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Review of Geothermal Power Generation Projects in the Basin and Range Province, 1993

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Introduction

This is the first of a series of planned annual update articles to be published in the GRC *BULLETIN* covering the major geothermal regions of the United States. Much information presented here has been graciously supplied by the various individuals and companies cited at the end of the article. Other information comes from notes taken during the recent workshop on geothermal power plants. Without the assistance of many people, both directly and indirectly, this would be a much less complete review. As the author of this article is primarily resource-oriented, the overall focus tends to be on the various resources, rather than the above-ground hardware.

In 1984 the first geothermal power plants in the Basin and Range province came on line at Roosevelt, Utah and Wabuska, NV. By the end of 1992, 14 widely separated geothermal reservoirs in the province were producing anywhere from 0.8 to 260 MW (net) (Table 1 and Figure 1). The region's 26 individual power plants have a combined installed capacity of approximately 508 MW (net). The individual plants vary in potential net output from 0.8 to 90 MW and comprise every major type of conversion technology that has been put to commercial use. Nowhere else in the world can as great a variety of geothermal power plants be visited as in the Basin and Range province. A total of 84 geothermal turbines and 78 generators are powered by fluids from 156 production wells in the Basin and Range province. Individual turbines and generators range from 0.375 to 67 MW in capacity. Fluid temperatures range from 204° to 640°F. One wood-chip power plant utilizes geothermal fluid for preheating its boiler water.

Of the 25 operating projects, only four small plants, accounting for about 15 MW, have recent capacity factors less than 75 percent. As a minor point of historical interest, only two completely failed geothermal power generation projects (where power generation equipment was installed) exist in the Basin and Range province. Both are very small and, by chance, both are near Lakeview, Oregon. Recently it was announced that the equipment from one of these, the Hammersly Canyon project, will be placed in service in southernmost New Mexico.

In addition to the operating projects, ongoing exploration and development activity at several other reservoirs will, hopefully, result in additional operating power plants in the latter half of the 1990s.

The year 1993 was an interesting and notably active year for geothermal exploration and development in the Basin and Range province in California, Nevada, Oregon and Utah. Extensive exploratory drilling occurred at eight or nine geothermal fields. Infield drilling, either for additional production or injection capacity, occurred at five operating fields. During 1993, a total of 12 large-diameter production or injection wells were drilled to support existing operating power plants. In addition, at least six major redrills were completed in 1993. In the exploration or development category for future power plants, 18 holes, including both slim core holes and large diameter wells, were completed during 1993. Some form of drilling occurred at fully half of the operating fields.

Operating Projects

Beowawe, Nevada

At Beowawe, the dual-flash power plant operated normally throughout the year with an availability factor in excess of 99 percent. Capacity declined modestly from the two previous years due to ongoing cooling of all three production wells. As of the end of 1993, the wells have cooled a total of between 28° and 42°F. An older existing well was reworked so it can be placed in service as a second injection well in early 1994. The overall strategy of this injection modification is to return as much brine as possible directly to the reservoir to attempt to eliminate, or at least reduce, a major cold water inflow.

Brady's, Nevada

The Brady's project came on line in 1992 as a pumped dual-flash plant with two high-pressure turbines and one low-pressure turbine. Shortly after commencing operation, a pronounced cooling trend began; it has lowered the average

