Vol. 16, No. 4 OCTOBER 1995

GEO-HEAT CENTER QUARTERLY BULLETIN

ISSN 0276-1084

A Quarterly Progress and Development Report on the Direct Utilization of Geothermal Resources

CONTENTS

Cover: (1) 1974 International Conference on Geothermal energy for Industrial, Agricultural and commercial-Residential Uses, held at OIT; (2) OIT experimental greenhouse; (3) aerial view of OIT experimental aquaculture ponds; (4) giant freshwater prawn, Macrobrachium Rosenbergii, raised in OIT ponds; (5) Gene Culver looking at OIT geothermal production well; and (6) GHC staff injecting geothermal fluids, from left: Paul Lienau, John Lund, Donna Gibson, Penny Lewis, Gene Culver, Don Karr, Kevin Rafferty and Chuck Higbee.

PUBLISHED BY

GEO-HEAT CENTER
Oregon Institute of Technology
3201 Campus Drive
Klamath Falls, OR 97601
Phone: 541-885-1750
Email: geoheat@oit.edu

All articles for the Bulletin are solicited. If you wish to contribute a paper, please contact the editor at the above address.

EDITOR

Paul J. Lienau and John W. Lund
Typesetting and Layout – Donna Gibson

FUNDING

The Bulletin is provided compliments of the Geo-Heat Center. This material was prepared with the support of the U.S. Department of Energy (DOE Grant No. DE-FG07-90ID13040). However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors(s) and do not necessarily reflect the view of USDOE.

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20th ANNIVERSARY OF GEO-HEAT CENTER

P. J. Lienau
J. W. Lund
Geo-Heat Center

INTRODUCTION

The beginning of the Geo-Heat Center (GHC) can be traced to an international conference held on geothermal energy at the Oregon Institute of Technology (OIT) campus during October of 1974. The meeting was organized to review nonelectric, multipurpose uses of geothermal energy in Hungary, Iceland, New Zealand, the United States and Russia (U.S.S.R). As a result of the conference and interest in the need to exchange and disseminate information on low-to moderate-temperature resources and their utilization, the Geo-Heat Center (first known as the Geo-Heat Utilization Center) was established in 1975. Initial funding was provided by the Pacific Northwest Regional Commission (PNRC), a branch of the Executive Department of the Governors of the states of Oregon, Washington and Idaho. A sum of $3,000 was granted to distribute information to participants of the October 1974 international conference. The proceedings were published in a volume titled "Multipurpose Use of Geothermal Energy-Proceedings of the International Conference on Geothermal Energy for Industrial, Agricultural, and Commercial/Residential Uses." The primary functions of the Center were to disseminate information to potential users of geothermal resources, perform applied research on the utilization of low-temperature resources, and to publish a quarterly newsletter on the progress and development of direct-use geothermal energy in the United States and other countries.

Over the years a number of people were employed by the Center on a full time basis or for special projects. Many of the these individuals started their careers in geothermal with the Center and are still involved with geothermal energy today. We recognize and thank the following persons, who have been associated with the GHC, for their contributions:

Figure 1. Speakers at the 1974 International Conference on Geothermal Energy for Industrial, Agricultural and Commercial-Residential Uses include from front left: B. Ogle, Alaska; E. Storey, Klamath Falls; J. Barnea, New York; R. Bowen, Portland; T. Boldizsar, Hungary; C. Lieb, Klamath Falls; M. Linton, New Zealand; W. Brewer, Washington; K. Hall, Washington DC; R.D. Wilson, New Zealand; J. Howard, Lawrence Livermore Labs.; D. Storey, Klamath Falls; E Wehlage, California; P. Lienau, GHC; J. Zoega, Iceland; and J. Lund, GHC. Not in the picture were: B. Lindal, Iceland; W. Burrows, New Zealand; G. Culver, GHC; L. Svanevik, GHC; T. McCall, Govenor of Oregon; W.D. Purvine, OIT; S. Eisenstat, Washington, DC.; D. Pitts, Washington DC; J. Schatz, Salem; and A. Ullman, U.S. House of Representatives.

GEO-HEAT CENTER EMPLOYEES FROM 1975 to 1995

	GHC Position	Current Position
Paul J. Lienau	Director 1975-present	Director
Gene Culver	Assoc. Dir. 1975-1994	Retired
John Lund	Research Assoc. 1975-present	Research Assoc.
Kevin Rafferty	Research Assoc. 1980-1994	Assoc. Dir.
Tonya Boyd	Research Assist. 1994-present	Research Assist.
Lars Svanevik	Research Assoc. 1974-1995	Research Assoc.
Charles Higbee	Research Assoc. 1977-1988	Retired
Gene Ryan	Research Assoc. 1979-1983	Retired
Don Karr	Research Assoc. 1976-1982	Retired
Bill Johnson	Research Assoc. 1976-1983	Retired
Kenan Smith	Research Assist. 1980-1981	?
Jay Silva	Research Assoc.1980-1987	Retired
Saul Laskin	Research Assoc. 1976-19	Prof. in South Carolina
Wayne Phillips	Research Assoc. 1980	Retired
Robert Koeppen	Research Assoc. 1977-1979	USGS
Debra Justus	Research Assist. 1978-1982	International Energy Agency
R. Gordon Bloomquist	Research Assoc. 1978-1980	Washington State Energy Office
Neil Bascescu	Research Assist. 1978-1980	?
Stuart Simpson	Research Assist. 1979-1980	Washington State Energy Office
Keith Brown	Research Assist. 1978-1980	?
Richard James	Research Assist. 1978-1980	?
David McClain	Research Assist. 1978-1979	California Energy Company
Donald Markle	Research Assist. 1978-1980	North Carolina Energy Off
Leah Street	Research Assist. 1979-1980	DOE Idaho
Ann Fornes	Research Assist. 1979-1985	?
Roger Riveness	Research Assist. 1980-1982	K. Falls S. Sub. Sanitary Dist.
Mark Dellinger	Research Assist. 1980-1982	Lake Co. Sanitary Dist.
Ardelle Godfrey	Secretary 1975-1976	Nurse at MWMC
Colleen Fry	Secretary 1977-1981	Secretary - Salem, OR
Sandy Buckner	Secretary 1979-1981	?
Cindy Nellipowitz	Secretary 1981-1988	Legal Secretary
Joyce Pryor	Secretary 1981-1989	Retired
Penney Lewis	Secretary 1985-1989	Secretary-Unemployment Office
Kathleen Moore	Secretary 1988-1989	?
Donna Gibson	Secretary 1988-present	GHC Secretary
International Affiliates		
Derek Freeston	1981	New Zealand
Thorbjorn Karlsson	1984-1985	Iceland
Wanda Wang	1984-1985	China
Weimen Li	1984-1985	China
Mingze Shi	1984-1985	China
Herman Guillen	1987	Philippines
Mike Dunstall	1989-1990	New Zealand

Figure 2. Staff members of Direct Applications Operations Research Planning include: G. Bloomquist, Washington; D. Justus, Oregon; N. Bascescu, Washington; S. Simpson, Washington; K. Brown, Montana; D. Markle, Alaska; D. McClain, Idaho; L. Street, Idaho; R. James, Wyoming; R. Koeppen, GHC; and D. Karr, GHC.

Since 1975, the GHC has been involved in a number of studies and projects, funded by a variety of sources but primarily from the Department of Energy, to meet its goals. A summary of these projects and activities are recounted below:

SUMMARY OF GHC PROJECTS

The following table is a listing of the geothermal projects completed from 1974 to 1995.

		Date Completed	Funding Source
1.	Klamath Falls Hot Water Well Study	1974	US AEC
2.	Corrosion of Downhole Heat Exchangers	1975	US DOE
3.	Geo-Heat Quarterly Bulletin	1976	PNRC
4.	Use of Geothermal Energy for Aquaculture	1976	Sea Grant
5.	Feasibility and Design of a Geothermal Heating District in Klamath Falls	1976	Klamath Co.
6.	Study of the Use of Geothermal Waters for Greenhouse Heating	1977	State of OR
7.	Geo-Heat Quarterly Bulletin	1977	PNRC
8.	Investigation of the Geology and Hydrology of the Klamath Falls KGRA	1977	USGS
9.	Study of the Use of Geothermal Energy for Agribusiness Purposes in the Klamath and Snake River Basins	1977	US DOE
10.	Downhole Heat Exchanger Performance	1978	US DOE
11.	Geo-Heat Quarterly Bulletin	1978	PNRC/ODOE
12.	Direct Applications Operations Research Planning (site data base)	1978	US DOE
13.	Use of Geothermal Energy for Aquaculture (Phase I)	1977	PNRC
14.	Use of Geothermal Energy for Aquaculture (Phase II)	1978	PNRC
15.	Geothermal Heating Systems for Greenhouses	1980	PNRC
16.	TA for Commercial Utilization of Geothermal Energy (Phase I)	1979	US DOE
17.	Direct Utilization of Geothermal Energy: Development of 4 Educational Reports	1980	US DOE
18.	Direct Use Geothermal Potential Within the BPA Marketing Area	1980	BPA
19.	Use of Geothermal Energy for Aquaculture (Phase III)	1980	PNRC
20.	Technical Assistance (Phase II) and Quarterly Bulletin	1980	US DOE
21.	Technical Assistance (Phase III)	1980	US DOE
22.	Market Development and Regional Coordination of Geothermal Energy for Region X	1980	US DOE
23.	Technical Assistant (Phase IV)	1982	US DOE
24.	Lakeview, OR, Electrical Generation Project Review (Jack Wood)	1982	WOOD
25.	Technology Transfer and Information Dissemination for Regions IX & X	1983	US DOE
26.	California Technical Assistance	1983	CEC
27.	Oregon TA for Local Governments	1983	ODOE
28.	Ashland, Oregon's Geothermal Resource Plan Document	1983	BPA
29.	Compendium of Wellhead Generators	1983	EPRI

30.	Klamath Falls Aquifer Test	1984	US DOE
31.	Binary Power Plant Research	1986	ODOE
32.	Technology Transfer	1984	US DOE
33.	Biomass Conversion for Washington Dept. of Corrections Facilities	1984	WSEO
34.	Lake Elsinore, California District Heating Project	1984	City of L.E.
35.	Paso Robles, California District Heating Project	1984	City of P.R.
36.	Geothermal Technology Transfer	1985	US DOE
37.	Technical Assistance for California (Subcontract to BGI)	1985	CEC
38.	Information Dissemination & Technology Transfer	1986	US DOE
39.	City of Klamath Falls	1986	City of K.F.
40.	Technical Assistance for California (Subcontract to Envirosphere)	1987	CEC
41.	Information Dissemination & Technology Transfer	1987	US DOE
42.	Specialized Training for Philippines	1987	UN
43.	TA for California (Sub to Envirosphere)	1988	CEC
44.	TA for California	1989	CEC
45.	TA for California	1990	CEC
46.	Geothermal R & D Assistance	1990	US DOE
47.	TA for California	1991	CEC
48.	Geothermal Direct-Heat Utilization Assistance	1991	US DOE
49.	Geothermal Direct-Heat Utilization Assistance	1992	US DOE
50.	TA for California	1992	CEC
51.	Low-Temp Assessment	1993	EG&G
52.	Geothermal Direct-Heat Utilization Assistance	1993	US DOE
53.	TA for California	1993	CEC
54.	Low-Temp Assessment	1994	EG&G
55.	Geothermal Direct-Heat Utilization Assistance	1994	US DOE

Information on some of the major projects are briefly summarized below.

1974 Klamath Falls Hot Water Well Study. During the summer of 1974, a study was made of approximately 75 geothermal wells in Klamath Falls. Data on temperature, well depth, downhole heat exchanger use, heating system characteristics, water chemistry and corrosion problems were gathered. In addition, an economic study and analysis was made on the capital and operation cost of owning a geothermal well and associated heating systems. These costs were then compared with alternate energy forms. Detailed maps were prepared for the area showing contour of well depth and temperature. This was the first comprehensive study and documentation of geothermal direct use in Klamath Falls. The work was funded by Lawrence Livermore Laboratory. A report was presented at the 2nd UN Geothermal Symposium in San Francisco in 1975.

1975-1995 Geo-Heat Center Quarterly Bulletin. The Geo-Heat Center Bulletin has been the main and continuous source of information on direct use projects both domestic and internationally that have been disseminated by the Center. Starting with a modest blue print on yellow paper, 6-page, Vol. 1, No. 1 in May of 1975, it has grown into a colorful professional publication of 20 to 40 pages. This is the 59th issue of the Quarterly Bulletin. A total of 294 articles have been published, including ones from 22 foreign countries.

1976-1980 Use of Geothermal Energy for Aquaculture. During1975, an aquaculture project raising large freshwater Malaysian prawns (Macro brachium rosenbergii) in geothermal effluent from the campus geothermal heating system was initiated. The project started with ten (4 x 4 ft) indoor tanks raising 1,000 post-larval prawns. During the summer of 1976 outdoor ponds were constructed to demonstrate commercial feasibility by evaluating the best methodology for intensive aquaculture through PNRC funding. The ponds were stocked with 48,000 post-larval stage prawns. These were successfully raised, showing substantial growth rates and low mortality rates. Other aquaculture experimentation included raising 20,000 fingerling trout with growth rates of more than three times that experienced in the hatchery. A final aspect of the project in 1980, involved raising tropical fish which showed high survival rates and exceedingly fast growth rates. Funding for the project ended in September, 1981.

1977-1980 Geothermal Heating Systems for Greenhouses. Construction of 30 x 60 ft greenhouse was initiated on the OIT campus during September of 1977. The facility was designed as a demonstration project of cascading geothermal applications using the effluent from the OIT campus geothermal heating system as its heat source. Efficiency and cost analysis studies were performed by students and faculty at OIT. Experimental use of the greenhouse was also shared by Oregon State University's (OSU) agricultural experimental station. Alternate heating systems using various flows and temperatures were investigated. The final design included use of unit heaters and finned tube radiators installed around the perimeter of the structure. Following completion of the study, responsibility for maintenance was transferred to the OIT physical plant to raise flowers and decorative plants for campus beautification. The structure was torn down in 1982 due to the construction of Purvine Hall at the site.

1977-1978 Study of the Use of Geothermal Energy for Agribusiness Purposes in the Klamath and Snake River Basins. Resource assessment and methods of geothermal energy direct utilization for existing and prospective food processing plants were determine. Ore-Ida Foods, Inc. and Amalgamated Sugar Company in the Snake River Basin were evaluated. In the Klamath Basin, Western Polymer Corp. (potato starch extraction) and three prospective industries--vegetable dehydration, alfalfa drying, and greenhouses were analyzed for utilization of geothermal fluids. Existing geologic knowledge was integrated to indicate locations, depth, quality and estimated productivity of the geothermal reservoirs. Energy-economic needs along with cost and energy saving associated with field development, delivery systems, in-plant applications, and fluid disposal were calculated for interested industrial representatives.

1977-1978 Study to Develop More Efficient Downhole Heat Exchangers. A contract was awarded to the GHC and Oregon State University Mechanical Engineering Dept. by ERDA to provide an experimental and analytical research program to evaluate and improve the design of DHE's for direct applications of geothermal energy. During the study progress was achieved in (1) characterizing flows in wells with perforated casings and DHE's installed, (2) determination of energy extraction rates for short multi-tube DHE's in wells, (3) improve and substantiate models of heat transfer within the well including the mixing of aquifer and well waters, (4) development of new flow measuring techniques, and (5) economic analysis comparisons of DHE's and surface heat exchanger systems.

1977-1980 Direct Applications Operations Research Planning. The Geo-Heat Center, in cooperation with state energy offices, developed status reports for geothermal development in the states of Alaska, Idaho, Montana, Oregon, Washington and Wyoming. State-by-state institutional analyses are included that address major obstacles to geothermal development. The collective goal of these studies was to summarize, on a site specific basis, the various factors affecting development. Information includes: resource data, site geologic descriptions, reservoir characteristics, environmental characteristics, leasing and development status, institutional factors, population and market potential that could be used by geothermal developers as an aid to planning and commercialization.

