Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

Electronically Filed
Nov 08 2022 04:38 p.m.
Elizabeth A. Brown
Clerk of Supreme Court

ADAM SULLIVAN, P.E., NEVADA STATE ENGINEER, et al.

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

JOINT APPENDIX

VOLUME 43 OF 49

PRINCIPAL FACTS FOR GRAVITY STATIONS IN THE VICINITY OF COYOTE SPRING VALLEY, NEVADA, WITH INITIAL GRAVITY MODELING RESULTS

by **Geoffrey A. Phelps, E.B. Jewel, V.E. Langenheim and R.C. Jachens**

Open-File Report 00-420

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Prepared in cooperation with the Southern Nevada Water Authority

U.S. DEPARTMENT OF THE INTERIOR
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ABSTRACT

Gravity measurements were made along 5 profiles across parts of the Coyote Spring Valley and vicinity in order to aid in modeling the depth and shapes of the underlying basins and to locate faults concealed beneath the basin fill. Measurements were taken at 200 m (660 ft) spacing along the profiles. Models based on these and existing regional data reveal two north-south-trending basins beneath Coyote Spring Valley that reach maximum depths of greater than 1 km (0.6 mi). A small valley, located just east of Coyote Spring Valley and containing Dead Man Wash, includes a small basin about 500 m (1600 ft) deep that appears to be the southern continuation of the northern basin beneath Coyote Spring Valley. The profile gravity data are further used to identify the locations of possible faults concealed beneath the basin fill.

INTRODUCTION

At the request of the Southern Nevada Water Authority, the U.S. Geological Survey conducted a gravity survey in the Coyote Spring Valley and vicinity, Clark and Lincoln Counties, Nevada, during May, 2000. The purpose of the survey was to help define the shapes of young basins filled with Cenozoic rocks and alluvium, and to identify any possible faults within these basins that might influence the movement of groundwater. The gravity measurements were taken along detailed profiles crossing the southwestern end of Kane Springs Valley, parts of Coyote Spring Valley, and the small valley (located 25 km (15 mi) WNW of Glendale and Moapa, NV) just east of Coyote Spring Valley that contains Dead Man Wash and a section of Pahranagat Wash (fig. 1).

Coyote Spring Valley is a north-south-trending valley about 80 km (50 mi) north of Las Vegas, NV. The valley areas containing the gravity profiles are bounded on the west by the Sheep and Las Vegas Ranges, on the north by the Delamar Mountains, and on the east by the Meadow Valley Mountains. The Arrow Canyon Range projects from the south into the southernmost gravity profiles (figs. 1 and 2).

The valleys in the study area were created by Miocene extension of the crust that formed the basins and ranges that make up most of Nevada today (Stewart, 1980). The ranges

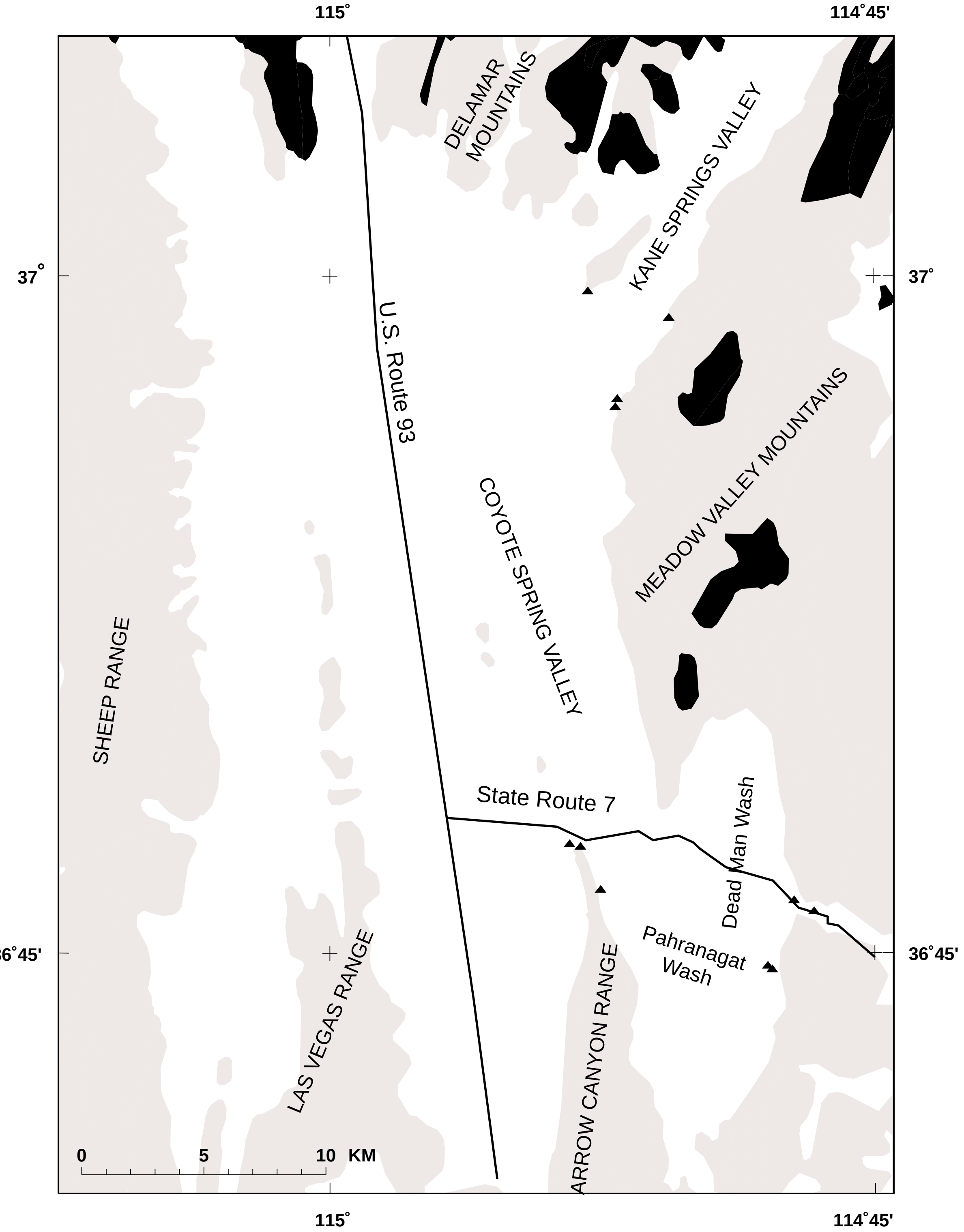

Figure 1. Index map showing Coyote Spring Valley study area and vicinity, Nevada. Black areas have outcrops of Cenozoic volcanic rocks, gray areas have outcrops of Paleozoic rocks, and white areas indicate areas covered by Cenozoic basin fill. Solid triangles indicate locations where samples of Paleozoic rock were collected for density measurements.

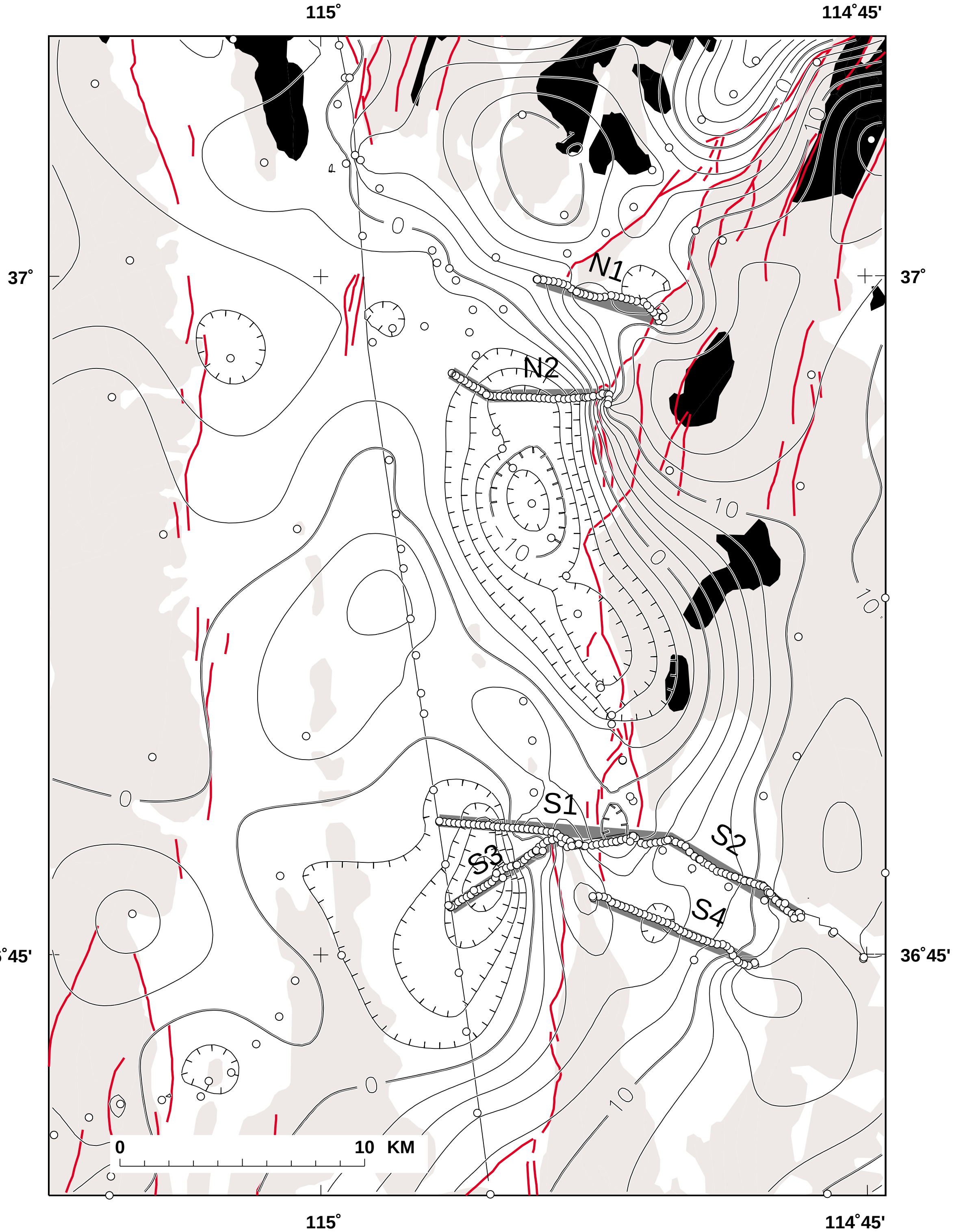

Figure 2. Map showing isostatic residual gravity of Coyote Spring Valley and vicinity. Contour interval = 2 mGal. Open circles show gravity stations. Gray bands labelled N1-N2 and S1-S4 are detailed gravity profiles that were modeled to define basin shape. Red lines indicate faults mapped by Dohrenwend and others (1996). See figure 1 for geology and culture. Refer to Plate 1 for larger scale presentation of these data.

surrounding the study area (and presumably the floors of the intervening basins) are composed primarily of Paleozoic carbonate rocks (Stewart and Carlson, 1978) which typically have densities of 2.7 g/cm^3 or greater. The basins are filled primarily with Miocene tuffaceous sedimentary rocks (with minor tuff) and Quaternary alluvium. These basin fill deposits are typically much lower in density than the Paleozoic carbonate rocks with which they are in contact. Because of the large density contrast between the basin fill and the surrounding carbonate rocks, gravity techniques are well suited for defining the subsurface shapes of the basins and the geometries of the faults that bound the basins.

Previous geophysical work relevant to the present study are limited. Kane and others (1979) and Healey and others (1981) published gravity maps containing about 50 measurements in the vicinity of Coyote Spring Valley. Although more recent compilations more than doubled the number of measurements (Ponce, 1997), the coverage remained too sparse for the purposes of the present study. Geophysical logs for 8 wells in the Coyote Springs Valley area, including 4 wells drilled by the U.S. Air Force as part of the Nevada-Utah MX missile-siting investigation, contain lithologic, density, and electrical information (Berger and others, 1988). Saltus and Jachens (1995) examined the shape and distribution of basins throughout the Basin and Range Province by inverting regional gravity data to yield the thickness of Cenozoic deposits. However, their spatial resolution (2 km) is too coarse to provide useful local information for the present study. Carpenter and Carpenter (1994) analyzed seismic reflection profiles in southern Nevada and surrounding areas, one of which coincides with one of the southern gravity profiles included in this study. This seismic reflection profile provides a valuable check and confirmation of the gravity interpretations.

DATA COLLECTION AND REDUCTION

224 gravity measurements, spaced 200 m (660 ft) apart, were taken along 5 profiles (fig. 2 and plate 1). Measurement locations were determined using a Trimble 1440 RTK (real-time kinematic) Global Positioning System (GPS) to record longitude, latitude, and elevation. Locations were recorded relative to GPS base stations located on local benchmarks. Benchmarks were located horizontally using Rockwell PLGR GPS units, which have an uncertainty of 7 m (23 ft). The vertical datum was provided by the elevation posted on the benchmarks, which gave elevation to the nearest foot. The Trimble RTK System typically has a relative error of 5 to10 cm (2-4 in) in the horizontal direction and 10-20 cm (4-8 in) in the vertical direction. Therefore, the absolute locations of the gravity observations have uncertainties of at least 7 m (23 ft) horizontally and 0.3 m (1 ft) vertically, but have smaller uncertainties in the relative positions and elevations of data along each profile. The relative positional uncertainties are the important ones for defining the shapes of the basins.

Page-size version of plate 1

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PLATE 1
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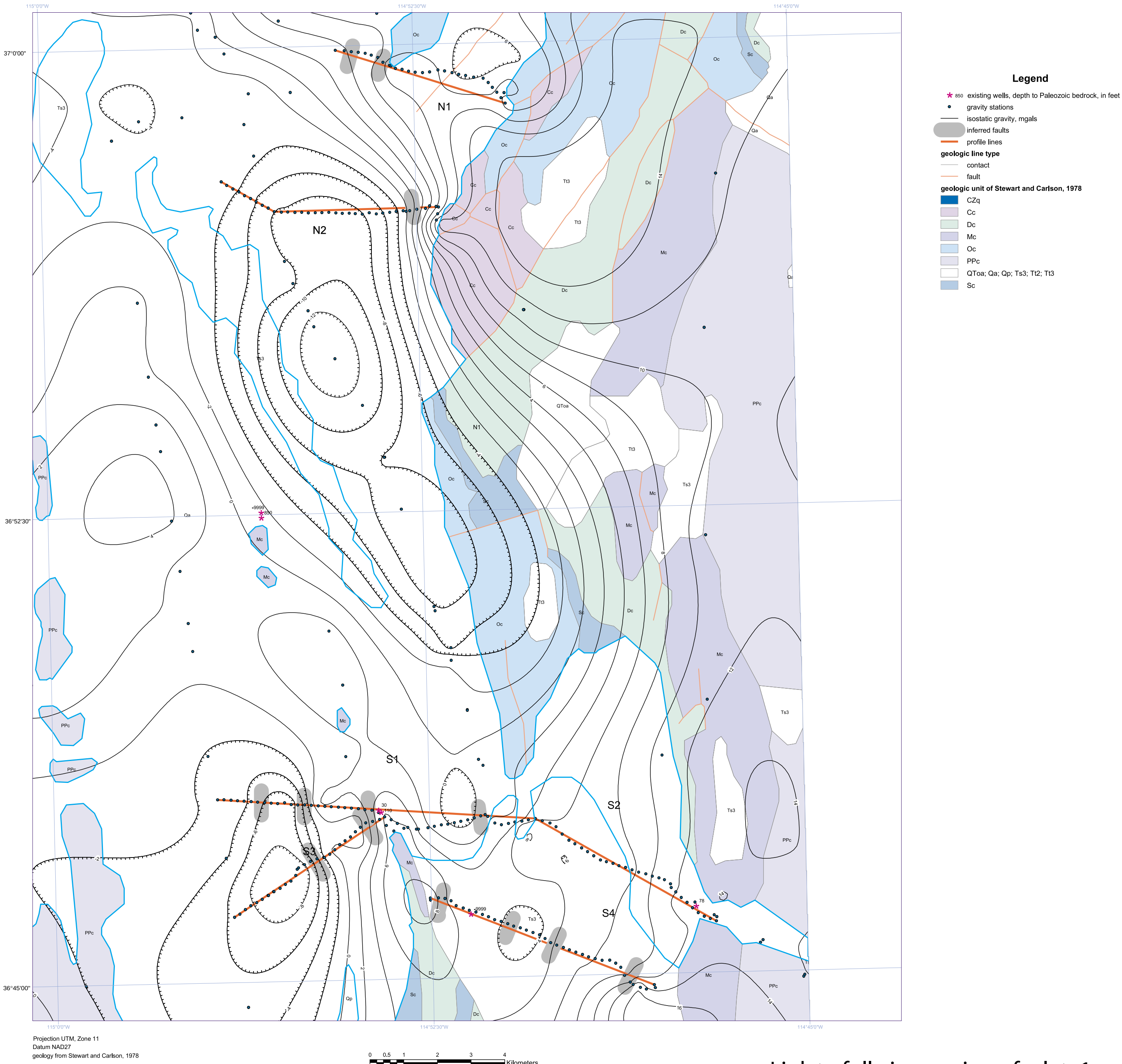

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Isostatic Gravity Anomaly for the Coyote Spring Valley Area

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Gravity data were collected during May 2000 using LaCoste and Romberg gravity meter G17c. All gravity data were tied to a gravity base station, GLEN, established at the Glendale Hotel in Glendale, NV. GLEN has a value of 979,682.63 mGal based on ties to LVGS, a gravity base station in front of the U.S. Geological Survey office in Las Vegas, NV (observed gravity 979,593.62 mGal).

Gravity data were reduced using the Geodetic Reference System of 1967 (International Union of Geodesy and Geophysics, 1971) and referenced to the International Gravity Standardization Net 1971 gravity datum (Morelli, 1974, p. 18). Gravity data were reduced to isostatic residual gravity anomalies using standard procedures (e.g. Telford and others, 1976) with a reduction density of 2.67 g/cm^3 and include earth-tide, instrument drift, free-air, latitude, Bouguer, curvature, and terrain corrections. An isostatic correction, using a sea-level crustal thickness of 25 km (16 mi), an upper crustal density of 2.67 g/cm^3, and a mantle-crust density contrast of 0.40 g/cm^3, was applied to the gravity data to remove long-wavelength gravity anomalies resulting from isostatic compensation of the topography by deep density distributions. The resulting isostatic residual gravity anomalies reflect, to first order, density variations within the middle and upper crust (Simpson and others, 1986).

Terrain corrections were computed to a radial distance of 167 km (104 mi) and involved a 3-part process: 1) Hayford-Bowie zones A and B with an outer radius of 68 m (223 ft) were estimated in the field with the aid of tables and charts; 2) Hayford-Bowie zones C and D with an outer radius of 590 m (1936 ft) were computed using a 30-m (100-ft digital elevation model; and 3) terrain corrections from a distance of 0.59 km (1936 ft) to 167 km (104 mi) were calculated using a digital elevation model and procedure by Plouff (1977). Total terrain corrections for stations measured during this study range from 0.24 to 3.73 mGal, averaging 1.14 mGal. 95% of the terrain corrections are less than 2 mGal. Uncertainties in the total terrain corrections, based on experience in other areas of Nevada, are estimated to be about 10% of the total correction. Because most of the gravity measurements were made far from the rugged topography that results in large terrain corrections, we estimate the uncertainty in terrain corrections for typical observations in this survey to be less than 0.2 mGal.

The reduced gravity data collected during this study are presented in Appendix 1. We estimate that the total uncertainty associated with these data, based on uncertainties in observed gravity (from meter drift and calibration uncertainties), horizontal position, elevation, and terrain correction, to be typically less than 0.3 mGal, although slightly larger uncertainties correspond to measurements with large terrain corrections (Appendix

1). These uncertainties are substantially smaller than the gravity anomalies associated with the basins, typically on the order of 5.0-10.0 mGal, and do not limit the modeling of the gravity anomalies in terms of basin structure.

The isostatic residual gravity field of the study area, as defined by our new data and all other existing data, is shown in figure 2 and on plate 1. As expected, the valleys are characterized by gravity lows (associated with the low-density deposits contained in them) and the surrounding ranges are characterized by gravity highs.

DENSITY DATA

Sixteen samples were taken at several outcrops (fig. 1) and measurements of sample density were made in the laboratory. With 1 exception the samples are Paleozoic carbonate rocks, which exhibit a mean density of 2.70 g/cm^3. The density of Quaternary alluvium was not measured directly, but was inferred to be approximately 2.15 g/cm^3 based on density logs in shallow wells within the study area (Berger and others, 1988). Densities of older and deeper basin-filling deposits have not been measured locally within the study area, but have been estimated region-wide (Saltus and Jachens, 1995; Jachens and Moring, 1990), and indirectly measured in a deep well in Morman Mesa 50 km (30 mi) to the east (Langenheim and others, 2000).

DEPTH TO PALEOZOIC ROCKS

We combined the gravity data collected during this study with existing data to estimate the areal form and distribution of basins in order to provide a regional framework within which to interpret the detailed gravity profiles. We used an iterative gravity inversion method that combines the gravity data with exposed geology, drill hole information, and other geophysical data to estimate the thickness of basin-filling deposits. The method used is an updated version of the method developed by Jachens and Moring (1990) that incorporates additional point data where the basin-fill thickness is known. The method partitions the gravity field into two components, one caused by variations in the thickness of the low-density basin fill, and the other caused by variations of density within the underlying Paleozoic rock. The 'basin-fill' component, together with an assumed vertical variation of density within the basin fill, are inverted to produce a 3-dimensional image of the basins. The method is iterative, successively yielding improved approximations to the shapes of the basins while simultaneously accounting for the gravity field variations caused by density variations within the Paleozoic rock and those caused by the lateral effects of low density basin deposits at locations in the surrounding ranges. For details of this method, the reader is referred to Jachens and Moring (1990) and Saltus and Jachens (1995).

The results of this inversion for Coyote Spring Valley and vicinity are shown in figure 3. The results show two deep basins (the northern crossed by profile N2 and the southern crossed by profiles S1 and S3) beneath the axis of Coyote Spring Valley, both reaching maximum depths greater than about 1 km (3300 ft). The deepest parts of both basins are aligned north-south and are separated from each other by a NNW-trending, shallowly-buried, bedrock ridge that is the northward continuation of the Arrow Canyon Range. A smaller basin (maximum depth of about 500 m (1600 ft)) lies beneath the valley containing Dead Man Wash and part of Pahranagat Wash, and appears to be the southern continuation of the northern basin beneath Coyote Spring Valley.

The general shapes and locations of the basins are reasonably well constrained by the gravity data, but the details of the basins must be viewed with caution. Except along the detailed gravity profiles, gravity data are sparsely distributed and the resulting basin definition is poor at best. In particular, the southern part of the northernmost basin and the northern part of the Dead Man Wash basin are quite uncertain because of the absence of gravity stations in the Meadow Valley Mountains (fig. 2). A better distribution of gravity stations in the ranges would lead to an improved estimate of the depths of the basins. An interesting characteristic of the southernmost basin beneath Coyote Spring Valley is that the main basin edge (as defined by the abrupt increase in basin depth), does not lie along the western edge of the Arrow Canyon Range, but rather some 2-3 km (1.5-2 mi) west of the range front. The seismic reflection profile analyzed by Carpenter and Carpenter (1994) confirms the offset between the Arrow Canyon Range front and the basin boundary (presumably a normal fault). We do not have enough data to say whether the eastern edge of the northern basin also is systematically displaced westward relative to the range-front of the Meadow Valley Mountains, but the results from gravity modeling discussed in the next section suggest that the basin's edge is within about 1 km (0.6 mi) of the range front.

INTERPRETATION OF DETAILED GRAVITY PROFILES

Gravity models were constructed along 5 profiles (N1-N2 and S1-S4 on figure 2) in order to examine the detailed cross-sectional shapes of the basins and the structures that bound them. A constant density contrast of –0.55 g/cm^3 was used for each model based on a density of 2.70 g/cm^3 for the Paleozoic carbonate rocks and a basin fill density of 2.15 g/cm^3, the average density of the alluvium measured in two wells near the study area (CSV-1 and CSV-3, in Berger and others, 1988). The results of this modeling are shown in figures 4-6.

Within the Basin and Range province, faults resulting from the Miocene crustal extension often are characterized by abrupt lateral changes in the thickness of Cenozoic basin fill of

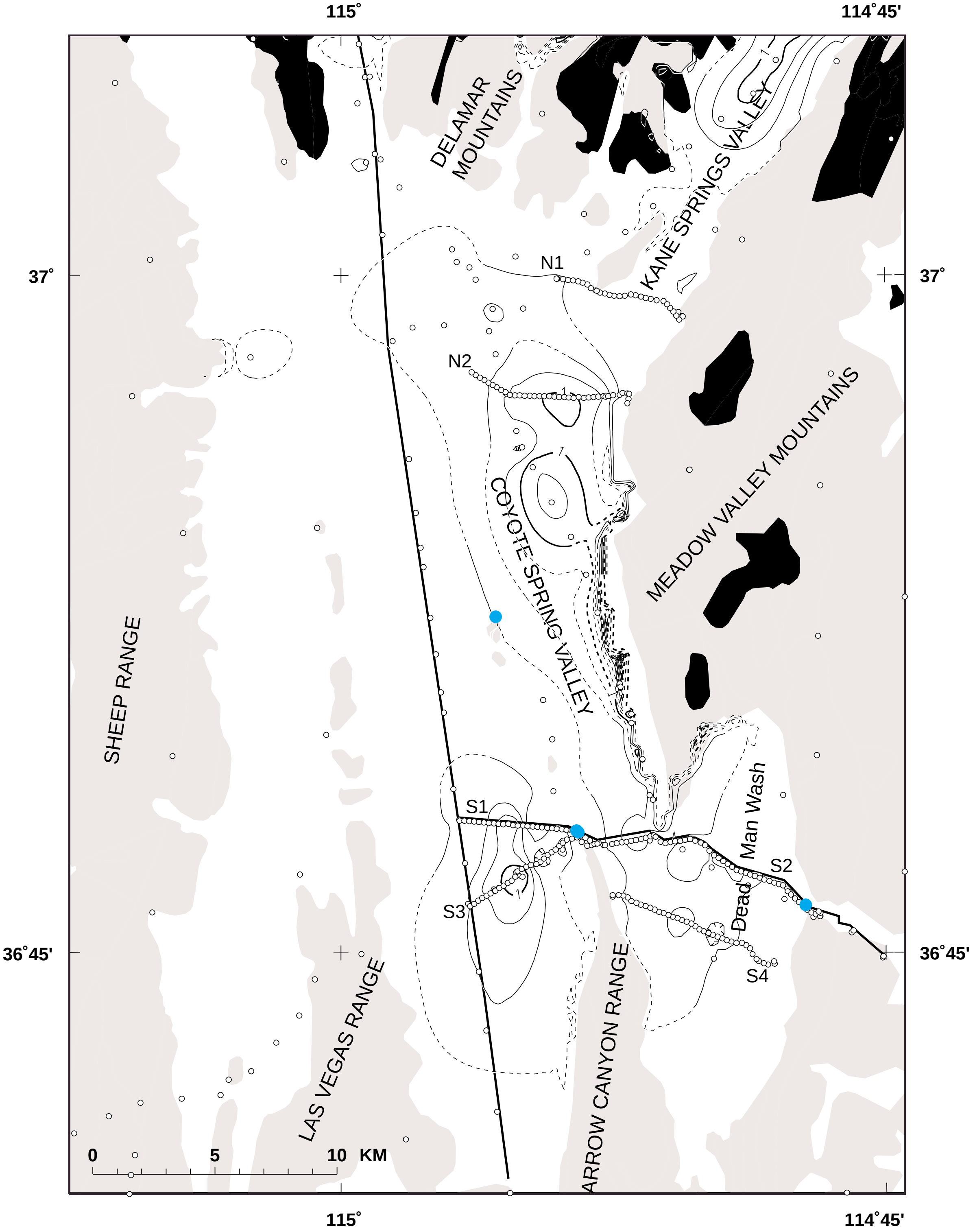

Figure 3. Basin thickness map of the study area. Contour intervals, 250 m, 1 km. Contours dashed where poorly constrained. White and black circles, gravity stations; blue dots, wells that penetrate pre-Cenozoic basement. Black areas have outcrops of Cenozoic volcanic rocks, gray areas have outcrops of Paleozoic rocks, and white areas indicate areas covered by Cenozoic basin fill.

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a few hundred meters or more. This relationship is well illustrated along model-profile S1 (fig. 4) where four possible faults are identified in areas of abrupt lateral changes in the thickness of the basin fill. Three of these (identified by asterisks) correspond to faults identified by Carpenter and Carpenter (1994) on the basis of seismic reflection profiling and two (identified by open circles) correspond to faults mapped by Dohrenwend and others (1996). The fourth and westernmost possible fault in figure 4 lies beyond the western end of the seismic reflection profile.

Figure 5 shows gravity models along the two northern profiles, N1 and N2, and figure 6 shows two additional gravity models along southern profiles S3 and S4. Locations of abrupt lateral changes in the thickness of basin fill are identified as possible locations of faults on figures 5 and 6, and their locations in map view are shown on plate 1. A model along profile S2 yielded only a thin, relatively uniform layer of basin fill a few hundred meters thick, and showed no characteristic features that would suggest faults.

The models shown are based on an assumed density contrast of –0.55 g/cm^3 between Paleozoic rock and the basin fill. This density contrast is uncertain primarily because actual measurements of the density of the basin fill are few, and because the density of the fill in the deeper parts of the basin has not been measured locally. We estimate that these uncertainties could be as large as 0.1 g/cm^3 or about 20%. If the actual density contrast along any profile is smaller in magnitude than –0.55 g/cm^3, the actual depth to Paleozoic rock will be greater than that shown (roughly in proportion to the percentage error). If the actual density contrast is larger, then the depth will decrease. In general, however, the shape of the basin and the locations of abrupt lateral changes in the thickness of the basin fill will not change. Therefore, the locations of possible faults defined by the gravity modeling should not be affected by any reasonable uncertainty in the density contrast used to model the gravity data.

DISCUSSION

Gravity surveys provide an effective method for defining the configuration of concealed Cenozoic basins in the vicinity of Coyote Spring Valley, and, based on a comparison between gravity modeling results and seismic reflection profiling along S1, detailed gravity profiles can be effective in identifying concealed faults. Although the subsurface configuration of the basins are well constrained along the detailed profiles of the present study, the gravity data throughout the rest of Coyote Spring Valley are too sparsely distributed to give more than a generalized image of the basins and their bounding faults. Additional gravity surveys could be used to refine the image of the basins and faults and to trace individual fault strands and establish their continuity. Analysis of aeromagnetic data over the study area in conjunction with the gravity field produced by the Paleozoic

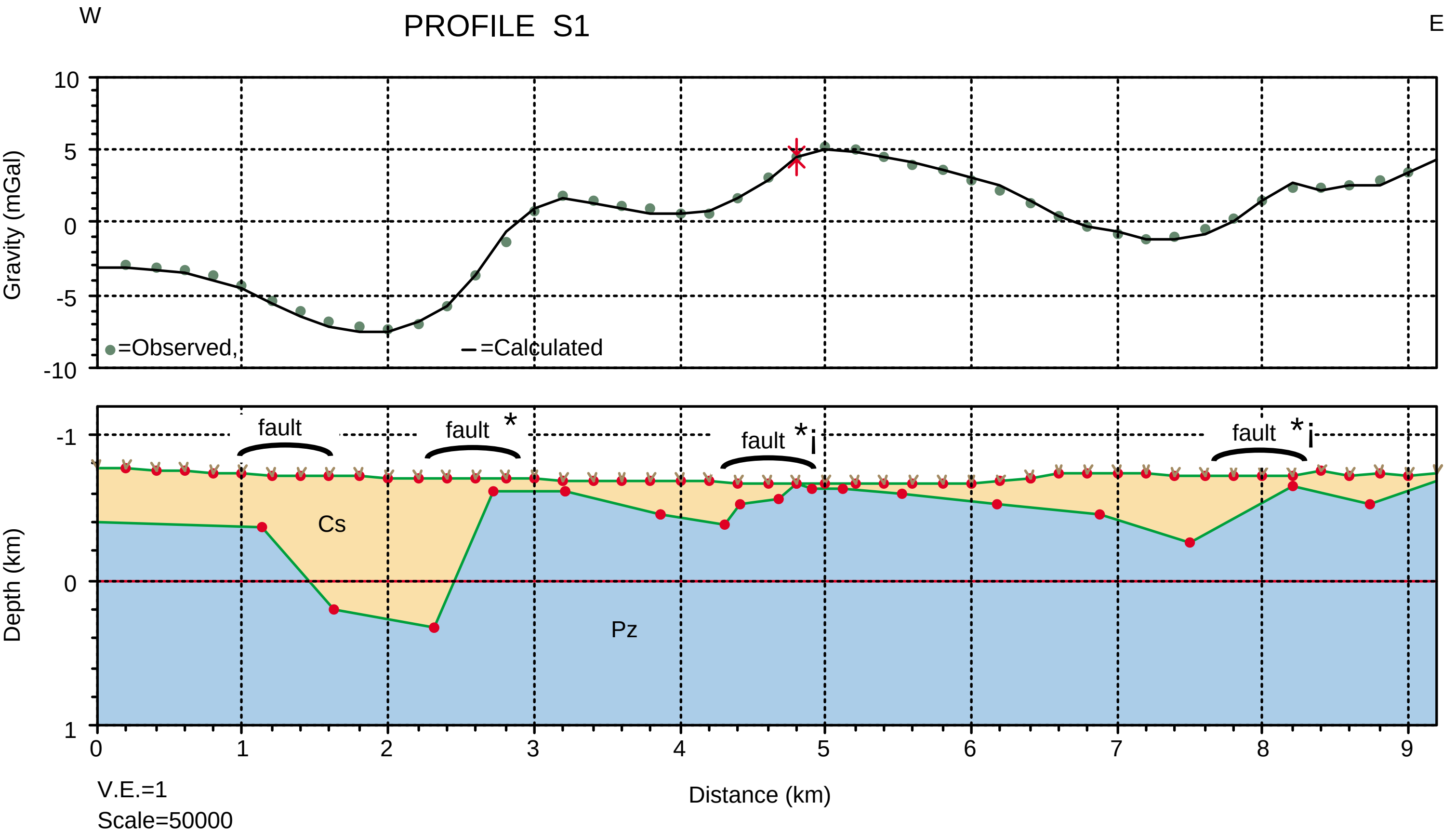

Figure 4. Gravity model along profile S1. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm^3. Pz--Paleozoic rock; Cs--Cenozoic basin fill. Faults marked by asterisks correspond to faults identified by Carpenter and Carpenter (1994) on the basis of seismic reflection profiling and faults marked by open circles correspond to faults mapped by Dohrenwend and others (1996).

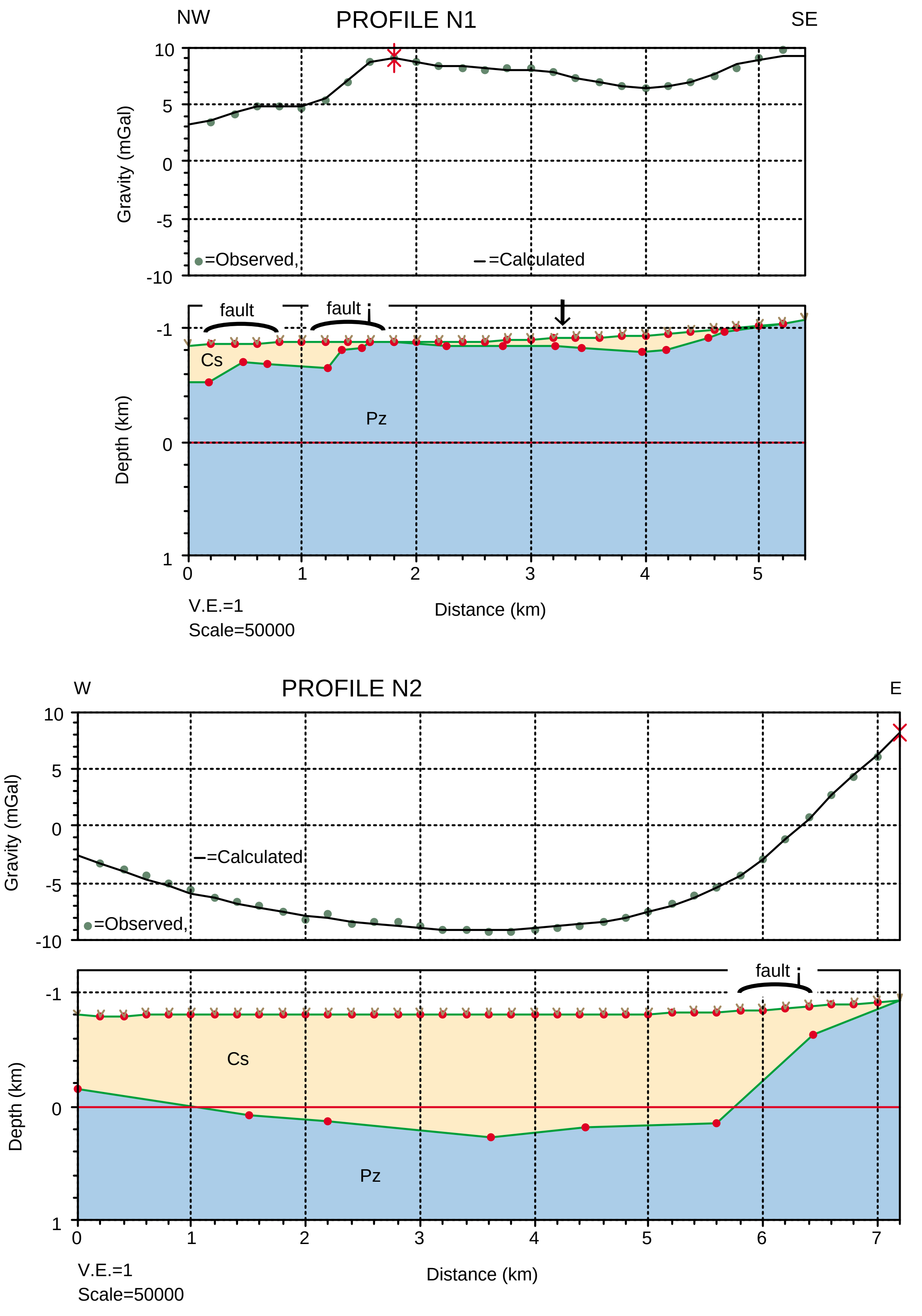

Figure 5. Gravity models along profiles N1 and N2. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm^3. Pz--Paleozoic rock; Cs--Cenozoic basin fill. Faults marked by open circles correspond to faults mapped by Dohrenwend and others (1996). Arrow indicates location of fault shown by Stewart and Carlson, 1978.

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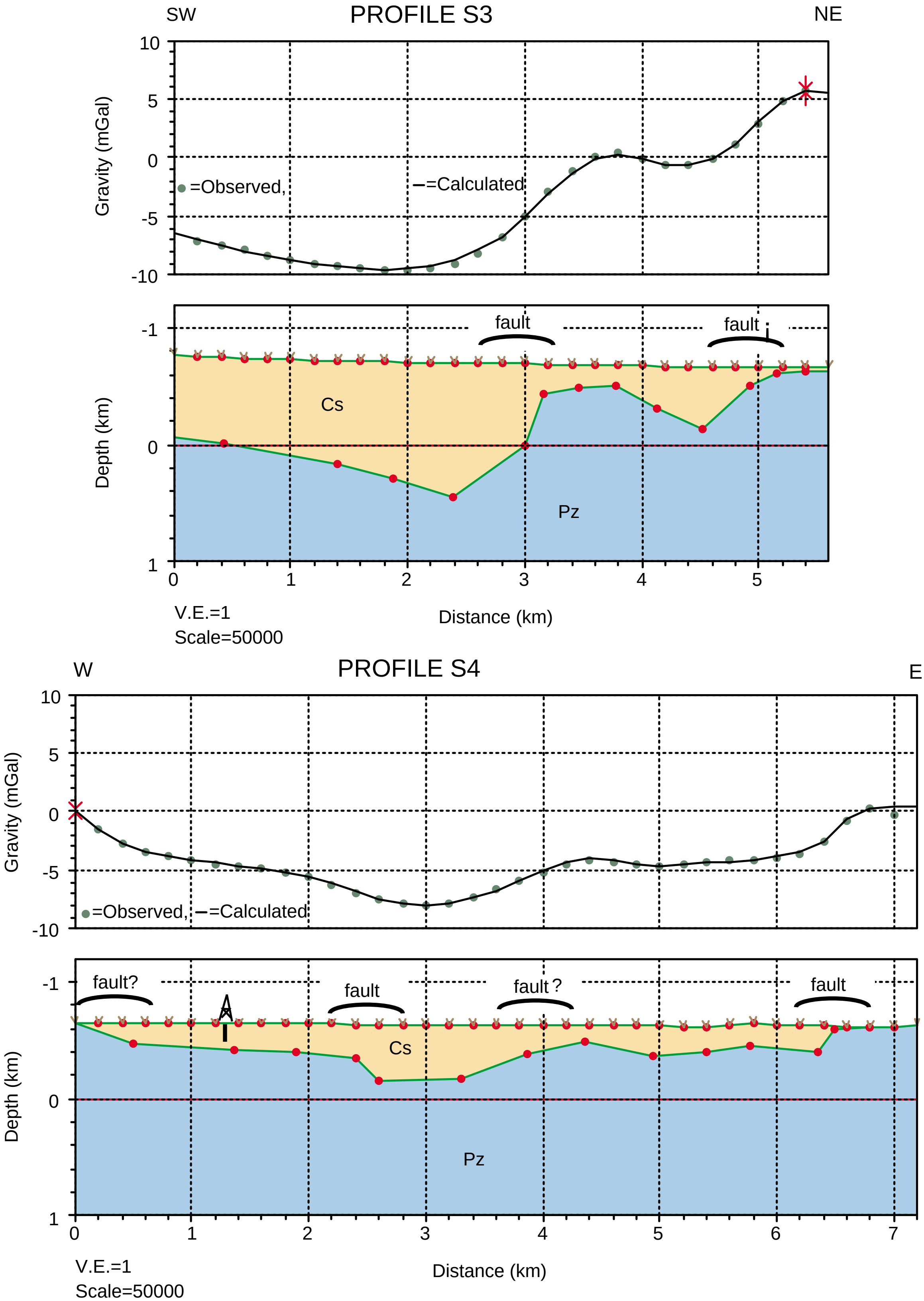

Figure 6. Gravity models along profiles S3 and S4. Density contrast between Paleozoic bedrock and Cenozoic basin fill, -0.55 g/cm^3. Pz--Paleozoic rock; Cs--Cenozoic basin fill. A linear, westward decreasing regional gradient was removed from profile S4 prior to modeling. Fault marked by an open circle corresponds to a fault mapped by Dohrenwend and others (1996). Well CSV-1 (Berger and others, 1988) is 765 ft deep and did not reach Paleozoic rock.

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bedrock (a map that is an outgrowth of the basin-depth inversion) can yield additional information about the lithology and structures within the pre-Cenozoic rock. All of this information could serve as the basis for improving the hydrogeologic framework of the region which, in turn, could be used in a refined ground-water flow model.

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APPENDIX 1: Principal facts for new gravity stations in Coyote Spring Valley and vicinity.

Key to gravity file

Record 1 Station identifier
Record 2 Latitude (in degrees)
Record 3 Latitude (in minutes, to 0.01)
Record 4 Longitude (in degrees)
Record 5 Longitude (in minutes, to 0.01)
Record 6 Elevation (in feet, to 0.1)
Record 7 Observed Gravity (in mGal, to 0.01)
Record 8 Free Air Anomaly (in mGal, to 0.01)
Record 9 Simple Bouguer Anomaly (in mGal, to 0.01)
Record 10 Inner Zone Terrain Correction (in mGal, to 0.01)
Record 11 Total Terrain Correction (in mGal, to 0.01)
Record 12 Complete Bouguer Anomaly (in mGal, to 0.01)
Record 13 Isostatic Residual Anomaly (in mGal, to 0.01)

GLEN	36	3996	114	3409	15030	97968263	-5181	-10307	0	24D	-10342	702
WC001	36	5742	114	5546	26017	97960458	-5178	-14051	6	70D	-14074	-815
WC002	36	5943	114	5110	31515	97958799	-1958	-12707	7	194D	-12620	636
WC002	36	5943	114	5110	31556	97958794	-1925	-12687	7	193D	-12602	654
WC003	36	5919	114	5069	33539	97957767	-1052	-12491	93	373D	-12231	988
WC004	36	5902	114	5067	34375	97957316	-693	-12417	45	355D	-12176	1025
WC005	36	5911	114	5075	33522	97957763	-1061	-12494	36	320D	-12286	925
WC006	36	5920	114	5083	33002	97958009	-1317	-12573	22	273D	-12411	813
WC007	36	5928	114	5092	32424	97958315	-1566	-12624	13	239D	-12495	738
WC008	36	5936	114	5100	31849	97958631	-1802	-12665	10	219D	-12553	693
WC009	36	5945	114	5129	31159	97958995	-2100	-12727	5	163D	-12671	593
WC010	36	5948	114	5145	30819	97959178	-2241	-12752	5	145D	-12713	560
WC011	36	5950	114	5159	30500	97959394	-2328	-12730	4	131D	-12704	577
WC012	36	5953	114	5172	30228	97959637	-2345	-12654	3	121D	-12638	652
WC013	36	5956	114	5187	29920	97959889	-2387	-12591	3	111D	-12584	713
WC014	36	5958	114	5200	29679	97960135	-2370	-12493	3	105D	-12491	812
WC015	36	5955	114	5217	29366	97960349	-2446	-12462	2	100D	-12464	844
WC016	36	5954	114	5231	29126	97960458	-2561	-12495	1	96D	-12501	811
WC017	36	5955	114	5246	28968	97960578	-2591	-12471	1	91D	-12481	837
WC018	36	5957	114	5259	28891	97960631	-2614	-12467	1	87D	-12481	843
WC019	36	5960	114	5272	28797	97960707	-2630	-12452	2	84D	-12468	862
WC020	36	5962	114	5285	28707	97960783	-2642	-12433	3	83D	-12451	886
WC021	36	5967	114	5297	28723	97960857	-2560	-12356	6	82D	-12375	972
WC022	36	5972	114	5310	28568	97960754	-2816	-12560	3	77D	-12583	771
WC023	36	5966	114	5294	28821	97960798	-2526	-12355	6	81D	-12375	969
WC024	36	5980	114	5320	28535	97960575	-3038	-12770	3	75D	-12795	568
WC025	36	5984	114	5333	28763	97960332	-3072	-12882	1	69D	-12914	457
WC026	36	5987	114	5345	28550	97960465	-3144	-12881	4	71D	-12911	467
WC027	36	5989	114	5359	28117	97960764	-3255	-12844	6	74D	-12870	514
WC028	36	5990	114	5373	28011	97960792	-3328	-12881	4	71D	-12910	481
WC029	36	5992	114	5387	27801	97960809	-3511	-12993	3	70D	-13021	376
WC030	36	5993	114	5405	27748	97960793	-3579	-13042	1	66D	-13074	330
WC031	36	4605	114	5644	25062	97960133	-4756	-13304	3	152D	-13243	-636
WC032	36	4610	114	5633	24801	97960249	-4893	-13352	3	150D	-13291	-690
WC033	36	4617	114	5622	24555	97960367	-5016	-13391	2	147D	-13333	-735
WC034	36	4623	114	5611	24316	97960481	-5136	-13429	2	145D	-13372	-780
WC035	36	4628	114	5599	24067	97960602	-5256	-13464	2	144D	-13409	-824
WC036	36	4633	114	5588	23849	97960708	-5362	-13496	2	143D	-13441	-861
WC037	36	4639	114	5576	23661	97960798	-5458	-13528	1	140D	-13474	-900

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WC040	36	4639	114	5575	23657	97960801	-5458	-13527	1	140D	-13474	-901
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WC046	36	4682	114	5514	22972	97961320	-5646	-13481	3	129D	-13436	-880
WC047	36	4687	114	5502	22837	97961496	-5604	-13393	21	148D	-13329	-778
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WC049	36	4696	114	5477	22573	97962004	-5357	-13056	8	134D	-13005	-468
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WC052	36	4710	114	5441	22228	97962756	-4950	-12531	18	145D	-12469	50
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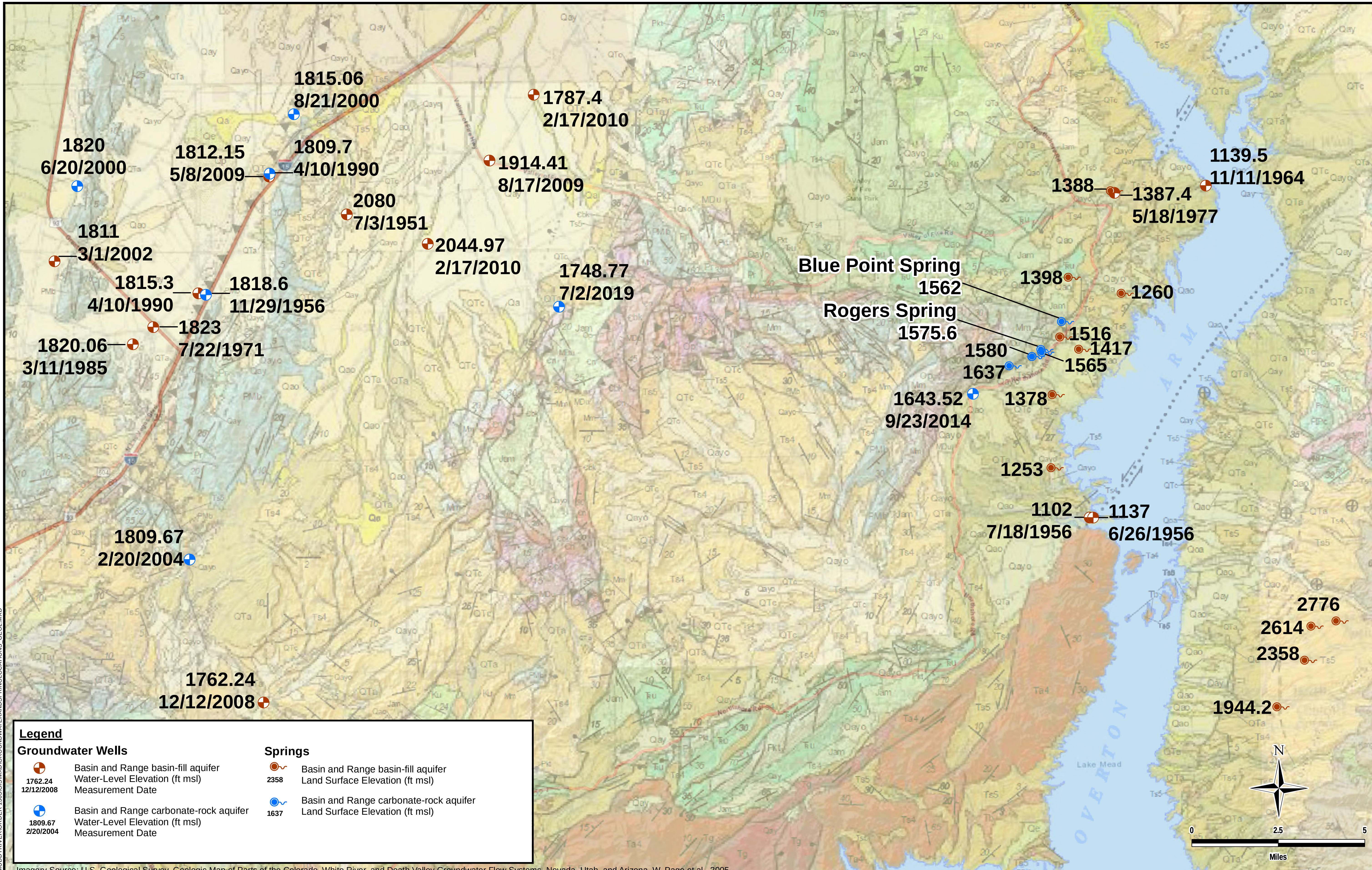

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Introduction

The U.S. Geological Survey (USGS) and the Bureau of Land Management (BLM) initiated a cooperative study through the Southern Nevada Public Land Management Act (Bureau of Land Management, 1998) to install six wells in the carbonate-rock and basin-fill aquifers of Clark County, Nevada, in areas of sparse groundwater data. This map uses water levels from these new wells, water levels from existing wells, and altitudes of spring discharge points to update a regional potentiometric map of the carbonate-rock aquifer and provide evidence to interpret the direction of regional groundwater flow. This potentiometric surface map is accompanied by drilling and borehole geophysical logs, well-construction information, lithology, water chemistry, and water levels from the newly drilled wells.

Carbonate-Rock Aquifer and Regional Groundwater Flow

The carbonate-rock aquifer in Clark County consists of thick sequences of Paleozoic-age limestone and dolomite with thinner beds of shale, sandstone, and quartzite that are deformed and extended. Mountain blocks of carbonate rock, separated by intermountain basins, thicken westward from the Muddy Mountains toward the Las Vegas and Sheep Ranges (Dettinger and others, 1995; Harrill and Prudic, 1998; Heilweil and Brooks, 2011). Groundwater in the aquifer flows through fractures and faults associated with regional deformation and through small-scale brittle fractures.

The aquifer is primarily recharged through fractures in high-precipitation areas that are in high-altitude mountain ranges near groundwater divides. Regional discharge is from springs and riparian areas at low altitudes in major drainage basins. Discharge from springs at the regional scale is generally constant and less transient than from springs discharging from more localized flow systems (Toth, 1963). Active groundwater withdrawals (or pumping) can affect local spring discharge, producing fluctuations not characteristic of discharge from regional springs.

Parts of three groundwater flow systems compose the carbonate-rock aquifer in Clark County: (1) the Colorado System, (2) Death Valley System, and (3) Mesquite Valley System (Harrill and others, 1988). In Clark County, groundwater flow in the Colorado System is principally to the southeast, discharging at the headwaters to the Muddy River. Flow in the Death Valley System is principally to the west, discharging to springs in Amargosa Valley and Death Valley (Faunt and others, 2010). Localized flow in the Mesquite Valley System discharges by evapotranspiration from phreatophytes and evaporation on the valley playa (Glancy, 1968).

Groundwater flow directions and gradients are proposed on potentiometric maps by Bedinger and Harrill (2010) and Brooks and others (2014). Both studies used available groundwater levels, spring altitudes, and discharge data to classify groundwater and springs as regional or local. Bedinger and Harrill (2010) generalized hydrogeologic and geologic characteristics as proxy data to define regional hydraulic heads, which are described as water levels that are (1) lower than the water table in areas of recharge, (2) above the altitude of intermediate and regional discharge areas, and (3) below the altitude of non-discharging dry playas.

Brooks and others (2014) developed a regional-scale numerical groundwater flow model to evaluate groundwater availability in the Great Basin. The published potentiometric contours, representative of the carbonate-rock aquifer, were based on water-level observations from wells completed in basin fill and carbonate rock. These studies were conducted at a regional scale and included relatively few direct observations from wells in Clark County, which are completed in carbonate rock.

Selected Existing Hydrogeologic Data

Water levels, water chemistry, lithology, and construction data from monitoring wells were compiled from the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2016) and from Thomas and others (1996), and compared to information obtained from the six new wells. Sites near production wells were excluded from this selection because of the potential for pumping related drawdown to affect water levels, and monitoring wells were excluded if they were screened in the carbonate-rock aquifer or in the basin-fill aquifer at depths greater than 500 feet. It is assumed that basin-fill wells at this depth are in hydraulic connection with the carbonate-rock aquifer (Prudic and others, 1995). In Clark County, 24 wells completed in carbonate rock, 28 wells completed in deep basin-fill deposits, and 5 springs were selected from the USGS NWIS database (table 1) and discussed in this report.

Table 1. Existing monitoring wells representative of the carbonate-rock and basin-fill aquifers in Clark County, Nevada.

[ID, identifier; USGS, U.S. Geological Survey; NWIS, National Water Information System; mm/dd/yyyy, month/day/year; NGVD 29, National Geodetic Vertical Datum of 1929; CR, carbonate rock; BF, basin fill; —, no data]

Map ID	USGS site ID	USGS NWIS site name	Site type	Well depth (feet)	Hole depth (feet)	Contributing aquifer	Date of water-level measurement (mm/dd/yyyy)	Water level, in feet below land surface	Water-level altitude, in feet above mean sea level (NGVD 29)
1	361816115241301	212 S19 E59 18AAC 1	Well	542	542	CR	09/01/1999	417.00	3,484
2	363506115400001	214 S16 E56 16 1 Indian Springs Sewage Co	Well	550	590	CR	06/01/1963	54.00	3,146
3	362846114495501	216 S17 E64 09DDCB1 CRYSTAL 2	Well	565	565	CR	08/21/2000	254.94	1,815
4	364741114332801	210 S13 E63 26AAAA1 USGS-MX CE-DT-5	Well	628	628	CR	08/13/1999	349.81	1,820
5	360016115365301	163 S22 E57 29DABC1 USBLM NDOT 01	Well	660	660	CR	09/07/2010	306.15	3,917
6	364741114333101	210 S13 E63 23DDDC1 USGS-MX CE-DT-4	Well	669	669	CR	10/15/2015	356.27	1,819
7	362312115240301	212 S16 E58 23DDD 1 USFWS SBH-1	Well	720	720	CR	05/28/2015	575.20	2,891
8	362531114524201	216 S18 E64 07BB 1 WELL (REPORT R50)	Well	793	793	CR	11/29/1956	226.40	1,819
9	355829115150601	212 S23 E60 03DBCB1 TORTOISE CENTER	Well	800	800	CR	03/19/1999	555.00	2,150
10	361734114533601	215 S19 E63 13DCAA1 EBM-3	Well	900	1,241	CR	02/20/2004	578.73	1,810
11	363308114553001	210 S16 E63 09DDAB1 USBLM SHV-1	Well	920	920	CR	10/01/2015	833.69	1,815
12	363332115224001	212 S16 E58 14A 1 USFWS DR-1	Well	930	960	CR	05/28/2015	813.40	2,760
13	364604114471301	219 S13 E64 35DCAD1 USGS-MX CE-DT-6	Well	937	937	CR	11/01/2002	456.00	1,819
14	364830115512601	160 S13 E55 19 1 TW-3	Well	1,127	1,660	CR	08/25/2015	1,103.00	2,381
15	363407115251301	212 S16 E59 08 2 USGS - Corn Camp	Well	1,403	1,403	CR	07/29/2015	1,330.30	2,856
16	362507114572701	216 S18 E63 05AADB1	Well	1,979	2,007	CR	03/01/2002	755.00	1,811
17	360946115421601	162 S20 E56 33CCAA1 TROUT CANYON 01	Well	718.5	720	CR	01/05/2015	467.30	4,794
18	364451114585001	210 S14 E62 01ADDD1 CSVM-5	Well	1,780	1,783	CR	09/20/2011	1,081.20	2,048
19	362700114564401	216 S17 E63 21DCCC1 HV-1	Well	2,480	2,480	CR	06/20/2000	882.00	1,815
20	361811115404601	212 S19 E56 15ABBD1	Well	660	660	CR	01/26/1983	214.40	8,500
21	364738114534001	210 S13 E63 26AABD1 CSV-RW-2	Well	710	720	CR	09/14/2011	383.40	1,819
22	364728114531001	210 S13 E63 25BDBB1 CSVM-1	Well	1,040	1,060	CR	09/21/2011	341.90	1,819
23	364529114482601	210 S13E64 33DBBC1 UMVM-1	Well	1,200	1,200	CR	04/22/2003	247.00	1,831
24	363943114552301	210 S15 E63 03BBCC1 CSVM-2	Well	1,400	1,425	CR	09/20/2011	750.70	1,822
25	360201115204701	212 S22 E59 15DAAB1	Well	532	532	BF	03/14/1990	267.21	2,823
26	363201115333801	211 S16 E57 28B 1 Hwy95 Cons 1	Well	550	550	BF	04/22/1963	98.00	3,083
27	360247115224401	212 S22 E59 09CBDB1 HUMANE	Well	570	570	BF	01/21/2009	354.80	2,896
28	363452115405101	161 S16 E56 09BACC1 USAF Well 3	Well	600	600	BF	07/29/2015	68.00	3,062
29	363447115404601	161 S16 E56 09BAAD1 USAF Well 106-2	Well	604	604	BF	07/29/2015	63.15	3,067
30	363255115158601	163 S16 E54 24BCBA1 Army 2	Well	627	658	BF	09/17/2015	495.20	3,318
31	355015115102601	166 S24 E61 20DDAC1 HIDDEN VALLEY	Well	640	640	BF	12/03/1956	605.00	2,423
32	355454115205401	164A S25 E59 27AACA1 JAIRPORT	Well	650	650	BF	12/11/2008	280.90	2,499
33	361136115101201	212 S23 E61 03BCC 1 Sky Harbor Airport	Well	650	650	BF	04/18/2011	215.36	2,160
34	360941115104801	212 S20 E61 32CDC 1	Well	665	665	BF	04/18/2011	18.47	2,077
35	355923115174201	212 S22 E60 32CB 1	Well	700	700	BF	08/06/1979	460.00	2,420
36	360826115020001	212 S21 E62 16ACAA1 Nevada Power Company	Well	715	715	BF	04/20/2011	21.94	1,683
37	364601114514301	210 S13 E63 31DADA1 USGS CSV-1	Well	765	765	BF	07/31/2009	346.91	1,813
38	361939115154801	212 S19 E60 04DAB 2 NV Division of Forestry	Well	780	780	BF	04/21/2011	77.51	2,376
39	364127114553001	210 S14 E63 27AACD1 USGS CSV-3	Well	780	780	BF	09/20/2011	594.00	1,820
40	355947115163501	212 S22 E60 33BB 1	Well	785	785	BF	12/10/1976	585.00	2,120
41	360931115083802	212 S21 E61 03ABB 2	Well	807	807	BF	04/18/2011	9.08	2,005
42	361843115161001	212 S19 E60 09BCC 1	Well	830	830	BF	04/28/2011	155.76	2,354
43	361231115021501	212 S20 E62 15BBAB1 USAF Nellis 12 (C)	Well	1,000	1,000	BF	04/27/2011	124.71	1,691
44	361344115115901	212 S20 E61 06CBDD1 CNLV Desert Aire	Well	1,000	1,000	BF	04/27/2011	60.72	2,150
45	361400115040901	212 S20 E62 05CAAA1 CNLV Wildlife	Well	1,000	1,000	BF	10/01/2015	62.56	1,806
46	361305115140301	212 S20 E60 11CAAA1 LVVWD W028	Well	1,003	1,003	BF	01/18/2007	202.05	2,085
47	361232115061001	212 S20 E61 13ABDB1 CNLV Diana Terrace	Well	1,230	1,230	BF	10/01/2015	31.83	1,845
48	361626115090701	212 S19 E61 21DDB 1 CNLV Regional Park 1	Well	1,300	1,300	BF	09/01/2015	40.72	2,119
49	360809115252601	212 S21 E58 12DDDD1 RED ROCK WASH	Well	503	503	BF	11/07/2008	400.54	3,288
50	364041114315101	220 S14 E67 11DACD1	Well	387	620	BF	03/19/1997	116.00	1,574
51	364912114041201	222 S13 E71 09BDCA1 PS27	Well	1,450	1,493	BF	07/08/1994	84.00	1,573
52	364044114165201	222 S14 E69 33ABC 1 D & HA	Well	880	880	BF	03/10/1985	37.26	1,341
53	362239114263501	215 S18 E67 12DDAD1 ROGERS SPRING	Spring	—	—	CR	—	—	1,576
54	362321114252601	215 S18 E68 07ABBA1 BLUE POINT SPRING	Spring	—	—	CR	—	—	1,562
55	09419625	CORN CK SPGS AT NATIONAL FISH & WILDLIFE HDQRS, NV	Spring	—	—	CR	—	—	2,930
56	09415910	PEDERSON SPGS NR MOAPA, NV	Spring	—	—	CR	—	—	1,811
57	362450115442001	161 S18 E55 01DACC1 COLD CREEK SPRING	Spring	—	—	CR	—	—	6,324

Drilling, Borehole Geophysical Logs, Lithology, and Well Construction

Groundwater monitoring wells were installed at six locations in Clark County. Criteria for selecting drill sites included (1) the carbonate-rock aquifer was relatively close to the surface, (2) there were no nearby groundwater withdrawals, and (3) access for drilling equipment was possible on existing roads.

Drilling techniques were dependent upon borehole advancement rate and lithology. Mud rotary drilling was predominantly used when drilling through unconsolidated material consisting mostly of sand, gravel, and cobbles. At all sites, the drill penetration rate through unconsolidated material was relatively consistent and progressed rapidly with this technique. When penetration rate decreased in denser rock units, air-hammer drilling was used. A change in drilling method allowed for consistent downward progress and limited drill time and cost.

Spontaneous potential (SP), natural gamma, caliper, and resistivity (borehole, 16- and 64-inch normal) wireline geophysical logs were obtained at each newly drilled borehole. The SP logs measure the voltage between the borehole and an electrode at the surface and are used to identify permeability changes and boundaries between formations at depth. Natural gamma logs show formation radiation intensity, which is generally higher for clay-rich rocks and sediments that tend to emit elevated levels of radiation from natural decay of uranium and thorium to potassium-40. Caliper logs measure borehole diameter and can indicate the presence of fractures along the borehole wall. Resistivity logs record the electrical resistivity of the formation and can indicate higher-porosity transmissive zones. These logs are used together to provide information on the subsurface geology.

Drill cuttings (chips of broken geologic material brought to the surface by drilling fluids) were washed and analyzed. These cuttings, borehole geophysical data, and observations made during drilling provide an indication of the subsurface geologic characteristics at each new drill site. Borehole geophysical logs, drill penetration rate, and subsurface lithology are presented with the study area map.

Wells were constructed of steel or polyvinyl chloride (PVC) well casing ranging from 4.5 to 6.625 inches in diameter. Vertically slotted screens were installed in water-bearing zones interpreted from borehole geophysics. A summary of well-construction information for each of the newly drilled wells is shown in table 2.

Table 2. Summary of well construction information for newly drilled wells in Clark County, Nevada.

[USGS, U.S. Geological Survey; NWIS, National Water Information System; ID, identifier; NDWR, Nevada Division of Water Resources; OD, outside dimension; DCR, depth to consolidated rock; WP, water production; gpm, amount of water pumped from well in gallons per minute; SCH, schedule; PVC, polyvinyl chloride; CR, carbonate rock; BF, basin fill; MR, mud rotary; AH, air hammer; >, greater than; —, no data; NA, not applicable]

Well name	USGS NWIS site ID	Map ID	NDWR log ID	Hole depth (feet)	Well depth (feet)	Diameter of casing (OD), in inches	Screened interval depth: From (feet)	Screened interval depth: To (feet)	Casing material	DCR (feet)	Aquifer completion	Drilling method	Well test data: WP (gpm)	Well test data: Time (hours)
BW-01	364204114454501	A	109838	1,928	1,926	4.500	1,786	1,926	SCH 80 PVC	595	CR	MR/AH	3 to 5	24
LSC-01	362454115270201	B	112697	905	890	6.625	336 808	417 889	SCH 40 steel	65	CR	MR	150	6
	(nested)		—	—	210	2.250	190	210	SCH 80 PVC	—	BF	MR	0 (dry)	0 (dry)
RB-01	362135114285401	C	113526	975	973	6.000	810	952	SCH 40 steel	755	CR	MR/AH	>150	3
BUFPKTS-01	362352114414501	D	114409	1,200	1,198	4.500	988	1,198	SCH 40 steel	221	CR	MR	20	10
IVPH-01	354849115225001	E	115275	1,295	1,290	4.500	1,065	1,275	SCH 40 steel	38	CR	MR/AH	30	10
JM-01	362901115220001	F	121811	1,103	1,080	4.500	200 780	300 1,080	SCH 40 steel SCH 40 steel	NA	BF	MR	50 to 75	50

Table 3. Total dissolved solids and concentrations of major ions in water samples collected from new wells in Clark County, Nevada.

[mm/dd/yyyy, month/day/year; mg/L, milligrams per liter; <, less than; CR, carbonate rock; BF, basin fill]

Well name	Date (mm/dd/yyyy)	Total dissolved solids (mg/L)	Calcium (mg/L)	Magnesium (mg/L)	Sodium (mg/L)	Potassium (mg/L)	Chloride (mg/L)	Sulfate (mg/L)	Carbonate (mg/L)	Bicarbonate (mg/L)	Principal contributing aquifer
BW-01	04/30/2010	616	60.8	24.4	101	11.0	56.3	195	< 1.0	264	CR
LSC-01	06/14/2012	249	45.1	28.2	5.0	1.46	2.90	21.4	< 1.0	246	CR
RB-01	04/09/2014	2,980	399	135	272	18.5	312	1,570	< 1.0	145	CR
BUFPKTS-01	04/10/2014	234	7.6	4.8	72.4	5.68	17.9	20.6	8.4	166	CR
IVPH-01	04/11/2014	499	67.1	38.2	53.9	3.33	105	86.4	< 1.0	210	CR
JM-01	03/14/2013	283	35.7	28.5	33.4	1.82	5.85	19.0	< 1.0	299	BF

Water Chemistry

Water-quality samples for major-ion chemistry and the stable isotopes of water (deuterium, $\delta^{2}H$, and oxygen, $\delta^{18}O$) were collected at each new well site, and results of analysis were compared to existing values from springs and wells near the drill sites. Total dissolved solids (TDS) and concentrations of calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), chloride (Cl), sulfate (SO_4), carbonate (CO_3), and bicarbonate (HCO_3) were measured by the USGS National Water Quality Laboratory (NWQL), in Denver, Colorado (table 3). Deuterium ($\delta^{2}H$) and oxygen ($\delta^{18}O$) isotopes were analyzed by the USGS Radiogenic Isotope Facility in Denver, Colorado (table 4).

Standard three-well-casing volumes were purged from each well, and water samples were collected with a submersible pump except at two sites (wells IVPH-01 and BUFPKTS-01) where samples were obtained through bailing. A 20-foot-long bailer was used to purge water from the well and collect a representative water sample.

Table 4. Isotopic ratios of deuterium ($\delta^{2}H$) and oxygen ($\delta^{18}O$) in water samples collected from new wells drilled in Clark County, Nevada.

[‰, deuterium (^{2}H) to protium (^{1}H) isotopic ratio relative to VSMOW; $\delta^{18}O$, oxygen-18 to oxygen-16 isotopic ratio relative to VSMOW; VSMOW, Vienna Standard Mean Ocean Water; ‰, per mil (parts per thousand)]

Well name	$\delta^{2}H$ (‰)	$\delta^{18}O$ (‰)
BW-01	−97.49	−12.89
LSC-01	−103.00	−13.98
RB-01	−91.70	−12.18
BUFPKTS-01	−82.50	−11.26
IVPH-01	−92.30	−12.71
JM-01	−95.67	−13.01

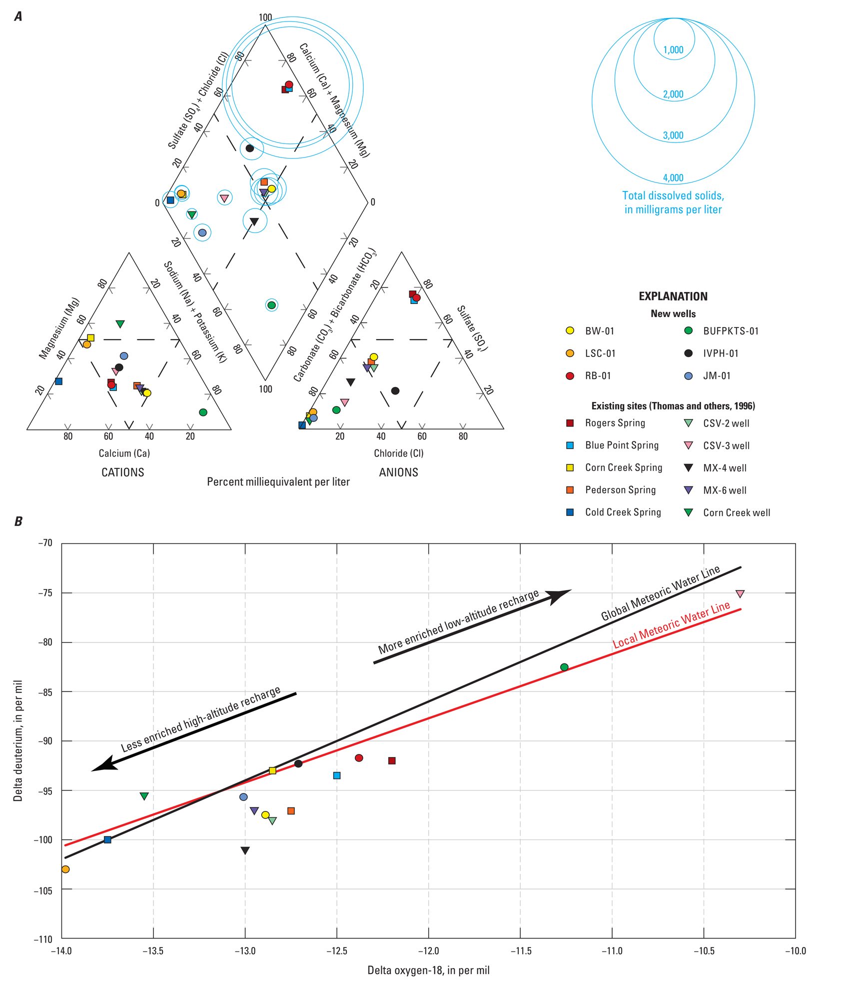

Figure 1. *A*, Total dissolved solids and major-ion concentrations in water samples collected from wells and springs associated with regional groundwater flow, and *B*, isotopic ratios of delta deuterium ($\delta^{2}H$) and delta oxygen-18 ($\delta^{18}O$) in samples collected from new and reference wells and springs in Clark County, Nevada (Global Meteoric Water Line [$\delta^{2}H = 8\times\delta^{18}O + 10$; Craig, 1961], and Local Meteoric Water Line [$\delta^{2}H = 6.5\times\delta^{18}O - 5.7$; Friedman and others, 1992]).

Major-ion chemistry is important to an understanding of the migration of water through a groundwater flow system. A Piper diagram (fig. 1A) can be used to evaluate the chemical characteristics of groundwater and the effects of chemical processes occurring between minerals and water. Groundwater samples from newly drilled wells show similar major-ion chemistry to previously sampled wells and springs (Thomas and others, 1996) that are assumed to represent groundwater from the regional carbonate-rock aquifer.

Isotopic ratios of $\delta^{2}H$ and $\delta^{18}O$ in water samples collected from wells drilled for this study and in samples previously collected from wells and springs, are compared to the Global Meteoric Water Line (GMWL) and a Local Meteoric Water Line (LMWL) on figure 1B. This plot provides a comparison of recharge from low-altitude and high-altitude precipitation sources to water from previously published data (Thomas and others, 1996).

Water-Level Information

Water levels from newly drilled wells were measured periodically from 2009 to 2015 and stored in the USGS NWIS database (https://waterdata.usgs.gov/nwis). These data were quality assured, which included evaluating measurements for temporal irregularity and adjustment due to known borehole deviation. Water levels were relatively stable throughout the duration of this project except for well BW-01, which experienced a decline of approximately 3 feet from January 2010 to May 2013, and a subsequent recovery of approximately 1 foot from June 2013 to June 2014.

Variations in borehole direction during drilling (drift) are common and can require corrections to water-level measurements. Borehole drift was monitored, and deviation was measured where drift was detected during the drilling of all new wells. The borehole at well BUFPKTS-01 was the only site that needed correction because borehole drift occurred above the depth of the static water level. The water level for this well was corrected using the equation from Elliott and Fenelon (2010):

$$V_d = \left(M_d - M_{top}\right) \times \left(\frac{\Delta V_{int}}{\Delta M_{int}}\right) + V_{top} \qquad (1)$$

$$V_d = M_d \times 0.993 - 3.45 \qquad (2)$$

where

V_d is the corrected vertical depth,
M_d is the measured depth,
M_{top} is the difference in the true vertical depth between the top of the correction interval,
ΔV_{int} is the difference in the measured top and bottom of the correction interval, and
ΔM_{int} is the difference in the measured top and bottom of the correction interval, and
V_{top} is the corrected vertical depth to the top of the interval over which the correction applies.

Regional Potentiometric Surface

Groundwater levels from the six wells drilled for this project and wells fitting the criteria described in the section "Selected Existing Hydrogeologic Data," were compiled and used to construct a groundwater-level map representing the regional potentiometric surface of the upper carbonate-rock aquifer in Clark County, Nevada, in 2009–2015. Data used to construct the potentiometric surface are published separately as a USGS data release (Wilson, 2019). This map is similar to the regional potentiometric surface shown on previous maps by Bedinger and Harrill (2010) and Brooks and others (2014). In general, the potentiometric surface on this map follows the overlying land-surface topography. Higher topographic altitudes typically have higher groundwater altitudes, hydraulic gradients generally are steeper near mountain ranges and low (flatten) in basins, and water-level contours parallel and intersect surface-water features.

Area on map	Description
A	In the Las Vegas and Sheep Ranges, and the Spring Mountains, mountain block recharge contributes to and directs regional groundwater flow in Clark County.
B	Water-level contours generally indicate groundwater flow to the east, terminating at discharge points along the Las Vegas Wash in the Las Vegas Valley, and the Muddy River near Moapa Valley.
C	A low water-level gradient near Moapa Valley indicates slow groundwater movement toward the Muddy River and Lake Mead.
D	A low water-level gradient in northeast Clark County indicates that groundwater in this area flows toward the Virgin River.

Summary and Conclusions

During 2009 and 2015, the U.S. Geological Survey in cooperation with the Bureau of Land Management installed six wells in Clark County, Nevada. The wells were installed to address the spatial gaps of wells completed in the carbonate-rock aquifer. This map describes new and existing water-level and hydrologic data in Clark County, and (1) develop a potentiometric map, and (2) provide additional supporting evidence for the direction of regional groundwater flow in the upper carbonate-rock aquifer in Clark County. Results from this study indicate that the Spring Mountains and the Las Vegas and Sheep Ranges provide primary recharge to the groundwater system in western Clark County. Additionally, potentiometric contours indicate eastward groundwater flow in much of Clark County that terminates at springs along Las Vegas Wash, the Muddy River, and the Virgin River. Previous maps by Bedinger and Harrill (2010) and Brooks and others (2014) show similar water-surface altitudes and gradients. This study introduces new water-level measurement sites that cover data gaps and support previous regional water-surface interpretations. Additionally, comparison of lithologic descriptions, geophysical logs, and groundwater chemistry from the six wells drilled during this study to existing data, substantiates that water levels in the new wells represent the regional carbonate-rock aquifer.

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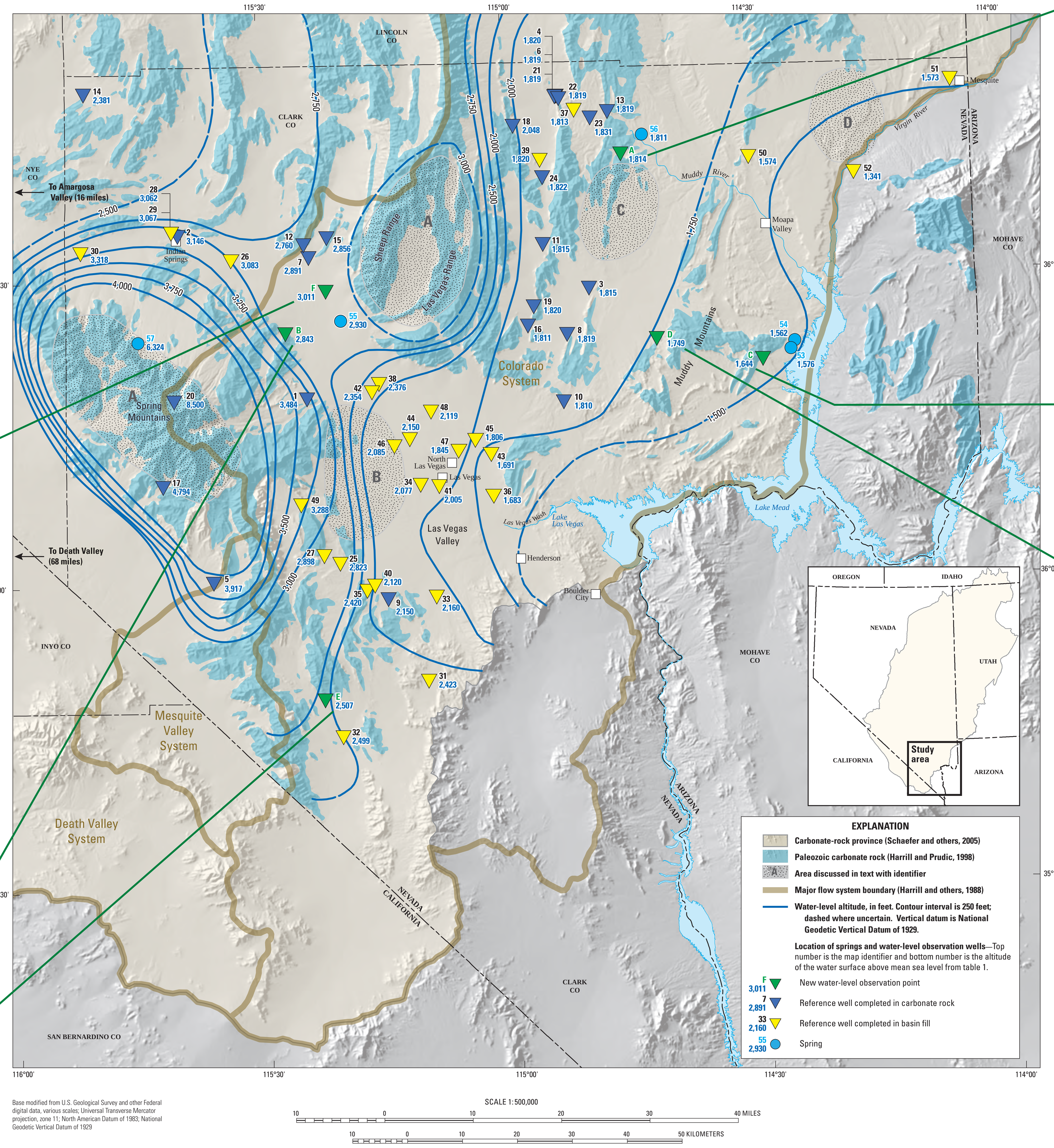

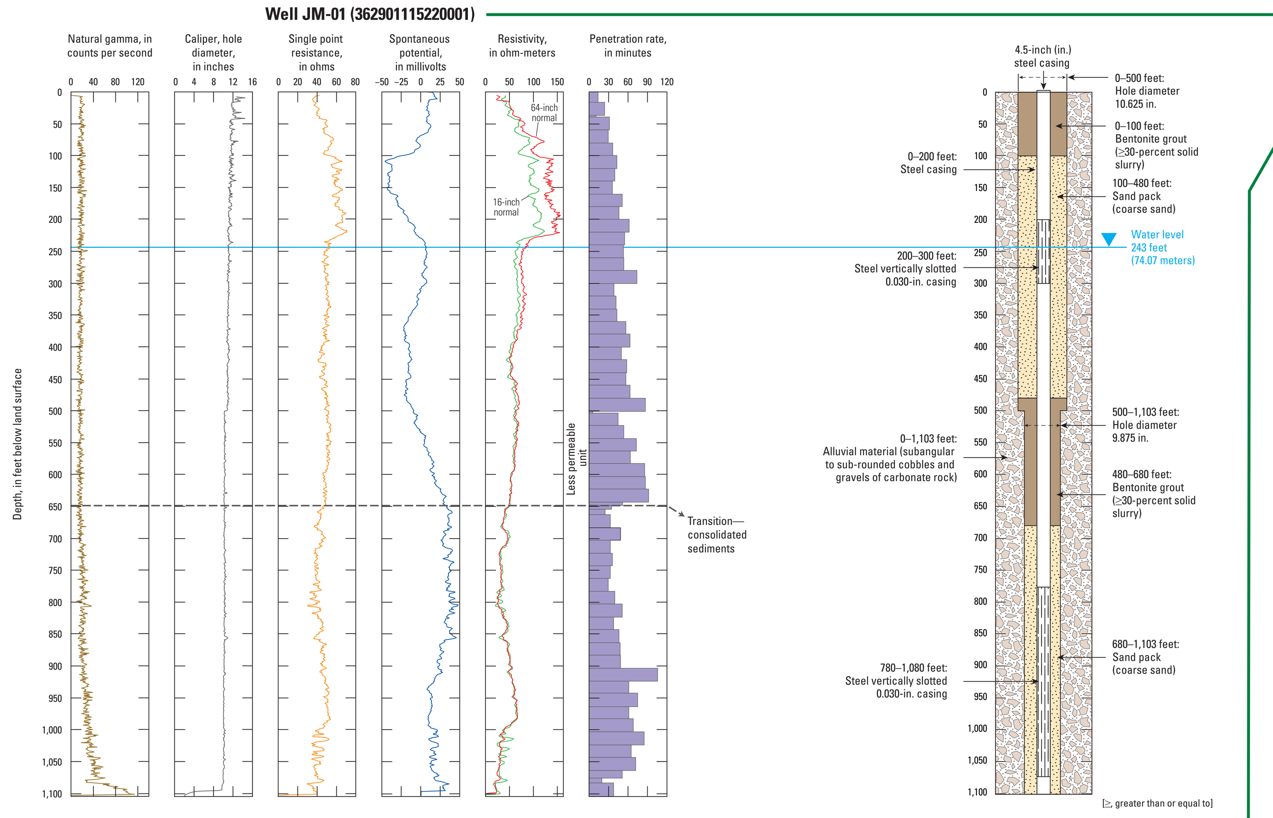

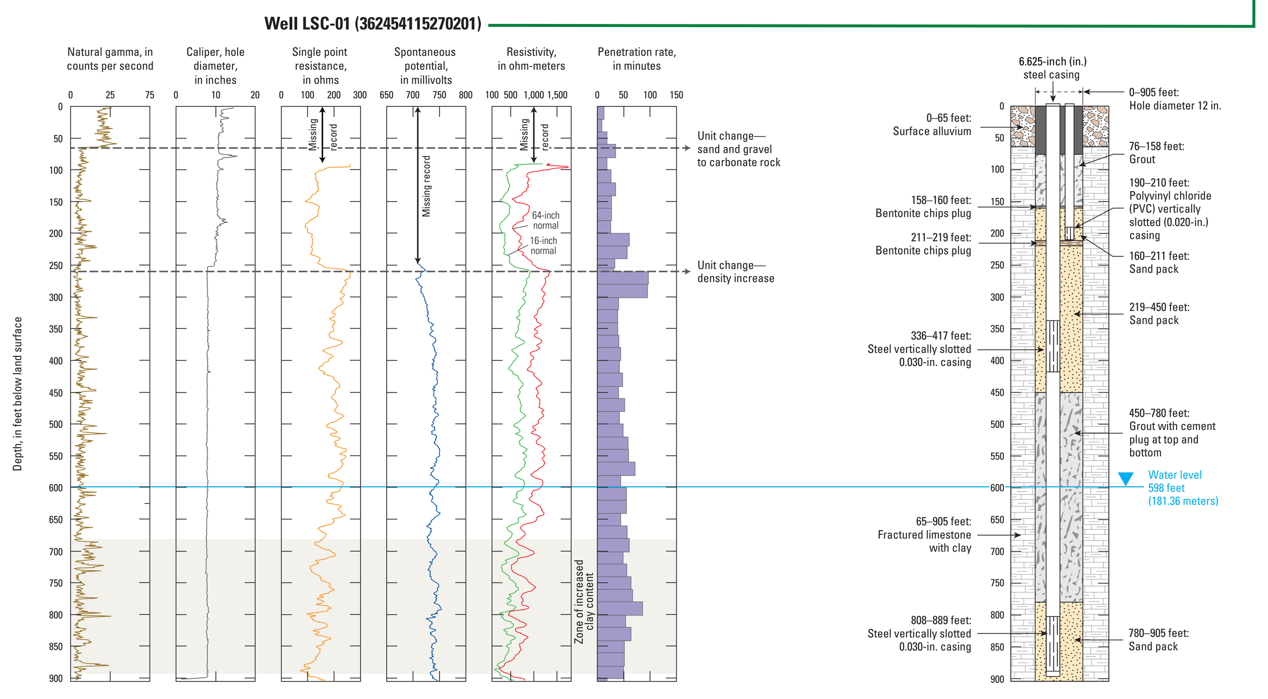

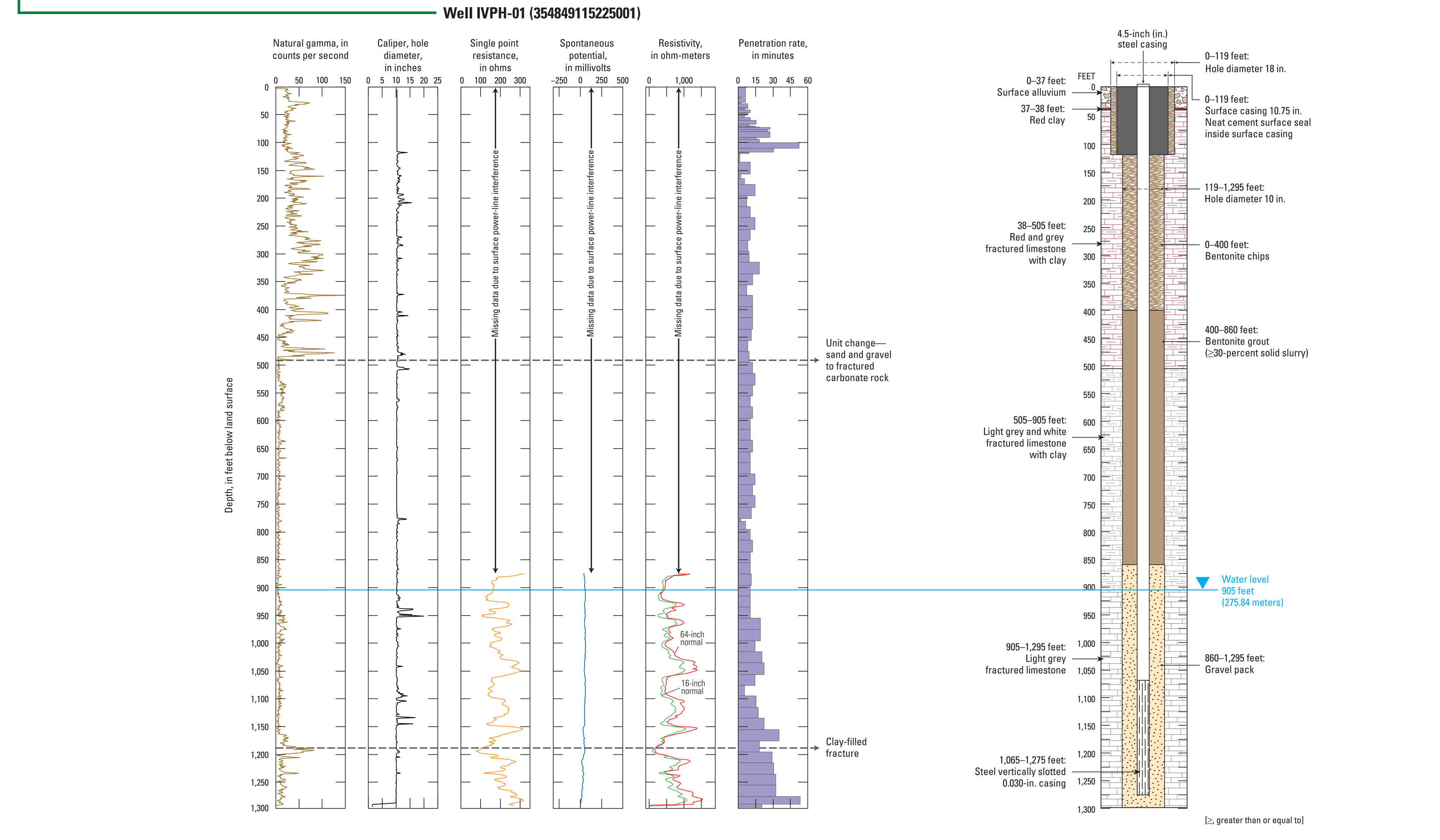

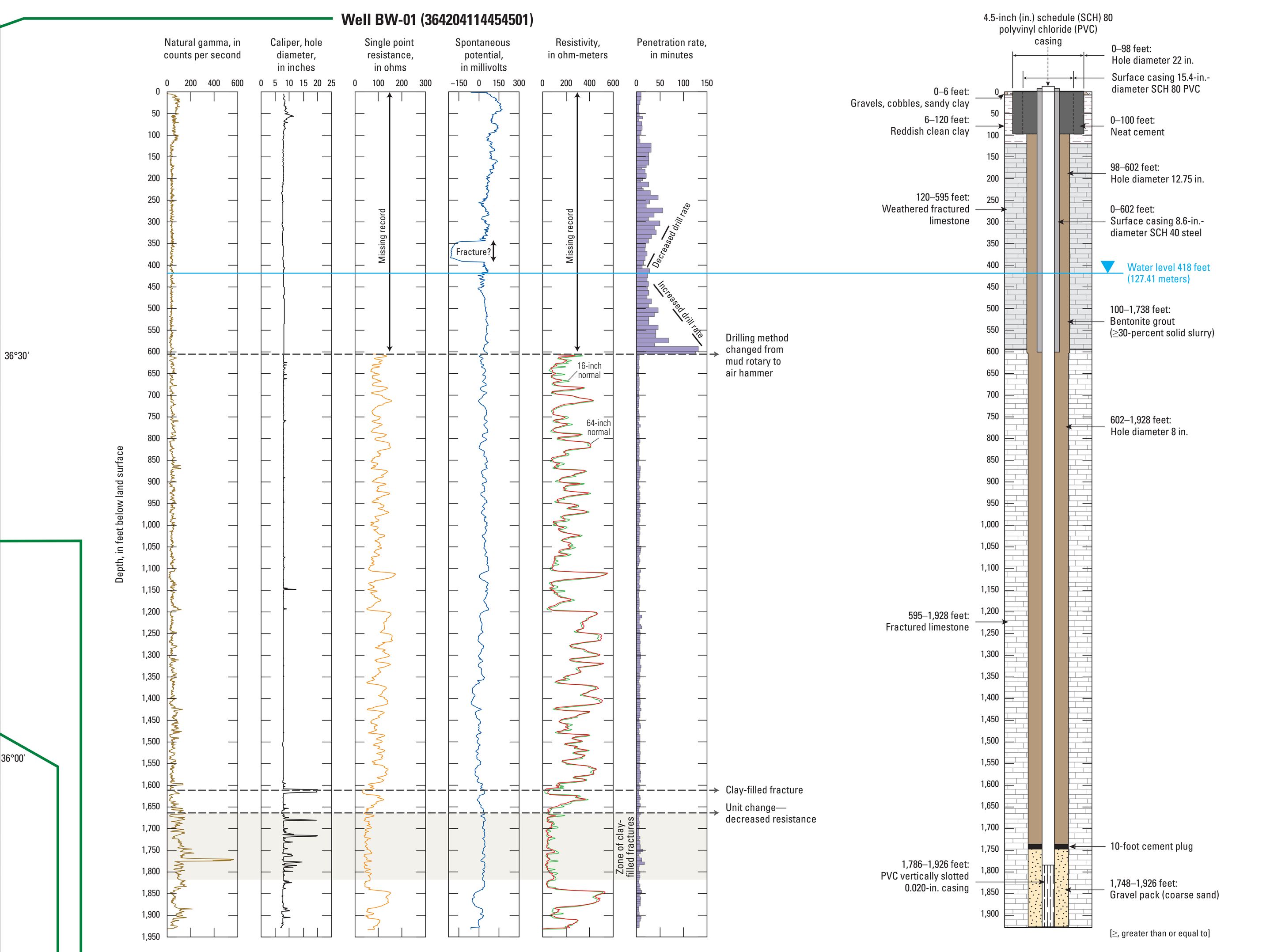

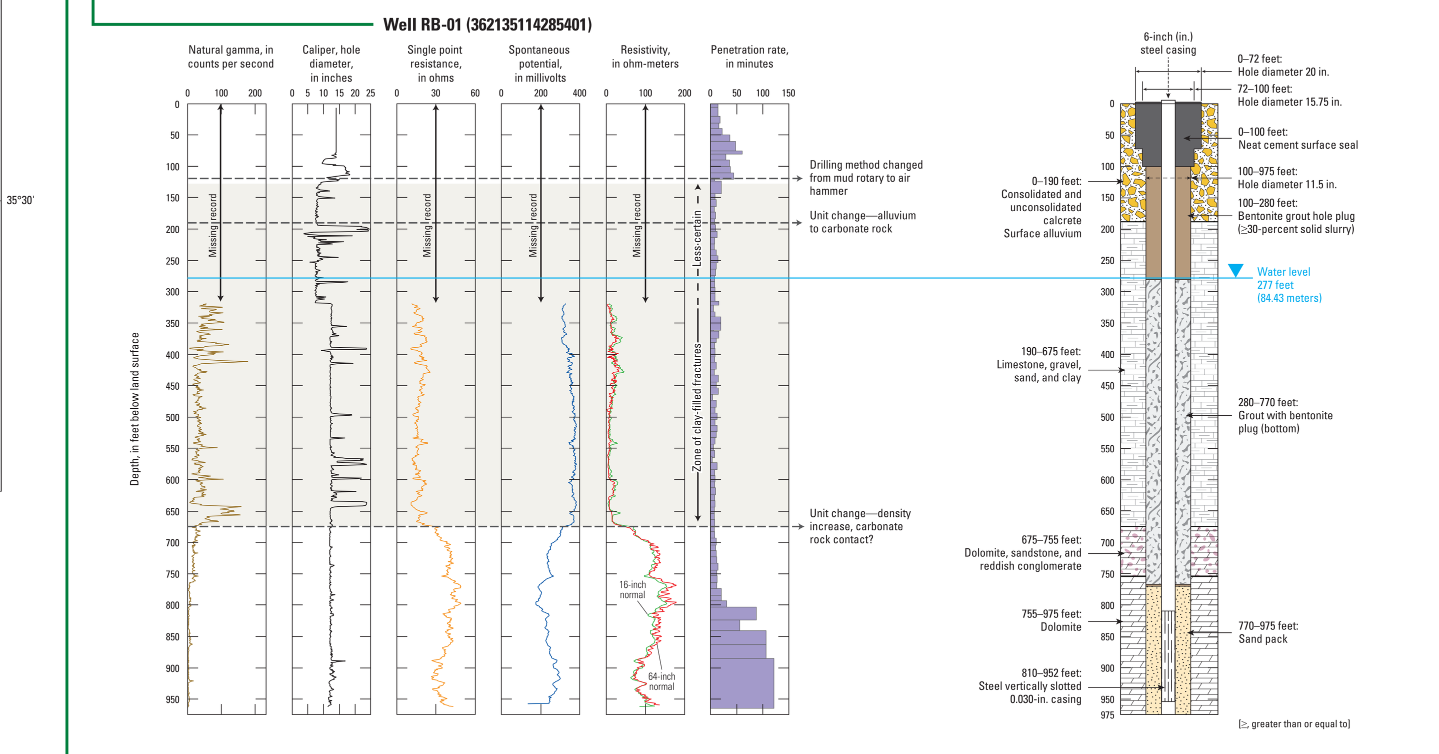

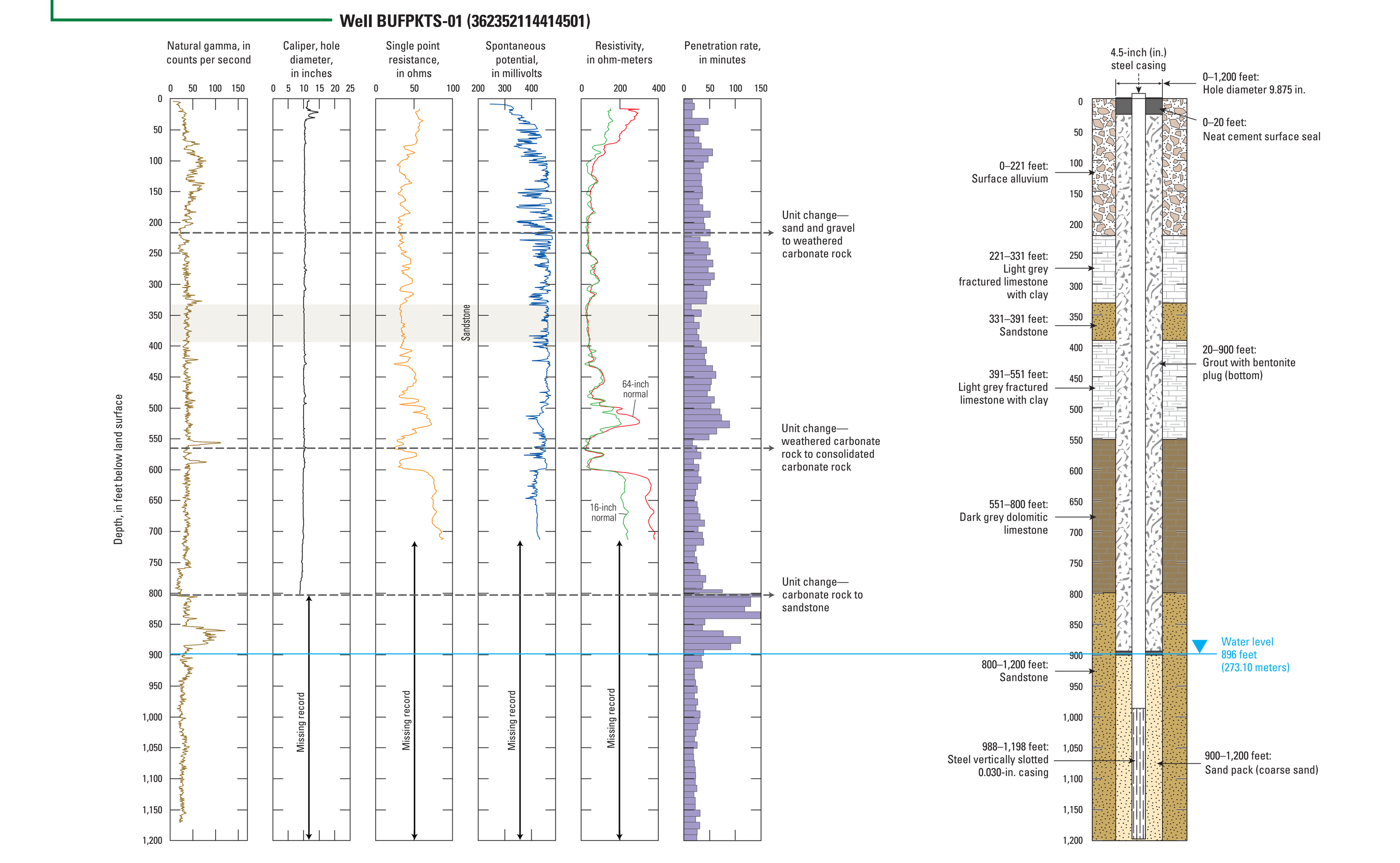

Drilling, Construction, Water Chemistry, Water Levels, and Regional Potentiometric Surface of the Upper Carbonate-Rock Aquifer in Clark County, Nevada, 2009–2015

By
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2019

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Environmental Isotopes in Hydrogeology

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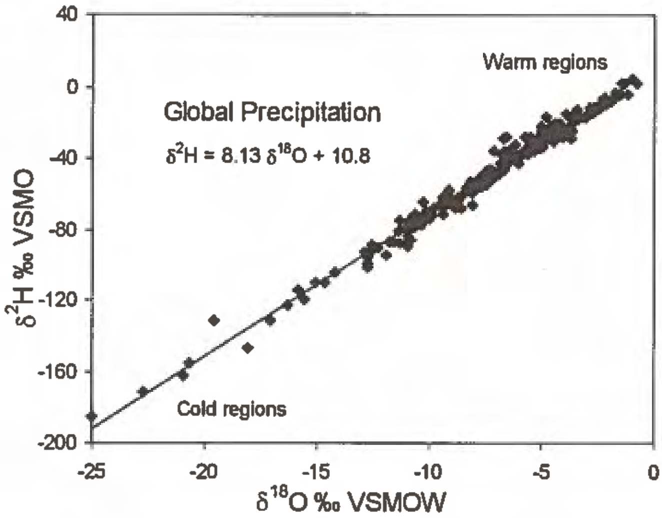

Fig. 2-1 The meteoric relationship for ^{18}O and ^{2}H in precipitation. Data are weighted average annual values for precipitation monitored at stations in the IAEA global network, compiled in Rozanski et al. (1993).

