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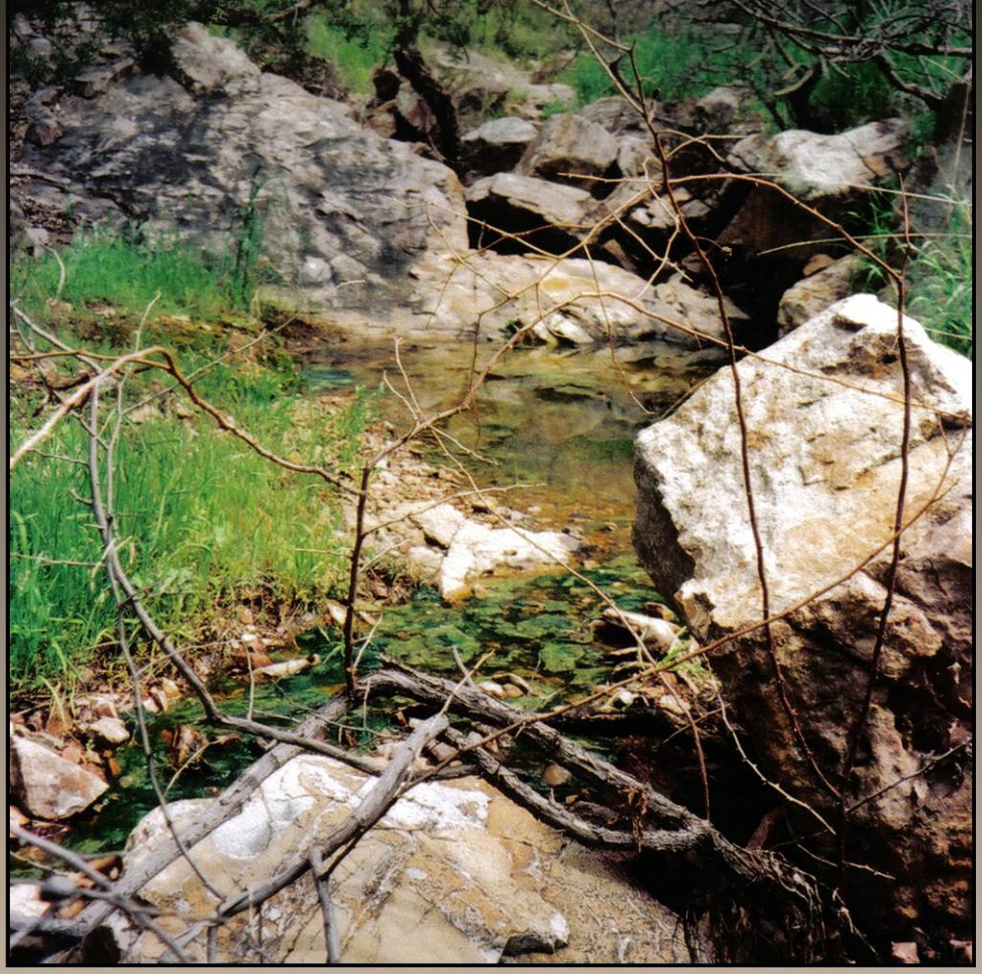
Ambient Groundwater Quality of the Dripping Springs Wash Basin

A 2004-2005 Baseline Study



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Ambient Groundwater Quality of the Dripping Springs Wash Basin: A 2004-2005 Baseline Study

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Maps by Jean Ann Rodine

Arizona Department of Environmental Quality
Open File Report 2010-02

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Thanks:

Field Assistance:	Karla Burnley and Shaunel Wytcherley. Special recognition is extended to the many well owners who were kind enough to give permission to collect groundwater data on their property.
Photo Credits:	Douglas Towne
Report Cover:	Stone Cabin Spring, located in the Dripping Springs Mountains, supplies water for livestock use. The sample from the spring (DSW-8), as with all twelve samples collected from the Dripping Springs Wash basin, met all health-based and aesthetics-based water quality standards.

Other Publications of the ADEQ Ambient Groundwater Monitoring Program

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

McMullen Valley Basin	OFR 11-02, June 2010, 99 p.
Gila Valley Sub-basin	OFR 09-12, November 2009, 99 p.
Agua Fria Basin	OFR 08-02, July 2008, 60 p.
Pinal Active Management Area	OFR 08-01, June 2007, 97 p.
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.

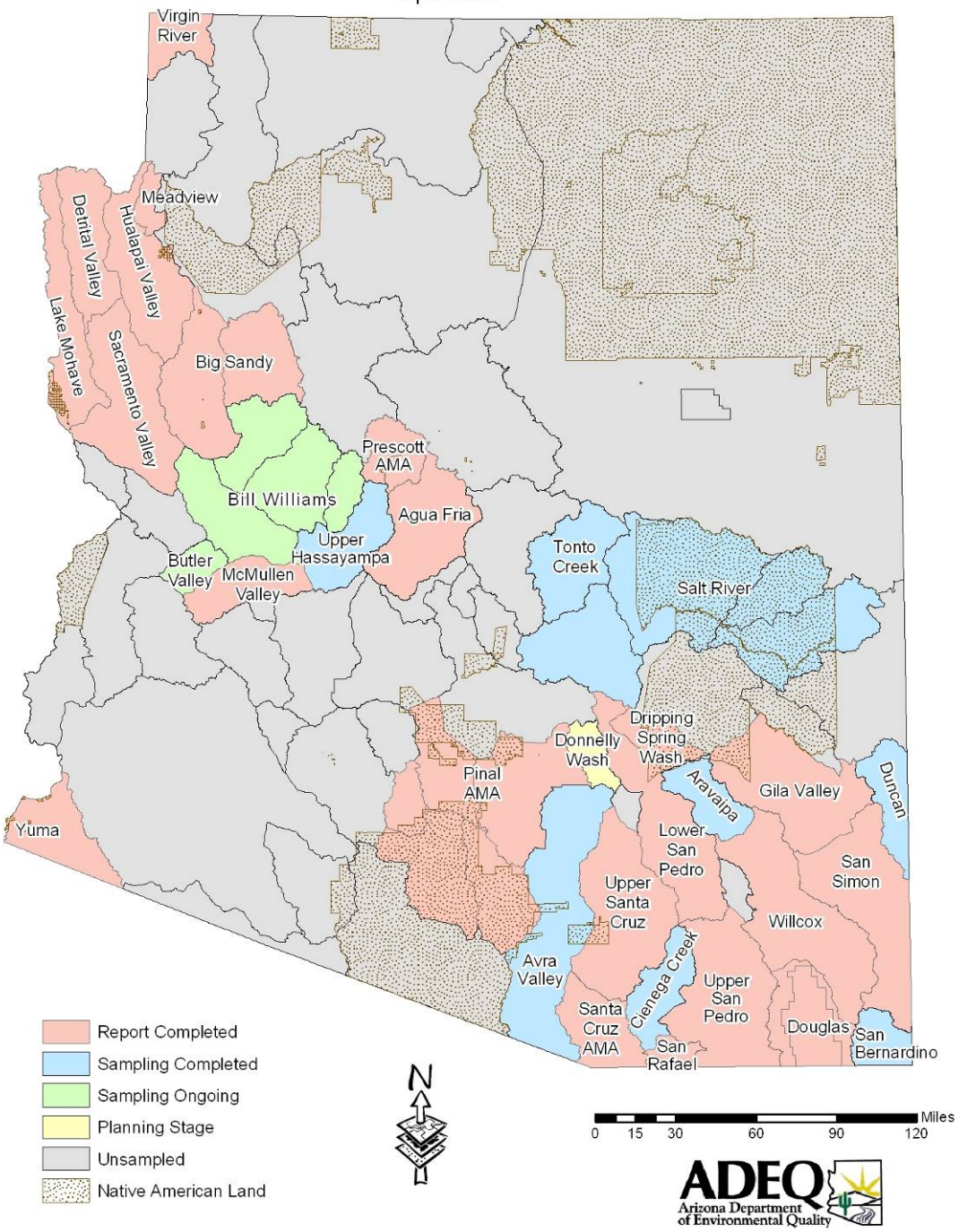
ADEQ Ambient Groundwater Quality Fact sheets (FS):

Dripping Springs Wash Basin	FS 11-02, July 2010, 4 p.
McMullen Valley Basin	FS 11-03, June 2010, 6 p.
Gila Valley Sub-basin	FS 09-28, November 2009, 8 p.
Agua Fria Basin	FS 08-15, July 2008, 4 p.
Pinal Active Management Area	FS 07-27, June 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 at:
www.azdeq.gov/environ/water/assessment/ambient.html

ADEQ Ambient Groundwater Monitoring Program Studies

April 2010



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Abbreviations

amsl	above mean sea level
ac-ft	acre-feet
AGF/yr	acre-feet per year
ADEQ	Arizona Department of Environmental Quality
ADHS	Arizona Department of Health Services
ADWR	Arizona Department of Water Resources
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
^{o}C	degrees Celsius
$CI_{0.95}$	95 percent Confidence Interval
Cl	chloride
DSW	Dripping Springs Wash basin
EPA	U.S. Environmental Protection Agency
F	fluoride
Fe	iron
gpm	gallons per minute
hard-cal	hardness concentration calculated from calcium and magnesium concentrations
HUC	Hydrologic Unit Code
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
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 Dripping Springs Wash Basin:
A 2004-2005 Baseline Study

Abstract - In 2004-2005, the Arizona Department of Environmental Quality (ADEQ) conducted the first ever baseline groundwater quality study of the Dripping Springs Wash basin located in central Arizona. The Dripping Springs Wash basin covers about 445 square miles; its western and southern portions are in Pinal County, its northern portion is in Gila County and its eastern portion is in Graham County. Most of the eastern half the groundwater basin is located within lands of the San Carlos Apache tribe. [4]

The basin is located in a mountainous area that contains small sediment-filled valleys which store only minor amounts of groundwater. The largest of the valleys is drained by the Dripping Springs Wash which is a tributary to the Gila River. The Gila River enters the basin from the east, just down gradient of Coolidge Dam, and splits the basin roughly in half flowing from the northeast to southwest. Groundwater development in the basin is mostly limited to domestic and stock wells located along the alluvium of the Dripping Springs Wash. [5]

Since much of the Dripping Springs Wash basin is located within lands of the San Carlos Apache tribe, the report essentially covers the western portion of the basin including the groundwater quality along the Dripping Springs Wash and its drainages. The main source of groundwater in the basin is the alluvium of the Dripping Springs Wash; the hard rock constituting the surrounding mountains contain only minor amounts of groundwater from which springs emanate flowing at less than two gallons per minute. [5]

To characterize regional groundwater quality, samples were collected from 12 sites, consisting of domestic and stock wells and springs, located on non-tribal lands north of the Gila River. Collecting more samples than this proved to be difficult because of the lack of well development in the basin and the extreme remoteness of many of the springs in the basin. Inorganic constituents and oxygen and deuterium isotopes were collected at all twelve sites. Radon and radiochemistry samples were also collected at seven sites. At two surface water sites, samples were also collected for oxygen and deuterium isotopes.

