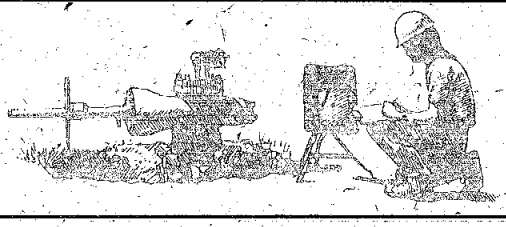
GEOTHERMAL
CALIFORNIA DEPARTMENT OF CONSERVATION DIVISION OF OIL, GAS, AND GEOTHERMAL RESOURCES
HOT LINE



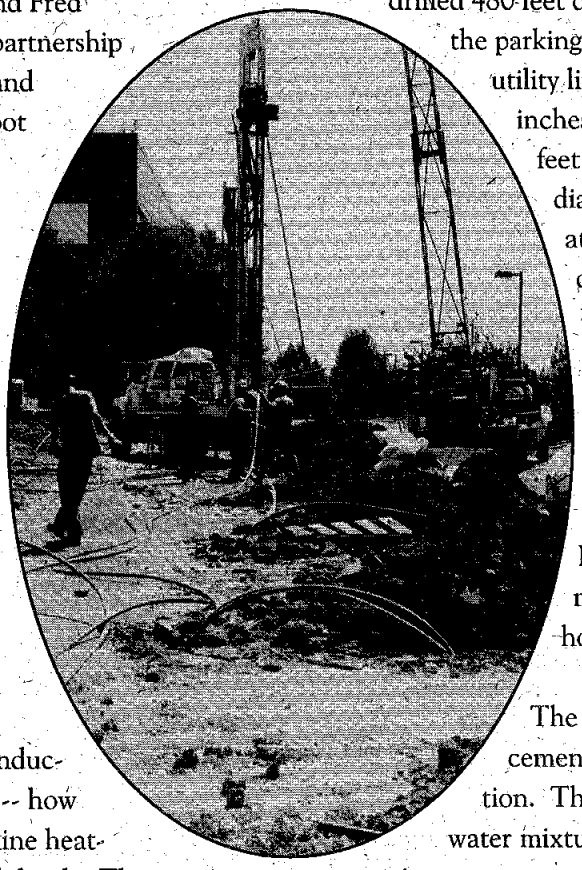
VOLUME 22, NUMBER 1 January 1996

Arena Retrofit Includes Ground-source Heat Pump

The venue for Sacramento's first professional basketball games was the "old Arco Arena," built in 1985 just north of the downtown area and converted to offices after a larger, permanent arena was constructed. In 1994, the "old arena" was acquired by Buzz Oates, William Cummings, and Fred Anderson in a California general partnership called Del Paso Venture. To heat and cool the 3-story, 211,000-square foot structure, Del Paso has installed a ground-source heat pump system.

The project is significant for the ground-source heat pump industry. The installer, Garen Ewbank of Ewbank and Associates (Fairview, Oklahoma) said, "This is the first ground-source heat pump site ever designed specifically for the energy load of the building it will serve. Other projects have been calculated by rule-of-thumb.

"First we measured the thermal conductivity of earth around the building -- how fast the soil takes heat -- to determine heat-field size and borehole number and depth. The Davis Energy Group Inc. (Davis, California) used our calculations -- along with building and climate data -- to simulate a representative section of the ground loop and design the bore-field system," Mr. Ewbank said.



Boreholes drilled in the parking lot. Drilling rigs are in the background.

According to Mr. Ewbank, the system has 265 boreholes drilled 480 feet deep. They are in rows through the parking lot amid trees, light poles, and utility lines. The boreholes are 3 1/2 inches in diameter and about 15- to 20-feet apart. A precut length of 1-inch diameter unicoil polypipe is folded at a U-bend joint and hand-pushed down each borehole to a depth of 450 feet.

"These are the smallest borehole and pipe diameters for any ground-source heat pump system in the United States," said Mr. Ewbank. "The small sizes maximize heat exchange in the boreholes."

The top 50 feet of each borehole is cemented to prevent surface contamination. The rest is filled with a bentonite-water mixture, forestalling aquifer communication.

by Susan F. Hodgson

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RESOURCES AGENCY
Douglas P. Wheeler, *Secretary for Resources*
STATE OF CALIFORNIA
Pete Wilson, *Governor*
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GEOTHERMAL HOT LINE

The *Geothermal Hot Line* is published periodically by the California Department of Conservation, Division of Oil, Gas, and Geothermal Resources. Subscriptions are free. To subscribe, send your name and address to Ms. Cheryl Brown, Division of Oil, Gas, and Geothermal Resources, 801 K St., MS 20-20, Sacramento, CA 95814-3530.
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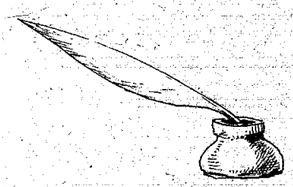


From the editor...

The first issue of the *Geothermal Hot Line* appeared in January 1971 and the last in 1992. Then, time constraints halted publication, which has resumed with this issue. We hope you find the new focus on California stories useful and interesting -- and the *Brief Geothermal Dictionary* helpful, as well.

As always, I invite you to call with comments, suggestions, and story ideas. Let us hear from you.

Susan

In memory

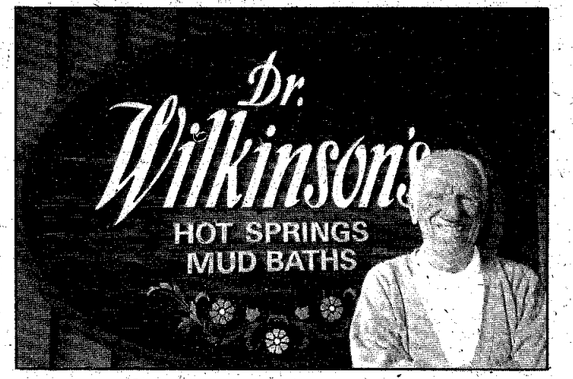
Shirley J. Valine, secretary for the geothermal unit, passed away on March 3, 1995. Her meticulous work on issues of the *Geothermal Hot Line* and her friendship were appreciated by everyone. Shirley is survived by her husband William F. Valine and her sons John P. Russell, William F. Valine Jr., and Preston Raines.

In This Issue

California; Federal and State News; Technology Transfer; California Wells

CALIFORNIA

50 YEARS IN CALISTOGA, AN INTERVIEW WITH DR. WILKINSON



I came to Calistoga in 1946," said Dr. John Wilkinson, sitting in the busy lobby of Dr. Wilkinson's Hot Springs and Mud Baths. "I've always had an interest in natural health. After I became a chiropractor, someone told me about a hot spring in Calistoga called Pacheteau's, now Indian Springs. I leased it for five years and left in 1952 to establish this place nearby. I've been here ever since. Combining the chiropractic and the hot spring business just suited me exactly.

"Through the years, my clientele has changed," he continued. "In 1946, most were born in Europe, people with a tradition of going to hot springs. They came here in the summertime, usually from the outlying Bay Area. The winters were dead. Most people were about 60 years old and took mud baths. Around 1980, an interest began in natural health, in preventive health care. Today the average client is maybe 35 years old. It's the younger people who come first, who return later with their parents.

"Basically our main business is almost the same: mud baths and the mineral and steam, blanket wraps and massage. The regular routine hasn't changed through the years, though I have added swimming pools and hot pools, and in very late years a facial salon.

"I'm a believer in natural health," he said. "I've visited spas around California and New Mexico and talked about spas with people from all over the world. I ask what their basic concept is, just what they are doing. I ask about the natural resources, about the water and mud. In Europe there is a greater emphasis on water analysis, and the different spas specialize.

"Mud baths, of course, have been taken worldwide, probably for thousands of years. A lightweight, volcanic deposit close by is the basis of our mud baths. Traditionally mud baths are used for rheumatic, arthritic, and articular aches and pains. But today, many people use mud baths and treatments to relieve stress and tension."

I asked Dr. Wilkinson about wells at the spa. He told me, "Calistoga has a true natural resource for a hot spring town. I pump a combination of water and steam from several wells. One well 200 feet deep has water temperatures of 250° F at the bottom and 212° F at the top. We have tanks where we cool the water, and we can raise temperatures a bit by adding a little boiling water. I have not had problems with the wells, and the water has stayed the same. The wells don't seem to clog up. The pipes and other plumbing wear out faster.

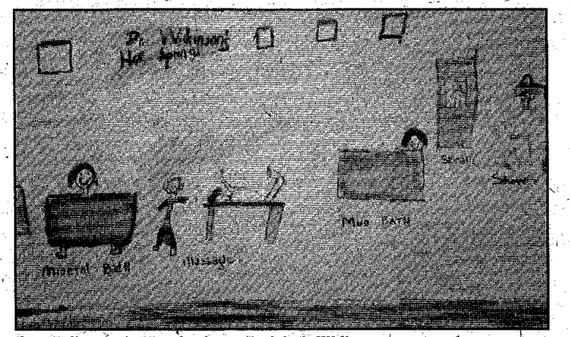
"From 1860 to 1924," he said, "millions of people came to this country, mostly from Europe. In 1900, there were 50 to 75 hot spring resorts in California, which is very rich in geothermal water. These resorts did well until World War II. Then they fell apart. By 1980, almost all were gone. The water was still there but it wasn't used to any degree. Calistoga was one of the few spots that was

by Susan F. Hodgson

kept going on a continuous basis.

"I won't speculate about the future. Today it is expensive to build a brand new place and more expensive to operate it and meet regulations. My son Mark manages the spa today, and this picture on the wall is one he drew of spa guests when he was eight years old.

"I have stuck to the traditional treatments. I made an excellent choice. I would probably do the same thing again. I found my contribution to being alive. We're very satisfied with being able to provide this type of service," he concluded.



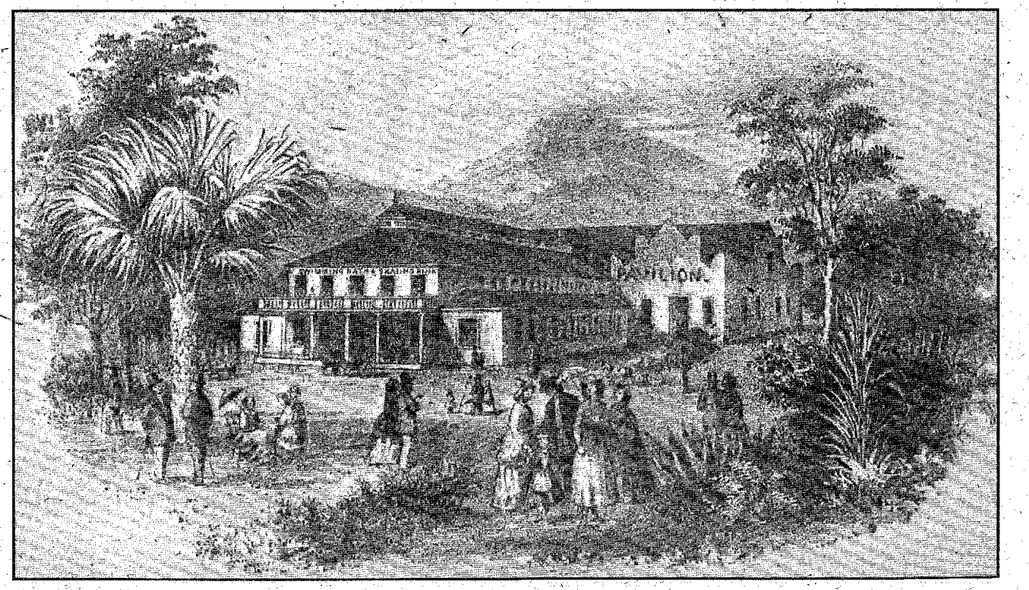
Dr. Wilkinson's Hot Springs. By Mark Wilkinson, age eight.

Calistoga mineral spas were extolled 125 years ago, 75 years before Dr. Wilkinson arrived.....

The Swimming Bath

It is justly claimed that a warm bath is a luxury, if it is only in a tub; but fancy bathing-tanks forty feet long and wide, and five feet deep, with nice boards for a bottom and steps leading down into them from all sides; every appliance for swimming; room to dive and splash about in sparkling waves of delightfully tepid water, whose every drop as it purls around you, bears comfort and healing. It enters on one side, bubbling copiously up, warm from its mysterious subterranean source, medicated by the hand of Dame Nature, and flows out on the other, thus ever renewing itself in crystal purity. Add to this, pyramids of towels fresh from the natural boiling laundry close at hand, and large light and airy buildings, with an atmosphere softened and tempered by the unceasing evaporation, and one may almost picture himself in some scene of magical delights, or Elysium of Oriental story.

From the 1871 *Handbook of Calistoga Springs or, Little Geysers, its Mineral Waters, Climate, Amusements, Baths, Drives, Scenery.*



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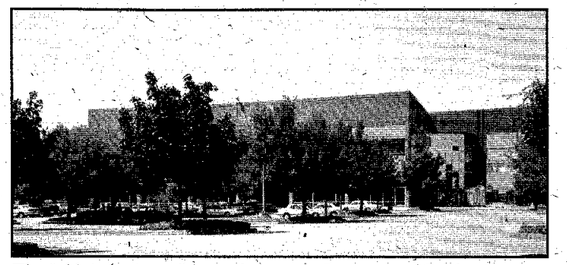
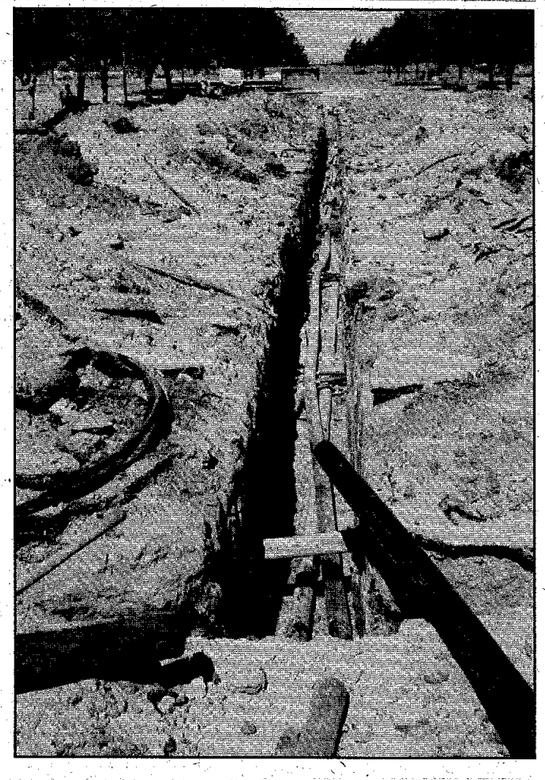


The "old Arco Arena", near downtown Sacramento, California. *Photos by S. Hodgson.*

Each length of unicoil polypipe folds at a U-bend installed at the factory.



Headers in long trenches collect water from loops of polypipe in each borehole. The headers carry water to and from the building.

Two tube ends extending from each borehole are fastened to two wider tubes, called headers. One header carries water from boreholes to the building, and one returns it.

Temperatures -- as water leaves the borehole and enters the header -- range from 57° to 99° Fahrenheit. About 1,560 gallons per minute of water is pumped at an average velocity of 2 to 5 feet per second through the system, which is operated at 32 pounds per square inch of pressure.

Workers push a folded length of polypipe into the borehole.

To balance heat flow in a bore field, all water must spend equal time within it. Thus a reverse-return system was designed, which means that the first water returned to the bore field from the building is the last water taken to the building from the bore field.

There are no underground valves or fittings on the pipelines, and all junctions are heat fused. The system, once tested and judged ready, is expected to last 50 years.

How does it all work? In hot weather, heat in the building is transferred from air to freon gas in a heat exchanger, from freon gas to water in a tube-and-shell

GRC PLANS CLASSES

"Ground-source heat pumps are spreading across the country," said Dave Anderson, executive director of the Geothermal Resources Council (GRC). "Many are installed in the Midwest and the South, and now they've come to the West Coast.

"The GRC is planning classes for utilities on ground-source heat pumps. We'll explain how they can fit into the power mix and details of project economics. The big advantage for utilities is that ground-source heat pumps take users away from the grid at peak-load periods," he concluded.

HOME HEAT-PUMP DEMONSTRATION PROJECT

Geothermal heat pumps are being installed in homes within the Sacramento Municipal Utility District and the Truckee Donner Public Utility District, under a joint project with the California Energy Commission (CEC). Heat-pump performance is being monitored and benefits to customers and utilities assessed. A state-wide commercialization plan may be prepared that could enhance widespread applications of geothermal heat pumps.

The two utilities were chosen for the project because they service areas with very different soil types, climatic conditions, and summer and winter peak-load demands. Information collected from them may be applicable in many other California utility territories. The project steering committee includes manufacturers, installers, building inspectors, utility representatives, environmental regulators, and CEC staff members.

Between 1994 and 1996, about 175 geothermal heat-pump systems will be installed in the two service territories, almost all in residences. About 24 will be monitored under the CEC project.