1979-1995 Technical Assistance for Commercial Utilization of Geothermal Energy (Phase I). In August, 1978, a grant was awarded to the GHC by the Division of Geothermal Energy of the USDOE to provide technical assistance for development and commercial utilization of geothermal energy for space/process heating, aquaculture, and agriculture. The assistance applied to the states of Alaska, Washington, Oregon, California, Hawaii, Arizona, and Nevada. The program provided on-site investigations, limited resource evaluation studies, help in matching resources with applications, preliminary cost and economic analysis, information on institutional factors, help in materials and component selection, conceptual geothermal system designs, and consultation with engineers or designers involved in final design. Until 1983, up to 100 hours could be applied to projects, resulting in about 75 completed feasibility studies. Renewed USDOE grants continue to provide these services, limited to 8 hours per project, to potential users.

1980 Direct Utilization of Geothermal Energy: Development of 4 Educational Reports. During February of 1979, a three-day workshop was held at Diamond Lake Lodge, just North of Klamath Falls. The purpose of the workshop was to develop four educational reports on the "Direct Utilization of Geothermal Energy." These included a technical version (" A Technical Handbook") of 250 pages published by the Geothermal Resources Council as Special Report No. 7., a non-technical version ("A Laymans' Guide") of 97 pages published by GRC as Special Report No. 8, a series of articles for newspaper release, and a pricing parameter report. Each Working group had from five to eight people participating in outlining and writing the initial draft at Diamond Lake. The workshop was funded by a DOE grant and administered jointly by the Geo-Heat Center and the Geothermal Resources Council.

1983-1995 California Technical Assistance. The California Energy Commission provides annual funding to private and public entities for geothermal energy projects. Practically all aspects of geothermal planning; technology research, development and demonstration; resource development; technology commercialization; and impact mitigation are eligible for funding. All projects must have a hardware component (e.g., well drilling; resource assessments; small-scale electricity production; direct-use systems; or testing or demonstration of innovative geothermal assessment techniques, components or systems). The GHC, through, a subcontract provides Technical Assistance to help resolve technical problems relating to a planned or ongoing project. For Fiscal Year 1995-96, $5.7 million is available for project funding. To receive an application packet, call (916) 654-5129 or write California Energy Commission, Geothermal Program, 1516 9th Street MS-43, Sacramento, CA 95814-5512.

1983-1984 Klamath Falls Aquifer Test. This research evaluated the geothermal potential of the shallow hot water aquifer at Klamath Falls. Funded by a grant from the USDOE, the work included tracer studies by Stanford University, a pumping and injection test by Lawrence Berkeley Laboratories, temperature studies and collection of aquifer discharge and use data by the GHC, and sampling for chemical analysis by USGS. This effort, believed to be the most extensive testing of a direct-use aquifer, provided scientific data to be used to evaluate alternatives for district heating by the city of Klamath Falls and other users of the resource, to assess potential impacts of possible alternatives, and to aid in the evaluation of other fault-controlled geothermal systems.

1986 Binary Power Plant Performance. Three nominal 24-hour tests under summer, winter and spring weather conditions, were run on a 600 kW ORMAT geothermal binary power generation machine. The machine, located at Wabuska, Nevada, was supplied with approximately 830 gpm of geothermal fluid at 221°F and has two spray cooling ponds. During the tests, temperature, pressure and flows of supplied fluid, working fluid, cooling water and instantaneous electrical production were recorded at hourly intervals. Performance analysis was conducted on the system as a whole and on each subsystem (i.e., production well and pump, binary machine, and cooling ponds). This consisted of energy balance calculations and comparison of the results with predictions of a computer program. Further analysis of the system was performed to obtain Second Law efficiencies for each component using energy analysis. This work provided valuable information on both machine performance and instrumentation selection.

1988-1995 Injection Well Monitoring Program. The Geo-Heat Center designed and maintains a computerized well testing and long-term monitoring network of observation wells (5). The purpose is to monitor reservoir (water level and bottom hole temperature) and environmental effects due to injection of geothermal fluids by Oregon Institute of Technology and Merle West Medical Center wells.

1988-1989 A Materials and Equipment Review of Selected U.S. Geothermal District Heating Systems. Information was assembled by the GHC on the original design and subsequent performance of a selected group of geothermal district heating systems, which have logged at least three years of operation. Specific areas of investigation were equipment type and materials of construction for: production pumps, transmission piping, customer connect time, and disposal. The operational performance of the equipment in each of these areas was described and will serve as a reference to designers of new systems and operators of existing systems.

1989-1991 Geothermal Direct Use Engineering and Design Guidebook. The OIT GHC published the Guidebook for the technical community and users of low-to moderate-temperature geothermal resources. The Guidebook, 401 pages, represented two years of cooperative effort by the Geo-Heat Center, Idaho National Engineering Laboratory, University of Utah Research Institute, Battelle Pacific Northwest Laboratories, Radian Corporation and Washington State Energy Office. Its purpose is to provide engineers with comprehensive technical information for space heating and cooling of buildings, district heating, greenhouse heating, aquaculture and industrial processing using geothermal resources. It also covers geology, exploration, well drilling, reservoir engineering, materials selection, well pumps, piping, heat exchangers, space heating equipment, heat pumps, absorption refrigeration, engineering cost analysis, regulatory codes and environmental aspects. The Guidebook was updated and reprinted in 1991.

1992-1995 Low Temperature Assessment for 10 Western States. The purpose of the project was to bring the inventory of the nation's low-to moderate-temperature (20 to 150°C) geothermal resources up-to-date and to encourage development of the resources. A database of more than 9,000 thermal wells and springs has been compiled for ten western states, an increase of 80% compared to the previous assessments in the early 1980s. The databases developed by State Teams include location, descriptive data, physical parameters, water chemistry and references for sources of data. Computer generated maps are also available for each state. State Teams have identified more than 50 high priority areas for near-term comprehensive resource studies and development. Collocated resources (a city within 5 miles of a resource) were identified for 256 cities in nine western states and resource information was sent to Economic Development Centers in the counties.

CONCLUSIONS

The Geo-Heat Center continues to provide geothermal services to the public, consultants and potential users of resources. These services are in the form of Technical Assistance, R&D activities and dissemination of information through the publication of the Quarterly Bulletin, technical papers, reports and tours of geothermal facilities in the Klamath Basin. The Technical Assistance program provides information to about 360 requests per year. R&D projects to help solve problems and reduce the cost of building and operating direct-use systems, projects planned for FY-96 include: (1) economics of moderate density geothermal district heating systems, (2) geothermal district heating marketing strategy continuation and (3) strategies for geothermal greenhouses. A geothermal library of over 5,000 volumes is maintained and made available through the Geothermal Resources Council's online library system. A publications list of over 120 items can be obtained by writing the Center.

HISTORICAL IMPACTS OF GEOTHERMAL RESOURCES ON THE PEOPLE OF NORTH AMERICA

John W. Lund
Research Associate
Geo-Heat Center

ABSTRACT

The Indians of North America considered hot springs as a sacred place where the "Great Spirit" lived, and thus were great believers in the miraculous healing powers of the heat and mineral waters. These areas were also known as neutral ground; where warriors could travel to and rest unmolested by other tribes. Even though archeological finds date Native American presence at hot springs for over 10,000 years, there is no recorded history prior to the arrival of the Europeans in the 1500's. Many legends concerning geothermal activities are part of the Native American oral history, such as about Madame Pele, the Hawaiian goddess of volcanic fire, and the story of the battle between Skell and Llao describing the eruptions of Mt. Mazama (Crater Lake) and Mt. Shasta. Obsidian was one of the prized volcanic trading items used by the Indians for tools and weapons.

INTRODUCTION

The history of geothermal use prior to the industrial revolution, centers itself mainly in the volcanic region of western North America. A few isolated locations are also found in the middle and eastern part of the continent. The use of the geothermal resources during this period was by Paleo-Indians and Indians, the latter also referred to as Native Americans. Even though archeological finds date Native American presence at hot springs for over 10,000 years, there is no recorded history prior to the arrival of the Europeans in the 1500's. Rock paintings (pictographs) and rock carvings (petroglyphs) are their only source of writing available; however, as far as the author knows, none depict geothermal phenomena. With the discovery of these geothermal phenomena by the Europeans, the "ownership" and use changed considerably, with many becoming commercial operations. Thus, the use of geothermal springs and related phenomena have gone through three stages of development in North America: first (1) use by Indians as a sacred place, then (2) development by the early European settlers to emulate the spas of Europe, and finally (3) as a place of relaxation and fitness, and as an energy source for heating and/or cooling in modern times.

EARLY SETTLEMENTS

The time of the first human incursions into North American are subject to debate; however, it is generally accepted that it is associated with the land bridge between Siberia and Alaska, called Beringia, that was formed during the Pleistocene epoch (Figure 1). In the last stage of this glacial period, the Wisconsin or Weichsel glacial advance, so much of the ocean's water was tied up in glaciers, that the oceans were approximately 100 m lower (Figure 2). As a result a dry land bridge formed between the Bering and Chukchi seas that was up to 2000 km wide. The land bridge probably existed from 50,000 to 40,000 ybp (years before present) and from 25,000 to 14,000 ybp. It vanished all together about 10,000 ybp (Figure 2). (Fagan, 1985).

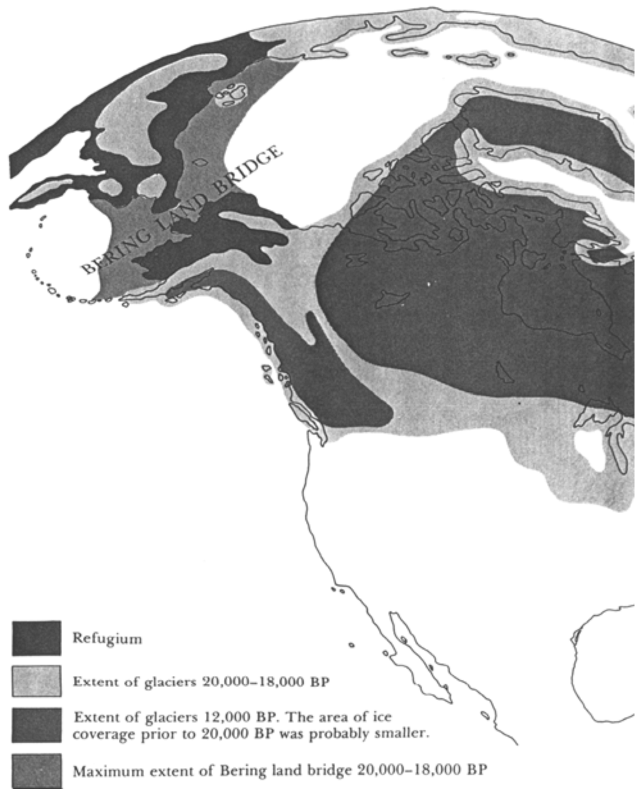

Figure 1. Bering land bridge (Beringin)(Fagan, 1985).

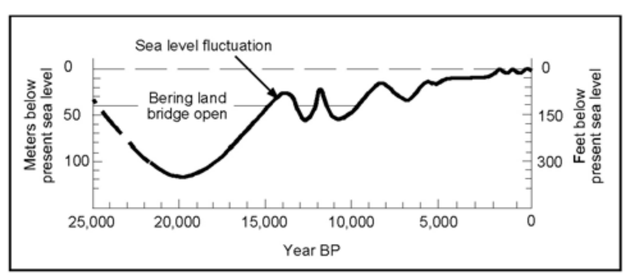

Figure 2. Beringia chronology (Fagan, 1985).

Small bands of hunters from east Asia probably followed game migrating eastward across this wide area characterized by long winters, short summers, and continual winds. However, the snow thawed in summer exposing many marsh areas and lush meadows, thus making it somewhat attractive for these migrations. This ice free summer bridge, led into the ice free interior of Alaska called Refugium (the refuge) (Jennings, 1978). It was in this area that the first Paleo-Indian site was discovered, and is the oldest dated site in North America. Old Crow Flats near the Alaska-Canada border, depending upon the reference, is dated between 40,000 and 25,000 ybp (Dumond, 1978, and Fagan, 1985).

Later on, ice free corridors did open up into the central portion of North America between the Cordilleran and Laurentide ice sheets. This corridor is estimated to have existed before 18,000 ybp and after 12,000 ybp, and emptied into the central plains around present day Edmonton, Canada. Some advanced parties of Paleo-Indian hunters, pursuing game such as mammouth and bison may have moved into the central plains as early as 25,000 to 20,000 ybp as evidenced by dated sites in the Ohio Valley (Meadowcroft Cave) and hunted remains as far south as Mexico. The dates on these sites are questionable, with the first well-attested settlement dated at 15,000 ybp (Fagan, 1985). However, significant groups of the Paleo-Indians hunters of the Llano and Folson-Plano groups had only moved as far as Edmonton by 11,500 ybp.

The early documented sites such as Clovis and Folsom, New Mexico; Lindenmeier, Colorado; Borax Lake north of San Francisco; Tule Springs, near Las Vegas, Nevada; and Fort Rock Cave and Alvord Lake in eastern Oregon, are dated from 13,000 to 11,000 ybp and were Paleo-Indian sites. These Paleo-Indians are best known to exist in the Great Plains and the Great Basin provinces. Around 10,000 to 9,000 ybp the Paleo-Indians were replaced by the specialized hunter-gatherer cultures or Indians. Most of Canada, due to the Cordilleran ice sheet, was not occupied until about this time. Numerous sites are dated after this period, but plains and basin sites are difficult to find due to the migratory nature of the Indians in search of game. The Indians dominated North American until they were essentially replaced by the Europeans in the east around the early 1700's and in the west around the middle 1800's.

INDIAN LEGENDS

There have been a number of legends passed down orally from generation to generation by the Native Americans. Some are still recited and others were recorded by the early European settlers and survive today. Two noted legends related to volcanic phenomena, and one related to the use of a hot spring are retold here.

<u>Hawaii - The Goddess Pele</u>

Pele rules the volcanoes of Hawai'i, and Mankind has no power to resist her. She is Pele-honua-mea of the sacred land, as Pele-'ai-honua, eater of land, and as Ka-'ula-o-ke-ahi, the spirit of the redness of the fire. In folklore she may appear as a tall, beautiful young woman, or as an old woman, wrinkled and bent with age, sometimes accompanied by a white dog. When enraged she may appear as a woman all aflame or as pure flame. Her personality is volcanic - unpredictable, impulsive, given to sudden rages and violence. Hers is both thepower to destroy and the power to create new land (Kane, 1987).

Tradition states that Pele came, as did the Polynesian discovers, by sailing-canoe from the ancient homeland in the islands of the Tahiti group. She was supposedly driven from this ancestral home by her elder sister, goddess of the sea and of water, for seducing her husband. Her first landfall was in the northern islands of the Hawaiian archipelago. Pele needed a deep pit for her home wherein the sacred fires could be protected. Her sister followed and put out the fire, thus Pele moved southeastward along the island chain digging new craters. But each effort was flooded out by her sister (Figure 3). We thus find that on the geologically-older island of Kaua'i the craters have become wet swamps, and volcanic evidence becomes progressively more recent as we move down the island chain toward the Big Island of Hawai'i. The myth coincides with the modern geological theory of shifting plates, in which the islands are built in an assembly line as the ocean floor slid northwestward over a "hot spot" in the crust. the power to destroy and the power to create new land (Kane, 1987).

