

**Summary of Ground-Water Sampling
in the Courthouse Wash Area, Grand County, Utah**

by

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EXECUTIVE SUMMARY

This report presents data from ground-water sampling of springs and wells in the Courthouse Wash area. A total of eight sites, including four wells and four springs, were sampled in March of 2006. All samples were analyzed for 1) general solute chemistry including major anions and cations, nitrite and nitrate, total and dissolved phosphate, 2) stable isotopes of deuterium and oxygen, 3) tritium, and 4) carbon isotopes. Results indicate that the three springs that issue near the base of the Moab Member of the Curtis Formation, including Sevenmile Canyon Boundary Spring, Poison Ivy Spring, and Sleepy Hollow Spring, consist of ground water recharged approximately since or just prior to 1950. These three springs also have a distinct solute composition, different from that of all other sampling sites. Based on the data presented these three springs do not likely receive any ground water from beyond the recharge areas delineated by Hurlow and Bishop (2003). By contrast, Courthouse Wash Boundary Spring likely contains a mixture of old ground water recharged at least several thousand years ago and premodern ground water recharged just prior to 1950. The presence of old water requires that flow paths are long and or recharge rates are low for this spring. This implies the potential for interference from future ground-water development in the Slick Rock and Moab Member aquifer upgradient of the spring, beyond the recharge area delineated by Hurlow and Bishop (2003). All wells, except the Arches Headquarters well, consist of a mix of old ground water (recharged between several thousand and ten thousand years ago) and modern ground water (recharged since 1950). Ground water sampled at the Arches Headquarters Well consists of modern water recharged since 1950.

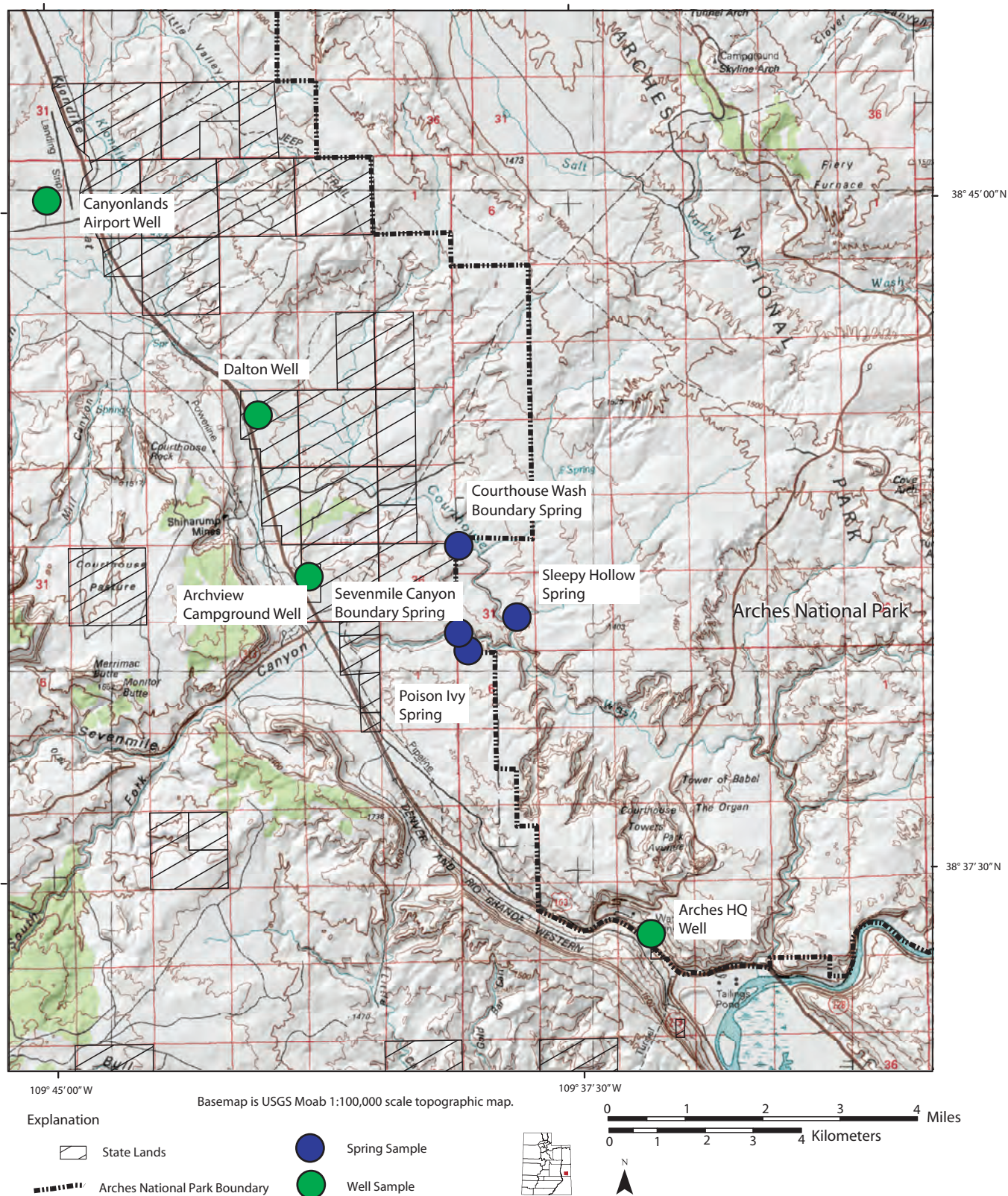
BACKGROUND

Introduction

New ground-water sampling in the Courthouse Wash area, funded by the National Park Service Water Resources Division, was undertaken in the spring of 2006. The goal of this sampling is to better delineate the relationship between ground water that supplies important springs within Arches National Park, and ground water beneath the upper portions of Courthouse Wash that may experience further development as a culinary-water source in the future.

