3293

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INJECTION IN BASIN AND RANGE TYPE RESERVOIRS - THE RAFT RIVER EXPERIENCE

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ABSTRACT

Injection testing at the Raft River KGRA has yielded some interesting results which can be useful in planning injection systems in Basin and Range type reservoirs. Because of inhomogeneities and possible fracturing in basin fill sediment, rapid pressure response to injection has been observed in one shallow monitor well, but not others. In some monitor wells in the injection field, pressure drops are observed during injection suggesting plastic deformation of the sediments. Seismicity, however, has not accompanied these observed water level changes.

INTRODUCTION

While geothermal injection can have other advantages such as prolonging reservoir productivity and reducing the potential for subsidence, its primary purpose is to "get rid of" geothermal fluids in an acceptable manner. Designing an injection system to meet this objective is never easy. Such has been the experience at Raft River, Idaho, where the geothermal resource is being developed for R&D by the U. S. Department of Energy (DOE).

The Raft River resource is considered typical of those resources encountered in the Basin and Range Province in that primary production is from fractures with aquifers in overlying sediments. The water quality of the resource is relatively good (TDS averages 2200 mg/l in the production wells). The maximum temperature of the produced fluid is 141°C. DOE's objective is to demonstrate the technical and environmental feasibility of generating 5 MW of electricity from this moderate temperature resource.

The acceptability of the Raft River injection system has been the subject of some controversy in the past; even with recent injection testing, uncertainties still remain. The concerns associated with the system include:

Will the existing wells provide enough injection capacity?

Should wellhead pressures be limited to avoid hydrofracturing?

What is the nature of the connection between the injection zone, the production zone, and shallower aquifers developed for irrigation?

Will the injected fluids eventually recharge the reservoir?

Are the parasitic power loads associated with injection too high?

Will the system comply with EPA's Underground Injection Control regulations?

Geologic and Hydrologic Characteristics

The Raft River Valley, located at the northern margin of the Basin and Range Province, is a structural downwarp bounded on three sides by mountains. The valley contains as much as 1600 m of alluvial fan and fluvial deposits and tuffs of the Salt Lake and Raft Formations. Correlation of units in these formations is difficult due to rapid lateral changes of facies and thickness, steep dips, and alteration (Covington, 1980).

The primary faults in the geothermal area are a north-trending series of steep normal faults. Geologic and geophysical evidence suggests that a northeast-trending basement shear zone transects these faults. The abundance of fractures increases with depth and the near-vertical, open fractures in the lower basin sediments are considered to control movement of the geothermal fluids (Covington, 1980).

The Raft Formation is the principal unconfined aquifer in the valley. Data from deep wells indicate that at least one and probably several confined aquifers occur between the shallow aquifer and the geothermal system. It is postulated that each of these aquifers is recharged in part by upward leakage from deeper aquifers. Results of hydrologic modeling by Nichols (1979), indicate that two-thirds of the recharge to the shallow aquifer is vertical leakage from below. In some locations, there is direct, probably fracture-related, communication between the geothermal system and shallow aquifers as indicated by hot walls and seeps.

Injection System

There are presently two injection wells at Raft River, RRGI-6 and RRGI-7 (Figure 1). RRGI-6 was drilled to a depth of 1176 m and cased to 518 m. RRGI-7 is 1167 m deep and is cased to 623 m. The injection wells are located 2.5 km southeast of the primary production field. Concerns over potential breakthrough of cool injected fluids and the availability of land dictated the well locations. Drilling costs were the primary reason for selecting an intermediate depth for injection, although the possibility of low permeability deeper was also a concern. These factors were traded-off against the increased potential for adversely affecting shallow aquifers as a result of pressure-induced fracture communication.