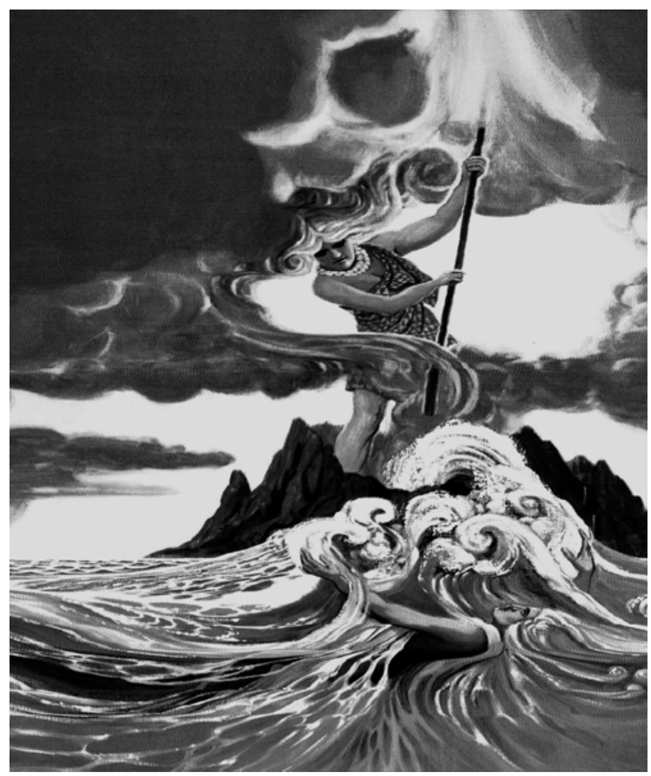

Figure 3. Madam Pele and her sister Kahai, on Hawaii (Kane, 1987)

Since Pele's sister, Na-maka-o-Kaha'i was older, she was also more powerful, for water was believed to be more powerful than fire. The two finally locked in battle on the island of Maui, in which Pele was torn apart. A hill named

Ka-iwi-o-Pele (the bones of Pele) stands at the site of the battle and is believed to be her mortal remains. With Pele's death, her spirit was freed and elevated to godly status and took flight to the island of Hawai'i. She now has a permanent home on Mauna Loa, Earth's largest mountain.

This legend was brought home to the author during a lecture tour of several of the islands where the use of geothermal energy was discussed. Our lecture group was on Maui, the island just northwest of Hawaii. We were proposing to drill on the slopes of the volcano Hale-a-kala (last erupted in 1790, but was most active 400,000 to 800,000 years ago) and use the geothermal energy. After our presentation, an old Native Hawaiian stood up and lectured us for over an hour about volcanic geology from Pele's point of view. He warned us that drilling on Maui, would bring Pele back from the island of Hawaii and cause destruction to the residents of Maui.

Pele still lives in the hearts and minds of the native Hawaiians. Her personification is in the natural phenomena of volcanic activity. Hawaiians refer to her as Tutu Pele (an affectionate term for grandparents), and look upon her with respect. In a recent eruption where lava destroyed part of the village of Kalapana, a Hawaiian resident interviewed after losing his land said: "I love my home, live here all my life, and my family for generations. But if Tutu like take it, it's her land" (Kane, 1987). As part of the respect for Pele, older Hawaiians still offer the first 'ohelo berries picked to her, before eating any. Some still bring gifts of flowers, food and drink and set them on the rim of Halema'uma'u crater within the Kilauea caldera. They also refrain from any acts that might be disrespectful to Pele. Tourist who have taken souvenirs of rock with them home from Hawaii Volcano National Park, have often returned them to the National Park Service with a note describing misfortunes that have occurred since their removal. They hope by this action, to be released from Pele's terrible spell.

Oregon - The Battle of Llao and Skell

American Indians commonly interpreted natural catastrophes as the actions of invisible spirits who controlled the physical world. The Klamath Indians of southern Oregon devised a remarkable myth to explain the origin of Crater Lake (Harris, 1990). This legend was told to a young soldier by Lalek, an aged Klamath chief in 1865. He emphasized that the story was ancient, when his people lived in rock houses and white men ran wild in the woods. The story explains the cataclysmic eruption of Mt. Mazama, its collapse and the formation of the Crater Lake caldera about 7,700 ybp (Figure 4).

It is a story about Llao, Chief of the Below World, Skell, Chief of the Above World, and Loha, a beautiful young woman. Llao saw this woman one day when standing atop of Mt. Mazama, and begged her to return with him to his lodge in the Underworld. Even though he promised her eternal life, the maid refused to go with him. Her people would not force Loha to accept Llao's offer; thus, he thundered angrily and tried to destroy her people with fire. Skell came to the rescue by descending from heaven to the summit of Mt. Shasta (200 km south of Mt. Mazama). In the battle that followed the sky glowed and then turned dark, and the earth shook and fire flowed from Llao's mountain to burn the forests. Loha's tribe was driven from their home and forced to flee into the waters of Klamath Lake to the south.

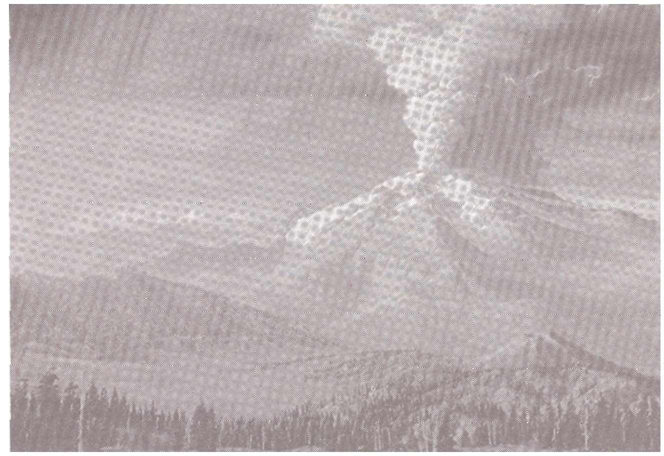

Figure 4. Mt. Mazama during eruption (P. Rockwood).

Two brave medicine men tried to save their people by hurling themselves into the fiery mouth of the underworld. Noting their sacrifice, Skell again shook the earth, causing Llao's mountain to crash down upon him. When finally the dark clouds of ash cleared and light returned, the lofty peak was gone and was replaced by a giant hole. The curse of fire was lifted and the caldera was gradually filled with rainwater, forming Crater Lake. This myth is similar to the Greek story of Hades, god of the Underworld who pursued the Maid Persephone and carried her off to his underworld kingdom.

The Llao-Skell myth described closely the geologic events that occurred in the formation of the Crater Lake caldera. It also states correctly that Mt. Mazama did not loose its summit by blowing itself apart, but by emptying much of its underground magma reservoir, allowing the volcanic cone to collapse instead. It also describes the frequent eruptions of Mt. Shasta over the last 10,000 years, as the Klamath myth reports that Skell visited Shasta often, starting fires upon each visit. Finally, the subsequent eruption in the Crater Lake caldera forming the Wizard Island cinder cone, represents the maid Loha.

Montana - Sleeping Child

Sleeping Child Hot Springs is located in the Rocky Mountains south of Missoula, Montana. The beauty of this hot springs was first discovered by the Nez Perce Indians in the 1870's. Chief Joseph of the Nez Perce led his tribe out of the reservation and through the Lolo Pass into the Bitter Root Valley. In pursuit of Chief Joseph and his people were General Howard and a group of soldiers. Trying to avoid a confrontation, Chief Joseph split his tribe into smaller groups. One such group traveled through what is now Sleeping Child Creek and, facing a possible battle, they left their infants by the hot springs. When they returned, the infants were safe and peacefully sleeping, protected by the natural hot springs. Thus, Sleeping Child Hot Springs was named (Figure 5).

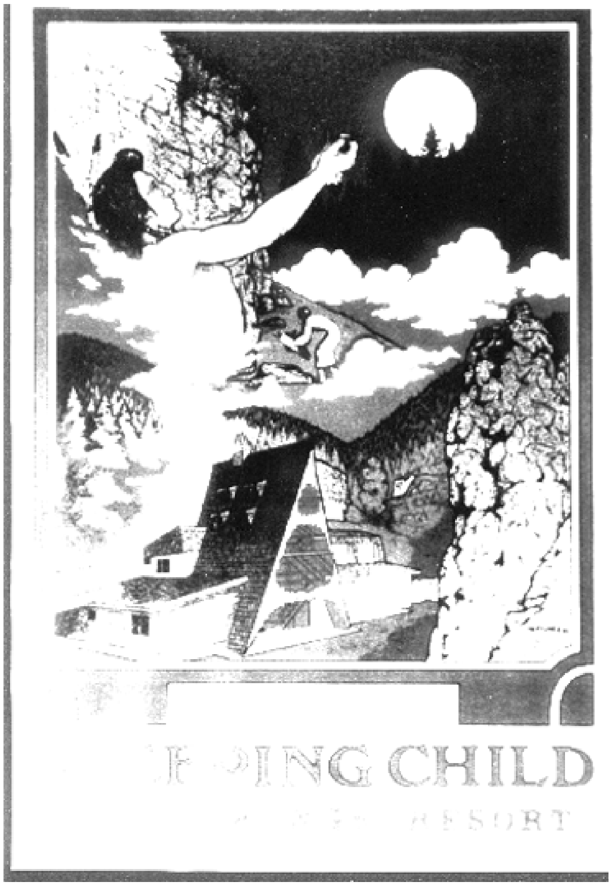

Figure 5. Poster from Sleeping Child Hot Springs.

THE INFLUENCE OF HOT SPRINGS

The Indians of the Americas considered hot springs as a sacred place where the "Great Spirit" lived, and thus were great believers in the miraculous healing powers of the heat and mineral waters. Every major hot springs in the U.S. and Canada has some record of use by the Indians. They were also known as neutral ground, where warriors could travel to and rest unmolested by other tribes. Here they would recuperate from battle. In many cases, they jealously guarded the spring and kept its existence a secret from the arriving Europeans for as long as possible. Battles were sometimes fought between Indians and settlers to preserve these rights. The early Spanish explorers such as Ponce de Leon and Hernando DeSoto were looking for the "Fountain of Youth", which may have been an exaggerated story of the healing properties of one of the hot springs (Lund, 1993).

The early European settlers in the 1700 and 1800's, found and used these natural hot springs and later realizing their commercial value, developmented many into spas after the tradition in Europe. Many individual developments were successful such as at Saratoga Springs, New York; White Sulphur Springs, West Virginia; Hot Springs, Virginia; Warm Spring, Georgia; Hot Springs, Arkansas; Calistoga, California; and Harrison Hot Springs, British Columbia. However, the U.S. did not have the government, trade unions, social security and a national health insurance program to support these developments. Thus, in spite of the benefits of spa therapy that had been proven successful in Europe and elsewhere in the world, the U.S. lagged behind in the development of these mineral springs even though some were acquired by states and the federal government. By the 1940's, the interest in spas languished, and most of the majestic resorts went into decline and closed. In recent years, the interest in hot springs soaking and physical finess has renewed the development of spas. Since these recent developments are beyond the scope of this paper, the reader is referred to Geo-Heat Center Quarterly Bulletin (Vol. 14, No. 4, March, 1993) for further details.

Examples of some of the early uses of hot springs by Native Americans are summarized below.

<u>Warm Springs, Georgia</u>

Warm Springs is the most famous of Georgia's seven known warm springs. It has the largest flow of up to 58 L/s with an average temperature 31ºC. The main mineral constituent is bicarbonate. For the local Creek Indians, the springs were probably a place of healing where the Indians of all tribes were allowed to bring their sick and wounded to drink the waters and bathe in the mud. The Iroquois Indians of New York State (1500 km north) used to visit the Creeks in Georgia and called this country "the land where the waters are warm." A number of trails ran through the area, maintained by the Indians and used by all travelers, many who stopped at the springs. The trails later became military and post roads, and a number of taverns with crude accommodations were set up along them, including one at Warm Springs in the early 1800's. The land was obtained by white settlers in 1825 after signing a treaty with the Lower Creek Indians. The original springs were called Meriweather Warm Springs after General David Meriweather of Revolutionary War fame. After several stages of commercial development, the springs became the site of a polio treatment center, made famous by President Franklin Delano Roosevelt.

<u>Saratoga Springs, New York</u>

The Saratoga Springs are located approximately 40 km north of Albany, New Work and just south of the Adirondack Park. Approximately 18 springs discharge 13ºC carbonated mineral water along the Saratoga fault between Whitehall and Albany, a distance of 105 km. The springs have been used for drinking and bathing in spas where it has been considered a cure for everything from skin disorders to digestive problems, and the water and carbon dioxide bottled and sold as a commercial product. The Mohawk and Iroquois Indian tribes used this area for hunting and frequented the springs, especially High Rock Spring (Figure 6). The Mohawks, a fierce warring tribe, fought to defend their hunting grounds around the springs on many occasions. They called the area Kayaderosseras. The springs were probably used by other tribes, as they lay on the path between Quebec and the Mohawk Valley. The first written record of the springs was in 1642, when the Mohawks returning from a raid on Quebec, brought with them a Jesuit priest who they had captured. They stopped by a spring and were refreshed by the bubbling waters (Swanner, 1988). There is an unsubstantiated story of Sir William Johnson being carried to the springs in 1767 by Mohawk braves for treatment of a wound he had received in the Battle of Lake George in 1755. Probably the first settlers to visit the spring were surveyors in the 1760's. They were most likely attracted to the area by the great number of animals that frequented it as a salt lick. The spring was included in the Kayaderosseras Patent in 1771 and purchased by European settlers. After a number of different ownerships and over exploitation, a majority of the land was taken over by the State of New York and is now administered as a state park.

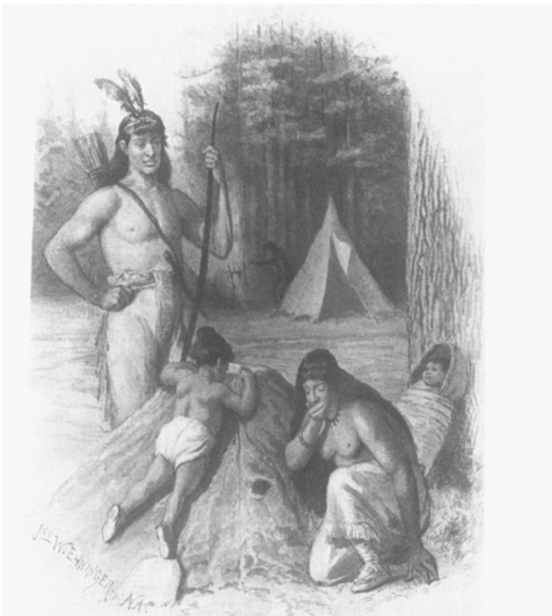

Figure 6. Mohawk Indians at High Rock Springs, NY (Swanner, 1988)

Hot Springs, Arkansas

Hot Springs, Arkansas was one of the most popular commercial spa areas in the United States, created to imitate the development of great spas in Europe - so popular that in 1832, it was made into a Federal Reservation and finally by 1921 into a National Park. It is the only national park in the U.S. created just to protect hot springs for spa use. This natural geothermal resource consists of 47 springs producing a total of about four million liters per day of 61^{o}C water.

The National Park Service estimates that the Arkansas hot springs have been used by humans for at least 10,000 years. The "Valley of the Vapors" was an honored and sacred place to the Indians. They believed this was the home of the "Great Spirit" who brought forth the healing warmth of "Mother Earth." The waters were supposedly warmed by "His" breath. Like many hot springs of the "New World", this was neutral ground. Warriors of all tribes could rest and bath here is peace - a refuge from battle. Stone artifacts found near the springs give archeological evidence that Indians used the waters extensively. Early European explorers and settlers on the east coast pushed the Indians westward, and as a result Quapaws and part of the Cherokee Nation wandered into the area. Legend reports that DeSoto or one of his scouts from the 1541 expedition were the first Europeans to visit the site (Figure 7). He was evidently in the areas as he claimed the territory for Spain. It is certain that French trappers, hunters, and traders were familiar with the area in the late 1700's (Bedinger, 1988).

Figure 7. DeSoto's legendary visit to the hot springs is depicted by this statue in the Fordyce Bathhouse (Bedinger, 1998).

The French actually ruled the area until 1763 when the territory west of the Mississippi was ceded back to Spain. It was again taken by France in 1800 under Napoleon Bonaparte, and finally purchased by the United States as part of the Louisiana Territory in 1803. During this period, no written record of travel to the hot springs are known; but, they were probably visited many times as evidenced by crude log cabins and huts found at the site in 1804. The spring water was first analyzed in 1804, and permanently settled starting in 1807. The first settler, Jean Emanuel Prudhomme, a plantation owner, was introduced to the springs for his health by the Natchitoches Indians, and remained in the area for a year. It became famous for curing ailments and thus the first bathhouse was opened in 1830 for visitors. The Federal Reservation followed and the development reached a peak in the early to middle 1900's. The National Park Service still exercises control over the geothermal resource and commercial development in the approximately 2000 ha park.

