WILDERMUTH ENVIRONMENTAL, INC.

March 15, 2018

Mr. Patrick Hayes, General Manager
Mammoth Community Water District
1315 Meridian Blvd.
Mammoth Lakes, CA 93546

Subject: ***Groundwater Quality Monitoring West of the CD-IV Geothermal Area, Long Valley Caldera, California***

Dear Mr. Hayes:

Per your request, Wildermuth Environmental, Inc. (WEI) reviewed the new data regarding groundwater quality in the Casa Diablo IV (CD-IV) geothermal area that has been collected since the Great Basin Unified Air Pollution Control District certified the Environmental Impact Statement/Environmental Impact Report (EIS/EIR) for the CD-IV Project on July 17, 2014. This letter report discusses our scientific observations and conclusions regarding these new data. As discussed in this letter report, the new data regarding water temperatures and groundwater quality that have been collected since July 17, 2014 indicate that that the shallow groundwater aquifer from which the Mammoth Community Water District (MCWD) pumps water for its customers and the deep geothermal reservoir from which the CD-IV Project would pump geothermal fluids have some hydraulic connectivity and are not completely isolated from each other. This evidence is very serious for the MCWD, because, with such hydraulic connectivity, the CD-IV Project could cause depletions to or contamination of the shallow groundwater aquifer that is a critical component of the MCWD's water supplies.

Background

Potential Impacts of Casa Diablo IV Project on MCWD Water Supplies

The CD-IV Project would expand the gross electrical generation in the Long Valley Caldera from 40 megawatts electric MWe (gross) to approximately 80 MWe (gross) through the extraction of geothermal fluids at higher rates by existing and new wells in Basalt Canyon and the conveyance of these geothermal fluids to a new binary generation facility that would be located northwest of the existing Casa Diablo facilities.

Up to sixteen geothermal wells (two existing and fourteen new) are proposed for the CD-IV Project. Fourteen of the wells would be located in the Basalt Canyon area and two wells would be located southeast of proposed new power plant, east of U.S. Highway 395. Each of these wells might be used for either production or injection of geothermal fluids. Figure 1 shows the locations of the existing and proposed new Basalt Canyon geothermal wells. The new geothermal production wells would be drilled to between 1,600 and 2,000 feet-below ground surface and would provide capacity for the Project to increase total geothermal production from the current rate of approximately 12,000 to about 18,000 gallons per minute. The new injection wells would be located and operated to discharge the geothermal fluids back into the geothermal reservoir after the heat from them is used to generate electricity.

The CD-IV Project would place new stresses on the region's complex hydrologic system. The CD-IV Project's proposed new wells and associated pumping would be located about two miles from MCWD's well field. The MCWD is concerned that geothermal pumping from the CD-IV Project may reduce the supply of groundwater available to the MCWD from the Mammoth Groundwater Basin and may degrade the water quality of waters in the shallow groundwater aquifer used by the MCWD. Specifically, if there is a long-term imbalance between new geothermal production and injection in Basalt Canyon, then the resulting reductions in piezometric pressures in the geothermal reservoir may cause groundwater to seep downwards into the geothermal reservoir. Such pressure reductions in the deep geothermal reservoir also may cause the geothermal fluids in the reservoir to boil and release steam and other gases that could seep upwards through fractures and contaminate the shallow groundwater aquifer used by the MCWD. As documented by Sorey et al. (1993)[1] and Howle and Farrar (1996),[2] rapid pressure declines in the geothermal reservoir near the Casa Diablo geothermal well field occurred between 1991 and mid-1992. Pressure declines in the geothermal reservoir led to boiling in the overlying shallow groundwater system, which subsequently led to the release of steam through faults and fractures (Howle et al., 2003).[3] Howle et al. (2003) document that by August

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[1] Sorey, M.L., Farrar, C.D., and Marshall, G.A. (1993). Hydrologic and topographic changes in Long Valley caldera, California, induced by geothermal development 1985-1992. *Proceedings from the 15th New Zealand Geothermal Workshop,* p. 149-154.

[2] Howle, J.F. and Farrar, C.D. (1996). Hydrologic data for Long Valley caldera, Mono County, California, 1987-93. *U.S. Geological Survey Open-File Report 96-382, 286 pp.*

[3] Howle, J.F., Langhbein, J.O., Farrar, C.D., and Wilkinson, S.K. (2003). Deformation near the Casa Diablo geothermal well field and related processes Long Valley caldera, Eastern California, 1993-2000. *Journal of Volcanology and Geothermal Research, 127,*363-390.

1993, diffuse steam discharge had spread more than one-kilometer (0.62-miles) west, northeast, and southeast of the Casa Diablo geothermal well field.

These changes in conditions may not become apparent immediately after the start of CD-IV Project operations and could take several years to manifest themselves in groundwater monitoring data. The seepage volume from the shallow groundwater aquifer to the geothermal reservoir probably could appear to be comparatively small and unnoticeable to ORNI 50, LLC (ORNI), the project developer, and at the CD-IV well field, but could be significantly large to the MCWD and the Town of Mammoth Lakes.

EIS/EIR Certification and Subsequent Data Collection

On July 17, 2014, the Great Basin Unified Air Pollution Control District's Air Pollution Control Officer, Theodore Schade, certified the EIS/EIR for the CD-IV Project.

On January 13, 2017, the United States Department of the Interior, Bureau of Land Management (BLM), approved the CD-IV Groundwater Monitoring and Response Plan (GMRP). The GMRP established a monitoring network for the shallow groundwater aquifer and deeper geothermal reservoir and specifies details of monitoring frequency, sample collection, and analyses.

Table 1 lists the wells to be sampled for geochemical analyses under the GMRP. Figure 1 shows the locations of these wells. As specified in the GMRP, the United States Department of the Interior, Geological Survey (USGS), has coordinated and performed, and will be coordinating and performing, the quarterly sampling from the shallow groundwater aquifer, the dual-nested monitoring wells, and some of the geothermal reservoir monitoring and production wells (see entries in column titled "Monitoring Entity" in Table 1), and the analyses of these samples. From 2016 to October 2017, the USGS conducted eight sampling events from the shallow groundwater aquifer and dual completion monitoring wells (28A-2501, 28A-2502, and 14A-2501, and 14A-2502) as part of its actions under the GMRP.

The USGS has also sampled deep geothermal reservoir wells 57-25 and 66-25. However, the data from this sampling have not been published to the USGS's National Water Information System (NWIS), because ORNI has taken the position that these data are proprietary, and has required the USGS to enter into a non-disclosure agreement that prevents the disclosure of these data.

Unresolved Issues

One of the fundamental determinations in the CD-IV Project EIS/EIR was that the available geologic and geochemical data indicated that the shallow groundwater aquifer used by the MCWD was physically separated and completely isolated from the deeper geothermal reservoir from which the CD-IV Project would pump geothermal fluids. The EIS/EIR describes a physical geologic barrier separating the shallow groundwater aquifer from the deeper geothermal reservoir as a thick, low-permeability section of altered Early Rhyolite to mostly impermeable clays. Statements in the EIS/EIR regarding alleged physical separation and complete isolation between the shallow groundwater aquifer and deeper geothermal reservoir are on the following pages: D-25, D-27, D-35, D-36, D-39, D-42, D-43, D-44, D-46, D-47, and D-48.[4] For example, on page D-47, the EIS/EIR states: "The shallow cold groundwater aquifers farther west in the Mammoth Groundwater Basin are separated from the underlying geothermal system by thick altered and impermeable sections of ash-rich Early Rhyolite." Based on this determination that the deeper geothermal reservoir is physically separated from the overlying shallow groundwater aquifer, the EIS/EIR discounted the potential impacts of the proposed CD-IV Project on the overlying shallow groundwater aquifer and did not include any monitoring or mitigation measures to protect this aquifer from any stresses that may be caused by the new geothermal pumping.

The CD-IV Project EIS/EIR asserts that groundwater quality monitoring data from the Long Valley Caldera support the EIS/EIR's determination that the shallow groundwater aquifer is physically separated from the deeper geothermal reservoir because the chemical signature of geothermal fluid is distinct from the chemical signature of groundwater. However, the EIS/EIR relies on only a very small and incomplete water quality dataset to make this determination. Table 2a contains a summary of water quality data collected from sampling sites in the Long Valley Caldera, including the eight MCWD production wells and one monitoring well, between 1984 and 2011, as reported by Sorey (2011).[5] As Table 2a shows, for the period between 1984 and 2011, there are no complete or multi-year water quality datasets for the shallow groundwater aquifer. Instead, the groundwater quality data presented in Sorey (2011) and relied upon in the EIS/EIR consist primarily of data regarding physical parameters (temperature, pH, TDS, and specific conductance) and results from a single cation-anion analysis of the MCWD wells, based on data collected by the USGS from these wells in August 2011 (unpublished data).

Sorey (2011) concedes that, because of limitations on laboratory accuracy and precision, these data may not conclusively demonstrate the EIS/EIR's determination of physical separation and complete isolation of the shallow groundwater aquifer and the deeper geothermal reservoir:

> Measured concentrations of Cl and other conservative cations for the MCWD wells are most likely to be low enough that they are close to, and influenced by, the limits of laboratory accuracy and precision for these elements. Thus some, if not most, of the variability in reported cation concentrations and ionic ratios may be

[4] "D" refers to Appendix D in the EIS/EIR.

[5] Sorey, M.L. (2011). *Hydrologic and Geochemical Analyses of Reservoir Fluids in the Geothermal and Groundwater Systems in the Western Part of Long Valley Caldera.* Prepared for Ormat, Nevada, Inc.

> primarily related to laboratory limitations for accurate determinations or relatively low cation concentrations. (Sorey (2011), p. 7)

Sorey (2011) also concedes that the conclusion that the shallow groundwater aquifer is physically separated from the deeper geothermal reservoir is potentially flawed due to the limitations of the laboratory's reported accuracy and because there was no multi-year analysis of conservative elements by the same laboratory, which could have assessed any data trends. (Sorey (2011), pp. 8, 9, 10, 12, and 18.)

Objectives of Present Investigation

The objectives of the present investigation that is described in this report were: 1) to document the groundwater quality data relied upon in the CD-IV Project EIS/EIR (all of which were collected before July 17, 2014); 2) to document the new groundwater quality data collected and reported by the USGS under the GMRP since July 17, 2014; and 3) to analyze the new data to test the determination in the CV-IV Project EIS/EIR that there is a hydraulic separation between the shallow groundwater aquifer and the deeper geothermal reservoir and that they are completely isolated from each other.

Pre-July 17, 2014 and Post-July 17, 2014 Groundwater Quality Data

Geochemical research and analyses of data collected in the Long Valley Caldera that were performed by the USGS Volcanic Monitoring Program and Long Valley Hydrologic Advisory Committee (LVHAC), Sorey et al. (1991),[6] Evans et al. (2002),[7] Brown et al. (2013),[8] as well as several other researchers, examined the relationships between the data collected from non-geothermal waters and geothermal fluids, using data concerning water temperatures, concentrations and ratios of conservative elements, and isotopes.

For this investigation, we divided the available groundwater quality data into two bins: (a) pre-July 17, 2014 data, and (b) post-July 17, 2014 data. The pre-July 17, 2014 data are listed in Table 2a and the post-July 17, 2014 data are listed in Table 2b. Figure 2 shows the locations of the sampling sites for the data listed in Tables 2a and 2b.

Table 2a shows that the pre-July 17, 2014 data:

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[6] Sorey, M.L., Suemnicht, G.A., Sturchio, N.C., and Nordquist, G.A. (1991). New evidence on the hydrothermal system in Long Valley caldera, California, from wells, fluid sampling, electrical geophysics, and age determinations of hot-spring deposits. *Journal of Volcanology and Geothermal Research, 48*, 229-263.

[7] Evans, W.C., Sorey, M.L., Cook, A.C., Kennedy, B.M., Shuster, D.L., Colvard, E.M., White, L.D., and Huebner, M.A. (2002). Tracing and quantifying magmatic carbon discharge in cold groundwaters: lessons learned from Mammoth Mountain, USA. *Journal of Volcanology and Geothermal Research, 112*, 291-312.

[8] Brown, S.T., Kennedy, B.M., DePaolo, D.J., Hurwitz, S., and Evans, W.C. (2013). *Geochimica et Cosmochimica Acta, 122*, 209-225.

- Primarily are for physical parameters (temperature, pH, TDS, and specific conductance) and the results from a single cation-anion analysis of data collected from the MCWD wells by the USGS in August 2011 (unpublished data);
- Contain multi-year data gaps in the water quality records;
- Are based on, at most, only one sample being collected each year; and,
- Do not have any consistencies regarding the sampling and testing of specific analytes (arsenic, boron, bromide, chloride, silica).

In contrast, Table 2b shows that the post-July 17, 2014 water quality data:

- Are for both physical parameters and cation-anion analyses, for both the MCWD production and monitoring wells and the new 28A-25 and 14A-25 dual-nested monitoring wells;
- Were collected by the same sampling entity (USGS), at the sampling frequency, and analyzed by the same water quality lab [USGS National Water Quality Lab (NWQL) in Denver, CO]; and,
- Are the results[9] of the NWQL's consistent and state-of-the art methodology with extremely low-detection levels. For example, the lowest chloride concentration in MCWD-17 (8.59 mg/L measured on July 18, 2017) is approximately 400 times that of the NWQL's reporting limit for chloride.

Physical Water Quality Data (Water Temperatures, pH, Specific Conductance, and Total Dissolved Solids)

Figure 3 contains plots of the temperature data for the geothermal fluids and non-geothermal waters that were collected between August 2005 and October 2017. Temperature data from the Basalt Canyon wells are shown in Brown et al. (2013) and additional temperature data were recorded during the Basalt Canyon 2015 Memorial Day Flow Test. No other temperature data have been reported by the USGS or ORNI for the Basalt Canyon wells since implementation of the GMRP began. Temperature data for MCWD wells collected before July 17, 2014 were derived from the MCWD's continuous down-hole temperature sensors. Beginning in 2016, temperature measurements were obtained from USGS measurements recorded at the time of the quarterly groundwater quality sampling events.

Pre-July 17, 2014 Data

The two data points for pre-July 17, 2014 data shown in the upper left part of Figure 3 (from Well 57-25) indicate that fluid temperatures from Basalt Canyon wells were approximately 170°C. Temperatures in MCWD wells before July 17, 2014 were between

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[9] The groundwater quality data published on NWIS are currently flagged by the USGS as "provisional." Provisional data are defined by the USGS as, "Data that has not received [the] Director's approval and as such are provisional and subject to revision." At the time of writing, Evans (USGS) is currently in the process of reviewing and approving the post-July 17, 2014 groundwater quality data (Evans, written communication, February 9, 2018).

approximately 8 and 28°C, with waters in MCWD-16, -17, -20, and -26 being the warmest. Figure 3 shows that there was a distinct temperature difference between the temperatures in MCWD-1, -6, and -15 (about 9°C) and those in MCWD-16, -17, -20, and -26 (about 14 to 24°C).

