McGinness Hills—Case Study of a Successful Expansion

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Keywords

McGinness Hills, Ormat, case study, temperature trend, conceptual model, permeability, tracer tests, reservoir pressure, pump-setting depth, gas breakout

ABSTRACT

Ormat expanded the McGinness Hills geothermal project with the addition of a second power plant in February 2015. The first year of operation of the second power plant has showed that the expansion was successful. Generation has increased from a nominal initial capacity of 30 MW net to more than 90 MW net. Production and injection are in two distinct grabens that appear to be linked at depth by intersecting faults. This is interpreted to have created a U-tube path for injected water to extract heat from the depths of the system. Production temperatures have remained constant at 337°F, and declines in reservoir pressure near the production area have been modest (3 to 6 psi per year). Tracer testing has showed long times to initial tracer arrival (over one month) and low tracer response peaks (less than 11 ppb). Downhole production pumps have a sufficient liquid column above the pumps to avoid gas breakout at the pump inlets. In addition, the casing configuration would allow deepening the pump-setting depths by several hundred feet, which provides a further buffer against the possibility of gas breakout in the longer term.

Introduction

The McGinness Hills Geothermal Project in Lander County, Nevada, has been operating for nearly four years. The first unit (MH-1) came on line in June 2012 with a nominal capacity of 30 megawatts (MW) net (Ormat, 2012). The actual output of MH-1 averaged 36 MW net over its first 2½ years of operation. In February 2015, a second unit (MH-2) came online, essentially twinning the plant capacity of MH-1 and bringing the project's nominal capacity to 72 MW net (Ormat, 2015). In its first year of operation with two plants, the project

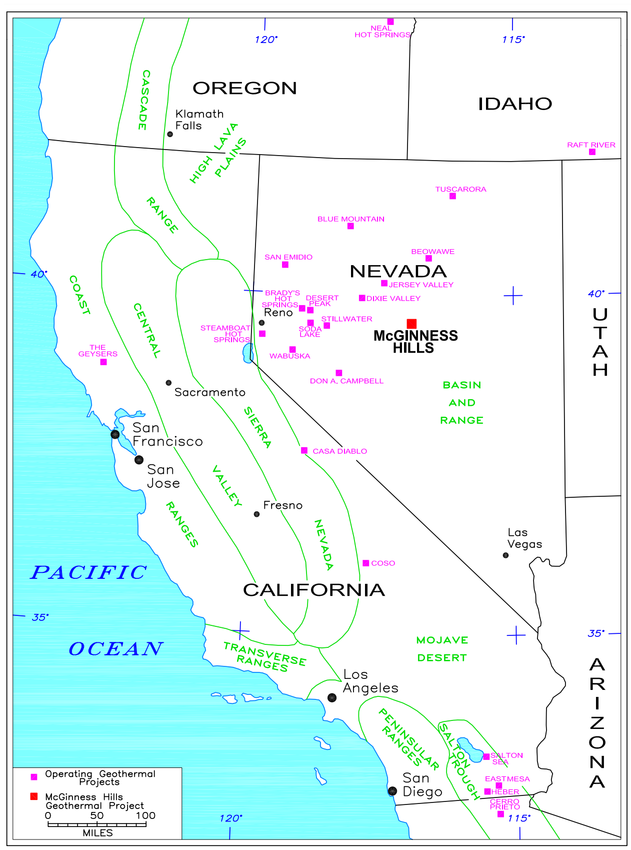

Figure 1. Location of the McGinness Hills geothermal project.

has again exceeded the nominal capacity amount, with an average output of 82 MW net. This paper describes some of the factors that have driven this favorable performance and that provide confidence in the continuation of good performance in the future.

Project Description

McGinness Hills is located in central Nevada, about 11 miles northeast of the town of Austin (Nordquist and Delwiche, 2013). Figure 1 shows the location of the project with reference to other geothermal projects in the region. The project now has 10 production wells and 6 injection wells (Delwiche, 2015). The production wells are clustered in one quarter-section in the north of the project area, and the injection wells are spread out over about a mile in the south, with a separation of at least one mile from the production cluster (Figure 2). The production wells range in depth from about 2,100 feet to about 3,900 feet. They are completed with either 13⅜inch or 16-inch production casing, and most have 9⅝inch slotted liner through the production zone, with liner tops at a depth of approximately 1,800 feet.