Partitioning of Isotopes Through the Hydrological Cycle

The meteoric relationship of ^{18}O and ^{2}H arises from fractionation during condensation from the vapour mass. However, it is a Rayleigh distillation during rainout that is responsible for the partitioning of ^{18}O and ^{2}H between warm and cold regions. The evolution of the $\delta^{18}O$ and $\delta^{2}H$ composition of meteoric waters begins with evaporation from the oceans.

Isotopic composition of ocean waters

The isotopic composition of modern seawater is close to VSMOW although it has varied considerably over geologic time. Carbonates precipitated from Archean and Proterozoic oceans which were up to 8‰ lighter in ^{18}O than those from modern seawater, indicating that the early earth's oceans were isotopically depleted and warmer than today (Veizer et al., 1989; 1992). The oceans became gradually enriched through Proterozoic and Phanerozoic time by exchange with isotopically enriched crustal rocks (Wadleigh and Veizer, 1992). This evolution of seawater occurs mainly through the alteration of basalts at mid-oceanic ridges and release of crustal fluids along subduction zones, both of which contribute ^{18}O to the oceans (Lawrence, 1989).

Shackleton and Opdyke (1973) show that the growth and decay of ^{18}O-depleted ice sheets during the late Cenozoic has imparted significant variations on seawater. These variations are recorded by the ^{18}O in calcite foraminifera which grow in equilibrium with the prevailing seawater and provide the SPECMAP record of global ice (Fig. 2-2). Corrected for mass-balance and temperature considerations, the difference between the highest $\delta^{18}O$ values during maximum glaciation and the lowest values during interglacial times is 1.5 to 2.0‰. Ocean sediment ($\delta^{18}O$) and water data are available through the U.S. National Oceanic and Atmospheric Administration at <**http://nodc.noaa.gov**>.

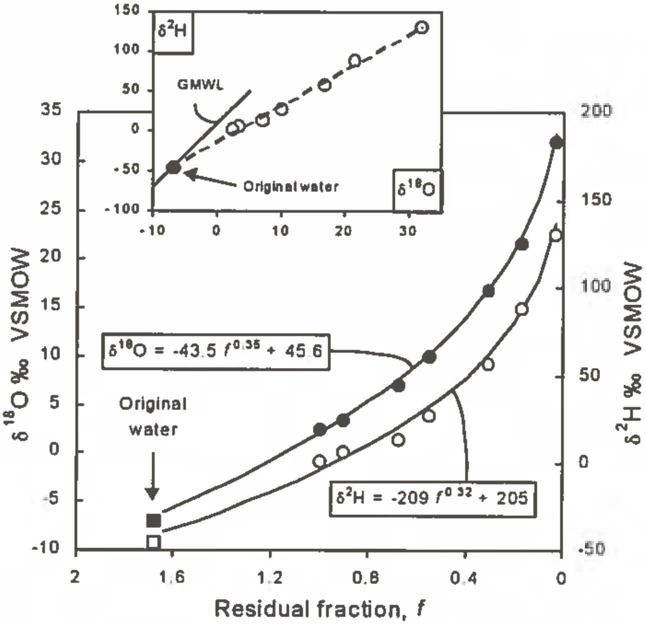

Fig. 2 -24 The strong enrichment in both ^{18}O and ^{2}H observed in an ephemeral lake during evaporation under extremely arid conditions in the Sahara desert (Gonfiantini and Fontes, 1967). Data (circles) are regressed with an exponential function and extrapolated to determine the original isotopic composition of the water, shown in square symbols ($\delta^{18}O$ = −7‰; $\delta^{2}H$ = −46‰). This gives residual water fractions greater than 1 and accounts for evaporative water loss prior to sampling. Inset shows the low slope of this enrichment trend (s = 4.5) due to evaporation under conditions of low humidity.

Evaporation of brines

Restricted basins show under conditions of extreme evaporation $\delta^{18}O$ values which increase asymptotically to a steady-state value controlled by the influx of fresh water, influx of ocean water, and relative humidity. However, as Fig. 2 -25 shows, the effects of solutes are important. The Dead Sea brines, which encrust the shores with salt, has a salinity exceeding 23% (7 x seawater), and yet a $\delta^{18}O$ value approaching only 4.5‰ VSMOW (Horita and Gat, 1989). The Red Sea brines, which have solute concentrations over 2 x seawater, are enriched in ^{18}O by about 2.5‰ above VSMOW. Deuterium is also enriched by evaporation, but because it is a nonequilibrium process, ^{2}H and ^{18}O fractionate differently.

These effects are discussed at length by Gonfiantini (1986). With increasing salinity (after 20 to 50% water loss for seawater), the decreased activity of water decreases the saturated water content in the boundary layer (h/a_w) and reduces the humidity contrast with the adjacent dry air.

At higher salinities, ion hydration imparts an isotope depletion on the water. The hydration sheath, particularly for polyvalent ions, is enriched over free water. For example, the hydration water for $CaCl_2$ in solution is 26‰ enriched over free water for ^{18}O and 341‰ enriched for ^{2}H (Sofer and Gat, 1975). As salts precipitate, the incorporation of crystallization water adds a further effect. These effects are evident in Fig. 2 -25 by a reversal in the evaporation trend. O'Neil and Truesdell (1991) have examined the fractionation of ^{18}O between CO_2 and concentrated aqueous solutions for insights into solute-water interactions. They provide measurements of fractionation between pure water and a variety of important aqueous solutes.

2. A southward gradient extends across the northern Yukon from the north coast, indicating vapour originating from the Beaufort Sea during summer.
3. Low values are found in the vicinity of the high latitude Mackenzie Mountains along the Yukon - Northwest Territories border.
4. The gradient across eastern maritime Canada indicating vapour arriving from the Atlantic, with the contouring of isopleths around the Appalachian Mountains due to the local alpine effect.

Recharge by snowmelt

Snow melt imparts an isotopic depletion on groundwater recharge although its $\delta^{18}O$ is modified by the melting process. During storage and spring thaw, two main processes modify the stable isotope distribution in the melting snowpack. One is sublimation and vapour exchange within the snowpack. The other is exchange between the snow and meltwater as it infiltrates from the melting upper surface through to the base of the snowpack.

The isotopic enrichment of evaporating snow surfaces at below-zero temperatures (–10 °C) was investigated experimentally by Moser and Stichler (1975). Their data document a kinetic isotopic enrichment similar to that of evaporating water, which indicates mass exchange between the vapour and snow (or ice) crystals (Fig. 4-6). Unlike evaporation of water, the high humidity within the snowpack permits a greater degree of equilibrium exchange between solid and vapour. The slope of the "evaporation" trend in Fig. 4-6 ($s = 5.75$) is therefore steeper than for evaporation of water from an open surface which is generally closer to 5 (Fig. 2-8). Friedman et al. (1991) show the importance of diffusion along the temperature gradient between the base of the snowpack and exterior, and the role of soil moisture diffusing into the snowpack.

When melting of the snowpack occurs, isotope exchange between meltwater infiltrating on snow surfaces and the snow itself will also cause isotopic enrichments. Data for a snow surface in southern Ontario (Fritz, unpublished) showed that $\delta^{18}O$ evolved from about –23‰ to –8‰ with a slope of close to 8 on the $\delta^{18}O$–$\delta^{2}H$ diagram. Runoff from this snow pack had a $\delta^{18}O$ of ~ –11‰, indicating that snowmelt is a mixture of melt from the original snow and an isotopically enriched snow surface. Similar results were found in an experiment undertaken by Bùason (1972), who melted a snow column from the top and noted a continuous enrichment in deuterium in the meltwater draining from the bottom.

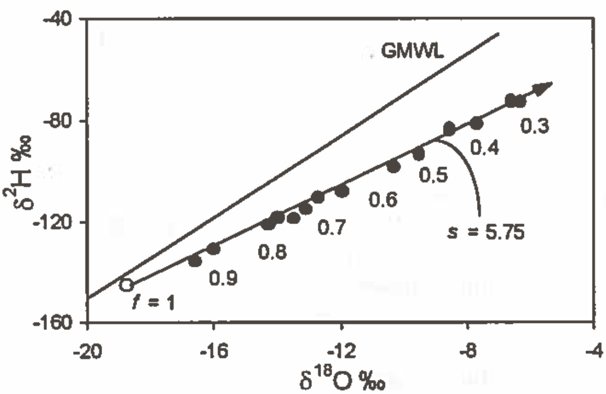

Fig. 4-6 Evolution of $\delta^{18}O$ and $\delta^{2}H$ in snow during evaporation under controlled conditions, with the fraction f of snow remaining during sublimation (Moser and Stichler, 1975).

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Investigation of the Origin of Springs in the Lake Mead National Recreation Area

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ABSTRACT

Increasing demands for water supply have accompanied rapid population growth in the Las Vegas Valley and portions of surrounding southern Nevada. Exploration and development of groundwater resources to meet these demands increases the potential for impact on groundwater systems to the north and west of the Lake Mead National Recreation Area. Because the park is located down-hydraulic-gradient from these areas, large-scale changes in groundwater use may affect groundwater resources and, ultimately, discharge from natural springs within the park. This study was conducted for the National Park Service to investigate the hydrology and hydrogeochemistry of selected springs in the Lake Mead and Black Canyon areas, and to determine the source areas associated with these springs.

Thirty six springs were visited and described. Historic geochemical data were compiled and supplemented by new stable and radioactive isotopic data. Three classifications of source area were defined, primarily based on hydrogeologic setting and stable isotopic data. Almost one third of the springs were found to discharge from local groundwater systems, many of which are entirely contained within the park boundaries. These springs are generally not related to major structural features and their stable isotopic values indicate that they receive most or all of their recharge locally and at low elevations, despite the minimal groundwater recharge generally assumed for low elevations in southern Nevada. A second set of springs was found to discharge groundwater that originates outside local flow systems, and therefore outside the park boundaries. Many of these springs are related to major, regional structural features, and their stable isotopic values are indicative of recharge at elevations higher than most of the region surrounding Lake Mead, although they do not appear to be directly related to regional groundwater flow from the White River Flow System or the Virgin River basin. Data obtained from a third set of springs, located below Hoover Dam in Black Canyon, suggests that these springs are strongly influenced by recirculated Lake Mead water, confirming earlier work.

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INTRODUCTION

Springs on the western edge of Lake Mead and in the Black Canyon of the Colorado River are important natural hydrologic features of the Lake Mead National Recreation Area. Although many springs are little more than seeps, their discharge represents the only available perennial surface flow in large portions of this arid region. These springs appear to originate from a variety of sources ranging from precipitation in local drainage basins to regional interbasin groundwater flow systems.

Rapid population growth in portions of southern Nevada, particularly in the Las Vegas Valley, has increased the need for additional water supplies in the area, including groundwater. As a result, there has been a dramatic increase in the potential for additional large-scale development of groundwater resources to the west and north of Lake Mead, areas which are hydraulically upgradient of many of the springs. If large-scale development of groundwater resources occurs in source areas or along flow paths leading to springs, the discharge of these springs could be impacted.

To address concerns regarding potential impacts on spring resources, and to plan for their management and protection, the National Park Service (NPS) requires scientific information on the hydrology and hydrogeochemistry of springs near Lake Mead, and particularly whether the waters are of local or regional origin. This investigation was undertaken to: 1) provide a comprehensive database of spring chemical and isotopic composition; and 2) determine the source areas of and flow paths to selected springs.

Geography and Climate

The waters of the Colorado River impounded by Hoover Dam form Lake Mead and divide southeastern Nevada from northwestern Arizona (Figure 1). The lake is located near the transition between the Great Basin and Colorado Plateau physiographic provinces. Elevations in the region adjacent to the lake are generally less than 1000 m (all elevations given in this report are referenced to mean sea level), and range from about 200 m at the Colorado River below Hoover Dam to over 1600 m in the Muddy Mountains. The highest mountain ranges in southern Nevada are the Spring Mountains (3630 m) and the Sheep Range (3020 m) which rise 60 km to the west and northwest, respectively, of Lake Mead.

The climate is one of extremes, ranging from arid in the low elevation basins, where the highest temperatures and lowest precipitation amounts in the Great Basin occur, to sub-humid in the higher mountains. In the Las Vegas Valley, the mean summer temperature at an elevation of 640 m is 30.8°C and the mean annual precipitation is 10.4 cm (Western Regional Climate Center, 1997). Orographic effects cause precipitation amounts to increase with elevation such that the upper elevations of the Spring Mountains receive up to 70 cm of precipitation annually (Malmberg, 1961).

Annual precipitation trends show a pronounced seasonality, with maximum amounts typically received in December and August. Winter precipitation generally falls as long-duration, low-intensity frontal storms derived from moisture moving eastward from the Pacific Ocean, while summer precipitation originates to the south in the Gulf of California and the Gulf of Mexico and is often delivered as short-duration, intense thunderstorms (Quiring, 1965; French, 1983). The rainshadow effect of the Sierra Nevada Mountains in the winter and the incomplete flow of moisture

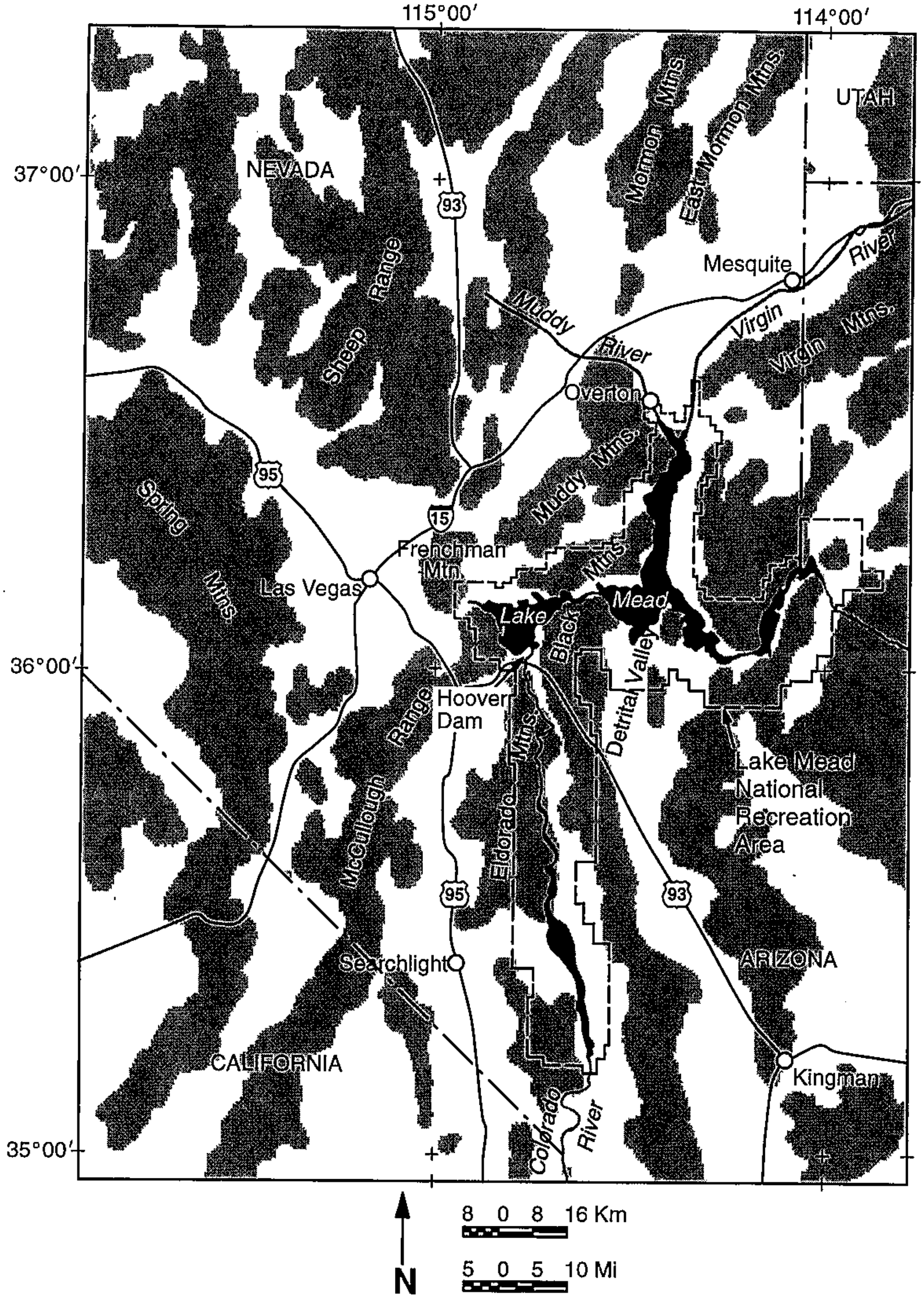

Figure 1. Location of the study area in southeastern Nevada and northwestern Arizona.

from the south in the summer forms a zone of precipitation deficit in the western portion of southern Nevada (Quiring, 1965). The eastern portion is less affected by the Sierra Nevada rainshadow and is open to the flow of moisture from the south in the summer, thus causing a zone of precipitation excess.

Estimates of groundwater recharge from precipitation in Nevada are commonly developed using the Maxey-Eakin method (Maxey and Robinson, 1947; Maxey and Eakin, 1949), which is based on empirically-derived relationships between precipitation and recharge in several groundwater basins in the state. In the Las Vegas Valley, the Maxey-Eakin method predicts that groundwater recharge is negligible where annual precipitation is less than 25.4 cm, corresponding to elevations below approximately 1800 m (Maxey and Robinson, 1947). Below this elevation, the estimated annual precipitation volume is calculated to be lost to evapotranspiration (due to high air temperatures and low humidity) and surface runoff (due to sparse vegetation and low-permeability soils). Thus, on the scale of groundwater basins, recharge is considered to be minimal in much of southern Nevada.

Previous Studies of Springs in the Region

Chemical and isotopic data are available for numerous springs in southeastern Nevada, primarily as a result of the Nevada Carbonate Aquifer Program studies. Lyles *et al.* (1987) compiled chemistry data for wells and springs in Nevada within a 160 km radius of Las Vegas. Thomas *et al.* (1991) compile a similar database, but include isotopic data collected from wells, springs, and streams. Thomas *et al.* (1997) supplement the earlier database with data from additional sampling sites, describe chemical and isotopic processes and composition of groundwater in basin-fill and carbonate aquifers, and delineate flow systems in the carbonate rocks of southern Nevada. Studies of hydrogeologic resources pertinent to the present study have been conducted by Laney (1981) and Laney and Bales (1996) as part of an ongoing series of reconnaissance studies of the Lake Mead National Recreation Area. These reports provide physical descriptions, geologic setting, and chemical data for many of the springs. In the only detailed interpretive study of springs within the recreation area, McKay and Zimmerman (1983) investigated springs in Black Canyon using hydrogeochemical, stable isotope, and tritium data. Finally, the Southern Nevada Water Authority (SNWA) has initiated an investigation of the origins of groundwater issuing from springs on the Nevada side of Black Canyon, collecting extensive chemical and isotopic data.

Acknowledgements

The authors wish to thank Paul Christensen of the National Park Service, Water Resources Division, for facilitating this research and providing guidance in the early going. Bill Burke and the Resource Management staff at the Lake Mead National Recreation Area are thanked for providing background information on the history and locations of the springs. Alan McKay of the Desert Research Institute and James Thomas of the U.S. Geological Survey are thanked for invaluable insights into the hydrogeology of the region. The majority of this work was funded by the National Park Service.

METHODOLOGY

The chemistry of groundwater is a result of the type and amount of minerals present in the rocks through which the groundwater moves, and the conditions of recharge and discharge. Generally groundwater chemistry evolves along flow paths from recharge areas to discharge areas as geochemical reactions occur between the water and rock. At the local scale, however, local geologic complexity can lead to large variations in groundwater chemistry.

Although flow paths that supply groundwater to springs can be described using the geochemistry of spring discharge, delineation of recharge sources is often more effectively approached using the spring's isotopic composition. Because the principal objective was to delineate groundwater source areas, this study focused on several stable and radioactive isotopes in groundwater. Ratios of the stable isotopes in water molecules, oxygen-18 (^{18}O) to oxygen-16 (^{16}O) and deuterium (D) to hydrogen (^{1}H), often provide more definitive identification of source areas for groundwater than water chemistry. In addition, the radioactive isotopes tritium (^{3}H) and carbon-14 (^{14}C) can be used to determine relative ages of groundwater. A relatively young age reflects the dominance of local recharge and short residence times, while an older age reflects a longer residence time and often indicates lengthy travel times in regional flow systems. Finally, radioactive isotopes of uranium (^{234}U and ^{238}U) can be used for tracing groundwater masses from recharge areas to discharge areas. Background information on these techniques is provided below for ease of reference.

The stable isotopes D and ^{18}O are useful tools for tracing groundwater because, unlike major ion geochemistry, stable isotopic composition is essentially unchanged by the rocks through which groundwater travels (under non-geothermal conditions). The stable isotopic composition of groundwater recharge is related to the temperature, amount, distance from the ocean, and altitude of precipitation (Mazor, 1997), therefore, groundwaters originating in a common source area often share similar stable isotopic composition. Stable isotopes are particularly useful in this study because the pervasive gypsum deposits and other evaporites in the region cause dramatic changes in groundwater geochemistry near spring discharge areas, effectively masking the original geochemical composition of the groundwater.

The stable isotope ratio $^{13}C/^{12}C$ (expressed in a delta notation as $\delta^{13}C$) is very sensitive to biologic processes and thus there can be large differences in $\delta^{13}C$ of carbon subjected to differing photosynthetic, bacterial and other processes. Recharge water, percolating through soils, dissolves CO_2 gas that has a $\delta^{13}C$ signature characteristic of the local plant cover. Reactions with carbonate rocks impart enriched $\delta^{13}C$ values, sensitive to the carbonate origin in pedogenic and marine deposits. In addition to this tracing function of $\delta^{13}C$, the isotope is also used to correct ^{14}C groundwater ages for dilution by dissolved rock carbon. ^{14}C is a radioactive isotope present in dissolved inorganic carbon in groundwater. As such, ^{14}C does not provide a direct age measurement of the water, as tritium does, but requires an understanding of the source of the dissolved inorganic carbon for correct interpretation (Mook, 1980). The long half-life of ^{14}C (5730 years) makes it useful for dating groundwaters with residence times in excess of several decades.

The radioactive isotope tritium provides a semi-quantitative means for dating groundwater with residence times of several decades or less (Mazor, 1997). Groundwaters having tritium concentrations below 5 pCi/L are considered to be derived primarily from recharge prior to the onset of atmospheric testing of nuclear bombs in 1952, while groundwaters having concentrations greater than 5 pCi/L are considered to have at least some component recharged after 1952. Due to its short half life (12.3 years), tritium concentrations in atmospheric precipitation have declined since the period of maximum testing in 1962. In 1994 through 1996, tritium concentrations in southern Nevada precipitation ranged between 10 and 20 pCi/L in the winter and between 20 to 60 pCi/L in the summer (Dennis Farmer, U.S. EPA, personal communication). This cycle between winter lows and summer highs is observed worldwide and is related to the circulation of moisture in the upper atmosphere (Roether, 1967).

The radioactive isotopes of uranium can be useful groundwater tracers because of their high solubility, insensitivity to chemical reactions, and long half-lives (Osmond and Cowart, 1976; Cowart, 1979). They are especially useful in southern Nevada because of the wide range of natural uranium concentrations in the groundwaters of the region (Farmer, 1996). Since uranium is presently less widely-used for tracing groundwater than the isotopes described above, a more detailed description of the method follows. Uranium is a naturally-occurring element which dissolves in groundwater when dilute recharge waters interact with uranium-bearing minerals in the subsurface. The vast majority (99.725 percent) of natural uranium occurs as the isotope ^{238}U, which has a half-life of 4.46×10^9 years. The radioactive decay of ^{238}U produces ^{234}U, which comprises about 0.005 percent of naturally-occurring uranium, and has a half-life of 2.45×10^5 years.

The activity of a radionuclide is defined by the equation $A = N\lambda$, where A is the activity of any radionuclide, N is the number of atoms of that nuclide present in the system being examined, and λ is the decay constant for that nuclide (Osmond and Cowart, 1976). The value of λ indicates the number of disintegrations an isotope undergoes per unit time, and is thus inversely proportional to the half-life of an isotope. The activity equation shows that two radionuclides that have significantly different numbers of atoms present in a system can have the same activities if their half-lives are sufficiently different. This proves to be the case with ^{234}U and ^{238}U, which, in closed geologic systems (such as unweathered rocks), tend to achieve a state known as secular equilibrium, where the activity of ^{234}U (low number of atoms, but relatively short half-life causing a high number of decays per unit time) and that of ^{238}U (high number of atoms, but relatively long half-life causing a low number of decays per unit time) become equal. It takes approximately 10^6 years from the time of formation for a system to achieve this secular equilibrium (Osmond *et al.*, 1968).

^{234}U and ^{238}U tend to achieve secular equilibrium in closed geologic systems. However, in natural rock-groundwater systems, disequilibrium between ^{234}U and ^{238}U is quite common (Thurber, 1962) and thought to be present due to side effects resulting from the radioactive decay process (Gascoyne, 1992). Disequilibrium is typically quantified via the $^{234}U/^{238}U$ activity ratio (AR). A system in secular equilibrium would have an AR equal to one; a system with "excess" ^{234}U activity would have AR greater than one, and a system with "excess" ^{238}U would have an AR less than one. The majority of groundwaters exhibiting disequilibrium show AR greater than one, indicating an excess of ^{234}U (Osmond and Cowart, 1976).

Uranium has two naturally occurring valence states (+4 and +6). U^{6+}, which is present in oxidizing conditions, is soluble, while U^{4+}, which predominates in reducing conditions, has an extremely low solubility, and is thus considered immobile. The presence of reducing conditions can greatly complicate the analysis of uranium, but the waters sampled for this study consistently showed dissolved oxygen content indicative of oxic waters (Table A-1). Although deep groundwater is typically thought to be anoxic, deep waters in Nevada and other parts of the Basin and Range physiographic province are commonly found to be oxic (Winograd and Robertson, 1982).

Most of the springs in the present investigation have been visited and described during the studies described above, and discharge measurements, chemical indicator measurements, and water chemistry analyses are available. However, few of the springs have been sampled for stable and radioactive isotope analysis. The historic inventories and previous studies provided a basis for identifying the locations of springs and for the building of the present database of physical, chemical, and isotopic data. Data collection for the present study focused on isotopic constituents.

All of the springs were visited at least once during the course of this study. Spring coordinates were determined using a Magellan 9500 Pro hand-held GPS unit in autonomous mode. Low discharge rates were measured using a beaker and stopwatch and high discharge rates were measured using a Marsh-McBirney Flo-Mate 2000 flow meter. Field measurements were made of temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), and alkalinity (HCO_3) using standard field analytical equipment. The physical, chemical, and isotopic data derived from previous studies, and data collected for the present study, are compiled in Appendix A. Geologic descriptions and sketch maps were developed for each spring area and are included in Appendix B. Isotopic data for selected southern Nevada groundwaters are compiled in Appendix C.

This report describes thirty-six springs which are located in two general areas (Table 1). One is the Lake Mead basin, including the area west of the Overton Arm and the area north of Lake Mead (Figure 2). The other is the area of the Black Canyon of the Colorado River, downstream of Hoover Dam (Figure 3).

GEOLOGIC SETTING

The Lake Mead National Recreation Area is located near the eastern margin of the Basin and Range geologic province, a region comprised of broad, flat-lying valleys underlain by thick alluvial deposits and bordered by narrow, nearly parallel mountain ranges. Situated between mountain ranges composed of Paleozoic to Mesozoic sedimentary rocks and a Precambrian terrain intruded by Cenozoic igneous rocks (Figure 4), the recreation area lies near the southeastern end of the regional carbonate-rock aquifer system. This large aquifer system is defined as the area where 80 percent of the measured section is over 50 percent carbonate rock (Mifflin, 1968), and underlies 260,000 km^2 of eastern Nevada, western Utah, southeastern Idaho, and extreme southeastern California (Dettinger, 1989). Table 2 presents a simplified stratigraphic column used in the present study.

Table 1. Identification Numbers and Names of Springs Included in this Study. Names in the Lake Mead basin are official names. Names in Black Canyon are unofficial names given by McKay and Zimmerman (1983), with the exception of springs given unofficial names by the National Park Service.

ID	Name	Comments
		Lake Mead Basin
1	Kelsey Spring	
2	Unnamed	Located in Magnesite Wash
3	Unnamed	Located in Kaolin Wash
4	Getchel Spring	
5	Unnamed	Uppermost Spring in Valley of Fire Wash
6	Unnamed	Upper Spring in Valley of Fire Wash
7	Unnamed	Lower Spring in Valley of Fire Wash
8	Blue Point Spring	
9	Unnamed	Located 0.8 km south of Spring 8
10	Unnamed	Located 0.8 km southeast of Spring 9
11	Rogers Spring	
12	Scirpus Spring	
13	Corral Spring	
14	Unnamed	Located northwest of Rogers Bay
15	Bitter Spring	
16	Sandstone Spring	
17	Cottonwood Spring	
18	Gypsum Spring	
19	Unnamed	South of Rainbow Gardens
		Black Canyon
20	Pupfish Spring	
21	Arizona Hot Spot	
22	Sauna Cave	
23	Nevada Hot Spring	NPS name, "Fort Lucinda" of McKay and Zimmerman (1983)
24	Nevada Hot Spot	
25	Palm Tree, Hot	
26	Palm Tree, Cold	
27	Unnamed Spring	Located in Horsethief Canyon
28	Boy Scout Canyon, Hot Spring	NPS name, "Rifle Range" of McKay and Zimmerman (1983)
29	Boy Scout Canyon, Cold Spring	
30	Arizona Hot Spring	NPS name, "Ringbolt Rapids" of McKay and Zimmerman (1983)
31	Unnamed	Cold Spring located near Arizona Hot Spring
32	Nevada Falls	
33	Bighorn Sheep Spring	
34	Arizona Seep	
35	Latos Pool	
36	Unnamed	Located in Aztec Wash

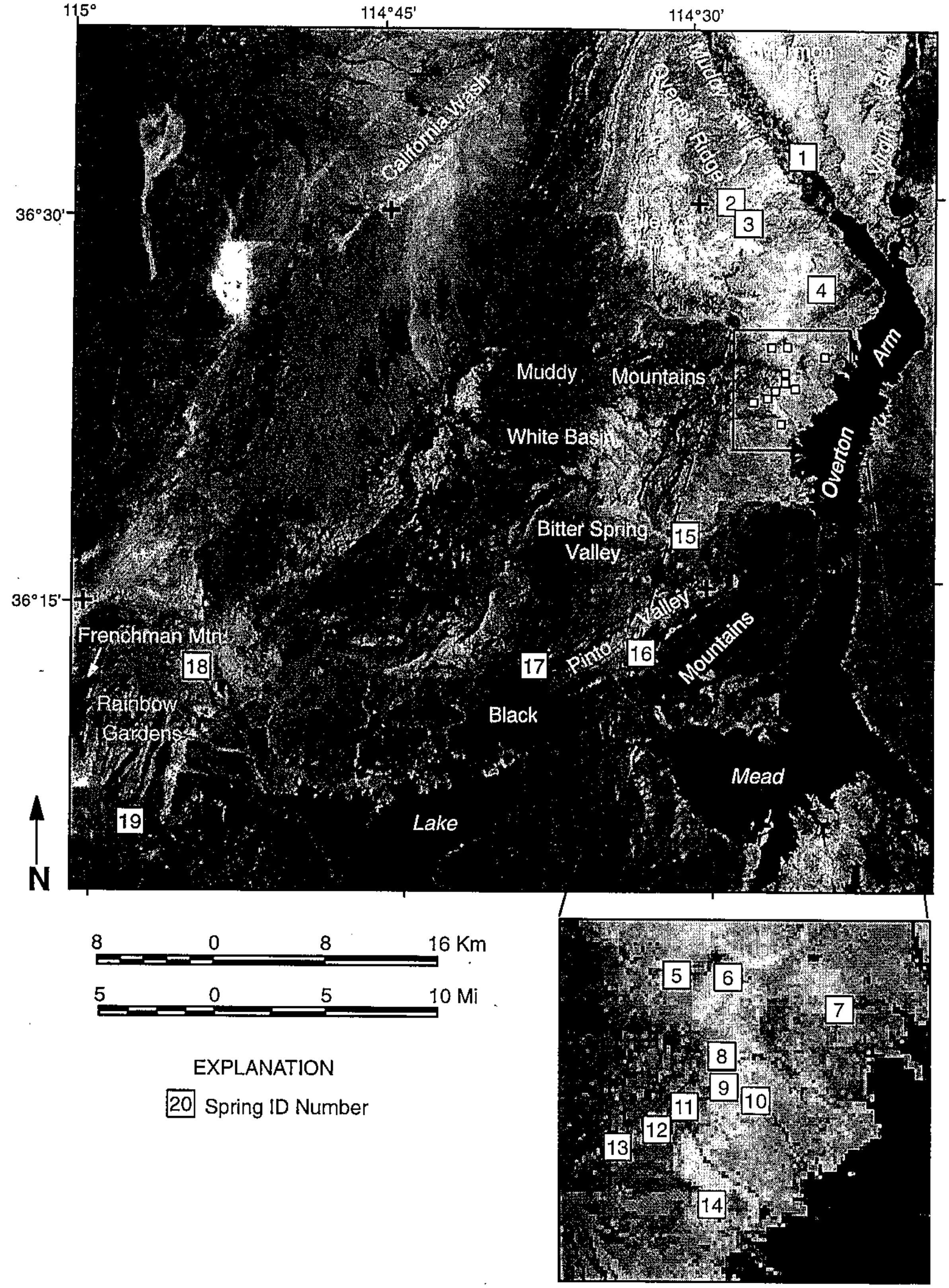

Figure 2. Locations of springs in the Lake Mead basin. Detail shows springs in the North Shore complex.

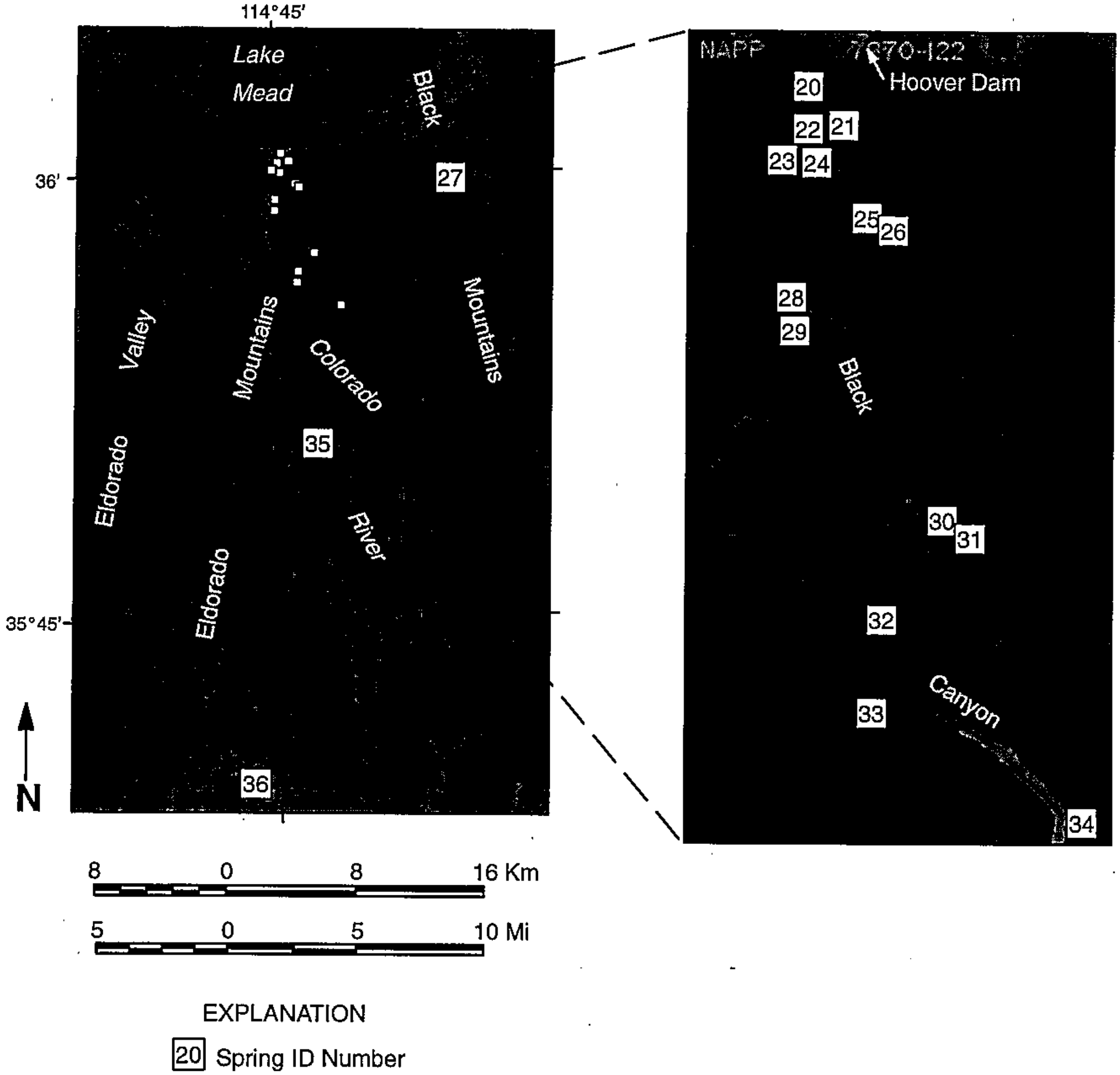

Figure 3. Locations of springs in the Black Canyon area. Detail shows springs in Black Canyon proper.

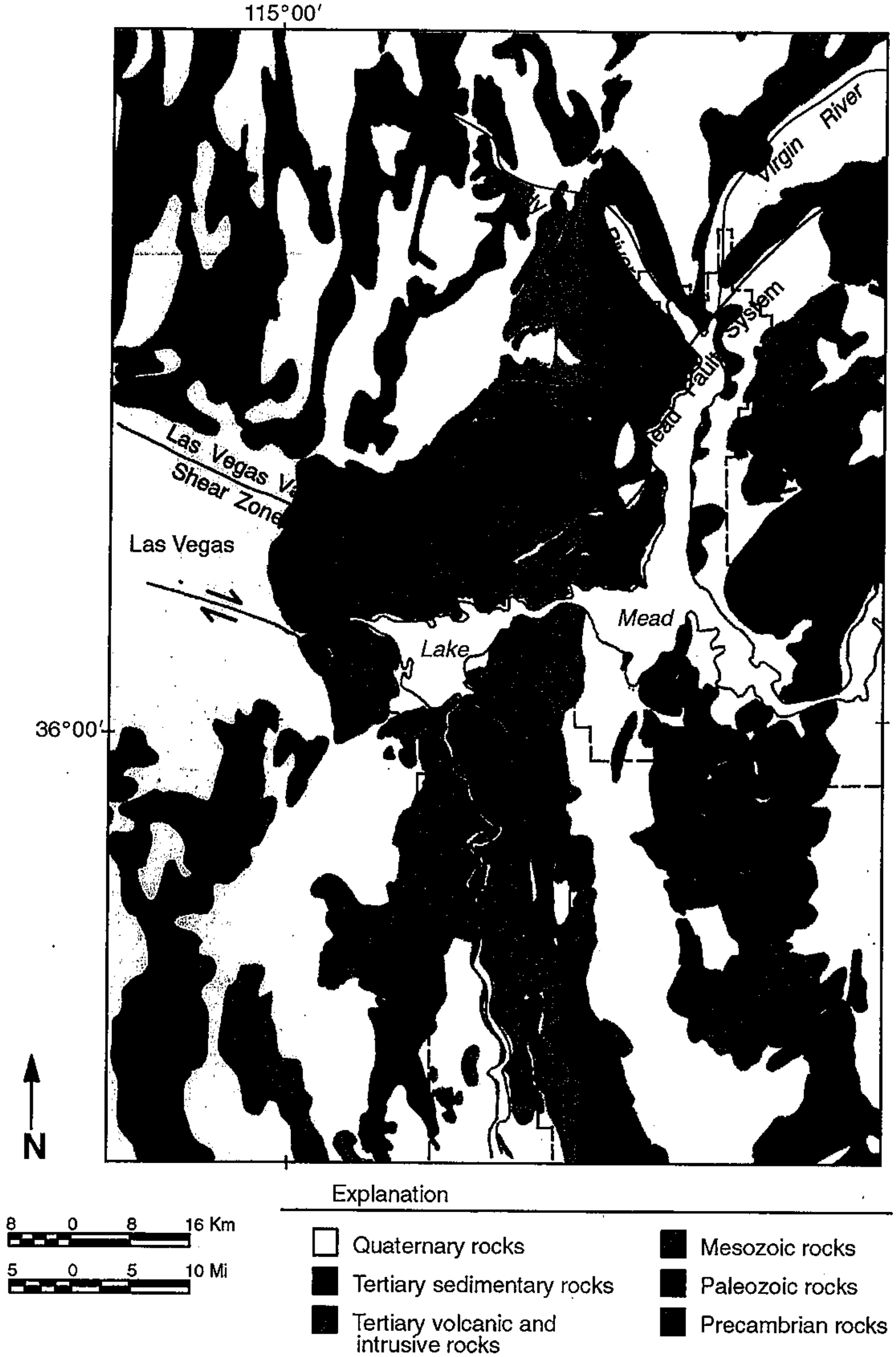

Figure 4. Generalized geologic map of southeastern Nevada and northwestern Arizona. Modified from Longwell *et al.* (1965), Reynolds (1988), and Campagna and Aydin (1994).

Table 2. Generalized Stratigraphic Column for the Study Area.

Time		Unit	Symbol	Description and Reference
Cenozoic	Quaternary	Alluvium (Holocene to Pleistoncene?)	Qal	Silts, sands, pebbles, cobbles, and boulders in modern drainages. Angular to subrounded particles. Unconsolidated, locally derived. (Bohannon, 1984).
		Older Alluvium (Pleistocene)	Qoa	Silt, sand, pebbles, cobbles, and boulders in alluvial fans, thick colluvial deposits, alluvial flood plains, and channels. Poorly sorted, angular to subround unconsolidated particles. Locally derived. (Bohannon, 1984).
		Terrace Deposits (Pleistocene?)	Qt	Silt, sand, pebbles, cobbles, and boulders. Compacted and/or cemented. Locally derived. (Bohannon, 1984).
	Tertiary	Miocene Volcanics (undifferentiated)	Tmv	Lava flows of Callville Mesa and Overton Arm and intrusive rocks north of Callville Mesa, western Bitter Spring Valley, and northeastern Muddy Mountains. (Bohannon, 1984).
		Muddy Creek Formation	Tm	Bedded siltstone, sandstone, gypsum, gypsiferous siltstone, and conglomerate near basin margins. (Bohannon, 1984).
		Horse Spring Formation	Th	Limestone, dolomite, conglomerate, sandstone, volcanic tuff, gypsum and breccia. Includes clastic and gypsum facies of the Thumb Member. (Bohannon, 1984).
		Rainbow Gardens Basal Conglomerate	Thrc	Conglomerate consisting of sandstone, siltstone, gypsum, gypsiferous siltstone, carbonates, and magnesite. Lowest unit in the Horse Spring Fm, and marks the Tertiary unconformity. (Bohannon, 1984).
		Mount Davis Volcanics (undifferentiated)	Td	Miocene lava and flow breccias. (Anderson, 1978).
		Intrusive Rocks (undifferentiated)	Ti	Miocene intrusive rocks. Includes the Boulder City pluton, a mixture of medium-grained granodiorite and andesitic border facies (Anderson, 1969), and the Wilson Ridge pluton, a biotite granite through horneblende-biotite granodiorite to pyroxene-biotite diorite. (Anderson, 1978).
		Patsy Mine Volcanics (undifferentiated)	Tpv	Miocene. In the study areas andesitic lava and breccia. (Anderson, 1978).
Mesozoic	Jurassic-Cretaceous	Autochthonous Jurassic and Cretaceous Formations	JKau	Baseline Sandstone (K): sandstone and conglomerate. Willow Tank Formation (K): Conglomerate, claystone, sandstone, tuff, and mudstone. Aztec sandstone (J, K?): red quartz arenite w/hematite cement. (Bohannon, 1984).
	Triassic	Autochthonous Triassic Formations	TRau	Moenave and Kayenta Formations: gypsiferous sandstone and siltstone. Chinle Formation: sandstone, siltstone, claystone, conglomerate, minor limestone. Moenkopi Formation: siltstone, sandstone, gypsum, gypsiferous siltstone, limestone, conglomerate. (Bohannon, 1984).

Table 2. Generalized Stratigraphic Column for the Study Area (Continued).

Paleozoic	Permian	Autochthonous Permian Red Beds and Kaibab-Toroweap Formations	Pau	Permian Red Beds (lower P): sandstone, siltstone, gypsum. Kaibab-Toroweap Fms (P): limestone, chert, siltstone, gypsum. (Bohannon, 1984).
	Cambrian-Pennsylvanian	Allochthonous Paleozoic Rocks (undifferentiated)	O|Pal	Bonanza King Fm. (Є) through Bird Spring Fm (P |P): limestone, dolomite, sandstone, quartzite, shale. (After Bohannon, 1984).
Proterozoic	Precambrian	Variegated Metamorphic Rocks	pЄ	Predominantly biotite-almandine gneiss and schist and garnetiferous granite pegmatite. (Anderson, 1978).

The Precambrian/Cenozoic terrain in the southern portion of the study area includes the Black Mountains, the Eldorado Mountains, and Black Canyon. The Precambrian section is comprised of variegated metamorphic rocks consisting of biotite-almandine gneiss and schist and garnetiferous granite pegmatite (Anderson, 1978). These rocks are exposed in the Lake Mead area where structural highs formed during the late Cretaceous to early Tertiary Sevier orogeny resulted in erosion of the overlying Paleozoic and Mesozoic sedimentary rocks (Bohannon, 1984). Tertiary volcanic and intrusive rocks (described below) extensively intrude the Precambrian rocks.

Paleozoic rocks are exposed in the northern portion of the study area in the Muddy Mountains, North Muddy Mountains, and the western portion of Frenchman Mountain. The Paleozoic rocks are predominantly limestone and dolomite (carbonate rocks), with lesser amounts of sandstone, quartzite, and shale. To the northwest, the Paleozoic section reaches a thickness of 5,000 m near the Sheep Range (Longwell *et al.*, 1965) and 7600 m near the Nevada Test Site (Tschanz and Pampeyan, 1970). However, the section thins dramatically eastward in the area west of the Overton Arm, reflecting a hinge line between deep-water and shelf deposits (Stewart, 1970). At the Muddy Mountains, the Paleozoic section is reduced to a thickness of 1200 m (Longwell *et al.*, 1965).

Mesozoic rocks are exposed in the Valley of Fire area, the northern edge of the Black Mountains bordering Pinto Valley, and the eastern portion of Frenchman Mountain. Mesozoic rocks are predominantly sandstones, siltstones, and conglomerates, with varying amounts of gypsum. The Formations exposed in the study area are shown in the stratigraphic column (Table 2).

Tertiary volcanic and intrusive rocks are found within the Precambrian terrain in the southern portion of the study area. The oldest Tertiary rocks are andesitic lava and breccia of the Miocene Patsy Mine volcanic rocks (Anderson, 1971) and are well exposed along the cliffs of Black Canyon. The intrusive rocks include the Miocene-aged Hoover Dam and Wilson Ridge plutons, and numerous dikes of rhyolitic to basaltic composition (Anderson, 1978).

Tertiary sedimentary rocks are exposed throughout the study area, yet predominate in the north. These rocks were initially deposited in a broad shallow basin unconformably covering the autochthonous rocks (Bohannon, 1984). The Rainbow Gardens Member of the Horse Spring Formation represents the lower Tertiary section. The Rainbow Gardens includes clastic rocks ranging in grain size from conglomerate to claystone, several types of carbonates, evaporites, and cherts. Later faulting disrupted this broad basin, and sedimentation of the upper Horse Spring Formation (the Thumb Member and above) occurred within smaller, fault-controlled basins (Bohannon, 1984). The upper Horse Spring includes clastic, carbonate, and turfaceous rocks. The nearly unconsolidated Tertiary Muddy Creek Formation and Quaternary fanglomerates filled most of the fault-controlled basins, reaching thicknesses of at least 215 m in the Muddy and Virgin river valleys, and 425 m in Detrital Valley (Bohannon, 1984). The Muddy Creek Formation consists of siltstone, sandstone, gypsum, gypsiferous siltstone, and conglomerate. Tertiary and later sediments are thin or absent in the Black Canyon area, having been scoured away by the Colorado River (Anderson and Laney, 1975).

Unconsolidated Pleistocene or Recent alluvial deposits are composed of alluvial fan, fluvial, fanglomerate, lakebed, and aeolian deposits (Longwell *et al.*, 1965). Locally, coarse-grained Quaternary deposits are cemented with calcium carbonate. Older, moderately-well-cemented, fluvial deposits are exposed in the walls of Mormon Mesa, between the Virgin and Muddy Rivers.

One of the earlier periods of deformation that strongly affected the study area was the Sevier orogeny during late Cretaceous to early Tertiary. This event of eastward-directed thrust faulting disrupted the stratigraphic section, placing Paleozoic carbonates over Jurassic sandstones. One of the easternmost thrust systems is the Muddy Mountain thrust system which formed the Muddy Mountains located in the northern portions of the study area (Longwell, 1922).

During late Tertiary, major strike-slip and normal faulting associated with Basin and Range extension disrupted the Lake Mead area. Strike-slip faulting dominates the study area north of the lake and these late Miocene faults are known collectively as the Lake Mead fault system (Anderson, 1971). Comprised of numerous discontinuous left-lateral strike-slip faults, the Lake Mead fault system has an estimated total displacement of 60 km distributed along its entire length and fault segments (Bohannon, 1984). Two of these fault segments, the Bitter Spring Valley and the Rogers Spring faults, bound the Overton Arm pull-apart basin (Campagna and Aydin, 1994). Several large springs in the study area are located along the Rogers Spring fault near its southwestern terminus. There, the Rogers Spring fault separates the younger Tertiary through Quaternary sediments of the Overton Arm basin on the east from the allochthonous Paleozoic section of the Muddy Mountains on the west. In this area, the fault strikes N50°E, is vertical to 75°SE dipping, and has a gouge zone up to 5 m thick (Campagna and Aydin, 1994). Northeast of the Muddy Mountains, the Rogers Spring fault lies entirely within the Muddy Creek Formation, strikes N60°E, and is nearly vertical. The thickness of the zone of low-permeability fault gouge and the transition from transmissive carbonate rocks to low-permeability basin-fill sediments creates a barrier to further eastward flow of groundwater.

The extreme western portions of the study area include Frenchman Mountain, which is bounded by northwest trending right-lateral strike-slip faults of the Las Vegas Valley shear zone. Longwell (1960) first identified the Las Vegas Valley shear zone as a northwest-trending right-lateral strike-slip fault beneath the alluvial fill of Las Vegas Valley. One of the faults passes north of Frenchman Mountain and terminates at or near the southwestern extension of the Lake Mead fault system (Cakir, 1990; Duebendorfer and Wallin, 1991). Other faults within the system continue southeast past Frenchman Mountain (Campagna and Aydin, 1994), presumably terminating at the River Mountains and McCullough Range.

Normal faults, characteristic of Basin and Range extensional deformation, are most common south of the lake. In the Black Canyon area, normal faults are associated with magmatism, strike North-South, and dip at high angles to the west and east (Anderson *et al.*, 1994). These high-angle faults may become listric at depth (Anderson, 1971), providing horizontal pathways for groundwater flow in the volcanic terrain (McKay and Zimmerman, 1983). In addition, numerous small faults in this area strike N50°W and are oblique right-lateral strike-slip faults (Anderson, 1971).

In summary, the most important stratigraphic units that shape the hydrogeologic setting are the thick Paleozoic carbonates in the northwest, the thick Tertiary sediments that fill structural basins in the north, and the Precambrian and Tertiary igneous and metamorphic rocks in the south. The most important structural features are the Lake Mead strike-slip fault system in the north, and the normal faulting in the south.

GROUNDWATER FLOW SYSTEMS

Regional Flow Patterns

Groundwater flow systems in the Basin and Range province range in size from small local systems to regional systems that extend over hundreds of kilometers. Local systems usually occupy a single topographic or hydrographic basin and have short flow paths relative to regional systems. Regional systems incorporate multiple topographic basins and therefore interbasin flow is important. While local systems may receive the majority of their recharge in the local topographic basin, regional systems typically receive recharge from multiple basins, and local recharge in any particular basin may be minimal.

Southeastern Nevada comprises the ultimate groundwater discharge location for much of the eastern portion of the regional carbonate aquifer (Dettinger *et al.*, 1995). Major groundwater flow systems comprised of thick carbonate rocks enter the area from the north and meet hydrogeologic barriers to flow, formed by thick, low-permeability Tertiary basin-fill deposits and a Precambrain terrain intruded by Cenozoic igneous rocks. Near these barriers, groundwater is discharged directly at regional springs, or by upward flow into basin-fill aquifers and subsequently discharged by evapotranspiration, spring flow, and streams. Groundwater flow in northwestern Arizona is less well-defined, but generally occurs as northward flow in the basin-fill deposits of Detrital Valley, with ultimate discharge to Lake Mead, and westward flow in basin-fill deposits, and perhaps igneous rocks, toward the Colorado River (Bedinger *et al.*, 1984). The generalized directions of groundwater flow in southeastern Nevada and northwestern Arizona are shown in Figure 5.

Most groundwater in the Basin and Range geologic province flows through carbonate-rock aquifers interconnected with unconsolidated basin-fill aquifers. In southern Nevada, basin-fill aquifers tend to be isolated by topographic divides and contribute to multi-basin groundwater flow

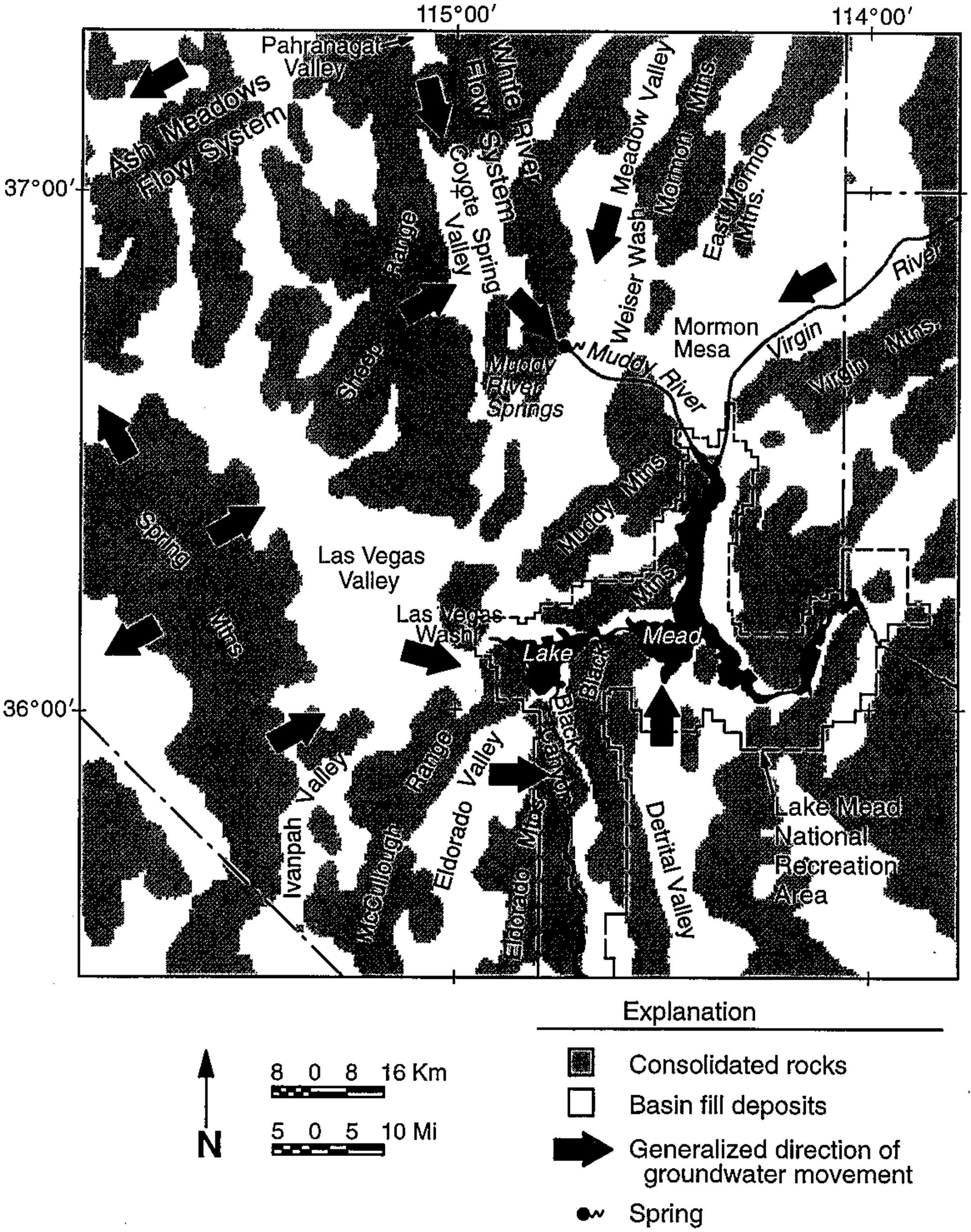

Figure 5. Regional groundwater flow patterns in southeastern Nevada and extreme northwestern Arizona. Modified from Harrill *et al.* (1988) and Bedinger *et al.* (1984).

systems only when they are in close hydraulic connection with underlying carbonate rocks. The most permeable basin-fill sediments were deposited as alluvial-fan, lake-bed, or fluvial deposits in basins formed by late Tertiary and Quaternary normal faulting. The earlier Tertiary basin-fill sediments of the Horse Spring and Muddy Creek Formations are generally less permeable due to finer grain size.

High transmissivities in carbonate rocks result from their great thickness, numerous faults and fractures caused by extensional deformation of the brittle carbonate rock, and to a lesser degree, solution enlargement of fractures and joints (Dettinger *et al.*, 1995). The high transmissivity of these rocks has been demonstrated during pumping tests in several wells, including the MX wells in Coyote Spring Valley (Bunch and Harrill, 1984) and the Arrow Canyon well in the Moapa Valley (Buqo, 1993), and by the high discharge rates from regional springs in the carbonate-rock province (Eakin, 1964). The carbonate rocks do not form a continuous unit, but rather are composed of many discrete structural blocks bounded by faults (Plume and Carlson, 1988). This pattern is manifested at land surface as distinct, often closed, topographic basins surrounded by mountain ranges. The transmissive carbonate rocks often provide a mechanism for deep groundwater flow between basins where topographic divides prevent shallow flow between adjacent basin-fill aquifers (Eakin, 1966).

Orographic effects cause most recharge within the carbonate rock province to be derived from precipitation in the higher elevations of east-central Nevada (Eakin, 1966). Groundwater recharge is minimal in low-elevation basins because potential recharge from precipitation is quickly lost to evapotranspiration (Maxey *et al.*, 1966). The carbonate aquifers of southern Nevada are recharged primarily from precipitation at high altitudes in the nearby Sheep and Spring Mountains (Winograd and Riggs, 1984), and from flow that enters the region from carbonate aquifers to the north.

Two major flow systems have been delineated within the southern part of the carbonate terrain. One discharges approximately 130 km west of the study area at Ash Meadows and Death Valley (Winograd and Thordardson, 1975) and the other, the White River flow system, discharges at the Muddy River Springs in the Moapa Valley (Eakin, 1966). The latter flow system is pertinent to any study of groundwater resources in southeastern Nevada because it supplies the vast majority of groundwater flow into the region. It comprises thirteen interconnected groundwater basins that extend over 370 km north to Long Valley (Eakin, 1968). The Muddy River springs are believed to be the primary regional discharge point of the White River System (Eakin, 1968), although groundwater from other basins, namely Meadow Valley, may contribute some discharge to the springs (Schroth, 1987; Kirk and Campana, 1988; Thomas *et al.*, 1997). In addition, Thomas *et al.* (1997) suggest that most groundwater recharge in the Sheep Range, which is located directly west, may be discharged at the Muddy River Springs. The Muddy River spring area represents the single greatest groundwater discharge point in southern Nevada, with estimated annual discharge of approximately 36,000 acre-ft/year (AFY) (Eakin, 1964; Prudic *et al.*, 1993; Thomas *et al.*, 1997).

Dettinger *et al.* (1995) summarize the evidence for the discharge at the Muddy River Springs and the related upward flow into overlying basin-fill aquifers in the area as being the terminus of the White River flow system. First, geologic constraints to the east and southeast of the Muddy River Springs suggest further flow in those directions and toward Lake Mead is unlikely. These constraints include the thinning of carbonate rocks and exposure of Precambrian crystalline basement rocks on the western edge of the Mormon Mountains; thick (over 1200 m), low-permeability basin-fill sediments just east of the springs below California Wash; and, except for isolated areas, few carbonate rocks extending below Lake Mead (Longwell, 1936). Second, Longwell's mapping of the floor of present-day Lake Mead revealed no evidence of spring discharge. Finally, spring temperatures and stable isotopic data (to be discussed in more detail in a later section of this report) suggest that large down-gradient springs (Rogers and Blue Point springs near the Overton Arm of Lake Mead) are not directly related to discharge at the Muddy River Springs.

There is, however, evidence of groundwater discharge to the Muddy River about 20 km downstream of the Muddy River springs. Here, the Muddy River passes through "The Narrows" formed by the North Muddy Mountains and the Mormon Mountains. Rush (1968) reports gains in Muddy River discharge of 170 L/s in this reach and suggests that the most probable source for the flow is consolidated rocks underlying the thin alluvium. Although not discussed by Rush (1968), this discharge might represent the last point of discharge for flow from the White River flow system, or might represent flow from the Weiser Wash and Mormon Mountain regions directly north.

Another source of groundwater flow into southeastern Nevada is the Virgin River Valley to the northeast of the Overton Arm, although there is disagreement as to the amounts and locations of discharge. Glancy and Van Denburgh (1969) estimate groundwater discharge to Lake Mead through the valley fill and underlying consolidated rocks to be as much as 40,000 AFY. Most of this discharge was thought to be seepage from the Virgin River, which is a losing stream through much of the lower Virgin River Valley. However, Prudic *et al.* (1993) include no subsurface discharge from the Virgin River Valley to Lake Mead in their numerical model of regional groundwater flow. Instead, all groundwater in the near-surface aquifer is simulated as discharge by evapotranspiration (8000 AFY) or baseflow to the Virgin River (5000 AFY), while all discharge in the lower layer of the model (presumably consolidated rocks) is simulated as discharge at Rogers and Blue Point Springs (1200 AFY). The remainder of the discharge is considered surface flow in the Virgin River, and is not included in the model.

In the Las Vegas Valley, numerical modeling (Harrill, 1976; Morgan and Dettinger, 1994) and stable isotopic data (Thomas *et al.*, 1997) indicate that the majority of groundwater originates in the Spring Mountains to the west, with only minor amounts of recharge received from the Sheep Range. Thomas *et al.* (1997) suggest that structural constraints to the west, south, and southeast of the Sheep Range prevent groundwater flow in those directions, thus forcing flow toward Coyote Spring Valley to the northeast. Based on hydraulic head data, Thomas *et al.* (1997) suggest that a small amount of groundwater flow may also originate from Ivanpah Valley to the southwest, although, based on stable isotopic data, the southern portion of the Spring Mountains is the most important source of recharge to the southwestern portion of the Las Vegas Valley.

Hydraulic head relationships indicate that discharge from the Las Vegas Valley is to the east toward Lake Mead, although the amounts are likely to be small (Rush, 1968). Significant subsurface flow beneath Las Vegas Wash is unlikely because the basin fill below the channel is comprised of deposits of the low-permeability Muddy Creek Formation (Rush, 1968). Elsewhere, subsurface flow must pass through low permeability consolidated rocks and is therefore considered minimal. Calibration of numerical models (Harrill, 1976; Morgan and Dettinger, 1994) suggests less than 2000 AFY is discharged from the Las Vegas Valley toward Lake Mead in the area of Frenchman

Mountain. There exists little evidence for significant groundwater flow in the Tertiary volcanic rocks near Lake Mead (Laney and Bales, 1996).

The termini of groundwater flow systems in southern Nevada are located in areas where geologic constraints prevent further subsurface flow, causing discharge at the surface via springs and evapotranspiration; or where land surface elevations are sufficiently low to intersect groundwater flow paths. As previously described, the Muddy River Springs area is representative of the first mechanism, forming the terminus of the White River flow system and discharging approximately 36,000 AFY. The locations of Rogers and Blue Point springs, which have a combined discharge of approximately 1200 AFY (Laney and Bales, 1996), and other nearby springs, are also related to geologic constraints; that is, the transition from transmissive carbonate rocks to low-permeability basin-fill formed by the Rogers Spring Fault. Until recently however, the origin of groundwater discharged at these springs has been uncertain. Similarities between the geologic setting west of the Overton Arm and in the Moapa Valley lead early workers to group them with the Muddy River springs, making Rogers and Blue Point springs the terminal end of the White River flow system. Additional information about the physical, chemical, and isotopic nature of groundwater flow systems in southern Nevada has lead to new interpretations, including probable flow from the Virgin Valley to the north (Prudic *et al.*, 1993) and from recharge areas in the Sheep Range to the west and/or Mormon Mountains to the northwest (Dettinger *et al.*, 1995; Thomas *et al.*, 1997).

The Black Canyon of the Colorado River is suggested by Rush and Huxel (1966) and Mifflin (1968) as another discharge area within southern Nevada, primarily for the McCullough Range and Eldorado Valley. Evidence includes the presence of several springs and seeps at the base of Black Canyon near the present location of Hoover Dam that were noted during investigations for, and construction of, the dam (U.S. Bureau of Reclamation, 1950). The adjacent Black Mountains and Eldorado Mountains are suggested by McKay and Zimmerman (1983) as possible sources for several springs in Black Canyon, based on stable isotopic data that indicate low-elevation recharge. However, stable isotopic data for local precipitation and groundwater recharge were not available at the time of their study, and McKay and Zimmerman conclude that insufficient evidence existed for significant groundwater recharge at the low elevations in these areas. In addition, McKay and Zimmerman (1983) suggest that the permeability of faults and fractures in the volcanic rocks of Black Canyon is sufficient to provide important pathways for groundwater flow. Finally, McKay and Zimmerman (1983) provide strong evidence for the influence of recirculated Lake Mead water on several springs in Black Canyon.

Chemical Composition of Groundwaters

The limestone and dolomite that form carbonate aquifers are dominated by the soluble minerals calcite and dolomite, resulting in a calcium and magnesium-bicarbonate water composition that is fairly homogeneous throughout the carbonate-rock province of eastern and southern Nevada (Hess and Mifflin, 1978). Other minerals, such as gypsum and halite, are present in carbonate rocks in minute amounts but are more soluble than the carbonate minerals. Maxey and Mifflin (1966) show that solution of these minerals causes characteristic increases in the concentrations of the ions sodium, potassium, chloride, and sulfate as groundwater moves along regional flow paths. Overall, the water quality in carbonate rocks in southern Nevada is generally good, with TDS concentrations less than 600 mg/L (Lyles *et al.*, 1987).

Hershey and Mizell (1995) demonstrate the evolution of groundwater chemistry in the carbonate flow system of southern Nevada using a trilinear plot of major dissolved ions in regional carbonate springs (Figure 6). The groundwater flow paths implied on this plot are based on regional flow patterns proposed by Harrill *et al.* (1988). Groundwater intermediate in the flow system is represented by springs in Pahranagat Valley and White River Valley (the next valley north and upgradient of Pahranagat Valley) which show the calcium, sodium-bicarbonate and sulfate composition typical of carbonate waters. One evolutionary trend follows the flow path toward the regional discharge point at the Muddy River Springs. Groundwater flow along this path is

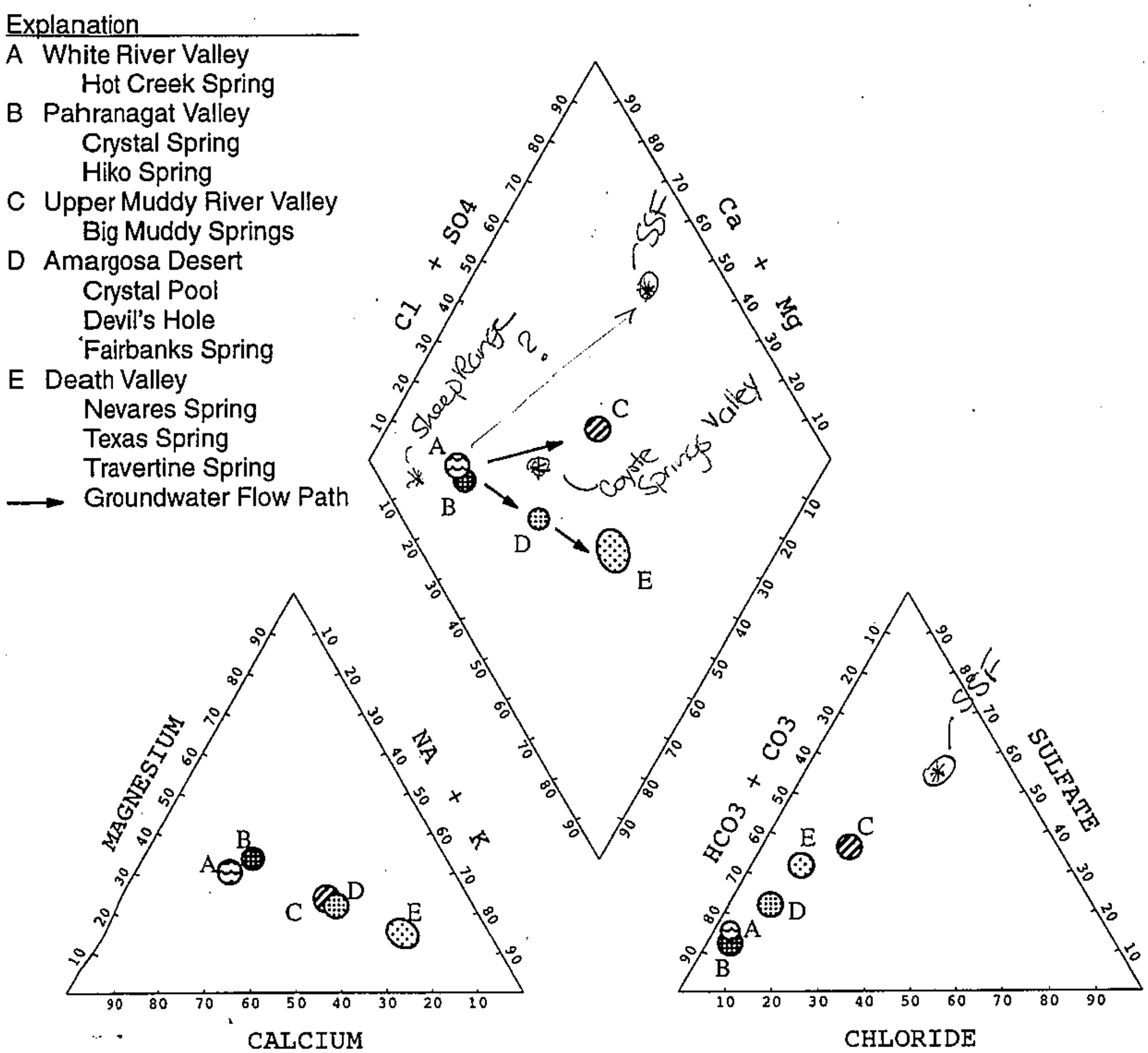

Figure 6. Trilinear diagram showing major dissolved ions of regional springs in the carbonate-rock province of eastern Nevada, showing evolution of groundwater chemistry along two flow paths. Modified from Hershey and Mizell (1995).

accompanied by increases in the concentrations of sodium, potassium, sulfate, and chloride ions attributed to solution of evaporite minerals in the Horse Spring and Muddy Creek Formations near the discharge point. Calcium and magnesium also increase, but to a lesser degree. The other evolutionary trend follows a flow path through Ash Meadows to the regional discharge point in Death Valley. Increases in the concentrations of all major ions except calcium and magnesium along this flow path to Ash Meadows are attributed to solution of Tertiary silicic volcanic rocks (Winograd and Thordardson, 1975). From Ash Meadows to Death Valley, concentrations of all major ions except calcium and magnesium increase as a result of solution of Tertiary and Quaternary lacustrine and alluvial deposits. Declines in the concentrations of calcium and magnesium are attributed to cation-exchange with clays and precipitation of travertine deposits at the springs.

Groundwater in volcanic rocks northwest of Las Vegas is generally of sodium and potassium-bicarbonate composition, reflecting dissolution of feldspar and mafic minerals along relatively long flow paths (Winograd and Thordardson, 1975; Lyles *et al.*, 1987). Locally, waters collected from springs south of Las Vegas in the McCullough Range and a well and springs in the Eldorado Mountains have a mixed cation-sulfate or a mixed cation-bicarbonate composition (Lyles *et al.*, 1987; SNWA, unpublished data) (Figure 7), similar to springs that represent early-stage recharge chemistry in volcanic rocks of central Nevada (Raker and Jacobson, 1987). TDS concentrations of the McCullough Range samples range from 414 mg/L to 664 mg/L while the Eldorado Mountains samples range from 957 mg/L to 1390 mg/L.

Groundwater in basin-fill deposits is categorized as calcium and magnesium-bicarbonate, mixed cation-sulfate, and sodium and potassium-bicarbonate composition (Figure 7) (data from Lyles *et al.*, 1987). Composition varies considerably across the region, depending on lithology, residence time, and origin. Groundwater quality is poorest in the eastern portion of the region, and is characterized by TDS concentrations that range from about 1000 mg/L to well over 2000 mg/L, and mixed cation-sulfate composition (Lyles *et al.*, 1987). The sulfate is derived from solution of evaporite minerals, including gypsum and thenardite (Lyles *et al.*, 1987), in sedimentary rocks of Tertiary age (Muddy Creek and Horse Springs Formations), Triassic age (Moenave, Kayenta, and Moenkopi Formations), and Permian age (Permian Red Beds and Kaibab-Toroweap Formations) (Bohannon, 1984). These rocks are abundant at the surface and in the near surface from Frenchman Mountain northeast to the Overton Arm, and commonly overlie, or are structurally adjacent to, Paleozoic carbonate rocks. Thus, groundwater in this area is likely to pass through evaporite deposits at some point along flow paths, greatly increasing TDS and sulfate concentrations.

Isotopic Composition of Groundwaters

Groundwater in southern Nevada is derived from two principal sources: recharge from local precipitation, and groundwater flowing into the area from regional and subregional aquifer systems described above. Groundwater recharge can be further divided into recharge at altitudes less than 1500 m, which includes most of the region; and recharge at altitudes above 1500 m, which in southern Nevada is limited primarily to the Spring Mountains and Sheep Range. Although smaller in area and lower in altitude than these ranges, the Mormon Mountains also receive precipitation

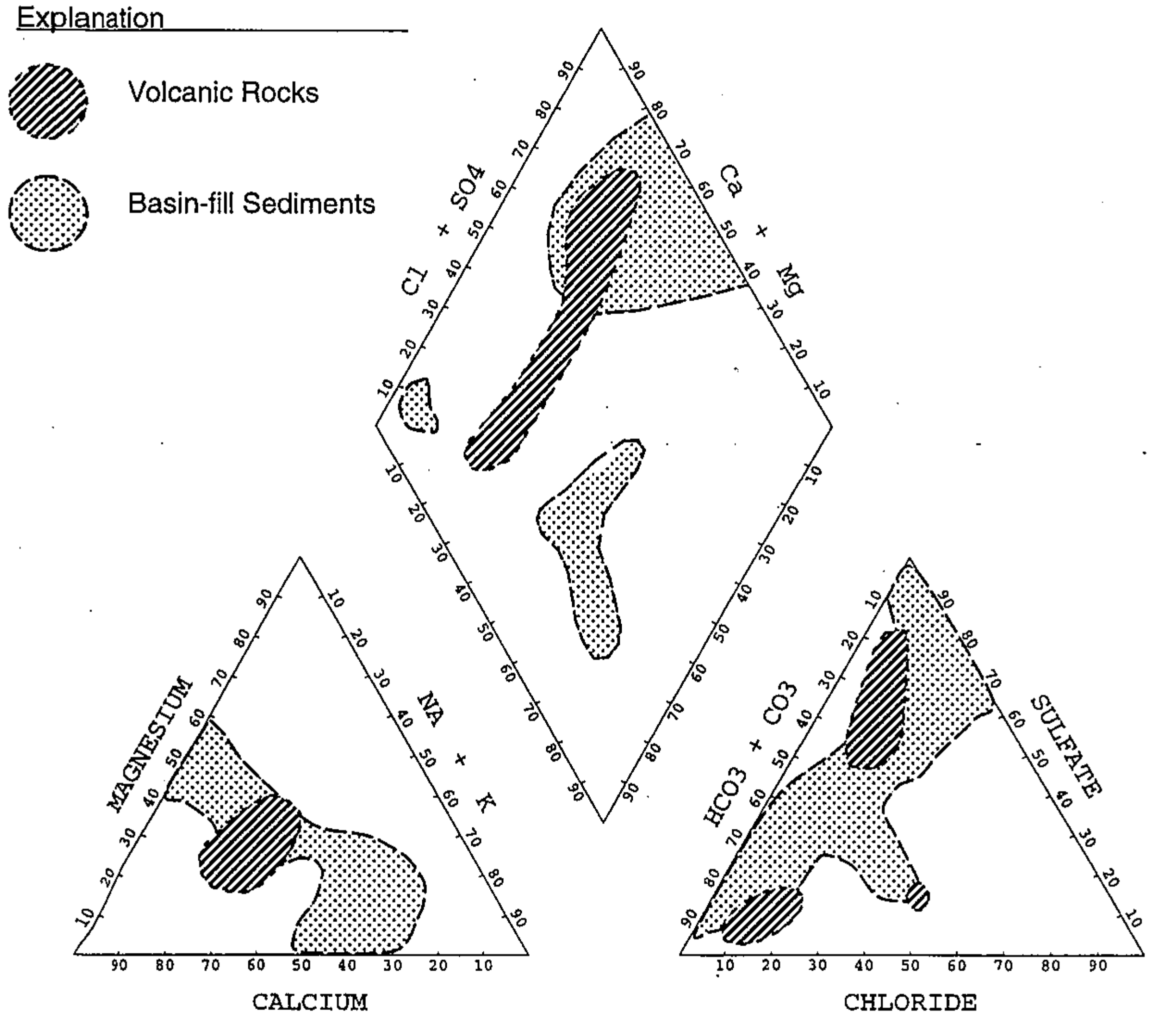

Figure 7. Trilinear diagram showing major dissolved ions in groundwaters collected from volcanic rocks and basin-fill sediments in southern Nevada. Modified from Lyles *et al.* (1987), with additional data from SNWA (unpublished data).

at altitudes above 1500 m and are located much closer to Lake Mead. Although precipitation is the ultimate source of groundwater recharge, evaporation and associated isotope fractionation during recharge under arid conditions causes recharge waters to have a different isotopic composition than the original precipitation. Therefore, selected spring data are used in the present study to represent the stable isotopic composition of groundwater recharge. In addition, local precipitation data were not available at the time of the present study and the timeframe of the study did not allow for long-term precipitation collection.

The stable isotopic values of springs in selected groundwater recharge areas are shown in Figure 8. Also shown is the global Meteoric Water Line (MWL) that represents the linear relationship between $\delta^{18}O$ and δD described by Craig (1961) using data from over 400 rivers, lakes, and precipitation. The local MWL shown represents precipitation (falling as rain) at 32 sites in

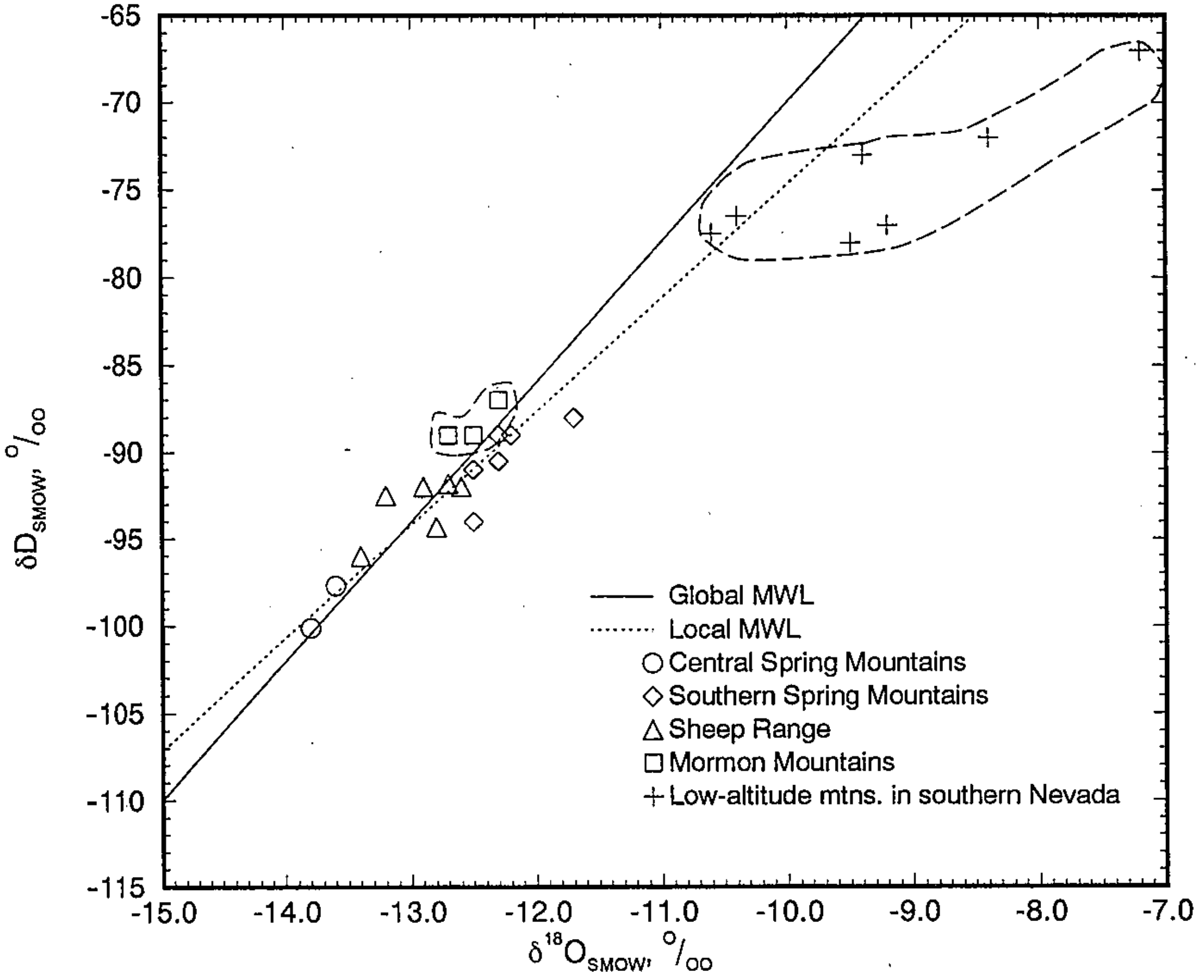

Figure 8. Stable isotopic composition of springs in groundwater recharge areas in southern Nevada, the global meteoric water line (after Craig, 1961), and a local meteoric water line (see text for description). Groundwater recharged at high altitudes in the Spring Mountains, Sheep Range, and Mormon Mountains is isotopically lighter than groundwater recharged in low-altitude mountain ranges. Data are compiled in Table C-1.

southeastern California between April 1986 and October 1987 (Friedman *et al.*, 1992). The equation for the least squares line for this data set is $\delta D = 6.5\delta^{18}O - 9.7$. Springs located at altitudes above 1100 m in the Spring Mountains, Sheep Range, and Mormon Mountains plot as the isotopically lightest points on Figure 8 (data from Thomas *et al.*, 1997). As atmospheric moisture rises up the mountain fronts, the heavier isotopes of hydrogen and oxygen are selectively removed with precipitation and the residual moisture becomes isotopically lighter. Thus, groundwater recharged at high altitudes in these mountains is isotopically lighter than groundwater recharged at lower altitudes. Thomas *et al.* (1997) also note that the higher altitudes of the central Spring Mountains result in more depleted stable isotopic compositions compared to the southern Spring Mountains. Springs in both portions of the Spring Mountains also contain tritium concentrations of up to 257 pCi/L (analyzed in 1976), indicating a major component of post-1952 recharge. The $\delta^{13}C$ concentrations range from -7.9 to -11.2 per mil, reflecting the enrichment of $\delta^{13}C$ by dissolution of carbonate rocks.

The isotopically heavier, low altitude points shown on Figure 8 represent springs that are derived from recharge that occurs at altitudes less than 1500 m in the McCullough Range and Eldorado Mountains adjacent to Black Canyon, the Highland Range and New York Mountains south of Eldorado Valley, and the East Mormon Mountains northwest of Lake Mead (Thomas *et al.*, 1997; SNWA, unpublished data). These springs are located in ranges, or in portions of ranges, that receive most of their recharge at altitudes lower than about 1500 m. Because they are located at altitudes above the adjacent valleys, and therefore are unrelated to regional groundwater flow systems, groundwater discharged from these springs represents local, low-elevation recharge rather than regional groundwater flow. The existence of these springs indicates that local recharge can be more significant than basin-wide predictions developed using the Maxey-Eakin method.

