



THE GEYSERS GEOTHERMAL FIELD

UPDATE 1990-2010

SPECIAL REPORT NO. 20

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INTRODUCTION

In this report, we have presented data in four sections:

SECTION 1. THE GEYSERS HISTORICAL UPDATE 1990 – 2010

A historical update of the primary developments at The Geysers between 1990 and 2010 which uses as its start point Section IIA of the Monograph – “Historical Setting and History of Development” that included articles by James Koenig and Susan Hodgson.

SECTION 2. THE GEYSERS COMPREHENSIVE REFERENCE LIST 1990 - 2010

In this section we present a rather complete list of technical articles and technical related to The Geysers that were issued during the period 1990 -2010. The list was compiled from many sources including, but not limited to scientific journals and conference proceedings. While the list was prepared with care and considerable assistance from many geothermal colleagues, it is very possible that some papers could have been missed and we apologize to their authors in advance.

The list was subdivided according to the following topics: (1) Field characterization; (2) Drilling; (3) Field development and management; (4) Induced seismicity; (5) Enhanced Geothermal Systems; (6) Power production and related issues; (7) Environment-related issues; and (8) Other topics.

SECTION 3. GRC 2010 ANNUAL MEETING GEYSERS PAPERS

Included in this section are the papers presented at the GRC 2010 Annual Meeting that relate to The Geysers.

SECTION 4. ADDITIONAL GEYSERS PAPERS 1990 - 2010

Eighteen additional technical papers were included in this publication in order to give a broad background to the development at The Geysers after 1990. The articles issued during the 1990-2010 period were selected by colleagues considered knowledgeable in their areas of expertise. We forwarded the list of references given in Section 2 to them asking to send us with their selections with a preference, because of limited time, to focus on those papers that would not require lengthy copyright approval. We then chose the articles presented in this section with the purpose of providing the broadest possible view across all technical fields, as related to The Geysers steam-dominated geothermal system.

The Geysers has seen many fundamental changes between 1990 – 2010 and yet the geothermal resource seems still to be robust to the extent that, long after its anticipated life span, we are seeing new geothermal projects being developed on the north and west peripheries of the field. It is hoped that this report provides a focused data source particularly for those just starting their geothermal careers, as well as those who have been involved in the interesting and challenging field of geothermal energy for many years.

SECTION 1. A GEYSERS HISTORICAL UPDATE: 1990-2010

The Geysers, being the largest producing steam-dominated geothermal system in the world, is of special interest to all those working on the practical and theoretical aspects of field development, field management and power production. The work being conducted at The Geysers is of particular importance to the geothermal industry because the steam reservoir has been subjected to continuous commercial exploitation since 1960, the longest of any geothermal reservoir in the U.S.

The main purpose of this section is to update the historical information previously published in the GRC Monograph on The Geysers Geothermal Field, Special Report No. 17. The start point for this update is the excellent development history described by Koenig (1992), which covered the period up to the end of 1990. Since that date there have been several articles and reports discussing the history of the field (Section 2: Comprehensive Geysers Reference List). Other documents presenting historic information on The Geysers include:

- Various publications by Susan Hodgson including a video (Hodgson, 1993) and an album of early photographs that has recently been updated (Hodgson, 2010).
- The Geysers Geothermal Association newsletter, which contains articles of general interest about happenings affecting the geothermal industry at The Geysers and the people that have an impact upon the affairs of The Geysers (<http://www.thegga.org/newsletter.html>).

Presented in Table 1 are the current producing power plants at The Geysers. The table has been assembled in a way that will allow the reader to compare generation data with a similar table (Table 1 in Koenig, 1992) in the Monograph. Table 1 takes its data primarily from the Geothermal Energy Association list of U.S. geothermal power plants (<http://www.geo-energy.org/plants.aspx>).

Production Decline at The Geysers

The peak in steam production and electricity generation at The Geysers occurred in 1987 and was followed by a significant decline in reservoir pressure because of increased steam production associated with rapid and excessive development (Sanyal, 2000). This pressure decline in part led to the closure of the PG&E Unit 15 (59 MWe) plant in 1989 and of the Department of Water Resources Bottle Rock plant (55 MWe) in 1991. In addition, high production costs associated with elevated non-condensable gas concentrations and continuing problems with corrosive steam from the Northwest Geysers led to the closure of the Central California Power Agency (CCPA) Units 1 & 2 in 1996 followed by demolition of the power plant and abandonment of most of the wells in that portion of the field. Table 2 presents the power plants decommissioned or shut down since 1990.

