Case No. 84739

IN THE SUPREME COURT OF THE STATE OF NEVADA

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

Appellants,

vs.

LINCOLN COUNTY WATER DISTRICT, et al.

<u>JOINT APPENDIX</u>

VOLUME 18 OF 49

IN THE OFFICE OF THE STATE ENGINEER

OF THE STATE OF NEVADA

RECEIVED 2019 SEP -6 PM 3:33

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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LIST OF WITNESSES AND EXHIBITS OF
<u>LINCOLN COUNTY WATER DISTRICT AND VIDLER WATER COMPANY, INC.</u>

LINCOLN COUNTY WATER DISTRICT and VIDLER WATER COMPANY, INC., 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 Amended Notice of Hearing dated August 26, 2019, provide their list of hearing witnesses and exhibits. LINCOLN COUNTY WATER DISTRICT ("LINCOLN COUNTY") and VIDLER WATER COMPANY, INC. ("VIDLER") may call any or all of the following witnesses and utilize any or all of the following exhibits in this proceeding, along with the State Engineer's exhibits and the exhibits listed by any other participant to this proceeding. LINCOLN COUNTY and VIDLER do not waive any legal issues or positions by making this submission pursuant to the State Engineer's Amended Notice of Hearing. This submission does not waive any objections by LINCOLN COUNTY and VIDLER to witnesses or exhibits submitted by the other participants in this proceeding.

LINCOLN COUNTY and VIDLER may call any or all of the following witnesses and utilize any or all of the following exhibits in this proceeding:

///

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

A. **List of Hearing Witnesses**:

1. Greg L. Bushner, P.G.
Vice President of Water Resource Development/Chief Hydrogeologist
Vidler Water Company, Inc.
3480 G.S. Richards Blvd., Suite 101
Carson City, Nevada 89703

Mr. Bushner is a registered geologist in Arizona and professional geologist in California and a professional hydrogeologist recognized by the American Institute of Hydrology. Mr. Bushner will testify concerning his expert report entitled *Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit*, prepared by Lincoln County Water District and Vidler Water Company in association with Zonge International Inc., dated July 3, 2019, and his expert rebuttal report entitled *Rebuttal Submittal to Reports Submitted in Response to Interim Order #1303, Attachment A*, dated August 16, 2019. Mr. Bushner may testify regarding LINCOLN COUNTY/VIDLER's work in Kane Springs Valley. Mr. Bushner may also testify regarding any other matters included in the reports submitted by LINCOLN COUNTY/VIDLER in this proceeding. Mr. Bushner has been qualified by the State Engineer as an expert in hydrogeology. Mr. Bushner's Curriculum Vitae LC-V_003 provides Mr. Bushner's further qualifications.

2. Peter A. Mock, Ph.D., R.G./P.G.
Peter Mock Groundwater Consulting, Inc.
6130 N. Camelback Manor Dr.
Paradise Valley, Arizona 85253

Dr. Mock is a registered geologist in Arizona and a professional geologist in California. Dr. Mock will testify concerning his Technical Memorandum entitled *Lower White River Flow System Interim Order #1303 Rebuttal Report to the Nevada State Engineer*, dated August 16, 2019. Dr. Mock may testify regarding LINCOLN COUNTY/VIDLER's work in Kane Springs Valley. Dr. Mock may also testify regarding any other matters included in the reports submitted by LINCOLN COUNTY/VIDLER in this proceeding. LINCOLN COUNTY/VIDLER will seek to have Dr. Mock qualified by the State Engineer as an expert hydrologist and geologist with a specialty in groundwater modeling, and computational hydrology. Dr. Mock's Curriculum Vitae LC-V_004 provides Dr. Mock's further qualifications.

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

3. Thomas W. Butler, II, PG, CHG, CEG
Stantec Consulting Services, Inc.
1340 Treat Boulevard
Walnut Creek, California 94597

Mr. Butler is a certified engineering geologist, certified hydrogeologist and professional geologist in the State of California and will testify regarding his Technical Memorandums entitled *Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development*, dated July 3, 2019, and *Review of Preliminary Geochemical Evaluation of Sources of Water Discharge at Rogers and Blue Point Springs, Southeastern Nevada*, dated August 16, 2019. Mr. Butler may testify regarding LINCOLN COUNTY/VIDLER's work in Kane Springs Valley. Mr. Butler may also testify regarding any other matters included in the reports submitted by LINCOLN COUNTY/VIDLER in this proceeding. Mr. Butler has been qualified by the State Engineer as an expert in geology and geochemistry. LINCOLN COUNTY/VIDLER may also seek to have Mr. Butler qualified as an expert in hydrogeology. Mr. Butler's Curriculum Vitae LC-V_005 provides Mr. Butler's further qualifications.

4. Todd G. Umstot
Senior Hydrogeologist
Daniel B. Stephens & Associates, Inc.
6020 Academy NE, Suite 100
Albuquerque, New Mexico 87109

Mr. Umstot is a hydrogeologist, qualified as an expert in hydrogeology in the state district courts of Arizona and New Mexico and before the New Mexico Office of the State Engineer. Mr. Umstot will testify regarding his Technical Memorandum entitled *Drought and Groundwater*, dated August 16, 2019. Mr. Umstot may testify regarding LINCOLN COUNTY/VIDLER's work in Kane Springs Valley. Mr. Umstot may also testify regarding any other matters included in the reports submitted by LINCOLN COUNTY/VIDLER in this proceeding. LINCOLN COUNTY/VIDLER will seek to have Mr. Umstot qualified by the State Engineer as an expert in hydrogeology, vadose zone processes, groundwater recharge, and geostatistical techniques. Mr. Umstot's Curriculum Vitae LC-V_006 provides Mr. Umstot's further qualifications.

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ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

5. Norman R. Carlson
Chief Geophysicist
Zonge International, Inc.
3322 East Fort Lowell Road
Tucson, Arizona 85716

Mr. Carlson is a registered professional geoscientist (geophysics) in Texas. Mr. Carlson will testify concerning his expert report entitled *Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit*, prepared by Lincoln County Water District and Vidler Water Company in association with Zonge International Inc., dated July 3, 2019, and his Technical Memorandum entitled *Zonge International, Inc., Rebuttal Response to the July 3, 2019 Reports Submitted to the Nevada State Engineer in Response to IO#1303*, dated August 16, 2019. Mr. Carlson may testify regarding LINCOLN COUNTY/VIDLER's work in Kane Springs Valley. Mr. Carlson may also testify regarding any other matters included in the reports submitted by LINCOLN COUNTY/VIDLER in this proceeding. Mr. Carlson has been qualified by the State Engineer as an expert in geophysics. Mr. Carlson's Curriculum Vitae LC-V_007 provides Mr. Carlson's further qualifications.

LINCOLN COUNTY and VIDLER reserve the right to call additional witnesses as may be identified resulting from the testimony or exhibits disclosed by other participants and rebuttal or impeaching witnesses as may be required at the hearing.

B. **List of Exhibits**:

LC-V_001. Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit, prepared by Lincoln County Water District and Vidler Water Company in Association with Zonge International Inc., dated July 3, 2019.

LC-V_002. Rebuttal Submittal to Reports Submitted in Response to Interim Order #1303, dated August 16, 2019 and Attachments A, B, C, D and E containing the reports or technical memorandums of Greg Bushner, Peter Mock, Thomas Butler, Todd Umstot and Norman Carlson.

LC-V_003. Curriculum Vitae of Greg L. Bushner, P.G.

LC-V_004. Curriculum Vitae of Peter A. Mock, Ph.D., R.G./P.G.

LC-V_005. Curriculum Vitae of Thomas W. Butler, PG, CHG, CEG.

LC-V_006. Curriculum Vitae of Todd G. Umstot.

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

LC-V_007. Curriculum Vitae of Norman R. Carlson.

LC-V_008. PowerPoint Presentation of Greg L. Bushner, P.G., entitled Lincoln/Vidler's Presentation in Response to the Nevada State Engineer's Lower White River Flow System Interim Order #1303 Presenting New Geophysical Data of the Northern Lower White River Flow System Boundary Fault.

LC-V_009. PowerPoint Presentation of Peter A. Mock, Ph.D., R.G./P.G., entitled Order 1303 Rebuttal Summary.

LC-V_010. PowerPoint Presentation of Thomas W. Butler, PG, CHG, CEG, entitled Lower White River Flow System Interim Order #1303, Review and Interpretation of Geochemical Data.

LC-V_011. PowerPoint Presentation of Todd G. Umstot, entitled Drought and Groundwater.

LC-V_012. PowerPoint Presentation of Norman R. Carlson, entitled Collection of new geophysical data February & March 2019 Northern Coyote Spring Valley.

LC-V_013. State Engineer's Ruling #5712, dated February 2, 2007.

LC-V_014. Memorandum to R. Michael Turnipseed, P.E., State Engineer, from Hugh Ricci, P.E., Deputy State Engineer, Subject: Pumping in the Carbonates, dated June 21, 2000, with attachment showing high-lighted paragraph text typed out.

LC-V_015. Stipulation for Dismissal of Protests entered into between Lincoln County, Vidler Water Company, Inc. and the United States Department of the Interior, National Park Service, dated May 9, 2002.

LC-V_016. Amended Stipulation for Withdrawal of Protests entered into between Lincoln County Water District, Vidler Water Company, Inc., and the United States Department of the Interior, Fish and Wildlife Service, dated July 19, 2006.

LC-V_017. Hydrologic Assessment of Kane Springs Valley Hydrographic Area (206): Hydrologic Framework, Hydrologic Conceptual Model, and Impact Analysis, Presentation to the Office of the Nevada State Engineer, Prepared for Lincoln County Water District and Vidler Water Company, Prepared by CH2MHill, dated April 2006.

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

LC-V_018. Cooperative Agreement among Lincoln County, the Southern Nevada Water Authority and the Las Vegas Valley Water District effective April 17, 2003.

LC-V_019. Groundwater, Vol. 44, No. 1—January-February 2009 (pages 24-34), The AEM and Regional Carbonate Aquifer Modeling, by Cady Johnson and Martin Mifflin.

LC-V_020. September 5, 2019 Email string and attachments re: USFWS/Vidler agreement.

LINCOLN COUNTY and VIDLER reserve the right to introduce records from the State Engineer's files and records and additional exhibits as may be identified resulting from the testimony or exhibits disclosed by other participants and any exhibits to be used for impeachment or rebuttal purposes as may be required at the hearing.

DATED this 6th day of September, 2019.

LINCOLN COUNTY DISTRICT ATTORNEY
181 North Main Street, Suite 205
P.O. Box 60
Pioche, NV 89043
Telephone: (775) 962-8073
Email: dfrehner@lincolncountynv.gov

~ and ~

ALLISON MacKENZIE, LTD.
402 North Division Street
Carson City, Nevada 89703
Telephone: (775) 687-0202
Email: kpeterson@allisonmackenzie.com

BY: ______________________________
KAREN A. PETERSON, ESQ.
Nevada State Bar No. 0366

Attorneys for LINCOLN COUNTY WATER DISTRICT and VIDLER WATER COMPANY, INC.

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

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 or Electronic Transmission as follows:

Via Hand Delivery:

Micheline N. Fairbank
Deputy Administrator
Nevada State Engineer's Office
901 S. Stewart Street, Suite 2002
Carson City, NV 89701

Via Electronic Transmission:

8milelister@gmail.com;
ablack@mcdonaldcarano.com;
admin.mbop@moapabandofpaiutes.org;
aflangas@kcnvlaw.com
alaskajulie12@gmail.com;
andrew.burns@snwa.com;
barbnwalt325@gmail.com;
bbaldwin@ziontzchestnut.com;
bherrema@bhfs.com;
bostajohn@gmail.com;
bvann@ndow.org;
chair.mbop@moapabandofpaiutes.org;
Chris.Benkman@nsgen.com;
Colby.pellegrino@snwa.com;
Coop@opd5.com;
coopergs@ldschurch.org;
counsel@water-law.com;
craig.primas@snvgrowers.com;
craig.wilkinson@pabcogypsum.com;
dan.peressini@lasvegaspaving.com;
david_stone@fws.gov;
Dbrown@ldalv.com;
dennis.barrett10@gmail.com;
derekm@westernelite.com;
devaulr@cityofnorthlasvegas.com;
dfrehner@lincolncountynv.gov;
dixonjm@gmail.com;
dorothy@vidlerwater.com;
doug@nvfb.org;
dvossmer@republicservices.com;
dwight.smith@interflowhydro.com;
edna@comcast.net;
emilia.cargill@coyotesprings.com;
fan4philly@gmail.com;
gary_karst@nps.gov;
gbushner@vidlerwater.com;
glen_knowles@fws.gov;

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

gmorrison@parsonsbehle.com;
golden@apexindustrialpark.com;
golds@nevcogen.com;
greatsam@usfds.com;
greg.walch@lvvwd.com;
hartthethird@gmail.com;
Howard.Forepaugh@nsgen.com;
ircady@yahoo.com;
JCaviglia@nvenergy.com;
jeff.phillips@lasvegaspaving.com;
jim.watrus@snwa.com;
joe@moapawater.com;
Karen.glasgow@sol.doi.gov;
kbrown@vvh2o.com;
Kevin_Desroberts@fws.gov;
kimberley.jenkins@clarkcountynv.gov;
kingmont@charter.net;
kpeterson@allisonmackenzie.com;
krobison@rssblaw.com;
kurthlawoffice@gmail.com;
lazarus@glorietageo.com;
lbelenky@biologicaldiversity.org;
lbenezet@yahoo.com;
liamleavitt@hotmail.com;
Lindseyd@mvdsl.com;
Lisa@ldalv.com;
lle@mvdsl.com;
lon@moapawater.com;
lroy@broadbentinc.com;
LuckyDirt@icloud.com;
luke.miller@sol.doi.gov;
luke.stewart@pabcogypsum.com;
martinmifflin@yahoo.com;
MBHoffice@earthlink.net;
michael_schwemm@fws.gov;
mjohns@nvenergy.com;
mmmiller@cox.net;
moapalewis@gmail.com;
moorea@cityofnorthlasvegas.com;
muddyvalley@mvdsl.com;
onesharp1@gmail.com;
paul@legaltnt.com;
pdonnelly@biologicaldiversity.org;
progress@mvdsl.com;
rafelling@charter.net;
raymond.roessel@bia.gov;
rberley@ziontzchestnut.com;
rhoerth@vidlerwater.com;
robert.dreyfus@gmail.com;
Rott@nvenergy.com;
rozaki@opd5.com;
rteague@republicservices.com;
Sarahpeterson@blm.gov;
SCarlson@kcnvlaw.com;
sc.anderson@lvvwd.com;
sc.anderson@snwa.com;

sharrison@mcdonaldcarano.com;
stever@stetsonengineers.com;
sue_braumiller@fws.gov;
technichrome@jps.net;
tim@legaltnt.com;
tommyers1872@gmail.com;
trobison@mvdsl.com;
twtemt@hotmail.com;
veronica.rowan@sol.doi.gov;
vsandu@republicservices.com;
whitfam@mvdsl.com;
william.paff@rocklandcapital.com;
wpoulsen@lincolnnv.com;
mfairbank@water.nv.gov;
mlflatley@water.nv.gov;
jmordhorst@water.nv.gov

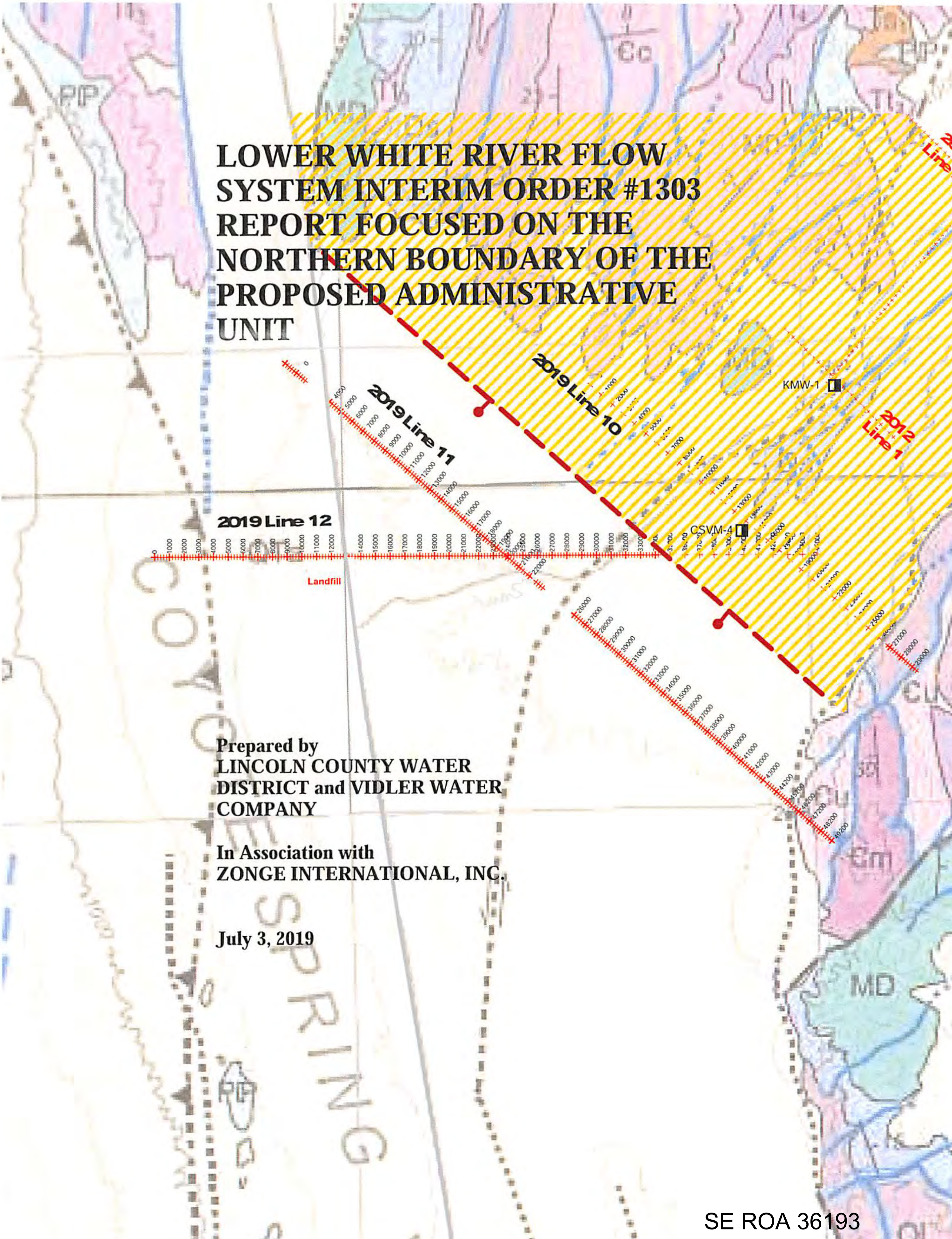
DATED this 6th day of September, 2019.

Nancy Fontenot
NANCY FONTENOT

4813-0204-7394, v. 1

ALLISON MacKENZIE, LTD.
402 North Division Street, P.O. Box 646, Carson City, NV 89702
Telephone: (775) 687-0202 Fax: (775) 882-7918
E-Mail Address: law@allisonmackenzie.com

LOWER WHITE RIVER FLOW SYSTEM INTERIM ORDER #1303 REPORT FOCUSED ON THE NORTHERN BOUNDARY OF THE PROPOSED ADMINISTRATIVE UNIT



Prepared by
LINCOLN COUNTY WATER DISTRICT and VIDLER WATER COMPANY

In Association with
ZONGE INTERNATIONAL, INC.

July 3, 2019

LOWER WHITE RIVER FLOW SYSTEM INTERIM ORDER #1303 REPORT FOCUSED ON THE NORTHERN BOUNDARY OF THE PROPOSED ADMINISTRATIVE UNIT

Prepared by
LINCOLN COUNTY WATER DISTRICT and VIDLER WATER COMPANY

In Association with
ZONGE INTERNATIONAL, INC.

July 3, 2019

LOWER WHITE RIVER FLOW SYSTEM
INTERIM ORDER #1303 REPORT
FOCUSED ON THE NORTHERN BOUNDARY OF THE PROPOSED ADMINISTRATIVE UNIT

Prepared for:

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

Prepared by:

Lincoln County Water District
1005 Main Street, Suite 103
P.O. Box 936
Panaca, Nevada 89042

Vidler Water Company
3480 GS Richards Blvd., Suite 101
Carson City, Nevada 89703

And

Zonge International, Inc.
3322 East Fort Lowell Road
Tucson, Arizona 85716

July 3, 2019

AMERICAN INSTITUTE OF HYDROLOGY
Certificate Number 1125
Greg Bushner
Professional Hydrogeologist
Greg L Bushner
Expires January 15, 2020

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LIST OF ACRONYMS

ac-ft	acre-feet
ac-ft/yr	acre-feet per year

amsl	above mean sea level
CEMP	Community Monitoring Environmental Program
COOP	Cooperative Observer Network
CSAMT	Controlled Source Audio Frequency Magneto Telluric
CSV	Coyote Spring Valley
°F	Degrees Fahrenheit
Ds	Devonian Simonson Dolomite
IO	Interim Order
KSV	Kane Springs Valley
KSW	Kane Springs Wash
LVVWD	Las Vegas Valley Water District
Lincoln/Vidler	Lincoln County Water District and Vidler Water Company
LMVW	Lower Meadow Valley Wash
LWRFS	Lower White River Flow System
Mg/L	milli-grams per liter
MRSA	Muddy River Springs Area
NSE	Nevada State Engineer
NW-SE	northwest—southeast
pmc	percent modern carbon
RDCA	Regional Deep Carbonate Aquifer
RAWS	Remote Automated Weather Station
SNWA	Southern Nevada Water Authority
TDSS	Total Dissolved Solids Sum
WRFS	White River Flow System
Zonge	Zonge International, Inc

1.0 EXECUTIVE SUMMARY

The Nevada State Engineer (NSE) through Rulings #5712 (NSE 2007) and #6254 (NSE 2014) has made several findings about Kane Springs Valley (KSV), the impacts from KSV and the effects of pumping from KSV on springs in the Lower White River Flow System (LWRFS) and further south of the LWRFS. The NSE has historically supported and affirmed the exclusion of KSV from the LWRFS since the Order No. 1169 requirements, including the Order No. 1169 aquifer test (NSE 2002) and since the hearing on by Lincoln County Water District and Vidler Water Company (Lincoln/Vidler) groundwater rights in 2006 (NSE 2007).

In this report, groundwater elevation data from wells in KSV and in the LWRFS groundwater basins[1], precipitation and recharge data, and groundwater chemistry and temperature data are used to illustrate the hydrologic differences between KSV and the basins of the LWRFS. Using the groundwater level data, which can be found on the NSE's website: *http://www.nv.gov/WaterLevelData.aspx*, Lincoln/Vidler identified a distinct "break" in water levels in the regional hydraulic gradient, including several distinct breaks in water levels from wells throughout the LWRFS. These "breaks" in gradient can mostly be attributed to geologic structures in the Regional Deep Carbonate Aquifer (RDCA). As a general statement, wells within the LWRFS exhibit very consistent groundwater levels that are indicative of high transmissivity values across this area. However, in KSV the gradient between well KPW-1 and down-basin wells is much steeper, which again implies some type of impediment to groundwater flow near the mouth of KSV.

There was an exceptional precipitation event that occurred in 2005 that overwhelmed the hydrologic system in KSV as identified in monitor wells KMW-1 and CSVM-4 groundwater levels. This event obscured the overall regional trend in groundwater levels in this region making identification of a response to the Order No. 1169 aquifer test not relevant neither appropriate. The

[1] The "joint administrative unit" includes the following hydrographic basins: Coyote Spring Valley (210), a portion of the Black Mountains Area (215), Garnet Valley (216), Hidden Valley (217), California Wash (218), and the Muddy River Springs Area (AKA Upper Moapa Valley) basin (219).

finding that water levels in KSV did not response to the Order No. 1169 aquifer test is supported by the lack of response or correlation of groundwater levels in well KMW-1 to groundwater pumping from Coyote Spring Valley (CSV).

Lincoln/Vidler have been collecting groundwater recharge data for over a decade in order to better understand and quantify the actual recharge that is occurring in the KSV hydrographic basin. These data have been submitted to the NSE and interested parties in the form of quarterly reports. A preliminary analysis of these data indicates in-basin groundwater recharge values that range from 4,700 acre-feet per year (ac-ft/yr) to 11,000 ac-ft/yr (T. Umstot, Daniel B. Stephens & Associates (DBS&A), unpublished data and analysis, 2019).

A comprehensive analysis of the regional geochemistry data including stable isotopes, temperature, and carbon-14 data was presented during the Lincoln/Vidler groundwater rights hearing in 2006. That analysis found that the groundwater pumped from KSV could not be identified in the source water for the Big Muddy Springs, nor other springs farther south and outside the geographic boundaries of the LWRFS. This means that groundwater pumped from production well KPW-1 is on a different groundwater flow path from the springs, which is again consistent with the differences in hydraulic gradients, groundwater levels, and the existing and recently collected geophysical data that documents the structural changes between KSV/northern CSV and the rest of the LWRFS groundwater basins.

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 in this area are different in KSV and northern CSV, than in the LWRFS groundwater basins to the south. The geophysical data identified significant changes in resistivities between the Delamar Mountains, 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 exclusion of KSV from the LWRFS administrative basin.

As will be shown later in this report, virtually all of the reduction in flows of the Muddy River and its associated springs over the past several years can be explained by the amount of groundwater pumping within the documented declines in the Muddy River Springs Area (MRSA). This provides a road map for the NSE in administering rights in this area with the intent of mitigating impacts to these springs. Focus should first be placed on both the carbonate and alluvial pumping in the MRSA. Secondly, since there is approximately 8,000 acre-feet of groundwater inflow from Lower Meadow Valley Wash (LMVW) to the MRSA, more research should be done to identify and quantify this inflow into the MRSA as it lies adjacent to and directly down-gradient of LMVW.

Lincoln/Vidler are not a party to, nor have ever been a participant of the Order No. 1169 aquifer test proceedings. The NSE never requested that Lincoln/Vidler provide a report on the outcome of the Order No. 1169 aquifer test results; hence none was ever developed.

In conclusion, KSV should remain excluded from the LWRFS administrative unit. Any revisions to the current LWRFS administrative unit boundary should also exclude northern CSV.

2.0 INTRODUCTION

The purpose of this report is to provide additional data and documentation that demonstrates KSV is hydrologically and geologically-structurally separate from the area defined by the NSE as the "joint administrative unit" known as the LWRFS, see Figure 2-1. This report is submitted by Lincoln/Vidler as owner of water rights, in addition to pending applications Nos. 74147, 74148, 74149, and 74150 in KSV.

Consideration of water rights in KSV fits squarely in the administrative boundaries of Nevada Water Law for the appropriation of groundwater from a hydrographic basin. This is based on a basin-by-basin analysis of perennial yield and is very dis-similar from what the NSE proposes for the LWRFS, which is as a managed unit. The basis of this report is new data collected to support the NSE in their determination of the proposed boundary of the LWRFS. Review of the relevant administrative policy that affects groundwater appropriations in Nevada and specific to KSV is provided below (Section 2.1). This is followed by a review of the matters requested to be addressed by the NSE in Interim Order (IO) #1303 (NSE 2019; Section 2.2). The remainder of the report provides hydrologic, geochemical, and geophysical data that supports the conclusion that KSV is not and should not be, included as part of the LWRFS administrative unit.

2.1 RELEVANT ADMINISTRATIVE POLICY

The NSE defines the perennial yield of a groundwater reservoir or basin as the maximum amount of groundwater that can be salvaged each year over the long term without depleting the groundwater reservoir. Perennial yield is ultimately limited to the maximum amount of natural discharge that can be salvaged for beneficial use. The perennial yield cannot be more than the *natural recharge* to a groundwater basin and in some cases is less.

The NSE's application of the groundwater appropriation system is based on a basin-by-basin analysis. This would change if KSV were to be included in the LWRFS and result in setting the precedent to include many other groundwater basins as part of the LWRFS. For instance, Cave, Dry Lake, and Delamar Valley basins have groundwater flow components that connect them together, and to CSV, and to KSV. Tacking on Cave, Dry Lake, Delamar, and KSV to the LWRFS administrative unit due solely to shared groundwater flows between them would override the historic basin-by-basin perennial yield analysis used by the NSE to administratively manage basins required by law, and instead in essence would create what would look strikingly like a "pachinko game" wherein if you had priority groundwater rights in the last basin downgradient you would get to withdraw the collective flow. This means that no water would be available from upgradient groundwater basins and the counties where these basins occur would not have the ability to utilize water for economic development in their county.

2.1.1 Previous Determinations by the Nevada State Engineer Regarding Kane Springs Valley

The NSE has already ruled on the issue of whether the appropriation of groundwater from KSV would affect the MRSA, or for that matter other springs of interest. This was documented in Nevada State Engineer Ruling #5712 (2007), on page 20 where it is 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."[2]

New geophysical data provided in this report and collected in response to IO #1303 (NSE 2019), provides strong evidence of faulting and fracturing of the regional carbonate system in southern KSV and northern CSV. Specifically, these data explain why there are differences in water levels in wells located in southern KSV and northern CSV versus the rest of the proposed LWRFS. These geophysical and water level data show why groundwater withdrawn based on the perennial yield of KSV would not likely impair flow at Muddy River Springs, not to mention Rogers or Blue Point Springs. Therefore, these data support the exclusion of KSV, and for that matter, exclusion of northern CSV (north of the major fault structures) from the LWRFS.

The NSE's determination that there would be no impairment from pumping in KSV was affirmed seven years later in Ruling #6254 issued in 2014. In Ruling #6254 (NSE 2014), the NSE

[2] No party appealed the NSE's determinations in Ruling #5712.

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. Specifically, NSE (2014) Ruling #6254 at page 23 states:

> "...the State Engineer found that where no significant effects would be felt for hundreds of years, the upgradient water could be appropriated."

The NSE speaks explicitly to the difference between KSV and the Order 1169 groundwater basins (see footnote 1) further in Ruling #5712 (NSE 2007) by stating at page 21:

> "...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 veracity and reliability of this statement by the NSE is confirmed by the extensive, new geophysical data Lincoln/Vidler has collected. As will be shown from these new data, there is a significant change in the continuity of lithology that occurs near the mouth of KSV and the end of the Delamar Mountains in northern CSV.

The NSE in Ruling #5712 (2007) further concluded on page 21:

> "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."

That finding was not challenged by any of the Order No. 1169 (NSE 2002) participants, including Southern Nevada Water Authority (SNWA) or Las Vegas Valley Water District (LVVWD).

Subsequently, neither SNWA or LVVWD provided any information or data in their October 5, 2018 (SNWA and LVVWD 2018) letter that indicate that appropriation of water in KSV will impact any of the springs in the MRSA.

2.2 REQUIREMENTS BY THE NEVADA STATE ENGINEER FOR THE INTERIM REPORT

In IO #1303 (NSE 2019), the NSE requested that the reports submitted 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 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."

The direct response to each of these items is specifically addressed in Section 6.0 under Key Findings and Conclusions. Lincoln/Vidler's response is focused on the northern boundary of the administrative unit. However, Lincoln/Vidler do provide information, data, and/or opinion on other issues that would be beneficial and helpful to the NSE in his decision-making process related to IO #1303 (NSE 2019). Indeed, clear evidence of the primary factors that have historically reduced Muddy River flows and headwater springs flows is presented and offers a road map for the NSE's technical deliberations supporting a LWRFS administrative unit.

3.0 REVIEW OF EXISTING DATA

This report includes a discussion and submission of existing data that includes: (a) groundwater elevation data from existing wells, including wells from KSV and CSV, (b) data collection activities that include analysis of water recharged in the KSV groundwater basin, (c) geochemistry, including whole water chemistry and stable isotopic age dating data, and (d) groundwater temperature data.

3.1 GROUNDWATER LEVEL DATA FROM WELLS IN KANE SPRINGS VALLEY AND NORTHERN COYOTE SPRING VALLEY

Groundwater elevation data have been collected throughout the LWRFS for over two decades. Figure 3-1 shows the location of the wells throughout the area of interest including KSV, CSV, and the MRSA. Hydrographs of these wells are provided in Appendix A, and the supporting data can be found at: *http://water.nv.gov/WaterLevelData.aspx*.

Lincoln/Vidler have been measuring water levels in monitor well KMW-1 quarterly since April 2007 (Figure 3-2). This well, located at the mouth of KSV and near northern CSV, encountered the Willow Springs Fault, which is a western bounding fault of the KSW Fault Zone (Figure 3-3). KMW-1 and associated production well KPW-1 are both completed in carbonate rocks that are considered part of the RDCA system of eastern Nevada. Wells KMW-1 and KPW-1 were constructed within 100 yards of each other and have the same well completion.

3.1.1 Regional Water Level Data in the Lower White River Flow System

During the administrative hearing for groundwater 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 (see footnote 1) groundwater basins. Groundwater elevation data from wells completed in the RDCA in southern CSV are remarkably flat across the LWRFS groundwater basins, whereas water levels in KSV/northern CSV have a steeper gradient, as shown in Figure 3-4. In summary, a key finding is that groundwater levels in RDCA wells are very similar in elevation (pre-pumping or minimal pumping of Order 1169 [NSE 2002] groundwater basins) everywhere downgradient of the KSW Fault Zone (CH2M Hill 2006a). Figure 3-5 is an update to a subset of the data provided in Figure 3-4 using the most current water level measurements.

To further illustrate the differences in groundwater elevations, an excerpt from Figure 3-5, identified in the red box, is presented as Figure 3-6, illustrates the differences in heads between the northern CSV (monitor wells CSVM-4 and CE-VF-2) and the rest of the wells, further south in the LWRFS (CSVM-6, MX-5, CSVM-1, UMVM-1, CSVM-5, and MX-6). 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.

Another way to view the data is to plot all the groundwater elevations at the same scale for elevation and over time (Figure 3-7). The graph in Figure 3-7 shows the distribution of heads across the northern and central part of the LWRFS, and also KSV. What is striking about this presentation of the data is the consistency in water level elevations for the wells in groundwater basins in the central LWRFS at below elevation 1,825 feet. What's also notable is that when plotted at this 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.

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."

Given all these data and information, the NSE does have reason to view many of the basins in the LWRFS as a unit based on the remarkably consistent groundwater levels among wells completed in the RDCA (Figure 3-7). The NSE clearly noted this in Ruling #6254 (NSE 2014) at Page 12:

> "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."

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.

3.1.2 KMW-1 and CSVM-4 Groundwater Level Data

Detailed hydrographs of groundwater elevation data from monitor well KMW-1, located at the mouth of KSV, and CVSM-4, located in the north central portion of CSV (Figure 3-1) are provided in Figures 3-2 and 3-8, respectfully.

Groundwater elevations in monitor well KMW-1 declined approximately 2 feet from the time it was installed in early 2007 to early 2014 and then fluctuated over a range of approximately 1 foot. The actual groundwater elevations were at approximately 1,880 feet above mean sea level (amsl) in April 2007 (Figure 3-2) and approximately 1,878.4 feet amsl in April 2019.

The hydrograph from Well CSVM-4 is provided in Figure 3-8. Groundwater level elevations during the same time period, described in the previous paragraph concerning well KMW-1, in June 2007 was approximately 1,874.5 feet amsl, or approximately 5½ feet lower than at KMW-1. This difference of 5 ½ feet is larger than the gradient across much of the LWRFS and indicates a distinctly different situation in the RDCA. The period of record for well CSVM-4 started more than 3 years earlier than that of KMW-1 (July 2003) and measurement continues to the present.

The hydrographs for both KMW-1 and CSVM-4 are plotted with the same time and water-level elevation scale for their combined period of record in Figure 3-9. The difference in head between these wells is explained due to the presence of a fault that occurs between them based on the newly collected geophysical data (Section 4.0). What is also striking regarding the hydrographs from both these wells is the consistency in their trends, suggesting that they are related and again how KSV and northern CSV are isolated from the rest of the LWRFS. Without the groundwater elevation data from well CSVM-4, prior to the installation of well KMW-1, what would have been missed is the huge recharge precipitation event that occurred in 2005 that created a strong response of water levels in the hydrologic system in this area. This event took years to dissipate in the aquifer as manifested by the change in groundwater elevations. The precipitation event and data that supports it are discussed below in Section 3.2. If this recharge event is removed from the data set, then a long-term decline in groundwater levels over time is revealed as approximately 1-foot per decade (0.1 foot per year; Figure 3-9).

3.2 IN-BASIN RECHARGE AND PRECIPITATION

The basis for a groundwater appropriation under the Law of the State of Nevada within a hydrographic basin is to document the availability of water in that basin that can be withdrawn over the long term without (1) affecting existing water rights, and (2) causing excessive groundwater mining in the hydrographic basin. Lincoln/Vidler have been actively collecting and using recharge data to estimate recharge throughout KSV. These data provide a solid technical basis for determining the perennial yield within KSV, which in turn identifies the volume of water that can be withdrawn from this hydrographic basin. These data quantify additional precipitation and recharge in KSV and the available water that can be appropriated.

3.2.1 In-Basin Recharge Data Collection

In order to develop a solid technical foundation for determining the perennial yield value for KSV, Lincoln/Vidler, beginning over a decade ago in October 2007, have been collecting basin-specific data through the use of totalizing rain gages, tipping bucket rain gages, runoff event data loggers, and chloride collectors. We continue to collect and submit these data, to the NSE and interested parties, in an effort to better understand and quantify recharge occurring in KSV and to share that technical foundation transparently with others. Based on analysis of the ongoing basin-specific data collection effort, there is unappropriated water available in KSV. This is due to the fact that recharge values clearly show that there is more water available under Nevada State Law than has been appropriated. Much like Cave Valley, Dry Lake Valley, and Delamar Valley, groundwater appropriated in KSV is also recharged within the basin (NSE 2014). A copy of the second quarter 2019 quarterly recharge report that presents the runoff, precipitation, and chloride data collected to date, is provided in Appendix B. Based on a preliminary analysis of these data, estimates of in-basin recharge are approximately between 4,700 to 7,500 ac-ft/yr from the chloride mass balance analysis method and approximately 7,100 to 11,000 ac-ft/yr from the watershed model (T. Umstot (DBS&A), unpublished data and analysis, 2019).

Independently of the data Lincoln/Vidler have been collecting to support the recharge value in KSV, SNWA conducted an analysis of recharge for hydrographic basins in the White River Flow System (WRFS). SNWA derived an annual recharge value of 4,329 acre-feet for KSV (SNWA 2009, pages 9-13 and 9-14). This too, indicates that there is water available under Nevada State Law for appropriation within KSV.

In summary, groundwater recharge is documented to occur in KSV and does not contribute to the proposed local recharge of the LWRFS administrative unit, i.e., the recharge occurs within KSV and not in the LWRFS basins. This recharged water is available for appropriation in KSV, according to Nevada State Law, as the perennial yield based on a solid recharge data collection and analysis research program in KSV. Our research demonstrates that significant in-basin groundwater recharge occurs within the KSV, primarily in Delamar Mountains (Appendix B). However, local recharge in the Upper WRFS, which includes Cave, Dry Lake, and Delamar Valleys is not counted in the discharge of groundwater to the LWRFS, neither should local groundwater recharge that occurs within KSV be included in the LWRFS administrative unit.

3.2.2 Precipitation During Winter Water Year 2005

An extreme precipitation event occurred during water year 2005 (Figure 3-10 and Table 3-1) that resulted in clear groundwater responses across the hydrologic system in southeastern Nevada. Table 3-1 shows precipitation data from the Remote Automated Weather Station (RAWS) in KSV as well as five other stations in the surrounding area. Precipitation for that water year in KSV was approximately 26 inches. To put that in perspective, the average yearly precipitation for the RAWS in KSV is approximately 7½ inches per year (Figure 3-10). This event was 3.5 times larger than the average precipitation of other years in the area. The Elgin COOP Station, located at the north end of KSV, also had an extreme amount of precipitation during water year 2005 and in the amount of 30.69 inches (Table 3-1).

Table 3-1. Precipitation Date in Kane Springs Valley and Surrounding Areas for the 2005 Water Year

	Kane Springs RAWS	Alamo CEMP	Pahranagat Widlife Refuge	Hiko COOP	Elgin COOP	Caliente CEMP
Oct-04	4.93	2.30	1.76	3.38	5.18	4.73
Nov-04	1.04	1.14	1.27	1.25	2.48	1.74
Dec-04	2.91	1.02	0.84	0.23	2.66	1.50
Jan-05	5.54	2.44	3.13	2.94	6.49	2.26
Feb-05	3.15	2.07	1.93	2.72	3.31	1.60
Mar-05	1.56	0.99	1.03	0.84	2.38	2.05
Apr-05	1.85	1.06	0.88	0.85	1.75	1.83
May-05	0.31	0.36	0.57	0.45	0.24	0.28
Jun-05	0.32	0.25	0.13	0.80	0.58	1.08
Jul-05	0.43	0.43	0.50	0.11	0.65	0.23
Aug-05	3.79	1.93	2.03	2.52	4.95	2.54
Sep-05	0.09	0.57	0.68	0.64	0.02	0.28
	25.92	14.56	14.75	16.73	30.69	20.12

3.3 GEOCHEMISTRY AND GROUNDWATER TEMPERATURE DATA

There are some significant differences in the general groundwater chemistry data exhibited in monitor wells from southern KSV and northern CSV compared with the general chemistry of groundwater and surface water of the LWRFS. An extensive geochemistry investigation and analysis was made of KSV and surrounding groundwater basins from Pahranagat and Delamar Valleys through and including the LWRFS by Lincoln/Vidler during the 2006 hearing on their pending groundwater rights applications. The data and analysis still hold true as presented in CH2M Hill's 2006 report: *Hydrologic Assessment of Kane Springs Hydrographic Area (2006): Geochemical Framework,* which is provided in its entirety in Appendix C. The salient point of this report, based on the regional geochemistry, including stable isotopes, temperature, and carbon-14 data is that:

> "A comparison of these chemical and isotopic relationships with Big Muddy Springs and particularly Rogers Spring and Blue Point Spring indicates that the groundwater from KPW-1, assumed representative of the KSV groundwater, is too strongly attenuated with CSV to be identifiable in these springs." (Appendix C: CH2M Hill 2006b, Pages 12 and 13).

To further support this statement, Lincoln /Vidler provides the following a discussion of general chemistry data, groundwater and spring temperature data, and carbon-14 data.

3.3.1 General Chemistry Data

These data are used to illustrate the groundwater chemistry at samples analyzed from production well KPW-1 and monitor well CSVM-4, the closest monitor well to and down gradient of the KSV groundwater basin, and other wells and springs in the LWRFS and surrounding areas. An extensive database of water quality data is included in CH2M Hill (2006b) reproduced from Thomas, Calhoun, and Apambire (2001) and supplemented by other sources as noted in Appendix C. A discussion of Total Dissolved Solids Sums (TDSS) is presented first followed by a discussion of Carbon-14 data, and groundwater temperature data.

3.3.1.1 Total Dissolved Solids Sums

The TDSS is the summation of the concentrations of silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate, and chloride (CH2M Hill 2006b). The analysis from well KPW-1 is provided in Table 3-2. The TDSS from the groundwater produced from well KPW-1 is calculated to be 774 milli-grams per Liter (mg/L) and the TDSS for well CSVM-4 is calculated to be 682 mg/L (Table 3-2). Groundwater from well KPW-1 is either on a different groundwater flow path exiting the KSV hydrographic basin, or it comingles with groundwater in northern CSV that has a fresher source of water. This fresher source of water would need to be such that mixing with Kane Springs groundwater would be enough to reduce the Total Dissolved Solids by approximately 100 mg/L. One such source of groundwater mixing is from monitor well CSVM-7, installed in volcanic rocks to the northeast of CSVM-4 (Figure 3-1). In fact, the water chemistry, stable isotope data, and temperature at CSVM-4 can be simulated quite precisely by assuming approximately 74% KPW-1 groundwater and approximately 26% groundwater similar to that measured at CSVM-7. These data provide evidence that groundwater in southern KSV and northern CSV may commingle or have similar recharge sources. Furthermore, CH2H Hill (2006b) found that groundwater in KSV is chemically and isotopically "unique for the regional carbonate groundwater in this area," and greatly attenuated in CSV, and not likely present at Big Muddy Springs, nor Rogers Spring, and Blue Point Spring. The recently collected geophysical data provides the structural basis for why groundwater movement through southern KSV and northern CSV to the LWRFS is restricted and why it is unlikely related to spring flow at Big Muddy Springs, Rogers Spring, and Blue Point Spring.

Table 3-2. Total Dissolved Solids Sum for Selected Wells and Springs

	Parameter						
Water Source	Na + K	Ca	Mg	Cl	HCO3	SO4	TDSS
Big Muddy Spring	108	64	27	61	276	177	713
Pederson's Warm Spring	111	71	26	60	270	190	728
KPW-1	168	48	14	63	341	140	774
MX-5	96.3	48.7	21	35.7	294	93.1	588.8
CSVM-4	145	40	13	53	311	120	682

3.3.1.2 Carbon-14 Data

Carbon 14 data can be used to obtain the age of groundwater or in this case the apparent age of the groundwater. CH2MHill (2006b) provided a comprehensive analysis of carbon-14 data in their report which is reproduced here in its entirety below. In addition to the quote below, CH2M Hill (2006b) also provided a table of percent modern carbon analyzed from various wells and springs in and surrounding KSV. This table is reproduced for this report as Table 3-3 (which is labelled as Table 3 in the CH2M Hill (2006b) report). The following quote is from the CH2M Hill (2006b) report.

> "Table 3 lists a summary of carbon-14 data and the simple apparent age for hydrographic areas, KSV well KPW-1 as well as Big Muddy, Rogers and Blue Point Springs. Most of the apparent ages are in the 14,000 to 35,000 years before present range. The KSV well, KPW-1, has one of the oldest apparent ages at 29,900 years. Assuming that the apparent ages are somewhat true, and in this case may be, it is not probable that KSV groundwater represented by KPW-1 with this age could represent a significant contribution to the flow at Big Muddy Springs."

Table 3-3. Carbon - 14 percent modern carbon (pmc) values and apparent ages for hydrographic areas KSV well KPW-1, major springs in Pahranagat Valley as well as Big Muddy, Rogers, and Blue Point Springs

Hydrographic Area/Well/Spring	Carbon -14 (pmc)	Apparent Age (Years Before Present)
Pahranagat Valley, Major Springs	6.3-8.4	20,300-21,700
KPW-1	2.7	29,900
Coyote Springs Wells	4.2-17.9	14,200-26,200
Garnet Valley Wells	3	29,000
MRSA	8.4	20,500
Big Muddy Springs	7	22,000
Rogers Spring	1.6,2.4	30,900-34,200
Blue Point Spring	7.2,5.4	21,800-24,100

Note that the older age of KPW-1 can also be an indicator of deeper circulation of water compared to other sources in the area, which is supported by its higher water temperature as discussed below.

3.3.1.3 Temperature Data

Representative temperature data for groundwater and springs in the LWRFS and in KSV are provided in Figure 3-11. The data used to create Figure 3-11 are provided in Table 3-4. The local geothermal gradient can be used to estimate that expected temperature distribution due to a relatively uniform heating and allows identification of unusual values of groundwater temperature that indicate distinctive local groundwater flow processes. A typical geothermal gradient in this area is about 3.6 degrees Fahrenheit (°F) per 328 feet of depth beginning at approximately 96 feet (Nicholson 2007). Using the data from Table 3-4, the groundwater temperature data from wells completed in the RDCA center around two values of approximately 78°F and 99°F. The warm springs that occur in the MRSA are consistently centered around 89°F to 90°F, which is in the middle of this expected range. The production well drilled and tested in KSV (KPW-1) yielded a groundwater temperature of 136°F at the end of the seven-day aquifer test (URS 2006a), which is well above this expected range and suggests deep circulation of groundwater arriving at this location and/or a geothermal source. Using the typical geothermal gradient as noted above and applying it to the production well in KSV (Figure 3-3), the change in groundwater temperature based solely on the geothermal gradient would be approximately 19°F. Applying this value to either set of carbonate wells yields groundwater temperatures of 97°F to 118°F. None of these values are close to the 136°F of the groundwater found at KPW-1, which indicates local groundwater flow, distinct from any other groundwater data point in the LWRFS.

The differences in groundwater temperatures suggest distinctive groundwater flow paths through the RDCA in this area. Most importantly the difference in the temperature data from well KPW-1 versus that of the rest of the wells in the RDCA indicates a very different source for the groundwater flowing through KSV as compared to the rest of LWRFS. Figure 3-12 is the graphical representation of the data from Table 3-4 and from the map shown in Figure 3-11. It's evident from Figure 3-12 that there are several wells that can be connected based on temperature, as well as, wells that do not connect with any other data. The same colors on Figure 3-12 represent the same flow paths on Figure 3-11, and are typically north to south. These groundwater temperatures are consistent with the geophysics and the mapped geologic structures in the LWRFS. In summary, the groundwater temperature data from KPW-1 doesn't fit the groundwater temperature data from the other wells, with the exception of some mixing with well CSVM-4, and therefore indicate a flow path distinctive from that of wells in the LWRFS.

Table 3-4. Temperature Data from Selected Carbonate Sourced Groundwater Wells and Springs		
Well/Spring Description	Temperature Range	Source
CSVM-2	99.87° - 99.82°	1
CSVM-3	78.02° - 77.04°	1
CSVM-4	106.56° - 107.89°	1
CSVM-5	75.69° - 76.11°	1
KPW-1	129.91° - 135.77°	2
Big Muddy Spring	89.78°	3
Pederson Warm Springs	89.96°	3
CSI-1	89°	3

References - Source of Data:

1. URS – 2006b CSV Monitor Well Sampling Report
2. URS – 2006a KSV Final Well Completion Report
3. CH2MHILL – 2006b Geochemistry Report

4.0 GEOPHYSICAL DATA

Lincoln/Vidler have collected extensive lines of geophysical data in both KSV and CSV. The Controlled Source Audio Frequency Magneto Telluric (CSAMT) method has been used for this work, an explanation of which is provided below. Lincoln/Vidler has applied CSAMT for characterization of the RDCA to thousands of feet below land surface over several decades and in several hydrographic basins with great success. For this discussion, existing geophysical data is considered to be that collected in KSV in 2012 by Zonge International, Inc. (Zonge). These existing data are discussed in the following section. New geophysical data were collected in February and March of 2019 for this report to the NSE to augment the existing geophysical data from KSV. The new geophysical data were collected in northern CSV and both sets of data are considered together for the purposes of this report.

A CSAMT geophysical survey is a high-resolution electromagnetic sounding technique that uses a fixed grounded dipole as a signal source (a dipole is a pair of equal and oppositely charged or magnetized poles separated by a distance). A complete, published, and peer-reviewed discussion of the CSAMT method can be found in Zonge and Hughes (1991) and Zonge (1992).

As applied here, the CSAMT geophysical survey method used a CSAMT transmitter signal source that usually consists of a grounded electric dipole 3,500 and 6,500 feet in length located three to six miles from the area where the measurements are to be made (Figure 4-1). At the receiver site, grounded dipoles detect the electric field and a magnetic field coil antenna detects the magnetic field (Figure 4-2). The electrical resistivity of the geologic formations can be determined from the combination of these electric and magnetic field measurements. Varying the frequencies of the observations controls the depth of investigation using the CSAMT method. Depth sections can be generated using the CSAMT method by measuring the electric and magnetic fields over a range of frequencies and using computer modeling to produce a cross-section of resistivity at different depths.

CSAMT data are usually shown as resistivity values in ohm-meters. Resistivity is essentially a measure of the ground's ability to conduct electrical current. Though the resistivity contour lines often at first glance appear to be indications of contacts between lithologic layers they are lines of equal resistivity and not necessarily boundaries between different lithologies. While different rock types do indeed often exhibit different resistivities, most rock types exhibit a range of resistivities, and the resistivity ranges for different rock types may overlap. The ranges in resistivity result from the fact that there are several factors that affect resistivity, including the amount of pore fluids, the type of pore fluids, mineralization, clay content, and the size and interconnectedness of the pore spaces, as examples. As a result of all these variables, in some cases two different lithologies may exhibit similar resistivity, and in other cases, a single lithologic unit may exhibit different resistivities in different areas.

This survey technique is a well-established method, commonly used primarily by the minerals, geothermal, and groundwater exploration industries, and has been in use since the early 1980's when CSAMT equipment was first commercialized. It is not a proprietary method so it can be, and has been, replicated or repeated by independent exploration geophysicists. Zonge is one of several manufacturers of CSAMT equipment whose systems have been purchased by and are in use by numerous government agencies including the US Geological Survey, universities, national laboratories, and private entities.

4.1 DISCUSSION ABOUT USE OF THE CSAMT GEOPHYSICAL METHOD

It is not unusual for faults or other geologic structures to not be apparent to non-geophysicists reviewing a CSAMT resistivity cross section. The following is provided to help explain how various structures are identified in these CSAMT cross sections. In resistivity plots, faults can be manifested in several different ways, since the data are showing an electrical property of the subsurface that may or may not be indicative of changes in lithology. Figure 4-3 provides two examples of the CSAMT geophysics plots that can be used to identify different fault structures. The fault on the left in Figure 4-3 looks like a vertical, narrow, low resistivity feature centered at station 350 (where the client drilled and accessed water). On the right-hand side of Figure 4-3 is a more traditional looking plot of faulting, with the left side of the section offset higher relative to the right part of the section, with the fault between stations -300 and -150. Both of these examples show how geologic structures can be identified in transects conducted through southern KSV and northern CSV using the CSAMT geophysical method.

4.2 GEOPHYSICAL DATA COLLECTED IN KANE SPRINGS VALLEY

An extensive geophysical survey using the CSAMT method was conducted by Zonge in 2012 to further refine potential well locations in KSV. Several geophysical transects were conducted perpendicular to the axis of the KSV basin (Figure 4-4). A transect was also conducted along the axis of the southern part of the basin. For the transects conducted in CSV, the same northwest-southeast (NW-SE) orientation as the KSV transects was used to assist in evaluating the geologic structures in this area.

To best understand the geologic structures in northern CSV, a review of the first geophysical transects, Lines 1 and 2, through the southern end of KSV is warranted. These transects in both southern KSV and northern CSV are plotted on an excerpt (Figure 4-4) of the most recent geologic map of this area by Rowley and others (2017).

4.2.1 CSAMT Transect Line 2 through Southern Kane Springs Valley

In order to track the geologic structures that occur in southern KSV into northern CSV, the northern-most transect used in this report is discussed below and provided as Figure 4-5. The view of the transect is looking to the northeast into the KSV basin.

Beginning on the right side (or east side) of Line 2 illustrated in Figure 4-5, the data exhibits a very highly resistive block essentially from land surface to final investigation depth. This demonstrates "ground-truthing" of the CSAMT method as this is an exposed block of RDCA. From station number (the station numbers are across the top of the transect) 15100 the high resistivity values occur adjacent to low resistivity values and are representative of faulting in this area as also interpreted at this location on the geologic base map. These values represent the eastern boundary of the Kane Springs Wash (KSW) Fault Zone (Figure 4-4).

Numerous other faults are represented on the Line 2 transect through southern KSV. This area ranges from approximately station number 8500 through station 15100. This area represents the KSW Fault Zone and is very consistent with the surficial geologic map by Rowley and others (2017).

The next significant feature shown on Figure 4-5 is the block of high resistivity that occurs between stations 7500 and 8500 with a top at an elevation of approximately 1,500 feet. This feature ties directly to the large carbonate rock outcrop mapped at the mouth of KSV (Figure 4-4, between Lines 1 and 10, labelled "Ds"). The northwest side of the transect of Line 2 (Figure 4-5) confirms the presence of the mapped Willow Springs Fault on the geologic map (Figure 4-4). This occurs between stations 500 to 700 (Figure 4-5).

4.2.2 CSAMT Line 1 through Southern Kane Springs Valley

Line 1 of the KSV CSAMT transect (closest to southwest end of KSV) is provided in Figure 4-6. This transect includes and is ground-truthed using both the down-hole geophysics and geologic log of wells KPW-1 and KMW-1. These wells were drilled adjacent to the exposed outcrops of Devonian Simonson Dolomite (Ds) illustrated in Figure 4-4. This well also intersects the Willow Springs Fault as shown on Figure 3-3. The geophysical transect confirmed the exposure of dolomite, the attitude (dip) of both geologic units, and the occurrence of the KSW Fault Zone. The ground-truthing of CSAMT across the exposed dolomite outcrop in the center of Line 1 is convincing.

Unlike Line 2 (Figure 4-5), the Line 1 (Figure 4-6) CSAMT transect does not extend to the exposed hard rock outcrops of either the Delamar Mountains or the Meadow Valley Mountains. Other important features shown on Line 1 include:

- Faulting within KSW Fault Zone at stations 8100 through the end of this transect (Figure 4-6).
- Faulting on west side of KPW-1 near boundary of outcrops at Station 2100.

4.3 GEOPHYSICAL DATA COLLECTED IN NORTHERN COYOTE SPRING VALLEY

New geophysical data were collected in February and March 2019 in northern CSV just south of the KSV basin boundary (Figure 4-4). These data were collected in direct response to the request from the NSE in IO #1303 (NSE 2019) calling for new data to be provided in order to assist him in addressing the issues identified in the Interim Order (see Section 1.2).

Two new CSAMT geophysical transects, in CSV, were conducted parallel to the previously collected Lines 1 and 2, in southern KSV. The southwestern-most transect in KSV, Line 1, includes wells KPW-1 and KMW-1. The new transects in CSV are labelled Lines 10 and 11 (Figure 4-7), with Line 10 being the most northerly transect closest to the mouth of KSV. Both of these transects are located in a NW-SE orientation, perpendicular to the known geologic structures identified on the geologic map of the area (Rowley and others 2017). A third transect, Line 12, was conducted in an east-west alignment in northern CSV and intersected both Lines 10 and 11 (Figure 4-4).

The following sections specifically discuss the new CSAMT data, and then discuss what this information means relative to the geology and associated controls on groundwater flow in southern KSV and northern CSV.

4.3.1 CSAMT Line 10 Northern Coyote Spring Valley

The northern most transect in CSV (Figure 4-7) is located just southwest of the exposed outcrop of dolomite (Ds) at the mouth of KSV (Figure 4-4). Monitor well CSVM-4 is also located to the southwest of station 13900 on Line 10.

There are several significant features that can be identified on CSAMT Line 10.

- The transect is dominated by high resistivity blocks.
- From the ground-truthing discussed previously for Lines 1 and 2, and on this line at its far southeast end, these high resistivity blocks are most likely RDCA.
- This transect also shows the down thrown nature of the boundary fault on the far southeastern end – stations 23900 to 24300. This fault occurs to the western side of the Meadow Valley Mountains and forms the eastern boundary of the Kane Springs West Fault Zone (Figures 4-4 and 4-7) which is consistent with the geologic map (Rowley and others 2017). This fault can be traced through these transects (Figures 4-4 and 4-7) from KSV into CSV (Rowley and others 2017).
- Well CSVM-4 was drilled near the highly resistive block of exposed dolomite in KSV. This block of dolomite is not exposed at the surface in CSV but can be traced from KSV through to the geophysical transect of Line 10 in northern CSV.

- The concealed Delamar Thrust Fault drawn on Rowley and others (2017) cannot be identified—or is not present—on CSAMT transect of Line 10. If present, it would be located at approximate station 4100.
- Faulting does occur from stations 8300 to 10500. This would agree with the concealed strike slip fault identified on Rowley and others (2017) along the northwest edge of the outcrop Ds at the mouth of KSV (Figure 4-4).
- The highly resistive block that outcrops as Ds at the mouth of KSV continues to occur beneath the surface as shown in Line 10. This occurs from stations 13500 to 16300.
- There are numerous faults that occur from station 16300 though station 24300, which is representative of the KSW Fault Zone.

4.3.2 CSAMT Line 11 in Northern Coyote Spring Valley

CSAMT Line 11 is located approximately 12,500 feet to the southwest of Line 10 (Figure 4-4). Monitor well CSVM-4 is located approximately 11,700 feet to the northeast of station 31100 of Line 11.

There are several significant features that can be identified on CSAMT Line 11.

- The most striking difference of Line 11 from Line 10 is the virtual lack of the highly resistive blocks that dominated the transect of Line 10. This constitutes over 2,800 feet or a half mile of thickness of highly resistive block not present just 12,500 feet or approximately two miles south of Line 10.
- This transect also shows the down-thrown nature of the southeastern boundary fault. This fault occurs to the western side of the Meadow Valley Mountains and forms the eastern boundary of the Kane Springs West Fault Zone (Figures 4-4 and 4-7, stations 45300 - 45700).
- Again, the southeastern boundary fault (or northwest exposed side of the Meadow Valley Mountains [Figures 4-4 and 4-7]) is identified by the geophysics and can be traced through this transect from KSV into CSV (Rowley and others 2017).

- Similar to Line 10, there are numerous faults throughout this transect and especially so on the southern half of this transect.
- There is no evidence of the Delamar Thrust Fault (that would be at station 21500) as extrapolated from the Delamar Mountains on the geologic map (Rowley and others 2017) from the geophysical transect of Line 11.
- The concealed strike-slip fault that forms the western boundary of the KSW Fault Zone, i.e., the strike slip fault identified on Rowley and other (2017) along the northeast edge of the outcrop Ds at the mouth of KSV may be located at approximately station 26700 on Line 11 (Figure 4-7).
- The low resistivity zones may be the result of thicker volcanics versus higher resistivity carbonates, or it may just be different materials in the alluvial cover (i.e., more or less clays in some alluvial sediment layers than others, obviously much more in an overall sense than in the RDCA). Also, along some parts of the line, there are multiple low resistivity layers (stations 30000 to 38000, for example).
- Comparison of Line 10 to Line 11 suggests that the structural boundary between southern KSV/northern CSV and the rest of CSV to the south occurs between these two lines.

4.3.3 CSAMT Lines 12 East – West Line through Northern Coyote Spring Valley

CSAMT Line 12 (Figure 4-8) is an east-west transect that intersects both CSAMT Lines 10 and 11 at stations 42700 and 23800, respectively, at a 45-degree angle. There are several significant features that can be identified on this transect.

- The Gass Peak Thrust Fault (a very large, regional structural feature) appears to be present at station 1300 (Figure 4-8; Rowley and others 2017).
- Low resistivity values occur at the land surface on the western side of this transect. This 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.
- There is no real evidence of the regional normal fault mapped on the geologic map around station 13000 (Rowley and others 2017).
- Remnants of KSW Fault Zone, i.e., the strike slip fault identified on Rowley and others (2017) along the northwest edge of the outcrop Ds at the mouth of KSV, occur from

approximately station 30300 through 44100. Specifically, there is an obvious change between the layering of resistivities east and west of approximately station 30000.

- Well logs from monitor wells CSV3009 and CSV3011 confirm the presence of unconsolidated or alluvial materials, i.e., silts, clays, sands, and gravels to at least a depth of approximately 1,580 feet below land surface (Figures 3-1 and 4-4). There are no highly resistive (carbonate) rocks that occur on the western portion of Line 12 (Figure 4-8).

4.4 MAJOR POINTS IDENTIFIED AND DERIVED FROM THE GEOPHYSICAL DATA

The following major points can be made about the geophysical data from lower KSV and northern CSV.

- Geophysics validate many but not all of the concealed faulting extrapolated on the geologic map.
- It is reasonable to connect the highly resistive feature that extends from southern KSV (Line 2) through northern CSV (Line 10) and in exposed Devonian rock in southern KSV.
- The KSW Fault Zone is a massive geologic feature that extends from northern KSV where it transects the KSV Caldera Complex into northern CSV.
- Well KPW-1 was drilled near the confluence or intersection of the Willow Springs Fault and the western boundary fault of the KSW Fault Zone. In fact, the Willow Springs Fault Zone joins with, if it doesn't replace the western bounding fault of the KSW Fault Zone (Figures 4-4 through 4-7).
- The KSW Fault Zone expands from the southern part of KSV into northern CSV where it extends to approximately 18,500 feet across (Figure 4-7).
- The KSW Fault Zone in northern CSV is dissected by dozens of faults as shown in the geophysical transect of Line 11 (Figure 4-7). This area exhibits an "accommodation zone" pattern of faulting where numerous normal faults occur "en-echelon," or parallel to each other, throughout the area (Figure 4-7).
- Because of the potential for incorporating less permeable materials in the process at a regional scale, groundwater will flow easier along fault zones than across fault zones. Small sections of faults may certainly have enhanced permeability and focus groundwater flow

along their extents, but this is rarely maintained over miles of extent, which is the scale being considered here of hydrographic basins and their relation to the LWRFS.

- CSAMT geophysics run perpendicular to the axis of KSV and known faulting in northern CSV was captured by the geophysics and shows the structure quite clearly to depths of approximately 3,000 feet bls.
- The faulting that occurs in northern CSV (especially the difference between Lines 10 and 11 presented here) explains why the water levels in KMW-1 and CSVM-4 are distinctly higher than those found in the rest of the basin (Figures 3-4 through 3-9).
- These faults significantly impede the flow of groundwater from KSV and northern CSV (where monitor well CSVM-4 is located) into the southern portion of CSV, south of the transect of Line 11 (Figure 4-7).
- Comparison of Line 10 to Line 11 suggests that the structural boundary between southern KSV/northern CSV and the rest of CSV to the south occurs between these two transects (Figure 4-7).
- This extensive faulting provides a basis (along with other, associated hydrogeologic data) for excluding KSV from being included in the LWRFS. This extensive faulting provides an explanation as to why the water levels are different in the KMW-1 and CSVM-4 wells and at CSVM-3 and CSVM-7.

4.5 DISCUSSION OF GEOHPHYSICAL DATA AND HOW IT RELATES TO THE HYDROGEOLOGY AND BASIN WATER LEVEL DATA

The geophysical data combined with the known water level data provide an explanation of groundwater flow from KSV through northern CSV. Figure 4-9 illustrates the interpretation of what we're calling the Northern LWRFS Boundary Fault that has been identified by the new CSAMT geophysical data. The Northern LWRFS Boundary Fault is a very large structure at the end of the Delamar Mountains that provides an explanation of the abrupt end of the Delamar Mountains in this area. Groundwater flowing southwest out of KSV, and southwest out of the Delamar Mountains in the RDCA, would run directly into this large fault system. Since the highly resistive blocks occur in Line 10, interpreted to be the RDCA, and not in Line 11 (Figure 4-7), the Northern LWRFS Boundary Fault is interpreted to be down thrown to the southwest as shown on

Figure 4-9. This means that groundwater flowing out of the Delamar Mountains and KSV would run into lower permeability Tertiary basin fill materials, perhaps interbedded with Tertiary volcanics (as identified in Section 4.3.2). This would cause the water levels to build up on the upthrown side of the fault (to the northeast – Figure 4-9) until there is enough head built up (a few tens of feet) for groundwater to push through into northern CSV.

The geophysical data collected in northern CSV shows that there is approximately 3,000 plus or minus feet of remarkably flat Tertiary Basin fill, that is perhaps interbedded with volcanics, that are lithologically different or much more highly fractured and faulted en-echelon in a band against the Meadow Valley Mountains (see Section 4.4, above). The RDCA from the southern Delamar Mountains and KSV runs directly and unavoidably into these Tertiary basin fill sediments, which directly affects the flow of groundwater in this area as shown by the geophysical data and corroborating water level, groundwater chemistry, and temperature data.

A long-term aquifer test, approximately 25 ½ months, was conducted (Order No. 1169) to look at the effects of groundwater pumping on the MRSA, but there were no effects ascribable to the start and subsequent stop of a major pumping stress in monitor wells KMW-1 or CSVM-4. There are several reasons for this including the significant distance the cone-of-depression would have to extend out from the pumping well for the pumping and recovery effects to be identifiable in the monitor well in southern KSV. This is a distance of over 15 miles from the MX-5 well. It should be noted that the distance from the KPW-1 well to the springs in the MRSA is over 23 miles if measured by line-of-sight. Secondly, there is a very large sequence of carbonate rocks between the location of the Order No. 1169 pumping and KSV and northern CSV and that thick sequence likely has a very large transmissivity, which is indicated by the nearly flat-water level elevation in much of the LWRFS. For hydraulic head changes (drawdown and build-up/recovery) to travel through these thick sequences of carbonate rocks, they would also have to travel through much more restrictive structures such as the en-echelon faulting that was found farther north in the KSW Fault Zone. Finally, groundwater from KSV has to flow through the Northern LWRFS Boundary Fault where the geologic structure changes as demonstrated by the new geophysical data (Figure 4-9).

5.0 OTHER ISSUES OF THE NEVADA STATE ENGINEER'S REQUEST

There are four other matters the NSE requested be addressed in IO #1303 (NSE 2019) in addition to the request for information regarding the geographic boundary. The other four issues are:

- The information obtained from the Order No. 1169 aquifer test and subsequent to the aquifer test and Muddy River headwater spring flow as it related to aquifer recovery since the completion of the aquifer test;
- 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;
- The effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and,
- Any other matter believed to be relevant to the State Engineer's analysis.

Lincoln/Vidler are responding to each issue below although it may not be germane to whether KSV is included in the LWRFS administrative unit.

5.1 ORDER 1169 AQUIFER TEST

As stated in Lincoln/Vidler's correspondence to Jason King, NSE, dated October 10, 2018 (Lincoln/Vidler 2018):

"Lincoln/Vidler have not been involved in any of the Order 1169 studies to date."

There was no indication at the time the Order No. 1169 aquifer test was completed and the NSE called for an analysis of the pumping test data, that KSV would be part of the LWRFS administrative unit. In fact, the NSE made this clear in his Ruling #5712 (NSE 2007) by stating at page 21:

"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 provisions of Order No. 1169."

Because KSV was not included in Order No. 1169, Lincoln/Vidler were not noticed via Order 1169A (NSE 2012) requesting reports on the outcome of the Order No. 1169 aquifer test results (NSE 2002) to participate and provide their input in the Order No. 1169 proceedings. As stated in Lincoln/Vidler's correspondence dated October 10, 2018 (Lincoln/Vidler 2018), and we reiterate in this report:

> "Putting us [Lincoln/Vidler] into this Order now puts us at a great disadvantage as we have not been privy to or participated in any of the meetings, data collection activities, nor have we had the ability to analyze any of the collected data or, as would likely be the case, collect our own data and information relevant to the issue of Order 1169."

5.2 LONG-TERM ANNUAL QUANTITY OF GROUNDWATER PUMPING FROM THE LWRFS

Lincoln/Vidler provides no statement or analysis here as to the long-term annual quantity of groundwater that could be pumped from the LWRFS administrative unit. Lincoln/Vidler do however state that KSV can be part of the solution to the water issues affecting the LWRFS groundwater basins. There is unappropriated water within KSV that can be used as a source of supply for down-gradient groundwater basins with little reasonable likelihood of impacting or affecting the MSRA because of the large distances and complex geologic structures in between.

5.3 IMPACTS AND EFFECTS OF PUMPING FROM ALLUVIAL AND CARBONATE WELLS NEAR THE MRSA

Lincoln/Vidler have previously stated in a letter to the NSE (Bushner 2018) that all of the groundwater pumped from the Order No. 1169 aquifer test can be explained by data provided by SNWA. Figure 5-1 (reproduced from SNWA 2018) is very illustrative of what was stated at the beginning of Lincoln/Vidler's 2018 comment letter. This analysis benefits from considering the reliable data spanning over two decades, not just the duration of the Order No. 1169 Test.

First, SNWA normalized the flows of the Muddy River, where flood flows have been removed from the hydrograph and diversions from the Muddy River have been added back into the hydrograph. The red line on Figure 5-1 shows the calculated Muddy River flow deficit. Groundwater pumping over time is plotted from wells in the alluvium (tan colors) in the MRSA and groundwater pumping from wells in the carbonate rock aquifer (dark blue color) in the MRSA. The light blue bars represent groundwater pumping from carbonate wells in the CSV. What can be concluded from this chart and graphical representation of the Muddy River flow and groundwater pumpage is that the red line plots in between the dark blue (MRSA carbonate rock aquifer pumpage) and the light blue (CSV carbonate rock aquifer pumpage). This indicates that pumpage from the MRSA completely explains the reductions in flows of the Muddy River and associated springs. Groundwater pumpage from CSV (light blue bars) is not needed at all to explain the declines since the 1990s in the flows in the Muddy River.

5.4 ANY OTHER MATTER BELIEVED TO BE RELEVANT TO THE STATE ENGINEER'S ANALYSIS

With a clear understanding of the cause of reduced flows on the Muddy River and its headwater springs, the NSE can proceed directly to define how the LWRFS administrative unit will work and where the focus should be when trying to protect springs that are at issue in the MRSA. First and foremost, the impacts from groundwater pumping on the MRSA are within the MRSA itself, and therefore, the focus should be within the MRSA first. Secondly, CSV should be monitored, however, impacts from pumping in the CSV do not cause the biggest impacts to the springs. Finally, inflows to the MRSA from the Lower Meadow Valley Wash hydrographic area should be monitored and protected. Lincoln/Vidler also addressed this issue in the correspondence to the NSE (Bushner 2018) stating:

> "...as identified by SNWA through the Cave, Dry Lake, and Delamar Valleys hearing and associated reports, identifies 8,000 acre-feet of groundwater inflow from upgradient hydrographic basin Lower Meadow Valley Wash ... If one of the

goals to the LWRFS administrative unit determined by the NSE is to protect the springs in the MRSA then the Lower Meadow Valley Wash hydrographic basin and its groundwater inflow should not only be included as part of the LWRFS administrative unit but should also be the focus and the priority of the NSE."

6.0 KEY FINDINGS AND CONCLUSIONS

The following are the key findings and conclusions from this existing data and geophysical data documentation report.

6.1 KEY FINDINGS

- KSV is a perennial yield groundwater basin under the Laws of the State of Nevada.
- KSV is too distant and isolated due to geologic structures for pumping the perennial yield there to likely cause impairment of Muddy River Springs, Blue Point, or Rogers Springs.
- The effects of pumping from KSV would not be felt for over 100 years outside of KSV.
- The NSE did not include KSV in the Order No. 1169 aquifer test.
- Groundwater elevation data show distinctive differences in heads between KSV/northern CSV and the southern portion of CSV, which are confirmed by the geologic structures that occur in KSV and northern CSV.
- There is no discernable trend/pattern in water levels overtime between production well KPW-1 and pumping trends.
- There is no correspondence between the water level trends in wells in KSV/northern CSV, and wells located in southern CSV.
- Lincoln/Vidler have been collecting data for nearly over a decade to better quantify the volume of precipitation that occurs in KSV and that becomes local in-basin recharge.
- There was an over-arching precipitation event that occurred in southern Nevada in 2005 that had a major effect on water levels in wells throughout the area.
- The trend in water levels in both KMW-1 and CSVM-4 indicate water levels are still being affected by the 2005 precipitation event.
- The key finding of the geochemistry data is that "A comparison of these chemical and isotopic relationships with Big Muddy Springs and particularly Rogers Spring and Blue Point Spring indicates that the groundwater from KPW-1, assumed representative of the KSV groundwater, is too strongly attenuated with CSV to be identifiable in these springs." (Appendix C: CH2M Hill 2006b, Pages 12 and 13).

- Groundwater from KPW-1 and CSVM-4 are related and on similar groundwater flow paths based on the TDSS values and other geochemical data. This supports the existence of a significant fault in northern CSV corroborating the geophysical data.
- KPW-1 groundwater has one of the oldest apparent ages of 29,000 years. Assuming that the apparent ages are somewhat true, and in this case may be, it is not likely that KSV groundwater represented by KPW-1 with this age could contribute to the flow at Big Muddy Springs.
- Based on the groundwater temperature data, none of the other groundwater temperature data are close to the 136°F of the groundwater found at KPW-1, suggesting deep circulation of groundwater in KSV.
- Groundwater temperature data are consistent with the geophysical data and represent differing groundwater flow paths occurring in southern KSV and the northern most portion of CSV compared to groundwater flow paths elsewhere in CSV.

6.2 CONCLUSIONS

It is clear that a Management Order and presumably a conjunctive use element for that Management Order and the Order No. 1169 basins is appropriate. However, there is no evidence-based reason to impose that plan on basins outside of the Order No. 1169 geographic area. In fact, and on the contrary, there are science-based reasons to exclude KSV/northern CSV from the LWRFS as identified in this report.

While we appreciate the gravity of the issues before the NSE in managing the water resources of the State, frankly the record and science is clear relative to KSV: there is no likely impact to the Order No. 1169 basins.

7.0 RECOMMENDATIONS

Lincoln/Vidler submit the following recommendations as requested by IO #1303.

1. Continue to exclude KSV from the LWRFS administrative unit.

The scientific data supports excluding KSV from the LWRFS administrative unit. The most salient point is that the carbonate wells KPW-1 in southern KSV and CSVM-4 in northern CSV have different hydraulic heads than other heads further south in the LWRFS. This was explained by the new geophysical data that was collected from northern CSV which shows that there are several structural controls, including faults, that occur in the northern CSV and would represent impediments for groundwater flowing from KSV/northern CSV into the LWRFS groundwater basins.

There is no indication from the water level data of either KMW-1 or CSVM-4 that there were any noticeable effects from the Order No. 1169 aquifer test. What was observed and was significant was the dissipating effects of an over-arching precipitation event in 2005 that affected water levels in these wells for years.

2. Recommended boundary revisions.

Lincoln/Vidler recommend that in addition to KSV remaining excluded from the LWRFS administrative unit, the northern portion of CSV should also be excluded from the LWRFS administrative unit based upon the geophysical data and corroborated by groundwater level data, geochemistry data, and groundwater temperature data.

3. Additional recommendations:

Lincoln/Vidler recommend the NSE reduce or eliminate pumping adjacent to or near the springs in the MRSA, and also define and protect the up-gradient watershed of LMVW. The data provided by SNWA (2018) demonstrates that the depletions on the spring flows in the MRSA are completely explained by groundwater pumping from wells in the alluvial and carbonate rock aquifers within the MRSA hydrographic basin. Secondly, but much less impactful, is groundwater pumping from CSV. Thirdly, there is approximately 8,000 acre-feet of groundwater inflow from the LMVW. If one of the goals of the LWRFS administrative unit determined by the NSE is to protect the springs in the MRSA, then the LMVW hydrographic basin, where there is a dearth of data, and its groundwater inflow should not only be included as part of the LWRFS administrative unit but should also become a focus and the priority of the NSE.

Lincoln/Vidler concur the NSE has reason to view many of the basins in the LWRFS as hydraulically connected based on the remarkably consistent water levels among wells completed in the RDCA. Lincoln/Vidler identified this effect in 2006 during the initial KSV hearing before the NSE for applications for new groundwater appropriations in this basin. Although we concur with the effective administration of these basins collectively based on the hydrogeology, Lincoln/Vidler disagree that the effects are all the same across the entire LWRFS administrative unit.

We must reiterate what we stated previously in Lincoln/Vidler's letter to the NSE dated October 10, 2018:

> "While we appreciate the gravity to the issues before the State Engineer in managing the water resources of the State, frankly the record and the science is pretty clear relative to Kane Springs Valley and its lack of impact to the 1169 basins. While there are no easy tasks ahead for water solutions in much of Nevada, perhaps the focus should rest on viewing many of the existing water resources upgradient as pieces of the puzzle for solutions by willing participants not as "taking away" flow that some would improperly characterize as gratuitously "*belonging*" to the downgradient basin even if it is within the perennial yield of the upgradient basin. Our basin and range geography still allows for the appropriation of perennial yield within those upgradient basins."

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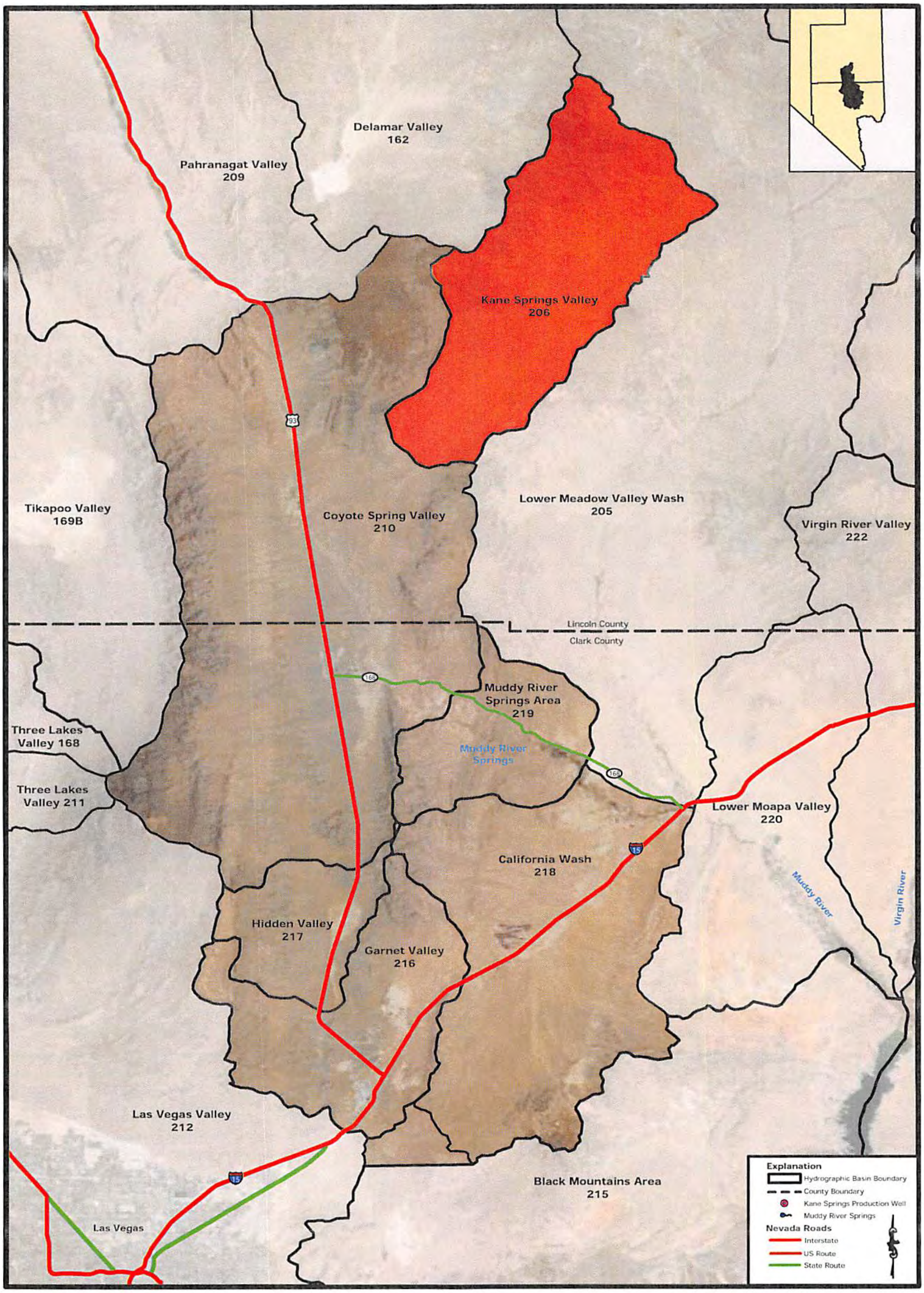
Zonge, Kenneth L., 1992. "Broad Band Electromagnetic Systems," *in* Practical Geophysics II for the Exploration Geologist, ed. Richard Van Blaircom, Northwest Mining Association, pages 459-523.

FIGURES

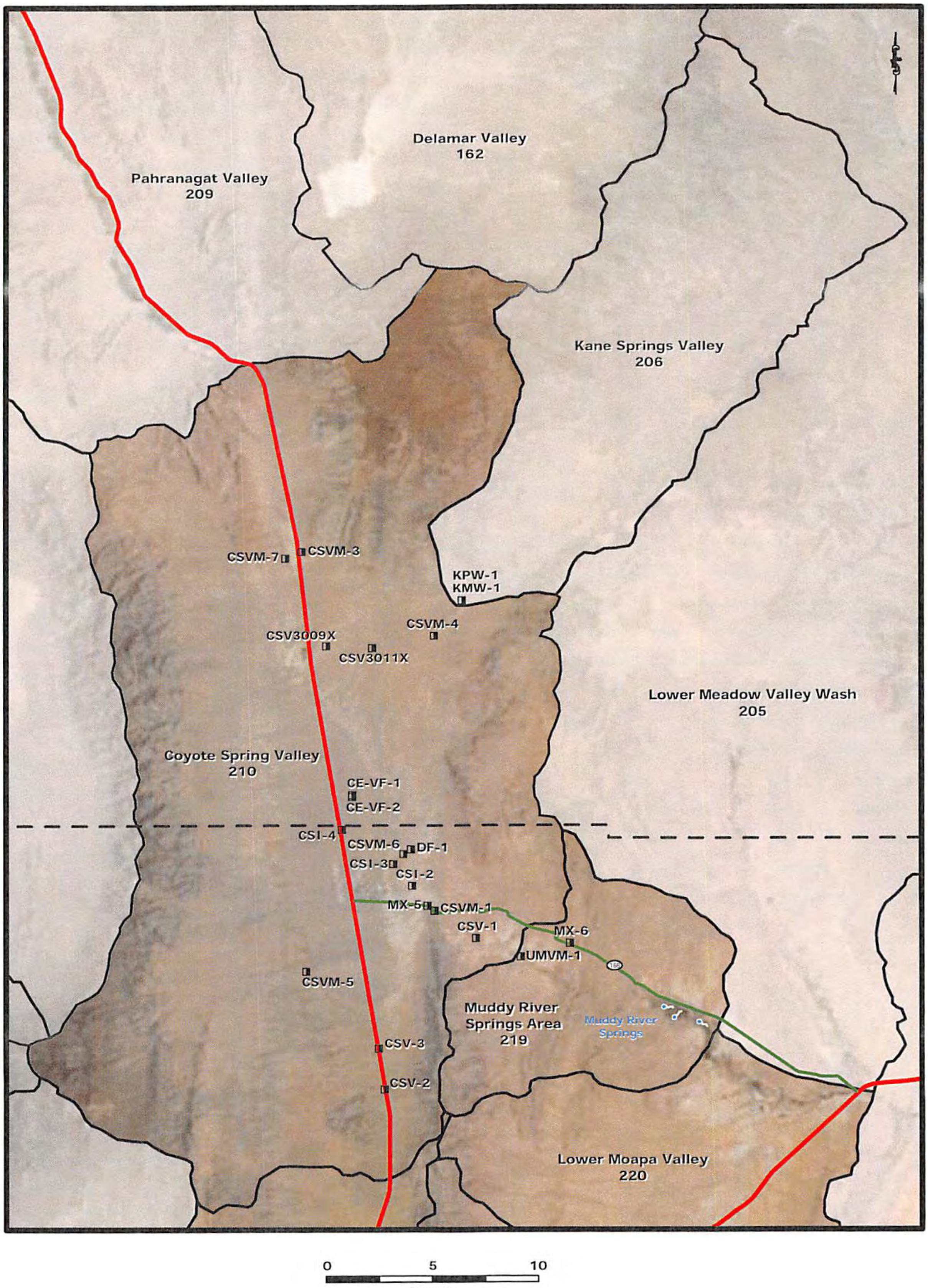
FIGURE 2-1. LOCATION MAP OF THE LOWER WHITE RIVER FLOW SYSTEM AND ADJACENT GROUNDWATER BASINS

Coyote Spring Valley, Muddy River Springs Area, Hidden Valley, Garnet Valley, California Wash, and a portion of Black Mountains Area



SE ROA 36242

FIGURE 3-1. WELL LOCATION MAP



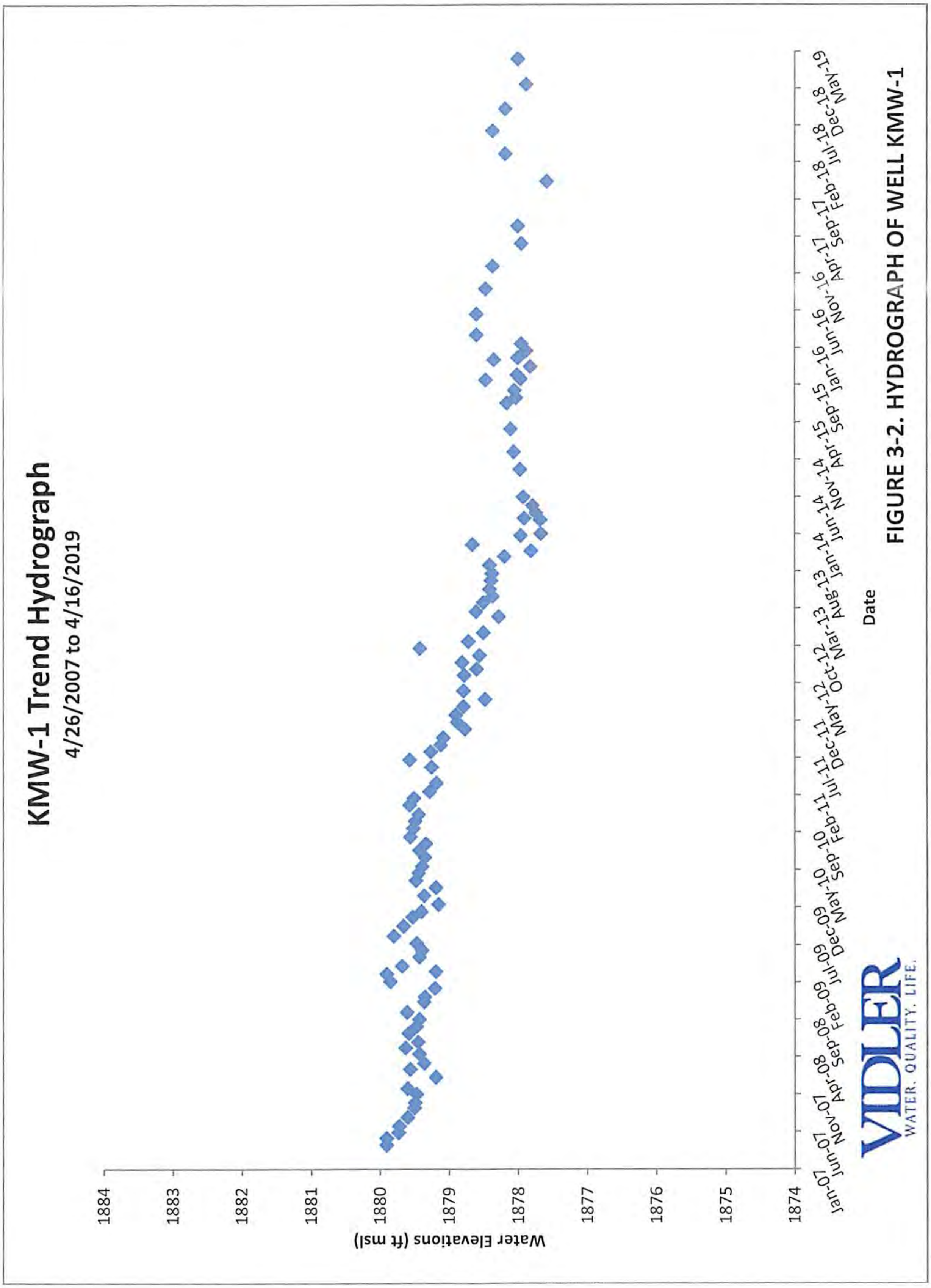


FIGURE 3-2. HYDROGRAPH OF WELL KMW-1

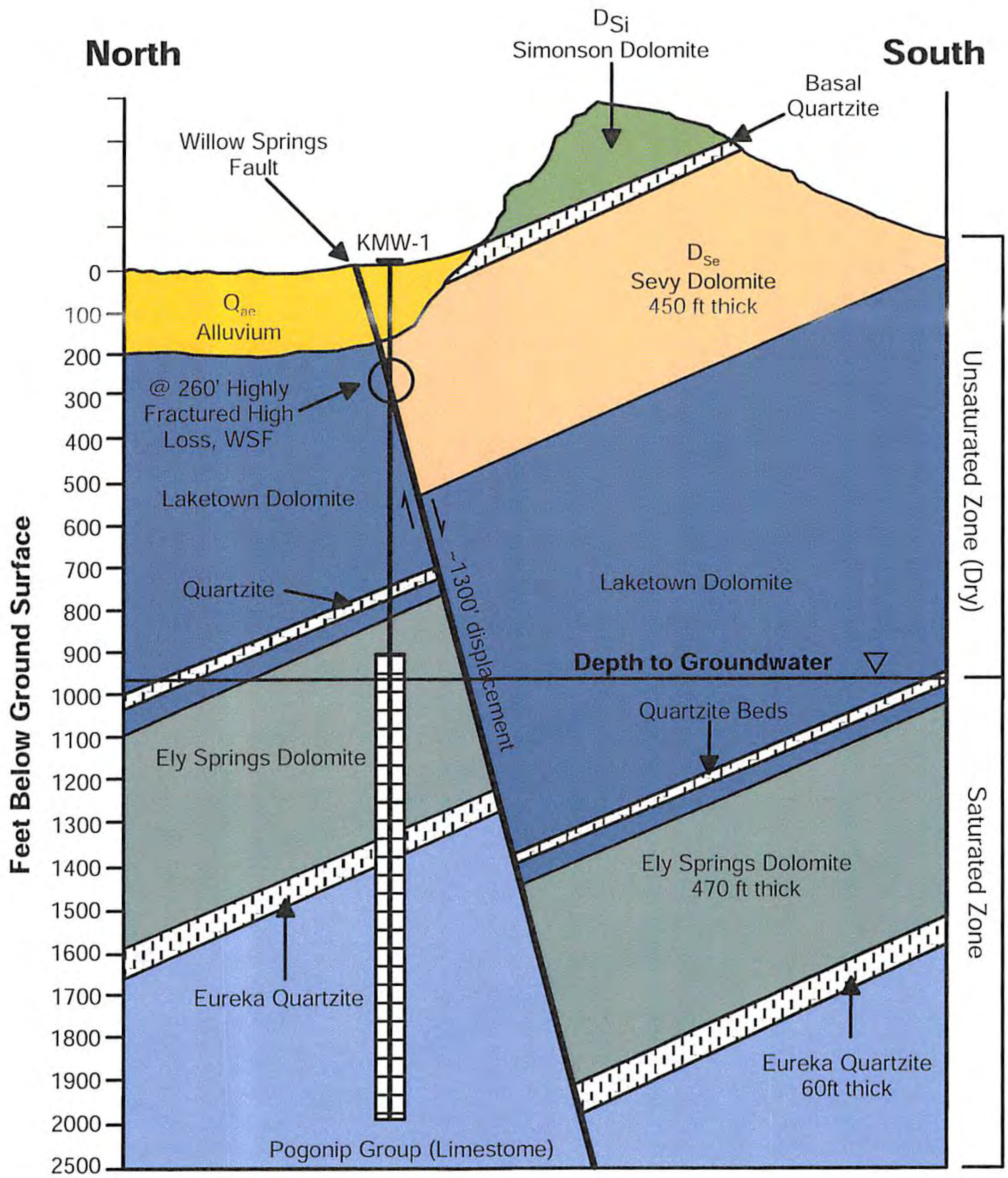
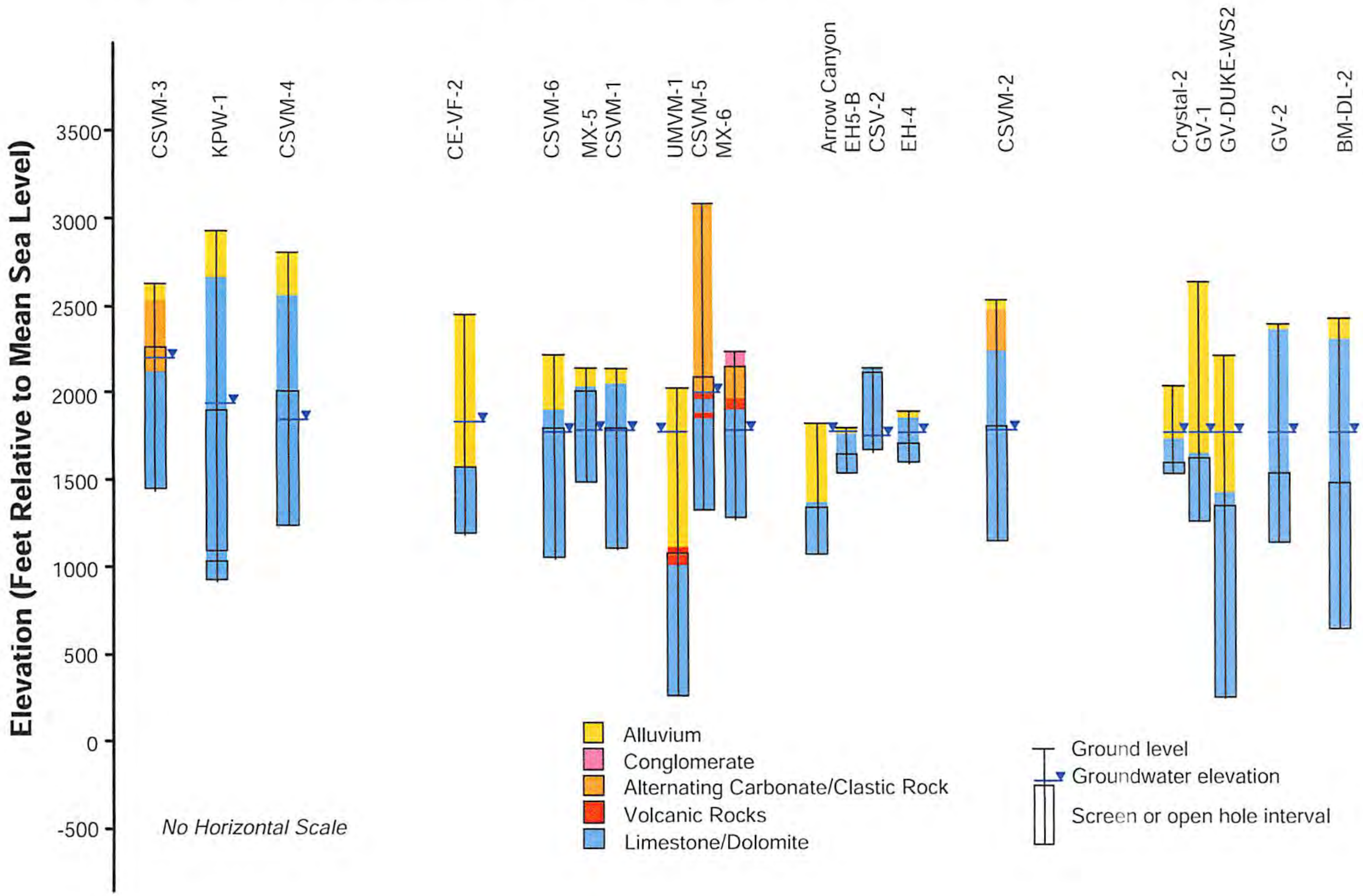


FIGURE 3-3 LOCALIZED CROSS SECTION THROUGH KMW-1, KANE SPRINGS VALLEY

Source: URS: Unpublished field notes taken during Drilling KMW-1 by Feast Geosciences

FIGURE 3-4. VERTICAL PROFILE THROUGH SELECTED CARBONATE WELLS IN STUDY AREA



Source : CH_2MHill (2006)

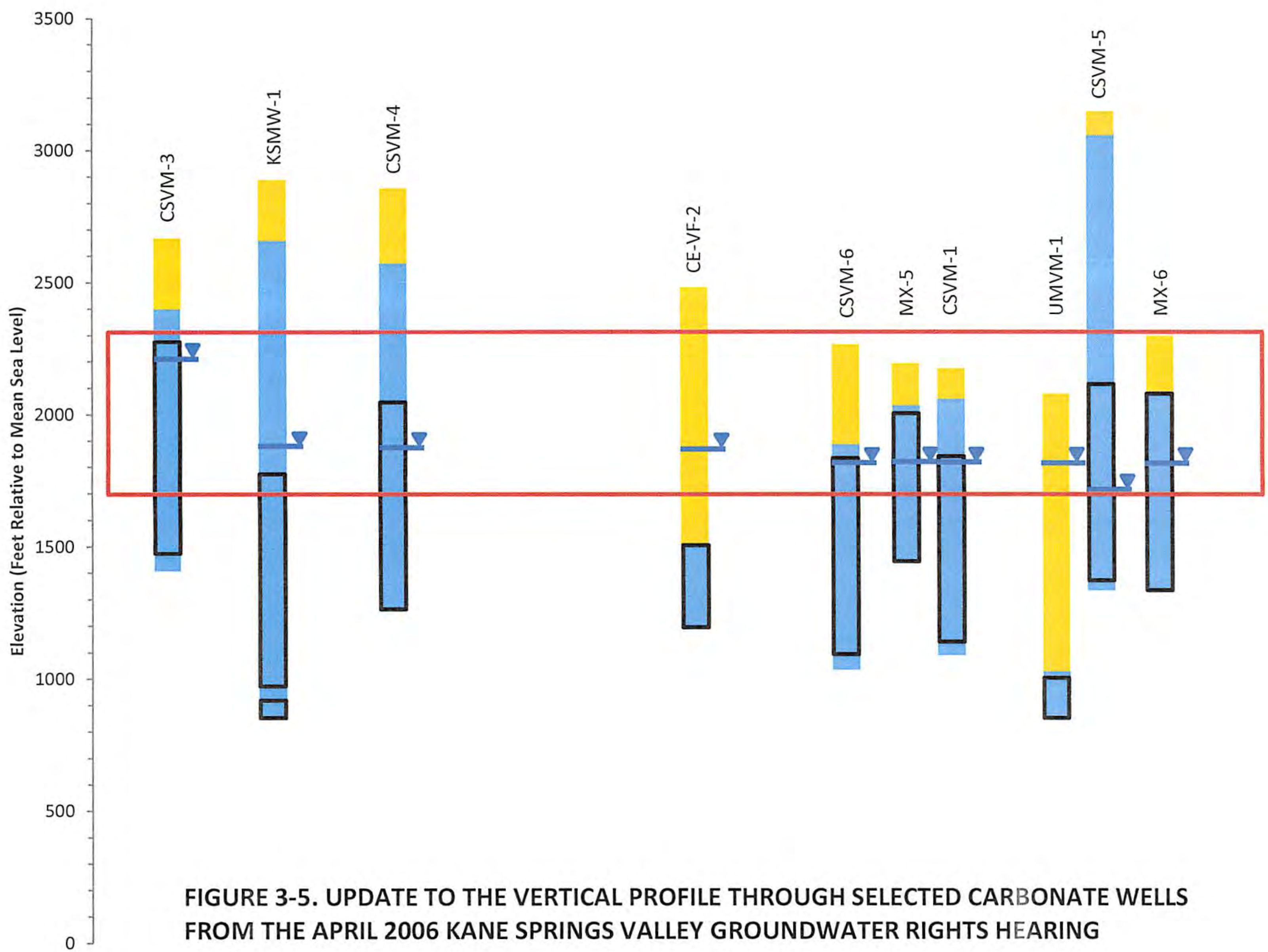


FIGURE 3-5. UPDATE TO THE VERTICAL PROFILE THROUGH SELECTED CARBONATE WELLS FROM THE APRIL 2006 KANE SPRINGS VALLEY GROUNDWATER RIGHTS HEARING

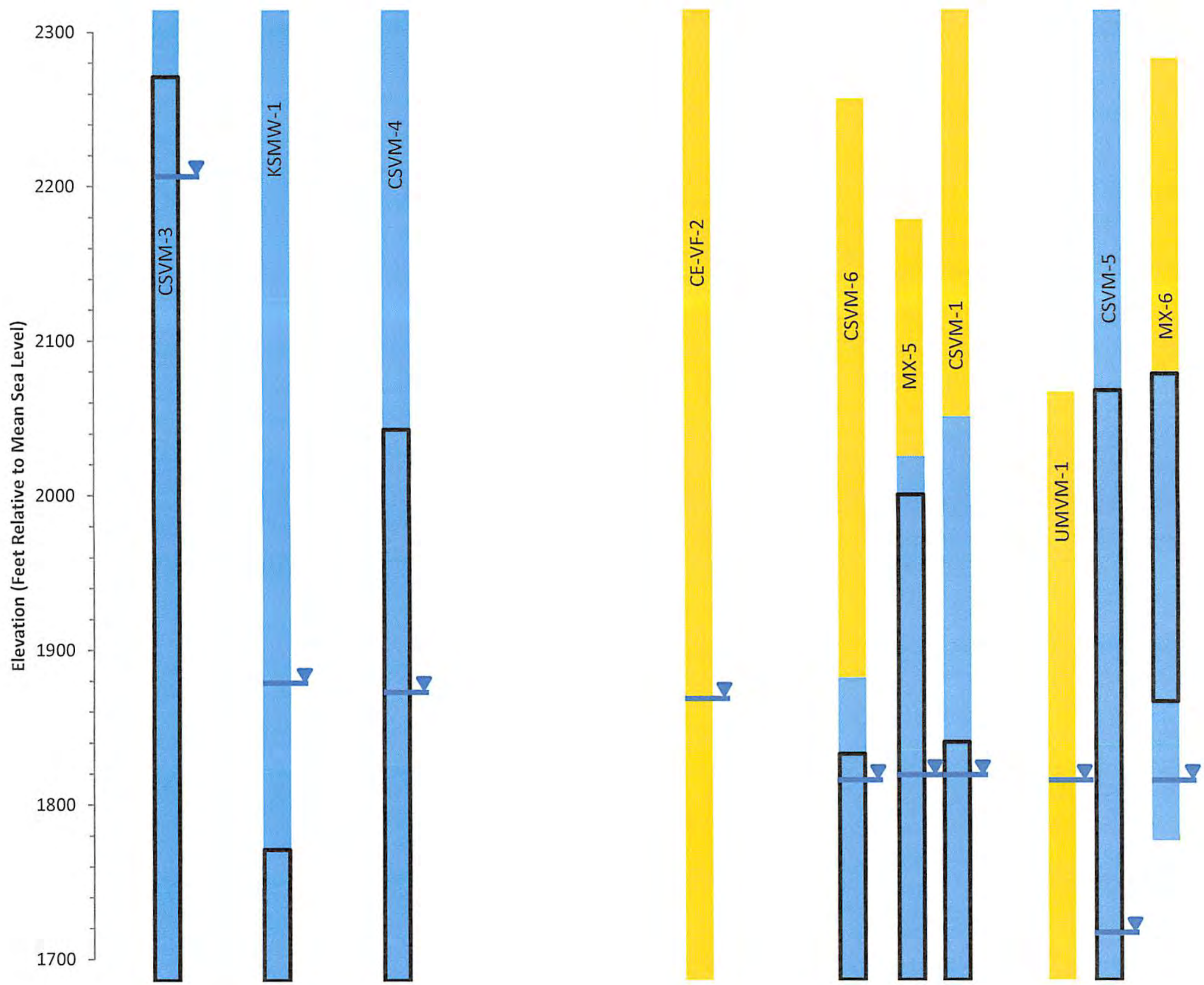


FIGURE 3-6. FOCUSED GROUNDWATER ELEVATIONS IN SELECTED CARBONATE WELLS IN KANE SPRINGS VALLEY AND NORTHERN COYOTE SPRING VALLEY

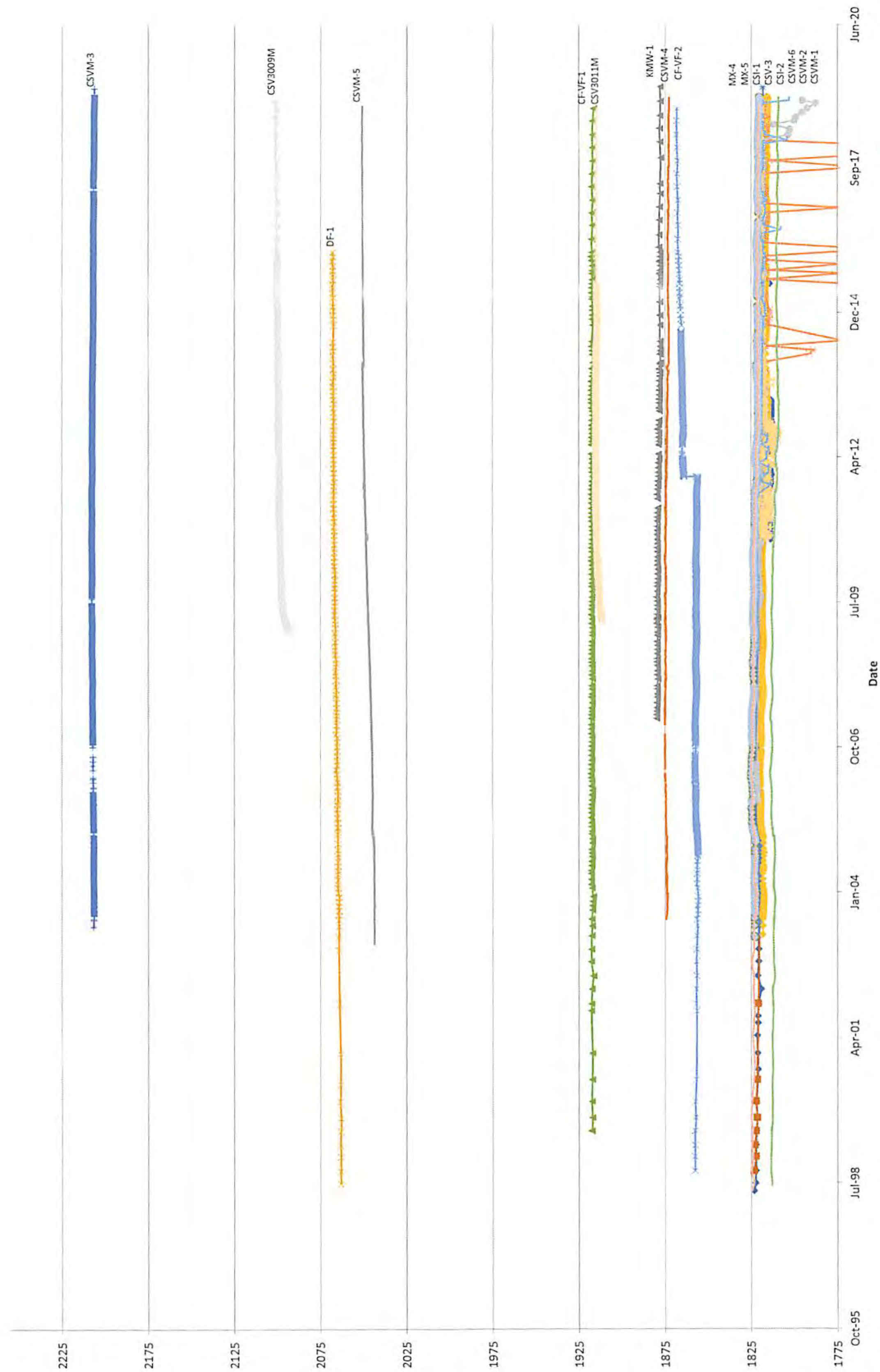


FIGURE 3-7. COMBINATION PLOT OF HYDROGRAPHS FOR WELLS THROUGHOUT THE NORTHERN PORTION OF THE LWRFS AND INCLUDING KANE SPRINGS VALLEY

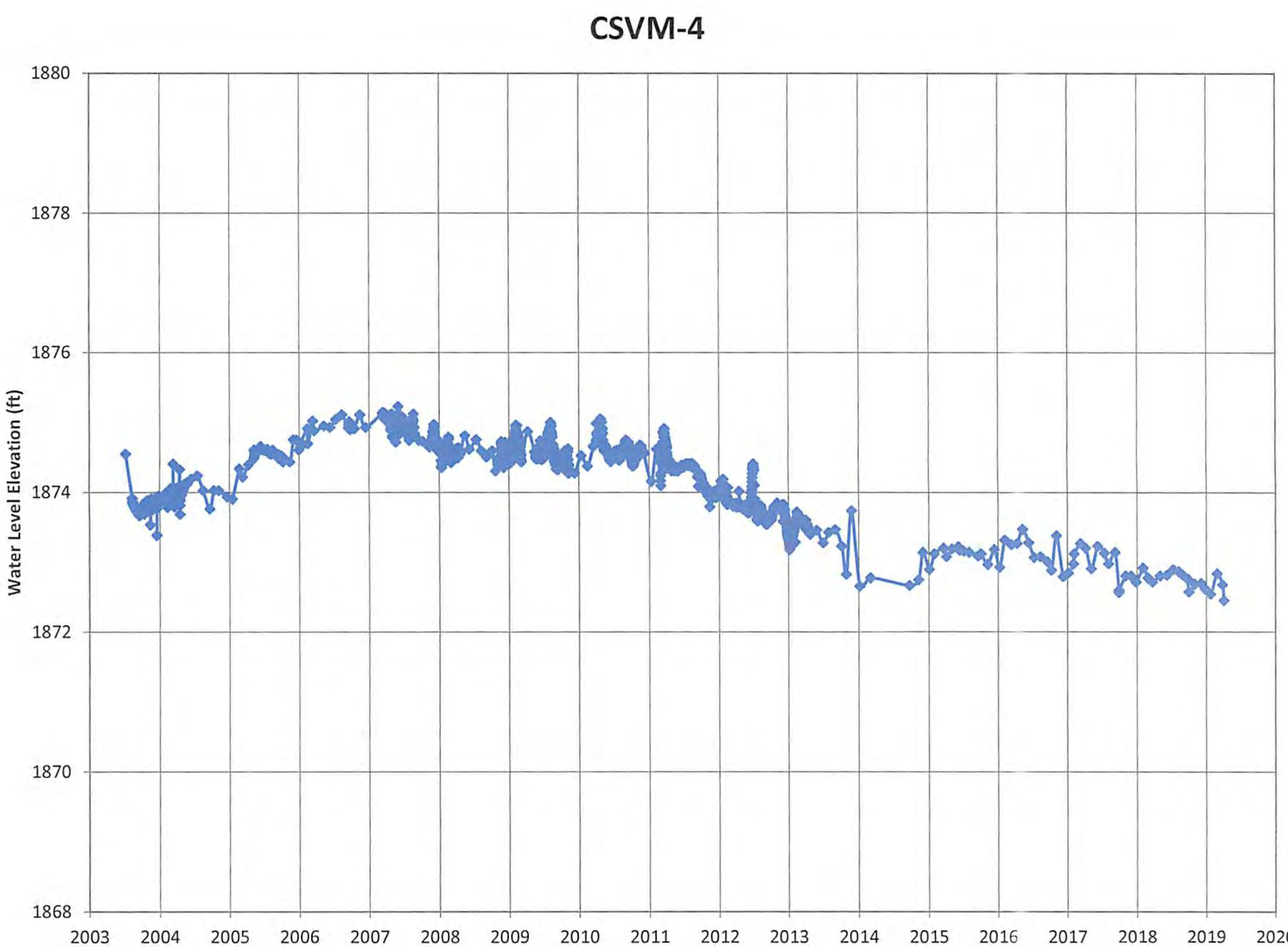


FIGURE 3-8. HYDROGRAPH OF WELL CSVM-4

FIGURE 3-9. COMBINED HYDROGRAPHS OF WELLS KMW-1 AND CSVM-4

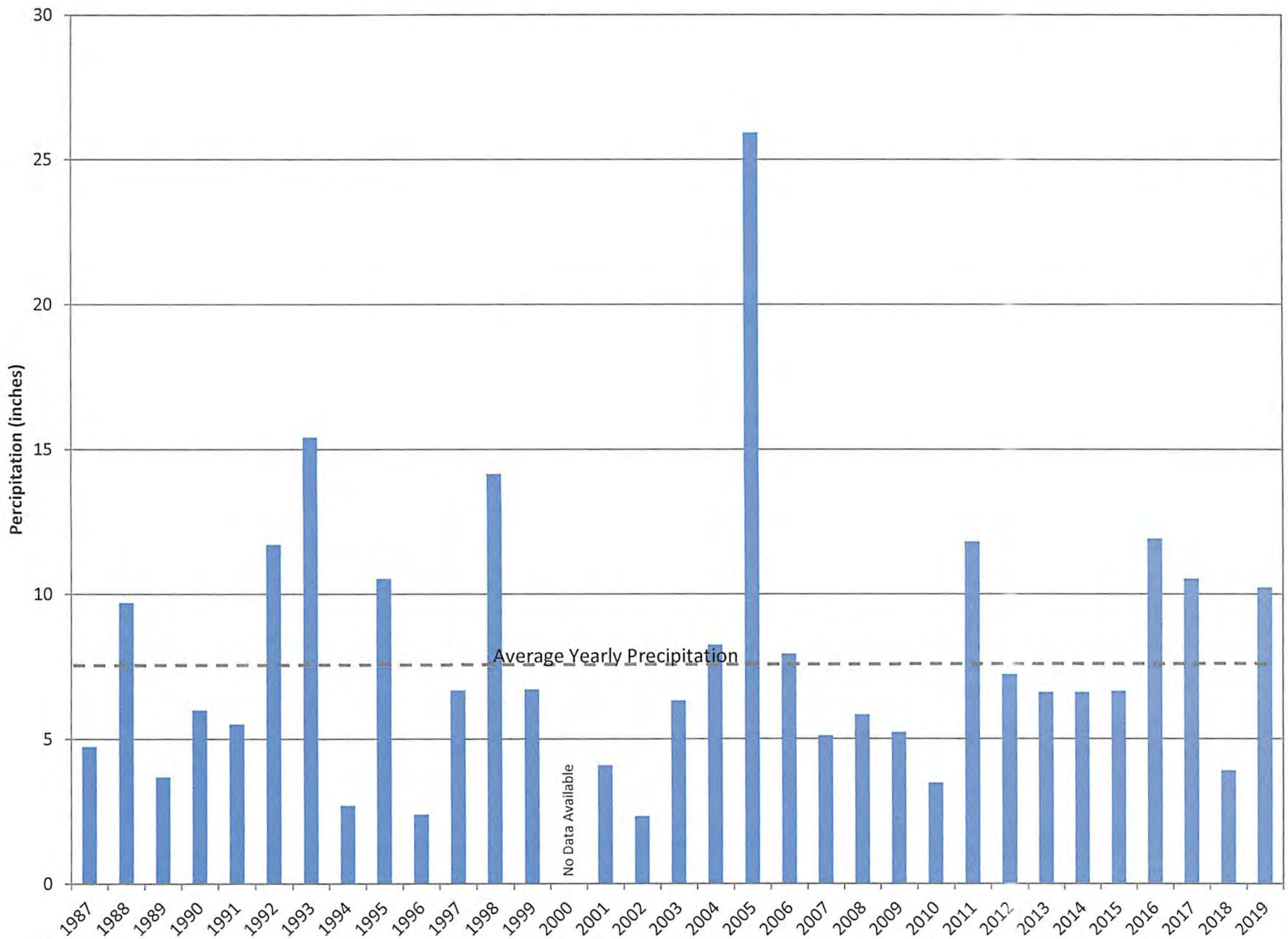
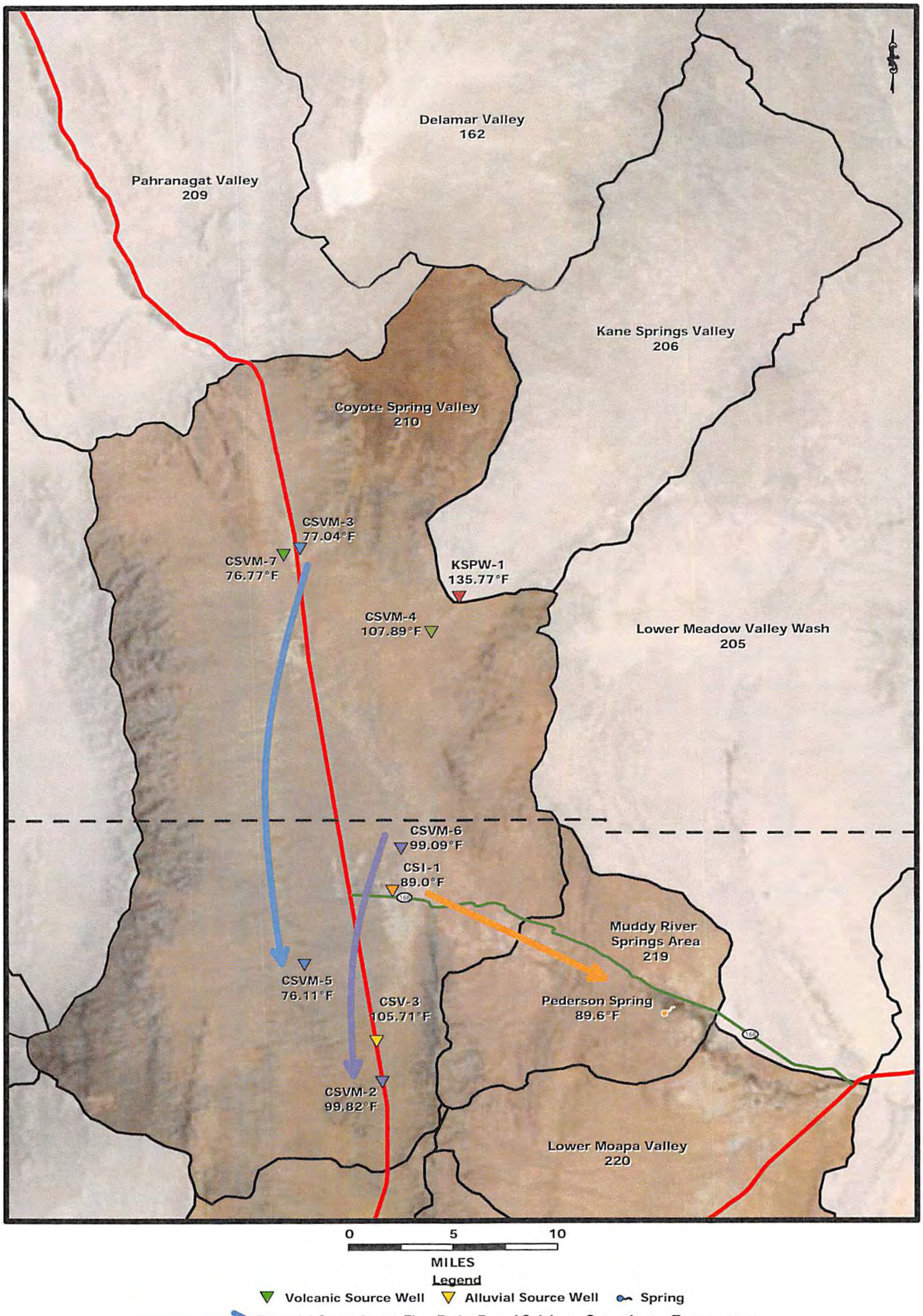


FIGURE 3-10. PRECITITATION DATA FROM THE KANE SPRINGS VALLEY REMOTE AUTOMATED WEATHER STATION

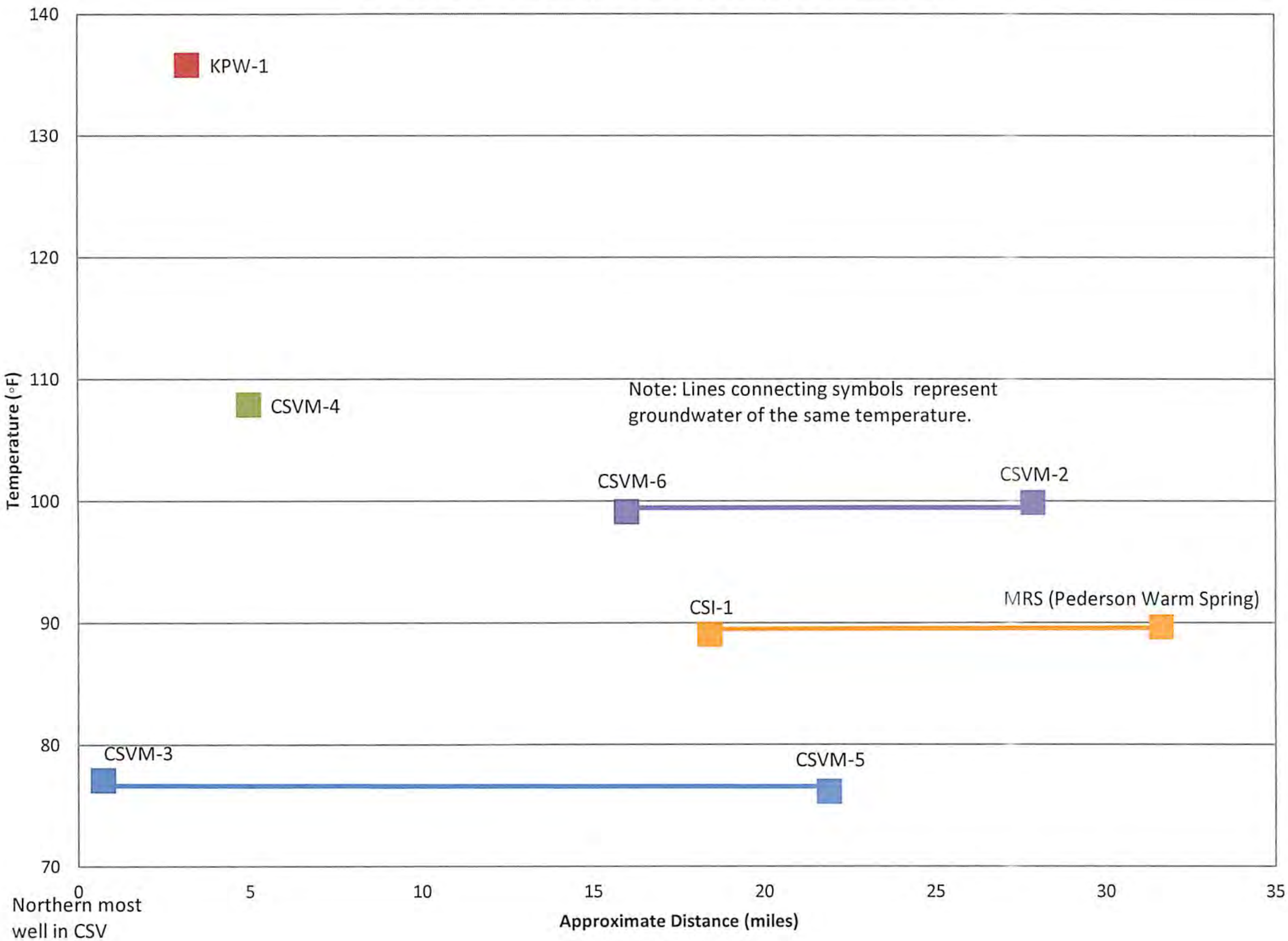
FIGURE 3-11

Map of Temperature Data from Selected Groundwater Wells and Springs



SE ROA 36253

FIGURE 3-12. GROUNDWATER TEMPERATURE DATA FROM SELECTED CARBONATE WELL IN KANE SPRINGS VALLEY AND NORTHERN LWRFS



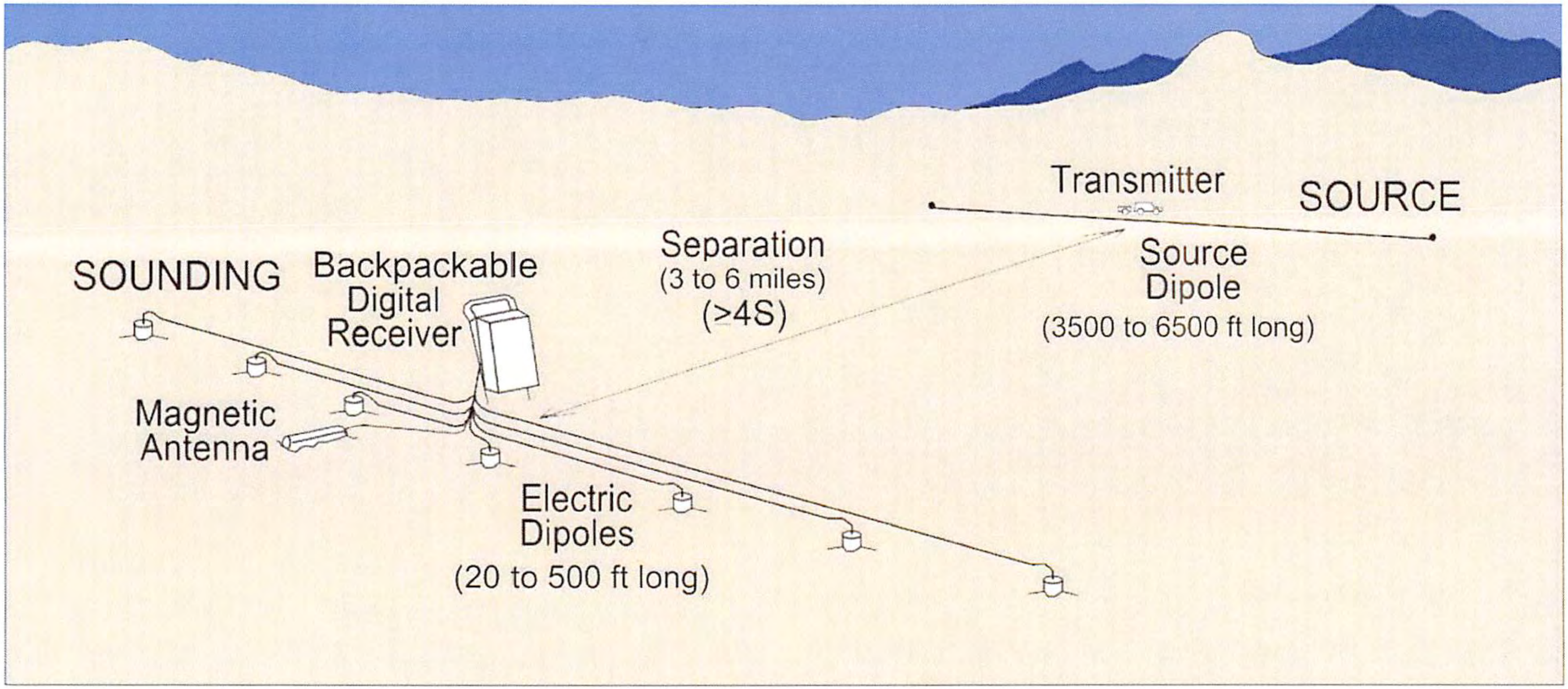


FIGURE 4-1: CSAMT FIELD SURVEY SET-UP SCHEMATIC (NOT-TO-SCALE)
SOURCE: ZONGE INTERNATIONAL MANUALS.

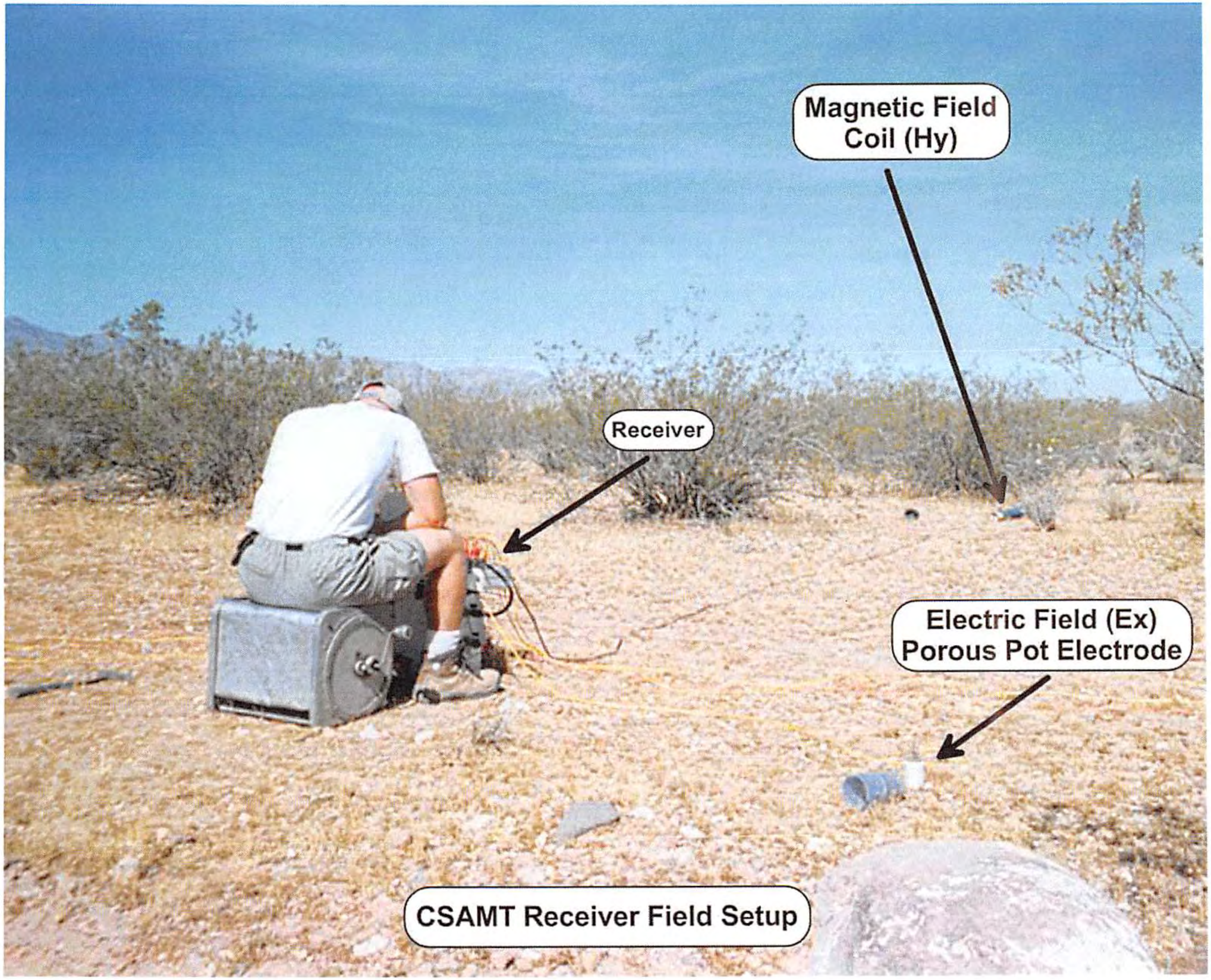


FIGURE 4-2: CSAMT RECEIVER SET-UP IN THE TULE DESERT, LINCOLN COUNTY, NEVADA.
SOURCE: ZONGE INTERNATIONAL MANUALS.

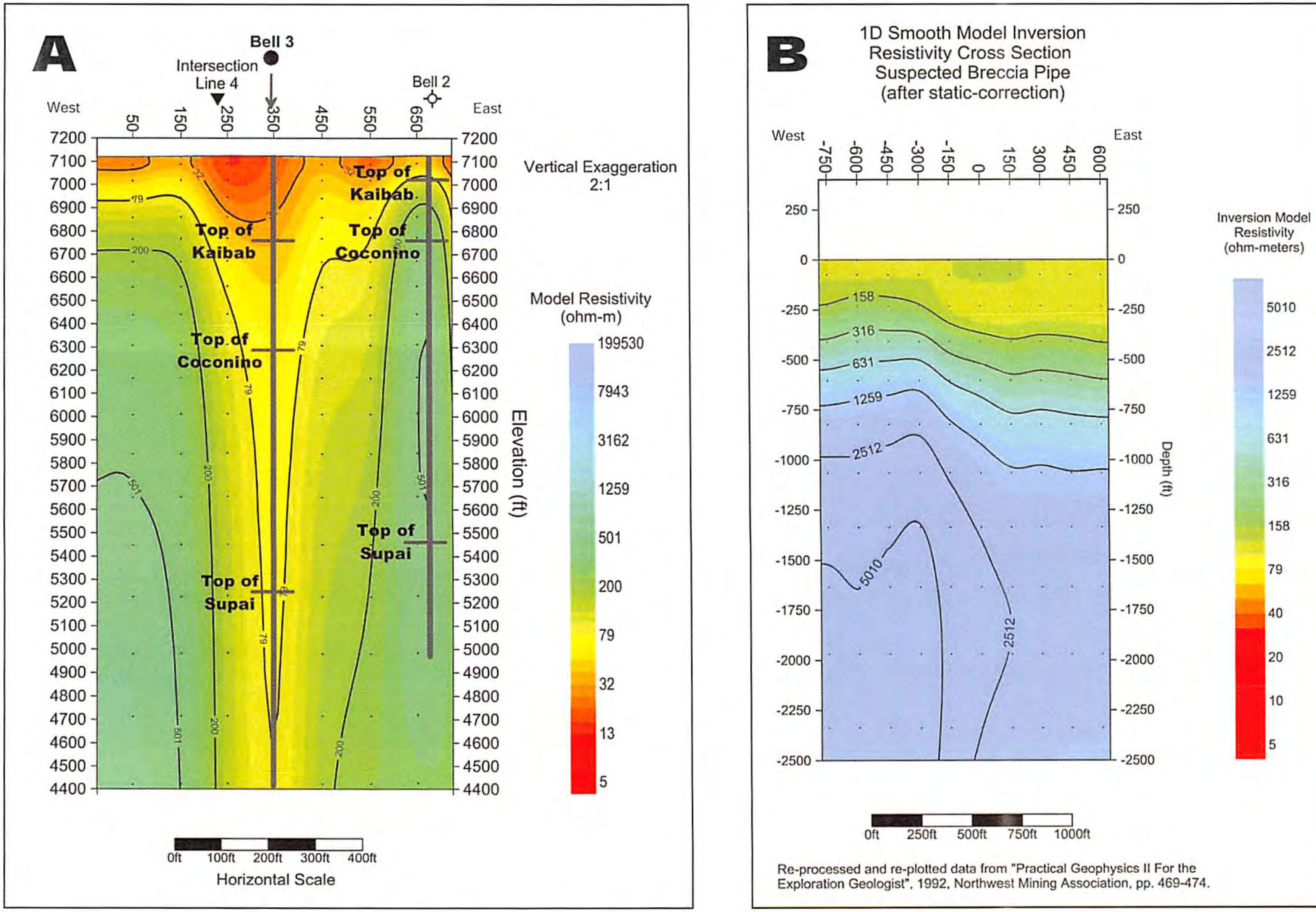


FIGURE 4-3: EXAMPLE OF FAULTS IN TWO CSAMT DATA SETS AS A) A NARROW LOW RESISTIVE ZONE AT STATION 350, VERSUS B) AS AN OFFSET IN LAYERING AT STATION -150.

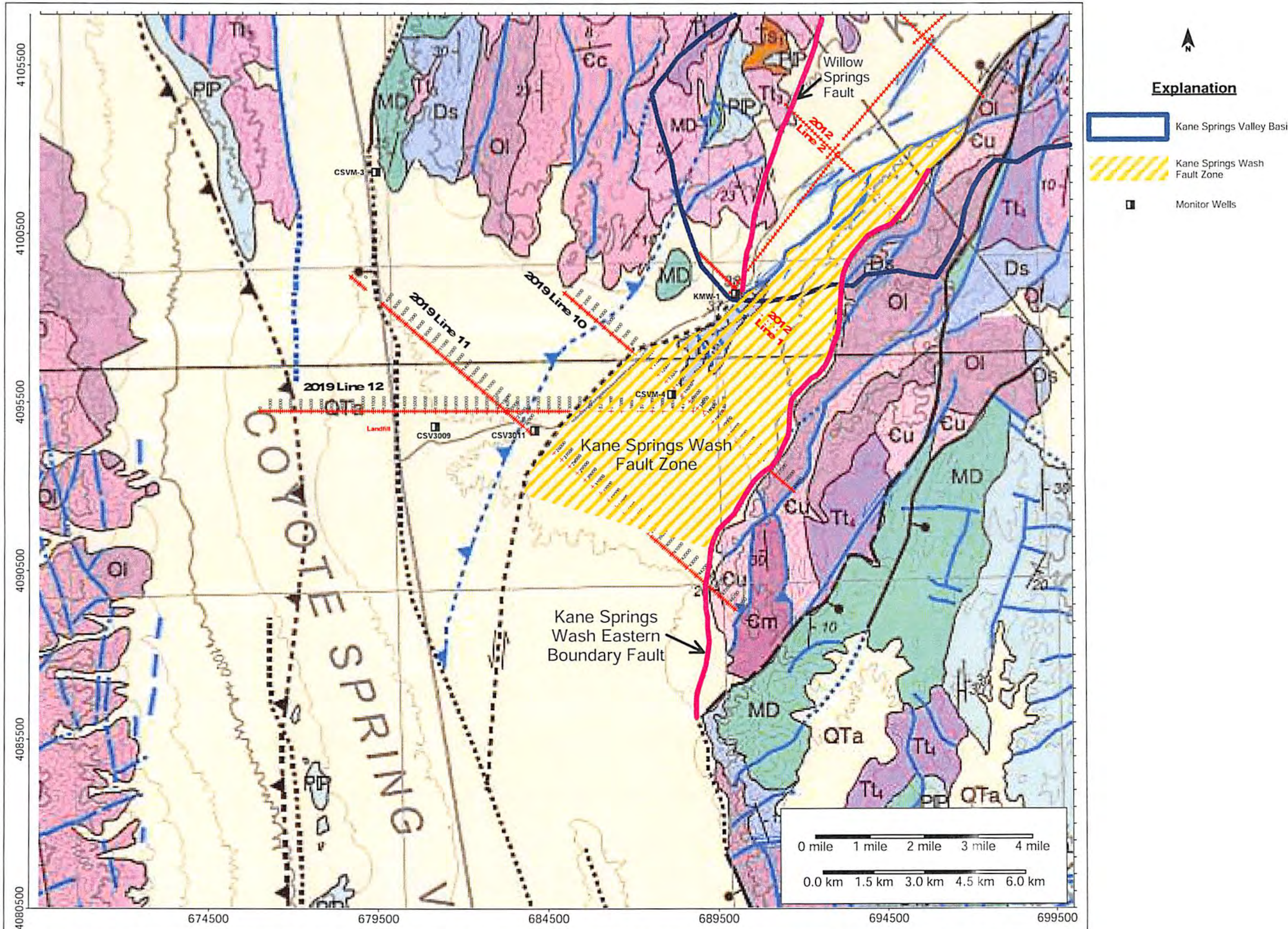


FIGURE 4-4: GEOLOGIC MAP AND LOCATION MAP OF CSAMT TRANSECT THROUGH SOUTHERN KANE SPRINGS VALLEY AND NORTHERN COYOTE SPRING VALLEY.

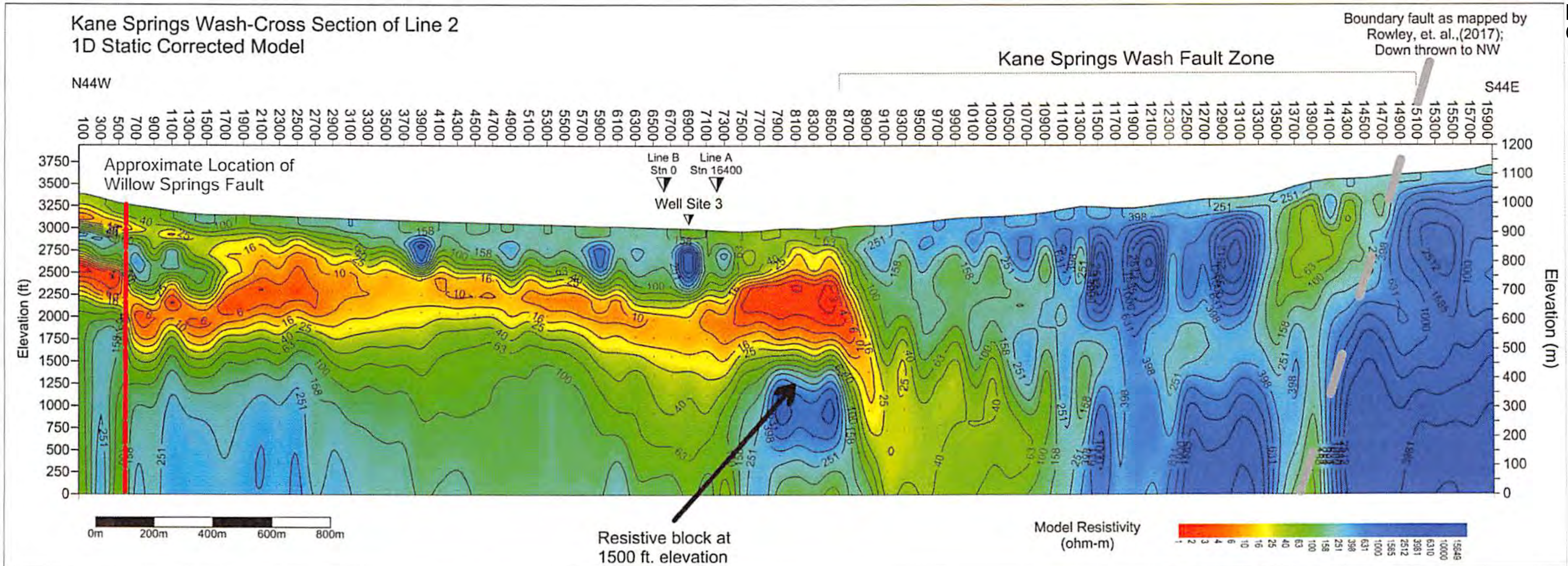


FIGURE 4-5: CSAMT TRANSECT OF LINE 2 THROUGH SOUTHERN KANE SPRINGS VALLEY

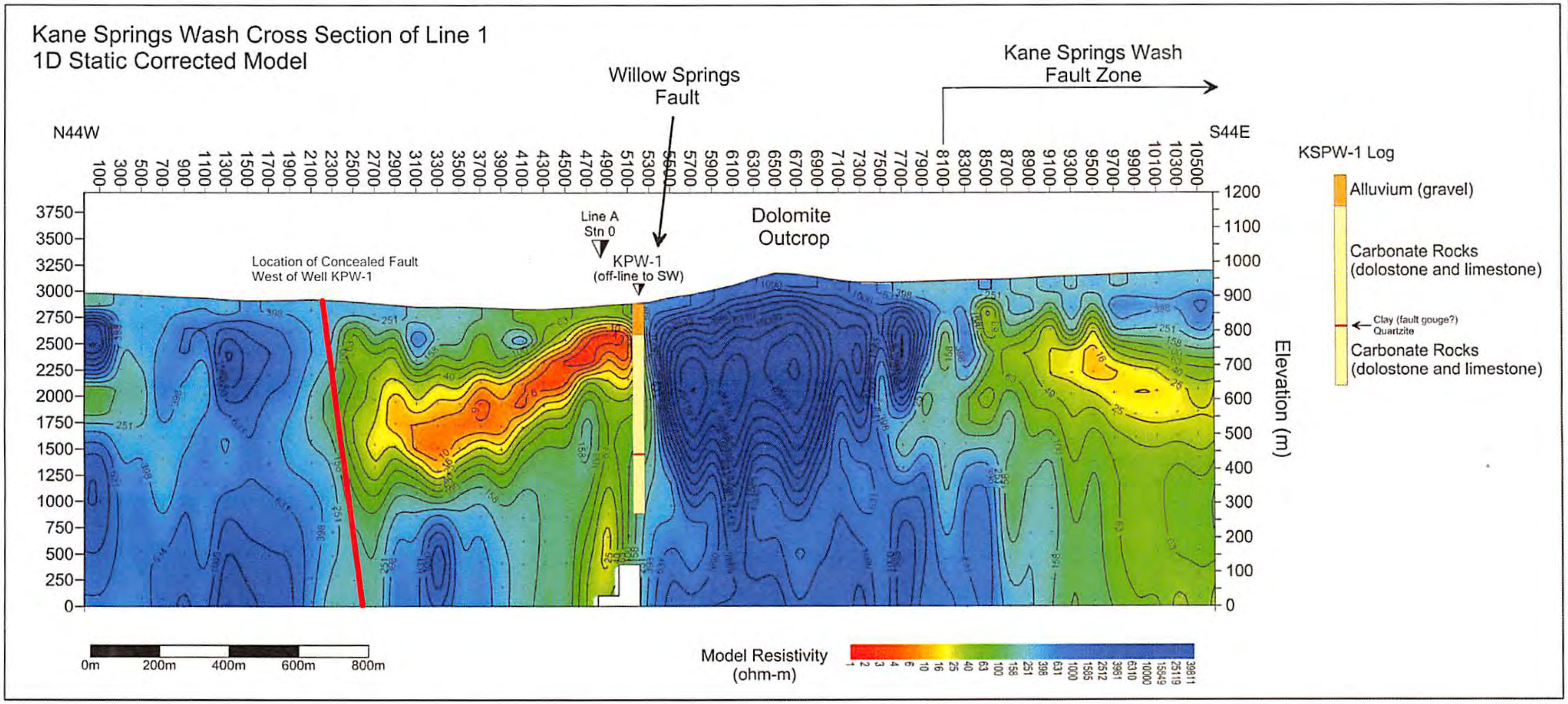


Figure 4-6: CSAMT TRANSECT OF LINE 1 THROUGH WELL KPW-1 OF SOUTHERN KANE SPRINGS VALLEY

SE ROA 36260

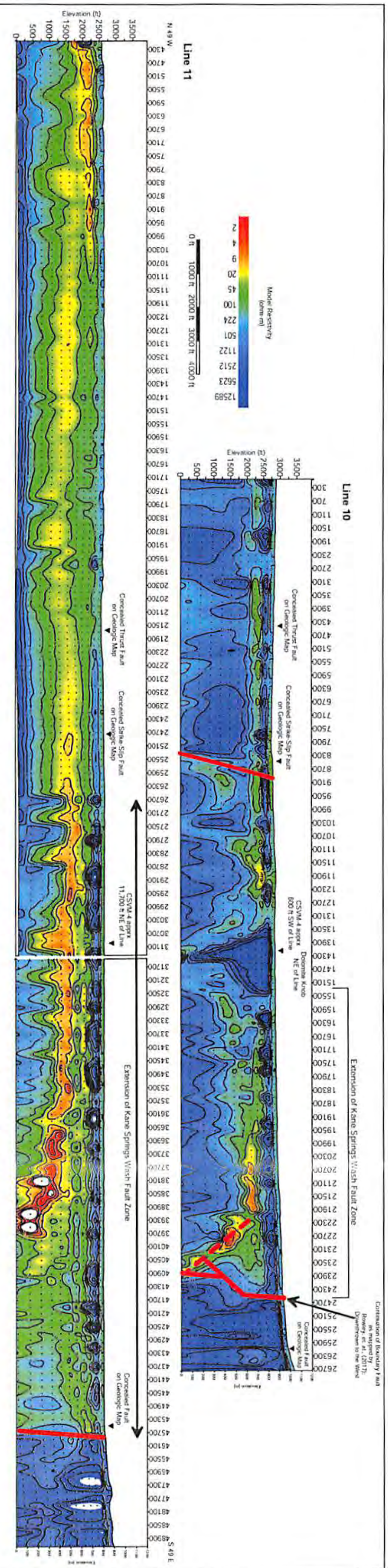


FIGURE 4-7: CSAMT TRANSECT FOR LINES 10 AND 11 THROUGH NORTHERN COYOTE SPRING VALLEY

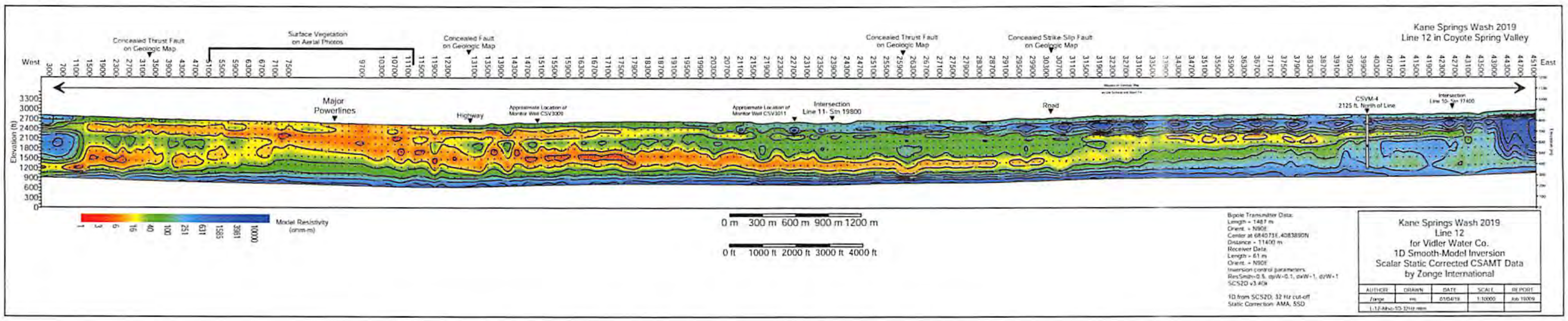


FIGURE 4-8: EAST-WEST CSAMT TRANSECT OF LINE 12 THROUGH NORTHERN COYOTE SPRING VALLEY

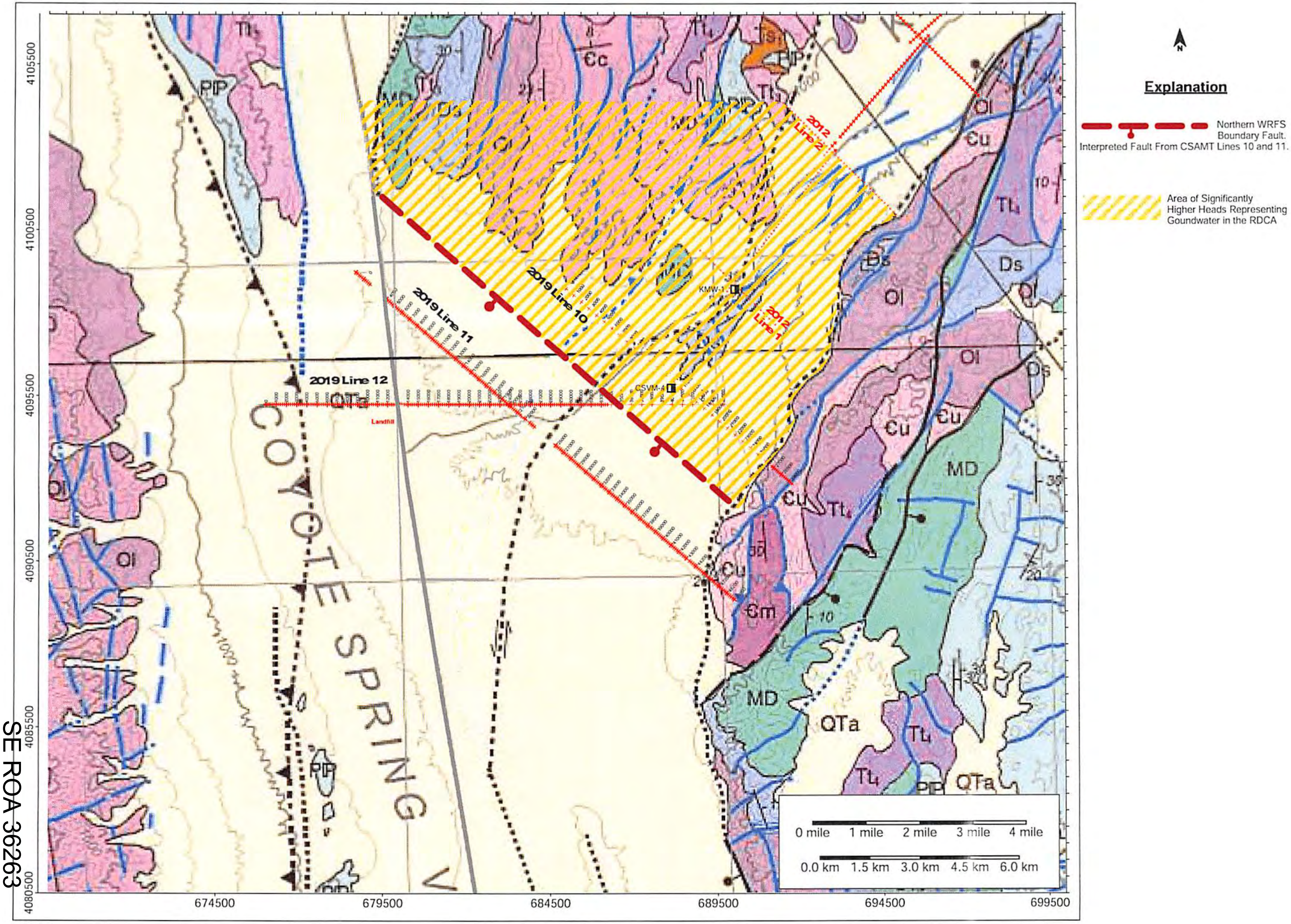
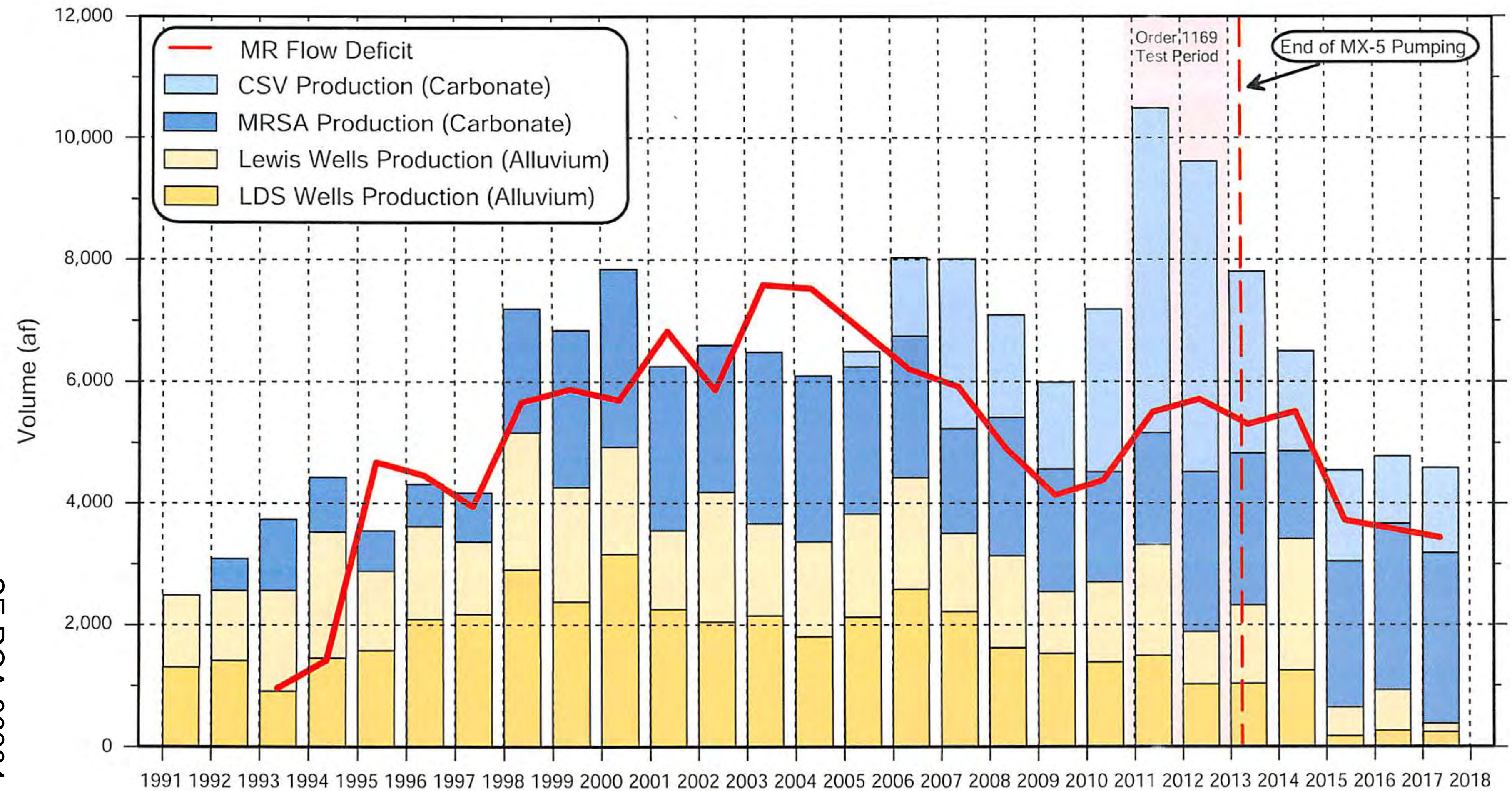
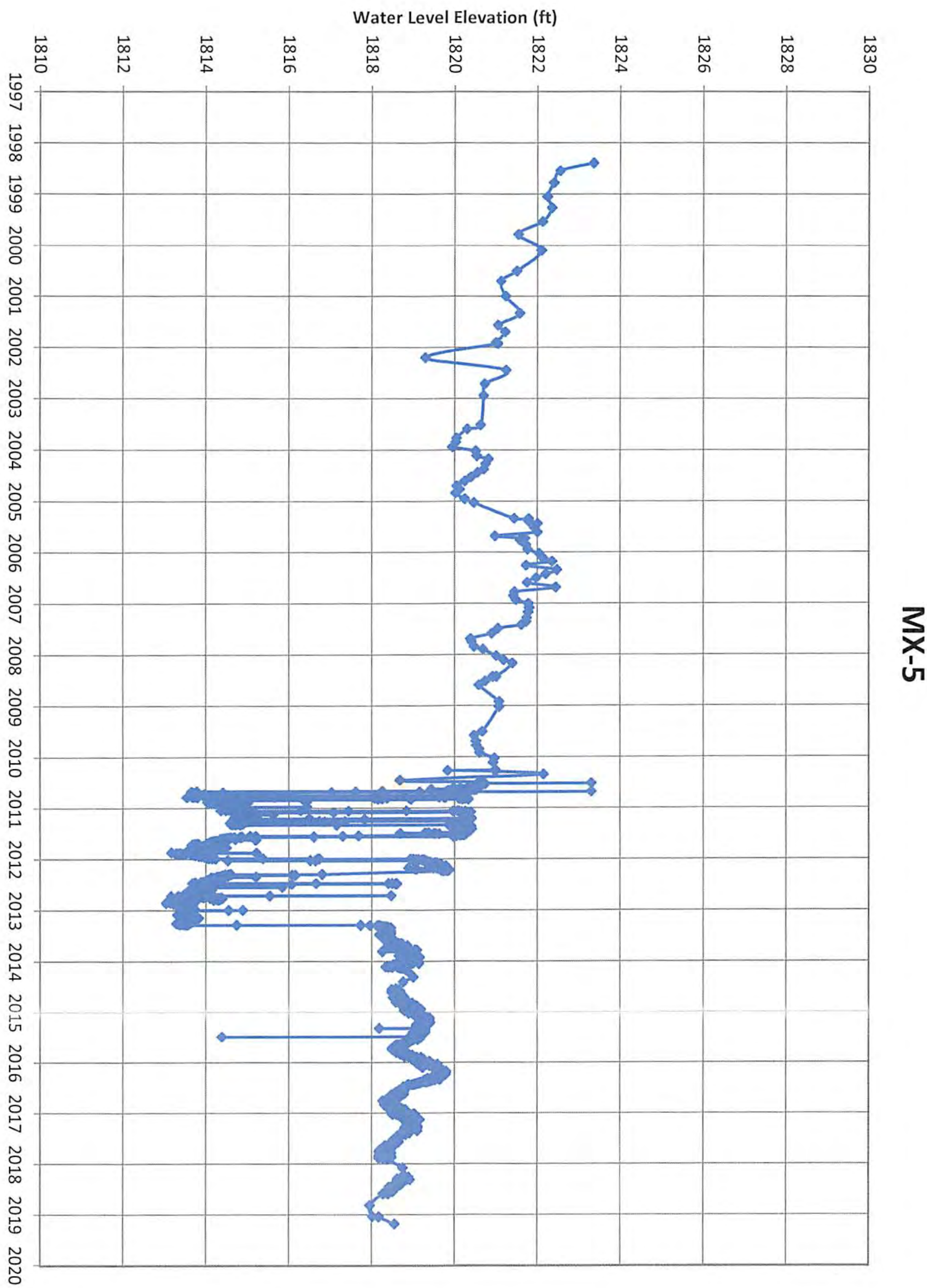


FIGURE 4-9: LOCATION MAP SHOWING THE NORTHERN LWRFS BOUNDARY FAULT

FIGURE 5-1. REPRODUCTION OF SNWA(2018) FIGURE 5-4, TITLED MR FLOW DEFICIT AND COYOTE SPRING VALLEY AND MRSA GROUNDWATER PRODUCTION



APPENDICES


MX-5
Water Level Elevation (ft)
1810
1812
1814
1816
1818
1820
1822
1824
1826
1828
1830
1997
1998
1998
1999
1999
2000
2000
2001
2001
2002
2002
2003
2003
2004
2004
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2005
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2006
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2014
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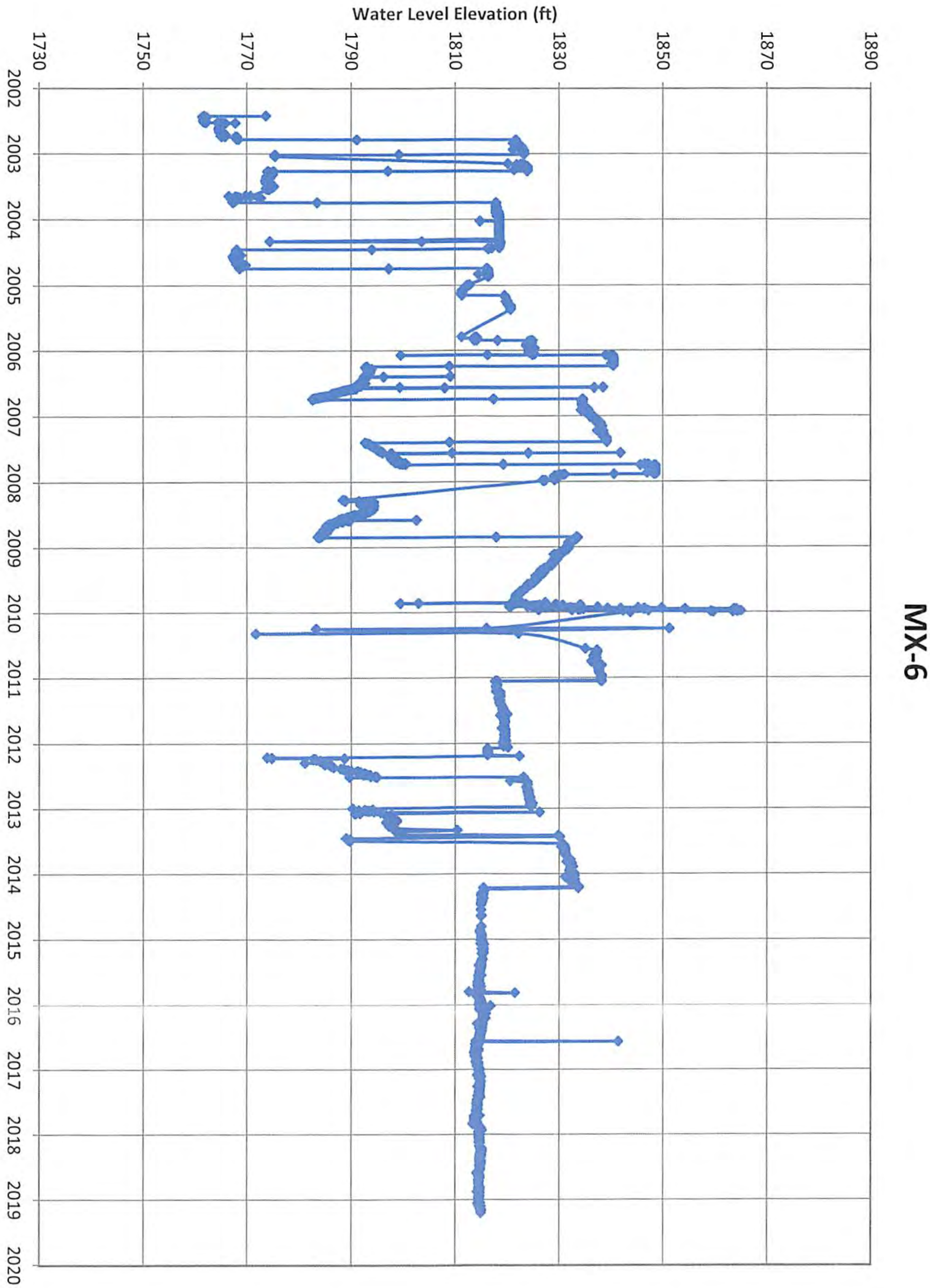
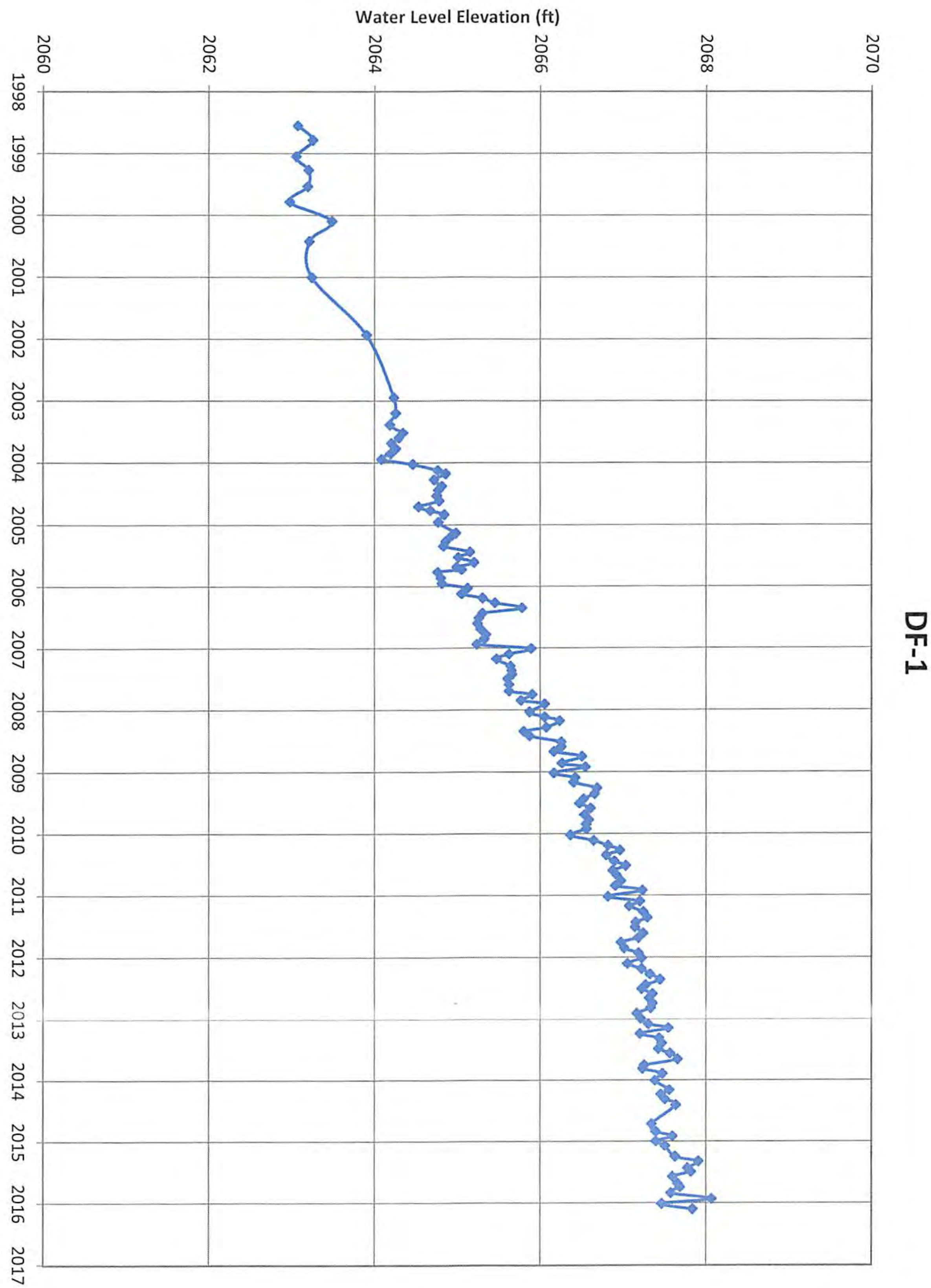
2015
2016
2016
2017
2017
2018
2018
2019
2019
2020


MX-6
Water Level Elevation (ft)
1730
1750
1770
1790
1810
1830
1850
1870
1890
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