Post-July 17, 2014 Data

As shown by the four data points for Wells 57-25 and 66-25 in the upper right part of Figure 3, the fluid temperatures measured from Basalt Canyon wells in 2015 ranged from approximately 175 to 190°C. Between 2016 and 2017, temperatures from the new dual-nested monitoring wells (28A-2501 and 28A-2502), which are located between the MCWD production well field and Basalt Canyon, ranged from approximately 42 to 46°C. The distinct differences between the temperature data for MCWD-1, -6, -15, and -25 (an average of about 9°C) and the temperature data for MCWD-16, -17, -20, and -26 (an average of about 20°C) are still apparent in the post-July 17, 2014 data. MCWD-26 continued to be the warmest MCWD well, with groundwater temperatures near approximately 37°C since July 17, 2014—approximately 25 degrees C warmer than the MCWD colder-temperature wells (MCWD-1, -6, -15, and -25).

Table 3 summarizes the physical water quality parameters for data from the Basalt Canyon wells, data from the new dual-nested monitoring wells (28A-2501 and 28A-2502), and data from the MCWD production and monitoring wells. Pre-July 17, 2014 data from Basalt Canyon wells are shown in the table because these are the only available data from Basalt Canyon, and they are used in the comparisons of data for geothermal versus non-geothermal fluids. For the other wells, only data collected after July 17, 2014 are listed in this table.

Table 3 shows that temperatures and total dissolved solids (TDS) concentrations were much higher in geothermal fluids than in the non-geothermal waters, and that the geothermal fluids were slightly more acidic (slightly lower pH values) than the non-geothermal waters. This table also shows that there were higher temperatures, specific conductance (SC) values and TDS concentrations and lower pH values in the dual-nested monitoring wells and the warmer-temperature MCWD wells than in the colder-temperature MCWD wells. For example, the SC values of data from the dual-nested monitoring wells and the warmer-temperature MCWD wells ranged from approximately 336 to 581 µS/cm, while the SC values for data from the colder-temperature MCWD wells ranged from 204 to 345 µS/cm. Similarly, the TDS concentrations of the warmer-temperature MCWD and the dual-nested monitoring wells were substantially higher (240 to 433 mg/L) than those of the colder-temperature MCWD wells (143 to 229 mg/L).

If the determination in the CD-IV Project EIS/EIR that the Early Rhyolite forms an impermeable barrier that physically separates and completely isolates the shallow groundwater aquifer from the deep geothermal reservoir were correct, then we would not expect to see such warmer temperatures or higher TDS or specific conductance values in the data from the MCWD warmer-temperature wells or in the dual-nested monitoring wells. However, the post-July 17, 2014 data from such wells show such warmer temperatures and higher TDS and specific conductance values. These new data from these wells indicate that waters in the shallow groundwater aquifer may already be affected by fluids from the deep geothermal reservoir, and thus that the shallow cold groundwater aquifer and the deep geothermal reservoir may be hydraulically connected.

It is conceivable that the anomalously warmer temperatures in some of the MCWD wells could be explained by high conductive heat flow from the underlying deep geothermal reservoir, as discussed by Sorey (2011). For this reason, the fluid temperature data alone are not sufficient to make the determination whether or not the observed warmer fluid temperatures in some of the MCWD wells are a result of conductive heating, intermingling between the shallow cold groundwater aquifer and deep geothermal reservoir, or both. Nevertheless, the warmer fluid temperatures measured in the MCWD production and monitoring wells, and the 28A-25 dual-nested monitoring wells are evidence that waters in the shallow cold groundwater aquifer and deep geothermal reservoir may be intermingling and hydraulically connected. The following discussion on the shallow groundwater aquifer the deep geothermal reservoir fluid geochemistry is the necessary and sufficient step to assess whether or not the two systems are intermingling and hydraulically connected.

Geochemistry Data

Pre-July 17, 2014 Data

Table 2a lists physical, geochemical, and isotope data collected from the thermal wells and MCWD production and monitoring wells before July 17, 2014. Table 2a shows that the water quality data collected from each well during this period are sparse and are not sufficient for any multi-year analyses.

The CD-IV Project EIS/EIR states: "Analytical data for cold MCWD groundwater supply wells was not available until the USGS collected samples in 2011" (p. D-27). This statement indicates that the EIS/EIR relied upon water quality data only from one sample event conducted by the USGS in August 2011 that is considered unpublished data (Evans, written communication, July 2016) to develop the EIS/EIR's determination that geochemical data demonstrate that the shallow groundwater aquifer is physically separated from the deeper geothermal reservoir.

Table 4a lists conservative element geochemistry data collected from the Basalt Canyon production wells and the MCWD production and monitoring wells for the USGS August 2011 sampling event. The MCWD wells are listed in this table in separate columns for warmer-temperature and colder-temperature wells. There are clear differences between the conservative element concentrations for data from the Basalt Canyon wells and for data from the MCWD wells. However, MCWD-17 had substantially higher concentrations of three of the four listed elements (arsenic, boron, and chloride), which could have been caused by some contribution of geothermal fluids to the water pumped from this well.

Post-July 17, 2014 Data

Table 4b lists conservative element geochemistry data from the new dual-nested monitoring wells (28A-2501 and 28A-2502) and the MCWD production and monitoring wells that were sampled by the USGS since 2016 under the GMRP. Pre-July 17, 2014 data from the Basalt Canyon wells are included in this table because they are the only available data from Basalt Canyon. They are used here to compare the geochemical data from geothermal and non-geothermal wells. The MCWD wells in this table are listed in separate columns for warmer-temperature and colder-temperature wells.

Like the pre-July 17, 2014 data, the post-July 17, 2014 data show higher conservative element concentrations for arsenic, boron, and chloride in MCWD-17 than those for the other MCWD wells. Additionally, data collected by the USGS since 2016 under the GMRP for MCWD-26 and the dual-nested monitoring wells had higher conservative element concentrations than those for the other MCWD wells. Specifically, for MCWD-17 and -26, 28A-2501 and 28A-2502:

- Arsenic concentrations were about five to forty times greater than those for the colder-temperature MCWD wells;
- Boron and bromide concentrations were about two to fifteen times greater than those for the colder-temperature MCWD wells; and,
- Chloride concentrations were about three to twenty times greater than those for the colder-temperature MCWD wells.

If the determination in the CD-IV Project EIS/EIR that the Early Rhyolite forms an impermeable barrier that separates and completely isolates the shallow groundwater aquifer from the deep geothermal reservoir were correct, then we would <u>not</u> expect to see higher concentrations of these conservative elements in wells completed in the shallow groundwater aquifer. However, the conservative element concentrations in the post-July 17, 2014 data from the MCWD-17, -26, and the dual-nested monitoring wells are higher than those in the data from the other MCWD wells. These higher concentrations indicate that geothermal fluids have flowed upwards into the overlying shallow groundwater aquifer and that waters in the shallow groundwater aquifer and deep geothermal reservoir are not completely isolated and instead are intermingling. The fundamental determination in the EIS/EIR that the Early Rhyolite forms an impermeable barrier that physically separates and completely isolates the shallow groundwater aquifer from the deep geothermal reservoir therefore is not supported by these new data.

Mixing Trends and Percentages

At the LVHAC meetings on August 22, 2013, August 10, 2016, and February 2, 2017, Evans (USGS) presented draft and unpublished Cl/Br and Cl/B plots, which illustrated the differences in these ratios for geothermal fluids and non-geothermal waters in the Long Valley Caldera from various sites (springs, surface waters, and wells). These Cl/Br and Cl/B plots that were presented by Evans have been reproduced and are included in this report as Figure 4a (for the pre-July 17, 2014 data) and Figure 4b (for the post-July 17, 2014 data). (See Evans et al. (2002), Brown et al. (2013), and Evans (unpublished data, 2016).)

Pre-July 17, 2014 Data

As described by both Sorey (2011) and Evans (written communications, 2013; 2016; 2017), Figure 4a and 4b show the following distinct data groupings and ratios: 1) geothermal fluid concentrations (reduced by factors of 10 so they will fit on the plots) plot along a single trend line; 2) data from wells on the north side of Mammoth Mountain, where ski salt is applied to lower ski-slopes, had high chloride concentrations and much higher Cl/Br and Cl/B ratios; 3) data from MCWD wells located around the southern and northern edges of the Long Valley Caldera (which do not include MCWD-17) have Cl/Br and Cl/B ratios that are similar to those for samples from precipitation in the Long Valley Caldera, while the Cl/Br and Cl/B ratios calculated from data from MCWD-17 are similar to the ratios calculated from data from the geothermal fluids.

These data were used to develop a local mixing trend line for the geothermal fluids in the western Long Valley Caldera. This mixing line can be used to compare conservative element ratios like Cl/Br and Cl/B ratios for data from geothermal fluids and non-geothermal waters and to assess the degree of mixing between the shallow groundwater aquifer and deeper geothermal reservoir. As shown in Figures 4a and 4b, the August 2011 MCWD-17 sample points clearly have Cl/Br and Cl/B ratios that are like those for data from geothermal fluids. These ratios indicate that a component of geothermal fluid is present in the waters pumped from MCWD-17.

Based on the established local mixing line, the percent of geothermal fluid in MCWD-17 can be estimated using a binary mixing equation (Faure, 1998)[10]:

$$f_A = \frac{(X)_A - (X)_M}{(X)_A - (X)_B}$$

Where:

f_A = Mixing percentage (dimensionless)

$(X)_A$ = Representative conservative element concentration in geothermal fluids

$(X)_B$ = Any representative conservative element concentration in non-geothermal waters

$(X)_M$ = Any representative conservative element concentration in mixed waters

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[10] Faure, G. (1998). *Principles and Applications of Geochemistry.* Upper Saddle River, NJ: Prentice Hall.

If ratios calculated from data from Basalt Canyon Well 57-25 represent the geothermal reservoir or the mixing line end-member, if the conservative element is chloride, and if the chloride concentration in non-geothermal waters is assumed to be zero [$(X)_B$ = 0], then the calculated geothermal component mixing percentage in MCWD-17 (August 2011 sample) using the above equation is approximately two percent. Similar calculations using Basalt Canyon 66-25 as the mixing line end-member, and similar calculations using boron as the conservative element, also indicate a two-percent geothermal component mixing percentage in the August 2011 MCWD-17 sample.

Post-July 17, 2014 Data

Figures 5a and 5b contain plots of the same Cl versus Br and Cl versus B data that are shown in Figure 4a and 4b, and also include plots of data from the new USGS sampling from the MCWD wells and the dual-nested monitoring wells (28A-2501 and 28A-2502) after July 17, 2014. Pre-July 17, 2014 data are included in Figures 5a and 5b to help illustrate data groupings and multi-year trends.

The new data corroborate the trends established by Evans (written communications, 2013; 2016; 2017). Specifically, the Cl/Br and Cl/B ratios from the data from most of the MCWD wells plot along the precipitation trend lines. On the other hand, the data from MCWD-17 and -26 and 28A-2502 are closer to the ratio line for geothermal fluids. These ratios from the MCWD-17 and -26, and 28A-2502 data are consistent, indicating mixed-water type chemistry that fits the local thermal mixing line very well.

The amount of mixing of geothermal fluid with the non-geothermal water in MCWD-17, -26, and the dual-nested monitoring wells can be calculated using the above mixing equation for the Cl and B concentrations. Table 5 presents the calculated percentages of geothermal fluids in these wells for each sample date between 2016 and 2017, with calculations using Cl and B as the conservative elements and data from 57-25 and 66-25 as the mixing line end-members. These calculated mixing percentages show:

- The calculated percentage of geothermal fluids in MCWD-17 increased from approximately two percent in 2011 (see text above for the two-percent amounts) to approximately five percent in 2016, and ranged between approximately three and four percent in 2017;
- The calculated percentage of the geothermal fluids between 2016 and 2017 in MCWD-26 waters is approximately three percent; and
- The calculated mixing percentages for 28A-2501 and 28A-2502 are even higher, ranging between approximately four to almost seven percent.

These calculated mixing percentages from the post-July 17, 2014 data demonstrate that waters in the shallow groundwater aquifer and deep geothermal reservoir <u>are</u> intermingling, and that the fundamental determination in the CD-IV Project EIS/EIR that the Early Rhyolite forms an impermeable barrier that physically separates and completely isolates the shallow groundwater aquifer from the deep geothermal reservoir is not supported by the new geochemistry data.

Stable-Isotope Data

At the LVHAC meetings on August 22, 2013, August 10, 2016, and February 2, 2017, Evans presented stable-isotope data for deuterium and oxygen-18 that had been collected from the Long Valley Caldera area from various sites (springs, surface-waters, and wells; see Tables 2a and 2b for lists of the sites). The draft and unpublished deuterium versus oxygen-18 plots that were presented by Evans (written communications, 2013; 2016; 2017) have been reproduced and included in this report as Figures 6a and 6b. (See Evans, et al. (2002), Brown, et al. (2013), and Evans (written communication, July 2016).) Similarly, deuterium versus oxygen-18 plots for the Long Valley Caldera area were also shown in Sorey et al. (1991) and Sorey (2011). The Global Meteoric Water Line (GMWL) in the plots represents the ratio between deuterium and oxygen-18 values for samples from most groundwaters of the world (Craig, 1961).[11]

The EIS/EIR and Sorey (2011) rely on the isotopic data from the Long Valley Caldera collected prior to July 17, 2014 to assert that the shallow groundwater aquifer is physically separated from the deeper geothermal reservoir. Specifically, page 4.7-12 in the EIS/EIR states:

> Because the isotopic signature of the cold shallow groundwater and the geothermal water is distinct and unique, these data indicate that there is no influx of geothermal water into the shallow groundwater in the western part of the caldera. Stable isotopic compositions of cold groundwaters in the Mammoth Basin plot almost exactly on the meteoric water line, with no suggestion of measurable influence from geothermal fluids.

Sorey (2011, p. 2) states, "Taken together, the chemical, thermal, and isotopic data do not show consistent evidence for hydrologic connections between geothermal and nonthermal groundwaters beneath the western part of the Long Valley Caldera."

Pre-July 17, 2014 Data

As described by both Evans (written communications, 2013; 2016; 2017) and Sorey (2011), Figure 6a shows five distinct groupings of the deuterium and oxygen-18 data, for: 1) groundwaters draining Mammoth Mountain—isotope values are the highest for waters collected in this area; 2) Sherwin Creek waters; 3) northwest and south caldera rim waters; 4) Laurel Springs; and 5) geothermal fluids. Two data groups are apparent from the figure: those for the shallow groundwater aquifer tapped by the MCWD wells (which all are on or near the GMWL line) and those for fluids from the deep geothermal reservoir (which are significantly below and to the right of the GMWL line). Isotope data from

[11] Craig, H. (1961). Isotopic variations in meteoric waters. *Science, 133*, 1702-1703.

