

April 26, 2006

L54(2380)
HOSP/General

Memorandum

To: Superintendent, Hot Springs National Park

Through: William L. Jackson, Chief, Water Resources Division (WRD)
Gary Rosenlieb, Acting Chief, Water Operations Branch, WRD

From: Larry Martin, Hydrogeologist, Water Operations Branch, WRD

Subject: Trip Report for travel to Hot Springs National Park on April 12-13, 2006

Summary:

There is a chance that construction of the northeast segment of the Martin Luther King Bypass could impact the groundwater flow system that supplies the hot springs in the park. The primary areas of concern are diminished groundwater recharge due to interception of shallow groundwater at roadcuts and potential fracturing of rocks by blasting, which might change groundwater flow patterns. The potential for, and degree of, impact have not been determined due to incomplete assessment of the potential impacts in the NEPA documents for the project.

Discussion:

Construction of the northeast segment of the MLK Bypass highway around the City of Hot Springs may cross the recharge area of hot springs in the park. The northeast segment, as planned, would extend the recently completed southeast segment from the interchange with Highway 70 approximately 5 miles east of the hot springs to the intersection of Highways 5 and 7 approximately 6 miles northeast of the hot springs (Figure 1). Construction of the northeast segment has not yet started. Recent discovery of warm water in a domestic well near the planned bypass route has raised concern about the potential impact of highway construction, including blasting, on the hydrology of the geothermal resources of the area.

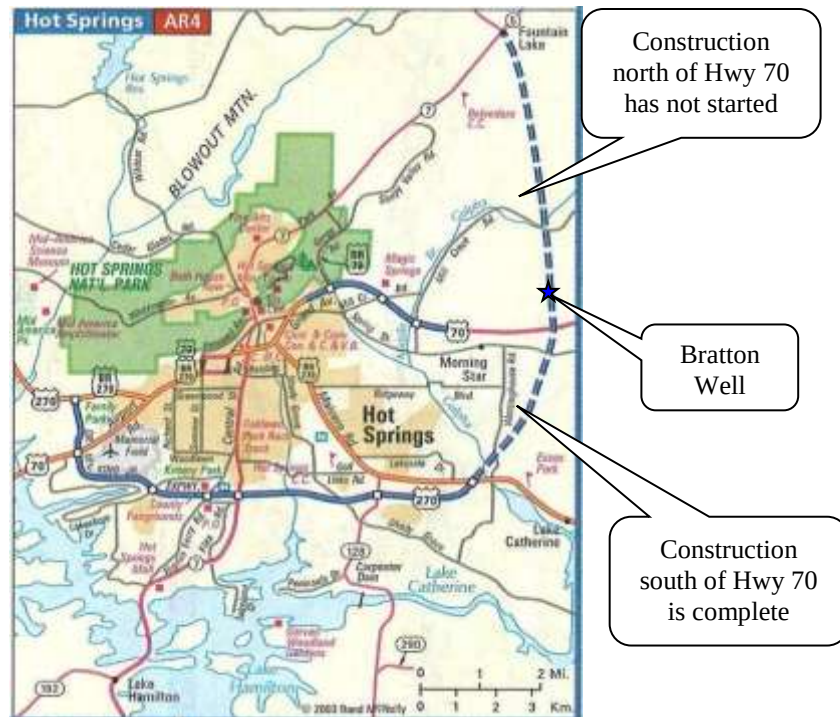


Figure 1. Location of the MLK Bypass at Hot Springs.

