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Ambient Groundwater Quality of the Ranegras Plain Basin

A 2008 - 2011 Baseline Study

By Douglas C. Towne
Maps by Jean Ann Rodine

ADEQ Water Quality Division
Surface Water Section
Monitoring Unit
1110 West Washington St.
Phoenix, Arizona 85007-2935

Open File Report 11- 07

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Thanks:

Field Assistance: Elizabeth Boettcher, Susan Determann, Jose Adriano, and John Weisser. Special recognition is extended to the many well owners who were kind enough to give permission to collect groundwater data on their property.

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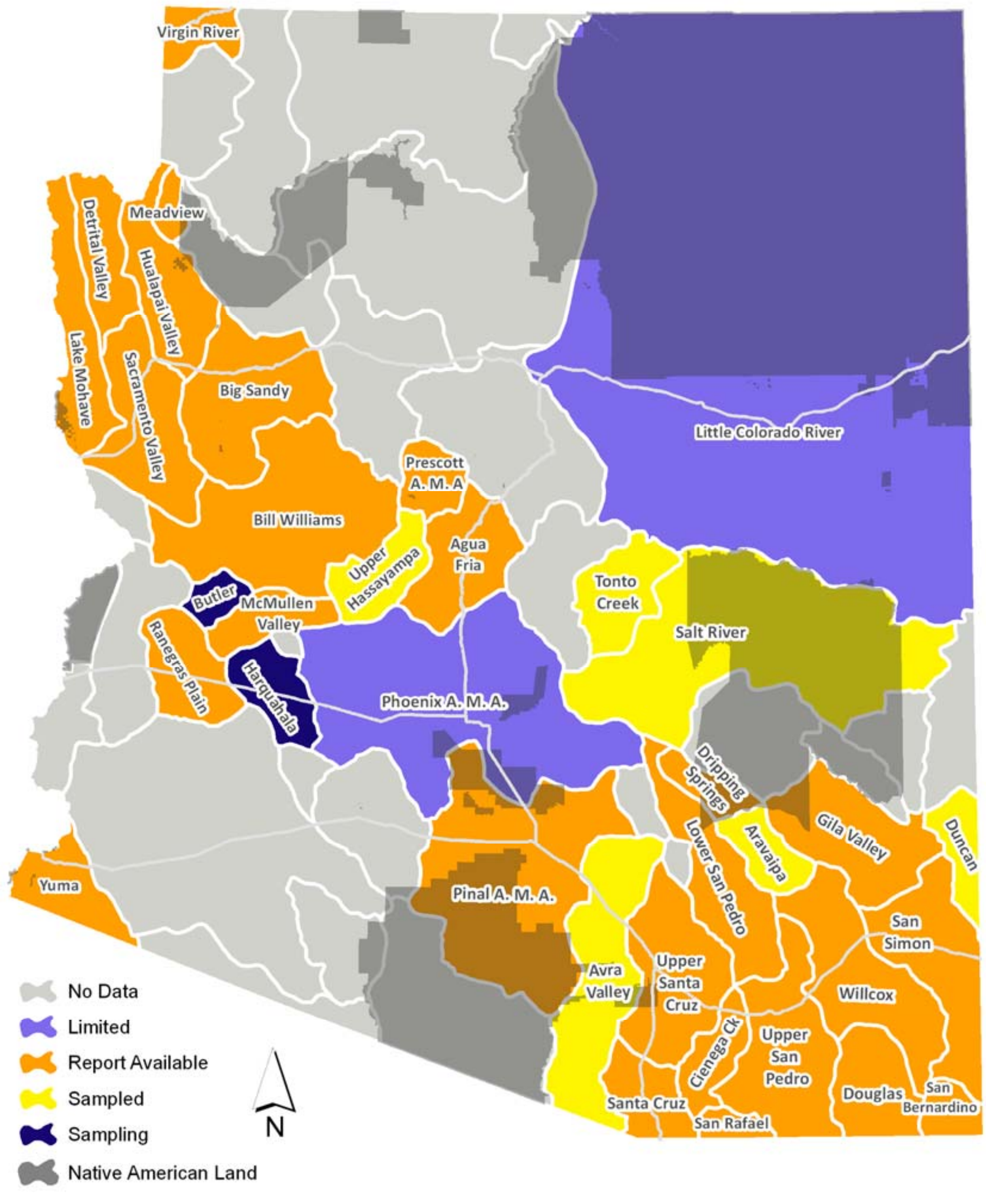
Report Cover: With Coyote Peak in the background, ADEQ's Susan Determann collects a sample from Spreaders House Well located in the Palomas Plain south of Interstate 10. The well, used for stock watering, had nitrate concentrations roughly four times the drinking water quality standard. Nitrogen isotope values indicated the source is likely to be naturally occurring organic nitrogen with potentially only minor inputs of effluent from livestock watering at the nearby corral.

Other Publications of the ADEQ Ambient Groundwater Monitoring Program

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

Groundwater Quality in Arizona	OFR 11-04, 26 p.	-
Bill Williams Basin	OFR 11-06, 77 p.	FS 12-01, 4.p.
San Bernardino Valley Basin	OFR 10-03, 43 p.	FS 10-31, 4 p.
Dripping Springs Wash Basin	OFR 10-02, 33 p.	FS 11-02, 4 p.
McMullen Valley Basin	OFR 11-02, 94 p.	FS 11-03, 6 p.
Gila Valley Sub-basin	OFR 09-12, 99 p.	FS 09-28, 8 p.
Agua Fria Basin	OFR 08-02, 60 p.	FS 08-15, 4 p.
Pinal Active Management Area	OFR 08-01, 97 p.	FS 07-27, 7 p.
Hualapai Valley Basin	OFR 07-05, 53 p.	FS 07-10, 4 p.
Big Sandy Basin	OFR 06-09, 66 p.	FS 06-24, 4 p.
Lake Mohave Basin	OFR 05-08, 66 p.	FS 05-21, 4 p.
Meadview Basin	OFR 05-01, 29 p.	FS 05-01, 4 p.
San Simon Sub-Basin	OFR 04-02, 78 p.	FS 04-06, 4 p.
Detrital Valley Basin	OFR 03-03, 65 p.	FS 03-07, 4 p.
San Rafael Basin	OFR 03-01, 42 p.	FS 03-03, 4 p.
Lower San Pedro Basin	OFR 02-01, 74 p.	FS 02-09, 4 p.
Willcox Basin	OFR 01-09, 55 p.	FS 01-13, 4 p.
Sacramento Valley Basin	OFR 01-04, 77 p.	FS 01-10, 4 p
Upper Santa Cruz Basin (w/ USGS)	OFR 00-06, 55 p.	-
Prescott Active Management Area	OFR 00-01, 77 p.	FS 00-13, 4 p.
Upper San Pedro Basin (w/ USGS)	OFR 99-12, 50 p.	FS 97-08, 2 p.
Douglas Basin	OFR 99-11, 155 p.	FS 00-08, 4 p.
Virgin River Basin	OFR 99-04, 98 p.	FS 01-02, 4 p.
Yuma Basin	OFR 98-07, 121 p.	FS 01-03, 4 p.

These publications are available on-line at:
www.azdeq.gov/environ/water/assessment/ambient.html


Virgin River
Meadview
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Hualapai Valley
Lake Mohave
Sacramento Valley
Big Sandy
Bill Williams
Prescott A. M. A
Agua Fria
Upper Hassayampa
Butler
McMullen Valley
Ranegras Plain
Harquahala
Phoenix A. M. A.
Little Colorado River
Tonto Creek
Salt River
Dripping Springs
Aravaipa
Gila Valley
Duncan
Lower San Pedro
Yuma
Pinal A. M. A.
Avra Valley
Upper Santa Cruz
Cienega Ck
Upper San Pedro
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Douglas
San Bernardino
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San Rafael
No Data
Limited
Report Available
Sampled
Sampling
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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
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
CAP	Central Arizona Project
^{o}C	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
GWPL	Groundwater Protection List pesticide
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
ns	not significant
ntu	nephelometric turbidity unit
pCi/L	picocuries per liter
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RAN	Ranegras Plain Groundwater Basin
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 Ranegras Plain Basin: A 2008-2011 Baseline Study

Abstract - In 2008-2011, the Arizona Department of Environmental Quality (ADEQ) conducted a baseline groundwater quality study of the Ranegras Plain basin located in west-central Arizona. The basin comprises 912 square miles within La Paz County.[4] Interstate 10 and U.S. Highway 60 traverse the basin east to west and the Central Arizona Project aqueduct crosses the basin in a northwest-southeast direction. The lightly populated basin includes the small communities of Bouse, Brenda, Harcuvar, Hope, Vicksburg, and Vicksburg Junction. Many residents are visitors who live seasonally in homes or trailer parks located in the north-central portion of basin. Irrigated farmland is mostly located between Interstate 10 and U.S. Highway 60. South of Interstate 10, the majority of land is publicly-owned and is used for low-intensity grazing or is part of the Kofa National Wildlife Refuge.

The basin's main drainage is the ephemeral Bouse Wash which exits the basin just northwest of the Town of Bouse. The main aquifer is the lower basin fill which is composed of sand, gravel, volcanics, and conglomerate.[16] The aquifer is overlain by a fine-grained unit that contains evaporates in its lower part. [20] The surrounding mountains may produce small quantities of groundwater. [4] Most groundwater pumped in the basin is used for irrigation. Groundwater is used for all domestic, public supply, stock and irrigation purposes except for some minor stock uses that utilize surface water. [4]

To characterize regional groundwater quality, samples were collected from 55 sites (53 wells and 2 springs). The wells were predominantly used for stock (20 wells), domestic (16 wells), irrigation (10 wells), and semi-public supply (7 wells) purposes. The 2 springs provide water for wildlife. Inorganic constituents and two isotopes (oxygen and deuterium) were collected from all 55 sites. At selected sites, radon (33 sites), radiochemistry (18 sites) and nitrogen isotope (10 sites) samples were also collected.

Health-based, Primary Maximum Contaminant Levels (MCLs) were exceeded at 39 of the 55 sites (71 percent). These enforceable standards define the maximum concentrations of constituents allowed in water supplied for drinking water purposes by a public water system and are based on a lifetime daily consumption of two liters. [25] Constituents exceeding Primary MCLs include arsenic (35 sites), chromium (4 sites), fluoride (28 sites), and nitrate (12 sites). Elevated concentrations of arsenic, chromium, and fluoride likely occur naturally. [16] Elevated nitrate concentrations at isolated stock wells also appear to be naturally occurring based on nitrogen isotope results. However, high nitrate concentrations in agricultural areas are likely influenced by nitrogen-laden recharge from irrigation applications.[21] Aesthetics-based, Secondary MCLs were exceeded at 51 of 55 sites (93 percent). These are unenforceable guidelines that define the maximum constituent concentration that can be present in drinking water without an unpleasant taste, color, or odor.[25] Constituents above Secondary MCLs include chloride (16 sites), fluoride (40 sites), manganese (1 site), pH (4 sites), sulfate (25 sites), and total dissolved solids (TDS) (44 sites).

Groundwater in the basin is typically *slightly-alkaline*, *fresh* or *slightly saline*, and *soft* to *extremely hard*, based on pH levels along with TDS and hardness concentrations. [9, 13] Evaporates in the lower part of the aquifer account for the relatively high salinity of groundwater in the basin. [20] Sodium was the dominant cation in most samples while the anion composition varied from a mixture to one dominated by either chloride or sulfate.

Oxygen and deuterium isotope values at 31 sites were generally lighter and more depleted than would be expected from recharge originating at the basin's elevation. These "old recharge" sites appear to consist of paleowater predominantly recharged 8,000-12,000 years ago when the basin was cooler and subject to much less evaporation. [10] Ten "mixed recharge" sites had slightly less depleted isotope values and may contain small amounts of more recently recharged groundwater. Enriched isotope values were found at 10 sites and appear to consist of "recent" mountain front recharge occurring in the Kofa, New Water, Plomosa, Granite Wash, and Little Harquahalas.

Groundwater constituent concentrations are strongly influenced by recharge age. Constituents such as pH-field, specific conductivity (SC), TDS, sodium, chloride, sulfate, arsenic, boron, chromium, and fluoride had significantly greater concentrations in "old recharge" than "recent recharge"; hardness, magnesium, and bicarbonate had the opposite pattern (Kruskal-Wallis test, $p \leq 0.05$). Because of these water quality differences, recent recharge is generally preferred over old recharge as a water source for domestic and public water supply uses; however, this source is spatially limited and was found only in some peripheral areas of the basin near the higher mountain ranges. Water quality at sites having a mixed recharge was slightly improved compared with sites having old recharge; however, mixed recharge sites were also spatially limited usually located downgradient of recent recharge sites.

INTRODUCTION

Purpose and Scope

The Ranegras Plain basin (RAN) comprises approximately 912 square miles within La Paz County in west central Arizona (Map 1).[4] The basin is located about 100 miles west of Phoenix. Lightly populated, the basin includes the small communities of Bouse, Brenda, Hope, Vicksburg, and Vicksburg Junction. Interstate 10 and U.S. Highway 60 traverse the basin from east to west; Arizona Highway 72 branches off U.S. Highway 60 at Hope and goes to the northwest. The Central Arizona Project (CAP) aqueduct crosses the basin in a northwest-southeast direction.

Many residents are seasonal visitors who live in the basin during the cooler winter months. The basin has numerous trailer parks which cater to the winter visitors. Groundwater is the only dependable source for domestic, public supply, irrigation, and stock water supply within the basin. Most water pumped in the basin is used for irrigation.[4]

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 characterization of regional groundwater quality conditions in the Ranegras Plain basin identifying water quality variations between groundwater of different ages.
- A process for evaluating potential groundwater quality impacts arising from mineralization, mining, 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 Ranegras Plain basin is a northwest-trending plain surrounded by low block-faulted mountains within the Basin and Range physiographic province. The valley floor slopes gently northwestward and is drained by Bouse Wash, an ephemeral stream. This tributary to the Colorado River has a drainage area that includes the Ranegras Plain and as well as Butler Valley and a small section of McMullen Valley.[4] There are no perennial or intermittent streams or large reservoirs although 16 stockponds are registered in the basin.[4]

The basin is bounded on the south by the Eagletail and Little Horn Mountains, on the west by the Plomosa, New Water, and Kofa Mountains, on the north by the Bouse Hills, and on the east by the Little Harquahala and Granite Wash Mountains. Elevations on the Ranegras Plain are about 2,805 feet above mean sea level (amsl) descending to 930 feet amsl near where the Bouse Wash exits the basin in the northwest into the Parker basin.[4]

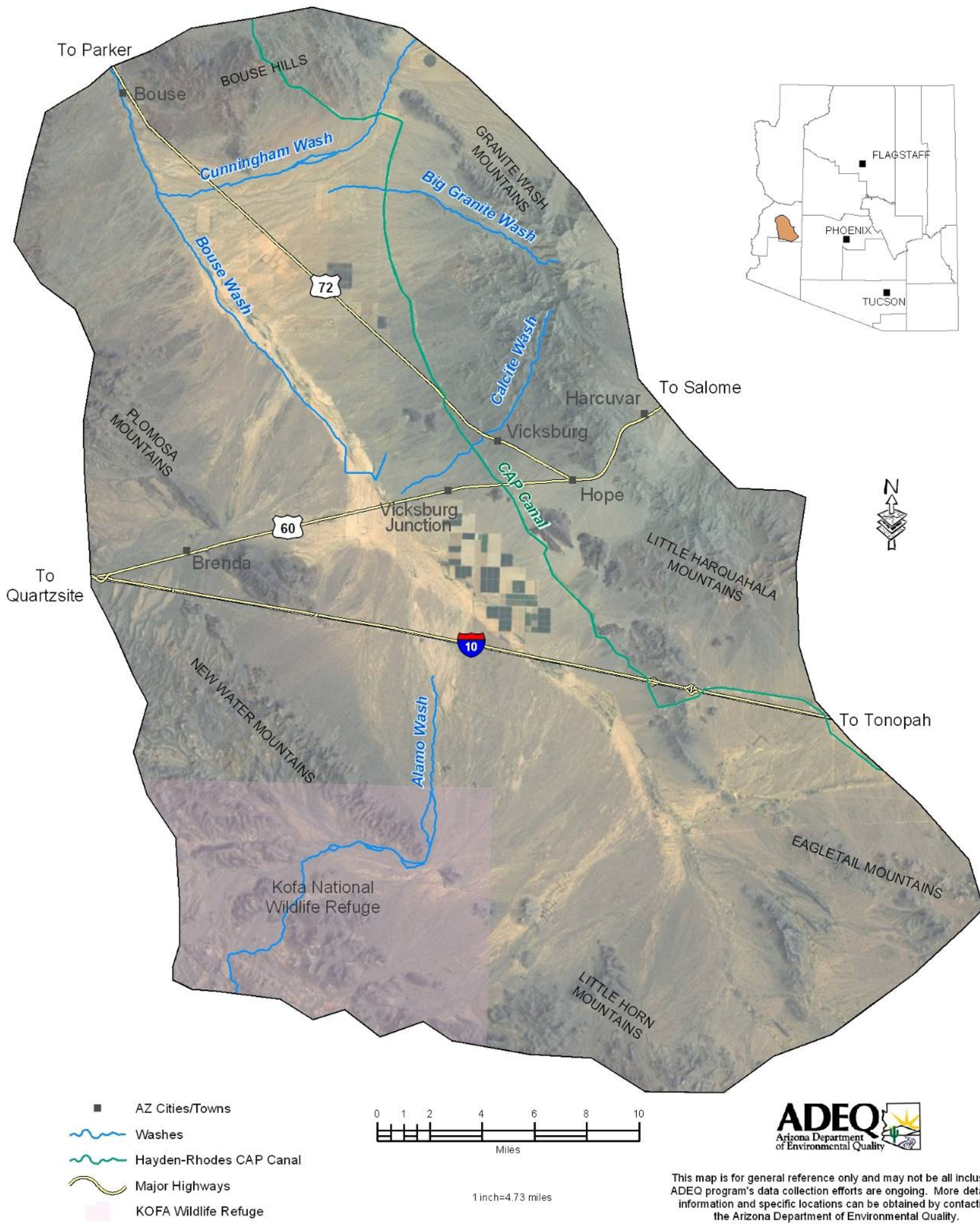
The Ranegras Plain basin predominantly consists of federal land (82 percent) managed by the Bureau of Land Management (66 percent) and the U.S. Fish and Wildlife (16 percent) which administers the Kofa National Wildlife Refuge. Private (11 percent) and State Trust lands (7 percent) are generally found in the center of the basin.[3]

Climate – The Ranegras Plain has an arid climate characterized by hot, dry summers and mild winters. Precipitation, which averages a little over five inches annually near Bouse, occurs predominantly as rain in either late summer, localized monsoon thunderstorms or, less often, as widespread, low intensity winter rain that rarely includes snow at higher elevations.[16]

Geology – The mountains surrounding Ranegras Plain has the following geology: Little Harquahala Mountains (basalt and granite), Granite Wash Mountains (granite), Little Horn, Eagle Tail and Kofa Mountains (basalt and andesite), Plomosa and New Water Mountains (andesite) and the Bouse Hills (andesite and granite).[18, 20]

A Tertiary sedimentary conglomerate is the basal unit of the basin-fill material. The basin-fill material is alluvium composed of late Tertiary clay to sand-sized particles with some gravel deposits and interbedded volcanics.[16] Depth of the basin-fill exceeds 1,500 feet below land surface (bls) and may extend to 3,200 feet

Map 1 - Ranegras Plain 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.

Name: Ranegras_Plain_inset_map1

bls in the basin's southern portion. Quaternary-aged streambed alluvium composed of sand and gravel lenses not more than several hundred feet thick occurs in Bouse Wash and its tributaries. [16]

HYDROLOGY

Groundwater Characteristics

Groundwater occurs primarily in the basin-fill sediments composed of clay, volcanics, conglomerate, and smaller amounts of sand and gravel.[16] The thickness of the these alluvium deposits is unknown but may exceed 1,500 feet bls in some areas.[16] Overlying the aquifer is an extensive fine-grained unit that can be up to 600 feet thick and contains evaporates in its lower portions.[20] The evaporates are largely responsible for the high salinity found in the groundwater. [20] The aquifer is generally unconfined though some areas of perched water occur that are 10 to 50 feet higher than the surrounding areas.[16]

Well yields vary widely in the basin though most wells have low to moderate production rates because of the high clay content of the basin fill. Yields range from 85 to 3,310 gallons per minute (gpm) in the basin-fill. [16] The most productive wells are located in coarser sediments and in stream-bed alluvium. High clay contents of the aquifer lowers well yields in other areas of the basin-fill. [20] The few wells drilled in the igneous, metamorphic, and consolidated sedimentary rocks have low yields suitable only for domestic or stock use. [16] There is an estimated 21.7 million acre-feet of water available in the basin to a depth of 1,200 feet. [4]

Groundwater moves from the surrounding mountains toward the central axis of the basin and follows the Bouse Wash to the northwest. Near the town of Bouse, underflow into the Parker Basin is estimated to be less than 1,000 acre-feet per year.[4] Groundwater levels vary from approximately 450 feet bls in the eastern part of the basin near the mountain fronts to 30 feet bls near Bouse.[4] Groundwater elevations have fluctuated with irrigation pumping. Currently, a major cone of depression occurs in the eastern part of the basin south of Vicksburg Junction. [16]

Most groundwater pumped in the Ranegras Plain is used for irrigation in the central part of the basin. Irrigated farming began in 1948 when two irrigation wells were drilled. [6] Within a decade, over 5,200 acres were irrigated by 15 wells. Cultivation peaked in 1981 when 50,000 acre-feet of water was pumped to irrigate 12,600 acres. [16] By 1990, roughly half the irrigated acreage was fallow.