SE ROA 36267


DF-1
Water Level Elevation (ft)
2060
2062
2064
2066
2068
2070
1998
1999
2000
2001
2002
2003
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2010
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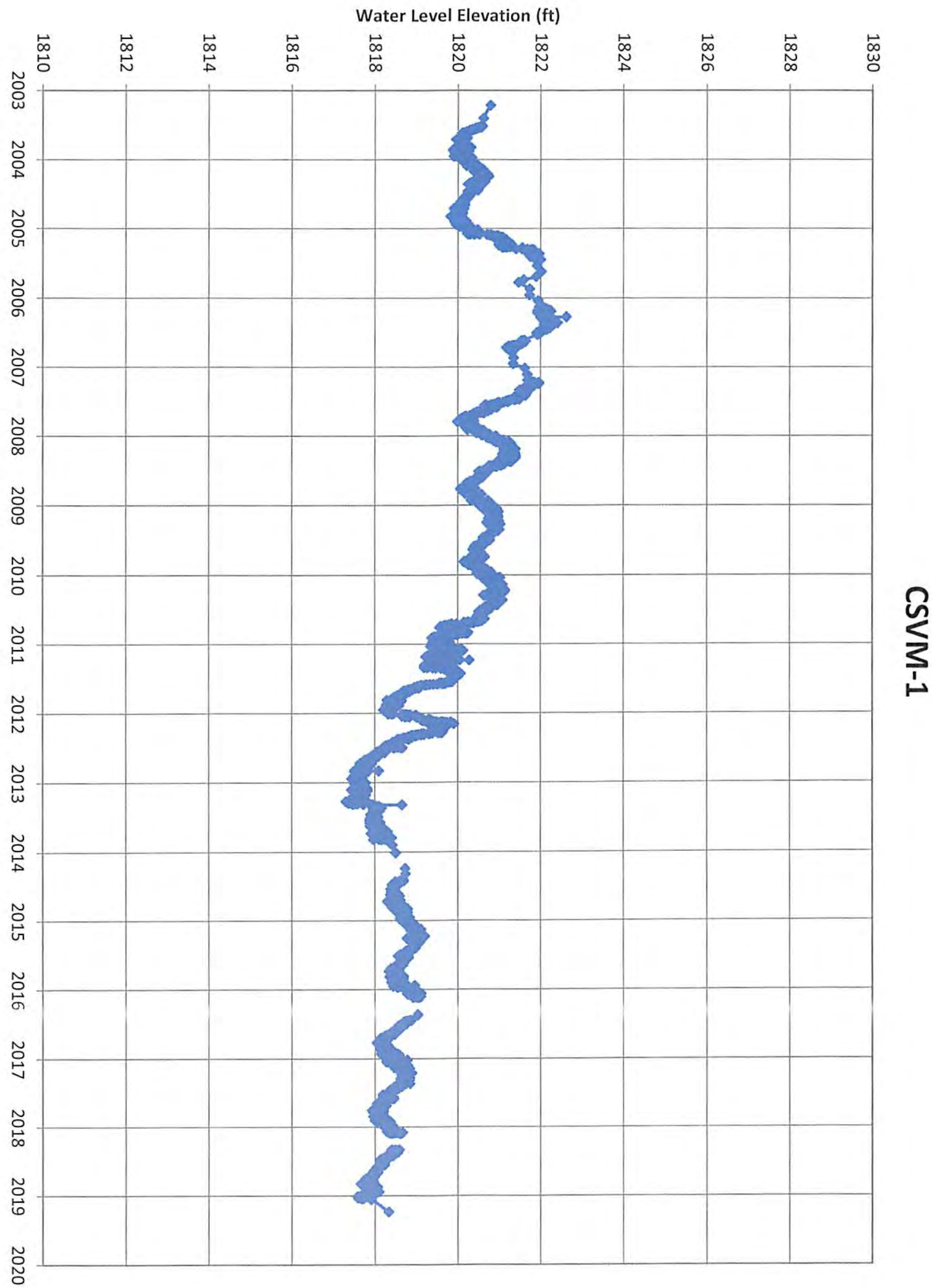
2015
2016
2017

SE ROA 36268


CSVM-1
Water Level Elevation (ft)
1810
1812
1814
1816
1818
1820
1822
1824
1826
1828
1830
2003
2004
2005
2006
2007
2008
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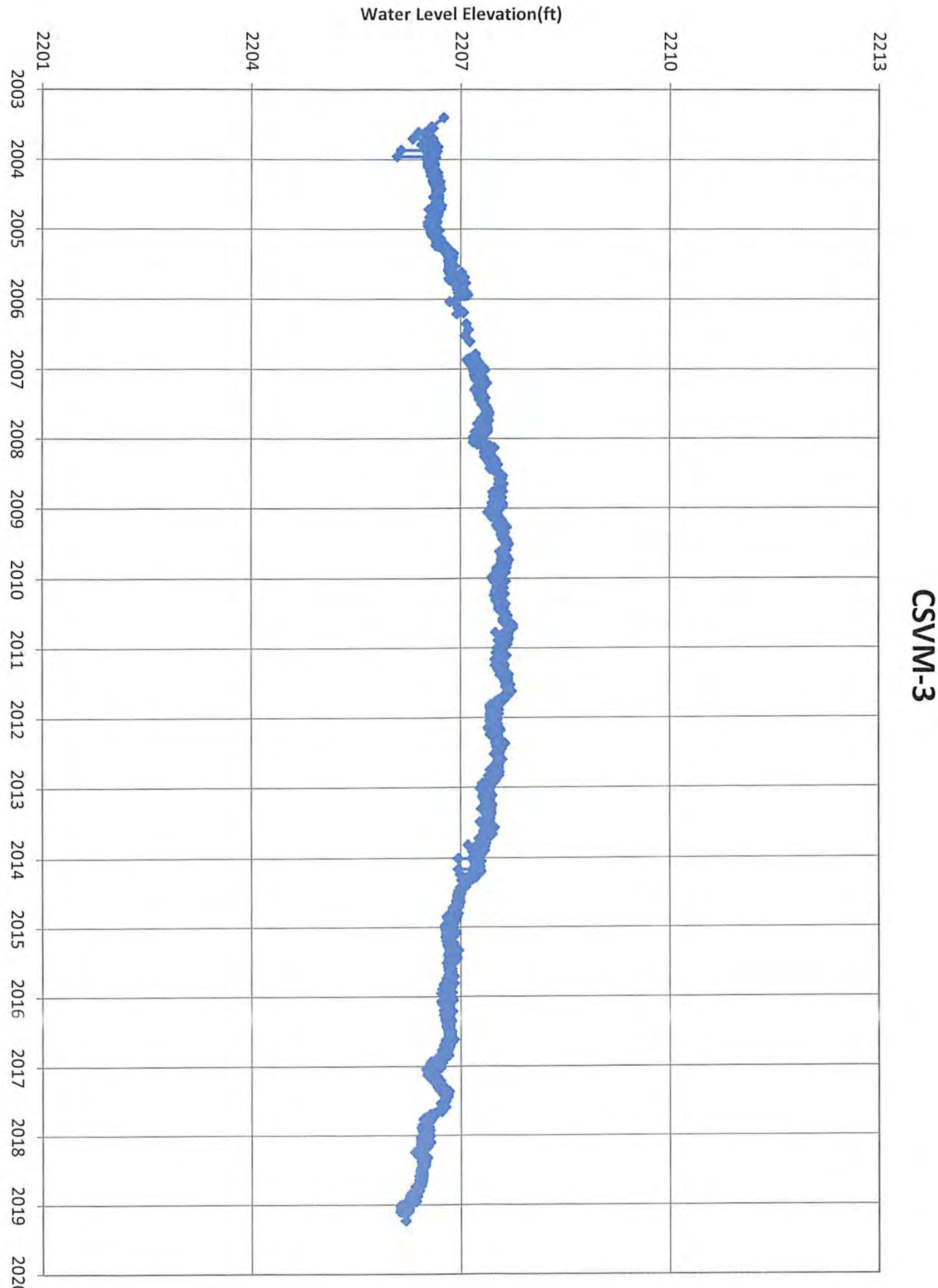
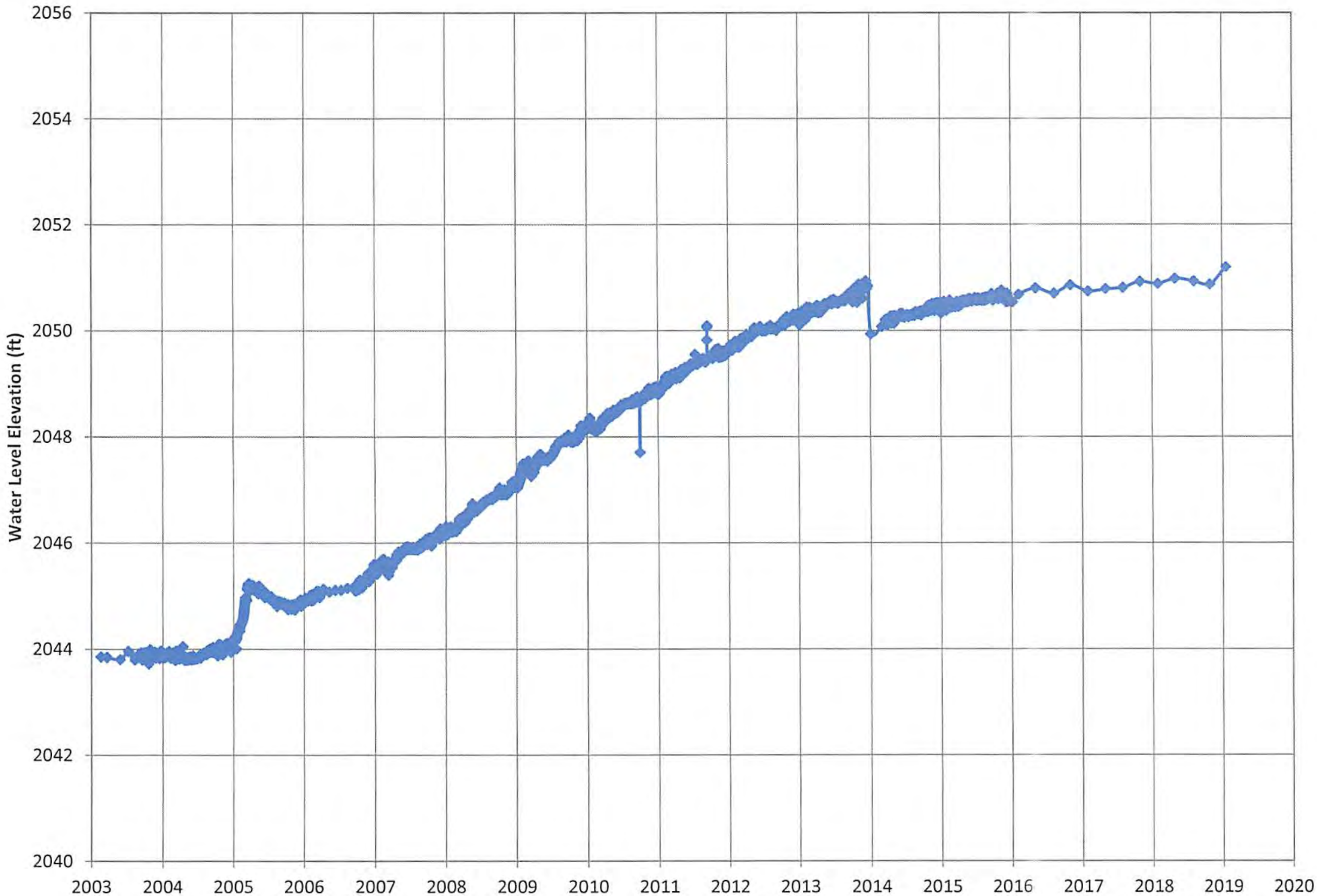
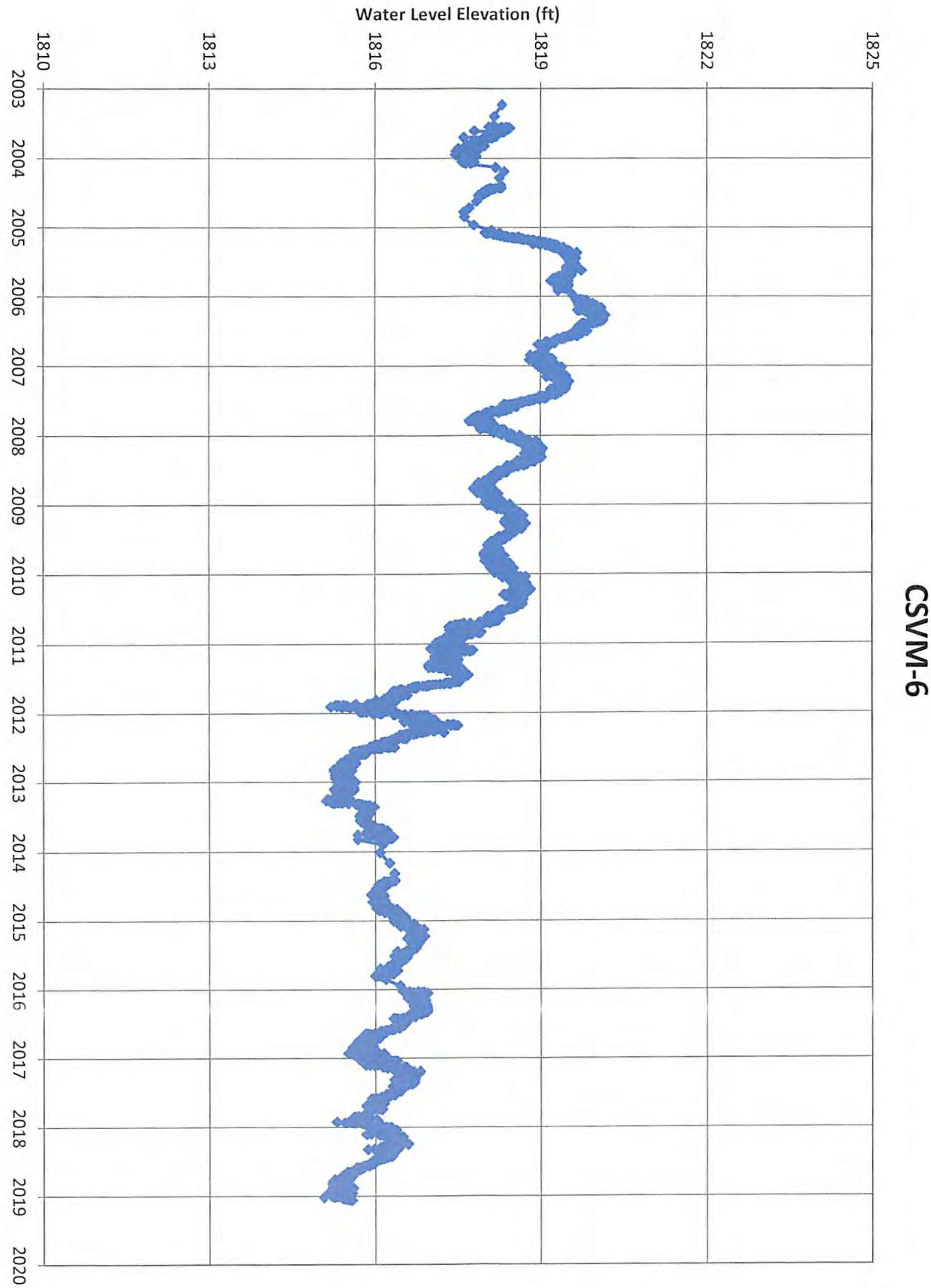
2016
2017
2018
2019
2020


CSVM-3
Water Level Elevation(ft)
2201
2204
2207
2210
2213
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020

CSVM-5



Water Level Elevation (ft)
2056
2054
2052
2050
2048
2046
2044
2042
2040
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020


CSVM-6
Water Level Elevation (ft)
1810
1813
1816
1819
1822
1825
2003
2004
2005
2006
2007
2008
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2010
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2012
2013
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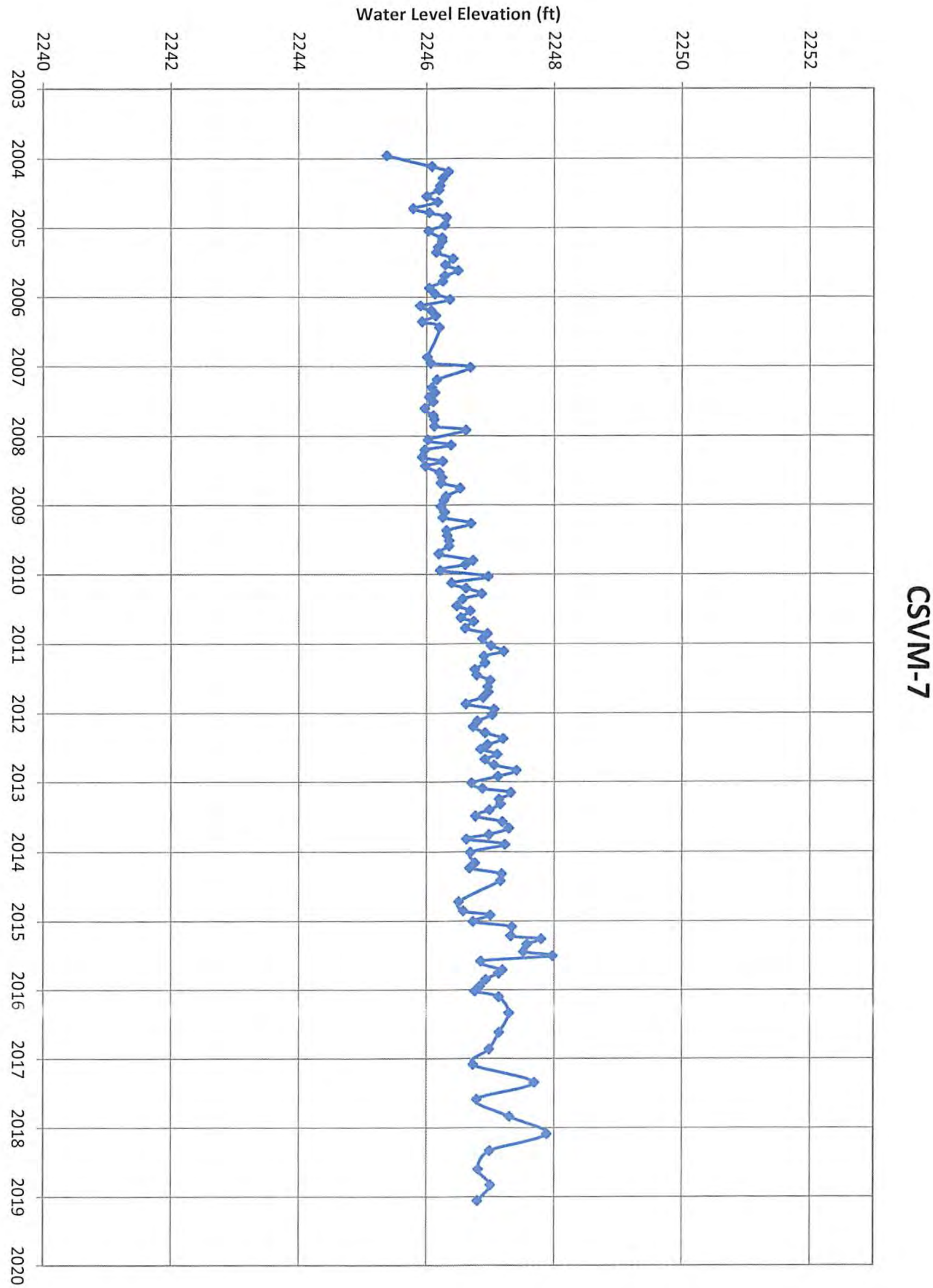
2015
2016
2017
2018
2019
2020


CSVM-7
Water Level Elevation (ft)
2240
2242
2244
2246
2248
2250
2252
2003
2004
2005
2006
2007
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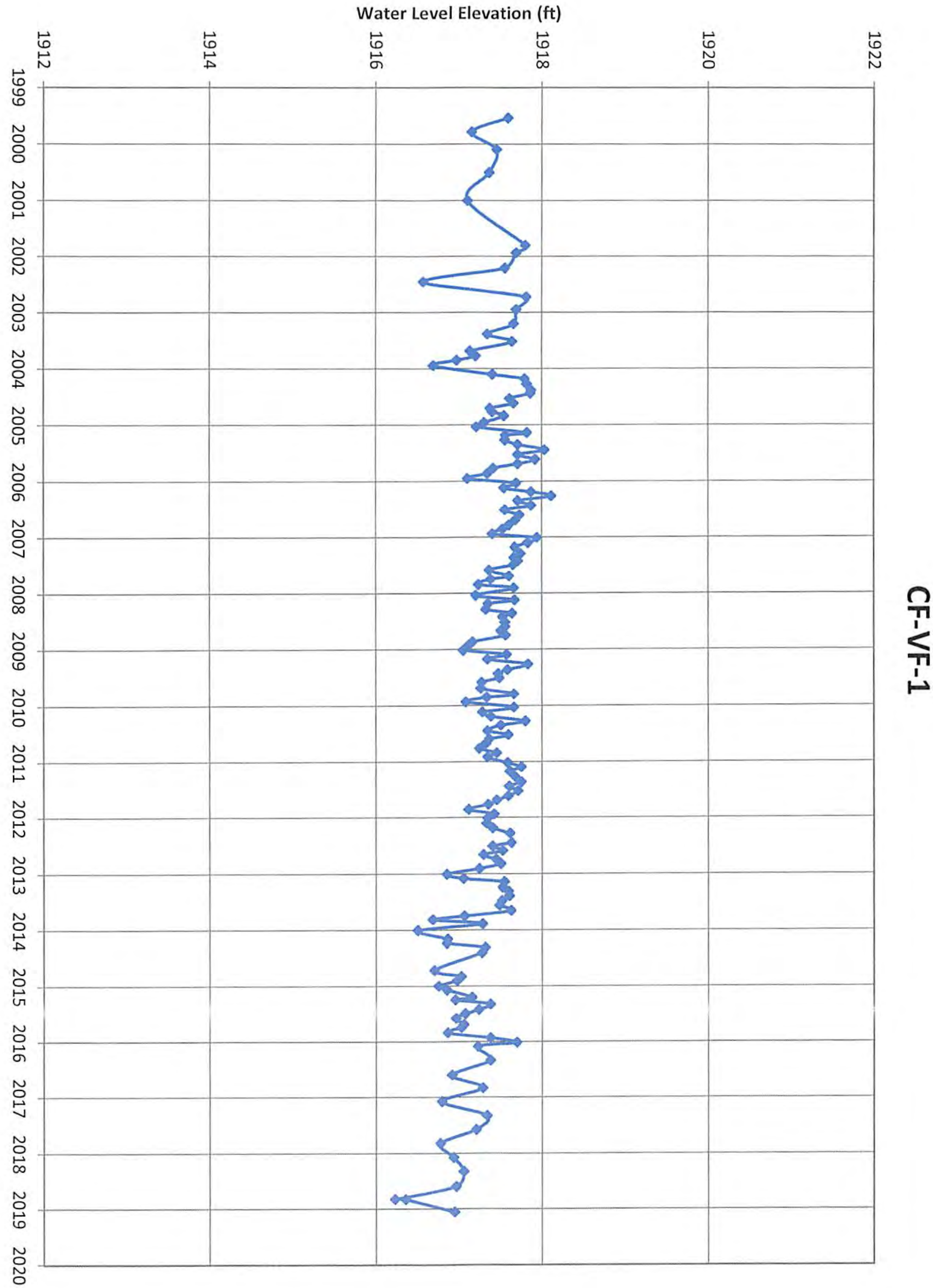
2016
2017
2018
2019
2020


CF-VF-1
Water Level Elevation (ft)
1912
1914
1916
1918
1920
1922
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
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2011
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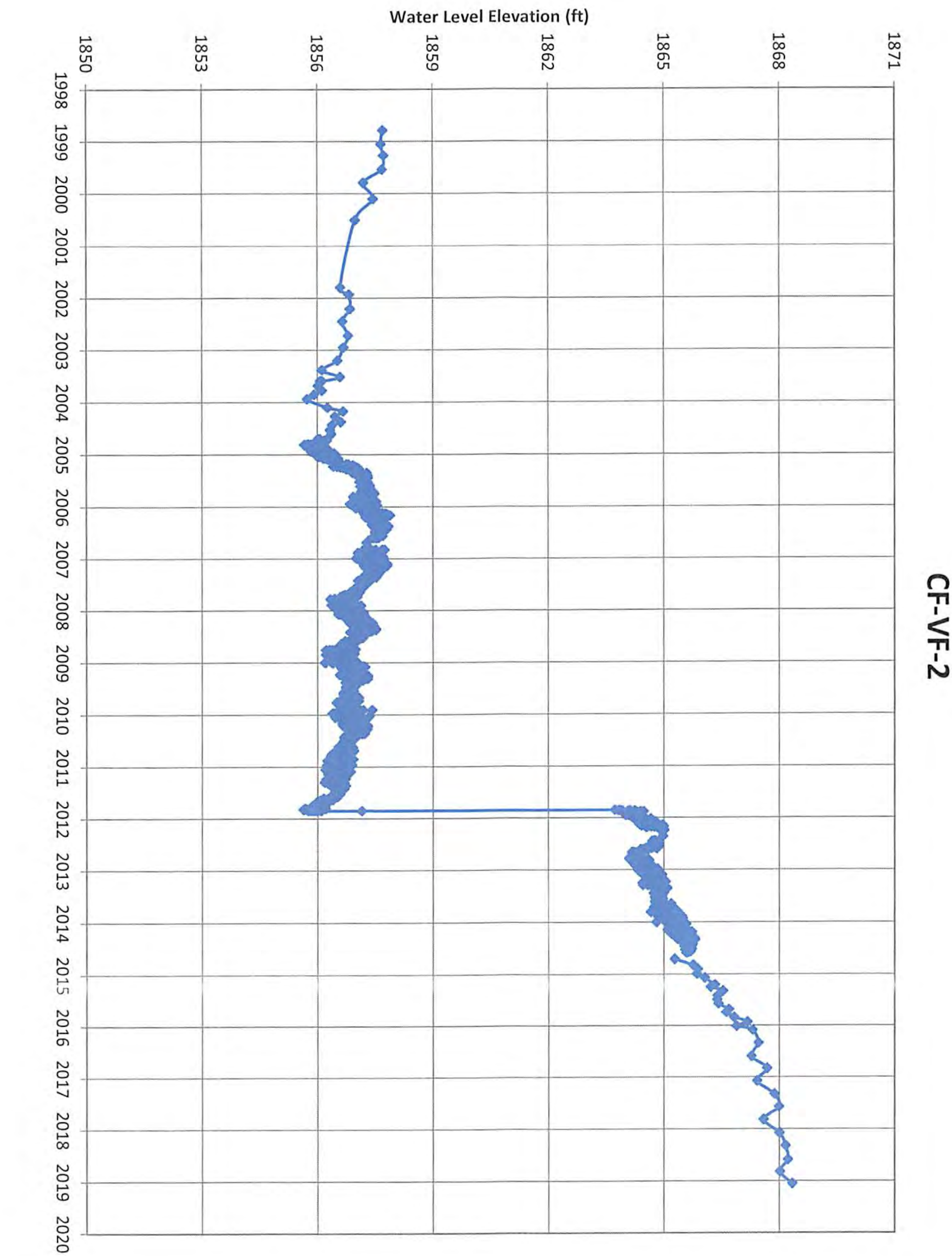
2019
2020

SE ROA 36274


CF-VF-2
Water Level Elevation (ft)
1850
1853
1856
1859
1862
1865
1868
1871
1998
1999
2000
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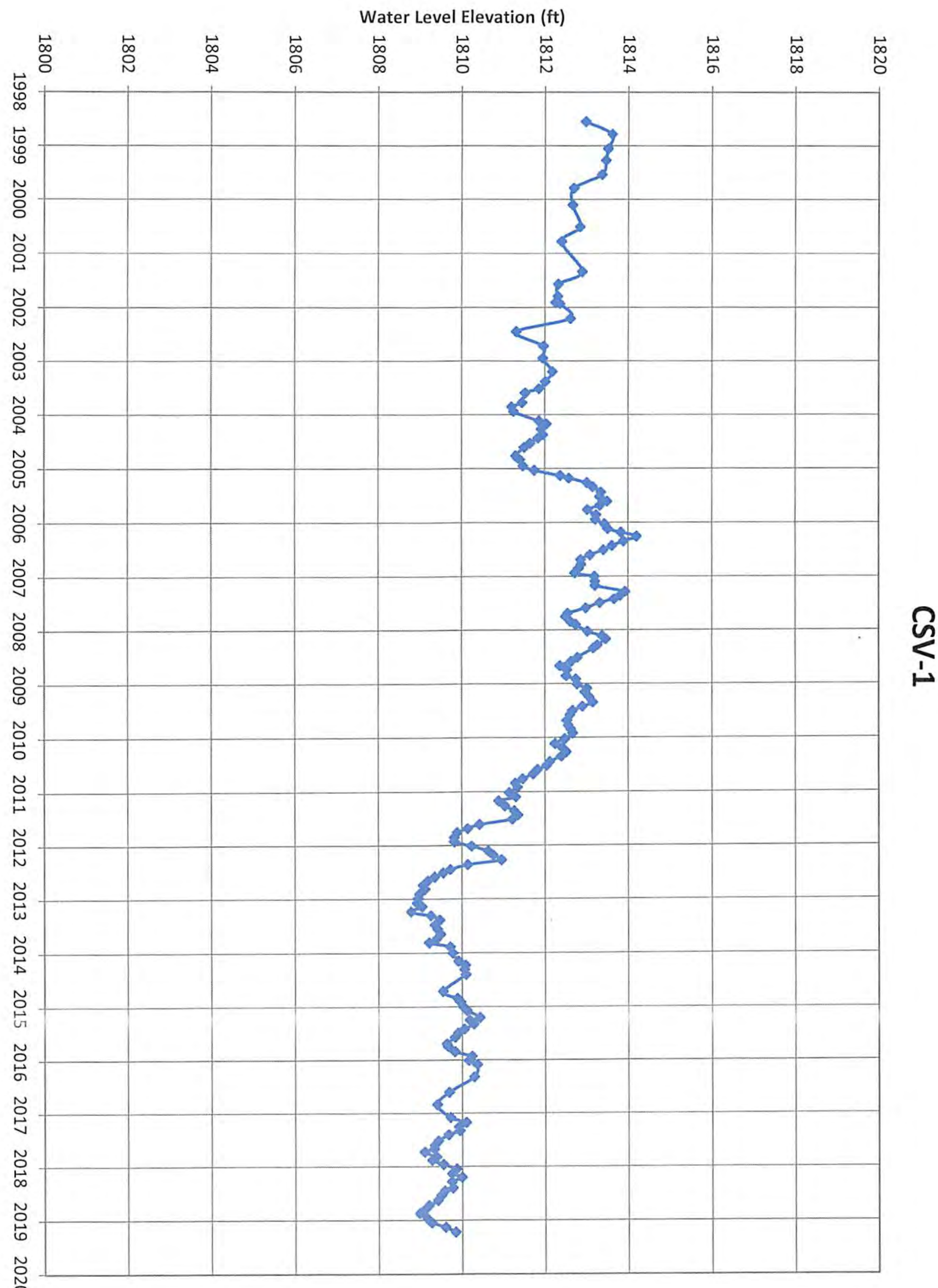
2020


CSV-1
Water Level Elevation (ft)
1800
1802
1804
1806
1808
1810
1812
1814
1816
1818
1820
1998
1999
2000
2001
2002
2003
2004
2005
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2016
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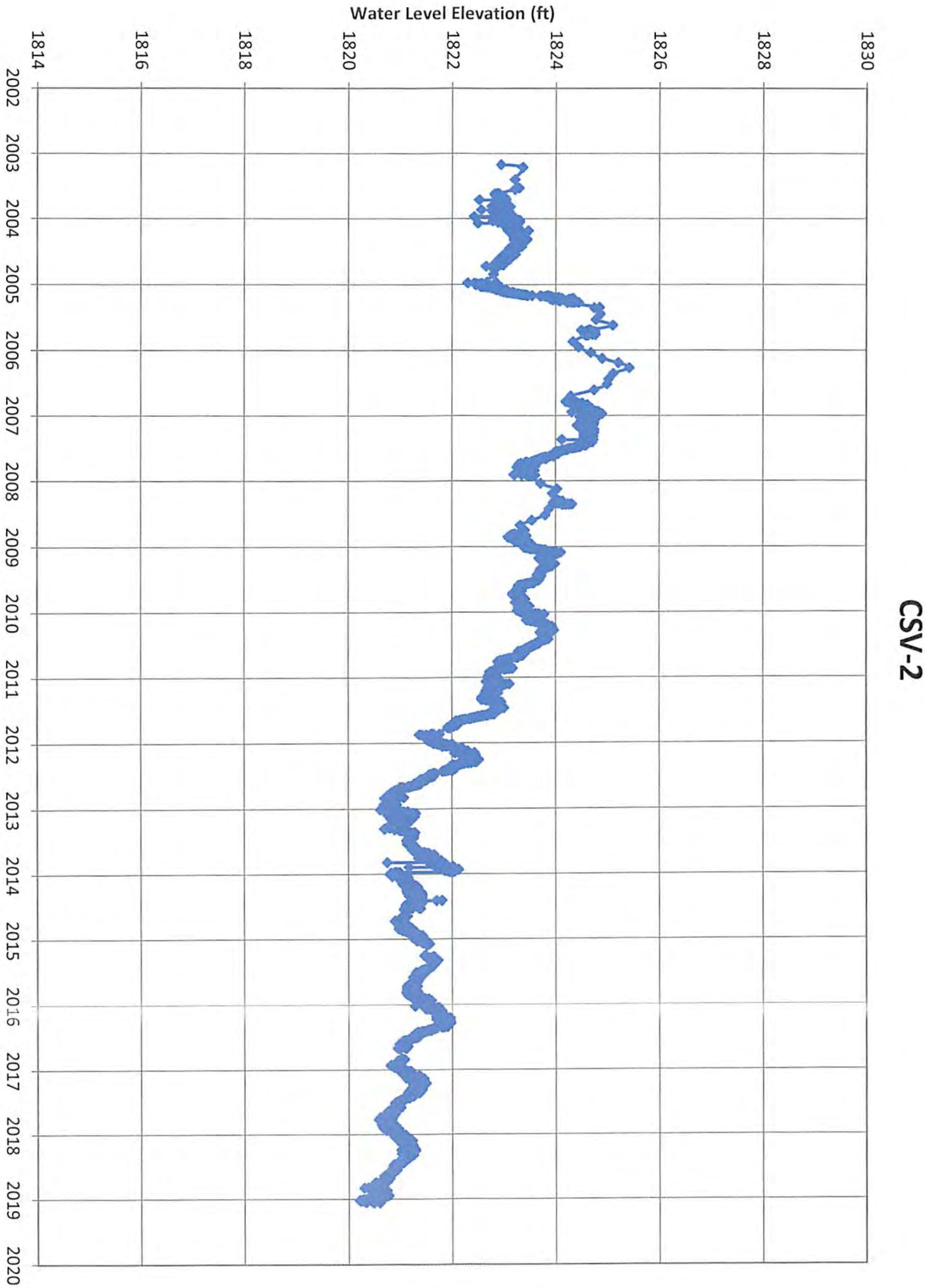
2020


CSV-2
Water Level Elevation (ft)
1814
1816
1818
1820
1822
1824
1826
1828
1830
2002
2003
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2006
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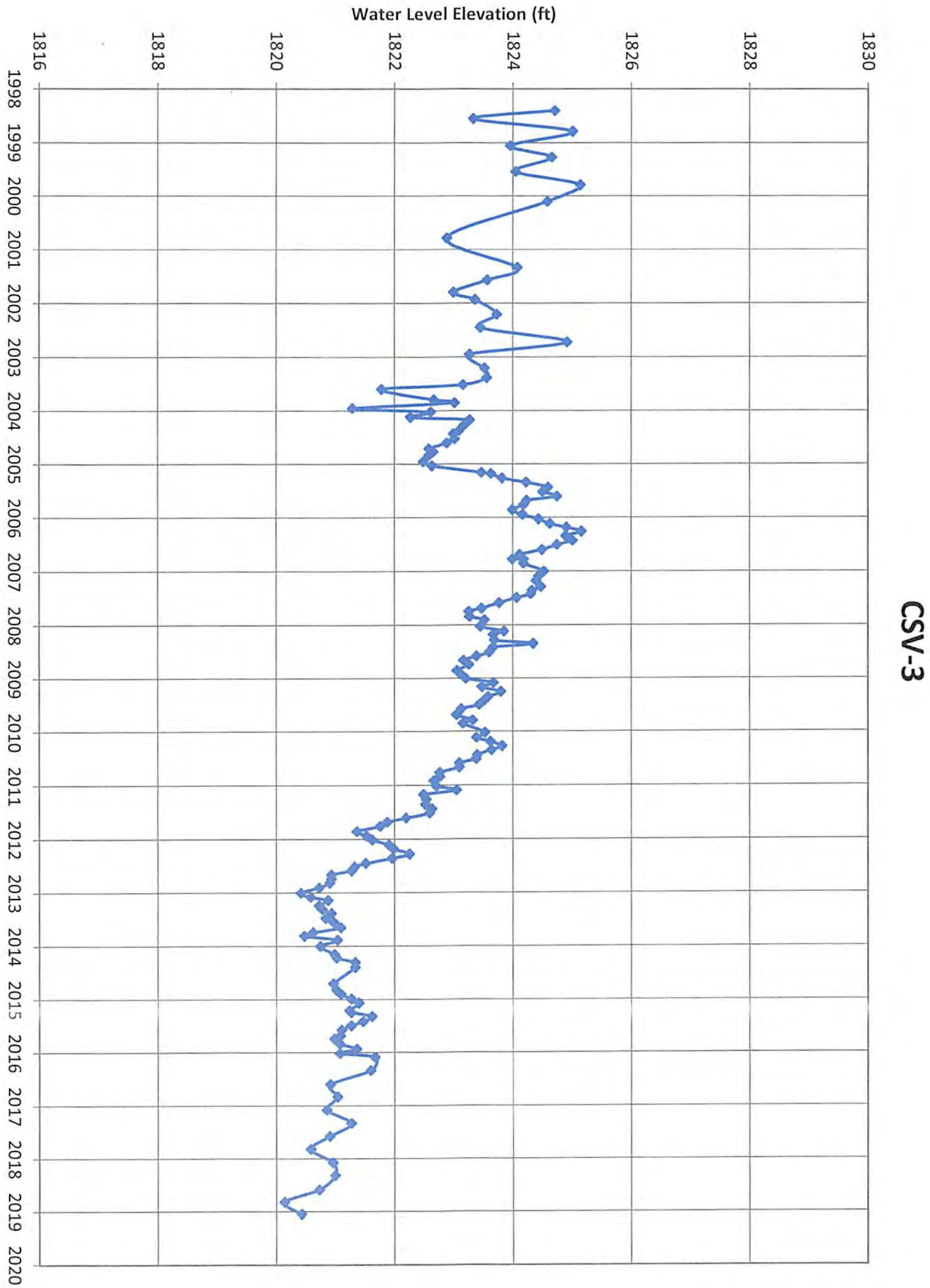
2016
2017
2018
2019
2020


CSV-3
Water Level Elevation (ft)
1816
1818
1820
1822
1824
1826
1828
1830
1998
1999
2000
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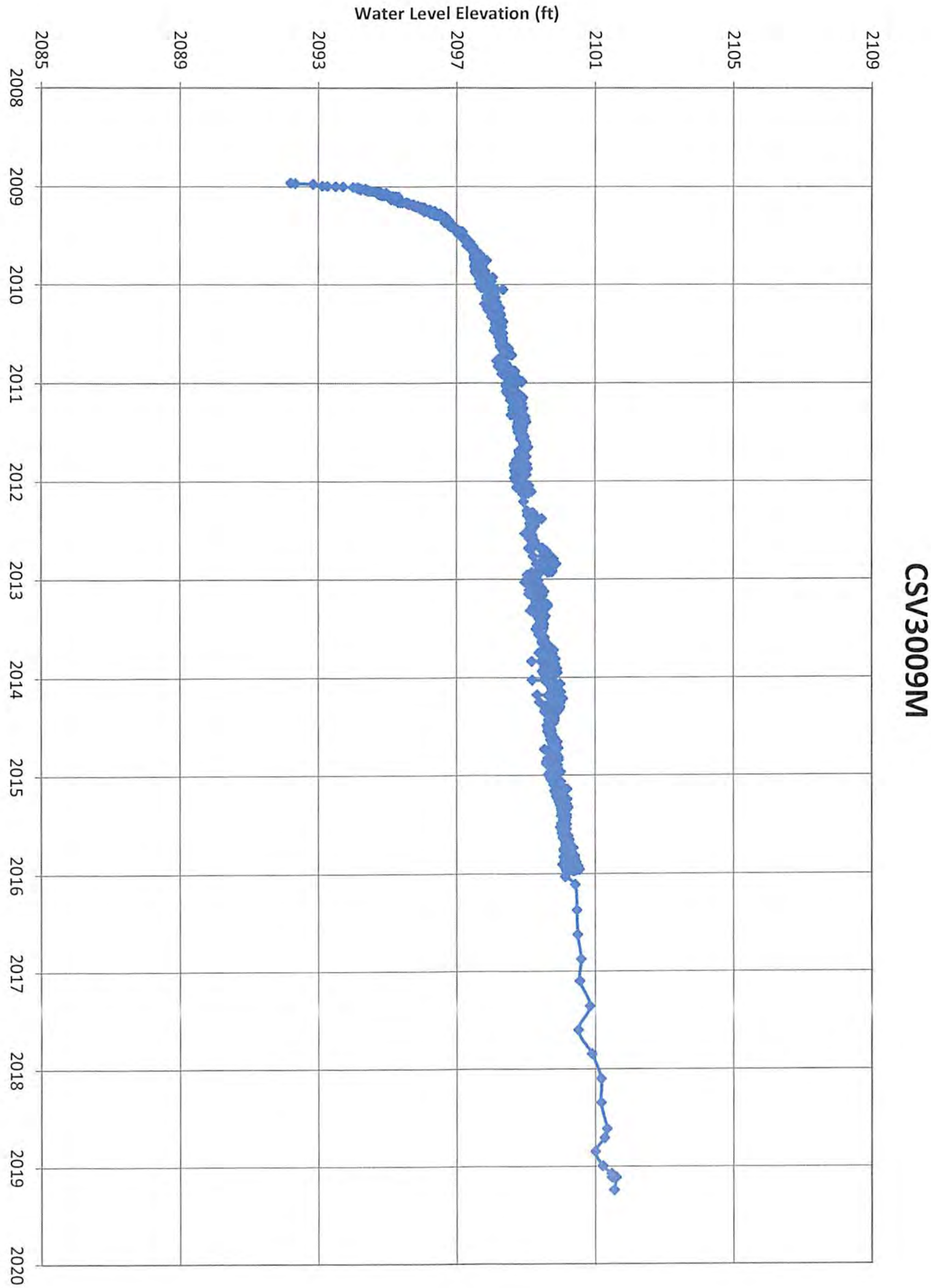
2016
2017
2018
2019
2020


CSV3009M
Water Level Elevation (ft)
2085
2089
2093
2097
2101
2105
2109
2008
2009
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2012
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2014
2015
2016
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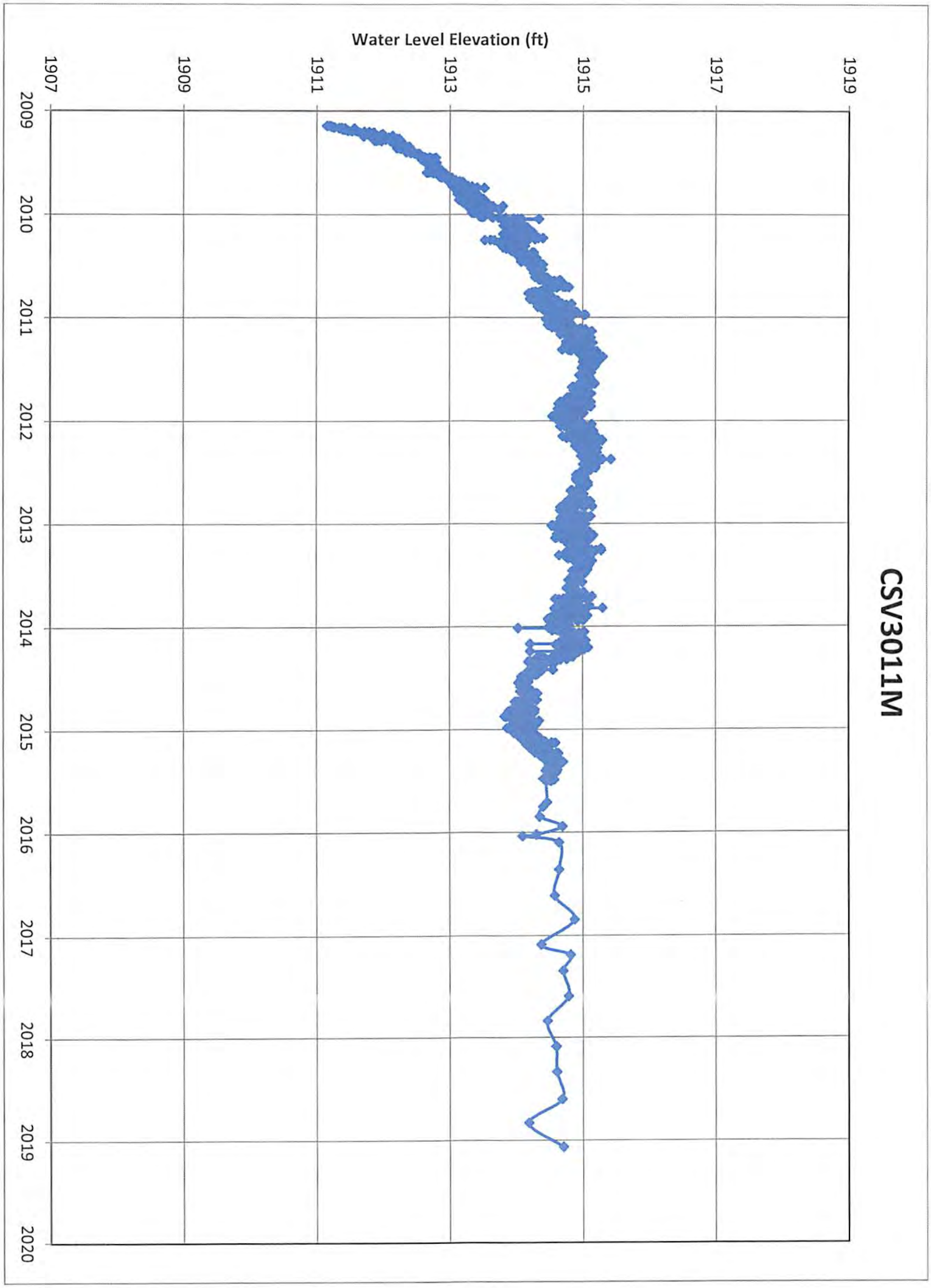
2018
2019
2020

SE ROA 36279



CSV3011M
Water Level Elevation (ft)
1907
1909
1911
1913
1915
1917
1919
2009
2010
2011
2012
2013
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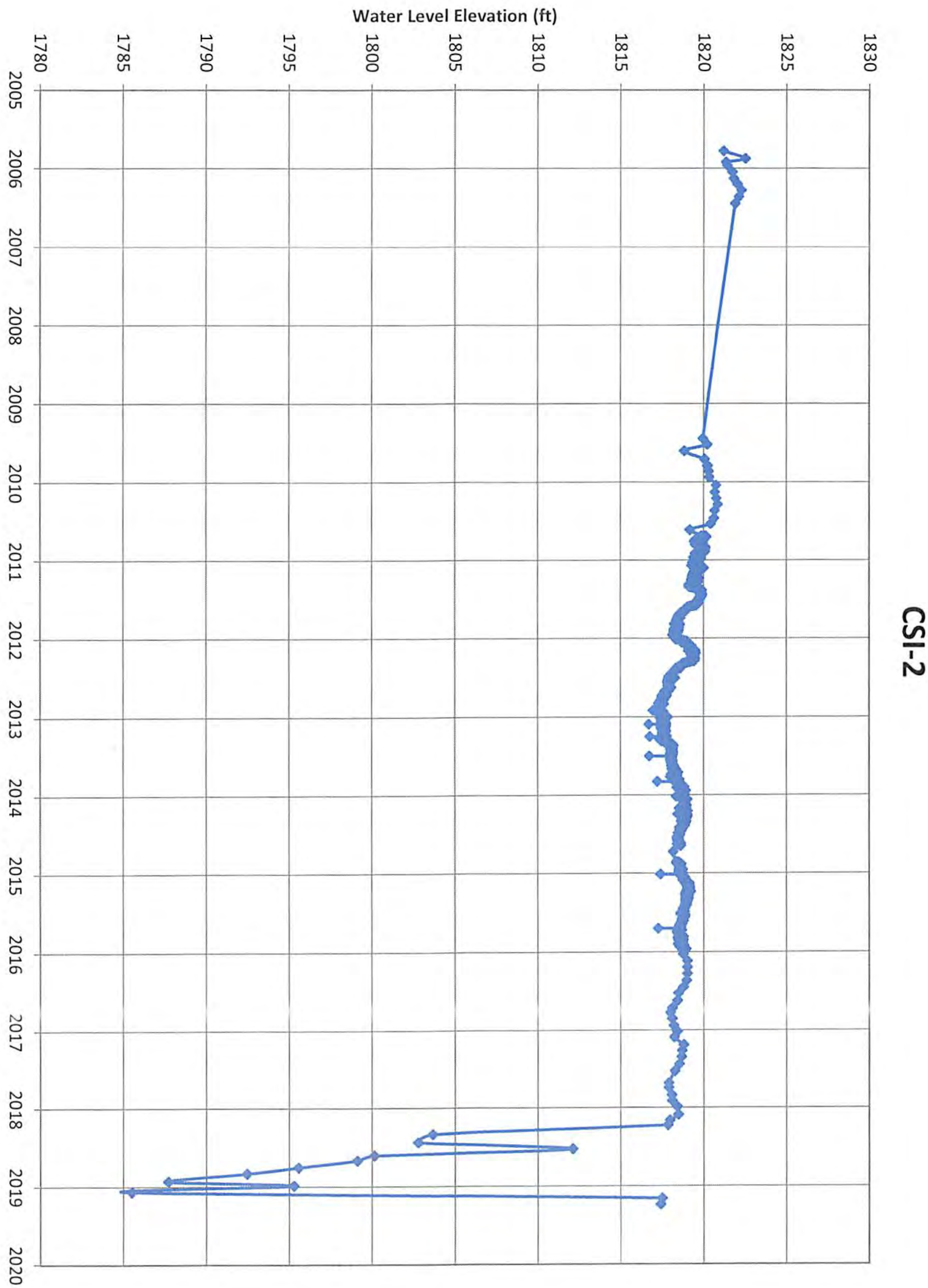
2016
2017
2018
2019
2020



CSI-2
Water Level Elevation (ft)
1780
1785
1790
1795
1800
1805
1810
1815
1820
1825
1830
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2006
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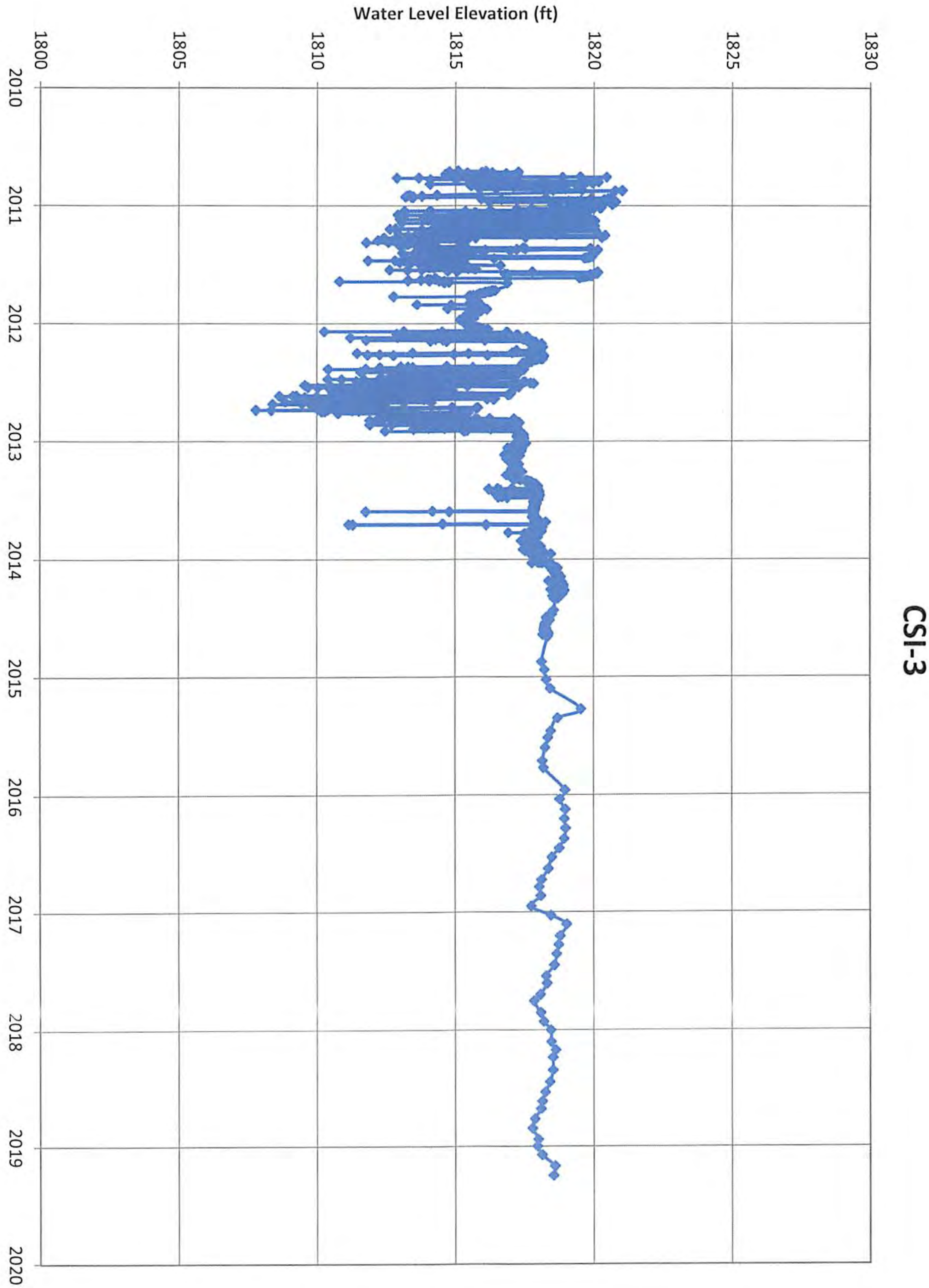
CSI-3
Water Level Elevation (ft)
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1805
1810
1815
1820
1825
1830
2010
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2016
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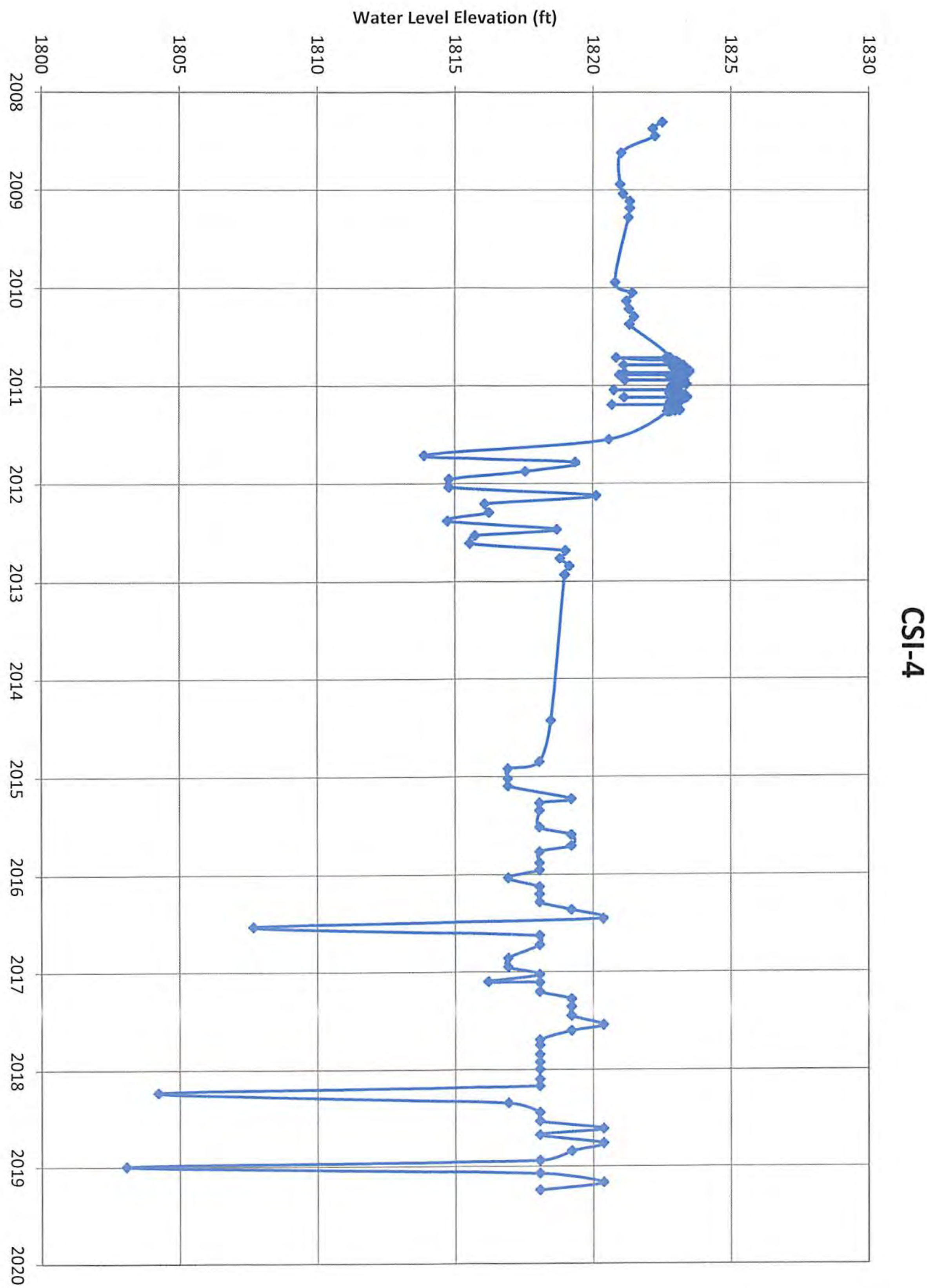
2020


CSI-4
Water Level Elevation (ft)
1800
1805
1810
1815
1820
1825
1830
2008
2009
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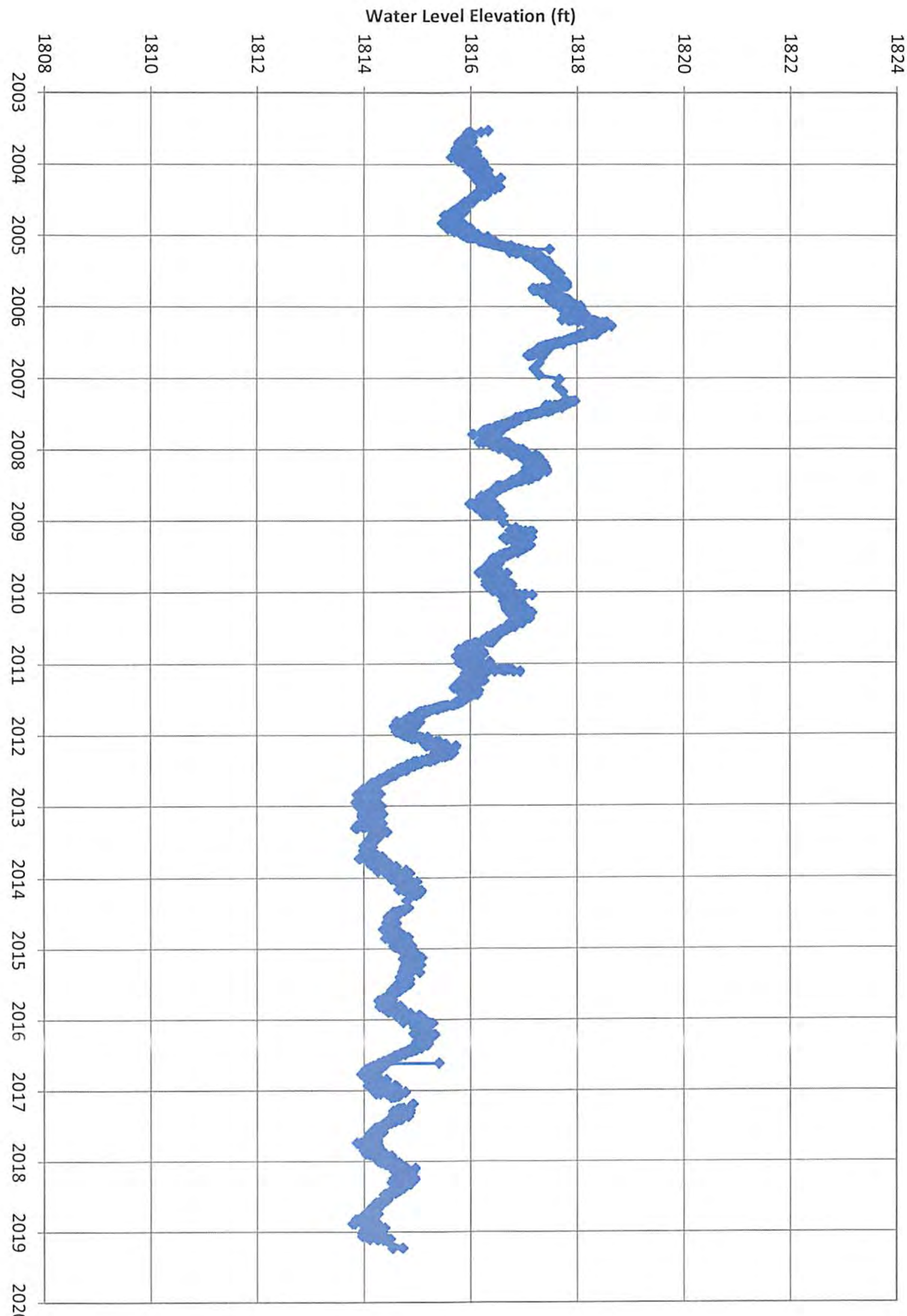
2019
2020

UMVM-1


Water Level Elevation (ft)
1808
1810
1812
1814
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1820
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2019
2020

May 8, 2019

Adam Sullivan
Deputy State Administrator
State of Nevada, Division of Water Resources
901 South Stewart St.
Carson City, NV, 89701

Subject: Quarterly update of ongoing data collection in Kane Springs Valley Hydrographic Basin No. 13-206, Lincoln County, Nevada.

Dear Mr. Sullivan,

This letter summarizes the ongoing data collection activities in the Kane Springs Valley Hydrographic Basin. Instrumentation consisting of totalizing rain gauges, tipping bucket rain gauges, runoff event dataloggers, and chloride collectors, were initially installed in October 2007. In December 2009 soil temperature sensors were installed in two places. The following is a summary of the data that has been collected until April 16, 2019 (from equipment installation through the second quarter of the 2019 water year). It should be noted that this is all raw data being reported with no analysis or data interpretation.

Precipitation

Three totalizing rain gauges from NovaLynx (Model 260-2510) were installed on October 31, 2007 (K-PT-01, K-PT-02, and K-PT-03) at elevations of 4.401, 3,747, and 2,919 feet above mean sea level (ft msl), respectively (Figure 1). The NovaLynx rain gauge has a total capacity of 20 inches of rainfall. Several millimeters of mineral oil are added to the rain gauge to prevent evaporation of the rainwater following precipitation events before staff can visit the site to read the data. Two additional totalizing rain gauges were installed in December 2008 (K-PT-04 and K-PT-05) at elevations of 4,401 and 6,456 ft msl, respectively. In addition, a six-inch diameter tipping bucket rain gauge with datalogger (TE525-L, Campbell Scientific, Inc.) was installed at the K-PT-01 location on December 4, 2008. The rain gauges are downloaded and/or measured approximately every three months by staff.

Table 1 summarizes the precipitation data recorded from the totalizing rain gauges between visits. Table 2 summarizes the monthly total precipitation for Kane Springs RAWS station (downloaded from the Western Regional Climate Center website) along with the monthly precipitation data from the tipping bucket at K-PT-01.

Runoff

In order to measure runoff in the Kane Springs Valley basin, nine Tru Track Ltd. Water height recorders were installed throughout the basin in October 2007 (K-S-01 through K-S-09) Figure 1. The WT-HR 1000 1-meter water height datalogger uses a capacitive sensor, and datalogger that is set to collect data at 20-minute intervals. Five of these were installed in the main wash, while four were installed in smaller side washes. Data are downloaded from the dataloggers approximately every three months. Figures 2 through 10 summarize the average daily stage values of these instruments over the 2019 water year. Data presented in these figures represent raw data. Raw baseline water height data were set to zero inches above stream bed.

In addition, channel depth profiles were measured at each of the Tru Track datalogger location. The slope of the channel was measured at the location of the profile using a surveying level.

Chloride

Chloride in precipitation was sampled using collectors that were stationed at each of the three initial rain gauge locations (K-PT-01, K-PT-02, and K-PT-03; Figure 1). The precipitation collectors consisted of a funnel that was connected to a 500-mL Nalgene bottle that contained a small layer of laboratory-grade mineral oil to prevent evaporation of the precipitation. These collectors were emptied when the rain gauges were visited by staff, on average every three months. The chloride samples were sent to Western Environmental Testing Laboratory (WETLAB), Inc. in Sparks, Nevada for analysis. Table 3 displays the results of the chloride analysis measured from precipitation.

Runoff samples were collected for chloride analysis using storm samplers from Nalgene. Three storm water samplers were installed in wash locations adjacent to Tru Track dataloggers (Figure 1). The samplers were buried in the washes exposing only the top to collect any runoff that might occur. They can collect a full one liter sample of first flush runoff that occurs in a wash. A ball-valve shuts off the sample once the bottle is full to prevent additional storms from filling the bottle. The samplers were emptied approximately every three months by staff and water samples were sent to WETLAB for chloride analysis. Table 4 displays the results of the chloride analysis measured from runoff.

Groundwater-Level Monitoring

Lincoln/Vidler has been collecting manual water level data since the start of activities in late 2007 of well KMW-1. In early 2007, the Southern Nevada Water Authority (SNWA) took over measurements. Wells are measured by hand quarterly by Lincoln County Water District and Vidler Water Company. Figure 11 represents a hydrograph of data for the project well in Kane Springs Valley.

The data presented in this report is raw data with no analysis or data interpretation. Should you have any questions or need additional information, please do not hesitate to contact me at 775.885.5000, ext. 119.

Sincerely,
VIDLER WATER COMPANY

Ryan Hoerth, P.E.
Project Manager

cc: Wade Poulsen, Lincoln County Water District
Todd Umstot, Daniel B. Stephens & Associates
Levi Kryder, Division of Water Resources

Table 1 - Precipitation Recorded in Totalizing Rain Gages					
Observed Percipitation Water Year	K-PT-01 Elevation 5,090 ft (in/yr)	K-PT-02 Elevation 3,747 ft (in/yr)	K-PT-03 Elevation 2,919 ft (in/yr)	K-PT-04 Elevation 4,401 ft (in/yr)	K-PT-05 Elevation 6,456 ft (in/yr)
2008	8.54	7.24	3.84	---	---
2009	6.18	8.66	5.97	6.18	6.98
2010	12.11	8.69	6.12	8.4	2.99*
2011	20.82	13.23	5.95	14.04	12.13
2012	13.18	7.25	4.35	7.65	6.63**
2013	16.53	8.45	4.85	8.57	10.24
2014	9.2	5.60~	6.7	5.72	7.06
2015	11.73	7.24	5.91	7.33	7.16
2016	13.34	12.76	8.89	9.54	7.87
2017	17.08	12.14	6.73	12.16	7.57
2018	6.14	4.67	2.21	4.51	4.47
2019	16.04	9.42	4.39	8.72	---

*Totalizer was found knocked over in December 2009, June 2010 , and September 2010

**Totalizer was found knocked over in December 2011 and September 2012

~Totalizer was found knocked over in June 2014

ND - No Data could not reach site due to snow.

Table 2 - Monthly Total Precipitation Measured at the Kane Spring RAWS Station and the K-PT-01 Tipping Bucket

Date	RAWS	K-PT-01	Date	RAWS	K-PT-01	Date	RAWS	K-PT-01
Oct-2007	0.00	---	Oct-2008	0.65	---	Oct-2009	0.01	0.01
Nov-2007	0.24	---	Nov-2008	0.26	---	Nov-2009	0.10	0.10
Dec-2007	0.22	---	Dec-2008	0.09	2.00	Dec-2009	0.74	2.39
Jan-2008	1.04	---	Jan-2009	0.07	0.35	Jan-2010	0.55	0.03
Feb-2008	1.79	---	Feb-2009	2.76	3.73	Feb-2010	0.94	0.00
Mar-2008	0.23	---	Mar-2009	0.00	0.00	Mar-2010	0.33	0.00
Apr-2008	0.00	---	Apr-2009	0.77	0.58	Apr-2010	0.09	0.40
May-2008	0.96	---	May-2009	0.05	0.30	May-2010	0.00	0.10
Jun-2008	0.00	---	Jun-2009	0.16	0.37	Jun-2010	0.08	0.07
Jul-2008	1.18	---	Jul-2009	0.17	0.32	Jul-2010	0.01	0.39
Aug-2008	0.18	---	Aug-2009	0.23	0.10	Aug-2010	0.27	0.45
Sep-2008	0.00	---	Sep-2009	0.01	0.15	Sep-2010	0.05	0.01
Total for 2008 Water Year	5.84	---	Total for 2009 Water Year	5.22	7.90	Total for 2010 Water Year	3.17	3.95

Date	RAWS	K-PT-01	Date	RAWS	K-PT-01	Date	RAWS	K-PT-01
Oct-2010	2.04	1.66	Oct-2011	1.97	3.28	Oct-2012	0.51	0.81
Nov-2010	0.17	0.56	Nov-2011	0.19	0.42	Nov-2012	0.00	0.00
Dec-2010	5.51	9.36	Dec-2011	0.46	0.47	Dec-2012	1.67	2.07
Jan-2011	0.00	0.21	Jan-2012	0.39	0.49	Jan-2013	0.67	0.83
Feb-2011	1.99	1.49	Feb-2012	0.43	1.05	Feb-2013	0.31	0.48
Mar-2011	0.66	1.17	Mar-2012	0.27	1.52	Mar-2013	0.91	0.87
Apr-2011	0.20	0.22	Apr-2012	0.41	0.45	Apr-2013	0.23	0.06
May-2011	0.45	0.67	May-2012	0.00	0.00	May-2013	0.19	0.75
Jun-2011	0.00	0.00	Jun-2012	0.00	0.00	Jun-2013	0.00	0.00
Jul-2011	0.47	1.03	Jul-2012	1.47	0.81	Jul-2013	1.61	2.55
Aug-2011	0.10	0.15	Aug-2012	1.55	1.74	Aug-2013	0.93	2.23
Sep-2011	0.48	0.21	Sep-2012	0.08	1.3	Sep-2013	1.00	4.09
Total for 2011 Water Year	12.07	16.73	Total for 2012 Water Year	7.22	11.53	Total for 2013 Water Year	8.03	14.74

Date	RAWS	K-PT-01	Date	RAWS	K-PT-01	Date	RAWS	K-PT-01
Oct-2013	0.49	0.67	Oct-2014	0.00	0.00	Oct-2015	2.38	2.97
Nov-2013	1.04	1.40	Nov-2014	0.08	0.22	Nov-2015	0.36	0.35
Dec-2013	0.00	0.10	Dec-2014	1.57	1.91	Dec-2015	0.04	0.59
Jan-2014	0.22	0.20	Jan-2015	0.57	0.58	Jan-2016	4.00	3.65
Feb-2014	1.10	1.86	Feb-2015	0.62	0.54	Feb-2016	0.09	0.48
Mar-2014	0.40	0.32	Mar-2015	0.61	0.91	Mar-2016	0.21	0.29
Apr-2014	0.75	0.44	Apr-2015	0.29	0.50	Apr-2016	1.69	2.23
May-2014	0.03	0.18	May-2015	1.43	1.96	May-2016	0.53	0.56
Jun-2014	0.01	0.00	Jun-2015	0.42	2.01	Jun-2016	0.59	0.61
Jul-2014	0.10	0.57	Jul-2015	0.62	0.32	Jul-2016	1.08	0.39
Aug-2014	1.77	2.28	Aug-2015	0.08	0.62	Aug-2016	0.91	0.74
Sep-2014	0.69	0.87	Sep-2015	0.36	0.27	Sep-2016	0.01	0.28
Total for 2014 Water Year	6.60	8.89	Total for 2015 Water Year	6.65	9.84	Total for 2016 Water Year	11.89	13.14

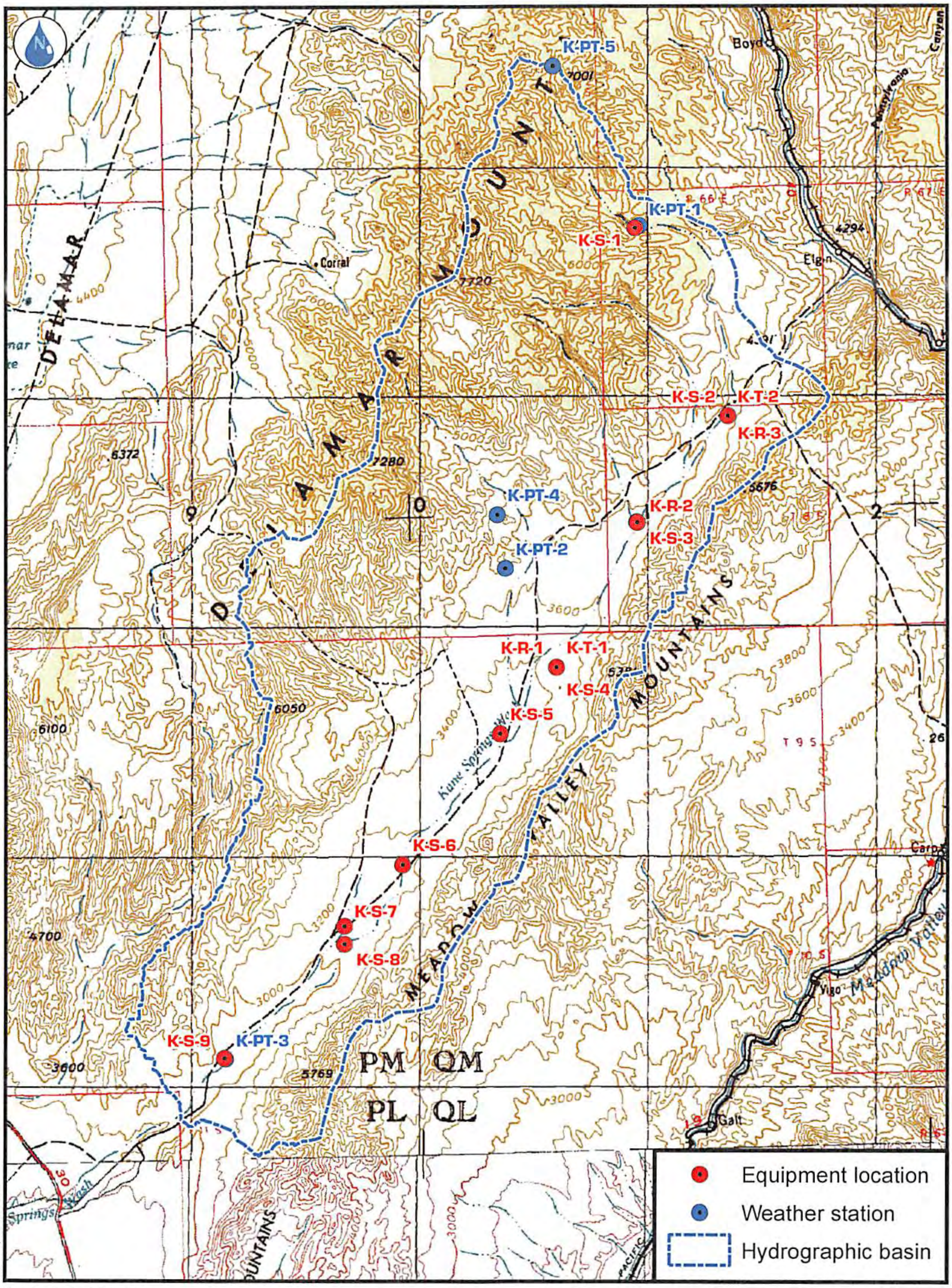
Date	RAWS	K-PT-01	Date	RAWS	K-PT-01	Date	RAWS	K-PT-01
Oct-2016	0.53	0.64	Oct-2017	0.00	0.00	Oct-2018	1.61	1.88
Nov-2016	0.09	0.26	Nov-2017	0.04	0.00	Nov-2018	0.62	0.61
Dec-2016	2.19	5.33	Dec-2017	0.00	0.00	Dec-2018	0.12	0.30
Jan-2017	4.23	2.75	Jan-2018	1.29	ND	Jan-2019	2.91	3.43
Feb-2017	1.25	1.97	Feb-2018	0.01	ND	Feb-2019	1.90	5.71
Mar-2017	0.84	0.65	Mar-2018	0.63	ND	Mar-2019	1.97	2.94
Apr-2017	0.00	0.03	Apr-2018	0.12	0.08	Apr-2019		
May-2017	0.01	0.03	May-2018	0.12	0.33	May-2019		
Jun-2017	0.00	0.01	Jun-2018	0.00	0.00	Jun-2019		
Jul-2017	0.19	5.53	Jul-2018	1.41	1.51	Jul-2019		
Aug-2017	0.55	0.37	Aug-2018	0.19	0.65	Aug-2019		
Sep-2017	0.64	0.06	Sep-2018	0.08	0.31	Sep-2019		
Total for 2017 Water Year	10.52	17.63	Total for 2018 Water Year	3.89	2.88	Total for 2019 Water Year	9.13	14.87

ND - No Data (tipping bucket was damaged)

Table 3 - Chloride Analysis Measured from Precipitation				
Date	K-PT-01 (mg/L)	K-PT-02 (mg/L)	K-PT-03 (mg/L)	PQL (mg/L)
1/21/2008	0.21	0.49	0.13	0.10
3/17/2008	0.39	0.32	0.26	0.10
5/15/2008	0.88	3.00	NS	0.10
8/12/2008	0.29	0.94	0.73	0.20
12/1/2008	0.22	0.31	0.58	0.10
3/16/2009	0.24	0.29	0.33	0.10
8/6/2009	ND	9.50	<2	2.00
11/12/2009	NS	ND	NS	0.10
2/9/2010	NS	ND	ND	2.50
4/6/2010	0.39	NS	NS	0.50
7/7/2010	NS	1.70	2.00	5.00
9/28/2010	1.20	NS	NS	2.50
12/1/2010	NS	ND	1.50	2.50
3/17/2011	NS	0.17	NS	0.50
12/1/2010	ND	NS	ND	0.50
6/16/2011	ND	ND	ND	2.50
9/28/2011	ND	2.10	ND	0.50
12/14/2011	NS	2.70	2.10	0.50
4/3/2012	1.20	1.00	0.75	0.10
6/13/2012	5.00	1.40	NS	0.15
10/3/2012	1.40	NS	1.90	0.15
12/4/2012	0.41	0.40	0.94	0.10
3/13/2013	0.24	0.90	1.00	0.10
6/13/2013	2.00	NS	NS	0.10
10/15/2013	0.25	0.43	0.65	0.10
1/7/2014	0.28	ND	0.15	0.10
3/18/2014	ND	0.15	0.17	0.10
6/13/2014	0.43	0.51	NS	0.10
10/1/2014	ND	0.26	0.49	0.10
12/10/2014	0.28	NS	NS	0.10
3/11/2015	ND	0.20	0.22	0.10
6/23/2015	0.48	0.37	1.5	0.10
9/23/2015	0.61	0.26	0.32	0.10
3/24/2016	ND	1.30	0.44	0.10
6/16/2016	ND	0.21	0.47	0.10
9/26/2016	0.63	NS	1	0.10
3/30/2017	0.17	0.18	0.31	0.10
6/8/2017	0.82	ND	ND	0.10
9/21/2017	0.73	0.24	0.84	0.10
3/26/2018	0.58	0.68	0.55	0.10
6/28/2018	NS	NS	2.00	0.10
9/25/2018	0.26	NS	1.7	0.10

Table 4 - Chloride Concentration Measured in Runoff				
Sample Location	Collection Date	Collection Time	Result (mg/L)	PQL (mg/L)
K-R-1 Runoff	11/11/2009	10:00	2.90	2.00
K-R-2 Runoff	11/11/2009	16:00	5.80	2.00
K-R-3 Runoff	11/11/2009	15:40	19.00	2.00
K-R-3 Runoff	7/6/2010	16:40	2.50	5.00
K-R-1 Runoff	9/28/2010	14:15	6.80	5.00
K-R-3 Runoff	12/1/2010	14:10	1.50	0.50
K-R-1 Runoff	6/16/2011	18:00	ND	2.50
K-R-3 Runoff	6/16/2011	8:00	8.40	2.50
K-R-1 Runoff	12/14/2011	11:45	2.10	0.50
K-R-3 Runoff	12/14/2011	13:15	0.30	0.50
K-R-1 Runoff	4/3/2012	13:00	15.00	1.00
K-R-2 Runoff	4/3/2012	14:30	4.40	0.10
K-R-3 Runoff	4/3/2012	15:00	2.00	0.10
K-R-1 Runoff	10/3/2012	12:45	6.30	0.15
K-R-2 Runoff	10/3/2012	14:20	4.10	0.15
K-R-3 Runoff	10/3/2012	15:00	1.50	0.15
K-R-1 Runoff	12/4/2012	8:00	5.00	0.10
K-R-3 Runoff	12/4/2012	9:30	2.20	0.10
K-R-1 Runoff	10/15/2013	11:00	1.60	0.10
K-R-2 Runoff	10/15/2013	13:00	0.49	0.10
K-R-3 Runoff	10/15/2013	14:00	0.55	0.10
K-R-3 Runoff	3/18/2014	13:00	0.44	0.10
K-R-1 Runoff	10/1/2014	11:30	1.10	0.10
K-R-2 Runoff	10/1/2014	12:30	0.80	0.10
K-R-3 Runoff	10/1/2014	13:00	0.42	0.10
K-R-3 Runoff	3/11/2015	9:30	0.22	0.10
K-R-1 Runoff	9/23/2015	12:00	1.30	0.10
K-R-2 Runoff	9/23/2015	13:00	0.53	0.10
K-R-3 Runoff	9/23/2015	14:11	0.57	0.10
K-R-1 Runoff	3/24/2016	15:00	0.56	0.10
K-R-2 Runoff	3/24/2016	14:15	0.60	0.10
K-R-3 Runoff	3/24/2016	15:40	1.30	0.10
K-R-1 Runoff	9/26/2016	12:00	3.90	0.10
K-R-3 Runoff	9/26/2016	14:00	0.37	0.10
K-R-1 Runoff	3/30/2017	10:00	2.6	0.10
K-R-3 Runoff	3/30/2017	8:30	5.3	0.10
K-R-1 Runoff	9/25/2018	10:00	1.2	0.10
K-R-2 Runoff	9/25/2018	8:30	0.66	0.10

Figure 1: Kane Springs Valley Equipment Locations



Scale is 1:250,000

5 0 5 10 15

Miles

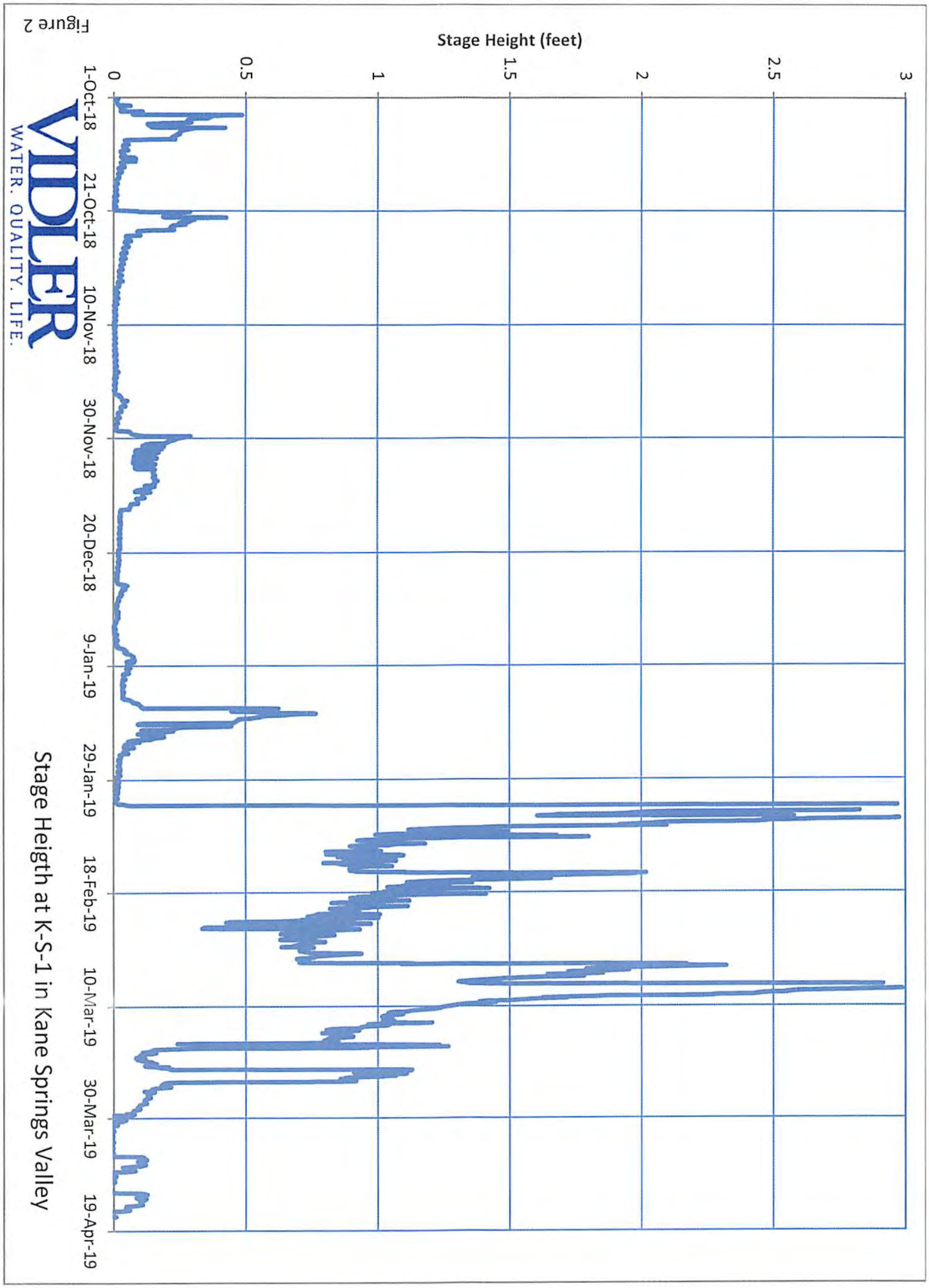


Figure 2
Stage Height (feet)
0
0.5
1
1.5
2
2.5
3
1-Oct-18
21-Oct-18
10-Nov-18
30-Nov-18
20-Dec-18
9-Jan-19
29-Jan-19
18-Feb-19
10-Mar-19
30-Mar-19
19-Apr-19
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Stage Heigth at K-S-1 in Kane Springs Valley

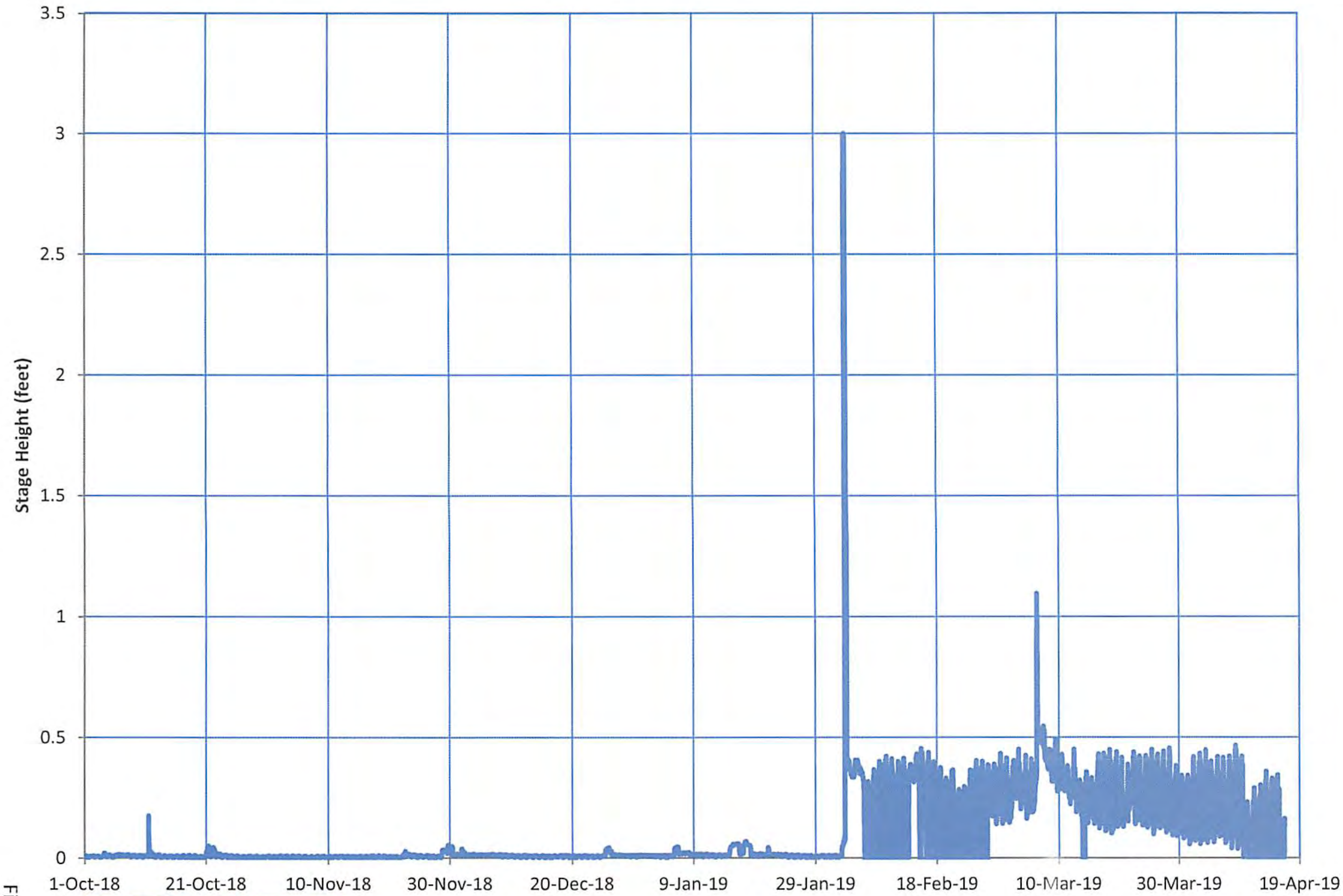

Figure 3

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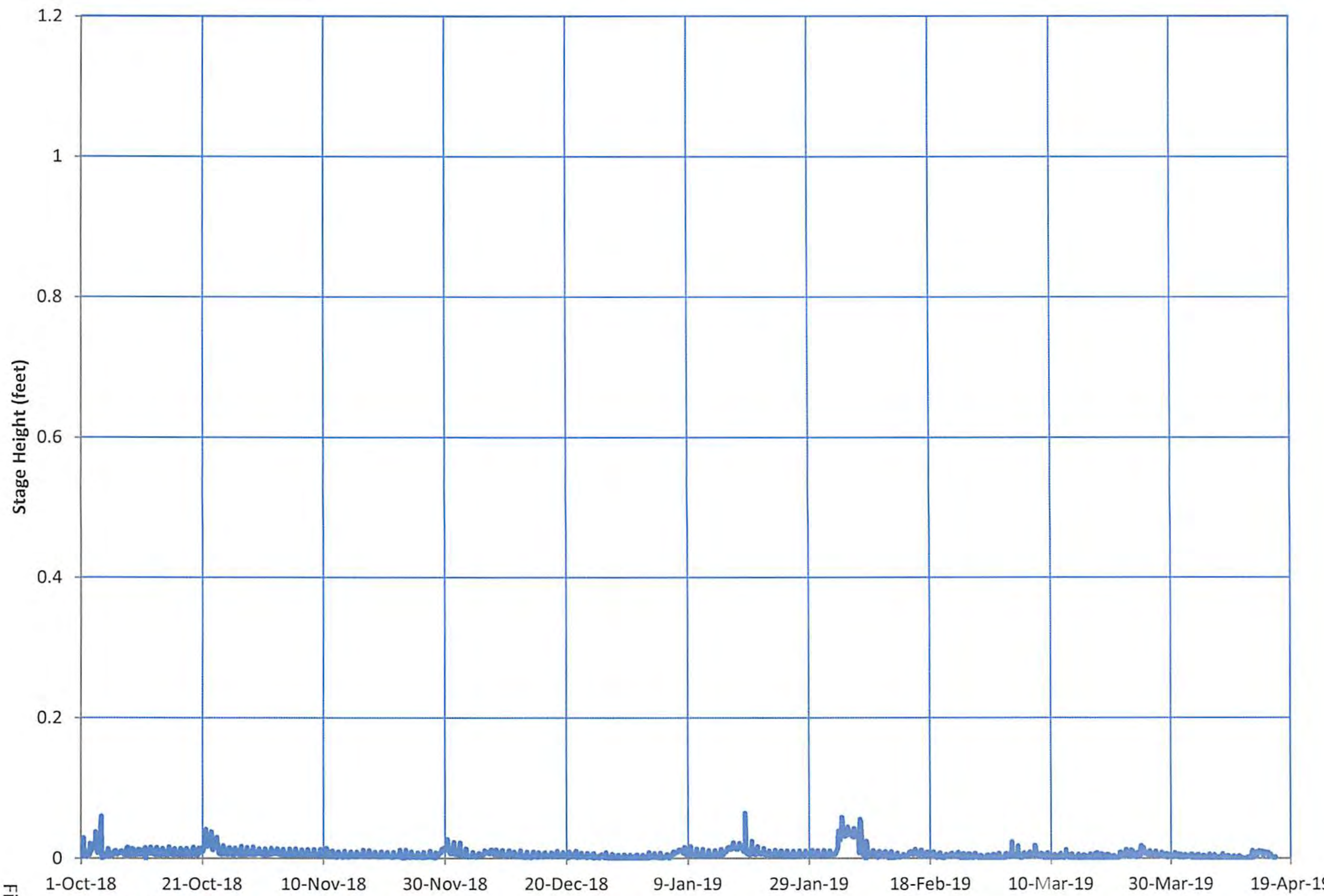
Stage Height at K-S-2 in Kane Springs Valley



Stage Height at K-S-3 in Kane Springs Valley

Figure 4

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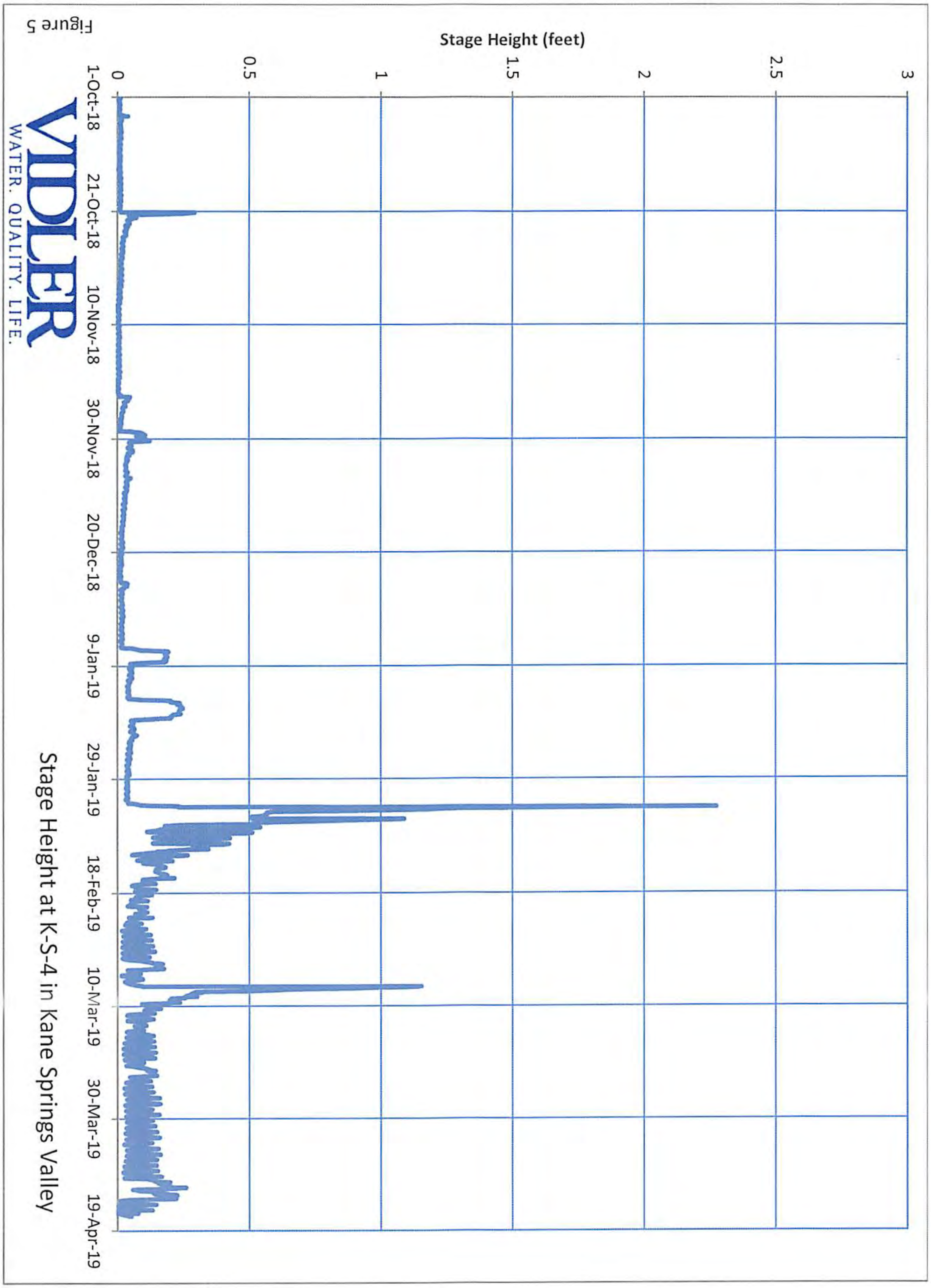
Figure 5
Stage Height at K-S-4 in Kane Springs Valley
Stage Height (feet)
0
0.5
1
1.5
2
2.5
3
1-Oct-18
21-Oct-18
10-Nov-18
30-Nov-18
20-Dec-18
9-Jan-19
29-Jan-19
18-Feb-19
10-Mar-19
30-Mar-19
19-Apr-19
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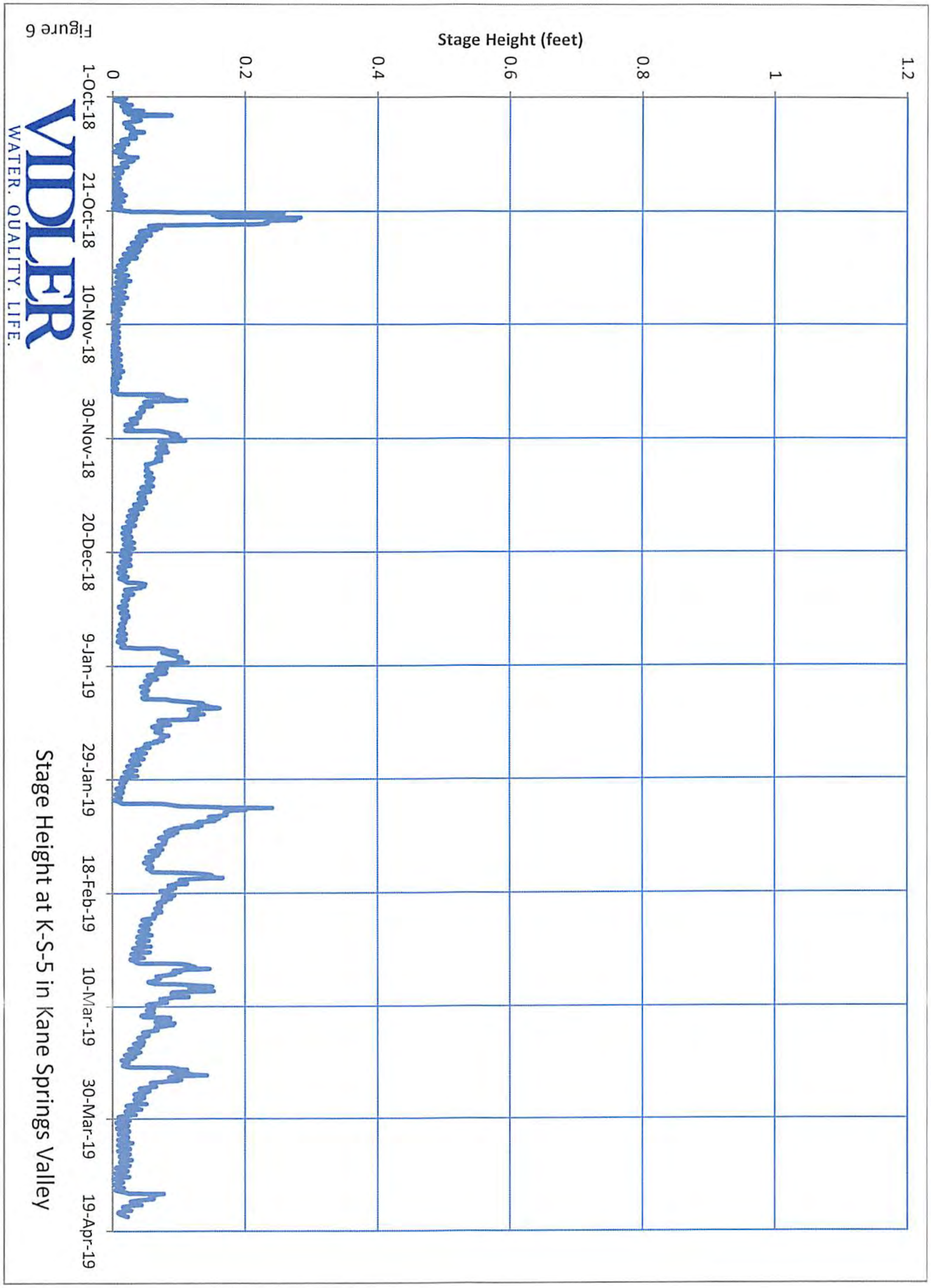
Stage Height at K-S-5 in Kane Springs Valley
Stage Height (feet)
0
0.2
0.4
0.6
0.8
1
1.2
1-Oct-18
21-Oct-18
10-Nov-18
30-Nov-18
20-Dec-18
9-Jan-19
29-Jan-19
18-Feb-19
10-Mar-19
30-Mar-19
19-Apr-19
Figure 6
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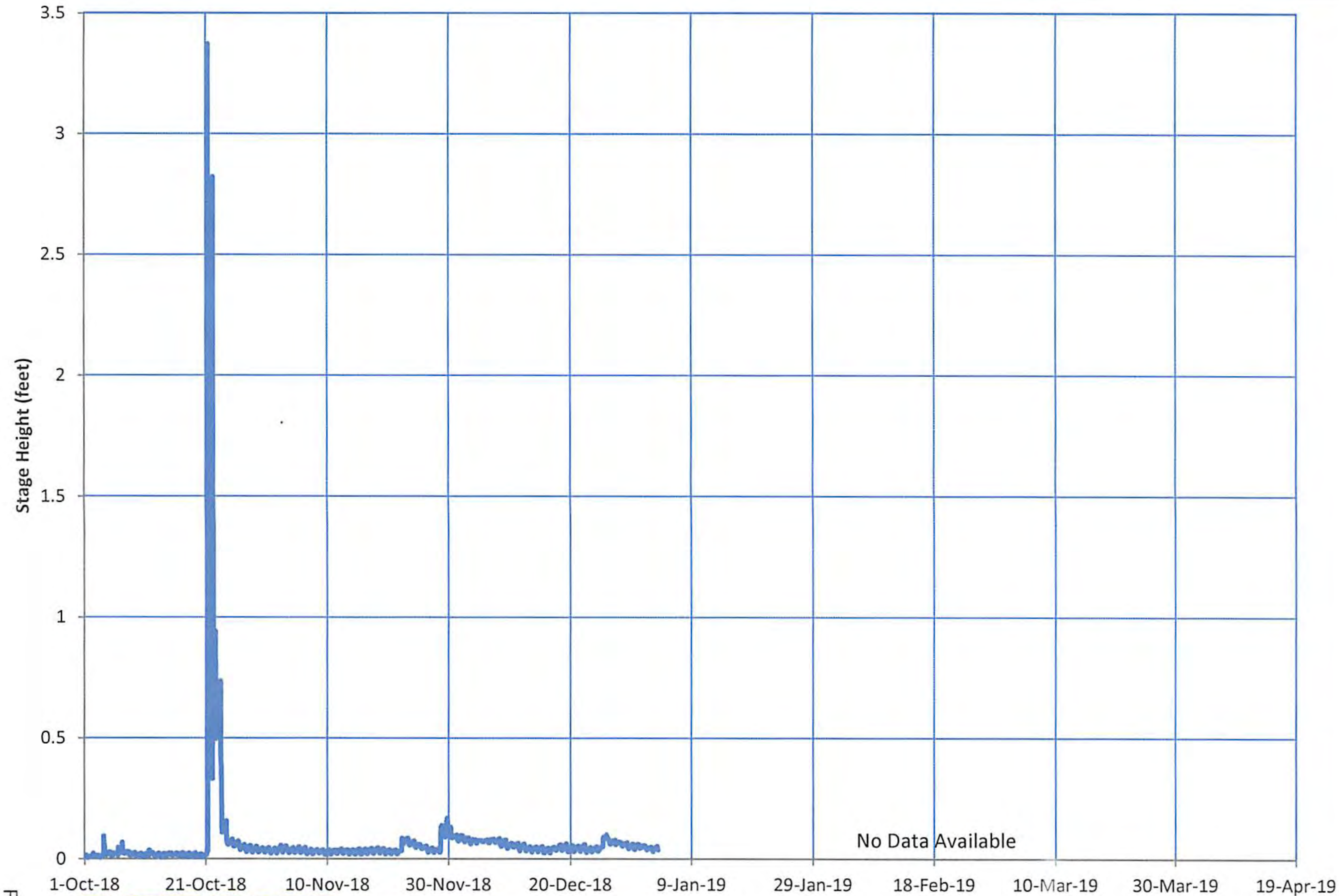

Stage Height at K-S-6 in Kane Springs Valley

Figure 7

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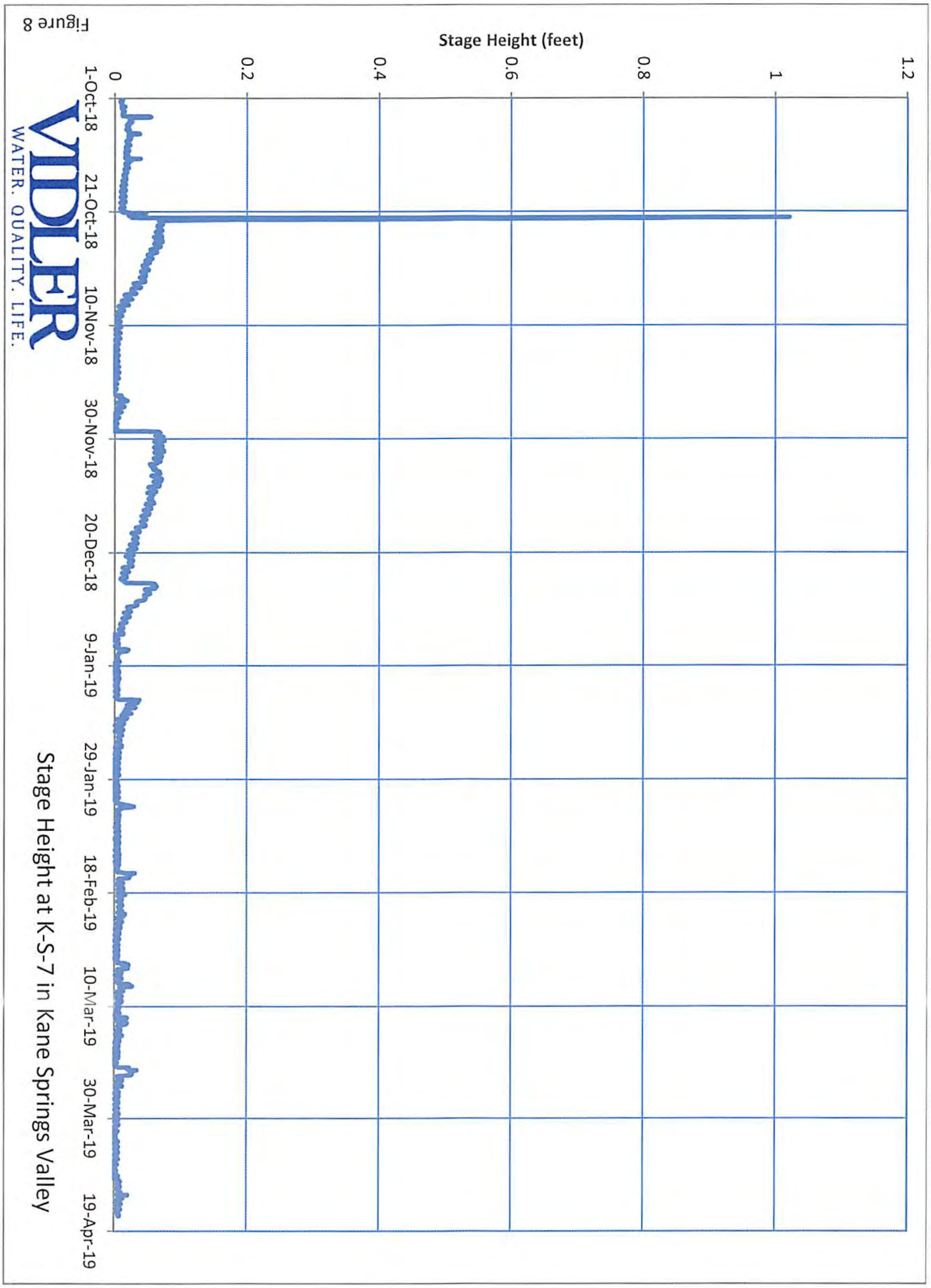
Figure 8
Stage Height (feet)
0
0.2
0.4
0.6
0.8
1
1.2
1-Oct-18
21-Oct-18
10-Nov-18
30-Nov-18
20-Dec-18
9-Jan-19
29-Jan-19
18-Feb-19
10-Mar-19
30-Mar-19
19-Apr-19
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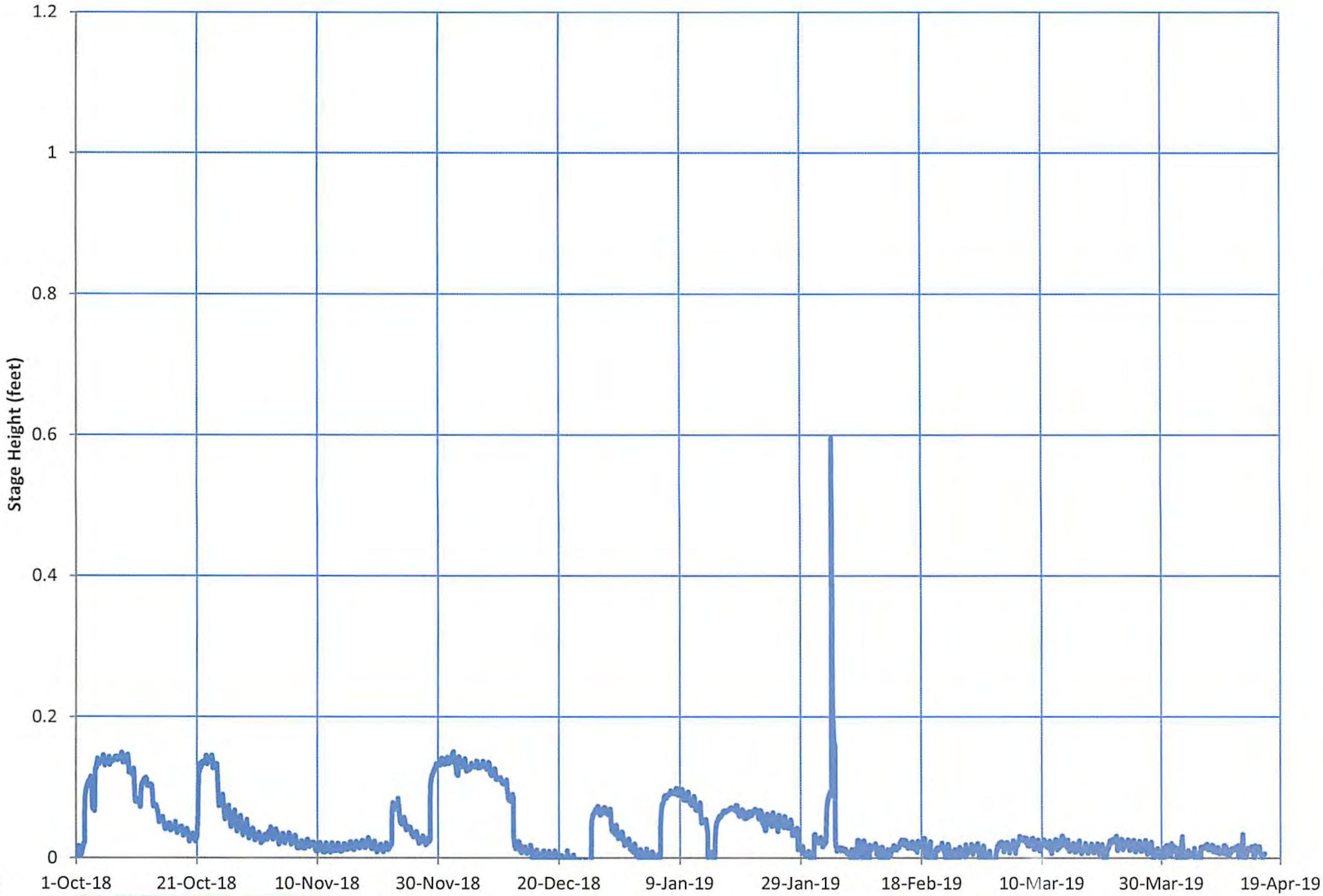
Stage Height at K-S-7 in Kane Springs Valley



Stage Height at K-S-8 in Kane Springs Valley

Figure 9

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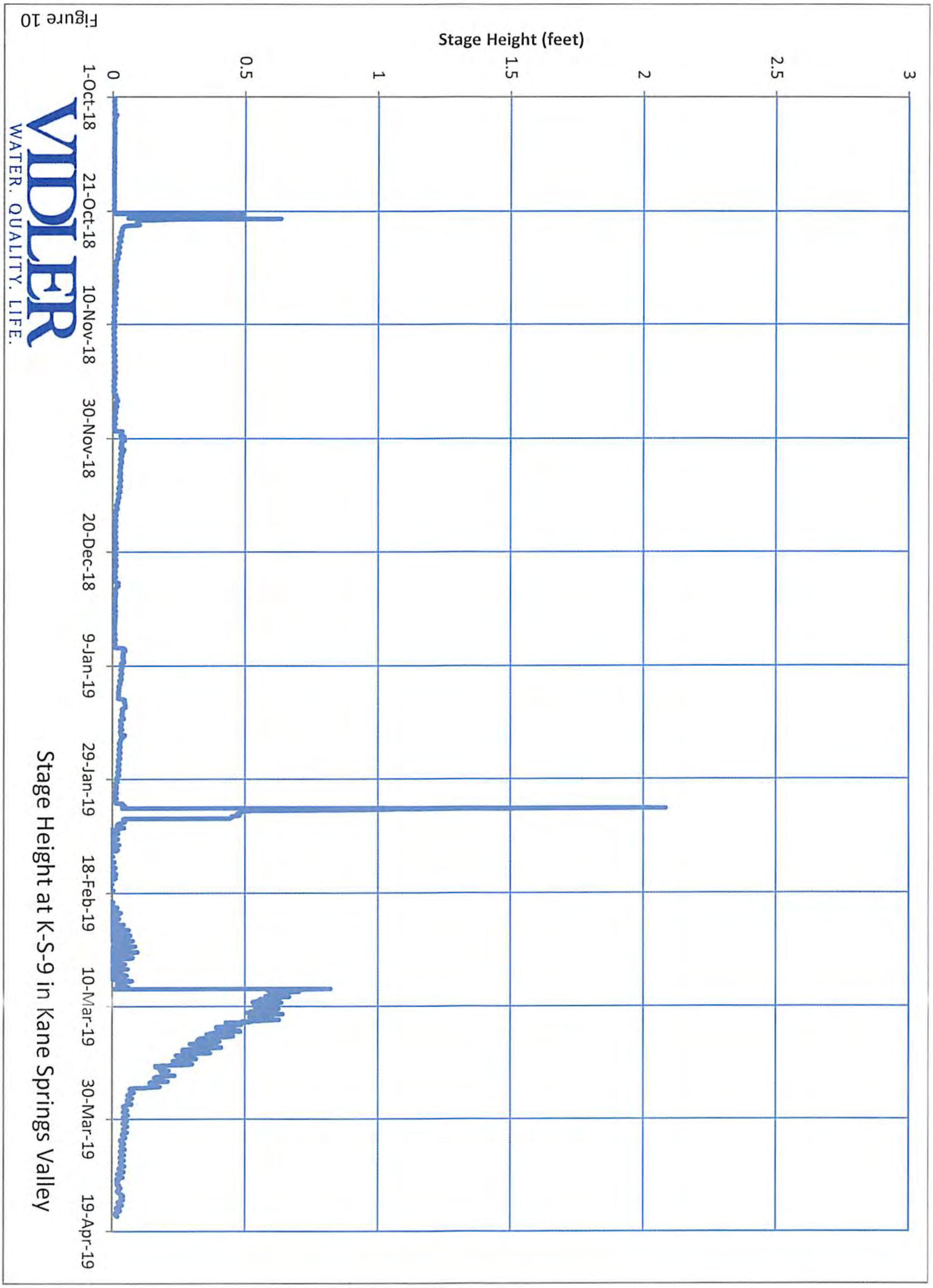
Figure 10
Stage Height at K-S-9 in Kane Springs Valley
Stage Height (feet)
0
0.5
1
1.5
2
2.5
3
1-Oct-18
21-Oct-18
10-Nov-18
30-Nov-18
20-Dec-18
9-Jan-19
29-Jan-19
18-Feb-19
10-Mar-19
30-Mar-19
19-Apr-19
VIDLER
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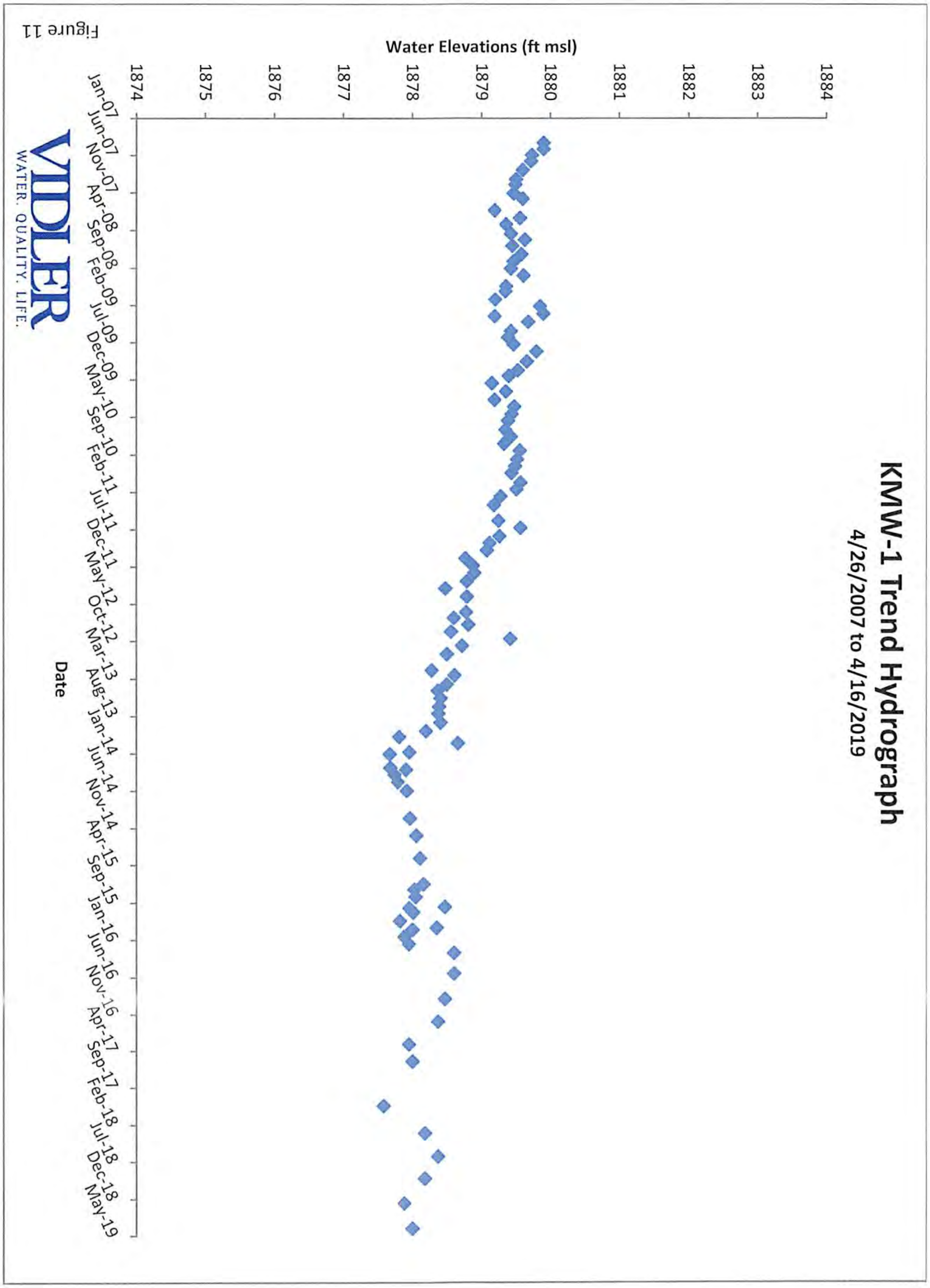
KMW-1 Trend Hydrograph
4/26/2007 to 4/16/2019
Water Elevations (ft msl)
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
Jan-07
Jun-07
Nov-07
Apr-08
Sep-08
Feb-09
Jul-09
Dec-09
May-10
Sep-10
Feb-11
Jul-11
Dec-11
May-12
Oct-12
Mar-13
Aug-13
Jan-14
Jun-14
Nov-14
Apr-15
Sep-15
Jan-16
Jun-16
Nov-16
Apr-17
Sep-17
Feb-18
Jul-18
Dec-18
May-19
Date
VIDLER
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Figure 11

CH2MHILL

Hydrologic Assessment of Kane Springs

Hydrographic Area (206):

Geochemical Framework

Presentation to the Office of Nevada State Engineer

Prepared for: Lincoln County Water District and Vidler Water Company, Inc.

April 2006

Hydrologic Assessment of Kane Springs Valley Hydrographic Area (206):

Geochemical Framework

Presentation to the Office of the Nevada State Engineer

Prepared for: Lincoln County Water District and Vidler Water Company

CH2M HILL

April 2006

The locations of the wells and springs in the hydrographic areas of the Colorado River Basin in Nevada for the 99 available chemical analyses are shown on Figure 1a through 1c and listed in Table 1. Subsequent base maps for individual parameters will use only figures 1a and 1c for illustration purposes. Green colored circles are spring locations and red inverted triangles are well locations. These data are used to determine the geochemical framework within which to characterize the Kane Springs Valley. The base of the chemical analyses is from Thomas, Calhoun and Apambire (2001) (all analyses with a site number). supplemented with chemical analyses from other sources noted in the "Sources" column and included in the references.

Total dissolved solids of groundwater from the Kane Springs Valley (KSV) is higher than the TDSS of the Coyote Springs Valley (CSV) but appears to become relatively rapidly attenuated within the CPV groundwater system. These relationships indicate relatively rapid mixing and dilution of groundwater moving from KSV into the CSV system. Figure 2a and 2b are maps showing the calculated total dissolved solids sum (TDSS) concentrations for each of the locations with sufficient water chemistry to calculate the TDSS. The TDSS was calculated by summing the silica, calcium, magnesium, sodium, potassium, bicarbonate, sulfate and chloride. TDSS generally increases relatively gradually south from Pahranagat Valley through the Coyote Springs Valley to the Muddy Springs Area. The KSVproduction well, KPW-1 has a TDSS of 653 mg/L. The downgradient CSV well CSVM-4 has 564 mg/L suggesting a relatively rapid decrease in TDSS in groundwater moving from KSV to CSV. At, and south of, the Muddy River Springs Area (MRSA) TDSS increases from between about 250 and 660 milligrams per liter (mg/L) in the CSV to between 500 and 4,000 mg/L. VF-2 Spring with a TDSS of 9,970 mg/L has the highest TDSS.

The temperature of the KSV well KPW-1 of 57 degrees Celsius (°C) indicates that the KSV has a high thermal gradient. The average temperature of the other 79 analyses ranges from 7 to 41.6°C with a mean temperature of 24.3°C. This next highest temperature (41.6°C) is from a sample of groundwater from CSV well CSVM-4 downgradient of KPW-1.

TABLE 1
List of locations and parameters included in the geochemical framework assessment for the Kane Springs Valley Hydrographic Area (206)

Sequential Number	Location	Type	Valley	Hydro Area	Latitude	Longitude	Site	Source	pH	Spec. Cond	Temp (°C)	Deuterium δD	Oxygen-18 δO18	Carbon-13 δC13	Carbon-14	Apparent Age	Tritium	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica	Fluoride	Total Diss. Solids Sum	Arsenic AS	Dissolved Iron	Dissolved Manganese	%RCAGW Continuous	%RCAGW Discon-tinuous	Sequential Number
					(degrees)	(degrees)				(µS/m)		(permil)	(permil)	(permil)	(pmc)	(yrs BP)	(TU)	Milligrams per Liter										Milligrams per Liter					
1	Pahroc Sprin	Spring	PHV	209	37.6642	-114.86	131	A				-83	-12.5																		20		1
2	Hiko Spring	Spring	PHV	209	37.596333	-115.214444	122	A	7.7		26.8	-108.7	-14.4	-6.3				46	23	27	7	267	36	22	32.7	0.8	327				90		2
3	Crystal Spring	Spring	PHV	209	37.531389	-115.23277	116	A	7.5	454	27.3	-108.7	-14.4	-6.2	8.4	20,500	2	44	22	24	5	255	33	9	24.6	0.3	280				99		3
4	Sturtle Canyon	Spring	PHV	209	37.492222	-115.088056	112	A	7.9		22	-93.4	-13.1	-11.9				45	11	17	1	207	12	3	49.6	0.1	242				44		4
5	Ash Spring	Spring	PHV	209	37.463611	-115.191667	110	A	7.4	460	33.8	-109	-14.1	-2.6	6.3	22,900	2	50	14	30	7	264	35	10	30	0.8	308				100		5
6	Little Ash Spring	Spring	PHV	209	37.463889	-115.191667	111	A	7.4	497	36.6	-107.2	-14.2	-4.6				61	15	30	6	250	35	15	30.3	4.8	307				94		6
7	Hells Acres	Spring	PHV	209	37.460278	-115.124722	109	A	8.3	366	13	-93	-12.3					45	9	21	2	198	20	8	39		243				43		7
8	Lone Tree Spring	Spring	PHV	209	37.201944	-115.058889	96	A	7.5		11	-89.5	-10.9	-5.8				45	43	184	20	539	145	60							30		8
9	Maynard Lake	Spring	PHV	209	37.191667	-115.033889	94	A	7.9		9.6	-94	-12.3					43	23	114	14	405	88	30							48		9
10	Spencer Well	Well	PHV	209	37.395	-115.180278	106	A	7.7		19	-104.1	-13.7	-9.3				54	44	119	15	468	158	48	59.8	1.8	729				83		10
11	Alamo City Well	Well	PHV	209	37.362222	-115.168333	104	A	7.8		18.5	-101.1	-13.6	-10.9				61	68	96	14	454	189	66	59.1	1.3	756				72		11
12	US Fish and Game	Well	PHV	209	37.273056	-115.118333	99	A	7.8		14	-87.3	-10.2	-9.1				79	64	130	19	628	192	83	48.1	1.6	919				23		12
13	Coyote Spring	Spring	DLV	181	38.0322	-114.8617	169	A	7.3	427	9	-95	-12.8					52	8	26	5	198	26	20	59		295				50		13
14	Black Rock Spring	Spring	DLV	181	37.911944	-114.918056	158	A				-94	-12.3																		48		14
15	Mustang Spring	Spring	DLV	181	37.7358	-114.9205	135	A	7	844	10	-91	-12.8					111	8	17	6	348	68	11	58		442				36		15
16	Fugro Dry Lake	Well	DLV	181	38.145833	-114.893333	179	A	7.1	740	27.6	-108	-14.2					73	29	20	7		27	6	25	0.6					96		16
17	SK-18	Well	DLV	181	37.71	-114.8	134	A				-85																			50		17
18	U.S. Air Force	Well	DLV	181	38.70389	-114.75222		F	7.9	480	24							20	10	76	5.2	218	44	21									18
19	Grassy Spring	Spring	Del	182	37.6408	-114.7909	117	A	7.4	638	13	-85	-10.9					65	15	31	1	289	68	37	33		395				14		19
20	Stock Well	Well	Del	182	37.349444	-114.758333	101	A				-83																			25		20
21	U.S. Air Force	Well	Del	182	38.445	-114.75889		F		285	26							21	6.2	42	2.7	152	23	6.1	31	0.6	206						21
22	Upper Riggs	Spring	KS	206	37.368333	-114.647778	105	A			10.6	-88	-11.9																		25		22
23	Boulder Spring	Spring	KS	206	37.27	-114.645556	98	A	7.9		16.8	-87.3	-12.3					21	5	12	2	100	8	6	41	1.7	146				23		23
24	Kane Springs	Spring	KS	206	37.248111	-114.705833	97	A	7.2		16.4	-86.8	-12.3					44	13	20	6	210	14	17	60	2.8	279				21		24
25	Grapevine Spring	Spring	KS	206	37.135556	-114.700556	93	A	7.3		18.6	-87.6	-11.8					75	22	17	2	280	40	27	22	0.9	345				24		25
26	Willow Spring	Spring	KS	206	37.092778	-114.831111	92	A	7.5		17.4	-87.3	-11.8					20	3	56	6	140	34	22	65	1.1	276				23		26
27	KPW-1	Well	KS	206				C	7.13	1,086	57	-104	-14	-2.8	2.7	29,900		48	14	150	18	341	140	63	49	8.1	653	46	0.1	0.01	82		27
28	Lamb Spring	Spring	CSV	210	38.945	-115.105833	88	A			13.5	-92.5	-13.2					37	41	9	1		24	9	12	0.2					41		28
29	Warm Spring	Spring	CSV	210	36.641667	-115.07	62	A	8.2	320	7	-81	-10.6					71	13	10	2	585	6	5	24	0.2	426				0		29
30	Mormon Well	Spring	CSV	210	36.643889	-115.097778	53	A	7.8	669	12.1	-91.8	-12.7	-9.9			41	78	41	12	1	395	22	18	16.3	0.1	382				39		30
31	CSVM-3	Well	CSV	210				C	8.2	700	25.4	-98	-13.1	-5.8	17.9	14,200		46	20	71	12	293	73	29	44	1.3	442	9.5	0.1	0.01	61		31
32	CSVM-7	Well	CSV	210				C	7.52	538	24.8	-93	-12.8	-5.9	7.9	21,000		38	16	44	9.6	213	45	21	32	1.1	312	12	0.1	0.039	43		32
33	CSVM-4	Well	CSV	210				C	7.45	1,031	41.6	-102	-13.8	-4.1	4.2	28,200		40	13	130	16	311	120	53	37	4.6	564	5	0.8	0.004	76		33
34	CE-VF-2 Well	Well	CSV	210	36.875	-114.945556	81	A	7.4	800	34	-101	-13	-8.1	7	22,000		47	21	81	11	303	90	34	34	1.7	470				71		34
35	USGS-MX CE,VF-1	Well	CSV	210	36.875278	-114.945278	82	A	7	460	28	-94	-12.7					41	8	34	1	158	20	42	14	0.5	238				48		35
36	CSVM-6	Well	CSV	210				C	7.21	1,014	37.3	-90	-13	-5.2	9.3	19,600		45	19	73	14	305	93	35	34	2.2	467	9.7	0.1	0.021	64		36
37	MX-5	Well	CSV	210	36.795555	-114.8922		B	7.2		34.7	-99.5	-12.9					48.7	21	83.7	12.8	294	93.1	35.7	35.7	2	478	17.9	1.2	0.1	68		37
38	Fugro CV Dee	Well	CSV	210	36.795558	-114.802222	77	A	7.2	720	31	-93.5	-12.9		8.1	20,800	2	48	20	76	11	300	100	34	33	1.9	472				68		38

TABLE 1
List of locations and parameters included in the geochemical framework assessment for the Kane Springs Valley Hydrographic Area (206)

Sequential Number	Location	Type	Valley	Hydro Area	Latitude	Longitude	Site	Source	pH	Spec. Cond	Temp (°C)	Deuterium δD	Oxygen-18 δO18	Carbon-13 δC13	Carbon-14	Apparent Age	Tritium	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica	Fluoride	Total Diss. Solids Sum	Arsenic AS	Dissolved Iron	Dissolved Manganese	%RCAGW Continuous	%RCAGW Discontinuous	Sequential Number
					(degrees)	(degrees)				(µS/cm)		(permil)	(permil)	(permil)	(pmc)	(yrs BP)	(TU)	Milligrams per Liter										Milligrams per Liter					
39	MX4 and MX-5	Well	CSV	210	36.79556	-114.892		B	7.3	760	34.7	-101	-13		7.6	21,300		46	20	81	11	295	105	34	33	1.9	478				71		39
40	MX-4, CE-DT-4	Well	CSV	210	36.765556	-114.892222	76	A	7.4		34	-102.5	-13					46	19	84	11	294	110	35	33	1.9	485				77		40
41	CSI-1	Well	CSV	210	36.388997	-114.923942		D	7.65		33.3							52.1	21.4	81.3	11.8	293	101	36	32	2.06	482	14	0.079	0.016			41
42	CSI-2	Well	CSV	210	36.60039	-114.90272		E	7.39		34							53.6	22	91.4	12.1	302	97	47	33	2.17	507	14	0.071	0.015			42
43	U.S. Air For	Well	CSV	210	36.79667	-114.89306		F										51	20	83	11	306	102	37	34	2.1	491						43
44	CSVM-5	Well	CSV	210				C	7.49	564	24.5	-93	-12.8	-7	8	20,900		45	30	220	12	244	82	18	22	0.69	514	1.5	0.1	0.029	43		44
45	CSV-3 Well	Well	CSV	210	36.690833	-114.925	60	A	7.4	650	41	-75	-10.4					51	25	38	10	239	54	26	24	1.2	348				-21	-16	45
46	CSV-3	Well	CSV	210	36.690833	-114.925		B	7.45	638	41	-75	-10.6	-5.4	3.4	28,000		58	26	35	11	220	54	22	22	1.1	339	15	0.1	0.044	-21	-15	46
47	CSVM-2	Well	CSV	210				C	7.12	1,280	37.7	-96	-13.2	-3.3	2.5	30,500		86	31	60	15	232	210	57	27	1.5	602	1.5	0.1	0.047	54	65	47
48	Iverson's Sp	Spring	Mud	219	36.710278	-114.711944	66	A				-97																			57	69	48
49	M-8 Spring	Spring	Mud	219	36.720833	-114.7275	68	A				-99	-12.8																		64	77	49
50	Big Muddy Spring	Spring	Mud	219	36.722222	-114.713333	69	A	7.3	930	32.1	-97.9	-12.9	-6	7	22,000	1	64	27	97	11	276	177	61	29.1	2.1	604				60	73	50
51	Pederson's Warm	Spring	Mud	219	36.71	-114.715	67	A	7.2	1,012	32.2	-97.5	-12.9					71	26	102	9	270	190	60	153.5	2.1	747				59	71	51
52	M-9 Spring	Spring	Mud	219	36.725833	-114.727222	70	A				-96.5	-12.5																		55	67	52
53	EH-4 Weiser	Well	Mud	219	36.706389	-114.716111	53	A	8.3	920	22.8	-98	-13					49	30	90	12	245	171	57	28		560				61	73	53
54	USGS CSV-1	Well	Mud	219	36.786944	-114.861944	71	A			29.6	-103	-13.6					260	93	160	30		1300	39	19	1.2					79	92	54
55	CE-DT-6 Well	Well	Mud	219	36.767778	-114.786944	72	A	7.2	980	33.5	-96	-13	-6	8.4	20,500	1.6	58	25	88	11	272	160	53	30	2.1	581				61	73	55
56	Arrow Canyon	Well	Mud	219				G	7.5	690	31.7							64	22	97	12	271	163	58		2.2							56
57	EH-5A	Well	Mud	219	36.73278	-114.743333		B	8.2	890	26	-101.5	-13.2					49	28	96	12	255	164	54	30		549				73	87	57
58	EH-3	Well	Mud	219	36.692222	-114.525556		B	7.8	3,700	24.1	-91	-12.7					511	201	170	22	123	2100	194	15		3275				38	48	58
59	CSV-2 Well	Well	Mud	219	36.780556	-114.722222	76	A	7.4	996	27	-98	-12.9	-5.5	8.4	20,500	4	60	27	100	10	276	160	61	30	2.3	586				61	73	59
60	Bishop Spring	Spring	MVW	205	37.418611	-114.840556	107	A				-85.5	-11.7																		16	25	60
61	Davies Spring	Spring	MVW	205	36.965556	-114.601944	90	A			14.3	-89	-12.5																		29	38	61
62	Caliente City	Well	MVW	205	37.615833	-114.513333	124	A			14.3	-89	-12.4																		29	38	62
63	LDS Well	Well	MVW	205	37.615833	-114.513333	125	A	7.5		24							53	16	69	20	337	54	23	95	1.4	499						63
64	Miller Well	Well	MVW	205	37.615833	-114.513333	126	A	7.8		39.7							489	6	47	16	254	44	20	113	1.4	844						64
65	Bradshaw Well	Well	MVW	205	37.349167	-114.543889	102	A	7.3	1,100	14.8	-88.5	-11.4					65	28	120	11	550	78	62	63	2.3	710				27	37	65
66	Railroad Well	Well	MVW	205	37.351111	-114.533889	103	A	7.8	730	16	-86	-11.6					42	14	98	9	300	60	42	51	2.3	466				18	27	66
67	Randono Well	Well	MVW	205	37.323889	-114.502222	100	A				-87.5	-11.7																		23	33	67
68	Jenson Well	Well	MVW	205	37.184167	-114.464444	95	A	7.7		18	-88.5	-11.5					65	14	100	7	340	80	45	56	2.1	527				27	37	68
69	UP Well at Carp	Well	MVW	205	37.083	-114.48	91	A																									69
70	Railroad Well	Well	MVW	205	36.813611	-114.653889	80	A	8	1,300	22.8	-97.5	-12.5					84	31	150	19	64	530	52	23	1.6	941				59	71	70
71	Th20 Nevada	Well	MVW	205	36.606944	-114.5025	62	A	7.1	3,500	24							195	147	497	13	475	1240	335	65		2730						71
72	EH-6 Weiser	Well	MVW	205	36.681667	-114.57	59	A	7.7	3,000	24.8	-99.5	-13.9					341	131	274	31	178	1800	41	13		2720				66	79	72
73	EH-8 Weiser	Well	MVW	205	36.673889	-114.575833	57	A				-96.5	-13.7																		56	67	73
74	DLLLC Hidden	Well	GV	218	36.4934	-114.92657	37	A				-97	-12.9																		57	69	74
75	Dry Lake Valley	Well	GV	218	36.455	-114.843889	34	A	7.3	1400	29	-97.5	-13.3	-4.2	3	29,000	7	110	48	120	13	210	360	170	21	2.1	947				59	71	75
76	US Lime Well	Well	GV	218	36.391389	-114.903889	27	A	7.4	1500	24	-97	-12.8	-4.9				120	47	140	1	226	370	180	23	1.8	924				57	69	76
77	Unnamed Well	Well	GV	218	36.362778	-114.916667	24	A	7.3		28.5	-98	-13.7					123	46	140	16	230	360	190	21	1.6	1011				54	65	77
78	GP Apex Well	Well	GV	218	36.341111	-114.926667	17	A	7	1700	31	-97.2	-13.5	-5.5				120	47	130	13	226	380	200	23	1.4	1026				68	70	78
79	Mirant3 Apex	Well	GV	218				H	7.45	1400		-100	-13.6					100	47	96	11	180	280	140	7.2	1.6	753	4.8	0.19		68	61	79

TABLE 1
List of locations and parameters included in the geochemical framework assessment for the Kane Springs Valley Hydrographic Area (206)

Sequential Number	Location	Type	Valley	Hydro Area	Latitude	Longitude	Site	Source	pH	Spec. Cond	Temp (°C)	Deuterium δD	Oxygen-18 δO18	Carbon-13 δC13	Carbon-14	Apparent Age	Tritium
					(degrees)	(degrees)				(µS/m)		(permil)	(permil)	(permil)	(pmc)	(yrs BP)	(TU)
80	WS-1	Well	GV	216				H	7.41	1220		-95	-13				
81	WS-2	Well	GV	216				H	7.41	1540		-98	-13.8				
82	Kerr McGee	Well	GV	216				H	8.09	1062							
83	USBLM SHV-1	Well	HV	217	36.5525	-114.923611	46	A	7.8	820	25	-90.5	-11.2				
84	NP, EH-2	Well	CW	218	36.647222	-114.843611	54	A	8.2	890	24	-99	-13.1				
85	NP, EH-1	Well	CW	218	36.660278	-114.831111	55	A				-95.5	-13.2				
86	Moapa Well	Well	CW	218	36.531389	-114.796667	41	A				-99	-13.4				
87	Calpine Test Well 1A	Well	CW	218	36.546111	-114.801944	43	A			30.6	-99	-13.5				
88	Cottonwood Spring	Spring	Blk Mtn	215	36.203333	-114.643611	8	A	7.7	3658	15.3	-80	-10.6				
89	Sandstone Spring	Spring	Blk Mtn	215	36.211111	-114.566667	10	A	7	1358	16	-79	-10.5				
90	Valley of Fire Well	Well	Blk Mtn	215	36.4225	-114.547778	31	A	7.4	1100	28	-82	-10.6	-8.6	18.7	13,900	
91	Corral Spring	Spring	Blk Mtn	215	36.370556	-114.46	19	A	7.3	4315	17	-91.5	-12.1				
92	Scirpus Spring	Spring	Blk Mtn	215	36.376944	-114.449167	20	A	7.1	4935	17	-90	-12				
93	VF Spring 1	Spring	Blk Mtn	215	36.401389	-114.401944	28	A	7.1	8520	23	-86	-11.2	-6.8			
94	VF Spring 2	Spring	Blk Mtn	215	36.403278	-114.430556	29	A	7.8	9024	13.8	-92	-11.8				
95	VF Spring 3	Spring	Blk Mtn	215	36.405833	-114.443889	30	A	7.8	3590	16	-93	-12.2				
96	Rogers Spring	Spring	Blk Mtn	215	36.3775	-114.44389		A	7.4	3800	30	-92	-12.2	-4.05	1.8	34,200	
97	Rogers Spring	Spring	Blk Mtn	215	36.3775	-114.443889	21	A	7.2	3807	30.2	-91.7	-12.3	-3.9	2.4	30,000	2
98	Blue Point Spring	Spring	Blk Mtn	215	36.389167	-114.432222		A	7	3800	30	-93	-12.4	-5.3	7.2	21,800	
99	Blue Point Spring	Spring	Blk Mtn	215	36.389167	-114.432222	26	A	7.3	4403	29.9	-92.6	-12.4	-5.8	5.4	24,100	

Sequential Number	Calcium	Magnesium	Sodium	Potassium	Bicarbonate	Sulfate	Chloride	Silica	Fluoride	Total Diss. Solids Sum	Arsenic AS	Dissolved Iron	Dissolved Manganese	%RCAGW Continuous	%RCAGW Discontinuous	Sequential Number
	Milligrams per Liter										Milligrams per Liter					
80	67	53	78	12	170	220	130	13	1.9	678	2.6	0.14		60	62	80
81	120	48	120	14	180	290	160	16	1.5	858	9	0.41		61	73	81
82	106	53	141	13	220	336	205	18	1.47	982		0.65				82
83	33	30	86	12	245	90	64	27	1.2	465				34	44	83
84	38	28	101	16	250	149	55	15		625				64	77	84
85														52	63	85
86														64	77	86
87														64	77	87
88	524	220	200	11	205	2410	64	17.4		3566				-4	4	88
89	208	79	22	5	249	726	17	13.8		1195				-7	0	89
90	118	53	39	8	164	449	21	8.3	0.2	778				4	12	90
91	510	180	340	23	180	1900	400	16	1.6	3439				39	48	91
92	513	196	350	25	286	2040	386	20.4		3653				32	42	92
93														25	35	93
94	590	610	1900	130	240	4800	1900	16	2	9966				39	50	94
95	537	206	295	51	169	2290	278	12.4		3756				43	54	95
96	430	130	290	20	163	1633	333	18	1.4	2942				39	50	96
97	421	137	288	20	161	1656	328	17.6	1.4	2945				38	49	97
98	510	170	360	23	100	2300	600	18	1.4	3961				43	54	98
99	470	160	330	23	180	1900	400	16	1.5	3379				41	52	99

A) Thomas et al., 2001
B) Thomas, et al., 1996
C) URS, 2006
D) Johnson1, 2005
E) Johnson2, 2005
F) USGS, 1984
G) Vidler, 2006
H) Univ. of Arizona, 2006

MAJOR ION CHEMISTRY OF GROUNDWATER

The major ion groundwater chemistry indicates three end-members water chemistry types: calcium-bicarbonate, sodium-bicarbonate and a mixture of calcium-sodium-sulfate water chemistry types. These water chemistry types for the end-members documenting mixing trends in both the springs and wells. Spring water chemistry forms more representative groups within the three end-members indicating more unique end-member representation than groundwater from the wells. Big Muddy Springs and associate springs in the MRSA are intermediate between all three end-members indicating they are a mixture of the three. In other words, the flow at MRSA do not originate from a single source but are a mixture of the three sources. Rogers and Blue Point Springs form a calcium-sodium-sulfate end-member. Groundwater from most of the wells indicates a mixing of the three end-members. Groundwater from only a few wells represent end-member water chemistry types indicating that most of the groundwater from wells are a mixture of water primarily between the regional carbonate aquifer and volcanics in the northern part of this segment of the Colorado River Basins. Beginning with the MRSA, this mixed groundwater continues to mix and is impacted by the evaporite-rich Muddy Creek Formation. The water chemistry reflects groundwater flowpaths presented in Eakin (1966). Northern and central CSV groundwater is primarily a mixture of recharge water from springs and regional carbonate aquifer groundwater in upgradient basins that includes groundwater from KSV. Regional carbonate groundwater from Pahanagat Valley appears to dominate the source of groundwater to CSV. Hidden Valley groundwater is very nearly the same type as the northern and central CSV. There is a water chemistry type trend that is compatible with two major groundwater flowpaths: one from central CSV through not only MRSA to Rogers and Blue Point springs but also one that moves from the central CSV through both Hidden and Garnet valleys.

Figure 3 shows the major ion relationships for all the analyses. Figures 4 and 5 are trilinear diagrams for all the springs and wells, respectively. Figure 6 illustrates the overlapping of well and spring data. Groundwater from the wells shows the mixing between the spring chemical types. Figure 7 shows the three-end-member distributions and their general associations. The calcium-bicarbonate type represents water primarily associated with calcite and carbonate rock. Regional carbonate aquifer groundwater from both the springs and wells forms a major part of this water chemistry type. Water from many mostly higher elevation springs are also represented in this type. The sodium-bicarbonate type represents water primarily in contact with and chemically reflects volcanic rocks. Groundwater from KSV Willow Springs and KPW-1 as well as CSV well CSVM-4 are indicative of this type. Gypsum in the evaporite-rich Muddy Creek Formation significantly impact groundwater within the boundary of this formation beginning with the MRSA and extending through the Rogers Blue Point springs in the Black Mountain Area. The sodium-chloride mineral, halite, is present in the Muddy Creek Formation in the extreme southern part of the Black Mountain Area and is probably responsible for the higher chloride in southern springs. Water from VF Spring 2 probably reflects a near boundary of halite associated with the groundwater.

Figure 8 is a trilinear diagram showing the average water chemistry types for the springs and groundwater from wells in each of the hydrographic areas. Groundwater from Pahranagat Valley springs and wells, KSV springs and groundwater from KPW-1 are most closely associated with northern and central CSV groundwater suggesting that these two valleys provide major sources of recharge to CSV. CSV springs are on a direct mixing line with KSV springs and are also a probable source of groundwater to the CSV mixed water chemistry type. Hidden Valley groundwater is closely associated with the CSV groundwater suggesting groundwater moves to Hidden Valley from CSV with little change in water chemistry. The average for MRSA groundwater includes CSV groundwater mixed with and/or impacted by association with the Muddy Creek Formation. Rogers and Blue Point springs represent the groundwater most impacted by evaporite minerals in the Muddy Creek Formation. Groundwater in Garnet Valley is more strongly influenced by the Muddy Creek Formation than Hidden Valley groundwater.

Major ion chemistry does not indicate the origin of water that is associated with either the volcanic rocks or the Muddy Creek Formation. In other words, it does not separate water from the regional carbonate aquifer that moves into and within the volcanic rocks and Muddy Creek Formation from localized sources of recharge water moving into and within these two major chemistry altering units. From the above water chemistry types on the trilinear diagrams, all of these conditions are probable within the groundwater system. The stable isotope, deuterium is capable of making these distinctions and provides a quantitative estimate of the mixture for each sample location.

DEUTERIUM

Deuterium is not only a naturally occurring stable isotope of hydrogen present in all water it is also an integral part of the water molecules themselves. It initially becomes part of the water molecules forming rain and snow that recharges the groundwater system. The deuterium value in parts per thousand (δD in permil units) depends on the storm tracks from the ocean to where it reaches the land surface and the elevation of the land surface where it infiltrates into the subsurface groundwater system. Deuterium is an excellent marker to track a specific water source because it does not participate in chemical reactions. It retains an essentially constant δD in the groundwater as groundwater moves along and through the various flowpaths. Deuterium in the groundwater packet of recharged water does not change by chemical reactions with the rock but the δD does change if the groundwater mixes with another groundwater with a different δD. The δD change is proportional to the volume and δD of the mixing water.

There have been many excellent groundwater investigations that include this area utilizing deuterium for estimating the groundwater exchanges as the regional carbonate groundwater moves through the basins (Winograd and Friedman, 1972, Kirk and Campana, 1990, Thomas et al., 1996; and Thomas et al., 2001 to name a few). Most recently Smith et al. (2002) concluded that geologically historical "δD values of groundwaters in southern Nevada fall within the range of present-day recharge." This conclusion supports a time independent nature of the δD indicating that recent and ancient deuterium values in water recharging the aquifers in this area have remained essentially the same over time therefore δD depend only on the dominant storm path contributing recharge and land surface elevation.

Figures 8 and 9 show the 88 deuterium analyses for the locations having deuterium data. The δD ranges from -109 permil in the northern Pahranagat Valley spring water to -75 permil in the southern part of CSV. Overall, the δD becomes more positive to the south indicating increasing mixing of recharge water with the regional carbonate groundwater. The KSV well KPW-1 has a δD close to the lowest Pahranagat δD with -104 permil. A duplicate sample analyzed by SNWA reported a δD of -105 permil.

Figure 11 is a standard δD-δoxygen-18 plot showing data points for all the springs and groundwater from wells. Many of the points fall near or on the global meteoric water line (GMWL) defined by [$\delta D=8(\delta^{18}O)+10$] based on worldwide precipitation data (Craig, 1961) indicating some degree of evaporation affecting the precipitation forming recharge to the groundwater system in this area. Only three locations fall to the right of the dashed line defined by [$\delta D=8(\delta^{18}O)+0$] used by Thomas et al., 1996 to "eliminate samples significantly affected by evaporation for use in estimating groundwater flow systems." The three samples are groundwater from the Hidden well SHV-1 very near the line, Pahranagat Valley, Lone Tree Spring in the middle and US FWS Well also in Hidden Valley farthest from the line indicating significant evaporation has affected these waters. Figure 12 shows the average δD-oxygen-18 for each of the hydrographic area wells and springs. These average points also show a considerable amount of mixing of δD values.

Mixing between the regional carbonate aquifer and other recharge sources (annual recharge from precipitation and geologically historical water recharge) is indicated by the intermixture of springs and wells virtually over the entire δD range. If mixing did not occur then the δD plotted on Figures 11 and 12 would consist of essentially two clusters of points with the regional carbonate aquifer clustering around -109 permil plus or minus about 2 permil and the other waters clustering around about -87 permil. Some springs and wells do occur around these δD but by far most of the δD of both wells and springs plot between these two end-members indicating that they represent a mixture of the two.

Mixing naturally occurs between the regional carbonate groundwater and the other sources. Mixing is promoted by geological structures including faults, fractures, joints and karst features in the carbonate rocks. Mixing also occurs by pumping a well completed across two or more contributing depth intervals with different δDs. Figure 12 plots δD against the depth interval that contributed the δD in the California Wash area showing a shallow very high δD of about -70 permil but by a depth of about 400 feet the groundwater becomes considerably lighter with a range of values between -90 and -105 permil. The shallow groundwater is likely geologically recent recharge water and the deeper groundwater is probably the regional carbonate groundwater. Figure 13 shows what the δD of groundwater sampled from open-hole wells completed at deeper and deeper depths from the surface. Mixing between the geologically recent recharge water and the regional carbonate groundwater would occur from this pumped groundwater. The δD would significantly change toward that of the regional carbonate groundwater with completion depth of the well but it would not achieve the full δD signature even with full depth completion. Of course, a sample collected from a well completed over the entire depth during the earliest pumping time would likely have a recharge signature and the signature would become more like the regional carbonate groundwater as pumping continues.

Since the δD of the groundwater appears to be a mixture of regional carbonate groundwater and other waters the proportion of both groundwaters can be calculated by the simple mixing equation:

PRCGW= (δDSample – δDSGW)/(δDRCG – δDSGW) where PRCGW is the percent of regional carbonate groundwater (RCG) in the spring or well sample, SGW; δDSample is the δD for the groundwater sample collected from a spring or well in the area; δDSGW is the δD for the end-member of the other water mixing with the RCG; and δD RCG is the end-member of the regional carbonate groundwater. All that is needed is the end-member δD for the regional carbonate groundwater and the end member δD of recharge water.

The upgradient regional carbonate aquifer is believed to have a δD of about -109 permil represented by the δD of Hiko, Crystal and Ash springs in Pahranagat Valley. This δD is supported by the Fugro Dry Lake Well in Dry Lake Valley with a δD of -108 permil. Groundwater from the KSV well KPW-1 has a δD of -104 permil (-105 permil from SNWA sample) suggesting minor mixture with recharge water from this new carbonate aquifer well. Finally, in the MRSA, groundwater in well EH-5, at a depth of 265 feet, had a δD of -107 permil (Thomas et al., 1996). These spatial relationships indicate a δD for the regional carbonate aquifer is probably between -107 and -109 permil and probably closer to -109 than -107 permil. Therefore, if groundwater in the regional carbonate aquifer forms a continuous flow from Pahranagat Valley and above to all southern basins without mixing with another groundwater along the way then this end-member has a δD of about -109 permil. The available δD data indicate that minimal mixing occurs at least between Pahranagat Valley to the MRSA. Data on the carbonate aquifer south of the MRSA is very sparse and available data, for example at Rogers and Blue Point Springs, are highly mixed groundwaters. If the regional carbonate groundwater mixes with other groundwater below the MRSA then it will have a more positive δD. Groundwater from the EH well depth sampling indicates that this may have occurred in California Wash with a probable regional carbonate groundwater shift to a δD of about -105 permil (Figure 12). The Eh-2 well depth distribution clearly indicates that this is a possibility (Thomas et al., 1996). Therefore, a δD of -105 permil is the regional carbonate groundwater end-member δD for the calculated discontinuous groundwater flowpath between the MRSA and Rogers-Blue Point Springs in the Black Mountain Area.

Springs from six of the hydrographic areas cluster around an average δD of -87 permil. Average spring water indicate a surprisingly narrow range of δD with an average of 87.1 per mil. The average δD for spring waters of Delamar Valley is -85; KSV, -87.4; CSV, -88.4; Meadow Valley Wash, -87.2 and California Wash-Black Mountain -87.2 permil. This indicates that a δD value of -87 permil represents an end-member for recharge and therefore, groundwater other than the regional carbonate groundwater in these areas. This end-member δD is used to calculate continuous mixing proportions between the regional carbonate groundwater for all springs and well samples. However, there are a number of analyses below the MRSA with lower δD so a discontinuous groundwater flowpath end-member for this water used a δD of -79 permil.

The above mixing equation was used to estimate the percentage of regional carbonate groundwater for each of the analyses with a δD. Since the average δD is used as end members in the equation, the estimate for some springs will have percentages of regional carbonate groundwater that may be too high. For example, in the high mountain springs of KSV and CSV, the estimated percentages of regional carbonate groundwater may be too high because the regional carbonate groundwater elevation is too low for it to be currently contributing to the spring flow. However, regional carbonate groundwater could still be present in todays spring waters from geologically historical regional carbonate groundwater when its water level could have been higher. Therefore, the estimated regional carbonate groundwater percentages are retained and shown for all samples to be conservative and eliminate bias.

The estimated percentages of regional carbonate groundwater in each water sample with a δD are listed in Table 1 and shown on Figures 15 and 16. These two figures assume a continuous regional carbonate groundwater flow from Pahranagat Valley south through springs in the Black Mountain area using the same end members for the entire flowpath. Figure 17 shows the percentage of regional carbonate groundwater assuming that the δD end members of the regional carbonate groundwater and recharge water change (shift) to -105 and -79 permil, respectively, within and/or downgradient of the MRSA (southern part of the area). This shift in the δD end members results for the discontinuous groundwater flowpath causes the estimated regional carbonate groundwater percentages to be 10 to 15 percent higher than the estimates for the continuous groundwater flowpath.

Figure 18 shows the estimated percentages of regional carbonate groundwater in each well and spring sample for the continuous groundwater flowpath. As would be expected, groundwater from most wells have a higher percentage of the regional carbonate groundwater and most springs have higher percentages of recharge water. Most of the well samples form a trend line of increasing recharge from their high latitude locations to the lowest latitude. This trend line suggests an average increase in recharge of about 0.3 per mile along the groundwater flowpath. The cluster of springs at a latitude of about 36.4 are the Rogers, Blue Point and other springs in the Black Mountain area. They are considerably below the well trend line with an estimated average of about 40 percent regional carbonate groundwater.

Figure 19 separates out the springs for the continuous groundwater flowpath. Only the Pahranagat Valley and MRSA (including Big Muddy Springs) are above 50 percent regional carbonate groundwater. Most of the springs approach and are parallel to that percentage but others like CSV and a couple of the very southern Black Mountain Area springs imply a trend of increasing recharge water along a groundwater flow to the south.

Figure 20 shows the estimated regional carbonate groundwater for the individual wells (continuous flowpath). The trend is toward increasing recharge with groundwater flow to the south in an envelope of all the wells. The single well sample in the Black Mountain Area contains virtually no estimated regional carbonate groundwater and, therefore is almost all recharge water. Figure 21 segments the upper tier of wells and springs by groups showing a consistent trend from Pahranagat through CSV and MRSA to Garnet Valley. Rogers and Blue Point springs and other Black Mountain Area springs are below the trend.

Table 2 lists the average estimated percentages of regional carbonate groundwater in wells for the hydrographic areas, KPW-1, Big Muddy Spring and both Rogers and Blue Point Springs. Values are for the continuous groundwater flowpath except for Rogers and Blue Point Springs where the continuous and discontinuous groundwater estimates, respectively, are listed. There is a dominance of about 60 percent for most of the hydrographic areas suggesting that this is the average percentage of regional carbonate groundwater moving south from Pahranagat Valley through Garnet Valley and California Wash. CSV has an estimated five percent more recharge water mixing with the regional carbonate groundwater while Meadow Valley Wash has an estimated 22 percent more recharge water. However, the Rogers and Blue Point springs estimate is about 20 percent below the about 60 percent continuous groundwater flowpath that probably documents the major flowpath to

Table 2. Average percentage of regional carbonate Groundwater in wells of the hydrographic areas plus KPW-1 well, Big Muddy, Rogers Springs and Blue Point Springs.

Hydrographic Area/Well/Spring	Average Percent Regional Carbonate Groundwater
Pahanagat Valley	60
KPW-1	82
Coyote Springs Valley	55
Garnet Valley	58
Muddy River Springs Area	62
Big Muddy Spring	60
Meadow Valley Wash	38
California Wash	61
Rogers Spring	39 and 50
Blue Point Spring	42 and 53

the south. This relationship suggests that either Rogers and Blue Point springs are on a entirely different flowpath origin, for example the Virgin-River-Mesquite groundwater flowpath, a mixture of this different flowpath or are a weak secondary groundwater flowpath from the major MRSA flowpath. Given this ambiguity of the regional carbonate groundwater flow path to these two springs, the latter is included in this work. Therefore, the estimated regional groundwater percentages suggest two major groundwater flowpaths south of CSV, one through Garnet Valley moving south and a second moving through the MRSA into California Gulch flowing to the south but with the potential for a weak secondary flowpath that might include the Rogers Spring and Blue Point Spring to the east of this second major groundwater flowpath.

CARBON-14

Carbon-14 is a radionuclide that decays with a half-life of 5,370 years occurring as part of the carbon molecules that comprise the bicarbonate, carbonate and organic carbon in a water. Unlike deuterium, carbon-14 can be lost along groundwater flowpaths by carbonate precipitation or gained by dissolution of carbonate minerals and rocks as well as degraded organic carbon compounds. There are several geochemical models that approach accounting for these sources by using carbon-13 values and other techniques but there are insufficient data to approach modeling the carbon-14 date. Even the current geochemical models cannot really account for the relative amounts of mixing of groundwater with many different ages. The carbon-14 values typically reported in percent modern carbon (pmc) for the bulk groundwater in some cases can be, for example, almost all regional carbonate groundwater so that an apparent age calculated by using only the carbon-14 half-life may be near the true age of the groundwater. Alternately, and perhaps more usual, the bulk groundwater has a considerably more complex history that involves not only the products of precipitation and dissolution reactions but also mixing between groundwaters of considerably variable ages. There are significant problems with age dates in southern Nevada as described by Winograd and Pearson (1976). This problem is still being worked on but at this point there is no readily available method that can give a consistently true "age" of any groundwater sample.

Figures 22 and 23 show the available carbon-14 values and their locations within the Colorado River Basin area. Table 3 lists a summary of carbon-14 data and the simple apparent age for hydrographic areas, KSV well KPW-1 as well as Big Muddy, Rogers and Blue Point springs. Most of the apparent ages are in the 14,000 to 35,000 years before present range. The KSV well, KPW-1, has one of the oldest apparent ages at 29,900 years. Assuming that the apparent ages are somewhat true, and in this case it may well be, it is not probable that KSV groundwater represented by KPW-1 with this age could represent a significant contribution to the flow at Big Muddy Springs. Again assuming that the apparent ages are somewhat true, the average apparent age for CSV of 20,800 years is essentially the same as MRSA which would support the above second major groundwater flowpath to the south.

Table 3. Carbon-14 percent modern carbon (pmc) values and apparent ages for hydrographic areas, KSV well KPW-1, major springs in Pahranagat Valley as well as Big Muddy, Rogers and Blue Point springs.

Hydrographic Area/Well/Spring	Carbon-14 (pmc)	Apparent Age (Years Before Present)
Pahranagat Valley, Major Springs	6.3-8.4	20,300-21,700
KPW-1	2.7	29,900
Coyote Springs Wells	4.2-17.9	14,200-26,200
Garnet Valley Wells	3	29,000
MRSA	8.4	20,500
Big Muddy Springs	7	22,000
Rogers Spring	1.6,2.4	30,900-34,200
Blue Point Spring	7.2,5.4	21,800-24,100

A longer travel time is estimated with the same assumption applied to travel time from CSV to Garnet Valley of 8,000 years. A similar assumption would mean a travel time from Big Muddy Springs to Rogers Spring on the order of about 10,000 years. The difference between Rogers Spring and Blue Point Spring apparent ages bring a common source to each spring into question. The difference could be a somewhat true age but may be related to either mixing differences between the water arriving at each spring or simply significantly more recent organ carbon present within the Blue Point Spring than Rogers Spring. The apparent ages indicate that the groundwaters within the Colorado River Basin flowpath are not young but are within the range of groundwater ages of groundwater in other basins in the southwestern U.S. Furthermore, travel time between hydrographic areas is probably on the order of thousands of years.

FLUORIDE

Fluoride is commonly elevated in groundwater associated with volcanic rocks. Figures 24 and 25 show the fluoride concentrations and their locations. Fluoride has an average concentration of 1.6 mg/L for the 63 analyses that include fluoride. Fluoride ranges from 0.1 to 6.1 mg/L with three analyses exceeding the current drinking water standard of 4.0 mg/L: groundwater from the KSV well KPW-1 with 6.1 mg/L; Little Ash Spring in the Pahranagat Valley, 4.8 mg/L; and the CSV well CSVM-4 downgradient of KPW-1 with 4.6 mg/L. All of the remaining springs and wells have less than 3 mg/L. The fluoride concentrations support groundwater flow from both Pahranagat and KSV into the CSV by an overall elevated concentration probably related to both volcanic rocks from the caldera complex and the tuffaceous sediments deposited within the basins during and following the development of the caldera complex. As shown on Figure 26, dissolved fluoride concentrations are generally controlled to less than about 2 mg/L by calcium both as a dissolved form and particularly within carbonate rocks by the precipitation of the calcium-fluoride mineral fluorite. Groundwater with less than about 100 mg/L calcium has the highest fluoride concentration. The elevated calcium concentrations above 400 mg/L include Rogers, Blue Point, Corral and VF-2 springs that also have highly elevated TDSS.

ARSENIC

An elevated arsenic concentration of 46 micrograms per Liter (µg/L) is reported for the KSV groundwater from KPW-1. There are too few arsenic data reporting arsenic concentrations to evaluate the arsenic concentrations throughout the area but the dissolved arsenic concentration is often elevated in water associated with volcanic rocks. Other groundwater samples analyzed for this investigation indicate that groundwater in the CSV probably ranges from about 10 to 20 µg/L. Bateman (1976) included additional arsenic concentrations in some groundwaters from this segment of the Colorado River Basin. Ash Spring in Pahranagat Valley contained 30 µg/L; Little Ash Spring contained 20 µg/L; and groundwater from a well in Pahranagat Valley is reported to contain 250 µg/L (Alamo Farmstead System Well). Below CSV, Pederson Warm Spring in the Muddy Area contained 20 µg/L and the Bhemer Well downgradient of Big Muddy Springs is reported to contain 2.8 mg/L (2800 µg/L) arsenic.

These relationships indicate a high probability that groundwater in this area contains dissolved arsenic concentrations in excess of the new arsenic drinking water standard of 10 µg/L arsenic. The arsenic probably originates from the volcanic rocks and volcanic sediments through which the part of the groundwater flows.

SUMMARY

Groundwater from the KSV well KPW-1 is a relatively old and warm regional carbonate aquifer groundwater with a sodium-bicarbonate water chemistry type. Along with the age, this water chemistry type is unique for the regional carbonate groundwater in this area. It is both older than and has a higher TDSS than the CSV. However, these signatures are considerably attenuated within the CSV. The δD for this groundwater identifies this groundwater as being regional carbonate groundwater that is mixed with about 18 percent recharge water. A comparison of these chemical and isotopic relationships with Big Muddy Springs and particularly Rogers Spring and Blue Point Spring indicates that the groundwater from KPW-1, assumed representative of KSV groundwater, is too strongly attenuated within CSV to be identifiable in these springs.

Mixing relationships between the regional carbonate groundwater and recharge water of younger age estimates a regional groundwater flowpath moving from the Pahranagat Valley south through the CSV that includes groundwater flow from KSV. Regional groundwater flow below CSV separates into two major groundwater flowpaths: one moving south through Garnet Valley and a second moving south through California Gulch. It is unclear if Rogers Spring and Blue Point Spring groundwater are on a weak secondary groundwater flowpath from the MRSA or from the Virgin River-Mesquite flowpath or a mixture of the two.

The regional groundwater appears to contain an average of about 60 percent regional carbonate groundwater and 40 percent recharge water as it moves through these hydrographic areas. Estimated percentages of regional carbonate groundwater indicate that the percentage of recharge water increases with distance below Pahranagat Valley. Big Muddy Springs is estimated to be comprised of 60 percent regional carbonate groundwater while Rogers Spring and Blue Point Spring are estimated to contain 60 percent recharge and only about 40 percent regional carbonate groundwater.