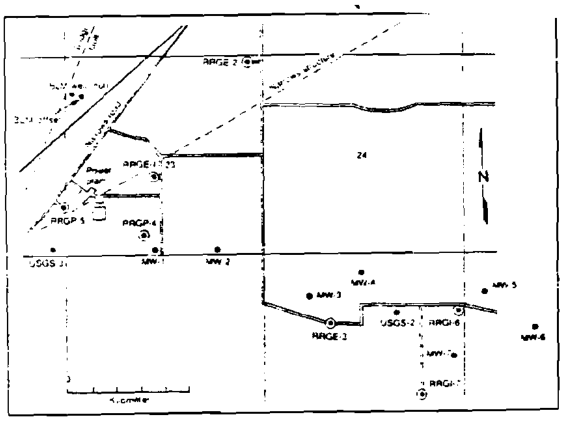

Figure 1. Raft River Geothermal Area and well locations.

Injection Testing

Most of the injection testing at Raft River has been at RRGI-6. Six tests ranging in length from 72 hours to over 21 days have been conducted. A spinner survey by the USGS indicated that nearly half of the injected fluids enter the formation in the first 90 m below the casing. (It is of interest to note that the design depth for the casing in RRGI-6 was 90 m deeper than where the casing was actually set when it became stuck in the hole.) Logs of this zone suggest that it may be fractured (W. S. Keys, personal communication). Lost circulation during drilling at this depth also indicated a very high permeability thief zone.

Observations and conclusions that have been made based on injection testing at RRGI-6 are:

1) Interference build-up of similar magnitude was measured both in RRGI-7 and in a 300 m deep monitor well (MW-4). The interference at the monitor well indicates that there is vertical communication between the injection zone and shallower aquifers, possibly along soft sediment fractures (Figure 2).

2) There are sufficient undissolved solids in the fluids to cause injection loss due to formation plugging (without treatment).

3) A water level drop recorded in three monitor wells coincident with the 21-day test may be attributable to elastic deformation in the shallow aquifer materials resulting in local dilations. Elevation surveys conducted during subsequent tests provided inconclusive data on this theory (See Figure 3).

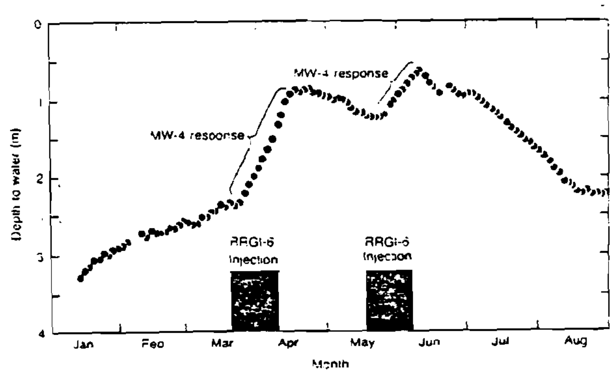

Figure 2. MW-4 water level record showing response to injection.

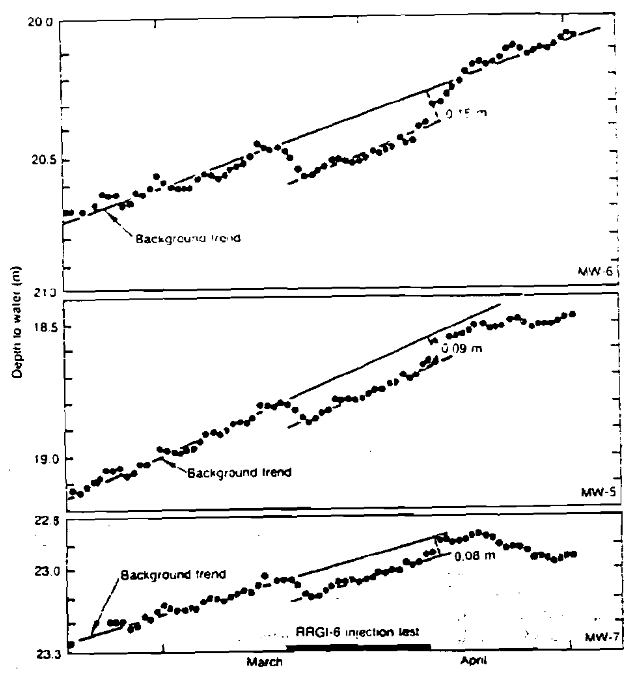

Figure 3. MW-5, 6, 7 water level records illustrating aquifer distortion.