The Courthouse Wash area is located northwest of Moab, Utah, and consists of upland benches cut by wash and canyon systems that drain to the southeast along Courthouse Wash (figure 1). Ownership along the upper portion of Courthouse Wash is divided among parcels of Bureau of Land Management, School and Institutional Trust Lands Administration, and private tracts. The lower portion of Courthouse Wash is entirely within Arches National Park (figure 1). Stream flow in Courthouse Wash is intermittent above the Arches National Park Boundary. A series of springs, including the four springs sampled in this study, provide a section of perennial flow along Courthouse Wash and its tributary, Sevenmile Canyon, in Arches National Park.

Ground water 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). Ground water from these aquifers supports culinary and irrigation uses at several sites in the study area, and also provides flow at important perennial springs in Arches National Park.

Limited water-level data suggest regional ground-water flow to the southeast toward the Colorado River in the Navajo Sandstone, Moab Member, and Slick Rock Member aquifers where these rocks are present in the subsurface (Rush and others, 1982). Locally ground-water flow is more complex, controlled by a combination of the hydrogeology of the aquifers and surface topography (Hurlow and Bishop, 2003).

Sample Sites and Sampling Methods

A total of eight sites, including four wells and four springs, were sampled in March of 2006. Sampling sites were chosen on the basis of relevance to the ground-water system and accessibility. We sampled three wells in the upper Courthouse Wash drainage and one well at the Arches National Park Headquarters (figure 1, table 1).

Wells sampled at Archview Campground and the Canyonlands Airport are completed in the Slick Rock Member of the Entrada Formation and possibly the Moab Member of the Curtis Formation (Utah Division of Water Rights, 2006) (table 1). The Arches Headquarters Well is completed in the Navajo Sandstone (Utah Division of Water Rights, 2006). Based on conflicting well-log information and descriptions by the driller (Utah Division of Water Rights, 2006; Bob Beaman, personal communication, 2006) the

Table 1. Summary of sampling sites in the Courthouse Wash area. 1) Coordinates are in meters UTM zone 12N NAD 27; 2) Public Land Survey Location are from the Utah Division of Water Rights water well drilling database; 3) Geologic unit in which well is completed or from which spring issues, Qa= Unconsolidated alluvium, Jcm=Moab Member of the Curtis Formation, Jes=Slick Rock Member of the Entrada Formation, Jn=Navajo Sandstone; 4) Total depth of well in feet; 5) Flow rate in gallons per minute; 6) Screen interval in feet below the land surface. -- denotes no data.

Sample Site	ID	East(1)	North(1)	PLS Location (2)	Unit (3)	TD (4)	Flow Rate (5)	Screen (6)	Sample Location
Archview Campground	CHW 1	614206	4281747	S500 E1104 W4 35 24S 20E	Jse	388	10	328-388	spigot near well head
Arches HQ Well	CHW 2	620919	4274848	S2700 W3600 NE 21 25S 21E	Jn	172	44	115-170	spigot in maintenance shed
Dalton Well	CHW 3	613073	4285297	S1850 W285 N4 22 24S 20E	Jn/Jse	?	200	?	outlet on well head
Courthouse Boundary Spring	CHW 4	617234	4282707	--	Qa/Jcm	--	13	--	pool below seep
Canyonlands Airport Well	CHW 5	608463	4290192	S1420 E2060 NW 06 24S 20E	Jse	1200	7.8	?	spigot near well head
7-mile Boundary Spring	CHW 6	617149	4280806	--	Base of Jcm	--	7.04	--	below seep
Poison Ivy Spring	CHW 7	617400	4280523	--	Base of Jcm	--	1.14	--	below seep
Sleepy Hollow Spring	CHW 8	633464	4170209	--	Base of Jcm	--	9.6	--	below seep

Dalton Well may be completed in both the Navajo Sandstone and overlying Slick Rock Member of the Entrada Formation (table 1).

Prior to sampling, all wells were pumped until approximately three well-bore volumes were removed from the well. Flow rates for each well were estimated using a five-gallon bucket and stopwatch at the sampling point. Well samples were collected at the access point nearest the wellhead.

The four sampled springs include 1) three springs that issue near the base of the Moab Member of the Curtis Formation: Sevenmile Canyon Boundary Spring, Poison Ivy Spring, and Sleepy Hollow Spring; and 2) Courthouse Wash Boundary Spring, which issues from the top of the Moab Member of the Curtis Formation, along Courthouse Wash. Further hydrogeologic description and periodic solute chemistry and flow data for the springs are presented in Hurlow and Bishop (2003).

Spring samples were taken from spring flow as near the actual point of seepage as possible at Sleepy Hollow, Sevenmile Canyon Boundary, and Poison Ivy Springs. Courthouse Wash Boundary Spring was sampled from a pool directly below the point of seepage. Flow rates at each spring were measured down stream of the sampling sites, by Jim Harte of the National Park Service Water Resources Division, and Mary Moran of the National Park Service, using temporary or permanent flumes at sites measured periodically by National Park Service personnel.

Ground-water samples were collected using standard U.S. Geological Survey field techniques summarized by Wilde and others (1998). Samples for all analyses except total phosphate were collected in triplicate in thoroughly rinsed, brown one-liter HDPE bottles. Samples for total phosphate were collected in preacidified 500 ml bottles provided by the Utah Department of Health Laboratory. Each bottle was sealed with electrical tape at the sampling site and kept iced until delivery to the Brigham Young University Hydrogeology Laboratory and the Utah Department of Health Laboratory. Copies of all chain-of-custody forms are included with this letter. 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 2).

All laboratory work, except carbon isotope and total phosphate analysis, was preformed at the Brigham Young University Hydrogeology Lab. Carbon isotope analyses were preformed offsite at the University of Georgia Center for Applied Isotope Studies. Total phosphate was analyzed at the Utah Department of Health Laboratory in Salt Lake City, Utah.