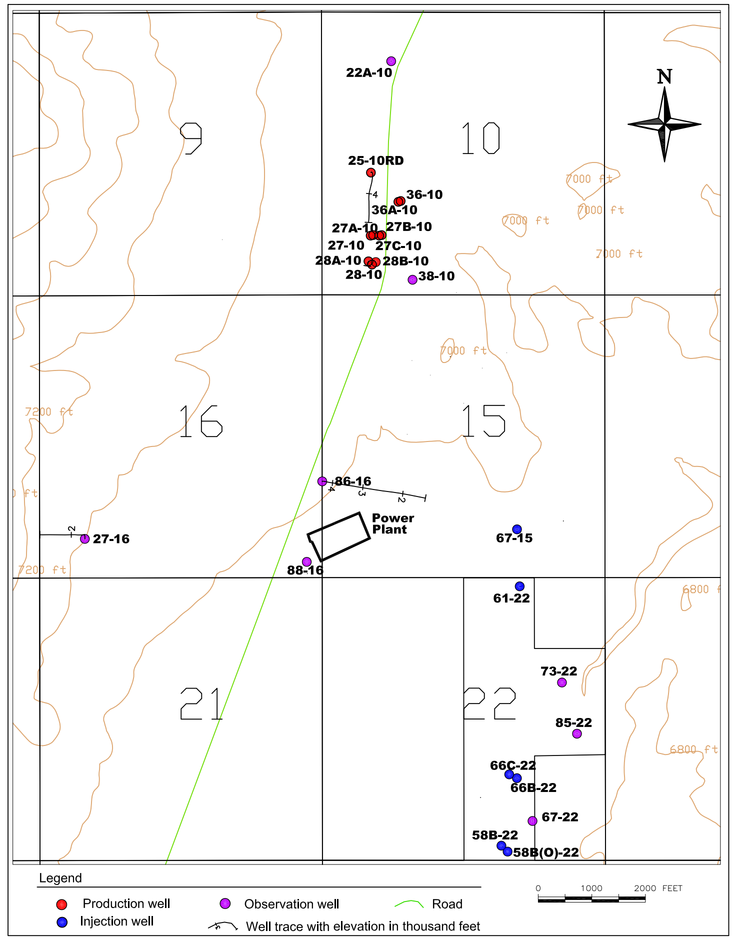

Figure 2. Well locations at the McGinness Hills geothermal project.

Project Performance

Figure 3 illustrates the project performance since start-up. During the first 2½ years of operation, with just MH-1 on line, generation ranged from 35 to 50 MW gross (30 to 45 MW net) (upper panel of Figure 3). As expected for an air-cooled binary unit, generation was somewhat lower in the summer. With the start-up of MH-2 in February 2015, generation rose to over 100 MW gross (90 MW net). The dip in generation in the summer of 2015 was exacerbated by pump failures in three wells, which were subsequently repaired. Turbine repairs in March 2015 and again in March 2016 caused brief dips in generation at those times. As of late March 2016, the project was generating 117 MW gross (100 MW net).

Flow rates at the production and injection wells (middle panel of Figure 3) were generally very steady with just MH-1 on line. Production rates started at about

