USGS Suggestions for Hydrologic Monitoring of the CD-IV Geothermal Project

The Bureau of Land Management (BLM) has requested that the U.S. Geological Survey (USGS) make technical recommendations to the Long Valley Hydrologic Advisory Committee (LVHAC) for the hydrologic monitoring of the CD-IV Project. The USGS participates on the LVHAC in a non-regulatory role to provide input regarding hydrology and geology topics. The monitoring elements discussed today are only suggestions. The technical recommendations for hydrologic monitoring are intended to provide the LVHAC with a means of tracking conditions (static or changing) in the hydrothermal and cold-water aquifers with the goal of protecting both resources. Ultimately, the decision of which monitoring elements are implemented falls with the permitting agencies at the Federal, State and County levels.

Conceptual Overview of Pressure Monitoring

Ideally pressure monitoring would occur along a northeast to southwest transect between the geothermal production wells and cold water production wells. This suggested monitoring scenario would allow for the temporal and spatial assessment of a laterally migrating change in the vertical hydraulic gradient that could potentially impact the Mammoth Community Water District (MCWD) supply wells. We suggest that pressure monitoring be conducted at three locations: (1) at the geothermal well field; (2) at a point approximately midway between the geothermal well field and cold water production wells; and (3) near the MCWD supply wells.

(1) – Geothermal Production and Injection Monitoring Wells

We suggest that one of the proposed 16 new wells in the CD-IV project be completed to monitor pressure in the production zone and that another well be completed to monitor pressure in the injection zone. Ideally these wells would be in the geothermal well field. (i.e., we consider well 12-31 to be too far removed and not aligned with the northeast to southwest transect). Furthermore, the production zone monitoring well would ideally be on the SW side of the geothermal well field. Preferably these wells would be instrumented long before any significant changes in geothermal production to characterize baseline conditions.

(2) – Separate Cold and Thermal Monitoring Wells at the Approximate Midway Location

We suggest that two (2) monitoring wells be established approximately midway between the geothermal production wells and existing cold water supply wells. One well completed in the cold/ warm-water aquifer and another well completed in the hot geothermal production zone.

Information from MCWD monitoring well (M26), located near the water district office, indicates that warm (90° F / 32° C) water exists below a depth of 600’ below land surface (BLS) at that location. Another, now abandoned, MCWD well (M8), which was located along the Sawmill Cutoff road, also encountered a cold and underlying warm interval. See Figure 1 for the locations M26 and M8.

Based on these borehole data we recommend one of the monitoring wells be a dual-piezometer well completed in both the cold-water and underlying warm-water aquifers [a piezometer is a well designed with a short open section to the formation which provides hydraulic pressure data for a specific depth interval]. In close proximity (within several tens of meters) to the shallow cold/ warm-water monitoring well, we recommend that a deep monitoring well also be drilled to monitor the pressure in the geothermal production zone.

The pressure record from the deep geothermal well, coupled with the pressure records of the nearby dual-piezometer well, would provide information needed to assess potential changes in the vertical hydraulic gradient at a location which is roughly midway between the geothermal production wells and existing MCWD supply wells. See Figure 1 showing the locations of MCWD wells and existing and proposed geothermal wells.