Thermopolis, Wyoming

Thermopolis, a Greek word for "Hot City", is located in north central Wyoming at the mouth of the Wind River Canyon, approximately 160 km south of Yellowstone National Park. At least eight hot springs in the area have created large travertine terraces along the river. The Big Horn Spring, claimed to be the largest mineral hot spring in the world, flows at 120 L/s with a temperature of 56^{o}C.

Indians have lived in the area for at least 2000 years based on evidence associated with Legend Rock Petroglyphs in sandstone cliffs about 40 km northwest of town. The hot springs were known as having "healing water" and were known as "Bah-gue-wana" or "smoking waters" by the Shoshones. Chief Washakie of the Shoshone tribe (who later signed the treaty with the Federal Government) is reported to have had a bathhouse erected over Black Sulfur Springs at Thermopolis. Originally the Big Horn Spring was included in the Shoshone Indian Reservation Treaty of 1868. The spring became know for its "health giving properties" and the U.S. Congress was requested to set aside the area for a National Park or Reservation. In 1896, a treaty was signed between the Shoshone and Arapahoe Indians and the federal government which gave the public use of the hot springs. The condition of the treaty was that one quarter of the water of the Big Horn Spring would be set aside for free use by the public. The management of the springs was turned over to the State of Wyoming in 1897 forming Hot Springs State Park. The State Bathhouse was constructed to fulfill the condition of the treaty.

Today the State Park provides geothermal water to four commercial establishments, the Pioneer Center a retirement home for state residents, and The Gottsche Rehabilitation Center, a therapy center.

Wyoming - Yellowstone National Park

Since 1808, when John Colter described the hot springs of "Colter's Hell," attention has focused on Yellowstone. The Indians, of course, knew and used the spring for centuries. White men "discovered" many of the springs early in the 1800's, following Colter's visit. Public interest in the preservation of the many spectacular thermal features in Wyoming's northwest corner led to the establishment of Yellowstone National Park, the nation's first, in 1872.

Wyoming - Guernsey

Even though this is the location of a few small springs near the southeast corner of the Wyoming, it is probably the most famous thermal feature in the state. Although early immigrants may have heard vague tales of "Colter's Hell" and the Yellowstone country, thousands of them had actually seen the Guernsey springs. The immigrants of the famous Oregon Trail knew this spring as a welcome landmark, a place to soak sore feet and wash dusty clothes. It was appropriately named "Immigrants' Washtub." In 1858, soldiers of nearby Ft. Laramie set up a lime kiln to use the limestone from which the springs rise. The springs were then known as "Lime Kiln Springs." Today the 21ºC springs serve as watering holes for cattle (Breckenridge and Hinckley, 1978).

California - Calistoga

Located approximately 120 km north of San Francisco, this resource is at the northern end of the famous Napa Valley and is also the southern end of The Geysers geothermal field. The area is noted for numerous geysers and hot springs with surface temperature near 100ºC. The area was originally settled by the Pomos and Mayacmas Indians. These early people, called Wappo by settlers, came from a wide area to use the natural hot springs, fumaroles, and heated muds to soothe aches and pains. To the Native Americans this was "Tu-la-ha-lu-si, the beautiful land"; and the hot, spongy turf was "Coo-lay-no-maock, the oven place", according to a local historian. As with many geothermal areas of the west, the Indians were the original geothermal users and appreciated this natural energy resource. They also used the local cinnabar for red war paint. Later on, this mercury ore would also be mined by white men (Archuleta, 1977).

In the early 1800's, the Spanish explorers visited the area looking for a possible mission site. Naturally, they referred to the site as "Aqua Caliente - Hot Water", as are many other geothermal areas in the southwest of the United States. These missionaries did not establish a mission here, but it is believed that they planted the first grape vines to be used for sacramental wines, and the golden mustard which even today is found in the orchards and vineyards in early spring. In 1862, Samuel Brannan established a resort and spa similar to Saratoga Hot Springs in New York. The name Calistoga resulted in a combination of California and Saratoga. The area is still a spa community today, in the heart of the Napa Valley wine country.

British Columbia - Harrison

Geothermal resources in Canada are primarily located in British Columbia where one of the most famous is Harrison Hot Springs located about 80 km east of Vancouver. The springs and resort are referred to as "The Spa of Canada." Two hot springs at 50 and 65ºC are located near the south end of Lake Harrison. The Indians knew of the springs and of "Keekwully Tybee who sent up the medicine waters all hot from below." They believed the springs of boiling water - "Warum Chuck" - were of supernatural origin, and regarded the hot water in the lake with reverence and awe. They also believed that those who drank the water were given some mystic powers of endurance over their fellow men. According to some of the stories they believe the waters will boil as long as there is sickness in the land. The natives referred to the lake as "Lake Qualts", meaning hot water (Rendall, 1981).

The springs were probably discovered by Europeans in 1859, when one member of a nearly frozen group of miners sailing on the lake, toppled into the water from weakness. He was so content with the warmth, that the rest joined him. They survived and continued their journey. In the late 1800's a hotel and bath house were built adjacent to the springs. It boasted that the hot sulphur springs provided "a sure cure for paralysis, rheumatism, syphilis, diabetes, neuralgia, skin diseases, mercurial poisoning, dipsomania, and all diseases of the womb, liver, and kidneys, besides many other maladies to which human flesh is heir." The Harrison Hot Springs Hotel, without the promise of cures, is a luxury resort operating today at this location.

Alaska

Indians and Eskimos throughout Alaska, from the Seward Peninsula to the isles of southeastern Alaska, were aware of geothermal springs. Kruzgamepa Hot springs, 80 km north of

Nome, now known as Pilgrim, was utilized for bathing years before the white man arrived. People visiting Chief Shakes Hot Springs, near Wrangell in southeastern Alaska, still use the wooden cribs placed there by the Tlingit Indians prior to the Russian arrival in Alaska. Some springs held mystical powers, such as Kilo Hot Springs in north central Alaska. Hooniah or Tanakee Hot Springs, one of the best known resorts in the early part of this century in southeastern Alaska, are still used by he natives, although it is still in a primitive state (Markle, 1979).

When the Russians began colonizing Alaska, they followed the Indian's example of leaving most springs as they found them. Most of the Russian and early American settlements, were not located near a geothermal resource. This was due in part to the nomadic fur traders who did not tarry long at any one place, and travelled mainly along the coast; whereas most of the springs were located inland. In the late 1800's, with the discovery of gold, many of the hot springs were developed for use by the miners who had now moved inland. Chena, Manley and Circle hot springs are examples of those developed by miners in the Fairbanks area, and are still operating. Many others have gone into decline and are little used today.

THE INFLUENCE OF VOLCANOES

Arizona - Sunset Crater

About 900 ybp (1075 AD), the eruption of Sunset Crater east of Flagstaff spread a blanket of volcanic cinders and ash over a large part of the land occupied by the Sinagua Indians. This eruption produced a marked change in the living patterns of the area. After it produced a brief disruption, the Sunset Crater cinder fall is thought to have provided a moisture-conserving mulch that made the area more attractive to dry farmers to grow maize. The larger number of sites in the immediate posteruptive period and the appearance of traits from other Indian tribes (Anasazi, Mogollon, and Hohokam) suggest that there was in-migration from neighboring areas at this time (Lipe, 1978).

Oregon - Mt. Mazama

Eastern Oregon was inhabited by a historic people from approximately 11000 ybp to present time. However, evidence of occupation all but disappear after the eruption of Mt. Mazama (forming Crater Lake) around 7,700 ybp. The landscape was blanketed with a layer of volcanic ash and pumice, measured over eight meters in depth in some places. There was not significant reoccupation of the area until about 5000 ybp. The characteristics of the tools, baskets and plant food resources changed markedly with this reoccupation (Aikins, 1978). The eruption of Mt. Mazama was dated by carbon-14 means based on charred sandles found buried under the pumice and ash in Ft. Rock Cave, about 100 km northeast of the mountain.

Hawaii - Kilauea

In 1790 the rule of Hawaii was being contested by several chiefs. The two main contenders were Keoua, considered a dangerous upstart by the other chiefs, and Kamehameha, the future ruler. After several inconclusive battles on the "Big Island" of Hawaii, Keoua was returning to his home district with his army, accompanied by wives and children of the soldiers. They were walking along the flank of Kilauea volcano when part of Keoua's army was completely destroyed by a rain of hot ashes, rocks and poisonous gasses from the mountain (Figure 8). Badly shaken by this disaster, no doubt believing the Pele had turned against him, Keoua lost the will to continue the war and Kemhameha became the ruler (Kane, 1987).

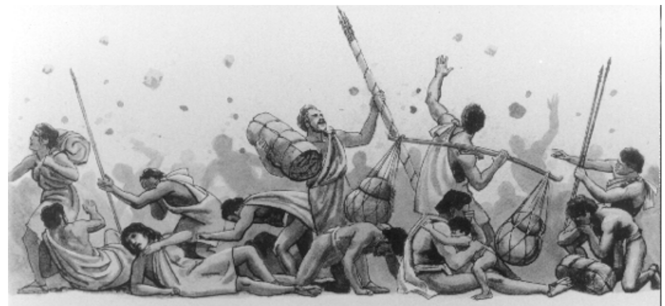

Figure 8. Keoua's army being destroyed by Kilauea's eruption (Kane, 1987).

USE OF VOLCANIC AND HOT SPRING MATERIAL

Obsidian and basalt have been formed into tools and weapons by the Indians since the first migrations into western North America. These implements and extensive middens of obsidian flakes can be found all through the west, but are now protected from "pot hunters" by federal law. Muds colored by sulfur and mercury deposits have also been used as paint for pottery, skins and rock art or writing (pictographs and petroglyphs). Obsidian hydration rates on the fresh surface of fractured pieces, have been used to date many prehistoric sites as far back as 800,000 years ago.

Arkansas - Hot Springs

Tunicas Indians of the Caddo Nation lived in the area of the present Hot Springs National Park. For centuries, they mined the very hard and even textured flintstone called novaculite (a form of silica similar to chert), in quarries adjacent to the hot springs. The Indians used it for weapons such as arrowpoints, spearheads, and for tools. Later, Europeans mined the novaculite for whetstones, and this "Arkansas Stone" is still mined outside the park - highly prized for its uniform sharpening characteristics (Bedinger, 1988).

California - Coso

Obsidian was highly prized by the Indians of California for tools and weapons due to being able to produce an extremely sharp cutting edge. Deposits of this material were available on the volcanic Great Basin side of the Sierra Nevada and traded across the mountains to the west side into the central valley. Finds of such material have been date as early as 5000 ybp. One source, located near Coso Hot Springs (the present site of a geothermal power plant) on the present China Lake Naval Weapons Center, had inclusion of white Christobolite (amorphous silica) in the obsidian. This unique source has been found all through the central valley. The author inspected this site in the 1960's and was amazed at the large deposit and associated midden. The author also discovered obsidian pieces from this site at nearby Little Lake attributed to the Pinto culture, estimated to be between 7000 and 2500 years old.

Similar obsidian trading from the east side of the Cascades to the west side occurred from a source in Newberry Crater of central Oregon.

Ohio - Hopewell

Over 136 kg of worked obsidian fragments were found at the Hopewell burial site in southern Ohio. These included between 250 and 500 magnificent spears probably made around 2000 ybp. Since there is no obsidian in the midwest, the source of this obsidian was traced to what is now Yellowstone National Park, about 2500 km to the northwest. Many other unusual items such as copper, mica, galena, and chlorite have also been found in these burial sites. This trade reflects the wide geographical knowledge of much of the eastern United States that some of its aboriginal inhabitants possessed. Trade helps to explain the apparent speed with which new ideas and techniques moved across long distance (Griffin, 1978).

California - Calistoga

The Indians at the north end of Napa Valley where the hot springs, geysers and fumaroles were located, traded for fish and other sea products from the coastal Indians with obsidian from the nearby Glass Mountain. In fact, Indians came from all over for the curative waters of "Coo-la-no-maock - the oven place". The Indians also came to trade for cinnabar, to be used for vermilion war paint. Later, mercury was mined here and in the Geysers geothermal field to the north. The Indians also built sweat houses over the hot pools.

CONCLUSIONS

North American Indians have a long history of association with and use of geothermal phenomena, going back at least 10,000 years. Many of these hot springs, geysers, and fumaroles were sacred places for these Native Americans, who had a special respect and understanding of the natural environment. Unfortunately, much of the oral history and legends concerning geothermal activities have been lost. We are dependent today upon archeological evidence and speculation. The present trend of hot spring users to "get back to nature" and to preserve and protect this natural resource, is not unlike the philosophy of our earliest settlers.

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Note: This is a revision of the paper published in the Proceedings of the 1995 World Geothermal Congress, Florence, Italy

COLLOCATED RESOURCES

Tonya L. Boyd
Geo-Heat Center

INTRODUCTION

Low- and moderate-temperature (20°C to 150°C) geothermal resources are widely distributed throughout the western and central United States. Numerous resources occur in the areas indicated in Figure 1, with individual reservoir areas one to ten square miles in extent. In the northern Great Plains, major aquifers with fluid temperatures exceeding 50°C extend in a continuous manner for thousands of square miles. Geothermal resources also occur at certain locations in the east.

The last major effort in assessing the national potential of low-temperature geothermal resources occurred in the early 1980s. Since that time, substantial resource information has been gained through drilling for hydrologic, environmental, petroleum and geothermal projects; but there has been no significant effort to update information on low-temperature geothermal resources.

While there has been a substantial increase (49%) in direct-heat (excluding geothermal heat pumps) utilization during the last decade, the large resource base (266 Quads, the U.S. uses about 80 Quads/yr) is greatly under-utilized. Since the thermal energy extracted from these resources must be used near the reservoir, collocation of the resource and user is required.

PURPOSE

The major goal of the Low-Temperature Geothermal Resources and Technology Transfer program was to update and compile a database of thermal springs and wells with temperatures greater than or equal to 20°C. State geothermal resource teams (State Teams) initiated their resource evaluation and database compilation efforts and have updated their resource inventories. The new digital database reports are in most cases available as Open File Reports from each State Team listed in the reference. A second important goal of the contract was to complete a statewide collocation study of these geothermal resources with communities and other potential users. This article covers the findings for the second goal, which was to complete a collocation study of geothermal resources and communities in the western states in order to identify, and encourage those communities to develop their geothermal resources.

COMPILATION OF DATA OF COLLOCATED RESOURCES

The State Teams databases were searched for all the wells and springs with temperatures greater than or equal to 50°C. From that list a Paradox database was compiled which

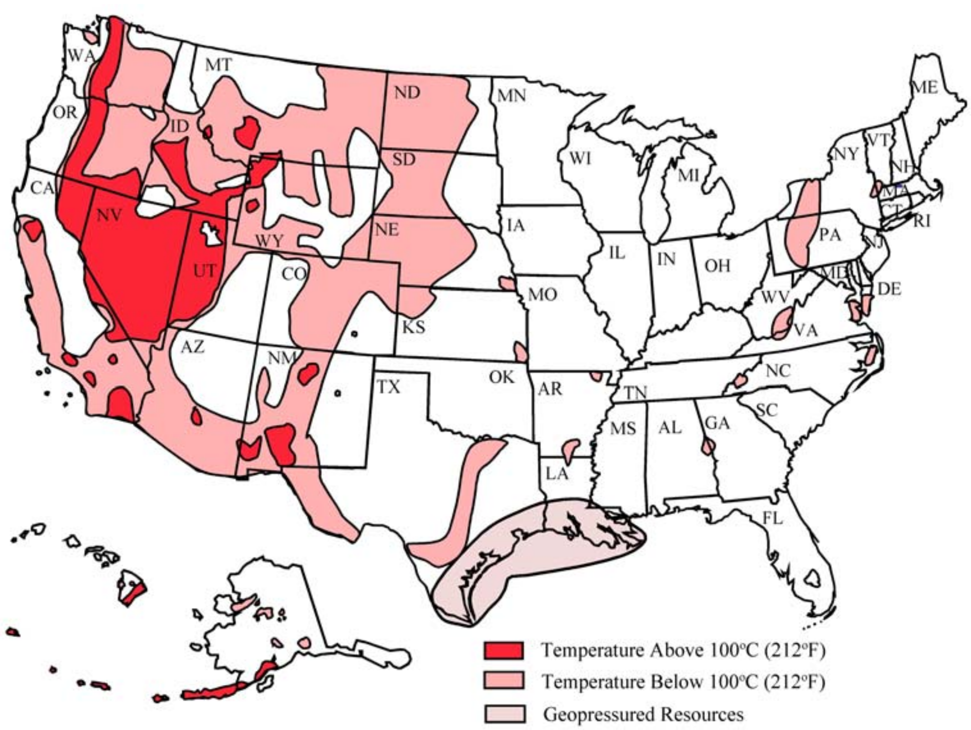

Figure 1. Geothermal resource areas of the United States.