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Figure 1a

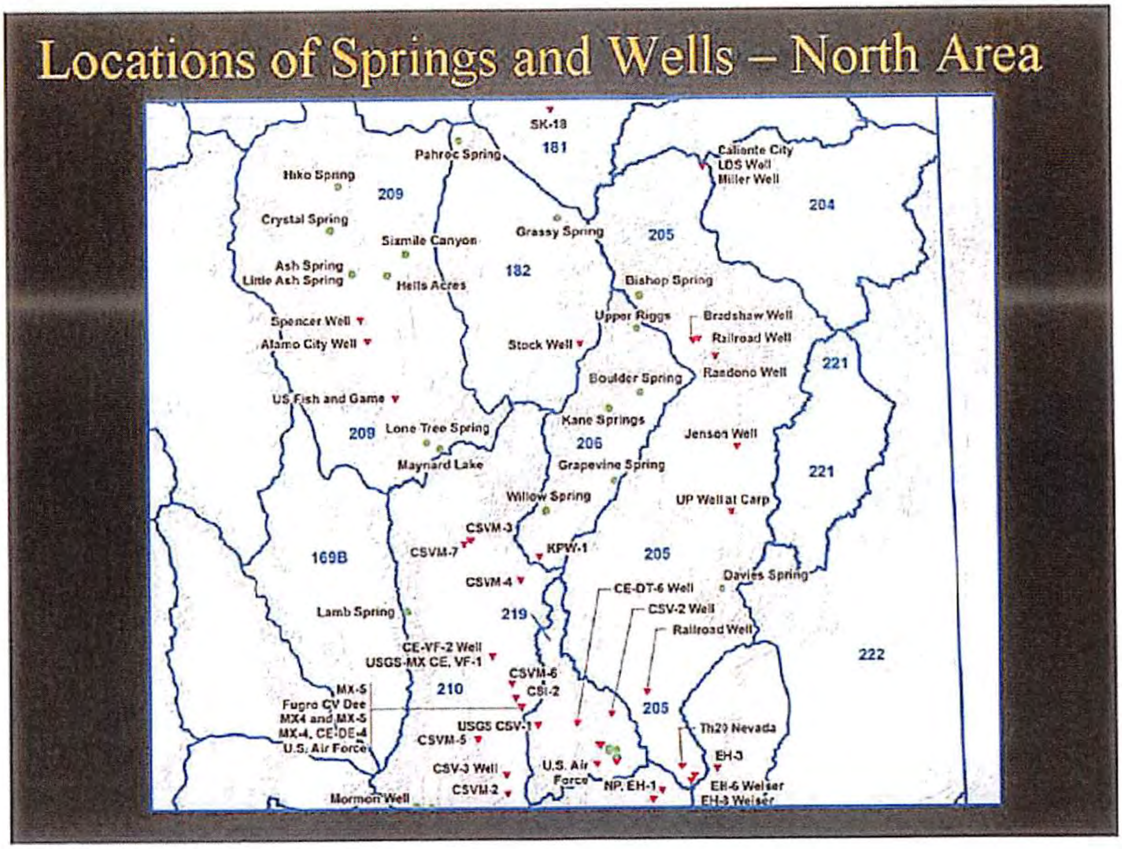

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Figure 1b

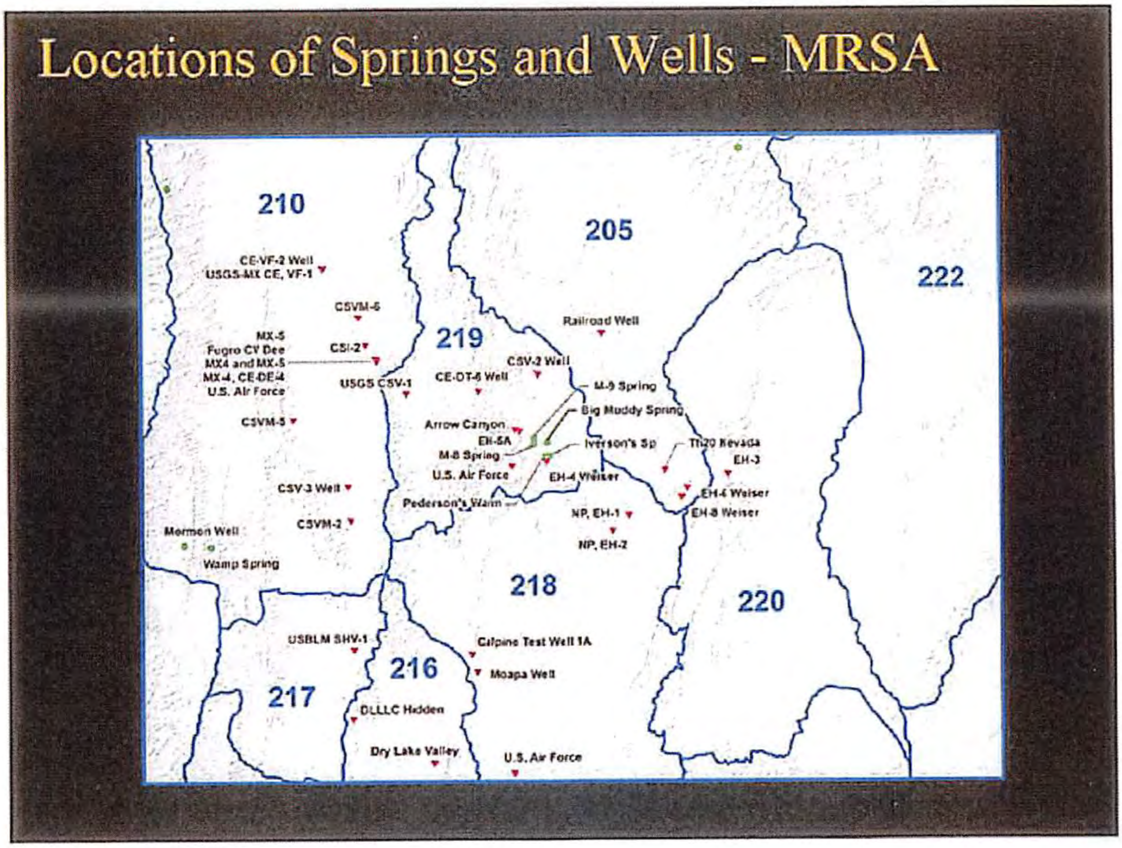
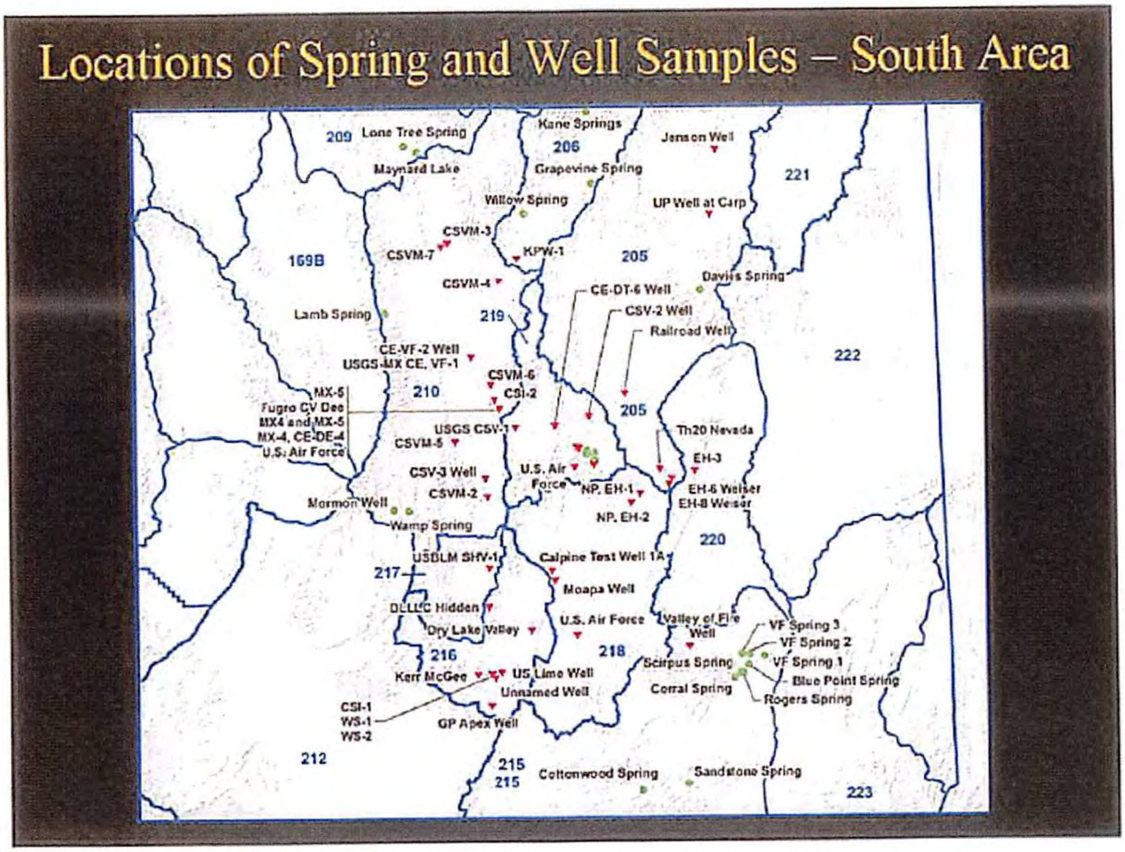
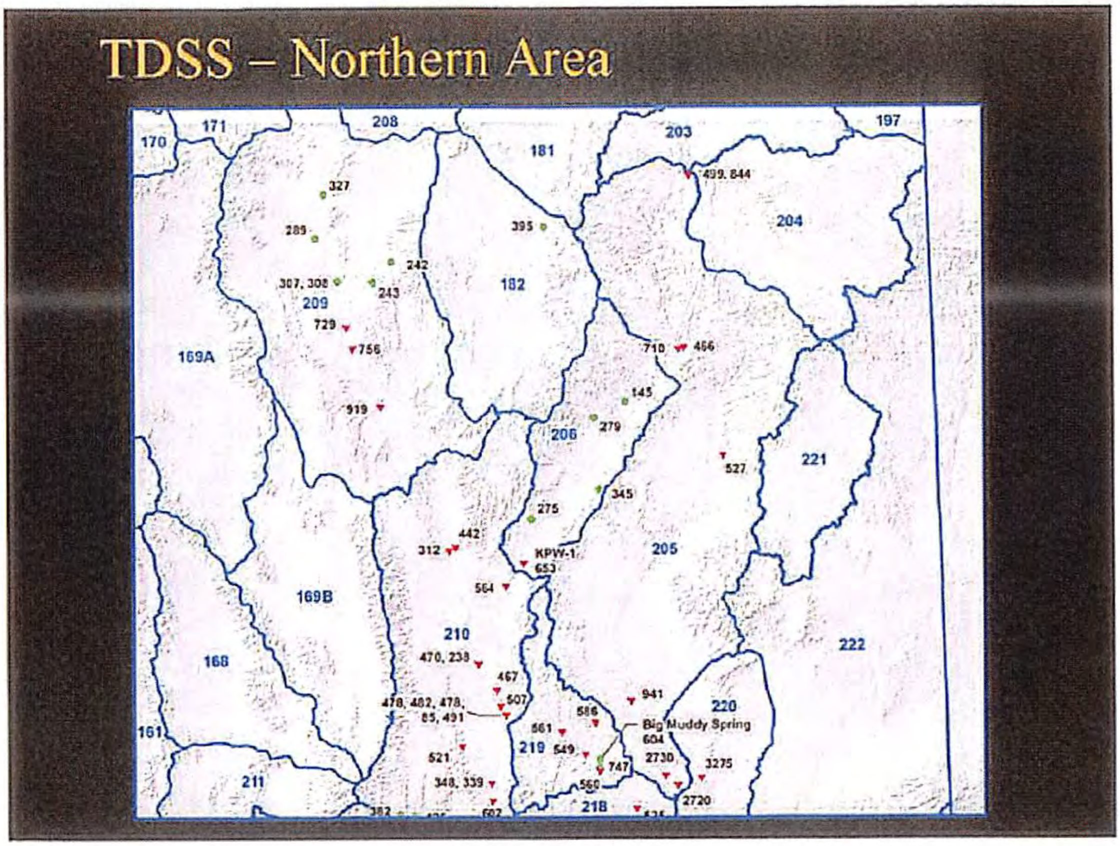

Locations of Springs and Wells - MRSA
210
205
222
219
218
220
216
217
CE-VF-2 Well
USGS-MX CE, VF-1
CSVM-6
MX-5
Fugro CV Dee
MX4 and MX-5
MX-4, CE-DE-4
U.S. Air Force
CSI-2
USGS CSV-1
CSVM-5
CSV-3 Well
CSVM-2
Mormon Well
Wamp Spring
Railroad Well
CSV-2 Well
CE-DT-6 Well
M-9 Spring
Big Muddy Spring
Arrow Canyon
EH-5A
M-8 Spring
U.S. Air Force
Iverson's Sp
EH-4 Weiser
Pederson's Warm
EH-3
EH-6 Weiser
EH-8 Weiser
NP, EH-1
NP, EH-2
USBLM SHV-1
Calpine Test Well 1A
Moapa Well
DLLLC Hidden
Dry Lake Valley
U.S. Air Force

Figure 1c



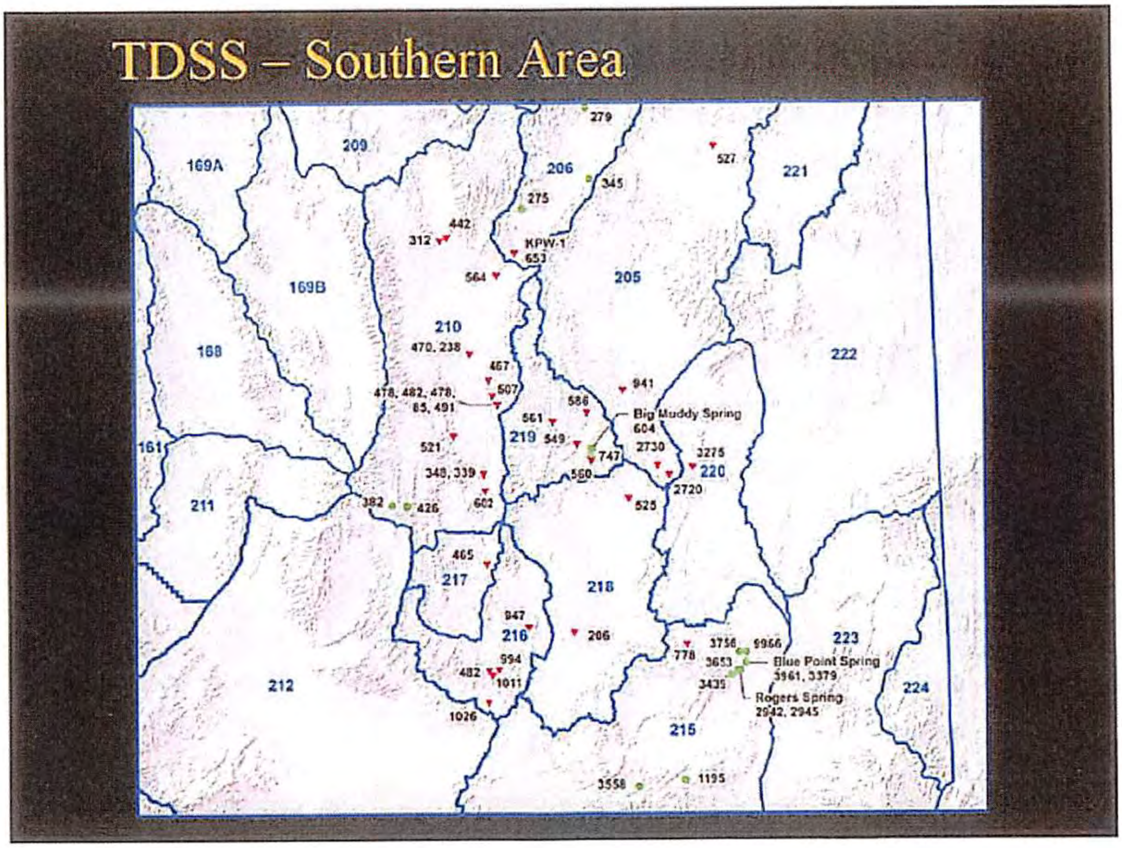
Locations of Spring and Well Samples – South Area
209
Lone Tree Spring
Maynard Lake
Kane Springs
206
Grapevine Spring
Jenson Well
221
Willow Spring
UP Well at Carp
CSVM-3
CSVM-7
KPW-1
205
169B
CSVM-4
Davies Spring
CE-DT-6 Well
CSV-2 Well
Lamb Spring
219
Railroad Well
222
CE-VF-2 Well
USGS-MX CE, VF-1
CSVM-6
CSI-2
MX-5
Fugro CV Dee
MX4 and MX-5
MX-4, CE-DE-4
U.S. Air Force
210
205
USGS CSV-1
CSVM-5
Th20 Nevada
EH-3
CSV-3 Well
U.S. Air Force
CSVM-2
NP, EH-1
EH-6 Weiser
EH-8 Weiser
Mormon Well
Wamp Spring
NP, EH-2
220
USBLM SHV-1
217
Calpine Test Well 1A
Moapa Well
DLLLC Hidden
Dry Lake Valley
U.S. Air Force
Valley of Fire Well
VF Spring 3
VF Spring 2
VF Spring 1
216
218
Scirpus Spring
Blue Point Spring
Kerr McGee
US Lime Well
Corral Spring
Rogers Spring
Unnamed Well
CSI-1
WS-1
WS-2
GP Apex Well
212
215
215
Cottonwood Spring
Sandstone Spring
223

Figure 2a


TDSS – Northern Area
170
171
208
181
203
197
204
209
182
169A
206
221
205
169B
210
222
168
220
219
161
211
218
327
395
242
243
729
756
710
466
145
919
279
527
345
275
442
312
KPW-1
653
470, 238
467
941
507
Big Muddy Spring
604
561
549
747
2730
3275
521
348, 339
560
2720

18

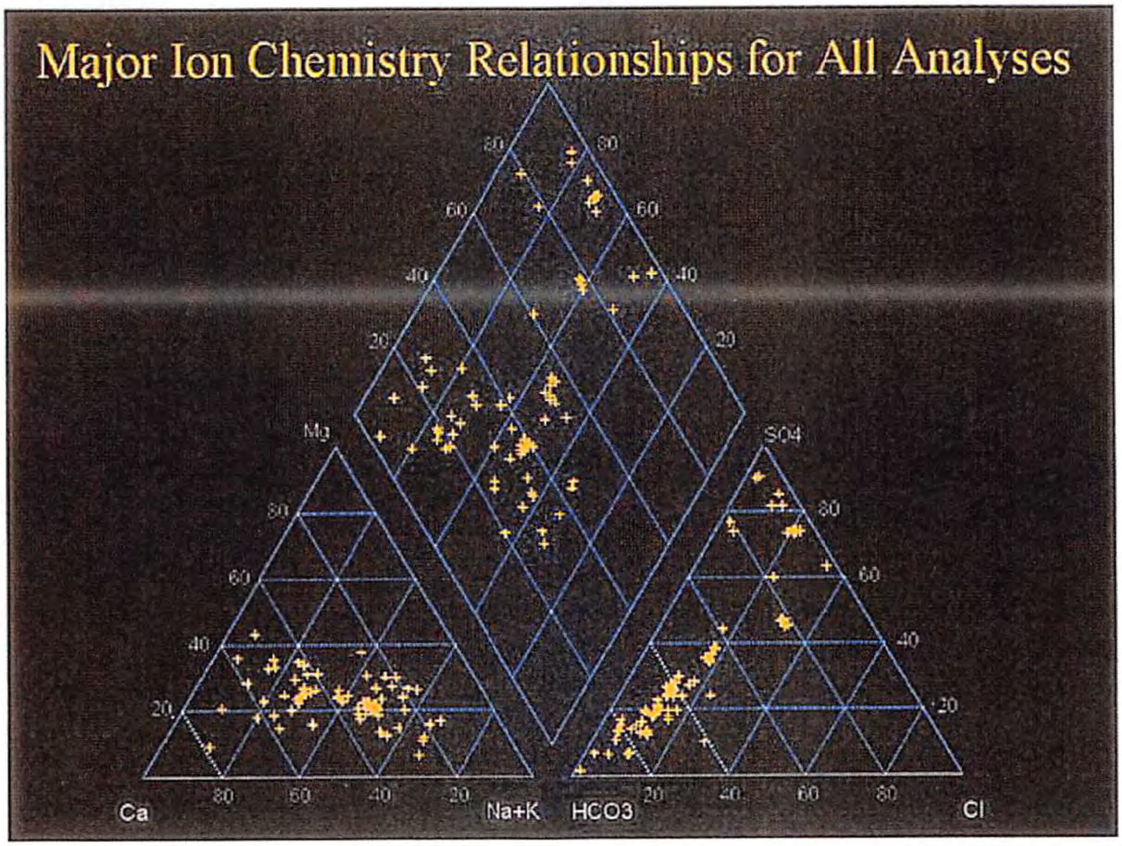
Figure 2b



SE ROA 36322

JA_8056

Figure 3



SE ROA 36323

JA_8057

Figure 4

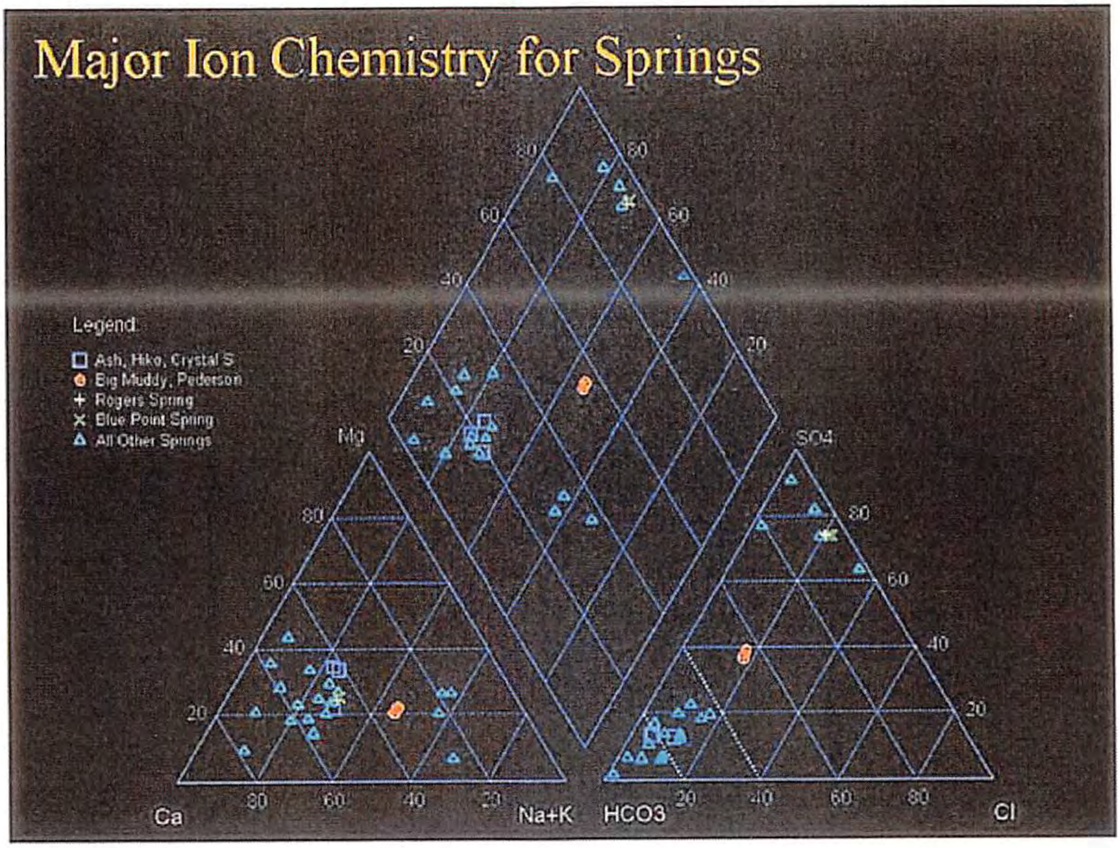

Major Ion Chemistry for Springs
Legend
Ash, Hiko, Crystal S
Big Muddy, Pederson
Rogers Spring
Blue Point Spring
All Other Springs
80
60
40
20
Mg
SO4
Ca
Na+K
HCO3
Cl

Figure 5

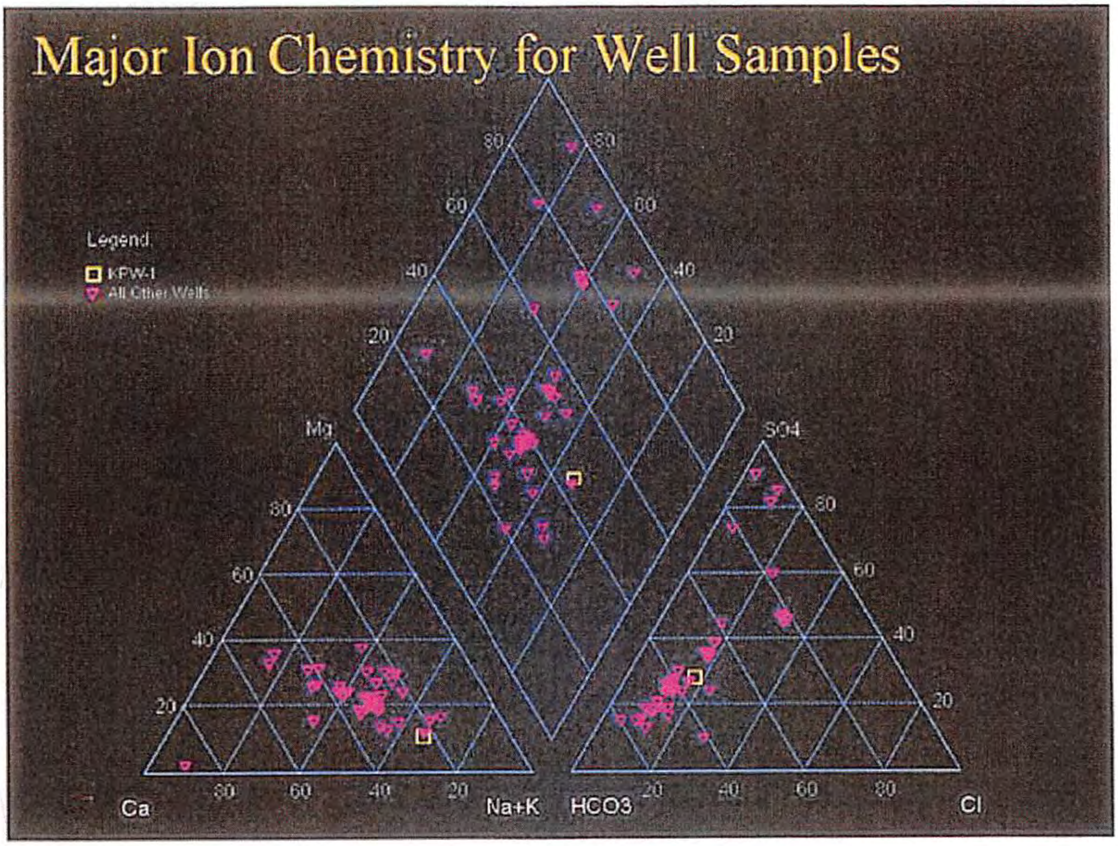
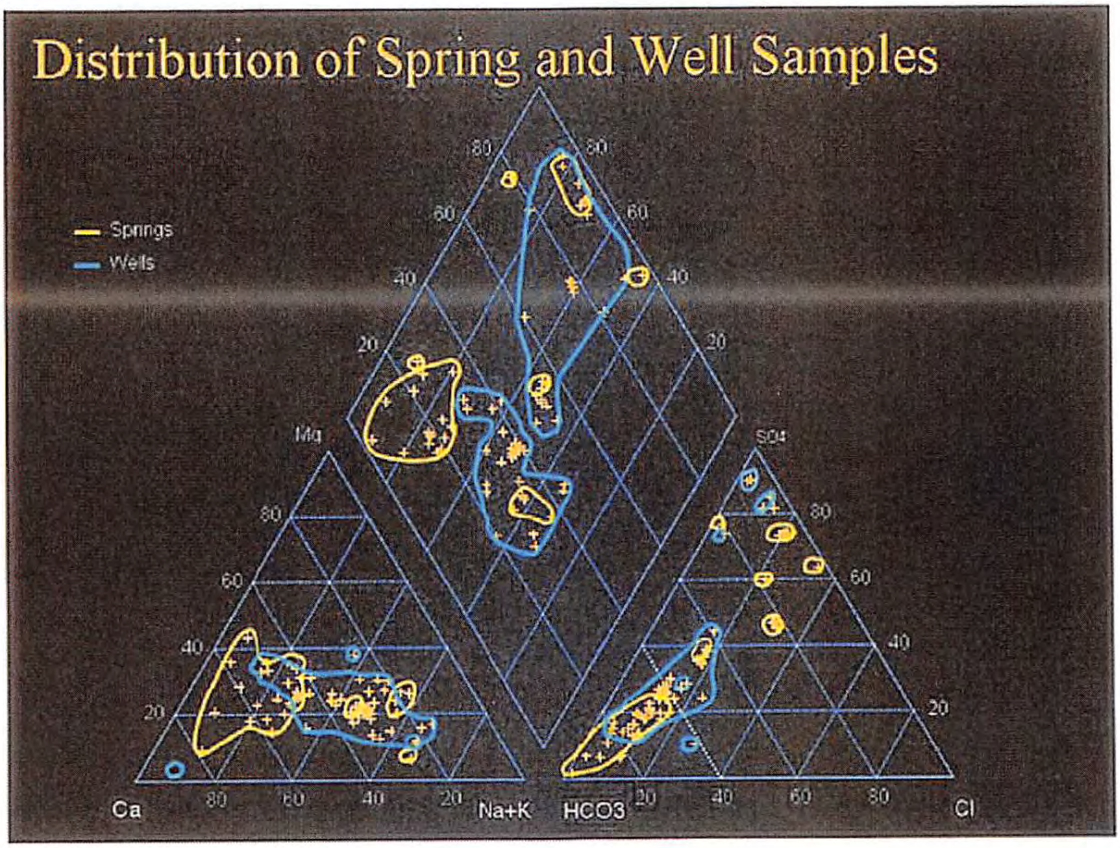
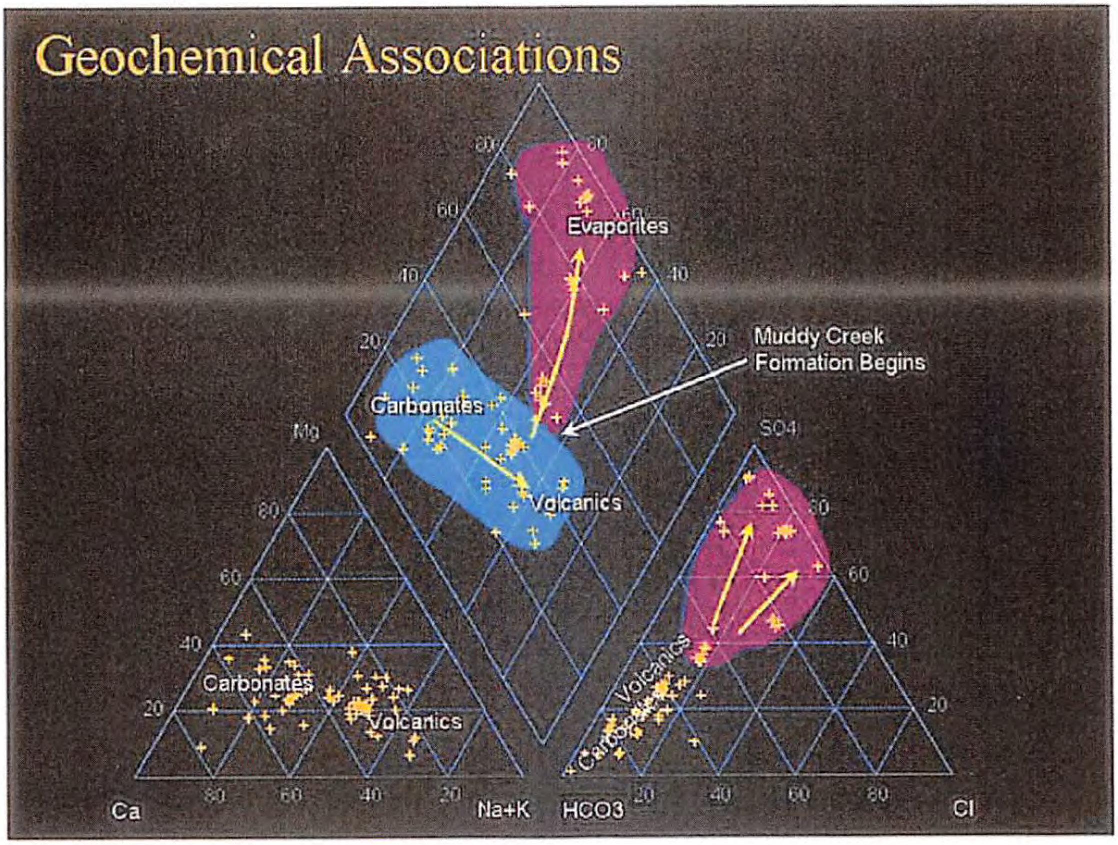

Major Ion Chemistry for Well Samples
Legend
KPW-1
All Other Wells
Mg
SO4
Ca
Na+K
HCO3
Cl
80
60
40
20

Figure 6



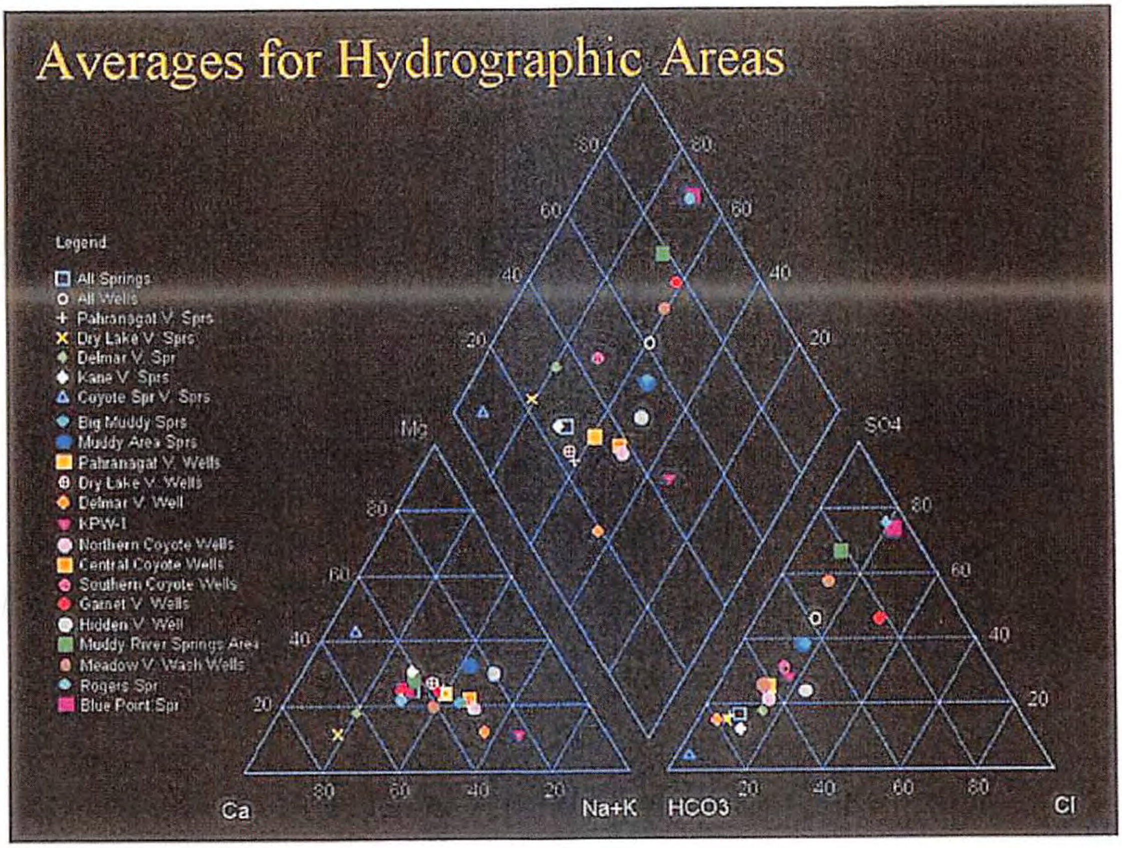
Distribution of Spring and Well Samples
Springs
Wells
Mg
SO4
Ca
Na+K
HCO3
Cl

Figure 7



Geochemical Associations
Evaporites
Muddy Creek
Formation Begins
Carbonates
Volcanics
Mg
SO4
Carbonates
Volcanics
Volcanics
Carbonates
Ca
Na+K
HCO3
Cl

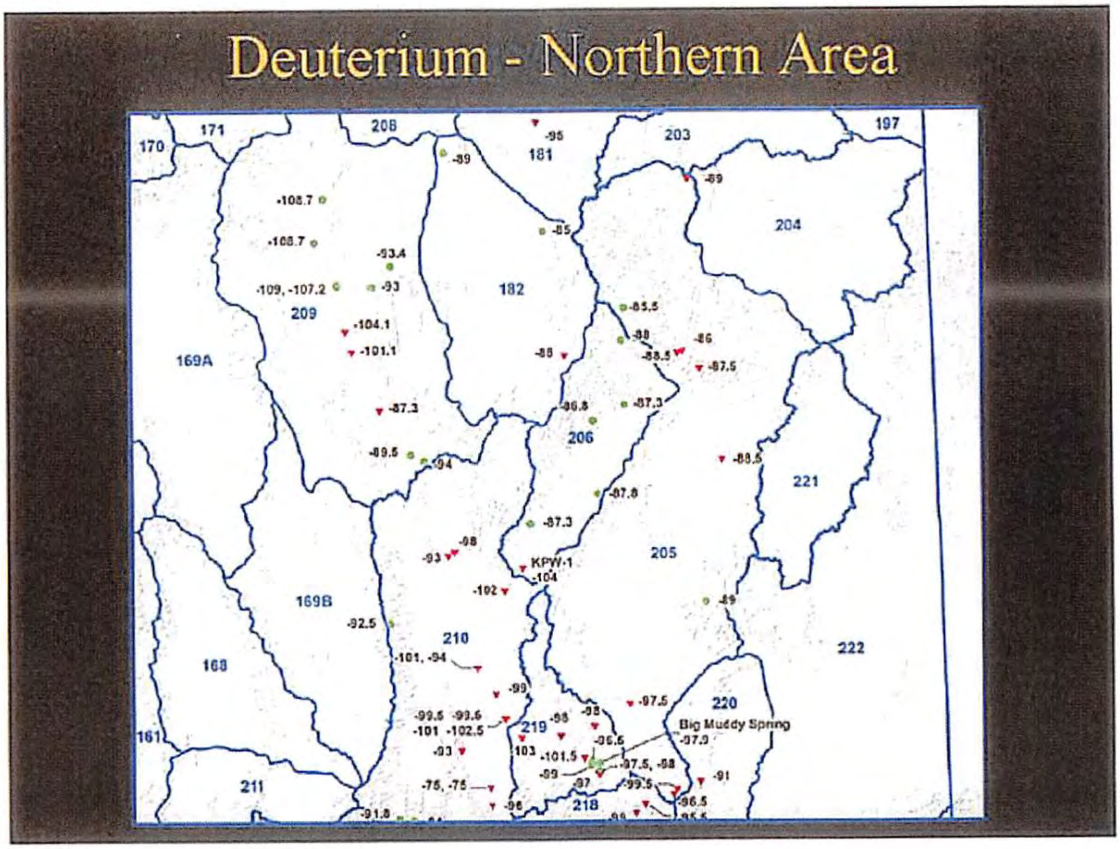
Figure 8



SE ROA 36328

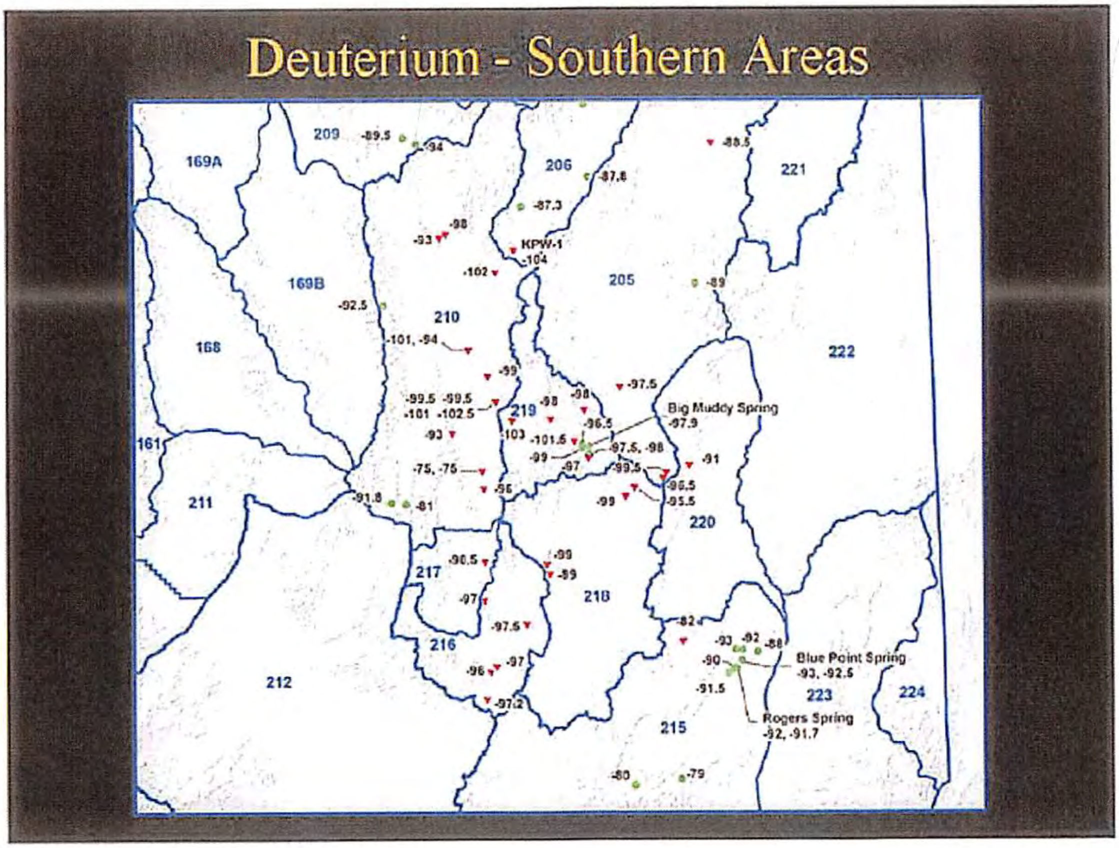
JA_8062

Figure 9



Deuterium - Northern Area
170
171
208
181
203
197
204
182
209
169A
206
221
205
169B
210
168
222
220
219
161
211
218
KPW-1
Big Muddy Spring

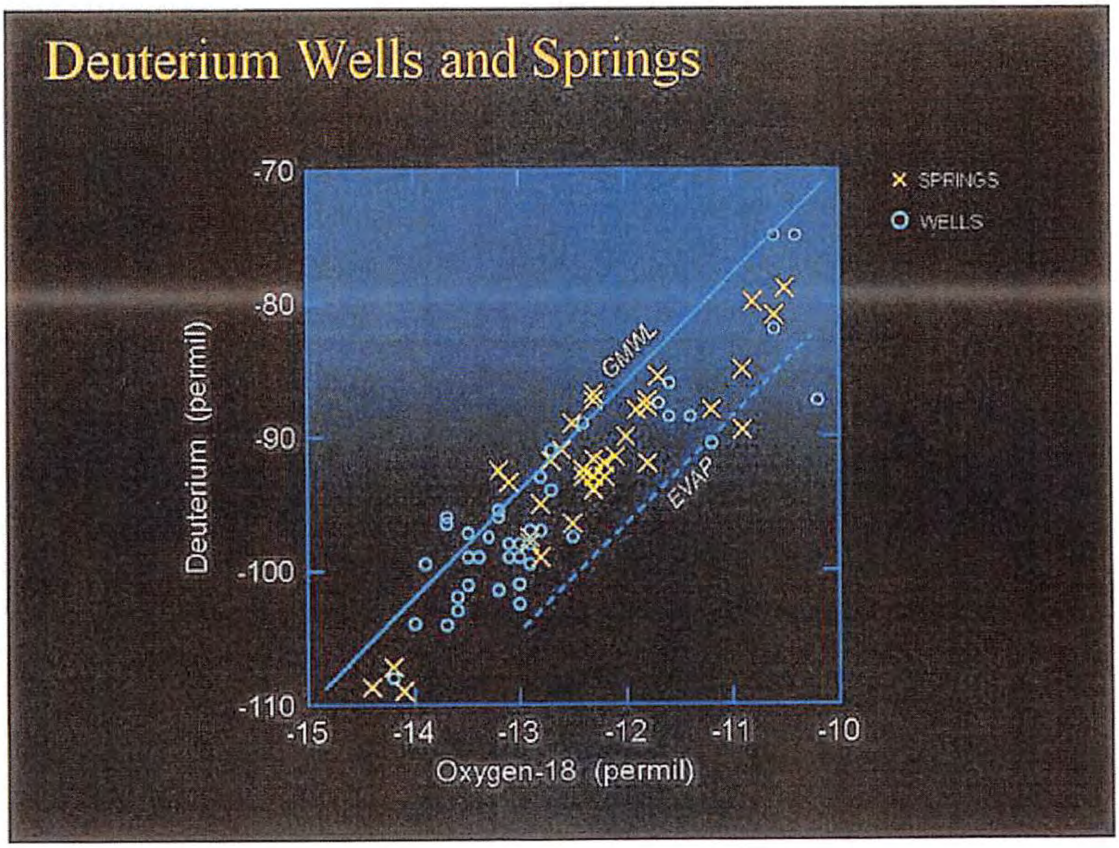
Figure 10



SE ROA 36330

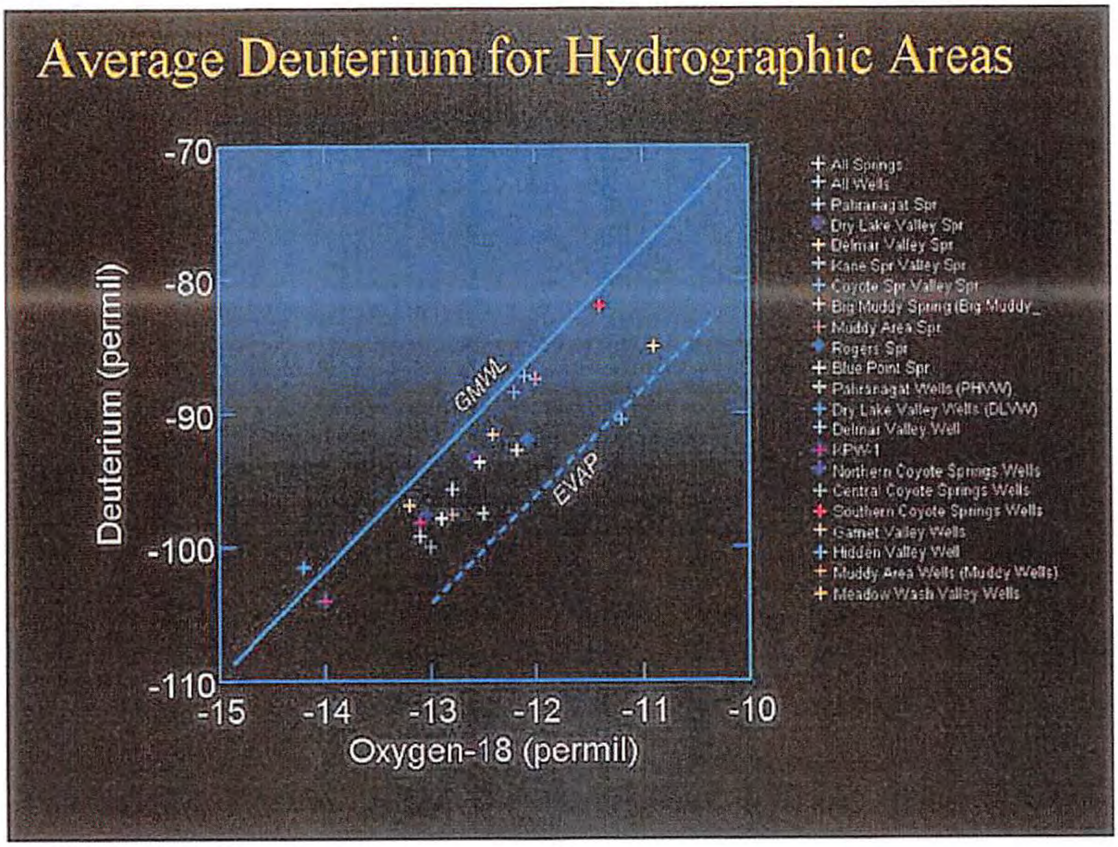
JA_8064

Figure 11



Deuterium Wells and Springs
SPRINGS
WELLS
GMWL
EVAP
-70
-80
-90
-100
-110
Deuterium (permil)
-15
-14
-13
-12
-11
-10
Oxygen-18 (permil)

Figure 12



Average Deuterium for Hydrographic Areas
-70
-80
-90
-100
-110
Deuterium (permil)
-15
-14
-13
-12
-11
-10
Oxygen-18 (permil)
GMWL
EVAP
All Springs
All Wells
Pahranagat Spr
Dry Lake Valley Spr
Delmar Valley Spr
Kane Spr Valley Spr
Coyote Spr Valley Spr
Big Muddy Spring (Big Muddy_
Muddy Area Spr
Rogers Spr
Blue Point Spr
Pahranagat Wells (PHVW)
Dry Lake Valley Wells (DLVW)
Delmar Valley Well
KPW-1
Northern Coyote Springs Wells
Central Coyote Springs Wells
Southern Coyote Springs Wells
Garnet Valley Wells
Hidden Valley Well
Muddy Area Wells (Muddy Wells)
Meadow Wash Valley Wells

Figure 13

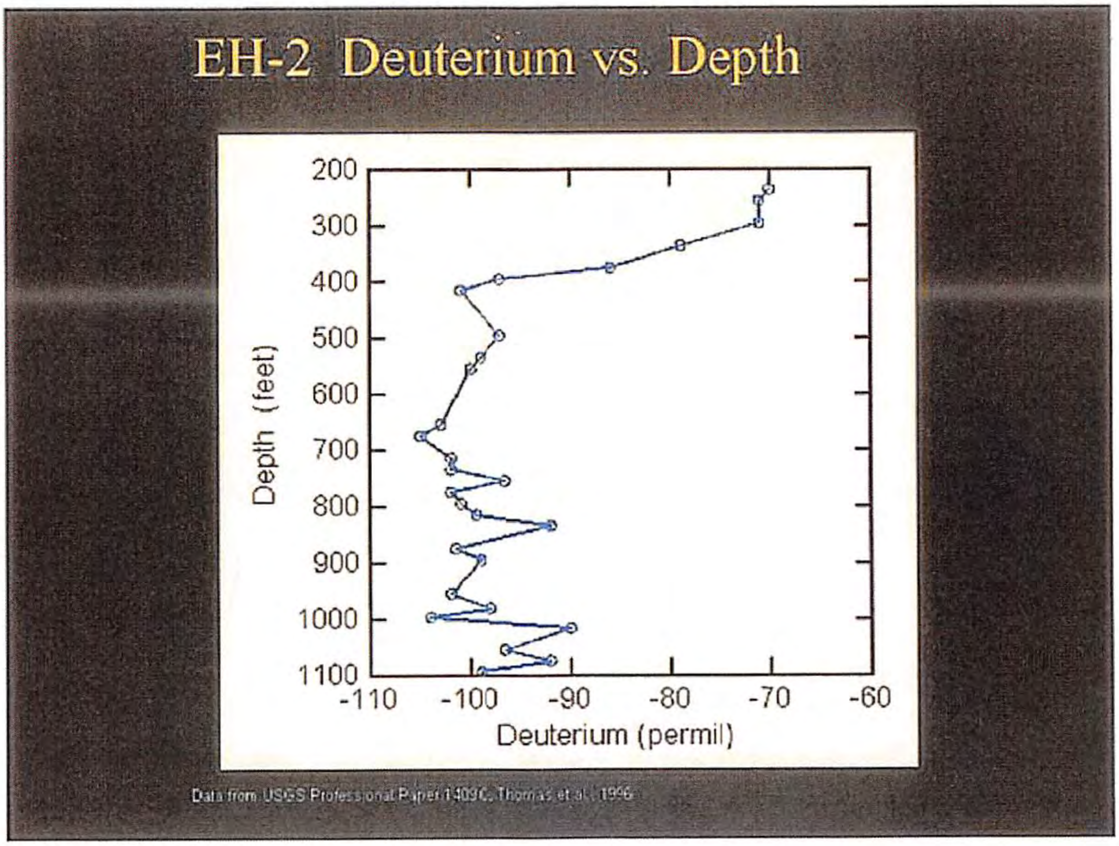
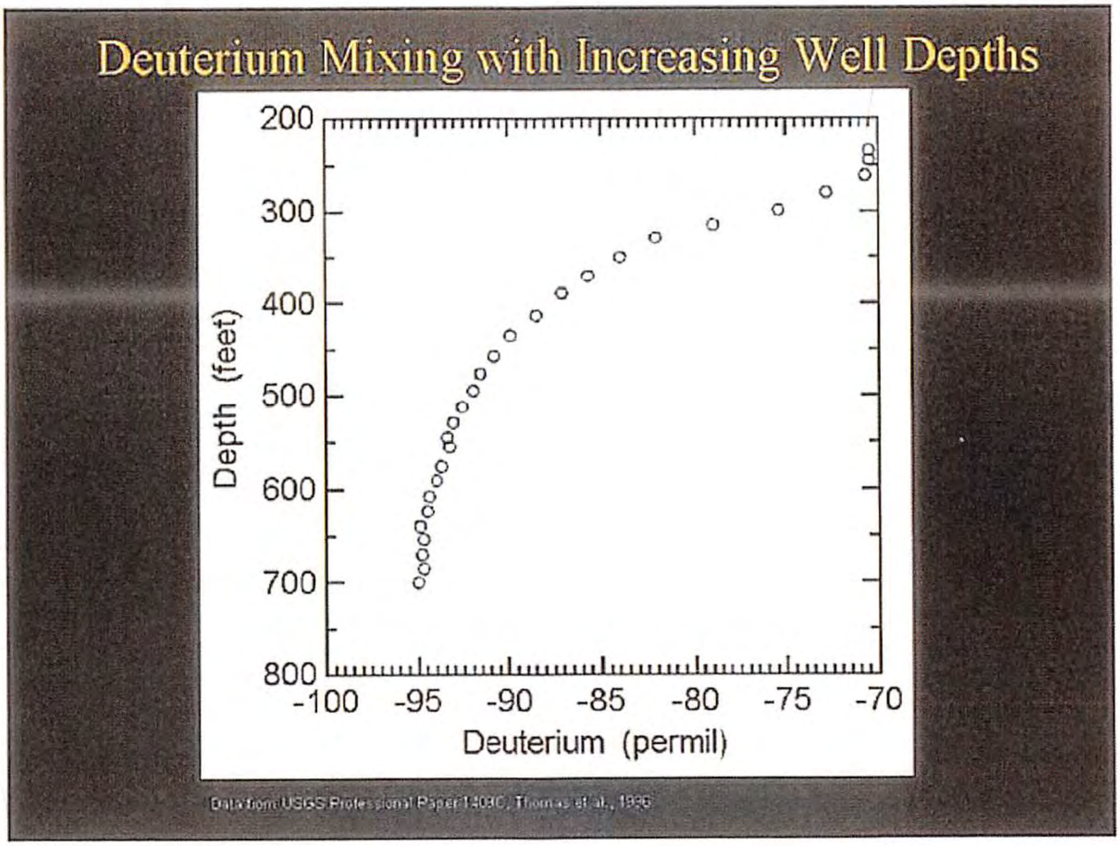

EH-2 Deuterium vs. Depth
Depth (feet)
200
300
400
500
600
700
800
900
1000
1100
-110
-100
-90
-80
-70
-60
Deuterium (permil)
Data from USGS Professional Paper 1409C, Thomas et al., 1996

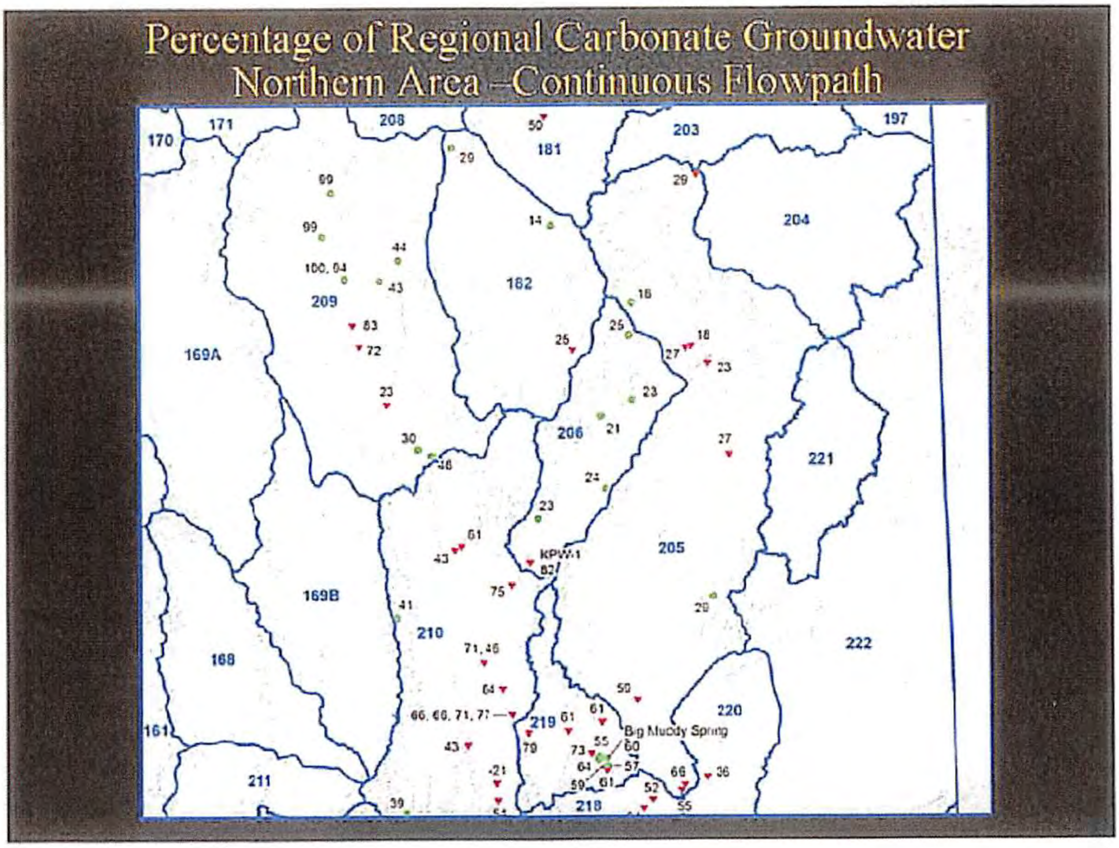
Figure 14



SE ROA 36334

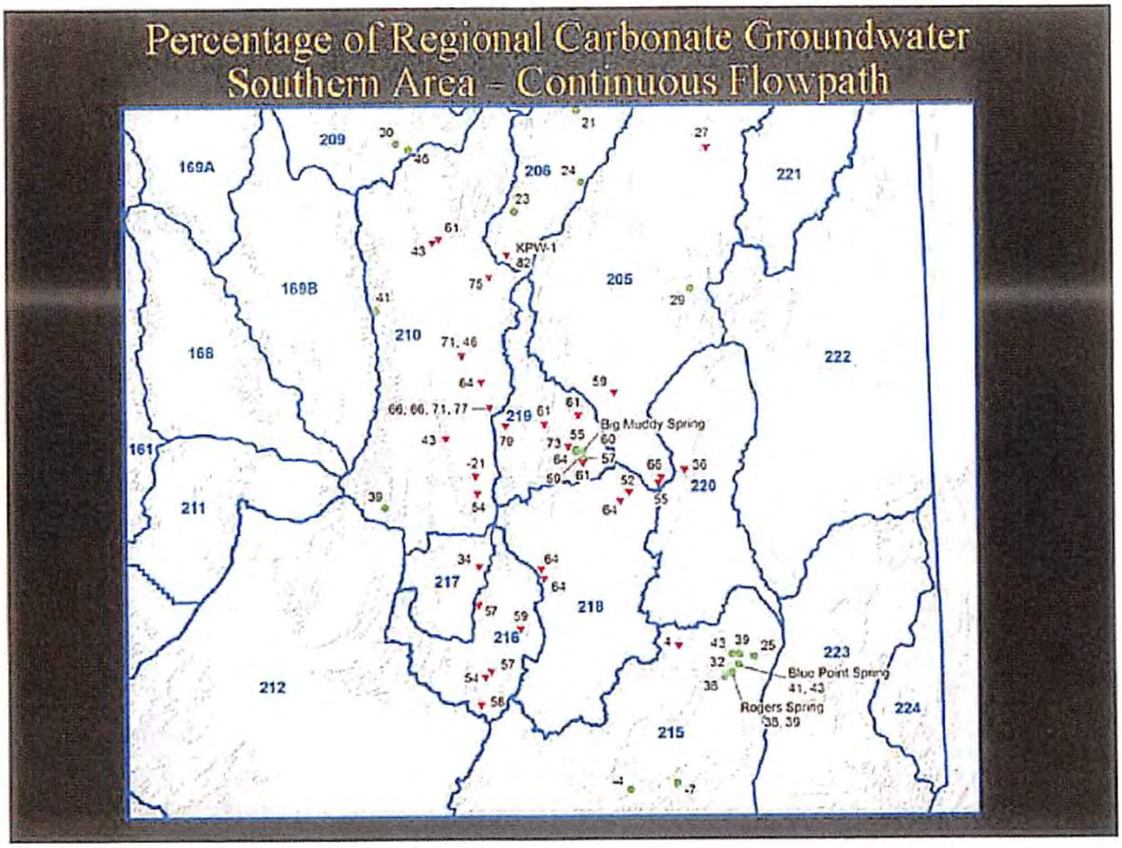
JA_8068

Figure 15



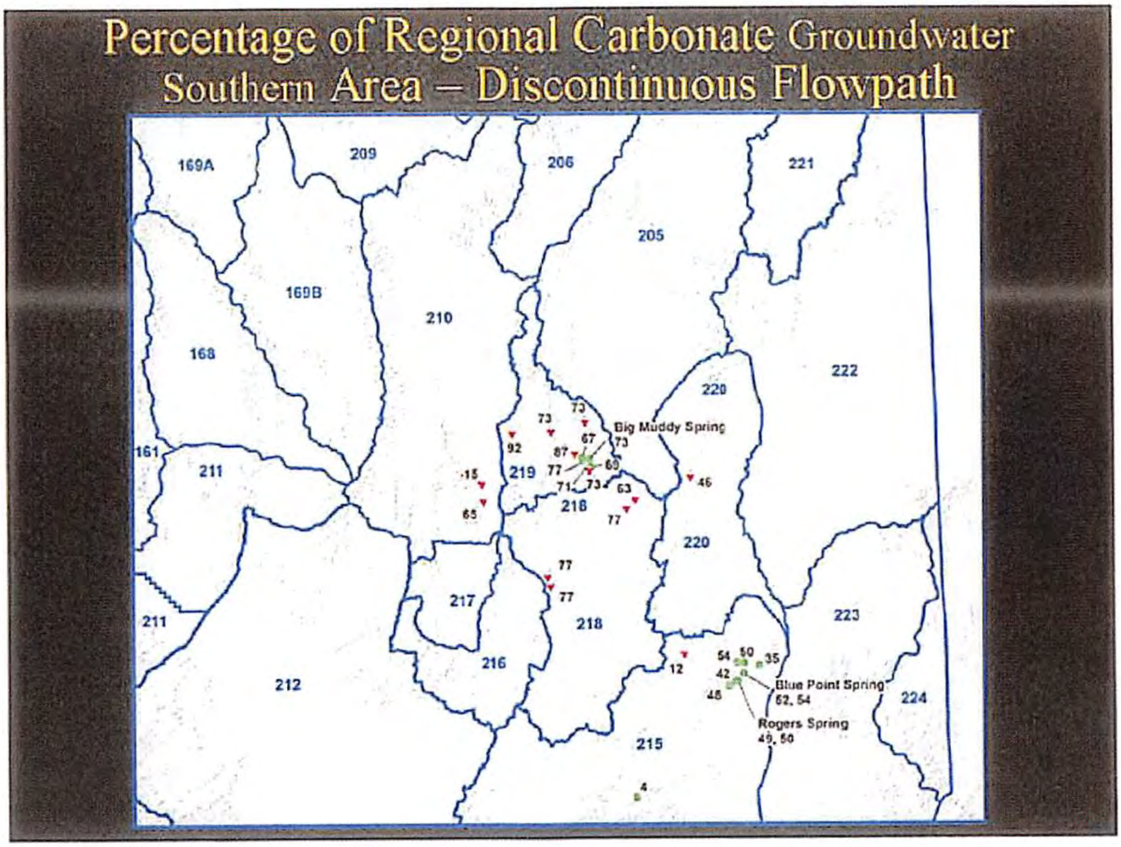
Percentage of Regional Carbonate Groundwater
Northern Area –Continuous Flowpath
170
171
208
181
203
197
204
209
182
169A
206
221
205
169B
210
168
222
220
219
218
161
211
KPW-1
Big Muddy Spring

Figure 16



Percentage of Regional Carbonate Groundwater
Southern Area - Continuous Flowpath
169A
209
206
221
169B
205
222
168
210
219
Big Muddy Spring
161
220
211
217
218
216
223
212
Blue Point Spring
Rogers Spring
224
215
KPW-1

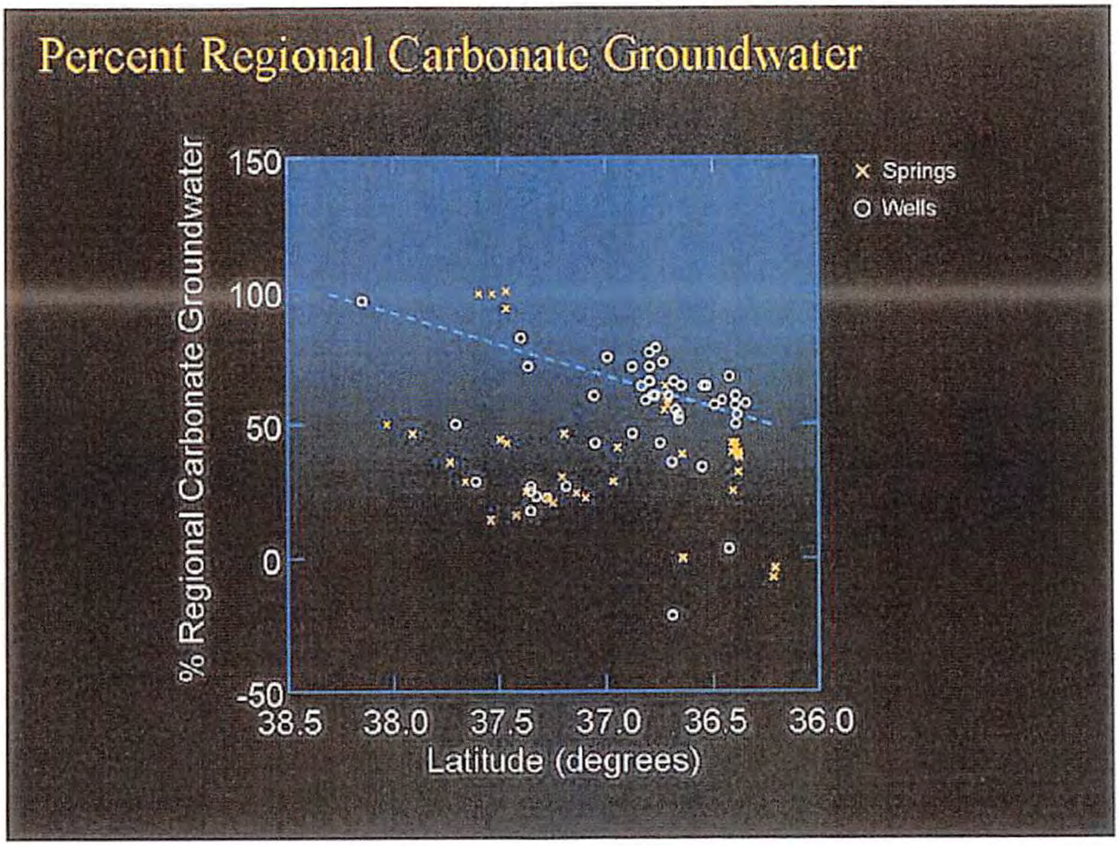
Figure 17



SE ROA 36337

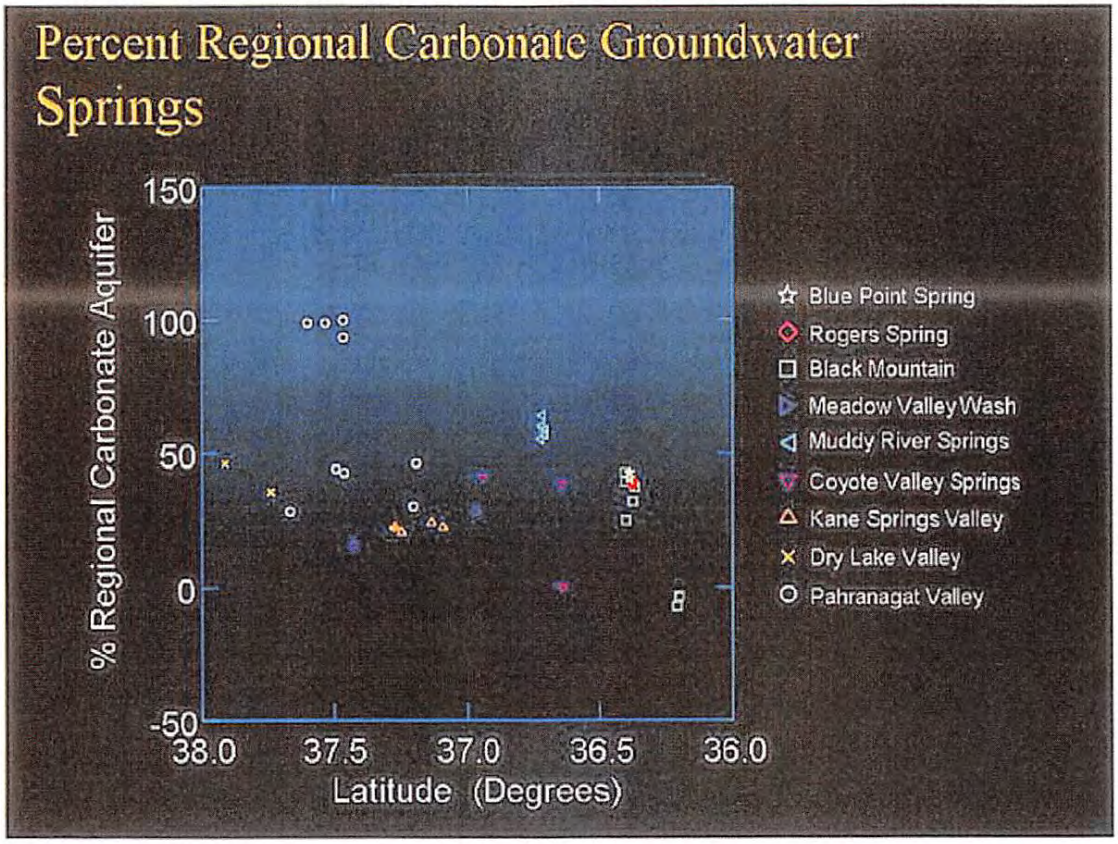
JA_8071

Figure 18



Percent Regional Carbonate Groundwater
% Regional Carbonate Groundwater
150
100
50
0
-50
38.5
38.0
37.5
37.0
36.5
36.0
Latitude (degrees)
Springs
Wells

Figure 19



Percent Regional Carbonate Groundwater Springs
% Regional Carbonate Aquifer
150
100
50
0
-50
38.0
37.5
37.0
36.5
36.0
Latitude (Degrees)
Blue Point Spring
Rogers Spring
Black Mountain
Meadow Valley Wash
Muddy River Springs
Coyote Valley Springs
Kane Springs Valley
Dry Lake Valley
Pahranagat Valley

Figure 20

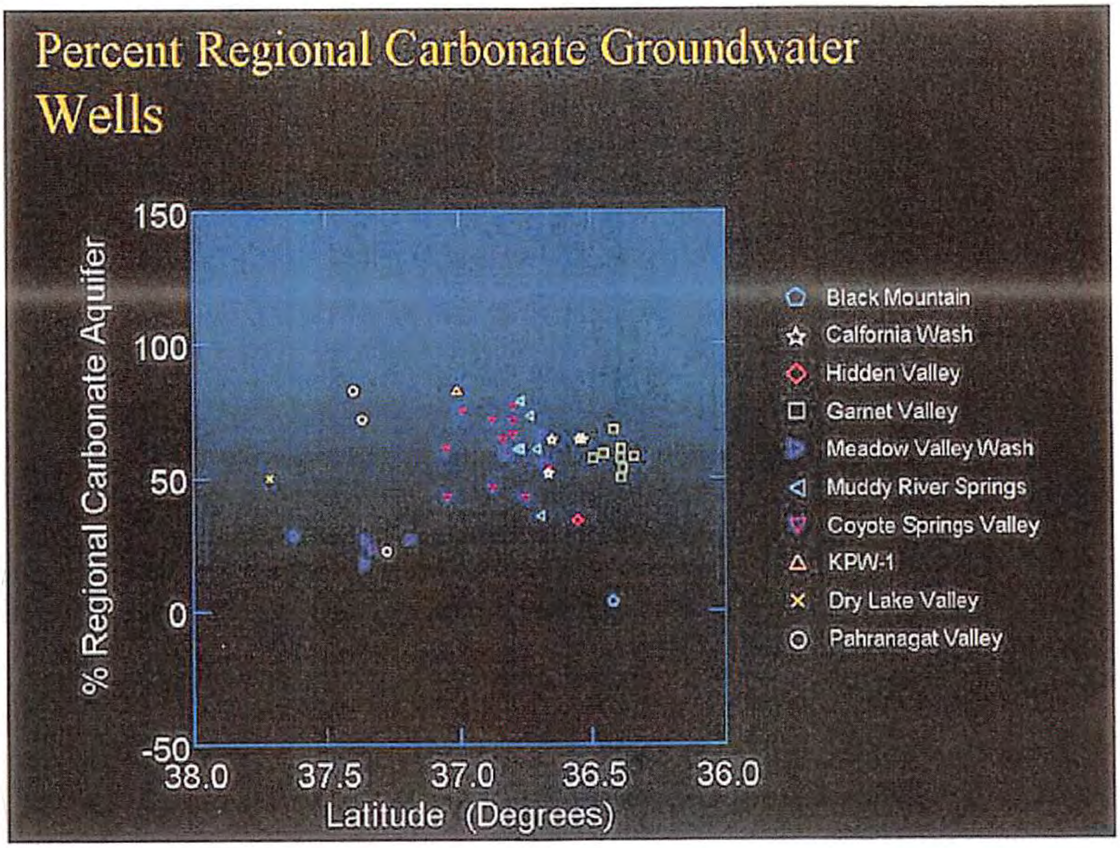
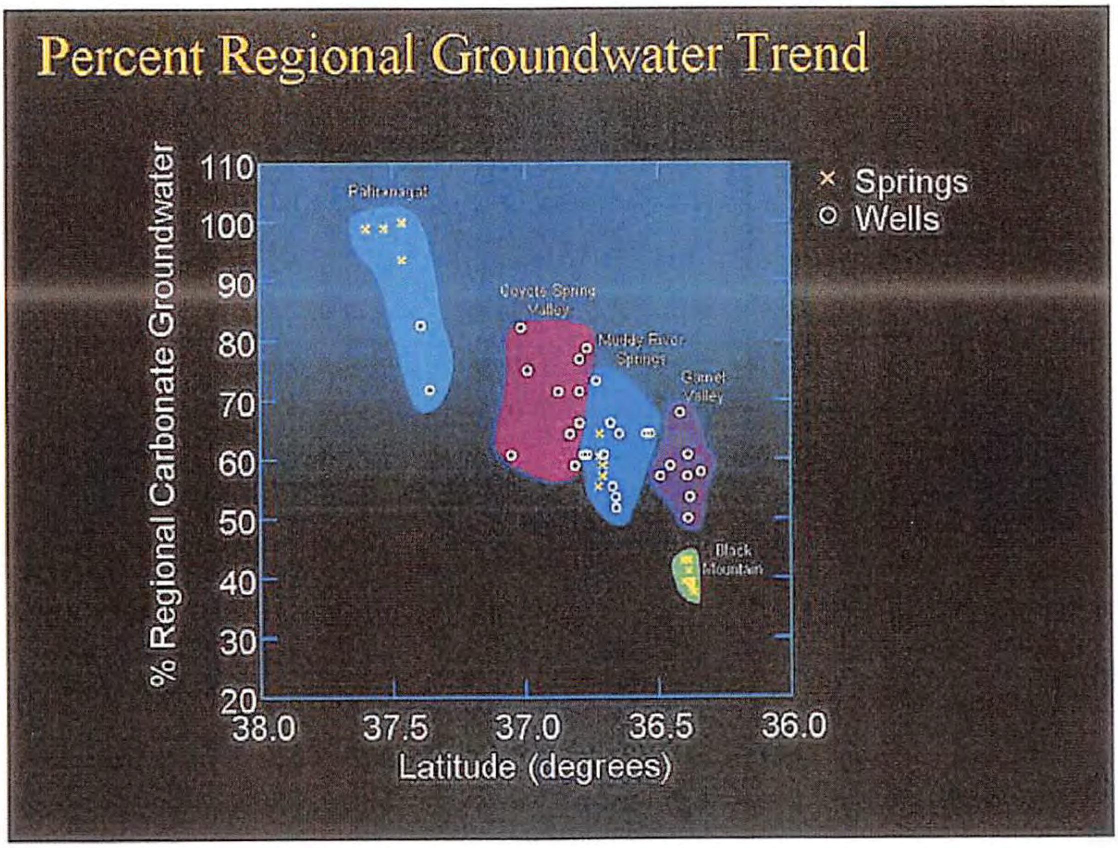
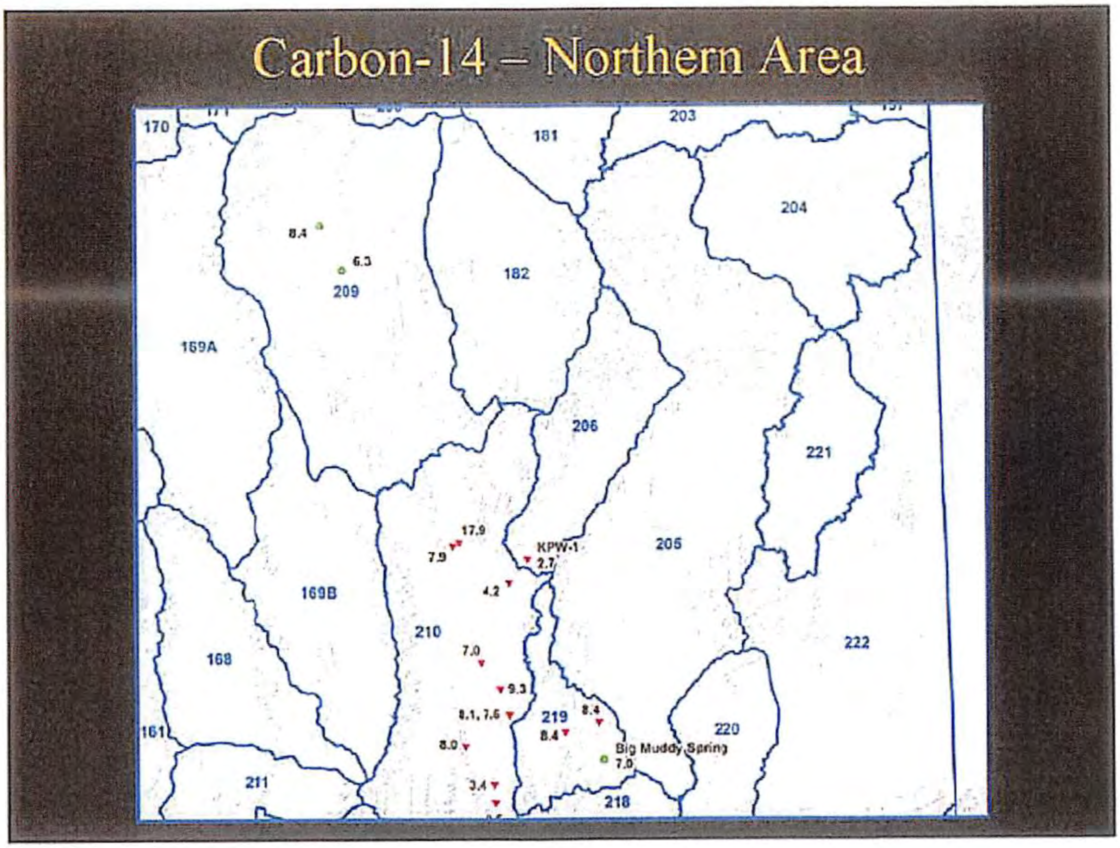

Percent Regional Carbonate Groundwater Wells
% Regional Carbonate Aquifer
150
100
50
0
-50
38.0
37.5
37.0
36.5
36.0
Latitude (Degrees)
Black Mountain
Calfornia Wash
Hidden Valley
Garnet Valley
Meadow Valley Wash
Muddy River Springs
Coyote Springs Valley
KPW-1
Dry Lake Valley
Pahranagat Valley

Figure 21



Percent Regional Groundwater Trend
% Regional Carbonate Groundwater
110
100
90
80
70
60
50
40
30
20
38.0
37.5
37.0
36.5
36.0
Latitude (degrees)
Springs
Wells
Pahranagat
Coyote Spring Valley
Muddy River Springs
Garnet Valley
Black Mountain

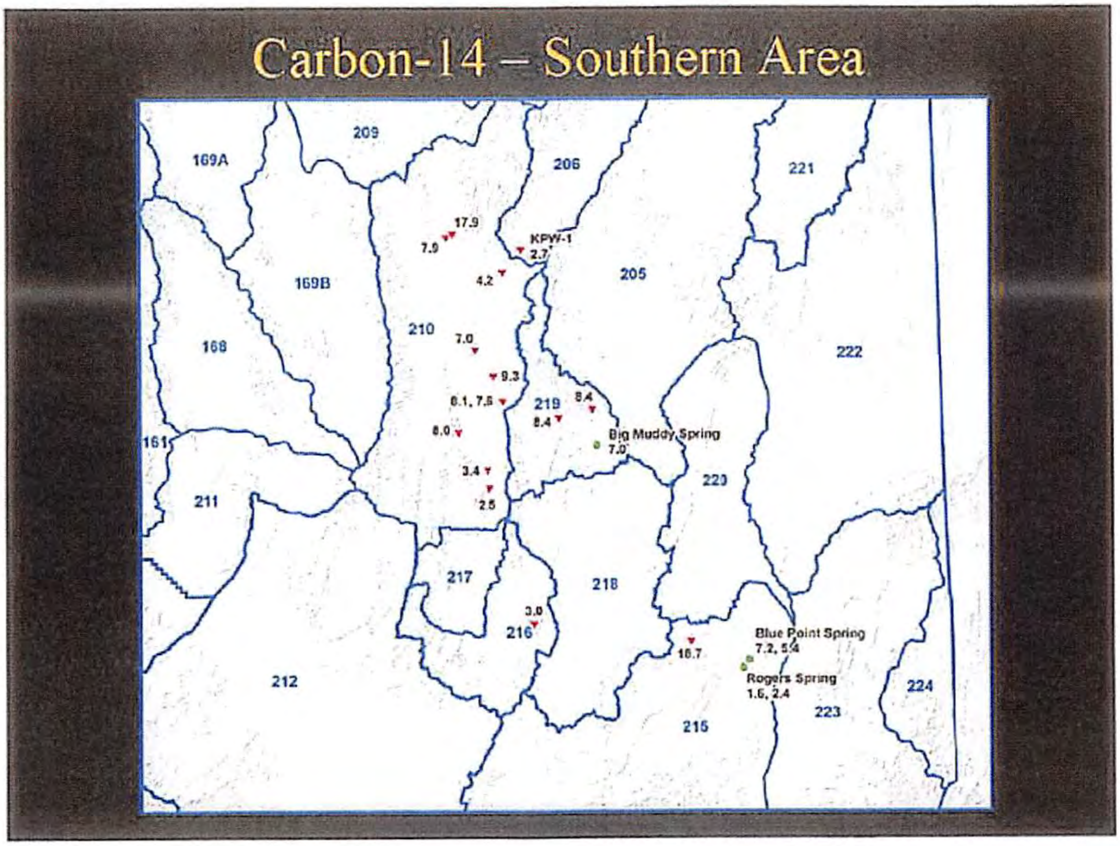
Figure 22



SE ROA 36342

JA_8076

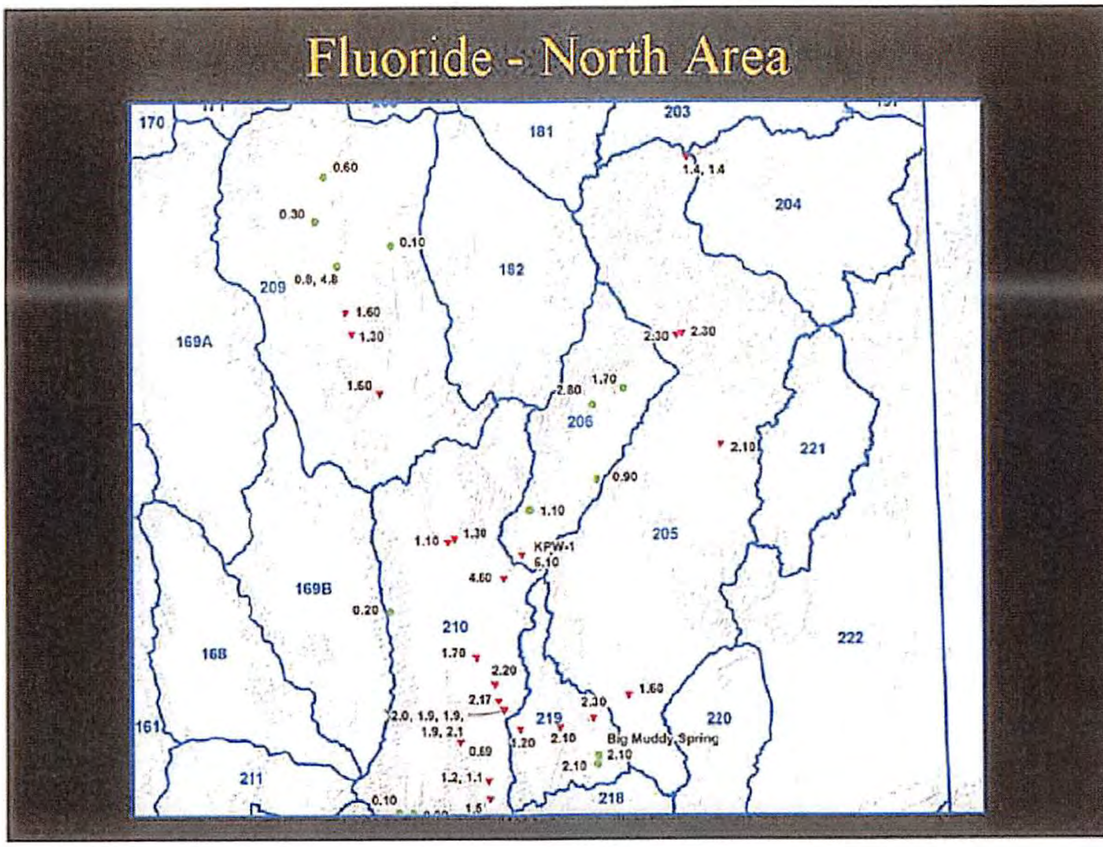
Figure 23



SE ROA 36343

JA_8077

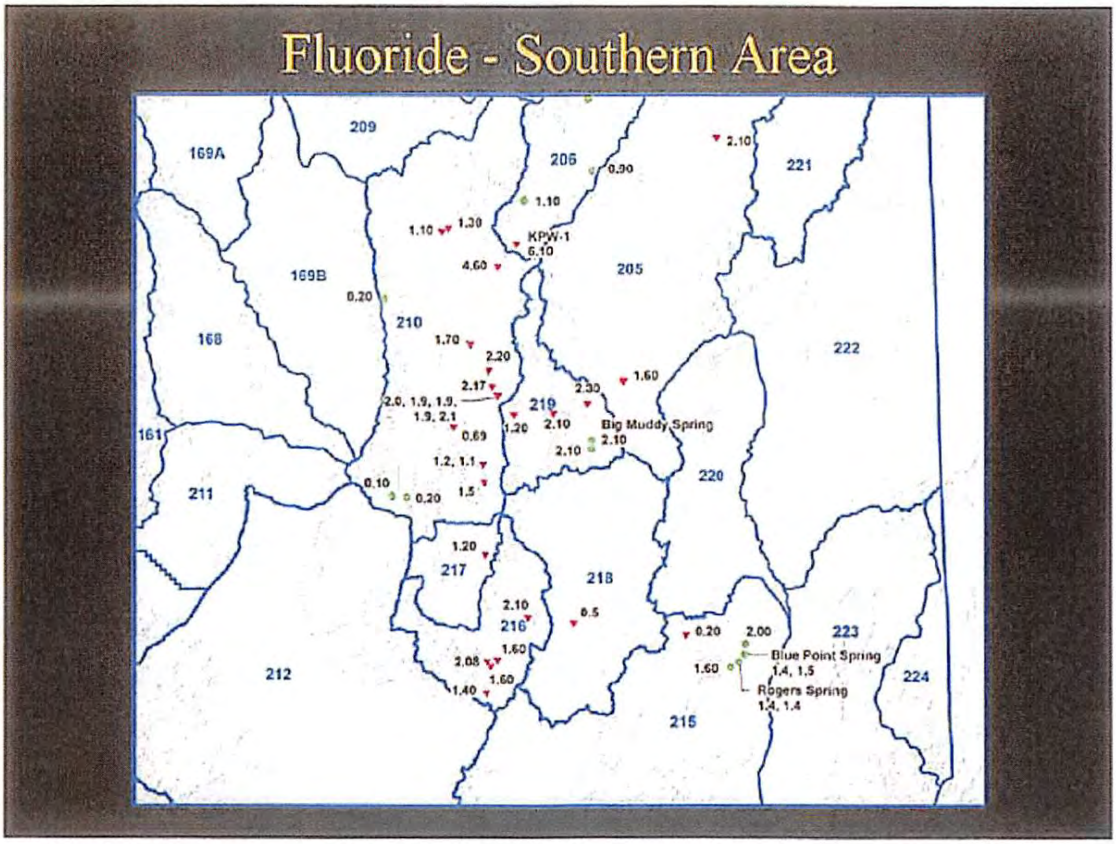
Figure 24



SE ROA 36344

JA_8078

Figure 25



SE ROA 36345

JA_8079

Rebuttal Submittal

by

Lincoln County Water District and Vidler Water Company

to the

Interim Order #1303 Reports

Submitted on July 3, 2019

Prepared for:

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

Prepared by:

Lincoln County Water District
1005 Main Street, Suite 103
P.O. Box 936
Panaca, Nevada 89042

and

Vidler Water Company
3480 GS Richards Blvd., Suite 101
Carson City, Nevada 89703

Submitted August 16, 2019

Preface

Lincoln County Water District and Vidler Water Company (Lincoln/Vidler) respectfully submit this rebuttal response that rebuts statements made in reports submitted to the Nevada State Engineer (NSE) regarding Interim Order #1303. This rebuttal submittal includes responses from the following:

- Greg Bushner, RG, Vidler Water Company, Lincoln/Vidler (Attachment A),
- Peter Mock, PhD, RG, of Peter Mock Groundwater Consulting, Inc. (Attachment B),
- Thomas Butler, PG, CHG, CEG, of Stantec Consulting Services, Inc. (Attachment C),
- Todd Umstot, of Daniel B. Stephens & Associates (Attachment D), and
- Norman Carlson, of Zonge International, Inc. (Attachment E).

A report or a section of a report not rebutted should not be interpreted as Lincoln/Vidler's agreement with the report or section of a report submitted to the NSE on July 3, 2019.

VIDLER
WATER. QUALITY. LIFE.

Attachment A

Rebuttal Submittal to Reports Submitted in Response to Interim Order #1303

Prepared by:

Lincoln County Water District

1005 Main Street, Suite 103

P.O. Box 936

Panaca, Nevada 89042

And

Vidler Water Company

3480 G.S. Richards Blvd., Suite 101

Carson City, Nevada 89703

August 16, 2019

AMERICAN INSTITUTE OF HYDROLOGY
Certificate Number 1125
Greg Bushner
Professional Hydrogeologist

Greg L. Bushner

Expires January 15, 2020

SE ROA 36348

Introduction

Lincoln/Vidler are providing comments to reports submitted by other entities in response to the NSE's IO #1303. Lincoln/Vidler are providing comments on the following reports:

- Las Vegas Valley Water District and Southern Nevada Water Authority's report dated June 2019,
- Moapa Valley Water District's letter dated July 1, 2019,
- National Park Service's report dated July 3, 2019
- Center for Biological Diversity's Technical Memorandum dated July 1, 2019,
- Great Basin Network's letter dated June 27, 2019,
- Moapa Band of Paiutes report dated June 27, 2019,
- City of North Las Vegas's submittal by Interflow Hydrology, Inc., dated July 2, 2019, and
- U.S. Fish and Wildlife Service's report dated July 3, 2019
- Coyote Springs Investment, LLC's report dated July 3, 2019

The following attachments are provided along with Lincoln/Vidler's rebuttal comments:

- *Attachment A-1:* Technical Memorandum from Peter Mock of PMGC, Inc, to Greg Bushner, Vidler Water Company, Subject: A brief overview of an two simulations using the model described in: "Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southern Nevada, Version 1.0," prepared for the National Park Service, U.S. Fish & Wildlife Service and Bureau of Land Management, by Tetra Tech, Inc., of Louisville, Colorado, dated September 28, 2012.
- *Attachment A-2:* U.S. Department of the Interior Fish and Wildlife Service Biological Opinion dated October 29, 2008, File Nos. 84320-2008-F-0007 and 84310-2008-I-0216.
- *Attachment A-3:* Vertical Profile through selected carbonate wells in study area, reproduced from CH2M Hill 2006a.
- *Attachment A-4:* Localized Cross Section through KMW-1, Kane Springs Valley reproduced from URS 2006a.

Comments in italics are direct quotations from other reports that are rebutted. The following text provides Lincoln/Vidler's comments by report.

Lincoln/Vidler's Rebuttal Comments to the Las Vegas Valley Water District and Southern Nevada Water Authority's June 2019 Report.

1. *Page ix, Abstract, paragraph 4, section (a):* LCWD/VWC concur with the statement made by LVVWD and SNWA on page ix of the Abstract that "*…the geographic boundary of the LWRFS* [Lower White River Flow System] *as defined by the NSE is appropriate….*"

2. *Page1-1, Section 1.0, Introduction, paragraph 1:* The statement made at the end of this paragraph that "*…the adjacent Kane Springs Valley* [KSV] *which is included in this assessment because it is tributary to the LWRFS and contributes to the local recharge.*" is factually incorrect. KSV is a separate hydrographic basin as defined by the Nevada Department of Water Resources, and therefore has its own defined perennial yield. There is no "local recharge" from KSV to the LWRFS. There is however, local recharge that occurs ***within*** KSV that contributes to the hydrologic system within the valley and that becomes the perennial yield of KSV.

   Lincoln/Vidler, beginning over a decade ago in October 2007, have been collecting basin-specific data through the use of totalizing rain gages, tipping bucket rain gages, runoff event data loggers, and chloride collectors. We continue to collect and submit these data, to the Nevada State Engineer (NSE) and interested parties, in an effort to better understand and quantify recharge occurring in KSV and to share that technical foundation transparently with others. Based on analysis of the ongoing basin-specific data collection effort, there is unappropriated water available in KSV. This is due to the fact that recharge values clearly show that there is more water available under Nevada State Law than has been appropriated. Much like Cave Valley, Dry Lake Valley, and Delamar Valley, groundwater appropriated in KSV is also recharged within the basin (NSE 2014). Based on a preliminary analysis of these data, estimates of in-basin recharge are between approximately 4,700 to 7,500 acre-feet/year (ac-ft/yr) from the chloride mass balance analysis method and approximately 7,100 to 11,000 ac-ft/yr from the watershed model (T. Umstot (DBS&A), unpublished data and analysis, 2019).

3. *Page 1-3, Section 1.1.2, Order 1169:* Although this is not directly related to the requested information of the NSE's Interim Order (IO) #1303, it is noted that Lincoln/Vidler were not included in the NSE's Order 1169. Lincoln/Vidler are not a party to, nor have they

ever been participants in the Order No. 1169 aquifer test proceedings. The NSE never requested that Lincoln/Vidler provide a report on the outcome of the Order No. 1169 aquifer test results; hence none was ever developed.

4. *Page 1-4, Section 1.1.3, 2006 Memorandum of Agreement:* Lincoln/Vidler are not a part to, nor are they a signatory in the 2006 Memorandum of Agreement, and thus, Lincoln/Vidler are not bound by this agreement.

5. *Page 2-1, Section 2.0, Sources of Information, Section 2.1.1, SNWA (2013b):* Lincoln/Vidler concur with the statement made by SNWA that "*The aquifer test* [referring to the NSE Order 1169 Aquifer test] *confirmed that extensive hydraulic connectivity exists in the carbonate aquifer. However, the presence of boundaries and spatial variations in hydraulic conductivity affect the carbonate aquifer's response depending on location. For example,* ***no discernible responses*** [emphasis added] *were observed north of the Kane Springs Fault….*"

   This observation is validated by the new geophysical data that Lincoln/Vidler and CSI have collected in response to the IO #1303 request by the NSE for new data regarding the boundary of the LWRFS. Lincoln/Vidler documented through the use of geophysics that a distinct change in lithology occurs in northern CSV that explains differences in water levels in wells completed in the regional deep carbonate aquifer (RDCA). It should also be noted that the wells drilled by Lincoln/Vidler located in KSV are on the northwest side of the Willow Springs Fault, interpreted to be the western most boundary of the Kane Springs Wash Fault Zone.

6. *Page 2-2, Section 2.0, Sources of Information, Section 2.1.1, USFWS, Bureau of Land Management (BLM), and NPS (2013):* As previously stated before, Lincoln/Vidler have the following comments on the numerical groundwater flow model developed by Tetra Tech (2012) and its use.

   Lincoln/Vidler take issue with this reference to the Tetra Tech model development and predictive scenarios for several reasons and any reliance on it. The Tetra Tech model has not been through a rigorous peer-review process and Lincoln/Vidler have identified several additional issues with the Tetra Tech model including:

   - The steady-state flow is almost completely out of alignment with available measurements,

- There are no data that provide in-situ information on the rate and propagation of drawdown out from production wells in KSV,
- It has never been subjected to evaluation by the Technical Review Team,
- It is based on the no longer supported HUF MODFLOW numerical groundwater flow model package that averages out the strong formation breaks known to occur throughout the modeled area, and
- For whatever reason, the model does not measure the effects of pumping by Lincoln/Vidler, but uses assumptions that include the maximum pumping rate of the pending applications in all of the basins, which is completely unrealistic.

Lincoln/Vidler have previously commented on the Tetra Tech model (2012) and those comments are provided as Attachment A-1 to this rebuttal report. Additional rebuttal to the NPS and its reliance and uses of this model can be found in Attachment B by Dr. Peter Mock of Peter Mock Groundwater Consulting, Inc included with this rebuttal submittal.

7. *Page 2-3, Section 2.0, CSI (2013):* Lincoln/Vidler agree with the statement made by CSI in 2013 that "*The Kane Springs Fault acts as a groundwater barrier to groundwater flowing from north to south in Coyote Spring Valley and may also serve as a barrier to pumping from wells located north of the fault.*" This is supported by the new geophysical data Lincoln/Vidler have collected in northern CSV.

8. *Page 3-2, Section 3.3.1 Structural Setting, Thrust Faults:* Lincoln/Vidler agree with the statement by SNWA regarding thrust faults by stating "*…these faults have juxtaposed the carbonate-rock sequence with low permeability rocks that are older (e.g. Gass Peak Thrust in the southern Sheep Range) or younger (e.g. muddy Mountain Thrust). In these areas, this juxtaposition effectively truncates the extent of LWRFS. The thrust fault themselves may also act as barriers to groundwater flow (Page et al., 2005).*"

   Lincoln/Vidler have identified the occurrence of thrust faults as well as the lack of thrust faults where they were previously thought to occur through the use of the geophysical data that has been collected in northern CSV (Lincoln/Vidler 2019). This data should be used by the NSE to further refine the boundary of the LWRFS in northern CSV.

9. *Page 3-4, Section 3.3.1 Strike-Slip Faults, last sentence top of page:* Based on the geophysical data collected in northern CSV and previously in southern KSV, the

difference in water level data from wells in southern KSV and northern CSV, geochemistry data, and groundwater temperature data, we know that "*… the Kane Springs Wash Fault Zone may act as a partial barrier to flow, impeding flow across the fault from north to south.*" Lincoln/Vidler agree with this statement.

10. *Page 3-4, Section 3.3.2, Delamar Mountains:* There is opportunity for groundwater to flow through the Pahranagat Shear Zone in Delamar Valley through the lower portion of KSV where the Tertiary caldera complex is not present. The higher precipitation rates that occur on the Tertiary caldera complex located in the Delamar Mountains would likely create perennial or at a minimum intermittent streams in this are if there were such barriers to groundwater flow. Refer to Attachment B by Dr. Peter Mock of Peter Mock Groundwater Consulting, Inc included with this rebuttal submittal.

11. *Page 3-11 and continued on Page 3-13, Section 3.4.2.2, Occurrence and Movement, 4th paragraph in that section and the rest of that paragraph and the next paragraph on page 3-13:* Lincoln/Vidler would add that through the use of the new geophysical data collected in response to the NSE's IO #1303, there exists a fault occurring in northern CSV. This fault is termed the Northern LWRFS Boundary Fault and bounds higher resistivity carbonates of the RDCA that occur in southern Delamar Valley and northern CSV juxtaposed against low resistivity zones that may indicate a thick sequence of Mesozoic sediments or Tertiary volcanic rocks or Tertiary alluvial basin fill cover. This geophysical data shows the geologic conditions that explain the differences in heads between the wells in southern KSV and northern CSV versus the rest of the LWRFS (Lincoln/Vidler 2019).

12. *Page 5-4, Section 5.1.3 MRSA Surface-Water Diversions, top of page last sentence of section:* Lincoln/Vidler agrees that this statement sums up the effects to the Muddy River Springs Area (MRSA): "*…the difference between the pre-development baseflow and the natural flow record must be mostly associated with groundwater production within the MRSA.*" and should be the focus of how to manage the area.

13. *Page 5-6, Section 5.2.1, Comparison of Hydrologic Responses:* Lincoln/Vidler do not agree with the interpretation of the hydrograph data from wells KMW-1 and CSVM-4 as being "*similar to those of other wells in the basin, but appear to be slightly attenuated by the Kane Springs Fault.*" The general trend of the hydrographs of CSVM-4 and KMW-1 do show the response of water levels to the extreme precipitation event that occurred in

2005. This event is also seen in the water level response from wells throughout the LWRFS. However, the water level response in wells KMW-1 and CSVM-4 do not show the seasonal pumping response of water levels in all of the other wells provided in Figure 5-5, and also well CSVM-1 in Figure 5-4. This is distinctly different from a "slight attenuation" due to the Kane Springs Fault Zone.

14. *Page 5-17, Section 5.2.3.2, Recovery Period:* Lincoln/Vidler agree with the factors that influence the recovery period of the NSE Order 1169 aquifer test, the extreme precipitation event that occurred in 2005 is captured in the water level data in every hydrograph from wells in the LWRFS and surrounding basins. While the hydrologic system was recovering from this event, the Order 1169 aquifer test was initiated, and where the actual drawdowns from the aquifer test pumping reached a particular well, the recovery from the extreme precipitation event compounded the downward water level trend at that well. This factor clearly also obscured the ability to identify the recovery from the aquifer test. The other issue from the hydrographs as noted above is that the seasonal responses are more likely due to seasonal groundwater pumping throughout the area versus "recharge pulses."

15. *Page 6-1, Section 6.1, Qualitative Assessment of Historical Responses, middle of paragraph in this section*: Lincoln/Vidler disagree with the statement that there is a "*…lack of any significant recovery response after the completion of the Order 1169 aquifer test and the fact that the system has yet to recover to pre-test levels….*" The Order 1169 aquifer test was conducted at a time of declining water levels in the hydrologic system where additional drawdown from the test is imposed on the dissipation of temporarily higher water levels due to the extreme precipitation event in 2005. The hydrographs show a declining water table before the 2005 event where this event pervasively impacted the hydrologic system in the LWRFS basins and surrounding basins. It's not that significant recovery did not occur; it is simply that the recovery occurred coincident with the hydrologic system recovering from the 2005 precipitation event.

16. *Page 6-3, Section 6.1.1, Implications of Continued Pumping, first paragraph, second sentence:* This sentence states and makes the assumption that the MRSA "*…constitutes the majority, if not all, of the discharge from the [carbonate] flow system.*" Lincoln/Vidler disagree with this statement, see U.S. Geological Survey Scientific Investigations Map 3434 (Wilson 2019) provides a potentiometric map of the upper

RDCA in the LWRFS based on existing well data in this area. This map shows groundwater flowing from recharge areas in the western portion of the LWRFS (i.e., the Sheep Range and the Las Vegas Range) and based on the water level contours groundwater flow east towards Lake Mead and surrounding hydrographic basins to the north. It does not indicate a significant discharge area in the MRSA. Lincoln/Vidler do not disagree that the springs in the MRSA are supported by discharge from the RDCA, we simply think as supported by this US Geological Survey publication that not all of the flow from the LWRFS discharges in this area and in fact a large portion of the flow may discharge elsewhere in the system.

Lincoln/Vidler's Rebuttal Comments to the Moapa Valley Water District's July 1, 2019 Letter.

It should be noted that this is not a technical report from Moapa Valley Water District (MVWD) nor is there any new data, information, or analysis. Lincoln/Vidler's comments are provided below.

1. *Page 1, Section A, Paragraph 3:* Lincoln/Vidler explicitly disagrees with the statement that the LWRFS include KSV. There is little if any justification for this as is documented in Lincoln/Vidler's Report prepared in response to the NSE Interim Order #1303 titled "Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit," submitted to the NSE on July 3, 2019 (Lincoln/Vidler 2019).

   There is no direct connection that can be drawn between the change in water levels in KMW-1 and the Order 1169 aquifer test. Groundwater levels in KMW-1 have been declining steadily since the well was constructed in 2006 at an average rate of 0.1 foot/year. What significantly impacted the groundwater level in this well was the over-arching impact of the 2005 precipitation. The MVWD offers no data, analysis, or credible science to support statements made that there was a response seen in well KMW-1 from the NSE Order 1169 aquifer test.

2. *Pages 1and 2, Section A, fourth paragraph:* Lincoln/Vidler agree that there is inter-basin flow from KSV to CSV similar to the occurrence of inter-basin groundwater flow from Pahranagat Valley and Delamar Valley to CSV. The simple fact that there is inter-basin groundwater flow does not mean that KSV should be included in the proposed

administrative unit of the LWRFS. The NSE's groundwater appropriation system is based on a basin-by-basin perennial yield analysis that is used to manage each groundwater basin. Lincoln/Vidler are entitled to pursue the full perennial yield available in KSV per our pending groundwater applications.

3. *Page 2, Section A, first full paragraph:* Although there may be an inter-basin groundwater flow between KSV and CSV, there is much geologic structure that changes in the northern portion of CSV as documented in Lincoln/Vidler's report to NSE addressing his issues identified in IO #1303. There is an extensive fault that occurs in northern CSV as documented by the new geophysical data submitted in Lincoln/Vidler's report. The Northern LWRFS Boundary Fault identifies a significant change in lithologic characteristics from southern KSV and northern CSV where carbonate rocks occur to the north of this fault and to the south of the fault where lower permeability Tertiary basin fill materials occur. This change in geologic structure in northern CSV is what controls the flow of groundwater into the LWRFS and also controls the effects of any hydrologic impacts from KSV to northern CSV.

   The NSE should deny the request by the MVWD that KSV be added to the proposed "Super Basin," see Lincoln/Vidler's July 3, 2019 report submittal.

4. *Page 3, Section B, Influence of Climate, first full paragraph:* While Lincoln/Vidler do not disagree with the analysis of the hydrographs that show the effects of above average precipitation in 2004 and 2005, it should also be noted that these effects also occurred in monitor wells KMW-1 in southern KSV and CSVM-4 in northern CSV.

5. *Page 4, Section 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 the Muddy River flow, second paragraph:* There is an obvious typo in this paragraph as there are only **6** basins that are proposed to be included in the LWRFS.

6. *Page 5, Section D, the effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River, first paragraph:* The same typo is made in this paragraph as there are only **6** basins that are proposed to be included in the LWRFS as per IO #1303.

7. *Page 6, Section E, under sub-title Municipal Use as the Preferred Use in the LWRFS basins, second paragraph bullet 1:* The same typo is made in this paragraph as there are only **6** basins that are proposed to be included in the LWRFS as per IO #1303.

8. *Page 7, last sentence of the first paragraph*: This sentence states: "*Based on SNWA's (2013) and Johnson's (2019) conclusions that carbonate pumping has minimal or no impact on Muddy River flows above the Moapa gage, the District has met its obligation to protect dace habitat and senior water rights.*" Apparently SNWA has evolved in their conclusion that carbonate pumping has minimal or no impact on Muddy River flow above the Moapa gage. Page 5-6 of SNWA's submittal to the NSE in response to IO#1303 states "*Based on the accounting depicted in Figure 5-4, the MRSA carbonate production wells have depleted MR* [Muddy River] *streamflow approaching a 1:1 basis.*"

Lincoln/Vidler's Rebuttal Comments to the National Park Service's July 3, 2019 Report Titled: Prediction of the Effects of Changing the Spatial Distribution of Pumping in the Lower White River Flow System.

1. *General Comment:* The continued use of the Tetra Tech model by the National Park Service (NPS) to evaluate groundwater pumping effects in the LWRFS and other groundwater basins in the vicinity of the MRSA and also outside of this area is an exercise in futility. Lincoln/Vidler re-iterate our previous concerns regarding this model and it's use as we stated previously in our correspondence to the NSE (Attachment A-1).

   The most significant issue is that this model has not been accepted by the scientific community through a rigorous peer-review process. The same standard should apply to the consultants of the Department of Interior (DOI) bureaus (defined as the NPS, Bureau of Land Management [BLM], and U.S. Fish and Wildlife Service [USFWS]) as was applied to Lincoln/Vidler with the requirement of a peer-review of all of our scientific investigations for the NSE's acceptance of our Tule Desert submittals. This included a numerical groundwater modelling effort, a geochemical report, and an in-depth basin-specific recharge analysis, see US Geological Survey Open File Report 2008-1354 (Berger and others, 2008). Either a rigorous peer review should be required of this numerical model and geochemical report before they can be used for this assessment or the NSE should publicly state he decline to use the NPS report and model.

2. *Page 7, Section 2.3, 2013 Post Audit Summary and Conclusions, Last Paragraph:* The critically flawed Tetra Tech model that is relied upon for the basis of this current analysis admittedly falls short of the request by the NSE IO #1303 which states that "… *the State Engineer finds that input by means of reports by the stakeholders in the interpretation of the data from the aquifer test and from the years since the conclusion of the aquifer test is important to fully inform the State Engineer prior to setting a limit on the quantity of groundwater that may be developed in the LWRFS or to developing a long-term Conjunctive Management Plan for the LWRFS and Muddy River.*" (NSE 2019, page 11, paragraph 2). By their own admission, the NPS did nothing to advance their modeling effort or to incorporate new data that has been collected since the end of the Order 1169 pumping test. The NPS specifically states "*The data collected during 2012 and the six years since the completion of the Order 1169 pumping test could be used to improve the calibration of the model to the observed effects of pumping in Coyote Spring Valley and neighboring LWRFS basins….This additional work was beyond the scope and timeframe for the modeling simulation effort conducted as part of this report.*"

It is not clear why the additional work was not performed in light of NPS' request for an extension of time to July 3rd to submit its report, the IO #1303 was issued in January of this year, and therefore NPS had time to plan for and update its model with new data. Also, NPS has had the results of the Order 1169 aquifer test since 2012.

3. *Page 14, Section 3.2, Current Predictive Scenarios Evaluated, Simulation 3, third full paragraph:* Lincoln/Vidler disagree and flat out reject the use of this model to simulate pumping effects in KSV, or the rest of the LWRFS for that matter, and including other areas such as Tule Desert, Virgin Valley, and Clover Valley, which by the way are not at issue in the NSE's IO #1303. The problem is that while the NPS funded the work of Page and others (2006, 2011) that now stands as a widely-accepted interpretation of the geologic structure, they did not make sure that Tetra Tech incorporated this structure into the Tetra Tech model effectively. Until this is done, this model is unreliable for use as a predictive tool.

4. *Page 14, Section 3.2, Current Predictive Scenarios Evaluated, Simulation 3, fourth full paragraph:* In addition to the comment made above, by the NPS's own admission "*The largest model residuals are in high gradient areas, where model errors can result in large differences, in the Clover Mountains where the volcanic stratigraphy is greatly*

simplified, and in the Tule Desert where some of the structural complexity may not be incorporated in the geologic model and the model grid is relatively coarse." See Page 5, Section 2.1 2012 Groundwater Model Calibration, of the July 3, 2019 NPS report.

Lincoln/Vidler's water rights in Tule Desert are not within the scope or purview of NSE's IO #1303, nor for that matter are Virgin Valley Water District's. Any reference or model prediction made by the NPS to Tule Desert or Virgin Valley should be ignored by the NSE as it is un-responsive to his request in IO #1303.

5. *Page 15, Section 4.1 Model Setup, first paragraph top of page:* For a boundary condition the lake stage elevation representing Lake Mead is too high. Lake Mead's average stage elevation is 1095 feet for the time period 2011 through 2017, not 1,133 feet as reported. If the data were actually incorporated as stated, then the predictive runs would have a stage height of 1,133 feet or approximately 37 feet higher than the updated simulations. The difference in stage elevations for 2011 through 2017 ranged from a high of 1,121 feet (2012) to a low of 1,077 feet (2016) which is over a 56-foot difference from an elevation of 1,133 feet. If the model was updated to incorporate new data, this isn't even close to accurate. This type of boundary condition would have a widespread impact on the overall heads in the model.

6. *Page 22, Section 5.2.1.2, Kane Springs Valley (HA 206):* Lincoln/Vidler disagree with the conclusion that the water levels in monitor wells CSVM-4 and KMW-1 show drawdown caused by the pumping during the Order 1169 aquifer test (Lincoln/Vidler 2019).

Lincoln/Vidler's Rebuttal Comments to the Center for Biological Diversity's Technical Memorandum by Tom Myers, Ph.D., dated June 1, 2019.

1. *Page 2, Paragraph 1, referencing Figure 1:* This is a poor reference to the LWRFS administrative unit groundwater basins. Not included in the LWRFS basins are Kane Springs Valley, Lower Meadow Valley Wash, and Lower Moapa Valley.

2. *Page 2, Item #2:* KSV should not be included as part of the LWRFS, and not just because of the difference in water level between CSVM-4 and KMW-1. There are several reasons that KSV should continue to be excluded from the proposed LWRFS administrative unit by the NSE, including but not limited to the following reasons set forth below:

a. Groundwater elevation data show distinctive differences in heads between KSV/northern CSV and the southern portion of CSV, which are confirmed by the geologic structures that occur in KSV and northern CSV.
b. There is no discernable trend/pattern in water levels overtime between production well KPW-1 and pumping trends.
c. New geophysical data collected in northern CSV identified a very large fault structure at the end of the Delamar Mountains which would affect groundwater flow from KSV into northern CSV. This fault is deemed the Northern LWRFS Boundary Fault.

To review all of the supportive data refer to the Lincoln/Vidler report submitted to the NSE on July 3, 2019, titled *Lower White River Flow System Interim Order #1303 Report Focused on the Northern Boundary of the Proposed Administrative Unit*.

3. *Page 15, Figure 12:* This figure provides a very weak argument that there are any effects from the Order 1169 aquifer test on well CSVM-4. There is no significant change in head at this well and as stated before any change in head is attributable to hydrologic effects other than pumping. For further comment on the correlation of groundwater elevations to the Order 1169 aquifer test see Attachment D, a technical memorandum by Todd Umstot of Daniel B. Stephens & Associates.

4. *Page 17, Last sentence of third full paragraph:* Lincoln/Vidler interpret CSVM-4 to be located in the same structural block in northern CSV that KMW-1 is located in within southern KSV. However, a complicating factor is the Kane Springs Wash Fault Zone, the western boundary of which is intersected by both of these wells CSVM-4 and KMW-1. There is a gradient in northern CSV that is inconsistent with the data from wells throughout the central and lower portion of CSV.

5. *Page 19, second paragraph:* Lincoln/Vidler assert that northern CSV should continue to be excluded from the LWRFS based on the structural geology as identified by the geophysics that we have collected in this area. Lincoln/Vidler do believe as identified in our July 3rd report submittal that there is a significant fault that occurs and juxtaposes highly transmissive carbonate rocks with significantly lower transmissive sediments in

this area. This would inhibit the flow of groundwater south into the central and southern portions of CSV.

6. *Page 19, second paragraph:* Lincoln/Vidler disagree that the perennial yield is low. What is the basis of this assertion, i.e., where is the data that Dr. Myers used to make this statement? Lincoln/Vidler have been collecting in-basin precipitation, runoff, and chloride data for over a decade. Based on this data we estimate that the available recharge in KSV ranges from 4,700 acre-feet/year (ac-ft/yr) to approximately 11,000 ac-ft/yr depending on the method use. SNWA independently derived an annual recharge value of 4,329 acre-feet (SNWA 2009).

7. *Page 19, second paragraph:* It would take a very long time for drawdowns in the carbonate system to propagate south into CSV from the location of a pumping well in KSV. This is due both to the large distance and intervening geologic structures, and in particular to the Northern LWRFS Boundary Fault, identified by the geophysical investigation Lincoln/Vidler conducted in response to the NSE's IO #1303, that exists in northern CSV and that separates northern CSV and KSV from the rest of the LWRFS.

8. *Page 19, second paragraph:* Lincoln/Vidler disagree that the groundwater source in KSV is limited and not sustainable. Again, where is the data to support this statement? What does the statement "*…KSV is not a sustainable means of increasing the available water in LWRFS.*" mean? The water resources of KSV have been studied extensively by Lincoln/Vidler (CH2M Hill 2006a, CH2M Hill 2006b, URS 2006a, URS 2006b) as well as the geological setting through several geophysical investigations conducted in the basin. KSV is a distinct groundwater basin delineated by the Nevada Department of Water Resources that is managed separately according to Nevada Water Law and should continue to be managed separately and not as part of the LWRFS.

9. *Page 19, third paragraph:* Lincoln/Vidler conducted a geophysical investigation in northern CSV that identified a fault structure, called the Northern LWRFS Boundary Fault, effectively limiting the flow of groundwater flowing south through CSV as well as propagation of drawdowns. Refer to the July 3rd Lincoln/Vidler report to the NSE in response to IO #1303.

10. *Page 19, third paragraph:* There is no data to suggest that groundwater development in KSV and northern CSV would decrease flow to springs and downgradient water rights. Dr. Myers does not cite to any data supporting his statements.

11. *Page 26, Conclusion, paragraph 2:* Lincoln/Vidler disagree with this conclusion that KSV should be managed as part of the LWRFS. The "flat water table" referred to in this paragraph is referencing the water table between KSV and northern CSV as documented from the water levels in both monitor wells KMW-1 and CSVM-4. The potentiometric surface between these two wells is not flat (a difference in head of approximately 6 feet) and compared with the rest of the proposed LWRFS administrative unit of approximately 50 feet and that truly represents a consistent head across that majority of the proposed LWRFS basins (Lincoln/Vidler 2019). There is a reason that the water table elevation is not consistent from all of CSV into KSV and that's because of a significant change in geologic structure that is identified by new geophysical data collected by Lincoln/Vidler that is interpreted to be the Northern LWRFS Boundary Fault that extends trending east-west at the base of the Delamar Mountains (Lincoln/Vidler 2019).

    The Center for Biological Diversity does not provide any evidence to support their assertion that water pumped from KSV would quickly contribute to the depletion of the carbonate aquifer in CSV and in the MRSA, over 20 miles from the southern boundary of KSV, if measured by line-of-sight.

Lincoln/Vidler's Rebuttal Comments to the Great Basin Network's June 27, 2019 Letter.

It should be noted that this is not a technical report nor is there any new data, information, or analysis. Lincoln/Vidler's comments are provided below.

1. *Pages 1 & 2 (note that there are no page numbers on this letter), third full paragraph and Section 2(a) extending to the top of the next page:* Lincoln/Vidler disagree that the LWRFS administrative unit should include all of the groundwater basins in the White River Flow System (WRFS). This is completely counter to Nevada Water Law that is based on a basin-by-basin system of groundwater appropriation of the perennial yield of each groundwater basin. Groundwater rights holders and applicants expend a huge effort in collecting the best scientific information in support of their groundwater rights and applications. This directly correlates to extensive time and money being expended. If Nevada Water Law is changed and the entire WRFS was included in the administration

of the LWRFS basins, this means that no water would be available from upgradient groundwater basins and the counties where these basins occur would not have the ability to utilize water for economic development in their county.

2. *Page 2, Section 2(c):* See above comment.

Lincoln/Vidler's Rebuttal Comments to the Moapa Band of Paiutes Report by Mifflin & Associates, Inc. dated June 27, 2019.

1. *Page 54, Appendix III, second full paragraph:* The calculation of groundwater travel times is not reasonable. The distance between Preston Big Spring in the northern White River Valley Basin (HA 207) to Crystal Spring in Pahranagat Valley (HA 209) is approximately 100 miles by a line-of-sight measurement. So, if it only takes 25 years for groundwater, under a non-pumping gradient, to flow 100 miles, that means that the groundwater is flowing at 4 miles per year, or 21,120 feet per year. This groundwater flow rate is two to three orders of magnitude too high for the RDCA. The average groundwater flow velocity can be calculated using the hydraulic gradient times the hydraulic conductivity divided by the effective porosity. These values are 0.00631 ft/ft (calculated from Figure 3 of Lincoln/Vidler 2008), 3 to 5 ft/day (Mock 2008), and an assumed effective porosity of 0.10, respectively. Using these data to calculate the average groundwater velocity of the RDCA yields a groundwater flow rates ranging from 69 ft/yr to 115 ft/yr. Refer to Attachment B by Dr. Peter Mock of Peter Mock Groundwater Consulting, Inc included with this rebuttal submittal.

2. *Page 59, Appendix III, third full paragraph:* The model developed by Mifflin and Associates, Inc. (MAI) presented in this report cannot be used for any predictive analysis. The MAI model completely ignores the geologic structures throughout eastern Nevada that have a huge effect on the flow and travel time of groundwater thought the RDCA. It also ignores and does not calibrate to existing groundwater temperature data from within KSV. And as stated above, the groundwater travel times are completely unrealistic.

3. *Page 60, Critique of the Model, first full paragraph*: One cursory review of a geologic map, i.e., Page et al (2006) and associated geologic cross-sections, or Rowley and others (2017) and associated cross-sections all show basement rocks that are exposed throughout the basin and range physiographic province of eastern Nevada. This model completely ignores the geology so this critique applies to the entire model domain.

4. *Pages 7 through 11, Figures 2 through 9*: All of these hydrographs of water level changes from wells throughout the LWRFS and the one for KSV ignore the extreme precipitation event that occurred in 2005 (see Lincoln/Vidler 2019). Hydrographs for wells CSVM-4, MX-4, TH-2, and SHV-1 shown in these figures all show data starting in 2006 and ignore the huge precipitation event, over 300% of average, that occurred in 2005. Hydrographs for wells BM-DL-2 and GV-1 provide data prior to 2006 and the 2005 precipitation event is clearly shown on the hydrograph. However, the authors chose to ignore the water level trend prior to the event occurring. If the data is used prior to 2005 then the trend is still declining but not at a third of a foot per year. These graphs portray a more severe condition than is actually occurring in the LWRFS.

Lincoln/Vidler's Rebuttal Comments to the City of North Las Vegas's Submittal by Interflow Hydrology, Inc., Technical Memorandum RE: Garnet Valley Groundwater Pumping Review for APEX Industrial Complex, City of North Las Vegas, Clark County, Nevada, dated July 2, 2019.

1. *Page 8, first paragraph*: Lincoln/Vidler generally agree with the statement made in this paragraph regarding known barriers to groundwater flow, however through the use of CSAMT geophysical studies in southern KSV and northern CSV, Zonge International, Inc., have identified structures that exist and explain the differences in water levels seen in wells in southern KSV and northern CSV, as compared to the rest of the LWRFS. This structure has been identified as a fault named the Northern LWRFS Boundary Fault. Lincoln/Vidler have identified that the high resistivity carbonates of the RDCA are juxtaposed to lower permeable geologic formations to the south which do form a barrier to groundwater flow. Lincoln/Vidler do agree that this barrier is not impermeable but impedes the flow of groundwater into the rest of the LWRFS and would also reduce the effects of any pumping in the LWRFS to KSV and vice versa. Refer to Attachment B by Dr. Peter Mock of Peter Mock Groundwater Consulting, Inc included with this rebuttal submittal.

Lincoln/Vidler's Rebuttal Comments to the U.S. Fish and Wildlife Service's July 3, 2019 Report.

1. *General Comment:* The U.S. Department of the Interior Fish and Wildlife Service issued a biological opinion (BO) on October 29, 2008, for the Kane Springs Valley Groundwater Development Project in Lincoln County, Nevada (File Nos. 84320-2008-F-

0007 and 84320-2008-I-0216). This biological opinion is provided to these rebuttal comments in Attachment A-2. The finding on page 37 of the BO sums up the conclusion from the USFWS on impacts to the MRSA, and on the Moapa Dace, of the proposed Kane Springs Valley Groundwater Development Project, as follows:

> *"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."*

Based on this BO, any reference that the USFWS makes to the addition of KSV to the proposed administrative unit should be ignored as the USFWS has already made a determination in this case. Lincoln/Vidler are still providing comments on the USFWS report but all of our comments below should be viewed in light of this determination.

2. *General Comment:* The USFWS should identify the author(s) of this report and the sections of text they are responsible for, if there is more than one author.

3. *Page 20, Under Heading Kane Springs Valley and first paragraph under heading The 2007 Finding:* The new geophysical investigation conducted by Zonge International, Inc., for Lincoln/Vidler, found that there is a significant fault structure named the Northern LWRFS Boundary Fault, as documented in Lincoln/Vidler's July 3, 2019 report submittal to the NSE. This validates the 2007 finding by the NSE in Ruling #5712 that

> "*…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 validation of the existence of a fault structure in northern CSV and the original assessment was based on data from wells KMW-1 in KSV and CSVM-4 in CSV and water levels in other wells further to the south in the LWRFS, site specific data, and not generalized locations. There is no reasonable professional doubt of the existence of this fault structure based on the new geophysical data (Lincoln/Vidler 2019). Figure 3-4 (Lincoln/Vidler 2019) shows the geologic completions for each well and heads for wells throughout the LWRFS (Attachment A-3). Attachment A-3 was taken directly from the 2006 presentation to the NSE by CH2M Hill (2006a) during the first hearing on Lincoln/Vidler's groundwater applications in KSV.

The geophysical data collected by Lincoln/Vidler illustrates why there are changes in heads in southern KSV and northern CSV compared to the rest of the LWRFS. This is new data and the water level data were never based on "generalized" well locations as suggested by the U.S. Fish and Wildlife Service (USFWS).

4. *Pages 20 and 21, under heading 'The 2007 Finding', third paragraph that continues to the top of the next page*: No reasonable professional doubt remains as to what is causing the differences in water level from KMW-1 to CSVM-4, and from CSVM-4 to CSVM-6. Well KMW-1 is drilled on the upthrown side of the Willow Springs Fault (Figure 3-3, Lincoln/Vidler 2019), and well CSVM-4 is drilled into the carbonate formation on the eastern side of the extension of the Kane Springs Wash Fault Zone in northern CSV (Figures 4-4 and 4-7, Lincoln/Vidler 2019). This is based on the geologic log of KMW-1 (URS 2006), the geophysics collected in 2012, and the new geophysical data collected in 2019.

   Regarding the differences in water levels between wells CSVM-4 and CSVM-6, new geophysical data was collected by CSI as reported by them in their July 3, 2019 submittal to the NSE. Well CSVM-6 is located between two faults just north of a highly resistive block of carbonate rocks (Figures 10 and 11, Reich and Moran, 2019). The geophysics of northern CSV shows numerous faults between well CSVM-6 and wells CSVM-4 (Figure 4-7, Lincoln/Vidler 2019).

5. *Page 21, first full paragraph and Figure 6 (page 65)*: the Kane Springs Wash Fault is mis-labelled on Figure 6. What's labelled as the Kane Springs Wash Fault on Figure 6 is actually the Willow Springs Fault (Swadley et al, 1994).

6. *Page 21, first full paragraph referencing Figures 7, 8, and 8a:* The problem with all of these hydrographs and correlating effects of pumping from the Order 1169 aquifer test is that the test occurred during a period of time in the hydrologic system when the overall water level trend was downward which is attributable not to the pumping in the LWRFS, but the dissipation of the extreme precipitation event that occurred in 2005. If the 2005 precipitation event is considered then there is no impact from the Order 1169 aquifer test on water levels in well CSVM-4 (Figure 3-9, Lincoln/Vidler 2019).

7. *Page 21, first full paragraph*: Lincoln/Vidler disagrees with the statement made by the USFWS that "*Based on the continuity of water level responses across this portion of the carbonate aquifer, any changes in lithology or discrete low permeability structures present in the carbonate aquifer between KMW-1 and central CSV are not sufficiently impermeable to preclude or significantly minimize the impacts of carbonate pumping in KPW-1 on carbonate water levels in CSV ….*" Unlike most of the participants, Lincoln/Vidler have collected current geophysical data in northern CSV which shows that there is a significant fault structure, named the Northern LWRFS Boundary Fault, that exists in northern CSV and that provides a significant limiting control to groundwater flow. These data are supported by water level data from wells in KSV and throughout the CSV that illustrate the effects of the fault structure on heads in these areas. We believe an authentic, realistic scientist will understand the value of good, reliable, repeatable data that has been proven to accurately identify geologic structures to help update former hypotheses once held.

8. *Page 21, second full paragraph*: The statement by the USFWS that "*…to the extent that the completion of KMW-1 relative to the KSWF zone is unclear…*" is a patently false statement. We know exactly where the Kane Springs Wash Fault Zone is and exactly what the dip of the fault is because Lincoln/Vidler drilled through it during the construction of monitor well KMW-1. In addition to the downhole geophysics conducted on the well bore of KMW-1, the geologic log of well KMW-1 (URS 2006), and the CSAMT geophysics collected in 2012 show the Willow Springs Fault, which is an extension of the Kane Springs Wash Fault in the vicinity of the wells. (Figure 3-3 [Lincoln/Vidler 2019], Attachment A-4) shows the geologic interpretation of the location where KMW-1 and KPW-1 were drilled.

9. *Page 22, first full paragraph*: The USFWS provide no data to support or substantiate the statement that pumping on the east side of the Kane Springs Wash Fault Zone would

impact water levels in central CSV. This is especially glaring since they have mis-labelled the fault on the west side of KSV as the KSW fault.

10. *Page 22, second full paragraph*: There is a big "wedge" of high resistive carbonate rocks that occur in northern CSV and that run into lower resistive and much less permeable lithology south of this feature (Figure 4-7, Lincoln/Vidler 2019). Also, based on this geophysical data the locations of faults as identified in the USFWS report are mis-located or not present in this area. The Kane Springs caldera complex is nowhere near monitor wells CE-VF-2 and CSVM-3 in CSV.

    Well KMW-1 (and well KPW-1) intersects the upthrown block of the Kane Springs Wash Fault Zone. This has been known and this data publicly available since the 2006 NSE hearing on Lincoln/Vidler's groundwater rights applications in KSV.

11. *Page 22, under the heading Proposed KMW-1 Pumping Test*: The USFWS was an initial participant in the 2006 NSE Kane Springs water rights hearing and was well aware of the exhibits submitted during this hearing, including the well completion and testing report for wells KMW-1 and KPW-1 (URS 2006). The statement "*…a pumping test has reportedly been performed on KMW-1, the details and results of the test are not widely known or evaluated.*" Is disingenuous at best as the report has been publicly available since 2006. The USFWS continues to postulate about something that has been known for over a decade and that has been publicly available data almost since the day that it was collected.

12. *Pages 22 and 23, under heading 'Proposed KMW-1 Pumping Test'*: There is no need for an additional pumping test of well KMW-1 as the new geophysical data collected provides new information on what is indicated and known from water levels in wells KMW-1 and CSVM-4 as compared with the rest of the wells in the LWRFS. In addition to this new geophysical data, Lincoln/Vidler's support for excluding KSV from the LWRFS is also supported by other geochemistry data including but not limited to general chemistry, Carbon-14, and groundwater temperature data, and hydrologic data in the form of basin specific precipitation and runoff data (Lincoln/Vidler 2019). If it were so found by the proposed, very expensive pumping test, finding that drawdowns reach into KSV from nearby northern CSV pumping or vice versa is irrelevant to whether those drawdowns can reach the surface features within the MRSA and measurably reduce their flows.

13. *Page 28, Section 1.3.3 Boundaries and Boundary Conditions*: Why wouldn't the USFWS use the latest geologic data and information available for the assessment of the boundary conditions of the LWRFS as available by Rowley et al (2017)?

14. *Page 28, Under heading 'Pahranagat Shear Zone'*: Lincoln/Vidler disagree with the characterization of flow from the Pahranagat Shear Zone through Delamar Valley and KSV. The Kane Springs Wash caldera complex begins approximately 14 miles from the southern boundary of the KSV basin. This would not necessarily preclude inflow from the southern part of Delamar Valley to CSV. In fact, the same logic would hold true, i.e., if there is flow through the Pahranagat Shear Zone from Pahranagat Valley into Coyote Spring Valley then why would that change for the portion of the Pahranagat Shear Zone adjacent to Delamar Valley? The FWS provide no evidence of this change in boundary condition. Lincoln/Vidler also disagree that there is no inflow from Delamar Valley to KSV because of the "*…caldera complex and outcrop of basement rocks….*" This statement is not supported by any evidence. Also, examination of the geologic cross sections from Rowley et al (2017) indicates that the basement complex is not present near the surface in this area of Delamar Valley, see geologic cross-section B-B' (Rowley et al 2017). And finally, there is local in-basin recharge that occurs in and must then flow via groundwater flow out through the Delamar Mountains within KSV based upon data collected by Lincoln/Vidler (Lincoln/Vidler 2019).

15. *Page 30, third bullet*: The request by the NSE to define the boundaries of the LWRFS have nothing to do with Clover Valley or Tule Desert and any analysis regarding these basins should be ignored. Even though the USFWS reference Page et al (2005), there is no geophysical data provided to support its assertions in this bullet.

16. *Page 31, Section 1.3.2 Areal Extent of the LWRFS – Proposed Boundaries:* The USFWS stated on Page 31 that "The locations of likely no-flow boundaries on the LWRFS area as follows…: [first bullet] boundary of Delamar Valley with northern Coyote Spring Valley and Kane Springs Valley." Although their reasoning is flawed, i.e., "*…that groundwater flow is precluded by plutonic rocks of the KSW caldera complex….*" If this was truly the case then there would be no water available to pump from well KPW-1 (USR 2006); there also would be perennial or at least intermittent flowing streams in the Delamar Mounts portion of the caldera complex.

Based on the new geophysical data collected by Lincoln/Vidler in response to the NSE Order #1303 request, KSV and northern CSV should be excluded from the proposed LWRFS administrative unit. However, if KSV and northern CSV are truly no-flow boundaries, they should be excluded from the proposed LWRFS administrative unit. USFWS contradicts itself by stating on the one hand that KSV and northern CSV are no flow, yet on the other hand, USFWS wants to include them as part of the proposed LWRFS administrative unit.

17. *Page 33, first paragraph*: Lincoln/Vidler disagree with the statements made in the continuation of this paragraph. Pumping from the RDCA in the vicinity of well CSVM-4 in northern CSV is located in an area of the aquifer system that is separated by the Northern LWRFS Boundary Fault in northern CSV as discovered and documented by new geophysical data collected by Lincoln/Vidler in response to the NSE's Order #1303. This new information also explains the large discrepancies in water levels between wells in northern CSV and southern KSV and the central and southern portion of CSV. The FWS provide no data to substantiate the assertion made that these areas of northern CSV and southern KSV have continuous, thick blocks of carbonates.

18. *Page 38 top of page, first partial paragraph*: It should be noted that KSV is not part of the LWRFS.

19. *Page 45, first 3 bullets of Section 1.7:* Lincoln/Vidler disagree with each of these statements as made by the USFWS and have addressed each of these comments previously. See Responses to USFWS Report Nos. 3, 4, 6, 7, 8, 12, 16, and 17 above.

20. *Pages 39 through 45, Section 1.6, and pages 47 through 53, Section 2*: These sections are non-responsive to the NSE's request for additional information from Order #1303, and should be ignored.

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Attachment A-1

Technical Memorandum from Peter Mock of PMGC, Inc., to Greg Bushner, Vidler Water Company

Subject: A brief overview of an two simulations using the model described in: "Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southern Nevada, Version 1.0," prepared for the National Park Service, U.S. Fish & Wildlife Service and Bureau of Land Management, by Tetra Tech, Inc., of Louisville, Colorado, dated September 28, 2012.

Memorandum

To: Greg Bushner/Vidler Water Company

From: Peter Mock/PMGC, Inc.

Date: November 7, 2012

Subject: A Brief Overview of and Two Simulations using the Model Described in: "Development of a Numerical Groundwater Flow Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada, Version 1.0, prepared for the National Park Service, U.S. Fish & Wildlife Service and Bureau of Land Management, by TetraTech, Inc. of Louisville, Colorado, dated September 28, 2012.

The report referenced above is one of two that you provided me in October of 2012. The other is a predictive simulations report. The MODFLOW input files for both reports were provided as well. The reports and MODFLOW input files arrived on one CD. I have not conducted a detailed, that is, sentence by sentence, review. I selected what I thought were key highlights and potential concerns with respect to evaluations of Tule Desert (and Clover, while we're at it) groundwater development.

This report describes the current status of what is now a decades-long effort in groundwater flow model construction. The Nevada State Engineer's deliberations early in the 1990s concerning proposed pumping from Coyote Springs Valley drew the attention of three bureaus within the U.S. Department of the Interior: the National Park Service, the U.S. Fish & Wildlife Service, and the Bureau of Land Management. After initial funding by the NPS alone, the three DOI Bureaus joined to share in the cost of this model. We have known this effort for the last decade as that of Geotrans, Inc., working for the National Park Service. They give references for two reports on that modeling with dates of 2001 and 2003, but curiously these two references are not given in the reference section. They make no mention of other model efforts in the region, except a notation late in the text that they are conducting one part of the work in a manner similar to that of SNWA.

Geotrans, Inc. has been a part of TetraTech since 1988 according to their website, but evidently only recently has the TetraTech name taken precedence on this project. The authors of the report are not given. I assume that Rick Waddell and Guy Romer are still the principal “architects” of this model.

Brief Overview

The model is a large one, encompassing the following Hydrographic Areas:

- Clover Valley - #204
- Lower Meadow Valley Wash - #205
- Kane Springs Valley - #206
- Coyote Spring Valley - #210
- Garnet Valley - #216
- Hidden Valley (North) - #217
- California Wash - #218
- Muddy River Springs Area - #219
- Lower Moapa Valley - #220
- Tule Desert - #221
- Virgin Valley - #222
- part of Black Mountains Area #215) north and east of the Las Vegas Valley Shear Zone
- part of Las Vegas Valley (#212) north of the Las Vegas Valley Shear Zone and east of the crest of the Sheep Range.

The report lists the following as the effort accomplished since the last model (Geotrans, Inc., 2003):

1. Added lower Virgin Valley and Clover Valley
2. New 3-D geologic framework model (still based on - and the reason for - Page’s (USGS) work in 2005, 2006 and 2011, also funded by NPS)
3. Incorporation of recent USGS ET studies (funded by NPS – DeMeo and others, 2008)
4. Incorporation of geologic, hydrologic and geochemical data from SNWA/LVVWD, Vidler and others
5. Calibration to observed water levels, stream flow and spring discharge and responses to evaporation and pumping rates varying over time

The model and efforts are consistent with what we thought they had been doing to date.

The geology is based on the work of Page (USGS) from 2005-2006, though they now note an update to Page’s cross sections published in 2011 (OFR 2006-1040). Here’s the summary of changes quoted from Page (2011):

- *Cross section C–C' includes revisions in the east Mormon Mountains in the east part of the section;*
- *D–D' includes revisions in the Mormon Mesa area in the east part of the section;*
- *E–E' includes revisions in the Muddy Mountains in the east part of the section;*
- *F–F' includes revisions from the Muddy Mountains to the south Virgin Mountains in the east part of the section; and*
- *J–J' includes some revisions from the east Mormon Mountains to the Virgin Mountains.*
- *The east end of G–G' was extended about 16 km from the Black Mountains to the southern Virgin Mountains, and*
- *the northern end of I–I' was extended about 45 km from the Muddy Mountains to the Mormon Mountains, and revisions were made in the Muddy Mountains part of the original section.*

I extracted the geologic layer tops and thicknesses from the MODFLOW HUF files, imported and georeferenced them in GIS, and reviewed the units that occur under Tule Desert in a cursory fashion. In general, the units defined beneath Tule Desert are what are shown on the Page cross sections in this area, but that we may want to at some point check the distributions of contact elevations against cross-sections and structural geology interpretations developed to date by Vidler. I would note at this point that the regional carbonate aquifer as input to the HUF package of this model thins along the boundary between Tule Desert and Virgin Valley, but that thinning is modest: from 3,000-3,400 meters down to 2,700-3,000 meters in crossing that boundary from either side. This is a major boundary, as expressed at the surface by the East Mormon Mountains, but the model makes this a short, limited island breaking up only a short distance of the regional carbonate aquifer – only where it is present at the surface. With 9,000 to 10,000 feet of saturated thickness, there is essentially no barrier to flow (or propagating drawdowns) between the Tule Desert and Virgin Valley Hydrographic Areas, even when taking into consideration the strong decline in hydraulic conductivity with depth that they apply in this model. To my way of looking at the structural geology, this representation of this boundary is completely incorrect.

In general, the model is bounded around its edges by large fault alignments. They conclude that flow is low across most of their model boundaries due to a work by Harrill (2007), which I located only in their reference list: "Evaluation of Boundary Fluxes for the Ground-Water Flow Model being prepared as part of the SNPLMA-5 Project, unpublished consultant report, December 2007, 17 pages". That this is J.R. Harrill of the USGS, now retired, is encouraging (though I still may or may not agree with what he has written in this undisclosed report), but an unpublished consulting report is not an acceptable reference unless it is attached.

Recharge was estimated using the famous Maxey-Eakin recharge factors (converted from discrete steps to a continuous cubic equation) and PRISM 800-meter resolution 1971-2007 mean monthly precipitation. They do not explain how they go from monthly values to annual values so that Maxey-Eakin can be applied, though I would hope they just added the monthly values before applying the Maxey-Eakin factors. No recharge is calculated for precipitation values less than 7 inches. No reason is given for extending the lower limit for recharge downward from 8 inches to 7 inches. The exception is that recharge was added at 0.5 in/yr in the Muddy Mountains area above 3,000 feet, despite the precipitation being less than 7 inches there. Recharge was later adjusted overall during calibration to match their assumed discharge rates. In fact, the adjustment was a decrease of 35%.

They used the DRAIN package in all 18 model layers in one horizontal cell location to simulate Rogers and Blue Point Springs. The combined discharge of all 18 nodes is used to track this discharge and to serve as a calibration target. Many other springs were simulated with the DRAIN package. The springs in the Muddy River area were simulated with the stream flow routing (SFR) package.

Evapotranspiration was estimated from DeMeo (2008) and simulated as a constant withdrawal using the WELL package.

Pumping was simulated with the first multi-node well (MNW1) package, which apportions flow over multiple layers based on current water-level and hydraulic conductivity along the well.

The Horizontal Flow Barrier (HFB) package was used to simulate a few selected fault alignments, including the Tule Desert Fault System. A hydraulic characteristic (transmissivity or hydraulic conductivity divided by barrier width –"TDW") of 1 x 10^{-6} ft/d was used for all but the Tule Desert (1.31 x 10^{-6} ft/d) and Kane Springs Wash (4.74.x 10^{-6}) Faults

Although a large number and variety of calibration targets were used, they are largely clustered in a fraction of the model area. Tule Desert and Clover Valley are not well represented in the calibration data set. Also, there are no data on the propagation of drawdowns in or out of Tule Desert or Clover Valley.

An important (to the authors) part of the calibration process was simulation of test pumping of Coyote Spring Valley under Order 1169 during the period August 2010 to December 2011. I don't think the simulated drawdowns matched the measured drawdowns well in this exercise of the model. Calibration of the carbonate system hydraulic conductivity using pilot points resulted in isolated unique values in a circle around each pilot point, which is not realistic. This is not a fault of pilot points, but of their application here. One pilot point value was 19,500 ft/d; another was 4,560 ft/d; six more were larger than 1,000 ft/d. The hydraulic conductivity value used in most of the model (which does not contain pilot points) for the carbonate unit ranges from 1,000 to 10,000 ft/day. These are not realistic values for regional simulation of the carbonate unit. I think the regional value should be approximately 3 ft/d as we used in our Tule Desert Model.

They also caused the hydraulic conductivity to decline exponentially with depth using a modification made by these authors to the modification made by the USGS to the HUF package.

The authors' change was to put a limit (floor) on the minimum value that could be reached at depth. The carbonate unit was simulated to decline by an order of magnitude for every 1,333 feet of depth, limited to a minimum of .0003 ft/d. We (i.e., me, Vidler, Wayne Belcher, and Keith Halford) disagree that the hydraulic conductivity of the carbonate unit declines significantly with depth. This feature is reasonable for representing Tertiary sedimentary basin fill, but not for the regional carbonate unit.

The extremely large hydraulic conductivity values obtained from pilot point calibration and the extremely strong decline function with depth lead to flow in and between basins being funneled through the top of the model, which I do not think is representative of this system. I think flow circulates to depths of tens of thousands of feet in the regional carbonate system.

The specific yield of the carbonate system is 0.02, which I agree with. The specific storage is 1×10^{-6} ft^{-1}, which I also agree with.

Overall in this model, prior to large-scale pumping, 50% of discharge is to streams, 40% of discharge is to evapotranspiration, and the remainder is a combination of springs and Lake Mead discharge. They make a point of describing pre-Dam observations (but don't provide a reference) that indicated few and minor discharges of groundwater to what would become the bed of Lake Mead. In this model, they simulate 4,500 ac-ft/yr discharge to Lake Mead. Overall in this model, 38,000 ac-ft/yr comes in through the boundaries and 6,500 ac-ft/yr leaves the boundaries. As I made abundantly clear in discussions of our Tule Desert model, I disagree that flow across this tremendous thickness of carbonates comes essentially to a stop at these boundaries.

This quote from the summary at Page 61 will be of interest to Vidler:

> *"The largest model residuals [mismatch between simulation and measurement] are in high gradient areas, where model errors can result in large differences, in the Clover Mountains where the volcanic stratigraphy is greatly simplified, and in the Tule Desert where some of the structural complexity may not be incorporated in the geologic model and the model grid is relatively coarse."*

Indeed the errors range from 560 feet too low to 149 feet too high in Tule Desert and from 150 feet too low to 730 feet too high in Clover Valley. Also of interest is a quote from Page 62:

> *"Cross sections developed in the Tule Desert by consultants for Vidler Water Company were not used in the construction of the geologic model. There are differences between the interpretations presented in these cross sections and other cross sections developed by Page and others (2011). Given the scale of the modeling and the use of the sections by Page and others in the remainder of the model, some of the information contained in the sections developed by Vidler Water Company was not incorporated. In future work, evaluation and*

incorporation of some of the more detailed information might improve the model in the Tule Desert."

One additional quote related to Vidler's interests, on Page 63:

> *"There are aquifer-testing data available in the Tule Desert, but no long-term pumping has yet occurred, and thus there is no information on long-term productivity or on response to pumping in areas distant from wells. Thus, there is substantial uncertainty on the magnitude and timing of drawdown in the Tule Desert. The most uncertainty is in the Clover and Delaware Mountains. The drawdown that will occur will be very dependent on local conditions and rock properties because of the complex volcanic stratigraphy, which has been generalized."*

Finally, I note that the recently available hydrogeochemistry or geochemistry information described as incorporated in the introduction and summary of this report, was not discussed.

Attachment A-2

U.S. Department of the Interior Fish and Wildlife Service Biological Opinion dated October 29, 2008, File Nos. 84320-2008-F-0007 and 84310-2008-I-0216.

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Nevada Fish and Wildlife Office
4701 North Torrey Pines Drive
Las Vegas, Nevada 89130
Ph: (702) 515-5230 ~ Fax: (702) 515-5231

October 29, 2008
File Nos. 84320-2008-F-0007 and
84320-2008-I-0216

Memorandum

To: Field Manager, Ely Field Office, Bureau of Land Management, Ely, Nevada

From: Field Supervisor, Nevada Fish and Wildlife Office, Reno, Nevada

Subject: Request for Formal and Informal Consultation on the Kane Springs Valley Groundwater Development Project in Lincoln County, Nevada

This document transmits the U.S. Fish and Wildlife Service's (Service) biological opinion based on our review of the proposed Kane Springs Valley Groundwater Development Project and its possible adverse effects on the desert tortoise (*Gopherus agassizii*) (Mojave population), listed as threatened under the Endangered Species Act of 1973, as amended (Act) (16 U.S.C. 1531 *et seq.*), and its designated critical habitat, and the Moapa dace (*Moapa coriacea*), listed as endangered under the Act. No critical habitat has been designated for the Moapa dace. Further, the Bureau of Land Management (BLM) requests concurrence that the proposed project *may affect, but is not likely to adversely affect* the southwestern willow flycatcher (*Empidonax traillii extimus*), listed as endangered under the Act. No designated critical habitat for the southwestern willow flycatcher occurs in the project area. The Lincoln County Water District (LCWD) has applied for a BLM right-of-way to construct and operate a system of water facilities on BLM-managed land in southern Lincoln County.

This biological opinion is issued in accordance with section 7 of the Act and based on information provided in BLM's memorandum dated September 27, 2007, to the Service (received on September 28, 2007), and revised biological assessment (BA), dated December 2007 (ARCADIS 2007); Amended Stipulation for Withdrawal of Protests (Stipulated Agreement) dated August 8, 2006; discussions between the Service and BLM; and our files. A complete administrative record of this consultation is on file in the Service's Nevada Fish and Wildlife Office in Las Vegas.

This biological opinion does not rely on the regulatory definition of "destruction or adverse modification" of critical habitat at 50 CFR 402.02. Instead, we have relied upon the statutory provisions of the Act to complete the following analysis with respect to critical habitat.

INFORMAL CONSULTATION

Southwestern willow flycatcher

No habitat is present for the southwestern willow flycatcher within the project area. The closest breeding populations occur at Pahranagat National Wildlife Refuge (NWR) approximately 23 miles northwest and in the Warm Springs Area, approximately 25 miles southeast. Since the springs in the Warms Springs Area are supplied by water from the deep carbonate aquifer, groundwater pumping in the Kane Springs Valley Hydrographic Basin could affect water levels in the Muddy River System. These effects to riparian vegetation will be minimized by actions contained in the Stipulated Agreement among the Service, LCWD and Vidler Water Company, Inc (VWC), which are designed to maintain minimum in-stream flows in the Warm Springs Area of the Muddy River system in order to protect and recover the Moapa dace. (See section below entitled "Proposed Minimization Measures for Moapa Dace"). The project is anticipated to have insignificant effects to the southwestern willow flycatcher since any decreases in groundwater flow to the Muddy River system will be minimized by the Stipulated Agreement.

In consideration of the proposed action, potential effects of the proposed action, and measures proposed by BLM, the Service concurs with BLM's determination that the proposed action *may affect, but is not likely to adversely affect* the southwestern willow flycatcher. This response constitutes informal consultation under regulations promulgated in 50 CFR§402.14, which establishes procedures governing interagency consultation under section 7 of the Act. This informal consultation does not authorize take of any listed species.

CONSULTATION HISTORY

The following chronology documents the consultation process that culminated in the following biological opinion for the desert tortoise and its designated critical habitat and for the Moapa dace:

On May 8, 2006, the Service sent BLM a memorandum containing a species list of endangered, threatened, and candidate species that may occur in or near the proposed Kane Springs Valley Groundwater Development Project (Service File No. 1-5-06-SP-499).

On July 12, 2007, BLM sent the Service a memorandum requesting formal consultation on the Kane Springs Valley Groundwater Development Project for potential adverse effects to the desert tortoise and its designated critical habitat. A BA accompanied the memorandum.

On September 4, 2007, the Service sent BLM a memorandum recommending formal consultation for the Moapa dace and requesting additional information necessary to initiate formal consultation for the desert tortoise (Service File No. 1-5-07-F-558).

On September 27, 2007, BLM sent the Service a memorandum requesting formal consultation on the project for potential adverse effects to the desert tortoise and its designated critical habitat and the Moapa dace. A revised BA accompanied the memorandum.

On October 19, 2007, the Service sent BLM a memorandum that initiated formal consultation on September 28, 2007, since the revised BA contained sufficient information (Service File No. 84320-2008-F-0007).

On December 4, 2007, BLM, the Service, and the project proponent participated in a conference call to discuss several topics including the monitoring wells that are required by the stipulated agreement among LCWD, VWC, and the Service for withdrawal of the Service's protests of water rights applications in Kane Springs Valley. It was decided that the BA would include acreages and potential effects associated with the two new monitoring wells.

On December 6, 2007, ARCADIS, the project consultant, sent the Service a revised BA on behalf of BLM, which included acreages associated with the two new monitoring wells.

On January 28, 2008, the Service sent BLM a memorandum extending the consultation period for this project by 60 days due to a substantial consultation workload.

On June 17, 2008, VWC sent the Service comments on the terms and conditions of the draft biological opinion.

On June 18, 2008, the Service provided BLM a copy of a draft biological opinion via email.

On June 30, 2008, a Memorandum of Understanding (MOU) among LCWD, VWC, and the Service was signed. Pursuant to the MOU, the Service will issue a biological opinion for the project which will include an incidental take statement authorizing such take of Moapa dace as may occur in connection with the pumping and transfer of 1,000 acre-feet of groundwater under Phase I of the Project and implementation of the Monitoring, Management and Mitigation Plan. Upon receiving authorization from the Nevada State Engineer to appropriate more than 1,000 and up to 5,000 acre-feet per year of groundwater from the Kane Springs Valley for use in the Coyote Springs Valley, the Service will reinitiate consultation for the project pursuant to section 7 of the Act.

On July 15, 2008, the Service received a copy of BLM's comments on the draft biological opinion via email.

On July 28, 2008, the Service and BLM met to discuss the draft biological opinion.

On August 18, 2008, BLM sent the Service proposed language for term and condition 4.d. and 5. of the biological opinion via email.

On October 1, 2008, BLM sent the Service updated proposed language for term and condition 4.d. of the biological opinion via email.

On October 1, 2008, the Service and BLM met to discuss deposition of remuneration fees for offsetting desert tortoise habitat loss.

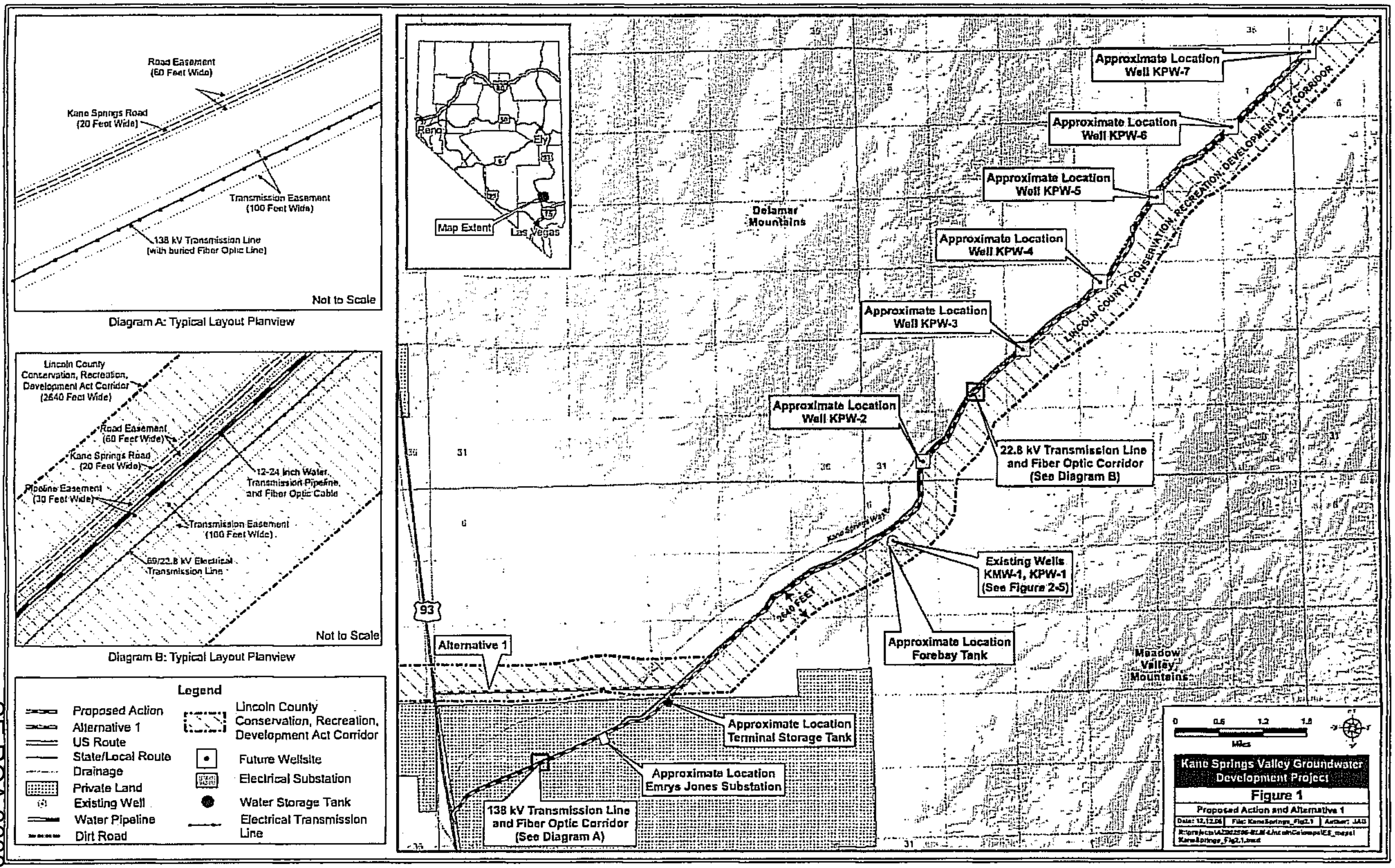
BIOLOGICAL OPINION

A. Description of the Proposed Action

The purpose of the proposed action is to develop a system for tapping groundwater resources in the Kane Springs Valley Hydrographic Basin for municipal water purposes within the Coyote Spring Valley Hydrographic Basin. The project proponents applied to the Nevada State Engineer's Office for 17,375 acre-feet per year (afy), but to date have been granted 1,000 afy under Ruling # 5712. The proposed pipeline would have capacity to transport up to 5,000 afy. Construction and operation of the proposed action would supply a small, but initially substantial portion of the total water requirements for the Coyote Springs Investment (CSI) development projects in southern Lincoln County. The majority of the proposed facilities would be located along or near the Kane Springs Road, within the 2,640-foot wide Lincoln County Conservation, Recreation, and Development Act (LCCRDA) utility corridor on public land, or on private land owned by CSI. The project area extends approximately 16.6 miles along Kane Springs Road from the intersection with US 93 (US 93).

The proposed action consists of several components including, groundwater production wells, monitoring wells, water pipelines, storage tanks, power transmission lines and substations, access roads and a fiber optic line. Figure 1 shows the approximate location of the project components in the lower Kane Springs Valley. LCWD is developing this project in cooperation with Lincoln County Power District (LCPD) Number 1 and Lincoln County Telephone Company. Each utility agency is responsible for the construction, operation, and rehabilitation of disturbed land associated with their utility. Each utility agency may be required to apply for a separate right-of-way with BLM.

Although the BA included the construction of the Emrys Jones Substation and power line west of the Substation, LCPD is constructing these facilities under another project, the Coyote Springs Transmission Line Project. Therefore, these facilities are not considered to be part of the proposed action for this consultation.



Road Easement (60 Feet Wide)
Kane Springs Road (20 Feet Wide)
Transmission Easement (100 Feet Wide)
138 kV Transmission Line (with buried Fiber Optic Line)
Not to Scale
Diagram A: Typical Layout Planview
Lincoln County Conservation, Recreation, Development Act Corridor (2640 Feet Wide)
Road Easement (60 Feet Wide)
Kane Springs Road (20 Feet Wide)
Pipeline Easement (30 Feet Wide)
12-24 Inch Water Transmission Pipeline, and Fiber Optic Cable
Transmission Easement (100 Feet Wide)
69/22.8 kV Electrical Transmission Line
Not to Scale
Diagram B: Typical Layout Planview
Legend
Proposed Action
Alternative 1
US Route
State/Local Route
Drainage
Private Land
Existing Well
Water Pipeline
Dirt Road
Lincoln County Conservation, Recreation, Development Act Corridor
Future Wellsite
Electrical Substation
Water Storage Tank
Electrical Transmission Line
Reno
Ely
Las Vegas
Map Extent
Approximate Location Well KPW-7
Approximate Location Well KPW-6
Approximate Location Well KPW-5
Approximate Location Well KPW-4
Approximate Location Well KPW-3
Approximate Location Well KPW-2
Delamar Mountains
Lincoln County Conservation, Recreation, Development Act Corridor
22.8 kV Transmission Line and Fiber Optic Corridor (See Diagram B)
Existing Wells KMW-1, KPW-1 (See Figure 2-5)
Approximate Location Forebay Tank
Kane Springs Wash
2640 FEET
93
Alternative 1
Meadow Valley Mountains
Approximate Location Terminal Storage Tank
Approximate Location Emrys Jones Substation
138 kV Transmission Line and Fiber Optic Corridor (See Diagram A)
0 0.6 1.2 1.8
Miles
Kane Springs Valley Groundwater Development Project
Figure 1
Proposed Action and Alternative 1

1. Project Features

a. Wells

Groundwater from the Kane Springs Valley Hydrographic Basin would be supplied to the Coyote Spring Valley area from up to seven groundwater production wells. All production wells would be located within the LCCRDA corridor on public land, spaced approximately 1.3 to 1.8 miles apart. The first well (KPW-1), approved under BLM Serial Number NVN-079630, was drilled in 2005. Each wellhead would be enclosed in a masonry block structure, which would also contain all aboveground piping, shutoff valve, check valve, flow meter, air release valve, and electrical equipment. The size of each fenced well yard would be approximately 150 feet by 150 feet. Production wells would be equipped with an electric pump.

An existing monitoring well, KMW-1, is located adjacent to KPW-1 (Figure 1). The monitoring well was installed in 2005 to assist in assessing the hydrogeology of the Kane Springs Valley Hydrographic Basin. Two new monitoring wells may also be installed per the stipulated agreement for withdrawal of the Service's protests of LCWD and VWC's water rights applications in Kane Springs Valley. The wells would be placed on CSI land and would each have a footprint of less than 1 acre in size. The final location would be coordinated through the Technical Review Team (TRT) established under the stipulated agreement. Should the TRT decide that these monitoring wells are not necessary, funds for the material and construction of the monitoring would be used instead for Moapa dace conservation.

b. Pipelines

There are two types of pipelines associated with the proposed action: the well field pipeline collection system and the main transmission pipeline. Ancillary pipeline components include isolation valves, cathodic protection, control valves, air release/vacuum valves, blow-off valves, access manways, fiber optic splice vaults, and pipe alignment markers.

The well field pipeline collection system would consist of individual branch pipelines from each well to a single main collection pipeline terminating at the forebay storage tank. The total pipeline collection system would extend approximately 9.4 miles. The pipeline, to be constructed of ductile iron, would vary in size (telescope) from 12 inches to 24 inches in diameter, with the largest diameters located closest to the forebay storage tank. The pipeline would be buried to a minimum depth of three feet below grade, or three times scour depth in washes in accordance with engineering requirements. In general, the pipeline would parallel the Kane Springs Road to the south, with a 60-foot wide construction easement and a 30-foot wide permanent easement. If cross-country construction is required, the temporary construction easement would be 75 feet wide, with a permanent easement of 60 feet.

Approximately 3.8 miles of buried 24-inch diameter transmission pipeline would be constructed adjacent to the Kane Springs Road between the forebay storage tank and the terminal storage tank. Appurtenant groundwater facilities (e.g., isolation valves, control valves) would occur, on average, every mile along the alignment. These facilities would be located predominantly below existing grades in traffic-rated, lockable, concrete vaults that would vary in dimension. Typically, these vaults would be located outside of traffic areas and may require small location markers extending several feet above the surface of the ground.

c. Storage Tanks

A 50,000-gallon forebay storage tank would be installed adjacent to the existing production well (KPW-1) and would initially serve as the termination point for the groundwater collection system. This tank would be used to normalize flow pressures in the system and provide storage for secondary lifting to the terminal storage tank, if required. The water level in the forebay storage tank would control the operation of the well field via telemetry. Either wireless telemetry or direct-burial fiber optic telemetry cable located in pipeline trenches would enable communication between the collection system, forebay storage tank, and the terminal storage tank.

A terminal water storage tank would ultimately be located at the southern end of the water transmission pipeline to receive the imported water and to serve as a water distribution source for the northern Coyote Spring Valley area. The storage tank would be constructed with a maximum capacity of 700,000 gallons, subject to final design requirements.

d. Power Distribution

In order to provide reliable electric service to the well fields, LCPD would construct and operate transmission lines and substations. Power facilities built for this project would connect to the Emrys Jones Substation, part of the Coyote Springs Transmission Line Project.

Under the proposed project, LCPD would construct an overhead transmission line with a 69 kV/22.8 kV distribution circuit from the Emrys Jones Substation to the proposed well fields along the Kane Springs Road, parallel to the pipeline. A total of 14 miles of transmission line would be installed. The 69 kV/22.8 kV transmission line would be a single-circuit line supported by wood pole structures. The 69 kV/22.8 kV transmission line would primarily be located on public lands managed by BLM, with a short section near the Emrys Jones Substation located on private property. Each wood pole structure would require a temporary construction easement of 0.07 acre and after construction, each structure would occupy 0.02 acre. The transmission line would have a 100-foot permanent easement.

At each well location, a fenced power substation (approximately 155 feet by 95 feet) would be constructed to serve the well pump motor and ancillary equipment. The substation yards would consist of a 69 kV/22.8 kV to 4.16 kV pad-mounted step-down transformer, primary metering, switch cabinet, capacitor bank, and a station service transformer.

e. Fiber Optic

The Lincoln County Telephone Company is proposing to install fiber optic cables within the proposed project right-of-way. The fiber optic line would be buried in the same trench as the pipeline and adjacent to the 138 kV transmission line on private lands proposed under the Coyote Springs Transmission Line Project. The fiber optic cables would be used for communication to manage the pipeline operation. The fiber optic cables would tie into an existing fiber optic line located on the east side of US 93.

f. Additional Project Components

Approximately 50 acres may be used for temporary extra work spaces. These areas would be spaced approximately 0.5 mile apart and would cover approximately 2 acres. Some larger staging areas may be sited in suitable areas near steeply incised drainages, above and below slopes where construction is expected to be difficult, and at pipe laydown areas. All extra work spaces on Federal lands would be located within the project right-of-way. Staging areas on private lands would be used during construction for storage of materials and equipment, construction office trailers, fuel storage, equipment maintenance, stockpiling and handling of excavated material, and other construction-related activities. Following construction, the staging areas would be restored as described in the Kane Springs Valley Groundwater Development Project Environmental Impact Statement (EIS).

g. Road Access and Transportation

US 93 and the Kane Springs Road would provide primary access into the project area. Spur roads would be constructed from the Kane Springs Road to temporary and permanent facilities sites, such as contractors' yards, well fields, and power pole locations, within the project right-of-way corridor. The number of new spur roads would be held to a minimum, consistent with their intended use (e.g., facility construction, conductor stringing and tensioning). It is estimated that seven new minor access roads would be required to access the proposed well houses. Each of these roads would be approximately 100 feet long and 12 feet wide. Access roads not required after construction would be removed and restored to their approximate original contour and dimensions and made to discourage vehicular traffic. All temporary road surfaces would be ripped or harrowed to establish conditions appropriate for reseeding, drainage, and erosion prevention.

Table 1 lists the estimated temporary and permanent disturbance acreage required for construction and operation of the proposed project. The estimated disturbance acreage is based on preliminary engineering plans and therefore may change slightly.

Table 1 Estimated Surface Disturbance by Land Ownership (at full buildout of the proposed project)		
	Temporary (acres)*	Permanent (acres)*
Federal (BLM)		
Well House and Well Substation	3.2	3.0
KPW-1 Well, Forebay Tank, KMW-1 Well	0.3	1.0
Pipeline Construction right-of-way	148.7	0.0
Terminal Storage Tank	0.0	0.0
Electrical Substation	0.0	0.0
Electrical Transmission Line	14.8	5.0
Electrical Transmission Line Access Roads	0.0	8.0
Fiber Optics Line	0.0	0.0
Subtotal	**167.0**	**17.0**
Private		
Well House and Well Substation	0.0	0.0
KPW-1 Well, Forebay Tank, KMW-1 Well	0.0	0.0
Pipeline Construction right-of-way	0.0	0.0
Terminal Storage Tank	0.7	0.3
Electrical Substation	0.0	0.0
Electrical Transmission Line	2.4	1.1
Electrical Transmission Line Access Roads	0.0	0.7
Fiber Optics Line	14.2	0.0
Two Groundwater Monitoring Wells	4.0	2.0
Subtotal	**21.3**	**4.1**
Total	**188.3**	**21.1**

h. Construction Procedures

Each utility agency would conduct all activities associated with the construction, operation, and rehabilitation of temporarily disturbed areas within the authorized limits of their BLM right-of-way. To supply electrical power to the well fields, it is anticipated that LCPD would be the first utility agency to begin construction after all approvals have been acquired. During construction activities, water would be used to suppress dust in the construction area.

Construction of the electric transmission lines and substation would involve the following general sequence: engineering surveys and staking, clearing and grading, material storage and handling, creation of structure holes or foundations, structure assembly and erection, installation of security fencing around substation, post construction cleanup and reclamation, and construction monitoring. Construction of the overhead lines would be completed in two phases: setting the pole structures and installing the cable. The setting of the pole structures is accomplished with a single multi-purpose truck. The truck has a small crane suitable for lifting and placing poles. A pole trailer is towed behind the crane truck to transport the poles to the installation site. Affixed to the crane is an auger for boring the holes for the pole structures. Soil excavated during construction would be used for backfill and for restoration of disturbed areas. The cable would be installed using two vehicles: a cable truck and a truck with a power lift. The cable would be strung out along the installation route and the man lift would be used to place the cable on the pole structure.

Construction of the groundwater facilities and fiber optic line would involve the following sequence: engineering surveys and staking, topsoil salvage and storage, clearing and grading (including access road construction), trenching and blasting, pipeline stringing/installation, installation of fiber optic line in common pipeline trench; backfilling, hydrostatic testing, re-grading, post-construction cleanup, and reclamation, and construction monitoring. Trenching would consist of excavating the trench using either a trenching machine or track-mounted excavator. In general the bottom of the trench would be five feet wide and up to six feet deep to provide the required cover over the top of the installed pipe. In areas of weathered rock, track-mounted excavators may be preceded by a bulldozer equipped with a single-shank ripper. Limited blasting may be required in areas where shallow or exposed bedrock is present. This project would be constructed utilizing a "Dig and Lay" procedure. In other words, a portion of trench would be dug, the pipe would be laid, welded, and back filled and another segment would begin. There would be minimal (less than 500 feet) open trench at any one time and the backfill would occur almost immediately following pipe installation.

i. Operation and Maintenance

The electrical facilities would be in continuous operation and water facilities would be operated and maintained to ensure safe operation and integrity of the pipeline. Periodic inspection and maintenance of power and water facilities would be required. If a pipeline break were to occur, immediate steps would be taken to isolate the break, the break would be repaired, and the trench backfilled. Areas would be contoured and revegetated after these types of repairs. Emergency maintenance of power lines, such are repairing downed wires and correcting unexpected outages would be performed by LCPD.

j. Project Phases

Construction of the project would occur in three phases, with one to three years between phases. Phases would correspond to demand for water and issuance of permits for additional water rights. Eventually LCWD would like to harvest 5,000 afy from the carbonate aquifer within the Kane Springs Valley Hydrographic Basin but so far has been granted an appropriation of 1,000 afy by the Nevada State Engineer. This appropriation granted four points of diversion, which constitutes the initial production under Phase 1 of the project. If additional appropriations are granted, production from Phase 1 wells could be increased, and Phase 2 and Phase 3 wells could be developed.

- Construction of Phase 1 would occur over a 90- to 180-day period and would begin upon completion of environmental reviews and the acquisition of necessary permits and approvals. Phase 1 water facilities would include the transmission pipeline (main water line) and approximately 9.4 miles of well field collection pipelines for up to four wells (main collection plus laterals to wells), up to four production wells, the storage tanks, and up to two monitoring wells. Power facilities would include 14 miles of 69 kV/22.8 kV overhead power lines and up to four smaller substations to serve each well.

- Construction of Phase 2 would occur over a 30- to 60-day period. Phase 2 water facilities would include one to two production wells and lateral pipelines from these wells to the main collection pipeline (combined length of the two lateral pipelines is expected to be less than 1 mile). Power facilities would include 22.8 kV underground power lines from the main transmission line to the substation(s) and one to two smaller substations to serve the new well(s).
- Phase 3 construction would only occur if production from Phase 1 and Phase 2 were insufficient to meet anticipated demand or if production from previous wells were lower than estimated or designed. Phase 3 facilities and construction times are similar to Phase 2.