Project funding is as follows:

Sacramento Municipal Utility District	$819,000
California Energy Commission	181,000
Homeowners	92,000
Truckee-Donner Public Utility District	90,000
US Dept. of Energy	20,000

For further information, contact Roger Peake at the CEC, (916) 654-4609.

coiled mechanism, and from water to earth surrounding the boreholes in the well field. In cold weather, the process is reversed. Warmed to the constant temperature of the earth, water is pumped from boreholes to the building. Here the heat is transferred to freon gas and then to inside air. Building temperatures are controlled by compressing and decompressing the freon.

System operating costs -- mainly pumping costs -- are almost constant year round. Operations are most economical in the coldest and hottest times when the system is needed the most, when the most heat is transferred to or from the building. Most savings come from heating during the colder months. Most midsummer savings come from higher compressor efficiencies and less parasitic energy use by blowers.

"Starting from scratch, this ground-source heat pump system would cost $500,000 to $600,000 more to install than a conventional unit," said Kyle Venolia of KC Engineering (Sacramento), who designed the interior building system for the project. Davis Energy Group Inc. has projected annual energy cost savings of more than $158,000, about 81 percent from reduced energy consumption and 19 percent from reduced demand. Annual electrical use reductions of about 40 percent and peak load reductions of about 37 percent are expected.

The Sacramento Municipal Utility District (SMUD) is studying ground-source heat pump systems. "SMUD has reached no final decision about them, but research is underway," said Bruce Vincent, senior demand side specialist.

Seeing a potential commercial-demonstration project in the Arco retrofit, SMUD contributed $400,000 toward the project. "Although many buildings have water-source heat pump systems with cooling towers and boilers, SMUD wanted to study a ground-loop system in a large commercial building," Mr. Vincent said.

SMUD will monitor the Arco project. "Nobody we know of has monitored geothermal heat-pump performance in detail, certainly never in California with our climate and soil," he concluded.

Each year about 40,000 ground-source heat pump systems are installed in the United States. The Geothermal Heat Pump Consortium hopes to raise this to 400,000 by the year 2000. California is seen as a major market.

The newness of ground-source heat pump projects raises questions of resource protection and regulation. To answer these in a timely way, the California Energy Commission formed the Ground-source Heat Pump Collaborative in July 1994. The 62 members include manufacturers, contractors, designers, utilities, consulting groups, research organizations, federal and state agencies, suppliers, and distributors. Linda Joy DeBoard is collaborative facilitator and Jay Guettler assistant facilitator. They seek a streamlined regulatory framework that encourages development, protects resources, and ensures proper and safe project installation and operation.

Are boreholes in ground-source heat pump projects geothermal wells? "We are looking into this," said Dick Thomas, geothermal officer, whose unit regulates geothermal wells in California for the Department of Conservation, Division of Oil, Gas, and Geothermal Resources. The division is one of nine state agencies that have formed a task force to write legislation and standards for the technology. "We believe the boreholes, which are shallow and uncased, resemble geophysical boreholes or water wells. It may be appropriate to modify California water well standards currently in place," Mr. Thomas concluded.

As Phillip Ewbank, also of Ewbank and Associates, walked around the heat field, he said "It's more efficient to install a ground-source heat system initially than to retrofit. Some day people will own heat fields and sell energy. It's only a matter of time."

GEOTHERMAL RESOURCES DATABASE

A new database of California's low- and moderate-temperature geothermal resources updates a 1980 survey. The database contains 989 entries for thermal springs and wells, 354 more than in 1980.

The project was undertaken by Les Youngs at the California Department of Conservation, Division of Mines and Geology. The database, designed for personal computers, is described in *California Low-temperature Geothermal Resources Update -- 1993.* Work on the project was performed under sponsorship of the US Department of Energy -- Geothermal Division. The Oregon Institute of Technology Geo-Heat Center and the University of Utah Research Institute established subcontracts and coordinated efforts.

Data were collected on low- and moderate-temperature geothermal resources and entered in 35 fields on a LOTUS 1-2-3 spreadsheet. Data groups can be compared by using search and sort parameters on standard database management software. Computer-generated maps of selected data can be made from plot files using latitude and longitude coordinates.

Mr. Youngs identified 56 California communities within eight kilometers of a known geothermal resource of at least 50° C (*see* map). In Southern California, most are in sedimentary basins and desert valleys associated with

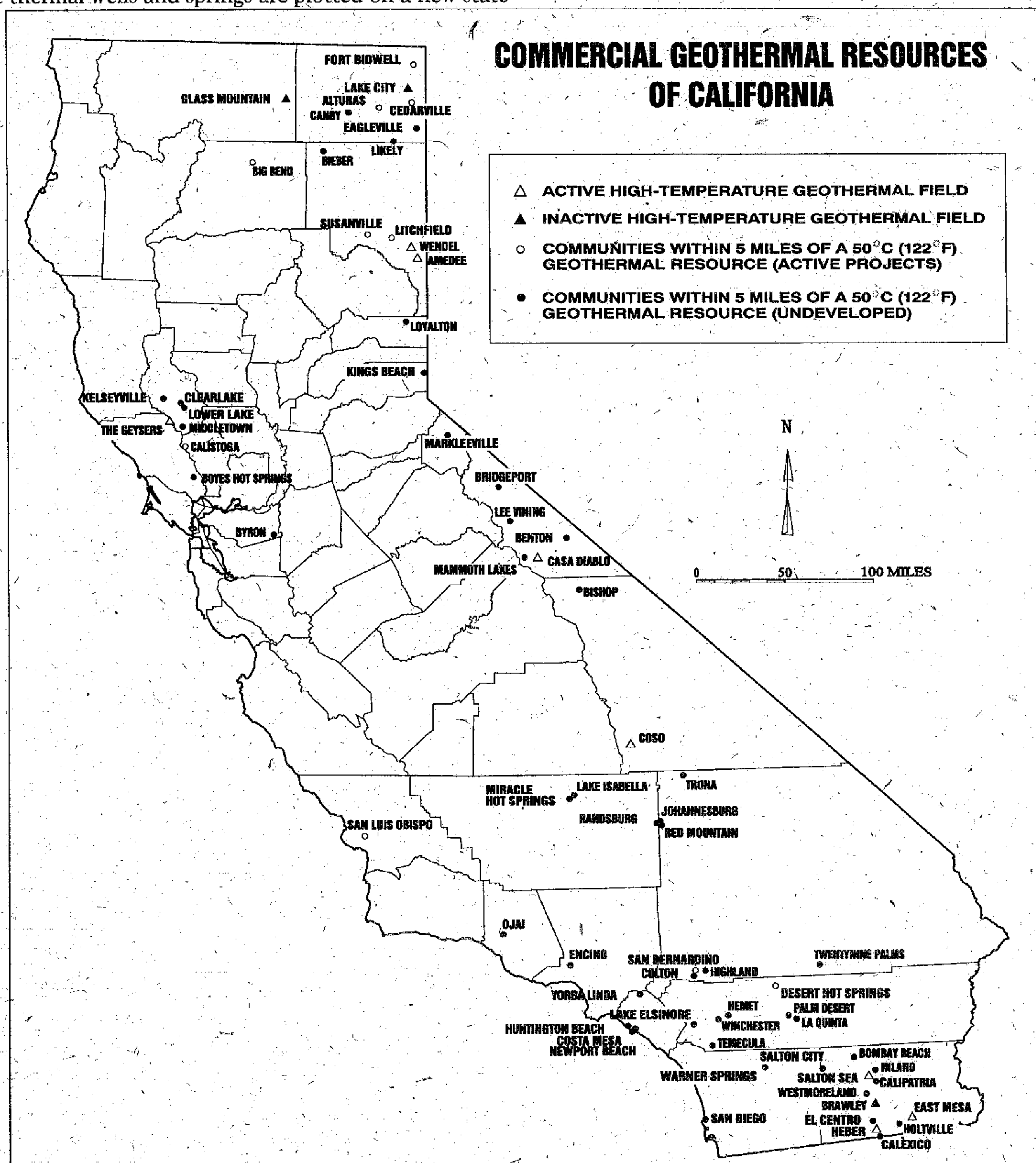
UTAH HAS SIMILAR DATABASE

A similar, low-temperature geothermal database accessible by personal computer is available in Utah. It is titled the *Utah Geological Survey Open-file Report 311*. Data from a previous geothermal assessment are added to new information, more than doubling the numbers of wells and springs. In all, there are 964 records for 492 wells and springs derived from nonproprietary sources through 1992. With few exceptions, data from deep oil and gas wells and thermal-gradient boreholes are not in the database. These will be included later.

major faulting. The resources include hot springs, hot-water reservoirs, steam-and-hot brine fields, and hot water produced from petroleum reservoirs. Most communities have developed the geothermal resources to some extent. However more development is possible, including some high-temperature projects.

The thermal wells and springs are plotted on a new state map at a scale of 1:1,000,000. The map is included in the report.

For further information, contact Les Youngs at the California Department of Conservation, Division of Mines and Geology, 801 K St., MS 08-38, Sacramento, CA 95814-3531. Phone (916) 322-8078.



Map of California's geothermal resources, modified from *California Low-temperature Geothermal Resources Update -- 1993.*

5 Years of Electrical Generation at The Geysers Geothermal Field

by Kenneth F. Stelling

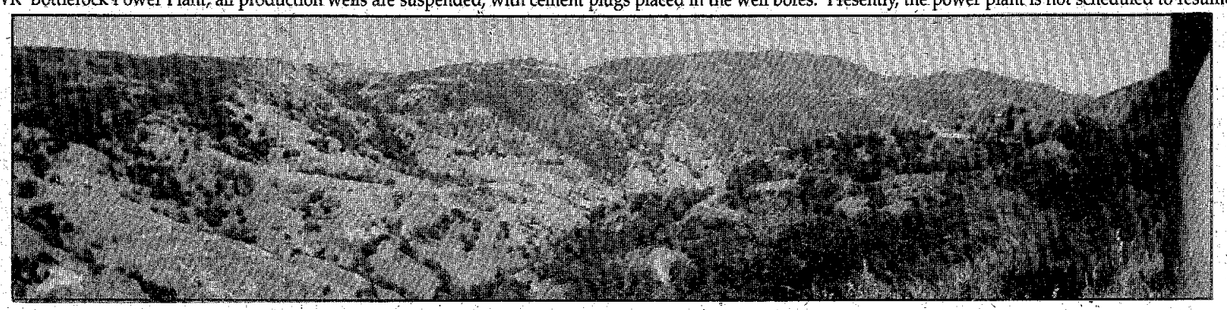
NOTE: Five years of electrical power generation data at The Geysers Geothermal field are included on this table. The data were not collected in exact 12-month intervals because they were gathered for other purposes. Because the months are very close, we have published the information.

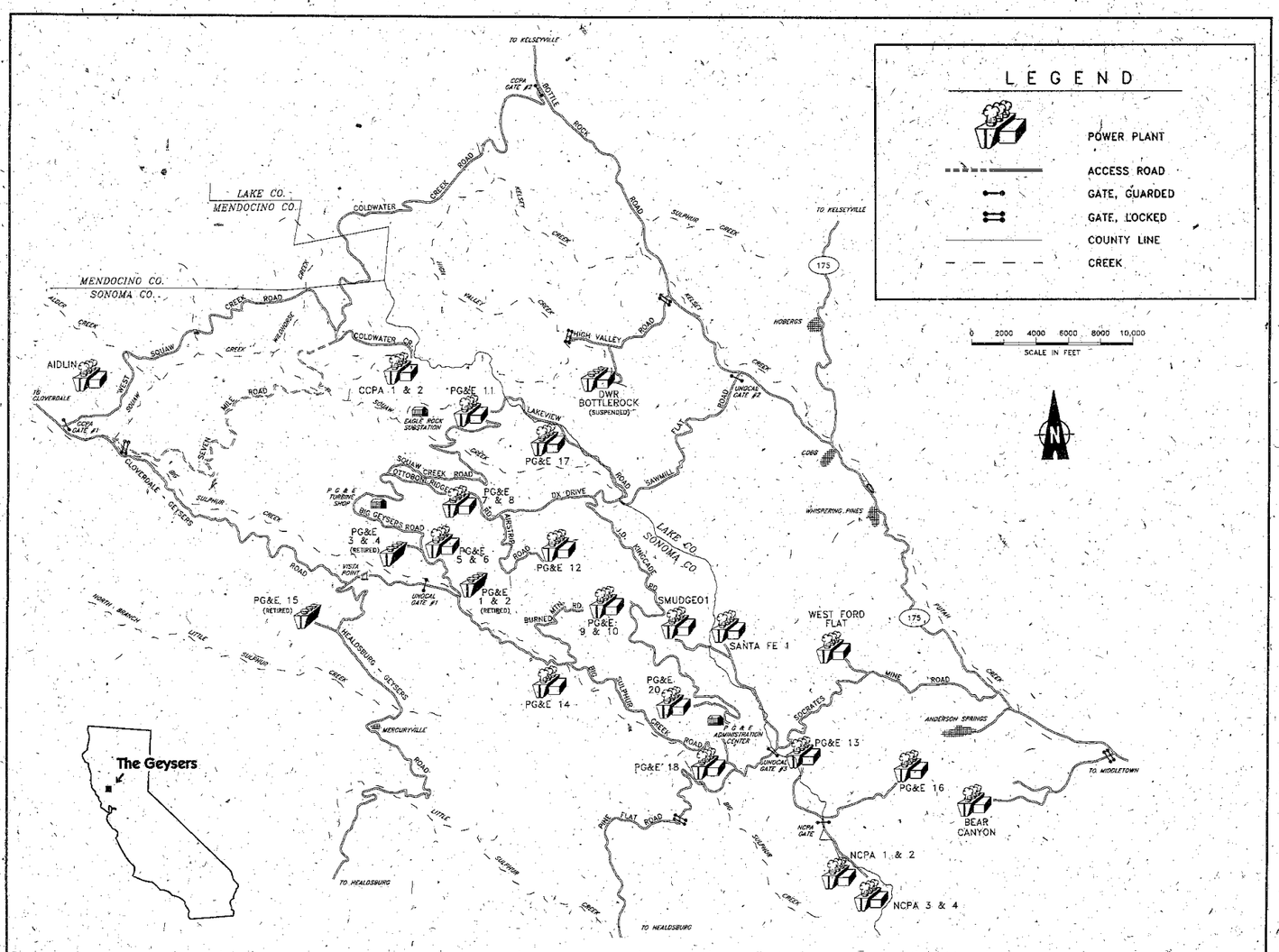
Steam Supplier (as of 8/95)	Power Plant Owner (as of 8/95)	Power Plant Unit	Date On Line	Gross Capacity (Megawatts)	Output in Oct. 1991 (Megawatts)	Output in Aug. 1992 (Megawatts)	Output in Sept. 1993 (Megawatts)	Output in Nov. 1994 (Megawatts)	Output in Aug. 1995 (Megawatts)
UNION OIL CO. OF CA.	PG&E	Unit 1	9/60	12	Standby	Retired	Retired	Retired	Retired
		Unit 2	3/60	14	8	Retired	Retired	Retired	Retired
UNION OIL CO. OF CA.	PG&E	Unit 3	4/67	28	Standby	Retired	Retired	Retired	Retired
		Unit 4	11/68	28	Standby	Retired	Retired	Retired	Retired
UNION OIL CO. OF CA.	PG&E	Unit 5	12/71	55	42	50	44	44	47
		Unit 6	12/71	55	48	49	46	23	49
UNION OIL CO. OF CA.	PG&E	Unit 7	11/72	55	31	Down	38	38	42
		Unit 8	11/72	55	37	49	39	39	46
UNION OIL CO. OF CA.	PG&E	Unit 9	11/73	55	44	38	36	33	Standby
		Unit 10	11/73	55	44	39	37	30	40
UNION OIL CO. OF CA.	PG&E	Unit 11	5/75	110	70	75	70	70	80
UNION OIL CO. OF CA.	PG&E	Unit 12	3/79	110	81	43	45	40	62
GEO OPERATOR CORP.	PG&E	Unit 15	6/79	62	Retired	Retired	Retired	Retired	Retired
CALPINE GEYSER CO.	PG&E	Unit 13	5/80	138	109	99	98	95	89
UNION OIL CO. OF CA.	PG&E	Unit 14	9/80	114	64	61	69	65	70
UNION OIL CO. OF CA.	PG&E	Unit 17	12/82	119	51	49	43	45	62
NORTHERN CA. POWER AGENCY	NCPA	NCPA 1	1/83	122	75	75	71	75	75
UNION OIL CO. OF CA.	PG&E	Unit 18	2/83	119	82	71	73	70	94
CALPINE GEYSER CO.	SMUD	SMUDGEO 1	10/83	78	78	78	62	65	70
SANTA FE GEOTHERMAL	SANTA FE GEOTH.	Santa Fe 1	4/84	85	80	80	80	80	80

Steam Supplier (as of 8/95)	Power Plant Owner (as of 8/95)	Power Plant Unit	Date On Line	Gross Capacity (Megawatts)	Output in Oct. 1991 (Megawatts)	Output in Aug. 1992 (Megawatts)	Output in Sept. 1993 (Megawatts)	Output in Nov. 1994 (Megawatts)	Output in Aug. 1995 (Megawatts)
CA.DEPT. OF WATER RESOURCES	DWR	Bottlerock*	3/85	55	Suspended	Suspended	Suspended	Suspended	Suspended
UNION OIL CO. OF CA.	PG&E	Unit 20	10/85	119	84	76	63	65	88
CALPINE GEYSER CO.	PG&E	Unit 16	10/85	119	98	89	80	85	89
NORTHERN CA. POWER AGENCY	NCPA	NCPA 2	11/85	124	75	75	71	75	75
COLDWATER CREEK OPER. CORP.	CCPA	Unit 1	5/88	65	55	55	56	52	55
CALPINE GEYSER CO.	CALPINE GEYSER CO.	Bear Canyon Creek	9/88	22	22	22	22	22	22
COLDWATER CREEK OPER. CORP.	CCPA	Unit 2	10/88	65	Standby	Standby	Standby	Standby	Standby
CALPINE GEYSER CO.	CALPINE GEYSER CO.	West Ford Flat	12/88	30	30	30	30	30	30
GEOTHERMAL ENERGY PARTNERS	GEO. ENERGY PARTNERS	Aidlin 1	6/89	30	18	18	20	18	20
	TOTALS (Data for federal leases included)			**2,098**	**1,326**	**1,221**	**1,193**	**1,159**	**1,285**

CCPA = Central California Power Agency
PG&E = Pacific Gas & Electric Company
DWR = Calif. Dept. of Water Resources
SMUD = Sacramento Municipal Utilities District
NCPA = Northern California Power Agency

*At the DWR Bottlerock Power Plant, all production wells are suspended, with cement plugs placed in the well bores. Presently, the power plant is not scheduled to resume operation.