Table 1. Geothermal Power Plants Operating at The Geysers (August 2010)

Current Power Plant Name	Operator	Previous Power Plant Name (1990)	Start-Up Date	Installed Capacity (MWe-gross)	Current Output (MWe-net)
Aidlin Calpine 1	Calpine	Aidlin	06/89	20	18 ¹
Bear Canyon Calpine 2	Calpine	Bear Canyon	09/88	20	13 ¹
Sonoma Calpine 3	Calpine	SMUDGE 1	10/83	78	36 ¹
West Ford Flat Calpine 4	Calpine	West Ford Flat	12/88	27	27 ¹
McCabe Calpine 5&6	Calpine	PG&E 5&6	12/71	110	85 ¹
Ridge Line Calpine 7&8	Calpine	PG&E 7&8	11/72	110	78 ¹
Eagle Rock Calpine 11	Calpine	PG&E 11	05/75	110	64 ¹
Cobb Creek Calpine 12	Calpine	PG&E 12	03/79	110	51 ¹
Big Geysers Calpine 13	Calpine	PG&E 13	05/80	60	57 ¹
Sulfur Springs Calpine 14	Calpine	PG&E 14	09/80	114	47 ¹
Quicksilver Calpine 16	Calpine	PG&E 16	10/85	119	48 ¹
Lake View Calpine 17	Calpine	PG&E 17	12/82	119	49 ¹
Socrates Calpine 18	Calpine	PG&E 18	02/83	119	46 ¹
Calistoga Calpine 19	Calpine	Santa Fe	04/84	80	66 ¹
Grant Calpine 20	Calpine	PG&E 20	10/85	119	40 ¹
NCPA Units 1 & 2	NCPA	NCPA Units 1 & 2	02/83	110	56 ²
NCPA Units 3 & 4	NCPA	NCPA Units 3 & 4	11/85	110	52 ²
Bottle Rock	Bottle Rock Power Co.	Bottle Rock	(03/85) 10/07 ³	55	11 ²

1. Calpine Data from NERC Generating Availability Data System (GADS).

2. NCPA and Bottle Rock Data from GEA Power Plant Database – <http://www.geo-energy.org/plants.aspx>.

3. The Bottle Rock plant was re-commissioned on 10/2007 after being “mothballed” in 1991.

Table 2. Geysers Power Plants Decommissioned and Dismantled since 1990

Power Plant Name	Previous Power Plant Name (1990)	Start up Date	Decommissioning Date
PG&E Units 1&2	PG&E Unit 1&2	09/60	Decommissioned and Dismantled – 1993
PG&E Units 3&4	PG&E Unit 3&4	03/63	Decommissioned and Dismantled - 1995
PG&E Units 9&10	PG&E Units 9&10	11/73	Unit 9 Offline – 2001 Unit 10 Offline - 2000
PG&E Unit 15	PG&E Unit 15	06/79	Decommissioned and Dismantled - 1997
CCPA Coldwater Creek 1	CCPA Coldwater Creek 1	05/88	Decommissioned and Dismantled – 2000
CCPA Coldwater Creek 2	CCPA Coldwater Creek 2	10/88	Decommissioned and Dismantled - 2000

Power Deregulation and the Exit of PG&E and Unocal from The Geysers

In 1990, several companies were producing steam at The Geysers, the largest being Unocal Geothermal Inc. Other steam producers included Northern California Power Agency (NCPA), Sacramento Municipal Utility District (SMUD), Department of Water Resources (DWR), Santa Fe Geothermal, CCPA, and Calpine Corporation (Calpine). At that time PG&E was the main power producer (Koenig, 1992).

A chronological history of power plant startups and shutdowns is presented in Figures 1-5 for each of the decades starting in 1960. Figures 4 and 5 show specifically the plants operating during the 1990 – 2010 period and the corresponding operators for each facility. The set of figures were prepared by the Geysers Geothermal Association (GGA) for the GRC Annual Meeting celebrating the 50th anniversary of commercial power generation at The Geysers.

Deregulation came to the power generation industry in California in 1996 and, as a result, PG&E was required to sell off most of its generation capacity. The PG&E power plants at The Geysers were put up for sale in 1999 in response to California's Electric Utility Industry Restructuring Act (Assembly Bill AB 1890) (<http://www.eia.doe.gov/cneaf/electricity/california/assemblybill.html>).