The greater spread of the low altitude data points on Figure 8 likely results from local differences in conditions and seasons of recharge in each individual spring catchment area. The isotopic composition of these springs is reasonably consistent with precipitation data collected at Searchlight, Nevada between the years of 1982 to 1989 (average annual δD of -73 per mil) (Friedman *et al.*, 1992) and at the Nevada Test Site (average annual δD of -80 per mil) (Ingraham *et al.*, 1991). Therefore, the stable isotopic composition of local, low-elevation recharge in the area of study is assumed to be that of these low-elevation mountain springs. It should be noted that these springs plot close to the estimated composition of present-day groundwater recharge near Searchlight, Nevada (δD of -80 per mil) (Smith *et al.*, 1992).

Tritium data for the low-elevation springs are sparse. However, tritium values have been measured at two springs in the Eldorado Mountains. These concentrations (19 and 24 pCi/L – analyzed in 1995; SNWA, unpublished data) indicate that post-1952 recharge contributes to flow at these springs. The only ^{14}C data available for low-elevation springs is for a single spring in the McCullough Range. This spring contains 68.1 percent modern carbon (PMC), for an uncorrected age of 3,175 years, which further distinguishes it from older, regional groundwater flow.

The stable isotopic composition of groundwater in regional and subregional flow systems is shown in Figure 9. Data from the White River flow system of the regional carbonate aquifer (Thomas *et al.*, 1991; DRI, unpublished data) show a trend toward heavier composition along the flow path from Pahranagat Valley (white triangles), through Coyote Spring Valley and other nearby valleys (light shaded triangles), to the Muddy River Springs (dark triangles). Groundwater is isotopically lightest at the recharge areas in east-central Nevada, where recharge occurs at higher elevations and under different climatic conditions, and becomes isotopically heavier as local, lower-elevation precipitation recharges the system. Between Pahranagat Valley and the Muddy River Springs, the addition of isotopically heavier groundwater originating from the Meadow Valley flow system to the northeast, and recharge in the Sheep Range to the west is thought to cause the composition observed at the Muddy River Springs (Kirk and Campana, 1988; Thomas *et al.*, 1997).

Tritium is below detection levels in the southern part of the regional carbonate aquifer (Hershey and Mizell, 1995), reflecting long travel times from recharge areas and/or the dilution of local recharge with regional flow. In addition, the carbonate system shows trends of decreasing PMC and

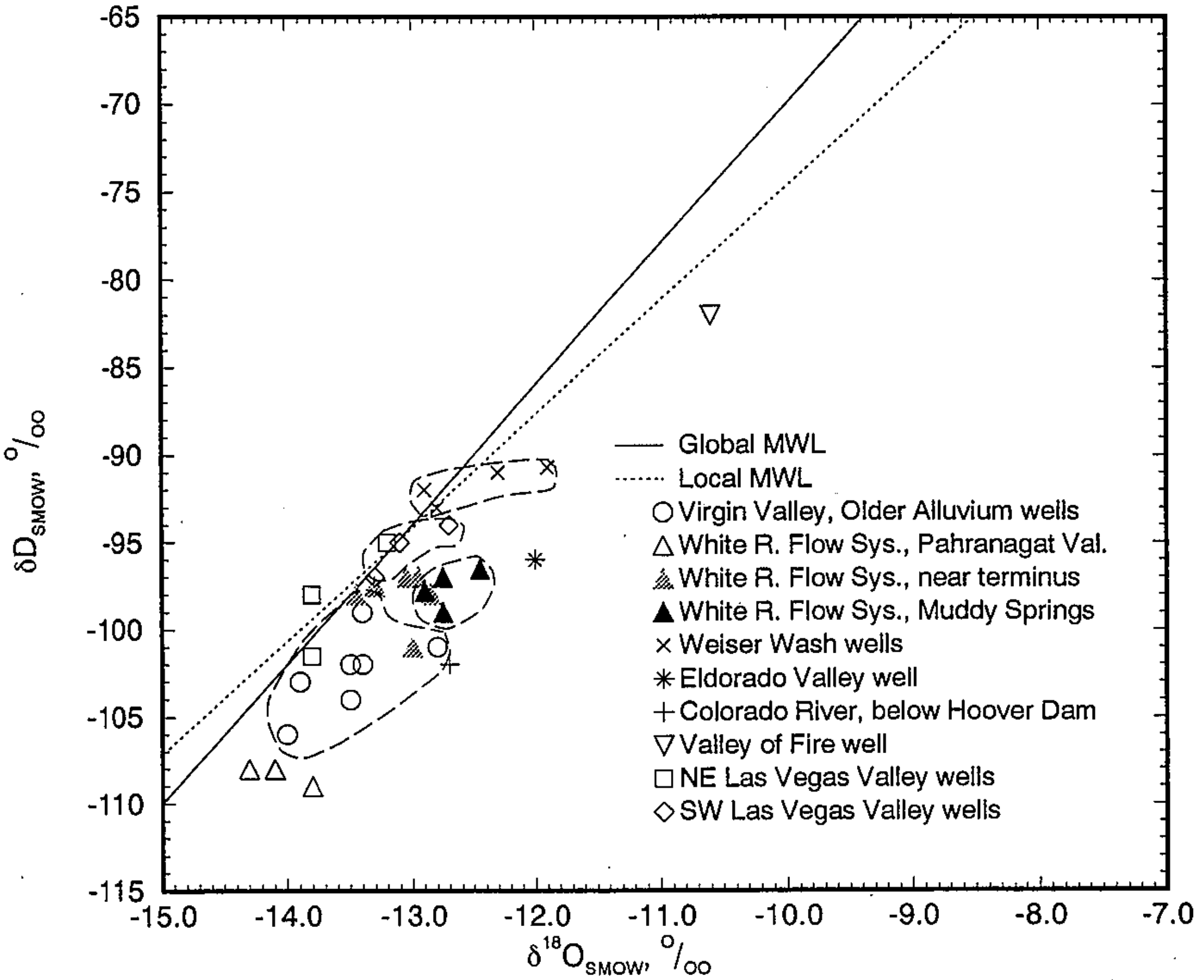

Figure 9. Stable isotopic composition of selected groundwaters of southern Nevada. Data are compiled in Table C-1.

increasing $\delta^{13}C$ values along regional flow paths, reflecting the increasing age of groundwater and dissolution of carbonate minerals with the addition of dead carbon and enrichment of $\delta^{13}C$ (Hershey and Mizell, 1995). Known regional springs in the carbonate aquifer system have PMC values of 2.8 to 11.2 and $\delta^{13}C$ values of -5.8 to -3.9 per mil (Hershey and Mizell, 1995).

In the Virgin Valley, groundwater obtained from wells in the Older Alluvium (which includes the Tertiary Muddy Creek Formation) is isotopically lighter than groundwater in the near surface aquifers and the Virgin River, suggesting a different origin (Metcalf, 1995). The composition is similar to that of groundwater at the southern end of the White River flow system, which may reflect a similar recharge source for Older Alluvium waters, such as carbonate aquifers to the north of the Virgin Valley (Glancy and Van Denburgh, 1969).

Isotopic similarities between groundwater in the basin-fill of Eldorado Valley and of southwest Las Vegas Valley, suggest a common origin. In addition to their similar δD values (Figure 9), groundwater in these two areas share $\delta^{13}C$ values between -6.8 and -7.8 which suggests flow in carbonate rocks (or possible reactions with pedogenic carbonates or carbonate dust). Furthermore, PMC values of 7.75 and below are similar to the older, regional groundwaters noted above. Finally, the lack of detectable tritium in the Eldorado Valley sample suggests a pre-1952 age. Thomas *et al.* (1997) propose that groundwater in southwest Las Vegas Valley originates from low elevation recharge in the southern Spring Mountains. Although only a single data point is available in Eldorado Valley, the similarity to groundwater in southwest Las Vegas Valley is consistent with the idea of interbasin groundwater flow into and through Eldorado Valley, as proposed by McKay and Zimmerman (1983) and Harrill *et al.* (1988).

Groundwater of a more local, low-elevation origin is found in the Weiser Wash area, between the Mormon Mountains and the Muddy River. Here, water in the Muddy Creek Formation and underlying rocks is isotopically heavier (DRI, unpublished data) than groundwater in the Older Alluvium of Virgin Valley and groundwater discharged at the Muddy River Springs. This groundwater may represent a mixture of groundwater from the Meadow Valley Wash flow system (described by Thomas *et al.*, 1997) and isotopically heavier recharge (average δD of -88 per mil) in the Mormon Mountains. Tritium and carbon data are not available for this area.

Groundwater that appears to have a major component of locally-derived recharge occurs at Valley of Fire State Park, where a sample collected from the headquarters well has a heavier isotopic composition than most other groundwater in the region. Although the hydraulic head measured in this well conforms to the regional hydraulic head gradient between the Muddy River springs and Lake Mead, this area may represent a groundwater cell receiving local recharge through the Mesozoic sandstone terrain that covers the area. The $\delta^{13}C$ value of -8.5 per mil might represent reactions with pedogenic carbonates or carbonate dust, or might suggest a portion of the groundwater flows through carbonate rocks. The PMC value of 18.7, which is at least twice that of the upgradient Muddy River springs, indicates the presence another source of modern carbon.

Colorado River water (collected just below Hoover Dam) is isotopically lighter than most groundwater in the region, reflecting the isotopically-depleted composition of precipitation at higher elevations and cooler climates in the upper Colorado River drainage basin. The tritium concentration was 51 pCi/L in a water sample collected in 1997.

A selected set of uranium data for groundwaters in the region, including Rogers and Blue Point springs, is shown in Figure 10. This plot displays the $^{234}U/^{238}U$ activity ratio (AR) as a function of the inverse of total uranium concentration (µg/L). This plot reveals that there is an inverse relationship between uranium concentration (note that the x-axis is the reciprocal of concentration, so high concentrations plot to the left, and low concentrations plot to the right) and $^{234}U/^{238}U$ AR. This relationship has been widely observed, and has often been attributed to a trend line which shows evolution along a flowpath. According to this scenario, AR increases with the time that water has in contact with the aquifer matrix, and the concentration decreases as groundwater moves deeper along a flowpath, because it encounters reducing zones which causes uranium to precipitate from solution (Osmond and Cowart, 1992). Obviously, this scenario does not apply to waters of the region examined during this study, as no reducing zone is known to exist, even at great depths below ground

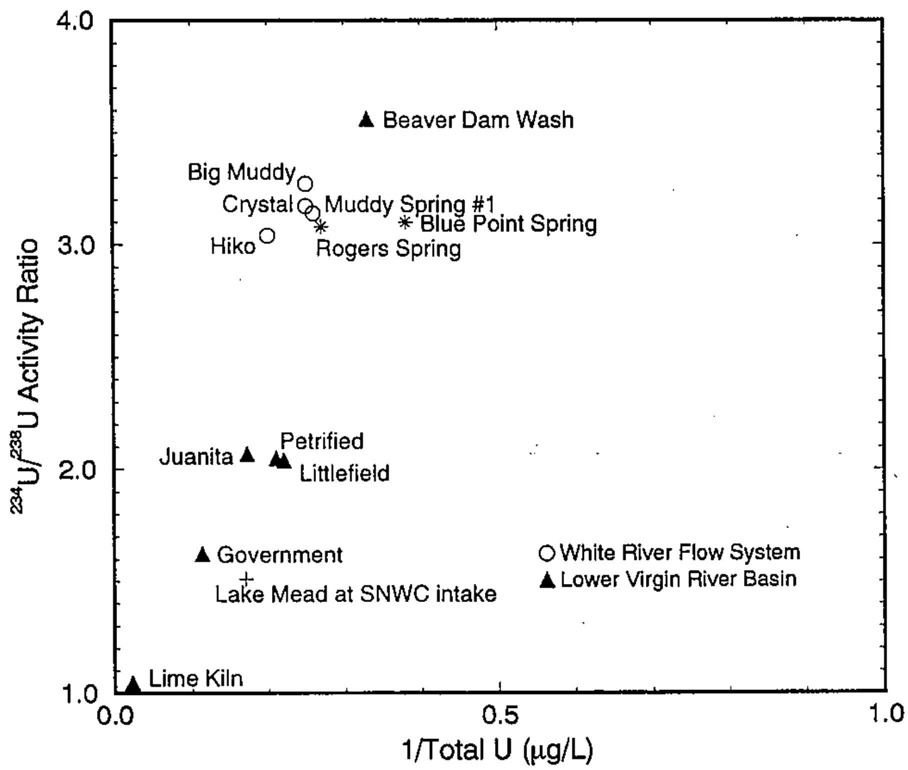

Figure 10. Uranium data for selected groundwaters of southern Nevada and southwestern Utah. Data compiled from Yelken (1996) and Farmer (1996).

surface. Kronfeld *et al.* (1994) present a scenario applicable to the deep oxygenated waters of the Basin and Range province, based on their study of an oxygenated carbonate aquifer in South Africa. The aquifer was found to exhibit a similar trend line to that seen in the present study, with the AR inversely related to concentration. Using ^{3}H and ^{14}C to date waters collected along the flowpath of the aquifer, the AR was shown to increase with the age of the water, indicating that a water moving along a flowpath would evolve from a low AR-high concentration signature to a high AR-low concentration signature with increasing residence time in the aquifer. Rainwater, which is typically very dilute, will begin to leach uranium from the soil and rock materials it encounters while recharging and flowing through an aquifer. As water flows through the aquifer, its AR increases, because ^{234}U, which is produced by alpha decay, is preferentially introduced due to a process called "alpha-recoil". Alpha-recoil enrichment is the result of the alpha decay process, which damages mineral crystal lattices in which decay occurs, making decayed mineral grains more susceptible to leaching than undamaged crystal sites; in other cases, the product of a decay can be injected directly into the liquid phase (Osmond and Cowart, 1994). Kronfeld *et al.* (1994) show that the uranium concentration in an oxygenated carbonate aquifer declines as water moves along the flowpath as a result of extensive ion exchange and/or sorption reactions with the aquifer matrix, with the ion exchange scenario appearing more likely. Based on these results, uranium data from this study may be interpreted such that waters with low ARs and high concentrations have had relatively short periods of interaction with aquifer materials, and waters with high ARs and low concentrations have experienced relatively long periods in contact with aquifer materials.

The data shown in Figure 10 are derived from two primary areas – the lower Virgin River basin (Yelken, 1996) and the White River flow system (Farmer, 1996). Rogers and Blue Point Springs plot near members of the White River flow system, suggesting that waters from these two systems flow through rocks of similar type, and may have similar residence times. Waters in the Lower Virgin River Basin exhibit a wide rage of values, with outlier values suggesting both short and long residence times. The majority of these values are positioned so as to indicate intermediate travel times, suggesting that the springs in this region discharge waters having relatively short to intermediate residence times. These data support the classification of springs in the Virgin Mountains (Lime Kiln, Government, and Juanita Springs) as locally-derived, based on geographic considerations and stable isotope composition (Metcalf, 1995). Intermediate residence times for Petrified and Littlefield Springs (adjacent to the Virgin River, northeast of Mesquite, Nevada) support Metcalf's (1995) conclusion, based on stable isotope data, that these springs are not entirely locally-derived. The high AR of the sample from Beaver Dam Wash indicates a long residence time, suggesting that regional groundwater flow may form a significant component of baseflow to the wash.

RESULTS AND DISCUSSION

The physical, chemical, and isotopic data derived from previous studies, and collected for the present study, are compiled in Appendix A.

Spring Classification

For the purpose of the following discussion, the thirty-one springs in the Lake Mead National Recreation Area and the five nearby springs are divided into three sets based on the geographic nature of their source areas: local springs, subregional springs, and springs derived from Lake Mead water. Local springs discharge groundwater from small flow systems that receive most or all of their recharge locally and at low altitudes. Many of these local flow systems are contained entirely within the park boundaries. Subregional springs are dominated by groundwater that originates outside local topographic basins and flow systems, and may include groundwater recharged at higher altitudes. Most of the groundwater systems supplying the subregional springs extend beyond the park boundaries. In southern Nevada, a "regional" groundwater system generally denotes one that is part of the multi-basin carbonate aquifer system that extends over hundreds of kilometers. The term "subregional" is used here to avoid confusion. A third set of springs is derived from recirculated Lake Mead water.

Springs within each of the three sets share similar hydrogeologic settings and stable isotopic compositions, while discharge rates, temperatures, and tritium concentrations generally show considerable overlap. The distinct D and ^{18}O compositions of groundwater source areas and flow systems in southern Nevada makes the use of stable isotopes ideal for relating springs to their associated recharge sources. The following discussion will therefore focus on the hydrogeologic settings and the isotopic compositions of springs as they relate to spring source areas. Discussion of the uranium data, which are available only for springs in the Lake Mead basin, follows in a separate section.

Local Springs

Lake Mead Basin

Six springs in the Lake Mead basin are considered local springs (Springs 1, 15, 16, 17, 18, and 19). Other than Spring 15, these springs have the lowest discharge rates in the Lake Mead basin, and their temperatures are strongly influenced by fluctuations in ambient air temperature (Table A-1 shows the pronounced differences between temperatures measured in October and February at these springs). These springs are not related to major structural features in the region, instead issuing from stratigraphic contacts, small faults or fractures, or simply at the intersection of the water table with land surface. With the exception of Spring 1, which issues from Quaternary terrace deposits at the base of Mormon Mesa, these springs discharge from alluvium or consolidated rocks in wash channels, and all support varying degrees of vegetation at their orifices. Evapotranspiration is a major controlling factor on the flow rate from these low-discharge springs, as evidenced by the variation in discharge observed at several springs between the seasons and time of day. Although a systematic study was not possible during the present investigation, flow rates at several low-discharge springs were highest during the winter months, and in the early morning hours during the summer months, when evapotranspiration rates of the vegetation surrounding the orifice are low. Discharge rates at these same springs was observed to be lower in the middle of the day in the summer months, when evapotranspiration rates are high.

Local springs in the Lake Mead basin exhibit a mixed cation-sulfate composition (Figure 11). Despite relatively short groundwater flow paths, these springs all have TDS values that exceed 1,200 mg/L. The high sulfate and TDS concentrations both originate from solution of the evaporite minerals so ubiquitous to the Permian, Triassic, and Tertiary rocks of the Lake Mead region.

The stable isotopic compositions of Springs 1, 15, 16, 17, 18, and 19 support their geographic and geologic designations as local springs. The stable isotopic compositions resemble local, low-elevation precipitation, especially if more depleted winter precipitation (Ingraham *et al.*, 1991) is considered (Figure 12). Springs 16 and 17 are located at altitudes above regional hydraulic heads, thus they may extend our definition of local recharge to more depleted δD values of -80 per mil. Additionally, these springs are significantly enriched in heavy isotopes compared to regional groundwater, indicating no relation to groundwater flow systems outside the study area.

The recharge areas for Springs 16 and 17 lie entirely within the park boundaries, in the Black Mountains area. The other local springs in the Lake Mead basin are recharged at least in part outside the park boundaries. Springs 1 and 15 lie on or near the eastern boundary, and their recharge areas extend outside the park. Recharge to Spring 15 originates within Bitter Spring Valley and White Basin, with possible contributions from the surrounding Muddy Mountains and other nearby, low-elevation areas. The δD composition of Spring 1 (-81 per mil) falls midway between the average

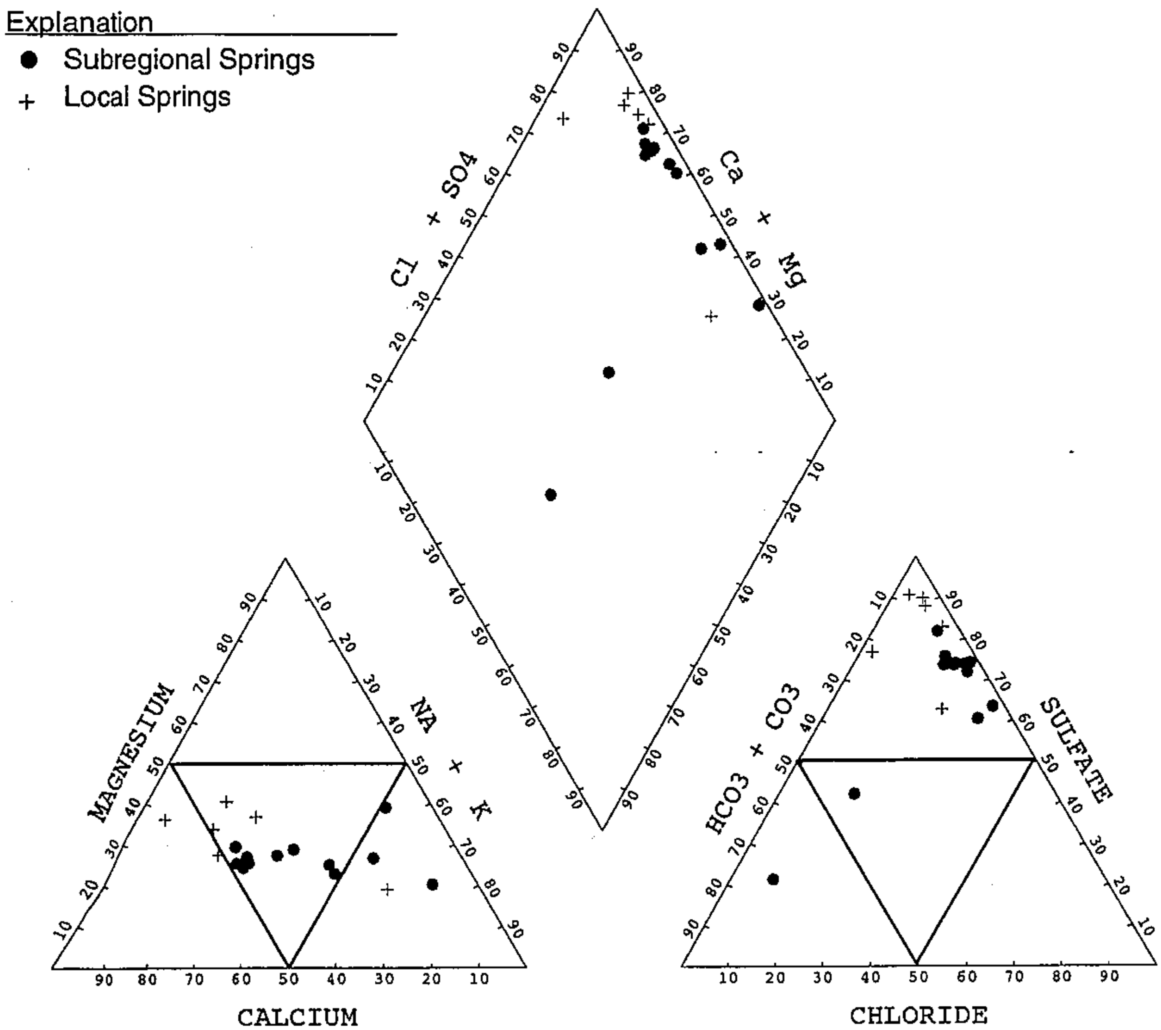

Figure 11. Trilinear diagram showing major dissolved ions of springs in the Lake Mead basin.

δD compositions of springs in the Mormon Mountains and springs in the East Mormon Mountains. Thus, it appears likely that flow from Spring 1 originates in the Mormon and East Mormon Mountains to the north, and travels through the alluvium that forms the upper portion of Mormon Mesa.

With the exception of Spring 1, local springs in the Lake Mead basin issue from alluvium or consolidated rocks in wash channels. However, the absence of atmospheric tritium indicates that groundwater travel times are long and that spring flow does not simply represent discharge of groundwater recharged during recent precipitation events.

Spring 18 appears to be controlled by the intersection of the water-bearing unit with land surface; as no structural control is evident. This spring plots in the region of low-elevation recharge which indicates that its flow originates locally. Although the elevation of the spring is lower than water levels in the carbonate aquifer to the north in Dry Lake Valley and to the west in the Las Vegas

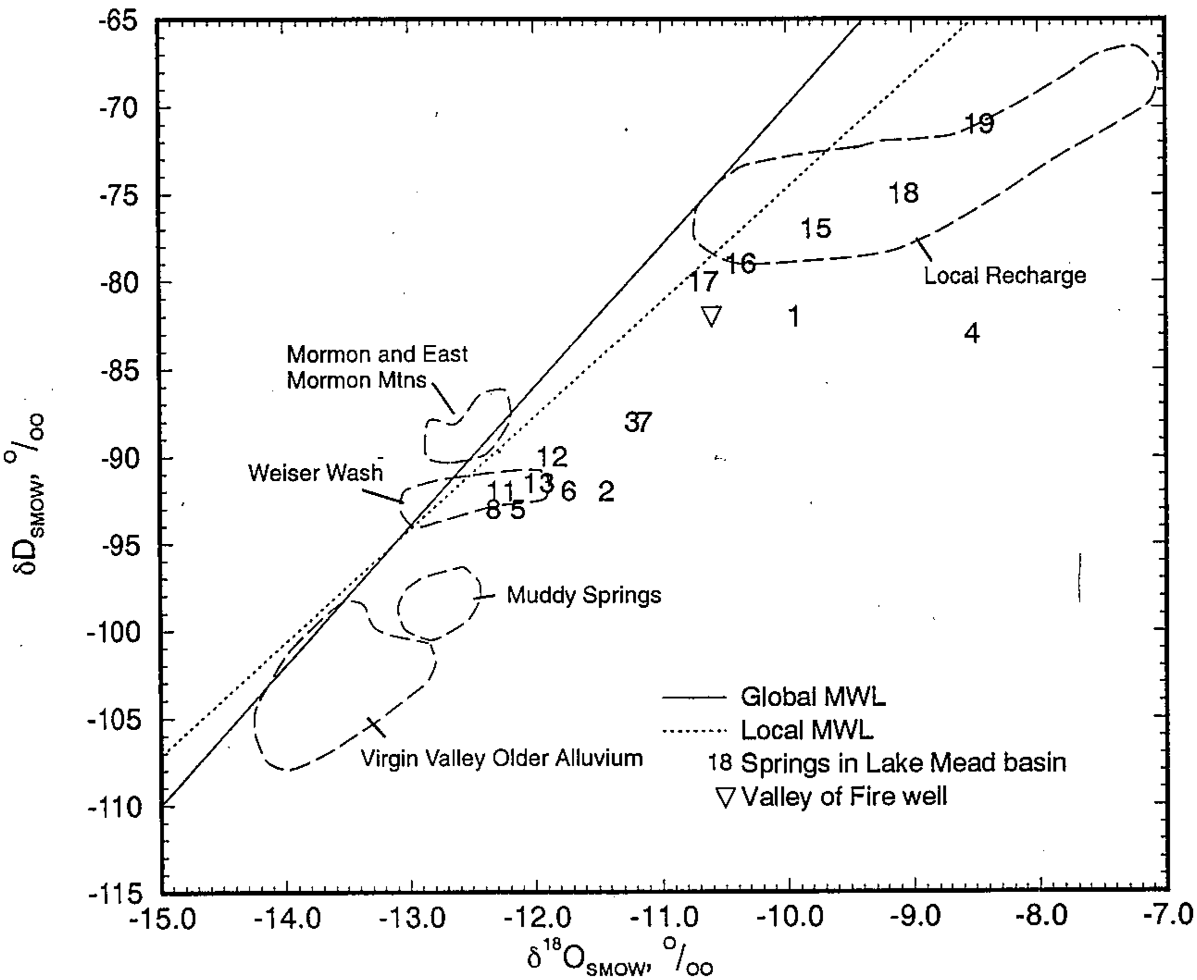

Figure 12. Stable isotopic composition of springs in the Lake Mead basin, as compared to other waters in the region.

Valley, the much more enriched δD composition of -75 per mil indicates that neither the carbonate aquifer nor Las Vegas Valley aquifers are the source.

Black Canyon

Three springs (Springs 27, 35, and 36) in the Black Canyon area are considered to be entirely of local origin. Discharge rates from these springs are less than 2 L/min, temperatures are less than 25°C, and though these springs issue from alluvium in wash channels, their flow appears to originate from small faults or fractures in the underlying rock. Springs 27 and 36 are located at altitudes above regional hydraulic head in the Black Mountains and Eldorado Mountains, respectively, and their stable isotopic compositions fall within the region of low-elevation recharge on a plot of δD as a function of $\delta^{18}O$ (Figure 13). Spring 35 is located at a much lower altitude (960 m) and might be thought to be related to subregional flow; however, the stable isotopic composition clearly indicates local origin.

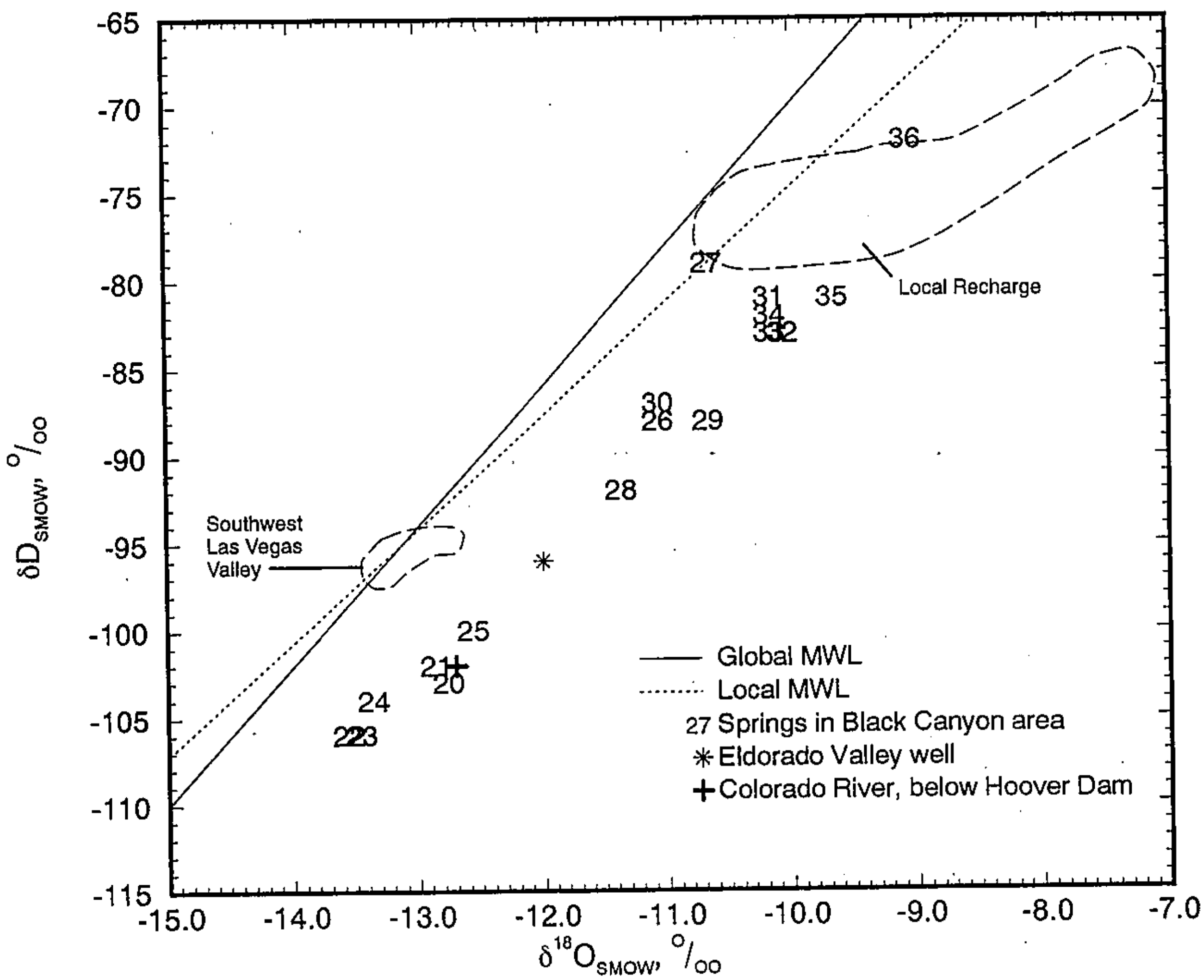

Figure 13. Stable isotopic composition of springs in the Black Canyon area, as compared to other waters in the region.

Unlike other locally-derived springs in the study area, Springs 27, 35 and 36 contain small quantities of detectable atmospheric ^3H (8.0, 8.2, and 18 pCi/L, respectively), indicating part of their discharge was recharged from precipitation after 1952. The fact that these springs contain atmospheric ^3H, while springs in the Lake Mead basin do not, may result from differences in the morphology of recharge catchment areas, and/or reflect infiltration of more recent precipitation in the alluvium upgradient of the springs. (Springs 27, 35, and 36 were sampled approximately one year after the others).

Four other springs in the Black Canyon area (Springs 31, 32, 33, and 34) are considered to be locally derived, but unlike Springs 27, 35, and 36, these springs are located in or near the bottom of Black Canyon. These springs range in distance from 6 to 11 kilometers south of Hoover Dam, and with the exception of Spring 31, issue directly from small faults in volcanic rock. Spring 31 issues from alluvium in the base of a wash channel, immediately upstream of where the channel becomes incised in volcanic bedrock. The discharge rates of these springs are higher than most of the other locally-derived springs in the study area, ranging from less than 1 L/min to 10.2 L/min. Temperatures also tend to be higher, ranging from 19° to 32°C, reflecting the geothermal influence of intrusive rocks in the region (McKay and Zimmerman, 1983).

Springs 31, 32, 33, and 34 have virtually identical stable isotopic compositions (Figure 13), suggesting very similar conditions of groundwater recharge, despite the fact that two of the springs are located on the east side of the Colorado River and two are located on the west. The location of these springs at low altitudes near the groundwater discharge zone of the Colorado River suggests a potential relation to subregional flow, represented on the Nevada side by Eldorado Valley groundwater, and on the Arizona side by Detrital Valley groundwater. However, their stable isotopic compositions are very similar to local, low-elevation recharge, and are much more enriched in heavy isotopes than the Eldorado Valley well sample (δD composition of -96 per mil). These springs are slightly isotopically lighter than most of the other locally-derived springs, although the δD difference between them and locally-derived Spring 27 is only 3.3 per mil. Though this could result from different conditions of recharge, mixing of local precipitation with isotopically light subregional groundwater could also account for the isotopic composition and would be consistent with these springs' elevation, temperature, and flow rates. Due to their proximity, the Eldorado Mountains and Black Mountains represent the most likely sources of local, low-elevation recharge for these springs. Recharge from the McCullough Range, or other more distance ranges appears less likely due to the absence of any evidence of mixing with subregional groundwater (e.g., Eldorado Valley).

Though Spring 34 has a $\delta^{13}C$ composition similar to that of many other springs (-7.0 per mil, indicating a dissolved carbonate mineral contribution), Springs 31 and 33 are more unique, with their lighter carbon compositions (-13.2 and -24.9 per mil, respectively) indicating less contact between the groundwater and solid carbonate phases. For Springs 31 and 33, this suggests recharge through poorly developed soil and flow through strictly igneous terrain. A $\delta^{13}C$ value is not available for Spring 32. Considering the similar geologic settings of Springs 31, 33, and 34, the differences between their $\delta^{13}C$ values are not well understood at this time.

The absence of detectable atmospheric tritium in Springs 31, 32, 33, and 34 indicate that groundwater travel times are long and that these springs do not simply represent discharge of groundwater recharged during recent precipitation events. Limited ^{14}C data confirm this, but indicate widely varying apparent ages from 1660 to 15,500 years. Groundwater travel times from recharge areas to the springs of several thousands of years are consistent with their "local" designation and the arid environment. However, the age of 15,000 years obtained for Spring 33 seems inconsistent with other evidence of local origin, and indicates a more complex hydrochemical history than assumed here.

Subregional Springs

Lake Mead Basin

The majority of the springs studied in the Lake Mead basin are considered to be subregional springs. Most of these springs are located along North Shore Road, and as a group are termed the

North Shore Complex. These springs can be geographically divided into three areas: the Rogers/Blue Point group (consisting of Springs 8 through 14 and numerous small springs and seeps); the Valley of Fire Wash group (Springs 5, 6, and 7); and Springs 2, 3, and 4 located further to the north. Many of these springs are related to regional structural features and generally have higher discharge rates and temperatures than locally-derived springs. Furthermore, these springs have similar isotopic compositions that are distinct from the compositions of the local springs.

Springs comprising the Rogers/Blue Point group are directly related to the Rogers Spring Fault, a major strike-slip fault in the Lake Mead area. The fault separates lower Paleozoic carbonate rocks of the Muddy Mountains on the northwest from Quaternary and Tertiary basin-fill deposits on the southeast. The low permeability basin-fill deposits form a barrier to eastward groundwater flow and cause the Rogers Spring Fault to act as a conduit for upward flow from the carbonates. Springs 8, 11, 12, and 13 issue directly from the fault, and Springs 9, 10, and 14 issue from the basin fill between the fault and Lake Mead. In addition, Spring 8 is located at the point of intersection of the Rogers Spring Fault and the Arrowhead Fault. Discharge rates of 1040 and 2750 L/min from Springs 8 and 11 (respectively) are the highest in the Lake Mead basin, reflecting the role of the Rogers Spring fault as an important conduit for groundwater flow in the region.

The regional nature of these springs is also reflected in the absence of a relation between discharge and precipitation patterns. Continuous measurements of the discharge rate at Spring 11 have been collected by the U.S. Geological Survey since October 1985. A comparison of the monthly discharge at Spring 11 (U.S. Geological Survey Water-Data Reports, Water Years 1984 through 1996) and the monthly precipitation in southern Nevada (based on data from 16 low elevation stations) (National Climatic Data Center, 1997) is shown in Figure 14. There is no consistent relationship between

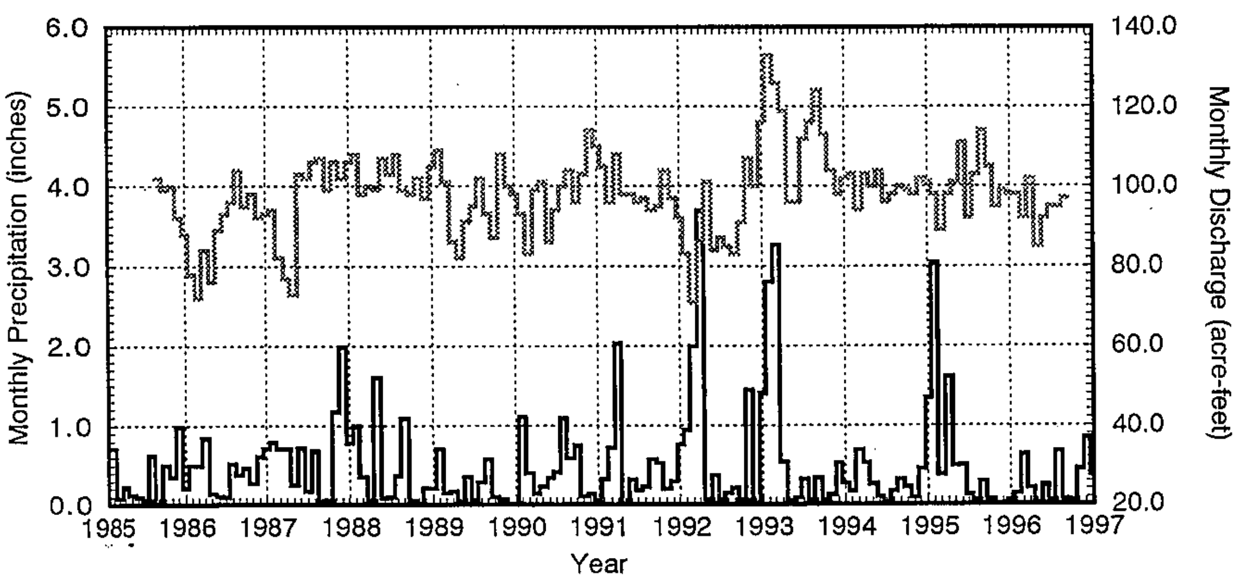

Figure 14. Comparison of monthly discharge at Spring 11 —— with monthly precipitation —— in southern Nevada.

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precipitation and discharge, and although precipitation is generally greatest in the winter months when groundwater recharge is expected to be greatest, there is no consistent seasonal variation in discharge rate. This evidence suggests that discharge patterns at the North Shore Springs are more strongly related to regional flow than to local groundwater recharge.

In addition to the direct discharge represented by the North Shore springs, diffuse groundwater discharge occurs by evaporation and transpiration in several areas between the Muddy Mountains and the Overton Arm. Salt crusts on the soil surface indicate that evaporation from the water table is occurring near spring orifices and along drainage channels. Transpiration is indicated by thick stands of tamarisk, mesquite, acacia, various grasses, and other vegetation surrounding spring orifices and lining drainage channels. The amount of groundwater discharged by evapotranspiration (ET) may be significant relative to surface discharge at the spring orifice. Investigation of the amount of ET in the area of each spring was beyond the scope of the present study, though there is literature that can provide insight into the magnitude of groundwater discharge by this mechanism (Ball *et al.*, 1994; Smith *et al.*, 1996).

Springs of the Valley of Fire Wash group (Springs 5, 6, and 7) do not issue directly from the Rogers Spring Fault. Instead, Springs 5 and 6 are located in the area of an unconformable contact of Jurassic and Triassic clastic rocks on the west with the Tertiary Muddy Creek Formation on the east, near the Rogers Spring Fault. The mechanism of discharge is similar in that the springs occur where eastward flowing groundwater meets a low-permeability barrier formed by the Muddy Creek Formation and is forced upward, possibly along fault planes, to discharge points at ground surface. Spring 7 issues from Quaternary Older Alluvium near an exposure of the Muddy Creek formation.

The other subregional springs (Springs 2 and 3) in the Lake Mead basin are also unrelated to major structural features. Springs 2 and 3 are located near the unconformable contact of the Tertiary Horse Spring Formation on the west with the Tertiary Muddy Springs Formation on the east. Both springs are located in wash channels that cut through Overton Ridge, at the lowest land-surface elevations just upgradient from the low-permeability barrier of the Muddy Creek Formation. Thus, if groundwater in the area is assumed to be moving generally northeast or east toward the Muddy River and Colorado River, then these springs discharge at the intersection of the water table with land surface. Spring 4 issues from a gypsum unit within the Muddy Creek Formation.

Most subregional springs in the Lake Mead basin are of the mixed cation-sulfate composition (as shown in Figure 11), which is typical of the regional groundwaters in southern Nevada discussed earlier. Exceptions are the mixed cation-bicarbonate compositions of Springs 2 and 3, which will be discussed below. The generally higher Na and K concentrations of the subregional springs distinguish them from the local springs. Despite this relationship, this pattern does not represent an evolutionary trend from local springs to subregional springs in the Lake Mead basin because groundwater flow paths do not exist between the areas of local and subregional springs.

Despite differences in major ion chemistries, subregional springs in the Lake Mead basin show remarkably similar stable isotopic compositions (Figure 12); with the exception of Spring 4, their δD compositions range from -93.5 to -88 per mil. The stable isotope values of Spring 4 are indicative of evaporation. The loose and open structure of the gypsiferous soil in the vadose zone near the spring and the high potential for evaporation from the slow moving water at the orifice suggest that significant evaporation occurs at the spring discharge point. A line extending from the subregional group to the composition of Spring 4 has a slope of about 2.6, which is consistent with kinetic isotopic enrichment during evaporation under conditions of low humidity. However, because Spring 4 issues from gypsum deposits, there is the possibility of altering the groundwater's isotopic composition by exchange and/or mixing with gypsum hydration water. Under dry conditions, gypsum can conserve its primary isotopic composition, but the exchange process is relatively rapid under wet conditions (Sofer, 1978). The effect of hydration water on groundwater composition would be a shift toward a heavier isotopic composition, reflective of the evaporated condition of the water that precipitated the gypsum. Thus, mixing with hydration water could account for the enriched composition of Spring 4, but without data on the gypsum composition, this cannot be proved. Despite their enrichment, the general coincidence of the isotopic composition of Spring 4 with other area groundwaters suggests the influence of hydration water, if any, is minimal, and that Spring 4 is subregionally-derived rather than local.

The stable isotopic compositions of the North Shore springs are isotopically lighter than locally-derived springs sampled in the Lake Mead basin, but are heavier than the regional carbonate aquifer at the terminal end of the White River Flow System (Figure 12). It is unlikely that the composition at the North Shore springs results from mixing isotopically lighter groundwater from the White River system with local, isotopically heavier groundwater because the volume of local recharge appears to be insufficient to cause the observed shift. A mixture of 75 percent groundwater having the composition of the Muddy River springs (average δD of -97.5 per mil) and 25 percent local recharge (average δD of -76 per mil) would be required to reach the composition of the North Shore springs. Twenty-five percent of the discharge of the North Shore springs is approximately 418 AFY (this value is a minimum since it does not include discharge by evapotranspiration), which is over 2.5 times larger than the amount of groundwater recharge estimated by Rush (1968) to originate from precipitation in the lower Moapa Valley, Black Mountains area (including the Muddy Mountains), and California Wash. In addition, extensive geologic evidence suggests that the Muddy River Springs form the terminus of the White River flow system (Dettinger *et al.*, 1995).

It is also unlikely that groundwater in the lower Virgin Valley is a major contributor to spring flow at the North Shore springs. Heads at the North Shore springs are higher than most of the heads measured by Metcalf (1995) in wells in the Older Alluvium in the Virgin River Valley, and higher than the altitude of the pre-Lake Mead confluence of the Muddy River and Virgin River, which lies between the Virgin Valley and the North Shore springs. Although limited to a single data point, the pre-Lake Mead hydraulic head near the confluence of the Muddy and Virgin Rivers appears to be approximately 265 m above mean sea level (Carpenter, 1915), which is 223 m below the Rogers Spring orifice. Furthermore, the Muddy Creek Formation may be more than 800 m thick below the Overton Arm and includes at least 300 m of very low permeability salt (Anderson and Laney, 1975). Finally, the limited volume of local, isotopically heavy groundwater is insufficient to cause the shift from the very light groundwater in the Older Alluvium to the composition of the North Shore Springs.

The isotopic composition of the North Shore springs is in fact very similar to basin-fill aquifers in Weiser Wash, which appear to represent a mixture of groundwater moving south from Meadow Valley with groundwater recharged in the Mormon Mountains. This groundwater is isotopically heavier than the regional carbonate aquifer because these aquifers receive recharge from precipitation at lower elevations. Not surprisingly, the range of $\delta^{13}C$ values at Springs 8 and 11 (-3.9 to -6.2 per mil; Thomas *et al.*, 1991; Hershey and Mizell, 1995) indicate interaction with carbonate rocks, since these springs issue from carbonates. The ^{14}C values range from 3.0 to 7.2 PMC, indicating a long residence time in the groundwater system and the contribution of dead carbon from rock dissolution (uncorrected ages of approximately 20,000 to 30,000 years). The absence of atmospheric tritium in any North Shore springs indicates that all the groundwater is of a pre-1952 age.

Further discussion of the springs in Magnesite Wash and Kaolin Wash (Springs 2 and 3, respectively) is necessary here. These springs are located in wash channels that cut through Overton Ridge, down-gradient from a basin in Valley of Fire State Park that is comprised of Mesozoic sandstones and covered by thick, sandy soils. The lack of vegetation in this basin suggests that precipitation may infiltrate rapidly and is not available to support plant growth. The relatively low TDS contents of these springs (462 and 626 mg/L, respectively) suggest that they may originate from local recharge with minimal chemical interaction with the aquifer matrix in the basin, which is typical of groundwater flow in quartz arenites. However, the stable isotopic composition of these springs is much lighter than local, low-elevation recharge, instead plotting with the springs in the North Shore Complex. The $\delta^{13}C$ composition of these springs (-5.0 and -6.5) falls within the range of the North Shore Complex and indicates a contribution from dissolved carbonate minerals. Furthermore, the lack of atmospheric tritium indicates the groundwater residence time is relatively long. The apparent disagreement between the local origin suggested by the geographic and geochemical evidence and the subregional origin suggested by the isotopic evidence illustrates the complex hydrogeologic setting of these springs and indicates that their origin remains uncertain. However, one possible explanation is that these springs represent discharge from a subregional system that originates in the Mormon Mountains, as discussed below.

Taken as a whole, the isotopic data suggest that groundwater discharged at the North Shore Spring Complex is recharged in the region surrounding Lake Mead and is not directly related to flow in the regional carbonate aquifer of the White River Flow System. The most likely possibilities include the Muddy Mountains and the Mormon Mountains. Recharge in the Muddy Mountains alone is insufficient to provide the volume of discharge at the North Shore Springs. Evidence indicates that recharge in the Mormon Mountains represents the most likely source for the subregional flow system that discharges at the North Shore Spring Complex. Autochthonous Paleozoic carbonate rocks, well exposed throughout the mountains, provide the point of infiltration and recharge to the carbonate aquifer system. These autochthonous carbonate rocks continue southwest and plunge below ground surface at the Muddy Mountains. The autochthonous carbonate rocks are also exposed in the North

Muddy Mountains, though at lower elevations than at the Mormon Mountains. Not until crossing the Arrowhead fault do the autochthonous carbonate rocks descend completely into the subsurface, covered by the Mesozoic clastic formations and the allochthonous Paleozoic carbonate rocks of the Muddy Mountain thrust system. The autochthonous carbonate section is exposed again south of White Basin in the ridges just north of the Black Mountains. Here, the units are topographically much higher than at the major spring discharge of the subregional system at the Rogers/Blue Point complex.

The only structural obstruction in this flow path might occur near Glendale, just north of the North Muddy Mountains. It has been postulated that a strike-slip fault, the Moapa shear zone, separates the Mormon Mountains from the Virgin River depression to the south (Wernicke *et al.*, 1988). Whereas a major fault does separate the Mormon Mountains from the Tertiary sediments of the Virgin River depression, Anderson and Bernhard (1993) argue against a major through-going fault separating the North Muddy Mountains from the Mormon Mountains. The existence of this flow path is supported by evidence of groundwater discharge to the Muddy River reported by Rush (1968) in the reach passing through The Narrows at the northern edge of the North Muddy Mountains. This discharge indicates the presence of significant flow through the carbonate rocks between the Mormon and North Muddy Mountains, with upward flow occurring at favorable locations where overlying rocks are thin. Further evidence of this flow path may be provided by springs in Overton Ridge (Springs 2 and 3), that are located between The Narrows and the North Shore springs, are slightly lower in elevation than The Narrows, and have stable isotopic compositions indicative of subregional flow. Finally, the consistency of stable isotopic signatures of groundwater in the Mormon Mountains, Weiser Wash, Overton Ridge, and the North Shore Spring Complex indicate no major structural obstruction of the groundwater system's flow path until its primary discharge at the Rogers Spring Fault.

Black Canyon

In Black Canyon, Springs 26, 28, 29, and 30 are classified as subregional springs. Though these springs have widely varying temperatures (13° to 55°C) and discharge rates (13.2 to 960 L/min), their stable isotopic compositions are similar (as shown in Figure 13) and indicative of a common origin. In addition, these springs all possess a similar sodium and potassium-chloride composition (Figure 15), suggesting that their flow passes through rocks of similar minerology. Springs 26 and 30 issue from Tertiary volcanic rocks near northwest trending, right lateral strike-slip faults. Springs 28 and 29 issue from the Miocene Boulder City pluton at points where near vertical, north-south-trending faults intersect from below an unconformable barrier. This unconformity appears to act as a "ceiling", preventing further upward flow within the plutonic rocks.

The stable isotopic composition of Springs 26, 28, 29, and 30 is approximately midway between the end member compositions of subregional groundwater in Eldorado Valley, and local, low-elevation recharge. Note that using the Eldorado Valley water as an end-member is highly uncertain for the following reasons: only one sample is available from this basin; there are few data available from other, nearby deep basins; and there are no data from Arizona. Though Lake Mead

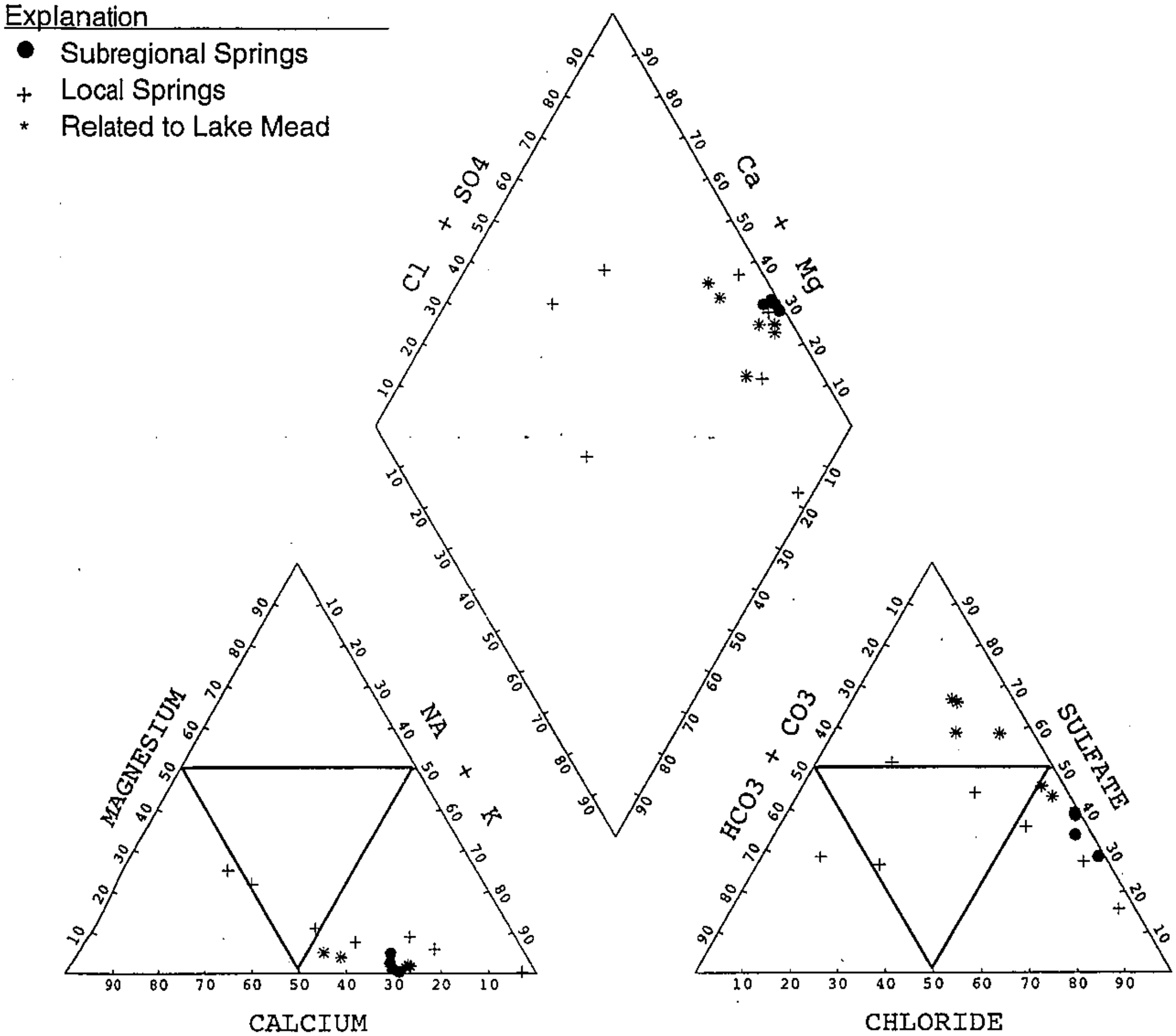

Figure 15. Trilinear diagram showing major dissolved ions of springs in the Black Canyon area.

water also represents a possible stable isotope end-member, Springs 26, 28, 29, and 30 can be distinguished from the springs affected by Lake Mead water by the following: with the exception of Spring 26, they contain no atmospheric tritium (the tritium content of Spring 26 is 21 pCi/L); they have TDS concentrations over 2000 mg/L; and they are at least 10 per mil enriched in δD with respect to springs located near the dam. Therefore, it appears unlikely that these springs are influenced by groundwater originating from Lake Mead.

Springs Influenced by Lake Mead Water

McKay and Zimmerman (1983) use environmental isotopes and water chemistry to demonstrate the hydraulic connection between Lake Mead and thermal springs in Black Canyon. Additional data collected for the present study confirm many of those results, and provide for some further refinement. Springs near Hoover Dam (Springs 20, 21, 22, 23, 24, and 25) share several physical, geochemical, and isotopic properties: They tend to have the highest discharge rates and the highest temperatures (32° to 58°C) of springs in Black Canyon. Additionally, the TDS contents more closely resemble Colorado River water than other high discharge, subregional springs. The high discharge rates of many of the Black Canyon springs appear to result from the large hydraulic gradient imposed on the system by the altitude of the surface of Lake Mead, which is approximately 166 m above the river. The high temperatures reflect circulation near the Boulder City pluton. The temperature of Spring 20 is significantly lower than the others. This spring is closest to the dam, and the lower temperature may reflect less contact with the pluton than the other springs.

Springs near Hoover Dam also have the highest tritium activities (72 to 148 pCi/L) and the lightest $\delta^{18}O$ and δD values (δD of -106 to -100 per mil) (Figure 13). The high tritium activities indicate post-1952 groundwater recharge (a sample from the Colorado River on February 11, 1997 had a tritium activity of 51 pCi/L). The stable isotopes reflect the influence of Lake Mead water (a sample from the Colorado River on February 11, 1997 water had a δD content of -102 per mil). McKay and Zimmerman postulate a decreasing influence of the lake downstream, although they state that it is likely that all the springs in Black Canyon are influenced to some degree by Lake Mead. However, the tritium and stable isotope data collected during the present study suggest that the influence of Lake Mead water appears to end at a distance beyond Spring 25, which is 2.4 km downstream from the dam (Figure 16). Lake Mead water does not appear to impact Spring 26, which is within several hundred meters of Spring 25, is 35°C cooler, and is much more isotopically enriched. This suggests very different flow paths and/or origins for these two springs. Spring 26 is considered a subregional spring, as discussed above.

Uranium Signatures

The uranium data gathered for this study are shown, along with pertinent data from other sources, in Figure 17. The springs shown in this plot can be divided into two major groups – one with high uranium concentrations and low activity ratios (Springs 4, 15, 16, 17, 18, 19, and 36), the other with higher ARs, but generally lower uranium concentrations than the first group (Springs 1, 2, 3, 6, 7, and 11). The uranium signature of the first group suggests residence times which are relatively short, as relatively little leaching has taken place. The second group appears to have had a longer residence time, as increased leaching has caused a shift in the U signatures to a higher AR, with lower concentration. One obvious explanation for the different uranium signatures relates to the source area for any given spring – water discharging from springs which have a local source would have relatively short flowpaths, while water discharging from springs which have source areas outside local basins would typically require a longer transport time from recharge to discharge. Thus, locally-derived springs would display low activity ratios and high concentrations, and regional springs would display high ARs and low concentrations.

The springs that exhibit high concentrations and low ARs share similar uranium isotope signatures with locally-derived springs in the Virgin Mountains (the lower most triangles in Figure 17). With the exception of Spring 4, the uranium isotope signature of these springs supports their geographic and stable isotope designation as local springs. The stable isotope data suggests Spring 4

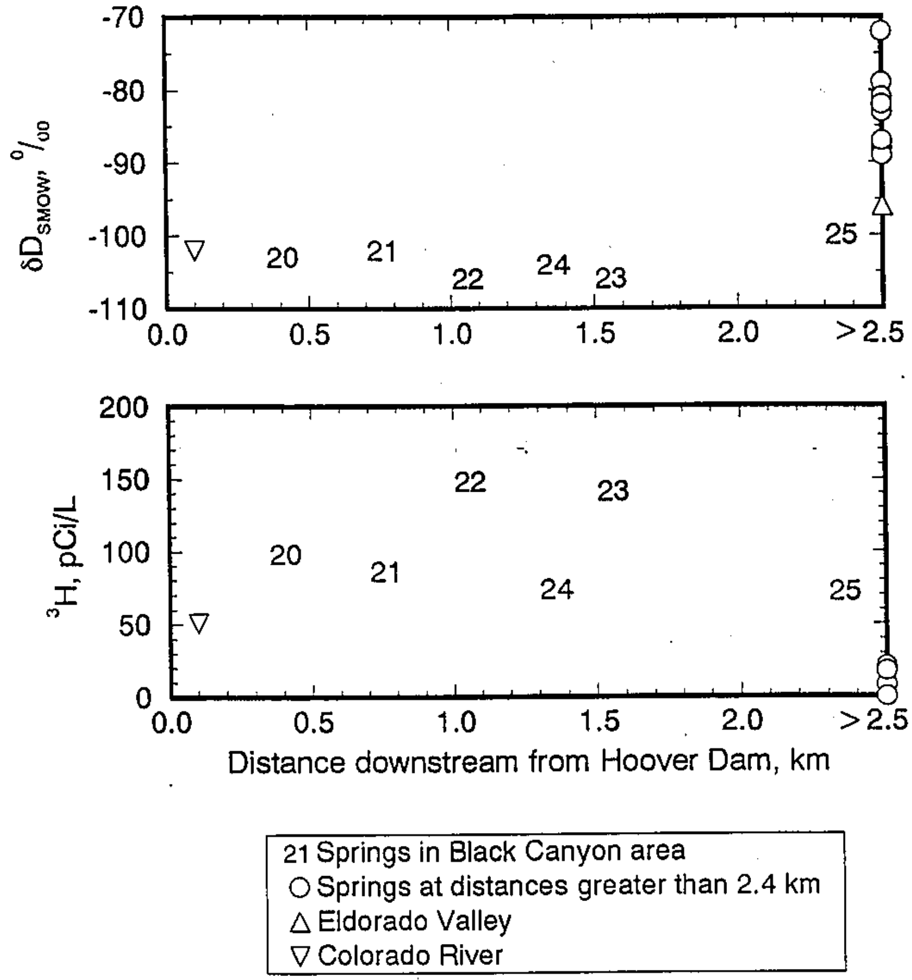

Figure 16. Plot of δD and ^3H as a function of distance downstream from Hoover Dam.

is derived from flow outside the local basin and that the discharge has been subjected to evaporation, as discussed above. The uranium isotope signature of the other group of springs is indicative of longer residence times, and supports their designation as subregional springs based on geographic and geologic settings and the stable isotopic data. For the most part, these springs have lower ARs than other regional springs in southern Nevada and southwestern Utah for which data are available. Although regional data for uranium are not as abundant as data for stable isotopes, the recent studies by Farmer (1996) and Yelken (1996) may be indicative of broader awareness and acceptance of uranium-series disequilibrium as an interpretive tool for investigating groundwater flow in southern Nevada. If this is the case, further interpretation of spring sources and water evolution along flowpaths will be possible as the regional uranium database grows.

For springs in the Valley of Fire Wash group, the uranium data may provide additional insight into flow patterns delineated using stable isotope data. Stable isotope data in non-geothermal systems provides information on initial recharge conditions and any subsequent

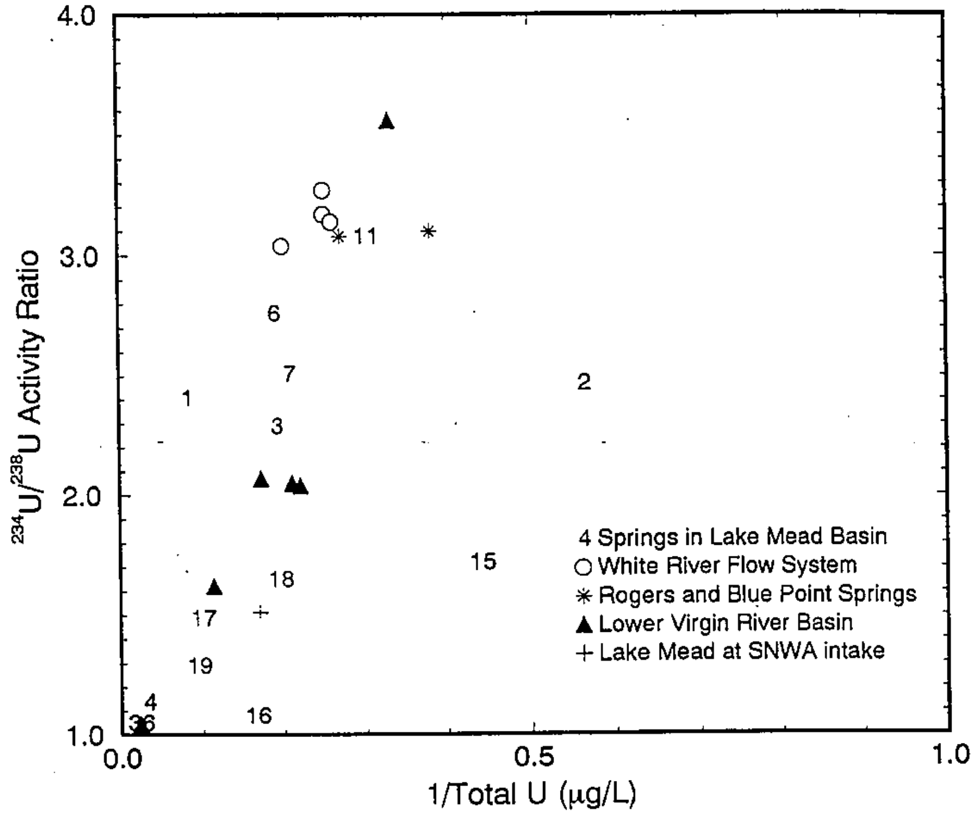

Figure 17. Uranium composition of springs in the Lake Mead basin, as compared to other waters in the region.

evaporation, but typically are not affected by water-rock interaction. Uranium isotope values can change as water moves along a flowpath and evolves due to interaction with aquifer materials.

Springs 6 and 7, which plot together with the Rogers/Blue Point group on the stable isotope graph, exhibit lower activity ratios and slightly higher concentrations than do Rogers and Blue Point springs. This may be suggestive of mixing between a lower-concentration, higher-AR water (discharge at Rogers and Blue Point springs) and a water which is leaching a "fresher" source of uranium. Water flowing through a rock body which has had less leaching take place would tend to provide a higher uranium concentration, but a lower AR than a water interacting with a more highly leached rock body (Osmond and Cowart, 1992). Perhaps, then, the springs in Valley of Fire Wash share a common water source with Rogers and Blue Point Springs, but are more recent in origin.

The uranium signature for Spring 2 indicates a significantly lower concentration than the North Shore Complex springs, to which it is related by location and stable isotope signature. Since evaporation is not apparent in the stable isotope data, the two most likely explanations for the uranium signature are either dilution at some point along the flowpath for this spring, or flow toward other springs in the group passing through a localized area of anomalously high uranium concentration.

CONCLUSIONS

Thirty-six springs in and around the Overton Arm, Boulder Basin, and Black Canyon areas of the Lake Mead National Recreation Area were visited and described Historical data, which generally included discharge measurements, chemical indicator measurements, and water chemistry analyses, were compiled and supplemented by stable and radioactive isotopic data collected during the present study.

Three classifications of source area have been defined for the springs, primarily based on hydrogeologic setting and the stable isotopic data. Distinguishing characteristics of these three classifications, and the springs included in each, are listed in Table 3.

Table 3. Characteristics of the Three Spring Classifications Defined by this Study, and the Springs Included in Each.

	Local	Subregional	Lake Mead
Geologic Setting	Generally not related to regional structural features.	Often related to regional structural features such as faults.	Related to normal faulting around Boulder City pluton.
Discharge Rate	Less than 20 L/min, most less than 3 L/min	1 to 2750 L/min	10 to 1540 L/min
Temperature	10 to 25°C	15 to 30°C	32 to 58°C
δD	-67 to -80 per mil	-88 to -93 per mil	-106 to -100 per mil
^3H	Less than 5 to 18 pCi/L	Less than 5 pCi/L	74 to 141 pCi/L
Uranium Activity Ratio	Less than 2.0	Greater than 2.0	—
Spring Name and ID	Kelsey (1) Bitter (15) Sandstone (16) Cottonwood (17) Gypsum (18) Unnamed, in Rainbow Gardens (19) Unnamed, in Horsethief Canyon (27) Unnamed, near Spring 30 (31) Nevada Falls (32) Bighorn Sheep (33) Arizona Seep (34) Latos Pool (35) Unnamed, in Aztec Wash (36)	Unnamed, in Magnesite Wash (2) Unnamed, in Kaolin Wash (3) Getchel (4) Unnamed, in Valley of Fire Wash (5) Unnamed, in Valley of Fire Wash (6) Unnamed, in Valley of Fire Wash (7) Blue Point (8) Unnamed (9) Unnamed (10) Rogers (11) Scirpus (12) Corral (13) Unnamed (14) Palm Tree, Cold (26) Boy Scout Canyon, Hot (28) Boy Scout Canyon, Cold (29) Arizona Hot Spring (30)	Pupfish (20) Arizona Hot Spot (21) Sauna Cave (22) Nevada Hot Spring (23) Nevada Hot Spot (24) Palm Tree, Hot (25)

Almost one third of the springs studied are considered to be of local origin. Locally-derived springs discharge groundwater from small flow systems that receive most or all of their recharge locally and at low altitudes. These springs are generally not related to major structural features, instead discharging from small fractures or joints, or the bottoms of wash channels. The low discharge rates of local springs result from the limited groundwater recharge that occurs at low elevations in this arid region. Temperatures are lower than the other springs because of rapid equilibration of the low volume discharge with ambient land surface and air temperatures, and because groundwater does not circulate to great depths. The stable isotopic values are indicative of low-elevation recharge in southern Nevada. Low uranium activity ratios and relatively higher uranium concentrations are indicative of relatively short residence times, which generally result from shorter flow paths, and support the designation of these springs as locally derived. Despite their local origin, however, non-detectable to very low tritium concentrations suggest travel times longer than several decades and very limited recharge by recent precipitation events.

Local springs are unrelated to regional groundwater flow systems such as the carbonate aquifer system. For springs in the Lake Mead basin, recharge occurs in the Black Mountains, Bitter Spring Valley (and possibly the slopes of surrounding ridges), and the area surrounding Rainbow Gardens. Local springs in Black Canyon originate from recharge in the Black Mountains and Eldorado Mountains. Most of the local springs in the recreation area discharge from localized groundwater flow systems that are contained within the park boundaries. Although the Maxey-Eakin method predicts that groundwater recharge is neglibible at low elevations in southern Nevada, the existence of these springs indicates that certain geologic, topographic, climatic, and hydrologic conditions can combine to produce local flow systems that are capable of supplying perennial springs. The small sizes of these flow systems, which suggests that their groundwater storage potential is small, means that locally-derived springs are more sensitive to local climate and recharge conditions than the larger, subregional springs, and therefore may require special management and protection.

Subregional springs are dominated by groundwater that originates outside local flow systems, and therefore outside the recreation area, and may include groundwater recharged at higher elevations. The locations of subregional springs are often related to major, regional structural features. Most of the subregional springs in the Lake Mead basin (the Rogers/Blue Point and Valley of Fire Wash groups) are related to the Lake Mead strike/slip fault system, while most of the subregional springs in the Black Canyon area are related to a system of north-south-trending normal faults. Most of these springs represent the ultimate discharge of subregional groundwater flow systems and therefore have higher discharge rates than the local springs. Their higher temperatures result from deeper circulation and less equilibrium with ambient land surface and air temperatures. The stable isotopic values are indicative of higher elevation recharge sources than most of the region surrounding Lake Mead. Non-detectable tritium concentrations and low percentages of modern carbon indicate that these waters have long residence times. Higher uranium activity ratios are indicative of longer residence times, and generally longer groundwater flow paths, where the water has more time in contact with the rock.

Subregional springs in the Lake Mead basin appear to be most strongly related to groundwater systems that extend north to the Weiser Wash and Mormon Mountains area, rather than to the regional White River Flow System or Virgin River basin. Subregional springs in the Black Canyon area appear to originate from a mixture of subregional flow (e.g., Eldorado Valley in Nevada, possibly Detrital Valley in Arizona) and local, low-elevation recharge in the Black Mountains and Eldorado Mountains. The subregional origin of these springs suggests that they may be more sensitive than previously thought to groundwater impacts in the areas adjacent to the park.

A third set of springs is derived from recirculated Lake Mead water, as first described by McKay and Zimmerman (1983). These springs are related to normal faulting around the Boulder City pluton, which provides the heat source for their high temperatures. The high discharge rates exhibited by several of these springs probably relate to the very high gradient of hydraulic head that results from the impoundment of Lake Mead by Hoover Dam. The stable isotope values form a range around the present composition of the Colorado River, implicating it as the most probable source. In addition, the tritium contents of these springs indicates that at least a portion of these waters were recharged after 1952.

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APPENDIX A

PHYSICAL, CHEMICAL, AND ISOTOPIC DATA

Table A-1. Field Measurements.

ID	Latitude (d m s)	Longitude (d m s)	Altitude (m)	Discharge Rate (L/min)	Temp (°C)	EC (µS/cm)	pH (Std. Units)	DO (mg/L)	HCO_3 (mg/L)	Date
1	36 31 38	114 24 51	375	<1	22	3561	7.05	3.8	147	03/07/96
2	36 29 59	114 28 35	427	<1	16	470	7.85	8.1	—	10/04/95
2	36 29 59	114 28 35	427	<1	11.1	552	8.25	8.8	200	02/09/96
3	36 29 14	114 28 00	439	<1	19	545	8.13	7.6	—	10/04/95
3	36 29 14	114 28 00	439	<1	14.1	770	8.46	6	180	02/09/96
4	36 26 36	114 24 17	424	<1	10.8	23905	7.88	8.8	—	02/09/96
5	36 24 21	114 26 38	450	~1	15	3590	7.61	5.25	156	03/07/06
6	36 24 19	114 25 50	450	13.1	13.5	8024	7.76	3.9	118	03/07/96
7	36 24 05	114 24 07	381	~40	23	5520	7.1	5	—	02/09/96
8	36 23 24	114 25 59	470	—	30	4535	7.03	2.1	—	10/04/95
8	36 23 24	114 25 59	470	1040	29.6	4270	7.05	2.65	—	02/08/96
9	36 22 59	114 26 00	494	<1	17	4235	8.02	7	—	02/08/96
10	36 22 45	114 25 30	430	>40	15	8100	7.55	7.5	—	02/08/96
11	36 22 37	114 26 40	488	2750[2]	30	4190	7.22	4.6	—	10/03/95
11	36 22 37	114 26 40	488	—	30	3860	7.03	2.6	—	02/08/96
12	36 22 37	114 26 57	480	<1	17	4935	7.13	0.7	—	02/07/96
13	36 22 14	114 27 36	485	<1	17	4315	7.31	6.2	152	02/07/96
14	36 21 28	114 26 14	396	30	17	5590	8.04	8.6	—	02/08/96
15	36 17 06	114 30 51	506	12	25	4090	7.43	3.15	—	10/03/95
15	36 17 06	114 30 51	506	—	17.2	4021	7.58	4.75	104	02/06/96
16	36 12 40	114 33 24	601	<1	19	1265	7.06	1.25	—	10/03/95
16	36 12 40	114 33 24	601	<1	11	1450	7.03	1.95	146	02/07/96
17	36 12 12	114 38 37	661	<1	18	3690	7.63	2.4	—	10/03/95
17	36 12 12	114 38 37	661	0.07	12.6	3625	7.81	6.5	173	02/06/96
18	36 12 29	114 54 44	530	<1	22	4860	7.56	7.2	—	10/02/95
18	36 12 29	114 54 44	530	<1	15.8	4230	7.38	4.2	114	02/06/96
19	36 06 26	114 58 10	500	<1	25	4900	7.05	2.5	—	10/02/95
19	36 06 26	114 58 10	500	<1	15.5	4785	7.81	3.8	129	02/05/96
20	36 00 40	114 44 35	240	636	36	1204	7.79	3.3	—	02/11/97
21	36 00 05	114 44 30	210	60	55.1	2775	7.62	3.1	—	01/31/97
22	36 00 11	114 44 36	220	22.2	45	1893	7.66	4	—	02/01/97
23	36 00 10	114 44 58	280	1536	46	1788	7.36	1.6	—	01/31/97
24	36 00 04	114 44 36	210	18	58	2323	8	3	—	01/31/97
25	35 59 43	114 44 19	230	10.2	48	3599	7.55	2.5	—	02/01/97
26	35 59 41	114 44 15	235	13.2	13	7059	7.95	10.0	—	02/01/97
27	35 59 56	114 37 58	988	2	12	1069	7.66	—	—	02/03/97
28	35 58 59	114 44 49	260	960[1]	55	4601	7.43	1.9	—	02/02/97
29	35 58 59	114 44 49	263	—	24	4313	7.10	8.0	—	02/02/97
30	35 57 39	114 43 32	245	126	44	4991	7.70	2.4	—	02/01/97
31	35 57 39	114 43 32	249	4.2	19	3368	7.78	6.8	—	02/01/97
32	35 56 43	114 43 55	211	8.4	19	1022	7.34	—	—	02/02/97
33	35 56 21	114 44 03	245	10.2	32	816	7.92	4.2	—	02/02/97
34	35 55 35	114 42 24	220	<1	24	7171	7.47	—	—	02/03/97
35	35 50 55	114 43 33	293	2	25	750	8.08	4.5	—	05/06/97
36	35 39 36	114 46 20	605	<1	18	1505	7.34	1.7	—	02/05/96
36	35 39 36	114 46 20	605	2	15	1874	7.54	3.45	—	02/11/97
ES[3]	35 48 13	115 00 14	550	—	23	891	8.68	3.6	96	05/02/97
CR[3]	36 00 35	114 44 40	200	—	14	927	8.18	8.4	—	02/11/97

[1] Combined discharge of hot and cold springs
[2] Annual mean based on water years 1985 to 1994 in U.S.G.S. Water-Data Reports
[3] ES Eldorado Substation Well
CR Colorado River, below Hoover Dam

Table A-2. Major Ion and Trace Metal Chemistry.

ID	EC (lab) (µS/cm)'	pH (lab) Std. Units	TDS mg/L	HCO_3 (lab, mg/L)	CO_3 mg/L	Cl mg/L	SO_4 mg/L	NO_3 mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	SiO_2 mg/L	Li mg/L	F mg/L	Fe mg/L	N mg/L	B mg/L	Mn mg/L	Date	Source[1]
1	3640	7.5	2721	319	—	332	1180	—	547	25.4	156	92.9	46.8	—	—	—	0.84	—	—	03/07/96	f
2	574	8.27	462	249	0	18.9	60	—	52	25.6	34.7	16.8	5	—	—	—	0.04	—	—	02/09/96	f
3	819	8.35	626	213	2.2	46.5	168	—	77.6	21.3	48.9	25.9	19.1	—	—	—	3.32	—	—	02/09/96	f
4	17500	8.1	16300	270	0	2100	8800	—	3800	300	470	610	54	—	2.6	0.2	—	17	0.3	05/17/78	g
5	4350	7.62	3841	169	—	278	2290	—	295	51.1	537	208	12.4	—	—	—	—	—	—	03/07/06	f
6	—	7.9	9970	240	0	1900	4800	—	1900	130	590	510	16	1.1	2	0.01	0.05	7.3	0.02	05/05/77	g
7	—	—	4710	140	0	600	2600	—	600	45	510	260	24	—	1.6	0	—	2.2	0.03	05/19/78	g
8	4100	7.8	—	160	—	400	1900	—	330	23	470	160	16	0.68	1.5	<0.009	0.2	—	<0.003	07/01/85	a
9	4190	7.5	3710	220	0	370	2100	—	340	27	560	180	21	—	1.5	0.01	—	1.4	0.01	05/19/78	g
10	—	7.7	9270	650	0	1700	4300	—	1700	130	300	720	89	—	4.5	0.02	—	6.2	0.04	05/19/78	g
11	—	7.48	—	161	0	327	1620	—	291	22.7	423	143	16.8	—	1.4	—	0.27	—	—	03/19/92	e
12	4440	7.6	3787	266	0	386	2040	—	350	25.3	513	186	20.4	—	—	—	<0.04	—	—	02/07/96	f
13	—	—	3440	180	0	400	1900	—	340	23	510	160	16	0.7	1.6	0.01	0.1	1.3	0.01	05/04/77	g
14	5600	—	4930	170	0	680	2700	—	580	18	580	250	33	0.96	2	0.03	0	1.8	0.02	05/19/77	g
15	4200	8.1	3730	140	0	160	2400	—	270	22	580	190	33	0.83	2.8	0.01	0.02	1.5	0.01	05/03/77	g
16	1550	7.58	1215	249	0	16.9	725	—	21.9	4.96	209	79.2	13.8	—	—	—	1.15	—	—	02/07/96	f
17	3890	7.99	3660	205	0	63.6	2410	—	209	10.7	524	220	17.4	—	—	—	<0.04	—	—	02/06/96	f
18	4450	7.79	4253	146	0	151	2840	—	231	21.5	532	308	23.6	—	—	—	<0.04	—	—	02/06/96	f
19	5280	7.62	4931	144	0	379	3040	—	405	38.8	569	332	13.9	—	—	—	9.26	—	—	02/05/96	f
20	1250	—	757	116	—	108	335	1.77	188	4.5	59.9	2.9	29.6	—	—	—	0.4	—	—	05/02/95	b
21	—	—	1749	77.5	—	476	589	<0.4	451	9.48	140	5.9	34.3	—	—	—	—	—	—	01/31/97	f
22	1780	—	1280	141	—	134	584	0.27	210	8.27	150	11	50.1	—	—	—	0.06	—	—	05/02/95	b
23	1780	—	1260	135	—	145	584	0.31	226	7.53	138	8.4	48	—	—	—	0.07	—	—	05/02/95	f
24	2340	—	1580	98.1	—	283	644	<0.04	343	8.24	133	4.1	48.7	—	—	—	<0.01	—	—	05/02/95	b
25	—	—	2017	70.7	—	591	644	0.09	522	11	172	6.11	36.8	—	—	—	—	—	—	02/01/97	f
26	—	—	4235	151	—	1514	1100	0.31	1030	16.9	382	40.7	53.6	—	—	—	—	—	—	02/01/97	f
27	—	—	784	324	—	101	140	<0.04	51.8	11.9	120	34.8	62	—	—	—	—	—	—	02/03/97	f
28	4500	—	2920	28.5	—	956	843	0.09	695	14.4	247	2.3	44.7	—	—	—	0.02	—	—	05/03/95	b
29	4500	—	2490	33.2	—	962	827	<0.04	680	15.8	257	6	51.7	—	—	—	<0.01	—	—	05/03/95	b
30	—	—	2635	37.3	—	1078	587	4.92	650	15.2	249	13.5	39.4	—	—	—	—	—	—	02/01/97	f

Table A-2. Major Ion and Trace Metal Chemistry (Continued).

ID	EC (lab): (µS/cm)	pH (lab) Std. Units	TDS mg/L	HCO_3 (lab, mg/L)	CO_3 mg/L	Cl mg/L	SO_4 mg/L	NO_3 mg/L	Na mg/L	K mg/L	Ca mg/L	Mg mg/L	SiO_2 mg/L	Li mg/L	F mg/L	Fe mg/L	N mg/L	B mg/L	Mn mg/L	Date	Source[1]
31	—	—	1933	97.9	—	755	410	11	407	11	212	28.6	33.2	—	—	—	—	—	—	02/01/97	f
32	1210	—	691	83.8	—	194	182	6.91	178	3.14	38.2	7.5	29	—	—	—	1.56	—	—	05/03/95	b
33	820	—	493	81.5	14.6	89.7	145	12.5	164	0.89	4.26	0.3	24.4	—	—	—	2.82	—	—	05/04/95	b
34	—	—	4228	148	—	2019	525	18.5	1103	25.4	313	76.4	40.6	—	—	—	—	—	—	02/03/97	f
35	347	—	215	112	6.7	13.5	42	8.95	34.3	6.46	28.5	4.6	11.1	—	—	—	2.02	—	—	04/20/95	b
36	—	—	1298	363	—	102	445	<0.04	118	5.89	178	47.6	38.9	—	—	—	—	—	—	02/05/96	f
ES[2]	795	—	498	124	10.6	119	60.9	14.4	154	4.01	6.84	0.5	64.9	—	—	—	3.24	—	—	09/26/95	b
CR[2]	—	—	689	160	—	80	245	1.51	94.6	4.87	74.4	28.3	8.7	—	—	—	—	—	—	02/11/97	f

[1] Sources of data:
a Thomas *et al.*, 1991
b SNWA, unpublished data
e Hershey and Mizell, 1995
f This study
g Laney and Bales, 1996

[2] ES Eldorado Substation Well
CR Colorado River, below Hoover Dam

Table A-3. Isotopic Compositions.

ID	^3H (pCi/L)	$\delta^{18}O$ (per mil)	δD (per mil)	$\delta^{13}C$ (per mil)	14 PMC	$^{234}U/^{238}U$ (act. ratio)	Total U (µg/L)	Date	Source[1]
1	—	−10	−82	−7.6	—	2.41	13.3	03/07/96	f
2	<10	−11.5	−92	−5.0	—	2.47	1.8	02/09/96	f
3	<10	−11.3	−88	−6.5	—	2.29	5.45	02/09/96	f
4	<10	−8.6	−83	—	—	1.14	37.9	02/09/96	f
5	—	−12.2	−93	—	—	—	—	03/07/96	f
6	—	−11.8	−92	—	—	2.76	5.50	03/07/96	f
7	—	−11.2	−88	−6.8	—	2.51	5.0	02/09/96	f
8	—	−12.4	−93	−6.2	3.5	3.07	—	06/24/85	a
8	—	−12.5	−93.5	−5.3	7.2	—	—	07/01/85	a
8	<10	−12.3	−91	—	—	—	—	02/08/96	f
11	<10	−12.4	−92	−3.9	3	~4.0	~2.9	03/19/92	e
11	—	−12.4	−91	—	—	3.08	3.49	02/08/96	f
12	—	−12	−90	—	—	—	—	02/07/96	f
13	—	−12.1	−91.5	—	—	—	—	02/07/96	f
15	<10	−9.9	−77	−4.3	—	1.72	2.35	02/06/96	f
16	—	−10.5	−79	—	—	1.08	6.69	02/07/96	f
17	<10	−10.8	−80	—	—	1.49	12.0	02/06/96	f
18	<10	−9.2	−75	—	—	1.65	5.59	02/06/96	f
19	<10	−8.6	−71	—	—	1.29	12.8	02/05/96	f
20	—	—	—	−6.6	—	—	—	02/11/97	f
20	98	−12.9	−103	—	—	—	—	05/02/95	b
21	86	−13	−102	−7.4	—	—	—	01/31/97	f
22	148	−13.7	−106	—	—	—	—	05/02/95	b
23	141	−13.6	−106	−28.65	62.9	—	—	05/02/95	b
24	74	−13.5	−104	—	—	—	—	05/02/95	b
25	72	−12.7	−100	−8.0	—	—	—	02/01/97	f
26	21	−11.2	−88	−11.8	—	—	—	02/01/97	f
27	8	−10.8	−79	—	—	—	—	02/03/97	f
28	<10	−11.5	−92	−27.64	26.98	—	—	05/03/95	b
29	<10	−10.8	−88	—	—	—	—	05/03/95	b
30	<5	−11.2	−87	−11.5	50.71	—	—	02/01/97	f
31	<5	−10.3	−81	−13.2	81.82	—	—	02/01/97	f
32	<10	−10.2	−83	—	—	—	—	05/03/95	b
33	<10	−10.3	−83	−24.91	15.34	—	—	05/04/95	b
34	<5	−10.3	−82	−7.0	—	—	—	02/03/97	f
35	8.2	−9.8	−81	−11.9	—	—	—	05/06/95	f
36	18	−9.2	−72	—	—	1.05	134	02/05/96	f
36	—	—	—	−13.2	—	—	—	02/11/97	f

[1] Sources of data:
a Thomas *et al.*, 1991
b SNWA, unpublished data
e Hershey and Mizell, 1995
f This study

SE ROA 52007

JA_17112

APPENDIX B

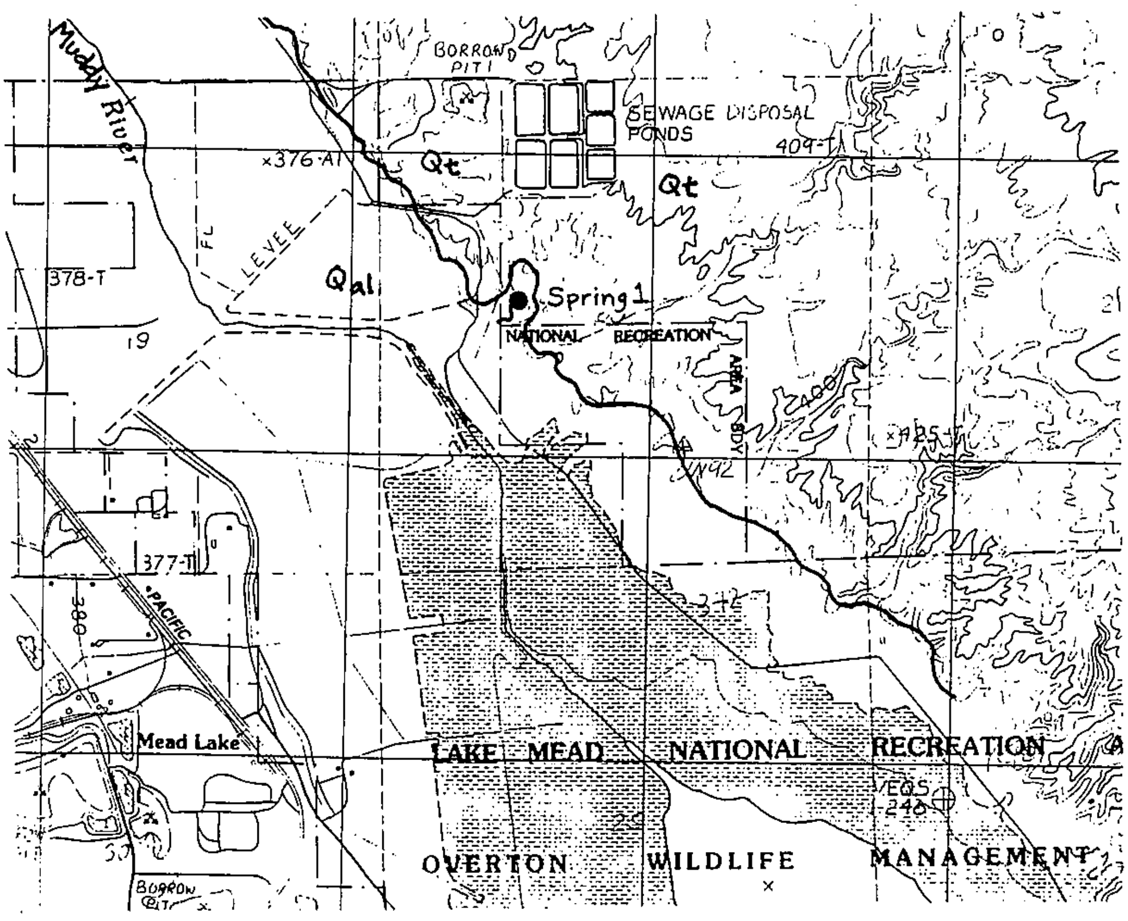
GEOLOGIC DESCRIPTIONS

Spring 1 – Kelsey Spring

Topographic base: 7.5' Overton Quadrangle
Geology references: This study

Kelsey Spring is located at the northeast edge of the Overton Wildlife Management area at the base of Mormon Mesa. The orifice is covered by a concrete vault (having dimensions 1.5 by 2 m wide and 1.5 m high) with an access door in the top. There was approximately 0.75 m of standing water in the vault when this spring was visited on 3-7-96. Seepage from the vault occurs in cracks in the concrete near its base. Samples were collected from this seepage. In addition, a 10-cm-diameter steel pipe extends south about 20 m from the vault and discharges at ground surface within a stand of very dense vegetation. A large area of reeds extends north and slightly uphill from the vault, suggesting that groundwater is near ground surface and that additional discharge may be occurring in that area.

Kelsey Spring discharges near the base of Quaternary terrace deposits at the edge of Mormon Mesà. Other seeps are located at the base of the terrace, as indicated by several stands of palm trees to the northwest.



SE ROA 52009

JA_17114

Spring 2 – Unnamed spring in Magnesite Wash

Topographic base: 7.5' Overton Quadrangle
Geology references: Bohannon (1983)

The spring is located in a gap in Overton Ridge though which the Magnesite Wash channel passes. The spring issues as subsurface discharge into a 10-m-diameter pool. Additionally, minor seepage can be observed up to 5 m above the pool from fractures in the Tertiary Basal Conglomerate. Surface flow occurs for only a few 10s of meters downstream from the pool, which is surrounded by reeds, willows, and grape vines.

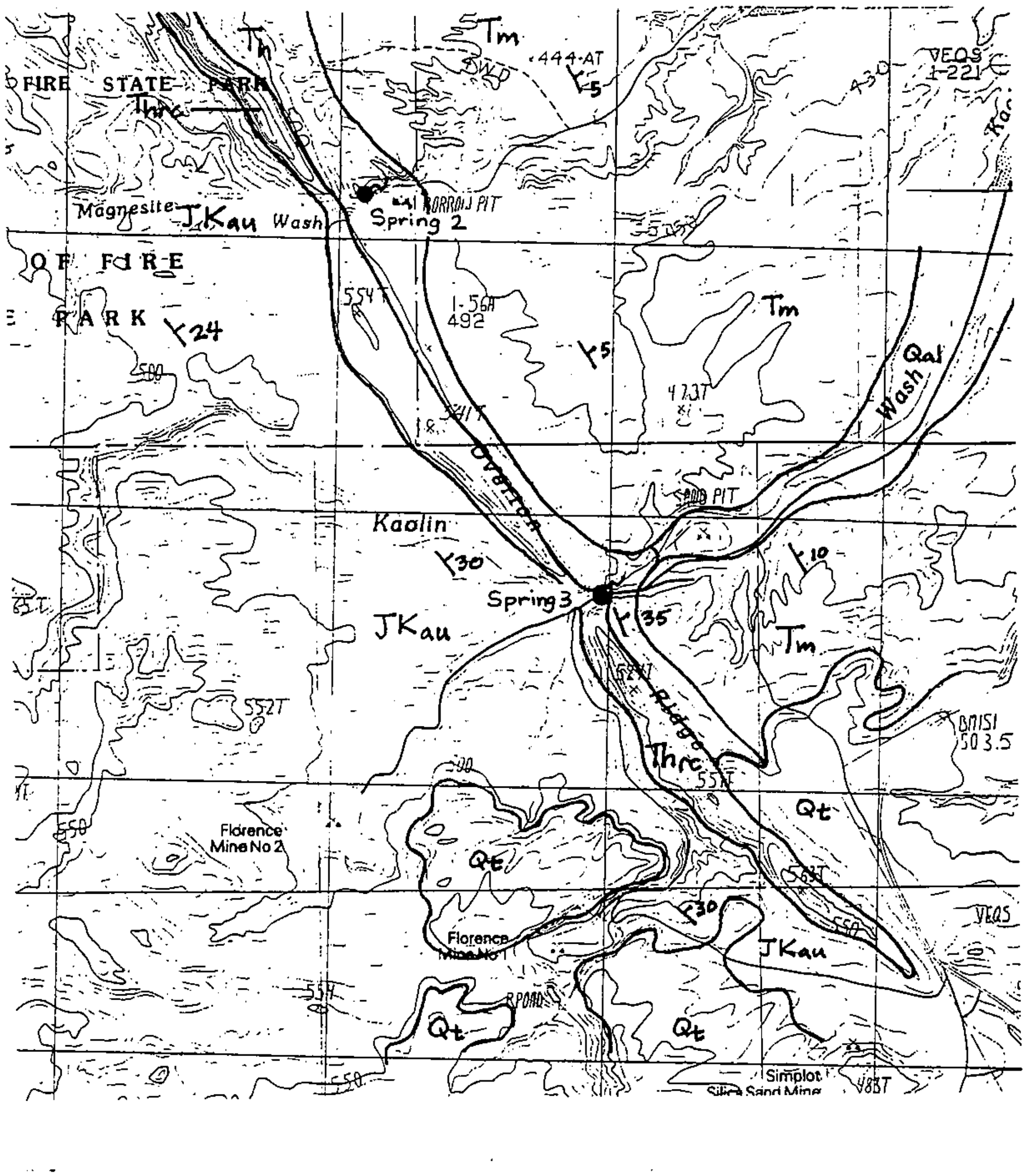
The spring is located at the contact of the Basal Conglomerate with the upper Rainbow Gardens Member (both of the Tertiary Horse Spring Formation), and about 200 m west of the unconformable boundary with the Tertiary Muddy Springs Formation. The spring is not associated with any major structural features. Rather, if groundwater is assumed to be moving generally west or northwest toward the Muddy River and Colorado River, then the spring is located at the lowest elevation just upgradient from the low-permeability barrier of the Muddy Creek Formation. Upstream of the spring, Magnesite Wash passes through a basin comprised of Mesozoic sandstones and covered by thick, sandy soils.

