL-23	329	-	-	-	-	-	- 8.2	- 64	mixed-mixed
PNL-24	-	-	-	-	-	ND	- 7.8	- 59	calcium-mixed
PNL-25	365	-	-	-	-	-	- 7.6	- 58	mixed-mixed
PNL-26	-	-	-	-	-	ND	- 7.6	- 56	calcium-mixed
PNL-27	752	6.0	3.9	< LLD	-	-	- 8.3	- 58	sodium-mixed
PNL-28	-	-	-	-	-	-	- 8.2	- 58	sodium-mixed
PNL-29	-	-	-	-	-	-	- 8.2	- 57	sodium-mixed
PNL-30/31	-	-	-	-	-	ND	- 7.7	- 58.5	sodium-mixed

bold = Primary MCL Exceedance
LLD = Lower Limit of Detection
italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 (pCi/L)	Uranium (µg/l)	Pesticides (µg/l)	δ^{18} O ($^0/_{00}$)	δ D ($^0/_{00}$)	Type of Chemistry
PNL-32	-	-	-	-	-	ND	- 8.2	- 63	mixed-mixed
PNL-33/34	-	-	-	-	-	ND	- 8.1	- 63	mixed-chloride
PNL-35	203	-	-	-	-	-	- 8.1	- 63	mixed-mixed
PNL-37	-	-	-	-	-	-	- 1.8	- 10	-
PNL-38	-	-	-	-	-	-	- 9.1	- 75	-
PNL-39	-	-	-	-	-	-	- 6.7	- 53	-
PNL-40	-	-	-	-	-	-	- 10.5	- 84	-
PNL-41	-	-	-	-	-	-	- 8.6	- 64	-
PNL-42/43	238	1.8	5.5	-	-	-	- 10.0	- 73	sodium-mixed
PNL-44	-	-	-	-	-	-	- 10.6	- 79	-
PNL-45	-	-	-	-	-	-	- 7.7	- 64	mixed-mixed
PNL-46	-	-	-	-	-	-	- 8.8	- 66	mixed-mixed
PNL-47	146	-	-	-	-	-	- 7.8	- 60	calcium-mixed
PNL-48	232	-	-	-	-	-	- 8.6	- 61	mixed-mixed
PNL-49/50	-	-	-	-	-	-	- 8.95	- 62	sodium-mixed
PNL-51	-	-	-	-	-	-	- 8.6	- 60	sodium-bicarbonate
PNL-52	-	-	-	-	-	-	- 8.3	- 58	sodium-bicarbonate
PNL-53	-	-	-	-	-	-	- 8.2	- 56	sodium-mixed
PNL-54	-	-	-	-	-	-	- 8.8	- 61	calcium-mixed
PNL-55	-	-	-	-	-	-	- 8.7	- 62	calcium-mixed
PNL-56	-	-	-	-	-	-	- 8.9	- 62	calcium-mixed
PNL-57	-	-	-	-	-	-	- 7.7	- 54	sodium-mixed
PNL-58	-	-	-	-	-	-	- 7.4	- 61	sodium-mixed
PNL-59	819	-	-	-	-	-	- 8.4	- 60	sodium-mixed
PNL-60	-	-	-	-	-	-	- 8.4	- 60	sodium-chloride
PNL-61	-	-	-	-	-	-	- 7.8	- 56	sodium-mixed