Natural basin recharge is estimated to be 5,000 acre-feet per year occurring predominantly by infiltration of runoff in Bouse Wash and its tributaries. [16] Subsurface inflow of groundwater from Butler Valley and the Harquahala basins also annually provides about 500 acre-feet of recharge. Recharge also occurs from the Central Arizona Project Canal, which crosses the northeast part of the Ranegras Plain basin. Seepage losses from the canal are thought to be approximately 6,000 acre-feet annually. [16]

INVESTIGATION METHODS

ADEQ collected samples from 55 groundwater sites to characterize regional groundwater quality in the Ranegras Plain basin (Map 2). Specifically, the following types of samples were collected:

- oxygen and deuterium isotopes at 55 sites
- inorganic suites at 55 sites
- radionuclide at 18 sites
- radon at 33 sites
- nitrogen isotopes at 10 sites

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. [12]

Wells pumping groundwater for domestic, semi-public supply, irrigation, and stock purposes were sampled for the study provided each well met ADEQ requirements. A well was considered suitable for sampling when: the owner has given permission to sample, a sampling point existed near the wellhead, and the well casing and surface seal appeared to be intact and undamaged.[1, 5] 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 53 wells all served by submersible pumps except for 2 pump jacks and 11 turbine pumps. Two springs were also sampled for the study. Of the 53 wells sampled, their primary purposes were stock (20 wells), domestic (16 wells), irrigation (10 wells), semi-public water supply (7 wells). The two springs served wildlife. Additional information on groundwater sample sites is compiled from the Arizona Department of Water Resources (ADWR) well registry in Appendix A. [4]

Figure 1 – Wells located in the Kofa National Wildlife Refuge, such as the Kofa Windmill, were unable to be sampled because there was no access to freshly pumped groundwater before it flowed into storage tanks.

Figure 2 – Owl Head rock formation located within the Kofa National Wildlife Refuge which comprises the southwest corner of the Ranegras Plain basin. Only springs were able to be sampled in the refuge.

Figure 3 – After sampling Holly Seep (RAN-28) within the Kofa Wildlife Refuge Wilderness, ADEQ's Susan Determann poses next to the partially frozen water source. A camera to document wildlife visits is mounted on the canopy shading the seep.

Figure 4 – Dun Well (RAN-52) is used for stock watering south of the Town of Bouse. Originally a windmill was used to fill the water tank; currently a submersible pump powered by a portable generator supplies water.

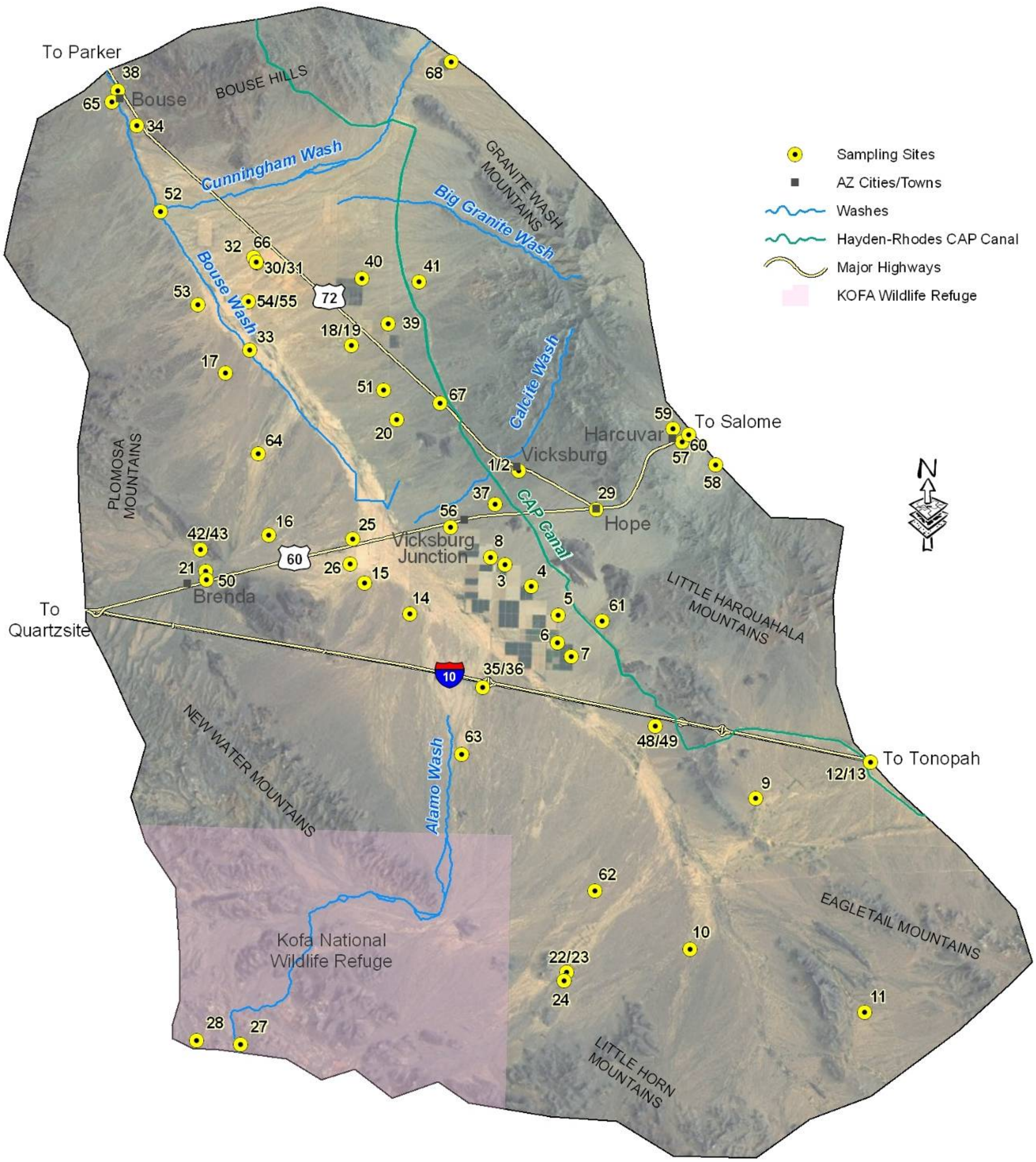
Figure 5 – Water pumped from Dun Well (RAN-52) pours into a nearby water tank formerly served by a windmill. Ranchers in the basin prefer using submersible pumps powered by portable generators to supply water for livestock.

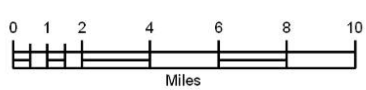
Figure 6 – A vintage jack pump produces water from Chico's Well (RAN-53) to supply livestock. ADEQ's Liz Boettcher can be seen collecting the sample where the pipeline empties into a former underground storage tank.

Figure 7 – Ranch foreman Jose Adriano assists ADEQ's Susan Determann in collecting a sample from MacLean Well (RAN-20). The well was one of 28 in the study in which fluoride concentrations exceeded health-based standards.

Figure 8 – The faucet on Plamosa Well (RAN-16) provides a perfect sampling location to obtain freshly pumped groundwater. The arsenic concentration at the well, 0.034 mg/L, exceeded the water quality standard of 0.010 mg/L.

Map 2 - Sample Sites





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Name: Ranegras_Sites_map2

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*. [5] 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 well owner, 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 either a Hach or 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. Inorganics
3. Radionuclides
4. Isotopes

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.[22]

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. [19, 22, 29]

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. [11]

Oxygen and hydrogen isotope samples were collected in a 250 ml polyethylene bottle with no preservative. Nitrogen isotope samples were collected in a 500 ml polyethylene bottle filled ¾ full. [24]

All samples were kept at 4°C with ice in an insulated cooler, with the exception of the oxygen and hydrogen isotope and radiochemistry samples. [11, 25] Nitrogen samples were frozen upon returning from the field and shipped in dry ice to the laboratory. [25] Chain of custody procedures were followed in sample handling. Samples for this study were collected during 15 field trips between October 2008 and December 2011.

Laboratory Methods

The inorganic analyses for samples RAN-1 through RAN-8 were conducted by the Arizona Department of Health Services (ADHS) Laboratory in Phoenix, Arizona. Inorganic sample splits analyses for RAN-2 were conducted by Test America Laboratory in Phoenix, Arizona.

For samples RAN-9 through RAN-68, inorganic analyses were conducted by Test America Laboratory in Phoenix, Arizona. Inorganic sample splits analyses were conducted by Xenco Laboratory in Phoenix, Arizona. A complete listing of inorganic parameters, including laboratory method, and Minimum Reporting Level (MRL) for each laboratory is provided in Table 1.

Radon samples were submitted to Test America Laboratory and analyzed by Radiation Safety Engineering, Inc. Laboratory in Chandler, Arizona.

Radionuclide analyses for samples RAN-1 through RAN-8 were conducted by the Arizona Radiation Agency Laboratory in Phoenix. For samples RAN-9 through RAN-68, radionuclide analysis was conducted by Radiation Safety Engineering, Inc. Laboratory in Chandler, Arizona. 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. [11]

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

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

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America / Xenco Minimum Reporting Level
Physical Parameters and General Mineral Characteristics			
Alkalinity	Electrometric Titration	SM 2320B / M 2320 B	2 / 6 / 20
SC (uS/cm)	Electrometric	EPA 120.1/ M 2510 B	-- / 2 / 1
Hardness	Titrimetric, EDTA	SM 2340 C / SM 2340B	10 / 1 / 2.5
Hardness	Calculation	SM 2340 B	--
pH (su)	Electrometric	SM 4500 H-B	0.1
TDS	Gravimetric	SM 2540C	10
Turbidity (NTU)	Nephelometric	EPA 180.1	0.01 / 0.2 / 0.1
Major Ions			
Calcium	ICP-AES	EPA 200.7	1 / 2 / 1
Magnesium	ICP-AES	EPA 200.7	1 / 0.25 / 1
Sodium	ICP-AES	EPA 200.7	1 / 2 / 2
Potassium	Flame AA	EPA 200.7	0.5 / 2 / 2
Bicarbonate	Calculation	Calculation / M 2320 B	2
Carbonate	Calculation	Calculation / M 2320 B	2
Chloride	Potentiometric Titration	SM 4500 CL D / E 300	5 / 2 / 1
Sulfate	Colorimetric	EPA 375.4 / E 300	1 / 2 / 1
Nutrients			
Nitrate as N	Colorimetric	EPA 353.2	0.02 / 0.1 / 0.1
Nitrite as N	Colorimetric	EPA 353.2	0.02 / 0.1 / 0.05
Ammonia	Colorimetric	EPA 350.1/ EPA 350.3	0.02 / 0.5 / 0.1
TKN	Colorimetric	EPA 351.2 / M 4500-NH3	0.05 / 1.3 / 0.2
Total Phosphorus	Colorimetric	EPA 365.4 / M 4500-PB	0.02 / 0.1 / 0.05

All units are mg/L except as noted
Source [19, 22, 29]

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

Constituent	Instrumentation	ADHS / Test America Water Method	ADHS / Test America / Xenco Minimum Reporting Level
		Trace Elements	
Aluminum	ICP-AES	EPA 200.7	0.5 / 0.2 / 0.1
Antimony	Graphite Furnace AA	EPA 200.8	0.005 / 0.003 / 0.002
Arsenic	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.001 / 0.003
Barium	ICP-AES	EPA 200.8 / EPA 200.7	0.005 to 0.1 / 0.01 / 0.01
Beryllium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.0005 / 0.001 / 0.0005
Boron	ICP-AES	EPA 200.7	0.1 / 0.2 / 0.1
Cadmium	Graphite Furnace AA	EPA 200.8	0.0005 / 0.001 / 0.002
Chromium	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01 / 0.005
Copper	Graphite Furnace AA	EPA 200.8 / EPA 200.7	0.01 / 0.01 / 0.002
Fluoride	Ion Selective Electrode	SM 4500 F-C	0.1 / 0.4 / 0.5
Iron	ICP-AES	EPA 200.7	0.1 / 0.05 / 0.1
Lead	Graphite Furnace AA	EPA 200.8	0.005 / 0.001 / 0.002
Manganese	ICP-AES	EPA 200.7	0.05 / 0.01 / 0.01
Mercury	Cold Vapor AA	SM 3112 B / EPA 245.1	0.0002
Nickel	ICP-AES	EPA 200.7	0.1 / 0.01 / 0.01
Selenium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.005 / 0.002 / 0.002
Silver	Graphite Furnace AA	EPA 200.9 / EPA 200.7	0.001 / 0.01 / 0.001
Strontium	ICP-AES	EPA 200.7	0.1 / 0.1 / 0.05
Thallium	Graphite Furnace AA	EPA 200.9 / EPA 200.8	0.002 / 0.001 / 0.0005
Zinc	ICP-AES	EPA 200.7	0.05
		Radionuclides	
Gross alpha	Gas flow proportional counter	EPA 600 / 00.02	Varies
Gross beta	Gas flow proportional counter	EPA 900.0	Varies
Radium 226	Gas flow proportional counter	EPA 903.0	Varies
Radium 228	Gas flow proportional counter	EPA 904.0	Varies
Radon	Liquid scintillation counter	EPA 913.1	varies
Uranium	Kinetic phosphorimeter	EPA Laser Phosphorimetry	Varies

All units are mg/L Source [3, 13, 20, 29]

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 Ranegras Plain 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, 5] Types and numbers of QC samples collected for this study are as follows:

- Inorganic: (1 duplicate, 8 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 – Two equipment blanks for inorganic analyses were collected and delivered to the ADHS laboratory to ensure adequate decontamination of sampling equipment, and that the filter apparatus and/or de-ionized water were not impacting the groundwater quality sampling.[5] 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 both equipment blanks) and turbidity (detected in one equipment blank).

For SC, the two equipment blanks had a mean value (4.3 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.[19]

For turbidity, equipment blanks had a mean level of 0.03 nephelometric turbidity units (ntu) less than 1 percent of the turbidity median level for the study and was 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.[19]

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

One duplicate sample was collected and submitted to the Test America laboratory for this study. Analytical results indicate that of the 40 constituents examined, 21 had concentrations above the MRL. The duplicate sample had an excellent correlation as the maximum variation between constituents was less than 5 percent (Table 2).

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.[5] Overall, eight inorganic split samples were collected; one split sample between the ADHS and Test America labs and seven split samples between Test America and Xenco labs. The 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, 14 had concentrations above MRLs for both ADHS and Test America laboratories (Table 3). The maximum variation between constituents was 5 percent. In addition, selenium was detected at 0.0054 mg/L in the ADHS sample and not detected in the Test America sample at an ADHS split at an MRL of 0.002 mg/L. 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.[14] There were no significant differences in constituent concentrations between the labs (Sign test, $p \leq 0.05$).

Table 2. Summary Results of Ranegras Plain Basin Duplicate Sample from Test America 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	1	-	-	2 %	-	-	1
SC (uS/cm)	1	-	-	0 %	-	-	0
Hardness	1	-	-	0 %	-	-	0
pH (su)	1	-	-	1 %	-	-	0.04
TDS	1	-	-	0 %	-	-	0
Turb. (ntu)	1	-	-	0 %	-	-	0
Major Ions							
Calcium	1	-	-	5 %	-	-	10
Magnesium	1	-	-	1 %	-	-	0.1
Sodium	1	-	-	1 %	-	-	10
Potassium	1	-	-	0 %	-	-	0
Chloride	1	-	-	0 %	-	-	0
Sulfate	1	-	-	1 %	-	-	10
Nutrients							
Nitrate (as N)	1	-	-	0 %	-	-	0
Trace Elements							
Arsenic	1	-	-	0 %	-	-	0
Barium	1	-	-	3 %	-	-	0.001
Boron	1	-	-	0 %	-	-	0
Chromium	1	-	-	1 %	-	-	0.001
Copper	1	-	-	3 %	-	-	0.0002
Fluoride	1	-	-	0 %	-	-	0
Selenium	1	-	-	1 %	-	-	0.0001
Strontium	1	-	-	0 %	-	-	0

All concentration units are mg/L except as noted with certain physical parameters.

Table 3. Summary Results of Ranegras Plain Basin Split Samples between Test America / ADHS 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	1	3 %	3 %	10	10	ns
SC (uS/cm)	1	0 %	0 %	0	0	ns
Hardness	1	3 %	3 %	10	10	ns
pH (su)	1	1 %	1 %	0.1	0.1	ns
TDS	1	5 %	5 %	60	60	ns
Turbidity (ntu)	1	0 %	0 %	0	0	ns
Major Ions						
Calcium	1	1 %	1 %	1	1	ns
Magnesium	1	2 %	2 %	1	1	ns
Sodium	1	3 %	3 %	10	10	ns
Potassium	1	3 %	3 %	0.4	0.4	ns
Chloride	1	1 %	1 %	1	1	ns
Sulfate	1	2 %	2 %	10	10	ns
Nutrients						
Nitrate as N	1	5 %	5 %	0.2	0.2	ns
Trace Elements						
Boron	1	5 %	5 %	0.06	0.06	ns
Fluoride	1	3 %	3 %	0.05	0.05	ns

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

All units are mg/L except as noted

Table 4. Summary Results of Ranegras Plain Basin Split Samples between Test America / Xenco 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	7	1 %	7 %	2	12	ns
SC (uS/cm)	7	1 %	9 %	28	710	ns
Hardness	7	1 %	36 %	1.7	373	ns
pH (su)	7	0 %	2 %	0.01	0.4	ns
TDS	7	0 %	34 %	2	512	ns
Turbidity (ntu)	3	12 %	31 %	0.14	4.2	ns
Major Ions						
Calcium	7	1 %	4 %	0.7	19	ns
Magnesium	7	1 %	11 %	0.005	5.7	ns
Sodium	7	0 %	6 %	2	117	ns
Potassium	5	0 %	4 %	0	0.48	ns
Chloride	7	1 %	25 %	1.1	140	ns
Sulfate	7	0 %	25 %	1	180	ns
Nutrients						
Nitrate as N	7	3 %	32 %	0.35	36.8	ns
Trace Elements						
Arsenic	6	0 %	39%	0	0.0047	ns
Barium	6	0 %	18 %	0.00011	0.0058	ns
Boron	7	0 %	7 %	0.004	0.046	ns
Chromium	6	3 %	9 %	0.00065	0.012	ns
Copper	6	48 %	86 %	0.00201	0.01512	ns
Fluoride	7	0 %	13 %	0.01	1.38	ns
Selenium	3	10 %	27 %	0.00101	0.00289	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
Arsenic was detected at 0.0047 mg/L by Test America and not detected by Xenco at an MRL of 0.003 mg/L
Potassium was detected at 2.1 mg/L by Xenco and not detected by Test America at an MRL of 2.0 mg/L
Selenium was detected at 0.0219 mg/L by Xenco and not detected by Test America at an MRL of 0.01 mg/L
Turbidity was detected at 0.272 ntu by Xenco sample and not detected by Test America at an MRL of 0.20 ntu

Analytical results indicate that of the 36 constituents examined, 20 had concentrations above MRLs for both Test America and Xenco laboratories (Table 4)

The maximum variation between constituents was 86 percent and 12 constituents exceeded 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.[14] Total alkalinity and copper had significant differences in constituent concentrations between the labs; arsenic and sulfate also have significantly different constituent concentrations (Sign test, $p \leq 0.05$).

Based on the results of blanks and duplicate samples collected for this study, no significant QA/QC problems were apparent with the study. Although used in the study, split samples using Xenco laboratory were determined not to be a valuable QA/QC measurement based on the following factors: significant constituent concentration differences between split samples, high maximum variation between constituents, failure to meet cation/anion balance, and SC/TDS validation measurements.

Data Validation

The analytical work for this study was subjected to four QA/QC correlations and considered valid based on the following results. [15]

Cation/Anion Balances - In theory, water samples exhibit electrical neutrality. Therefore, the sum of milliequivalents 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.[15]

Overall, cation/anion meq/L balances of Ranegras Plain basin samples were significantly correlated (regression analysis, $p \leq 0.01$). Of the 55 samples, 48 were within +/-10 percent and 41 were within +/-5 percent. Of the 14 samples exceeding 5 percent, 9 samples had high cation/low anion sums and 6 samples had low cation/high anion sums. The largest difference was in sample RAN-66, which had a 42 percent difference with the total cation sum more than doubling the total anion sum. Test America Laboratory was contacted but could not locate the error although the dilution factor of 20 for both chloride and sulfate seemed to be a likely reason. [22]

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.[15] 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.[15]

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

pH - The pH value is closely related to the environment of the water and is likely to be altered by sampling and storage.[15] 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, $r = 0.66$, $p \leq 0.05$).

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. [15] Groundwater depth was not significantly correlated with temperature (regression analysis, $r = 0.44$, $p \leq 0.05$). Well depth (Diagram 1) was however, significantly correlated with temperature (regression analysis, $r = 0.57$, $p \leq 0.01$).

Statistical Considerations

Various methods were used to complete the statistical analyses for the groundwater quality data of the study. All statistical tests were conducted using SYSTAT software.[28]

Data Normality: Data associated with 27 constituents were tested for non-transformed normality using the Kolmogorov-Smirnov one-sample test with the Lilliefors option.[7] Results of this test revealed that 4 of the 27 constituents (fluoride, pH-field, pH-lab, and radon) examined were normally distributed.

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 aquifers were the same. The Kruskal-Wallis test uses the differences, but also incorporates information about the magnitude of each difference.[28] 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. 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. [28] 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.[14]

Correlation Between Constituents: 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. [28] Like Kruskal-Wallis and Tukey tests, the Pearson test is not valid for data sets with greater than 50 percent of the constituent concentrations below the MRL.[14]

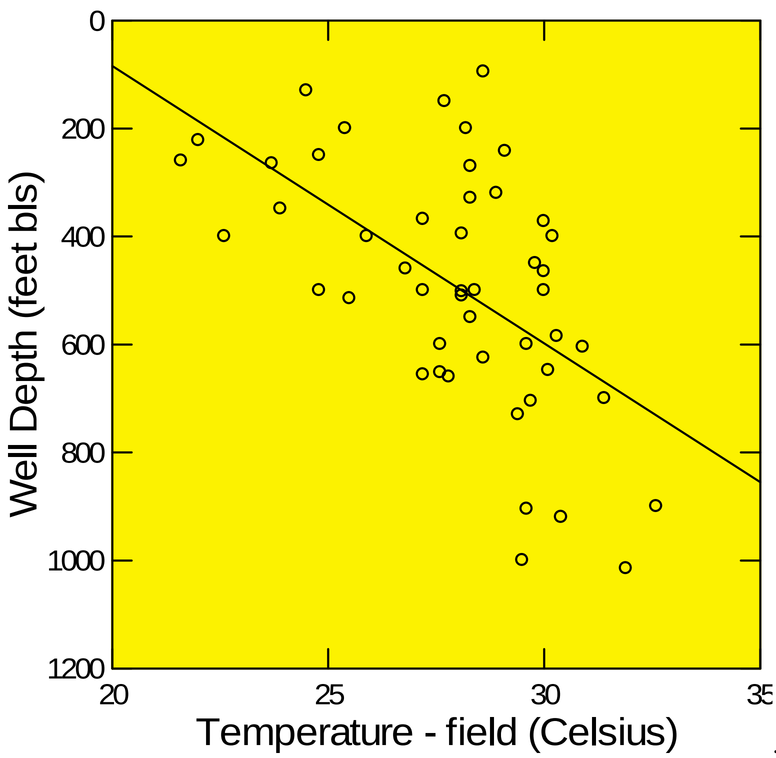


Diagram 1 – The graph illustrates a strong positive correlation; as well depth increases water temperature as measured in the field also increases. The regression equation for this relationship is y = 51x - 944, n = 48, r = 0.57. Groundwater temperature should increase with depth, approximately 3 degrees Celsius with every 100 meters or 328 feet. [15]

Figure 9 – (RAN-17) ADEQ's Elizabeth Boettcher is shown sampling Swadley Well that provides water for livestock. The sample collected from the well had an arsenic concentration of 0.034 mg/L, one of 35 of 55 sampled sites that exceeded standards.