2. State Engineer Ruling

On February 2, 2007, the Nevada State Engineer issued Ruling 5712, which granted 1,000 afy of groundwater from the Kane Springs Valley Hydrographic Basin to LCWD and VWC for municipal purposes within the Coyote Spring Valley Hydrographic Basin. Specifically 500 afy was granted under Application 72220 and applications 72218, 72219, and 72221, were granted for a total combined duty of 500 afy.

The State Engineer concluded that to permit the appropriation of water in an amount greater than permitted under this ruling would conflict with existing rights and threaten to prove detrimental to the public interest. After reviewing the existing information, the State Engineer concluded that a small amount of water can be developed in the Kane Springs Valley and not unreasonably impact existing rights in the discharge areas of the White River carbonate-rock aquifer system, which are already fully appropriated. The State Engineer found that no water has been previously appropriated in the Kane Springs Valley Hydrographic Basin and by limiting the quantity of water authorized for appropriation the potential impacts to existing waster rights in down-gradient hydrographic basins would be minimized.

3. Proposed Minimization Measures for Desert Tortoise (Mojave population)

a. The applicant will implement an Environmental Training Program. Prior to beginning work, all contractor personnel assigned to the field for construction-related activity will attend a mandatory one-time Worker Environmental Training Program presented by the project developer's Environmental Compliance Team. The presentation will review topsoil salvage, access restrictions, general site restrictions, and other environmental requirements regarding the project. Participants will sign a statement declaring that they understand and will abide by any guidelines set forth in the material presented.

b. All areas around structures will be backfilled, compacted, and returned as close as possible to the original condition and grade.

c. Signs will be placed along the access roads to discourage off-highway vehicle use of adjacent areas.

d. Clearance surveys will be performed prior to any construction activities within the right-of-ways. Any tortoises located will be handled and relocated by a qualified tortoise biologist in accordance with Service-approved protocol (Desert Tortoise Council 1994, revised 1999). Burrows containing tortoises or nests will be excavated by hand, with hand tools, to allow removal of the tortoise or eggs. Desert tortoises moved during the tortoise inactive season or those in hibernation, regardless of date, must be placed into an adequate burrow; if one is not available, one will be constructed in accordance with Desert Tortoise Council (1994, revised 1999) criteria. During mild temperature periods in the spring and early fall, tortoises removed from the site will not necessarily be placed in a burrow. Tortoises and burrows will only be relocated to federally managed lands. If the responsible Federal agency is not BLM, verbal permission, followed by written concurrence, will be obtained from BLM and the Service before relocating the tortoise or eggs to lands not managed by BLM.

e. Construction monitoring will employ a field contact representative, authorized biologist(s), and qualified biologist(s) during construction activities except in those areas with high disturbance. The Service employs a specific set of guidelines for such monitoring.

f. Tortoises requiring moving will only be handled by the authorized and qualified tortoise biologist or other trained personnel approved by the Service and the Nevada Department of Wildlife (NDOW).

g. A 25 mile per hour (mph) project access road speed limit will be enforced for all project vehicles and personnel.

h. The area limits of project construction and survey activities would be predetermined based on the temporary and permanent disturbance areas noted on the final design engineering drawings to minimize environmental effects arising from the project, with construction activities and traffic restricted to and confined within those limits.

i. Littering is not allowed. Project personnel would not deposit or leave any food or waste in the project area, and no biodegradable or non-biodegradable debris would remain in the right-of-way following completion of construction.

j. No wildlife, including rattlesnakes, may be harmed except to protect life and limb.

k. Project personnel are not allowed to bring pets to any project area in order to minimize harassment or killing of wildlife and to prevent the introduction of destructive animal diseases to native wildlife populations.

l. Wildlife species may not be collected for pets or any other reason.

m. Project supplies or equipment where wildlife could hide will be inspected prior to moving or working on them, to reduce the potential for injury to wildlife. Supplies or equipment that cannot be inspected or from which wildlife cannot escape or be removed, will be covered or otherwise made secure from wildlife intrusion or entrapment at the end of each work day.

n. All steep-walled trenches or excavations used during construction will be inspected twice daily (early morning and evening) to protect against wildlife entrapment.

o. All new access roads constructed as part of the project that are not required as permanent access for future project maintenance and operation would be permanently closed to minimize impacts from increased public access.

p. To minimize perching opportunities for raptors near habitats supporting sensitive prey species, structures incorporating a design to discourage raptor perching will be selected.

q. Only the minimum amount of vegetation necessary for the construction of structures and facilities will be removed. Topsoil will be conserved during excavation and reused as cover on disturbed areas to facilitate re-growth of vegetation.

r. Construction holes left open overnight will be covered. Covers will be secured in place nightly, prior to workers leaving the site, and will be strong enough to prevent livestock or wildlife from falling through and into a hole.

s. Holes and/or trenches will be inspected prior to filling to ensure absence of mammals and reptiles.

t. Where necessary, a biological resource monitor shall be present during the construction to ensure resources are protected in the construction area.

u. Excavations will be sloped on one end to provide an escape route for small mammals and reptiles.

v. A revegetation plan will be developed and implemented for the project which describes procedures the LCWD and its contractors would use to conduct revegetation of the disturbed areas. The Plan describes seedbed preparation; seed mixtures; seeding, salvaging, and transplanting methods; revegetation schedule; post-construction monitoring; evaluation of revegetation success; remediation; and reporting.

w. A noxious weed management plan will be developed and implemented for the project which includes site-specific measures that LCWD and its contractors would implement to control noxious weeds including, but not limited to, the use of cleaned, weed-free equipment, pressure washing of all vehicles and equipment prior to arrival at the work site, and the use of certified weed-free straw/hay bales to control erosion. A key element of the noxious weed management plan is to identify and treat existing weed infestations prior to construction.

x. A fire mitigation plan will be developed and implemented for the project which identifies measures to be taken during construction, operation, and maintenance of the project facilities to prevent and suppress fires. The purpose is to establish standards and practices to minimize the risk of fire or, in the event of fire, to implement immediate suppression procedures.

4. Proposed Minimization Measures for Moapa Dace

On August 8, 2006, the Service entered into a stipulated agreement with LCWD and VWC for water rights applications in the Kane Springs Valley Hydrographic Basin, then under review by the Nevada State Engineer's Office. The Service agreed to withdraw its protests for the granting of these water rights in exchange for the parties agreeing to implement the Monitoring, Management, and Mitigation Plan which would help protect senior Federal water rights in the Muddy River Springs/Warm Springs Area from unreasonable adverse impacts from groundwater pumping. The common goal of the parties is to manage the development of the LCWD and VWC water rights in their entirety from the Kane Springs Valley Hydrographic Basin, without resulting in any losses to senior water rights or unreasonable adverse impacts to Federal water resources.

The Monitoring, Management, and Mitigation Plan lists monitoring requirements in relation to the production wells, two new monitoring wells, elevation control and springflow, water quality, data quality, and reporting. The management requirements include action criteria to help to maintain minimum in-stream flows in the Warm Springs Area in order to protect and recover the Moapa dace. The parties agreed to the following, summarized from the Plan:

a. The Average Flow Level shall be determined by flow measurements at Warm Springs West flume. See the Plan for the definition of Average Flow Level.

b. If the Average Flow Level decreases to an amount within the Trigger Range of 3.2 cubic feet per second (cfs) or less, the parties agree to meet as soon as practically possible to discuss and interpret all available data and plan for mitigation measures in the event that flows continue to decline.

c. If the Average Flow Level is within the Trigger Range of 3.15 cfs or less but greater than 3.0 cfs, LWCD and VWC agree to reduce pumping from all wells in Kane Springs Valley by 50 percent or to a pumping level not greater than 2,500 afy, whichever results in the lesser amount of pumping, until the Average Flow Level exceeds 3.15 cfs. The subsequent State Engineer ruling limited pumping to 1,000 afy. Accordingly, under this scenario, LCWD and VWC would be required to reduce pumping by 50 percent.

d. If the Average Flow Level is within the Trigger Range of 3.0 cfs or less, LWCD and VWC agree to cease pumping from all wells in Kane Springs Valley until the Average Flow Level exceeds 3.0 cfs. However, if LWCD and VWC, together with CSI, effectuate a reduction in the quantity of water, CSI would have otherwise been entitled to pump in a given year from wells within the Coyote Spring Valley, then LWCD and VWC shall have the right to pump a like quantity of water from wells within Kane Springs Valley in that year.

The management requirements also include the establishment of a TRT with two representatives each from LCWD/VWC and the Service. The objectives of the TRT include reviewing existing data, making recommendations concerning the monitoring efforts required by this Plan, and determining whether other criteria, such as water levels in the monitoring wells, are a better indicator of potential effects of the pumping wells on the springs in the Muddy River Springs/ Warm Springs Area. As part of their commitment to the recovery of the Moapa Dace, LCWD and VWC will commit annual funds for a period of five years following the granting of the water rights applications, for the restoration of Moapa dace habitat outside the boundaries of the Moapa Valley National Wildlife Refuge (NWR).

B. Definition of the Action Area

The action area is defined as all areas to be affected directly or indirectly by the Federal action, including interrelated and interdependent actions, and not merely the immediate area involved in the action (50 CFR § 402.02). Subsequent analyses of the environmental baseline, effects of the action, cumulative effects, and levels of incidental take are based upon the action area as determined by the Service.

For the desert tortoise and its designated critical habitat, impacts will be tied to the project area and a zone-of-influence extending 0.5 miles (2,400 feet) beyond the project area to cover potential effects to desert tortoises that could move into construction areas or onto access roads.

For the Moapa dace, which depends on thermal springs in the Warm Springs Area for survival, the action area includes the Kane Springs Valley Hydrographic Basin and the hydrographic basins down gradient of this basin in the White River Groundwater Flow System that are hydrologically connected to the Muddy River ecosystem. These hydrographic basins are the Coyote Spring Valley (Basin 210) and Muddy River Springs Area (Basin 219). The Service acquired the Moapa Valley NWR to secure habitat and assist the recovery efforts for the endangered Moapa dace, a species restricted to the Warm Springs Area and the mainstem of the upper Muddy River. Springs in this area are considered regional discharge points for the carbonate aquifer of the White River Flow System.

C. Status of the Species- Rangewide

1. Desert Tortoise (Mojave population) and Designated Critical Habitat

The current rangewide status of the desert tortoise and its critical habitat consists of information on its listing history, species account, recovery plan, recovery units, distribution, reproduction, and numbers, and critical habitat units and their constituent elements. This information is provided on the Service's website at: http://www.fws.gov/nevada. If unavailable, contact the Nevada Fish and Wildlife Office in Las Vegas at (702) 515-5230 and provide File No. 84320-2008-F-0007.

2. Moapa Dace

See the description in the Intra-Service Programmatic Biological Opinion for the Proposed Muddy River Memorandum of Agreement Regarding the Groundwater Withdrawal of 16,100 afy From the Regional Carbonate Aquifer in the Coyote Spring Valley and California Wash Basins and Establishment of Conservation Measures for the Moapa Dace, Clark County, Nevada (Service 2006c) (File No. 1-5-05-FW-536). Updated information on the Moapa dace is provided below.

Warm Springs Natural Area

In September 2007, Southern Nevada Water Authority (SNWA) purchased 1,179 acres of private property that encompasses several springs in the Muddy River headwaters area, including the former Warm Springs Ranch. The property includes 3.8 miles of the mainstream Muddy River. The Warms Springs Natural Area is to be managed as a nature preserve for protection of Moapa dace; and restoration and management of the areas as an ecological reserve.

Current Distribution and Abundance

Moapa dace surveys have been conducted annually throughout the upper Muddy River system. Dace surveys conducted semi regularly between 1994 and 2006 indicate Moapa dace numbers range between 1,296 and 3,825 individuals. The 2007 survey data indicate that there were approximately 1,172 fish in the population that occurred throughout 5.6 miles of habitat in the upper Muddy River system. Approximately 97 percent of the total population occurred within one major tributary that included 1.78 miles of spring complexes that emanate from the Pedersen, Plummer, and Apcar spring complexes on the Moapa Valley NWR and their tributaries (upstream of the gabion barrier). Approximately 48 percent of the population was located on the Moapa Valley NWR and 48 percent occupied the Refuge Stream supplied by the Pederson-Plummer springs. The highest densities of Moapa dace occurred on the Moapa Valley NWR's Plummer and Pedersen units.

In 2008, there was an approximately 60 percent decrease in the number of Moapa dace, from 1,172 fish in 2007 to 460 in 2008. Most of this decline is due to large changes in the numbers of dace in the Pederson, Plummer, and Refuge Stream areas which supported more than 92 percent of the population in 2007. The cause of the population decline is currently unknown, although beavers have recently changed stream characteristics in the Refuge Stream and vegetation management occurred along the Pederson Unit. In addition, habitat restoration projects have been implemented over the past few years in the Pederson and Plummer units of the Moapa Valley NWR, restoring the streams to a more natural state to augment Moapa dace habitat and populations.

D. Environmental Baseline

1. Status of the Listed Species/Critical Habitat in the Action Area

a. *Desert Tortoise (Mojave Population) - Status within the Action Area*

The action area occurs in the Mojave Desert Scrub Biome (Turner 1982), along the Kane Springs Road located in the valley between the Meadow Valley Mountains to the south and the Delamar Mountains to the north. The project area crosses Kane Springs Wash, which flows southwest to its confluence with the Pahranagat Wash in the northern part of the Coyote Spring Valley, in several locations. The vegetation in the action area consists of creosote bush scrub and desert wash scrub along Kane Springs and Pahranagat washes. Elevations in the action area range from approximately 2,600 to 3,300 feet.

Between October 16 and 18, 2006, Greystone-ARCADIS biologists conducted desert tortoise presence-absence surveys in the project area for BLM (ARCADIS 2007). Evenly spaced along the project area were 18, 1.5 mile long by 10 yard wide triangular strip transects. Transects were surveyed for live or dead desert tortoise, and any tortoise sign including burrows, scat, tracks, and water scrapes. The total corrected sign method was used to estimate tortoise densities. Estimated tortoise densities ranged from 10 to 0 tortoises per square mile. No live tortoises were found and most of the tortoise sign was comprised of burrows and water scrapes. The highest tortoise densities were 10 per square mile at 3 transects, and 7 per square mile at 3 transects. The remainder of the transects had densities of 5 per square mile or less. No desert tortoise sign were found in the two transects that overlapped with a wildfire perimeter from 2005 at the northeast end of the project area. Over the project area, tortoise densities average 4 desert tortoises per square mile. Densities in the project area are therefore estimated to be very low.

Recent surveys have been conducted in the Coyote Spring Valley as part of the rangewide population monitoring program. Survey data from 2005 line-distance sampling in the Coyote Spring Valley, which includes transects in the CSI private and lease lands located in the Mormon Mesa Critical Habitat Unit (CHU), estimate the tortoise densities in the valley to be 8.3 tortoises per square mile (Service unpublished data). Over the first five years of line-distance sampling monitoring, tortoises were least abundant in the Northwest Mojave Recovery Unit (2 to 8 tortoises per square mile) as compared to other recovery units (Service 2006b). Tortoise densities in the Coyote Spring Valley are therefore among the highest in the recovery unit. These results are preliminary and additional analysis is needed, incorporating 2006 and 2007 survey results. Desert tortoise clearance surveys were conducted in 2006-2007 in the southern part of the Coyote Spring Valley. One hundred percent clearance surveys were conducted on 5,302 acres of CSI private lands in Clark County as of January 2008. Based on the total number of tortoises cleared during surveys (108 adults and juveniles), we estimate a density of around 13 tortoises per square mile on the CSI private lands in Clark County.

Older desert tortoise survey data exists for the action area including BLM strip triangle surveys and the Coyote Springs Permanent Study Plot (PSP). Prior to 1991, BLM surveyed for tortoises using the strip triangle method, recording all tortoise sign within approximately 5 meters (15 feet) of the transect and estimating species density based on methods described by Karl (1981) for southern Nevada. Densities within one half mile of Kane Springs Road ranged from high to very low. Densities averaged medium (45 - 90 tortoises per square mile) and low (10 - 45 tortoises per square mile) over the project area. Densities on the northeast part of the project area were very low (0 - 10 tortoises per square mile). It appears that densities have declined somewhat since 1991.

The closest 1-square-mile PSP to the project area is the Coyote Spring plot, which is located 1.9 miles east of US 93 and 1.9 miles north of Kane Springs Road. This plot was established in 1986 and resurveyed in 1992 and 1995. EnviroPlus Consulting (1995) characterized this site as having moderately high tortoise numbers, with a size distribution typical of that observed on other PSPs and a significantly skewed sex ratio with female tortoises comprising two-thirds of the observed sub-adult and adult population (however, this effect was not significant for tortoises >208 mm mid-carapace length). Over the three survey periods, total estimated population size on the plot ranged from 96 ± 31 to 116 ± 29 (Esque1986, Converse Environmental Consultants Southwest, Inc. 1992, EnviroPlus Consulting 1995). This is considerably higher than densities in the action area. The annual adult mortality rate for the Coyote Spring plot in 1995 was estimated at 4 percent, which is higher than the 2-3 percent rate that the Service believes necessary to sustain desert tortoise populations (Service 1994). However, the tortoise population at the Coyote Spring PSP was apparently stable over the 10 years that the surveys spanned (EnviroPlus Consulting 1995).

Tortoises with symptoms of cutaneous dyskeratosis and URTD were observed during plot surveys; however, comparisons across survey periods are unreliable due to differences in diagnosis/evaluation criteria used to evaluate health status. In 1995, approximately one-third of tortoises had trauma-related injuries, likely caused by a predator. Overall, mortality by predation was characterized as present, but not at a high rate. Human impacts on tortoise populations in this area were considered low and inconsequential (EnviroPlus Consulting 1995). The PSP is located in the northern part of the Coyote Spring Valley and BLM strip triangle survey data corroborates that this area north of the Kane Springs Road and east of US 93 has higher tortoise densities than the surrounding areas with several very high density (greater than 140 tortoises per square mile) and high density (90 -140 tortoises per square mile) survey triangles.

b. ***Desert Tortoise Critical Habitat - Status within the Action Area and the Mormon Mesa CHU***

The project area is located mostly within the 427,900 acre Mormon Mesa CHU of the Northeastern Mojave Recovery Unit for the desert tortoise. The primary vegetation community within the Mormon Mesa CHU is creosotebush-white bursage desert scrub, which in Nevada is found in broad valleys, lower bajadas, plains and low hills of the Mojave Desert. Shrub cover is sparse to moderately dense, consisting primarily of creosote bush (*Larrea tridentata*) and white bursage (*Ambrosia dumosa*) with a variety of different shrubs and cacti as co-dominants or understory species. Where poorly-drained soils with high salt and clay content are found on valley bottom floors, pockets of salt desert scrub community may be present, typified by one or more *Atriplex* species.

The CHU boundaries were based on proposed desert wildlife management areas (DWMAs) in the Draft Desert Tortoise Recovery Plan. The land management agencies have subsequently designated areas of critical environmental concern (ACECs) in each DWMA, where they are managing the land as reserves. In general, land management activities that may negatively affect the desert tortoise and its habitat such as domestic livestock grazing, grazing by wild burros and horses, commercial harvest of desert flora, and off-road vehicle use are mostly restricted or not allowed in these areas, as per Recovery Plan recommendations. The Mormon Mesa CHU contains the following ACECs: Kane Springs, Coyote Springs, and Mormon Mesa. The project area is in the Kane Springs ACEC.

CSI owns 29,055 acres of lands in Coyote Spring Valley, in Clark and Lincoln counties, Nevada, all of which is designated critical habitat for the desert tortoise. In addition CSI has a lease for approximately 13,767 acres of BLM-administered land in Coyote Spring Valley for 99 years. In Clark County, CSI is currently constructing a residential and golf community with associated commercial development on 6,881 acres of private land. Construction will occur over 25 years, with an eventual build out of 29,000 residential units, approximately 72,500 residents, and a visitor capacity equal to 14,500 residents (based on full-time equivalency). In Lincoln County, CSI proposes to develop 21,454 acres of private land over a 40 year period. It is estimated that there would be up to 111,000 residential units, resulting in an increase of population of 275,300 residents in Lincoln County. CSI plans to create a natural reserve on 13,767 acres of BLM leased land (approximately 7,548 acres in Lincoln County and 6,219 acres in Clark County).

EnviroPlus Consulting (1995) characterized the Coyote Spring PSP as having low historical and present-day human impact: Old Highway 93 was rarely used and had large shrubs growing through cracks in the pavement; little trash was observed on the plot; no power lines were present; no cattle or burros were observed; and while a few old two-track roads were discernible for short distances, none appeared to be recently made. Furthermore, this area was characterized as having somewhat variable but adequate tortoise habitat, with abundant forage and good soil for burrowing (EnviroPlus Consulting 1995).

The Mormon Mesa CHU is highly fragmented with an extensive network of primarily unimproved and two-track roads. The Desert Tortoise Recovery Plan (companion document for proposed DWMAs, Service 1994), describes this area as having the highest density of roads and trails (I.3 linear miles per square mile) of any desert tortoise *crucial* habitat in southern Nevada based on a 1984 status report [crucial habitat was defined by BLM in the California Desert Plan (1980) as "...Portions of the habitats of sensitive species that if destroyed or adversely modified could result in their being listed as threatened or endangered pursuant to section 4 of the Act or in some category implying endangerment by a State agency or legislature."]. US 93 runs along the western edge and bisects the southwestern tip of the unit, providing a substantial barrier between the unit and protected tortoise habitat in the Desert NWR to the west. State Route (SR) 168 also runs through the western part of the CHU, and I-15 traverses the southeastern edge of the unit. Other well-established roads include the Kane Springs Road and the Carp-Elgin Road which bisects the unit. Powerlines, pipelines, and access roads dissect much of the area.

The 2005 wildfire season in southern Nevada was severe due in large part to the high bio-mass of flammable non-native annual grasses after above-average moisture conditions the previous winter. Approximately eight acres in the northeast part of the project area burned in 2005 in the Meadow Valley Fire, which burned approximately 148,000 acres overall, including a small amount of the Mormon Mesa CHU. In total, over 56 fires of various sizes in southern Nevada, southwestern Utah, and northern Arizona burned roughly 964,806 acres in the Northeastern Mojave Recovery Unit in 2005 including 15,559 acres (4 percent) within the Mormon Mesa CHU. The wildfire hazard in the Mormon Mesa CHU remains significant although fire activity in 2006 and 2007 was lower due to dryer conditions over the winter and spring. Monitoring of the 2005 fires in critical habitat being conducted by the U.S. Geological Survey (USGS) shows that proportionally less tortoise activity occurred in burned areas (treatment plots and control plots) compared to unburned reference plots.

The Mormon Mesa CHU is primarily in Federal ownership, administered by BLM. In addition to CSI's private lands, there are several small privately-held parcels along the Meadow Valley Wash that are within or adjacent to the CHU. Other privately-held lands or Federal land slated for disposal adjacent or near the Mormon Mesa CHU have the potential for future development. Land near the extreme southwestern tip of the Mormon Mesa CHU and northeast of Las Vegas is also in private ownership. Future development of these private lands, as well as possible future disposals of Federal land to allow for expansion of existing cities will create additional challenges for the Service and Federal lands managers in terms of management of the Mormon Mesa DWMA/ACEC, and conservation and recovery of desert tortoises in the Mormon Mesa CHU.

c. *Moapa Dace - Status within the Action Area*

The action area encompasses the entire range of the Moapa dace. Population numbers were discussed in detail in the section entitled "Status of the Species Rangewide, C. Moapa Dace;" thus, no further details are provided here. The relationship of the dace's habitat to groundwater is discussed in more detail below.

2. *Factors Affecting the Listed Species/Critical Habitat in the Action Area*

The action area is located primarily within the Kane Springs Valley, Coyote Spring Valley and Muddy River Springs Area hydrographic basins. These basins are part of the White River Groundwater Flow System, a regional groundwater flow system located in southern Nevada (Eakin 1966, Harrill *et al.* 1988, Prudic *et al.* 1993). The flow system consists of numerous local basin fill aquifers underlain by a large regional carbonate aquifer that transmits groundwater from basin to basin, beneath topographic divides. Groundwater inflow or recharge to the regional carbonate aquifer is primarily through precipitation. The terminal discharge of the White River Groundwater Flow System is most likely the Warm Springs in the Upper Moapa Valley, an area consisting of about twenty regional springs, with numerous seeps and wetlands. Since the Moapa dace is dependent upon these springs for survival it is important to discuss the hydrology of this area in more detail.

The source water supporting spring discharge in the Warm Springs Area is from the regional carbonate groundwater (62 percent) and from local recharge based on precipitation in the surrounding mountain ranges (BLM 2008). The production wells in the Kane Springs Valley that would be pumped under the proposed action are located about 20 miles northwest of the Warm Springs Area. The high permeability and transmissivity of the carbonate aquifer underlying the Kane Springs Valley and down-gradient Coyote Spring Valley could connect the proposed action to springs in the Warm Springs Area. Long-term effects from groundwater extraction could be propagated over great distances. Barriers to flow, such as faults or rock units with low permeability, also affect the extent of drawdown. There may be a break in the regional hydraulic gradient at the location of the Kane Springs Wash fault zone; however until additional long-term pumping data are obtained, the true relationship cannot be fully evaluated (BLM 2008).

a. *Existing Groundwater Rights and State Engineer Rulings in the Action Area:*

Groundwater wells within the Kane Springs Valley and Coyote Spring Valley Hydrographic Basins are associated with municipal, mining, industrial, commercial and irrigation use. Permitted diversion rates for existing wells vary from 145 to 7,242 afy. Within the Kane Springs Valley Hydrographic Basin, permitted water rights are limited to the LCWD/VWC applications recently approved by the State Engineer under Ruling 5712. The LCWD has an additional four groundwater applications pending before the Nevada State Engineer. Currently, in the Kane Springs Valley Hydrographic Basin permitted groundwater rights are 1,000 afy (BLM 2008).

In the Coyote Spring Valley Hydrographic Basin, groundwater rights filed with the Nevada State Engineer include 15 industrial use permits owned by SNWA, 4 municipal use permits owned by CSI, 1 industrial use permit owned by Nevada Power Company, and 4 permits owned by Bedrock Limited, LLC associated with sand and gravel mining operations. Bedrock Limited, LLC also has one vested application for irrigation use. Currently, in the Coyote Spring Valley Hydrographic Basin permitted groundwater rights are 16,304 afy (BLM 2008). There are 34 pending applications by Las Vegas Valley Water District (LVWD); CSI; Dry Lake Water, LLC;

and Bedrock Limited, LLC in the Coyote Spring Valley Hydrographic Basin. A list of surface water and groundwater rights in the Kane Springs Valley and Coyote Spring Valley hydrographic basins is provided in Appendix D of the Kane Springs Valley Groundwater Development EIS (BLM 2008).

There are three Nevada State Engineer rulings that affect the withdrawal of groundwater in the action area. In these rulings the Nevada State Engineer has required "staged development," an incremental approach for phasing in development of the carbonate aquifer with adequate monitoring in cooperation with other parties in order to assist in assessing effects. This approach was adopted by the Nevada State Engineer "...in order to predict, through the use of a calibrated model, the effects of continued or increased development with a higher degree of confidence." Ruling 5712, granting 1,000 afy of groundwater from the Kane Springs Valley to LCWD and VWC was summarized in the section entitled "Description of the Proposed Action." The other two rulings are summarized below.

In Order 1169 issued in 2002, the Nevada State Engineer held in abeyance applications for new groundwater rights in the Coyote Spring Valley, Black Mountains Area, Garnet Valley, Hidden Valley, Upper Moapa Valley, and Lower Moapa Valley groundwater basins until a pump test is completed. All major water right holders in these basins (SNWA, LVVWD, Moapa Valley Water District [MVWD], CSI, and Nevada Power Company) were required to conduct a regional groundwater study, including the pumping of at least 50 percent of the permitted water rights within the Coyote Spring Valley hydrographic basin for a period of at least two consecutive years. Order 1169 is designed to evaluate how groundwater pumping activities in Coyote Spring Valley will impact water rights and the environment within the Warm Springs Area, including the Muddy River ecosystem. Data obtained from the study will be used to evaluate groundwater development activities within the regional carbonate groundwater system.

To date, there has been limited pumping of the permitted groundwater rights in Coyote Spring Valley. In 2005, CSI drilled and pump tested two wells in Coyote Spring Valley under Nevada Division of Water Resources permit numbers 70429 and 70430. Currently, CSI is monitoring and pumping water as needed for their development activities in Clark County.

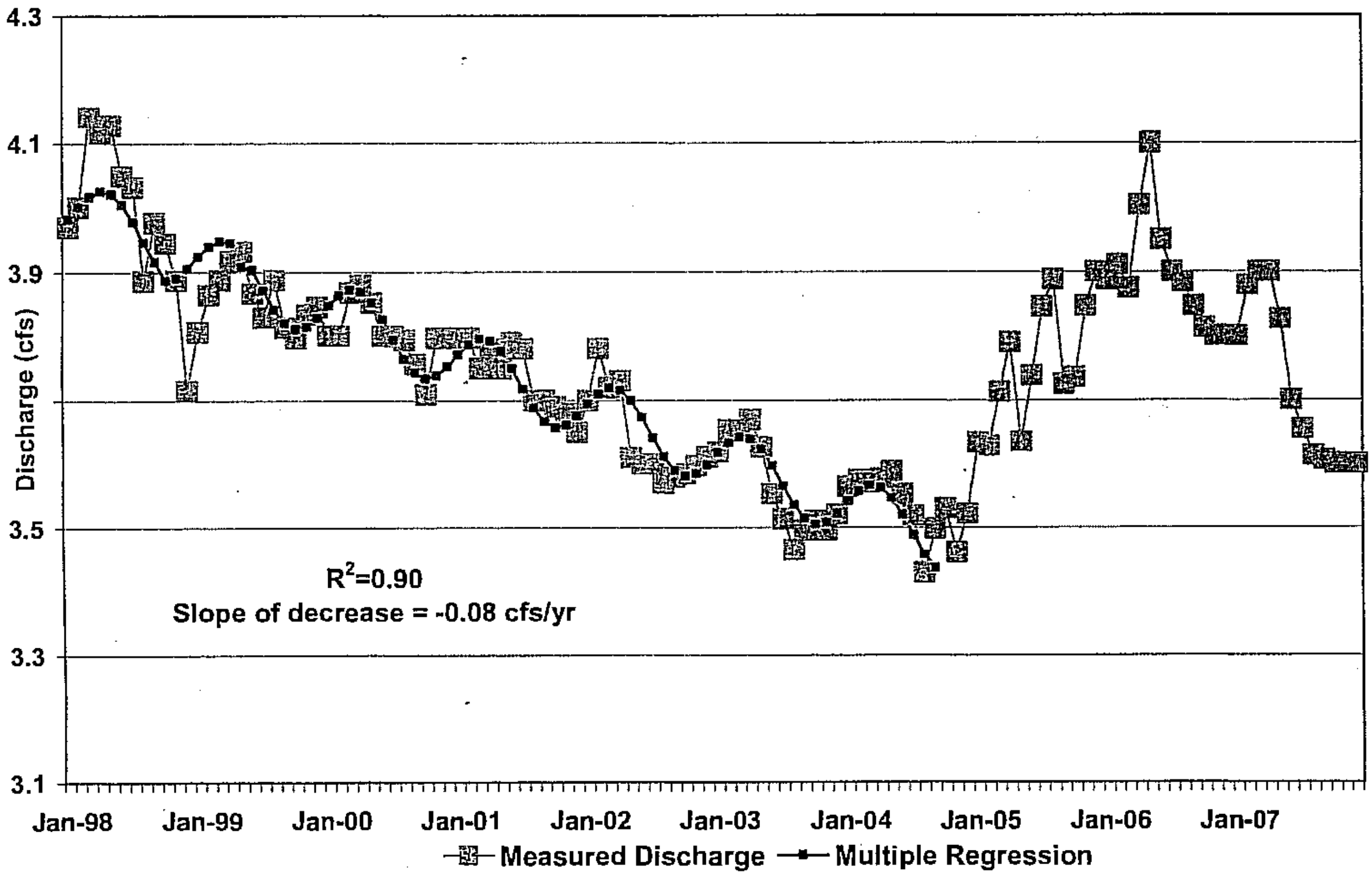
In Ruling 4243 in the Muddy River Springs Area Hydrographic Basin, the Nevada State Engineer granted permits to MVWD for 5,800 afy from Arrow Canyon Well, but with pumping phased in over a 10-year period while monitoring surface water flows and groundwater levels in order to assess potential effects to wells and springs. Annual volume pumped is limited to annual demand, up to the maximum permitted. Annual pumping has consistently been less than the amount allowed in the ruling.

As of 2002, the Nevada State Engineer had granted a total of approximately 14,800 afy of groundwater permits for the alluvial and carbonate aquifer in the Muddy River Springs Area Hydrographic Basin (Service 2006c). Included in these are MVWD permits for the Arrow Canyon Well totaling 7,240 afy (1,440 afy prior to Ruling 4243 plus 5,800 afy from Ruling 4243) from the carbonate aquifer. To date, the actual pumping from the Arrow Canyon Well has been far less than the permitted volume. Approximately 2,400 afy has been pumped on average since 1998.

Concurrent with groundwater pumping between 1998 and 2004, groundwater levels and spring discharge in the Warm Springs Area consistently declined (Service 2006c). Over the same period, the total spring discharge from the Pedersen Unit, as measured at Warm Springs West, decreased from 4.00 cfs to 3.55 cfs (Service 2006c) (Figure 2). The discussion in Mayer (2004) shows that the observed decreases in spring discharge are consistent with expected decreases based on the two-foot decline in groundwater levels observed in the carbonate monitoring wells in the Warm Springs Area. The extremely wet winter of 2005 appears to have recharged the springs with monthly discharge peaking at 4.1 cfs in May of 2006, and decreasing since that time (Mayer 2008). This is expected to be a transient response but the timing and level of a return to equilibrium conditions is not known for certain. Discharge has currently declined to 3.6 cfs (USGS 2008).

The exact timing of the groundwater level decline is important because if the actual decline precedes in time any action or event suspected of causing the decline (such as increased pumping or drought), then this is strong evidence that there are other factors causing the decline. The Service (2006c) analyzed the timing of the decline as it was concerned about the rate and magnitude of the 1998 to 2004 decrease. The start of the decline coincides with MVWD's increased pumping from the carbonate aquifer. In order to address the possibility that drought caused the groundwater level declines, the Service (2006c) compiled precipitation records from a number of stations in the southeastern Nevada area. Their analysis showed that the decline from 1998 to 2004 was not likely to be drought-related. These declines observed between 1998 and 2004 have occurred not only locally in the Warm Springs Area, but have also occurred in monitoring wells 12 miles upgradient in Coyote Spring Valley and 15 miles south in monitoring

Figure 3: Warm Springs West, Moapa Valley NWR - USGS Average Monthly Discharge, Apr 1998 to Dec 2007



wells in the California Wash Basin, based on USGS monitoring well data and monitoring well data shared with the Service in July 2004 (Service 2006c).

On July 14, 2005, a Memorandum of Agreement (MOA) was signed by the SNWA, MVWD, CSI, Moapa Band of Paiutes (Tribe), and the Service, regarding groundwater withdrawal of 16,100 afy from the regional carbonate aquifer in Coyote Spring Valley and California Wash Basins, and establishment of conservation measures for the Moapa dace. The MOA outlined specific conservation actions that each party would complete in order to minimize potential impacts to the Moapa dace should water levels decline in the Muddy River system as a result of the cumulative withdrawal of 16,100 afy of groundwater from two basins within the regional carbonate aquifer system.

To minimize effects to the Moapa dace, conservation actions were identified in the MOA. In order to be considered a benefit to the species, the proposed conservation measures will be initiated or fully implemented prior to the proposed groundwater withdrawal of 16,100 afy. Since development of these water rights requires the construction of facilities, as identified above, there would be a two to five year timeframe in which to implement many of these actions prior to the pumping of the full amount of water. CSI would utilize a small portion of their water right in Coyote Spring Valley prior to full implementation of all of the conservation measures. The action items identified in the MOA include development of a Recovery Implementation Program, restoration, ecological studies, construction of fish barriers, eradication of non-native fish, and dedication of water rights. Minimum in-stream flow levels were established in the MOA that trigger various conservation actions should those predetermined levels be reached. The flow levels will be measured at the Warm Springs West Flume located on the Moapa Valley NWR.

b. Section 7 Consultations Completed for Activities and Projects in the Action Area

1. **File Nos. 1-5-99-F-450 and 84320-2008-F-0078:** On March 3, 2000, the Service issued a programmatic biological opinion (File No. 1-5-99-F-450) to BLM's Ely District Office for implementation of actions in the Caliente Management Framework Plan Amendment (CMFPA). The planning area consisted of public lands in White Pine, Lincoln, and a portion of Nye counties in east-central Nevada. Cumulatively, 25,521 acres of desert tortoise habitat were projected to be affected by the proposed activities within the planning area over a 10-year period.

   On September 9, 2008, the Service issued a programmatic biological opinion (File No. 84320-2008-F-0078) to BLM for the Ely District Resource Management Plan (Ely RMP). This programmatic biological opinion superseded the March 3, 2000, programmatic biological opinion for the CMFPA. Programs in the 2008 programmatic biological opinion included: vegetation management; weed management; wild horse management; lands, realty, and renewable energy projects; travel and off-highway vehicle management;

recreation; livestock grazing management; geological and mineral extraction; and fire management.

Implementation of multiple-use activities (excluding vegetation and weed management) were projected to result in the disturbance of 22,624 acres of desert tortoise critical habitat and 37,311 acres of desert tortoise habitat. During the 10-year term of the programmatic biological opinion, the Service authorized the take of no more than 47 desert tortoises and estimated that 972 tortoises would be taken by non-lethal means (i.e. harassment).

2. **File Nos. 1-5-94-F-334, 335, 336, and 035:** On May 15, 1995, the Service issued a non-jeopardy biological opinion to BLM for the issuance of a right-of-way to install four proposed fiber-optic lines in Clark and Lincoln counties, Nevada. Four applicants comprising the Fiber Toll Joint Venture Project requested a 7.6-m-wide (25-foot-wide) right-of-way for construction of four buried fiber-optic lines. Segments of these lines would parallel SR 168 for approximately 23 miles, and for 43 miles along US 93 (File Nos. 1-5-94-F-334 and 336). Approximately 98 and 65 acres of long- and short-term habitat disturbance, respectively, was attributed to the two segments adjacent to US 93 and SR 168 described above, a majority of which runs through the action area for the CSI project. This included approximately 53 acres of long-term disturbance and 35 acres of short-term disturbance to designated critical habitat (Mormon Mesa CHU) for the desert tortoise. The Service anticipated that up to 34 tortoises would be incidentally taken, 8 through mortality and 26 through injury or harassment.

3. **File No. 1-5-98-F-053, as amended:** On June 18, 1998, the Service issued a programmatic biological opinion to BLM for implementation of the Las Vegas Resource Management Plan (RMP). The project area for this consultation covers all lands managed by BLM's Las Vegas Field Office, including desert tortoise critical habitat, desert tortoise ACECs, and BLM-withdrawn land. The Las Vegas Field Office designated approximately 648 square miles of tortoise habitat as desert tortoise ACEC in the Northeastern Mojave Recovery Unit, and approximately 514 square miles of tortoise habitat as desert tortoise ACEC in the East Mojave Recovery Unit, through the final RMP. As identified in the RMP, BLM manages 743,209 acres of desert tortoise habitat within four tortoise ACECs for desert tortoise recovery. To accomplish desert tortoise recovery in the Northeastern and Eastern Mojave Recovery Units, the Las Vegas Field Office implements appropriate management actions in desert tortoise ACECs.

4. **File No. 1-5-98-FW-177:** On November 2, 1998, the Service issued a non-jeopardy biological opinion to the Nevada Fish and Wildlife Office for the implementation of eradication of non-native fish activities and installation of fish barriers in the Apcar Stream in the Warm Springs Area of the Muddy River. The Service concluded that the project was not likely to jeopardize the continued existence of the Moapa dace.

Incidental take was authorized and Reasonable and Prudent Measures were identified to minimize take to the species.

5. **File No. 1-5-99-F-411:** On December 8, 1999, the Service issued a non-jeopardy biological opinion to BLM for issuance of a right-of-way permit for the Nevada segment of the Las Vegas to Salt Lake City Long-haul Fiber-Optic Project. This consultation evaluated impacts to the desert tortoise and designated critical habitat from the construction, operation, and maintenance of a buried fiber-optic cable and related structures over an 180-mile linear stretch from the Utah-Nevada border to its terminus north of Nellis Air Force Base in Las Vegas. The section of the fiber-optic cable that runs through the Mormon Mesa CHU and CSI lands was located in NDOT's right-of-way east of US 93. The final area of disturbance was calculated at approximately 270 acres, including 158 acres of permanent impacts. The Service estimated that 4 desert tortoises may be incidentally injured or killed and 200 tortoises could potentially be affected by project activities.

6. **File No. 1-5-01-F-463:** On December 26, 2001, the Service issued a non-jeopardy biological opinion to the Bureau of Indian Affairs for approval of a lease for lands on the Reservation for construction and operation of the Moapa Paiute Energy Center. The proposed project would disturb up to 7 percent of the total available spawning habitat for the Moapa dace. As of the date of this biological opinion, the proposed project has not moved forward and the Service is not aware of any plans in the near future to construct the project.

7. **File No. 1-5-02-FW-463:** On March 13, 2002, the Service issued a non-jeopardy biological opinion to the Desert NWR Complex, Las Vegas, Nevada for the implementation of riparian and aquatic habitat restoration activities in the Pedersen Unit of the Moapa Valley NWR. The Service concluded that the incidental take of less than 10 percent of the 180-200 individuals (18-20 individuals) that may be present in the project area, would not likely jeopardize the continued existence of the Moapa dace. Reasonable and Prudent Measures were identified and implemented to minimize take of the species.

8. **File No. 84320-2008-F-0066 and 1-5-94-F-28R:** On December 20, 2007, the Service issued a biological opinion to BLM-Las Vegas for their proposal to amend an existing right-of-way for construction, operation, and maintenance of a single-circuit, overhead 500 kV transmission line (Southwest Intertie Project). The southern portion of the project begins at the Harry Allen Substation in Clark County, Nevada, crossing through the planning area, and ending approximately 34 miles north of Ely in White Pine County, Nevada. The project would disturb 231 acres of non-critical and 365 acres of critical desert tortoise habitat.

9. **File No. 1-5-05-FW-536:** On January 30, 2006, the Service issued a non-jeopardy intra-Service programmatic biological opinion for the Proposed Muddy River MOA, regarding the groundwater withdrawal by multiple parties of 16,100 afy from the regional carbonate aquifer in the Coyote Spring Valley and California Wash Basins. Given that there will be groundwater withdrawn from the same regional carbonate aquifer concurrently by different users and at different locations, it was difficult to assign loss to a specific action. The most accurate way to establish incidental take is at the landscape-level, which was analyzed in the Programmatic Biological Opinion. In that parent document, the cumulative withdrawal of 16,100 afy from all parties associated with the MOA predicted a loss of approximately 22 percent riffle and 16 percent pool habitat (as measured at the Warm Springs West gage downstream from the Pedersen Unit) when the flows reach 2.78 cfs. This amount included habitat losses potentially occurring under both the CSI development and SNWA pipeline. Three tiered biological opinions have been issued under this programmatic opinion:

a. **File No. 1-5-05-FW-536 Tier 1:** On March 2, 2006, the Service issued a non-jeopardy tiered biological opinion to the Corps for the issuance of a Section 404 permit under the Clean Water Act of 1972, as amended, for the CSI residential development project. The Service concluded the proposed residential development is an interdependent activity with the Corps' action and will result in the permanent loss of 6,881 acres of desert tortoise habitat and take of no more than 645 desert tortoises. The proposed action falls within the scope and coverage of the 10(a)(1)(B) permit issued to Clark County for its multiple species habitat conservation plan (MSHCP), and exemption for the anticipated take of the desert tortoise is provided via the incidental take statement for the MSHCP. The Service estimated that the proposed action will result in the incidental take of Moapa dace associated with the loss of 6 percent of riffle habitat and 5 percent of pool habitat, in the Pedersen Unit. Incidental take was authorized, and reasonable and prudent measures were identified to minimize take of the species.

b. **File No. 1-5-05-FW-536 Tier 2:** On May 9, 2007, the Service issued a non-jeopardy tiered biological opinion to BLM for a right-of-way to the SNWA to construct a water conveyance pipeline. SNWA's appropriated water right of 9,000 afy from Coyote Spring Valley would be pumped in order to participate in the Nevada State Engineer Study (Order 1169), and to provide water to the Moapa Valley area for residential and commercial purposes. The right-of-way would allow construction of approximately 16 miles of 24-inch diameter pipeline to transport water from three existing groundwater pumping wells in the southern end of the Coyote Spring Valley to an existing storage tank and pipeline. The Service estimated that 12 percent of riffle habitat and 9 percent of pool habitat will be lost due to the withdrawal of 9,000 afy associated with the SNWA action; however there were other factors which complicated the establishment of incidental take at this level for the proposed action.

c. **File No. 1-5-05-FW-536 Tier 3:** On August 6, 2007, the Service issued a non-jeopardy tiered biological opinion to the U.S. Department of Housing and Urban Development for construction of a water pipeline from an existing well on the Moapa River Indian Reservation to the Moapa Valley of Fire Travel Plaza. The use of 7 of the 16,100 afy for the proposed Travel Plaza will independently have no significant impact on the Muddy River Springs area discharge and subsequently the Moapa dace, but was authorized under the Programmatic Biological Opinion.

On October 22, 2008, the Service issued a non-jeopardy intra-service biological opinion for the Coyote Springs Investment Planned Development Project Multiple-Species Habitat Conservation Plan (MSHCP) (File No. 84320-2008-F-0113). The Service subsequently issued a 40-year incidental take permit to CSI under the authority of section 10(a)(1)(B) of the Act. The Permit covers take of desert tortoise on up to 21,454 acres of private lands in Lincoln County, and management of 13,767 acres of lease lands in Clark and Lincoln counties as the Coyote Springs Investment Conservation Lands. Groundwater withdrawal is not a Covered Activity in the CSI MSHCP. Groundwater withdrawals and their effects to the Moapa dace are subject to evaluation under separate biological opinions for several groundwater development projects, and any appropriate incidental take would be authorized through those biological opinions when issued, or under section 10 (a)(1)(B) if these actions did not involve a Federal agency.

E. Effects of the Proposed Action on the Listed Species/Critical Habitat

Effects of the action refer to the direct and indirect effects of the proposed action on the listed species, together with the effects of other activities that are interrelated and interdependent with that action. Direct effects encompass the immediate, often obvious effect of the proposed action on the listed species or its habitat. Indirect effects are caused by or will result from the proposed action and are later in time, but still reasonably certain to occur. In contrast to direct effects, indirect effects can often be more subtle, and may affect listed species populations and habitat quality over an extended period of time, long after project activities have been completed. Interrelated actions are those that are part of a larger action and depend on the larger action for their justification. Interdependent actions are those that have no independent utility apart from the action under consideration.

1. Effects to the Desert Tortoise (Mojave Population)

Linear construction projects can negatively affect desert tortoise populations. Studies suggest that differences in the extent of the threat are related to the scale of the project, the ability of crews to avoid disturbing burrows, and timing of construction to avoid peak activity periods of tortoises (Boarman 2002). In addition to the discrete disturbance points formed by towers and lines, maintenance roads and repeated operations can (1) introduce continuous sources of disturbance and (2) provide potential sites for invasion of exotic species. Rights-of-way can cause habitat destruction and alteration where vegetation is minimal, possibly increasing mortality, directly or indirectly (Boarman 2002).

Direct impacts to the desert tortoise would be the permanent and temporary loss of habitat utilized by tortoises for foraging, breeding, and cover. Approximately 21 acres will be permanently lost by the construction of well houses and well power substations, water storage tanks, access roads, ancillary pipeline facilities, and power poles. Approximately 188 acres will be temporarily lost by the construction of the pipelines, power lines, fiber optic line, temporary access roads, and temporary workspaces such as pipe and power line laydown areas, power line pulling sites, staging areas, and construction easements. Many of these activities will involve blading and excavation of the area. These areas will be rehabilitated as described in the Revegetation Plan in the Plan of Development; however, it will likely take a long time (potentially more than 10 years) before these areas can provide foraging and cover sites for the desert tortoise.

Other areas that have heavy machinery moving over them will have crushed vegetation and compacted soil. LCWD and BLM propose to salvage topsoil during excavation and to reuse the topsoil later as cover on disturbed areas to facilitate re-growth of vegetation. LCWD and BLM will also flag the work areas so that unauthorized habitat removal does not occur.

Any tortoise within the construction area during work activities would be highly vulnerable. Desert tortoises may be killed or injured by project vehicles and equipment in the project area. Construction equipment and vehicles could crush tortoises or collapse burrows both occupied and unoccupied if not located during clearance surveys. Project vehicles and equipment that stray away from designated access roads and areas may crush desert tortoises aboveground or in their burrows. Tortoises may take refuge underneath project vehicles and equipment and be killed or injured when the equipment or vehicle is moved. Blasting during construction could collapse burrows and injure tortoises. Tortoises that wander into the project area could also fall into holes or trenches from which they are unable to escape. The following measures proposed by LCWD and BLM should reduce these potential effects to desert tortoises: 1) conduct tortoise clearance surveys within the project area; 2) enforce a 25 mph speed limit on project access roads; 3) cease project activities that may endanger a tortoise until it is moved out of harm's way by an authorized desert tortoise biologist; 4) present a worker education program; 5) cover construction holes left open overnight and check trenches twice daily to check for entrapment of wildlife; and 6) restrict vehicles and equipment to the work area boundaries and designated access roads.

Tortoises moved during clearance surveys and tortoises that are physically moved out of harm's way to prevent mortality or injury could be inadvertently harmed if not handled properly. Urine and large amounts of urates are frequently voided during handling and may represent a severe water loss, particularly to juveniles (Luckenbach 1982). Overheating can occur if tortoises are not placed in the shade when ambient temperatures equal or exceed temperature maximums for the species (Desert Tortoise Council 1994, revised 1999). Tortoise eggs moved during clearance surveys could also be harmed if not handled properly. The following measures proposed by LCWD and BLM should reduce these potential effects to desert tortoises: 1) implementing a worker education program; 2) utilizing Service-approved protocols for handling desert tortoises and tortoise eggs; and 3) ensuring that only authorized individuals handle tortoises.

The resulting indirect impacts to the desert tortoise may include the risk of death, injury, or lower reproductive potential through increased predation and degradation and fragmentation of the habitat surrounding the project area. There is a potential for an increase in the number of predatory and scavenger species due to the presence of humans and improper disposal of trash. Workers associated with the proposed project may provide food in the form of trash and litter; or water, which attracts important tortoise predators such as the common raven, kit fox, and coyote (BLM 1990, Boarman and Berry 1995). Natural predation in undisturbed, healthy ecosystems is generally not an issue of concern. However, predation rates may be altered when natural habitats are disturbed or modified (BLM 1990). Ravens likely would be attracted to human activities and buildings for perch sites and food sources, increasing the potential for predation on juvenile desert tortoise in adjacent habitats. LCWD and BLM will implement a litter-control program and a worker education program to avoid or minimize these potential effects.

The project may degrade habitat in the surrounding landscape by introducing non-native weeds or plants into the project area, which later spread in to the surrounding desert, increasing fuel loads for wildfires and competing with native forbs and shrubs. Land clearing activities in the project area may lead to increased soil erosion especially on steeper slopes. The following measures proposed by LCWD and BLM should help reduce these potential effects to desert tortoise habitat: 1) implementation of a Stormwater and Pollution Prevention Plan; 2) implementation of a Revegetation Plan; and 3) implementation of a Noxious Weed Management Plan.

Following construction, the public may use project access roads which may result in adverse effects to tortoise populations. Humans use the desert for off-road exploration, casual shooting and target practice, personal or commercial collection of animals and plants, searches and digging for minerals and gems, geocaching (GPS guided stash hunts), and even the production of illegal drugs. Desert tortoise shells found in the Mojave Desert with bullet holes were examined forensically with the finding that the tortoises were alive when they were shot (Berry 1986), suggesting that illegal shooting of tortoises could occur. Project personnel could illegally collect tortoises for pets or bring dogs to the project area. Measures proposed by LCWD and BLM to 1) clear project areas of tortoises, 2) prohibit pets from the project area, 3) impose a speed limit, and (4) close unnecessary roads following construction and control public access, should minimize the potential effects to the tortoise described above.

2. Effects to Critical Habitat for the Desert Tortoise (Mojave Population)

Direct impacts to desert tortoise critical habitat would be the permanent and temporary loss of areas that contain the PCEs of desert tortoise critical habitat. Approximately 18 acres will be permanently lost by the construction of well houses and well power substations, water storage tanks, access roads, ancillary pipeline facilities, and power poles. Approximately 155 acres will be temporarily lost by the construction of the pipelines, power lines, fiber optic line, temporary access roads, and temporary workspaces such as pipe and power line laydown areas, power line pulling sites, staging areas, and construction easements. Many of these activities that temporarily impact areas will involve blading and excavation of the area which would remove all of the PCEs of critical habitat. These areas will be recontoured and rehabilitated as described in the Revegetation Plan; however, it will likely take a long time before these areas can provide a sufficient quantity and quality of forage species (PCE 2) and sufficient vegetation to provide shelter from temperature extremes and predators (PCE 5). Other areas that have heavy machinery moving over them, will impact PCE 3 (suitable substrates for burrowing, nesting, and overwintering), PCE 4 (burrow, caliche caves, and other shelter sites), and PCE 5. These areas will also likely take a long time to recover and may also need some revegetation or soil de-compaction treatments. LCWD proposes to salvage topsoil during excavation and to reuse the topsoil later as cover on disturbed areas to facilitate re-growth of vegetation. As per the Revegetation Plan only native species will be used and cacti and yucca will be salvaged when possible.

Indirect impacts to the desert tortoise critical habitat may include fragmentation of the habitat surrounding the project area which will degrade PCE 1 (space to support viable populations and to provide for movement, dispersal, and gene flow). Since the project is linear, it has a greater potential to fragment habitat, although it does follow the existing Kane Springs Road. The project is in the LCCRDA corridor which is 0.5 miles wide. This project is the first to use this designated utility corridor so it may have greater impacts than future projects, although the proposed development on CSI lands in Lincoln County will be a greater barrier to tortoise movement.

Indirect impacts also include the introduction or spread of non-native plants in the project area and into the surrounding landscape which may impact PCE 2 and PCE 5. If red brome increases in the project area or surrounding landscape, this could increase the fuel load which increases the chance of large scale fires. Red brome can often out-compete native species because red brome extracts soil water and nutrients more rapidly than similar native annuals (DeFalco *et al.* 2003) and also reduces the growth of mature native perennials (DeFalco *et al.* 2007b). The project could also introduce new non-native plants into the area which could impact PCE 2 and PCE 5 in the future. LCWD and BLM should help reduce these potential effects to critical habitat by the implementation of a Noxious Weed Management Plan and the implementation of a Fire Management Plan. The Noxious Weed Management Plan includes the following measures: survey of area prior to land clearing, cleaning of vehicles and equipments, treating weed infestations, post-construction monitoring and employee education.

Project activities could also increase soil erosion. Increased soil erosion could negatively impact PCE 2, PCE 4, and PCE 5. LCWD and BLM should help reduce these potential effects to critical habitat by the implementation of a Stormwater and Pollution Prevention Plan.

3. Effects to the Moapa Dace

The Moapa dace will not be directly affected by the physical construction of the proposed groundwater wells, pipelines, and power facilities; however, groundwater pumping will likely indirectly affect the headwater spring discharges of the Muddy River, and therefore, the Moapa dace. The magnitude and timing of impacts from pumping in Kane Springs Valley are uncertain. Differences in boundary conditions relating to the areal extent of the aquifer, location of the pumping, transmissivity, and permeability, all influence the magnitude and timing of pumping impacts. Also, if the proposed pumping lowers carbonate water levels in the Warm Springs Area further, not all springs will be affected equally. The decrease in spring discharge will be proportional to the decrease in head elevation at each spring. Higher elevation springs have a lower head difference initially and are therefore more susceptible to decreases in groundwater levels. Therefore, the higher elevation springs will be affected proportionately more for a given decline in groundwater levels. The highest elevation springs occur on the Pedersen Unit of the Moapa Valley NWR, an area which also comprises some of the most important spawning habitat for Moapa dace in the system.

As discussed in the programmatic biological opinion for the Muddy River MOA (Service 2006c), existing data suggests that current groundwater pumping of the Arrow Canyon Well is causing a decline in the regional carbonate aquifer levels locally and in the Coyote Spring Valley, and a decrease in spring discharge in the Warm Springs Area (Mayer 2004). The average pumping rate at the Arrow Canyon Well since 1998 has been 3.3 cfs or 2,400 afy. Pumping rates will increase with commencement of the pump test, and may further increase pending the outcome of the pump test and associated monitoring. The proposed action includes pumping of an additional 1,000 afy from the same regional carbonate aquifer. The pumping will be located along the same flow path that supplies the Warm Springs Area and is within the low-gradient, high-transmissivity zone that connects Kane Springs Valley, Coyote Spring Valley and the Warm Springs Area.

Under the terms of the stipulated agreement, if the Average Flow Level reaches 3.15 cfs or less but greater than 3.0 cfs at the Warm Springs West gage, LWCD and VWC agree to reduce pumping from all wells in Kane Springs Valley by 50 percent. This would mean pumping at these flow levels would be reduced to 500 afy. If the Average Flow Level reaches 3.0 cfs or less, LWCD and VWC agree to cease pumping from all wells in Kane Springs Valley until the Average Flow Level exceeds 3.0 cfs. The exact magnitude and timing of the impacts from pumping groundwater from the carbonate aquifer in Kane Springs Valley are unknown at this time, as are the effects of reduced or cessation of groundwater pumping or whether there will be some equilibration of the aquifer to the proposed pumping.

In the programmatic biological opinion for the MOA, the Service (2006c) used the potential effects on spring discharge at the Warm Springs West gage to predict potential effects to Moapa dace habitat. The results indicated that both spring discharge and dace habitat are reduced with declines in groundwater levels. Flows and habitat loss were projected as a function of incremental declines in groundwater levels (Service 2006c). If flows were reduced to 3.02 cfs at the Warm Springs West gage this would be a 25 percent reduction of flows from the 1998 conditions which would reduce riffle habitat by 17 percent and pool habitat by 13 percent in the Petersen Unit. Because pumping for the Kane Springs project will occur concurrently with the potential pumping of 16,100 afy in the carbonate aquifer of White River Flow System, only a very small amount of this possible reduction would be attributable to pumping in Kane Springs Valley. Given the amount of 1,000 afy authorized by the State Engineer, effects from this project will be difficult to tease apart from effects of pumping 16,100 afy as described in the programmatic biological opinion for the MOA. However, monitoring of the Kane Springs wells concurrent with other monitoring under the MOA will lend greater understanding to the overall effects.

The primary effect to the Moapa dace of diminished flows within the spring channels will be a decrease in the hydraulic conditions that create the diversity of habitat. A decrease in velocity and depth within riffles would result in a decrease of invertebrate and phytoplankton (food) production. Drift stations in pools are maintained by the scouring effect of turbulent flow. Scour will decrease in pools as water velocity and depth at the upstream end of the pool decreases. Perhaps the most prominent impact that would occur, as a result of decreased discharge and subsequent depth, is the reduction of overall volume of water that will be available to the species within the channel. Scoppettone *et al.* (1992) demonstrated that Moapa dace size is scaled to water volume. Thus, larger water volumes provide the habitat necessary for increased food production and subsequently larger fish, therefore greater fecundity. Hence, more numerous, larger eggs provide a better opportunity for the long-term survival of the species.

Additional factors that would influence channel and hydraulic characteristics within the stream channels following a decline in spring discharge include, but are not limited to, changes in sediment transportation rates, and the alteration of riffle and pool maintenance that is accomplished at the present rate of discharge in each spring channel. Additionally, vegetative encroachment and subsequent channel obstruction may also occur as the wetted cross sectional area of the channel decreases, and new surfaces become exposed for vegetation growth. Decreases in these parameters will likely have an adverse impact on the overall diversity and quantity of hydraulic habitat.

The Pedersen Unit of the Moapa Valley NWR is one of the six spring complexes that the Moapa dace depends on for successful reproduction. It includes the highest elevation spring, presumed most susceptible to groundwater level declines. The analysis presented in the programmatic biological opinion for the MOA (Service 2006c) estimated that at 3.02 cfs, there is a 25 percent loss in flow on the Pedersen Unit from 1998 conditions. This loss is estimated to reduce available riffle habitat by 17 percent and pool habitat by 13 percent within the Pedersen Unit. In addition to the loss of habitat, decreased flows would also result in a loss of temperature that would extend downstream, thereby reducing the thermal load in the system and thus the amount of available habitat at the appropriate spawning temperature. The additional 1,000 afy of groundwater pumping under the Kane Springs Groundwater Development Project would potentially increase overall habitat loss and temperature declines, however, trigger levels identified in the Monitoring, Management and Mitigation Plan (starting at 3.2 cfs or less) are a higher threshold than those established under the MOA. Accordingly, adverse effects on Moapa dace habitat should be prevented.

Conservation Measures Identified to Minimize Effects of the Proposed Action

Guaranteed Groundwater Pumping Reductions (Trigger ranges): LCWD and VWC have agreed to reduce groundwater pumping by half in the Kane Springs Valley should stream flows reach 3.15 cfs or less but greater than 3.0 cfs at the Warm Springs West gage. The groundwater pumping will be stopped in the Kane Springs Valley should stream flows reach 3.0 cfs or less at the Warm Springs West gage. This conservation measure will result in a reduction in the rate of decline of water levels and spring discharge. Further reduction in the rate of decline will depend on the effect of remaining groundwater pumping by other parties in the Coyote Spring Valley, California Wash, and the Warm Springs Area.

Restore Moapa Dace Habitat Outside of the Moapa Valley NWR Boundary: LCWD and VWC agreed to provide funds annually for five years to be used for habitat restoration outside of the Moapa Valley NWR boundary to promote recovery of the Moapa dace. This funding will be applied towards various on-going or proposed activities that would improve and secure habitat that is currently not being utilized due to degraded conditions (i.e. illegal diversions or non-native species presence). The funding will provide a mechanism to restore habitat to a level that would provide a higher quality of habitat for the species. These habitat improvements would contribute to the long-term survival of the species by increasing the food production potential, providing additional habitat types that would be available for the various life stages and providing an environment that is devoid of predatory non-native fishes.

F. Cumulative Effects

Cumulative effects are those effects of future non-Federal (State, local government, or private) activities that are reasonably certain to occur in the action area considered in this biological opinion. Future Federal actions that are unrelated to the proposed action are not considered in this section because they require separate consultation pursuant to section 7 of the Act.

1. Desert Tortoise (Mojave Population)

The action area is on both Federal and private lands. The Service determined that future actions in the action area would likely require section 7 consultation or fall under purview of an HCP (section 10 of the Act). Thus, no future non-Federal activities are reasonably certain to occur in the action area; thus, there are no cumulative effects to the desert tortoise as a result of the proposed action. Private lands in the action area include CSI property. These activities are proposed to be covered under the Coyote Springs Investment MSHCP and associated incidental take permit, which are currently under development.

2. Critical Habitat for the Desert Tortoise (Mojave Population)

The Mormon Mesa Critical Habitat unit occurs mostly on Federal lands with CSI private land along US 93 and private property along Meadow Valley Wash. The Service determined that future actions in the action area would likely require section 7 consultation or fall under purview of an HCP (section 10 of the Act). No future non-Federal activities are reasonably certain to occur in the action area; thus, there are no cumulative effects to designated critical habitat as a result of the proposed action. Activities on CSI lands in Clark County are covered under the approved Clark County MSHCP and associated incidental take permit, and the activities in Lincoln County are proposed to be covered under the CSI MSHCP and associated incidental take permit, which are currently under development. The Southeastern Lincoln County Habitat Conservation Plan and associated incidental take permit, which are currently under development, will cover activities on private land along Meadow Valley Wash.

3. Moapa Dace

Future demand for groundwater will continue to threaten spring flows and surface water important for aquatic species such as the Moapa dace. In the Warm Springs Area, MVWD's existing permit would allow more groundwater to be pumped from the Arrow Canyon Well in the future. The maximum permitted pumping rate at the Arrow Canyon Well is 7,200 afy, as compared with the annual average of 2,400 afy pumped currently. Depending on the outcome of the pump study mandated in the State Engineer Order 1169 and subsequent ruling by the State Engineer, additional groundwater could potentially be pumped in Coyote Spring Valley. The maximum volume that could be removed from the Coyote Spring Valley and Muddy River Springs Area basins under existing permits is 31,100 afy. This represents more than a tenfold increase from current withdrawals in the system. In addition to the existing permitted water rights, there are pending applications for a far greater volume of groundwater above and beyond the permitted amount in the Coyote Spring Valley, Muddy River Springs Area, and Kane Springs Valley hydrographic basins.

G. Conclusion

1. Desert Tortoise (Mojave Population)

After reviewing the current status of the desert tortoise, the environmental baseline for the action area, the effects of the proposed project, and the cumulative effects, it is the Service's biological opinion that the project, as proposed and analyzed, is not likely to jeopardize the continued existence of the threatened desert tortoise (Mojave population). This conclusion for the desert tortoise is based on the following:

a. The proposed project will not result in a level of take of desert tortoise that would significantly affect the rangewide number, distribution, or reproduction of the species; tortoises that are taken as a result of the project are anticipated to remain in the wild with no long-term effects except for two desert tortoise estimated to be killed or injured by project activities.

b. The desert tortoise densities in the project area are considered low and measures have been proposed by LCWD and BLM to minimize the effects of the proposed action on the desert tortoise.

2. Critical Habitat for Desert Tortoise (Mojave Population)

The Service has reviewed the current rangewide status of designated critical habitat for the desert tortoise (Mojave population), the environmental baseline, the effects of the project, and the cumulative effects. Based on this review, it is the Service's biological opinion that these actions are not likely to destroy or adversely modify designated critical habitat for the desert tortoise (Mojave population). The project actions will not diminish the capability of the area to serve its role for recovery by continuing to provide the PCEs of critical habitat. The basis for this conclusion is summarized as follows:

a. The amount of critical habitat permanently and temporarily disturbed by the project is 173 acres, approximately 0.05 percent of the Mormon Mesa CHU.

b. Measures have been proposed by LCWD and BLM to minimize the effects of the proposed action on critical habitat for the desert tortoise.

3. Moapa Dace

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.

INCIDENTAL TAKE STATEMENT

Section 9 of the Act, as amended, prohibits take (harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct) of listed species of fish or wildlife without a special exemption. "Harm" is further defined to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing behavioral patterns such as breeding, feeding, or sheltering (50 CFR § 17.3). "Harass" is defined as actions that create the likelihood of injury to listed species to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR § 17.3). Incidental take is any take of listed animal species that results from, but is not the purpose of, carrying out an otherwise lawful activity conducted by the

Federal agency or applicant. Under the terms of sections 7(b)(4) and 7(o)(2) of the Act, taking that is incidental to and not intended as part of the agency action is not considered a prohibited taking provided that such taking is in compliance with the terms and conditions of this incidental take statement.

The terms and conditions may include: (1) restating measures proposed by BLM; (2) modifying the measures proposed by BLM; or (3) specifying additional measures considered necessary by the Service. Where these terms and conditions vary from or contradict the minimization measures proposed under the Description of the Proposed Action, specifications in these terms and conditions shall apply. The measures described below are nondiscretionary and must be implemented by BLM so that they become binding conditions of any project, contract, grant, or permit issued by BLM or other jurisdictional Federal agencies as appropriate, in order for the exemption in section 7(o)(2) to apply. The Service's evaluation of the effects of the proposed actions includes consideration of the measures developed by BLM, and repeated in the section entitled "Description of the Proposed Action" of this biological opinion, to minimize the adverse effects of the proposed action on the desert tortoise. Any subsequent changes in the minimization measures proposed by BLM may constitute a modification of the proposed action and may warrant reinitiation of formal consultation, as specified at 50 CFR § 402.16. These reasonable and prudent measures are intended to clarify or supplement the protective measures that were proposed by BLM as part of the proposed action.

BLM, or other jurisdictional Federal agencies as appropriate, have a continuing duty to regulate the activity that is covered by this incidental take statement. If BLM, or other jurisdictional Federal agencies as appropriate, fail to adhere to the terms and conditions of the incidental take statement through enforceable terms that are added to permits or grant documents, and/or fails to retain oversight to ensure compliance with these terms and conditions, the protective coverage of section 7(o)(2) may lapse.

A. Amount of Take

Desert Tortoise (Mojave Population)

Based on the analysis of effects provided above, measures proposed by BLM, and anticipated project duration the Service anticipates that the following take could occur as a result of the proposed action:

1. No more than two adults and an unknown number of hatchling and juvenile desert tortoises would be incidentally killed or injured as a result of the proposed project. Should any desert tortoise be killed or injured in association with the proposed action, all activity in the vicinity of the incident shall cease and the project proponent shall contact the Service within 24 hours to assess the circumstances and discuss if additional protective measures are necessary.

2. All desert tortoises located during clearance surveys or located in harm's way in work areas may be harassed by capture and removal from the project area. Based on survey data, timing of the proposed project, and description of the project area, the Service estimates that no more than 33 desert tortoises may be taken (other than killed or injured) by non-lethal means as a result of project activities.

3. An unknown number of desert tortoise nests with eggs may be excavated and relocated. The Service determined that no desert tortoise nests with eggs are anticipated to be destroyed as a result of project activities.

4. An unknown number of desert tortoises may be preyed upon by ravens or other subsidized desert tortoise predators drawn to trash in the project area; however, the Service estimates that the potential increase in ravens will be minimized by litter-control measures proposed by BLM.

Moapa Dace

The Service anticipates that incidental take of Moapa dace through harm (i.e., habitat modification or degradation that results in death or injury) will occur, but the actual death or injury of fish will be difficult to detect for the following reasons: the species has a small body size and finding a dead or impaired specimen is unlikely in a flowing stream environment. On the other hand, significant habitat modification or degradation that could result in take of Moapa dace will be detectable and measurable. Therefore, we are expressing take of Moapa dace in terms of habitat loss resulting from changes in habitat characteristics, such as water temperature or chemistry and water flows. Although the extent of effects to the species as a result of the proposed action is not yet known, future and on-going biological and hydrological studies will assist us in determining how flow reductions and thermal load losses will affect Moapa dace habitat, food availability, reproduction, and fecundity.

Perhaps the most significant impact to Moapa dace habitat that could result from implementation of the proposed action, as a result of decreased discharge and subsequent wetted area, is the reduction of overall volume of water that would be available to the species within the channel. The amount of groundwater pumping permitted under the Kane Springs Groundwater Development Project (1,000 afy) is substantially smaller than the amount of pumping that could potentially co-occur under Order 1169 (16,100 afy). A small but unquantifiable amount of take in the form of habitat loss would occur in the Pedersen Unit if flows reached 3.0 cfs at the Warm Spring West gage. Should flows at the Warm Springs West gage decline below 3.0 cfs, the amount of incidental take for this project would be exceeded for the Moapa dace.

B. Effect of Take

In the accompanying biological opinion, the Service determined that this level of anticipated take is not likely to result in jeopardy to the desert tortoise or Moapa dace. These determinations are based in part on the implementation of conservation easures detailed in the BA for this project.

C. Reasonable and Prudent Measures with Terms and Conditions

The Service believes that the following reasonable and prudent measures (RMPs) are necessary and appropriate to minimize take of desert tortoise or Moapa dace.

RPM 1: *BLM, LCWD, VWC, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of measures to minimize injury or mortality of desert tortoises due to surface-disturbing activities and operation of project vehicles or equipment:*

Terms and Conditions:

1.a. An authorized desert tortoise biologist shall be onsite at all locations where ground-disturbing activities are occurring within desert tortoise habitat. The authorized biologist will be responsible for approving, evaluating, and supervising monitors to assist in implementing the desert tortoise measures of this biological opinion. Potential biologists shall complete the Qualifications Form (Attachment A) and submit it to the Service for review and approval as appropriate. Allow 30 days for Service review and response.

1.b. Prior to initiation of construction, an authorized biologist or approved monitor shall present a desert tortoise awareness program to all personnel who will be onsite, including but not limited to contractors, contractors' employees, supervisors, inspectors, and subcontractors. This program will contain information concerning the biology and distribution of the desert tortoise and other sensitive species, their legal status and occurrence in the project area; the definition of "take" and associated penalties; the terms and conditions of this biological opinion; the means by which employees can help facilitate this process; responsibilities of workers, approved monitors, and biologists; and reporting procedures to be implemented in case of desert tortoise encounters or non-compliance with this biological opinion. The name of every individual trained will be recorded on a sign-in sheet. Each trained individual will be given evidence indicating they have received this training and will keep that evidence with them at all times when they are in the project area.

1.c. Immediately prior to surface-disturbing activities or traveling off of main access roads on the right-of-way, the authorized biologist shall survey for desert tortoises and their burrows using techniques providing 100-percent coverage of the right-of-way and an additional area approximately 90 feet from both sides of the right-of-way. Transects will be no greater than 30 feet apart. All potential desert tortoise burrows will be examined to determine occupancy of each burrow by desert tortoises and handled in accordance with Term and Condition 1.d. – 1.f and 2.a – 2.c. below.

1.d. All potential desert tortoise burrows located within the project area that are at risk for damage shall be excavated by hand by an authorized biologist, tortoises removed, and burrows collapsed or blocked to prevent occupation by desert tortoises.

1.e. Desert tortoises located in the project area, but outside of an area to be disturbed by ground disturbing activities, sheltering in a burrow during a period of reduced activity (*e.g.*, winter), may be temporarily penned. Tortoises shall not be penned in areas of moderate or heavy public use. Penning shall be accomplished by installing a circular fence, approximately 20 feet in diameter to enclose the tortoise/burrow. The pen should be constructed with durable materials (*i.e.*, 16 gauge or heavier) suitable to resist desert environments. Fence material should consist of ½-inch hardware cloth or 1-inch horizontal by 2-inch vertical, galvanized welded wire. Pen material should be 24 inches in width. Steel T-posts or rebar (3 to 4 feet) should be placed every 5 to 6 feet to support the pen material. The pen material should extend 18 to 24 inches aboveground. The bottom of the enclosure will be buried several inches; soil mounded along the base; and other measures should be taken to ensure zero ground clearance. Care shall be taken to minimize visibility of the pen by the public. An authorized biologist, approved monitor, or designated worker shall check the pen daily.

1.f. Desert tortoises and eggs found within construction sites shall be removed by an authorized biologist in accordance with the most current protocols identified by BLM and the Service. Desert tortoises will be moved solely for the purpose of moving them out of harm's way. Desert tortoises shall be relocated up to 1,500 feet into adjacent undisturbed habitat on protected public land in accordance with Service-approved handling protocol (Desert Tortoise Council 1994, revised 1999). The disposition of all tortoises handled shall be documented in accordance with 6.b. below.

1.g. All fuel, transmission or brake fluid leaks, or other hazardous materials shall not be drained onto the ground or into streams or drainage areas. All petroleum products and other potentially hazardous materials shall be removed to a disposal facility authorized to accept such materials. Waste leaks, spills or releases shall be reported immediately to BLM. BLM or the project proponent shall be responsible for spill material removal and disposal to an approved off-site landfill.

Servicing of construction equipment will take place only at a designated area. All fuel or hazardous waste leaks, spills, or releases will be stopped or repaired immediately and cleaned up at the time of occurrence. Service and maintenance vehicles will carry a bucket and pads to absorb leaks or spills.

1.h. Vehicles shall not exceed 25 mph on access roads. Authorized desert tortoise biologists and/or approved monitors will ensure compliance with speed limits during construction.

1.i. Project personnel shall exercise caution when commuting to the project area and obey speed limits to minimize any chance for the inadvertent injury or mortality of species encountered on roads leading to and from the project site. All desert tortoise observations, including mortalities, shall be reported directly to an authorized biologist and the Service.

1.j. Any vehicle or equipment on the right-of-way within desert tortoise habitat shall be checked underneath for tortoises before moving. This includes all construction equipment and the area under vehicles should be checked any time a vehicle is left unattended, as well as in the morning before any construction activity begins. If a desert tortoise is observed, an authorized biologist will be contacted.

1.k. Project activity areas shall be clearly marked or flagged at the outer boundaries before the onset of construction. All activities shall be confined to designated areas. The authorized biologist and approved monitors shall ensure that no habitat is disturbed outside designated areas as a result of the project, including ensuring that all vehicles and equipment remain on the right-of-way or areas devoid of native vegetation.

1.l. To prevent mortality, injury, and harassment of desert tortoises and damage to their burrows and coversites, no pets shall be permitted in any project construction area.

1.m. All desert tortoises observed within the project area or access road shall be reported immediately to the authorized biologist. The authorized biologist shall halt activities as necessary to avoid harm to a desert tortoise. Project activities that may endanger a desert tortoise shall cease until the desert tortoise moves out of harm's way or is moved out of harm's way by an authorized biologist.

1.n. Only water or an alternative substance approved by BLM shall be used as a dust suppressant. Water application shall avoid pooling of water on roadways. Pools of water may act as an attractant to desert tortoises.

1.o. In the event that blasting is required, a 200-foot-radius area around the blasting site shall be surveyed by an authorized biologist for desert tortoises prior to blasting, using 100-percent-coverage survey techniques. All tortoises located above ground or in pallets within this 200-foot radius of the blasting site shall be moved 500 feet from the blasting site. Additionally, tortoises in burrows within 75 feet of the blasting will be placed into an artificial or unoccupied burrow 500 feet from the blasting site. This will prevent tortoises that leave their burrow upon translocation from returning to the blasting site. Tortoises in burrows at a distance of 75 to 200 feet from the blasting site will be left in their burrows. Burrow locations will be flagged and recorded using a GPS unit and burrows would be stuffed with newspapers. Immediately after blasting, newspaper and flagging will be removed. Blasting would only occur in the brief time period after an area has been cleared by an authorized biologist, but before any relocated tortoises could return to the site.

1.p. If possible, overnight parking and storage of equipment and materials shall be located in previously-disturbed areas or areas to be disturbed that have been cleared by an authorized tortoise biologist. If not possible, areas for overnight parking and storage of equipment shall be designated by the authorized biologist.

1.q. Within desert tortoise habitat, any construction pipe, culvert, or similar structure with a diameter greater than 3 inches stored less than 8 inches above ground on the construction site for one or more nights shall be inspected for tortoises before the material is moved, buried, or capped. As an alternative, all such structures may be capped before being stored on the construction site.

1.r. Flagging and wire shall be removed from the project area at the end of project to ensure debris is not consumed by desert tortoises.

1.s. All project activities in desert tortoise habitat shall be conducted from dawn until dusk.

1.t. Any excavated holes left open overnight shall be covered, and/or tortoise-proof fencing (Attachment B) shall be installed to prevent the possibility of tortoises falling into the open holes.

1.u. Open pipeline trenches shall be fenced with temporary tortoise-proof fencing or inspected by an authorized biologist or approved monitor periodically throughout and at the end of the day, and immediately prior to backfilling, and tortoise escape ramps (of at least 3:1 slope) shall be installed at least every quarter mile. Any tortoise that is found in a trench or excavation shall be promptly removed by an authorized biologist in accordance with Service-approved protocol or alternative method approved by the Service if the biologist is not allowed to enter the trench for safety reasons.

1.v. In areas to be encircled by a security fence, such as well yards and well substations, the fence shall be installed at least one foot below the surface of the ground or install permanent desert tortoise fencing around the area, to ensure that tortoises do not get trapped inside. See Attachment B for the Service's recommendations on tortoise exclusion fencing, dated September 2005. Fences should be checked during regular maintenance of the facilities to ensure zero ground clearance.

1.w. Any tortoise injured as a result of the proposed project shall immediately be transported to a qualified veterinarian and reported to the Service's Nevada Fish and Wildlife Office in Las Vegas at (702) 515-5230.

RPM 2: *BLM, LCWD, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of the following measures to ensure that tortoises are not injured as a result of capture and handling:*

Terms and Conditions:

2.a. All appropriate NDOW permits or letters of authorization shall be acquired prior to handling desert tortoises and their parts, and prior to initiation of any activity that may require handling tortoises.

2.b. Tortoises and nests shall be handled and relocated by an authorized tortoise biologist in accordance with the Service-approved protocol (Desert Tortoise Council 1994, revised 1999). If the Service or Desert Tortoise Council releases a revised protocol for handling of desert tortoises before initiation of project activities, the revised protocol shall be implemented for the project area. A pair of new, disposable latex gloves shall be used for each tortoise that must be handled. After use, the gloves will be properly disposed. Burrows containing tortoises or nests shall be excavated by hand, with hand tools, to allow removal of the tortoise or eggs. Desert tortoises moved during the tortoises less active season or those in hibernation, regardless of date, must be placed into an adequate burrow; if one is not available, one shall be constructed in accordance with Desert Tortoise Council (1994, revised 1999) criteria. Desert tortoises that are located aboveground and need to be moved from the project area shall be placed in the shade of a shrub. All desert tortoises removed from burrows shall be placed in an unoccupied burrow of approximately the same size and orientation as the one from which it was removed.

2.c. Special precautions shall be taken to ensure that desert tortoises are not harmed as a result of their capture and movement during extreme temperatures (i.e., air temperatures below 55° F or above 95° F). Under such adverse conditions, tortoises captured will be monitored continually by an authorized biologist or approved monitor until the tortoise exhibits normal behavior. If a desert tortoise shows signs of heat stress, procedures will be implemented as identified in the Service-approved protocol (Desert Tortoise Council 1994, revised 1999). The disposition of all tortoises handled shall be documented in accordance with 6.b. below.

RPM 3: *BLM, LCWD, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of the following measures to minimize predation on desert tortoises by predators drawn to the project area:*

Terms and Conditions:

Trash and food items shall be disposed properly in predator-proof containers with resealing lids. During construction activities, trash containers will be emptied and waste will be removed from the project area daily. Trash removal reduces the attractiveness of the area to opportunistic predators such as desert kit fox, coyotes, and common ravens.

RPM 4: *BLM, LCWD, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of the following measures to minimize loss and long-term degradation and fragmentation of desert tortoise habitat, such as soil compaction, erosion, crushed vegetation, and introduction of weeds or contaminants as a result of construction activities:*

Terms and Conditions:

4.a Off-road travel outside construction zones shall be prohibited.

4.b. The designated utilities shall follow the Noxious Weed Management Plan which includes the following: washing vehicles and equipment prior to mobilizing to the project area, providing onsite personnel with BLM weed identification information, reseeding the project area with a BLM-approved certified weed-free seed mix, and controlling noxious weeds should they be introduced as a result of the proposed action.

4.c. After completion of the project, the designated utilities shall follow the Revegetation Plan to restore all temporarily-disturbed areas to functioning desert tortoise habitat, using native seeds or plants.

4.d. BLM shall ensure payment of remuneration fees by the project proponents, the designated utilities, for compensation of the loss of desert tortoise habitat as a result of the proposed project. BLM shall require a receipt of payment from each designated utility prior to issuing the Notice to Proceed.

The right-of-way applicant is required to submit a Final Plan of Development to the BLM, which must be approved by BLM prior to issuance of the Notice to Proceed. It is likely that the amount of disturbance will change with the final engineering design; therefore, BLM will reevaluate the project disturbance and adjust the total compensation fee accordingly. A copy of the Final Plan of Development and a breakdown of the final compensation fee will be provided to the Service. The applicant will be made aware that, depending on final engineering designs, the final compensation fee may be lower than the estimated value provided in this document.

Currently, the basic compensation rate for disturbance to desert tortoise habitat is $753 per acre. For disturbance to desert tortoise critical habitat a multiplier is used to increase the cost per acre as described in Hastey *et al.* (1991). For each project, this multiplier for critical habitat is based on assignment of ratings to the following five factors:

- Category of Habitat (value of the land to tortoise populations)
- Term of Effect (short term vs. long term)
- Existing Disturbance on Site
- Growth Inducement (growth inducing effects of the proposed action)
- Effect of Adjacent Lands (whether adjacent lands will be affected)

The proposed project will disturb 209 acres of desert tortoise habitat on lands in Lincoln County. The total compensation fee for this project is $808,722. Attachment C shows a breakdown of these calculations. Fees for disturbances on Federal land will be deposited into the Lincoln County Section 7 Account, while fees for disturbance on private land will be deposited into the CSI MSHCP Section 10 Trust Fund. The payee will fill out the attached fee payment forms (Attachment D) and include these with the payments.

Each year these fees will be indexed for inflation based on the Bureau of Labor Statistics Consumer Price Index for All Urban Consumers (CPI-U). Information on the CPI-U can be found on the internet at: http://stats.bls.gov/news.release/cpi.nr0.htm. The next rate adjustment will occur on March 1, 2009.

Fees deposited in the Lincoln County Section 7 account will be managed consist with an MOA to be developed between BLM and the Service. The development of a MOA will be initiated within 30 days of the ROD.

Section 7 fees collected under this biological opinion may be used in coordination with the mitigation program of the CSI MSHCP, to implement conservation and recovery measures within the Mormon Mesa critical habitat unit.

RPM 5: *BLM, LCWD, VWC, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of the following measures to minimize impacts to Moapa dace that may result from groundwater pumping associated with the project in the Kane Springs Valley:*

Terms and Conditions:

BLM shall assure that all provisions of the proposed actions including the Monitoring, Management and Mitigation Plan of the Stipulated Agreement are fully implemented.

RPM 6: *BLM, LCWD, and other jurisdictional Federal agencies as appropriate, shall ensure implementation of the following measures to comply with the reasonable and prudent measures, terms and conditions, reporting requirements, and reinitiation requirements contained in this biological opinion:*

Terms and Conditions:

6.a. LCWD shall designate a field contact representative. The field representative will be responsible for overseeing compliance with protective stipulations for the desert tortoise and coordinating directly with BLM and the Service. The field contact representative shall have the authority to halt activities or construction equipment that may be in violation of the stipulations. A copy of the terms and conditions of this biological opinion shall be provided to the field contact representative, biologists, and monitors for the project.

6.b. The authorized biologist shall record each observation of desert tortoise handled. Information will include the following: location, date and time of observation; whether tortoise was handled, general health and whether it voided its bladder; location tortoise was moved from and location moved to; and unique physical characteristics of each tortoise. A final report will be submitted to the Service's Nevada Fish and Wildlife Office in Las Vegas within 90 days of completion of the project.

The reasonable and prudent measures, with their implementing terms and conditions, are designed to minimize the impact of incidental take that might otherwise result from the proposed action. If, during the course of the action, the level of incidental take or loss of habitat identified is exceeded, such incidental take and habitat loss represents new information requiring reinitiation of consultation and review of the reasonable and prudent measures provided. The designated utilities must immediately provide an explanation of the causes of the taking and review with the Service the need for possible modification of the reasonable and prudent measures.

D. Reporting Requirements

Upon locating a dead or injured endangered or threatened species within the action area, notification must be made to the Service's Nevada Fish and Wildlife Office in Las Vegas at (702) 515-5230. Care should be taken in handling sick or injured endangered or threatened species to ensure effective treatment and be taken for handling of dead specimens to preserve biological material in the best possible state for later analysis of cause of death. In conjunction with the care of injured endangered or threatened species or preservation of biological materials from a dead animal, the finder has the responsibility to carry out instructions provided by the Service to ensure that evidence intrinsic to the specimen is not unnecessarily disturbed. All deaths, injuries, and illnesses of endangered or threatened species, whether associated with project activities or not, will be summarized in an annual report.

Desert Tortoise (Mojave Population)

The following actions should be taken for injured or dead tortoises if directed by the Service:

1. Injured desert tortoises shall be delivered to any qualified veterinarian for appropriate treatment or disposal.

2. Dead desert tortoises suitable for preparation as museum specimens shall be frozen immediately and provided to an institution holding appropriate Federal and State permits per their instructions.

3. Should no institutions want the desert tortoise specimens, or if it is determined that they are too damaged (crushed, spoiled, etc.) for preparation as a museum specimen, then they may be buried away from the project area or cremated, upon authorization by the Service.

4. The designated utilities shall bear the cost of any required treatment of injured desert tortoises, euthanasia of sick desert tortoises, or cremation of dead desert tortoises.

5. Should sick or injured desert tortoises be treated by a veterinarian and survive, they may be transferred as directed by the Service.

Moapa Dace

The following action should be taken for injured or dead Moapa dace if directed by the Service: Dead Moapa dace suitable for preparation as museum specimens shall be frozen immediately and provided to the Service's Nevada Fish and Wildlife Office in Las Vegas.

CONSERVATION RECOMMENDATIONS

Section 7(a)(1) of the Act directs Federal agencies to use their authorities to further the purposes of the Act by carrying out conservation programs for the benefit of endangered and threatened species. Conservation recommendations are discretionary agency activities to minimize or avoid adverse effects of a proposed action on listed species or critical habitat, to help implement recovery plans, or to develop information. The Service provides no conservation recommendations at this time.

REINITIATION

This concludes formal consultation on the actions outlined in your requested dated September 27, 2007. As required by 50 CFR § 402.16, reinitiation of formal consultation is required where the discretionary Federal agency involvement or control over an action has been retained (or is authorized by law) and if: (1) the amount or extent of incidental take is exceeded; (2) new information reveals effects of the agency action that may affect listed species or critical habitat in a manner or to an extent not considered in this opinion; (3) the agency action is subsequently modified in a manner that causes an effect to the listed species or critical habitat that was not considered in this opinion; or (4) a new species is listed or critical habitat designated that may be affected by the action. In instances where the amount or extent of incidental take is exceeded, any operations causing such take must cease pending reinitiation. In particular, if the State Engineer grants additional water rights beyond the currently permitted 1,000 afy for the Kane Springs Groundwater Development Project, then formal consultation should be reinitiated.

The incidental take statement provided with this Biological Opinion authorizes take of the Moapa dace as may occur in connection with the pumping and transfer of 1,000 afy of groundwater under Phase I of the Project, and implementation of the Monitoring, Management, and Mitigation Plan established under the amended stipulated agreement for the Kane Springs Valley Hydrographic Basin. In June 2008, the LCWD, VWC, and the Service executed a Memorandum of Understanding to ensure additional consultation on this project should additional water rights be appropriated to LCWD and VWC in the Kane Springs Valley Hydrographic Basin (Attachment E). Specifically, the Memorandum requires that the Service reinitiate Section 7 consultation, and, if required, LCWD and VWC will apply for an incidental take permit under Section 10(a)(1)(B) of the Act to cover any take that may occur due to the pumping and transfer of such additional groundwater.

If we can be of further assistance regarding this consultation, please contact me at (775) 861-6300, or Janet Bair in the Nevada Fish and Wildlife Office in Las Vegas at (702) 515-5230.

Sincerely,

Robert D. Williams
Field Supervisor

Attachments

cc:
Lincoln County Treasurer, Pioche, Nevada
Supervisory Biologist - Habitat, Nevada Department of Wildlife, Las Vegas, Nevada
Field Manager, Caliente Field Office, Bureau of Land Management, Caliente, Nevada
Nevada Groundwater Projects Office, Nevada State Office, Bureau of Land Management, Reno, Nevada
T&E Species Coordinator, Nevada State Office, Bureau of Land Management, Reno, Nevada

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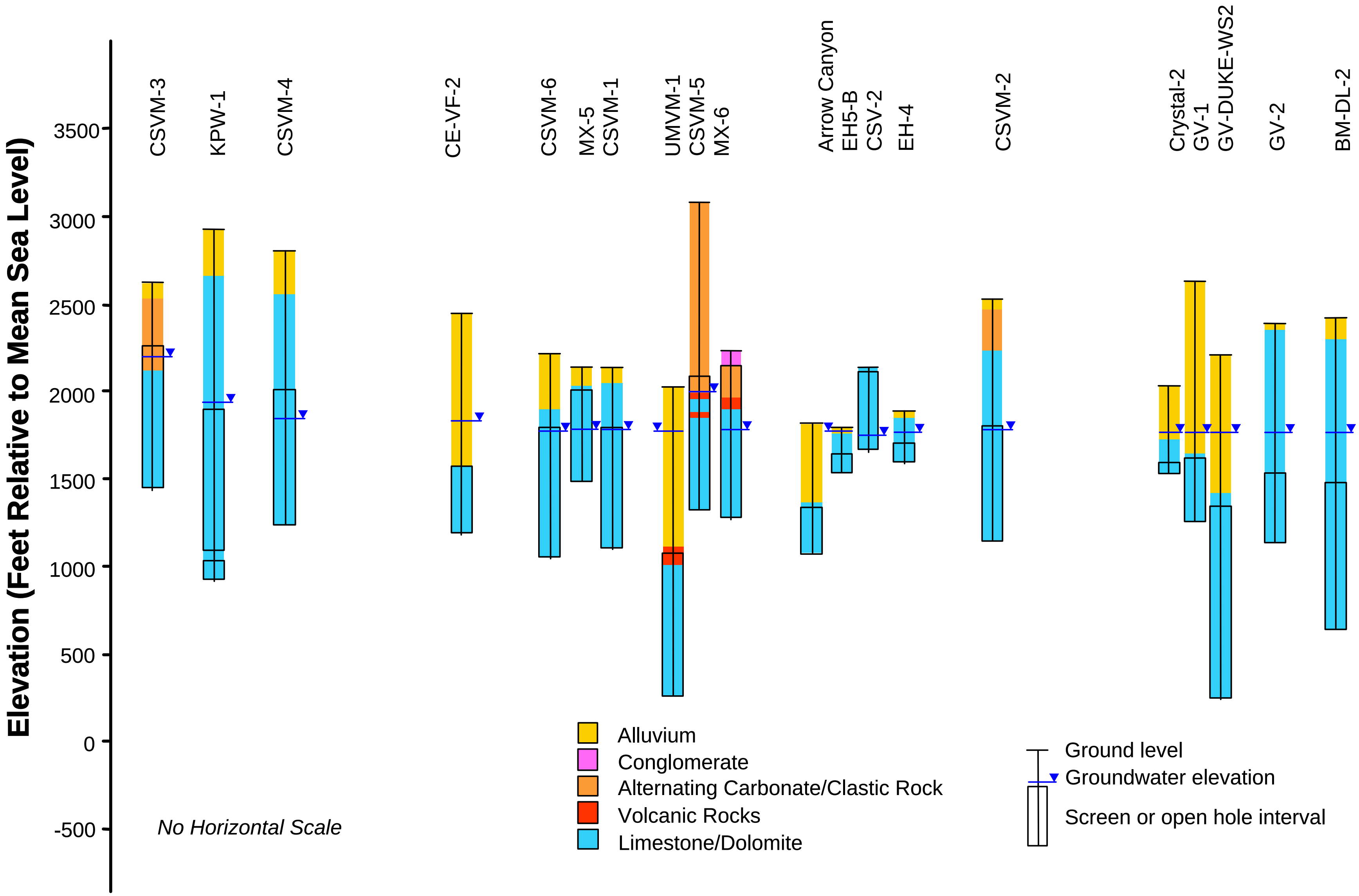
Attachment A-3

Vertical Profile through selected carbonate wells in study area, reproduced from CH2M Hill 2006a.

FIGURE 3-4. VERTICAL PROFILE THROUGH SELECTED CARBONATE WELLS IN STUDY AREA



Source : CH_2MHill (2006)

SE ROA 36436

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Attachment A-4

Localized Cross Section through KMW-1, Kane Springs Valley

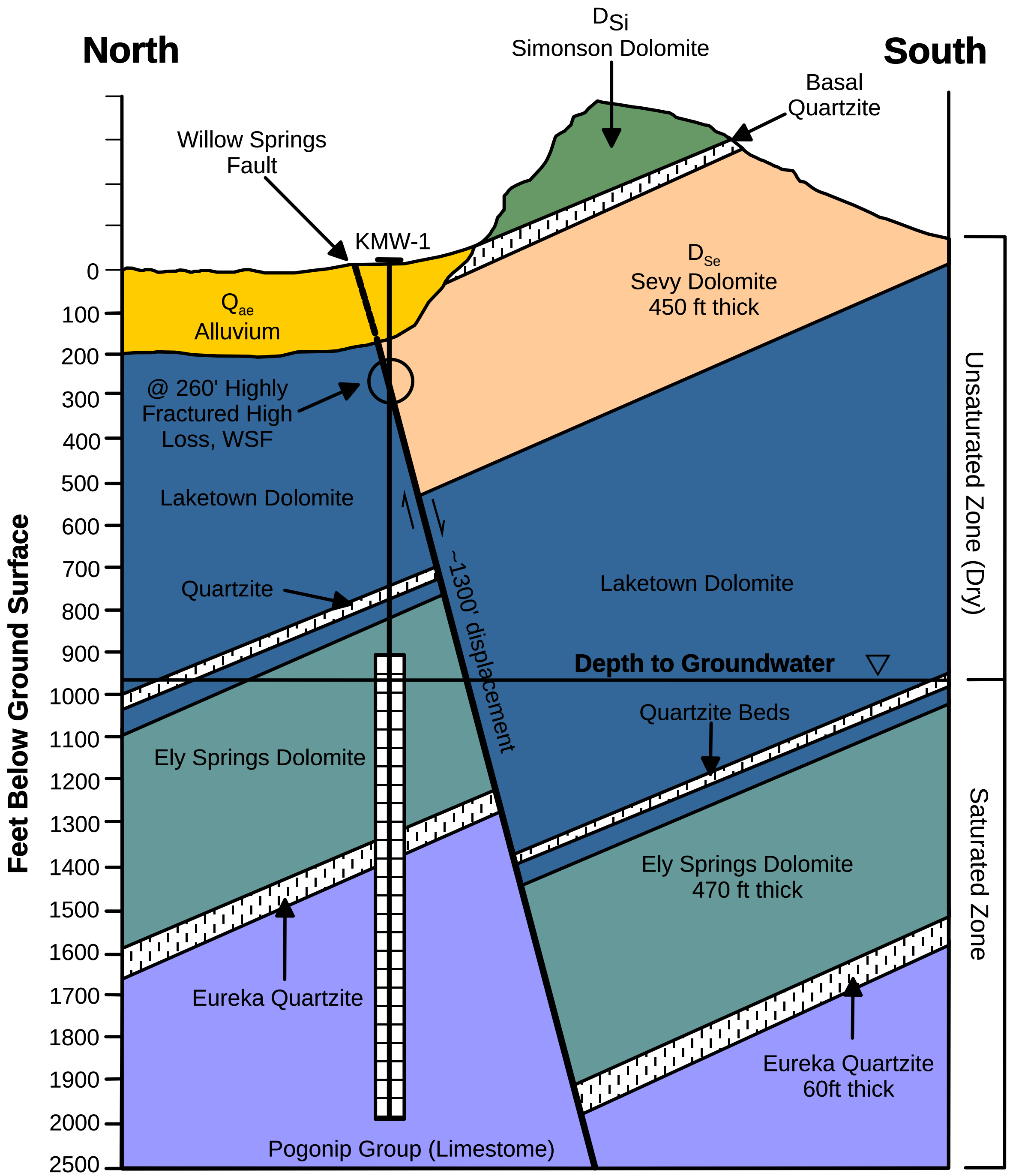

FIGURE 3-3 LOCALIZED CROSS SECTION THROUGH KMW-1, KANE SPRINGS VALLEY

Source: URS: Unpublished field notes taken during Drilling KMW-1 by Feast Geosciences

Attachment B

Lower White River Flow System Interim Order #1303 Rebuttal Report to the Nevada State Engineer

Prepared by

Peter Mock, Ph.D., R.G.

Peter Mock Groundwater Consulting, Inc.

Lower White River Flow System Interim Order #1303 Rebuttal Report to the Nevada State Engineer

Prepared by
Peter Mock, Ph.D., R.G.
Peter Mock Groundwater Consulting, Inc.

Prepared for:
Lincoln County Water District and Vidler Water Company

August 16, 2019

REGISTERED GEOLOGIST
CERTIFICATE
21614
PETER A.
MOCK
DATE SIGNED 8/16/19
ARIZONA U.S.A.
Expires: 9/30/2021

Executive Summary

Peter Mock Groundwater Consulting, Inc. respectfully submits to the Nevada State Engineer (NSE) rebuttal to selected portions of selected reports submitted July 3, 2019 to the NSE regarding Order 1303. The selection of reports and portions of reports for rebuttal here was typically based on noting new proposals to include the Kane Springs Valley (KSV) Hydrographic Area (HA) No. 206 in the proposed Lower White River Flow System (LWRFS) administrative unit. KSV HA was not included by the NSE in the LWRFS and accumulating evidence has consistently supported the NSE's findings in this regard. I conclude that the NSE should continue to maintain that the KSV HA is outside the LWRFS administrative unit due to distance and geologic structures in light of the goal of practically and efficiently protecting the springs and associated surface flows of the Muddy River Springs Area (MRSA) from depletion. My rebuttals will expand on my reasoning for this conclusion.

With respect to the Mifflin & Associates, Inc. Report of July 3, 2019 for the Moapa Band of Paiutes to the NSE, I primarily rebut the use of the results from a new groundwater flow simulation that does not explicitly incorporate the structural geology of the region to assert that pumping in KSV will have impacts in the MRSA in 10 years. I am also rebutting: 1) the use of the asserted correlations to distant river flows of previous decades to extend or filter real water well hydrographs, 2) the confusion of [particle] capture for hydraulic system capture (Theis 1940), 3) that drawdown impacts are transported solely within groundwater flow paths as if they were attached to water molecules, 4) that variable anisotropy in a slab of uniform thickness and transmissivity can be a valid substitute for explicitly incorporating the contacts between the Paleozoic carbonates and much less permeable structural blocks in this region, and 5) that the effective porosity of the Paleozoic carbonates is two orders of magnitude less than 0.1.

With respect to the two Interflow Hydrology, Inc. reports of July 2, 2019 for the City of North Las Vegas to the NSE, I rebut the use of a new groundwater model of the southern portion of the LWRFS for supporting the conclusion that groundwater enters the LWRFS from the Las Vegas Valley, as opposed to my opinion that groundwater flows out to the Las Vegas Valley. I am further rebutting the assertion that the total flow rate out to the Las Vegas Valley is of the magnitude of hundreds of acre-feet per year, as opposed to my opinion that it is thousands to tens of thousands of acre-feet per year.

With respect to the Tetra Tech Report of July 3, 2019 for the U.S. National Park Service to the NSE, I rebut the use of the Tetra Tech Model that includes the LWRFS, first reported on in 2012, for projecting regional impacts from pumping. The use of the HUF MODFLOW package averages away and thereby diminishes the structural controls of the regional geology. I infer from my understanding of this model that the projected drawdowns are too shallow and broad in extent because of the use of a hydraulic conductivity that decreases exponentially with depth for the Paleozoic carbonates and because of the use of Pilot Points in calibration of the model in such a way that localized areas of exceedingly high hydraulic conductivities are selected in the uppermost layer of the model.

With respect to the Report of Dr. Tom Myers, Hydrologic Consultant, of July 3, 2019 for the Center for Biodiversity to the NSE, I rebut the assertion that the variation in gradients at the boundary between KSV and CSV is a basis for the NSE to include KSV HA for the purpose of effectively protecting the springs and associated surface flows of the MRSA.

With respect to the Report by the U.S. Fish & Wildlife Service, no author given, on July 3, 2019 to the NSE, I rebut statements that parameters of the Theis Equation in the SeriesSEE model are meaningless followed by discussion of the results in terms of meaningful transmissivity and its variability, which itself is not allowed to vary in SeriesSEE. I further rebut assertions that the Tertiary Calderas of the region (higher elevations of which form the Delamar and Clover Mountains) are barriers to groundwater flow. Finally, I rebut a series of narrative (not calculated) projections of water level and groundwater flow responses to a variety of conditions given by the authors or authors of this report.

With respect to the Report by Andrew Burns, Warda Drici, Casey Collins, and James Watrus, Sr. for the Southern Nevada Water Authority and Las Vegas Valley Water District on June 27, 2019 to the NSE, I rebut the assertion that groundwater flows are negligible through the Tertiary Calderas of the region, specifically those in KSV.

Introduction

On July 3, 2019, several entities submitted reports to the Nevada State Engineer (NSE) regarding Interim Order #1303. Interim Order #1303 discusses management of multiple administrative hydrologic areas/basins as a single administrative unit for the express purpose of preserving the flows of springs and associated surface water flows in the Muddy River Springs Area (MRSA) Hydrographic Area (HA) No. 219, also known as Upper Moapa, and asked for the technical commentary that was later received on July 3, 2019.

This review comments on sections of a few reports that assert new perspectives on the regional flow of groundwater and the propagation of drawdowns in the regional aquifer in the Paleozoic carbonates of this region and/or that suggest or propose the addition of Kane Springs Valley (KSV) HA to what the NSE proposed for the administrative units of the Lower White River Flow System. Thus, not all reports or sections of the selected reports submitted in this matter on July 3, 2019 are reviewed here. I would also note that I have attempted to avoid rebutting repetitions of these statements in the selected reports as that would lead to a more voluminous rebuttal than I present here. My not rebutting a specific report or section of a selected report submitted to the NSE on or around July 3, 2019 should not be interpreted to mean that I agree with that specific report or report section that I have not rebutted here.

I earned Bachelor's and Doctoral degrees in Hydrology from the University of Arizona. My Ph.D. minor was in Applied Mathematics, focused on numerical analysis (i.e., the algorithms and programming instructions of simulation codes). I am recognized as a Geologist by the states of Arizona and California. I have visited and interpreted the geology and hydrology of this region and submitted reports to the NSE regarding Tule Desert and KSV and the potential impacts of groundwater development proposed by Lincoln County Water District and Vidler Water Company there. The groundwater flow model I developed for the Tule Desert work was reviewed by multiple local experts at the U.S. Geological Survey and was and remains unique in that the model layering explicitly incorporated the geology as published by the U.S. Geological Survey (Page and Others, 2005). I have also visited and interpreted the geology and hydrology of the Clover Valley and surrounding region for Lincoln County Water District and Vidler Water. I have been familiar with and have run the model developed by Tetra Tech (2012) for the U.S. National Park Service (USNPS) that includes this region and the model developed by Frank D'Agnese for the Southern Nevada Water Authority (SNWA) that includes a larger region.

The remainder of this report is organized by sections for each of five selected reports:

- Cady Johnson and Martin Mifflin of Mifflin & Associates for the Moapa Band of Paiutes,
- Dwight Smith and Alexa Terrell of Interflow Hydrology, Inc., for the City of North Las Vegas;
- Richard Waddell of Tetra Tech, Inc. for the USNPS,
- Tom Myers for the Center for Biodiversity, and
- Andrew Burns, Warda Drici, Casey Collins, and James Watrus, Sr. for the Southern Nevada Water Authority and Las Vegas Valley Water District

Following the considerations of these report sections, I provide my brief conclusions.

Selected Comments on: "Water-Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, Initial Report of Moapa Band of Paiutes in Response to Order #1303", prepared by Cady Johnson and Martin Mifflin (Mifflin & Associates, Inc.), dated July 3, 2019

This report was downloaded from the NSE website as an 84-page Acrobat-PDF file. I found many items to rebut in this report, so this rebuttal is organized into sub-sections to assist the reader.

Rebuttal Summary

I primarily rebut the use of the results from a new groundwater flow simulation that does not explicitly incorporate the structural geology of the region to assert that pumping in KSV will have impacts in the MRSA in 10 years. I am also rebutting: 1) the use of the asserted correlations to distant river flows of previous decades to extend or filter real water well hydrographs, 2) the confusion of [particle] capture for hydraulic system capture (Theis 1940), 3) that drawdown impacts are transported solely within groundwater flow paths as if they were attached to water molecules, 4) that variable anisotropy in a slab of uniform thickness and transmissivity can be a valid substitute for explicitly incorporating the contacts between the Paleozoic carbonates and much less permeable structural blocks in this region, and 5) that the effective porosity of the Paleozoic carbonates is two orders of magnitude less than 0.1.

Two Primary Points from the Executive Summary

The two key points of this report (MAI2019), as summarized from the Executive Summary are:

1. There are two primary [particle] capture zones in this region – one for the MRSA and one for the Las Vegas Valley – and they say that the NSE's rationale for selecting the LWRFS ignores this.

2. The regional declines in water levels are due to climatic factors and they say that there are two consequences of this: the response to the Order 1169 pumping was vastly over represented and there may be no point in conserving water resources as the surface flows and the life that depends on them are going to dry up anyway as the groundwater levels continue to respond to drought.

My responses to these two primary points are:

1. I agree that there are currently substantial flows of groundwater in this region that exit at the MRSA as well as out to the Las Vegas Valley. However, I disagree about what the current configuration of groundwater flow paths means for management of the LWRFS.

    a. Figure 1 of MAI2019 shows the "divide" they have defined between these two flow paths. I disagree that all of the flow from Meadow Valley Wash and all of the flow of north and central CSV or much of the flow of the uppermost part of Lower Moapa Valley has to exit at the MRSA springs and surface flows. These divides they say were derived from a new, FEFLOW-based model, which I will call MAI-FEFLOW-2019 here and which should not be relied upon for delineation of flow paths as it does not explicitly incorporate the structural geology of the region.

b. The current flow paths of groundwater through this system can be viewed as "capture zones" as the authors of MAI2019 state, but that is meaningless with respect to **preserving** the **flows** of springs and associated surface flows in the MRSA. Hydrologists distinguish between "**particle capture**", i.e. identifying the particles of water in a groundwater system that actually emerge from a well (or spring) and **hydraulic system capture**, i.e., the specific hydraulic changes in adjustable boundary conditions propagated across a porous medium in response to an imposed stress, e.g., pumping wells. This apparently non-intuitive, but primary distinction with a tremendous difference has been taught persistently by the USGS and leaders in the hydrologic community trained in the USGS for 60 years (starting with Theis in 1940 and more recently by Leake (2011), Barlow and Leake (2012) and Konikow and Leake (2014) among many. In this case, one can pump from a well in a hydrographic basin that has groundwater currently headed to a subsurface basin outflow line and cause water levels and flows to decline at springs in another hydrographic basin where the groundwater is currently headed distinctly towards a group of springs. **One can reduce surface flows by pumping while not completely rearranging the groundwater flow paths.** [Particle] capture zones became popular in the 1980s for designing remediation systems and rightly so: there the goal is explicitly to "capture" the actual "particles" of water with a contaminant dissolved in them and avoid collecting and treating the clean water outside of a plume of contaminated groundwater. Much to the profession's detriment, the term "capture" was thereby itself captured from the hydrogeologic lexicon where it had been used explicitly for system hydraulic capture. See Fetter (2001, [4th edition], page 436) for a classic exposition of the current and widely-applied concept of [particle] capture. Perhaps it helps to recognize that [particle] capture zone boundaries do not impose walls to advancing pressure or hydraulic head changes. The authors imply the opposite on Page 14: "... a rational and observable zero-flux boundary enclosing all ground-water flow paths to a regional discharge area". Also, contrary to the author's assertions of Page 14, unique chemistries do not uniquely define [particle] capture zones except in the most unusual and isolated of circumstances. That is, two different samples of groundwater can have the same chemistry and be from different flow paths, basins or even continents. A new pumping well will produce drawdowns that will quickly invade and pass through pre-existing [particle] capture zones that the authors imply are inviolable. Likewise, drawdowns will quickly pass through regions of unique water chemistry as long as the pore volumes are accessible to pressure or total hydraulic head changes. In fact, in porous media, propagating pressure or total hydraulic head changes (well impacts) do not run into and impede one another: they progress independently (except for the effects of changing aquifer thickness and hence the area for flow) and accumulate or **superimpose**, but they do not impede one another. This is primary, basic aquifer hydraulics, not of my development. On a more intuitive level, drawdowns proceed outward in all directions (radial flow) from a well irrespective of the groundwater flow direction until they encounter and cause changes in an adjustable boundary (e.g., lake, stream, transpiration through a patch of phreatophytes – see Theis (1940) for the primary presentation on this). Drawdowns, no matter where they travel from or what [particle] capture zones they enter, cross or leave, cause reductions to spring and stream flow in proportion to their magnitude.

   c. Particle capture zones are not the appropriate tool for assessing hydraulic impacts to springs or other surface flows. Therefore, the authors have made a reasonable observation that the regional groundwater flow system has two primary exits (though I disagree with the authors' delineation), but this recognition is not a basis for protecting the springs and associated surface flows of the MRSA. The NSE has been wise to ignore the current split in groundwater flowing to different exit locations from the LWRFS when deciding which HAs to include in the LWRFS. Distance and geologic barriers are the most germane to the NSE's selection of HAs to administer protection of the springs and other surface flows of the MRSA.

2. I agree that the region has been experiencing a decline in water levels since at least the winter of 2005 when precipitation in this area was approximately three times the historical average. I don't think we know unambiguously what was happening before or after in terms of decadal-long or longer trends in groundwater levels.

   a. The response of water levels in the wells available for measurement to the wet winter of 2005 is convincing: after that winter, the water levels rose and fell slowly and smoothly. Thus, the Order 1169 Test was run during the time of regional water level recession from this 2005 winter precipitation event, making the inference of the farthest extents of drawdowns due to the Order 1169 pumping questionable at best.

   b. On Page 29, the authors assert that the MODFLOW and SerieSEE (Theis Superposition) analysis by the DOI Bureaus of the Order 1169 Test data is erroneous because they did not recognize that the regionally-experienced water-level declines during the Test were not due to the Order 1169 Pumping. Trying to match a model of drawdowns propagating from a limited area outward to a larger area with essentially uniform declines will indeed be without physical basis, so I agree.

   c. The dedicated monitoring wells available for measurement largely came on line just before the winter 2005 event, so we have limited knowledge about the nature of the regional long-term trend for, say, decades before that.

   d. We also do not know if such an antecedent (to the 2005 event recession) decline, if it existed, will continue into the future.

e. Given this lack of local foundation for unambiguously declaring a persistent (multiple decades) regional decline in groundwater level, it is reasonable for the NSE to continue to work to preserve springs and associated surface water flows in the MRSA.

The MAI FEFLOW-2019 Model

Proceeding to the MAI2019 report as a whole, the authors pursue a novel and unique for this region technical analysis that was not in the end tied to the protection of the MRSA. Of particular novelty here is the application of the FEFLOW code to simulate coupled groundwater flow and heat flow in much of southeastern Nevada. This model is called by the authors different names in different places, e.g., "transmissivity" model or "scoping" model, both in lower case. The use of FEFLOW is novel in the arena of groundwater flow simulations developed to present to the NSE regarding water resources development. FEFLOW should simulate groundwater flow as well as, but practically no better than, any other widely-applied groundwater flow simulation code so the selection of FEFLOW itself is not of concern. It should not be considered superior for practical groundwater flow simulation to, say, MODFLOW.

The extension of groundwater flow models to include heat transport is well-founded and applied in the geothermal development and nuclear materials isolation communities and has seen a few, rare applications in more common hydrogeologic investigations. The additional information provided by consideration of heat transport with groundwater flow simulation has not yet been found by the hydrologic community at large to be valuable for projects despite several valid calls in the literature for its consideration (e.g., Anderson, 2005). I think there are rare circumstances where it may have value, but they are indeed very rare.

What is critical for understanding the MAI-FEFLOW-2019 is to recognize is that the heat transport extension in FEFLOW is strongly dependent on the accuracy of the groundwater flow simulation. As with mass transport, the flow simulation must be extremely accurate or the mass is carried to places it doesn't go and at rates it doesn't maintain. Considering heat transport cannot cure an inaccurate groundwater flow representation.

The application of FEFLOW here suffers a fatal flaw (not a fault of the FEFLOW code) that overshadows all further comments: its simulation of groundwater flow is without foundation (i.e., there is no clear and substantial support provided here for interpreting uniformity of thickness and hydraulic conductivity) and rigid uniformity actually conflicts with what is known about the basic structural geology of the region. I opened the FEFLOW simulation file downloaded from the NSE website and inspected it in FEFLOW (I currently have version 7.2), for which I have had a license for two decades. The MAI-FEFLOW-2019 model is two dimensional, has a uniform thickness of 1000 meters, and has uniform transmissivity. I need only point to the cross-sections of either Page and others (2005, revised in 2011) or Rowley and others (2017) and in particular point out the complex and dominant juxtapositions of Proterozoic basement units/early Cambrian quartzites with the Paleozoic carbonates of interest. The exposures of Proterozoic rock at the surface in the Mormon and East Mormon Mountains are just two of the most obvious clues that the Paleozoic carbonates have been spectacularly broken up. In short, in view of the currently accepted structural geology of this area, the saturated Paleozoic carbonates cannot reasonably be viewed as a continuous, uniform, slab aquifer or aquifer system. They are instead broken up and separated into corridors such as underlie Meadow Valley Wash, which is the largest of these corridors in this region. A labyrinth or maze of huge, elongated structural blocks is a better analogy than a simple block or slab for the flow of groundwater in the Paleozoic carbonate aquifer system.

The remarkably novel use of spatially variable anisotropy with a uniform transmissivity field by the authors to produce the sinuous particle tracks they infer from aquifer testing (Appendix V) is not supported by theory for this setting or by local demonstration of its applicability and is in any case insufficient to represent the huge separations imposed by shallow occurrences of Proterozoic granite or early Cambrian quartzite. The reason is that these blocks each have very different hydraulic conductivities, as a whole, than the Paleozoic carbonates. On Page 59 (Appendix III), the authors state that this anisotropy field is "experimental and based entirely on professional judgement…" So, once built from those assertions, it cannot be expected by itself to prove or suggest that it provides a foundation for inferences about this specific aquifer system.

Appendix V discusses analysis of aquifer tests in the CSV. The authors propose a sinuous anisotropy field to explain non-uniform responses to pumping at individual observation wells, which apparently perhaps lead to the MAI-FEFLOW-2019 model structure. As I understand it, the authors think of drawdown propagation as analogous to the procession of a plume of dissolved contaminant in flowing groundwater, which certainly can have a serpentine or sinuous appearance. However, I completely disagree that this is how drawdowns propagate in even highly heterogeneous porous media. In keeping with my education in the literature on total hydraulic head fluctuations in porous media, I instead recommend adoption of straight-forward consideration of heterogeneity, that is, variations in actual magnitudes of hydraulic conductivity and storage parameters by volumes (not just direction). I would point to the voluminous petroleum engineering literature on well tests and reservoir simulation in carbonate reservoirs, none of which follow the approach followed by these authors. That profession uses heterogenous permeability and storage property arrays to simulate flow and transport in fractured rock reservoirs. This literature has been extensively peer reviewed over several decades.

In further conflict with their uniform transmissivity model, the authors state from their presentation to a conference in 2003 (see top of Page 24) that the springs and associated surface flows of the MRSA are due solely to a southward transmissivity decrease. If they thought a non-uniform transmissivity in the Paleozoic carbonate system important enough to present to a national meeting of geologists, then it would seem to be important enough to build it into their MAI-FEFLOW-2019 model so that the MRSA springs and associated surface flows appear at the surface in the correct locations as they say. They do not put such a feature, or any other structural feature, in the MAI-FEFLOW-2019 model.

To put the problematic lack of structure of the MAI-FEFLOW-2019 into perspective, these same two authors published an extensive analytic element model (AEM) of this region in the journal of Ground Water (Johnson and Mifflin, 2006). Neither this AEM nor the intricate hydraulic conductivity zones and no-flow barriers (Las Vegas Shear Zone, Kane Springs Wash Fault, Weiser Syncline) they developed from calibrating it to available water-level measurements are mentioned in this MAI2019 report. Clearly, they thought highly of their groundwater flow modeling work by publishing it in 2006, but not only didn't they carry their findings forward in 2019, they didn't even mention this extensive previous work in what the NSE has defined as the LWRFS. Further, the article mentions a MODFLOW analysis they had subsequently developed based on the AEM, which was also not mentioned in the current report. The AEM was prescribed a uniform, infinitely extensive, 1,524-meter-thick slab, the selection of which, they said was supported for this system, by "available evidence". They then referenced the USGS Moapa West Quad preliminary geologic map as the support for relative continuity in the carbonate system in this area. How that map indicated this is not developed, but the cross sections of Page and others (2005, 2011) and Rowley (2017) clearly indicate to me that a single slab representation is not a reasonable approximation for the current disposition of the Paleozoic carbonates. In this globally-distributed article, they say that the Kane Springs Wash Fault, (a linear no-flow (impervious) boundary in their AEM model) had to be extended southwestward as it was "... required to fit *[the difference between]* VF-2 and CSV-3 water levels." Finally, in the abstract they say: "Using new monitoring well data collected in the south, and analyses confirming that seasonal pumping effects in the north are not propagated to the south, a later AEM model that included a barrier calibrated with relative ease." At even a broad conceptual level, it appears that the explicit incorporation of structure divisions and the results are somehow discarded in the current MAI-FEFLOW-2019 model and go against their unexpected statement at the end of the last Appendix to MAI2019 that pumping in KSV will impact the MRSA within 10 years.

Regional Models of Groundwater Flow in the Deep Carbonate Aquifers of Nevada

The authors repeatedly challenge simulation of groundwater flow in the Paleozoic carbonate system, for example, on Page 22: "In fractured-rock aquifers, pumping impacts do not decrease predictably with distance as they do in idealized porous media." If this is true, the authors should have avoided analyzing aquifer tests in fractured rock with continuous radial equations for groundwater flow and should have avoided creating or applying and making conclusions from their own AEM, MODFLOW or FEFLOW Models of the regional Paleozoic carbonate aquifer system.

A further challenge to regional models, despite the authors persistent construction and use of them, is found on Page 33: "Regional groundwater models are intrinsically general, and not reliable at the level of detail needed to evaluate groundwater-development proposals (water-rights applications) at the local (sub-hydrographic basin) level." I obviously disagree as I have used regional groundwater models for this purpose.

At the end of MAI2019, the authors indicate a concern for structural features, but don't recognize that this was ignored in their MAI-FEFLOW-2019 model or that it is actually a weakness of finite element models: "Because the structural grain is highly variable, MODFLOW grids (and for that matter finite difference codes in general) are inadequate for tracking regional groundwater flow and heat redistribution in the central and southern Great Basin. Instead, finite-element analysis of coupled water and heat transport is the appropriate study framework." If now resolution of highly-variable "structural grain" is a key determining factor, then a uniform slab "transmissivity model" as presented in this report would be inadequate, as they say. Actually, MODFLOW has always been a finite volume code and for two years (officially) now has had all the flexibility of any finite element code in terms of discretization. A little-known fact is that finite element codes do not locally mass balance when using heterogenous material properties in adjacent elements. This is because the finite element approach balances mass in a weak or integral sense, not element by element. Therefore, highly-variable "structural grain" would create inaccuracies and local mass balances in a finite element model. FEFLOW has recently changed their formulation so that it now employs a control volume solution (like the current MODFLOW) and this problem has in theory been resolved. Finite volume codes preserve mass both globally and locally.

Simulation of Heat Transport – the Eureka Low or High

The authors propose to address the "Eureka Low" and bring the resolution of that anomaly's explanation into the discussion of how to manage the LWRFS. I am not aware of nor could I find a call in the NSE's Order 1303 for resolving any question about the explanation of the Eureka Low. There has long been a simple and reasonable explanation for the Eureka Low and no one has publicly challenged the USGS' original explanation of the Eureka Low in the nearly 50 years since the explanation was proffered. Alongside their repeated assertions of success, the authors do not explain for practicing scientists and engineers participating in these proceedings how their approach to simulating the effects of the Eureka Low is relevant to the matter before the NSE in the LWRFS.

My research (largely USGS publications) turns up that the Eureka Low is an enclosed area of relatively lower heat flow from the earth compared to the surrounding western U.S. The USGS found this entity while compiling information on heat flow for the purpose of estimating the long-term natural (vertical) infiltration rate through the very large vadose zone of the Nevada Test site. Sass and Others (1971) provided the first plot of relevant regional heat flow measurements, identified the "Eureka Low" for the first time, and based on the abruptness of its boundaries, proposed high lateral groundwater circulation down to 3 km as the most likely cause. Sass and Others (1976) updated the publication of 1971 in terms of Heat Flow Units (1 HFU = 41.8 mW/m^2) for the coterminous US, and confirmed the delineation of the Eureka Low (< 1.5 HFU or 62.7 mw/m^2).

So, it appears that the phenomenon being pursued by the authors is that the Eureka Low is an area of remarkably deep and substantial groundwater flow that carries away heat coming up out of the earth much more so than surrounding areas. This is certainly consistent with understanding that fractures of the regional Paleozoic carbonate groundwater flow system of this region do not seal up significantly with depth as the effective porosity of Tertiary basin fill certainly does, but instead conduct groundwater to depths of tens of thousands of feet where blocks of the Paleozoic carbonate units are intact to those depths. The U.S. Geological Survey work in compiling hydraulic property estimates for the Death Valley Regional Flow Model (Belcher and Others, 2001) included tests from across southern Nevada, including CSV and MRSA and failed to quantitatively determine a relationship between hydraulic conductivity and depth for any unit in their estimation, including the Paleozoic carbonates. Figure 1 (attached) is a plot of only the Upper and Lower Carbonate Unit data from Belcher and Others (2001). Karstified (cavernous) or vuggy (oil field term for very large dissolution openings) values are enclosed on Figure 1 with an ellipse; the remaining values appear to be a relatively random band that is largely independent of depth, confirming the findings of Belcher and others (2001) from regression calculations on these same data.

This concept of the Paleozoic carbonates maintaining their hydraulic conductivity to great depths is also consistent with the widely expressed interpretation that there are exceedingly thick flows of groundwater in the connected, intact corridors of Paleozoic carbonates that remain from the tectonic events affecting this region. Such a gigantic system, even if broken into a maze or labyrinth, carrying groundwater across great thicknesses would clearly be expected to disturb the heat flow field compared to adjacent areas of much smaller lateral groundwater flow.

The distinguishing feature of the inputs to the heat flow portion of MAI-FEFLOW-2019 was a block of cells in the area of the Eureka Low that were assigned **much higher** heat flow than the surrounding area. The distribution is different from that of either Sass and others (1971) or Sass and others (1976) and is attributed to a map by researchers at Southern Methodist University (Blackwell and Others, 2011) that was obtained from the internet. The SMU map shows, as do the two Sass and Others (1971 and 1976) compilations, a closed area with heat flow 10 – 30 mW/m^2 **less** than the surrounding area. Thus, it appears that the MAI-FEFLOW-2019 simulation is the result of assumptions that are the converse of those typically ascribed to the Eureka Low. The opportunity for history matching/calibration and developing and communicating clearly additional understanding about the actual system, where the Eureka Low is cooler, is lost by not simulating the actual arrangement of heat flow in this system.

It appears from Page 51 that the authors understand that they have the simulation in reverse and it is not a mistake: *"The question studied is if rapid signal propagation indicated by modern climate response of springs in the MRSA is corroborated by plausible groundwater velocities needed to deliver the "missing" heat lost from the Eureka Low to the regional springs in a steady-state process".* Doing this with a steady-state model puts further logical distance between the simulation and the intended advance in understanding what the authors say elsewhere is the important transience of the system. Even if simulating the reverse of the actual distribution of heat flow is intended, the authors never show how simulating the Eureka Low as a heat source warming water otherwise at zero degrees proves their point, which apparently was to: "establish if regional flow from northern recharge areas in the highest mountains to discharge at the southern warm springs is physically possible and more importantly, plausible within the decadal scales suggested by climate response in the MRSA." I can't conceive of any trained geologist questioning at all that transport of heat at a regional scale by groundwater is possible or plausible at all conceivable time scales of practical interest. Heat transport in saturated porous media is an established and widely-accepted physical process and one need only read the literature of nuclear waste isolation simulation to see the great reliance physicists around the world place on this being true. The question is what this means for the NSE in considering the boundaries of the LWRFS and how to protect the springs and associated surface flows of the MRSA, and I conclude that as presented here it doesn't have meaning. That is, the MAI-FEFLOW-2019 heat transport simulations do not address: how, from where, and how fast do drawdowns from pumping in the LWRFs or surrounding areas reduce flow at the MRSA springs and associated surface flows.

In the MAI-FEFLOW-2019 model presented by the authors, the groundwater temperature is largely zero degrees Centigrade in much of the model domain and groundwater becomes much hotter to the southeast of and hydraulically down-gradient (as calculated by this groundwater flow model) of the Eureka Low. The authors claim to have calibrated their heat flow model to two points in their domain and from what they infer as success in calibration, they claim that the model's heat flow component was demonstrated to be valid and reliable and constraining on groundwater flow. This wasn't demonstrated in my opinion. For example, the results of the model and the field data for the two selected calibration points are not compared or discussed. The Steptoe MX point was off gradient from the Eureka Low and simulated with a temperature of zero degrees centigrade and it appears from Figure 5 that the Tule Springs point was downgradient and simulated with a temperature of 25 degrees centigrade. The dozens of other groundwater temperature values available in this region, especially the very warm 43+ degrees Centigrade value at the KPW-1 well in KSV were ignored and it is doubtful that this model could match them because the Eureka Low is simulated as an anomalously high heat flow area. Finally, being concerned for much of the simulated field being zero degrees centigrade (frozen), I confirmed from the FEFLOW simulation input that hydraulic conductivity was not linked to temperature. Thus, the water flows in this simulation based on hydraulic conductivity and porosity that stay the same no matter what its temperature and is not in fact frozen where simulated at zero degrees.

"Recharge Boundaries" – A New Source of Water for Development?

The authors further assert a unique interpretation of unique occurrences in the area, saying that aquifer tests of the Paleozoic carbonates find "recharge boundaries" (see Page 16, Figure 19 [Page 19], Page 23, Page 26 or 33, for example), but they do not explain these in terms of widely-recognized hydrologic features that match their selected aquifer test model. The authors go further to say that groundwater development should focus on finding and pumping from more of these "recharge boundaries" (Page 33) as if they were unique sources of groundwater. I studied well hydraulics specifically as part of my graduate studies and have taught aquifer test analysis courses for decades. The recharge boundaries that the authors simulate so as to compare with drawdown data are based on an expanding radially symmetric drawdown cone calculated with the Theis Equation encountering a linear, fully-penetrating source of infinite water. This was done with an image, injection well to provide as much water as the real well pulls from it, without limit. I submit that, other than at the edges of Lake Mead or Lake Powell, such fully-penetrating, laterally continuous walls of water are largely absent in southern Nevada. An "extensive (at least several kilometers) highly transmissive and highly anisotropic broken and karstified zone" asserted by the authors, if such indeed exists, is not reasonably represented by the Theis equation and an image well-based recharge boundary and in any case, would have very low storage capacity, i.e., without immediate connection to an actual, hydrologic feature such as a deep lake or large river, such a source would be exhausted rapidly by continued pumping.

Instead, the flattening of the drawdown curve during carbonate well tests is in my opinion often due to the transition in storage processes from a few, large fractures to a larger system of finer and denser fractures. This can be approximated with a dual-porosity solution, but the Theis solution should be avoided along with non-hydrologic recharge or no-flow boundaries applied with image wells. I would refer the reader to either early basic texts (Streltsova, 1988; Da Prat, 1990) or more recent discussions of well test analysis for fissured reservoirs (Bourdet, 2002; Stewart, 2011). The approach for modeling flow to wells in fractured reservoirs has not changed over decades of oil and gas field well testing – dual (or sometimes triple) porosity well-test models (not Theis) are the preferred approach.

Another potential is that the expanding drawdown cone reaches into volumes with larger transmissivity/hydraulic conductivity, which will cause a decrease in the rate of drawdown. This situation is not simulated by petroleum well test analysts with a constant head source, but instead they have used models with a circular change in transmissivity at a distance (see Streltsova [1988, page 246] for a discussion of a now dated approach to simulating radial discontinuity), or more appropriately in recent years with a full reservoir flow model that handles realistic heterogeneities in permeability (as could also be simulated with MODFLOW or FEFLOW).

Finally, if there is a very large fracture at the well, then the petroleum engineers have many well-test solutions for large vertical or horizontal fractures, but they are completely different from the Theis equation with recharge boundaries. What has been found by well test analysts in the petroleum industry is that the impact of large continuous fractures directly intercepting a pumping well is not to provide an additional source of (freely drawn in) water, but to conduct (oil or) water from the surrounding rock mass and, in effect, make a larger well. Again, recharge boundaries simulated via the Theis Equation are not the preferred approach for well test analysis in fractured rock across a variety of situations.

Even more novel, the authors choose to analyze the KPW-1 well test conducted by Lincoln County/Vidler in KSV using the <u>steady-state</u> **Thiem** (not Theis, but Thiem) equation with a fully-balancing steady-state image well. The graph offered by the authors of the monitoring well response (Figure 29) clearly shows that the drawdown was continuing to increase throughout the pumping period, so it cannot be construed as steady state. Use of the Thiem equation with an image well for this setting is even less reasonable than using the Theis equation, i.e., for a fractured aquifer that demonstrates dual-porosity behavior. The mathematical outer boundary condition of the Thiem Equation is a deep lake or perhaps ocean completely surrounding the pumping well, which itself is in a circular "island" of aquifer. There is no such deep lake or even deep perennial river in KSV to provide the full pumping rate of this well in a fully penetrating or any other fashion within a day or few days (during the test) and achieve steady-state.

In summary, I disagree with advising the NSE that well tests indicate that there are "recharge boundaries" – independent sources of groundwater - within the Paleozoic carbonate aquifers of the LWRFS. Therefore, I also disagree with the authors' proposition that such "recharge boundaries" should be pursued as yet-untapped sources for future development of groundwater supplies.

Statistical Correlations Rather than Physically-Based Simulations

The authors depend on many correlations to produce corrections to hydrographs, primarily to remove pumping effects and discern trends absent of pumping. See Figure 4 of MAI2019 for the first example. The EH-4 hydrograph in what the authors call "a more pristine form" is simulated using Virgin River, North Fork flows (far away) and sixteen years before (long ago). On page 15, the authors found and used a correlation between flow at Big Muddy Spring in the MRSA and a 12-22-year prior base flow of the Humboldt River. Again, the two things being correlated are far apart and far removed in time, which the authors ascribe elsewhere to movement through the system, yet water doesn't not move between the correlated entities in each case. Appendix II expands on these ideas to develop their "Two-Climate: Model" and mix both. I would note that they do not present and analyze the residuals of their reconstructions, a basic requirement of analyzing and deciding on the validity of a time series model. I disagree with this use of correlations as a replacement for physical models such as MODFLOW or FEFLOW. MODFLOW and FEFLOW use Darcy's Law and local and global mass balance to physically represent changes in total hydraulic head and associated groundwater flows. Location in space and time is critical in a physical model as it is in physical space, but these are ignored in the many correlations presented by the authors. Finally, correlation and common or related causation are easily mistaken for one another and I submit the many correlations presented here are not useful for adjusting or extending water-level or surface flow hydrographs in this setting despite their coefficients of fitting.

Appendix IV discusses regression modeling (Empirical Mode Decomposition Filtering) between pumping and the water levels at EH-4. While extensive, this approach also abandons physics in favor of empirical (non-physical) statistical fitting, which has been largely dismissed in hydrology. This dismissal of statistical fitting of non-physical models in hydrology has been due to the excellent and dependable process descriptions we have in hydrology and the highly erratic projections created by statistical regression fits outside of the exact data used to create them (the famous "over-fitting" problem). I would not depend on these correlations for simulating water levels from pumping rates in this setting.

Effective or Interconnected Porosity

On Page 20, the authors say that their regional modeling of the Eureka Low "suggests" that the "regionally-interconnected porosity" is 0.00015 and that the "active flow-zone porosity" is larger at 0.00064. These values are far less than those used or even considered by hydrologists to date for the carbonates. How the MAI-FEFLOW-2019 model itself suggests such unusual and here-to-fore unreported values is not stated. The value of 0.1 is widely accepted for the interconnected porosity (fractures overwhelming the matrix in defining this total) for regional groundwater flow in carbonate systems. The authors therefore have based their calculations on a porosity that is 150 to 650 times (or two to nearly three orders of magnitude) too small. The results of using such a value for transport calculations is to simulate water particle arrival times 1/150 to 1/650 of their actual values. Finally, the potential for matrix diffusion (pursued on Page 57) would be severely overstated if the fracture porosity is 150 to 650 times too small. In any case, I would submit that transport is not relevant to the deliberations of the NSE about Order 1303.

Unexpected and Unsupported Conclusions Concerning Pumping in Kane Springs Valley

On Page 59, the authors approach conclusion with a positive assessment of the MAI-FEFLOW-2019 model: *"The transmissivity analysis using FEFLOW (Diersch, 2014) was instructive in that time-of-travel capture zones for the MRSA were delineated in a simple (low-dimensional) conceptual framework (Figure 11) where behaviors of the process variables hydraulic head and temperature under different scenarios are easily visualized because there are no inhomogeneities. The anisotropy field used for this base case is experimental and based entirely on professional judgment, as is the operational recharge cutoff surface, OSDc-only recharge-area lithology selection, and admittedly low-confidence characterization of the Eureka Low heat source (see Critique below)."* Looking at these statements, it appears to me that the basis of the authors' confidence is that the model is low (two) dimensional and free of inhomogeneities. After spending some time with the surficial mapping and cross-sections of Page and Others (2005 and 2011) and Rowley and others (2017), I would say that these two simplifications not only do not support its use, but literally toss out the most important features controlling flow in this region, making these results of little use.

An unexpected conclusion surprises the reader at the end of Appendix III (Page 59). Using travel times along flow paths calculated by the steady-state MAI-FEFLOW-2019 model, the authors say: "…that carbonate-rock aquifer pumping in KSV would likely impact the MRSA within 10 years, and development impacts in Delamar Valley would likely be sensed at the MRSA in 20 years." This is a surprise as there is no mention of either of these two impact/sensing evaluations in the report, that is, neither was ever listed as an objective. Seeing from the MAI2019 report that the authors did not calculate transient drawdowns or depletions of the MRSA springs and associated surface flows anywhere in the model, this statement is without basis in MAI2019. The authors' confusion of [particle] capture with hydraulic system capture (see earlier in this rebuttal) appears to be the source of their thinking that lead to the conclusion that impacts would reach and be sensed at the MRSA due to pumping in KSV or Delamar. Steady-state [particle] capture zones only outline flow paths through an undisturbed groundwater flow system of water molecules and associated dissolved substances, such as sodium or bicarbonate ions. The assumption that flow with moving groundwater is the mechanism for distributing impacts from well pumping is all the more curious when one considers that pumping could only **remove** water molecules and associated dissolved substances from the groundwater system, so they would not be available to move along the groundwater flow paths downstream in any way and cause "impacts" or be "sensed". Movement of groundwater along flow paths does not deplete springs or streams; drawdowns do, and drawdowns are not transported like salts or other dissolved substances along groundwater flow paths with the flowing water. Drawdowns (declines in pressure or total hydraulic head) propagate in directions radiating out from a pumping well irrespective of local or regional flow directions. There is a Technical Commentary published in the journal Ground Water by Stan Leake of the USGS entitled "Capture – Rates and Directions of Groundwater Flow Don't Matter!" (Leake, 2011) that gives a current, peer-reviewed reminder of this common confusion. Finally, if the authors are instead thinking in terms of dissolved transport of some sort, the travel times for dissolved substances calculated using either porosities of 0.00015 or 0.00064 would be 150 to 650 times too fast. Despite how it may sound from the statements on Page 59, drawdown impacts on the MRSA's springs or associated surface flows from pumping in either Delamar or KSV were not calculated the MAI-FEFLOW-2019 Model.

Selected Comments on: "Garnet Valley Groundwater Pumping Review for APEX Industrial Complex, City of North Las Vegas", prepared by Dwight L. Smith and Alexa Terrell (Interflow Hydrology, Inc.), dated July 2, 2019

I am rebutting the use of a new groundwater model focused on the APEX area of Garnet Valley for supporting the conclusion that groundwater enters the LWRFS from the Las Vegas Valley, as opposed to my opinion that the opposite is more likely. I further rebut that the total flow rate prior to pumping through the area covered by this new model is low (hundreds of acre-feet per year). I think that one source of their mistake is that they only consider a small fraction (1/25 to 1/20) of the Paleozoic carbonate flow system in the model. The flow of regional groundwater leaving the LWRFS is related to the flow throughout the LWRFS, so changing that concept from tens of thousands of acre feet per year to hundreds of acre feet per year has important implications for what the NSE accepts as reasonable in regional groundwater flow modeling.

This report was downloaded from the NSE website as a 53-page Acrobat-PDF file. The authors focus on the area west and south of the MRSA for the City of North Las Vegas. Of interest is the MODFLOW model built to evaluate the area and a conclusion that the results indicate that groundwater flows north and out of the Las Vegas Valley basin across the Las Vegas Shear Zone.

Pages 7 and 8 present a summary of hydrogeology, which describes a very large Paleozoic carbonate groundwater flow system (20,000 to 25,000 feet) which carries flow from CSV to MRSA, but also to Hidden Valley. Though data are very sparse in Hidden Valley, this interpretation is reasonable, consistent with the interpretations of others, and the authors certainly support it while asking for additional monitoring wells to be completed in the carbonate system. Figure 7 presents the water-level elevations for the overall system and indeed water levels are higher in CSV and Hidden Valley than in Garnet Valley, supporting a southern flow path through these basins distinctive from the flow to the MRSA. I would submit that such a large aquifer with very large transmissivity and a southward gradient would be moving a not insignificant quantity of groundwater and that without another discharge location in Garnet Valley, that groundwater continues on to the Las Vegas Valley. On Page 16, the authors note the difference between the estimated recharge in the LWRFS (50,000 AF/yr.) and the discharge at MRSA (36,000 AF/yr.) and pumping in the LWRFS (9,000 AF/yr.). The recharge estimates are in particular uncertain, but together these estimates by themselves leave room for a significant flow of water (much more than hundreds of acre-feet per year) to exit through Garnet Valley to the Las Vegas Basin.

On Page 33, the authors pursue a comparison of water levels between southern Garnet Valley and northern Las Vegas Valley, but found only a scattering of drillers' estimates over many decades and concluded: "Based on the existing data in northeastern Las Vegas Valley, it is not possible to accurately determine the direction of groundwater flow." Therefore, the authors leave room from their own work for the flow to be out to the Las Vegas Valley.

The MODFLOW model developed and presented by the authors was a slab with a uniform thickness of 1,000 feet and had a uniform K of 5.5 ft/day (Page 37). Therefore, because of its thickness, the model does not represent the Paleozoic carbonate system as a whole and because of its uniformity in thickness and parameters, does not incorporate the structural geology of the area. Therefore, the testing of the largely general-head-boundary conditions lacks foundation for being definitive. In modeling terms, the PEST-based calibration of the general head boundaries suffered from structural error. That is, the lack of geologic structure and the lack of much of the carbonate flow thickness was compensated for by adjusting the boundary conditions to obtain a close fit. Sensitivity (page 38) is not an independent measure of this problem as structural errors rule the sensitivity as well. Therefore, I don't find the inference of inflow from Las Vegas Valley credible based on this model. Based on sheer size and data for the overall flow system (LWRFS scale), I would instead infer outflow to the Las Vegas Valley. If the full thickness and actual geologic structure of the Paleozoic carbonate system were simulated and with inflows reasonable from basins to the north, such as CSV, the much smaller pumping in Garnet Valley would not cause a flow reversal, i.e., draw water into Garnet Valley that normally flows out to the Las Vegas Valley.

Selected Comments on: "Concept Review of Artificial Recharge in Garnet Valley for the APEX Industrial Complex, City of North Las Vegas, Clark County, Nevada", prepared by Dwight L. Smith and Alexa Terrell (Interflow Hydrology, Inc.), dated July 2, 2019

This report was downloaded from the NSE website as a 23-page Acrobat-PDF file. The authors focus on the area west and south of the MRSA for the City of North Las Vegas. Of interest is the MODFLOW model built to evaluate the area and a conclusion that the results indicate that groundwater flows north and out of the Las Vegas Valley basin across the Lax Vegas Shear Zone.

The authors report on a steady-state (representing the year 2015) MODFLOW model of this local area with an inflow from Las Vegas to Garnet Valley of 698 AF/yr. (Table 1). Inflow from CSV and northern Hidden Valley is the next largest boundary condition at 456 AF/YR. In the analysis conducted prior to building the model, the authors found that the median/geometric mean transmissivity calculated from specific capacity of existing wells is 1,300 ft^2/d (Page 11). This represents just 1,000 feet of saturated thickness of a much larger Paleozoic carbonate aquifer, which they say is 20,000 to 25,000 feet thick (Page 5). The details of the model are referenced to the other report submitted to the NSE.

Two sentences from Page 14 indicate that the authors could entertain an alternative hypothesis:

- "The flow of groundwater from Las Vegas Valley to Garnet Valley is uncertain and needs to be verified by accurate groundwater elevation measurements (Interflow, 2019)."
- "However, if the gradients between Las Vegas Valley and Garnet Valley are different than assumed, then the analysis changes. If the groundwater gradient is from Garnet Valley to Las Vegas Valley…"

I submit that two reasons for the low flow rates through the model is the use of a very small fraction of the thickness of the aquifer and the extensive use of general-head boundaries. Based on the accumulation of flow from northern basins, such as CSV, and considering the more likely full thickness and geologic structure of the Paleozoic carbonate system, I instead infer that groundwater in Garnet Valley flows largely south to and enters the Las Vegas Valley at a rate of the magnitudes of thousands to tens of thousands of acre feet per year. Because the clear goal of the authors was not to characterize regional flow, but to size a well-based recharge project, I understand their focus on the uppermost 1,000 feet of the tremendously thick aquifer. However, this model accidently led to inferring, even if tentatively by these authors, that flow is <u>in</u> from the Las Vegas Valley.

Selected Comments on: "Prediction of the Effects of Changing the Spatial Distribution of Pumping in the Lower White River Flow System", prepared by Richard K. Waddell of Tetra Tech, dated July 3, 2019

I rebut the use of the Tetra Tech Model of Selected Basins within the Colorado Regional Groundwater Flow System, Southeastern Nevada, first reported on in 2012, for projecting regional impacts from pumping. The use of the HUF package to average out and diminish the structural controls of the regional geology, the use of hydraulic conductivity that decreases exponentially with depth for Paleozoic carbonates, and the use of Pilot Points in calibration of the model in such a way that localized areas of exceedingly high hydraulic conductivities are selected in the uppermost layer of the model by the parameter-estimation algorithm make the projected drawdowns too broad in extent.

This report was downloaded from the NSE website as a 29-page Acrobat-PDF file. The model used for the simulations described in this report is the same one presented to the NSE back in 2012. This 2012 Model is called in the text the "updated model", which does not mean it has been updated since 2012, but that the 2012 Model was updated from an earlier (2001 – see text on Page 3, 2nd paragraph of Section 1.2), preliminary model. That being the case, we would reiterate the comments we made on the 2012 model at that time and which have not been heeded in the interim.

In essence, the model starts from the cross sections of Page and others (2005, 2011), but, rather than using the unit contacts to become MODFLOW layers with dramatically different hydraulic conductivities, e.g., Proterozoic basement rocks, early Cambrian quartzites, Mesozoic sediments, or Neogene Basin Fill versus Paleozoic carbonates, they select several flat layers and allow the HUF package of an earlier version of MODFLOW to average the hydraulic conductivity of whatever portion of the units is in the layer and use that. This in effect strongly "blurs" the strong breaks between the blocks of units depicted in Page and others (2005, 2011). On Page 6, the text clearly shows that the author is aware of this approximation: "The complex stratigraphy is not incorporated in the model." Finally, they apply with that HUF package an exponential decrease in K with depth, which causes the flow in the model to be artificially pushed up to its shallowest layers. I disagree that the Paleozoic carbonates have an exponential decrease in hydraulic conductivity with depth. See the attached Figure 1 for a plot of the Belcher and others (2001) data for the Paleozoic carbonates (a primary unit for groundwater flow here). I interpret a regional value of the magnitude of 1 foot/day (shown also on Figure 1) for much of the Paleozoic carbonates in this region, even to thousands of feet of depth. Tetra Tech did prescribe a smallest value (a floor) on their exponential decline with depth of hydraulic conductivity: 3×10^{-4} foot/day and this is also shown on the attached Figure 1. This floor does not affect the exponential decline with depth from above this value and leads to this very low value dominating the deepest layers of the model. The artificial forcing of much higher values to the top of the model combined with a calibration via pilot points that created bulls-eyes of exceptionally high hydraulic conductivities in the shallowest layers leads to a model much different than what I would interpret from the cross sections of Page and others (2005 and 2011). To move the specified quantities of regional Paleozoic carbonate groundwater through the shallowest layers, the PEST algorithm, when saddled with this situation, is not to be faulted in assigning very large hydraulic conductivities individual pilot points in the top most layers. I don't think it represents the regional Paleozoic carbonate system accurately because it excessively limits what should be deep circulation (as much as tens of thousands of feet in some areas). The effect of selecting the HUF package plus exponentially declining hydraulic conductivity in the Tetra Tech 2012 model is for pumping impacts to spread very widely and rapidly across the top of the model, no matter what the actual materials are in place.

On Page 22, the author states his opinions about pumping in KSV: "Thus, the model predicts that the carbonate aquifers in KSV and Coyote Spring Valley are connected. Observations of water levels in wells CSVM-4 and KMW-1 show drawdown caused by the pumping in MX-5 during the Order 1169 test, showing that pumping effects are transmitted into this area in a few months. Based on this evidence, we would recommend including all of Kane Springs Valley within the final boundary of the LWRFS." I don't agree that this model predicts that these areas are connected; clearly, connections are built in from the very beginning of the conceptual model and carry through to the selection of inactive cells and the variations in hydraulic conductivity. That is, an assumption shouldn't be given as proof. The excessive and excessively shallow connections in the Tetra Tech 2012 Model are pervasive, as discussed above, and the problem would also be present in the Northern Coyote Springs and Kane Springs Valleys. KSV and **northern** CSV are connected, but they together are isolated to a significant degree from southern CSV by geologic structure, as most recently confirmed by the data presented in Lincoln/Vidler's report of July 3, 2019 to the NSE. Following up on this, KSV is quite distant from the MRSA and it should be remembered that the springs and associated surface flows of the MRSA, not northern CSV's deep aquifer, are what are intended for protection by the NSE's administrative unit under Order 1303. The author says nothing about what their model shows about effects of pumping in KSV on the springs of the MRSA; they only say that the drawdown cones from KSV coalesced with those of (from inspecting the figures with drawdowns, **northern**) CSV. Finally, the declines in water levels in both CSVM-4 and KMW-1 during the Order 1169 test were virtually identical and are due to regional recession from the winter precipitation event of 2005, not pumping at MX-5, as has been stated not only by Lincoln County/Vidler, but in other reports to the NSE as well.

The flow path outline, shown on page 22 of Appendix A, was developed with the Tetra Tech 2012 model. Because that model assumed that all flow in the southern part of the model can only exit at Blue Point and Rogers, Springs, indeed, that is what the flow path shows. This conceptual model and the boundary conditions applied to the model ignore a discharge south through Garnet Valley to the Las Vegas Valley. On Page 22, this assumption by Tetra Tech in building the 2012 Model is confirmed: "The Las Vegas Valley Shear Zone is considered to be the down-gradient end of the LWRFS. While there is a gradient across the shear zone indicating that there may be groundwater flowing from the LWRFS into the rest of Las Vegas Valley, the amount of flow is believed to be very low. The model simulates that boundary flow to be 0 afy, using a no-flow boundary condition, based on estimates developed by USGS hydrologists Jim Harrill and Doug Bedinger." I typically agree with USGS hydrologists, but with regard to the Las Vegas Valley Shear Zone, I disagree with this specific boundary flow interpretation, which is that the water flowing southward out of the LWRFS is forced to take an abrupt/right angled, left turn to discharge only at Blue Point and Rogers Springs, and not cross the Las Vegas Valley Shear Zone. I would note in closing my discussion of this topic that the Pahranagat Shear Zone is not generally considered to be a no-flow boundary (completely sealed), but to allow very large flows of groundwater across it.

Selected Comments on: "Technical Memorandum, Groundwater Management and the Muddy River Springs, Report in Response to Nevada State Engineer order 1303", prepared by Dr. Tom Myers, Hydrologic Consultant, dated June 1, 2019

I rebut the recommendation of Dr. Tom Myers that KSV should be included in the LWRFS administrative unit because he bases this on his inference that drawdowns from pumping from KSV could reduce or reverse the flow of groundwater into (northern) CSV. He makes no calculations using groundwater models to estimate either these drawdowns or the flows at the edge of KSV due to KSV pumping or, more to the relevance to what the NSE is considering, the potential for KSV pumping to measurably reduce flows in the springs and associated surface features of the MRSA.

This report was downloaded from the NSE website as a 27-page Acrobat-PDF file. On Page 1, the author states four points, the second of which is: "2. The [Dr. Myers'] report considers the reasons to consider Kane Springs Valley (KSV) as part of the LWRFS (the water level is just five feet higher in Coyote Springs Valley (CSV), and pumping in KSV could reverse the gradient pulling water from CSV.[sic]" The text associated with this point, on Page 19, expands only slightly on this conclusion by saying the gradients are low and that responses to MX-5 were fast, but then says: "Because of the very low perennial yield in Kane Springs Valley and lack of inflow to the valley from upgradient valleys, pumpage in Kane Springs Valley could reverse the gradient and draw water from CSV."

I rebut the statements of the previous paragraph as a basis for changing the composition of the LWRFS selected by the NSE primarily because it is based on consideration of drawdowns that may be experienced in (northern) CSV when wells are pumped in KSV. The goal of the NSE's designation of multiple HAs as the LWRFS administrative unit was to protect the springs and associated surface flows in the MRSA, not the current water levels in (northern) CSV. Due to distance and the intervening geologic structure, drawdowns that do make it out of KSV into northern CSV are also limited in their propagation to the MRSA. Further, I rebut that a water level difference of a few feet is a basis for calculating changes in or even complete reversals of flows or the timing guessed at here of a few years. If the "rapid response" being referred to is associated with CSVM-4 and KMNW-01 during the MX-5 test, I would say it was not a very fast response to pumping at MX-5, but was instead was a roughly simultaneous recession across a region from the winter precipitation of 2005. Also, the author assumes a continuous high transmissivity aquifer from (southern) CSV, near MX-5, into KSV. This is not what has been found, as most recently confirmed by the report of Lincoln County/Vidler to the NSE on July 3, 2019. Finally, I rebut that the perennial yield of or the inflow to the KSV HA at any level (and I do not think either is low or lacking) determine that pumping could reverse the gradient and draw water from CSV. Even if this happened at the boundary of KSV and (northern) CSV, it does not address the potential depletion of springs and associated surface flows in the MRSA.

Selected Comments on: "Issues Related to Conjunctive Management of the Lower White River Flow System, Presentation to the Office of the Nevada State Engineer in Response to Order 1303", prepared by the U.S. Fish and Wildlife Service, dated June 3, 2019

I downloaded the 82-page Acrobat-pdf report from the NSE website. The author or authors are not given; the cover letter says it is the "Services'". The report discusses what was requested by the NSE with a focus towards the potential for impacts to the Moapa Dace (a small, officially-Endangered, fish).

I rebut the proposed addition of KSV to the LWRFS administrative unit, but agree with the addition of Lower Meadow Valley Wash, both proposed on Page 2. KSV is relatively far away and has geologic structures impinging between KSV and the MRSA; the MRSA HA is, from a structural geology perspective, "cut-out" of the LMVW HA. That is, the MRSA is drawn from surface topography but is in the same block of Paleozoic carbonates as the rest of LMVW. Even respecting the HA boundaries as drawn, LMVW is immediately adjacent to the MRSA.

I rebut the discussion of SeriesSEE application to pumping during the Order 1169 Test Page 15 to 16) in which it is defended forcefully in the introduction by dismissing the core Theis solution and its "parameters" as merely fitting coefficients and that "successfully reproducing" the "measured changes in water levels across the study area" means that application was useful. If fitting is the measure, and the coefficients aren't important as long as the match is close, then they should have instead used a much more powerful tool: artificial neural networks. The general finding has been that artificial neural networks match the available data extremely precisely, but fail immediately upon application to a slightly different set of inputs. In this case, I would return to viewing the Theis solution as an actual physical model of groundwater flow (as Theis clearly intended it) intentionally selected by the authors of SeriesSEE as such. SeriesSEE is most reasonably applied where groundwater flow is radially uniform and there are places where this is very useful. In the case of the LWRFS, the structural geology presented in Page and others (2005, 2011) indicates to me that the Theis Equation (either through SeriesSEE or in other code) should not in general be applied to analysis of the drawdown responses to the MX-5 test. A numerical model which allows explicit incorporating of the local structural geology is more reasonable. Finally, in the case of the Order 1169 test, the problem of matching the measured water level changes through any model was that the simultaneous regional decline from the recharge of the winter of 2005 was mis-identified as drawdown due to pumping. In my opinion, matching uniform water-level declines during the Order 1169 Test throughout the LWRFS and adjacent areas, in light of the 2005 winter event, via any model using pumping as the lone cause for water-level decline is cause for concern about that model application, not attribution of success. The text says specifically on Page 16: "… and long-term trends in area groundwater levels were not accounted for during the analysis. Additionally, no-flow boundaries cannot be "simulated" (accounted for) during SeriesSEE curve fitting; SeriesSEE not [sic] a distributed groundwater flow model. Consequently, although a number of no-flow boundaries are known or likely to exist in the vicinity of the portion of the regional carbonate-rock aquifer stressed during the test, they were not accounted for during the estimation of MX-5 induced drawdowns." Therefore, the authors know that they are intentionally ignoring the structural geology of the region; it is not a mistake. I disagree with leaving the structural geology of this region out of groundwater flow and drawdown calculations. Finally, given the initial extended cautions by the author or authors to not view the physical Theis Equation as the selected mathematical transform and the parameters found by Series SSES as anything but meaningless regression coefficients, I find the extended discussions of Pages 17 and 18 of advancing cones of depression, controlled by local variations in transmissivity (a meaningful coefficient in the Theis Equation) contrary to these clear warnings.

I rebut the challenge across Pages 19 to 23 by the author or authors of the NSE's earlier finding in excluding KSV from the 1169 Order Test. In summary, I find that their arguments about similarity of declines in central-northern CSV and KSV being proof of drawdowns are flawed in that they are instead widespread essentially simultaneous decline from recharge due to the heavy winter rains of 2005. For example, see the first full paragraph of Page 21. Secondly, I find their arguments for hydraulic continuity from KSV into CSV are counter to the water-level differences and the geophysical data provided by Lincoln County/Vidler in the July 3, 2019 Report. See for example the first full paragraph on Page 22. From this proposition of continuity, the author or authors then expect water level impacts at Muddy River Springs and Muddy River, but they do not provide a groundwater flow simulation with the known structural geology to support their projection of impacts.

I rebut the assertion that the Kane Springs Wash caldera complex makes flow from Pahranagat Valley the primary source of groundwater flowing through KSV (bottom of Page 28). Elsewhere, I have pointed out that the distinctly larger recharge rates on the Delamar Mountains would surely create perennial or at least intermittent streams on them if the Tertiary Caldera units were such barriers to groundwater flow as asserted here. This rebuttal also applies to a parallel discussion on Page 29 with regard to groundwater flowing south from northernmost LMVW, i.e., groundwater flows through (not just between and around) the Caliente Caldera Complex (Clover Mountains) or there would be perennial or at least intermittent streams across the crest of the Clover Mountains. Given my objections to the Tertiary Calderas being impermeable, I rebut the first three bullets of Page 30.

I rebut the second bullet from bottom of Page 30 that asserts that flow across the Las Vegas Valley Shear Zone is negligible due according to the author or authors to discontinuous carbonates across the shear zone. I would infer instead that the shearing may not have created a no-flow boundary, but may have provided for a large portion of the flow in the LWRFS to enter the Las Vegas Valley.

I rebut the generalized projections of pumping impacts into northern CSV and thence into KSV, or the reverse given on the top of Page 33. Given that the topic being addressed by the NSE is protecting springs and associated surface water features of the MRSA, the narrative projections given here must assume that the drawdowns they envision will measurably reduce those surface water features in the MRSA. No groundwater model of any kind is offered to support the consequences of these projections on the MRSA. In particular, I disagree with saying in this forum that the drawdown experienced at the edge of a central, high transmissivity area would be transmitted “at least some magnitude over a large area; i.e., at 650 square miles…”. Although “at least some magnitude” as written would strictly include ridiculously miniscule numbers, such as 1×10^{-10} foot, I assume the author or authors intend significant, i.e., measurable and causing measurable impact to springs or surface flows. I would recommend that the NSE dismiss narrative projections implying unacceptable impacts to the MRSA from pumping in distant HAs. The author or authors' narrative projections ignore the complex structural geology of the region and are free from the restrictions of combining Darcy's Law with strict mass balance as are found in groundwater models such as the Theis Equation, MODFLOW or FEFLOW. The narrative groundwater flow and water-level response projections continue across pages 33 to 35, but here they assert the specific responses to assumed constancy or variation in inflow through the Pahranagat Shear Zone and Panaca Valley's boundary with LMVW, transmission of climate signals, and groundwater development and pumping impacts and recovery. All of these narrative projections are presented for the NSE in determining how to protect the springs and associated surface water features of the MRSA without an actual calculation involving a groundwater flow model code.

Selected Comments on: "Assessment of Lower White River Flow System Water Resource Conditions and Aquifer Response, Presentation to the Office of the Nevada State Engineer", prepared by Andrew Burns, Warda Drici, Casey Collins, and James Watrus, Sr. for the Southern Nevada Water Authority and Las Vegas Valley Water District, dated June 27, 2019

This report was downloaded from the NSE website as a 143-page Acrobat-PDF file. I rebut the statement on Page 3-4 that the "Tertiary caldera complexes forming the northern boundary of Kane Springs are effective barriers to groundwater flow. The calderas are barriers primarily because of their underlying intracaldera intrusions and both hydrothermal clays and contact-metamorphic rocks formed by emplacement of the intrusions into intracaldera tuffs (Rowley et al., 2011)." While I understand the inferences about Caldera Complexes repeated from past studies, I would note that they in fact have not been drilled and tested. What we can note is that the much higher recharge volumes falling on the Delamar (or Clover) Mountains (compared to the valley plains) would create persistent perennial or intermittent streams if the Caldera Complexes that form them were barriers to groundwater flow. Instead, I infer that the much higher recharge volumes falling on the Delmar or Clover Mountains instead sink in and flow through the caldera systems out through their lateral boundaries.

Conclusion

My conclusion after reading the selected report sections is that I support the NSE's previous finding that the KSV HA should not be included in the LWRFS. My basis for saying this is that, due to its distance and the intervening structural geology, it is reasonable to conclude that pumping from the KSV HA would have negligible, if any, effect on the springs and associated surface flows in the MRSA HA and therefore is not an effective area for management efforts focused on protecting those features.

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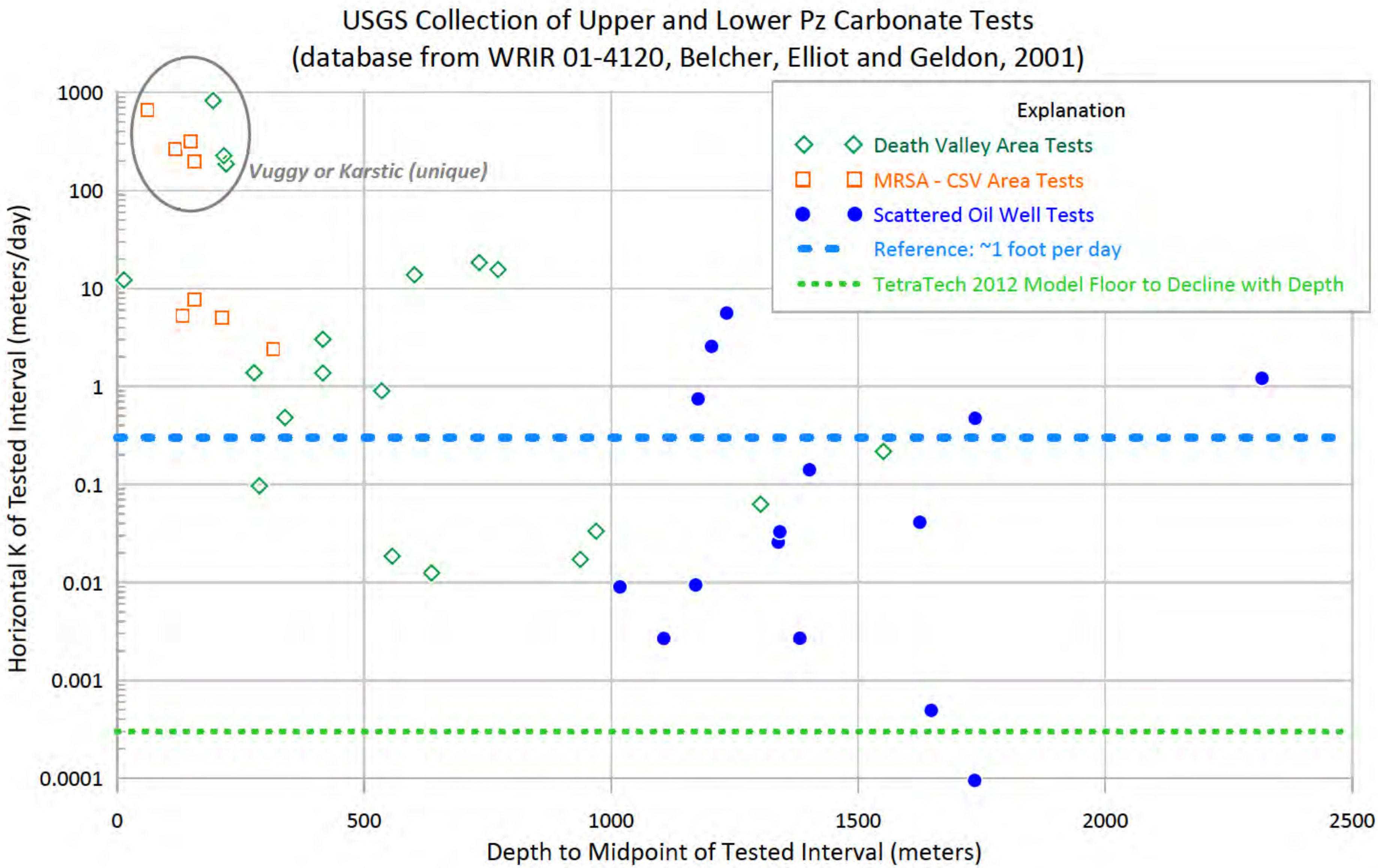

Figure 1 - Distribution of Horizontal Hydraulic Conductivity with Depth in Paleozoic Carbonates of Nevada

Attachment C

Technical Memorandums:

Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019

And

Review of Preliminary Geochemical Evaluation of Sources of Water discharge at Rogers and Blue Point Springs, Southeastern Nevada

Prepared by

Thomas Butler, P.G., C.H.G., C.E.G.

Stantec Inc.

Stantec

Memo

To:	Mr. Greg Bushner, R.G. Vice President of Water Resource Development Vidler Water Company	From:	Thomas Butler, PG, CHG, CEG Senior Hydrogeologist/Geochemist
		Date:	August 16, 2019

Reference: Review of Preliminary Geochemical Evaluation of Sources of Water discharge at Rodgers and Blue Point Springs, Southeastern Nevada.

This memo has been prepared to provide comments to the report titled *Preliminary Geochemical Evaluation of Sources of Water discharge at Rodgers and Blue Point Springs, Southeastern Nevada,* dated September 2012 and prepared by Geochemical Technologies Corporation and Tetra Tech (Report). In the following sections, italicized text is provided as direct quotes from the Report, while plain text is provided as comments.

Comment 1, Page 17, Paragraph 1 and 2 states: *Blue Point Spring δD of -93 ‰ and $\delta^{18}O$ of -12.4 ‰ contrast with the carbonate wells that have an average δD of -97 ‰ and $\delta^{18}O$ of -13 ‰. This difference is significant and results in a separation of the plotted values (Figure 2). If the water emerging from Rogers and Blue Point Springs is principally water that originates in the carbonate aquifer, and is modified only by reaction with reactions with rocks or other water along the flow path, then there are only two explanations for the difference in the isotopic values. The shift to more enriched values would occur if the spring water has been evaporated or has mixed with a water with a more enriched signature.*

It is clear that relying on evaporation as a cause is not plausible since both springs have values that plot on the MWL.

The difference in water isotope values (δ^2H and $\delta^{18}O$) from Rogers and Blue Point Springs from that of the average computed value for the carbonate aquifer are not significant, as inferred in the Tetra Tech Report (September 2012). The process of evaporation can reasonably occur as groundwater moves from a deeper aquifer (such as the carbonate aquifer) to much shallower zones that are in contact with the atmosphere or as it pools at/near the surface. To test this hypothesis a simple evaporation model was constructed using published enrichment factors. Based on that model, the δ^2H and $\delta^{18}O$ values at Rogers and Blue Point Springs can be approximated by evaporating only 5% of the water that has original isotope values similar to that of the average computed values for the carbonate aquifer wells, suggesting this process could indeed explain the values found at Rogers and Blue Point Springs. Therefore, in contrast to the findings of the Tetra Tech Report, evaporation is a process that can account for the slightly more enriched values of δ^2H and $\delta^{18}O$ present at Rogers and Blue Point Springs. Note that we agree with the finding that mixing could also account for the isotopic values at Rogers and Blue Point Springs.

Comment 2, Page 20, Point 2, Preliminary Modeling Results states: *The δD and $\delta^{18}O$ compositions of Blue Point Spring can only be matched by addition of recharge water with a heavier isotopic composition than the water from the three postulated source areas. This implies mixing of local recharge. The Muddy Mountains are the most feasible source of recharge. ^{14}C data from the Simplot and Valley of Fire wells support this conclusion. The ^{14}C value from Blue Point Spring is best matched by using a source of water in the southern part of the study area.*

Similar to comment 1, the isotopic composition of water at Rogers and Blue Point Springs are not that different and can be modeled by evaporating only 5% of water from the average computed values of the carbonate wells.

Reference: **Review of Preliminary Geochemical Evaluation of Sources of Water discharge at Rodgers and Blue Point Springs, Southeastern Nevada.**

Stantec Consulting Services, Inc.

Thomas Butler, PG, CHG, CEG
Senior Hydrogeologist/Geochemist

Phone: 925-296-2126
thomas.butler@stantec.com

References:

CH2M Hill, 2006. Hydrologic Assessment of Kane Springs Hydrographic Area (206): Geochemical Framework, Presentation to the office Nevada State Engineer, April 2006. 42 pages.

Stantec

Memo

To:	Mr. Greg Bushner, R.G. Vice President of Water Resource Development Vidler Water Company	From:	Thomas Butler, PG, CHG, CEG Senior Hydrogeologist/Geochemist
		Date:	August 16, 2019

Reference: Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019.

This memo has been prepared to provide comments to the report titled *Water-Level Decline in the LWRFS: Managing for Sustainable Groundwater Development,* dated July 3, 2019 and prepared by Cady Johnson and Martin Mifflin of Mifflin & Associates, Inc (Report). Specifically, comments provided herein address portions of the report focusing on the interpretation of geochemical data as it relates to the potential movement of groundwater within and between Kane Springs Valley (KSV), Coyote Spring Valley (CSV), and the Muddy River Springs Area (MRSA). In the following sections, italicized text is provided as direct quotes from the Report, while plain text is provided as comments. As the Report did not present extensive tabular summaries of water chemistry data, Appendix C from the report titled *Hydrologic Assessment of Kane Springs, Hydrogeographic Areas (206): Geochemical Framework by CH2M Hill*, dated April 2006 *(CH2M Hill Report)* was utilized extensively for discussion purposes. The major finding of the discussion provided below is that, based on the analysis of available geochemical and isotope data, KSV is not likely part of the MRSA capture zone, as suggested, and is instead likely locally mixing with northeastern portions of the CSV represented by CSVM-4. Recently collected geophysical data obtained in this region support this conclusion and suggest that the northeastern CSV and KSV are structurally isolated from the greater groundwater flow system to the south and southeast.