RESULTS AND LABORATORY METHODS

Solute Chemistry Results

Ground water samples were analyzed for major dissolved cations, anions, nitrate, nitrite, and total and dissolved phosphate. Concentrations of major dissolved anions and cations, nitrate, nitrite, and dissolved phosphate were determined using standard

Table 2. Summary of sampling site field data. 1) Celsius; 2) Dissolved oxygen in milligrams per liter; 3) Specific conductivity in millisiemens per centimeter.

Sample Site	ID	Sample Date	Time	Temp(1)	DO(2)	Conductivity (3)	PH
Archview Campground	CHW1	3/21/2006	17:05	15.70	3.16	0.673	7.39
Arches HQ Well	CHW2	3/22/2006	7:31	16.63	2.71	1.376	7.25
Dalton Well	CHW3	3/22/2006	11:01	18.60	2.15	1.111	7.29
Courthouse Boundary Spring	CHW4	3/22/2006	16:27	17.24	2.12	0.657	7.91
Canyonlands Airport Well	CHW5	3/22/2006	18:17	20.03	1.28	0.561	7.42
7-mile Boundary Spring	CHW6	3/23/2006	9:48	10.06	2.27	0.231	7.66
Poison Ivy Spring	CHW7	3/23/2006	12:24	11.44	1.68	0.228	7.69
Sleepy Hollow Spring	CHW8	3/23/2006	14:58	10.78	2.40	0.261	7.81

techniques presented in Fishman and Friedman (1989) and Fishman (1993) at the Brigham Young University Hydrogeology Lab. Total phosphate was analyzed using standard digestion techniques and flow injection colorimetry at the Utah Department of Health following methods presented by the U.S. Environmental Protection Agency (1983).

Concentrations of total and dissolved phosphates and nitrite are below the detection limits at all sampling sites. Nitrate concentrations range from 0.01 mg/l at Courthouse Boundary Spring (CHW 5) to 2.86 mg/l at the Arches HQ Well (CHW 2). Most samples had nitrate concentrations between 0.13 and 0.42 mg/l (table 3).

The relative concentrations of the principle anions and cations are plotted on a trilinear diagram shown in figure 2. Major ion chemistry of ground water from wells and springs is primarily calcium-magnesium-sodium- and either bicarbonate and or sulfate type (table 3). All springs (CHW 6,7, and 8), except Courthouse Wash Boundary Spring (CHW 4) are calcium-bicarbonate type with very similar solute concentrations (figure 2). Ground water from the Arches HQ Well (CHW 2) has higher chloride concentrations than other sites. This may result from an incompletely shut off inline chlorination system upstream of the sampling point. Dalton Well (CHW3) has increased sulfate concentrations relative to other sites but plots near the Arches HQ Well (CHW 3) on the piper diagram (figure 2). Archview Campground (CHW 1) and the Canyonlands Airport (CHW 5) sites also plot near one another on the piper diagram (figure 2).

Table 3. Summary of analyzed chemistry of ground- and surface-waters in the Courthouse Wash area. See text for Piper and Stiff diagrams of the data and discussion of trends. All concentrations are in mg/L.

Sample Site	ID	Water Type	Ca	Mg	Na	K	HCO3	F	Cl	Br	SO4	NO2	NO3	Total HPO4	Dissolved HPO4
Archview Campground	CHW 1	Mg-Ca-HCO3-SO4	50.72	33.30	22.30	4.59	227	0.38	10.63	0.11	134.57	< 0.01	0.13	< 0.02	< 0.01
Arches HQ Well	CHW 2	Ca-Mg-SO4-Cl-HCO3	87.06	33.70	125.40	5.87	219	0.33	154.88	< 0.01	232.25	< 0.01	2.86	< 0.02	< 0.01
Dalton Well	CHW 3	Ca-Mg-SO4-HCO3	124.38	36.26	41.57	3.97	183	0.36	9.30	0.10	396.34	< 0.01	0.18	< 0.02	< 0.01
Courthouse Boundary Spring	CHW 4	Na-Mg-Ca-HCO3-SO4	31.94	21.57	62.67	2.07	239	0.29	7.40	< 0.01	111.54	< 0.01	0.01	< 0.02	< 0.01
Canyonlands Airport Well	CHW 5	Ca-Mg-HCO3-SO4	49.98	26.12	8.74	3.11	187	0.30	3.95	< 0.01	111.87	< 0.01	0.17	< 0.02	< 0.01
7-mile Boundary Spring	CHW 6	Ca-HCO3	35.20	3.53	1.26	0.71	116	0.06	3.02	< 0.01	7.06	< 0.01	0.29	< 0.02	< 0.01
Poison Ivy Spring	CHW 7	Ca-HCO3	36.99	3.39	1.41	0.73	114	0.13	2.68	< 0.01	8.49	< 0.01	0.42	< 0.02	< 0.01
Sleepy Hollow Spring	CHW 8	Ca-HCO3	39.10	2.30	0.76	0.71	120	0.15	1.90	< 0.01	7.75	< 0.01	0.27	< 0.02	< 0.01

