SUMMARY RESULTS FROM THE COURTHOUSE WASH MONITORING WELL

by Stefan M. Kirby, J. Lucy Jordan, and Gary Hunt

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Cover photo: *Water flowing from the Courthouse Wash monitoring well borehole drilled into the Entrada Sandstone. Photo provided by James Harte, National Park Service, Water Resources Division*

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EXECUTIVE SUMMARY

This open-file report presents results from a new groundwater monitoring well and groundwater sampling campaign in the Courthouse Wash area near Moab, Utah. The purpose of the monitoring well and new groundwater samples is to better delineate the relationship between groundwater that supplies important springs within Arches National Park, and groundwater beneath the upper portions of Courthouse Wash that may experience development in the future. The monitoring well was designed as a single borehole that penetrates both the Navajo and Entrada aquifers, directly upgradient of Courthouse Wash Boundary Spring. The borehole was completed with two separate piezometers, one near the base of the Entrada aquifer and the other near the top of the Navajo aquifer. Water levels range from approximately 35 feet below top of casing for the Navajo completion to approximately 7 to 11 feet above top of casing for the Entrada completion. Total offset between the two water levels is approximately 43 feet. Groundwater samples were collected from the Entrada and Navajo completions and the nearby Courthouse Wash Boundary Spring. Groundwater chemistry is unique for each of the three samples and the Entrada completion has significantly higher concentrations of Na, Cl, HCO3, and SO4 than either the Navajo completion or Courthouse Wash Boundary Spring. Stable isotopic ratios and concentrations of percent modern carbon and tritium are also unique for each sample. Both the Navajo and Entrada completions have no evidence of modern recharge and these samples likely contain water recharged tens of thousands of years ago. Courthouse Wash Boundary Spring likely contains a mixture of young water recharged since 1950 and older water recharged more than 4000 years ago. The dissolved gas concentrations and modeled recharge temperatures are unique for each of the three samples. The calculated recharge temperatures are between 10°C for Courthouse Wash Boundary Spring and 7 and 6°C for the Entrada and Navajo completions respectively. Taken together the results presented here suggest little if any connection between the Entrada and Navajo aquifers at the monitoring well site. These results may, however, only be valid for static predevelopment conditions at the monitoring well location. Future groundwater development should include tests of the connection between the Entrada and Navajo aquifer under realistic pumping scenarios to confirm the hydrologic separation of these two aquifers.

INTRODUCTION

This open-file report presents data and describes results from a new groundwater monitoring well and groundwater sampling campaign in the Courthouse Wash area near Moab, Utah. The purpose of the monitoring well and new groundwater samples is to better delineate the relationship between groundwater that supplies important springs within Arches National Park, and groundwater beneath the upper portions of Courthouse Wash.

Groundwater in the Courthouse Wash area resides in several aquifers, including the Navajo Sandstone, the Slick Rock Member of the Entrada Sandstone, the Moab Member of the Curtis Formation, and other consolidated and unconsolidated units (Rush and others, 1982; Doelling and Morgan, 2000; Hurlow and Bishop, 2003). For subsequent discussions the Slick Rock Member and the Moab Member are considered part of the larger Entrada aquifer system. Groundwater from the Entrada aquifer provides flow at important perennial springs in Arches National Park, including Courthouse Wash Boundary Spring. Groundwater from the Entrada and Navajo aquifers also supports culinary uses and irrigation at several sites near Courthouse Wash. The Entrada aquifer is separated from the underlying Navajo aquifer by the potentially impermeable Dewey Bridge Member of the Carmel Formation. The degree of connection, if any, between the Navajo and Entrada aquifers is unknown and critical to current and future groundwater development in areas outside of Arches National Park in the Courthouse Wash area. The purpose of the new monitoring well and groundwater samples is to test the hydrologic connection between the Entrada and Navajo aquifers upgradient of important springs in Arches National Park.

WELL DRILLING SUMMARY

The monitoring well was designed as a single borehole that penetrates both the Navajo and Entrada aquifers, directly upgradient of Courthouse Wash Boundary Spring along the Willow Springs Road, on land managed by the Utah State and Institutional Trust Lands Administration (figure 1). The well was drilled and completed in January 2012 by the U.S. Geological Survey western region scientific drill crew. The well was mud logged during drilling and geophysically logged by Utah Geological Survey personnel after the borehole reached a total depth of 880 feet (figure 2) (complete lithologic and geophysical logs are available at http://waterrights.utah.gov/wellinfo/welldrilling/wlbrowse.asp?WIN=435519).