Comment 1, Page 14, Paragraph 1 states: *The groundwater captures zones for Las Vegas Valley and Pahranagat Valley bound the MRSA capture zone to the west, forming an important hydrodynamic divide that should be recognizable from diagnostic chemical (F, As) and isotopic (D, ^{18}O, $^{87}Sr/^{86}Sr$, $^{243}U/^{238}U$) differences.*

When evaluating groundwater chemistry data for markers of groundwater sources, movement, or to identify groundwater capture zones it is important to identify those constituents that are conservatively transported in groundwater, that is they do not readily participate in geochemical reactions that may affect concentration significantly and be spatially transient, regardless of groundwater flow. Arsenic, in particular, is the exact opposite of the definition of a “conservative” constituent and thus should not be used to identify groundwater movement, groundwater sources, or potential captures zones. Specifically, arsenic concentrations are significantly affected by many processes including geothermal activity, REDOX potential, pH, and the presence of iron oxyhydroxides. Accordingly, processes that release arsenic to groundwater include hydrothermal activity, low pH, and reducing conditions (low REDOX). Conversely, arsenic is removed from solution as water oxidizes or as arsenic is adsorbed by iron oxyhydroxides that may be present in the aquifer matrix, causing the measured concentrations to vary significantly spatially. The elevated concentration within southern KSV at KPW-1 was 46 ug/l and illustrates this point perfectly. This high concentration is not observed to this magnitude elsewhere in the Lower White River Flow System (LWRFS) and is likely due to a combination of reducing conditions and local hydrothermal activity. At best, due to the lack of similarly high arsenic concentrations at other locations within the LWRFS, one could conclude that the transport of high arsenic groundwater out of southern KSV is not occurring. A similar discussion of how fluoride is an ineffective geoforensic marker is provided in the Comment 2 discussion below.

Reference: **Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019.**

Comment 2, Page 14, Paragraph 1 states: *The MRSA capture zone is characterized by dissolved fluoride concentrations that can exceed 4 mg/liter, whereas groundwater in the Las Vegas Valley and upstream Pahranagat Valley capture zones have dissolved fluoride generally well below 1 mg/liter.*

(1) Fluoride should not be used as a geochemical marker to define the MRSA capture zone principally due to the fact that the concentration range in virtually each basin is too similar to make it a diagnostic marker. Conversely, (2) the temperature dependent solubility of the mineral fluorite does provide evidence that groundwater is not likely flowing from the southern portion of Kane Springs Valley (the most hydraulically down gradient portion of the KSV) or northeastern CSV into the MRSA. A discussion of these two points is provided as follows:

The Report is stating that fluoride concentrations are diagnostic in determining the source of water to the MRSA (e.g., the capture zone) and that elevated fluoride concentrations in the southern KSV (KPW-1, F = 6.1 mg/l) and the northeastern portion of CSV (CSVM-4, F = 4.6 mg/l) indicate that groundwater from these areas is flowing into the MRSA as they have concentrations greater than 4 mg/l. I do not agree with this interpretation. In fact, the highest concentrations of fluoride in the KSV is at well KPW-1, located in the southern most portion of the KSV and upgradient of CSV and MRSA. However, none of the fluoride concentrations measured in the MRSA approach the concentration measured at KPW-1 (or CSVM-4). Instead, MRSA fluoride concentrations range from 1.2 to 2.3 mg/l, similar to that measured in most of the other basins in the LWRFS, making it non-unique and thus not a useful marker in defining the MRSA capture zone. In fact, if fluoride were to be used as a geochemical marker of groundwater flow, it would have been more plausible to use the elevated concentrations in southern KSV to illustrate how groundwater is not flowing from KSV to the MRSA as the concentrations in southern KSV and northeastern CSV are not found anywhere else in the studied groundwater system.

It is important to note that a potential process responsible for the elevated fluoride concentrations at KPW-1 and CSVM-4 is the temperature dependence of the solubility of the mineral fluorite. Fluorite is a mineral associated with hydrothermal activity and common in carbonate and volcanic rocks. To test this hypothesis (temperature dependent solubility control on fluoride concentrations), a simple geochemical equilibrium model was constructed using the USGS modeling software PHREEQC, modeling the concentration of fluoride in equilibrium with the minerals fluorite and calcite, at KPW-1, and as a function of temperature (Figure 1). The blue line in Figure 1 indicates the modeled equilibrium concentration of fluoride as a function of temperature. The modeled equilibrium fluoride concentration at KPW-1 was found to be 6.2 mg/l at the actual measured sample temperature of 57 °C, compared to the actual measured concentration of 6.1 mg/l, demonstrating the local geothermal control on fluoride concentrations at this location. Similarly, the measured temperature at CSVM-4 was 41.6 °C with a modeled fluoride concentration of 4.9 mg/l, again comparing well to the measured concentration of 4.6 mg/l. As can be seen from Figure 1, of all the samples, where both fluoride concentration and temperature were available from the CH2M Hill Report (April 2006), only KPW-1, CSVM-4, and Little Ash Spring are near equilibrium with the mineral fluorite, suggesting these sample locations are unique compared to other samples in the LWRFS.

Similarly, the green line in Figure 1 illustrates the concept of completive ion effect to mineral solubility. Adding the mineral gypsum (another common mineral) to the equilibrium system, has the effect of reducing the solubility of the mineral fluorite. Therefore, in contrast to KPW-1, CSVM-4, and Little Ash Spring, the green line indicates that the rest of the samples within the LWRFS also may be influenced by gypsum solubility or are in disequilibrium, likely due to reaction kinetics (lack of sufficient residence time to reach equilibrium). These data again demonstrate that over most of the LWRFS, fluoride is a poor indicator of water source due to similar concentration ranges and apparent equilibrium with fluorite-calcite-gypsum or disequilibrium.

Reference: Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019.

Conversely, KPW-1, CSVM-4, and Little Ash Spring are unique and appear to be near equilibrium with the minerals fluorite and calcite, providing evidence that water from these areas is not a significant source of water to other portions of the LWRFS, including the MRSA. It is important to note that although other geochemical evidence, including major cations and anions, water and carbon isotopes, fluoride, and temperature all suggest that KPW-1 and CSVM-4 may be related, this is not the case for Little Ash Spring, which is geochemically different (see Piper and Durov Diagrams below) to water from these two wells. The only similarity between Little Ash Spring and KPW-1 and CSVM-4 appears to be equilibrium with the mineral fluorite.

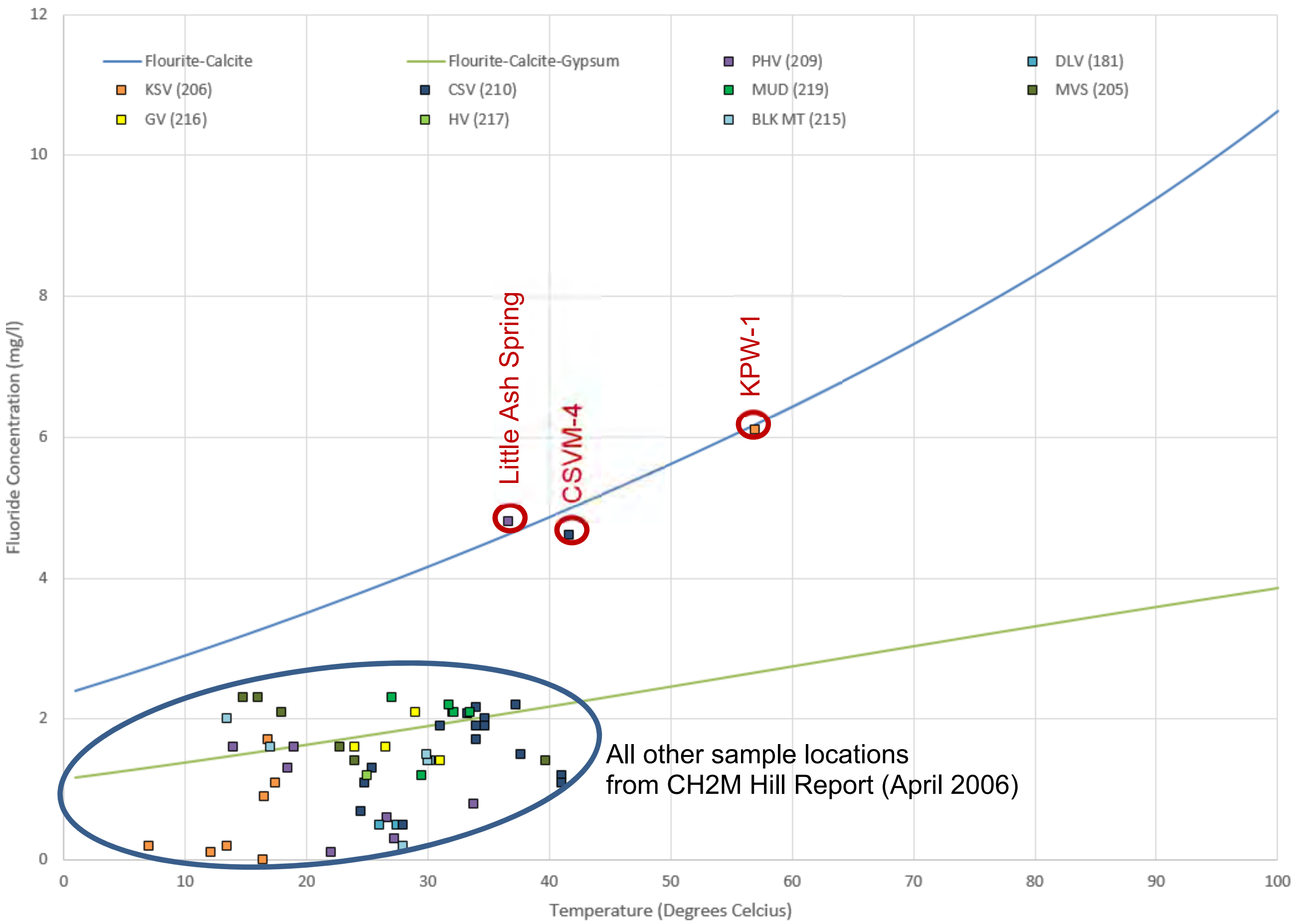

Figure 1: Fluoride concentrations from equilibrium of fluorite and changes in temperature.

Comment 3, Page 14, Paragraph 1 states: *Much depleted deuterium and ^{18}O are (values) are to be expected in groundwater west of the divide (blue dots on Figure 1) that is tributary to Pahranagat or Las Vegas Valley, while elevated fluoride and arsenic are expected to the east in water bypassing Panaca Spring and tributary to the MRSA (Johnson and Mifflin 2019).*

Reference: Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019.

The water isotopes δ^2H and $\delta^{18}O$ data presented in Appendix C of the CH2M Hill Report (April 2006) illustrate the opposite may be occurring, with δ^2H and ^{18}O values from samples collected southwest of the groundwater divided (Figure 1, Johnson and Mifflin, July 2019) in CSV being more enriched (less negative/heavier) than samples collected within northeastern CSV, southern KSV, or the MRSA. In fact, the δ^2H and $\delta^{18}O$ values in southern KSV and northeastern CSV are generally more depleted (more negative/lighter) compared to most sample sites presented in the CH2M Hill Report (April 2006). The isotopically light values of δ^2H and $\delta^{18}O$ in southern KSV and northeastern CSV likely reflect the source of recharge being at higher elevations or during a cooler period in earth's history. Other samples within KSV are not as light suggesting a different recharge source to the north and/or potential deep circulation of groundwater in the vicinity of KPW-1 and CSVM-4 from distance, supported by the elevated water temperatures at these locations and presence of numerous faults.

Comment 4, Appendix I, Page 41, Figure 1: Conceptual model for groundwater system in terminal "LWRFS" flow corridor, with bounding faults from Felger and Beard (2010).

Figure 1 from Appendix I of the Report depicts the MRSA capture zone with regional and local groundwater flow vectors, with KPW-1 from the KSV within the MRSA capture zone. Available geochemical and isotope data do not support the conclusion that KPW-1 is in the MRSA capture zone. In addition to the discussion in the previous comments, Figure 2 represents a Piper Diagram constructed using data from the CH2M Hill Report (April 2006). As can be seen from this figure, the chemistry data from southern KSV and northeastern CSV, represented by KPW-1 (solid blue circle) and Willow Spring (solid black circle) and CSVM-4 (solid purple circle), are chemically dissimilar to wells in central CSV (solid diamonds) or the MRSA (open stars), providing chemical evidence that water from KVS is not flowing to the MRSA capture zone, as suggested by the CSV-MRSA mixing arrow (black arrow in Figure 2). Furthermore, groundwater/springs from northern portions of KSV (open circles) are chemically dissimilar from CSV, MRSA, and southern KSV groundwater despite groundwater flow vectors suggesting a southerly/southwestern flow in this area. Mixing between water sources present in the MRSA and central CSV cannot however be ruled out. Figure 3 is a Durov Diagram (similar to a Piper Diagram but also incorporates salinity and pH) and also illustrates potential mixing between central CSV and MRSA area wells (black arrow), with KPW-1, Willow Spring, and CSVM-4 again being chemically dissimilar and not plotting on the mixing trend line.

Reference: **Review of Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, dated July 3, 2019.**

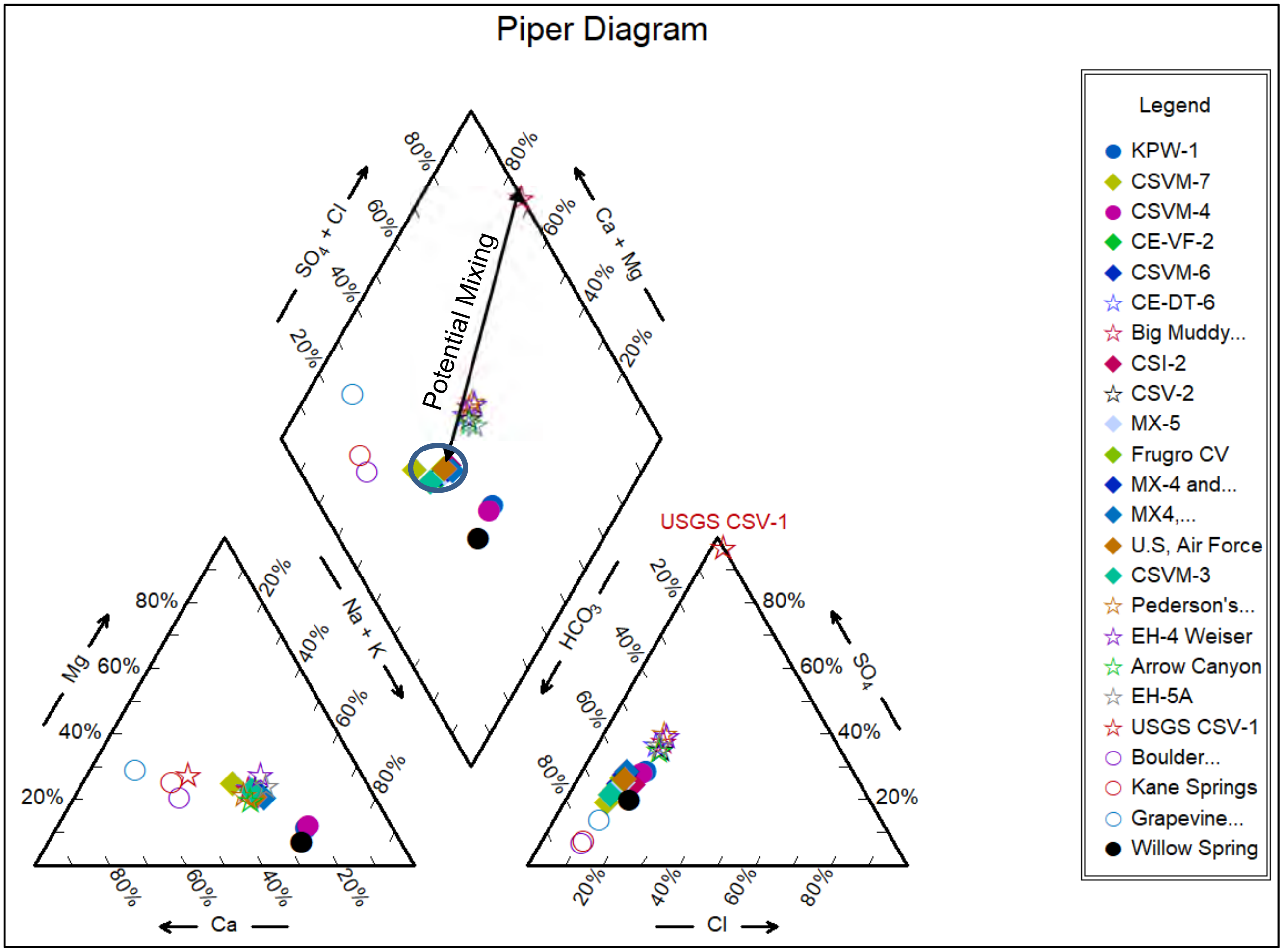

Figure 2: Piper Diagram depicting groundwater geochemistry from southern KSV, northern CSV, central CSV, Muddy River Springs, and Black Mountain basins. Circled area depicts central CSV well chemistry (solid diamonds), open stars are wells from the Muddy Springs Basin, solid circles depict southern KSV and northern CSV wells, and open circles are for northern KSV springs.

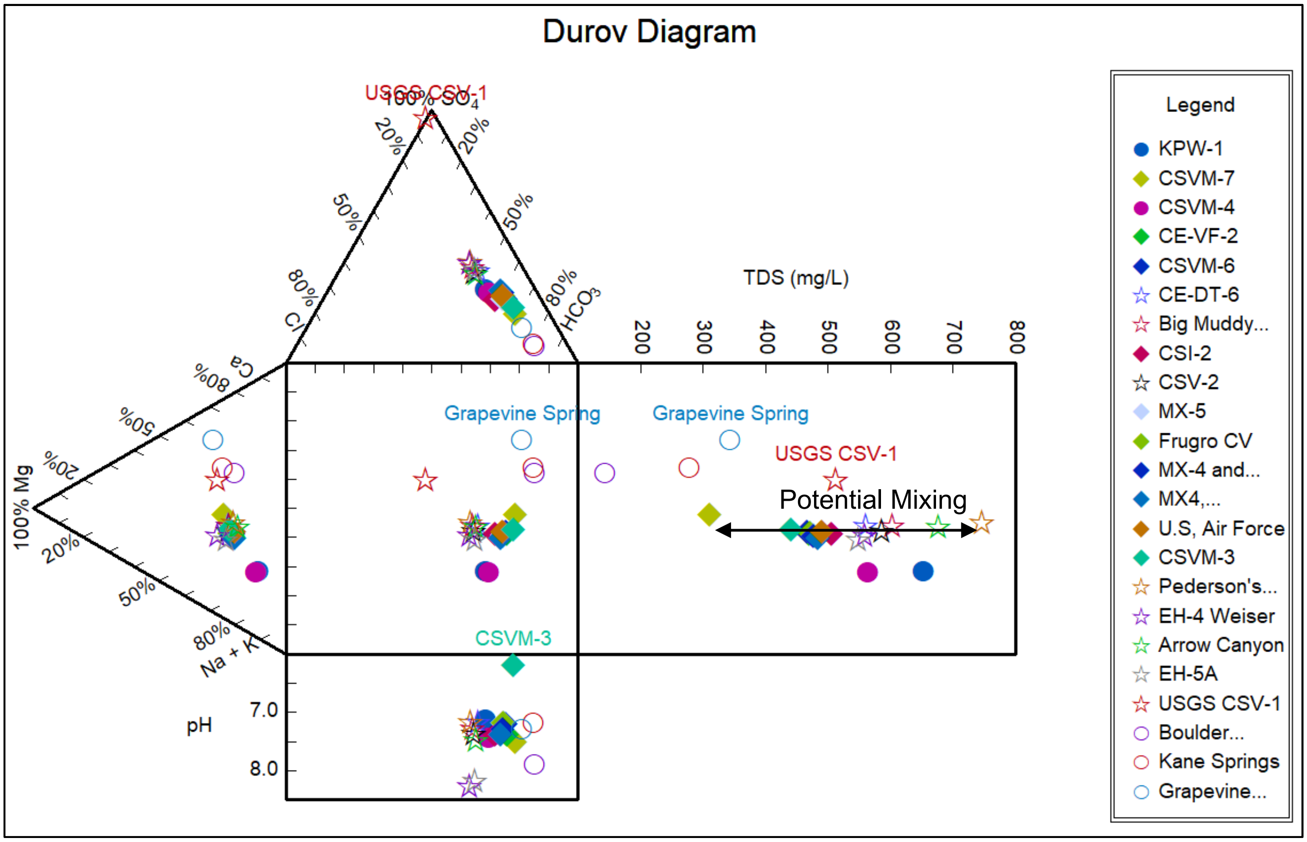

Figure 3: Durov Diagram depicting groundwater geochemistry from southern KSV, northern CSV, central CSV, Muddy River Springs, and Black Mountain basins. Circled area depicts central CSV well chemistry (solid diamonds), open stars are wells from the Muddy Springs Basin, solid circles depict southern KSV and northern CSV wells, and open circles are for northern KSV springs.

Comment 5, Appendix III, Page 54, Second Paragraph states: *Preston Big Spring (northern White River Valley) shows 11.2 pmc, Crystal Spring in Pahrangat Valley has ~6.2 pmc for an apparent age difference of 4,941* years…. *Big Muddy Spring (MRSA) has 9.7 pmc, which is not consistent with Pahranagat Valley source without significant local (younger) input suggested by Thomas and others (1996).*

It is important to note that southern KSV and northeastern CSV, represented by KPW-1 and CSVM-4, have even lower percent modern carbon values than Pahrangat Valley, with reported values of 2.7 and 4.2 pmc, respectively. Therefore, groundwater from these regions are also inconsistent with a groundwater source (capture zone) for the MRSA, as they are older than MRSA groundwater, and cannot be accounted for without a significant influx of younger water into the MRSA. Furthermore, matrix diffusion cannot account for the differences, as KSV is hydraulically up gradient of the MRSA and thus the longer groundwater flow path would result in the input of more ^{14}C dead carbon to the system, resulting in less (older) pmc values in the MRSA, not the higher pmc values (younger) that are actually observed. Instead, based on pmc data provided in *Hydrologic Assessment of Kane Springs, Hydrogeographic Areas (206): Geochemical Framework*, dated

April 2006, the more plausible source of water entering the MRSA would be from the west and from the central portions of the CSV, not from KSV.

As previously stated, the intent of this discussion is to provide additional information regarding the geochemical discussions embedded in the Report. Accordingly, based on the interpretation of available geochemical and isotope data previously provided as part of the *Hydrologic Assessment of Kane Springs, Hydrogeographic Areas (206): Geochemical Framework*, dated April 2006 study, the KSV is not part of the MRSA capture zone, as suggested in the Report. KSV is instead likely locally mixing with northeastern portions of the CSV, represented by CSVM-4. Recently collected geophysical data obtained in this area (Lincoln County Water District and Vidler Water Company, 2019) support this conclusion and suggest that the northeastern CSV and KSV are structurally isolated from the greater groundwater flow system to the south and southeast, including the MRSA.

Stantec Consulting Services, Inc.

Thomas Butler, PG, CHG, CEG
Senior Hydrogeologist/Geochemist

Phone: 925-296-2126
thomas.butler@stantec.com

References:

CH2M Hill, 2006. Hydrologic Assessment of Kane Springs Hydrographic Area (206): Geochemical Framework, Presentation to the office Nevada State Engineer, April 2006. 42 pages.

Johnson and Mifflin, 2019. Water-Level Decline in the LWRFS: Managing for Sustainable Groundwater Development, Initial Report of Mopa Band of Paiutes in Response to Order #1303. Submitted to the Nevada State Engineer July 3, 2019. 39 pages.

Lincoln County Water District and Vidler Water Company, 2019. Lower White River Flow System Interim Order #1303 report focused on the Northern Boundary of the proposed administrative unit. Submitted to the Nevada State Engineer July 3, 2019. 47 pages.

Attachment D

Technical Memorandum

Subject: Drought and Groundwater

Prepared by

Todd Umstot

Daniel B. Stephens & Associates, Inc.

TECHNICAL MEMORANDUM

To: Greg Bushner, Vidler Water Company.

From: Todd Umstot

Date: August 16, 2019

Subject: Drought and Groundwater

I, Todd Umstot, from Daniel B. Stephens & Associates, Inc. (DBS&A) have reviewed the reports presented before the Nevada State Engineer (NSE) regarding Interim Order 1303 as they pertain to the inclusion of Kane Springs Valley (KSV) into the Lower White River Flow System (LWRFS), an administrative unit of six conjoined basins designated by the NSE. The NSE defines the LWRFS as the hydrographic areas (HAs) of Coyote Spring Valley (CSV) (HA 210), Hidden Valley (HA 217), Garnet Valley (HA 216), California Wash (HA 218), Muddy River Springs Area (HA 219), and the northwest portion of the Black Mountains Area (HA 215) (NSE, 2019). The KSV is located northeast of the CSV and the LWRFS. The KSV and Northern CSV are separated from the southern LWRFS by a low-permeability structure or change in lithology (NSE, 2007). I also reviewed drought, precipitation, and groundwater elevation data for the LWRFS region.

In my review, I evaluated (1) whether there has been an increase in the frequency of drought in southern Nevada over the past two decades, (2) whether the groundwater elevations in Northern CSV and KSV are influenced by drought and precipitation, and (3) whether monitoring wells CSVM-4 in Northern CSV and KMW-1 in KSV were influenced by pumping at the MX-5 well during the two-year aquifer test (November 15, 2010 through December 31, 2012) referred to as the Order 1169 Aquifer Test. I found that (1) there has been an increase in the frequency of drought in southern Nevada, (2) groundwater elevations in wells CSVM-4 and KMW-1 show a response to recharge and drought, and (3) CSVM-4 and KMW-1 respond to trends in precipitation and drought and were not influenced by pumping at MX-5 during the Order 1169 Aquifer Test.

Long-Term Trends in Precipitation and Drought Indicate an Increase in Drought Conditions

SNWA (2019) reports that southern Nevada has been wetter since 1965 than was found previously from 1895 through 1964 (SNWA, 2019, section 5.1.1), and therefore drought has not influenced recent water levels. However, the Palmer Drought Severity Index (PDSI) (NOAA, 2019) for southern Nevada (Nevada Climate Divisions 3 and 4) indicates an increase in drought conditions over recent decades (Figures 1 and 2). The PDSI measures the cumulative departure in the surface water balance based on precipitation, temperature, and soil moisture conditions. The PDSI for Nevada Climate Division 4 indicates that the occurrence of drought is higher in recent decades. The PDSI from 1895 through 1964 had an occurrence of drought in 58 percent of the months. Since 1965, drought conditions have occurred in 69 percent of the months. Figure 3 shows the occurrence of drought by decade for Nevada Climate Divisions 3 and 4. The 1980s were relatively wet compared to other decades, but subsequent decades have shown an increased occurrence of drought. Long-term trends in groundwater levels are affected by an increase in drought conditions (e.g., GGI, 2019, p. 3). A long-term increase in drought will lead to a general decline in groundwater levels and spring flows without any groundwater pumping. These long-term trends in water levels must be accounted for when analyzing the response of wells to the Order 1169 Aquifer Test.

The Recent Increase in Drought Conditions Affects Groundwater Elevations in Kane Springs Valley and Northern Coyote Spring Valley

The fluctuations in groundwater elevations in Kane Springs Valley at well KMW-1 and in Northern Coyote Spring Valley at well CSVM-4 are due to precipitation and drought. Figures 4 and 5 show a comparison between KMW-1 and CSVM-4, respectively, and the 12-month trailing average in the PDSI. The 12-month trailing average PDSI is the average monthly PDSI over the current month and the previous 11 months. The plots show an extraordinary wet period in the PDSI record in 2005 with a peak in fall 2005 that corresponds with a peak in groundwater elevations at CSMV-4 about a year later in fall 2006. The PDSI returns to drought conditions in 2006 and then generally increases to normal conditions by the end of 2010. The groundwater elevations at CSVM-4 and KMW-1 are relatively stable during this period with a slightly declining trend.

Next, the PDSI has a drying trend from the end of 2010 through 2014 and the groundwater elevations at CSVM-4 and KMW-1 show a corresponding steady rate of decline over this period. This drying period includes the Order 1169 Aquifer Test and an additional 20 months after the pumping at MX-5 ends in March 2013. The start of the drying trend corresponds with the start of the Order 1169 Aquifer Test. However, the end of the drying trend does not correspond with the end of pumping at the MX-5 well. The rate of decline in groundwater elevation at CSVM-4 and KMW-1 is similar before and after the MX-5 pumping, indicating that the decline observed during the aquifer test was due to an increase in drought conditions and not the pumping at MX-5. If there was a connection between the pumping at MX-5 and the CSVM-4 and KMW-1 wells, the CSVM-4 and KMW-1 wells should have had an increase in groundwater elevation after the cessation of pumping at MX-5. The lack of an increase in the groundwater elevations at CSVM-4 and KMW-1 over 20 months after the cessation of pumping at MX-5 indicates that drought has a strong influence on the groundwater elevations at wells CSVM-4 and KMW-1. This response in the groundwater elevations to drought rather than groundwater pumping is in contrast to statements by the U.S. Fish and Wildlife Service (USFWS) that "any response to dry conditions in the record is either too incremental to observe or is obscured by the simultaneous effects of ongoing water supply pumping" (USFWS, 2019, p. 27).

After precipitation in winter 2014/2015, the PDSI remains in drought conditions, but generally increases from 2015 through 2017. Groundwater elevations are stable at CSVM-4 during this period and generally increase at KMW-1. The PDSI has a drying trend in 2018 and the groundwater elevations at CSVM-4 and KMW-1 show a slight decline. The correspondence of the PDSI and the fluctuations in groundwater elevation at CSVM-4 and KMW-1 show that the fluctuations are due to long-term drought trends; any influences from pumping cannot be discerned.

Correlation Analyses do not Support that Groundwater Elevations in Kane Springs Valley and Northern Coyote Spring Valley are Hydraulically Connected to Carbonate Wells during the Order 1169 Aquifer Test

SNWA (2019) presents correlation analyses to support a hydraulic connection between the Order 1169 Aquifer Test and wells in Kane Springs Valley and Northern Coyote Spring. However, correlation does not prove causation. For example, similar regression correlation coefficients ($r^2 = 0.68$) can be obtained between KMW-1 and EH-4 as can be found between KMW-1 and CSVM-5 (Figure 6). The similarity in regression correlation coefficients implies that there is an equal hydraulic connection between EH-4 and KMW-1 as there is between KMW-1 and CSVM-5. Well CSVM-5 was reported to have no discernable response to the Order 1169 Aquifer Test (SNWA, 2019, p. 2-1), while EH-4 did show a response to the Order 1169 Aquifer Test. Therefore, the correlation analyses on their own do not support opinions on hydraulic connection.

The correlation analysis used by SNWA is flawed in that it does not account for the error in the groundwater elevation measurements. SNWA uses correlation analysis to predict that the drawdown at CSVM-4 is 0.37 foot per foot of drawdown at MX-4, and claims that this correlation provides “undeniable” evidence of the connection between CSVM-4 and MX-5 (SNWA, 2019, p. 5-17). However, SNWA has previously reported that the water levels in the CSVM-4 have an error rate of about 1 foot:

> 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 has 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 (SNWA, 2013, p. 36).

The correlation analysis by SNWA needs to account for the error in the water level measurements at well CSVM-4 in making the prediction of 0.37 foot per foot of drawdown at MX-4.

The correlation analysis by SNWA needs to account for the downward trend in water levels due to drought in the correlation between CSVM-4 and MX-4. The groundwater elevations at CSVM-4 continued to decline for 20 months after pumping had stopped at MX-5 in March 2013 due to drought conditions (Figures 1 and 2). The decline in groundwater elevations at CSVM-4 continued until the end of 2014, when precipitation increased. The overall rate of decline due to increased drought conditions during this period was 0.47 foot per year. The combination of a downward trend in groundwater elevations due to an increase in drought at CSVM-4 and the error rate in the measurements for the CSVM-4 indicates that the groundwater elevation data cannot support a connection between CSVM-4 and MX-5.

SNWA used a 3-month lag on EH-4 groundwater elevations when correlating EH-4 with CSVM-4 (SNWA, 2019, Figure 5-10) and a 3-month lag on MX-4 groundwater elevations when correlating MX-4 with CSVM-4 (SNWA, 2019, Figure 5-14), but SNWA did not provide any support on the use of the 3-month lag. No lags were used for any other well correlations. The 3-month lag increased the correlation coefficient from 0.77 to 0.82 for the correlation between EH-4 and CSVM-4 and increased the correlation coefficient from 0.71 to 0.78 for the correlation between MX-4 and CSVM-4. The removal of the 3-month lag decreased the SNWA estimated rate of drawdown from 0.37 foot per foot of drawdown in MX-4 to 0.33 foot per foot of drawdown in MX-4.

The groundwater elevations at well MX-4 used by SNWA (2019) in their correlation analyses are inconsistent with the heads previously reported by SNWA and the heads reported by the NSE. Figure 5-14 in SNWA (2019) plots the MX-4 well with observed heads greater than 1,822 feet above mean sea level (feet msl) between November 2010 and April 2013. However, the maximum head observed during this period at well MX-4 was 1820.2 feet msl in November 2010, as was shown previously by SNWA in their report (SNWA, 2013, Figure C-54). The correlation analyses presented by SNWA (2019) between MX-4 and other wells appear to be in error.

References

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NSE. 2019. Interim Order 1303 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.

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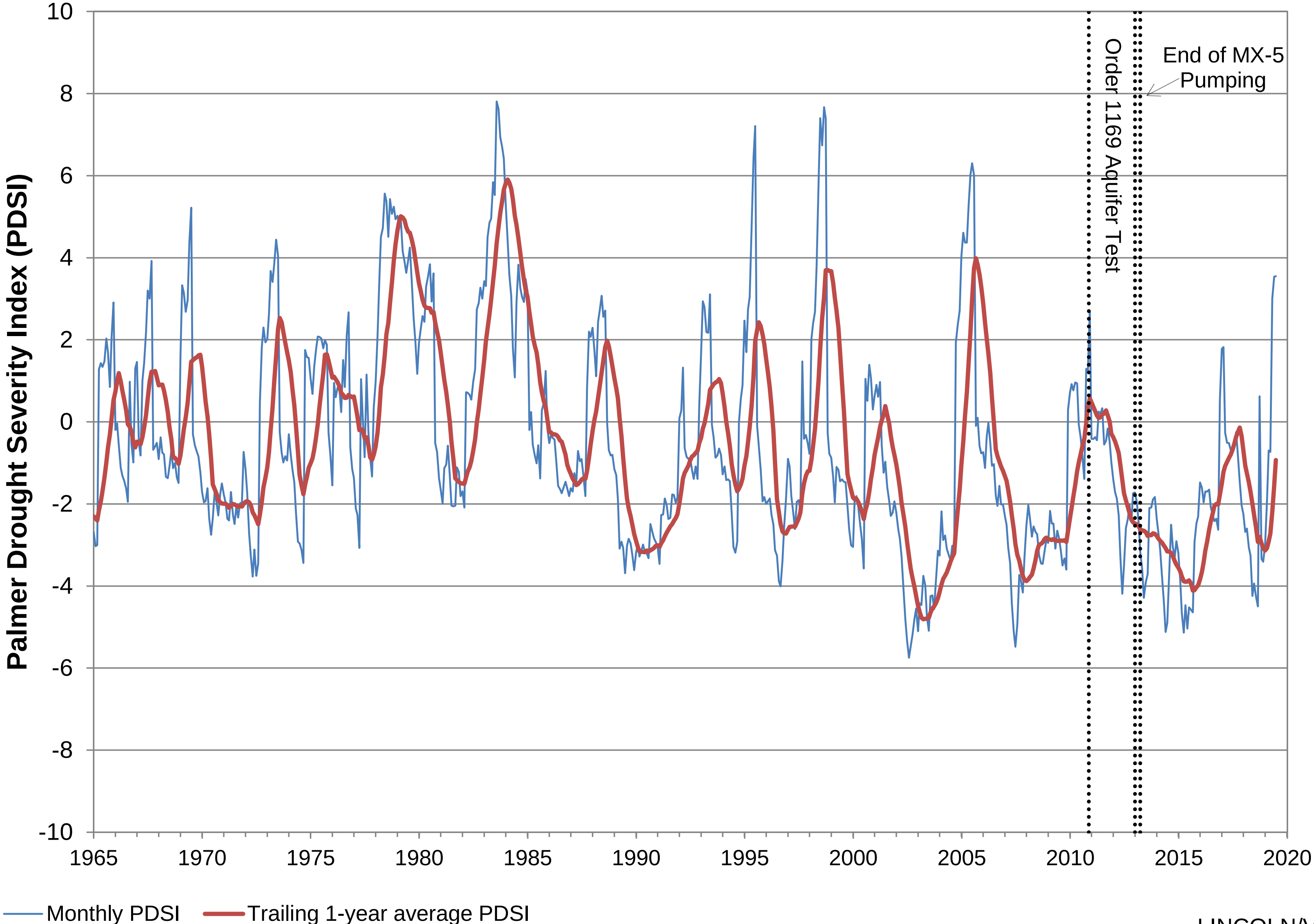


LINCOLN/VIDLER

Palmer Drought Severity Index for Nevada Climate Division 3

Figure 1

Daniel B. Stephens & Associates, Inc.

8/14/19

SE ROA 36485

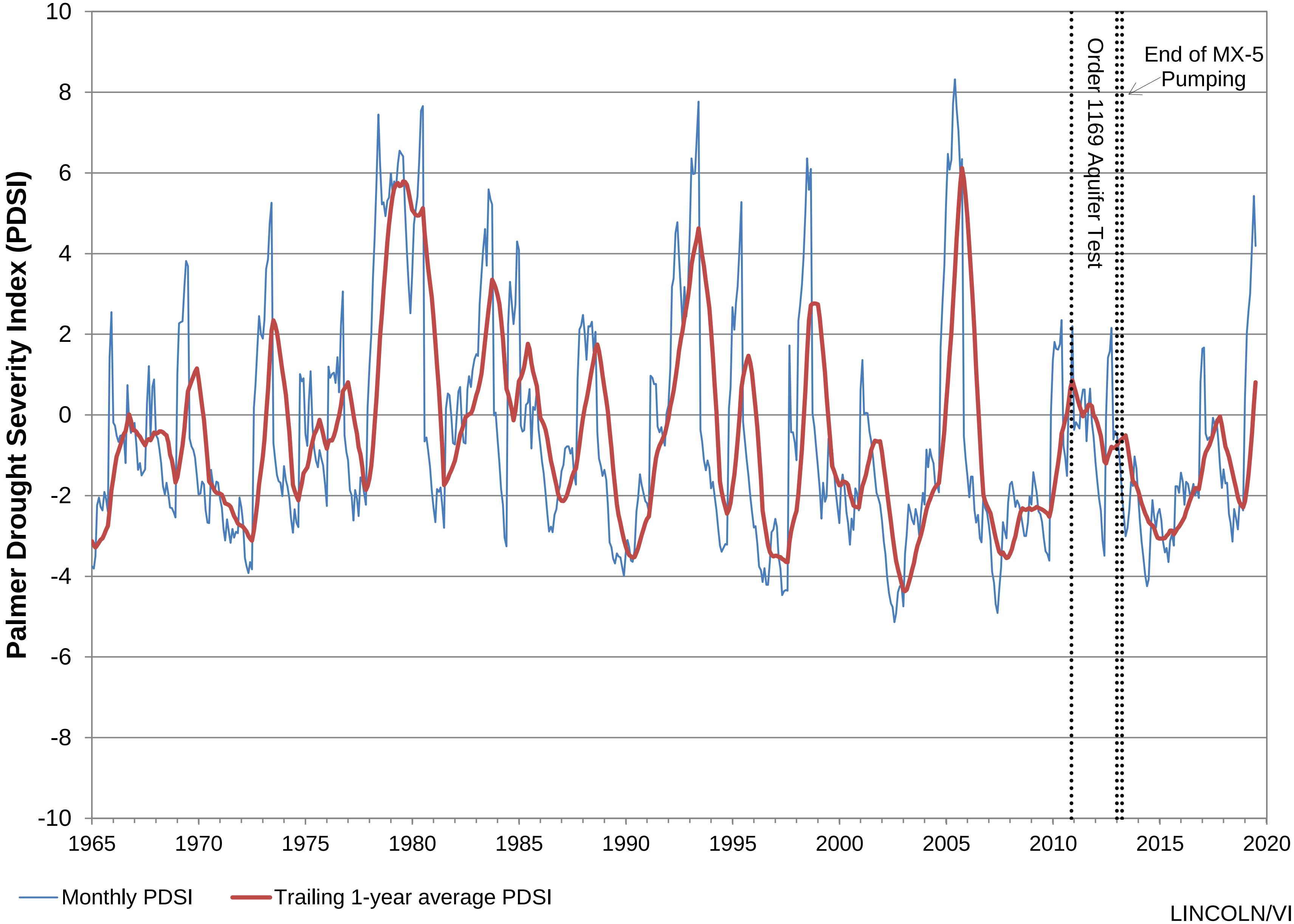


Figure 2

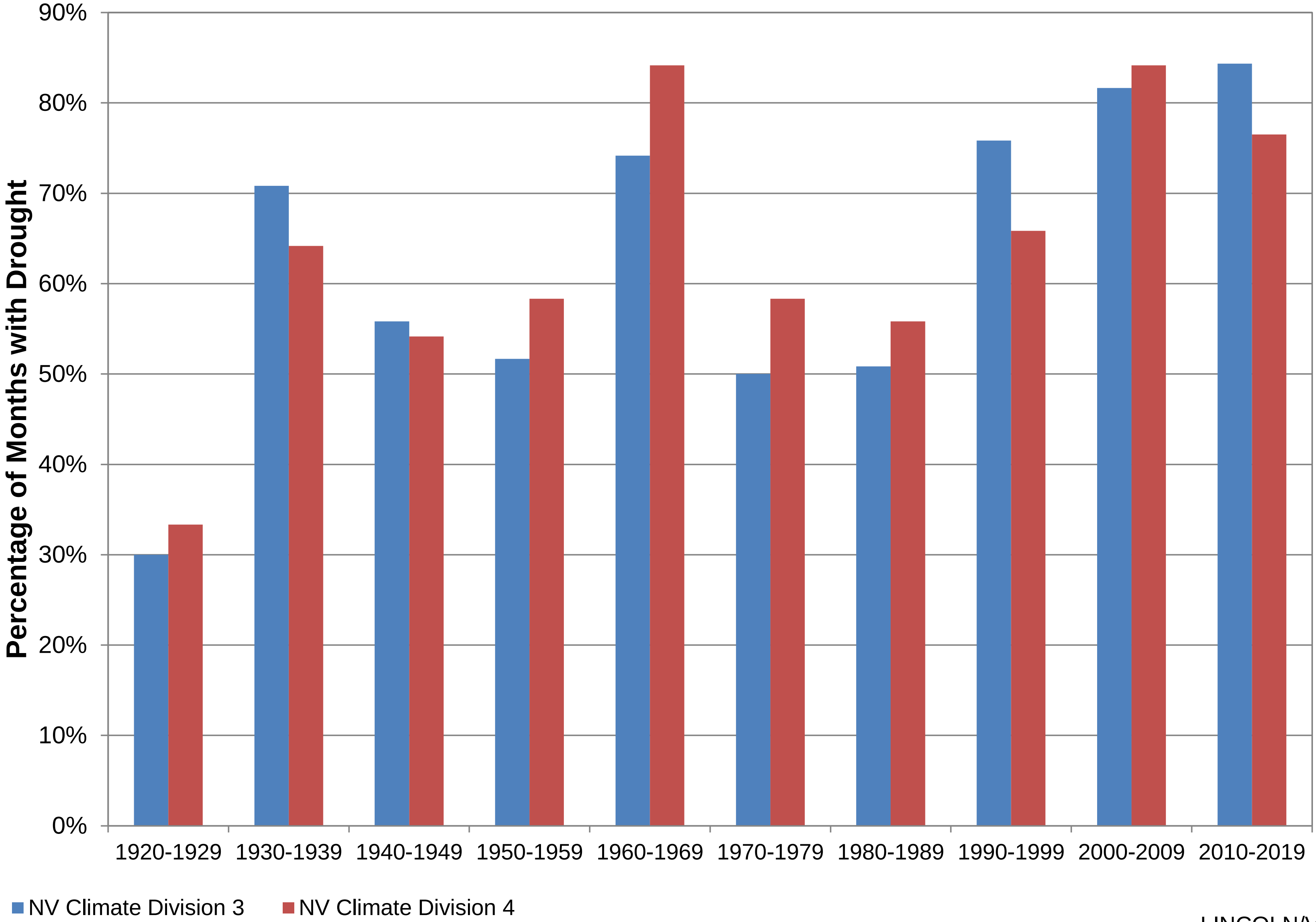
LINCOLN/VIDLER

Palmer Drought Severity Index for Nevada Climate Division 4

Daniel B. Stephens & Associates, Inc.

8/14/19

SE ROA 36486



LINCOLN/VIDLER

Occurrence of Drought in Southern Nevada by Decade from Palmer Drought Severity Index

Figure 3

Daniel B. Stephens & Associates, Inc.

8/14/19

SE ROA 36487

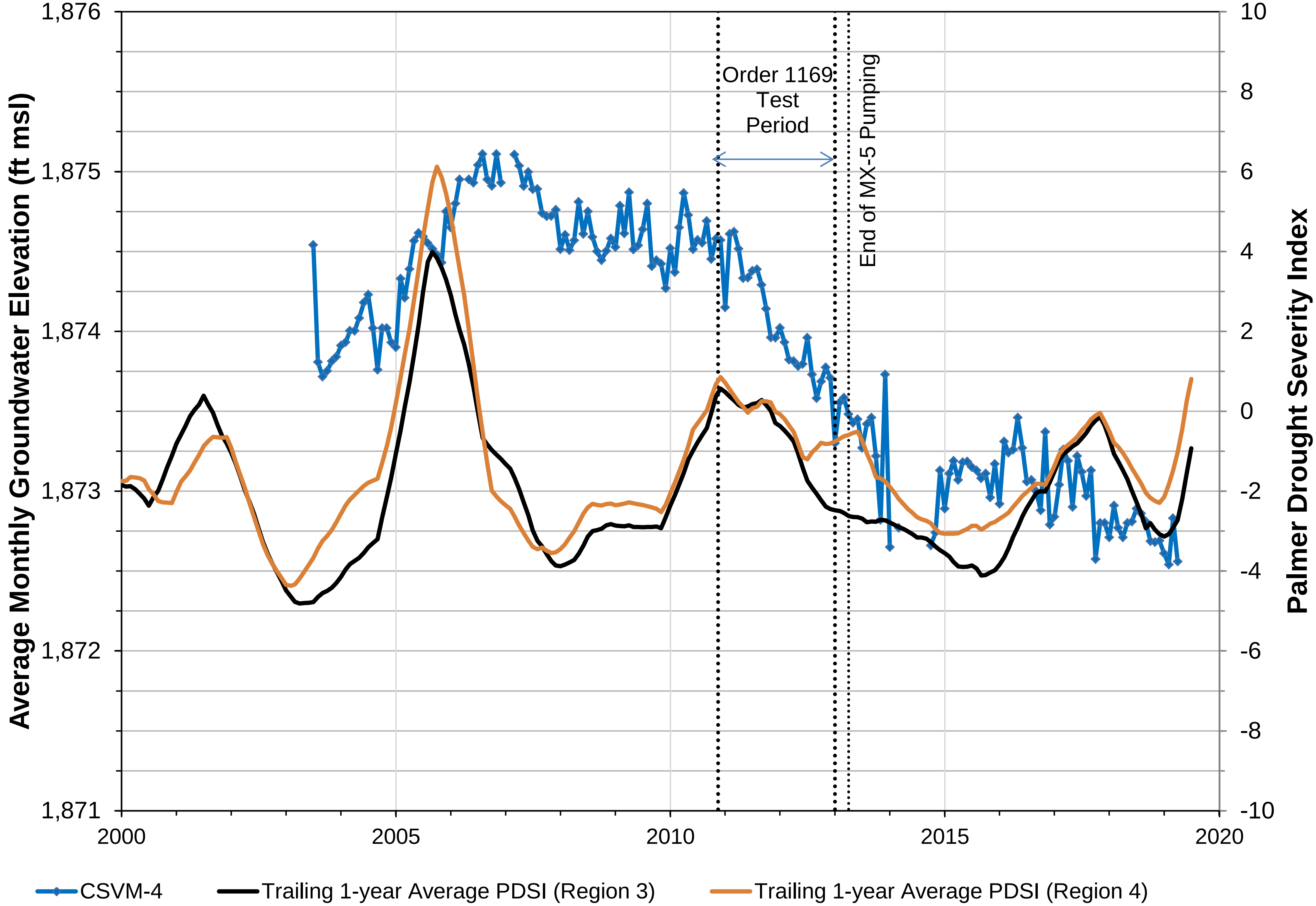


Figure 4

LINCOLN/VIDLER

Comparison of Palmer Drought Severity Index to Groundwater Elevation at CSVM-4

Daniel B. Stephens & Associates, Inc.

8/14/19

SE ROA 36488

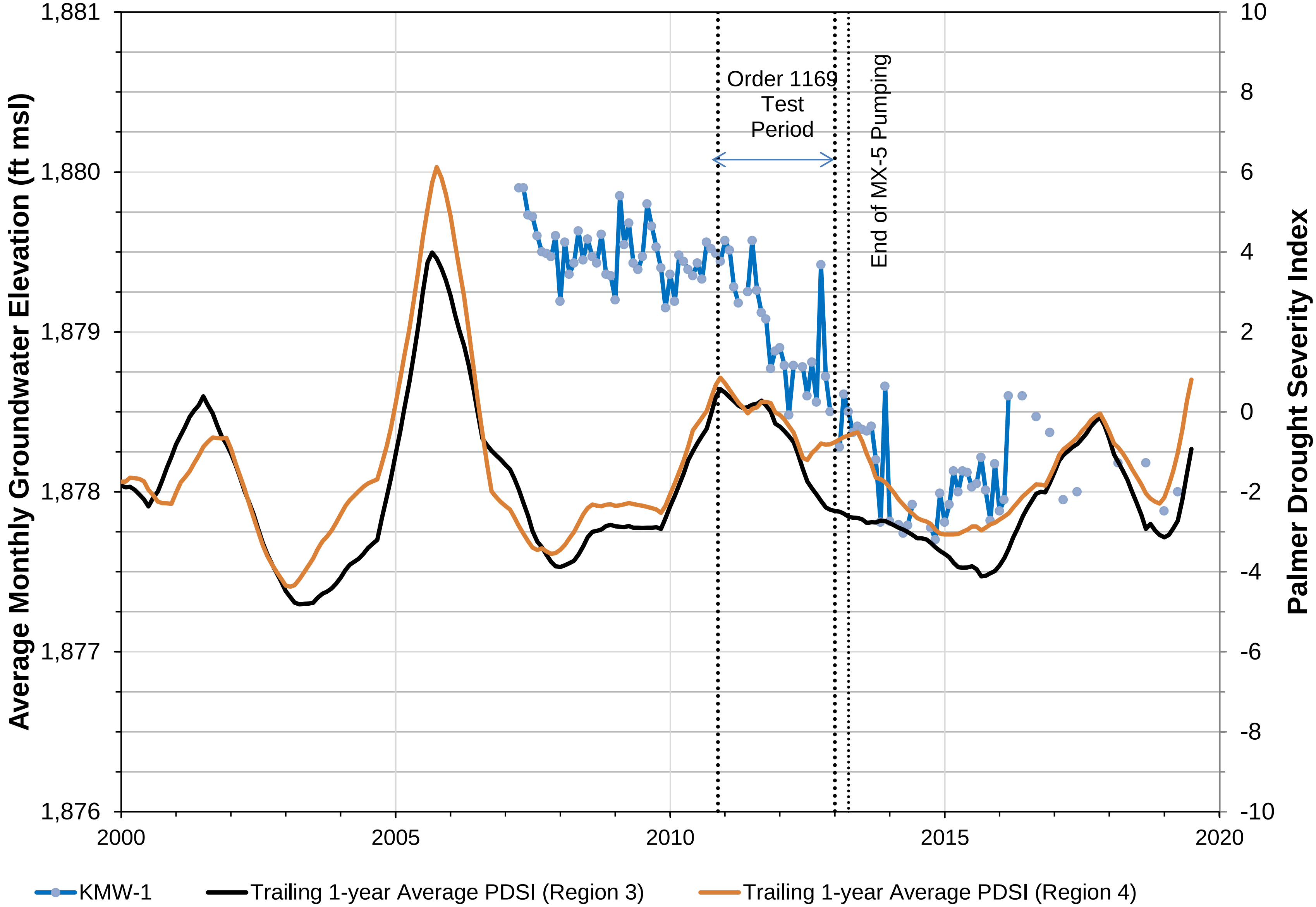


Figure 5

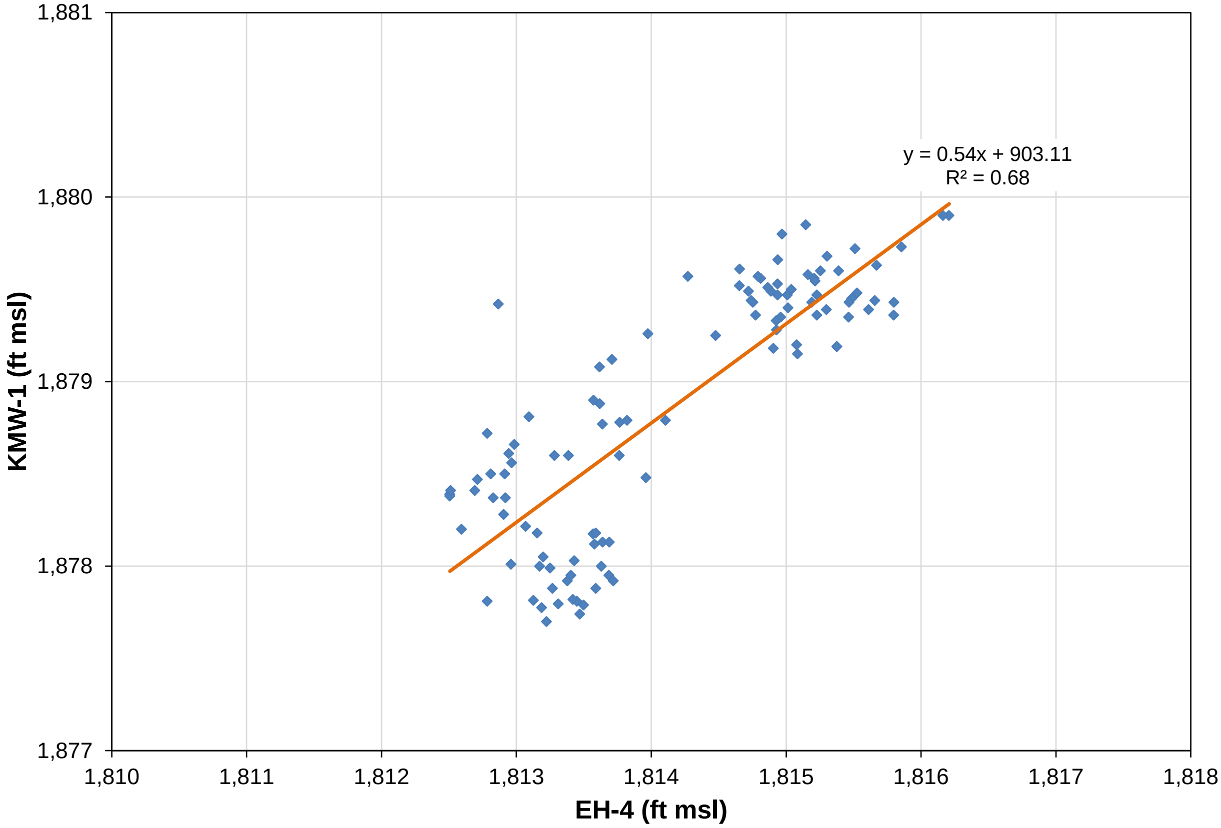
LINCOLN/VIDLER

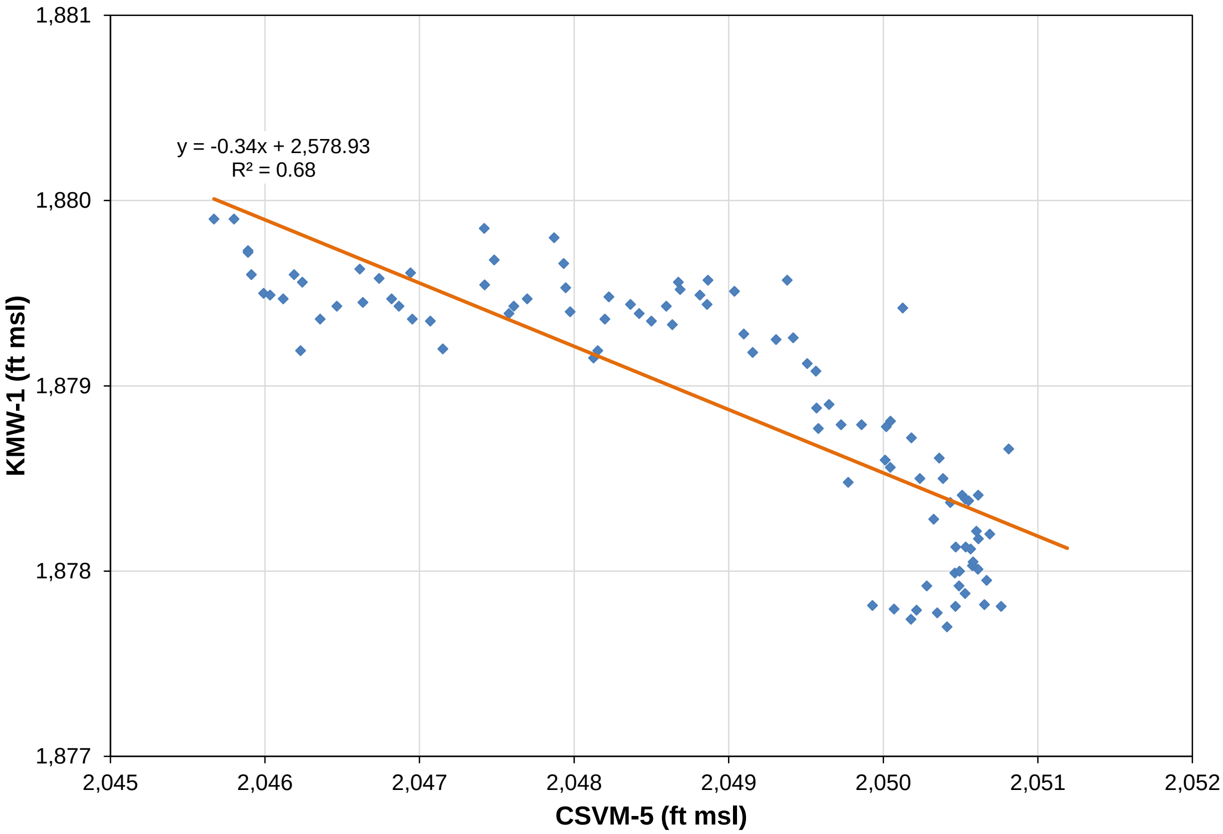
Comparison of Palmer Drought Severity Index to Groundwater Elevation at KMW-1

Daniel B. Stephens & Associates, Inc.

8/14/19

SE ROA 36489





LINCOLN/VIDLER

Correlation of KMW-1 with EH-4 and CSVM-5

Daniel B. Stephens & Associates, Inc.

8/14/19

Figure 6

Q:\Projects\LT06.0106_Vidler\Production\TechMemo.8-19\Figures\Word\Fig06_WL Crrltn.doc

Attachment E

Technical Memorandum

Re: Zonge International, Inc., Rebuttal Response to the July 3, 2019 Reports Submitted to the Nevada State Engineer in Response to IO#1303.

Prepared by

Norman Carlson

Zonge International, Inc.

TRUSTED GEOPHYSICS™

Zonge International, Inc.
3322 East Fort Lowell Road
Tucson, Arizona 85716 USA
PH 520.327.5501
FX 520.325.1588
www.zonge.com

August 16, 2019

Technical Memorandum

To: Greg Bushner
Vice President of Water Resources Development
Vidler Water Company
3480 GS Richards Blvd., Suite 101

Re: Zonge International, Inc., Rebuttal Response to the July 3, 2019 Reports Submitted to the Nevada State Engineer in Response to IO #1303.

This response is provided based on review of the Coyote Springs Investment, LLC (CSI) IO #1303 Report discussing the April 2019 Geophysical Investigation.

As noted in the CSI IO #1303 Report, one of the primary geologic reports and map sets used in the most recent investigation of was the relatively new 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", by Rowley, et. al., Nevada Bureau of Mines and Geology Report 56. This significant mapping effort was intended to compile and update numerous older studies and maps. In the Introduction of the 2017 Rowley report, it notes specifically the lack of geophysics in older reports that the 2017 work is intended to update. The value of geophysics is clear in the Rowley report. In their discussion of the preparation of the map, Rowley, et. al. remind the reader that "(S)ubsurface geometries are relatively unconstrained in cross sections constructed from surface geology alone. Therefore, geophysics and well logs, when located near the line of the sections, are valuable."

In addition, in the final paragraphs of the 5-page "Conclusions", Rowley, et. al., state:

> "Concealed normal faults, whether defining the edges of most basins or within basins, can be located by gravity (maxspots) and AMT [audio-frequency magnetotellurics] data. Upward-continued gravity and aeromagnetic maxspots and some AMT profiles can determine which way the fault or caldera wall dips. Of the two types of geophysics, AMT profiles also provide information on depths to groundwater in some parts of basins. AMT profiles are sufficiently detailed to allow siting of wells on faults, which are the best places to locate production and monitoring wells. Ideally, the best location would be a rangefront fault of a large range with abundant recharge, near

> the mouth of a perennial creek that carries some of that recharge. The objective to site a well is to drill the downthrown side of a high-angle normal fault, the larger the better, to intersect the fault beneath the water table. If the dip of this fault is not known but the direction of throw (and the depth to the water table) is, one can assume an average dip of 60 degrees, then position the drill rig with respect to the fault accordingly."

The geophysical method highlighted in the conclusion for investigating the subsurface and targeting drill holes, referred to as AMT, is the same method discussed in Lincoln/Vidler's IO #1303 Report and the CSI IO #1303 Report, referred to there as both CSAMT and AMT. AMT is a well-established geophysical method for measuring either man-made or naturally-occurring electromagnetic fields at a suite of frequencies in order to calculate resistivity at various depths in the subsurface. Many of the AMT surveys referenced in Rowley, et. al., were completed by the USGS as part of a USGS/SNWA joint funding agreement, and are published as Open-File Reports. In reviewing the AMT studies cited by Rowley, while some specific survey parameters are different from those used in Kane Springs Valley and Coyote Spring Valley, primarily due to equipment constraints such as transmitter size and power, which determines the distance between the transmitter and receiver equipment, the survey methodology and logistics are consistent with the work in Kane Springs Valley and Coyote Spring Valley.

In addition, many of the USGS reports referenced in Rowley, et. al., cite, in their introductions to the method, Zonge's description of AMT and CSAMT in our 1991 chapter in the book "Electromagnetic methods in applied geophysics", edited by M.N. Nabighian, published by the Society of Exploration Geophysicists.

We note this here primarily to highlight not only the importance of geophysics in general, but also the fact that the geophysical method used is a well-accepted, reliable technique. In decisions as important and far-reaching as the creation of the joint administrative unit, including portions of six basins, it is certainly prudent that the State Engineer base decisions on information and data from methodologies that are generally well-accepted and reliable, similar to the "Daubert Standards" established in Federal courts.

Although none of the AMT surveys included in Rowley, et. al., show results from Coyote Spring Valley, very similar results are noted in a general sense with respect to data across similar lithologies. For example, Figure 1 below shows Rowley et. al.'s Figure 28, cited from MacPhee, et. al., 2006, which is an AMT cross section crossing the southern section of Spring Valley.

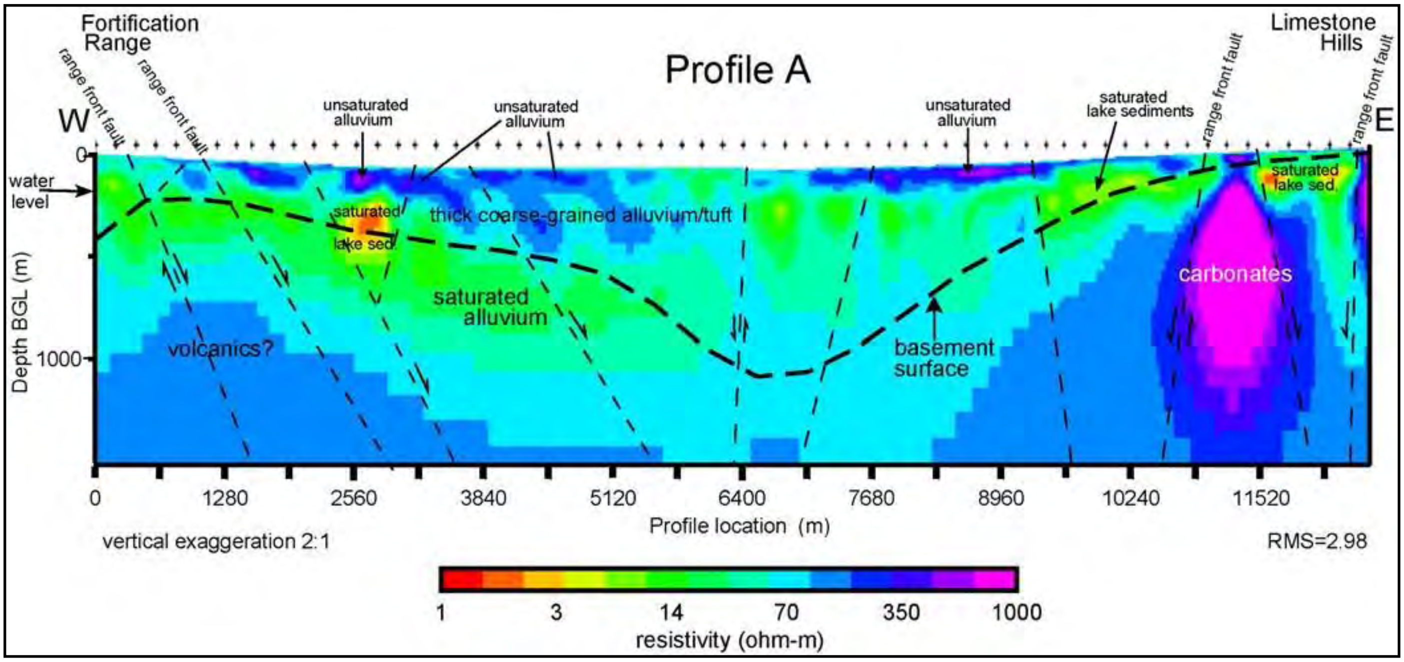


Figure 1: An AMT resistivity cross section from Spring Valley, Nevada (McPhee, et. al., 2006)

The USGS's AMT results are in good agreement with my typical results, in that carbonates are evident as very high resistivity features (1000+ ohm-meters), sharp changes are seen associated with range front faults, resistivity differences are seen associated with saturated versus unsaturated alluvium, and even some extremely low resistivities (approaching the levels of sea water) are evident in some parts of the alluvium, all of which are evident in the work in the IO #1303 Reports. The similarity of general results from different operators using different equipment systems with different processing and modeling software lends credence to the reliability of the AMT methodology. The method used for the Kane Springs Valley and Coyote Spring Valley studies is intentionally not a one-of-a-kind, "black box" system. It is a method that can be duplicated by independent scientists.

It is also useful to note that the maps and geologic cross sections (Plates 1 through 4) included in Rowley, et. al., do not include all of the faults and structure that are shown in the AMT cross sections in the Rowley report figures themselves, primarily due to simple scaling issues. Again, from Rowley's conclusions:

> "Geologic maps at 1:250,000 scale cannot do justice to the actual fault complexity of the study area, for thousands of real faults cannot be shown. AMT profiles, as presented here, determined the fault architecture of parts of some basins and of their range-bounding faults, most of which were buried by young basin-fill and surficial sediments. All of the AMT profiles shown in the geophysics chapter, and especially several of the longer profiles, demonstrate this detailed complexity."

Thus, it is clear that the additional complexity delineated in the Kane Springs Valley and Coyote Spring Valley surveys when compared to Rowley's Plate 2 map is completely consistent with Rowley's discussion and final maps.

To summarize, given the amount of ground covered by alluvial material, and the resulting "unconstrained" interpretation of the subsurface, the geophysics in Kane Springs Valley and Coyote Spring Valley is very important to the proper understanding of groundwater flow. In addition, the geophysical work in Kane Springs Valley and Coyote Spring Valley is a valid use of a well-established, scientifically accepted method to further the understanding of the subsurface.

Respectfully submitted,

STATE OF TEXAS
Norman R. Carlson
Geophysics
4703
LICENSED
PROFESSIONAL GEOSCIENTIST

Norman Carlson, PG
(Texas, License # 4703)
Chief Geophysicist
Zonge International, Inc.
www.zonge.com
Offices in Tucson, AZ and Reno, NV.

References noted above:

McPhee, D.K., Pellerin, L., Chuchel, J.E., and Dixon, G.L., 2006a, Resistivity imaging in eastern Nevada using the audiomagnetotellurics method for hydrogeologic framework studies, *in* Proceedings of the 19th Annual Symposium on the Application of Geophysics to Engineering and Environmental Problems (SAGEEP), Seattle, Washington, April 20-6, 2006, p.712-718.

Rowley, P.D., Dixon, G.L., Mankinen, E.A., Pari, K.T., McPhee, D.K., McKee, E.H., Burns, A.G., Watrus, J.M., Ekrem, 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, The University of Nevada, Reno.

Zonge, K.L., and L.J. Hughes, 1991. "Controlled source audio-frequency magnetotellurics," *in* Electromagnetic Methods in Applied Geophysics, ed. Nabighian, M.N., Vol. 2, Society of Exploration Geophysicists, pages 713-809.

Governor

STATE OF NEVADA

PETER G. MORROS
Director

R. MICHAEL TURNIPSEED, P.E.
State Engineer

DEPARTMENT OF CONSERVATION AND NATURAL RESOURCES
DIVISION OF WATER RESOURCES
123 W. Nye Lane, Suite 246
Carson City, Nevada 89706-0818
(775) 687-4380 • Fax (775) 687-6972

June 21, 2000

MEMORANDUM

TO: R. Michael Turnipseed, P.E.
State Engineer

FROM: Hugh Ricci, P.E.
Deputy State Engineer

SUBJECT: Pumping in the Carbonates

After what seems years of trying to get a plan for someone to start stressing the carbonate system and monitor its effects and failing (mainly because I tried to include too many people) I believe the following outline is a method in which to achieve the goal of stressing the carbonate system.

1. Present water use of Moapa Valley Water District (MVWD) is approximately 3,500 AF of which approximately 2,400 AF (5.5 cfs) comes from Arrow Canyon Well (ACW). At present ACW has the capability of pumping 2,900 gpm (6.5 cfs). After some time the pump is turned on the rate reduces to approximately 2,700 gpm (6.0 cfs). MVWD has filed Application No. 66043 to change permit 58269. This application to change seeks permission to move 5 cfs to another well approximately 100 feet from ACW. Upon obtaining a permit for 66043 (provided you choose to issue the permit) a new pump will be placed in the ACW to pump 2,250 gpm (5.0 cfs). The new well is scheduled to go on line in December 2000.

2. Southern Nevada Water Authority (SNWA) and MVWD have been in discussions about building a pipeline between the ACW and MX-5. This distance is approximately 10 miles. This pipeline as would be designed is that water could flow in either direction. This is in anticipation that MVWD will serve the development planned by Coyote Springs Investment which at first would be all in Clark County. SNWA would like to start on the pipeline soon, but MVWD would like to get the pumping up to close to the 10 cfs from the ACW and their new well to see what if any impacts occur as a result of that pumping. This appears to be the most prudent plan since if impacts occur at

the springs from pumping at ACW then the pipeline would be reassessed. The reassessment could include shutting down of ACW and pumping MX-5.

3. My recommendations are (and I believe in the order listed):

a. Set a meeting with SNWA, Nevada Power Company (NPC), MVWD and Coyote Springs Investments (CSI). Those in attendance must be some type of upper management in order to get commitments from all present to agree on such things as having the data in a format that can be easily transferred from one group to another electronically. If this can be accomplished a big hurdle will have been cleared. If this is unacceptable we could do one of two things: 1: order it be done, or 2) have each party submit to USGS in electronic format for USGS to assemble and publish as a data report (this should not take long since if only a data report, peer review is not necessary).

b. The above assemblage of data would assume that all are in agreement of what should be monitored and what frequency. This can be done before the meeting. I also believe there should be at least two more wells into the carbonate on the north end of CSI's proje[redacted] The biggest drawback to this from the previous meet[redacted] (which USGS, USFWS and NPS would be in favor of doing) it just is going to be an educated guess as to where to put additional monitoring wells. These wells should be drilled as soon as possible and begin to get background data. USGS plans to do real time monitoring on two wells in the carbonate, SCV-2 in Coyote Springs Valley and the Steptoe Valley Well.

c. Allow MVWD to pump ACW and the new well as close to 10 cfs as possible. This will require some discharge to the Muddy River below the USGS gage so as not to bias what the spring discharge is. MVWD is already in discussion with DEP to obtain a discharge permit to the Muddy River. The only other use of MVWD is from Jones Springs which pumps and will continue to pump 450 gpm. The reason they need to pump this spring is because of distribution constraints. This test could go on as long as one year. If the monitoring shows no significant impacts (remember there were trigger levels set in the ruling on the spring discharge) then the next step could be taken. One other item is that NPC should be convinced that they should curtail any pumping from the alluvial well field for Reid Gardner during this test and take the water from the MVWD. The 1999 pumping report of Nevada Power shows that the wells in the alluvium pump 4,700 acre-feet out of a total of 7,300 acre-feet (65%). The majority of alluvial well pumping occurred May through September. This is apparently a sticking point between NPC and MVWD and maybe intervention by DWR could influence NPC to take the water.

d. After the pumping of ACW for the period set and if no significant impacts are found, pumping could commence on MX-5 in Coyote Springs (a determination as to when to build the pipeline could be made during the testing of ACW, though it could be a gamble if significant impacts on the springs are detected late in the test period). The pumping of MX-5 could be 10 cfs also for a year with no pumping of ACW. Monitoring and the same usage pattern and discharge to the Muddy would continue as before.

e. An analysis of the two years data could be done at this point to determine what to do next. Some ideas as to what to do next could be as stated in the following paragraphs.

f. MX-5 could be stepped up to 15 cfs or higher (the total permits for CSI and SNWA is 8,666 AF [12 cfs] plus what ever CSI and/or SNWA got of NPC's 7,500 AF [10+ cfs] with no pumping of ACW.

g. Another well could be drilled into the carbonate in the northern part of Coyote Spring Valley and that well pumped for a period of time. What the disposal of the water would be is a whole different matter. If the water pumped could not be used for the service area of MVWD that would require MVWD to pump ACW and thus make it more difficult in the analysis of impacts on the springs.

4. It is possible that the speculation as to what to continue pumping in 3f and 3g might be a little far into the future. But as to what I recommended in other parts of paragraph 3 I believe is a systematic approach as to get to what long term pumping at elevated rates may or may not do to the springs. One other item of significance not addressed above is the potential pumping of wells in the carbonate of the Moapa Band of Paiutes south of the reservation and how that could or should be factored into this procedure.

I will have maps to show relative locations of all of the wells of all of the four above mentioned parties.

HR/bk
Attachments
cc: Peter G. Morros, Director
Bob Coach, SNBO

Paragraphs with high-lighted text reproduced from the Ricci memo dated June 21, 2000.

b. The above assemblage of data would assume that all are in agreement of what should be monitored and what frequency. This can be done before the meeting. I also believe there should be at least two more wells into the carbonate on the north end of CSI's project. One should be along a line between MX-5 and Ash Springs and the other somewhere in the mouth of Kane Springs Wash as it enters Coyote Springs Valley. The biggest drawback to this from the previous meetings was how would it be decided as to where to place these wells. Short of doing a major study again (which USGS, USFWS and NPS would be in favor of doing) it just is going to be an educated guess as to where to put additional monitoring wells. These wells should be drilled as soon as possible and begin to get background data. USGS plans to do real time monitoring on two wells in the carbonate, SCV-2 in Coyote Springs Valley and the Steptoe Valley Well.

g. Another well could be drilled into the carbonate in the northern part of Coyote Spring Valley and that well pumped for a period of time. What the disposal of the water would be is a whole different matter. If the water pumped could not be used for the service area of MVWD that would require MVWD to pump ACW and thus make it more difficult in the analysis of impacts on the springs.

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STIPULATION FOR DISMISSAL OF PROTESTS

This Stipulation is made and entered into between the Lincoln County and Vidler Water Company, Inc. ("LC&VWC") and the United States Department of the Interior, National Park Service ("NPS").

RECITALS

A. On December 11, 1998, LC&VWC filed Applications 64692 and 64693, for a combined maximum duty of approximately 14,500 acre-feet per year, with the Nevada State Engineer's Office. On November 8, 2000, LC&VWC filed Application 66932 to change the point of diversion of Application 64693. The above listed applications shall hereinafter be referred to as the "Applications". LC&VWC initially intend to pump up to 7,240 acre-feet of groundwater from the Tule Desert Hydrographic Basin pursuant to these rights, [for a period of up to 42 years for power plant cooling purposes by the Toquop Energy Project], and thereafter, for municipal and domestic uses in Lincoln County.

B. The NPS filed timely protests to the granting of water rights under the Applications pursuant to the NPS' responsibility to protect the water rights and resources of the NPS. In resolving its protests, the NPS has stated its area of interest as Tule Desert, the southern portion of the Virgin River Basin, Lower Moapa Valley and Black Mountains Area hydrographic basins.

C. LC&VWC assert that the withdrawal of up to 7,240 acre-feet per year of groundwater from the proposed wells in the Tule Desert hydrographic basin will not have an unreasonable adverse impact on the water rights of the NPS. LC&VWC propose to request the State Engineer hold in abeyance the remaining amount requested in the Applications, until a determination is made from the monitoring of the initial groundwater withdrawals that there are no unreasonable adverse affects due to LC&VWC's groundwater pumping.

D. The NPS asserts that the proposed groundwater withdrawals from Tule Desert pose a risk of adversely impacting the water rights and resources of the NPS. The NPS is required by law to manage, protect and preserve these rights and resources. Impacts to these resources might include impacts to springs in the Overton Arm area of Lake Mead National Recreation Area, including but not limited to Rogers Spring and Blue Point Spring (hereafter called Overton Arm Area Springs, See Table 1 and Figure 1 attached hereto as Schedule 1 to Exhibit A) and depletion of surface flows of the Virgin River within the Lake Mead National Recreation Area (hereafter Virgin River). The NPS desires to work in a cooperative manner with LC&VWC to protect the water rights and resources of the NPS and resolve any differences concerning these Applications.

E. There are a number of existing monitoring programs required by the State Engineer for existing rights and pending applications within Lower Meadow Valley Wash, Muddy Springs Area, Coyote Spring Valley, Hidden Valley, and Garnet Valley hydrographic basins. The State Engineer has determined in Order No. 1169 (Order) that further hydrological study is needed before a final determination can be made on pending applications and new filings to appropriate water from the carbonate-rock aquifer system in Coyote Springs Valley (Basin 210), Black Mountains Area (Basin 215), Garnet Valley (Basin 216), Hidden Valley (Basin 217), Muddy River Springs aka as Upper Moapa

Valley (Basin 219) and Lower Moapa Valley (Basin 220) in Lincoln and Clark Counties, Nevada. The Applications are excluded from the affects of the Order, however, the NPS and LC&VWC wish to develop data relating to a better understanding and analysis to assist the State Engineer in studying the impacts from the pumping of groundwater in the regional aquifer system.

F. The parties acknowledge that pursuant to NRS 534.110(4) each right to appropriate groundwater in the State of Nevada carries with it the right to make a reasonable lowering of the static water level at the appropriator's point of diversion and that pursuant to NRS 534.110(5) the State Engineer may allow, at his discretion, the water level to be lowered at the point of diversion of a prior appropriator so long as the rights of holders of existing appropriations can be satisfied under such express conditions.

G. The State Engineer has set an administrative hearing to consider the protested Applications commencing May 14, 2002.

H. The parties acknowledge that the Virgin Valley Water District has lodged protests to the Applications, but that Virgin Valley Water District is not a party to or is in any way bound or prejudiced by this Stipulation.

I. The parties agree that the preferred conceptual approach for protecting the water rights and resources of NPS from unreasonable adverse impacts from groundwater pumping is through the use of monitoring, management and mitigation of groundwater pumping. The common goal of the parties is to manage the groundwater development without causing unreasonable adverse impacts to the water rights and resources of the NPS. Groundwater and the effects of pumping need to be properly monitored and managed to avoid unreasonable adverse impacts to the water rights and resources of the NPS. There is a need to obtain accurate and reliable information of the aquifer's response to pumping stresses and the impact of that pumping on the water rights and resources of the NPS. This is to be accomplished by implementing the monitoring, management and mitigation plan as set forth in Exhibit A to this Stipulation. The parties have determined that it is in their best interests to cooperate in the collection of additional hydrologic and hydrogeologic information as set forth in Exhibit A to this Stipulation.

J. The parties desire to resolve the issues raised by the protests according to the terms and conditions contained herein.

NOW, THEREFORE, in consideration of the mutual promises and covenants contained herein, the parties do agree as follows:

1. The NPS hereby expressly agrees to withdraw its protests to the Applications and agrees that the State Engineer may rule on the Applications based upon the terms and conditions set forth herein. It is expressly understood that this Stipulation is binding only upon the parties hereto and their successors, transferees and assigns, and shall not bind or seek to bind or prejudice any other parties or protestants. The execution and filing of this Stipulation with the State Engineer shall have the effect of withdrawing NPS' protests as provided for in Nevada Administrative Code §533.150.

2. The parties agree to implement the Monitoring, Management and Mitigation plan, attached hereto as 'Exhibit A', which is expressly incorporated into this Stipulation as if set forth in full herein upon the State Engineer's granting of the Applications, in total or in part, and upon the terms and conditions contained in Exhibit A.

3. This Stipulation does not waive any authorities of the NPS or the United States, including any other agency or bureau not specified in this Stipulation, nor relieves LC&VWC, or any party acting in conjunction with or through LC&VWC, from complying with any federal laws, including, but not limited to, the National Environmental Policy Act, the Endangered Species Act, the Federal Land Policy and Management Act, and any and all rules and regulations thereunder. It is the expressed intention of the parties that by entering into this Stipulation, the NPS and the United States are waiving no legal rights of any kind, except as expressly provided herein. Likewise, LC&VWC, or any party acting in conjunction with or through LC&VWC, by entering into this Stipulation, are not waiving any legal rights or positions of any kind regarding any other approvals or permits requested or required from any other governmental agencies.

4. Further, this Stipulation does not affect any other legal or administrative process or proceeding concerning rights-of-way or any other action believed necessary to further the development and/or use of the water sought under the Applications.

5. The parties expressly acknowledge that the Nevada State Engineer has, pursuant to both statutory and case law, the authority to allocate and administer groundwater resources in the State of Nevada and, furthermore, that nothing contained in this Stipulation shall be construed as waiving or in any manner diminishing such authority.

6. The parties agree that a copy of this Stipulation shall be submitted to the Nevada State Engineer prior to the commencement of the administrative proceedings scheduled to begin on May 14, 2002. The parties shall request on the record at the beginning of the scheduled proceeding that the State Engineer include Exhibit A of the Stipulation as part of the permit terms and conditions in the event that he grants such Applications 64692,

64693 and 66932, in total or in part. The NPS, at its option, may attend the hearing, but will present no issues or statements that are adverse to the interests of LC&VWC.

7. Notices. If notice is required to be sent by the parties, the addresses are as follows:

If to NPS:

Branch Chief
Water Rights Branch
National Park Service
1201 Oak Ridge Drive, Suite 250
Fort Collins, CO 80525

If to LC&VWC:

Chairman
Lincoln County Board of Commissioners
P.O. Box 685
Pioche, NV 89043

And

Dorothy Timian-Palmer
Vidler Water Company, Inc.
3264 Goni Road, Suite 153
Carson City, NV 89706-7952

8. LC&VWC may transfer or assign their interest in the water rights here involved. Any and all transferees and assignees shall be bound by the terms and conditions of this Stipulation. As a condition to any such transfer or assignment, the transferee and/or assignee shall execute a stipulation expressly stating it is bound to all of the terms and conditions of this Stipulation.

9. This Stipulation shall be governed by and interpreted in accordance with the laws of the State of Nevada to the extent not inconsistent with federal law.

10. Copies of all correspondence between and data gathered by the parties pursuant to the terms of Exhibit A to this Stipulation shall be submitted to the State Engineer. It is the

intention of the parties hereto that the State Engineer shall be kept informed of all activities in the same fashion as are the parties hereto.

11. By entering into this Stipulation, the NPS does not become a party to any proceeding other than the protest proceeding referenced above or waive its immunity from suit or consent to or acknowledge the jurisdiction of any court or tribunal. Nothing in the Stipulation shall affect any federal reserved water rights of the NPS, any other federal agency, and the United States on behalf of any Indian Tribe and the NPS by entering into this Stipulation does not waive or prejudice any such rights. The NPS reserves all legal rights, of any kind, it possesses pursuant to or derived from Executive Orders, acts of Congress, judicial decisions, or regulations promulgated pursuant thereto. Neither party waives its rights to seek relief in any appropriate forum of its choice not expressly prohibited by this Stipulation.

12. Any commitment of funding by the NPS or Lincoln County in this Stipulation or otherwise is subject to appropriations by Congress or the governing bodies of Lincoln County as appropriate.

13. This Stipulation may be amended by mutual written agreement of the parties.

14. This Stipulation sets forth the entire agreement of the parties and supercedes all prior discussions, negotiations, understandings or agreements. No alteration or variation of this Stipulation shall be valid or binding unless contained in an amendment in accordance with paragraph 13.

15. The terms and conditions of this Stipulation shall be binding upon and inure to the benefit of the parties hereto and their respective successors, transferees and assigns.

16. This Stipulation will become effective as between the parties upon all parties signing this Stipulation. The parties may execute this Stipulation in two or more counterparts, which shall, in the aggregate, be signed by all parties. Each counterpart shall be deemed an original as against any party who has signed it.

17. Other entities may become parties to this Stipulation by mutual assent of the parties.

18. Nothing contained herein shall limit the right of LC & VWC, or their successors, transferees or assigns to assign, pledge or encumber as security the Applications that are the subject of this Stipulation.

IN WITNESS WHEREOF, the parties have executed this Stipulation as of the dates written below.

UNITED STATES DEPARTMENT OF THE INTERIOR

Date: 5/7/02

NATIONAL PARK SERVICE

By ______________________

for Title: Superintendent of Lake Mead National Recreation Area

Date: 5/9/02

NATIONAL PARK SERVICE

By [signature]

Title: Regional Director, Pacific West Region

Date: May 6, 2002 LINCOLN COUNTY

By ______________________

Title: Chairman

ATTEST:

____

Date: May 6, 2002

VIDLER WATER COMPANY, INC.

By ______________________

Title: Chief Operating Officer

JUL-08-02 10:13 From: T-481 P.12/21 Job-101

EXHIBIT A
for
Stipulation between LC&VWC and the National Park Service for Withdrawal of Protests

MONITORING, MANAGEMENT AND MITIGATION PLAN FOR FUTURE PERMITTED GROUNDWATER DEVELOPMENT IN TULE DESERT

The purpose of this plan is to describe the agreements of Lincoln County and Vidler Water Company, Inc. (LC&VWC) and the National Park Service (NPS) regarding the monitoring, management, and mitigation of potential impacts due to development of ground-water resources in the Tule Desert area. This plan applies to proposed ground-water development in Tule Desert that consists of the use of water under State of Nevada water-rights applications numbered 64692, 64693, and 66932, filed by LC&VWC.

It is anticipated that the following provisions will apply to proposed ground-water development in Tule Desert up to the first 7,240 acre feet per year (afy). Prior to permitting any additional amount of groundwater, the parties shall determine if additional monitoring, management, or mitigation is required. In the event that less than 3,620 afy are permitted, the far-field monitoring-wells requirement (see Section 1.B.) will be reduced to the regional carbonate-rock well only. All other provisions of this plan will still apply.

This plan consists of four principle components, as follows:

1. *Monitoring Requirements*, related to production wells, monitoring wells, elevation control, streamflow and springflow, water quality, a seepage run, precipitation stations, quality of data, and reporting;
2. *Management Requirements*, related to the creation and role of a Technical Review Panel (hereinafter referred to as "the TRP"), the development and use of a numerical ground-water flow model, the establishment of action criteria, and the details of the decision-making process;
3. *Mitigation Requirements*; and
4. *Modification of the Plan.*

The common goal of the LC&VWC and the NPS (hereinafter referred to as "the parties") is to develop data relating to a better understanding and analysis to assist the Nevada State Engineer in managing the development of the regional aquifer system by the LC&VWC without resulting in unreasonable adverse impacts to the water rights and resources of the NPS. The parties agree that decisions will be based on the best scientific information available and the parties will collaborate on technical data collection and analysis.

1. Monitoring Requirements

A. *Production Wells*

- LC&VWC will record discharge and water levels in their production wells in Tule Desert on a continuous basis as is feasible.

B. *Monitoring Wells*

- LC&VWC will record water levels on a continuous basis as is feasible in selected (near-field) monitoring wells in Tule Desert, as determined by the parties to this agreement, in consultation with the Nevada State Engineer.

- LC&VWC, as determined by the parties to this agreement, in consultation with the Nevada State Engineer, shall locate and construct two early warning (far-field) monitoring wells downgradient from the proposed ground-water production: (1) one well in the shallowest principal aquifer (i.e. probably the basin-fill aquifer) in the general vicinity of Toquop Gap; and (2) one well in the regional Paleozoic carbonate-rock aquifer system between the Mormon Mountains and the East Mormon Mountains in the general vicinity of the boundary between the Tule Desert and Virgin Valley hydrographic areas, subject to the acquisition of rights-of-way from the U.S. Bureau of Land Management. NPS shall work with LC&VWC in good faith to ensure that these wells are located and constructed in a cost-effective manner, while meeting the objectives of early-warning detection of effects, if any, from proposed ground-water production in Tule Desert. Total cost of drilling and construction of the far-field wells will not exceed $325,000.

- LC&VWC will record water levels on a continuous basis as is feasible in each of the early warning (far-field) monitoring wells.

- All near-field monitoring wells used as part of this plan shall be installed and water levels recorded on a continuous basis as is feasible, for at least one year prior to groundwater production. The early warning (far-field) monitoring wells shall be installed and water levels recorded on a continuous basis as is feasible, as soon as possible prior to groundwater production, recognizing the desire of the NPS to obtain one year of baseline data prior to ground-water production. LC&VWC will record water levels on a continuous basis as is feasible in each aquifer from which ground water is withdrawn.

- The term "as is feasible" shall relate to mechanical failures or other events outside the control of the parties that do not permit data collection.

- The locations and monitoring frequency of the monitoring-well network will be reviewed by the TRP on an annual basis beginning with the 2004 annual meeting, and may be reduced or expanded in scope upon its recommendation.

C. *Elevation Control*

- LC&VWC will conduct a detailed elevation survey of all their wells used for monitoring as part of this plan. LC&VWC will cooperate in any regional plan organized by the Nevada State Engineer to determine elevation above sea level of all major spring orifices and monitoring and production wells in the Lower Colorado Flow System region.

D. *Streamflow and Springflow*

- NPS, in cooperation with USGS, will install, operate and maintain a stream gaging station on the Virgin River within Lake Mead NRA for a period not less than five consecutive years. The cost of the installation and operation of the gaging station may also be shared by other Federal, State, or private parties. After the period of five years, the NPS may discontinue or reduce their participation in the operation of the gaging station. It is understood that the data will be available in the Annual USGS Water Resources Data report for Nevada.

- NPS, in cooperation with USGS, will equip and maintain continuous surface water measurement sites at Rogers and Blue Point Springs.

E. *Water Quality*

- LC&VWC will collect water quality samples and have them analyzed for major ions, trace elements, and isotopes at all production and monitor wells used as part of this plan (as specified in Sections 1.A and 1.B.) semi-annually commencing July 1, 2002 for one-and-one-half years.

- In addition, LC&VWC will collect and analyze water-quality samples for major ions, trace elements, and isotopes at all production and monitoring wells used as part of this plan every five years thereafter.

- Samples will be collected, analyzed and reported according to standard methods.

- Frequency, sampling location, and water quality parameters will be reviewed by the TRP on an annual basis beginning with the 2004 annual meeting, and may be reduced or expanded in scope upon its recommendation.

F. *Seepage Run*

- LC&VWC and the NPS will each provide financial assistance to the USGS to conduct a seepage run of the lower Virgin River from Mesquite to Lake Mead NRA. The cost to LC&VWC shall not exceed $5,000.00. The cost of the seepage run may also be shared by other Federal, State, or private parties. Interested parties may provide additional assistance to the USGS if requested, such as the participation by qualified professional personnel, or other material resources. The seepage run will be conducted in 2003, prior to the commencement of the irrigation season, as is feasible.

G. *Precipitation Stations*

- LC&VWC shall establish one precipitation station in the Tule Desert in the area referred to as Subbasin 1 between 4000 and 5000 feet. The cost to LC&VWC to establish the precipitation station shall not exceed $10,000.00.

- LC&VWC, in cooperation with the Desert Research Institute (DRI), shall operate and maintain the precipitation station. Total daily precipitation, average daily maximum and minimum air temperature, and other parameters shall be recorded at the precipitation station. The design and operation of the precipitation station shall meet the standards of the DRI.

H. *Quality of Data*

- LC&VWC and NPS will ensure that measurements are made and data are collected according to USGS standard protocol, unless otherwise agreed to by the parties.

I. *Reporting*

- All data collected under or as described in this plan, shall be fully and cooperatively shared among the parties.

- Water level and production data shall be provided to the NPS within 60 days of its collection by LC&VWC. LC&VWC will use its best efforts to provide data to the NPS within 30 days of its submission to LC&VWC, or in the case of water quality data, within 90 days of laboratory results.

- LC&VWC will report the results of all monitoring and sampling under this plan in an annual monitoring report.

2. <u>Management Requirements</u>

A. *Technical Review Panel (TRP)*

- The parties will create a TRP consisting of one representative from each party to this agreement. Each party may invite additional staff or consultants to attend as needed. The parties mutually agree to invite a representative of the State Engineer's Office to participate as the chair of the TRP.

- The TRP shall meet by February 1, 2003, or at such earlier date as mutually agreed upon by the parties, and annually thereafter.

- The purposes of the TRP are to:

  1. provide a forum for review of relevant data and analyses;
  2. share information regarding modeling efforts and model results;
  3. evaluate the predictive numerical ground-water flow model (see Section 2.B.) and determine whether refinement and/or recalibration is warranted;
  4. identify needs for additional data collection and scientific investigations;
  5. form recommendations about monitoring, modeling, ground-water management, and mitigation, including but not limited to additional or replacement monitoring wells;
  6. recommend values for monitored variables (water levels, spring discharges, etc.) known as "action criteria", which, if exceeded, are of concern to the parties;
  7. develop/refine standards and QA/QC for data collection and analysis; and
  8. recommend courses of action on technical issues.

B. *Numerical Ground-Water Flow Model*

- NPS will expand the domain of its existing numerical ground-water flow model of the Lower Colorado Flow System of Nevada to include the Virgin River Valley hydrographic area, and to incorporate new geologic and hydrologic information for the Tule Desert hydrographic area, as is feasible.

- LC&VWC will provide all geologic, geophysical, hydrologic, and geochemical data that it has collected in the Tule Desert and vicinity to the NPS for consideration of use with the numerical model.

- The NPS will use its numerical ground-water flow model to estimate the potential effects of pumping by LC&VWC on water rights and resources of the NPS.

- The NPS will update the model annually for the first five years of groundwater production under the subject ground-water permits, and at 5-year intervals thereafter, unless otherwise recommended by the TRP. (Note: As the effects of pumping in the region on water levels, streamflows, and spring flows are measured, refinement of the model will probably be required to achieve better agreement with the measurements. Furthermore, the collection of additional geologic, geophysical, and/or geochemical data may indicate that modification of the conceptual and numerical model of the groundwater system is warranted.)

- The NPS will provide model output in the form of drawdown maps at appropriate intervals as determined by the TRP, plots of simulated water levels for the aquifer system, and discharge for the Virgin River and Rogers and Blue Point Springs or other Overton Arm Area Springs. Maps and plots will include comparison with available measurements for the appropriate time period.

C. *Action Criteria*

- Specific quantitative criteria (action criteria) are identified in this plan that will "trigger" management actions.

- Action criteria will be set to provide early warning of adverse impacts to the State and/or Federal water rights of the NPS.

- The initial action criterion will be a measured water-level change in any far-field monitoring well in excess of one-foot.

- If and when the action criterion is reached, management actions that are triggered are as follows:
  (1) LC&VWC will notify the NPS, and the parties will confer within 30 days;
  (2) if the parties agree that the action criterion exceedance is not attributable to ground-water withdrawals under the subject ground-water permits, then further management actions will not be required at that time;
  (3) if either or both parties conclude that the action criterion exceedance is attributable to ground-water withdrawals under the subject ground-water permits, then the TRP will meet to determine the cause;
  (4) the NPS will use its numerical ground-water flow model to predict the effects of the existing ground-water pumping by LC&VWC on water rights and resources of the NPS; and
  (5) if the NPS numerical ground-water flow model, after review by the TRP, predicts any drawdown in hydraulic head at Rogers Spring, Blue Point Spring or other Overton Arm Area Springs, or the Virgin River attributable to ground-water withdrawals under the subject ground-water permits in the ensuing 100 years, then the TRP will review all other available data and analyses and will recommend a prescribed course of action.

- Action criteria will be evaluated by the TRP at the annual meetings, based on results from monitoring and from the predictive numerical ground-water flow model.

- Any member of the TRP may propose a change to any action criterion. Any such change must be presented in writing to other members of the TRP, and must be accompanied by data and scientific analyses to support the proposed change. If the supporting analyses are found to be technically sound, then the action criterion may be adjusted, as appropriate.

D. *Decision-Making Process*

- The TRP will review all available data and recommend a prescribed course of action. If there are: (1) different interpretations regarding aquifer response and/or the significance of that response to the water rights and resources of the NPS; or (2) different opinions on the prescribed course of action, the parties will jointly agree to conduct additional data collection, analyses, and/or modeling directed at resolving the different interpretations or opinions, if feasible. If that is not successful, the parties will refer the issue to their respective managers. LC&VWC will inform the State Engineer or his representative of all agreed upon courses of action. Nothing herein limits or changes the State Engineer's authority and any party can petition the State Engineer to consider the issue.

- In the event that the parties disagree as to whether LC&VWC's proposed or ongoing pumping will result in adverse impacts to the NPS's water rights and resources, any party may petition the State Engineer to request that he determine whether there is or is not adverse impact that requires the implementation of mitigation measures by LC&VWC.

3. **<u>Mitigation Requirements</u>**

- LC&VWC will mitigate unreasonable adverse impacts either as agreed upon by the parties or after the Nevada State Engineer determines whether there are unreasonable adverse impacts due to LC&VWC pumping. LC&VWC will take the necessary steps to ensure that mitigation actions are feasible.

4. **<u>Modification of the Plan</u>**

- LC&VWC and the NPS may modify this plan by mutual agreement. The parties also acknowledge that the State Engineer has the authority to modify this plan. In addition, LC&VWC and the NPS may individually or jointly petition the State Engineer to modify this plan in the event that mutual agreement cannot be reached. Any such petition shall only be filed after 90 days written notice to the remaining party. Either LC&VWC or the NPS may submit written comments to the State Engineer regarding the merits of any such petition for modification.

Schedule 1, Exhibit A
Stipulation between LC&VWC and the National Park Service for Withdrawal of Protests

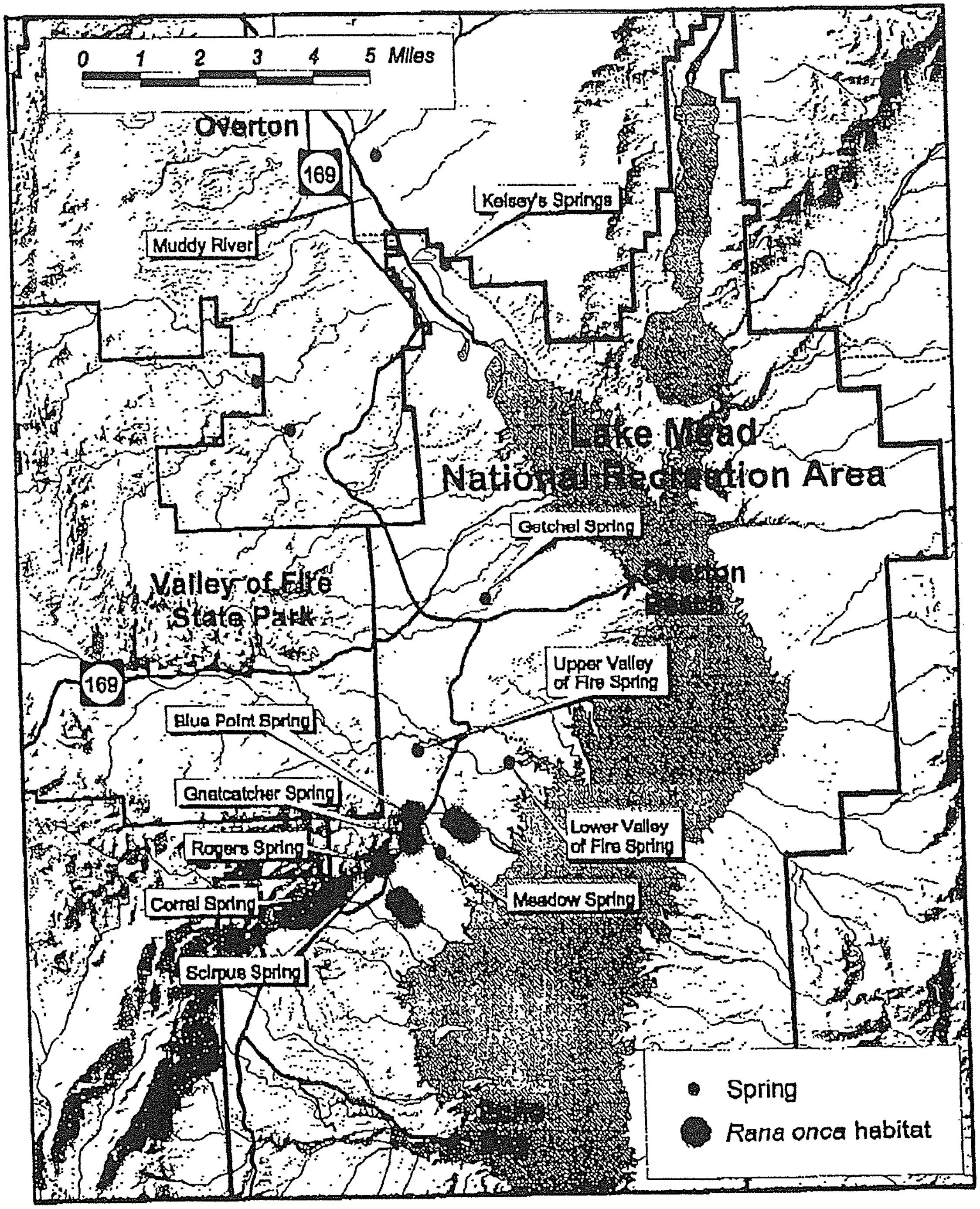


Figure 1. Springs along the Overton Arm of Lake Mead

Source: National Park Service, Lake Mead National Recreation Area, Resource Management Division

Schedule 1, Exhibit A
Stipulation between LC&VWC and the National Park Service for Withdrawal of Protests

Table 1. WATER SOURCES, LOCATIONS, AND ASSOCIATED WATER-RELATED RESOURCES AND VALUES OVERTON ARM, LAKE MEAD NATIONAL RECREATION AREA

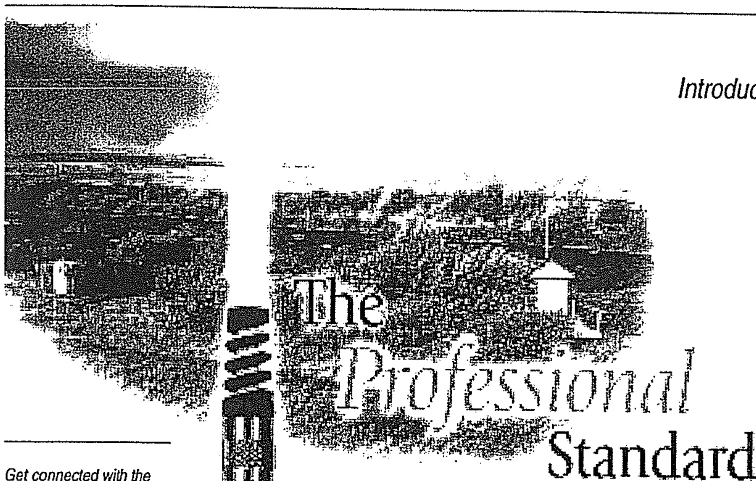
WATER SOURCE	LOCATION OF RESOURCE (MDB&M)	ASSOCIATED WATER-RELATED RESOURCES AND VALUES
Muddy River	Sections 19 and 20, T16S R68E	wetland/riparian--wetland/riparian vegetative community, wetland/riparian wildlife community--migratory waterfowl, shorebirds, wintering bald eagle, other avifauna and wildlife, recreation, scenic
Kelsey's Springs	SW1/4 NW1/4 Sec. 20, T16S R68E	Riparian community--vegetation, wildlife, amphibians, invertebrates, reptiles, avifauna
Getchel Spring	SW1/4 NW1/4 Sec.21, T17S R68E	Spring no longer flows
Rogers Spring	SE1/4 SE1/4 Sec. 12, T18S R67E	Riparian community--vegetation - 46 species, amphibians - Rana onca (once thought extinct, only known populations are in LMNRA), bighorn sheep, bobcat, coyote, reptiles, avifauna, recreation, scenic
Blue Point Spring	NW1/4 NE1/4 Sec. 7, T18S R68E	Riparian community--vegetation - 39 species, amphibians - Rana onca (once thought extinct, only known populations are in LMNRA), invertebrates, coyote, rabbit, reptiles, avifauna, recreation, scenic
Corral Spring	SW1/4 NW1/4 Sec. 13, T18S R67E	Riparian community--vegetation, amphibians - Rana onca (once thought extinct, only known populations are in LMNRA), invertebrates, bighorn sheep, bobcat, rabbit, reptiles, avifauna
Upper Valley of Fire Spring	NW1/4 SE1/4 Sec. 31, T17S R68E	Riparian community--vegetation - (not yet surveyed), amphibians, invertebrates, rabbit, reptiles, coyote, avifauna
Gnatcatcher Spring	SW1/4 NE1/4 Sec.7, T18S R68E	Riparian community--vegetation - (not yet surveyed), amphibians - Rana onca (once thought extinct, only known populations are in LMNRA), invertebrates, rabbit, reptiles, coyote, avifauna, scenic
Scirpus Spring	NW1/4 NE1/4 Sec. 13, T18S R67E	Riparian community--vegetation- 29 species, amphibians, invertebrates, bighorn sheep, coyote, bobcat, reptiles, avifauna
Meadow Spring	NE1/4 SE1/4 Sec. 7 T18S R68E	Riparian community—vegetation (not yet surveyed), amphibians, invertebrates, coyote, reptiles, avifauna
Lower Valley of Fire Spring	NW1/4 NW1/4 Sec. 4 T18S R68E	Riparian community--vegetation - (not yet surveyed), amphibians, invertebrates, rabbit, reptiles, coyote, avifauna

APPENDIX 2

In-Situ Inc.

miniTROLL

LEVEL · TEMPERATURE · DATA LOGGING



Introducing the leading instrument for water monitoring—the miniTROLL. Powerful, dependable, versatile, easy-to-use and small. The miniTROLL has become the instrument of choice for water professionals who need accurate, reliable data for water level and temperature monitoring applications.

Get connected with the world's most advanced submersible cable. Quick-ConnectTM cables available in Polyethalyne, Polyurethane or FEP. Or, suspend it with Teflon-coated wire using a sealed backshell.

2 AA batteries provide long-term operation. And they are user replace-able—slide them in, no tools required.

SMALLEST DIAMETER AT ONLY 0.72"(18.3MM)

Now, 1-inch wells (25mm) can be monitored with room to spare! The miniTROLL packs a pressure/level sensor, temperature sensor, data logger, up to 1MB of memory (220,000 data points), real-time crystal clock, and internal power all into an industrial stainless steel housing with a diameter of only 0.72" (18.3mm). Sound extreme? We think so.

SIMPLE TO USE AND VERY POWERFUL

Since the miniTROLL houses everything needed to monitor, installation is easy. Just place it in water and have it collect data. Our intuitive Win-Situ software walks you through all the steps so you can start getting data fast and it's included with every purchase.

AUTOMATIC BAROMETRIC COMPENSATION

Why make things complicated and introduce inaccuracy into your test by using a separate barometer for compensation? With vented cable, the miniTROLL automatically compensates for barometric pressure so you don't have to. We also offer a low-cost 'BaroTROLL' unit to measure barometric pressure when using the units without cable.

SIMPLY THE MOST POWERFUL

An internal data logger with 1MB of onboard memory can store more than 1-million data points. Think of all the possibilities!

Our pressure sensors set the standard for high-accuracy. NIST- traceable calibrations compensated across the ENTIRE temperature meet the most rigorous government standards.

ROBUST QUICK-CONNECT™ CABLE OR WIRE SUSPENSION

Our Quick-Connect cables are fully detachable and are available in FEP (Teflon equivalent), Polyurethane, or Polyethalyne. Or you can use the miniTROLL without cable. For this application, we offer low-cost Teflon®-coated stainless steel wire for suspension without cable as well as Direct-Read cables for programming.

FIELD-RUGGED POCKET PC READER

Why take an expensive and hard to handle laptop to the field when you can take the Pocket PC in your pocket? Our rugged ProfilerPlusTM system adds a hard case with watertight connections to make it extremely simple and reliableto use and with all of the power of a PDA. Only from In-Situ.

EXTREME ACCURACY

miniTROLLs are calibrated using NIST-traceable standards and compensated for temperature across the entire range. A calibration report is shipped with every unit offering extra assurance that your equipment meets or exceeds the rigid accuracyrequirements specified by many agencies.

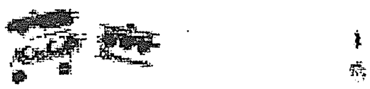
USER REPLACEABLE BATTERIES

Insert two AA batteries. It's that simple. Replace your batteries virtually anywhere on earth. No need to send the instrument back to the factory or worse yet, no need to throw it away.

CALL 1-800-446-7488 · 1-970-498-1500 · EXPERIENCE THE MINITROLL AT WWW.IN-SITU.COM!

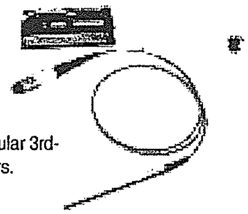
Accessories

Networking
Multiple unit installations are a snap using T-Boxes or Quad-Boxes. Create networks of up to 32 TROLL 9000s. Saves money!

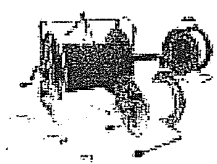


Extreme power
Need more power? Try a long-lasting external battery pack. Up to 7 years of operation.

SDI-12
Now available with optional SDI-12 output.
Connects to popular 3rd-party data loggers.



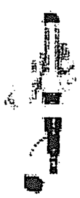
Reels, Well Docks and caps
Reels are available in three sizes in steel or ABS plastic. Well Docks make well installations a snap. A real asset!



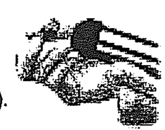
Non-vented backshell
Use the miniTROLL with or without vented cable by attaching a stainless steel backshell.

Snap ring kit
Snap ring kit for non-vented miniTROLLs and BaroTROLL. Handy when changing batteries

Desiccants
High humidity? Try a MAXUM high-capacity desiccant. Screws right onto the cable!



Cables
Vented or non-vented Quick-Connect™ cables. Available in polyethylene, polyurethane or FEP (Teflon*).



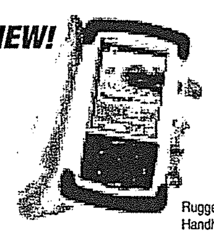
miniTROLL

Sensor Specifications		VERSIONS:	Standard T	BaroTROLL	Low-Cost (Std A) FSR	Standard P	Advanced	Professional
Depth, Level, Pressure, Barometric	Principle	Integrated silicon strain-gauge pressure sensor						
	Sensor Type / Range							
	Depth / Pressure	3.5, 11, 21, 70, 210, 351m (11.5, 35, 69, 231, 692, 1153 ft / 5, 15, 30, 100, 300, 500 psi)	○	○	●	●	●	●
	Barometric	30 psia (usable range is 16.5 psi)	○	●	○	○	○	○
	Sensor venting options							
	Vented (gauged)		○	○	○	●	●	●
	Non-vented (absolute)**		○	●	●	●	●	●
	Accuracy	±0.05 at 15°C / ±0.1% across entire pressure and temperature range (3.5m / 11.5 ft / 5 psi sensor provides ±3mm (0.01 ft) accuracy)						
	Resolution	16-bit A-D converter: 1mm (0.00531% FS) for a 21m (30 psi) sensor						
	Pressure rating	2x range/3x burst (11 m = 3x range/5x burst)						
Temperature	Principle	Silicon temperature sensor	●	○*	○*	○*	○*	●
Range		-5°C to 50°C (23°F to 122°F) *(pressure readings are temperature compensated)						
Accuracy		±0.25°C						
Resolution		±0.001°C						
Hardware Specifications								
Data Logging	Number of programmable tests		1	16	1	1	2	16
	Logging Modes: linear (0.5 sec. minimum), linear average, true logarithmic or event							
Memory	Up to 1MB / Data points:		30K	220K	30K	30K	80K	220K
Power	Internal: 2 internal user-replaceable AA batteries Estimated battery life: 990K data points at a 1-sec interval or 1.5 years at a 20-min interval External: 6VDC							
SDI-12 communications (optional with SDI-12 Adapter)								
Dimensions	Internal Power: 18.3 mm (0.72 in) OD, 295.9 mm (11.65 in) long External Power: 18.3 mm (0.72 in) OD, 197.4 mm (7.77 in) long							
Weight	Internal Power: 0.31 kg (0.68 lb) with batteries (includes backshell) External Power: 0.22 kg (0.48 lb) (includes backshell)							
Wetted materials	316 stainless steel, Viton®, FEP**, polyurethane or polyethylene (cable), both models							

*The temperature sensor is used to compensate pressure, but its readings are not displayed
**5 & 15 psia (absolute) sensors not available

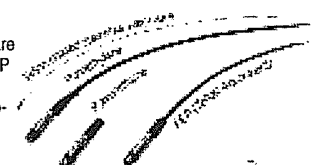
RuggedReader™ System
Say goodbye to that expensive and heavy handheld unit and say hello to the new, ultra-Rugged RuggedReader™ running Pocket-Situ! View and download data real-time, start and stop logging operations, manage your schedule, save contacts, and more. Pocket PC handheld option also available!

NEW!



RuggedReader Handheld

Quick-Connect Cables
Vented Quick-Connect cables are available in Polyurethane or FEP for contaminated sites. Vented cable allows for automatic atmospheric pressure correction! A Polyethalyne non-vented (direct read) cable is also available.



AND

Sealed backends with wire suspension
Since the miniTROLL contains everything needed to monitor, it can also be suspended using low-costTeflon-coated wire and sealed using a backshell.An external 'BaroTROLL' can be used to recordbarometric pressure for easy correction.

Purchase · Rent · Lease the miniTROLL Today!

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The Standard for Water Quality & Level

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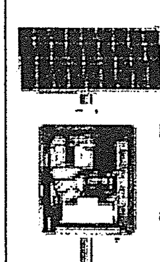
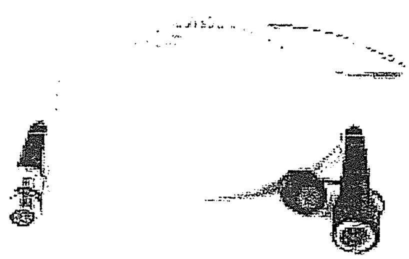


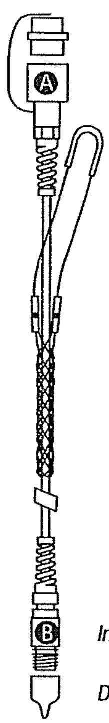
NEW! ETS Telemetry Systems
Modem, cellphone/ modem, radio and satellite telemetryoptions are available with solar or line power.

In-Situ Inc.

Product Specifications



QUICK-CONNECT SUBMERSIBLE CABLE



APPLICATION

Closes off the back end of a miniTROLL or Multi-Parameter TROLL 9000; provides power and communication signals, cable strain relief, venting, a connection to communication/power accessories, and a means to anchor the instrument to a wellhead or other stationary object. Standard & custom lengths available; reels optional.

PHYSICAL DESCRIPTION

Cable type	Vented yellow polyurethane Vented blue FEP* Non-vented black HDPE**
Wetted materials	Polyurethane/FEP/HDPE, stainless steel, nylon
Recommended bend radius	Vented ≥ 63.4 mm (2 ½ in) Non-vented ≥ 16 mm (¾ in)
Connector environmental rating	Vented cap: IP67 (temporary immersion) Non-vented cap: IP68 (sustained immersion)

SIGNALS

Voltage	≤ 12 VDC miniTROLL ≤ 14 VDC TROLL 9000
Communication	RS485

CONNECTIONS

A The surface connector connects to
- Communication cables and accessories
- High-volume desiccant pack
- External battery packs
- Network boxes
- SDI-12 adapter

B The backshell attaches directly to the miniTROLL or MP TROLL 9000.

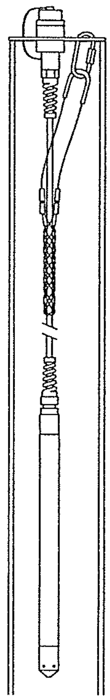
* FEP = fluorinated ethylene propylene, the generic equivalent of DuPont Teflon®
**HDPE = High-Density Polyethylene

SE ROA 36685

TROLL 9000/miniTROLL Cabling

QUICK-CONNECT SUBMERSIBLE CABLE

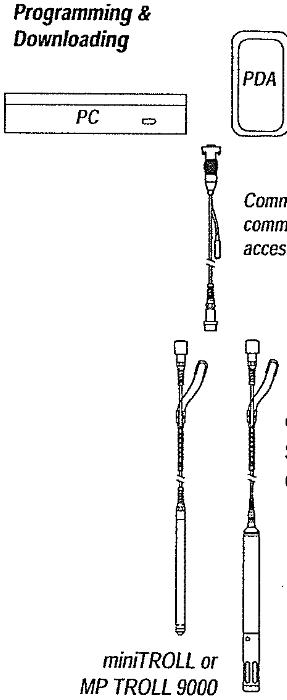
Single Installation



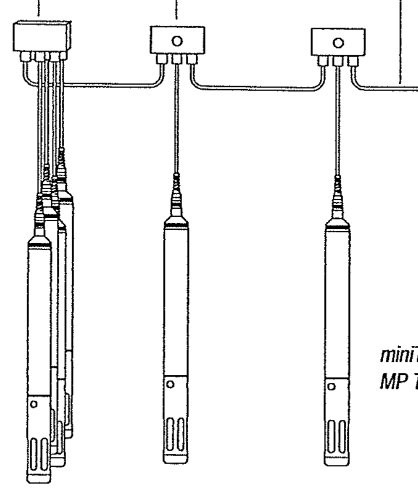
GUIDELINES & PRECAUTIONS

- Protect the contact board on the backshell with its protective dust cap when the cable is not attached to an instrument.
- Replace the vented cap when the indicating desiccant appears colorless.
- Replace the o-rings on the backshell if they appear cracked or warped.
- To protect the vent tube in vented cable, do not allow the cable to kink or bend too tightly. The recommended bend radius for vented cable is 63.4 mm (2.5 in) or more.
- Consult your In-Situ Regional Sales Manager for available communication options.

Programming & Downloading



Network Installation



1 800 4INSITU
(toll-free, US and Canada) or 970 498 1500 **www.in-situ.com**

In-Situ Inc.

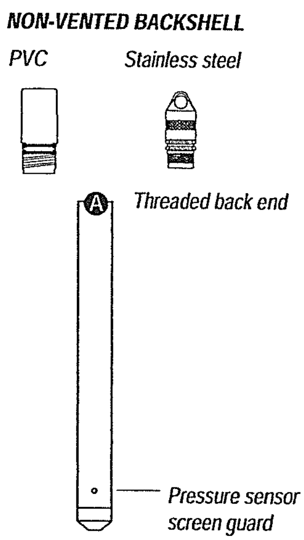
0021175 rev. 004 10/04

In-Situ Inc.

Product Specifications

Catalog No. 28390

BAROTROLL



APPLICATION

Measures and records barometric (atmospheric) pressure from 0 to 16.5 psia. A cost-effective way to collect barometric pressure data to compensate pressure readings from an Absolute miniTROLL or MP TROLL 9000 for variations in barometric pressure. Designed for installation on land near a submerged absolute instrument. One-test capacity; sampling interval user-selectable from 0.5 seconds to 7 days. Internally powered with 2 replaceable AA alkaline (supplied) or lithium batteries. Barometric pressure compensation is software-selectable.

SPECIFICATIONS

Materials	316L stainless steel, Viton®
Dimensions	295.9 mm (11.65 in) long, 18.3 mm (0.72 in) O.D.
Weight (includes backshell)	0.31 kg (0.68 lb), with batteries
Voltage	3 VDC nominal
Communications	RS485
OperatingTemperature	-5°C to 50°C (23°F to 122°F)
Storage Temperature	
with Alkaline Battery	-20°C to 54°C (-4°F to 129°F)
with Lithium Battery	-30°C to 60°C (-22°F to 140°F)
Typical Battery Life*	
Alkaline	1.5 yr
Lithium	2.0 yr
Pressure Sensor Type	Silicon strain-gauge
Range	0-16.5 psia (0 - 33.59 inches of mercury)
Overpressure tolerance	90 psi
Burst pressure	150 psi
Temperature Compensation	-5°C to 50°C (23°F to 122°F)
Accuracy	± 0.3% full scale

CONNECTIONS

Ⓐ The back end connects to quick-connect submersible cable, programming cable, non-vented PVC backshell, and non-vented stainless steel backshell.

**Assumptions: 20°C, 20-minute sample interval, downloading every 220,000 readings*

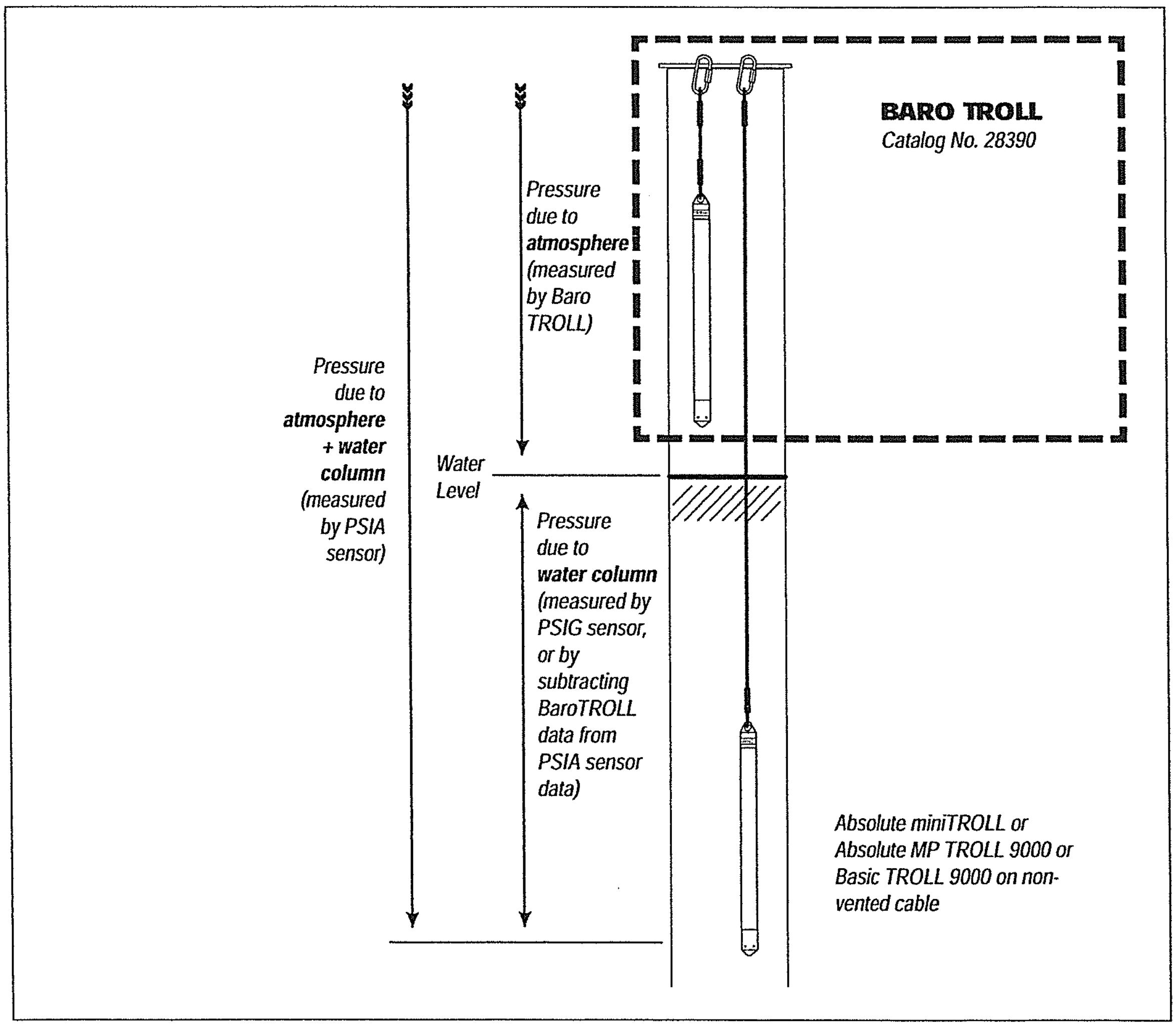
BAROTROLL

Catalog No. 28390

ACCESSORIES	CATALOG NO.
Non-vented stainless steel backshell	28140
Non-vented PVC backshell	28380
ComIT™ communication interface	31580

GUIDELINES & PRECAUTIONS

- Program before installation. Be sure to set the clock.
- Schedule a test as close as possible to the programmed test time in the Absolute miniTROLL or MP TROLL 9000. Select a similar measurement interval.
- Install outdoors in a protected location above water level near submerged PSIA unit. One possibility is shown below, using optional non-vented stainless steel backshell and suspension cable.



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0028395 rev. 002 11/02

AMENDED STIPULATION FOR WITHDRAWAL OF PROTESTS

This Amended Stipulation is made and entered into between the Lincoln County Water District and Vidler Water Company, Inc. ("LCWD&VWC") and the United States Department of the Interior, Fish and Wildlife Service (FWS). Collectively, LCWD&VWC and the FWS are referred to as the "Parties".

RECITALS

A. On February 14, 2005, LCWD&VWC filed Applications 72278, 72219, 72220, and 72221, for a combined maximum duty of approximately 17,375.28 acre-feet per year (afy), with the Nevada State Engineer's Office. The above listed applications shall hereinafter be referred as the "Applications". LCWD&VWC initially intend to pump up to 5,000 afy of groundwater from the Kane Springs Valley Hydrographic Basin (hereinafter referred to as "Kane Springs Valley") pursuant to these Applications, for municipal and domestic uses associated with the Coyote Springs Project in Lincoln County.

B. The FWS filed timely protests to the granting of water rights under the Applications pursuant to the FWS' responsibilities under the Endangered Species Act and administration of the National Wildlife Refuge System. FWS holds a Nevada State water right certificate for a flow rate of not less than 3.5 cfs as measured at the Warm Springs West flume (Permit No. 56668; Certificate No. 15097 issued subject to the terms of Permit No. 56668) for the maintenance of habitat of the Moapa dace and other wildlife purposes ("FWS Water Right"). The Moapa dace (Moapa coviacea) is an endemic fish that inhabits the upper Muddy River and tributary thermal spring systems within the Muddy River Springs/Warm Springs Area in Clark County, Nevada. The Moapa dace was federally listed as endangered on March 11, 1967 (32 FR4001). FWS manages the Moapa Valley National Wildlife Refuge established in 1979 as part of the National Wildlife Refuge System.

C. LCWD&VWC assert that the withdrawal of up to 5,000 afy of groundwater from the proposed wells in Kane Springs Valley will not have an unreasonable adverse affect on endangered species in the Coyote Springs Valley or the Muddy River Springs/Warm Springs Area. LCWD&VWC propose to request the State Engineer hold in abeyance the remaining amount requested in the Applications, until a determination is made from the monitoring of the initial groundwater withdrawal that there are no unreasonable adverse affects due to LCWD&VWC's groundwater pumping.

D. The FWS together with the United States National Park Service sent a letter to the Nevada State Engineer, dated February 6, 2006, recommending that the State Engineer amend his Order 1169 to include Kane Springs Valley and these Applications. This Stipulation is entered into in part to address the FWS's concern expressed in the February 6, 2006 letter. As such, the FWS will withdraw its request to the State Engineer by so stating on the record at the beginning of the hearing when the Stipulation is presented to the State Engineer as provided in paragraph 6 of the Stipulation.

E. The FWS asserts that the proposed groundwater withdrawals from Kane Springs Valley pose a risk of adversely impacting senior federal water rights and water-related resources, as described above, and are desirous of working in a cooperative manner with LCWD&VWC to protect these resources.

F. There are a number of existing monitoring programs required by the State Engineer for existing rights and pending applications within Coyote Spring Valley Hydrographic Basin. The State Engineer has determined in Order No. 1169 (Order) that further hydrological study is needed before a final determination can be made on pending applications and new filings to appropriate water from the carbonate-rock aquifer system in Coyote Spring Valley (Basin 210), Black Mountains Area (Basin 215), Garnet Valley (Basin 216), Hidden Valley (Basin 217), Muddy River Springs (Basin 219) and Lower Moapa Valley (Basin 220) in Lincoln and Clark Counties, Nevada. While the Order does not currently include Kane Springs Valley or the Applications, the FWS and LCWD&VWC agree there is a need to develop data relating to a better understanding and analysis to assist the State Engineer in studying the impacts from the pumping of groundwater in the regional aquifer system.

G. The Parties acknowledge that Nevada Water Law provides pursuant to NRS 534.110(4) that "It is a condition of each appropriation of ground water acquired under this chapter [534] that the right of the appropriator relates to a specific quantity of water and that the right must allow for a reasonable lowering of the static water level at the appropriator's point of diversion." Further, pursuant to NRS 534.110(5), Nevada Water Law "does not prevent the granting of permits to applicants later in time on the ground that the diversions under the proposed later appropriations may cause the water level to be lowered at the point of diversion of a prior appropriator, so long as the rights of holders of existing appropriations can be satisfied under such express conditions." It is the intent of the Parties that this Stipulation provides the initial "express conditions" to allow the development of the LCWD&VWC Applications to proceed, however, such future conditions may be different based on implementation of the monitoring, management and mitigation plan specified in Exhibit A, attached to this Stipulation and made a part hereof.

H. The State Engineer has set an administrative hearing on the protests of the FWS and other protestants commencing April 4, 2006.

I. The Parties acknowledge that White Pine County, Wayne, Ruby and Bevan Lister, and the United States National Park Service have lodged protests to the Applications, but that those entities are not Parties to or in any way bound or prejudiced by this Stipulation. Further, these protestants may enter into stipulations with LCWD&VWC concerning the LCWD&VWC Applications. Such stipulations shall not require the participation of the FWS nor modify in anyway the intent or content of this Stipulation, nor shall the FWS be bound or prejudiced by such stipulations.

J. The Parties agree that the preferred conceptual approach for protecting senior federal water rights from injury and federal water-related resources from unreasonable adverse impacts from ground water pumping is through the use of monitoring, management and mitigation of groundwater pumping. The common goal of the Parties is to manage the development of the regional carbonate-rock aquifer and overlying basin-fill aquifer systems as a water resource without causing any injury to senior federal water rights and/or unreasonable adverse impacts to federal water-related resources. Groundwater and the effects of pumping need to be properly monitored and managed to avoid adverse impacts to the water rights and water resources of the FWS. To accomplish this goal, there is a need to obtain accurate and reliable information of the aquifer's response to pumping stresses and the impact of that pumping on water rights and resources of interest. This is to be accomplished by implementing the monitoring, management and mitigation plan as set forth in Exhibit A to this Stipulation. The Parties have determined that it is in their best interests to cooperate in the collection of additional hydrologic and hydrogeologic information as set forth in Exhibit A to this Stipulation.

K. The Parties desire to resolve the issues raised by the protests according to the terms and conditions contained herein.

L. On April 10, 2006, LCWD & VWC filed application nos. 74147, 74148, 74149, and 74150 to appropriate underground water in Kane Springs Valley Hydrographic Basin (subsequent applications). Each of these subsequent filings are identical in quantity (in cfs and acre-feet per year) and point of diversion to the water right applications which are the subject of the Stipulation (application nos. 72218, 72219, 72220, and 72221). LCWD & VWD filing of the subsequent applications was precautionary in nature, and was made to protect Lincoln County Water District and Vidler Water Company's standing in the Kane Springs Hydrographic Basin in the event that applications 72218, 72219, 72220, or 72221 are denied by the State Engineer on a technical or administrative ground. The filing of the subsequent applications raises the same concerns by the FWS as stated in Recital E above. In lieu of filing protests to the subsequent applications, the parties agree that the subsequent applications shall be subject to the terms and conditions of this Amended Stipulation and do not in any way supplement applications 72218, 72219, 72220, and 72221, which are currently under consideration by the State Engineer.

NOW, THEREFORE, in consideration of the mutual promises and covenants contained herein, the Parties do agree as follows:

1. The FWS hereby expressly agrees to withdraw its protests to the Applications and agrees that the Nevada State Engineer may rule on the Applications based upon the terms and conditions set forth herein. The FWS agrees not to file protests to the subsequent applications based on the inclusion of the subsequent applications in this Amended Stipulation (hereinafter referred to as "Stipulation") and that the terms and condition of this Stipulation apply equally to the subsequent applications. Hereinafter in this Stipulation, the term "Applications" shall also refer to the subsequent applications. It is expressly understood that this Stipulation is binding only upon the Parties hereto and their successors, transferees and assigns, and shall not bind or seek to bind or prejudice

any other Parties or protestants, including the United States as trustee on behalf of the any Indian tribe. The execution and filing of this Stipulation with the State Engineer shall have the effect of withdrawing the FWS protests as provided for in Nevada Administrative Code § 533.150.

2. The Parties agree to implement the Monitoring, Management and Mitigation plan, attached hereto "Exhibit A", which is expressly incorporated into this Stipulation as if set forth in full herein upon the State Engineer's granting of the Applications, in total or in part, and upon the terms and conditions contained in Exhibit A.

3. This Stipulation does not waive any authorities of the FWS or the United States, including any other agency or bureau not specified in this Stipulation, nor relieves LCWD&VWC, or any party acting in conjunction with or through LCWD&VWC from complying with any federal laws, including, but not limited to, the National Environmental Policy Act, the Endangered Species Act, the Federal Land Policy and Management Act, and any and all rules and regulations thereunder. It is the expressed intention of the Parties that by entering into this Stipulation, the FWS and the United States are waiving no legal rights of any kind, except for the withdrawal of its protests as provided in Paragraph 1 of this Stipulation. Likewise, LCWD&VWC, or any party acting in conjunction with or through LCWD&VWC, by entering into this Stipulation, are not waiving any legal rights of any kind, except as expressly provided in this Stipulation and its Exhibit A.

4. Further, except as expressly stated in this Stipulation or its Exhibit A, this Stipulation does not affect any legal or administrative process or proceeding concerning rights-of-way or any action that may be necessary to further the development and/or use of the water sought under the Applications.

5. The Parties expressly acknowledge that the Nevada State Engineer has, pursuant to both statutory and case law, broad authority to administer groundwater resources in the State of Nevada and, furthermore, that nothing contained in this Stipulation shall be construed as waiving or in any manner diminishing such authority.

6. The Parties agree that a copy of this Stipulation shall be submitted to the Nevada State Engineer prior to the commencement of the administrative proceedings scheduled to begin on April 4, 2006. The Parties shall request on the record at the beginning of the scheduled proceeding, that the State Engineer include Exhibit A of the Stipulation as part of the permit terms and conditions, in the event that he grants Applications 72278, 72219, 72220, and 72221, in total or in part. The FWS, at its option, may attend the hearing, but will present no issues or statements unless necessary to explain or defend this Stipulation or Exhibit A.

7. Notices. If notice is required to be sent by the Parties, the addresses are as follows:

If to FWS:

Supervisor
Nevada Field Office
Fish and Wildlife Service
1340 Financial Blvd., #234
Reno, NV 89502

If to LCWD&VWC:
Chairman
Lincoln County Water District
P.O. Box 685
Pioche, NV 89043

And:
Dorothy Timian-Palmer
Vidler Water Company, Inc.
704 W. Nye Lane, Suite 201
Carson City, NV 89703

8. LCWD&VWC may transfer or assign its interest in the water rights here involved. Any and all transferees and assignees shall be bound by the terms and conditions of this Stipulation. As a condition to any such transfer or assignment, the transferee and/or assignee shall execute a stipulation expressly stating it is bound to all of the terms and conditions of this Stipulation.

9. This Stipulation shall be governed in accordance with the laws of the State of Nevada to the extent not inconsistent with federal law.

10. Copies of all correspondence between and data gathered by the Parties pertinent to the terms of Exhibit A shall be submitted to the Nevada State Engineer. It is the intentions of the Parties hereto that the Nevada State Engineer shall be kept informed of all activities in the same fashion as are the Parties hereto.

11. By entering into this Stipulation, the FWS does not become a party to any proceeding other than the protest proceeding referenced above or waive its immunity from suit or consent to or acknowledge the jurisdiction of any court or tribunal. Nothing in the Stipulation shall affect any federal reserved water rights of the FWS or the United States on behalf of any Indian Tribe and the FWS by entering into this Stipulation do not waive or prejudice any such rights. The FWS reserves all legal rights, of any kind, it possesses pursuant to or derived from Executive Orders, acts of Congress, judicial decisions, or regulations promulgated pursuant thereto. Neither party waives its rights to seek relief in any appropriate forum of its choice not expressly prohibited by this Stipulation.

12. Any commitment of funding by the FWS or Lincoln County Water District in this Stipulation or otherwise is subject to appropriations by Congress or the governing body of the Lincoln County Water District as appropriate.

13. This Stipulation may be amended by mutual agreement of the Parties.

14. This Stipulation sets forth the entire agreement of the Parties and supercedes all prior discussions, negotiations, understandings or agreements. No alteration of variation of this Stipulation shall be valid or binding unless contained in an amendment in accordance with paragraph 13.

15. This Stipulation is entered into for the purpose of resolving a disputed claim. The Parties agree that the Stipulation shall not be offered as evidence or treated as an admission regarding any matter herein and may not be used in proceedings on any other application or protest whatsoever, except that the Stipulation may be used in any future proceeding to interpret and/or enforce the terms of this Stipulation. Further, the Parties agree that neither the Stipulation nor any of its terms shall be used to establish precedent with respect to any other application or protest in any water rights adjudication or water rights permitting proceeding before the Nevada State Engineer or any other proceeding.

16. The terms and conditions of this Stipulation shall be binding upon and inure to the benefit of the Parties hereto and their respective, successors, transferees and assigns.

17. This Stipulation will become effective as between the Parties upon all Parties signing this Stipulation. The Parties may execute this Stipulation in two or more counterparts, which shall, in the aggregate, be signed by all Parties; each counterpart shall be deemed an original as against any Party who has signed it.

18. Other entities may become Parties to this Stipulation by mutual assent of the Parties.

19. Nothing contained herein shall limit the right of LCWD & VWC, or their successors, transferees, or assigns to assign, pledge, or encumber as security the Applications that are the subject of this Stipulation.

IN WITNESS WHEREOF, the Parties hereto have executed this Agreement on the dates written below.

UNITED STATES DEPARTMENT OF THE INTERIOR

Date: 8/1/2006

Fish and Wildlife Service

By [signature]

Title: CNO MANAGER

Date: 7-17-06 [signature]

LINCOLN COUNTY WATER DISTRICT

By Ronda Hornbeck

Title: Chairwoman

Date: 7-19-06

VIDLER WATER COMPANY, INC.

By [signature]

Title: Chief Operating Officer

ATTEST:

[signature]

LCWD Legal Counsel

EXHIBIT A
for
Amended Stipulation between LCWD&VWC and the United States Fish and Wildlife Service

MONITORING, MANAGEMENT AND MITIGATION PLAN GROUNDWATER DEVELOPMENT IN KANE SPRINGS VALLEY

The purpose of this plan is to describe the agreements of Lincoln County Water District and Vidler Water Company, Inc. (LCWD&VWC) and the United States Fish and Wildlife Service (FWS) regarding the monitoring, management, and mitigation of potential impacts due to development of ground-water resources in the Kane Springs Valley area. This plan applies to proposed ground-water development in Kane Springs Valley that consists of the use of water under State of Nevada water-rights applications numbered 72218, 72219, 72220 and 72221 and the subsequent applications 74147, 74148, 74149, and 74150, filed by LCWD&VWC.

The Plan describes the LCWD&VWC and FWS (hereinafter referred to as "the parties") obligations regarding the development, monitoring, management, and mitigation related to the above numbered applications in Kane Springs Valley Hydrographic Basin for use that water in Coyote Spring Valley Hydrographic Basin.

This plan consists of four principle components, as follows:

1. *Monitoring Requirements,* related to production wells, monitoring wells, elevation control, and springflow, water quality, quality of data, and reporting;
2. *Management Requirements,* related to the creation and role of a Technical Review Team (hereinafter referred to as "the TRT"), the development and use of a numerical ground-water flow model, the establishment of action criteria, and the details of the decision-making process;
3. *Mitigation Requirements;* and
4. *Modification of the Plan.*

The common goal of the parties is to manage the development of the LCWD&VWC Water Rights in their entirety from Kane Springs Valley Hydrographic Basin, without resulting in any losses to senior federal water rights or unreasonable adverse impacts to federal water resources. The parties will collaborate on technical data collection and analysis and will rely on the best scientific information available in making decisions required by the Plan.

1. Monitoring Requirements

A. Production Wells

- LCWD&VWC will record discharge and water levels in their production wells in Kane Springs Valley on a continuous basis as is feasible.

B. Monitoring Wells

LCWD&VWC, as determined by the parties to this agreement, in consultation with the Nevada State

Engineer, shall locate and construct two monitoring wells down gradient from the Kane Springs Valley ground-water production well (KMW-1). The location of the first proposed monitoring well (CSIMW-1) is to be an equal distance between the existing Southern Nevada Water Authority Monitoring Well Four (CSVM-4) and the Coyote Spring Investment monitoring well CE-VF-2. Further, CSIMW-1 will be located on the north (hydraulically upgradient) side of the interpreted southwestern extension of the Kane Springs Wash fault zone on Coyote Springs Investment property along the existing abandoned Highway 93. The second proposed monitoring well (CSIMW-2) is to be located on the south (hydraulically downgradient) side of the interpreted southwestern extension of the Kane Springs Wash fault zone on Coyote Springs Investment property along the existing abandoned Highway 93. Specifically, the second well would be sited such that the distance between the monitoring well CSIMW-1 and the aforementioned fault zone is approximately equal to the distance between the fault zone and CSIMW-2. See Attachments "A-1", "A-2", "A-3" and "A-4" to this Exhibit A. FWS shall work with LCWD&VWC in good faith to ensure that the well is located and constructed in a cost-effective manner, to enable the monitoring of the potential southward progression of groundwater level declines resulting from proposed ground-water production in Kane Springs Valley.

- All monitoring wells used as part of this plan shall be installed and water levels recorded on a continuous basis as is feasible, beginning as soon as possible after the State Engineer decision relative to the Kane Springs Valley Applications.

- The initial groundwater level would be established at the time that the pumping wells in Kane Spring Valley were ready to go on-line.

- The term "as is feasible" shall relate to mechanical failures and the issues associated with the remoteness of the locations, or other events outside the control of the parties that do not permit data collection.

- The locations and monitoring frequency of the monitoring-well network will be reviewed by the TRT on an annual basis beginning in 2007, and may be reduced or expanded in scope upon its recommendation.

C. *Elevation Control*

- LCWD&VWC will conduct a detailed elevation survey of all their wells used for monitoring as part of this plan. LCWD&VWC will cooperate in any regional plan organized by the Nevada State Engineer to determine elevation above sea level of all major spring orifices and monitoring and production wells in the Lower Colorado Flow System region. LCWD/VWC will match the Southern Nevada Water Authority's current datum relating to monitoring and production well elevations.

D. *Water Quality*

- LCWD&VWC will collect water quality samples and have them analyzed for major ions, trace elements, and isotopes at all production and monitor wells used as part of this plan (as specified in Sections 1.A and 1.B.) commencing July 1, 2007.

- Thereafter, LCWD&VWC will collect and analyze water-quality samples for major ions, trace elements, and isotopes at all production and monitoring wells used as part of this plan every five years thereafter.

- Samples will be collected, analyzed and reported according to standard methods.

- Frequency, sampling location, and water quality parameters will be reviewed by the TRT on an annual basis beginning in 2007, and may be reduced or expanded in scope upon its recommendation.

E. *Reporting*

- All data collected under or as described in this plan, shall be fully and cooperatively shared among the parties.

- Water level and production data shall be provided to the FWS within 60 days of its collection by LCWD&VWC. LCWD&VWC will use its best efforts to provide data to the FWS within 30 days of its submission to LCWD&VWC, or in the case of water quality data, within 90 days of receipt of laboratory results.

- LCWD&VWC will report the results of all monitoring and sampling under this plan in an annual monitoring report

2. <u>Management Requirements</u>

A. Action Criteria

The Parties recognize that maintenance of minimum in-stream flows in the Warm Springs area is essential for the protection and recovery of the Moapa dace. Further, the parties recognize that existing data is insufficient to determine if the groundwater development in Kane Springs Valley Hydrographic Basin, that is the subject of the Plan, affects the in-stream flows in the Muddy River Springs/Warm Springs Area, and if so, to what extent. Thus, the parties agree as follows:

1. For purposes of this paragraph A., all "Average Flow Levels" specified herein shall be determined by flow measurements at the Warm Springs West flume. Average Flow Levels will be determined to have reached a particular level within a range specified in paragraphs B(2) through (7) ("Trigger Range"): (1) if the daily average flow for each of 45 consecutive days decreases to an amount within the Trigger Range, or if the 90 day average flow over any 90 consecutive day period decreases to an amount within the Trigger Range; or (2) if the daily average flow for each of 90 consecutive days increases to an amount within the Trigger Range, or if the 135-day average flow over any 135 consecutive day period increases to an amount within the Trigger Range. Any adjustment in the rating curve for the Warm Springs West flume shall result in a pro-rata adjustment of the Trigger Ranges.

2. If the Average Flow Level decreases to an amount within the Trigger Range of 3.2 cfs or less, the Parties agree to meet as soon as practicably possible to discuss and interpret all available data and plan for mitigation measures in the event flows continue to decline; and

3. If the Average Flow Level is within the Trigger Range of 3.15 cfs or less but greater than 3.0 cfs, LCWD&VWC agree to reduce pumping from all wells in Kane Springs Valley by 50% or to a pumping level no greater than 2,500 afy, whichever results in the lesser amount of pumping, until the Average Flow Level exceeds 3.15 cfs.

4. If the Average Flow Level is within the Trigger Range of 3.0 cfs or less, LCWD&VWC agree to cease pumping from all wells in Kane Springs Valley until the Average Flow Level exceeds 3.0 cfs. However, if LCWD&VWC, together with Coyote Springs Investment, LLC ("CSI"), effectuate a reduction in the quantity of water CSI would have otherwise been entitled to pump in a given year from wells within the Coyote Spring Valley, then LCWD&VWD shall have the right to pump a like quantity of water from wells within Kane Springs Valley in that year.

B. Technical Review Team

1. Upon execution of this Stipulation, the Parties shall establish a Technical Review Team ("TRT") whose members shall include two representatives ("TRT Representatives") each from LCWD&VWC and the FWS, including at least one with substantial formal training and experience in hydrogeology ("Technical Representative"). Except as otherwise provided herein, the two TRT Representatives shall together have one vote on TRT matters. By consensus, the TRT Representatives may offer voting or non-voting TRT membership to others who provide regional monitoring records and analyses to the TRT.

2. The objectives of the TRT shall be to review existing data, make recommendations concerning the monitoring efforts required by this Plan, and determine whether other criteria, such as water levels in monitoring wells, are a better indicator of potential effects of the pumping wells on the springs in the Muddy River Springs/Warm Springs Area. Either party may advance any recommendation for consideration by the other party to modify the action criteria. However, no change in the action criteria shall occur within the first five (5) years following the effective date of the Plan. After this five year period, and if the TRT reaches a consensus on changes to the action criteria, such criteria may be changed.

3. If the TRT Representatives are unable to reach consensus on the action criteria, the Parties shall refer the matter to a qualified panel of third party reviewers ("Panel") consisting of three scientists unaffiliated with any Party and having substantial formal training and experience in hydrogeology. If the Parties cannot agree by consensus on the make-up of the Panel, one member of the Panel shall be designated by each of the following from its own ranks: U.S. Geologic Survey, Nevada State Engineer (if the Nevada State Engineer declines to participate, then the Desert Research Institute shall be substituted), and a private firm with the requisite expertise designated by a majority of the Parties ("Appointing Entities"), provided that the Parties by consensus may designate different similarly qualified Appointing Entities. If any Appointing Entity for any reason is unable or refuses to designate a member of the Panel, the Parties by majority vote shall designate a qualified replacement Appointing Entity. The purpose of the referral to the Panel will be to obtain peer review of the then-current action criteria, the data upon which it is based, all previously submitted data and reports, and any other relevant and available data and analytical materials. The Panel will be asked to make its recommendation

based on the foregoing information concerning the appropriate content of the action criteria. All Parties shall have a fair and reasonable opportunity to present factual and analytical submissions in person and/or in writing to the Panel. The Parties contemplate that a determination of the Panel on the action criteria will constitute the best available scientific information concerning the impacts on Muddy River Springs/Warm Springs Area and Muddy River flows resulting from regional groundwater pumping, and the appropriateness of any proposed pumping restriction adjustments. The cost of the Panel shall be borne equally by the Parties.

3. **Mitigation Requirements**

- LCWD&VWC will mitigate unreasonable adverse impacts either as agreed upon by the parties or after the Nevada State Engineer determines whether there are unreasonable adverse impacts due to LCWD&VWC pumping. LCWD&VWC will take the necessary steps to ensure that mitigation actions are feasible.

- As part of their commitment to the recovery of the Moapa dace, LCWD&VWC shall commit $50,000, annually for a period of five (5) years following the granting of the Applications, in total or in part, for the restoration of Moapa dace habitat outside the boundaries of the Moapa National Wildlife Refuge. Such restoration shall be conducted as agreed to by the FWS. In the event that the Applications as granted by the State Engineer total less than 2,500 afy, the parties agree to meet and renegotiate the annual funding amount to be consistent with the lesser quantity of water granted and the commitment by LCWD&VWC to participate in restoration activities of the Moapa dace. FWS acknowledges that Coyote Springs Investment LLC, a Nevada limited liability company (CSI), has dedicated certain quantities of water pursuant to a Memorandum of Agreement by and between the Southern Nevada Water Authority, the United States Fish and Wildlife Service, CSI, the Moapa Band of Paiutes, and the Moapa Valley Water District. FWS further acknowledges that CSI is the intended beneficiary of the water to be developed pursuant to the Applications. Thus, in the event that pumping of groundwater pursuant to the Applications is restricted pursuant to Section 2. A. of this Exhibit A to the Stipulation, FWS agrees to use any quantities of water dedicated by CSI pursuant to the MOA for the survival and recovery of the Moapa dace as directed in the MOA.

4. **Modification of the Plan**

- LCWD&VWC and the FWS may modify this plan by mutual agreement. The parties also acknowledge that the State Engineer has the authority to modify this plan. In addition, LCWD&VWC and the FWS may individually or jointly petition the State Engineer to modify this plan in the event that mutual agreement cannot be reached. Any such petition shall only be filed after 90 days written notice to the remaining party. Either LCWD&VWC or the FWS may submit written comments to the State Engineer regarding the merits of any such petition for modification.

Report

Hydrologic Assessment of Kane Springs Valley Hydrographic Area (206): Hydrologic Framework, Hydrologic Conceptual Model, and Impact Analysis

Presentation to the Office of the Nevada State Engineer

Prepared for
Lincoln County Water District and Vidler Water Company

Prepared by

CH2MHILL

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Contents

Introduction/Objectives

A hydrologic assessment of the local and regional conditions that affect the movement and storage of groundwater in the Kane Springs Hydrographic Area (206) was conducted to address the following objectives:

- Develop an understanding of the existing conditions of local groundwater resources within Kane Springs Valley (KSV).
- Assess the availability of these resources.
- Assess potential impacts to local and downgradient water users and water resources including local and regional springs, and water courses.
- Develop a conceptual framework to support potential monitoring and/or mitigation measures, as appropriate.

The principal components of the assessment included the following:

- Development of a hydrologic framework to provide physical context for the assessment.
- Installation of test well and companion monitoring well, and conduct aquifer testing. This component of the assessment was performed by URS Corporation and the specific results and analyses that arose from this work is presented under separate cover in URS (2006).
- Conducting groundwater sampling from both KSV and adjacent Coyote Spring Valley.
- Evaluation of the local and regional geochemical conditions of the groundwater based on the analyses of water chemistry and stable isotopes.
- Development of hydrologic conceptual model of KSV both locally and in the context of regional groundwater flow.

Based on the resulting conceptual model:

- Assess the availability of groundwater in the KSV
- Assess potential impacts resulting from groundwater withdrawals from the KSV.

Hydrologic Framework

KSV – Physical Features and Conditions

Kane Springs Valley is an elongated north-northeast/south-southwest trending valley in southern Nevada that is flanked by the Delamar Mountains to the west and north, and the Meadow Valley Mountains to the south. Covering an area of approximately 232 square miles, KSV is approximately 28 miles long and an average of approximately 8 miles wide. The floor of the valley slopes south-southwest from a high of approximately 4000 feet near the base of the Clover Mountains toward the mouth of the valley where the elevation is approximately 2900 feet. Within the KSV hydrographic area, the Delamar Mountains reach 7720 feet and receive most of the local precipitation. The Meadow Valley Mountains are considerably lower with a maximum elevation of 5676 feet. The Clover Mountains, while technically east of the KSV basin, affect precipitation patterns within the northeastern portion of KSV.

The ephemeral Kane Springs Wash, which drains the entire valley, is the dominant surface water feature in the basin. Springs discharging from the surrounding mountains are generally low-flowing (i.e., less than 10 gallons per minute [gpm]) and are considered to be locally recharged based on their water chemistry (Thomas et al., 1996). With the exception of small areas below these springs, phreatophytic vegetation is generally absent; therefore, groundwater discharge through transpiration is a negligible component of the water budget for the KSV basin.

Figure 1 shows the location of the study area focused on KSV. Figure 2 shows the location of KSV Hydrographic Area with respect to the Colorado River Basin and other hydrographic areas within the Colorado River Basin. Figure 3 shows detail of KSV highlighting the various local geographic features: Kane Springs Wash, the Meadow Valley Mountains, the Clover Mountains, the Delamar Mountains, and the locations of various local springs.

Geologic Framework

The general lithology of much of the mountains surrounding KSV is Tertiary volcanic rocks, although outcrops of underlying Paleozoic carbonate rocks can be found in the western portion of both the Delamar and Meadow Valley Mountains. The valley bottom is composed of Quaternary basin-fill deposits, which form soils that are fairly uniform throughout the valley.

KSV is located is located in the middle of the vast Carbonate-Rock Province, which underlies as much as 50,000 square miles in Nevada alone, but also stretches into Idaho, Utah, and California (Dettinger et al., 1995). The location of KSV in relation to the Carbonate Rock Province is shown in Figure 4.

The specific geology of the study area is shown in Figure 5, and geologic cross sections (indexed and shown in Figures 6 through 17) reveal the subsurface structure and lithology with important implications with respect to the occurrence and movement of groundwater through the carbonate rocks, which underlie the study area.

Based on examination of these cross-sections, the following conclusions can be drawn:

- Carbonate aquifer truncated by Clover Mountain calderas in upper portion of KSV.
- Considerable thickness of carbonate rock units (over 1 Km) in lower portion of KSV.
- Considerable faulting has occurred both within and along the margins of KSV.
- Faulting is mapped as occurring deep in the carbonate rocks implying the potential for deep groundwater occurrence and flow.
- Kane Springs Wash fault zone truncates carbonate rocks along the northern flank of the Meadow Valley Mountains.
- Basin-fill deposits in KSV are relatively thin.
- Thick sequences of carbonate rocks are present down Coyote Spring Valley and into the Muddy Springs Area, Hidden Valley, Garnet Valley, California Wash and Black Mountains Area.
- Considerable vertical faulting occurs in all these areas.

Hydrologic Conceptual Model

The groundwater environment in KSV includes both basin-fill deposits and fractured rock, which includes primarily volcanic and carbonate rocks.

Basin-Fill Deposits

In the absence of much direct information on the composition and extent of the basin fill, these deposits are assumed in this study to be composed principally of fine-textured sediments (silt and clay) across much of the basin, except immediately adjacent to the basin margins where alluvial fan deposits contain more coarse-textured sediments. The lithologic logs from the boreholes drilled near the mouth of the basin support the hypothesis of a primarily fine-textured basin fill (URS, 2006). The basin-fill deposits are the product of the erosion of the surrounding mountains, which are mainly volcanic in origin. These volcanic rocks readily weather to clay-size particles. In addition, both the Delamar and Meadow Valley Mountains are generally low in relief, and do not engender high-energy erosion environments capable of transporting large quantities of relatively coarser material (i.e., gravel, cobbles) onto the basin floor.

As a result, the basin-fill deposits in KSV are generally not favorable for the development of laterally continuous aquifer units, although these deposits are undoubtedly locally saturated over some depth interval at least seasonally.

Fracture-Rock

The fractured-rock groundwater medium in KSV is composed of both local volcanic and regionally occurring carbonate rocks. Volcanic rocks of the Clover and Delamar Mountains, which are composed of various ash-flow tuffs, rhyolite and basalt, typically do not support development of significant aquifer system because of heterogeneous intrinsic permeability and the general lack of continuous faulting and folding structures. Volcanic rocks, however, do provide local conduits for groundwater to recharge into deeper (carbonate) aquifer system. Carbonate rocks, which are highly fractured and laterally/vertically continuous, are the primary groundwater medium in KSV, and provide the principal means of inter-basin groundwater flow from KSV.

Groundwater Recharge to KSV

Walker (2006) performed an analysis of recharge to KSV that involved multiple means of estimating precipitation, and used two separate means to estimate recharge based on the precipitation estimates. Precipitation was estimated using vegetation mapping in two ways: (1) vegetation/precipitation/elevation correlations were developed resulting in precipitation estimates representative of sequential bands of elevation, and (2) vegetation communities were mapped to develop a map of the spatial distribution of precipitation irrespective of elevation. In addition, precipitation data from PRISM was used to develop a spatial distribution of precipitation across KSV as a third means of comparison.

Recharge was approximated both using a slightly modified version of the Maxey-Eakin approach (Maxey and Eakin, 1949), and through a water budget approach. For the water-budget approach, the areas of the basin where evapotranspiration was at least 12 inches, based on literature values (see Walker, 2006), were subtracted from a given precipitation distribution resulting in the amount of water available for infiltration or surface runoff. Subtracting estimates of surface runoff and discharge from local springs, resulted in estimates of groundwater recharge that are summarized in the following table.

Precipitation Estimation Method/Source	Total Precipitation (AF/yr)	Recharge Estimation Method	Recharge Estimate (AF/yr)	Recharge/Total Precipitation (percentage)
Vegetation Indicators as function of elevation	128,270	Maxey-Eakin	5,700	4
		Water-Budget	6,350	4
Vegetation Communities	118,668	Maxey-Eakin	5,300	4
		Water-Budget	6,600	5
PRISM-based	133,920	Maxey-Eakin	9,600	7
		Water-Budget	14,155	10
LVVWD (2001)[a]	140,218	Maxey-Eakin	6,757	4
		Water Budget	5,950	4
State Water Plan–1971[b]	80,000	--	500	0.6

a LVVWD (2001).

b Nevada Department of Natural Resources, Division of Water Resources. 1971. State of Nevada Planning Report

From these results, Walker (2006) estimated that the average annual recharge to groundwater in the KSV is on the order of 5,000 acre-feet/year (AF/yr).

It is concluded here that a value of 5,000 AF/yr is a reasonable estimate for average annual recharge based on:

- General consistency among different estimating approaches.
- Size of basin (232 square miles), which is considerable area over which to receive precipitation.
- Significant area within KSV that is of higher elevation (69 square miles > 5,000 ft, or 30% of basin)
- The various methods for estimating average annual precipitation results in a reasonable value of roughly 120,000 AF/yr, which translates to an average precipitation across the basin of approximately 9 inches/year, which is considered a reasonable estimate.
- An overall percentage of precipitation that becomes recharge (approximately 5 percent) is considered reasonable.

Groundwater Conditions

Figure 18 shows the locations of selected wells in the study area. A subset of these wells through which a vertical profile has been developed is shown in Figure 19. The vertical profile, in turn, is shown in Figure 20.

Key conclusions from the vertical profile in Figure 20 are as follows:

- Only the upper-most 1,000 to 2,000 feet of the aquifer is penetrated by existing wells. Accordingly, only a fraction of the carbonate rock is penetrated by existing wells based on published geologic cross sections that indicate that the carbonate units are typically 2-4 kilometers (6,500 – 13,000 feet) thick.
- Differences in lithology within screen interval influences water level.

Figure 21 shows the location of the test well and monitoring well installed in KSV relative to local geologic features; principally the Kane Spring Wash fault zone and the Willow Spring fault. Figure 21 also shows the location of a geologic cross section through the well site. The cross section is shown in Figure 22. The significance of the cross section is that it shows the vertical proximity of the Willow Spring fault relative to the test well KPW-1. During aquifer testing on KPW-1, a recharge boundary was encountered within the first hour of the test reflecting a higher transmissivity zone associated with the Willow Spring fault. Figure 23 shows the drawdown in monitoring well KMW-1. One of the Hantush-Jacob type curves used to calculate aquifer transmissivity and storage coefficient is also shown on the figure. The level portion of the curve clearly demonstrates a source of water to the well that truncates further drawdown.

Another important implication of the aquifer testing results based on Figure 23 is that the shape of the drawdown curve is indicative of a porous medium (i.e., there is no evidence of conduit or discrete fracture flow).

A summary of the aquifer test results are shown in the following:

Summary of Results From 7-Day Sustained Aquifer Test Pumping KPW-1 at 1,800 gpm

Data	Method*	Transmissivity (gal/day/ft)	Storage Coefficient	Source
KMW-1 drawdown	Hantush-Jacob (leaky-confined)	30,000	10^{-4}	URS (2006a)
	Jacob-Cooper (mid-time)	30,000	10^{-4}	Feast Geosciences**
	Jacob-Cooper (late-time)	240,000		Feast Geosciences
KMW-1 Recovery	Theis (mid-t/t')	95,000	--	URS (2006a)
	Theis (late-t/t')	240,000	--	URS (2006a)
	Jacob-Cooper (mid-t/t')	85,000	--	Feast Geosciences
	Jacob-Cooper (late-t/t')	236,000	--	Feast Geosciences
KWPW-1	Theis Recovery (late-t/t')	380,000	--	URS (2006a)

* Methods based on Lohman (1979)

** Feast Geosciences unpublished aquifer test analysis, 2006

Based on the aquifer test results, two values of transmissivity determined:

1. Representative of the "regional" aquifer between approximately 30,000 and 80,000 gallons per day per foot (gpd/ft).

2. Representative of higher transmissivity zone associated with the Willow Springs Fault of approximately 300,000 gpd/ft.

Figure 24 shows the location of local geologic structure affecting groundwater conditions in KSV. The hydraulic affect of these structures are apparent from the aquifer test and groundwater level data. Of note is evidence for the extension of the Kane Springs Wash fault zone southwestward into Coyote Spring Valley.

Figure 25 is a schematic diagram of Kane Springs Wash fault influence on groundwater levels in Coyote Spring Valley. Based on geologic logs of the wells obtained from Berger et al. (1988) and the most current water levels from December 2005 obtained from Southern Nevada Water Authority Central Data Repository, it is clear that there is a steep hydraulic gradient between these wells CE-VF-2 and CSVM-6. The Kane Spring Wash fault zone likely:

- Acts to impede but not inhibit groundwater flow across the fault zone.
- Has the potential to limit the northward advance of the cones of depression from pumping wells downgradient of the fault (as a function of distance – the closer the pumping to the fault, the less the limiting influence.)
- Has the potential to limit the southward advance of the cones of depression from pumping wells upgradient of the fault (as a function of distance from the fault).

Evidence of the influence of the fault zone is also shown on Figure 26, which depicts the spatial distribution of the most recent water levels on record for selected carbonate wells in the study area. Based on this map of water levels (Figure 26):

- Kane Springs Wash fault zone causes break in regional (carbonate rock) hydraulic gradient in Coyote Spring Valley.
- Upgradient of fault: Gradient "steeper"
- Downgradient of fault: Gradient "flatter"
- With a few exceptions (e.g., CSVM-5, CSV-2), carbonate groundwater levels are very similar generally everywhere downgradient of Kane Springs Wash fault zone.
- Implication of "flat" gradient is relatively high transmissivity across the southern half of the study area.
- Implication of relatively high transmissivity is high potential for regional groundwater flow

Figure 27 shows the spatial distribution of transmissivity values across the study area. The results on the figure are consistent with the water level data, which indicate that high transmissivity values are present across the study area.

Estimation of Groundwater Flow Through Kane Springs Valley

Groundwater flow through Kane Springs Valley was roughly approximated based on the following 1-D application of Darcy's Law:

$Q = Tw\Delta h$

where,

Q = groundwater discharge across a given cross sectional area

T = aquifer transmissivity

w = aquifer width over which T is assumed representative

Δh = horizontal component of hydraulic gradient perpendicular to the aquifer width

The rationale for determining representative thickness of the carbonate aquifer underlying KSV is based on the following:

- Published geologic cross sections which indicate:
  - Considerable thickness of carbonate rock in vicinity of KSV (> 3,000 feet).
  - Considerable faulting has occurred both within and along the margins of KSV.
  - Vertical faulting is mapped across (deep) all carbonate rock in KSV implying the potential for deep groundwater flow through this basin.
- Groundwater temperature from KPW-1 is very hot (~ 130 °F) and deuterium concentrations light (-104) indicating circulation of deep groundwater under KSV.
- Published data on carbonate wells elsewhere in Nevada indicate the potential for carbonate wells to exceed depths of 5,000 feet (Dettinger et al., 2005, Table 6).

It is therefore concluded that 3,000 feet is a reasonable, and likely conservative, estimate for the thickness of the carbonate aquifer in KSV.

Based on an assumed representative value of aquifer thickness of 3000 feet, a representative value for aquifer transmissivity was determined using the aquifer test results as a starting point. Specifically, using the relationship,

Transmissivity = aquifer thickness x hydraulic conductivity

the following table runs through the procedure followed to develop values of aquifer transmissivity that reflect the total aquifer thickness.

Portion of Aquifer	Calculated Range of T (gpd/ft)	Aquifer Thickness Tested (Based on KPW-1 Construction, ft)	Calculated Hydraulic Conductivity (ft/day)	Assumed Total Aquifer Thickness (ft)	Revised Transmissivity (Based on total aquifer thickness, gpd/ft)	Assumed Representative Value of Transmissivity (gpd/ft)
Bulk Aquifer	30,000 – 80,000	1,000	4 – 9	3,000	90,000 – 200,000	150,000
Local Fault Zone	300,000	1,000	40	3,000	900,000	900,000

* From 8-day aquifer test at KPW-1

The next step is to determine the regional horizontal component of hydraulic gradient that would be representative of the gradient driving groundwater flow into the KSV.

The bases for estimating regional horizontal component of hydraulic gradient are presented in the following table.

Location	Representative Water Level Elevation (ft amsl)*	Distance Between Locations (ft)				
		Pahranagat Springs	CSVM-3	KPW-1	CSVM-4	CE-VF-2
Pahranagat Springs**	3190	0	68,500	96,500	96,500	132,000
CSVM-3	2206	68,500	0	37,190	36,060	66,130
KPW-1	1879	96,500	37,190	0	10,760	56,450
CSVM-4	1874	96,500	36,060	10,760	0	45,950
CE-VF-2	1857	132,000	66,130	56,450	45,950	0

* Well data from December 2005

** Approximated by elevation of Lower Pahranagat Lake

In the absence of readily available data for groundwater level in the carbonate rock in the Pahranagat Springs area, the elevation of Lowe Pahranagat Lake was used as a general approximation as it represents a lower area collecting discharge from regional carbonate springs.

The regional horizontal component of hydraulic gradient was subsequently estimated by considering the change in water level elevation between Pahranagat Springs, CSVM-3, and CE-VF-2:

Pahranagat Springs/CSVM-3 = (3190 – 2206)/68,500 = 0.014

CSVM-3/CE-VF-2 = (2206 – 1857)/66,130 = 0.0053

The gradient between Pahranagat Springs and CSVM-3 is considered to be too steep to be representative of flow into KSV. It is therefore concluded that a representative value for the regional hydraulic gradient is on the order of 0.005

In estimating the hydraulic gradient for groundwater flow from KSV it was assumed the gradient along Willow Spring fault would be most representative and roughly approximated by the change in water level elevation between

KPW-1/CSVM-4 = (1879 – 1875)/10,760 ≈ 0.0005

The final step in the determination of groundwater flow through KSV is the approximation of representative values of aquifer width through which groundwater flows into and out of the KSV. Assuming flow through carbonate rocks, the inflow width of aquifer is defined as being perpendicular to assumed regional hydraulic gradient where carbonate rocks mapped within KSV (approximately 3 miles). Figure 28 shows the location and length of the width of aquifer identified as being representative of groundwater flow into KSV.

The width of the aquifer though which groundwater flows out of the aquifer is defined as being perpendicular to the assumed direction of local flow from KSV, and parallel and controlled by the Kane Springs Wash fault zone.

Due to the influence of the Willow Spring fault on the aquifer test results, two components to the local aquifer width are considered:

- Width representative of fault zone transmissivity (approximately 0.5 miles);
- Width of aquifer representative of transmissivity unaffected by fault zone (approximately 3.5 miles).

The location and length of the representative width of the aquifer through which groundwater flows out of KSV is shown on Figure 29.

With values for all of the parameters required to apply the Darcy's Law approach, the approximation of the volumetric flux of groundwater through KSV is summarized in the following table.

Groundwater Flow Component	Transmissivity (gpd/ft)	Aquifer Width (ft)	Hydraulic Gradient	Calculated Volumetric Groundwater Flow (AF/yr)	Volumetric Groundwater Flow (rounded down to nearest 1,000 AF/yr)
Regional Groundwater flow into Kane Springs Valley	150,000	15,840	0.005	13,300	13,000
Groundwater outflow from Kane Springs Valley into Coyote Springs Valley	150,000	18,480	0.005	15,500	15,000
	900,000	2,640	0.0005	1,300	1,000
Combined Groundwater Outflow from Kane Springs Valley	--	--	--	16,800	16,000

Based on the resulting values of volumetric groundwater flow, the following summary of groundwater inflow and outflow from KSV was developed:

Inflow to Kane Springs Valley:

Regional groundwater flow ....13,000 AF/yr

Recharge within Kane Springs Valley*..5,000 AF/yr

Total groundwater inflow to Kane Springs Valley ....18,000 AF/yr

Outflow from Kane Springs Valley:

Local groundwater discharge into Coyote Spring Valley ....16,000 AF/yr

* based on analysis by Walker (2006)

Clearly the inflow estimate does not balance with the estimate of outflow, but the difference is within about 10 percent, and reflects the uncertainty in parameter values and the applicability of the approach. In particular, the aquifer thickness is likely significant, but unknown.