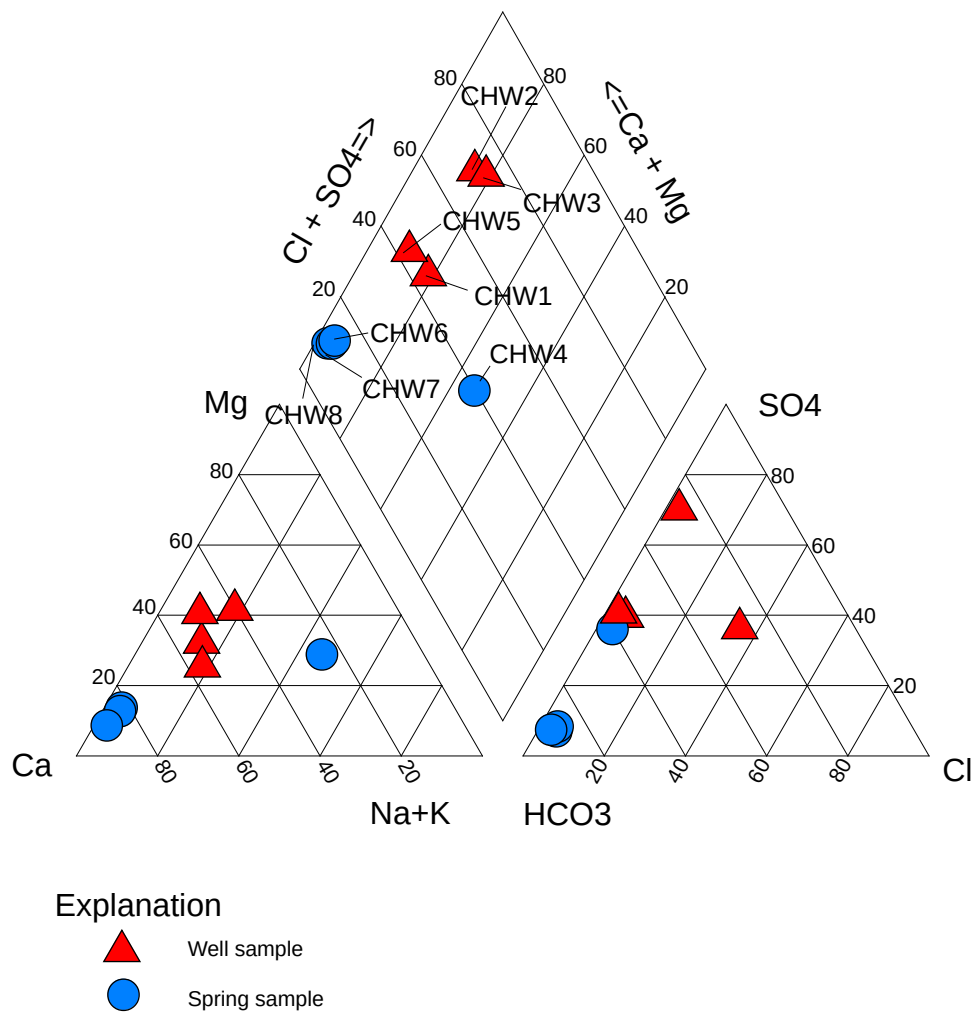


Figure 2. Piper diagram of ground-water samples from the Courthouse Wash area. Complete solute chemistry results are in table 3.

Stiff-diagram plots of ground-water samples (figure 3) illustrate the relative difference in total and specific solute concentrations among sampling sites. Springs that issue from the base of the Moab Member of the Curtis Formation (CHW 6, 7, and 8) have relatively low solute concentrations and distinct stiff diagram profiles that likely result from dissolution of calcite cement and other reactions within the Moab Member aquifer (Hurlow and Bishop, 2003). Other samples taken from wells and Courthouse Wash Boundary Spring have stiff diagrams that show higher concentrations of all analyzed solute constituents relative to the spring samples (CHW 6, 7, and 8) (figure 3).

Solute chemistry appears strongly dependent on the rock type in which the sampled ground water resides. Samples from wells completed in the Navajo, including the Arches HQ Well (CHW 2) and Dalton Well (CHW 3), have similar solute chemistry (table 3, figure 2). Samples from the Archview Campground Well (CHW 1) and the Canyonlands Airport Well (CHW 5) have similar solute compositions and both wells are completed in the Slick Rock Member of the Entrada Formation. Spring samples, including Sevenmile Canyon Boundary (CHW 6), Poison Ivy (CHW 7), and Sleepy Hollow (CHW 8), all issue from the base of the Moab Member of the Curtis Formation and also have similar solute compositions (figures 2, table 3). Courthouse Wash Boundary Spring (CHW 4) has a distinct solute composition and issues near the top of the Moab Member of the Curtis Formation, just below its contact with the overlying unconsolidated deposits and Summerville Formation (figure 2, table 3).