The Geysers GGA Tour Map, reprinted courtesy of the Geysers-Geothermal Association. For a copy of the map in an attractive brochure, write the GGA, at PO Box 6501, Santa Rosa, CA 95406.

RAIN UNDERSCORES NEED FOR INJECTION

Since 1987, steam production totals at The Geysers Geothermal field have fallen and water injection totals have remained quite stable, except for the unusually dry winter months of 1994 when injection fell by a record amount (*see* table). The heavy rainfall in the first half of 1995 altered the long-term production and injection patterns and underscored the need to increase injection in the field.

From January to June 1995, steam production at The Geysers was reduced by 37 percent from the amount produced during the same period in 1994 -- because the rain increased availability of hydroelectric power. (Hydro is cheaper to produce than geothermal power, and Pacific Gas & Electric Company curtailed electrical output from several power plants at The Geysers in favor of its hydro facilities for the first few months of the year.) At the same time, water injection in the field rose by 25 percent because more rainwater was available for injection.

Consequently, both reservoir pressure and available steam reserves grew, and most power plants that returned on line in the second half of the year produced more megawatts with less steam. This confirmed findings from several injection studies at The Geysers: injection increases reservoir pressure and available steam.

Dedicating the Southeast Geysers Effluent Pipeline Project. *Photo by W. Guerard.*

Year	Average number of producing wells	Gross steam produced kilograms (thousands)	Average number of active injection wells	Water injected kilograms (thousands)	Percent injected
The Geysers Geothermal field:					
1960	3	306,180	0	0	0
1961	3	857,431	0	0	0
1962	3	913,804	0	0	0
1963	7	1,530,900	0	0	0
1964	7	1,838,314	0	0	0
1965	7	1,727,581	0	0	0
1966	7	1,709,872	0	0	0
1967	13	2,862,470	0	0	0
1968	13	3,515,849	0	0	0
1969	26	6,812,616	1	410,788	6.0
1970	27	6,457,453	1	847,490	13.1
1971	30	7,813,799	2	1,224,598	15.7
1972	45	15,777,373	3	2,904,923	18.4
1973	60	21,464,314	4	4,064,929	18.9
1974	72	26,329,259	5	5,364,196	20.4
1975	84	30,514,607	5	7,473,397	24.5
1976	92	31,995,187	6	7,717,116	24.1
1977	95	32,527,275	6	7,496,076	23.0
1978	95	27,622,596	6	6,522,400	23.6
1979	123	36,138,118	9	8,723,633	24.1
1980	150	46,966,791	10	10,866,000	23.1
1981	165	52,864,353	12	13,595,090	25.7
1982	174	48,174,347	11	13,549,916	28.1
1983	225	65,893,108	15	19,081,541	29.0
1984	253	80,067,099	17	23,312,221	29.1
1985	309	95,232,214	22	26,517,067	27.8
1986	354	106,561,865	23	30,771,676	28.9
1987	390	111,821,897	23	31,495,280	28.2
1988	429	108,523,641	23	28,325,113	26.1
1989	439	100,205,378	23	28,348,657	28.3
1990	442	95,646,626	25	27,318,499	28.6
1991	436	89,660,288	26	25,747,804	28.7
1992	444	88,513,172	29	27,344,280	30.9
1993	+450	84,379,560	29	30,183,128	35.8
1994	447	78,442,435	28	24,581,237	31.3

* Data for federal leases included.
\+ Contains corrected data.

Reprinted from the *Eightieth Annual Report of the State Oil and Gas Supervisor*, California Department of Conservation, Division of Oil, Gas, and Geothermal Resources.

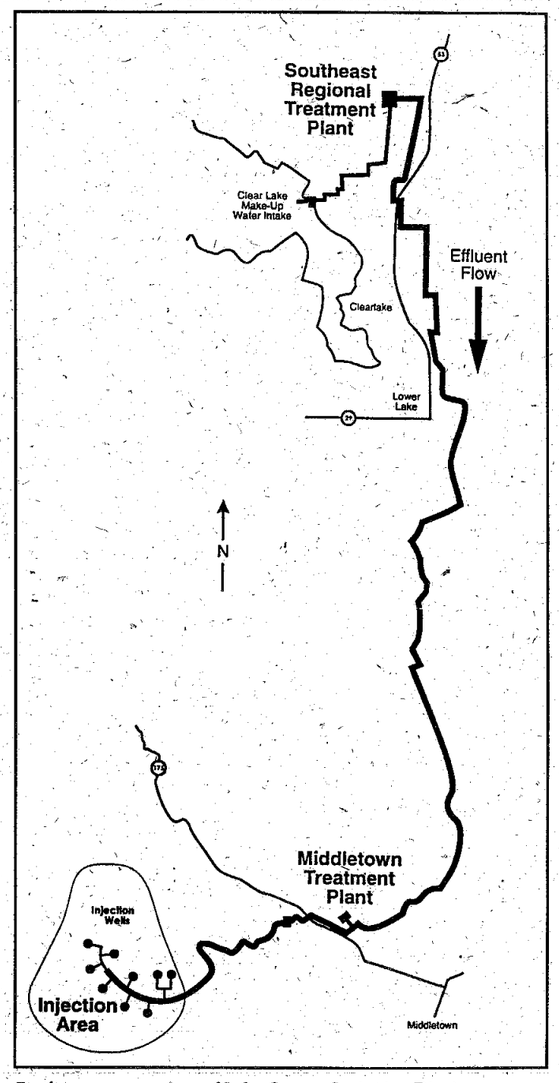
by Kenneth F. Stelling
District Engineer

Construction Budget (in $ millions)	
Treatment plant improvements	$ 8.0
Pipeline	18.2
Pump stations	5.8
Support facilities	5.1
Environmental mitigation	0.5
Right-of-way	0.8
Design and construction management	3.7
TOTAL	$42.1

The Pipeline Project

Most water injected at The Geysers is power-plant condensate. The remainder is plant-site runoff and water extracted from Big Sulphur Creek, which runs through the field. However, a new project is underway.

In early 1997, injection water will come to the field from the Southeast Geysers Effluent Pipeline Project, which was dedicated on October 6, 1995. The buried pipeline will be 29 miles long and 20 inches in diameter. About 7.8 million gallons a day of treated wastewater effluent and lake make-up water will flow from Lake County Sanitation District treatment plants at Clearlake and Middletown to leases at The Geysers operated by Unocal Corporation, Calpine Corporation, and the Northern California Power Agency (NCPA). Secondary pipelines constructed and operated by the companies will carry effluent to geothermal injection wells. Produced steam will go to power plants operated by NCPA and Pacific Gas & Electric Company.



Pipeline route, courtesy of Lake County Sanitation District.

Construction costs are estimated at about $42 million for the effluent pipeline and associated improvements to the Southeast Regional Wastewater Treatment Plant. Monies for the public-private financing plan include county wastewater funds (20%); federal and state financial assistance (energy resource conservation funds, 20% and economic development funds, 20%); and funding from operators at The Geysers (40%). Operators at The Geysers will also spend another $7 million on secondary distribution and injection facilities in the field.

The Lake County Sanitation District will own and operate the main effluent pipeline up to a delivery point near Highway 175. Unocal, Calpine, and NCPA will own and operate the final stretch of pipeline to The Geysers Geothermal field, including the lift-pump

stations. NCPA will use the effluent-based steam in its own power plants. PG&E will purchase steam from Unocal and Calpine for its power plants.

Participants in the public-private partnership are the Northern California Power Agency; Calpine Corporation; Unocal Corporation; Pacific Gas & Electric Company; Lake County Sanitation District; California Energy Commission; US Departments of Energy, the Interior, and Commerce; the US Environmental Protection Agency; and the State Water Resources Control Board.

For more information, call Mark Dellinger, Lake County Special Districts, Lakeport, California, at (707) 263-2273.

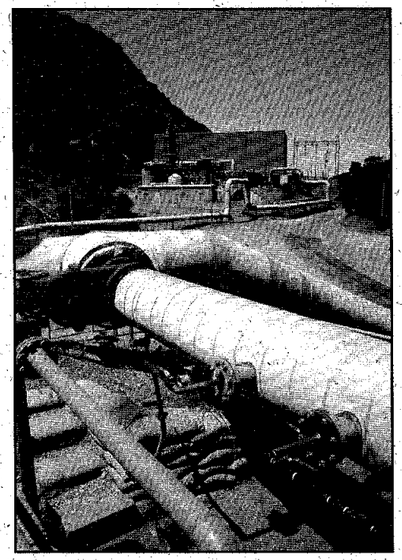
WELLS DEGRADING AT UNIT 15

Unit 15, a 62-megawatt power plant owned by Pacific Gas & Electric Company, went on line at The Geysers Geothermal field in June 1979. Steam to operate the power plant was produced from wells operated by Geo Operator Corporation (GEO), which has since filed for bankruptcy.

Unit 15 and the wells have not been operated since 1989. Recent corrosion measurements by Department of Conservation engineers show some wells degrading and some leaking hydrogen sulfide.

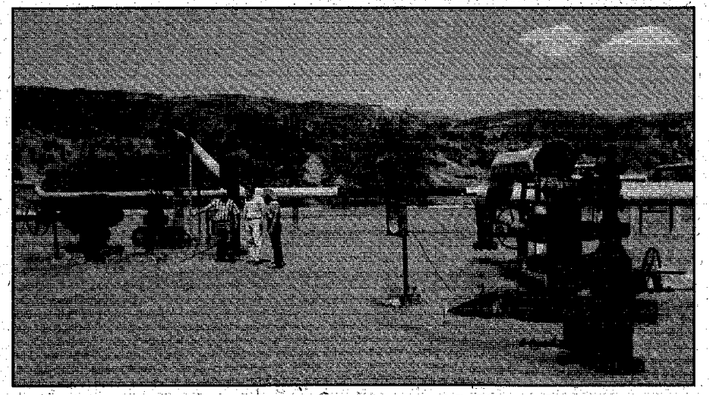
On June 10, 1994, the State Oil and Gas Supervisor issued a Formal Order to plug and abandon the 23 production and injection wells (including wells drilled as such but not operated). However, complex, unresolved legal issues leave no clear title to the wells.

The cost to plug and abandon the wells is estimated between $2 and $3 million, which will be partially offset by GEO's well indemnity bond of $100,000.



View of Unit 15, The Geysers Geothermal field.

Well near Unit 15, The Geysers Geothermal field. *Photos by W. Guerard.*



Ken Stelling, division engineer, shows a Unit 15 well to B.B. Blevins, Chief Deputy Director, and Pat Meehan, Deputy Director, for the Department of Conservation.

NCPA CONSIDERS BOND REFINANCING

Northern California Power Agency (NCPA) may refinance and restructure a portion of its outstanding Geothermal Project Number 3 revenue bonds.

"NCPA hopes to realize significant annual debt service savings as a result of such transactions. This is an important step in the process of enhancing NCPA's competitive position as a wholesale supplier of electricity," said Michael McDonald, general manager for NCPA.

NCPA, formed in 1968, is a nonprofit California joint exercise of powers agency. Members are the Cities of Alameda, Biggs, Gridley, Healdsburg, Lodi, Lompoc, Palo Alto, Redding, Roseville, Santa Clara, and Ukiah, and the Port of Oakland, the Plumas-Sierra Rural Electric Cooperative, the Truckee-Donner Public Utility District, and the Turlock Irrigation District.

SUBSIDENCE AND UPLIFT AT HEBER GEOTHERMAL FIELD, CALIFORNIA

Heber Geothermal field is in the Imperial Valley near the City of Heber, California, about 3 1/2 miles north of the Mexican border (Fig. 1). The field is at the southern end of a network of irrigated agricultural fields extending across the valley floor.

The Heber geothermal system is circular, producing water of moderate temperature (360° F) and low-salinity (13,000-14,000 ppm TDS). In cross section, the geothermal system resembles a lopsided mushroom. The system has three major permeability units: capping clays from 500 to 1,800 feet; a high-matrix-permeability, deltaic-sandstone outflow reservoir from 1,800 to 5,500 feet; and feeder faults and fractures in indurated sediments below 5,500 feet (Fig. 2). The deltaic sandstones were deposited by the ancestral Colorado River. The structure of the hydrothermal system is described by James, Hoang, and Epperson (1987) (Figs. 3,4,& 5).

In the early 1960s, Chevron U.S.A. Inc. discovered a positive Bouguer gravity feature south of the City of Heber while exploring for oil and gas in the Imperial Valley. In 1964, Chevron drilled a 500-foot temperature gradient well on the anomaly. Although a significant geothermal resource was discovered, it was not developed for many years.

In 1984 a company subsidiary, Chevron Geothermal Company, began developing the field. Anticipating

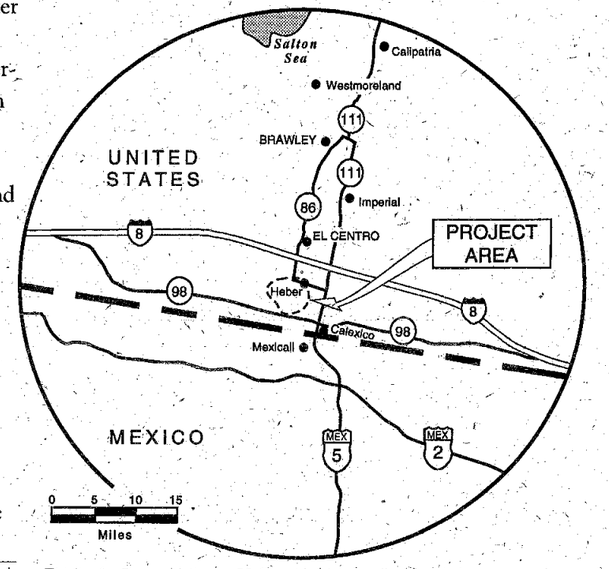


Figure 1. Location map, Heber Geothermal field. *Courtesy of San Diego Gas and Electric Company, 1979.*