However, it is concluded that:

– At least approximately 15,000 AF/yr flows through the aquifer system of KSV.

– KSV perennial yield, however, is on the order of 5,000 AF/yr based on recharge analysis.

This conclusion is shown conceptually on Figure 30.

Impact Analysis

The impacts analysis focused on the assessment of potential effects of lowering groundwater levels on local permitted points of diversion and local and regional springs

Permitted Groundwater Points of Diversion

Complex aquifer conditions in KSV (local presence of fault structures that both enhance and impede groundwater flow), multidimensional groundwater flow, together with limited spatial distribution of data on water levels and aquifer parameters, make meaningful predictions of groundwater level decline problematic. Accordingly, a simple analytical approach, which most likely over estimates resulting groundwater declines, is applied here.

Specifically, the analytical solution for transient groundwater flow to well developed by Theis (1935) is applied to approximate "worst case" water level declines within reasonable distance (~ 10 miles) from pumping well in KSV. Theis (1935) provides the transient solution to the partial differential equation for the radial flow to pumping well, arranged to solve for drawdown (s), as follows:

$$s = \frac{Q}{4\pi T} \int_u^\infty \frac{e^{-u} du}{u}$$

where, Q = pumping rate

T = aquifer transmissivity

and,

$$u = \frac{r^2 S}{4Tt}$$

where, r = the radial distance from the pumping well

S = storage coefficient

t = time since pumping began

In applying the Theis solution to determine the lateral extent of the cone of depression from a point of hypothetical pumping in KSV, the following general approach was followed. First, the Theis-predicted water level declines at distances from the pumping well were compared to locations of the nearest existing permitted groundwater points of diversion. Second, the resulting groundwater declines were assessed as to whether they would impair the permit (e.g., assess if predicted water level decline would dewater an existing well at a permitted point of diversion).

The Theis solution assumes an ideal porous medium consisting of an aquifer of homogenous properties, including isotropic permeability, over infinite extent. In addition the application for the impact analysis assumed the following:

- Pumping from a single well at 3,000 gpm (5,000 AF/yr) for 100 years.
- Location of pumping well at KPW-1
- Values of input parameters based on KSV aquifer test results.

Using the Theis solution to predict long-term drawdowns as a result of pumping from KSV will overestimate the predicted water level declines for the following reasons:

- The approach assumes that there is no local or regional hydraulic gradient, which would restrict propagation of the cone of depression both lateral to the horizontal orientation of the gradient and downgradient of the pumping well (i.e., the resulting circular cone of depression extends further downgradient and in directions perpendicular to the local natural direction of groundwater flow).

- The resulting circular cone of depression is also in contradiction with the probable effects of both the Willow Spring fault (positive boundary) and the Kane Springs Wash fault zone (negative boundary), which would ultimately impede the propagation of the cone of depression.
- Single pumping well concentrates drawdown at a point. Less drawdown would occur at same distance from the pumping well if pumping divided among multiple wells spaced at least 1 mile or more apart.

Based on the following values for the input parameters:

Q = 3,000 gpm
$S = 10^{-4}$
t = 100 years

the predicted drawdowns for two different values of transmissivity are as follows:

Transmissivity (gpd/ft)	Predicted drawdown at distance = r (ft)	
	r = 5000	r = 50,000
150,000	30	20
300,000	16	11

A transmissivity value of 300,000 gpd/ft is representative of the local aquifer conditions affected by the Willow Spring fault. However, over 100 years, a lower value of transmissivity may be more applicable. Accordingly, results for 150,000 gpd/ft are presented. Using a value of 50,000 gpd/ft was not considered representative of long-term pumping at the KPW-1 location.

The permitted points of diversion within 10 miles are identified on Figure 31.

Based on the results, wells 10 miles away from KPW-1 location would experience a maximum additional water level decline of between 10 and 20 feet. Wells greater than 10 miles away from KPW-1 would experience less decline.

This level of additional drawdown is not considered to be deleterious. Because of the inherent assumptions in the Theis solution (i.e., homogenous aquifer of infinite extent), the use of these results to predict potential reductions in downgradient regional spring flow is inappropriate because it the method overestimates water level declines at greater distances.

Local Springs

Based on field observations, permitted local springs in KSV represent groundwater flowing through the surrounding upland areas that are not connected to the regional carbonate aquifer. Accordingly, pumping from the carbonate aquifer locally within KSV would not affect the discharge from these springs.

Regional Springs

The approach to assessing potential impacts to regional springs generally consisted of conducting a review of water chemistry and hydraulic data, and published geologic interpretations to assess the potential linkage between groundwater withdrawals in KSV and the discharge of Muddy River Springs and Rodgers/Blue Point Springs.

Figure 32 repeats the spatial distribution of the most recent groundwater level elevations in selected carbonate wells within study area and Figure 33 presents hydrographs for selected carbonate wells in the study area.

Based on Figures 32 and 33, the following conclusions can be drawn:

- Groundwater levels progressively lower from north to south across the study area, supporting concept of generally southerly groundwater flow in regional carbonate aquifer.
- Kane Springs Wash fault zone causes a break in the regional hydraulic gradient ("steeper" to the north, "flatter" to the south).
- Regardless of fault, there is a general trend of rising groundwater levels since spring of 2005 in most wells (less so in wells near Arrow Canyon Well).
- Similar water level trend implies regional influence on carbonate aquifer.

- Flat hydraulic gradient south of KSW fault indicative of fairly homogeneous distribution of high aquifer transmissivity.
- High aquifer transmissivity supports high potential for substantial groundwater flow through the carbonate aquifer within the study area.

Figure 34 repeats the vertical profile through selected carbonate wells in study area and shows the conceptual location of the Kane Springs Wash fault zone.

Based on Figure 33 the following conclusions can be drawn:

- Wells down downgradient of KSW fault have similar groundwater levels despite variable screen intervals.
- Implication is that the aquifer is highly transmissive and fairly homogeneous in this regard with depth (suggesting isotropic permeability).
- Water levels in wells at elevations above top of rock indicative of groundwater under pressure, and therefore driven by deep regional gradients.

This hydrologic assessment also included a geochemistry component that is presented under separate cover in CH2M HILL (2006). The key points developed in that report with respect to regional groundwater flow are summarized as follows:

- Deep carbonate aquifer groundwater flows from north to south across the study area; specifically, from Pahranagat Valley and Kane Spring Valley into Coyote Spring Valley, and from there to both the Muddy River Springs Area and into Hidden Valley and Garnet Valley.
- Discharge to Muddy River Springs is comprised of approximately 60 percent regional carbonate groundwater.
- The remaining 40% of the discharge is comprised of water of non-carbonate aquifer origin. This 60/40 split of carbonate to non-carbonate origin groundwater is prevalent in wells throughout the downgradient portion of the carbonate aquifer within the study area (i.e., Garnet Valley and California Wash, in addition to the Muddy River Springs). The implication of this prevalence is that groundwater flowing through the regional

carbonate aquifer in Coyote Spring Valley does not necessarily have a preferred flow path toward the Muddy River Springs, but also flows into Garnet Valley via Hidden Valley. This conclusion regarding the origin of carbonate aquifer groundwater in Garnet Valley is supported by C-14 data from GV wells. Specifically, the C-14 data imply that the groundwater in Garnet Valley is very old (29,000 years). Therefore, a more local source of this water in GV (e.g., from the Sheep Range) at least in any significant proportion, is unlikely.

- Discharge at Rogers and Blue Point Spring is comprised of roughly 40% regional carbonate groundwater.
- The remaining 60 percent of the discharge is comprised of water of non-carbonate aquifer origin.
- Rogers and Blue Point Springs are not the terminus of all carbonate groundwater that by-passes the Muddy River Springs.
- Groundwater movement between basins is on the order of thousands of years, consistent with the low hydraulic gradients observed.

The generalized regional groundwater flow in the study area is summarized in Figure 35.

Based on the combination of water chemistry (CH2M HILL, 2006) and hydraulic data, and published geologic interpretations the following fundamental conclusions and other considerations are presented:

- It is understood that the carbonate aquifer within the study area underlies hundreds of square miles and likely extends to depths of several thousand feet. The implication is that there is a considerable volume of groundwater flowing through this aquifer system within the study area.
- The carbonate rock aquifer appears to be highly transmissive across much of the study area enabling movement of significant amounts of groundwater.
- Areas of high transmissivity are not limited to the Arrow Canyon area that leads to the Muddy River Springs. Accordingly, a preferred groundwater flow path specifically from Coyote Spring Valley toward these springs can only currently be assumed.

- The “flat” hydraulic gradients over large areas caused by high transmissivity result in poorly defined groundwater flow paths in the southern portion of the study area.
- Flat hydraulic gradient does not necessarily imply that there is little groundwater movement through the aquifer as evidenced by large discharge from Muddy River Springs downgradient of area of high transmissivity.
- Within the KSV, the Kane Springs Wash fault zone will have the effect of concentrating the resulting drawdown from local pumping to within KSV.
- In Coyote Spring Valley, the Kane Spring fault zone will likely have the effect of impeding the propagation of a cone of depression originating within KSV from migrating south.
- Approximately 40 percent of the discharge of the Muddy River Springs is comprised of water that is not from the regional carbonate aquifer (i.e., the discharge represents both carbonate and non-carbonate groundwater that have mixed along the flow path leading to the springs. The implication is that if it is assumed that the regional carbonate aquifer only contains a finite amount of ancient water that has entered the system many miles to the north of the study area, then 40 percent of the water in the carbonate rock flow system is missed because it is derived from non-carbonate sources (e.g., recharge through the alluvium). This conclusion is supported both by deuterium ratios and by major ion chemistry that indicates non-carbonate signatures are observed in wells completed in carbonate rock (indicating that the groundwater from those wells has flowed through media other than carbonate rock).

Lastly, pumping 5,000 AF/yr from KSV should not affect downgradient regional springs because local recharge in KSV is on the order of 5,000 AF/yr. However, roughly 10,000 AF/yr over the local amount recharged is estimated to flow into Coyote Spring Valley from KSV.

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FIGURE 1
Kane Springs Valley Study Area

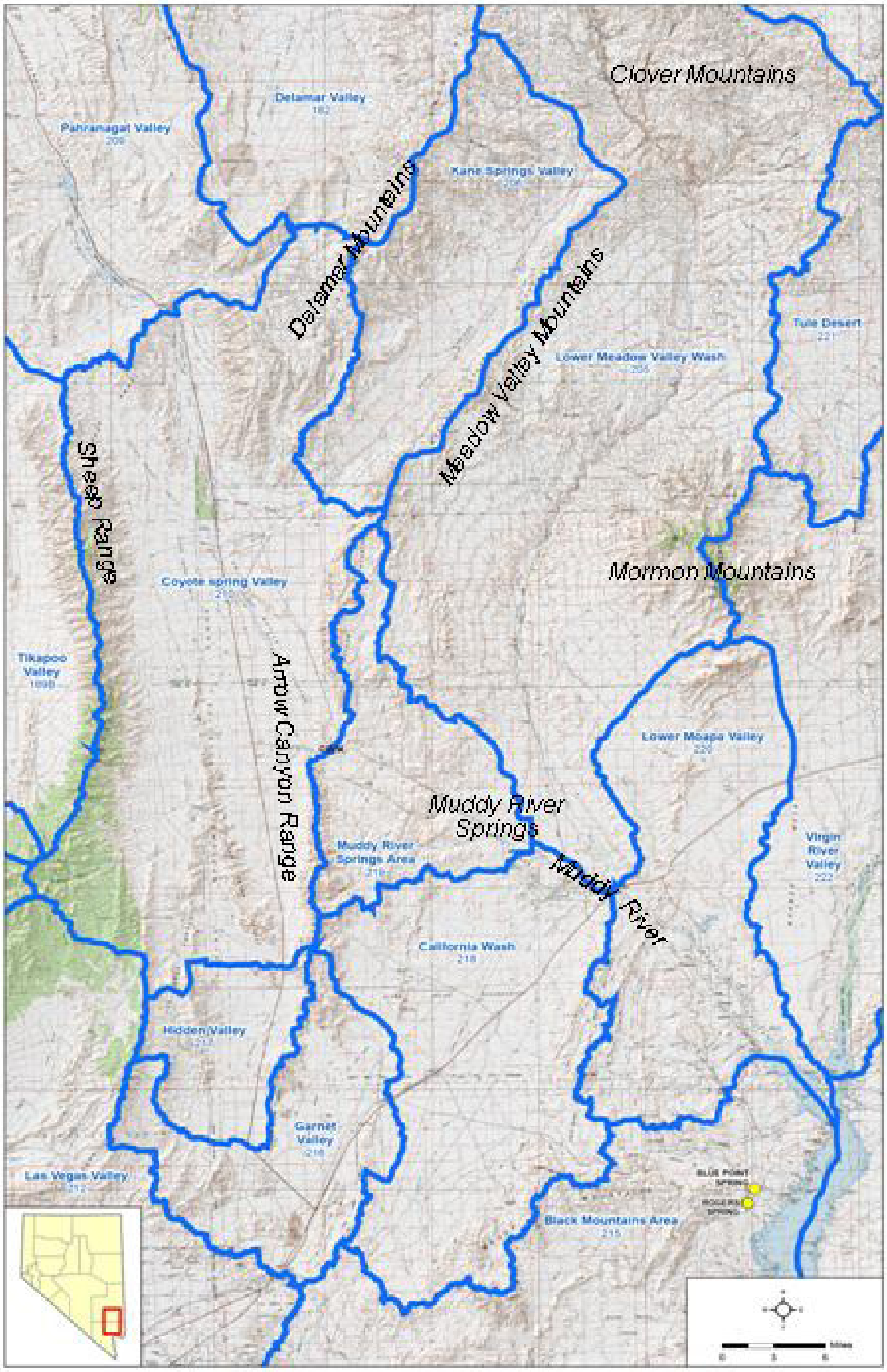

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FIGURE 2
Location of Kane Springs Valley (206) With Respect to Colorado River Basin

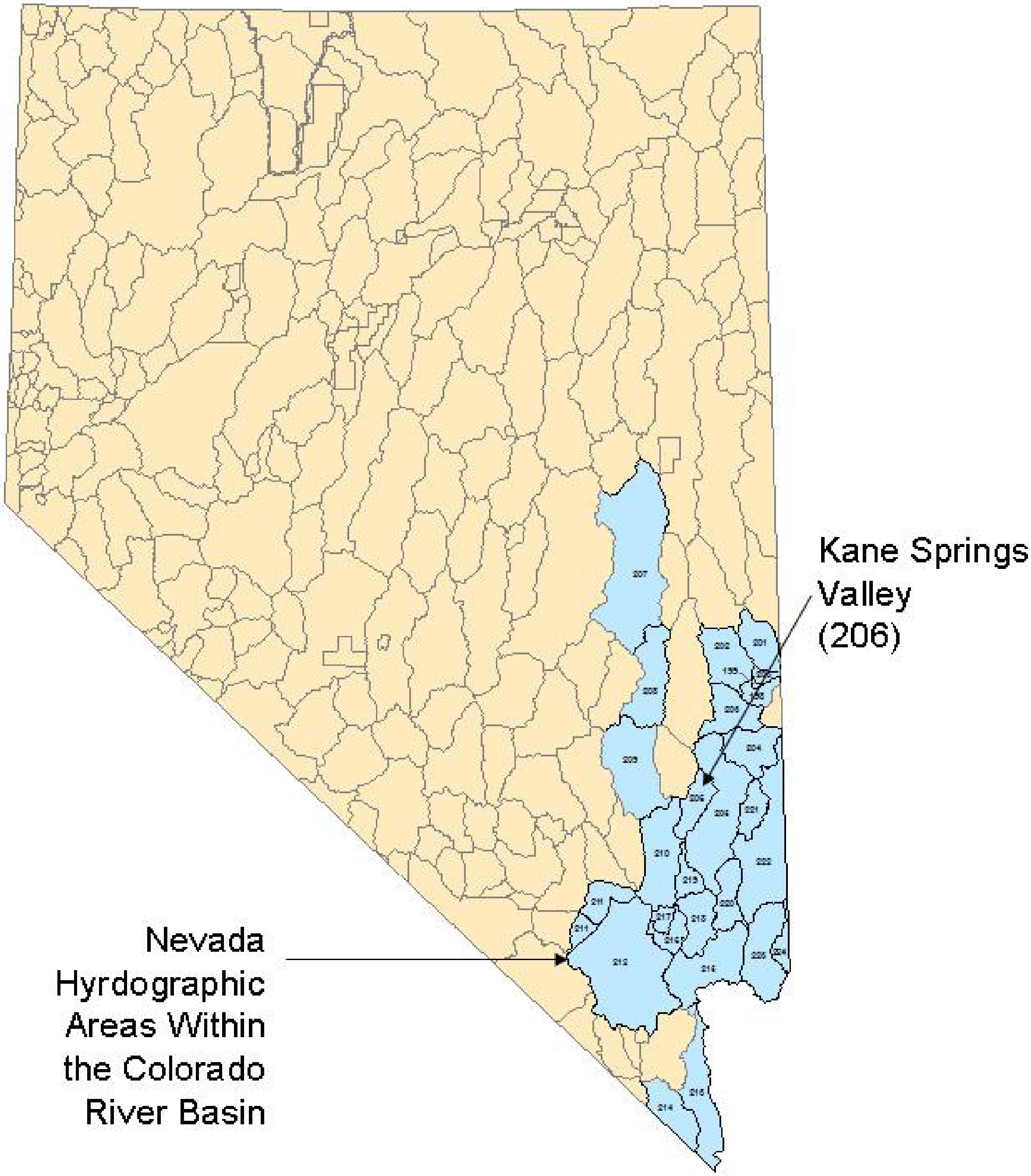
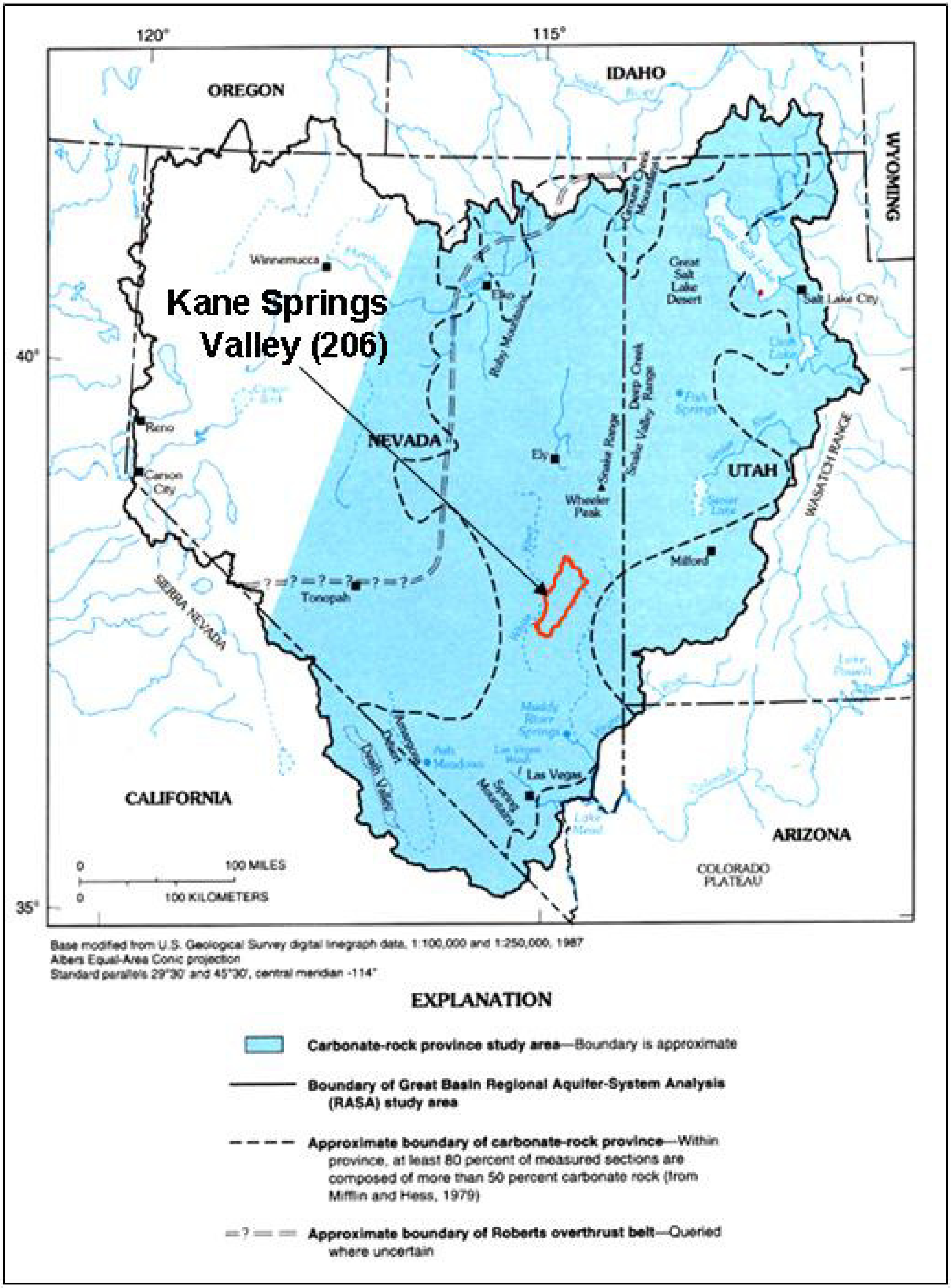


FIGURE 3
Kane Springs Valley (206) Hydrographic Area

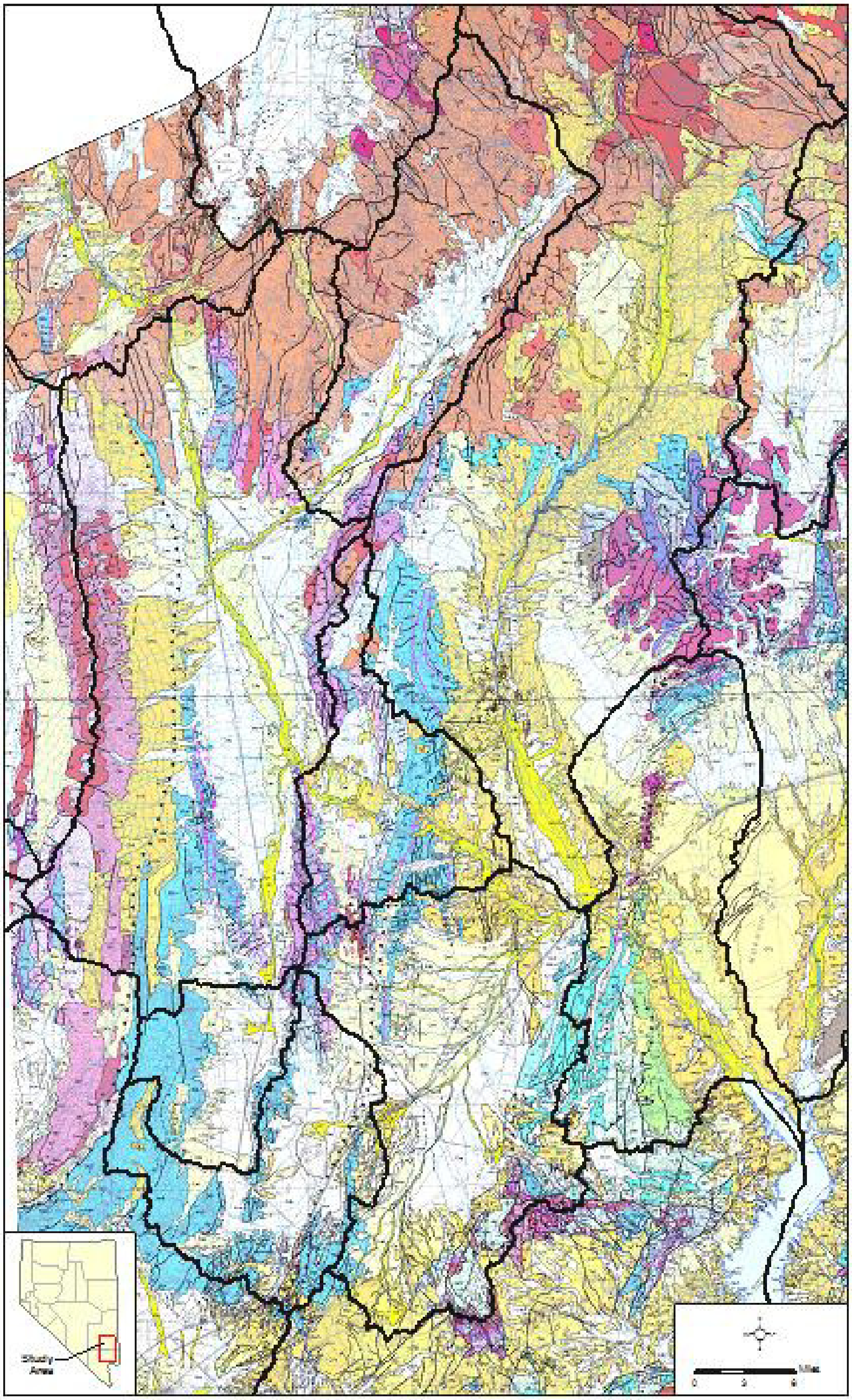
FIGURE 4

Kane Springs Valley In Relation to Carbonate-Rock Province



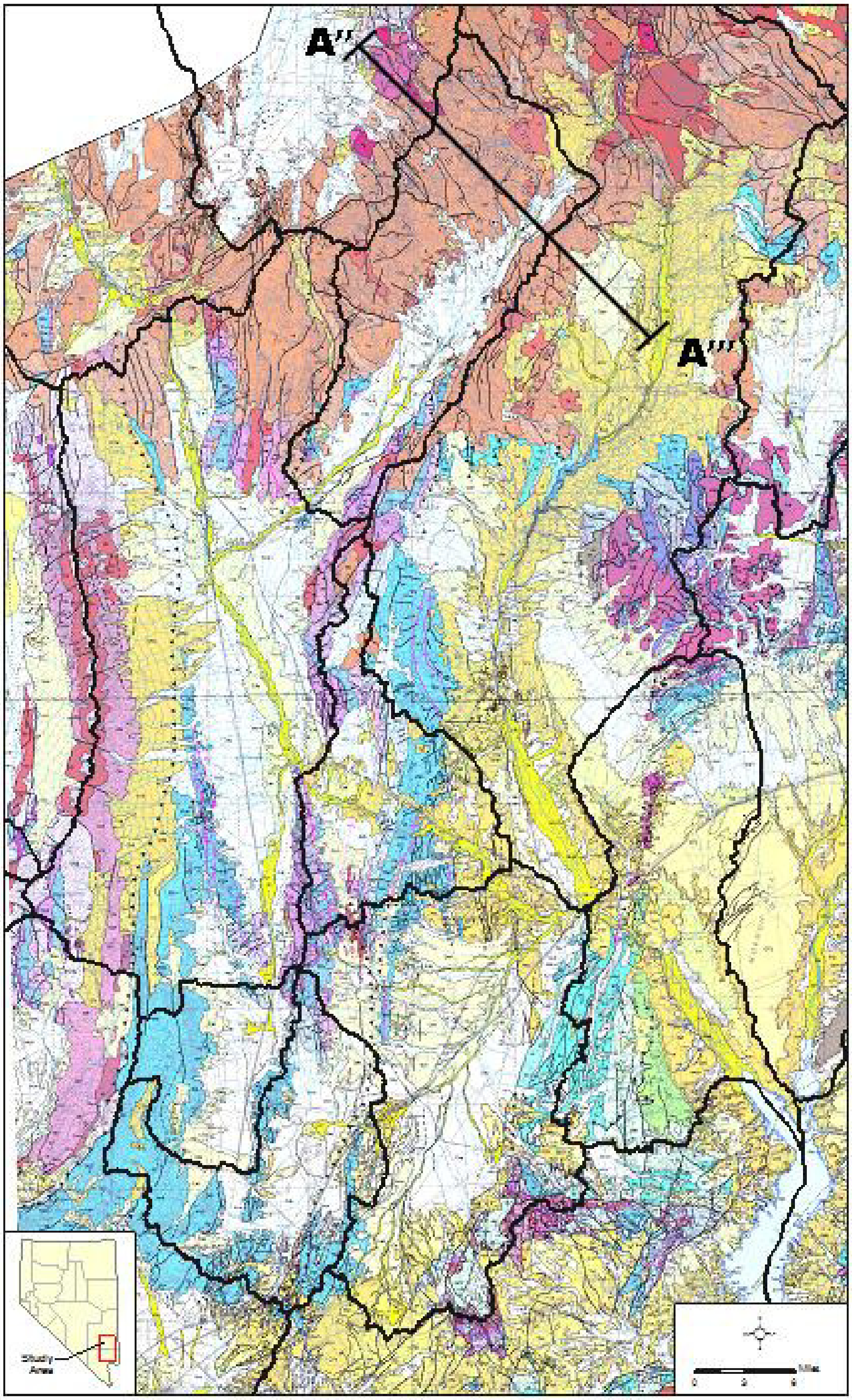
Modified from: Prudic, David E., James Harrill and Thomas Burbey. 1995. Conceptual Evaluation of Regional Ground-Water Flow in the Carbonate-Rock Province of the Great Basin, Nevada, Utah, and Adjacent States. US Geological Survey Professional Paper 1409-D.

FIGURE 5
Geologic Map of Parts of the Colorado River Basin



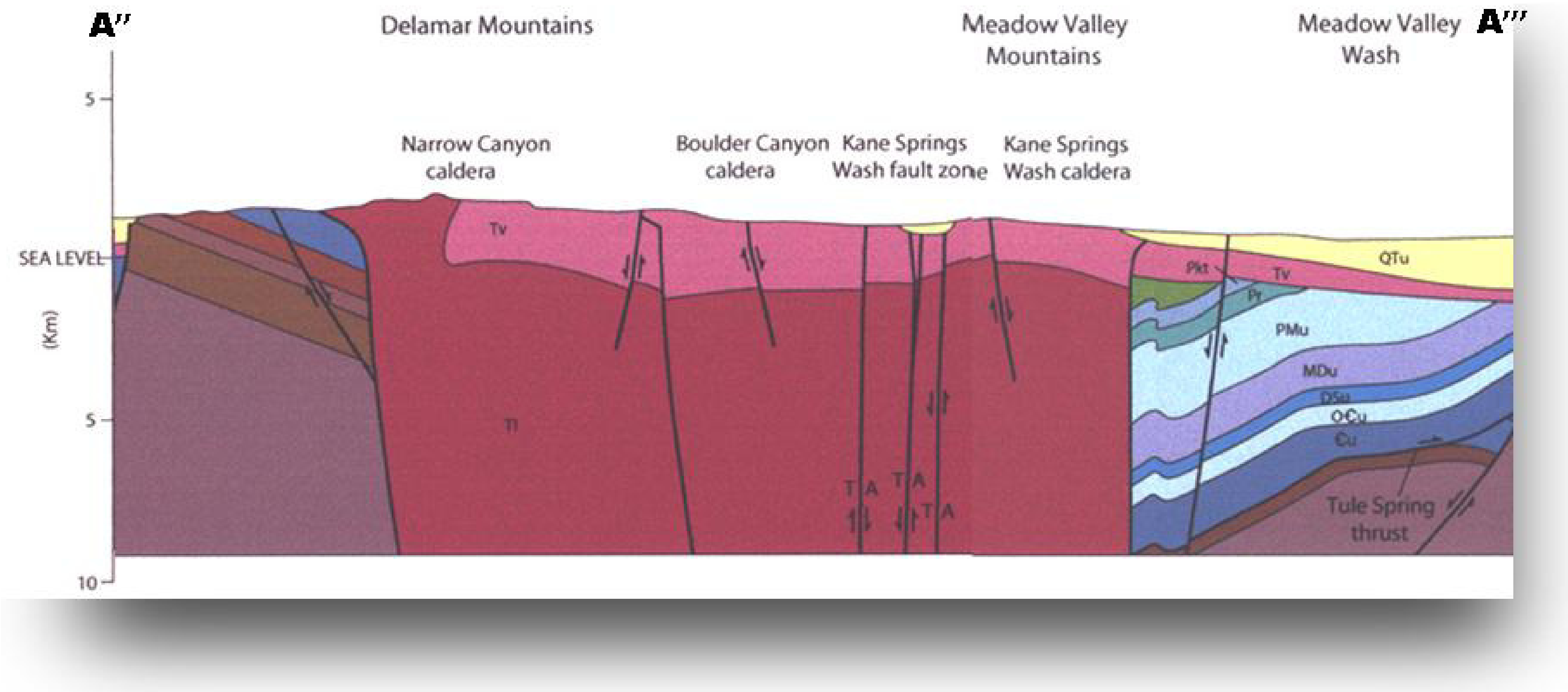
Source: Page, W. R., G. Dixon, P. Rowley, and D. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 6
Location of Geologic Cross Section A''-A'''



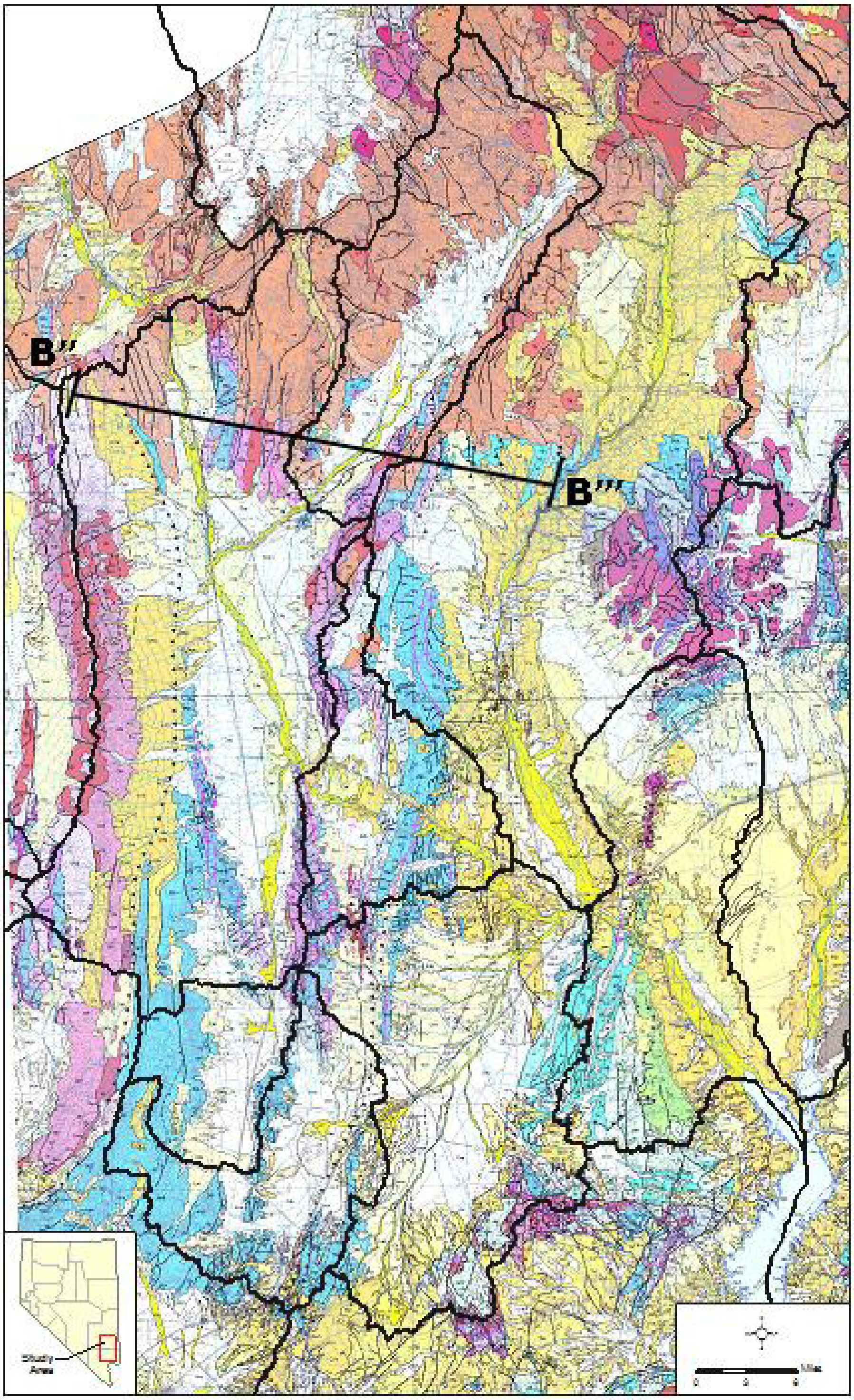
Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 7
Geologic Cross Section A''-A'''



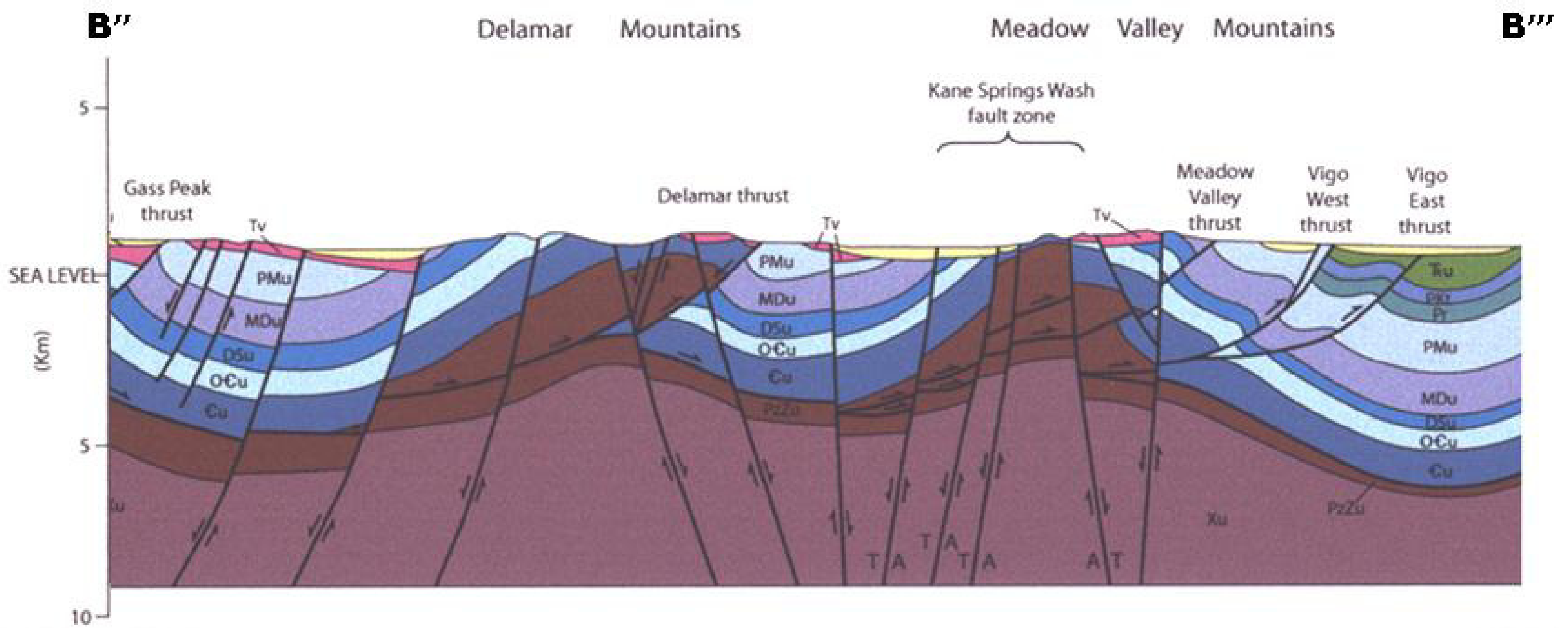
Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

FIGURE 8
Location of Geologic Cross Section B''-B'''



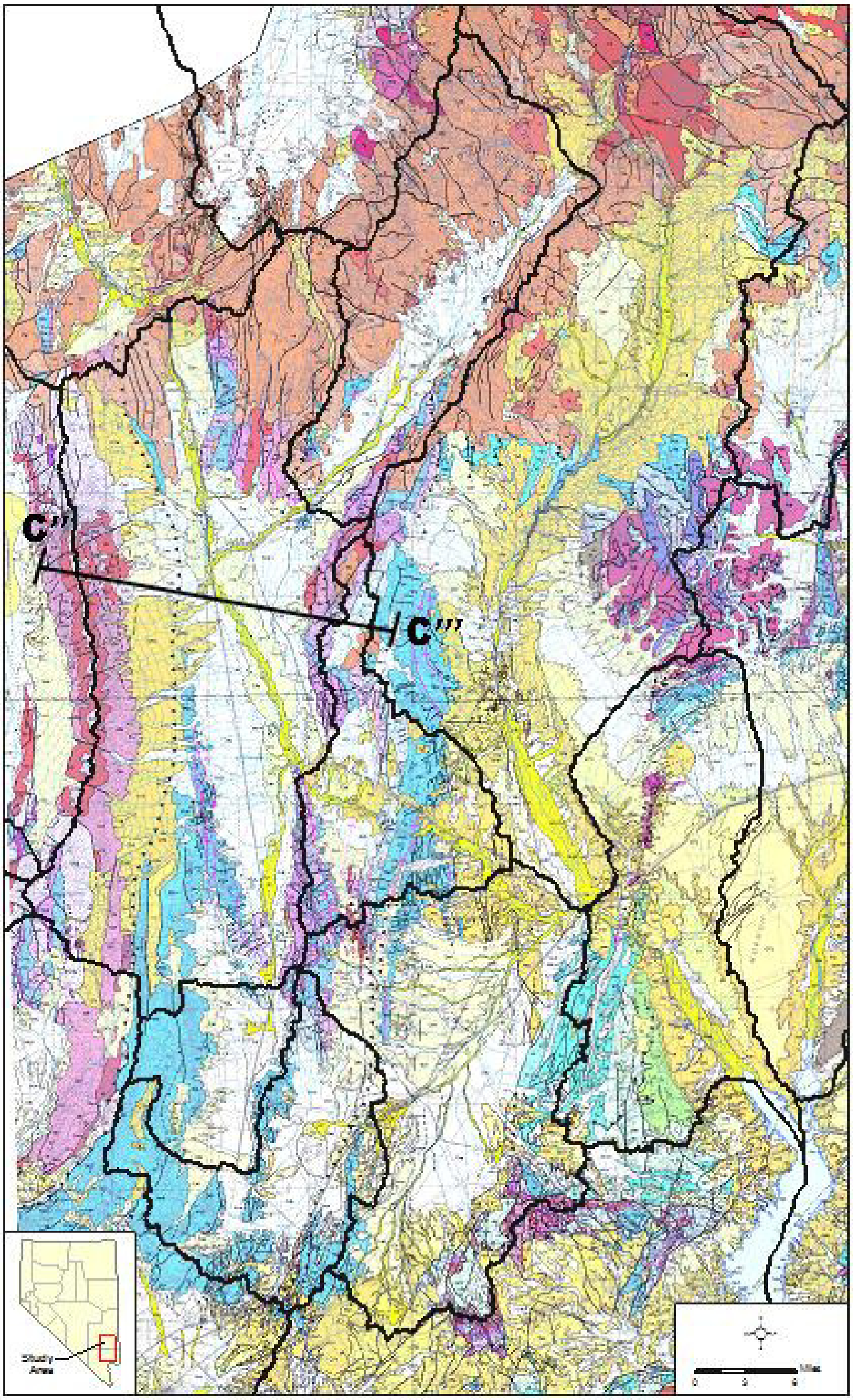
Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 9
Geologic Cross Section B"-B"'



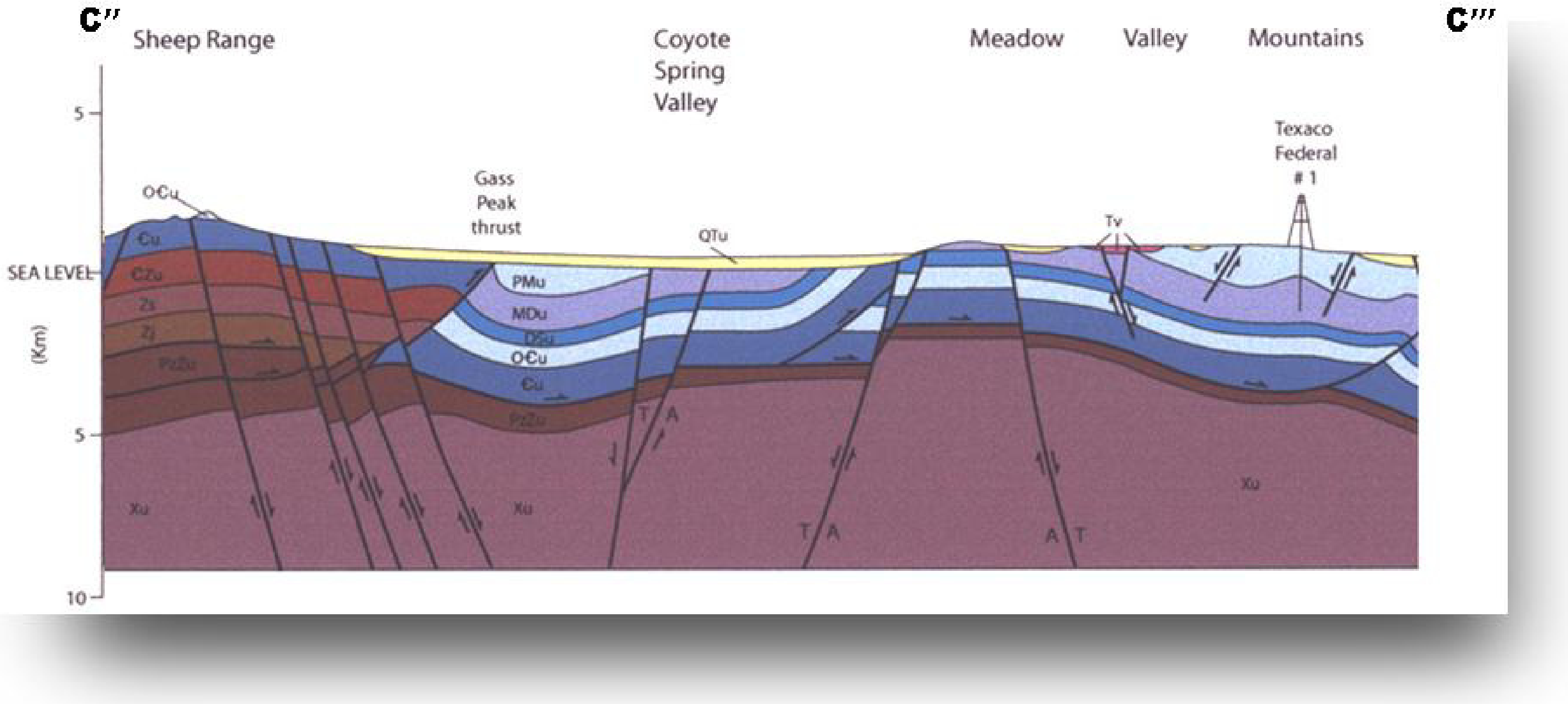
Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

FIGURE 10
Location of Geologic Cross Section C''-C'''



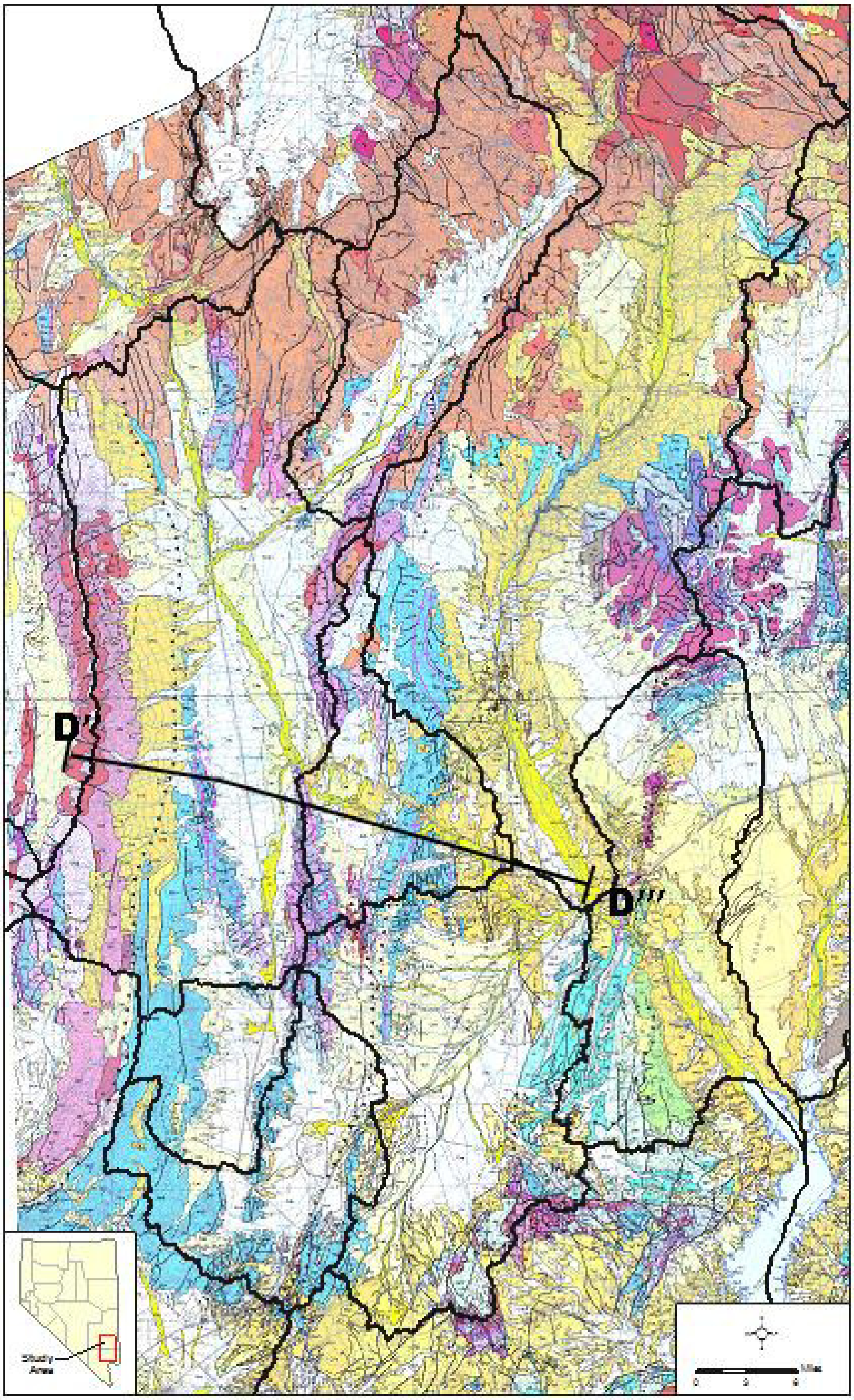
Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 11
Geologic Cross Section C"-C'"



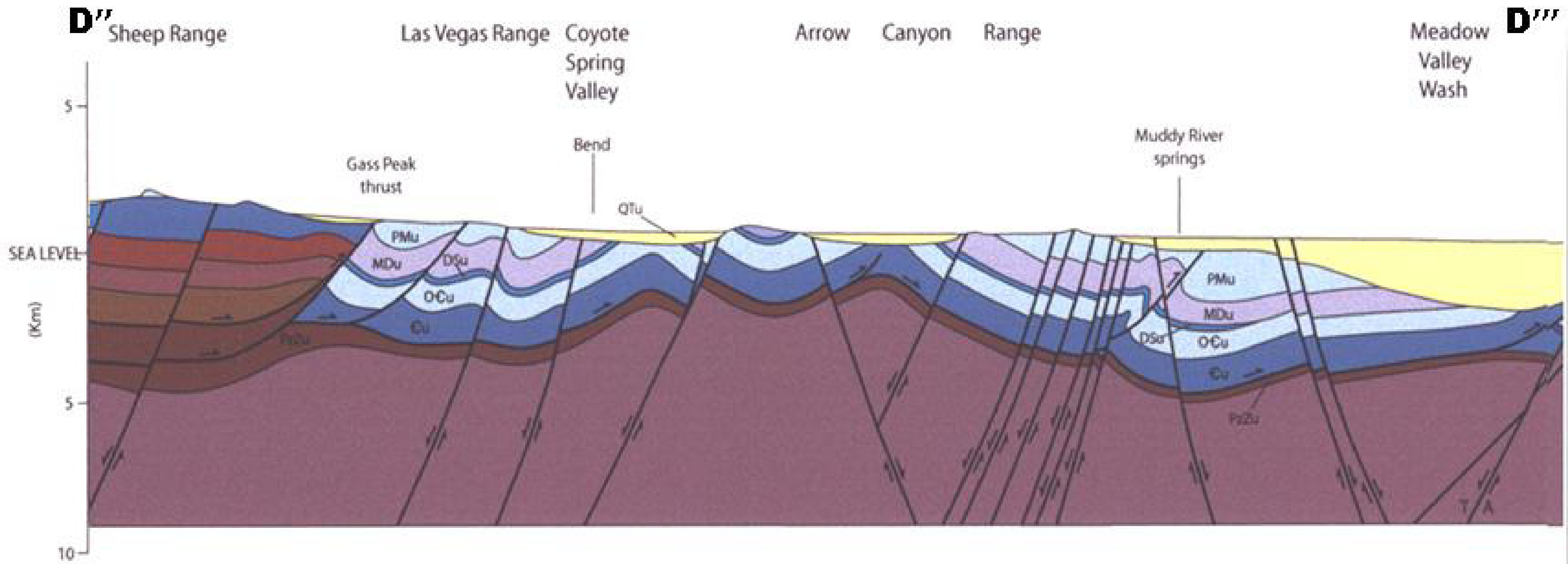
Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

FIGURE 12
Location of Geologic Cross Section D''-D'''



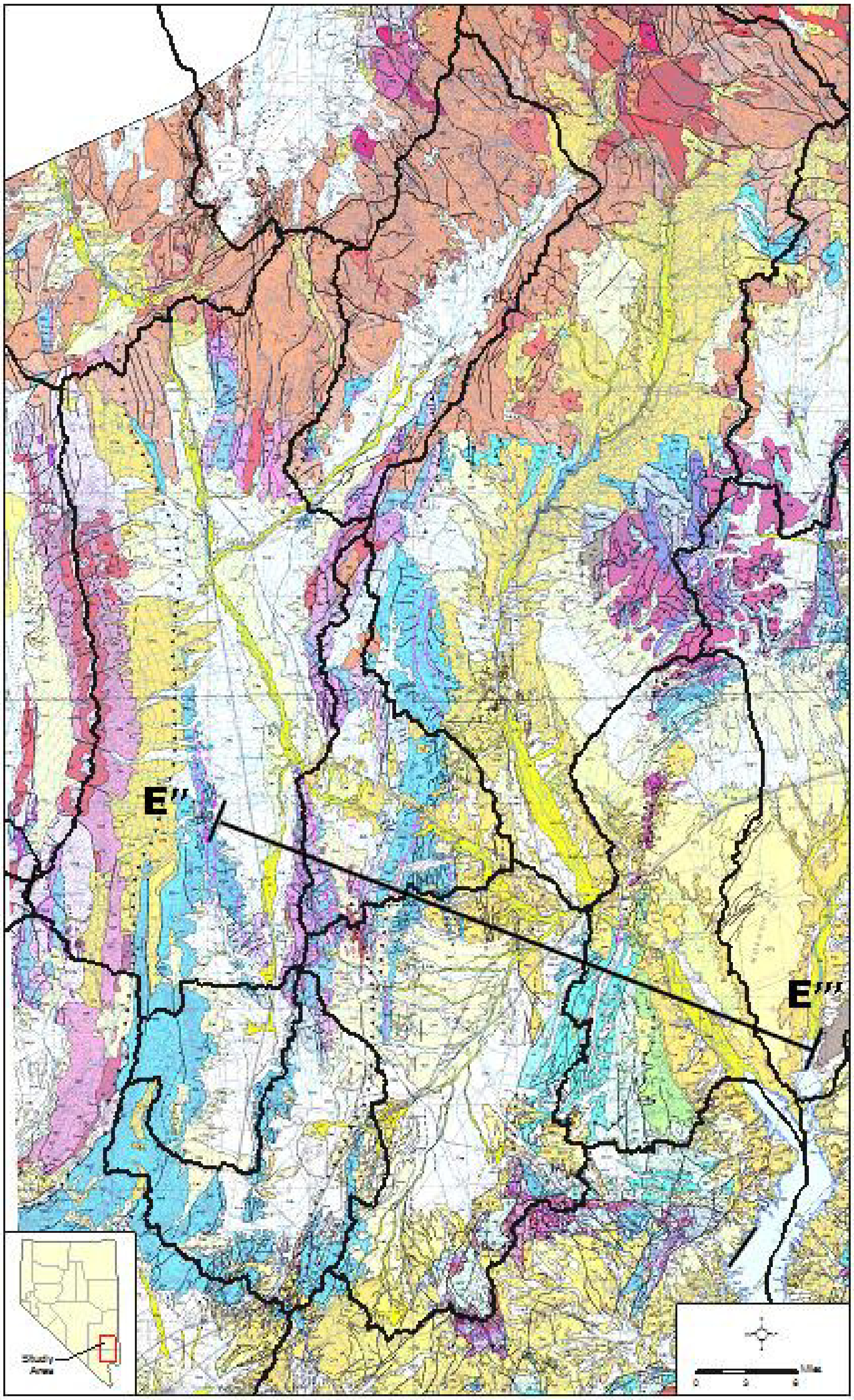
Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 13
Geologic Cross Section D''-D'''



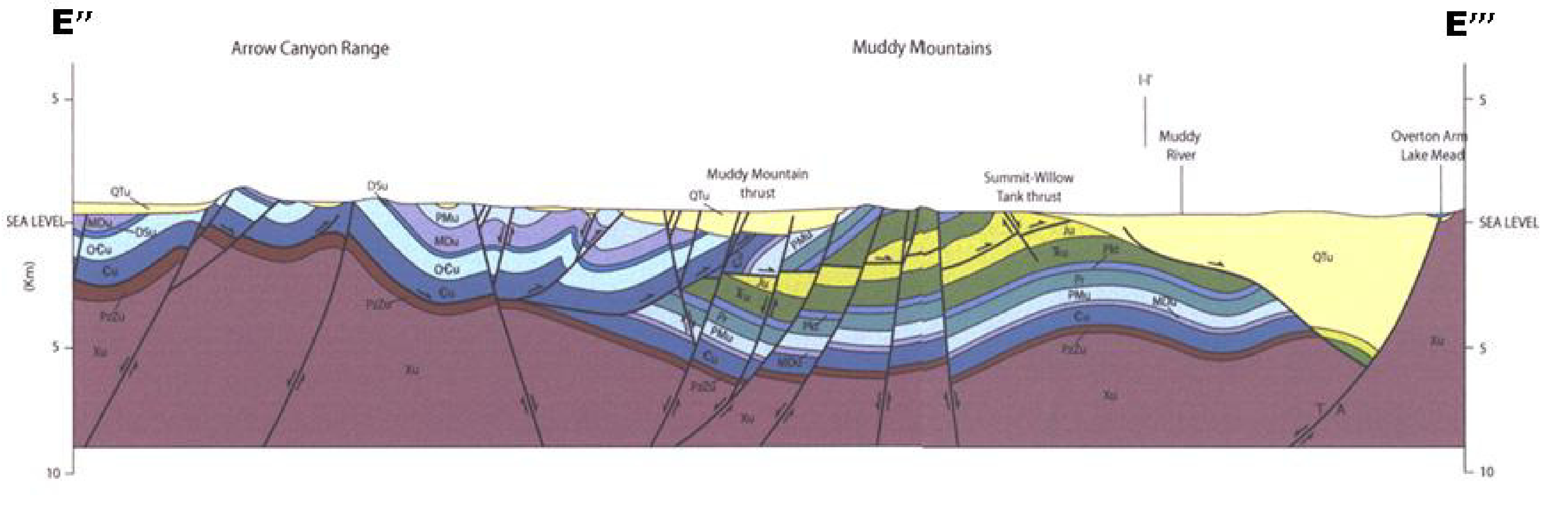
Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

FIGURE 14
Location of Geologic Cross Section E''-E'''



Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 15
Geologic Cross Section E"-E'''



Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

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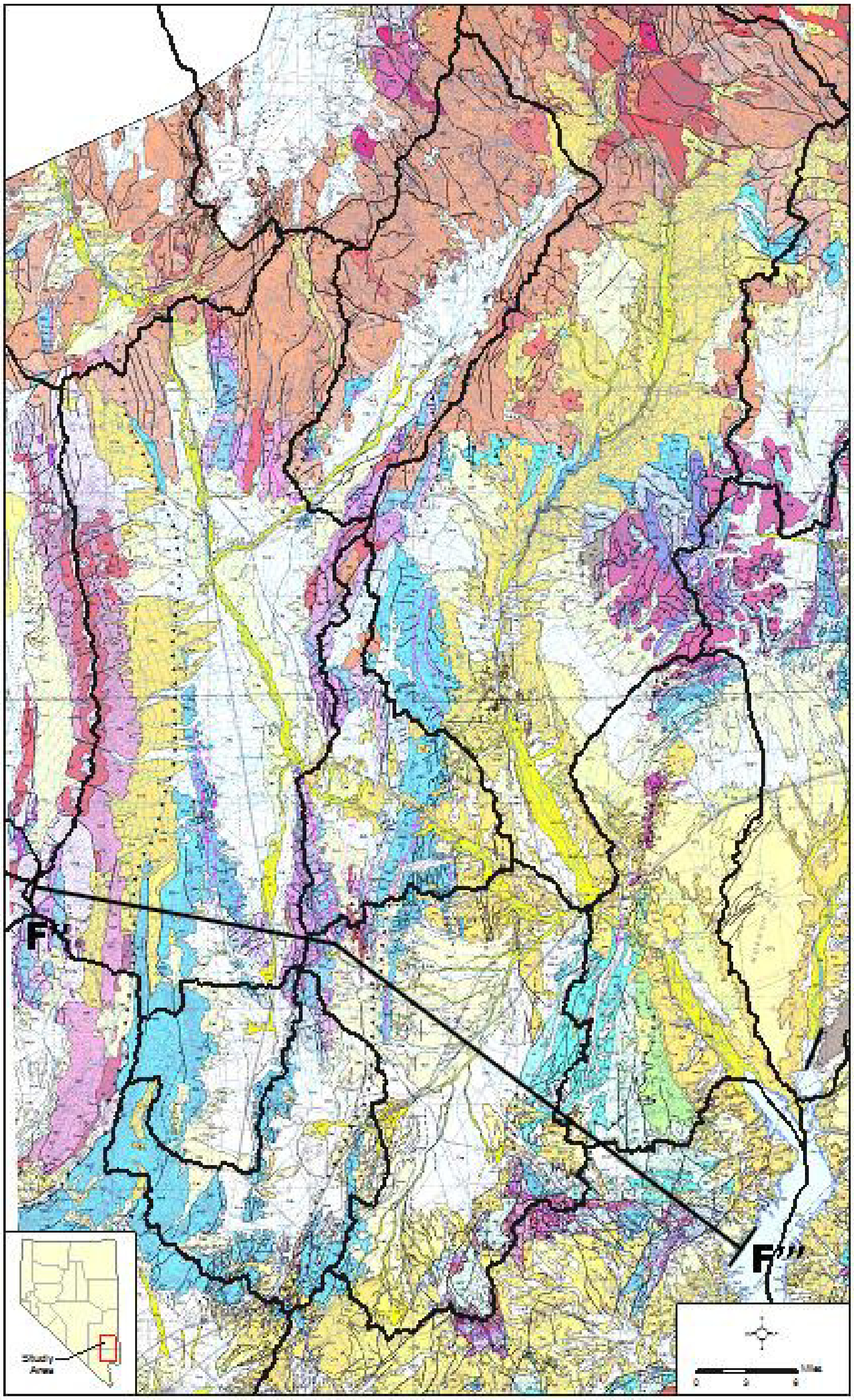
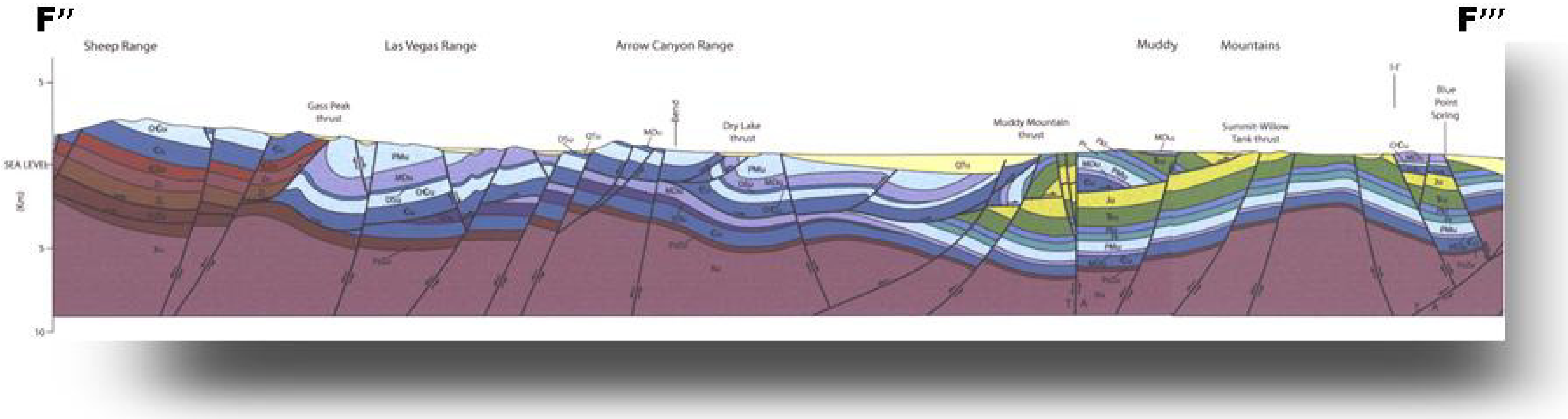
FIGURE 16
Location of Geologic Cross Section F''-F'''



Source: Page, W.R., G. Dixon, P. Rowley, and R. Brickey. 2005. Geology Map of Parts of the Colorado, White River and Death Valley Groundwater Flow Systems. Nevada Bureau of Mines and Geology Map 150.

FIGURE 17
Geologic Cross Section F"-F'"



Source: Page, W.R., D.S. Schreirer, and V.E. Langenheim. 2006. Geologic Cross Sections of Parts of the Colorado, White River, and Death Valley Regional Ground-Water Flow Systems. Nevada, Utah, and Arizona. U.S. Geological Survey Open-File Report 2006 – 1040.

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FIGURE 18
Location of Selected Wells in Study Area

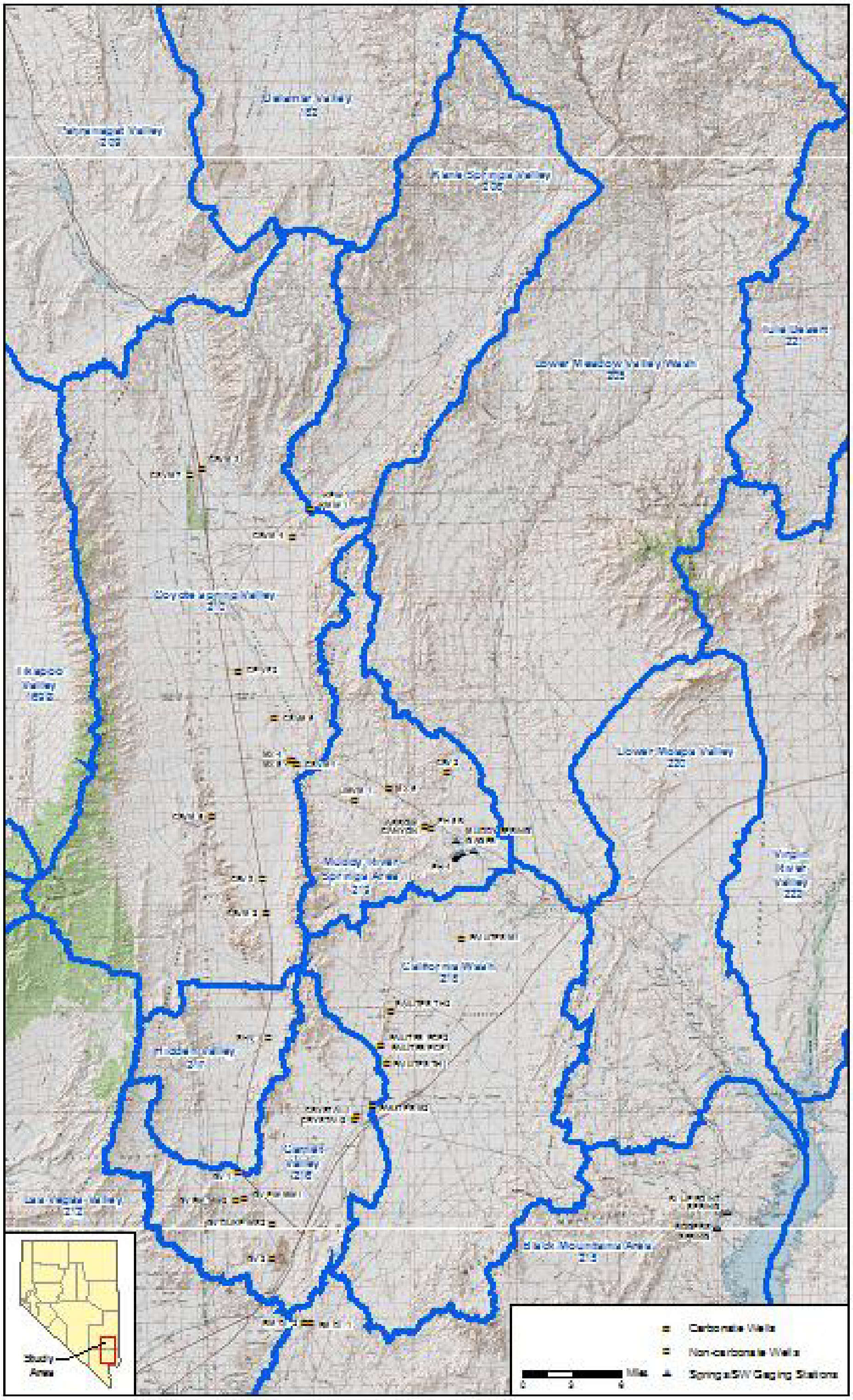

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FIGURE 19
Location of Selected Carbonate Wells Used in Schematic Cross Section

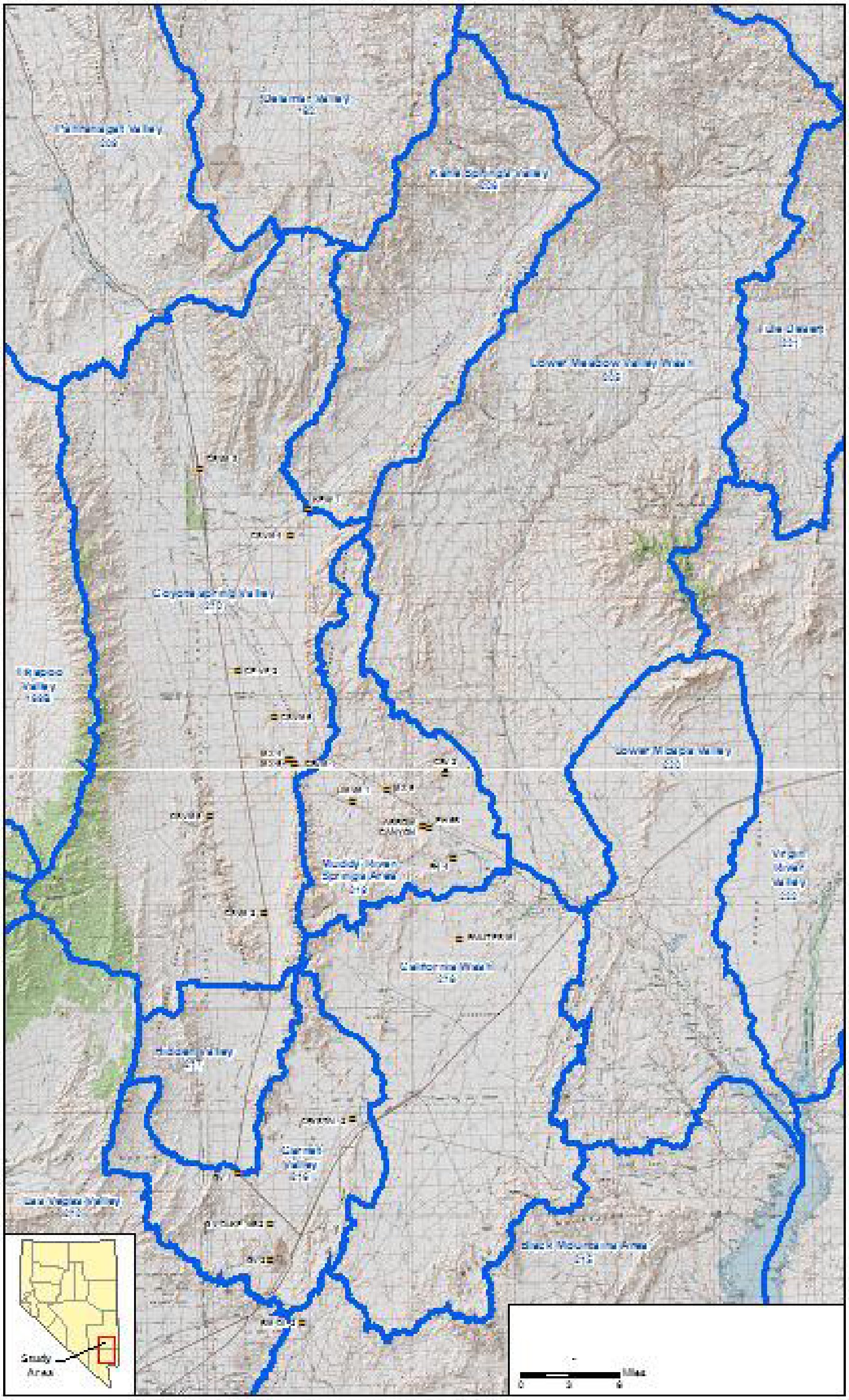


FIGURE 20
Vertical Profile Through Selected Carbonate Wells in Study Area

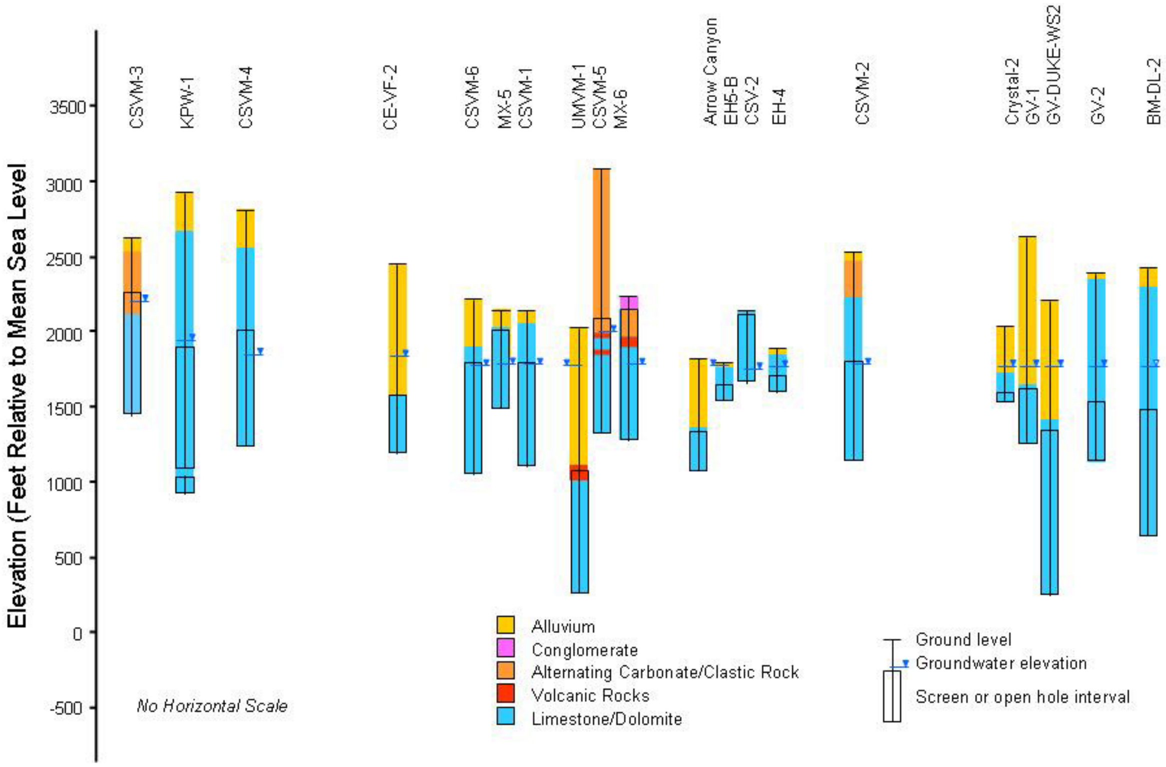
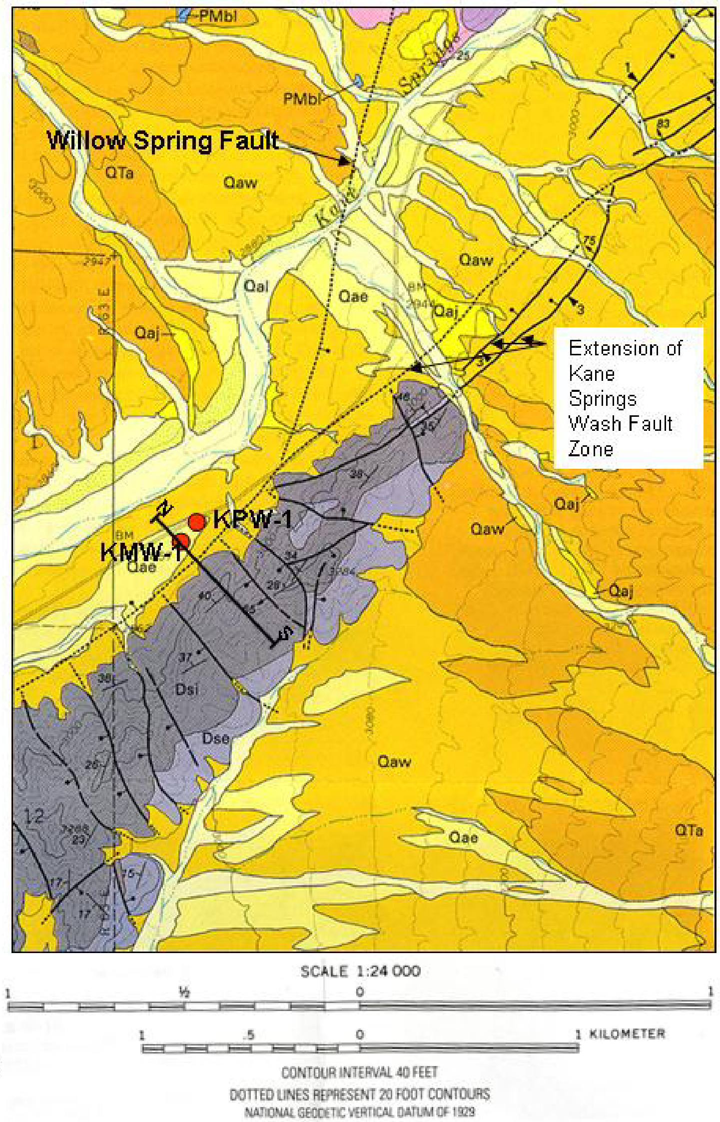


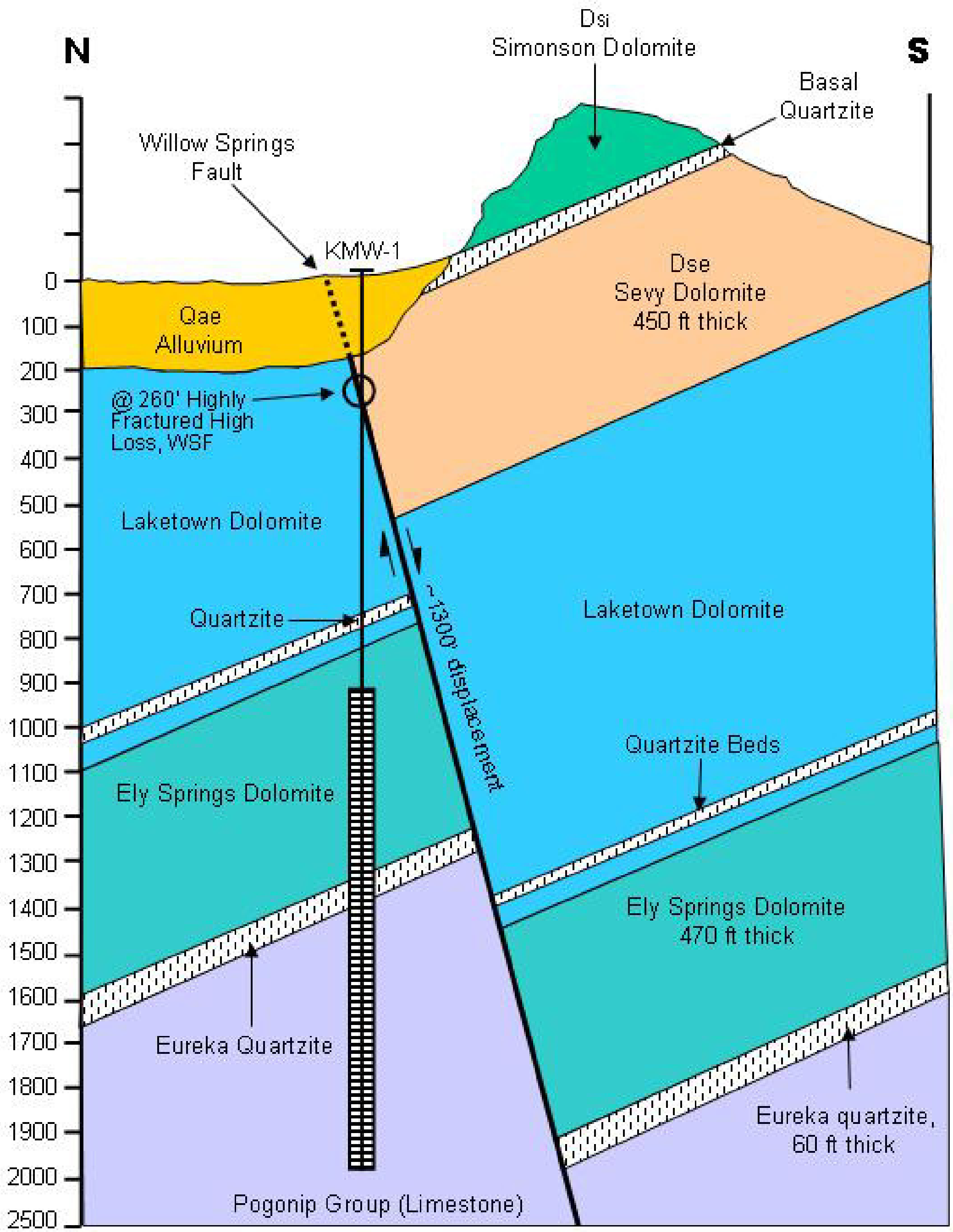
FIGURE 21
Location of Kane Spring Valley Wells Relative to Local Geologic Features



Dsi = Simonson Dolomite
Dse = Sevy Dolomite
Q = Quaternary Alluvial Deposits (Various Ages)

Source: Swadley, W. C., W. R. Page, R. B. Scott, and E. H. Pampeyan. 1994. Geologic Map of the Delamar 3SE Quadrangle Lincoln Co., Nevada. USGS Geologic Quadrangle Map, GQ-1754.

FIGURE 22
Localized Cross Section Through KMW-1, Kane Springs Valley



Source: Unpublished field notes taken during Drilling KMW-1 by Feast Geosciences

FIGURE 23
Drawdown Curve in Monitoring Well KMW-1 at a Distance of 143 Feet; KPW-1 Pumping @ 1800 gpm

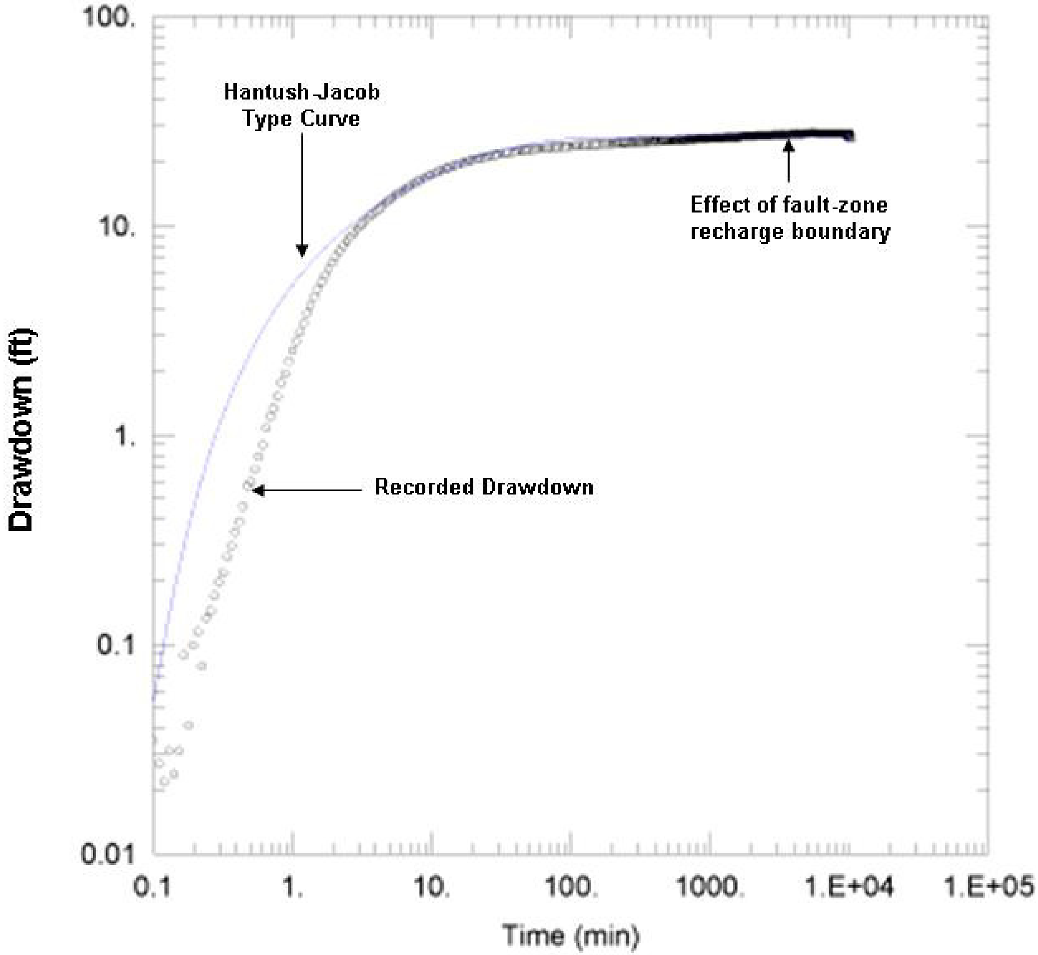
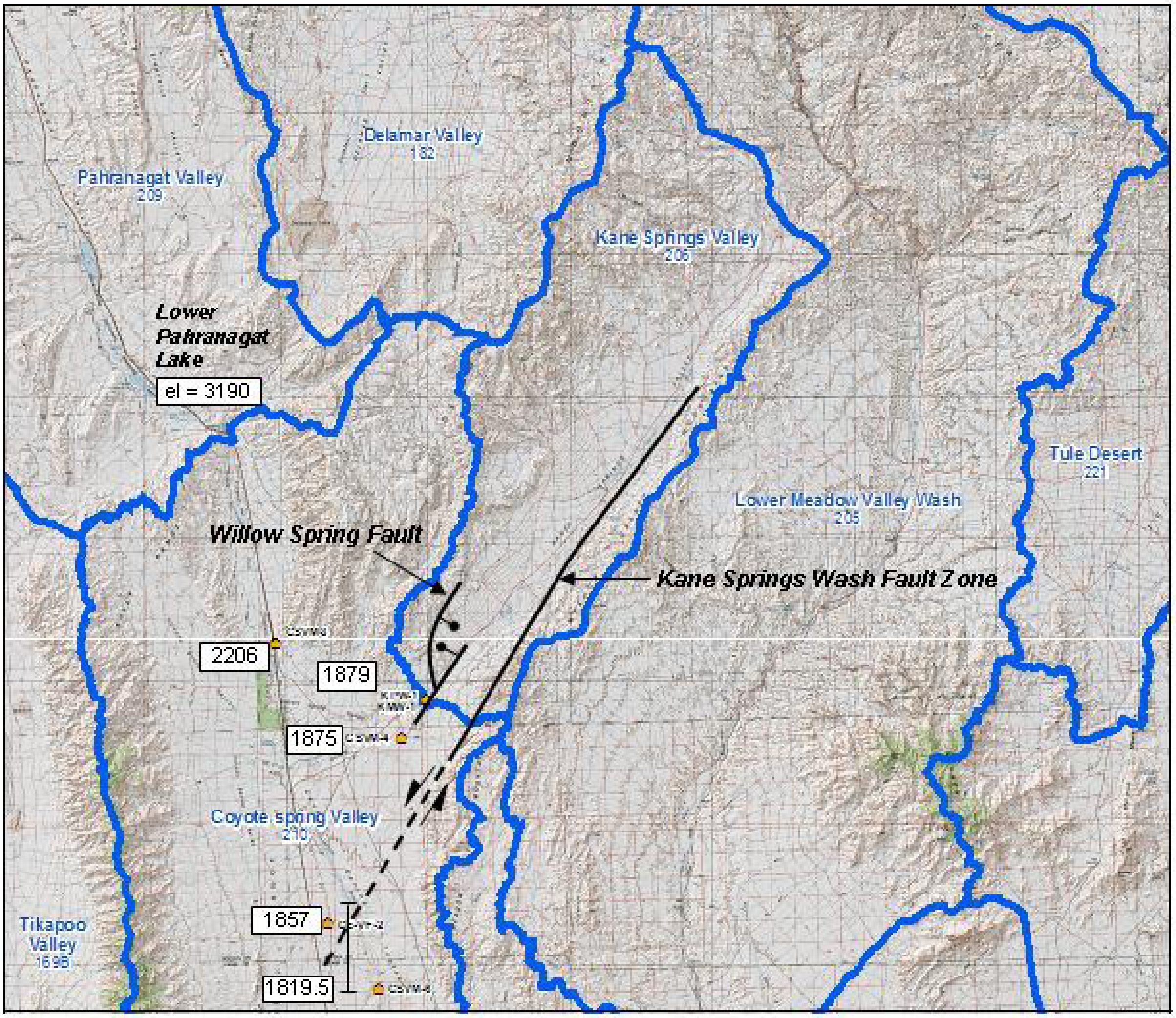


FIGURE 24
Local Geologic Structure Affecting Groundwater Conditions



2206	Dec. 2005 Water Levels (ft amsl)
	Source: Southern Nevada Authority Central Data Repository

FIGURE 25
Schematic Diagram of Kane Springs Wash Fault Influence on Groundwater Levels in Coyote Spring Valley

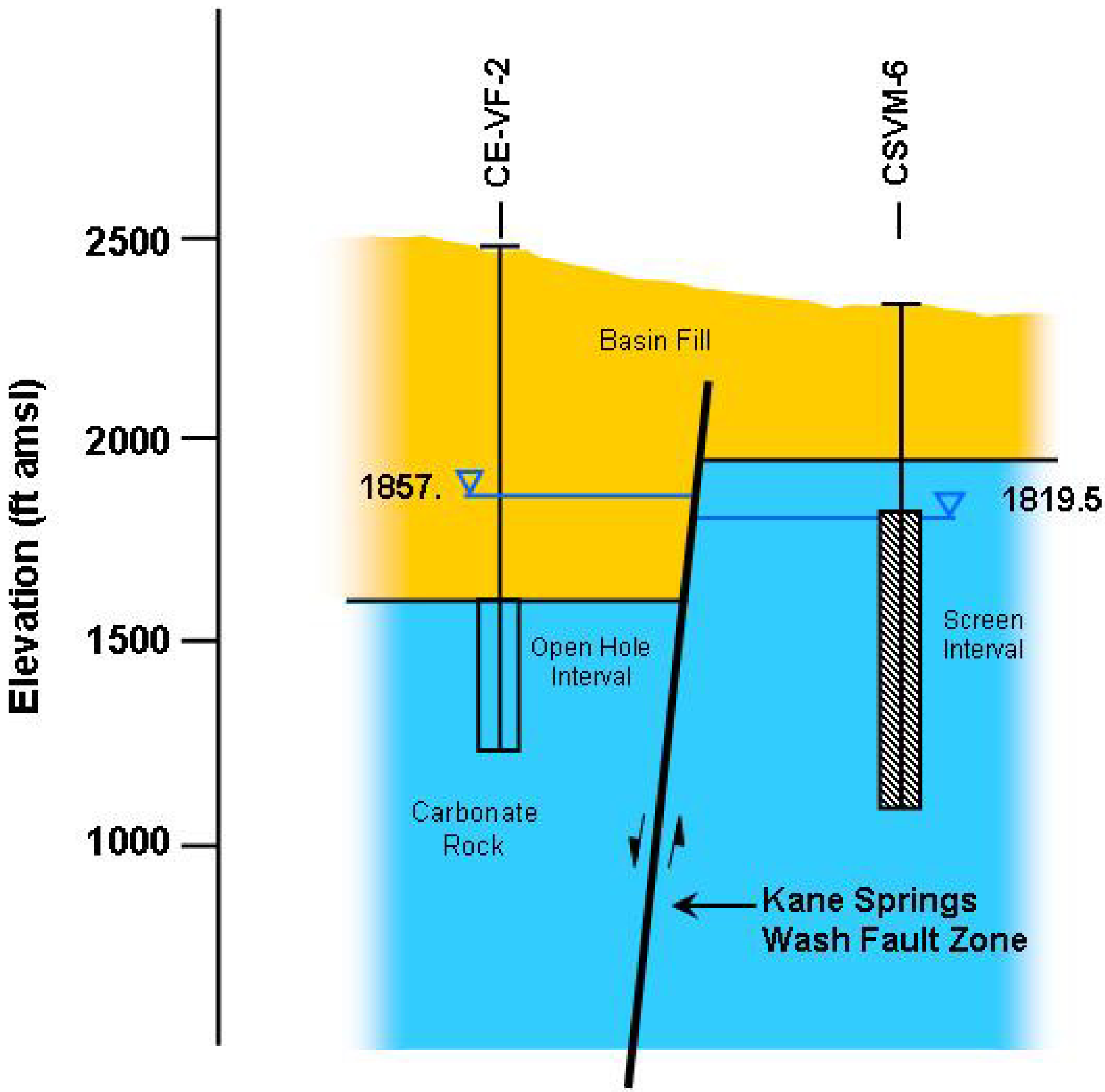
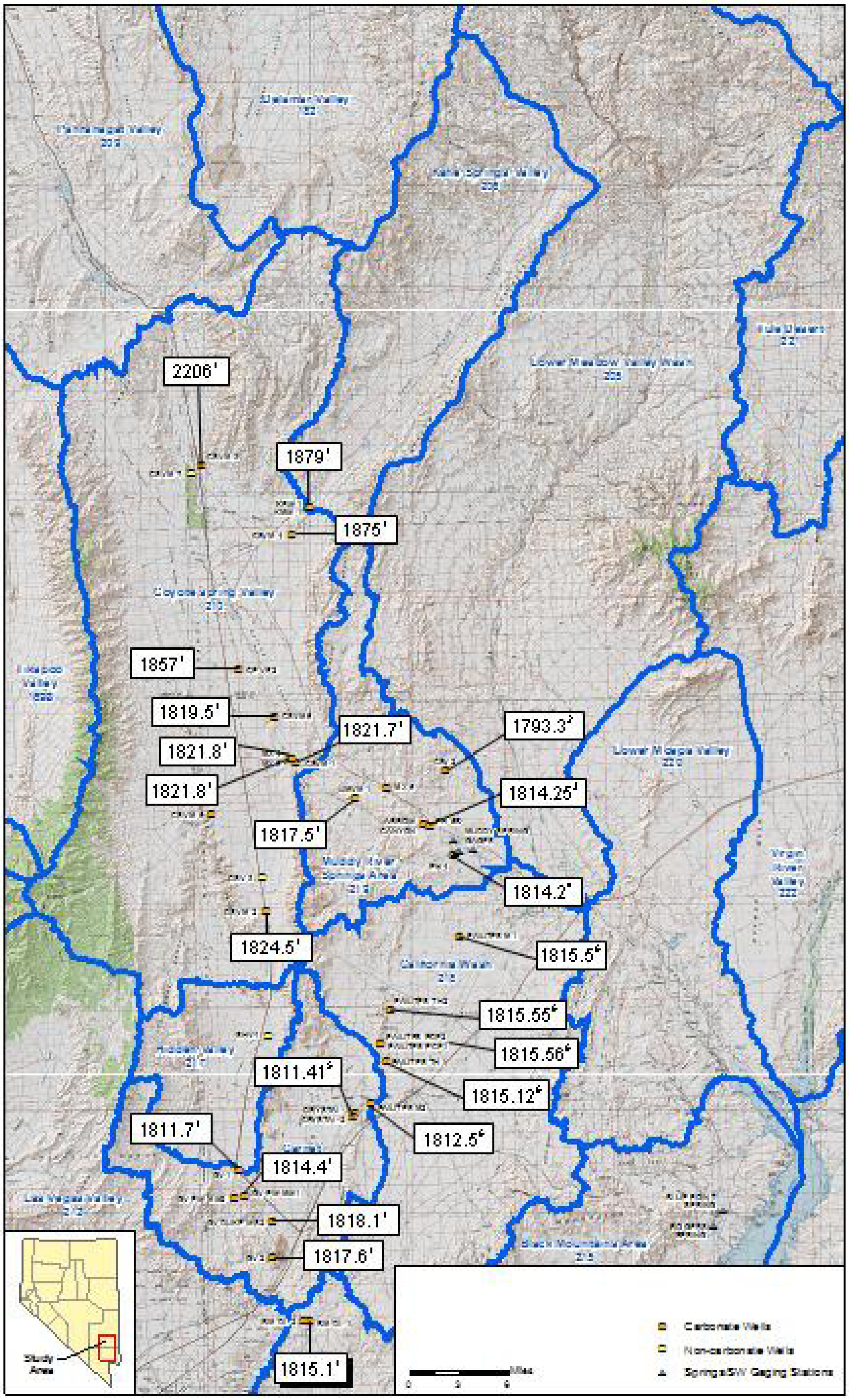


FIGURE 26
Most Recent Groundwater Level Elevations (ft amsl) in Selected Carbonate Wells Within Study Area

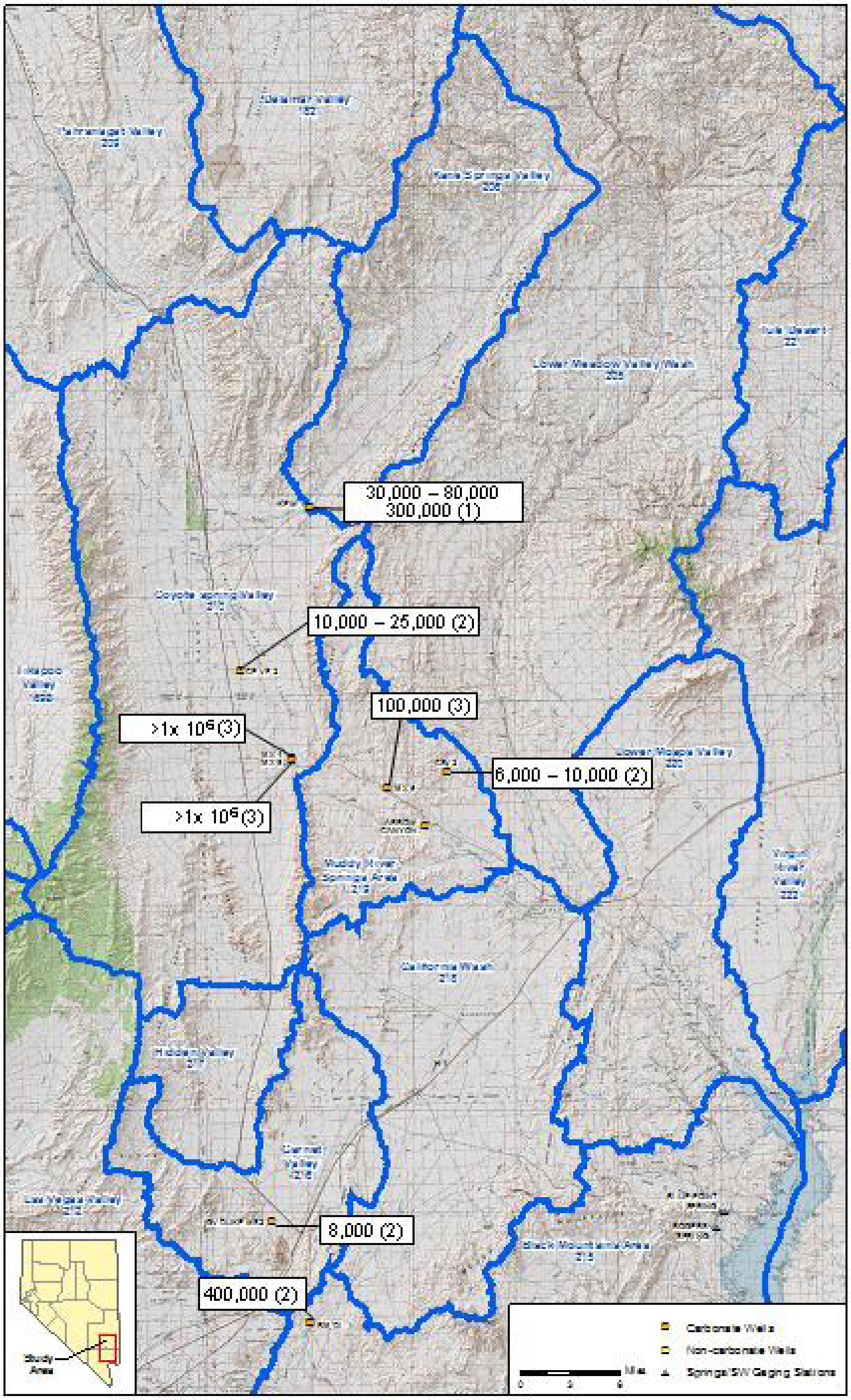


[1]Dec 05
[2]June 04
[3]Dec 04
[4]Nov 04
[5]Mar 04
[6]Feb 01

Water Level Source:

Southern Nevada Water Authority
Central Data Repository

FIGURE 27
Aquifer Transmissivity (gpd/ft) at Selected Carbonate Wells in the Study Area



Sources:
(1) URS (2006)

(2) CH2M HILL Unpublished Analysis

(3) Dettinger et al. (1995)

FIGURE 28
Width of Carbonate Aquifer Through Which Groundwater Flows into Kane Springs Valley

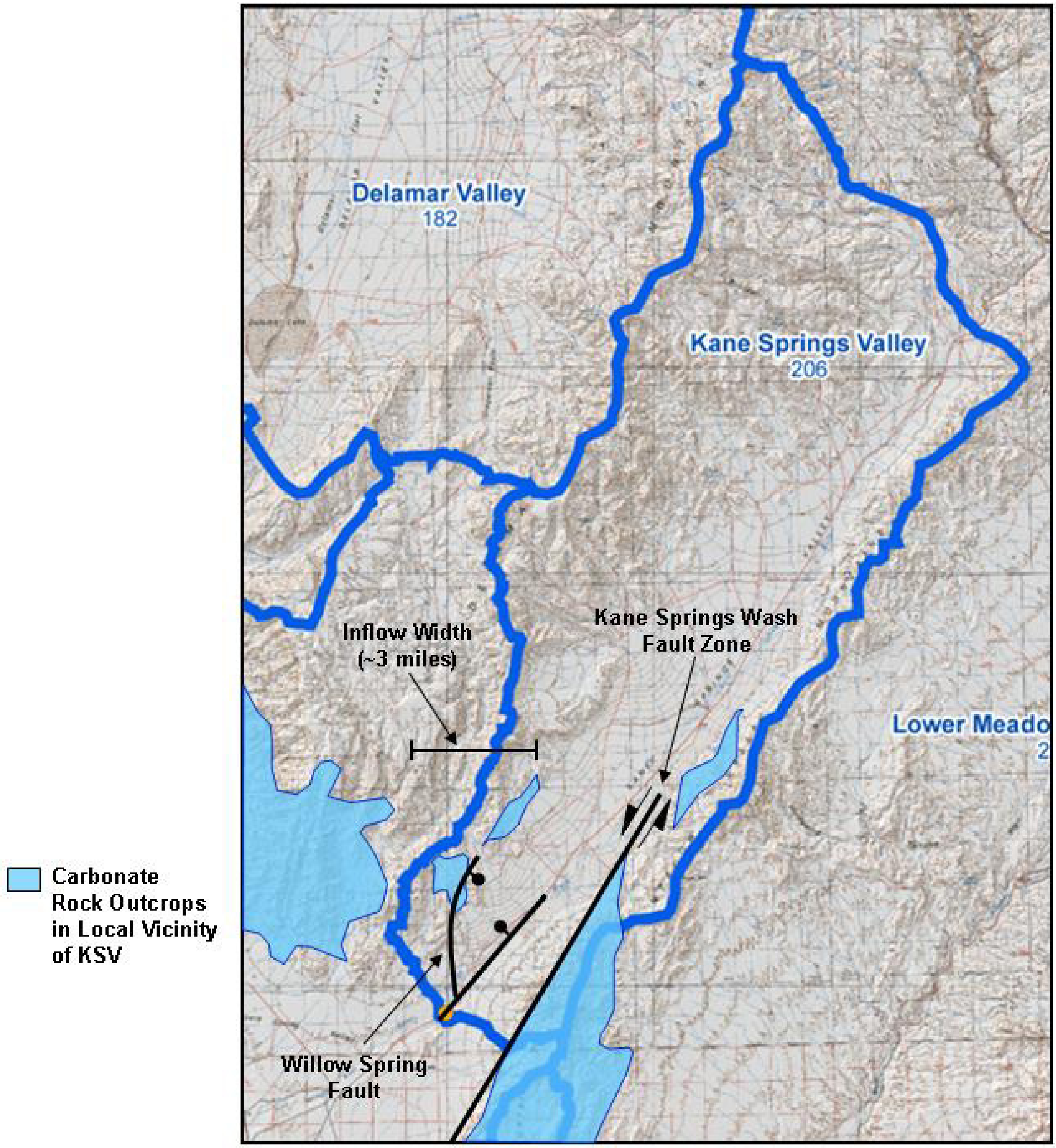


FIGURE 29
Width of Carbonate Aquifer Through Which Groundwater Flows out of Kane Springs Valley

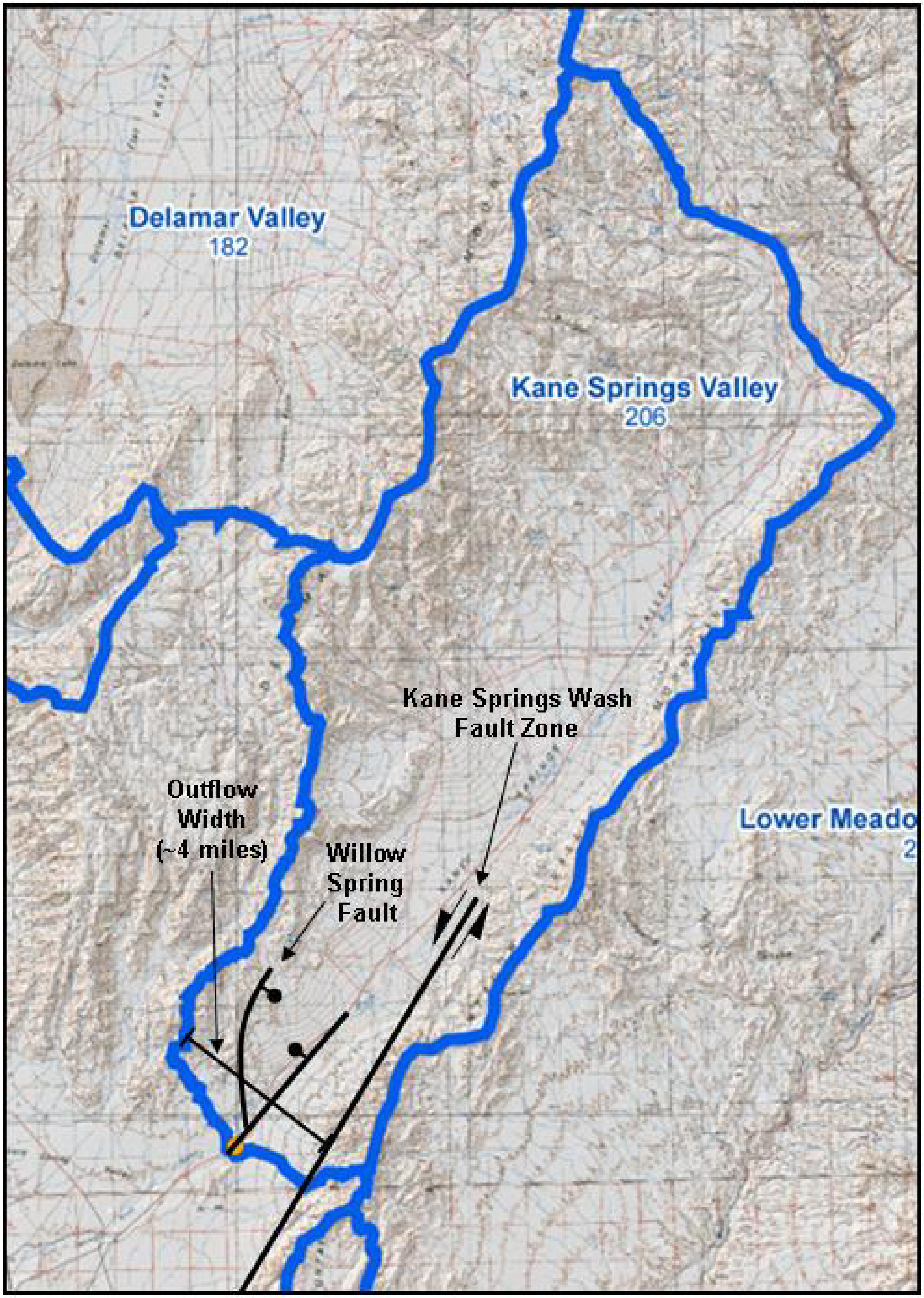


FIGURE 30
Conceptual Groundwater Flow Through Kane Springs Valley

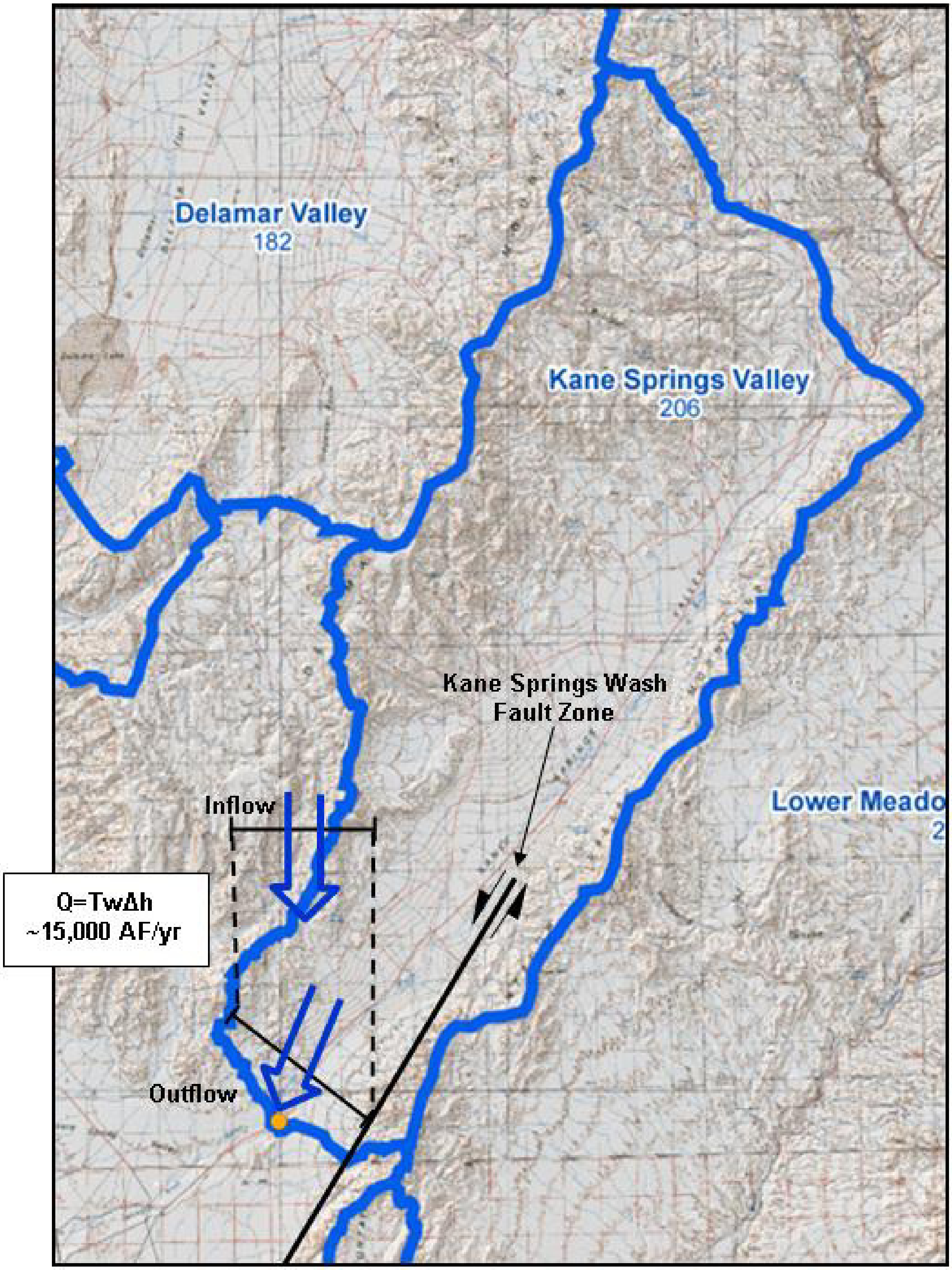


FIGURE 31
Ten-Mile Radius from KPW-1 and Permitted Points of Diversion in the Vicinity of Kane Springs Valley

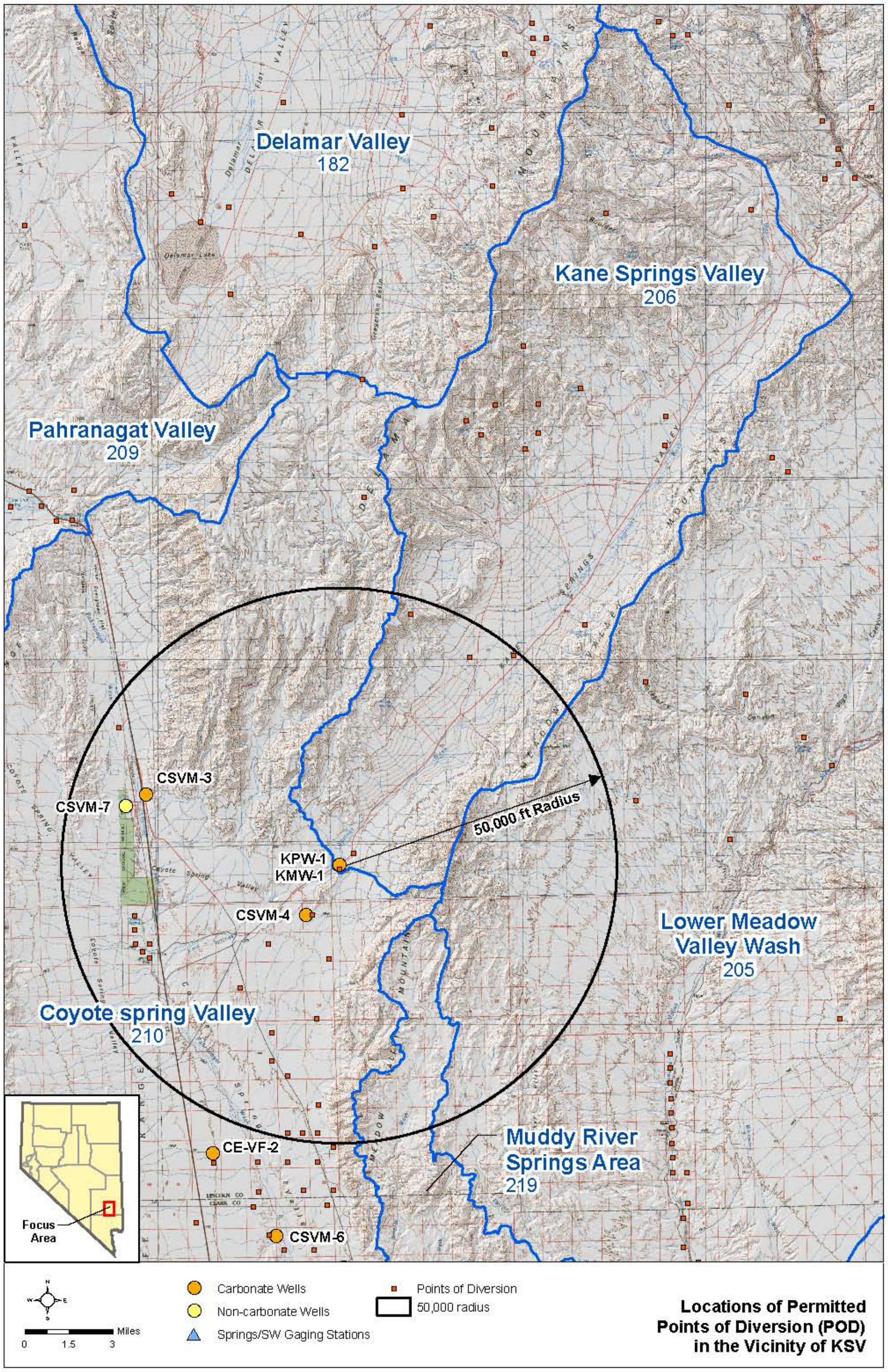
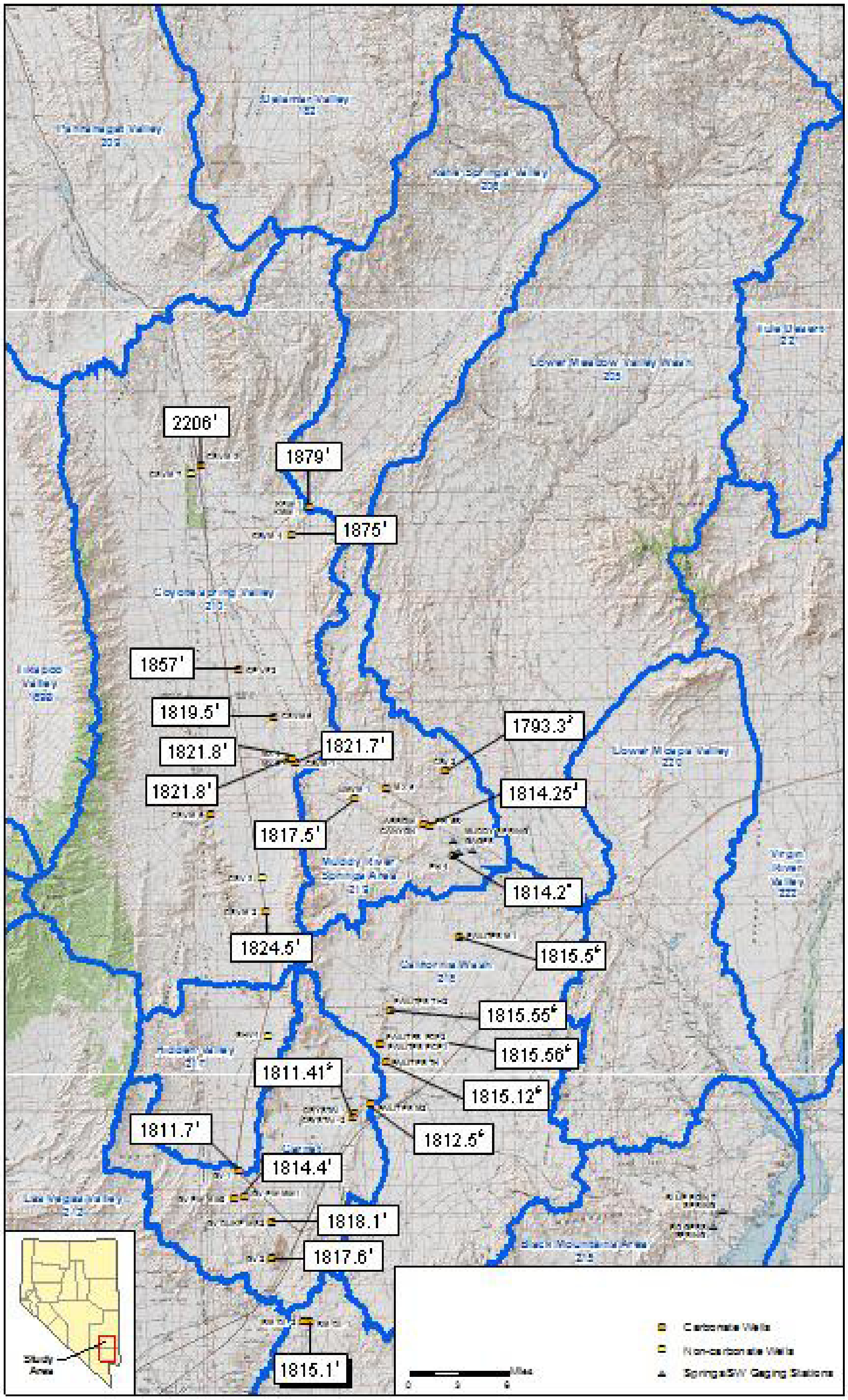


FIGURE 32
Most Recent Groundwater Level Elevations (ft amsl) in Selected Carbonate Wells Within Study Area



[1]Dec 05
[2]June 04
[3]Dec 04
[4]Nov 04
[5]Mar 04
[6]Feb 01

Source: Southern Nevada Water Authority Central Data Repository

FIGURE 33
Hydrographs for Selected Carbonate Wells in the Study Area

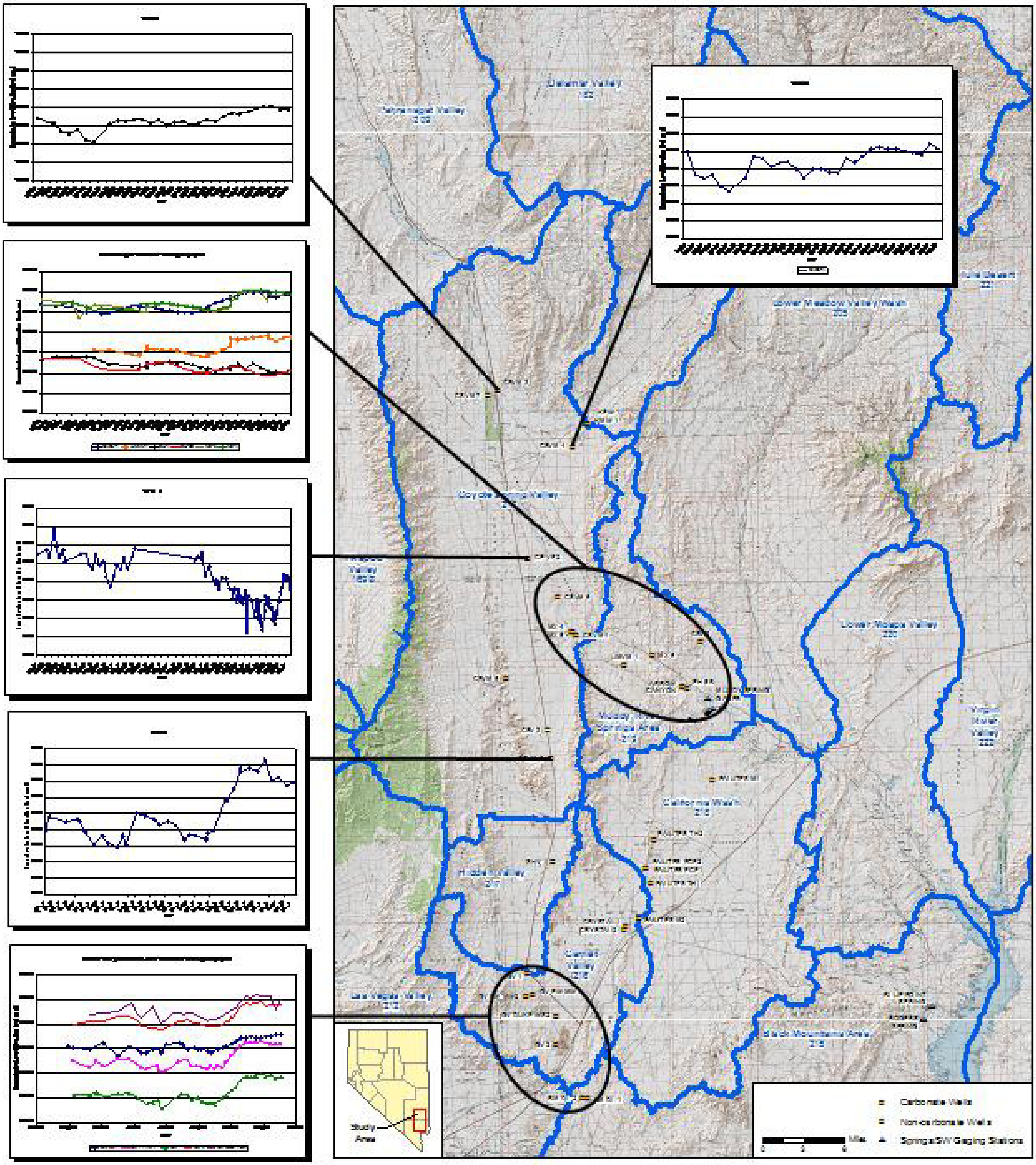


FIGURE 34
Vertical Profile Through Selected Carbonate Wells in Study Area

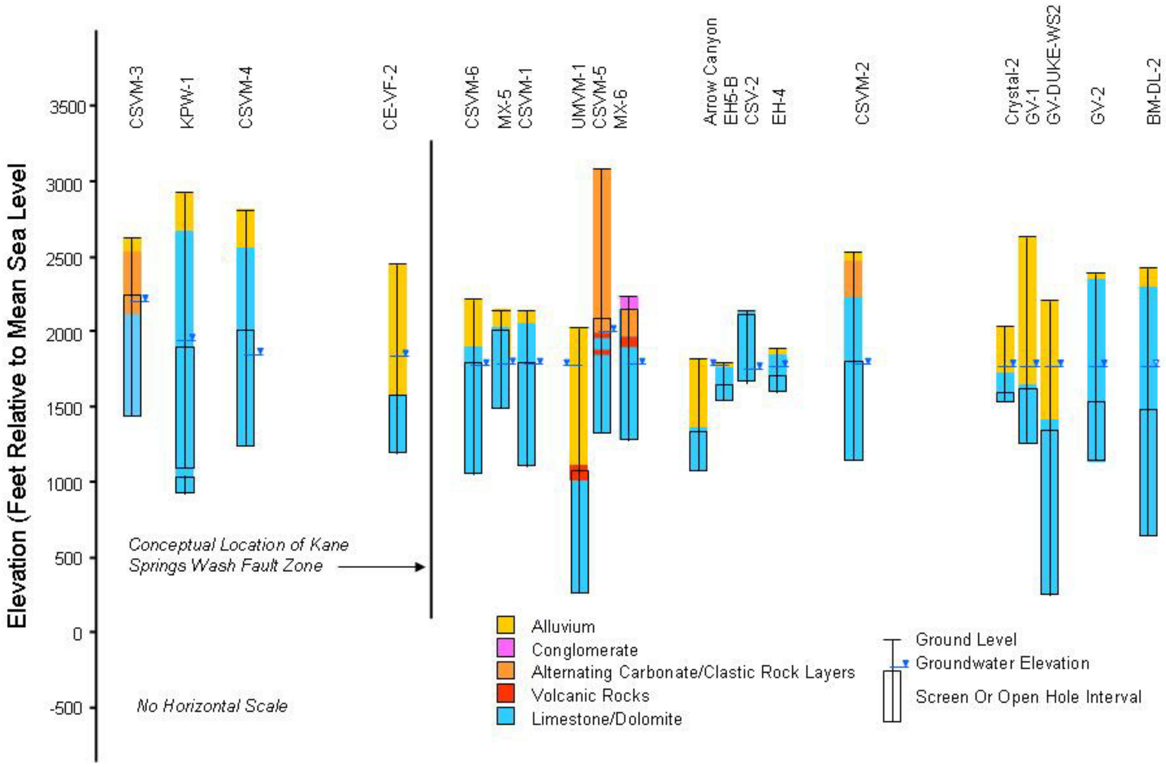
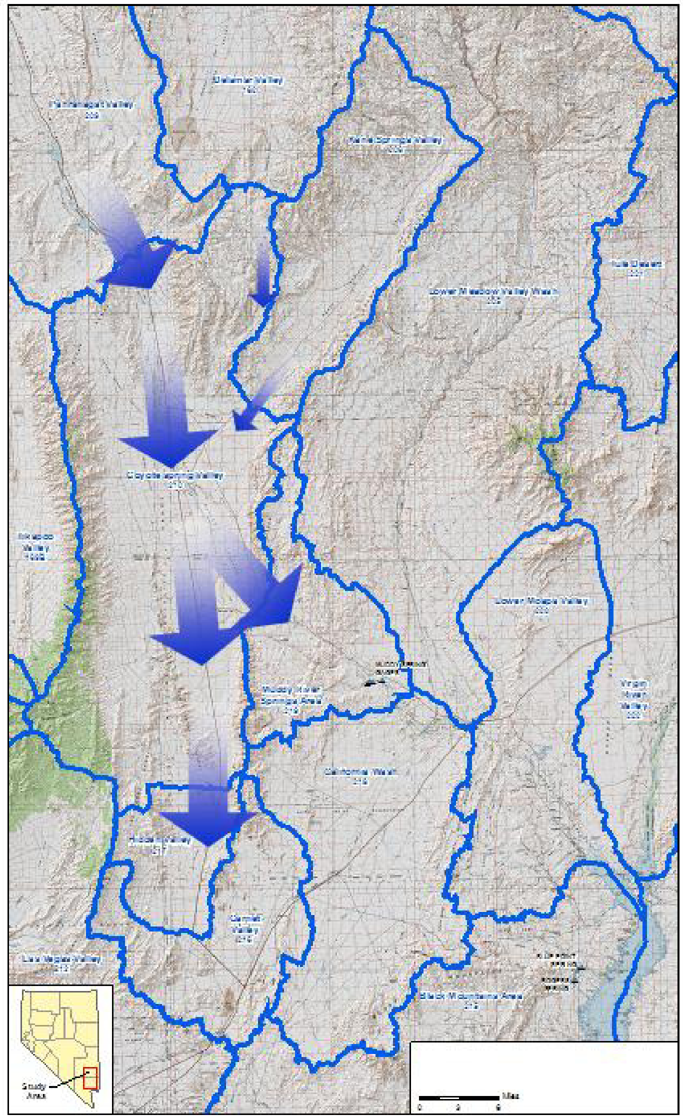


FIGURE 35
Generalized Regional Groundwater Flow in Portion of the Carbonate Aquifer System, Colorado River Basin.



General Direction of Groundwater Flow
in Carbonate Aquifer with the Study Area

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 MOUNTAIONS 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.	**EVIDENTIARY AND WITNESS DISCLOSURE OF THE MOAPA BAND OF PAIUTE INDIANS FOR ORDER 1303 HEARING**

Pursuant to Paragraph V of the Notice of Hearing issued August 23, 2019, the Moapa Band of Paiute Indians submits the follow disclosures:

1. Witness List: The Band will offer the expert testimony of Dr. Cady Johnson, a hydrogeologist, at the Order 1303 hearing. Dr. Johnson will testify as to his opinions expressed in the technical expert reports he authored and submitted to the State Engineer under Order 1303, including his opinions and supporting evidence relating to the geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System; 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; the long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, including relationships between the location of pumping on discharge to the Muddy River Springs, and the capture of Muddy River flow; the effect of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River; and any other matter believed to be relevant to the State Engineer's analysis described in his reports. Dr. Johnson will also respond to criticisms of his opinions expressed in rebuttal reports filed by other parties on August 16, 2019 and provide

rebuttal testimony that explains, counteracts or disproves facts and opinions offered into evidence by other parties.

Dr. Johnson's Curriculum Vitae is included with this disclosure as MBOP Exhibit No. 1. His reports will be offered into evidence as MBOP Exhibit Nos. 2 and 3.

Dr. Johnson was previously admitted as an expert witness in the discipline of hydrogeology before the Nevada State Engineer in the Matter of Applications 54075 and 54076 Filed to Appropriate Underground Water from the California Wash Hydrographic Area (218), Clark County, Nevada. *See* State Engineer Ruling # 5115, p. 21 n. 33 (April 18, 2002).

2. Exhibit List: The Tribe submits the following relevant documents and evidence that the Tribe will ask the State Engineer to consider and that Dr. Johnson will use in support of his testimony:

Exhibit No.	**Name**
MBOP Ex. No. 01	Dr. Cady Johnson, Curriculum Vitae
MBOP Ex. No. 02	Johnson, C., and Mifflin, M. Water Level Decline in the LWRFS: Managing for Sustainable Groundwater Development. Initial Report of the Moapa Band of Paiutes in Response to Order #1303: unpublished report and appendices, July 3, 2019. 84 p.
MBOP Ex. No. 03	Johnson, C., and Mifflin, M. Rebuttal Report of the Moapa Band of Paiutes in Response to Stakeholder Technical Reports Filed under Order #1303: unpublished report and appendices, August 16, 2019. 27 p.
MBOP Ex. No. 04	Blackwell, David, M. Richards, Z. Frone, J. Batir, A. Ruzo, R. Dingwall, and M. Williams 2011, Temperature at depth maps for the conterminous US and geothermal resource estimates, GRC Transactions, 35 (GRC1029452).
MBOP Ex. No. 05	Bredehoeft, J., 2007. It Is the Discharge: Ground Water v. 45 issue 5, Sep-Oct, p. 523.
MBOP Ex. No. 06	CH2M Hill, 2006. Hydrologic Assessment of Kane Springs Hydrographic Area (206): Geochemical Framework: unpublished report prepared for Lincoln County Water District and Vidler Water Company, Inc., April, 2006, 42 p.
MBOP Ex. No. 07	Chamberlain, A.K., 1999. Structure and Devonian Stratigraphy of the Timpahute Range, Nevada: Ph.D. Dissertation, Colorado School of Mines, Golden, CO

Exhibit No.	Name
MBOP Ex. No. 08	Fricke, H.C. and J.R. O'Neil, 1999. The correlation between $^{18}O/^{16}O$ ratios of meteoric water and surface temperature: its use in investigating terrestrial climate change over geologic time: Earth and Planetary Science Letters, v. 170, pp. 181-196.
MBOP Ex. No. 09	Hershey, R.L., S.A. Mizell, and S. Earman, 2010. Chemical and physical characteristics of springs discharging from regional flow systems of the carbonate-rock province of the Great Basin, western United States: Hydrogeology Journal 18(4):1007-1026.
MBOP Ex. No. 10	Johnson, C., 2011. Empirical Mode Decomposition - Applications to the Muddy River Hydrograph - Preliminary Evaluation and Results: unpublished report distributed to HRT March 23, 2011, 21 p.
MBOP Ex. No. 11	Johnson, C., 2019. Isotopic characteristics of regional-spring capture zones in eastern Nevada: unpublished report for LWRFS study, April 4, 2019, 6 p.
MBOP Ex. No. 12	Johnson, C. and M. Mifflin, 2013a. Technical note: Order 1169 post-audit analysis of pumping response: unpublished HRT report, October 1, 2013, 10 p.
MBOP Ex. No. 13	Johnson, C. and M. Mifflin, 2013b. Hydrologic Review Team Presentation: unpublished HRT report, Sept. 12, 2013, 15 p.
MBOP Ex. No. 14	Johnson, C. and M. Mifflin, 2014. Derivation of responses to Order 1169 pumping by the method of differences: Mifflin & Associates, Inc., unpublished HRT report, January 6, 2014, 17 p.
MBOP Ex. No. 15	Johnson, C. and M. Mifflin, 2018. A Climate "Sweet Spot" may Refute Groundwater Model Forecasts": Devils Hole Workshop, Beatty, NV, May 2-4, 2018.
MBOP Ex. No. 16	Donghoh Kim and Hee-Seok Oh (2009) EMD: A Package for Empirical Mode Decomposition and Hilbert Spectrum. The R Journal, 1, 40-46.
MBOP Ex. No. 17	Kruseman, G.P. and N.A. de Ridder, 1994. Analysis and Evaluation of Pumping Test Data (2nd ed.): International Institute for Land Reclamation and Improvement, The Netherlands, 377 p. (selected excerpts)

Exhibit No.	Name
MBOP Ex. No. 18	Masbruch, M.D., V.M. Heilweil, and L.E. Brooks, 2012. Using Hydrogeologic Data to Evaluate Geothermal Potential in the Eastern Great Basin: GRC Transactions, Vol. 36, pp. 47-52.
MBOP Ex. No. 19a	McQuarrie, N. and B.P. Wernicke, 2005. An animated tectonic reconstruction of southwestern North America since 36 Ma: Geosphere, v. 1, no. 3, p. 147-172.
MBOP Ex. No. 19b	From McQuarrie, N. and B.P. Wernicke, 2005. An animated tectonic reconstruction of southwestern North America since 36 Ma (movie depicting animation described in Ex. No. 19a)
MBOP Ex. No. 20	Reynolds, A.R., and A.J. Jefferson, 2014. Sensitivity of precipitation isotope meteoric water lines and seasonal signals to sampling frequency and location: CUAHSI poster, https://sites.google.com/a/kent.edu/d-edgeo/
MBOP Ex. No. 21	Salzer, M.W., A.G. Bunn, N.E. Graham, and M.K. Hughes, 2014. Five millennia of paleotemperature from tree-rings in the Great Basin, USA: Clim Dyn 42:1517-1526.
MBOP Ex. No. 22	Schroth, B.K., 1987. Water Chemistry Reconnaissance and Geochemical Modeling in the Meadow Valley Wash Area, Southern Nevada: M.S. Thesis, University of Nevada, Reno, 104 p.
MBOP Ex. No. 23	Southern Nevada Water Authority and Las Vegas Valley Water District, 2018. Assessment of Water Resource Conditions in the Lower White River Flow System: Southern Nevada Water Authority, Las Vegas, Nevada Doc. No. WRD-ED-0051, 116 p.
MBOP Ex. No. 24	Swanson, E., and Wernicke, B.P., 2017, Geologic map of the east-central Meadow Valley Mountains, and implications for reconstruction of the Mormon Peak detachment, Nevada: Geosphere, v. 13, no. 4, p. 1234-1253.
MBOP Ex. No. 25	Wahl, K. L., and Wahl, T. L., 1995, Determining the Flow of Comal Springs at New Braunfels, Texas, Texas Water '95, American Society of Civil Engineers, August 16-17, 1995, San Antonio, Texas, pp. 77-86.

Exhibit No.	Name
MBOP Ex. No. 26	Johnson, C., M.D. Mifflin, R.J. Johnson, and H. Haitjema, 2001. Hydrogeologic and groundwater modeling analyses for the Moapa Paiute Energy Center: in PBS&J, 2001, Moapa Paiute Draft Environmental Impact Statement, Appendix D., prepared for U.S. Bureau of Indian Affairs and Bureau of Land Management, Case #N66776, March, 2001.
MBOP Ex. No. 27	Mackley, R.D., F.A. Spane, T.C. Pulsipher, and C.H. Allwardt, 2010. Guide to using Multiple Regression in Excel (MRCX v.1.1) for Removal of River Stage Effects from Well Water Levels: Pacific Northwest National Laboratory, PNNL-19775, Rev. 1, 52 p.
MBOP Ex. No. 28a	Sass, J.H. and A.H. Lachenbruch, 1982. Preliminary interpretation of thermal data from the Nevada Test Site: U.S. Geological Survey Open-File Report USGS-OFR-82-973, 30 p.
MBOP Ex. No. 28b	Sass, J.H., A.H. Lachenbruch, W.W. Dusley, Jr., S.S. Priest and R.J. Munroe. 1987. Temperature, thermal conductivity, and heat flow near Yucca Mountain, Nevada: Some tectonic and hydrologic implications: U.S. Geological Survey Open File Report 87-649, 124 p.
MBOP Ex. No. 29	Anderson, M.P., W.W.Woessner, and R.J. Hunt, 2015. Applied Groundwater Modeling - Simulation of Flow and Advective Transport: Elsevier, 564 p. (selected excerpts)
MBOP Ex. No. 30	Johnson, C. and M.D. Mifflin, 2006. The AEM and Regional Carbonate Aquifer Modeling: Groundwater, Vol. 44, Issue 1, pp. 24-34, January-February 2006.
MBOP Ex. No. 31	Johnson, C. and M. Mifflin, 2012a. Analysis Progress Report – Order 1169 Impacts Assessment: unpublished report distributed to HRT March 17, 2012, 15 p.
MBOP Ex. No. 32	Johnson, C. and M.D. Mifflin, 2012b. Parameter Estimation for Order 1169: unpublished report distributed to HRT August 27, 2012, 25 p.
MBOP Ex. No. 33	Mifflin and Associates, Inc, 2010. Order 1169 Impacts (with September 8, 2010 Addendum): unpublished report. 31 p.

As required by the Notice of Hearing, two paper copies of this disclosure and the exhibits listed above are enclosed. Electronic copies of the exhibit list in Excel format and the exhibits listed above can be found on the included USB flash drive for publication on the State Engineer's LWRFS website.

3. Request for Administrative Notice and Acceptance Into Evidence By Reference to Contents: Under NAC 533.300, the Moapa Band of Paiutes requests that the State Engineer take administrative notice of, and accept into evidence by reference to their contents, the following files and records of the State Engineer, public records that have been prepared by other governmental agencies, and technical or scientific data including textbooks that have been generally accepted by the scientific community and are within the field of expertise of the Office of the State Engineer:

Exhibit No.	**Name**
MBOP Ex. No. 34	Bennett, G.D., 1989. Introduction to Ground-Water Hydraulics – A Programmed Text for Self-Instruction: U.S. Geological Survey, Techniques of Water-Resources Investigations, Book 3, Chapter B2, 172 p. Available at: https://water.usgs.gov/ogw/pubs/TWRI3-B2/TWRI3-B2-with-links.pdf
MBOP Ex. No. 35	Freeze, R.A. and Cherry, J.A., 1979. Groundwater: Prentice-Hall, 604 p. Hard copy will be available at hearing.
MBOP Ex. No. 36	Heilweil, V.M., and Brooks, L.E., eds., 2011, Conceptual model of the Great Basin carbonate and alluvial aquifer system: U.S. Geological Survey Scientific Investigations Report 2010-5193, 191 p. Available at: https://pubs.usgs.gov/sir/2010/5193/PDF/SIR2010-5193.pdf
MBOP Ex. No. 37	Southern Nevada Water Authority, 2009. Delamar, Dry Lake, and Cave Valleys Stipulation Agreement Hydrologic Monitoring Plan Status and Historical Data Report: SNWA Water Resources Division, Doc. No. WRD-ED-0005, Appendix F – Water-Chemistry Data. Available at: http://water.nv.gov/hearings/past/Spring%20-%20Cave%20-%20Dry%20Lake%20and%20Delamar%20Valleys%202011/Exhibits/SNWA%20Exhibits/SNWA_Exh_166_SNWA%20DDC%20Historical%20Data%20Report%20WRD-ED-0005.pdf
MBOP Ex. No. 38	Thomas, J.M., S.C. Calhoun and W.B. Apambire, 2001. A deuterium mass-balance interpretation of groundwater sources and flows in southeastern Nevada: Desert Research Institute Publication No. 41169.

Exhibit No.	Name
	Available at: http://images.water.nv.gov/images/Hearing%20Exhibit%20Archives/Dry%20Cave%20Delamar/SNWA/Volume_7/301_DRI_2001.pdf
MBOP Ex. No. 39	Thomas, J.M. and T.M. Mihevc, 2011. Evaluation of Groundwater Origins, Flow Paths, and Ages in East-Central and Southeastern Nevada: University of Nevada, Desert Research Institute, Division of Hydrologic Sciences, Publication No. 41253, 64 p. Available at: http://water.nv.gov/hearings/past/Spring%20-%20Cave%20-%20Dry%20Lake%20and%20Delamar%20Valleys%202011/Exhibits/SNWA%20Exhibits/SNWA_Exh_077_Thomas%20Report/SNWA_Exh_077_Thomas%20Report.pdf
MBOP Ex. No. 40	U.S. Fish and Wildlife Service, 2006. Intra-Service Programmatic Biological Opinion for the Proposed Muddy River Memorandum of Agreement Regarding the Groundwater Withdrawal of 16,100 Acre-Feet per Year from the Regional Carbonate Aquifer in Coyote Spring Valley and California Wash Basins, and Establish Conservation Measures for the Moapa Dace, Clark County, Nevada: memorandum from FWS Field Supervisor (Reno) to FWS Manager of California/Nevada Operations, January 30, 2006, File No. 1-5-05-FW-536, 125 p. including draft Memorandum of Agreement (MOA). Available at: http://water.nv.gov/hearings/past/Cave%20-%20Dry%20Lake%20and%20Delamar%20Valleys%202008/exhibits/USFWS/Exhibit%20602%20Muddy%20River%20MOA.pdf
MBOP Ex. No. 41	Burns, A.G., and Drici, W., 2011, Hydrology and water resources of Spring, Cave, Dry Lake, and Delamar valleys, Nevada and vicinity: Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada. Available at: http://water.nv.gov/hearings/past/Spring%20-%20Cave%20-%20Dry%20Lake%20and%20Delamar%20Valleys%202011/Exhibits/SNWA%20Exhibits/SNWA_Exh_447_Slide_Show_Burns_and_Drici_2nd.pdf
MBOP Ex. No. 42	Interior Secretarial Order 3360 (Dec. 22, 2017) Available at: https://www.doi.gov/sites/doi.gov/files/elips/documents/3360_-_rescinding_authorities_inconsistent_with_secretarys_order_3349_american_energy_independence.pdf

Exhibit No.	Name
MBOP Ex. No. 43	Interior Secretarial Order 3369 (Sept. 28, 2018) Available at: https://www.doi.gov/sites/doi.gov/files/elips/documents/so_3369_promoting_open_science.pdf

The Tribe has not provided paper copies of these documents, but the accompanying USB flash drive contains electronic copies in addition to hyperlinks listed above. Paper copies can be made available at the State Engineer's request.

The Tribe reserves it rights to introduce other documents contained within the State Engineer's files and records, to rely on exhibits disclosed by or relied upon by other parties in this proceeding, and to introduce exhibits used solely for rebuttal or impeachment.

4. Undersigned counsel for the Tribe has secured local Nevada counsel for the purposes of satisfying Part III of the August 23, 2019 Notice of Hearing and NAC 533.200. However, local counsel is currently out of the country until September 9, 2019. Local counsel will submit their Notice of Appearance and applications for undersigned counsel to appear *pro hac vice* under Nevada Supreme Court Rule 42 as soon as possible.

ZIONTZ CHESTNUT

Dated: September 6, 2019

By s/ Beth Baldwin

Richard Berley, WA Bar # 9209
Beth Baldwin, WA Bar #46018
2101 – 4th Ave., Suite 1230
Seattle, WA 98121
Phone: 206-448-1230
Email: rberley@ziontzchestnut.com
bbaldwin@ziontzchestnut.com

CERTIFICATE OF SERVICE

I hereby certify that on September 6, 2019, I caused a copy of the forgoing **Evidentiary and Witness Disclosure of the Moapa Band of Paiute Indians for Order 1303 Hearing** to be served upon the following parties:

Via Federal Express (2 paper copies of Disclosure and all Exhibits, with USB flash drive containing Disclosure, all Exhibits and Excel spreadsheet of Exhibit List):

Nevada State Engineer
Nevada Division of Water Resources
901 South Stewart Street, Suite 2002
Carson City, NV 89701

Via Email:

8milelister@gmail.com
ablack@mcdonaldcarano.com
aflangas@kcnvlaw.com
alaskajulie12@gmail.com
andrew.burns@snwa.com
barbnwa1t325@gmail.com
bherrema@bhfs.com
bostajohn@gmail.com
bvann@ndow.org
Chris.Benkman@nsgen.com
Colby.pellegrino@snwa.com
Coop@opd5.com
coopergs@ldschurch.org
counsel@water-law.com
craig.primas@snvgrowers.com
craig.wilkinson@pabcogypsum.com
dan.peressini@lasvegaspaving.com
david_stone@fws.gov
Dbrown@ldalv.com
dennis.barrett10@gmail.com
derekm@westernelite.com
devaulr@cityofuorthlasvegas.com
dfrehner@lincolncountynv.gov
dixonjm@gmail.com
dorothy@vidlerwater.com
doug@nvfb.org
dvossmer@republicservices.com
dwight.smith@interflowhydro.com
edna@comcast.net
emilia.cargill@coyotesprings.com
fan4philly@gmail.com
gary_karst@nps.gov
gbushner@vidlerwater.com
glen_knowles@fws.gov
gmorrison@parsonsbehle.com
golden@apexindustrialpark.com
golds@nevcogen.com
greatsam@usfds.com
greg.walch@lvvwd.com
hartthethird@gmail.com
Howard.Forepaugh@nsgen.com
info4gbwn@gmail.com
JCaviglia@nvenergy.com
jeff.phillips@lasvegaspaving.com
jharris@kcnvlaw.com
jim.watrus@snwa.com
joe@moapawater.com
Karen.glasgow@sol.doi.gov
kbrown@vvh2o.com
Kevin_Desroberts@fws.gov
kimberley.jenkins@clarkcountynv.gov
kingmont@charter.net
kpeterson@allisonmackenzie.com
krobison@rssblaw.com
kurthlawoffice@gmail.com
lazarus@glorietageo.com
lbelenky@biologicaldiversity.org
lbenezet@yahoo.com
liamleavitt@hotmail.com
Lindseyd@mvdsl.com

Lisa@ldalv.com
lle@mvdsl.com
lon@moapawater.com
lroy@broadbentinc.com
LuckyDirt@icloud.com
luke.miller@sol.doi.gov
luke.stewart@pabcogypsum.com
MBHoffice@earthlink.net
mfairbank@water.nv.gov
Michael_schwemm@fws.gov
MJohns@nvenergy.com
mmarsh@kcnvlaw.com
mmmiller@cox.net
moapalewis@gmail.com
moorea@cityofnorthlasvegas.com
muddyvalley@mvdsl.com
onesharp1@gmail.com
paul@legaltnt.com
pdonnelly@biologicaldiversity.org
progress@mvdsl.com
rafelling@charter.net
raymond.roessel@bia.gov
rhoerth@vidlerwater.com
robert.dreyfus@gmail.com
Rott@nvenergy.com
rozaki@opd5.com
rteague@republicservices.com
Sarahpeterson@blm.gov
SCarlson@kcnvlaw.com
sc.anderson@lvvwd.com
sc.anderson@snwa.com
sharrison@mcdonaldcarano.com
stever@stetsonengineers.com
sue_braumiller@fws.gov
technichrome@jps.net
tim@legaltnt.com
tommyers1872@gmail.com
trobison@mvdsl.com
twtemt@hotmail.com
veronica.rowan@sol.doi.gov
vsandu@republicservices.com
whitfam@mvdsl.com
william.paff@rocklandcapital.com
wpoulsen@lincolnnv.com

s/ Beth Baldwin
Beth Baldwin
Attorney for the Moapa Band of Paiutes

Water-Level Decline in the LWRFS:
Managing for Sustainable Groundwater Development

Initial Report of Moapa Band of Paiutes in Response to Order #1303

Cady Johnson and Martin Mifflin
Mifflin & Associates, Inc. (MAI)

July 3, 2019

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The LWRFS designation and Order 1303 are responses to a flawed conceptual model based on conflated climate and pumping effects, because widespread water-level declines associated with Order 1169 pumping of MX-5 were mistakenly attributed entirely to pumping rather than to the superposition of local, fracture-controlled pumping responses with regional, climate-driven decline. The LWRFS as drawn by the State Engineer ignores hydrochemical and hydrodynamic divides that suggest the existence of two separate capture zones influencing groundwater flow through the five designated basins. Approximately 40,000 afy of south-flowing groundwater may be the flux within the Las Vegas Valley capture zone south and southwest of the MRSA. Pumping from California Wash has little to no impact on the MRSA and much more groundwater is available in California Wash than previously assumed. The State Engineer should supplement and extend the LWRFS concept to an analysis domain based on regional-spring capture zones, as delineated by the best available science. If the long-term drought trend evident in climate records persists, no amount of pumping curtailment will restore or maintain high-elevation spring flows, curtailment of pumping in sustainable locations will serve no purpose and thus mitigation measures, including curtailment, will not likely prove effective in protecting senior-rights holders in the Muddy River and Moapa dace habitat from continued drought impacts.

PART I. INTRODUCTION

On January 11, 2019, the Nevada State Engineer issued Interim Order 1303, signaling a major change in how the State Engineer may administer groundwater rights in much of southern Nevada. Order 1303 recognizes a "Lower White River Flow System" (LWRFS) super-basin consisting of the Coyote Spring Valley, Muddy River Springs, California Wash, Hidden Valley, Garnet Valley and a portion of the Black Mountains Area, which the State Engineer proposes to treat as a single unit for administering groundwater rights. The justifications for this are the State Engineer's conclusions that (1) the groundwater and surface water systems are hydrologically connected in the super-basin; (2) the surface waters of the Muddy River are fully appropriated; (3) pumping tests have shown that groundwater pumping in the basin may affect discharge at the Muddy River Springs and thus flow of the Muddy River; and (4) the total water budget within the super-basin is insufficient to satisfy the 38,000 acre-feet of groundwater appropriations in the super-basin (Figure 1) without impacting senior rights to the connected surface waters.

Order 1303 called for technical reports from stakeholders on the following five topics:

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.

We address these questions below in Part II, with supporting analyses further explained in five Appendix reports that address (I) flow-system boundaries and groundwater flux in the LWRFS, (II) a preliminary two-climate model for Muddy River discharge, (III) the MAI finite-element transmissivity model that reconciles heat flow with regional groundwater flow, (IV) a multiple-regression procedure to remove Arrow Canyon Well pumping effects from the EH-4 hydrograph, and (V) aquifer analyses in Coyote Spring Valley.

In our view, the LWRFS designation and Order 1303 are responses to a flawed conceptual model based on conflated climate and pumping effects. Widespread water-level declines associated with Order-1169 pumping of the MX-5 well were mistakenly attributed entirely to pumping rather than to the superposition of local, fracture-controlled pumping responses with regional, climate-driven decline. Identification and separation of forcing by climate and forcing by pumping as hydrograph components reveals the most imminent risk to senior water-rights holders and Moapa dace habitat is continued drought.

The LWRFS hydrogeologic system is complex, but likely possesses more sustainable resource potential than previously suggested (see Appendix I) because drought-trend impacts have been misinterpreted as cumulative pumping impacts (see Appendix II). The climatic trends in the LWRFS hydrographs are directly responsible for masking the more localized effects of pumping within sub-environments of Coyote Spring Valley (Appendix V), California Wash (Johnson and others, 2001), Black Mountains Area (Mifflin and others, 1992), and the Muddy River Springs Area (MRSA) (Appendix IV). If the drought trend persists, no amount of pumping curtailment will restore or maintain high-elevation spring flows, and curtailment of pumping in sustainable locations will serve no purpose. The mitigation measures, including curtailment, will not likely prove effective in protecting senior-rights holders in the Muddy River and Moapa dace habitat from continued drought impacts.

In the face of a continuing drought trend, high-elevation spring habitats will continue to be impacted first by climate-induced discharge reductions (Appendix II). The details of regional groundwater movement need not be understood in detail at this point (Appendix III). In the case of Coyote Spring Valley (CSV) carbonate-aquifer wells there is a finite but *not* a 1:1 impact in terms of detectable discharge reductions in the MRSA (Appendix V). The Arrow Canyon Wells are shown to reversibly (i.e., complete recovery in 3 months) impact the high-elevation springs (Appendix IV), but their proportional impact on the Muddy River is uncertain because the effect is spread over about 3 months and cannot be visually resolved in the Muddy River hydrograph.

LWRFS groundwater not discharging in the MRSA is probably destined for northern and northeastern Las Vegas Valley, where net ~60,000 acre-feet per year (afy) of groundwater is being extracted by SNWA (personal communication, A. Burns, 2018). Groundwater production in Las Vegas Valley far exceeds the sustainable yield of 25,000 afy estimated by Malmberg (1965, p. 90). Modeling and water chemistry (Appendix III) suggest that wells in California Wash, southernmost Coyote Spring Valley, Hidden Valley, and Garnet Valley may divert groundwater from a different regional-spring capture zone than the MRSA capture zone (Figure 1).

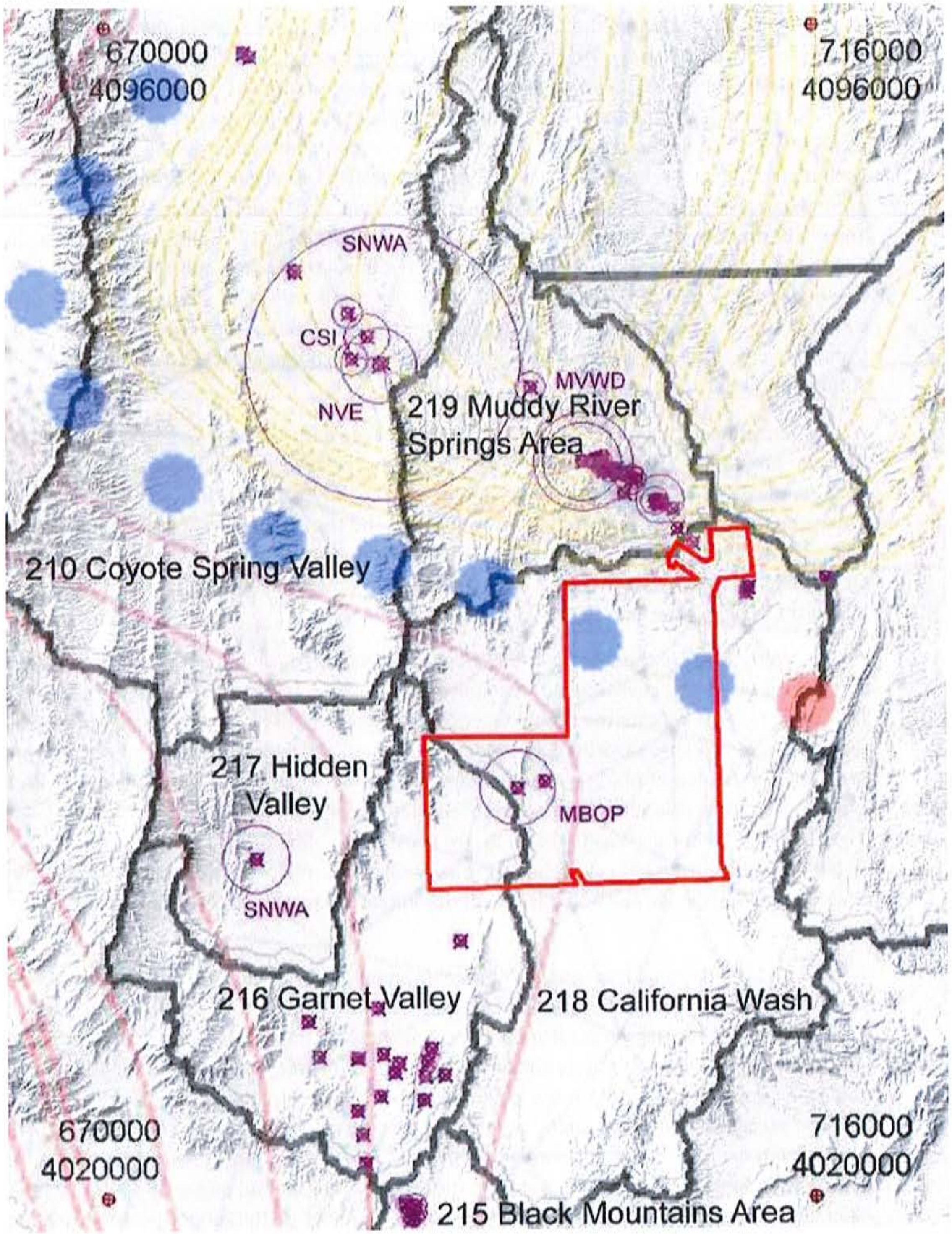


Figure 1. Scaled representation of permitted and perfected water rights in the LWRFS area, with streamlines to regional springs and hydrodynamic divide (blue dots) from MAI transmissivity model (Appendix III) [LWRFSprioritiesDivideSR83.jpg]

At LWRFS latitudes the large production wells capture a component of far-traveled groundwater that is largely tributary to regional springs except those in Pahrump Valley and Indian Springs where mounded recharge from the Spring Mountains is responsible for water developed in these communities. But the Spring Mountains cannot be the major contributor to Las Vegas Valley (Appendix I). There are questions about the capacity of the Spring Mountains to fully recharge adjacent areas, particularly Las Vegas Valley, in part because groundwater discharge from Ash Meadows (Winograd and Thordarson, 1975) and in the Tecopa Basin and lower Amargosa River (Belcher and others, 2018) is also attributed to the Spring Mountains, and in part because the structural dip in the Spring Mountains is away from Las Vegas. We consider it unlikely that this small (relative to northern sources) recharge area supports the present-day net steady-state groundwater extraction rate of at least 60,000 afy from Las Vegas Valley in addition to supporting major discharge areas west and north of the Spring Mountains.

Only the marine carbonate rocks of Devonian age and older, the Lower Paleozoic Shelf Domain, are sufficiently extensive and continuous to provide regional hydraulic continuity between east-central and southern Nevada (Heilweil and Brooks, 2011). More locally, the Mississippian Monte Cristo Limestone is reported to be the primary aquifer in Coyote Spring Valley (Ertec, 1981; Johnson, 2007). In this discussion "upstream" and "downstream" locations are considered to be generally north and generally south respectively, consistent with regional topography (Figure 1).

Water levels in the 5-basin LWRFS have exhibited net declines over the past 2 decades in response to less effective moisture, as indicated by upstream hydrographs (Figures 2 and 3). The longer records indicate the drought trend began about 1999 (Figure 4). Superimposed on generally linear declines since 2006 are widespread but diminishing-with-distance effects from Order-1169 pumping of MX-5, evident as far south as the Apex area (Figures 5 and 6). Well hydrographs from paleodischarge and present-day upwelling areas in Coyote Spring Valley (Figure 7) and California Wash (Figure 8) are substantially identical except for the subdued Order-1169 effect from 2011-2013 in California Wash. The SHV-1 well in Hidden Valley displays no Order-1169 response and a smaller linear decline rate than wells in the other Basins (Figure 9).

The MAI regional transmissivity model (Appendix III) suggests a hydrodynamic divide in the Moapa River Indian Reservation area between the capture zones for the MRSA and (former) Las Vegas Springs areas (Figure 1 and Appendix I). "LWRFS" groundwater that is not tributary to the MRSA is tributary to Las Vegas Valley, at a rate that approaches 40,000 afy. However, some qualifications for this estimate follow. First, hydraulic gradients utilized in the Darcy's Law calculation in Appendix I are consistent but very small. Possible density effects of deeper, high-density waters influencing fluid potentials in the Apex area are uncertain because the extent of brackish to brine-like waters in the Muddy Creek and subjacent formations (Harry Allen site) and depth of active groundwater flow in the thrust-thickened Paleozoic section beneath Garnet Valley (Adenle and Mifflin, 1995) north of Apex are unknown. If the lower part of the water column is denser than the upper part, equivalent freshwater heads in portions of the LWRFS could be higher than what is being measured. Second, the transmissivity value from the EBM-4 aquifer test by Mifflin and others (1992), used as the basis for the computed Darcy flux, may not be representative of the geologically-constrained flow corridor into Las Vegas Valley from the north. The Order-1169 test of MX-5 showed that area to be three times more transmissive, and the test by Johnson and others (2001) of ECP-1 measured transmissivities an order of magnitude lower than EBM-4. Nonetheless, this preliminary work suggests that the amount of water available in the LWRFS is uncertain but likely more than prior estimates.