The Bratton Well – On March 1, 2006, Mr. Bratton, an area resident, contacted park personnel regarding a water well on his property. A well that had supplied his personal residence for many years, now only used occasionally for garden irrigation use, had begun yielding higher temperature water, as high as 93° F. The well had never before been observed to produce warm water. The well is located approximately 5.5 miles east of the spring discharge zone in the park; also of note is that the well is located slightly more than a mile from a highway construction zone where blasting had recently occurred. On March 3, 2006, the HOSP Natural Resource Program Manager and USGS water-quality specialists measured water temperature and specific conductance, and sampled the well for selected water-quality constituents. During well pumping and continuous monitoring of selected field parameters, a maximum temperature of 87° F was observed during initial stages of pumping, and temperatures remained above 71° F after two hours of pumping. Compared to non-geothermal groundwater temperatures in the area, these values ranged from about 7° F to about 23° F warmer than would be expected. Applying a bimodal mixing model to the data indicates that the Bratton well was yielding an estimated 8% to 26% geothermal water during the pumping and sampling. The well was observed to quickly attain a maximum temperature of 87° F and then declined over a period of an hour and a half pumping to 71° F. (Phil Hays, USGS, written comm.)

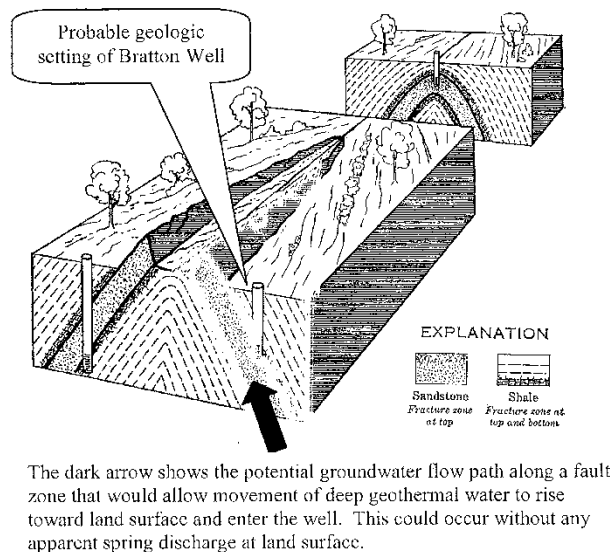


Figure 2. Geologic setting of the Bratton Well.

The well is located off the nose of a southwest-trending, plunging anticline as depicted in Figure 2. The geologic setting of the Bratton Well is similar to that of the hot springs in the park, associated with faulting on the limb of an anticline. That there is warm water in the Bratton Well should not be a big surprise; McClendon Spring, located about ¼ mile north of the Bratton Well, had a temperature of 65°F (measured in 1972). Another spring located about 1½ miles west of the Bratton Well (in a similar geologic setting) had a temperature of 69°F (also measured in 1972) (USGS NWIS database). Cold water springs in the area generally produce water around 59-60°. (The temperature of water pumped from the Bratton Well stabilized at 71°F after 1½ hours of continuous pumping.) Given the geologic structure of the general area, a series

of tightly folded anticlines and synclines bisected by faults, and the known occurrence of geothermal water, it should be no surprise that there are areas other than the hot springs where some amount of geothermal water rises toward the surface and mixes with the shallow, cold groundwater in an underground mixing zone. We can not explain the seemingly sudden occurrence of warm water in a well that had no record of warm water during the previous 15 years of regular use. Part of the answer may lie with the non-use of the Bratton Well during the preceding months, following the introduction of a public water supply to homes in the area. It may be related to blasting associated with highway construction, as some people have suggested. It's possible that regular pumping of private wells in the Bratton Road area prior to the introduction of the public water supply masked the presence of geothermal water by regular mixing of a small amount of warm water with a large amount of cold water during pumping of the wells.

Although we can not yet explain the presence of warm water in the Bratton Well, it has caused many people (including park staff and state and federal highways staff) to take a closer look at the potential impact of extending the 4-lane bypass highway through the area. The USGS has prepared a proposal to investigate the extent to which geothermal water (mixed with cold water) occurs in the shallow groundwater system in the general area.