Spring 3 – Unnamed spring in Kaolin Wash

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983)

The setting for this spring is similar to the Magnesite Wash spring; a gap in Overton Ridge through which Kaolin Wash passes, although the gap at Kaolin Wash is much narrower. At Kaolin wash, the spring issues as subsurface discharge into a 5-m-diameter pool. Additionally, minor seepage can be observed from fractures in the Thumb Member. Surface flow occurs for approximately 400 m downstream from the pool, which is surrounded by reeds.

The spring issues from the Thumb Member of the Teriary Horse Spring Formation, and about 1 km upstream (southwest) of the contact between the the Thumb Member and the Muddy Creek Formation. And, similar to the Magnesite Wash spring, the Kaolin Wash spring is located near the lowest elevation just upgradient from the low-permeability barrier of the Muddy Creek Formation.



B-4

SE ROA 52011

JA_17116

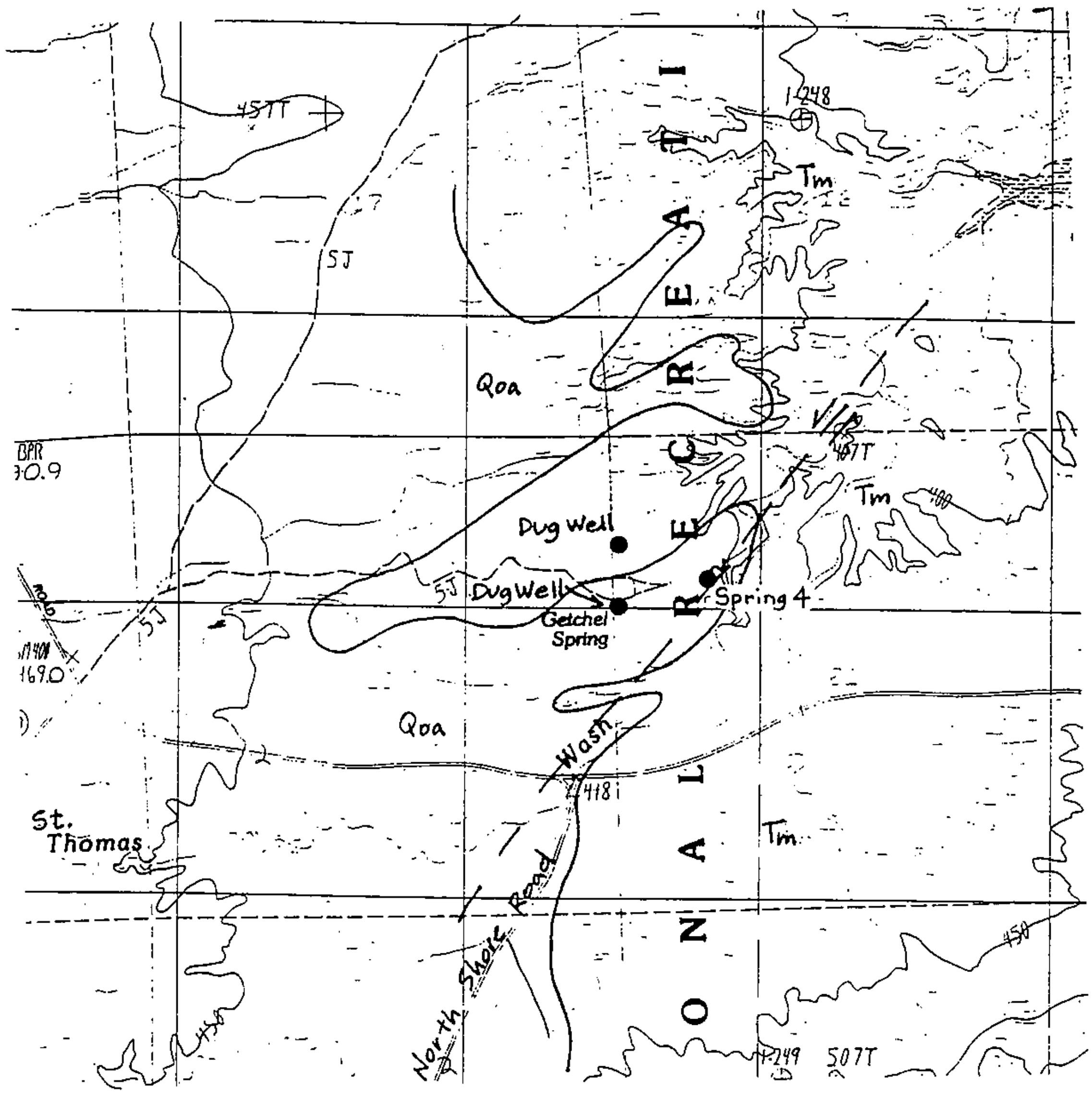
Spring 4 – Getchel Spring

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983)

Getchell Spring is located approximately 0.75 km northeast of the intersection of Northshore Road with the Overton Beach Road. Discharge occurs in the bottom of a 4-m-deep ravine cut into unconsolidated sands and silts of the Muddy Creek Formation. Many gypsum beds are evident within the Muddy Creek Formation near the spring. Surface flow was observed for an approximate 50 m length of the ravine on 2-9-96, although the flow was very slow to stagnant. Small amounts of vegetation were present at the orifice but very little vegetation was observed downstream.

Much of the area surrounding the spring is capped by a gyspum unit which could be in place or colluvium from above. There are no major structural features evident at ground surface, but Bohannon (1983) maps a strike-slip fault through the area, possibly related to the Lake Mead Fault System. The Rogers Spring Fault lies about 1.5 km to the southeast.

There is a dug well to the northwest of Getchel spring which contained standing water at both visits to the area (10-4-95 and 2-9-96). The well is about 2 m in diameter, 2 m deep, and filled with reeds. There is also a brick-lined cavity (cistern?) about 50 m south of the dug well and 100 m west northwest of Getchel Spring. This feature is 3 m deep and 2 m in diameter at the surface, and though it contained no water at either of our visits, it appears to be the feature labeled as Getchel Spring on the "Valley of Fire, East" 7.5' quadrangle map.


457T
1248
Tm
5J
Qoa
ONAL RECREATI
Dug Well
Dug Well
Getchel Spring
Spring 4
407T
Tm
400
Qoa
Wash
1418
St. Thomas
Tm
North Shore Road
450
1249
507T

Spring 5 – Unnamed uppermost spring in Valley of Fire Wash

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Campagna (1990) unpublished mapping

This spring issues from several seeps at the base of the northern bank of Valley of Fire Wash, at the boundary of the recreation area. Surface flow in the wash was observed for a distance of 200 to 300 m on 3-7-96.

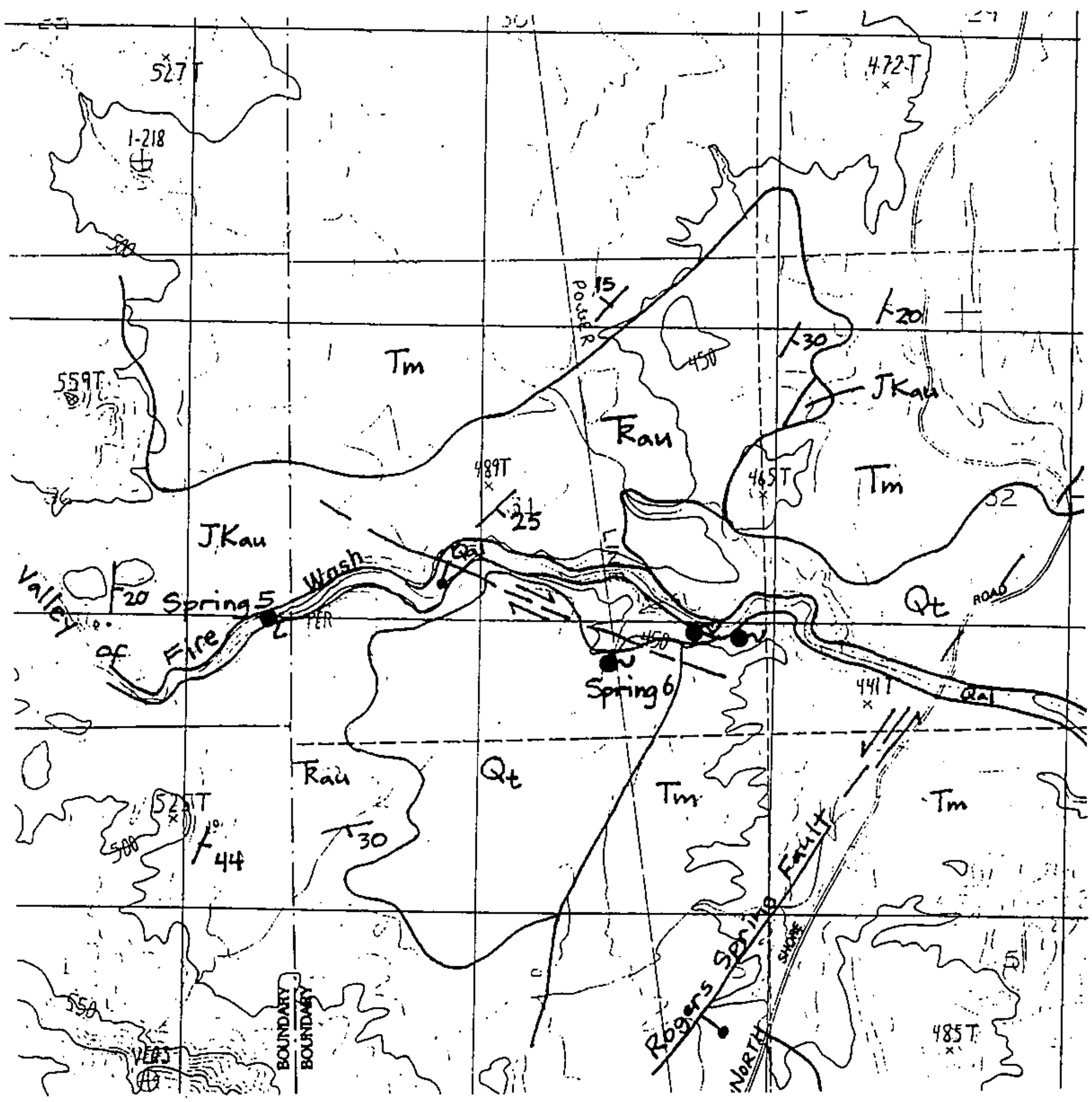
The spring is located on a fault contact between JKau on the west and TRau on the east, but is probably a result of the proximity of the contact between the Jurassic and Triassic clastic rocks with the Tertiary Muddy Creek Formation (see description of Spring 6).

Spring 6 – Unnamed upper spring in Valley of Fire Wash

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Campagna (1990) unpublished mapping

Several orifices and seeps are located along the banks of the Valley of Fire Wash near the power line crossing. Surface flow from this spring area extended to within a few hundred m of North Shore Road at our 3-7-96 visit. The spring area supports a great deal of vegetation along the banks of the wash. Most of the springs and seeps are on the south side of the wash and within 5 m of the wash bottom; however, one small channel extends to the south out of the wash, originating at a spring just southwest of the power line road. Our samples were collected at this orifice, which issues from a thin veneer of Quaternary gravels on top of the Triassic Moenavi and Kayenta Formations. There appears to be considerable subsurface flow within these gravels because flow at the orifice is much lower than flow from the same channel downstream at the Valley of Fire Wash.

The spring area is located at an unconformable contact of Jurassic and Triassic clastic rocks on the west with the Tertiary Muddy Creek Formation on the east, and near the Rogers Spring Fault. The springs occur where eastward flowing groundwater meets the low-permeability barrier formed by the Muddy Creek Formation and is forced upward, possible along fault planes, to discharge points at ground surface.



SE ROA 52015

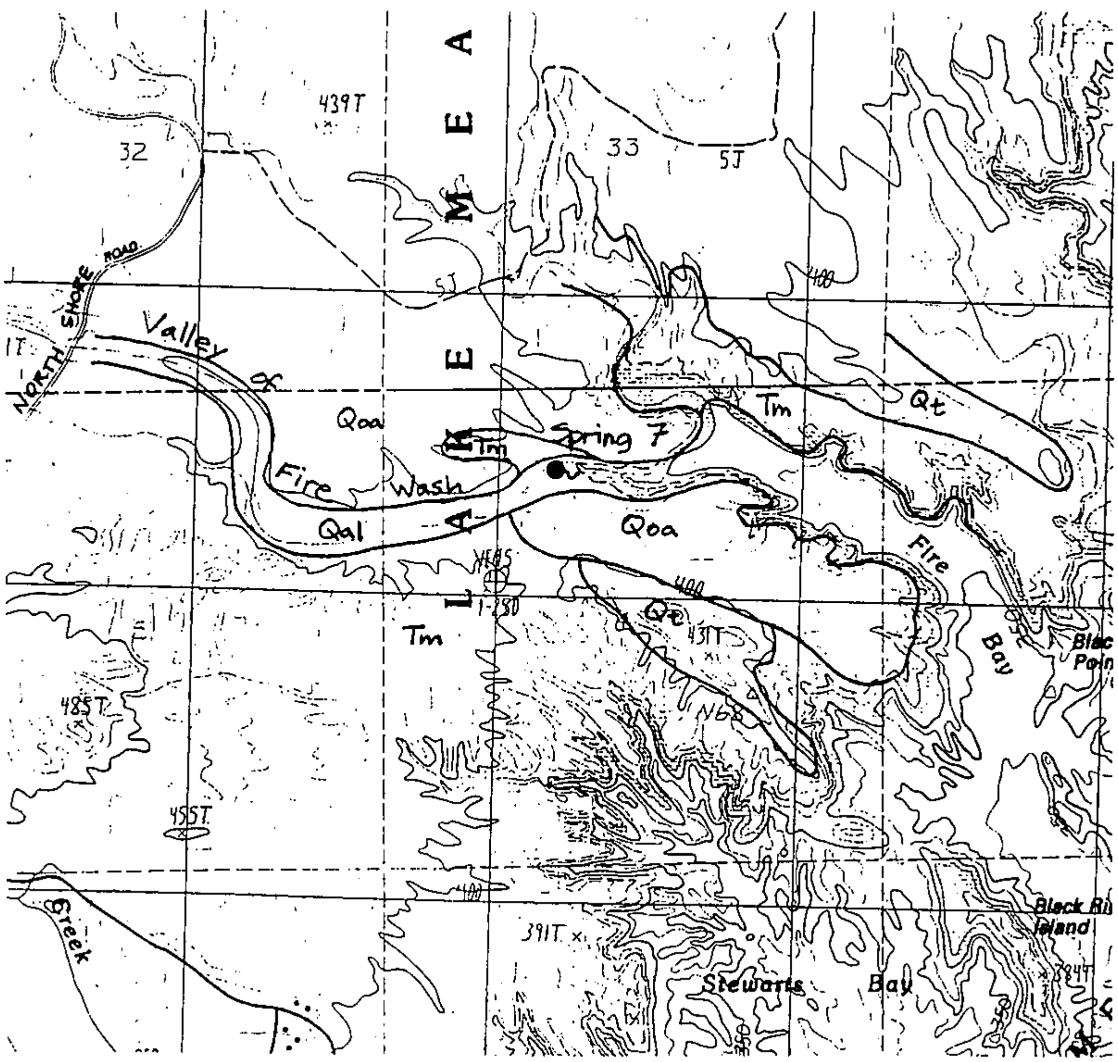
JA_17120

Spring 7 – Unnamed lower spring in Valley of Fire Wash

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983)

The spring is located on the north bank of the Valley of Fire Wash and about 5 m above the base of the wash. Surface flow was evident in the wash from the spring to Lake Mead on our 2-9-96 visit, a distance of about 1 km. Seepage into the wash may be occurring along this stretch. The banks of the wash are covered by thick stands of tamarisk and other vegetation, but the main spring is in a small clearing. Several orifices and seeps are distributed along the bank. Samples were collected from the largest.

The spring issues from Quaternary Older Alluvium near an exposure of the Muddy Creek formation.



SE ROA 52016

JA_17121

Spring 8 – Blue Point Spring

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Blue Point Spring is at the base of the Muddy Mountains, 350 m west of North Shore Road. The spring issues from colluvium about 10 m horizontally from the nearest limestone exposure, and into a 3-m-deep ravine. The surface flow forms Slim Creek, which flows southeast toward Stewarts Point and Lake Mead. Parts of Slim Creek flow underground in locations where the gypsum–rich soils have been dissolved. The spring orifice is surrounded by thick acacia and other vegetation. Samples were collected at the orifice.

The spring is located at the point of intersection of the Rogers Spring Fault and the older west-northwest-trending Arrowhead Fault.

Spring 9 – Unnamed spring 0.8 km south of Spring 8

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Spring is located approximately 50 m east of a culvert under North Shore Road. No surface flow was evident although saturated soils support a dense stand of cat tails and other vegetation, including several cottonwood trees, in an area about 20 m wide.

Spring issues from unconsolidated and partially consolidated red and tan silts, with interbedded sand, pebbles, and gypsum.

Spring 10 – Unnamed spring 0.8 km southeast of spring 9

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Spring is located about 0.8 km southeast and in the same wash channel as Spring 9. Discharge is diffuse and widely-distributed across the base of the wash channel (25 to 30 m wide), although several small (less than 1 m across and 0.1 m deep) channels have been developed. Dense vegetation throughout seep area, including mesquite, tamarisk, and reeds. Our discharge measurement was made upstream of the most diffuse flow and therefore does not account for the diffuse discharge, which is the majority of the discharge from this spring.

Spring issues from Quaternary terrace deposits.

Spring 11 – Rogers Spring

Topographic base: 7.5' Valley of Fire, East Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Rogers Spring is 300 m west of the North Shore Road at the base of the Muddy Mountains. The spring issues from brecciated limestone into a manmade pool having a diameter of about 25 m. The orifice is below the surface of the pool. Overflow from the pool enters Rogers Wash and flows southeast across basin-fill deposits about 3 km to where it enters Lake Mead. Rogers Spring is the largest spring in the study area, with a relatively constant discharge of 2,550 L/min measured since 1985 (USGS, 1996). Samples were collected by submerging and opening the sample bottles below the pool surface at the spring orifice.

The spring is located on the Rogers Spring Fault, a major strike-slip fault in the Lake Mead area. The fault separates lower Paleozoic carbonate rocks of the Muddy Mountains on the west from Quaternary and Tertiary basin-fill deposits to the east. The low permeability basin fill is a barrier to groundwater flow that causes the Rogers Spring Fault to act as a conduit for flow from depth within the carbonates. Four springs issue directly from the fault and several more issue from the basin fill between the fault and Lake Mead.

Rogers Spring is at a step-over in the main Rogers Spring Fault. Fracture density increases near step-over zones in extensional terrains, increasing the potential for groundwater flow paths.

Spring 12 – Scirpus Spring

Topographic base: 7.5' Echo Bay Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Scirpus Spring is 550 m southwest of Rogers Spring. The spring consists of a primary pool 3 m long and 0.5 m wide that is surrounded by very thick reeds, shrubs, and grape vines. No surface flow was evident when this spring was visited (2-7-96). However, abundunt phreatophytes grow in the ravine below the spring indicating evapotranspiration is a major component of spring discharge. Samples were collected from the pool.

The spring is located along the Rogers Spring fault and issues from brecciated limestone about 25 m downslope from bedded limestone of the Muddy Mountain front.

Spring 13 – Corral Spring

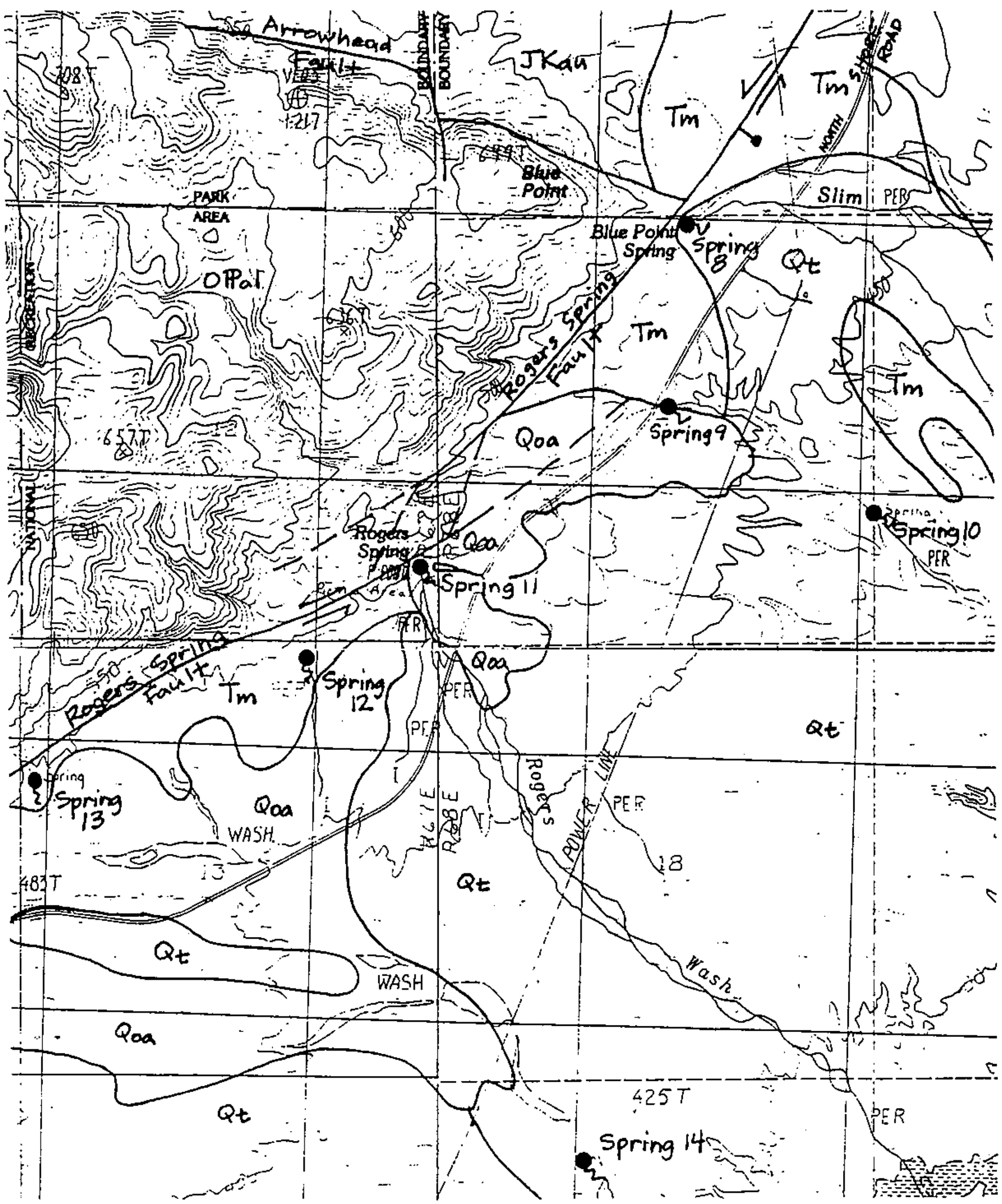
Topographic base: 7.5' Echo Bay Quadrangle
Geology references: Bohannon (1983), Campagna and Aydin (1994)

Corral Spring is the southernmost spring on the Rogers Spring Fault and is located about 1.7 km southwest of Rogers Spring. The spring issues from colluvium in a steep canyon that extends into the limestone of the Muddy Mountain front. The spring consists of several isolated seeps and small pools distributed along a 100 m length of the base of the canyon. Little surface flow was evident, however. This area supports a great deal of vegetation, suggesting that evapotranspiration is a major component of spring discharge. Samples were collected from the highest pool, which was about 4 m long and 2 m wide, and half filled with reeds, at our 2-7-96 visit.

Spring 14 – Unnamed spring northwest of Rogers Bay

Topographic base: 7.5' Echo Bay Quadrangle
Geology references: Bohannon (1983)

Spring issues from wash bottom as seeps. Discharge measurement made approximately 20 m downstream from highest seep. Grasses and mesquite surround the spring area, but there is considerably less vegetation than at other springs in the North Shore Spring Complex. Spring issues from Quaternary terrace deposits.



SE ROA 52019

JA_17124

Spring 15 – Bitter Spring

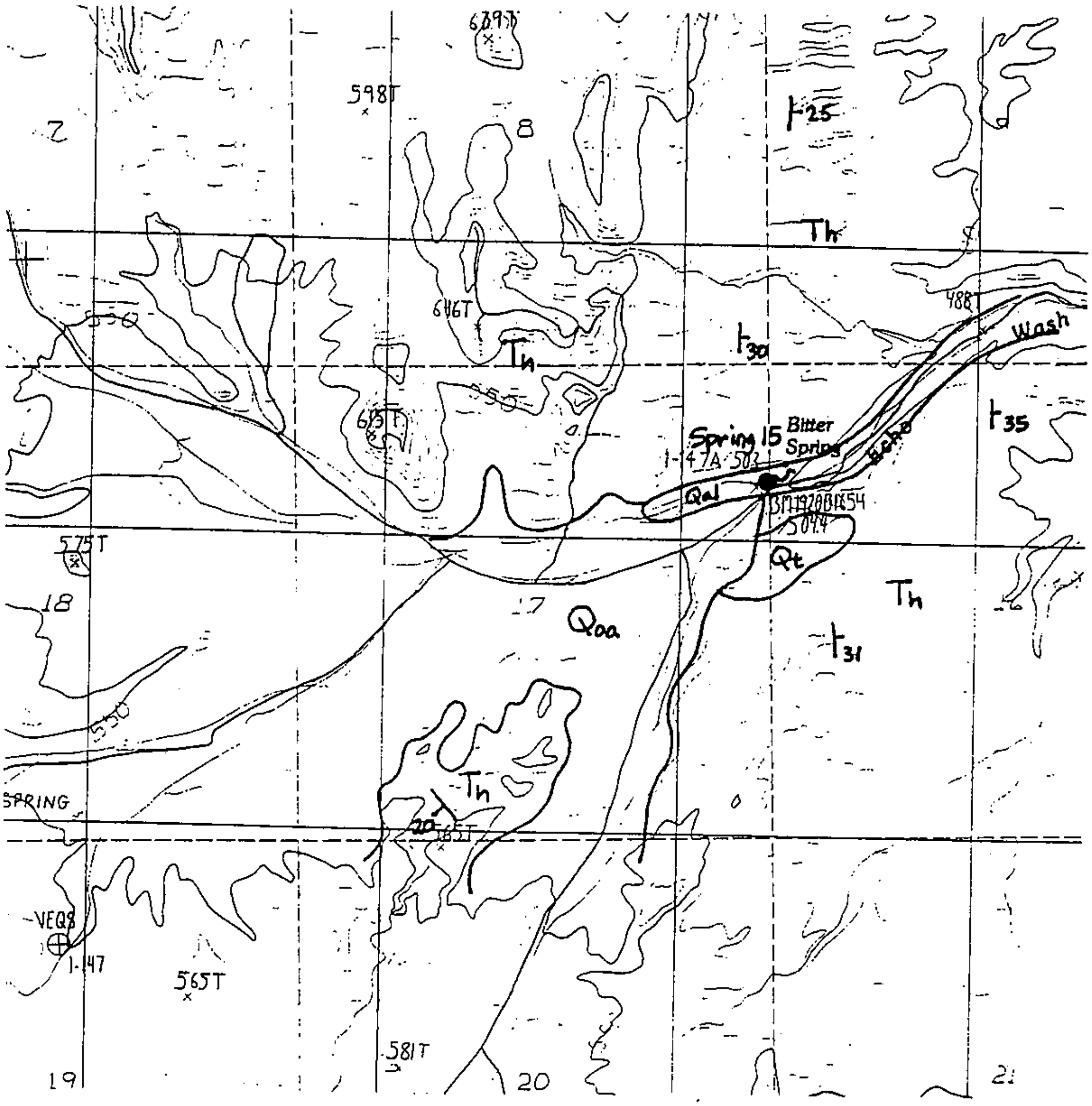
Topographic base: 7.4' Bitter Spring Quadrangle
Geology references: Bohannon (1983)

Bitter Spring is located in Echo Wash at the eastern margin of Bitter Spring Valley. The spring consists of relatively diffuse flow issuing from coarse sand and gravel alluvium in the center of the wash, approximately 0.5 km east and downstream of the channel knick point, which is composed of consolidated Older Alluvium. At the spring, the wash channel is incised in clastic and associated chemical and tuffaceous rocks of the Thumb member of the Tertiary Horse Springs Formation, which dips 25 to 35 degrees east.

Surface drainage to Bitter Spring originates in Bitter Spring Valley directly to the west, and White Basin to the northwest of that. Bitter Spring Valley is composed of approximately 1,500 m of Horse Spring Formation and is covered by Pleistocene alluvium, Pleistocene terrace deposits, and Thumb Member. Bohannon (1983) hypothesizes a section of Paleozoic carbonate rocks below the Thumb. The Bitter Spring Valley margins are composed of Horse Spring Formation to the north and west (Bitter Ridge), and autochthonous Triassic and Permian formations to the south (Razorback Ridge and Pinto Ridge). The subsurface geology of White Basin is similar, but the surface geology differs in that Thumb Member is not exposed and large deposits of Miocene Red Sandstone are present. On the west, White Basin is bordered by Autochthonous Jurassic, Cretaceous, and Triassic rocks; and on the north by Allochthinous lower Paleozoic rocks (Muddy Mountains).

Bitter Spring is located near the eastern terminus of the Borax Fault, and the southern end of East Longwell Ridge; however, the spring does not appear to be directly related to any major structural feature.

Surface flow from the spring is evident, but discontinuous, over a 300 m distance below the orifice, and is accompanied by dense stands of phreatophytes (primarily tamarisk). It is likely that our measurement of discharge at Bitter Spring represents only a small portion of the total spring flow when compared to underflow in the wash sediments, evaporation from the surface channels, and transpiration from plants. Samples were collected from the highest discharge point.



639T
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Spring 15
Bitter Spring
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18
17
Qoa
Th
SPRING
20
VEQ8
1-47
565T
581T
19
20
21

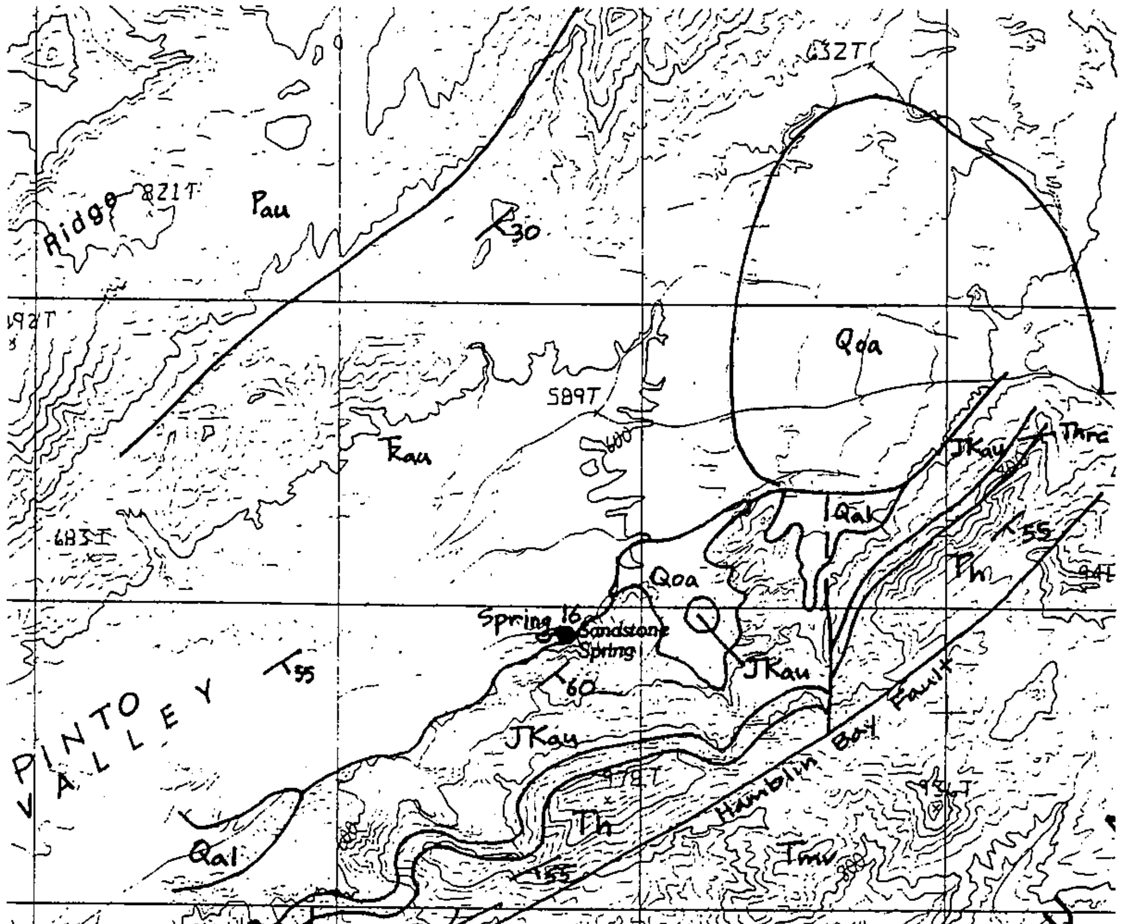
Spring 16 – Sandstone Spring

Topographic base: 7.5' Boulder Canyon Quadrangle
Geology references: Bohannon (1983)

Sandstone Spring is located at the southeast margin of Pinto Valley, and northwest of the Black Mountains. The spring issues at the base of a cliff composed of Aztec Sandstone, which is several hundred meters in height, and into a single pool having a diameter of approximately 2 m. A steel pipe leads from the pool to a steel tank about 20 m downhill from the spring, but the tank contained no water at either of our visits (10-3-95 and 2-7-96). Samples were collected from seepage into the pool. Longwell noted the existence of this spring in his (date?) report and described its quality and quantity as sufficient for watering horses.

Large surface runoff events are evident through the spring area as indicated by the wash channel that cuts into the alluvial fan deposits northwest of the spring and then extends downstream from the spring, and the eroded surface of the sandstone on the cliff face above the spring. Surface flow of this type may serve to recharge shallow sediments and provide temporary "spring discharge" during wet periods; however, atmospheric tritium was not detected in a sample collected 2-7-96 indicating that flow paths are long and that recent recharge was not a major component of spring discharge at that time.

Sandstone Spring is located at a contact of the Jurassic Aztec Sandstone with the underlying Triassic Moenave and Kayente Formations (clastic, nearshore marine and nonmarine rocks). The contact trends N 60 E and dips 60 degrees to the southeast. Discharge at Sandstone Spring may be related to nearly vertical fractures in the Aztec that trend north-south.



Ridge
821T
Pau
30
Qoa
792T
589T
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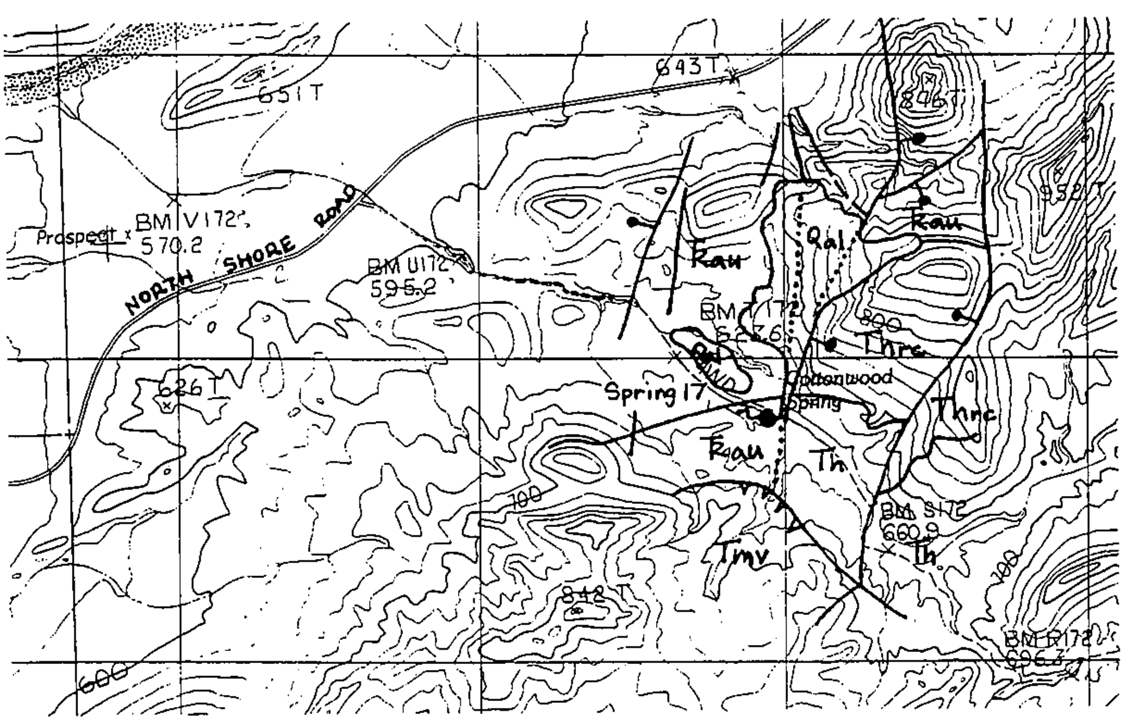
683T
Spring 16
Sandstone Spring
55
60
Qoa
JKau
Qal
PINTO VALLEY
JKau
Th
55
Thrc
Tmv
Hamblin Bay Fault
55
Th
Thrc
828T
BM B 1618
632T
M O U

Spring 17 – Cottonwood Spring

Topographic base: 7.5' Callville Bay Quadrangle
Geology references: Anderson (1973), Campagna (1990) unpublished mapping

Cottonwood Spring is located approximately 2.5 km north of Hamblin Mountain and 1.5 km southeast of North Shore Road, in a wash channel that is tributary to Callville Wash. It appears that spring discharge has in the past occurred from alluvial sediments in the northwest-trending wash channel just downstream of a 3-m high dry waterfall. There are two cottonwood trees located here and evidence of several holes dug by bighorn sheep, burros, or horses in search of water. However, surface discharge was not evident at this location during either of our visits (10-3-95 and 2-6-96). The only discharge evident from the area was from a steel pipe into a metal tank about 40 m southwest of the cottonwood trees. On 10-3-95, the tank was only partially full, indicating some leakage through the sides and insufficient spring discharge to keep it completely full. On 2-6-96, the tank was completely full and overflowing, suggesting that discharge was somewhat greater than observed during the 10-3-95 visit. The tank is useful to wildlife, as we observed several desert bighorn sheep during the 10-3-95 visit. Samples were collected from the pipe as it discharged into the tank.

The orifice is located at a north-south-trending fault contact of the Tertiary Rainbow Gardens basal conglomerate (on the east) with the Triassic upper red unit of the Moenkopi Formation (on the west). The basal conglomerate is approximately 10 to 20 m thick in the area of the spring. The alluvium filling the wash is probably less than 10 m thick.



SE ROA 52024

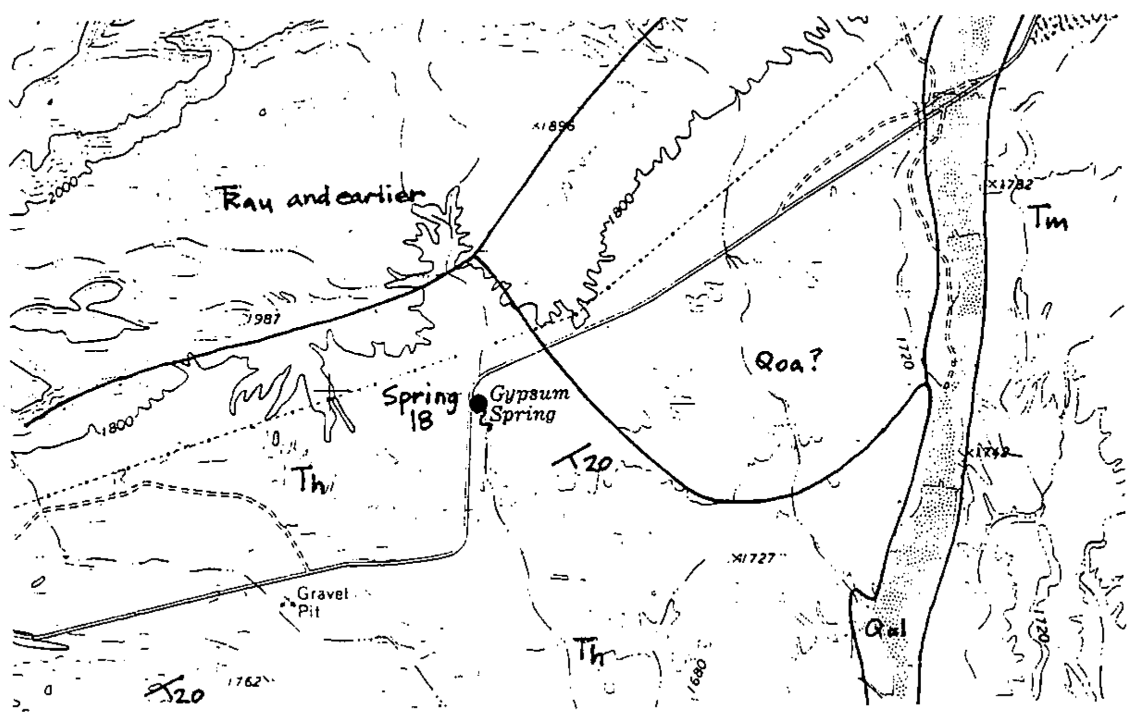
JA_17129

Spring 18 – Gypsum Spring

Topographic base: 7.5' Frenchman Mtn. Quadrangle
Geology references: Bohannon (1978), Longwell *et al.* (1965)

The spring is located approximately 6 km east southeast of Sunrise Mountain and about 1.5 km southwest of Gypsum Cave. The surface discharge is characterized by several seeps and pools in a 3-m-deep, north-south-trending wash channel. The pools were less than 1 m in diameter at both visits (10-2-95 and 2-6-96) and surface flow was present for less than 15 m downstream of the highest orifice. Very dense stands of tamarisk and reeds surround the orifice and line the banks of the wash channel. Samples were collected from surface flow as it emerges from dense vegetation near the orifice.

Gypsum Spring issues from gypsum beds of the Thumb Member about 0.5 km south of a ridge composed of Triassic and older rocks. The spring discharge appears to be controlled by the intersection of the water-bearing unit with land surface; no structural control is evident. Although the elevation of the spring is lower than water levels in the carbonate aquifer to the north in Dry Lake Valley, stable isotopic data indicate that the carbonates are not the source for discharge at Gypsum Spring. Rather, this spring plots in the region of low-elevation precipitation which indicates that its flow was recharged locally. As with other locally-derived springs, the absence of detectable atmospheric tritium in the spring water indicates that despite the local origin, travel times are long and the discharge does not simply represent discharge of groundwater recharged during recent precipitation events.



SE ROA 52025

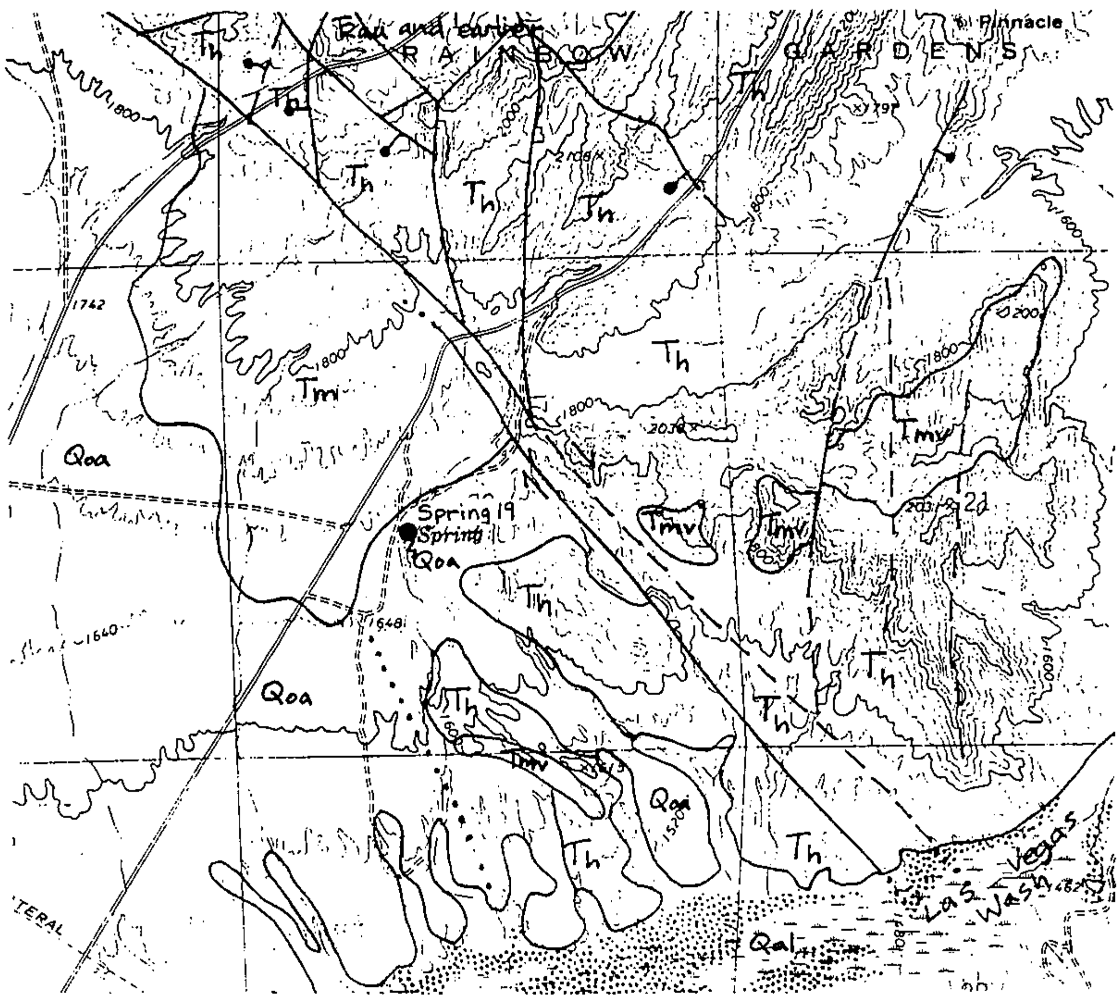
JA_17130

Spring 19 – Unnamed spring south of Rainbow Gardens

Topographic base: 7.5' Henderson Quadrangle
Geology references: Bell and Smith (1980)

The spring is located at the southern end of Rainbow Gardens and about 1.75 km north of Las Vegas Wash. The spring issues from Quaternary alluvial fan deposits in the bottom of a 5-m-deep wash channel incised in the fan surface. The surface flow originates from a single orifice but the area around the spring supports thick tamarisk, mesquite, and grasses; presumably related to shallow groundwater throughout the area. Flow is at the surface for approximately 10 m before it infiltrates into the alluvial deposits. A pipe and circular concrete tank suggest that the spring has been utilized as a water supply in the past, but both are presently filled with sediment.

The spring is near a step-over in a major northwest-trending strike-slip fault (Bell and Smith, 1980). The fault forms a boundary between the Tertiary Horse Spring Formation to the northeast and Quaternary alluvial fan deposits and Tertiary Muddy Creek Formation to the southwest.



SE ROA 52026

JA_17131

Spring 20 – Pupfish Spring

Topographic base: 7.5' Hoover Dam Quadrangle
Geology references: Mills (1994)

The main spring is 30 m upslope of a concrete tank, which is located on the west side of the Lower Portal Road, just above the tunnel to the base of Hoover Dam. The pool issues as a 6-m-high waterfall into a 4-m-diameter pool. The top of the waterfall was inaccessible, so samples were collected from the pool. Dense vegetation surrounds the pool and the channel that leads to the river. Measurements of flow rate were made just above where the channel enters the river. In addition to the main spring, there are numerous seeps along the cliff face between the spring and the river.

Spring 21 – Arizona Hot Spot

Topographic base: 7.5' Hoover Dam Quadrangle
Geology references: Mills (1994)

Several seeps and springs issue from the Arizona side of the river, about 1.6 km downstream of Hoover Dam. The largest of these is the furthest downstream and is located almost directly across the river from the mouth of Goldstrike Canyon. Samples were collected from an orifice at the margin of a talus slope, about 10 m above the river.

The springs issue from Miocene Patsy Mine volcanics (undifferentiated).

Spring 22 – Sauna Cave

Topographic base: 7.5' Hoover Dam Quadrangle
Geology references: Mills (1994)

Sauna Cave is a shaft mined into the wall of Black Canyon on the Nevada side of the river, and is located 1.4 km below the dam. Groundwater discharges at the back end of the shaft and flows out of the mouth. Samples were collected at the point of discharge at the back end of the shaft. Flow measurements were made at the mouth.

The shaft is mined into the Boulder City Pluton and intersects a north-south-trending fault.

Spring 23 – Nevada Hot Spring

Topographic base: 7.5' Hoover Dam Quadrangle
Geology references: Mills (1994)

Several springs issue from the floor and walls of Goldstrike Canyon about 600 m upstream from the river. Although most of the discharge into the channel is relatively diffuse, we sampled from a point orifice at the base of the north wall, about 100 to 150 m below the highest point of discharge. Discharge measurements were conducted about 75 m upstream from the concrete dam at the riverbank.

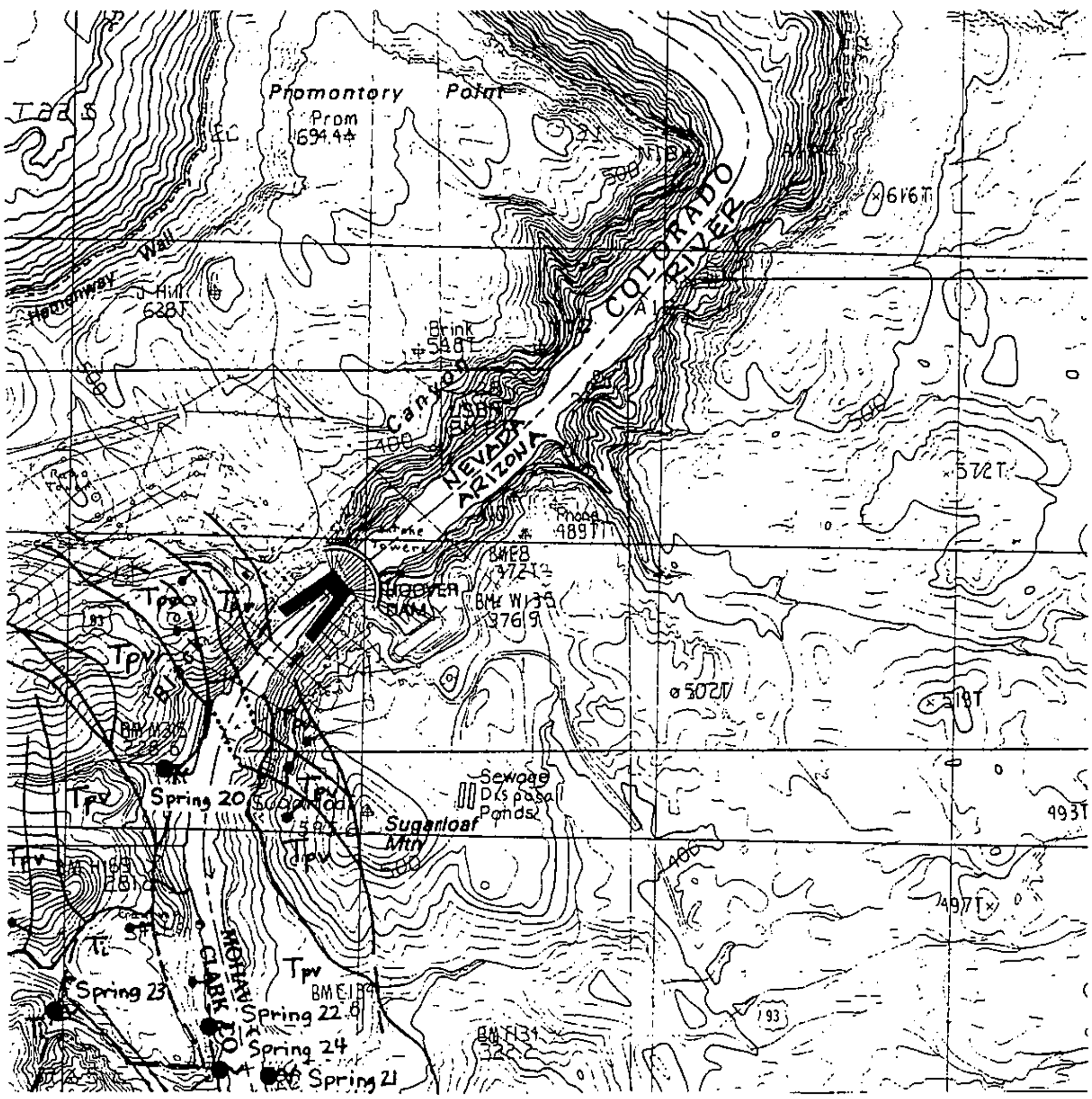
The spring issues from a north-south-trending high angle fault in the Miocene Boulder City Pluton.

Spring 24 – Nevada Hot Spot

Topographic base: 7.5' Hoover Dam Quadrangle
Geology references: Mills (1994)

The spring issues into a small cove on the Nevada side of the river, about 1.6 km below Hoover Dam. There are two main orifices above the river, but many seeps and drips, and possible subsurface discharge to the river. Large ferns overhang the river.

The spring issues from a north-south-trending high angle fault in the Miocene Boulder City Pluton.



SE ROA 52028

JA_17133

Spring 25 – Palm Tree, Hot

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

This spring is located about 100 m from the river in a ravine that meets the river about 2.25 km below the dam. The spring issues as diffuse flow from the banks of the ravine. A cold spring (Palm Tree Cold) issues about 100 m upstream of the hot spring. The floor of the ravine is covered by very dense tamarisk. The combined surface flow of the warm and cold springs extends down the ravine to the river.

The spring issues from Miocene Patsy Mine volcanics (undifferentiated) near a northwest trending right lateral strike-slip fault.

Spring 26 – Palm Tree, Cold

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

This spring is located about 200 m from the river in a ravine that meets the river about 2.25 km below the dam. A warm spring (Palm Tree Hot) issues about 100 m below the cold spring. The floor of the ravine is covered by very dense tamarisk, making access to the cold spring very difficult. An area of reeds grows just above the highest orifice of the cold spring, where the ravine widens and the floor flattens. Surface flow extends down the ravine to the warm spring, and the combined flow extends to the river.

The spring issues from Miocene Patsy Mine volcanics (undifferentiated) near a northwest trending right lateral strike-slip fault.

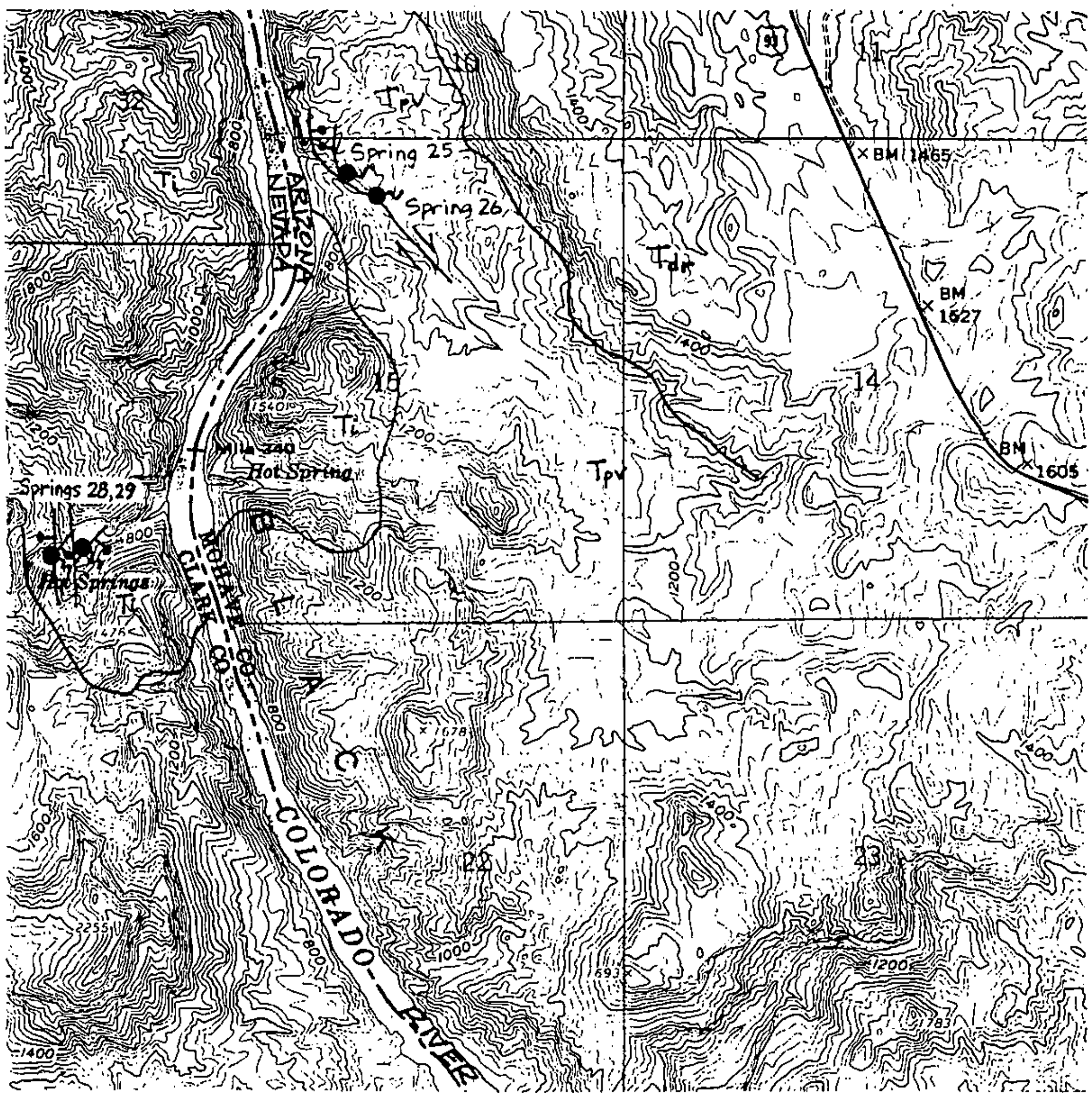
Springs 28 and 29 – Boy Scout Canyon

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

There are a number of springs and seeps in Boy Scout Canyon, and a wide variety of temperatures. Boy Scout Canyon is on the Nevada side and meets the river about 3.5 km below the dam. The lowest point of discharge is about 400 m up the canyon from the river. At this location, cold water discharge forms a waterfall about 12 m high and warm water discharge issues from seeps just above the floor of the canyon. The highest area of warm discharge occurs as seepage from an overhanging wall about 50 m upstream from the springs just described. The surface flow above this point is cold and passes over several waterfalls. Samples were collected of both the warm and cold discharge. Note that despite their difference in temperature, these springs have very similar geochemical and isotopic composition.

Although the discharge rate from this spring is relatively high, only a small fraction of the surface flow reached the river on our visit of 2-2-97. Several reaches of the channel carried no surface flow. The discharge measurement was made at the farthest downstream location of channel flow over a bedrock bench.

The springs issue from the Miocene Boulder City pluton at points where near vertical, north-south-trending faults intersect from below an unconformable barrier. This unconformity appears to act as a "ceiling", preventing further flow within the plutonic rocks.

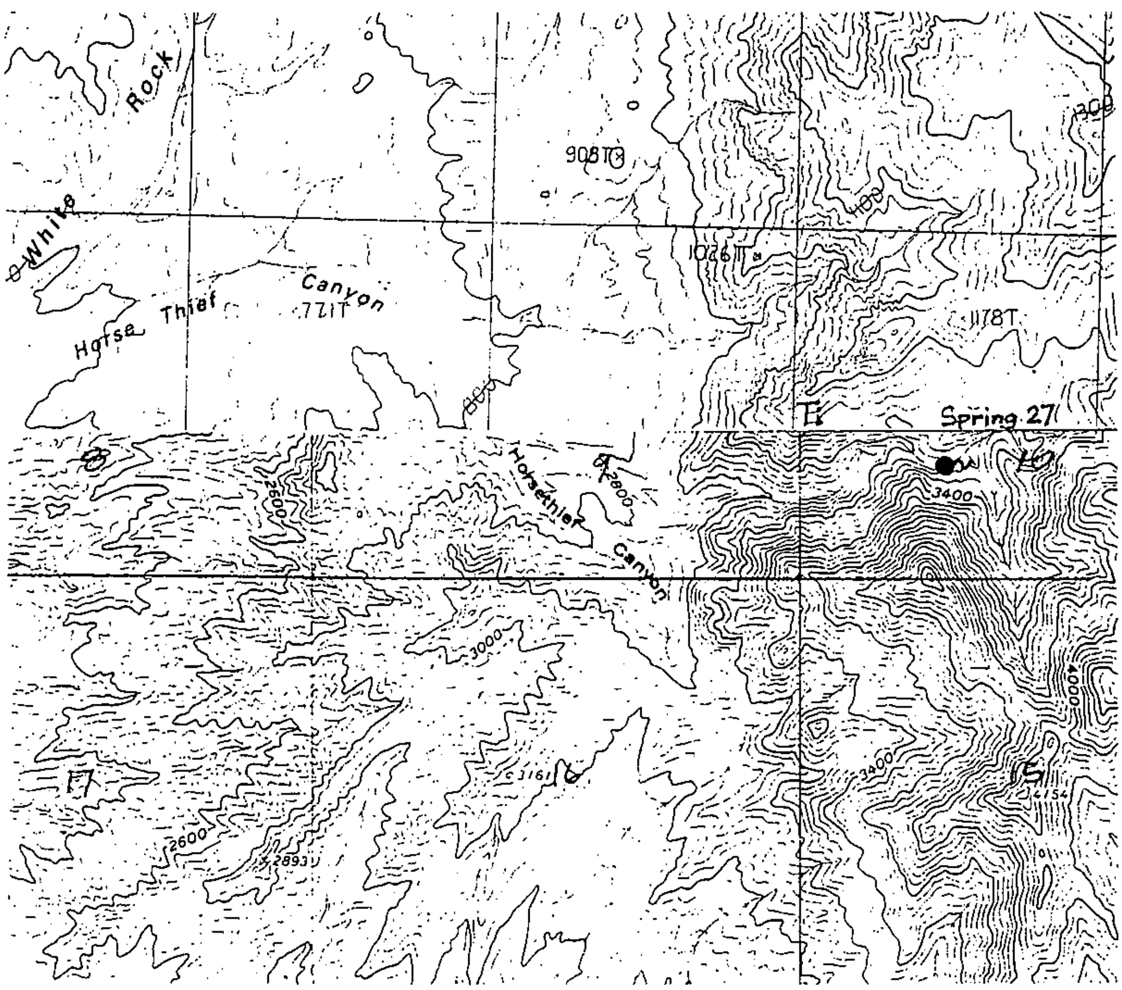


Spring 27 – Unnamed Spring in Horsethief Canyon

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

Horsethief Canyon extends into the west side of Mount Wilson of the Black Mountains in Arizona. Several springs and seeps occur in the canyon above a dry waterfall, supporting a wide variety of vegetation. At the time of our visit (2-3-97), the highest flow rate occurred about 1 km upstream from the waterfall, and supported a stand of cottonwood trees, reeds, and other vegetation. Surface flow was discontinuous over a total length of several hundred meters. Flow was on the surface in reaches where bedrock benches formed the base of the canyon, or where the alluvial deposits were thin. In other reaches, flow presumably occurs within the alluvial deposits.

The spring issues from Tertiary intrusive granite of the Wilson Ridge pluton (described by Anderson *et al.*, 1972).



Spring 30 – Arizona Hot Spring

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

Arizona Hot Spring is located in a dramatic slot canyon that meets the river just downstream of Ringbolt Rapids, and about 6.6 km downstream of the dam. The spring issues into several manmade pools that are located about 300 m up the canyon from the river. The canyon walls near the pools are nearly vertical and 2 to 3 m apart at the base. Above the pools, the canyon opens up and the walls slope gently away from the alluvium-filled channel. Surface flow extends about 150 m down the canyon from the pools, much of it in a bedrock channel, but infiltrates when the channel passes over alluvial gravels.

The spring issues from Miocene Patsy Mine volcanics (undifferentiated) near a northwest trending right lateral strike-slip fault. This fault is offset by a north-south-trending normal fault and the spring issues from near the intersection of the two faults.

Spring 31 – Unnamed cold spring near Arizona Hot Spring

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

The spring is located about 20 m up the canyon from the highest (man-made) pool of Arizona Hot Spring. Above this spring, the canyon is wide, the walls slope gently, and the floor is covered by alluvium. Below the spring, the canyon narrows dramatically (forming a "slot canyon"), the walls are nearly vertical, and the floor is scoured bedrock. The flow issues from alluvium in the base of the canyon, just above the point where the channel enters the slot canyon.

Spring 32 – Nevada Falls

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

Nevada Falls spring is located in a small cove on the Nevada side, approximately 8.2 km below the dam. Surface flow originates about 11 m above the gravel bank of the river, and drops to the river in a series of waterfalls. Only the highest pool contains vegetation. Samples were collected from the second pool up from the riverbank, which is about 3 m above the bank.

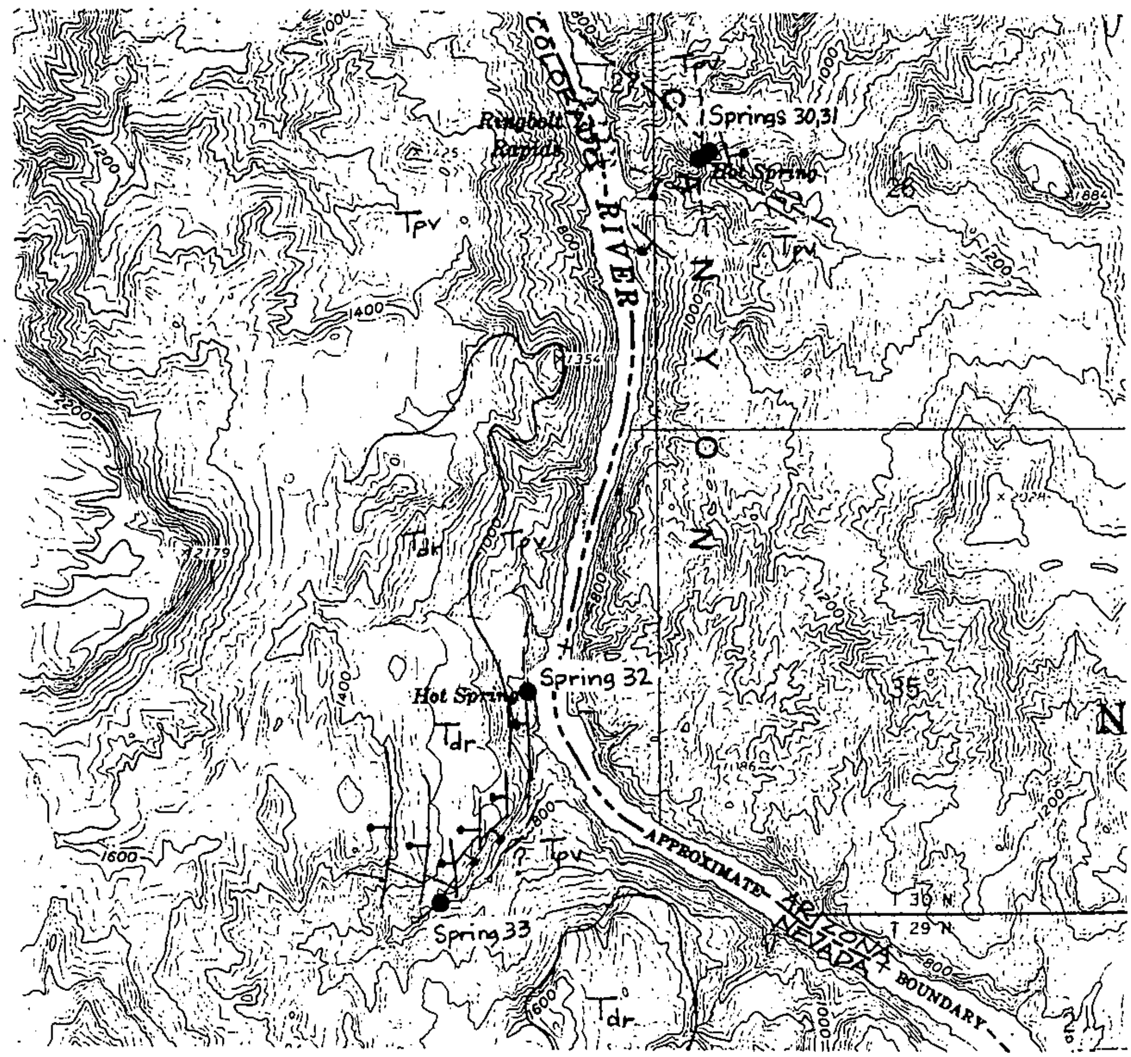
The flow issues from a north-south trending fault in the Miocene Patsy Mine volcanics (undifferentiated), about 100 m east of a contact with Tertiary Mount Davis lavas.

Spring 33 – Bighorn Sheep Spring

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

Bighorn Sheep spring is located in a steep-sided canyon that meets the river 8.4 km below the dam. The main orifice forms a 5-m-high waterfall on the north side of the canyon, about 600 m up the canyon form the river. Because the orifice was inaccessible, the samples were collected near the base of this waterfall. Additional discharge occurs at several small seeps located upstream of the main orifice, all discharging from the north wall of the canyon. Surface flow is present in the channel to within 100 m of the river, but did not reach the river on our 2-2-97 visit. Dense stands of tamarisk extend from the orifice all the way to the river.

The spring issues from a northeast-trending fault in the Tertiary lavas (Mount Davis Volcanics).



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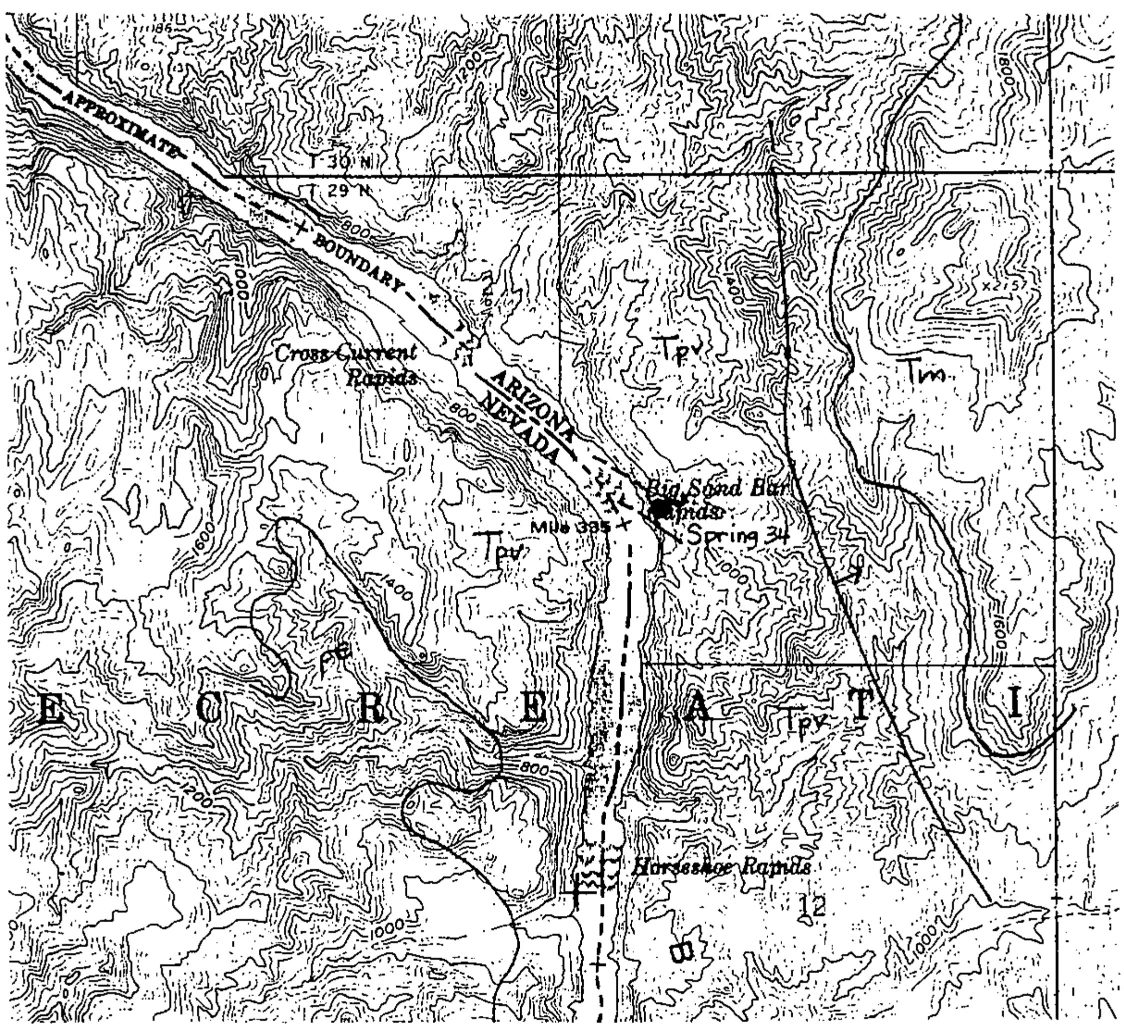
JA_17138

Spring 34 – Arizona Seep

Topographic base: 7.5' Ringbolt Rapids Quadrangle
Geology references: Anderson (1978)

Arizona seep is 11.3 km below Hoover Dam, on the Arizona side of the river. The spring issues as drips and seeps from a rock overhang ("rain cave"), about 20 m above the river. There is no main orifice. The moist soil resulting from the spring discharge supports thick vegetation that extends down to the river. Samples were collected from the seeps with the highest discharge rate.

The spring issues from Miocene Patsy Mine volcanics (undifferentiated) near several northwest trending right lateral strike-slip faults. These faults offset low-angle faults, which produce the spring flow. A north-south trending high angle fault is located 0.5 km to the east of the spring.



SE ROA 52034

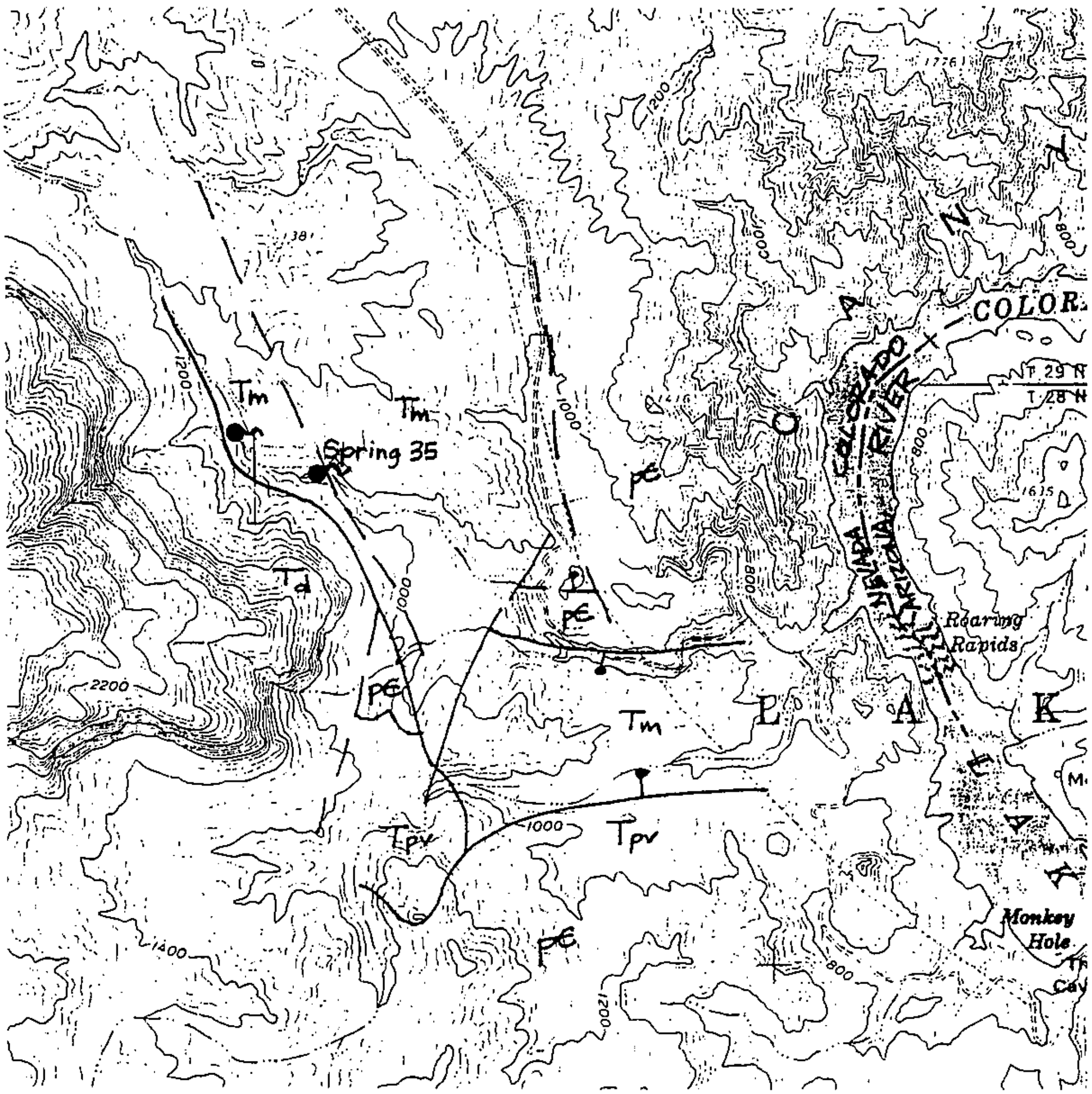
JA_17139

Spring 35 – Latos Pool

Topographic base: 7.5' Willow Beach Quadrangle
Geology references: Anderson (1978)

Latos Pool is located in Burro Wash on the eastern slope of the Eldorado Mountains, and about 1.6 km west of the Colorado River. Three pools fill a narrow portion of the wash, where the channel cuts through consolidated conglomerate. The two lower pools are connected and are both about 4 m long, 2 m wide, and over 1.5 m deep. The lowest pool is almost completely filled with reeds. The upper pool is smaller and is located about 15 m upstream. Another seepage area is located about 200 m upstream in a drainage extending from the southwest. This seep supports a thick stand of mesquite and grass. A third seepage area is located on a bench above the wash channel and about 100 m south of the pools. This seep also supports a thick stand of mesquite and grasses. Samples were collected from surface flow in the channel, below a seep area in the ravine walls and about 50 m below the pools. At the time of our visit (5-6-97), surface flow was discontinuous for about 100 m below the pools. However, evidence of recent surface flow (dried algae and salt deposits) extended from where the power line road crosses Burro Wash all the way upstream past the three pools.

Latos Pool is located on a fault trending N 15° W within a consolidated conglomerate of the Tertiary Muddy Creek Formation.



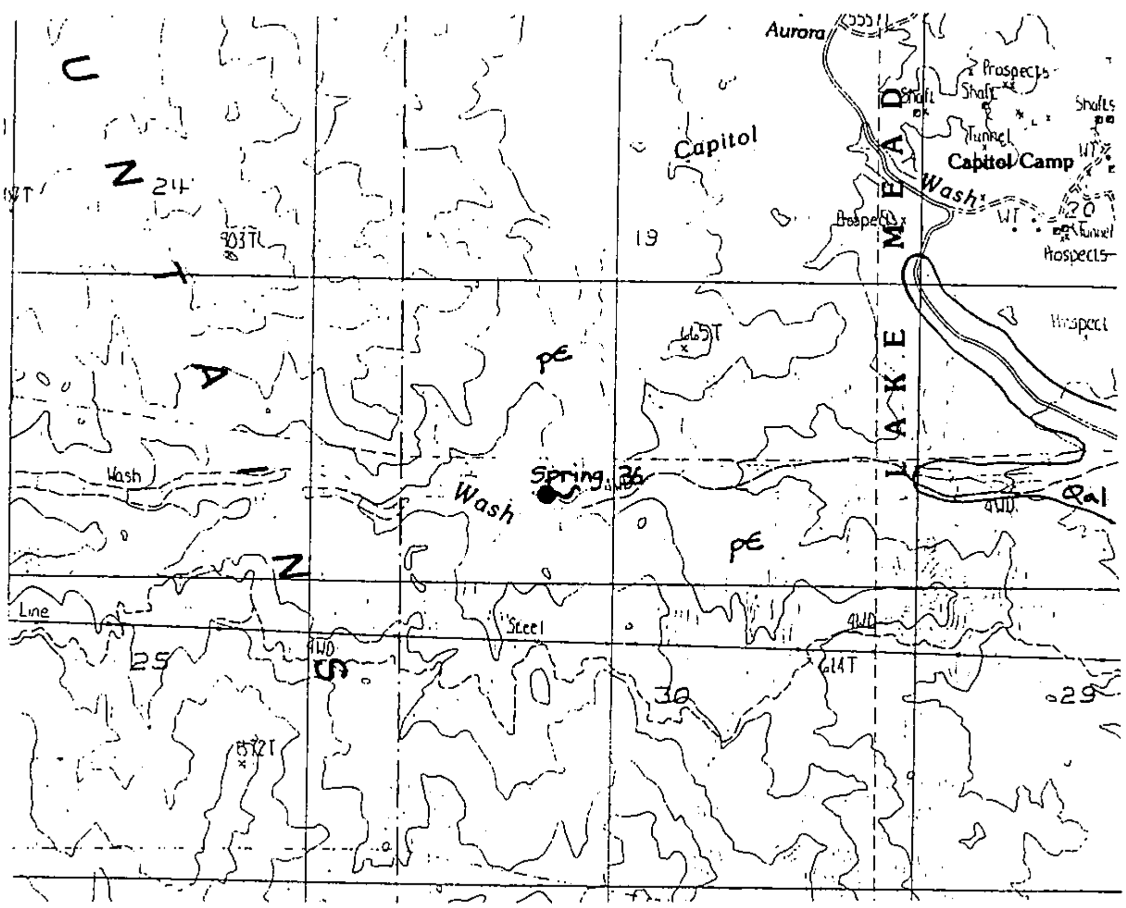
Spring 35
Tm
Tm
Td
pЄ
pЄ
pЄ
Tm
Tpv
Tpv
pЄ
COLOR
COLORADO
RIVER
NEVADA
ARIZONA
T 29 N
T 28 N
Roaring
Rapids
Monkey
Hole
L
A
K

Spring 36 – Unnamed Spring in Aztec Wash

Topographic base: 7.5' Nelson Quadrangle
Geology references: Longwell (1963)

Aztec Wash extends out of the Eldorado Mountains toward Lake Mohave, south of Nelson, Nevada. The spring issues as seeps from alluvial deposits and directly from fractures in the granite walls of the channel, and flows discontinuously at the surface for about 150 m. The highest point of discharge was about 100 m upstream from a small concrete dam in the wash channel at our visit of 2-5-96. A pipe extends from the dam about 2 km down Aztec wash, although its poor condition prevents it from conveying any water. In addition, the channel behind the dam is filled with alluvial deposits. At the time of our second visit (2-11-97) the highest point of discharge was downstream about 20 m, and the discharge rate was lower. Grass and reeds line the banks of the ravine where a soil layer has developed; other areas consist of exposed granite with no soil or vegetation. Vegetation is sparse above the spring, suggesting that groundwater is deeper below ground surface.

The spring issues from steeply-dipping fractures in the Precambrian Rapakivi granite.



SE ROA 52037

JA_17142

Table C-1. Isotope Composition of Selected Southern Nevada Groundwaters. Values shown are averages if multiple samples are available. Number in parentheses is number of samples, if greater than one.

Site Name	Latitude (d m s)	Longitude (d m s)	Altitude of Land Surface (m AMSL)	δD (SMOW, ‰)	$\delta^{18}O$ (SMOW, ‰)	$\delta^{13}C$ (PDB, ‰)	PMC (uncor-rected)	^3H (pCi/L)	Source[1]
McCullough Range, Eldorado Mountains, Highland Range, New York Mountains									
Crescent Spring	35 28 43	115 10 47	1292	-73.0	-9.4	—	—	—	c
Ora Hana Spring	35 37 25	115 04 07	1170	-72.0	-8.4	—	—	—	c
McClanahan Spring	35 41 42	115 11 05	902	-67.0	-7.2	-7.0	68.1	—	c
Rand Spring	35 42 03	114 51 20	1140	-78.0	-9.5	—	—	24.0	b
Bridge Spring	35 43 36	114 49 06	1032	-77.0	-9.2	—	—	19.0	b
Mormon Mountains									
Huckberry Spring	36 55 04	114 26 16	1580	-87	-12.3	—	—	—	c
Horse Spring	36 56 29	114 26 47	1750	-89	-12.7	—	—	—	c
Davies Spring	36 57 56	114 30 07	1825	-89	-12.5	—	—	—	c
East Mormon Mountains									
Peach Spring	36 57 16	114 17 23	950	-76.5	-10.4	—	—	—	c
Gourd Spring	36 57 31	114 17 30	950	-76.5	-10.6	—	—	—	c
Central Spring Mountains									
Trout Spring	36 13 22	115 40 59	2360	-97.7(19)	-13.6(22)	-8.1(5)	90.8(1)	257(3)	c
Cold Creek Spring	36 24 05	115 44 20	1930	-100.1(16)	-13.8(18)	-9.6(5)	76.0(4)	92(4)	c
Southern Spring Mountains									
Bird Spring	35 53 20	115 22 12	1326	-88.0	-11.7	-7.8	67.5	—	c
Sandstone Spring #1	36 03 47	115 28 09	1207	-89.0	-12.2	-10.6(2)	49.8(2)	<15(1)	c
BLM Visitors Center Well	36 07 44	115 26 03	1152	-89.0	-12.25	-9.3	46.0	9.0	c
Red Spring	36 08 40	115 25 10	1116	-89.0	-12.25	-10.5(2)	62.4(2)	3.0	c
Willow Spring	36 09 41	115 29 51	1402	-90.5	-12.3	—	—	—	c
White Rock Spring	36 10 27	115 28 43	1469	-91.0	-12.5	-12.0	—	<2.0	c
Castillo Well	35 50 02	115 26 09	1140	-94.0	-12.5	-9.3	39.4	—	c
Sheep Range									
Wiregrass Spring	36 38 00	115 12 29	—	-94.3(9)	-12.8(9)	-10.2	96.8	89.6	c
Moorman Well Spring	36 38 38	115 05 52	1963	-91.8	-12.7	-9.9	—	—	c
Cow Camp Spring	36 35 01	115 18 26	—	-92.0	-12.6	—	—	—	c
Lamb Spring	36 56 42	115 06 21	1700	-92.5	-13.15	—	—	—	c
Sawmill Spring	36 40 50	115 10 34	—	-92.0	-12.85	—	—	—	c
Sheep Spring	36 53 42	115 06 53	—	-96.0	-13.35	—	—	—	c
Meadow Valley Wash Flow System									
Wells and Springs	—	—	—	-87.3(14)	-11.8(13)	—	—	—	c
Lower White River Flow System									
Hiko Spring	37 35 54	115 12 49	—	-109.0	-13.8	-5.4	—	<10	e
Crystal Spring	37 31 58	115 13 50	—	-108(d)	-14.3(d)	-5.3	6.2	<10	e
Ash Spring	37 27 49	115 11 34	1102	-108.0	-14.1	-6.7	6.3	0.0	c
Big Muddy Spring	36 43 20	114 42 48	542	-97.8(3)	-12.9(3)	-6.0	6.7	<1.0	c
M-8 Spring	36 43 15	114 43 39	—	-99.0	-12.75	—	—	—	c
M-9 Spring	36 43 33	114 43 38	—	-96.5	-12.45	—	—	—	c

Table C-1. Isotope Composition of Selected Southern Nevada Groundwaters. Values shown are averages if multiple samples are available. Number in parentheses is number of samples, if greater than one (Continued).

Site Name	Latitude (d m s)	Longitude (d m s)	Altitude of Land Surface (m AMSL)	δD (SMOW, ‰)	$\delta^{18}O$ (SMOW, ‰)	$\delta^{13}C$ (PDB, ‰)	PMC (uncorrected)	^{3}H (pCi/L)	Source[1]
Lower White River Flow System Continued									
Pederson's Warm Spring	36 42 36	114 42 54	555	-97.0	-12.75	—	—	—	c
Iverson's Spring	36 42 37	114 42 43	—	-97.0	—	—	—	—	c
CE–VF–2 Well	36 52 30	114 56 44	752	-101.0(2)	-13.0(2)	-6.1	7.0	<1.0	c
CE–DT–6 Well	36 46 04	114 47 13	693	-97.0	-12.95	-8.0	8.4	1.8	c
CSV–2 Well	36 46 50	114 43 20	666	-98.0	-12.85	-5.5	8.4	4.0	c
Dry Lake Valley Well	36 27 18	114 50 38	638	-97.5	-13.3	-4.2	3.0	7.0	c
GP Apex Well	36 20 28	114 55 36	753	-98.0	-13.45	-5.5	2.7	<.3	c
CE–DT–4 Well	36 47 44	114 53 32	662	-101.0	-13.0	—	7.6	<2.0(1)	c
CE–DT–5 Well	36 47 44	114 53 32	661	-101.0	-13.0	—	7.6	<2.0(1)	c
Genstar Well	36 23 29	114 54 14	661	-97.0	-13.05	-4.9	1.5	<1.0	c
South Hidden Valley Well	36 33 08	114 55 30	807	-90.5	-11.2	—	—	—	c
CSV–3 Well	36 41 27	114 55 30	736	-75.0	-10.3	—	—	—	c
Weiser Wash Flow System									
EH–3 Well (Tmc)	36 41 32	114 31 32	530	-90.7(3)	-11.9(3)	—	—	—	d
EH–7 Well (Tmc)	36 40 14	114 31 53	512	-91.0	-12.3	—	—	—	d
EH–3 Well (below Tmc)	36 41 32	114 31 32	530	-92.0	-12.9	—	—	—	d
EH–7 Well (below Tmc)	36 40 14	114 31 53	512	-93.0	-12.8	—	—	—	d
Eldorado Valley									
Eldorado Substation Well	35 48 13	115 00 14	550	-96.0	-12.0	-7.8	7.75	<10	b
Colorado River									
Below Hoover Dam	36 00 35	114 44 40	200	-102.0	-12.7	-5.7	—	51.0	f
Valley of Fire									
Valley of Fire Well	36 25 21	114 32 52	683	-82.0	-10.6	-8.5	18.7	—	c
Northeast Las Vegas Valley									
Nellis AFB Well #13	36 12 44	115 03 00	552	-98.0	-13.8	-8.0	—	—	c
Lake Mead Base Well #3	36 14 21	115 00 16	568	-101.5	-13.8	-5.3	5.6	<.3	c
Nellis AFB #4	36 14 56	115 00 15	585	-95.0	-13.2	-6.3	21.0	—	c
Southwest Las Vegas Valley									
Sky Harbor Airport	35 58 16	115 08 50	—	-95.0	-13.1	-6.8	—	—	c
Showboat Country Club #2	36 02 51	115 04 48	—	-97.0	-13.3	—	—	—	c
Jean Prison Well	35 47 18	115 20 43	—	-95.0	-12.1	-7.6	2.4	—	c
Sunset Park Well	36 03 49	115 05 51	—	-94.0	-12.7	-6.7	4.0	—	c

[1] Sources of data:
a Thomas *et al.*, 1991
b SNWA, unpublished data
c Thomas, *et al.*, 1997
d DRI, unpublished data
e Hershey and Mizell, 1995
f This study

IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA	Regarding Interim Order 1303 and Hearing Beginning on September 23, 2019

DEPARTMENT OF THE INTERIOR, NATIONAL PARK SERVICE WITNESS LIST

1. Richard Waddell, Jr., Ph.D, PG

A summary of Doctor Waddell's testimony is provided in a separate document.

IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA	Regarding Interim Order 1303 and Hearing Beginning on September 23, 2019

Evidentiary disclosures of the Department of the Interior, National Park Service

The Department of the Interior, National Park Service, by and through its counsel, Karen D. Glasgow, Field Solicitor, Office of the Solicitor, Pacific Southwest Region, San Francisco Field Office, Department of the Interior, pursuant to the State Engineer's August 23, 2019 Notice of Hearing, submit the following attachments: 1) witness list with a summary of his testimony; 2) exhibit list; and 3) expert witness CV and; 4) transcript excerpts evidencing expert witness' previous qualification as an expert by the Nevada State Engineer.

Respectfully submitted,

Karen D. Glasgow
Field Solicitor-SF Field Office
Office of the Solicitor
Department of the Interior

CERTIFICATE OF SERVICE

RE: Interim Order 1303 Hearing Beginning on September 23, 2019

I, the undersigned, declare that:

I am a citizen of the United States, over the age of eighteen, and on September 6th 2019, I served via e-mail to the addresses indicated below the **Evidentiary disclosures of the Department of the Interior, National Park Service:**

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I certify under penalty of perjury that the foregoing is true and correct. Executed on the 6th day of September 2019.

Karen D. Glasgow, Field Solicitor

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STATE ENGINEERS OFFICE

Board of County Commissioners

Lincoln County, Nevada

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November 4, 2019

Tim Wilson, Nevada State Engineer
Division of Water Resources
Department of Conservation and Natural Resources
901 S. Steward St., Suite 2002
Carson City, NV 89701

RE: Public Comment to Interim Order #1303 Hearing, Reports, and Evidence on the Lower White River Flow System.