Figure 10 – ADEQ's Susan Determann samples the Stendel domestic well (RAN-21) located in the adjacent shed. Domestic wells are mostly found north of Interstate 10; the sample from this well met all health-based water quality standards.

Figure 11 – A split sample (RAN-35/36) is collected at the Tomahawk Truck Stop well by ADEQ's Susan Determann. Test America Laboratory analyzed most samples for the study and Xenco Laboratory was used for split samples.

Figure 12 –Sore Finger Well (RAN-12) is used for watering livestock on the basin's eastern boundary just south of Interstate 10. Four constituents exceeded health-based standards in the sample collected from the well.

Figure 13 – Ranch foreman Jose Adriano assists ADEQ's Elizabeth Boettcher in collecting a sample from CAP Tank Well (RAN-61). In many areas of the basin, stock wells were the only available sources to collect groundwater samples.

Figure 14 – This irrigation well on State land was recently reactivated to irrigate alfalfa that will be used to feed dairy cattle near Buckeye. The sample (RAN-54/55) exceeded both arsenic and fluoride health-based water quality standards.

Figure 15 – The population of the Ranegras Plain basin fluctuates seasonally peaking during the cooler months. Many residents live in trailer parks served by wells such as the Eden Park (above) that was sampled (RAN-37) for the study.

Figure 16 – One of the world's largest jojoba farms is located in the basin north of State Highway 72. Two farm wells powered by diesel generators were sampled including Purcell Well #5 shown above (RAN-39).

Figure 17 – Many livestock wells in the basin had faucets at the wellhead that made the collection of defensible groundwater samples much easier.

Figure 18 – Irrigation wells that were sampled (RAN-8) on the Vicksburg Ranch, located in the center of the basin, often exceeded health-based water quality standards for nitrate.

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.[25]

- 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 except for arsenic which is at 0.05 mg/L compared with the Primary MCL of 0.01 mg/L. [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.[25]

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.[25] Exceedances of specific constituents for each groundwater site is found in Appendix B.

Overall Results - Of the 55 sites sampled in the Ranegras Plain basin, 4 (7 percent) met all SDW Primary and Secondary MCLs, 51 (93 percent) exceeded Secondary MCLs, and 39 (71 percent) exceeded Primary MCLs.

Inorganic Constituent Results – Health-based Primary MCL water quality standards and State aquifer water quality standards were exceeded at 39 of 55 sites (71 percent; Map 3; Table 5). Constituents exceeding Primary MCLs include arsenic (35 sites), fluoride (28 sites), nitrate (12 sites), and chromium (4 sites).[25] Potential health effects of these chronic Primary MCL exceedances are provided in Table 5.

Aesthetics-based Secondary MCL water quality guidelines were exceeded at 51 of 55 sites (93 percent; Map 3; Table 6). Constituents above Secondary MCLs include TDS (44 sites), fluoride (40 sites), sulfate (25 sites), chloride (16 sites), pH-field (4 sites), and manganese (1 site). Potential impacts of these Secondary MCL exceedances are provided in Table 6.

Radiochemical Results – Of the 18 sites sampled for radionuclides in the Ranegras Plain basin, none exceeded SDW Primary (health-based) MCLs.[2, 25]

Radon Results - Of the 33 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. Twenty-four (24) sites exceeded the proposed 300 pCi/L standard that would apply if Arizona doesn't develop a multimedia program. [25]

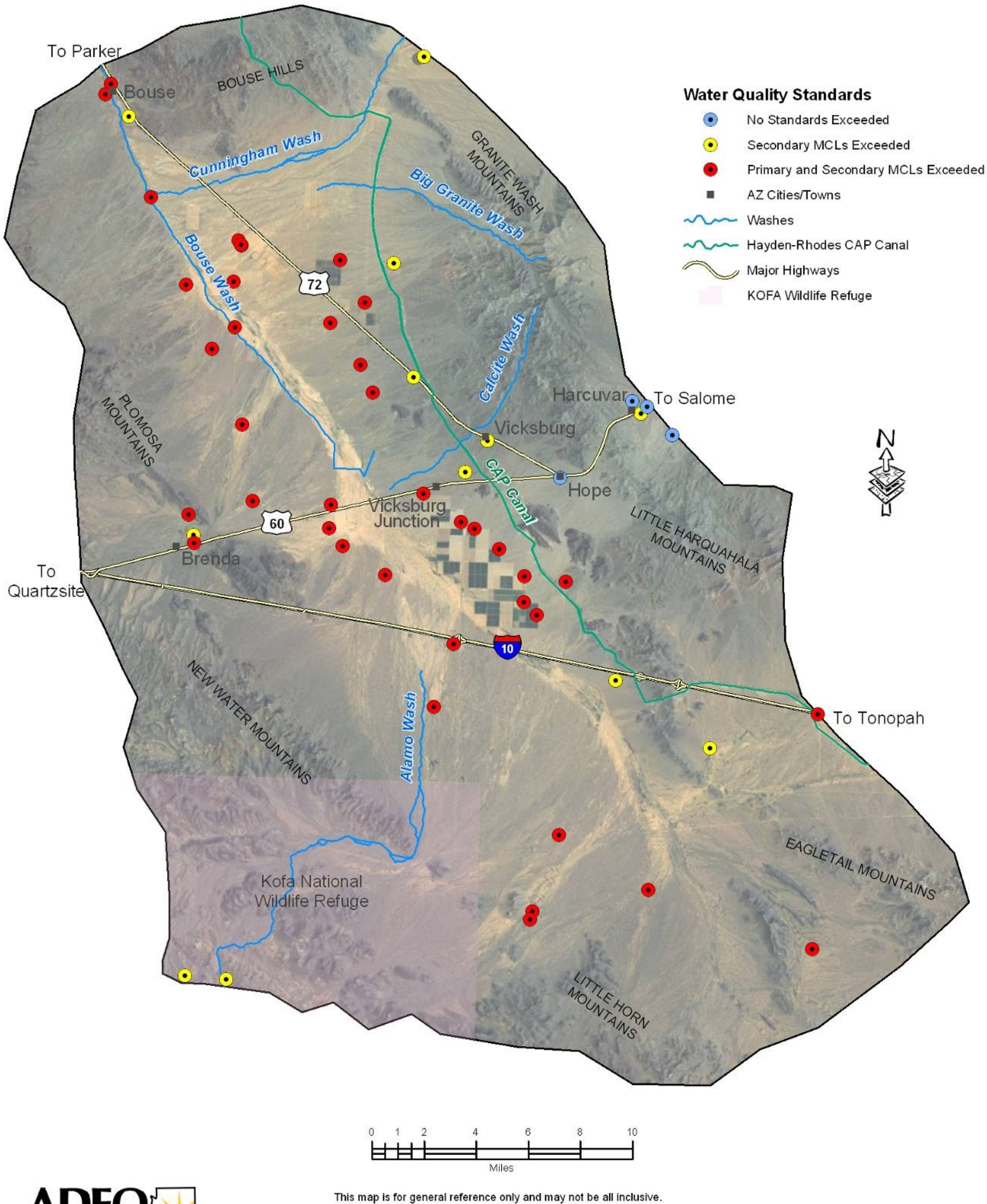
Suitability for Irrigation

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. [26] Groundwater sites in the Ranegras Plain basin display a wide range of irrigation water classifications. The alkalinity and salinity hazard categories that the 55 sample sites fall within are provided in Table 7.

Analytical Results

Analytical inorganic and radiochemistry results of the Ranegras Plain basin 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.[28] Specific constituent information for each sampled groundwater site is in Appendix B.

Map 3 - Water Quality Standards



ADEQ Arizona Department of Environmental Quality

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.

Name: Ranegras_WQ_map3

Table 5. Ranegras Plain Basin Sites Exceeding Health-Based (Primary MCL) Water Quality Standards

Constituent	Primary MCL	Number of Sites Exceeding Primary MCL	Highest Concentration	Potential Health Effects of MCL Exceedances *
		Nutrients		
Nitrite (NO_2-N)	1.0	0	-	-
Nitrate (NO_3-N)	10.0	**12**	53	methemoglobinemia
		Trace Elements		
Antimony (Sb)	0.006	0	-	-
Arsenic (As)	0.01	**35**	0.11	dermal and nervous system toxicity
Arsenic (As)	0.05	**4**	0.11	dermal and nervous system toxicity
Barium (Ba)	2.0	0	-	-
Beryllium (Be)	0.004	0	-	-
Cadmium (Cd)	0.005	0	-	-
Chromium (Cr)	0.1	**4**	0.146	allergic dermatitis
Copper (Cu)	1.3	0	-	-
Fluoride (F)	4.0	**28**	10.6	skeletal damage
Lead (Pb)	0.015	0	-	developmental effects kidney damage
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	0	-	-
Ra-226+Ra-228	5	0	-	-
Radon **	300	**24**	1,547	cancer
Radon **	4,000	0	-	-
Uranium	30	0	-	-

All units are mg/L except gross alpha, radium-226+228 and radon (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.[25]
** Proposed EPA Safe Drinking Water Act standards for radon in drinking water.[25]

Table 6. Ranegras Plain Basin 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	0	-	-
pH - field	> 8.5	**4**	9.05	*high pH:* slippery feel; soda taste; deposits
		General Mineral Characteristics		
TDS	500	**44**	4,300	hardness; deposits; colored water; staining; salty taste
		Major Ions		
Chloride (Cl)	250	**16**	1,170	salty taste
Sulfate (SO_4)	250	**25**	1,240	salty taste
		Trace Elements		
Fluoride (F)	2.0	**40**	9.4	tooth discoloration
Iron (Fe)	0.3	0	-	-
Manganese (Mn)	0.05	**1**	0.55	black staining; bitter metallic taste
Silver (Ag)	0.1	0	-	-
Zinc (Zn)	5.0	0	-	-

All units mg/L except pH is in standard units (su). Source: [25]

Table 7. Alkalinity and Salinity Hazards for Sampled Sites in the Ranegras Plain Basin

Hazard	Total Sites	Low	Medium	High	Very High
		Alkalinity Hazard			
Sodium Adsorption Ratio (SAR)		0 - 10	10- 18	18 - 26	> 26
Sample Sites	55	16	21	15	3
		Salinity Hazard			
Specific Conductivity (uS/cm)		100–250	250 – 750	750-2250	>2250
Sample Sites	55	0	9	35	11

Table 8. Summary Statistics for Ranegras Plain 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	55 / 51	28.3	27.2	27.9	28.6
pH-field (su)	0.01	55 / 55	8.08	7.99	8.10	8.21
pH-lab (su)	0.01	55 / 55	8.19	8.09	8.16	8.23
Turbidity (ntu)	0.01 / 0.20	55 / 38	0.10	0.55	10.52	20.49
General Mineral Characteristics						
T. Alkalinity	2.0 / 6.0	55 / 55	100	92	107	121
Phenol. Alk.	2.0 / 6.0	55 / 4	> 50% of data below MRL			
SC-field (uS/cm)	N/A	55 / 55	1341	1380	1729	2079
SC-lab (uS/cm)	N/A / 2.0	55 / 55	1300	1359	1690	2022
Hardness-lab	10 / 6	55 / 55	233	236	284	333
TDS	10 / 20	55 / 55	140	172	243	313
Major Ions						
Calcium	5 / 2	55 / 55	41	52	74	97
Magnesium	1.0 / 0.25	55 / 52	7.9	9.5	14.9	20.3
Sodium	5 / 2	55 / 55	216	216	273	331
Potassium	0.5 / 2.0	55 / 53	3.9	3.6	4.3	5.0
Bicarbonate	2.0 / 6.0	55 / 55	120	111	129	146
Carbonate	2.0 / 6.0	55 / 4	> 50% of data below MRL			
Chloride	1 / 20	55 / 55	180	185	253	321
Sulfate	10 / 20	55 / 55	230	232	306	381
Nutrients						
Nitrate (as N)	0.02 / 0.20	55 / 54	5.0	5.5	7.9	10.3
Nitrite (as N)	0.02 / 0.20	55 / 3	> 50% of data below MRL			
TKN	0.05 / 1.0	55 / 2	> 50% of data below MRL			
Ammonia	0.02 / 0.05	55 / 7	> 50% of data below MRL			
T. Phosphorus	00.02 / 0.10	55 / 3	> 50% of data below MRL			

Table 8. Summary Statistics for Ranegras Plain Basin Groundwater Quality Data— Continued

Constituent	Minimum Reporting Limit (MRL)*	# of Samples / Samples Over MRL	Median	Lower 95% Confidence Interval	Mean	Upper 95% Confidence Interval
Trace Elements						
Aluminum	0.5 / 0.2	41 / 0	> 50% of data below MRL			
Antimony	0.005 / 0.003	55 / 0	> 50% of data below MRL			
Arsenic	0.01 / 0.001	55 / 50	0.017	0.016	0.022	0.027
Barium	0.1 / 0.001	55 / 42	0.018	0.014	0.023	0.032
Beryllium	0.0005 / 0.001	55 / 0	> 50% of data below MRL			
Boron	0.1 / 0.2	55 / 53	0.68	0.64	0.77	0.90
Cadmium	0.001	55 / 0	> 50% of data below MRL			
Chromium	0.01 / 0.001	55 / 46	0.035	0.032	0.042	0.052
Copper	0.01 / 0.001	55 / 44	0.003	0.003	0.004	0.005
Fluoride	0.2 / 0.4	55 / 51	4.0	3.3	4.0	4.7
Iron	0.1 / 0.05	55 / 3	> 50% of data below MRL			
Lead	0.005 / 0.001	55 / 0	> 50% of data below MRL			
Manganese	0.05 / 0.01	55 / 3	> 50% of data below MRL			
Mercury	0.0005 / 0.0002	55 / 0	> 50% of data below MRL			
Nickel	0.1 / 0.01	55 / 0	> 50% of data below MRL			
Selenium	0.005 / 0.002	55 / 23	>50% of data below MRL			
Silver	0.001	55 / 0	> 50% of data below MRL			
Thallium	0.002 / 0.001	55 / 0	> 50% of data below MRL			
Strontium	0.10	41 / 38	0.9	1.3	2.4	3.5
Zinc	0.05	55 / 5				
Radiochemical						
Gross Alpha **	Varies	18 / 11	1.0	0.5	1.7	2.8
Gross Beta **	Varies	18 / 3	> 50% of data below MRL			
Radon **	Varies	33 / 32	442	369	480	590
Isotopes						
Oxygen-18 ***	Varies	55 / 55	- 8.8	- 8.7	- 8.5	- 8.3
Deuterium ***	Varies	55 / 55	- 67.0	- 65.8	- 63.7	- 61.7

* = ADHS MRL / Test America MRL

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

GROUNDWATER COMPOSITION

General Summary

The water chemistry at the 55 sample sites in the Ranegras Plain basin (in decreasing frequency) includes sodium-mixed (21 sites), sodium-chloride (14 sites), sodium-sulfate (9 sites), sodium-bicarbonate (5 sites), mixed-bicarbonate and calcium-sulfate (2 sites apiece), and mixed-chloride and mixed-mixed (1 site each) (Diagram 2 – middle diagram) (Map 4).

Of the 55 sample sites in the Ranegras Plain basin, the dominant cation was sodium at 49 sites and calcium at 2 sites; at 4 sites, the composition was mixed as there was no dominant cation (Diagram 2 – left diagram).

The dominant anion was chloride at 15 sites, sulfate at 11 sites and bicarbonate at 7 sites; at 22 sites the composition was mixed as there was no dominant anion (Diagram 2 – right diagram).

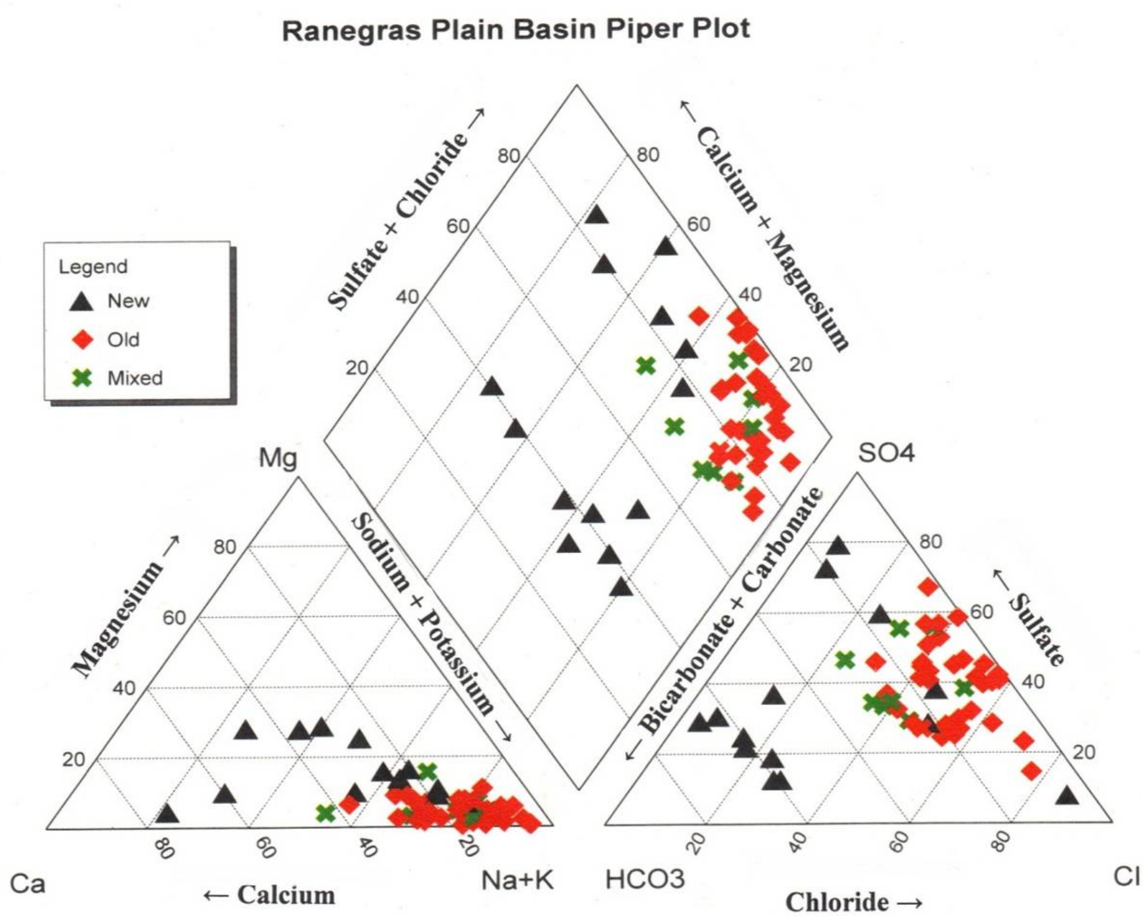
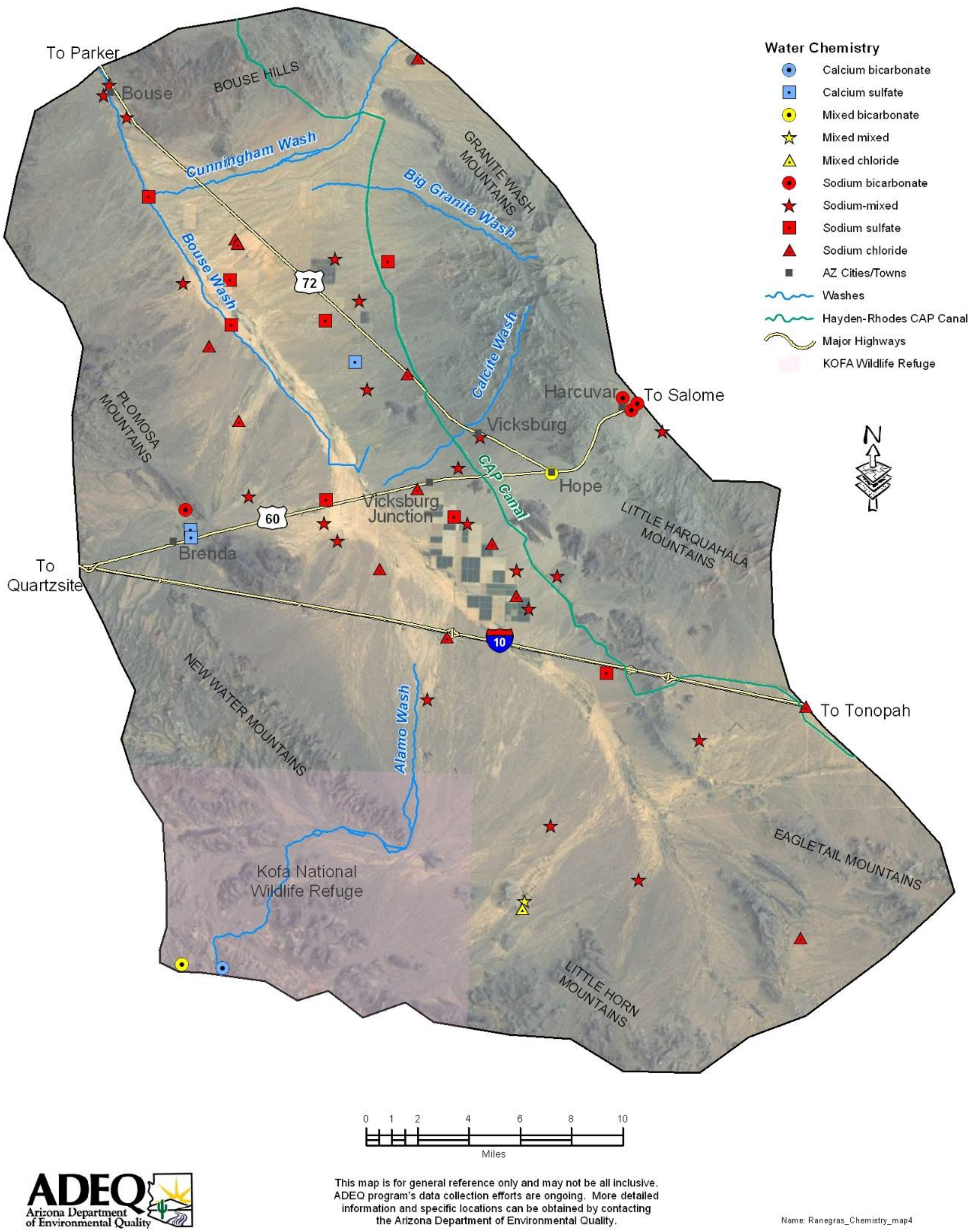