Health-based, primary maximum contaminant levels (MCLs) are enforceable standards that define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system. These water quality standards are based on a lifetime daily consumption of two liters. [23] Health-based primary MCLs were not exceeded at any of the 12 sites. Aesthetics-based Secondary MCLs are unenforceable guidelines that define the maximum constituent concentration that can be present in drinking water without an unpleasant taste, color, or odor.[23] Aesthetics-based Secondary MCLs were not exceeded at any of the 12 sites. Radon is a naturally occurring, intermediate breakdown product from the radioactive decay of uranium-238 to lead-206.[23] Of the 7 sites sampled for radon, none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air. Six sites exceeded the proposed 300 pCi/L standard that would apply if Arizona doesn't develop a multimedia program. [23]

Interpretation of the analytical results of the groundwater quality samples indicates that groundwater in the Dripping Springs Wash basin meets drinking water quality standards and guidelines and is suitable for domestic, municipal, stock and irrigation purposes. The groundwater can be characterized as generally *fresh*, *slightly-alkaline*, *hard* to *very hard* based on total dissolved solids, pH and hardness concentrations.[12, 15] The majority of sites were of calcium-bicarbonate or mixed-bicarbonate chemistry. Nutrient concentrations were low. Fluoride and zinc were the only trace elements detected at more than twenty percent of the sites.

Six sample sites consisted of generally shallow wells located in the alluvium of Dripping Springs Wash. The remaining six samples consisted of five springs and one windmill located up-gradient in the hard rock of surrounding mountains. Comparing these two groups, the sample sites in the alluvium exhibited significantly higher temperature and concentrations of, sodium, and nitrate then sample sites in the up-gradient, hard rock areas; the opposite pattern occurred with potassium (Kruskal-Wallis test, $p \leq 0.05$). The potential reasons for these groundwater quality patterns vary according to constituent. For sodium, in down-gradient areas, the dominant cation often evolves from calcium to sodium which would explain the significantly higher concentrations found along Dripping Springs Wash.[21] There is more development in down-gradient alluvial areas along Dripping Springs Wash; impacts from domestic septic systems and livestock likely affect the significantly higher nitrate concentrations found in those locations. [18]

INTRODUCTION

Purpose and Scope

The Dripping Springs Wash groundwater basin encompasses approximately 445 square miles in central Arizona.[5] The western and southern portions of the basin is located in Pinal County, the northern portion is in Gila County and the eastern portion is in Graham County (Map 1). Approximately the eastern half the groundwater basin is located within lands of the San Carlos Apache tribe while the western half consists of Bureau of Land Management, State trust, private and Forest Service lands. [6]

Located in a remote mountainous region, there are no towns located within the boundaries of this lightly populated basin. The settlement of Christmas is shown on some maps but this is now a ghost town located on private property ever since the nearby Christmas Mine closed in 1980. Arizona Highway 77 runs through the basin providing access to scattered ranches and domestic residences along Dripping Springs Wash. Groundwater is the primary source for agricultural, stock and domestic water supply within the basin.[6] This ADEQ study is the first comprehensive examination of the groundwater quality of the Dripping Springs Wash basin.

Sampling by the Arizona Department of Environmental Quality (ADEQ) Ambient Groundwater Monitoring program is authorized by legislative mandate in the 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*." [2]

Benefits of ADEQ 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 conditions in the Dripping Springs Wash basin including identifying areas with impaired conditions.
- 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.

Physical Characteristics

Geography – The Dripping Springs Wash basin overlaps the Basin and Range and Central Highlands physiographic provinces and consists of mountainous areas with small, sediment-filled valleys. [5] The basin is bounded by the Mescal and Pinal Mountains to the northeast and the Dripping Springs Mountains to the southwest. Elevation ranges from over 7,800 feet above mean sea level to around 1,900 feet where the Gila River exits the basin to the west.

The Gila River dissects the basin cutting across the northwest-southeast trending mountains. This perennial portion of the Gila River is controlled by releases from Coolidge Dam to meet downstream legal obligations.[6]

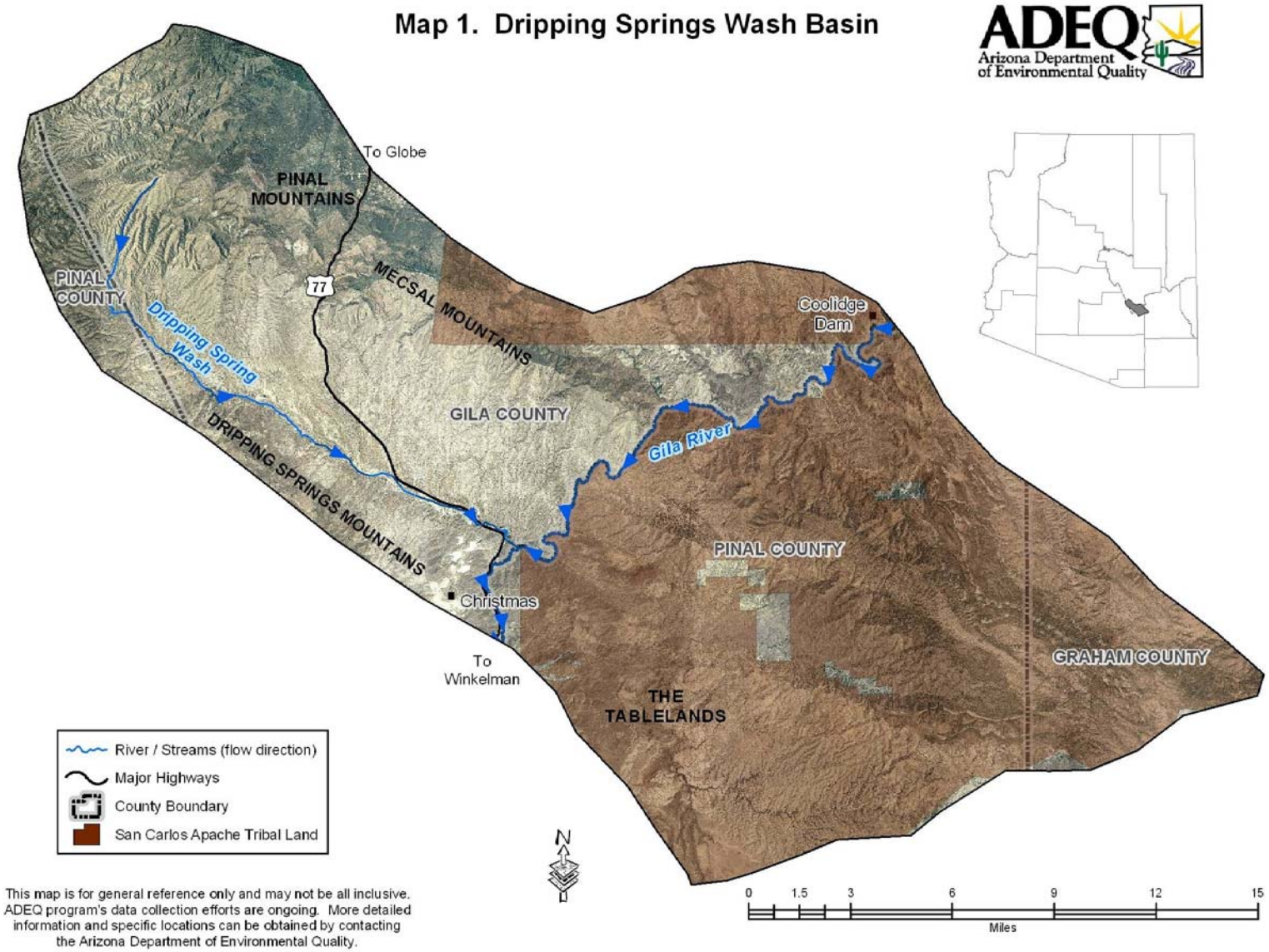
The basin is characterized by a mid-elevation mountain range and Arizona uplands Sonoran desert scrub, interior chaparral, semi-desert grassland and madrean evergreen woodland vegetation. Riparian vegetation includes mesquite along the Gila River. [6]

Climate – The arid climate of the Dripping Springs Wash basin is characterized by hot summers and mild winters. Precipitation occurs predominantly as rain in either late summer, localized monsoon thunderstorms or widespread, low intensity winter rain that sometimes includes snow at higher elevations. Annual precipitation averages almost 16 inches at Coolidge Dam. [6]

HYDROLOGY

Previous research indicates that three hydrologic units are found along Dripping Springs Wash. These include the younger alluvium, the Gila Conglomerate (or older alluvium) and the consolidated rocks, predominately of sedimentary origin along with volcanic rocks south of the Gila River and outcrops of granitic rock north of the Gila River. [5, 19]

Map 1. Dripping Springs Wash Basin



This map is for general reference only and may not be all inclusive. ADEQ program's data collection efforts are ongoing. More detailed information and specific locations can be obtained by contacting the Arizona Department of Environmental Quality.

Figure 1 – The basin looking down-gradient toward the alluvium of Dripping Springs Wash. The image illustrates the remoteness and pristine nature of the region.

Figure 2 – Pinal Peak, located on land managed by the U.S. Forest Service, denotes the northern extent of the Dripping Springs Wash basin.

Figure 3 – Dripping Springs Wash, labeled with a highway sign where it crosses Dripping Springs Road, is an ephemeral waterway that is the main drainage in the northwestern half of the basin.

Figure 4 – In the northern portion of the Dripping Springs Wash basin, springs such as Walnut Spring (DSW-6/7) pictured above, are often the only means of collecting groundwater quality data.

Figure 5 – Squaw Spring (DSW-10/11), located near the summit of Pinal Peak, is sampled by former ADEQ hydrologist Karla Burnley. The sample from the spring had a TDS concentration of 110 mg/L, the lowest of any site in the basin.

Figure 6 – Most samples collected in down-gradient areas of the basin were low production, domestic and stock wells drawing water from the alluvium of the Dripping Springs Wash shown here at Dripping Springs Road.

Figure 7 – This 89-foot-deep well (DSW-14/15) providing water for domestic uses is located along Dripping Springs Wash. Like all samples collected in the basin, samples from the well met all health and aesthetics based water quality standards.

Figure 8 – The Tablelands, an easily recognizable sedimentary geologic feature, are located south of the Gila River within the Dripping Springs Wash basin. This area of the basin is mostly lies within lands of the San Carlos Apace tribe.

Figure 9 – A 392-foot-deep Challenger windmill (DSW-9) provides water for domestic and stock uses in an upgradient area of the basin. The sample from the well contained hard water but met all health and aesthetics based water quality standards.

The major water producing unit is the younger alluvium that consists of sand, silt and a small amount of gravel located along the course of Dripping Springs Wash. Probably not more than 150 feet thick, the younger alluvium is used for domestic and stock purposes. The older alluvium consists of stream deposits containing gravel and silty sand as well as lake deposits consisting of clay, silt, tuff and gypsum.[5] The consolidated rocks which make up the surrounding mountains contain only minor amounts of groundwater and issue less than two gallons per minute to springs in the basin.[6]

Limited water development has occurred in the Dripping Springs Wash basin with most wells having been drilled along Dripping Springs Wash. In 1985, an estimated 620 acre-feet of groundwater was pumped.[5] Groundwater levels range from about 10 to 300 feet below land surface.