Dear. Mr. Wilson:

Pursuant to its Interim Order #1303, the Nevada Division of Water Resources ("NDWR") conducted a fact-finding hearing on September 23rd through October 4th, 2019 in Carson City, Nevada to review reports and evidence from interested parties to address the following matters:

a) The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System[1];
b) The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test:
c) The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River Flow;
d) The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and
e) Any other matter believed to be relevant to the State Engineer's analysis.

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[1] The Lower White River Flow system, or the "LWRFS" is a designation established by the State Engineer designating 5 basins and part of a 6th basin, as a single administrative unit, it is not a designated hydrographic basin with a designating numeric number.

At the conclusion of the hearing, NDWR provided a period of 60 days in which to allow public comment on the reports and evidence submitted. Although not an official party to the proceedings, Lincoln County appreciates the opportunity to provide public comment in the hearing.

Nevada water law is based on a priority basis of first in time, first in right. In applying this priority system, the Nevada State Engineer has historically reviewed water right applications on a basin-by-basin analysis of perennial yield. Lincoln County supports the continued use of a basin-by-basin approach to the management of water rights in Nevada. Lincoln County further wishes to express its concerns about the formation of "super basins" that encompass several hydrographic basins and/or portions of regional water flow systems across hydrographic boundaries, even if only designated as an "administrative unit". Every hydrographic basin in Lincoln County is part of a larger regional flow system. However, because of, and in reliance on, each basin being managed individually, residents, farmers, and businesses within Lincoln County have been able to apply for and capture the portions of the perennial yield of those separate basins and put water to beneficial use within the County.

Lincoln County recognizes that as a result of the 1169 pump tests the data indicates concerning drawdown of water levels in the Muddy River Springs Area, south-eastern portion of the Coyote Spring Valley and other surrounding hydrographic basins that have similar water levels. However, despite the drawdowns in the areas with similar water levels, Lincoln County encourages NDWR to move slowly and avoid drastic actions that would move NDWR away from its historic treatment of water rights in the State. In particular, Lincoln County supports the efforts of Lincoln County Water District and Coyote Springs Investments in providing new and relevant scientific information to NDWR. Lincoln County supports the use of as much scientific information as possible to assist NDWR in continuing to manage groundwater on a basin-by-basin basis. This includes understanding subsurface geology and other potential impediments to groundwater flow in the Coyote Spring Valley and the Kane Springs Valley so as to properly place water diversions in locations where perennial yield in those basins can be captured with minimal or no impacts on other senior rights in the LWRFS.

Lincoln County believes that based on the evidence submitted there are insufficient grounds to include Kane Springs Valley within the boundary of the administrative unit designated as the Lower White River Flow System. Therefore, Lincoln County respectfully requests that the State Engineer continue to exclude Kane Springs Valley from the proposed LWRFS administrative unit. Further, Lincoln County encourages NDWR's further study of the Coyote Spring Valley to determine if water can be pumped from either the northern or western boundary areas of the basin without impacting the Muddy River Springs Area, instead of simply automatically denying all subdivision, construction or development applications or submittals within the Coyote Spring Valley basin.

Just as water is the most precious asset in the State of Nevada, it is likewise the most precious asset in Lincoln County. Lincoln County relies upon the use of water resources within its boundaries for survival, growth and ongoing development.

Thus, Lincoln County encourages the continued basin-by-basin approach to allow the capture and use of perennial yield.

Sincerely,

Varlin S Higbee

Varlin Higbee, Chairman
Lincoln County Board of County Commissioners

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IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA.	**CLOSING BRIEF OF THE CHURCH OF JESUS CHRIST OF LATTER-DAY SAINTS**

I. INTRODUCTION

The Church of Jesus Christ of Latter-day Saints, a Utah corporation sole (the "Church") offers the following Closing Brief for the State Engineer's consideration. In response to the State Engineer's directives set forth in Interim Order #1303 ("Order #1303") and considering the testimony offered by the various stakeholders from September 23, through October 4, 2019, the Church requests that the State Engineer consider and adopt the testimony and recommendations of the City of North Las Vegas' ("CNLV") expert, Dwight Smith, PE, PG ("Smith"), and to specifically enter an order that: (1) continues the administration and management of the Lower White River Flow System consisting of the six basins (five entire basins and one partial basin) set forth in Order #1303, and (2) allows for the consideration of permanent applications to change the point of diversion, place of use, and manner of use of water rights throughout the hydrographic basins comprising the Lower White River Flow System. This approach serves as a tool to mitigate impacts from groundwater pumping on the Muddy River, while also providing for the protection of senior groundwater rights in the Lower White River Flow System. The Church urges the State Engineer, that to the extent he enters an order after the 2019 hearing, he enter it with caution, since the State Engineer has yet to seek input from stakeholders regarding the issues of policy and management of the administrative unit. *See* Transcript of August 9, 2019, Pre-Hearing Conference at p. 10, ll. 18-20. The recommendations made by Smith are reasonable scientifically based next steps that allow the State Engineer and the stakeholders to develop further reliable data on how to manage precious water resources in the country's driest state.

II. THE CHURCH'S SURFACE AND GROUNDWATER RIGHTS IN THE MUDDY RIVER SPRINGS AREA

Order #1303 found that total groundwater pumpage inventories in the Muddy River Springs Area have been published by the State Engineer since 2016. In the years 2016 and 2017 pumping has ranged from 3,553 acre-feet to 4,408 acre-feet, with an average of 3,801 acre-feet. *See Order #1303* at p. 9.

Order #1303 also found that annual groundwater pumpage inventories in the Garnet Valley area have been published by the State Engineer since 2001. In the years 2001 through 2017, pumping has ranged from 797 acre-feet to 2,181 acre-feet, averaging 1,358 acre-feet.

To provide some context, the Church has appropriated approximately 2,001 acre-feet of surface water rights from the Muddy River (the "Surface Rights"). *See generally*, Records of the State Engineer. The Surface Rights are subject to a lease with the Southern Nevada Water Authority ("SNWA") and have been put to beneficial use as a result of SNWA's ongoing management of water resources for its member water purveyors. In addition to the Surface Rights, the Church has also appropriated approximately 2,330 acre-feet of groundwater in the Muddy River Springs Area ("Groundwater Rights"). *See generally*, Records of the State Engineer; *see also* CNLV Ex. 3 at p. 47. The Groundwater Rights are all certificated and have priority dates from 1947, 1949, and 1965. *Id.* These priority dates make the Groundwater Rights the most senior groundwater rights in the Muddy River Springs Area and some of the most senior groundwater rights in the entire Lower White River Flow System. *See* State Engineer's LWRFS Groundwater Rights By Priority Spreadsheet.

The Groundwater Rights have historically been used for power generation at the Reid-Gardner Station power plant and prior to that for irrigation in the Muddy River Springs Area. *Id.* at 47-48. The Church has historically used its Surface Rights and Groundwater Rights either directly or through lease agreements, whereby the general population benefits from the resource being put to beneficial use through local government water purveyors or for purposes of generating and supplying power. In furthering this goal, the Church has entered into an agreement with the CNLV to assist that local government in securing water resources as a part of its governmental purpose and mission. The potential loss of water rights, based on decisions of the State Engineer relative to the Lower White River Flow System, could not only impair the Church's property rights, in its Surface Rights and Groundwater Rights, but also could jeopardize the benefits various southern Nevada communities realize through the beneficial use of the Church's water rights.

III. SMITH'S RECOMMENDATIONS SHOULD BE ADOPTED BY THE STATE ENGINEER.

"One issue that we feel is critically important is permitting the opportunities for transfer of water rights from in between alluvial and carbonate aquifer systems." Testimony of D. Smith, October 1, 2019, Hearing Transcript at p. 1419, ll. 9-11. "[t]here are examples that transfer [of] water rights between those two aquifer units could have positive water management implications." *Id.* at p. 1419, ll. 19-21.

Smith concluded, "In summary, it appears that pumping at 1500 AF/yr and possibly up to 2000 AF/yr in the APEX area **has not caused detrimental water level declines**. As a water development and management strategy for APEX, a controlled pumping test with increased pumping from the Playa and Kapex wells up to 1000 AF/yr could reveal more information, from which a sustainable pumping volume in the APEX area may be determined." CNLV Ex. 3 at p. 46 (emphasis added). In furtherance of that goal, Smith noted: "Leasing senior groundwater rights located in the LWRFS has merit in a couple regards." *See* CNLV Ex. 3 at p. 52. The "[t]ransferring of senior groundwater rights out of this environment [alluvium of the Muddy River Springs Area] and to a distal and down-gradient portion of the LWRFS will help alleviate this potential water right conflict [between decreed surface rights and senior groundwater rights in the Muddy River Springs Area]." *Id.*

Smith further notes that, "...ceasing to pump these water rights [the Church's Groundwater Rights] at the existing points of diversion will mitigate potential impacts to existing decreed water rights on the Muddy River [including the Church's Surface Rights which are leased to SNWA], and perhaps will provide an advantage to sustaining spring flows on the valley floor. This could in turn benefit the Moapa Dace habitat." *See* CNLV Ex. 3 at p. 48. During his testimony, Smith stated, "Pre-1998 water levels at EH-4 were stable and there was a history of pumping in Garnet Valley." *See* October 1, 2019, Hearing Transcript at p. 1455, ll. 15-17. He went on to say, "I believe this suggests that there is a manageable amount of pumping in Garnet Valley that can occur without detrimentally impacting the EH-4 water levels and therefore, high altitude spring discharges." *Id.* at p. 1455, ll. 18-21.

The State Engineer should adopt Smith's recommendation to allow for change applications that provide for pumping of groundwater further away from the Muddy River Springs Area and from the alluvium to the carbonate, not only as a water resource management tool, but as a means to develop further data relative to potential impacts on decreed rights in the Muddy River Springs Area and the Moapa Dace, while also providing an avenue for senior groundwater rights holders to continue to beneficially use their water.

IV. SNWA's Multi-Linear Regression Analysis is Invalid

During Smith's October 1 testimony, he offered a criticism to his colleagues at SNWA regarding its multi-linear regression analysis. *See* October 1, 2019, Hearing Transcript at pp. 1446-1448. In his presentation, Smith highlights the flaw in SNWA's analysis. SNWA's erroneous input of Garnet Valley pumping in its multi-linear regression model ignored significant pumping that occurred in Garnet Valley during the 1980's and 1990's. Smith's presentation noted: "The input pattern of pumping artificially creates a higher association between Garnet Valley pumping and EH-4 water level variations, which in turn affects the association assigned to the other explanatory variables. The erroneous Garnet Valley pumping input INVALIDATES the analysis for ALL pumping center outcomes" Smith presentation at p. 23 (emphasis in original). As such, the analysis is unreliable and should be disregarded by the State Engineer.

V. Conclusion

The Church urges the State Engineer that, to the extent he enters an order after the 2019 hearing, he enter it with caution since the State Engineer has yet to seek input from stakeholders regarding the issues of policy and management of the administrative unit. The State Engineer, when rendering any decisions should also follow Nevada water law's primary tenets of prior appropriation and beneficial use. The Church's groundwater rights are senior to most groundwater rights in the Lower White River Flow System, with only a few exceptions. That being said, the State Engineer should continue to administer and manage the Lower White River Flow System as it is defined in Order #1303, with a consistent application of the primary tenets of Nevada water law – prior appropriation and beneficial use. As such, the State Engineer should allow for permanent change applications to the point of diversion, place of use, and manner of use of water rights within the Lower White River Flow System, and through that process, obtain additional reliable data from stakeholders, taking steps to preserve Muddy River flows, Moapa Dace habitat, while still protecting senior groundwater rights.

DATED this 3rd day of December, 2019.

KAEMPER CROWELL

By: [signature]

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CERTIFICATE OF SERVICE

I hereby certify that I am an employee of KAEMPFER CROWELL, and on this date, I caused the foregoing document to be served via electronic transmission as follows:

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Additionally, I caused the original document to be delivered to the Office of the State Engineer at 901 S. Stewart Street, Suite 2002, Carson City, Nevada 89701, on December 3rd, 2019.

DATED this 3rd day of December, 2019.

An employee of Kaempfer Crowell

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Affirmation: This document does not contain the social security number of any person.

IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN THE COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA	**CITY OF NORTH LAS VEGAS' CLOSING STATEMENT**

City of North Las Vegas (the "City"), by and through its counsel, Therese A. Ure and Laura A. Schroeder of Schroeder Law Offices, P.C., hereby submit this written Closing Statement to the Hearing Officer and State Engineer in the above captioned proceedings as outlined below.

///

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INTRODUCTION

On January 11, 2019, the State Engineer issued Interim Order 1303 designating the Lower White River Flow System ("LWRFS") as a joint administrative unit. Order 1303 further directed interested parties to submit reports to address their position regarding:

a. The geographic boundary of the hydrologically connected groundwater and surface-water system comprising the LWRFS;

b. The information obtained from the State Engineer's Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test;

c. The long-term annual quantity of groundwater that may be pumped from the LWRFS, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;

d. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and

e. Any other matter believed to be relevant to the State Engineer's analysis.

A hearing was set for September 23, 2019 – October 4, 2019, for interested parties to present evidence in support of the positions in their respective reports. At the conclusion of the hearing, the Hearing Officer ordered that written closing statements be submitted by December 3, 2019. Transcript Vol. X, 1821:12-16[1].

CLOSING ARGUMENT

Given the significance of the State Engineer potentially administering once separate and distinct hydrographic basins into one, for the first time in Nevada history, the City maintains that the interested parties could benefit from more analysis and study of the LWRFS before decisions are made relating to the administration of the flow system. Casting aside the legal issues related

[1] All transcript citations referenced herein are to the September 23, 2019 – October 4, 2019 hearing unless otherwise noted.

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to combining basin priorities into one system, the evidence and testimony presented at the hearing did not establish any consensus on basic principles of water availability, and what basin(s) or aquifer(s) are actually connected within the LWRFS. Making global decisions when basic concepts are unsettled is a recipe for future litigation.

1. **<u>The geographic boundary of the hydrologically connected groundwater and surface-water system comprising the LWRFS.</u>**

The City opines that the administrative boundary as proposed by the State Engineer is generally appropriate, with possible uncertainties in the southern boundaries. Transcript Vol. VII, 1418:22 – 1419:8. Focusing its review on the southern end of the LWRFS, the City believes there is uncertainty in the boundary areas between California Wash (Basin 218) and Garnet Valley (Basin 216), and between Garnet Valley and Las Vegas Valley (Basin 212). Thus, the City suggests the State Engineer keep this uncertainty under consideration as more data are collected. Transcript Vol. VII, 1426:11-19.

The testimony and reports provided by Dwight Smith, the City's expert, discuss southern LWRFS boundary uncertainty, faulting boundaries, water level elevations, and model testing. The Dry Lake Thrust Fault daylights in a N-S direction on the east side of Garnet Valley and may provide the eastern boundary to the hydrologically connected flow system. CNLV Ex. 3 at 14, Figure 8; Transcript Vol VII, 1427:7-8. There is also some evidence that the southern LWRFS hydrographic basin boundary should be shifted to the Las Vegas Valley Shear Zone, thus incorporating a small portion of Las Vegas Valley. Transcript Vol. VII, 1426:7-10. Regardless, the City only opines that the southern boundary conditions are uncertain and need further data to more conclusively define.

As outlined in Smith's July 2, 2019 Report (CNLV Ex.3), there is some southern movement of groundwater in the LWRFS, specifically from the southern end of Coyote Springs Valley to Hidden Valley, Hidden Valley to Garnet Valley, and Garnet Valley out to the California Wash. Transcript Vol. VII, 1429:13-19. This is groundwater in the flow system that

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does not necessarily reach the Muddy River Springs Area ("MRSA"). "An apparent potentiometric gradient exists between Hidden Valley and northern Garnet Valley, supporting possible groundwater flow through the Arrow Canyon Range." CNLV Ex. 3 at 15. However, the available data in Hidden Valley are sparse and additional monitoring wells and data collection are recommended. CNLV Ex. 3 at 7.

There also appears to be groundwater flow from Las Vegas Valley to Garnet Valley. CNLV Ex. 3 at 33, Figure 13 (Smith Presentation, Slide 10); Transcript Vol. VII 1430:8-14. In reviewing well log data, Smith looked at a variety of factors including depths to water and depths to top of limestone for those wells completed into the top of the carbonate aquifer. Transcript Vol. VII, 1432:5-10. Based on recorded well specific capacity data, Smith was able to estimate aquifer transmissivity noting that wells in Garnet Valley have a transmissivity value of about two orders of magnitude lower than in the MX-5 and Arrow Canyon areas. Transcript Vol. VII, 1432:13-24. The change in transmissivity values to a more moderate factor shows a difference in geology that potentially affects the magnitude of groundwater movement, as contrasted from that in the greater LWRFS, to the north as seen in Coyote Spring Valley, and the MRSA.

Smith reviewed the boundary line between Las Vegas Valley and Garnet Valley finding a potential gradient based on groundwater elevations that supports a flow direction from Las Vegas Valley to Garnet Valley. Smith Presentation, Slide 16; CNLV Ex. 3 at 33, 36 (Table 5); Transcript Vol. VII, 1437:12-14.

Using the water level elevation data and carbonate aquifer transmissivity, Smith prepared a test model to assess groundwater inflow and outflow from Garnet Valley. Transcript Vol. VII, 1438:4-13. In running a 2D numerical flow model to test boundary conditions based on 2015 pumping magnitudes, Smith likewise concluded a potential connection of groundwater flow from Las Vegas Valley to Garnet Valley. Smith Presentation, Slides 14-15, Transcript 1439:10-12; CNLV Ex. 3 at 37-44. The model calibrated well to existing available data in Garnet Valley. Transcript Vol. VII, 1439:21. The model set a local recharge value of 400 AF/yr. CNLV Ex. 3 at

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37. The model exercise found 1217 AF/year inflow to Garnet Valley with: 1) 518 AF/yr inflow to Garnet Valley from the most northern part of the valley from southern Coyote Spring Valley and/or northern Hidden Valley; and, 2) 698 AF/yr inflow to Garnet Valley from Las Vegas Valley. CNLV Ex. 3 at 38; *see also discussion at* Transcript Vol. VII 1440:11 – 1442:4. The model outflow simulated 111 AF/yr from northern Garnet Valley to the northwestern California Wash. CNLV Ex. 3 at 38. Interestingly, there was no outflow on the central and southern California Wash boundaries. CNLV Ex. 3 at 38.

While this model is only a preliminary test of boundary conditions, its results support further research to determine the amount of water contributing to Garnet Valley which is not distinctly part of the LWRFS, or that would otherwise not contribute to the groundwater discharge at the MRSA.

2. **The information obtained from the State Engineer's Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test.**

In order to look at the information obtained in Order 1169 aquifer test, the City completed an analysis pertaining to Garnet Valley to better understand the dynamics of what was going on prior to, during, and after Order 1169. The City provided a summary of current water rights in Garnet Valley (CNLV Ex. 3 at Table 4) and provided information as to historical pumping in the Valley (CNLV Ex. 3 at Figure 10 as amended at CNLV Ex. 4). *See also*, Smith Presentation, Slides 17-20; Transcript Vol. VII, 1442:5 – 1444:14. The water rights issued and permitted in Garnet Valley are 3715.55 AF/yr. CNLV Ex. 3 at 17. Yet the actual pumping is much less, with the average pumping at 805 AF in 2001 in Garnet Valley, when adjusted to remove that amount pumped from the alluvium, and approximately 1500 AF/yr in the ten years preceding 2016. Smith Presentation, Slide 20; Transcript Vol. VII, 1444:7 - 1445:3[2]. In 2016 and

[2] Transcript Vol. VII at 1444:9 should state "for about ten years was a plus or minus around 1500." As opposed to "15,000."

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2017, water use in Garnet Valley increased significantly when temporary water use commenced for constructions projects in APEX. *See* CNLV Ex. 4 (Amended Figure 10); Testimony Vol. VII, 1443:11-15. Despite this increase, there was no noticeable response in the Garnet Valley water level hydrographs (CNLV Ex. 3 at 45), there was no observed response in EH-4 water levels (the indicator well to MRSA), and, there is an observed stability in EH-4 water levels in the past 4 years. Smith Presentation, Slide 25; CNLV Ex. 3 at 46 (Figure 24).

SNWA argued that the history of increased pumping in Garnet Valley (from a baseline of zero pumping through the mid-1990's) has high correlation with EH-4 water level variation in its MLR analysis. Smith, however, pointed out the inaccuracies in the input data SNWA used for historical Garnet Valley which invalidated the analysis and the reported correlation. The error not only caused a false relationship to Garnet Valley pumping, but also impacted all the other reported correlations, or lack thereof, for all simulated pumping centers. Smith Presentation, Slides 21-25; Transcript Vol. VII, 1446:2 – 1448:20.

A long term declining trend is observed on a regional level throughout the study area of 0.3 ft/yr from approximately 1998-2018. CNLV Ex. 3 at 45; Transcript Vol. VII, 1450:2-12[3]. However, there was significant pumping occurring in Garnet Valley in the 1980s and 1990s (rather than zero pumping as SNWA used for the MLR analysis), over the time period when levels are stable at EH-4. Transcript Vol. VII, 1450:9-12. Smith opined that the system wide decline is likely due, in part, to climatic conditions, as there is a clear response in Garnet Valley and throughout the LWRFS from the 2005 wet year. CNLV Ex. 3 at 46 (Figure 24). Upon review, it appears that a perceived water level declining trend may actually be a mix of climate and pumping signals. Smith Presentation, Slides 26-28; Transcript Vol. VII, 1450:22-24.

Barometric responses also result in seasonal water level fluctuations in many wells completed in the carbonate aquifer of the LWRFS, and such barometric responses have not been

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[3] Transcript Vol. VII at 1450:5 should state "have this decline in trend about 0.3 feet per year." As opposed to "23 feet per year."

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appropriately factored into consideration by entities offering interpretations related to a presence or absence of seasonal water level fluctuations as an association with seasonal pumping stresses. *See discussion at* Transcript 1452:18 – 1455:13. This is important due to the mild magnitudes of water level fluctuations being scrutinized in the LWRFS. It is suggested that the State Engineer's office look for barometric response filtering in all interpretations pertaining to seasonal water level variance and association, or lack thereof, to any pumping stresses in the LWRFS carbonate aquifer monitoring wells. *Id.*

In summary with regards to post Order 1169 water levels, Smith opined: 1) Pre-1998 water levels were stable at EH-4 when pumping in Garnet Valley was occurring; 2) EH-4 water level declines appear to be leveling off, which may mean that effects of local (MRSA) carbonate pumping are getting close to establishing an equilibrium with discharge capture; 3) Climate may be driving some of the regional decline, but there is likely a mix between pumping and climate response in Garnet Valley; and, 4) Pumping of at least 800 AF/yr, and possibly up to 2000 AF/yr in the APEX area has not caused detrimental water level decline in the MRSA. Smith Presentation Slide 28; Transcript Vol. VII, 1455:15 – 1456:15; CNLV Ex. 3 at 46.

3. **<u>The long-term annual quantity of groundwater that may be pumped from the LWRFS, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow.</u>**

Smith, opined that a groundwater budget should be based on a safe yield concept in the LWRFS. CNLV Ex. 3 at 16. Smith suggested that this safe yield management scheme may require establishing different geographic areas. Transcript Vol. VII, 1420:6 – 12. "The safe yield is really associated with water levels at Pederson and EH-4 or the high altitude springs, that's the driver for water [management] decisions." Smith Testimony, Transcript Vol. VII, 1459:23 – 1460:1[4]. Using a safe yield concept allows management that moves away from stream flow

[4] While the transcript says "granting" it should read management.

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capture in order to manage groundwater resources on a pumping center basis, rather than over the entire LWRFS geographic area. Transcript Vol. VII, 1460:1-5. Safe yield amounts for Garnet Valley, and specifically the APEX industrial park, will have to be determined through additional testing and monitoring. Transcript Vol. VII, 1488:18 – 1489:24. See also, discussion under Section 2 above.

4. **The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River.**

Transfers of water rights from alluvial to carbonate aquifer systems should be permitted with an analysis on a case by case basis. Transcript Vol. VII, 1419:9 – 1420:1; 1461:12-17. In reviewing a capture analysis of Muddy River flows (SNWA Ex. 7), pumping proximal to the Muddy River is primarily responsible and can explain historical stream flow depletion. Smith Presentation, Slides 29-30. Pumping from the alluvium along the Muddy River corridor has an immediate capture of Muddy River flows. Transcript Vol. VII 1456:21 – 1457:16. It also appears likely that pumping from the carbonate aquifer at locations proximal to the Muddy River Springs is nearing to equilibration with river flow capture after about two decades of pumping. However, Smith testified that he did not observe the same situation from pumping in Garnet Valley, approximately 25 miles from the MRSA, Smith opined: "I don't think we felt much, if any, effect to reduction of the Muddy River flows from those [Garnet Valley] distant pumping centers." Transcript Vol. VII, 1457:19-21. A simple 1:1 impact analysis is not appropriate in a system that is complex. Smith Presentation, Slides 29-30; *see also discussion at* Transcript Vol VII, 1458:7 – 1460:5. Duration, location, and magnitude of pumping all play important roles in physical capture of stream flow. Smith Presentation, Slide 30; Transcript Vol. VII, 1458:5-7. Pumping of alluvial water rights in the Muddy River Springs has captured river flow since the 1940s, but also some ET. Smith Presentation, Slide 30; Transcript Vol. VII, 1458:7-9. However, it is not observed to capture high-altitude spring discharge. Smith Presentation, Slide 30.

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"The exact process of stream flow capture by pumping is not clearly known, and could be due to direct lowering of the water table adjacent to the stream bed (classic stream flow capture), or could be by indirect means of capture of flow from springs that discharge through the alluvium on the valley floor, producing discharge to the Muddy River." CNLV Ex. 3 at 48. Because of this unknown, pumping from the shallow wells that tap into the alluvium in the Muddy River Springs corridor "may potentially capture flow of the Muddy River as measured at the down-stream Moapa Gage by both induction of river flow and by indirect means of capture of spring discharge tributary to the river." CNLV Ex. 3 at 48. Regardless of exact capture mechanism, stream flow capture by alluvial pumping is not known to directly affect the sensitive MRSA habitat for the Moapa Dace.

The transfer of water rights is an important water management tool. When combining more than five groundwater basins, and thereby merging priority dates, a once senior water right could now be junior. The free movement of water within the combined basins will allow flexibility for all water users under any new management scheme. *See discussion at* Transcript Vol. VII, 1460:24 – 1461:11. Moving alluvium groundwater in the MRSA to other areas in the carbonate system may serve to decrease the alleged "1:1" impact on the springs.

Moving water away from the most sensitive area to the outskirts of the LWRFS will reduce the impact to the springs, including that of duration, location, and magnitude. Furthermore, leaving water in the aquifer near the springs area will help to offset impacts allowing for new and innovative management and water use project installation. Smith testified and provided a concept outline of the proposed artificial recharge project, pipeline project, and phased construction approaches. CNLV Ex. 2. This concept considers use of both surface water and groundwater for its sources, but moving water rights from MRSA alluvial wells, to Garnet Valley, may have a net positive effect on the MRSA. *See also,* CNLV Ex. 2. Movement of water rights between the alluvial and carbonate aquifers should not be precluded without a case-by-case analysis at the time a change application is proffered. *See discussion at* Transcript Vol. VII,

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1461:12 - 1462:23. Other indirectly related water management plans, such as aquifer recharge to the carbonate aquifer for example, may be integral to considerations that relate to transfers of water rights.

Permits under change applications that move water from the MRSA alluvium to other carbonate locations, can include restrictions and monitoring plans as express conditions in the permit terms. In the case of the City, moving water away from the alluvium into Garnet Valley's APEX area carbonate aquifer may not show any impacts in the MRSA. Based on the geology and fault locations, the inflow of water from Las Vegas Valley, and the boundary conditions, a transfer under this condition may show no response in the MRSA. A transfer in this circumstance should be considered on a case by case basis and can be properly conditioned with express terms. This will serve to set expectations on water use, decrease undesirable impacts in the LWRFS, and include conditions that allow for analysis related to impacts and conflicts with existing rights. A properly conditioned permit will have safeguards in place to protect against impacts should they even occur.

5. <u>Other matters.</u>

All parties and the State Engineer could benefit from additional monitoring and data collection. If any management decisions are made based on the current information, litigation will follow. Further, the legality and policy considerations of combining basins and priority schemes should be considered now as the current law allowing the State Engineer to act to implement a conjunctive management scheme, is at best, sparse.

While the State Engineer grapples with conjunctive management in other areas of the state (e.g., Humboldt River Basin), a one size fits all approach may not be sound. Regardless, the science on the Humboldt River Basin appears to be a bit more settled than that presented during the Order 1303 hearings. Without taking into consideration what conjunctive management means for the LWRFS, and how to deal with those not connected, or only connected in part, the State Engineer could initiate a critical groundwater management area and

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leave it to the water right holders to come up with a plan. However, consensus among water right holders is unlikely when there is no agreement on the amount of water available for pumping or what pumping is actually causing an impact to the MRSA.

Fundamental issues must be addressed by the State Engineer before moving on to system management, or in the alternative, the State Engineer should continue to manage each basin as it has done in the past making case-by-case determinations as to impacts and conflicts.

CONCLUSION

The testimony and evidence in regards to the Order 1303 issues leads us to the following conclusions and recommendations as we move into any administration of the LWRFS:

1) The LWRFS administrative boundary is likely appropriate as proposed in the Interim Order 1303 for the southern LWFRS area, however, some uncertainty exists in the southern boundaries that would benefit from additional data.
2) Alluvium to carbonate water right transfers should not be limited in general or conditioned without a review of the individual application, as some water right transfers will likely advance the water resource management goals for the LWRFS.
3) Muddy River stream flow capture outside the immediate areas of the Muddy River Springs is not conclusively demonstrated and quantified. Capture should be managed as a separate issue, and incorporate other geographic areas with pumping occurring along the river corridor and in tributary areas outside the LWRFS, specifically in Lower Meadow Valley (220), with separate mitigation options (i.e., pumpers acquire sufficient decreed water rights to offset capture, etc. – capture does not necessitate immediate cessation of all pumping).
4) Post Order 1169 water level trends likely reflect commingled pumping and climate response. Monitoring will continue to bring forth data to review the contributions, but it may not be necessary to absolutely define, in order to begin taking water management

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actions. The water level declines are present and can be incorporated into safe yield considerations (i.e. preservation of flows for Moapa Dace).

5) The safe yield for Garnet Valley is hard to define with existing data, however, there is evidence that pumping in the 1980s through mid-1990s of the magnitude of about 800 AF/yr did not cause declining water levels or spring discharge at the MRSA. Some magnitude of groundwater can be safely pumped in Garnet Valley, but further pumping (or injection) testing along with more comprehensive monitoring are needed to define a safe yield for the APEX geographic area within the LWRFS. Water management strategies such as aquifer recharge and conjunctive use may also play an important factor in determining future safe yield.

DATED this _3rd_ day of December, 2019.

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CERTIFICATE OF SERVICE

I hereby certify that on December 3, 2019, I caused a copy of the foregoing ***CITY OF NORTH LAS VEGAS' CLOSING STATEMENT*** to be served on the following parties as outlined below:

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Dated this 3rd day of December, 2019.

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STATE ENGINEERS OFFICE

STATE OF NEVADA

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES

DIVISION OF WATER RESOURCES

BEFORE MICHELINE N. FAIRBANK, HEARING OFFICER

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210) A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY HYDROGRAPHIC BASIN (219)	**INTERIM ORDER 1303** **COYOTE SPRINGS INVESTMENT LLC'S CLOSING STATEMENT REGARDING NEVADA STATE ENGINEER INTERIM ORDER 1303 PUBLIC HEARING THAT OCCURRED BETWEEN SEPTEMBER 23, 2019 AND OCTOBER 4, 2019 ("HEARING")**

Pursuant to the determination of Nevada State Engineer ("State Engineer") Hearing Officer Micheline N. Fairbank on the concluding day of the Public Hearing (October 4, 2109) in the matter regarding State Engineer Interim Order 1303 dated January 11, 2019 ("IO 1303"), Coyote Springs Investment, LLC ("CSI") submits the following Closing Statement.

In the face of regional climatic conditions and issues of drought, an evolving and sustainable water rights management plan is essential.

This Closing Brief highlights the salient conclusions of CSI's responses to the questions raised by the State Engineer in IO 1303.

I. CSI'S SHORT ANSWERS TO THE QUESTIONS RAISED.

1. ***Geographic boundary of the Lower White River Flow System ("LWRFS")***. The State Engineer's proposed IO 1303 boundary for the proposed administrative unit known as the LWRFS is workable, provided there is an accounting for all water resources affecting the LWRFS and the unit is managed as a grouping of heterogeneous, geographically discrete

regions (i.e. Management Areas) affected by surrounding basin flows and hydrologic conditions. Kane Spring Valley ("KSV") was not, and should not, be included as a part of the LWRFS.

2. ***Order 1169 aquifer test and subsequent data, including Muddy River headwater spring flow and sufficient aquifer recovery thereafter***. The hydrologic, geophysical, and climatic data collected since the inception of the Order 1169 test demonstrate that climatic conditions dominate the water level signature and carbonate wells and geologic structures control the movement of water within the system, signifying that the impacts of pumping within the flow system are decidedly dependent on their location.

3. ***Long-term annual quantity that may be pumped from the LWRFS***. CSI contends there is up to 30,630 AFA of natural evapotranspiration and subsurface outflow available for extraction from the LWRFS. CSI further contends and proposes that the State Engineer adopt a sustainable management practice for the LWRFS, including adaptive management techniques, with an initial pumping level based on a time-dependent three-phased approach of sustainable management to begin at a value based on the average pumping rate of 11,400 AFA[1]. Furthermore, and within the LWRFS, local recharge from the Sheep Range into Coyote Spring Valley ("CSV"), supports 5280 AFA of sustainable pumping due to the presence of structural faulting that creates a non-preferential flow path in the west-to-east direction; this fault system effectively isolates the west side of CSV from the east side of CSV and the springs and surface flow in the Muddy River Spring Area ("MRSA"). Therefore, CSI should also be able to exercise all of its water rights due to the in-basin recharge of 5280 AFA.

4. ***Moving water rights between alluvial and carbonate wells within the LWRFS***. Movement of water rights between alluvial and carbonate wells must be reviewed on a case-by-case basis by assessing the quantities in issue, locations, depths, subsurface geologic features, historical test results, and other prescient factors. At the Hearing all

[1] State Engineer Draft Order distributed at the Sept. 19, 2018, "Working Group Meeting", at Page 7, describes that 11,400 AFA is the approximate average of pumping before and after the 1169 test within the LWRFS.

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parties agreed that moving pumping away from the MRSA will have an immediate and positive impact on stream and spring flow in the MRSA.

5. ***Other relevant matters to the State Engineer***. CSI addresses three other matters relevant to the State Engineer's analysis. One: the Moapa dace is a species covered by the Endangered Species Act, however, CSI, along with the other parties to the 2006 MOA,[2] already agreed upon and carried out mitigation measures requested by FWS. FWS established these mitigation measures to offset any effects of the 2006 MOA parties' Coyote Spring Valley pumping on the Moapa dace. CSI has FWS authorization to exercise its water rights, subject to the terms of the 2006 MOA.[3] Other entities with water rights within the LWRFS and in Muddy River must separately seek FWS authorization in order to exercise their water rights. Two: the Muddy River Decree[4] does not trump all others without exception: and there are exceptions which result in a pro-rata reduction of water rights from the Muddy River. Three: Water right holders within the LWRFS whose annual submittals to the State Engineer demonstrate pumping in excess of allocated water rights or duty should be pursued, regardless of creative interpretations about artificial recharge or other justifying bases provided. Also, the exercise of water rights must be in accordance with the allowed beneficial uses.[5]

II. CSI'S CLOSING STATEMENT ANSWERS TO THE FIVE QUESTIONS RAISED BY THE STATE ENGINEER IN IO 1303.

1. ***The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the LWRFS.***

A. *Management of the LWRFS as heterogeneous regional areas.*

Although the boundaries of the administrative unit the State Engineer proposes to

[2] The "2006 MOA" shall refer to that certain Memorandum of Agreement dated April 20, 2006, as amended from time to time, among CSI, Moapa Band of Paiutes ("MBOP"), US Fish and Wildlife Service ("FWS"), Southern Nevada Water Authority ("SNWA"), and the Moapa Valley Water District ("MVWD").

[3] The State Engineer is not a party to the 2006 MOA.

[4] The "Muddy River Decree" shall refer to the set of Court orders and stipulations and agreements arising from the State Adjudication which resulted in the Stipulation dated April 23, 1919 and the Order dated March 12, 1920, governing the stream flow and ownership of water rights in the Muddy River. *See* NSE Ex. No. 333 from the IO 1303 Hearing.

[5] Meaning, there may be uses which are not allowed, depending on the basin and permit.

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designate as the LWRFS are reasonable, it should not be regarded as a single homogeneous unit. The LWRFS is a highly geologically, geophysically, and hydro-geologically diverse region, both at surface and subsurface levels. From the surface there is the northern extension of the Arrow Canyon Range as it plunges northwestward into CSV, creating a preferred north-to-south groundwater flow path parallel to the normal faults that bound either side of the range. Located further west of the Arrow Canyon Range structure block and fault system, the fault identified by Zonge International ("Zonge") in the April 2019 Controlled Source Audio-Frequency Magnetotelluric ("CSAMT") geophysical study, an "Unnamed Normal Fault parallel to and west of the plunging Arrow Canyon Range in the center of CSV"[6] creates another preferred groundwater pathway that directs regional flow from Pahranagat/Delamar Valleys southward into Garnet Valley. The sub-parallel faults on the east side of the Arrow Canyon Range in eastern CSV, provide a second preferred flow path for regional groundwater flow from Pahranagat, Delamar, and Kane Springs Valley into MRSA. Lastly, as evidenced by the lack of observed impacts at Big Muddy Spring, an additional preferred pathway for regional flow exists from the Lower Meadow Valley into MRSA and California Wash. The subsurface carbonate aquifer with its folds, faults, slips, strikes, other geologic formations, and hydraulic gradient, act together to divert, direct, compartmentalize, and otherwise dominate the multiple subsurface flow-paths throughout the LWRFS.

As CSI has emphasized in its reports and during the Hearing, groundwater level variations due to long-term climatic variability should not be confused with responses to pumping. Long-term climatic variability strongly affects groundwater levels throughout the LWRFS. Signals and responses from these long-term climatic effects also vary; they are neither instantaneous nor predictably guaranteed to occur at a specific time.

These fundamental principles relate directly to the issues that the State Engineer delineated for inquiry in IO 1303. The amount of groundwater available under sustainable management conditions, taking into consideration surface flow, subsurface flow, pumping,

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[6] CSI Rebuttal Report, August 16, 2019 ("CSI Rebuttal Report"), Appendix C "Controlled-Source Audio-Frequency Magnetotelluric Survey" by Zonge International.

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rainfall, recharge, evapotranspiration, and other conditions come together and correlate to pumping impacts that may occur at various locations within the LWRFS. Taken together with new evidence such as the Unnamed Normal Fault parallel to and west of the plunging Arrow Canyon Range in the center of CSV, identifying the separation and compartmentalization of pumping impacts on the west side of CSV from impacts on the east side of CSV is important to the State Engineer's analysis of what can be sustainably pumped and from what locations in CSV, as well as from other regions within the LWRFS.

B. *Kane Springs should continue to be excluded from the LWRFS.*

Reports submitted to the State Engineer include detailed scientific analysis and explanation regarding structural faults and other matters describing the reasons that KSV should continue to be excluded from the LWRFS.

For instance, and as described in the Vidler Report,[7] the high groundwater gradient between CSVM-4 and KMW-1 is due to the presence of a series of parallel faults. These parallel faults are a barrier against any impacts from MX-5 reaching KMW-1 and the KSV as a result of the hydraulic head that would be required to flow against the steep hydraulic gradient that exists north-to-south across those parallel faults. These parallel faults are a barrier to impacts but not to flow. The parallel faults impede the quantity of flow from north-to-south but do not prevent flow altogether due to the hydraulic gradient present. The boundary of the LWRFS unit should not be modified to include KSV due to, among other things, a lack of pumping impact between KSV and the southern CSV and the MRSA.

CSI and Vidler Water Company each retained Zonge International to conduct geophysical testing which further supports the exclusion of the KSV from the LWRFS.[8] Zonge's report supports the limited transmissivity and flow from KSV to lower CSV and the MRSA.

CSI disagrees with MVWD that the KSV should be included in the LWRFS. MVWD postulates that because KSV is a part of the interconnected system of carbonate rock aquifers that

[7] IO 1303 Report issued by Vidler Water Company "Vidler" and Lincoln County Water District ("LCWD") and dated July 3, 2019 (the "Vidler Report").

[8] *See*, IO 1303 Report issued by CSI and dated July 3, 2019 ("CSI Report"), and Vidler Report.

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make up the overall White River Flow System, KSV should be included.[9] MVWD also relies on observation of a 6-inch decline in water levels at KMW-1 during the Order 1169 test.[10] During Vidler's testimony this was shown to be unreliable data and CSI agrees with the explanation.

2. ***The information obtained from the Order 1169 aquifer test, subsequent to the aquifer test, and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test.***

A. *CSI's active participation in CSV basin matters.*

CSI has diligently participated in proceedings relating to the physical characteristics of and water availability within the Coyote Spring Basin, such as the Order 1169 test, including the proceedings' expansion to include designation of the LWRFS, matters leading up to IO 1303, and IO 1303 reports and the Hearing.

B. *CSI commissions new scientific study.*

As a result of the IO 1303 charge to provide new information and interpretation of Order 1169 test and subsequent pump records, CSI commissioned a study of the geophysical characteristics of the LWRFS within the CSV. Both CSI and Vidler engaged Zonge to conduct CSAMT geophysical surveys, to enhance their understanding of the faulting within the CSV and KSV region of the LWRFS that had previously been identified in the Rowley Report.[11]

While many others have postulated as to how Order 1169 test data might infer the physical characteristics and communication among the separate basins composing the LWRFS, CSI and Vidler were the only parties that invested in additional study of these issues. The data obtained through the Zonge 2019 CSAMT surveys provides objective scientific evidence required for an accurate interpretation of Order 1169 test data and groundwater level information gathered since the conclusion of the Test. Specifically, the CSAMT surveys corroborate the existence of

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[9] IO 1303 Report dated July 1, 2019 submitted by Moapa Valley Water District and Glorieta GeoScience Inc. ("MVVWD Report").

[10] MVWD Report, page 1.

[11] CSI Hearing Exhibit #14. Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee D.K., et al., 2017. Geology and geophysics of Spring, Cave, Dry Lake, and Delamar valleys, White Pine and Lincoln Counties and adjacent areas, Nevada and Utah: The geologic framework of regional groundwater flow systems. Nevada Bureau of Mines and Geology Report 56.

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the faults identified by Rowley and identify new structural faults that can reasonably be inferred as a barrier to flow from western CSV to eastern CSV. Coupled with aquifer test data, the Rowley report and the CSAMT data show that portions of the aquifer are compartmentalized from other areas and that separate flow paths exist within the LWRFS through CSV, which should be managed independently from one another under sustainable parameters.

3. ***The long-term annual quantity of groundwater that may be pumped from the LWRFS, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;***

A. ***LWRFS is sustainably managed in current conditions with 30,630 AFA established as the available resource, with a sustainable solution to management commencing with an initial 11,400 AFA available to be pumped; and 5280 AFA of local recharge available to be pumped in CSV.***

Water resources within the LWRFS derive from surface flow, recharge, evapotranspiration, subsurface flow into the LWRFS, and adjacent basin inflows. When these resources are considered together, there remains a calculated 30,630 AFA of available resources in the LWRFS.[12] The State Engineer can permit the appropriation of all, or a portion, of this subflow for the benefit of the users within the LWRFS. It is from this calculation that CSI proposes a suggestion for a three-phased sustainable solution for management of the LWRFS that commences with an initial extraction rate of 11,400 AFA.

The goal of the following plan is to initiate sustainable management practices in the LWRFS without the need for the State Engineer to curtail water rights. While there are numerous theories regarding the occurrence and movement of water through the LWRFS, all parties agree that carbonate and alluvial pumping in the MRSA impacts the springs and surface flow in the MRSA. Therefore, in order to protect the dace and surface flow of the Muddy River, CSI suggests that the State Engineer limit the initial production of water in the LWRFS to 11,400 AFA. Specifically, the ideas presented regarding climate impacts, heterogeneities in geology and

[12] CSI Report, page 54.

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structure, impact from lag-time and well location, and overall connectivity of the aquifer need long-term stresses and monitoring to provide supporting data to the State Engineer to continue administration of the LWRFS. Pumping up to one-half of the local recharge from the Sheep Range from the west side of CSV over the next six years, CSI will present the results of the pumping in Year 7 to identify potential impacts to the MRSA's springs and surface flow. CSI expects other parties that have interests in development or prevention of development of water rights will also use the six-year period to collect data and develop reports. During year seven, all parties will reconvene to review reports and discuss initiating Phase II pumping.

In an abundance of caution, CSI suggests the State Engineer initiate sustainable management at 11,400 AFA, and adopt adaptive management techniques that allow for data collection from known stresses in order to approve Phase 2 (15,315 AFA) within seven years, and Phase 3 (30,630 AFA) in 15 years. CSI reasons that under these management conditions the moratorium in Order 1303 should be removed and transfers of water rights be allowed to move pumping out of the MRSA.[13]

This plan, which is a furtherance of the Concept Paper found at CSI Hearing Exhibit 3, includes these additional recommendations to start:

<u>Phase 1 (years 1 through 6) – Initiate Sustainable Management at 11,400 for 6 years</u>

a. Limit carbonate pumping in MRSA to current 2015-2018 average
b. Limit alluvial pumping and surface water extractions in MRSA to 2015-2019 average
c. Limit pumping on west side of CSV to one-half of Local Recharge – 2600 AFY
d. Remove all restrictions on development in the LWRFS, including, the temporary moratorium in IO 1303
e. Allow for transfer of Senior Rights away from the MRSA
f. If all stakeholders agree, all stakeholders to financially share in the development and implementation of a mitigation-monitoring-management plan and its results

<u>Phase 2 (Years 7 through 15) – Increase pumping to one-half of the LWRFS evapotranspiration and subsurface outflow (15,315 AFY), for 9 years</u>

a. Increase pumping in MRSA based on Phase 1 results
b. Increase pumping in west-side of CSV to 5240 AFY

<u>Phase 3 (after year 15) - Increase groundwater pumping up to 30,630 AFY</u>

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[13] *See also*, Stetson Engineers, Concept Paper by Stephen Reich, PE, PG, "Framework for Sustainable Groundwater Management in the LWRFS" dated October 4, 2018, entered into evidence at the Hearing as CSI Exhibit No. 3.

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This concept by CSI includes the Sheep Range conservative recharge calculations of 5280 AFA, meaning, CSI would be able to produce its full 4140 AFA[14] from its wells on the west side of the 2019 CSAMT Unnamed Normal Fault parallel to and west of the plunging Arrow Canyon Range in the center of CSV. The April 2019 CSAMT survey and groundwater level responses in CSV show that pumping on the west side of CSV has no measurable impact on flow to the MRSA. CSI's research and analysis[15] revealed a historical basin recharge to CSV which ranged from 1590 AFA to 7380 AFA from the Sheep Range.[16] Based on local and regional flow in southeastern Nevada and regional inflow to CSV along with comparison that included other estimates, CSI contends that an estimated local recharge in CSV of 5280 AFA is reasonable based on recent studies and updated precipitation estimates.[17] This recharge is captured in the alluvium and into the carbonate aquifer as it flows east off of the Sheep Range and to the subsurface flows heading into CSV from the north, and staying on the west side of the structural fault in CSV identified by Zonge.[18] Thus, conservatively, up to 5280 AFA can be produced from the western side of CSV with minimal impacts to the MRSA or the Muddy River Decreed Rights.

B. *Subflow through the LWRFS is available for State Engineer to appropriate*.

Previous State Engineer hearings have identified more than 50,000 AFA of groundwater subflow from Pahranagat, Delamar, and KSV into CSV. The mass balance equation for the LWRFS requires that subflow out of the LWRFS must be occurring because only 37,000 AFA is being measured at the Muddy River Moapa gage (yet, 50,000 AFA is entering as inflow). Any other interpretation would result in the ponding of surface water or creation of phreatophytes throughout the LWRFS, including the easternmost portion of CSV along the Pahranagat Wash. This analysis is strengthened by data which shows that inflow from the Lower Meadow Valley Wash (which is excluded from the LWRFS) toward the MRSA provides an additional 9000 AFA

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[14] Note: CSI is agreeing to only pump up to 50% of the local recharge in the amount of 2600 AFA under its solution for sustainable management.
[15] CSI Report, Section 4.1.
[16] Id. At page 40.
[17] CSI Report, Section 4.3.
[18] CSI Report, Figures 10 through 13. And Appendix C to the CSI Rebuttal Report. Each identifying the Unnamed Normal Fault parallel to and west of the plunging Arrow Canyon Range in the center of CSV, described in the Stetson Report.

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of recharge. The lack of response to carbonate pumping at the Big Muddy Spring strongly suggests an alternative flow path—one from the Lower Meadow Valley Mountains to the Lower Meadow Valley Wash, supporting groundwater resources in MRSA. Collectively, this is strong scientific evidence that subflow out of the LWRFS must be occurring.

CSI's analysis that subsurface flow <u>is available</u> for appropriation based on capture of phreatophyte evapotranspiration and adjacent basin outflow as shown in the groundwater budget proposed by CSI[19] is reasonable. When current discharge from MRSA (32,000 AFA) is compared to total inflow from Pahranagat, Delamar, KSV, and Lower Meadow Valley Wash, the mass balance equation shows that there are multiple flow paths occurring through CSV, thus, resulting in subsurface outflow from the LWRFS. A mass balance equation is important for understanding the conceptual flow model of the LWRFS. While some parties at the Hearing suggested that a water budget is not appropriate, they are incorrect. Unless the LWRFS is acting as a pond, a water budget is an appropriate management tool that requires periodic adjustment as flows change, pumping changes, climate changes, and new scientific studies are commissioned. Therefore, there is a quantity of subflow out of the LWRFS available for appropriation.

C. *<u>Hydrologic factors play a role in sustainable basin management</u>*.

Hydrologic conditions play an important role in determining how the State Engineer can sustainably manage resources in the LWRFS. Hydrologic data for extreme southern Nevada indicates that the area has been in long-term below normal hydrologic condition since 2006.[20] During the Hearing SNWA and FWS, among others, argued that Southern Nevada, including the LWRFS is <u>not</u> in a drought. [21] However, and exceptionally notable, SNWA's own website states: "***THE COLORADO RIVER SYSTEM <u>IS</u> FACING THE WORST DROUGHT IN THE BASIN'S RECORDED HISTORY***"[22] [Emphasis added]. Precipitation data within the LWRFS and adjacent basins indicate strong drought factors exist in most areas of the LWRFS.[23] Although

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[19] CSI Report, Tables 8 and 9.
[20] CSI Report, Section 6.1, and *See also*, CSI testimony on Sept. 23, pages 48-52 of Official Transcript.
[21] Official Transcript, Sept. 27, 2019, SNWA testimony at Page 1065, Lines 1-6; *See also*, Official Transcript, Sept. 24, 2019, FWS testimony at Page 307, Lines 9-11.
[22] https://www.snwa.com/importance-of-conservation/responding-to-drought/index.html (last visited 10/08/2019).
[23] CSI Report, Sections 4 and 6.

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drought factors exist through the LWRFS, the region is sustained in part by adjacent and up-gradient basins that have been experiencing above-normal precipitation conditions in the most recent several years.

Although rainfall data from Pahranagat Valley indicates below normal hydrologic conditions existed from 2006 through the end of 2012, its up-gradient basins have been experiencing above normal hydrologic conditions from 2013 through 2017.[24] These up-gradient basins benefit CSV through recharge and positively impact the perennial yield available in the CSV through existing subsurface flows.

D. ***SNWA's and FWS's convoluted conceptual models do not work.***

CSI offered a simple groundwater level comparison to demonstrate that the LWRFS, and in particular the flow path from the western side of CSV to MRSA, is not a homogeneous basin. Using the Theis solution, CSI's estimated impacts to groundwater levels in the MRSA, due to pumping in eastern CSV, may not provide a finite quantity of groundwater level drawdown, but it does provide a relative comparison. Pumping from the carbonate aquifer in eastern CSV ***has less impact*** on groundwater levels in EH-4 than pumping from nearby carbonate wells in the MRSA. Meaning, while there is a hydraulic connection between the eastern side of CSV and MRSA, the distance and high value of transmissivity minimizes the impact of the distal pumping in CSV from the carbonate groundwater levels in MRSA.

CSI's analysis demonstrates that the LWRFS is not a vast lake or pool, but instead a region characterized by normal faulting and geologic structures that support multiple flow paths and result in compartmentalization. However, SNWA and FWS proposed conceptual models to determine what quantity of pumping in the LWRFS is acceptable and these models incorrectly characterized the LWRFS in a homogenous manner and provided unsupportable solutions and results. In short, these models drastically oversimplify the LWRFS by failing to take into consideration the highly variable local conditions affecting groundwater flow through the system.

For its part, FWS used a SeriesSEE analysis first performed in 2013 by Keith Halford to

[24] CSI Report, Section 4.

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support a claimed homogenous water level drawdown across the LWRFS.[25] However, the SeriesSEE analysis is not repeatable[26] and is flawed because the model does not take into account recharge, faults, or boundaries, among other exclusions from the model.[27] Further, the SeriesSEE analysis[28] should be given little to no weight on the basis that FWS, in contravention of the State Engineer's order to produce all experts for cross examination whose analysis would be presented at the Hearing, did not produce Keith Halford, the author of this particular SeriesSEE model.[29] The SeriesSEE is also flawed because it does not account for any subsurface geologic structures or faults, neither climate nor recharge are factors considered in the analysis, and it does not account for any lag-time from "event" to a "signal."[30] Thus, the State Engineer should not rely upon the SeriesSEE analysis in making any determinations regarding the LWRFS.

The number of variables involved, the distance between wells and the diverse geology both above-ground and underground, make any conceptual model of the LWRFS a complex and intricate framework, susceptible to disagreement over the correct conclusion(s) among a multitude of parties, such as are involved in the Order IO 1303 proceedings.

SNWA proposed a complicated multiple linear regression analysis ("Regression Analysis") to argue that pumping should be limited at 4000 to 6000 AFA for the entire LWRFS. Like the FWS model, SNWA's model is based on a flaw that the LWRFS is a homogeneous unit. In building the Regression Analysis SNWA did not account for climate, subsurface structural blocks, other geologic impediments, or recharge rates, to name key factors that SNWA ignored.[31] In fact, SNWA argues that the region is not in a drought, and that climate is irrelevant to a water resource analysis of the LWRFS.

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[25] Official Transcript, Sept. 24, 2019, FWS Testimony, Pages 324-329.
[26] Id., Page 325.
[27] Id., Pages 325, 342-348, and 372-376.
[28] Id., Pages 326-328. A "curve fitting tool" into which exact numbers are not used, instead parameter estimations are relied upon.
[29] Id., Pages 324 and 375-376.
[30] Id., Page 324.
[31] Official Transcript, Sept. 27, 2019, SNWA Testimony, Pages 903-922.

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As presented in testimony at the Hearing, SNWA included incorrect input data for certain wells which were key components of their Regression Analysis.[32] A multiple-linear-regression methodology and analysis such as SNWA performed is inappropriate for a study area of the geographic size and characteristic as the LWRFS.[33] Instead, what SNWA did was to selectively include only the data that best suited the result that they desired; selecting wells and data, and including, or excluding, model parameters that skew the results.[34]

Further, SNWA used a simple linear relationship between flows at Warm Springs West and the Moapa gage to say that 5908 AFA of pumping would result in flow at the Warm Springs West gage of 3.2 CFS.[35] This analysis by SNWA did not consider lag time, heterogeneities, climate, structure, or other factors that control the occurrence and movement of groundwater. Although CSI does not believe the 2006 MOA is pertinent to the State Engineer's analysis of matters in IO 1303[36], a flow rate of 3.2 CFS is not the trigger to target. A trigger level equating to flows of 2.7 CFS or 2.8 CFS at the Warm Springs West gage is more appropriate. This 2.8 CFS threshold is notable because in the 2006 MOA, FWS agrees to not assert a claim for diminution in flows at Warm Springs West above 2.7 CFS.[37]

4. ***The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River.***

Pumping from carbonate wells in the MRSA affects the amount of recharge from the carbonate aquifer to the alluvial aquifer. Pumping from the alluvial fill aquifer and surface diversions in the MRSA affects the flow of the Muddy River. Surface diversions, carbonate pumping and alluvial pumping in the MRSA affect springs and surface flow that support the

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[32] Official Transcript, Oct. 1, 2019, City of North Las Vegas Testimony, at Pages 1446-1448, 1449. *See also*, City of North Las Vegas Hearing Presentation Slides at slides 22-23. Including, Dwight Smith's testimony regarding how SNWA used incorrect data sets for their analysis, and at page 1449, Mr. Smith states that SNWA made a "prejudgment of the outcome of climate variable" that was not in keeping with scientific methods for the type of analysis that was performed.
[33] Id.
[34] Id.
[35] IO 1303 Report submitted by SNWA and Las Vegas Valley Water District, Table 6-2.
[36] *See also*, Page 15, Line 4 to 8 of this Closing Statement submitted by CSI "CSI disagrees that the State Engineer's permitting of pumping…."
[37] 2006 MOA, on page 8.

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Moapa dace and Muddy River Decreed Rights. Future goals and objectives for sustainable management must take into account location and geologic structure as key factors when establishing triggers and thresholds.

Movement of water rights between alluvial and carbonate wells must be reviewed on a case-by-case basis. For instance, alluvial and carbonate pumping and diversions within the MRSA directly and immediately affect resources along the Muddy River and in the Muddy River Springs Area ("MRSA"), while the only common links between groundwater level signatures in Garnet Valley and the MRSA are climatic conditions and annual variability. Meaning, under those circumstances, a change of alluvial water rights from MRSA to the carbonate in Garnet Valley may be beneficial to stream and spring flows in the MRSA.

Carbonate pumping further upstream of MRSA (in eastern CSV) has far less impact than alluvial pumping closer to MRSA. Carbonate pumping in western CSV is immediately isolated from MRSA due to a system of north-south parallel faults and structural barriers that impede west-to-east flow, as previously mentioned. Bedroc's argument that alluvial pumping in northern CSV does not impact carbonate groundwater levels in CSV does not make sense; where does the water go if there is 750 AFA of local recharge? Any recharge coming off of the Sheep Range and flowing across Bedroc's property into the center of CSV and onto CSI's property must eventually recharge the carbonate aquifer since the alluvial groundwater levels in CSV are higher than the carbonate groundwater levels. The vertical gradient is downward.

The normal faults on either side of the northern extension of the Arrow Canyon Range as it plunges into CSV act as a barrier to groundwater flow from the west side of CSV to the east side of CSV. While some have postulated groundwater flows from CSV to MRSA along the normal faults in the Pahranagat Wash, and from CSV towards Hidden Valley, the exposed portion of the Arrow Canyon Range south of the Pahranagat Wash has not been shown to be permeable in the west-east direction. Thus it follows that, as this structure plunges below the surface, it is likewise a barrier to flow subsurface as it plunges toward the center of CSV.

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5. ***<u>Any other matter believed to be relevant to the State Engineer's analysis</u>***.

A. *<u>The Moapa dace is not relevant to State Engineer analysis</u>*.

The Moapa dace is protected under the Endangered Species Act. CSI[38] has already implemented and completed its mitigation obligations set forth in the 2006 MOA, including payment of $200,000, dedication of 460 AFA, and along with other parties to the 2006 MOA, other mitigation measures for the benefit of the Moapa dace.[39] CSI disagrees that the State Engineer's permitting of pumping in the LWRFS should be modified based in any way on the 2006 MOA. The various mitigation measures, including provisions regarding the quantity of water flowing through the Warm Springs West Gage or the Moapa Gage are not binding on the State Engineer in his analysis in the consideration of an order arising from IO 1303.[40]

The 2006 MOA[41] established mitigation measures designed to protect and benefit the Moapa dace. The parties to the 2006 MOA have satisfied these obligations, including dedication of water, payment of monies, and other projects for the benefit of the Moapa dace. Other parties involved in the LWRFS who were not a party to the 2006 MOA will have to independently, and separate from IO 1303 proceedings, complete the necessary review and permit process with FWS. It is undisputed that CSI has met all of its mitigation obligations set forth in the 2006 MOA.[42]

The Center for Biological Diversity ("CBD") instituted legal proceedings challenging the 2006 MOA and the associated Biological Opinion in Federal District Court in 2010.[43] The Court upheld the MOA and ruled CBD was incorrect.[44] CBD appealed. However, the Ninth Circuit Court of Appeals affirmed the District Court ruling and held that the 2006 MOA did not violate the Endangered Species Act.[45] Relevant to the court's holding, and relevant to the facts of IO

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[38] Along with the other parties to the 2006 MOA.

[39] Official Transcript, Sept. 30, 2019, SNWA Testimony, Page 148, Lines 4-16.

[40] *See also*, Page 13, Lines 11-13 of this Closing Statement submitted by CSI, describing the relevant flow triggers at the Warm Springs West gage.

[41] Notably, while the State Engineer is not a party to the 2006 MOA and the State Engineer has no enforcement authority as to the terms of the 2006 MOA, the diminishment of flows to these trigger levels, does not necessarily require a reduction in groundwater pumping.

[42] Cite to SNWA & FWS transcript that CSI met its obligations.

[43] <u>Center for Biological Diversity v. U.S. Fish and Wildlife Service et al</u>., 3:10-cv-00521-ECR-WGC *Complaint for Declaratory and Injunctive Relief* (Filed D. Nev. August 23, 2010).

[44] <u>Id</u>., *Opinion*, Filed September 17, 2015. Page 5.

[45] <u>Center for Biological Diversity v. U.S. Fish and Wildlife Service, et al</u>., 807 F.3d 1031, 1036 (9th Cir. 2015).

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1303 and the Hearing, the Court reasoned in its opinion that: "*It is proper for FWS to rely on mitigation and offsets in its jeopardy analysis, and it may view the effect of all such efforts on the species as a whole, rather than requiring a tit-for-tat offset in every subsection of species habitat.*"[46] The Court further held[47] that it was acceptable for FWS to approve a no-jeopardy finding where mitigation plans were expected to offset adverse effects to endangered species.[48] The Court further held that "*the ESA does not require that FWS replace impacted habitat on an acre for acre basis*")[49] and also reasoned in its opinion that adverse effects to species are outweighed by the benefits of mitigation plans.[50]

If the 2006 MOA impacts on the Moapa dace are to be considered, then the State Engineer must rely on the reasoning in Rock Creek and Selkirk regarding mitigation being an offset to adverse effects to a species. Likewise, the benefits from the mitigation undertaken must also be recognized and considered; no party has disputed the positive effects of the mitigation and conservation measures. These successful measures were, in part, described by FWS expert Dr. Michael Schwemm in his Hearing Testimony.[51] Dr. Schwemm described population increases to 1500 animals, habitat and stream improvements, and invasive species removals, among other measures taken.[52] Thus, if effects to the Moapa dace are considered by the State Engineer in his post-Hearing deliberations, the mitigation accepted by FWS must be given substantial weight for the parties who are in compliance with their respective mitigation measures.

B. Muddy River Decree is not as relevant as parties assert.

Much ado has been made of the Muddy River Decreed Rights. CSI acknowledges the state adjudication of the Muddy River[53] in 1920.[54] However, CSI disagrees the Muddy River Decree is an obstacle to other water-rights holders' pumping in the LWRFS. The Muddy River

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[46] Id. At 1052, *citing to* Rock Creek Alliance v. US Fish and Wildlife Service, 663 F.3d 439, 443 (9th Cir. 2011).
[47] *See* Selkirk Conservation Alliance v. Harv Forsgren, 336 F.3d 944 (9th Cir. 2003)
[48] Selkirk, 336 F.3d 944 at 955.
[49] Rock Creek, 663 F.3d at 443.
[50] Rock Creek, 663 F.3d at 443, *see also*, Selkirk, 336 F.3d at 955.
[51] FWS Testimony, pages 287-298.
[52] Id.
[53] In fact, CSI owns water rights arising under the Muddy River Decree and is a shareholder of preferred and common shares in Muddy Valley Irrigation Company.
[54] Muddy River Decree dated 3/12/1920

Decree includes provisions to proportionately reduce holders' water from the Muddy River in certain circumstances, such as abnormal losses:[55] "That all abnormal losses from the flow of this stream shall be pro-rated and shared among the parties holding water rights on the stream…."[56] The term "abnormal losses" was to includes losses from natural events; diversions by the reservation in excess of 1.25 CFS, and **water resources awarded or decreed to any party not a party to the [Muddy River Decree] in a subsequent action(s)**. [Emphasis added][57]

The State Engineer has already awarded additional water rights in MRSA, Lower Moapa Valley, and the LWRFS, some of which have been put to beneficial use. These awards of additional water rights may be considered "abnormal losses" under the Muddy River Decree. Thus, a pro-rata reduction could occur pursuant to the Court Order arising from the "abnormal losses". This is important to note, as the Muddy River Decreed rights, while "senior" are not a strict prohibition to the State Engineer's permitting of the development of water in the LWRFS. Thus, the Muddy River holders' water rights are subject to pro-rata reduction for "abnormal losses" which have, in fact, occurred following the issuance of the Muddy River Decree.

C. *It is imperative that Alluvial and Carbonate Overpumping must cease*.

All water rights holders in the LWRFS using their water rights, regardless of date of seniority or type of water right must be held to all of the rules and regulations regarding water rights. Pumping and duty limitations must be in compliance, places of use, points of diversion, and manners of use, and all of the other rules and regulations must be reviewed by State Engineer staff and brought into compliance. Non-compliant pumpers cause a trickle-down effect that may skew the effect of any decision made by the State Engineer if violations are excused.

A party with an argument similar to BedRoc, that their use of alluvial wells and any related artificial recharge that may (or may not) occur from uses such as irrigation or dust control, does not have the legal authority to pump, ad infinitum, an amount that such party believes is equal to recharge. Any such pumping should be held in abeyance until such time that the party

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[55] Muddy River Decree, Page 7, defining "abnormal losses".
[56] Muddy River Decree, 11th Order, page 22.
[57] Muddy River Decree, Pages 7 and 13.

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requesting the recharge permit has submitted appropriate permits and application documents to the State Engineer and been approved to pump such recharge for beneficial use.

III. IN CONCLUSION, THE LWRFS HAS SUFFICIENT AND QUANTIFIABLE WATER RESOURCES TO ALLOW ALL CURRENT PUMPING TO CONTINUE, LIFT THE MORATORIUM, AND SUSTAINABLY MAINTAIN THE BASINS.

Science-based geophysical and hydrogeologic data has been provided by CSI that demonstrates the heterogeneity of the LWRFS; that in fact, the LWRFS does not act as a pool with only one point of discharge in the MRSA. Multiple flow paths defined by faults and structural elements control the occurrence and movement of regional and local groundwater along the western side of CSV, the eastern side of CSV, and from Lower Meadow Valley Wash into the LWRFS. While others have suggested that a water budget analysis for the LWRFS is obsolete, the same parties have also suggested that all pumping in the LWRFS impacts flow at the springs and Moapa gage. Evidence submitted by others during the hearing to suggest that the LWRFS acts as a "pool" did not account for lag time, climatic conditions, and structural elements that control the occurrence and movement of water in the LWRFS. In fact, the need for a water budget to sustainably manage the LWRFS is as important as in any other basin in Nevada. The entire LWRFS can be sustainably managed through the creation of "Management Areas" that recognize these flow paths and their relative contributions to spring-flow, surface flow, evapotranspiration, and sub-surface outflow. CSI has demonstrated that 30,630 AFA can be pumped from the LWRFS, and that in particular, the CSV can sustain 5280 AFA of pumping without impact to the MRSA or the Muddy River.

Recharge from surrounding mountain ranges, including the Sheep Range into western CSV, groundwater flow into the LWRFS from all adjacent basins, groundwater outflow, spring and stream flow within the LWRFS, and surface water outflow, all describe the variety of water resources that constitute the LWRFS. When these resources are combined with the new science from the April 2019 CSAMT survey that indicates groundwater in CSV flows in a north-to-south direction along preferred flow paths, separated by a relatively impermeable carbonate block, CSI's position regarding 30,630 AFA in the LWRFS (initial estimates of 11,400 AFA available to be pumped), and 5280 AFA available for pumping on the western side of CSV, is reasonable.

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CSI's assertion takes into account that the State Engineer must balance groundwater inflow, evapotranspiration, groundwater outflow, use, and long-term sustainability. A quantity of 30,630AFA achieves that result.

Groundwater pumping from the carbonate aquifer in MRSA affects flow in the carbonate aquifer to the alluvial basin, which then affects flow from the alluvial basin to the Muddy River. The effects are dependent on well location(s), geologic formations, hydraulic gradients, and elevation, among other factors. Transfers may be made between carbonate and alluvial pumping, but may not be carte-blanche. Review and analysis of place of use, points of diversion, and quantity, must be a part of the consideration on a case-by-case basis.

The Muddy River Decree should be revisited and considered when balancing the LWRFS water resources. The Muddy River Decreed Rights may be proportionally reduced as to the holders of those decreed rights.

All water rights holders in the LWRFS should be held to comply with the same set of rules and regulations. All holders' pumping and duty limitations must be in compliance and the State Engineer should issue firm mandates on these requirements and proceed with curtailment when and as necessary. Non-compliant pumpers affect compliant pumpers, and may alter the effect of any decision made by the State Engineer if violations are ignored.

Moapa dace recovery under the 2006 MOA, to which FWS is a party, has been successful and thus mitigation measures as set forth in that agreement should remain as planned.

A long-term sustainable supply of water resources in the LWRFS is 30,630 AFA, and the State Engineer should designate the 30,630 AFA as the total resource based on science known today, and limit initial pumping to 11,400 AFA pursuant to a plan of sustainable management and lifting the moratorium in IO 1303.

Furthermore, and within the LWRFS, local recharge from the Sheep Range within CSV supports CSI pumping all of its water rights, from available local Sheep Range recharge which is at least 5280 AFA. This recharge is available to be pumped as a result of the presence of structural faulting identified by Zonge in the April 2019 CSAMT survey, and identification of the Unnamed Normal Fault parallel to and west of the plunging Arrow Canyon Range in the center of

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CSV that creates an impediment to flow in the west-to-east direction; effectively isolating the west side of CSV from the east side of CSV and the springs and surface flow in the MRSA.

DATED this 3rd day of December, 2019

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By: [signature]

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CERTIFICATE OF SERVICE

I certify that I am an employee of Brownstein, Hyatt, Farber, Schreck, LLP, and that on this date I caused a true copy of **COYOTE SPRINGS INVESTMENT LLC'S CLOSING STATEMENT REGARDING NEVADA STATE ENGINEER INTERIM ORDER 1303 PUBLIC HEARING THAT OCCURRED BETWEEN SEPTEMBER 23, 2019 AND OCTOBER 4, 2019 ("HEARING")** to be served on all parties to this action by emailing an attached Adobe Acrobat PDF version of the document to the email addresses below:

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IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINSTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHOC BASIN (218), AND MUDDY RIVER SPRINGS AREA (aka UPPER MOAPA VALLEY HYDROGRAPHOC BASIN (219).	**Regarding Interim Order 1303 Hearing Commenced on September 23, 2019**

CLOSING ARGUMENT OF GEORGIA PACIFIC CORPORATION AND REPUBLIC ENVIRONMENTAL TECHNOLOGIES, INC.

Georgia Pacific Corporation ("Georgia Pacific") and Republic Environmental Technologies, Inc. ("Republic") (collectively the "Parties"), hereby jointly submit the following Closing Argument in response to the Hearing Officer's directive in the above-referenced proceedings.

I. The Parties and their Interest in this Matter

Both Georgia Pacific and Republic are long-established businesses located in Garnet Valley that use and rely on certificated and proven groundwater rights to support their operations. The potential loss of water rights that could occur based on the State Engineer's decisions in this matter would seriously jeopardize the viability of these operations and threaten the loss of the significant benefits they provide to the State and local economies.

Georgia Pacific has gypsum wallboard, gypsum plaster and polymer extrusion manufacturing operations located twenty miles north of the City of Las Vegas, Nevada, along

U.S. Highway 91, in Apex, Nevada. This facility is a very important asset for Georgia Pacific and has been in operation since 1987 and employs approximately 156 employees.

The wallboard operation consists of crushers, screens, calciners, aggregate dryers, impeller mills, mixers, storage bins, conveyors, and a board dryer to manufacture wallboard. The plaster operation produces two grades of plaster designated as alpha and beta and consists of crushers, screens, calcining units and packaging equipment. The polypropylene resin mat operation consists of a vacuum loader, hopper dryer, pigment feeder, resin extruder and die head, water tank cooling and forming system, cutter/slitter, and winder.

This Facility has one permitted on-site well which is the only source of water available for production and domestic water usage. The facility is permitted to withdraw 47 million gallons per year. The majority of the permitted water is used in wallboard production with the remainder being used in the polymer extrusion process as well as the site's domestic water uses.

Republic's Apex Regional Landfill complex ("Apex Landfill") is located at 13550 N Highway 93, Las Vegas, Nevada and encompasses over 2,200 acres. Apex Landfill performs the critical task of providing environmentally safe and reliable daily waste disposal services for nearly 3 million residents and hundreds of businesses in the Cities of Las Vegas, North Las Vegas, and Henderson, as well as Clark County.

To ensure the highest quality of service for its customers, Apex Landfill operates twenty-four hours per day, seven days per week, fifty-two weeks per year. Republic safely disposes of over 8,000 tons of waste per day at Apex Landfill through its resources of 478 trucks, more than 1200 employees and 2 transfer stations.

To perform its daily operations, the site utilizes approximately 150 million gallons of water per year from its three permitted wells. A predictable and stable water supply is critical to allow Apex Landfill to continue to provide uninterrupted service for its millions of customers, as well as plan for meeting the increasing demand for future disposal capacity.

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II. The Evidentiary Hearing was Inconclusive, both as to the Scientific Evidence Presented and as to Policies for Management of the Lower White River Flow System

A. Inconclusive Science

Although the State Engineer may have hoped clear answers would emerge from the reports and presentations of the participants in the evidentiary hearing held from September 23 through October 4, 2019, pursuant to Interim Order 1303 (the "Hearing"), little consensus was developed on the substantive questions. Instead, the stakeholders focused on distinct concerns and highlighted disconnects, gaps, flaws in the data and analyses, as well differences in interpretation among experts.

With respect to the first question presented by the Order, most participants generally supported the boundary of the administrative unit, to include the five basins and one partial basin as designated by the State Engineer. Some advocated including Kane Springs Valley, but this was opposed by Lincoln County/Vidler. Some evidence emerged during the hearing that groundwater coming from the Lower Meadow Wash hydrographic basin could be feeding Big Muddy Spring and could be a source for as much as 15% of Muddy River Water. There was no evident consensus as to the way water rights would be managed within the unit.

No consensus emerged during the Hearing as to sustainable supply of water within the LWRFS. Amounts presented ranged from 0 to 40,000acre feet per annum ("afa"). The range is due in part to differing estimates of the amounts and rates of groundwater flow into and out of the LWRFS, but also due to differing view of what "sustainable" means. At least to date, no process has been presented for exploring this question.

The question pertaining to the interpretation of the Order 1169A pumping test also received diverse responses; the results are certainly less clear than would allow the State Engineer to assume a homogenous cause and effect of pumping throughout the LWRFS. Some parties, such as the Moapa Tribe and Lincoln County/Vidler, argued the change in water level observed in wells throughout the basin that occurred contemporaneous with or shortly following the pump test was due at least in part to climatic signals. Others, including the Southern Nevada Water Authority ("SNWA") and US Fish and Wildlife Service, argued the drop in water levels

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following the pump test was obvious evidence of extraordinarily high transmissivity and connection throughout the carbonate aquifer. SNWA concluded from the test that pumping in any of the areas affected by the pump test would necessarily result in decrease in water levels throughout the administrative unit and provided linear regression modeling to argue that pumping from distal locations, like Garnet Valley, would result in diminished flows in the Muddy River Springs Area similar to the effects caused by the test pumping.

The City of North Las Vegas ("CNLV"), however, effectively challenged the models that SNWA used to support its contention that pumping anywhere in the basin would diminish groundwater levels throughout the unit. Dwight Smith, testifying on behalf of CNLV, argued SNWA's multi-linear regression analysis is invalid due to erroneous input of Garnet Valley pumping, which ignored significant pumping that occurred during the 1980's and 1990's. He explained "The input pattern of pumping artificially creates a higher association between Garnet Valley pumping and EH-4 water level variations, which in turn affects the association assigned to the other explanatory variables. The erroneous Garnet Valley pumping input INVALIDATES the analysis for ALL pumping center outcomes." Smith presentation p 23.

In determining his estimates of early Garnet Valley pumping, Mr. Smith relied in part on priority dates of certification or proofs of beneficial use from the State Engineer's records. For example, Georgia Pacific holds a certificated right with a priority date of 1986 with a duty of 144.15 afa; proof of beneficial use was filed in 1993. Republic Environmental Services holds several permits with a priority dates of 1981 and 1988 with a total duty of 468 afa; proofs of beneficial use were filed in 1993. Mr. Smith provides a hydrograph illustrating stable water levels in Garnet Valley from 1986 through approximately 1999 during the time water was being pumped from the carbonate aquifer, which again has stabilized over the past five years, with no observed response to increased pumping in 2016 and 2017. Smith presentation p 25.

Clearly, any management decisions based on assumptions of rapid connectivity throughout the proposed administrative unit would be premature. As evidenced by the long-term pumping records from Garnet Valley, the more distal areas of the proposed unit could potentially be managed sustainably as discrete pumping centers.

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If anything became clear from the Hearing, it is that more scientific evidence is needed for a more complete understanding of the LWRFS.

B. Inconclusive Management and Policies

As the Hearing Officer advised during the August 9, 2019 Pre-Hearing Conference, the Hearing was not intended to deal with questions of policy. Instead, The Hearing was to be limited to the four questions "solicited in the Order 1303 report. This larger substantive policy determination is not part of the particular proceeding. That's part of later proceedings...." Transcript of August 9, 2019 Pre-Hearing Conference (Tr. at 10:18-20). During the course of the Hearing, the Hearing Officer attempted to steer witnesses away from policy discussions, with reasonable success. Nonetheless, the four questions posed in the Order necessarily impinge on policy questions; for example, the question regarding the boundaries of the proposed multi-basin unit subsumes the question whether a multi-basin unit should be established at all. The blurring of lines between evidentiary questions and policy questions may induce the State Engineer to make administrative decisions as a result of the Hearing without input from the promised "later proceedings." For example, while there may have been at least a lukewarm consensus among the stakeholders participating in the Hearing that conjunctive management of the five-basin unit was justified, it would be a mistake for the State Engineer to conclude there was any level of consensus as to what "conjunctive management" might mean. Coupled with the lack of a clear scientific record, it is doubtful that any attempt at management or policy decisions would be supportable or justified.

Although the Hearing Officer signaled the State Engineer's intention to issue a "decision" within 240 days (Tr. at 74:15), it is not at all clear what questions he will decide and what the "later proceedings" will encompass, what form they will take, and when they will occur. It may be more logical and defensible for the State Engineer to seek additional input from stakeholders regarding the issues of policy and management of the administrative unit, extending a decision deadline until such input is received. This could take the form of written submissions and/or additional hearings. Significant outstanding management and policy questions that must be addressed for the LWRFS include the following:

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- Will the State Engineer establish a "critical management area" pursuant to NRS 534.110? If so, will he develop a groundwater management plan or defer to the stakeholders to develop one?
- Does Nevada law give the State Engineer authority to designate such a management area that encompasses more than one basin?
- Does Nevada law allow the State Engineer to conjunctively manage multiple hydrographic basins in a manner that modifies the relative priority of water rights due to the administrative consolidation of basins?
- Should "safe-yield" discrete management areas be established within the proposed administrative unit?
- Do water rights holders enjoy a "property right" in the relative priority of their water rights such that impairing that right may constitute a "taking"?
- Should unexercised (or only sporadically exercised) senior water rights take precedence over certificated junior rights, particularly where these junior rights are in continuous use to support economically significant enterprises?
- What are the State Engineer's responsibilities with respect to habitat or species protection under the federal Endangered Species Act?
- Can States compel quantification of federal reserved rights by a date certain?
- Should the State Engineer approach the legislature to seek different or additional management tools or authority?

This is not an exhaustive list and the complexity of these questions suggests the State Engineer should seek input from stakeholders on these questions as part of the Interim Order procedures.

C. Recommendations

Data gaps that became apparent during the Hearing include a lack of monitoring wells in critical areas of the LWRFS unit. For example, there are no monitoring wells in the Hidden Valley hydrographic basin. Monitoring in this area would help clarify flow paths from the western and southern parts of Coyote Spring Valley. There is a lack of data from the southern and eastern parts of Garnet Valley, where understanding possible inflow from Las Vegas Valley

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or possible outflow to the east are critical questions. In addition to installation of a monitoring well in Hidden Valley, we recommend the installation of three additional monitoring wells in the carbonate aquifer to further understand the relationship of pumping in Garnet Valley relative to flow in the Muddy Springs Area, the effects of the Dry Lake Thrust Fault on carbonate aquifer groundwater flow, and the potential groundwater inflow from the Las Vegas Basin to the south. General well locations should include the following:

- One well situated between the Garnet Valley pumping area and the Muddy Springs Area. This well would monitor the effects of pumping in the Garnet Valley relative to the Muddy Springs flow and elevations in monitor well EH-4.
- Another monitor well should be positioned on the east side of the Dry Lake Thrust Fault. This would aid in the understanding of the lateral relationship and potential flow boundaries associated with the Dry Lake Thrust Fault.
- Finally, one well should be located at the southernmost extent of Garnet Valley Basin on the boundary between Garnet Valley (216) and Las Vegas Valley (212). This well should provide additional information associated with the potentiometric surface and potential flow between the two basins.

The question as to the source of water for Big Muddy Spring should be further explored given the importance of better understanding the resources for senior Muddy River water rights.

More attention should be paid to standardizing existing monitoring efforts, particularly given the small variations in water levels within the unit. Changes in barometric pressure, variations in relative salinity, and different measuring methods can all contribute to distortions in the data that may have a disproportionate effect on management decisions.

In addition, as recommended by some participants, more time should be allowed – several years – to observe the actual behavior of the LWRFS at current levels of pumping and determine whether the system is approaching equilibrium.

It would be helpful for the State Engineer to issue another procedural order following receipt of the closing reports to clarify any future proceedings to receive input on policy and management of the LWRFS, and the timing and nature of anticipated decisions.

The State Engineer should also consider approaching the legislature for additional appropriations to assist in rectifying the problems caused by apparent over-appropriation of

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water rights within areas of the LWRFS. Funds should be requested for installation of additional monitoring wells and systematic monitoring activities, purchase and retirement of water rights (particularly where beneficial to the Moapa dace) and possible artificial supplements to Warm Springs west flows. In addition, the Division of Water Resources will likely need additional personnel; if the Division establishes a "critical management area" planning efforts could encompass many of the activities discussed above. Further, it is foreseeable that the Division will see a significant increase in the number of change applications it will need to process as water rights holders in the LWRFS seek to convert priorities and change pumping locations. These applications should be considered on an expedited basis in order to help create some certainty for water users exploring these remedies. Finally, while the legislature has provided the Division with authority for conjunctive management of water resources, it seems apparent that the Division needs more depth and better tools to allow it to better understand the hydrology of these complex multi-sourced systems and to more reasonably craft management strategies that do not rely on blunt application of newly-relative priority dates in the LWRFS.

DATED: December 2, 2019. McDONALD CARANO LLP

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Pursuant to NRCP 5(b), I hereby certify that I am an employee of McDONALD CARANO LLP, and that on December 2, 2019, I served the foregoing CLOSING ARGUMENTS OF GEORGIA PACIFIC CORPORATION and REPUBLIC ENVIRONMENTAL TECHNOLOGIES via direct email to the addresses indicated below:

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STATE ENGINEERS OFFICE

IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219).
_______________________________________/

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WRITTEN CLOSING STATEMENT OF

LINCOLN COUNTY WATER DISTRICT

AND

VIDLER WATER COMPANY, INC.

LINCOLN COUNTY WATER DISTRICT ("LINCOLN COUNTY") and VIDLER WATER COMPANY, INC. ("VIDLER"), by and through their attorneys, DYLAN V. FREHNER, ESQ. the LINCOLN COUNTY DISTRICT ATTORNEY and KAREN A. PETERSON, ESQ. of the law firm of ALLISON MacKENZIE, LTD., in accordance with the State Engineer's order at the conclusion of the hearing on October 4, 2019, respectfully provide their written closing statement.

1. **INTRODUCTION**

A. Interim Order #1303

In Interim Order (IO) #1303, the Nevada State Engineer (NSE) requested reports be submitted to address: (a) the geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System (LWRFS), (b) an analysis regarding aquifer recovery since the completion of the Order 1169 aquifer test, (c) the long-term annual quantity of groundwater that may be pumped from the LWRFS and how that would affect the hydrology of the Muddy River Springs Area (MRSA), (d) the effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River, and (e) any other matter believed to be relevant to the State Engineer's analysis. [NSE Ex. 1 Order 1303, at 13-14]. The NSE will make a determination on the above five matters using the best available science. *Id.* at 10.

B. Scope Of This Proceeding

At the prehearing conference held on August 8, 2019, the following statements were made by the NSE's office regarding the scope of this proceeding:

- "...this is a threshold reporting aspect, that this is part of a multi-tiered process in terms of determining the appropriate management strategy to the Lower White River Flow System." [8-08-19 Tr. 10:8-10 (Prehearing Conference)].
- The four specific matters listed in IO #1303 are threshold matters; larger substantive policy determinations are not part of this proceeding. [8-08-19 Tr. 10:16-19 (Prehearing Conference)].
- This part of the proceeding is based on scientific analysis and data analysis; [8-08-19 Tr. 11:1-2 (Prehearing Conference)].
- Future policy considerations which are not encompassed within the issues specifically identified in IO #1303 will not be considered during these proceedings; the NSE anticipates the order

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from this proceeding will address the four specific matters identified in Order 1303. [8-08-19 Tr. 11:8-22 (Prehearing Conference)].

- "And the purpose of the hearing is not to resolve or address allegations of conflict between groundwater pumping within the LWRFS and Muddy River decreed rights. That is not the purpose of this hearing and that's not what we are going to be deciding at this point in time…." [8-08-19 Tr. 12:6-10 (Prehearing Conference)].

- The State Engineer is looking for the following information, however it is not an exhaustive list: 1. How conclusions are supported by the available data; 2. How those conclusions differ from positions the NSE's office has previously taken; 3. Whether there are new interpretations of data based upon what has been observed since the conclusion of the Order 1169 aquifer test; 4. Whether conclusions drawn are sufficiently supported by the available data and cited to data; 5. Whether the conclusions and data and evidence relied upon in rendering those conclusions are independently reproducible and verifiable; 6. If NSE's office can't go through and reproduce the data relied upon in terms of making conclusions, it will be difficult for NSE to substantiate those findings; and 7. Commonalities and conclusions amongst the various participants. [8-08-19 Tr. 12:20-13:17 (Prehearing Conference)]. Parties were directed to distill their reports and conclusions into a succinct presentation of the salient opinions and direct the NSE to the data and other information supporting those conclusions. [8-08-19 Tr. 8:10-13; 14:10-15 (Prehearing Conference)].

2. LINCOLN COUNTY WATER DISTRICT and VIDLER WATER COMPANY (LINCOLN/VIDLER)

A. Reasons Why Lincoln/Vidler Participated In This Hearing

Lincoln/Vidler have existing groundwater rights (Permit Nos. 72220, 72221, 82727 and 82728) and the following pending applications Nos. 74147, 74148, 74149, and 74150 in Kane Springs Valley (KSV). [LC-V_001, July 3, 2019 Report Submittal at 2-1]. Because KSV is adjacent to the defined LWRFS administrative unit and groundwater flows from KSV into Coyote Spring Valley (CSV), some participants want to include KSV as part of the LWRFS administrative unit. Lincoln/Vidler oppose including KSV in the LWRFS administrative unit or that KSV be part of any next management phase in this proceeding. No participant provided any new evidence, data or information supporting a change in the NSE's past determinations to exclude KSV from the LWRFS.

B. Previous Determinations By The NSE Excluding Kane Springs Valley From The LWRFS

Every NSE has excluded KSV from the LWRFS since the issuance of Order No. 1169 in 2002 requiring the Order 1169 aquifer test through the issuance of Order 1169A in 2012 declaring the completion of the aquifer test. [NSE Ex. 2 Order 1169A, NSE Ex. 3 Order 1169]. Order 1169A specifically references that Southern Nevada Water Authority (SNWA) was ordered to submit model simulations results showing the predicted effects of pumping both existing rights and current applications in numerous basins, including Kane Springs Valley. [NSE Ex. 2 at 2]. Based upon the information provided pursuant to the pump test, the NSE determined SNWA was not required to update Exhibit No. 54, its model, from the July 2001 hearing. Kane Springs Valley was not included in Order 1169A. Further, the 2006 Memorandum of Agreement (MOA) does not include KSV water right holders. [NSE Ex. 236 2006 MOA]. The NSE affirmed that KSV should not be included in the Order 1169 proceedings in Ruling # 5712 issued in 2007.

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In Ruling #5712, the NSE made several findings about KSV, the effects of pumping from KSV on springs in the LWRFS, and further south of the LWRFS. The NSE ruled on the issue of whether the appropriation of groundwater from KSV would affect the MRSA, or for that matter other surface water sources (springs) of interest. Ruling #5712 stated:

> "The State Engineer finds there is not substantial evidence that the appropriation of the limited quantity [of water] being granted under this ruling will likely impair the flow at Muddy River Springs, Rogers Springs or Blue Point Springs."

[NSE Ex 12 Ruling 5712 at 20]. No party appealed the NSE's determinations in Ruling #5712, including National Park Service (NPS), a protestant to Lincoln/Vidler's applications. [LC-V 001, July 3, 2019 Report Submittal at 2-2].

The NSE's determination that there would be no impairment from pumping in KSV was affirmed seven years later in NSE Ruling #6254 issued in 2014. The NSE concluded and found that where no significant impact would be felt for hundreds of years, the upgradient groundwater could be appropriated. KSV groundwater can be developed because there will be no significant impact, if any, from appropriation of the groundwater for hundreds of years. [NSE Ex 14 Ruling 6254 at 23].

The NSE spoke explicitly to the difference between KSV and the Order 1169 groundwater basins further in Ruling #5712 by stating:

> "The State Engineer finds the evidence indicates a strong hydrologic connection between Kane Springs Valley and Coyote Spring Valley, specifically, that ground water flows from Kane Springs Valley into Coyote Spring Valley. However, carbonate water levels near the boundary between Kane Springs Valley and Coyote Spring Valley are approximately 1,875 feet in elevation, and in southern Coyote Spring Valley and throughout most of the other basins covered under Order No. 1169, carbonate-rock aquifer water levels are mostly between 1,800 feet and 1,825 feet. This marked difference in head supports the probability of a low-permeability structure or change in lithology between Kane Springs Valley and the southern part of Coyote Spring Valley. The State Engineer finds there is not substantial evidence that the appropriation of a limited quantity of water in Kane Springs Valley Hydrographic Basin will have any measurable impact on Muddy River Springs that warrants the inclusion of Kane Springs Valley in Order No. 1169. Therefore, the State Engineer denies the request to hold these applications in abeyance and include Kane Spring Valley within the provision of Order No. 1169."

[NSE Ex 12 Ruling 5712 at 21]. That finding was not challenged by any of the Order No. 1169 participants, including SNWA or Las Vegas Valley Water District (LVVWD). Subsequently, neither SNWA or LVVWD provided any information or data in their October 5, 2018 letter indicating that appropriation of water in KSV will impact any of the springs in the MRSA. [LC-V 001, July 3, 2019 Report Submittal, pages 2-3 and 2-4].

3. KANE SPRINGS VALLEY SHOULD NOT BE INCLUDED IN THE PROPOSED LOWER WHITE RIVER FLOW SYSTEM ADMINISTRATIVE UNIT

Lincoln/Vidler provided the NSE with extensive evidence, testimony and analysis of new and existing data that supports why KSV should not be included in the proposed LWRFS administrative unit. These data include:

- Existing water level data in the form of hydrographs for wells throughout the LWRFS,
- Climate effects and its impacts on groundwater elevations in the LWRFS,
- Existing historical geochemical data, and
- New geophysical data collected in northern CSV combined with existing geophysical data collected in KSV.

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All of the new and existing data provide a better understanding of the groundwater flow system in KSV. [LC-V 001, July 3, 2019 Report Submittal at 2-1].

A. No Response in CSVM-1 and KMV-1 Groundwater Elevation Data To Order 1169 Pumping

The groundwater elevations in monitor wells CSVM-4 and KMW-1 were not responsive to the Order 1169 Aquifer Test, but were responsive to local climatic events. [LC-V 001, July 3, 2019 Report Submittal at 3-3 and 3-4]. There was no response in well CSVM-4 to the cessation in MX-5 pumping during the Order 1169 Aquifer Test - - not once but twice. [9-30-19 Tr. 1298:2-5, 1298:7-8 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 7]. The MX-5 well went through two periods of time where it stopped pumping. [9-30-19 Tr. 1298:4-5 (Umstot Testimony)]. Further, "...if you compare the pumping signal to the hydrographs, you don't see any response to when MX-5 well stopped pumping." [9-30-19 Tr. 1298:2-4 (Umstot Testimony)]. There was no recovery signal seen and the water levels in well CSVM-4 continued to rise after the completion of the MX-5 pumping test. [9-30-19 Tr. 1298:9-17 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 7]. Dr. Johnson testified "...that mid-test recovery is what is diagnostic and it's absent here." referring to wells in the southern [LWRFS] flow field. [9-26-19 Tr. 743:5-15 (Johnson Testimony)]. Dr. Johnson also stated that "...there's no mid-test recovery from that 2012, 5-month shutdown." referring to both monitor wells KMW-1 and CSVM-4. [9-26-19 Tr. 743:16-19 (Johnson Testimony)].

Referring to the hydrograph for monitor well CSVM-4: "But it's very clear during the period of recovery that you don't have a response to the MX-5 [cessation of pumping]. So I think that's very diagnostic that this well is not connected to pumping of the MX-5 location." [9-30-19 Tr. 1298:20-24 (Umstot Testimony)]. For the monitor well located at the mouth of KSV, KMW-1 "You don't see any recovery responses in KMW-1.... But you can definitely see because a lack of recovery signal that the MX-5 is not connected to the KMW-1 well location." [0-30-19 Tr. 1299:11, 1299:13-15 (Umstot Testimony)]. Furthermore, regarding the seasonal pumping patterns, Mr. Umstot testified "You don't see that seasonal pattern from the carbonate wells pumping before the MX-5 test began." [9-30-19 Tr. 1301:1-3 (Umstot Testimony)].

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In comparison, there is a difference in response in the water levels in several other wells after the MX-5 well was shut off at the end of the Order 1169 Aquifer Test, meaning that these wells show a recovery response or an identifiable rise in water levels at the end of the MX-5 test. [9-30-19 Tr. 1300:5-22 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slides 11, 12, and 13]. Several wells in the vicinity of MX-5, the pumping well, showed a recovery response by rising water levels in response to the end of the Order 1169 Aquifer Test. Other wells further to the north in CSV showed no response to pumping in the "...vicinity of CE-VF-1 or CE-VF-2 and areas to the north." [9-30-19 Tr. 1301:24-1302:10 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 15].