Diagram 2 – Groundwater in the Ranegras Plain basin evolves as it moves through the basin based on water chemistry and oxygen and hydrogen isotope values. Recent recharge occurring from precipitation in the higher elevation mountains along the boundaries of the basin and (or "new" groundwater) starts as a calcium-bicarbonate or mixed-mxed chemistry and evolves into "older" groundwater that has a sodium-chloride/sulfate chemistry. [16, 20]

Map 4 - Water Chemistry



At all 55 sites, levels of pH-field were *slightly alkaline* (above 7 su), 30 sites were above 8 su, and 2 sites had pH-field levels over 9 su.[13]

TDS concentrations were considered *fresh* (below 999 mg/L) at 37 sites, *slightly saline* (1,000 to 3,000 mg/L) at 15 sites, and *moderately saline* (3,000 to 10,000 mg/L) at 3 sites (Map 5).[13]

Hardness concentrations were *soft* (below 75 mg/L) at 13 sites, *moderately hard* (75 – 150 mg/L) at 16 sites, *hard* (150 – 300 mg/L) at 12 sites, *very hard* (300 - 600 mg/L) at 6 sites, *extremely hard* (> 600 mg/L) at 8 sites (Diagram 3 and Map 6).[9]

Nitrate (as nitrogen) concentrations at most sites may have been influenced by human activities according to one source often cited (Map 7). Nitrate concentrations were divided into natural background (1 site at < 0.2 mg/L), may or may not indicate human influence (10 sites at 0.2 – 3.0 mg/L), may result from human activities (31 sites at 3.0 – 10 mg/L), and probably result from human activities (13 sites > 10 mg/L).[17] However, nitrogen isotope analysis on a subset of samples at isolated stock wells indicates many of the nitrate concentrations typically thought to be the result of human activities likely are the consequence of natural conditions.[21]

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

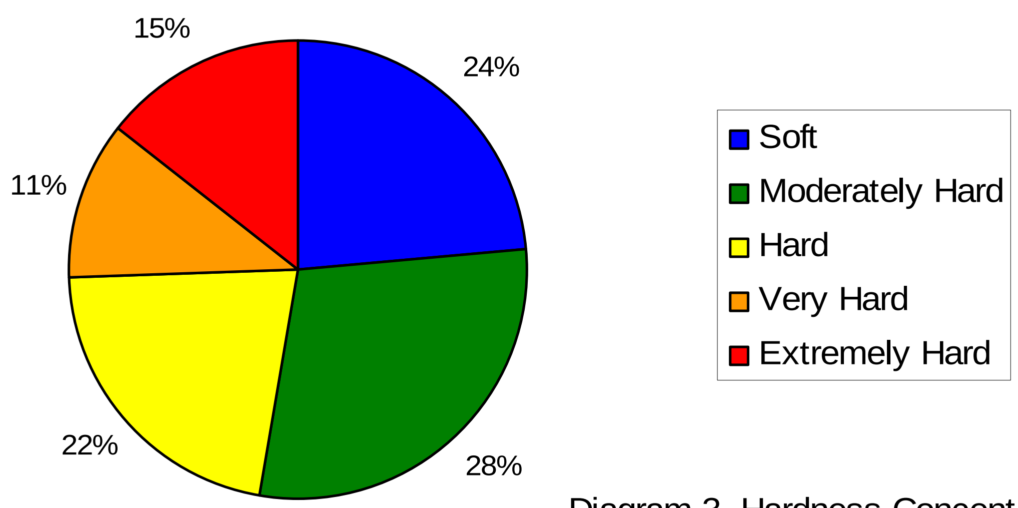
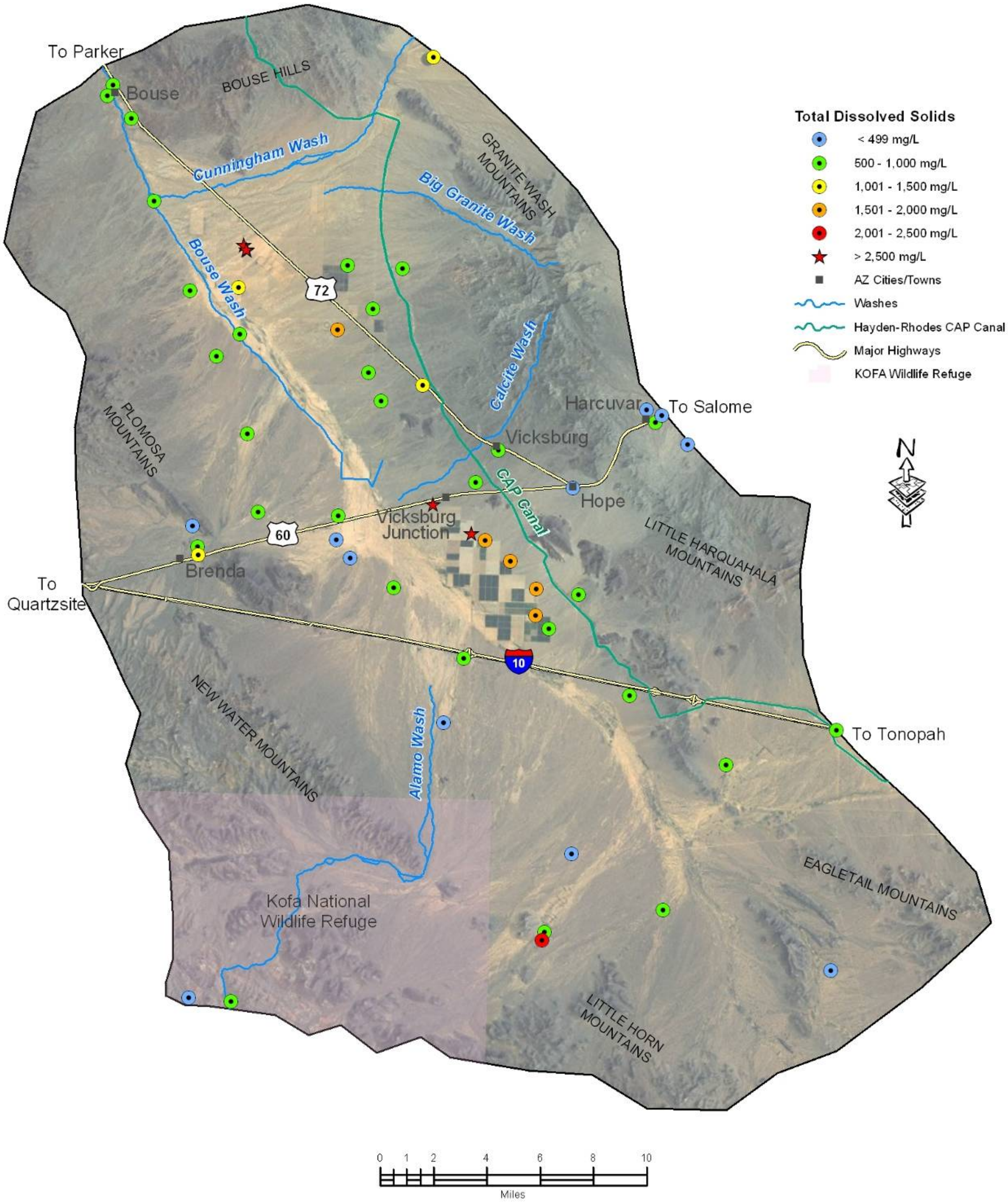


Diagram 3. Hardness Concentrations of Ranegras Plain Basin Samples

Diagram 3 – In the Ranegras Plain basin hardness concentrations vary widely ranging from 16 to 950 mg/L. Although there doesn't appear to be any spatial patterns to hardness variability, classifying sample sites based on oxygen and deuterium isotope values indicates "recent" recharge has significantly greater concentrations than "old" recharge. Recent recharge usually occurs in the west, southwest and northeast peripheries of the basin.

Map 5 - Total Dissolved Solids (TDS)



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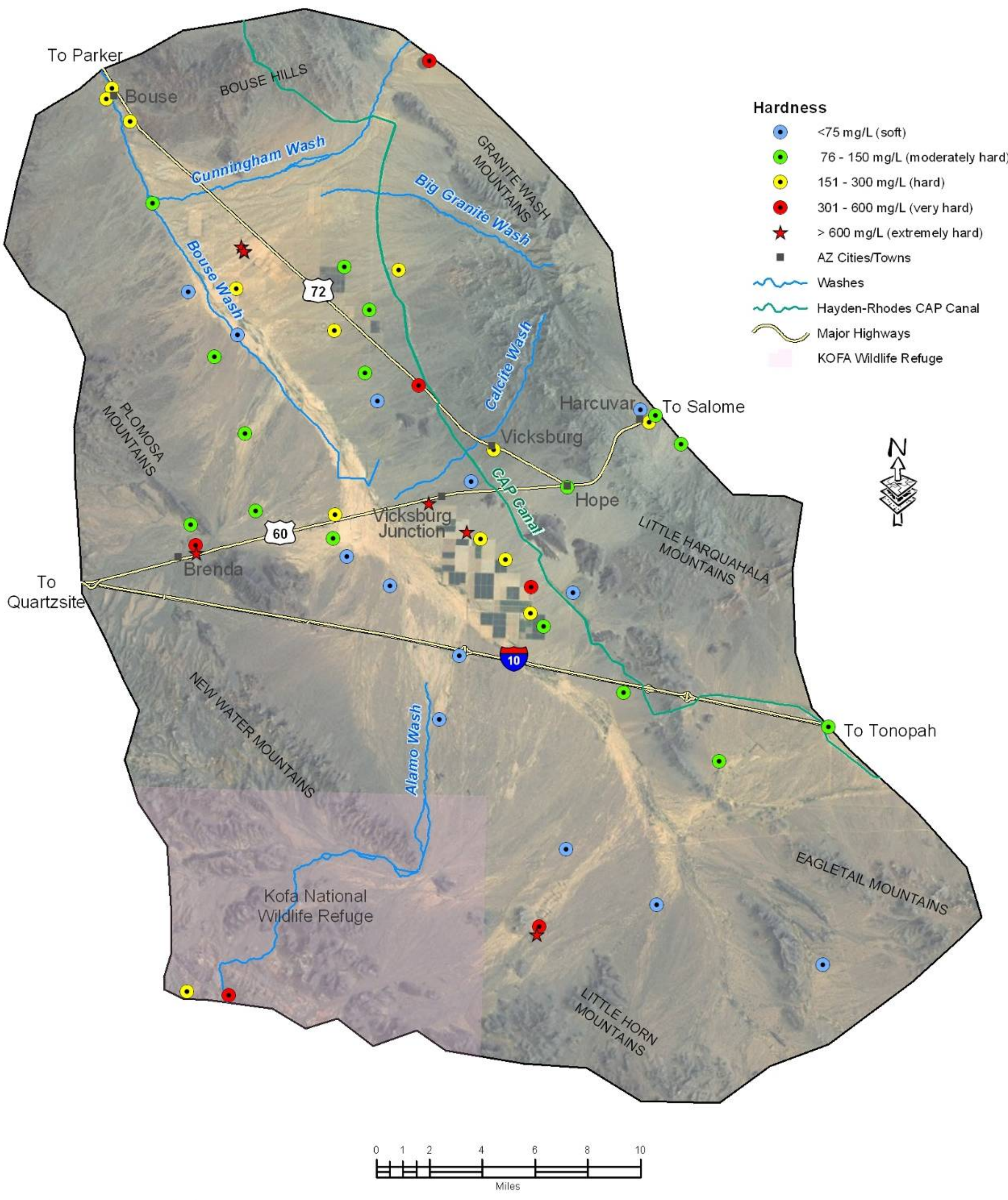
Name: Ranegras_TDS_map5

Map 6 - Hardness



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Name: Ranegras_Hardness_map6

Constituent Co-Variation

The correlations between different chemical parameters were analyzed to determine the relationship between the constituents that were sampled. The strength of association between the chemical constituents allows for the identification of broad water quality patterns within a basin.

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.[28]

Several significant correlations occurred among the 55 sample sites (Table 9, Pearson Correlation Coefficient test, $p \leq 0.05$). Four groups of correlations were identified:

- Oxygen and deuterium were negatively correlated with pH-field, sodium, chloride, arsenic, boron, chromium and fluoride (Diagram 4).

- Arsenic and fluoride (Diagram 5) were positively correlated with each other, pH-field, boron, and chromium and negatively correlated with hardness, magnesium and bicarbonate.

- Positive correlations occurred among TDS, calcium, magnesium, sodium (Diagram 6), potassium, chloride, and sulfate.

- Bicarbonate was negatively correlated with pH-field, TDS, sodium, chloride, sulfate, nitrate, arsenic, boron, chloride, and fluoride. Positive correlations occurred with oxygen and deuterium.

TDS concentrations are best predicted among major ions by sodium concentrations (standard coefficient = 0.63), among cations by sodium concentrations (standard coefficient = 0.65) and among anions, by chloride concentrations (standard coefficient = 0.64) (multiple regression analysis, $p \leq 0.01$).

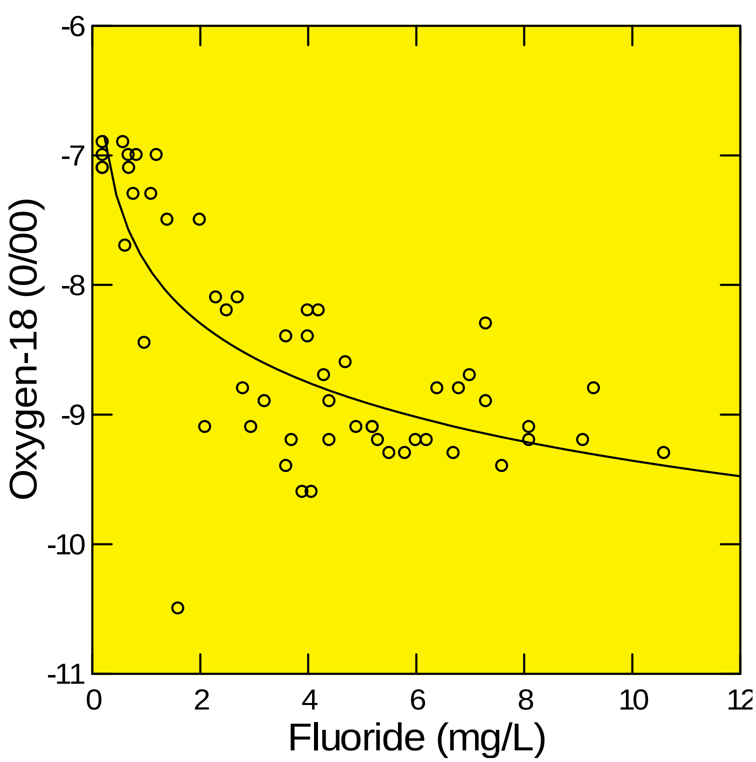


Diagram 4 – The graph illustrates a strong negative correlation between two constituents; as fluoride concentrations increase, oxygen-18 values decrease. Every sample site with an oxygen-18 value that was greater than -8 concurrently had a fluoride concentration that was less than the 4.0 mg/L, which is the Primary MCL. The relationship between oxygen-18 and fluoride is influenced by factors such as long residence aquifer time.[20]

Table 9. Correlation Among Ranegras Plain Basin Groundwater Quality Constituent Concentrations Using Pearson Correlation Probabilities

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

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 $p \leq 0.01$

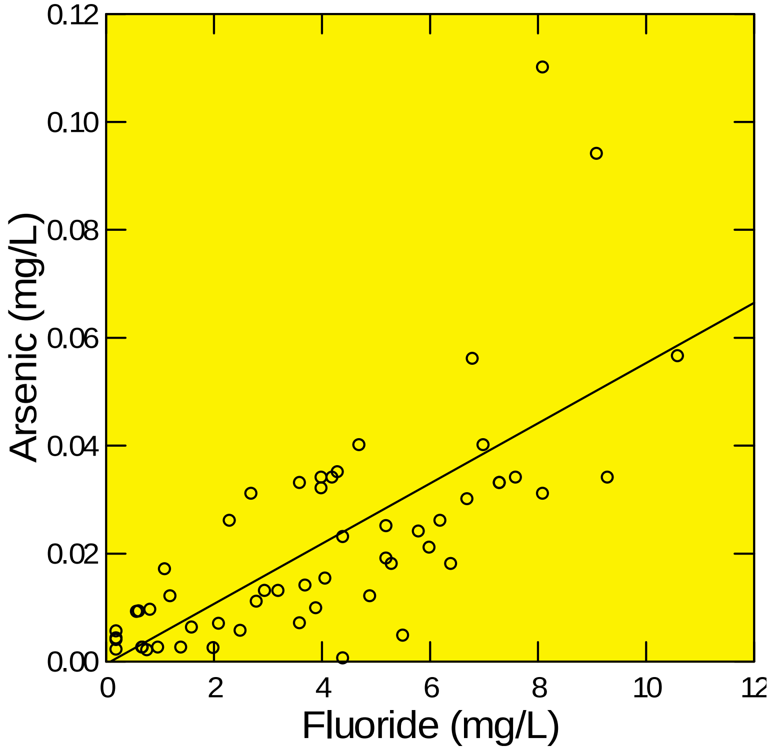


Diagram 5 – The graph illustrates a strong positive correlation between two constituents; as fluoride concentrations increase so do arsenic concentrations. The regression equation for this relationship is y = 0.006x +0.0, n = 55, r^2 = 0.72. Most sample sites exceed both the Primary MCL of 4.0 mg/L for fluoride and the Primary MCL of 0.01 mg/L for arsenic. Both fluoride and arsenic concentrations can be influenced by similar reactions including exchange on clays or with hydroxyl ions along with other factors such as long residence aquifer time. [20]

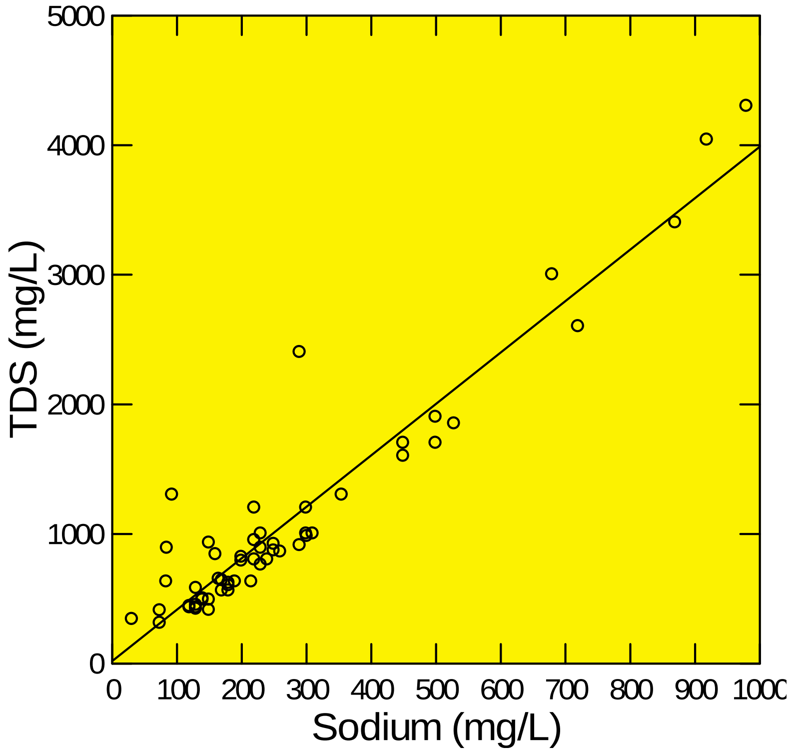


Diagram 6 – The graph illustrates a strong positive correlation between two constituents; as sodium concentrations increase so do TDS concentrations. The regression equation for this relationship is y = 3.97x +19, n = 55, r^2 = 0.95. Among major ions, sodium concentrations best predict TDS concentrations. Evaporate deposits in the lower part of the basin-fill influence the relatively high salinity of the groundwater. [20]

Oxygen and Hydrogen Isotopes

The data for the Ranegras Plain basin roughly conforms to what would be expected in an arid environment, having a slope of 8.3, with the Local Meteoric Water Line (LMWL) described by the linear equation:

$$\delta D = 8.3\ \delta\ ^{18}O + 6.4$$

The LMWL for the Ranegras Plain basin (8.3) is higher than other basins in Arizona including Dripping Springs Wash (4.4), Detrital Valley (5.2), Agua Fria (5.3), Bill Williams (5.3), Sacramento Valley (5.5), Big Sandy (6.1), Pinal Active Management Area (6.4), Gila Valley (6.4), San Simon (6.5), San Bernardino Valley (6.8), McMullen Valley (7.4) and Lake Mohave (7.8).