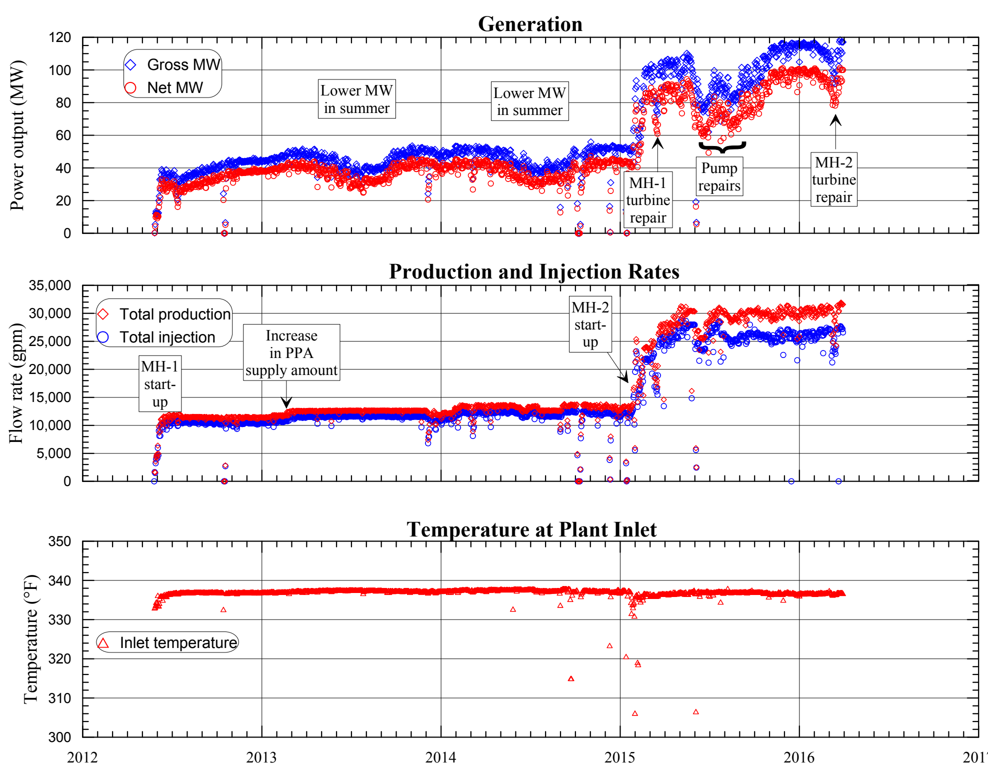

Figure 3. Performance of the McGinness Hills geothermal project since start-up.

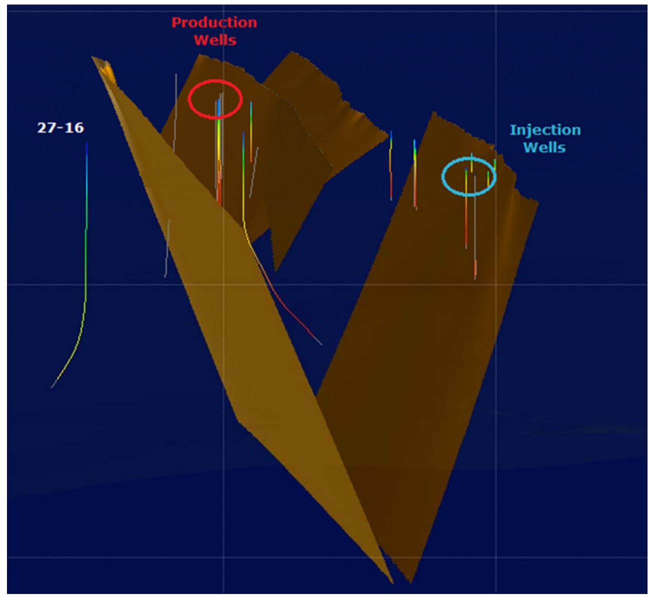

Figure 4. Schematic view of intersecting injection and production areas at depth.

11,250 gallons per minute (gpm) and increased to about 12,500 gpm in February 2014, when an increase in the supply amount under the power purchase agreement (PPA) was authorized. When MH-2 came on line, production rates initially doubled and then were raised in increments to about 30,000 gpm.

A remarkable feature of McGinness Hills performance is that production temperatures have remained virtually constant over nearly four years of operation (bottom panel of Figure 3). The plant-inlet temperature was 337°F at the start-up of MH-1 and was still 337°F after a year of operation at more than double the initial flow rate. There were only minor deviations in the plant-inlet temperature at the time of starting up the new MH-2 wells in February 2015.

Conceptual Model

Geological evidence and drilling results indicate that the cluster of production wells are completed in a fractured graben in the north, and the injection wells are completed in a fractured graben in the south (Delwiche, 2015). Multi-well testing prior to plant start-up showed that there was hydraulic communication between the production and injection areas. The steadiness of production temperatures suggests that the flow path from injectors to producers is via deeper fractures that link the two grabens. This is compatible with interpretations of the slip and dilation tendency of faults at McGinness Hills, as described by Faulds (2015a, 2015b) and Delwiche (2015). In this interpretation, faults striking north-northeast (NNE) are favorably oriented for both slip and dilation, and these faults appear to be the source of permeability in both the northern (production) and southern (injection) grabens. Faults striking northwest (NW) are not favorably oriented for slip or dilation, and they appear to contribute little to the hydraulic connection between the two grabens. The permeable

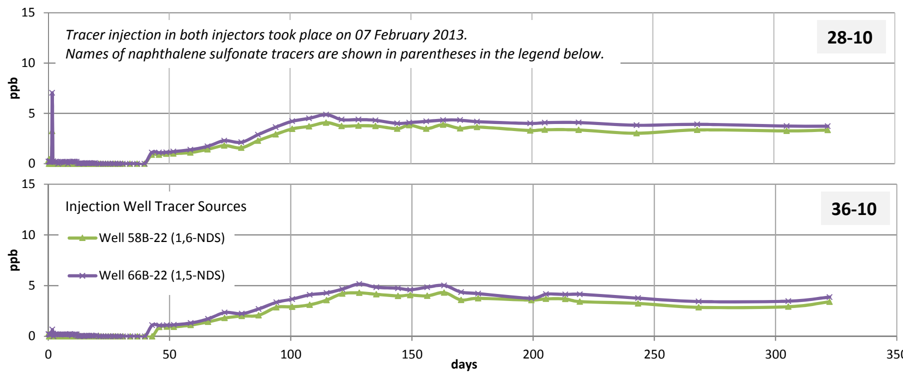

Figure 5. 2013 tracer test – response with just MH-1 operating intersecting.