Groundwater moves from both the north and south toward the Gila River in the center of the basin; outflow from the basin occurs via the Gila River near the community of Christmas. Recharge occurring from both mountain-front and streambed sources in the basin is estimated at 3,000 acre-feet per year. Groundwater storage in the basin, to a depth of 1,200 feet below land surface, is estimated at 0.15 million acre feet.[6]

INVESTIGATION METHODS

ADEQ collected samples from 12 groundwater sites to characterize regional groundwater quality in the Dripping Springs Wash basin (Map 2). Specifically, the following types of samples were collected:

- oxygen and deuterium isotopes at 12 sites
- inorganic suites at 12 sites
- radionuclide at 7 sites
- radon at 7 sites

Two (2) additional surface water sites were also sampled for oxygen and deuterium isotopes. 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.[14]

Wells pumping groundwater for domestic and stock purposes were sampled for this study provided each well met ADEQ requirements. A well was considered suitable for sampling if the 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.[1, 7] Other factors such as construction information were preferred but not essential. Some requests to sample wells were denied because of fears of how the data would be used; other wells were not sampled because they lacked proper sampling ports.

For this study, ADEQ personnel sampled 7 wells all served by submersible pumps except for 1 windmill. Five springs were also sampled for the study. Additional information on groundwater sample sites is compiled from the ADWR well registry in Appendix A.[6]

Sample Collection

The sample collection methods for this study conformed to the *Quality Assurance Project Plan* (QAPP)[1] and the *Field Manual For Water Quality Sampling*.[7] 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.

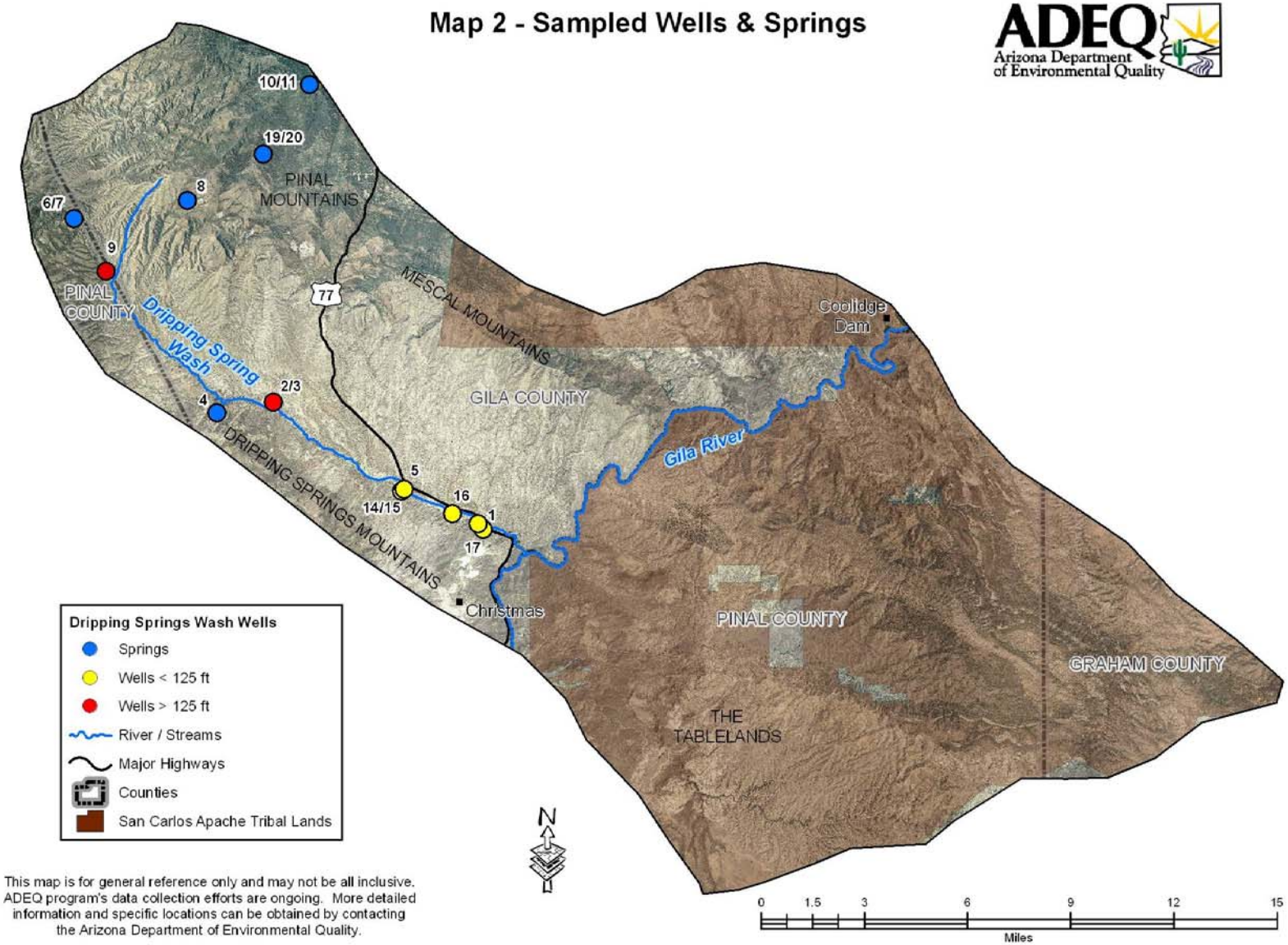
To assure obtaining fresh water from the aquifer, after three bore volumes had been pumped and physical parameter measurements had stabilized within 10 percent, a sample representative of the aquifer was collected from a point as close to the wellhead as possible. In certain instances, it was not possible 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. Radon
2. Inorganic
3. Radionuclide
4. Isotope

Radon, a naturally occurring, intermediate breakdown from the radioactive decay of uranium-238 to lead-206, was collected in two unpreserved, 40-ml clear glass vials. Radon samples were filled to minimize volatilization and subsequently sealed so that no headspace remained.[13]

Map 2 - Sampled Wells & Springs



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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 groundwater capsule 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 were unpreserved. [20]

Radionuclide 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. [3]

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

All samples were kept at 4°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 three field trips between December 2004 and May 2005.

Laboratory Methods

The inorganic 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 Test America 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.

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

Radionuclide samples were analyzed by the Arizona Radiation Agency Laboratory in Phoenix. 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. [3]

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

DATA EVALUATION

Quality Assurance

Quality-assurance (QA) procedures were followed and quality-control (QC) samples were collected to quantify data bias and variability for the Dripping Springs Wash basin 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*. [1, 7]

Types and numbers of QC samples collected for this study are as follows:

- Inorganic: (2 duplicates, 3 splits, and 2 blanks).
- Radionuclide: (no QA/QC samples)
- Radon: (no QA/QC samples)
- Isotope: (no QA/QC samples)

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

Blanks – Three 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.[7]

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. The equipment blanks contained specific conductivity (SC)-lab and turbidity contamination at levels expected due to impurities in the source water used for the samples. The blank results indicated systematic contamination with SC (detected in 3 equipment blanks) and turbidity (detected in 3 equipment blanks). A single detection of phosphorus (0.020 mg/L) also occurred.

For SC, the three equipment blanks had a mean (4.9 uS/cm) which was less than 1 percent of the SC mean concentration for the study and were not considered significantly affecting the sample results. The SC detections may be explained in two 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.[20]

For turbidity, equipment blanks had a mean level (0.05 ntu) less than 1 percent of the turbidity median level for the study and were not considered significantly affecting the sample results. 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.[20]

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.[7] Duplicate samples were collected from sampling sites that were believed to have elevated constituent concentrations as judged by SC-field values.

Two duplicate samples were collected in this study. Analytical results indicate that of the 36 constituents examined, 17 had concentrations above the MRL. The maximum variation between duplicates was less than 10 percent (Table 2). The only exceptions were TKN (76 percent), turbidity (67 percent), nitrate (37 percent), potassium (15 percent) and sulfate (12 percent). However, constituents with a high percentage variation of concentrations often have a low difference in actual concentrations.

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.[7] Three 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 15 had concentrations above MRLs for both ADHS and Test America laboratories (Table 3). The maximum variation between splits was 10 percent. Split samples were also evaluated using the non-parametric Sign test to determine if there were any significant differences between ADHS laboratory and Test America laboratory analytical results.[16] There were no significant differences in constituent concentrations between the labs (Sign test, $p \leq 0.05$).

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 five QA/QC correlations and considered valid based on the following results.[17]

Cation/Anion Balances - In theory, water samples exhibit electrical neutrality. Therefore, the sum of milliquivalents per liter (meq/L) of cations should equal the sum of meq/L of anions. However, 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.[17] Overall, cation/anion meq/L balances of Dripping Springs Wash basin samples were significantly correlated (regression analysis, $p \leq 0.01$). Of the 12 samples, all were within +/-12 percent. Because of high cation/low anion sums, 9 samples had +/- 5 to 12 percent differences. These samples with high cation sums were collected on the first two of three field trips conducted for the study. The ADHS laboratory was alerted but found no reason for the differences.[20]

SC/TDS - The SC and TDS concentrations measured by contract laboratories were significantly correlated as were SC-field and TDS concentrations (regression analysis, $r = 0.99$, $p \leq 0.01$). 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.[17] Groundwater high in bicarbonate and chloride will have a multiplication factor near the lower end of this range; 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.[17]

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)].[17]

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

Table 1. Laboratory Water Methods and Minimum Reporting Levels Used in the Study

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America Minimum Reporting Level
Physical Parameters and General Mineral Characteristics			
Alkalinity	Electrometric Titration	SM2320B / M2320 B	2 / 6
SC (uS/cm)	Electrometric	EPA 120.1/ M2510 B	-- / 2
Hardness	Titrimetric, EDTA	SM 2340 C / SM2340B	10 / 1
Hardness	Calculation	SM 2340 B	--
pH (su)	Electrometric	SM 4500 H-B	0.1
TDS	Gravimetric	SM2540C	10 / 10
Turbidity (NTU)	Nephelometric	EPA 180.1	0.01 / 0.2
Major Ions			
Calcium	ICP-AES	EPA 200.7	1 / 2
Magnesium	ICP-AES	EPA 200.7	1 / 0.25
Sodium	ICP-AES	EPA 200.7	1 / 2
Potassium	Flame AA	EPA 200.7	0.5 / 2
Bicarbonate	Calculation	Calculation / / M2320 B	2
Carbonate	Calculation	Calculation / / M2320 B	2
Chloride	Potentiometric Titration	SM 4500 CL D / E300	5 / 2
Sulfate	Colorimetric	EPA 375.4 / E300	1 / 2
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 / M4500-NH3	0.05 / 1.3
Total Phosphorus	Colorimetric	EPA 365.4 / M4500-PB	0.02 / 0.1

All units are mg/L except as noted
Source [13, 20]

Table 1. Laboratory Water Methods and Minimum Reporting Levels Used in the Study--Continued