In summary Mr. Umstot concluded "...there's too much error in the data to be able to discern drawdown response from the MX-5 test [represented by water level data from well MX-4] and to determine that there's a hydraulic connection to the southern carbonate pumping in the LWRFS to the location of KMW-1 to CSVM-4 and that climate conditions would explain the general trends, the downward trends, that you do see in the groundwater elevations. So, I don't see any evidence, hydraulic connection, to southern LWRFS." [9-30-19 Tr. 1318:7-15 (Umstot Testimony)].

B. Climate Affects And Impact On Groundwater Elevations In The LWRFS

During the Order 1169 Aquifer Test, southern Nevada was experiencing drought conditions as documented by the National Oceanic and Atmospheric Administration (NOAA), publisher of the Palmer drought data. [9-30-19 Tr. 1293:6-13 (Umstot Testimony)]. Based on this data "There was a general increase in drought conditions that would be expected to cause the decline in groundwater elevation [s in wells in CSV].[1] So, if you look at the...one-year period, before the MX-5 pumping began, there were drought conditions about 42 percent of the time. And if you look at the period when the 1169 aquifer test took place and the additional time the MX-5 pumped beyond that into April 2013, drought occurred 82 percent of the time. So you had drought conditions occurring twice as often during the test as you had occurring in the year just before the test started." [9-30-19 Tr. 1295:5-16 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 4]. This was also noted by the City of North Las Vegas "...[the] Climate Drought Severity Index for climate zone three, which is to the north, the northern part of the

[1] The text in brackets within quoted testimony represents explanatory text that was added to make the testimony clearer or to insert a word that was either left out or misspelled by the court reporter.

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White River Flow System that I see in this record that you have a dominance of negative values. So moving into the dryer regimes for the last two decades as contrasted to the decade prior." [10-01-19 Tr. 1451:13-19 (Smith Testimony); CNLV Smith Demonstrative Slide 26].

Just as drought conditions affected regional groundwater elevations, intense precipitation events that occurred in the LWRFS and surrounding groundwater basins affected groundwater levels in the opposite way. Mr. Umstot noted "You also have in 2005 a very wet period. Precipitation that occurred in 2005 water year is probably the first or second highest precipitation in the hundred years that occurred in this area. So you had a very large recharge pulse to happen in 2005. Smaller recharge pulses in 2010. But overall a general decline in groundwater elevations that occurred to this generally increasing level of drought." [9-30-19 Tr. 1295:17-24 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 4;]. Mr. Umstot testified further "But, again, you see a similar effect where there's wet conditions just before the MX-5 pumping began and then increasing the level of drought as you go in to the period of time the MX-5 was pumping." [9-30-19 Tr. 1296:7-11 (Umstot Testimony)].

Both the drought and the recharge that occur in the LWRFS and surrounding basins have a definite affect on the groundwater hydrographs for wells in these areas. Mr. Umstot further testified that "…what you're going to see in the groundwater elevations, they're going to see a combination of these different processes, depending on where the recharge in the system is sourced. If the recharge is sourced from further away, it's going to be a more ~~dense~~ [dampened] response that's going to reach the well. If it is recharge that is coming from an arroyo that's right next to the well, then that's going to be a quicker response for the well." [9-30-19 Tr. 1294:10-17 (Umstot Testimony)].

The overall effect of these hydrologic processes, both the occurrence of drought and the intense precipitation events, cause the variations that are seen in the hydrographs of these wells [in the LWRFS]. [9-30-19 Tr. 1294:18-23 (Umstot Testimony)].

C. <u>Groundwater Elevations In The Lower White River Flow System</u>

The water level elevations in monitor well KMW-1 are 55 to 60 feet higher than the water level elevations of wells in the current LWRFS basins. The carbonate wells within the LWRFS are all connected as demonstrated by the water level response from hydrographs of these wells in the LWRFS. [LC-V 001, July 3, 2019 Report Submittal at 3-2]. During the administrative hearing for groundwater

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rights in KSV in 2006, Lincoln/Vidler identified the differences in hydraulic heads between wells drilled in the LWRFS versus wells drilled in KSV and northern CSV. A "break," or local increase, in the regional hydraulic gradient was shown between KSV/northern CSV and the LWRFS administrative unit groundwater basins. Groundwater elevation data from wells completed in the Regional Deep Carbonate Aquifer (RDCA) in southern CSV are remarkably flat across the LWRFS groundwater basins, whereas water levels in KSV/northern CSV have a steeper gradient.

In summary, a key finding is that groundwater levels in the RDCA wells are very similar in elevation (pre-pumping or minimal pumping of Order 1169 groundwater basins) everywhere downgradient of the Kane Springs Wash Fault Zone, using the most current water level measurements. Since northern CSV is downgradient of KSV, the difference in water levels indicates that KSV is not directly connected to the LWRFS. Just as in the 2006 testimony before the NSE and after several thousands of acre-feet pumped from wells in the LWRFS, the same groundwater elevation pattern persists. [LC-V 001, July 3, 2019 Report Submittal at 3-2].

Also notable is that when all the hydrographs from wells in the LWRFS are plotted at the same scale groundwater pumping from groundwater basins in the LWRFS has very little impact on water levels across these groundwater basins illustrating how exceptionally stable water levels in this aquifer system are. [LC-V 001, July 3, 2019 Report Submittal at Figure 3-7].

Bushner (2018) noted another significant difference in the response in groundwater levels from wells in southern CSV compared to the response of water levels in wells in northern CSV and KSV by stating:

> "…monitor wells in the southern portion of CSV responded immediately to the start and end of the [Order No. 1169] aquifer test. However, this is not what occurred in CSVM-4 … which reflects a downward trend even after the end of the test. This is not reflective of recovery after an aquifer test especially given the significantly high hydraulic conductivities that exist south of the Kane Springs Wash Fault."

[LC-V 001, July 3, 2019 Report Submittal at 3-2].

Given all these data and information, the NSE does have reason to include the already identified basins in the LWRFS as a single "unit" based on the remarkably consistent groundwater levels among wells completed in the RDCA. The NSE clearly noted this in Ruling #6254:

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> "Changes in the potentiometric surface in any one of these basins [referring to the Order No. 1169 (NSE 2002) groundwater basins] occur in lockstep directly affecting the other basins, further demonstrating the regional nature of the aquifer across these basins."

[NSE Ex 14 Ruling 6254 at 12].

Although Lincoln/Vidler concur with the effective administration of these basins collectively based on the hydrogeology, we disagree that the effects are all the same across the entire LWRFS administrative unit. In particular, northern CSV should be excluded from the LWRFS administrative unit as was done for most of the Black Mountains Area Hydrographic Basin. KSV should remain excluded from the proposed LWRFS administrative unit. [LC-V 001, July 3, 2019 Report Submittal at 3-3].

There was much testimony and reliance on water levels from monitor well CSVM-4, however SNWA had previously identified issues with measurements collected from this well as documented in its Order 1169 Report: "CSVM-4 may be showing a slight response with December 2012 water levels approximately 1 ft lower than September 2010 water levels, but the transducer in CSVM-4 had a high failure rate due to the high water temperature in the well, so fluctuations of a foot or less should not be used to infer an absolute response." [NSE Ex. 245 SNWA Order 1169 and 1169A Report dated June 2013 at 36]. SNWA witness Andrew Burns responded to questioning about this: Q. "And has anybody that you've heard testify earlier this week indicated in any of their hydrographs that they've accounted for this transducer error failure of a foot or so?" A. "Not that I heard." Q. "All right. And the drawdowns that were – or the impacts, I guess, or the effects that everybody's been talking about this week with regard to CSVM-4 are in that one-foot range; aren't they?" A. "Yes." [9-27-19 Tr. 978:2-10 (Burns Testimony)].

D. Geochemistry Data Shows KSV Water Is Not Similar To MRSA Water

On behalf of Lincoln/Vidler, Mr. Butler provided extensive testimony on a mixing model that used all of the geochemistry data from both monitor well KMW-1 and CSVM-4. This data shows that the groundwater from these wells "…do compare…[and] that they are very similar." [9-30-19 Tr. 1282:20-22 (Butler Testimony); LC-V Butler Demonstrative Exhibit Slide 4; LC-V 001, July 3, 2019 Report Submittal, Appendix C]. Mr. Butler further demonstrated from the available geochemistry data using a geochemical mixing model and a piper diagram that "KPW-1 and CSVM-4 appear to be unique

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and not a significant component of groundwater in central CSV or MRSA." [LC-V Butler Demonstrative Exhibit Page 4, Mixing Model]. Also Mr. Butler testified: "Piper Diagram suggest KSV groundwater is NOT a significant component of recharge to the MRSA." [LC-V Butler Demonstrative Exhibit Page 5, Piper Diagram]. Mr. Butler also testified that "In the Kane Springs and the CSVM-4 are chemically unique and do not appear on any of those mixing relationships. That would indicate that they are not a part of that mixing relationship. Not likely a significant component of water to the MRSA." [9-30-19 Tr. 1284:17-21 (Butler Testimony)].

Using the general chemistry data analyses that includes Total Dissolved Solids as represented by a Durov Diagram "...suggest that Kane Valley [groundwater] is not a significant component of water entering the MRSA (sic) or is mixing with it." [9-30-19 Tr. 1285:13-15 (Butler Testimony); LC-V Butler Demonstrative Exhibit Page 6, Durov Diagram]. Furthermore, KSV groundwater is not represented by samples from Blue Point and Rogers Springs noting that "If we were to plot them, they would plot about right here way off the graph." [9-30-19 Tr. 1286:1-2 (Butler Testimony); LC-V Butler Demonstrative Exhibit Page 6, Durov Diagram].

The Percent Modern Carbon (pmc) values indicate groundwater from KSV is older in age than the spring water in the MRSA, meaning that "...the groundwater would have to get younger, not older, as it flowed along the groundwater flow path." Suggesting "...that Kane Springs Valley is not a significant component of water to the MRSA...." [9-30-19 Tr. 1286:20-22 (Butler Testimony)].

The geochemical findings taken collectively "...suggests that the MRSA is not dominated by Kane [ground]water but it's more likely dominated by water from central CSV or the Lower Meadow Valley Wash area." [9-30-19 Tr. 1290:20-23 (Butler Testimony)].

Cross examination of Mr. Butler by Mr. Berley of the Moapa Band of Paiutes (MBOP) provided the following exchange: "Q. And you saw that the chemistry indicated that the carbonate aquifer water in Kane Springs was distinct from what was going on closer to the Muddy River Springs area; is that correct? A. That's correct. Q. Where do you see that the water in Kane Springs is going, if anywhere? A. '...It is clear there is a chemical link between...CSVM-4 in the northeastern Coyote Valley and Kane Springs. I don't see it anywhere else. I don't see it – That could mean it's so greatly attenuated you don't see it elsewhere or has some alternate flow path that I'm not aware of.'" [9-30-19 Tr. 1333:6-12,

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1333:15-20 (Butler Testimony)]. Further cross examination of Mr. Butler by Mr. Berley of the MBOP highlights the use of the geochemical data: Q. "You didn't see any other place other than – You didn't look to see where this water might go if it didn't go to the Muddy Springs -- A. I was specifically looking at chemical signatures. I wasn't looking at groundwater. I wasn't looking at basin deposits. I wasn't looking at structure. I wasn't looking at groundwater flow paths particularly, other than just a generalized gradient in the Kane Springs Valley. And the chemical signatures are quite different. I mean, it wasn't – it's not like we were just looking at one particular chemical signature. We're looking at soluble chemistry, isotope data, everything pointing to the same conclusion." [9-30-19 Tr. 1334:3-15 (Butler Testimony)].

E. <u>New Geophysical Data Confirms the Boundary Fault Between KSV and CSV</u>

Lincoln/Vidler collected new geophysical data in northern CSV to compliment the existing geophysical data that Lincoln/Vidler has in KSV. [LC-V 001, July 3, 2019 Report Submittal (Section 4)]. The importance and usefulness of this data is that it provides insight into the geologic structures that are covered by alluvium, i.e., "hidden" and not identified by surficial geologic mapping. [9-23-19 Tr. 34:22-35:1 (Carlson Testimony)]. This was also recognized by the NPS's witness Dr. Richard Waddell: "I like CSAMT. I think that is does a very good job of picking up changes in electrical resistivity which can provide clues as to not only the geology but the hydrology." [9-25-19 Tr. 532:19-22 (Waddell Testimony)].

Although the geophysics alone cannot tell you what the hydrologic properties are of the material that has been surveyed, its usefulness cannot be understated when trying to determine geologic structures near surface and at depth. The geophysical data in combination with the known geologic data, the known aquifer property data and the known hydraulic property data provide a very robust picture of the hydrogeologic system in KSV and northern CSV. [LC-V 001, July 3, 2019 Report Submittal (Section 6)].

The Northern LWRFS Boundary Fault (NB Fault) is identified by the change in material types, i.e., resistivity, between geophysical lines 10 and 11 that were conducted for Lincoln/Vidler. The new geophysical data collected in northern CSV showed "...high resistivity ground..." referring to all of Line 10. This is interpreted to be "...almost entirely carbonate in the subsurface." [9-30-19 Tr. 1266:12-

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21 (Carlson Testimony); LC-V 012 Carlson Power Point Presentation Slide 12]. Line 10 crosses northern CSV just south of the mouth of KSV. Line 11 however, shows "...primarily moderately low resistivities...that can be interpreted as basin fill." [9-30-19 Tr. 1267:8-13 (Carlson Testimony); LC-V 012 Carlson Power Point Presentation Slide 14]. The resistivity results also provide "good ground truth" where the geophysics crew went up on the carbonate outcrop and the resultant plot is solid blue, representing carbonate rocks as shown on Line 11. [9-30-19 Tr. 1267:14-18 (Carlson Testimony); LC-V 012 Carlson Power Point Presentation Slide 14].

Mr. Carlson further testified: "It has to be a major fault and it has to -- Since the carbonates and the higher resistivity material on line ten are virtually right up to the surface, almost, but on line 11 they're down at the depth of 2500 feet, that means that that fault has to be a big step downward of 2500 feet some place in between line ten and 11. So very significant fault." [9-30-19 Tr. 1272:4-9 (Carlson Testimony)].

To further substantiate the NB Fault, Mr. Carlson reviewed and compared the geophysical data collected by Lincoln/Vidler to the U.S. Geological Survey (USGS) gravity data that covers portions of the LWRFS documented in Open File Report 00-420. Mr. Carlson testified: "But I wish we had seen the USGS report before we laid out our line. Similar to Coyote Springs, we would have laid things out a little differently, because it's unusual when we get two different data sets from two different groups that are measuring two different physical properties of the ground and you're seeing the same surprising unexpected thing. They see this high density change in low density over a very short distance. We see high resistivity change to low resistivity over a very short distance. And the only thing I can come up with is a very significant fault in between lines ten and 11." [9-30-19 Tr. 1278:17-1279:4 (Carlson Testimony); LC-V 012 Carlson Power Point Presentation Slides 30 and 31]. This is supported by testimony from Coyote Springs Investment's witness Stephen Reich: "My understanding – or my review of the data indicates that there's a series of en echelon faults that help to create a – some type of a hydraulic barrier or a barrier to groundwater flow in this area that isolates the Kane Springs Valley area from the – from the Coyote Spring Valley." [9-23-19 Tr. 160:5-9 (Reich Testimony)]. And also supported by the NPS: "And the two lines that trend from southeast to northwest have a different

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response. They show different geology. That was their interpretation. That's my interpretation." [9-25-19 Tr. 537:5-8 (Waddell Testimony)].

The existence of this structure, appropriately named the Northern LWRFS Boundary Fault causes groundwater flowing from KSV into CSV to be greatly retarded, as demonstrated by the significant change in heads. This is due both to the change in lithology and the structure. The heads in wells in the LWRFS show responses that are similar to each other but not to wells CSVM-4 and KMW-1. [9-30-19 Tr. 1318:7-15 (Umstot testimony)]. Nevada Energy (NV Energy) witness Richard Felling agreed: "And I agree that that evidence is fairly compelling that there is a range front structure there." [10-4-19 Tr. 1760:13-14 (Felling Testimony)].

The combined existing and new geophysical data collected in and around KSV allows the recognition of significant geologic structures in southern KSV and northern CSV that explain why groundwater level elevations are different in KSV and northern CSV than in the LWRFS groundwater basins to the south. [9-30-19 Tr. 1300:23-1301:7 (Umstot Testimony)]. The explanation for this is supported by the NPS: "So we're basically in agreement with CSI that there's faulting in this area and that those faults may impede flow through Kane Spring Valley into Coyote Spring Valley." [9-25-19 Tr. 540:7-10 (Waddell Testimony)]. NPS also agreed that pumping from KSV would not impact the Muddy River Springs: "…if you could test it by pumping only Kane Spring[s] Valley and not other wells, then you would detect that at Muddy River Springs. My opinion is that you wouldn't…." [9-25-19 Tr. 644:7-10 (Waddell Testimony)]. The geophysical data identified significant changes in resistivities between southern KSV and northern CSV. These changes are consistent and correlate well with the distribution of existing geochemistry and groundwater temperature data that can be used to identify different groundwater flow paths. The extensive faulting that occurs in southern KSV and northern CSV, explained by the interpretation of the geophysical data forms the basis for the continued exclusion of KSV from the LWRFS administrative basin. [LC-V 001, July 3, 2019 Report Submittal at 4-8 – 4-9]. Dr. Peter Mock summarized his testimony "…Kane Spring[s] Valley is outside of and distant from the Muddy River Springs Area." [09-30-19 Tr. 1321:23 - 1322:1 (Mock Testimony)] "So conjectures about Kane Springs Valley being an effective important place to manage and so as to protect

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the springs and associated surface flows of the Muddy River Springs area are erroneous." [09-30-19 Tr. 1322:23 – 1323:2 (Mock Testimony)].

4. UNSUBSTANTIATED THEORIES BASED ON FALSE PREMISES BY OTHER PARTICIPANTS

The regression analysis developed by SNWA, and supported by other participants, cannot be relied upon to determine hydraulic connections throughout the LWRFS. Also, the water level measurements that are used to create the hydrograph of monitor well CSVM-4 that are relied upon by SNWA and others for the regression analysis should not be used other than for a general trend analysis due to faulty measurements. SNWA relied on a correlation analyses to support hydraulic connection and then combined the correlation analysis with a linear regression to estimate drawdown [9-30-19 Tr. 1302:12-16 (Umstot Testimony)]. SNWA referenced a USGS report that does not support the use of linear regression to estimate water level drawdown from an aquifer test [9-30-19 Tr. 1302:24-1303:2 (Umstot Testimony)]. A regression of CSVM-5 (not connected to the MX-5 pumping region) and KMW-1 yielded a "...fairly high R-squared value of 0.68 and is similar to the type of regression that you get using between EH-4 and KMW-1...." This is deemed a "spurious correlation" and is not "...enough evidence to show hydraulic connection and it's not sufficient to be used to predict drawdowns from an aquifer test [9-30-19 Tr. 1303:8-18 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 17].

Mr. Umstot states further "And simply having correlation is not proof of causation. Causation is neither proved nor evaluated in a regression analysis." [9-30-19 Tr. 1303:19-21 (Umstot Testimony)]. To this point, a linear regression analysis done between MX-4 had a higher correlation to a well in Cave Valley than between MX-4 and CSVM-4, leading to the conclusion that "...this is just not sufficient evidence to support hydraulic connection or to estimate impacts from MX-5 pumping at the CSVM-4 location." [9-30-19 Tr. 1303:22-1304:5 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 18]. Even SNWA's witness Drici doesn't believe its regressions analysis, i.e., it's a forgone conclusion: "as for the Muddy River Springs area, I do not just go by the statistical results. I have to use facts and like what I know. Does anybody think that production from the carbonate aquifer in the MRSA does not affect EH-3 water levels. So this value is a little bit higher than the .05, but I still believe and I know

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that production in the Muddy River Springs area does affect water levels in EH-4 because they're in the same basin." [9-27-19 Tr. 984:21-985:5 (Drici Testimony)].

SNWA provided no evidence that a regression analysis of water level data determines the interconnectedness of an aquifer system. SNWA provided no peer reviewed or other scientific basis or reference that uses a regression analysis comparing water levels to infer connectivity or causation. The response SNWA witness Burns provided to support this type of statistical application to water level data was convoluted and confusing as illustrated in the following Questions and Answers: "Q. Right. But the concept that you can do a regression analysis and compare water levels, and therefore, conclude that there's some kind of connectivity between them, where – who – what scientific basis is there for that principle? A. Well, first, I think there's a professional judgment. We're trained, as observers of data, to understand what these responses are, what these – what factors would contribute to these responses. And it's not difficult, you don't maybe need to even be a hydrologist to see that these time series plots behaved in a same way and in a linear fashion, as Ms. Drici described, and that's what we tested with the analysis. Q. Okay. So it's your professional judgment? A. I think it's more than that. I think it's a standard approach. Q. But can you give me a site? A. Well, not off the top of my head, but it's something professional hydrologists are trained to." [9-27-19 Tr. 981:21-982:16 (Burns Testimony)].

Others relied on the flawed and inappropriate regression analysis: Nevada Cogeneration Associates 1 and 2 (NCA) relied upon the SNWA regression analysis as stated in their testimony "We took SNWA's regression analysis. I reproduced it to make sure I could get the exact same results." [10-03-19 Tr. 1624:19-20 (Dixon Testimony)]. To further their support for inclusion of KSV in the LWRFS, NCA's expert witness Coache performed "…a direct visual comparison of hydrograph of CSVM-4 and KMW-1 wasn't[was] done. The visual comparison was done because at the time I could not locate the data to actually do the actual analysis." [10-03-19 Tr 1637:9-12 (Coache Testimony)]. Direct visual comparison of data is not a scientific method taught, practiced, or endorsed by the scientific community.

The linear regression exercise failed to account for the discrepancy in the water level elevations of well MX-4. The water levels in MX-4 are noted to be 1,820 or less during the MX-5 test, and then for the correlation analyses and linear regression analyses, they're all above 1,820, identified as a two (2) foot offset. [9-30-19 Tr. 1307:20-1308:9 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit

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Slide 24]. This means that "…if we're looking and trying to estimate a half foot of drawdown to CSVM-4 and there's errors in these data of one to two feet, the data themselves are not sufficient to be used to estimate the drawdown and the estimated impact at KWM-1 or CSVM-4." [9-30-19 Tr. 1308:9-13 (Umstot Testimony)].

Obviously, the water level elevation is off in well MX-4. The water level is much higher than the water level elevations in the wells surrounding MX-4, this higher water level in this well would indicate a source of recharge. [9-30-19 Tr. 1308:16-22 (Umstot Testimony)]. Therefore "…it may not be appropriate to use the MX-4 well for any kind of a correlation analysis or a linear regression prediction of drawdown." [9-30-19 Tr. 1309: 3-5 (Umstot Testimony)].

There are wells that show a distinct head difference as demonstrated by the hydrographs of wells CE-VF-2 and CSI-4. Using correlated water level data, the groundwater elevation in well CE-VF-2 was about 1,856, whereas the groundwater elevation of CSI-4 is about 1,822. "So there's a change in head here of over 30 feet over for this area a relatively short distance. And others have testified that this is more of a bathtub with fairly flat gradient. You wouldn't expect to see this much offset from these two locations that are only two miles apart." [9-30-19 Tr. 1310: 16-23 (Umstot Testimony); LC-V Umstot Demonstrative Exhibit Slide 27].

On cross examination by the City of North Las Vegas, Mr. Umstot testified: Q. "So my question is does an outcome from the linear regression analysis that all responses at EH-4 are from Garnet Valley make hydraulic sense? A. If you look at slide 22, which was accepted in to evidence from my presentation, I showed SNWA analysis. My opinion is not that Garnet Valley is the sole cause of fluctuations at EH-4. That does not make hydrologic sense. I think my point is that this whole analysis of linear regression as given by SNWA is not useful for any conclusions." [9-30-19 Tr. 1348:20 – 1349:5 (Umstot Testimony)].

5. POSITIONS OF OTHER PARTICIPANTS ON INCLUDING KANE SPRINGS VALLEY IN THE LOWER WHITE RIVER FLOW SYSTEM ADMINISTRATIVE UNIT

With regard to the proposed geographic boundary, a few participants proposed that KSV be included as part of the LWRFS. There was much testimony and evidence that KSV should not be

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included as part of the LWRFS or that the geographic boundaries remain the same as originally proposed by the NSE.

Colby Pellegrino, a witness for SNWA, testified that the boundaries of the LWRFS should not change: "So we make the recommendation that the boundaries should not change..." [9-27-19 Tr. 876:11-12 (Pellegrino Testimony)]. This was also stated by SNWA in its July 2019 report submittal: "The boundary of the LWRFS should be as defined by the NSE in Order 1303. The LWRFS is underlain by an interconnected distribution of carbonate rocks that constitute a laterally extensive and continuous aquifer extending beneath the basins and across the ranges. The data presented in Section 5.0 demonstrate that the aquifer responds similarly to changes in both groundwater production and recharge throughout the six basins composing the LWRFS. Observed trends are uniform across the system, with only slight variations in the magnitude of the responses. Drawdown responses to pumping stresses are small throughout the region; however, they are unequivocal and occur in very short time frames given the distances between the pumping centers and points of observation. This demonstrates the aquifer has a very high degree of hydraulic connection and should be treated as a single administrative unit." [SNWA EX 007, July 2019 Submittal Report, p. 82].

NCA's witness Robert Coache concurred with SNWA's position and testified: "Therefore, NCA supports SNWA's position that the current boundary of the Lower White River Flow System should stay the same pending the water management decisions in the next phase." [10-3-19 Tr. 1645:7-10 (Coache Testimony)].[2]

The Muddy Valley Irrigation District agreed with the NSE regarding the proposed boundary of the LWRFS administrative unit: "Q. And the Muddy Valley Irrigation Company did not disagree with the State Engineer's determination as set forth in Order 1303, did it? A. We did not." [10-3-19 Tr. 1698:2-5 (Robison Testimony)]. Likewise, testimony by the City of North Las Vegas was that the current boundary of the LWRFS should remain: "Again it's our opinion...that the boundaries as proposed for the Lower White River Flow System are sufficient, are adequate." [10-01-19 Tr. 1463:1-4 (Smith Testimony); CNLV Smith Demonstrative Exhibit Slide 32]. The United States Fish & Wildlife

[2] Lincoln/Vidler oppose including KSV in any phase of this proceeding including any future management phase.

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Service (FWS) witness also backed away from recommending KSV be included in the LWRFS. [9-24-19 Tr. 464:1-19 (Braumiller Testimony)].

Others relied on the flawed regression analysis and faulty water level measurements by SNWA to support inclusion of KSV in the LWRFS administrative unit. For example, Moapa Valley Water District (MVWD) believes that KSV should be included in the proposed LWRFS administrative unit. Testimony by MVWD witness Jay Lazarus: "So what we're looking at really is the summation of my testimony regarding geographic boundary of the LWRFS, and the water district proposes, and we believe we have sound science to back it up, that Kane Springs Valley basin should be included as part of a seven-basin super basin should be included as part of the administrative basin regulated by the Department of Water Resources State Engineer." [9-30-19 Tr. 1197:6-13 (Lazarus Testimony)]. However, Mr. Lazarus simply focused on the northern boundary and contrary to his testimony above brought no new "sound science," data, or analysis to the NSE in response to IO #1303: "Q. You just stated that your focus was on Kane Springs Valley with regards to the boundaries? A. Not the southern portions. Yes. Q. Just the northern portions? A. Correct. Q. Now, in your report – let's go back – you – you also stated that you didn't do any independent data gathering with regards to Kane Springs? A. This is correct. Q. So you pick and choose from other people's information and supplied that here today? A. Well given the limited budget we have, that's what we are allowed to work with, was what was out there. Q. And given the slides that you've presented today and gone over, those were not submitted in the report, correct? Those hydrographs that you referenced and the other data have not been supplied in the report? A. That's correct, but hydro—the hydrographs are out there in the public record, and we've taken, like I said, information from other reports. Yes, sir." [9-30-19 Tr. 1222:22-1223:18 (Lazarus Testimony)].

Similarly, the Center for Biologic Diversity's (CBD) witness testified that he simply did a qualitative analysis to determine the geographic boundary of the proposed LWRFS administrative unit: "Observation of the water levels in comparison to the carbonate pumping that occurred throughout Lower White River Flow System. Now, I am clearly qualitatively moving that removal of groundwater from the carbonate to the mouth of Kane Springs Valley and assuming – and at least making a leap of logic that indeed that would have a similar effect." [10-2-19 Tr. 1563:14-19 (Meyers Testimony)].

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Clearly what this shows is that the entities proposing that KSV be included in the LWRFS administrative unit provided no new data, analysis, or independently reproducible and verifiable information to support their position.

Other entities seemingly decided that KSV should be included, not based on what they recommended in their report, or based on any sound science that they independently conducted, but out of a revisionist view. NV Energy witness Rick Felling testified: "We put in our report that the State Engineer could manage Kane Springs Valley without including it in the Lower White River Flow System. There has been an abundance of very compelling evidence. And we now say that we should include Kane Springs Valley in the joint management area." [10-4-19 Tr. 1789:14-19 (Felling Testimony)]. No evidence was provided or cited to by Mr. Felling to support his change in position. Further, Mr. Felling did not change his other opinions in his rebuttal report "Those two basins have water levels that are significantly higher than the LWRFS carbonate aquifer and did not immediately respond during the Order 1169 aquifer test. If one were to add all basins whose groundwater flows into the LWRFS basins, then we would also need to add the entire White River Flow System as well as the Meadow Valley Flow System." [NVE Ex. 1 NV Energy Rebuttal Report at page 1]. Thus, according to NV Energy's own expert, if KSV is included in the LWRFS, then the entire White River Flow System as well as the Meadow Valley Flow System need to be added to this proceeding. Obviously, the NV Energy last minute change in position at the conclusion of the hearing was not well thought out.

6. BIOLOGICAL OPINION FOR KANE SPRINGS VALLEY

The FWS issued a biological opinion (BO) on October 29, 2008 for the KSV Groundwater Development Project in Lincoln County, Nevada [LC-V 002, August 16, 2019 Rebuttal Report Submittal at pages 16 and 17]. The finding on page 37 of the BO sums up the conclusion from the FWS on impacts to the MRSA, and on the Moapa Dace, of the proposed KSV Groundwater Development Project:

> *"After reviewing the current status of and environmental baseline for the Moapa dace, the effects of the project, and the cumulative effects, it is the Service's biological opinion that the action, as proposed and analyzed, is not likely to jeopardize the continued existence of the endangered Moapa dace. The project could contribute to groundwater level declines and spring flow reductions; however, implementation of the project's conservation actions will minimize these impacts."*

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Based on this BO, any reference that the FWS makes to the addition of KSV to the proposed administrative unit should be ignored as the FWS has already made a determination in this case. [LV-C 002 August 16, 2019 Rebuttal Report at Attachment A-2, p. 37]. The BO was signed by Robert D. Williams, Field Supervisor, who testified on behalf of SNWA. [9-30-19 Tr. 1138:10-23 (Williams Testimony)]. Mr. Williams was asked if "…the Kane Springs Valley Groundwater Development Project is not likely to jeopardize the continued existed of the endangered Moapa Dace." And Mr. Williams response was "Yes." [9-30-19 Tr. 1139:7-12 (Williams Testimony)]. Mr. Williams also testified the "…implementation of the [KSV Groundwater Development Project] project's conservation action will minimize any potential impacts." [9-30-19 Tr. 1139:13-16 (Williams Testimony)].

In addition to the BO, Lincoln/Vidler have a settlement agreement with the FWS for the withdrawal of their protests during the NSE's hearing on Lincoln/Vidler's groundwater applications in KSV. [LV-C 0016 Amended Stipulation]. Mr. Williams testified "…that the parties of the Kane Springs agreement and stipulation, the biological opinion, are clearly covered under the ESA." [9-30-19 Tr. 1140:9-11 (Williams Testimony)].

7. <u>CONCLUSION</u>

Kane Springs Valley should not be included in the proposed LWRFS administrative unit. The new geophysical data in northern CSV shows the existence of the Northern LWRFS Boundary Fault, that taken in context with the other existing data explains the difference in heads in wells in northern CSV and KSV compared to the rest of the LWRFS, as does the geochemistry. Just the mere statement that there was a response in water levels from wells CSVM-4 and KMW-1 to the Order 1169 Aquifer Test doesn't make it a fact. There is not a scientific evidence-based reason to include KSV in the proposed LWRFS administrative unit. On the contrary there are science-based data and analysis that support the continued exclusion of KSV from the proposed LWRFS administrative unit. The NSE must rely on the scientific data analysis that Lincoln/Vidler provided in testimony and exhibits and consider all of the scientific data provided and what that means.

Lincoln/Vidler request that Kane Springs Valley remain excluded from the proposed LWRFS administrative unit.

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CERTIFICATE OF SERVICE

I hereby certify that I am an employee of **ALLISON MacKENZIE, LTD.**, Attorneys at Law, and on this date, I caused the foregoing document to be served on the following via Hand Delivery and/or Electronic Transmission as follows:

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DATED this 3rd day of December, 2019.

/s/ Nancy Fontenot
NANCY FONTENOT

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IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA.	**CLOSING STATEMENT BY THE MOAPA BAND OF PAIUTE INDIANS FOR ORDER 1303 HEARING**

The State Engineer's factual findings must be supported by substantial evidence. *Revert v. Ray*, 95 Nev. 782, 786, 603 P.2d 262, 264 (1979). Substantial evidence is "that which a reasonable mind might accept as adequate to support a conclusion." *Bacher v. State Engineer*, 122 Nev. 1110, 1121, 146 P.3d 793, 800 (2006). Under Nev. Rev. Stat. § 533.024(c), the Legislature encourages the State Engineer "to consider the best available science in rendering decisions concerning the available surface and underground sources of water in Nevada." Nevada law doesn't define "best available science." Under federal law, "best available science" does not mean the best scientific data possible. *San Luis & Delta-Mendota Water Auth. v. Jewell*, 747 F.3d 581, 602 (9th Cir. 2014). Even "credible anecdotal evidence" can "represent[] the best scientific . . . data available." *Nw. Ecosystem Alliance v. FWS*, 475 F.3d 1136, 1147 (9th Cir. 2007).

Any decision to manage the LWRFS as a "superbasin" must be supported by substantial evidence. Absent support by the best available science, management as a superbasin would be arbitrary and capricious. We believe that the State Engineer should focus on areas of scientific consensus when reviewing the Order 1303 hearing testimony, which demonstrates that there is no substantial evidence supporting managing the entire LWRFS as one basin. There is still disagreement over why water levels declined in much of the region during the Order 1169 pump test. The Tribe's view is that much of this can be attributed to drought, which is regional and can be expected to manifest in water levels in wells throughout the region. The alternative—that this over 1,000 square-mile region is analogous to a single giant bathtub, from which withdrawals from anywhere will have near-immediate and near-identical consequence—is not supported by the best available science because the fundamental assumptions arise from improper use of a 2013 SeriesSEE analysis. There is little consensus on the sustainable yield of the LWRFS such that any hard caps on pumping would not be well-supported by the available science. Thus, temporary uses (as opposed to permanent uses) and transfer of rights from alluvial to carbonate wells should be allowed on a case-by-case basis.

Finally, given the lack of scientific consensus and substantial evidence supporting managing the LWRFS as a single basin, the State Engineer should be protective of the Tribe's rights. The Tribe's groundwater and surface water rights are back-stopped by federally-reserved claims under *Winters v. United States*, 207 U.S. 564 (1908), which are the most-senior rights in the LWRFS. The failure of the U.S. Fish and Wildlife Service (USFWS) and the National Park Service (USNPS) to meet their trust responsibility to defend the Tribe's rights in this proceeding accordingly diminish the weight of their combined testimony.

1. There is scientific consensus that climate plays a major, but unclear, role in groundwater levels.

Several experts agree with the Tribe's view that both long- and short-term climate play a major role in hydrographs. MBOP Exs. No. 2 and 3; CSI, Testimony of Stephen Reich, 9/23/19 at 1:23:00ff (discussing his direct presentation slide 34) and 2:12:40ff (*id.*, slide 57)[1]; USFWS, Testimony of Sue Braumiller, 9/24/19 at 00:25:00ff (wet periods detectable in carbonate and alluvial water levels, and spring and Muddy River flows); USFWS, Testimony of Tim Mayer, 9/24/19 at 6:06:30ff (groundwater levels react to wet periods); USNPS, Testimony of Rick Waddell, 9/25/19 at 2:43:00ff (same); *id.*, 2:54:30 (particular importance of winter precipitation to groundwater levels has been known for decades); NSE Ex. No. 273 (Mayer and Congdon 2008 at 220, noting "the system response appears to be asymmetric and more sensitive to wet years than to dry years."); SNWA, Testimony of Warda Drici and Andrew Burns, 9/27/19 at 3:09:00 (2005 precipitation event recharge from local mountains shows up in hydrographs within months, but recharge from areas further away comes in pulses that appear on longer time-scales and hydrographs could be showing effects from recharge events anytime during the last 30 years).

However, there is little agreement on exactly how climate effects appear in LWRFS hydrographs. There is a lack of data regarding winter high-elevation precipitation in areas that contribute recharge to the LWRFS. No data was presented or discussed regarding precipitation in Nevada Climate Division 2, even though high-elevation areas in Division 2 are within the larger White River groundwater flow system and contribute recharge to the LWRFS. MBOP Ex. No. 3 at 1-2; CSI Ex. 1, Fig. 7; MBOP Ex. No. 41 (Burns and Drici 2011, Figs. F-4, F-6); https://www.esrl.noaa.gov/psd/data/usclimdivs/data/map.html#Nevada.

Precipitation measurements in the LWRFS are biased toward lower elevation stations as there are no high-altitude stations. CSI, Testimony of Molly Palmer, 9/23/19 at 1:06:30ff; NSE Ex. No. 273 (Mayer and Congdon 2008 at 220, noting that Division 4 climate data "are primarily

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[1] The Tribe has not obtained a transcript of the hearing. We cite to portions of live testimony using the date and approximate time of the testimony from the hearing videos posted on the State Engineer's website.

based on valley floor weather stations, as a surrogate for recharge in the system.”). USNPS and USFWS testified that trends in winter precipitation and snowmelt are key to understanding groundwater recharge. USFWS, Mayer testimony, 9/24/19 at 6:06:30ff; USNPS, Waddell testimony, 9/24/19 at 2:54:30; *accord* SNWA, Drici testimony, 9/27/19 at 1:10:15 (recharge starts as high-elevation precipitation during the winter). Precipitation and snowpack data are just proxies for recharge. MBOP, Testimony of Cady Johnson, 9/26/19 at 21:15. Without high-elevation precipitation data for all areas contributing recharge to the LWRFS, it is difficult to really understand what recharge pulses and events do, or don’t, appear in the hydrographs.

There is consensus that climate effects could be observed in hydrographs on both short and long-time scales. *See* Johnson testimony, 9/26/19 at 19:45ff; FWS Ex. No. 41 (Eakin 1964, suggesting 15-20 year time lag in spring discharge response to regional precipitation); FWS Ex. No. 41 (Maxey 1966); NSE Ex. No. 273 (Mayer and Congdon 2008, suggesting LWRFS groundwater levels respond to Division 4 24-month moving average monthly precipitation); MBOP Ex. No. 2, p. 45 at Fig. 2; USFWS Ex No. 5 at Section 1.2; USNPS Ex. No. 3 at Section 8 (discussing groundwater level responses); SNWA Ex. No. 9, section 3 (acknowledging short-term impact from extraordinary precipitation events but difficulty in identifying normal variations in recharge or stresses at longer time scales). However, differentiating these effects from man-made effects continues to confound the experts, as there is no consensus as how this can be accomplished.

There is also consensus that the LWRFS is experiencing dry conditions. Contrary opinions proffered by USFWS and USNPS are outliers, are not supported by their own data or the Department of the Interior as a whole, and rely on untested opinions by USGS scientists who were not offered as witnesses or cross-examined.[2] Dr. Waddell testified extensively about the sharp increase in some LWRFS groundwater levels in response to the 2004-05 wet winter and resulting "recharge pulse." Waddell testimony, 9/25/19 at 0:46:20ff (discussing hydrographs of CSVM-1, CSV-2, CE-VF-2, CSVM-3, and CSVM-5 from NSE Ex. No. 228). Dr. Mayer's analysis of hydrographs in the Dry Lake Valley, Delamar Valley and Tule Desert basins does not extend back to 2005 so it's unclear whether that same recharge pulse existed there, but no water-level response to the wet winter in 2011 is evident. *See* FWS Ex. No. 7, figs. 6, 7, 8; Mayer testimony, 9/24 at 6:06:30ff. Thus, the comparative value of using rising hydrographs in those basins to hypothesize climate impacts in the LWRFS is limited.

However, there is little consensus as to what a "drought signal" would look like in a hydrograph. Dr. Mayer testified that we're already seeing the effects of climate change in warmer winter temperatures, more heavy rain events, more winter precipitation falling as rain than snow and earlier snowmelt causing earlier runoff signals. 9/24/19 at 6:07:15ff. Indeed, his opinion is that even in an average water year, if more winter precipitation fell as rain than snow, groundwater levels could actually decrease. *Id.* Thus, decreasing groundwater levels in the LWRFS in recent years could be a heretofore-unseen response to rapid climate change and winter warming trends. *Accord* SNWA, Burns testimony, 9/27/19 at 1:53:00 (above-normal winter precipitation coincident with reduced production yet groundwater levels declining, is an unexpected response).

Annual precipitation in Nevada Climate Division 4 shows 30-year drying trend from 1945-1975, followed by a 10-year wetting trend from 1977-1985. CSI Ex. No 1, Fig. 1. Drier-than-

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[2] The Tribe objected to expert testimony by USNPS regarding the work of the USGS looking at whether there is a regional wetting trend. *See* Waddell testimony, 9/25/19 at 2:37:30ff. It's hearsay when USFWS and USNPS experts act as a conduit for other scientists' opinions and use those opinions to bolster their own. *Id.* Neither USNPS nor USFWS presented the USGS scientists to be cross-examined on their opinions. Cross-examination is particularly important in this situation because the USGS opinions are outliers compared to the opinions proffered by other parties.

average conditions exist from 2006 through 2017. CSI Ex. No. 1, p. 5; *accord* MBOP Ex. No. 23 at 4-3 to 4-4 (SNWA 2018); FWS Ex. No. 7, figs. 3 and 5 (PDSI for Nevada Climate Divisions 3 and 4 since 2002 appears to show more negative values, indicating drier conditions, than positive values); Dr. Mayer testimony, 9/24/19 at 4:48:15 (same)*; see also* Vidler/Lincoln County, Testimony of Todd Umstod 9/30/19 at 6:07-15; Testimony of Peter Mock, 10/1/19 at 0:51-52 (concurring with view that region is currently experiencing drier than normal conditions).

USFWS and USNPS opinions on drought are inconsistent with positions that the Department of the Interior recently expressed prior to and in signing the 2019 Lower Basin Drought Contingency Plan in May 2019, which reflect the Department's acknowledgement of an extended regional drying trend. *See*, *e.g.*, Dep't of the Interior, *Responding to Historic Drought and Ongoing Dry Conditions in the Colorado River Basin: Request for Input*, 84 Fed. Reg. 2244 (Feb. 6, 2019) ("Since 2000, the Colorado River Basin has experienced historic drought and dry conditions. . . ."). Little weight should be given to countervailing opinions set forth at the hearing, as they are outliers, based on work of USGS scientists who were not subject cross-examination, and do not represent the views of the Department of the Interior as a whole.

The best available science presented to the State Engineer demonstrates that the region experiences wet and dry trends on multiple time scales, that groundwater levels respond to those trends but in ways that are not always clear, and that hydrographs could be declining due to changes in temporal and spatial distribution of winter precipitation. Additional work is needed in this area to support any other conclusions with substantial evidence.

2. There is still a lack of scientific consensus supporting the LWRFS "superbasin" theory.

The basic premise of Order 1303 suffers from a lack of substantial supporting evidence. First, apparently there is no known region of this size that would act as a unitary basin as hypothesized by USFWS and others, without internal structures that would create divisions within the region from which pumping might have different effects, or at least show some variability among well hydrographs based on distance from the pumping stress. If the federal agencies argue that pumping and recovery signals propagate differently through the aquifer, or vary in their timing, this apparently violates the fundamental physics of hydrology. Vidler/Lincoln County, Mock testimony, 10/1/19 at 0:51 ff.

CSI's experts testified that they detected at least one structural anomaly located within Coyote Springs Valley that could be impacting groundwater flows and admitted that such undetected or mislocated faults could exist elsewhere in the LWRFS, contributing to local structure that would defy the "superbasin" theory. CSI, Testimony of Mr. Reich and Mr. Carlson, 9/23/19 at 4:32:00ff. Faults can, and do, affect and disturb groundwater flow. CSI Ex. No. 14 (Rowley et al. 2014); Waddell testimony, 9/25/19 at 0:28:00 (because carbonate rock generally has low matrix permeability, understanding fracturing and faulting is important to understand hydraulic connectedness). Without understanding the local structures contributing to groundwater flow, particularly in wells more distant from the MRSA, we cannot accurately describe the LWRFS as analogous to a unitary bathtub-like basin.

Another major problem with the superbasin theory is that it depends upon conclusions about hydraulic connectivity that are not supported by available data. If the State Engineer does anything as a result of the Order 1303 hearing, it should be to repudiate its use of the 2013 USFWS SeriesSEE analysis as best available science on supposed pumping impacts to MRSA springs and Muddy River surface water. USFWS testified extensively about its 2013 SeriesSEE analysis during the Order 1303 hearing and acknowledged that its 2013 SeriesSEE analysis is foundational to several assumptions contained within Order 1303, including the geographic limits of the

LWRFS and that the five-plus basins possess "exceptionally high field-scale transmissivity." Braumiller testimony, 9/24/19 at 00:11:30; 2:28:15 (MX-5-pumping-induced drawdown in five wells generated from SeriesSEE is the basis for conclusion that carbonate aquifer possesses exceptionally high field-scale transmissivity); 2:49:19 (able to infer high transmissivity from SeriesSEE result); 5:27:30 (same); 5:54:00 (extent of LWRFS encompasses areas of high transmissivity revealed by SeriesSEE analysis of five wells). However, repudiation of this particular use of the SeriesSEE analysis is key to ensuring that that the State Engineer relies on the best available science to make decisions regarding the LWRFS.

First, this is not an acceptable use of SeriesSEE and its Theis transforms. The Theis equation is a non-equilibrium well equation meant to correlate drawdown in a well to pumping rate. CSI, Testimony of Jean Moran, 9/23/19 at 1:14:00ff. The assumptions required to use Theis transforms are not valid assumptions for the LWRFS; *i.e.*, assuming a homogeneous aquifer of infinite extent, with no recharge, assuming the analyzed well is fully penetrating to fully-saturated thickness of aquifer and 100% efficient, and assuming that potentiometric surface is flat so that all water pumped is from storage. *Id.* at 1:15:20 ff.

There is consensus that the aquifer is heterogeneous, including Rowley *et al*. 2017; Reich testimony, 9/23/19 at 2:38:30ff and 4:32:15ff; Braumiller testimony, 9/24/19 at 2:26:42; Johnson testimony, 9/26/19 at 55:00. To account for faults that affect groundwater flows in a basin, the Theis analysis requires use of image wells, which USFWS apparently doesn't know how to do. Moran testimony, 9/23/19 at 4:51:30ff; Braumiller testimony, *supra*. There is consensus that faults and other boundary conditions exist and are crucial to determining hydraulic connectedness. Waddell testimony, 9/25/19 at 00:40:15 (geology is necessary consideration for connectedness); *id.* at 4:43:30 (addition of fault locations to Tetra Tech model would change distribution of drawdown). There is consensus that recharge is an important but difficult-to-assess part of the system. *See, e.g.*, SNWA Ex. No. 9 at p. 16 ("[T]he sources and volumes of natural recharge can only be interpreted and estimated. The effects of recharge on the LWRFS is complex because recharge pulses caused by precipitation during a given year arrive at different times as they originate from different recharge areas within and external to the LWRFS. Thus, the effect of the normal variations in recharge on the LWRFS may not be readily identified from well and spring hydrographs.") Thus, use of SeriesSEE for this purpose in this aquifer is not supported by substantial evidence.

Regardless, when interpreting the results of its 2013 SeriesSEE analysis, USFWS didn't adhere to the instructions or cautions provided by SeriesSEE's authors, Keith Halford and the USGS. There is strong consensus that SeriesSEE is a curve-fitting tool and not a groundwater flow model, and that one cannot infer actual aquifer parameters from the transmissivity (T) or storativity (S) fitting co-efficients used. Moran testimony, 9/23/19 at 3:16:09; Braumiller testimony, 9/24/19 at 2:26:45. However, USFWS's July 3, 2019 report states that its experts inferred high transmissivity to the LWRFS by "the pattern of near uniform drawdown in response to the test pumping." USFWS Ex. No 5 at 18; *see also id.* at 19; *id.* at 32 ("[d]ue to its exceptionally high transmissivity (and for no other reason) pumping in this portion of the carbonate aquifer creates nearly uniform drawdown throughout the high transmissivity part of the aquifer."). Ms. Braumiller testified that the SeriesSEE analysis "clearly established this area of exceptionally high field scale transmissivity in the carbonate aquifer underlying those five [LWRFS] basins," which is "an important conclusion." 9/24/19 at 2:24:40ff. Thus, the foundational concept behind the LWRFS superbasin theory—that the carbonate rock aquifer underlying the LWRFS is exceptionally transmissive—comes from USFWS inferring that hydraulic property directly from the Theis model results. This is an improper use of the Theis equation per at Halford *et al.* 2012, USFWS Ex No. 65.

USFWS claims that SeriesSEE isolated a remarkably uniform 1.5ft-to-1.6ft drawdown in 5 carbonate wells in the LWRFS (CSVM-6, CSVM-2, GC-1, M-1 and CSV-2) due to MX-5 test pumping. Braumiller testimony, 9/24/19 at 00:12:20 and USFWS Ex. No. 5 at 17. According to USFWS, that uniform-drawdown result from SeriesSEE demonstrated the exceptionally high field-scale transmissivity over a roughly 1,050 square mile area that is foundational to the assumptions of Order 1303. 9/24/19, Braumiller, 00:15:30. Yet none of these wells have measured transmissivities as the result of an aquifer test, or at least did not in 2012. *See* NSE Ex. No. 280 at Table 3-1. USFWS was unable to explain where it obtained T and S values used for its SeriesSEE analysis, other than to repeat that the values were "fitting coefficients" obtained through the optimization of the program itself. Braumiller testimony, 9/24/19 at 2:46:50. However, picking T and S values that yield the best fit to water levels assumes that all water levels are responding to drawdown; as a result, the SeriesSEE analysis fails at its basic task by not differentiating pumping-caused drawdown from other background and environmental stresses. *See* USFWS Ex. No. 65 (Halford et al. 2012 at 11). This is especially problematic because, as the Department of the Interior acknowledged in 2012, "there is high variability of values [of T and S] obtained even for wells close together." NSE Ex. No. 280 at 10. Notably, the Tribe's TH-1 and TH-2 wells have measured T values well below 100,000 ft^2/day. *See id.* at Table 3-1.

Nor has any work been done since 2013 to correct the SeriesSEE results to remove background effects on water levels, or to verify whether the SeriesSEE results are scientifically sound. CSI's Jean Moran testified that when she attempted to cross-check FWS's SeriesSEE results, she obtained anomalous results that pumping from a well further away from EH-4 (*i.e.*, MX-5) contributes more to EH-4 drawdown than the nearer Arrow Canyon wells. Moran testimony, 9/23/19 at 3:05:55ff. Ms. Braumiller admitted that she did not create the SeriesSEE analysis done in 2013 nor did she recreate it for 2019. 9/24/19 at 2:23:30ff. She was unfamiliar with the use of image wells to determine the effects of recharge and other environmental conditions and indeed, wasn't even sure it was possible to do so in SeriesSEE. *Id.* at 2:25:15ff. However, it is possible to account for recharge in SeriesSEE by using a gamma transform. USFWS Ex. No. 65 (Halford *et al.* 2012 at 11); Waddell testimony at 6:43:20 (noting that recharge can be accounted for in SeriesSEE). The use of background wells, via moving averages, to correct for longer-term trends in groundwater levels is apparently standard and recommended for SeriesSEE by Halford *et al.*, 2012, at pp. 5 and 19. However, USFWS did not do this in 2013 "given continued uncertainties concerning the availability of a 'reference' well that can be used to make such corrections," NSE Ex. No. 256 at 9 (USFWS 2013 Report). Nor did USFWS go back and use post-2013 data to verify or calibrate the 2013 analysis because it was assumed to be "irrelevant." Braumiller testimony, 9/24/19 at 2:27:56. However, water-level model components in SeriesSEE "must be calibrated to reliably differentiate small pumping responses from environmental fluctuations." Halford *et al.* 2012 at 12.

Indeed, "[d]rawdown detection with the Theis-transform approach becomes ambiguous . . . where environmental fluctuations and pumping signals can be correlated." *Id.* at 13. "The potential for correlation increases as hydraulic diffusivity decreases, distance between observation and pumping well increases, or recovery diminishes"—all factors that could exist in the SeriesSEE analysis for the LWRFS yet that USFWS apparently ignored. *See id.* at 14. Other experts acknowledged that wells in the LWRFS apparently respond to the same stresses, whether man-made or environmental. SNWA, Testimony of Andrew Burns, 9/27/19 at 42:00. Thus, differentiating between environmental and drawdown responses in hydrographs is extremely important in the LWRFS. Furthermore, little information has been provided by USFWS regarding RMS values and signal-to-noise ratios for its SeriesSEE analysis—information that is critical to understanding whether the analysis fits reality. *See* Halford *et al.* 2012 at 14. USFWS provided "a visual comparison of the estimated drawdown with the residuals, and allow[ed] the viewer to decide whether the remaining noise (residuals) obscures the drawdown" in an appendix to its 2013 report. NSE Ex. No. 257. However, without signal-to-noise ratios or RMS values, the graphs are limited in their utility. These problems suggest that SeriesSEE is not the best available science for determining hydraulic connectedness in the LWRFS and thus, a foundational underpinning of Order 1303 and LWRFS conjunctive management is not supported by substantial evidence.

Another fundamental problem with the LWRFS "superbasin" theory is that because it relies heavily on observations of superficially-similar hydrographs, it is confounded by hydrographs of wells that lack pumping signatures or post-test recovery signals. *See* Vidler/Lincoln County, Umstot testimony, 9/30/19 at 6:10-15 (focused mostly on northern Coyote Spring Valley and Kane Valley); 6:17-24. CSI's experts testified that CSVM-4's hydrograph appears driven by climate and precipitation as opposed to pumping. Reich testimony, 9/23/19 at 5:03:00ff; *id.* 1:52:50 (CSVM-4 shows only climatic response, no seasonal variation and no recovery during Order 1169 shutdown in 2011 and 2012); *accord* Johnson testimony, 9/26/17 at 1:06:00 (mid-test recovery is diagnostic pumping signal and is lacking in CSVM-4). CE-VF-2 shows no immediate response in 2011 to Order 1169 shutdown and no response to MRSA seasonal pumping but a seasonal response to western side of CSV pumping is evident. Reich testimony, 9/23/19 at 1:51:30 (discussing direct presentation slides 51-52). And CSVM-5 is unique compared to other hydrographs in the basin, likely due to underlying geologic structures. *Id.*,1:54:45ff, *id.* 6:09:30ff; Braumiller testimony, 9/24/19 at 5:48:50; Waddell testimony, 9/25/19 at 1:01:30 (CSVM-5 not connected to MRSA). Similarly, the Tribe's ECP-1 well demonstrated recharge boundary effects during a pumping test and thus is apparently isolated from the highest-transmissivity-area of the aquifer. MBOP Ex. No. 1 at 16, 23; MBOP Ex. No. 33.

Many experts testified about the seeming disconnectedness of Big Muddy Spring from the rest of the carbonate aquifer. Big Muddy Spring contributes more to Muddy River flows that Warms Springs West or other higher-elevation springs. *E.g.*, Burns testimony, 9/27/19 at 3:07:00. One explanation for Big Muddy Spring's behavior is a delayed response to climate signals. *E.g.*, USFWS Ex. No. 5 at 26-28; MBOP Ex. No. 2 at 15 and App. II; Johnson testimony, 9/26/19 at 30:00. Further analysis is needed, given that Moapa dace population counts appear correlated with Big Muddy Spring discharge. *See* MBOP Ex. No. 15 (Johnson and Mifflin 2018 at 2).

If portions of the LWRFS are weakly connected or not connected, pumping from different portions of it will have different consequences as is expected in any normal aquifer system. Notably, there is building consensus that existence of separate flow paths confounds the LWRFS "superbasin" theory. USFWS and the Tribe have hypothesized a Pananca-MRSA flow connection, and CSI, USFWS and the Tribe have hypothesized a flow system from Pahranagat through northern and western Coyote Springs Valley into California Wash. *See* CSI Ex. No. 1 at 29; MBOP Ex. No. 1, App. 3 (scoping model using heat and stable isotopic data to trace a Pahranagat-Las Vegas flow path and Panaca-MRSA flow path); Braumiller testimony, 9/24/19 at 00:28:30ff (~49,500 afy constant inflow between Pahranagat and northern CSV); *id.*, 00:30:52ff (4,700 afy-inflow from Panaca into Lower Meadow Valley Wash and LWRFS).

A significant amount of water appears to be bypassing the MRSA via a Pahranagat-Las Vegas path. Johnson testimony, 9/26/19 at 14:30ff, 39:30 (SNWA's Las Vegas Valley pumping suggests incoming flow from LWRFS); Mock testimony, 10/1/19 at 0:38-41 (evidence for large discharges into Las Vegas Valley based in part on geological continuity of directional carbonate corridors); Smith testimony, 10/1/19 at 1:38ff (evidence for water moving between Garnet Valley and Las Vegas Valley); *id.* at 1:26ff, 1:44ff (evidence for flow from the northwest entering Hidden and Garnet Valleys and California Wash, bypassing the MRSA, based primarily on differences in water levels between the western part of the flow system and the MRSA). If there is "bypass" water within the LWRFS that is no longer up-gradient from the MRSA and does not contribute to MRSA flows, it could be taken with less risk of harm to MRSA flows, particularly as the distance from the MRSA increases.

If the region is not a bathtub, and water can be moved down-gradient from the MRSA, then ordinarily, the farther one takes water from a sensitive area, the more attenuated the likely harm. The 2006 MOA and companion agreements manifest this concept in several ways. *See* NSE Ex. No. 236 ("2006 MOA"). First, the pumping reductions mandated by the 2006 MOA are asymmetrical. If MRSA discharges decline below the MOA trigger levels, pumping restrictions required of the Tribe down-gradient in more distant portions of California Wash are at a significantly reduced rate from MOA parties with rights closer to and up-gradient from the MRSA in the Coyote Springs hydrologic basin. SNWA acknowledges this disproportionality but continues to assert that this asymmetry was a rational approach to protecting the dace. *See* Testimony of Bob Williams and Zane Marshall, 9/30/19 at 0:59.

Second, the 2006 agreements provide that change applications by the Tribe of its groundwater rights in California Wash are not to be protested by the other parties so long as the new pumping site is at least one mile (in the case of a carbonate well) or two miles (for an alluvial well) from the MRSA and the Muddy River. NSE Ex. No. 242, Ex. A, April 20, 2006 Water

Supply Agreement, sec. 3.d. These provisions reflect the view that the farther from the MRSA and the Muddy River the Tribe pumps, the less harm it is likely to do. Relative proximity of pumping to sensitive areas, and the benefits to the region of increasing distance of withdrawals from such areas, are discussed further below.

Although SNWA presented multiple linear regression (MLR) results that purport to show drawdown at EH-4 from pumping in California Wash, the State Engineer should reject SNWA's MLR modeling because its results, at least as to the Tribe's wells, do not correspond with reality. Even though SNWA attempted to demonstrate that TH-2 pumping in California Wash has a significant effect on EH-4, *see* SNWA Ex. No. 9, Fig. A-4 (1.7-ft drawdown at EH-4 due to a single-year pumping of 400 afy from TH-2), the analysis is flawed. First, it depends upon invalid assumptions of constant transmissivity. *See* Drici testimony, 9/27/19 at 1:02:00 (SNWA's MLR analysis depends upon assuming that aquifer is "acting like confined aquifer"). Second, if true, this would mean that removing 400 afy at TH-2 has a 6:1 impact on Muddy River flows. *Id.* at 5:32:30 to 5:41:10 (NV Energy cross-examination of Ms. Drici exploring correlation between TH-2 pumping and EH-4 drawdown of 1.7 feet, which would allegedly cause a .267 cfs reduction in Warm Springs West flow and then applying SNWA's 0.76 ratio to .267 cfs to yield 3.42 cfs reduction in Muddy River flow or 2,450 afy). Clearly, this cannot be squared with reality.

The MLR analysis suffers from other shortcomings on its face. SNWA acknowledged that its analysis assumes that all wells respond the same to the same stresses; but this does not take into account local conditions such as lower transmissivity or recharge and could reflect that all the wells are responding to the same recharge or other climate impacts. Burns testimony, 9/27/19 at 43:15; *id.* at 3:05:00; SNWA Ex. No. 9 at Section 3. Furthermore, SNWA asserts that "[a]ll relationships [shown in the MLR analysis] exhibit linear trends with very high R^2 values," SNWA

Ex. No. 7 at 5-17, to demonstrate the value of its MLR analysis. However, "[v]alues of R^2 close to 1 are often incorrectly deemed an indicator of a good model. This is a dangerous, blind reliance on the computer software. An R^2 near 1 can result from a poor regression model." SNWA Ex. No. 13 (Helsel and Hersch 2002 at 228). Thus, there is little scientific evidence supporting the fundamental conclusion that all of the LWRFS functions as one bathtub-like basin,

3. There is no scientific consensus on the sustainable yield of the LWRFS.

Nearly all parties disagreed on how much water is available and how much groundwater can be pumped without affecting senior surface water rights or Moapa dace populations, with estimates ranging from 0 (CBD's July 3, 2019 report, indicating no carbonate pumping but estimating a sustainable yield of 4,000 afy of basin-fill pumping) to 4,000-6,000 afy (SNWA) to 9,313 afy (USFWS) up to 30,000 afy (CSI). USFWS and USNPS declined to opine on "sustainable yield" due to outstanding questions regarding connectedness and lack of sufficient models equal to the task. Based on conversations with SNWA about SNWA's pumping in Las Vegas Valley, the Tribe's experts believe there is significant flow bypassing the MRSA, which complicates discussions of sustainable yield. MBOP Ex. No. 2, Fig. 1 and App. 1; Johnson testimony, 9/26/19 at 14:30ff, 39:30. Given the lack of consensus, a permanent finding of a specified amount of groundwater available in the region is not supported by best available science. In addition, during the 13 years since the 2006 USFWS-sponsored MOA, no party has argued either to modify the proposed critical limitation of 3.2 cfs flow at Warm Springs West, or to change the pumping restrictions provided for in that agreement. *E.g.*, Testimony of Bob Williams and Zane Marshall, 9/30/19 at 0:47-50, 0:57.

However, it is likely that additional data will yield new information, particularly if additional monitoring of different kinds is required, as several parties have requested. Also, the amount of water available at any given time appears to be dynamic, particularly if drought conditions change, or there are recharge events such as the wet year of 2005. Differences of opinion exist regarding the source and amount of local recharge. CSI Ex. No. 1, pp. 31-40 and Palmer testimony 9/23/19, 2:22:55 (discussing direct presentation slide 61). Thus, any pumping limits imposed by the State Engineer should be explicitly subject to revision based on more data showing increased total availability, internal or external boundary conditions, or demonstrated lack of hydraulic connectivity between a point of diversion and the MRSA. *E.g.*, Waddell testimony, 9/25/19 at 6:45:49 (describing test and results that would demonstrate lack of connection); Smith testimony, 10/1/19 at 2:22-23 (in lieu of a sustained yield approach leading to a particular region-wide number, the State Engineer might implement a "safe yield" approach which takes into account sub-regional variations, especially for areas far from sensitive locations that don't seem to be contributing directly to springflow declines).

4. The State Engineer should differentiate temporary from permanent rights.

Given the uncertainties and lack of consensus on sustainable yield, the State Engineer should also acknowledge the difference between temporary and permanent pumping. Zane Marshall for SNWA testified that they were far more concerned with permanent rights (residences, continuing industries) than temporary rights. 9/30/19 at 0:48ff. Dwight Smith for City of North Las Vegas argued that mitigation to protect spring and river flows should also be addressed on a case-by-case basis, as withdrawals far from sensitive areas would likely cause less harm than more proximate pumping. 10/1/19 at 2:09ff.

5. Transfers between alluvial and carbonate aquifers should be addressed on a case-by-case basis.

The Tribe has a pending application to transfer a 500-afy alluvial right in the Muddy Springs area, which the Tribe acquired from NV Energy, to the carbonate aquifer beneath

California Wash—significantly further away. Permitting such a transfer would provide flexibility for the overall system within a heterogeneous system. Impacts to MRSA will be dependent upon location of extraction. Reich testimony, 9/23/19 at 2:31:25; Smith testimony, 10/1/19 at 1:09-11, 2:09-13, 2:15ff (pumping very near MRSA and Muddy River headwaters will capture more water otherwise destined for those bodies; thus transfers from the alluvial to carbonate aquifers, particularly when the movement of pumping will be to points much farther from sensitive areas, shouldn't be generally denied and should be analyzed on a case-by-case basis).

USNPS and USFWS both expressed the views that moving alluvial pumping to the carbonate aquifer would only delay, rather than prevent, impacts to the MRSA and senior Muddy River rights. USNPS Ex. No. 2 at 5.2.4; USFWS Ex. No. 5 at Section 1.5. However, this conclusion fails to consider that some carbonate wells, including the Tribe's, may be located in areas of measured low transmissivity downgradient of the MRSA and thus may be pumped with less or no impact to the MRSA. *See* MBOP Ex. No. 1 at 16, 23, NSE Ex. No. 280 at Table 3-1.

6. The State Engineer should require additional monitoring.

The Tribe supports more monitoring, as do many of the other parties. *E.g.*, USFWS Ex. No. 5 at Section 1.7 (listing unresolved technical questions and potential ways to address); USNPS, 9/25/19 at 3:24:30; SNWA, 9/30/19 at 0:47-48; City of North Las Vegas, 10/1/19 at 2:22-23. The State Engineer should remain open to additional analyses and future proceedings regarding the LWRFS should allow additional evidence to be presented based on further research.

7. The State Engineer should be cognizant of the special position of the Tribe.

In addition to water rights acquired under state law, the Tribe holds senior unadjudicated and unquantified claims to Muddy River surface water as well as groundwater beneath the Reservation. The priority date for the Tribe's reserved surface water claims dates from establishment of the Tribe's original reservation in 1873, and its reserved groundwater rights in California Wash date no later than the expansion of the Reservation in 1980. The Tribe did not present evidence regarding its water rights, as the hearing was focused on technical matters described in Order 1303. However, to the extent that the State Engineer is seeking to protect senior groundwater and Muddy River surface rights in this proceeding, the Tribe's rights are the most senior by far. *See* NSE Exs. No. 227 (LWRFS priority dates), 333 (Muddy River Decree).

The hearing record is devoid of scientific evidence that adequately supports the conclusion that pumping the Tribe's carbonate wells has any impact at the MRSA. If the Tribe's carbonate pumping impacts Muddy River flows, the Tribe is only injuring itself so long as MRSA flows do not fall below MOA trigger levels. Any future development of the Reservation will require groundwater supply from our California Wash wells and the Tribe has already agreed to provide water for several solar projects currently in development. If the State Engineer takes steps to manage the LWRFS as a single basin and curtail the Tribe's carbonate pumping, the Tribe may be compelled to assert its federally-reserved rights to ensure that those projects (and others) proceed.

The Tribe's reserved right claims are held in trust for the Tribe by the United States. To the extent that positions adopted by USNPS and USFWS in this proceeding fail to account for the Tribe's reserved rights, the federal agencies are in breach of that trust. Neither agency acknowledged that its interests in this proceeding include the Tribe's reserved rights, instead limiting their participation to protecting the agencies' own reserved rights and the Moapa dace. This is improper as a matter of law and should be reflected in the weight accorded to the agencies' testimony. Neither agency consulted with the Tribe before or during the hearing; if the agencies had considered their duty to protect the Tribe's reserved rights, their testimony likely would have been very different. The agencies' testimony and positions are further diminished by the fact that neither agency's Regional Director has verified the agency's positions. *See* Nev. Rev. Stat. § 533.365(2)(b) (if USFWS or NPS file protests against granting an application to appropriate, protest must be verified by affidavit of Regional Director). Thus, the Tribe requests that the State Engineer avoid making any findings that rely on USFWS or USNPS testimony.

Managing the LWRFS as a single basin, with a hard cap on carbonate groundwater production, will not save the Moapa dace, or protect senior Muddy River rights. It will, however, stymie future economic and community development by the Tribe. This is a grave injustice. People have been trying to separate the Paiutes from their land and water for the better part of 250 years. The Tribe's 1,000-acre reduced Reservation was selected from lands astride the Muddy River in 1875 specifically to preserve the Tribe's access to water. For years, LWRFS water users have taken water from the Muddy River and alluvial and carbonate aquifers—the *Tribe's* water—to fuel development of resorts, ranches, golf courses, and distant communities while providing none of the benefits from that development to the Tribe. In many cases, such as the Reid Gardner Generating Station, the Tribe was saddled with devastating impacts to tribal members' health and welfare. If the State Engineer makes any decisions regarding LWRFS management, he should ensure that those decisions do not further perpetuate this environmental injustice or ignore the Tribe's unique position in the LWRFS.

(signature block on following page)

Respectfully submitted this 3rd day of December, 2019.

By s/ [signature]

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CERTIFICATE OF SERVICE

I hereby certify that on December 3, 2019, I caused a copy of the forgoing **Closing Statement by the Moapa Band of Paiute Indians for Order 1303 Hearing** to be served upon the following parties:

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IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDRIGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA.

POST-HEARING BRIEF OF MOAPA VALLEY WATER DISTRICT

Moapa Valley Water District, through its undersigned counsel, hereby submits this post-hearing brief.

I. INTRODUCTION

In Interim Order 1303 ("IO 1303"), the State Engineer asked any stakeholder with interests that might be affected by water right development in the Lower White River Flow System ("LWRFS") to provide information addressing the following five matters:

i. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the LWRFS;

ii. The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the test;

iii. The long-term annual quantity of groundwater that may be pumped from the LWRFS, including the relationship between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;

iv. The effects of movement of water rights between alluvial wells ad carbonate wells on deliveries of senior decreed rights to the Muddy River; and

v. Any other matter believed to be relevant to the State Engineer's analysis.

In response to that request, the Moapa Valley Water District ("MVWD") submitted a Letter Report dated July 1, 2019 ("MVWD Report") as well as Rebuttal Comments to IO 1303 Reports ("MVWD Rebuttal"). After reviewing all expert reports and rebuttals, as well as the testimony of multiple expert witnesses over the course of the two-week hearing, MVWD does not alter any of the conclusions included in the MVWD Report and MVWD Rebuttal. Those conclusions remain supported by substantial evidence in the record. The discussion that follows will highlight key evidence and testimony from the two-week hearing that supports each of MVWD's conclusions.

II. EVIDENCE AND TESTIMONY RELATING TO IO 1303 QUESTIONS

A. Kane Springs Valley Hydrographic Basin should be Included in the LWRFS Management Area.

As relates to the issue paramount to the District's interests—whether Kane Springs Valley should be included in the management area—virtually all parties agree that it should be included. The best available science and historical observations show that Kane Springs Valley is underlain by the same regional carbonate aquifer that feeds the Muddy River Springs, and that increased groundwater pumping in Kane Springs Valley will undoubtedly adversely impact spring flows. Only two parties—Coyote Springs Investments ("CSI") and Lincoln County/Vidler Water Company ("Lincoln/Vidler")—argued against its inclusion. Another commonality, apart from being the only two parties to the proceeding that found evidence of a hydraulic barrier between Kane Springs Valley and the LWRFS, is the contract between them for Lincoln/Vidler to pump groundwater from pending applications in Kane Springs Valley to deliver to CSI's development in Coyote Springs Valley. That relationship, paired with the questionable science used to support exclusion of Kane Springs Valley from the management area, are enough for the State Engineer to discount the reports and testimony provided by two parties' expert witnesses as relates to Kane Springs Valley.

1. <u>Substantial Evidence Supports Inclusion of Kane Springs Valley in the LWRFS Management Unit.</u>

Multiple parties and experts presented evidence and testimony that wells in northern Coyote Spring Valley and Kane Springs Valley responded to the Order 1169 pumping tests. Hydrographs prepared by SNWA showed that Order 1169 pumping at MX-5 resulted in a drawdown of approximately .5 feet at the KMW-1 monitoring well.[1] SNWA noted that responses in KMW-1 were "slightly attenuated" by the fact that KMW-1 was drilled in the Kane Springs fault zone.[2]

In its report, the Unites States Fish and Wildlife Service ("FWS"), recommended that the entirety of Kane Springs Valley be included in the LWRFS management area based on modeling results and observations of water levels in CSVM-4 and KMW-1 resulting from MX-5 pumping tests.[3] The United States National Park Service also recognized the responses to MX-5 pumping at KMW-1.[4]

MVWD's expert witness explained to the State Engineer that the gradient between KMW-1, CSVM-4, and EH-5B was "remarkably flat."[5] That flat gradient exists from Kane Springs Valley to the Muddy River Springs Area ("MRSA"), regardless of any minor anomalies or

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[1] *Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response* (June 2019) ("SNWA Report"), at p. 5-8, Fig. 5-6; Transcript Vol. V, at p. 892:1-5 (Burns).
[2] *Id.* at 5-6.
[3] *Issues Related to Conjunctive Management of the Lower White River Flow System* (July 3, 2019) ("FWS Report"), at p. 22, p. 67 (Fig. 8a and 8b).
[4] *Prediction of the Effects of Changing the Spatial Distribution of Pumping in the Lower White River Flow System* (July 3, 2019) ("NPS Report") at p. 22; Transcript Vol. III, at p. 524:8-19 (Waddell).
MVWD Rebuttal Comments ("MVWD Rebuttal") at p. 3-4; Transcript Vol. VI, at pp. 1177:7-1178:11 (Lazarus).
[5] Transcript, Vol. VI, at p. 1177:17-18.

localized head differences between wells. The "shockingly flat" gradient from Kane Springs Valley throughout the entirety of the MRSA indicates an uninterrupted, continuous carbonate aquifer. The USFS and Center for Biological Diversity ("CBD") expert witnesses corroborated that flat gradient.[6] Additionally, in Ruling 5712, the State Engineer relied in part on the flat groundwater gradient to conclude that groundwater from Kane Springs Valley flows into Coyote Springs Valley.[7]

All parties to the proceeding who evaluated the northern boundary of the management area, including CSI and Lincoln/Vidler, recognize interbasin flow leaving Kane Springs Valley and entering the LWRFS. CSI's expert witness estimated 4,200 afa of flow from Kane Springs Valley.[8] SNWA estimated that subsurface flow to be approximately 6,000 afa.[9] The National Park Service did not estimate a volume of flow leaving Kane Springs Valley, but recognized that some volume of interbasin flow takes place.[10] Lincoln/Vidler also indicated approximately 4,200 afa of flow, and agreed that a hydrologic connection between Kane Springs Valley and Coyote Spring Valley exists.[11]

MVWD, FWS, Nevada Cogeneration Associates ("NV Cogen"), CBD, and NPS all recommended, supported by the extensive evidence identified above, that Kane Springs should be included in the management area. SNWA recommended that Kane Springs Valley be included as recently as 2018, but – without any new studies or data on the matter – did not recommend the inclusion at the 2019 hearing. Expert witnesses on behalf of Nevada Cogeneration Associates

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[6] Transcript, Vol. IX, p. 1557:21-1558:2 (Meyers)
[7] *State Engineer Ruling 5712* (Feb. 2, 2007), at p. 10.
[8] Transcript, Vol. I, p. 200:14-24.
[9] The LVVWD 2001 report entitled *Water Resources and Ground-Water Modeling in the White River and Meadow Valley Flow Systems, Clark, Lincoln, Nye and White Pine Counties* indicates approximately 6,000 afa of interbasin flow from Kane Springs Valley to Coyote Springs Valley.
[10] Transcript, Vol. III, p. 550:19-24 (Waddell).
[11] Transcript, Vol. VII, p. 1336:13-1337:1 (Bushner).

("NV Cogen"), including a former State Engineer, testified at length about the interconnectivity of Kane Springs Valley and the remainder of the LWRFS.[12]

2. <u>The Evidence Presented by CSI and Lincoln/Vidler Indicating a Fault between Kane Springs Valley and the Remaining LWRFS is Based on Questionable Science and Conjecture.</u>

Both CSI and Lincoln/Vidler argue that Kane Springs Valley is separated from the administrative LWRFS unit by a fault or other structural boundary. Although they both acknowledged that Kane Springs Valley discharges groundwater into Coyote Springs Valley, CSI and Lincoln/Vidler appear to have created an impermeable barrier to groundwater flows—a fault—that would allow their joint project to proceed, and worked backward from there to justify its existence. As Lincoln/Vidler's expert witness acknowledged, the alleged fault that forms a barrier at the southern end of Kane Springs Valley does not appear on any of the maps created by any previous geophysical studies completed on behalf of the USGS.[13] Thus, the first suggestion by anyone that there might be a fault at the south end of Kane Springs Valley that impeded southward groundwater flow was prepared by Lincoln/Vidler specifically for IO 1303 and this hearing.

There are several issues with the Lincoln/Vidler Report and expert testimony. Lincoln/ Vidler relied on CSAMT to map geologic conditions in southern Kane Springs Valley and northern Coyote Spring Valley. For its CSAMT study, Lincoln/Vidler ran three lines: (i) "Line 10", which trended from southeast to northwest in the southern portion of the basin; (ii) "Line 11", which ran parallel to Line 10, slightly to the southwest in northern Coyote Spring Valley; and (iii) "Line 12", which ran east to west and transected the other two lines at an approximately 45 degree angle. Lincoln/Vidler claims to have discovered a fault that acts as a barrier to outflows from Kane

[12] Transcript, Vol. IX, p. 1629:23-1639:7 (Coache)
[13] Transcript, Vol. VII, p. 1381:10-1382:9 (Carlson).

Springs Valley that sits between, and runs parallel to, Lines 10 and 11.[14] This "extensive faulting" was discovered through comparison of those two *parallel* CSAMT lines and relies solely on that comparison to substantiate existence of the fault.[15] Lincoln/Vidler's expert witness stated at the start of his testimony that running CSAMT lines parallel to a fault is not an effective use of the technology.[16]

To locate faults, CSAMT lines must run perpendicular to a fault, otherwise, the image is distorted and unreliable.[17] The error in methodology is compounded by the fact that Lincoln/Vidler had a CSAMT line that ran across its postulated fault—Line 12—but Lincoln/Vidler did not rely on that Line 12 to interpret a fault at the mouth of Kane Springs Valley. That is because Line 12 did not clearly indicate any such fault.[18] Even if Lincoln/Vidler had proven that a fault exists in southern Kane Springs Valley, it did not present any evidence relating to permeability. Without actual proven impermeability, the State Engineer cannot simply assume that a fault is impermeable.

In addition to the suspect conclusions above, Lincoln/Vidler claims that its newly-discovered fault is also evidenced by the difference in head between the CSVM-4 and KMW-1 wells.[19] While a 5.5 foot difference between water levels in those two wells is concededly a larger gradient than the rest of the LWRFS management area, the fact remains that the overall gradient between KMW-1 and EH-4 in the Muddy River Springs Area is "shockingly flat."[20] So while the difference in heads might indicate a slightly lower transmissivity in the aquifer between CSVM-4

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[14] *Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit* (July 3, 2019) ("Lincoln/Vidler Report"), at p. 4-9.
[15] Transcript, Vol. VI, p. 1344:16-1345:6 (Carlson).
[16] Transcript, Vol. VI, at p. 1262:2-10 (Carlson).
[17] Transcript, Vol. VI, at p.1344:16-1345:6 (Carlson).
[18] *See* Lincoln/Vidler Report at Fig. 4-8.
[19] Lincoln/Vidler Report at 3-3 through 3-4.
[20] Transcript, Vol. VI, p. 1178:1 (Lazarus).

and KMW-1, it does not indicate the presence of an impermeable fault or other impermeable structural barrier. Lincoln/Vidler punctuated its unsupported fault claim in its report to the State Engineer, in which, despite relying on well head difference to support its claim of a fault, it drew the proposed fault line to the south of CSVM-4, rather than north of it, between it and KMW-1.[21]

Until the State Engineer began discussions regarding a LWRFS management unit, Lincoln/Vidler had historically recognized the connectedness of Kane Springs Valley to the LWRFS. In order to get 1,000 afa of groundwater applications approved in 2006, Lincoln/Vidler entered into a settlement agreement with FWS and agreed to monitor flows at Warm Springs West; if those flows dropped below certain triggers levels, Lincoln/Vidler would curtail pumping.[22] If there really is a barrier to flow at the south end of Kane Springs Valley, it would have been absurd to agree to those triggers.

Prior to joining Lincoln/Vidler's staff, Lincoln/Vidler's own expert witness, Greg Bushner, accurately explained the aquifer conditions in Kane Springs Valley. In a KPW-1 well completion report filed with the State Engineer in 2006, Bushner stated that "the carbonate rock aquifer behaves as a porous media similar to an alluvial aquifer system and therefore can be analyzed as such" and also noted that "...hydraulic barriers to groundwater flow were not encountered during [a] 7-day aquifer test" detailed in that report.[23]

Finally, Lincoln/Vidler repeatedly pointed out that the Order 1169 pump testing did not require monitoring in Kane Springs Valley, as if that fact was somehow dispositive of the proper management area boundary. However, Kane Springs Valley groundwater levels were actually monitored before, during, and after the Order 1169 pumping test. Further, two of the men who

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[21] Lincoln/Vidler Report, at Fig. 4-9.
[22] Lincoln/Vidler Exhibit 016.
[23] Final Well Completion Report Kane Springs Valley, Lincoln County, Nevada (March 15, 2006) (cited in LC-V_001 at. p. 8-3), at pp. 5-4 through 5-5.

initially excluded Kane Springs from the management area—former State Engineer Hugh Ricci and former State Engineer staffer Bob Coache—stated that, if they knew then what they know now, they both would have included Kane Springs Valley in the LWRFS.[24]

B. Although the Carbonate Aquifer is not Fully Recovered from Order 1169 Pumping, Levels Appear to have Stabilized Under Current Pumping Conditions.

Evidence indicates that the carbonate aquifer underlying the LWRFS is not yet recovered from the Order 1169 pump testing, but drawdowns are no longer occurring. The State Engineer stated that "the current amount of pumping corresponds to a period of time in which spring flows have remained relatively stable and have not demonstrated a continuing decline."[25] Nothing presented at the hearing indicated that the State Engineer's position was incorrect.

In its report, MVWD noted that although water levels and spring discharges have not quite recovered to pre-1169 test levels, no trigger levels from the 2006 Memorandum of Understanding have been reached and water levels are no longer declining.[26] Thus, although the carbonate aquifer is not yet recovered from the 1169 tests, data does not suggest claims of ongoing drawdowns.

NV Energy also stated that at current pumping levels, the LWRFS is at or nearing a new steady state. Although water levels in most areas continue to decline slightly, discharge at both the Muddy River Springs Area and Warm Springs West is steady or even increased slightly over the past few years.[27]

SNWA argues that water levels are still declining lightly, that current pumping levels will not allow aquifer recovery, and in fact will result in triggers from the 2006 MOA being reached.[28]

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[24] Transcript, Vol. IX, at p. 1659:9-22 (Coache); p. 1660:12-14 (Ricci); p. 1660:16-20 (Coache).
[25] Interim Order 1303, at p. 10.
[26] MVWD Report, at
[27] Transcript, Vol. X, at P. 1766:2-9, (Felling); NV Energy Slide 35.
[28] SNWA Rebuttal Report at p. 19.

The Moapa Band of Paiutes recognize that water levels in the carbonate aquifer are declining slightly, but attribute that decline to drought and climate-driven influences rather than pumping from the carbonate aquifer.[29]

MVWD is open to the idea that slight drawdowns might be continuing based on current pumping levels but reiterates that the system is currently at or nearing steady state.

C. Current Pumping Levels are Sustainable and No Additional Pumping Should be Permitted in the LWRFS Basins, Including Kane Springs Valley

1. Current Levels of Pumping are Sustainable

As MVWD stated in its IO 1303 Report, it agrees with the State Engineer's statement from IO 1303 that "the current amount of pumping corresponds to a period of time in which spring flows have remained relatively stable and have not demonstrated a continuing decline."[30] While it is possible that the carbonate aquifer system is nearing a steady-state condition, additional data is required to verify this conclusion. NV Energy agreed with this conclusion, stating that the "[c]urrent pumping regime may have reached equilibrium in the Muddy River Springs Area. I think we need more time for sure to know…."[31] FWS also agreed with that conclusion, stating "9,318 [afa] appears to be the best initial estimate of the sustainable yield of the system, based on the optimum method currently available for arriving at an estimate of the maximum allowable rate of pumping in the LWRFS, i.e., the average annual rate of pumping from 2015-2017."[32]

Other stakeholders arrived at lower estimates—some reasonable and slightly below current pumping and some unreasonable and unsupported by any real science. SNWA estimates 4-6,000 afa of annual safe withdrawals, and stated that "current pumping will cause continued

[29] MBOP Rebuttal Report, at p. 1.
[30] MVWD Report, at p. 4 (quoting IO 1303 at p. 10).
[31] Transcript, Vol. X, p. 1775:21-23 (Felling).
[32] FWS Report, p.3.

drawdowns."[33] NV Cogen stated that it "does not completely agree with the current pumpage goal of 9,318 AFY," but also that it "understands the complexity of the determination."[34] While MVWD disagrees with those decreased estimates for safe Pumpage, it has already conceded that more data gathered over time could result in actual safe Pumpage of slightly less than current levels. The CBD statement that no amount of carbonate pumpage is safe is inaccurate and unsupported by any reliable science or historical data.[35]

2. Additional or Increased Pumping from the Carbonate Aquifer will Accelerate Spring Drawdowns at MRSA.

Other parties argued in favor of increased carbonate aquifer pumpage, but failed to identify where that water would come from or where it could be safely pumped. CSI estimated that as much as 30,000 afa could be pumped from the LWRFS, based strictly on proper well location.[36] Unsurprisingly, however, CSI could not identify exactly where that pumping could take place safely.[37] It also acknowledged that although impacts from pumping farther away from the MRSA would take longer to manifest than pumping nearer the springs, impacts would eventually be realized on the springs.[38]

Virtually all parties except CSI and Lincoln/Vidler agree that increasing pumping above current levels will have disastrous results on the MRSA. NPS stated that "since the Muddy River Springs ... are derived almost entirely from the carbonate aquifer, total carbonate pumping should not be increased ... even if total carbonate and alluvial pumping is maintained at a 'sustainable' overall level."[39] NV Energy agreed that "additional carbonate aquifer pumping will likely result

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[33] Transcript, Vol.V, at p. 1002:5-9 (Burns)
[34] NV Cogen, Slide 42; Transcript, Vol. IX, at p. 1646:11-13 (Coache).
[35] Center for Biological Diversity, Slides 15, 45 (Meyers) (arguing that no carbonate pumping is sustainable).
[36] Transcript, Vo. 1, p. 91:8-11 (Reich).
[37] Transcript, Vol 1, p. 222:1-11 (Reich).
[38] Transcript, Vol 1, p. 202:10-14 (Reich).
[39] NPS Rebuttal Report, at p. 4.

in the Warm Springs West 3.2 cfs trigger being reached."[40] As SNWA's position is that even current pumping levels are unsustainable, it follows that any additional carbonate pumping would impact springs.[41] Whether current pumping levels are sustainable, or if pumping will need to be reduced at some point in time will be determined by additional data gathered. No reliable evidence was presented by any party that indicates that carbonate pumping could be safely increased.

D. Pumping from the Carbonate Aquifer Impacts MRSA Flows; Pumping from the Alluvium Impacts Muddy River Surface Flows.

Virtually all parties agree with MVWD that pumping from the carbonate aquifer will have impacts on the MRSA, and pumping from the alluvial aquifer will directly capture Muddy River surface flows and impact senior decreed water rights.[42] The FWS stated that decreasing pumping from alluvium will reduce capture of surface flows.[43] NV Energy agreed that alluvial pumping does not affect the MRSA, but captures Muddy River surface flows.[44] While CSI attempted to pinpoint the source of MRSA depletions at Arrow Canyon, it ultimately agreed that carbonate wells impacted the MRSA and alluvial wells have a direct impact on surface flows.[45]

None of the parties appeared to believe that moving pumping from the carbonate aquifer to the alluvial aquifer, or the inverse of that, would do anything to protect both spring or river flows. In discussing the possibility of moving pumping from alluvial wells to the carbonate aquifer, the NPS stated that there might be a small delay in impacts to Muddy River flows, but the net change will be zero.[46] SNWA stated that "it doesn't matter where you move it. You may change the timing of impacts, but impacts will still occur to the Muddy River Springs and senior decreed

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[40] Transcript, Vol. X, p. 1791:15-19 (Felling) (noting that Warm Springs West flows are just over 3.2 cfs under current pumping levels, and "[t]here is no room for additional stresses").
[41] Transcript, Vol. II, p. 1002:5-9 (Burns); Slide 46.
[42] MVWD Report, p. 4.
[43] USFWS/TetraTech Report at p. 23.
[44] Transcript, Vol. X, p. 1812:17-21 (Felling) (calling the connectivity of the alluvium and the river "very clear").
[45] Transcript, Vol. I, p. 97:15-20 (Reich)
[46] NPS Slide 74.

water rights."[47] SNWA continued that changing points of diversion to move groundwater production from the MRSA alluvial aquifer to locations sourced by the carbonate aquifer will not mitigate impacts, only delay their inevitable occurrence.[48] FWS argued that because (after spring flows) the remainder of water in the river comes from alluvium adjacent to the river in the MRSA and California Wash, alluvial pumping should not be increased (e.g., in exchange for reductions in carbonate pumping elsewhere), even if total alluvial and carbonate pumping is maintained at a "sustainable" overall level.[49] The Moapa Band of Paiutes noted that "the majority of River flow begins as seeps from the gravel aquifer that are impacted by alluvial-aquifer pumping," so increased alluvial pumping will impact surface water flows.[50]

E. The State Engineer Must Consider MVWD's Legal Obligation to Serve its Customers, as well as Risks Assumed by CSI and Lincoln/Vidler, when Determining how to Manage the LWRFS.

As one of the oldest communities in southern Nevada, MVWD's ability to serve its customers must be preserved. There are approximately 8,500 people who live in MVWD's service area, including the entirety of the Moapa Band of Paiutes' reservation. Those customers rely on a reliable source of water to sustain their community—water that MVWD pumps from the carbonate aquifer at Arrow Canyon. To protect the customers of MVWD, certificated rights—those for which beneficial use has been documented with the State Engineer—must be prioritized above permits that have not been pumped. MVWD has been beneficially using its water to serve its customers since before CSI even considered developing a community in Coyote Springs Valley.

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[47] Transcript, Vol. V, p. 877:5-8 (Pellegrino).
[48] SNWA Slide 47.
[49] FWS Report, p. 4.
[50] *Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development* ("MBOP Report"), at p. 24.

In the same vein, both CSI and Lincoln/Vidler were aware of the severe water shortage in the area when plans for the development in Coyote Springs Valley began. They assumed the risk of their investments, and those investments should not inform any decisions that the State Engineer will make relating to LWRFS management.

III. CONCLUSION

Although the evidence and conclusions presented in response to the questions posed by the State Engineer in IO 1303 by the stakeholders are inconsistent, there is consensus among many stakeholders on multiple issues.

i. Kane Springs Valley is connected to and should be included in any LWRFS management area.

ii. The carbonate aquifer is at or nearing equilibrium at current pumping levels; while pumping might require a slight downward adjustment as more data becomes available, increased carbonate pumping must not be allowed.

iii. To protect surface water flows, alluvial pumping should not be increased.

iv. Proven and certificated existing uses should be prioritized over long-unused permitted rights.

Future LWRFS management decisions should be made pursuant to those principles.

DATED: December 3, 2019.

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CERTIFICATE OF SERVICE

I certify that I am an employee of Parsons Behle & Latimer and that on the 3rd day of December, 2019, I caused a true and correct copy of the foregoing document to be delivered via email to the following:

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IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219). LINCOLN AND CLARK COUNTIES, NEVADA.	**INTERIM ORDER 1303**

MUDDY VALLEY IRRIGATION COMPANY
POST HEARING CLOSING STATEMENT

Pursuant to the direction of this Nevada Division of Water Resources' Hearing Officer at the close of the hearings on October 4, 2019, the Muddy Valley Irrigation Company ("MVIC") files its Post Hearing Closing Statement.

I
Introduction

Pursuant to an Amended Notice of Hearing dated August 26, 2019, hearings were held in Carson City, Nevada from September 23, 2019 through October 4, 2019 relative to Interim Order 1303. Though not in the nature of an adversarial or adjudicatory proceeding at said hearings the Hearing Officer accepted into evidence the participant's July 3, 2019 Reports, August 16, 2019 Rebuttal Reports, Exhibits, Power point handouts (for demonstrative purposes) and heard participant witnesses direct examination and cross examination. Fourteen participants presented testimony by a witness or witnesses over the ten days of hearings regarding the matters presented in Interim Order 1303 including MVIC. Accordingly, MVIC's Closing Statement relies on and references the evidence heard and entered into the record of the Interim Order 1303 proceedings.

To briefly restate for the record, MVIC is a Nevada corporation which has been in existence since 1895 and it owns the majority of Muddy River decreed surface water rights adjudicated in Muddy Valley Irrigation Company v. Moapa and Salt Lake Produce Company et al. ("Muddy River Decree"). MVIC's water rights were appropriated and placed to beneficial use prior to 1905 and they are senior in priority to all Nevada groundwater rights within the Lower White River Flow System ("LWRFS"). The Muddy River Decree Court determined the Muddy River and all of its sources of supply to be fully appropriated and ruled that MVIC is entitled to divert and use all Muddy River waters, not otherwise adjudicated to the other parties whose relative rights to the use of Muddy River water were also confirmed in the Decree. MVIC entered into evidence its Rebuttal Report on August 15, 2019 and presented the witness testimony of MVIC President Todd Robison at the hearings which presented these facts in more comprehensive detail.

At the hearings substantial evidence was offered that confirmed that groundwater pumping within the LWRFS, whether in the carbonate or alluvial aquifers causes reduced Muddy River and Muddy River spring flows. The Decree Court determined that the relative rights of MVIC and the other parties to the Muddy River Decree exhausts all of the available flow of the Muddy River, its head waters, sources of supply, springs and tributaries. Because substantial evidence demonstrated that groundwater pumping within the LWRFS captures and decreases spring and river flows, said evidence demonstrated and confirmed that LWRFS groundwater pumping conflicts with MVIC's senior decreed surface water rights.