Table 1. Section of the Collocated Resource Database for California.

	Bombay Beach	Boyes Hot springs	Brawley	Bridgeport	Bryon
County	Imperial	Sonoma	Imperial	Mono	Contra Costa
Latitude	33.3500	38.3167	32.9833	38.2500	37.8472
Longitude	115.7167	122.4833	115.5333	119.2333	121.6305
Population	500	5,937	19,450	900	1,100
Resource Temperature °C	88.0	53.1	138.0	82.0	51.0
Number of Wells	11	2	5	3	1
Typical Depth m	201.0	396.0	2,545.0	300.0	75.0
Flow L/min	2,660.0	757.0	500.0	450.0	600.0
TDS	3,800.0	1,287.0	28,000.0	4,320.0	
Current Use	Aquaculture	Baths/pools & Space heating		Power Plant	
HDD	925	3,311	925	6,022	2,806
Design Temperature	38	30	38	10	30
Remarks	11 wells, located with 5 miles of Bombay Beach.	1 spring/1 well, located with 0.5 miles of Boyes Hot Springs, and 2 miles from Sonoma.	5 wells, located within 2 miles of Brawley.	2 springs/1 well, located within 3 miles of Bridgeport.	1 well, located within 1 mile of Byron.

contained 18 data fields. The information included within the data fields are the collocated city, latitude and longitude, resource temperature, number of wells within the area, typical depth, total flow for all the resources within the area, current use, and weather data. Table 1 shows a section of the California database consisting of 5 sites out of a total 70 sites.

A collocated community was identified as being within 8 km (5 miles) of a geothermal resource with a temperature of a least 50°C (120°F). At least 1393 thermal wells and springs were identified by the State Teams of having temperatures greater than or equal to 50°C. Of those 1393 wells and springs, 1173 were located within 8 km of a community. There has been 256 collocated communities identified within the nine western states databases. The breakdown of the collocated communities by states are listed in Table 2. The communities for each state are shown on the state maps in Figures 2 through 10.

Table 2. Number of Collocated Communites within Nine Western States.

State	Number of Collocated Communities
California	70
Colorado	15
Idaho	51
Montana	18
Nevada	30
New Mexico	12
Oregon	32
Utah	23
Washington	6

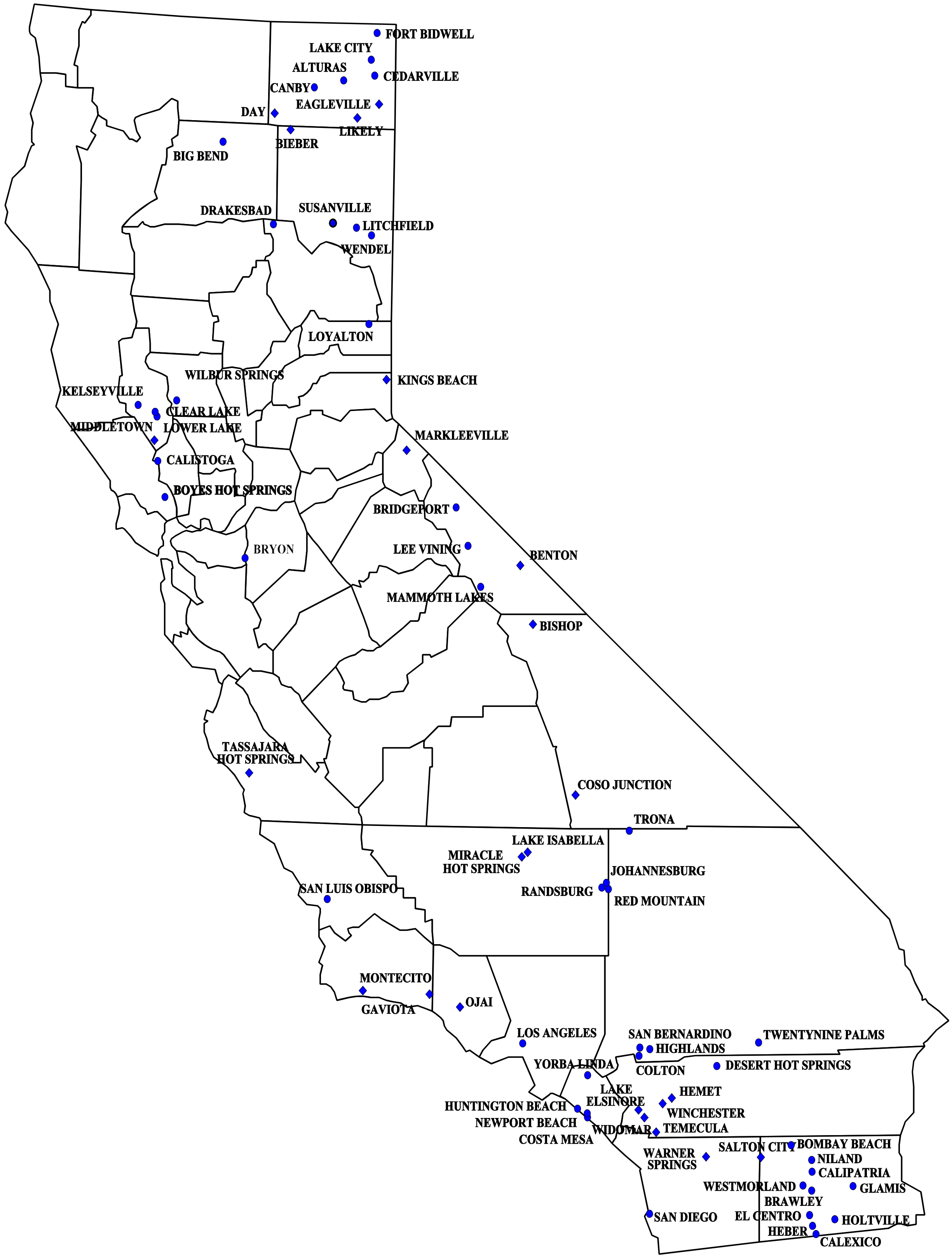

Figure 2. The 70 collocated communities located within California

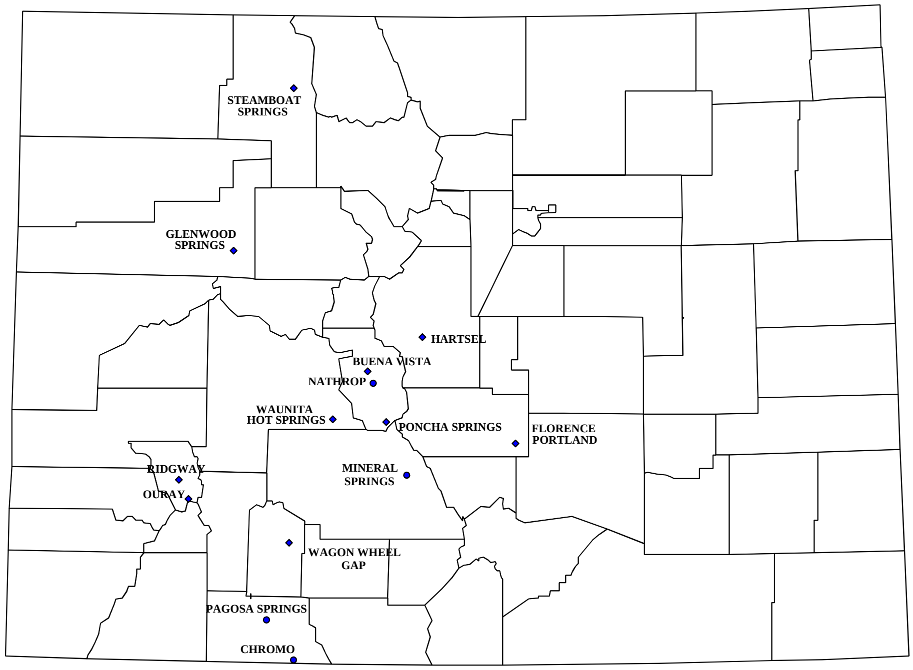

Figure 3. The 15 collocated communities located within Colorado.

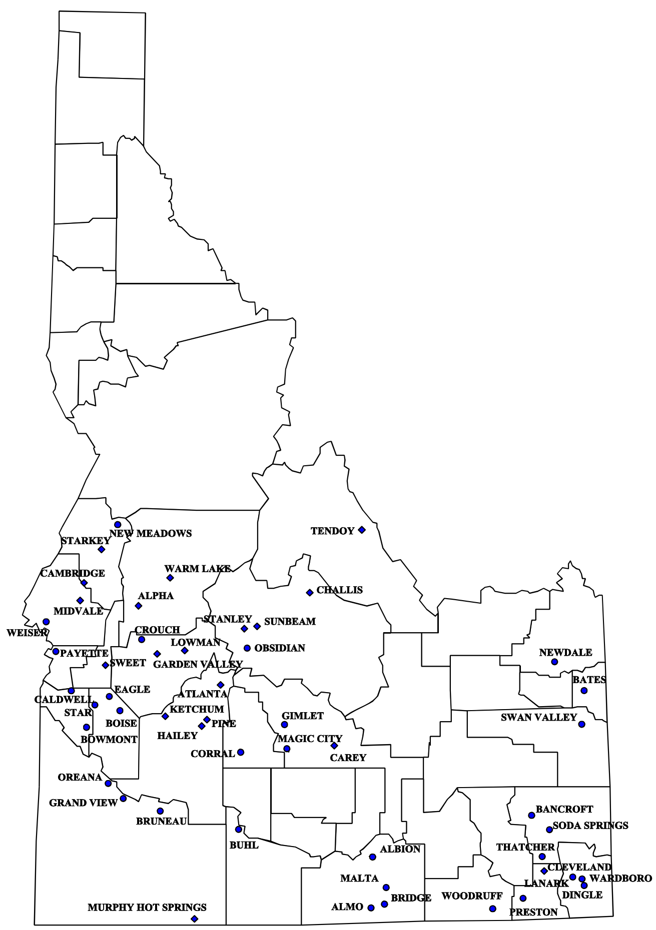

Figure 4. The 51 collocated communities located within Idaho.

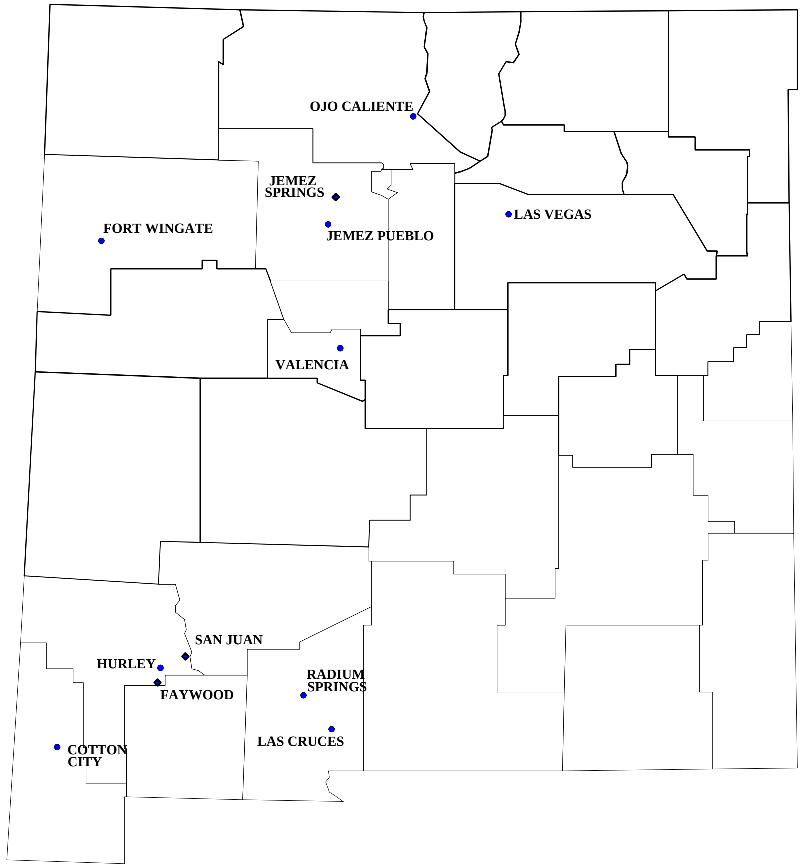

Figure 5. The 12 collocated communities located within New Mexico.

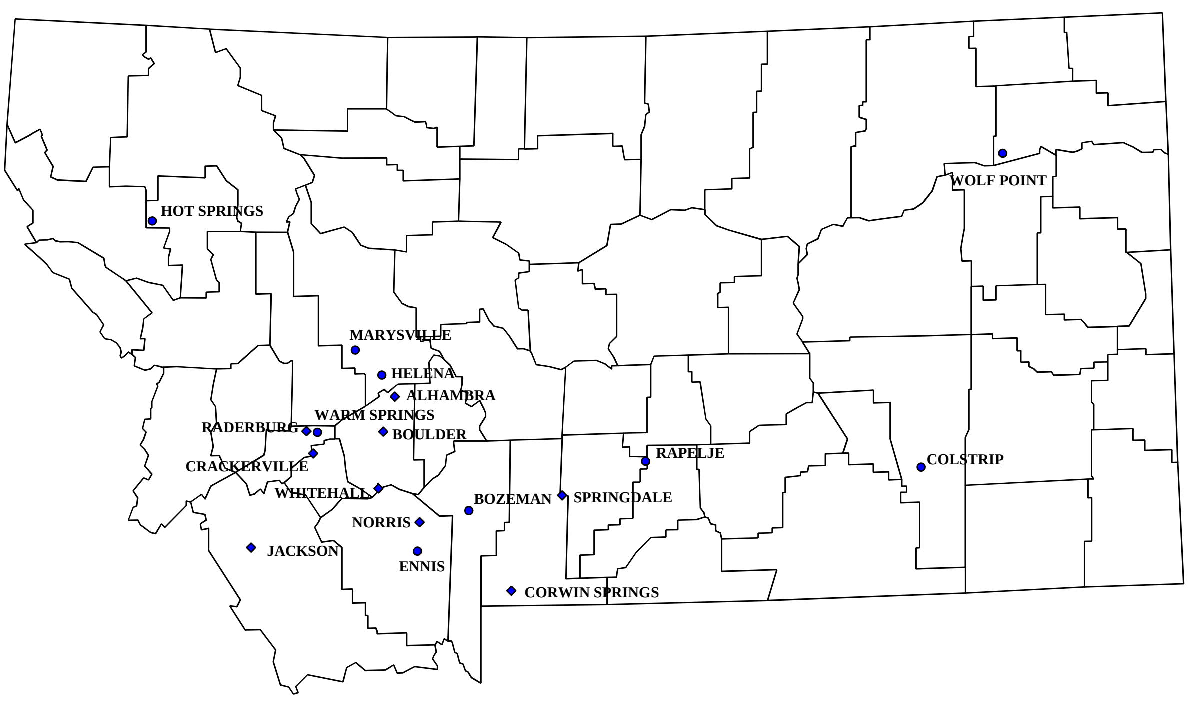

Figure 6. The 18 collocated communities located within Montana.

Figure 7. The 6 collocated communities located within Washington.