Regional Geology – Rocks underlying the Hot Springs area (and for tens of miles) were originally deposited as sediments in the ocean, reaching a thickness of more than 30,000 feet over hundreds of millions of years. A period of mountain building began about 300 million years ago, during which compressive forces from the south and southeast squeezed the accumulated sediments until they formed a series of folds, or anticlines and synclines (similar to pushing a rug up against a wall). In some places the folding was so severe that the folds folded over on themselves. Where they were unable to withstand the pressure, the rocks fractured and masses of rock moved up or down along fault planes relative to adjacent rock masses. Subsequent differential erosion (softer rocks less resistant to erosion forming the valleys and harder rocks more resistant to erosion forming ridges) has left the area with a “hill and swale” topography corresponding to the underlying

anticline/syncline geologic structure. The bedrock formations north of the park dip to the southwest. As a result, the anticlines and synclines in the area also plunge to the southwest. Highway 70 generally parallels the transition between the anticline/syncline structure to the north and the flat-lying shale formation (Malvern Shale) to the south, which underlies the City of Hot Springs. Differential erosion of the plunging anticlines and synclines has produced the distinctive outcrop pattern referred to as the Zigzag Mountains.

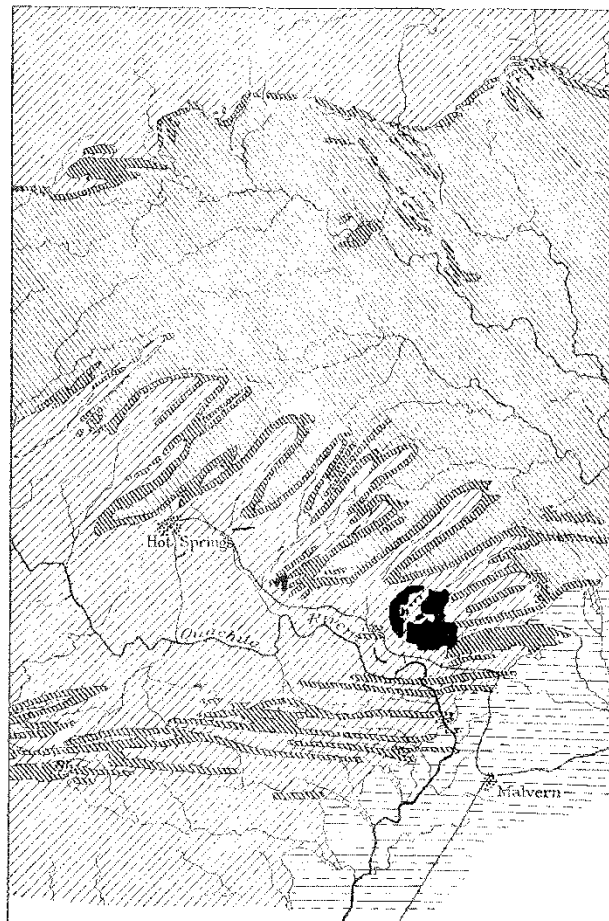


FIG. 40 - Geologic map of Hot Springs, Ark., and vicinity.

The general geologic map of the Hot Springs vicinity (Figure 40 in Fuller, 1905) shows the zigzag pattern of the plunging anticlines and synclines. In general, each tongue or finger extending toward the southwest is the crest of an anticline. The softer, overlying rocks have been eroded, leaving Bigfork Chert exposed (at the surface) along the crest of each anticline. The narrow band of rocks adjacent to Bigfork Chert is Arkansas Novaculite, which is more resistant to erosion and forms ridges (including Sugarloaf, West, Hot Springs, North, Indian, and Grapevine Mountains). The main recharge area for the hot springs in the park is generally thought to be the finger of Bigfork Chert immediately north-northwest of the city (the area between Sugarloaf and West/North Mountains). As will be discussed later, the finger northeast of the city is also a potential recharge area. The extent of the recharge area to the north and northeast is unknown, but groundwater in the Bigfork Chert throughout quite a large area to the north and northeast is likely interconnected with the hot springs geothermal system.