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America Minimum Reporting Level
		Trace Elements	
Aluminum	ICP-AES	EPA 200.7	0.5
Antimony	Graphite Furnace AA	EPA 200.8	0.005 / 0.003
Arsenic	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.001
Barium	ICP-AES	EPA 200.8 / EPA 200.7	0.005 to 0.1 / 0.01
Beryllium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.0005 / 0.001
Boron	ICP-AES	EPA 200.7	0.1 / 0.2
Cadmium	Graphite Furnace AA	EPA 200.8	0.0005 / 0.001
Chromium	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01
Copper	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01
Fluoride	Ion Selective Electrode	SM 4500 F-C	0.1 / 0.4
Iron	ICP-AES	EPA 200.7	0.1 / 0.05
Lead	Graphite Furnace AA	EPA 200.8	0.005 / 0.001
Manganese	ICP-AES	EPA 200.7	0.05 / 0.01
Mercury	Cold Vapor AA	SM 3112 B / EPA 245.1	0.0002 / 0.0002
Nickel	ICP-AES	EPA 200.7	0.1 / 0.01
Selenium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.002
Silver	Graphite Furnace AA	EPA 200.9 / EPA 200.7	0.001 / 0.01
Thallium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.002 / 0.001
Zinc	ICP-AES	EPA 200.7	0.05
		Radionuclides	
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	Kinnetic phosphorimeter	EPA Laser Phosphorimetry	varies

All units are mg/L
Source [3, 13, 20]

Table 2. Summary Results of Dripping Springs Wash Basin Duplicate Samples from the ADHS Laboratory

Parameter	Number of Dup. Sites	Difference in Percent			Difference in Concentrations		
		Minimum	Maximum	Median	Minimum	Maximum	Median
Physical Parameters and General Mineral Characteristics							
Alk., Total	2	0 %	1 %	-	0	6	-
SC (uS/cm)	2	0 %	0 %	-	0	0	-
Hardness	2	1 %	2 %	-	10	10	-
pH (su)	2	0 %	0 %	-	0	0	-
TDS	2	0 %	0 %	-	0	0	-
Turb. (ntu)	2	10 %	67 %	-	0.8	1.1	-
Major Ions							
Bicarbonate	2	0 %	1 %	-	0	10	-
Calcium	2	0 %	2 %	-	0	3	-
Magnesium	2	0 %	2 %	-	0	1.5	-
Sodium	2	0 %	4 %	-	0	2	-
Potassium	2	7 %	15 %	-	0.3	0.5	-
Chloride	2	0 %	3 %	-	0	1	-
Sulfate	2	2 %	12 %	-	2	14	-
Nutrients							
Nitrate (as N)	2	5 %	37 %	-	0.027	0.1	-
TKN	1	-	-	76 %	-	-	1.12
Trace Elements							
Barium	2	0 %	0 %	-	0	0	-
Fluoride	2	0 %	1 %	-	0	0.02	-

All concentration units are mg/L except as noted with certain physical parameters.
Iron was detected at 0.41 mg/L in one duplicate sample and not detected in the other duplicate sample at an MRL of 0.1 mg/L.
TKN was detected at 0.28 mg/L in one duplicate sample and not detected in the other duplicate sample at an MRL of 0.10 mg/L

Table 3. Summary Results of Dripping Springs Wash Basin Split Samples From the ADHS/Test America Labs

Constituents	Number of Split Sites	Difference in Percent		Difference in Levels		Significance
		Minimum	Maximum	Minimum	Maximum	
Physical Parameters and General Mineral Characteristics						
Alkalinity, total	3	0 %	0 %	0	0	ns
SC (uS/cm)	3	0 %	4 %	0	50	ns
Hardness	3	0 %	4 %	0	10	ns
pH (su)	3	1 %	5 %	0.09	0.57	ns
TDS	3	0 %	2 %	0	10	ns
Turbidity (ntu)	1	0 %	0 %	0	0	ns
Major Ions						
Calcium	3	0 %	3 %	0	1	ns
Magnesium	3	0 %	6 %	0	4	ns
Sodium	3	0 %	6 %	0	2	ns
Potassium	4	4 %	10 %	0.1	0.5	ns
Chloride	3	1 %	4 %	0.1	1	ns
Sulfate	3	2 %	9 %	0.2	5	ns
Nutrients						
Nitrate as N	3	3 %	10 %	0.2	0.5	ns
Trace Elements						
Chromium	1	0 %	0 %	0.007	0.007	ns
Fluoride	3	4 %	9 %	0.2	0.4	ns
Zinc	1	4 %	4 %	0.008	0.008	ns

ns = No significant ($p \leq 0.05$) difference
* = Significant ($p \leq 0.05$) difference
** = Significant ($p \leq 0.05$) difference

All units are mg/L except as noted
Zinc was detected at 0.055 mg/L in the Test America split and not detected in the ADHS split at an MRL of 0.05 mg/L

pH - The pH value is closely related to the environment of the water and is likely to be altered by sampling and storage.[17] Thus, the pH values measured in the field using a YSI meter at the time of sampling were not significantly correlated with laboratory pH values (regression analysis, $r = 0.39$, $p \leq 0.05$).

Temperature / GW Depth /Well Depth – Groundwater temperature measured in the field was compared to well depth and groundwater depth. Groundwater temperature should increase with depth, approximately 3 degrees Celsius with every 100 meters or 328 feet. [8] Well depth was not significantly correlated with temperature (regression analysis, $r = 0.44$, $p \leq 0.05$).

GROUNDWATER SAMPLING RESULTS

Water Quality Standards/Guidelines

The ADEQ ambient groundwater 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 that reflect the best current scientific and technical judgment available to evaluate the suitability of groundwater in the basin 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.[23]

- State of Arizona Aquifer Water Quality Standards. These apply to aquifers that are classified for drinking water protected use. All aquifers within Arizona are currently classified and protected for drinking water use. These enforceable State standards are identical to the federal Primary MCLs. [2]

- 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.[23]

Health-based drinking water quality standards (such as Primary MCLs) are based on the lifetime consumption (70 years) of two liters of water per day and, as such, are chronic not acute standards.[23]

Inorganic Constituent Results - Of the 12 sites sampled for the full suite of inorganic constituents in the Dripping Springs Wash study, none exceeded any SDW Primary (health-based) MCLs or Secondary (aesthetics-based) MCLs (Map 3).[2, 23]

Radiochemical Constituent Results – Of the 7 sites sampled for radionuclides in the Dripping Springs Wash study none exceeded any SDW Primary (health-based) MCLs.[2, 23]

Radon Results - Of the 7 sites sampled for radon none exceeded the proposed 4,000 picocuries per liter (pCi/L) standard that would apply if Arizona establishes an enhanced multimedia program to address the health risks from radon in indoor air. Six (6) sites exceeded the proposed 300 pCi/L standard that would apply if Arizona doesn't develop a multimedia program. [23]

Suitability for Irrigation

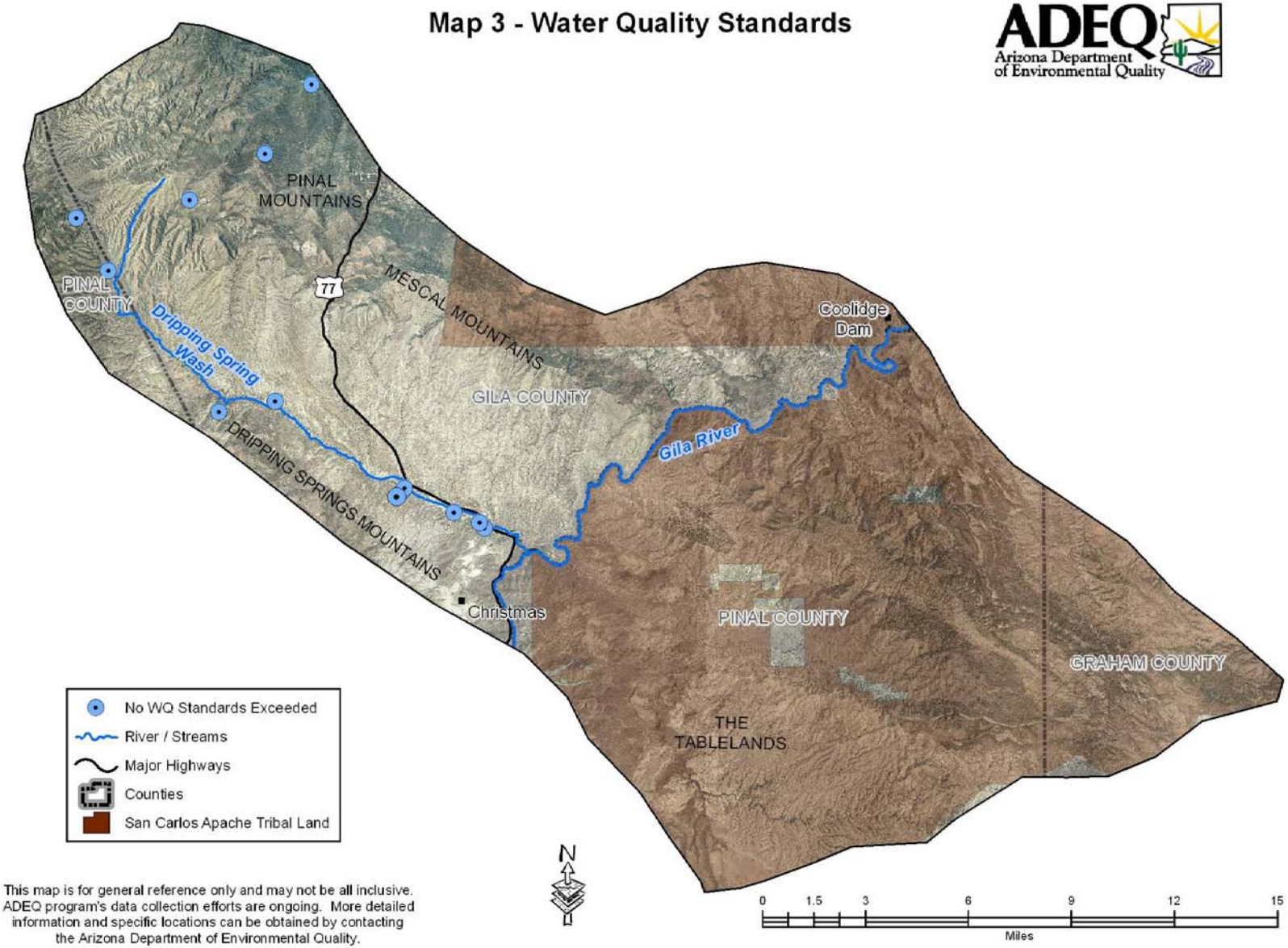
The groundwater at each sample site was assessed as to its suitability for irrigation use based on salinity and sodium hazards. Excessive levels of sodium are known to cause physical deterioration of the soil and vegetation. Irrigation water may be classified using specific conductivity (SC) and the Sodium Adsorption Ratio (SAR) in conjunction with one another. [24]

Groundwater sites in the Dripping Springs Wash basin display a narrow range of irrigation water classifications. The 12 sample sites are divided into the following salinity hazards: low or C1 (1), medium or C2 (10), high or C3 (1), and very high or C4 (0). The 12 sample sites are divided into the following sodium or alkali hazards: low or S1 (12), medium or S2 (0), high or S3 (0), and very high or S4 (0).

Analytical Results

Analytical inorganic and radiochemistry results of the Dripping Springs Wash basin sample sites are summarized (Table 4) 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.[25] Specific constituent information for each groundwater site is in Appendix B.

Map 3 - Water Quality Standards



This map is for general reference only and may not be all inclusive. ADEQ program's data collection efforts are ongoing. More detailed information and specific locations can be obtained by contacting the Arizona Department of Environmental Quality.