The most depleted isotope sample is Butler Valley Farm Well #18 (RAN-68) which is probably pumping groundwater that consists of subsurface inflow from the Butler Valley basin (Diagram 7). The light signature of this sample suggests extreme depletion though the majority of samples (31) collected are more depleted than would be expected from either plain or nearby low elevation mountain recharge within the basin. This suggests that these "old recharge" samples may consist of paleowater that was recharged during cooler climate conditions roughly 8,000 – 12,000 years ago.[10] This determination is supported by the elevated concentrations of trace elements such as arsenic, chromium and fluoride found in these samples that are often indicative of long aquifer residence time.[20]

In contrast, 14 isotope samples collected in the southwest and east-central portions of the basin are more enriched (Map 7). Their isotope values that suggest that much of the groundwater at these wells and springs consists of "recent recharge" stemming from precipitation originating in the Kofa, New Water, Plomosa and Granite Wash mountains. Recharge from the Plomosa Mountains near the Bear Hills is indicated from water level contours.[6]

Situated on the LWML in between these two recharge groups are a group of 10 wells that appear to consist primarily of paleowater but also receive more recent recharge. These "mixed" recharge sites are all located downgradient from sampled wells and springs that had groundwater consisting of recent recharge.[10]

Oxygen and Hydrogen Isotopes

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.[8] This is accomplished by comparing oxygen-18 isotopes ($\delta\ ^{18}O$) and deuterium (δD), an isotope of hydrogen, data to the Global Meteoric Water Line (GMWL). The GMWL is described by the linear equation:

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

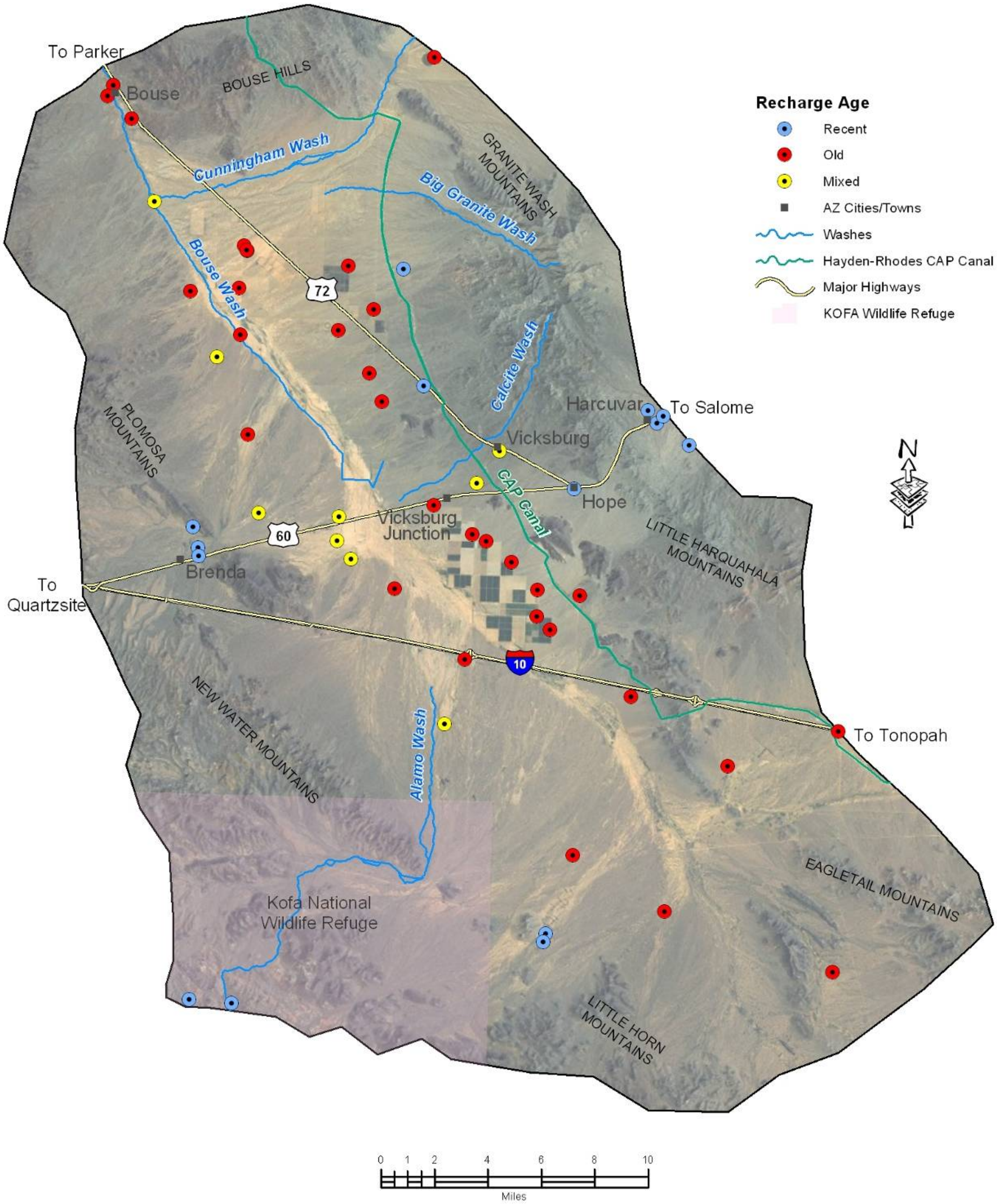
where δD is deuterium in parts per thousand (per mil, $^{0}/_{00}$), 8 is the slope of the line, $\delta\ ^{18}O$ is oxygen-18 $^{0}/_{00}$, and 10 is the y-intercept.[8] The GMWL is the standard by which water samples are compared and is a universal reference standard based on worldwide precipitation without the effects of evaporation.

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.[8] The LMWL created by $\delta\ ^{18}O$ and δD values for samples collected at sites in the Ranegras Plain basin plot to the right of the GMWL.

Meteoric waters exposed to evaporation are enriched and 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. In contrast, meteoric waters that experience little evaporation are depleted and tend to plot increasing to the left of the GMWL and are isotopically lighter.[8]

Groundwater from arid environments is typically subject to evaporation, which enriches δD 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.[8]

Map 7 - Isotopes



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Name: Ranegras_Isotope_map7

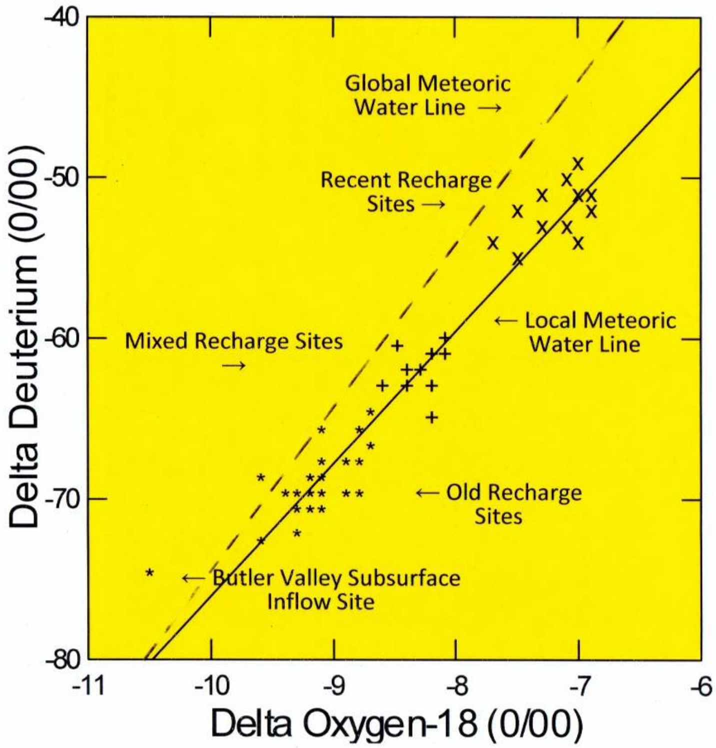


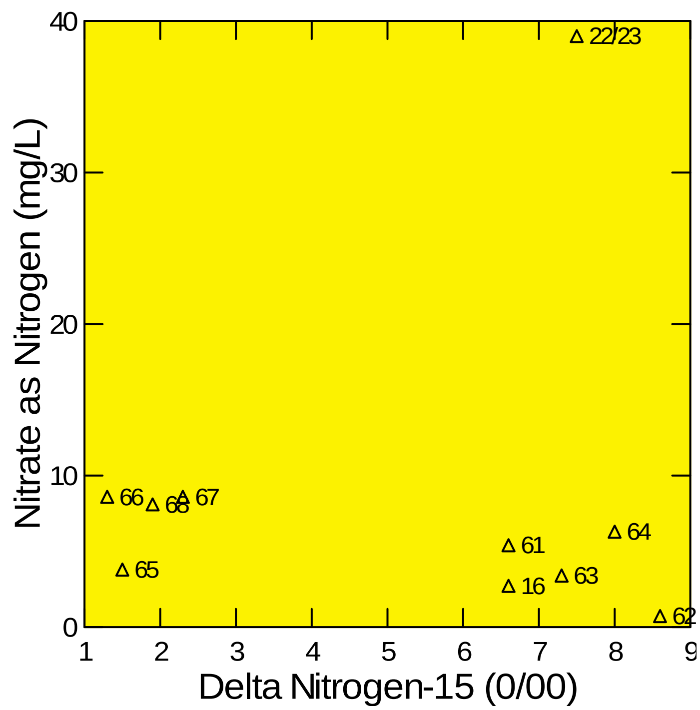
Diagram 7 – The 55 isotope samples are plotted according to their oxygen-18 and deuterium values. Along the Local Meteoric Water Line starting from highest on the precipitation trajectory (upper right of the graph), the following ages of samples plot: recharge from recent precipitation, mixed recharge sites consisting predominately of old recharge, and old recharge consisting of paleowater from precipitation that occurred roughly 10,000 years ago when the basin's climate was much cooler.[10] Lowest on the precipitation trajectory is RAN-68 which in very depleted and consists of subsurface inflow from the Butler Valley basin. [16]

Nitrogen Isotopes

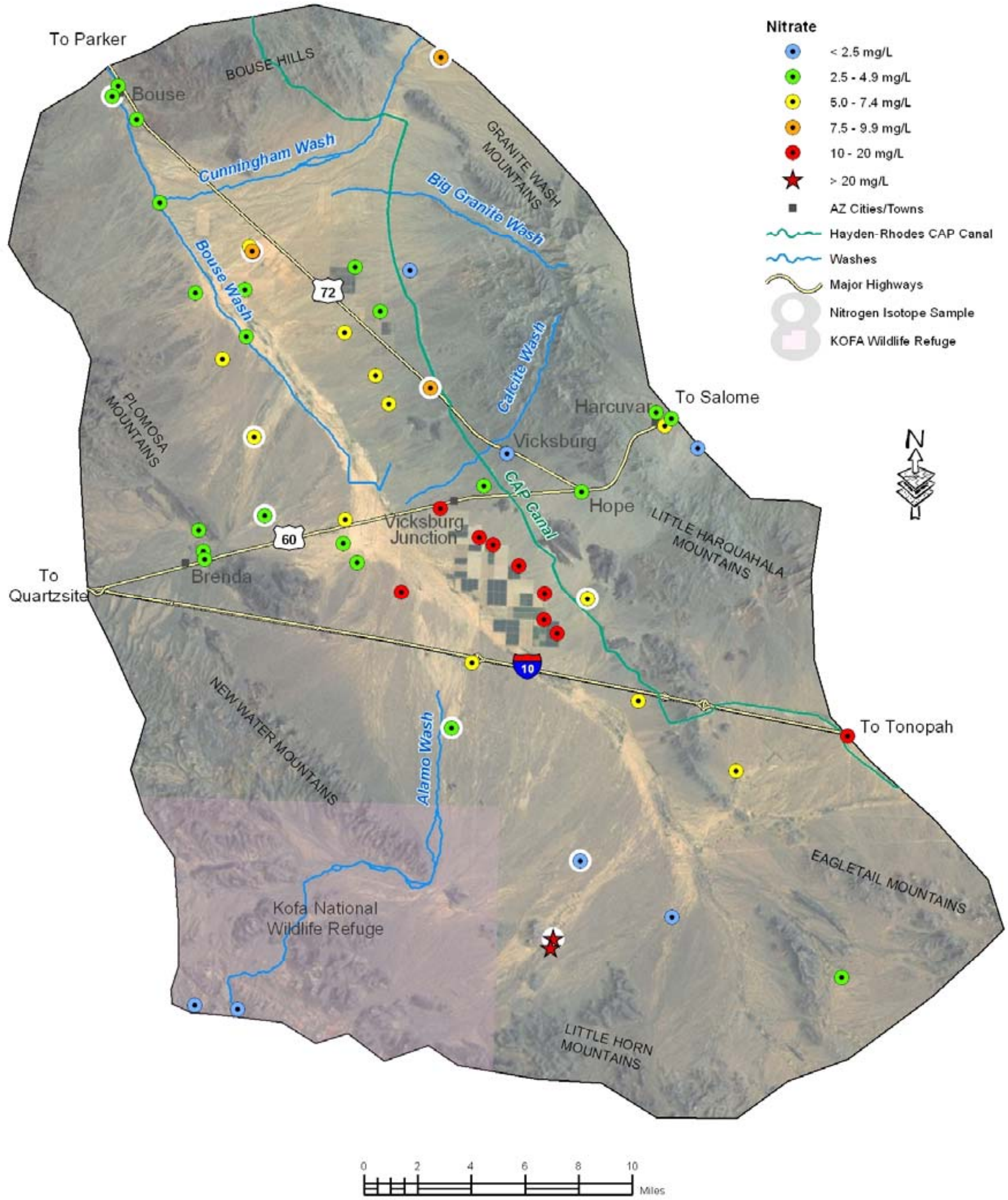
Sources of nitrate in groundwater may be distinguished by measuring two stable isotopes of nitrogen, nitrogen-14 and nitrogen-15, often represented by $\delta^{15}N$. Although the percentage of the two isotopes is nearly constant in the atmosphere, certain chemical and physical processes preferentially utilize one isotope, causing a relative enrichment of the other isotope in the remaining reactants. Because of these isotopic fractionation processes, nitrate from different nitrogen sources has been shown to have different N isotope ratios. The $\delta^{15}N$ values have been cited as ranging from +2 to +9 per mil for natural soil organic matter sources, -3 to +3 for fertilizer sources, +10 to +20 per mil for animal waste. [21]

Groundwater samples for $\delta^{15}N$ analysis were collected at 10 isolated stock wells in the Ranegras Plain basin (Map 8). The $\delta^{15}N$ values ranged from +1.3 to +8.0 0/00 while nitrate values ranged from 0.73 to 39.7 mg/L (Diagram 8). [24] Based on these results, it appears that the nitrogen source is predominantly natural soil organic matter with the potential for a partial manure/effluent source. No nitrogen isotope samples were collected from irrigation wells with elevated nitrate concentrations in the center of the basin.

Diagram 8 – The graph illustrates that natural organic soil is likely the major source of nitrogen in at least 10 isolated stock wells at which nitrogen isotope samples were collected. The highest $\delta^{15}N$ value corresponds to the lowest nitrate concentration; the highest nitrate concentration corresponds to one of the middle $\delta^{15}N$ values. No nitrogen isotope samples were collected from irrigation wells near the center of the basin.



Map 8 - Nitrate Isotope



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Groundwater Quality Variation

Among Two Recharge Ages - Fifty-five (55) groundwater quality constituent concentrations were compared between two recharge types: old (41 sites) and recent (14 sites).

Significant concentration differences were found with 17 constituents: groundwater depth, pH-field, SC-field, SC-lab, TDS, hardness, magnesium, sodium, bicarbonate (Diagram 9), chloride, sulfate, arsenic (Diagram 10) (Map 9), boron, chromium, fluoride, oxygen-18 and deuterium (Kruskal-Wallis test, $p \leq 0.05$).

Complete statistical results are in Table 10 and 95 percent confidence intervals for significantly different groups based on isotope recharge ages are in Table 11.

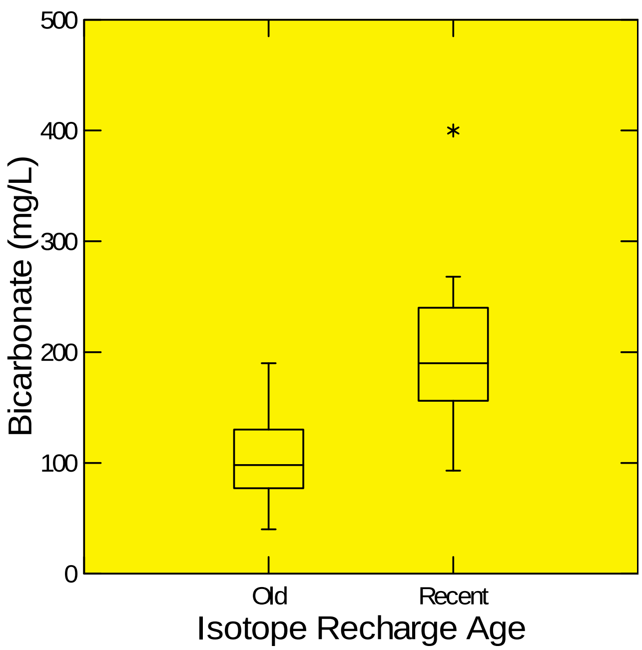


Diagram 9 – Sample sites with recent recharge have significantly higher bicarbonate concentrations than sample sites derived from "old recharge" group. (Kruskal-Wallis, $p \leq 0.01$). Elevated bicarbonate concentrations are often associated with recharge areas. [20] Hardness and magnesium are also significantly higher in the "recent recharge" which is another indication that this groundwater is of a more recent origin than the majority of sampled wells in the Ranegras Plain basin.

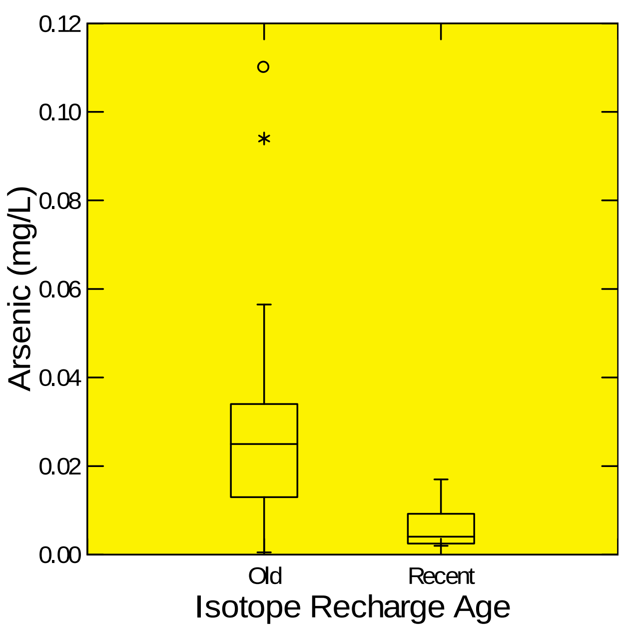
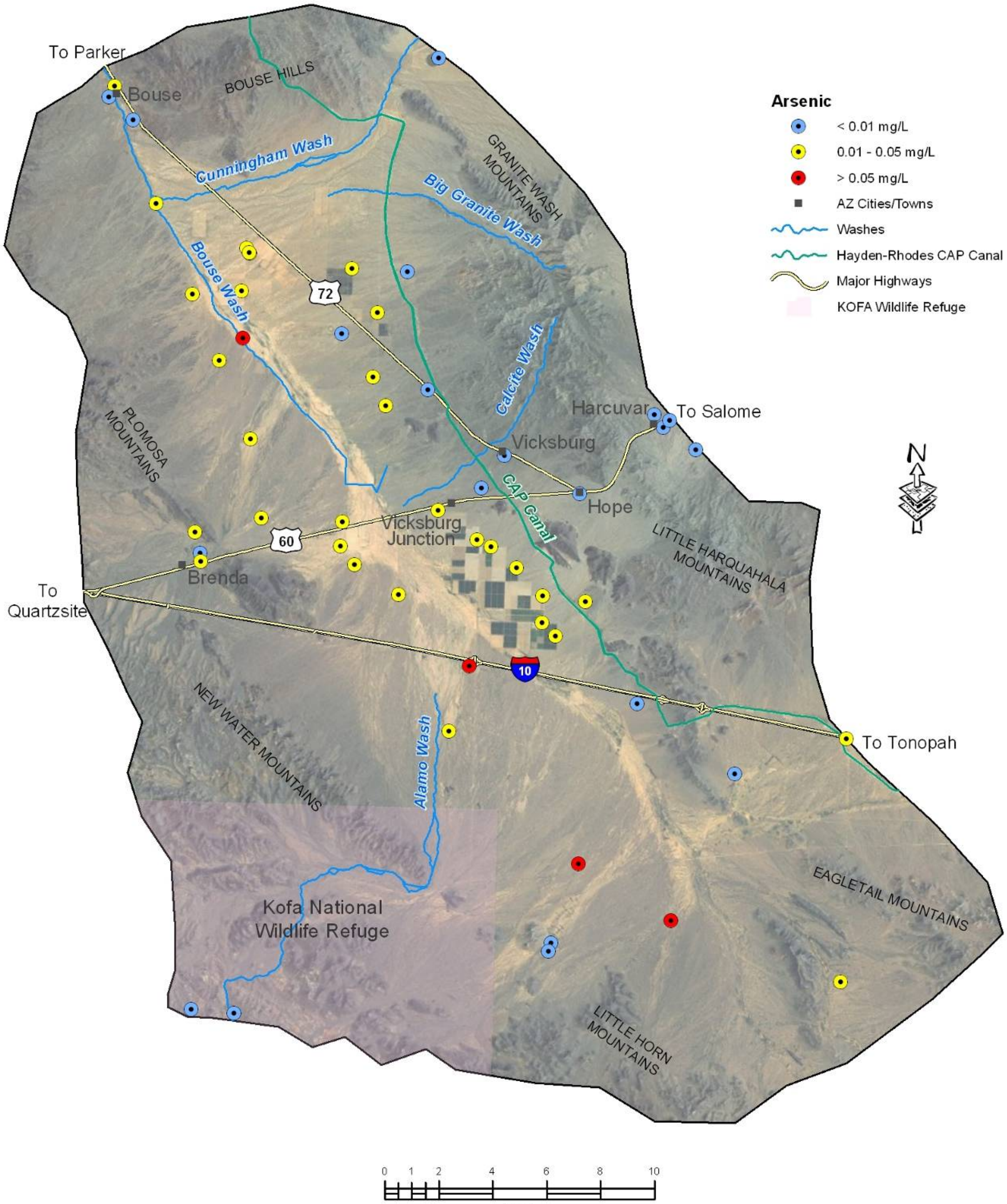