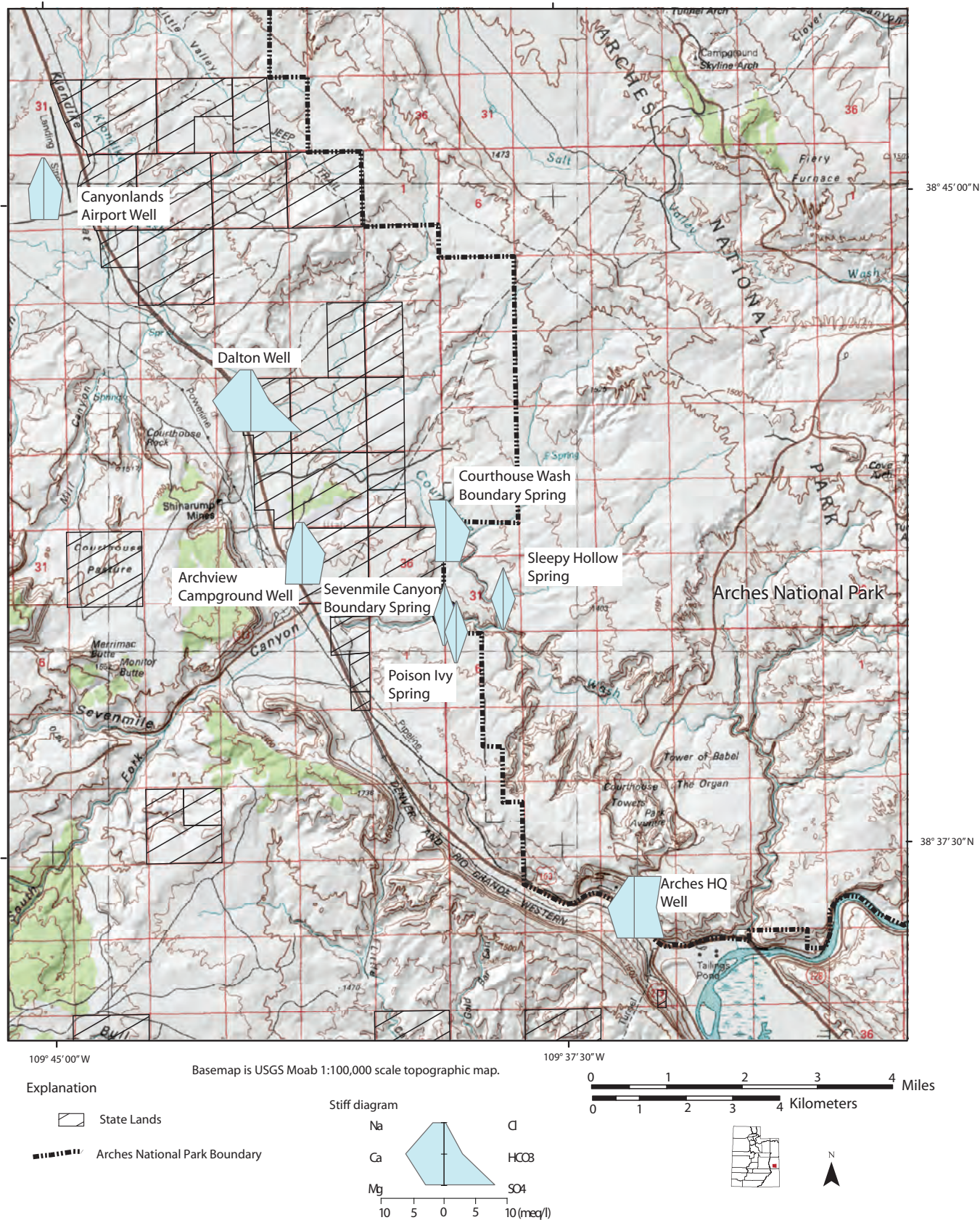


Figure 3. Stiff diagrams of ground-water samples in the Courthouse Wash area. See figure 2 and table 3 for complete solute data.

Stable Isotope Results

Stable-isotope ratios $\delta^{18}\text{O}$ and δD were measured 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). $\delta^{18}\text{O}$ 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 for wells and springs in the Courthouse Wash area lie between the isotopic compositions of samples from Dalton Well (CHW 3) and the Canyonland Airport Well (CHW 5) (figure 2). All samples except Dalton Well (CHW 3) are depleted compared with the modeled mean annual $\delta^2\text{H}$ field of Meehan and others (2004). All samples plot below the meteoric water line of Craig (1961) (figure 4). Samples from springs define a zone of isotope composition that is bracketed by the isotope composition of wells.

All samples have depleted (lighter) isotope compositions relative to modeled mean annual deuterium values for the study area from Meehan and others (2004). Depleted isotope compositions imply precipitation and subsequent recharge of water that is generally cooler than the annual mean precipitation (Clark and Fritz, 1997). Therefore most of the recharge across the Courthouse Wash area likely occurs from infiltration of isotopically depleted winter precipitation. Stable isotope composition of all springs

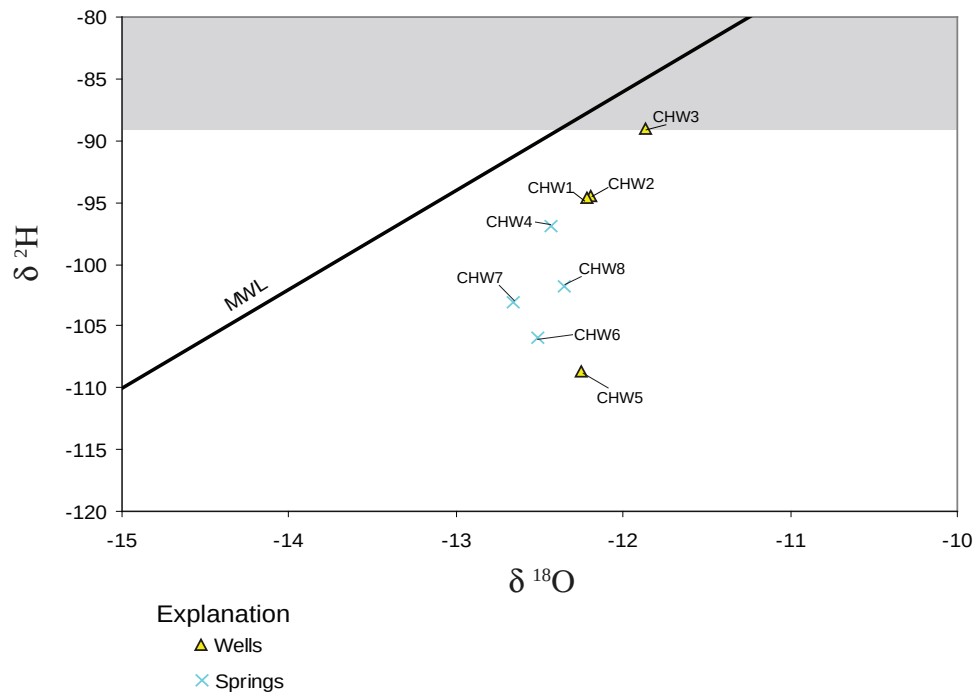


Figure 4. Stable isotope composition of ground water in the Courthouse Wash area. MWL is the meteoric water line from Craig (1961). Gray shading represents the modeled $\delta^2\text{H}$ range of annual mean precipitation across the Courthouse Wash area (Meehan and others, 2004). With the exception of CHW3 all samples plot below this field and therefore must have been recharged from relatively depleted waters. See table 4 for complete isotope results.

sampled are distinct from one another, but lie within a zone between those of the Canyonlands Airport Well (CHW 5) and the other well samples (figure 4).