Table 4. Summary Statistics for Dripping Springs Wash Basin Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Physical Parameters						
Temperature (C)	0.1	12 / 11	20.1	15.8	18.8	21.8
pH-field (su)	0.01	12 / 12	7.23	7.03	7.24	7.46
pH-lab (su)	0.01	12 / 12	8.00	7.70	7.89	8.09
Turbidity (ntu)	0.01	12 / 12	0.23	0.12	0.32	0.52
General Mineral Characteristics						
T. Alkalinity	2.0	12 / 12	299	194	251	308
Phenol. Alk.	2.0	12 / 0		> 50% of data below MRL		
SC-field (uS/cm)	N/A	12 / 12	627	443	559	674
SC-lab (uS/cm)	N/A	12 / 12	620	440	557	673
Hardness-lab	10.0	12 / 12	280	195	255	315
TDS	10.0	12 / 12	375	272	339	406
Major Ions						
Calcium	5.0	12 / 12	68	46	61	76
Magnesium	1.0	12 / 12	31	21	27	33
Sodium	5.0	12 / 12	25	17	22	26
Potassium	0.5	12 / 12	1.5	1.4	1.7	2.1
Bicarbonate	2.0	12 / 12	368	237	306	376
Carbonate	2.0	12 / 0		> 50% of data below MRL		
Chloride	1.0	12 / 12	13	10	13	15
Sulfate	10.0	12 / 12	28	21	32	43
Nutrients						
Nitrate (as N)	0.02	12 / 12	1.9	1.0	1.6	2.3
Nitrite (as N)	0.02	0 / 0		> 50% of data below MRL		
TKN	0.05	12 / 6		> 50% of data below MRL		
T. Phosphorus	0.02	12 / 3		> 50% of data below MRL		

Table 4. Summary Statistics for Dripping Springs Wash Basin Groundwater Quality Data

Constituent	Minimum Reporting Limit (MRL)	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Trace Elements						
Antimony	0.005	12 / 0		> 50% of data below MRL		
Arsenic	0.01	12 / 0		> 50% of data below MRL		
Barium	0.1	12 / 2		> 50% of data below MRL		
Beryllium	0.0005	12 / 0		> 50% of data below MRL		
Boron	0.1	12 / 0		> 50% of data below MRL		
Cadmium	0.001	12 / 0		> 50% of data below MRL		
Chromium	0.01	12 / 1		> 50% of data below MRL		
Copper	0.01	12 / 2		> 50% of data below MRL		
Fluoride	0.20	12 / 12	0.29	0.23	0.34	0.45
Iron	0.1	12 / 0		> 50% of data below MRL		
Lead	0.005	12 / 0		> 50% of data below MRL		
Manganese	0.05	12 / 0		> 50% of data below MRL		
Mercury	0.0005	12 / 0		> 50% of data below MRL		
Nickel	0.1	12 / 0		> 50% of data below MRL		
Selenium	0.005	12 / 0		>50% of data below MRL		
Silver	0.001	12 / 0		> 50% of data below MRL		
Thallium	0.002	12 / 0		> 50% of data below MRL		
Zinc	0.05	12 / 4		> 50% of data below MRL		
Radiochemical Constituents						
Radon*	Varies	4 / 4	377	221	361	500
Gross Alpha*	Varies	7 / 4	1.5	- 0.9	2.1	5.1
Gross Beta*	Varies	7 / 7	1.7	1.2	1.8	2.3
Ra-226+228*	Varies	7 / 0		> 50% of data below MRL		
Uranium**	Varies	7 / 0		> 50% of data below MRL		
Isotopes						
Oxygen-18***	Varies	12 / 12	- 9.7	- 10.4	- 9.9	- 9.4
Deuterium***	Varies	12 / 12	- 69.5	- 73.1	- 70.8	- 68.5

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

GROUNDWATER COMPOSITION

General Summary

Groundwater in the Dripping Springs Wash basin was predominantly of calcium-bicarbonate or mixed-bicarbonate (Map 4) (Diagram 1). The water chemistry at the 12 sample sites, in decreasing frequency, includes calcium-bicarbonate (6 sites), mixed-bicarbonate (5 sites) and magnesium-bicarbonate (1 site) (Diagram 1 – middle diagram).

Of the 12 sample sites in the Dripping Springs Wash basin, the dominant cation was calcium at 6 sites and magnesium at 1 site; at 5 sites, the composition was mixed as there was no dominant cation (Diagram 1 – left diagram).

The dominant anion was bicarbonate at 12 sites (Diagram 1 – right diagram).

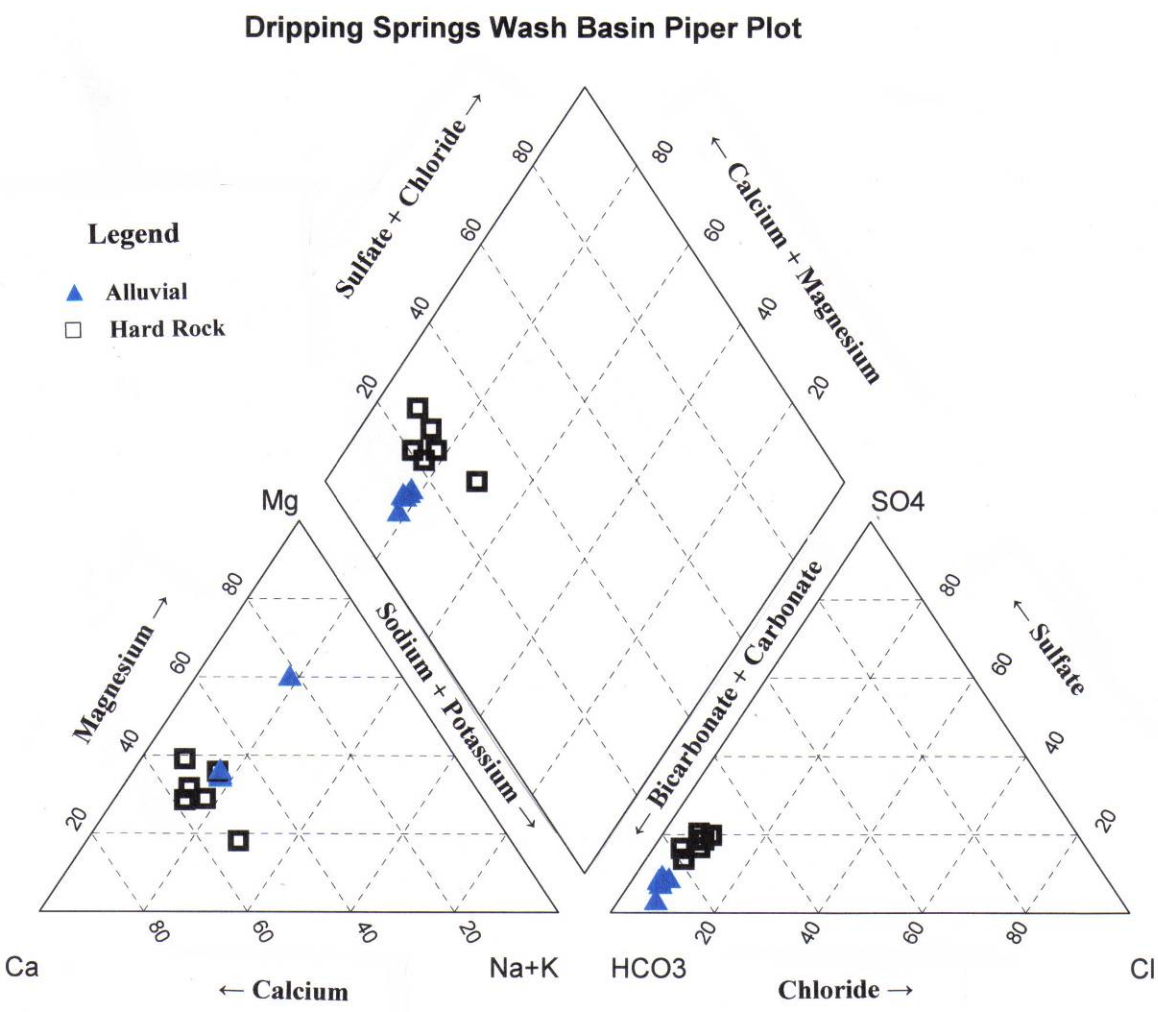
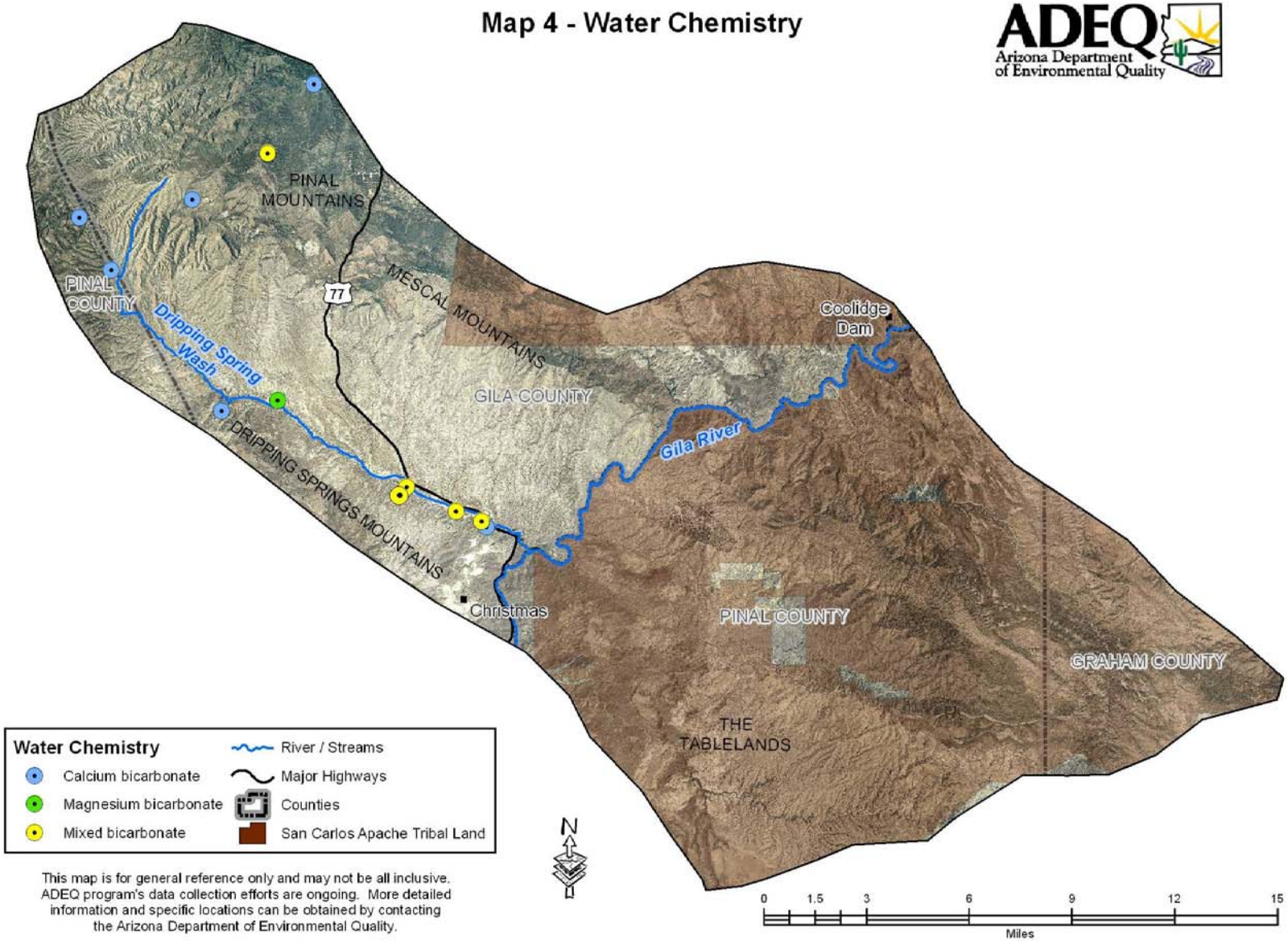


Diagram 1 – The Piper trilinear diagram shows that all the samples have a similar chemistry and consist mainly of calcium-bicarbonate or mixed-bicarbonate.