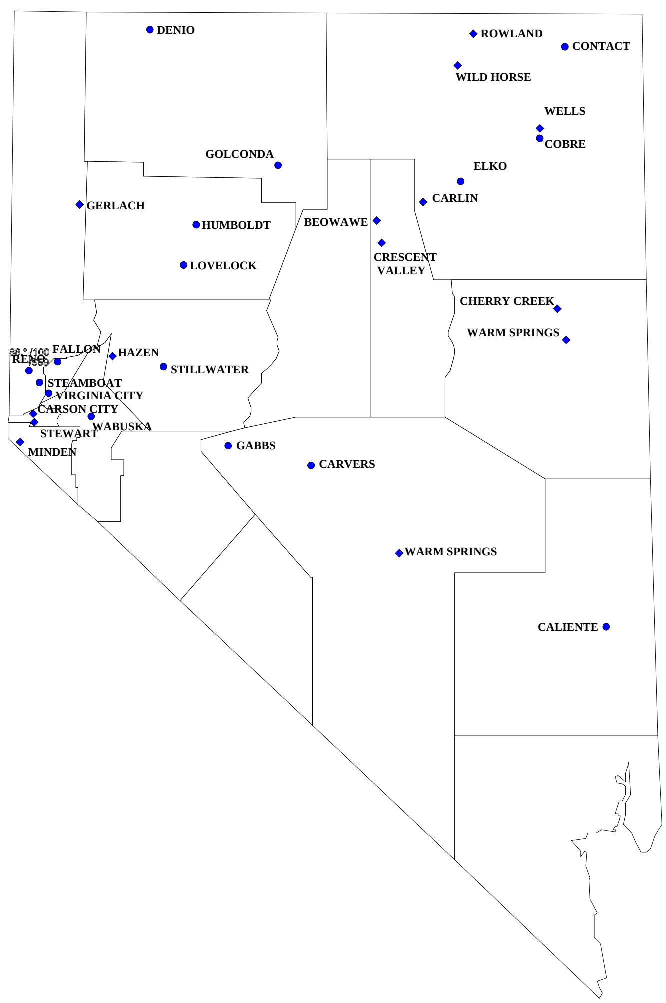

Figure 8. The 30 collocated communities located within Nevada.

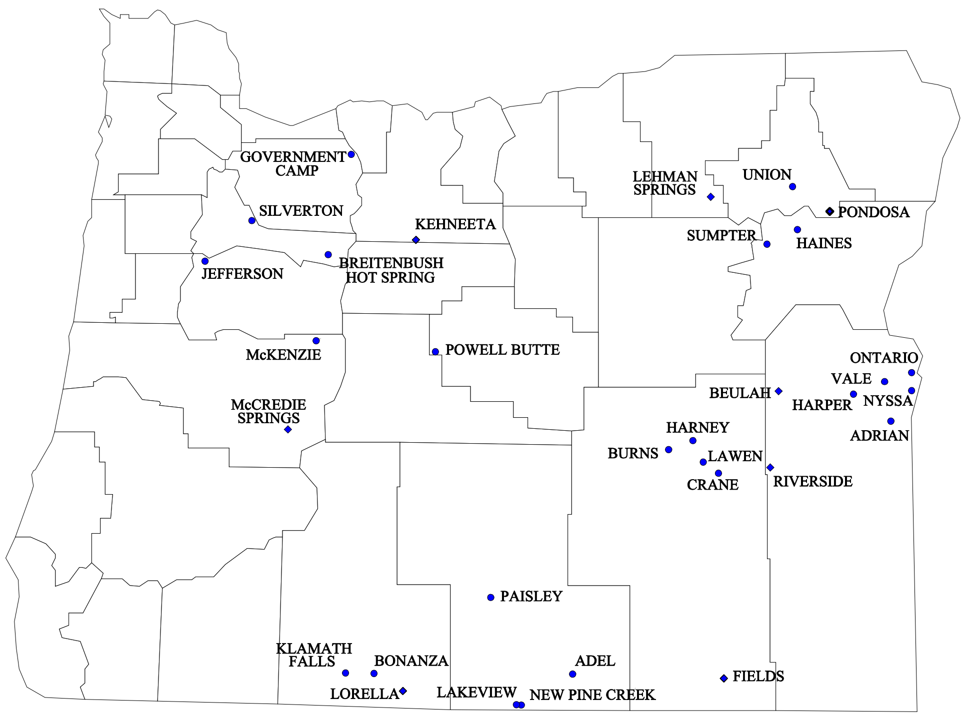

Figure 9. The 32 collocated communities located within Oregon.

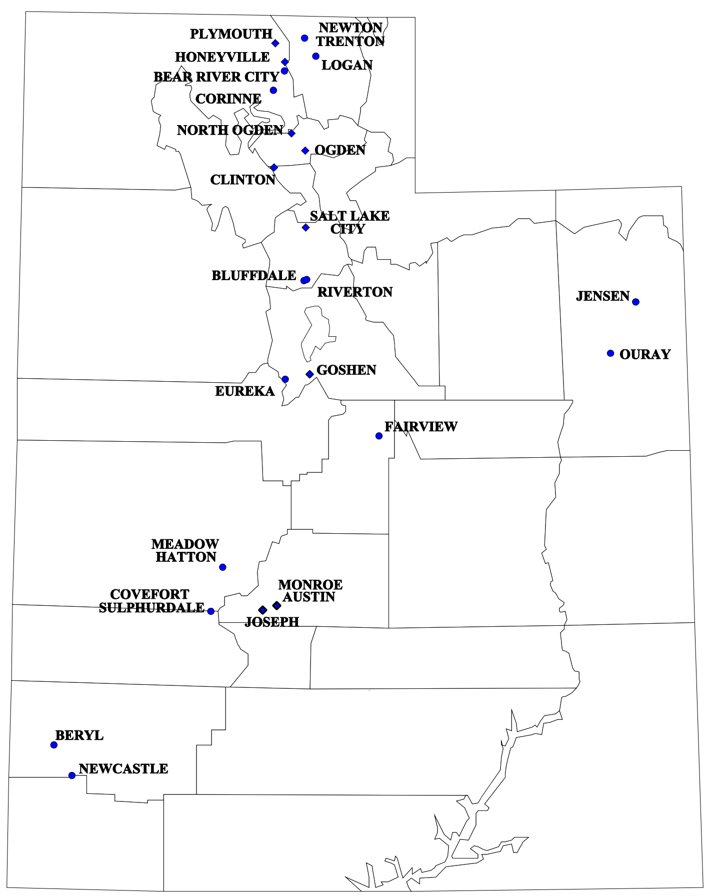

Figure 10. The 23 collocated communities located within Utah.

Historically, most of the communities that were identified have experienced some development of their geothermal resources. However, depending on the characteristics of the resource, the potential exists for increased geothermal development for applications such as space and district heating, resort/spa facilities, aquaculture, industrial and greenhouse operations, and possible electrical generation in some areas. The Geo-Heat Center has sent out information about the resources to the Economic Development Centers for the collocated communities in hopes of promoting geothermal use.

HEATMAP PROGRAM

It is important to characterize energy sources in terms of cost, both capital and unit energy cost. Geothermal energy costs vary with depth and other characteristics of the resource, number of production and injection wells, and many other parameters. Software is currently being evaluated by the Geo-Heat Center for possible use in energy cost evaluation.

The HEATMAP software has been developed by Washington State Energy Office (WSEO). HEATMAP is a computerized system that provides a fast and reliable means of modeling a district heating and cooling (DHC) system. It can be used to identify the cost of geothermal supplied heat in a similar fashion to that used for conventional-fuel heat sources.

HEATMAP requires at the least a digitized map of the area and general building information for each proposed building on the system: building size (sq. ft.), number of stories, and buildings end use to assist in assessing the economic feasibility. The program will: 1) size the central plant heating and cooling equipment, and distribution pipe sizes, 2) finds the most economic operating strategy for selected equipment, 3) calculates annual energy use for each fuel type using the economic operating strategy, 4) calculates annual energy costs to operate central plant equipment, and 5) calculates annual central plant emissions. The HEATMAP economics analysis determines the minimum average price for DHC service that can be charged to a customer while meeting the DHC systems operating parameters and financing assumptions.

CONCLUSIONS

Low- and moderate-temperature geothermal resources are widely distributed throughout the western and central United States. Since the last major effort in assessing the national potential of these resources in the early 1980s, there has been a substantial increase in direct-heat utilization. However, the large resource base is greatly under-utilized. To help expand utilization of the direct-heat resource base, a current inventory of these resources has been developed.

A further breakdown of the current inventory, identifies 256 collocated communities. These communities could benefit by utilizing the geothermal resource. The Geo-Heat Center has sent out information about the resources to the Economic Development Centers for the collocated communities in hopes of promoting geothermal use.

HEATMAP is a computerized system that provides a fast and reliable means of modeling a district heating and cooling system. It can be used to identify the cost of geothermal supplied heat in a similar fashion to that used for conventional-fuel heat sources. The HEATMAP program is currently being evaluated by the Geo-Heat Center as a possible energy cost evaluation tool.

ACKNOWLEDGMENT

This work was supported by the U.S. Department of Energy under INEL Subcontract No. C92-120253 to Oregon Institute of Technology-Geo-Heat Center (OIT-GHC). Such support does not constitute an endorsement by the Department of Energy of the views expressed herein.

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KLAMATH FALLS DOWNTOWN REDEVELOPMENT GEOTHERMAL SIDEWALK SNOWMELT

Brian Brown, P.E.
Mechanical Engineer
Ft. Klamath, OR

INTRODUCTION

The Klamath Falls, Oregon, downtown has seen a period of decline over the past 20 years as businesses have moved to new suburban shopping centers. Downtown business owners and the Klamath Falls Downtown Redevelopment Agency are working to reverse that trend with a Downtown Streetscape Project intended to make the downtown a more pleasant place to work and do business. The visible elements of the project include new crosswalks with brick pavers, wheelchair ramps at sidewalk corners, new concrete sidewalks with a consistent decorative grid pattern, sidewalk planters for trees and flowers, and antique-style park benches and lighting fixtures (Figure 1). A less visible, but equally valuable feature of the project is the plastic tubing installed under the sidewalks, wheelchair ramps and crosswalks, designed to keep them snow and ice free in the winter. A unique feature of the snowmelt system is the use of geothermal heated water on the return side of the Klamath Falls Geothermal District Heating System, made possible by the recent expansion of the district heating system.

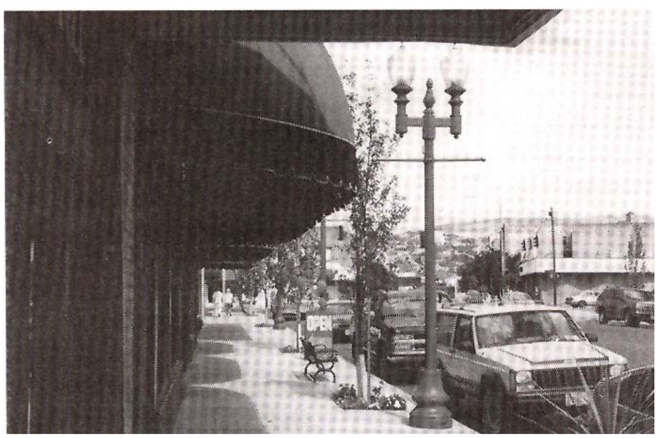

Figure 1. View of a completed section of the Streetscape Project.

HISTORICAL BACKGROUND

The Klamath Falls area has had a long history of geothermal heat utilization, beginning with Indian use of the natural hot springs. With the growth of the city, many wells were drilled to utilize the geothermal resource. Notable examples include: over 500 private homes and small businesses, the White Pelican Hotel (1911, burned in 1926, replaced with Balsiger Ford 1928, building still geothermal heated), Klamath Union High School (1930), the Esplanade Street ramp and bridge (1948), Oregon Institute of Technology campus (1964), Merle West Medical Center (1977), and the Klamath Falls Geothermal District Heating System (1983).

Geothermal District Heating System

In 1976, the Geo-Heat Center investigated the feasibility of developing a geothermal district heating system to serve the Klamath Falls downtown (Lienau, 1991). Options investigated included a limited system to serve 14 government buildings only, a larger system to serve 110 buildings in the downtown core area, and an even larger system including street snowmelt for the downtown. In 1980, the district heating system was installed, with the specific objective of providing heat to the government buildings, but with the expectation of future expansion. The system began operation in 1983. Most of the system was shut down in 1986 due to system leaks. The defective distribution piping was replaced in 1990, and the system has been operational since.

The district heating system consists of two production wells, a geothermal water transmission pipeline, a heat exchanger and pumping facility, and a closed-loop heating water delivery system. Geothermal water is pumped from the ground at about 215^{o}F, conveyed to the heat exchanger building at the County Museum, circulated through a plate-and-frame heat exchanger, and discharged back to the geothermal aquifer at about 180^{o}F. On the secondary side of the heat exchangers, water in the district heating loop is heated to about 180^{o}F and pumped to the district heating customers. The system was designed for a 40^{o} ΔT, with water returned from the customers to the heat exchanger at 140^{o}F.

The system was designed to meet the estimated load of 14 government buildings, with some limited capacity for expansion. Actual observation of the operation of the 11 buildings that were connected showed the system peak load to be much less than anticipated, requiring only about 5-10% of design thermal capacity. Faced with available capacity and revenues not sufficient to meet operation and debt service costs, the city, in 1992, began marketing the district heating system to other buildings in the downtown area (Rafferty, 1993). To date, an additional 10 facilities (12 buildings) have connected to the system.

The original distribution loop was routed down an alley between Klamath Avenue and Walnut Street, about 1-1/2 blocks south of Main Street. The Ross Ragland Theater, a non-profit community theater, was able to secure grant funding for extending the distribution lines about four blocks to the theater. The line extension crosses Main Street at Eighth, providing a source of geothermal heat near the center of the

10-block downtown portion of Main Street. Six of the new service connections have been made along that line extension, and that line extension made the Main Street sidewalk snowmelt possible.

Downtown Redevelopment

Concurrent with the city effort to add customers to the geothermal district heating system, a group of downtown business owners started an effort to beautify and revitalize the downtown core. This effort led to the establishment of a tax-increment financing district to fund improvements, and a downtown streetscape plan. The streetscape was envisioned to include decorative sidewalk pattern, tree planters, antique-style light fixtures, park benches, and brick crosswalks. Street and sidewalk snowmelt was briefly considered; but, initial estimates led to the conclusion that it was too expensive. The first block considered for the streetscape project, the "demonstration block", was to be the 800 block of Main Street, coincidentally adjacent to the new district heating main extension.

Reconsideration of the feasibility of geothermal sidewalk snowmelt led to the conclusion that with the sidewalks and crosswalks already torn up for the streetscape project, the extra cost of the snowmelt system was manageable. The snowmelt system enhances the project with several benefits, including:

- Elimination of cost and inconvenience of snow and ice removal.
- Reduced wintertime liability exposure from slick sidewalks.
- Reduced mess and inconvenience in buildings from tracked-in sand, salt and slush.
- Elimination of damage to sidewalks and brick pavers from freeze-thaw cycles.

The individual property owners will be responsible for the operating cost of the snowmelt system, about $0.25 per square foot of sidewalk per year. Each business owner was also responsible for the cost of the sidewalk concrete in front of his building; but, the installation cost of the snowmelt system was carried by the redevelopment agency. The added value of the snowmelt system was instrumental in encouraging full participation by the business owners in the redevelopment project.

SNOWMELT DESIGN

The required heat load for snowmelt will vary tremendously depending on the air temperature, wind, snowfall rate, and how much snow accumulates. For the downtown Klamath Falls Main Street sidewalks and crosswalks, the snowmelt is a convenience, not a necessity. The design objective was to provide a reasonable level of performance, while limiting installation and operation costs and load on the district heating system. The variables in the snowmelt design are climate, available snowmelt loop temperature and flow, tube depth, and tube spacing.

Klamath Falls is located east of the Cascade Mountain Range, at an elevation of 4100 feet. The climate is moderated by on-shore flow from the Pacific Ocean, 120 miles to the west. Average annual snowfall is about 30 inches. Average December and January temperatures are right around freezing. Northeast air flow can bring cold Arctic air into the area, with temperatures as low as -30°F; but, the temperature seldom goes below 0°F. In a typical year, there are about 120 hours below 15°F. Typically there is little wind coincident with extremely cold temperatures.

The snowmelt system was designed to maintain a slab surface temperature of 38°F at 15°F air temperature and 5-mph wind speed. This requires about 85 Btu/hr/ft^2. By comparison, the Esplanade Street ramp and bridge snowmelt system, installed in 1948, is operating successfully at about 58 Btu/hr/ft^2 (Thurston, et al., 1995).