MCWD-1, -15, and -23 are similar to isotope data from waters from the non-geothermal springs sampled around the northern base of Mammoth Mountain, and isotope data from MCWD-6, -10, -17, and -20 are similar to isotope data from non-geothermal springs near the Sherwin Creek area. For fluids sampled from the geothermal reservoir, the isotope data are significantly to the right of the GMWL, indicating higher ratios of oxygen-18 to deuterium. The geothermal fluid isotopic values are lower for the geothermal wells that are farther to the east and south in the caldera, which reflects some dilution from local meteoric water (Sorey, 2011).

Post-July 17, 2014 Data

Figure 6b contains plots of the data in Figure 6a, and also includes plots for the data from the new USGS sampling of MCWD wells and the new 28A-2501 and 28A-2502 dual-nested monitoring wells, all collected after July 17, 2014. Points for pre-July 17, 2014 data are included in Figures 6b to help illustrate data groupings. The isotopic compositions of samples from the MCWD wells collected between 2016 and 2017 are unchanged from those of the samples collected since August 2011 and still are along the GMWL. Isotope values in MCWD-1 and -15 continue to match isotope values in waters sampled near the northern base of Mammoth Mountain, and isotope values in MCWD-17 and -20 continue to match isotope values in waters sampled near the Sherwin Creek area. New isotopic data from MCWD-26, 28A-2501, and 28A-2502 also plot along the GMWL and match the isotopic values of waters from the springs in the Sherwin Creek area.

The EIR/EIS and Sorey (2011) relied on isotope data, including data from MCWD-17, which has been shown here to contain a small percentage of geothermal fluids, to support their determinations that there is a hydraulic separation between the shallow groundwater aquifer and deep geothermal reservoir. However, if the CD-IV Project EIS/EIR's determination that the shallow groundwater aquifer and deep geothermal reservoir are physically separated and completely isolated were correct, then the isotopic values of these waters could be calculated using the mixing equation described in the previous section. Figure 6c shows the isotopic values of samples from the MCWD-17, -26, 28A-2501 and 28A-2502 wells, adjusted to reflect the assumption that there are no thermal contributions to these wells (pre-July 17, 2014 data is included in Figure 6c to help illustrate data groupings and multi-year trends). Under this assumption, the values of oxygen-18 would be slightly lower and the values of deuterium would be slightly higher, which would cause each ratio point to be slightly further to the left, as shown in Figure 6c. Because these shifts in these ratio points would be so small, isotope ratios cannot be used to determine whether geothermal fluids have mixed with the shallow groundwater aquifer at the calculated percentages discussed above, and the conclusions in the EIS/EIR and Sorey (2011) that the isotopic data demonstrate hydraulic isolation are incorrect.

MCWD Groundwater Model

WEI developed a groundwater model of the shallow groundwater aquifer that MCWD uses to meet its water supply demands. This model was developed in 2008 and 2009 based on the information available to WEI for the period 1992 through 2006. In our work to develop this model, we assumed that the shallow groundwater aquifer used by the MCWD was hydraulically isolated from the deeper geothermal reservoir. However, after we developed that model in 2008-2009, additional data became available. Based on our review of data collected after 2009, we have revised our conclusion that the shallow groundwater aquifer is <u>not</u> hydraulically separated from the underlying geothermal reservoir. For the reasons discussed in previous sections of this report, the data collected since July 17, 2014 re-affirm our more-recent conclusion that the shallow groundwater aquifer and geothermal reservoir are not hydraulically isolated.

Changes in Hydraulic Gradients between the Shallow Groundwater Aquifer and the Underlying Geothermal Reservoir Caused by the CD-IV Project Operations

As discussed earlier in this report, up to sixteen geothermal wells (two existing and fourteen new) are proposed for the CD-IV Project. Each of these wells might be used for either production or injection of geothermal fluids. The EIS/EIR does not indicate which of the proposed geothermal wells would be used for production and which wells would be used for injection. This creates great uncertainty regarding how the proposed operation of CD-IV Project would affect pressure distributions in the deep geothermal reservoir and pressure gradients between the shallow groundwater aquifer and the underlying geothermal reservoir.

In areas where pressures in the deep geothermal reservoir would decline due to net geothermal fluid extraction, the pressure gradient between the shallow groundwater aquifer and the underlying geothermal reservoir would increase in a downward direction, which would cause groundwater flow from the shallow groundwater aquifer into the underlying geothermal reservoir to increase. This new loss of groundwater to the geothermal reservoir caused by the CD-IV Project operations would reduce the sustainable yield of the MCWD's groundwater production wells. Pressure declines in the deep geothermal reservoir from the CD-IV Project also could cause geothermal fluid, formerly in liquid form and under pressure, to vaporize and create steam, releasing undesirable constituents to the overlying groundwater supply and degrading water quality and creating other hazards at the ground surface. The amount of reduction in sustainable yield and the water quality impacts that would occur from pressure declines due to implementation of the CD-IV Project cannot be quantified at this time because of the paucity of hydrogeologic information, the inadequate number of monitoring wells (particularly deep geothermal monitoring wells), and the uncertainty (discussed above) regarding how ORNI would operate the geothermal production wells and the injection wells in Basalt Canyon.

In areas where pressures in the deep geothermal reservoir would increase due to net geothermal fluid injection, the pressure gradient between the shallow groundwater aquifer and the underlying geothermal reservoir would increase in an upward direction, which would cause geothermal fluids to intrude in the shallow groundwater aquifer and cause significant groundwater quality deterioration. As discussed earlier in this report, the new data collected since July 17, 2014 indicate that geothermal fluids already have intruded into the shallow groundwater aquifer in the western part of the Mammoth Basin. If pressures in the deep geothermal reservoir were to increase, then the rates of such intrusions also would increase.

The average arsenic concentration in MCWD-17 in data collected since July 17, 2014 is 0.113 mg/L, which is about 10 times the California and federal Maximum Contaminant Level (MCL) of 0.010 mg/L. To meet drinking water standards, the MCWD already must blend high-arsenic waters from MCWD-17 with groundwater from MCWD wells with low-arsenic concentrations and then treat this blended supply to produce water that meets arsenic concentrations below the MCL. The arsenic concentration in the geothermal fluid is very high (1.0 to 1.5 mg/L, which is 10 to 15 times the arsenic concentration in MCWD-17) and this arsenic is a source of the high arsenic concentration in MCWD-17. Future increases in arsenic concentrations in MCWD-17 waters due to increases in geothermal fluid intruding into the shallow groundwater aquifer would increase the MCWD's treatment costs and, at some point, would require MCWD to shut down MCWD-17 until the MCWD could upgrade the groundwater treatment capacity to handle the increased arsenic concentration, which would be very expensive.

The amounts of geothermal intrusion that could occur from pressure increases from implementation of the CD-IV Project cannot be quantified at this time because of the paucity of hydrogeologic information, the inadequate number of monitoring facilities (particularly deep geothermal monitoring wells), and the uncertainty regarding how ORNI would operate geothermal production and injection wells in Basalt Canyon.

Conclusions and Recommendations

Data collected and sampled from seven MCWD wells (six production wells and one monitoring well) and the new dual-nested monitoring wells (28A-2501 and 28A-2502) between 2016 and 2017 by the USGS provide important new information regarding the temperatures and geochemistry of the waters in these wells. These data and analyses of them indicate that some degree of mixing between geothermal fluids and non-geothermal waters is occurring and that the determination in the CD-IV Project EIS/EIR that the Early Rhyolite forms an impermeable barrier that physically separates and completely isolates the shallow groundwater aquifer from the deep geothermal reservoir is not supported by the new data. The new data also demonstrate the potential hazards to the overlying shallow groundwater aquifer (water quality degradation and reduction in sustainable groundwater yield) from the proposed CD-IV Project.

Most of these deficiencies could be cured with data collection from two new deep geothermal monitoring wells drilled, instrumented, and monitored to USGS standards at the locations of 28-25 (at Shady Rest Park) and BLM-2 (at the Mammoth Mountain RV Park), and analyses of these data. These data and analyses would provide new, geophysical and geochemical data from the area between the shallow groundwater aquifer and deep geothermal reservoir. This information and long-term pressure and geochemical monitoring data from the MCWD production and monitoring wells and the 28A-25 dual-nested monitoring wells would provide the data necessary to assess the horizontal and vertical hydraulic gradients and degree of vertical connectivity and mixing between the shallow groundwater aquifer and deep geothermal reservoir. Likewise, the Shady Rest Park and Mammoth Mountain RV Park monitoring well clusters would serve as "sentry wells" to detect how far the pressure signals from CD-IV project production would propagate outwards and towards the shallow groundwater aquifer.

The drilling and construction of deep monitoring well 28-25 was completed in fall 2017. We recommend that deep monitoring well BLM-2 also be constructed, and that data from both of these wells then be collected and analyzed over a baseline period of at least 18-months to establish a baseline dataset before CD-IV Project operations begin. Subsequent data collected from these wells after CD-IV Project operations begin then could be used to determine the effects of the CD-IV Project on the shallow groundwater aquifer.

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Encls.:

Table 1: Baseline Monitoring Well Network and Parameters to be Monitored by Individual Well

Table 2a: Summary of Selected Physical, Geochemical, and Isotope Fluid Samples from Wells, Surface-water, and Spring Sites in the Long Valley Caldera (pre-July 17, 2014)

Table 1*

Baseline Monitoring Well Network and Parameters to be Monitored by Individual Well

Well Type	Well Name	Well Status	Monitoring Entity	Monitoring Parameters & Frequency			
				Temperature	Pressure	Water Level	Geochemical
Shallow Groundwater Monitoring Wells	MCWD 14	Existing	MCWD			D (t)	
	MCWD 19	Existing	MCWD			D (m)	
	MCWD 24	Existing	MCWD			D (t)	
	MCWD 26	Existing	MCWD & USGS	D (t)		D (t)	Q
	SC-1	Existing	Ormat & USGS	D (t)		D (t)	
	SC-2	Existing	Ormat & USGS	D (t)		D (t)	
Shallow Groundwater Production Wells	MCWD 1	Existing	MCWD & USGS			D (t)	Q
	MCWD 6	Existing	MCWD & USGS			D (t)	Q
	MCWD 15	Existing	MCWD & USGS			D (t)	Q
	MCWD 16	Existing	MCWD & USGS			D (t)	Q
	MCWD 17	Existing	MCWD			D (t)	Q
	MCWD 18	Existing	MCWD & USGS			D (t)	
	MCWD 20	Existing	MCWD & USGS			D (t)	Q
	MCWD 25	Existing	MCWD & USGS			D (t)	Q
Dual Completion Monitoring Wells	Ormat 14A-25[1]	Existing	USGS	Q (VTP)	D (b)		Q
	Ormat 28A-25	Existing	USGS	Q (VTP)	D (b)		Q
	BLM Off-Lease 1	Existing	USGS	Q (VTP)	D (b)		Q
Geothermal Reservoir Monitoring Wells	Ormat 12-31	Existing	Ormat	D (b)	D (b)		
	Ormat 65-32	Existing	Ormat	D (b)	D (b)		
	Ormat 48-29	Existing	Ormat	D (t)	D (t)		
	Ormat 28-34	Existing	Ormat	D (b)	D (b)		
	Ormat CW-3	Existing	Ormat	D (t)	D (t)		
	USGS CH10B	Existing	USGS		D (b)		
	Ormat 28-25	Existing	USGS	Q (VTP)	D (b)		Q[4]
	BLM Off-Lease 2[2]	Prospective	USGS	Q (VTP)	D (b)		Q[4]
Geothermal Reservoir Production Wells	Ormat 57-25	Existing	Ormat & USGS	D (b)	D (b)		Q
	Ormat 66-25	Existing	Ormat & USGS	D (b)	D (b)		Q
	Ormat 12-25[3]	Existing - idle	Ormat	TBD	D (b)		TBD
	Ormat 14-25[3]	Existing - idle	Ormat	TBD	D (b)		TBD

*Modified from Table 1 in the GMRP v 1.1 (January 19, 2018)

[1]14A-2502 has been sampled by the USGS quarterly, but the lab results are not posted to NWIS due to USGS-reported well contamination issues resulting from drilling the borehole.

[2]If BLM determines BLM-2 is a necessary addition to the monitoring well network based on new scientific information and/or the analysis of monitoring data collected as part of the GMRP in accordance with the regulations at 43 CFR 3200.

[3]Geothermal wells 12-25 and 14-25 are likely to become production or injection wells once the CD-IV Project comes on-line. Collection of temperature and geochemistry data will be added to any future production well.

[4]Well 28-25 and prospective well BLM-2 will be sampled quarterly for geochemistry if the BLM determines that sampling can be performed safely and will not compromise the ability to collect temperature and pressure data. If the BLM determines that it is not safe or will compromise the ability to get pressure and/or temperature data, then these wells will be removed from the quarterly geochemical sampling schedule.