Map 4 - Water Chemistry



Water Chemistry

- Calcium bicarbonate
- Magnesium bicarbonate
- Mixed bicarbonate
- River / Streams
- Major Highways
- Counties
- San Carlos Apache Tribal Land

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Levels of pH-field were *slightly alkaline* (above 7 su) at 9 sites and slightly acidic (below 7 su) at 3 sites.[15] Of the 9 sites above 7 su, no sites had pH-field levels over 8 su.

TDS concentrations were considered *fresh* (below 1,000 mg/L) at 12 sites (Map 5).[15]

Hardness concentrations were *soft* (below 75 mg/L) at 1 site, *moderately hard* (75 – 150 mg/L) at 1 site, *hard* (150 – 300 mg/L) at 6 sites, and *very hard* (above 300 mg/L) at 4 sites (Diagram 2 and Map 6).[12]

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities. Nitrate concentrations were divided into natural background (0 sites at <0.2 mg/L), may or may not indicate human influence (11 sites at 0.2 – 3.0 mg/L), may result from human activities (1 site at 3.0 – 10 mg/L), and probably result from human activities (0 sites >10mg/L).[18]

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

Constituent Co-Variation - TDS concentrations are best predicted among major ions by calcium concentrations (standard coefficient = 0.42), among cations by calcium concentrations (standard coefficient = 0.61) and among anions, bicarbonate (standard coefficient = 0.84) (multiple regression analysis, $p \leq 0.01$).

Hardness Concentrations in the Dripping Springs Wash Basin

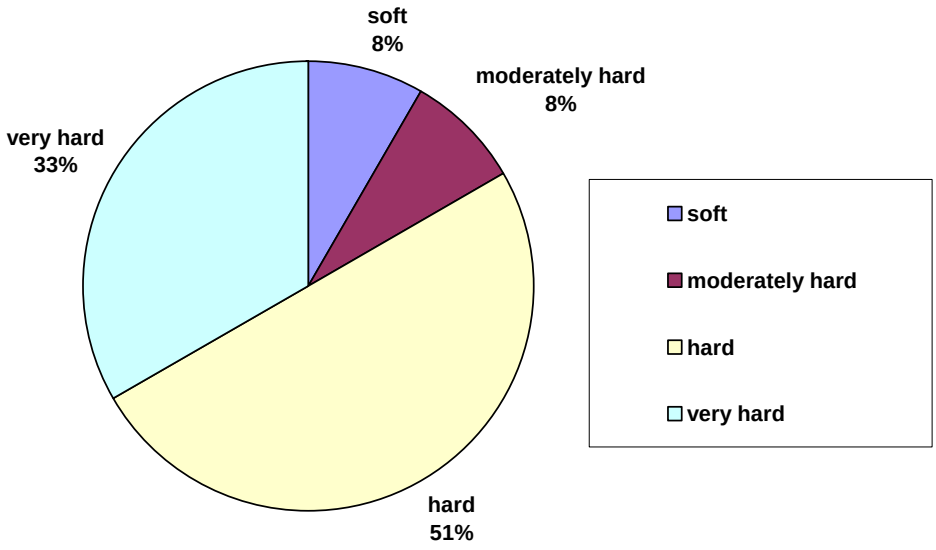
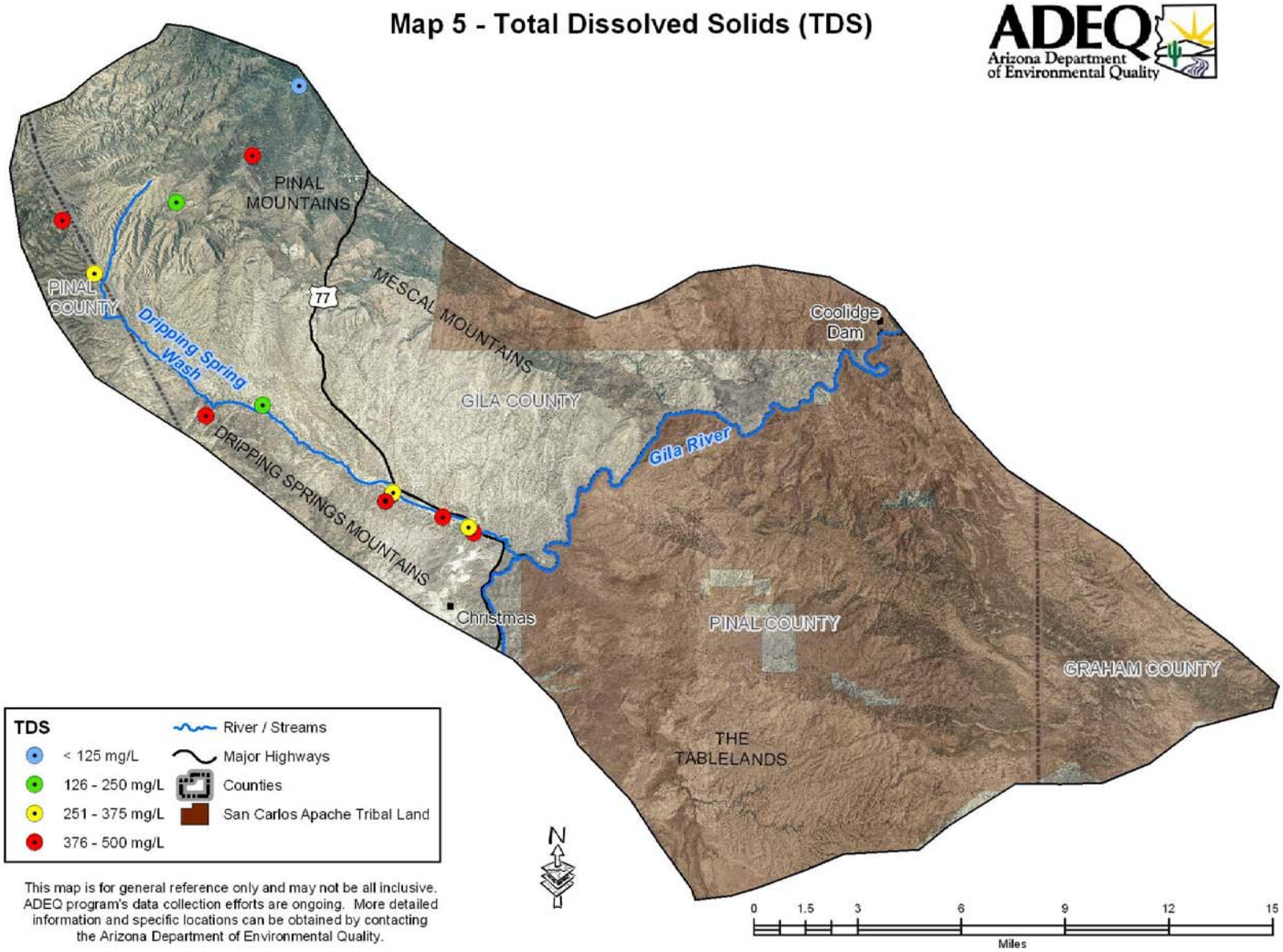


Diagram 2 – Samples collected from springs issuing from consolidated rocks in the upgradient areas of the basin had variable hardness concentrations. The two samples collected from the highest elevation springs had the two lowest hardness concentrations; the other upgradient spring samples typically had *very hard* water.

Map 5 - Total Dissolved Solids (TDS)



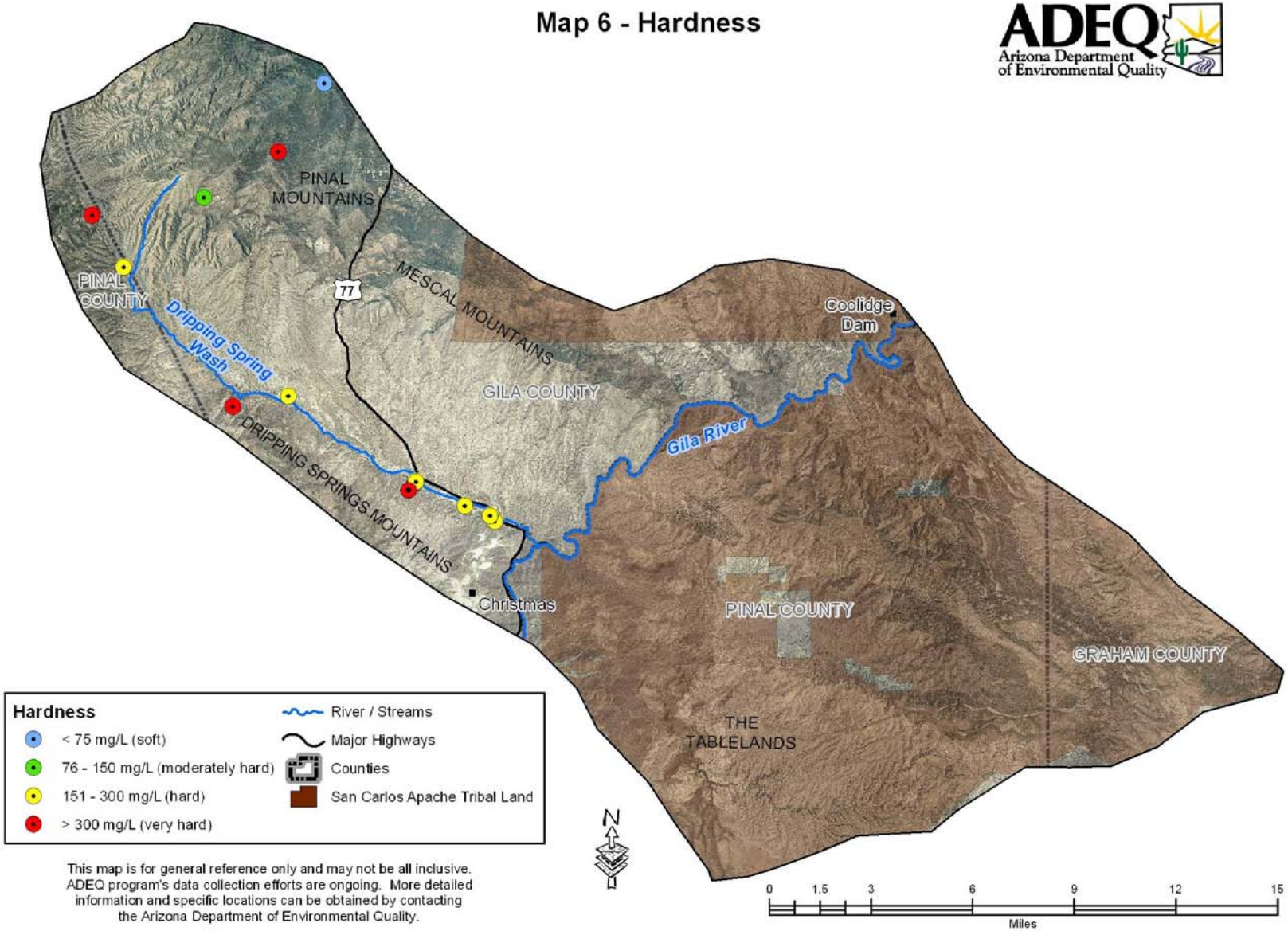
TDS

- < 125 mg/L
- 126 - 250 mg/L
- 251 - 375 mg/L
- 376 - 500 mg/L

- River / Streams
- Major Highways
- Counties
- San Carlos Apache Tribal Land

This map is for general reference only and may not be all inclusive. ADEQ program's data collection efforts are ongoing. More detailed information and specific locations can be obtained by contacting the Arizona Department of Environmental Quality.

