The Don A. Campbell Geothermal Project – Development of a Low-Temperature Resource

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ABSTRACT

In December 2013, Ormat Technologies Inc. placed in operation the 16 MW Don A. Campbell geothermal plant in Mineral County, Nevada, USA. The project utilizes a relatively low-temperature resource, with production temperatures of approximately 264°F (129°C). Exploration took place over a 5-year period, and included geologic mapping, geophysical surveys, geochemical analysis of fluids, shallow temperature mapping, core-hole drilling, and several deep, full-diameter wells. Resource assessment included a one-month test of production and injection wells prior to plant construction, and numerical modeling to project long-term performance. The production wells tap the reservoir at relatively shallow depths, and several wells have extra-large-diameter casings to take advantage of the high flow capacities resulting from the high formation permeability. Plant construction and commissioning was quite rapid, requiring just nine months from start of mechanical construction to operation at full output.

1. INTRODUCTION

The Don A. Campbell Geothermal Project in Mineral County, Nevada, began commercial operations in late November 2013 and reached firm operation in December 2013 with steady output in excess of its nominal capacity of 16 megawatts (MW) net. The project is located in the general vicinity of numerous operating geothermal projects (Figure 1), but it is the first commercial geothermal plant in Mineral County. The project is on federal lands managed by the Bureau of Land Management (BLM), approximately 26 miles north-east of the town of Hawthorne. The BLM has historically referred to geothermal area as Deadhorse Wells, and Ormat called the project Wild Rose during exploration and development. Prior to plant start-up, Ormat re-named the project in honor of Don A. Campbell, a long time Ormat employee and a pioneer in the exploration, development and reservoir management of geothermal resources. The project sells power to the Los Angeles Department of Water and Power (LADWP) and Burbank Water and Power (BWP) in southern California, using a wheeling arrangement that includes transmission through the newly constructed 231-mile 500-kV One Nevada Transmission Line. This represents the first time LADWP and BWP have added geothermal power to their generation portfolios.

2. DEFINING THE RESOURCE

2.1 Exploration

The geothermal system at the Don A. Campbell project is entirely “blind”, with no apparent surface thermal features or related mineralization. Ormat’s geologists identified this property as potentially having geothermal potential based on data from mineral exploration campaigns that took place in the area in the early 1990’s. These data included summaries of an aeromagnetic survey and exploration drilling. The aeromagnetic survey delineated a large magnetic-low anomaly along gently northward sloping alluvial fans. The magnetic anomaly was elongated NE-SW (with a length of approximately 4 km and a width of approximately 1.5 km), and it was inferred to correlate with strong argillie alteration observed over depth ranges of ~50 to 500 ft. Summaries of several exploration wells drilled by mineral companies indicated strong flow of 140°F to 190°F fluids and 203°F vapors at shallow depths over an area of approximately 46 square kilometers (Figure 2). All wells were completed in alluvial sands and gravels that exhibited propylitic alteration within 100 ft. of the surface with an assemblage of secondary minerals that included argillite, pyrite, chalcedony, and chlorite. The mineral prospectors did not find sufficient indications for precious metals like gold and silver to exist in commercial quantities. Nevertheless, the coincidence of propylitic alteration in young Quaternary rocks with very anomalous shallow temperatures and the presence of hot fluids and steam suggested a possible commercial-grade geothermal system at depth. This led Ormat nominating this property with the BLM in 2001, and in August 2007 Ormat secured site control through the BLM’s competitive geothermal lease auction.