Monitoring Parameters & Frequency Codes

D = Daily Average, Q = Quarterly, TBD = To Be Determined, (t) = Transducer, (b) = Bubbler Tube, (m) = Manual, VTP = Vertical Temperature Profile

Table 2a
Summary of Selected Physical, Geochemical, and Isotope Fluid Samples from
Wells, Surface-water, and Spring Sites in the Long Valley Caldera (pre-July 17, 2014)

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	Alkalinity	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	$d^{18}O$	$d^{2}H$
		°C	mg/L	µS/cm	mg/L		mg/L						parts per thousand (‰)	
Thermal Wells - Western Caldera[1,2]														
44-16	1/20/1986	218	2,200	-	-	9.3L	1.0	14	-	280	9.8	353	-	-
	6/27/2005	190	-	-	-	5.7	0.5	11.8	0.49	284	11.7	332	-14.0	-113
RDO-8	11/15/1986	202	1,430	-	-	5.9L	ND	12.0	-	280	12.0	250	-	-
	7/18/2007	-	-	-	-	6.8C	1.9	11.8	0.52	277	15.0	301	-14.2	-114
12-31	6/29/2005	184	-	-	-	6.5	0.6	7.5	0.30	149	6.0	196	-15.9	-123
57-25	10/12/2006	170	-	-	-	5.9	1.5	11.1	0.48	253	11.4	285	-14.8	-119
	6/28/2007	170	-	-	-	-	-	-	-	-	-	-	-14.8	-116
66-25	10/12/2006	170	-	-	-	6.1	1.4	10.0	0.44	234	13.0	230	-15.1	-120
	6/28/2007	170	-	-	-	-	-	-	-	-	-	-	-15.0	-121
MBP-3	1996	158	-	1750e	420	7.2	1.6	-	ND	230	10.5	-	-	-
24-32	10/12/2006	150	-	-	-	6.5	1.5	10.0	0.42	237	11.3	236	-14.9	-119
24A-32	6/28/2005	150	-	-	-	6.4	-	-	-	-	-	-	-14.9	-118
	9/30/2005	150	-	-	-	-	-	-	-	-	-	-	-14.9	-118
	10/12/2006	150	-	-	-	-	1.8	10.0	0.41	234	11.3	236	-14.9	-118
	6/28/2007	150	-	-	-	-	-	-	-	-	-	-	-14.8	-119
24D-32	6/28/2005	150	-	-	-	-	-	-	-	222	-	-	-14.9	-118
	9/30/2005	150	-	-	-	-	-	-	-	-	-	-	-15.1	-118
25-32	10/12/2006	150	-	-	-	6.4	1.5	10.5	0.41	238	11.4	230	-14.9	-118
	6/28/2007	150	-	-	-	-	-	-	-	-	-	-	-14.9	-120
25A-32	7/1/2005	150	-	-	-	-	-	-	-	238	-	-	-15.0	-119
	9/30/2005	150	-	-	-	-	-	-	-	-	-	-	-14.9	-117
	6/28/2007	150	-	-	-	-	-	-	-	-	-	-	-14.9	-118
Thermal Wells - Eastern Caldera[1]														
28-34	6/28/2005	150	-	-	-	6.4	1.4	9.1	0.37	202	12.8	230	-15.1	-121
CW-3	7/17/2007	-	-	-	-	6.4	1.4	9.6	0.44	202	12.0	200	-14.6	-117
CH-10B	7/15/2007	100	-	-	-	7.0	0.6	7.4	0.48	154	6.68	96	-15.5	-120
Hot Springs - Eastern Caldera[1]														
BAL	8/12/1998	57	-	-	-	6.7	-	-	-	148	-	-	-	-
	7/13/2006	-	-	-	-	-	0.4	6.6	0.24	148	4.9	200	-	-
LHC	8/125/1998	79	-	-	-	6.8	-	-	-	200	-	-	-	-
	7/13/2006	-	-	-	-	-	0.7	9.1	0.32	200	9.0	101	-	-
HBP	8/12/1998	79	-	-	-	7.5	-	-	-	217	-	-	-	-

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	Alkalinity	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	$d^{18}O$	$d^{2}H$
		°C	mg/L	µS/cm	mg/L		mg/L						parts per thousand (‰)	
	7/14/2007	-	-	-	-	-	1.6	10.2	0.39	217	12.4	216	-	-
Cold Wells, Surface-Waters, and Springs[3]														
BS	8/5/1996[4]	11.8	-	196	-	7.2	-	-	0.01	5.9	0.44	-	-	-
	Aug-98	12.3	-	225	-	7.2	-	0.25	0.01	5.0	0.44	61	-15.76	-115
	9/10/1999[4]	12.4	-	234	-	7.1	0.03	0.27	0.01	4.80	0.40	66	-	-
	8/19/2001[4]	-	-	-	-	-	0.02	0.30	0.01	5.70	0.37	62	-	-
CTRAW	Jun-97	13.0	-	-	-	-	-	-	-	-	-	-	-	-
	Aug-98	13.8	-	246	-	7.0	-	0.15	0.01	2.50	0.48	65	-15.72	-112
	8/21/2001[4]	-	-	-	-	-	0.03	0.17	0.01	3.00	0.30	68	-	-
CTW-2	Aug-98	17.6	-	148	-	4.0	-	0.16	0.01	4.20	0.25	46	-16.6	-123
CH12S	9/24/1996[4]	2.4	-	171	-	5.2	-	0.00	ND	0.33	0.15	40	-	-
	Jun-97	2.4	-	108	-	5.2	-	-	-	-	-	-	-14.8	-105
	Aug-97	2.6	-	206	-	5.2	-	-	-	-	-	-	-	-
	Aug-98	2.4	-	147	-	5.1	-	ND	0.001	0.28	0.19	35	-	-
RMCS	Aug-96	7.5	-	227	-	5.5	-	0.009	0.004	0.28	0.07	81	-	-
	Aug-98	7.4	-	248	-	5.4	-	-	-	-	-	-	-14.9	-107
	Jun-99	7.1	-	246	-	5.4	-	-	-	-	-	-	-	-
	Sep-99	7.3	-	244	-	5.4	-	-	-	-	-	-	-	-
SLS	Sep-96	18.0	-	256	-	6.0	-	0.262	0.008	1.14	1.15	67	-14.8	-104
	Sep-99	17.7	-	276	-	6.0	-	-	-	-	-	-	-	-
CCS	Oct-98	6.8	-	102	-	5.8	-	0.023	0.003	0.21	0.50	36	-	-105
MLS	Aug-96	2.8	-	284	-	5.6	-	-	4.400	33.30	ND	-	-14.7	-105
MMSA-1	Aug-96	5.3	-	229	-	5.4	-	0.010	2.500	17.60	ND	48	-14.9	-106
MMSA-2B	Aug-96	10.1	-	372	-	5.8	-	-	0.003	5.70	0.15	-	-15.1	-109
MMSA-3	Aug-96	7.3	-	73	-	6.0	-	-	0.006	3.40	ND	-	-15.1	-110
DCWELL2	Oct-98	7.8	-	710	-	6.1	-	0.015	0.002	4.20	0.22	81	-	-109
DCWELL6	Oct-98	7.1	-	731	-	6.4	-	0.012	0.003	2.90	0.25	72	-	-108
VSS	Aug-96	-	-	-	-	-	-	0.005	0.005	0.46	0.13	75	-	-
	Aug-97	6.7	-	278	-	5.4	-	-	-	-	-	-	-15.0	-107
CH15S	Sep-96	7.7	-	381	-	5.9	-	0.014	0.009	1.08	0.10	72	-15.2	-108
ASS	Aug-97	6.9	-	200	-	5.4	-	-	-	-	-	-	-14.7	-106
	Aug-98	6.2	-	199	-	5.5	-	0.018	0.003	0.27	0.12	60	-	-
	Jun-99	7.1	-	182	-	5.4	-	-	-	-	-	-	-	-
	Sep-99	6.8	-	201	-	5.4	-	-	-	-	-	-	-	-
	8/20/2001[4]	-	-	-	-	-	0.02	0.033	0.003	0.34	0.11	65	-	-
LBCS	Jun-97	6.9	-	-	-	5.4	-	-	-	-	-	-	-	-
	Aug-97	7.8	-	225	-	5.4	-	-	-	-	-	-	-	-

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	Alkalinity	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	$d^{18}O$	$d^{2}H$
		°C	mg/L	µS/cm	mg/L		mg/L						parts per thousand (‰)	
	Aug-98	7.2	-	224	-	5.4	-	0.034	0.003	0.40	0.12	66	-14.7	-105
	Jun-99	7.0	-	222	-	5.5	-	-	-	-	-	-	-	-
LBCN	Aug-98	6.8	-	253	-	5.5	-	0.021	0.001	0.45	0.09	75	-14.7	-105
LS	6/3/1984[5]	-	-	-	-	-	-	-	-	-	-	-	-16.8	-124
	8/5/1996[4]	-	-	-	-	-	-	-	0.005	0.40	0.09	-	-	-
Shallow Cold Groundwater Aquifer Production and Monitoring Wells														
MCWD-1	1985	-	-	120	58	6.6	0	-	-	2	0.3	-	-	-
	7/24/1991	-	-	-	-	-	-	-	-	-	-	-	-14.9	-108
	1995	-	-	230	93	7.6	-	-	-	0	0.5	-	-	-
	6/6/1996	8	168	240	-	7.4	-	-	-	-	-	-	-	-
	9/12/1997	9	96	190	-	7.2	-	-	-	-	-	-	-	-
	7/6/1998	8	120	210	-	7.4	-	-	-	-	-	-	-	-
	7/14/1999	9	165	208	-	7.6	-	-	-	-	-	-	-	-
	8/22/2000	9	156	210	-	7.2	-	-	-	-	-	-	-	-
	7/27/2001	9	140	220	-	6.5	-	-	-	-	-	-	-	-
	9/5/2002	9	116	232	-	6.6	-	-	-	-	-	-	-	-
	11/3/2005[4]	-	-	-	-	-	-	-	-	-	-	-	-14.6	-109
	8/26/2011[4]	-	-	-	-	-	0.005	0.035	0.014	1.23	0.32	51	-14.6	-109
MCWD-6	1984	8.1	-	370	190	8.1	0.053	-	-	0.94	0.22	-	-	-
	1989	-	-	380	120	7.4	0.02	-	-	0	0.3	-	-	-
	7/20/1990	13.5	267	397	-	7.1	0.016	0.1	-	7	0.3	58.0	-15.7	-114
	7/24/1991	-	-	432	-	-	-	-	-	-	-	-	-15.7	-113
	7/26/1995	15.0	262	423	-	7.3	0.016	0.1	-	1	-	-	-15.3	-113
	6/6/1996	9	283	470	-	7.5	-	-	-	-	-	-	-	-
	9/12/1997	12	198	397	-	7.1	-	-	-	-	-	-	-	-
	7/7/1998	11	160	300	-	8.2	-	-	-	-	-	-	-	-
	7/14/1999	10	172	305	-	7.6	-	-	-	-	-	-	-	-
	7/28/2000	10	166	310	-	7.4	-	-	-	-	-	-	-	-
	7/26/2001	11	230	380	-	7.4	-	-	-	-	-	-	-	-
	9/5/2002	11	190	350	-	7.2	-	-	-	-	-	-	-	-
	11/3/2005[4]	-	-	-	-	-	-	-	-	-	-	-	-15.5	-114
	8/26/2011[4]	-	-	-	-	-	0.038	0.085	0.002	0.47	0.23	44	-15.4	-114
MCWD-10	6/6/1996	10	315	465	-	7.3	-	-	-	-	-	-	-	-
	9/12/1997	13	179	359	-	7.2	-	-	-	-	-	-	-	-
	6/30/1998	9	240	350	-	7.6	-	-	-	-	-	-	-	-
	7/14/1999	9	231	353	-	7.5	-	-	-	-	-	-	-	-
	7/28/2000	10	228	360	-	7.5	-	-	-	-	-	-	-	-

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	Alkalinity	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	$d^{18}O$	$d^{2}H$
		°C	mg/L	µS/cm	mg/L		mg/L						parts per thousand (‰)	
	7/26/2001	11	300	470	-	6.6	-	-	-	-	-	-	-	-
	9/5/2002	11	225	410	-	7.0	-	-	-	-	-	-	-	-
MCWD-15	7/28/1995	11	176	259	-	7.5	0.0	0.1	-	1	0.5	56.0	-14.8	-110
	6/6/1996	13	152	240	-	7.4	-	-	-	-	-	-	-	-
	9/12/1997	13	144	288	-	7.2	-	-	-	-	-	-	-	-
	6/30/1998	12	210	360	-	7.5	-	-	-	-	-	-	-	-
	7/14/1999	13	190	355	-	7.6	-	-	-	-	-	-	-	-
	8/22/2000	12	187	350	-	7.3	-	-	-	-	-	-	-	-
	7/2/2001	13	220	330	-	7.4	-	-	-	-	-	-	-	-
	9/5/2002	12	185	290	-	7.2	-	-	-	-	-	-	-	-
	11/3/2005[4]	-	-	-	-	-	-	-	-	-	-	-	-14.6	-109
	8/26/2011[4]	21	-	-	-	-	0.012	0.059	0.015	1.41	0.4	51	-14.6	-109
MCWD-16	1992	-	-	690	366	7.1	0.018	-	-	0	2.00	-	-	-
	7/11/1996	21	432	660	-	7.5	-	-	-	-	-	-	-	-
	9/11/1997	23	317	632	-	7.1	-	-	-	-	-	-	-	-
	7/6/1998	21	500	710	-	7.1	0.027	-	-	2	0.6	-	-	-
	8/20/1999	21	480	690	-	7.2	-	-	-	-	-	-	-	-
	8/22/2000	23	485	695	-	7.3	-	-	-	-	-	-	-	-
	10/1/2001	21	490	710	-	6.9	0.038	-	-	1	0.5	-	-	-
	9/9/2002	21	490	705	-	6.7	-	-	-	-	-	-	-	-
MCWD-17	1992	-	-	350	158	7.7	0.042	-	-	3	2	-	-	-
	7/11/1996	18	265	360	-	7.3	-	-	-	-	-	-	-	-
	7/6/1998	16	280	350	170	7.1	0.037	-	-	2	0.4	-	-	-
	8/20/1999	16	280	350	-	7.2	-	-	-	-	-	-	-	-
	8/22/2000	17	276	355	-	7.2	-	-	-	-	-	-	-	-
	7/2/2001	16	310	410	190	6.7	0.06	-	-	5	0.6	-	-	-
	9/3/2002	16	290	400	190	6.6	0.06	-	-	5	0.6	-	-	-
	8/26/2011[4]	16	400	-	-	7.7	0.077	0.234	0.011	5.17	0.56	95	-15.5	-115
MCWD-18	1992	-	-	530	274	7	0.018	-	-	0	2	-	-	-
	10/1/1998	21	-	490	230	6.9	0.03	-	-	2	1	-	-	-
	10/1/2001	19.4	-	530	260	6.4	0.017	-	-	0	1	-	-	-
MCWD-20	1992	-	-	350	-	7	0.011	-	ND	0	2	-	-	-
	7/26/1995	15.5	226	323	-	6.9	0.006	0.1	-	1	1	70.0	-15.5	-115
	7/11/1996	15	164	217	-	7.1	-	-	-	-	-	-	-	-
	9/11/1997	16	168	336	-	6.9	-	-	-	-	-	-	-	-
	8/20/1999	16	190	310	-	7.1	-	-	-	-	-	-	-	-
	7/27/2001	16	250	340	160	6.8	0.008	-	ND	0	0.5	-	-	-
	9/5/2002	17	195	400	-	6.6	-	-	-	-	-	-	-	-

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	Alkalinity	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	d^{18}O	d^{2}H
		°C	mg/L	µS/cm	mg/L		mg/L						parts per thousand (‰)	
	8/26/2011[4]	-	-	-	-	-	0.01	0.1	0.0	1	0.5	74.0	-15.6	-114
MCWD-26	2006	42	-	-	-	-	-	-	0.7	6.40	0.7	-	-	-

ND = Non-detect

"-" = Data not analyzed or available

e = represents the estimated conductance for the 1996 analyses, based on a value determined on a sample collected in 1990.