Diagram 10 – Sample sites with "old recharge" have significantly higher arsenic concentrations than sample sites derived from "recent recharge" (Kruskal-Wallis, $p \leq 0.01$). Most sample sites having "old recharge" exceeded the Primary MCL for arsenic. In contrast, sites having "recent recharge" were generally below water quality standards. Arsenic concentrations are impacted by aquifer residence time as well as other factors such as an oxidizing environment and lithology and are thought to be influenced by similar reactions as fluoride including exchange on clays or with hydroxyl ions. [20]

Map 9 - Arsenic



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Name: Ranegras_Arsenic_map9

Table 10. Variation in Groundwater Quality Constituent Concentrations between Two Recharge Sources Using Kruskal-Wallis Test

Constituent	Significance	Significant Differences Among Recharge Sources
Well Depth	ns	-
GW Depth	**	Old > Recent
Temperature - field	ns	-
pH – field	**	Old > Recent
pH – lab	ns	-
SC - field	**	Old > Recent
SC - lab	*	Old > Recent
TDS	*	Old > Recent
Turbidity	ns	-
Hardness	*	Recent > Old
Calcium	ns	-
Magnesium	**	Recent > Old
Sodium	**	Old > Recent
Potassium	ns	-
Bicarbonate	**	Recent > Old
Chloride	**	Old > Recent
Sulfate	**	Old > Recent
Nitrate (as N)	ns	-
Arsenic	**	Old > Recent
Barium	ns	-
Boron	**	Old > Recent
Chromium	**	Old > Recent
Copper	ns	-
Fluoride	**	Old > Recent
Strontium	ns	-
Oxygen	**	Recent > Old
Deuterium	**	Recent > Old

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level

Table 11. Variation in Groundwater Quality Constituent Concentrations between Different Recharge Sources Using Kruskal-Wallis Test and 95 Percent Confidence Intervals

Constituent	Significance	Recent	Older
Well Depth	ns	-	-
GW Depth	**	318 to 391	202 to 279
Temperature - field	ns	-	-
pH – field	**	7.62 to 7.93	8.09 to 8.33
pH – lab	ns	-	-
SC - field	**	720 to 1617	1484 to 2357
SC - lab	*	733 to 1610	1454 to 2281
TDS	*	473 to 1119	906 to 1512
Turbidity	ns	-	-
Hardness	*	156 to 456	139 to 303
Calcium	ns	-	-
Magnesium	**	8.9 to 40.7	6.6 to 16.5
Sodium	**	87 to 176	252 to 392
Potassium	ns	-	-
Bicarbonate	**	154 to 245	93 to 116
Chloride	**	1 to 280	215 to 369
Sulfate	**	78 to 302	255 to 438
Nitrate (as N)	ns	-	-
Arsenic	**	0.003 to 0.009	0.020 to 0.034
Barium	ns	-	-
Boron	**	0.24 to 0.45	0.77 to 1.06
Chromium	**	0.004 to 0.013	0.41 to 0.64
Copper	ns	-	-
Fluoride	**	0.5 to 1.1	4.4 to 5.8
Strontium	ns	-	-
Oxygen	**	-7.3 to -7.0	-9.1 to -8.8
Deuterium	**	-53.1 to -51.1	-68.9 to -66.5

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
All units are mg/L except temperature (degrees Celsius) and SC (uS/cm).

Among Three Recharge Ages - Fifty-five (55) groundwater quality constituent concentrations were compared between three recharge types: recent (14 sites), mixed (10 sites), and old (31 sites). The 10 mixed sites consisted of what were considered older sites in the previous grouping but were higher on the Local Meteoric Water Line (LMWL) precipitation trajectory.

Significant concentration differences were found with 19 constituents: groundwater depth, temperature, pH-field, SC-field, SC-lab, TDS, magnesium, sodium, bicarbonate, chloride, sulfate, nitrate, arsenic, boron, chromium, fluoride (Diagram 11) (Map 10), oxygen-18 (Diagram 12), and deuterium (Kruskal-Wallis with Tukey test, $p \leq 0.05$).

Complete statistical results are in Table 12 and 95 percent confidence intervals for significantly different groups based on isotope recharge ages are in Table 13.

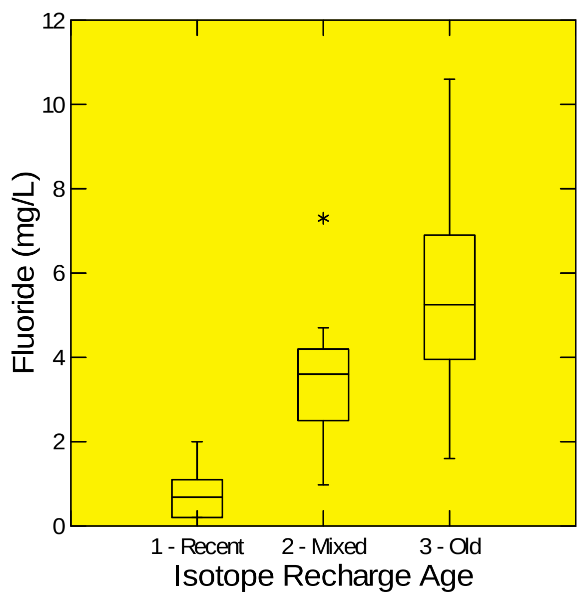


Diagram 11 – Sample sites with "old recharge" have significantly higher fluoride concentrations than sample sites derived from "recent recharge." "Mixed recharge" sample sites have fluoride concentrations in between and significantly different from both recent and older recharge (Kruskal-Wallis with Tukey test, $p \leq 0.05$). Generally, fluoride concentrations in recent recharge are below both Primary and Secondary MCLs, fluoride concentrations in mixed recharge exceed the Secondary MCL of 2 mg/L, and fluoride concentrations in old recharge exceed the Primary MCL of 4 mg/L.

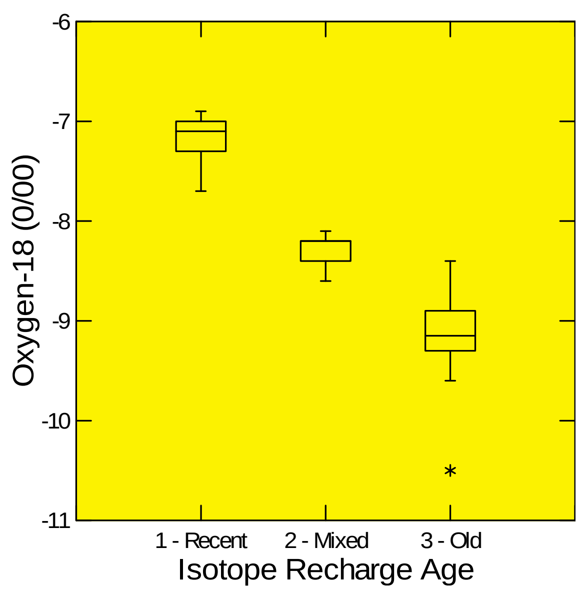
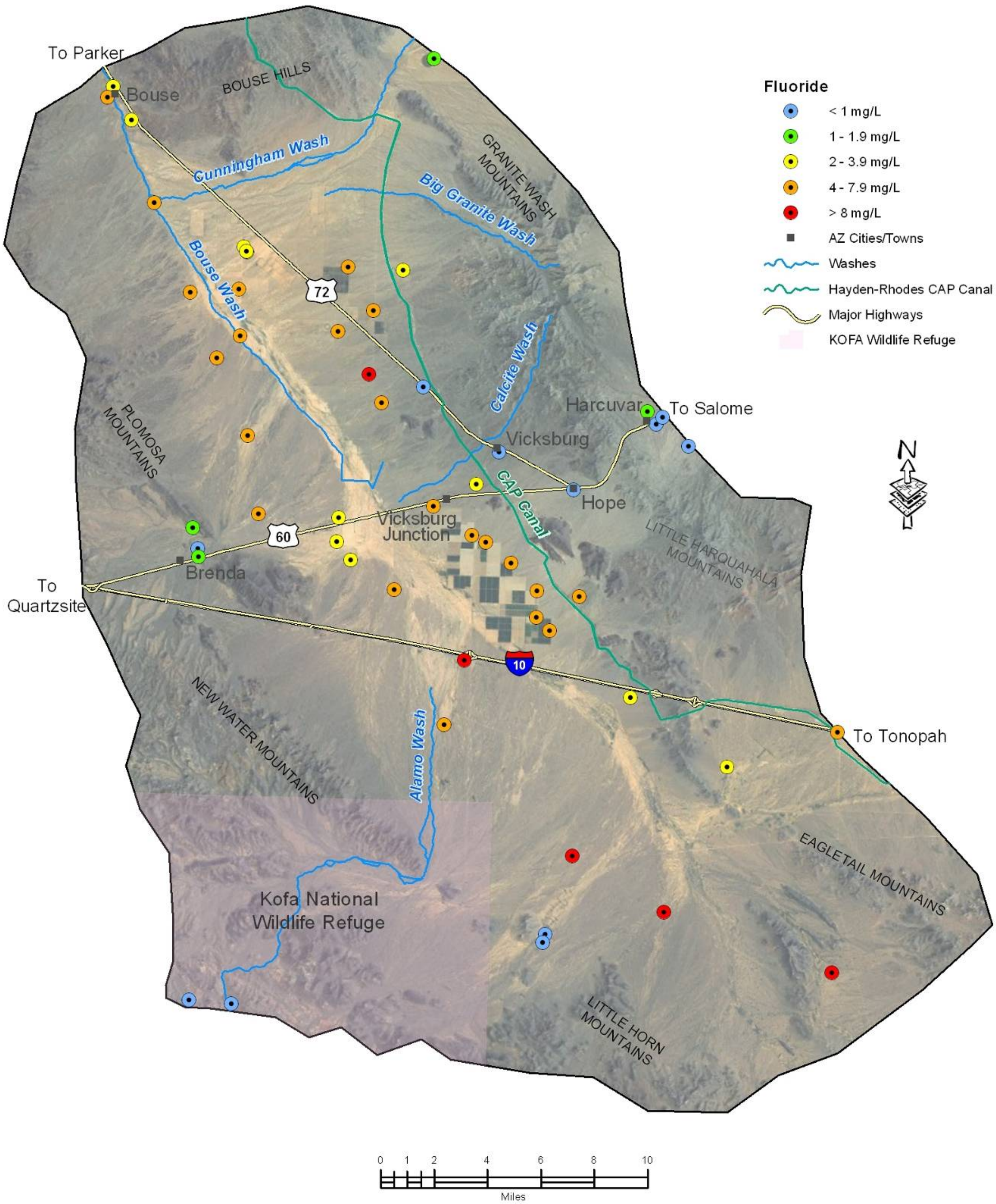


Diagram 12 – Sample sites can be divided into groups based on their oxygen and hydrogen isotope values. Most of the sample sites were of old recharge. One very light outlier collected from the northernmost well appears to be subsurface inflow from Butler Valley basin.[16] More recent heavier isotopic water was found at sites on the basin's northeast, west and southwest areas. Sample sites that appeared to be a mix of these two water types were also found in these areas. Each recharge group had significantly different oxygen-18 values from one another (Kruskal-Wallis with Tukey test, $p \leq 0.01$).

Map 10 - Fluoride



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Name: Ranegras_Fluoride_map10

Table 12. Variation in Groundwater Quality Constituent Concentrations among Three Recharge Sources Using Kruskal-Wallis Test

Constituent	Significance	Significant Differences Among Recharge Sources
Well Depth	ns	-
GW Depth	**	Old ** & Mixed * > Recent
Temperature - field	*	-
pH – field	**	Old & Mixed > Recent **
pH – lab	ns	-
SC - field	**	Old > Mixed & Recent *
SC - lab	**	Old > Mixed & Recent *
TDS	**	Old > Mixed *
Turbidity	ns	-
Hardness	ns	-
Calcium	ns	-
Magnesium	**	-
Sodium	**	Old > Mixed * & Recent **
Potassium	ns	-
Bicarbonate	**	Recent > Mixed & Old **
Chloride	**	Old > Recent *
Sulfate	**	Old > Recent *
Nitrate (as N)	*	-
Arsenic	**	Old ** & Mixed * > Recent
Barium	ns	-
Boron	**	Old > Mixed * & Recent **
Chromium	**	Old ** & Mixed * > Recent
Copper	ns	-
Fluoride	**	Recent > Mixed > Old **
Strontium	*	-
Oxygen	**	Recent > Mixed > Old **
Deuterium	**	Recent > Mixed > Old **

ns = not significant
* = significant at $p \leq 0.05$ or 95% confidence level
** = significant at $p \leq 0.01$ or 99% confidence level

Table 13. Variation in Groundwater Quality Constituent Concentrations among Different Recharge Sources Using Kruskal-Wallis Test and 95 Percent Confidence Intervals

Constituent	Significance	Recent	Mixed	Older
Well Depth	ns	-	-	-
GW Depth	**	318 to 391	111 to 340	204 to 286
Temperature - field	ns	-	-	-
pH – field	**	7.62 to 7.93	8.04 to 8.49	8.04 to 8.34
pH – lab	ns	-	-	-
SC - field	**	721 to 1617	891 to 1335	1633 to 2730
SC - lab	**	733 to 1610	847 to 1295	1608 to 2640
TDS	**	-	501 to 809	1006 to 1769
Turbidity	ns	-	-	-
Hardness	ns	-	-	-
Calcium	ns	-	-	-
Magnesium	**	-	-	-
Sodium	**	87 to 176	143 to 220	280 to 454
Potassium	ns	-	-	-
Bicarbonate	**	154 to 245	96 to 149	86 to 111
Chloride	**	1 to 280	-	243 to 435
Sulfate	**	-	-	280 to 509
Nitrate (as N)	*	-	-	-
Arsenic	**	0.003 to 0.009	0.018 to 0.036	0.018 to 0.036
Barium	ns	-	-	-
Boron	**	0.24 to 0.45	0.54 to 0.74	0.82 to 1.18
Chromium	**	0.004 to 0.013	0.021 to 0.059	0.043 to 0.071
Copper	ns	-	-	-
Fluoride	**	0.5 to 1.1	2.4 to 4.9	4.8 to 6.4
Strontium	ns	-	-	-
Oxygen	**	-7.3 to -7.0	-8.4 to -8.2	-9.29 to -9.04
Deuterium	**	-53.1 to -51.1	-63.1 to -61.1	-70.3 to -68.8

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
All units mg/L except temperature (degrees Celsius) and SC (uS/cm).

DISCUSSION

Oxygen and Hydrogen Isotopes

The most important determination impacting water quality in the Ranegras Plain basin is the recharge age of the groundwater. The 55 sampled sites can be grouped into three categories for comparison.

Old Recharge – 31 sites had very light and depleted water that was recharged under cooler climate conditions 8,000 – 12,000 years ago. [10] Sites with old recharge generally had more water quality problems; 87 percent exceeded both Primary and Secondary MCLs while the remaining 13 percent exceeded Secondary MCLs. Old recharge was found in most of the basin including lower elevation areas stretching along a groundwater flowpath that moves from upgradient areas in the southeast to the northwest where subsurface flow enters the Parker basin.

Recent Recharge – 14 sites had enriched water that appears to consist of recently recharged precipitation originating from mountains in the basin. Sites with recent recharge exhibited better water quality: 29 percent met all water quality standards, 42 percent only exceeded Secondary MCLs, and 29 percent exceeded both Primary and Secondary MCLs. Although recent recharge is a better quality source of groundwater, particularly for domestic and public water supply, this source is spatially limited and was found in this study only in locations near the Kofa, New Water, Plomosa, Granite Wash, and Little Harquahala Mountains.

Mixed Recharge – 10 sites had light and depleted water that was recharged under cooler climate conditions 8,000 – 12,000 years ago but also may have limited amounts of recent recharge. Sites with older recharge generally had more water quality problems; 80 percent exceeded both Primary and Secondary MCLs while the remaining 20 percent exceeded Secondary MCLs. Sites having a mixed recharge source exhibit only a marginally better water quality source than older recharge. Mixed recharge sites were generally located downgradient of recent recharge sites.

Wells pumping old recharge are generally the most productive in the Ranegras Plain basin, with those in the center of the basin capable of producing 2,000 gpm.[4] While information concerning well yields around the fringes of the basin is incomplete, available data suggest that wells pumping recent or mixed recharge are less productive with some averaging less than 100 gpm. [4]

Water Quality Standard Exceedances

Health-based Primary MCL water quality standards were exceeded at 39 of 55 sites (71 percent). Constituents exceeding Primary MCLs include arsenic (35 sites), chromium (4 sites), fluoride (28 sites), and nitrate (12 sites). Aesthetics-based Secondary MCL water quality guidelines were exceeded at 51 of 55 sites. Constituents above Secondary MCLs include chloride (16 sites), fluoride (40 sites), manganese (1 site), pH (4 sites), sulfate (25 sites), and total dissolved solids (TDS) (44 sites).

The elevated constituent concentrations appear to be predominantly naturally occurring and some of their occurrences have documented in previous studies. [6, 16] Long aquifer residence time of groundwater and evaporate deposits in the basin are major factors in elevating these constituents over water quality standards. [16, 20]

Trace Elements - Previous studies have also found large concentrations of trace elements such as arsenic, boron, chromium, and fluoride that commonly also exceed Primary MCLs. [4, 6, 16] This ADEQ study confirmed these constituent water quality exceedances.

However, previous studies have also found occasional water quality exceedances of barium, lead, and selenium concentrations which were not found in this ADEQ study. The highest barium concentration was 0.17 mg/L, well below the 2.0 mg/L Primary MCL. Lead was not detected in the study above the MRL of 0.001 mg/L. The highest selenium concentration was 0.033 mg/L, well below the 0.05 mg/L Primary MCL. While barium and, to a lesser degree, selenium are found above MRLs in groundwater in Arizona, lead detections are rare.

Arsenic - Arsenic concentrations are influenced by factors such as aquifer residence time, an oxidizing environment, and lithology. In common with fluoride, arsenic concentrations are effected by reactions that also influence fluoride concentrations such as exchange on clays or with hydroxyl ions. [20]

Chromium - Chromium concentrations in groundwater are closely related to the geology, hydrology, and geochemical environment of the aquifer. Occurrence and magnitude are associated with source rock types and with areas in basins that contain groundwater that is old, oxidizing, high in pH, and that are bounded by volcanic rocks. [20] Overall, 4 of the 55 sample sites (7 percent) exceeded the 0.1 mg/L Primary MCL for total chromium. In a previous study that sampled for hexavalent instead of total chromium, 13 of 39 wells (33 percent) exceeded the 0.05 mg/L water quality standard for hexavalent chromium. [16]

Fluoride - Fluoride concentrations above 5 mg/L are controlled by calcium through precipitation or dissolution of the mineral, fluorite. In a chemically closed hydrologic system, calcium is removed from solution by precipitation of calcium carbonate and the formation of smectite clays. High concentrations of dissolved fluoride may occur in groundwater depleted in calcium if a source of fluoride ions is available for dissolution. [20]

Overall, 28 of the 55 sample sites (51 percent) exceeded the 4.0 mg/L Primary MCL for fluoride and ranged from 0.2 to 10.6 mg/L. In 14 wells sampled for a 1969 study, fluoride ranged from 4.1 to 8.9 mg/L. [6] Fluoride concentrations ranged from 0.1 to 21.0 mg/L with 37 of the 48 wells exceeding 4.0 mg/L in samples collected between 1984 and 1989. [4, 27] The lower percentage of fluoride exceedances in the ADEQ study is the result of sampling more wells in the basin's periphery that consisted of recent or mixed recharge.

TDS – The evaporate deposits contained in the Ranegras Plain basin-fill are an important influence on the relatively high salinity of the basin's groundwater. Overall, 44 of the 55 sample sites (80 percent) exceeded the 500 mg/L Secondary MCL for TDS and ranged from 310 to 4,040 mg/L. In 14 wells sampled for a 1969 study, TDS ranged from 462 to 3,700 mg/L. [6] In 48 wells sampled between 1984 and 1989, only five wells had TDS levels below 500 mg/L and they ranged from 293 to 3,660 mg/L with wells in the north-central part of the basin having the highest levels. [4]

Nitrate - Elevated nitrate concentrations in the basin were likely influenced by several factors. Natural background concentrations of nitrate in Sonoran Desert areas such as the Ranegras Plain can exceed the 10 mg/L Primary MCL. [23] Nitrogen-15 isotope samples were collected at a subset of 10 isolated stock wells to determine the likely source of nitrogen. Results indicated that natural organic nitrogen was the major source with potentially some minor inputs from waste associated with livestock lingering in corrals adjacent to wells. [21]Nitrogen isotope samples were not collected in other areas of the basin, particularly near large expanses of irrigated agriculture. Nitrate concentrations that exceeded the water quality standards in these areas were likely influenced from fertilizer applications and effluent from septic systems and dairy operations based on water quality patterns in other Arizona basins.