Table 1. Basin and Range 1993 Summary Table

									1993 Drilling			
Reservoir	Net MW	Types of Plants	Dates On Line	No. of Plants	No. of Turbines	No. of Generators	No. of Prod. Wells	No. of Inj. Wells	Prod. Wells	Inj. Wells	Redrills	Small Diameter and Exp. Wells
OPERATING PROJECTS												
Beowawe, NV	12.5	Dual-Flash	1985	1	1	1	3	1				
Brady's, NV	21	Dual-Flash	1992	1	3	3	8	7		2		
Desert Peak, NV	9	Dual-Flash	1985	1	1	1	2	1				1
Dixie Valley, NV	56	Dual-Flash	1988	1	1	1	9	8			2	1
Empire, NV	3	Binary	1987	1	4	4	3	4				
Soda Lake, NV	12.5	Binary	1987, 1991	2	16	10	4	5	1			
Steamboat, NV	42.5	Binary and Single-Flash	1987-1992	5	14	14	15	7	1			2
Stillwater, NV	12	Binary	1989	1	14	14	5	5				
Wabuska, NV	1.2	Binary	1984	1	2	2	2	1				
Coso, CA	260	Dual-Flash	1987-1990	4	9	9	75	22	6		1	
Mammoth Lakes, CA	40	Binary	1986, 1991	3	8	8	14	9	1	1		
Amedee, CA	1.6	Binary	1989	1	2	2	2	0				
Wineagle, CA	.8	Binary	1985	1	2	2	1	0				
Geoproducts, CA	3	Wood Chip					1	2				
Cove Fort, UT	10	Binary, Single-Flash, Dry Steam	1985-1990	2	6	6	8	1				
Roosevelt, UT	23	Single-Flash	1984	1	1	1	4	3				
DEVELOPMENT PROJECTS												
Fallon, NV												1
Fish Lake Valley, NV											3	3
Gerlach, NV												2
Rye Patch, NV												6
Pueblo Valley, OR												2
TOTALS	**508.10**			**26**	**84**	**78**	**156**	**76**	**9**	**3**	**6**	**18**

inlet temperature by approximately 25°F. During 1993, efforts to mitigate this included the drilling of two injection wells, with the overall strategy of shifting injection from depths of 300 to 500 ft. in the Brady's fault to depths of 4,000 to 6,000 ft. The shift in injection strategy has greatly reduced the cooling rate, and plans for 1994 include additional deeper injection wells.

Desert Peak, Nevada

The dual-flash Desert Peak power plant has had no makeup drilling since it came on line in 1985. It has generally operated at availability levels in excess of 97 percent, but a gearbox problem in 1993 reduced the availability to 94 percent. A new rotor with upgraded buckets on the last three stages is planned; this could boost the output to 13 MW. The condenser was originally constructed of mild steel, and various coatings have been only partially successful in dealing with an ongoing corrosion problem. Currently a zinc phosphate chemical is being tested. During 1993, an exploratory corehole was drilled a couple miles northeast of the production wells.