Heat for the snowmelt system will be provided from the return main of the Klamath Falls Geothermal District Heating System. The district heating return water will be pumped from the return main at 140°F, through a plate-and-frame heat exchanger, and back into the return main downstream. The snowmelt loop will contain a propylene glycol/water mix, supplied to the snowmelt grid at a maximum temperature of 130°F.

Tube Depth and Spacing

The civil engineer responsible for the redevelopment sidewalk design was adamant that the snowmelt tubing not be placed in the concrete sidewalk slab. Placement under the slab minimizes the impact of the snowmelt tubing on the integrity of the sidewalk, and allows removal of a section of sidewalk without damaging the tubing. The greater tubing depth also results in greater percentage back losses and more temperature drop between the tube and the sidewalk surface. The design compensates for varying tubing depth by adjusting the tube spacing and flow rates as a function of tube depth. Tubing under the sidewalks is placed at a depth of about 6 inches below the slab surface, 14 inches on center. Under the cross-walks, the tubing depth is about 10 inches, and the tubes spacing is reduced to 8 inches on center (Figures 2 and 3). The tubing was continually pressurized with water during construction to assure that any damage to the tubing would be evident prior to placement of the concrete.

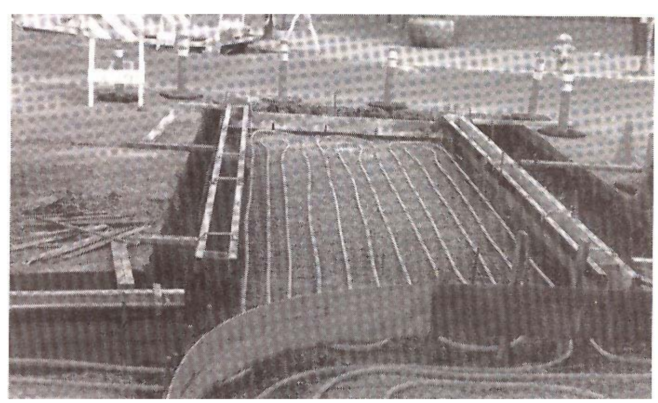

Figure 2. View of the tubing under a crosswalk.

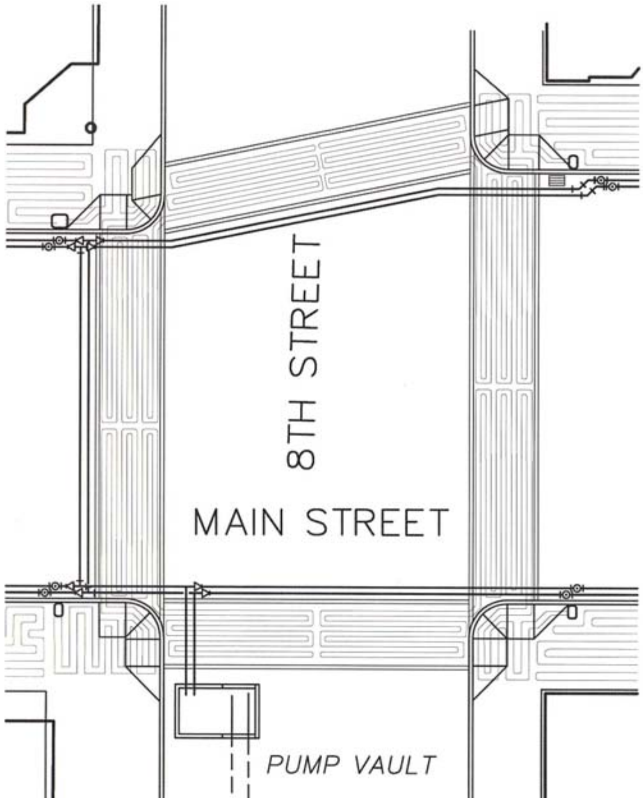

Figure 3. Details of the tubing layout.

Pump Vault

The entire snowmelt system, planned to extend for 10 blocks, will be operated from a single pump and heat exchanger vault. The system includes a plate-and-frame heat exchanger, a primary pump to circulate district heating loop return water through the heat exchanger, a snowmelt loop pump to circulate the snowmelt loop, and an expansion tank to pressurize and provide makeup water to the snowmelt loop. Both pumps are operated with adjustable frequency drives to provide variable pumping rate.

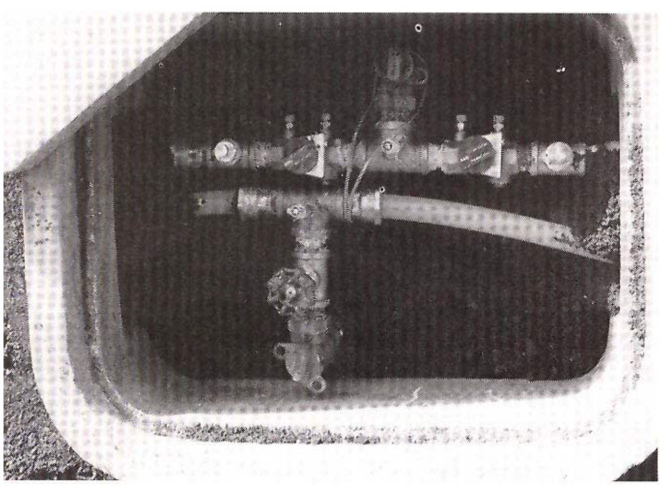

Figure 4. Balance valve and pressure-temperature test port.

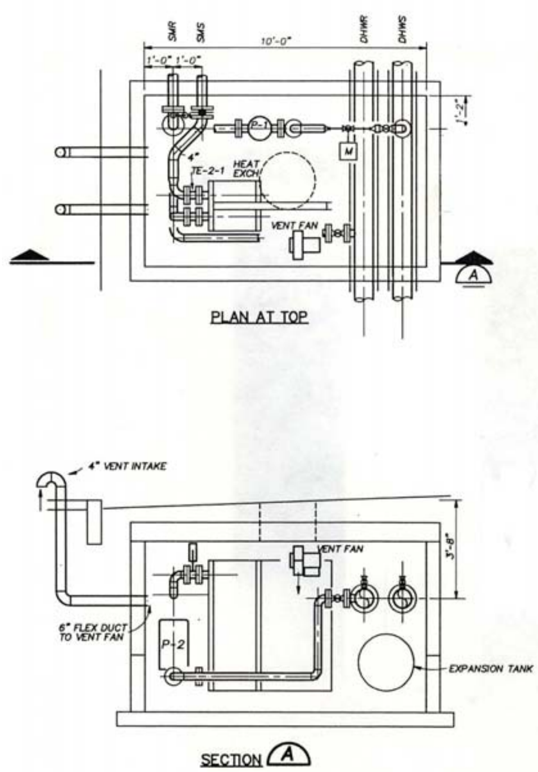

Figure 5. Sidewalk snowmelt service vault.

The flow of the snowmelt loop will be manually set based on the area of sidewalk served. Initially the system will serve three blocks. Flow will be increased as additional blocks are added. Balance valves and pressure-temperature test ports are provided at each snowmelt tubing loop to allow balancing between the loops (Figures 4 and 5). As the system is expanded, rebalancing will compensate for increased pressure drop along the snowmelt distribution mains.

Controls

The simplest controls for a snowmelt system are a manual ON-OFF switch. For this installation, while the geothermal heat is essentially "free", it costs money to run the pumps and operate the system. To offset those costs, the city has valued the geothermal energy at half the cost of natural gas. A spreadsheet energy use analysis showed an annual operation cost of \$0.90 /ft^2/year for uncontrolled operation all winter, compared to \$0.25 /ft^2/year for carefully controlled operation. Since the system will ultimately cover about 60,000 ft^2, it made sense to install automatic controls.

The basic control strategy will be to maintain a slab surface temperature of 38^{o}F continuously throughout the winter. The heat stored in the warm slab should quickly melt snowfall even if the instantaneous heat requirement exceeds the system heating capacity. The control system will monitor outside air and sidewalk slab temperature, adjusting system operation accordingly. When air and slab temperatures both drop below 38^{o}F, the pumps automatically start. When the system is on, the speed of the primary pump will be modulated to maintain the desired snowmelt loop supply temperature. The snowmelt loop temperature required to maintain the design slab temperature will vary with air temperature, wind and precipitation. The supply temperature set-point will be reset over a range of about 80^{o}F to 130^{o}F as required to maintain the desired slab temperature.

The control system will also provide monitoring of the operation of the snowmelt system and the geothermal district heating system main loop. On unusual conditions, the control system can dial-out over a phone line to notify maintenance staff.

PROJECT STATUS

Construction is currently complete on the 800 block of Main Street, and on the north side of the 600 and 700 blocks. Construction on the south side of the 600 block and a portion of the 700 block is expected to be complete within a few weeks. The system should be operational before the first major snowfall. Construction will continue next year as funds allow, with an ultimate goal of about 10 blocks on the system. Updates on system operation and construction will be reported periodically to the Geothermal Pipeline.

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PRAWN PARK - TAUPO, NEW ZEALAND

John W. Lund
Geo-Heat Center

Richard Klein
Director, Prawn Park
Taupo, New Zealand

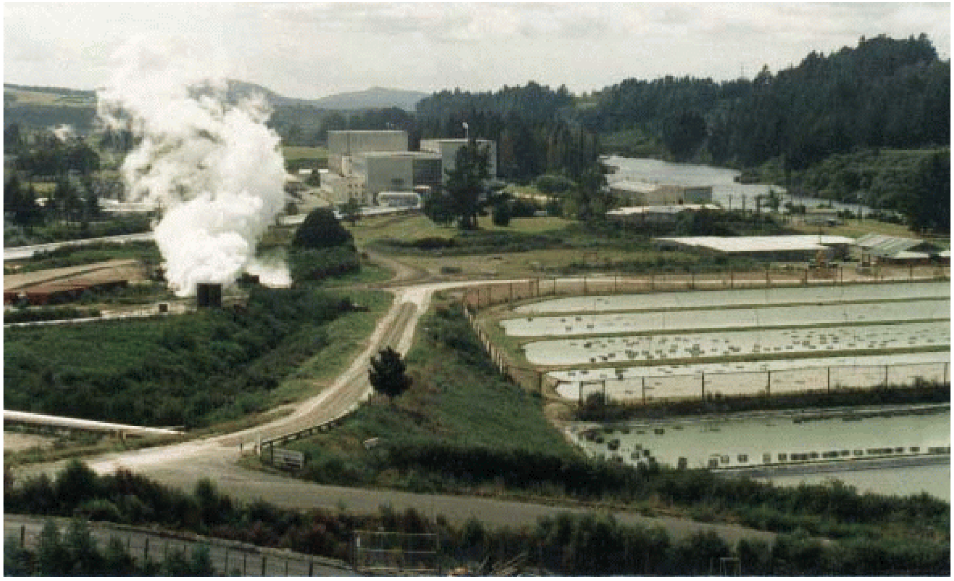

Figure 1. Prawn Park with Wairakei Power plant and Waikato River.

New Zealand's only freshwater prawn farm was established in 1987 to take advantage of geothermal waste heat from the Wairakei power generating field on North Island. Since approximately 2000 tonnes (2200 tons) per year of prawns are imported annually into New Zealand, the motivation was to try and capture some of this market with a domestic product.

Giant Malaysian Freshwater Prawns (Macrobrachium Rosenbergii) were imported from Malaysia in 1988. Half of these were lost in transit due to delays in lifting import restrictions. A second import of 25 breeding males and females had to be quarantined for 15 months to assume that they were disease free. Also, officials required that if prawns escaped into the adjacent Waikato River they would not survive and reproduce. It turns out that the prawns will die in 14°C (57°F) water, and since the river water is at 10°C (50°F), there was no chance of survival. Thus, a license was issued in 1989 for the firm to start commercial production.

The original farm consisted of five outside ponds totaling one hectare (2.5 acres), and a small hatchery and nursery. Shortly, another four ponds were added to bring the total area to 2.5 ha (6.2 acres).

In 1993, the New Zealand Enterprise Board joined New Zealand Prawns Ltd. in partnership, and another 10 ponds were developed bringing the total pond surface area to 5.8 ha (14.3 acres), with the entire facility occupying 10.2 ha (25.2 acres) (Figure 1).

The present 19 ponds vary in size from 0.2 to 0.35 ha (0.5 to 0.9 acres) and have a depth of 1.0 to 1.2 m (3.3 to 3.9 ft), providing a slope for ease of harvest. The length to width ratio of the pond surface is approximately 20:1. The sides are sloped for stability and the bottom material is composed of an impermeable volcanic ash that also stores nutrients for the prawns (Figure 2).

Figure 2. Detail of outdoor pond.

Ideally, the ponds should be kept at a temperature of 28°C (82°F); but presently, they are at 24°C (75°F) with a temperature variation from one end of the pond to the other of 1°C (2°F). A temperature probe controls the flow of water into the ponds and an aerator is used to obtain vertical mixing of the pond water. Without the vertical mixing, the ponds become temperature stratified, reducing the production of prawns.

Water for the ponds comes from two sources, the plate heat exchanger at 55°C (131°F) and river water at 10°C (50°F). Water is circulated throughout the system from a storage and settling pond that is kept at 21°C (70°F). Approximately 90% of the water is recirculated, with the 10% makeup water coming from the river. Water is circulated through the plate heat exchanger at a rate of 250 tonnes per hour (1100 gpm) (Figure 3) in summer and 400 tonnes per hour (1760 gpm) in winter. The primary side of the plate heat exchanger takes waste water from the Wairakei power plant just before it flows into the Waikato River. Approximately 4000 tonnes per hour (17,600 gpm) of over 90°C (194°F) waste water is discharged from the plant and flow across the pumps supplying the plate heat exchanger. The geothermal water cannot be used directly in the ponds due to the presence of detrimental sulphur, lithium and arsenic. However, there is an experimental project nearby funded by ECNZ (Electricity Corporation of New Zealand), that is attempting to extract these elements for commercial use.

Figure 3. Hot water intake and plate heat exchangers.

The Prawn Farm pays a royalty to ECNZ for the heat source; however, the Prawn Farm is still the third largest annual electricity consumer in the Taupo District. The farm would not be economically viable if electricity were used for heating, instead of the waste hot water. The farm does pay water rights to use the Waikato River water, and this is reviewed on an annual basis.

Presently the farm is capable of producing up to 30 tonnes (33 tons) of prawns per annum of prawns (Figure 4). The life of the prawn starts in salt water inside in breeding tanks and end in the freshwater ponds outside where they are harvested after nine months averaging 30 to 40 per kg (14 to

Figure 4. Harvest prawns.

18 per lb) or about 30 g (1 oz) each. They are sold at $NZ 25/kg wholesale and $NZ 40/kg retail ($US 17 to $US 27 per lb).

The life cycle and stocking rates of the prawns start with the breeding tanks. These hold between 100 to 150 breeding stock at a ratio of one male to five or six females. The males last about 18 months at which time they are replaced. A female prawn spawn five times a year in brackish water (1/3 saltwater and 2/3 freshwater) and produce between 20,000 to 80,000 larvae per spawning. A total of one million larvae are produced per cycle giving total production of post larvae per year of nine million.

After spawning, the larvae are attracted by light where they are siphoned off into a catching bucket and placed in the larval tanks. The larvae undergo eleven different moults to metamorphose into a post larvae in 30 days. They are fed three times a day with a mixture of crushed mussels and scrambled eggs (Figure 5).

Figure 5. Larval tank.

The larvae are then moved to nursery ponds holding up to 200,000 animals each and kept at 28°C (82°F) (Figure 6). Here they grow from 0.01 g to 4 - 6 g (0.004 to 0.14 - 0.21 oz.) in four months. They are fed a diet of pellets containing fishbone, minerals, etc. still at three times a time.

Figure 6. Nursery ponds.

After four months in the nursery, the prawns are transferred to the outdoor growout ponds for their final growth of a further five months. The prawns are moved manually using a net with mesh openings that catches only the larger ones.

They are again fed pellets, with zooplankton growing in the ponds providing additional food. Prawns are voracious eaters and will turn cannibalistic if undernourished. Two kilograms (4.4 lbs) of food produces one kilogram (2.2 lbs) of prawns.