[1] Brown et al. (2013)

[2] 1986 samples reported by Sorey et al. (1991)

[3] Evans et al. (2002)

[4] Evans (written commun., 2016)

Table 2b
Summary of Selected Physical, Geochemical, and Isotope Fluid Samples from the MCWD Wells and 28A-25 Dual-nested Monitoring Well (post-July 17, 2014)

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	d^{18}O	d^{2}H
		°C	mg/L	µS/cm		mg/L						parts per thousand (‰)	
Shallow Cold Groundwater Aquifer Production and Monitoring Wells[1]													
MCWD-1	1/25/2016	8.0	149	229	7.2	0.005	0.048	0.011	0.82	0.38	47	-14.4	-107
	4/25/2016	8.0	157	233	6.8	0.005	0.048	0.010	0.77	0.41	52	-14.4	-107
	7/11/2016	7.9	164	244	7.1	0.005	0.038	0.018	0.96	0.40	49	-14.2	-106
	10/11/2016	7.8	166	231	7.3	0.005	0.038	0.018	0.79	0.37	49	-14.2	-105
	1/24/2017	7.6	144	302	7.0	0.004	0.034	0.019	0.88	0.35	48	-14.1	-106
	4/3/2017	7.6	143	214	7.3	0.004	0.032	0.021	0.97	0.36	48	-14.1	-106
	7/17/2017	7.6	152	204	6.9	0.005	0.031	0.033	1.40	0.34	48	-14.2	-107
	10/10/2017	7.5		213	7.0	-	-	-	-	-	-	-	-
MCWD-15	1/26/2016	11.4	229	342	7.4	0.015	0.173	0.011	1.73	0.47	56	-14.9	-110
	4/26/2016	9.3	182	256	7.1	0.013	0.074	0.015	1.42	0.42	57	-14.6	-108
	7/12/2016	9.0	163	245	7.3	0.010	0.056	0.015	1.31	0.42	54	-14.5	-108
	10/12/2016	8.8	169	244	7.7	0.010	0.051	0.017	1.24	0.40	53	-14.5	-107
	4/4/2017	8.7	162	244	7.4	0.010	0.047	0.015	1.30	0.40	51	-14.5	-108
	7/18/2017	9.8	174	268	7.2	0.012	0.064	0.014	1.27	0.43	53	-14.5	-109
	10/11/2017	9.1	-	241	7.3	-	-	-	-	-	-	-	-
MCWD-16	1/26/2016	19.4	380	572	6.6	0.011	0.106	0.014	0.62	0.56	81	-15.6	-113
	4/26/2016	18.4	362	538	6.5	0.007	0.090	-	0.56	0.58	81	-15.5	-113
	7/12/2016	20.0	371	579	6.7	0.008	0.116	0.003	0.67	0.58	82	-15.5	-112
	10/13/2016	19.3	371	563	6.3	0.014	0.113	0.004	0.65	0.53	83	-15.5	-112
	1/26/2017	18.1	368	545	6.5	0.007	0.098	-	0.58	0.56	80	-15.3	-112
	4/4/2017	18.4	357	538	6.5	0.006	0.098	-	0.59	0.57	80	-15.5	-113
	7/18/2017	18.6	365	550	6.3	0.007	0.097	-	0.60	0.56	79	-15.5	-113
	10/11/2017	18.2	-	530	6.4	-	-	-	-	-	-	-	-
MCWD-17	1/27/2016	27.6	401	554	7.0	0.123	0.513	0.038	12.20	0.65	110	-	-
	4/26/2016	27.1	393	539	7.0	0.123	0.486	0.035	11.40	0.64	112	-15.4	-113
	7/13/2016	27.2	364	544	6.8	0.115	0.494	0.034	11.50	0.63	110	-15.5	-114
	10/13/2016	25.3	341	505	6.8	0.121	0.466	0.033	10.30	0.62	105	-15.5	-114
	1/25/2017	24.3	351	440	6.9	0.103	0.416	0.030	9.40	0.60	102	-15.5	-115
	4/4/2017	23.4	347	487	6.9	0.100	0.410	0.028	9.07	0.59	101	-15.5	-115
	7/18/2017	24.7	357	498	6.8	0.108	0.386	0.028	8.59	0.60	102	-15.4	-115

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	d^{18}O	d^{2}H
		°C	mg/L	µS/cm		mg/L						parts per thousand (‰)	
	10/11/2017	22.6	-	449	6.9	-	-	-	-	-	-	-	-
MCWD-20	1/26/2016	18.2	296	433	6.6	0.009	0.070	0.004	0.76	0.49	79	-15.6	-113
	4/26/2016	15.3	276	384	6.5	0.006	0.055	-	0.80	0.46	78	-15.5	-113
	7/12/2016	16.0	282	411	6.6	0.005	0.063	0.005	0.76	0.45	78	-15.5	-113
	10/13/2016	16.4	281	412	6.3	0.006	0.059	0.004	0.69	0.47	77	-15.5	-113
	4/4/2017	14.9	240	336	6.5	0.006	0.062	-	0.80	0.48	74	-15.6	-114
	7/18/2017	15.5	246	368	6.3	0.006	0.065	-	0.77	0.48	74	-15.6	-115
	10/11/2017	15.6	-	365	6.4	-	-	-	-	-	-	-	-
MCWD-25	1/25/2016	9.5	182	284	7.3	0.006	0.051	0.021	1.52	0.27	47	-14.8	-109
	4/26/2016	8.7	180	265	7.0	0.004	0.043	0.042	2.45	0.25	51	-14.5	-107
	7/12/2016	8.7	162	275	7.1	0.004	0.043	0.031	2.17	0.27	48	-14.3	-108
	10/12/2016	8.6	177	269	7.7	0.004	0.040	0.058	2.24	0.26	47	-14.3	-107
	1/25/2017	8.5	167	345	7.1	0.004	0.037	0.034	2.20	0.24	46	-14.3	-107
	4/3/2017	8.1	165	254	7.1	0.004	0.032	0.042	2.51	0.23	45	-14.2	-106
	7/18/2017	8.7	171	266	7.0	0.005	0.040	0.028	1.92	0.27	47	-14.2	-108
	10/11/2017	8.2	-	237	7.0	-	-	-	-	-	-	-	-
MCWD-26	1/27/2016	37.3	386	544	7.1	0.157	0.380	0.032	7.14	0.66	127	-15.7	-115
	4/25/2016	35.6	382	558	7.0	0.165	0.369	0.031	6.99	0.65	137	-15.8	-116
	7/13/2016	38.0	391	551	7.0	0.157	0.385	0.031	7.02	0.64	128	-15.7	-116
	10/11/2016	37.6	392	581	7.1	0.174	0.397	0.031	6.87	0.63	129	-15.8	-114
	1/25/2017	36.4	388	496	6.9	0.161	0.357	0.031	6.71	0.62	127	-15.8	-116
	4/4/2017	36.0	399	559	6.9	0.161	0.416	0.031	7.34	0.64	128	-15.8	-116
	7/18/2017	36.2	397	567	6.8	0.169	0.420	0.032	7.57	0.66	130	-15.7	-117
	10/11/2017	35.2	-	540	6.9	-	-	-	-	-	-	-	-
Dual Completion (Shallow and Intermediate Depth) Monitoring Wells[1]													
28A-2501	2/23/2016	43.0	400	506	6.6	0.188	0.621	0.036	11.9	0.66	136	-15.7	-116
	5/17/2016	44.4	393	515	6.6	0.187	0.625	0.041	11.6	0.64	142	-15.7	-116
	8/16/2016	45.0	407	529	6.6	ND	0.673	0.034	11.6	0.68	142	-15.7	-116
	12/13/2016	42.0	414	516	6.6	0.210	0.674	0.032	11.7	0.63	144	-15.7	-116
	2/14/2017	43.0	410	512	6.5	0.203	0.672	0.031	11.7	0.63	144	-15.7	-115
	5/23/2017	45.9	408	520	6.5	0.201	0.662	0.033	11.7	0.61	145	-15.8	-115
28A-2502	2/24/2016	44.0	427	552	6.5	0.140	0.621	0.035	11.7	0.58	149	-15.7	-116
	5/18/2016	44.1	420	537	6.5	0.141	0.630	0.031	11.3	0.54	153	-15.7	-115
	8/16/2016	45.0	427	542	6.3	0.154	0.663	0.030	11.2	0.57	151	-15.7	-116

Site Name	Sample Date	Fluid Temperature	TDS	Specific Conductance	pH (field)	Arsenic	Boron	Bromide	Chloride	Fluoride	Silica	d[18]O	d[2]H
		°C	mg/L	µS/cm		mg/L						parts per thousand (‰)	
	12/13/2016	41.4	433	535	6.3	0.159	0.661	0.031	11.3	0.54	153	-15.8	-117
	2/14/2017	44.0	424	535	6.3	0.161	0.665	0.030	11.3	0.52	155	-15.7	-117
	5/23/2017	44.5	-	541	6.3	-	-	0.032	-	-	-	-15.8	-115
14A-2501	2/25/2016	51	817	944	6.4	0.097	3.080	0.087	26.5	0.29E	245	-15.1	-117
	5/19/2016	52.4	784	897	6.3	0.105	3.160	0.077	24.9	0.23E	267	-15.1	-116
	8/17/2016	53	875	970	6.4	0.132	3.610	0.079	28.9	0.25E	284	-15.0	-117
	12/14/2016	42.8	799	874	6.2	0.134	3.480	0.068	24.6	0.21	273	-15.0	-116
	2/15/2017	51.5	773	877	6.2	0.135	3.480	0.065	24.6	0.22E	276	-15.1	-116
	5/18/2017	60.8	593	528	5.7	0.047	1.550	0.046	24.6	0.23	270	-15.9	-121

ND = Non-detect

"-" = Data not analyzed or available

E = Estimated value

[1] https://waterdata.usgs.gov/nwis

Water quality data from 14A-2501 are shown here, but according to Evans' reports to the LVHAC, are considered to be potentially contaminated as a result of borehole drilling.

Water quality data from 14A-2502 are not shown here. According to Evans' reports to the LVHAC, 14A-2502 are considered to be contaminated as a result of borehole drilling.

Table 3

Summary of Physical Water Quality Parameters from Select GMRP Monitoring Well Sites (post-July 17, 2014)

Parameter	Basalt Canyon Wells[1]			Dual-Nested Monitoring Wells[2,3]		MCWD Warmer-Temperature Wells[2]				MCWD Colder-Temperature Wells[2]		
	RDO-8	57-25	66-25	28A-2501	28A-2502	16	17	20	26	1	15	25
Temperature (C°)												
Minimum	202	170	170	42.0	41.4	18.1	22.6	14.9	35.2	7.5	8.7	8.1
Maximum	202	190	174	45.9	45.0	20.0	27.6	18.2	38.0	8.0	11.4	9.5
Average	202	180	172	43.9	43.8	18.8	25.3	16.0	36.5	7.8	9.4	8.6
pH												
Minimum	5.9	5.9	6.1	6.5	6.3	6.3	6.8	6.3	6.8	6.8	7.1	7.0
Maximum	6.8	5.9	6.1	6.6	6.5	6.7	7.0	6.6	7.1	7.3	7.7	7.7
Average	6.4	5.9	6.1	6.6	6.4	6.5	6.9	6.5	7.0	7.1	7.3	7.2
SC (µS/cm)												
Minimum	-	-	-	506	535	530	440	336	496	204	241	237
Maximum	-	-	-	529	552	579	554	433	581	302	342	345
Average	-	-	-	516	540	552	502	387	550	234	263	274
TDS (mg/L)												
Minimum	1,430	-	-	393	420	357	341	240	382	143	162	162
Maximum	1,430	-	-	414	433	380	401	296	399	166	229	182
Average	1,430	-	-	405	426	368	365	270	391	154	180	172

[1] 57-25 and 66-25 sampled in 2006, and temperature data collected during the 2015 Basalt Canyon Memorial Day Flow Test; RDO-8 sampled in 1986 and 2007.

[2] Wells sampled between 2016 and 2017.

[3] Water quality data from 14A-25 are not included in this table due to USGS-reported well contamination issued related to the well drilling and construction.

Table 4a

Summary of Select Conservative Element Geochemical Data from the Basalt Canyon and MCWD Wells for the USGS August 2011 Sample Event (pre-July 17, 2014)

mg/L

Conservative Element	Basalt Canyon Wells		MCWD Warmer-Temperature Wells				MCWD Colder-Temperature Wells			
	57-25	66-25	16	17	20	26	1	6	15	25
Arsenic	1.5	1.4	-	0.077	0.006	-	0.005	0.038	0.012	-
Boron	11.1	10.0	-	0.234	0.064	-	0.035	0.085	0.059	-
Bromide	0.48	0.44	-	0.011	0.002	-	0.014	0.002	0.015	-
Chloride	253	234	-	5.17	0.74	-	1.23	0.47	1.41	-

Table 4b

Summary of Selected Conservative Element Geochemical Data from the Basalt Canyon, MCWD, and 28A-25 Dual-nested Wells (post-July 17, 2014)

mg/L

Conservative Element	Basalt Canyon Wells[1]		Dual-Nested Monitoring Wells[2]		MCWD Warmer-Temperature Wells				MCWD Colder-Temperature Wells		
	57-25	66-25	28A-2501	28A-2502	16	17	20	26	1	15	25
Arsenic											
Minimum	1.5	1.4	0.187	0.140	0.006	0.100	0.005	0.157	0.004	0.010	0.004
Maximum	1.5	1.4	0.210	0.161	0.014	0.123	0.009	0.174	0.005	0.015	0.006
Average	1.5	1.4	0.198	0.151	0.009	0.113	0.006	0.163	0.005	0.012	0.004
Boron											
Minimum	11.1	10.0	0.621	0.621	0.090	0.386	0.055	0.357	0.031	0.047	0.032
Maximum	11.1	10.0	0.674	0.665	0.116	0.513	0.070	0.420	0.048	0.173	0.051
Average	11.1	10.0	0.655	0.648	0.103	0.453	0.062	0.389	0.038	0.078	0.041
Bromide											
Minimum	0.48	0.44	0.031	0.030	0.003	0.028	0.004	0.031	0.010	0.011	0.021
Maximum	0.48	0.44	0.041	0.035	0.014	0.038	0.005	0.032	0.033	0.017	0.058
Average	0.48	0.44	0.035	0.032	0.007	0.032	0.004	0.031	0.019	0.015	0.037
Chloride											
Minimum	253	234	11.6	11.2	0.56	8.59	0.69	6.71	0.77	1.24	1.52
Maximum	253	234	11.9	11.7	0.67	12.20	0.80	7.57	1.40	1.73	2.51
Average	253	234	11.7	11.4	0.61	10.35	0.76	7.09	0.94	1.38	2.14