At that time Unocal had also decided to divest itself of its remaining geothermal operations in the U.S. However Unocal exercised a first right of refusal to acquire all of PG&E's assets and then sold all its accumulated power plant and steam field interests in The Geysers to Calpine Corporation, thus consolidating Calpine's position as the primary operator of both steam production and power generation. On the other hand, the position of NCPA at The Geysers has not changed significantly since the 1990s, as the Agency continues producing the steam that feeds its two power plants in the SE portion of the field (see Table 1).

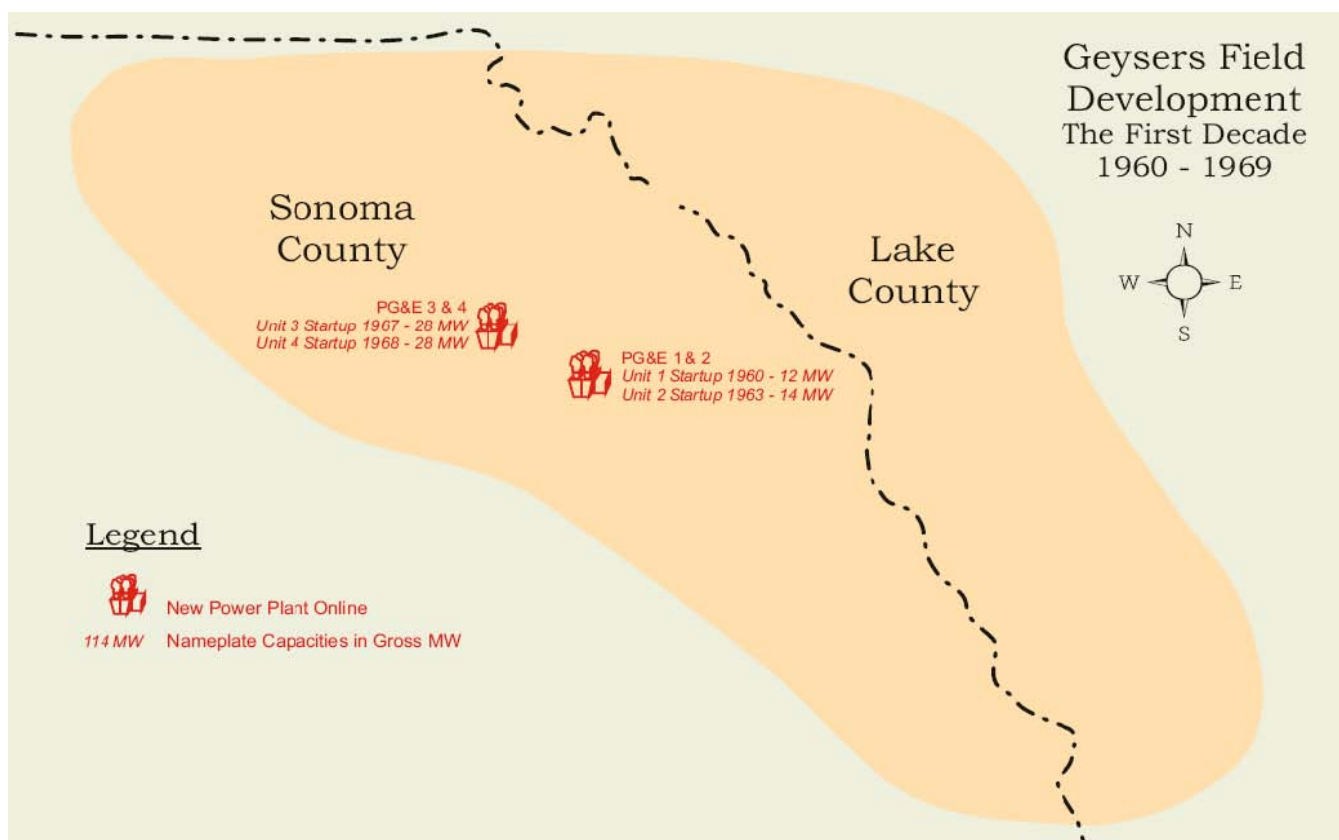


Figure 1: 1960 - 1969

(Courtesy of GGA)