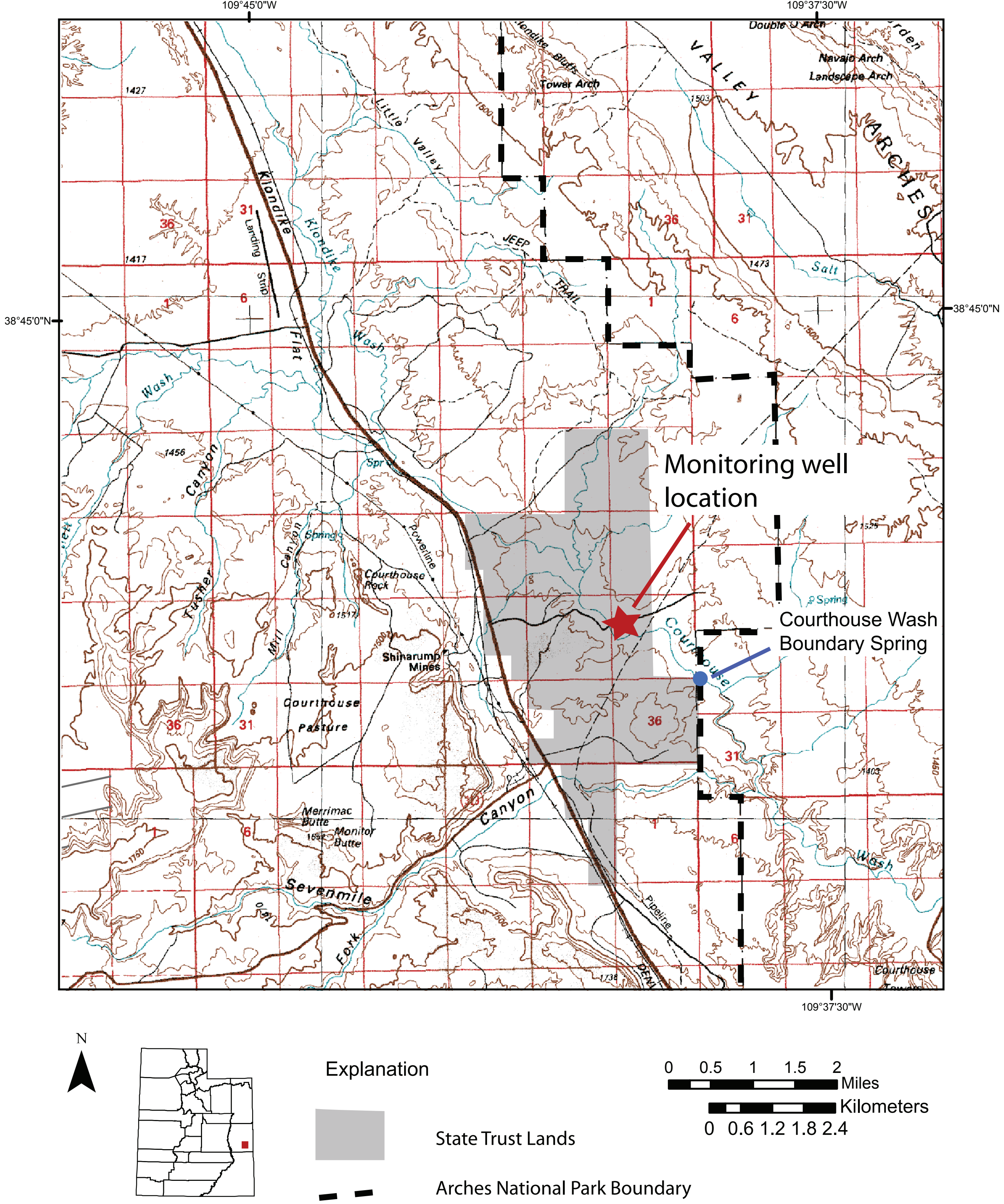

Figure 1. Monitoring well location map.

Unconsolidated deposits of sand and gravel were encountered from the land surface to a depth of 25 feet. Between the depths of 25 feet and 195 feet the borehole encountered members of the Morrison and Summerville Formations. The Entrada aquifer, including the Moab Member of the Curtis Formation and the Slick Rock Member of the Entrada Sandstone, was encountered from depths of 195 to 715 feet. The Dewey Bridge Member of the Carmel Formation was encountered between 715 and 840 feet and the Navajo Sandstone was encountered from 840 feet to the total depth of 880 feet. The results of logging were used to plan completion of the well with two piezometers, one screened in uppermost Navajo aquifer and the other screened in the lower Entrada aquifer (figure 3).