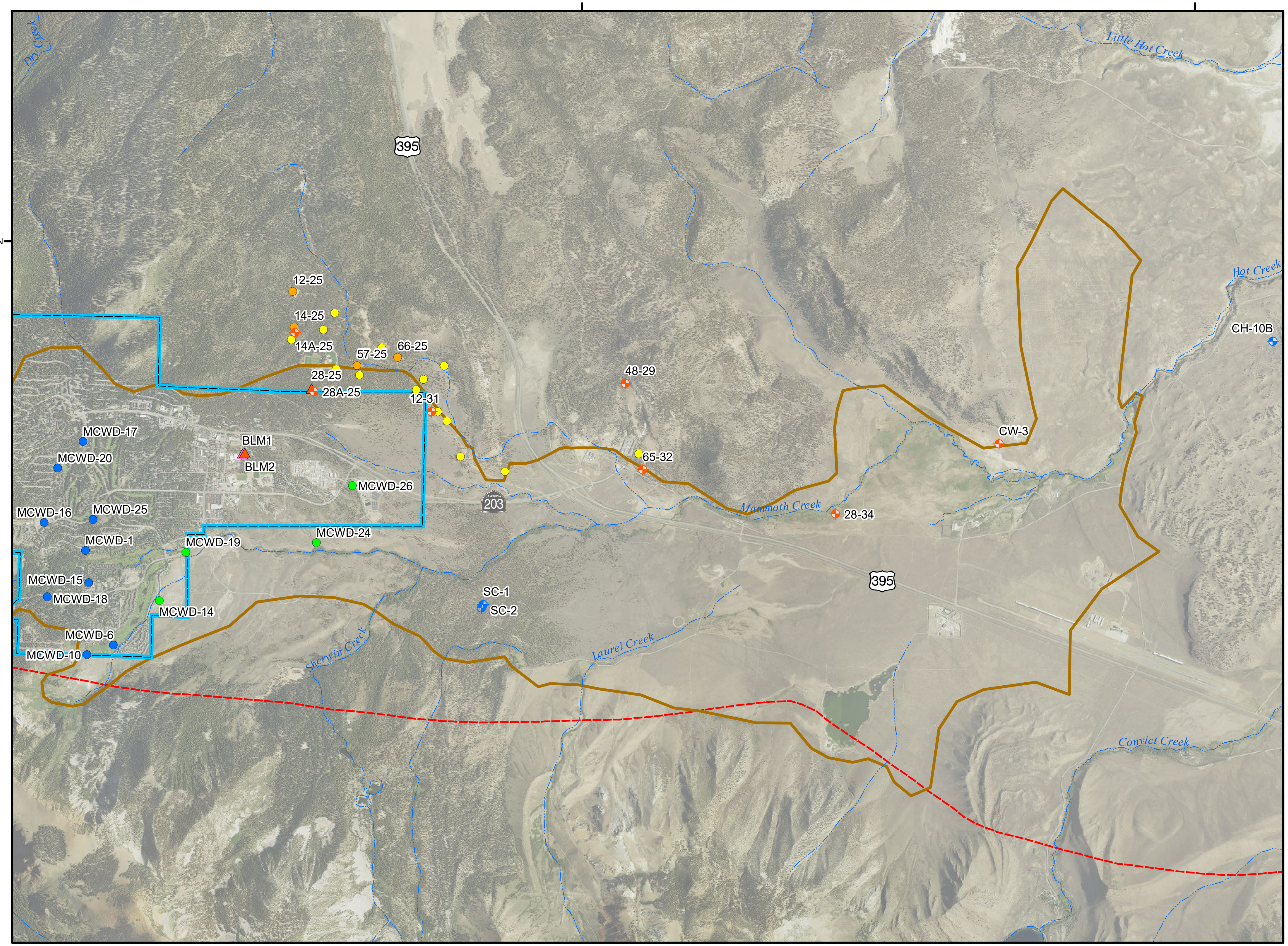
[1] 57-25 and 66-25 sampled in 2006. The 2006 data is the only publically available data from Basalt Canyon geothermal wells 57-25 and 66-25.

[2] Water quality data from 14A-25 is not included in this table due to USGS-reported well contamination issued related to the well drilling and construction.

Table 5

Percent of Mixing (Geothermal Fluids in Non-Geothermal Waters) for Warm-Temperature MCWD and 28A-25 Dual-nested Wells (post-July 17, 2014)

Site Name	Sample Date	Conservative Element			
		Chloride		Boron	
		Mixing Line End-Member			
		57-25	66-25	57-25	66-25
MCWD-17	1/27/2016	4.8%	5.2%	4.6%	5.1%
	4/26/2016	4.5%	4.9%	4.4%	4.9%
	7/13/2016	4.5%	4.9%	4.4%	4.9%
	10/13/2016	4.1%	4.4%	4.2%	4.7%
	1/25/2017	3.7%	4.0%	3.7%	4.2%
	4/4/2017	3.6%	3.9%	3.7%	4.1%
	7/18/2017	3.4%	3.7%	3.5%	3.9%
MCWD-26	1/27/2016	2.8%	3.1%	3.4%	3.8%
	4/25/2016	2.8%	3.0%	3.3%	3.7%
	7/13/2016	2.8%	3.0%	3.5%	3.9%
	10/11/2016	2.7%	2.9%	3.6%	4.0%
	1/25/2017	2.7%	2.9%	3.2%	3.6%
	4/4/2017	2.9%	3.1%	3.7%	4.2%
	7/18/2017	3.0%	3.2%	3.8%	4.2%
28A-2501	2/23/2016	4.7%	5.1%	5.6%	6.2%
	5/17/2016	4.6%	5.0%	5.6%	6.3%
	8/16/2016	4.6%	5.0%	6.0%	6.7%
	12/13/2016	4.6%	5.0%	6.1%	6.7%
	2/14/2017	4.6%	5.0%	6.0%	6.7%
	5/23/2017	4.6%	5.0%	5.9%	6.6%
28A-2502	2/24/2016	4.6%	5.0%	5.6%	6.2%
	5/18/2016	4.5%	4.8%	5.7%	6.3%
	8/16/2016	4.4%	4.8%	6.0%	6.6%
	12/13/2016	4.5%	4.8%	5.9%	6.6%
	2/14/2017	4.5%	4.8%	6.0%	6.6%
	5/23/2017	-	-	-	-

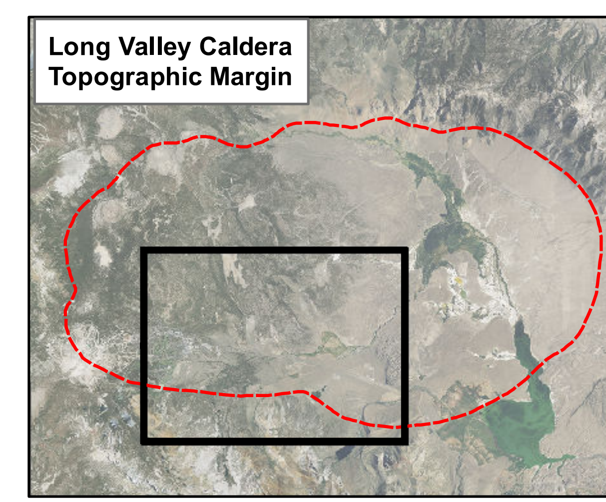


Explanation

- MCWD Monitoring Well
- MCWD Production Well
- USGS Monitoring Well
- Ormat Geothermal Monitoring Well
- Existing Geothermal Production Well*
- CD-IV Project Proposed Geothermal Well
- BLM Dual Completion Monitoring Well
- BLM Geothermal Monitoring Well (Prospective)

**Geothermal wells 12-25 and 14-25 are likely to become production or injection wells once the CD-IV project comes on-line.*

- Caldera Topographic Margin
- WEI (2009) Mammoth Groundwater Basin
- MCWD Service Area



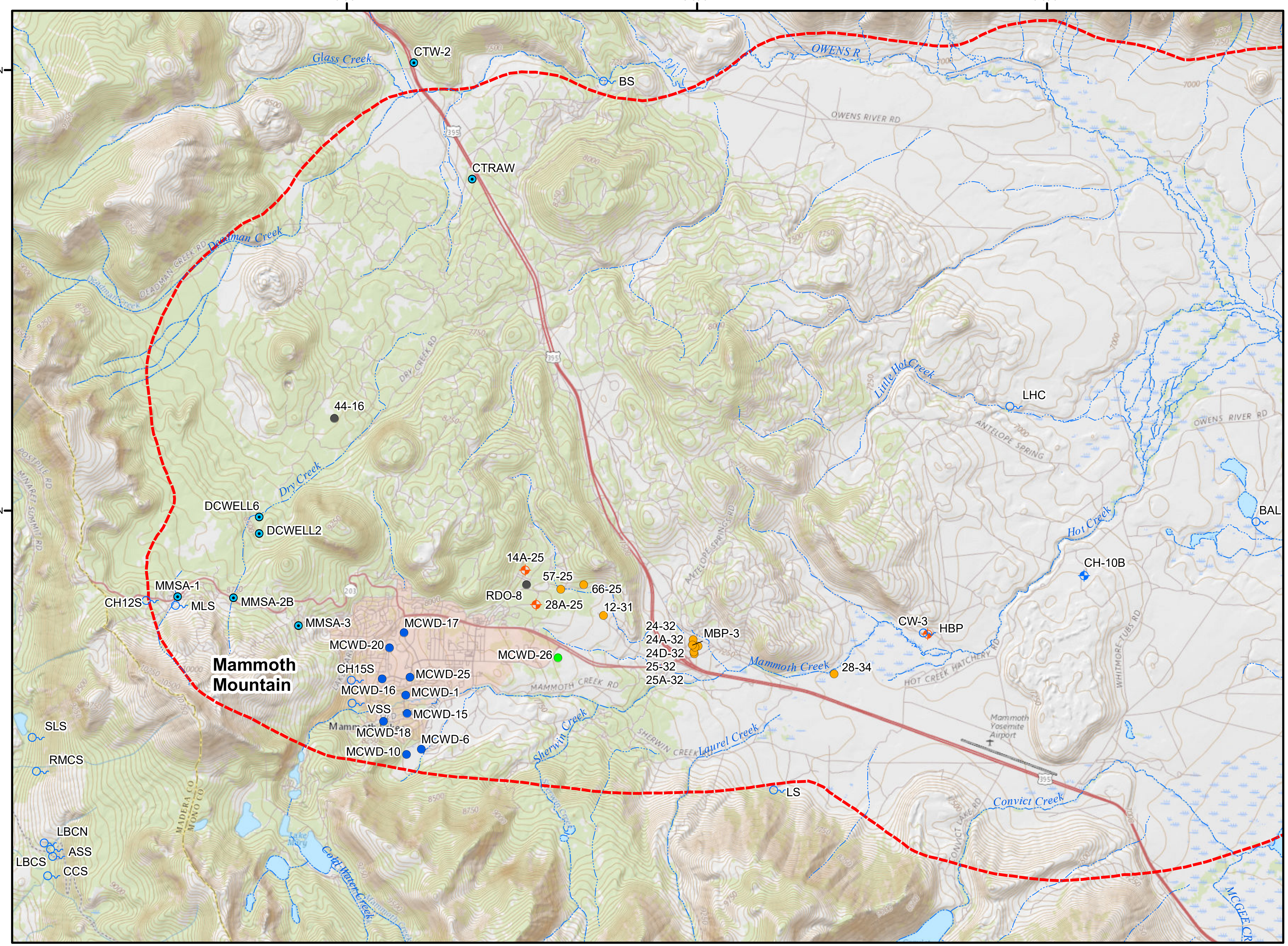
0 1 2 Miles
0 1 2 Kilometers

WEI
WILDERMUTH ENVIRONMENTAL, INC.

Author: MAB
Date: 3/14/2018
Document Name: 20171222_MCWD_OrmatWells11x17

CD-IV Project and MCWD Well Locations

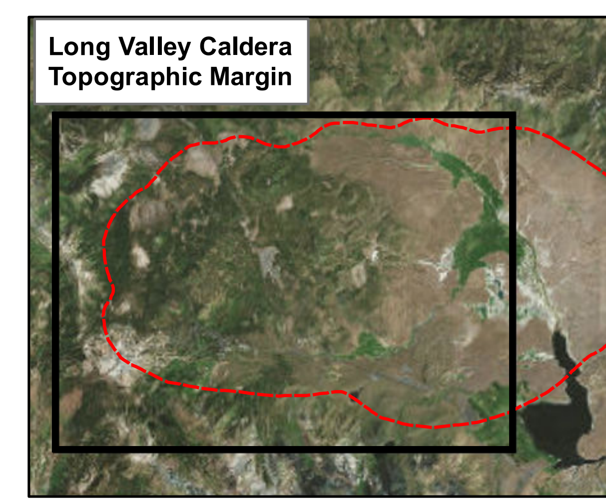
Figure 1



Well and Spring Sampling Locations

- MCWD Monitoring Well
- MCWD Production Well
- USGS Monitoring Well
- Ormat Geothermal Monitoring Well
- Existing Geothermal Well
- Groundwater Well
- Surface-water Site

Caldera Topographic Margin



WEI
Wildermuth Environmental, Inc.

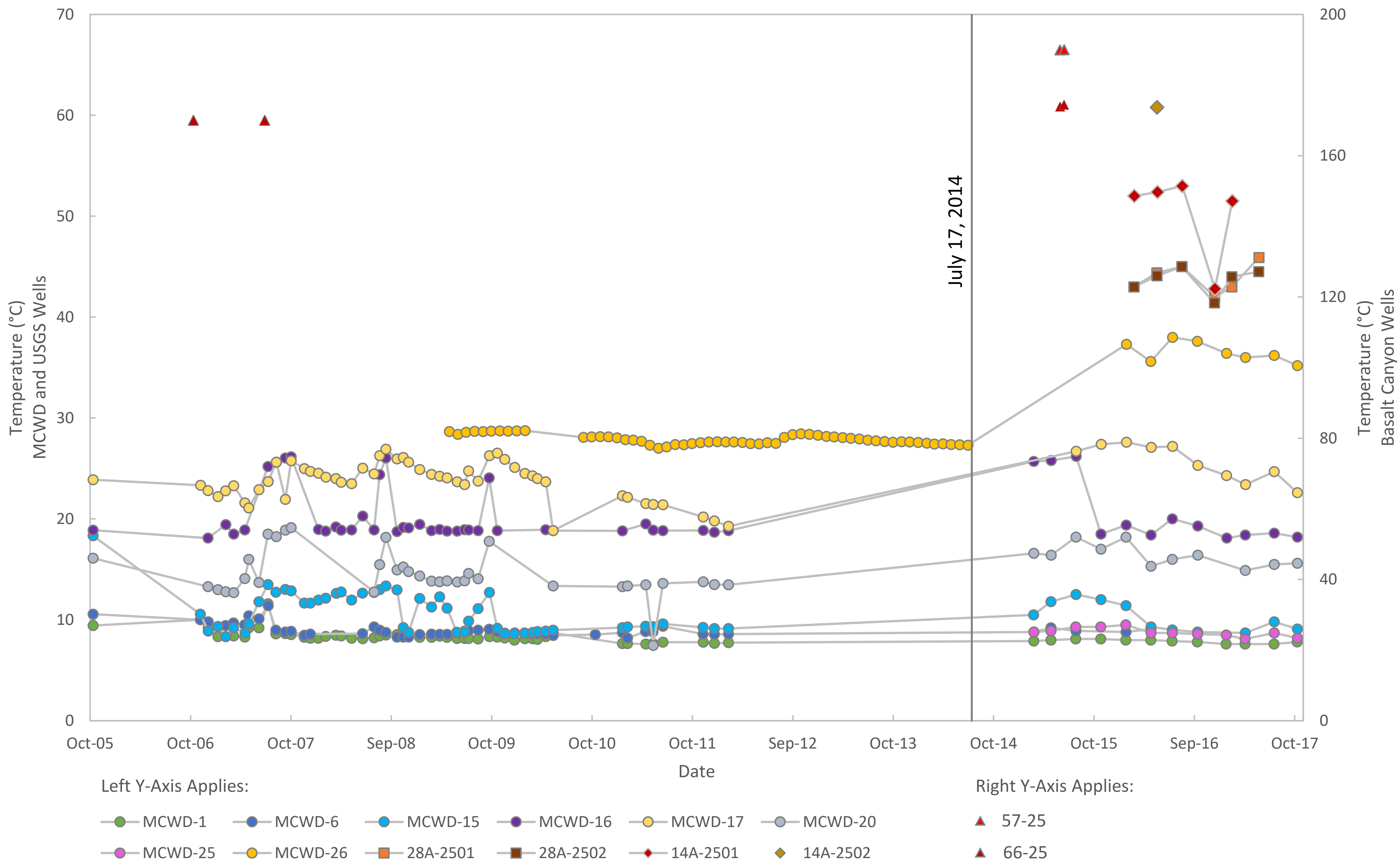
Author: MAB
Date: 3/14/2018
Document Name: 20171114_MCWD_OrmatWells11x17_v2