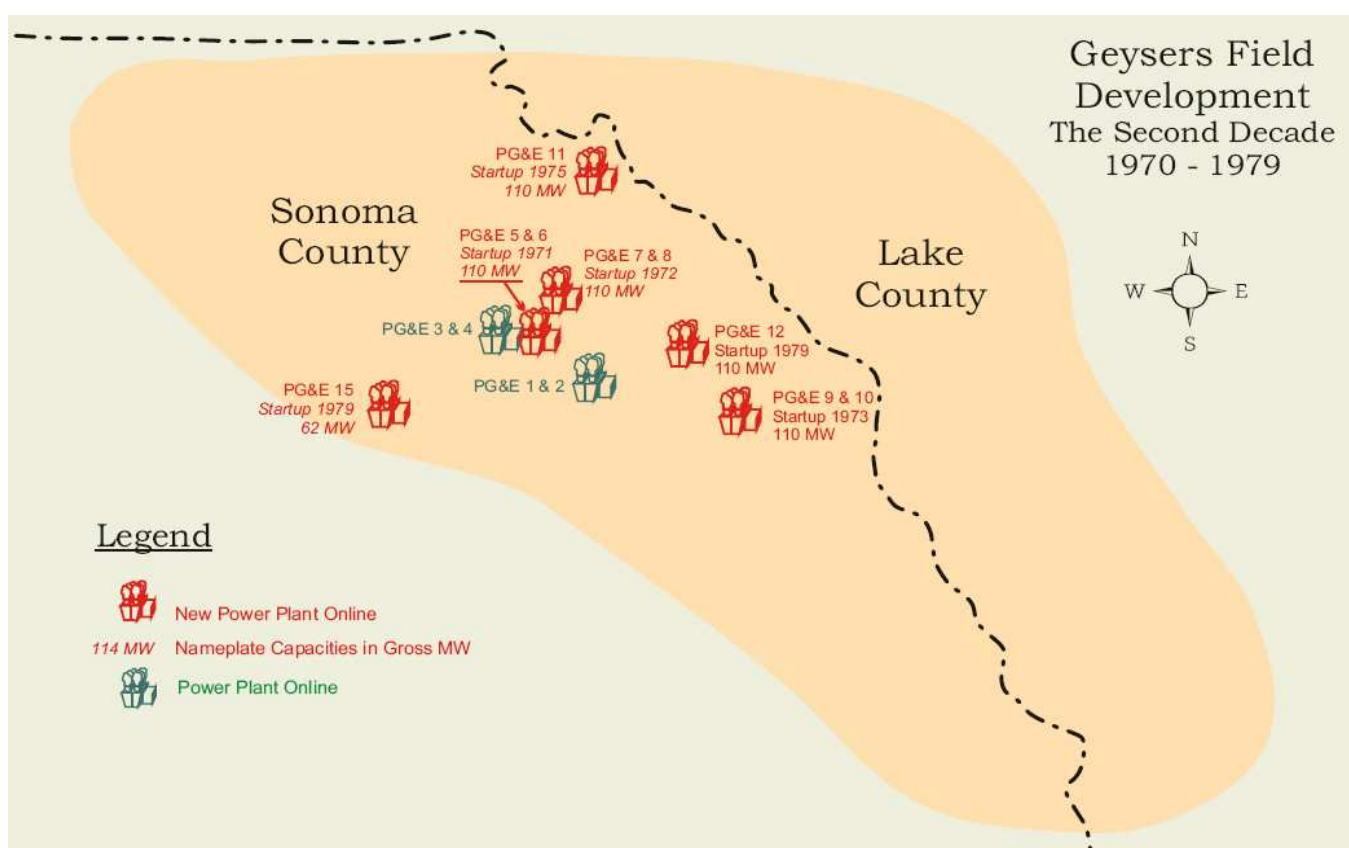


Figure 2: 1970 - 1979

(Courtesy of GGA)