Map 6 - Hardness



This map is for general reference only and may not be all inclusive. ADEQ program's data collection efforts are ongoing. More detailed information and specific locations can be obtained by contacting the Arizona Department of Environmental Quality.

Isotope Comparison

Groundwater characterizations using oxygen and hydrogen isotope 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 extensive evaporation prior to collection.[11] This is accomplished by comparing oxygen-18 isotopes ($\delta\,^{18}O$) and deuterium ($\delta\,D$), an isotope of hydrogen, data to the Global Meteoric Water Line (GMWL). The GMWL is described by the linear equation:

$$\delta D = 8\,\delta\,^{18}O + 10$$

where $\delta\,D$ is deuterium in parts per thousand (per mil, $^{0}/_{00}$), 8 is the slope of the line, $\delta\,^{18}O$ is oxygen-18 $^{0}/_{00}$, and 10 is the y-intercept.[11] The GMWL is the standard by which water samples are compared and represents the best fit isotopic analysis of numerous worldwide water samples.

Isotopic data from a region may be plotted to create a Local Meteoric Water Line (LMWL) which is affected by varying climatic and geographic factors. When the LMWL is compared to the GMWL, inferences may be made about the origin or history of the local water.[11] The LMWL created by $\delta\,^{18}O$ and $\delta\,D$ values for samples collected at sites in the Dripping Springs Wash basin were compared to the GMWL. The $\delta\,D$ and $\delta\,^{18}O$ data lie to the right of the GMWL. Meteoric waters exposed to evaporation characteristically plot increasingly below and to the right of the GMWL. Evaporation tends to preferentially contain a higher percentage of lighter isotopes in the vapor phase and causes the water that remains behind to be isotopically heavier.[11]

Groundwater from arid environments is typically subject to evaporation, which enriches $\delta\,D$ and $\delta\,^{18}O$, resulting in a lower slope value (usually between 3 and 6) as compared to the slope of 8 associated with the GMWL.[11]

The data for the Dripping Springs Wash basin conforms to this theory, having a slope of 4.4, with the LMWL described by the linear equation:

$$\delta D = 4.4\,\delta\,^{18}O - 27.2$$

The LMWL for the Dripping Springs Wash basin (4.4) is lower than most other basins in Arizona.[22]

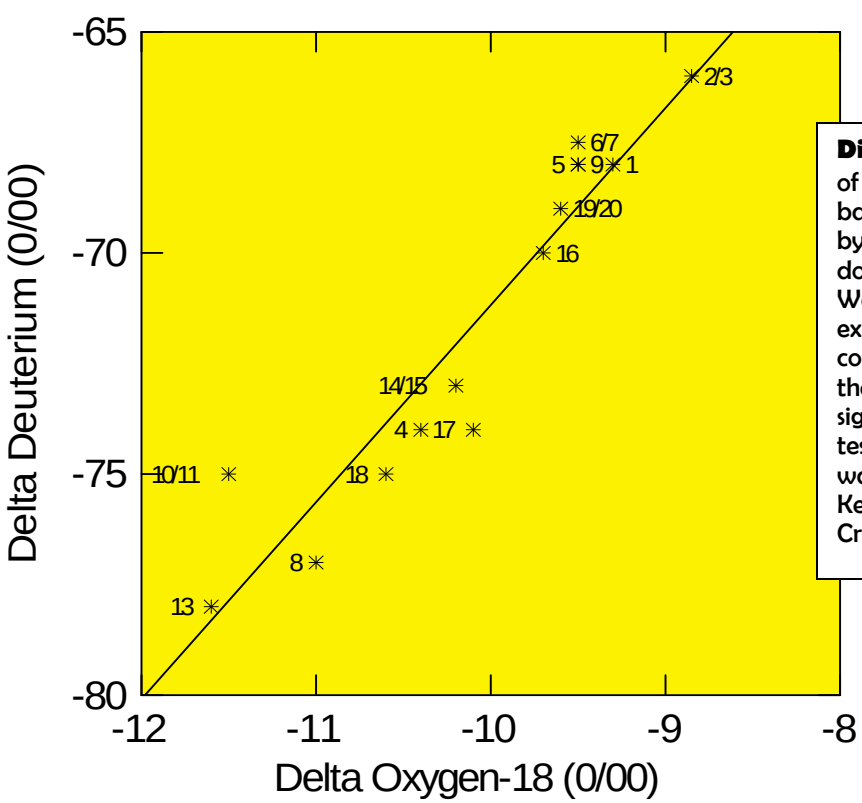


Diagram 3 – Two distinct clusters of isotope values were found in the basin with each group represented by both up-gradient springs and down-gradient wells (Kruskal-Wallis test, $p \leq 0.05$). However, examining other constituents for concentration differences using these groupings found no significant patterns (Kruskal-Wallis test, $p \leq 0.05$). The two surface water samples are represented by Kellner Canyon (#13) and Pioneer Creek (#18). The extreme

Groundwater Quality Variation

Among Aquifers - Twenty-five (25) groundwater quality constituent concentrations were compared between six sites (all wells) located in down-gradient alluvium along the Dripping Springs Wash and six sites (5 springs and 1 well) located in up-gradient hard rock areas.

Significant concentration differences were found with four constituents (Kruskal-Wallis test, $p \leq 0.05$). Temperature, sodium (Diagram 4) and nitrate (Diagram 5) were significantly higher at sites located down-gradient in alluvium than at sites located up-gradient in hard rock; the opposite pattern occurs with potassium.

Complete results are found in Table 5. Summary statistics in the form of 95% confidence intervals are provided for those constituents with significant concentration differences between aquifers in Table 6.

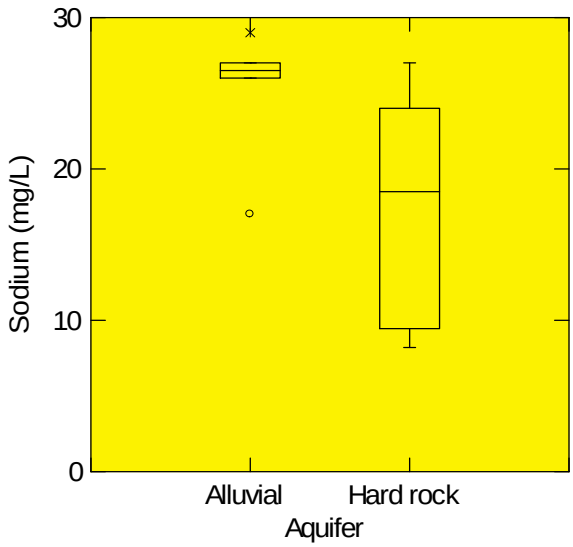


Diagram 4. Sample sites collected from wells located along the alluvium of the Dripping Springs Wash in down-gradient areas of the basin had significantly higher sodium concentrations than sample sites collected from springs located in hard rock in up-gradient areas of the basin (Kruskal-Wallis test, $p \leq 0.05$). In downgradient areas, the dominant cation often evolves from calcium to sodium.[21]

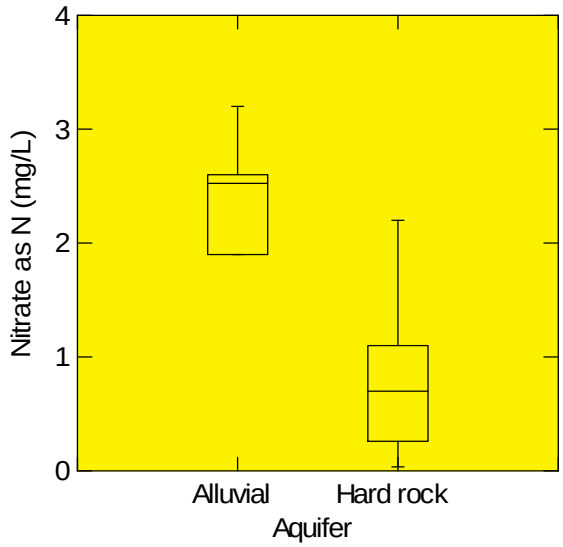


Diagram 5. Sample sites collected from wells located along the alluvium of the Dripping Springs Wash in down-gradient areas of the basin had significantly higher sodium concentrations than sample sites collected from springs located in hard rock in up-gradient areas of the basin (Kruskal-Wallis test, $p \leq 0.05$).

There is more development in down-gradient area and impacts from domestic septic systems and livestock likely affect this trend. However, nitrate concentrations at all sites were all well below the health-based 10 mg/L Primary MCL.

Table 5. Variation in Groundwater Quality Constituent Concentrations Using Kruskal-Wallis Test

Constituent	Significance	Significant Differences Among Aquifers
Well Depth	ns	-
Groundwater Depth	ns	-
Temperature - field	*	Alluvium > Hard rock
pH – field	ns	-
pH – lab	ns	-
SC - field	ns	-
SC - lab	ns	-
TDS	ns	-
Turbidity	ns	-
Hardness	ns	-
Calcium	ns	-
Magnesium	ns	-
Sodium	*	Alluvium > Hard rock
Potassium	*	Hard rock > Alluvium
Bicarbonate	ns	-.
Chloride	ns	-
Sulfate	ns	-
Nitrate (as N)	**	Alluvium > Hard rock
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

Table 6. Summary Statistics (95% Confidence Intervals) for Groundwater Quality Constituents With Significant Concentration Differences Between Aquifers

Constituent	Significant Differences	Alluvial	Hard Rock
Well Depth (feet)	ns	-	-
Groundwater Depth (feet)	ns	-	-
Temperature – field (C)	*	19.3 to 23.6	10.1 to 21.2
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	ns	-	-
Magnesium	ns	-	-
Sodium	*	21 to 30	9 to 26
Potassium	*	0.9 to 2.0	1.4 to 2.5
Bicarbonate	ns	-	-
Chloride	ns	-	-
Sulfate	ns	-	-
Nitrate (as N)	**	1.9 to 3.0	0 to 1.7
Fluoride	ns	-	-
Oxygen (0/00)	ns	-	-
Deuterium (0/00)	ns	-	-
Gross Alpha	ns	-	-
Gross Beta	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

SUMMARY AND CONCLUSIONS

The Dripping Springs Wash groundwater basin is a sparsely populated, remote area. Little about the hydrology of the Dripping Springs area was previously known as this is the first study that comprehensively examines the groundwater quality of the basin. Roughly the eastern half of the basin lies within the lands of the San Carlos Apache tribe and was not sampled as part of this study. [4]

The western portion consists of a combination of Bureau of Land Management, State Trust, Forest Service and private lands. [6] The little groundwater development in this area consists of domestic and stock wells mostly located along the alluvium of Dripping Springs Wash. [5] Half of the dozen sample sites consisted of wells located in this area. Springs located up-gradient to the north in the consolidated rock of the surrounding mountains constituted the remainder of the sampled sites.