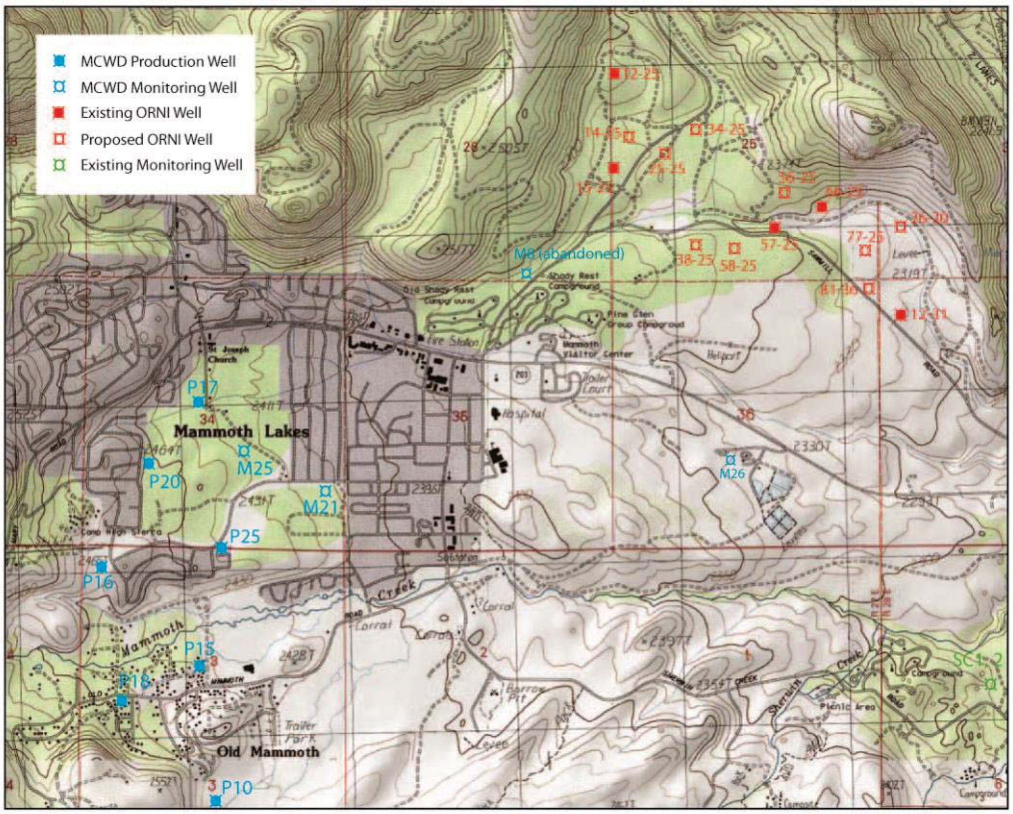

Figure 1. Locations of MCWD wells and existing and proposed geothermal wells.

We also recommend that the deep geothermal monitoring well be drilled first. Information gleaned during the drilling of the deep well would help guide the careful design and well construction of the relatively shallow cold/ warm monitoring well. Additionally, the lithologic and geophysical logs would help characterize the permeability of the aquitards separating the cold, warm, and hot intervals. Ideally, these wells would be established prior to any significant changes in geothermal production to characterize baseline conditions and seasonal variations.

Potential locations for the two nearby monitoring wells are: (1) in the north-central part of Section 35 and northwest of the Hwy 203 / Sawmill Cutoff junction on USFS property in the vicinity of the Old Shady Rest Campground; (2) east-northeast of the Mammoth Visitor Center on USFS property near the USFS 'junk yard'; and (3) in the SE corner of Section 26, southeast of the intersection of the Sawmill Cutoff road and the road leading into Shady Rest Park. See Figure 2 showing proposed locations of monitoring wells.