By Timothy S. Boardman
District Engineer

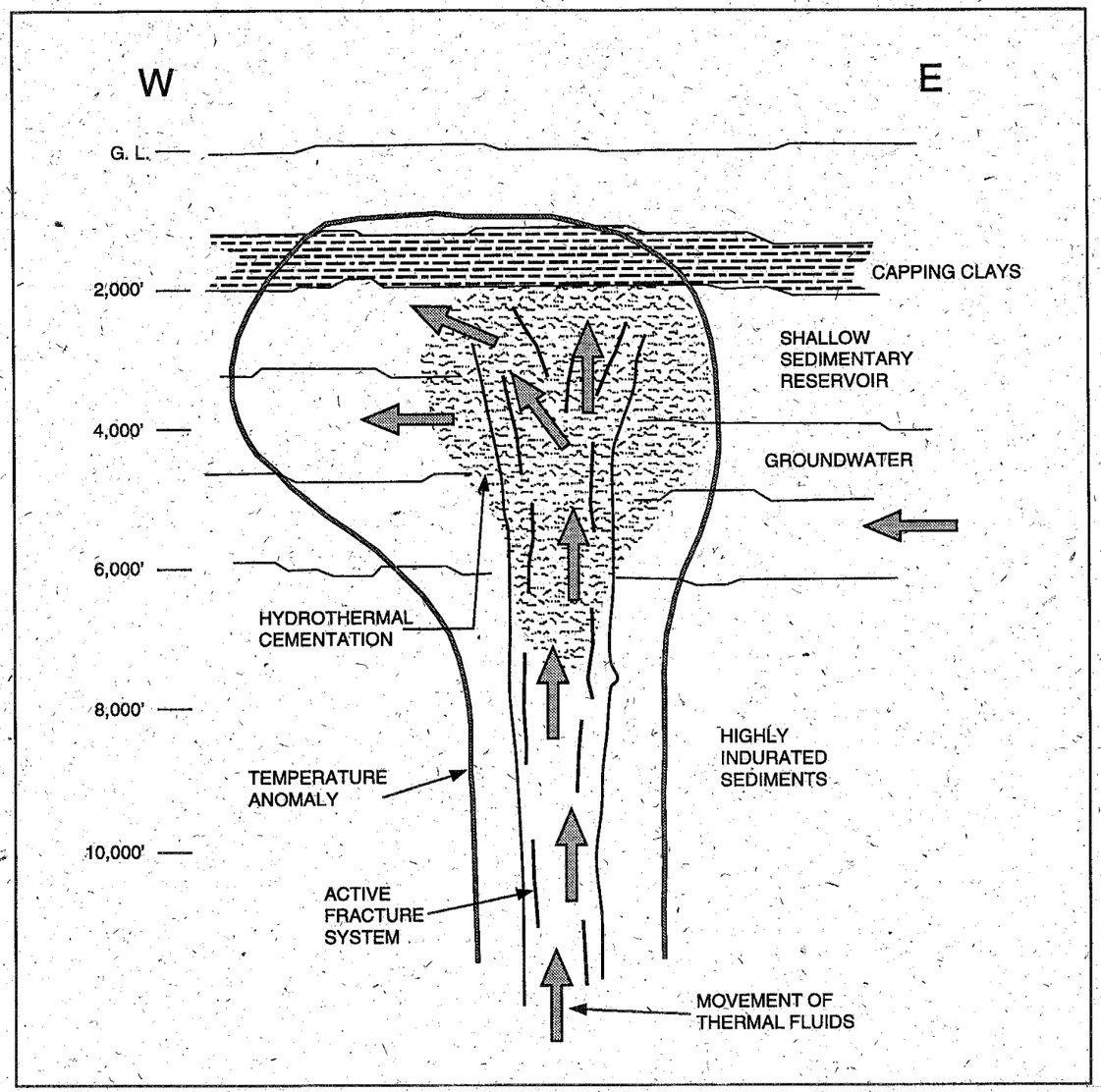


Figure 2. Heber geothermal anomaly, a fault conduit-barrier model. *Courtesy of E. D. James et al., November 1987.*

subsidence, the company established a subsidence monitoring network.

Production wells were drilled directionally between June 1984 and December 1986 from drilling islands at the power-plant sites. Injection well islands were sited away from the power plants.

By 1987, the geothermal field spanned more than 4,000 acres of mostly private land and two power plants were operating: a 52-megawatt dual-flash plant operated by Heber Geothermal Company (HGC) and a 67-megawatt binary plant operated by San Diego Gas and Electric (SDG&E). Both power-plant operators purchased geothermal fluids from Chevron.

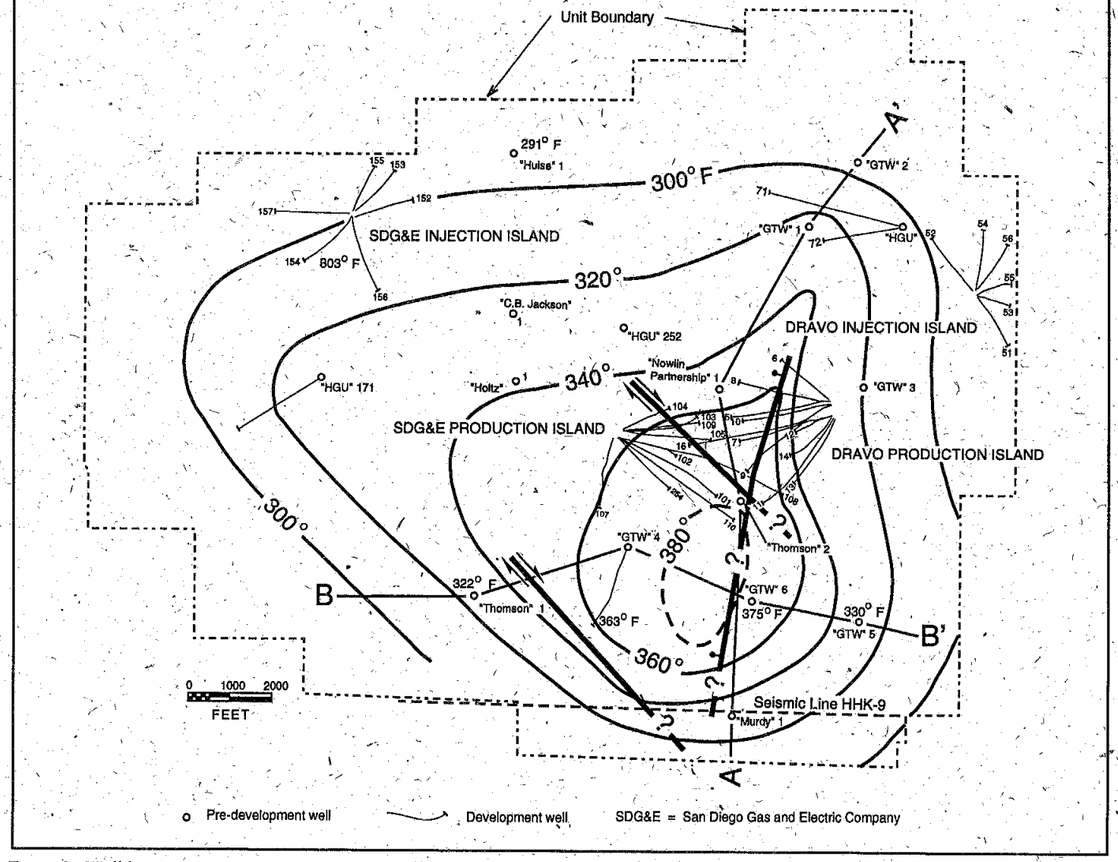


Figure 3. Well locations, structure, and temperature contours at 6,000 feet, Heber Geothermal field. *Courtesy of James et al., 1987.*

From 1985 to 1987, the HGC dual-flash power plant and the SDG&E binary power plant were operated simultaneously in the field and severe well interference occurred.

The SDG&E binary power plant was not economically feasible on a commercial scale. In the spring of 1987, fluid production peaked at 3.5 billion kilograms per month, but the reservoir could not supply the volume of fluid needed to operate both power plants fully. In periods of high production, fluids in some pumped wells dropped below pump settings.

With poor operating results, the SDG&E binary power plant was shut down in July 1987. [The entire SDG&E binary project at Heber is described in detail by Nelson (1987).] Currently, the SDG&E binary plant owner does not have rights to the geothermal resource and the plant awaits decommissioning or salvage.

Recent Developments

In 1991, Chevron Geothermal Company sold Heber Geothermal field to Heber Field Company, a partnership of Ogden and Centennial -- also partners in Heber Geothermal Company, lessor of the HGC 52-megawatt dual-flash power plant. Today, Ogden Geothermal Operations Inc. operates the field for Heber Field Company.

In 1993, Second Imperial Geothermal Company (SIGC)

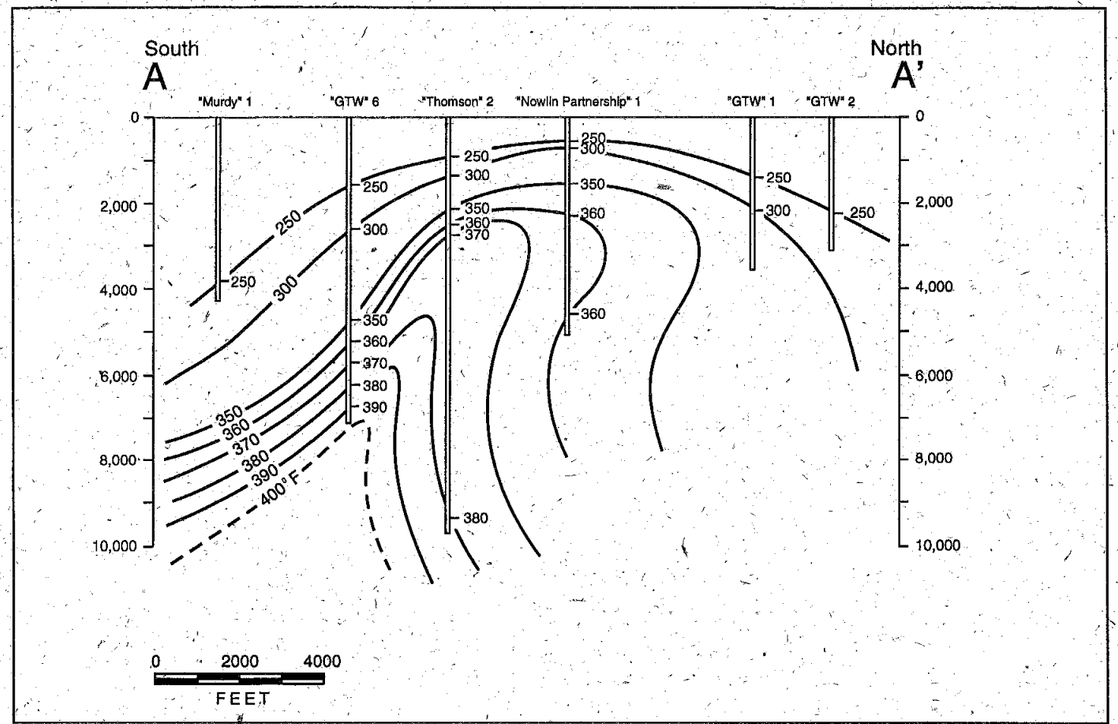


Figure 4. Temperature cross section A-A', *courtesy of James et al., 1987.* "The contours illustrate the deflection of the rising plume from south to north by groundwater movement. It is also clear from this section that the source of the thermal waters is south of current development near well "GTW" 6. The shallow matrix reservoir currently under production is at the northern end of the plume. The collapse of the isotherms at the top of the plume is the result of the capping clays sealing in the thermal waters. The strong control of the fracture permeability in the indurated sediments below 5,500' is seen in temperature cross section B-B'. The plume is quite narrow east to west and most likely controlled by a narrow structure of high permeability.

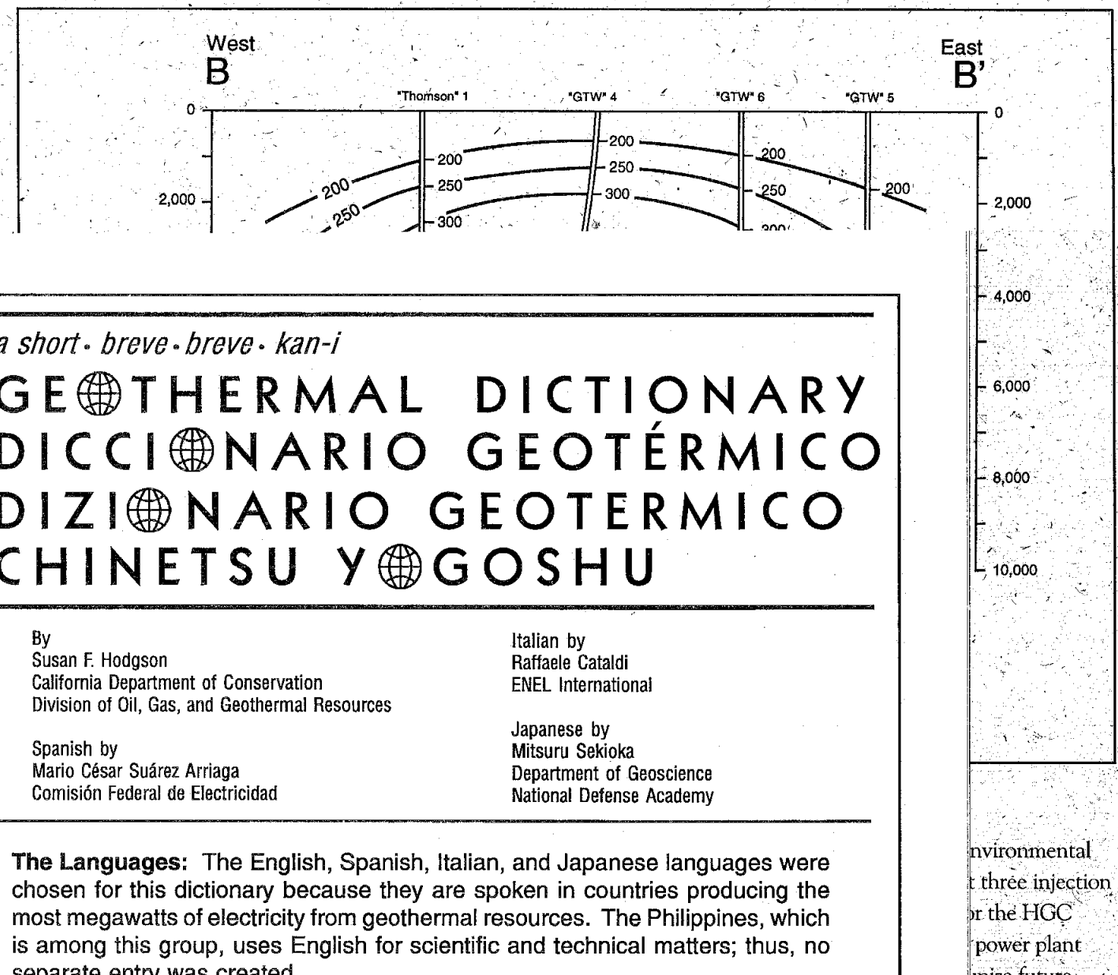
"The range of Kh (permeability-thickness) values calculated from well test data is indicative of the different sources of permeability in the Heber reservoir. Values in Zone I (2,000' to 4,000') range from 40-80,000 md-ft in the strike slip fault to over 200,000 md-ft in the normal fault. The values in Zone II (4,000' to 6,000') are generally lower, reflecting the increasing induration of the sedimentary section.

"The sources of permeability are also clearly seen in spinner surveys taken while the wells are producing. The production from the matrix permeability of the sedimentary section is evenly distributed over the entire open interval. Production from fractures comes in very short intervals. The interplay between matrix and fracture permeability explains the wide range of Kh's seen in the well testing."

developed a new 33-megawatt binary power plant owned by the United States Trust Company, the project lender. The new power plant, north of the defunct SDG&E binary power plant, is operated by Ogden Geothermal Operations.

Heber Geothermal field has 22 active production wells, 23 active injection wells, and 13 observation wells. Nine idle production wells were once part of the defunct SDG&E binary project. From July 1987 to June 1993, between the closure of the SDG&E binary power plant and the start of the SIGC binary power plant, 10 wells were used for production and 9 for injection by the HGC dual-flash power plant (Fig. 6).

Production wells for the SIGC plant penetrate the reservoir in an area north and west of the original production area. The nearly vertical production wells were completed at depths between 2,500 feet and 6,000 feet, about 1,200 feet apart. By drilling new production wells over a large area, the operator hopes to avoid well-interference problems noted in earlier projects. The



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GEOTHERMAL DICTIONARY
DICCIONARIO GEOTÉRMICO
DIZIONARIO GEOTERMICO
CHINETSU YOGOSHU

By
Susan F. Hodgson
California Department of Conservation
Division of Oil, Gas, and Geothermal Resources

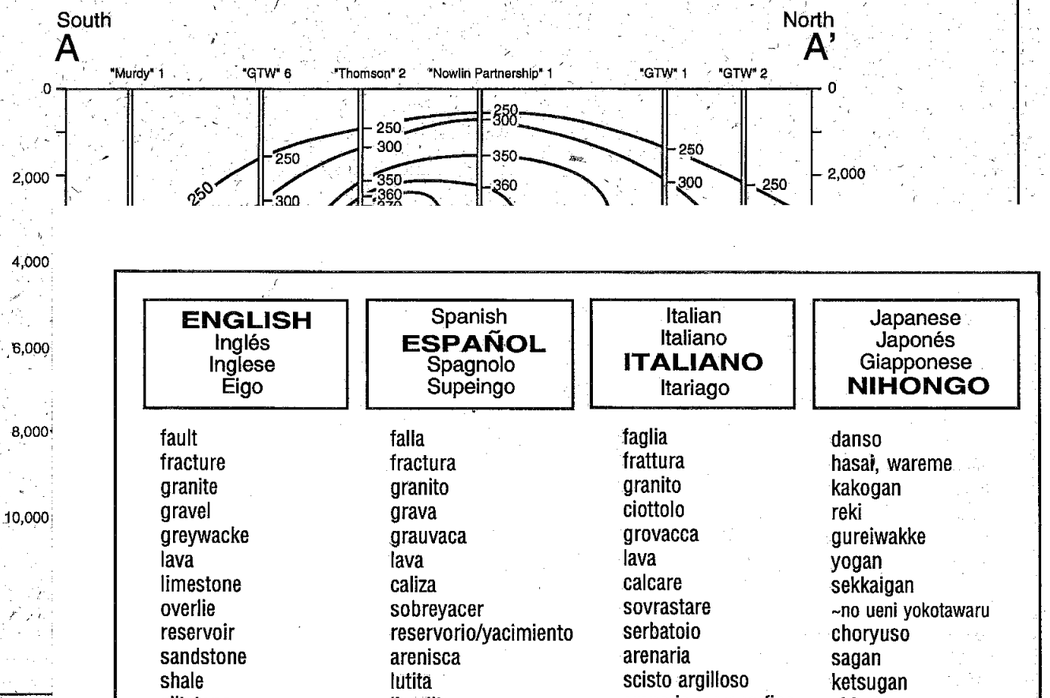
Spanish by
Mario César Suárez Arriaga
Comisión Federal de Electricidad

Italian by
Raffaele Cataldi
ENEL International

Japanese by
Mitsuru Sekioka
Department of Geoscience
National Defense Academy

The Languages: The English, Spanish, Italian, and Japanese languages were chosen for this dictionary because they are spoken in countries producing the most megawatts of electricity from geothermal resources. The Philippines, which is among this group, uses English for scientific and technical matters; thus, no separate entry was created.