0 1 2 Miles
0 1 2 Kilometers

GMRP and Long Valley Caldera Water Quality Sampling Locations

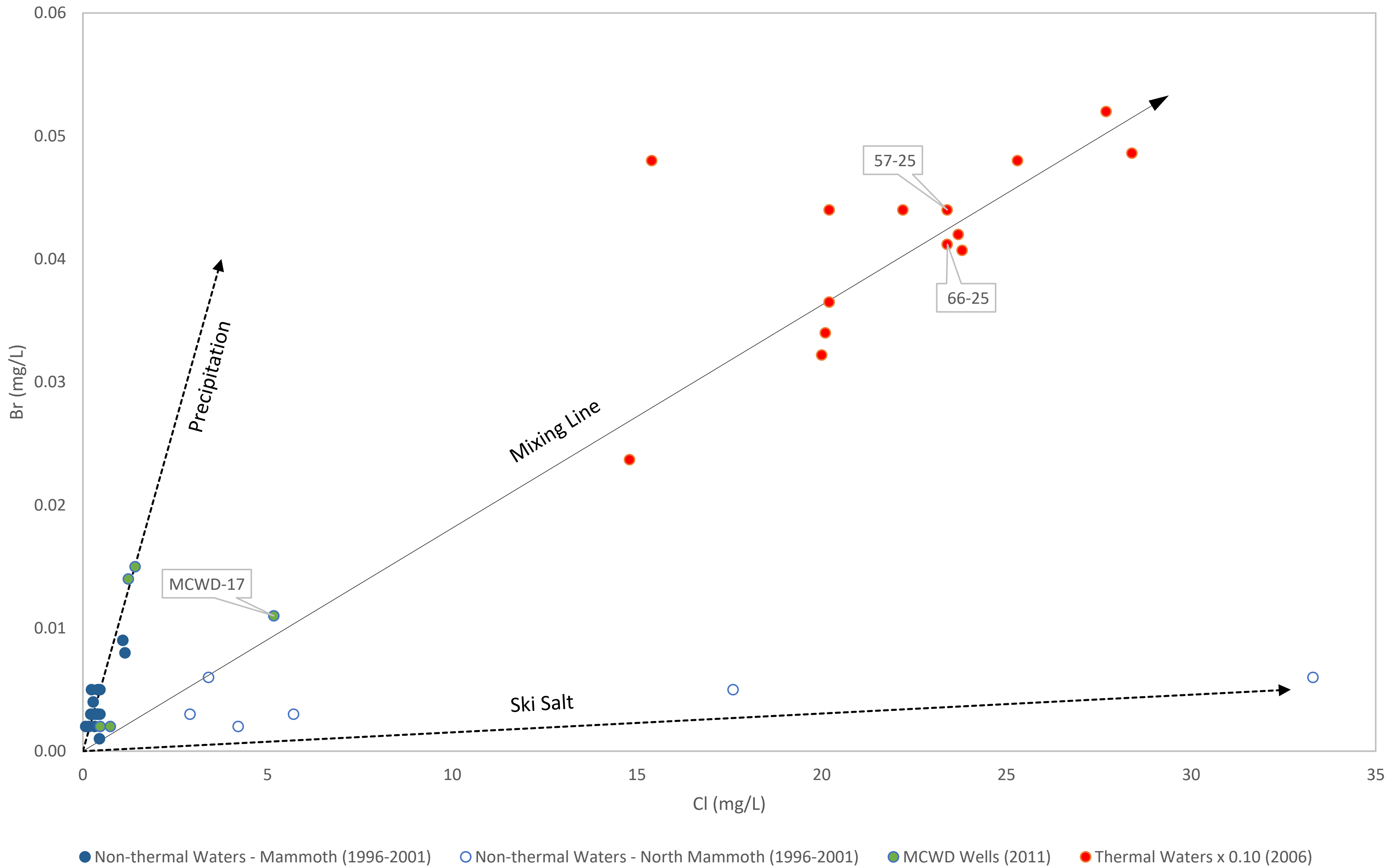
Figure 2

Figure 3
Groundwater Temperatures from the Basalt Canyon Production, MCWD, and 28A-25 Dual-nested Wells



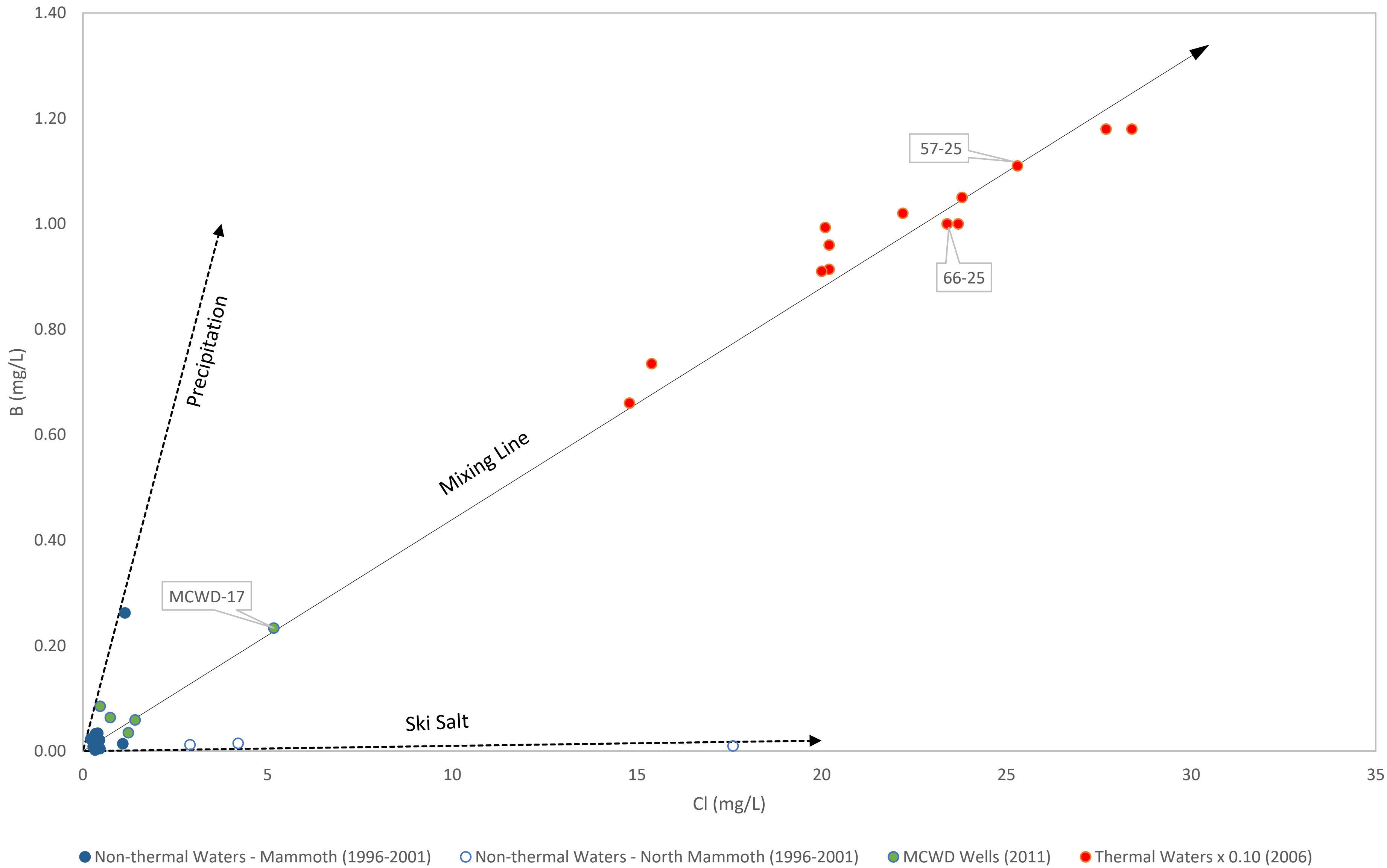
3/6/2018 -- 6:03 PM
20180122_USGS_LVC_MCWD_CDIV_HDX_WQ

Figure 4a
Chloride and Bromide Concentrations for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera
(pre-July 17, 2014)



3/6/2018 -- 6:04 PM
20180122_USGS_LVC_MCWD_CDIV_HDX_WQ

Figure 4b
Chloride and Boron Concentrations for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera
(pre-July 17, 2014)

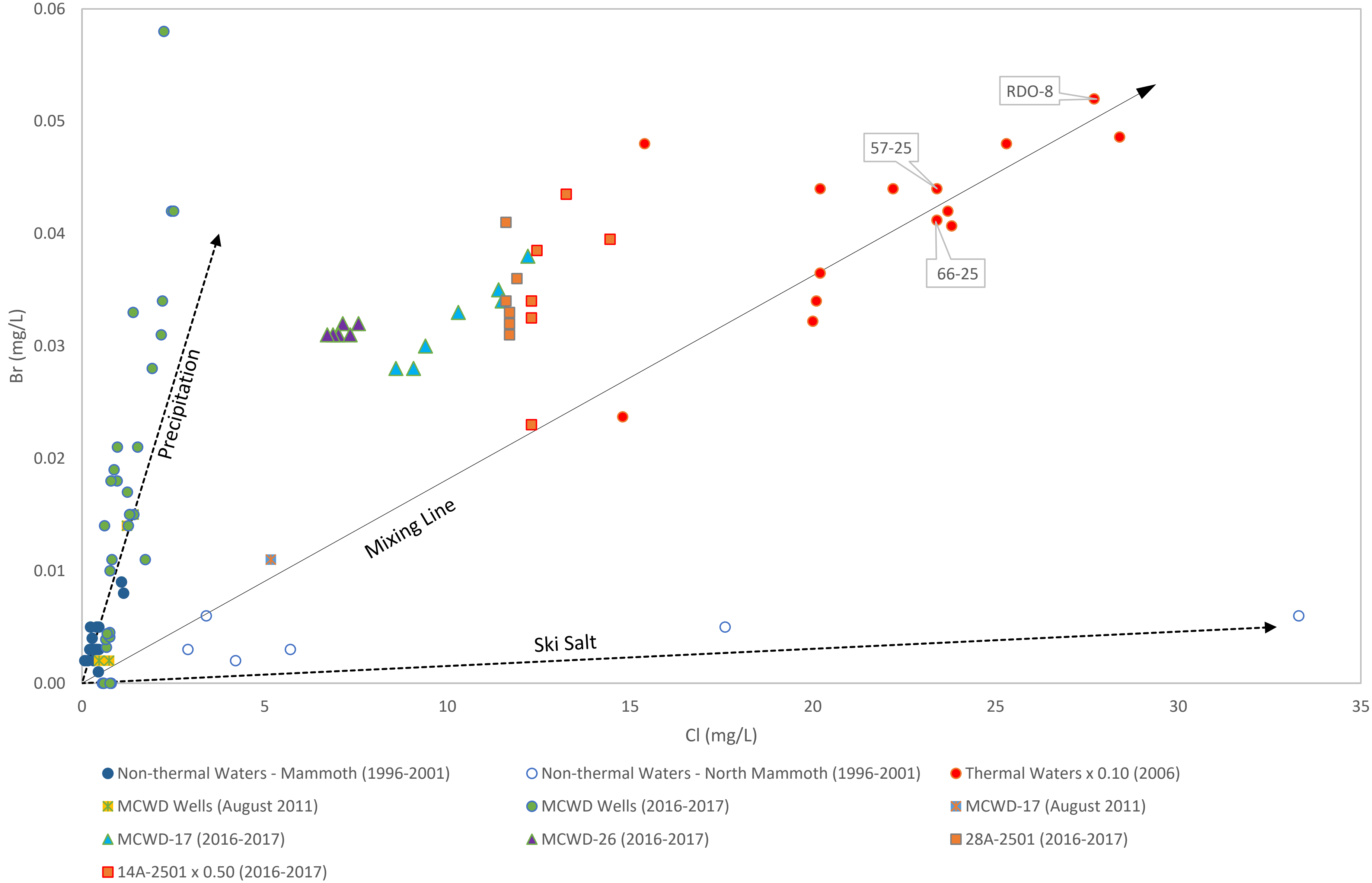


3/6/2018 -- 6:04 PM
20180122_USGS_LVC_MCWD_CDIV_HDX_WQ

Figure 5a

Chloride and Bromide Concentrations for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera