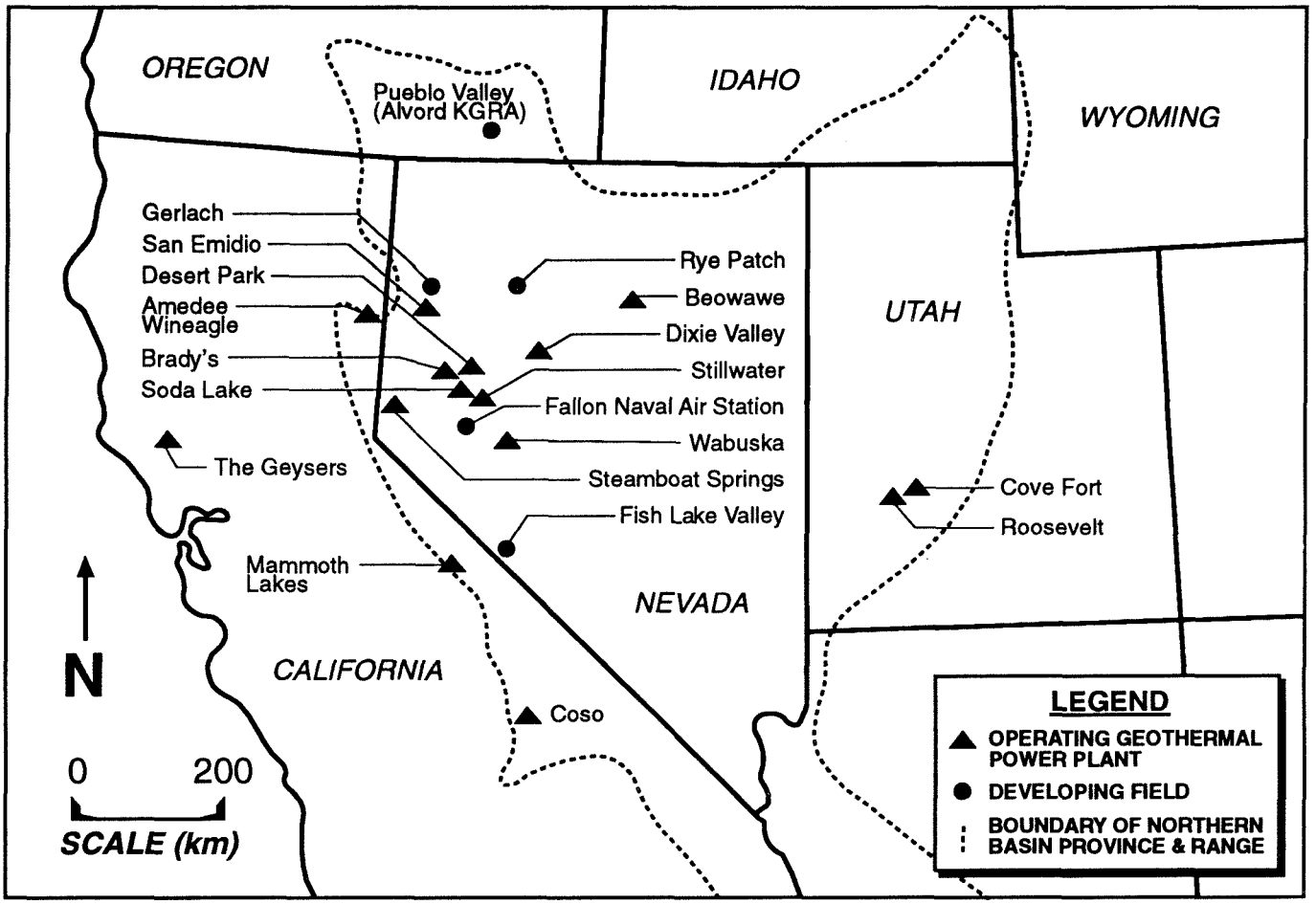


Figure 1. Location Map (modified from Edmiston).

Dixie Valley, Nevada

At Dixie Valley, Nevada, the dual-flash power plant continued to operate at more or less contract capacity, with an availability factor in excess of 99 percent for the second year in a row. The capacity factor exceeded 110 percent. The major resource modification during the year was the deepening of well 76-7 in response to injection-caused cooling. The deepening turned into a major redrill due to unrepairable liner damage. Minor workovers of three other production wells provided the first opportunity in almost 3 years to obtain deep flowing temperature surveys. These data show no detectable cooling of the main reservoir since injection commenced in September 1988.

The scale inhibition system continued to perform very effectively, with a few wells now having between 1,100 and 1,200 days of continuous inhibition with no changes in hardware. A noncorrosive inhibition chemical was successfully tested over a couple of months, and long-term testing is underway in one well.

Dixie Geothermal Corp., an affiliate of Caithness Inc., drilled and redrilled a deep exploratory well a few miles southwest of the existing power plant. While the well did not encounter any permeability, temperatures of 513°F were measured in the second leg, making this the hottest well in Nevada and about 35°F hotter than the existing Dixie Valley production wells. Additional drilling is planned in early 1994.

Empire, Nevada

Prior to 1993, this binary project suffered cooling of the production zones, presumably due to injection breakthrough. During 1993, a balancing of injection patterns minimized the temperature decline but the plant was operated below its rated capacity throughout the year.

Soda Lake, Nevada

These two binary plants are the only project in the country to have both air- and water-cooled units. In 1993, a production-enhancement program was instigated, providing additional injection support to existing production wells and the drilling of additional production wells. One new production well was successfully completed and another is planned for 1994.

At the start of 1993, the combined flow to the plants was 3,850 gpm. The additional pressure support, and the com-

pleted new well, will increase the production to about 5,600 gpm, which remains about 500 gpm short of the design value of 6,100 gpm of 365°F fluid. New injection to an idle well has shown a 70 percent effectiveness in increasing production levels at the other wells, and present rates of injection are expected to provide 500 gpm of additional production.

Soda Lake has achieved the distinction of being, perhaps, the most difficult operating reservoir in the Basin and Range province in which to successfully locate adequate permeability.

Steamboat Springs, Nevada

Development by different operators at Steamboat Springs has resulted in five plants with three differing types of turbines, a variability matched only at Cove Fort in Utah. Late in 1992, Far West Capital placed two binary plants in service. This gives a total of 30 MW installed binary capacity at Steamboat. In 1993 the two new units (SB2 and SB3) had 99.4 percent availability and over 110 percent projected capacity. The resource withdrawal rate in the terrace area increased by a factor of four due to the new plants, but no significant temperature decline or pressure drawdown has been noted. Late in 1993, the U.S. Department of Energy awarded a $7.2 million grant for development of the first Kalina cycle geothermal plant in the country, which will further increase the hardware variety.