ENGLISH Inglés Inglese Eigo	Spanish **ESPAÑOL** Spagnolo Supeingo	Italian Italiano **ITALIANO** Itariago	Japanese Japonés Giapponese **NIHONGO**
GEOLOGY	GEOLOGÍA	GEOLOGIA	CHISHITSUGAKU
alluvium	aluvión	alluvioni	chusekiso
andesite	andesita	andesite	anzangan
basalt	basalto	basalto	gembugan
basement	basamento	basamento	kiban
bed	lecho/capa	letto	chiso
cap rock	capa sello	coltre di ricoprimento	bogan
clay	arcilla	argilla	nendo
consolidated	consolidado	consolidato	sekika
deep	profundo	profondo	fukai
deposit	depósito	deposito	taisekibutu
displace	desplazar	dislocare	ido



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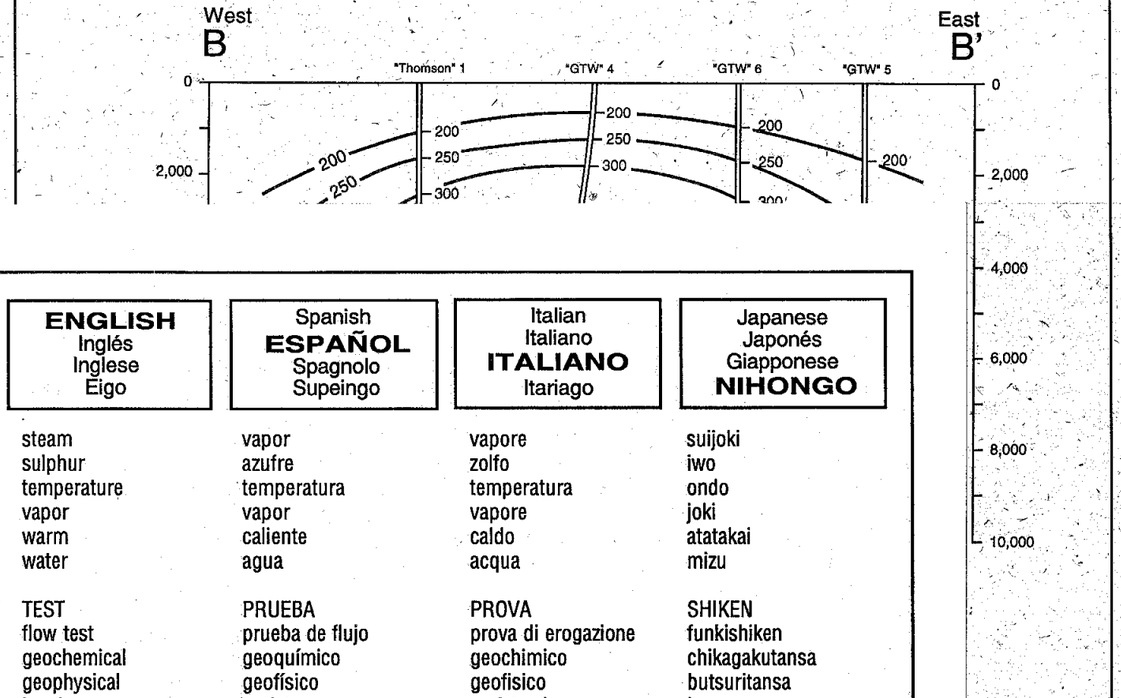
ENGLISH Inglés Inglese Eigo	Spanish ESPAÑOL Spagnolo Supeingo	Italian Italiano ITALIANO Itariago	Japanese Japonés Giapponese NIHONGO
fault	falla	faglia	danso
fracture	fractura	frattura	hasaı, wareme
granite	granito	granito	kakogan
gravel	grava	ciottolo	reki
greywacke	grauvaca	grovacca	gureiwakke
lava	lava	lava	yogan
limestone	caliza	calcare	sekkaigan
overlie	sobreyacer	sovrastare	~no ueni yokotawaru
reservoir	reservorio/yacimiento	serbatoio	choryuso
sandstone	arenisca	arenaria	sagan
shale	lutita	scisto argilloso	ketsugan
siltstone	limolita	arenaria a grana fine	shirutogan
slate	pizarra	ardesia	nembangan
strata	estratos	strato	chiso
tuff	toba	tufo	gyokaigan
underlie	subyacer	sottostare	~no shitani yokotawaru
volcano	volcán	vulcano	kazan
GEOTHERMAL	GEOTERMIA	GEOTERMICO	CHINETSU
aquifer	acuífero	acquifero	taisuiso
boiling	ebullición	bollente	futto
brine	salmuera	salamoia	ensui
cold	frío	freddo	tsumetai
dry steam	vapor seco	vapore secco	kawaki joki
fluid	fluido	fluido	ryutai
fumarole	fumarola	fumarola	funkiko
geyser	géiser	geyser	kanketsusen
groundwater	agua subterránea	acqua di falda	chikasui
hot	caliente	molto caldo	atsui
hot dry rock	roca seca caliente	rocce calde secche	kanso koon gantai
hot spring	manantial termal	sorgente calda	onsen
hydrogen sulfide	sulfuro de hidrógeno	idrogeno solforato	ryukasuiso
hydrothermal	hidrotermal	idrotermale	nessuikei
liquid	líquido	liquido	ekitai
mineral	mineral	minerale	kobutu
mixture	mezcla	miscela	kongobutu
noncondensable gas	gas incondensable	gas incondensabile	higyoshukuseigasu
parts per million	partes por millón	parti per milione	pipiemu
salinity	salinidad	salinità	enbunryo
silica	sílice	silice	nisankakeiso



ENGLISH Inglés Inglese Eigo	Spanish ESPAÑOL Spagnolo Supeingo	Italian Italiano ITALIANO Itariago	Japanese Japonés Giapponese NIHONGO
steam	vapor	vapore	suijoki
sulphur	azufre	zolfo	iwo
temperature	temperatura	temperatura	ondo
vapor	vapor	vapore	joki
warm	caliente	caldo	atatakai
water	agua	acqua	mizu
TEST	PRUEBA	PROVA	SHIKEN
flow test	prueba de flujo	prova di erogazione	funkishiken
geochemical	geoquímico	geochimico	chikagakutansa
geophysical	geofísico	geofisico	butsuritansa
logging	registro	registrazione	kenso
pressure test	prueba de presión	prova di pressione	atsuryoku sokutei
WELL	POZO	POZZO	KOSEI
exploratory	exploratorio	esplorazione	tansa
injection	inyección	iniezione	kangen/chunyu
observation	observación	osservazione	kansoku
production	producción	produzione	seisan
slim hole	agujero reducido	piccolo diametro	shokokeisei
temperature-gradient	gradiente de temperatura	gradiente di temperatura	ondokobai
DRILLING	PERFORACIÓN	PERFORAZIONE	KUSSAKU
blowout	reventón/descontrol	erogazione	funshutsu
blowout preventer	preventor de rompimiento/descontrol	valvola di prevenzione	funshutsusuru
to blow out	reventar/descontrolar (se)	erogare	buroautosuru
casing	tubería de revestimiento	tubazione di rivestimento	keshingu
cement	cemento	cemento	semento
completion	terminación	completamento	shiage
drilling bit	barrena de perforación	scalpello	bitto
drilling rig	equipo de perforación	impianto di perforazione	kussakusochi
to drill	perforar	perforare	kussakusuru
liner	"liner"	"liner"	raina
mud	lodo	fango	deisui
perforation	perforación	perforazione	kantsu
pipe	tubería	tubazione	paipu
separator	separador	separatore	bunriki
valve	válvula	valvola	barubu
wellhead	cabezal del pozo	testa pozzo	koko

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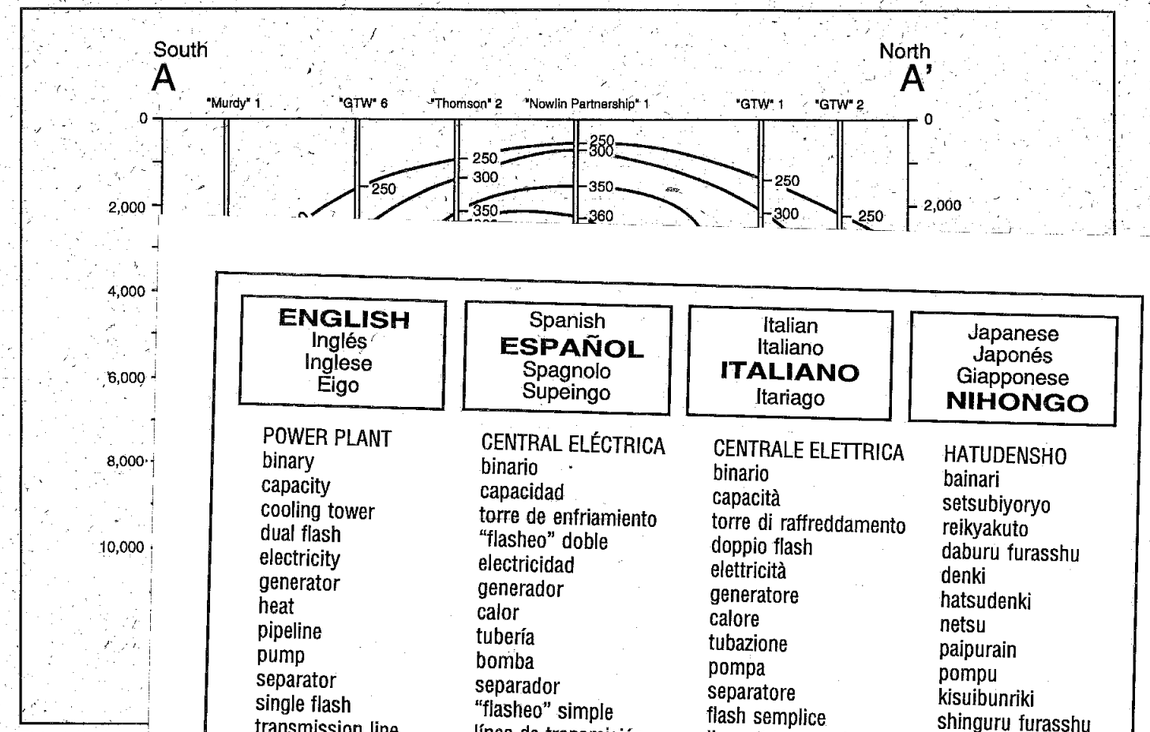

ENGLISH Inglés Inglese Eigo	Spanish ESPAÑOL Spagnolo Supeingo	Italian Italiano ITALIANO Itariago	Japanese Japonés Giapponese NIHONGO
POWER PLANT	CENTRAL ELÉCTRICA	CENTRALE ELETTRICA	HATUDENSHO
binary	binario	binario	bainari
capacity	capacidad	capacità	setsubiyoryo
cooling tower	torre de enfriamiento	torre di raffreddamento	reikyakuto
dual flash	"flasheo" doble	doppio flash	daburu furasshu
electricity	electricidad	elettricità	denki
generator	generador	generatore	hatsudenki
heat	calor	calore	netsu
pipeline	tubería	tubazione	paipurain
pump	bomba	pompa	pompu
separator	separador	separatore	kisuibunriki
single flash	"flasheo" simple	flash semplice	shinguru furasshu
transmission line	línea de transmisión	linea di trasmissione	yusokan
turbine	turbina	turbina	tabin
ENVIRONMENT	MEDIO AMBIENTE	AMBIENTE	KANKYO
air	aire	aria	kuki
animal	animal	animale	dobutsu
discharge	descarga	discarica	haishutsu
emission	emisión	emissione	shashutsu
field	campo	campo	yagai
land	terreno	terreno	riku
plant	planta	impianto	shokubutsu
road	camino	strada	doro
solid waste	desecho sólido	residuo solido	kotaihaikibutsu
subsidence	subsidencia	subsidenza	chinka
waste water	agua de desecho	acqua di scarico	haisui
DIRECT USE	USO DIRECTO	USO DIRETTO	CHOKUSETURIYO
aquiculture	acuacultura	acquacultura	yoshoku
to dehydrate	deshidratar	disidratare	dassuisuru
dry	seco	secco	kanso
to dry	secar	essiccare	kansosaseru
fish farm	criadero de peces	itticultura	yoshokugyogyo
greenhouse	invernadero	serra	onshitsu
heat exchanger	intercambiador de calor	scambiatore di calore	netsukokanki
heat pump	bomba de calor	pompa di calore	hitopompu
lumber	madera	legname	zaimoku
nursery	vivero	allevamento	yoshokujo
residual heat	calor residual	calore residuale	yonetsu
space heating	calefacción	riscaldamento di ambienti	dambo

1-96 California Department of Conservation, Division of Oil, Gas, and Geothermal Resources

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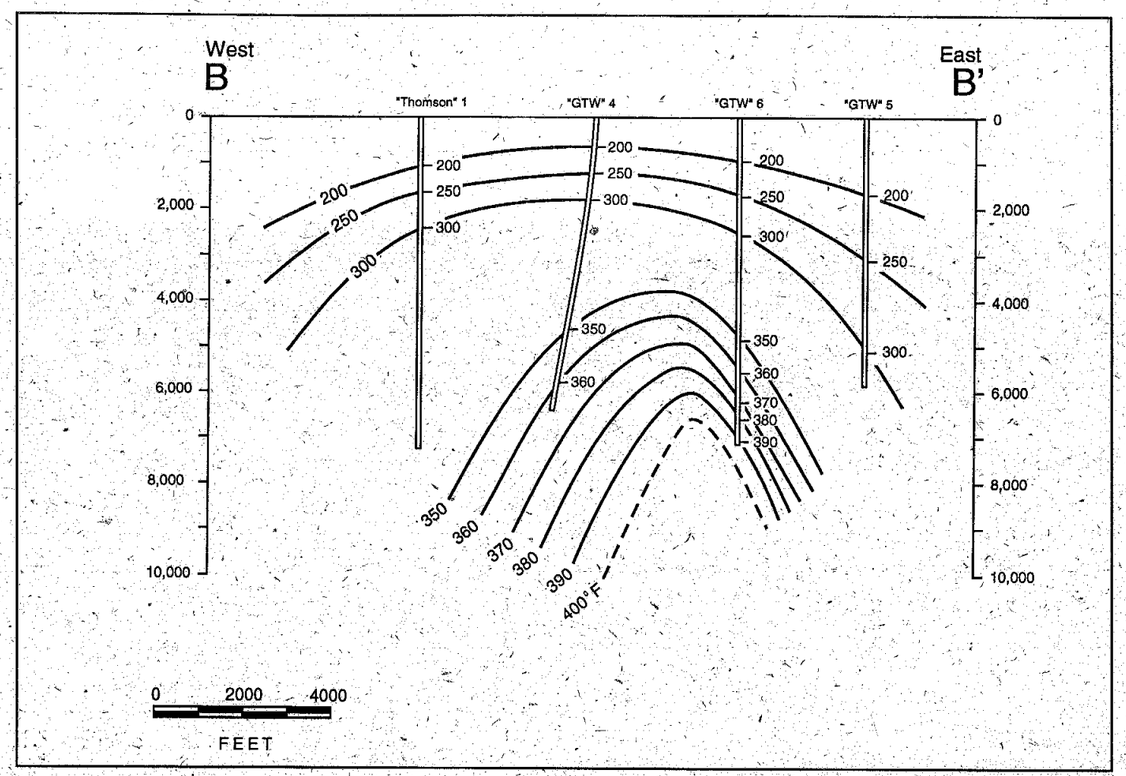


Figure 5. Temperature cross section B-B'. *Courtesy of James et al., 1987.*

completion zones for the SIGC production wells are generally those used for the 52-megawatt dual-flash power plant.