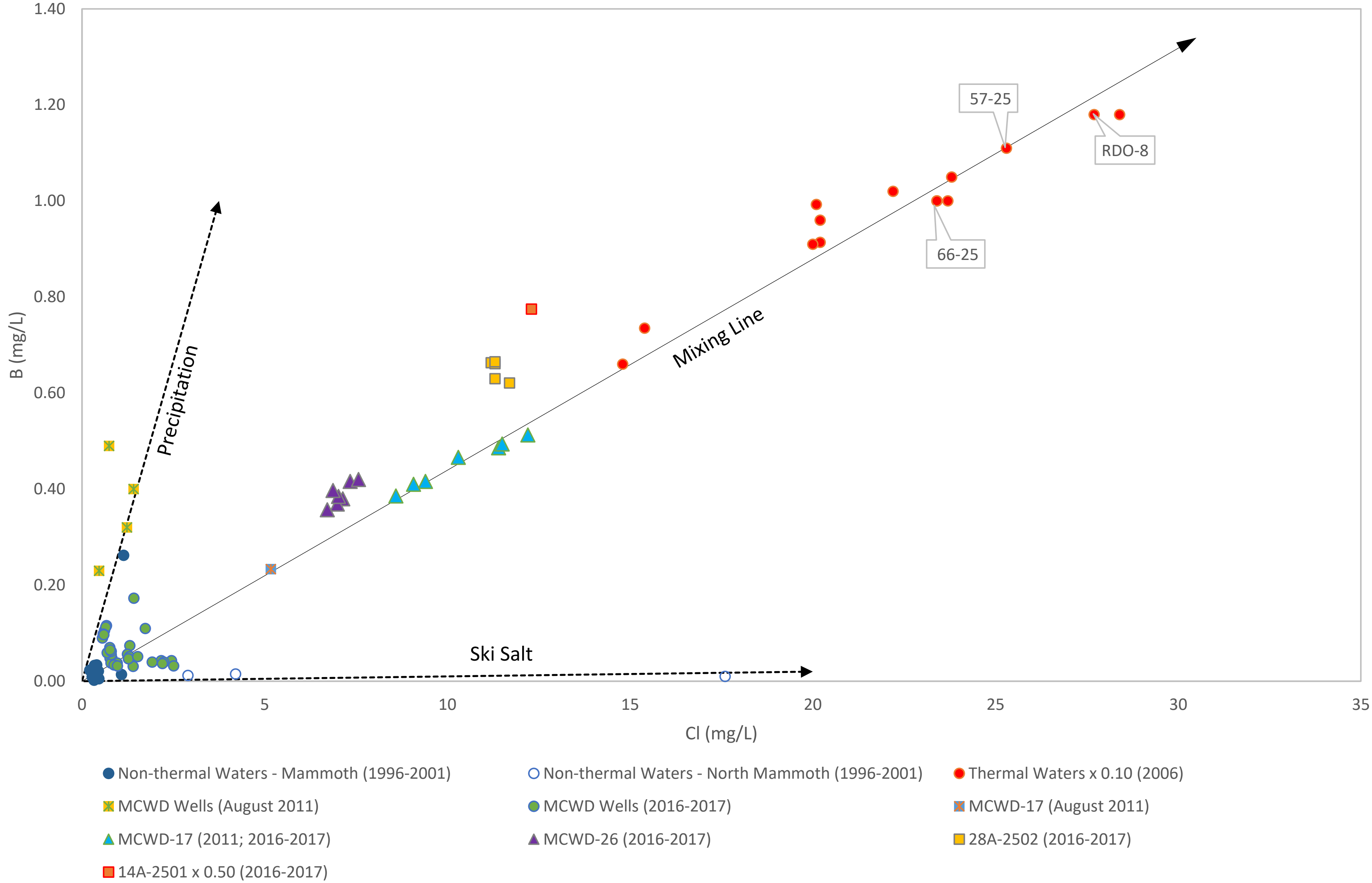
(pre- and post-July 17, 2014)



3/6/2018 -- 6:05 PM

20180122_USGS_LVC_MCWD_CDIV_HDX_WQ

Figure 5b
Chloride and Boron Concentrations for Geothermal Fluids and Non-Thermal Waters in the Long Valley Caldera
(pre- and post-July 17, 2014)



3/6/2018 -- 6:07 PM
20180122_USGS_LVC_MCWD_CDIV_HDX_WQ

Figure 6a
Stable Isotopic Compositions for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera
(pre- and post-July 17, 2014)

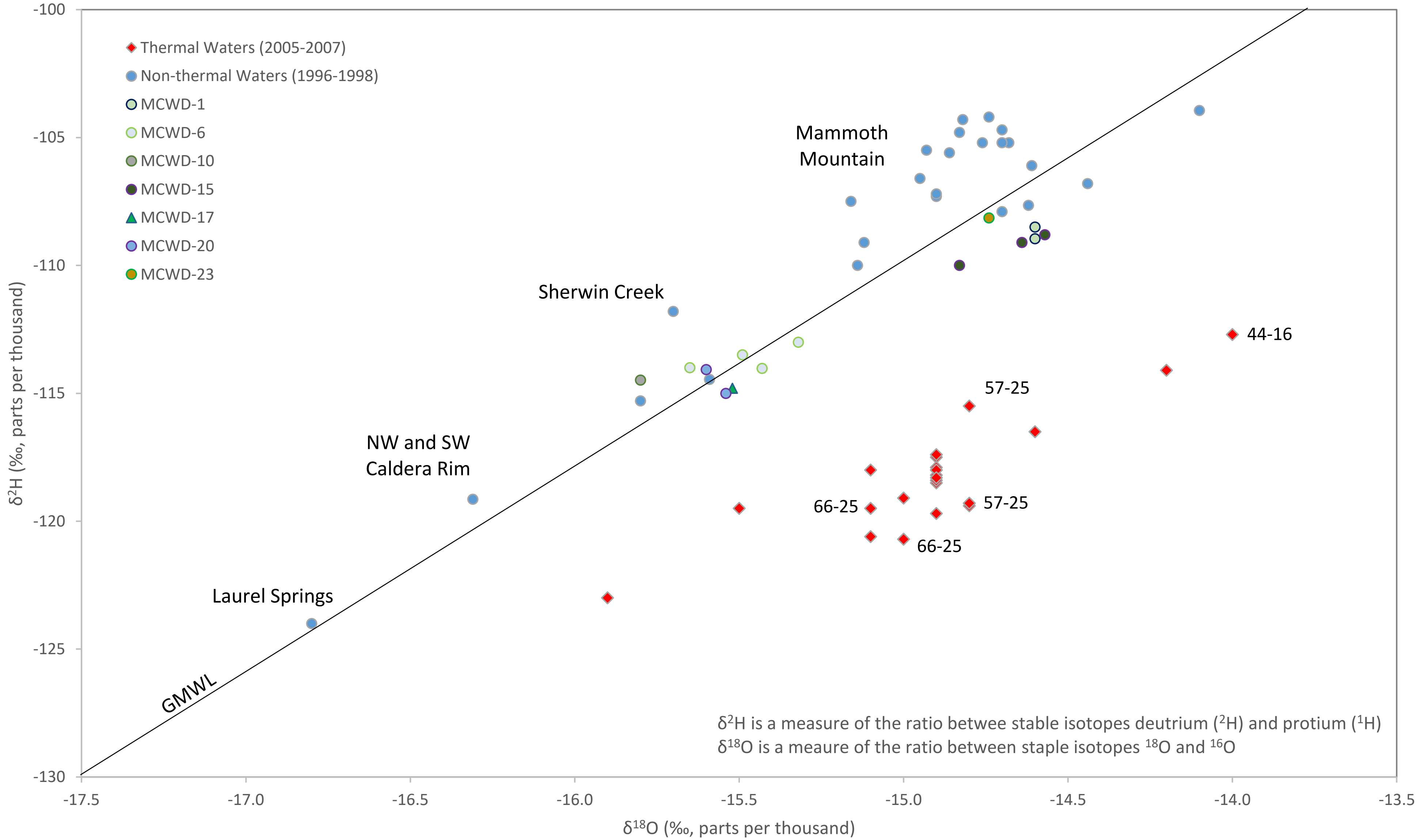


Figure 6b
Stable Isotopic Compositions for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera
(pre- and post-July 17, 2014)

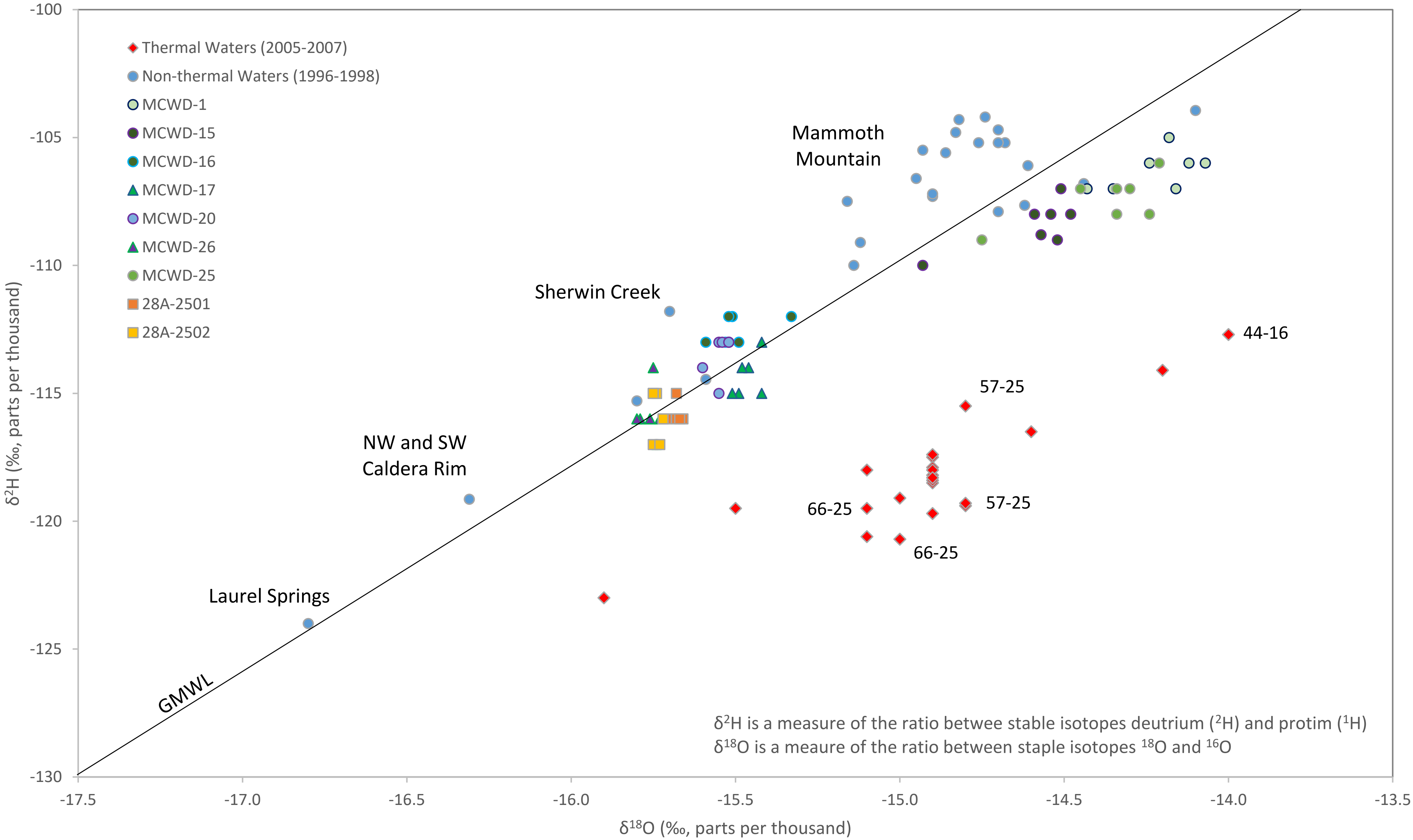
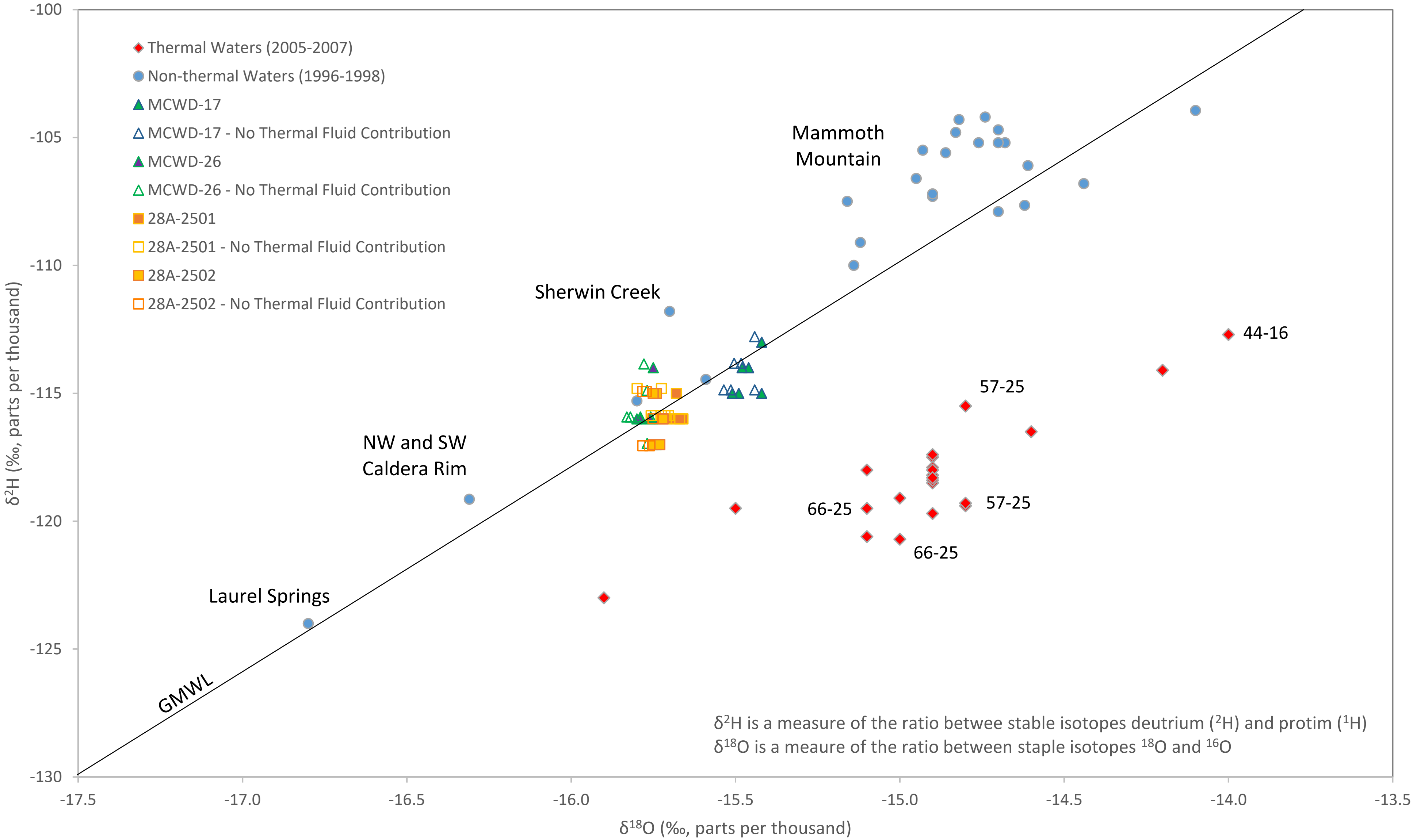


Figure 6c

Stable Isotopic Compositions for Geothermal Fluids and Non-Geothermal Waters in the Long Valley Caldera

(pre- and post-July 17, 2014)



3/6/2018 -- 6:11 PM

20180122_USGS_LVC_MCWD_CDIV_HDX_WQ