WATER LEVEL DATA

Water levels in the two monitoring well piezometers have been measured directly several times since completion of the well. They range from approximately 35 below top of casing for the Navajo completion to approximately 7 to 11 feet above top of casing for the Entrada completion. The Entrada completion is flowing and direct measurement of this completion is difficult due to slow head buildup and the height above casing to which the water level will rise. Because of this, head values (approximately 7.5 feet above top of casing) taken from a transducer in the sealed Entrada completion likely represent the best estimate of head for this piezometer (figure 4). Groundwater elevations adjusted for piezometer stickup and land surface elevation range from approximately 4315 feet for the Navajo completion to 4358 feet for the Entrada completion. Total offset between the two water levels is approximately 43 feet and groundwater elevation for both completions varies little over the period of record. Additional water level information is available from the U.S. Geological Survey at http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=384149109400901 and http://waterdata.usgs.gov/nwis/inventory?agency_code=USGS&site_no=384149109400902.

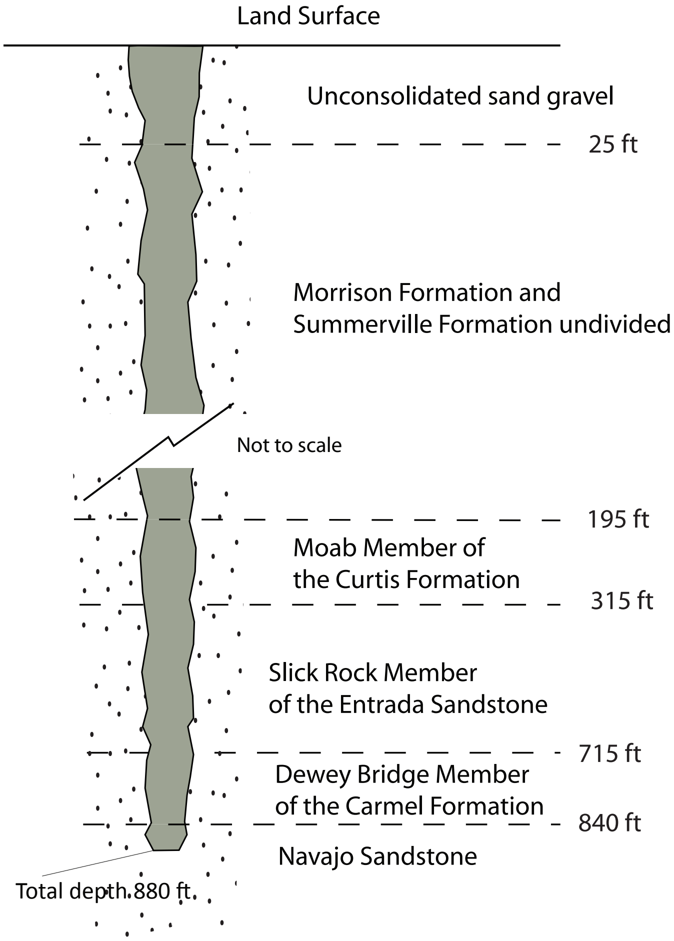

Figure 2. *Summary lithologic log for the Courthouse Wash monitoring well.*

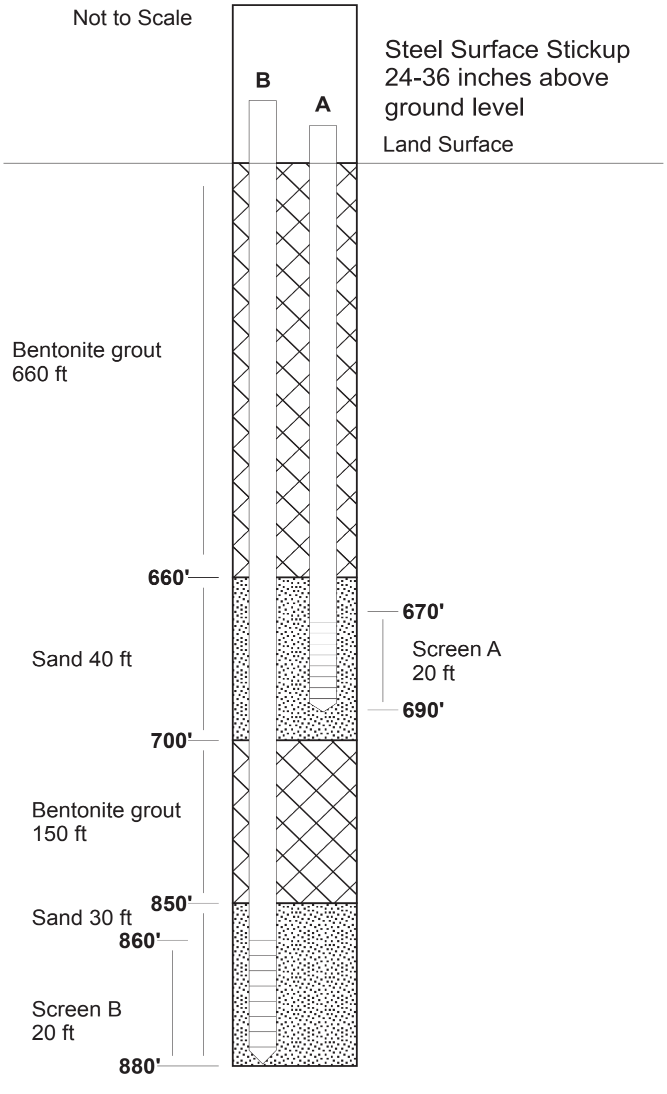

Figure 3. *Courthouse Wash monitoring well completion plan.*

GROUNDWATER SAMPLING