Two core holes were drilled to depths of 700 and 4,000 ft. in the terrace area. The 4,000 ft. hole, which had a maximum temperature of 325°F, was drilled in cooperation with the Department of Energy to evaluate the feasibility of using slim holes to production-test geothermal reservoirs. Both core holes encountered resource at predicted depths, and both encountered extensive fractures. The 4,000 ft. core hole was extensively flow tested below depths of 1,000 ft. These holes have provided evidence of sufficient fluid to support the SB4 and SB5 projects which are in an advanced developmental stage.

The 12.5 single-flash Yankee Caithness Joint Venture power plant operated normally throughout the year. A new production well was drilled; it encountered a maximum temperature of 450°F. Permitting is complete to allow the increase in production and injection rates scheduled for early 1994.

Stillwater, Nevada

The most important event at the Stillwater project during 1993 was the continuing recovery of production temperatures. The binary plant was designed to accept 330°F brine, but premature injection breakthrough one month after operations commenced lowered the average inlet temperature to as low as 265°F in mid-1991. The cooling problem was remedied by two courses of action. A remedial program eliminated certain injection intervals in selected wells which were suspected to be the cause of the cooling. Also, two new injectors were drilled one mile north of the production zone and to the south. Since 1991, the individual well temperatures have increased to between 314° and 325°F. The silica geothermometers track the recovery and predict the hottest well will recover to 334°F.

The events at Stillwater are very significant for the geothermal industry, as it is the first time in the United States that a severe cooling problem has been successfully reversed and most of the temperature recovered through changes in injection strategy. This has often been discussed as a possibility and now has, at last, been accomplished.

Wabuska, Nevada

This binary plant operated routinely throughout the year. The spray cooling ponds were cleaned out for the first time since the plant began operations a decade ago. Plans are underway for installing a computerized control panel.

Amedee Geothermal Venture 1, California

The binary Amedee project continued to suffer temperature declines during 1993. The overall decline since startup in late 1988 has been from 224° to 204°F, but the rate of decline is diminishing. Flows are now approximately 10 percent from design, and approximately 25 percent of the heat available for energy conversion has been lost. The average output during 1993 was 0.91 MW, but availability was over 92 percent. This and the nearby Wineagle power plants are unique in that they are not staffed by an onsite crew.

Coso, California

During 1993, the total output of the 4 dual-flash power plants increased by about 10 MW due to an ongoing aggressive drilling program utilizing as many as four drilling rigs. This field, at 640°F, has, by far, the hottest temperatures in the Basin and Range province. It produces just over half of the geothermally-generated megawatts in the province. BLM and DOM records indicate that six new wells and one redrill were completed in 1993.

The Calpine/LADWP power-purchase negotiations, begun in 1992, continued throughout 1993 with no announcement of a completed agreement.