Tritium and Carbon Isotope Results

Tritium samples were distilled and electrolytically enriched to increase tritium concentration by a factor of at least 10. Analysis was done using a Perkin Elmer Quantulus 1220 ultra low-level liquid scintillation counter. Samples were evaluated against blanks and a NIST traceable standard (SRM 4361C) (David Tingey, Brigham Young University, written communication, 2006).

Measurable concentrations of tritium were found at all sites except Sevenmile Canyon Boundary Spring (CHW 6). Courthouse Wash Boundary Spring (CHW 4) contains low levels of tritium, just 0.3 TU (table 4). All other sites have tritium levels greater than 0.5 TU, and values range from 9.7 TU at the Canyonlands Airport Well (CHW 5) to 0.6 TU at the Archview Campground Well (CHW 1) (table 4).

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 Accelerator Mass Spectrometry. Samples were analyzed for ^{13}C and ^{14}C using a National Electrostatics Corporation Model 1.5SDH-1 AMS. $\delta^{13}\text{C}$ values were calculated using standard methods described by Coplen (1996). ^{14}C data is expressed as percent modern carbon by

Table 4. Summary of stable and radiogenic isotope sampling results for sites in the Courthouse Wash Area. See text for discussion of mixing ratios. 1) Error for all samples is 1.0; 2) Error for all samples is 0.20; 3) Units are tritium units, error is second value; 4) $\delta^{13}\text{C}$ values were calculated using standard methods described by Coplen (1996); 5) PMC is percent modern carbon, second value is error; 6) Carbon 14 apparent age in years before present, modern water is assumed to be < 50 years old. Carbon 14 apparent age estimates have the potential for significant errors see text for further description of apparent age determination.

Site ID	Sampling Date	Sample type	$\delta^2\text{H}_{(1)}$	$\delta^{18}\text{O}_{(2)}$	Tritium ₍₃₎	$\delta^{13}\text{C}_{(4)}$	PMC ₍₅₎	^{14}C apparent age ₍₆₎
CHW 1	4/10/2006	well	-99.7	-12.66	0.6, 0.2	-9.62	18.19, 0.16	9000 mixed w/ modern
CHW 2	4/11/2006	well	-100.0	-13.78	2.0, 0.2	-9.96	60.71, 0.37	modern
CHW 3	4/11/2006	well	-103.0	-12.13	2.3, 0.6	-8.46	20.47, 0.19	8500 mixed w/ modern
CHW 4	4/11/2006	spring	-97.3	-12.73	0.3, 0.3	-8.54	28.32, 0.24	5000
CHW 5	4/11/2006	well	-96.1	-12.37	9.7, 0.3	-7.84	19.49, 0.16	8500 mixed w/ modern
CHW 6	4/11/2006	spring	-97.9	-12.66	< 0.2, 0.4	-9.32	88.72, 0.45	modern
CHW 7	4/11/2006	spring	-87.4	-10.99	6.3, 0.6	-8.5	91.05, 0.48	modern
CHW 8	4/11/2006	spring	-101.0	-13.89	1.3, 0.2	-11.76	91.04, 0.47	modern

comparing measured ^{14}C activities against the activity of a National Bureau of Standards oxalic acid reference solution.

Data from carbon isotope analyses are presented in table 4. $\delta^{13}\text{C}$ represents a measure of carbon isotope fractionation, values from the Courthouse Wash area range from -8.5 to -11.76 (table 4). Percent modern carbon (pmc) for the sample sites range from 18 to 91 percent. Springs including Sevenmile Canyon Boundary, Poison Ivy, and Sleepy Hollow all have pmc values greater than 85 percent. Arches HQ Well has a pmc value of 60 percent, and all other sampling sites have pmc values less than 30 percent (table 4).

Apparent Age of Recharge

Apparent age data in table 4 include qualitative and quantitative age estimates of the components of recharge, based on the tritium and carbon isotope data. Because ground water commonly represents a mixture of water recharged at different times, all age data should be assumed to represent the mean age of a given sample. Weighted according to the relative percentage of different recharge components. Therefore the apparent age estimate based on ^{14}C data is younger than the actual age of the old component when the sample includes a significant young fraction (Clark and Fritz, 1997).

Tritium-count data provides 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). Taken alone, tritium results indicate at least a component of modern recharge, since 1950, at all sites except Courthouse Wash Boundary Spring and Sevenmile Canyon Boundary Spring.

Carbon isotope data is used to constrain the presence of modern recharge and provide an estimate of the average residence time since recharge of the old component of ground water based on the radioactive decay of ^{14}C . Percent modern carbon (pmc) values greater than approximately 50 percent likely represent a component of modern water recharged since 1950 (Alan Mayo, Brigham Young University, written communication, 2006). Ground water that contains both tritium values greater than 0.5 TU and pmc values less than 50 percent indicate ground water that is a mixture of old and modern water (Alan Mayo, written communication, 2006).