Interpretation of the analytical results from the samples indicates that groundwater in the Dripping Springs Wash basin meets drinking water standards and is suitable for domestic, stock, municipal, and irrigation purposes. Samples from all 12 sites met all health and aesthetics based water quality standards. [2, 23]

The few groundwater quality patterns found in the basin appear to be of minor importance and probably result from both natural and anthropogenic causes. [18, 21] In down-gradient areas of alluvial basins, the dominant cation often evolves from calcium to sodium. This would explain the significantly higher sodium concentrations found along Dripping Springs Wash compared to sampled springs located up-gradient in consolidated rock.[21] There is more residential and ranch development in down-gradient alluvial areas along Dripping Springs Wash; impacts from domestic septic systems and livestock likely affect the significantly higher nitrate concentrations found in this area. [18]

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Appendix A. Data for Sample Sites, Dripping Springs Basin, 2004-05

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Geology
1st Field Trip, December 15-17, 2004 - Towne & Aguilar (Equipment Blank, GV-85)									
DSW-1	D(4-16)08ddd submersible	33°05'34.404" 110°43'46.218"	602062	64263	Bibbs Well	Inorganic, Radiochem Radon, O & H Isotopes	60'	20'	Alluvial
DSW-2/3 split	D(3-15)29ba submersible	33°08'48.780" 110°50'04.077"	502917	64264	Windspirit Well	Inorganic, Radon O, H isotopes	365'	160'	Alluvial
DSW-4	D(3-14)25adc spring	33°08'32.58" 110°51'46.74"	-	64322	Dripping Springs	Inorganic, Radiochem, O, H isotopes	-	-	Hard Rock
DSW-5	D(4-15)01cdb submersible	33°06'35.552" 110°46'10.516"	-	64265	Hoover Well	Inorganic, Radon, O, H isotopes	110'	40'	Alluvial
2nd Field Trip, March 24, 2005 - Towne & Brunley (Equipment Blank, DSW-12)									
DSW-6/7 duplicate	D(2-14)29dda spring	33°13'27.663" 110°56'04.213"	-	64689	Walnut Spring	Inorganic, Radiochem, O, H isotopes	-	-	Hard Rock
DSW-8	D(2-14)09dd spring	33°13'55.452" 110°52'38.727"	-	64690	Stone Cabin Spr.	Inorganic, Radiochem O, H isotopes	-	-	Hard Rock
DSW-9	D(3-14)4aca windmill	33°12'07.695" 110°55'05.888"	632798	64691	Challenger Windmill	Inorganic, Radiochem Radon, O, H isotopes	392'	175'	Hard Rock
DSW-10/11 split	D(2-15)4c spring	33°16'51." 110°48'58."	-	64692	Squaw Spring	Inorganic, Radiochem O, H isotopes	-	-	Hard Rock
DSW-13 surface H20	at Pinal Peak Road	--	--		Kellner Canyon	O, H isotopes	--	--	-
3rd Field Trip, May 19, 2005 - Towne (Equipment Blank, DSW-21)									
DSW-14/15 split	D(4-15)01cca submersible	33°06'33.282" 110°46'13.012"	644487	64867	Evans Well	Inorganic, Radon O, H isotopes	89'	79'	Alluvial
DSW-16	D(4-16)7add submersible	33°05'58.903" 110°44'41.113"	519967	64868	Teague Well	Inorganic, Radon O, H isotopes	90'	-	Alluvial
DSW-17	D(4-16)8dca submersible	33°05'42.740" 110°43'55.209"	--	64869	Kishbaugh Well	Inorganic, Radon O, H isotopes	60'	47'	Alluvial
DSW-18 surface H2o	At FS Road	--	--		Pioneer Creek	O, H isotopes	-	-	-
DSW-19/20 duplicate	D(2-15)20dda spring	33°15'05.7" 110°50'21.9"	--	64870	Green-house Spr.	Inorganic, Radiochem O, H isotopes	-	-	Hard Rock

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05

Site #	MCL Exceedances	Temp (°C)	pH-field (su)	pH-lab (SU)	SC-field (µS/cm)	SC-lab (µS/cm)	TDS (mg/l)	Hard (mg/l)	Hard - cal (mg/l)	Turb (ntu)
DSW-1	-	17.9	6.96	*8.0*	647	660	390	290	310	*0.30*
DSW-2/3	-	21.3	7.71	*8.16*	406	395	235	175	190	*ND*
DSW-4	-	20.1	7.56	*7.9*	702	730	420	360	370	*ND*
DSW-5	-	20.4	7.21	*7.9*	624	640	370	280	290	*0.21*
DSW-6/7	-	17.0	6.49	*7.9*	726	760	440	355	360	0.06
DSW-8	-	13.8	7.15	*8.0*	276	280	180	110	140	0.78
DSW-9	-	18.4	7.28	*8.0*	574	600	360	260	260	0.84
DSW-10/11	-	8.8	7.22	*7.01*	154	160	110	53	56	0.25
DSW-14/15	-	22.9	6.94	*7.65*	661	645	395	302.5	300	0.03
DSW-16	-	23.5	7.24	*8.0*	629	590	380	280	290	0.65
DSW-17	-	22.7	7.56	*8.1*	610	570	370	270	280	0.08
DSW-19/20	-	--	7.61	*8.1*	695	650	420	320	310	0.59

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05--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)
DSW-1	71	31	29	1.1	300	370	ND	14	25
DSW-2/3	19.5	33	17	2.55	190	230	ND	8.75	5.5
DSW-4	85	38	14	2.0	300	370	ND	20	60
DSW-5	66	31	26	1.2	300	370	ND	12	20
DSW-6/7	93	32	23	2.3	340	410	ND	17.5	46
DSW-8	37	11	8.2	2.8	100	120	ND	5.8	24
DSW-9	68	22	24	1.5	240	290	ND	16	42
DSW-10/11	16.5	3.4	9.45	1.55	57	70	ND	4.3	12.5
DSW-14/15	69	32	27	1.25	310	370	ND	12.5	28.5
DSW-16	67	30	27	1.2	300	370	ND	13	28
DSW-17	64	28	26	1.4	280	340	ND	12	30
DSW-19/20	72.5	32.75	27	1.65	297	365	ND	14	60

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05--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
DSW-1	1.9	1.9	*ND*	0.076	ND	0.022	0.7	C2-S1
DSW-2/3	3.2	3.2	*ND*	0.10	ND	ND	0.6	C2- S1
DSW-4	1.1	1.1	*ND*	ND	ND	ND	0.3	C2- S1
DSW-5	1.9	1.9	*ND*	ND	ND	0.026	0.7	C2- S1
DSW-6/7	1.05	1.05	ND	ND	ND	ND	0.5	C3- S1
DSW-8	0.26	0.26	ND	0.16	ND	0.036	0.3	C2- S1
DSW-9	2.2	2.2	ND	ND	ND	ND	0.6	C2- S1
DSW-10/11	0.35	0.35	ND	0.11	ND	ND	0.6	C1- S1
DSW-14/15	2.55	2.55	ND	ND	ND	ND	0.7	C2- S1
DSW-16	2.5	2.5	ND	ND	ND	ND	0.7	C2- S1
DSW-17	2.6	2.6	ND	0.10	ND	ND	0.7	C2- S1
DSW-19/20	0.036	0.036	ND	1.55	ND	ND	0.7	C2- S1

italics = constituent exceeded holding time

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05--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)
DSW-1	ND	ND	ND	ND	ND	ND	ND	0.063	0.45
DSW-2/3	ND	ND	ND	ND	ND	ND	0.0145	ND	0.25
DSW-4	ND	ND	ND	ND	ND	ND	ND	0.066	0.18
DSW-5	ND	ND	ND	ND	ND	ND	ND	ND	0.32
DSW-6/7	ND	ND	0.14	ND	ND	ND	ND	ND	0.31
DSW-8	ND	ND	ND	ND	ND	ND	ND	ND	0.18
DSW-9	ND	ND	ND	ND	ND	ND	ND	ND	0.23
DSW-10/11	ND	ND	ND	ND	ND	ND	ND	ND	0.165
DSW-14/15	ND	ND	ND	ND	ND	ND	ND	ND	0.27
DSW-16	ND	ND	ND	ND	ND	ND	ND	ND	0.44
DSW-17	ND	ND	ND	ND	ND	ND	ND	ND	0.51
DSW-19/20	ND	ND	0.17	ND	ND	ND	ND	ND	0.74

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05--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)
DSW-1	ND	ND	ND	ND	ND	ND	ND	ND	0.060
DSW-2/3	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-4	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-5	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-6/7	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-8	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-9	ND	ND	ND	ND	ND	ND	ND	ND	1.2
DSW-10/11	ND	ND	ND	ND	ND	ND	ND	ND	0.055
DSW-14/15	ND	ND	ND	ND	ND	ND	ND	ND	0.091
DSW-16	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-17	ND	ND	ND	ND	ND	ND	ND	ND	ND
DSW-19/20	ND	ND	ND	ND	ND	ND	ND	ND	ND

Appendix B. Groundwater Quality Data, Dripping Springs Basin, 2004-05--Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Ra-226 (pCi/L)	Uranium (µg/l)	$\delta^{18}O$ (‰)	δD (‰)	Type of Chemistry
DSW-1	358	0.4	1.2	-	-	- 9.3	- 68	calcium-bicarbonate
DSW-2/3	444	-	-	-	-	- 8.85	-66	magnesium-bicarbonate
DSW-4	-	1.6	2.7	-	-	-10.4	-74	calcium-bicarbonate
DSW-5	385	-	-	-	-	- 9.4	- 68	mixed-bicarbonate
DSW-6/7	-	4.8	1.7	-	-	- 9.5	- 67.5	calcium-bicarbonate
DSW-8	-	< LLD	2.1	-	-	- 11.0	-77	calcium-bicarbonate
DSW-9	449	<LLD	1.3	-	-	-9.5	-68	calcium-bicarbonate
DSW-10/11	-	<LLD	1.1	-	-	- 11.5	- 75	calcium-bicarbonate
DSW-13	-	-	-	-	-	- 11.6	- 78	-
DSW-14/15	377	-	-	-	-	- 10.2	- 73	mixed-bicarbonate
DSW-16	377	-	-	-	-	- 9.7	-70	mixed-bicarbonate
DSW-17	239	-	-	-	-	-10.1	-74	mixed-bicarbonate
DSW-18	-	-	-	-	-	-10.6	-75	-
DSW-19/20	-	1.4	2.3	-	-	- 9.6	- 69	mixed-bicarbonate

LLD = Lower Limit of Detection