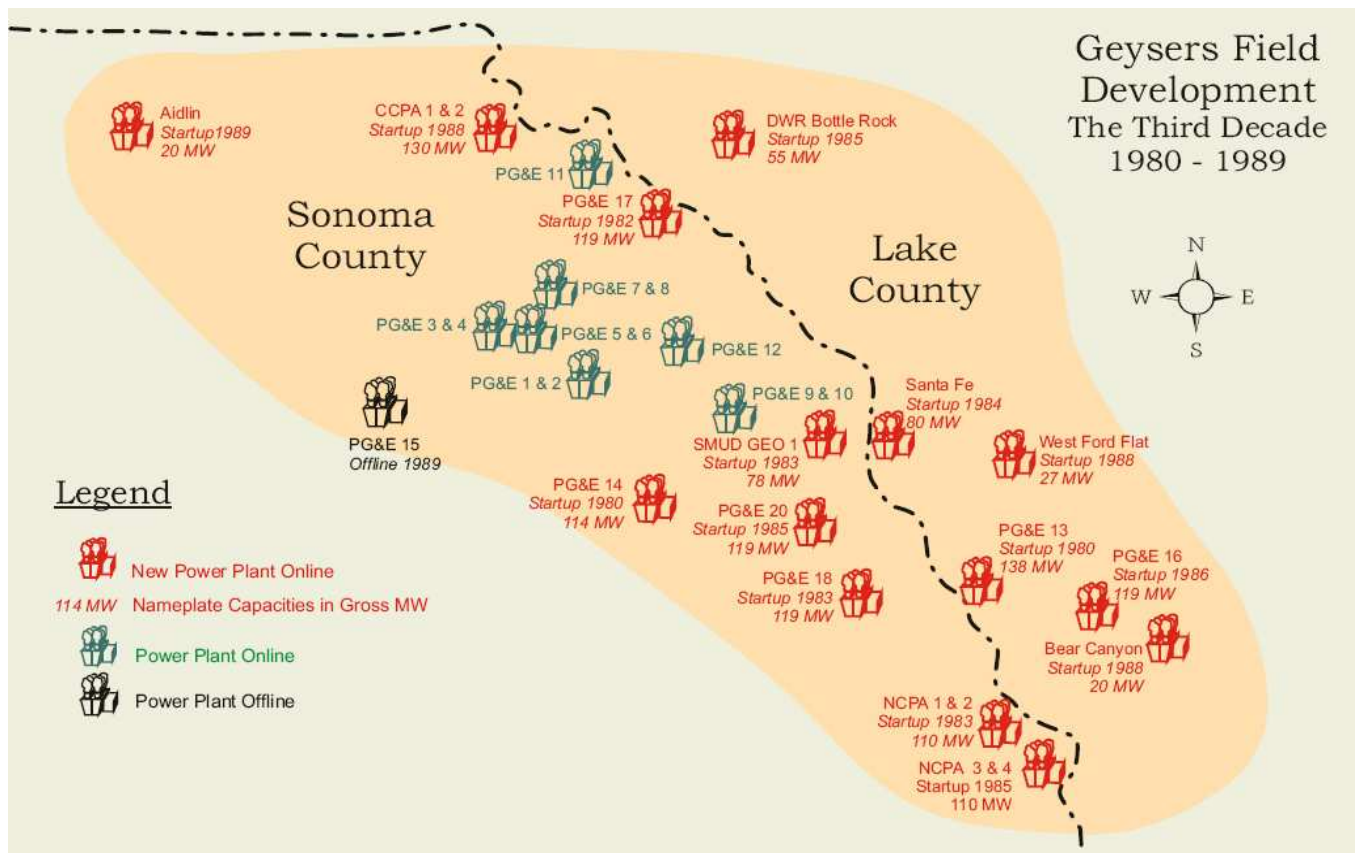


Figure 3: 1980 - 1989

(Courtesy of GGA)
(Courtesy of GGA)



Figure 4: 1990 - 1999

(Courtesy of GGA)