Samples from Poison Ivy and Sleepy Hollow springs have pmc values greater than ~ 90 percent and tritium concentrations greater than 0.5 TU, and therefore likely consist entirely of modern water recharged since 1950 (figure 5). Sevenmile Canyon Boundary Spring has pmc of 88 percent and tritium levels below the detection limit (< 0.2 TU) and likely consists primarily of ground water recharged just prior to 1950. The Arches HQ Well has a pmc of 60 percent and a tritium level 2.0 TU, implying primarily modern recharge at this site (figure 5). Samples from Archview Campground, Dalton Well, and Canyonlands Airport have pmc values less than 30 percent and levels of tritium greater than 0.5 TU (figure 5), indicative of a mixture of small amounts of modern water

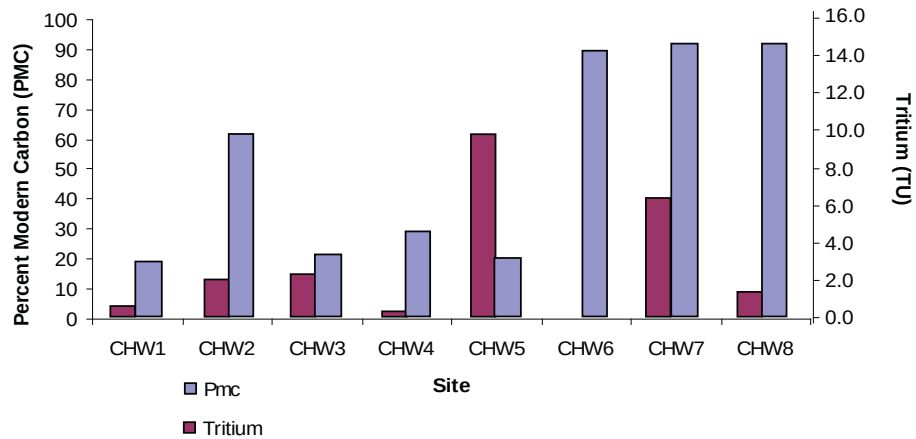


Figure 5. Summary of carbon-14 and tritium isotope composition of ground water in the Courthouse Wash area. Sites including CHW 2, 6, 7, and 8 have PMC values greater than 60 percent and consist primarily of water recharged after or just prior to 1950 depending on the presence or absence of tritium. The remaining sites (CHW 1, 3, 4, and 5) have pmc values lower than 30 percent and contain a significant fraction of ground-water recharged at least several thousand years ago. All sites, except CHW 4 and 6, have tritium concentrations greater than 0.5 TU indicating at least a component of recharge since 1950. PMC is percent modern carbon. See table 4 for complete isotope results.

and larger components of significantly older water (Alan Mayo, written communication, 2006).

Alan Mayo of Brigham Young University estimated apparent recharge ages using the measured pmc values, and isotopic mixing (Pearson and others, 1972) and isotopic mixing-exchange (Fontes and Garnier, 1979) models. These models were used to account for both closed and open carbon systems in the presence of abundant carbonate. Input parameters for the apparent age calculations are ^{14}C soil gas equal to 100 percent modern carbon, carbonate- mineral ^{14}C equal to 0 pmc, $\delta^{13}\text{C}$ soil gas -18 to -22‰ , carbonate-mineral $\delta^{13}\text{C}$ equal to 0‰ . Results of the two methods were generally within 10% of each other for a given sample (Alan Mayo, written communication, 2006).

The apparent age of the old fraction of ground water, for samples having pmc values less than 50 percent, ranged from 5,000 years at Courthouse Wash Boundary Spring to 9,000 years at the Archview Campground Well. Both the Dalton Well and the Canyonlands Airport Well contain a component of old ground water with an approximate age of 8,500 years (Alan Mayo, written communication, 2006). Each of these sites, except Courthouse Wash Boundary Spring, also contain tritium concentrations greater than 0.5 TU and at least some component of modern recharge (since 1950).

In reality the assumptions and models used to estimate apparent ages from carbon isotope data are commonly not representative of the actual carbonate geochemistry of a given sample (Clark and Fritz, 1997; Zhu and Murphy, 2002). More recent methods

involving geochemical modeling, such as NETPATH, along assumed flow paths may provide more accurate estimates of the carbonate isotope evolution of a given flow path (e.g. Plummer and others, 1991; Parkhurst, 1995, 1997), but are beyond the scope of this investigation. The apparent age of the old component based on carbon isotope data presented above may therefore be significantly different from the actual age of the old component of recharge. Qualitative estimates based on pmc values instead provide the most reliable conclusions. In this case samples from Canyonlands Airport, Dalton Well, and Archview Campground all contain water that was recharged at least several thousand years ago and no more than ten thousand years ago. The old component of ground water at Courthouse Wash Boundary Spring was likely recharged more recently than these samples but still has an age of at least several thousand years. The remaining samples likely represent modern or nearly modern recharge.

DISCUSSION

The three springs that issue from the base of the Moab Member in Arches National Park (Sevenmile Canyon Boundary, Poison Ivy, and Sleepy Hollow Springs) differ from the other samples in most of the analyzed constituents. Ground water at these springs consists of water recharged since or just prior to 1950, and contains little or none of the older water found at the Canyonlands Airport, Dalton Well, Archview Campground, and Courthouse Wash Boundary Spring sites. Solute composition of water from these springs is calcium-bicarbonate type and contains lower concentrations of all dissolved constituents and distinct chemical composition relative to all other sites. Stable isotopic data for the three springs is depleted relative to other sampling sites and

modeled mean annual deuterium values for the study area, suggesting that 1) most recharge results from infiltration of cool, isotopically depleted, winter-season precipitation and 2) most recharge results from different sources than ground water found at other sampling sites across the Courthouse Wash area.

Based on the data collected in this study the flow systems that supply ground water to the three springs that issue from the base of the Moab Member of the Curtis Formation in Arches National Park are not likely connected to and/or contain ground water from upgradient portions of the Moab Member, Slick Rock Member, and Navajo aquifers sampled at the Archview Campground, Canyonlands Airport, or the Dalton Well sites. These data qualitatively support the recharge areas calculated by Hurlow and Bishop (2003). Additional wells completed in the either the Navajo or Entrada (Moab and or Slick Rock Member) aquifers outside of the delineated recharge areas are not likely to directly withdraw water from the flow systems of these springs.