At the end of the five months, the ponds are drained and the prawns picked up manually from the bottom by four to six harvesters. The prawns are then transferred to the hatchery for washing before they are taken fresh to the restaurant (Bar and Grill) or snap frozen for future use (Figure 7).

Figure 7. Bar and Grill restaurant.

The stocking rate in the outdoor growout ponds are approximately 30 per square meter (3 per square foot) or 20 to 30,000 prawns per pond, depending upon the size. At harvest time, 400 to 500 kg (880 to 1100 lbs) are produced from the smaller ponds and 800 to 1000 kg (1770 to 2200 lbs) produced from the larger ponds.

Ninety percent of the harvested prawns are sold to the Bar and Grill next door, with the rest going to gourmet restaurants in Queenstown, Wellington and Whakatane. Over a recent three year period, the restaurant has served more than 30 tonnes (33 tons) of prawns to more than 45,000 visitors (Figure 8). This is 10 percent of the prawns consumed annually by Kiwis. The restaurant offers a plate of 16 prawns for NZ$ 22 (US$ 15) or a half plate of 8 prawns for NZ$ 12.50 (US$ 8). This past year, with a full-time marketing manager and half-hour hatchery tours operating five hours a day (at NZ$ 4 - US$ 2.7 per head), more than 25,000 tourists, 50 percent domestic and 50 percent overseas, have been attracted.

Figure 8. A satisfied customer.

Prawn farming is labor-intensive with high overheads. Six hectares (14.8 acres) cost NZ$ 500,000 (US$ 330,000) a year to operate--compared to farming dairy cattle yielding NZ$ 2500 per hectare (US$ 660 per acre). Prawns return NZ$ 150,000 per hectare (US$ 40,500 per acre).

In the near future, another 40 ha (99 acres) will be added on land on the other side of the power plant using waste cooling water from a proposed binary power generator. This would create a unit capable of becoming the third largest freshwater prawn producer in the world, producing 400 tonnes (440 tons) a year. At NZ$ 25,000 a tonne (US$ 15,000 per ton), that would mean an annual turnover of more than NZ$ 10 million (US$ 6.7 million).

GEOTHERMAL PIPELINE

Progress and Development Update
from the Geothermal Progress Monitor

CALIFORNIA

Northern California Power Agency Approves Project to Convert Waste Water to Geothermal Energy

On 27 July 1995, the Northern California Power Agency (NCPA) Commission formally approved participation in the Southeast Geysers Effluent Pipeline Project (Project). The Project involves construction of a pipeline to deliver treated sewage effluent from Lake County to NCPA's Geysers geothermal generating facility for deep injection into the hot geothermal reservoir.

Michael McDonald, NCPA's general manager, said "the Project will provide a good source of injection water to sustain geothermal electrical generation into the next century while solving wastewater disposal problems for the city of Clear Lake and other residents of Lake County." Action by the NCPA Commission follows closely on the heels of recent approval by the Lake County Board of Supervisors of all agreements necessary to construct the pipeline, including all environmental documents. The project has been in the planning for more than 3 years and involves NCPA, Lake County, and all of the operators in the Southeast Geysers geothermal field, including Unocal Corporation (Unocal), Calpine Corporation (Calpine), and Pacific Gas & Electric CO. (PG&E). Additional injection water via the pipeline is expected to extend by at least 15 years the useful life of NCPA's existing 200 MW power generation facilities at The Geyser, located in Lake and Sonoma counties. Extending the useful life of NCPA's existing geothermal power facilities will allow the NCPA better to serve the future electrical needs of its member utilities.

Total construction costs of the main pipeline and pumping facilities are estimated at approximately $34.1 million. Ground breaking is scheduled in late September 1995, with completion expected by December 1996. The project's innovative public/private cost-shared financing plan includes Lake County wastewater funds; federal grants from the Department of Energy, Environmental Protection Agency, Bureau of Land Management, and the Economic Development Administration; a grant from the State of California (California Energy Commission); and equity investments by all geothermal operators (NCPA, Unocal, Calpine and PG&E) totaling $21.5 million.

NCPA estimates that the project will result in a gain of approximately 40 MW in electrical power output. Over the next 20 years, this will equate to an annual delivery of 350,000,000 kWh of clean, low-cost and renewable electrical generation. Beside the project's obvious energy benefits to NCPA and its partners, the project will provide an environmentally superior method of wastewater disposal, while providing added tax, lease and royalty revenues to local communities, the state of California, and the federal government. (Source: GRC Bulletin)

HAWAII

Two-Year Anniversary in Hawaii

The Puna Geothermal Venture's (PGV) Pohoiki power plant is 2 years old. Over this period, it has produced an average of 25 MW of power--about a fifth of the county's electrical load. The operator of the plant PGV--which is a partnership between Constellation Energy Inc., a subsidiary of Baltimore Gas & Electric Co. and OSI Power Corporation--has stated that the power plant can produce 30 MW of electrical power. PGV is now in the progress of negotiating with Helco, the local utility, to sell the extra 5 MW.

It has been estimated that a conventional power plant operating on oil would have burned about 800,000 barrels of oil--about eight tanker loads during the 2-year period.

PGV would like to further develop the geothermal field and construct another power plant. It was noted that the resource is available and is indigenous, so money does not have to leave the island to pay for fuel to produce electrical power. (Source: GRC Bulletin)

New Hydrogen Sulfide Study in Hawaii

The Puna Malama Pano, an organization of Puna residents who are opposing geothermal energy, has received a $20,000 federal grant from the Environmental Protection Agency (EPA) to purchase the equipment and make a sustained test of the air around the PGV power plant. The organization believes that the monitoring equipment now being used is not properly set up to accurately monitor H_2S that is heavier than air.

The organization will monitor H_2S in the following manner:

- Set up the monitoring equipment in the low areas around the power plant.
- Shorten the length of the pick-up tubes so that they will receive air samples closer to the ground.
- Because H_2S sometimes moves like a stream of water, the monitoring stations
- will be at the most optimum sites to detect the gas.

The H_2S standards set by the state of Hawaii allow 25 parts per billion (ppb) from any facility. The PGV permit states that the air around the plant may not contain more than an average of 5 ppb per hour. This means that the air around the plant can register momentary surges of greater than 5 ppb, but the plant would still meet the state requirements as long as the average reading for an hour is below 5 ppb.

The standard set by the Occupational Safety and Health Administration (OSHA) is 10,000 ppb. This means that a healthy worker can be exposed to this level of H_2S for eight hours per day.

At 500,000 ppb, H_2S can cause immediate respiratory distress and paralysis, and can be fatal. (Source: GRC Bulletin)

MEXICO

Calpine Enters International Power Market; Company Initiates Program at Cerro Prieto Geothermal Resource

On 9 June 1995, the Calpine Corp. of San Jose, CA, announced that it had entered into a series of agreements with Grupo EPN S.A. de C.V. (Grupo EPN) and its affiliate, Perforadora Magma S.A. (Magma), to participate in geothermal steam production and well drilling, and repair projects at the Cerro Prieto geothermal resources in Baja California, Mexico. Representing the company's first international energy venture, the proposed projects will be under contract to Mexico's national utility, Comision Federal de Electricidad (CFE). The agreements were executed on 8 May 1995 at a ceremony held under the auspices of the U.S. Department of Energy in support of the Global Climate Change Initiative. The agreements were witnessed by Secretary of Energy Hazel O'Leary.

Grupo EPN, a Mexican resource development company, and Calpine have entered into a memorandum of understanding to produce approximately 1,600 tons per hour of geothermal steam at Cerro Prieto for CFE. Calpine also entered into a separate agreement with Magma for the drilling of 10 new geothermal wells to expand the capacity of the Cerro Prieto field and for the restoration of 20 of CFE's geothermal wells also at Cerro Prieto. The well drilling projects are managed in conjunction with two CFE contracts, totaling $26 million, which were awarded to Magma in 1995. The initial 10-well program began in early July. Calpine will provide funding for the projects as well as technical, administrative and operating services.

Consistent with its long-term strategy, the Cerro Prieto projects represent Calpine's first international venture. The company anticipates strengthening its relations with CFE and Grupo EPN to further develop geothermal opportunities at Cerro Prieto.

The Cerro Prieto geothermal resource, commercially developed since 1973, is located in the Mexicali Valley on the Baja California peninsula. The resources currently produces approximately 600 MW of electricity from three geothermal power plants. This production supplies nearly 70 percent of northern Baja California's electricity demand. (Source: GRC Bulletin)

NEVADA

Nevada School Bets on Geothermal to Win

The White Pine County High School in Ely, Nevada, only opened in February, but school officials are already betting its environmental system will save $25,500 annually in utility bills and operating costs.

The 82,000-sq-ft facility houses 550 students in a town 260 miles north of Las Vegas. Its indoor climate is controlled by a closed-loop heat exchanger made of nearly 78,000 ft of Phillips "Driscopipe" 5400 high-density polyethylene (HDPE) pipe produced by Phillips Driscopipe Inc., a subsidiary of Phillips Petroleum Co.

"One of the biggest hurdles faced by utilities and contractors promoting geothermal energy is the local community's fear of water table pollution," said Jim Lewis, acting manager, Mount Wheeler Power Co. He said the pipe was selected because of its resistance to cracking and leaking, as well as its longevity.

<u>Desert Requirements</u>

The town of Ely endures abrasive desert conditions, cold winter months and high altitudes. Temperatures plummet to -20°F, heating is often required for seven months each year. Conditions like that call for a strong pipe.

Glenn Messner, Phillips Driscopipe's new market development manager, said the pipe has been used in ground-source heat pump installations at Phillips 66 gas stations, where it averages $15,000 savings in reduced utility costs.

Inter Mountain Pipe Supply, Centerville, Utah, supplied the 72,000 ft of 1-in. pipe, 5200 ft of 3-in. pipe, 440 ft of 6-in. pipe, and 240 ft of 8-in. pipe used at the school.

The system was designed by Peterson Associates, Reno, in conjunction with Earth Energy Technology and Supply, Inc., Marietta, Oklahoma. Earth Energy provides a computer model for the heat exchanger and designed the heat fields.

"The rock, rock aggregate, and other potentially abrasive materials found throughout the site necessitated a strong pipe," said Phil Schoen, Earth Energy's director of marketing.

"We've used Driscopipe 5400 on other projects at schools and homes, and know the material has a strong resistance to abrasion. The pipe also is highly conductive which facilitates the extraction of heat from the soil."

<u>Thermal Transfer</u>

The pipe transfers heat exchanged between the heat pump and the ground. System fluid, water or water and antifreeze, is circulated through the buried pipe system, which absorbs heat from the earth and carries it to the heat pump.

At the high school, the heat pump extracts heat from the pipes, compresses it to a higher temperature, and distributes it to individual heating-cooling units in each classroom. The individual units enable each teacher to determine individual classroom temperatures.

Heat may be drawn from one classroom to a cooler one. Unneeded heat is returned to the earth via the piping network.

<u>Construction</u>

Christiansen Drilling, Ely, drilled 144 boreholes 250 ft deep and inserted U-shaped, closed-loop, 1-in. pipe filled with water. After insertion, the pipes were hooked to a pressure pump as a quality-control check-up to 100 psi.

The boreholes were then filled to the surface with bentonite grout, to bond the pipe to the hole walls and prevent air cavities from forming. The natural clay material seals the boreholes from bottom to top, to protect the integrity of the system and of nearby aquifers. It also provides a thermal bridge between the earth and the pipe.

O'Flaherty Plumbing & Heating excavated 5 ft down the borehole to butt-fuse the 1-in. well loop to a common 3-in. prefabricated manifold. The manifold leads to the valve vault, where the piping was butt-fused to 6-in. pipe and a series of circuit setters and valve headers.

The System

The school's system has two heat loop fields, each consisting of six well clusters or zones. (A well cluster has 12 wells.) Interconnecting the wells into one cluster took the crew eight to 12 hours.

One 8-in. supply and return line coming from the school teed-off into two 6-in. ones, one for each heat loop field. The 6-in. lines fed to the valve vaults, where valve manifolds comprised of six valves and six circuit setters isolated each well cluster. (Valve vaults enable individual or group control of the clusters to monitor temperature and pressure.)

Benefits

Although the project involved a lot of work, all involved seem to think it worth the effort.

"Ground-source pumps cost more to install than conventional heating systems, but geothermal energy pays for itself in only a few years," Lewis said. "In two demonstration projects completed in Ely, electric bills were 78% less using geothermal energy."

The school's system was estimated to cost $340,000 more initially than a $423,000 conventional heating and cooling system. Officials estimated it would save more money in the long run. Mount Wheeler Power financed the project with a 12-year lease option.

"We offered financial assistance on this installation to prove to the community that geothermal energy works," Lewis said. "The school will save $25,000 in reduced heating costs each year, which calculates to nearly $800,000 savings during the projected 50-year life of the school." (Source: Engineered Systems)

PENNSYLVANIA

Two-Phase Geothermal Fluid Standard Developed

The chemical analysis of geothermal fluids is important to the maintenance and operation of geothermal wells and power plants.

And, although sampling of geothermal fluids is performed around the world, experts believe there has been no consensus standard developed, which ensures that consistent and reliable data is gathered from different sources.

According to Paul Hirtz, that will change.

Hirtz is chairman of a task group with the American Society for Testing and Materials (ASTM). His committee, Task Group E44.15.01 on Sampling and Chemical Analysis, has helped produce the society's Standard E 1675, "Practices for Sampling Two-Phase Geothermal Fluid for Purposes of Chemical Analyses."

According to ASTM, the purpose of the practice is to obtain representative samples of liquid and steam as they exist in a pipeline transporting two-phase geothermal fluids. The chemical composition data may be used for many applications important to geothermal energy exploration, development, and the long-term managed exploitation of geothermal resources, the association said.

According to ASTM, applications include resource evaluations, such as determining reservoir temperature and the origin of reservoir fluids, compatibility of produced fluids with production, power generation, and reinjection hardware exposed to the fluids, long-term reservoir monitoring during field exploitation, and environmental impact evaluations, including emissions testing.

The organization said the natural chemical produced in geothermal fluid can cause a number of problems, such as scale deposits and corrosion of the well-bore casing and production piping.

ASTM added that a significant feature of the practice is the use of a cyclone-type separator for high-efficiency phase separation, operated at flow rates high enough to prevent significant heat loss, while maintaining an internal pressure essentially the same as the pipeline pressure.

ASTM said Standard E 1675 is available from its customer service, 215-299-5585. For more information about E 1675, contact Hirtz, Thermochem Inc., 5347 Slylane Blvd., Santa Rosa, California 95403, 707-575-1310. (Source: Air-Conditioning, Heating & Refrigeration News)

VIRGINIA

Geothermal Teleconferences to be Broadcast

The sponsors of the natural geothermal heating and cooling teleconferences announced the 1995-96 continuation of the series developed in conjunction with the Geothermal Heat Pump Consortium.

In 1995 and 1996, there will be three teleconferences each year, every one focusing on a specific topic, type of building, or customer segment.

Dates and topics for 1995 are Sept. 14--"Geothermal Heat Pumps in Commercial Buildings", and Nov. 16--"Geothermal Heat Pumps for Residential Customers."

The two-hour teleconferences will provide information for audiences of commercial and residential designers, utility personnel, facility managers, users, realtors/developers, and others interested in the technology.

Downsite participants will be given the opportunity to telephone questions to GHP authorities, users, designers, and installers who will be in the teleconference studio.

For more information, contact the Conference Coordinator, Policy Research Associates, Inc., 703-742-8402, 703-742-8671 (fax).

Topics for the 1996 teleconferences will be, spring--"Multi-Family Residential Buildings", early fall--"Small Office Buildings", late fall - "Retail Buildings."

The teleconferences will be broadcast via satellite from 10:30 a.m. to 1 p.m. eastern time (10:30 to 11 a.m. is the test pattern).

Major sponsors include the U.S. Department of Energy, U.S. Environmental Protection Agency, Electric Power Research Institute, Geothermal Heat Pump Consortium, International Ground Source Heat Pump Association, National Rural Electric Cooperative Association and Edison Electric Institute. (Source: Air-Conditioning, Heating & Refrigeration News)