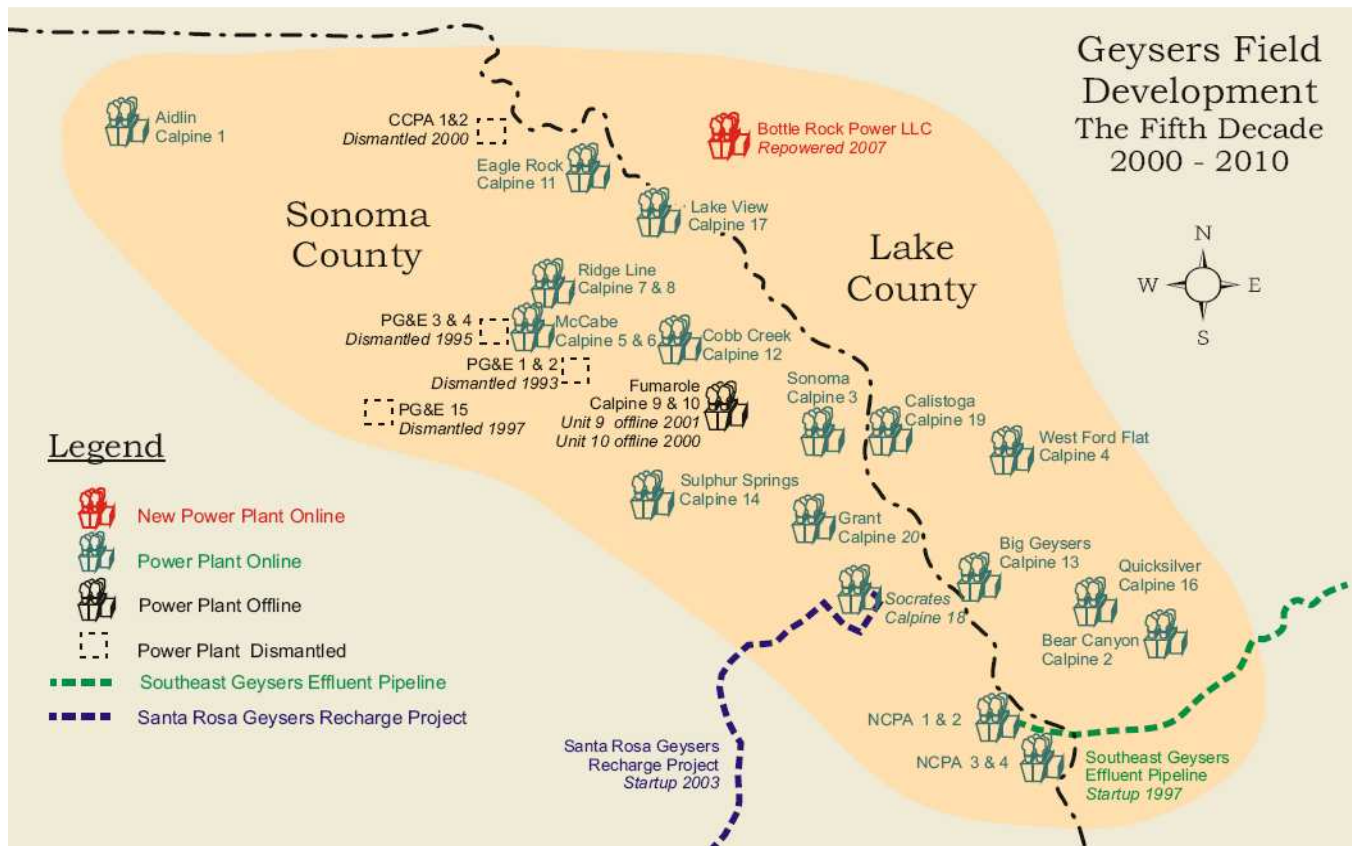


Figure 5: 2000 - 2009

(Courtesy of GGA)

Rejuvenation of The Geysers Reservoir through Injection

In 1991, the decline in power generation at The Geysers caught the attention of the California Energy Commission (CEC). The CEC were responsible for, and participated in, the formation of a Technical Advisory Committee (TAC) whose main objective was to find ways to reduce decline rates and to increase the life of the field. Among their many recommendations, the TAC suggested bringing water from outside sources for injection to replace the withdrawn mass (Goyal and Pingol, 2007). Consequently, The Geysers operators sought external water sources to supplement injection at the field, which until then consisted of creek waters collected during the rainy season and steam condensate.

The first injection project, the Southeast Geysers Effluent Pipeline (SEGEP), started bringing lake water and secondary treated waste waters from the Lake County Sanitation District to the field in September 1997. The second project, the Santa Rosa Geysers Recharge Project (SRGRP), began in October 2003 delivering tertiary treated waste water from the city of Santa Rosa (Goyal and Pingol, 2007). Several reports and publications described the two pipeline projects (e.g., California Energy Commission, 2002; Dellinger and Allen, 2004), as well as the beneficial impact of the increased water recharge on Geysers steam production (e.g., Goyal and Conant, 2010; Khan and Truschel, 2010).