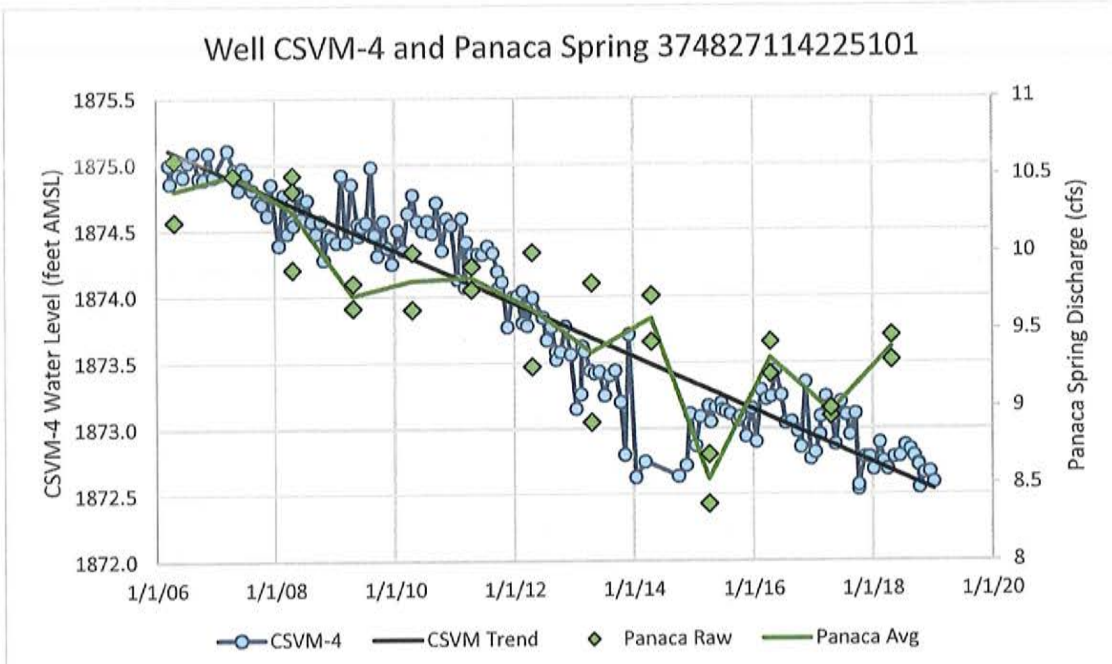


Figure 2. Pattern of duplicate April measurements at Panaca Spring, with downstream CSVM-4 for reference [PanacaSpring.xlsx]

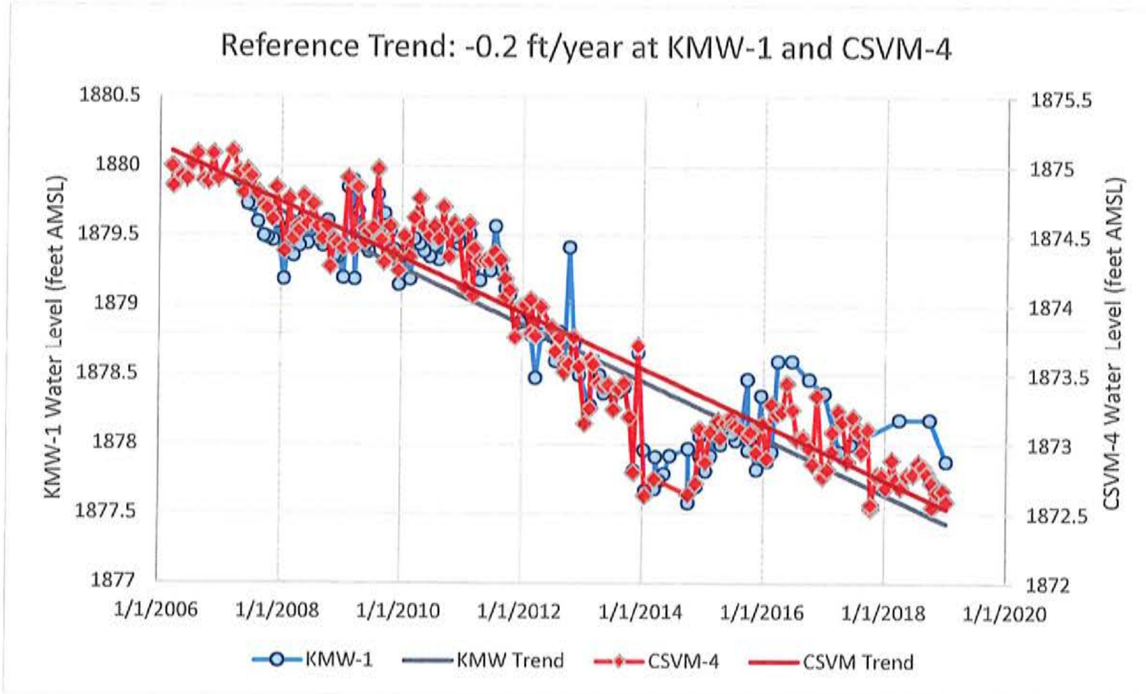


Figure 3. Corresponding hydrographs of CSVM-4 in Coyote Spring Valley and KMW-1 in Kane Springs Valley. No known pumping event explains the low water levels in 2014. [Order1169wlData20190508]

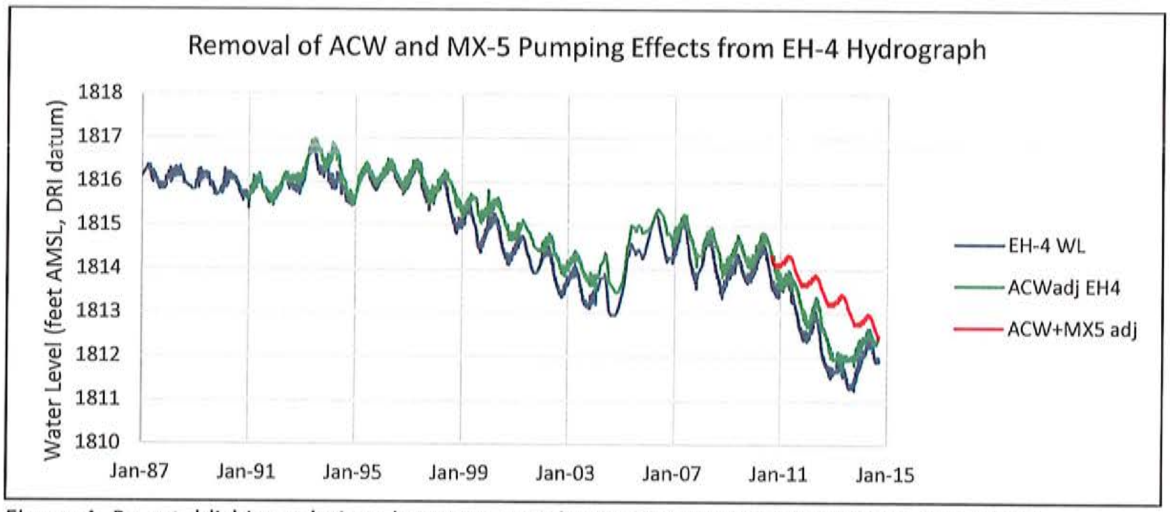


Figure 4. By establishing relations between pseudo-steady-state EH-4 drawdown and Arrow Canyon Well (ACW) pumping rate, then extrapolating the adjusted decadal trend across the MX-5 pumping interval, the EH-4 hydrograph is restored to a more pristine form that is explained through multiple regression by climate (base flow of the Virgin River North Fork 1-16 years prior) [EH4_1169response.xlsx]

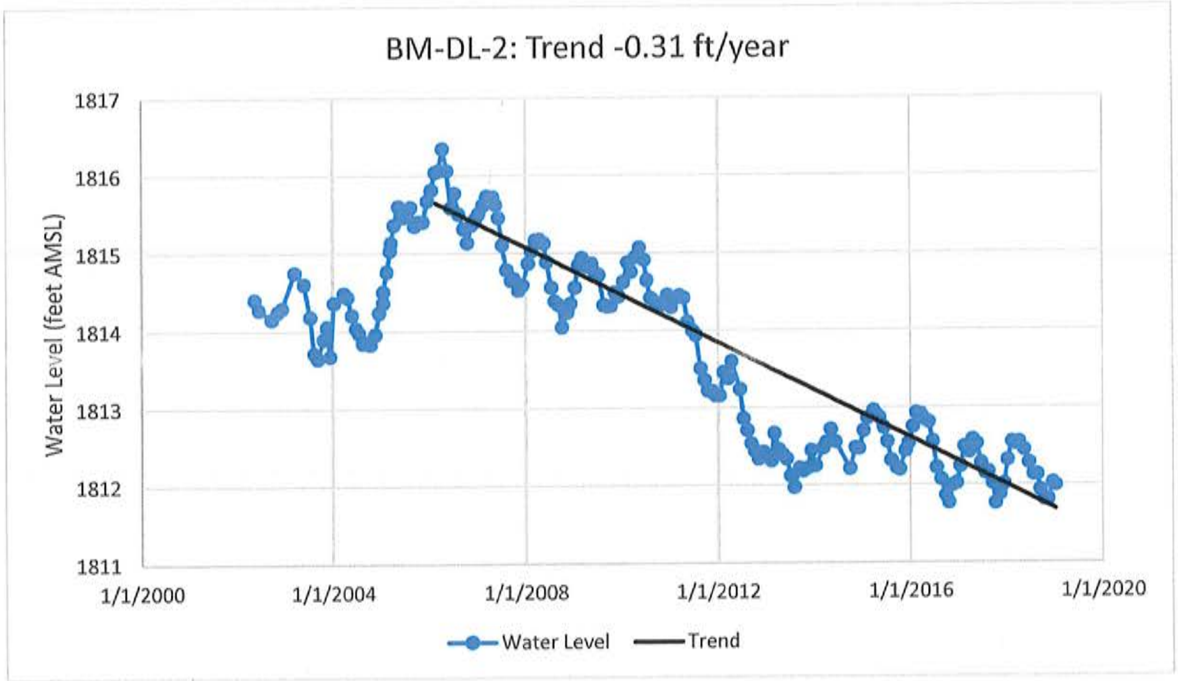


Figure 5. Periodic water levels in monitoring well BM-DL-2 (Black Mountains Area [Order1169wlData20190508]

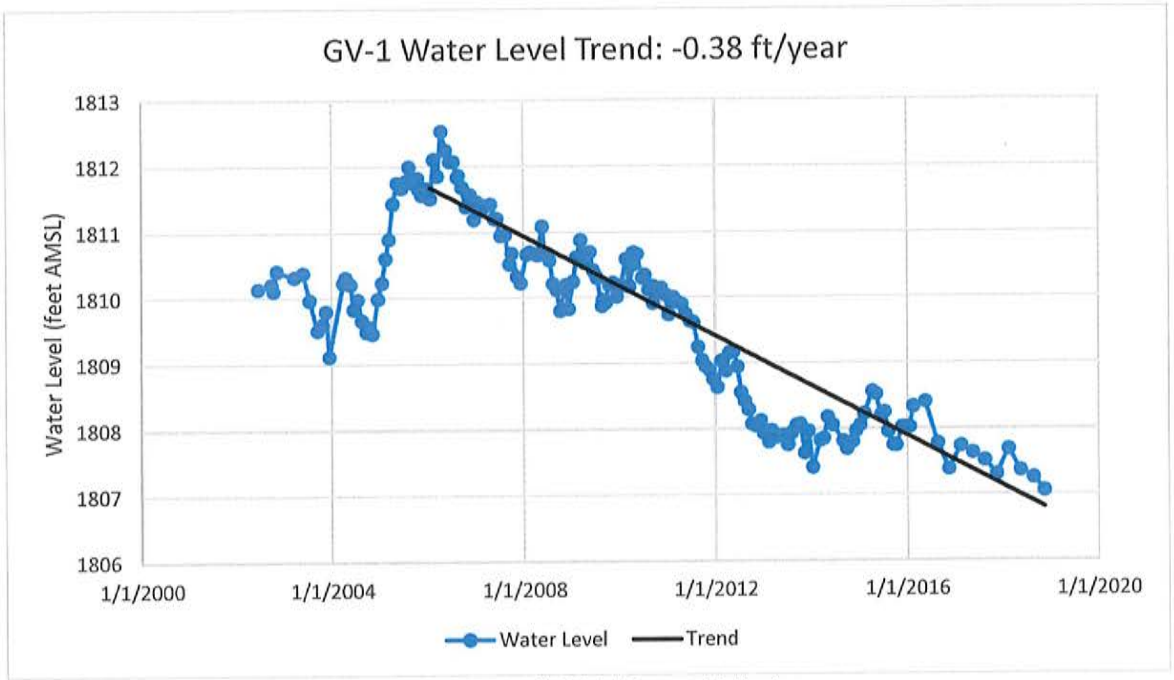


Figure 6. Periodic water levels in monitoring well GV-1 (Garnet Valley) [Order1169wlData20190508]

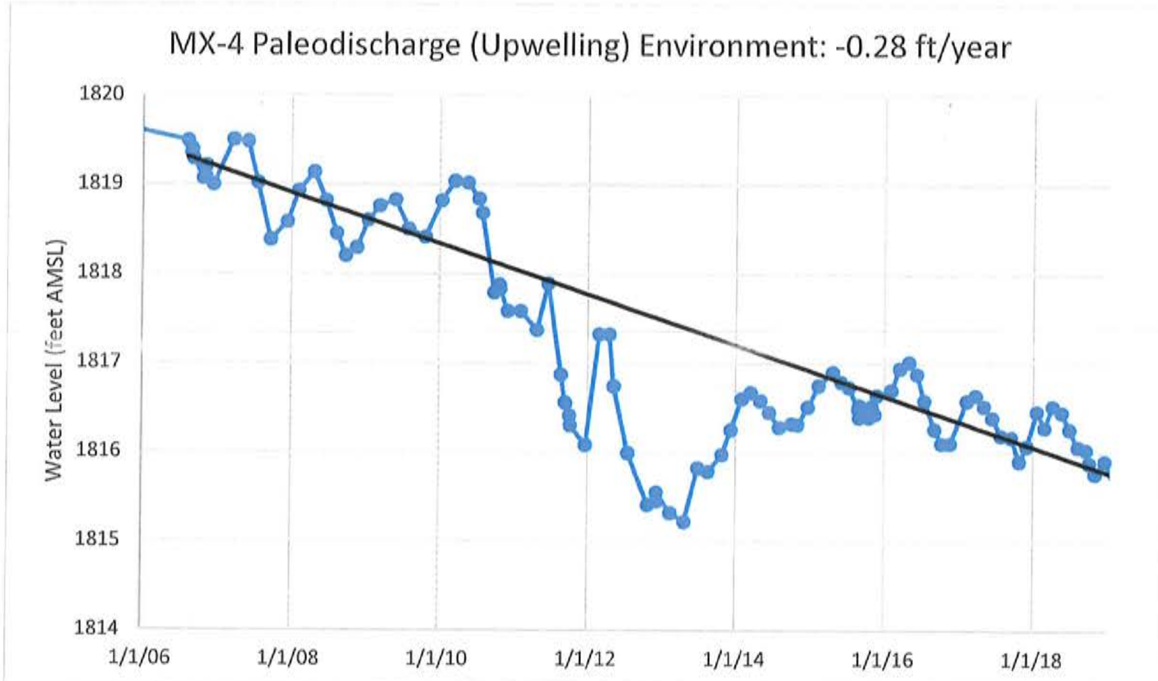


Figure 7. Periodic water levels in monitoring well MX-4 (Coyote Spring Valley) [MX-4_periodic.xlsx]

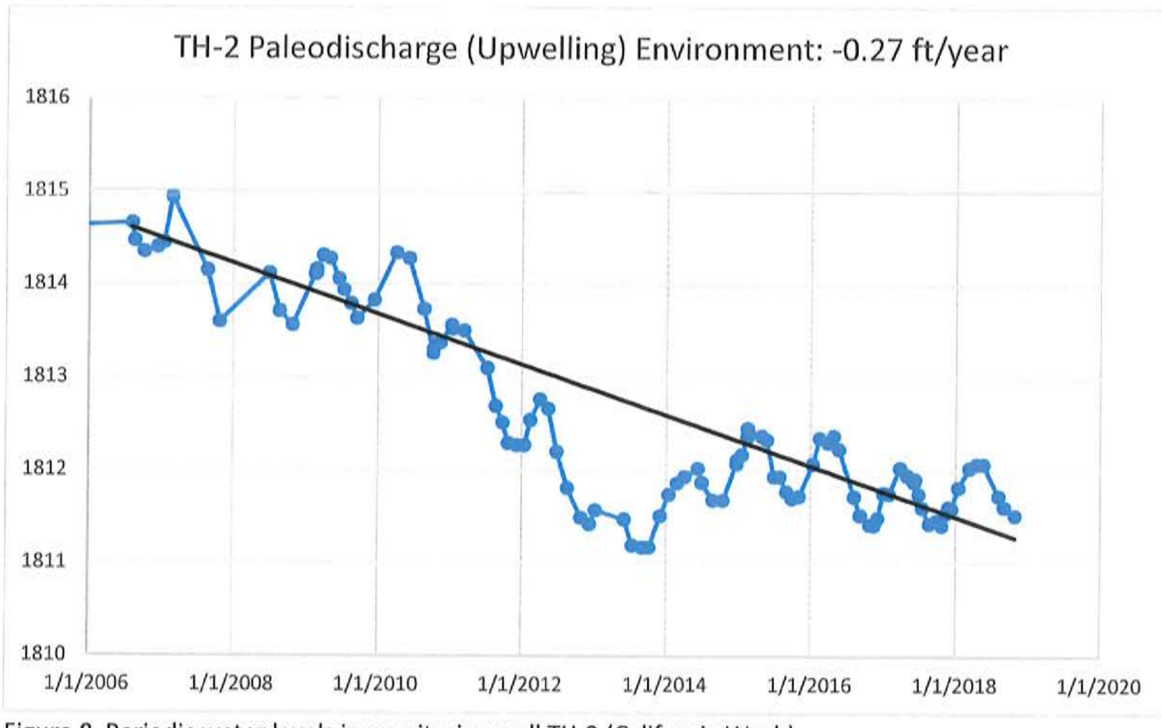


Figure 8. Periodic water levels in monitoring well TH-2 (California Wash) [Order1169wlData20190508]

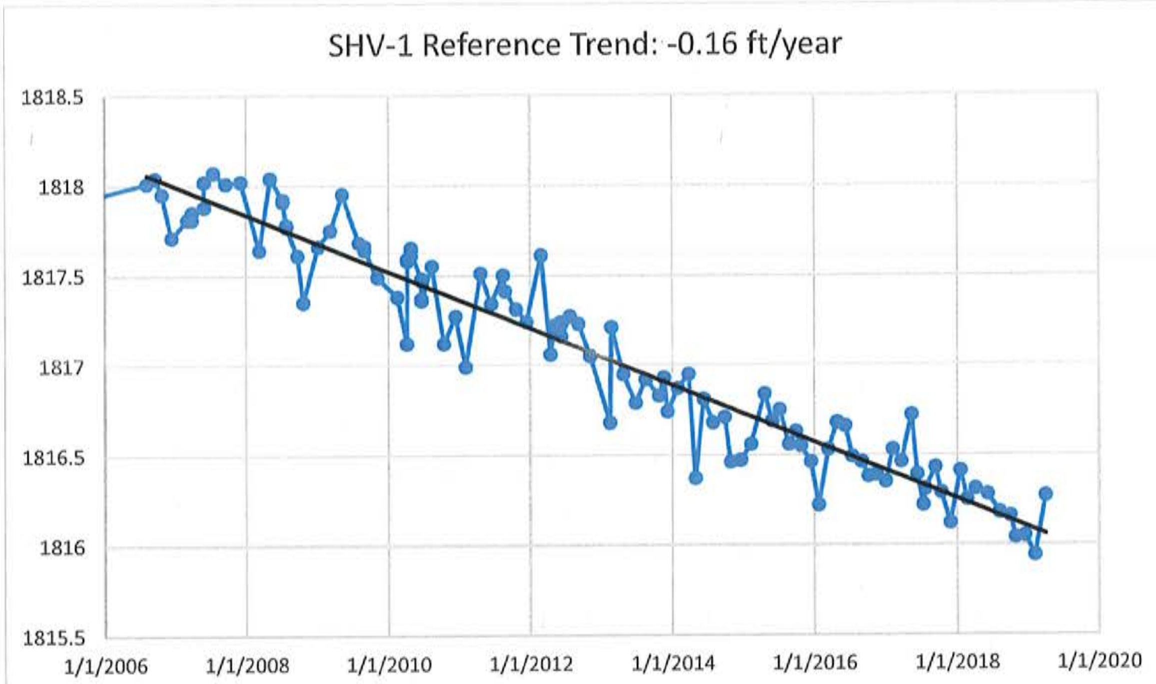


Figure 9. Periodic water levels in the BLM Hidden Valley stock well [SHV-1_USGS.xlsx]

Managers face an uncertain climate future, but it is certain that, at some point, effects of the past two decades' drought will propagate through the hydrologic system to regional springs, producing less discharge in accord with lowered fluid potentials in their capture zones in years prior. Multiple-regression analyses have shown well and spring hydrographs to correlate with regional climate proxies (Appendix II) after removal of relatively minor pumping effects (Figure 4 and Appendix IV). Although outside the scope of this Order 1303 process, our analyses suggest evidence of a larger and much-improved water budget for Las Vegas Valley than previously accepted by the State Engineer. Inflow to Las Vegas Valley from the north in quantities on the order of 40,000 afy exclusive of the Spring Mountains would relieve present-day incentives toward curtailment of pumping or permits, but the opportunities presented by this information go far beyond satisfying pending water requests. South of the Pahranagat Shear Zone (Figure 1 of Appendix I) a broad groundwater flow corridor, tributary to Las Vegas Valley and hydrodynamically isolated from the MRSA, invites a paradigm shift such as adjudication as a stream.

PART II. ANSWERS TO QUESTIONS POSED BY INTERIM ORDER 1303

a. The geographic boundary of the hydrologically connected groundwater and surface water systems comprising the Lower White River Flow System.

Hydrographic basin water budgets, the standard approach to groundwater-resource development, are not reliable management tools if the groundwater resource is dominated by interbasin flow that cannot be estimated reliably at a hydrographic-basin scale; a regional process requires regional analyses. We recommend the capture zones of the Muddy River

Springs Area and Las Vegas Valley, extending north to about the latitude of Panaca Spring, 39°15′ (Figure 5 of Appendix III) as the analysis region to supplement and extend the LWRFS concept based on hydrodynamic and hydrochemical divides evident from a regional transmissivity model and isotope analyses (Appendix III). The Devonian-Mississippian unconformity, a stratigraphic boundary, should constitute an important aquifer distinction from Delamar Valley northward. Pre-Mississippian strata in the zone of lateral flow are regionally continuous (Figure 10) and should be regulated for new water-rights applications because they are presumed tributary to regional springs to the south. South of the Pahranagat Shear Zone the most productive wells are in sub-thrust Mississippian rocks within a ~20 km wide corridor between the Gass Peak Thrust and California Wash Fault (Figure 1 of Appendix I). A groundwater flux of ~40,000 afy to Las Vegas Valley is calculated from *measurements* of pumping rate and response to provide a transmissivity estimate, water levels yielding a hydraulic gradient, and width of the flow corridor from geology.

The current proposed LWRFS boundaries cut through areas of highly-transmissive Mississippian carbonate rock rather than following a more logical boundary where the carbonates meet less permeable strata. Unlike younger strata, Devonian and older rocks of the Lower Paleozoic Shelf Domain that include the Sunnyside Basin sequences of Chamberlain (1999; Figure 10 here) are modeled (Appendix III) as continuous between the mountainous terrain of east-central Nevada and warm-spring areas in southern Nevada (Heilweil and Brooks, 2011). In southern Nevada, warm springs are either closely associated with the pre-Mississippian carbonate-rock aquifer as at Panaca and Ash Meadows, or issue from alluvium as in the MRSA down-gradient from highly-transmissive but locally-distributed Mississippian carbonate-rock aquifers in Coyote Spring Valley, or discharge as artesian flow as from the Bird Spring Formation (e.g. the Joe W. Brown well, API # 27-003-05008) in Las Vegas Valley.

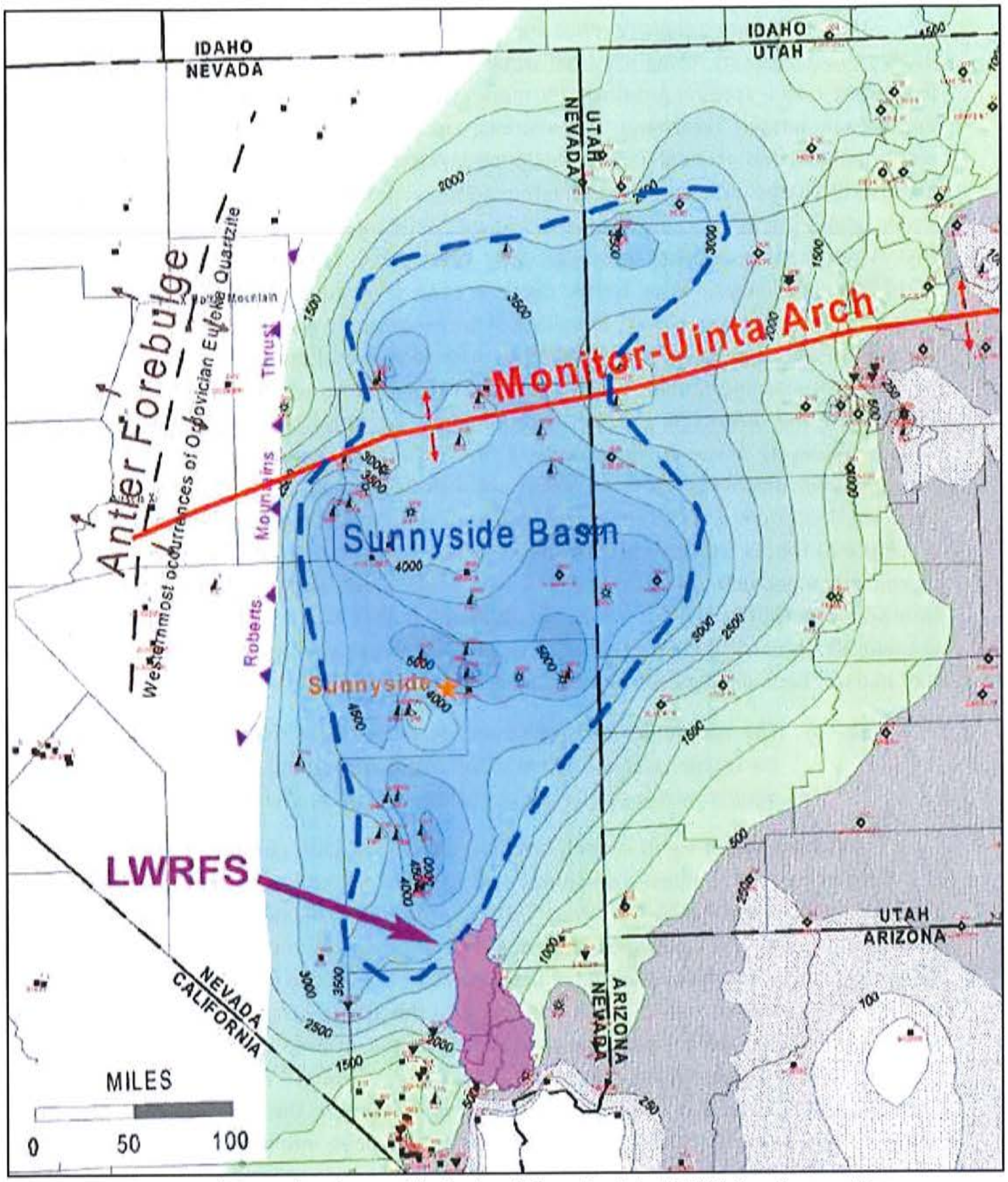


Figure 10. Unrestored Devonian Sunnyside Basin of Chamberlain (1999), locally reaching thicknesses of over 5,000 feet, with LWRFS indicated. Carbonate rocks of the Lower Paleozoic Shelf Domain give way westward to deep-water, silicious sediments that were thrust over the shelf in the latest Devonian Antler Orogeny, then eroded to produce extensive and notably low-permeability Mississippian clastic detritus that was shed eastward over the autochthonous shelf rocks. The steep thickness gradient on the southeast side of the basin, beneath the LWRFS, is the result of Mesozoic Sevier crustal shortening along the northeast-trending Utah hingeline. [SunnysideBasinUTM83.tif]

Regional-spring capture zones are mappable by standard methods, particularly water-quality investigations using isotope tracer techniques. A regional-spring capture zone illustrated with a scoping groundwater model (Appendix III) is a mappable entity that must enclose a mountainous recharge area or areas, conceptually surrounding a regional spring area with a rational and observable zero-flux boundary enclosing all ground-water flow paths to a regional discharge area. The groundwater capture zones for Las Vegas Valley and Pahranagat Valley bound the MRSA capture zone to the west, forming an important hydrodynamic divide that should be recognizable from diagnostic chemical (F, As) and isotopic (D, ^{18}O, $^{87}Sr/^{86}Sr$, $^{234}U/^{238}U$) differences. The MRSA capture zone is characterized by dissolved fluoride concentrations that can exceed 4 mg/liter, whereas groundwater in the Las Vegas Valley and upstream Pahranagat Valley capture zones have dissolved fluoride generally well below 1 mg/liter (Thomas and others, 1996). From the MRSA southward, mixed compositions near 2 mg/liter are not diagnostic of either capture zone. Between Pahranagat Valley and Panaca Valley, however, there is necessarily a hydrochemical boundary associated with the hydrodynamic divide between the MRSA and Pahranagat/Las Vegas capture zones. Much-depleted deuterium and ^{18}O are to be expected in groundwater west of the divide (blue dots on Figure 1) that is tributary to Pahranagat or Las Vegas Valley, while elevated fluoride and arsenic are expected to the east in water bypassing Panaca Spring and tributary to the MRSA (Johnson and Mifflin 2019). Paces and Wurster (2014) found isotopes of strontium and uranium to be particularly useful for discriminating water sources within Pahranagat Valley that had not been distinguished based on chemistry.

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.*

Declining water levels entirely attributed to Order-1169 pump test drawdown by the U.S. Department of the Interior's Fish and Wildlife Service, Bureau of Land Management and the National Park Service ("DOI Bureaus"), SNWA, and eventually the State Engineer are better explained as pumping superimposed upon a climate-driven decline trend. Recovery from the Order-1169 test must be considered in the context of a 2-decade drought punctuated by wet winters in WY 2005 and WY 2010, and likely again this water year 2019. Since 2006, decline rates in the LWRFS area have ranged from 0.2 ft/year in areas remote from pumping in northern Coyote Spring Valley and Kane Springs Valley (Figure 3) and 0.16 ft/year in Hidden Valley (Figure 9) to 0.38 ft/year near the center of pumping in the Apex area adjacent to Las Vegas Valley (Figure 6). Drought-induced trends have been interpreted as pumping effects rather than climate-driven changes. Analysis of pumping response reveals system parameters and boundaries that constrain the range of possible pumping effects from wells that have been tested.

The role of climatic signals in forming similar-appearing hydrographs has generally been unrecognized or ignored in reports submitted under Order 1169 and in subsequent State Engineer rulings. Water levels and water-level changes in California Wash, Coyote Spring Valley, the Muddy River Springs Area, and Hidden and Garnet valleys have been observed as "nearly identical," thus "groundwater withdrawal in any of the five basins will have a similar effect on the hydrologic system" (State Engineer Ruling 6258, Page 27, first partial paragraph).

However, the water-level rise of 2005-2006 refutes this; cessation of pumping somewhere could not have caused water levels to rise over 1 foot at CSVM-4 in northern Coyote Spring Valley and 3 feet at GV-1 in southern Garnet Valley beginning in late 2004 (Figure 6) because there was no cessation of pumping. Pumping in the Apex area was relatively steady at about 200 acre-ft/month without a trend during this time of rising water levels, and the Arrow Canyon Wells and MX-6 were all in service producing a combined average of 165 acre-ft/month. Between October 2004 and May 2006, water levels were *rising* at a rate of 1.6 ft/year in the Apex area (Figure 11) while groundwater extraction (exclusive of MRSA gravels and domestic wells) was occurring at an average rate of 3,200 afy in the LWRFS area. The only logical explanation for these water-level increases is a response to temporarily wetter conditions. High-elevation springs and numerous wells with hydrographs of the EH-4 form are responding to 16 years of climate (Appendix II), with the 2006 peak reflecting the 2004-2005 wet winter plus the 15 winters before 2004-2005 with a seemingly bimodal weighting from the regression coefficients. The anisotropic and compartmentalized nature of the aquifer at multiple scales imparts a variety of analyzable pumping responses that are masked and made to appear similar if the underlying climate trend is not recognized and filtered from analysis hydrographs. Order 1169 recovery is complete and was completed by 2016.

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

A straightforward Darcy's Law calculation indicates that ~40,000 afy of south-flowing groundwater may be the flux within the Las Vegas Valley capture zone south and southwest of the MRSA (Appendix I). We believe there are significant shortcomings in the State Engineer's assertion that all pumping from within the LWRFS necessarily causes declines elsewhere in the system. Absent is explicit recognition of the regional groundwater system's transience in several frequency modes including years to decades as suggested by climate responses, heat flow, transmissive flow zones related to Quaternary faulting, stable isotopes, radiocarbon, and diffusion studies. Previous analysis relied on accepting prolonged time delays (i.e., centuries) for impacts to develop from groundwater development in up-gradient basins identified as inter-basin sources for regional springflows. Some groundwater models and C-14 analyses indicating very old spring waters have been offered to support these postulated prolonged delays for impacts (Burns and Drici, 2011), but they may be incorrect (Appendix III).

Recent climate response modeling (2016; Appendix II) and three years of validation data show that multi-year climate signals are delayed by only a decade or two, based on the positive correlation between discharge at Big Muddy Spring in the MRSA and a 12-22-year prior period of base flow of the Humboldt River, a northern-climate proxy, by multiple regression. The MAI transmissivity model (Appendix III; Johnson and Mifflin, 2019) considered 35,000 afy of regionally-derived groundwater tributary to the MRSA (Heilweil and Brooks, 2011) and 59,000 afy tributary to Las Vegas Valley from model calibration (Johnson and Mifflin, 2019). Embedded in the MRSA and Las Vegas regional capture zones, respectively, are the capture zones of Panaca Spring (7,900 afy) and Pahranagat Valley (26,000 afy). Input to these four discrete regional-spring capture zones at latitude 38^0N totals about 128,000 afy. Most recharge in the Spring Mountains is considered to be consumed locally and to not substantially recharge the regional system. The Sheep Range does contribute significant recharge to both the regional system and the MRSA based on isotopic evidence (Thomas and others, 1996) and lack of another nearby, high-elevation recharge source to explain the seasonal pulse in many LWRFS hydrographs.

Groundwater in Las Vegas Valley discharges in an upwelling zone in the western Valley at fluid potentials significantly higher than most of the LWRFS, except relative to the northwestern-most portion of Coyote Spring Valley. Groundwater flux between the Apex area and northeastern Las Vegas Valley has not been quantified but is probably greater than 10,000 afy based on a Darcy flux calculation (Appendix I) and a larger flow rate supported by water-level time-trends and groundwater temperatures as described below. Water-level decline rates in Apex wells (Figures 5 and 6) have been constant since 2006 except for the prominent Order-1169 effect. Since 2006, demand has increased on average by about 50 acre-feet per year, less than 2% of an average 3,000 afy extraction rate (Figure 12). The decline rate in GV-1 (Figure 6) is 0.38 ft/year compared with the 0.2 ft/year reference trend in CSVM-4 at the north end of Coyote Spring Valley (Figures 2 and 3), suggesting that pumping might be responsible for the additional 0.18 ft annual decline in the Apex area. But this is not necessarily true; the climate-forced water level rise of Figure 11 provides the best evidence to date that a 3,200 acre-ft/year extraction rate from the central and southern LWRFS produces very small drawdowns in the region, much smaller than the changes produced by climate forcing.

In Coyote Spring Valley the climate-driven decline rate is 0.28 ft/year (Figure 7) in conjunction with depressed Coyote Springs Investments (CSI) demand for a decade, averaging less than 1,500 afy from 2009 through 2017, less than half the 2007 peak (Figure 13). The larger rate of decline in Coyote Spring Valley (Figure 7) relative to the reference trend after 2006 (Figure 3) may be attributable to CSI pumping after 2006, but there was a near-complete absence of pumping in Coyote Spring Valley prior to 2006 so the rising hydrograph in 2005-2006 cannot be recovery from pumping, because there was no pumping. Thus, water-level declines after 2006 are not automatically explained by pumping.

Residual drawdown from the Order-1169 test (Figure 14), where MX-5 was pumped at an unsustainable rate (Figure 15), may explain the slightly-greater apparent decline rate in Coyote Spring Valley (MX-4, Figure 7) relative to California Wash (TH-2, Figure 8). In contrast to the widespread effects of pumping MX-5 (Figure 15), test pumping of three high-capacity production wells (ECP-1, CSI-2, and CSI-3) indicated pumping cones encountered recharge boundaries that limit propagation of a cone of depression (Mifflin and Johnson, 2013; Johnson 2005, 2007). In each of these wells, with transmissivities an order of magnitude less than in the MX-5 vicinity, drawdowns stabilized after a few minutes to hours and recovered quickly and completely, as did 2 wells in the Apex area and the Arrow Canyon Well (Mifflin and others, 1990, 1992; Buqo, 1994). In all 3 cases the recharge boundary is probably in the Monte Cristo Limestone, which contains an extensive (at least several km), highly transmissive and highly anisotropic broken and karstified zone first encountered by Ertec (1981) and is the producing horizon at MX-5 and locus of past groundwater discharge. This zone continues to receive upwelling of warm, regionally-derived, south-flowing groundwater without which there would necessarily be a cooling trend in LWRFS groundwater.

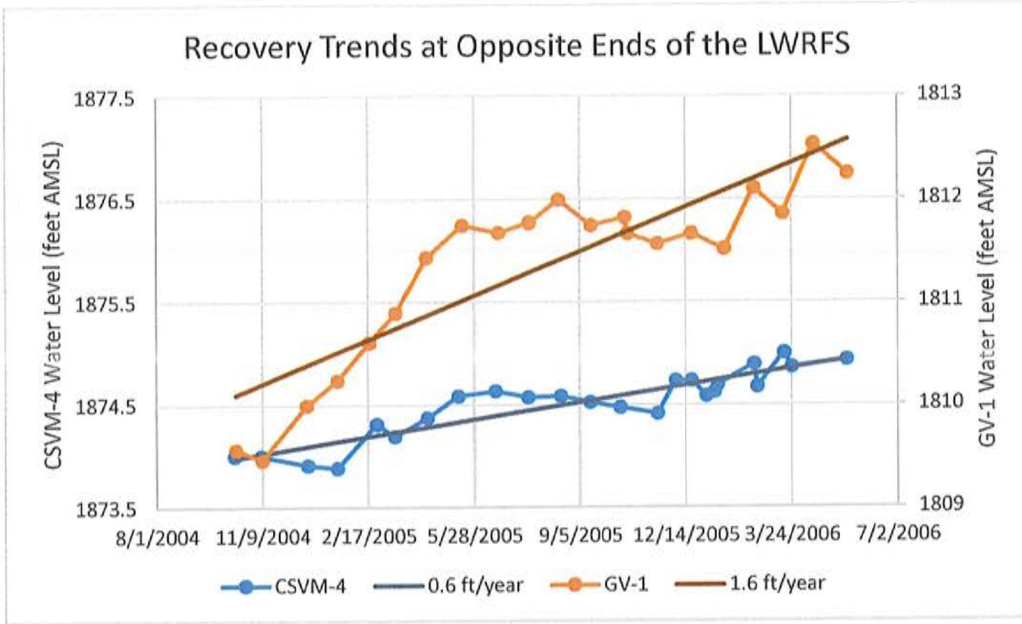


Figure 11. Climate-forced water-level rise occurred between October 2004 and May 2006, much larger near Apex (GV-1) than up-gradient in Coyote Spring Valley (CSVM-4). The annual cycle, evident in hydrographs of the form typified by EH-4 (Figure 4), is prominent here and throughout the LWRFS, but pumping effects cannot be discerned. [Order1169wlData20190508.xlsx]

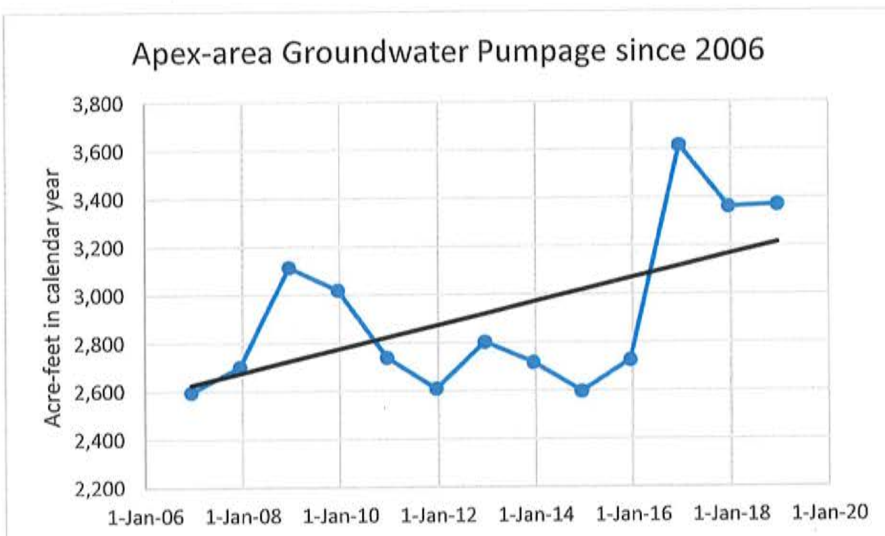


Figure 12. Consumptive use of groundwater in the Apex area since 2006, the most recent interval of multi-year drought and associated water-level decline in the region. Pumpage increased about 2% per year in this time interval, shown by black trend line. There is no indication of the 2016 increase in the GV-1 monitoring well hydrograph (Figure 14). [Order_1169_Monthly_Pumpage (Apr19).xlsx]

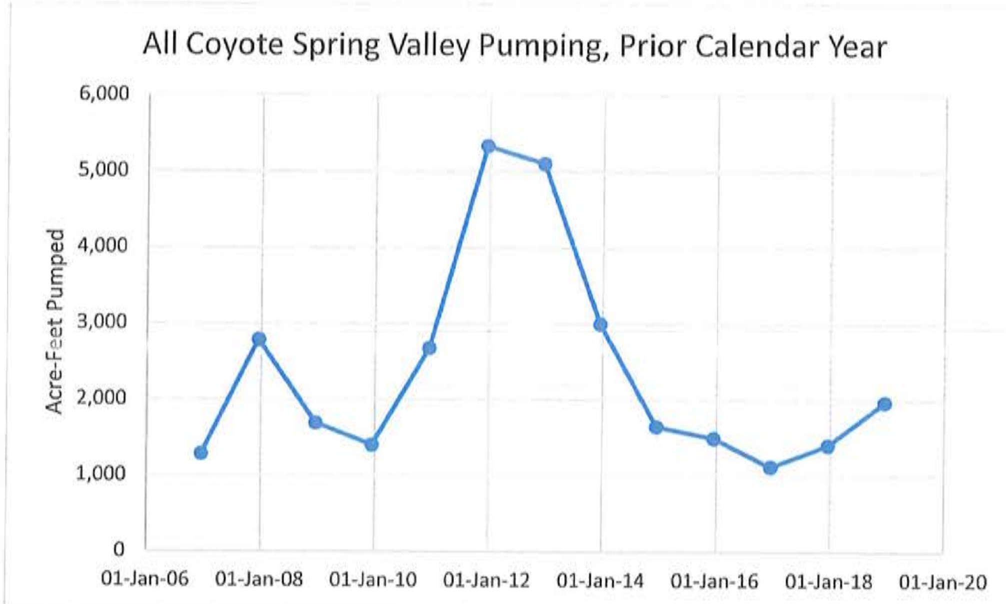


Figure 13. [Order_1169_Monthly_Pumpage (Apr19).xlsx]

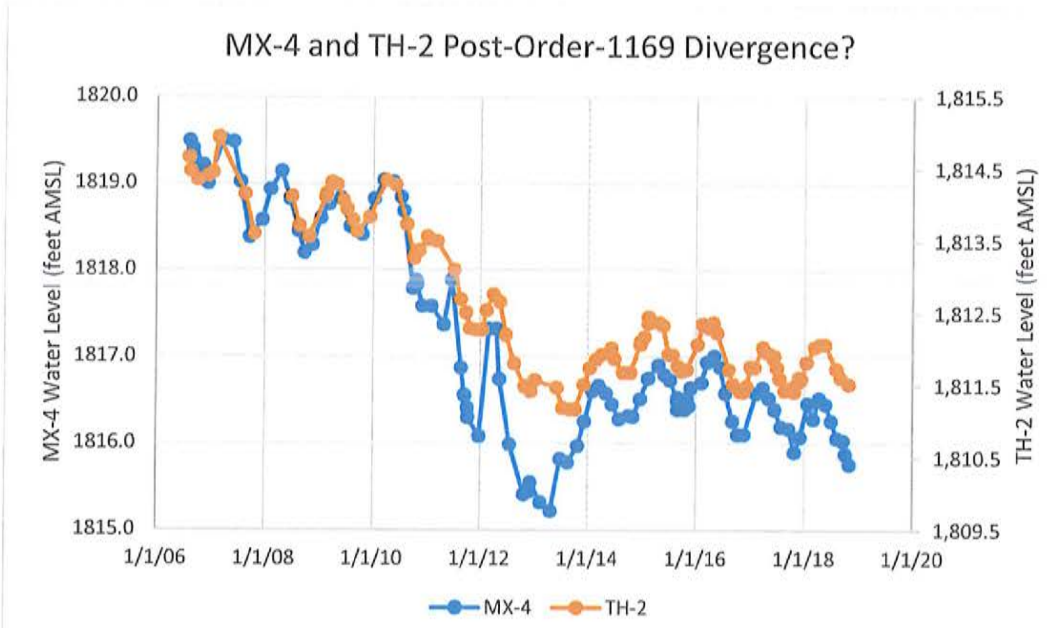


Figure 14. Water levels at MX-4 (closely adjacent to pumping well MX-5) may have recovered to a lower level relative to TH-2 after the Order 1169 test as a result of over-pumping. [MX-4_periodic.xlsx]

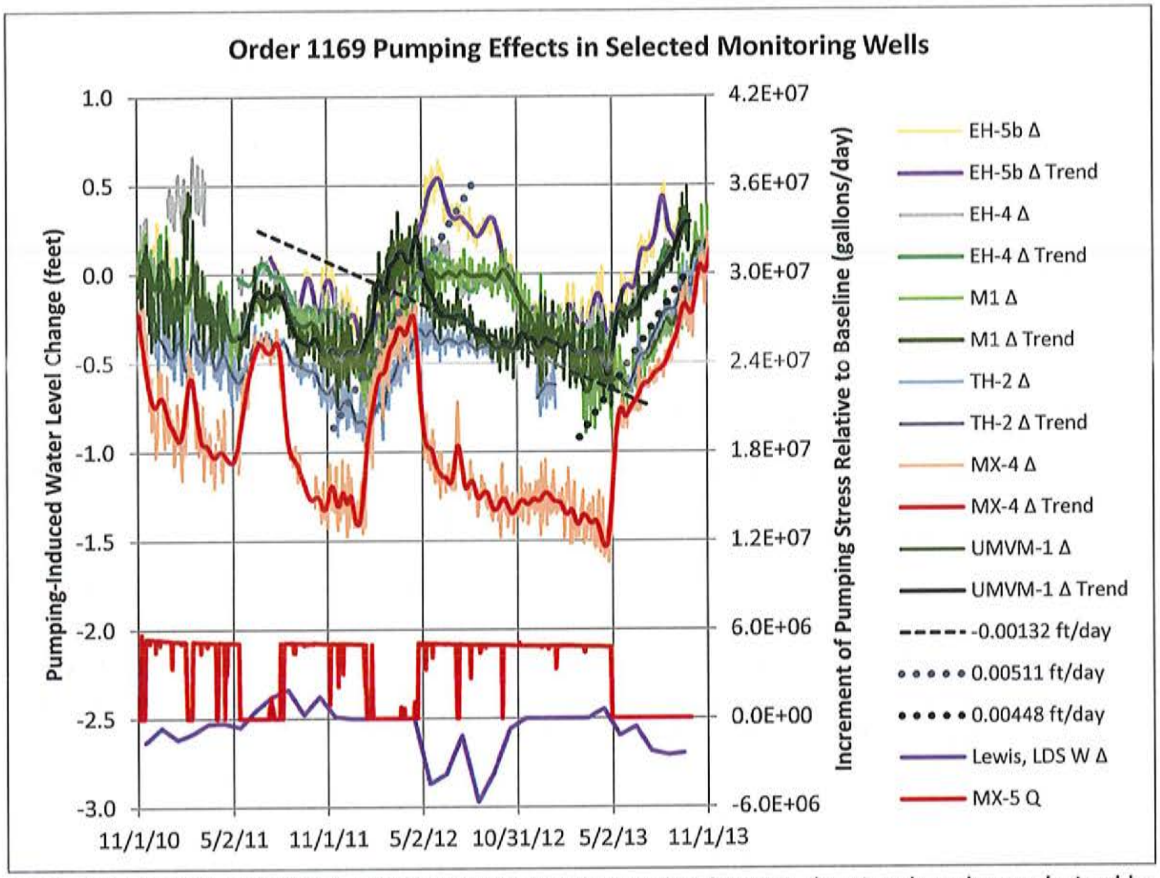


Figure 15. Analysis by Johnson and Mifflin in January 2014 for the HRT, showing drawdowns derived by comparing water levels from the 2000-2004 drought [1169differenceTrends3.xlsx, sheet 'Detrend']

The Eureka Low of Sass and Lachenbruch (1982) has never been explained satisfactorily in terms of the regional groundwater flow field until recently (Appendix III; Johnson and Mifflin 2019), though heat is a ubiquitous natural tracer. How long would it take carbonate-aquifer groundwater to cool by 10°C through a blanket of Muddy Creek Formation, a question of residence time? A cooling-time model is applicable to either static or flowing conditions and might constrain the flux of regional groundwater into and through the LWRFS.

The Moapa Band of Paiutes' ECP-1 well produces 30.5°C water (Thomas and Mihevc, 2011), and the USGS reports 31°C groundwater in the Georgia Pacific Apex well, ID # 362028114553601. Both occurrences are more than 10°C warmer than the mean annual (1952-2012) air temperature (MAT) of North Las Vegas (19.4°C, per https://wrcc.dri.edu/cgi-bin/cliMAIN.pl?nv5705). Even within the MRSA, discharge hydrographs reveal different flow paths for nearly-identical waters appearing in different springs. Upwelling near TH-2 is an example of regional groundwater recharge of shallower subsurface environments (similar to recharge from below of the alluvial gravels in the MRSA) revealed by a well-hydraulics model of pumping response (Figure 16).

To evaluate thermal constraints, we prescribe a hypothetical 10,000 afa (33,771 m^3/day) inflow boundary condition and assume: 1) groundwater in the LWRFS is on average

10°C warmer than mean annual air temperature; 2) 80 mW/m^2 of heat is input from below (Blackwell and others, 2011); and 3) the geothermal gradient dT/dz to be considered is across an unsaturated 200-m blanket of Muddy Creek Formation overlying the carbonate-rock aquifer. With these boundary conditions, dT/dz is 0.05°C/m, so assuming thermal conductivity of the Muddy Creek $k_{MC} = 2Wm^{-1}K^{-1}$ and ignoring convective and radiative heat losses, heat flux at land surface $q=k(-dT/dz) = 100\ mW/m^2$, greater than heat flux measured in underlying pre-Tertiary rocks (Blackwell and others, 2011). The difference represents an ongoing net heat loss rate of 20 mW/m^2, 67.4 MW for the whole LWRFS.

The regional hydraulic-head gradient, estimated between the Steptoe MX well (686,889 E, 4,310,380 N, 2103 m) and Tule Springs Pond (655,804 E, 4,021,669 N, 757 m), is 0.0046 and establishes generally southward regional groundwater flow from mountainous terrain of east-central Nevada. Using the 2,832 m^2/day transmissivity determined by Mifflin and Johnson (2013) the width of California Wash aquifer required to transmit the hypothetical inflow is $w = Q/Ti = 33{,}771\ m^3/day / ((2{,}832\ m^2/day)*(0.0046)) = 2{,}592$ m or 2.6 km. High-capacity wells from the Moapa Reservation to Apex are aligned along footwall exposures of folded strata beneath the Dry Lake Thrust, and 2.6 km (1.6 miles) appears to be a reasonable width estimate for this moderately-high-diffusivity groundwater-flow corridor. Extensive networks of discrete features (fractures) and a higher-transmissivity and more porous broken zone in the MX-4/MX-5 vicinity are indicated by pumping response. The corridor is bounded abruptly on the east by the California Wash Fault along the range front of the North Muddy Mountains, but the hydrogeology of the Las Vegas Valley capture zone between Tule Springs and Apex is untested.

With respect to the thermal budget, regional modeling of the Eureka Low (Johnson and Mifflin, 2019; Appendix III) suggests that the regionally-interconnected porosity, the porosity that allows heat to be removed convectively with groundwater from recharge areas associated with the Eureka Low to warm springs far to the south, is very low, on the order of 0.00015. Imagining a cross-section of the 2.6-km-wide flow corridor, each meter of width would need to transmit 13 m^3/day. Further assume for trial calculation purposes, guided by the MAI transmissivity model that generally accounts for the Eureka Low, that based on the upper limit of groundwater temperatures in the LWRFS the aquifer is on the order of 1 km thick, with an active flow-zone porosity of 0.00064 (Figure 19) and well-mixed. Cross-sectional pore area transmitting 13 m^3/day in this aquifer strip is 0.64 m^2, requiring an interstitial velocity of 20 m/day. Thus, residence time in California Wash, which is ~20 miles (32 km) from north to south, would be less than 5 years. In 5 years, one cubic meter of water losing heat at a rate of 20 mW while transiting California Wash would cool by 0.76 °C. Longer residence times offer no mechanism for sustaining the elevated (>30°C) temperatures observed. A flow corridor 5 km (3.1 miles) wide with these attributes could be transmitting nearly 20,000 afy from Coyote Spring Valley to Las Vegas Valley according to this model. This modeling suggests, at the very least, that further study of the thermal regime is warranted. If correct, the model demonstrates that pumping from California Wash has little to no impact on the MRSA and that much more groundwater is available in California Wash than has been assumed by some.

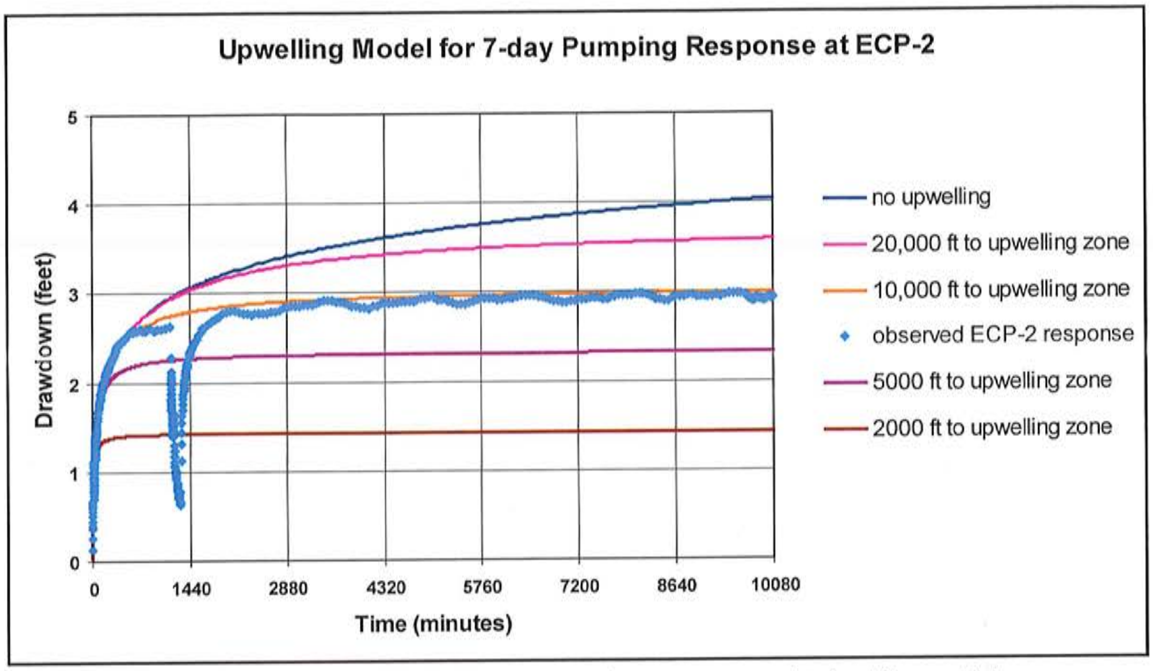


Figure 19. Theoretical response at ECP-2 based on aquifer parameters obtained from a 7-day constant-discharge test and one image well to locate a recharge boundary: Theis aquifer with T=30484.4 ft^2/d, S=0.000640805, Q_{ECP-1}=1005 gpm, and r_{ECP-2}= 500 feet. [UpwellMatch.aqf]

The LWRFS water-level record since 2006, by comparison of developed and reference areas, indicates that drought is responsible for more than half the decline rate in all monitoring wells evaluated, from northern Coyote Spring Valley to Apex. From 2006 through 2018, 30,856 acre-feet were pumped from Coyote Spring Valley and 37,964 acre-feet from the Apex area. In northern Coyote Spring Valley and Kane Springs Valley, remote and up-gradient from any pumping, drought conditions in the region produced an 0.2 ft/year decline rate, the reference rate. With this background, it is suggested that pumping around Apex is contributing at most 0.18 ft/year of the overall GV-1 decline per year (Figure 6). It is clear from the distinctive signal in regional hydrographs of the 4-month pumping break during January through April 2012 (Figure 15) that an attenuated Order-1169 pumping signal propagated to Apex (Figures 5, 6). It is therefore reasonable to suggest Coyote Spring Valley pumping caused some of the 0.18 ft/year non-climate decline in the Apex area after 2006. In this incremental model, CSV pumping adds about 0.07 ft/year to the 0.2 ft/year background decline rate as sensed at TH-2, then (Figure 8, compare Figure 3) pumping around Apex contributes another 0.07 ft/year to produce the GV-1 hydrograph (Figure 6).

Management challenges presented by inter-basin flow systems in carbonate-rock terranes are due in part to intra-basin and inter-basin flow zones that are not necessarily indicated by surface topographic features (e.g., hydrographic basin boundaries). These transmissive zones may involve both intra-basin and inter-basin patterns of flow. The contrasting hydrographs of Big Muddy Spring (Figure 20) and Warm Springs West (WSW) (Figure 21), and the hydraulic isolation of monitoring well CSVM-6 from production well CSI-3 in Coyote Spring Valley (Appendix V) attest to these scale and anisotropy effects. In fractured-rock aquifers, pumping impacts do not decrease predictably with distance as they do in idealized porous media.

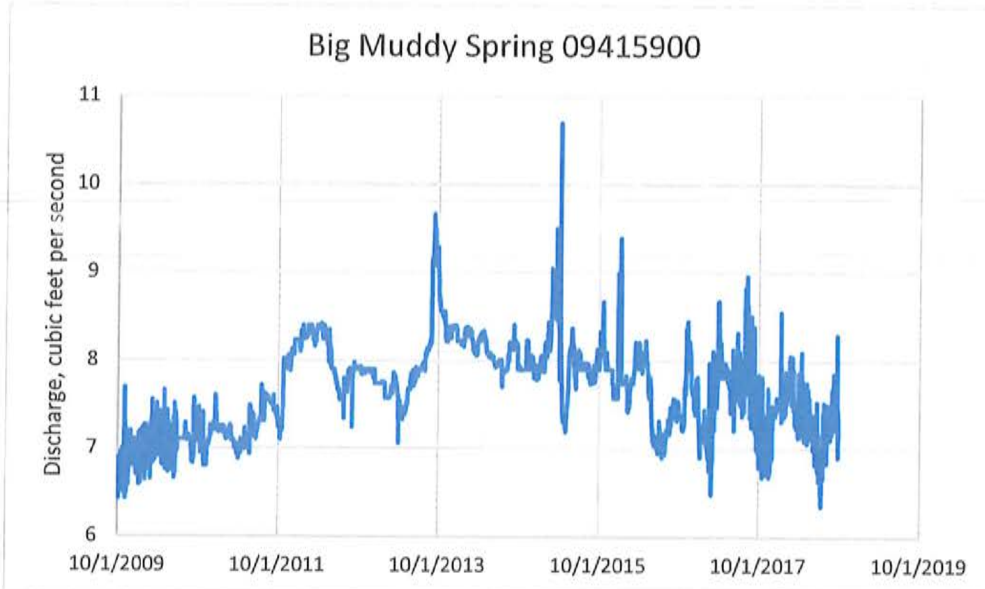


Figure 20. Daily discharge from Big Muddy Spring [MuddySpringDailyWY10-18.xlsx]

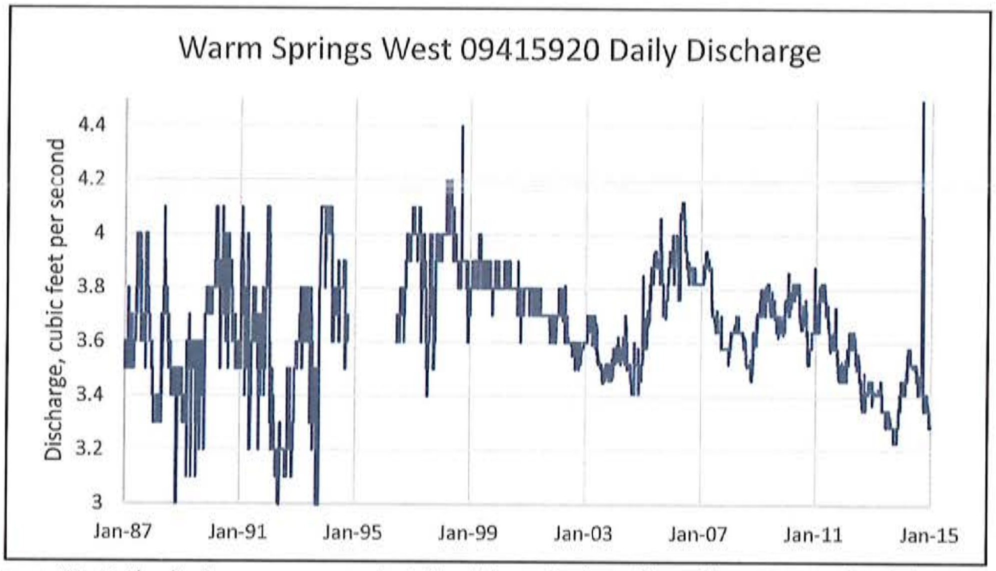


Figure 21. Daily discharge measured at the Warm Springs West flume. Details of diversions occurring prior to 1999 are not known, but the signal became less noisy thereafter. [WSWdaily.xlsx]

In the five-basin LWRFS, Order-1169 drawdowns have been sensed in wells tens of kilometers apart while the CSVM-6 monitoring well is completely unresponsive to pumping at CSI-3, only 1 km away. The implication is that pumping CSI-3 would not perceptibly impact hydraulic head in the largest-scale fracture set, where Order-1169-induced drawdowns were greatest. In contrast, as illustrated in Figure 15, water levels in MX-4 and several other wells do not stabilize when MX-5 is pumped at the 7.5 cfs level. This is an important result from Order 1169: 7.5 cfs from MX-5 is unsustainable based on persistence for one year of a linear drawdown rate of 0.48 ft/year in affected monitoring wells. The varying effects of pumping at distances is determined by plumbing, but the plumbing can only be determined by interference testing of wells and springs.

A re-test of MX-5 at lower rate, essentially an extended step-drawdown test to establish a sustainable extraction rate for central Coyote Spring Valley, is feasible since only MX-4 would need to be monitored, removing much of the ambiguity due to very small drawdowns at distant wells from well-hydraulics analyses. However, barometric and tidal corrections would need to be an integral part of the analysis so a flexible schedule based on weather forecasts should be factored into the testing strategy to avoid atmospheric-pressure disturbances adding uncertainty to derivations of small drawdowns. Since the carbonate-rock aquifer is not infinite, all wells will show boundary effects. Low-transmissivity boundaries can create tank-like behavior when a relatively high-transmissivity aquifer compartment is pumped, and such a compartment could be essentially dewatered, as shown by the linear late-time drawdown trends that characterize responses to the Order-1169 test (Figure 15).

Where aquifer testing and observation demonstrate that wells are hydraulically isolated from the highest-transmissivity domain (such as CSI-3 and ECP-1, which exhibit recharge boundaries), prolonged pumping will likely produce minimal impacts at those locations. Thus, wells influenced by a recharge boundary (e.g., CSI-3, ECP-1) could be permitted if demonstrated to be outside the MRSA capture zone, while wells producing declines that do not stabilize with time (e.g., MX-5) should only be allowed after a sustainable pumping rate is established by additional testing.

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

Moving the MRSA alluvial water rights to carbonate-aquifer production will produce similar (proportional to pumping) levels of impacts on the MRSA flows as already documented for the carbonate-aquifer production in Coyote Spring Valley and Arrow Canyon Wells. A move of the alluvial rights to carbonate-aquifer production in down-gradient basins (California Wash and basins to the south) where current production levels have demonstrated no impacts on MRSA flows, is the likely strategy to maximize the extent of development without unacceptable impacts on MRSA flows. Of course, such rights could be subject to curtailment if determined to cause unacceptable impacts to senior rights.

For the purposes of this report, consideration of "alluvium" is restricted to Muddy River alluvium between Arrow Canyon and White Narrows, not the thick and extensive alluvial-fan systems and basin-fill alluvium in Nevada's typical basins that are recharged primarily by infiltration of runoff along the basin margins. Basin 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.

Johnson and Mifflin (2003) believe instead that the MRSA owes its existence to a southward transmissivity decrease encountered by flowing groundwater (Appendix I Figure 1). The MRSA alluvial aquifer is recharged from below by warm, upwelling groundwater that constitutes the base flow of the Muddy River as registered at the Moapa Gage. The gravel aquifer functions as a storage volume that increases the average residence time of discharged groundwater in the MRSA, creating a range of temperatures from about 32°C downward (or upward) to ambient air temperature in the smaller springs and springbrooks. Diverting groundwater from the gravel aquifer is no different than diverting surface water from the Muddy River; both occupy a channel in the much-less-permeable Muddy Creek Formation. The Muddy Creek Formation generally contains stagnant, poor-quality water that is easily recognized when over-pumping the MRSA gravel aquifer causes a deterioration of water quality in the pumped well. As shown in Figure 22 (reproduced from Burns and Drici, 2011), beneath Quaternary-Tertiary sediments of the Muddy Creek Formation is a large cross-sectional area of carbonate rock "likely" to transmit inter-basin flow to California Wash and Hidden Valley.

Rights to 35,000 afy on the Muddy River were established by the Muddy River Decree. Subsequent groundwater allocations to various MRSA farms (Lewis, Taylor, Perkins) beginning in 1948 and to Nevada Energy beginning in 1965 are not consonant with the Decree because the alluvial aquifer is intimately interconnected with the Muddy River, though less so below the Moapa Gage where the gravels are confined and down-gradient from sensitive areas. Large springs supply less than half of the base flow of the Muddy River. The majority of River flow begins as seeps from the gravel aquifer that are impacted by alluvial-aquifer pumping, unlike the large springs (Eakin and Moore, 1964). Groundwater rights in the MRSA are nearly all junior to the those who hold surface water rights under Muddy River Decree. However, there are differences in pumping effects from the Lewis Farm (upstream) area compared to pumping from alluvial gravels in the Perkins (downstream) area where the gravels are confined.

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

Any decision by the State Engineer regarding groundwater pumping in the LWRFS must consider that 30 years of monitoring have recorded primarily a climate response in water levels; thus, curtailment of existing duties would be ineffective in stopping water-level declines caused by prolonged drought. In addition, there are conditions that warrant additional examination of local aquifer response (see Part IV below). For example, CSI-3 well is seemingly isolated from the highest-diffusivity fracture zone yet encountered in Coyote Spring Valley (Appendix V). Available evidence indicates that moving CSI production sufficiently far to the west could protect the Muddy River Springs.

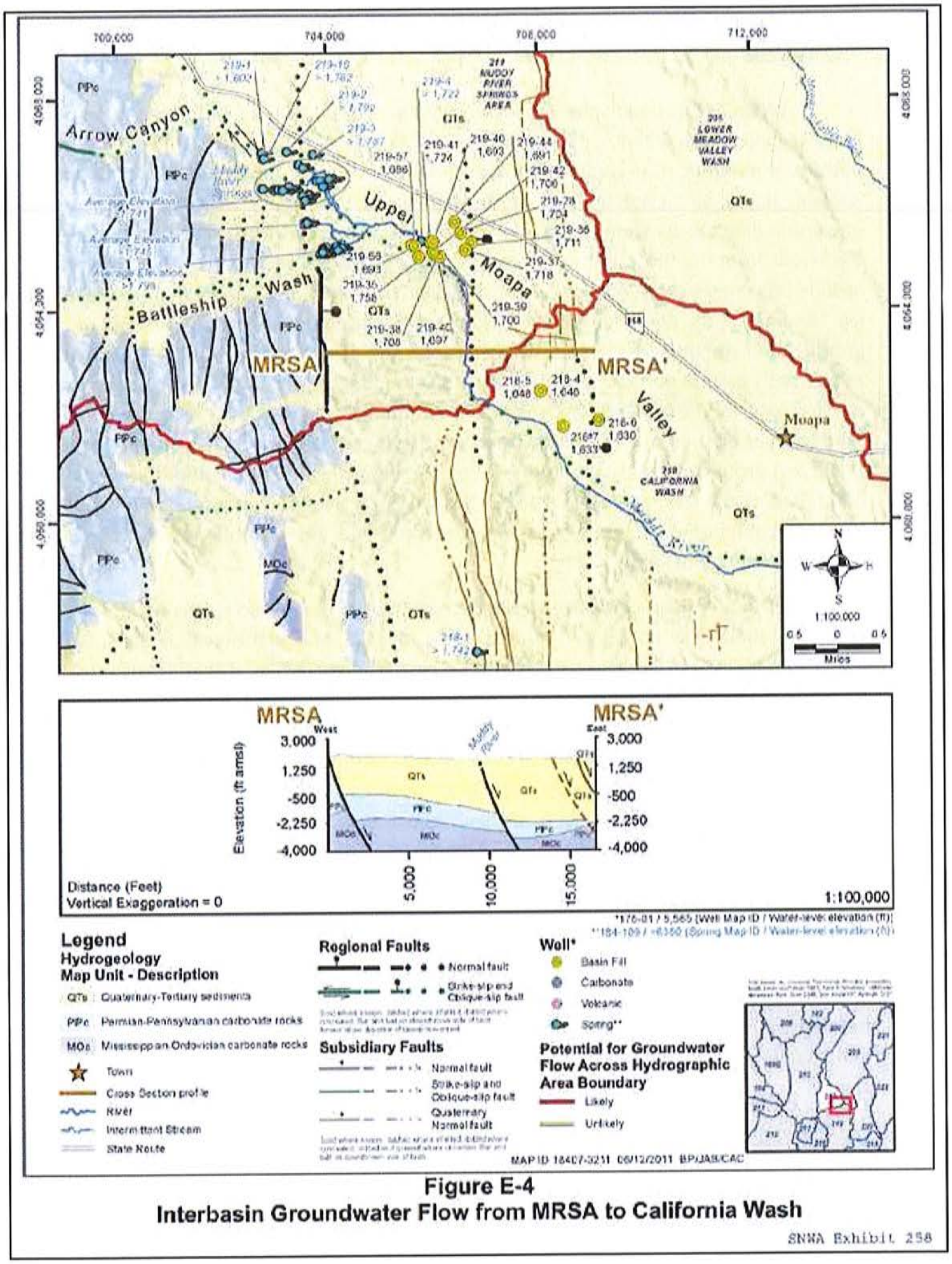


Figure 22. No limitations to interbasin flow are identified south and east of the MRSA [SNWA_Exh_447_Slide_Show_Burns_and_Drici_2nd.pdf]

PART III. RECOGNIZING THE FORCING AGENTS RESPONSIBLE FOR WATER-LEVEL DECLINE IN THE REGION

When MAI groundwater monitoring on the Moapa River Indian Reservation began in 2000 in conjunction with a 7-day aquifer test of the new ECP-1 production well, the seasonal pattern of pumping from Muddy River alluvium and from the Arrow Canyon Wells was well-known. It was also clear that Muddy River flows at the Moapa Gage declined from 1965 onward in direct proportion to Nevada Energy's pumpage from the alluvial aquifer and direct diversions from the River, but no reconstitution of River flows had yet been accomplished to include lesser diversions. Arrow Canyon Wells and MX-6 might require consideration of a time lag for impact on River flows. Ideally, a reconstitution analysis of the rate of natural groundwater discharge to the Muddy River over the past 70 years would be established to reveal both natural variations and sources of pumping-related impacts on River flows. The primary focus of the MBOP/MAI Order-1169 test analysis was just that: reconstituting natural Muddy River discharge was accomplished with high confidence up to 2006, the first year of significant groundwater production in Coyote Spring Valley. The only measurable discharge reductions attributable to the Order-1169 test were too small to be sensed at the Muddy River gage, so pumping effects were less than expected and not quantified except at the high-elevation (Pederson) springs.

As monitoring records from 5 wells on the Reservation began to accumulate, it became clear that there was no lag or attenuation of the annual signal between those wells and monitoring well EH-4. By measuring the hydraulic diffusivity (T/S) and confidently identifying a recharge boundary in the 7-day ECP-1 test, it was shown that annual fluctuations across the Reservation could not be attributed to MRSA pumping (Johnson and others, 2001). This is further confirmed because the annual cycle persists after cessation of most pumping from the alluvial MRSA aquifer in 2017. By 2001, a uniform decline was occurring in all Reservation monitoring wells, but distance-drawdown effect was absent—additional evidence that declines could not be attributed to MRSA pumping. The declining trend continued through 2004. Therefore, the widespread water-level recovery that occurred in 2005-2006 was no surprise. However, other analyses (USFWS 2013, Appendix A, using SeriesSEE and TetraTech, 2012a, 2012b, using MODFLOW) confused climatically-induced water-level declines with pumping-induced drawdown in all cases. There has been a general failure to recognize that drawdown is expressed as subtle differences in general appearance and common features between multi-year hydrographs of the same general form that contain multi-year drought and recovery intervals and *not* a predominance of pumping effects.

Because the drought trend has not been properly recognized, pumping effects on water levels were substantially over-predicted in both the TetraTech MODFLOW and USFWS SeriesSEE analyses, and attenuation of embedded pumping signals with distance substantially under-predicted. There is a drought trend in the region possibly induced by anthropogenic warming that, if it continues for several more decades, places the MRSA springflows and some Moapa dace habitats at risk even in the complete absence of pumping.

a. Climate trends and hydrologic responses from the geologic record

A perennial, saline lake last occupied Death Valley between 35 and 10 ka (Lowenstein and others, 1999). Oxygen Isotope Stage (OIS) 2 records from this interval record markedly colder and wetter conditions than those in modern Death Valley, with the lake sustained primarily by groundwater discharge and runoff in the Amargosa River basin. Applying present-day Lake Tahoe evaporation rates (Huntington and McEvoy, 2011), the ancient lake would have lost several hundred thousand acre-feet per year and thus required sustained voluminous groundwater discharge originating in mountainous terrain of central Nevada centered on the Monitor and Toquima Ranges, coincident with the Eureka Low of Sass and Lachenbruch (1982). Groundwater-discharge deposits in the Amargosa Desert have been investigated extensively, and distributions indicate regional net hydraulic head declines of up to hundreds of feet have occurred since the Holocene pluvial climatic state (Forester and others, 1998, p. 57). Similarly, spring mounds have been used to locate zones of ancient groundwater upwelling; an undated spring mound near TH-2 (Figure 23) stands at about 400 feet above the water table at that location.

The paludal (marsh) groundwater-discharge deposits studied in detail by Quade (1986) attest to much more areally-extensive groundwater discharge in southern Nevada as recently as 10 ka, leaving sediments similar to those occurring at the CSI-3 site in Coyote Spring Valley (Figures 24 and 25) below an elevation of about 706 meters (2,316 feet) there. These undated paleodischarge deposits are about 500 feet higher than the measured water level in CSI-3. Thus, local geology bears ample record of Nevada's wetter ancient climate.

The Holocene epoch (beginning approximately 11,650 years before present) is characterized by rapid adjustment to a drier and warmer climatic state. Multiple lines of evidence such as tree rings (Salzer and others, 2014) indicate subsequent effective moisture fluctuations including the Little Ice Age and ongoing warming associated with the Industrial Revolution. Since 2000, climate-driven water-level declines in the LWRFS area have been about 5 feet, or 0.25 ft/year. Several monitoring wells exhibited declines of 0.4 ft/year in 2000-2004.

Figure 23. Undated fossil spring mound east of monitoring well TH-2, two miles northeast of ECP-1, the site of a 7-day aquifer test in 2000. A zone of upwelling groundwater is indicated by the spring mound.

Figure 24. Paleodischarge deposits (whitish bedded unit) behind diffuser tank from the Johnson (2007) CSI-3 drilling and testing report. [CSI3paleodischargeDeposits.jpg]

b. Pumping effects

Order-1169 pumping produced drawdown in numerous observation wells (Figure 15), but *erroneous analysis results have been obtained in all cases where climatic signals were not isolated and filtered from pumping response signals.* MODFLOW and SeriesSEE-based analyses by the DOI Bureaus overestimated drawdowns by conflating combined climatic trends and pumping effects in analyzing monitoring-well hydrographs. The best available science does not support present-day pumping as the cause of dewatering the LWRFS at the observed linear rates (Figures 2, 3, 5, 6, 7, 8, and 9). The basic misunderstanding began in the early 2000s when the Arrow Canyon Well entered service, with the assumption by USFWS that the 4-year decline at EH-4 between 2000 and 2004 was primarily due to pumping the Arrow Canyon #1 well.

Mayer and Congdon (2008) called upon some unique explanatory variables (cubic transform of 24-month moving average monthly precipitation, for example) to include climate as a driver for the 2005-2006 water-level recovery in EH-4 but failed to recognize that most recharge to the regional flow system occurs far to the north and integrates over a time scale much longer than 2 years (Appendix II). The MAI multiple-regression analysis, using annual base flow of the Virgin River (North Fork) as the EH-4 water-level explanatory variable set, reveals a lag of 16 years before climate effects are fully expressed in the EH-4 hydrograph (Johnson, 2016). Base flow of the two perennial streams in the two climatic zones have proven to be far better climatic-hydrologic proxies than data derived from precipitation gages to explain carbonate-aquifer water levels and spring discharge.

During the last phase of the Order-1169 test, between May 2012 and May 2013, a steady cone of depression with a widespread decline rate of 0.00132 ft/day (0.48 ft/year, Figure 15) was established in response to a measured withdrawal rate of 5,372 acre-feet that year from MX-5. From absence of flattening of the response curves at late times, which would indicate an extensive aquifer or a recharge boundary, test conditions indicate that 7+ cfs from MX-5 would be unsustainable if the linear drawdown trend were to continue.

The historical EH-4 record through 2014 (Figure 4) shows an overall decline of about 4 feet over 27 years of water-level measurements, or about 0.15 ft/year. Since the start of the ongoing drought in 1999, the rate has been about 0.27 ft/year. In the drought period of 2000-2004 water levels in EH-4 declined about 1.5 feet in 4 years, or nearly 0.4 ft/year. Removing Order-1169 (MX-5) pumping effects from the EH-4 hydrograph requires an adjustment slightly over a foot (Figure 4). The Arrow Canyon Wells' influence on the EH-4 hydrograph is never more than about 0.5 foot and demonstrates no cumulative effect since recovery occurs within minutes of pumping cessation (Buqo, 1994).

c. Reductions in springflow

The discharge hydrograph at Warm Springs West (WSW, Figure 21) generally mirrors EH-4 water levels (Figure 4) after 2000. In the summers of 2007 and 2008, WSW appears to be influenced by two years of heavy CSI pumping but any CSI effect in the EH-4 hydrograph during 2007 and 2008 is too small to resolve. The Order-1169 response at WSW appears to be on the order of 0.3 cfs.

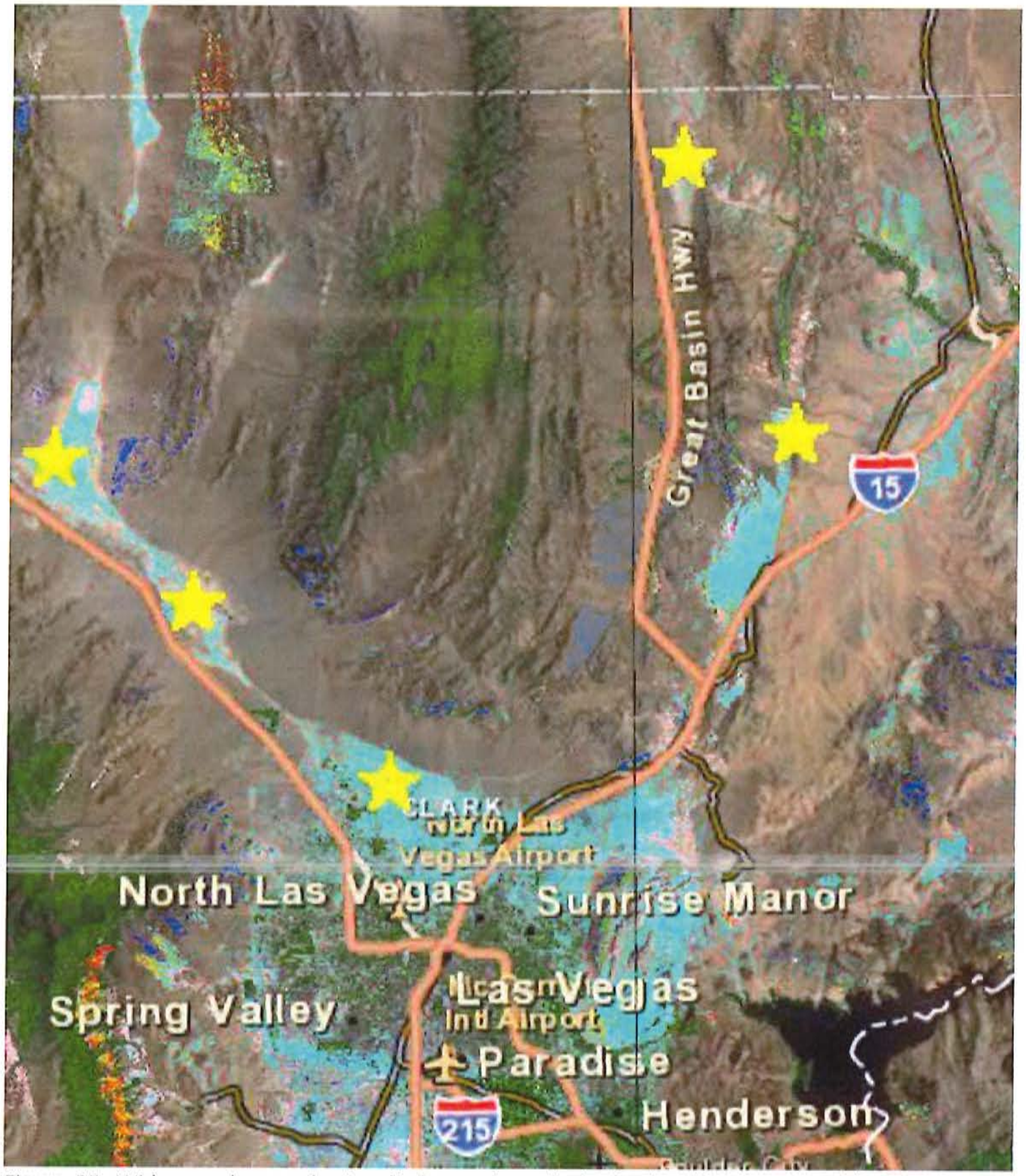


Figure 25. Widespread groundwater-discharge deposits in the Las Vegas area, with more magnesian (pink) and calcic (light blue) compositions revealed by infrared reflectance spectra [ASTER_CSV_NAD83.tif]

Flows at WSW declined by about 0.6 cfs between 2000 and 2015, a reduction of 15% or 1% per year. Compared with EH-4 changes over 15 years, 0.6 cfs / 4 ft. drawdown suggests that each foot of water-level decline at EH-4 is associated with 0.15 cfs decrease at Warm Springs West. Hypothesizing continuation of the drought-induced trend and applying the 15-

year rate, Warm Springs West (Pederson Springs) would cease to flow in 100 years even if there was no pumping in up-gradient areas, triggering potentially ineffective curtailment along the way.

After 2009, when WSW flows were no longer contributing to Iverson measurements, discharge at Iverson decreased by about 0.1 cfs or 2%, about 0.2% per year (Figure 26). It appears the Order-1169 response at Iverson was on the order of 0.3 cfs—about the same as WSW. Order-1169 impacts were therefore 0.3 cfs at WSW plus 0.3 cfs at Iverson plus none at Big Muddy. These 3 largest MRSA springs, which together contribute about one-third of MRSA discharge, showed a cumulative 0.6 cfs in spring-flow reduction attributable to pumping 7.5 cfs out of MX-5. Spring discharge has not unequivocally recovered to the baseline trends because water levels in the most heavily-pumped area (MX-4/5) may have been lowered long-term relative to at least one remote monitoring well, TH-2, due to the ~7.5 cfs pumping rate during the Order 1169 test (Figure 14). Other monitoring-well hydrographs have not been compared with MX-4 in this way.

The Big Muddy Spring record contains no demonstrable pumping responses (Figure 20) and multiple-regression analyses indicate the hydrograph is explained by a northern-climate proxy (base flow of the Humboldt River at Palisade) 12-22 years prior to observations (Appendix II).

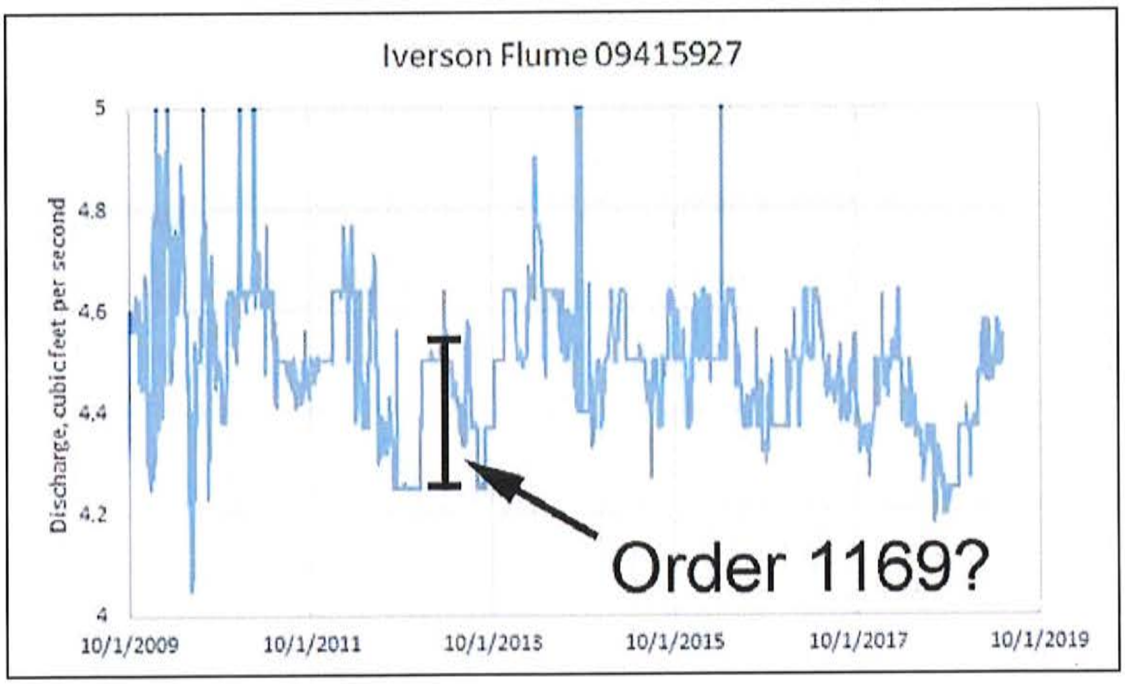


Figure 26. Daily discharge at the Iverson Flume following exclusion of the WSW component in WY 2009, with 0.3 cfs of Order-1169 impact suggested by annotation [IversonDaily.xlsx]

Discharge from Panaca Spring, far from any LWRFS pumping effects, appears to have decreased by 2% per year in the decade after 2006, based on duplicate annual measurements in April of each year by the USGS (Figure 2). Increases appear in 2018 and 2019, but 2019 data are rated "poor" and are not posted on Figure 2. The CSVM-4 hydrograph shown for reference mirrors the KMW-1 hydrograph in Kane Springs Valley (Figure 3). There is no known pumping event to which the low water levels in CSVM-4 and KMW-1 in 2014 can be attributed, given the physical properties of the aquifer and observed local responses to pumping stress (Appendices IV and V).

The Warm Springs West and Iverson streams have been decreasing at 0.3% and 0.7% per year respectively in the nine water years since October 2009 when the Refuge Stream was re-routed (Figure 27). However, between 2010 and 2014, discharge from Big Muddy Spring *increased* by one full cfs, then subsequently declined (Figures 20 and 27). This natural increase of more than 12% in Big Muddy Spring while the Orde-1169 test was underway followed by a decline after cessation of pumping demonstrates climate-dominance rather than pumping as a forcing agent for water-level change within the MRSA, and perhaps a complete absence of Order-1169 pumping effects in Big Muddy Spring. This behavior in the largest spring in the MRSA is inconsistent with near-infinite hydraulic diffusivities that would be required to drain the 5 LWRFS basins by pumping as claimed by USFWS and others (2013). Only by inference, using the correlative high-quality proxy hydrograph from EH-4, can pumping effects from the Arrow Canyon Well be discerned at WSW, and there is no evidence of Arrow Canyon impact at other MRSA springs. The discharge hydrographs give no indication that peak pumping rates of 6 cfs from the Arrow Canyon Wells have any significant effect (Figure 27).

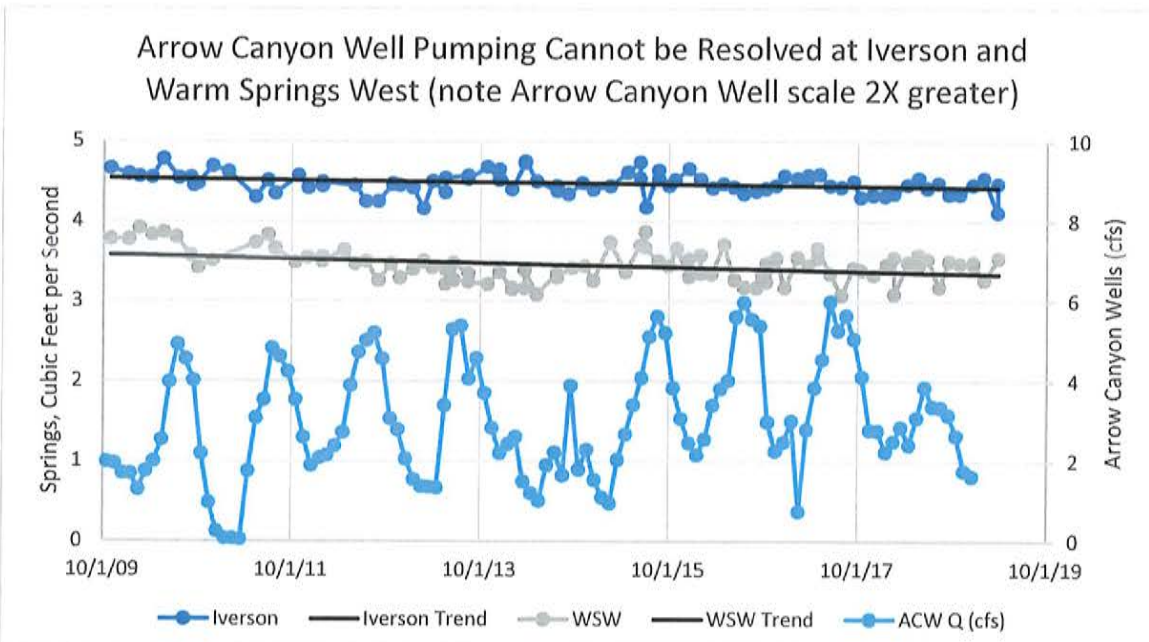


Figure 27. Periodic measurements at Iverson and Warm Springs West and monthly Arrow Canyon Well pumpage for the period after the Refuge Stream was re-routed. [IversonPeriodic.xlsx]

PART IV. SUGGESTIONS FOR FURTHER INVESTIGATION.

Case-by-case pumping response analyses may prevent detectable pumping impacts on MRSA flows. Regional groundwater models are intrinsically general, and not reliable at the level of detail needed to evaluate groundwater-development proposals (water-rights applications) at the local (sub-hydrographic basin) level. Local models, however, are not defensible without boundary conditions derived from a regional model in the absence of natural geologic boundaries, as is the case with LWRFS. To date, a local model has not been successfully embedded in a process-based regional model, despite the attempt by TetraTech (2012a, 2012b). Likewise, the SeriesSEE (Theis transform superposition) approach fails to consider aquifer boundaries or anisotropy and competes with a handful of well-documented exceptions (Appendices IV and V) and both process-based (Appendices I and III) and data-driven (Appendix II) aquifer-hydraulics models for relevance. It is site-specific well-hydraulics analyses, designed to detect system boundaries and to support local models authorized by NRS 533.368 that may lead to successful evidentiary investigations for water-rights allocations.

Similar to what was observed during the constant-rate test at CSI-3 (Figure 28), a recharge boundary is indicated by flattening of the response curves relative to the Theis model and located by image-well theory for ECP-1 (Figure 19) and KPW-1 (Figure 29) pumping. ECP-1 has additional advantages based on hydrochemistry (Johnson and others, 2001) and a regional transmissivity model (Johnson and Mifflin, 2019) of being in an area that may not be tributary to the MRSA. Thus, additional testing and analysis of the ECP-1 ("Belly Tank Flat") area is expected to validate the findings of Johnson and others (2001) with respect to isolation from the MRSA, in spite of recent (Johnson and Mifflin 2019) evidence of more extreme anisotropy than was evident in 2001. The Arrow Canyon Wells produce a pumping signal that impacts high-elevation springs but is reversible within 3 months (Appendix IV) and has not produced observable decreases in gaged Muddy River discharge.

The suggested management strategy of avoiding the highest-diffusivity fracture networks based on well-hydraulics tests is counterintuitive relative to the maximum discharge with minimum drawdown that is generally sought in groundwater exploration and development. Production wells could instead be restricted to locations where a recharge boundary has been demonstrated in a lower-T environment than the 10^5 m^2/day measured in the MX-5 area. Less-than-optimal production wells such as CSI-3 and ECP-1 pose much less risk to the MRSA environment than do MX-5 and RW-2, which cause far-reaching impacts, particularly southward (downstream) because they occupy the fracture system with the highest hydraulic diffusivity known in the area.

An aquifer test in Kane Springs Valley (URS, 2006) indicated non-Theis early-time response and an indefinite recharge boundary, reaching steady-state conditions after the first day of pumping KPW-1 (Figure 29). Analysis as a Thiem well instead of the URS Theis ideal and Hantush-Jacob leaky aquifer methods results in a calculated transmissivity of only about 200 m^2/day and if the regionally interconnected porosity of 0.00015 (Appendix III) is assumed, a distance of about 1 km to the linear (?) recharge boundary is indicated.

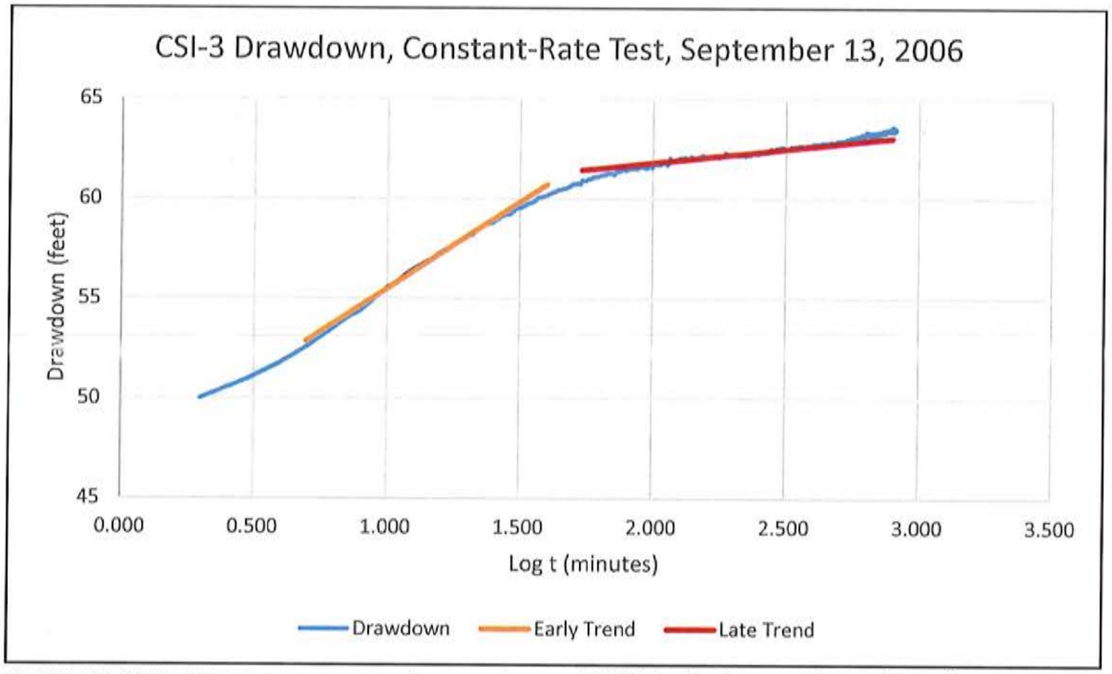


Figure 28. Flattening response curve in pumping well CSI-3 indicates a recharge boundary [CSI#3data Appendix D_cj.xlsx]

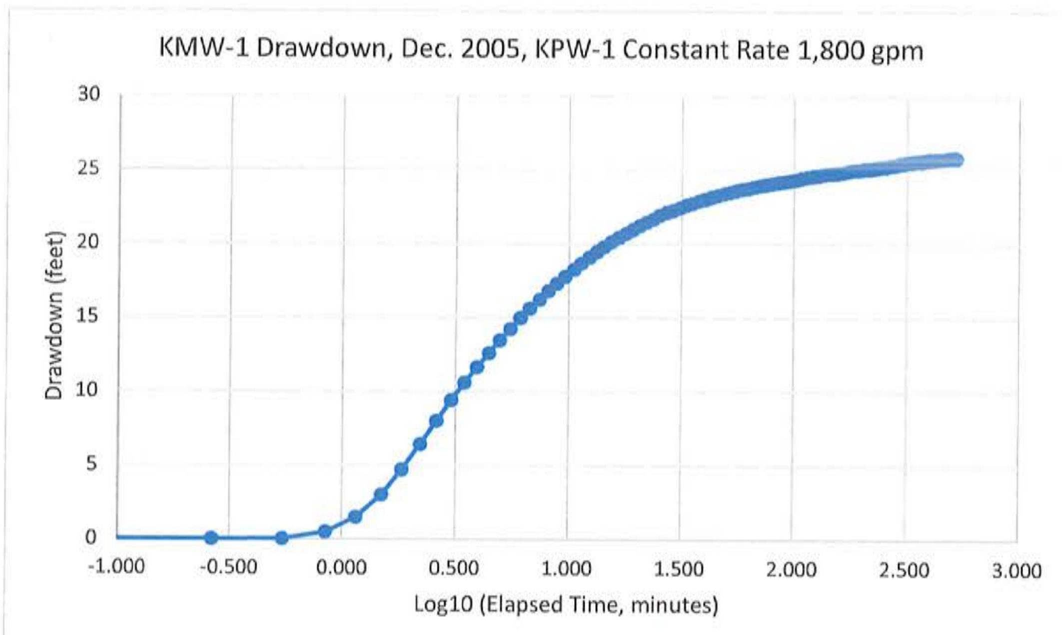


Figure 29. Non-Theis response at KMW-1 indicating irregular recharge boundary [KMWresponse_p01.xlsx]

PART V. CONCLUSION

In response to Order 1303, we undertook analysis of the LWRFS hydrogeologic system in an attempt to answer the State Engineer's request for technical information on the geographic boundary of the LWRFS, aquifer recovery after the Order-1169 aquifer test, long-term annual quantity of groundwater that may be pumped from the Lower White River Flow System, and the effects of movement of water rights between alluvial wells and carbonate wells on deliveries of senior decreed rights to the Muddy River. We believe our work constitutes new scientific evidence that demonstrates significant flaws in the analyses that underpin Order 1303's findings and call into question the scientific conclusions of Rulings 6254 through 6261 (and perhaps other State Engineer determinations as well). The State Engineer is required to use the best available science to make decisions (NRS 533.024 subd. 1(c)) and to order additional studies where needed to make a final determination on an application (NRS 533.368).

We submit this report and the attached Appendices I through V as new evidence that:

> (1) the LWRFS designation and Order 1303 are responses to a flawed conceptual model based on conflated climate and pumping effects, because widespread water-level declines associated with Order 1169 pumping of MX-5 were mistakenly attributed entirely to pumping rather than to the superposition of local, fracture-controlled pumping responses with regional, climate-driven decline;
>
> (2) the LWRFS as drawn by the State Engineer ignores hydrochemical and hydrodynamic divides that suggest the existence of two separate capture zones influencing groundwater flow through the five designated basins;
>
> (3) ~40,000 afy of south-flowing groundwater may be the flux within the Las Vegas Valley capture zone south and southwest of the MRSA;
>
> (4) pumping from California Wash has little to no impact on the MRSA and much more groundwater is available in California Wash than previously assumed;
>
> (5) the State Engineer should supplement and extend the LWRFS concept to an analysis domain based on regional-spring capture zones, as delineated by the best available science; and
>
> (6) if the long-term drought trend evident in climate records persists, no amount of pumping curtailment will restore or maintain high-elevation spring flows, curtailment of pumping in sustainable locations will serve no purpose and thus mitigation measures, including curtailment, will not likely prove effective in protecting senior-rights holders in the Muddy River and Moapa dace habitat from continued drought impacts.

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Appendix I:
Flow-System Boundaries and Groundwater Flux in the LWRFS Arrow Canyon Range Corridor

Cady Johnson
Mifflin & Associates, Inc.

June 30, 2019

Analysis Summary

Darcy's Law can be written Q = T x I x L where

Q = groundwater flux (m^3day)
T = transmissivity (m^2/day)
I = hydraulic gradient (dimensionless)
L = width of aquifer (m)

Mifflin and others (1992) calculated an effective transmissivity of 1.06x10^6 gallons per day per foot (13,164 m^2/day) near BM-DL-2 (Figure 1), which is equal to the square root of $T_X T_Y$, the product of the principal-axis transmissivities (Kruseman and DeRidder, 1994, Chapter 8). The major axis of transmissivity in the Arrow Canyon Range Corridor is oriented generally north-south. Based on an anisotropy ratio of 10:1 the major transmissivity is 3.2x10^4 m^2/day for the southern portion of the groundwater flow corridor at the latitude of Apex, one-third of the effective transmissivity at MX-5. Water-level control for the calculation is as follows:

E (m, NAD83)	N (m, NAD83)	h (m)	ID
697482	4071381	553.2	MX-6
679399	4094151	731.8	Bedroc
658007	4017259	714.8	Gilcrease
673274	4012305	539.5	Wilshire

Hydraulic gradients parallel/tangent to the structural grain are nearly identical (0.00021) between control points (Figure 1). With these data and considering a 20-km width of the groundwater corridor,

Q = (3.2x10^4 m^2/day)(0.00021)(2x10^4 m) = 134,400 m^3/day ≈ **39,800 acre-feet/year.**

This quantity is two-thirds of the present-day steady-state (sustained) yield of Las Vegas Valley, which no modern study has shown can be supported by the Spring Mountains. Estimates by Maxey and Jameson (1948) and Malmberg (1965) have been proven low. The Spring Mountains continue to be invoked as the source of groundwater in western areas including the lower Amargosa River (Belcher and others, 2018). Las Vegas Valley owes its unforeseen capacity to sustain groundwater extraction to inflow from the north, through the thick section of Paleozoic strata occupying a strongly anisotropic, 20-km-wide flow corridor between the Gass Peak Thrust and the California Wash Fault (Figure 1). The Gass Peak Thrust is not necessarily a lateral barrier, for folded footwall rocks beneath the Dry Lake Thrust in California Wash host all the high-capacity wells there and in Garnet Valley to the south, so by structural analogy sub-thrust rocks beneath the Gass Peak Thrust may be highly transmissive.

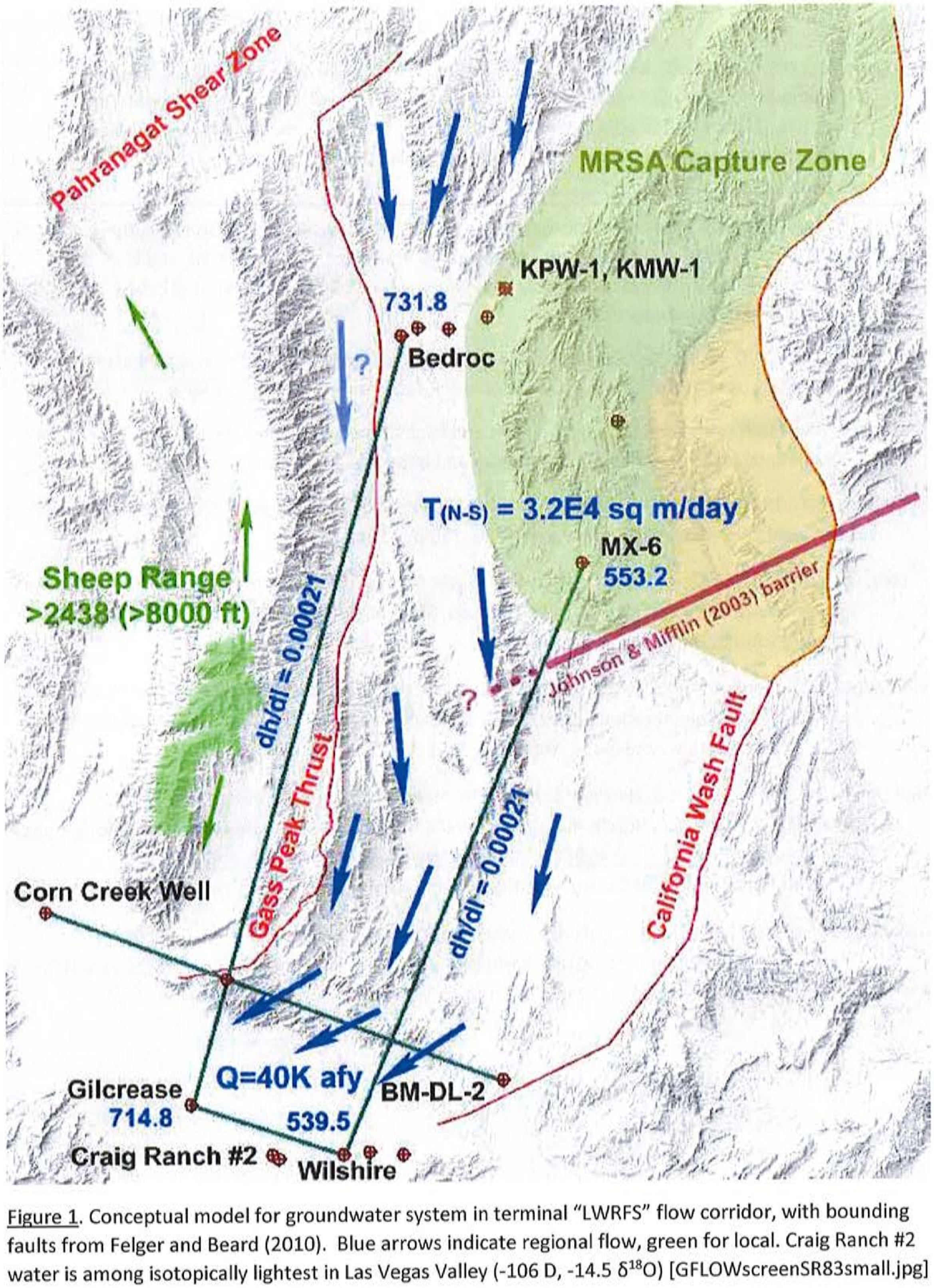

Figure 1. Conceptual model for groundwater system in terminal "LWRFS" flow corridor, with bounding faults from Felger and Beard (2010). Blue arrows indicate regional flow, green for local. Craig Ranch #2 water is among isotopically lightest in Las Vegas Valley (-106 D, -14.5 $\delta^{18}O$) [GFLOWscreenSR83small.jpg]

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Appendix II:
Preliminary Two-Climate Model for the Muddy River: Observations and Analysis Opportunities

Cady Johnson, January 22, 2016 (minor editorial revisions June 2019)

The Muddy River is nourished by two proximal but distinct springflow regimes as revealed by 30-year monitoring records (Figure 1). Intensity differences in a regional discharge area likely owe their contrast to the windows of climate history during which their (different) sustaining waters were recharged, primarily in distant mountains. A meaningful "window of climate history" is characterized by its width (years) and lag (amount of time before the effect of climate forcing is felt, measured in years), and a sequence of climate indices (candidate explanatory variables with respect to springflow) within that period of record. Analysis of springflow or groundwater level as a function of past climate is amenable to multiple regression, but the modeling environment must include a very large number of candidate time intervals and associated lags. This short paper provides a complete accounting of the "forcing space" provided by roughly a century of streamflow measurements on the Humboldt and Virgin Rivers; annual base flow is taken as a climate index that samples the climate of the catchment. Results indicate that fluctuations in the fluxes of two tributary groundwater regimes are attributed to about 2 decades of regional climate.

Big Muddy Spring (USGS ID 09415900) is the largest spring in the Muddy headwaters area and has been monitored by the USGS since 1986. The proportion of conduit-spring discharge, or of overall Muddy River discharge (conduit + seepage) represented by Big Muddy Spring, is unknown. The Warm Springs area, which contains relatively small, high-elevation springs that discharge in proportion to groundwater levels west and south of the headwaters, is a significant contributor to the Muddy River, but the proportion of Muddy River flow attributable to this southern hydrodynamic regime is unknown.

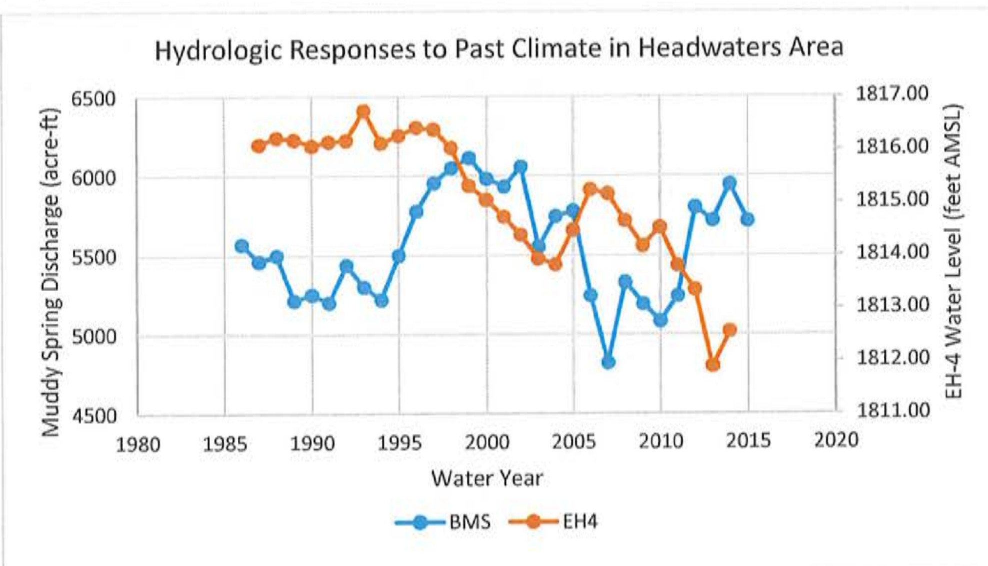

Figure 1. Average spring (April 16 –May 15) water levels in monitoring well EH-4, and annual discharge of Big Muddy Spring (BMS). EH-4 water levels are a proxy for southern-regime discharge, while Muddy Spring is proportional to northern-regime discharge [file SouthernLagComparison.xlsx, sheet 'ShowBMS_EH4']

The relationships between northern climate and Muddy Spring (Figure 2), and southern climate and water levels in the Arrow Canyon Range Cell (Figure 3), are established, allowing each hydrograph to be hindcast to the mid-1940s as the Muddy River's period of continuous record. Using discharge records from the Humboldt River at Palisade (USGS ID#10322500) and Virgin River North Fork (USGS ID#09405500), the number of contributing years and lag required to fit climate-driven annual fluctuations in spring discharge and groundwater level using river-based annual measures of effective moisture as the sole explanatory variables have now been systematically evaluated.

The amount of groundwater that discharges to form the Muddy River is influenced by both northern and southern climate regimes. It was established in the 1960s that the "White River Regional Groundwater Flow System" carries water that was recharged hundreds of kilometers north of the discharge area. Muddy Spring is the largest spring at the headwaters of the Muddy River, and we claim that it responds to past "northern" climate as sensed by historic base flow of the Humboldt River. We have assumed the record of Humboldt River discharge is sufficiently long and have searched for the right piece of history that explains the 30 years of Muddy Spring discharge that we have been able to observe. Note that Water Year 1995 and most of 1996 Muddy Spring discharge were interpolated. Uniformly positive regression coefficients for lags of 12-22 years allow the discharge of Muddy Spring to be modeled in terms of northern climate indices (Figure 4).

Water levels at EH-4 have been shown to correlate with discharge fluctuations at the small, high-elevation Pederson Springs (Mayer and Congdon, 2008). The Pederson and Warm Springs West hydrographs look nothing like Muddy Spring, but clearly the Warm Springs area is a major tributary to the Muddy River. We can model EH-4 water levels, adjusted for nearby pumping, using annual base flow of the Virgin River (North Fork) within a lag window of 1 to 16 years prior as the explanatory variable set (Figure 5).

What proportion of Muddy River discharge is contributed by the "northern" and "southern" groundwater flow domains? How do we answer that question, and why should we care? The Warm Springs West flume produces at best a mixed record that is blind to the more remote -in-time conditions that determine the hydrodynamic controls on Big Muddy Spring. Isolating a component of pumping response from an otherwise fluctuating and largely climate-driven signal is aided by a climate model that reproduces the underlying trend, and only when pumping response has been confidently isolated can aquifer parameters be applied in a meaningful way to reproduce (by calculation) those observed responses filtered from a messy record.

We offer a two-climate model to explain reconstituted annual discharge of the Muddy River, using the combined set of explanatory variables that work individually with northern (Muddy Spring) and southern (EH-4 and high-elevation springs) multiple regression analyses (Figure 6). The significance of over half (17 of 27) the regression coefficients being negative in the combined model is not understood. It is important to assess the validity of the two-climate model, given the projected 2013-2015 natural discharge decrease (Figure 6) that the model shows to have occurred. Perhaps the most significant aspect of these findings is that fluctuations in recharge to the two tributary groundwater regimes feeding the Muddy River are expressed as springflow variations within 2 decades. This is a matter of concern because prior groundwater permitting and development in the area assumed that a century would be required for the Muddy River to sense impacts. Our work suggests the response time will be considerably less.

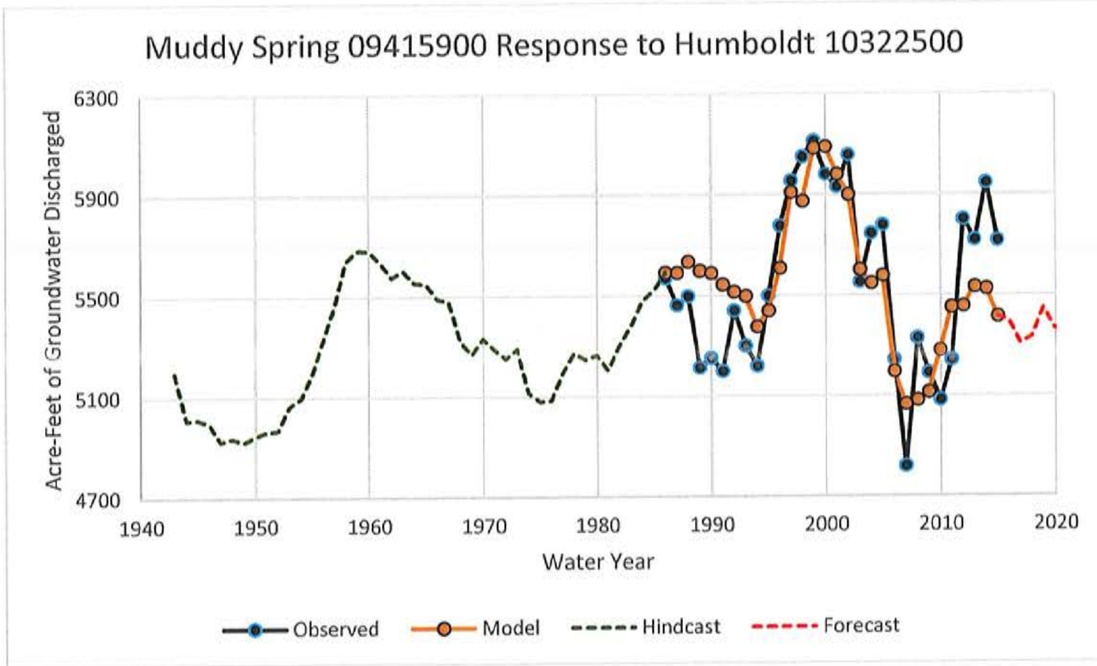

Figure 2. The annual total base flow of the Humboldt River at Palisade provides a climate index time-series dating to 1912, which contains the explanatory variable set that determines discharge at Big Muddy Spring. [file HumboldtBFI.xlsx, sheet 'Hindcast1222']

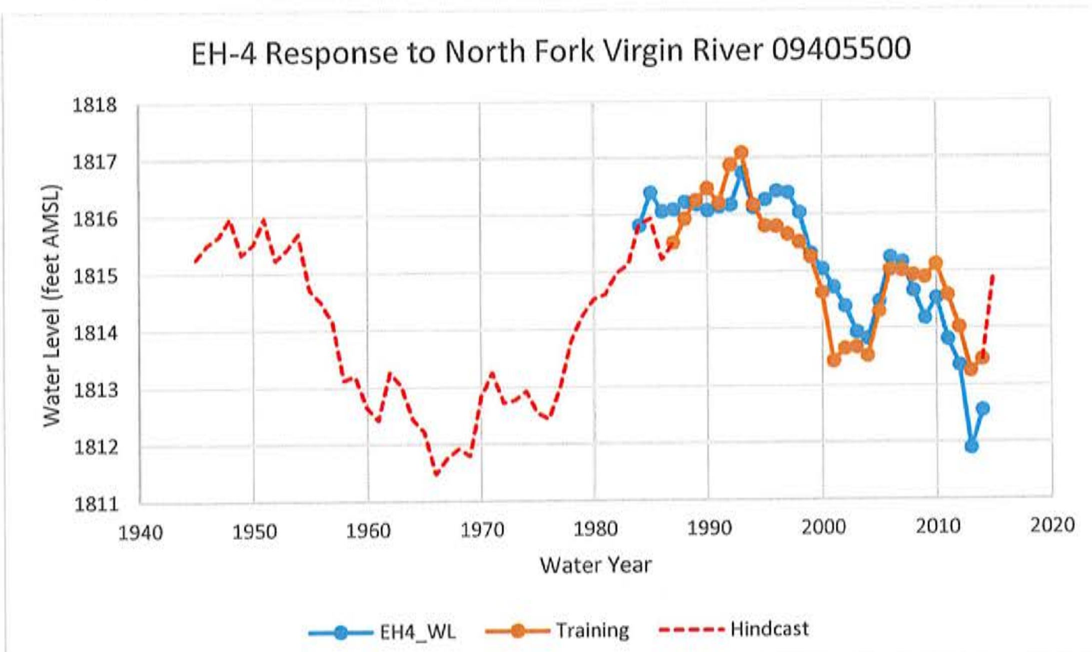

Figure 3. The annual total base flow of the Virgin River (North Fork) at Springdale provides a climate index dating to 1928, which contains the explanatory variable set that determines groundwater elevations in the Reservation area. [file NFvirginBFI2.xlsx, sheet 'Hindcast_0116']

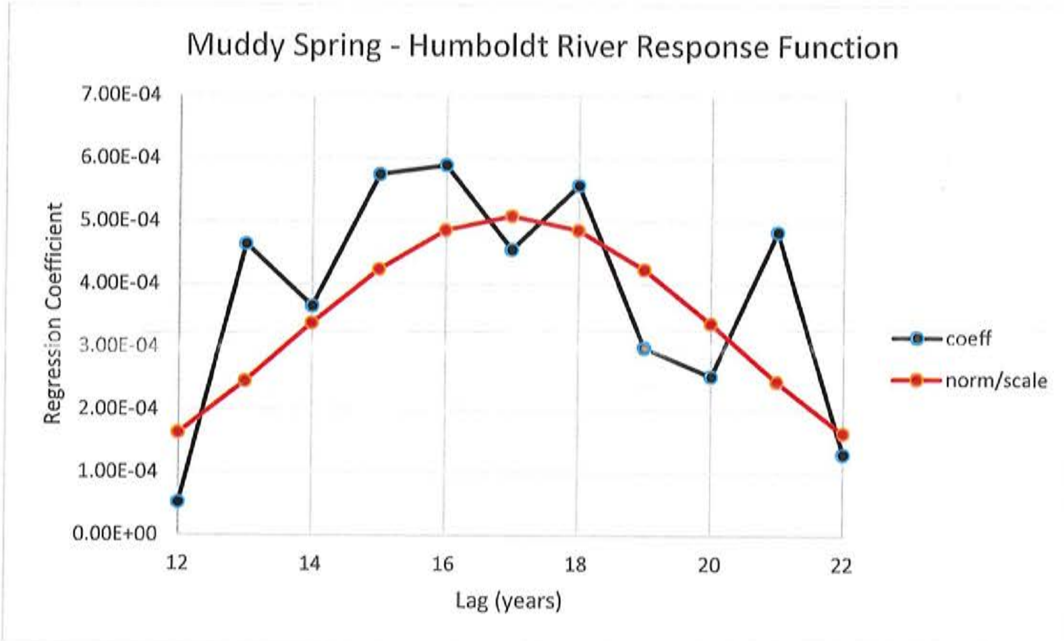

Figure 4. Weighting (regression) coefficients for the time window 12 to 22 years before target observations of annual Muddy Spring discharge, with an approximating normal distribution [file HumboldtBFI.xlsx, sheet 'Hindcast1222']

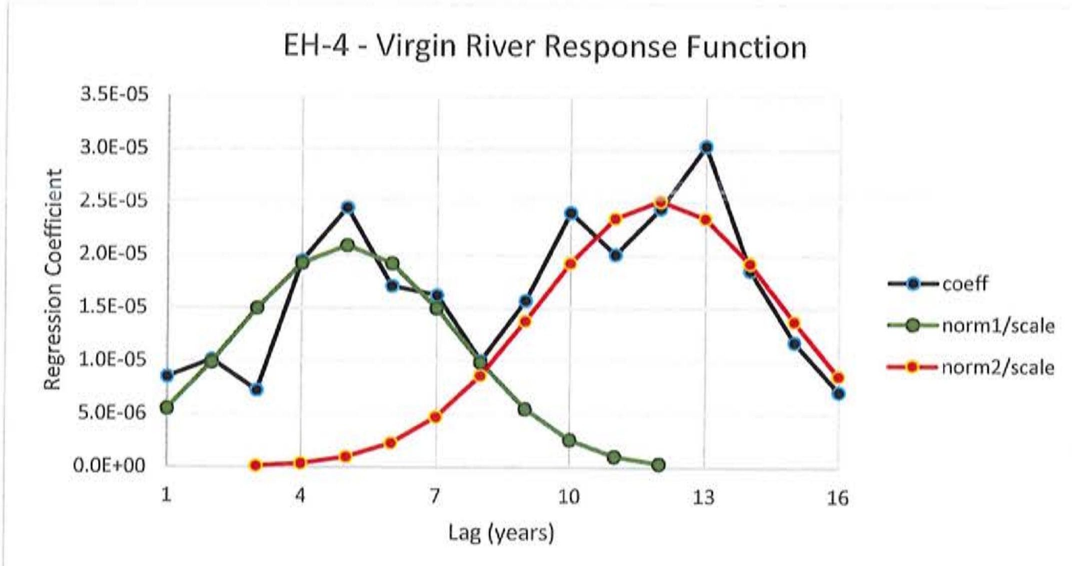

Figure 5. Weighting (regression) coefficients for the time window 1 to 16 years before target observations of spring (April 16 – May 15) water levels at monitoring well EH-4. Approximating normal distributions are shown. [file NFvirginBFI2.xlsx, sheet 'VirginEH4_0116a']

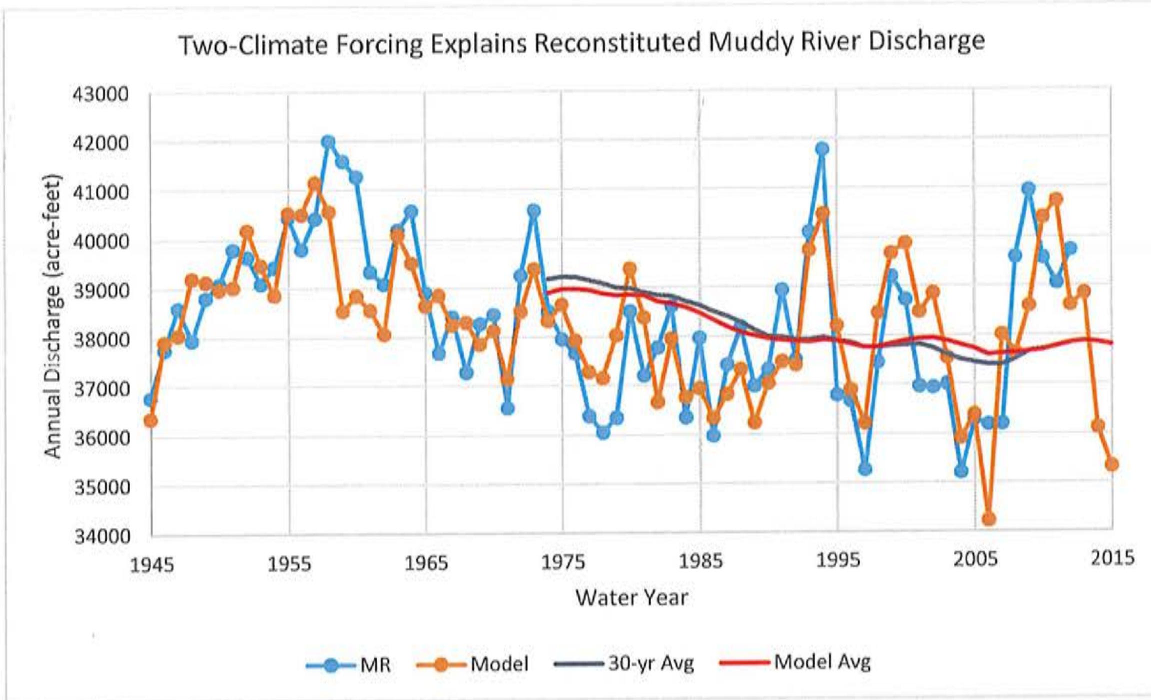

Figure 6. Reconstituted discharge is measured discharge plus all known diversions and evapotranspiration effects, giving the rate of natural discharge to the headwaters area. Explanatory variables are climate indices (annual base flows of the Virgin and Humboldt Rivers) within lag intervals of 1-16 and 12-22 years before the present, respectively [file TwoClimateMuddyRiver.xlsx, sheet 'TwoClimateMuddyRiver4']

Appendix: R Console Log Illustrating Iterative Multiple Regression Process, with Output from One Step

```
> filepath<-system.file("data","NFvirginBFI2.txt",package="stats")
> WLmodel<-read.table(filepath,header=TRUE)
#
# assign names to columns of complete source data file with water year, EH-4 water level,
# and lagged Virgin River (North Fork) annual base flows as explanatory variables
#
> VarNamesLV <- c("WY", "EH4", "LV0",
+ "LV1", "LV2", "LV3", "LV4", "LV5", "LV6", "LV7", "LV8", "LV9", "LV10",
+ "LV11", "LV12", "LV13", "LV14", "LV15", "LV16", "LV17", "LV18", "LV19", "LV20",
+ "LV21", "LV22", "LV23", "LV24", "LV25", "LV26", "LV27", "LV28", "LV29", "LV30",
+ "LV31", "LV32", "LV33", "LV34", "LV35", "LV36", "LV37", "LV38", "LV39", "LV40",
+ "LV41", "LV42", "LV43", "LV44", "LV45", "LV46", "LV47", "LV48", "LV49", "LV50",
+ "LV51", "LV52", "LV53", "LV54", "LV55", "LV56", "LV57", "LV58")
#
# initialize counters
#
> LagStart <- 2                                  # first column of lagged climate indices
> LagEnd <- 17                                   # last column of lagged climate indices
> nCases <- 0                                    # step in the loop
#
# begin loop to move fixed-width time window containing explanatory variables back in time,
# performing multiple regression to explain EH-4 water levels at each step
#
> while(LagEnd<58){          # number of steps is limited by the width of the lag table WLmodel
+ LagStart <- LagStart+1                         # increment counters to move window
+ LagEnd <- LagEnd+1
+ myvars <- c("EH4",VarNamesLV[LagStart:LagEnd])  # assemble the column names to be called
+ LVdata <- WLmodel[myvars]                      # create temporary data frame for analysis
+ fit <- lm(EH4~.,data=as.data.frame(LVdata))    # perform the multiple regression
+ out <- capture.output(summary(fit))            # multiple regression output for this step
+ nCases <- nCases+1                             # count steps of window movement
+ cat(nCases, out,file="data/sumEH4_16x43.txt", sep="\n", append=TRUE) # append output file
+ }                                              # end loop for 16-year windows
```

Output from the second step of this loop, which analyzes seasonal EH-4 water levels as the dependent variable, represents variables LV1 through LV16 from columns 4 through 19 of the source table 'WLmodel', as written to file sumEH4_16x43.txt, which is named to indicate the width (in years) of the moving window processed by this iteration and the 43 steps that are possible as the window is moved back in time to the limit of data (Water Year 1928 here). The loop was run enough times to exhaust the degrees of freedom by successively changing the initial value of 'LagEnd' and the output file name in a working script, then pasting the script into the R console to execute the number of steps required to explore all lags of the prescribed time window. [reference 'ConsoleLog20151227', a text file]

```
2

Call:
lm(formula = EH4 ~ ., data = as.data.frame(LVdata))

Residuals:
   Min     1Q  Median     3Q    Max
-1.3469 -0.4373  0.1067  0.4324  1.3020

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 1.800e+03  3.187e+00 564.807   <2e-16 ***
LV1         8.518e-06  1.061e-05   0.802   0.4393
LV2         1.015e-05  1.032e-05   0.984   0.3464
LV3         7.238e-06  1.057e-05   0.685   0.5075
LV4         1.947e-05  1.121e-05   1.737   0.1103
LV5         2.446e-05  1.037e-05   2.359   0.0379 *
LV6         1.710e-05  9.739e-06   1.756   0.1068
LV7         1.624e-05  8.375e-06   1.939   0.0785 .
LV8         1.007e-05  7.695e-06   1.309   0.2174
LV9         1.574e-05  7.604e-06   2.070   0.0628 .
LV10        2.402e-05  8.876e-06   2.707   0.0204 *
LV11        2.008e-05  9.376e-06   2.142   0.0554 .
LV12        2.439e-05  1.098e-05   2.222   0.0482 *
LV13        3.031e-05  1.138e-05   2.663   0.0221 *
LV14        1.858e-05  1.173e-05   1.584   0.1414
LV15        1.182e-05  1.178e-05   1.003   0.3373
LV16        7.169e-06  1.194e-05   0.601   0.5603
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.9487 on 11 degrees of freedom
Multiple R-squared:  0.7694,     Adjusted R-squared:  0.434
F-statistic: 2.294 on 16 and 11 DF,  p-value: 0.08342
```

Appendix III:
A Scoping Model of Interbasin Groundwater Flow in Eastern Nevada Constrained by Anisotropy and Regional Heat Flow, with Suggestions of Millennial-Scale Climate Memory

Cady Johnson and Martin Mifflin
Mifflin & Associates, Inc.

June 29, 2019

Nevada's prior appropriation doctrine that determines water rights seniority, economic growth policies, federally-mandated protection of endangered species, and climate change-induced prolonged droughts have combined to present vexing and growing problems for state water regulators. The "best available science" has not provided regulators a decision framework that incorporates the element of time and clarifies the relevance of different time frames in a rational fashion. To the contrary, regulators at times appear to require rapid equilibration in determining the amount of water available for appropriation (e.g. Ruling 6446 at 9 and cited remand order), while in other circumstances they accept potential conflicts notwithstanding delayed equilibrium if the delay to impact on senior water rights and endangered species is sufficient (i.e., centuries). To date, state water regulators have failed to explicitly recognize the transience of the regional groundwater system in several frequency modes including years to decades as suggested by climate responses, heat flow, transmissive flow zones related to Quaternary faulting, stable isotopes, radiocarbon, and diffusion studies.

If administrative water-management units (hydrographic basins) are combined into larger management entities such as the 5-basin "Lower White River Flow System" (LWRFS) to address interbasin groundwater flow there may be no improvement in analysis potential even as new water-rights issues are created. Groundwater flows sustaining the regional springs of southern Nevada are not sustainable new water resources, as springflows are generally fully appropriated with most-senior rights. Regulators have accepted prolonged (up to centuries) time delays for impacts to develop from groundwater development in up-gradient basins identified as interbasin sources for regional springflows. Some groundwater models and C-14 analyses indicating very old spring waters have been offered to support these postulated, prolonged delays for impacts in the arguments in support of applications for large blocks of groundwater rights.

A groundwater scoping-model exercise was triggered by evidence that multi-year climate signals are delayed by only a decade or two, based on the positive correlation between discharge at Big Muddy Spring in the Muddy River Springs Area (MRSA) and a 12-22-year prior period of base flow of the Humboldt River, a northern-climate proxy, by multiple regression. The scoping model seeks to evaluate interbasin groundwater flow within a region sufficiently large to encompass the "Eureka Low" of Sass and Lachenbruch (1982) by using heat as a hydrologic tracer to constrain the physics. Regional springs are *assumed* to be coupled via capture zones to principal recharge areas constituted by Ordovician, Silurian, and Devonian carbonate-rock (OSD_C) outcrop areas in the high, mountainous terrain that develops significant winter snowpacks. Regional topography in eastern and southeastern Nevada is *assumed* to force generally southward groundwater movement that is sweeping heat from the Eureka Low to regional warm-spring areas in the south. In this exercise we select the analysis domain (Figure 1), define a recharge-cutoff surface, assign anisotropy directions, and select the heated area to characterize the

Eureka Low (Figures 2 and 3). The model simulates a groundwater flow field and the temperature distribution within it, constraining the amount of regional groundwater reaching southern Nevada.

The FEFLOW finite-element modeling environment (Diersch, 2014) was utilized under demonstration license of Version 7.2q of FEFLOW for two weeks in February and March 2019 to prepare this scoping analysis. FEFLOW is flexible-mesh groundwater flow and transport simulation software, offering convenient pre- and post-processing options. The conceptual model for the MAI scoping exercise uses heat lost within Eureka Low to explain similar-temperature waters discharging at the warm springs of southern Nevada. The question studied is if rapid signal propagation indicated by modern climate response of springs in the MRSA is corroborated by plausible groundwater velocities needed to deliver the "missing" heat lost from the Eureka Low to the regional springs in a steady-state process. The scoping model is designed to establish if regional flow from northern recharge areas in the highest mountains to discharge at the southern warm springs is physically possible and more importantly, plausible within the decadal time scales suggested by climate response in the MRSA.

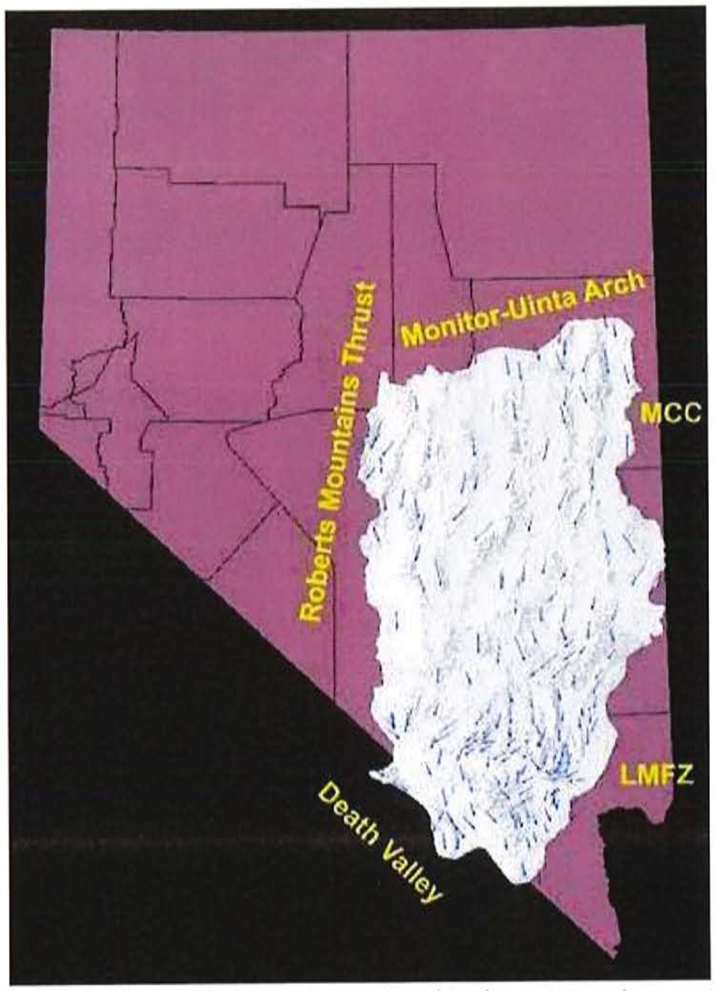

Figure 1. Portion of Lower Paleozoic Shelf Domain considered in the MAI scoping groundwater model, with generalized geologic boundaries and anisotropy picks. MMC = metamorphic core complexes, LMFZ – Lake Mead Fault Zone [StructuralGrainInset27V2.jpg]

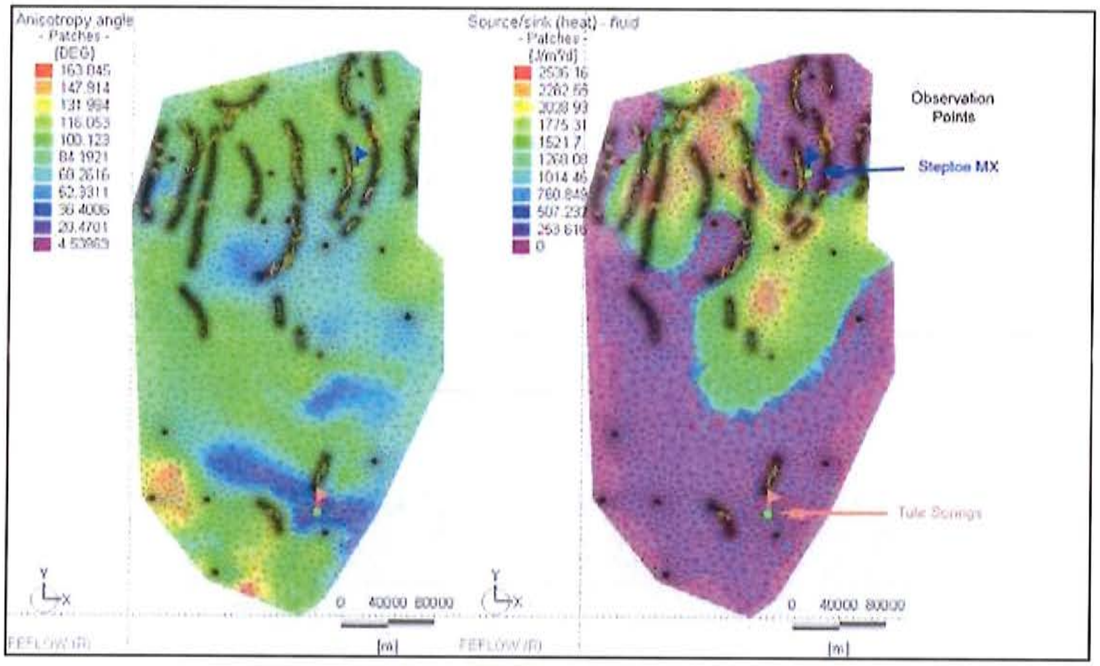

Figure 2. Anisotropy angles as mapped to the finite-element mesh (left) and characterization of the Eureka Low in terms of rate of heat input to the aquifer (right) [AnisotropyAnglesAndEurekaLowV2.jpg]

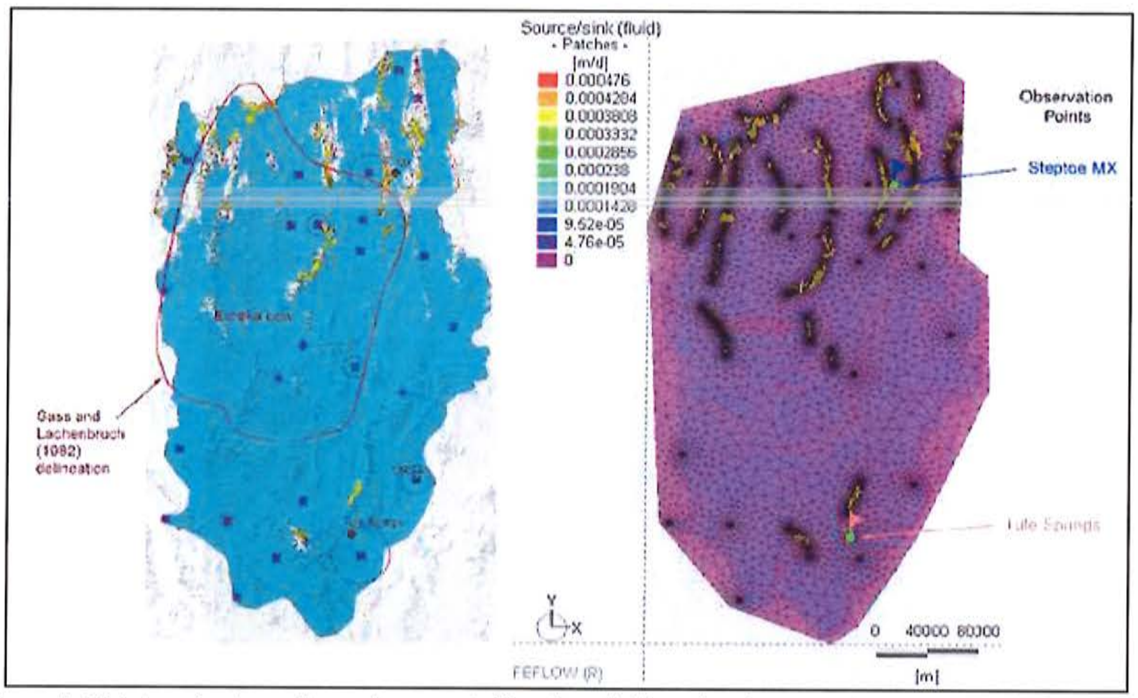

Figure 3. High terrain above the recharge-cutoff surface (left) and recharge assignment to Ordovician, Silurian, and Devonian carbonate (OSD_C) rocks (right). Eureka Low of Sass and Lachenbruch (1982) shown. The Steptoe Valley MX well (blue flag) and Tule Springs (pink flag) are manual calibration points for hydraulic head and temperature. [RechargeCutoffOSDandRatesV3.jpg]

A north-dipping, planar recharge-cutoff surface isolates mountainous terrain ranging from 8,500 feet (2,590 m) at Latitude 36°N, down to 7,000 feet (2,134 m) at Latitude 40N (Figure 3). OSD_c rocks, mapped at 1:250,000 (Hess and Johnson, 1997) in these "islands" of high terrain, are allocated recharge to balance the discharge of regional springs, 15.6 cm/year in the base case.

Output from the model (Figure 4) is a steady-state solution for head and temperature. Hydraulic head is smoothly distributed in the region, reflecting the southerly fluid-potential gradient driven by regional topography. In contrast, simulated temperatures are highly variable, reflecting complex interplay between distributed recharge, an irregular heat source, and the anisotropy field. With streamlines, the solution for head can be presented to illustrate capture zones of the regional springs (Figure 5).

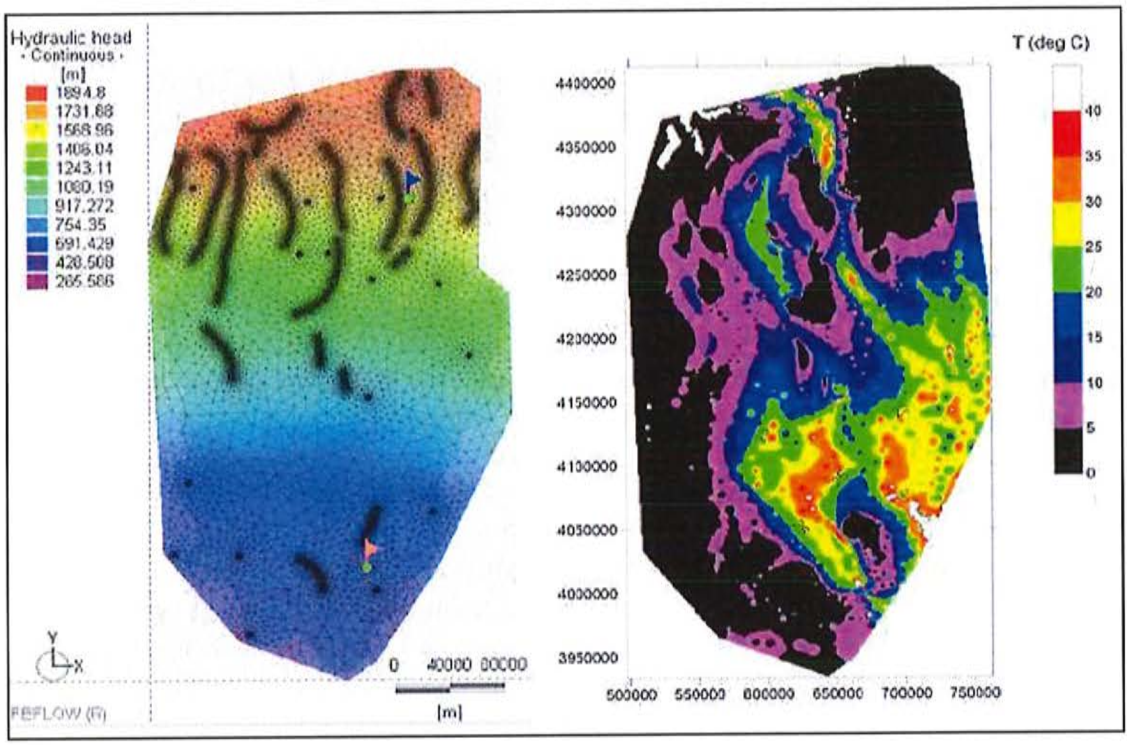

Figure 4. FEFLOW solutions for hydraulic head and temperature in the base case scoping model of March 2019. Calibrated regional transmissivity in base case is 300 m^2/day, porosity 0.00015 [HeadAndTempSolutions20190310]

Except for Las Vegas Valley, discharge data are from Heilweil and Brooks (2011). In this model Las Vegas Valley is a much larger sink (59,000 acre-feet per year, afy, based on calibration) and the Spring Mountains a much smaller regional source (5,200 afy, based on geologic structure and stratigraphy) than estimated historically (Maxey and Jameson, 1948). Pahrump and Indian Springs are considered local based on their elevations and locations adjacent to the Spring Mountains, the source of 11,500 afy non-regional recharge to those flanking spring areas. Groundwater passing within about 100 km west of Pahranagat Valley does not reach Ash Meadows in this conceptualization, instead turning southeast toward Las Vegas. Discharge at Oasis Valley, Furnace Creek, Ash Meadows, and Tecopa originates in central Nevada and is not being heated in the scoping model by the 30°C or more observed in those regional springs. The no-flow boundary on the west side should allow some outflow of water and heat toward Big Smoky Valley, which might ultimately contribute to groundwater discharge in Clayton Valley, or the salt marshes (Rhodes, Columbus, Teels) of Esmeralda and Mineral Counties following the topographic trough associated with the arcuate structural grain of lower Big Smoky Valley (Meinzer, 1917).

In a recent and most-relevant report on isotope and chemical mass-balance geochemistry, Thomas and Mihevc (2011, p. 31) state that "[c]orrecting the model ages for diffusion processes is beyond the scope of this report." They also state, in their Executive Summary (Thomas and Mihevc, 2011, p. iii), that "[c]arbon-14 corrected groundwater ages were also estimated for the regional warm spring areas of the WRFS to provide information on recharge timing and groundwater travel times within the WRFS." It does not appear they were successful. The following quote states the fundamental problem with ignoring matrix diffusion:

> *By plotting the ratio of the rate of diffusion to the rate of decay of carbon-14 over the length scales representative of several common hydrogeologic settings, it is demonstrated that diffusion of carbon-14 should often be not only a significant process, but a dominant one relative to decay.*

W.E. Sanford, 1997.

Radiocarbon data from regional springs is not diagnostic of groundwater travel time (GWTT), but instead is subject to major uncertainties due to matrix diffusion effectively constituting another ^{14}C decay mechanism along the groundwater flow path, causing ages to appear older than they actually are. However, comparison of percent-modern-carbon (pmc) analyses in regional springs can be informative, as follows. Preston Big Spring (northern White River Valley) shows 11.2 pmc, Crystal Spring in Pahranagat Valley has ~6.2 pmc for an apparent age difference of 4,941 years. If, however, 200x more matrix water is available to exchange with actively-flowing water, then the actual groundwater travel time is 4,941/200 ≈ 25 years. Missing is the radiocarbon lost to the matrix and observed is mostly older radiocarbon released from the matrix (Figure 6). Big Muddy Spring (MRSA) has 9.7 pmc, which is not consistent with a Pahranagat Valley source without significant local (younger) input suggested by Thomas and others (1996). Panaca Valley, given elevated fluoride in several locations, is the more logical source region for MRSA discharge with flow paths beneath the Meadow Valley Mountains, Kane Springs Wash, and Coyote Spring Valley (Figure 5). Hershey and others (2010) provide a radiocarbon analysis from Panaca Spring, 23.1 pmc, so the apparent age difference between Panaca Spring and Big Muddy Spring is 7,169 years. The ongoing crustal extension in the region and numerous successful production wells in areas of Quaternary faulting suggest that these radiometric age differences are far too large for the system not to be diffusion-dominated.

Interpretation of stable-isotope analyses should account for matrix storage volume in the region roughly 200 times greater than the volume of active flow zones, with consequent "smearing" of discharge chemistry relative to input (recharge) compositions. This dilution factor is based on 3% porosity for the rock matrix from laboratory studies (Hershey and Fereday, 2016) and borehole geophysics (Berger, 1992), and from 0.00015 effective (interconnected) regional porosity from calibration of the coupled-process finite element model reported here.

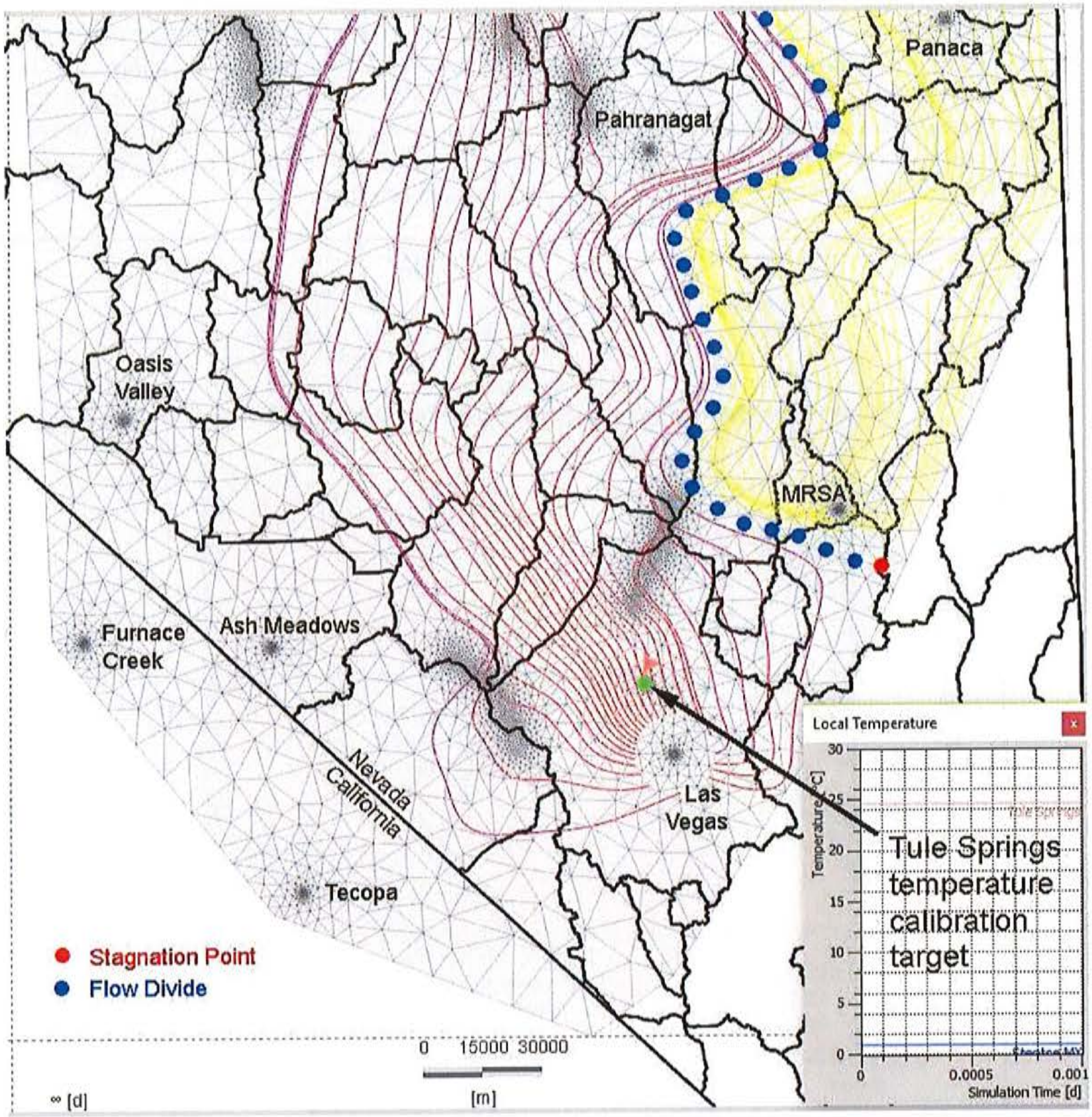

Figure 5. A flow divide between groundwater tributary to the Muddy River Springs and groundwater tributary to Las Vegas Valley is demarcated (blue dots). At the stagnation point the calculated temperature is too high but the model is numerically stable and constitutes the MAI base case scoping model of March 2019 with obvious shortcomings remaining in the western areas. [FlowDivide20190401.jpg, derived from Supermesh3h.fem]

When same-day (or within a day) samples were collected more than once from a group of associated springs, similar isotopic shifts between times of sampling suggests that analytical uncertainty is not responsible for the temporal difference, in which case the differences would be random. Same-day samples from regional springs in eastern Nevada provide a powerful argument that spring-water compositions are transient on a time scale of years to decades (Figure 7). Two regional groundwater systems (two primary systems are suggested here, Figure 5) are discharging a once-only record of past climate that should not be ignored or minimized in terms of importance. When the output signals (time-series of isotopic compositions) have been characterized at the main groundwater discharge areas for a sufficiently long monitoring interval the net signals arriving from present *and past* recharge may hold the key to refined understanding of present *and past* capture zones. The proposed U.S Department of Energy high-level waste program and Nevada Test Site environmental stakeholders face the same reality as water-users in the "LWRFS" geographic area: uncertain flow paths and velocities.

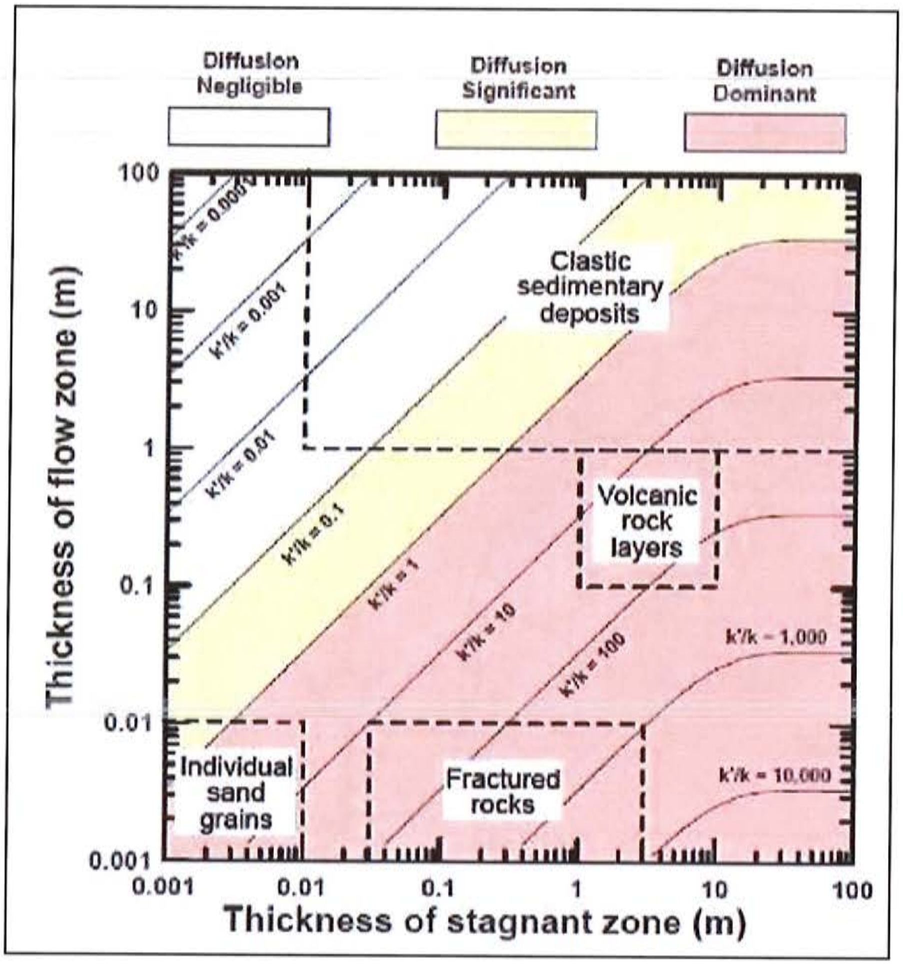

Figure 6. The OSD_C carbonate-rock aquifer can be characterized as plotting near the lower left corner of the "Fractured rocks" field and even below the x-axis, diffusion-dominated and reflecting the heat-constrained sub-millimeter-diameter active flow zones (Sanford, 1997) [SanfordDiffusion.jpg]

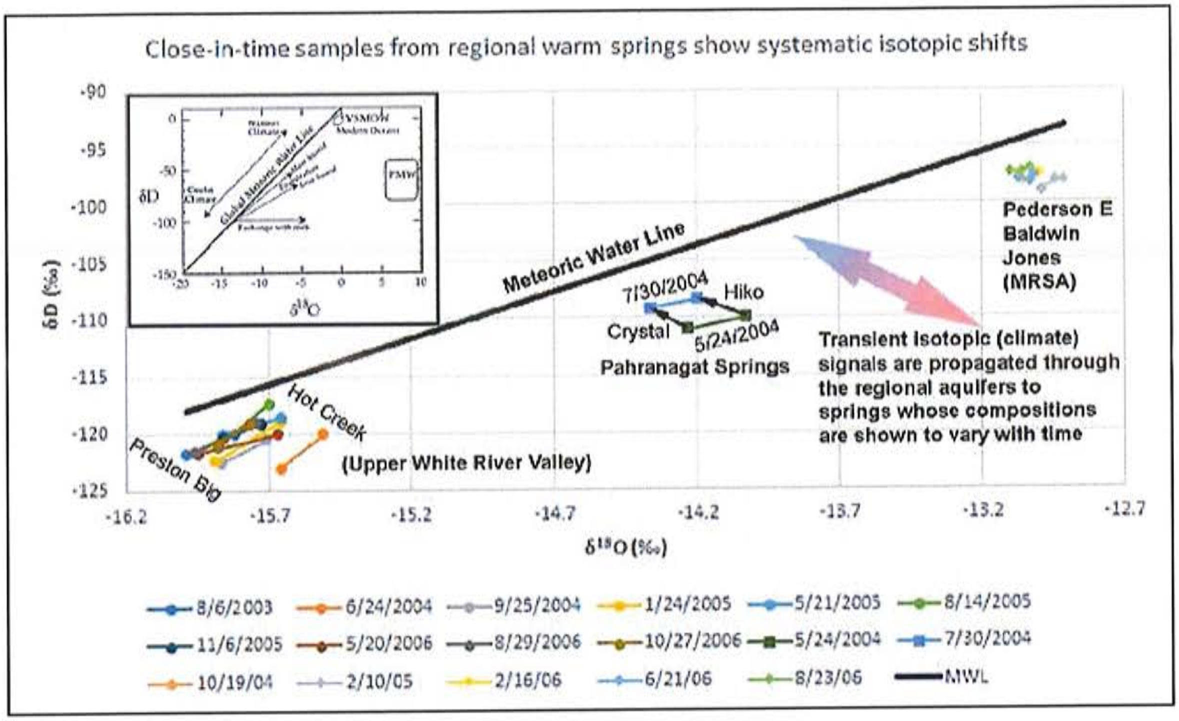

Figure 7. Analytical uncertainty notwithstanding, covariance of isotopic compositions in sub-areas reflects past climate variability, because neither evaporation nor rock-water interactions can produce the observed trends. The large double-headed arrow is intended to suggest variable equilibrium temperatures based on $\delta^{18}O$ (inset from Seal and others, 2000) [AllSameDay.xlsx, IsotopicShifts3.jpg]

The high-resolution temperature-anomaly record from bristlecone pine tree-rings in the Great Basin (Salzer and others, 2014) reveals by proxy the isotope enrichment- and depletion-producing climate modes that must now be in memory in the regional groundwater system (Figure 8). Unprecedented warming since 1850 is evident in the tree-ring record, preceded by a very cold 3 decades that included 1827-1833, during which Spanish explorer and missionary Francisco Garces coined the name "Nevada," meaning "snow-covered."

A diffusion-dominated groundwater system will "smear" the compositional makeup of the active flow zone through matrix diffusion, with fracture water on relatively long flow paths acquiring the composition of the volumetrically much-larger and relatively stagnant matrix pore water. Matrix diffusion will therefore lessen the amplitude of compositional variations that are propagated to discharge locations and eliminate the higher-frequency components of the input signal. Therefore, the concentration distribution of a natural tracer is a "smeared" signal, like what is obtained by a 100-year moving average (Figure 9; compare to Figure 8). In the 100-year-average representation there is an apparent ~200-year periodicity of ±0.2°C in an overall thousand-year temperature decline before the recent warming that began with the Industrial Revolution in the mid-1800s. This observation suggests the thermal history of the recharge areas is in memory in the regional groundwater systems of eastern Nevada, not as temperatures, but observable as variable stable-isotopic compositions with time at any representative monitoring location.

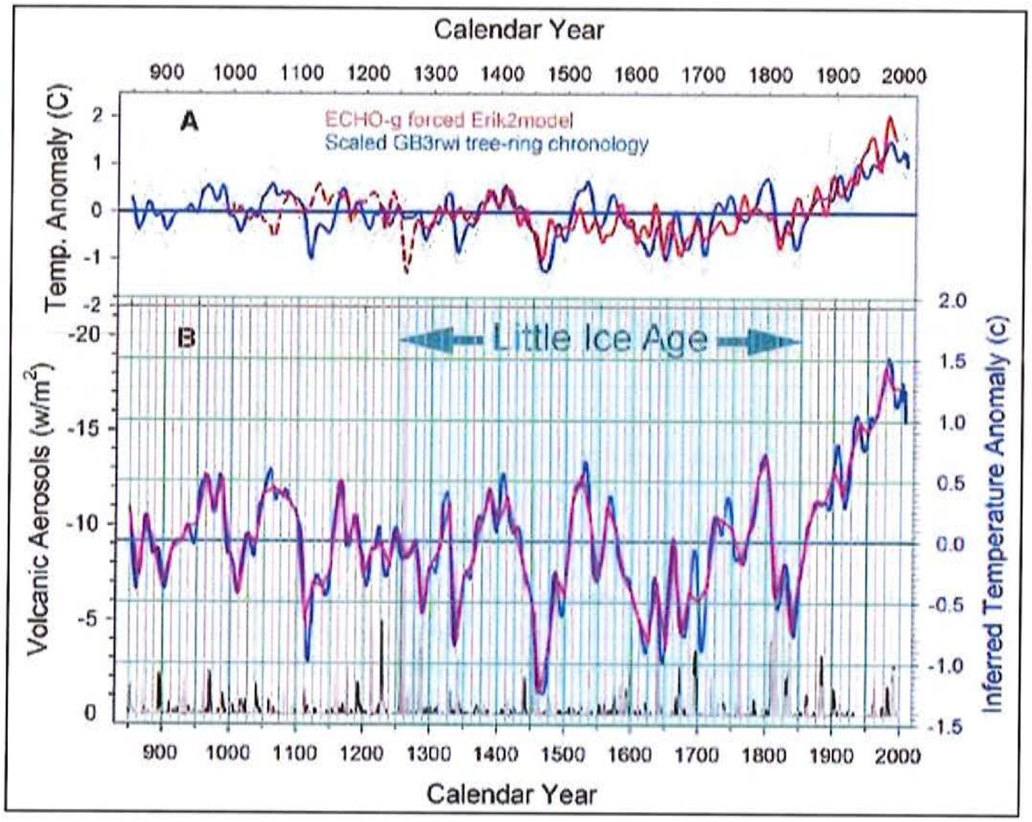

Figure 8. Temperature anomalies in the Great Basin relative to long-term average, with model picks by the author (Johnson) at 12.5-year intervals shown by purple line segments to permit smoothing approximations and mode decomposition to be explored (modified after Salzar and others, 2014; global climate model ECHO-g from Legutke and Voss, 1999) [Salzar2014chronology.jpg]

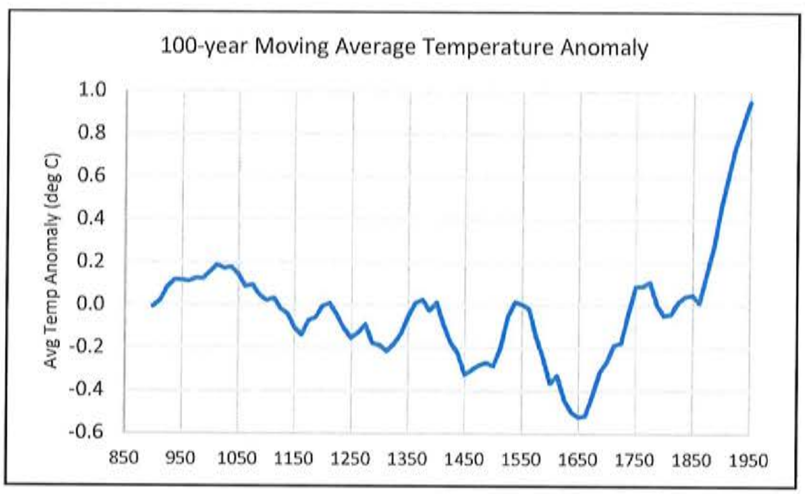

Figure 9. 100-year moving average of 12.5-year-interval picks from Salzar and others (2014) as shown in Figure 8. Note the apparent 200-year periodicity [AllSameDay.xlsx, sheet 'BristleconeT']

Calculated equilibrium temperatures from springs presumed to represent modern recharge by Thomas and Mihevc (2011) and those near the Fish Hatchery in Ruby Valley follow the same trend with latitude as Panaca and Muddy River Springs. As suggested by Figure 10, the Preston-Pahranagat trend is different and representative of a different recharge temperature regime than Panaca-MRSA. If the input signal is smeared along flow paths to the extent shown in Figure 9 by 100-year averaging, the range between maximum and minimum *observable* late Holocene recharge temperatures is reduced to about 1.5°C from 2.5°C (compare Figure 8 range). If we are now at about the warmest point since 1850, why are these "modern" waters so light isotopically, or is their makeup somehow not unusual?

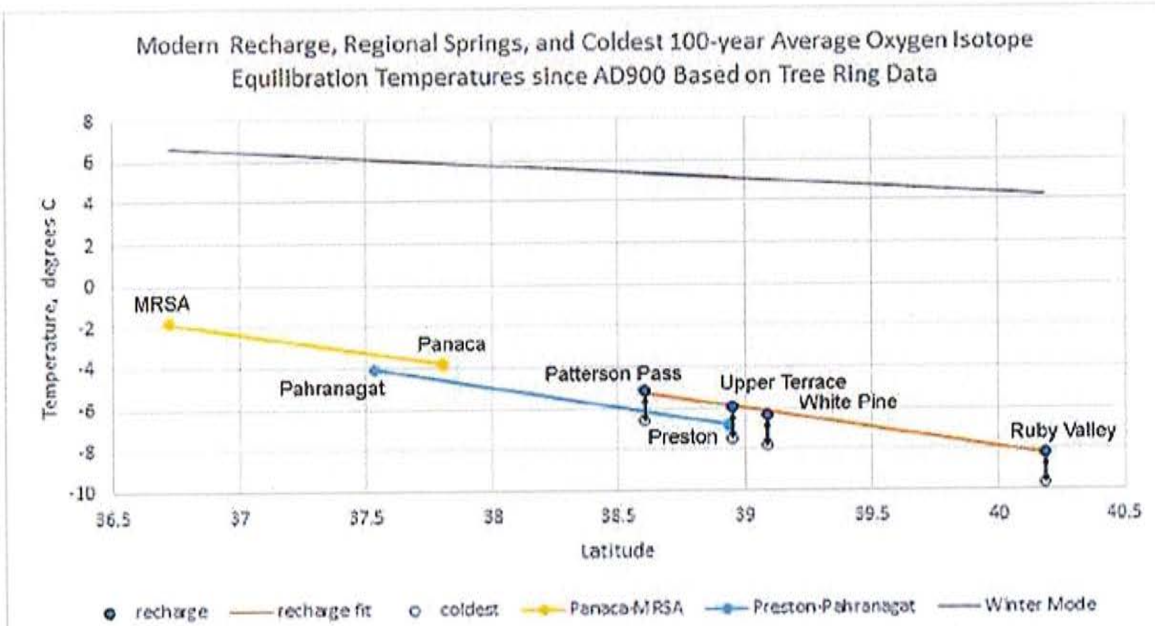

Figure 10. Equilibrium temperatures, computed as a function of $\delta^{18}O$ and plotted as a function of latitude where the sample was collected, indicate two capture zones. Recharge under colder-than-modern conditions is suggested by all samples, but more importantly, equilibrium temperatures in the traditional (Preston to Pahranagat) north-central White River Flow System approach the coldest input conditions in over a thousand years and are offset from the trend in easternmost Nevada. [EquilibriumTemperatures2.jpg]

The transmissivity analysis using FEFLOW (Diersch, 2014) was instructive in that time-of-travel capture zones for the MRSA were delineated in a simple (low-dimensional) conceptual framework (Figure 11) where behaviors of the process variables hydraulic head and temperature under different scenarios are easily visualized because there are no inhomogeneities. The anisotropy field used for this base case is experimental and based entirely on professional judgment, as is the operational recharge cutoff surface, OSD_C-only recharge-area lithology selection, and admittedly low-confidence characterization of the Eureka Low heat source (see Critique below).

The 10- and 20-year time-of-travel capture zones indicate that carbonate-rock aquifer pumping in Kane Springs Valley would likely impact the MRSA within 10 years, and development impacts from Delamar Valley would likely be sensed at the MRSA within 20 years.

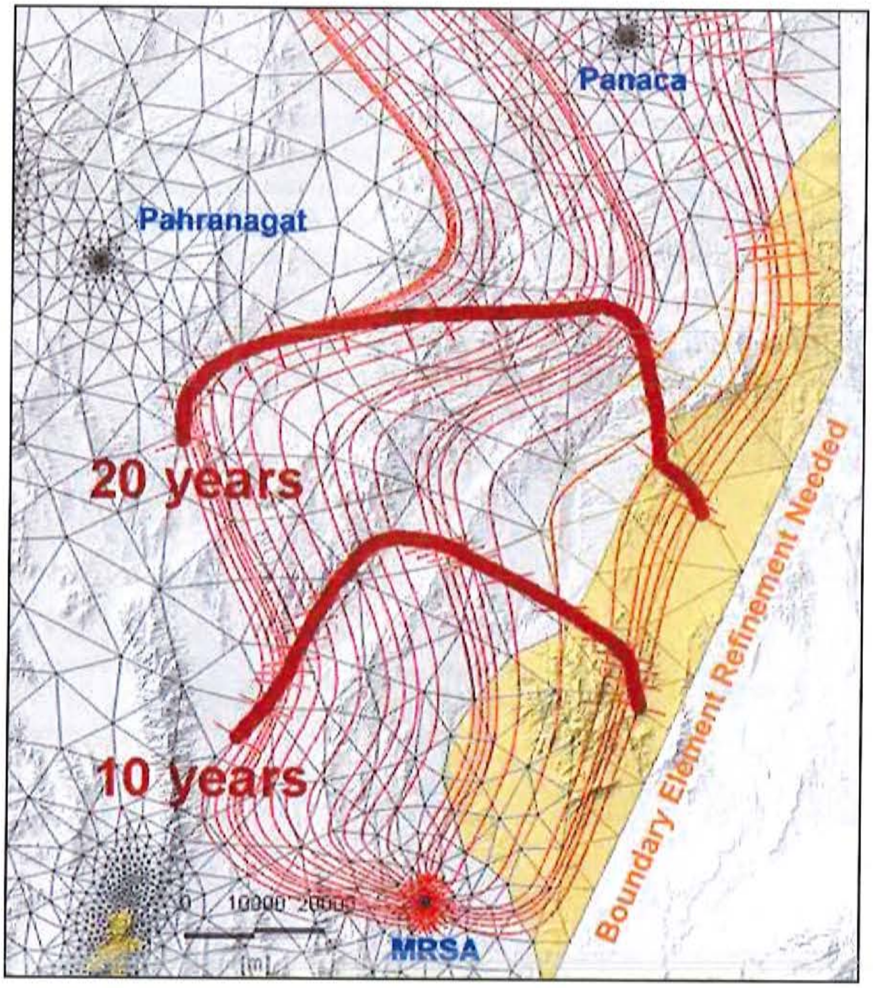

Figure 11. Time-of-travel groundwater capture zones for 10 and 20 years, plotted as streamlines and isochrons by the FEFLOW program, showing feature-based mesh refinement around regional recharge and discharge areas, where steady-state hydraulic gradients are largest [TimeOfTravelCaptureZonesSR.jpg, derived from Supermesh3h.fem]

Critique of the Model

The meshing process produces some extra elements where straight lines are necessarily used to approximate flow-domain boundaries; as non-participating sub-domains are identified they can be removed by assigning them zero transmissivity and thermal conductivity to improve calibration. Shading in Figure 11 shows a boundary segment that includes the Mormon Mountains that should be removed from the model domain because basement rocks are exposed and at shallow depth east of Meadow Valley Wash. Clipping the model domain here would compress the streamlines and shift the Panaca-MRSA capture zone slightly westward, producing a new base case model for archival if numerical stability is preserved, which depends on many factors.

It is evident from the simulated temperature map (Figure 4) that the heated region used to represent the Eureka Low is too small, since almost no warming of groundwater is simulated in the western area from Oasis Valley to Tecopa. How much heat is missing from the Eureka Low is not known; all that is known is that heat flux is lower than expected over a large area in the Great Basin, but the expectation depends on uncertain concepts of heat generation and transport in the crust and mantle. In the absence of a better heat-source model from geophysics, methodical adjustment of the footprint, distribution, and intensity of the heat source in the model (Figure 12) will be needed to increase warming in the southwestern area and smooth the calculated temperature field in eastern Nevada. Much-too-cool conditions along the western edge of the model are due in part to the no-flow boundary there, which may need adjustment to allow southwestern outflow (into Big Smoky Valley?). Researching the most up-to-date concepts of the Eureka Low in terms of conditions in the lower crust from the viewpoint of solid-earth geophysics perspective was beyond the scope of this exercise.

In summary, model-derived capture zones of Las Vegas and Muddy River Springs, which envelop the capture zones of Pahranagat and Panaca Springs, respectively (Figure 5) are supported by stable isotopes and radiocarbon in addition to the simple mass-balance computations of Johnson and others (2001). Groundwater travel time is conceptually complex when matrix diffusion causes climate-driven (decades or less) hydraulic pulses of groundwater to regional springs that are compositionally representative of an integrated pore water composition acquired from the rock matrix, older and with smeared memory of variable climate history. Matrix water largely replaces by diffusion the soil water molecules and solutes moving through active regional flow zones, masking the original makeup of groundwater that was recharged more recently than spring-water radiocarbon suggests. Flow in the eastern capture zone (Panaca-MRSA) is more sluggish and/or diffusive than the central (Preston – Las Vegas) zone based on radiocarbon comparisons and relative distances along streamlines.

The information presented here adds support to the idea that Las Vegas Valley is the terminus of a regional groundwater flow system originating north of White River Valley, but not ending at the Muddy River Springs Area as Eakin (1966) proposed, which instead is fed by a separate capture zone that includes Panaca Valley and terminates at the MRSA. The implication for water management is that developments in areas tributary to Las Vegas Valley may not cause harm or even be sensed by monitoring, whereas developments in areas tributary to the MRSA , which might exclude alluvial-aquifer systems demonstrably isolated from the carbonate-rock aquifer, would impact endangered species and senior water-rights holders.

A copy of the binary FEFLOW model file, entitled "Supermesh3i.fem," has been provided to the State Engineer's office along with this Report and Appendix.