Groundwater samples were collected using standard U.S. Geological Survey field techniques summarized by Wilde and others (1998). Each piezometer was purged of at least 3 well volumes prior to sampling, either using a downhole sampling pump in the case of the Navajo completion or by allowing the well to flow for an extended period in the case of the Entrada completion. Samples collected from Courthouse Wash Boundary Spring were collected via a peristaltic pump from the deepest part of the large spring pool near the point of seepage. Samples were collected in triplicate in thoroughly rinsed, brown one-liter glass bottles with sealed polycone caps. Each bottle was sealed with electrical tape at the sampling site and kept iced until delivery to the Brigham Young University Hydrogeology Laboratory. Field parameters including temperature, specific conductance, pH, and dissolved oxygen were measured at the time of sampling using a Hydrolab Quanta multi-parameter meter that was periodically calibrated with reference solutions (table 1). Samples for dissolved gas analysis were collected using standard diffusion samplers placed in the purged piezometers at a depth of 30 feet below water level or the deepest part of the spring pool. Diffusion samplers were allowed to equilibrate for 24 hours prior to retrieval.

All laboratory work for groundwater samples, except carbon isotopes, was performed at the Brigham Young University Hydrogeology Lab. Concentrations of major dissolved anions and cations, and dissolved nitrate were de-