Perturbations to the groundwater system at distant locations may have an effect on the geothermal system of the park by decreasing hydraulic pressure throughout the formation.

That is, while groundwater in more distant areas (north and northeast of the park) require thousands of years to flow to park hot springs, decreases in system pressure due to pumping, drainage, or reduced recharge could result in near instantaneous decreases in the rate of discharge from the springs.

Hydrogeology of the geothermal system – The generally accepted theory for the occurrence of hot springs at the park is that infiltration of water on outcrop areas of Bigfork Chert migrates to several thousand feet below ground surface where it is warmed by the natural geothermal gradient. The water then quickly flows back to the surface along faults, emerging as hot springs. This process is illustrated in Figure 4 (from Yeatts 2006).

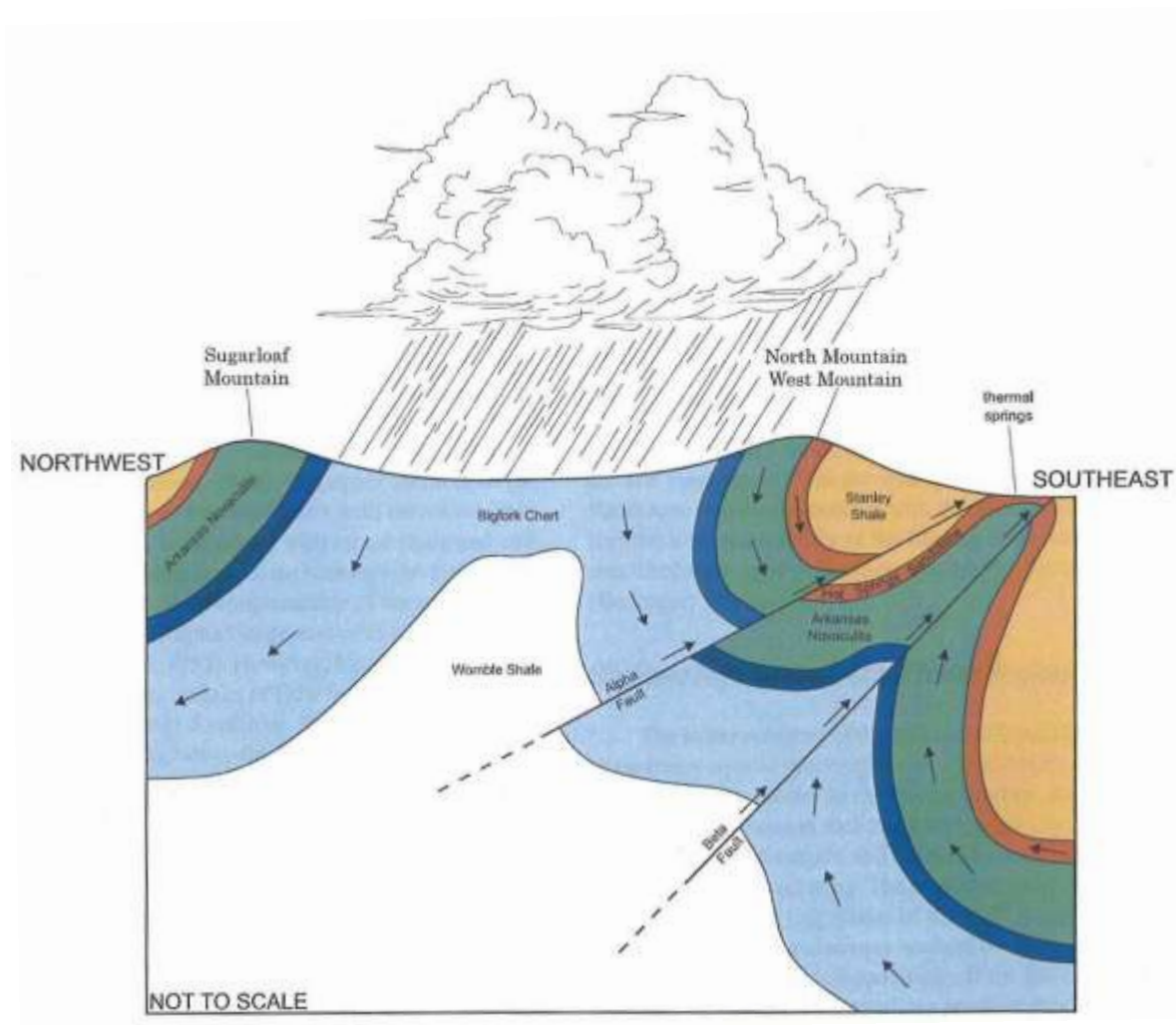


Figure 4. Conceptual model of the hydrogeologic system at Hot Springs National Park (from Yeatts, 2006).

Earlier conceptualizations have focused on the infiltration of rain, downward percolation, and groundwater flow back to the surface along fault zones as shown in the center portion of this schematic (recharge originating in the area between Sugarloaf and North/West Mountains). However, upward movement of geothermal water, as shown on the right portion of the schematic, is equally likely. The source of this water would be recharge on the outcrop areas of Bigfork Chert to the north and northeast (Figure 5).

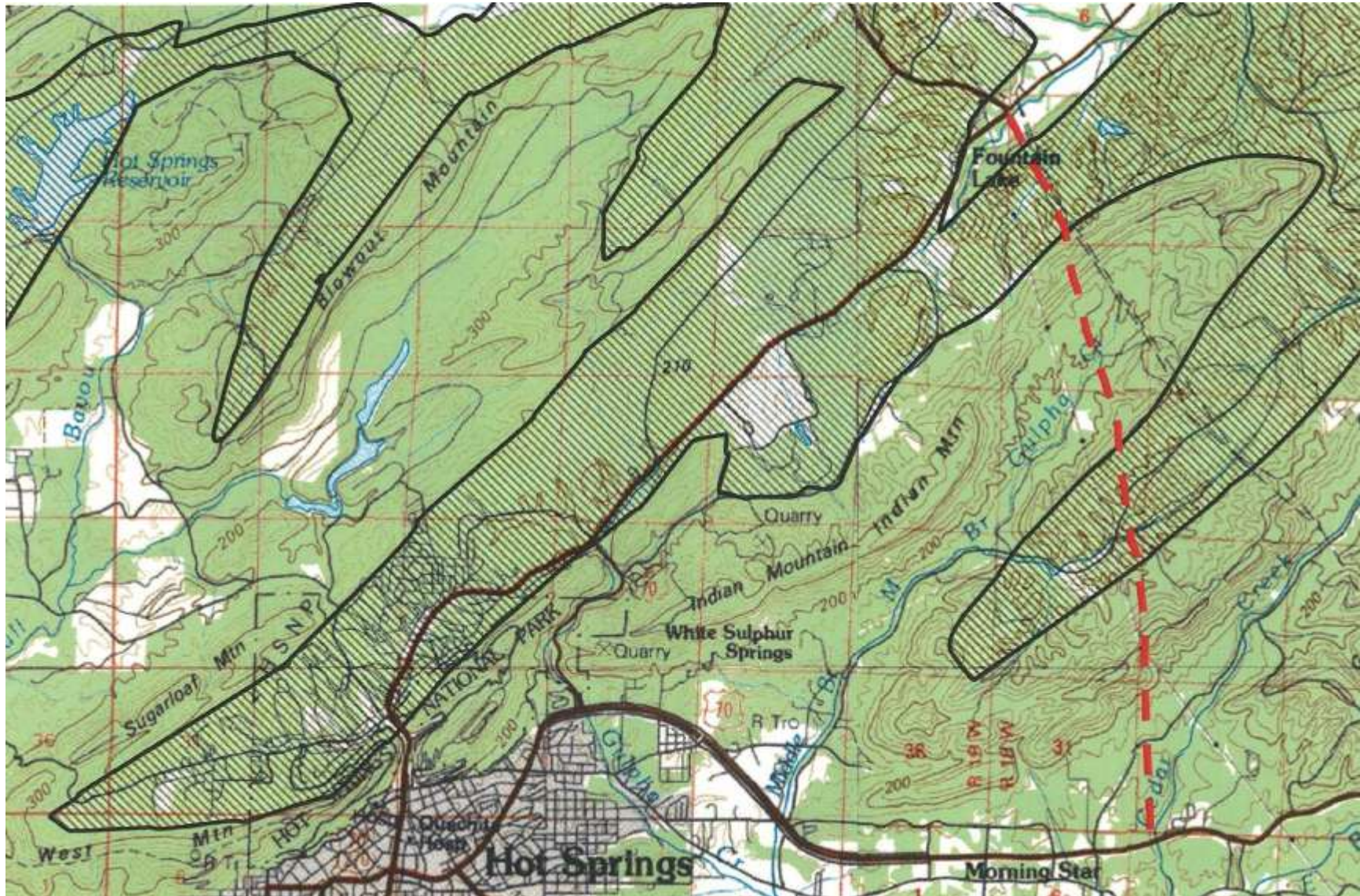
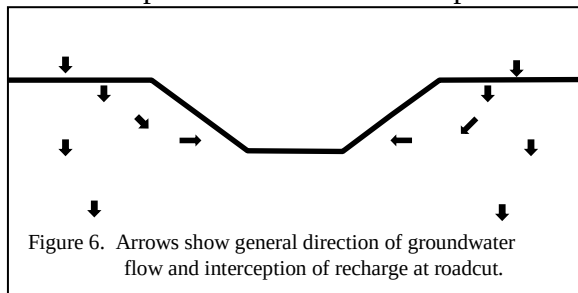