Some injection wells for the SIGC power plant were used at the defunct SDG&E power plant. Injection depth is from 2,500 feet to 4,500 feet.

About 80 percent of the fluid used to generate electricity in the HGC dual-flash power plant is injected. Some condensate produced by the flashing process goes into an agricultural drain, as approved by the California Regional Water Quality Control Board.

All fluid produced to operate the SIGC power plant is injected after use. Water for the cooling towers is purchased from the Imperial Irrigation District.

Reservoir modeling studies by Yearsley for Environmental Management Associates (1992) suggest that three injection wells drilled between the production wells for the HGC dual-flash power plant and the SIGC binary power plant could control bottomhole pressure and minimize future subsidence. An application was submitted to the Imperial County Planning Commission for a Conditional Use Permit to drill new wells based on the assumptions.

Leveling Surveys and Pressure Monitoring

First order leveling surveys of the Imperial Valley from the 1970s are critical for monitoring subsidence and uplift in Heber Geothermal field. The surveys established base-line data against which all ground movements are measured. Geothermal fluid extraction and tectonic activity are thought likely causes of ground

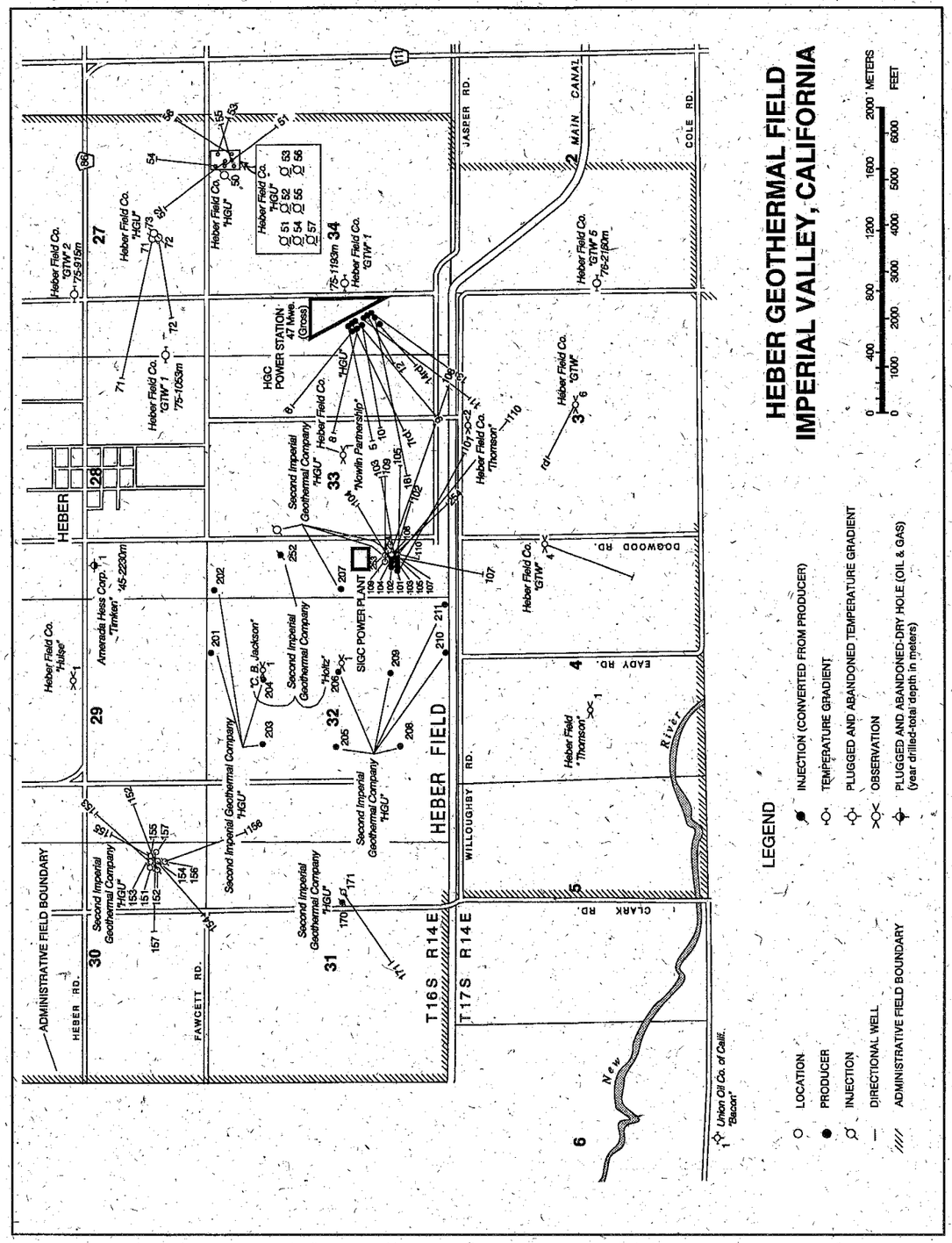


Figure 6. Well locations in Heber Geothermal field. Down-hole tracks are shown for the directional wells.

movements. The nature of the movements is influenced by the young, unconsolidated character of the sediments. Based on measurements from the 1970s, estimated natural subsidence in Heber Geothermal field, caused by tectonic activity associated with the Salton Trough, is about one centimeter (0.39 inch) per year, tilting down to the north (US Department of Energy, 1980).

The California Department of Conservation, Division of Oil, Gas, and Geothermal Resources regulates the drilling, operation, maintenance, and plugging and abandonment of geothermal wells, including injection wells. It holds primary responsibility for subsidence detection and abatement in geothermal areas, and injection-well permit conditions specify how often leveling surveys are made.

At Heber Geothermal field, Imperial County required leveling surveys every six months for the period of rapid field development from 1986 to 1990. (Eventually, it was determined that the Heber area affected by uplift extended beyond the surveyed portion. In 1989, benchmarks were added to fully delineate the uplifted area in the eastern part of the field.)

Since 1990, yearly leveling surveys have been accepted by the division and the county. Survey measurements must have 2nd order accuracy and Class I closure, with a vertical accuracy of 4.7 millimeters per kilometer (0.31 inch per mile).

Geothermal companies in the field maintain about 150 elevation benchmarks that are replaced if they are damaged by construction or agricultural activities. All benchmark elevations in the leveling grid are measured relative to benchmark A1225 in Calexico, California. The benchmark is thought far enough away from Heber Geothermal field to remain unaffected by field activities.

Several observation wells in the field are used to monitor reservoir pressure. The wells are fitted with capillary tubing to a depth of about 1,000 feet. After the tubing is purged with nitrogen gas, the fluid level inside the wellbore is calculated by reading surface pressure in the tubing.

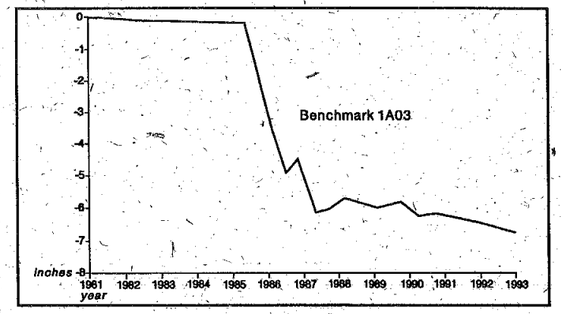


Figure 7. Benchmark 1A03 is in the center of the production area. Note the rapid loss of elevation immediately after the start-up of the Heber Binary Project and the 52-megawatt dual-flash power plant. After the Heber Binary Project was shut down, elevation stabilized.

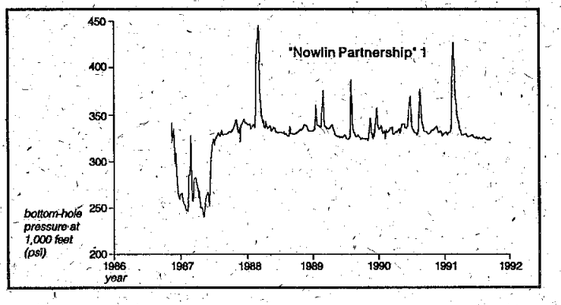


Figure 8. Observation well "Nowlin Partnership" 1 is at the northern edge of the main production area. The down-hole pressure on the well dropped dramatically after the start-up of the Heber Binary Project and the 52-megawatt dual-flash power plant. The pressure recovered after the Heber Binary Project was shut down. Pressure spikes are due to power plant shut-downs for normal operations and repairs.

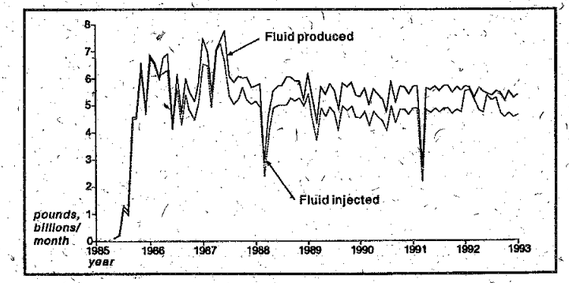


Figure 9. Monthly fluid production, Heber Geothermal field. The graph is in billions of pounds per month. Production peaked when both the Heber Binary Project and the 52-megawatt dual-flash power plant were running, a time with the highest rate of subsidence (Fig. 7) and the highest loss in reservoir pressure (Fig. 8).

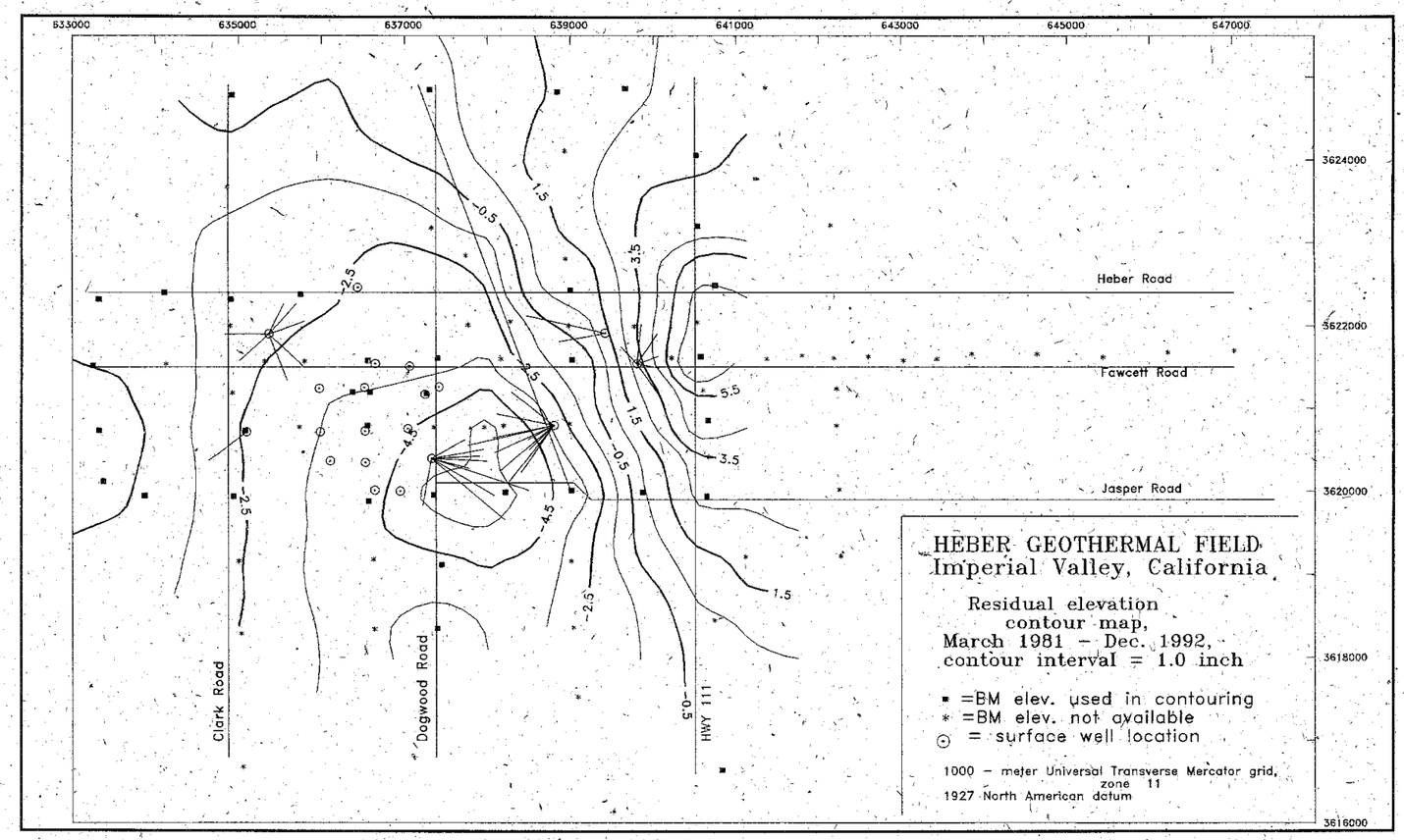


Figure 10. Elevation changes at Heber Geothermal field, March 1981 to December 1992. The down-hole tracks of the wells are shown.

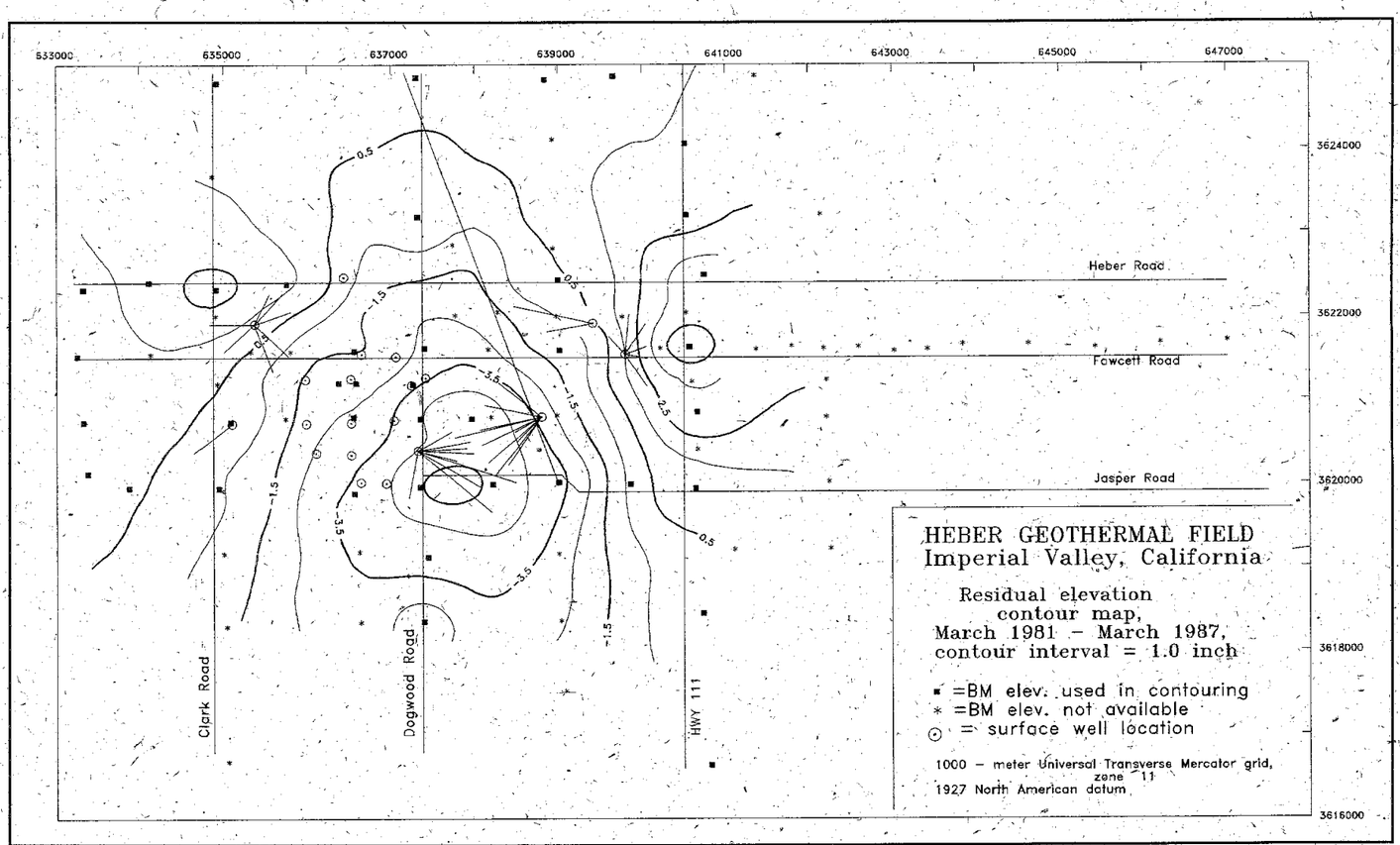


Figure 10a. Elevation changes at Heber Geothermal field, 1981 to 1987. The Heber Binary Project and the 52-megawatt dual-flash power plants started up in late 1985 to 1987. The subsidence bowl is defined and uplift is shown in both injection areas. The uplift associated with the Heber Binary Project in the northeastern portion was erased almost completely by 1992 (Fig. 10).