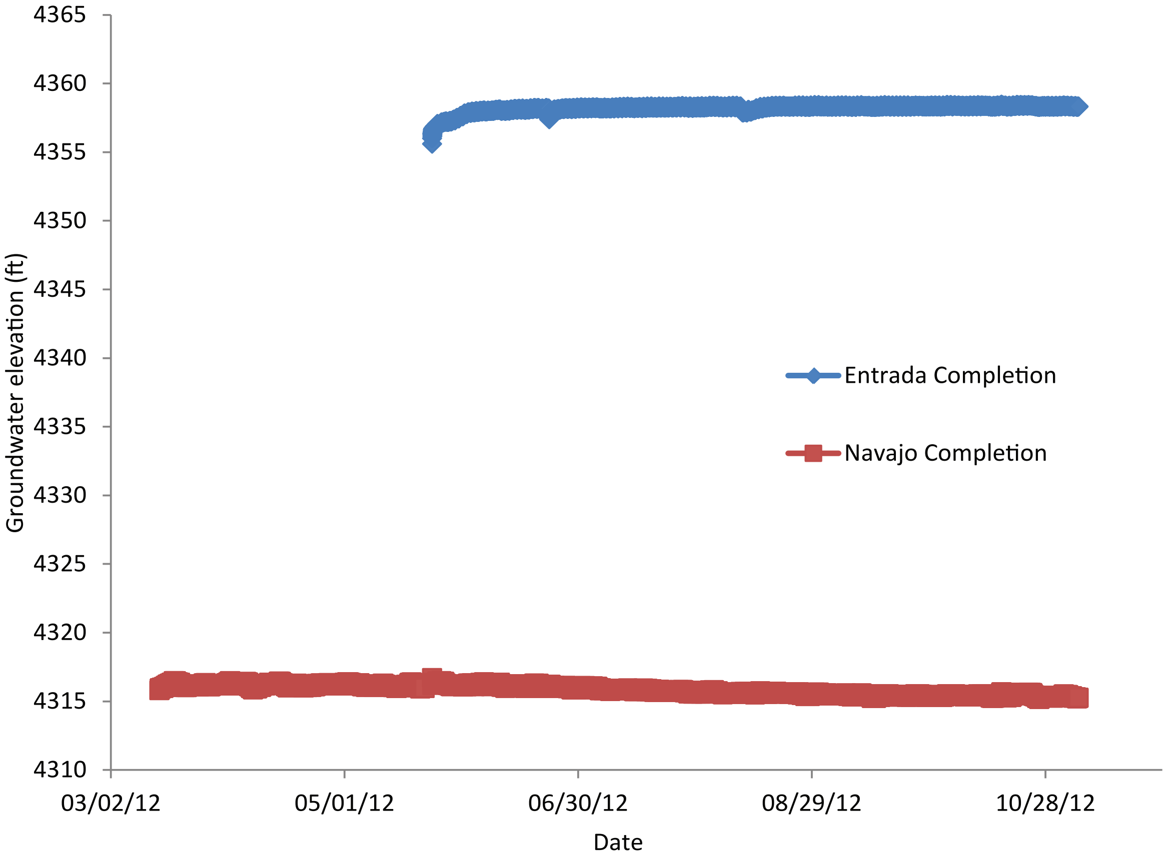

Figure 4. *Water levels based on transducer data for the Courthouse Wash monitoring well.*

***Table 1**. Field parameters and site locations.*

Name	East (m)[1]	North (m)	Elevation (ft)[2]	Sample date	Time	Flow rate (gpm)	Temp °C	DO (mg/L)[3]	Cond (µS/cm)[4]	pH
Entrada completion	615720	4283983	4330	5/22/12	11:13	0.15	15.4	0.16	3535	7.74
Navajo completion	615720	4283983	4330	5/22/12	15:20	3.5	15.7	2.8	693	7.51
CHW Boundary Spring	617234	4282707	4297	5/23/12	9:10	~3	16.3	2.4	832	7.14

[1] Location coordinates in NAD 83 UTM zone 12 projection
[2] Land surface elevation at sampling site
[3] Dissolved oxygen
[4] Conductivity

termined using standard techniques presented in Fishman and Friedman (1989) and Fishman (1993). Carbon isotope analyses were performed at the University of Georgia Center for Applied Isotope Studies via accelerator mass spectrometry (AMS) techniques. Dissolved gas samples were analyzed at the University of Utah Dissolved Gas Lab.

SOLUTE CHEMISTRY RESULTS

Groundwater type chemistry ranges from Na-SO4-HCO3 for the Entrada completion to Na-Mg-HCO3-SO4 for the Navajo completion to Na-Ca-Mg-HCO3-SO4 for Courthouse Wash Boundary Spring (table 2). A piper plot shows the relative concentrations of solutes for the three samples (figure 5). The Entrada completion has significantly higher concentrations of Na, Cl, HCO3, and SO4 than either the Navajo completion or Courthouse Wash Boundary Spring. Water quality of the Entrada completion is consequently much lower than that of either the Navajo completion or Courthouse Wash Boundary Spring. Total dissolved solids range from 502 for the Navajo completion to 648 mg/L for Courthouse Wash Boundary Spring. The Entrada completion has significantly higher TDS of 3138 mg/L. Based on these TDS concentrations both the Navajo completion and Courthouse Wash Boundary Spring having drinking water quality water. The Entrada completion is lower quality and not drinking water quality. Nitrate concentrations were below detection for all sites.

ISOTOPIC RESULTS

Water samples were analyzed for the stable isotope ratios $\delta^{18}O$ and δD at the Brigham Young University Hydrogeology Lab with a Finnigan Delta^{plus} isotope ratio mass spectrometer using methods similar to that described by McCrea (1950), Epstein and Mayeda (1953), and Gehre and others (1996). $\delta^{18}O$ and δD values were normalized to the VSMOW/SLAP scale following the procedure of Coplen (1988), Nelson (2000), and Nelson and Dettman (2001).