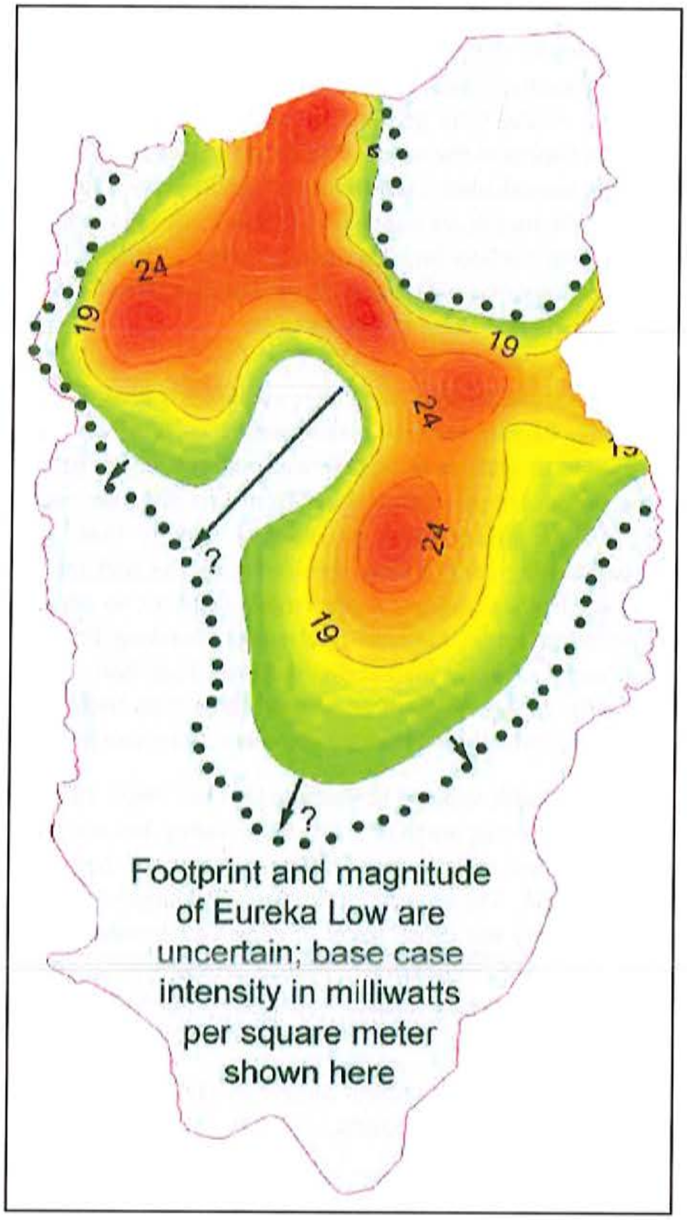

Figure 12. Representation of the Eureka Low within the scoping model flow domain, with first refinement step suggested by dotted line. There is no single operational definition for the Eureka Low. Filled contours show the rate of heat input into both solid and liquid phases in the base case (March 2019) as shown in Figure 2. The dotted line bounds the area with less than 70 mW/m^2 heat flow as represented by Masbruch and others (2012). Within that area, heat flow is locally as low as 45 mW/m^2 so the advective losses to flowing groundwater could be locally of the same magnitude if conductive heat transfer from basement rock is 90 mW/m^2, less than heat flow of much of northern Nevada where a regional aquifer is absent (Sass and Lachenbruch, 1982; Blackwell, 2011). [HeatFlowOnSupermesh2_UTM27.tif]

Conclusions and Management Implications

- A finite-element transmissivity model, constrained by physical boundaries, estimated rates of groundwater discharge, and groundwater temperatures, suggests groundwater moves within hydrodynamic flow-domains that do not respect basin physiography in southeastern Nevada. Instead, primary capture zones (tributary flow fields) of the Muddy River Springs and Las Vegas regional discharge areas are suggested.

- A strongly anisotropic, heat-coupled modeling approach associates known discharge areas of regional, interbasin groundwater flow systems with probable (based on lithology) major high-elevation recharge areas far to the north and demonstrates decadal-scale groundwater travel times are physically possible as indicated by climatic signals in the spring-discharge records.

- Adjustment of radiocarbon ages (residence times) to account for matrix diffusion produces an independent and much larger (than that of Thomas and Mihevc, 2011) estimate of groundwater velocity between Preston Big Spring and Pahranagat Valley (divide apparent age difference by 200, the matrix:fracture porosity ratio) that supports the thermohydrologic finite-element model.

- Two sources of water for the MRSA, suggested by multiple-regression analysis of climate response (prior-year ADR appendices), appear in this characterization to be associated with northeastern Coyote Spring Valley, and with the Meadow Valley Mountains (bounded by Meadow Valley Wash) to the east.

- Radiocarbon analyses suggest groundwater movement between Panaca Valley and the MRSA is more sluggish and/or more diffusive than flow between northernmost White River Valley and Pahranagat Valley, but "ages" are uncertain.

- Important: The chemical and isotopic compositions of regional springs are transient and therefore rich in climate signals spanning perhaps thousands of years, produced as stagnant but relatively high-volume matrix pore water replaces active flow-zone water along flow paths to and from which diffusion can occur. Conversely, the matrix-water compositions are always seeking equilibrium with fast-moving water in the volumetrically very small regional flow channels.

- In this conceptualization a portion of the groundwater flow field tributary to Las Vegas Valley underlies Delamar and Dry Lake Valleys, following a sinuous boundary with the capture zone of the Panaca-MRSA system to the east.

- The southern and westernmost areas of Coyote Spring Valley may be tributary to Las Vegas Valley, as is most of California Wash; neither of these areas, Garnet Valley, or Hidden Valley is tributary to the MRSA, which appears hydrodynamically isolated from the Las Vegas capture zone at the present time.

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Appendix IV:
Procedure for establishing Arrow Canyon Well pumping drawdowns at EH-4 and with this proxy, predicting pumping-related discharge reductions at the Moapa National Wildlife Refuge Springs

Cady Johnson
Mifflin & Associates, Inc.

May 28, 2019

Drawdown at EH-4 resulting from Arrow Canyon Wells (ACW) pumping has been established by comparing the hydrographs of EH-4 and reference well MX-4 (Figure 1), noting that differences are attributable to pumping the ACW and analyzable by multiple regression. Differences (drawdowns at EH-4) are simulated by 13 weeks of variable weekly ACW pumping, the explanatory variable set, producing R-squared = 0.897 and regression coefficients given in Table 1.

The relationship developed here constitutes a data-driven model that may not apply under climate states from which we have no data; note the non-zero intercept in Table 1. The strong correlation between pumping and drawdown permits adjustment of EH-4 water levels during the 121-day test of 1993-1994 (Figures 4, 5, and 6) and throughout the remaining period of record (Figure 7). In the semi-log plot (Figure 6) there are two boundaries indicated, first in time a less permeable boundary than initially sensed and ultimately a recharge boundary that causes drawdown to stabilize at 0.8 feet. The Muddy River may be that boundary (Figure 8).

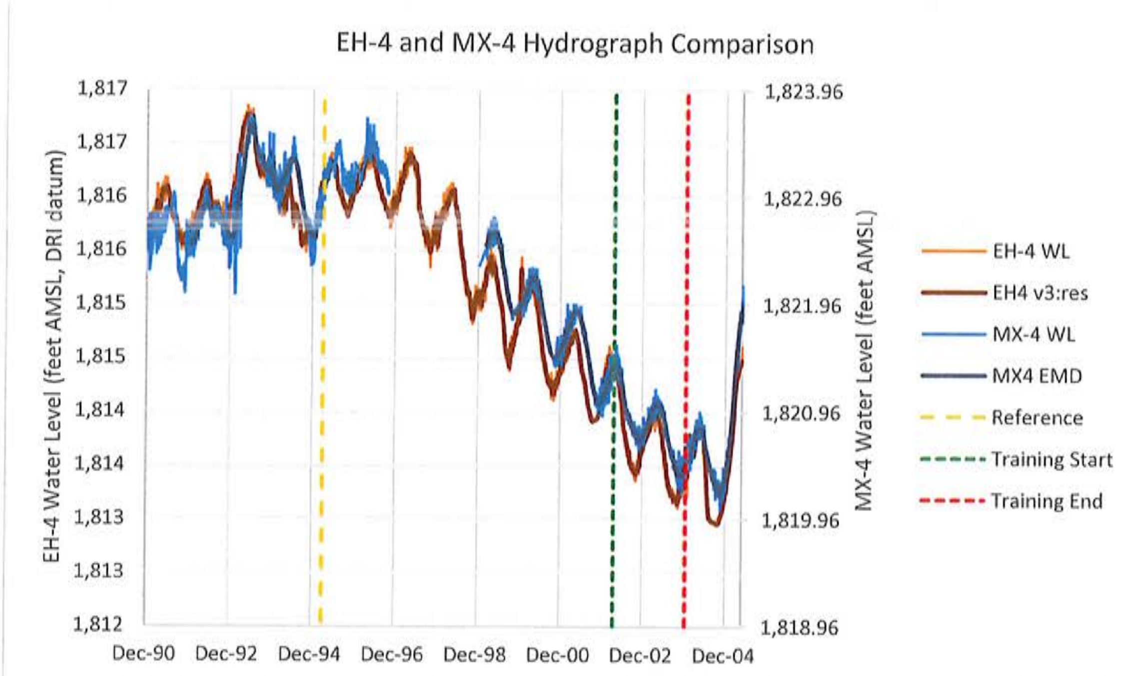


Figure 1. Training period of April 2002 through December 2003 produces excellent multiple-regression statistics (Table 1). The daily hydrograph was smoothed by Empirical Mode Decomposition (EMD) filtering to retain weekly and lower-frequency modes. [EH4ACWresponse2.xlsx, sheet 'DailyWLs']

SUMMARY OUTPUT

Regression Statistics	
Multiple R	0.947248
R Square	0.897278
Adjusted R Square	0.880158
Standard Error	0.041409
Observations	92

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	13	1.168279	0.089868	52.4102	4.83E-33
Residual	78	0.133746	0.001715		
Total	91	1.302025			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	0.248548	0.018676	13.30866	9.12E-22	0.211368	0.285729	0.211368	0.285729
Lag0	**-0.03265**	0.011958	-2.73057	0.007814	-0.05646	-0.00885	-0.05646	-0.00885
Lag1	**-0.01243**	0.017516	-0.70971	0.48	-0.0473	0.022441	-0.0473	0.022441
Lag2	**-0.00758**	0.017612	-0.43045	0.668053	-0.04264	0.027481	-0.04264	0.027481
Lag3	**-0.00661**	0.017605	-0.37569	0.708169	-0.04166	0.028435	-0.04166	0.028435
Lag4	**-0.00869**	0.016958	-0.51267	0.609633	-0.04246	0.025067	-0.04246	0.025067
Lag5	**-0.01098**	0.016589	-0.66181	0.510046	-0.044	0.022047	-0.044	0.022047
Lag6	**-0.00788**	0.016617	-0.47434	0.636584	-0.04096	0.025199	-0.04096	0.025199
Lag7	**-0.01062**	0.016624	-0.63906	0.524654	-0.04372	0.022472	-0.04372	0.022472
Lag8	**-0.00834**	0.016574	-0.50332	0.616156	-0.04134	0.024654	-0.04134	0.024654
Lag9	**-0.00631**	0.017068	-0.36989	0.71247	-0.04029	0.027666	-0.04029	0.027666
Lag10	**-0.01031**	0.017382	-0.59286	0.55499	-0.04491	0.0243	-0.04491	0.0243
Lag11	**-0.00542**	0.017224	-0.31472	0.753813	-0.03971	0.02887	-0.03971	0.02887
Lag12	**-0.00319**	0.011361	-0.28054	0.779806	-0.02581	0.019431	-0.02581	0.019431

Table 1. Multiple-regression coefficients representing how pumpage in the current week (Lag0) and the 12 prior weeks (Lag1 through Lag12) explain drawdown at EH-4 as a function of weekly pumpage at the Arrow Canyon Well(s). Note all coefficients are negative, indicating that each of the 13 weeks has the expected effect. [EH4ACWresponse2.xlsx, sheet 'WeeklyMR']

Order-1169 pumping from MX-4 created about 1 foot of drawdown at EH-4, and about 0.6 cfs reduction of flows at Warm Springs West and Iverson combined. The 121-day Arrow Canyon Well test produced 0.8 foot of drawdown at EH-4, which corresponds to about an 0.5 cfs springflow reduction at the Warm Springs Refuge resulting from a 6.5 cfs pumping rate at the Arrow Canyon Well. Less than 8% of ACW discharge is captured from the sensitive (Pederson, Plummer) springs. Figure 8 suggests that ACW pumping is likely capturing groundwater that is tributary to the MRSA, but with such small impacts in the Refuge springs and none at Big Muddy, and with many springbrooks not monitored, flows at the Muddy River Gage must be carefully reconstituted to provide a quantitative estimate of total impact.

The Arrow Canyon wells do not affect the MRSA uniformly. There is measurable reduction of springflow in the Refuge, no effect at Big Muddy, and signal to noise conditions at the Moapa Gage that do not permit confident identification of the Arrow Canyon Well's pumping signal (Figure 8). Recovery at EH-4 is complete 3 months after cessation of pumping; there is no cumulative drawdown. The Arrow Canyon wells have far softer impacts on the River than alluvial pumping, such as alluvial pumping for Reid Gardner Generating Station that intermittently reduced the River to half its normal flow due during the past five decades (but which has now ceased). If the climate-driven water-level and spring-flow declines in the region continue, the Pederson springs will perhaps be the first to cease flowing.

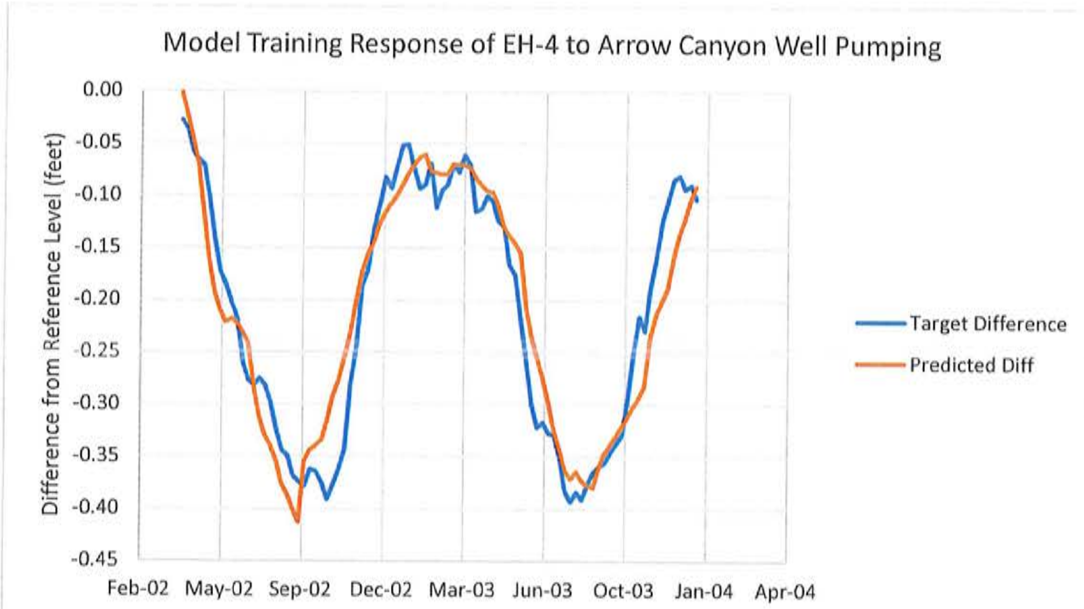


Figure 2. Regression coefficients were developed for a training interval, then applied to the remaining period of record to remove the ACW effect from the EH-4 hydrograph. Empirical Mode Decomposition (EMD) was used to estimate weekly pumping from monthly records because a monthly lag model failed to capture the abrupt response to the MVWD 121-dy test. [EH4ACWresponse2.xlsx, sheet 'WeeklyMR']

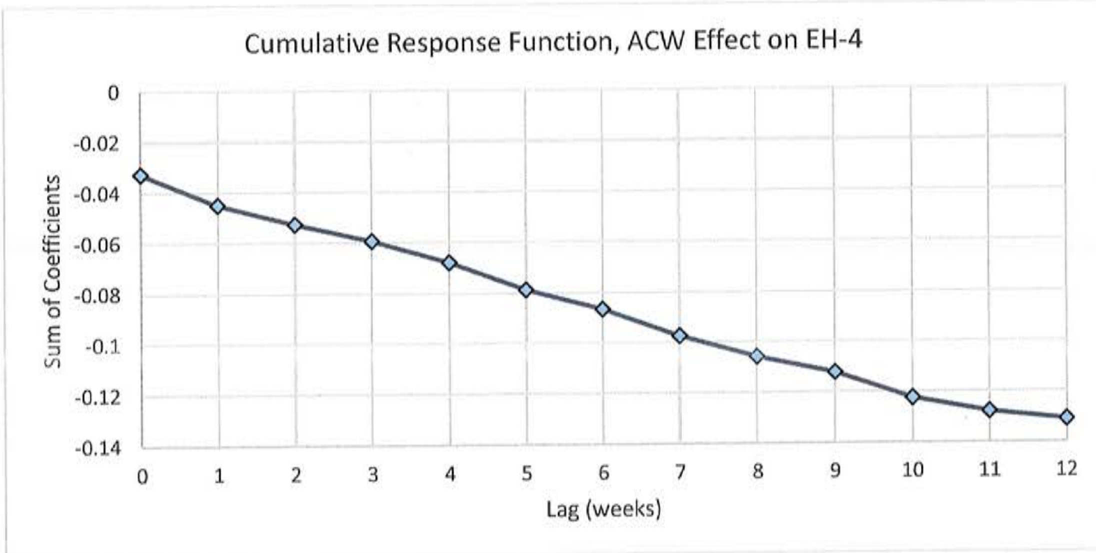


Figure 3. Cumulative response function where lag represents the number of weeks prior to a water-level observation that the Arrow Canyon Well was pumped. Pumping more than 12 weeks prior to an observation has negligible effect on the predicted observation [EH4ACWresponse2.xlsx, sheet 'WeeklyMR]

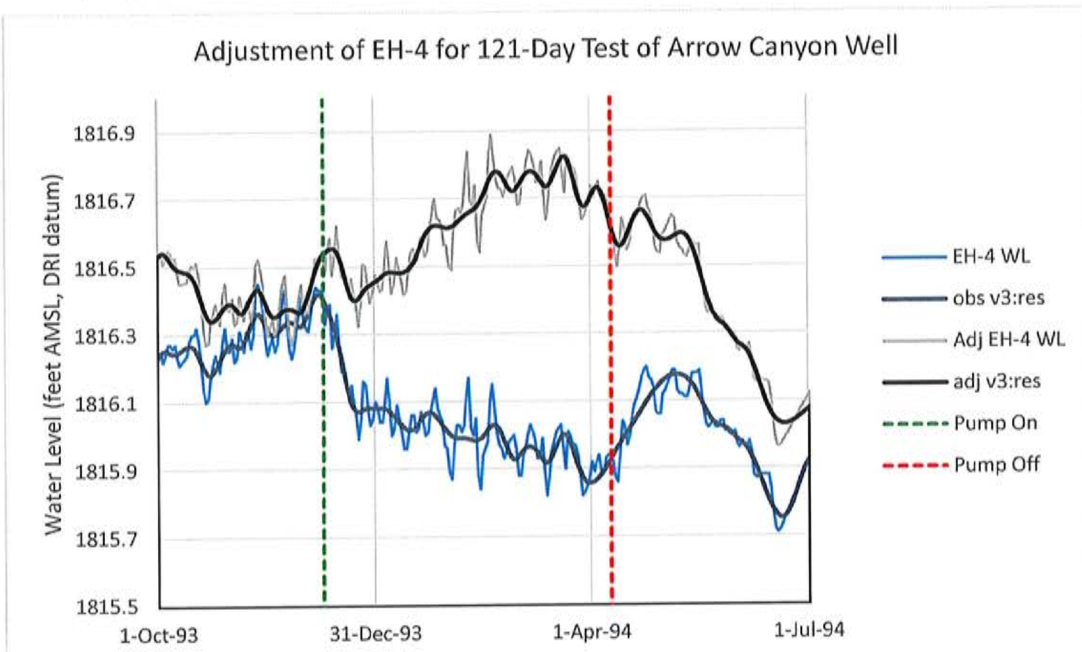


Figure 4. Raw and adjusted EH-4 hydrographs; 1994 spring water-level recovery is restored to its pristine form at EH-4 with the multiple-regression model adjustment [EH4ACWresponse2.xlsx, sheet 'AdjAllDays']

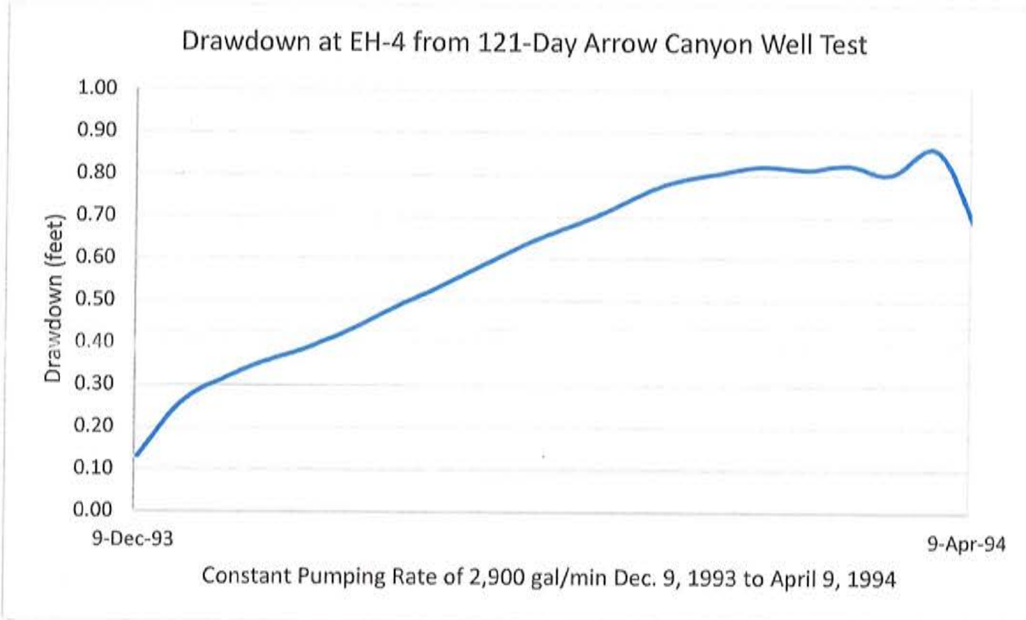


Figure 5. Drawdown derived using a multiple-regression model where weighted pumping in the current week and 12 prior weeks constitutes the explanatory variable set that produces the observed differences between MX-4 and EH-4 [EH4ACWresponse2.xlsx, sheet 'AdjAllDays']

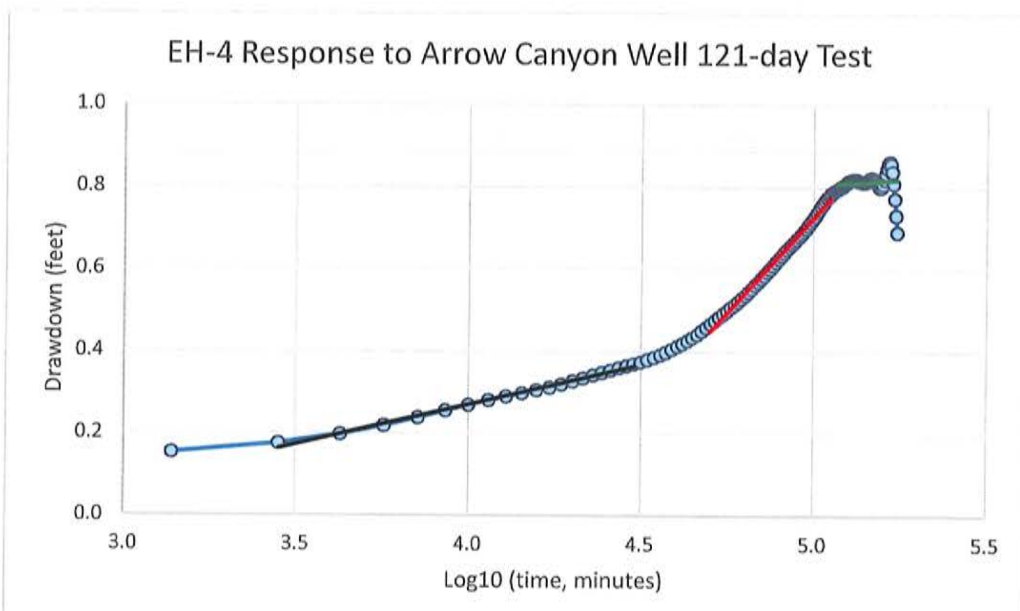


Figure 6. Aquifer-system boundaries include a less-transmissive domain encountered after 3-4 weeks of pumping (red trend line) and a recharge boundary (Muddy River?) where drawdown stabilizes (green trend line) after about 11 weeks [Buqo121dayMRmodel.xlsx, sheet 'DateDrawdown']

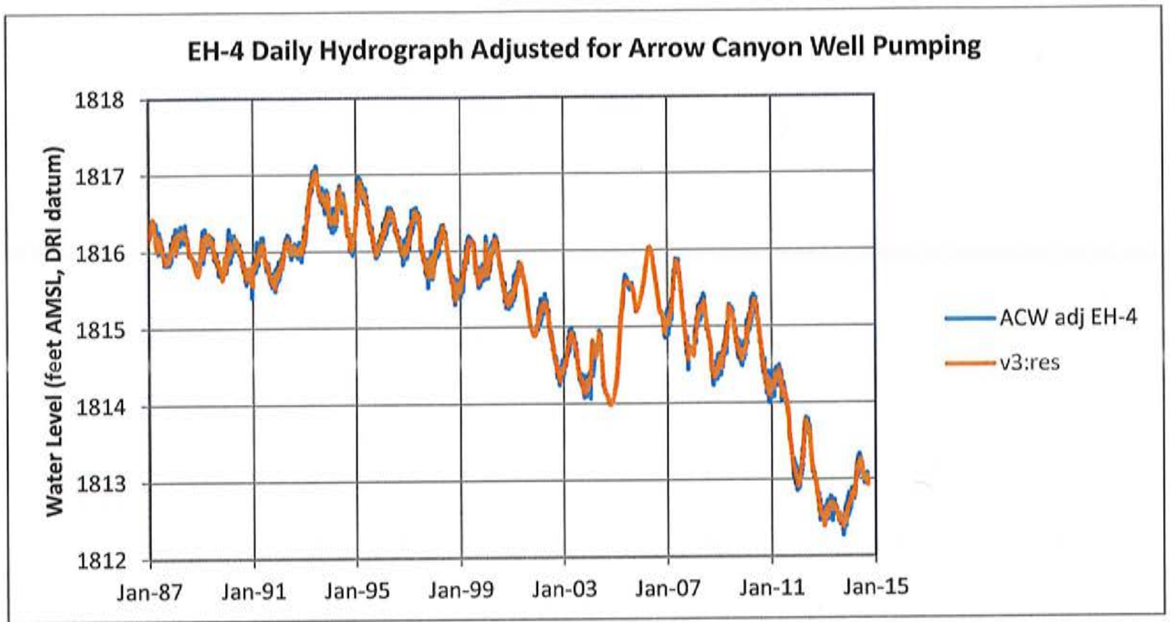


Figure 7. Historic EH-4 hydrograph cleaned of Arrow Canyon Well pumping effects. Lewis/Nevada Energy (Reid Gardner) pumping from the alluvial aquifer of the MRSA has not been shown to affect water levels in EH-4. Empirical Mode Decomposition (EMD) removes the high-frequency signal components to better illustrate the annual mode in the aperiodic climate signal that is the primary forcing agent for this hydrograph. [EH-4_AdjAll3.xlsx, sheet 'EH4cleanAdj4EMD]

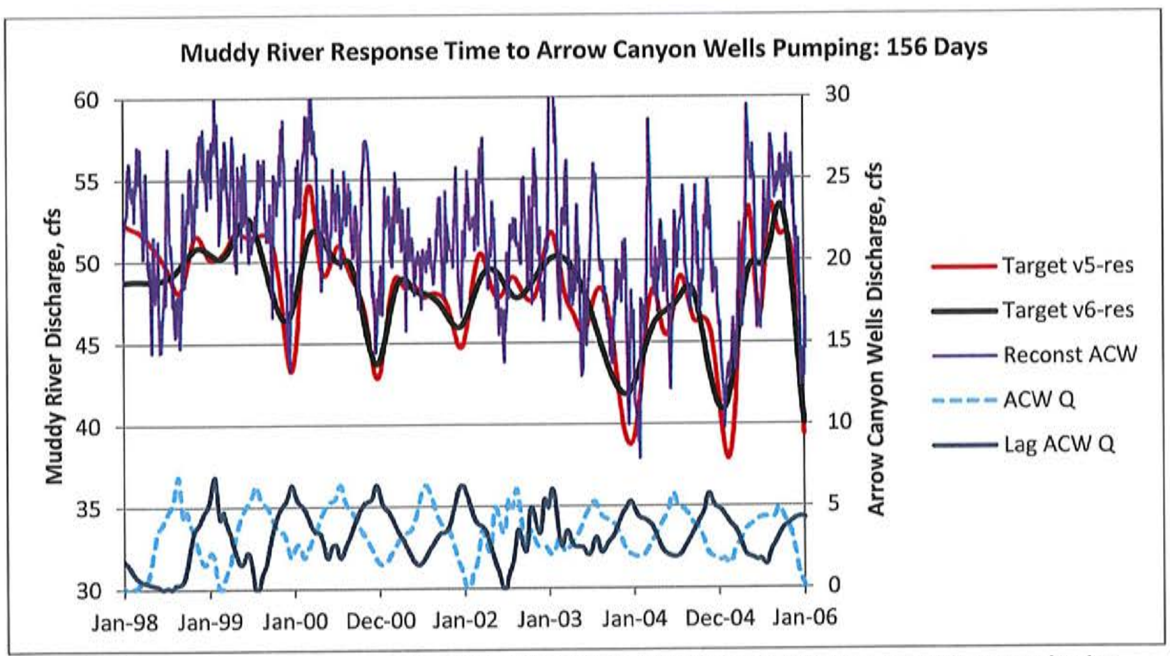


Figure 8. Alignment of pumping maxima with target (Muddy River) minima occurs with a 156-day lag and produces a reconstituted hydrograph with minimal seasonality. [ReconstSimple4.xlsx, sheet 'ACW']

Historical Perspective

Testing of the Arrow Canyon #1 well by MVWD in 1993-1994 produced controversial results in part because water levels in observation well EH-4 were affected by a poorly-constrained, seasonally-rising hydrograph during the constant-rate test (Figure 9). Figure 9 represents an early attempt to establish pumping response at EH-4 by defining a restored hydrograph as the average of 4 prior years. While the form of the restored 1993-1994 hydrograph segment in Figure 9 is close to that obtained by multiple regression and shown in Figure 4, there is no way to generalize the averaging approach to the remainder of the EH-4 water-level record, or to quantify uncertainty, and selection of which years to average is subjective (Figure 10). Now, weekly drawdown at EH-4 resulting from ACW pumping can be calculated as a straightforward function of the 13 prior weekly pumping rates.

Daily water-level measurements at EH-4 by Buqo (1994) reveal clear evidence of boundaries encountered by the second day (Figure 6) but the small (<0.2 foot) early response, lack of precise high-frequency measurements in the first minutes of the test, and lack of corresponding barometric-pressure records have delayed analysis of early response for parameter estimation. It should be possible, however, to coordinate among MRSA water users to quiet their pumps for a 48-hour re-test of Arrow Canyon #1 without interference from alluvial-aquifer pumping. Early response, whether Theis-like or conforming to another conceptual model[1] from which transmissivity and storativity can be computed, is needed.

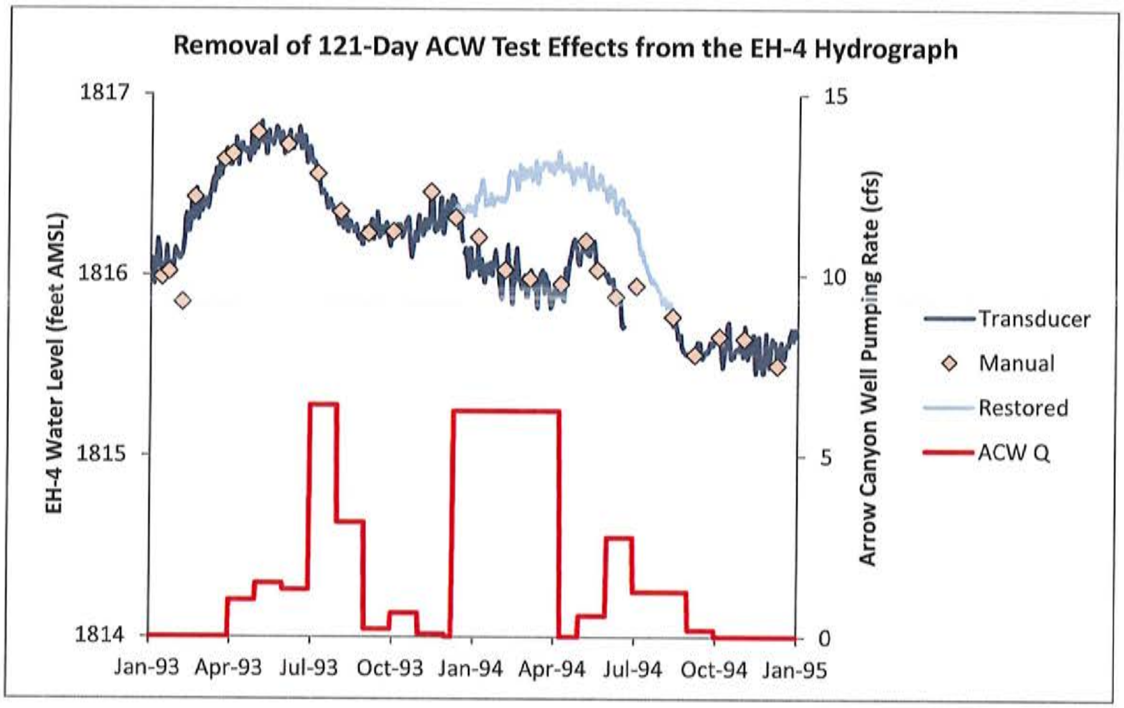


Figure 9. Average trend from 4 previous years provides a reference water level from which drawdown can be calculated, but uncertainty associated with this approach cannot be quantified. [EH4_9394.xlsx]

[1] Gringarten, A.C. and P.A. Witherspoon, 1972. A method of analyzing pump test data from fractured aquifers, Int. Soc. Rock Mechanics and Int. Assoc. Eng. Geol., Proc. Symp. Rock Mechanics, Stuttgart, vol. 3-B, pp. 1-9.

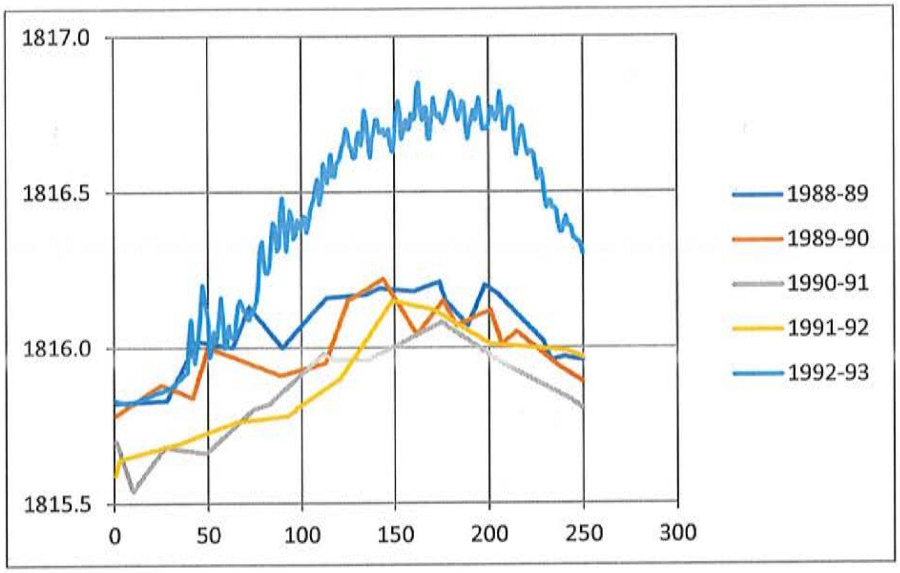


Figure 10. Interpolated daily water levels at EH-4 in years prior to 121-day test; day of year shown on X-axis. There was a much larger spring water-level rise in 1992-1993 than in the previous 4 years. Note also the concavity of the 1992-1993 hydrograph in July-August of 1993, reflecting step-drawdown testing. Whether EH-4 responses to the 121-day ACW test should be referenced to the anomalous 1992-1993 trend or the more typical seasonal trend shown in Figure 9 was a difficult issue now circumvented by the multiple regression approach. [EH4_9394.xlsx]

Appendix V:
Aquifer Analysis in Coyote Spring Valley

Cady Johnson and Martin Mifflin
Mifflin & Associates, Inc.

June 2, 2019

Pumping responses and lack of responses in Coyote Spring Valley are important indicators of aquifer characteristics, providing the information needed to choose between alternate conceptual models: (A) the LWRFS concept, in which regional water-level changes are attributed to pumping and affects 5 designated "LWRFS" hydrographic basins uniformly, or (B) a strongly anisotropic regional flow field with small regionally-interconnected porosity in Lower Paleozoic Shelf Domain rocks, with embedded but not regionally-interconnected transmissive zones that, in the case of Coyote Spring Valley, extend up-section into Mississippian carbonate rocks of the Monte Cristo Limestone, considered to be the host aquifer there. Pumping is superimposed on a climate-driven baseline.

In Coyote Spring Valley, monitoring wells MX-4 and CSVM-6 present nearly identical hydrographs in response to Order-1169 pumping in 2011 and 2012, and their recovery was complete in early 2015 (Figure 1). Remarkably, these wells are 2.6 miles apart (Figure 2). Over the long term the correspondence is striking, including nearly-identical water levels. Both hydrographs have the form of the EH-4 hydrograph (Figure 3), in which spring maximum water levels adjusted for pumping in the MAI 2016 analysis correlate with base flows of the Virgin River (North Fork) in prior years (Figure 4). Drawdown at EH-4 from Order-1169 pumping was only about half that experienced at MX-4 and CSVM-6 (Figure 5) consistent with *measured* aquifer properties (Table).

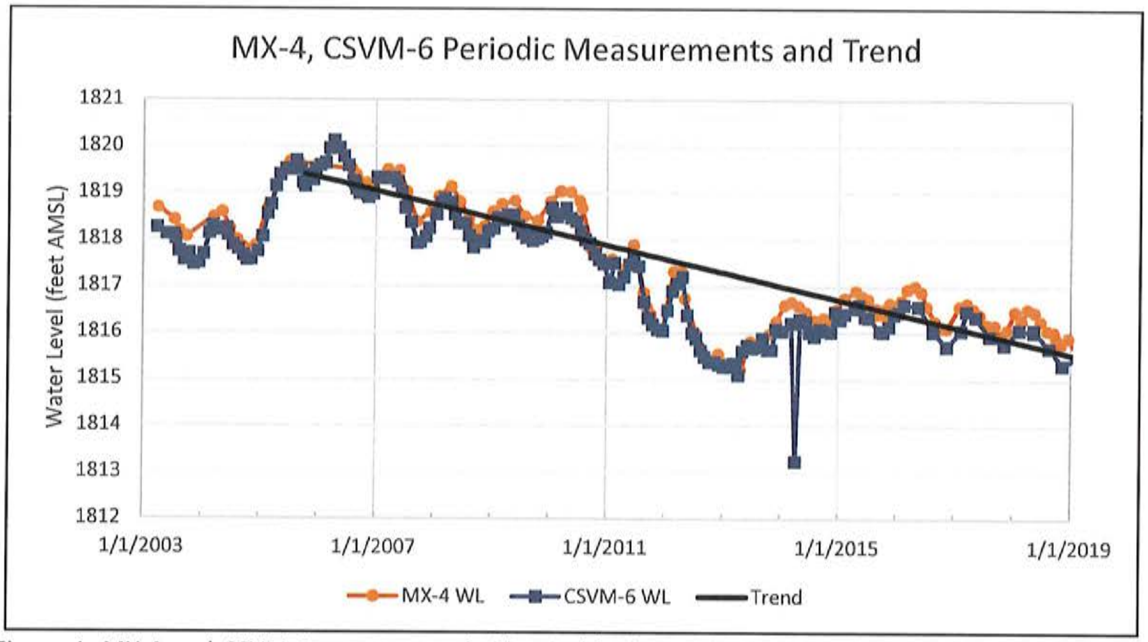


Figure 1. MX-4 and CSVM-6 present nearly identical hydrographs. Ground level is taken as the MX-4 reference; the NAVD88 elevation for MX-4 reported in the USGS NWIS database was converted to NAVD29 for plotting. [CSVM-6_Raw_Transducer_Pressure_POR]

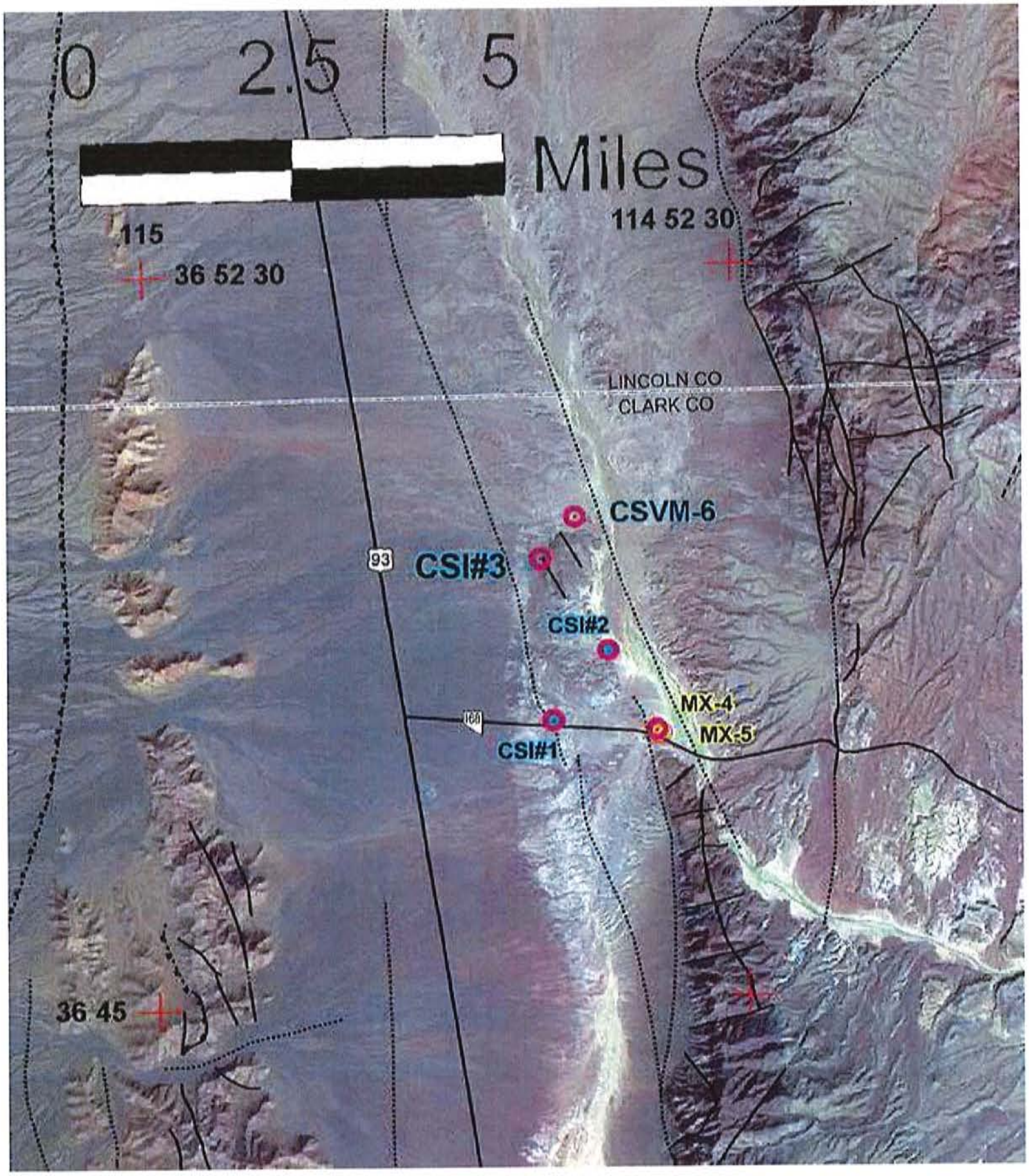


Figure 2. Locations of wells discussed in this report (modified after Johnson, 2007). Paleodischarge deposits at an elevation of 2320 feet about 0.1 mile west of CSI-3 are 500 feet higher than present-day water levels [CSI_Monitor_Points_Inset_UTM83.tif]

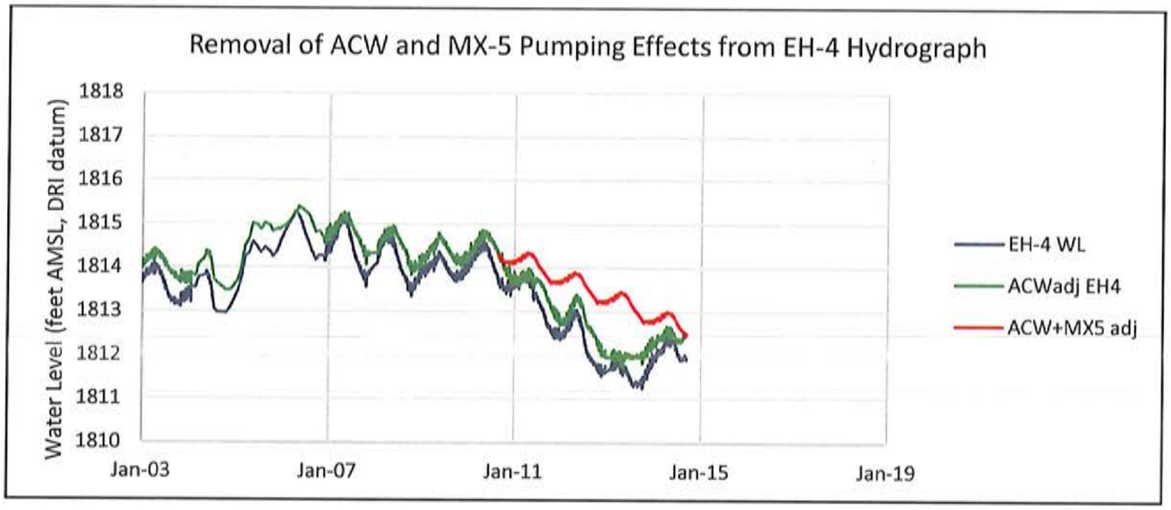


Figure 3. The dominant, aperiodic signal component in hydrographs of the CSV – California Wash area is now shown to be produced by climate, with pumping a very subtle overlay. After completing by interpolation and restoring the EH-4 hydrograph to remove pumping effects, the climatic forcing of spring (April 16 – May 15) average water levels was explored by multiple regression using annual Virgin River (North Fork) base flows as explanatory variable sets. [EH4_1169response.xlsx]

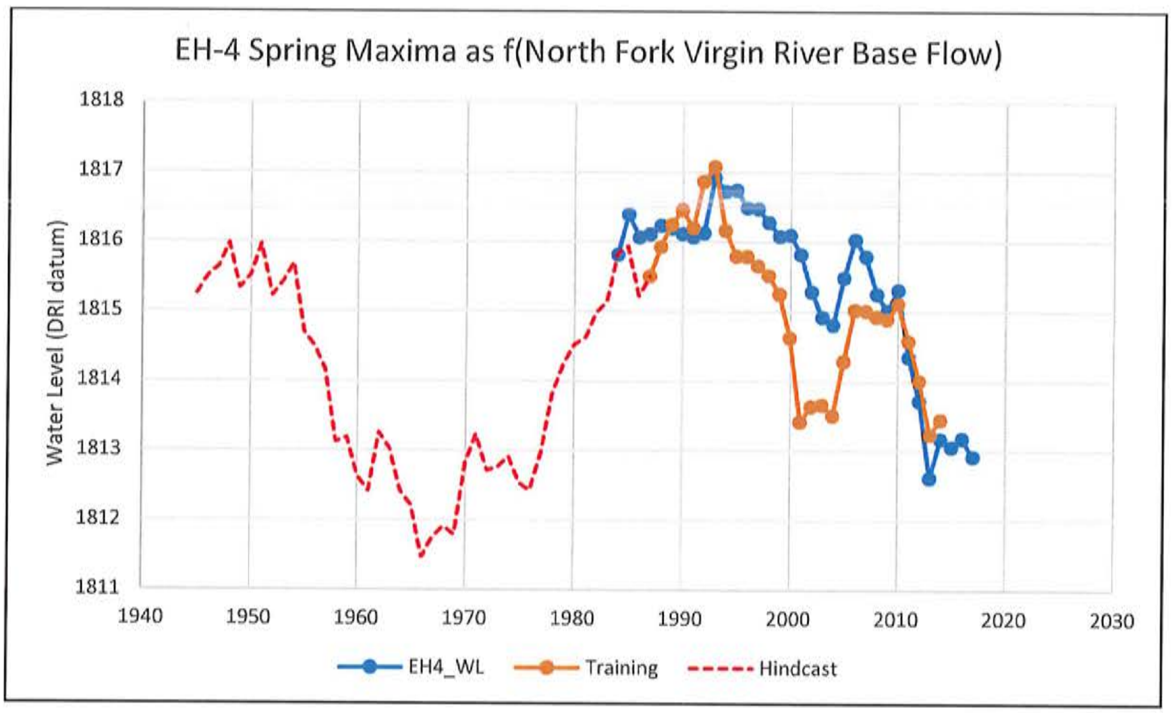


Figure 4. Multiple-regression model of adjusted EH-4 water level as a function of Virgin River (North Fork) base flows 1-16 years prior. [NFvirginBFI2update.xlsx]

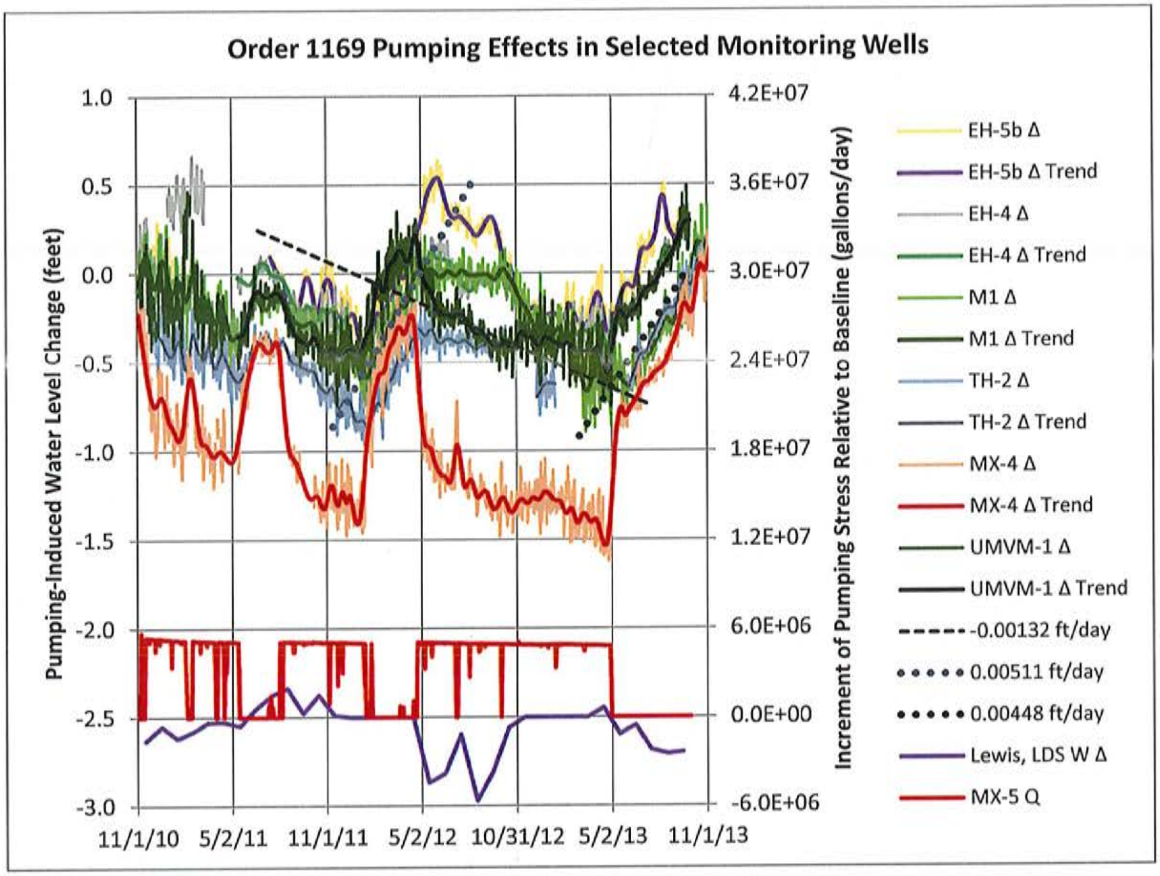


Figure 5. Analysis by Johnson and Mifflin in January 2014 for HRT, showing drawdowns derived by comparing water levels from the 2000-2004 drought [1169differenceTrends3.xlsx, sheet 'Detrend']

Table: Aquifer Parameters Derived from Early Pumping Response

Pumped	Observed	T (ft^2/day)	T (m^2/day)	Sy
MX-5	CSVM-1	956219	88,836	0.00708
MX-5	RW-2	957145	88,922	0.04486
MX-5	MX-4	1.26E+06	117,088	0.12559
RW-2	MX-4	1.75E+06	162,422	0.04469
RW-2	MX-5	3.00E+06	279,165	0.01983
	GEOMETRIC MEANS		**133,206**	**0.03233**

These observations set the stage to discuss the significance of well interference in Coyote Spring Valley, with prior knowledge of the forcing agents based on a climate-response model and a pumping-response model. These models show that climate is the driver for the long-term trends, pumping effects generally decrease with distance, and water levels fully recover after cessation of pumping. The actively-extending, fractured-rock environment creates highly-transmissive local features at least as large as the

MX-4 – CSVM-6 well spacing (2.6 miles) but on average can be no more than a few miles in length to remain non-connected as required by regional heat-flow constraints.

First consider test pumping of well CSI-3 in September 2006 (Johnson, 2007). Following development pumping and a step-drawdown test, a single-well, constant-rate test of ~3,300 gallons per minute (gpm) was conducted on September 13. Drawdown of about 60 feet occurred within an hour in the pumping well (Figure 6). The semilog plot (Figure 7) is characterized by two linear segments, with flattening indicating a recharge boundary, since delayed yield is ruled out by confined conditions at this location.

Monitoring well CSVM-6 is only 0.6 mile northeast of CSI-3, yet the raw pressure range for September 2006 is only about 0.22 psi, or 0.5 foot (Figure 8). On September 13, the hydrograph was rising throughout the day to a plateau in the evening hours, forced perhaps by barometric pressure but clearly not by CSI-3 (Figure 9). Well CSI-2 is, however, a suspect. Pumping at CSI-2 was shut down on September 13 (Figure 10) producing a 10-foot water-level rise that might have produced an 0.1 psi (0.23-foot) response at CSVM-6, 1.6 miles to the NNW.

To recap, there is very good hydraulic continuity between MX-4 and CSVM-6 along a NNW trend, but no connection or hydraulic continuity exists between CSI-3 and CSVM-6 along a NE trend. These relations suggest a strongly anisotropic system, and CSI-1 offers additional evidence.

Between the months of November 2005 and June 2006 inclusive, CSI-1 was the only large production well in Coyote Spring Valley that was pumping (Figure 11). CSVM-6, 2.4 miles NNE of CSI-1, was being monitored and, except for a mid-December – mid-January data gap, produces a detailed water-level record (Figure 12). We suspect that CSVM-6 responds to CSI-1 pumping. Prior to April 2006, when CSI-1 pumping rate doubled, the antecedent trend was linear, and in May 2006 a telltale concave-upward segment of the hydrograph begins to develop, 0.5 foot of drawdown relative to the antecedent trend.

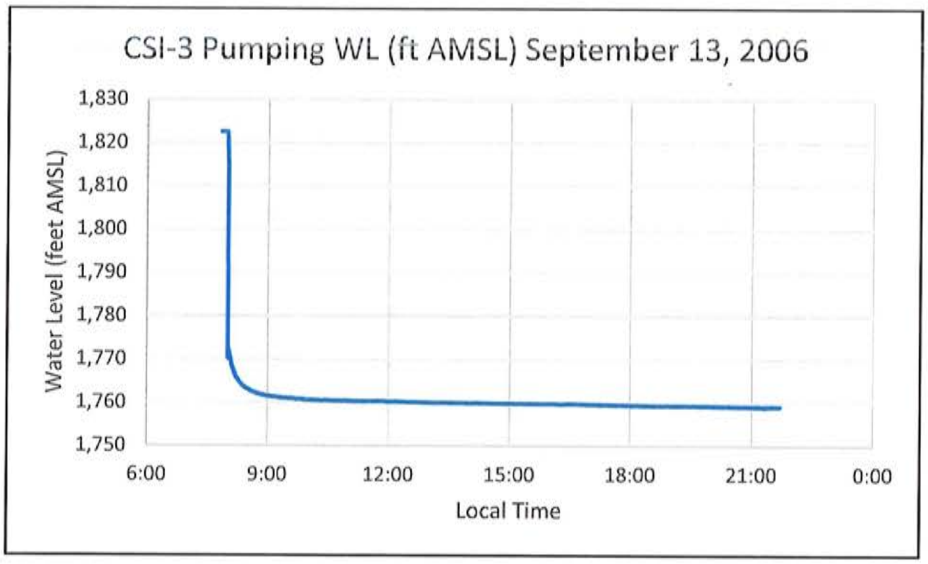


Figure 6. Drawdown at CSI-3 during ~3,300 gpm constant-rate test of September 13, 2006 [CSI#3data Appendix D_cj.xlsx]

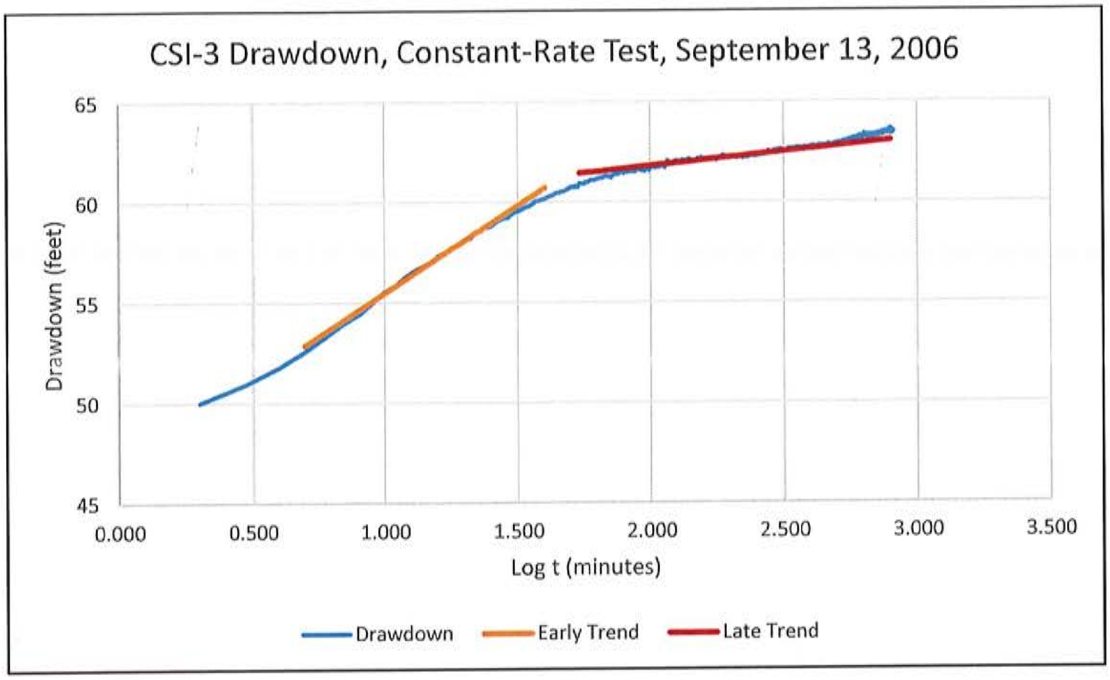


Figure 7. Response in pumping well CSI-3 suggests recharge boundary [CSI#3data Appendix D_cj.xlsx]

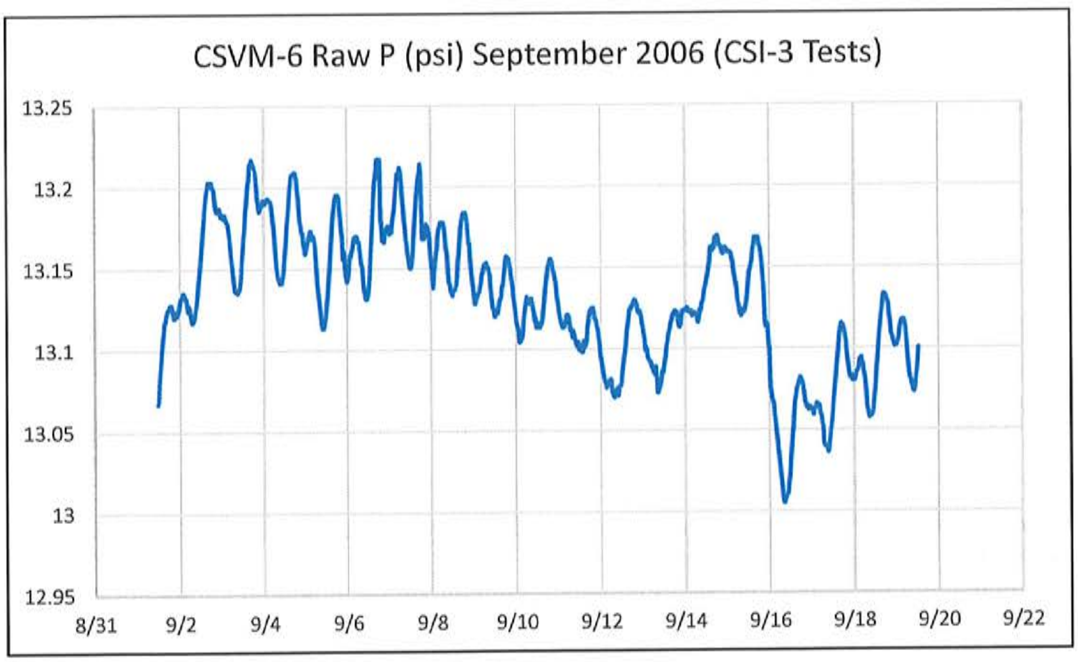


Figure 8. Uncorrected CSVM-6 pressure record from September 2006, when initial aquifer-testing was conducted at CSI-3, 0.6 mile to the SW. The rising hydrograph on September 13 occurred while CSI-3 was being pumped at ~3,300 gal/min for a constant-rate test. [CSVM-6_Raw_Transducer_Pressure_POR]

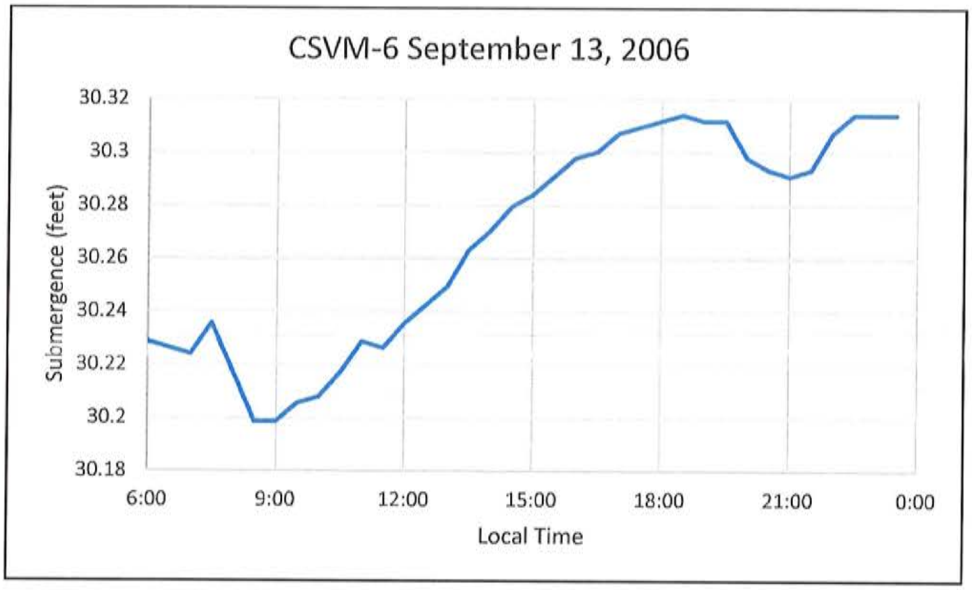


Figure 9. Uncorrected submergence at CSVM-6 (no B.P. adjustment) [CSVM-6_Raw_Transducer_Pressure_POR.xlsx]

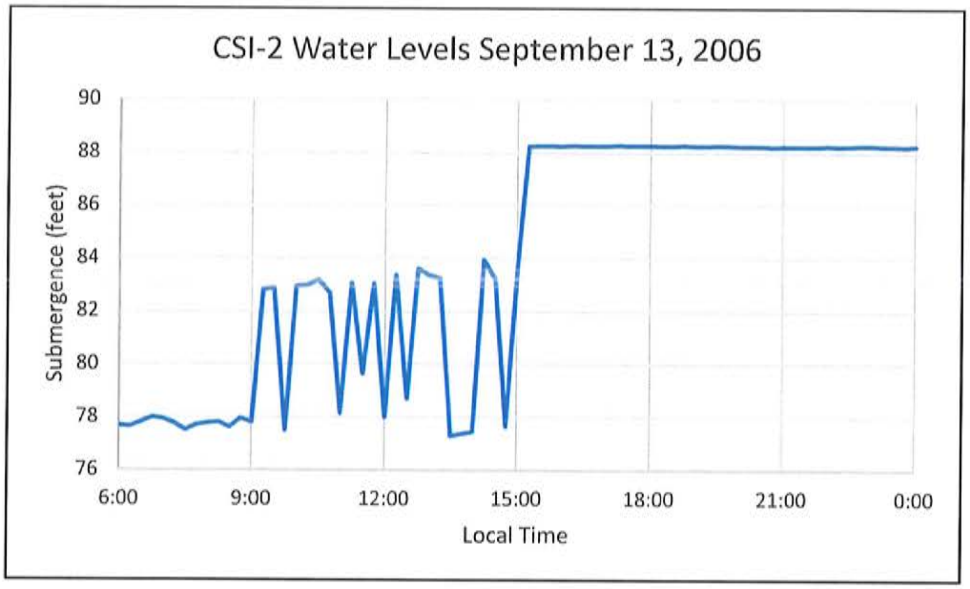


Figure 10. Recovery of water levels at CSI-2 following cessation of pumping during the CSI-3 constant-discharge test [CSI-2_Raw_Pressure_Data_POR_cj.xlsx]

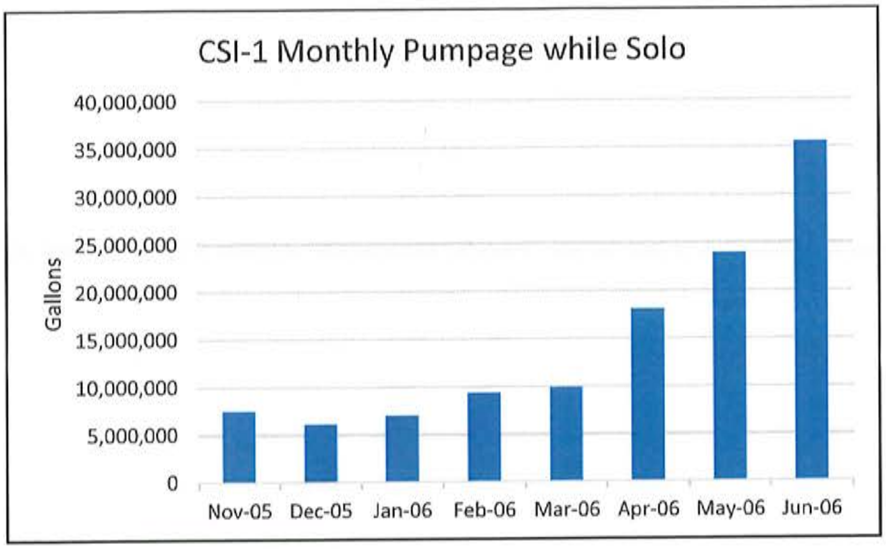


Figure 11. Monthly pumping rate from CSI-1 for the 8 months it was the only CSI production well in service [CSVM-6_Raw_Transducer_Pressure_POR]

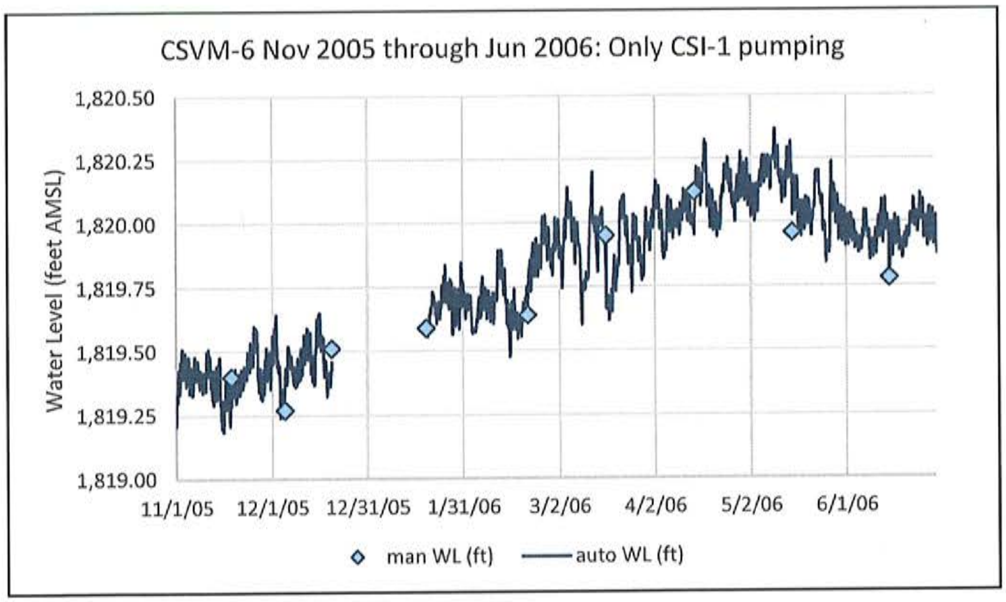


Figure 12. Water levels based on MAI cable-length regression procedure using periodic measurements, for the period when the only credible pumping influence was CSI-1, 2.4 miles SSW of CSVM-6. [CSVM-6_Raw_Transducer_Pressure_POR]

A sinuous anisotropy field (Figure 13) best explains the relationships described above, in which the CSI-3 production well is largely hydraulically-isolated from 3 neighboring CSI wells that are not isolated from one another. By inference, those 3 wells must sense MX-5's pumping effects and CSI-3 must not. It has not been possible to suggest a single ellipse of anisotropy to central Coyote Spring Valley absent unambiguous pumping response from which transmissivity (T) and storativity (S) could be calculated. The clearest relations, which should be very helpful with respect to assessing risks from future CSI production,

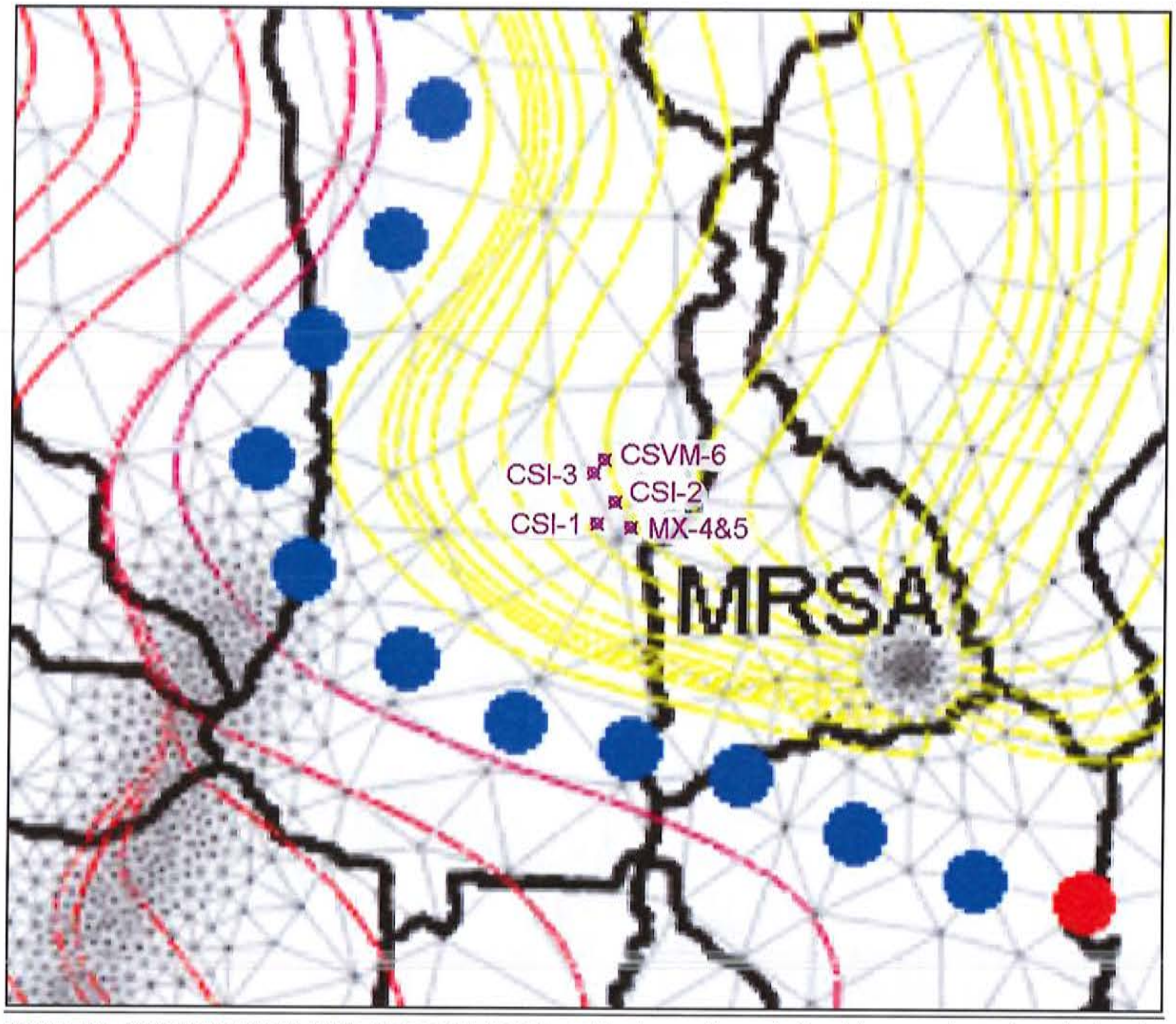


Figure 13. Locations of CSI wells discussed herein, with streamlines derived from a strongly anisotropic regional scoping model (described in separate reporting) suggesting local anisotropy, possibly fault-related. The ellipse of anisotropy is an algebraic concept to explain the association of MX-4 and CSVM-6 as aligned NNW-ESE with the most transmissive axis, but isolation of CSI-3 is indicated because detectable pumping effects are not transmitted from there northeastward to CSVM-6 along the least transmissive axis of the conceptual ellipse. Blue dots indicate a hydrodynamic divide between Las Vegas and MRSA regional spring capture zones, and the red dot is a stagnation point in the MAI scoping model. Refined mesh in the lower left is to represent the Sheep Range recharge area; note how some streamlines representing tributary flow to Las Vegas Valley originate there. [CSIwellsStreamlines2.jpg]

are very high T in the NNW-SSE zone containing MX-4, MX-5, and CSVM-6, and very low T in the perpendicular direction between CSI-3 and CSVM-6. *There has been no demonstrable or even suggestable interference between CSI-3 and any other CSI or MX well in any of the test configurations reviewed here.* It is a distinct possibility that CSI-3 was completed in a different local aquifer compartment than many wells and springs characterized by hydrographs of the Figure 1 form, though Figure 13 suggests, from a regional perspective, that climate effects and therefore the baseline hydrograph should be similar among wells in Coyote Spring Valley, high-elevations springs of the southern MRSA, and northernmost California Wash Basin.

Discussion

Periodic water-level measurements at CSVM-6 (Figure 1) illustrate the 3 main intervals of pumping MX-5 during the Order-1169 test, with full recovery to the trendline after the first and third intervals, and almost complete recovery after the second. Two years were required for the aquifer to fully recover after the test concluded, symmetrical with the pumping cycle. In 2007 and 2008, when the heaviest pumping by CSI to date occurred (Figure 14), the amplitude of the annual cycle (Figure 1) was slightly greater than in 2003-2004 when there was no CSI pumping, but less than double the amplitude of those early years. CSI-2 was in service both years, with CSI-3 replacing CSI-1 in WY 2008. The well change plus a 38% reduction in CSI-2 pumping renders CSI effects on the long-term hydrograph almost imperceptible by 2008. Alluvial pumping by Nevada Energy cannot be blamed for the annual mode of periodicity, for the cycle remains in 2017-2018 after cessation of Nevada Energy pumping from the alluvial aquifer in the MRSA.

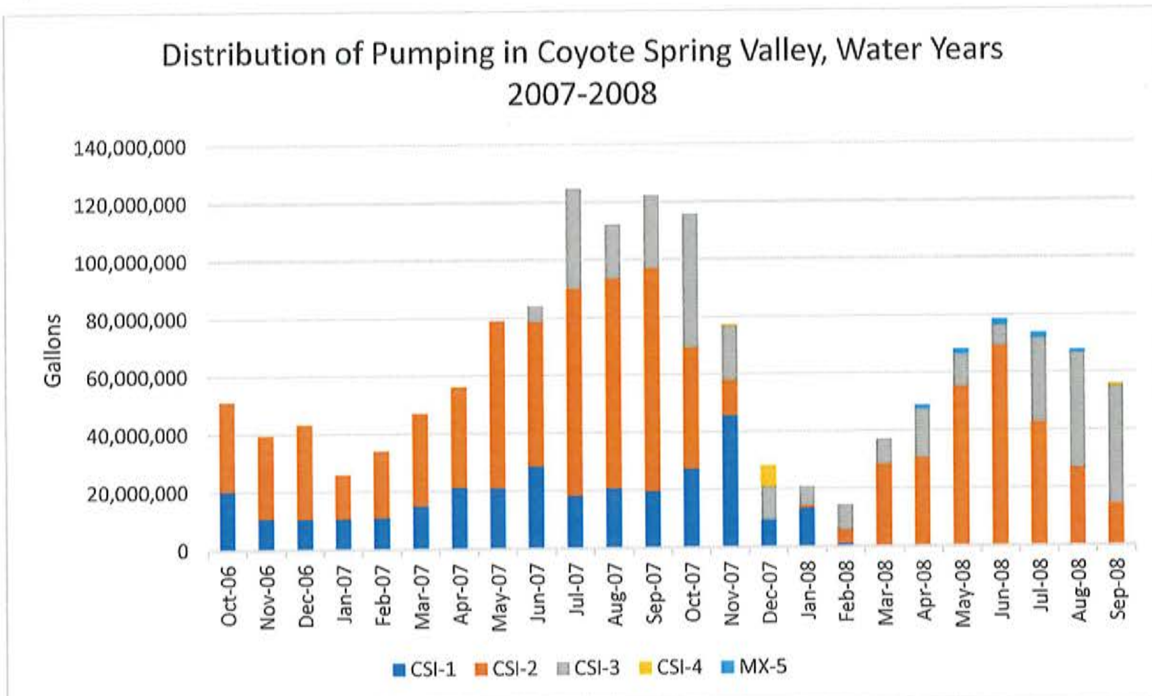


Figure 14. Pumpage in Coyote Spring Valley, Water Years 2007-2008. [Order_1169_Monthly_Pumpage (Apr19).xlsx]

MAI's successful correlation of spring maxima in the pumping-adjusted EH-4 hydrograph (Figure 4), which is of the same form as CSVM-6, with base flow of the Virgin River (North Fork, a climate proxy), provides a climate-based model for the hydrograph absent pumping. A homogeneous but variably anisotropic, heat-constrained, regional capture-zone model with embedded but regionally noninterconnected fracture systems appears to be the simplest and therefore most conceptually-useful modeling approach currently available.

Because the structural grain is highly variable, MODFLOW grids (and for that matter finite-difference codes in general) are inadequate for tracking regional groundwater flow and heat redistribution in the central and southern Great Basin. Instead, finite-element analysis of coupled water and heat transport is the appropriate study framework. With evidence accumulating that regional spring discharge in the MRSA varies in isotopic composition, as would be expected if matrix diffusion along groundwater flow paths does not wipe out all evidence of climate history in the recharge areas, the modeling environment replacing MODFLOW should be comprehensive enough to include flexible options for representing fracture networks, plus diffusion and chemical retardation (solute transport) processes and radioactive decay.

Reference

Johnson, M.E., 2007. Drilling and Development of CSI Well No. 3 for Coyote Springs Investment LLC, Coyote Spring Valley, Clark County, Nevada: unpublished consulting report, 94 p.

Rebuttal Report of Moapa Band of Paiutes

in Response to Stakeholder Technical Reports Filed under Order #1303

Cady Johnson and Martin Mifflin
Mifflin & Associates, Inc. (MAI)

August 16, 2019

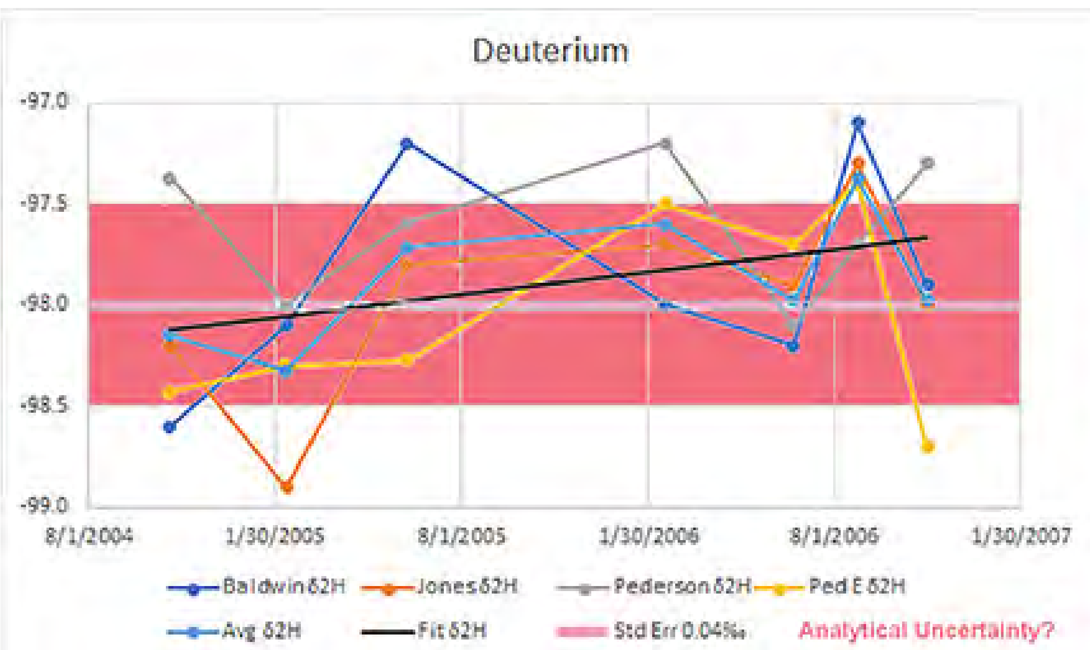
Two analytical problems need to be overcome to establish sustainable groundwater resource development in the Carbonate-Rock Province of Nevada which includes the LWRFS subregion. The most difficult is to recognize and separate groundwater pumping impact (drawdowns) from climatically-induced multi-year drought declines in monitoring records. The associated problem is to determine where and how much of the groundwater resources can be sustainably developed without major impacts on the regional discharge in areas related to interbasin flow systems (e.g. MRSA).

SNWA and USFWS have continually conflated climate effects with pumping impacts. Water-level decline does not equate to drawdown, which is the component of water-level decline attributable to pumping. Without quantitatively referencing a representative storage coefficient for the MRSA, or citing an aquifer test or thermal model from which porosity might be estimated, SNWA (in Burns et al. 2019, pp. 6-11) states that "…a reduction in MRSA discharge from predevelopment conditions can be considered equivalent to a volume of groundwater withdrawn from the carbonate aquifer" and "[i]n the long term, the location of the production wells does not matter, groundwater withdrawn anywhere within the connected carbonate aquifer or the MRSA alluvial reservoir will impact the MRSA discharge and, consequently, deplete Muddy River streamflow." Every aquifer test to date has proven these statements to be incorrect, including the Order 1169 test when climate effects are recognized and filtered out.

SNWA and USFWS have both committed to a modeling environment that relies on a controversial and unverified geologic framework (SNWA, 2009; Burns and Drici, 2011). Swanson and Wernicke (2017 and references therein) present a very different kinematic model with hydrogeologic implications that have not been considered by SNWA, such as the hydrogeologic significance of the ramp syncline of the Mormon Thrust beneath the Meadow Valley Mountains and Meadow Valley Wash. SNWA has not even attempted to explain the hydrogeologic reasons why groundwater discharges in the MRSA. Is a lateral ramp in the Muddy Mountains – Mormon thrust responsible for impeding southward groundwater flow? The phrase "detachment fault" does not appear in the text of SNWA's Order 1303 report, though it does appear in the legend to their Figure 3-1, "Hydrogeologic Map of the Lower White River Flow System", which is nearly devoid of detachment faults and therefore itself indicative of important geologic framework model errors in light of Swanson and Wernicke (2017).

SNWA and USFWS consider "climate of the LWRFS" to be Nevada Division 4 Extreme Southern climate. This fails to consider that most groundwater discharging in the MRSA has a more northerly origin, as evidenced by regional topography, hydraulic gradients, groundwater temperatures, isotopic evidence, and our successful correlation of Big Muddy Spring discharge with a proxy for Division 2 (Northeastern) climate. The inadequacy of Nevada's low, southern basins to sustain the warm springs at the MRSA and elsewhere has been understood since the time of Eakin (early 1960s), and substantial winter snowpacks occur only far to the north and at the higher elevations most years.

USFWS and SNWA have not addressed the significance of stable-isotope trends in the MRSA. USFWS references Thomas and others (1996) and the Kirk and Campana (1990) discrete-compartment model, using the phrase "It is well established that…" repeatedly with respect to what are in reality poorly-understood boundary conditions. E.g., USFWS 2019, pp. 9, 11. Most notably, neither USFWS nor SNWA have acknowledged the significance of stable-isotope trends in the MRSA (Figures 1 and 2). These enigmatic 3-year trends fit a cooler and dryer (evaporating) recharge environment at the end of the 3 years relative to initial conditions, and strongly suggest rapid (decades) signal propagation through the regional system. The study by Reynolds and Jefferson (2014) reports a standard error of 0.01‰ for $\delta^{18}O$ and 0.04‰ for $\delta^{2}H$ using a Picarro L-2130*i* isotope analyzer at Kent State University, far less than the "analytical uncertainty" claimed by SNWA.



<u>Figure 1</u>. Time-series of MRSA Deuterium trend, indicating Standard Error of 0.04‰ and analytical uncertainty of 1‰ [DOtrends.xls, DeuteriumStdErr.jpg]

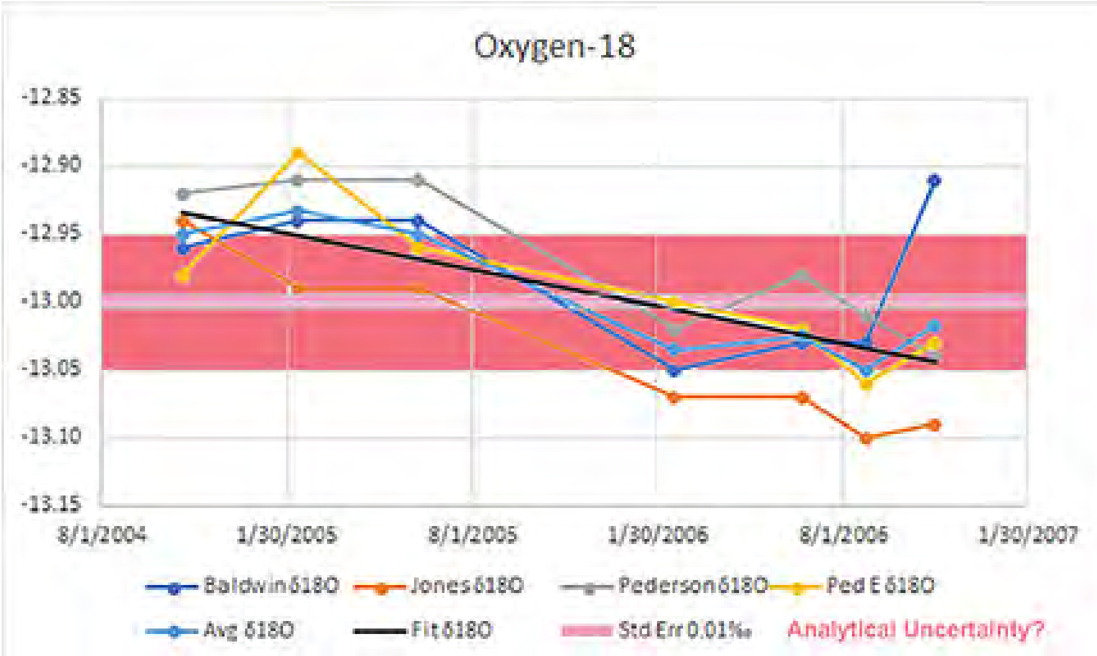


Figure 2. Time-series of MRSA ^{18}O trend, indicating Standard Error of 0.01‰ and analytical uncertainty of 0.1‰ [DOtrends.xls, O18stdErr.jpg]

The alluvial aquifer within the MRSA receives transmission losses from ephemeral flows in Pahranagat Wash, amounting to roughly 0.4% of total flow based on five years of monitoring storm runoff in conjunction with Muddy River discharge. Two analyses appended to this report (Johnson 2011, 2019) document the only quantitative record of infiltration in the MRSA. The Muddy gains downstream of the MRSA between the Moapa Gage and Glendale gage a historical average of about 2 cfs, while California Wash is barren of saturated alluvium with only minor transmission losses to the Muddy Creek Formation underlying the Wash. USFWS has relied extensively on "simple inspection" of water-level hydrographs (USFWS, 2019, pp. 9 and 11) is little more than an assumption that all is pumping-related. The idea that LDS-Central and LDS-East are receiving alluvial inflows from Lower Meadow Valley Wash (USFWS, 2019, p. 11) is preposterous based on elevations (simple inspection of a topographic map) and contradictory stable-isotope facts.

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US Fish and Wildlife Service, 2019. Issues Related to Conjunctive Management of the Lower White River Flow System: Presentation to the Office of the Nevada State Engineer in Response to Order 1303.

Discussion of MRSA Alluvial Aquifers

Cady Johnson
Mifflin & Associates, Inc.

July 18, 2019

USFWS was wise to reconsider the February 7, 2001 seepage run (Beck and Wilson, 2006) and alluvial inflows that might occur below the Moapa Gage (09416000). The approved USGS record (Figures 1 and 2) shows nominally 1.9 cfs of gain between the Moapa Gage and Glendale (09419000) on that day, all attributable to tributary inflow from Meadow Valley Wash where alluvial gravels were developed then abandoned as an industrial water source due to poor quality. The median daily discharge for the 79-year period of record at the Moapa gage is 44 cfs, and the median discharge at Glendale is identical, 44 cfs, based on 69 years of record (Figures 1 and 2). Deterioration of water quality in the Muddy River immediately below Reid Gardner Station and the former Hidden Valley Searles dairy farm upstream from the Meadow Valley Wash confluence does not reflect inflow from California Wash, which is barren of water-bearing alluvium, and is more likely the signature of industrial and/or agricultural influences.

A more significant result of the 2001 "seepage run" (Beck and Wilson, 2006) was the discovery that water quality in the main-stem Muddy River improved significantly between September of 1963,

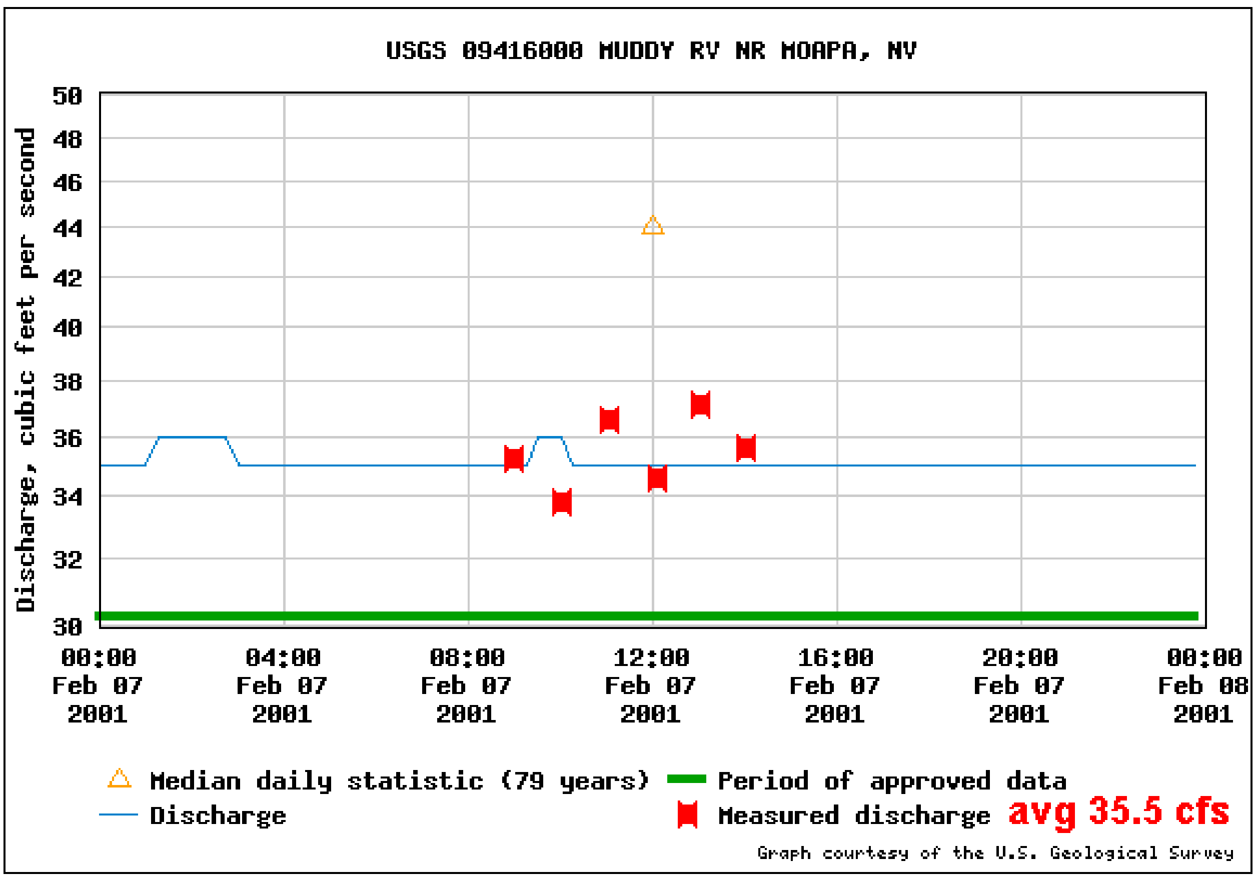

Figure 1. Muddy River discharge at Moapa Gage, February 7, 2001. [MoapaGage20010207.tif]

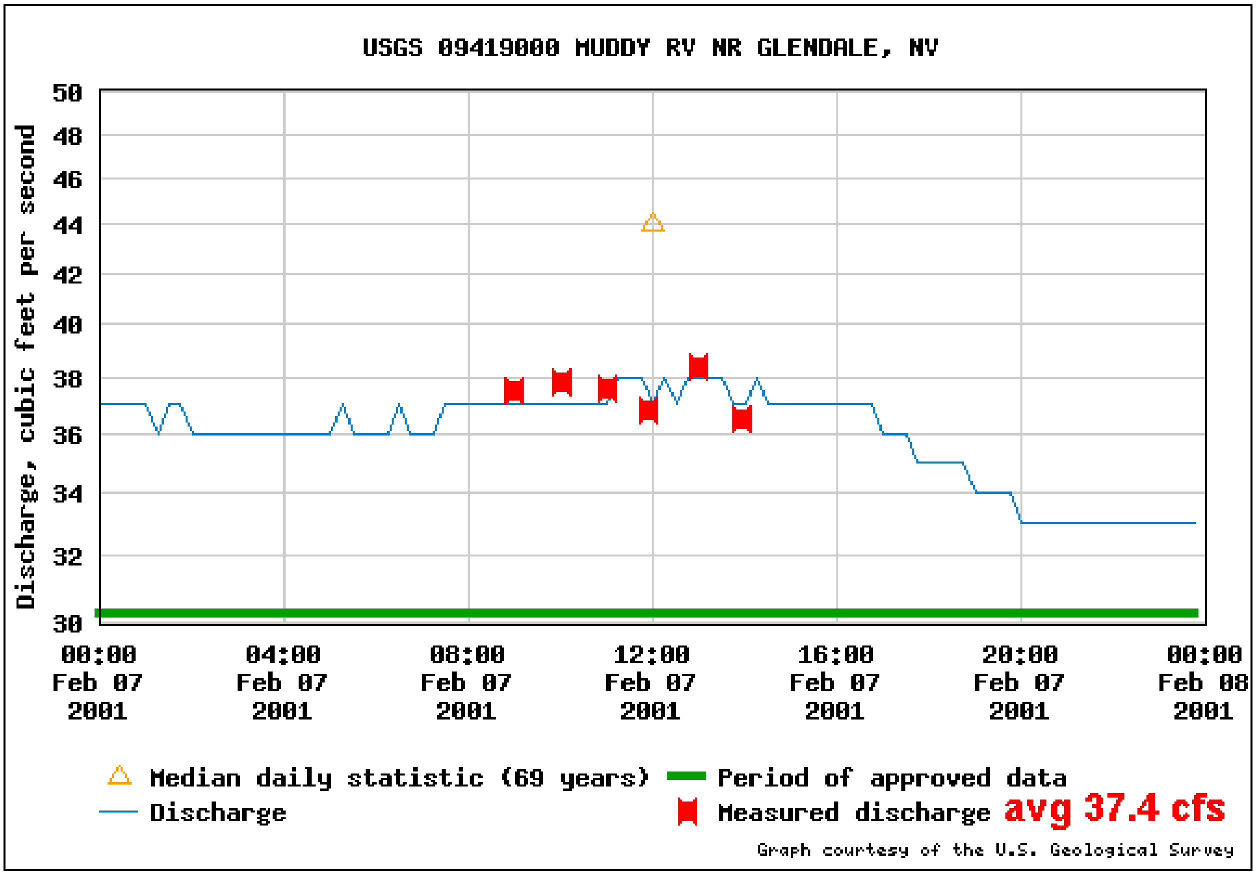

Figure 2. Muddy River discharge at Glendale gage, February 7, 2001 [Glendale20010207.tif]

when flood irrigation was widespread in Upper Moapa Valley, and February of 2001, when Nevada Power Company was exporting groundwater from the Lewis, LDS, Behmer, and Perkins wells to Reid Gardner Station during the summer months. Electrical conductivity (EC, µS/cm) decreased from 1,290 µS/cm in 1963 (Eakin's site 27) to 988 µS/cm in 2001 (Beck and Wilson's site 09415885), an improvement of over 22% immediately upstream of Big Muddy Spring where fields formerly irrigated by the LDS wells were fallowed in 1987. The improvement carries downstream to the Moapa Gage (09416000) where EC decreased from 1,120 µS/cm in 1963 to 1,020 µS/cm in 2001, an improvement of about 9% and proportional in terms of flows to the changes upstream of Big Muddy. Dissolution of halite, mirabilite, and gypsum in irrigated soils accounts for the pre-1987 elevated Cl^-, SO_4^{2-}, and Na^+.

As shown in Figure 3 (reproduced from Burns and Drici, 2011), beneath "Quaternary-Tertiary sediments" of exposed Muddy Creek Formation SNWA asserts there is carbonate rock "likely" to transmit inter-basin flow to California Wash and Hidden Valley. In contrast, Johnson and Mifflin (2003) believe that the MRSA owes its existence to a transmissivity decrease encountered by southward-flowing groundwater (Figure 4). The MRSA alluvial aquifer is recharged from below by warm, upwelling groundwater that constitutes the base flow of the Muddy River as registered at the Moapa Gage. Temperature monitoring by MAI for Nevada Power Company in the Lewis Well Field area illustrates the vanishingly small (~0.4%) contribution of storm runoff from Pahranagat Wash to the MRSA alluvial aquifer (Figures 9 and 10), and the insensitivity of groundwater temperatures there to pumping from Muddy River alluvium (Johnson and Mifflin, 2013, Appendix D and appended 2011 report here).

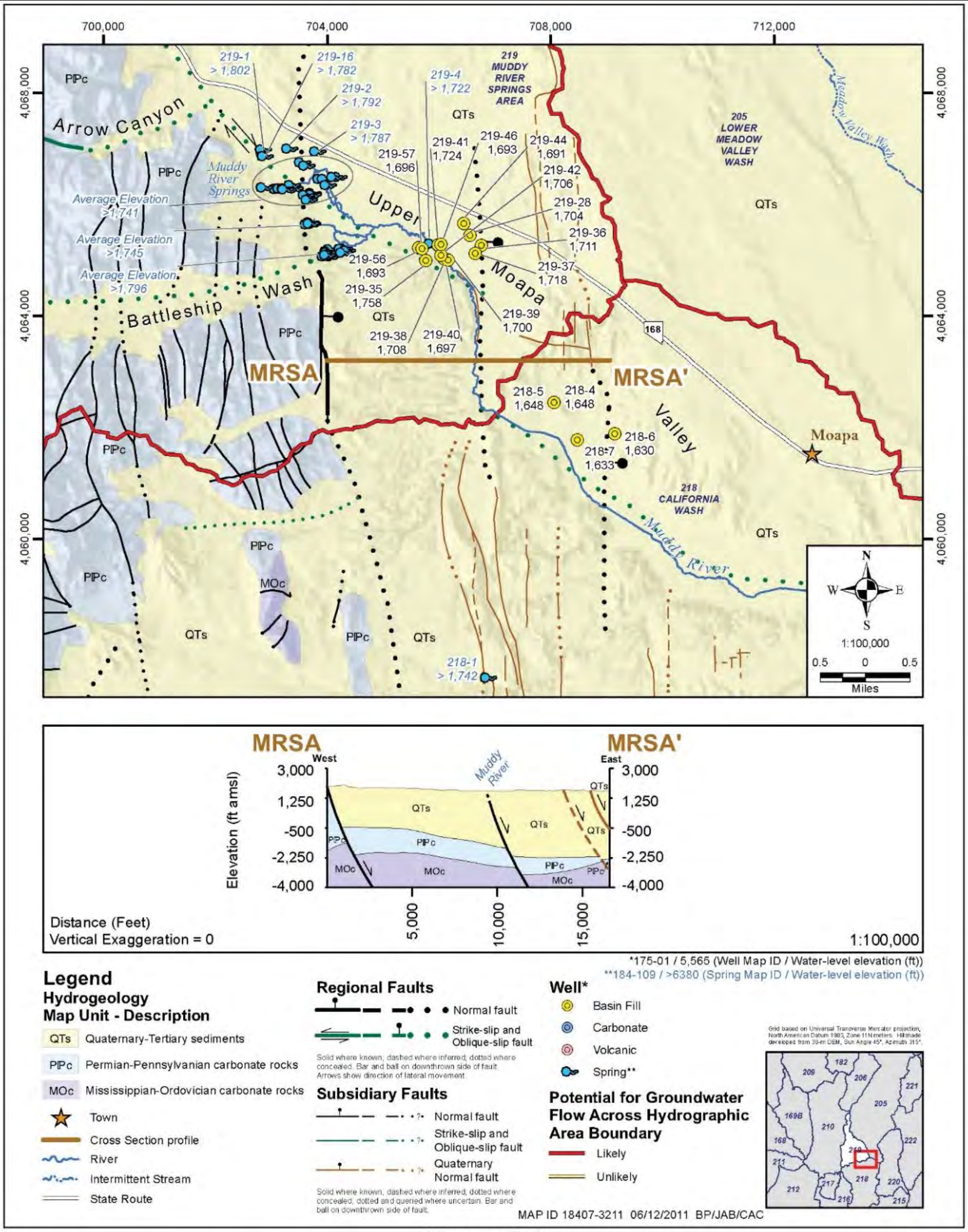

Figure E-4
Interbasin Groundwater Flow from MRSA to California Wash

SNWA Exhibit 258

Figure 3. No limitations to interbasin flow are identified by SNWA south and east of the MRSA [SNWA_Exh_447_Slide_Show_Burns_and_Drici_2nd.pdf]

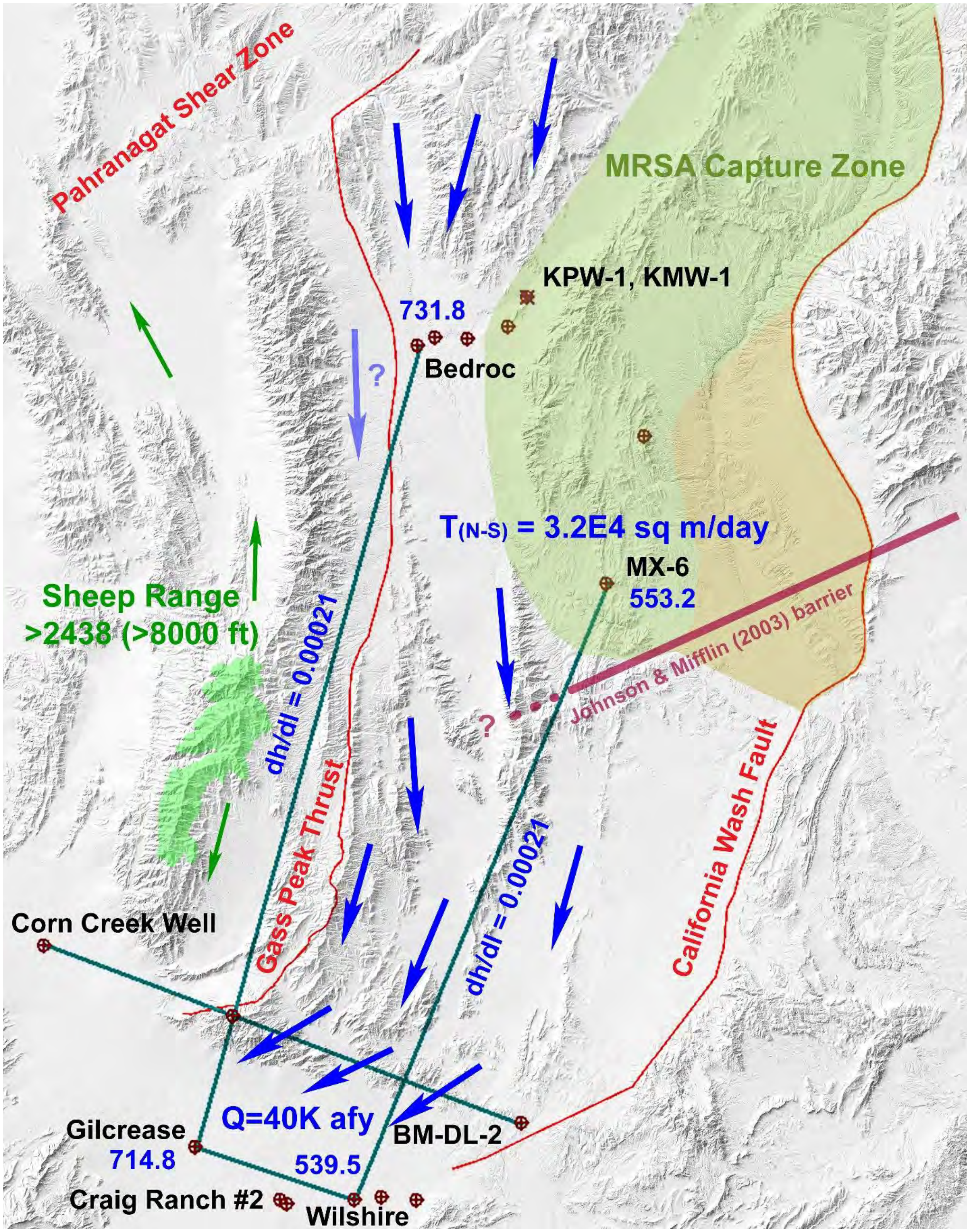

Figure 4. Conceptual model for groundwater system in terminal "LWRFS" flow corridor, with bounding faults from Felger and Beard (2010). Blue arrows indicate regional flow, green for local. Craig Ranch #2 water is among isotopically lightest in Las Vegas Valley (-106 D, -14.5 $\delta^{18}O$) [GFLOWscreenSR83small.jpg]

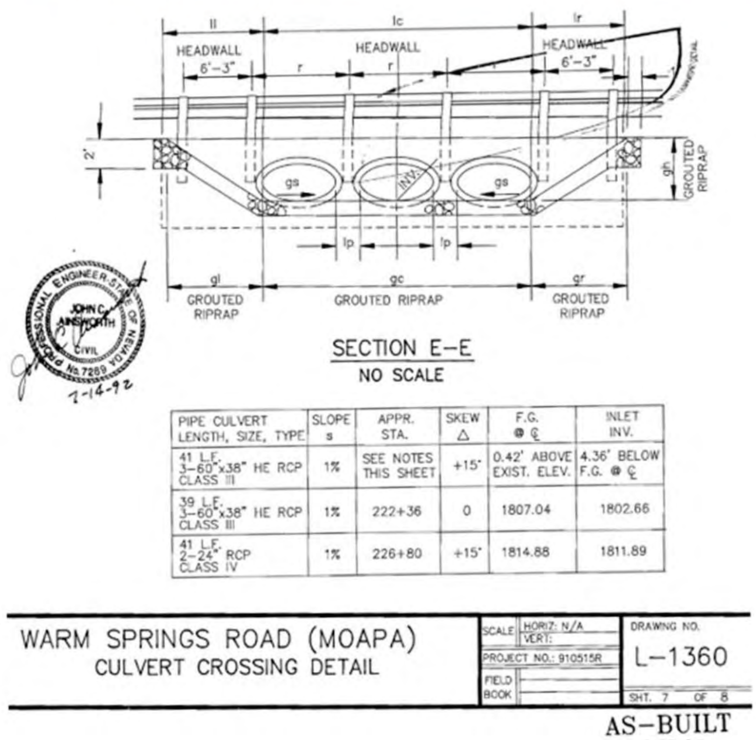

Figure 5. Recession conditions in Pahranagat Wash at Warm Springs Road crossing, December 25, 2010, 7:49 AM PST, flowing 56 cfs based on Manning Equation, water temperature 7^{o}C. Note waterline, dry surroundings, blue sky. [CulvertAndDetail.jpg]

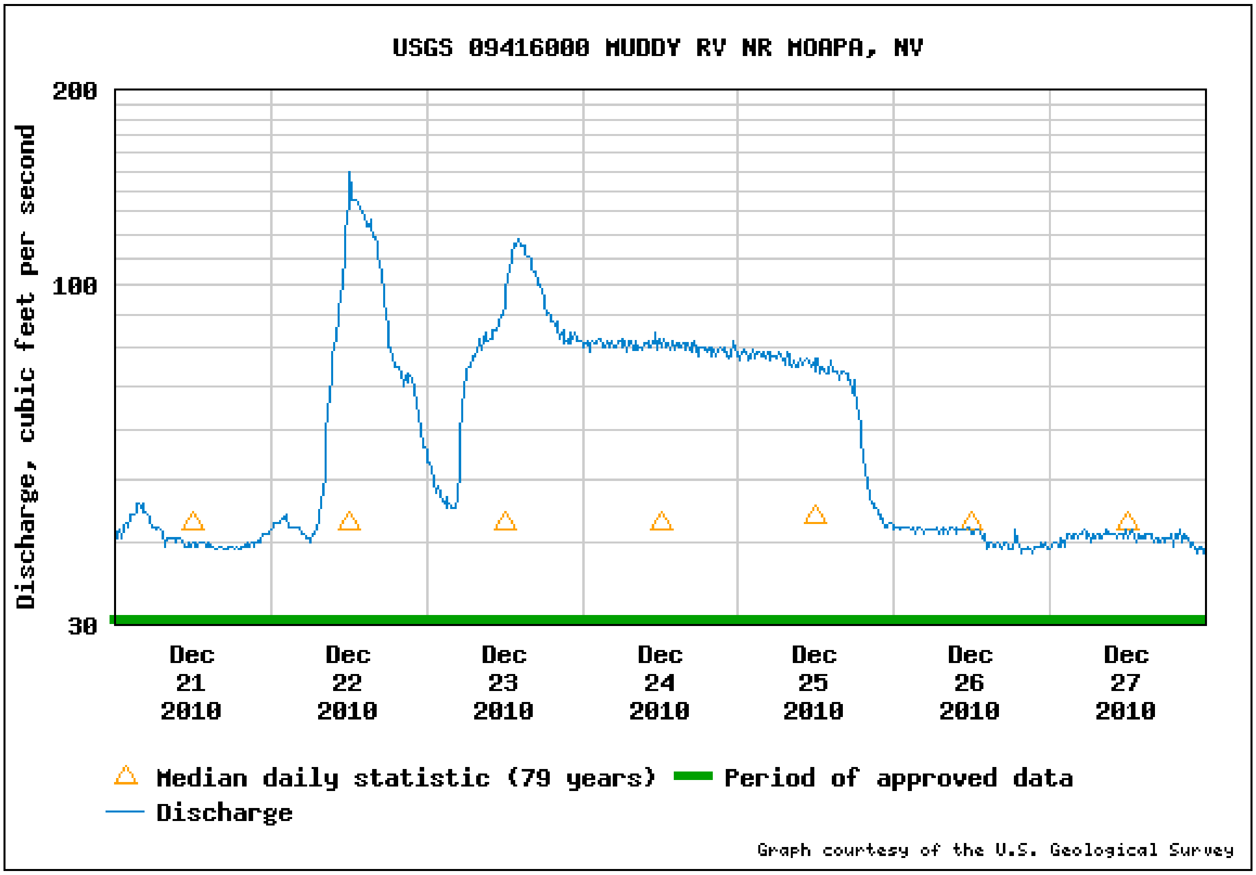

Figure 6. Response at Moapa Gage to storms of December, 2010. [MoapaGage2010Dec21-27]

The 3-dimensional temperature (T) and electrical conductivity (EC) distributions in the Lewis Well Field (Figure 7) were monitored from 1987 through 1996. A PowerPoint slide show LewisTvsProduction88-96.pptx illustrates the generally steady temperature field with exceptions that included incursions of warm water in NPC #4 while the Arrow Canyon Well was being reamed (Figure 9) and relatively cold water in NPC #1 after a rainy winter and several runoff events in Pahranagat Wash (Figure 10).

In the appended analysis from October of 2011, a catalog of 15 runoff events and associated records was prepared from 5 years of Pahranagat Wash monitoring data, and total runoff volumes entering the MRSA were compared with surge volumes registered at the Moapa Gage (09416000) where storm runoff exits the MRSA as a component of the Muddy River. When no storm runoff is generated within the MRSA catchment (Basin 219) losses to the MRSA alluvial aquifer can be calculated directly from infiltration losses = streamflow input – streamflow output increment, leading to the conclusion that a total of about 740 acre-feet of storm runoff can be shown to have infiltrated and recharged the MRSA alluvial aquifer in five relatively wet years, about 0.4% of the historically-accepted rate of 37,000 acre-feet/year at which groundwater has discharged to the MRSA under natural conditions.

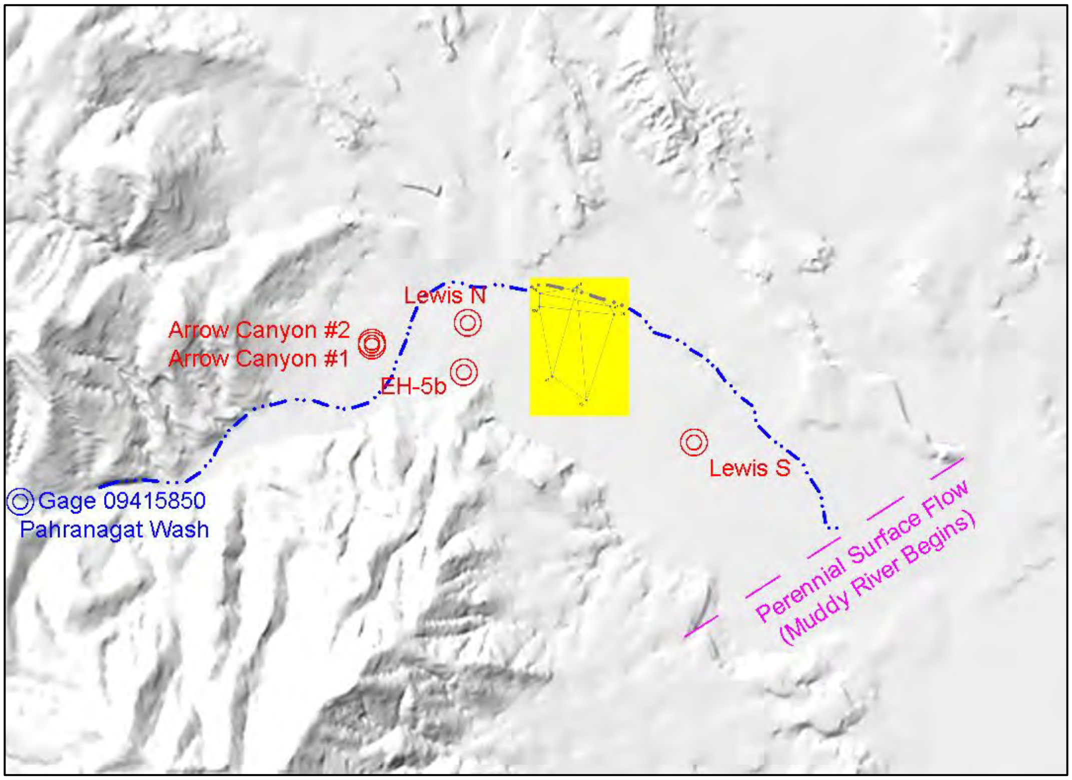

Figure 7. Shaded-relief illustration of Lewis Well Field (Figure 8) at mouth of Arrow Canyon, with overlay showing fence diagram used in temperature animation LewisTvsProduction88-96.pptx and headwaters lineament in violet: Yellow overlay is 500 meters wide E-W. [MRSAfenceLocationSR83.tif]

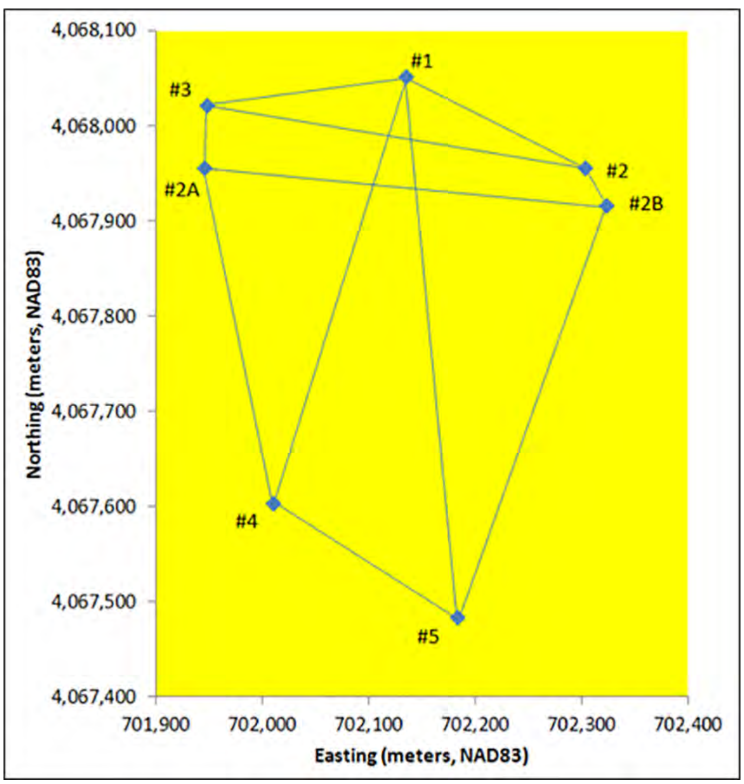

Figure 8. Well locations in NPC Lewis Well Field, Upper Moapa Valley [TempECfenceMap.tif]

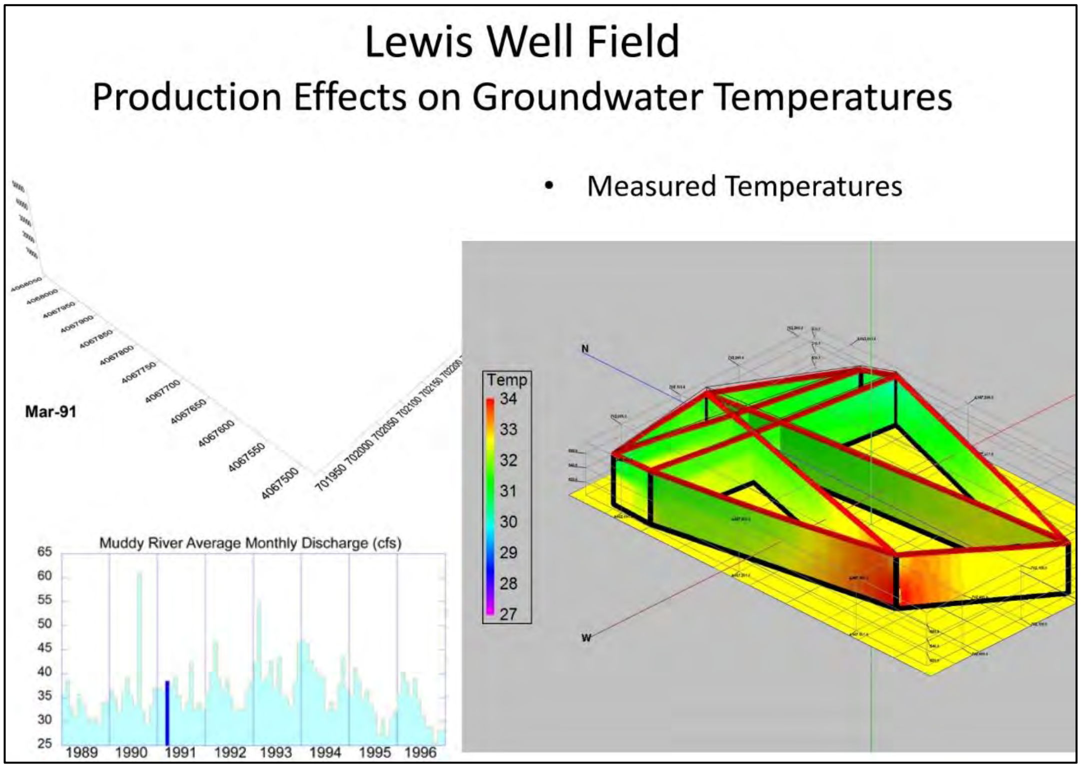

Figure 9. March 1991 incursion of warm water at NPC #4 in absence of any NPC pumping from the Lewis wells, during reaming of the Arrow Canyon Well.

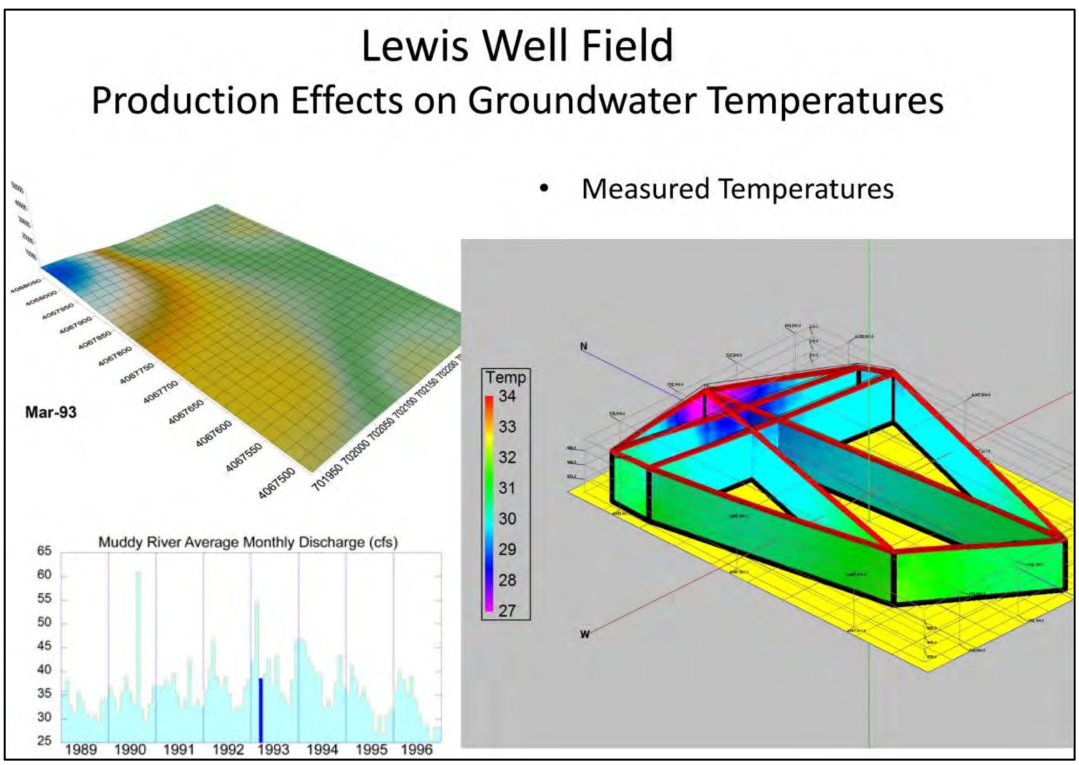

Figure 10. March 1993 incursion of cold water at NPC #1 in response to multiple runoff events in Pahranagat Wash during the previous weeks (Figure 11).

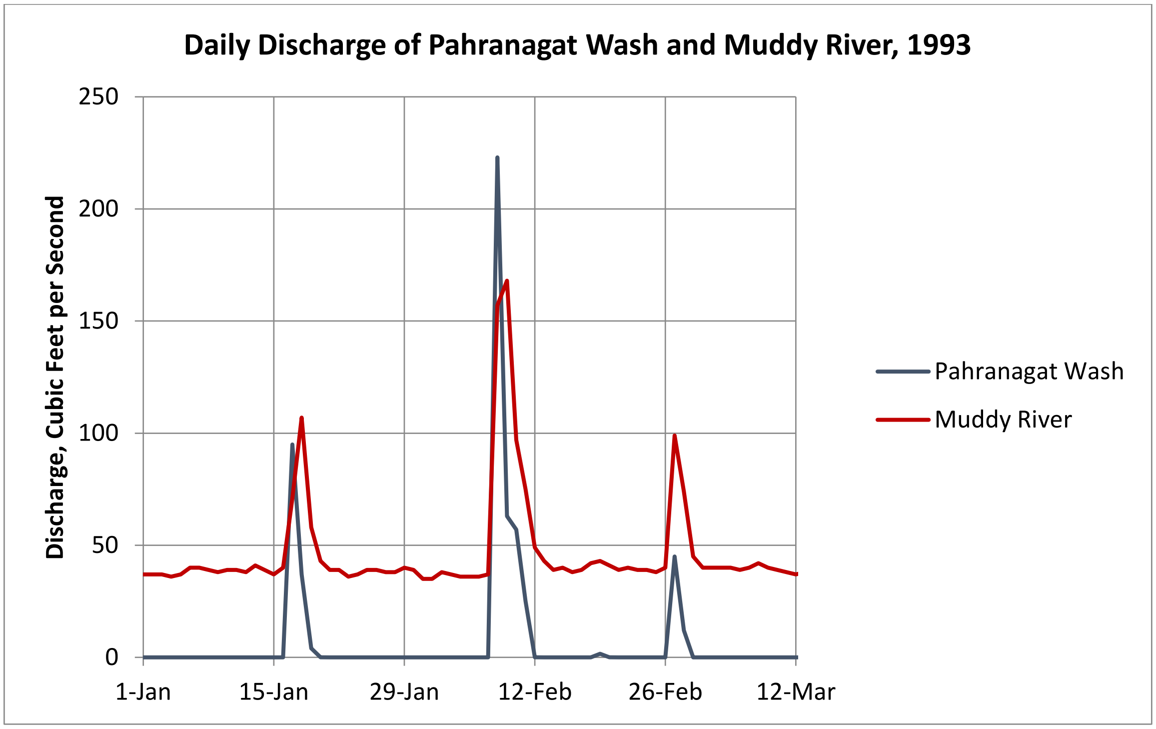

Figure 11. Transition of storm surges through the MRSA area, early 1993

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Beck, D.A. and J.W. Wilson, 2006. Synoptic Discharge, Water-Property, and pH Measurements for Muddy River Springs Area and Muddy River, Nevada, February 7, 2001: U.S. Geological Survey Scientific Investigations Report 2006-5237, 12 p.

Burns, A.G. and W. Drici, W., 2011. Hydrology and water resources of Spring, Cave, Dry Lake, and Delamar valleys, Nevada an d vicinity: Presentation to the Office of the Nevada State Engineer: Southern Nevada Water Authority, Las Vegas, Nevada.

Eakin, T.E., 1964. Ground-water appraisal of Coyote Spring and Kane Spring Valleys and Muddy River Springs Area, Lincoln and Clark Counties, Nevada: Nevada Department of Conservation and Natural Resources, Ground-water Resources-Reconnaissance Series, Report 25, 39 p.

Johnson, C.L. and M.D. Mifflin, 2003. Evidence of a sub-regional hydraulic barrier in southeastern Nevada (abstract): Geological Society of America 115th Annual Meeting, Seattle, WA

Johnson, C.L. and M.D. Mifflin, 2013. Summary of Order 1169 Testing Impacts, per Order 1169A: unpublished report submitted to Nevada State Engineer on behalf of the Moapa Band of Paiutes, 66 p.

Tributary Recharge to the Muddy River System
Understanding Annually-Variable Base Flow

Cady Johnson
Mifflin & Associates, Inc.

October 10, 2011

The discharge of the Muddy River, as measured at the Moapa Gage (USGS ID 09416000), is a key parameter in the assessment of Order 1169 pumping impacts, as the Muddy River hydrograph registers the aggregated effects of springflow, discharge from the alluvial aquifer, groundwater export, and land-use (evapotranspiration; ET) changes in the headwaters area. Detection of River-flow reductions attributable to groundwater development in southeastern Coyote Spring Valley presents a formidable analytical challenge, because there is no quantitative method for estimating flows of the Muddy River in the absence of pumping, other than reference to the historical baseline.

The Instantaneous Data Archive (IDA) and National Water Information System (NWIS) records of Pahranagat Wash discharge available from the USGS (Figures 1 and 2; Appendix 1) provide the basic data considered here. The brief (1988-1993) discharge record from Pahranagat Wash (USGS ID 09415850) provides an indication that infiltration losses from ephemeral, tributary runoff are returned to the Muddy River as a delayed increment of base flow. Because the locally-recharged component of River discharge can mask pumping effects in “wet” years, we seek to estimate the magnitude of local infiltration effects on the Muddy River using the available Pahranagat Wash record and corresponding Muddy River responses as a guide. Runoff in Pahranagat Wash is infrequent, with only 15 runoff events represented by instantaneous 1-hour or 30-minute measurements (IDA) and 2 by daily averages (NWIS) during more than 5 years (July 27, 1988 to September 30, 1993) of monitoring (Figure 3).

Two approaches to performing the comparison are recognized at this time; losses of overland flow between the Pahranagat Wash Gage and Moapa Gage represent infiltration to the alluvial aquifer in the headwaters area, and contrasts in the character of the Muddy River hydrograph between years when flow in Pahranagat Wash is frequent versus those when it is infrequent attest to the larger role of distributed recharge.

We begin at a very local scale, comparing the flows entering the headwaters area, registered by the Pahranagat Wash gage, with those leaving the headwaters area, registered by the Moapa Gage. When significant rainfall occurs in the intervening area, the storm surge at the Moapa Gage can begin earlier than the onset of flow in Pahranagat Wash, which otherwise leads the Moapa Gage by several hours. The addition of water between the two gages is therefore easy to recognize, but difficult to resolve from throughput from Pahranagat Wash. Plotting the quantities of water associated with individual events as a scatter diagram (Figure 4) allows the “pure” hydrographs (Figures 5A and 5B, for example) to be identified. In these cases the Moapa Gage does not begin responding to the causative precipitation event before flow begins in Pahranagat Wash in a volumetrically significant way, and the shapes of the two hydrographs are similar.

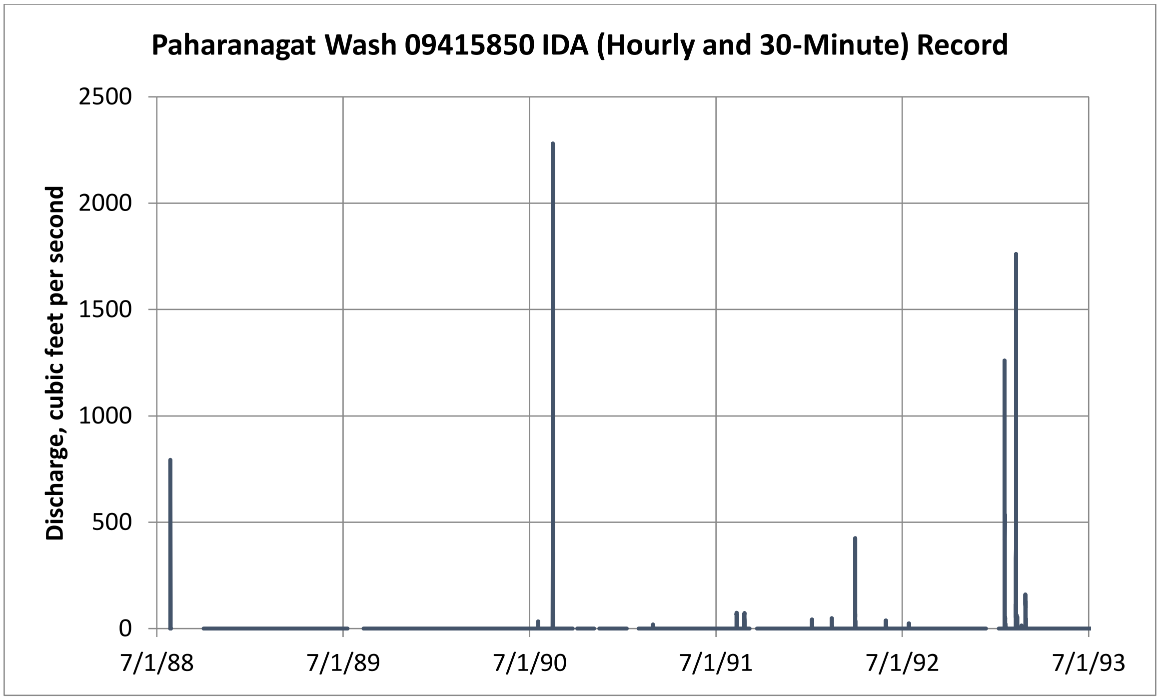


Figure 1. Instantaneous Data Archive (IDA) Record of Pahranagat Wash [file AllPWdata1988-93.xlsx, sheet 'Plot']

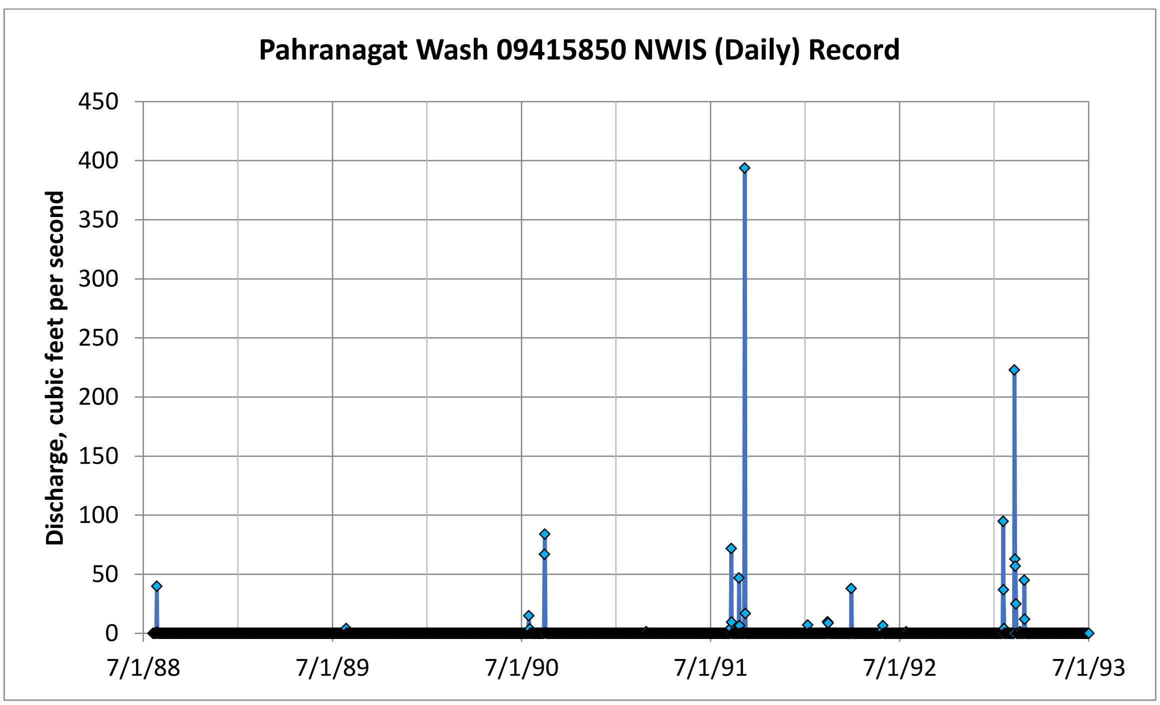


Figure 2. National Water Information System (NWIS) record of Pahranagat Wash [file PahranagatWash88-93.xlsx, sheet 'PahranagatWash88-93']

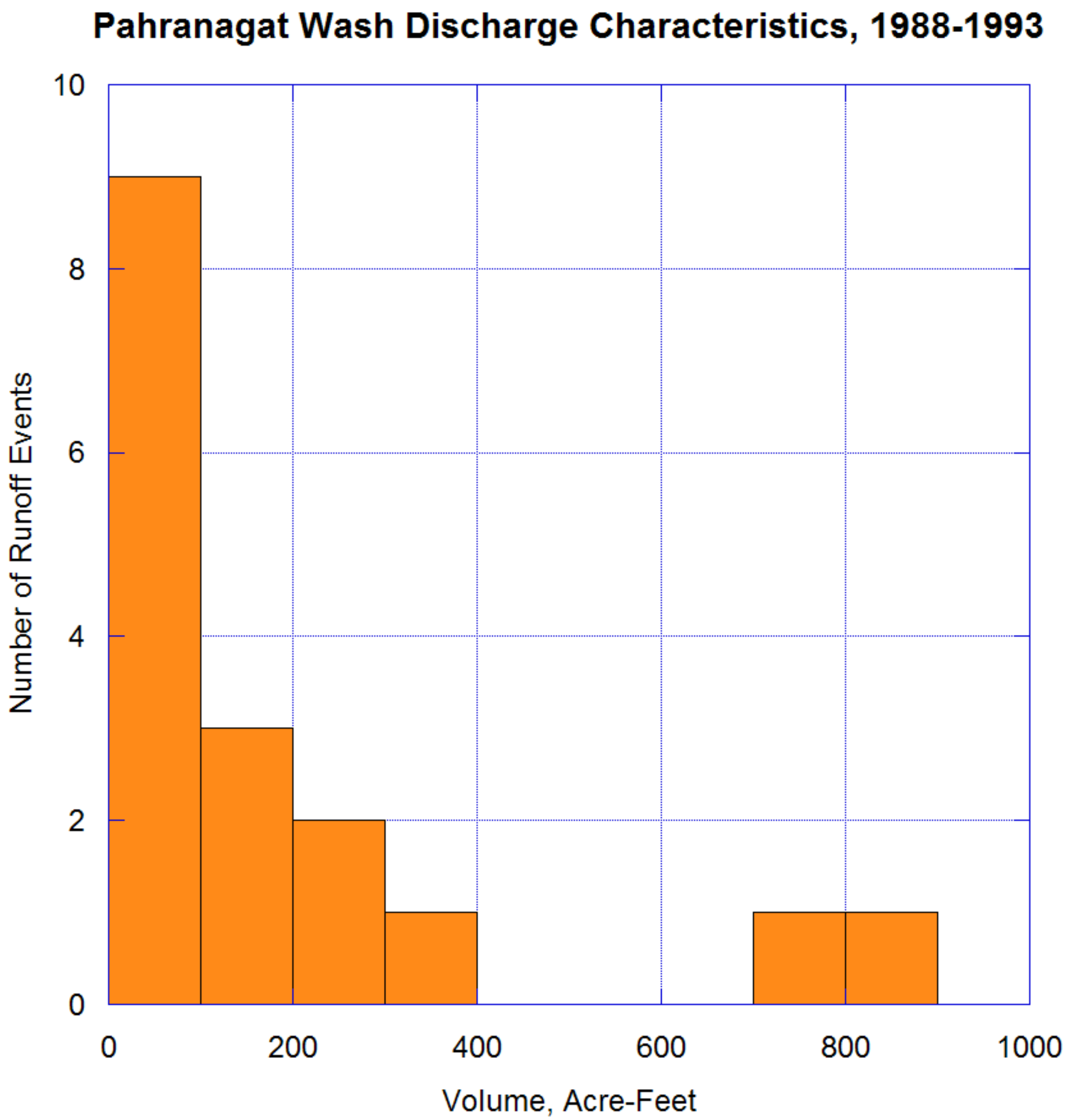


Figure 3. Frequency distribution of Pahranagat Wash runoff events, 1988-1993 [file PWhistogram.tif]

The seemingly linear relationship between runoff volume in Pahranagat Wash and infiltration losses in the headwaters area (60-70% of surge volume) is dominated by one high-flow data point, which relies on flows estimated by the USGS. Still, these results suggest that most tributary flow from Pahranagat Wash recharges the alluvial aquifer in the headwaters area, though evaporation losses from the floodplain cannot be discounted at this time. The regression relation shown in Figure 4, if correct, indicates that 350 acre-feet of water were recharged directly to the North Fork of the Muddy River in early 1993, following the wet winter of 1992 when 150 acre-feet were recharged locally.

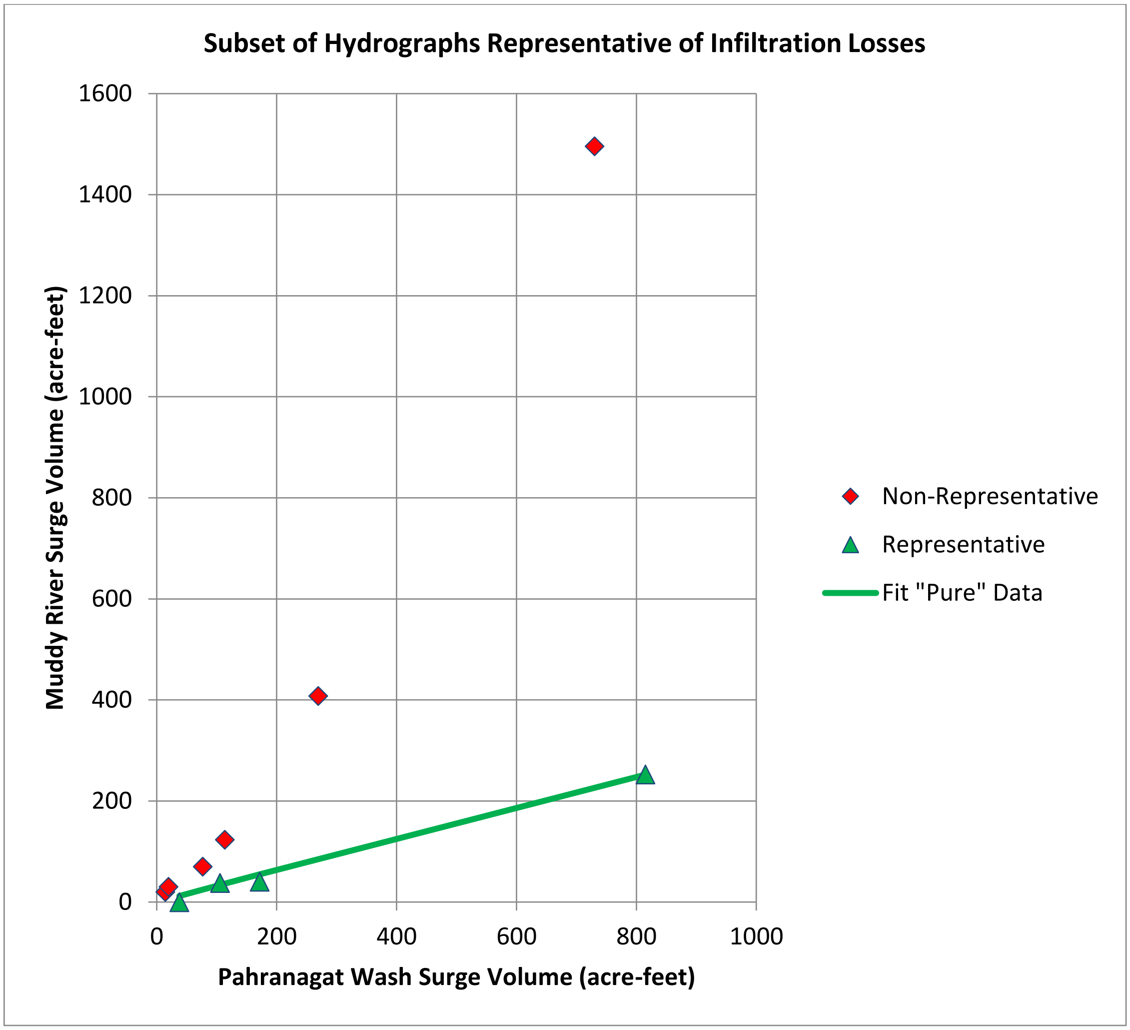
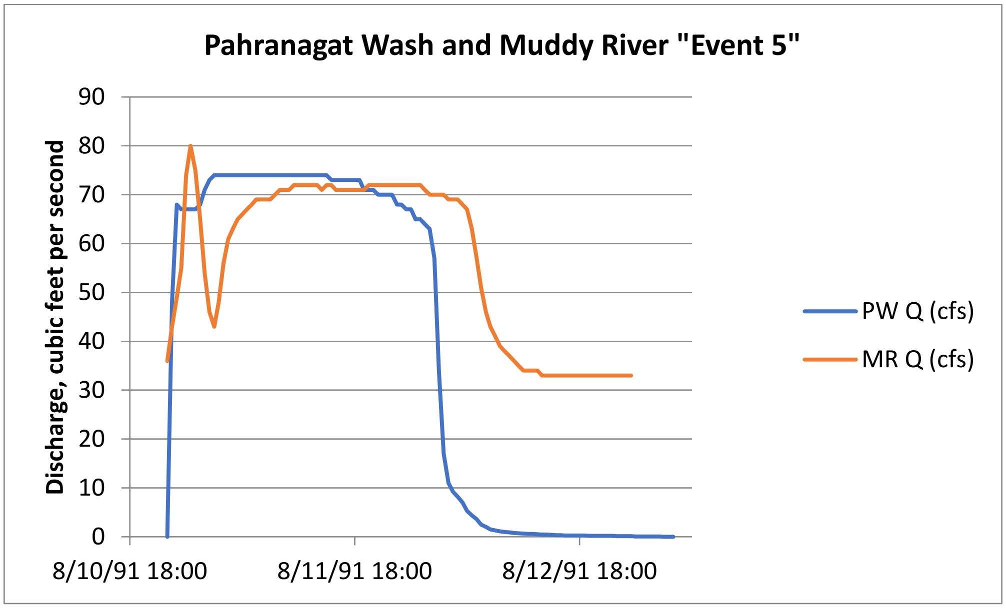


Figure 4. When ephemeral runoff reaching the Moapa Gage originates downstream of the Pahranagat Wash Gage, flows greater than those sensed at the Pahranagat Wash Gage can be recorded (red symbols). When runoff from Pahranagat Wash to the Muddy River occurs without local additions, there are channel losses (green symbols and regression line) [file HeadwatersAreaQinQout.xlsx]

In contrast to infiltration along North Fork, which can be satisfactorily quantified by comparison of Pahranagat Wash and Moapa Gage records, monitoring does not exist that can be applied to channel infiltration in reaches above the Pahranagat Wash Gage. Losses within Arrow Canyon and at its upstream end, where a Civilian Conservation Corps (CCC) rubble masonry arch dam was completed in 1934 for flood and silt control, are unknown. Shamberger (1940, p. 28) states:

"*As a storage reservoir (the Arrowhead Dam) has no apparent value due to the long porous stream channel below the dam which consumes all the water, mainly by percolation*."

Comparison of winter hydrographs from 1992 and 1993 with those from 1989-91, when winter runoff in Pahranagat Wash did not occur, indicates a difference of about 7 cfs between average "wet" and "dry" years (Figure 6). This difference, equivalent to 13.9 acre-foot/day, could be sustained for only about 11 days by the quantity of water shown here to have been recharged directly to North Fork in early 1993. The drainage area contributing to the Moapa Gage record is 3,820 square miles, however (http://waterdata.usgs.gov/nv/nwis/nwismap/?site_no=09416000&agency_cd=USGS). The observations of Shamberger (1940) likely apply to extensive channel reaches above the Pahranagat Wash Gage, significantly recharging shallow aquifers during wet years.



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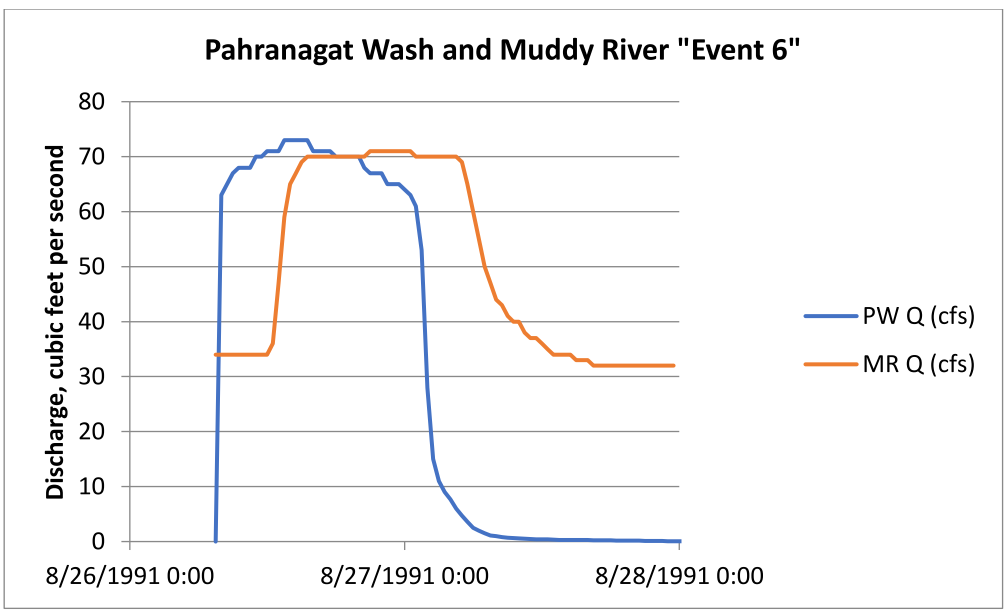

B

Figure 5. Examples of relatively "pure" hydrographs, unaffected by rainfall and runoff between the Pahranagat Wash and Moapa Gages [files Event5hydrograph.xlsx, Event6hydrograph.xlsx]

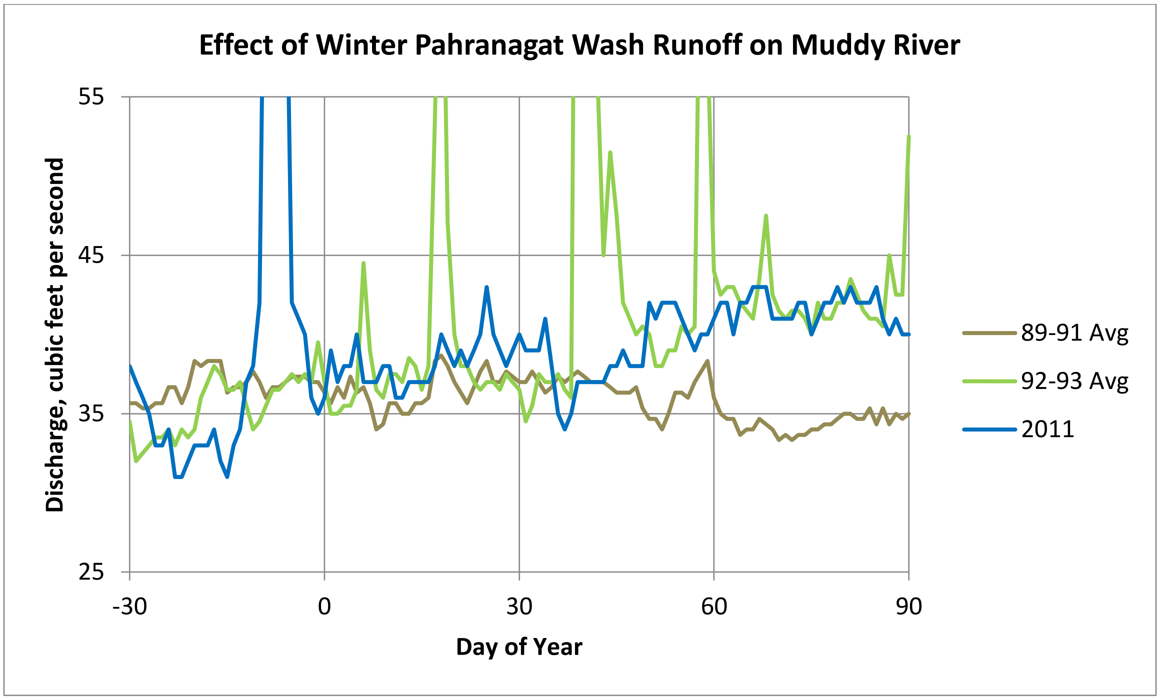

Figure 6. During years when winter runoff events in Pahranagat Wash have occurred (1992-93), the spring hydrographs are different than those from years with no runoff (1989-91). A major runoff event was observed on December 25, 2010, and the 2011 record through March closely resembled that from 1992-93, when winter runoff also occurred. Therefore, as Order 1169 testing effects develop, the 1992-93 hydrographs may provide a better basis for comparison than long-term averages or extrapolated trends. [file MR_Jan-Mar_Comparison.xlsx, sheet 'Plot']

References

Shamberger, Hugh A., 1940. Report on Muddy River, Clark County, Nevada: unpublished report to Nevada State Engineer, January, 1940, 36 p.

Appendix 1

Characteristics of Instantaneous Data Archive (IDA) Runoff Event Hydrographs

The 15 event hydrographs available from Pahranagat Wash via the IDA are characterized as follows:

Event 1, July 27-28, 1988: 793 cfs peak, 82.05 acre-ft total, no IDA data available for Muddy River.

Event 2, July 18-20, 1990: 34 cfs peak, 8.23 acre-ft total, no response at Moapa Gage (complete infiltration?)

Event 3, August 15-16, 1990: 2280 cfs peak, 299.73 acre-ft total, no IDA data available for Muddy River.

Event 4, February 28 – March 1, 1991: 18 cfs peak, 3.39 acre-ft total, possible 3 cfs response at Moapa Gage

Event 5, August 10-12, 1991: 74 cfs peak, 171.61 acre-ft total, 40 cfs response at Moapa Gage with 97.48 acre-ft surge volume

Event 6, August 26-27, 1991: 73 cfs peak, 105.72 acre-ft total, 38 cfs response at Moapa Gage with 59.55 acre-ft surge volume

Event 7, Jan 6, 1992: 42 cfs peak, 14.27 acre-ft total, 20 cfs response at Moapa Gage with 15.74 acre-ft surge volume

Event 8, Feb 13-14, 1992; 48 cfs peak, 37.74 acre-ft total, no response (?) at Moapa Gage

Event 9, March 30-31, 1992; 424 cfs peak, 76.70 acre-ft total, 70 cfs response at Moapa Gage with 55.29 acre-ft surge volume

Event 10, May 29-30, 1992; 38 cfs peak, 19.51 acre-ft total, 30 cfs response at Moapa Gage with 17.69 acre-ft surge volume

Event 11, July 14, 1992; 25 cfs peak, 2.94 acre-ft total, no response at Moapa Gage (complete infiltration?)

Event 12, January 17-20, 1993; 1260 cfs peak, 269.41 acre-ft total, 408 cfs response at Moapa Gage with 231.79 acre-ft surge volume

Event 13, February 8-11, 1993; 1760 cfs peak, 730.00 acre-ft total, 1496 cfs response at Moapa Gage with 724.92 acre-ft surge volume

Event 14, Feb 19-20, 1993; 14 cfs peak (9/14 doublet), 3.20 acre-ft total, possible ~5 cfs response at Moapa Gage

Event 15, Feb 27-28, 1993; 160 cfs peak, 113.68 acre-ft total, 123 cfs response at Moapa Gage with 196.5 acre-ft surge volume

The September 6, 1991 runoff event is represented by daily average flows in the NWIS, indicating 815.25 acre-ft surge volume, and by IDA records indicating a surge volume of 252.36 acre-ft at the Moapa Gage.

CAVEAT: The IDA and NWIS databases differ significantly in the way runoff events are reported (or not reported), and appear to contain errors. For example, The Instantaneous Data Archive (IDA) records a large runoff event on August 15-16, 1990 (Figure A1.1) that was not sensed (or minimally sensed) by the Moapa Gage (Figure A1.2), suggesting equipment malfunction. The very small July 27, 1988 and very large September 6, 1991 events (Figure 2) are flagged as *estimated* daily averages in the NWIS but are associated with data gaps in the IDA; the latter event is well-represented in the Moapa Gage record (Figure A1.3).

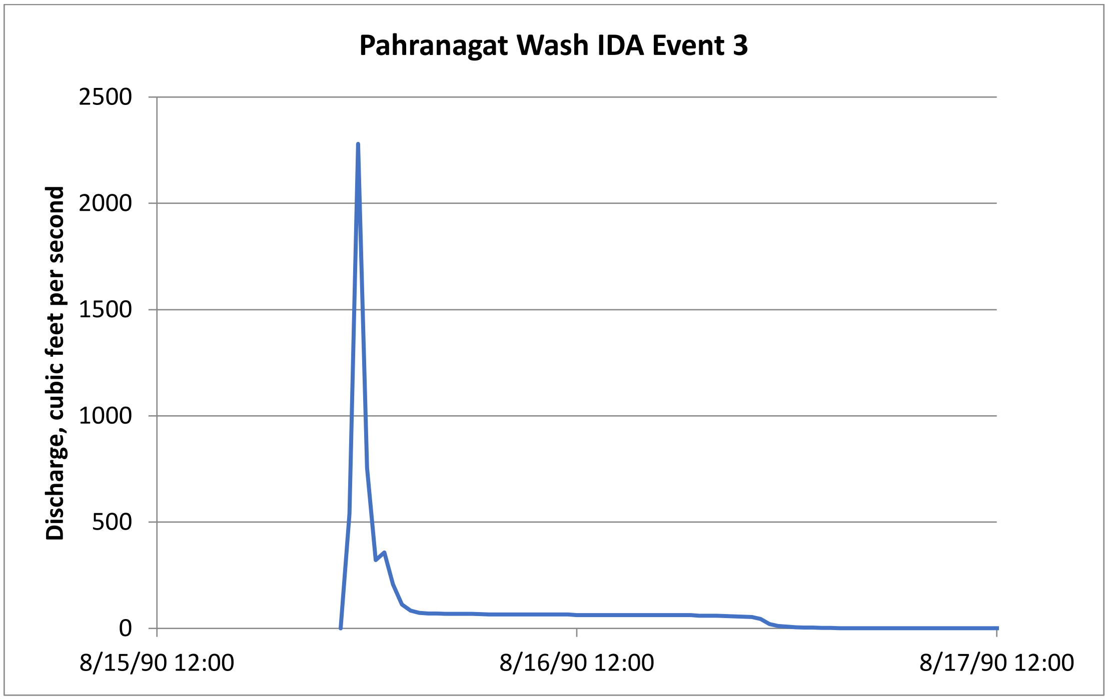

Figure A1.1. The largest runoff event in the IDA is not complemented by a corresponding record from the Moapa Gage [file AllPWdata1988-93.xlsx, sheet 'Plot']

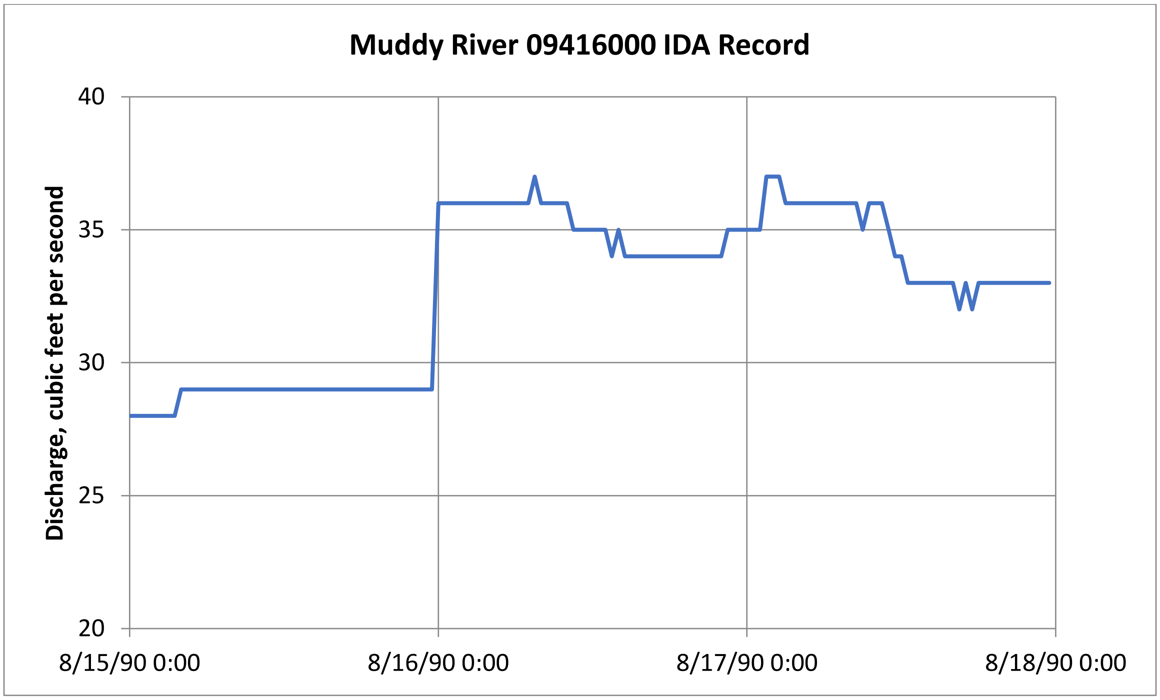

Figure A1.2. Insensitivity of Moapa Gage to August, 1990 runoff event (Figure A1.1) in Pahranagat Wash [file AllMRdata1988-93.xlsx, sheet 'Aug90event']

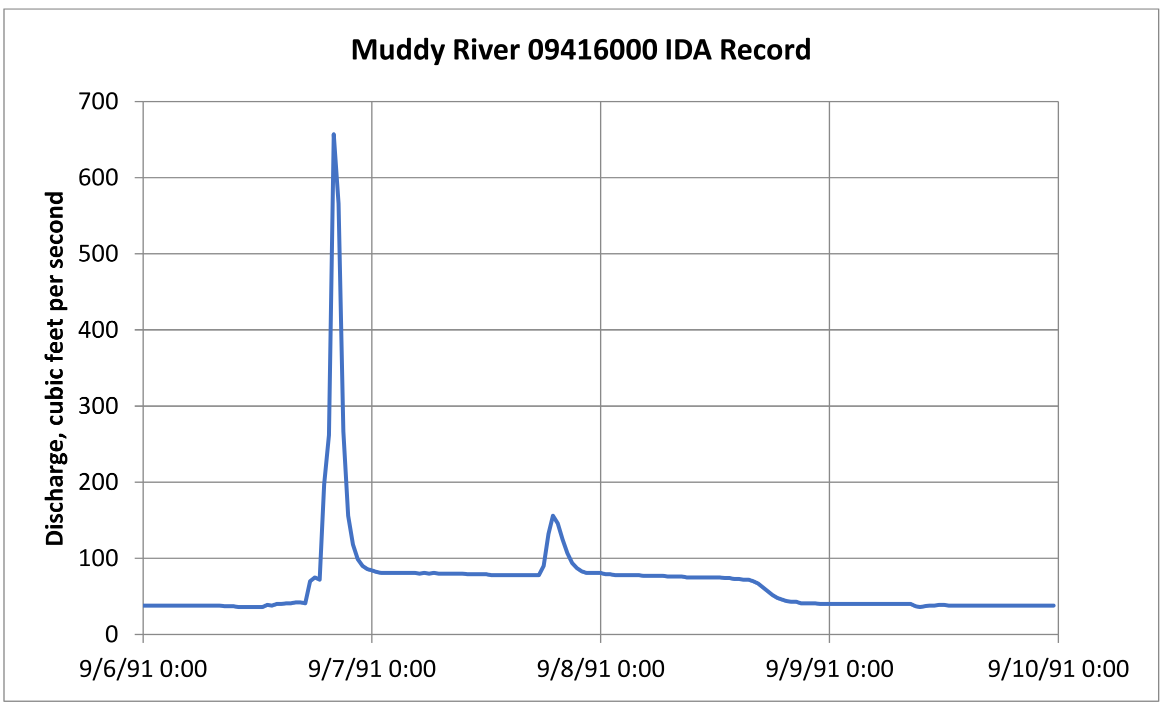

Figure A1.3. The record of this runoff event from Pahranagat Wash was estimated by the USGS as daily average discharge, preventing quantitative comparison of the Pahranagat and Muddy River hydrographs [file AllMRdata1988-93.xlsx, sheet 'Sept91event']

CADY L. JOHNSON

hydrogeology
geochemistry
modeling analyses
infrared thermography
flight operations logistics

EDUCATION

University of Nevada, Reno: Ph.D., Geology and Hydrology/Hydrogeology, 1982
Oregon State University: B.S., Geology, 1976

DOCTORAL DISSERTATION

"Correlation and Origin of Carnotite Occurrences in the Southern Nevada Region", 1982. Carnotite [$K_2(UO_2)_2(VO_4)_2 \cdot 3H_2O$] associated with a pre-Colorado River geomorphic surface was evaluated through a combination of geologic reconnaissance, geochemical modeling, and natural analogue studies. The preferred interpretation is that the carnotite formed by evaporation of shallow groundwater prior to incision of the Colorado River.

PROFESSIONAL CERTIFICATIONS

Licensed Professional Geologist, State of Utah, #6295290
Certified Nuclear Testing Equipment Operator #11671
Certified Infrared Thermographer (Level III) #3156
Airline Transport Pilot, Rotorcraft/Helicopter #3452061 (retired)
Certified Flight Instructor #3452061CFI (retired)
Airframe and Powerplant Mechanic #3452061

EMPLOYMENT HISTORY

GeoLogic VR, LLC, Principal, 2003-present
Petroleum Helicopters, Inc., Pilot, 1998-2003
Papillon Grand Canyon Helicopters, Pilot, 1997
Woodward-Clyde Federal Services, Senior Project Hydrogeologist, 1991-1997
Helicopter Services of Nevada, Pilot/Mechanic, 1990-1991
Mifflin & Associates, Inc., Associate/Hydrogeologist, 1986-1989
Desert Research Institute, Assistant Research Professor, 1985-1986
Coffey & Partners Pty. Ltd., Senior Hydrogeologist/Geochemist, 1984
Intera Environmental Consultants, Staff Consultant, 1983
Bendix Field Engineering Corp., Geologist & Research Geoscientist, 1979-1982

REPRESENTATIVE EXPERIENCE

Dr. Johnson has 40 years of full-time professional experience as a hydrogeologist. He is Principal of GeoLogic VR, LLC, an Arizona company engaged with exploration, monitoring, and visualization services related to natural resources.

For the past 19 years Dr. Johnson has led hydrogeologic assessments of the Muddy River Springs area, where a regional groundwater flow system discharges and sustains the base flow of the Muddy River. Through water-balance accounting, empirical mode decomposition, well-hydraulics analyses, and numerical modeling it has been possible to reconstitute historic base flows, quantify diversions of tributary groundwater, and characterize "memory" in the hydrologic system.

While associated with the Gault Group, Inc. in 2007-2008, hydrogeologic and geochemical data from the Mission Mine complex south of Tucson were processed and analyzed to estimate infiltration rates from tailings and waste-rock areas, and the possibility of degradation of local groundwater quality from ASARCO's long history of mining and ore processing at Mission. Hydrochemical evidence led to the surprise finding that ASARCO's impacts to shallow groundwater beneath and adjacent to the Santa Cruz River were negligible, settling a key component of litigation.

His most recent employment as a rotorcraft pilot was with AirEvac (Emergency Medical) Services (a subsidiary of Petroleum Helicopters, Inc.) in Phoenix. He relocated temporarily to Antarctica to fly personnel and cargo for the National Science Foundation in 2001, but remained active as a consulting hydrogeologist while "on the ice".

Dr. Johnson served for over five years as Senior Project Hydrogeologist in the Yucca Mountain Site Characterization group of Woodward-Clyde Federal Services in Las Vegas. In this position he was responsible for integration of field activities from numerous technical disciplines, including development of staff positions on fluid-flow modeling and issue resolution strategies. The Site Characterization Program was a 22-year effort to assess the suitability of Yucca Mountain, Nevada, as the host environment for a high-level radioactive waste repository.

Previously, Dr. Johnson worked as a consultant to the Nevada Nuclear Waste Project Office while a Partner in Mifflin & Associates, Inc., a private consultancy, and with the Desert Research Institute (University of Nevada System). Additional duties at these positions included water quality and water resource evaluations for utility companies and the mining industry, and occasional graduate-level teaching assignments.

He was employed as Senior Hydrogeologist/Geochemist with Coffey & Partners Pty. Ltd. in Sydney, Australia, and contributed to a variety of mine dewatering, environmental, and corrosion-related evaluations.

As a Staff Consultant with Intera Environmental Consultants in Houston, he contributed to performance assessment modeling of regional ground-water flow at candidate salt-repository sites in Texas and Louisiana, and to evaluations of the validity of ion-activity approximations at high ionic strengths.

At Bendix Field Engineering Corp., he contributed to three (Kingman, Las Vegas, and Reno) 2°×1° quadrangle evaluations for the National Uranium Resource Evaluation (NURE) Program, and was Principal Investigator on the Las Vegas NTMS Quadrangle Evaluation. He designed the groundwater monitoring network for the Monticello Facility under the Uranium Mill Tailings Remedial Action (UMTRA) Program, and conducted interference tests and modeling analyses using production wells to evaluate aquifer parameters.

Dr. Johnson is a retired 4000-hour professional helicopter pilot and rotary-wing flight instructor, and a licensed airframe and powerplant mechanic. Flight experiences in Nevada, Arizona, Utah, and California have been particularly helpful to appreciating some regional stratigraphic, erosional, and fault relations thanks to elevated views and access to remote areas. As a Certified Infrared Thermographer, he has used modeling analyses to develop a thermal-barometric time constant for barometric pumping in the vadose zone near Yucca Mountain. Dr. Johnson discovered a breccia-pipe uranium occurrence by analyzing transient concentrations of barometrically-pumped radon in rock gas exhausting from a fault zone in Arizona. The rock-mass properties that govern surficial thermal responses to barometric pumping would also govern the modes of heat and moisture redistribution in partially-saturated rock above a nuclear waste repository, and are diagnostic of convective versus conductive heat transport.

PUBLICATIONS

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