II
MVIC's Surface Waters Rights are Senior in Priority to all LWRFS Groundwater Rights and the Muddy River Decree Court Confirmed the Muddy River and all its Sources to be Fully Appropriated

Interim Order 1303 cites foundational Nevada prior appropriation water law precepts to the questions considered relative to groundwater pumping within the LWRFS and MVIC's senior surface water rights. Specifically, Interim Order 1303 at page 7 noted that:

> "...the Muddy River, a fully appropriated surface water source, has its headwaters in the Muddy River Springs Area and has the most senior rights in the LWRFS. Spring discharge in the Muddy River Springs Area is produced from the regional carbonate aquifer. Prior to

groundwater development, the Muddy River flows at the Moapa gage were approximately 34,000 acre-feet annually."...and...

"...the State Engineer has determined that pumping of groundwater within the LWRFS has a direct interrelationship with the flow of the decreed and fully appropriated Muddy River, which has the most-senior rights."

At page 10 Interim Order 1303 additionally stated:

"...NRS 533.024(1)(e) was added in 2017 to declare the policy of the State to "manage conjunctively the appropriation, use and administration of all waters of this state regardless of the source of the water".

MVIC asserts that the above statements in Interim Order 1303 necessarily must be read in the broader factual and legal context presented to and decided by by the Muddy River Decree Court. The Court considered the relative water rights of MVIC and the defendant party appropriators in and to the waters flowing from the large group of springs which is the source of supply and head water of the Muddy River stream system. Today this source of supply is known as the Warm Springs or Muddy River Springs Area ("MRSA"). The Court held in 1920 that all of the water sources of the Muddy River and flows thereof were fully appropriated and consumed and the water rights allocated were and are entitled to protection from capture and depletions by other parties.

Importantly as the threshold matter in these Interim Order 1303 proceedings the current State Engineer should reaffirm the legal parameters set by the Nevada Decree Court on March 20, 1920. There the Nevada District Court, pursuant to Nevada law, authorized and accepted State Engineer J. G. Scrugham's Final Order of Determination dated January 21, 1920 and his Further and Supplemental Order of Determination dated March 11, 1920 in adjudicating the rights to the Muddy River. The Court held that the pre 1905 water rights adjudicated to MVIC and the other users are fully consumptive of all sources of supply of water to the Muddy River springs and Muddy River flows. Thus any evidence of reduced flows to either and any sources of supply by groundwater pumping creates a conflict with MVIC's rights.

As above stated MVIC was incorporated for purposes which include the acquisition of water rights and for the construction operation and maintenance of their associated irrigation works of diversion and distribution for MVIC's shareholders and others for the beneficial use of Muddy River water within the Moapa Valley.

The Muddy River Decree determined that with the exception of the rights of the other named defendants, that MVIC is the holder of all rights in the Muddy River and all of said water rights are vested rights acquired by valid appropriation and beneficial use prior to March 1, 1905. That they are also considered as equal in rank without one having priority over any other, that the Muddy River is to be operationally divided into two parts (as far as practicable) the upper and the lower, and that the Muddy River is fully adjudicated; specifically holding:

> "Muddy Valley Irrigation Company is declared and decreed to have acquired by valid appropriation and beneficial use and to be entitled to divert and use... all of the waters of said Muddy River, its head waters, sources of supply and tributaries said water sources, supply save and accept the several amounts and rights hereinbefore specified and described as awarded and decreed...". page 20, par 7.

Not only did the Court hold that MVIC owns all the water rights not decreed to others, but that the Company is to divert all those waters for the use of the shareholders. The Court provided for the State Engineer to supervise the Muddy River with the administration and control of the lower Muddy River provided by MVIC:

> "The Muddy Valley Irrigation Company, although under the supervision and control of the state engineer and commissioner shall subject to said supervision and general control, distribute and control the distribution of the waters diverted and conveyed by its works to its stockholders and other persons obtaining waters by means thereof." page 21, par 9,

and further:

> "That the aggregate volume of the several amounts and quantities of water awarded and allocated to the parties...**is the total available flow of the said Muddy River and consumes and exhausts all of the available flow in the said Muddy River, the head water, sources of supply and tributaries.",** (emphasis added) page 22-23, par 12.

Additionally in the above referenced Further and Supplemental Order of Determination (incorporated by the Court as Exhibit B to the Decree), State Engineer Scrugham further identified the source of waters appropriated and protected by the Muddy River Decree from subsequent use or depletion where in a section with reference to the Baldwin Springs flow but not otherwise limited he held:

> **"No further development of water on the head of the Muddy River stream system shall be made which in any way diminishes the flow of waters of the Muddy River or impairs rights defined and referred to in this order."**, (emphasis added) at page 3.

The above restated history of MVIC's senior surface water rights adjudicated and protected by the Muddy River Decree (said evidence also found in MVIC's Rebuttal Report/Exhibit No.1 and in Mr. Robison's testimony) is provided as additional support for the State Engineer's recognition of the Muddy River Decree Court adjudication which set the baseline legal protections for MVIC's interests with respect to LWRFS groundwater pumping determinations in this proceeding."

III
Substantial Evidence Was Introduced at the Hearings Which Confirms that Groundwater Pumping Depletes Muddy River Flows Which Water Was Fully Appropriated to MVIC and Others in the Muddy River Decree

In MVIC Exhibit No. 1/Rebuttal Report in answer to Interim Order Question MVIC offered the following:

> "MVIC concurs with the technical analysis and conclusions in the SNWA Report at Section 8.2-8.4 where SNWA states that
>
> groundwater production in the MRSA and to a lesser extent the rest of the LWRFS has depleted Muddy River stream flows and thus conflicts with Muddy River Decree senior surface water rights."

Many of the hearing participants offered written evidence and witness testimonies that focused on whether Muddy River spring flows have stabilized or reached a steady state since the Order 1169 aquifer pump tests ended and from there moved to analysis and conclusions as to what amount of carbonate and alluvial pumping is a "sustainable" level or yield within the LWRFS. MVIC respectfully notes that this kind of evidence, thought germane to better understanding the hydrologic connectivity between Muddy River flows and LWRFS groundwater development is not responsive to the threshold questions concerning harm to senior decreed water rights which Interim Order 1303 requests answers to.

Witness testimony by Nevada Cogeneration Associates (portion of Black Mountain Basin), City of North Las Vegas (portion of Garnet Valley Basin) and Bedrock (discrete alluvial aquifer in Coyote Springs Valley Basin) argued that at very specific locations within the LWRFS some groundwater pumping can occur without depleting the Muddy River. No participant disputed the general conclusion that groundwater production within the MRSA and to a lesser extent the rest of the LWRFS (except as noted in the above sentence) is depleting Muddy River stream flows.

Some concise examples of evidence in this regard follow.

Coyote Springs Investment witness Dr. Stephen Reich on cross examination by SNWA when questioned on whether alluvial pumping in the MRSA affected Muddy River flows answered "yes". When questioned on whether carbonate pumping affected Muddy River flows Dr. Reich answered "yes". When questioned on whether pumping in the Coyote Springs Valley at the MX5 well affected Muddy River spring flows Dr. Reich answered "yes".

U.S. Fish and Wildlife Service witness Dr. Tim Meyer on cross examination by SNWA when asked agreed that pumping in the LWRFS affects flows of the Muddy River and Muddy River spring flows.

U.S. Fish and Wildlife witness Ms. Sue Braumiller on cross examination by the Center for Biological Diversity when asked if carbonate pumping reduces Muddy River spring flows and causes depletions in the Muddy River spring flows answered "yes".

U.S. National Park Service witness Dr. Richard Waddell in his testimony (while referring to his power point at page 28) concerning the question on what the long-term quantity of pumping within the LWRFS, or an acceptable rate of capture of Muddy River sources of supply should be, offered the dispositve answer which one would expect by the Decree Court if presented with this question and likewise by the State Engineer when protecting the senior decreed water rights from depletion. His answer to this question and here I paraphrase, went along the lines of:

> "... someone needs to set a limit and that might be to protect senior water rights...to me that sounds reasonable."

Southern Nevada Water Authority witness Ms. Colby Pellegrino's testimony supported the technical analysis found in SNWA's July 3, 2019 Report which concluded that no quantity of alluvial or carbonate long term pumping within the LWRFS could occur without conflicting with Muddy River senior decreed water rights.

City of North Las Vegas witness Mr. Dwight Smith testified that he believes there is an amount of pumping, in the Apex area, within the Garnet Valley that can occur without effecting the flows at the higher springs to the Muddy River. Interestingly in reaching this conclusion his review appears to have been based, at least in some respect, by a subtle shifting of the question of pumping to a "safe yield" analysis, instead of the relevant legal question of whether LWRFS pumping conflicts with senior rights. He also testified however that capture of Muddy River flows overwhelmingly occurs from alluvial and carbonate pumping locations in close proximity to the Muddy River and the Muddy River Spring Area.

The Center for Biological Diversity witness Dr. Tom Myers testified that no carbonate pumping within the LWRFS should be allowed because there is a direct correlation between carbonate pumping and decreased spring flows in the MRSA.

NVEnergy witness Mr. Richard Felling testified that pumping from the carbonate aquifer anywhere in the LWRFS will capture Muddy River flows.

IV
Because the Muddy River Decree Court Ruled in 1920 that the Muddy River and all of its Sources of Supply are Fully Appropriated and Protected Against Impairment and Depletion, the State Engineer's LWRFS Groundwater Development Analysis is Limited as a Matter of Law

The State Engineer is obliged to uphold and enforce Nevada water law. Nevada is a strict prior appropriation water law state for both surface and groundwater appropriations and conflicts.

NRS 533.024(1)(e) declares it to be the policy of the State of Nevada to "manage conjunctively the appropriation, use and administration of all waters of this State regardless of the source of the water". NRS 533.024(1)(c) directs the State Engineer "to consider the best available science in rendering decisions concerning the availability of surface and underground sources of water in Nevada."

Substantial evidence was placed on the record in these proceedings which confirmed, using the best available science, that groundwater pumping in the LWRFS captures and depletes the water supply of the Muddy River. Said groundwater pumping is occurring under Nevada underground water rights which are all junior in priority to MVIC's senior decreed surface water rights.

The Muddy River Decree protects against any impairment of the water rights adjudicated therein, specifically forbidding capture and depletion of said water rights' sources of supply.

In the absence of an agreed upon conjunctive management plan, acceptable to the owners of Muddy River Decree senior surface water rights including MVIC, Nevada law provides limited options to the State Engineer (other than curtailment) where a clear conflict and impairment of senior rights has been determined. MVIC made this observation earlier in its Rebuttal Report.

V
Conclusion

Substantial and uncontradicted evidence presented in these proceedings and the hearings therefor clearly confirmed two things; first that groundwater pumping in the LWRFS is depleting Muddy River flows and second that all of said Muddy River flows are absolutely protected against said depletions by the water allocations and determinations made in the Muddy River Decree.

Respectfully submitted this 2rd day of December, 2019

Muddy Valley Irrigation Company

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CERTIFICATE OF SERVICE

I certify that I, Steven D. King, on this date, caused a true copy of **MUDDY VALLEY IRRIGATION COMPANY POST HEARING CLOSING STATEMENT,** to be served on all parties to this action by emailing an attached copy of the document to the email addresses below:

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Dated this 3rd day of December, 2019.

Steven D. King
STEVEN D. KING

United States Department of the Interior

OFFICE OF THE SOLICITOR
Pacific Southwest Region
San Francisco Field Office
333 Bush Street, Suite 775
San Francisco, CA 94104

IN REPLY REFER TO:

December 2, 2019

Tim Wilson, P.E., Acting State Engineer
Nevada Division of Water Resources
901 S. Stewart Street, Suite 2002
Carson City, Nevada 89701-5250

Subject: Closing Statements in Response to Interim Order 1303

Dear Mr. Wilson:

On behalf of the National Park Service (NPS), and at the invitation extended by Ms. Micheline Fairbank on the last day of the Interim Order 1303 administrative hearing, I am submitting the NPS' closing statements in response to Interim Order 1303. The closing statements provided are intended as a summation of the main "take home" issues and findings important to the NPS. We hope this summary is useful as your staff prepares to evaluate the considerable information that has been presented and formulate a final order related to the conjunctive management of surface water and groundwater resources in the Lower White River Flow System (LWRFS) administrative unit.

The NPS appreciates the opportunity to provide these closing statements to your office and to work with you and the other interested stakeholders to determine how best to manage these public resources. If you or your staff have any questions or need further information, please contact me (415-296-3381) at your convenience.

Sincerely,

Karen Glasgow
Field Solicitor
San Francisco Field Office
Office of the Solicitor
Department of the Interior

CLOSING STATEMENTS
INTERIM ORDER 1303 HEARING TESTIMONY

Prepared by the National Park Service in cooperation with Tetra Tech, Inc.

The National Park Service (NPS) appreciates the opportunity to participate in the Interim Order 1303 hearing process and to provide the Nevada State Engineer (NSE) and staff with some closing statements for final consideration. The closing statements provided below are intended to leave the NSE with a summation of the main "take home" issues and findings important to the NPS, as the NSE prepares to evaluate the considerable information that has been presented and formulate a final order related to the conjunctive management of surface water and groundwater resources in the Lower White River Flow System (LWRFS) administrative unit.

Inclusion of the Black Mountains Area within the LWRFS Geographic Boundary.

The NPS is the only stakeholder holder who has requested that all of the Black Mountains Area basin be included in the geographic boundary of the LWRFS administrative unit being considered by the NSE. Based on the information contained in the NPS reports that were submitted to the NSE, as well as testimony presented by Dr. Richard Waddell at the hearing, the NPS believes that there is sufficient scientific evidence to conclude that a considerable portion of the flow issuing from Rogers Spring, Blue Point Spring and several other springs in the same vicinity is derived from carbonate-rock aquifer groundwater moving to the east-southeast beneath Garnet Valley, California Wash and the Black Mountains Area. This evidence includes:

- *Favorable geologic conditions exist allowing for carbonate groundwater flow beneath the Muddy Mountains.* Although the Muddy Mountain thrust fault superposes permeable Paleozoic carbonate rocks in the upper plate over less permeable Mesozoic rocks in the lower plate, the overprinting of the thrust fault by Cenozoic faults in certain areas provides linkage between rocks in the upper and lower plates, thereby allowing for some groundwater flow across the thrust fault in both the upper and lower plates. One area where this linkage likely has been created by Cenozoic faulting is the upper plate area extending from the west side of the Muddy Mountains to the Rogers Spring and Blue Point Spring area on the east side of the Muddy Mountains, which is overprinted by the Arrowhead Fault and other smaller faults.
- *Spring chemistry and isotopic composition can be explained by water mixing and rock-water reactions along the pathways.* The groundwater discharging from Rogers Spring and Blue Point Spring has a stable isotopic signature that suggests a substantial contribution from the carbonate aquifer. Geochemical modeling indicates that the stable isotopic composition of these springs requires the mixing of the lighter isotopic carbonate aquifer groundwater with heavier isotopic local recharge water. The higher content of dissolved solids and major ions at Rogers Spring and Blue Point Spring likely is attributable to dissolution of evaporite minerals as groundwater flows through the Mesozoic rocks, Tertiary volcanic rocks, and/or Tertiary basin-fill sediments present in the Muddy Mountains.

- *Favorable hydraulic head conditions allow for carbonate groundwater flow beneath the Muddy Mountains.* Recent potentiometric surface mapping of the upper carbonate-rock aquifer in southern Nevada indicates an east-southeast flow direction through Garnet Valley, California Wash and the Black Mountains Area toward the NPS' springs. This recent groundwater level data also indicates the presence of a significant head differential (100 to 190 feet) that is sufficient to sustain groundwater flow beneath the Muddy Mountains area.

We would like to address an observation that was made by Mr. Jon Benedict of the NSE's staff during cross examination of Dr. Waddell that groundwater temperatures in several of the carbonate aquifer wells in Garnet Valley are cooler than the water temperatures measured at Rogers Spring and Blue Point Spring (approximately 30° to 31° C), suggesting that the Garnet Valley-California Wash pathway may not be the source of water to these springs. At that time, Dr. Waddell did not have readily available temperature data to be able to make an informed reply. Subsequent examination of temperature data, which is contained in Table 1 of Appendix A of the NPS' July 3, 2019 data report, indicates that there are at least two (2) existing wells (RW-1 and G.P. Apex) in Garnet Valley, and three (3) other periphery wells in western California Wash (ECP-1 & ECP-2) and western Black Mountains Area (EBM-4), respectively, with measured groundwater temperatures similar to these two springs. Therefore, this pathway cannot be discounted as a primary source of water to Rogers Spring and Blue Point Spring, based solely on small temperature differences in a few wells.

Another factor that should be considered in explaining water temperature differences between these springs and some of the groundwater wells in Garnet Valley and California Wash relates to the potential warming of the groundwater from a nearby Tertiary volcanic center located on the north shore of Lake Mead, south of the Rogers Spring area. Similar to the volcanic caldera complexes in Kane Springs Valley that are believed to provide a remnant heat source to warm the groundwater temperature (57° C) observed in well KMW-1, these Tertiary volcanic rocks may be providing a remnant heat source to groundwater flowing toward Rogers Spring and Blue Point Spring, thus warming water temperatures before discharging at the surface. This instance of remnant heating is believed to be similar to the case of Tertiary volcanic centers located further south in the Black Canyon area below Hoover Dam, which are likely responsible for several hot springs in the canyon, where water temperatures ranging from 36° to 56° C have been measured.

Some of the other participating stakeholders (SNWA and NV Energy) provided supporting statements in their reports and/or testimony that some amount of carbonate groundwater in the LWRFS bypasses the Muddy River Springs Area (MRSA) and flows toward Lake Mead. Although these parties did not endorse the incorporation of the rest of the Black Mountains Area into the LWRFS, NV Energy's expert (Mr. Richard Felling) raised important questions that were never answered about how the partial exclusion of a hydrographic area (such as the Black Mountains Area) from the LWRFS would be managed by the NSE. Specifically, would the unincorporated (weakly connected) portion of a hydrographic basin become a new (or reconstructed) basin with a revised perennial yield?

In conclusion, there is a hydraulic connection between Rogers Spring and Blue Point Spring, and the carbonate aquifer beneath California Wash and Garnet Valley, and thus with the carbonate aquifer in up-gradient areas. The NPS recognizes these spring areas are weakly connected to up-gradient portions of the LWRFS due to the lower permeability of the intervening geology in the Muddy Mountains area. Even though this hydraulic connection is weaker than other areas of the LWRFS, the NPS believes it is necessary to incorporate the rest of the Black Mountains Area basin into the boundary of the LWRFS for purposes of protecting the NPS' state appropriative and Federal reserved water rights at these springs. It is worth reiterating that the NPS has a state appropriative water right at Rogers Spring with a priority date of February 16, 1937, which is senior to all other groundwater rights in the currently defined LWRFS, with the exception of the rights held by Bedroc Limited, LLC in Coyote Spring Valley. By excluding the rest of the Black Mountains Area from the LWRFS, the NPS is concerned that if our springs are adversely affected by up-gradient junior groundwater users in the LWRFS basins, the NPS' ability to claim injury will be substantially reduced if the NSE does not recognize this hydraulic connectedness.

In order to increase the potential success of future conjunctive water resources management , the NPS recommends that the NSE include all existing hydrographic areas within the final LWRFS administrative unit where a hydraulic interconnection (strong to weak) between surface water and groundwater can be reasonably demonstrated within any portion of the hydrographic areas being considered. This approach will allow appropriate management decisions to be made for designated sub-regions with differences in hydraulic connectedness that are contained within the final LWRFS boundary, thereby eliminating the need to create new hydrographic areas from the remnants of areas that were not fully incorporated into the final LWRFS administrative unit. As more information becomes available on the different degrees of hydraulic connectedness (or lack thereof) within a given hydrographic area, these designated sub-region boundaries can be modified, and appropriate management conditions and approaches can be applied to these different sub-regions accordingly.

Inclusion of Kane Springs Valley within the LWRFS Geographic Boundary.

It is noteworthy that in the data reports and rebuttal reports submitted to the NSE, Kane Springs Valley was recommended most often for inclusion into the LWRFS, with recommendations provided by the NPS, U.S Fish & Wildlife Service (USFWS), Moapa Valley Water District (MVWD), the Center for Biological Diversity (CBD), the Southern Nevada Water Authority (SNWA) and Nevada Cogeneration Associates (NCA). In all cases, the prime reason stated for including this basin within the LWRFS was the hydrologic connection between this basin and Coyote Spring Valley, which was established by the distinct and unambiguous pumping response that is seen in the hydrographs for wells CSVM-4 and KMW-1 during the Order 1169 pumping test period.

Although Lincoln County/Vidler collected useful geophysical data to define subsurface geologic structures such as the high resistivity carbonate block near the mouth of Kane Springs Valley, their contention that this block acts as a significant impediment to groundwater flow in this region should not be accepted at face value alone without additional corroborating evidence. The geophysical method that was used detects changes in the electrical conductivity of rocks, but it does not provide a measure of the hydrologic properties of the rocks. Therefore, it should not be assumed that high resistivity values necessarily equate to intra-fault blocks having low permeability without adequate aquifer testing and evaluation of hydraulic gradients across the fault blocks to substantiate the resistivity data. The NPS believes the attenuated Order 1169 pumping test response expressed in the hydrographs for wells CSVM-4 and KMW-1 proves that this carbonate block and associated faults do not significantly impede groundwater flow in this area. Although the NPS and others testified that the aquifer transmissivity appears to be lower in this area than throughout much of the LWRFS, the hydrologic evidence conclusively establishes that this area is hydrologically connected to the LWRFS. Additionally, the other lines of evidence proffered by Lincoln County/Vidler, such as differences in water levels, water chemistry and water temperatures in the area, when viewed in proper context, tend to support the hydrologic connection of Kane Springs Valley with the LWRFS.

Finally, of particular significance was the testimony of several former employees of the Nevada State Engineer's office, which strongly support the incorporation of Kane Springs Valley into the LWRFS. Former State Engineer, Hugh Ricci and former Deputy State Engineer, Robert Coache, who were directly involved in establishing Order 1169 and permitting Lincoln County/Vidler's existing water rights in Kane Spring Valley, both testified that in hindsight, if they had the current hydrogeological data available to them when deciding which basins to include under Order 1169, they would have included Kane Springs Valley under the order. Similarly, former Deputy Administrator and Chief of the Hydrology Division, Richard Felling, after initially taking the position in NV Energy's rebuttal report that Kane Springs Valley should not be included in the LWRFS joint management area, subsequently testified that he found that the scientific and technical evidence presented in the reports and at the hearing was so compelling that he was convinced of the need to include Kane Springs Valley into the joint management area.

Groundwater Level Trends in the LWRFS.

Within the carbonate aquifer in the LWRFS basins, there has been a trend of declining water levels observed for at least two decades. Many hydrologists have attributed this decline to drought conditions. However, this interpretation does not take into account that water levels have been rising in many other areas in southern Nevada. The NPS and USFWS presented numerous examples of groundwater hydrographs in their rebuttal reports that clearly show that water levels have been rising for several decades in southern Nevada in areas where groundwater production is absent or minor. The fact that there are numerous examples of rising groundwater levels in neighboring basins to the west, south, east and north of the current LWRFS basins suggests that the LWRFS basins also would have been affected by rising groundwater levels during the same period of time reflected in the water level records in these valleys. With the exception of one objection to the NPS' presentation of this information during the hearing, it's noteworthy that no other stakeholder testimony was presented to refute that rising groundwater levels have been occurring throughout much of southern Nevada for several decades.

In the LWRFS basins, where groundwater pumping has been occurring throughout much of this same period, groundwater levels have been on a decline. This decline only can be explained by the pumping occurring in the LWRFS basins and not by current drought conditions that may or may not be occurring. The groundwater pumping in the LWRFS has been of sufficient magnitude to overwhelm the rising water level response that likely would have been widely observable in the LWRFS basins in the absence of any pumping. Even though a significant reduction in alluvial pumping in the MRSA since 2015 has resulted in noticeable recovery of groundwater levels and spring discharge in the MRSA, continued pumping at current levels still appears to be limiting (or extending the period to) full recovery from the pumping effects observed from the Order 1169 pumping test.

If the amount of recent pumping has been sufficient to overwhelm the rising water level trend and create the observed water level declines, then there are more serious management implications ahead when the current period of wetter conditions reverts to a period of drier conditions. If the recent amount of pumping is allowed to continue, then this declining trend will be exacerbated not only for groundwater levels, but also for spring and river discharges in the MRSA and elsewhere in the LWRFS during an extended period of drier conditions. Conjunctive management in the LWRFS should factor in long-term monitoring of groundwater levels in several surrounding basins that are distant from pumping in the LWRFS basins to gauge the real-time climatic response being transmitted through the aquifers in southern Nevada. Such information could then be used to adjust the amounts of permissible groundwater pumping in order to prevent injurious declines in groundwater levels, and spring and river discharges.

The Relationship of Pumping Location on the Capture of Spring and River Flows.

The NPS was the only stakeholder to provide a robust qualitative evaluation of the possible effects on spring and river flows from the redistribution of groundwater pumping within and between the carbonate and alluvial aquifers in the LWRFS. This evaluation was achieved using the current version of the Tetra Tech groundwater flow model and the same total annual pumping rate that occurred during the Order 1169 pumping test period for each of the simulations conducted. The simulation results indicated that pumping at approximately 14,535 afy under several different pumping configurations caused similar declines in discharge in the MRSA area over time, thus indicating to the NPS that the annual sustainable quantity of groundwater available is less than 14,500 afy. Similar modeling simulations conducted at lower pumping rates, coupled with long-term water level and discharge monitoring, may help to ascertain what this annual sustainable quantity may be.

The simulations indicated that there would be short-term benefit on the flows of the Muddy River Springs and the Muddy River from moving greater amounts of alluvial and/or carbonate withdrawals from the northern basins into the southern basins. The similarity in the results from all three simulations over time appears to refute some stakeholder contentions that redistributing pumping further away from the MRSA would permit more groundwater to be withdrawn without adversely affecting senior rights. The simulations also revealed that moving greater amounts of pumping closer to the NPS' springs would raise the likelihood of adverse impacts to these springs over time.

Although it has been suggested that decreasing pumping from the Muddy River alluvium would reduce the capture of the surface flow and result in having more surface water available to satisfy downstream decreed water rights, the simulations indicate that this increase is not enough to fully offset the reduction in surface flow that is predicted in later years. Moving greater amounts of pumping further away from the MRSA and from the alluvial aquifer to the carbonate aquifer delays impacts by a few decades, but does not eliminate subsequent injurious effects. Ultimately, the degree of hydraulic connectedness will be a primary factor in determining whether relocating pumping will be effective in minimizing injurious effects to senior surface water rights.

IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219).

Post-hearing brief of Nevada Cogeneration Associates Nos. 1 and 2 pertaining to Amended Notice of Hearing Interim Order #1303 following the hearing conducted September 23, 2019, through October 4, 2019, before the Nevada State Engineer

Nevada Cogeneration Associates Nos. 1 and 2 (collectively "NCA," and separately "NCA 1" and "NCA 2"), provides the following post-hearing brief for consideration by the Nevada State Engineer following the completion of the Phase 1 hearings in the above referenced matter involving the Lower White River Flow System ("LWRFS"), which hearings were conducted over a two-week period from September 23, 2019, through October 4, 2019. This brief is presented on behalf of NCA by counsel for NCA, Alex J. Flangas of the firm of Kaempfer Crowell, with the assistance of Mr. Jason M. Dixon, P.E. (Dixon Hydrologic, PLLC), Mr. Robert A. Coache, P.E., and Mr. Hugh Ricci, P.E. both of whom are working in conjunction with Mr. Dixon through Dixon Hydrologic PLLC.

Background: Interim Order #1303 acknowledges in the first paragraph on page 1 that the "purpose of this Interim Order *is to designate a multi-basin area* ***known to share a close hydrologic connection*** *as a joint administrative unit,* which shall be known as the Lower White River Flow System." The third full paragraph on page 1 of Interim Order #1303 then expressly ended up defining the scope of the Phase 1 hearings and their purpose:

> … during the interim period that this Order is in effect, holders of existing rights and other interested parties are encouraged to submit reports to the Nevada Division of Water Resources (NDWR) analyzing the data available *regarding sustainable groundwater development in the LWRFS*, the *geographic extent of the LWRFS*, and considerations relating to groundwater pumping *within the LWRFS* and *its effects on the fully decreed Muddy River*. This collected and analyzed data is an essential step to optimize the beneficial use of the available water supply in the LWRFS.

(Emphasis added.) The concluding paragraphs of Interim Order #1303, at pages 13 and 14, further clarified the points to be included in the "reports," stating:

Reports filed with the Office of the State Engineer should address the following matters:

a. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System;
b. The information obtained from the Order 1169 aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test;
c. The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;
d. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and
e. Any other matter believed to be relevant to the State Engineer's analysis.

The first four of those points – (a) through (d) -- became the focus *and the limitation* of the Phase 1 hearings, as outlined in the State's Amended Notice of Hearing issued August 26, 2019, and as reiterated several times by Deputy Administrator Micheline Fairbank during the hearing.

During the hearing, NCA focused its presentation on essentially two of the four elements that were at issue: items (a) the geographic boundary of the LWRFS; and item (c) the long-term annual quantity of groundwater (*sustainable groundwater development)* that may be pumped from the LWRFS. Some discussion was had on the other points, but this brief will focus primarily on those two elements, as they are the main post-hearing points to which NCA will direct the State Engineer with some focus on testimony and evidence that was presented to clarify those points – especially as they affect NCA's interests in this proceeding.

1. The Evidence and Analysis presented to the State Engineer strongly suggests that the Geographic Boundary of the LWRFS may need to be adjusted in two areas:
   a. to *exclude* the NCA production wells in the Black Mountains Area, and
   b. to *include* the Kane Springs Valley Basin in the LWRFS.

A. <u>Evidence supports excluding NCA's production wells from the LWRFS.</u>

(i) <u>SNWA's experts agree that "the Black Mountain area production wells probably should not be within the Lower White River Flow System boundary."</u>

Significantly, a primary source of initial analysis for the conclusion that the NCA production wells are likely *outside* the boundary of the LWRFS came not directly from NCA's experts, but rather from other experts who independently reached the conclusion that NCA's production wells did not appear to be connected to the LWRFS system. The significance of this independent determination should not be minimized.

Southern Nevada Water Authority ("SNWA") presented an August 13, 2019, rebuttal report entitled, "Response to Stakeholder Reports Submitted to the Nevada State Engineer with Regards to Interim Order 1303."[1] The authors of that report emphasize that carbonate wells *inside* the LWRFS demonstrate impacts on wells near the Muddy River Springs Area ("MRSA"), whereas other wells appear unconnected suggesting the boundary in that area is likely "off."

The SNWA authors initially comment at page 2 of their Rebuttal Report that the data they have observed, "do not support interpretations of hydraulically-isolated flow paths, capture zones, or structural blocks *within the LWRFS." (Emphasis added here.)* Rather, say the authors, assertions that blocks of carbonate rock "within" the LWRFS can be hydrologically isolated is erroneous, as is demonstrated by the significant evidence of responses shown through their multiple linear regression ("MLR") analysis of well response data. For most locations, that data demonstrates a close connection between the pumping from the various basins and a particular well located near the MSRA that was used for the analysis – that being EH-4.

As was explained by both SNWA and Jay Dixon during NCA's testimony, that MLR analysis partitioned the EH-4 hydrograph into several hydrographs of responses to groundwater production from each of the five LWRFS basins. It demonstrated close connections at several locations; indeed, for the period 2006 through 2019, the hydrographs for CSVM-2 and CSVM-1 (Coyote Springs Valley), UMVM-1 (Muddy River Springs Area), and GV-1 (Garnet Valley) all virtually mirror the hydrograph for EH-4 (Muddy River Springs Area).[2] Notably, however, that same MLR analysis produced a significantly *different* result when it was applied to the production wells in the Black Mountains Area ("BMA").

SNWA's Rebuttal Report discusses the MLR at pages 15-20 and specifically recognizes at p.17 that a strong correlation applies between EH-4 in the MSRA and a monitoring well located in the Black Mountains Area, BM-DL-2, that showed an extremely high correlation value (R^2 of 0.95), but no such correlation was found to exist in connection with the NCA wells. The authors concluded, "[t]his indicates that while well BM-DL-2 is undoubtedly within the carbonate aquifer of the LWRFS, ***the current production wells (Figure 2-8) are probably not.***" (Emphasis added.) At the hearing, when Ms. Warda Drici, the lead hydrologist who co-authored the SNWA Rebuttal Report, was asked, "[n]ow, that means 'are probably not' within the

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[1] Burns, A., Drici, W., and Marshall, Zl, 2019, Response to Stakeholder Reports Submitted to the Nevada State Engineer with Regards to Interim Order 1303: Southern Nevada Water Authority, Las Vegas, Nevada. (Hereinafter, "SNWA Rebuttal Report")
[2] *See Fig. 2.4*, SNWA Reb. Report at p. 8.

carbonate aquifer of the LWRFS; isn't that correct? Isn't that what that means?," Ms. Drici answered in the affirmative, [y]es, it is."[3] Importantly, Mr. Andrew G. Burns, who co-authored the SNWA Rebuttal Report with Ms. Drici, confirmed that he concurred in the analysis, as did Jim Rogers at SNWA.[4]

In her direct testimony during the hearing, at pages 905 and 906, Ms. Drici was even more specific about the "boundary" of the LWRFS and the production wells in the Black Mountains Area. Referencing slide No. 17 in SNWA's presentation which contained Figure A-3, Ms. Drici discussed the BMA in particular and explained the MLR (multiple liner regression) analysis, stating as follows:

> So when we conduct this analysis and we extract the responses to the individual basin groundwater production from the carbonate aquifer, and if you look at the first graph there, the slide [No. 17, Fig. A-3], that would be the Black Mountain area. And it appears, from this analysis, that the groundwater production from Black Mountain is not really affecting water levels at EH-4.
>
> *So it's an indication that, perhaps,* ***the boundary down there might be a little bit off because the boundary was defined based on the observation well, the VMDL-2 [sic][5], I believe.***
>
> *And* VMDL-2 did respond to the MX-5 pumping during the Order 1169 aquifer test, and these wells, the production wells are just a little bit south of there. *So this is an indication that, perhaps,* ***the boundary might be a little bit off.*** (Emphasis added.)[6]

Notably, Fig. A-3 from SNWA's presentation (depicting the BMA production pumping wells) shows a completely horizontal line for the water levels in EH-4 throughout the entire time that SNWA tracked data from 1996 through 2018 – which is significantly different than what was shown in MLR results for California Wash, Coyote Springs Valley, and Garnet Valley (Figures A-4, A-5, and A-6 – slides 17 and 18 of SNWA presentation).

Finally, Ms. Drici confirmed that a part of her conclusion in this regard was based upon the 'P' values calculated for the responses observed from the various wells and pumping in the different basins, including in the BMA. In response to cross examination by Ms. Karen Peterson,

[3] Transcript of Hearings, Vol. V, p.m. session, Sept. 27, 2019, p.1019, lines 13-21. Ms. Drici then clarified her report statement somewhat, stating that the word "probably" simply meant that she could not say, "with hundred percent certainty that it is true. I mean to demonstrate things like this, you would need to look at it from different angles. So, this analysis indicates that maybe they are not in there…." *Id.* At p. 1019, lines 21-24, and p. 1020, lines 1-4.

[4] Trans., Vol. V, p.m. session, Sept. 27, 2019, p. 1020, lines 13-14, p. 2021 lines 1-3 (Mr. Burns referenced Mr. Rogers, specifically, as having concurred in the analysis along with he and Ms. Drici.).

[5] The Ct. Reporter heard "VMDL-2," but this should be "BM-DL-2."

[6] Trans., Vol. V, a.m. session, Sept. 27, 2019, p. 905, lines 11-24, p. 906, line 1.

the attorney for Lincoln/Vidler, Ms. Drici discussed the differing P values for the BMA, and again confirmed that, "we already showed the results that we think that Black Mountain area production wells ***probably should not be within the Lower White River Flow System boundary***."[7]

In summary, the experts for SNWA uniformly suggested in both SNWA's Rebuttal Report and in their direct testimony at the hearing that the ***boundary*** in the Black Mountains Area was questionable by including the NCA production wells, because those wells *probably should not be within the LWRFS*.[8]

(ii) NCA's Experts' review and analysis of the data and conclusions of SNWA also supports removal of the NCA wells from the BMA, as well as a relocation of the Boundary in the BMA.

The data relied upon and the conclusions reached by SNWA's experts were analyzed by NCA's own experts, and they too concluded that NCA's wells reacted noticeably differently than the other monitoring well only 3,600 feet away, BM-DL-2. At the hearing Jay Dixon, the lead hydrologist on NCA's team, discussing slides Nos. 7 and 8 of the NCA presentation, testified that the NCA production wells were intentionally sited by Marty Mifflin in the early 1990s (acting as a consultant to the owners of NCA) because "[h]e was aware of a series of strike slip faults and you can see coming off the east side of the Dry Lake Range."[9] As Mr. Dixon explained:

> Again, still staying on this recommendation regarding this boundary and focusing on the geologic section GG that I pointed out in the previous slide. The NCA wells, as you can see, are put right in the middle of those strike-slip faults. That's where Marty purposely sited them.

---

[7] Trans. Vol. V, a.m. session, Sept. 27, 2019, p. 984, lines 17-20.

[8] Curiously, despite the repeated testimony of Ms. Drici and Mr. Burns testimony that he and Jim Rogers of SNWA had reviewed and supported the conclusions reached in SNWA's Reb. Report regarding the production wells not appearing to affect the Muddy Springs Area or being part of the LWRFS, when asked by the State Engineer whether SNWA still supported the State Engineer's recommendations on the LWRFS "boundary" even with regard to the Black Mountains Area Mr. Burns stated he would still support the recommendation that the boundary "was appropriate." (*See* Trans. Vol. V, p.m. session, Sept. 27, 2019, p. 1051, lines 1-6.) Notably, however, Mr. Burns quickly referenced Ms. Colby Pellegrino's position, stating, "[b]ut, what I'm also saying or what we're also saying is that it's, as Colby mentioned this morning, if there is prospects of moving production from one part of an adjacent basin to the boundary of LWRFS, and particularly this boundary *which I think a little uncertain,* we think applications to change those points of diversion in that regard should be scrutinized." (*Id.* at lines 6-14).

The undersigned would suggest that Mr. Burn's reticence to directly respond to the State Engineer has more to do with the fact that SNWA did not identify a specific line or point where the boundary should be moved in the Black Mountains Area, and thus did not want to wade in without more information. The conclusion those experts drew, however, is unmistakable: the **LWRFS boundary** should ***not*** include the NCA production wells, and since it currently does, it should probably be changed to exclude them because the boundary in that area is "a bit off."

[9] Trans. Vol. IX, Oct. 3, 2019, at p.1618, lines 4-23.

> And referring back to the larger question should the entire basin be included? As you continue to the east, you see a complete different map[ped] geology on this side. There is no apparent consistency in the geology on the other side of that Muddy Mountain thrust fault, at least relative to this pumping.[10]

Mr. Dixon further acknowledged that well EBM-3 "has a monitoring record that goes back to 1993 and its continuous,"[11] and Mr. Dixon explained that after hearing what SNWA had concluded and reviewing their P values and MLR analysis, he and his colleagues "did a little investigation, obviously, we spent a lot of time reviewing Marty Mifflin's work. He did a very good job of documenting what he saw when he was out there in the early nineties."[12] Mr. Dixon then described certain "high angle fractures," fractured limestone, and – importantly – confirmation that the wells were located *in the fault.*[13] Finally, he noted that "SNWA didn't look at it beyond what they have,"[14] but Mr. Dixon and his colleagues did, and they provided even more information for consideration by the State Engineer.

Finally, Mr. Dixon discussed the same P-values that Ms. Drici had briefly touched upon, and Mr. Dixon explained the significance of the difference that was demonstrated by the BMA production well, EBP-2 (as reported by EBM-3, its adjacent monitoring well), as compared to the monitoring well only 3,600 feet away, BM-DL-2. Both wells are approximately 30 miles from EH-4, yet BM-DL-2 correlates nearly 1 to 1 with EH-4, while the NCA well is statistically so far off on the correlation that it caused SNWA to question whether there was any connection whatsoever. Indeed, SNWA's Figure A-3 showed no influence from BMA pumping of production wells, which Mr. Dixon explained would be consistent with the vastly different P-values. However, Mr. Dixon did note that there was "noise" associated with the well data for EBM-3 (the NCA well), and noted that it would be helpful to have additional work done to analyze the data more thoroughly.[15]

Following the conclusion of the hearing, Mr. Dixon did precisely that – he analyzed the existing monitoring record back to 1993, and performed a more thorough review of information already in the State's record. Notably, nothing herein is added to the record that was made available to the Nevada State Engineer during the hearing, but instead is rather a more thorough review of the materials from the NCA Permit files that are part of the record, using the data

[10] Trans. Vol. IX, Oct. 3, 2019, at p. 1619, lines 3-13.
[11] *Id.* at p. 1619, line 24, p. 1620, line 1.
[12] *Id.* at p. 1620, lines 23-24, p. 1621, lines 1-2.
[13] *Id.* at p. 1621, lines 3-24, p. 1622, lines 1-2.
[14] *Id.* at p. 1622, lines 20-21.
[15] *Id.* at p. 1622, lines 21-22, p. 1625, lines 2-6.

provided therein and assessing exactly what was discussed at the hearing involving the Black Mountains Area and the differing effects noted from the production wells in that area as compared to nearly all the other wells reported upon and analyzed by SNWA and others. Mr. Dixon provided the following analysis, which is included as part of this closing brief:

BACKGROUND

The purpose of this Memorandum is to provide a summary of an additional review and analysis of regional carbonate groundwater level response and pumping in the Black Mountain Area (BMA) basin from the Nevada Cogeneration Associates (NCA) wells. The justification for this follow-up analysis was to further examine the possibility that pumping in the BMA from the NCA wells may have limited or no effect on observed spring flow and carbonate groundwater responses in the Muddy River Springs Area (MRSA) and therefore, could be managed outside of the proposed Lower White River Flow System (LWRFS) administrative unit. The data used for this work relied on existing information and reports at NDWR, with some of that data being filtered and used in support of the same (type of) analyses reported by NCA and others for the Order 1303 Hearing (hereinafter, the "Hearing").

ORDER 1303 – BMA PUMPING AND EFFECTS CONCLUSIONS

The Southern Nevada Water Authority (SNWA) provided detailed information on historical pumping, surface water flows and water levels within the proposed LWRFS in their initial report, SNWA (2019a)[16], including interpretations on the extent of correlation between groundwater levels in the LWRFS basins and MRSA responses (spring flow and carbonate groundwater levels). However, the report did not discuss the apparent lack of contributions from pumping in the BMA. The follow-up SNWA (rebuttal) report (SNWA, 2019b)[17] presented results of a multiple linear regression (MLR) analysis that partitioned the EH-4 hydrograph into several hydrographs of responses to groundwater production from each of the five (5) LWRFS basins. As shown in **Figure 1** attached to this Closing Brief, SNWA (2019b) demonstrated "*that groundwater production from the Black Mountains Area causes the least effect ….*" *See* SNWA (2019b) at p. 16. The analysis performed by SNWA as described in SNWA (2019b) concluded that production wells in the BMA are "probably not" within the proposed LWRFS. *See* SNWA (2019b) at p. 17. The same conclusions were reiterated by SNWA experts during the Order 1303 Hearing in Sept. – Oct. 2019.

FOLLOW-UP REVIEW OF NCA PUMPING AND GROUNDWATER LEVELS

During the Order 1303 Hearing, evidence was presented by SNWA and NCA experts that reiterated that carbonate groundwater levels in the BMA behaved differently than elsewhere in the LWRFS and pumping in the BMA appears to have little to no effect on spring flow and carbonate groundwater levels in the MRSA. However, these conclusions were repeatedly conditioned with uncertainty due to apparent differences in the responses to pumping based on carbonate groundwater observations at EBM-3 when compared to BM-DL-2 and EH-4. Some of this uncertainty was likely due to interference at EBM-3, a non-pumping observation well, from nearby pumping well EBP-2, which is located only 200 ft away (*see* **Map 1,** attached to this Closing Brief). As shown in **Map 1**, BM-DL-2 is located 2,660 ft northwest of the nearest NCA pumping wells (and approximately 3,600 feet from EMB-3). The data used by SNWA, NCA and other experts during the Hearing originated from records at NDWR made available via an online database. This data is reported to NDWR by various stakeholders in the LWRFS with ongoing monitoring and reporting obligations, which includes the years 1992 to 2017.

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[16] Burns, A., Drici, W., Collins, C., and Watrus, J., 2019, Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response, Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.

[17] Burns, A., Drici, W., and Marshall, Zl, 2019, Response to Stakeholder Reports Submitted to the Nevada State Engineer with Regards to Interim Order 1303: Southern Nevada Water Authority, Las Vegas, Nevada.

In order to further investigate the relationship between BMA pumping and carbonate groundwater observations, a series of steps were taken as summarized below:

1. Extensive review of NCA pumping files at NDWR, which included hard-copy reports submitted by NCA to NDWR on a quarterly basis beginning in 1992 through 2017. Beginning in 2017 the reports were submitted in digital format (Excel spreadsheets). Each hard-copy report was manually digitized and converted and transferred into a digital format (Excel spreadsheet). These reports included monthly pumping and water level observations.

2. Groundwater level observations have been reported by NCA for three (3) wells (see **Map 1** for locations). Wells EGV-3 and EBM-4 were reported as pumping wells from December 1991 through June 2015. Beginning in September 2015, Wells EGV-3 and EBM-4 were replaced (as pumping wells) and converted to monitoring wells. Water level observations for these wells is sporadic and highly variable, depending when the levels were measured relative to pumping as shown in **Figure 2** (attached to this Closing Brief). The NCA reports filed at NDWR generally indicate whether the groundwater levels are taken when the production wells are on or off, but the amount of time between pump shut-in and water level measurements was never indicated.

3. Groundwater level observations have been reported by NCA for EBM-3 since 1993. The data from this well has the longest continuous record in the BMA as reported on the NDWR database. The database also includes eight (8) water level observation reported by the USGS, but the earliest record (August 1991) appears to have been taken directly from the Well Log (#46122). Even though well EBM-3 was used only for monitoring purposes, it is located only 200 ft away from NCA pumping well EBP-2. EBM-3 was no longer accessible for groundwater monitoring purposes after December 2017. As discussed by NCA during the Hearing, water levels measured at EBM-3 appear to vary by approximately 5 ft over short periods of time. This variability has been interpreted as dynamic influence from nearby pumping, particularly at EBP-2. The NCA reports filed at NDWR do not indicate (directly) the pumping status of nearby wells, and most importantly the status of EBP-2, when the EBM-3 water levels are measured.

4. EBM-3 groundwater level data was filtered such that only NCA water level observations made during months when EBP-2 registered no pumping were plotted over time. This data was also combined with USGS observations in the NDWR database for months when EBP-2 was not pumping. For this analysis, it was assumed that using only water level data reported during months with no pumping (from EBP-2) helped ensure that groundwater levels were more representative of actual background, or relative static aquifer conditions, at the well. As shown in **Figure 3** (attached to this Closing Brief), some variability in EBM-3 data still exists, but an interpretive (average) plot was added to provide a better, or more continuous, visual representation of observed trends within the time-series data points.

5. During the Hearing, NCA experts presented the results of a simple linear regression analysis for BM-DL-2 vs. EH-4 and EBM-3 vs. EH-4 (NCA hearing presentation Slide 16[18]). Results of the BM-DL-2 vs. EH-4 analysis indicated a high correlation with an R^2 value of 0.95, which matched the results presented by SNWA (2019a, b). The results of the EBM-3 vs. EH-4 correlation analysis indicated low correlation with a R^2 value of 0.52. However, as was noted during the Hearing, the data included several water level measurements that were the same value within the nearest 1-ft and measurements taken when nearby EBP-2 was being pumped or had recently pumped which are considered unrepresentative of actual (background) groundwater conditions at the EBM-3 well. **Figure 4** (attached to this Closing Brief) includes a revised regression plot for EBM-3 vs. EH-4 using only data reported by NCA and USGS during months when EBP-2 was not pumped.

[18] Dixon, J., Coache, R. and Ricci, H., October 3, 2019. Administrative Hearing in the Matter of Administration and Management of the Lower White River Flow System – Demonstrative Presentation in Support of Direct Testimony. Carson City, Nevada.

6. Additionally, the reports filed prior to and testimony provided during the Hearing did not examine water level data at BM-DL-1. As shown in **Map 1**, BM-DL-1 is located 2,176 ft east of BM-DL-2 and approximately 1,530 ft north of the northern-most NCA production well (EBM-5). As shown in **Figure 5** (attached to this Closing Brief), the hydrographs from BM-DL-1 and BM-DL-2 are shown in the same hydrograph plot to provide a simple visual comparison between groundwater levels in the two wells.

RESULTS OF FOLLOW-UP REVIEW

Using only data reported by NDWR, an additional review was performed to further investigate the relationship, if any, between NCA pumping in the BMA and water level responses in the regional carbonate aquifer *within the proposed LWRFS boundary*. No new analyses were performed as part of this follow-up review. Existing data was filtered as described herein and presented in **Figures 1** through **4**. A summary of the results of this follow-up review and limited analysis is listed below:

1. The SNWA (2019a, b) reports incorrectly reported the start of pumping (from NCA) in the BMA as being 1996. As shown in **Figure 3**, NCA pumping within the BMA actually began in July 1992.

2. Carbonate pumping in the BMA was 0 ac-ft in 1991, 479 ac-ft in 1992 and averaged 1,537 ac-ft from 1993 through 1997, ***yet the carbonate groundwater levels in the MRSA as observed at EH-4 were stable during this time reflecting only normal seasonal trends***. In fact, groundwater levels at EH-4 actually ***increased*** by 0.9 ft between 1992 and 1993 within the first full year of NCA groundwater production while static groundwater levels at EBM-3 in the BMA dropped by 14 ft from NCA pumping. *See* **Figure 3**.

3. Overall seasonal carbonate groundwater hydrograph trends are nearly identical for BM-DL-2 and EH-4 even though the wells are 29.5 miles apart and in separate hydrographic basins. However, same seasonal trends are **not** observed in EBM-3 as compared to BM-DL-2 and EH-4 even though EBM-3 is located only approximately 3600 ft away from BM-DL-2. This suggests that while a strong hydrologic connection appears to exist between EH-4 and BM-DL-2, the same does not appear to be true for EH-4 and EBM-3, or between BM-DL-2 and EBM-3.

4. As shown in **Figure 5**, visual comparison between the hydrographs for BM-DL-1 and BM-DL-2 reflect a significant departure in groundwater level trends between 2007 and 2011, which seems to indicate different hydrogeologic conditions between those two wells.

5. Even though it appears that some regional response in carbonate levels can be seen in EBM-3 observations (**Figure 3**), as shown in **Figure 4**, groundwater levels at EBM-3 do **not** correlate well with corresponding levels at EH-4 with regression analysis results indicating an (updated) R^2 value of less than 0.5, and by inference EBM-3 does not correlate well with nearby BM-DL-2 either.

6. During the Hearing, NCA experts provided testimony in review of the Mifflin and Associates 1992 well completion reports for NCA, which indicated the presence of significant structural features encountered during well drilling. As shown in **Map 2**, Rowley (2017)[19], Mifflin's descriptions are supported by the mapping of a (buried) strike-slip fault extending south of the Dry Lake Range through the NCA well field. Because of the lack of response in the LWRFS to pumping from the NCA wells in the BMA, the poor correlation in groundwater level (response) between observations

[19] Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee, D.K., McKee, E.H., Burns, A.G., Watrus, J.M., Ekren, E.B., Patrick, W.G., and Brandt, J.M., 2017, Geology and Geophysics of White Pine and Lincoln Counties, Nevada, and adjacent parts of Nevada and Utah: The geologic framework of regional groundwater flow systems, Nevada Bureau of Mines and Geology Report 56, Prepared cooperatively by Geologic Mapping, Inc., New Harmony, Utah, U.S. Geological Survey, Menlo Park, California, Southern Nevada Water Authority, Las Vegas, Nevada and Private consultant, White Sulphur Springs, Montana.

made at EBM-3, BM-DL-1 and EH-4 it is apparent that ***an adjustment to a portion of the proposed LWRFS boundary in Basin 215 (BMA) is warranted***. As shown in **Map 2**, the proposed boundary modification would generally place the south and western-most boundary within the Basin 215 portion of the LWRFS to be coincident with the strike-slip fault mapped by Rowley (2017) with a slight adjustment west such that the fault and boundary lie west of the NCA well field and BM-DL-1. Essentially this modified portion of the area currently within Basin 215 should become part of the administrative boundary for Basin 216 (Garnet Valley), leaving the NCA wells (EBP-2, EBM-5 and EBM-6) and BM-DL-1 inside of Basin 215, but outside of the LWRFS administrative unit.

CONCLUSIONS

Based on the results of this limited follow-up analysis using only existing data available at NDWR, it appears that pumping from carbonate wells in the BMA does not have an appreciable influence on carbonate groundwater levels observed in EH-4. This lack of correlation corroborates SNWA's statements and conclusions regarding contributions from NCA pumping in the BMA to observed impacts in carbonate groundwater levels and changes in spring flow in the MRSA.

Due to the lack of response to pumping from the BMA and poor correlation between carbonate groundwater levels near the NCA well field and within the LWRFS (EH-4) an adjustment to the portion of the LWRFS boundary within Basin 215 is warranted. The boundary adjustment, as shown in **Map 2,** is further supported by mapped geologic structural features from Rowley (2017).

Conclusion as to the boundary in the Black Mountains Area: Notably, **Map 2** included by Mr. Dixon shows a meaningful, geologic structure that should be used to form the actual Southern (LWRFS) boundary proposed for what is currently part of the Black Mountains Area. It is based on an actual strike-slip fault that was mapped, photographed, and into which NCA's production wells were intentionally sited. It is not surprising, really, that they perform outside the LWRFS. All of this data was discussed during the hearing; Mr. Dixon explained during the hearing the reasons why this made sense and explained precisely why NCA's production wells did *not* affect EH-4 the way that other wells in other basins *within the LWRFS* did.[20]

B. Evidence and Analysis supports the inclusion of Kane Springs Valley Basin as part of the LWRFS.

An additional geographic 'boundary' adjustment is also warranted by the evidence and analysis that was presented to the State Engineer both by the initial Reports, the Rebuttal Reports, and the testimony presented during the hearing. Several sources demonstrated that a direct, hydrologic connection exists in the carbonate aquifer between Kane Springs Valley Basin and the MSRA such that it would be appropriate to include Kane Springs Valley in the LWRFS.

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[20] Mr. Dixon's supplemental discussion for the Post-Hearing Brief does, in fact, identify a better and more scientifically supported boundary than the arbitrary straight-line previously applied to form the Southern boundary of the LWRFS. As such, it is a "recommendation" made to a public agency by an engineer, and thus this Post-Hearing Brief of NCA will bear Mr. Dixon's professional engineer's stamp and signature, along with the undersigned, as representatives of NCA, in order to comply with NAC 625.612.

As such, the geographic boundary of the LWRFS should be adjusted to include Kane Springs Valley Basin.

In NCA's Rebuttal Report at section 4, beginning on page 8, NCA's experts addressed several comments made by Lincoln County/Vidler in their initial report titled, "Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit," dated July 3, 2019 (the "Lincoln/Vidler Report"), beginning with the reliance by Lincoln/Vidler on the purported statement that the State Engineer had supposedly found that there would be no significant impact for hundreds of years. In fact, as pointed out by NCA's experts, no such determination was made by the State Engineer with regard to Kane Springs Basin or Lincoln/Vidler's rights.

An actual review of Ruling 5712 -- issued February 2, 2007, at a time when the State Engineer had only limited data relevant to the impacts caused by carbonate groundwater pumpage within the LWRFS and no direct statutory right to "conjunctively manage" water sources – nonetheless *still* highlights the following findings made by the State Engineer *at that time:*

- "The State Engineer further finds that the Applicants' pumping test supports the conclusion that there is considerable potential for ground-water flow in the carbonate rocks in the vicinity of well KPW-1" (Pg. 7)

- "The State Engineer finds the evidence indicates a strong hydrologic connection between Kane Springs Valley and Coyote Spring Valley, specifically, that ground water flows from Kane Springs Valley into Coyote Spring Valley." (Pg. 21)

- "Given the unique hydrologic connection between the Kane Springs Valley Hydrographic Basin and the Coyote Spring Valley Hydrographic Basin, the development of ground water within Kane Springs Valley will ultimately affect water levels and flows in the White River regional carbonate-rock aquifer system." (Pg. 15)

Notably, as was pointed out in slide 31 of the NCA presentation, several parties – not just NCA – found that CSVM-4 and KMV-1 (in Kane Springs Valley Basin) showed effects resulting from the Order 1169 aquifer test; SNWA, Moapa Valley Water District, US Fish and Wildlife Service, National Park Service, the Center for Biological Diversity, and NCA all made similar findings. Additionally, the values for several wells including CSVM-4 were then plotted against EH-4 for various periods and there was a high correlation between all the carbonate wells within the LWRFS plotted against EH-4, indicating a high level of hydraulic connectivity across the basins within the LWRFS; CSVM-4 vs. EH-4, for example, resulted in a value of 0.82 – a high correlation indeed, taken from the SNWA Initial Report.[21]

But SNWA did *not* calculate a correlation between EH-4 and KMW-1. NCA's experts, however, did perform a visual comparison of the hydrographs for KMW-1 and CSVM-4 (as the correlation had been made between CSVM-4 and EH-4), and the hydrographs were *virtually identical*. Slide 33 of NCA's presentation demonstrated the similarity, and the testimony of Robert Coache on this topic cemented the analysis by estimating the R^2 value to be greater that 0.9, which Mr. Coache explained, "indicates a high correlation between KMW-1 and carbonate wells in the Lower White River Flow System with a high level of hydrologic connectivity across all of the basins within the Lower White River Flow System."[22]

Importantly, when SNWA discussed the analysis provided by Mr. Greg Bushner (a Lincoln/Vidler panel expert) and his supposed "science-based reasons" to exclude Kane Springs Valley and northern Coyote Spring Valley from the LWRFS, SNWA concluded that Bushner's reliance was primarily on new geophysical surveys and "an implausible interpretation of the hydrogeologic framework in which a new, unmapped fault is postulated in northeastern Coyote Spring Valley."[23] The SNWA analysis points out the errors in the postulated position, including the convenient perpendicular manner in which the new fault would run in comparison to the range-front faults of the Delamar Mountains and Meadow Valley Mountains – and even to the Kane Springs Fault Zone, which is the dominant feature in the area. Also coincidentally, the new, unmapped fault just happens to be coincident with the boundary of the two basins.[24]

SNWA also questions the Bushner analysis based on water quality, geochemical, and stable-isotope data wherein Bushner relied on CH2M Hill (2006), noting that the water that makes up the carbonate comes from many different sources – which is what makes the carbonate aquifer such an issue to begin with. The conclusion, therefore, that Kane Springs Valley water cannot be *identified* does not mean it is not mixed with the other carbonate sources; indeed, it is precisely the opposite. The connection shown by the hydrographs and the gradient from KSV into Coyote Spring Valley demonstrate the connection – and the water eventually makes its way to the MSRA.

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[21] Slide 32, NCA presentation, taken from SNWA Initial Report, Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response, June 27, 2019, p. 5-12.
[22] Trans. Vol. IX, Oct. 3, 2019, at p.1637, lines 16-20.
[23] SNWA Reb. Report, at Sec. 2.1, p.2.
[24] SNWA Reb. Report, Sec. 2.1 at p. 2.

Also, additional engineering reports known well to Lincoln/Vidler found that significant amounts of water were flowing from Kane Springs Valley Basin, through the carbonate, into Coyote Spring Valley. During cross examination of Lincoln/Vidler's panel, Mr. Bushner confirmed his knowledge of the 2006 CH2M Hill report that found "local groundwater discharge into Coyote Spring Valley" "16,000 acre-feet a year based on analysis by Walker."[25] Mr. Bushner confirmed that if there was such a flow, it was coming "[m]ost likely through the carbonate."[26] Notably, Lincoln County commissioned that report, but – while they did not present it at the Hearings – Lincoln/Vidler did nothing at the Hearing to discredit its findings.

And, perhaps most tellingly, certain stakeholders' counsel took the opportunity to question two of NCA's panel members who were instrumental in the establishment of the Order 1169 pump tests that brought this matter to a head and foreshadowed these proceedings -- former State Engineer Hugh Ricci, and former Deputy State Engineer Robert Coache – asking each what they would have concluded regarding whether to include Kane Springs Valley Basin in the proposed administrative unit that is the Lower White River Flow System *had they known then what they know now* after all these studies have been performed and all these reports have been presented. Given the State Engineer's prior statements in Ruling 5712 expressing concerns nearly twelve years ago about the pumping of Kane Springs Valley Basin water and the potential "effect" on the "White River regional carbonate aquifer system," it is not surprising that the responses were as follows:

> Q: (by Greg Morrison) There's a substantial amount of institutional knowledge up there at the table right now. I'll start with Mr. Ricci. If you were the State Engineer October 2019 faced [with] all the evidence we've been looking at for the last couple of weeks, would you include Kane Springs in the management area?
>
> A: (by Hugh Ricci) Hugh Ricci. I would have another option. I could retire. But I will have to go back to 2002, actually 2001, when the hearing was held on Coyote Springs Valley as far as the Southern Nevada Water Authority applications in Coyote Springs Investments. And when that order was written, it did not include Kane Springs at that time. And the reason I think was that there was nothing going on in Kane Springs. Had I had the knowledge that I would today as of a result and had to issue Order 1169 again, Kane Springs would have been included.

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[25] Trans. Vol. VII, Oct. 1, 2019, at p. 1390, lines 9-17.
[26] *Id.* at p. 1391, lines 3-7.

Q: (Mr. Morrison) Okay. Thanks. Mr. Coache, what about you, if I posed the same question. If you were sitting where Mr. Wilson is today, would you want to include Kane Springs in this management area?

A: (by Robert Coache): MR. COACHE: Yes, I would.[27]

In response to follow up questions by Ms. Peterson, the attorney for Lincoln/Vidler, who questioned why "presentation" slide No. 40 of NCA suggested the boundary should remain the same, Mr. Coache explained that perhaps this first phase of the proceedings wasn't the proper venue for making that determination (to modify the boundary for Kane Springs), but he did not waiver as to whether Kane Springs Valley should be included.[28] Mr. Ricci, too, did not alter his testimony regarding whether – if he knew then what he knows today – he would have included Kane Springs Valley Basin in the Lower White River Flow System for management purposes.[29] Like Mr. Coache, Mr. Ricci was not certain at the time of the testimony whether a 'boundary' adjustment was in order during this phase, or during another phase of these proceedings.

Conclusion as to Kane Springs: At this point, it is the position of NCA that, having considered the fundamental purpose of Interim Order #1303 and its direct recommendation that the parties work to inform the State Engineer where they believe the *extent* of the "geographic boundary" of the Lower White River System is, then NCA now takes the position – despite its statement on Slide 40 of its presentation – that the "boundary" should be adjusted to include Kane Springs Valley Basin as part of the management area that is the Lower White River Flow System. There is simply too much data to ignore the hydrologic connection, and too much reason previously given by the State Engineer years ago that foreshadowed that result. The inclusion of Kane Springs Valley Basin makes good scientific sense, and its exclusion is not based on sound principles but rather on past comments made at a time when the parties knew less of the workings of the system than they do today.

2. The long-term annual quantity of groundwater that may be pumped from the LWRFS is less than 9,318 afa once the Black Mountains Area boundary is adjusted to exclude the NCA production wells.

NCA has repeatedly endorsed the State Engineer's figure of 9,318 afa as a supportable figure for the pumping that should continue to be allowed within the LWRFS. It is NCA's understanding that the figure was arrived at in large part through a determination of the actual

[27] Trans. Vol. IX, Oct. 3, 2019, at p. 1659, line 24, p. 1660, lines 1-20.
[28] *Id.* at p.1662, lines 7-12.
[29] *Id.* at p. 1661, lines 11-24, p.1662, line 1.

pumping that was occurring in the system, coupled with the finding that the system appears to have somewhat stabilized and is essentially in a recovery mode. If NCA was to be included in the LWRFS, then NCA would still support that figure of 9,318 afa as a figure for sustainable groundwater development in the system.

NCA's contention, however, was predicated on the understanding that the pumping calculation included the groundwater production from the BMA made by NCA for its facilities in the BMA. NCA averages approximately 1,600 afa annually for its pumping to operate its facilities, and has done so for many years. Indeed, NCA is one of few water right stakeholders in this process who has fully perfected its rights by completing its beneficial use and, as a result, has fully certificated water rights. But NCA has demonstrated a strong position that the NCA production wells *are not within the LWRFS as currently proposed.* This position is based in part on science developed by an independent stakeholder – SNWA – who agrees that the 'boundary' in the southern part of the BMA is probably "a bit off," and the NCA's production wells are probably "not within the LWRFS."

As a result, should the State Engineer agree with NCA and make the determination to adjust the boundary in the BMA to exclude the NCA production wells from the LWRFS, then the pumping figure attributable to NCA's production well pumping should be removed from the 9,318 afa number in arriving at the proper amount for actual LWRFS pumping. It would be intellectually inaccurate to ignore this result if the 9,318 figure was arrived at based on the *inclusion* of NCA's pumping, and then eliminate those wells from the "boundary" but not eliminate the pumping from those wells in the annual amount of sustainable groundwater that can be developed from the LWRFS.[30]

3. Lower Meadow Valley Wash water rights should Not be included in the LWRFS

As was explained by Jay Dixon in NCA's Rebuttal Report at Sec. 3, pp.3-7, bolstered by NCA's presentation slides at Nos. 19-24 and his accompanying testimony[31], the geology of the Lower Meadow Valley Wash ("LMVal.W") and the actual water use there does not support its inclusion for several reasons: (a) there is no carbonate pumping occurring in that area (the wells there are shallow, alluvial-depth wells), and thus the "connection" must be inferred but has not been proven, nor has the effect of actual pumping been determined; (b) the depth to the carbonate is great in the LMVal.W, making it difficult to establish a carbonate source of water

[30] Of course, if the State Engineer does not adjust the BMA boundary and leaves NCA's production wells inside the LWRFS, there is no reason to reduce this figure from the 9,318.
[31] Trans. Vol. IX, Oct. 3, 2019, at pp.1627-1629.

there[32]; (c) there were no effects from LWRFS pumping observed in groundwater levels; (d) the current pumping in the basin is minimal; and (e) if the water rights are simply *included* in the LWRFS the potential exists for inactive water rights to be given artificial *new life* by virtue of potentially being classified as "carbonate, underground rights" when they have essentially never been pumped or managed in that fashion previously, to the detriment of other LWRFS stakeholders – especially those who have actually put water rights to use.

FINAL CONCLUSION

For all the foregoing reasons, NCA recommends: (1) the modification of the LWRFS boundary in the BMA in accordance with the recommendation of Mr. Jay Dixon, P.E. as shown on **Map 2,** which would exclude NCA's production and monitoring wells from the LWRFS; (2) the modification of the LWRFS boundary to include Kane Springs Valley Basin within the LWRFS; (3) the total, annual groundwater development in the LWRFS be considered with regard to a figure that is something less than the 9,318 afa determined to be the appropriate amount should NCA's production wells be excluded from the LWRFS, as would be proper given the circumstances and the evidence; and (4) the Lower Meadow Valley Wash *not* be included in the LWRFS.

Date: December 3, 2019.

KAEMPFER CROWELL

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12-3-2019

[32] NCA's Reb. Report at p. 7 stated that, as explained in Burbey (1997) and shown in geologic sections included in Rowely, et al. (2017), development of a carbonate aquifer source in the LMVal.W (anywhere near the southern boundary would require a well completed to a depth of approximately 4,000 ft., which is highly unlikely.

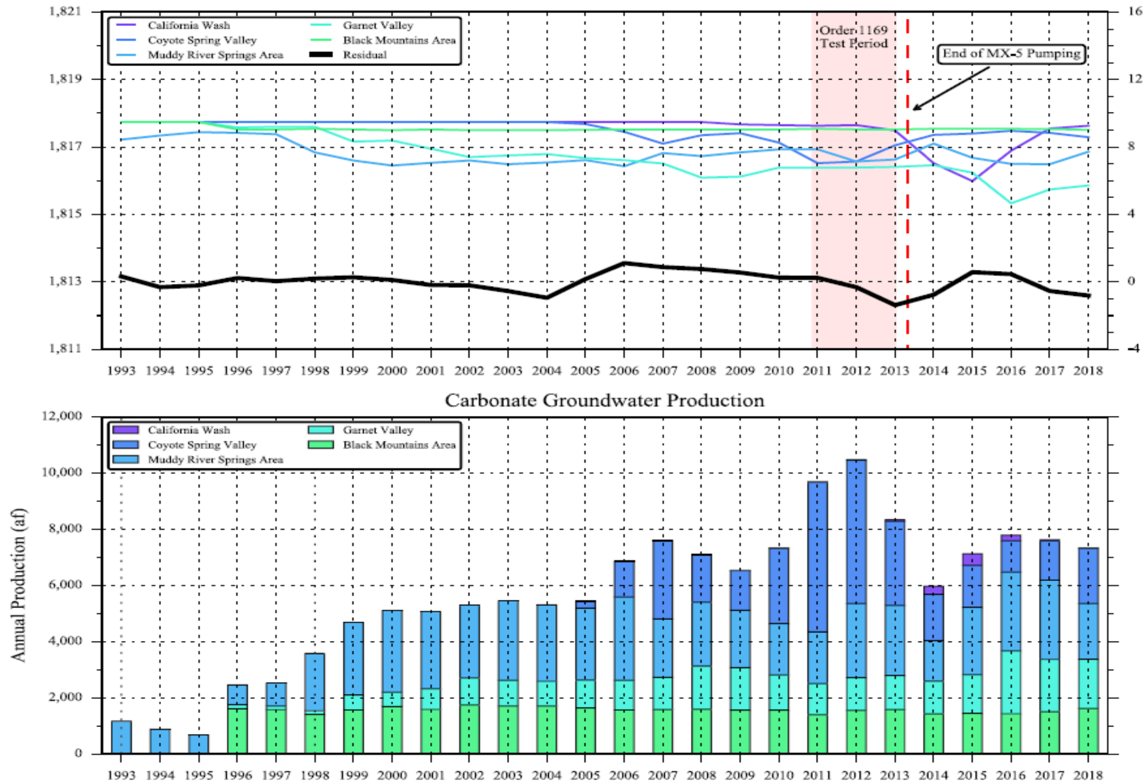


Figure 1. Taken from SNWA 2019b (Figure 3-1). MLR results reflecting decomposed Well EH-4 water levels due to carbonate groundwater production by basin. Results indicate limited to no response at EH-4 due to pumping in the BMA due to NCA (carbonate) wells.

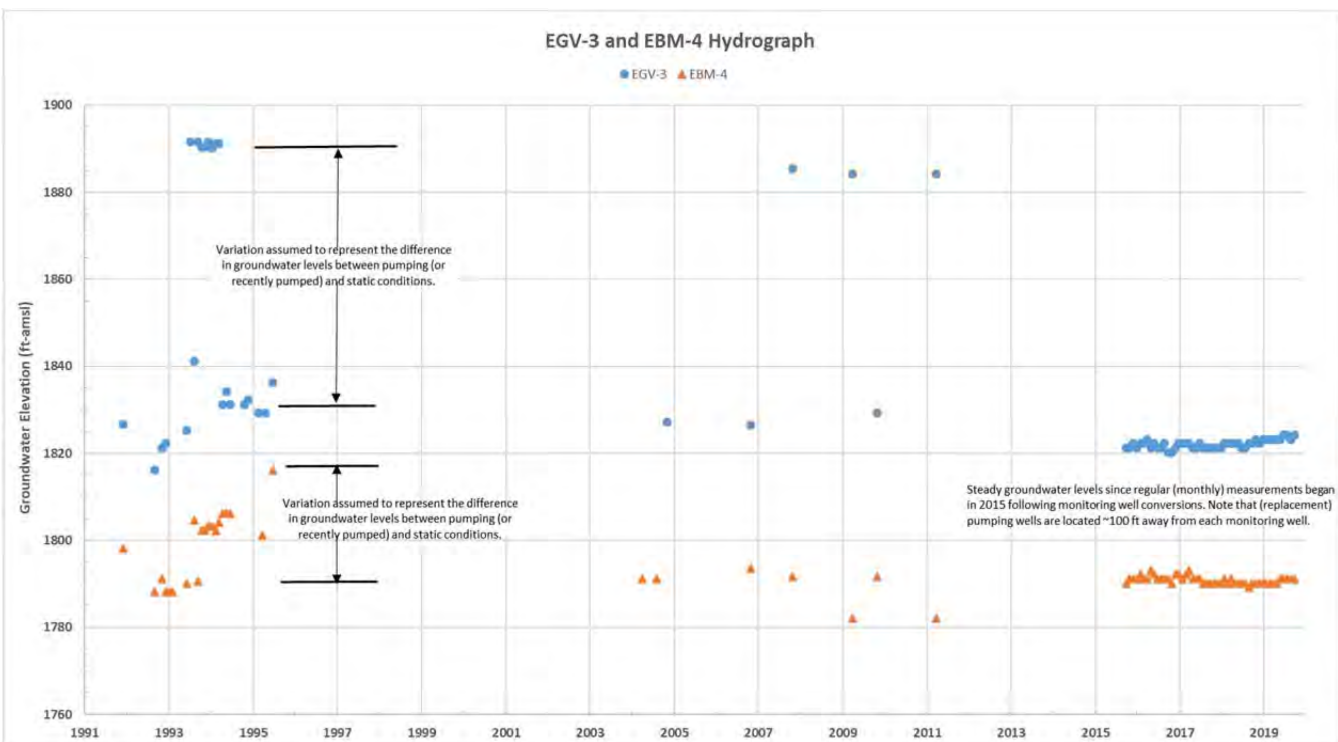


Figure 2. Hydrograph data based on hard-copy and digital reports filed by NCA at NDWR

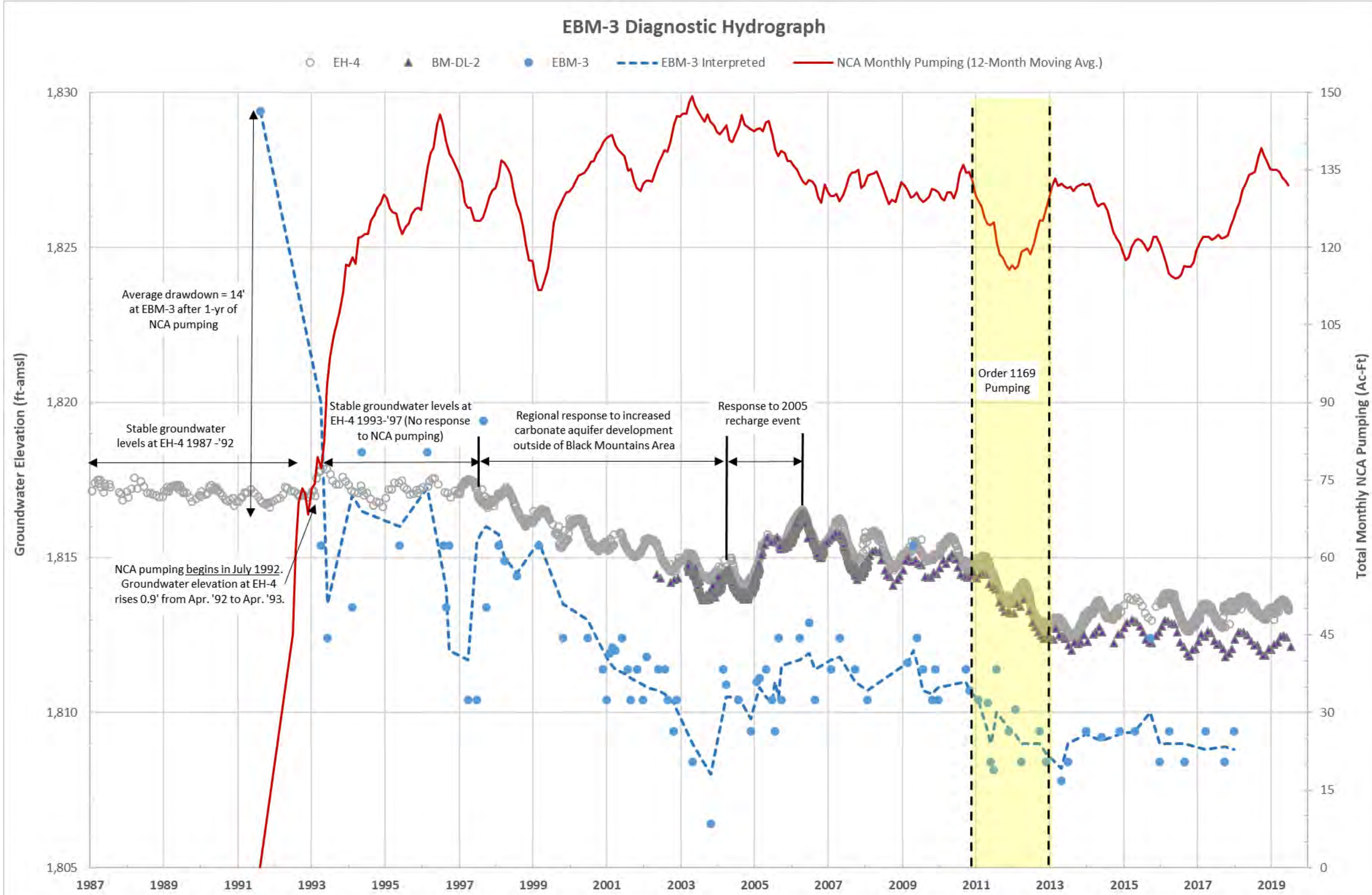


Figure 3. Diagnostic composite hydrograph data based on non-pumping filtered water level data from hard-copy and digital reports filed by NCA and USGS at NDWR for EBM-3, water level data for BM-DL-2 and EH-4 as reported on NDWR database and monthly NCA pumping as reported by NCA to NDWR (hard-copy and digital reports).

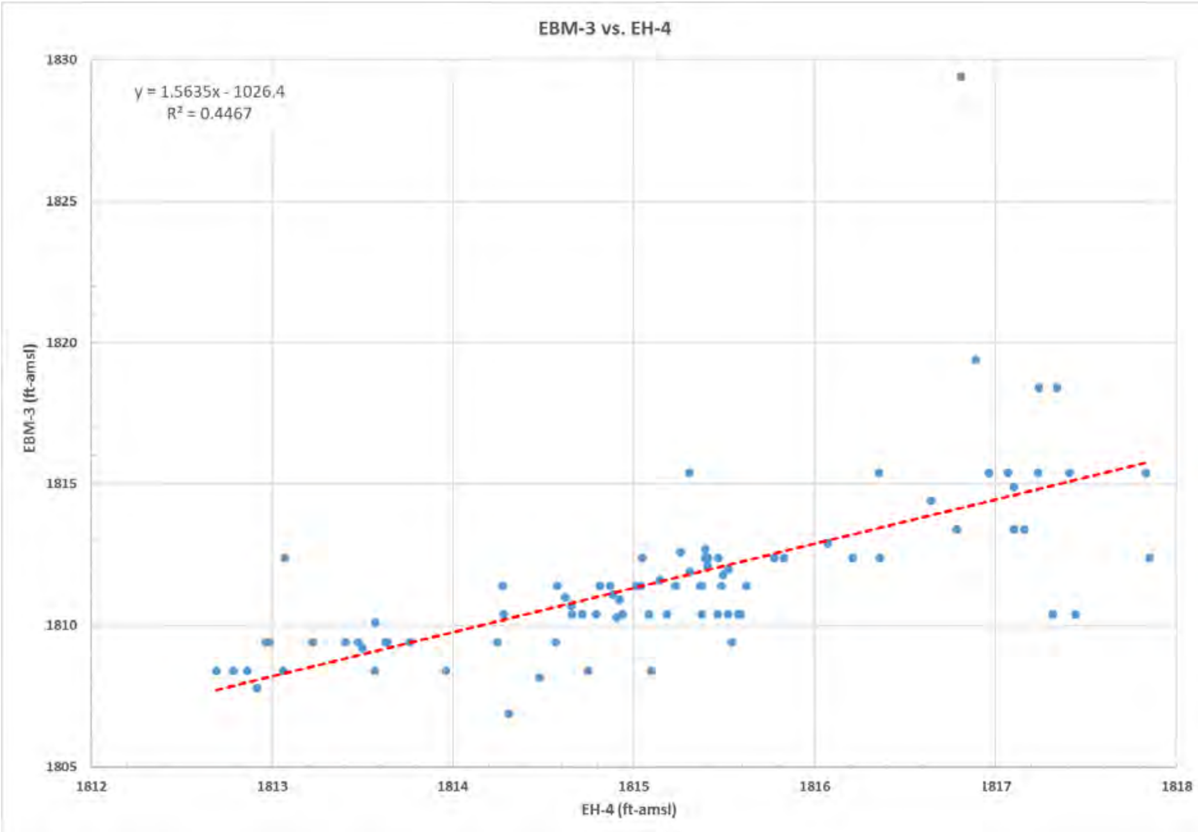


Figure 4. Results of the simple linear regression analysis between EBM-3 and EH-4 based on filtered (non-pumping influenced) data from EBM-3.

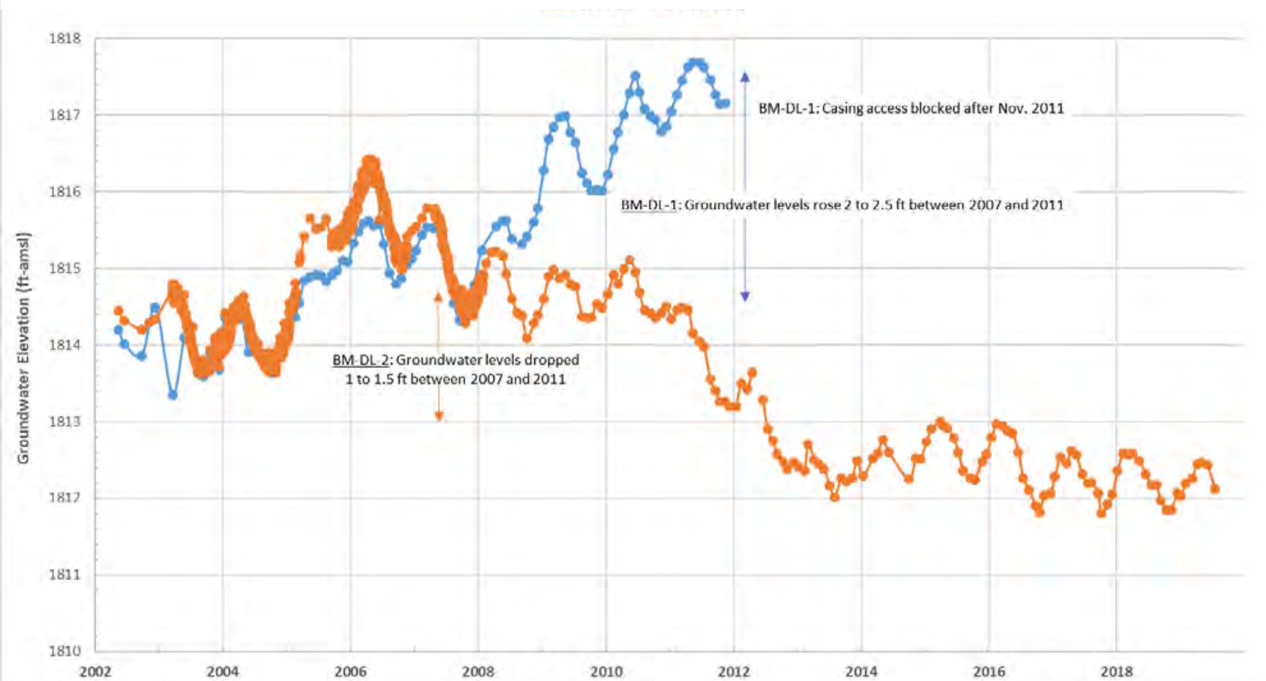
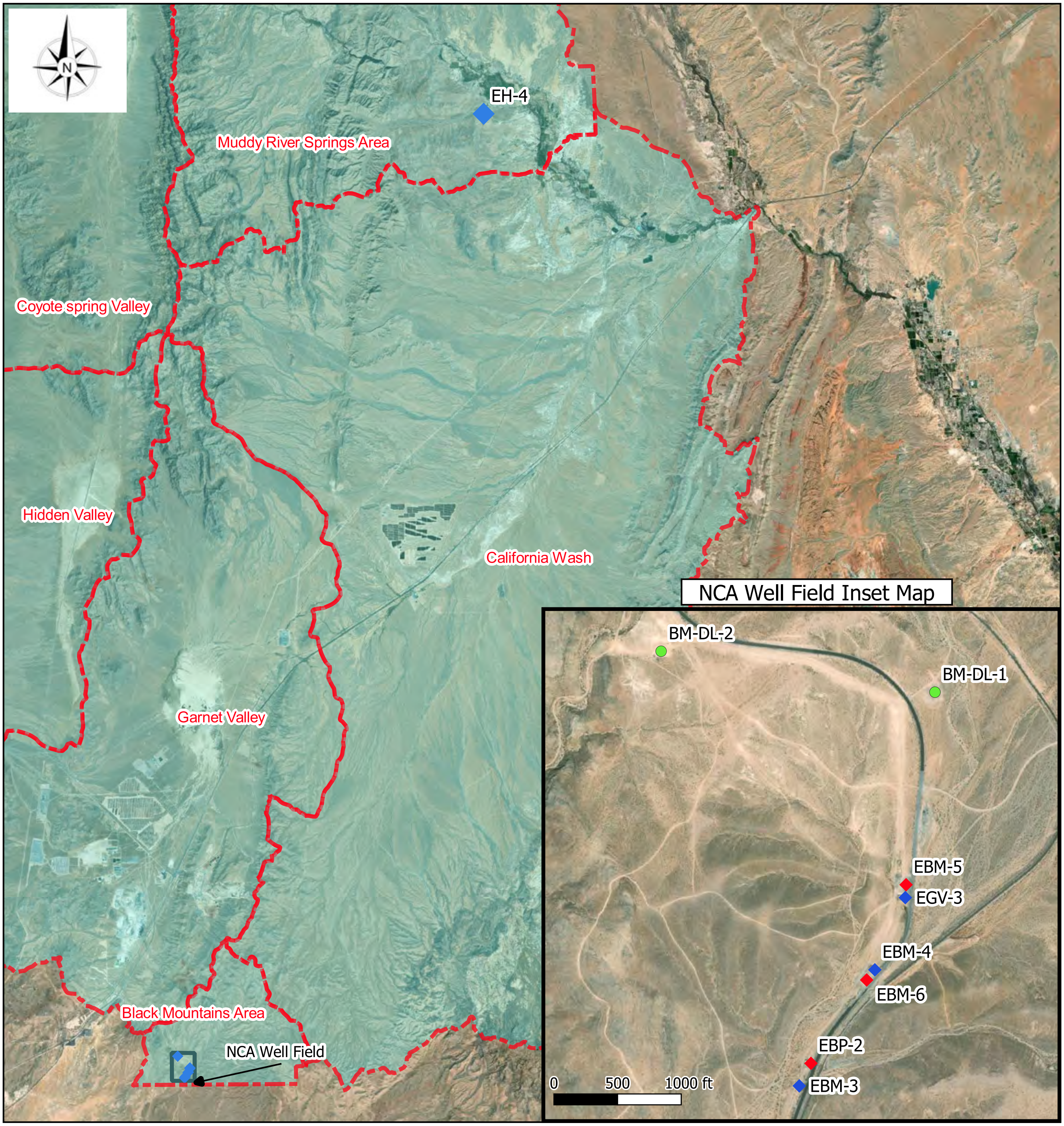


Figure 5. Groundwater elevation (hydrographs) for BM-DL-1 and BM-DL-2.



Legend

Regional Boundaries

LWRFS Basins (As Proposed in Order 1303)

NDWR Basins 2015

Water Levels

Post 1303 Hearing Analysis Wells

NCA Well Field (Vicinity Wells)

Monitoring

Pumping

Non-NCA Wells

DRG Layers

Google Eath Aerial

Graphic Scale

0 5 10 mi

Dixon Hydrologic, PLLC

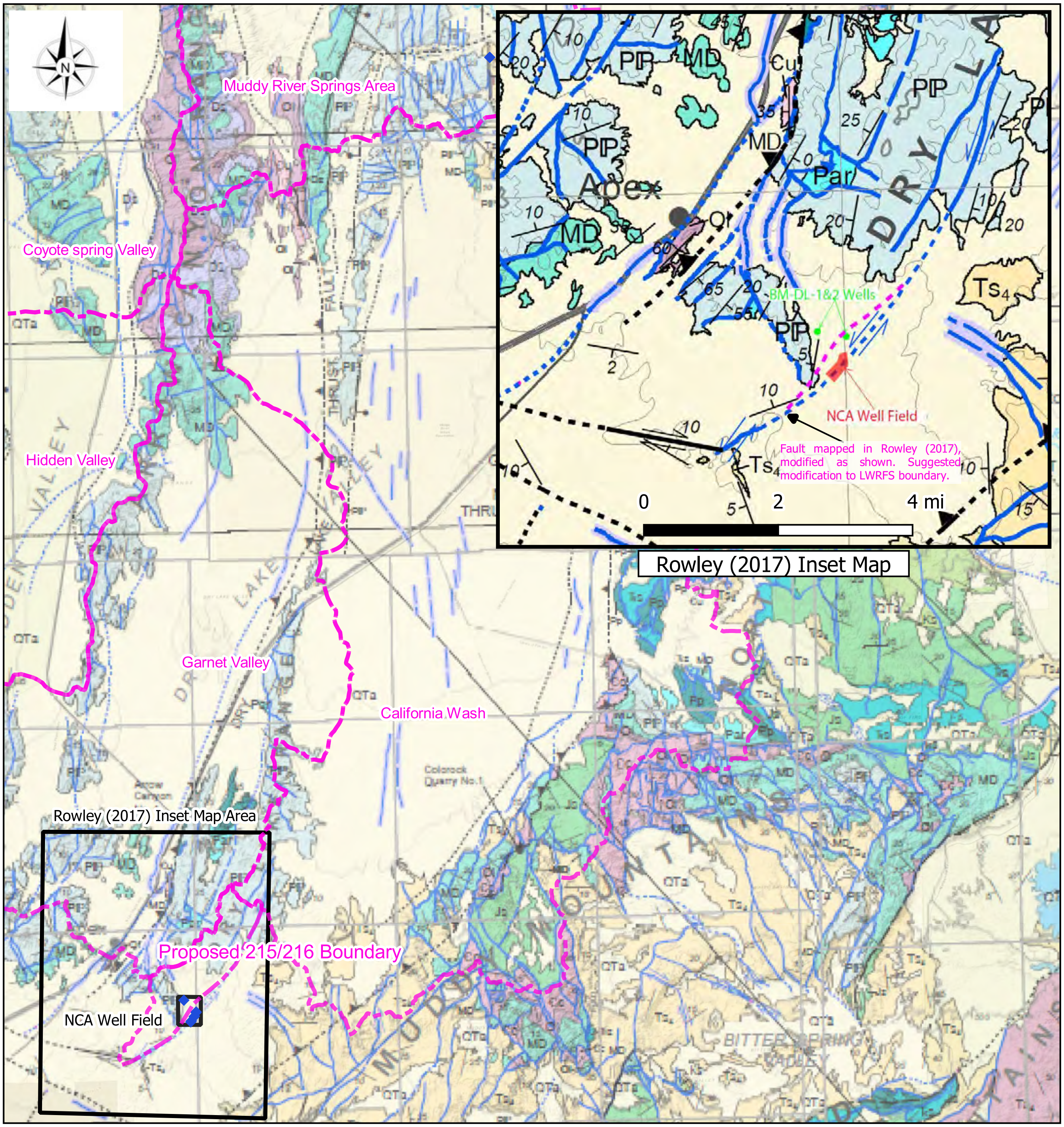
Nevada Cogeneration Associates

Order 1303 Follow-Up Review

Map 1

Date: 12/1/2019

Jay Dixon, P.E.



Legend

Regional Boundaries

- LWRFS Basins (As Proposed in Order 1303)
- Proposed Modification- Basins 215/216
- NDWR Basins 2015

Water Levels

- Post 1303 Hearing Analysis Wells

NCA Well Field (Vicinity Wells)

- Monitoring
- Pumping
- Non-NCA Wells

DRG Layers

Rowley (2017) Digitized Map

Graphic Scale

0 5 10 mi

Dixon Hydrologic, PLLC

Nevada Cogeneration Associates

Order 1303 Follow-Up Review

Map 2

Date: 12/1/2019	Jay Dixon, P.E.

SE ROA 52909

CERTIFICATE OF SERVICE

I hereby certify that I am an employee of KEMPFER CROWELL, and on this date, I caused the foregoing document to be served via electronic transmission as follows:

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mmmiller@cox.net;
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Additionally, a the original and a copy of this document was delivered for filing to the Division of Water Resources this same day.

DATED December 3, 2019.

Employee of Kaempfer Crowell

2468473_1

Nevada Power Company
and Sierra Pacific Power Company
d/b/a NV Energy

**IN THE OFFICE OF THE STATE ENGINEER
OF THE STATE OF NEVADA**

DESIGNATING THE ADMINISTRATION OF ALL WATER RIGHTS WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA BASIN (215), GARNET VALLEY BASIN (216), HIDDEN VALLEY BASIN (217), CALIFORNIA WASH BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) BASIN (219) AS A JOINT ADMINISTRATIVE UNIT, HOLDING IN ABEYANCE APPLICATIONS TO CHANGE EXISTING GROUNDWATER RIGHTS, AND ESTABLISHING A TEMPORARY MORATORIUM ON THE REVIEW OF FINAL SUBDIVISION MAPS.	INTERIM ORDER No. 1303

NEVADA ENERGY'S CLOSING STATEMENTS

I. INTRODUCTION

On January 11, 2019, the Nevada State Engineer ("State Engineer's) issued Interim Order No. 1303 setting forth a procedural schedule for briefs, reply briefs and a hearing to address five questions relating to the Lower White River Flow System ("LWRFS"):

a. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System;

b. The information obtained from Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recover since the completion of the aquifer test;

c. The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of the pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;

d. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River;

e. Any other matter believed to be relevant to the State Engineer's analysis.

In response to Interim Order No. 1303, Nevada Energy submitted a rebuttal report on August 16, 2016 and participated in the September 23 through October 4, 2019 hearing along with Coyote Springs Investments, LLC ("CSI"); United States Fish and Wildlife Service ("USFWS");

United States National Park Service ("NPS"); Moapa Band of Paiutes ("MBOP"); Southern Nevada Water Authority and Las Vegas Valley Water District (collectively "LVVWD/SNWA"); Moapa Valley Water District ("MVWD"); Lincoln County Water District and Vidler Water Company (collectively "Vidler"); City of North Las Vegas ("CNLV"); Center For Biological Diversity and Great Basin Water Network ("CBD"; Dry Lake Water LLC, Georgia Pacific Corporation, Georgia Pacific Gypsum, LLC, and Republic Environmental Technologies (collectively "GP"); Nevada Cogeneration Associates ("NCA); Muddy Valley Irrigation Company ("MVIC"); and Bedrock Limited and Western Elite Environmental Inc. (collectively "Bedroc").