Subsidence and Performance

Elevation changes were detected immediately when the HGC dual-flash and the SDG&E binary power plants at Heber Geothermal field were operated simultaneously from 1985 to 1987. Leveling surveys showed that a subsidence bowl was developing above the production area, and the rate of subsidence was measured at 1.4 inches per year. When the SDG&E plant was shut down, total subsidence equaled 5.96 inches relative to the Calexico benchmark (Figs. 7,8,&9).

From July 1987 to June 1993, only the HGC dual-flash power plant was operated in the field. An average of 5.5 billion pounds of fluid was produced each month, except for periods with repairs or outages. Since July 1987, the subsidence rate in the field has been relatively stable (Fig. 4). A residual elevation contour map showing activity from March 1981 to December 1992 includes the entire subsidence area (Fig. 10). The land surface above the main production area continues to subside at a reduced rate (Fig. 7).

"Nowlin Partnership" 1 is an observation well near the middle of the main production area at the center of the subsidence bowl. A pressure plot of the well shows rapid pressure drawdown, especially from 1986 to 1987 when both the SDG&E binary project and the HGC dual-flash power plant received fluid from the center of the main production area. The rapid fluid withdrawal rate during this period corresponds with the high subsidence rate at benchmark 1A03. After the SDG&E binary project was shut in, reservoir pressure increased -- as measured at well "Nowlin Partnership" 1 -- indicating significant hydraulic connectivity in the reservoir (Fig. 8).

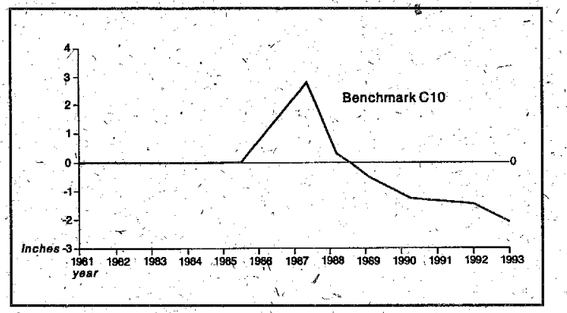


Figure 11. Benchmark C10 in the injection area of the Heber Binary Project. The benchmark uplifts rapidly during injection, and subsides as the main subsidence bowl expands (Figs. 10 and 10a).

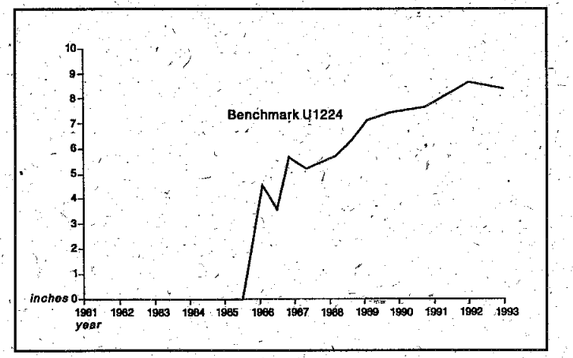


Figure 12. Benchmark U1224 in the injection area for the 52-megawatt dual-flash power plant. Note the rapid uplift since the power plant start-up. The recent decline in uplift rate is encouraging.

Uplift in Injection Areas

Northeast of the production area, two well islands are used as injection areas for the HGC dual-flash power plant. Maximum field uplift occurs east of the main injection island. After uplift was detected here in 1989, more benchmarks were added, starting from CH50. No earlier leveling data exist for the area.

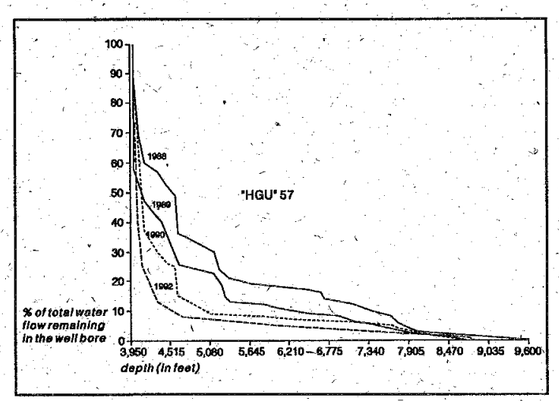


Figure 13. Injection profile for well "HGU" 57, an injection well for the 52-megawatt, dual-flash power plant. The profile shows that, over time, less water reaches the deeper portions of the reservoir and the upper portion of the reservoir accepts more of the total injected mass. Injection profile surveys are required by the Division of Oil, Gas, and Geothermal Resources. Before 1991, these surveys were required each year. Now they are required bi-annually.

Surveys made from 1981 to 1987 show a small amount of uplift near the injection area for the SDG&E binary plant, northwest of the main production area (Fig. 10a). Since the SDG&E plant was shut down in 1987, uplift in the area has reversed; although by December 1992, the subsidence bowl associated with production had encompassed the area completely, eliminating uplift (Fig. 11).

Uplift continues in the area centered around the main injection island for the HGC dual-flash power plant. From March 1990 to December 1992, vertical movement exceeded one inch between benchmarks CH02 and CH51.

A plot at benchmark U1224 indicates uplift near the injection area of the HGC dual-flash power plant (Fig. 12). Uplift was noted here until the December 1991 survey. Then the uplift trend reversed at benchmark U1224, as indicated by the December 1992 survey.

That injection-well perforations in the deeper portions of the wells accept ever smaller portions of the injected fluids is confirmed by regular radioactive tracer/spinner surveys. This indicates that proportionately more flow enters shallower reservoir areas (Fig. 13).

To maintain well injection capability, operators inject from 9 to 35 barrels of acid in the brine stream every 3 to 6 weeks. The acid stimulates the formation and increases well injectivity. Unfortunately, plugged perforations are unaffected by the acid and the project operator is seeking ways to unplug perforations.

In 1993, Heber Field Company drilled injection well "HGU" 72 on the same well pad as injection well "HGU" 71. The well pad is a satellite injection island northwest of the main injection island. Wells "HGU" 71 and 72 were drilled directionally to the west, away from the center of the uplifted area. A fault is believed to cross this area and cause an increase in permeability. For this reason, the area is considered a superior injection site. As of late 1993, the two wells were injecting nearly half of the total fluid from the HGC dual-flash power plant, and the western area has remained stable. Maximizing use of the two wells should slow the rate of uplift for other field areas.

Maximum uplift has occurred 3,000 feet east of the HGC dual-flash power plant main injection island, not directly over the injection wells. Perhaps a permeability barrier separates the field production and injection areas, or strengths may differ among reservoir matrix materials (sediments). Sediments east of the island probably have less cementation than those at or near wells.

Effects of Subsidence and Uplift

The division shares survey leveling data with the Imperial Irrigation District (IID), the agricultural water-delivery agency for the Imperial Valley. Water is transported in the valley through surface irrigation channels, and any vertical land movement could damage the system. The channels are extensive and changes in the surface gradient are monitored carefully.

So far, the IID has found no damage to irrigation channels from observed subsidence and uplift. Apparently, vertical changes in the canal system have not exceeded design tolerances or safety factors. Heber field, itself, shows no visual evidence of movement, such as surface cracking. Only leveling surveys reveal the changes.

Future of the Field

As both power plants continue operating in Heber field, the need persists to monitor subsidence and uplift. The field's subsidence bowl is not expected to expand significantly, but some small changes are expected due to pressure changes caused by production for the SIGC binary power plant. The three SIGC injection wells, located between the production areas for the two power plants, will be managed for adequate reservoir pressure support.

Uplift will be monitored closely, especially in the HGC dual-flash plant injection area. The possible presence of

a permeability barrier separating the main HGC dual-flash plant injection area from the rest of the field suggests the injected fluid is not providing pressure support to the produced portion of the field. Thus, injection for the HGC dual-flash plant should not be affected by operations at the SIGC plant.

Any vertical movement at the injection area of the HGC dual-flash plant will reflect cumulative effects of operating the plant since start up. In fact, long-term benefits for maximizing the satellite injection island by operating "HGU" 72, the second injection well, may halt or reduce the uplift rate in the plant's main injection area.

Selected References

1. Bell, F.G., Culshaw, M.G., Cripps, J.C., and Lovell, M.A. 1988. Engineering Geology of Underground Movements. Geological Engineering Geology Special Publication No. 5, p. 363-376.

2. Environmental Management Associates, 1992. Analysis of Potential Surface Subsidence and Uplift from the Proposed Second Imperial Geothermal Project, Heber Geothermal Field, Imperial County, California. EMA Report No. 0432-01, June 1992.

3. James, E.D., Hoang, V.T., and Epperson, I.J., 1987. Structure, Permeability and Production Characteristics of the Heber, California Geothermal Field. Proceedings, Twelfth Workshop on Geothermal Reservoir Engineering, Stanford University, Stanford, California, January 20-22, 1987, p. 267-271.

4. Lippman, M.J. and Bodvarsson, G.S., 1983. A Modeling Study of the Heber Geothermal Field, California. Geothermal Resources Council Tran., Vol. 7, p.441-448.

5. Lippman, M.J. and Bodvarsson, G.S., 1985. The Heber Geothermal Field, California: Natural State and Exploitation Modeling Studies. Journal of Geophysical Research, January 10, 1985, Vol. 90, No. B1, p. 745-758.

6. Nelson, T.T., 1987. Heber Binary Project. Geothermal Resources Council Trans., Vol. 11, p. 459-463.

7. Salveson, J.O. and Cooper, A.M., 1979. Exploration and Development of the Heber Geothermal Field, Imperial Valley, California. Geothermal Resources Council Trans., Vol. 3, p. 605-608.

FEDERAL & STATE NEWS

MINERAL AND BOTTLED WATER FACE NEW FDA RULES

From the Federal Register: November 13, 1995 (Volume 60, Number 218), Proposed Rules, pages 57131-57133

Under proposed regulatory amendments by the Food and Drug Administration (FDA), mineral water would be exempted from the allowable level for aluminum in the agency's quality standard for bottled water. The FDA also proposes to update testing methods referenced in the quality standard for bottled water. Elsewhere in this issue of the *Federal Register*, the agency is publishing a final rule to establish a standard of identity for bottled water. The proposal addresses two related issues that fell outside the scope of that rulemaking. The FDA tentatively concludes that the proposed actions will promote honesty and fair dealing in the interest of consumers.

Dates: Written comments should be made by January 29, 1996. The agency intends to make any final rule based upon this proposal effective 60 days following the date of publication of the final rule in the *Federal Register*.

Addresses: Submit written comments to the Dockets Management Branch (HFA-305), Food and Drug Administration, Rm. 1-23, 12420 Parklawn Dr., Rockville, MD 20857.

For further information, contact Shellee A. Davis, Center for Food Safety and Applied Nutrition (HFS-306), Food and Drug Administration, 200 C ST., SW, Washington, DC 20204, (202) 205-4681.

DOE GEOTHERMAL GOALS

Karl Rábago, Deputy Assistant Secretary for Utility Technologies, US Department of Energy (DOE), spoke at the 1995 Annual Meeting of the Geothermal Resources Council in October 1995. Mr. Rábago ended his keynote address with a list of DOE performance goals for geothermal energy in five major areas:

1. **Exploration** -- 10 new resource areas by the year 2000.
2. **Drilling** -- reduce costs by 30 percent by the year 2005.
3. **Reservoir technology** -- new technologies to characterize hydrothermal systems and improve dependability.
4. **Conversion** -- Improve energy conversion efficiency 10 percent to 20 percent by the year 2000.
5. **Environment** -- install more than one million geothermal heat pumps by the year 2005.

Mr. Rábago said by the year 2000, the achievements will bring:

1. More than $4 billion in annual fuel cost savings.
2. Reduced annual carbon-equivalent emissions by 7.2 million metric tons.
3. Total primary energy savings of 0.6 quads.

GEOTHERMAL PROGRAM SUPPORTS PRIVATE AND PUBLIC PROJECTS

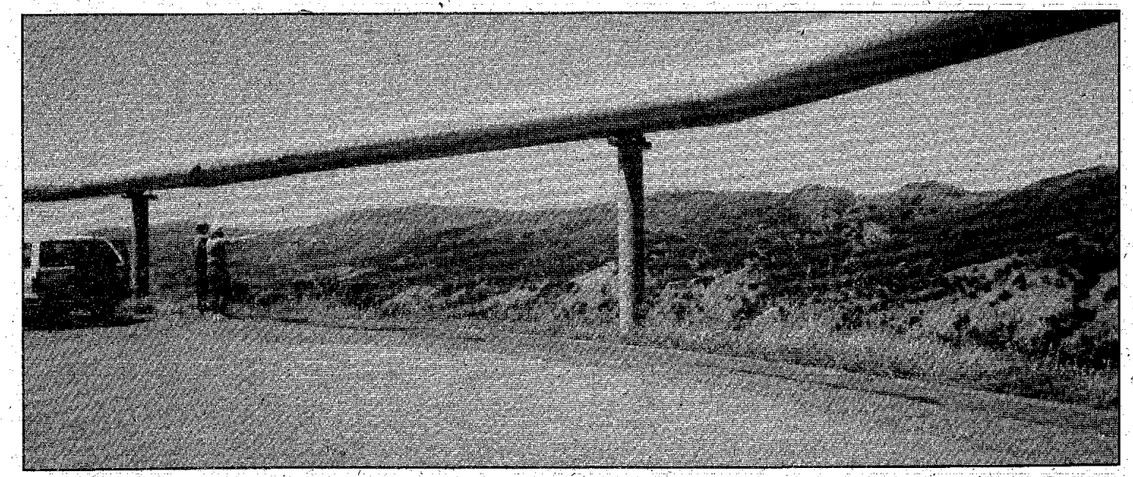
A $5.7 million funding cycle has begun for the Geothermal Program, sponsored by the California Energy Commission. The program supports geothermal research, development, demonstration, and commercialization projects by private and public entities.

The cycle ends June 30, 1996. Applicants may apply at any time. Approved proposals are funded in the order that completed applications were received.

Any funding level may be requested, but a matched contribution is required. Most private entities provide at least 50 percent of the overall project cost and public entities at least 20 percent.

Most types of geothermal projects qualify in California, and technical assistance is available.

For further information, contact The Geothermal Program, California Energy Commission, 1516 9th Street, MS-43, Sacramento, CA 95814-5512, or call (916) 654-5129.



TECHNOLOGY TRANSFER

GEOTHERMAL ON THE WORLD WIDE WEB

A preliminary list follows of home pages for geothermal destinations on the World Wide Web. Patrick Muffler, who helped assemble the list, suggests beginning a geothermal web search at the International Geothermal Association site. This site can link you to 26 more home pages with geothermal information -- from volcanoes to geysers, meetings, animated geothermal modelling, access points by country to general information, and a basic course on geothermal development.

Please send the *Geothermal Hot Line* other geothermal home pages to include in future issues.

ANSA News Agency (English-language service of the Italian news agency) for a wide variety of European news and events, including earth sciences, NATO, the IMF, and the EU.
http://www.mi.cnr.it

Boone REMC
http://www.a1.com/bremc/

California Department of Conservation
http://www.consrv.ca.gov

California Energy Commission
Access Energy, the home page --
http://www.energy.ca.gov/energy/homepage.html
Energy Quest, the energy education page --
http://www.energy.ca.gov/energy/education/eduhome.html

California Public Utilities Commission
http://www.cpuc.ca.gov
(For information on free-market purchase of electrical power in California)

Crest Geothermal Page
http://solstice.crest.org/renewables/geothermal/grc/index.html

Geothermal Education Office
http://www.ensemble.com/geo

Geothermal Energy in Iceland
http://www.os.is/os-eng/geo-div.html

Geothermal Resources Council
http://www.demon.co.uk:80/geosci/grclib.html

International Geothermal Association
http://www.demon.co.uk:80/geosci/igahome.html

POWER -- the University of California Energy Institute
http://www-ucenergy.eecs.berkeley.edu/ucenergy

Stanford Geothermal Program
http://ekofisk.stanford.edu/geotherm.html

The World Bank
http://www.worldbank.org

US Department of Energy, Energy Efficiency and Renewable Energy Network (EREN)
http://www.eren.doe.gov/ee_renen-geo.html

US Geological Survey
http://www.usgs.gov

In addition, a book called ***Energy Guide to the Internet*** is just out. It was created by TASC, Inc. to document over 350 World Wide Web sites with energy information. The directory pinpoints energy-related home pages, gopher servers, news groups, and mailing lists that the author, Roland W. Schumann, noted while doing energy research for TASC. His energy references include industry, natural resources, associations, and universities. There's some -- not a lot -- about geothermal, he says.