Immediately after obtaining site control, Ormat embarked on a 5-year exploration campaign, which comprised pre-drilling exploration surveys; followed by shallow exploration drilling; followed in turn by full-size and deep core drilling that served to discover and delineate the resource. The exploration program concluded with a 29-day multi-well production-injection flow test that helped determine a sustainable MW capacity for the first increment of plant capacity. The pre-drilling exploration surveys included water sampling; surveying existing well temperatures, water levels and depths; mercury soil sampling; geologic mapping; multispectral and thermal imagery analysis; shallow 2-meter temperature surveying; detailed gravity surveying; controlled source audio-frequency magnetotellurics (CSAMT) surveying; magnetotellurics (MT) surveying; and ground magnetic surveying. Figure 2 illustrates the location of mineral exploration holes (1990-1992), aeromagnetic contours (1990), and the results of a shallow 2-meter temperature survey (2011). Ormat synthesized all of data to generate a geological model that was used to select the initial temperature-gradient exploration core holes. In May 2010, five temperature-gradient holes were drilled vertically to 500 ft. depth. Core samples were analyzed, and temperatures and water levels were monitored over a period of several months. Anomalous high temperatures up to 267°F were encountered at depths within 200 ft. of the surface, and argillite and siliceous alteration was observed in core samples.
The results of the temperature-drilling campaign were integrated with the other data for selection of a first deep exploration drilling target. That first target was drilled as a full-diameter well, and it encountered total loss of circulation at 1,245 ft. depth while drilling in silicified and fractured alluvial sand and gravel. The well was flow tested in mid-November 2010 and results indicated commercial fluids at temperatures around 266°F contained within a fracture system. Fluid samples were also taken, and geothermometers calculated from the reservoir fluid chemistries indicated a 300°F temperature of source fluids at depth. A second full-diameter well, located approximately 1.5 km to the southwest of the first deep well, also encountered total loss of circulation, at 1,256 ft. depth in silicified and fractured alluvial sand and gravel. Flow testing the well indicated commercial temperatures similar to the first well, which were also likely predominately contained within a fracture network.

Next, two deep core holes were drilled (one to 4,000 ft. and the other to 2,663 ft.), in order to delineate the resource area. Then, in January 2012, the third full-diameter well was drilled in the northeastern part of the field. This well experienced total loss of circulation at 683 ft. within silicified and fractured sand and gravel, and it encountered maximum temperatures near 266°F. The results of this well were integrated with the other datasets into GIS and 3D software for analysis. Figure 3 summarizes the temperatures measured in the various deep exploration wells.

2.2 Multi-well Test
In the spring of 2012, a long term (29-day) multi-well production-injection test was conducted. The purpose of the test was to assess the capacity of geothermal reservoir by producing and injecting enough fluid to create a significant reservoir pressure drawdown. The pressure change due to pumped production from a single well (with injection into two other wells) was observed at two locations. A tracer test conducted during the 29-day test showed no returns of tracer, indicating that there was not rapid communication between the injection and production areas. Numerical modeling based on the test results predicted that the reservoir could support sustained production of at least 16 MW (net) of electricity generation. Development drilling then took place, comprising 4 more production wells and one more injection well. All wells exhibited very high permeabilities, and the production wells measured fluid temperatures slightly above 260°F. By the end of 2012, Ormat had completed drilling all wells needed to support a commercial power plant. Figure 4 shows the distribution of production wells, injection wells, and core holes in the field.

3. INITIAL OPERATIONS
Since coming on line in November 2013, the Don A. Campbell plant has showed steady output in excess of its nominal capacity of 16 MW net. Figure 5 illustrates the performance of the field in the first four months of operation. The plant is supplied by four active production wells, with one productive well shut in as spare capacity. The project’s injection requirements are met with three active injection wells. Both production and injection wells have very high capacities, with several production wells capable of flow over 4,000 gpm and average injection capacities of about 5,000 gpm per well. The temperatures at the plant inlet have showed no temperature decline over the initial operating period, maintaining a constant level of approximately 264°F. Figure 6 illustrates that there has been negligible pressure draw-down associated with the start of operations.

4. CONCLUSIONS
The Don A. Campbell plant illustrates a successful exploration program in identifying and delineating a blind geothermal resource. The relatively low production temperature is compensated for by the high permeability of the wells and the shallow reservoir depths, which have allowed for economical development of the resource.

REFERENCES
Figure 1: Location of Don A. Campbell project.

Figure 2: Map illustrating location of mineral exploration holes (1990-1992), aeromagnetic contours (1990), and summary of shallow 2-meter temperature survey (2011). Black triangles are shallow 2 meter temperature probe sites.
Figure 3. Static temperature profiles of deep exploration wells at Don A. Campbell project

Figure 4. Well location map for Don A. Campbell project
Figure 5. Performance of Don A. Campbell geothermal project since start-up

Figure 6. Observation well pressures at Don A. Campbell geothermal project since start-up