During the course of the two week long hearing to summarize the parties' thousands of pages of briefs, reports and studies on the LWRFS, NV Energy's position with respect to the geographic boundaries of the LWRFS changed. As such, at the conclusion of the hearing, NV Energy requested permission to file a closing statement to address its new position. CSI and SNWA also requested permission to file closing briefs and draft orders. The State Engineer granted CSI, SNWA and NV Energy's request to allow the parties to file written closing statements. As such, NV Energy hereby files its Interim Order No. 1303 Closing Statement to address its change in position with respect to the inclusion of Kane Springs Valley into the geographic boundary of the LWRFS and provide a brief closing statement on the other issues addressed in in Interim Order No. 1303.

II. CLOSING ARGUMENT

A. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System should include Kane Springs Valley.

Through careful review of the reports, evidence and presentations of all the parties, NV Energy has changed its position and now agrees with MVWD, NPS, USFWS, CBD, and LVVWD/SNWA's[1] earlier position that Kane Springs Valley be included in the LWRFS boundary. Evidence and testimony overwhelmingly support the conclusion that virtually all of Kane Springs Valley's groundwater discharge flows downgradient into Coyote Spring Valley.

[1] October 23, 2018 Letter from Colby Pellegrino, SNWA to Jason King P.E.

While evidence shows there is faulting that may impede that flow of groundwater from Kane Springs Valley to Coyote Spring Valley, there is no evidence that this zone is impermeable. Rather evidence shows that during the Order 1169 pumping test the water levels in the wells in Kane Springs Valley were lowered, with a similar drawdown slope as other Coyote Spring Valley wells.[2]

Because the aquifer in Kane Springs Valley is clearly connected to the carbonate aquifer in Coyote Spring Valley, and because pumping in Coyote Spring Valley captures groundwater from Kane Springs Valley, it is clear that the reverse is also true. Pumping in Kane Springs Valley will reduce the current contribution of subsurface flow into Coyote Spring Valley, lower water levels and ultimately deplete the supply of water to the Muddy River Springs Area ("MRSA"). As there is no doubt that some, if not all, pumping in Kane Springs Valley will ultimately impact the MRSA, the Muddy River and ultimately the Moapa dace, it is imperative that Kane Springs Valley be included in the LWRFS Joint Management Area ("JMA").

B. The information obtained from order 1169 aquifer test and subsequent to the aquifer test and the Muddy River Headwater Spring Flow as it relates to aquifer recovery since the completion of the aquifer test indicates that the water level is reaching a steady state.

Since the Order 1169 aquifer test, evidence shows that maximum recovery was reached in 2016. Groundwater pumping during this period was primarily from the carbonate aquifer and averaged about 9,000 acre-feet per year. Since 2016, water levels in MRSA are approaching, or possibly have reached steady state. Flow at the Warm Springs West gage is staying above the 3.2 cfs trigger established under the 2006 Memorandum of Agreement ("MOA"). The current pumping regime of 7,000 to 8,000 acre feet annually should be maintained for additional time to ensure that steady state in the MRSA is reached and a minimum of 3.2 cfs is maintained at the Warm Springs West gage pursuant to the MOA.

[2] NPS Ex. 3 rebuttal page 10-11; USFS Ex. No 5, pg. 22 report

C. The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow supports current pumping levels.

Under the current pumping regime, steady-state conditions may already exist in the MRSA. Water levels and flows of the Muddy River and high elevation springs appear to have stabilized. Water levels in surrounding basins continue to decline at a very modest rate.

The post-Order 1169 analyses demonstrate that steady state conditions are being reached in the Muddy River Springs Area with 7,000 to 8,000 afy of carbonate pumping. The depletion of the Muddy River with this amount of pumping appears to be on the order of 2,300 to 3,750 afy, and is not increasing. Using these figures, impacts to the Muddy River appear to be on the order of 25% to 50% of the amount of groundwater pumped under the current pumping regime.

NV Energy agrees with respondents MBOP, CNLV and others that groundwater pumping at locations further south, toward the southern boundary of the LWRFS, are likely to have less effect on the Muddy River and springs than pumping in Coyote Spring Valley or the Muddy River Springs Area.

D. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River.

The movement of a water right from an alluvial well in the MRSA to a carbonate well in Garnet Valley, for example, would be evaluated by the State Engineer under NRS 533.370(2). Any change application within the LWRFS involves water already appropriated. Therefore, the first clause concerning unappropriated water at the source of supply is moot. Whether the proposed use in a change application conflicts with existing rights has always been evaluated by the State Engineer as a comparison between the effects on existing rights from pumping at the original Point of Diversion ("POD") as compared to effects from pumping on existing rights at the proposed POD. The preponderance of evidence submitted (e.g., NPS report and rebuttal reports) definitively show that carbonate pumping captures less Muddy River flow (senior and existing water rights) than alluvial pumping at all points in time. That is, the proposed POD whether it be in Garnet Valley or California Wash, would impact existing rights less than pumping from the an existing POD in the MRSA. Whether any impacts to existing water rights will occur is not necessarily a consideration for a change application. If impacts to existing water rights occur due to any and all pumping, then the State engineer should consider other management actions. If no impacts to any existing water rights were allowed, there would be just one water right in each of Nevada's basins. Therefore, the conflict analysis for such a change application would be satisfied and the application approved. There is no conflict with existing groundwater rights because NRS 534.110(4 and 5) allows for reasonable drawdown. Existing water rights in the carbonate aquifer are in wells generally over 1,000 feet deep. A lowering of the water table by a few feet due to new pumping is not unreasonable. Finally, any change application will not prove detrimental to the public interest any more than pumping from the existing POD. Because change applications are evaluated relative to the existing POD, this clause is also satisfied.

Nevada water law's primary tenets are prior appropriation and beneficial use. NV Energy's groundwater rights in the MRSA are senior to most groundwater rights in the LWRFS.[3] A review of a Hydrographic Abstract of the basins will show that most of NV Energy's water rights are also certificated.[4] When the State Engineer considers public interest, preserving a consistent interpretation of those primary tenets of Nevada's water law should be paramount.

E. Any other matter believed to be relevant to the State Engineer's analysis.

With all complex water systems, more data is needed in the LWRFS. In order to ensure that the 3.2 cfs trigger at Warm Springs West gage is not met, one or two more years pumping at current rates and locations needs to be collected to verify equilibrium conditions in MRSA have been reached.

While the State Engineer does not have jurisdiction over the current MOA that set forth the 3.2cfs triggers in the MRSA, NV Energy believes that the MOA, or an appropriate agreement needs to be expanded to include all users in the LWRFS. As Warm Springs West flows are just

[3]NSE Exhibit 224.
[4] *Id.*

over 3.2 cfs, there is little room for additional stresses in the system and it is in the State's interest, as well as all of the water users in the LWRFS, to protect the Moapa dace.

III. CONCLUSION

The thousands of pages of exhibits and the two week long hearing has provided copious amounts of information for the State Engineer to work with, however, this is still more information that needs to be collected in certain areas of the LWRFS. However, there is substantial evidence that the LWRFS should include Kane Springs. Water levels in the MRSA are reaching steady state at the current pumping regime, however more information is needed to ensure that the 3.2 trigger is not reached. NV Energy looks forward to the future phase(s) of this proceeding.

Respectfully submitted this 4th day of December, 2019.

NV Energy

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RECEIVED
2019 DEC -3 PM 4:47
STATE ENGINEERS OFFICE

IN THE OFFICE OF THE STATE ENGINEER OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA.

CLOSING BRIEF OF SOUTHERN NEVADA WATER AUTHORITY AND LAS VEGAS VALLEY WATER DISTRICT

COME NOW SOUTHERN NEVADA WATER AUTHORITY ("SNWA") and LAS VEGAS VALLEY WATER DISTRICT ("LVVWD") by and through counsel, PAUL G. TAGGART, ESQ. and TIMOTHY D. O'CONNOR, ESQ., of the law firm of TAGGART & TAGGART, LTD., and STEVEN C. ANDERSON, ESQ., of SNWA, and hereby submits its closing brief in this matter.

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INTRODUCTION

I. SNWA and LVVWD Are the Primary Stakeholders in the LWRFS.

SNWA and LVVWD have substantial interests in the Lower White River Flow System ("LWRFS"). SNWA is a not-for-profit political subdivision of the State of Nevada consisting of seven member agencies (local municipalities and political subdivisions in Clark County) and is a wholesale water provider serving approximately 75 percent of Nevada's population. SNWA's water resource portfolio includes approximately 20,000 afa of senior Muddy River decreed water rights, 9,000 afa of groundwater in Coyote Spring Valley, and 2,200 afa of groundwater in Garnet and Hidden valleys. SNWA conducted the Order 1169 pumping test and is one of the primary participants in the 2006 Memorandum of Agreement ("MOA") concerning the Moapa dace. Clark County designated SNWA's largest member purveyor, LVVWD, to be the operating entity for the Coyote Springs Water Resources General Improvement District.

If Coyote Springs Investment, LLC ("CSI") is allowed to develop homes in the LWRFS, LVVWD and Clark County are responsible for providing long-term water service. SNWA and LVVWD, therefore, urge the State Engineer to exercise caution. Compelling evidence proves that only 4,000 to 6,000 afa can be sustainably pumped Based on the evidence presented, the State Engineer should not approve new subdivisions, or additional long-term pumping, because the public health and safety of a new community cannot depend upon LWRFS groundwater.

II. Order 1303 and Previous Factual Findings of State Engineer.

The State Engineer issued Interim Order 1303 to obtain stakeholder input on four specific factual questions. After factual findings are made on those questions, the State Engineer will use that factual predicate to evaluate groundwater management options for the Lower White River Flow System. This Closing Argument addresses those factual questions.

The State Engineer is not starting from scratch. The record of available information and data is rich, and the 2019 administrative proceeding simply built on the record related to applications filed over 30 years ago. In 2002, the State Engineer considered applications to appropriate water in Coyote Spring Valley, but issued Order 1169 because the lack of aquifer data prevented informed management. The State Engineer thus required a pumping test in Coyote Spring Valley to stress the aquifer. The pumping test yielded a substantial amount of information, and drastically altered the outlook for groundwater management and availability in the LWRFS.

As chronicled in Order 1303, the State Engineer made sound factual findings based on the Order 1169 pumping test. He found that groundwater rights within the LWRFS should be jointly managed because of a "unique" and "direct hydraulic connection" among basins that encompass over 1,100 square miles. He also determined water was not available for additional applications and denied all the pending applications in the LWRFS through Rulings 6254-6260. The State Engineer also found that:

1. pumping has a direct interrelationship with the flow of the decreed and fully appropriated Muddy River, which are the most senior rights;
2. the Muddy River had a pre-development flow of approximately 34,000 acre-feet annually;
3. pumping from the test caused "sharp declines in groundwater levels and flows in the Pederson and Pederson East springs," and throughout the LWRFS; and
4. pumping in the LWRFS must be less than occurred during the test, otherwise pumping will conflict with senior Muddy River rights or adversely impact the Moapa dace.[1]

Order 1303 was issued to solicit factual input from experts on discrete issues to build on these foundational findings from Rulings 6254-6260 – not to "start over."

Most stakeholders that presented evidence understood the work that was completed over the previous 20 years. They agreed that the State Engineer already rejected the water budget approach in favor of using aquifer tests and recovery data that was required by Order 1169. They acknowledged the exceptionally flat gradient and high degree of transmissivity throughout the LWRFS. Importantly, they reached consensus that the prior State Engineer findings were correct, and the lack of aquifer recovery since Rulings 6254-6290 means that existing pumping levels pose

[1] NSE Ex. 1 at 7-11.

an imminent threat to the endangered Moapa dace and senior water rights in the Muddy River. These parties also agree no new long-term pumping can occur, and a reduction in existing pumping is probably required. Most stakeholders further agree: (1) the precise LWRFS boundary is debatable, but ultimately, a hydrologic connection exists with Kane Springs Valley; (2) the carbonate aquifer is highly transmissive and pumping from virtually all reaches of the LWRFS impact the Muddy River and its springs; (3) pumping, not climate, is the primary factor for the declines; (4) maximum recovery has been reached and declines are once again occurring; and (5) a water user cannot pump "underflow" without capturing the source of supply for the Muddy River.

A few parties are outliers who ignored the prior findings of the State Engineer. For instance, CSI needs more water to build a large community in Coyote Spring Valley and sought to turn back the clock to a time before the Order 1169 pumping test. Without more groundwater pumping, CSI does not have enough water to provide a long-term supply to a new community. Thus, CSI's experts relied on water budgets, and not aquifer stress and recovery data even though the State Engineer, and virtually all other experts, acknowledged water budgets of little value at this time. And despite widely accepted expert conclusions regarding hydrologic connectivity in the LWRFS, CSI also proffered dubious CSAMT information to *hypothesize* new geologic barriers to flow, and a new compartment for conflict-free pumping, despite the consensus of experts that CSAMT cannot be used to for that purpose.

EVIDENCE RELATED TO FOUR FACTUAL INQUIRIES IN ORDER 1303

I. The Geographic Boundary Defined in Order 1303 for the LWRFS Should Not Be Amended At This Time.

Order 1303 requested input on the "geographic boundary of the hydrologically connected groundwater and surface water systems comprising" the LWRFS. During the hearing, a consensus of expert opinion emerged on this question. Nearly all parties acknowledged the high degree of hydraulic connectivity within the LWRFS.[2] That unique connectivity is supported by additional

[2] Hr'g on Order 1303 Tr. vol. 2, 266:3-11, Sept. 24, 2019 (Braumiller); Hr'g on Order 1303 Tr. vol. 3, 509:7-8, Sept. 25, 2019 (Waddell); Hr'g on Order 1303 Tr. vol. 5, 953:6-8, Sept. 27, 2019 (Burns); Hr'g on Order 1303 Tr. vol. 6,

information obtained in the years following the pumping test. Quantitative data assessments indicate that ground-water levels underlying these basins correlate to EH-4, an index well in the MRSA.[3] This is due to the "lithologic continuity"[4] or "uninterrupted, continuous, exceptionally flat gradient . . . from KMW-1 down to EH-4."[5] Certainly, all the areas within the currently constituted LWRFS are hydrologically connected, and none should be excluded.

A. New CSAMT Data Does Not Justify Excluding Northern or Western Coyote Spring Valley from the LWRFS.

CSI and Lincoln/Vidler introduced CSAMT data, erroneously claiming it was the only "new" evidence, to claim pumping can occur within certain parts of the existing LWRFS without conflicting with senior water rights, or impacting the Moapa dace. CSI and Lincoln/Vidler used CSAMT data to identify new faults, took great liberties with the precise placement of the faults, and incorrectly concluded the *new* faults represented impermeable geologic barriers to groundwater flow. CSI, for example, argued that faulting west of MX-5 (the "Highway Fault") created an east/west barrier to flow, which essentially created a western flow path where approximately 5,000 afa of groundwater can allegedly be pumped without impacting the rest of the LWRFS.[6] Similarly, Lincoln/Vidler contended that CSAMT data showed faulting in northern Coyote Spring Valley that creates an impermeable barrier.[7] These claims are without merit.

CSAMT data was obviously not the only new evidence introduced during the Order 1303 hearing, because new data and analysis were presented by other parties including more recent groundwater level data, correlations in groundwater change, and climate trend data. More importantly, CSAMT data was improperly conflated to identify hydrologic properties that are

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1178:1-18, Sept. 30, 2019 (Lazarus); Hr'g on Order 1303 Tr. vol. 8, 1526:23-27:5, Oct. 2, 2019 (Myers); Hr'g on Order 1303 Tr. vol. 9, 1645:7-10, Oct. 3, 2019 (Coache); Hr'g on Order 1303 Tr. vol. 10, 1763-65, Oct. 4, 2019 (Felling); Hr'g on Order 1303 Tr. vol. 1, 95:14-16, Sept. 23, 2019 (Reich).

[3] Hr'g on Order 1303 Tr. vol. 3, 509:11-12, Sept. 25, 2019 (Waddell); Hr'g on Order 1303 Tr. vol. 6, 1178:1-18, Sept. 30, 2019 (Lazarus); Hr'g on Order 1303 Tr. vol. 5, 903:2-5, Sept. 27, 2019 (Burns).

[4] Hr'g on Order 1303 Tr. vol. 3, 509:12, Sept. 25, 2019 (Waddell).

[5] Hr'g on Order 1303 Tr. vol. 6, 1178:10-11, Sept. 30, 2019 (Lazarus).

[6] Hr'g on Order 1303 Tr. vol. 1, 98:16-99:2, Sept. 23, 2019 (Reich) (*see* CSI Ex. 1 at 48, concluding "groundwater pumping in CSI-1, -3 and -4 will not likely cause impact to groundwater resources in the Muddy River Springs Area.").

[7] LCV Ex. 2 at 16.

inconsistent with actual empirical groundwater level data that was collected during and after the Order 1169 pumping test. While CSAMT may do a "good job of" identifying faults, "[i]t does not measure hydraulic properties."[8] CSAMT can be useful for making hypotheses, but such hypotheses must be proven through hydrology.[9] CSI and Lincoln/Vidler ignored known hydraulic properties, and all other experts roundly rejected CSI's and Lincoln/Vidler's CSAMT conclusions.

SNWA-LVVWD explained in their rebuttal report and testimony that "the available data do not support the conclusion by Reich and Moran (2019) that monitor wells CSVM-2 and CSVM-4 did not respond to pumping that occurred in the MRSA or eastern portion of Coyote Spring Valley."[10] To support this claim, SNWA-LVVWD's experts explained, "[m]onitor well CSVM-2 . . . is within the same structural block as production wells CSI-1, CSI-3 and CSI-4, . . . responds to natural and anthropogenic stresses in the same manner as all the other LWRFS wells completed in the carbonate aquifer."[11] Other experts agreed with this assessment. Also, water-level records that were needed to support CSI's claims were "conspicuously absent from their report."[12] Thus, notwithstanding any CSAMT "hypotheses," the hydrologic testing shows any new CSAMT faults are permeable and do not act as barriers.[13]

Similarly, Dr. Waddell, on behalf of NPS, explained that CSI and Lincoln/Vidler applied CSAMT in reverse order, as they used CSAMT to identify faults, then assumed the faulting and structures were impermeable.[14] "CSAMT does not provide you information on [permeability]" and "[y]ou just can't make the assumption because [the structure] has a high resistivity that it has low permeability."[15] In short, claiming these structures are barriers to flow is "an invalid interpretation."[16] To test the hypothesis formed from CSAMT data, one "can do aquifer tests,"

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[8] Hr'g on Order 1303 Tr. vol. 3, 533:6-10, Sept. 25, 2019 (Waddell).
[9] *Id.* at 628:5-9 (Waddell).
[10] SNWA Ex. 9 at 6.
[11] SNWA Ex. 9 at 7-8 (*see* Figure 2-4).
[12] SNWA Ex. 9 at 7. Such records do exist and demonstrate there is a clear hydraulic connection between these wells and the rest of the LWRFS from west to east and north to south. SNWA Ex. 9 at 7-9.
[13] Hr'g on Order 1303 Tr. vol. 3, 543:11-12, 628:5-9, Sept. 25, 2019 (Waddell) (making similar conclusions to those SNWA reached in notes 23-25, *supra*).
[14] *Id.* at 533-34 (Waddell).
[15] *Id.* at 534:4-7 (Waddell).
[16] *Id.* (Waddell).

such as Order 1169 in the LWRFS.[17] Aquifer tests are necessary because "when pumping is done and observations are made of discharge . . . your water levels are much more valid."[18] This data, along with factors such as low "hydraulic gradients across the block," shows CSI made an "invalid interpretation."[19] Thus, Dr. Waddell concluded that the supposed barrier was, in fact, *permeable*.[20]

Many experts took exception to CSI's and Lincoln/Vidler's CSAMT conclusions. Mr. Lazarus bluntly stated he "disagree[s] with this assertion" of a purported barrier in Coyote Spring Valley and agreed with Dr. Waddell that such conclusions are not "valid conclusion[s] based upon the evidence."[21] To support his opinion, Mr. Lazarus addressed the hydraulic gradients from KMW-1 to EH4, from CSVM-4 to CSVM-1 (a proxy for MX-5) and from CSVM-1 to EH-4, with EH-4 acting as a sentinel or index well for the MRSA. Calculating the gradient from various LWRFS wells to EH-4, Mr. Lazarus remarked that "the gradient is remarkably flat."[22] Mr. Lazarus explained, "[w]hatever heterogeneities might be there aren't affecting the groundwater gradient in those areas" or "interrupting groundwater flow."[23] Finally, in addressing whether "there are any compartments in Coyote Spring Valley that can be pumped without impacting the Muddy River Springs," Mr. Lazarus simply stated, "based on the data available to date, no."[24]

NV Energy's expert, Mr. Felling, also criticized CSI's and Lincoln/Vidler's CSAMT assertions. Regarding CSI's purported western flow path, Mr. Felling testified that the elevation at CSVM-2 is several feet higher than in the center of the valley. Mr. Felling further explained that the State Engineer already rejected the western flow path because "evidence showed that there was a water level at the south end of Coyote Spring Valley that was higher and it looked like there was a groundwater divide."[25] He testified that any faulting would only be an impediment, not a barrier to flow, as flow from Kane Springs Valley "makes it into Coyote Spring Valley where it

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[17] *Id.* at 534:8-9 (Waddell).
[18] *Id.* at 629:12-16 (Waddell).
[19] *Id.* at 534:2-7 (Waddell).
[20] *Id.* (Waddell).
[21] Hr'g on Order 1303 Tr. vol. 6, 1176:18-27:3, Sept. 30, 2019 (Lazarus).
[22] *Id.* at 1177:1-18 (Lazarus).
[23] *Id.* at 1165:23-66:1 (Lazarus), 1169:9-24 (Lazarus).
[24] *Id.* at 1220:7-10 (Lazarus).
[25] Hr'g on Order 1303 Tr. vol. 10, 1800:15-23, Oct. 4, 2019 (Felling).

joins the regional flow and heads southward towards the Muddy River Spring."[26] Similarly, Dr. Myers testified flow from the north "reach[es] southern Coyote Spring Valley and well MX-5 and of course then the Muddy River Springs Area," the "point being" that despite any geologic structures, flow from Coyote Spring Valley moves to the Muddy River Springs Area.[27]

Order 1303 plainly identifies the initial hydrologic work that was done in the LWRFS, including the significant pumping stress that provided real data on how various parts of the aquifer responded. That evidence, and the new groundwater level data and analysis, proves the CSAMT-based hypotheses of impermeable faults are plainly incorrect. Therefore, neither western nor northern Coyote Spring Valley should be excluded from the LWRFS.[28]

B. <u>Certain Adjacent Basins Should Be Managed With Recognition That Pumping In Those Basins Can Impact The LWRFS, But Adjacent Basins Should Not Be Added To LWRFS Until Establishment of Groundwater Management Rules.</u>

Throughout the hearing, various experts identified additional basins for possible inclusion in the LWRFS. The most notable candidates for inclusion were Kane Springs, Lower Meadow Valley Wash and the Las Vegas Valley. The case for inclusion of these basins varies from "compelling" for Kane Springs, to virtually unsupported for Las Vegas Valley. Regardless, as Mr. Felling testified, "the State Engineer could manage [the LWRFS] without including [additional basins] in the [LWRFS] management area" and thus, "at this point in time I don't think that it's necessary."[29] Similarly, Ms. Pellegrino testified, "regardless of the boundary, we know that the State will have to continue managing the adjacent basins to" protect the LWRFS from pumping in those basins.[30] Ultimately, the boundary must be protected from activities that could cause drawdown to propagate to the LWRFS, such as allowing a "pile-up" of "points of diversion along the boundary."[31] For instance, applications in Kane Springs seek to move pumping to the border

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[26] *Id.* at 1761:4-14 (Felling).
[27] Hr'g on Order 1303 Tr. vol. 8, 1518:9-24, Oct. 2, 2019 (Myers).
[28] Various parties claimed "underflow" could be captured, but no party could identify where underflow could be captured without capturing Muddy River flows or spring sources.
[29] Hr'g on Order 1303 Tr. vol. 10, 1763-65, Oct. 4, 2019 (Felling).
[30] Hr'g on Order 1303 Tr. vol. 5, 876:2-10, Sept. 27, 2019 (Pellegrino).
[31] *Id.* (Pellegrino).

of Coyote Spring Valley. While Kane Springs does not necessarily have to be included within the LWRFS, management of Kane Springs must account for the impacts Kane Springs applications will have on the LWRFS and, in particular, on its senior decreed rights and the Moapa Dace.

Accordingly, even though certain adjacent basins may merit inclusion in the LWRFS at some later time, inclusion now is not necessary. This point is made clearer by the fact the rules for groundwater management in the LWRFS, and when new basins are added to the LWRFS, have not been defined. Groundwater management rules in the LWRFS should not allow more flexibility in moving points of diversion freely from basin to basin. But until such rules are clear, the State Engineer should not create a potential opening for water rights to be moved to existing LWRFS basins from adjacent basins. For example, under the proposed LWRFS boundary, pumping in certain areas of the more tenuously-connected Black Mountains Area will likely not have significant impact on Muddy River springs or river flow. But, if such pumping moved closer to the MRSA, within the LWRFS, there would likely be quicker and more significant impacts.

As the State Engineer's Office has made clear, Interim Order 1303 created a process for addressing only factual issues, and groundwater management issues will be addressed in a subsequent phase of this proceeding. At this time, SNWA agrees that "the boundary defined by the State Engineer is appropriate."[32] But, depending on subsequent management decisions, the State Engineer should consider inclusion of other basins in the next phase of the proceedings.

C. <u>The Las Vegas Valley Should Not Be Added To The LWRFS.</u>

The Moapa Band of Paiute Indians ("Tribe") is the primary proponent of including the Las Vegas Valley within the LWRFS. But the Tribe's assertion, generally supported by CSI, is based on little more than conjecture. Burns and Drici explained that "any outflow to Las Vegas Valley," would be from the carbonate aquifer to the basin-fill, which is 3 to 4 kilometers thick," raising the question of "where this groundwater discharges in the Las Vegas Valley,"[33] and would require

[32] Hr'g on Order 1303 Tr. vol. 5, 953:7-10, Sept. 27, 2019 (Burns).
[33] SNWA Ex. 9 at 12.

"flow upgradient through the Las Vegas Valley Shear Zone".[34] Dr. Waddell also rejected the Tribe's argument. "Water has a hard time getting across the Las Vegas Valley shear zone" and that groundwater "has a hard time getting across some of the rock that intervene between the carbonate aquifer and the Colorado River, limiting flow and discharge out of the system."[35] Similarly, Dr. Myers, for CBD, stated that "for this to actually occur, water would have to go uphill."[36] And, Mr. Felling, on behalf of NV Energy, testified that he would not recommend "that [the State Engineer] extend the system to Las Vegas Valley" based on the shear zone.[37]

II. Order 1169 Pumping Test And Subsequent Recovery Of Impacts to Groundwater Levels And Spring Flows

The second inquiry in Interim Order 1303 related to aquifer recovery since the end of the Order 1169 pumping test. A consensus of experts agreed to the following.

A. Pumping Test (and Existing Pumping) Impacted Virtually All Areas of the LWRFS.

The LWRFS basins have been the subject of testing and assessment for nearly two decades. In Interim Order 1303, several foundational findings were made and those findings were confirmed during the recent administrative hearing. For example, "the resulting water-level decline" from the pumping test "encompassed 1,100 square miles and extended from northern Coyote Spring Valley through the Muddy River Springs Area, Hidden Valley, Garnet Valley, California Wash and the northwestern part of the Black Mountains Area."[38] Data revealed that the pumping test, with concurrent pumping in other LWRFS basins, "caused sharp declines in groundwater levels and flows in the Pederson and Pederson east springs."[39] Indeed, the Pederson Springs hydrograph

[34] SNWA Ex. 9 at 12, Figure 2-8.
[35] Hr'g on Order 1303 Tr. vol. 3, 517:15-19, Sept. 25, 2019 (Waddell).
[36] Hr'g on Order 1303 Tr. vol. 8, 1536:21-22, Oct. 2, 2019 (Myers).
[37] Hr'g on Order 1303 Tr. vol. 10, 1764:21-24, Oct. 4, 2019 (Felling).
[38] NSE Ex. 1 at 4.
[39] *Id.* at 5.

in Order 1303 shows the severe decline that occurred during the pumping test.[40] These findings and conclusions were not seriously debated by the experts.

Virtually all experts agree that MX-5 pumping caused corresponding drawdowns throughout the LWRFS carbonate aquifer and the decline of Muddy River spring flows.[41] For example, Mr. Burns testified that pumping at MX-5 caused corresponding drawdowns at MX-4 and CSVM-2 and, in turn, at the index well EH-4 in the MRSA.[42] The high correlation between hydraulic head at EH-4 with discharge at Pederson Spring[43] indicates MX-5 pumping is directly correlated to decreased spring flow for Moapa dace and senior water rights. Even pumping in CSI's western alleged "compartment of no conflict" is hydrologically connected to the Muddy River. Dr. Waddell explained how CSVM-2, which is in that "compartment," has a "gradient for flow back to the north [MX-5]."[44] "[W]ater levels are lower in the central part of the CSV than they are to the south" or in the northern potions.[45] Thus, water in southern Coyote Spring Valley *does not flow to Hidden Valley*, but moves north to MX-5, and then into the MRSA and discharges in the springs.[46]

B. Aquifer Levels And Spring Discharge Remain Below Pre-Test Levels.

When the Order 1169 pumping test ended at MX-5, groundwater pumping throughout the LWRFS continued. After the cessation of MX-5 pumping, carbonate aquifer levels began to increase. The recovery, however, did not reach pre-test levels. Throughout these proceedings, many experts offered evidence and testimony that recovery reached its maximum level in

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[40] *Id.* at 5.

[41] *See, e.g.*, Hr'g on Order 1303 Tr. vol. 5, 899:17-900:16, Sept. 27, 2019 (Burns); Hr'g on Order 1303 Tr. vol. 3, 521:5-24, Sept. 25, 2019 (Waddell), Hr'g on Order 1303 Tr. vol. 2, 251:4-52:12 Sept. 24, 2019 (Braumiller), Hr'g on Order 1303 Tr. vol. 6, 1187:11-88:21, Sept. 30, 2019 (Lazarus), Hr'g on Order 1303 Tr. vol. 8, 1526:23-27:5, Oct. 2, 2019 (Myers).

[42] SNWA Ex. 81; Hr'g on Order 1303 Tr. vol. 5, 945:14-46:16, Sept. 27, 2019 (Burns).

[43] *Id.* at 899:17-20 (Burns).

[44] Hr'g on Order 1303 Tr. vol. 3, 543:11-12, Sept. 25, 2019 (Waddell).

[45] *Id.* (Waddell).

[46] *Id.* (Waddell). The only exception to the hydrologically connected LWRFS is CSVM-5 – a high elevation monitoring well in the Sheep Range that required a Special Use Permit for construction. No party argued this source could support a production well, and for good reason. Beyond its location in the Desert Wildlife Refuge and federal management as wilderness area, CSVM-5 has a depth to water of 1,080 ft bgs, making production futile. *See* SNWA Ex. 7 at 3:11-13.

approximately 2016.[47] This was not unexpected, as Order 1303 states that "groundwater levels have not recovered to pre-test levels."[48] The stunted recovery, of course, has been limited by continued carbonate pumping.[49] And, while the recovery may have peaked and then "leveled off," the problem persists, as "we're starting to downward trend again."[50] Therefore, aquifer and spring flows remain at levels below pre-test levels with virtually no chance to return to pre-test levels.

C. <u>Drawdown is Still Occurring Due to Ongoing Pumping.</u>

Groundwater levels and spring flows are continuing to decline in the LWRFS due to ongoing pumping. Mr. Burns testified that since peak recovery, measurements and observations indicate declining trends in monitor wells throughout the LWRFS, such as EH-4.[51] If the potentiometric surface measured by EH-4 water levels continues to decrease, the spring complex discharge will also decrease.[52] Ms. Drici further explained that this indicates we have definitely not reached a "steady state" "because we're still capturing groundwater from storage."[53]

Several other experts agreed with SNWA-LVVWD's conclusion that after achieving maximum post-pumping recovery around 2016, declines continue due to ongoing pumping. For instance, Dr. Waddell testified that hydrographs still show a continuing decline that may continue for many decades.[54] Specifically, he testified that the evidence shows a *declining trend in water levels* in Coyote Spring Valley, Garnet Valley and California Wash, at EH-4, and by implication, at high-elevation springs supplying the Muddy River.[55] Dr. Waddell also agreed that the declines at EH-4 represent corresponding declines throughout the highly-interconnected LWRFS.[56] Dr. Myers indicated that water levels are not "steady but [are] going down."[57] Dr. Myers reinforced

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[47] *See, e.g.*, Hr'g on Order 1303 Tr. vol. 5, 941:2-7, Sept. 27, 2019 (SNWA); Hr'g on Order 1303 Tr. vol. 8, 1545:22-46:1, Oct. 2, 2019 (Myers); Hr'g on Order 1303. Tr. vol. 9, 1658:6-15, Oct. 3, 2019 (Coache).
[48] NSE Ex. 1 at 8.
[49] Hr'g on Order 1303 Tr. vol. 8, 1545:1-46:1, Oct. 2, 2019 (Myers).
[50] Hr'g on Order 1303 Tr. vol. 3, 519:24-20:4, Sept. 25, 2019 (Waddell).
[51] *Id.* (Waddell).
[52] Hr'g on Order 1303 Tr. vol. 5, 880:6-9, Sept. 27, 2019 (Burns).
[53] Hr'g on Order 1303 Tr. vol. 5, 932:21-22, Sept 27, 2019 (Drici).
[54] Hr'g on Order 1303 Tr. vol. 3, 642:21-45:23, Sept. 25, 2019 (Waddell).
[55] *Id.* at 644:1-10 (Waddell).
[56] *Id.* at 645:19-46:2 (Waddell).
[57] Hr'g on Order 1303 Tr. vol. 8, 1545:16-46:1, Oct. 2, 2019 (Myers).

his position when he described trends at EH-4 in the post-recovery years as continuing to decline. And, given that Arrow Canyon pumping declined at this time, "there should be a slight uptick in the flows and slight uptick in the water levels[.]"[58]

Even the few experts who initially opined to the existence of a new "steady state" or equilibrium recanted because more observations are needed to know for sure.[59] For instance, Mr. Felling testified, "[c]urrently, we're still losing water from storage in the [LWRFS],"[60] and, "*I think that water levels are declining everywhere because of groundwater pumping.*"[61]

D. Climate Is Not A Significant Factor in LWRFS Groundwater Declines.

Certain parties, primarily CSI and the Tribe, argued that sharp declines in aquifer levels were due to climate, not groundwater pumping. These assertions were refuted by expert testimony, and cannot be squared with findings the State Engineer already made.

SNWA-LVVWD submitted written evidence and testimony that established when "local and dominant natural or anthropogenic stress is imposed on the carbonate aquifer, its impact on water levels and spring flow can be detected on the hydrographs within short time periods, and everywhere within the interconnected carbonate aquifer."[62] Mr. Burns identified the extraordinary precipitation event of 2005 (natural), and the Order 1169 pumping test and subsequent pumping (anthropogenic), as obvious examples. To test this observation, multiple linear regression ("MLR") analysis was completed to extract the effects of groundwater pumping from other stresses, including climate.[63] The MLR analysis confirmed that groundwater production from the carbonate aquifer, not climate, is the main cause of the observed long-term declines in carbonate aquifer levels and Muddy River spring flows.[64]

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[58] *Id.* at 1552:20-53:22 (Myers).
[59] *See, e.g.*, NVE Ex. 1 at 2; Hr'g on Order 1303 Tr. vol. 10, 1790:6-10, Oct. 4, 2019 (Felling).
[60] Hr'g on Order 1303 Tr. vol. 10, 1783:7-8, Oct. 4, 2019 (Felling).
[61] *Id.* at 1812:1-2 (Felling) (emphasis added).
[62] SNWA Ex. 9 at 16.
[63] *Id.*
[64] *Id.*

A few experts expressed opinions regarding limitations or misapplication of SNWA's MLR method, but other experts supported the MLR analysis.[65] Mr. Felling recognized the importance of MLR as a critical piece of new evidence and analysis because it "goes to the question . . . none of the other parties tried to answer" and is "important for showing the effects of pumping in all of these different areas."[66] Regardless of critiques of method, the fact remains the pumping test demonstrated the high hydraulic connectivity and flat gradient of the carbonate aquifer.

SNWA-LVVWD's conclusion based on the MLR analysis is consistent with the opinions of the vast majority of experts. Ms. Braumiller and Dr. Mayer, on behalf of FWS, concluded pumping, not climate, is the primary cause of aquifer drawdown and spring flow declines. Dr. Mayer explained emphatically there is "no credible evidence that drought has impacted water levels in the LWRFS."[67] Consistent with this, Dr. Waddell presented compelling evidence that groundwater levels in similarly situated climatic basins are *increasing* where there is no human stress from groundwater pumping, yet the LWRFS aquifer levels continue to decline.[68] Dr. Myers concurred. He testified, "I see no evidence of a 20-year drought in this data" from the Western Regional Climate Center."[69] Dr. Myers directly addressed numerous shortcomings from the conclusion of the Tribe's experts, including the lack of a "direct analysis of climate data" in their report and numerous unwarranted assumptions, such as a purported 40,000 afa of flow to Las Vegas Valley.[70] Similarly, Mr. Felling explained climate is not a significant driver and in wet years, you may see an increase in aquifer levels, but "in dry years you don't see that much of a decline or any I think measurable decline."[71]

Mr. Lazarus echoed these conclusions on behalf of MVWD. He testified, "[i]f there are any seasonal fluctuations during the pumping test, the pressure response from the MX-5 pumping test throughout the highly confined aquifer system . . . had overridden any type of climate

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[65] Hr'g on Order 1303 Tr. vol. 9, 1644:11-14, 1645:7-10, Oct. 3, 2019 (Coache).
[66] Hr'g on Order 1303 Tr. vol. 10, 1785:18-20. 1787:1-2, Oct. 10, 2019 (Felling).
[67] Hr'g on Order 1303 Tr. vol. 2, 322:15-19, Sept. 24, 2019 (Mayer).
[68] Hr'g on Order 1303 Tr. vol. 3, 574:4-82:23, Sept. 25, 2019 (Waddell).
[69] Hr'g on Order 1303 Tr. vol. 8, 1508:20-24, Oct. 2, 2019 (Myers).
[70] *Id.* at 1534:17-36:10 (Myers).
[71] Hr'g on Order 1303 Tr. vol. 10, 1772:1-8, Oct. 4, 2019 (Felling).

response."[72] Mr. Lazarus testified that the stable groundwater levels during drought periods "contradict[] the idea that the declining water levels during the test were normalizing after 2004-2005.[73] Further,

> during the 1169 pumping test . . . we had rapid drawdown in CSVM-4 despite normal or near normal Palmer Drought Severity Index climate indicators here, [s]o while we're seeing the PDSI rise, we're seeing . . . the most rapid drawdown in the CSVM-4 hydrograph, and that's during the pumping test.[74]

In addition, "we're seeing the Palmer Drought Severity Index drop while water levels in CSVM-4 are increasing."[75] Climate simply cannot explain the drastic drawdown during the pump test and corresponding moderation in trend that has happened since the pump test.

Overwhelming evidence supports the State Engineer's prior finding of fact that pumping "*caused sharp declines in groundwater levels and flows in the Pederson and Pederson East Springs*."[76] Further, since the State Engineer can only control pumping, not the weather, groundwater pumping should remain the primary consideration for LWRFS management.

III. <u>No Pumping Can Occur In LWRFS Without Conflicting with Senior Decreed Rights, And Only 4,000-6,000 AFA Of Pumping Can Occur Without Harming Moapa Dace.</u>

The third factual inquiry the State Engineer sought input on was "[t]he long-term annual quantity of groundwater that may be pumped" in LWRFS without capturing Muddy River spring flow, or river flow.[77]

A. <u>LWFRS Groundwater Pumping Captures of Muddy River Flows and Should Be Limited Absent Mitigation.</u>

In Order 1303, the State Engineer properly indicated it is necessary to "evaluat[e] the amount of groundwater that may ultimately be developed within the LWRFS *without conflicting*

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[72] H'rg on Order 1303 Tr. vol. 6, 1190:8-12, Sept. 30, 2019 (Lazarus).
[73] *Id.* at 1190:24-91:2 (Lazarus).
[74] *Id.* at 1191:3-9 (Lazarus).
[75] *Id.* at 1191:11-15 (Lazarus).
[76] NSE Ex. 1 at 5 (emphasis added).
[77] *Id.* at 11 (emphasis added).

with senior decreed rights on the Muddy River[.]"[78] All expert witnesses agreed that any and all pumping within the LWRFS captures some amount Muddy River flow. SNWA owns and leases substantial water rights on the Muddy River and the capture of flow has deprived SNWA of use of its senior decreed water rights, resulting in an impermissible conflict with existing rights. Since LWRFS pumping conflicts with senior rights, pumping can only occur with effective mitigation.

The Muddy River Decree is broad, and its plain language is clear. The water rights that are recognized in the decree appropriate the "whole of said River system . . . as a fully adjudicated stream"[79] The Decree "*absorbs and exhausts all of the flow of the said stream, its sources of supply, headwaters and tributaries during the entire year*[.]"[80] The Muddy River Decree appropriated *all sources of its supply* to senior vested water rights, and those sources of supply include the LWRFS carbonate aquifer and the springs. The 1920 Decree *is not capped at 34,000 afa.*

SNWA submitted substantial evidence that the capture of flow has already conflicted with its senior decreed rights, and any future pumping will continue to conflict with senior vested rights. Capture occurs through carbonate and alluvial pumping. SNWA identified the "Muddy River Flow Deficit" is caused by that groundwater pumping. Prior to groundwater development in the LWRFS, Muddy River flows were approximately 34,000 afa.[81] Since groundwater development began, Muddy River flows have declined to under 29,000.[82] The "Muddy River Flow Deficit" calculated the difference between predevelopment flows and annual post-development flows.[83]

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[78] NSE Ex. 1 at 11 (emphasis added).
[79] NSE Ex. 333 at 6:13-7:7; *see also* NRS 533.0245 (The State Engineer shall not carry out his or her duties pursuant to this chapter in a manner that conflicts with any applicable provision of a decree or order issued by a state or federal court").
[80] *Id.* at 15 ¶ 8 (emphasis added). The Muddy River Decree court created an upper and lower division to the river. NSE Ex. 333 at 6:13-21; *see* SNWA Ex. 7 at 7-2, figure 7-1. While upper division water rights might be impacted from decreased flows, there is no evidence of conflict as these rights can be fully utilized and placed to beneficial use. Hr'g on Order 1303 Tr. vol. 5, 939:21-24 (Burns). However, decreased flows in the river are conflicting with the beneficial use of water in the lower division. Within the lower division, MVIC "acquired . . . all the waters of said Muddy River, its head waters, sources of supply and tributaries," and "the stockholders of said Company are the equitable owners of rights to use said waters in this decree[.]" NSE Ex. 333 at 19. SNWA is a significant shareholder of MVIC, and beneficially uses substantial water rights. SNWA Ex. 7 at 7-1 to 7-3.
[81] NSE Ex. 1 at 7.
[82] Hr'g on Order 1303 Tr. vol. 5, 942:4-6, Sept. 27, 2019 (Burns); *see also* SNWA Ex. 7 at 5-4.
[83] *See* SNWA Ex. 7, Figure 5-3.

This difference represents the impacts from pumping that are conflicting with SNWA's rights because SNWA is being deprived of the full beneficial use of its senior water rights at significant costs.[84]

Given the high degree of connectivity throughout the system, confirmed by qualitative and regression analyses, there is no location in the LWRFS where pumping can occur "without having some effect at EH-4 and, of course, the proportional effect at the springs."[85] SNWA-LVVWD demonstrated that impacts from alluvial pumping are 1:1 and impacts from carbonate pumping take longer to manifest but also are 1:1. Experts debated this exact ratio, but all agreed that LWRFS carbonate and alluvial pumping in the MRSA capture Muddy River flow. No party has identified a legitimate location in the carbonate aquifer where pumping can occur without negatively impacting the Muddy River springs or flows. Dr. Myers agreed with this assessment.[86] Similarly, Mr. Felling testified that alluvial pumping captures Muddy River flows at nearly a 1:1 ratio and that carbonate pumping captures spring flows, although not necessarily at the same rate as alluvial capture. Mr. Felling also acknowledged existing pumping captures approximately 2,300-3,750 afa to the Muddy River Flow, and thereby conflicts with senior decreed rights.[87]

Mr. Lazarus acknowledged that alluvial wells have a direct hydrologic connection with the Muddy River and directly capture Muddy River flows, and carbonate pumping results in some spring depletion.[88] Similarly, Mr. Coache and Mr. Ricci noted there was no practical way to pump carbonate "without detrimental impacts to the Muddy River Springs area."[89] Dr. Waddell testified that his initial assessment of allowable pumping did not consider impacts to senior water rights. When he considered the Muddy River Flow Deficit, he supported a prohibition on any additional pumping, and concluded long-term pumping cannot be above 9,318 afa.[90]

[84] Hr'g on Order 1303 Tr. vol. 5, 942 (Burns), SNWA Ex.7 at 7-5 to 7-6. (SNWA has suffered a loss of approximately 12,040 acre feet over the last 10 years, equating to over $2 million in costs for replacement supplies.).
[85] Hr'g on Order 1303 Tr. vol. 5, 943:22-44:5, Sept. 27, 2019 (Burns).
[86] Hr'g on Order 1303 Tr. vol. 8, 1555:8-56:22, Oct. 2, 2019 (Myers).
[87] Hr'g on Order 1303 Tr. vol. 10, 1815:19-16:8, 1791:5-10, Oct. 4, 2019 (Felling).
[88] Hr'g on Order 1303 Tr. vol. 6, 1149:19-50:3, Sept. 30, 2019 (Lazarus).
[89] Hr'g on Order 1303 Tr. vol. 9, 1646:4-10, Oct. 3, 2019 (Ricci).
[90] Hr'g on Order 1303 Tr. vol. 3, 653:19-54:7, Sept. 25, 2019 (Waddell).

In determining "the amount of groundwater that may ultimately be developed within the LWRFS *without conflicting with senior decreed rights on the Muddy River*," SNWA-LVVWD urges the State Engineer to give strong consideration to the Muddy River Flow Deficit and recognize the current conflicts caused by existing LWRFS pumping. Pumping, whether from carbonate or alluvial wells, will have approximately 1:1 impacts on the Muddy River springs and flows. While experts debate whether capture is on a 1:1 basis, they acknowledge all carbonate pumping will capture some portion of these flows. Thus, no quantity of long-term pumping can be allowed without needing to mitigate the long-term impacts to senior rights.[91] And, as the State Engineer is fully aware, these means SNWA will also lose the ability to pump its LWRFS rights.

B. Pumping Limitations Are Required To Protect Moapa Dace.

The State Engineer asked for input on "the amount of groundwater that may ultimately be developed" without "*adversely affecting the public interest in maintaining the habitat of the endangered Moapa dace*,"[92] but only a few stakeholders submitted any significant evidence regarding the Moapa dace. SNWA-LVVWD's experts Zane Marshall and Bob Williams are the most experienced individuals in the field of protecting Moapa dace. They testified that 3.2 cfs of flow at the Warm Springs West gauge is necessary to protect the Moapa dace. SNWA-LVVWD's hydrology experts determined that only 4,000 to 6,000 afa of LWRFS pumping can be allowed without causing Warm Springs West flows to fall below 3.2 cfs.

Protecting the Moapa dace has been a priority in southern Nevada for nearly half a century. Since the 1990s, habitat restoration and other conservation efforts have been completed to increase dace populations. To complete the Order 1169 pumping test, SNWA, FWS, CSI, the Tribe and MVWD entered into the Muddy River Memorandum of Agreement in 2006 ("2006 MOA"). The MOA required such conservation measures, and mandatory pumping restrictions to maintain in-

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[91] Many parties either did not investigate this issue, or provided non-responsive information. *See, e.g.*, Hr'g on Order 1303 Tr. vol. 2, 470:19-24, Sept. 24, 2019 (Braumiller). Others simply analyzed their discrete basin and suggested an amount they could pump without regard to the LWRFS generally, or the Muddy River Flow Deficit, specifically.
[92] NSE Ex. 1 at 11. The Moapa dace is thermophilic minnow that is endemic to the spring waters and the tributary headwaters of the Muddy River. The Moapa dace is protected under the ESA and was listed as endangered in 1967.

stream flows at the Warm Springs West gage at 3.2 cfs.[93] The effectiveness of the conservation efforts depends on a 3.2 cfs flowrate, and the 2006 MOA and Biological Opinion were conditioned on maintaining that flowrate.[94] The pumping test, however, caused flows to plummet, and experts agree the existing MOA pumping restrictions cannot effectively lead to higher flowrates.

Mr. Burns, SNWA-LVVWD's hydrological expert, testified that a maximum of 6,000 afa can be pumped from the carbonate aquifer in the LWRFS without causing flows at Warm Springs West to fall below 3.2 cfs.[95] This conclusion was supported by data from the 1169 pumping test, and expert opinions that flows would have immediately dropped below 3.2 cfs if the test continued.[96] No party seriously disputed this recommendation,[97] and other qualified experts supported pumping restrictions to protect Moapa dace. For example, Dr. Waddell affirmed there is a continuing downward trend in "spring discharge" and indicated that it would be appropriate to set pumping at levels protective of the dace.[98] Dr. Myers testified that no long-term LWRFS pumping can occur if Moapa dace are going to recover. He reaffirmed that a direct correlation exists between carbonate pumping and spring discharge, and that existing pumping is causing flows to decrease.[99] On that basis, he recommended the State Engineer not allow any pumping of the carbonate aquifer.[100] Mr. Felling also testified that "*there is no room for additional stresses in the system at this time*."[101] Thus, even at current pumping levels, there is a reasonable chance that the 3.2 cfs "will be reached."[102]

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[93] SNWA Ex. 8 at 1-1.
[94] SNWA Ex. 8 at 6-3.
[95] Hr'g on Order 1303 Tr. vol. 5, 921:13-17, Sept. 27, 2019 (Burns).
[96] SNWA Ex. 8 at 7-2.
[97] While CSI's expert Mr. Reich (who is not a biologist and has virtually no experience with the Moapa dace) argues that the flow data at the *Moapa gage* shows increased groundwater pumping can occur without adversely impacting the Moapa dace, he misses the point, as the Moapa gage is *downstream from the high elevation springs which provide most of the habitat for the Moapa dace*. Thus, the Moapa gage's flow data has little value in evaluating the health of the Moapa dace habitat.
[98] Hr'g on Order 1303 Tr. vol. 3, 611:20-17:15, Sept. 25, 2019 (Waddell).
[99] Hr'g on Order 1303 Tr. vol. 8, 1527:20-28:1, 1541:17-42:6, Oct. 2, 2019 (Myers).
[100] *Id.* at 1527:20-28:1 (Myers).
[101] Hr'g on Order 1303 Tr. vol. 10, 1791:18-19, Oct. 4, 2019 (Felling).
[102] *Id.* at 1788:20-24 (Felling).

Evidence indicates that protecting the 3.2 flowrate at Warm Springs West is important for other reasons. First, Mr. Felling warned that "it is absolutely in the state's interest and all of the water users to protect the Moapa dace."[103] Dace protection is like Devil's Hole – if proper water management actions are not taken to protect the endangered fish, "a federal district judge" will be "managing water in Nevada and not the state [engineer]."[104] Second, pursuant to the MOA, if flows drop below 3.2 cfs, mandatory pumping restrictions must occur, even to permanent groundwater uses.[105] Thus, if parcel maps and new long-term pumping are approved, and homes are constructed in the LWRFS, the source of water for those homes can be shut off. Third, not all water users or groundwater pumping is covered by the MOA and related Biological Opinions. Non-parties to the MOA, including the State Engineer, do not have incidental take permits, or ESA coverage. If their actions result in "take" or harm to the Moapa dace or its habitat, those parties are subject to civil and criminal penalties under the ESA.[106] Fourth, if FWS finds that groundwater pumping in the LWRFS by non-MOA parties is reducing spring flow, FWS could impose pumping restrictions beyond those contemplated in the MOA. To avoid these consequences, substantial evidence indicates the State Engineer must restrict LWRFS pumping to no more than 4,000 to 6,000 afa in order to ensure the Warm Spring West flowrate remains above 3.2 cfs.[107]

IV. <u>Groundwater Rights Cannot Be Moved Between Alluvial and Carbonate LWRFS Wells Without Harming Senior Muddy River Rights Or The Moapa Dace.</u>

The fourth inquiry in Interim Order 1303 concerned the effect of moving water rights between alluvial and carbonate wells on deliveries of senior decreed rights to the Muddy River.[108] Moving alluvial wells to the carbonate may delay the capture of Muddy River water, but will not

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[103] *Id.* at 1791:22-92:8 (Felling).
[104] *Id.* (Felling).
[105] SNWA Ex. 38 at 10-11.
[106] *Animal Prot. Inst., Ctr. for Biological Diversity v. Holsten*, 541 F. Supp.2d 1073, 1079 (D. Minn. 2008).
[107] In fact, SNWA-LVVWD is the only party that provided a defensible, evidence-based amount of pumping that could conceivably be pumped over the long-term in the LWRFS without harming the Moapa dace.
[108] Evidence clearly proves groundwater production from the alluvial aquifer may not reduce spring flows on which the Moapa dace relies, but it captures the groundwater that would otherwise discharge to the Muddy River, thus depleting the river's flows. SNWA Ex. 7 at 8-4; Hr'g on Order 1303 Tr. vol. 10, 1812:15-22, Oct. 4, 2019 (Felling).

eliminate the problem.[109] In fact, it creates a new problem, as that pumping will also reduce spring flows, thereby impacting the Moapa dace. Clearly, the Order 1169 pumping test, and modeling performed by NPS, indicate that moving water from alluvial to carbonate wells or from carbonate to alluvial wells will not change the ultimate outcome – harm to senior Muddy River rights and the Moapa dace.[110] Detectable impacts of groundwater production in areas farther away may take longer, but the properties of the aquifer indicate impacts will eventually result in capture of spring discharge and depletions of the Muddy River stream flow.[111] As Mr. Felling testified, "[c]arbonate pumping also will need to be mitigated to the extent of that conflict. Like I said, I don't think you can pump anything without basically capturing river flow. So, to the extent that there is that conflict, it would need to be mitigated."[112]

Mr. Lazarus and Ms. Braumiller both concluded that the transfer of alluvial rights to the carbonate aquifer that resulted in increased production from the carbonate aquifer would "increase and accelerate spring depletions."[113] Similarly, Mr. Coache determined transfers from the alluvial aquifer to the carbonate aquifer for new uses would be detrimental, and alluvial rights should only be moved to upgrade the priority date of existing carbonate pumpage.[114] Thus, changing the location of alluvial or carbonate pumping will not change impacts to the Muddy River and Springs.

CONCLUSION

The State Engineer should 1) refuse to permit any new long-term pumping 2) deny any subdivision maps in the LWRFS that rely upon groundwater, and 3) reduce current pumping to eliminate current conflicts and avoid negative impacts to the Moapa dace.

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[109] SNWA Ex. 7 at 8-4; Hr'g on Order 1303 Tr. vol. 5, 904:10-15, Sept. 27, 2019 (Burns).
[110] SNWA Ex. 7 at 8-4; Hr'g on Order 1303 Tr. vol. 5, 893:22-94:4, Sept. 27, 2019 (Burns); Hr'g on Order 1303 Tr. vol. 3, 594:12-15, Sept. 25, 2019 (Waddell).
[111] Hr'g on Order 1303 Tr. vol. 5, 904:20-05:6, Sept. 27, 2019 (Burns).
[112] Hr'g on Order 1303 Tr. vol. 10, 1813:16-20, Oct. 4, 2019 (Felling).
[113] Hr'g on Order 1303 Tr. vol. 6, 1150:13-15, Sept. 30, 2019 (Lazarus); *see also* Hr'g on Order 1303 Tr. vol. 2, 272:6-24, Sept. 24, 2019 (Braumiller).
[114] Hr'g on Order 1303 Tr. vol. 8, 1647:9-18, Oct. 2, 2019 (Coache).

DATED this 3 day of December, 2019.

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I hereby certify that I am an employee of TAGGART & TAGGART, LTD., and that on this day, I served, or caused to be served, a true and correct copy of the foregoing document via electronic delivery, addressed as follows:

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DATED this 3rd day of December, 2019.

Employee of TAGGART & TAGGART, LTD.

IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

IN THE MATTER OF THE ADMINISTRATION AND MANAGEMENT OF THE LOWER WHITE RIVER FLOW SYSTEM WITHIN THE COYOTE SPRING VALLEY HYDROGRAPHIC BASIN (210), A PORTION OF BLACK MOUNTAINS AREA HYDROGRAPHIC BASIN (215), GARNET VALLEY HYDROGRAPHIC BASIN (216), HIDDEN VALLEY HYDROGRAPHIC BASIN (217), CALIFORNIA WASH HYDROGRAPHIC BASIN (218), AND MUDDY RIVER SPRINGS AREA (AKA UPPER MOAPA VALLEY) HYDROGRAPHIC BASIN (219), LINCOLN AND CLARK COUNTIES, NEVADA	**WESTERN ELITE ENVIRONMENTAL, INC.'S AND BEDROC LIMITED, LLC'S CLOSING STATEMENT**

Western Elite Environmental, Inc., and Bedroc Limited, LLC (collectively "Bedroc") hereby submit this Closing Statement.

I. Introduction

As a steady and long-term water user located within the currently described boundaries of the Lower White River Flow System ("LWRFS"), Bedroc Limited, LLC and its operating entity Western Elite Environmental, Inc. (together "Bedroc") have an intense interest in protecting their ability to operate and grow. The Nevada Division of Water Resources ("NDWR") has received and reviewed initial and rebuttal reports and listened to two weeks' worth of testimony as part of this process regarding the following issues as set forth in Order 1303:

> a. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System;
>
> b. The information obtained from the Order 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it relates to aquifer recovery since the completion of the aquifer test;
>
> c. The long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including the relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow;

d. The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and

e. Any other matter believed to be relevant to the State Engineer's analysis as described by Order 1303.

Bedroc provides to NDWR this closing statement in an effort to compile and highlight the evidence related to the narrow issues of Bedroc's concern. Therefore, in the interest of brevity, Bedroc highlights the relevant information presented in the Initial Reports, the Rebuttal Reports and Testimony from the Order 1303 hearing. When examined together, the evidence shows that Bedroc's site, and perhaps others in similar circumstances, should be carefully and independently managed within the larger LWRFS. As expressed during the hearing, Bedroc is located in a unique geological setting in the Coyote Spring Valley, Bedroc is capturing recharge otherwise lost to evapotranspiration ("ET"), the data show that there appears to be no meaningful connection between alluvial groundwater produced from Bedroc's production wells and the carbonate aquifer that spans throughout the LWRFS, meaning there will likely be no measurable impact to the Muddy River Springs Area or the flow of the Muddy River attributable to alluvial pumping at the Bedroc site.

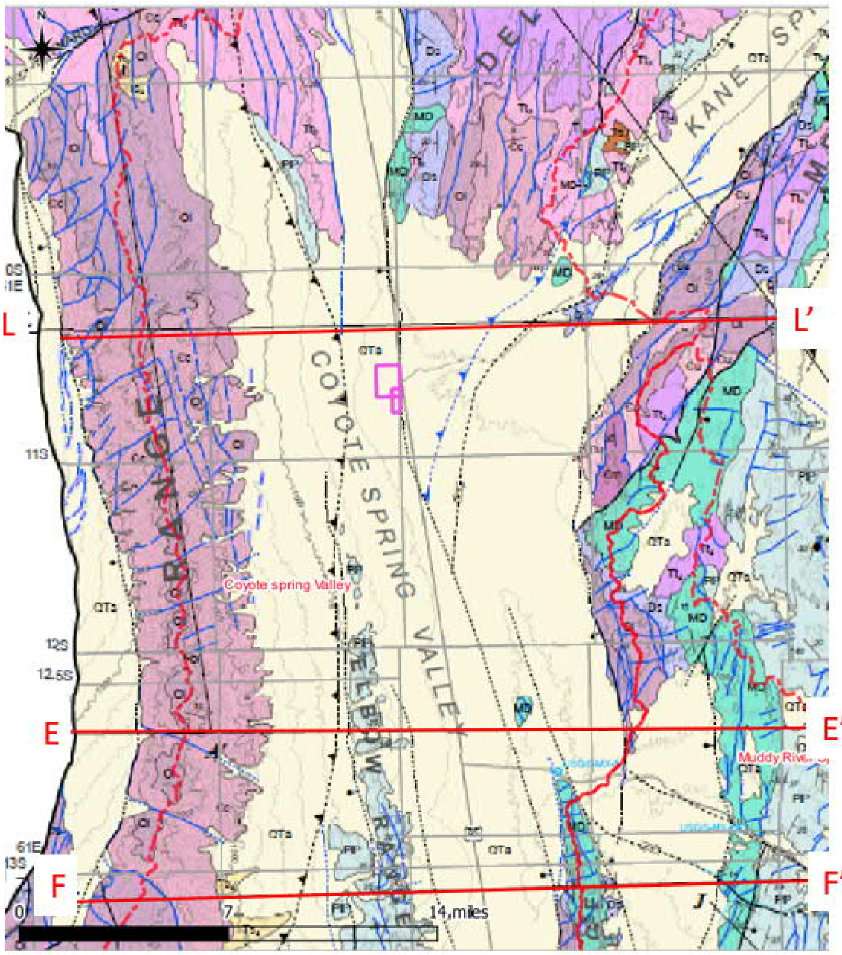
II. Bedroc is Situated in a Unique Geological Location Within Coyote Spring Valley

As a result of its location and local geology, Bedroc is the only current water user in the Coyote Spring Valley Hydrographic Basin with groundwater production originating from the basin fill alluvium (a water source that would otherwise be lost to evapotranspiration ("ET")). This assertion is supported by the geologic information presented by Bedroc's expert witness Jay Dixon, and other stakeholders throughout the course of the Order 1303 hearing process, all of which when taken as a whole, validate that Bedroc's operation is located in a unique geological setting within Coyote Spring Valley.

Geologic information, adapted from *Rowley* (2017), indicates the presence of a lower clastic unit consisting of sedimentary rocks (quartzite and shale) extending east from the Sheep Range toward the Gass Peak Thrust. As shown in Figure 1 (Bedroc hearing presentation slides 12 and 13), this layer of sedimentary rock is present south of the Bedroc site (see Sections E-E' and F-F', green layer), which acts as a confining unit allowing recharge from the Sheep Range to flow downgradient (to the east) until it encounters the formations that make up the Elbow Range to the south, at which point the groundwater tends to be forced toward the surface. As shown in Section L-L' (Figure 1), this confining shelf of sedimentary rock is noticeably absent in the vicinity of the Bedroc site where recharge from the Sheep Range rises toward the surface between the Gass Peak and Highway Thrust faults, which results in shallow groundwater that is subject to ET and capture from shallow groundwater wells at the Bedroc site. These conditions are supported by the noticeable presence of evaporites and transpiring vegetation supported by shallow groundwater (Figure 2), which lead to development of land now owned by Bedroc in the early 1900s. While Bedroc is clearly situated in a location for optimal capture of shallow alluvial groundwater, these geologic conditions may allow for the siting of alluvial wells capturing Sheep

Range recharge to the south and along the western side of the Elbow Range within the Coyote Spring Valley basin.

Utilizing information submitted by Coyote Spring Investments, Inc. (CSI) in their initial Order 1303 report (July 2019, Table 7), during the Order 1303 hearing, Mr. Dixon estimated the potential Sheep Range recharge in the vicinity of Bedroc to be approximately 750 acre-ft annually (see Bedroc hearing presentation slides 8 – 10).



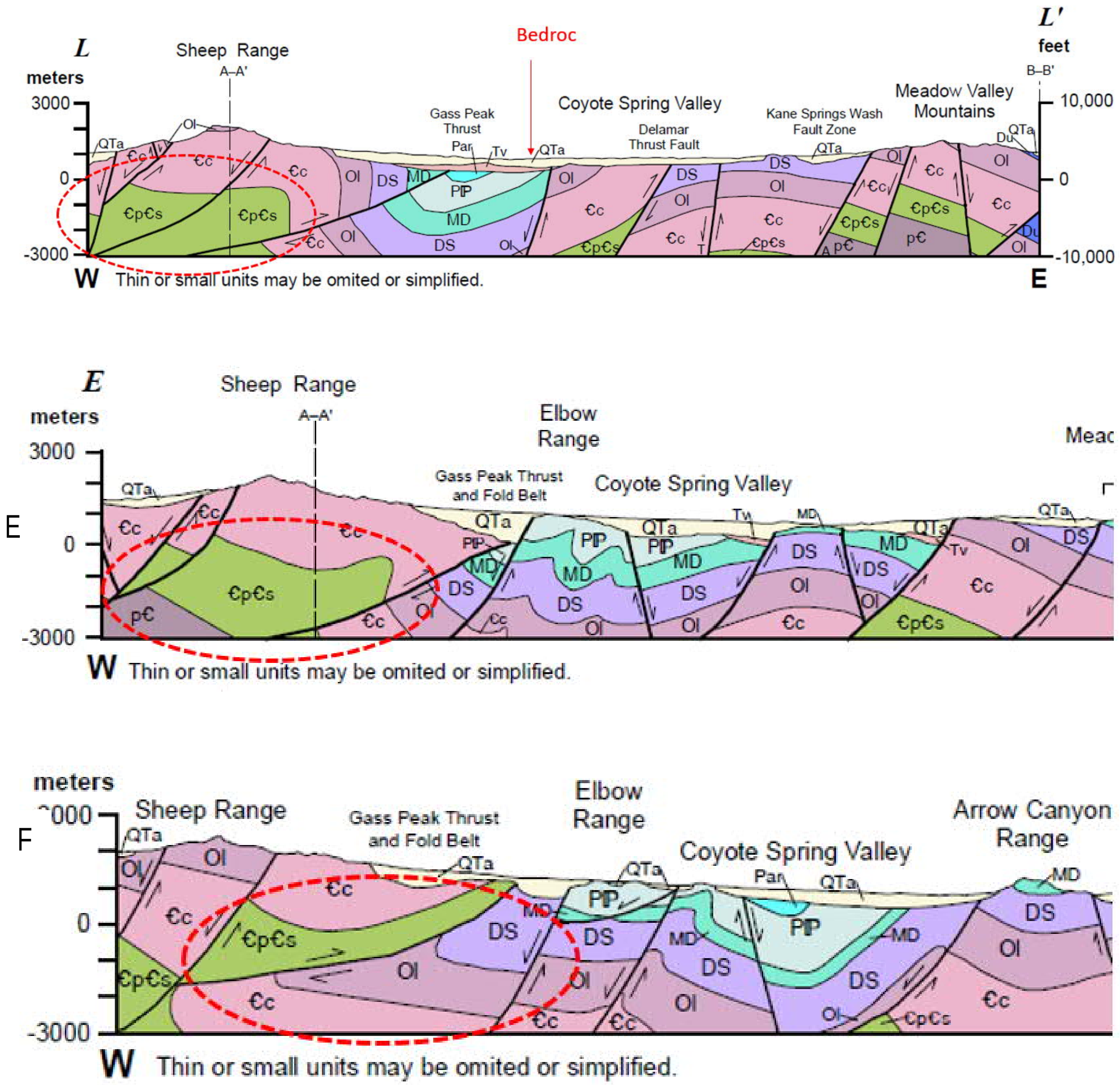


Figure 1. See Bedroc's Hearing Presentation slides at 12-13.

Vidler and Lincoln County performed a CSAMT survey in the northern part of Coyote Spring Valley to make their case regarding the geological differences occurring there. One of their CSAMT lines nearly ran directly through Bedroc's site and shows stark differences in northern Coyote Spring Valley between the lithology on the western side as compared to the eastern side.

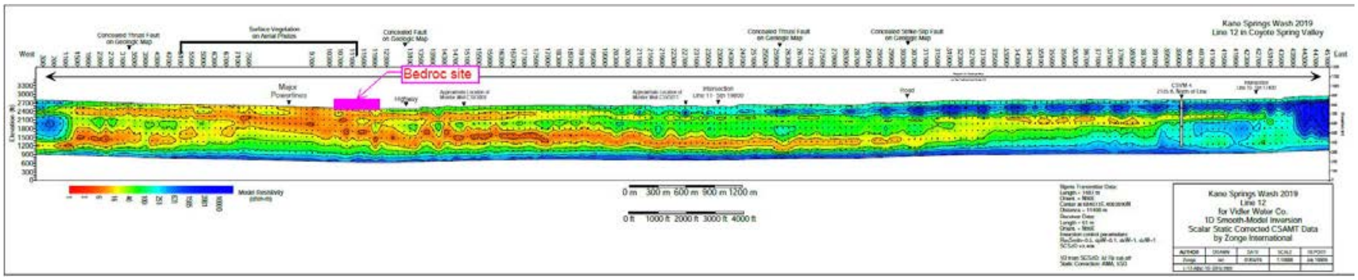


Figure 2. See Vidler/Lincoln County Direct Report dated July 2019 (Figure 4-8).

Southern Nevada Water Authority ("SNWA") did not present much by way of geologic data. Instead, SNWA choose to focus on actual groundwater responses measured across the basin. Regardless, SNWA's primary expert witness, Andrew Burns, acknowledged the unique location of Bedroc's site in one of the most definitive statements made by other stake holders on the subject during the hearing.

> Q. Do you believe that it is possible to pump from an alluvium aquifer within the proposed Lower White River Flow System boundary without causing a one-to-one impact on the Muddy River?
> A. In certain areas.
> Q. And what areas would those be?
> A. The only area I'm aware of is to the north, a portion of Coyote Springs Valley where Bedroc has some wells. I think pumping those won't impact the carbonate system.

Transcript of Proceedings Sept. 27, 2019 at 1024:20-1025:5. Thus, it is clear that based on geologic information presented by Bedroc's expert witness, as well as other experts in the Order 1303 hearings, that Bedroc is uniquely situated, and not causing an impact in LWRFS carbonate system.

III. Bedroc is Capturing Alluvial Recharge Otherwise Lost to Evapotranspiration

The geologically unique location of Bedroc results in a site specific environment for capturing groundwater that would otherwise be lost to ET. This is also a position that multiple stakeholders drew attention to throughout the course of the Order 1303 process.

SNWA's Initial Report (SNWA June 2019) references the "additional small springs in Coyote Spring and Kane Springs valleys which discharge groundwater sourced from local recharge." *See SNWA Initial Report at 3-6.* Thus, SNWA admits that discharge from local springs, like those in the vicinity of Bedroc, are independent surface water features. SNWA describes discharge from the spring at Coyote Spring by stating that "[w]ithin the LWRFS, natural groundwater discharge occurs through springs and seeps, ET from riparian and phreatophytic vegetation, leakage to gaining streams of the Muddy River, and by surface and subsurface outflow." *Id. at 3-13.*

In describing Line 12 of its CSAMT study (included at Figure 2 above), Vidler and Lincoln County detail the low resistivity values that occur at the land surface on the western side of the transect, where Bedroc is located. In their words, it "is significant because it correlates with an area of surface vegetation which is an indication of a source of water supported by the low resistive materials." *See Vidler Initial Report at pg. 4-7 (July 2019).*

The Moapa Band of Paiute's expert indicated that areas where this surface vegetation occurred could be pumped without problem:

> Now, as far as the basins, we'd suggest that any kind of phreatophyte capture up here, if you truly don't value those phreatophytes and what lives in them, take it. But it's not going to affect the regional aquifer hardly at all, you know, at this contrast.

See Transcript of Hearing, Sept. 26, 2019 pg. 753 at 20-24.

The Center for Biodiversity ("CBD"), the only other party other than Bedroc to directly addressed basin-fill pumping, implied that if there were a location within the Coyote Spring Valley where there was ET, there would exist the ability to sustainably capture that water. *See CBD Rebuttal Report at pg. 6.* Dr. Myers was simply unaware that Bedroc's site sits in perhaps the only region in the Coyote Spring Valley where groundwater from the basin fill alluvium is discharging through ET.

This is, of course, evident by the actual discharge of Coyote spring located in very close proximity of Bedroc's property: the thick surface vegetation and phreatophytes that are visible onsite and adjacent to Bedroc's property, and light colored evaporites left through the soil evaporation of near surface groundwater. These features are not found in any other known basin fill alluvium site in the Coyote Spring Valley. The Bedroc site is the one area in Coyote Spring Valley where Sheep Range recharge, due to underlying geologic and adjacent structural conditions, is daylighting and being lost to ET from the basin fill alluvium. See Figure 3 below.

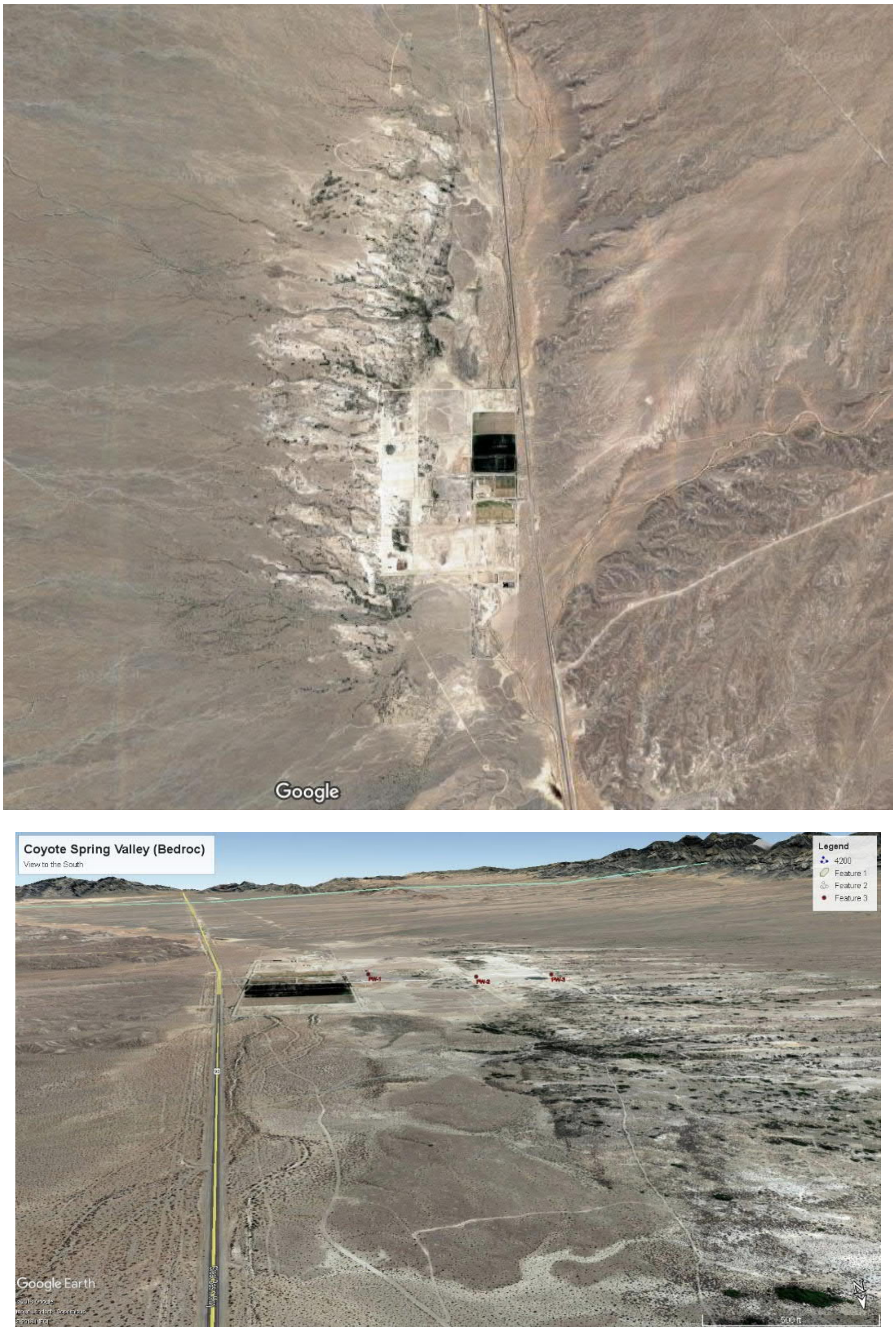


Figure 3. Current Google Earth imagery showing the Bedroc property and immediate vicinity.

An extensive summary of local groundwater conditions, which included Bedroc's data, was presented during Order 1303 hearing presentation. In comparing the alluvial groundwater elevations in northern Coyote Spring Valley to the extrapolated carbonate water elevations, Bedroc showed a significant difference between groundwater levels (see Figure 4).

While both the surface elevation and carbonate water levels decrease from north to south in northern Coyote Spring Valley near Bedroc's site, the alluvial water levels increase from north to south, contrary to typical water flow in the region. See Figure 4. Considering the general movement of groundwater in the basin, the only explanation for this increase in alluvial water levels is recharge from the west in the Sheep Range.

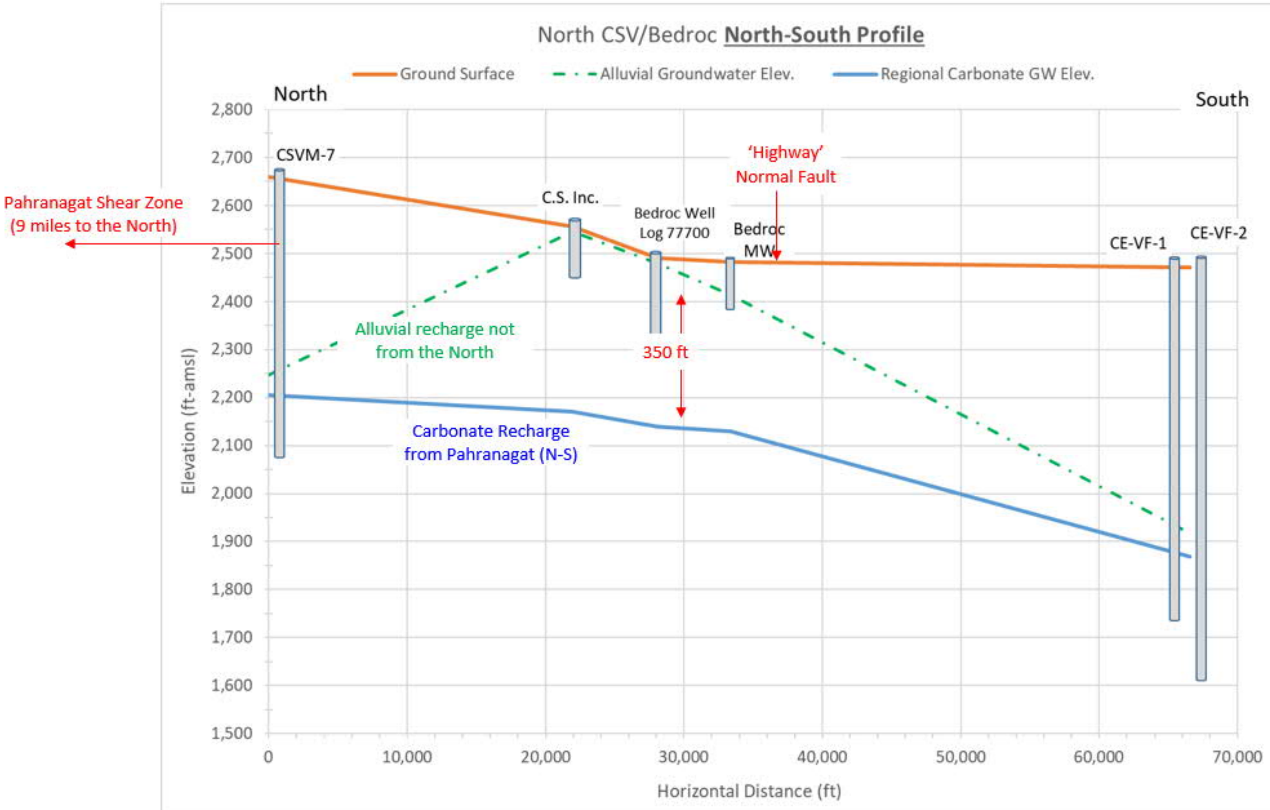


Figure 4. See Bedroc Hearing Presentation at slide 18.

Groundwater elevation data support the geologic information. Taken altogether, the evidence shows that Bedroc is capturing local recharge from the Sheep Range that would otherwise be lost to ET. The fact that phreatophytes are not disappearing, nearby springs are still flowing, and alluvial groundwater levels are not decreasing, indicate that Bedroc is pumping water that would otherwise be lost to ET. In fact, alluvial groundwater levels directly to the east of Bedroc's site are also increasing. Bedroc is the only stakeholder who highlighted CSV3009M in the hearing. CSV3009M levels are enlightening as they further show a disconnect between the Bedroc project area, the carbonate aquifer, and the effect of Sheep Range recharge on the alluvium in the area. *See Figure 5 below from Bedroc's Presentation at Hearing.*

As shown in Figure 5, alluvial groundwater levels continue to rise over time, including during the Order 1169 pumping test. This is additional evidence that not only is Bedroc capturing alluvial recharge from the Sheep Range that would otherwise be lost to ET, but there is more water available to capture than what Bedroc is currently capturing.

There is compelling evidence that Bedroc is not pumping water from the carbonate aquifer. Instead, Bedroc is capturing near surface water and basin fill alluvial recharge that would otherwise be lost to ET. Thus, the State Engineer should exclude Bedroc's pumping from the management totals in the LWRFS.

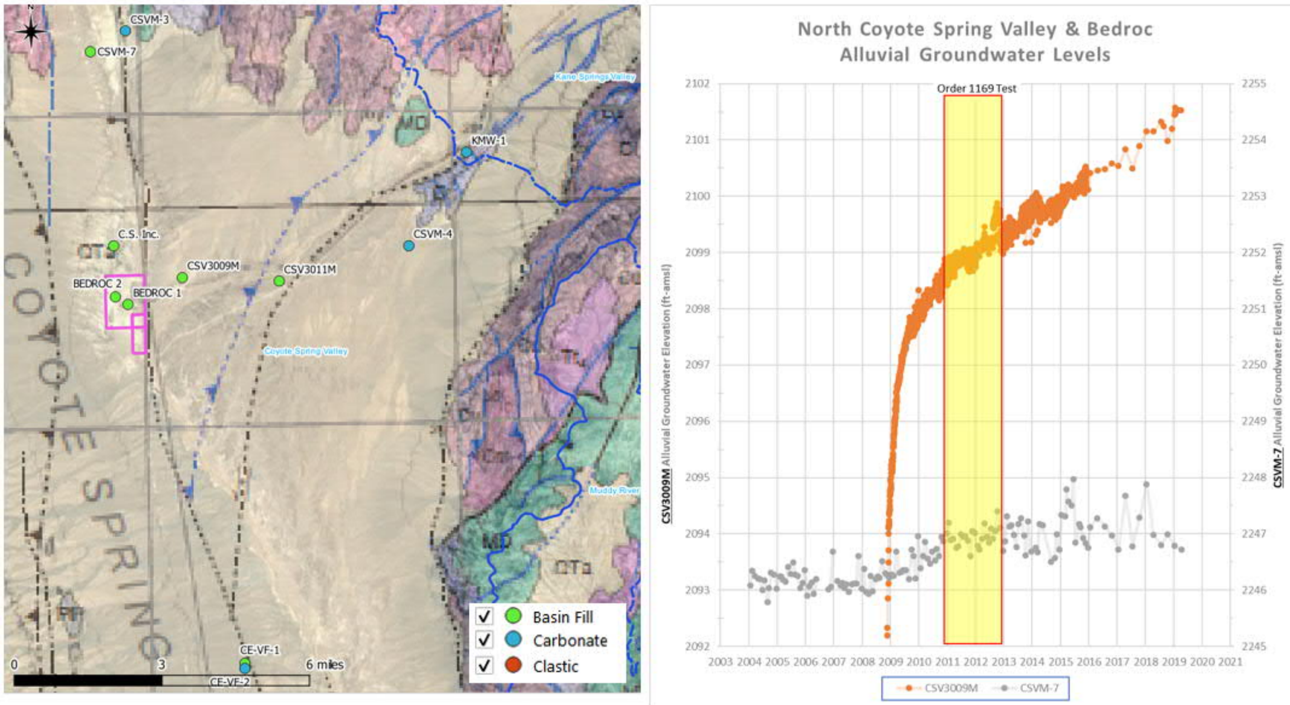


Figure 5. See Bedroc Hearing Presentation at slide 24.

IV. There is no Meaningful Connection or Measurable Impact from Bedroc's Production Wells upon the Muddy River Springs Area or the Carbonate Aquifer

There appears to be no meaningful connection or measurable impacts seen from Bedroc's production wells upon the Muddy River Springs Area ("MRSA") or the LWRFS carbonate aquifer. These two important points about Bedroc's location and the groundwater sustainability in the area is further bolstered by information presented by the stakeholders wherein the connection between basin fill alluvium and the carbonate aquifer is discussed.

For example SNWA stated "basin-fill aquifers within the LWRFS occur at great depths above the carbonate aquifer, <u>as perched, or semi-perched</u> systems." *See SNWA Initial Report at 3-10 (June 2019), emphasis added.* SNWA In citing Eakin's 1964 study in reference to Bedroc's location, SNWA stated that in "*many of the LWRFS basins, groundwater in the basin fill occurs at great depths or as <u>perched</u> systems as is the case in the extreme northern area of Coyote Spring Valley*." *Id. at 3-11.*

In fact, it is quite clear from SNWA's reports and earlier cited testimony that SNWA did not consider the basin-fill alluvium that Bedroc pumps from during their analysis because of this apparent disconnect. This was reiterated several times in the hearing.

> A. Okay. That might be a question for you. We performed the ratio analysis, a portion of a ratio analysis and we concluded 4 to 6,000-acre-feet as a range to manage this system. This is carbonate groundwater production we're talking about that would maintain a level at the Warm Springs West Gage at three point – approximately 3.2 cfs.

Andrew Burns testifying for SNWA, Transcript of Hearing Sept. 27, 2019 pg. 959 at 13-19.

> Q. Did you look at alluvial pumping at all in those analyses?
> A. Well, in the location of these – well, in these areas where these wells are, there's not a lot of or if any alluvial pumping. The alluvial pumping, any significant amount, is at the Bedroc Inc. to the northern Coyote Spring Valley, I did not look at that.

Id. at pg. 969 at 9-13.

Throughout SNWA's reports and presentation, their experts made it clear that they did not analyze or include Bedroc's basin fill alluvial pumping in their determination because of the apparent hydrologic disconnect present in that alluvial system.

The Moapa Band of Paiutes similarly commented on the groundwater found in alluvial fan and basin fill alluvium systems as being recharged primarily by infiltration of runoff along the basin margins. According to the Tribe's recommendation, "[b]asin fill in these large basins and underlying post-Devonian consolidated rocks could be managed with separate criteria than carbonate rock aquifers comprised of the Lower Paleozoic Shelf Domain underlying the large northern basins." *See Moapa Band of Paiutes Direct Report dated July 2019 at 23.*

The National Park Service (expert witness) also commented on the effects of alluvial fans during their Order 1303 testimony. Dr. Waddell had the following exchange regarding monitoring well CSVM-5:

> Q. Are you familiar with that monitor well?
> A. Yes.
> Q. Okay. And is it fair to say it's on the fan, alluvial fan coming down from the Sheep Range?
> A. Yes.
> Q. And that's on the west side of Coyote Spring Valley?
> A. Yes.
> Q. And I believe your testimony was that that hydrograph does not show a signal from the pump test – pumping test that Order 1169 allowed?
> A. That's correct.

See Transcript of Hearing Sept. 25, 2019 PM Session pg. 631 at 1-12.

The CBD also took an unequivocal position on this disconnect. Their expert, Dr. Tom Myers, stated:

> Because of the aridity of the area and because of the likely confining unit between the aquifers, it is unlikely the higher basin fill levels reflect substantial recharge to the carbonate. Rather it suggests a hydrologic disconnect. Groundwater levels in basin fill wells CSVM3009M and DF-1 have been trending upward, with no signal from the aquifer test; this also indicates there is no connection between carbonate and basin fill.

See CBD Initial Report (July 2019) at pg. 13.

The information presented by Bedroc aligns with the evidence and testimony presented by other stake holders and supports the exclusion, or independent management, of pumpage from the basin fill alluvium in the vicinity of the Bedroc project by the State Engineer as part of the entire LWRFS management plan.

V. There Would be no Measurable Impact to the Muddy River Springs Area from Pumping at Bedroc's Site

Given the lack of connection between the pumping at Bedroc and the carbonate aquifer, there is likely no impact at the MRSA caused by Bedroc. This concept is supported by many stakeholders in Order 1303 reports and hearing testimony.

Most stakeholders focused <u>solely</u> on carbonate production and completely ignored pumping from the alluvium in northern Coyote Spring Valley. Thus, it is implied that most stakeholders arguably believe that alluvial pumping in the vicinity of Bedroc's location will not impact the MRSA.

SNWA's experts stated that their analysis relating to the effects of pumping in the alluvium are specific to the alluvium in the MRSA. *See Transcript of Hearing, Sept. 27, 2019 pg. 995 at 5-8.* Further, as noted above, SNWA's expert specifically stated that pumping in the alluvium where Bedroc has wells will not impact the carbonate system. *See Transcript of Hearing, Sept. 27, 2019 pg. 1024 at 20 through pg. 1025 at 5.*

Moapa Valley Water District similarly did not make any independent analysis on the alluvium water rights in Coyote Spring Valley. *See Transcript of Hearing, Sept. 30, 2019 pg. 1243 at 2-6.* This is the reason why their report specifies the impacts of <u>carbonate</u> pumping only. Their initial report stated:

> The timing and magnitude of <u>carbonate</u> pumping effects on spring discharge is dependent on the volume of water pumped and the proximity of a pumping center to the springs – the closer it is, the sooner it will occur; the further away it is, the longer it will take to show effects, but in any case, all cumulative <u>carbonate</u> pumping in the 7 interconnected basins will eventually cause depletions on the MRS.

See MVWD Direct Report dated July 2019 at pg. 5 (emphasis added).

This type of language (focusing specifically on carbonate production) is found throughout both the initial and rebuttal reports in the Order 1303 proceedings. It makes it apparent that most stakeholders do not consider Bedroc's alluvial pumping as something causing an effect or decline in the LWRFS carbonate system. Bedroc was simply ignored in most analyses.

The data highlighted by Bedroc's expert supports the apparent disinterest in the alluvial pumping in northern Coyote Springs Valley. Bedroc's expert testified that CSV3009M and CSVM-7 hydrographs, both alluvial monitoring wells near Bedroc's site, show either increasing or at least leveling groundwater trends over the last ten years, despite almost every single carbonate well in Coyote Spring Valley showing a decreasing trend. *See Figure 5 and Slides 24 and 25, North Coyote Spring Valley & Bedroc Alluvial Groundwater Levels; Dixon Testimony, Transcript of Hearing, Oct. 4, 2019.* While the carbonate aquifer provides recharge to the alluvium in the MRSA, this is clearly not the case in northern Coyote Springs Valley. If there was a hydraulic connection between the basin fill alluvial and the carbonate aquifers in the Bedroc area, CSV3009M and CSVM-7 would most likely show declining groundwater levels in concert with the nearby carbonate wells. Instead, Bedroc's pumping shows absolutely no apparent impact on CSV3009M despite being less than half a mile away.

If Bedroc's pumping is not impacting a well half a mile away, and that neighboring well is showing increasing groundwater levels, there is likely no impact caused by Bedroc's pumping to the MRSA.

VI. Bedroc's Position on Order 1303 Questions:

With respect to the specific Order 1303 questions, issues that are specific to Bedroc's individual concerns and argument fall under Question 5. Regardless, Bedroc provides a brief response to each of the Order 1303 questions:

1) The geographic boundaries proffered by NDWR as comprising the hydrologically connected groundwater and surface water systems is appropriate for continued evaluation and administration. Bedroc suggests that NDWR continue to collect and review data, while remaining flexible to later modify the boundaries as information becomes more certain.

2) Data obtained since the Order 1169 aquifer test shows that recovery in the system comprising of the LWRFS is dependent upon source, ie shallow basin fill alluvium, deep basin fill alluvium, carbonate or Muddy River Springs Area alluvium.

3) The long-term annual quantity of groundwater that may be pumped from the system is still not determinable with any degree of certainty and will likely benefit from additional evaluation time. However in the interim, the State Engineer should set an annual quantity limit based on the best available data and adjust said limit up or down depending on future impacts.

4) The effects of movement of water rights from carbonate wells to Muddy River Springs Area alluvial wells on deliveries of senior decreed rights to the Muddy River appear to be present. However, the evidence indicates that the movement of water rights from carbonate wells to discrete disconnected areas within the LWRFS has no impact on deliveries of senior decreed rights to the Muddy River.

5) Other matters that should be relevant to the State Engineer's analysis:
   - The shallow basin fill alluvial groundwater in northern Coyote Spring Valley does not exhibit the connection to the carbonate aquifer or Muddy River flow that the alluvial water around the Muddy River Springs Area displays.
   - Bedroc's specific site is ideally situated for capture of basin fill alluvial groundwater that would otherwise be lost to evapotranspiration.
   - Any groundwater capture shown to be otherwise lost due to evapotranspiration near Bedroc's site should be managed outside of the LWRFS, due to the clear demonstration of a disconnect from the regional carbonate system and lack of impacts to existing rights within the Muddy River Springs Area.

VII. Conclusions

Based on the information provided by Bedroc and various other stakeholders engaged in the Order 1303 process, Bedroc offers the following conclusions and recommendations:

1) Basin fill alluvial groundwater in northern Coyote Spring Valley is hydraulically disconnected from the regional carbonate aquifer of the LWRFS as demonstrated by historical monitoring data, widely accepted geologic and structural mapping and subsurface geophysical studies.

2) Existing basin fill alluvial groundwater pumping by Bedroc has demonstrated that no impacts are occurring in the alluvial aquifer in north Coyote Spring Valley and the Muddy River Springs Area. Pumping from wells completed in carbonate aquifer of the LWRFS is having no measurable influence on basin fill alluvial aquifer levels in north Coyote Spring Valley.

3) There may be additional locally derived groundwater recharge available for pumping from the alluvial basin fill aquifer in the vicinity of the Bedroc site.

4) Historical and existing alluvial groundwater pumping from Bedroc wells appears to be capturing less groundwater than what may otherwise be lost to evapotranspiration in the vicinity of the Bedroc property based on substantial evidence of near-surface groundwater and the presence of phreatophytes in the area. Alluvial groundwater levels in north Coyote Spring Valley are stable over time and in many cases continue to rise.

5) Basin Fill alluvial groundwater pumping from Bedroc, should be managed outside of the proposed LWRFS joint administrative unit.

DATED this _3rd_ day of December, 2019.

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CERTIFICATE OF SERVICE

I hereby certify that on December 3, 2019, I caused a copy of the foregoing ***WESTERN ELITE ENVIRONMENTAL, INC.'S AND BEDROC LIMITED, LLC'S CLOSING STATEMENT*** to be served on the following parties as outlined below:

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Dated this 3rd day of December, 2019.

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