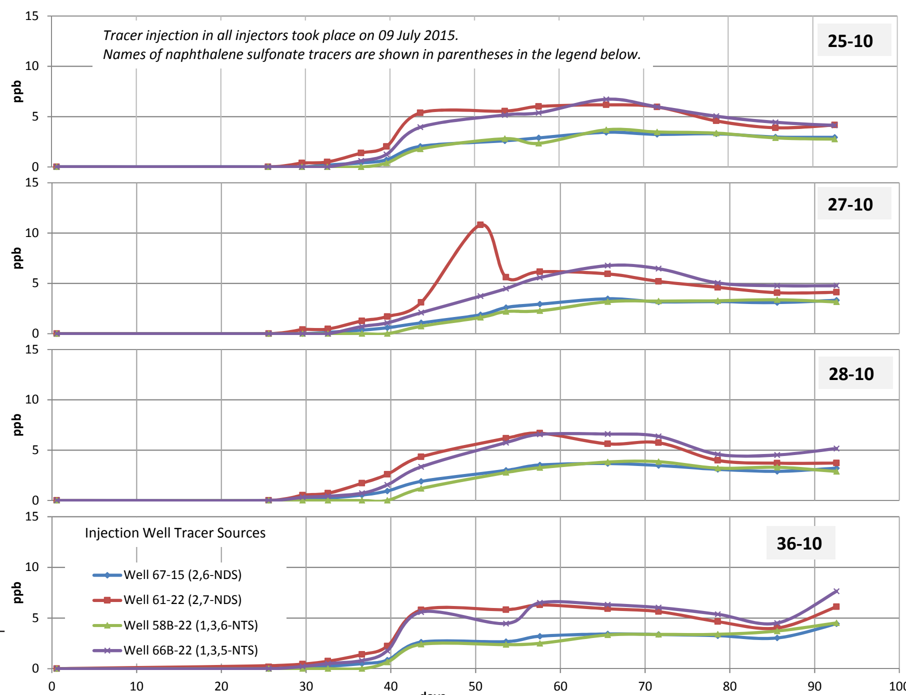

Figure 6. 2015 tracer test – response with both MH-1 and MH-2 operating.

NNE-striking faults generally dip to the NW. However, evidence from geophysics and drilling supports the existence of faults that dip southeast (SE) within both grabens. These SE-dipping faults could intersect permeable NWdipping faults at depth. This is illustrated schematically in Figure 4, which shows a SEdipping fault in the production area intersecting a NW-dipping fault in the injection area. This effectively creates a U-tube path for injected water to travel downward (due to cooler temperatures and higher density), and then upward to the production area after absorbing heat from the depths of the system. This is a much more robust heat-extraction mechanism than would be the case for a direct lateral flow at the elevation of the production and injection zones in the wells themselves.

Tracer Tests

Ormat has conducted two multi-well tracer tests at McGinness Hills to assist in characterizing the reservoir: one in 2013 and one in 2015. The tests used tracers in the naphthalene sulfonate family, with each injection well receiving a distinct tracer (approximately 100 kilograms per well). Both tests showed tracer returns to all active producers, thus confirming the hydraulic connection between the two grabens. However, the times to initial tracer responses were long, and the peak tracer responses were low, in comparison to tracer responses observed in other projects where thermal breakthrough has been an issue.

The 2013 test at McGinness Hills (Figure 5) used wells that were active with just MH1 on line. Initial arrivals of tracer from injectors to producers occurred at about 40 days, and the peak tracer responses (after more than 100 days) were 5 parts per billion (ppb) or less. The 2015 test (Figure 6) was conducted with both MH-1 and MH-2 on line. The time to initial tracer response was somewhat earlier (about 30 days rather than 40), but the peak responses were still low (as high as 11 ppb in one producer, less than 7 ppb in the others). By way of comparison, tracer testing at the Tuscarora geothermal project (where thermal breakthrough from one injector required reconfiguration of the production-injection strategy after 21 months of operation) showed initial tracer arrivals within hours and peak tracer concentrations in the range of 50 to 130 ppb (Chabora *et al.*, 2015). The results of tracer tests at McGinness Hills confirm that the potential for thermal breakthrough is low with the current configuration of production and injection.