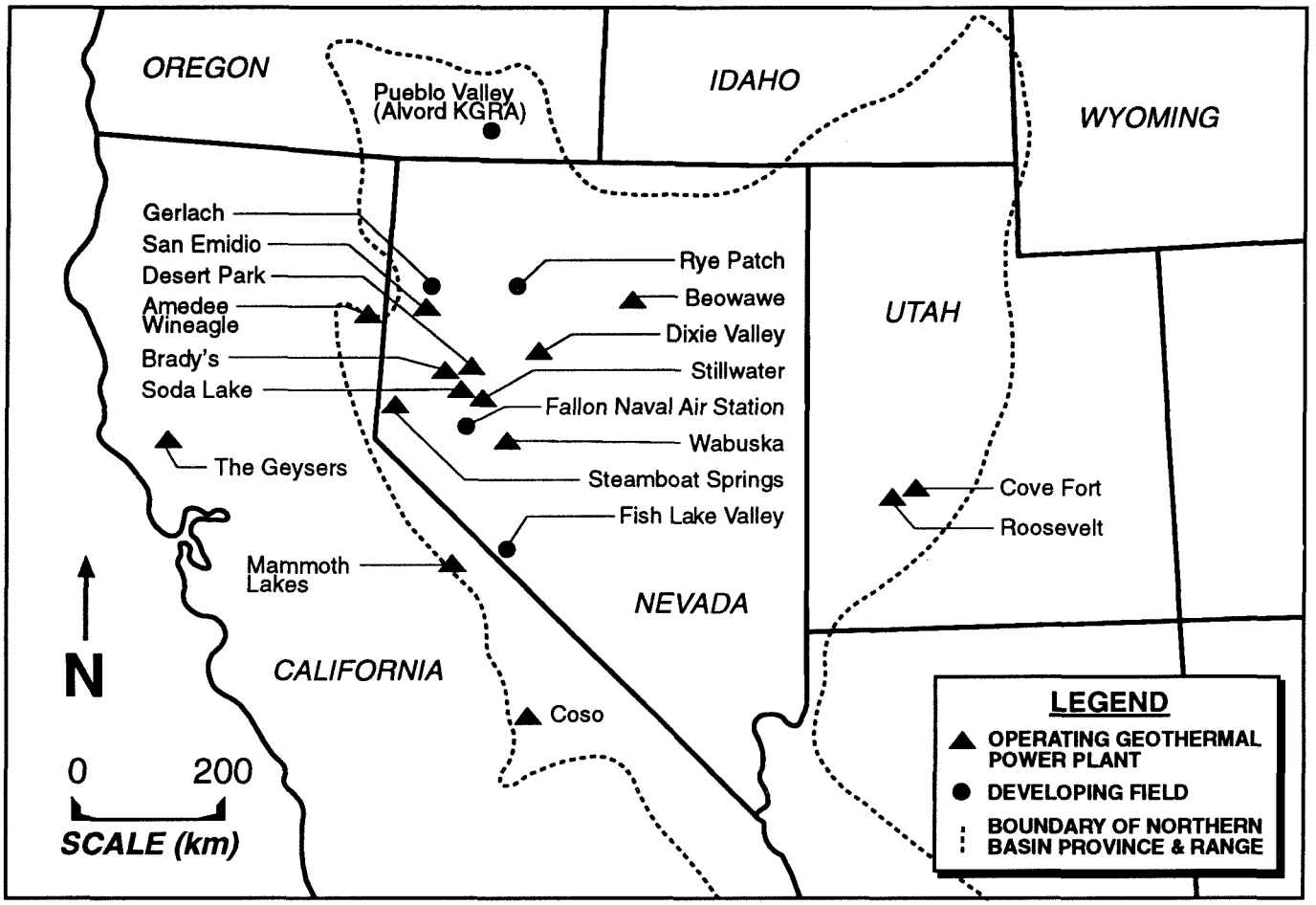
Mammoth Lakes, California

The three Mammoth-Pacific binary power plants continued to operate very well, with an overall availability factor of 99.4 percent. Two new wells were drilled in 1993. A production well was completed, increasing the resource reserve margin at two of the plants. A directional injector was also completed, after numerous drilling problems. The new injection well significantly reduced the project's injection system back pressure and auxiliary power consumption.

Permitting is underway for a 12 MW fourth binary plant at Mammoth.

Wineagle, California

This small binary power project, located a few miles from Amedee, and producing from the same reservoir, operated normally throughout the year. It has undergone a smaller temperature decline—an overall decrease from 227° to 217°F—than Amedee. The Standard Offer 4 Contract for



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Wineagle will "go over the cliff" in about 1 1/2 years, the first in the Basin and Range province to do so.

Cove Fort, Utah

During 1993, there were no substantive changes to the complex power plant at Cove Fort, Utah, consisting of binary units, a topping turbine, and a condensing turbine, or to the resource. The most recent drilling was of a hot water production well with a temperature in excess of 315°F. The temperature and pressure of the steam resource continued its decline, to 24 psig and a temperature of 258°F, from its initial conditions of 49 psig and 282°F at startup in October 1985.

The availability of the condensing turbine has been 97 percent over the past 2 years, and adjustments of frequency relays has reduced plant trips.

Roosevelt, Utah 1984

The dominant event of 1993 at this single-flash power plant was the second stage on the turbine rotor losing some buckets, possibly due to stress-corrosion cracking in January.