Integrated Steam Field Operations

Calpine's consolidation of generation and production in 1999 was followed by purchases of the former Santa Fe power plant and steam field, the SMUD power plant and the leasing of the former CCPA steam field. The production pipelines in these Geysers areas were interconnected with nearby production pipelines to other nearby power plants to maximize steam production and power generation from the field as a whole.

Calpine shut down Unit 9 power plant in 2001 and Unit 10 in 2000 because of their poor efficiency and high operating costs. A distributed control system using fiber optic connections to the operating power plants was installed in 2000, allowing Calpine's central operation facility to monitor power plant production and shift steam between plants. Calpine's ownership and ability to shift steam where it is needed effectively unitized approximately 80% of The Geysers production.

Research and Outreach Activities at The Geysers.

The Geothermal Technologies Program of the U.S. Department of Energy (DOE) has a long history of involvement with the development at The Geysers. A major research project was sponsored by the DOE at The Geysers with the drilling of the SB-15-D core hole in 1994. A special issue of *Geothermics* was dedicated to research related to this effort (Hulen, 2001). The DOE also funded many other research projects at The Geysers. The results of studies of the geochemistry, crystallization history and ages of the different phases of The Geysers plutonic complex, originally identified by Schreiner and Suemnicht (1980), were published in three separate articles by Schmitt et al. (2003a, 2003b, 2006). The tectonic controls on magmatism were interpreted from new geophysical models by Stanley et al. (1998) that, among other things, showed that the heat center for The Geysers geothermal system, which was previously associated with a gravity anomaly, was not at Mt. Hannah, but under The Geysers itself (Stanley et al., 1997).

More recently, two Enhanced Geothermal Systems (EGS) projects at The Geysers were funded by the DOE; one in the SE Geysers by AltaRock, and another in the NW Geysers by Calpine. The main objective of these two projects was to increase the permeability of the high-temperature portion of The Geysers reservoir.

The AltaRock project (Cladouhos et al., 2009) encountered drilling difficulties prior to reaching the felsite target, and has been suspended. The Calpine project has completed its initial phase activities (Rutqvist et al., 2010), and has reopened, deepened and recompleted the Prati State 31 and Prati 32 wells in 2010. Future work consists of stimulating the PS31 well and using these wells as an injection – production pair. Calpine has also received an Innovative Exploration Technologies grant from DOE to reopen three additional wells in the NW Geysers as part of their Caldwell Ranch project.

DOE is also sponsoring research activities on induced seismicity at The Geysers, as the growth in injection volumes over the past decade has led to an increase in the amount of microseismic activity in the area (Beall et al., 2010).

Calpine opened a Geothermal Visitor Center in Middletown in 2001, which has received over 60,000 visitors from all 50 states and from 77 countries around the world. The center is currently open four days a week, and hosts numerous community activities. DOE has provided funds to upgrade the displays for the Visitor Center.

Recent and On-going Projects to Increase Steam Production

In 2007, the Bottle Rock power plant, previously shut down by DWR in 1991, was recommissioned by a new company formed through a joint venture between U.S. Renewables Group and Riverstone Holdings. The plant was brought online with steam from both existing wells that were reopened and by new wells. In 2008, rights to the BLM lease to the north were acquired thereby doubling the potential acreage available for production.

Western GeoPower Corporation, a Canadian company, successfully drilled four wells in the former Unit 15 steam field in 2008 with the intention of constructing a 30 MWe power plant. However, in 2009, Western GeoPower, along with Polaris Geothermal, merged with RAM Power; the resulting operating entity has not yet acted on these construction plans.

Calpine has currently been redeveloping the former CCPA steam field. As many as three drilling rigs were operating in 2010 to delineate the resources for two additional power plants, and to increase the steam supply to its existing power plants in the Northwest Geysers.

Summary

Despite many hurdles The Geysers has continued to generate electrical power for 50 years and its sustainability has exceeded many early researchers' expectations. It also seems probable that, with the new projects described above, generation will continue for many years to come. The success of The Geysers is due to the technical skills and the financial acumen of many people, not only over the period covered by this report (1990 – 2010), but since the first kilowatt of power was generated in 1960.

This Special Report celebrates those 50 years of geothermal development at The Geysers and attempts to document the activities that have brought success to the project so that a permanent record can be maintained. It is strongly hoped and believed that a publication similar to this one will be necessary in another 20 years to document further activities in the field.

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SECTION 2. COMPREHENSIVE GEYSERS REFERENCE LIST: 1990 – 2010

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