4) Interpretation of build-up behavior at RRGI-6 indicated that hydrologic boundaries were intersected. Given the MW-4 response, the boundary effects may represent leakage to overlying aquifers.

5) No seismic activity was detected during any of the injection tests at RRGI-6.

6) If viscosity differences between 140°C injection testing and the planned 52°C power plant effluent effect the rate of wellhead pressure build-up, the wellhead pressure after three years of injection at 60 lps will be 2900 kPa.

Early tests at RRGI-7 were very short and suggested that the receiving zone in this well was of lower permeability than RRGI-6. More recent tests of longer duration have indicated permeabilities of the same order of magnitude as RRGI-6, or between 10×10^3 and 40×10^3 m d-ft according to the length of the test and method used to calculate kh. Observations made from recent testing at RRGI-7 are:

1) Interference at RRGI-6 is observed during injection at RRGI-7, but no definite response is observed in any monitor wells.

2) No boundary effects have been observed from pressure build-up at RRGI-7.

3) The water level drop observed in some monitor wells during injection into RRGI-6 has not been observed during injection into RRGI-7.

4) Geophysical logs and the lack of boundary effects during testing indicate that no high permeability thief zone exists at RRGI-7. The hole is cased to 623 m, through the depth at which the thief zone occurs at RRGI-6. However, no lost circulation occurred in this interval and logs indicate variable low to moderate porosities. Fractures were not observed in the borehole televiewer survey (Keys, personal communication).

5) No seismic activity has been measured in the vicinity of RRGI-7 during injection into this well. During a recent test with production from RRGP-5 and injection into RRGI-7 a series of microseismic events occurred in the vicinity of RRGE-2. Because no seismicity has occurred during previous tests, it is unlikely that this was related to testing.

6) Because the intrinsic transmissities at RRGI-6 and 7 are similar, cold water injection at 60 lps could result in build-up after three years of 3000 kPa at the wellhead at RRGI-7 if viscosity effects are important.

7) Although no long-term tests have been conducted, it appears that hydraulic communication between RRGI-7 and shallower aquifers is limited or does not exist. This may be due to a lack of fracturing in the sediments near RRGI-7.

CONCLUSIONS

Although Raft River is geologically on the edge of the Basin and Range province, the conceptual model of a fault controlled deep geothermal resource with recharge from meteoric waters and upward movement into overlying basin-fill sediments through fractures fits this area well. Thus, injection experience at Raft River can provide useful information for development of the many moderate temperature Basin and Range resources in the west. There is the potential for thermal breakthrough if cold water is injected into the fractures of the geothermal reservoir. High permeabilities in the sediments also make injection into this level an attractive alternative to deeper injection. However, protection of shallow aquifers requires that upward movement of geothermal fluids be limited.

Planning An Injection Strategy

1) Injection pressures at RRGI-6, where vertical movement has been observed, should be kept low, below 2070 kPa. This will require injecting smaller volumes of fluid into this well than previously planned.

2) If the 5 MW plant is operated as a research facility (i.e., non-continuously) the existing injection wells will recover between tests and will, therefore, provide adequate injection capacity.

3) If the facility is operated continuously for power generation, other means of fluid disposal will be necessary.

Recommended Future Testing

1) Use elevation surveys and tilt meters to determine if aquifer dilation is actually occurring.

2) Conduct a long-term injection test at RRGI-7 under otherwise quiet field conditions to determine if communication with shallow aquifers may be occurring.

3) Monitor pressure build-up during cold water injection to evaluate the effect of the viscosity change on pressure build-up.

REFERENCES

Covington, H. R., 1980, Subsurface Geology of the Raft River Geothermal Area, Idaho, Geothermal Resources Council Transactions, Volume 4, pp. 113-115.

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