Courthouse Wash Boundary Spring water differs from the other three spring samples. The old component of spring flow has an apparent age of at least several thousand years, and likely represents the regional flow and discharge of ground water in the Moab Member of the Curtis Formation and potentially other overlying units north and west of the spring. Based on the geologic setting of this spring young locally derived water that recharged just prior to 1950, likely provides a component of flow at this site. Young ground water recharged just prior to 1950 likely flows to this spring from the exposed portions of the Moab Member north and east of the spring and unconsolidated

deposits that line portions of Courthouse Wash above the spring. Ground water at this spring is therefore likely derived from a mixture of old water and premodern (recharged prior to 1950) ground water.

The recharge zone delineated for Courthouse Wash Boundary Spring by Hurlow and Bishop (2003) assumes that ground water discharging at this spring is part of a localized and modern flow system similar in extent to those that likely supply water to Sleepy Hollow Spring, Poison Ivy Spring, and Sevenmile Canyon Boundary Spring. The presence of old ground water having an apparent age of at least several thousand years, at Courthouse Wash Boundary Spring contradicts this assumption, and suggests that the area contributing water to this spring is relatively large and or the travel time from areas of recharge to discharge is great. In either case the recharge area is likely greater than that described by Hurlow and Bishop (2003). Quantitative constraints on the recharge area are beyond the scope of this investigation and will likely require finite element modeling and/or further hydrogeologic investigation. We can however assume that the actual recharge area is greater than the recharge area estimated by Hurlow and Bishop (2003). Therefore, the potential exists for interference from upgradient wells completed in the Moab Member and/or Slick Rock Member beyond the recharge area delineated by Hurlow and Bishop (2003). Because geologic conditions suggest a component of recharge from unconsolidated deposits lining Courthouse Wash and/or other units overlying the Moab Member of the Curtis Formation, wells completed in these units beyond the recharge area estimated by Hurlow and Bishop (2003) may also affect flow at these springs.

In addition to the potential for direct interference between wells completed within or near the recharge areas of the four sampled springs in Arches National Park, large scale lowering of the water table across the Courthouse Wash area could create or increase a downward ground-water gradient between the Moab Member of the Curtis Formation and the underlying Slick Rock Member of the Entrada Sandstone and other underlying units including the Navajo Sandstone. Such a reduction in regional water tables could vastly reduce flow at one or all of the sampled springs.

Ground water sampled at the Arches HQ well is modern, consisting of water recharged since 1950. Little if any ground water from older regional flow in the Navajo aquifer is present at this site. Ground water intercepted by this well is most likely the result of infiltration of direct precipitation on exposed portions of the Navajo Sandstone north and east of the well site in Arches National Park. Future ground-water development within areas of Arches National Park could impact this well, however increased ground-water development in the upper portions of the Courthouse Wash drainage outside of Arches National Park are unlikely to impact this site.

Samples from the remaining wells all consist of a mixture of old and modern water. The hydrogeologic conditions that produce the observed age mixture may be complex. The geologic setting of the wells sampled at Canyonlands Airport and Dalton Well likely preclude direct infiltration of modern water to portions of the aquifers intercepted by the wells. At both sites, aquifer rocks are overlain by structurally intact,

low permeability units that include the Late Jurassic Morrison Formation at the Dalton Well site and the Mancos Shale at Canyonlands Airport. Modern water found at these sites therefore likely results from leakage of near-surface ground water along or through the well casing. Mixing of modern and old ground water at the Archview Campground Well may also be the result of similar well leakage or the result of deep circulation of near-surface ground water along deep seated and pervasive fracturing typical of rocks in the immediate hanging wall of the Moab fault.

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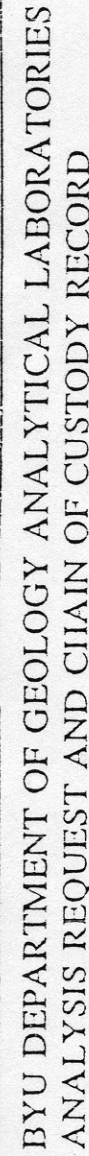
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- ☒ Hand delivered
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☐ Cooler returned

System/Agency Name: <u>Utah Geological Survey</u>		System/Agency Number:	Cost/Project Code: <u>UCHW</u>	REQUESTED TESTS				Received Date and Time:	
REPORTING/CONTACT				BILLING (list if different)					
Attn: <u>Stefan Kirby</u>				Special code:					
Address: <u>1594 W. North Temple</u>				Attn: <u>Janea Wallace</u>					
City, State, ZIP: <u>Salt Lake City, UT 84114</u>				Address: <u>1594 W. North Temple</u>					
Phone: <u>801 537 3349</u>				City, State, ZIP: <u>Salt Lake City, UT 84114</u>					
Fax: <u>801 537 3400</u>				Phone: <u>801-537-3300</u>					
Email: <u>stefankirby@utah.gov</u>				Fax: <u>801-537-3400</u>					
Submitted by: <u>Stefan Kirby</u>									
COLLECTION POINT DESCRIPTION	COLLECTED BY (initials)	COLLECTED DATE (mm dd yy)	COLLECTED TIME (24 hour)	COMMENTS	Receipt temperature	Receipt pH	Sample Receipt Conditions	LAB NUMBER	
CHW 1	SK	03/21/06	17:05	see field data sheet			COOLANT / NO COOLANT Yes ☐ No ☐ Documentation complete ☐ Temperature within-range ☐ Within holding time ☐ Proper containers and in-date ☐ Containers intact ☐ Acceptable pH ☐ N/A ☐ Custody seals intact ☐		
CHW 2	SK	3/22/06	7:31						
CHW 3	SK	3/22/06	11:01						
CHW 4	SK	3/22/06	16:27						
CHW 5	SK	3/22/06	18:17	↓					

Dispatched by:	Date and Time:	Counter Company Name:	Invoice/Airbill #:
Relinquished by:	Date and Time:	Received by:	Date and Time:
Relinquished to:	Date and Time:	Received to DLS by:	Date and Time:

Stefan Kirby 03/24/06 12:43 pm James new Person 03-24-06 12:43 pm 3 24 01 12:43