Stable isotope data are plotted versus the meteoric water line of Craig (1961) and a local Utah meteoric water line of Kendall and Coplen (2001) on figure 6. Stable isotope composition of all samples are distinct from one another, but lie along a trend below and parallel to the Utah meteoric water line. Samples from the Navajo and Entrada

***Table 2**. General chemistry results.*

Name	Entrada completion	Navajo completion	CHW Boundary Spring
Water type[1]	Na-SO4-HCO3	Na-Mg-HCO3-SO4	Na-Ca-Mg-HCO3-SO4
TDS (mg/L)[2]	3138	502	648
Ca(mg/L)	44.33	22.06	48.29
Mg(mg/L)	5.97	19.27	28.27
Na(mg/L)	907.60	80.13	85.02
K(mg/L)	8.41	7.85	5.36
Cl(mg/L)	122.31	40.49	11.04
HCO3(mg/L)	794.20	239.20	293.60
SO4(mg/L)	1255.50	92.79	176.45
HPO4(mg/L)	2.36	<0.1	<0.1
NO3(mg/L)	<0.1	<0.1	<0.1
Ca(meq/L)	2.41	1.10	2.21
Mg(meq/L)	2.33	1.59	0.49
Na(meq/L)	3.70	3.49	39.48
K(meq/L)	0.14	0.20	0.22
Cl(meq/L)	0.31	1.14	3.45
HCO3(meq/L)	4.81	3.92	13.02
SO4(meq/L)	3.68	1.93	26.16
Sum Cations[3]	8.58	6.38	42.4
Sum Anions	8.8	6.99	42.63
Percent error[4]	-1.27%	-4.56%	-0.27%

[1] Water type calculated using AquaChem software.
[2] Total dissolved solids calculated using AquaChem software.
[3] Sum of cations is the sum of Ca, Mg, Na, and K in meq/L. Sum of anions is the sum of Cl, SO4, and HCO3 in meq/L.
[4] Electroneutrality percent difference between the sum of cations and sum of anions.

completions are depleted (lower) relative to Courthouse Wash Boundary Spring (table 3). Depleted or lower values of δ^{18}O and δD may occur due to relatively cool recharge resulting from cool season precipitation, cool higher elevation recharge, or recharge under cooler climate conditions.

Tritium was measured by the University of Utah Dissolved Gas Laboratory via a tritium/^{3}He ingrowth method detailed by Solomon and Cook (2000). This method measures the concentration of the daughter product of the radioactive decay of tritium, the ^{3}He isotope, during a discrete interval.

Tritium data provide qualitative evidence for the presence of modern water recharged since 1950. All samples having tritium concentrations greater than 0.5 TU likely contain at least a portion of modern water recharged since the 1950's, and samples having tritium values less than 0.5 TU likely represent water recharged prior to 1950 (Clark and Fritz, 1997). Tritium concentration at Courthouse Wash Boundary Spring is 0.7 TU, indicating a component of modern recharge for Courthouse Wash Boundary Spring. Both the Entrada and Navajo completions have tritium concentrations less than 0.5 TU and therefore have no evidence of water recharged in the last 50 years.

Samples for carbon isotope analysis were processed to concentrate at the Brigham Young University Hydrogeology Lab. Concentrate was shipped to the University of Georgia Center for Applied Isotope Studies and analyzed by AMS. Samples were analyzed for δ ^{13}C and ^{14}C using a National Electrostatics Corporation Model 1.5SDH-I AMS. δ ^{13}C values were calculated using standard methods described by Coplen (1996). ^{14}C data is expressed as percent modern carbon (pmc) by comparing measured ^{14}C activities against the activity of a National Bureau of Standards oxalic acid reference solution.

All samples have pmc values less than 50 and therefore have a significant component of water recharged more than a thousand years ago. The Entrada and Navajo completions have pmc of 1.65 and 6.64 respectively. These low pmc concentrations indicate water that may have recharged more than 20,000 years ago. Courthouse Wash Boundary Spring has a higher pmc concentration of 35 and may consist of water recharged 4000 to 6000 years ago.