Development Projects

Fallon Naval Air Station, Nevada

After an exploration hiatus of several years, the Navy resumed exploration on the Fallon Naval Air Station, 6 miles southeast of Fallon, Nevada. A test hole was drilled to a depth of 6,952 ft. and unequilibrated maximum temperatures of 376° to over 400°F were reported from logging and testing operations. Fluid losses during drilling resulted in 200 ft. of slotted liner being run to protect four possible production zones. The well was flow tested, with the composite temperature being slightly lower than the maximum measured temperatures, presumably due to cooler fluids entering from one of the upper production zones. Evaluation of this well is continuing and is expected to result in the Navy resoliciting bids for development of the geothermal resource on the Naval Air Station.

This well is the only well drilled in the Basin and Range province in 1993 that may qualify as a discovery well in a new geothermal field.

Fish Lake Valley, Nevada

In 1992 the Fish Lake Power Company, a subsidiary of Magma Power Company, acquired one of the last Standard Offer 4 Contracts available to the geothermal industry, and during 1993 continued an aggressive drilling program to develop the resource for a 16 MW dual-flash power plant. This prospect was previously explored by Steam Reserve Corp., who drilled two deep exploratory wells in the area in 1984. A total of three wells and three redrills were completed in 1993 and the data indicate the identified resource will easily support the project. Flow rates in excess of 425 KPH have been measured from the 81-13 well. Two additional wells will be drilled in March 1994.

Power plant design, permitting and licensing are under way, including the transmission line right-of-way, the Utility Environmental Protection Act permit application, and the Environmental Assessment. A 29-mile, 55 kV transmission line will be built to SCE's Oasis metering station. The plant is due on-line in 1996.

Gerlach, Nevada

During 1993 several geophysical surveys were completed, which led to the drilling of two slim holes and a redrill to depths of 1,800 and 3,200 ft. These holes were drilled a short distance north and west of the Great Boiling Spring. Power from this future development would be sold to Sierra Pacific Power Co.

Pueblo Valley (Alvord KGRA), Oregon

In the far northern reaches of the province, Anadarko Petroleum Corporation drilled and tested two coreholes to depths of 2,376 and 2,520 ft. Both are in the immediate vicinity of the 1,479 ft. deep 1989 discovery corehole. All three wells have flowed at temperatures near 300°F. Due to the 4 1/2 inch casing size, flow rates are on the order of 300 gallons per minute.

Anadarko is negotiating a power sales agreement with Portland General Electric Co. that is intended to result in construction of a 21.1 MW binary power plant, possibly in 1998. Anadarko's discovery is located near Borax Lake, a 10 acre lake fed by hot springs, which was purchased by The Nature Conservancy to protect the local wildlife.

Rye Patch, Nevada

Six development wells were drilled to supply a new 12.5 MW binary plant in 1993. Unfortunately, only two of these wells are considered commercial. Plant construction is nearly complete, but is on hold pending further evaluation of the resource. Individual wells have temperatures in excess of 400°F and flow rates in excess of one million pounds per hour; however, production interference between wells and mixing with cooler fluids have made definition of confirmed resource an elusive and frustrating task.

In the late 1970s both Phillips Petroleum and Unocal drilled deep exploratory wells in the area. Each encountered only spotty success, in spite of geochemically predicted temperatures as high as 500°F. The 1993 drilling has unfortunately shown the Rye Patch geothermal system to be very complex, with fluid moving in steeply-dipping faults, laterally-charged units, and along the alluvial/bedrock contact. This apparent complexity may be rivaled only by geologic conditions at the Soda Lake reservoir.

Fluids to support 6 MW have been identified and plans to start the plant at reduced levels in mid-1994 are contemplated. The production scenario is a combination of pumped and flashed wells, with flow to Ormat-built generating units.

Conclusions

During 1993 the geothermal power generation industry had an active year in the Basin and Range province. Although no new plants came on line, there was extensive drilling and development activity at Rye Patch and Fish Lake Valley. It was also a year in which operators focused on improving operations and dealt with cooling problems. There was a continuing modest level of exploration which included deep drilling.

In a number of ways, 1994 is shaping up to be similar to 1993 in terms of overall modest activity levels. Development work on new power plants at Fish Lake Valley, Mammoth, Steamboat, and Dixie Valley can reasonably be expected to continue.

Acknowledgements

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