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Appendix A. Data for Sample Sites, Ranegras Plain Basin, 2008-2011

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Recharge Source
1st Field Trip, October 29, 2008 – Towne (Equipment Blank - MMU-126)									
RAN-1/2 split	B(5-14)30ddb submersible	33°44'31.343" 113°45'04.463"	902690	48059	Weisser Well	Inorganic, Radiochem, Radon, Isotopes	605’	465’	Mixed
2nd Field Trip, May 13, 2009 – Towne									
RAN-3	B(4-15)13bda turbine	33°41'33.619" 113°45'31.109"	600135	18152	Well #9	Inorganic O & H Isotopes	648’	242’	Old
RAN-4	B(4-14)19baa turbine	33°40'54.410" 113°44'29.949"	600137	18112	Well #11	Inorganic, Radiochem O & H Isotopes	730’	222’	Old
RAN-5	B(4-14)29baa turbine	33°40'02.102" 113°43’27.575"	600146	18117	Well #28	Inorganic O & H Isotopes	705’	318’	Old
RAN-6	B(4-14)32baa turbine	33°39'09.994" 113°43'27.575"	600131	18125	Well #5	Inorganic O & H Isotopes	905’	233’	Old
RAN-7	B(4-14)32add turbine	33°38'44.016" 113°42'56.025"	600132	18124	Well #6	Inorganic O & H Isotopes	920’	233’	Old
RAN-8	B(4-15)14aaa turbine	33°41'46.579" 113°46'03.091"	600127	18155	Well #1	Inorganic, Radiochem O & H Isotopes	1015’	220’	Old
3rd Field Trip, October 27, 2010 – Towne									
RAN-9	B(3-13)28adc pumpjack	33°34'27.568" 113°35'52.368"	603145	17938	Brown Well	Inorganic, Radiochem O & H Isotopes	368’	311’	Old
RAN-10	B(2-13)19baa submersible	33°29'39.255" 113°38'08.241"	603146	17660	Vinegaron Well	Inorganic, Radiochem O & H Isotopes	329’	305’	Old
RAN-11	B(1-12)5bcc submersible	33°27'27.185" 113°31'30.333"	603147	17062	Twin Tanks Well	Inorganic, Radiochem O & H Isotopes	700’	430’	Old
RAN-12/13 split	B(3-12)19aaa submersible	33°35'38.856" 113°31'33.219"	603144	17936	Sorefinger Well	Inorganic O & H Isotopes	510’	383’	Old
4th Field Trip, November 18, 2010 – Towne & Boettcher									
RAN-14	B(4-15)28bbd submersible	33°39'52.861" 113°49'01.011"	804210	18170	Stutz Well	Inorganic O & H Isotopes	200’	-	Old
RAN-15	B(4-16)13daa submersible	33°41'19.615" 113°51'16.757"	-	18175	Perry Well	Inorganic O & H Isotopes	250’	-	Mixed
RAN-16	B(4-16)9add submersible	33°42'22.994" 113°34'53.841"	600163	18174	Plamosa Well	Inorganic, Radiochem O & H Isotopes	270’	180’	Mixed
RAN-17	B(5-16)9bcc submersible	33°47'23.738" 113°56'21.808"	600166	18601	Swadley Well	Inorganic O & H Isotopes	150’	130’	Mixed
RAN-18/19 split	B(5-15)6acb submersible	33°48'27.254" 113°51'40.570"	600169	18574	Winebottle Well	Inorganic, Radiochem O & H Isotopes	500’	270’	Old
4th Field Trip, January 11, 2011 – Towne & Determann									
RAN-20	B(5-15)21baa submersible	33°45'59.624" 113°49'39.302"	600161	18585	Maclean Well	Inorganic, Radon Isotopes	242’	200’	Old
RAN-21	B(4-16)18dcc submersible	33°40'56.136" 113°56'54.709"	600150	18185	Brenda Well	Inorganic, Radiochem, Radon, Isotopes	600’	280’	Recent
RAN-22/23 split	B(2-14)28ccc submersible	33°28'45.287" 113°42'52.201"	634089	17663	Spreaders HouseWell	Inorganic, Radiochem, Radon, Isotopes	395’	300’	Recent
RAN-24	B(2-14)33bba submersible	33°28'41.949" 113°42'42.855"	600167	17665	Spreaders South Well	Inorganic O & H Isotopes	400’	260’	Recent

Appendix A. Data for Sample Sites, Ranegras Plain Basin, 2008-2011--continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Recharge Source
5th Field Trip, February 3, 2011 – Towne & Determann									
RAN-25	B(4-16)12daa submersible	33°42'13.266" 113°51'15.744"	553543	76781	Stendol Well	Inorganic, Radon O & H Isotopes	222’	129’	Mixed
RAN-26	B(4-16)13add submersible	33°41'27.227" 113°51'17.986"	563054	76782	Rogers Well	Inorganic, Radon O & H Isotopes	260’	145’	Mixed
RAN-27	B(1-16)16bdb spring	33°25'47.076" 113°55’06.556"	-	76783	Wilkinson Seep	Inorganic O & H Isotopes	-	-	Recent
RAN-28	B(1-16)18adb spring	33°25'52.284" 113°56'39.226"	-	76784	Holly Seep	Inorganic O & H Isotopes	-	-	Recent
6th Field Trip, March 2, 2011 – Towne & Boettcher									
RAN-29	B(4-14)04abd submersible	33°43'20.829" 113°42'09.045"	645190	48019	Rmbn Rose RV Well#2	Inorganic, Radiochem, Radon, Isotopes	652’	405’	Recent
RAN-30/31 split	B(6-16)22cba submersible	33°50'50.197" 113°55'08.588"	-	76802	Benson Well	Inorganic, Radiochem Radon, Isotopes	-	-	Old
RAN-32	B(6-16)22bcb submersible	33°51'00.265" 113°55'17.498"	210449	18854	Hickey Well	Inorganic, Radon O & H Isotopes	265’	154’	Old
RAN-33	B(5-16)03cbc submersible	33°48'06.044" 113°55'20.641"	216708	76803	Newsom Well	Inorganic, Radon O & H Isotopes	372’	124’	Old
RAN-34	B(7-17)26dbd submersible	33°55'01.426" 113°59'51.594"	532032	76804	Dst Pueblo RV Well	Inorganic, Radon O & H Isotopes	95’	62’	Old
7th Field Trip, March 23, 2011 – Towne & Determann									
RAN-35/36 split	B(3-15)02dac submersible	33°37'41.764" 113°46'12.890"	807544	58985	Tamahawk Oil of AZ	Inorganic, Radon O & H Isotopes	-	-	Old
RAN-37	B(4-15)01bbb submersible	33°43'28.353" 113°45'58.054"	571351	76861	Eden Park Asso.	Inorganic, Radon O & H Isotopes	585’	460’	Mixed
RAN-38	B(7-17)23bcc submersible	33°56'06.970" 114°00'33.827"	-	48100	Coyote Ridge RV	Inorganic, Radon O & H Isotopes	-	-	Old
RAN-39	B(6-15)32dad turbine	33°49'00.075" 113°50'08.849"	507161	18830	Purcell Well #5	Inorganic, Radon O & H Isotopes	625’	305’	Old
RAN-40	B(6-15)30aaa turbine	33°50'25.648" 113°51'11.665"	618506	18826	Purcell Well #2	Inorganic, Radiochem, Radon, Isotopes	1000’	300’	Old
8th Field Trip, April 13, 2011 – Towne & Boettcher									
RAN-41	B(6-15)27bba pumpjack	33°50'24.843" 113°48'55.088"	600154	18825	Quatro Well	Inorganic, Radiochem Radon, Isotopes	660’	400’	Recent
RAN-42/43 split	B(4-16)18baa submersible	33°41'46.747" 113°56'56.824"	642429	18180	Fisher Well	Inorganic, Radiochem, Radon, Isotopes	450’	350’	Recent
Spiked Samples									
RAN-44	TA F 4.0 mg/L spiked sample	-	-	-	-	-	-	-	-
RAN-45	TA SO4 400 mg/L spiked sample	-	-	-	-	-	-	-	-
RAN-46	Xenco F 4.0 mg/L spiked sample	-	-	-	-	-	-	-	-
RAN-47	Xenco SO4 400 mg/L spiked sample	-	-	-	-	-	-	-	-
9th Field Trip, May 18, 2011 – Towne & Boettcher									
RAN-48/49 split	B(3-14)11ccc submersible	33°36'37.8" 113°39'59.8"	628117	17941	Bouse Rest Area Well	Inorganic, Radon O & H Isotopes	656’	243’	Old
RAN-50	B(4-16)19sbs submersible	33°40'49.897" 113°56'41.650"	522243	18186	Black Rock Well #1	Inorganic, Radon O & H Isotopes	600’	465’	Recent
RAN-51	B(5-15)17aaa submersible	33°46'56421" 113°50'14.713"	597338	76961	Nebeker Well	Inorganic, Radon O & H Isotopes	320’	260’	Old

Appendix A. Data for Sample Sites, Ranegras Plain Basin, 2008-2011--continued

Site #	Cadastral / Pump Type	Latitude - Longitude	ADWR #	ADEQ #	Site Name	Samples Collected	Well Depth	Water Depth	Recharge Source
10th Field Trip, August 17, 2011 – Towne & Boettcher									
RAN-52	B(6-17)12dca submersible	33°52'36.442" 113°58'57.364"	600156	18868	Dun Well	Inorganic, Radon O & H Isotopes	200’	60’	Mixed
RAN-53	B(6-16)32bbc submersible	33°49'23.645" 113°57'20.766"	634117	18864	Chico’s Well	Inorganic O & H Isotopes	500’	120’	Old
RAN-54/55 duplicate	B(6-16)33aaa turbine	33°49'33.203" 113°55’23.256"	614503	18865	ASLD IR Well	Inorganic, Radon O & H Isotopes	550’	140’	Old
RAN-56	B(1-16)10baa turbine	33°42'39.110" 113°47'36.099"	600139	18144	NW Well	Inorganic O & H Isotopes	900’	201’	Old
11th Field Trip, December 18, 2009 – Towne (MMU-142)									
RAN-57	B(5-13)19bbb submersible	33°45'32.725" 113°38'59.323"	581224	71162	C. Wolfe Well	Inorganic, Radiochem, Radon, Isotopes	500’	340’	Recent
RAN-58	B(5-13)28bcb submersible	33°44'56.148" 113°37'33.719"	591221	71223	Rauber Well	Inorganic, Radiochem Radon, Isotopes	460’	338’	Recent
RAN-59	B(5-13)19bdb submersible	33°45'58.278" 113°39'20.101"	591355	72721	Christensn Well	Inorganic, Radon O & H Isotopes	515’	350’	Recent
RAN-60	B(5-13)20bab submersible	33°45'47.950" 113°38'43.445"	509107	72723	W. Salome Well	Inorganic, Radon O & H Isotopes	500’	375’	Recent
12th Field Trip, October 26, 2011 – Towne & Boettcher									
RAN-61	B(4-14)27bcb submersible	33°39'43.301" 113°41'51.781"	524771	48017	CAP Tank Well	Inorganic, Radiochem, Radon, Isotopes	465’	347’	Old
RAN-62	B(2-14)10cdc submersible	33°31'25.799" 113°41'31.147"	600171	17661	John Weisser Wl	Inorganic, Radon O, H & N Isotopes	400’	340’	Old
RAN-22A	B(2-14)28ccc submersible	33°28'45.287" 113°42'52.201"	634089	17663	Spreaders HouseWell	NO_3, N Isotopes	395’	300’	-
RAN-63	B(3-15)23bbb submersible	33°35'28.574" 113°46'47.706"	600153	17948	Crowder Well	Inorganic, Radon O, H & N Isotopes	502’	300’	Mixed
RAN-16A	B(4-16)9add submersible	33°42'22.994" 113°34'53.841"	600163	18174	Plamosa Well	NO_3, N Isotopes	270’	180’	-
RAN-64	B(5-16)27bad submersible	33°45'05.574" 113°54'51.333"	600165	18614	Sandoz Well	Inorganic, Radon O, H & N Isotopes	400’	160’	Old
13th Field Trip, December 14, 2011 – Towne & Boettcher									
RAN-65	B(7-17)22ddc submersible	33°55'44.212" 114°00'47.047"	220318	77541	Rollene Well	Inorganic O, H & N Isotopes	130’	45’	Old
14th Field Trip, December 19, 2011 – Towne & Determann									
RAN-66	B(6-16)22cba submersible	33°50'50.733" 113°55'09.945"	596673	77542	Drich Well	Inorganic, Radon O, H & N Isotopes	349’	152’	Old
RAN-67	B(5-15)15ad submersible	33°46'34.766" 113°48'07.998"	500766	18579	Cobb IR Well	Inorganic, Radon O, H & N Isotopes	492’	350’	Recent
RAN-68	B(7-15)15aad turbine	33°57'17.868" 113°48'03.210"	614546	19122	But Vly Well #18	Inorganic, Radon O, H & N Isotopes	580’	460’	Old

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011

Site #	MCL Exceedances	Temp (ºC)	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)
RAN-1/2	TDS, Radon	30.9	7.85	*8.05*	1107	1100	**650**	170	180	0.19
RAN-3	TDS, Cl, SO_4, NO_3, As, **F**	30.1	7.98	8.0	2698	2600	**1700**	290	300	0.11
RAN-4	TDS, Cl, SO_4, NO_3, As, **F**	29.4	8.22	*8.2*	2838	2700	**1700**	180	190	0.10
RAN-5	TDS, Cl, SO_4, NO_3, As, **F**	29.7	8.04	*8.1*	3020	2900	**1900**	310	320	0.06
RAN-6	TDS, Cl, SO_4, NO_3, As, **F**	29.6	8.46	8.4	2746	2600	**1600**	240	250	0.02
RAN-7	pH-f, TDS, Cl, NO_3, As, **F**	30.4	**8.52**	*8.4*	1589	1500	**910**	89	98	0.10
RAN-8	TDS, Cl, SO_4, NO_3, As, **F**	31.9	8.08	***8.0***	4348	4100	**3000**	650	700	0.03
RAN-9	TDS, F	27.2	8.16	8.24	1122	1100	**630**	110	100-T	1.6
RAN-10	TDS, As, **F**	28.3	8.49	*8.59*	933	900	**560**	31	23-T	ND
RAN-11	pH-f, As, **F**	31.4	**8.59**	*8.67*	839	830	490	63	58-T	0.31
RAN-12/13	TDS, Cl, NO_3 As, Cr, **F**	28.1	8.25	*8.19*	1648	1580	**980**	83	81-T	ND
RAN-14	TDS, Cl, NO_3, As, **F**	25.4	9.29 *	*8.55*	1341	1300	**760**		68-T	2.8
RAN-15	As, F	24.8	8.73 *	*8.17*	768	740	430		68-T	220
RAN-16	TDS, As, **F**	28.3	8.68 *	*8.05*	856	820	**500**		81-T	ND
RAN-17	TDS, As, **F**	27.7	8.59 *	*8.04*	1373	1300	**800**		130-T	1.0
RAN-18/19	TDS, Cl, SO_4, **F**	28.4	8.30 *	*7.85*	3023	2925	**1850**		293.4-T	17.9
RAN-20	TDS, SO_4, As, **F**, Radon	29.1	8.36	*8.30*	1307	1300	**800**	61		ND
RAN-21	TDS, SO_4	27.6	7.53	7.97	1162	1200	**890**	430		60
RAN-22/23	TDS, NO_3,	28.1	7.10	*8.205*	1395	1380	**881**	332		ND/0.2 72
RAN-24	TDS, Cl, NO_3,	22.6	7.59	*7.81*	3474	3400	**2400**	950		ND
RAN-25	TDS, SO_4, F, As, Radon	22.0	8.04	*8.00*	1521	1500	**1000**	210		ND
RAN-26	F, As, Radon	21.6	8.24	*8.31*	848	840	490	83		ND
RAN-27	TDS	-	7.83	*7.93*	988	1000	**630**	330		0.25
RAN-28	Fe, Mn *	-	7.96	*8.07*	475	510	340	210		100
RAN-29	Radon	27.6	7.83	7.99	521	520	310	96		ND
RAN-30/31	TDS, Cl, SO_4, NO_3, Cr, F, Radon	25.8	7.51	*7.685*	6117	5745	**4040**	827 /1200		0.635
RAN-32	TDS, Cl, SO_4, As, Cr, F	23.7	7.55	*7.70*	5382	5200	**3400**	880		0.20

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	MCL Exceedances	Temp (ºC)	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)
RAN-33	TDS, SO_4, As, **F**	30.0	8.26	*8.48*	1266	1300	**820**	73		ND
RAN-34	TDS, SO_4, F	28.6	7.70	*7.90*	1309	1300	**790**	180		ND
RAN-35/36	pH, TDS, As, **F**	28.5	**9.05**	*8.81*	1147	1210	**629**	24		ND
RAN-37	TDS, F	30.3	8.11	*8.25*	1132	1000	**620**	61	2.2	ND
RAN-38	TDS, SO_4, As, F	26.1	7.62	*8.05*	1551	1500	**950**	200		ND
RAN-39	TDS, SO_4, As, **F**	28.6	7.95	*8.20*	1436	1400	**870**	100		ND
RAN-40	TDS, SO_4, As, **F**	29.5	7.99	*8.21*	1515	1500	**920**	130		1.2
RAN-41	TDS, SO_4, F	27.8	8.11	*7.93*	1382	1300	**840**	250		10
RAN-42/43	As	29.8	8.11	*8.24*	661	604	408	130		ND
RAN-48/49	TDS, SO_4, F	27.2	8.41	*8.12*	1445	1680	**1000**	150		0.29
RAN-50	TDS, SO_4, As	29.6	7.57	*7.87*	1377	1600	**1300**	740		11
RAN-51	TDS, As, **F**	28.9	8.44	*8.22*	1168	1400	**860**	76		ND
RAN-52	TDS, SO_4, As, **F**	28.2	7.87	*7.96*	1620	1600	**1000**	140		ND
RAN-53	TDS, As, **F**	30.0	8.36	*8.39*	936	910	**560**	58		3.2
RAN-54/55	TDS, SO_4, As, **F**	28.3	8.27	*8.22*	2027	2000	**1300**	280		1.2
RAN-56	TDS, Cl, SO_4, NO_3, As, **F**	32.6	7.88	*7.98*	4075	4000	**2600**	610		ND
RAN-57	TDS, Radon	27.2	7.89	*8.2*	861	890	**580**	160		0.10
RAN-58	Radon	26.8	7.89	8.2	712	700	440	100		0.04
RAN-59	Radon	25.5	7.81	*8.2*	741	760	450	71		0.04
RAN-60	Radon	24.8	7.76	*8.2*	730	720	430	98		0.02
RAN-61	TDS, As, **F**	30.0	8.22	*8.28*	1023	940	**600**	64		130
RAN-62	As, **F**	30.2	8.54	*8.89*	751	700	410	16		0.74
RAN-22A	NO_3	26.6	7.59	-	1426	-	-	-	-	-
RAN-63	As, **F**	28.1	8.38	*8.60*	763	710	420	44		4.7
RAN-16A	-	28.0	8.11	-	861	-	-	-	-	-
RAN-64	TDS, As, **F**	25.9	8.16	*8.22*	1142	1100	**640**	100		4.2
RAN-65	TDS, SO_4 , **F**	24.5	7.88	*8.31*	1437	1500	**890**	190	-	0.43

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	**MCL Exceedances**	**Temp** (ºC)	**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)
RAN-66	TDS, Cl, SO_4 F, As, Cr	23.9	7.75	*7.75*	5748	5500	**4300**	1100		ND
RAN-67	TDS, Cl, SO_4	-	7.88	*8.18*	1884	1800	**1200**	380		3.9
RAN-68	TDS, Cl	-	7.80	*7.84*	1832	1700	**1200**	390		ND

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-1/2	37.5	20.5	165	5.9	155	190	ND	90.5	235
RAN-3	110	6.9	450	4.4	75	92	ND	**430**	**460**
RAN-4	62	8.8	500	3.6	74	91	ND	**480**	**470**
RAN-5	86	26	500	6.1	89	110	ND	**460**	**610**
RAN-6	70	19	450	2.9	76	87	3.0	**570**	**250**
RAN-7	23	9.8	290	2.1	110	130	3.8	**250**	160
RAN-8	260	12	680	6.0	32	40	ND	**610**	**1200**
RAN-9	19/18	14/13	190	3.2	130	160	ND	170	140
RAN-10	8.9/9.2	2.1/2.0	180	5.4	100	120	ND	88	180
RAN-11	23/23	1.4/ND	140	2.3	80	97	ND	140	85
RAN-12/13	16/16	10.8/10	301	3.9	131	160	ND	**257**	182
RAN-14	22/22	3.3/3.2	230	2.4	58	71	ND	**260**	160
RAN-15	16/17	6.0/6.2	130	ND	99	120	ND	94	110
RAN-16	23/23	6.2/5.9	140	2.5	120	146	ND	100	130
RAN-17	41/41	6.7/6.5	220	2.4	64	78	ND	230	230
RAN-18/19	87.5	18.2	528.5	7.64	121	146	ND	**415**	**695**
RAN-20	22	1.6	240	2.9	64	77	ND	190	**250**
RAN-21	150	15	85	4.6	130	156	ND	35	**450**
RAN-22/23	66.5	40.5	145	3.12	94	106	ND	144	160.5
RAN-24	200	110	290	4.4	77	93	ND	**920**	110
RAN-25	76	5.1	230	2.8	52	65	ND	180	**370**
RAN-26	21	7.7	150	2.5	89	110	ND	130	96
RAN-27	75	35	84	4.1	330	400	ND	99	61
RAN-28	52	19	31	3.0	150	180	ND	49	29
RAN-29	25	7.9	74	3.7	150	180	ND	43	46
RAN-30/31	340.5	67.2	919	14	53	68	ND	**1170**	**1180 /1299**
RAN-32	270	52	870	12	55	68	ND	**950**	**910**
RAN-33	27	1.5	200	2.0	53	66	ND	150	**330**