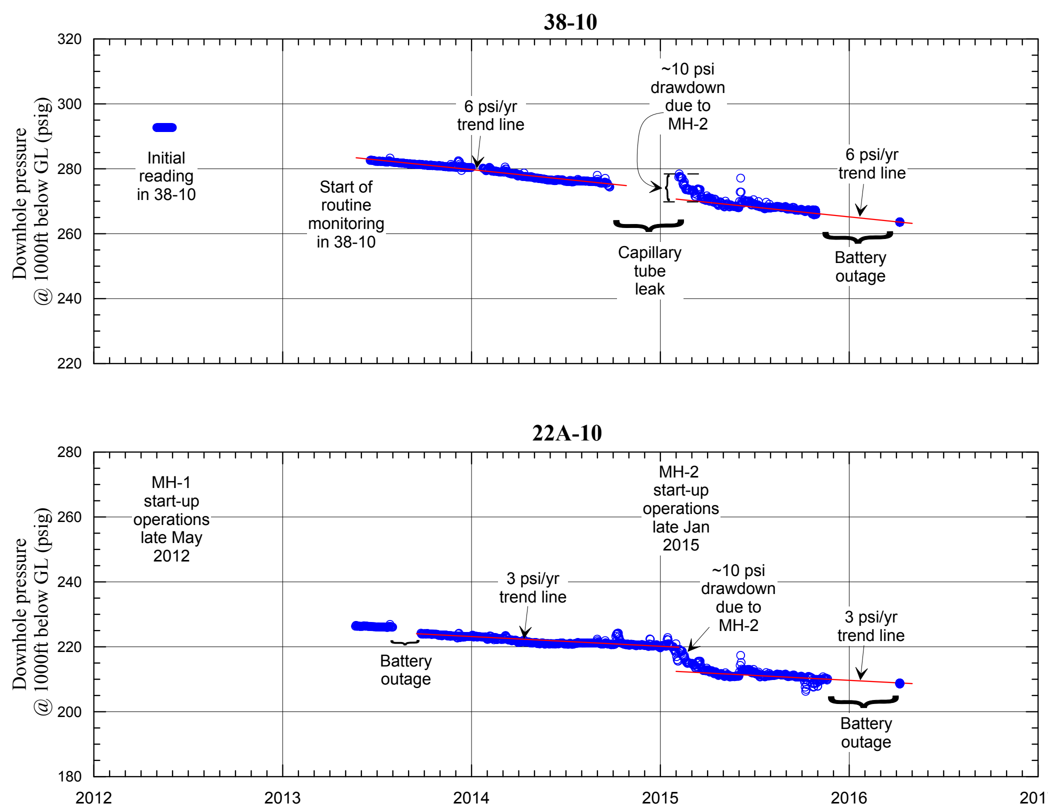

Figure 7. Trends in reservoir pressure near production wells at McGinness Hills.

Reservoir Pressure

Observation wells near the production area at McGinness Hills have showed modest pressure declines since start-up: on the order of 3 to 5 pounds per square inch per year (psi/yr) (Figure **7**). When MH-2 came on line, observation well pressures decreased about 10 psi over six months, then re-established the same long-term decline rates as previously. Within the production wells themselves, pressures at the inlets of downhole pumps (as indicated by bubble tubes) are in the range of 220 to 430 pounds per square inch gauge (psig), which provides an acceptable operating margin above the reported gas breakout pressure of 122 psig. In addition, the pumps in most production wells are set several hundred feet above the 9⅝inch liner tops, so potential exists for deepening the pump-setting depths in case this becomes necessary to avoid gas breakout at the pump inlets in the longer term.

Summary

The first year of operation of the second plant at McGinness Hills has showed that the expansion was successful. Production temperatures have been constant, and reservoir pressure declines have been modest. The production and injection areas are located in distinct grabens, which are interpreted to be linked at depth by intersecting faults. This conceptual model is consistent with the evidence of hydraulic communication from pressure responses and tracer testing, while at the same time explaining the remarkable stability in production temperatures.

Acknowledgements

The authors would like to thank Ormat Nevada, Inc., for permission to publish this paper. James Morrow provided valuable assistance in the organization of the field performance data and preparation of the figures.

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