The book is $120.00 and a disk $50.00. Both are available from UDI/McGraw-Hill at (800) 486-3660. If you have questions, call Mr. Schumann at (703) 834-5000.

CONFERENCES

21st Stanford Workshop on Geothermal Reservoir Engineering, January 22-24, 1996, Stanford, California. Organized by the Stanford Geothermal Program.

The workshop allows engineers, scientists, and managers of geothermal reservoir studies and developments to discuss locating, developing, and using geothermal resources.

A post-workshop short course is offered on January 25-26. Titled "Reservoir Engineering Technology -- Tools for Success", it will emphasize modern developments in geothermal reservoir engineering. A post-workshop field trip to The Geysers Geothermal field is planned for January 27.

For more information, contact Dr. Shaun D. Fitzgerald, Geothermal Program Manager, Department of Petroleum Engineering, Stanford University, Stanford, CA 94305-2220. Phone (415) 725-2728, fax (415) 725-2099.

Government Conference on the Environment, New Directions for Government & Industry, February 13-15, 1996, Sacramento, California. Sponsored by the U.S. Environmental Protection Agency, Region 9; 12 California state entities, including the Department of Conservation; and 7 professional organizations.

The conference will focus on governmental policy shifts from mandates and regulations to incentives and partnerships -- along with the political, fiscal, technical, and social implications.

For information, contact GCOE, 1333 Howe Avenue, Suite 202, Sacramento, CA 95825. Phone (800) 877-GCOE; fax (916) 927-4265.

POWER Research Conference, March 15, 1996, Berkeley, California. Sponsored by POWER -- the University of California Energy Institute.

The conference will unite scholars from around the country to exchange ideas and research results on topics related to restructuring the electricity industry, such as transmission access, stranded cost recovery, market structure, conservation, R&D and low income programs, performance-based ratemaking, market power, the political economy of restructuring, international comparisons, and the future role of regulation in electricity. For information, contact the POWER Research Conference, University of California Energy Institute, 2539 Channing Way, Berkeley, CA 94720.

International Seminar on High-temperature Geothermal Energy Development & Utilization in Tengchong, Yunnan, China, March 18-24, 1996 (in Kunming, March 18-20 and in Tengchong, March 21-24), sponsored by the Department of International Cooperation & Department of Industry, China State Science & Technology Commission, and ESCAP.

Geothermal experts and entrepreneurs are invited to help develop Tengchong's geothermal industry, speed construction of a 10-megawatt geothermal power plant, and plan a modern geological park for geothermal development, research, recreation, tourism, and vocational training.

For information, contact the seminar secretariat Sun Lanlan, or Wang Zhonggong, International Cooperation Division, Yunnan Provincial Commission of Science & Technology, #110 Beijing Road, Kunming, Yunnan, P.R. China 650051. Phone 0871-3130743; fax 0086-871-3136444.

3rd International HDR Forum, May 13-16, 1996, Santa Fe, New Mexico. Sponsored by Los Alamos National Laboratory, Earth and Environmental Sciences Division.

Forum participants will address issues related to hot dry

rock heat mining around the world. Plans include a field trip to the Fenton Hill site and other geological and cultural areas in Northern New Mexico.

For information on the technical program, contact David Duchane at (505) 667-9893. For conference arrangements, call LeeRoy Herrera at (505) 665-5593.

Fourth International Meeting: Heat Flow and the Structure of the Lithosphere, June 10-16, 1996, location unknown. Sponsored by the Geophysical Institute of the Czech Academy of Sciences, under the auspices of the International Heat Flow Commission of the IASPEI and the Czech Academy of Sciences.

Meeting topics include heat-flow studies with special attention to 2-D and 3-D geothermal modelling, crustal and lithospheric structures, deep-temperature assessment, correlating heat flow with other geoparameters, and climate-related borehole observations.

For information, contact Dr. Vladimir Cermak, Geophysical Institute, AVCR, 14131 Praha 4, Czech Republic. Phone (422) 67 103 385, fax (422) 76 15 79, or E-mail: cermak@ig.cas.cz

1996 Annual Meeting, September 29-October 2, 1996, Portland, Oregon. Sponsored by the Geothermal Resources Council.

For information, contact the GRC at PO Box 1350, Davis, CA 95617-1350.

Terrane Dynamics 97, February 10-14, 1997, Christchurch, New Zealand. Sponsored by the Department of Geological Sciences, University of Canterbury; Royal Society of New Zealand; and Institute of Geological and Nuclear Sciences.

The conference will highlight terrane place of origin, the dynamics of terrane displacement, identifying terranes in old orogenic belts, and developing a general theory of terrane geology.

For information, contact Dr. J.D. Bradshaw, Dept. of Geological Sciences, Univ. of Canterbury, Private Bag 4800, Christchurch, New Zealand.

PUBLICATIONS AND VIDEOS

A Guide to California State Permits, Licenses, Laws and Regulations Affecting California's Aquaculture Industry. $10.00. Prepared by the Interagency Committee for Aquaculture Development, State of California, 1994. Order from Bob Hulbrock, California Dept. of Fish and Game, 1416 9th Street, 12th Floor, Sacramento, CA 95814. Telephone (916) 653-9583.

Power Plays, Profiles of America's Independent Renewable Electricity Developers. Executive summary $25; publication $195 ($55 for governmental agencies and nonprofit organizations). Published by and available from the Investor Responsibility Research Center, 1350 Connecticut Ave., NW, Suite 700, Washington, D.C. 20036-1701. Telephone (202) 833-0700.

The report focuses on 100 companies -- not utilities -- spearheading renewable electrical development in the United States. A great deal of detailed information -- essentially a company history -- is included for 15 geothermal companies, as are data on electrical power generation issues in the U.S.

Of note is that 30.2 percent of the total electrical capacity from renewables in the U.S. at year-end 1994 came from geothermal. Biomass was 40 percent, wind 17, hydro 9.5, and solar thermal 3.8.

Energy Use and Carbon Emissions: Non-OECD Countries, 061-003-00880-1. December 1994. $5.50. Order from the US Govt. Printing Office, PO Box 371954, Pittsburgh, PA 15250-7954.

National energy uses are described and energy-use patterns compared. Ways are identified to lower fossil-fuel use and reduce greenhouse gas emissions. The content is interesting and presented clearly.

Geochemistry of Thermal/Mineral Waters in the Clear Lake Region, California, and Implications for Hot Dry Rock Geothermal Development, LA-12510-HDR. $18.00. 23 p. Order from the NTIS, US Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

Low and No-cost Educational Resources on Renewable Energy and Energy Efficient Technologies. Free with a stamped, self-addressed envelope mailed to Sun Day Campaign, 315 Circle Avenue #2, Takoma Park, Maryland 20912-4836.

Eight pages of excellent educational resources, including geothermal.

The US Geological Survey has many video tapes for loan, free of charge, for a two-week period. Ask for the ***Special Collections Video Tape Library List*** and the separate list of videos for children up to 10 years old. Contact Michael Moore, US Geological Survey Library, Audio Visual Collection, MS 955, 345 Middlefield Road, Menlo Park, CA 94025-3591. Telephone (415) 329-5009, fax (415) 329-5132.

NEW ADDRESSES

The Geothermal Energy Association (GEA) has moved to the office complex of the US Export Council for Renewable Energy. Ms. Perle M. Dorr is Director of Outreach Programs for the GEA and Ms. Ann McKinney is Director of Export Programs. Activities are being developed in both areas. The new GEA address is:

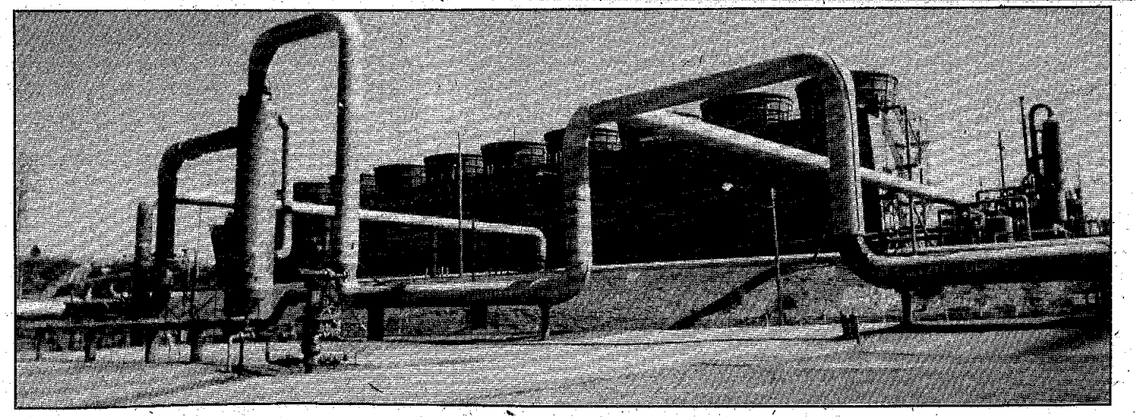
Geothermal Energy Association
122 C Street, NW, Suite 400
Washington, DC 20001

Phone (202) 383-2676; fax (202) 383-2678

The University of Utah Research Institute, *now* the **Earth Sciences & Resources Institute**, has moved. The new address is:

Earth Sciences & Resources Institute
University of Utah
1515 E. Mineral Square, Room 109
Salt Lake City, Utah 84112

Phone (801) 581-5126; fax (801) 585-3540



CALIFORNIA WELLS

Division Well Data Available

A computer-generated file of geothermal production and injection statistics for wells and records open to public inspection is available from the Division of Oil, Gas, and Geothermal Resources. All data are in metric units. The file may be purchased at cost from the division in Sacramento.

Drilling Permits for Geothermal Wells Approved January 1992 - November 1995 by the Division of Oil, Gas, and Geothermal Resources

(Contact the U S Department of the Interior, Bureau of Land Management, for information on drilling permits issued for wells on federal lands.)

Date Notice Received	Operator Well Name & No.	API Number	Sec.T.R.	Location & Elevation
	DISTRICT G1			
		Lassen County		
	FIRST AMERICAN GEOTHERMAL AND AGRICULTURAL			
09/07/93	"TG" 1-93	035-90100	15 28N 16E	Fr SW cor 925m N, 400m E, el 1315m rt
	BEST EXPLORATION INC.			
09/17/93	"O'Neill" 1-20	035-90101	20 38N 8E	Fr NEcor 400m S, 187m W, el 1275m kb
		Mono County		
	MAMMOTH PACIFIC, L.P.			
01/10/92	"Casa Diablo" 28-34	051-90156	34 3S 28E	Fr SW cor 46m N, 50m E, el 2179m gr
07/03/92	"MP" 24E-32	051-90157	32 3S 28E	Fr NW cor 823m S, 274m E, el 2228m gr
03/03/93	"MP" 14A-32	051-90161	32 3S 28E	Fr NW cor 690m S, 100m E, el 2242m gr
03/03/93	"MPI" 44B(43)-32	051-90162	32 3S 28E	Fr NW cor 635m S, 650m E, el 2236m gr
	MONO COUNTY ENERGY MANAGEMENT			
11/13/93	"BP-TG" 1	051-90163	33 5N 25E	Fr SW cor 280m N, 90m E, el 2156m gr
		Shasta County		
	BEST EXPLORATION INC.			
09/17/93	"Walker Trust" 1-27	089-90025	27 31N 1E	Fr NEcor 257m S,
		Sierra County		
	NEW AGE CHURCH OF BEING			
09/15/95	"SHS" 1	091-90009	18 20N 15E	Fr SW cor 61m N, 610 m E, el 1524m gr

Date Notice Received	Operator Well Name & No.	API Number	Sec.T.R.	Location & Elevation
	DISTRICT G2			
		Imperial County		
	HEBER FIELD COMPANY			
03/25/93	"HGU" 72	025-91229	27 16S 14E	Fr SW cor 352.2m N, 811.9m E, el 1.8m gr
03/25/93	"HGU" 73	025-91230	27 16S 14E	Fr SW cor 368.1m N, 828.5m E, el 1.8m gr
	RED HILL GEOTHERMAL, INC.			
08/16/93	"PR" 2	025-91234	33 11S 13E	Fr SE cor 81.2m N, 769.6m W, el 68m gr
	OSCAR BASHFORD			
11/19/93	"Bashford" 3	025-91235	1 9S 12E	Fr NW cor 365.8m S, 30.48m E, el 11m gr
	MAGMA OPERATING COMPANY			
09/06/94	"Sinclair" 24	025-91236	5 12S 13E	Fr SE cor 647.63m W, 55.57m N, el 66m gr
02/03/95	"IID" 15	025-91239	5 12S 13E	Fr SW cor 1519.96m N, 747.7m E, el 70.6m gr
02/03/95	"IID" 16	025-91240	5 12S 13E	Fr NW cor 122.5m S, 747.7m E, el 70.6m gr
04/24/95	"Sinclair" 26	025-91247	5 12S 13E	Fr SE cor 66.8m N, 97.6m W, el 222m gr
05/31/95	"Sinclair" 27	025-91248	5 12S 13E	Fr SE cor 66.98m N, 67.4m W, el 67.7m gr
	FISH PARTNERS			
08/10/95	"Ray" 2	025-91249	12 11S 14E	Fr NW cor 205m S, 286m E, el 14m gr
08/10/95	"Ray" 3	025-91250	12 11S 14E	Fr NW cor 379m S, 425m E, el 13m gr
	MAGMA OPERATING COMPANY			
09/18/95	"Sinclair" 11	025-91251	5 12S 13E	Fr SE cor 746.88m N, 419.66m W, el 69.2m gr
		Los Angeles County		
	FIR ENTERTAINMENT GROUP			
02/22/95	"Youn-APEE" 1	037-90001	19 1S 13W	Fr SW cor of property 170 Bimini Place, Los Angeles 36m N, 8m E

Date Notice Received	Operator Well Name & No.	API Number	Sec.T.R.	Location & Elevation
		Riverside County		
	MANDY EVANS			
02/09/93	"Evans" 1	065-90173	11 3S 5E	SE 1/4
	ANTHONY YONG-HAE LEE			
07/28/93	"Sahara Spa Motel"1	065-90176	30 2S 5E	NW 1/4, SE 1/4
	HIGHLANDER LODGE			
11/08/93	"Highlander Lodge"1	065-90177	33 2S 5E	NW 1/4
	WAGNER'S MOBILE HOME PARK			
11/15/93	"Wagner" 3	065-90178	23 3S 5E	Fr NE cor 2200' S, 1300' W, el 1060'gr
	ALMAR ACRES ASSOCIATION, INC.			
02/22/95	"Almar" 2	065-90179	11 3S 5E	70205 Dillon Rd., Desert Hot Springs
	EARLE POOLE			
03/23/95	"Poole" 1	065-90180	4 3S 5E	68255 Louisan Rd., Desert Hot Springs
	WILLIAM E. ENGLER			
05/22/95	"Niland" 4	065-90181	35 8S 12E	Fr SE cor 75m N, 75m W, el 24m gr
06/19/95	"Engler" 1	065-90182	35 8S 12E	Fr SE cor 600m N, 75m W, el 24m gr
06/30/95	"Engler" 2	065-90183	35 8S 12E	NE 1/4, NE 1/4, el 20m gr
	SAM'S FAMILY SPA			
11/03/95	"Money Pit" 1	065-90186	11 3S 5E	NE 4 1/4, SE 1/4. el 326m gr
		San Bernardino County		
	CITY OF TWENTYNINE PALMS			
07/13/94	"TNP" 5	071-90083	29 1N 9E	Fr NW cor 259m S, 579m E, el 646m gr
07/13/94	"TNP" 6	071-90084	11 1N 9E	Fr NE cor 61m S, 61m W, el 549m gr

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	DISTRICT G3			
		Lake County		
	CALPINE OPERATING PLANT SERVICES, INC.			
07/27/92	"Davis State 5206" 4	033-90734	36 11N 8W	Fr NW cor 1062m S, 470m E, el 585m gr
	CALPINE OPERATING PLANT SERVICES, INC.			
06/11/93	"East Ford Flat" 1	033-90736	26 11N 8W	Fr SW cor 675m N, 619m E, el 661m gr
		Napa County		
	JOSIF DUBROVSKY			
11/15/92	"Ester" 1	055-90129	36 9N 7W	Fr SE cor 137m N, 427m W, el 110m gr
	CRYSTAL GEYSER WATER COMPANY			
07/18/94	"Crystal" 3	055-90130	06 8N 8W	Fr NE cor 6m S, 22m W, el 107m gr
08/15/94	"Crystal" 4	055-90131	06 8N 8W	Fr NE cor 16m S, 22m W, el 107m gr
		Sonoma County		
	GEOTHERMAL ENERGY PARTNERS			
04/07/92	"Aidlin" 9	097-90825	04 11N 9W	Fr SE cor 1114m N, 1433m W, el 382m gr
05/26/95	"Aidlin" 10	097-90827	04 11N 9W	Fr SE cor 1132m N, 1418m W, el 383m gr

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Department of Conservation
Division of Oil, Gas, and
Geothermal Resources
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