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-34	55	9.8	200	4.9	100	120	ND	180	**270**
RAN-35/36	8.85	0.435	215.5	0.8	52.5	68	15	182	139.5
RAN-37	16	4.8	180	4.7	120	146	ND	150	130
RAN-38	65	8.3	220	4.5	110	130	ND	200	**310**
RAN-39	29	7.1	250	5.0	110	130	ND	190	**260**
RAN-40	35	11	250	4.9	120	146	ND	200	**270**
RAN-41	62	23	160	5.0	100	122	ND	110	**360**
RAN-42/43	40	7.0	74	2.0	173	212	ND	34	59
RAN-45	-	-	-	-	-	-	-	-	**420**
RAN-47	-	-	-	-	-	-	-	-	**405**
RAN-48/49	58	ND	297	2.35	53	65	ND	200	**409**
RAN-50	280	9.9	93	3.8	130	159	ND	43	**700**
RAN-51	22	5.0	260	4.6	100	122	ND	190	240
RAN-52	47	4.3	300	3.5	120	146	ND	180	**440**
RAN-53	23	ND	170	ND	65	79	ND	130	180
RAN-54/55	105	3.55	355	2.1	32.5	40	ND	230	**695**
RAN-56	230	9.4	720	5.1	69	84	ND	**820**	**960**
RAN-57	43	15	130	4.4	170	210	ND	7.9	72
RAN-58	26	9.7	120	5.1	160	200	ND	36	120
RAN-59	20	5.8	130	2.8	210	260	ND	17	100
RAN-60	27	7.9	120	3.2	200	240	ND	35	77
RAN-61	18	4.6	180	4.1	120	146	ND	120	160
RAN-62	6.6	ND	150	5.1	130	93	24	84	89
RAN-63	9.3	5.0	130	2.3	88	107	ND	92	110
RAN-64	32	5.3	170	2.6	95	116	ND	200	120
RAN-65	63	7.2	230	4.3	80	98	ND	190	**340**
RAN-66	320	68	980	13	52	63.5	ND	**520**	**500**
RAN-67	85	41	300	5.8	220	268	ND	**350**	**270**
RAN-68	130	13	220	8.2	79	96	ND	**470**	120

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	T. Nitrate-N (mg/L)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phosphorus (mg/L)	SAR (value)	Irrigation Quality	Aluminum (mg/L)	Strontium (mg/L)
RAN-1/2	2.2	ND	ND	ND	ND	5.2	C3-S1	-	-
RAN-3	**14**	ND	ND	ND	ND	11.2	C4-S3	ND	0.87
RAN-4	**15**	ND	ND	ND	ND	15.7	C4-S4	ND	0.56
RAN-5	**15**	ND	ND	ND	ND	12.1	C4-S3	ND	0.92
RAN-6	**20**	ND	ND	ND	ND	12.3	C4-S3	ND	0.79
RAN-7	**16**	0.075	ND	ND	ND	12.8	C3-S3	ND	0.34
RAN-8	**19**	ND	ND	ND	ND	11.2	C4-S3	ND	2.2
RAN-9	6.1	ND	ND	ND	ND	8.1	C3-S2	-	-
RAN-10	2.5	ND	ND	ND	ND	14.1	C3-S3	-	-
RAN-11	3.4	ND	ND	ND	ND	7.7	C3-S2	-	-
RAN-12/13	**13.6**	ND	ND	ND/0.130	ND	14.1	C3-S3	-	-
RAN-14	**12**	ND	ND	ND	ND	12.1	C3-S3	-	-
RAN-15	4.6	ND	ND	ND	0.66	7.0	C2-S1	-	-
RAN-16	3.2	ND	ND	ND	ND	6.7	C3-S1	-	-
RAN-17	5.2	ND	ND	ND	ND	8.4	C3-S2	-	-
RAN-18/19	6.76	ND	ND	ND	ND	13.5	C4-S3	-	-
RAN-20	5.3	ND	ND	0.062	ND	13.3	C3-S3	ND	0.37
RAN-21	3.8	ND	ND	ND	ND	1.8	C3-S1	ND	5.9
RAN-22/23	**38/75.8**	ND	ND	ND	ND	3.5	C3-S1	ND	1.23
RAN-24	**53**	ND	ND	ND	ND	4.1	C4-S2	ND	4.0
RAN-25	6.7	ND	ND	0.061	ND	6.9	C3-S2	ND	0.43
RAN-26	4.9	ND	ND	0.071	ND	7.1	C3-S2	ND	0.28
RAN-27	ND	ND	ND	ND	ND	2.0	C3-S1	ND	0.38
RAN-28	2.2	ND	9.3	0.070	0.88	0.9	C2-S1	ND	0.38
RAN-29	2.6	ND	ND	0.29	ND	3.3	C2-S1	ND	0.69
RAN-30/31	**11.95**	ND	ND	ND	ND	11.0	C4-S3	ND	13.4
RAN-32	7.1	ND	ND	ND	ND	12.7	C4-S3	ND	12
RAN-33	4.7	ND	ND	ND	ND	10.1	C3-S2	ND	0.64

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	T. Nitrate-N (mg/L)	$\delta^{15}N$ ($^0/_{00}$)	Nitrite-N (mg/L)	TKN (mg/L)	Ammonia (mg/L)	T. Phos (mg/L)	SAR (value)	Irrigation Quality	Aluminum (mg/L)	Strontium (mg/L)
RAN-34	2.9	-	ND	ND	ND	ND	6.5	C3-S2	ND	1.9
RAN-35/36	6.3	-	ND	ND	ND	ND	18.6	C3-S4	ND	ND
RAN-37	3.1	-	ND	ND	ND	ND	6.0	C3-S2	ND	0.28
RAN-38	3.5	-	ND	ND	ND	ND	6.8	C3-S2	ND	2.2
RAN-39	4.8	-	ND	ND	ND	ND	10.8	C3-S2	ND	0.71
RAN-40	4.9	-	ND	ND	ND	ND	9.4	C3-S2	ND	1.1
RAN-41	0.58	-	0.44	ND	0.076	ND	4.4	C3-S1	ND	2.8
RAN-42/43	4.95	-	ND	ND	ND	ND	2.8	C2-S1	ND	1.5
RAN-48/49	7.35	-	ND	ND	ND	ND	11.0	C3-S2	ND	0.50
RAN-50	4.6	-	ND	ND	ND	ND	1.5	C3-S1	ND	6.7
RAN-51	5.3	-	ND	ND	ND	ND	13.0	C3-S2	ND	0.42
RAN-52	4.3	-	ND	ND	0.082	ND	6.8	C3-S2	ND	2.2
RAN-53	4.6	-	ND	ND	ND	ND	9.4	C3-S2	ND	0.91
RAN-54/55	4.9	-	ND	ND	ND	ND	9.4	C3-S2	ND	1.3
RAN-56	**13**	-	ND	ND	ND	ND	12.6	C4-S3	ND	2.2
RAN-57	6.5	-	ND	0.084	ND	ND	4.3	C3-S1	-	-
RAN-58	2.3	-	ND	ND	ND	ND	5.1	C2-S1	-	-
RAN-59	2.7	-	ND	ND	ND	ND	6.6	C2-S1	-	-
RAN-60	4.7	-	ND	ND	ND	ND	5.2	C2-S1	-	-
RAN-61	5.4	6.6	ND	ND	ND	0.45	9.8	C3-S2	ND	0.33
RAN-62	0.73	8.6	0.23	ND	ND	ND	14.4	C2-S3	ND	ND
RAN-22A	**39.7**	7.5	-	-	-	-	-	-	-	-
RAN-63	3.4	7.3	ND	ND	ND	ND	8.6	C2-S2	ND	ND
RAN-16A	2.72	6.6	-	-	-	-	-	-	-	-
RAN-64	6.3	8.0	ND	ND	ND	ND	7.3	C3-S2	ND	0.64
RAN-65	3.8	1.5	ND	ND	ND	ND	7.3	C3-S2	ND	2.0
RAN-66	8.6	1.3	ND	ND	ND	ND	13.0	C4-S4	ND	14
RAN-67	8.6	2.3	ND	ND	ND	ND	6.7	C3-S2	ND	4.8
RAN-68	8.1	1.9	ND	ND	ND	ND	4.9	C3-S1	ND	6.0

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Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-1/2	ND	ND	0.0058	ND	0.65	ND	ND	ND	0.975
RAN-3	ND	**0.026**	ND	ND	0.85	ND	0.059	ND	**6.2**
RAN-4	ND	**0.021**	ND	ND	0.62	ND	0.071	ND	**6.0**
RAN-5	ND	**0.024**	ND	ND	0.96	ND	0.071	ND	**5.8**
RAN-6	ND	**0.030**	ND	ND	0.58	ND	0.095	ND	**6.7**
RAN-7	ND	**0.034**	ND	ND	0.60	ND	0.085	ND	**7.6**
RAN-8	ND	**0.025**	ND	ND	2.4	ND	0.045	ND	**5.2**
RAN-9	ND	0.0069	0.020	ND	0.68	ND	0.083	0.0038	**2.1**
RAN-10	ND	**0.11**	0.0073	ND	0.82	ND	0.027	0.0038	**8.1**
RAN-11	ND	**0.034**	0.0014	ND	0.51	ND	0.039	0.0032	**9.3**
RAN-12/13	ND	**0.0153**	0.16	ND	0.985	ND	**0.146**	0.0033	**4.07**
RAN-14	ND	**0.023**	0.027	ND	0.65	ND	0.060	0.0034	**4.4**
RAN-15	ND	**0.031**	0.027	ND	0.51	ND	0.050	0.0078	**2.7**
RAN-16	ND	**0.034**	0.043	ND	0.54	ND	0.030	0.0023	**4.2**
RAN-17	ND	**0.034**	0.026	ND	0.71	ND	0.037	0.0029	**4.0**
RAN-18/19	ND	0.0047	0.0066	ND	1.7	ND	0.0020	0.0070	**5.51**
RAN-20	ND	**0.019**	0.018	ND	1.4	ND	0.063	0.0037	**5.2**
RAN-21	ND	0.0091	0.024	ND	0.36	ND	0.0019	0.0014	0.58
RAN-22/23	ND	0.0042	0.039	ND	0.265	ND	0.010	.0027/.0 0069	ND
RAN-24	ND	0.0055	0.076	ND	0.29	ND	0.025	0.0052	ND
RAN-25	ND	**0.033**	0.016	ND	0.97	ND	0.095	0.0030	**3.6**
RAN-26	ND	**0.026**	0.026	ND	0.51	ND	0.060	0.0023	**2.3**
RAN-27	ND	0.0039	0.011	ND	ND	ND	ND	0.0017	ND
RAN-28	ND	0.0021	0.0047	ND	ND	ND	0.0016	ND	ND
RAN-29	ND	0.0092	0.052	ND	0.22	ND	0.0092	0.0012	0.62
RAN-30/31	ND	**0.013**	0.0169	.000260/ ND	1.235	ND	**0.124**	.00188	**3.20 / 2.7**
RAN-32	ND	**0.013**	0.020	ND	1.3	ND	**0.12**	0.0145	**2.95**
RAN-33	ND	**0.056**	0.014	ND	1.1	ND	0.052	0.0028	**6.8**

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-34	ND	0.0098	0.024	ND	0.61	ND	0.024	0.0028	**3.9**
RAN-35/36	ND	**0.0565**	0.002	ND	0.698	ND	0.0876	0.0028	**10.6**
RAN-37	ND	0.0056	0.025	ND	0.60	ND	0.025	0.0032	**2.5**
RAN-38	ND	**0.014**	0.024	ND	0.75	ND	0.032	0.0035	**3.7**
RAN-39	ND	**0.018**	0.023	ND	1.0	ND	0.063	0.0037	**5.3**
RAN-40	ND	**0.012**	0.025	ND	0.995	ND	0.055	0.0043	**4.9**
RAN-41	ND	0.0024	0.020	ND	0.69	ND	ND	0.0019	**2.0**
RAN-42/43	ND	**0.0170**	0.065	ND	0.33	ND	0.0195	0.0045	1.1
RAN-44	-	-	-	-	-	-	-	-	**4.2**
RAN-46	-	-	-	-	-	-	-	-	**3.07**
RAN-48/49	ND	0.0050	0.0088	ND	0.835	ND	0.0156	0.0031	**3.6**
RAN-50	ND	**0.012**	0.031	ND	0.34	ND	ND	ND	1.2
RAN-51	ND	**0.031**	0.023	ND	0.98	ND	0.064	0.0032	**8.1**
RAN-52	ND	**0.022**	0.026	ND	1.4	ND	0.024	0.0026	**5.9**
RAN-53	ND	**0.033**	0.021	ND	0.70	ND	0.0046	0.0022	**7.3**
RAN-54/55	ND	**0.040**	0.0145	ND	2.2	ND	0.0355	0.0030	**7.0**
RAN-56	ND	**0.018**	0.022	ND	2.0	ND	0.052	0.0079	**6.4**
RAN-57	ND	ND	ND	ND	0.26	ND	ND	0.020	0.69
RAN-58	ND	0.0095	ND	ND	0.28	ND	0.019	0.011	0.83
RAN-59	ND	ND	ND	ND	0.47	ND	ND	ND	1.4
RAN-60	ND	ND	ND	ND	0.44	ND	ND	ND	0.68
RAN-61	ND	**0.035**	ND	ND	0.66	ND	0.037	0.022	**4.3**
RAN-62	ND	**0.094**	ND	ND	0.71	ND	0.0115	0.0030	**9.1**
RAN-63	ND	**0.040**	ND	ND	0.54	ND	0.046	0.0019	**4.7**
RAN-64	ND	**0.032**	0.043	ND	0.66	ND	0.045	0.0026	**4.0**
RAN-65	ND	ND	0.0054	ND	0.90	ND	ND	0.0066	**4.4**
RAN-66	ND	**0.011**	0.016	ND	1.3	ND	**0.13**	0.015	**2.8**
RAN-67	ND	0.0020	0.041	ND	0.71	ND	ND	0.0023	0.77
RAN-68	ND	0.0062	0.17	ND	0.26	ND	0.020	0.0016	1.6

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-1/2	ND	ND	ND	ND	ND	0.0054/ND	ND	ND	ND
RAN-3	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-4	ND	ND	ND	ND	ND	0.0054	ND	ND	ND
RAN-5	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-6	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-7	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-8	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-9	ND	ND	ND	ND	ND	0.0027	ND	ND	ND
RAN-10	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-11	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-12/13	ND	ND	ND	ND	ND	0.00979	ND	ND	ND/0.0066
RAN-14	ND	ND	ND	ND	ND	0.0075	ND	ND	ND
RAN-15	ND	ND	ND	ND	ND	0.0034	ND	ND	ND
RAN-16	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-17	ND	ND	ND	ND	ND	0.0047	ND	ND	ND
RAN-18/19	ND	ND	0.010	ND	ND	0.0095	ND	ND	ND
RAN-20	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-21	ND	ND	ND	ND	ND	ND	ND	ND	0.099
RAN-22/23	ND	ND	ND	ND	ND	0.0054	ND	ND	ND
RAN-24	ND	ND	ND	ND	ND	0.010	ND	ND	ND
RAN-25	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-26	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-27	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-28	0.055	ND	**0.55**	ND	ND	ND	ND	ND	ND
RAN-29	ND	ND	ND	ND	ND	0.0030	ND	ND	ND
RAN-30/31	ND	ND	ND	ND	ND	0.0219/ND	ND	ND	ND
RAN-32	0.056	ND	ND	ND	ND	0.018	ND	ND	ND
RAN-33	ND	ND	ND	ND	ND	0.0026	ND	ND	ND

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bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---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)
RAN-34	ND	ND	ND	ND	ND	0.0034	ND	ND	ND
RAN-35/36	ND	ND	ND	ND	ND	0.00249/ ND	ND	ND	ND
RAN-37	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-38	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-39	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-40	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-41	ND	ND	0.038	ND	ND	0.0043	ND	ND	0.54
RAN-42/43	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-48/49	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-50	ND	ND	ND	ND	ND	ND	ND	ND	0.30
RAN-51	ND	ND	ND	ND	ND	0.0066	ND	ND	ND
RAN-52	ND	ND	ND	ND	ND	0.0040	ND	ND	ND
RAN-53	ND	ND	ND	ND	ND	0.0032	ND	ND	0.066
RAN-54/55	ND	ND	ND	ND	ND	0.00515	ND	ND	ND
RAN-56	ND	ND	ND	ND	ND	0.017	ND	ND	ND
RAN-57	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-58	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-59	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-60	ND	ND	ND	ND	ND	ND	ND	ND	0.16
RAN-61	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-62	0.076	ND	ND	ND	ND	ND	ND	ND	ND
RAN-63	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-64	ND	ND	ND	ND	ND	0.0036	ND	ND	ND
RAN-65	ND	ND	ND	ND	ND	ND	ND	ND	ND
RAN-66	ND	ND	ND	ND	ND	0.033	ND	ND	ND
RAN-67	ND	ND	ND	ND	ND	0.014	ND	ND	ND
RAN-68	ND	ND	ND	ND	ND	0.014	ND	ND	ND

italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Beta (mrem)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	δ^{18} O ($^0/_{00}$)	δ D ($^0/_{00}$)	Chemistry
RAN-1/2	**674**	7.8	13	-	< LLD	-	- 8.45	- 61	sodium-mixed
RAN-3	-	-	-	-	-	-	- 9.2	- 69	sodium-mixed
RAN-4	-	3.9	5.8	-	-	-	- 9.2	- 69	sodium-chloride
RAN-5	-	-	-	-	-	-	- 9.3	- 71	sodium-mixed
RAN-6	-	-	-	-	-	-	- 9.3	- 70	sodium-chloride
RAN-7	-	-	-	-	-	-	- 9.4	- 70	sodium-mixed
RAN-8	-	< LLD	1.2	-	-	-	- 9.1	- 66	sodium-sulfate
RAN-9	-	< 1.0	< 3.3	< 4	< 0.5	10.9	- 9.1	- 68	sodium-mixed
RAN-10	-	1.8	4.3	< 4	< 0.4	1.6	- 9.1	-70	sodium-mixed
RAN-11	-	0.8	2.9	< 4	< 0.4	< 1	- 8.8	- 68	sodium-chloride
RAN-12/13	-	-	-	-	-	-	- 9.6	- 73	sodium-chloride
RAN-14	-	-	-	-	-	-	- 8.9	- 70	sodium-chloride
RAN-15	-	-	-	-	-	-	- 8.1	-61	sodium-mixed
RAN-16	-	< 1.0	-	< 4	< 0.4	2.8	- 8.2	- 63	sodium-mixed
RAN-17	-	-	-	-	-	-	- 8.2	- 65	sodium-chloride
RAN-18/19	-	2.9	-	< 4	< 0.5	8.3	- 9.3	- 71	sodium-sulfate
RAN-20	**585**	-	-	-	-	-	- 9.1	- 71	sodium-mixed
RAN-21	229	2.1	-	< 4	< 0.5	8.6	- 6.9	- 51	calcium-sulfate
RAN-22/23	98	< 1	-	< 4	< 0.5	1.1	- 7.1	- 53	mixed-mixed
RAN-24	-	-	-	-	-	-	- 6.9	- 52	mixed-chloride
RAN-25	**923**	-	-	-	-	-	- 8.4	- 63	sodium-sulfate
RAN-26	**419**	-	-	-	-	-	- 8.1	- 60	sodium-mixed
RAN-27	-	-	-	-	-	-	- 7.1	- 53	mixed-bicarbonate
RAN-28	-	-	-	-	-	-	- 7.0	- 54	mixed-bicarbonate
RAN-29	**644**	1.1	-	< 4	< 0.3	5.8	-7.7	-54	sodium-bicarbonate
RAN-30/31	**508**	< 1	-	< 4	< 0.3	3.1	-8.9	-70	sodium-chloride
RAN-32	235	-	-	-	-	-	-9.1	-71	sodium-chloride

LLD = Lower Limit of Detection
italics = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level

Appendix B. Groundwater Quality Data, Ranegras Plain Basin, 2008-2011---Continued

Site #	Radon-222 (pCi/L)	Alpha (pCi/L)	Beta (pCi/L)	Beta (mrem)	Ra-226 + Ra-228 (pCi/L)	Uranium (µg/L)	δ^{18} O ($^0/_{00}$)	δ D ($^0/_{00}$)	Chemistry
RAN-33	232	-	-	-	-	-	-8.8	-66	sodium-sulfate
RAN-34	230	-	-	-	-	-	-9.6	-69	sodium-mixed
RAN-35/36	**303**	-	-	-	-	-	-9.3	-72.5	sodium-chloride
RAN-37	**512**	-	-	-	-	-	-8.2	-61	sodium-mixed
RAN-38	**489**	-	-	-	-	-	-9.2	-69	sodium-mixed
RAN-39	102	-	-	-	-	-	-9.2	-69	sodium-mixed
RAN-40	**511**	ND	-	ND	ND	5.0	-9.1	-69	sodium-mixed
RAN-41	**442**	1.1	-	ND	ND	1.5	-7.5	-55	sodium-sulfate
RAN-42/43	159	1.2		ND	ND	2.9	-7.3	-51	sodium-bicarbonate
RAN-48/49	**1547**	-	-	-	-	-	- 9.4	- 70	sodium-sulfate
RAN-50	**1165**	-	-	-	-	-	- 7.0	- 51	calcium-sulfate
RAN-51	**584**	-	-	-	-	-	- 9.2	- 71	calcium-sulfate
RAN-52	-	-	-	-	-	-	- 8.3	- 62	sodium-sulfate
RAN-53	-	-	-	-	-	-	-8.9	- 68	sodium-mixed
RAN-54/55	247	-	-	-	-	-	- 8.7	- 67	sodium-sulfate
RAN-56	-	-	-	-	-	-	- 8.8	- 68	sodium-chloride
RAN-57	**478**	7.1	7.6	-	< LLD	-	- 7.1	- 50	sodium-bicarbonate
RAN-58	**322**	5.9	4.7	-	< LLD	-	- 7.0	- 49	sodium-mixed
RAN-59	**699**	-	-	-	-	-	- 7.5	- 52	sodium-bicarbonate
RAN-60	**752**	-	-	-	-	-	- 7.0	- 51	sodium-bicarbonate
RAN-61	ND	ND	ND	ND	ND	8.3	- 8.7	- 65	sodium-mixed
RAN-62	**339**	-	-	-	-	-	- 9.2	- 70	sodium-mixed
RAN-63	**674**	-	-	-	-	-	- 8.6	- 63	sodium-mixed
RAN-64	**625**	-	-	-	-	-	- 8.4	- 62	sodium-chloride
RAN-65	-	-	-	-	-	-	- 9.2	- 69	sodium-mixed
RAN-66	**382**	-	-	-	-	-	- 8.8	- 70	sodium-chloride
RAN-67	**309**	-	-	-	-	-	- 7.3	- 53	sodium-chloride
RAN-68	**405**	-	-	-	-	-	- 10.5	- 75	sodium-chloride

LLD = Lower Limit of Detection *italics* = constituent exceeded holding time
bold = constituent concentration exceeded Primary or Secondary Maximum Contaminant Level