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Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 (pCi/L)	Uranium (µg/l)	Pesticides (µg/l)	δ^{18} O ($^0/_{00}$)	δ D ($^0/_{00}$)	Type of Chemistry
PNL-62	-	-	-	-	-	-	- 7.1	- 56	sodium-mixed
PNL-64	484	10	9.6	< LLD	-	-	- 9.0	- 67	mixed-mixed
PNL-65	202	5.5	5.2	< LLD	-	-	- 9.5	- 69	sodium-mixed
PNL-66	-	-	-	-	-	-	- 7.9	- 63	mixed-mixed
PNL-67	-	-	-	-	-	-	- 7.2	- 51	sodium-mixed
PNL-68/69	-	-	-	-	-	-	- 7.7	- 58	calcium-mixed
PNL-70	-	-	-	-	-	-	- 8.3	- 60	sodium-mixed
PNL-71	-	-	-	-	-	-	- 8.2	- 58	sodium-mixed
PNL-72/73	4769	**110**	56	0.78	**74**	-	- 7.3	- 54	sodium-mixed
PNL-74	1022	< LLD	1.7	-	-	-	- 8.1	- 60	sodium-mixed
PNL-76/77	165	-	-	-	-	-	- 8.2	- 60	mixed-mixed
PNL-78	193	-	-	-	-	-	- 9.0	- 62	sodium-mixed
PNL-79	483	-	-	-	-	-	- 8.8	- 64	sodium-chloride
PNL-80	147	-	-	-	-	-	- 7.7	- 61	sodium-mixed
PNL-81	-	-	-	-	-	-	- 7.8	- 61	sodium-sulfate
PNL-82	126	7.3	8.6	< LLD	-	-	- 8.6	- 69	sodium-mixed
PNL-83	-	**27**	13	< LLD	**34**	-	- 7.2	- 51	sodium-bicarbonate
PNL-84/85	686	14	15	0.79	-	-	- 9.4	- 67	sodium-mixed
PNL-87/88	676	6.1	8.1	< LLD	-	-	- 7.7	- 53	sodium-bicarbonate
PNL-89	226	-	-	-	-	-	- 7.7	- 55	sodium-mixed
PNL-90	-	4.7	4.6	-	-	-	- 7.4	- 53	sodium-mixed
PNL-91	923	-	-	-	-	-	- 7.0	- 49	sodium-bicarbonate
PNL-92	-	**54**	17	0.38	21	-	- 7.6	- 52	mixed-bicarbonate
PNL-93	-	-	-	-	-	-	- 8.1	- 58	sodium-mixed
PNL-94/95	114	1.3	1.85	-	-	-	- 7.45	-51	mixed-bicarbonate

bold = Primary MCL Exceedance
LLD = Lower Limit of Detection
italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Pinal AMA, 2005-2006—Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 (pCi/L)	Uranium (µg/l)	Pesticides (µg/l)	δ^{18} O ($^0/_{00}$)	δ D ($^0/_{00}$)	Type of Chemistry
PNL-96	772	11	8.2	< LLD	-	-	- 7.6	- 51	sodium-bicarbonate
PNL-97	-	-	-	-	-	-	- 8.8	- 61	mixed-mixed
PNL-98	1082	8.3	7.6	< LLD	-	-	- 8.4	- 60	sodium-mixed
PNL-100	-	-	-	-	-	-	- 8.5	- 60	sodium-mixed
PNL-101	-	-	-	-	-	-	- 8.3	- 59	-
PNL-102	741	-	-	-	-	-	- 7.6	- 53	mixed-chloride
PNL-103/04	1074	5.5	3.3	< LLD	-	-	- 8.4	- 59	sodium-mixed
PNL-105	-	-	-	-	-	-	- 8.5	- 57	sodium-bicarbonate
PNL-106	-	-	-	-	-	-	- 7.6	- 55	-
PNL-107	-	-	-	-	-	-	- 5.2	- 31	-
PNL-109	262	-	-	-	-	-	- 8.1	- 62	mixed-mixed
PNL-110	-	-	-	-	-	-	- 8.0	- 60	mixed-mixed
PNL-111/12	ND	5.4	2.9	-	6.9	-	- 6.95	- 48	mixed-mixed
PNL-113	-	-	-	-	-	-	- 8.7	- 61	mixed-mixed
PNL-114	-	-	-	-	-	-	- 7.5	- 52	sodium-mixed
PNL-115	-	-	-	-	-	-	- 7.4	- 53	calcium-mixed
PNL-116	-	-	-	-	-	-	- 8.4	- 59	sodium-mixed
PNL-119/20	-	-	-	-	-	-	- 7.9	- 55.5	sodium-bicarbonate

bold = Primary MCL Exceedance
LLD = Lower Limit of Detection
italics = constituent exceeded holding time