Tritium and pmc concentrations each provide indepen-

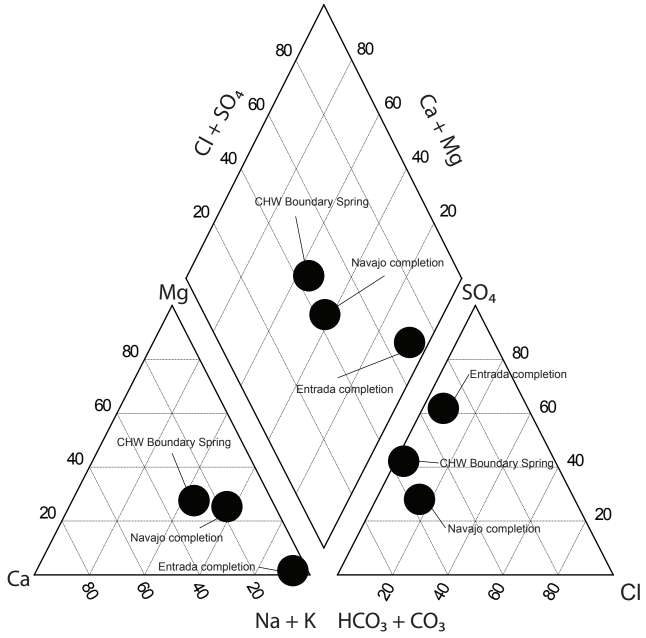

Figure 5. *Piper diagram of Courthouse Wash samples.*

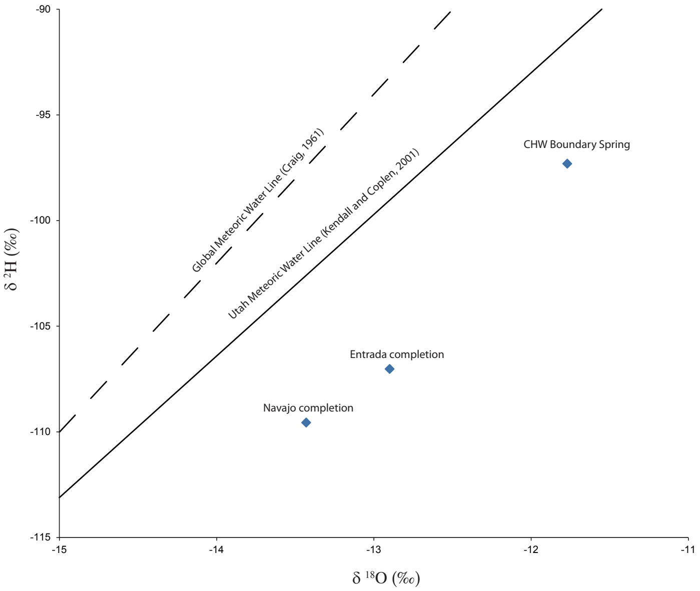

Figure 6. *Stable isotope plot.*

Table 3. *Isotopic results.*

Name[1]	δ^{2}H	δ^{18}O	Tritium (TU)	pmc [2]	δ^{13}C
Entrada completion	-107(0.5)	-12.9(0.2)	0.08(0.05)	1.65(0.02)	-6.39(0.04)
Navajo completion	-109.6(0.5)	-13.43(0.2)	0.08(0.07)	6.64(0.04)	-9.84(0.04)
CHW Boundary Spring	-97.3(0.5)	-11.77(0.2)	0.70(0.06)	35.01(0.13)	-13.82(0.04)

[1] Isotopic results; values in parenthesis are the lab reported error range
[2] Percent modern carbon

dent measure of the age of recharge of a given sample. Taken together these data show no evidence of modern recharge at the Navajo and Entrada completions, and these samples likely contain water recharged tens of thousands of years ago. Based on tritium and pmc data Courthouse Wash Boundary Spring contains a mixture of young water recharged since 1950 and older water recharged more than 4000 years ago.

DISSOLVED GAS RESULTS

Dissolved noble gases in groundwater provide information concerning the temperature and pressure conditions at which recharge occurred. By assuming elevation (pressure) at the time of recharge and the effect of excess air dissolved in recharging groundwater, it is possible to model the temperature under which recharge occurred (Aeschbach-Hertig and others, 2000). Water recharging within a few hundred feet of the land surface generally equilibrates at a temperature equal to the mean annual temperature at a given location. In the Courthouse Wash area the current mean annual temperature is approximately 15°C and recently recharged samples should have recharge temperatures near this value.

The dissolved gas concentrations were measured at the University of Utah Dissolved Gas Lab. The dissolved gas recharge temperature was calculated using measured concentrations of ^{4}He, ^{20}Ne, ^{40}Ar, ^{84}Kr, and ^{129}Xe via the closed equilibrium (CE) dissolved gas model (Aeschbach-Hertig and others, 2000). Multiple iterations of the CE model were run via an Excel spreadsheet and macro provided by the University of Utah Dissolved Gas Laboratory. The model requires the assumption of recharge elevation and this can reasonably vary between the elevation at the sampling site and the topographic high within the area possibly contributing recharge to a given site. Lacking any other information concerning the elevation of recharge, the preferred temperature of recharge is calculated based on the average of possible high and low elevations for a given site.

The dissolved gas concentrations and modeled recharge temperatures are unique for each of the three samples (table 4). The calculated recharge temperatures are between 10°C for Courthouse Wash Boundary Spring and 7 and 6°C for the Entrada and Navajo completions, respectively. Low recharge temperatures, less than 10°C may result from recharge under cooler climatic conditions and pmc data for these sites may further support this interpretation. The 10°C recharge temperature for Courthouse Wash Boundary Spring is less than expected for modern recharge in the area and may indicate a component of old water, with a cool recharge temperature mixed with younger water, with a warm recharge temperature.