Figure 5. Approximate outcrop area of Bigfork Chert (potential recharge area) from Purdue and Miser (1923) and approximate route of MLK Bypass.

In order to get the entire picture, imagine a mirror image of the cross-section flipped to the right to show the other half of the synclinal structure and adjacent anticline. We would then see that recharge to the Bigfork Chert in the adjacent anticline flows downward and toward the west (as shown on the left side of this figure), under the syncline (where it is subject to even greater geothermal heating), and then upward to the fault zones. Thus, the recharge area for the hot springs may include the next outcrop of Bigfork Chert to the east-northeast, in the area between the Middle Branch of Gulpha Creek and Cedar Creek.

Potential Impacts – The proposed alignment of the MLK Bypass will traverse both outcrop areas of Bigfork Chert that are thought to be the primary source areas for flow at the hot springs (Figure 5). While the bypass generally follows an arc about 5 miles east of the hot springs discharge area in the park, there is no way to know the exact extent of the recharge area at this time. Deep roadcuts across outcrop areas of Bigfork Chert will function (hydrologically) as



drainage ditches. Some of the water that currently infiltrates into the formation will flow toward, and drain into road cuts as illustrated in Figure 6. Additional information is needed regarding the location, size (depth and length), and geologic formations for the planned roadcuts so that an assessment of potential impacts on the groundwater flow system can be made.

Blasting in bedrock to construct deep roadcuts may cause uncontrolled, and undetected, fracturing in the bedrock that could change groundwater flow patterns in ways that can not be predicted. If undesired impacts occurred, such as diminished flow from the hot springs, there would be no way to correct the problem.

The potential for impact is very difficult to predict because we don't know the extent of the recharge area for the hot springs groundwater flow system. Computer modeling would be of little or no help, because there are no datapoints, no deep wells with which to calibrate or verify input and output for models. Given the lack of data available to predict the potential impacts of road construction and the lack of potential remedial actions, it may be prudent to reconsider alternative routes and/or road construction techniques that would have lower potential impact on the geothermal groundwater flow system.

If there are any questions regarding this trip report, please call me at (970) 225-3515.

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