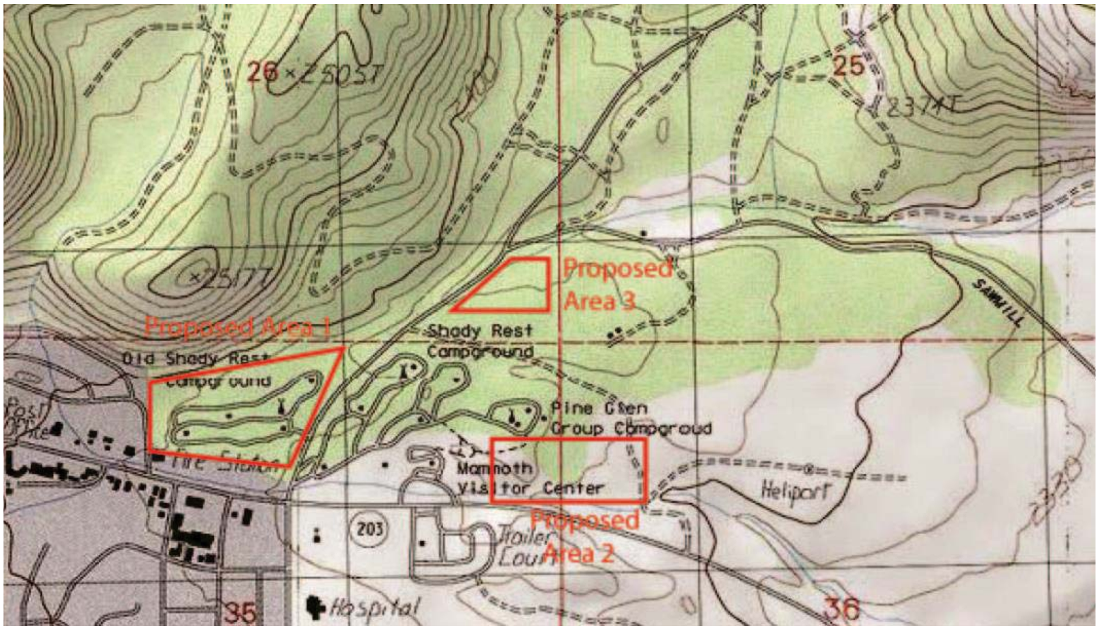

Figure 2. Map showing potential locations of proposed monitoring wells.

(3) – Cold Water Monitoring

We recommend that pressure monitoring data from MCWD well M21 be incorporated into the LVHAC monitoring program for hydrographic comparison with the previously proposed dual-piezometer record. Because the MCWD monitoring well M21 record could be influenced by the surrounding cold water production wells analysis of those pressure records and the proposed dual-piezometer records should include a hydrographic comparison with other cold water wells that are spatially removed from the existing MCWD supply wells and geothermal production wells.

We suggest that the existing monitoring wells SC-1 and SC-2 (see Figure 1) be instrumented with submersible pressure/ temperature transducers to produce a ground-water record for the purpose of hydrographic control. These two wells are valuable because they have long-term water level records dating back to 1983 and they monitor two different pressure zones in the cold water aquifer system.

(4) – Pressure Monitoring Equipment

The USGS recommends that the monitoring wells be instrumented with high-resolution pressure transducers which have a range that does not exceed 15 PSI (34.6 ft) and a minimum resolution that does not to exceed 0.02 PSI (0.05 ft). The cold and warm-water piezometers should be instrumented with submersible transducers that also provide water temperature to within 0.1° C. The hot geothermal well would require an ‘up-hole’ transducer coupled with a bubbler system, similar to the system currently in place at monitoring well CH10b.

The water pressure records should be corrected for instrument drift, based on periodic check measurements, which are made with an appropriate measuring device (steel tape for cold-water wells and calibrated electric sounder for warm or hot wells). Additionally, the monitoring well data should be transmitted via cell phone or GOES telemetry for near-real-time monitoring and assessing equipment status.

(5) – Water Quality Monitoring

The USGS recommends that water quality (QW) samples be collected from the proposed cold, warm, and hot monitoring wells, previously described, to characterize baseline conditions and to help assess potential changes over time. Ideally, this proposed QW sampling would start long before any significant increases in geothermal production. Initially the sampling could be more frequent (twice annual) to document any seasonal variations and to allow for a more robust time-series data set spanning the startup of significant increases in geothermal production. If, with time, changes in water quality were not observed a less frequent (annual) sampling interval could be implemented. We recommend that the water samples be analyzed for pH, specific conductance, alkalinity, major cations and anions, Chloride (Cl), Fluoride (Fl), Boron (B), Arsenic (As), Silicon (Si) and stable isotopes of hydrogen and oxygen.

We also recommend that the MCWD monitoring well M26 be included in the proposed QW sampling program. Furthermore, QW sampling of MCWD production wells would be a prudent measure to help assess potential changes in their domestic supply wells.

(6) – High-Resolution Temperature Logging

We recommend that vertical temperature profiles be collected in the proposed cold, warm, and hot monitoring wells to further assess potential changes over time. This monitoring is based on the idea that the cold aquifer could potentially be impacted by a temperature rise and that the rise would, most likely, occur from the bottom up. Initially these data could be collected on a twice annual basis, coinciding with the QW sampling. If changes were not observed over time then the frequency of the temperature logs could be reduced to once a year.

(7) – Gas Monitoring at Well Heads

Monitoring the concentrations of CO_2 and H_2S at the well heads would provide another tool to assess potential changes over time. Changes in gas emissions could supplement the analysis of subtle changes in water quality such as pH and alkalinity.