***Table 4**. Dissolved gas results.*

Name	Entrada completion	Navajo completion	CHW Boundary Spring
Sampling Date	5/23/12	5/23/12	5/23/12
TDGP (mmHg)[1]	638	687	603
N_2(ccSTP/g)	1.32E-02	1.41E-02	1.21E-02
CH_4(ccSTP/g)	3.78E-05	6.01E-05	7.23E-04
^{4}He(ccSTP/g)	2.72E-06	5.26E-07	3.57E-07
^{20}Ne(ccSTP/g)	1.58E-07	2.14E-07	1.52E-07
^{40}Ar(ccSTP/g)	3.50E-04	3.91E-04	3.25E-04
^{84}Kr(ccSTP/g)	4.49E-08	4.98E-08	4.24E-08
^{129}Xe(ccSTP/g)	3.13E-09	3.17E-09	2.76E-09
Hrmin (ft)[2]	4330	4330	4297
Trmax (°C)	8.1	7.4	11.4
Hrmax (ft)[3]	6316	6316	6316
Trmin (°C)	6.0	5.2	8.8
Hravg (ft)[4]	5322	5322	5306
Travg (°C)	7.2	6.3	10.0
χ^2 [5]	1.36	2.49	1.14

[1] Total dissolved gas pressure measured at position of diffusion sampler.

[2] Minimum recharge elevation, equal to the land surface elevation at the sample site. Used as input to calculate the maximum possible recharge temperature Trmax.

[3] Maximum recharge elevation, equal to the highest elevation at which recharge may occur upgradient of a given sample. Used as input to calculate the minimum possible recharge temperature Trmin.

[4] Average elevation of recharge taken as the average between the minimum and maximum recharge elevation. Used as input to calculate the average recharge temperature Travg.

[5] Chi-squared misfit between measured and modeled recharge parameters for the average recharge temperatures.

SUMMARY AND CONCLUSIONS

The Courthouse Wash monitoring well was drilled and completed in January 2012 with two separate piezometers, one near the base of the Entrada aquifer and the other near the top of the Navajo aquifer. Screened intervals in each case were 20 feet for both the Entrada and Navajo completions. Water levels range from approximately 35 feet below top of casing for the Navajo completion to approximately 7 to 11 feet above top of casing for the Entrada completion. Total offset between the two water levels is approximately 43 feet. Water levels have changed little over the period of record.

Groundwater chemistry, isotopic, and dissolved gas samples were collected from the Navajo and Entrada completions and nearby Courthouse Wash Boundary Spring. Groundwater chemistry is unique for each of the three samples and the Entrada completion has significantly higher concentrations of Na, Cl, HCO3, and SO4 than either the Navajo completion or Courthouse Wash Boundary Spring. Water quality is good for both the Navajo completion and Courthouse Wash Boundary Spring.

Stable isotopic ratios and concentrations of percent modern carbon and tritium are also unique for each sample location. Both the Navajo and Entrada completions have no evidence of modern recharge and these samples likely contain water recharged tens of thousands of years ago. Courthouse Wash Boundary Spring likely contains a mixture of young water recharged since 1950 and older water recharged more than 4000 years ago. The dissolved gas concentrations and modeled recharge temperatures are unique for each of the three samples. The calculated recharge temperatures are between 10°C for Courthouse Wash Boundary Spring and 7 and 6°C for the Entrada and Navajo completions respectively.

Taken together the results presented here suggest little if any connection between the Entrada and Navajo aquifers at the monitoring well site. These results may only be valid for static predevelopment conditions at the monitoring well location.

In addition to the potential for direct interference between new wells completed in the Entrada or Navajo aquifers with existing springs and wells, large scale lowering of the water table across the Courthouse Wash area could increase the downward groundwater gradient between the Entrada aquifer and the underlying Navajo aquifer. Such a reduction in regional water tables could vastly reduce flow at springs in Arches National Park as well as lower water levels at existing wells completed in the Entrada aquifer.

Future groundwater development should include tests of the connection between the Entrada and Navajo aquifer under realistic pumping scenarios to confirm the hydrologic separation of these two aquifers.

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Funding for the monitoring well installation, groundwater sampling, and interpretation was provided by the Utah Division of Water Rights, Grand County, and the National Park Service Water Resources Division. We thank Mike Lowe, Robert Ressetar, Kimm Harty, and Rick Allis for reviews that improved the content and clarity of this report.

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